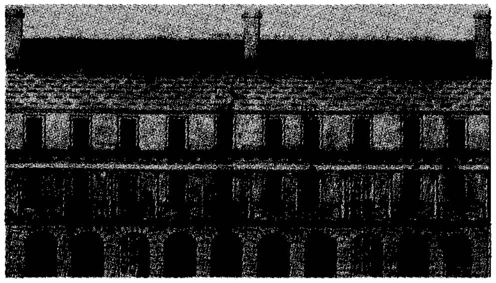
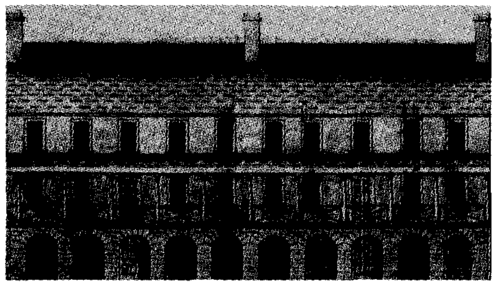
SUBSTANCE AND PRACTICE

BUILDING TECHNOLOGY AND THE ROYAL ENGINEERS IN CANADA





Elizabeth Vincent

Environment Canada Parks Service
Environnement Canada Service des parcs

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BUILDING TECHNOLOGY AND THE ROYAL ENGINEERS IN CANADA

Elizabeth Vincent

Studies in Archaeology
Architecture and History

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FOREWORD

The research for this study of building technology and the Royal Engineers in the 19th century was undertaken to assist restoration and interpretation of military sites and buildings under the custody of the Canadian Parks Service. But its use is not limited to the work of this organization. One of the articles of the World Heritage Convention, to which Canada is a signatory, stresses the dissemination of scientific and technical studies and research which will assist in the preservation of the nation's cultural or natural heritage. This particular study is of value to those interested in heritage preservation around the world and in Canadian architectural history. The Royal Engineers were responsible for military construction everywhere British troops were stationed and designs and methods used in one locale frequently were made use of in many others. The building materials discussed are those used in civilian as well as military construction and an understanding of their use by the Royal Engineers on this continent in the 19th century will be valuable to anyone interested in construction in this period.

In order to answer several major questions regarding historic building materials and construction techniques essential to accurate restoration work in the National Historic Parks and Sites system, cross-site studies of particular construction techniques and uses of materials were undertaken. These detailed individual studies were combined to produce a general examination of the work of the Royal Engineers in British North America in the 19th century. Rather than a narrow concentration on specific buildings at one particular time, my intention was to provide data and evidence of changes over time on such matters as purchasing policies, suppliers, prices, construction standards and professional practice.

Research for this book was done between 1978 and 1984. In its original form it was produced as part of the Canadian Parks Service's Microfiche Report Series in 1985. Extensive revisions have been made, but no further research has been done for this edition. Some works which have been published since 1985 have been included in the Bibliography.

INTRODUCTION

"Which of you, intending to build a tower, sitteth not down first, and counteth the cost?"[1]

This book focuses on military construction in British North America from 1820 to 1870. During this period the Board of Ordnance was responsible for the construction and maintenance of works of fortification in Britain and in British overseas possessions. An important concern of the officials in London who tried to control the construction and repair work being carried out at all these posts was to know how much the work was going to cost. Thus it is easier to find the estimated cost of any building than to discover how the work was done and exactly what materials were used.

Several types of structures must be dealt with in studying the work of the Royal Engineers in British North America. As well as fortifications the Royal Engineers built barracks, storehouses, hospitals, prisons, canal locks, offices, and even civil buildings such as Government House in Newfoundland. The military buildings constructed in British North America range from small temporary or unimportant structures, built quickly and with little or no attention to style or architectural detail, through more permanent but very utilitarian structures, to those designed to impress the bystanders with either their elegance or their solidity.

Another important aspect of this study is the examination of how well or ill the Royal Engineers adapted their European experience and training to fit North American conditions. Military construction did not exist in isolation. Buildings were erected to face the same climate, the same conditions as civilian buildings, and they were part of the streetscape of the towns or cities in which they were built. Construction of military buildings was carried out under the supervision of officers of the Corps of Royal Engineers, but the actual work was increasingly done by local builders under contract to the Ordnance Department. While official policy encouraged the purchase of manufactured articles in England, local purchase became common by the end of the period under study. Therefore military construction was often carried out by the same builders, using the same materials, as civilian construction.

The major focus of this work is on specific building materials. Individual chapters deal with limes and cements, plaster, roofing, asphalt, building hardware (specifically locks and nails) and window glass. In their use of window glass the Royal Engineers in British North America showed some awareness of local conditions, often using the type of window commonly in use locally, and suggesting the use of double windows, or of a better quality of glass than provided for in the regulations. The Royal Engineers not only kept in touch with the work of civilians in the development of stronger mortar which would set in damp conditions, but also experimented with various limes and mortars and attempted to find natural hydraulic limes in British North America. But with some other building materials the Royal Engineers seemed quite uninterested in technological developments and the specifications which they drew up continued to call for types of materials which were passing out of use in the civilian building industry.

Most of the building materials discussed herein were not produced specifically for the military but for the building industry in general. Whatever their level of awareness of the latest technological developments or of the latest fashion in architecture the Royal Engineers would have to use what was available. Even when they attempted to use what was provided by the Ordnance Department rather then what was in common local use they were sometimes frustrated. Contractors at times refused to use the materials provided, or the users of the buildings made their own additions (for example the replacing of the standard locks).

Sources

A study of building technology as applied to military construction in British North America is necessarily limited by the type and scope of the sources of information available. It is in the records created by the Royal Engineers and by the Board of Ordnance that we must look for documentary information on military construction. Except in cases of urgent necessity, estimates and plans for any work done at a military post, showing what sort of building was proposed, what materials would be needed, and what this would cost, had to be prepared by the local engineer officer, approved by the authorities in England and money allocated for the project by the Treasury before construction could begin. These estimates provide a rich source of information on the work being done, materials being used, and costs incurred.

The records available reflect the scope and extent of building activity, which was influenced both by local factors such as security needs or large-scale fires, as well as by changes in Board of Ordnance and War Office policy resulting in new designs and standards for military buildings. An increased interest in the comfort of the soldiers after the 1850s, new types of ordnance, and modifications in fortress design all resulted in greater building activity.

The availability of estimates and other documents relating to military construction is also affected by outside factors. Most of the records kept in the Royal Engineer office in Montréal were destroyed in the fire of 1852 and similar mishaps befell other records. The large-scale "weeding" of War Office documents carried out in the late 19th century in order to reduce the strain on the available space in the Public Record Office has been discussed by Richard Young in *Research Bulletin* No. 98, "The Destruction of War Department Records" (Parks Canada, Ottawa, July 1978). Many records which would have been valuable in documenting the work of the Royal Engineers after 1860 were destroyed at this time. Thus while there is a large number of estimates for some periods and for some stations, there are also large gaps.

The surviving estimates vary in the amount of information they contain, some being very detailed, while others, possibly only preliminary drafts, give much less information. Earlier estimates tend to give very little description of the work to be done, but provide detailed lists of the materials required and the estimated cost of these materials. By the 1830s much more detailed descriptions of the buildings themselves and of the work needed were provided but the practice was developing of estimating the cost by the amount of each type of work required rather than by the materials needed. The plans which usually accompanied these estimates are also valuable sources of information about the buildings which were being proposed.

As more and more of the work on the various military buildings came to be done by contract rather than by military labour, printed schedules for contracts, giving prices and specifications for all work which might be included, came increasingly into use. Those tendering for contract work would offer to perform the work at so much above or below the price in the schedule, and the printed schedule would become part of the contract. When new schedules were drawn up, an analysis of the prices in the schedules was prepared showing how prices were arrived at — for instance, how many days' labour, what type and what quantities of materials would be needed to build so many cubic feet of masonry or to plaster so many square feet of wall surface. At least two of these analyses survive, one for the proposed prices for triennial repairs in Canada from 1853 and one for work at Saint John, New Brunswick, in the early 1860s.[2] For Quebec, notarial records provide a particularly valuable source of information rarely available elsewhere. Because the notary involved in the signing of the contract was required to keep a copy of the document with his records, which eventually were deposited with the rest of his papers in the Archives Civiles, a large number of these contracts have been preserved. A few contracts survive for the period from 1824 to 1855 for specific items such as repairing part of a roof or building a wall. Large numbers of contracts dating from 1855 on are found in notarial records, particularly triennial contracts for repairs in which are specified all the types of work likely to be required, with descriptions and prices. These documents give information on costs, on the standards of construction expected and on the contractors who were working on military structures.

Documents such as these indicate only what was proposed to be done, or how the building was supposed to be erected. It is important to know whether the building was actually erected, if so whether the plans were followed closely, what changes were made to the plans in the course of construction, and what changes were subsequently made to the building. A number of sources of information exist about the buildings as they were actually constructed. In the first place some of the buildings themselves survive, in some cases more or less intact, in other cases fragmentally, as revealed by archaeological investigation. As many surviving buildings have been altered greatly over the years it is important to know what original fabric remains. Where the portion of the building above ground has disappeared archaeological investigation can reveal much about the foundations and often information about the lower part of the superstructure or paving of walkways or courtyards. Fragments of building materials may be found which can give some idea of what was used or how.

Because of the bureaucratic nature of the military organization, there exist not only extensive planning and construction documents, but also numerous reports on military property at various stations. While these often comprise reports on buildings they do not usually give much information about specific elements. Complaints about buildings are a more productive source of information. They often tell what was wrong with a building, what changes were proposed or made of it, and in what way contractors deviated from their instructions. Contract work sometimes led to disputes between the contractor and the supervising engineers which resulted in considerable correspondence, and at times lawsuits. Such documentation sometimes throws light on the differences in expectations between engineers trained in England and the contractors accustomed to local civilian construction methods and usually knowledgeable about the type of construction most suitable, or at least most common, under local conditions and using local building materials.

Chapter 1

THE BUREAUCRATIC BACKGROUND

"That band of conspirators known as the Respective Officers"

In Britain during the first half of the 19th century, control over the army was divided among several individuals and departments. Because of this divided control the lines of authority at overseas military posts were complicated. At each garrison responsibility for construction or repair work rested with a board known as the "Respective Officers," whom one author described as "that band of conspirators known as the Respective Officers, who represented the obstructive Board, and whose word carried far more weight than that of the General Commanding."[1]

The Secretary of State for War and the Colonies was generally responsible for determining the size of the military establishment and for the conduct of operations in wartime. The Secretary at War, who was the head of the War Office, was responsible for the preparation of the annual army estimates, for military finance and accounts, and for the framing of the Articles of War. The Commander-in-Chief was concerned with discipline, promotion and training in the regular infantry and cavalry. He was responsible to the Secretary at War in financial matters and to the sovereign in matters of discipline, command or patronage. The Lords of the Treasury had control of certain aspects of military policy, because all military administrative bodies wishing to spend funds had to seek authority to do so from the Treasury. Commissariat officers were originally civilian employees of the Lords of the Treasury attached to the office of the local commander of the forces. In 1822 the Barrack and Store Branch of the Commissariat at foreign stations was transferred to the Ordnance Department, a separate entity. The Commissariat was still responsible for various financial transactions.

Only someone like Marlborough or Wellington could make this cumbersome system work and maintain an effective army in the field. During the Crimean War the administrative system broke down completely.

Reform began in June 1854 with the creation of the position of Secretary of State for War, with sole responsibility for war. In December the Commissariat was transferred from the Treasury to the new department. It was not until 1863 that the office of Secretary at War was officially abolished, but the two Secretaryships had in effect been amalgamated since 1855. Various commissions and committees of inquiry were appointed, who studied European military systems as well as that of Britain in order to make further improvements.[2]

Up to the time of these changes the professional branches of the armed forces, the artillery and the engineers, were almost entirely separate from the army *per se*. Control of the artillery and engineers, the supply of weapons and ammunition for the army and the navy, and responsibility for all British fortifications at home and abroad resided with the Board of Ordnance, which was completely separate and distinct from the War Office. At the head of the Board was the Master General of the Ordnance, generally an illustrious and senior army officer, who by virtue of his office had a seat in the Cabinet. The members of the Board, after 1828, were the Surveyor General and the Clerk of the Ordnance, both of whom sat in Parliament, and the Principal Storekeeper. The Surveyor General was a quality control officer. The Principal Storekeeper accepted, stored and distributed the goods after their quality had been verified, and kept account of their use. The Clerk of the Ordnance was the senior financial officer of the Board. The activities of the Royal Engineers were under the supervision of the Inspector General of Fortifications, through whom engineer officers reported to the Master General and the Board. Until the changes of the 1850s the Board of Ordnance was responsible for the construction and maintenance of works of fortification, barracks, and other buildings including the military manufacturing establishments. At each garrison there was a miniature counterpart of the Board, the Respective Officers, consisting of the commanding officers of engineers and artillery, and the Storekeeper, who reported collectively to the Board rather than to the officer commanding the garrison, a frequent source of irritation to the latter.[3] Major administrative decisions were referred by the Inspector General to the Master General and Board of Ordnance through the Secretary to the Board, a permanent civil servant. In 1855, on the death of Lord Raglan, who was not only the Master General but in command of the British forces in the Crimea, the Board of Ordnance was amalgamated with the War Office.

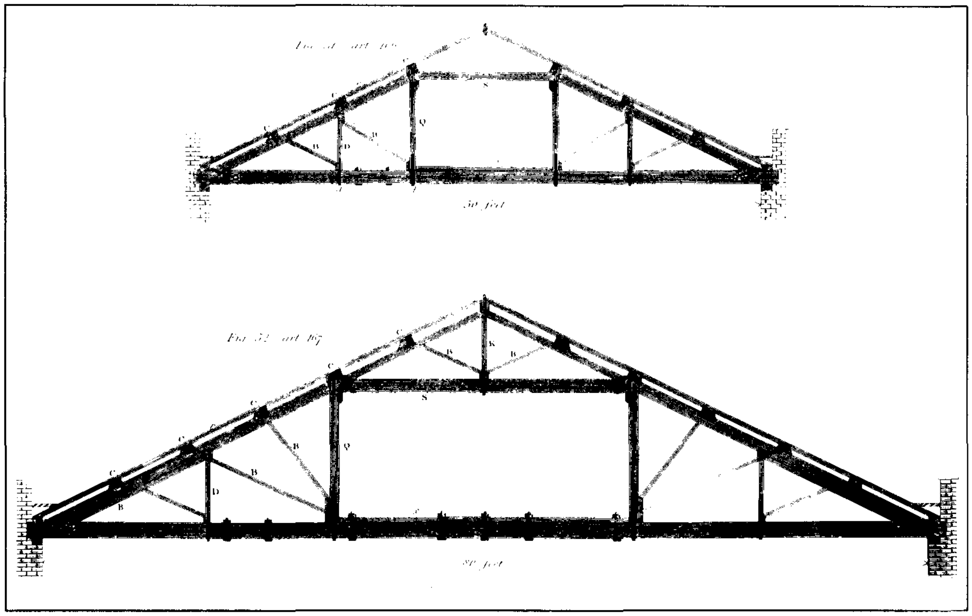
As the Royal Engineers operated under a separate jurisdiction from the rest of the army their training and promotion proceeded along different lines from those of the other branches. In the other branches of the army commissions were generally acquired by purchase. Those intended for army careers might be educated at the Royal Military College (founded in 1801) but such training was not an essential prerequisite for holding a commission. On the other hand, virtually all engineer and artillery officers began their military education at the Royal Military Academy at Woolwich, established in 1741. In 1812 a supplementary establishment, for the instruction of the Royal Sappers and Miners, and junior officers of engineers, in the duties of sapping, mining and other military field work, was set up at Chatham, under the direction of Major Charles W. Pasley. In the early years, instruction at Chatham was confined to matters such as field works, pontooning, escalading and other operations of war, combined with instruction in the various theories of fortification and in practical geometry. In 1826, as a result of the transfer of responsibility for military buildings to the Royal Engineers, the curriculum was broadened to include some instruction in practical architecture. By the 1860s students at Chatham followed a six-month architectural course with lectures on building materials and building trades, the examination of models and drawings of buildings, and practice in drawing up estimates and specifications.[4]

As noted, the problems encountered by the army in the Crimean War brought to light serious failings in every branch of the British army. As a result several Royal Commissions and committees of inquiry investigated specific aspects of army services and various reforms were instituted. Out of these examinations came a recognition of the need for instructing engineers in fields such as heating, ventilation, sanitation and drainage.[5] The education of military engineers continued to reflect changes in the preoccupations of the army, and, to some extent, current practices in civil engineering. In the construction of buildings such as barracks, storehouses and offices, engineer officers followed the same practices as civilian engineers or architects. In the design and construction of fortifications they had, in addition, to take into consideration such matters as new developments in weapons and military tactics.

Officers of the Royal Engineers were frequently called upon to give assistance with the construction of important non-military buildings. There was, however, some criticism of their work as civil engineers.

One anonymous critic complained in 1860 that "there is no body of men who adhere so well to each other in concealing their deficiencies from the authorities and the public as the officers of the corps of Royal Engineers." There was, he said, one civilian employed at Chatham as "Professor of Practical Architecture," but he did not have sufficient opportunity to instruct the future engineer officers in the civil skills expected of them. He felt it unrealistic of the authorities to expect engineer officers to combine a knowledge of military engineering responsibilities such as those necessary in seiges and the duties of civil engineer, architect, and builder. In general, according to this author, civil duties were entrusted to the civilians attached to the department, but when an officer of the Royal Engineers interfered with the civil staff disaster could occur. At Aldershot Barracks, he pointed out, the Royal Engineers had made such a mess of the drainage system that a civilian had to be called in to straighten things out. To prevent this sort of problem he suggested that the civil duties of the Royal Engineers should be turned over to men with practical training in architecture and civil engineering.[6]

A knowledge of the formal and informal education which the Royal Engineers received is important in understanding the preconceptions about architecture and building technology which officers stationed in British North America brought with them and which influenced military construction here. Manuals and handbooks for builders and architects proliferated in the 19th century and many of these were used by the Royal Engineers. For example comments from the Board of Ordnance on an estimate drawn up in Halifax in the 1840s for a garrison chapel referred the local engineer officers to a method of roof construction shown in Tredgold's *Treatise on Carpentry* (Fig. 1). A list of books belonging to the corps library which were in the possession of the Engineer Department in Canada in 1863 included Mahan's *Civil Engineering* (1846), Cresy's *Encyclopedia of Civil Engineering* (1847) and Mosely's *Engineering and Architecture* (1843).[7] Engineer officers were encouraged to keep themselves informed on matters affecting their profession and to continue to broaden their education. For example the Inspector General of Fortifications urged officers of the Royal Engineers to take advantage of the practices carried out by the Royal Artillery to gain information on matters of professional interest to their corps, such as the effect of explosions on embrasures, and the efficiency of magazines and of ventilating systems.[8] There were publications written by and for



1 Plate from Thomas Tredgold *Elementary Principles of Carpentry* (1853) showing roof construction.

engineer officers, through which knowledge gained by experimentation or observation of actual construction was made widely available. The several series of the *Professional Papers* of the Royal Engineers were published more or less annually from 1837 until after 1900. Between 1846 and 1852 there appeared an *Aide Memoire to the Military Sciences*, which was prepared by a committee of engineer officers to serve as a reference work particularly for officers in the field.

Various orders and regulations governed the work of engineer officers. Every engineer officer was required to have a copy of the *Orders and Regulations For the Guidance of the Corps of Royal Engineers and Royal Sappers and Miners* (known as the "Engineers' Code"). Much of this was concerned with the administrative duties of engineer officers: what reports were to be transmitted, to whom, and in what form; how estimates were to be drawn up and what information they were to contain; through what channels materials or services were to be requested, etc. Instructions were also given on various aspects of building. Engineer officers were also informed that they were "bound as far as accords with local and professional duties" by the "spirit and tenor" of the most recent edition of the *General Regulations and Orders for the Army*.[9] On occasion other rules and regulations governing the work of the Royal Engineers were circulated, either when policies were changed or when it was felt that there was a need to remind engineer officers of accepted procedures. In theory engineer officers in the field submitted all reports, estimates and plans for permanent works to the Inspector General of Fortifications and all authorizations were received from him. But in the Canadas at least the custom had developed by the 1820s of submitting plans and estimates to the Commander of the Forces for this approval and signature before they were sent to the Inspector General of Fortifications. Both the Master General and the Inspector General of Fortifications felt that this procedure weakened the control of the Board of Ordnance over the construction of works and buildings in the Canadas. In 1826 a solution was reached: ordnance officers were to submit plans and estimates for new works or alterations to the governor for his comments. Repairs could be carried out without waiting for instructions from the Board of Ordnance, but new works and alterations had to be approved in London before construction began. When the Barrack and Store Branch of the Commissariat was taken over by the Ordnance Department, regulations were issued for the guidance of the Respective Officers in dealing with the activities of this department. Similarly, in the 1840s, when the building of military prisons was authorized, regulations were circulated governing the procedure to be followed before new works or repairs were undertaken or stores were purchased.[10] Regulations regarding the duties of officers of the Ordnance Department, including such things as printed lists of stores and methods to be followed in certain types of construction, were forwarded to the various stations and were expected to be kept on file and updated when necessary.

Certain changes in British policy in the period under study had an effect on military construction in British North America. A drastic reduction in spending on defence after the long struggle against France and the War of 1812 meant a reduction in expenditures on garrisons and fortifications in the colonies. The demilitarization of the Great Lakes by the signing of the Rush-Bagot agreement in 1817 meant that in the event of war with the United States the Canadas would be deprived of their first line of defence against aggression from the south. When the Duke of Wellington became Master General of the Ordnance in 1819 he began to consider the problem of the defence of British North America. The previous year the Duke of Richmond, then Governor in Chief of Canada, had drawn up a report on Canadian defence, which Wellington studied before producing his own memorandum on the subject. In place of naval superiority, which he felt would be impossible to achieve, he substituted a system of strong points and protected supply routes. The key elements in Wellington's plans were communication and fortification. The Treasury granted money for the most urgent projects, fortifications at Québec and Île-aux-Noix and some work on canals, but there was no attempt to implement Wellington's recommendations systematically. In 1825, with the advent of another crisis in Anglo-American relations, the whole problem of North American defences once again came to the attention of the British government. A commission of three engineers, headed by Sir James Carmichael Smyth, was sent to North America to survey the situation. The Smyth report recommended the construction of major fortifications at Montréal, Kingston, Niagara and Halifax and of a canal system linking Montréal and Kingston by way of the Ottawa and Rideau rivers, along with various lesser works. Estimates were drawn up by local engineer officers for the various fortifications and sent to England, but the sum total of these estimates was so great that the government was unwilling to ask Parliament for sufficient funds to carry out all the projects suggested in Smyth's report. Work was, however, begun on the defences at Kingston and Halifax and on the construction of the Rideau Canal. At Montréal works were built on St. Helen's Island to provide a defended supply depot.[11]

Later war scares brought further spending on North American defences. For example, as a result of the Oregon Crisis in the mid-1840s four Martello towers were built at Kingston to protect the entrance to the harbour and to the Rideau Canal. Tension between the United States and Britain during the American Civil War produced another report on Canadian defences, which stated that the defence of the province would require a force of 150 000 men, improved communications and the construction of an elaborate system of fortification.[12] The vast scheme of fortifications which the commission proposed proved much too expensive even to be contemplated by the British government, particularly at a time when economy was the watchword in military planning. Britain was, however, still willing to spend some money on North American defences, as could be seen with the commencement in 1865 of work on forts at Lévis to improve the security of Québec. The new Liberal government which came into power in Britain under Gladstone in 1868 considered that part of the price of freedom for colonies must be the willingness to bear the cost of their defences. At the same time strategic apprehensions about Europe and the uncertain state of Anglo-American relations made the stationing of large bodies of troops in Canada less and less attractive to the British government. In 1870 the Canadian government was informed that all British troops were to be withdrawn except from Halifax. By the following year only the garrison at Halifax remained.[13] Thus ended the major involvement of the Royal Engineers in the construction and maintenance of military buildings in Canada.

Changes in policy relating to army administration also had an effect on military construction in British North America. In the 1830s a royal commission studied the question of military punishments, but it was not until 1844 that the Mutiny Act authorized the use of military prisons.[14] Existing buildings at garrisons in British North America were found to be ill-adapted for conversion into efficient prisons. Subsequently army prisons were erected at Montréal, Québec and Halifax, and cells were constructed or improved at various other posts. Desertion was a major problem facing military authorities in British North America. In hopes of lessening the desertion rate various attempts were made to alleviate the boredom of military life and improve conditions in the barracks. One project designed to promote more constructive use of the soldiers' leisure time was the creation of barrack libraries. From 1838 a charge was included in the army estimates to support libraries at all the principal stations at home and overseas. During the early 1840s barrack libraries were formed at the major garrisons in British North America. Formation of these libraries meant the alteration of rooms and construction of various items of furniture, for which patterns or drawings were often sent from England. As the desire to increase the comfort of the soldiers grew other amenities were added. In February 1858 it was announced that various games would be provided for garrison libraries, and commanding officers were permitted to provide tea and coffee in the recreation rooms. The benefits of these libraries and reading rooms were restricted because of the high rate of illiteracy in the army. Several officers pointed out the limitations of a scheme to establish libraries which included no plans to teach the soldiers to read the books being provided. Regimental schools were begun in 1846.[15] In later years the provision of school accommodation became the subject of various estimates and plans.

The flurry of investigations brought about by the very public chaos of army administration during the Crimean War led to changes in military construction practices. The report of the Army Sanitary Commission in 1857 called for a one-third increase in the minimum amount of space allowed per man in barracks and guard rooms. Urine tubs in barrack rooms were to be replaced by adequate facilities separate from the barracks; needed improvements in water supplies, lighting, heating, ventilation and sewage systems were outlined and the Commission urged the provision of ablution rooms, baths and day rooms. While there was considerable resistance to the changes proposed by the Commission, improvements in barrack conditions were made gradually.[16] This is reflected in the appearance in estimates for military construction of items such as ablution rooms, in the provision of more privies and in an interest in obtaining water from municipal water systems.

Purchasing Policy

As noted above, in the Ordnance Department the Clerk of the Ordnance was answerable for expenditures on supplies, the Surveyor was responsible for quality and the Principal Storekeeper kept a record of the use and service of the supplies.[17] The Board of Ordnance was responsible for policy regarding supplies for the department and certain rules were laid down to govern the purchase of supplies. In 1824 regulations were issued for carrying into effect the transfer of the Barrack and Store Branch of the Commissariat Department at foreign stations to the Ordnance Department, and in this a policy on the purchasing of supplies was stated. If it was necessary to purchase building materials on the spot they were to be obtained through competitive bidding. It was recommended, however, that articles which were produced or manufactured in the United Kingdom not be purchased locally.[18] The instructions concerning the purchase of stores in the Engineers' Code stated explicitly:

> *No stores or other articles are to be purchased at the Station without the Board's sanction, except in consequence of some urgency of the service, which could not be foreseen.*[19]

A Treasury directive of 1818 had established that in peace almost every article of supply purchased by the commissariat should be obtained by competition. This was the policy followed by the Board of Ordnance in its purchases. When goods were purchased they were usually placed in store for future issue and the wants of the department were to be drawn from a reserve.[20] Lists and descriptions of items held in store and information on agreements which had been made with British suppliers of certain articles were forwarded to the foreign stations, and officers of the Ordnance Department were to be guided by these in drawing up estimates and arranging to obtain supplies needed to carry out approved works and repairs.

On occasion the question of local purchase versus supply from England was studied with regard to particular items or particular areas. In 1833 the Clerk to the Principal Storekeeper was requested to report on the expediency of purchasing articles in Canada for the service of the Rideau Canal. He stated that he would have inferred as a general principle any article produced in Canada or its vicinity and requiring little labour to construct could usually be purchased economically on the spot and that articles of British produce or which were manufactured there with skilled labour could be supplied from Britain far more cheaply than they could be bought in the colony. This was particularly because the government was able to obtain cheaper freight rates than private suppliers and the goods were delivered directly to the user without passing through the hands of an agent or dealer. On referring to local prices as listed in the demands for stores sent from Canada and comparing them to the contract prices for these items supplied to the Ordnance Department in Britain, he found that it was indeed cheaper to supply such articles from Britain.[21]

Despite the stated policy of purchasing in England, the cost of shipping bulky articles and the risk of breakage in transporting fragile ones made it financially attractive at times for the Ordnance Department to find local suppliers. This became more and more the case with the growth of local mercantile communities in British North America during the 19th century and the increasing tendency of the Ordnance Department to have much of its construction work done by contract. Lumber, which was available in abundant quantities in British North America, was usually obtained locally even in the early part of the century. At the more remote posts, especially in the period when transportation was difficult and slow and there was no extensive mercantile community in the vicinity, some of the building materials were prepared by military labour. As towns grew up around the more remote posts and as transportation improved and commerce grew in British North America the army increased its purchases from local suppliers.

The lessening of the emphasis on purchase in England, particularly of manufactured articles, can be seen in some of the correspondence between engineer officers at stations in British North America and officials in London. When lists of materials needed for new construction and repairs were sent to London, a reply was sent to Ordnance officials at the local stations informing them what should be purchased locally and what would be sent from England. A cursory survey of these lists shows some changes in supply patterns, and differences also relating to local availability. An 1814 report on a demand for supplies from Halifax authorized the local purchase of glass. In 1822 glass, nails, paint and lead needed for work at St. John's, Newfoundland, were ordered to be supplied from England. Items to be purchased locally for work at Halifax in 1827 included timber, shingles, locks, pitch, tar, brick, gravel and a marble chimney piece. The reason given for authorizing local purchase was the lowness of the local price.[22] A demand for stores and materials for work on the Rideau Canal, sent to England in 1832, included a recommendation that various iron castings be purchased from Matthew Bell's foundry at Trois-Rivières which had in the past provided excellent articles.[23] By the 1840s the Ordnance Department was much more inclined to consider the convenience of local purchases. Evidence of the growing interest in the use of locally obtained building materials and of the need for engineer officers to become aware of the nature of the materials used locally can be seen in the collection of memoranda on the subject of building materials available in Canada prepared at the direction of Lieutenant Colonel Oldfield, the Commanding Royal Engineer in the Canadas and lithographed for circulation to officers of the Ordnance Department in 1841. In 1842 the Commanding Royal Engineer in Nova Scotia was asked by the authorities in London why the greater part of the stores needed in Nova Scotia could not be purchased on the spot as was being done in Canada. It was considered desirable to reduce as much as possible the losses, inconvenience and delays inherent in sending stores from England if similar items of good quality could be purchased locally at a reasonable cost. The Commanding Royal Engineer replied that the only impediment to purchasing locally had been the Board's order accompanying the annual estimate, which specified the items to be sent from England.[24]

Economy was not the only motive leading to the purchase of supplies locally. On occasion it was stated that local articles were better or more suitable. The demand for stores and materials for the Rideau Canal mentioned previously, not only pointed out the excellent quality of the goods to be obtained from Bell's foundry at Trois-Rivières, but it also contained a note that the local cement was of very good quality and could be obtained as required. Much of the emphasis on the quality of goods obtained locally seemed to centre on iron goods. Lt. Col. John By expressed the opinion that the iron from Bell's works was superior to that from England. The Ordnance Storekeeper at Halifax reported in 1829 to the Board of Ordnance that the grates received from England for his residence were incapable of providing sufficient heat. He requested permission to purchase Franklin stoves to replace the grates.[25] In this case the implication was clear that locally produced items were preferable for local conditions, particularly for the climate. One of the chief problems with obtaining supplies from England was the uncertainty of delivery. Throughout the correspondence between local Ordnance officers and officials in London echo complaints about the non-arrival of needed articles. In 1823 Colonel Durnford, writing from Québec, stated that because of the non-arrival of the expected supply of bricks he would have to lay off some men. In 1831 the engineer officer at Saint John, New Brunswick, requested permission to purchase linseed oil, hair and sheet lead on the spot, as these items had not been among the stores sent from England. A report sent from Halifax in 1846 on the effects of the non-arrival of stores ordered from England pointed out the shortness of the working season. One of the items that had not arrived was paint and by the time it did arrive it would be too late to use it, with the result that the work authorized in the estimate would not be completed before 31 March, the end of the financial year.[26] The delays involved in authorizing the expenditure for the service requested, obtaining the necessary items and arranging for their transport (this latter was sometimes a very lengthy process) often proved extremely exasperating to engineer officers in British North America, who saw their short working season slipping away while waiting for the necessary supplies to begin construction or repair work.

The prolonged time lapse between the drawing up of estimates and requests for stores and the arrival of the necessary stores was not the only problem associated with supplying building materials from England by the Ordnance Department. Sometimes the items sent were just not suitable for use in North America. In Nova Scotia and New Brunswick there were problems with nails sent from England for shingling. They were not found suitable and in at least one case the contractor who was supposed to use them bought some locally for the work he was doing and disposed of those supplied to him. The hazards of obtaining supplies from England also included the danger of damage to the goods being shipped. For example, in the 1840s Ordnance officers in Halifax complained of the large amount of breakage among bricks being sent from England.[27] Fragility was a factor favouring local purchase since the merchant bore the cost of breakage in transit rather than the Ordnance Department.

Contracts

As well as a shift to purchasing manufactured articles from local suppliers there was a growing tendency to have much of the work on military buildings done by local contractors under the supervision of the Royal Engineers, rather than by military labour. By the mid-1820s the Ordnance Department was beginning to express an interest in having a good deal of the military construction work in the North American colonies done under contract, and during the 1820 contracts were entered into for various projects. The Commanding Royal Engineer in Newfoundland in 1831 pointed out that obtaining contracts for masons' and carpenters' work, including both labour and materials, might be a way to solve the problems he was encountering in obtaining a supply of good quality building materials.[28] By the mid-1830s the expectation appeared to be that most of the work included in the annual Ordnance and Barrack estimates would be performed by local contractors. For new works precise specifications and plans were usually drawn up before the work was authorized. With this sort of detailed information available contracts could usually be obtained. For smaller works and general repairs, where the details and scope of the work could not be predicted in advance, there were greater difficulties in finding builders willing to tender for the contracts. In 1838 the Respective Officers at Halifax reported on their problems:

> *... there are not at this place any Building Establishments or Trades Sufficiently extensive of possessing the means to undertake the repairs and other casual works the extent of which cannot be foreseen or even estimated, upon the average of former years, sufficiently close to meet their views; added to which the Working Season is so very short in this Climate, that the Trades find full employment for their Men whose wages necessarily fluctuate considerably during that period according to the greater or less influx of Emigrants from Europe or Mechanics from the United States.... In these Provinces the several Trades being conducted with very limited Capital and not upon anything like the extensive Home Scale, contracts of the nature in question can only be obtained for Specific work upon plans and specifications previously furnished: for the Casual Repairs of Works and Public Buildings generally the particulars and extent of which cannot be foreseen or laid down, the Trades will not Tender.*[29]

The situation at other stations appears to have been similar. In 1835 requests for tenders were advertised in Kingston for any glazing which might be needed for the military buildings there. By 1840 the Commissariat Department in Kingston was advertising for tenders for building work and for the supply of building materials for up to three years. Tenders for the whole service were preferred, but it was stated that tenders for specific trades would be considered.[30] With the growth of the building trades in the larger centres it became easier to find contractors. Many of the schedules for Ordnance contracts available for the 1850s and 1860s are for triennial contracts for repairs at the various stations. In these the contractor undertook to do any type of repair work to military buildings which might be needed, with the contractor supplying the workmen in the various trades and the materials they used.

It was not the engineer officers who were directly responsible for obtaining contracts for construction work and building materials. The Commissariat had the responsibility for preparing tenders and contracting for building materials and construction work. The specifications for materials or workmanship were prepared by the engineer officers for the information of the Commissariat, who would then advertise for tenders.

Disputes sometimes arose over the interpretation of the specifications, particularly when the engineer officers were not consulted before a tender was accepted.[31] Under the army reforms of the late 1850s approval of all payments for military services was vested in the Controller of Army Expenditures, who was made responsible for contracts for services or supplies. Requisitions were to be submitted to him by the officer at the head of the branch concerned, whose concurrence was necessary in the selection of a tender for the contract.[32]

Unfortunately the Ordnance Department did not always show that measure of flexibility in its dealings with contractors which was needed if the system of contracting for military construction work was to work successfully. The standards of construction expected by the Ordnance Department were often quite different from those of local builders. In 1822 Patrick Walsh built a storehouse in Halifax for the Ordnance Department. Walsh had difficulties completing this building. He had problems getting the right type of stone, a sudden shortage of skilled masons had increased his costs and he had not realized when he tendered for the contract the greatly increased work involved in laying the stone in courses rather than building uncoursed rubble walls as was usual in Halifax. When Walsh requested payment for his work upon completion of the storehouse the Ordnance Storekeeper refused to pay him. It was claimed that the building had not been completed in accordance with the contract, and because it was not ready in time the Ordnance Department had incurred the expense of hiring storage space. Although it was acknowledged by the Ordnance Department that the storehouse Walsh had built was worth considerably more than the amount of the contract, Walsh was unable to obtain the full payment he felt was owing to him.[33]

One of the chief difficulties encountered by Walsh was that of building according to the specifications set down by the Royal Engineers rather than in the method customary locally. Other contractors sometimes found difficulty in building according to the standards imposed by engineer officers. In the 1840s Messrs. Tully and Miller tendered for a contract to build a sea wall at Toronto for the Ordnance Department. Almost as soon as the tender was accepted by the Commissariat there were difficulties, with the Engineer Department complaining that the contract called for a more expensive type of stone than that appearing in the original estimate. An agreement was reached between the Engineer Department and the contractors, but once construction was under way more problems developed. The engineer officer superintending the work refused to accept some of it and insisted on some portions of the wall being taken down and rebuilt. The contractors claimed that they had to use a more expensive type of stone than that called for in their contract, and eventually they sued for payment for the extra expense involved. Witnesses for the contractors stated that the work as originally done had been a reasonable approximation of the work described by the specifications and that the work as completed exceeded the specifications. Witnesses for the Ordnance Department said that the work as completed was to the specifications and no more. The jury awarded £600 to the contractors.[34] A similar case occurred the following decade in Halifax, when Henry G. Hill sued to recover money expended on building a stone wharf at the Ordnance Yard. On Hill's side it was argued that his failure to complete the contract was a result of government misrepresentation; the argument for the Ordnance Department was the fault lay in the inadequacy of Hill's construction. The jury awarded over £10 000 to Hill.[35] These two cases illustrated the sympathy local jurors tended to show for local businessmen in disputes with officials of the Ordnance Department.

The Ordnance Department at Halifax seemed to be particularly unsympathetic to the problems of local contractors. Messrs. Peters, Blaiklock and Peters, contractors for the construction of the Wellington Barracks in the 1850s, encountered great difficulties in manufacturing suitable bricks for their work. Because of this and other problems they incurred serious losses on the contract. When they submitted a petition in 1859 for some compensation for their losses Colonel Nelson, the Commanding Royal Engineer, wrote to the Inspector General of Fortifications "as far as this Department is concerned, I cannot urge the infraction of the Contract principle though the ruin of these unfortunate men be pretty nearly certain in consequence."[36] Shortly before this the question of compensation for another Halifax contractor for losses he had suffered in carrying out a War Department contract had arisen. In this case the contractor had been informed that his claim was inadmissible.[37]

Engineer officers in the Canadas were sometimes more sympathetic to the difficulties of local contractors. In 1821 Lieutenant Colonel Durnford recommended a payment be made to a contractor at Île-aux-Noix for laying in materials that would have to remain on hand for some time. Large-scale fires particularly in the Canadas led to a heavy demand for skilled tradesmen such as masons and carpenters and for building materials. The resulting escalation in prices and wages greatly increased costs for contractors committed to long-term contracts for work for the Ordnance Department. In 1852 the triennial contractor for work in Montréal asked for a one-third increase in the prices quoted in his contract because of the rise in his costs due to fires. This was recommended for approval by officials in Montréal, who pointed out that a similar indulgence had been granted after the fires of 1845 in Québec. In 1854 the contract painter at Québec asked for an increase in remuneration because of the extraordinary rise in prices. It was pointed out by the Commanding Royal Engineer in the Canadas in recommending a favourably reply to this petition that there had been a very great rise in prices and that this particular contractor had done very satisfactory work for the department.[38]

One difficulty that continued to exist throughout the period under study was a lack of understanding on the part of Ordnance officials in London of the problems caused by local conditions and in particular by the local climate. While engineer officers stationed in North America gradually became aware of the reasons why local builders did things the way they did, they were often unable to convince their superiors in London of the need to adapt their practices to local custom. They pointed out the need to paint buildings more frequently in North America or to improve heating and ventilation of barracks, but often in vain. The ways in which engineer officers followed or resisted local custom can be seen in more detail in the chapters dealing with specific materials.

Chapter 2

THE FOUNDATION AND WALLS — LIMES, CEMENTS AND MORTARS

"For economy, dispatch and military labour the advantage of concrete is undoubted"

Our consideration of the technology of building materials begins with the foundation and walls. Carefully cut and matched stone blocks, laid in even rows, made durable and aesthetically pleasing foundations and walls, but concrete, which was used increasingly in the second half of the 19th century, did not need as highly skilled a workforce for its use. An essential factor in both types of construction is the type of mortar used to hold the stones together. One of the problems in the stabilization of crumbling buildings, and in preservation and in restoration, is that of establishing the composition of the original mortar used by the builders. Various tests of the chemical composition of the mortar seem to be uncertain at best, although some success can be achieved in attempts to establish the hardness of the mortar. It is important to match as nearly as possible the original materials, and therefore it is important to know what type of materials were in use at the time the building was originally constructed. One obvious reason is that of the appearance of the restoration. The finished product will be aesthetically more pleasing if there is not an obvious dividing line between new and old with patches and repairs striking the eye. In more practical terms, if the mortar is of a different composition than the original it will not last as well and may even be the cause of damage to the fabric of the building. If it expands and contracts with climatic changes at a different rate than does the original mortar, it may cause cracking or it may break off. If it is more impermeable than the surrounding building materials, water may be forced out through the fabric of the building and cause many types of damage.

Amongst the great 19th-century advances in knowledge and understanding of the properties of materials, one of the most influential developments related to lime and cement and their application to construction. Many books and papers on this subject appeared in print, including several by Royal Engineer officers. Advances in the knowledge of the properties of limes and cements led to the availability of better quality materials for construction and to changes in the methods of construction. Builders needed an up-to-date knowledge of these developments in order to know not only what types of lime or cement were most readily available, but also what would be the most economical type to use and what type would be suited to any particular structure or location.

As the greater strength of Roman, and later Portland, cements became known in North America, builders and others began to seek suitable raw materials from which to produce good cement locally. The success of these efforts gave builders more types of cements to choose from and tended to lower the cost. Because of the lack of quality control by the producers of cement each batch delivered from the manufacturer had to be tested before it could be used. This is reflected in the emphasis placed on methods of testing these materials in various writings on limes and cements. It is important to consider the part played by the Royal Engineers in the study of limes and cements in order to understand what the average engineer officer would have known about this aspect of building technology. It is also important to know what was available for use at the time.

Early Developments

The Greeks and Romans used limestone mortars and were aware that if certain volcanic earths were finely ground and added to the mixture the resulting mortar attained greater strength on hardening and offered a good resistance to sea water. The water-resistant properties of these mortars enabled the Romans to use them for marine structures such as docks and breakwaters and also for aqueducts. The knowledge of how to produce this type of mortar was lost for several centuries, but by the 17th century the use of volcanic earths to strengthen lime mortar was once more widely known.[1]

Before discussing the experiments with various types of limes and mortars and the developments in their application in the late 18th and early 19th centuries, it is necessary to define the terms used. Cement is basically a substance used to bind other materials together, usually applied as a soft paste and allowed to harden. In building, the primary component of all such substances and compounds for binding together bricks or stones or other similar materials is lime. To obtain lime for building, one of the naturally occurring forms of calcium carbonate, such as limestone or chalk, is broken up into lumps and burned in a kiln at about 900°C to drive off the carbon dioxide and convert the rock into quicklime.[2] Slaking is the process of chemical combination of quicklime with water to form a hydrate of lime. This is usually done by sprinkling water on the quicklime. When purer limes are slaked they increase greatly in bulk, produce heat and then fall into a powder. Roche or roach lime is another term for unslaked lime.

For construction purposes lime is mixed into a paste with sand and water to form mortar. Mortar is used in brickwork or masonry to bind the bricks or stones together and to form a soft resting place in which to bed them. Grout is a mortar which is sufficiently fluid to penetrate the interstices and irregularities of the interior of brick or rough stone walls and fill the spaces not reached by regular mortar. The injection of grout is often used as a modern restoration technique. The term grouting is used to describe the process of using grout. Concrete is an artificial compound in which mortar is used as a matrix to bind together an aggregate such as broken stones or tiles.

The properties of the lime, and thus of the mortar for which it is used, depend upon the efficiency of the burning process and the composition of the raw materials. Earlier lime kilns tended to burn the lime unevenly, leaving portions of unburnt lime. This unburnt lime had to be guarded against by those using the lime for mortar or other purposes, as its inclusion weakened the mortar. Limes themselves are divided into classes according to their relative purity. Fat limes or rich limes are obtained from nearly pure carbonate of lime containing from one per cent to six per cent of impurities; poor limes contain a higher degree of impurities. Neither poor nor fat limes will provide much strength in works of any thickness as they will only harden properly when exposed to the atmosphere. A crust soon forms on the outside of the work which prevents the mortar that it covers from setting properly. Hydraulic limes are those which will harden under water or out of the atmosphere and which will resist the action of water. These limes contain a considerable amount of certain types of impurities. Hydraulic limes are divided into slightly hydraulic, simply hydraulic and eminently hydraulic, depending on the amount of impurities and the amount of time it takes a mortar made from the lime to set under water. Among the best hydraulic limes used in England in the late 18th century were blue limes, which were argillaceous or clay-bearing limes such as Aberthaw Lime.

In engineering today the term cement, when used without qualification, means Portland Cement. This is produced by burning an intimate mixture of lime and clay at a sufficiently high temperature to fuse them together. Formerly the term cement was used to refer to very hydraulic lime (containing about 50 per cent of impurities) or to artificial compounds of lime and other substances used to give hydraulic properties to the resulting mortar. Hydraulic limes, as opposed to true cements, contain a good deal of uncombined lime and must be slaked before using.

There was a pressing need in the mid-18th century for a quick-setting, hard mortar for use in structures exposed to fresh or salt water. In work on the design of a new lighthouse for the Eddystone Rocks in the 1750s, John Smeaton found that limestones producing a good water lime contained a considerable quantity of clay and when burned crumbled into a buff-coloured powder. Having found that a blue lias limestone produced the best hydraulic lime among the varieties he tested, Smeaton then experimented with various additions to this lime for making mortar. For the Eddystone Lighthouse he used a mortar compounded of equal portions of the blue lias lime and of pozzolana.[3] Smeaton's Eddystone Lighthouse stood for well over a century; by the time it was replaced, although its foundations had become somewhat undermined, the mortar had not been seriously affected by the action of the sea.

With the Industrial Revolution the need for a dependable hydraulic mortar increased, because of the demand for the building of canals, bridges, tunnels, docks and harbours, which required cements which would resist the penetration of water. In 1780, Bryan Higgins published his *Experiments and Observations ... with ... Calcareous Cements....* Higgins did not realize the importance of clay in giving hydraulicity to lime, but several observations from his experiments continued to be of value. He saw that the thorough burning of the lime was of the utmost importance;

and he also stressed the great importance of keeping the lime from exposure to the air once it was burned.[4]

Inspired perhaps by Smeaton's work, James Parker discovered in 1796 that by burning nodules of argillaceous limestone at a heat higher than that commonly used for burning lime and then grinding them to a powder, he could produce a cement that set rapidly even under water. Parker patented his discovery and sold it as "Roman Cement." It soon became popular for use in various engineering projects. The Roman Cement industry became mainly centred at Harwich. The cement was in such demand that the removal of vast quantities of material from the foreshore at Harwich — over a million tons between 1812 and 1845 — led to a government regulation in the latter year prohibiting the digging of stone within 50 feet of the cliffs.[5]

Experimental Work on Limes and Cements to 1870

The 19th century saw great advances in scientific knowledge and the application of this knowledge to practical purposes. In the case of limes and cements much experimenting was done in order to understand their properties and to find the best ways of utilizing the products available and of producing stronger and cheaper materials. Parker's Roman Cement was superseded by Portland Cement, which by the latter part of the century had become the standard cement for use in construction. Improvements in cement also led to a greater use of concrete and to later developments in the field of reinforced concrete, which lie outside the scope of this study, but were to have great implications for the construction industry in the 20th century.

Early in the 19th century a French engineer, Louis Joseph Vicat, began to study the properties of limestone in a search for a cementing material that would harden under water. Vicat found, as had Smeaton, that all lime which could be called hydraulic contained a certain quantity of clay. Proceeding further from this he reached the conclusion that it was the silica of the clay that was essential to the hardening process. Vicat found that he could produce a hydraulic material from a non-hydraulic lime by calcining an intimate mixture of chalk and a suitable clay.[6] The results of his researches were published in 1818 and 1828. An English translation of Vicat's second treatise by Captain J.T. Smith of the Madras Engineers, with additional notes by the translator, was published in 1837. Joseph Aspdin is generally credited with the invention of Portland Cement as we know it today. His 1824 patent for a carefully proportioned mixture of limestone and clay, which he calcined and ground to a fine powder, introduced the product, so-called because of its resemblance to a building stone quarried on the Isle of Portland. By 1828, Aspdin's Portland Cement was sufficiently water-resistant for Brunel to use for the Thames Tunnel. Isaac Johnson's experiments in the 1840s led to improved proportions for the lime/clay mix and a discovery of the correct temperature needed to vitrify the material without overburning. His company began to produce the first truly reliable Portland Cement. By the late 1850s its reputation as a reliable construction material was established.[7]

While manufacturers were developing stronger limes and cements, engineer officers began to take an interest in the changes in these materials and in the best way of using them. Some of the Royal Engineers began to keep records and exchange information on their experience with various mortars and cements in building. Captain Smith, who translated Vicat's work, had added there comments reflecting his experience and observations in construction work in India, and at Chatham, Lieutenant Colonel Pasley was carrying out experiments with water cements. In 1826, when the study of practical architecture was added to the course followed by engineer officers at Chatham, Pasley prepared an "Outline of a Course of Practical Architecture," as a basis for this study. In this work he summed up the existing state of knowledge of the various aspects of construction but, considering his own knowledge of the subject limited, he solicited advice and suggestions from his brother officers. The treatise dealt with both limes and cements and with "grouted gravel" (concrete), including the use of the latter material by Sir Robert Smirke for foundations in works such as the Millbank Penitentiary. Continuing his experiments with various types of limes, by 1830 Pasley considered that he had found an efficient water cement which could be produced on a large scale. In that year he prepared a pamphlet on the natural water cements of England which he sent to all Royal Engineer stations at home and abroad and to various stations in India. In May 1836 he began publication of *Observations on Limes, Calcareous Cements, Mortars, Stuccos and Concrete*, which was completed in the fall of 1838. As well as describing in detail his own experiments with these materials, Pasley tried to point out to his readers methods by which they themselves would be able to decide between the various sorts of calcareous mortars and cements available to them for construction purposes. He also included instructions designed to help engineer officers or others stationed or exploring abroad to judge the value of any calcareous rock that they discovered. Pasley felt that the government policy of advertising for tenders for building materials and accepting the lowest tenders tempted some suppliers to submit impossibly low tenders and then endeavour to pass off an inferior or adulterated article; therefore he included rules for judging the quality of a cement offered for sale and for ascertaining whether it had been adulterated. He concluded with an appendix containing an abstract of the writings of the most notable British and foreign authors on the subject of limes and mortars.[8]

The chief focus of Pasley's work was directed to those actually engaged in construction, particularly officers of the Royal Engineers who might, while still relatively inexperienced, be in charge of important buildings in situations where they were far removed from any help or advice from senior officers. At this period the officers of the Royal Engineers were becoming increasingly aware of a need to keep informed of new developments in engineering and to have some means of sharing the results of their own experience. One consequence of this recognition was the publication of *Papers on Subjects Connected with the Duties of the Corps of Royal Engineers* (subsequently referred to as *Professional Papers*), which began in 1837 and continued under various titles throughout the 19th century. Engineers of the East India Company were also invited to contribute to these papers, resulting in the presentation of a wider variety of experience. The first volume contained several papers on the use of concrete. Lieutenant William Thomas Denison in his "Notes on Concrete" discussed the employment of a mixture of lime and gravel for foundations in situations where, because of the nature of the soil, precautions against settlement were necessary. Stressing the need for sand in the mixture and outlining how the concrete should be mixed, he raised the question of whether common lime would do for foundations in damp soil.[9] In another paper in the volume Denison described the method used in underpinning the storehouses in the Chatham Dockyard with concrete. Denison's paper was followed by one dealing with a concrete bombproof casemate, built at Woolwich in 1835 to determine the resistance of concrete to mortar and cannon fire. The concrete used for this arch had been composed according to a method patented by a

Mr. Ranger, which combined gravel, sand, Dorking lime (a slightly hydraulic lime), and boiling water. After hardening for two months the casemate was subjected to firing by cannon and mortars at a distance of 500 yards; it was considered that the structure could still have been used to house powder after the bombardment. As, however, the penetration of the shot into the piers had shown that the interior was still damp, it was concluded that concrete in large masses would take a very long time to dry. The report on this structure stressed the economy of using concrete, which in foundations could be formed at one-third and in arches and walls at less than one-half the cost of brickwork, and recommended the adoption of concrete for small magazines and casemates.[10] The final paper on concrete in this volume was one by Lieutenant Colonel William Reid on a concrete sea wall at Brighton. Once again the lime used was only slightly hydraulic and as a result the concrete did not harden sufficiently to withstand the action the of sea.[11] Later volumes of the *Professional Papers* continued to reflect the interest of the Royal Engineers in experiments with concrete and with various limes and cements.

In North America as well as in England the era of canal building created a need for a hydraulic mortar. One of the most important projects begun soon after the end of the War of 1812 was the Erie Canal. Canvass White, one of the engineers working on this canal, had gone to England to observe canal building there. Having been impressed by the British use of hydraulic cement in canal construction, but finding this material very expensive to import, White began to explore the area along the route of the Erie Canal. In 1818 he discovered at Chittenango, N.Y., a limestone rock suitable for making hydraulic cement, which was used for the masonry of locks and aqueducts on the Erie Canal.[12] After the War of 1812 there was also a considerable interest in canals in British North America, where the military were particularly concerned with developing an alternative to the St. Lawrence system for communication between Upper and Lower Canada. In addition to canals constructed along the Ottawa River, the Rideau Canal, connecting Ottawa and Kingston, was built between 1827 and 1832 under military supervision and with British government funds. Because of the lack of a local hydraulic lime and the high cost of importing Harwich Cement, the decision was made to use lime mortar for laying the stonework of the locks and Harwich Cement only for pointing. Ruggles Wright, one of the contractors working on the canal, saw the need for a cheap, easily obtained, hydraulic lime, and he began to look for a suitable stone. In the summer of 1829 Wright sent to Colonel Durnford, the Commanding Royal Engineer in the Canadas, a specimen of what he believed to be a water lime, with the request that Durnford test it and suggest the best method of manufacturing cement from this rock. By the following year Wright was offering to supply up to 2000 bushels of water lime to the Royal Engineers at 5s. 6d. per bushel (price of the barrels not included). Wright's Hull Cement replaced Harwich Cement for pointing the stonework of the locks and was used to lay the stonework of some of the Entrance Valley locks and to grout the masonry of those already built.[13]

The need for locally available, cheap supplies of rock which would produce hydraulic mortar was a continuing one. Pasley's writings on cements and mortars stimulated engineers at posts abroad to experiment with local rock in hopes of finding some which could be used to produce hydraulic limes or cements. At Québec in the 1830s Lieutenant Frederick Henry Baddeley was working with the black rock of Cape Diamond in hopes that from it he could make a hydraulic mortar. The chemical properties of this rock led him to suspect that it was the type of rock he was looking for, but his first experiments were unsuccessful. From Pasley's writings on "water cements" he learned of the need for the calcined rock to be pulverized into as fine a powder as possible. Once he observed this precaution Baddeley was able to produce what he considered a useful "water cement." Experiments were carried on at Québec to test the relative strengths of the Quebec Cement, Harwich Cement and that from Hull, and the results were reported in the *Professional Papers* in 1839. The Harwich Cement was found to be the best, followed by that from Hull. The chief advantage of the Quebec Cement was its availability on the spot, which made it attractive for any work not requiring a quick-setting cement. Samples of the rock were sent to England for further tests by Colonel Pasley. On first testing some of this Pasley found that mortar made from it would not set under water. After further tests he discovered that if allowed to set in air, some of the samples produced very good water cements. Baddeley's work led Pasley to re-evaluate the slower setting cements and to conclude that these were not without value in situations where they would not be immediately exposed to water. The Commanding Royal Engineer in Canada recommended that some funds be granted to Baddeley to allow him to continue his work, but not only was this not done, the Inspector General of Fortifications refused even to recommend payment of the expenses already incurred in the work. This was ostensibly because Baddeley had patented his discovery and presumably might be expected to profit from it. Baddeley, however, stated that he was quite willing to let the Board of Ordnance manufacture his cement without payment to him, and he does not indeed seem to have derived any benefit from his discovery.[14]

Despite the refusal of the Board of Ordnance to reimburse him for the expenses he had already incurred Baddeley continued his search for good local hydraulic limestone, and on his transfer to Kingston began to investigate the rock there. In 1837 specimens of rock from Kingston were sent to Pasley, who found that the "Kingston cement," though it did not go to pieces under water like common lime, did not set or harden properly when immersed. He considered that it should not be used for works of any importance exposed to the action of water and agreed with the decision not to employ this cement for work on the Rideau Canal. He found it to be not merely a slow-setting cement, but a badly setting one. In certain circumstances, however, and where no other cement could be obtained, Pasley was prepared to condone its use.[15]

While the Board of Ordnance did not show much enthusiasm or encouragement for Baddeley's experiments to find rock which could be used to produce hydraulic limes, it did take some interest in determining what cement was available in Canada. In the early 1840s the Commanding Royal Engineer in Canada, responding to the Board's instructions, ordered an investigation into the nature of cement manufactured in the country. He found that the only cement actually manufactured in Canada was that produced at Hull, which had the disadvantage of taking much longer to harden than Harwich Cement. He considered this a point of great importance in the case of work on the Ordnance canals, where, in order not to interrupt the navigation, the water had to be let into the locks while the masonry was still being pointed and grouted. Also being used for public works in Canada was a cement made in New York State called Rosendale Cement, but it was not as dependable as Harwich Cement. No mention was made of Baddeley's Quebec Cement, which apparently was not in use at this time.[16]

Although no one in British North America seems to have followed up Baddeley's work there was still an interest among engineer officers in studying the uses of cement and concrete. In 1852 Captain F.C. Hassard reported on the use of concrete blocks for a breakwater at Aldernay, where both Portland Cement and Aberthaw Lime blocks had been used. While the lime blocks were allowed to set longer and the cement blocks had a larger proportion of aggregate, both appeared to withstand the action of the sea.[17] The following year Captain H. James published a description of works erected at Plymouth Dockyard where concrete had been extensively used for backing; one of the plates accompanying the article showed the use of concrete for a foundation for the North Sea Wall and for a backing to the wall.[18] The writings of the Royal Engineers on limes and cements up to the late 1850s indicate mainly an interest in already established uses of these materials and their performance under various conditions.

While other engineer officers were observing cement as it behaved in use, Captain Henry Scott was endeavouring to find subsitutes for materials currently being employed. While stationed at Gibraltar in the 1840s Scott had been impressed by the need for a stronger cementing material. Upon his return to England he carried on experiments in an effort to find a method of producing a good hydraulic lime. He found that by subjecting lime in a heated state to the fumes of sulphur he could produce a substance which, when combined with water, hardened to a rock-like consistency. When he was posted to Chatham in 1855 Scott was given charge of the chemical laboratory where he continued to experiment with limes and cements, eventually producing a material considerably stronger than the hydraulic lime then in use for most government work and much less expensive than Portland Cement. Scott's Cement, which he patented, was recommended for mortar and plaster and for use in making concrete. In a series of evening lectures given at Chatham and published in 1862, Scott discussed his work and that of earlier writers on limes, cements and mortars. At the same time he gave several practical suggestions for each of these substances — what criteria should be laid down for the sand and the lime or cement to be used, what proportions of ingredients worked the best in various situations and how they should be measured, how best to mix mortar, and how it should be applied.[19]

Unlike his predecessors Scott was willing to question the conclusions reached by Colonel Pasley in his work on limes and cements. He condemned the use of chalk lime mortars in any situation as they would never achieve a sufficient degree of hardness or adhesion. Scott also began to question the action of sand in mortar. It had been assumed that a chemical combination between the lime and the sand gave strength to the mortar, but Scott found that sand, while it prevented cracks from shrinkage or drying in plaster or coatings of mortar, weakened the mortar in heavy structures. Pasley had noticed that sand weakened the cement with which he was experimenting and had concluded that because of this cements should not be used for concrete. Because of the weakness of the concrete he was able to produce, Pasley had also concluded that concrete would not be suitable as a replacement for masonry and brickwork. Scott, experimenting with his own and with Portland Cement, found that with these the loss in strength caused by an increase in the amount of sand was not nearly so great as in the case of Roman Cement, which Pasley had been using. In the early 1860s both Scott and Captain Francis Fowke were urging that concrete should be used in the construction of fortifications. Because masonry was expensive, requiring skilled labour and considerable time, masonry construction was being kept to a minimum, with earthworks often being substituted in its place. Fowke and Scott argued that concrete could be used instead of stone in construction of casemates, magazines and revetments, with a saving of time and money and the utilization of a higher proportion of unskilled labour. Although a fortress with concrete revetments was built at Newhaven, Sussex, in 1865 this was an isolated case, and it was not until after 1870 that large scale utilization of concrete for fortifications became common in Britain.[20]

In British North America, too, the 1860s saw some use of concrete for fortifications. At Halifax in the 1860s the Ordnance Department was carrying out large-scale improvements in the defence system including the mounting of heavier guns in many of the batteries. The Royal Engineers found that they had to replace the concrete foundations for gun platforms built at some of the forts several years earlier because the concrete, being made of lime rather than cement, had not set properly.[21] Between 1862 and 1865 the use of cement concrete in the construction of fortifications was tried at Halifax and the results observed. Because of the difficulties with the hardening of lime mortar, its use for any substantial work was being abandoned in Nova Scotia. Although cement was more expensive it was successful. Problems encountered in storing the Portland Cement imported from England, particularly over the winter, led to the suggestion that American Cement be tried, but specimens of that cement were found to be unsatisfactory. Concrete was used in the mid-1860s for gun foundations, escarpment walls, in place of brick arches in galleries, and for expense magazines, at Fort Charlotte, Fort Ogilvie and York Redoubt. Its use on a large scale was resorted to because of a lack of skilled labour for masonry construction, and it proved quite successful. The Commanding Royal Engineer in Nova Scotia reported that while with ample funds and skilled workmen he would prefer masonry, "for economy, dispatch and military labour the advantage of concrete is undoubted."[22]

At Québec there was renewed interest in the use of the local rock to produce cement by the 1860s. Although Baddeley had patented his discovery while he was in Québec, a M. Gauvreau had taken out a patent in the 1850s for the same material and had commenced manufacturing it. When new fortifications were planned at Lévis, across the river from Québec, the use of locally produced cement was considered. Having been assured that because of Baddeley's earlier patent, Gauvreau did not have an exclusive claim to the production of this cement, both the contractors for the work at Lévis and the Royal Engineer Department began manufacturing the cement. The major use of the cement at Lévis was in place of lime mortar in situations such as arches where strength was particularly needed. Cement concrete was also used along with asphalt for weatherproofing.[23] There does not, however, seem to have been the same interest in cement concrete as a replacement for masonry or brickwork in fortifications at this time as was shown in Nova Scotia.

The work being done with cement in Halifax and Québec reflects the interest that the Royal Engineers took in this subject. The reports on the work at Lévis show a continuation of the earlier concern for making use of concrete for waterproofing, often in conjunction with asphalt, which seems to have been considered by many senior engineers the sovereign remedy for any problems of dampness or leakage. The reports from Halifax on the use of concrete in fortifications show the engineers there to be ahead of the mainstream of British military construction.

Limes, Cements and Mortars in Use in British North America

In studying the employment of limes and cements by the Royal Engineers in British North America some evidence can be gleaned from examining the structures themselves where they have survived either as a whole or in part. Where the portions of the buildings above ground have disappeared, archaeological investigations can reveal much about the foundations and often information about the lower part of the superstructure or paving of walkways or courtyards. Brick or masonry walls still standing may yield evidence of the type of mortar and how it was used, but restorations or repairs of the fabric of the buildings will often have obscured or covered up the original construction details.

Mortar was important in the building of all but the most insubstantial structures. The essential ingredient in mortar is lime, either hydraulic or non-hydraulic, or cement. An analysis of the frequency with which the different types of limes and cements are mentioned in requests for building materials reveals certain patterns in the period under study. The development of stronger hydraulic limes and cements has been discussed above and as shown there the practice of the Royal Engineers in British North America to some extent reflected technological developments in Britain. At the beginning of the 19th century the standard material used in the making of mortar was roche lime or ordinary ground lime. Knowledge of Smeaton's work with hydraulic limes was only just becoming widely available, and Parker's Roman Cement had been patented just before the turn of the century. The Royal Engineers continued to use ordinary lime for mortar throughout the period under discussion, though to a much lesser degree by the end of the 1860s. By this later period lime mortar was not used in situations where it would be exposed to the action of water, or even, at least in Halifax, in any heavy structure. Hydraulic lime began to appear in estimates and specifications in the 1840s. References to it are found mainly in documents relating to work to be done in Canada, with almost no mention of it for use in military construction in Halifax. The use of hydraulic lime was never very extensive.

Several types of cement were used by the Royal Engineers. The earliest mention of cement found in the records relating to military construction in British North America is a request from the Engineer Department in Newfoundland for supplies and stores needed for 1811, which includes an entry for five casks of Parker's Roman Cement to be used for water works. In 1813 Harwich Cement was supplied to Nova Scotia as requested for work being done there. The previous December a report on the properties and uses of Harwich Cement had been sent to the Commanding Engineer at Halifax. He had obviously taken this to heart.[24] These two instances are most unusual as there are no further suggestions of the use of cement in this area for almost 20 years. The greatest use of Harwich and Roman Cement occurred in the 1840s. These two types of cement virtually disappear from estimates and specifications by the end of the 1850s. Some references occur to the use of locally produced cement, particularly in the 1860s. In some cases references to cement do not specify the type, which may also indicate the use of a local product where it was available. As local cements improved in quality and decreased in price in comparison to the imported varieties, it is likely that they were employed where possible in work done under contract. Beginning in the 1840s some use was made of American Cement, which was limited mainly to Canada, as in Halifax it was considered to be unsatisfactory.[25]

By the late 1850s Portland Cement, now the normal basis for concrete or mortar, had established itself as a standard construction material. Though the Royal Engineers showed some interest in its use, it was some time before it superseded other cements for military construction. A report on work done at Portsmouth in 1848, in which Portland Cement was used with great success for stonework below high tide level, was circulated to senior officers of the Royal Engineers for their information and guidance.[26] Despite this seeming encouragement of the use of Portland Cement the authorities in London were obviously not prepared to see it adopted at once by engineers in the field. The officer commanding the Royal Engineers in Halifax, impressed by the successful use of Portland Cement by private individuals in situations where it was exposed to the actions of dampness and frost, requested a supply of Portland Cement for works to be carried out in 1851-52. When this request was forwarded to England it caused considerable stir, the cement "being a new article hitherto unknown to the Service." Before finding a supplier, the Inspector General of Fortifications felt it necessary to refer back to Halifax to ascertain why Portland Cement was being requested, with the result that the cement did not reach Halifax when it was needed.[27] By the 1860s Portland Cement was extensively used in Canada as well as in the Maritimes. At Halifax there was large-scale use of Portland Cement concrete, although it was not generally employed in England for fortifications until the following decade.

When studying the use of lime and cement in military construction in British North America an important consideration is that of supply. Where did the Royal Engineers obtain lime or cement? How was it packed and transported? How much did it cost? To what extent was the choice between local purchase and direct importation of materials dependent on the availability of local supplies, on cost, on the preferences of the engineer on the spot, or on the policy of the Supply Department? Changes in building technology often meant changes in the source of supply for building materials, as there was often a time lag between the appearance of a new material or design of article in England and its availability in British North America. When Harwich and Roman Cement and later Portland Cement first came into use by the Royal Engineers, they had to be supplied from England, as it took some time for local cement industries to develop. By mid-century natural cement plants were being established in the Canadas and on the eastern seaboard. But it was not until near the end of the century that the manufacture of Portland Cement was undertaken on a large scale in Canada. As with other building materials the use of locally purchased supplies of lime and later cement increased over the years.

It was a relatively simple matter to construct a lime kiln to produce lime for mortar wherever suitable rock was available. Hydraulic limes and natural cements were not as readily available as ordinary lime and required more careful handling to produce a material similar in quality to that which could be obtained from England. The manufacture of artificial cement needed controlled conditions and a considerable outlay of capital.

At St. John's there was an Ordnance lime kiln for many years. In 1811 a Mr. Winter requested the grant of a piece of land on the south side of King's Road in St. John's, opposite the Ordnance lime kiln, in order to build a lime kiln there. Because the Ordnance Department wanted to use this land to store limestone for its kiln Mr. Winter was not able to build a kiln where he had wished. In 1831 more than 44 tons of limestone were burnt in the Ordnance lime kiln in St. John's, producing 1049 bushels of lime. Lime from the Ordnance kiln supplied not only the Ordnance Department but sometimes civilian builders as well. In early 1831 a Court of Inquiry was held at St. John's to investigate the state of the Ordnance Service and the Engineer Department in Newfoundland. One of the witnesses stated that in the previous decade it had been the practice to lend lime from the kiln and to receive in return various other materials that were not in store or that the Department was not allowed to purchase. As long as the Ordnance Department in St. John's had limestone to burn in its kiln the price of lime remained relatively low. But, since a large amount of limestone was provided for the new Government House in the late 1820s (because of the poor quality supplied by the contractor), by the summer of 1831 supplies of limestone were low and the price was rising. Major Oldfield, the commanding engineer in the district, suggested that limestone could be brought out as ballast by vessels proceeding to Newfoundland with little expense to the government. The response to this letter was, however, that "if St. John's is so thriving a Place as is represented and the facility of importing limestone as great it is to be presumed that individuals will undertake to furnish it." Oldfield considered that the likelihood of his being able to contract for good lime was very small.[28]

In Québec lime was locally supplied by contract by 1821. Difficulties were encountered, as the contractor was not able to supply lime in sufficient quantities for the needs of the Ordnance Department, and arrangements had to be made to secure an additional amount from another supplier, a Mr. Cannon. When more lime was needed, a further supply was obtained from Mr. Cannon. Unknown to the engineer officer who issued the order for the purchase, this considerably exceeded the amount Cannon had originally agreed to supply, and for it he charged a higher price than previously. Although two respectable tradesmen certified that Cannon's charge was reasonable, the Commissariat, which was responsible for the purchase of supplies, objected to the cost.[29] This illustrates well one of the problems caused by the division of functions between the engineers, responsible to the Board of Ordnance, and the Commissariat, responsible to the Treasury. It was not until the reforms of the 1850s that the responsibility for supply and transport for the army were transferred from the Treasury to the War Office.

Lime was supplied by contract at Halifax. In the mid-1830s it was proposed that the Engineer Department construct its own lime kiln, because of the poor quality of lime supplied by the contractors. But Lieutenant Colonel Rice Jones, Commanding Royal Engineer in the district, felt that the cost of building a lime kiln would be greater than could be justified, as lime could be procured in Halifax or obtained from New Brunswick at a reasonable price.[30] The general policy in New

Brunswick as well as in Nova Scotia seems to have been to obtain lime from local suppliers. This seems also to have been the case in Kingston, where various advertisements from the Commissariat for tenders for the provision of lime as well as other building materials appeared in the local newspaper, despite the existence of a government lime kiln, which was operated under contract.[31]

The gradual introduction of the use of the hydraulic limes and cements posed new problems of supply. The tendency at first was to import these materials from England on the rare occasions when their use was considered desirable. As has been seen, early 19th-century requests for Harwich and Roman Cement for works in Halifax and St. John's were filled in London, and cement requested thereafter continued to be shipped from England. When the Engineer Department at Halifax requested a supply of Portland Cement in 1851, an English supplier had to be found, and a contract was entered into with Messrs. White & Sons to supply this material. In 1859, some Roman Cement, which had been sent to Halifax by error the previous year, was shipped to the Military Storekeeper at Bermuda, where it was apparently more acceptable. By the 1860s, Portland Cement for use in Nova Scotia and New Brunswick was generally obtained from Halifax suppliers, though when the price at Halifax proved particularly high it was still shipped by the War Department from England.[32] In the mid-1860s the Engineer Department at Saint John was trying to obtain good cement at a low price. Although cheap American Cement was obtainable locally they did not consider it strong enough. Finding it cheaper to import cement directly from England than to obtain it from Halifax suppliers, they made arrangements to purchase a supply from Messrs. Buchanan & Sons of Southampton.[33]

When cement came into use in the Canadas, various efforts were made to avoid the difficulties and expense involved in shipping it from England to the Engineer Department in the colony. It was suggested in 1832 that the Roman Cement stone might be sent out unmanufactured for use at Kingston and be burnt and ground there. While conceding this possibility, Lieutenant Colonel Nicolls, the Commanding Royal Engineer in Canada at the time, considered it preferable to find stone of a similar nature in the Kingston area. Although the rock which was tried at Kingston produced a very inferior type of cement, the ease and cheapness of the supply made it attractive for building use. In the construction of Fort Henry cement was manufactured from stone uncovered during the excavation of the ditch. This cement, however, did not prove very satisfactory, and in some work done in Kingston in the 1840s, for example the Murney Tower, hydraulic cement was imported from the United States. Despite Baddeley's discovery of the hydraulic properties of the Quebec Rock, Harwich Cement continued to be imported from England and was long the favourite cement for military construction at Québec and Montréal.[34] By the 1860s some locally produced cement was being used at Québec, but the supply of this was not always adequate. The contractors engaged in building the fortifications at Lévis, enquired in the fall of 1865 how much of the work was intended to be built in cement. If large quantities of cement were to be used they wanted to be able to make arangements to obtain a supply for the following spring, as there was insufficient locally manufactured cement to meet their needs. The Engineer Department at Quebec at this time was obtaining both Portland and Rosendale (American) Cement by contract from Messrs. Richard & Co., but the contractors were unable to supply the quantity required and what they did provide proved unsatisfactory. Because of this the Engineer Department decided to purchase cement wherever it could be obtained, probably Quebec or Hull Cement.[35]

Price was an important factor in influencing any decision on what type of lime or cement would be used in construction and where it would be obtained. It is difficult to compare prices at various posts and at different times because the units of measurement differed. Some trends in prices can be traced, however, as can some of the occasions on which prices influenced the choice of material or source of supply. At the beginning of the 19th century lime, which cost approximately 5s. per bushel at St. John's, could be obtained in England at half that price. Even allowing for the cost of transportation this price differential made it preferable to send lime needed for military construction from England rather than to purchase it locally. By the early 1830s the average market price for lime in St. John's had fallen to 1s. 9d. per bushel, with lime from the Ordnance lime kiln even cheaper, but as the supply of limestone decreased the price began to rise, leading to suggestions that the Ordnance import unburnt lime.[36] Between 1810 and 1814 the price of lime in Halifax rose, but by 1822, at the depth of the post-war depression, it had fallen to considerably below the 1810 level. By the end of the decade the price had risen again slightly. In 1831, when Harwich Cement was beginning to come into use in Halifax, the Commanding

Royal Engineer estimated that this material could be obtained in England and shipped to Halifax at half what it would cost to purchase it locally.[37] By the mid-1850s, while the price of cement purchased locally in Halifax had decreased, it still cost twice as much as lime. In December 1863 the Commanding Royal Engineer at Halifax proposed obtaining Portland Cement from England. In reply he was told that as at that season Portland Cement could not be sent from England to Halifax at a cost of less than 5s. a bushel, he should continue to obtain it locally, where the price was lower. There appears to have been a considerable fluctuation in the price of cement in Halifax in the 1860s, with the price in Fredericton and Saint John being considerably higher than that in Halifax. The Engineer department at Saint John found in 1864 that it could obtain cement directly from England at about three-quarters the cost of obtaining it by contract locally.[38]

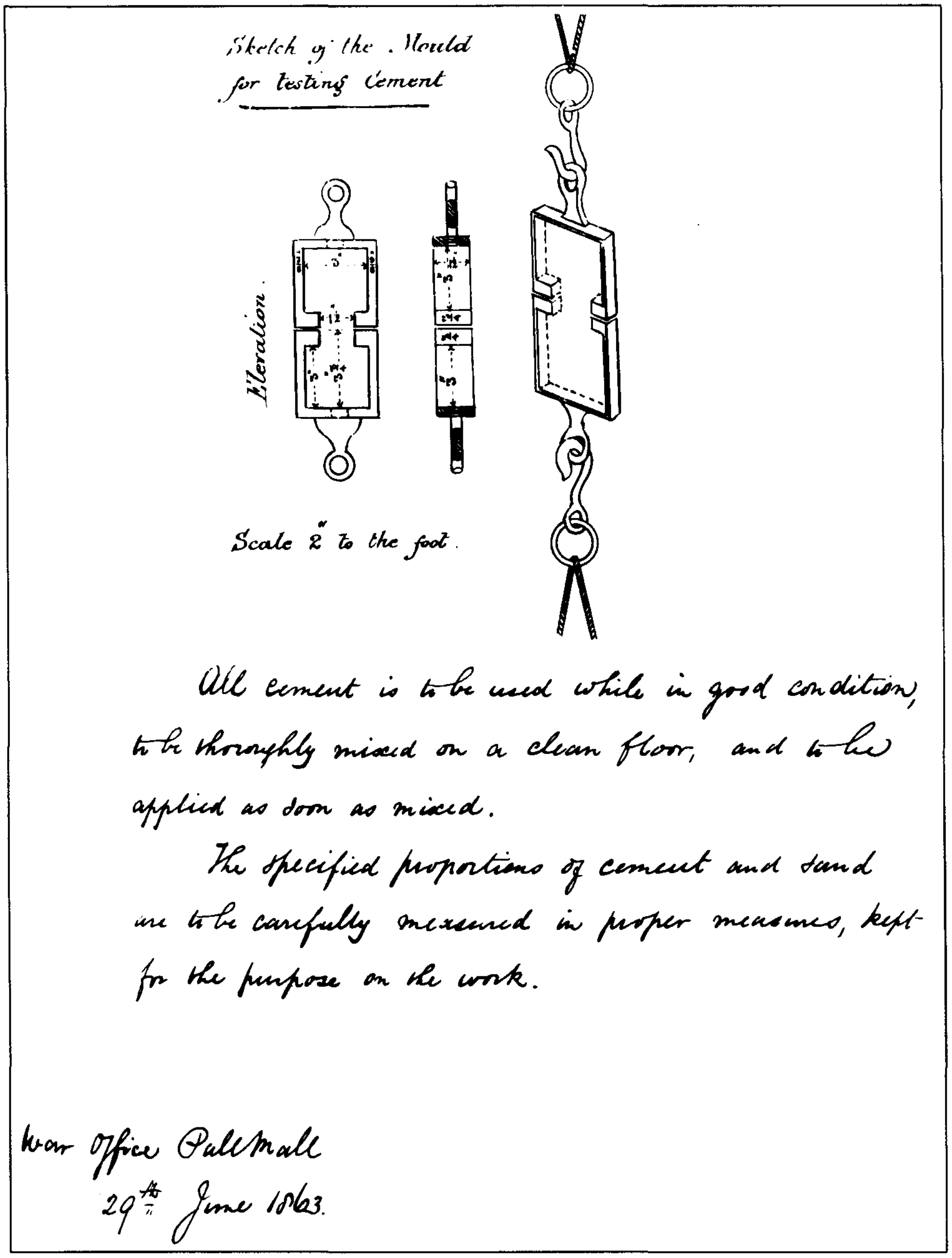
Lime appears to have been generally much cheaper at Québec than at Halifax. This was probably the reason why engineer officers at Québec were much slower than those at Halifax to turn from lime to cement for any substantial works. In the middle third of the 19th century the price of lime at Québec was generally 9d. or 10d. per bushel. The "Analysis of Schedule Prices Proposed to be Adopted for Triennial Contracts in Canada" yielded a price of 9d. per bushel for roche lime at Québec, Montréal, St-Jean, Bytown and Kingston; lld. in Toronto and Niagara and 1s. in London. The first quotation of a price for Harwich Cement at Québec was in 1838, when the price was estimated at 2s. 6d. per bushel. Hull Cement dropped in price from 5s. 6d. per bushel in 1830 to 2s. 10d. in 1843, while improving in quality; it thus became much more attractive for use in military construction. While Rosendale Cement from the United States or Harwich Cement could be delivered to Québec or Montréal at a lower price than that of the Hull Cement, the difference in transportation costs made the latter more economical for work at Bytown or on the Rideau Canal. In the mid-1860s the price quoted for American Cement at Québec was about half that given for Portland Cement, which makes the reluctance of the engineer officers to use Portland Cement in the works at Lévis more understandable.[39]

From the mid-1830s estimates and other documents showing prices for construction often quoted prices for amounts of work done rather than for the materials involved. Many of these estimates and contract schedules list prices for the same work done in both lime and cement, thus permitting comparison of the costs of the two materials. In an estimate for repairs at the Citadel at Québec in 1849-50, the cost for raking out joints of rubble masonry and pointing with mortar was given at 1½d. per superficial foot and of raking out joints of ashlar masonry and pointing with oil cement at 1¾d. Filleting with Roman Cement cost 4d. per linear foot and concrete 4½d. per cubic foot. The schedule of contract prices for work done at Montréal, printed in 1848, gave a price of 1½d. per superficial foot for raking out joints of ashlar masonry and pointing with water lime cement, and ¾d. for the same work done with mortar. Rubble masonry of approved quality stone in courses of 9 to 12 inches high built with roche lime and river or bank sand mortar was quoted at 5½d. per cubic foot; in general, masonry cost 4d. more per cubic foot if laid in water lime cement. Brickwork was quoted at 11d. per cubic foot in roche lime mortar and 5d. more if water lime was used. The "Analysis of Schedule Prices" (1 April 1853) showed how the costs for various types of work were estimated. It required 7½ cubic feet of mortar to build 20 cubic feet of rubble masonry. The cost of mortar was estimated at 6d. per cubic foot for stations east of Toronto and 7d. at Toronto, Niagara and London. In raking out joints of old rubble masonry and pointing with water lime cement three bushels of cement were required for 100 superficial feet of masonry. To rake out the joints of ashlar masonry and point with American Cement required one bushel of cement for 100 superficial feet; as the stones were larger and more regular than rubble masonry less cement was needed. For pointing with oil cement 25 pounds of oil cement were needed for 100 superficial feet. To make and lay 27 cubic feet of concrete required one yard of screened gravel, three bushels of lime and half a day's work of a labourer. Making plain mortar for repairs took nine bushels of lime, one yard of sand and two-thirds of a day's work to produce 27 cubic feet.[40]

When lime or cement was imported care had to be taken that it was properly packed, and both local and imported limes and cements had to be carefully stored to obviate the risk of spoilage. Authors writing on the subject of limes and cements stressed the importance of keeping them dry as moisture lessened their strength. Captain Scott pointed out that the strongly hydraulic limes suffered less from the action of the atmosphere than the pure or feebly hydraulic limes.[41] In 1831, when Lieutenant Colonel Nicolls requested an additional supply of Harwich Cement for Halifax, the Inspector General recommended that the cement be carefully packed in casks lined with paper. In Newfoundland two years later the Commanding Royal Engineer reported that the cement sent out the previous year in tar barrels was of good quality, but that which had been sent out in ordinary casks had become quite useless. He recommended that in future all cement being shipped to Newfoundland be packed in tar barrels. In the 1860s it was found at Halifax that the Portland Cement supplied from England did not remain in good condition more than two or three months. Some which had been kept all winter was found in the spring to be very much deteriorated, even though stored in dry, weather-tight buildings. By the 1860s the ordinary method of shipping supplies such as cement was by steam ship. A supplier submitting a tender for the supply of Portland Cement for the Engineer Department at Québec in 1866 explained why this was the lowest price he could offer for good Portland Cement. The only way of lowering the price would be to ship the cement in sailing vessels, which would, however, mean a greater risk of loss or damage and an uncertainty as to the time of delivery.[42]

Because the quality of lime and cement obtained from the manufacturers was so uncertain, samples had to be taken from each shipment and tested before it could be used. Colonel Pasley considered that the system of advertising for tenders for building materials and accepting the lowest was a temptation to the unprincipled to submit low tenders and furnish an inferior or adulterated article in hopes that it would be accepted. He therefore stressed the importance of testing limes or cements being furnished to the Engineer Department.[43] It is obvious from correspondence of the period that his concern was justified. In Halifax Captain Peake complained in 1833 that the kilns of the contractors who supplied lime for the Engineer Department were usually packed with six different sorts of stone, only two of which were good and that some of the work which had recently been taken down showed quite clearly that inferior lime had been supplied.[44] Specifications for building contracts usually stipulated what quality of materials was to be supplied by the contractor and that inferior materials were liable to be rejected by the engineer officer superintending the work. A memorandum from the Director of Works, sent to all Commanding Royal Engineers in July 1863, outlined the specifications for Portland and Scott's cements, and described how the cement should be tested. Portland Cement used by the Royal Engineers was to be of the best quality, ground extremely fine, weighing not less than 100 pounds per striked bushel (filled into a bushel measure as lightly as possible, somewhat like sifted flour) and capable of maintaining a breaking weight of 450 pounds seven days after being made into a mould of the form and dimensions shown in the diagram accompanying the memorandum (Fig. 2), the specimen having been immersed in water as soon as it set and left there for seven days. Scott's Cement was to be finely ground, to contain not less than ten per cent of soluble silica and to weigh at least 60 pounds per striked bushel. When mixed with two measures of sharp washed sand to one measure of cement and moulded into the form shown, it must form a sufficiently coherent mass in 24 hours to allow its removal from the mould, and after exposure to the air for seven days from the time of mixing it should support a longitudinal strain of not less than 65 pounds. These were practical tests which the engineer officer stationed at any post was expected to be able to perform.[45] When the Engineer Department at Saint John was endeavoring in 1864 to obtain a cheap and reliable supply of cement from England, a report from the Clerk of Works at Plymouth on the cement which they wished to purchase was submitted to the Commanding Royal Engineer in the district. According to the tests conducted at Plymouth, which were carried out in accordance with the rules laid down in the circular memorandum of July 1863, the cement bore a load of 560 pounds without breaking.[46]

At Québec the Royal Engineers encountered problems with the cement used to build the forts at Lévis. Because the Engineer Department did not plan to use Portland Cement in building these fortifications the schedule for the contract for this work prescribed a breaking weight for the cement much lower than that specified in the 1863 circular. The locally produced cement first supplied for these works was far below the comparatively unexacting standard set out in the schedule; it recorded a breaking weight of under 80 pounds. There continued to be problems with the cement supplied for the works at Lévis. The engineer officer superintending the works requested a copy of the circular memorandum on the subject of testing cements so that he might have a proper frame made for testing the materials supplied. In the spring of 1866 the inferior quality of the cement in use led to an order that no cement was in future to be used until a sample had withstood the prescribed tests. Despite the complaints about the cement being used at Lévis, a M. Gauvreau (probably the same one who had taken out a patent on the cement discovered



All cement is to be used while in good condition, to be thoroughly mixed on a clean floor, and to be applied as soon as mixed.

The specified proportions of cement and sand are to be carefully measured in proper measures, kept for the purpose on the work.

War Office Pall Mall
29th June 1863.

2 Sketch of the mould to be used for testing cement by the Royal Engineers, 1863. *National Archives of Canada, RG8, C Series, Vol. 1649, p. 252.*

by Baddeley) claimed a few years later that tests carried out by the Royal Engineers during construction of the forts at Lévis proved the great value of the Quebec Cement. The Quebec Cement supplied for the work at Lévis was not of very great strength, but it was not only the local cement which caused problems for the engineers. In the summer of 1866 a sample of Portland Cement supplied for use at Lévis was sent to the Director of Works in London for analysis, as the engineer officers at Québec suspected that it had been adulterated.[47] Testing of any cement or lime not supplied by the Ordnance Department itself was a necessary procedure, the importance of which became recognized as the properties of the various types of limes and cements became better known. Major John Maquay (who had served at Québec in the 1860s) wrote a paper on Portland Cement which appeared in the *Professional Papers* in 1874. Maquay gave directions for testing Portland Cement, using special testing machinery. One of the testing machines was to be filled from each cargo of cement and a report on each cargo was to be sent to the Testing Office. The standard for Portland Cement had become more stringent; the cement was to be ground fine enough for 80 per cent to pass a sieve of 2500 meshes per square inch; it was to weigh 110 pounds per striked bushel, and briquettes made of the cement and immersed for seven days were to have a minimum tensile strength of 562½ pounds to 2¼ square inches of section.[48] Testing of the lime and cement to be used in building was important to ensure the durability and strength of the construction.

In testing as in actual use the lime or cement which the engineer officers were requesting was mixed with water and sand to form a paste or mortar. The basic purpose of mortar is to bind together materials such as brick or stone to form a solid stable structure. In some cases the Royal Engineers built dry stone walls, but most masonry construction required mortar. A typical specification for masonry construction as given in an 1840 estimate for a redoubt at St-Jean provided for:

> *44,440 Feet Cube Ashlar Masonry of the best Limestone, laid with the best Roach Lime Mortar in horizontal courses not less than 14 in. in height, the outer face of each stone to be punched & the margins chisel dressed, laid with a close "worked" joint.*
>
> *41,580 Feet Cube Ashlar Masonry as above described in Scarp wall laid with the best Mortar & the joints pointed with cement.*[49]

Lime mortar was generally used for building ordinary walls, even after the properties and greater strength of hydraulic cements were becoming widely known. In situations where greater strength was needed in the walls cement was sometimes used for the mortar. In 1838 Harwich Cement was used in the mortar for brickwork at Québec, where garrison cells were being fitted up.[50] A little later brickwork laid in Roman Cement was specified for building retaining walls for parapets at St-Jean, a case where increased strength was important as the walls would have to withstand lateral pressure as well as their own weight.[51] For the walls of bombproof shelters and powder magazines, where strength was particularly important, the use of Portland Cement mortar became standard in Nova Scotia and New Brunswick by the 1860s. An estimate for a bombproof traverse to act as shelter for the gunners in a battery at Saint John, scheduled to be built in 1860-61, called for the walls to be of granite laid in Portland Cement, with the magazine for the battery to be of similar construction.[52] The report of a Board of Inquiry that examined the escarp wall at Fort Charlotte, Halifax, in 1865 indicated that ordinary lime mortar was "utterly worthless except in light brick walls, and that it should not on any account be used in heavy masonry or in foundations."[53] At Québec, however, the Royal Engineers were not so ready to condemn lime mortar out of hand. In the fall of 1865 Messrs. G & J. Worthington, the contractors who were building two of the forts at Lévis, inquired of the engineer officer in charge of the works whether the forts were to be built in common lime or in cement. In reply they were informed that the piers and walls would be built in Beauport lime (a slightly hydraulic local lime) and the arches would be of brick in Québec or some other good cement, but not Portland Cement.[54] Portland Cement was presumably excluded on account of its greater cost (about double that of American Cement), cheapness being preferred to strength. Even as late as the 1860s the use of lime mortar was still the rule and any deviation from this required an explanation.

Estimates and specifications for construction in this period frequently called for the use of grout. Pasley considered grouting most important in order to obviate the danger of empty spaces being left in vertical joints, although later writers pointed out that it was preferable to ensure that the mortar was so firmly pressed into the brick or stones that no voids were left which required filling by grout.[55] A major disadvantage of grout was that it was much slower to harden than ordinary mortar because of the greater proportion of water which it contained. Some specifications for construction work stipulated that the masonry or brickwork was to be grouted every course, others that it was to be grouted where necessary. Specifications for the construction of new barracks in Halifax, drawn up in the early 1850s, gave a description of how the grouting was to be prepared:

> *41. Grout for masonry and brick work to be composed of the same proportion of lime and sand as directed in Article 34 two parts sand to one part lime. The lime to be reduced to a liquid, or run in a large tub, previous to the sand being mixed, and used in a hot state for foundations, and other work, as required.*[56]

In general estimates and specifications called for grouting with hot lime and sand, but an estimate for repair work on a lock at the Carillon Rapids called for grouting the masonry through the joints of the ashlar with Harwich Cement.[57] The mix for grouting employed the same ingredients as that used in the mortar in each case.

Pointing involves filling in the joints of brickwork or masonry with mortar and smoothing them with a trowel. Pointing could be used to provide a smooth outer surface for poorly made joints as well as for the repair of defective joints. In the process of pointing the joints were scraped out to a depth of at least one-half inch, then the mortar was put in by trowel and pressed into the joint until it was full, when it was rubbed and polished. Very fine joints might have to be enlarged by a stonecutter before they were pointed. This enlarging of the joints increased the opportunity for frost and damp to weaken the joint. As one late 19th-century author suggested, it seemed much better policy to finish off the joints at once, without subsequent pointing.[58] On the other hand in heavy masonry the mortar in the thicker joints tended to be compressed and pushed outwards as the work settled. The mortar protruding from the joint was liable to crack. If it were raked out while still soft and the joint filled with a richer mixture it would be better protected from the effects of moisture and frost. When pointing was specified in estimates for new work it was to be done in cement, even in cases where the mortar was of ordinary lime, suggesting that the pointing was intended to protect the mortar from the effects of dampness. A justification for the expense of this process in an estimate for barracks proposed at Annapolis Royal in 1833 stated:

> *Raking out joints, pointing and striking, with Roman Cement although an expensive operation will be found ultimately economical, prevent the frost from rending the work when fresh, and tend to make the Building dry and warm.*[59]

The same year the engineer officer in Newfoundland reported that after trying various types of mortar he had concluded that cement in its most perfect state was the only pointing that would withstand the effects of the local climate.[60] At Kingston, however, the engineer officer recommended in the late 1830s that ordinary lime be used for pointing as much of the cement pointing had become detached from the joints.[61] The joints of old masonry and brickwork frequently needed repairs, with the mortar being washed away or cracked by frost. Defective joints had first to be cleaned out, to provide a proper surface to which the new mortar could adhere, and then filled with mortar and smoothed off. When the material to be used for pointing was specified, it was usually a cement; where justification was provided, it indicated the necessity to prevent dampness and to preserve the walls. An 1849 report on repairs needed to the armoury at the Québec Citadel recommended that the chimney and front walls, and the end walls seven feet down from the gables, be pointed with oil cement to preserve them. At the Sherbrooke Tower, Halifax, in 1859, the masonry of the base of the tower was to be repointed where defective with mastic cement (a mixture of lime, sand, litharge and oil). Mastic was considered to be waterproof and to adhere to stone, brick, metal or glass with great tenacity. In the late 19th century it was still used for pointing the juncture between wooden window frames and stone walls.[62]

Mortar was also used for fillets, which were narrow, raised strips, often used to protect the angles between two adjoining surfaces. For instance, when a new oakum room, a lean-to type of structure, was being added to the military prison at Québec in 1853, the estimate called for a cement fillet to make good the junction of the roof of the oakum room with the existing wall.[63] Fillets were also used where stove pipes or chimneys intersected the roof. As they were intended to protect the joint from dampness they were usually of cement mortar, sometimes with hair added to give extra strength.

The question of the proportion of materials used in making mortar was an important one, which was frequently discussed in the 19th century. Some writers suggested proportions for mortar by weight, but it was customary to measure the lime and sand by volume. The proportion generally used for lime mortar in military construction in British North America was one part lime to two parts sand, with enough water to make a stiff paste — though workmen generally preferred a wetter mixture than that recommended by engineers, finding this easier to work with. From the engineer's point of view too much water was likely to cause cracks, because of the shrinkage of the mortar from its evaporation, and to leave the mortar porous. The specifications drawn up in 1828 for building one of the walls of the Citadel at Halifax were typical of the directions given for the proportions to be used in mixing ordinary mortar: "The mortar to be composed on one third of the best white lime to two thirds of fresh water sharp sand."[64] These proportions appear to have remained standard for military construction throughout the period, although the proportions recommended by writers on the subject as being in common use were three of sand to one of lime, and one sample construction specification prepared in London in the early 1860s for the guidance of engineer officers called for proportions of two and a half of sand to one of lime.[65] At the end of 1839 Captain Benjamin Stehelin, reporting on the casemates at Fort Henry, recommended for pointing a mixture of one part brick dust, two parts sand and one part slaked lime, to which was added immediately before use one-half part finely powdered unslaked lime, as this would give the best adhesion to the stonework and would contract less on setting than the mixture previously in use.[66]

With the introduction of hydraulic limes and cements opinions varied as to the proper proportion of sand which should be used with them to make mortar. Colonel Pasley believed sand weakened cement mortar while it strengthened lime mortar. Therefore he felt that hydraulic limes would bear a smaller proportion of sand than lime, and cement a smaller proportion than hydraulic lime. Captain Scott found that sand always lessened the strength of a mortar. He considered that cement being so much stronger than lime would bear a larger proportion of sand, while still retaining its greater strength. In his "Account of the Manufacture of a New Cement," which appeared in the *Professional Papers* in 1861, he recommended that the quantity of sand should not exceed three parts to one of his new cement for brickwork or masonry, or four parts of sand to one of cement for plastering. In damp situations the amount of sand should be being reduced.[67] Where proportions were given for the use of hydraulic lime or cement in specifications and estimates for military construction in Canada, they varied somewhat. For paving and for water tanks and drains, where bricks laid in Roman Cement were used, the cement was generally mixed with an equal amount of sand. In walls and arches, because cement was often used in situations where greater strength was needed, there tended to be a lower proportion of sand than was used for lime mortars. Over the years, however, as engineers gained experience in working with hydraulic limes and cements and knowledge of the greater strength of Portland Cement in particular, there was a tendency to use a greater proportion of sand in the mixture. Captain Stehelin reported in 1839 that at Kingston a mixture of one part sand to two parts cement had been used for pointing. An estimate for building two towers at Kingston drawn up in 1841 called for a mixture of half Roman Cement and half sand for mortar for the walls of the basement and the arches in order to ensure the rooms being dry. For repair work on a lock of the Carillon Canal, a situation where resistance to lateral pressure was needed, an 1844 estimate called for the masonry to be laid in mortar consisting of one part sand to three parts Harwich Cement. The schedule for the contract for work on the Ordnance canals, printed in 1866, gave proportions of one and a half sand to one Portland Cement. As estimate for a bombproof magazine in Halifax in the mid-1860s called for the rear wall to be built in rubble masonry in one part Portland Cement to three parts sand.[68]

The way in which the mortar was mixed was also important. Authors of handbooks and manuals for builders, as well as those writing on the technology of mortar and concrete, suggested the best techniques for mixing these materials, both in large and small quantities. Specifications for construction work often included directions for mixing the mortar to be used. Writers on the subject recommended that mortar should not be mixed on the surface of the ground, but on a board, brick or stone floor and that only as much mortar as would be used immediately should be mixed at one time, as the mortar decreased in strength if it was reworked. Captain Scott, in his lectures on limes and cements at Chatham, stated that whenever the amount of work being done was great enough to justify the expense of providing machinery, mortar mixed by hand should not be allowed, as the use of a mixing machine ensured a more perfect mixture of the sand and lime.[69] The directions for mixing mortar contained in the regulations for mason's work for the contract for work done for the Engineer Department in Canada East commencing in 1859 were typical of the specifications given for construction work in British North America:

> *3. The Lime furnished by the contractor shall, when required, be slaked under cover, and the mortar made on a Stone, Brick, or Boarded Floor (to be provided by the Contractor) in the proportion of one of Lime and two of clear, sharp Sand; and properly worked until all the parts are thoroughly incorporated.*[70]

The specifications drawn up in the early 1850s for the construction of new barracks at Halifax directed that the mortar was to be made in quantities proportional to the demand as required and that it be ground in a mill on the spot instead of being mixed by hand.[71] By the 1860s, engineer officers at Québec were quite particular about what sort of machinery was being used to mix mortar. In May 1866 Lieutenant E. Grover wrote to Messrs. Worthington, the contractors for the works at Lévis:

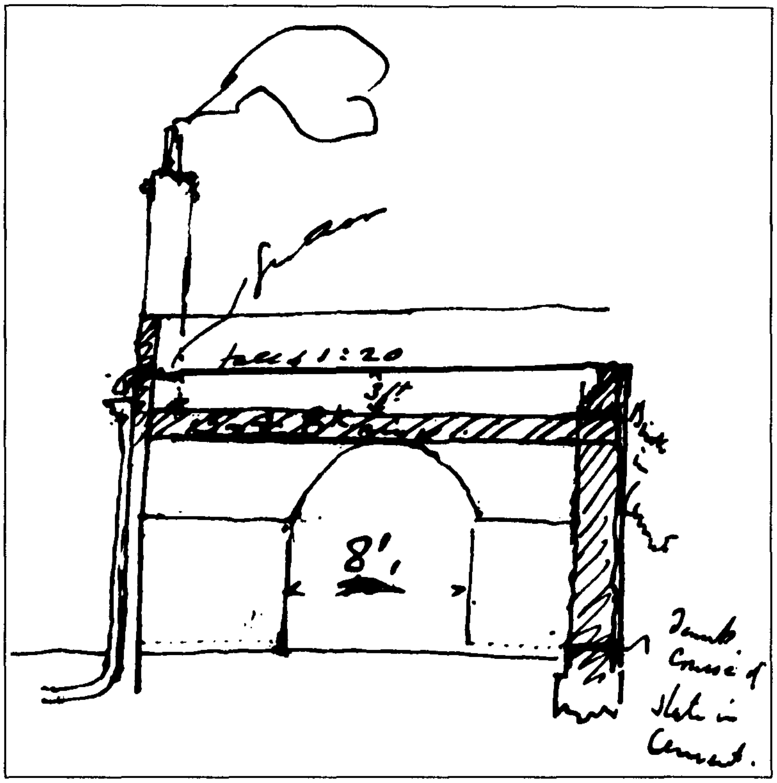
> *I beg to call your attention to Item 18 of Schedule No. 2 (or General Conditions) of your contract, which directs that "The mortar for masonry & brickwork (is) to be made on a hard dry floor under cover, and thoroughly ground in a pan with revolving cylinders," whereas you are now mixing the mortar in a pug mill. The CRE has, however, no objection to your continuing the use of the pug mill if the lime is properly pulverized & the mortar well mixed. Should this not be satisfactorily done the condition above quoted will be enforced.*[72]

The technological improvements of the 19th century meant that by the latter part of the century mortar was mixed by hand only in situations where small amounts were being used.

When the mortar was mixed and put into place it had next to set and harden. Proper setting depended on such factors as the quality of the lime or cement employed, the amount of water used in mixing the mortar, the condition of the stone or bricks to which it was applied and the climate. It was preferable to moisten the stones or bricks before applying the mortar as, if they were dry, they would draw water from the mortar and hinder the setting process. In British North America the extremes of the climate posed a particular hazard to the setting of mortar.

In hot weather it was considered advisable to water exposed surfaces for a day or two to prevent the mortar drying too quickly. Too much moisture was also a problem. At Halifax in 1831 Colonel Nicolls attributed part of his difficulties with the escarp wall of the Citadel to the moist climate, which retarded the setting of the mortar causing it to remain very spongy.[73] In Kingston in the late 1830s the pointing of the casemates at Fort Henry was breaking off. Captain Stehelin suggested that one cause of this was the fact that the work had been done in October when the frosty nights might have prevented the proper setting of the mortar.[74] The effects of winter on fresh masonry or brickwork were always a problem, and builders were always concerned with bringing the construction work to a point at the end of the building season where it would suffer as little as possible during the winter. In preparation for the next building season attempts were sometimes made to hasten the setting of mortar. For example, late in the winter of 1847-48, the Commanding Engineer, Canada East, requested an allotment of fuel to heat the new hospital under construction at Québec so that the masonry of the arches might be dried sufficiently to make them ready to receive the weight of the dos d'ânes at as early a period as the weather would permit the commencement of construction.[75] (In military construction, a dos d'âne was a peak built up over an arch in order to shed water.) In walls of any thickness pure lime mortar never set completely. The Royal Engineers in Halifax noted that when buildings forty or fifty years old were taken down, the mortar in the interior of the walls had not set. Cement mortar, on the other hand, was found to harden in a few days and to continue increasing in cohesion and tenacity. When fully set it was as hard as the rock which it was holding together.[76]

As the structural weaknesses caused by dampness and particularly the effect of dampness on lime mortar became better known, engineers grew more concerned with finding ways of keeping moisture out of buildings and out of the walls. It was realised that moisture rising from the ground was a frequent cause of problems with brickwork and masonry. One means of preventing this, at least in part, was the provision of adequate drainage around a building so that rain water, particularly that coming off the roof, would be carried away from the building rather than soaking into the ground at the base of it. Another means of guarding against the problem of rising dampness was the incorporation of a damp course in the walls as they were being built (Fig. 3). An 1841 estimate for towers



3 A drawing in a memorandum concerning the building of Forts Nos. 2 and 3 at Lévis, 1865, shows the provision of a damp course of slate in cement. *National Archives of Canada, RG8, C Series, Vol. 1586, p. 363.*

planned at Québec specified that one course of masonry at the level of the bottom of the ditch was to be built in cement in order to prevent damp rising. In the following decade an estimate for a powder magazine at Saint John specified that the walls at the level of six inches above the ground were to be covered with a one-half-inch coating of half Portland Cement and half sand to prevent damp from rising. An 1866 estimate for building a store for comestibles at St. Helen's Island called for a damp course of slate bedded in Portland Cement.[77] As the wooden floor of the Prince of Wales Tower in Halifax had decayed from dampness an estimate was drawn up in the late 1850s for rebuilding it. The estimate originally called for the new floor to be built of wood on a base of asphalt, but it was suggested that if a rendering of Portland Cement three-quarters of an inch thick were to be laid on the bed of concrete, it would keep the damp from rising and provide an adequate floor if the stores to be kept there were not very heavy. It was this procedure which the Commanding Royal Engineer decided to adopt.[78]

Problems were also encountered in preventing dampness from seeping in from above, particularly in casemates, and various methods of waterproofing upper surfaces were tried. In the Canadas by the early 1840s the dos d'ânes of casemates in fortifications being erected were covered with flagging laid in or pointed with cement, although in Halifax at this time laying the slates covering the dos d'ânes in cement was considered to have been proven incapable of resisting the effects of the climate. This was probably due to the relatively low quality of the Roman Cement in use at the time, which did not withstand the action of dampness and of frost nearly as well as the Portland Cement of a later period. In 1866 the contractors working on the forts at Lévis recommended that all masonry covered with earth should be built in cement to preserve it.[79]

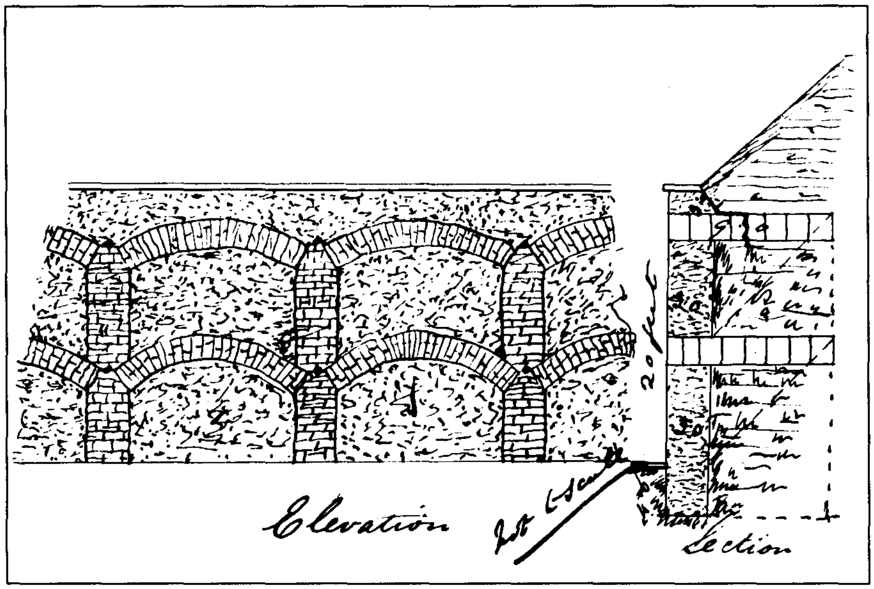
Another situation where resistance to the penetration of water was important was the construction of water tanks and drains. From the 1840s, when water tanks and drains began to appear in estimates, the use of cement mortar was standard in their construction. The brickwork was laid in cement and sometimes also coated with a layer of cement. In some cases a double floor was called for in a water tank. This was the case at Burlington Heights, Ontario, where the estimate for a water tank specified two floors, the lower one brick on edge laid in mortar, and the upper one brick laid flat in Roman Cement. The estimate also specified a floor of brick on edge laid in cement for the filtering chamber and a coating of Roman Cement for walls and floors of both the tank and the chamber.[80] As Portland Cement came into use it replaced Roman Cement in the construction of water tanks as it did in other uses where resistance to water was important. The use of cement in building water tanks was not always successful. The water obtained from the tank built to supply the military prison at Québec was so bad that the tank was pumped out and the interior coated with cement, but without any improvement in the quality of the water, which continued to be strongly impregnated with carbonate of lime. According to the September quarterly report on the military prison in 1860, "it was strongly represented that such would be the case, and a supply from the water works of the city advocated, but the commanding Engineer at Quebec would not be turned from his purpose, of the erection of the Tank, and the result is what I anticipated."[81] One solution for this sort of problem tried at Halifax in 1836 was to point the defective joints and arches of the rain water tanks with hydraulic cement and when this had dried to lay over the original brickwork a course of brickwork on flat set and coated with hot mastic. A few years later cement and asphalt were being used for water tanks in Halifax.[82] Brickwork on edge was also often used for paving of paths, areas or courtyards, and floors for laundry rooms or kitchens, with bricks being either set in sand and grouted or set in cement.

The penetration of water into the joints of masonry and brickwork was a problem which continued to plague engineers in the 19th century. Water that had penetrated the mortar would expand on freezing, causing the mortar to crack and often detaching it from the joints. The increased expense of pointing with Roman Cement was therefore justified on the grounds that it would keep out dampness and preserve the mortar. At St. John's the strong winds to which the buildings on Signal Hill were exposed caused problems. In 1844 the Inspector General was asking for an explanation of the damp state of the barracks built there a few years earlier. According to James Allen, former Clerk of Works at St. John's, the fluctuations of the local climate were so trying to masonry that even the best mortar was unable to resist its effects. Because of this, constant attention was needed to keep the joints well pointed. Allen said that he had several times seen the exterior walls of these buildings covered with a sheet of ice. Strong winds accompanied by heavy rain or sleet drove the water against these walls with such force as to penetrate the smallest opening. He felt that the only way to preserve the walls and keep the buildings from being extremely damp was to cover them with weather-boarding. A contributing factor to the problems with dampness encountered in these buildings was the fact that they had been empty most of the time since their construction. Allen alluded to a "strong feeling on the part of the garrison of St. John's against the Summit of Signal Hill becoming the resident position for the Troops," a feeling with which one can sympathize on reading Allen's description of the exposed nature of the site.[83] The casemates in the Halifax Citadel also had problems of dampness, with the joints of the masonry often soaking up water, making the rooms most uncomfortable.[84] At St-Jean the brick walls of the hospital required extensive repairs in the mid-1860s because the mortar had been washed out of many of the joints.[85] Despite the available evidence of the weakness of lime mortar in damp situations, construction of the escarp wall of Fort No. 3 at Lévis was begun in lime mortar in an effort to save money. In the spring of 1867, on examining this work after one winter's exposure, Colonel T.L. Gallwey, RE, found that water had forced itself through the walls, washing the mortar out of many of the joints. In response to Gallwey's report Colonel Jervois, the Director of Works, authorized building the escarp in cement.[86]

Concrete, and particularly reinforced concrete, has become one of the most important building materials in use today. In foundations concrete is used almost exclusively. Concrete had been used as far back as Roman times, but the development by the mid-19th century of a reliable cement which would attain a great deal of strength even in damp situations made the use of concrete in foundations or other situations where strength was important much more attractive to builders. The Royal Engineers were slow to appreciate the full possibilities of cement concrete. Colonel Pasley, while aware of the use of concrete for the foundations of large structures such as the Millbank Penitentiary, came to the conclusion that concrete was not suitable as a replacement for brickwork and masonry, because the concrete which he was able to produce with hydraulic lime was not of great strength. In his opinion combining sand with cement greatly weakened the cement and therefore he rejected the use of cement for concrete. In the 1830s the Royal Engineers experimented with the use of concrete for building a bombproof casemate at Woolwich. Despite the success of this experiment it was not until much later that any extensive use was made of concrete for building fortifications in England. Papers on the use of concrete continued to appear at intervals in the *Professional Papers*, but it was only with the work of Captains Scott and Fowke (both of whom were involved in the construction of important public works as well as military engineering) in the 1860s that the advantages of the large-scale use of cement concrete in fortifications became widely known among the Royal Engineers, and it was only after 1870 that this was put into practice in the construction of fortifications in Britain.

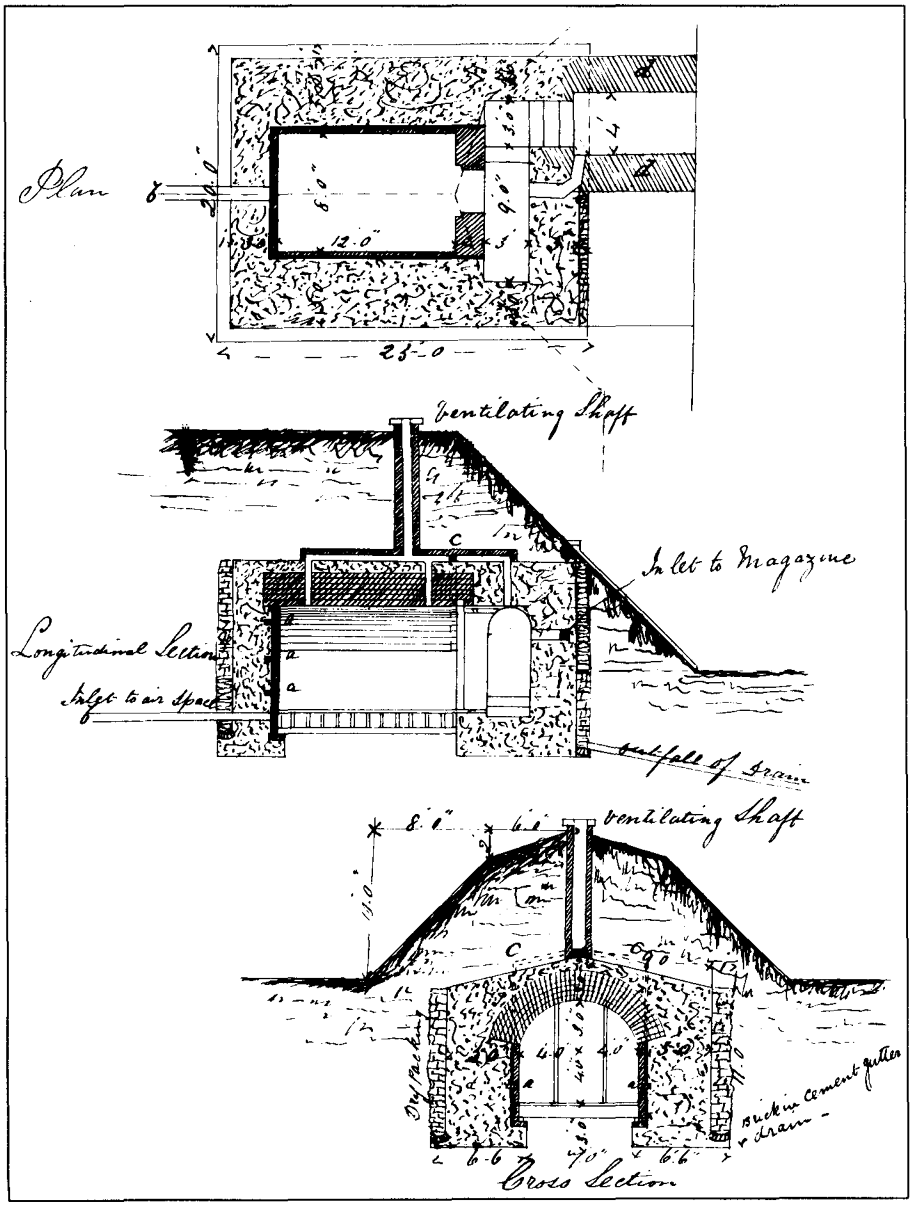
In British North America by the 1840s concrete was being used in some cases as flooring in military construction, and at the end of the decade a concrete gun platform was built at Kingston.[87] In the following decade estimates and specifications reveal some use of lime concrete, in some cases as a base for asphalt flooring.[88] At this time concrete was generally listed under pavior's work in specifications or estimates, indicating that it was thought of mainly as a flooring rather than as a substitute for masonry or brickwork. At Halifax concrete was also used for the footings of foundations and in the case of the Sherbrooke Tower for filling in the space between the tower and its stockade. In the latter instance, where resistance to water was important, Portland Cement was used as a basis for the concrete.[89] In the early 1860s model specifications for certain types of buildings were prepared in London for the use of engineers at the various posts. These give some indication of the views held by senior engineer officers in London on architecture and civil engineering. Although this was the period when Scott and Fowkes were stressing the values of cement concrete and were urging a more imaginative use of concrete in fortifications, the model specifications available show little use of concrete except for foundations and the base for flooring. Moreover, the concrete was to be made of ordinary lime rather than cement.[90] The Royal Engineers at Halifax, unlike their superiors in London, were, however, willing to heed the suggestions of Fowke and Scott. The reports which they prepared in 1865 on their use of concrete showed an awareness of the current literature on the subject, a willingness to experiment, and a painstaking care for detail. Different types of mixtures of aggregate were tried until the most satisfactory was found, and the proportion of ingredients which best combined economy with strength was determined by experiment. Observations were kept of any difficulties or faults that appeared in the concrete, and suggestions were made as to the probable causes and how best to avoid them in future. Concrete was not used merely for foundations and flooring. At Fort Charlotte, for example, concrete was used for the escarp wall, in the galleries of communication where it was employed instead of brick arching, and for bombproof traverses and magazines (Figs. 4 and 5). An expense magazine at York Redoubt was composed entirely of Portland Cement concrete with the exception of a half-brick-thick ring over the magazine proper "in order that the porous surface of the brick may not shew any slight condensation." A marginal note explained that while a cement surface would show condensation, brick would absorb it. In the view of the Commanding Royal Engineer at Halifax Portland Cement concrete had firmly proved itself of great value in military construction.[91]

In Québec at this time the strength of cement concrete walls was still considered dubious and needing careful testing. The reports prepared on

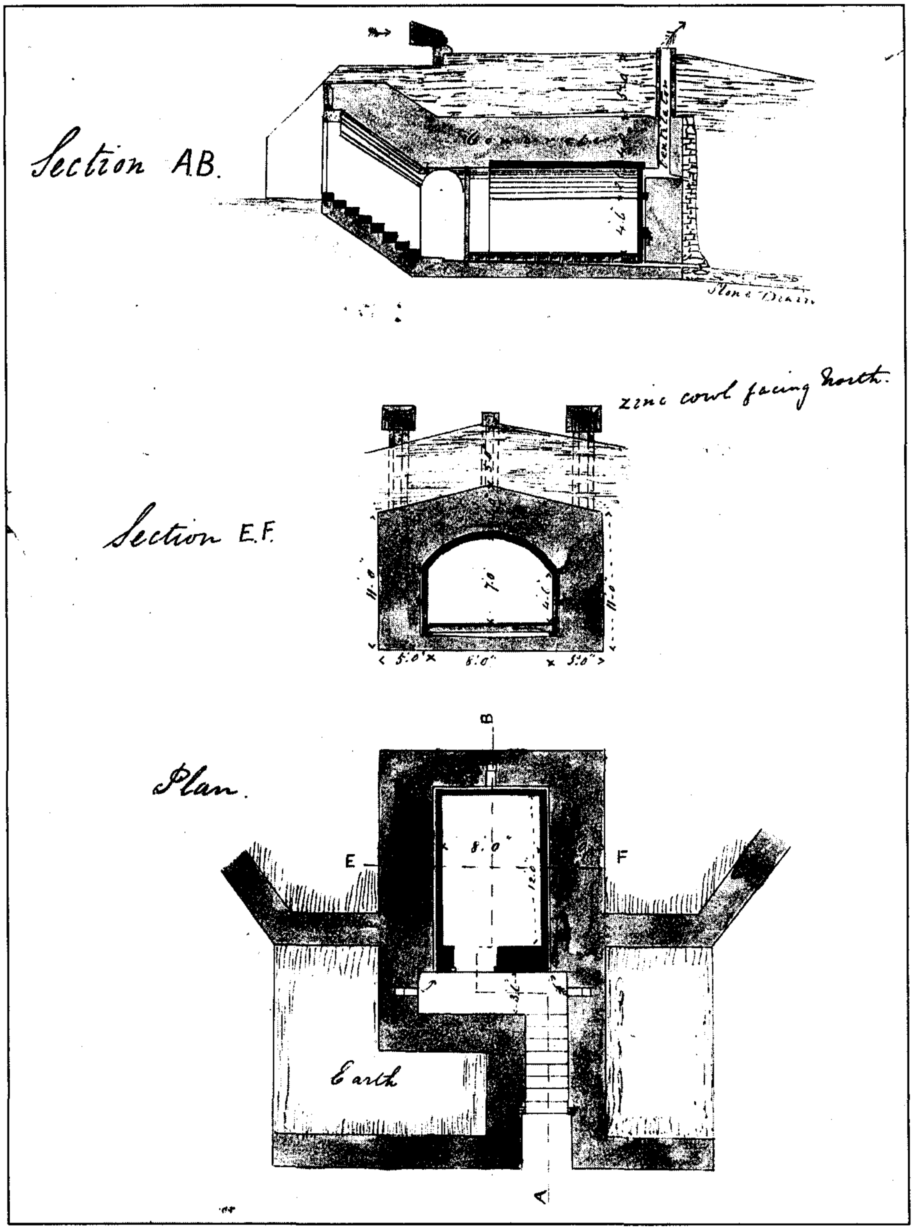


4 This sketch and those in Figures 5, 6 and 7 are from the series of reports written by engineer officers at Halifax describing their work with cement concrete. Here the use of concrete for the front wall of the scarp at Fort Charlotte is shown. In this wall the piers and arches, which were of masonry, were flush with the concrete, but it was suggested that it would have been an improvement to let them project. *National Archives of Canada, RG8, C Series, Vol. 1587, p. 165.*

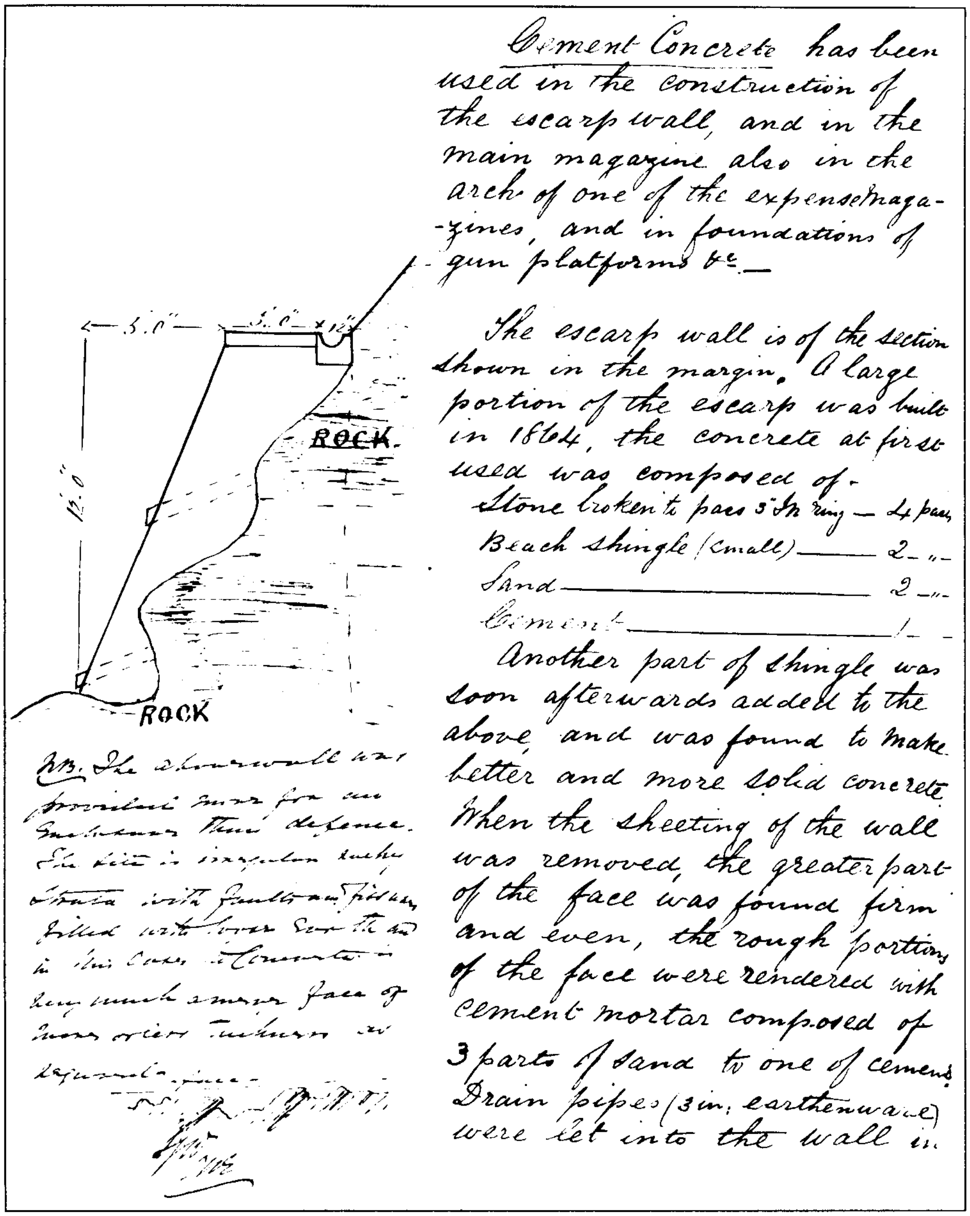
the work at Halifax were sent to Québec, but the substitution of concrete for masonry and brickwork in the work at Lévis was not considered advisable. Captain Akers, the engineer officer in charge of the works, felt that the heavy nature of the proposed buildings required extra strength in the foundations. He suggested either dressed stone foundations, or if that were too expensive, the use of Portland Cement concrete. Any other type of concrete he felt was not dependable. The Ordnance Department, however, unwilling to sanction the extra cost of the type of work suggested by Akers, decided that ordinary stone foundations would be ample.[92] An interesting variation in the construction of casemates was also considered in Québec at this time. Captain Robert Home, RE, suggested the substitution of wrought-iron girders and buckled plates covered by concrete for brick arches (Fig. 8). In the United States military engineers had already tried the substitution of flat for arched roofs in bombproof buildings and considered this construction technique successful. The system Home suggested for use at Québec was the one used



5 These sketches show the expense magazines at Fort Charlotte, which were of concrete lined with brickwork with an airspace between to help keep the magazines dry. *National Archives of Canada, RG8, C Series, Vol. 1587, p. 167.*



6 The expense magazine at York Redoubt. It was built entirely of Portland Cement concrete except for a half brick ring over the magazine proper. ***National Archives of Canada, RG8, C Series, Vol. 1587, p. 173.***



Cement Concrete has been used in the construction of the escarp wall, and in the main magazine also in the arch of one of the expense Maga-zines, and in foundations of gun platforms &c.—

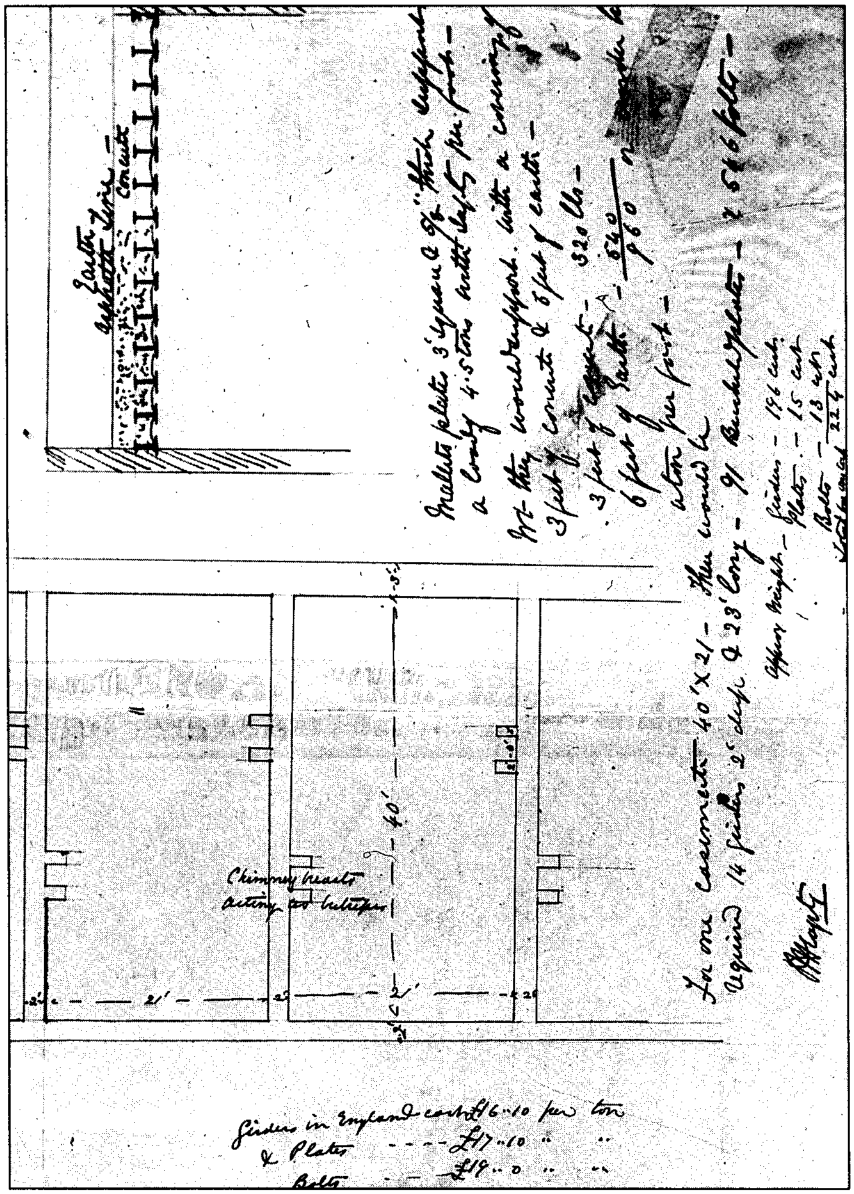
The escarp wall is of the section shown in the margin. A large portion of the escarp was built in 1864, the concrete at first used was composed of-

Stone broken to pass 3 In ring — 4 parts
Beach shingle (small) — 2 "
Sand — 2 "
Cement — 1 "

Another part of shingle was soon afterwards added to the above and was found to make better and more solid concrete. When the sheeting of the wall was removed, the greater part of the face was found firm and even, the rough portions of the face were rendered with cement mortar composed of 3 parts of sand to one of cement. Drain pipes (3 in. earthenware) were let into the wall in

N.B. The above wall was provided more for an Enclosure than defence. The site is irregular rocky strata with faults and fissures filled with loose earth and in this case a Concrete is [illegible] face of [illegible] as required.

7 Drawing of the cement concrete escarp wall at Fort Ogilvie, Halifax, built in 1864. *National Archives of Canada, RG8, C Series, Vol. 1587, p. 174.*



8 Sketches by Captain Robert Home, RE, accompanying his memorandum suggesting the use of wrought-iron girders and buckled plates covered by concrete in place of brick arches for casemates. He estimated that the girders would cost £16 10s. per ton in England, the plates £17 10s. per ton and the bolts £19 per ton. *National Archives of Canada, RG8, C Series, Vol. 1585, p. 3.*

for Westminster Bridge. He had in mind ready-made iron girders and plates which were standard items to be ordered from the manufacturer's catalogue.[93]

As with mortar the question of the proportion of the various materials used in making concrete was an important one frequently discussed in 19th-century literature on civil engineering. When concrete began to be used in military construction the amount of aggregate in the mix had to be decided upon as did the best variation in the size of the aggregate. Modern literature dealing with concrete recommends that "in properly made concrete each particle of aggregate, no matter how large or how small, is completely surrounded by paste and all spaces between aggregate particles are completely filled with the paste."[94] Cement normally constitutes between 7 per cent and 14 per cent of the concrete, and the aggregates make up about 66 per cent to 78 per cent with the rest being water. Gradation or particle size distribution of aggregate is important in the production of concrete. "In general, aggregates which do not have a large deficiency or excess of any size and give a smooth grading curve produce the most satisfactory results."[95] The more even the mix of large and small particles the more economical the concrete as there are fewer voids to fill. Concrete mixtures are designed to suit the particular needs of the job in hand, and it is usual to make trial batches in order to determine the correct mix, which will combine strength and durability with economy. The determination of the correct concrete mix to suit the requirements of each particular job is considered an important task, requiring consideration of many different factors and a technological expertise.

Construction practice in the early 19th century was not as precise as it is today. According to Pasley, no matter what proportion of ingredients was stated by the architect in his specifications, "No precise measurement ever takes place, the matter being left to the sagacity of the labourers employed, who produce mixtures of uniform quality with extraordinary accuracy."[96] In the experimental concrete bombproof casemate built at Woolwich in 1835 "Ranger's patent concrete" was used, which consisted of seven parts mixed gravel and sand, one part of lime and one and a half parts of boiling fresh water. In the same volume of the *Professional Papers* in which a description of this structure appeared, Lieutenant William Denison published his "Notes on Concrete."[97] Denison stated that the proportion of ingredients most commonly used for concrete in the London area was one part lime to seven of ballast, but he considered that the most perfect concretion could be obtained by using one part lime to eight of ballast. He stressed the importance of using at least twice as much sand as lime. The mixture used for concrete in military construction in British North America in the 1850s varied, though the most usual proportions were six parts gravel to one part lime. For example, the specifications for concrete to be used in the construction of new barracks in Halifax, printed in 1852, called for a mixture of four parts screened pit gravel or small broken stone, one part fresh pit sand and one part ground lime, while an estimate prepared the following year for new flooring in the magazine in the Citadel at Halifax specified that the concrete was to be composed of five parts screened gravel, one part freshwater sand and one part hot burned ground lime.[98] In some cases gravel or broken rock, sand and lime were all included in the specifications for the composition of the concrete and in others only gravel and lime were mentioned, the gravel used presumably being partly sand. The engineer officers at Halifax in the early 1860s, when concrete was being extensively used, were careful to note the mixtures being used for the concrete and changed the proportions when this seemed advisable. The broken stone used for the concrete was of two sizes, one that would pass through a 2½-inch ring and a smaller size that would pass through a 2-inch ring, with the two sizes mixed. Shingle and coarse and fine sand were used as well. The shingle was more expensive than the stone, but it was found economical to mix a certain amount of it with the stone so as to diminish the voids and save on mortar. By experiment the mixture of coarse aggregate giving the fewest voids was determined. Then sufficient sand and cement were used to form a mortar somewhat more than equal in bulk to the void spaces. The sand never exceeded three parts to one of cement, more commonly two and a half, the strength of the mortar depending on the purpose for which the concrete was to be applied. For gun foundations in made ground at Fort Charlotte, a work requiring considerable strength, every cubic yard of concrete contained 16 bushels broken stone (two sizes), 5 bushels fine shingle, 7 bushels sand and 3½ bushels cement (about 8½ bushels of mortar). An excessive amount of cement was used in this case because the cement was not fresh. At York Redoubt the concrete used was composed of 21 bushels broken granite, maximum diameter 1½ inches, 42 bushels broken ironstone, diameter 2½ inches, 21 bushels sand and 8 bushels cement, which contracted in mixing to about 60 bushels. At Fort Ogilvie the concrete first used for the escarp wall was composed of four parts stone, broken to pass a 2½-inch ring, four parts shingle, one part sand and one part cement, with a richer cement of three parts broken stone, two parts shingle, one part sand and one part cement over the arches.[99] The work done at Halifax showed a willingness to adapt the concrete mixture to suit the situation in which it was to be used and the materials available.

Careful mixing of the concrete was particularly important to maintain an even particle-size distribution of the aggregate. In making concrete the lime and sand could be mixed with water to form mortar and the broken rock then added, or all the dry ingredients could be mixed together and then moistened. Writers on the subject generally preferred the latter method. Lieutenant Denison in his "Notes on Concrete" recommended mixing the lime thoroughly with the ballast in a dry state, then throwing sufficient water over it to ensure a perfect mixture.[100] In a paper published in 1874 Captain Henry Seddon described in somewhat more detail how concrete should be mixed. A yard measure was to be half filled with ballast, the required amount of cement added and then the measure filled to the top with ballast. When the measure was removed the ingredients became partly mixed and the cement was not blown about as much as if it were placed on top of the ballast. The ballast and cement should then be turned over twice in a dry state and then shovelled into a third heap, with each shovelful being sprinkled with water from the fine rose of a watering can as it was thrown onto the heap.[101] In his "Notes on Portland Cement Concrete," which appeared in the same volume of the *Professional Papers* as Seddon's paper, Major John Maquay described the method which he considered should be followed in mixing concrete. Maquay considered that concrete could be mixed by machinery more uniformly, rapidly and economically than by hand. If it must be mixed by hand the materials should be measured in a measuring frame placed at one end of a boarded stage or floor, with the broken stone put into the frame first, the sand next and the cement on top. When the frame was lifted off the dry materials should be turned over to the other end of the stage, then about a barrow load at a time turned over again and water added from a watering pot fitted with a rose. Maquay warned that the water added should only be sufficient to moisten the ingredients and should not be allowed to flow over the surface of the mixing board or run down the sides of the heap being mixed lest it wash away the cement and fine sand. In his paper Maquay also described various types of mixing machines that could be used. He considered as best one consisting of a semi-cylinder fitted with a shaft with blades on it that mixed the concrete and delivered it out at the lower end of the machine.[102] A late 19th-century handbook for engineers quoted the method described by General Gillmore, an American engineer officer whose writings on the subject were studied by the Royal Engineers. The gravel and pebbles were first separated into sizes by screening and the gravel spread out on a platform of rough boards in a layer 8 to 12 inches thick, with the smaller pebbles at the bottom and the larger ones on top. The mortar was spread over the gravel as uniformly as possible and the materials turned over by shovels, while men with hoes rubbed each shovelful of gravel into the mortar.[103]

For military construction in British North America concrete was generally mixed by combining the dry ingredients before adding water. The specifications for general repair work on the Rideau and Ottawa canals, printed in 1844, stated that the lime and gravel were to be mixed with hot water. According to 1852 specifications for the construction of new barracks in Halifax, the gravel, sand and lime were to be mixed with a moderate quantity of fresh water on a solid bottom by turning the mass over with spades until all parts were properly incorporated. A contract in 1858 for a workshop in Québec stated that the stones, lime and sand were to be thoroughly mixed while dry in a box or tray in quantities not exceeding two bushels. Sufficient water was then to be added to form a paste.[104] In the series of memoranda describing the work with cement concrete in Halifax from 1863 to 1865, a sample form of specification for concrete was given. The instructions for mixing the concrete were as follows:

> *The mixing to be performed on a clean wooden platform, the sand and cement being first made into mortar, the ballast then added and the whole thoroughly incorporated and levelled and rammed in its place in layers not more than ______ft. thick within 15 minutes of the mortar being made up.*[105]

A detailed description was also given of how the concrete had been mixed for the work done at Halifax. The concrete was mixed on platforms of two-inch thick planking in sufficient quantities to use one barrel of cement. Sand or shingle was spread on the platform in a uniform layer four or five inches deep and about six feet wide, the cement spread on this and the broken stone spread on top. Mixing was begun at one end by two men with shovels who mixed about a barrowful at a time dry; water was then added and the mixing was repeated by another pair of men who then shovelled it into the barrows as fast as it was mixed. With larger gangs of men the concrete was mixed from both ends of the heap at once. Experience at Halifax indicated that where large amounts of concrete were required, it might be more economical, and it would certainly be more thorough, to mix the concrete by machinery. It was also considered that it might be better to mix the mortar separately from the coarse materials. The engineers superintending this work had consulted General Gillmore's writings on limes and cements and may have been influenced in this latter suggestion by what he had written on the subject.[106]

Once it was mixed the concrete could be put into moulds to form artificial stone blocks, or poured into forms in situ. Construction specifications generally dealt with concrete used in the latter way. Modern literature on the subject recommends that each step in transporting and placing the concrete be carefully controlled to maintain uniformity and prevent separation of the coarse aggregate from the mortar or of water from the other ingredients. The concrete should be placed as nearly as possible in its final location and should not be allowed to drop freely more than three or four feet.[107] Practice in the 19th century favoured quite different methods. In building the experimental bombproof casemate at Woolwich in 1835 the workmen "dashed" the concrete with shovels into the part of the building being constructed and then rammed it close together.[108] A building guide of the 1850s recommended that

> *to promote the required consolidation, the concrete should be deposited by flinging it in from a height of from 5 to 10 feet, according to the coarseness of the gravel, and should be levelled up, uniformly, in layers, each being allowed to settle down before depositing another layer.*[109]

The description of concrete given in the "Analysis of the Schedule Prices Proposed to be Adopted for the Triennial Contracts in Canada" commencing in 1853 stated that the concrete, once mixed, was to be thrown into the trench from a ten-foot platform.[110] Once the concrete had been poured into the trench or into the formwork it was rammed to consolidate it. It was recommended that the concrete be worked with the blade of a spade along the face of the formwork so as to bring the finer particles to the face of the work. This produced a cement-rich layer that in many cases has since become detached from the mass of the concrete.[111]

Problems encountered in the setting and hardening of concrete were similar to those found when using masonry or brickwork. Moisture is needed for the proper setting of the mortar, but too much water makes a weak concrete. In the series of memoranda discussing the experience of the Royal Engineers with concrete in Halifax in the 1860s it was recommended that "As a general rule concrete should be mixed as stiff and kept damp after putting in place as long as possible. In hot weather it is advisable to water exposed surfaces for a day or two to prevent it drying too quickly."[112] The major problem, however, in the setting of concrete was not lack of moisture but too much dampness, which tended to prevent the proper hardening of any concrete not made with Portland Cement. In the work with concrete in the early 1860s American Cement was tried but proved unsatisfactory, and engineers at Halifax condemned the use of lime for concrete as utterly unsuitable because experience had already shown that in Halifax lime would not set properly. At Fort Charlotte, where the foundation of the escarp wall was of lime concrete and the wall itself of cement concrete, with piers and arches of ironstone set in cement, the wall was forced out of plumb by the weight of the parapet because of the compression of the foundations, which had not set.[113]

Temperature is another factor influencing the setting of concrete. High temperatures in fresh concrete cause rapid stiffening and increase the danger of the hardened concrete cracking. Low temperatures are also a problem. The strength of concrete which has been subjected to a single freezing cycle at an early stage may be restored to normal by a resumption of favourable curing conditions, but such concrete will have lost some of its resistance to weathering and its impermeability. Where several cycles of freezing and thawing occur the strength of the concrete is permanently reduced. Nowadays fresh concrete is often covered with tarpaulins and heated to protect it from low temperatures.[114] In the construction of the forts at Lévis problems were encountered in protecting the unfinished structures from the effects of winter, particularly because work during the summer of 1867 had not proceeded as rapidly as had been anticipated. It had been intended that the concrete of the arches would be covered with a coating of asphalt. By late August 1867 the engineer officer superintending the work had begun to doubt that the asphalters would be able to do any work at Fort No. 3 before the onset of winter. The contractors agreed to cover the arches with a coating of fine concrete (two parts cement to five parts sand); if this were done at once the coating would have time to harden before the frost set in and would prevent water penetrating the arches. The Royal Engineer Department tried to insist that the contractors agree to be responsible for any repair work needed in the spring, which they refused to do unless they received a higher rate than that originally quoted. The contractors felt that it would have been quite possible to lay the asphalt at Fort No. 3 if a large enough force of workmen had been employed:

> *If the War Department fails to provide an adequate force or a sufficient quantity of materials and tools we do not feel we should be held responsible for any damage to works caused by failure to complete asphalting this season.*[115]

It was definitely considered essential to cover the concrete before the winter. The weakness of the concrete in the arches was probably due to the low quality of the cement used in building.

Most of the problems encountered in the hardening of mortar and concrete were due to dampness or low temperatures. As stronger cementing materials (hydraulic limes and cements) came into use it became possible to avoid many of these problems. It was at Halifax that the Royal Engineers became convinced by the mid-1860s of the value and usefulness of Portland Cement concrete, probably because of the greater availability and cheaper price of Portland Cement there than in the Canadas.

The work of the Royal Engineers in British North America reflected the 19th-century developments in the knowledge and use of mortars. The availability of mortars that would harden when out of contact with the atmosphere made possible the large-scale use of cement for foundations for substantial buildings and for walls where strength, economy and durability were important. The Royal Engineers were very much involved in the new developments in limes and cements. They were experimenting to find the best mortars and studying the practical application of the expanded knowledge of the properties of limes and cements. Engineer officers kept in touch with the work of civilians in this field and published the results of their work. The engineer officers showed a willingness to experiment to determine what methods would best suit the local climate and also an interest in what was being used in private construction in the areas where they were stationed. At Halifax in particular the work done with concrete in the mid-1860s was ahead of current British military construction practices.

In military construction, as in the civilian industry, finding a cheap and reliable source of supply for building materials was always an important factor to be taken into consideration. Even after the introduction of Roman Cement, lime was used for mortar because it was cheap and easily available. It became apparent, however, that lime mortars would not set properly, particularly in a damp climate. At the same time as engineer officers in Newfoundland and Nova Scotia were urging the use of more imported cement, officers in Canada were making efforts to discover natural cement rocks. They were successful to some extent, though the locally supplied cement was never a rival for imported Portland Cement in strength or durability during the period under study. Although lime mortar was still being employed for military construction by 1870, its use was decreasing because of the increased awareness of the need for the stronger cements to produce more durable structures. In correspondence with senior officers in London the officers stationed in British North America stressed the false economy of using cheaper mortars. The initial cost of Portland Cement might be higher but the need for repairs was so much less that the expense was justifiable.

Chapter 3

COVERING THE WALLS — PLASTER, RENDER AND STUCCO

"Needed to make the room habitable in winter"

As well as its use in mortar, lime was also used to make plaster to coat walls, ceilings and other surfaces. Plaster served to protect walls from dampness. A plaster covering to interior walls was sometimes considered to make rooms habitable in a North American winter. Plaster can also be used to form decorative ornaments. In the main, plaster work used for military structures was of the ordinary variety, with little attempt at any decorative effect.

Before proceeding to an examination of the military use of plaster in British North America a knowledge of plastering methods in 19th-century Britain is important. The most comprehensive book on the subject of plaster work is William Millar's *Plastering Plain and Decorative. A Practical Treatise on the Art & Craft of Plastering and Modelling*, written at the end of the 19th century. Millar was an extremely accomplished plasterer, who had studied all the available writings on the subject, and had worked for many years to produce a comprehensive text for those learning the craft and for the interested layman, covering all aspects of his profession. Most of the following remarks on 19th-century plastering are taken from Millar's work.[1]

For plaster both plaster of Paris (calcined gypsum, calcium sulphate) and lime (calcium carbonate) can be used. In the 19th century several patent "cements" were developed. Some of these, such as Keen(e)'s, Martin's and Parian, were intended for use as finishing coats in plastering where quick setting or a very polished surface was desired. These were basically gypsum with various additions. According to Millar the "white cements" such as Keen's were unequalled for sanitary purposes and were practically fireproof, but in situations where they would be exposed to dampness they should be applied over a coat of Portland

Cement. "Selenitic cement" developed by Captain Scott of the Royal Engineers was lime subjected to the action of sulphur fumes. Scott's cement produced a very hard surface and was considered suitable for exterior work.

For internal work the first coat of plaster generally contained a mixture of lime, sand, hair and water. Hair was used in order to bind the plaster together. Ox or cow hair was commonly used, though for various reasons other types of hair might be substituted and fibres such as hemp could also be used. Sand was needed in the mixture to prevent irregular shrinkage and cracking and to form channels for crystallization. It was necessary that the sand used in plaster be sharp and hard. The finer the quality of the plaster desired the finer the sand must be. For the final coat of plaster little or no sand was used in order to give a better finish. plaster of Paris was sometimes mixed with this final coat to make it set more rapidly, and was also used largely for cast ornaments, cornices and mouldings.

On brick, stone or concrete walls the plaster was generally laid directly on the walls. The first coat in this case was called rendering. Before putting on the plaster the superfluous mortar in the joints had to be cleaned off, the walls well swept and the surface thoroughly wetted. In some cases the joints of brickwork were raked out or the face of stone walls roughened. In order to provide a suitable surface for plastering on other types of walls or partitions, and on ceilings, laths or narrow strips of wood had to be nailed to the walls or ceilings. Laths were of various thicknesses, with the strongest being used for ceilings, and were usually nailed about three-eighths of an inch apart. The importance of lathing was to provide sufficient interstices for the plaster to obtain a proper key so that it would not fall off.

Ordinary plaster work on interior walls or on ceilings was classified as one-, two- or three-coat work. According to Millar one coat work was usually described as "lath and lay" or on brick walls as "render." "Laying" was simply spreading one coat of coarse stuff on lathing, leaving a fairly smooth surface with a trowel. This was the cheapest kind of plaster, generally used as an infill for partitions or roofs. Two-coat work was usually described as "lath, plaster and set," or "lay and set." This was used for the walls of factories or warehouses and sometimes for closets, attics or cellars in buildings where a better quality of work was used in the main rooms. The best quality of plastering was three-coat work, usually described as "lath, plaster, float and set" or "lath, lay, float and set." Three-coat work was generally specified for the better class of buildings.

Miller described in considerable detail the processes involved in applying three-coat work to a wall or ceiling. For the first coat a layer of "coarse stuff," containing more hair than would be needed in subsequent coats, was spread upon the walls and ceilings. The coarse stuff used for the first coat had to be stiff enough to hold up when laid, but sufficiently plastic to penetrate the interstices between the laths. The coarse stuff for rendering on brick or stone walls did not need to be as stiff as that for use on laths. The first coat should be about one-half inch thick. About an hour after the first coat was laid it was scratched with a moderately sharp pointed tool in order to provide a key for the next coat. The second coat, called floating, was put on when the first coat was sufficiently firm that ordinary pressure of the hand did not mark it. In first-class work plaster dots were first formed at the top and bottom of the wall angles. A narrow strip of plaster, a "screed," was then formed between the dots and was plumbed or levelled, thus dividing the wall or ceiling into bays. Once the screeds were firm the intervening space was filled in flush with coarse stuff and made even with the screeds. When the second coat had set until firm it was scoured with a floating rule, a straight piece of well-seasoned pine, ten feet or more in length and six inches wide, in order to consolidate and harden the surface. The final or setting coat should not be applied until the second coat was quite firm and nearly dry. The surface was roughened to give a good key, and dampened. In the best work the setting stuff was put on in two layers, the second applied immediately after the first. For a good finish the setting stuff had to be scoured with a float until a dense, even and close-grained surface was obtained. Following this the surface was trowelled and brushed with a wet brush. When the work was completely dry it could be coloured or papered.

Stucco is a term loosely applied to all kinds of external plastering. In the late 18th and early 19th centuries stucco was a popular external finish for buildings. Stucco was sometimes finished to imitate stone work. Rough cast or pebble dashing was the coarsest type of external plastering and was considered very durable if properly mixed. The wall was first coated with plaster, and then the rough cast, a mixture of pebbles or gravel and a small amount of lime and water, was splashed on and pressed into it while the plaster was still soft. As this was a coating used to protect external walls it was recomended that the lime used for rough cast should be weather resistant.

A great deal of Millar's discussion of plastering centres on ornamental work. While much of this is irrelevant to a discussion of the work of the Royal Engineers, buildings for which they were responsible did sometimes include some ornamental work such as cornices or ceiling enrichments. Cornices could be either plain or ornamented. If the cornice was to project more than seven or eight inches, brackets were fastened along the intended length of the cornice to which laths were attached to form a support for the cornice. A mould was made of the profile or section of the cornice and was then used by the workman to run the cornice. When making an ornamented cornice the plasterer left indentations for the plaster decorations to be set in. Ornaments were cast in plaster of Paris and a small amount of liquid plaster of Paris used to attach them to the cornice. Detached ornaments for the centre of the ceiling or other parts could be similarly cast and attached.

The plastering techniques described previously were those used in the civil architecture of England with which officers of the Royal Engineers would be familiar. What use was actually made of plaster in military construction in 19th-century British North America? In carrying out his professional duties the engineer officer was supposed to be guided at all times by the Engineers' Code. In the section of the Engineers' Code dealing with the construction and fitments of various buildings, the houses and quarters that the Royal Engineers might be required to build were divided into various classes ranging from quarters for general officers to ordinary barracks. No mention is made of which of these classes of buildings were entitled to have plaster walls and ceilings or what quality of plaster work was to be used; in fact the only mention of plastering was a regulation specifying what type of lath nail must be used.

Throughout the period under study the available records indicate a general trend towards an increasing use of plaster in military buildings in British North America. In general, plaster was used more in permanent posts and in the larger centres than for temporary buildings and outposts. In some cases where other materials were used for the walls, the ceilings were plastered. In the first third of the 19th century plaster tended to be found mainly in officers' quarters, offices and hospitals, although there is some evidence of plastering in men's barracks in a few locations. In the late 1830s and 1840s, there was a considerable amount of military construction, first to meet the threats of rebellion and then to counter increased hostility from the United States. The barracks, hastily fitted up in places such as Chambly and Sorel, had lath and plaster applied to walls, partitions and ceilings. In the case of the stone towers built in the early 1840s to defend against a threatened American invasion, only the room fitted up to accommodate the officer in command of the troops garrisoning the tower was plastered, with the interior walls in the rest of the tower being merely whitewashed. Estimates for the repair of buildings rented to provide additional accommodation for the military during this period show that the walls and ceilings of the rooms in these buildings were plastered, indicating that most of the better class of civilian buildings in the urban centres would likely be finished with plaster walls and ceilings. Estimates for new barracks establishments at Toronto and Burlington Heights at this period show the use of plaster in all the rooms, though at Burlington Heights only the ceilings of the soldiers' rooms were to be plastered. Of two estimates drawn up in 1846 for new barracks at Montréal, the earlier one indicated the use of plaster on walls and ceilings throughout, but the second stated specifically that it was not intended to use plaster in the soldiers' rooms. From the 1850s on most of the military construction intended for the accommodation of officers and men made use of plaster for walls and ceilings. Distinctions were still sometimes made. In military prisons, offices, chapels, the quarters for wardens and the ceilings of corridors might be plastered, but the cells usually were not. An 1852 estimate for new barracks in Halifax specified plaster ceilings for the officers' privies, but not for those for the officers' servants.[2]

The increased use of plaster in accommodations for troops was a reflection of the increased concern for the health and comfort of the soldiers that developed in the 1850s. Estimates for the conversion of storage areas to offices or quarters frequently included provision for lath and plaster for the walls and partitions. An estimate for repairs to barracks in Prince Edward Island in the late 1840s included provision for renewing the plastering of the guardhouse. Because of the dilapidated state of the plaster the room was so cold during the winter that those on guard duty complained constantly. When it was proposed to fit up a room in the ordnance storehouse at Saint John as a barrack office in the late 1850s, the estimate provided for covering the partition dividing this room from the rest of the storehouse with lath and plaster in order to make the new office habitable in the winter. While the increased use of plaster in soldiers' barracks added to their comfort during the winter by cutting down on drafts, plaster or render contributed to the comfort and convenience of the soldiers in other cases as well. When plans were being drawn up for ball courts at Québec in the late 1860s, it was recommended that the end walls be rendered with cement "to make them properly fit for use."[3] The sanitary value of lime plaster, being easier to keep clean and free from insect infestation, which Millar and other writers stressed, was not mentioned as a reason for plastering soldiers' barracks, though doubtless after the 1850s those in charge of military construction had this aspect in mind too.

If walls or ceilings were to be plastered some preparation was needed to fit them to receive lath and plaster or rendering. Some estimates, particularly those for repairs or changes to existing buildings, indicate what type of surface treatment was necessary as a base for plastering. The 1825 specifications for a new house for a storekeeper in Halifax stated that the walls to be plastered should be "battened with spruce boards an inch thick and two and a half inches broad, to be well nailed on the bands and placed 16 ins. from centre to centre." In later estimates and specifications the battening or studs to receive lathing tended to be closer together than in this case. For example, an 1846 estimate for fitting up a rented building in Kingston for use as a military hospital specified that the walls of the hospital orderly's room were to be battened with 2-by-1-inch rough pine placed 12 inches apart, centre to centre. Partitions were to have 4-by-2½-inch studs of rough framed pine 12 inches apart centre to centre. In the early 1840s estimates were prepared for repairing certain rented buildings in Toronto prior to returning them to the owners. In one of these, "Ritchey's Buildings," the walls, which had been whitewashed while the troops were in occupation, had to be made ready to receive plastering. In order to do this the joints of the brickwork had to be raked with a pointed instrument "in order to remove sufficient quantity of the old Mortar to give a proper bond for the plastering."[4] It would then be necessary to saturate the walls thoroughly with water immediately before plastering.

In examining the use of plaster in military buildings an important aspect to be considered is that of the materials used. What did the Royal Engineers use for lath and plaster work or rendering, and where did they obtain these materials? On wooden walls and partitions and on ceilings the plaster was applied to a layer of lathing. Millar in his work mentioned three thicknesses of lath: single, lath and a half, and double. Laths generally varied from three to four feet long. Sources relating to military construction made no reference to the thickness of the lath in use. What little evidence there is on the length of laths in use shows both three- and four-foot laths, with greater use of the longer laths. Laths were a widely used item and would be easily obtainable from local suppliers in any of the larger urban centres, who could also supply the needs of the outposts.

The Engineers' Code stated that the only lath nails to be used in the Ordnance service were to be nail No. 167, 1⅛ inches long (threepenny fine), and No. 168, ⅞ inches long (smaller than a twopenny nail).[5] Estimates of the early decades of the 19th century tended to specify fourpenny (inch and a half) nails for lathing. In most later estimates the size of the lath nail to be used was not specified, but an 1838 estimate for repairing barracks at Trois-Rivières called for the use of No. 168 nails.[6] In some of the earlier estimates it was stated that lath nails were to be supplied from England.

The standard materials used for "coarse stuff" for plastering were described in specifications drawn up in 1825: "the best merchantable white lime and sharp river sand ... well mixed with sufficient quantities of good cow hair."[7] Lime was used for mortar, for plaster, and for lime-whiting. In most of the estimates for new construction or repairs, which provided a detailed list of the materials needed, it is difficult to tell whether the lime included in the list was to be used for plaster. Lime was generally supplied locally. In some cases, such as St. John's, the Ordnance Department had its own lime kiln, operated by the military or under contract. Otherwise lime could be obtained from local merchants or, when work was done under contract, was supplied by the contractor. The hair for plaster, usually cow or ox hair, and the sand would also be supplied locally. Plaster of Paris was also needed for cornices or for the finishing coat in better work. No indication is given in the various estimates of where this was to be purchased, but except at the outposts it was probably obtainable locally.

Reference books such as Millar's on plastering describe the highest standard of work in 19th-century Britain and indicate what materials were being used for plaster work and in what proportion. Schedules for contracts give some information about the standards of plastering in military construction. The "Analysis of Schedule Prices Proposed to be Adopted for Triennial Contracts in Canada" for the 1850s shows the various types of plaster work standard in military construction at the time and the materials used. Rendering was classified as one coat, one coat and set, two coats and set, two coats and float, two coats float and set and rendering with American Cement (generally used for water tanks); this was followed by a similar division of lath and plaster work. To cover 38 superficial (square) feet with one coat of render (one day's work for a plasterer and a labourer) took 17½ cubic feet of mortar (made from lime, sand and water) and 6 pounds of hair. To render one coat and set with fine stuff took, in addition to the materials needed for one coat, 2½ cubic feet of fine stuff (consisting of lime and water) and an additional two-thirds of a day's labour. A second coat of render before the setting coat used two-thirds as much material as the first coat. To render two coats and float required 2¼ days of a plasterer and a labourer's work, 30 cubic feet of mortar and 10 pounds of hair. Rendering two coats, floating and setting cost about 15 per cent more than rendering two coats and setting. Lathing cost an extra five pence or six pence per superficial foot. One coat of rough cast on 60 yards superficial of brick or stone took 25 cubic feet of lime and gravel. Twenty feet of plain cornices including mitring took one-half a hundredweight of plaster of Paris and half a cubic foot of fine stuff, and occupied a plasterer and a labourer for two days. The additional expense of running beads and quirks on mouldings was listed, but any other ornamentation was usually individually priced.[8] The schedules of contract prices for the Canadas in this era which have survived divide rendering and plaster work into the same categories as this analysis though the prices quoted vary slightly. The proportions used for work in Halifax were very similar to those specified for work in the Canadas. According to the specifications drawn up in the early 1850s for the construction of new barracks in Halifax, the haired mortar for plastering was to be composed of equal portions of white lime and clean sharp fresh-water or pit sand, with one pound of dried, well-beaten cow or ox hair to three cubic feet of mortar.[9]

Very little information is available on the methods of plastering used in military construction in British North America. In 1822, in answer to a report on the failure of some of the plastering in the north wing of the barracks at Sydney, Cape Breton Island, Captain Philip Barry, RE, who had been in charge of building these barracks, described the care that had been taken in applying the plaster. Immediately after the first coat was put on it was scored with a blunt stick in order to provide a better key for the second coat. Barry stated that in most of the houses built in Nova Scotia the first coat of plaster was put on in the autumn and the second coat the following summer, implying that this practice was followed in plastering the barracks at Sydney. No mention was made of the first coat being dampened before the second coat was put on, as was recommended by experts on the subject, in order to prevent too much moisture being absorbed from the fresh plaster. According to specifications drawn up in 1825 for building a house for the storekeeper at Halifax, the third coat of plaster in the rooms and passages of the first and second floors was to be twice floated and well polished "so that nothing offensive to the sight may appear on the walls when they are painted."[10] In this instance the first two coats of plaster were to be of lime and sand mixed with cow hair, and the finishing coat of putty and plaster of Paris.

Most estimates for construction of military buildings specified what quality of plaster work or rendering was to be applied. Two-coat work was variously described as one coat and set or two coats, and three-coat work as two coats and set, two coats float and set, three coats, and lay, float and set. Very little use was made of one-coat work and that mainly in work such as the wooden barracks which were hurriedly fitted up in Lower Canada in 1837, and in some prison cells. In a few cases two-coat work was to be used for attics, kitchens or privies where three-coat work was specified for the main rooms of a building, but this does not seem to have been very common. By the 1850s most of the plaster work in military construction was being described as plaster or render two coats and set with fine stuff, although two-coat work was still being used occasionally. The analysis of prices shows that the use of three coats of plaster did not always involve "floating," as the expense for this was calculated separately. Presumably in much of the military architecture there was not as much care taken to ensure a perfectly flat, level surface as Millar considered essential to first-class work.

As well as plain plastering on walls and ceilings some military construction included cornices and ceiling enrichments. Cornices were usually to be found in officers' quarters or mess rooms. Some offices also had cornices. When Government House in St. John's was being built under the supervision of the Royal Engineers, one of the difficulties encountered in its construction was with the work done by the plasterers; the cornices in the hall and in the east wing had to be worked three times before they were properly done. There is no indication of the techniques used by the Royal Engineers to make cornices, but it was common procedure for these to be hollow, being run over lathing nailed to brackets. This was the method recommended by Millar for any cornice over seven or eight inches and was generally used because of the problems of shrinkage and weight posed by a solid cornice. Where cornices were to be built the more public rooms, such as mess rooms, usually had larger cornices than bedrooms, and in general the size of cornices used in military buildings increased from the 1820s to the 1860s. An 1833 estimate for barracks at Annapolis Royal specified a 6-inch cornice in officers' rooms and a 10-inch cornice in the mess. An 1840 estimate for a building to house Ordnance stores in Saint John called for 12-inch cornices in the offices, while an estimate of the same year for barracks at Montréal called for 10-inch cornices in the mess room and 8-inch cornices in the officers' rooms. By the 1850s and 1860s much larger cornices were being created. The specifications drawn up in 1852 for new barracks in Halifax stated that in the officers' mess room there was to be a "moulded cornice in plaster ... run round the ceiling not exceeding two and a half feet in girth."[11] The reception room was "to be finished with a corresponding moulded cornice in plaster not to exceed twenty one inches in girth." Field officers' dining and sitting rooms were to have cornices similar to that in the mess room, though the ceiling ornament was to be smaller. Twelve years later, plans for new officers' barracks at Halifax called for the sitting rooms in field officers' quarters to have plain cornices of 24-inch girth, while other sitting rooms and halls were to have cornices of from 18 to 20 inches. Some rooms with cornices also had ornamentations in the centre of the ceiling. The 1825 specifications for a house for the storekeeper in Halifax called for a lustre flower in the centre of the ceiling of the main hall. In the 1852 plans for new barracks at Halifax, the specifications called for the ceilings of the mess room and the field officers' dining and sitting rooms to have centre ornaments to correspond with the moulding in the cornices. The 1864 estimate for new officers' barracks in Halifax called for centre flowers, three feet in diameter for field officers' quarters, but not for the other rooms.[12]

As well as being used for interior wall finishes, plaster could also be applied to exterior walls, usually in the form of "rough cast." This finish was used to protect exterior walls from the weather, and also to give a uniform appearance to walls. For military construction it was used most widely in what is now the province of Quebec. When repairs were being carried out in the garrison hospital at Québec in 1822 it was noted that the rough casting of the exterior walls required repairs. When estimates were drawn up for reconstructing the Artillery Barracks at Québec following the destructive fire of 1852, it was recommended that the exterior of the building be rough cast to correspond with what remained of the original building. At St-Jean, engineer officers continued to stress the need for a covering of rough cast on the exterior of the expense magazine in order to prevent the weather affecting the stability of the rubble masonry of the walls. The dampness was penetrating to the interior and making the magazine useless for the storage of powder. In Halifax in the 1850s, the Commanding Royal Engineer noted that, in private construction, use was being made of external plastering of Portland Cement on exposed walls of brick and stone buildings in order to protect them from the damp but his suggestions that this might be appropriate for military construction do not seem to have been heeded by the authorities in London.[13]

As with any other aspect of construction certain problems were encountered with the use of plaster in military buildings in British North America. In the early 1820s the second coat of plaster on the walls of the men's barracks at Sydney on Cape Breton, was beginning to separate from the first coat and fall off at the least disturbance. In attempting to ascertain the cause of this and to find the best method of repairing the walls the Ordnance Department consulted both Captain Barry, the engineer officer who had been in charge of construction of the building, and some local builders. The local builders, blaming the method used to apply the plaster and the weakness of the lathing, suggested that the plastering should be redone, a solution that would supply them with considerable work. Captain Barry maintained that the original plastering had been well done, in the manner usual in that part of the world. He had learned from Major Stewart, who had commanded the troops occupying the building for two years, that during that time there had been no problem with the plaster. Less than a year after the troops under Stewart's command left the barracks it had been noticed that "the least disturbance causes it to fall off." Barry considered that the real cause of the problem was lack of proper supervision by the barrack master. He had found from experience that plaster in any barrack was liable to be destroyed by the troops throwing wood, water pails, etc., against the walls, or driving nails and bayonets into them. Because of this he recommended that the walls up to the level of the window sills at least should be boarded.[14] The use of a boarded finish for the lower part of walls in barrack rooms or in other places where plaster would be likely to suffer damages was not an uncommon one. In plans for new barracks at Woodstock, New Brunswick, at the beginning of the 1840s, it was originally suggested that the soldiers' rooms be lined with boards to a height of 3 feet 6 inches and recommended by the authorities in London that the boarding be extended to a height of 5 feet. When a barrack building at Kingston was being fitted up as a hospital in the 1840s, included in the estimate for this work was the cost of lining the walls of the staircase with pine boards "as hitherto the plastering had required constant repair from frequent and unavoidable damage occasioned by the narrowness of the staircases."[15]

Dampness often caused problems with plaster or rough cast surfaces. At St. John's there were always problems with dampness in the buildings on Signal Hill and this condition had a damaging effect on the plaster. In at least one case it was recommended that plaster be replaced by boarded walls in order to prevent further trouble. At Sorel in the 1860s problems were encountered with dampness in the expense magazine where the rough cast had peeled off the external walls. For external walls it was only a hydraulic lime or cement which could provide a sufficiently water-resistant material to protect the walls.[16]

In order to provide a satisfactory internal or external finish or a proper basis for painting or papering, plaster had to be carefully manipulated by experienced workmen. Plaster had to be properly dried before it was ready for the next coat or for the application of paint or paper, but before putting on a fresh coat of plaster the surface on which it was to be applied had to be dampened. One of the explanations put forward for the flaking off of the second coat of plaster in the barracks at Sydney was the fact that the first coat had been allowed to dry for so long before the second coat was put on. In some cases the drying of the plaster was artifically speeded up in order to make a barrack habitable more quickly. For example, because of the urgent necessity for accommodation for troops in Chambly to counter the unrest in the late 1830s, the plaster in the newly built barracks was dried by keeping fires in the rooms before they were occupied.[17] As these barracks were needed only for a short period any problems with the durability of the plaster caused by drying it more rapidly than usual were not important.

In their use of plaster and stucco the Royal Engineers do not appear to have departed significantly from the accepted practices of the time. Plaster came to be used more frequently in soldiers' barracks as well as for officers' quarters and offices. It was used on exterior wall surfaces as a protective coating for stone walls. In the preparation and handling of plaster the Royal Engineers followed the methods usual at the time though they do not appear to have placed as much emphasis on obtaining a perfectly flat, level surface as was recommended by texts on the subject. The main problems they encountered with plaster were caused by dampness and by rough usage, particularly in barrack rooms.

Chapter 4

THE ROOF

"A very permanent, and consequently economical roof"

The choice of roof design has been greatly influenced by climate. In northern countries a steep pitch or slope of about 60 degrees, with overhanging eaves, has been usual as this type of roof gives greater strength and a quicker dispersal of melting snow. In temperate climates where excessive snow is rare pitches of 30 to 45 degrees predominated, and in hot climates flat roofs have always been common.

Sun, rain, snow, wind, and alternate freezing and thawing all tend to cause damage to roofs. The chief factors influencing the choice of a roofing material are the slope of the roof, durability, initial cost, maintenance, resistance to fire, weight, type of roof construction and appearance. The asphalt shingle, in common use as a covering for houses today, is a development of this century. Pitched roofs of an earlier day were generally covered with tiles, slates, wooden shingles, metal sheets or thatch. In common with civilian builders the Royal Engineers sought a roofing material which would be long lasting and cheap. Modern flat roofing generally comprises several layers of asphalt- or tar-saturated felt cemented together with asphalt or tar roofing cement and covered with gravel.[1] In 19th-century military construction the necessity of discovering a suitable covering for a flat surface arose chiefly in the construction of casemates and redoubts. The solutions proposed and tried by the Royal Engineers in this context will be discussed in the chapter dealing with the use of asphalt.

Hand-split shingles or shakes were commonly used by the early settlers in both the United States and Canada. By 1850 many patents for shingle machines had been awarded and shingle making became an important branch of the North American lumber business. Wooden shingles are usually tapered. The best shingles were considered to be those made from cypress, redwood or cedar. A building manual first published in the United States in the late 19th century and based on both English and American references stated that cypress shinglès were usually 18 inches long and those from all other woods 16 inches long, but 18-inch pine shingles were often used by the Royal Engineers in British North America. Shingles were not generally of standard widths, but the average width of shingles in a bundle was usually taken as 4 inches. Shingles were laid in horizontal courses starting at the eaves with a two- or three-ply first course and subsequent courses overlapping the preceding ones. The amount of the shingle exposed to the weather varied according to the pitch of the roof. With a rise in the roof of 8 to 10 inches to the foot shingles were laid 4 to 4½ inches to the weather; with a rise of from 10 to 12 inches to the foot they were laid 4¼ to 4¾ inches to the weather; and on steeper roofs they were laid 4½ to 5 inches to the weather.[2] Shorter shingles would have a proportionally smaller exposure to the weather. One of the disadvantages of wooden shingles was their short life expectancy. In wet climates untreated wooden shingles were liable to discolouration, decay and the growth of moss, lichens and algae. Shingles were sometimes treated with tar or pitch, or painted to increase their durability and improve their appearance. In cities wooden shingled roofs were a fire hazard. In spells of hot dry weather they became increasingly flammable. Wooden roofs provided an easy pathway for fires and burning shingles often blew onto other roofs starting new fires. Shingles were a major cause of uncontrollable fires across North America until the 1920s.[3]

Another type of covering used for pitched roofs on the better class of buildings in the 19th century was slate. The slates used for roof coverings are derived from sedimentary rocks of a normally clayey composition which under the action of pressure have developed a very perfect cleavage, making the rocks easily split into thin plates suitable for laying. Slate should be hard and tough. If the slate is too soft the nail holes will become enlarged, if too brittle the slate will be easily broken.[4] A fine sound texture is also a most desirable quality of good slate. If the slate absorbs much moisture the boarding will become rotten. Slate is available in a great variety of colour. The slates most commonly used in 19th-century England were those from Wales and Westmoreland. These slates were generally classed in the following sizes:

Doubles	13 in. by 6 in.
Ladies	15 in. by 8 in.
Countesses	20 in. by 10 in.
Duchesses	24 in. by 12 in.
Welsh Rags	36 in. by 24 in.
Queens	36 in. by 24 in.
Imperials	30 in. by 24 in.
Patent Slate	30 in. by 24 in.

The average weight of first quality Duchess slate was considered to be 5 lbs. 8 oz. per slate.[5]

Slates can be laid on a board sheathing or on roofing laths. Each slate should lap the slate in the second course below at least three inches (the exact amount of the lap is stated in the specifications for the roof). Slates are fastened with two threepenny or fourpenny nails, depending on the size of the slate, one near each upper corner. Copper, composition, tinned or galvanized nails should be used and the nails should have a large thin head designed to fit within the countersunk holes in the slate. Roofs to be covered with slate should have a rise of not less than six inches to the foot for 20- or 24-inch slates, or eight inches for smaller sizes.[6]

As a roofing material slate has the advantages of being fireproof and long lasting. Slate has drawbacks as well. It is one of the more costly materials available for roofing. As well, the cost of a slate roof is increased by the fact that slate is heavy and therefore requires a more substantial framing system for support than lighter coverings such as shingles. In the mid-19th century slate became increasingly popular as a roof covering for houses, as a result of the growing interest in "picturesque" designs for dwellings in North America. With the increased demand for slate and the availability of better transportation slate quarrying became profitable in North America.[7]

One of the most popular roofing materials in the United States in the 19th century was tinplate. Tin was also widely used in the Canadas, but not in Nova Scotia, New Brunswick or Newfoundland. Roofing tin was made of sheets of wrought iron coated with tin. A new development in the 19th century was the use of an alloy of lead and tin as a coating. The plates produced in this manner were referred to as "Terne Plates." The most common sizes of tinplate were 10 by 14 inches and multiples of that size, 20 by 14 inches and by the 1870s, 20 by 28 inches. Tinplate was normally available in two "thicknesses" (weights): for IC tinplate the weight of the iron was 50 pounds per 100 square feet; for IX it was 62.5 pounds per 100 square feet. IC was generally the preferred weight for roofing. In laying sheets of tin on a roof it was important that provision be made for expansion and contraction of the tinplate due to temperature changes. All roofers were agreed that a tin roof should be kept painted. The under side of the tin should be painted before the tin was laid on the roof and the top painted after the tin had been thoroughly washed by rain to remove any grease on its surface. Brown and red were the colours commonly used.[8]

Tinplate had several advantages as a roofing material. One was the fire protection it afforded; sparks from chimneys could not start a blaze on a tin roof. However, the intense heat generated by the large-scale blazes so prevalent in 19th-century North American cities might cause a tin roof to roll up exposing the roof boarding underneath. Another advantage was that tinplate was less than one-tenth the weight of slate. This meant that a tin roof required a much less substantial framing system than was needed to support one of slate. Tinplate was also durable. It was estimated by the author of one building manual that a tin roof of good material properly put on and kept properly painted would last from thirty to forty years.[9] The tin used for roofing in North America in the 19th century was mainly imported from England.

Other types of metal plates were also used for roofing. In the 19th century the rolling of sheet zinc was developed. In the United States the use of zinc for roofing began in the 1820s. Zinc was popular for a time but fell out of use by the 1840s. Interest in zinc roofing revived in the 1850s only to die again in a few years. One of the objections raised to the use of zinc for roofing was a fear that it had a bad effect on drinking water. This was voiced by an American professor of geology and mineralogy who urged that the use of zinc for roofing be "entirely abandoned because of the deleterious effect it had on drinking water" (presumably that collected in roof gutters). Zinc was also used in the production of galvanized iron sheets, which had the benefit of being rust resistant. Galvanized iron became widely used for industrial structures. Copper and sheet iron were also used for roofing.[10]

A development of the later part of the 19th century was the composition or built-up roof. With the increasingly widespread use of flat roofs, particularly for industrial and commercial buildings there was a need for a type of roofing with fewer seams to lessen the likelihood of water seeping through the covering. Composition or built-up roofing consisted of pieces of cloth, felt or paper saturated with a cementing substance, which, when fastened to the roof, were coated with more of the cementing substance. For better protection several layers were sometimes used. The roof was finished with a coat of sand or gravel. When felt became available in long rolls it became particularly valuable for roofing. In the United States in the 1850s Messrs. S.M. and C.M. Warren advertised composition roofing of paper or felt saturated with tar. The Warrens continued to improve their composition roofing and experiment with various types of cementing material. As well as coal tar they used asphalt for saturating the felt and for the surface coating.[11] By the end of the 19th century composition roofing of felt and asphalt or coal tar was common across North America.

The roofing materials commonly used by the Royal Engineers in British North America in the period 1820-70 were shingles, tinplate and slate. Pine or cedar shingles were the most widely used roofing material. Most estimates for construction of or repairs to military buildings outside the main military stations called for the use of shingles for roofing. Slate was used to some extent in St. John's, Halifax, Saint John and Fredericton, mainly for the more important buildings. In the Canadas there appears to have been no interest shown by the Royal Engineers in the use of slate for roofing except at the very end of the period under study. Tin was used to a large extent in Québec and to a lesser degree in Montréal for both civil and military buildings. An agent of the Phoenix Assurance Co. of London, who visited North America in 1845, spoke of the towns of Upper Canada as having some tin roofs, the rest shingled, with the new houses being built of brick and covered with tin, but whatever the construction of the main house the outbuildings were invariably of wood, with shingled roofs. This observation on civilian buildings seems to have been equally true of the military. For example, an estimate for constructing various buildings at Point Frederick, Kingston, drawn up in 1847 called for tin roofs for most of the buildings, but shingled roofs for the privies.[12]

There were several considerations affecting the choice of roofing material by the Royal Engineers. Cost was always an important factor. First the initial cost of roofing the buildings had to be estimated. The expense involved not only the cost of the roofing material itself but the type of structure needed to support it. Shingles were the least expensive type of roofing material and also because they were much lighter than slate they did not require as substantial a roofing system to support them. Although only the initial cost appeared in estimates another expense to be considered was that of maintenance. Shingles cost less than other types of roofing but the cost of upkeep and replacement was greater. Engineer officers in drawing up estimates for buildings might give the future expense of maintenance as a reason for preferring other types of roofing to shingles, but this view was sometimes overruled in favour of the short-term saving of using a cheaper material.

In explaining their choice of a roofing material, engineer officers on occasion stated that they were influenced by local usage and by the local climate. Local usage seems to have carried more weight in influencing the choice of a roofing material for military buildings than in many other aspects of military building technology. Tin was at various times mentioned as the usual roof covering in Lower Canada, "generally made use of throughout the Principal Cities," and in use for "the roofs of the principal Buildings."[13] Climate was an important influence on local custom in the choice of roofing materials. The Royal Engineers were conscious of the effect of the climate at the various stations in British North America on the durability and suitability of roofing materials. Various types of roofing were recommended by officers on the spot as best suited to the local climate. There were places, however, where nothing seemed suitable. In St. John's it was extremely difficult to find any material that would withstand the rigours of the climate. In 1833 the Commanding Royal Engineer in Newfoundland, reporting to the Governor on the condition of the officers' barracks on Signal Hill stated that

> *the alternate drought and moisture of this climate, which with the frost are constantly in the extreme, will, in many cases, split the shingles, and on all occasions warp them, as well on the roofs as on the sides; consequently there is scarcely a building in this country that is perfectly weather proof.... The climate operates upon materials in a manner that could scarcely be believed, by persons unacquainted with the colony.*

Speaking of the buildings at Fort William, a less exposed location than the summit of Signal Hill, he reported, "The stone building is slated, with leaden gutters, but slates in this country do not appear to answer *unless* bedded in cement."[14] Eight years later Lieut. Col. Sir Richard Bonnycastle, then Commanding Royal Engineer in Newfoundland, told the Inspector General of Fortifications,

> *I am convinced that heavy slate coverings for the roofs on Signal Hill will never stand the almost continuous winds of this boistrous climate, and whenever the slates are displaced and commence falling it is next to impossible for the Garrison occupying Signal Hill to stir out of the Barracks as they are hurled about with immense force.*[15]

Another factor to be considered in choosing a roofing material, particularly in the larger centres was the ever-present hazard of fire. In 1845 Québec suffered two disastrous fires which left an estimated 20 000 homeless. The following summer in St. John's a fire spread by hurricane-strength winds burnt out over half the population and destroyed virtually all the mercantile heart of the town. A fire in Montréal in 1852 left about 10 000 homeless and destroyed among other things most of the records of the Royal Engineers for the district. In an 1859 fire in the business district of Halifax areas considered fire proof were destroyed. As well as the large-scale fires that destroyed entire districts of cities or towns, lesser fires were a common occurrence. The *Saint John News* noted in 1859 that serious fires had claimed "a hundred houses at a time every two or three years," and the *Montreal Pilot* pointed out to its readers after the 1852 fire in that city that smaller fires had "within the last six or seven years" turned almost "one-half of the City into ashes."[16] Stone buildings were clearly less likely to burn than wooden ones and this was recognized in many of the regulations restricting building practices passed by local municipalities in the wake of some of the more disastrous fires. The greatest potential source of danger was the roof. In discussing a proposal to put a zinc covering on the roof of a wooden building in the Military Store Yard in Halifax Colonel R.J. Nelson, the Commanding Royal Engineer, pointed out in 1859:

> *Besides the houses etc. etc. actually on fire, combustion is widely spread by large flakes of half burnt wood which are carried to a surprising height in the air, becoming in fact fire balloons rising from the surrounding volumes of atmosphere rarified by their own heat. This is especially the case when wooden stores, dockyards,*

> *Shipping, forests etc. etc. are in flames. I now speak from experience here and elsewhere.*
>
> *Since I have been here this Ordnance Establishment has been twice in serious danger from fires in its immediate neighbourhood.*
>
> *These buildings have all shingle roofs; their being superseded by zinc coverings materially reduces the chance of combustion whether they be contiguous to two buildings or not: fire flakes will lodge on such a roof though they cannot in the vertical faces of even a wooden building.*[17]

A report explaining an estimate for stripping off the shingle roof of the ordnance magazine at Fredericton and covering it with slate stated that the shingled roof was "highly dangerous during the frequent Fires in that city from the falling embers" — certainly not an overstatement of the hazard considering the damage a fire in a powder magazine could cause.[18]

For commercial buildings the difference in the cost of fire insurance was becoming an incentive encouraging the use of more expensive but less flammable materials. The military too showed an awareness of the advantages of fire-proof or at least fire-resistant construction, though they sometimes viewed the potential hazard of fire from a somewhat different perspective than that of civilian property owners. Colonel Holloway, when discussing in 1845 the plans proposed for a new barrack establishment at Montréal, stated:

> *These roofs to be covered with Tin, the usual preservative in this Country from accidental Fires: Unless it be thought that the danger of accidental fires of importance is so very remote, where Military arrangements exist, and the Troops numerous, and always at hand to render assistance, with the Roofs divided by arches of masonry from the lower apartments, that the Tin coverings may be dispensed with and the Expense saved.*[19]

The presence of a large body of troops was also of benefit to other property owners. The military were often called upon to assist in the fighting of fires, particularly in Québec, Halifax and St. John's, and were of great assistance to the small bodies of civilian fire-fighters.

Shingles were the cheapest and most widely used roofing material in British North America. Surviving estimates and reports on buildings indicate that the Royal Engineers in British North America in the 19th century made greater use of shingles than of any other roofing material. At St. John's the Commanding Royal Engineer reported in 1823 that all the storehouses in charge of the Ordnance Storekeeper were roofed with shingles. Shingles were used for the barracks at Fort Townshend, for the office and quarters of the Commanding Royal Engineer, for a hospital built on Signal Hill in the 1840s and for various sheds and other buildings. When the barracks on Signal Hill were converted into storehouses in the early 1840s, the slate roofs were replaced with shingles and it was reported that this had cured the problems of dampness coming into the buildings through the roofs.[20] In Halifax, many of the public buildings were stone or brick with slate roofs, and by the end of the 1870s many of the warehouses were also of masonry because of the lower insurance rates on such buildings. Most of the houses and smaller buildings, however, were built of wood with shingle roofs. Military buildings followed the same pattern as others in the city. Most of the barracks, storehouses and offices as well as sheds and outbuildings and the garrison chapel, garrison general hospital and the Cavalier Barrack in the Citadel had shingled roofs. Similarly Saint John was described in 1845 as "one mass of Timber and Shingled Building" and the older military buildings both at Saint John and Fredericton followed the same pattern with most of them having shingled roofs. In the smaller stations in the Atlantic area the use of shingles for roofing was even more universal with almost no use of any other roofing material. The estimates for a new barrack establishment at Annapolis Royal which were proposed in the early 1830s called for Bangor slates for the roofs, but the military buildings which actually existed in Annapolis had shingled roofs.[21]

In the Canadas shingles, while still the most widely used roofing material, were less predominant than in Nova Scotia and New Brunswick. Québec and Montréal still had many shingled buildings throughout the period under study, but the proportion was gradually diminishing. Among the military buildings in these cities shingled roofs were to be found mainly on sheds and outbuildings and on temporary buildings. At Kingston the older buildings were shingled. When the new fortifications were built at Point Henry and Point Frederick, although shingles were not used for the main buildings, they appear to have been used for privies and sheds. Some of the newer military buildings in Toronto had other types of roofs but the large majority of the buildings were shingled. At Niagara, with the exception of the tower in Fort Mississauga, all the military buildings appear to have been shingled, as do the military buildings at London and Amherstburg. Shingled roofs seem to have been almost universally used for military buildings at the various outstations in both the Canadas.

Very few of the estimates that included shingles indicated where they were to be obtained. Whenever lists of stores to be purchased on the spot were drawn up, shingles seem to have been included.[22] It was certainly possible to obtain locally produced shingles in most of the areas where military posts were located. In 1821 John Goudie was advertising in the *Quebec Mercury* that he had for sale at his steam saw mill at the St. Roch suburb mill-sawn shingles of all lengths and sizes. In 1824 A. McDonald of Québec was advertising American shingles for sale. In Halifax merchants were offering shingles for sale, some of which were manufactured in Nova Scotia and New Brunswick.[23] Shingles would be obtained through contracts with local firms or be supplied by a local builder who had obtained a contract to do the work of shingling.[24] When the shingles supplied by the contractor did not conform to the requirements laid down in the contract the engineer officer supervising the work purchased others to replace them. For example Major Freeth, the engineer officer at Saint John reported in 1850 that since over half the shingles provided by the contractor were less than 17 inches long and many were of rotten wood or too thin he had refused the certify the bill for payment and had purchased others.[25] Perhaps the contractor was trying to pass off on the military supplies he was unable to sell elsewhere.

In some estimates and other records dealing with military construction the size and type of shingle to be used were specified. The most commonly used were 18-inch shingles, laid 4½ inches to the weather. On a few occasions, mainly for buildings in Montréal, 16-inch shingles were requested. These were laid either 3½ inches or 4 inches to the weather. In many of the estimates or specifications for work to be done at Halifax the size of the shingles to be used was not given, but it was stated that they were to be laid 4 inches or 4½ inches to the weather. When the type of wood to be used was specified pine was the most often called for, with cedar used on occasion in Quebec and New Brunswick. In a few cases the quality of shingles to be used was indicated. Specifications drawn up in 1825, for shingling the roof of the house to be built for the residence of the Ordnance Storekeeper in Halifax, called for "the shingles to be of the best white pine, free from shakes and sap, laid 4½ inches to the weather, nailed with 5dy nails and finished with saddle boards."[26] In a few cases mention was made of special treatment to be given to shingled roofs. An 1823 estimate for repairs to various buildings in Québec stated that roofs being covered with shingles must be whitewashed. In 1832 Captain A. Marshall, stationed in Saint John, wrote to Lt. Col. Boteler, Commanding Royal Engineer at Halifax, asking whether it was the custom in Halifax to paint shingled roofs of government buildings as he considered the advantage of this to be doubtful. Marshall suggested washing the shingles with a strong solution of lime water mixed with a little salt and coloured with lamp black to give the appearance of slating, as he believed that this hardened the shingles. A few years later an estimate for work to be done at Montréal called for a shingled roof to be coated twice with coal tar.[27]

Despite the precautions taken to ensure that good quality shingles were used and that they were properly treated, the life of a wood-shingle roof was not long compared to other types of roofing. An engineer officer stationed in New Brunswick in 1819 estimated that a shingled roof for the barrack (size not given) would require to be renewed every 16 years at a cost of £175 (about half the cost of a slate roof, which would last much longer), aside from the expense involved in keeping it repaired and providing ladders on the roof so that fires caused by sparks from the chimneys or other sources might be extinguished. The life of a shingled roof might be extended beyond 16 years but not for any great length of time. In the estimates drawn up for works and repairs in Nova Scotia in 1843-44, it was noted that the roofs of many of the barracks needed to be completely renewed. The shingles, which had been put on in 1823, leaked badly and were past any partial repair.[28]

Slate was more commonly used for roofing in the Atlantic colonies than in the Canadas, though there were deposits of slate in the latter area. In St. John's, slate was used by the Royal Engineers for stone buildings, such as Government House, the powder magazine and barracks on Signal Hill (though the slate was later replaced by shingles when these barracks were converted into storehouses), and for some storehouses and barracks elsewhere. The proportion of slate roofs was higher for military buildings than for civilian ones in St. John's. In Halifax slate was used for powder magazines and some barracks and storehouses. The specifications for new barracks near Fort Needham, printed in 1852, called for slate roofs for both officers' and men's barracks. Some use was also made of slate for covering casemates in the Citadel; this will be discussed in the chapter dealing with the use of asphalt. As well the annual estimate for works and repairs in Halifax for 1860-61 included a new privy for the use of officers of the military store department, which was to have a roof of Bangor slate. At Fredericton and Saint John it was the newer stone and brick buildings, including officers' quarters, storehouses and powder magazines, that were covered with slate, though in 1849 the ordnance magazine at Fredericton was still covered with a shingle roof.[29] In the Canadas the Royal Engineers made almost no use of slate for roofing during the period under study. By the 1860s slate was coming into use in the Canadas. The barrack services estimate for 1863-64 included provision for a new expense magazine at Toronto to be covered with slate. The schedule for contract work for the Royal Engineers Department at Montréal, printed in 1866, included specifications for slaters' work using various sizes of slates.[30]

Throughout most of the 1820-70 period, the slate used by the Royal Engineers in British North America appears to have been imported from Britain, either directly through the Ordnance offices in London or by local suppliers providing materials on contract or building under contract for the military. The dependence on supplies from Britain caused some difficulties. In the fall of 1826 a ship hired to take a cargo of slate and bricks to Newfoundland after being at sea for four weeks was forced to put in to harbour at Penzance, thus delaying the arrival of the slates considerably. Delays such as this in the arrival of supplies could force a change in the type of roofing material used. The previous year the newly built house for the Ordnance Storekeeper at Halifax had been roofed with shingles in order to have the roof covered before winter, but the roof was made strong enough to bear the weight of slates when they became available.[31] In the 1850s problems were encountered in Halifax with the supply of certain building materials as the advertisements for tenders did not specify definite amounts to be contracted for. No contractor would undertake the supply of slates unless a specific quantity was named. An order was given for 94 000 slates and the contractor imported that number from England but payments were only made to him as the slates were actually required. It was recommended by the Commanding Royal Engineer that the contractor be paid for all of them at once, probably to avoid encountering further difficulties when a new contract for supplies was needed.[32] The difficulty in finding a contractor to supply slate was probably due to the fact that little use was being made of slate for civilian building in Halifax. An 1849 estimate for a slate covering to the roof of a magazine at Fredericton included the explanation that this was to be done with Countess slate as there was at the time no Duchess slate available in New Brunswick. By the 1860s the Royal Engineer Department in the Canadas was looking to local quarries for slate for military construction. The contract schedule printed in Montréal in 1866 specified best quality Canadian slate.[33]

When the size of slate to be used for military construction was specified it was almost always Duchess slate. There were a few exceptions to this. The 1854 estimate for a shifting room for a magazine at Fredericton called for the roof to be covered with Countess slate (20 by 10 inches) presumably because this had been the size used to cover the roof of the magazine. An 1849 list of stores required for a proposed garrison hospital at St. John's asked for Imperial slates. The request described Imperial slate as 30 by 34 inches but this was likely an error in copying as the London authorities noted that the usual size was 30 by 24 inches which was the accepted size for Imperial slate. Specifications for a regimental hospital and a riding school, prepared in London in 1862 and sent to engineer officers at the various posts, called for Countess slating.[34]

Instructions for laying the slate were sometimes included in estimates or contract specifications. When the amount of lap was given it varied from three to four inches, which was the usual amount of lap for slate at this period. An estimate for an ordnance storehouse of stone at Saint John, drawn up in 1840, stated that the roof was to be covered with "dutchess slating on inch rough boarding, bevel edged, nailed with copper nails, having sheet lead to the ridge."[35] The specifications printed in 1852 for new barracks near Fort Needham, Halifax, described the roof covering as follows:

> *To be covered with Welch [sic] Dutchess Slates. Vide item No. 74, laid on boards covered with F. McNeill's felt nailed with two strong zinc nails in each slate, the third slate to overlap the first three and three-fourths of an inch and to bed flat on the previous slate, eave courses to be laid double on all the roofs and solidly bedded, the slates to be properly squared and perfect at all the corners and the slating to butt close to the back of the rebate*

formed three inches deep in the stone coping on the gables, pointed flush with Portland Cement.[36]

In some situations extra precautions had to be taken in the laying of slate. The engineer officer in charge at St. John's, when reporting to the governor in March 1833 on the condition of the various military buildings at the post, said that the slates must be bedded in cement.[37] Later estimates for some of the buildings on Signal Hill called for the slates on the roof to be bedded in mortar. Even these precautions were not sufficient as problems were encountered with slates blowing off the roofs of buildings on Signal Hill during windstorms. The thought of being caught out in a windstorm when the slates started blowing off the roofs is somewhat daunting. One drawback to slate was its weight, which meant that a strong roof structure had to be built to withstand the load of a slate roof. Slate had to be handled carefully or it was liable to be broken before it was safely in place on the roof. In 1835 the Commanding Royal Engineer in St. John's reported to the Inspector General of Fortifications that the slates that had been sent to St. John's had suffered much breakage in shipping and unshipping, and from the above-average breakage rate more slate than the usual allowance had been used.[38]

The higher initial cost of slate as compared to shingles was compensated for by its longer life once properly put on the roof. The engineer officer at Saint John stated in 1819 that a slate roof did not need any appreciable repairs for a number of years and would besides guard against the possibility of fire.[39] It was the durability and the protection it offered from fire that were slate's chief advantages as a roofing material in the eyes of the Royal Engineers.

Tin, though widely used for roofing in the Canadas was very seldom used on the Atlantic coast, either by civilian builders or by the military. The only indication in military records that tin was in use at all in this region in the early part of the period under study is an 1829 estimate for three portable expense magazines and for a bombproof magazine at the Grand Battery, Halifax, stating that the roofs were to be covered with sheet tin.[40] The relatively light weight of tin was probably the reason for its use for the portable magazines, but no reason is given for the use of tin rather than slate for the bombproof magazine. It was not until after the middle of the century that any further indication of the use of tin roofing in Halifax appeared in the military records. In 1859, following a serious fire in Halifax, the General Officer Commanding in Nova Scotia noted that various buildings in the town were being covered with Terne Plate. He suggested the use of Terne Plate for covering various buildings in the Ordnance Store Yard in order to test its usefulness. At least two of the buildings were roofed with this type of tin, but the experiment was not considered a success as the roofs were in constant need of repair due to contraction and expansion at the solder points. An estimate for repairs to the roof of the verandah of the officers' quarters at Fredericton in the early 1860s called for the use of tin to cover the roof, but no reason was given for the choice of tin.[41] In the larger centres in the Canadas tin roofing was very common, particularly for the more substantial public buildings. The military made extensive use of tin in Québec, with powder magazines, barracks, storehouses, hospitals, guardhouses and even some outbuildings, having tin roofs. There was less use of tin at Montréal than at Québec, but estimates for military prison buildings, the garrison hospital, powder magazines and some barracks specified tin roofs. With the improvements to the defences at Kingston in the 1830s and 1840s many of the new buildings had tin roofs. The report of the Carmichael Smyth Commission, which studied the defences of British North America in 1825, noted:

> *The roofs of the principal Buildings in this Country [Upper and Lower Canada] are covered with plank, upon which sheets of Tin or Iron are nailed. We think this an excellent sort of roof, much less liable to be out of order, and to require repair, than slates or tile. We are of the opinion that the roofs of all Barracks, Storehouses or Government Buildings in the Canadas ought to be covered in this way, and we are not aware of any reason why this mode of covering a building should not be adopted more generally.... It might be advisable to cause some of the smaller Ordnance Buildings in different parts of the World to be covered in this manner as an Experiment. If found to answer it appears to us that it would be a very permanent, and consequently economical roof.*[42]

The commission's recommendation about roofs in the Canadas appears to have been largely followed.

Whether the work of putting on a tin roof was done by the military or under contract, the tin was imported from England as was almost all roofing tin used in North America. In 1859 a Halifax contractor stated that there was no roofing tin made in North America. When it was obtained through the ordnance authorities there were sometimes problems; perhaps because tin was not used as a roof covering in England, they were unfamiliar with the type needed in British North America. In response to a request for "single sheet tin" for use in Lower Canada several hundred sheets of double tin were sent from England in the early 1820s. This double tin was sent because there was a surplus of this type in the depot in London. Engineer officers in Québec and Montréal considered this type of tin much too valuable to be used for roofing and it was decided that the tin should be sold or exchanged for single tin.[43] In the later part of the period under study much of the tin used for roofing military buildings was obtained through local suppliers. In 1861, however, there was another attempt to get rid of a surplus of tin in London by sending it to North America. There was on hand at the Tower of London a supply of 433 boxes of tin sheets, 10 by 14 inches, each one-quarter pound in weight, which had been returned from some outstation. The estimates for work to be done in 1861-62 contained several items dealing with tin roofs. Samples of the tin being held in London were sent to Nova Scotia and to Canada with the hope that if it proved suitable most of it could "be sent to Canada where a great many roofs are authorized to be repaired this year." One sample was to be sent to the engineer officer at Fredericton, who had prepared an estimate which included a tin roof for a verandah for the officers' quarters. Before forwarding this Colonel Nelson, Commanding Royal Engineer at Halifax, had already noted on the memorandum from London, "Never mind about this tin; it is quite unfit and so I shall report." From Canada came the reply that the sample sent was much lighter than that ordinarily used in Canada and not suited to the climate.[44]

From the correspondence concerning the boxes of tin the officers in London were trying to get rid of it, would appear that the standard size of roofing tin used by the military was 10 by 14 inches, the smallest of the sizes used by civilian builders in this period. Up to 1833 estimates for tin roofs and requests for tin specified single sheet tin; after this date, when the weight of tin to be used was specified, it was IC tin, which was the weight most commonly used for roofing in the 19th century. The Halifax contractor who, at the request of Major General Trollope, the General Officer Commanding in Nova Scotia, examined one of the storehouses in the Ordnance Yard in 1859 and prepared an estimate for roofing it with tin, suggested the use of IX Terne Plate in 14-by-20-inch sheets. He did not explain why he preferred the heavier type of tin for this building, but it may have been because it was more exposed to the hazards of fire from its location.[45] The large majority of estimates and contract schedules stipulated that the tin was to be laid showing 5½ inches to the weather, but in a few cases an exposure of 6 inches or of 4½ inches was specified. This extract from an 1858 contract for renewing the roof of a shed near the Palace Gate, Québec is an example of the instructions given in contracts for laying tin:

> *Cover the whole of the roof ... with the best description of I.C. charcoal tin, sound & free from stains, laid folding, & secured with 1 1/2" tinned clout nails (not less than 6 to each) and shewing 5 1/2" to the weather; properly make good the flashing ... so that the whole, when completed, shall be perfectly water-tight.*[46]

The specifications for tin roofs in contract schedules for work in the Canadas did not mention painting the tin. In Halifax, however, it was customary to paint the tin three coats.[47]

The chief advantages of tin as a roofing material were its light weight, its resistance to fire and its durability. A tin roof had a much longer life than a shingled one. The Commanding Royal Engineer in Montréal, Colonel Holloway, informed the Inspector General of Fortifications in 1845 that "covering with Tin may be deemed to be eventually the most economical, no case being known of the Tin being worn out and requiring renewal."[48] Although tin was a long-lasting roofing material, Colonel Holloway's claim was somewhat of an exaggeration. In the early 1860s many of the tin roofs on military buildings in the Canadas required repairs or renewing. In one of the estimates for this type of work the roof of a powder magazine at St. Helen's Island was described as being so corroded that moisture was let into the building through numerous clusters of tiny holes. Some problems encountered with tin roofs were due to lack of care in building the roof. The roof of a storehouse at St. Helen's Island was letting in water in the mid-1820s because the tin at certain places had not been made to lap sufficiently. Some years later the tin roof of a storehouse at Kingston developed leaks because the shrinkage of the boards under the tin caused the plates of tin to separate. At stations such as Montréal and Québec tin roofing was considered particularly desirable because of the large number of fires. Major General Sir James Hope, reporting to the officer commanding the troops in Canada on the fire in Québec on 28 May 1845, stated that the Artillery Barracks had only escaped destruction because they were roofed with tin.[49] In explaining estimates for new construction or repairs engineer officers often stressed the need for tin roofs as a protection against fire.

Other types of metal roofing material beside tin, such as sheet iron, were also used for miliary buildings in British North America. The section of the Carmichael Smyth Commission report quoted previously suggested the use of sheet iron as well as tin. Some discussion on this subject followed the submission of the report. In the fall of 1827 Sir James Carmichael Smyth, who had headed the commission investigating the defences of British North America, suggested to the Inspector General of Fortifications that the comparative advantages of tin and sheet iron as roof coverings should be studied. He himself felt that sheet iron might prove to be a more durable material than tin. Lt. Col. J.R. Wright, Commanding Royal Engineer at Kingston in 1828, although relatively new in the country had observed that in Kingston tin had recently come into use for roofing some of the principal buildings, and that sheet iron was no longer used. The roof of the storekeeper's house had been covered with sheet iron, but when the building was being repaired, it was found that the sheet iron, though in place for only 10 years, was full of holes. The iron had been painted when put on the roof, and repainted four times in the 10 years it was on the roof. Every time it had been painted rust spots had reappeared within a year. Wright also reported that sheet-iron roofing was almost twice as heavy as tin, but from his observations the initial cost was less. He suggested using cast-iron plates, which could be laid in the same manner as slates. At Québec a comparison was prepared showing the cost of a sheet iron and a tin-roof covering in Canada. It was estimated that a *toise* (36 square feet) of sheet iron, including painting and laying would cost £1 13s. 5¼d. The same area of tin on a roof would cost £1 0s. 4½d. Not only was tin initially cheaper, according to this report from Quebec, but it was stated that a tin roof would last about 50 years, while a sheet iron one, even if painted every three or four years, would not last more than 30 years. On reconsidering the matter Major General Smyth also decided that tin would be preferable.[50] Sheet iron continued to be at least considered as a roofing material in military construction in the Canadas throughout the period under study. Contract schedules for work done for the Ordnance Department included prices for iron roofing as well as tin and shingles. The prices estimated for iron roofing in these schedules were usually about two-thirds of those for tin roofs rather than slightly more as in the comparison prepared at Québec in 1828.

Zinc, which was popular in North America as a roofing material in the 1850s, was also considered for use on military buildings. In Halifax in 1855 the Clerk of Works prepared plans for huts as temporary accommodation for soldiers. These he proposed to roof with zinc.[51] Colonel Nelson, Commanding Royal Engineer at Halifax from 1858 to 1861, was impressed by the virtues of zinc roofing. The annual estimates for works and repairs in Nova Scotia for 1860-61 contained estimates for zinc roofs for various storehouses and for the cavalier in the Citadel. The estimate for the Citadel work described how it was to be done:

> *cover the same with No. 14 Zinc ... the ends of the sheets to be lapped with tinker's joints and the edges to be turned up on pine rolls ... to be capped with similar zinc which is to be connected with the sheets on either side by laps, same as the ends of the sheets ... to be turned up and secured to the covering of the roof by a roller lap.*[52]

Major General Trollope observed that following the fire in Halifax's business district in 1859 several of the new buildings being constructed were being covered with tin. He obtained an estimate for tin roofing for a military storehouse, at a lower rate than the cost of zinc. According to the contractor, Mr. Symonds, while a warehouse with a tin roof had escaped damage in the recent fire "Mr. Lawson's Warehouse almost immediately adjoining had the zinc melted off the roof and the Wood under it much burnt." At Major General Trollope's urging two storehouses were roofed with tin rather than zinc, but the engineer officers at Halifax continued to prefer zinc although it is not clear whether they actually used it.[53]

The danger posed by the high frequency of fires in urban centres in the 19th century stimulated an interest in finding cheap and fire-resistant substitutes for wooden shingles as a roofing material. The Royal Engineers were aware of some of the patent roofing coverings being offered for sale. In 1861 F.N. Boxer of Montréal, the agent for Messrs. Anderson's "patented asphaltic roofing felt," sent samples of this roofing material to the Commanding Royal Engineer. The Andersons had been the contractors for covering the roofs of the army camp at Curragh, where the use of their felt had been successful. The felt could be used under tin, tiles or slate or it could be coated with a fire-proof composition. According to Boxer, when the felt was cemented and sand or gravel embedded in the cement it was both fire- and water-proof. The following year Boxer submitted two specimens of roofing materials which he considered suitable for temporary encampments. One was an asphalted felt, the other a cloth saturated with gutta percha, which was currently being used by the American army for encampments.[54] In Quebec some use was made of Warren's patent roof felting in the 1860s. It had been found to stand the test of both summer and winter conditions, but it was feared that it was not sufficiently fire-proof.[55]

In Nova Scotia, too, the Royal Engineers were showing an interest in the use of composition roofing. An 1864 estimate for a guardhouse and gunner's quarters at Sydney Mines specified that the roof was to be covered with two thicknesses of stout tarred paper, "tarred over and gritted."[56] That same year a suggestion was made that the roofs of the public buildings on the Queen's Wharf in Halifax be painted with Warren's fire-proof paint, which was said to be much in use in Canada. Before making any decision on the matter the Commanding Royal Engineer in Nova Scotia enquired from those who were knowledgeable about such matters, including his colleagues in Canada, what information they had about this treatment for roofing. The reports received about Warren's fire-proof paint were unfavourable. From the engineer officers in Canada came information about a newly patented substance, Montgomery's Fireproofing Solution, which they suggested might be tried. The Ordnance Department at Halifax appears to have decided not to try any of these new "fire-proof" solutions, but to use metal or slate for protection against fires.[57] At Québec in 1865, engineer officers resisted a suggestion from London that the portion of the military hospital damaged by fire be re-roofed with shingles treated with a "Patent Fire Proof Solution." They pointed out that the remainder of the roof was covered with tin and that the use of shingles would be contrary to the municipal regulations.[58]

In dealing with roofing the Royal Engineers seemed more aware of the demands of the local climate and the variations in North American usage than they were in their choice and handling of other building materials. While the decision to use tin for many of the buildings in the Canadas may have been partly a result of the recommendation contained in the Carmichael Smyth Commission report this recommendation was itself based upon observation of local practice and North American conditions rather than architectural practice in England, what was being taught at Chatham and Woolwich, or what had been done in the Peninsula under Wellington. The use of slate and shingles in the Atlantic region was in keeping with local practice, which was based on a knowledge of the effects of the local climate upon various roofing materials. When the Royal Engineers began to consider the use of metal roofing in this area this was partly at least a result of an observation of changes in local construction practices. Although there were some attempts by authorities in London to influence the choice of roofing materials for construction in British North America these were not persistent and were generally resisted by engineer officers on the spot.

Chapter 5

WATERPROOFING — ASPHALT

"Quite unfit for general use"

In the previous chapter we looked at the type of roofing materials for peaked roofs. Flat roofs require a different type of covering. Nowadays flat roofs are generally covered with large sheets of felt saturated with asphalt or tar and spread with gravel. The Royal Engineers encountered the problems of covering flat surfaces mainly in the construction of casemates and redoubts, and the attempts to use asphalt to produce a water-tight, weather-resistant covering provide an interesting example of the lack of understanding of North American conditions on the part of some segments of officialdom in London — summed up by the comment of one Commanding Royal Engineer at Québec that asphalt was "quite unfit for general use."[1]

Asphalt materials have been known and used in the construction of roads and buildings since ancient times. The chief source of natural asphalt in this century is from pitch lakes such as those in Trinidad and Venezuela. In the 19th century, deposits of "rock asphalt," which was a type of rock impregnated with asphalt, were utilized. It was used for damp-proof courses in walls, as a waterproof layer over arches or flat roofs, for lining tanks and for floors that required a very smooth surface or had to resist water. The best known of the 19th-century asphalts in England was "Claridge's Patent Seyssel Asphalte" which was made from a bituminous rock found near Seyssel in the Jura Mountains in France. There were three qualities of this available: Fine, without grit, to be used for magazine floors and as a cement for close joints in brickwork; Fine gritted, for covering roofs and arches, lining tanks and as a cement for brickwork; and Coarse gritted, used for pavements and flooring where great strength was required. Other asphalts were available from Switzerland and parts of Germany. In 1837 a Mr. Claridge, after a visit to France where he was impressed by the potentialities of asphalt mastic, obtained a British patent for "a Mastic Cement or Composition applicable to Paving and Road making, covering buildings...." etc. The use of this material was soon adopted by many British architects and engineers.[2] As all casemated stone structures had a tendency to leak, if Claridge's asphalt really could prevent leakage, it would be of immense value to military engineers.

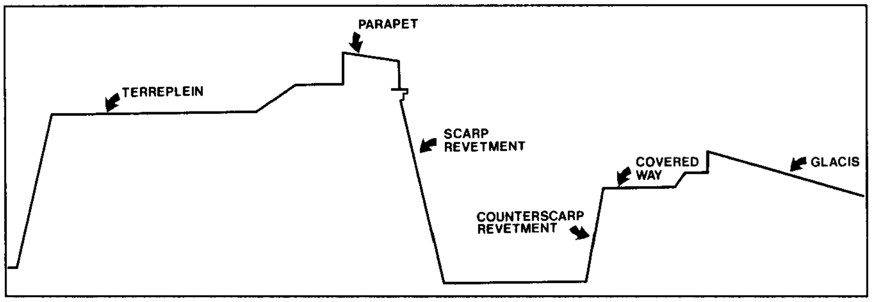
In the mid-19th century officials of the Board of Ordnance and some officers of the Corps of Royal Engineers were taking a keen interest in the use of asphalt, in particular of Claridge's Patent Seyssel Asphalte, for waterproofing and paving. An 1841 memorandum on the nature of building materials in Canada prepared for the Commanding Royal Engineer devoted considerable space to some observations on Seyssel Asphalte Mastic, including a description of how the rock asphalt was converted into mastic, the type of foundation needed for its use, how the mastic was prepared and spread and the cost. It was suggested that this asphalt might be of use for covering the arches of casemates and magazines.[3]

The Royal Engineers seem to have begun to use asphalt or a substance resembling asphalt in British North America in the early 1840s. No evidence has been found to indicate the use of asphalt by the Royal Engineers in England prior to this. At the beginning of 1841 an estimate for building a redoubt at Kingston was transmitted to London. This estimate provided for the space over the arches to be filled in with rubble stone. Over this was to be laid fine or macadamized stone and the whole was to be covered with asphalt.[4] The asphalt was to form the surface of the terreplein. The suggestion for the use of asphalt in this case originated in Canada rather than with the authorities in London. In May 1841 the Board of Ordnance approved the use of asphalt to cover casemated ramparts at Fort Henry. A supply of 35 tons of asphalt with a proper grate and other implements for its preparation and spreading were to be sent to Canada. Meanwhile Major L.A. Hall, Commanding Royal Engineer in the London District, sent a memorandum to the Board on the method of using "Bastenne Bitumen," which was apparently the bituminous product in favour with engineer officers in England in 1841 (see App. 3).[5] In 1842 estimates were prepared in Canada for the construction of ball courts for the use of the soldiers at the various posts. These estimates specified that the floors were to be of Claridge's Patent Asphalte.[6]

There appears to have existed a considerable degree of confusion about the types of asphalt or bitumen. In 1844 Col. J.R. Wright, Commanding Royal Engineer at Chatham, England, who had a decade earlier been the Commanding Royal Engineer at Kingston, wrote to the Inspector General of Fortifications on the subject of the use of asphalt at Kingston. Upon learning from an engineer officer recently returned from Canada that the asphalt used on the ramparts at Kingston had not been successful, Wright had spoken to the local agent for Claridge's Patent Asphalte. The latter had then written to the company's head office in London seeking information on the subject. According to the officials of Claridge's Patent Asphalte Co., none of their asphalt had been sent to Canada. They said that Major Hall had already asked if their asphalt had been sent to Canada and had spoken in glowing terms of the Seyssel asphalt. They felt he was pleased to have their assurances that it was not their product which had failed in Canada. According to the company:

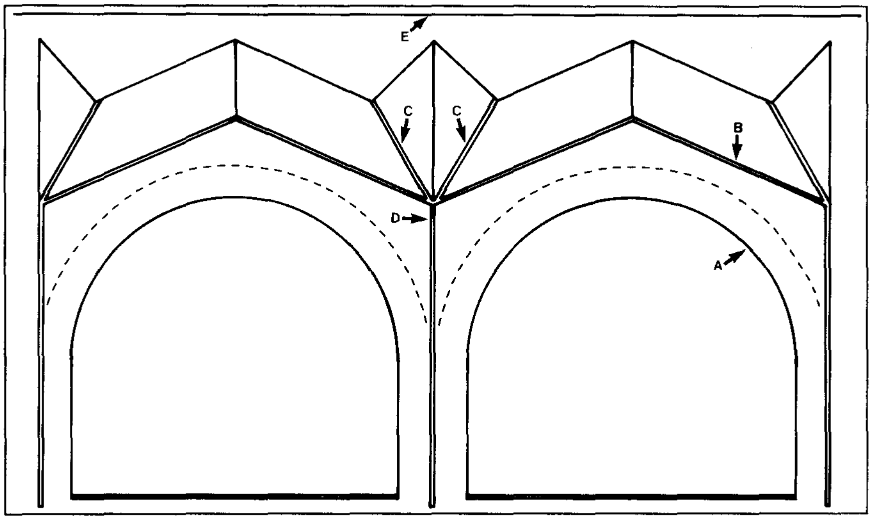
> *in every artificial imitation that calcareous particles are merely enclosed by pitch, the chalk is consequently unamalgamated and the composition, susceptible to the extremes of Heat and Cold, has failed whenever tried.... The Directors do not consider it of any importance to this Company to know what Material was used at Canada. It must be well known to the Ordnance Authorities that it was not the material of this Company and therefore the reputation of the Seyssel Asphalte is in no way affected by it, at least so far as this Company is connected with the Department.*[7]

The assertions of the asphalt company do not agree entirely with the statements of Ordnance officials. It was admitted that the first shipment of asphalt to Canada was not Claridge's. According to a note on the margin of Wright's letter the asphalt first sent to Canada, which had failed when used at Fort Henry, was the "Bastenne Bitumen," and this had been sent on the recommendation of Major Hall (whom the Claridge's Patent Asphalte Co. represented as being so strongly in favour of their product). The supply which had been authorized in 1842 was, according to the officials in London, "Seyssel Asphalte" and they had received no report of its having failed.[8] Either a supply of "Seyssel Asphalte" *had* been sent to Canada, or the Ordnance Authorities did not know the difference between the "Seyssel Asphalte" and its imitators.

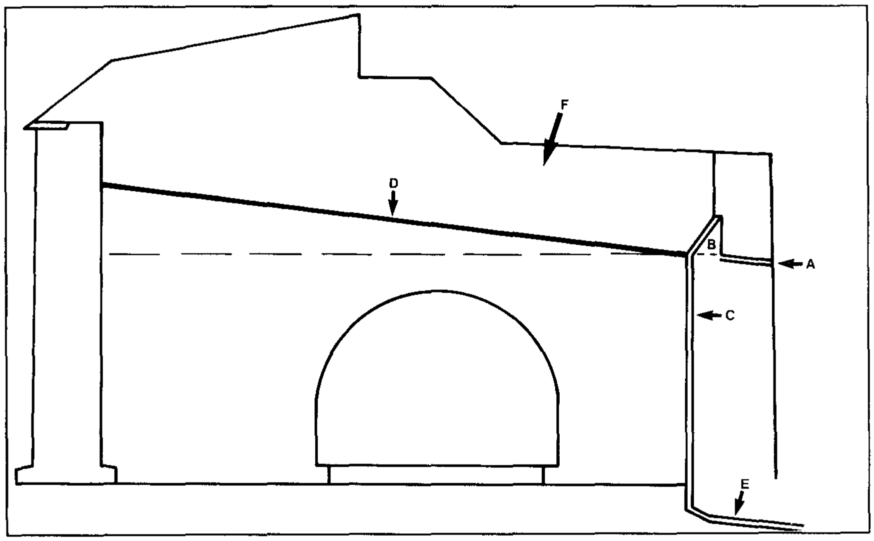


9 Profile of a fortification. *Redrawn by D. Sullivan from a sketch by the author.*

In the spring of 1844 the Commanding Royal Engineer in Canada, Colonel Holloway, also wrote to the Inspector General of Fortifications on the subject of the asphalt used at Kingston. He reported that the asphalt had been laid on the terreplein of the ramparts of Fort Henry according to the method described by Major Hall, but that it had completely failed to keep moisture out of the arches of the casemates below it. The material used had been that sent in accordance with the Board of Ordnance's orders of 7 May 1841. A further supply had been sent the following year, but had not yet been tried. Either Holloway had not examined this asphalt, or he was unable to distinguish between the types of asphalt. He referred to the letter from Claridge's Asphalt Co. as his authority for the assumption that no "Seyssel Asphalte" had been sent, only the "Bastenne Bitumen." Holloway stressed the severity of the Canadian climate, with its intensely cold winters, extremely hot summers and occasional thaws in spring and autumn. It was his opinion that under these conditions asphalt, even of the best quality, would not be likely to succeed in protecting the arches of the casemates from dampness if it were exposed on the surface as suggested in Major Hall's memorandum. According to Holloway extreme cold caused asphalt to shrink, producing cracks and fissures. In a thaw, rain and melted snow would penetrate through these cracks into the body of the work below. Because the water in the gutters and drains over the arches had become frozen at their points of exit, which were at the external facing of the casemates, water penetrating the terreplein was not carried away but would seep through the arches making the casemates damp and unhealthy. Holloway had decided that instead of being laid on top of the terreplein the asphalt should be laid on top of the covering of the arches (Figs. 10 and 11) and that the gutters should drain the water into pipes that were carried



10 This and Figure 11 are taken from Holloway's letter to the Inspector General of Fortifications, May 1844. (a) Casemate arch; (b) Dos d'âne, asphalted; (c) Gutters; (d) Drain pipe through pier of arch; (e) Parapet. *Redrawn by D. Sullivan.*



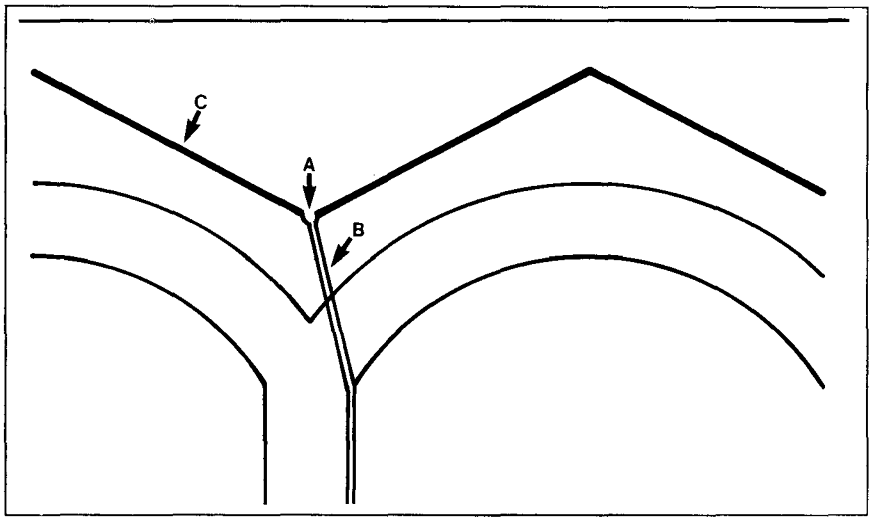
11 Holloway was using asphalt over the arches, but covered by earth, in conjunction with drains protected from the frost. (a) Old drain blocked up; (b) Masonry to lead water from the rear wall; (c) Drain through pier; (d) Line of gutter on dos d'âne; (e) Underground brick drain; (f) Earth covering. *Redrawn by D. Sullivan.*

through the arches and internal piers of the casemates so as to avoid exposing the moisture to the outward atmosphere. He found that casemates staunched in this way appeared to be dry and there was no risk of injury to the asphalt either from the severity of the weather or the weight of the guns placed on the ramparts.

The following spring Holloway was ordered to report on the results of the methods tried for staunching the leaks in the casemates of the Citadel at Québec and of Fort Henry. It was suggested that his report on these methods should be prepared in such a way that it could be copied and circulated for the information of other engineer officers. In reply to this Holloway reported that his suggested method of laying the asphalt over the arches at a depth of about four feet below the terreplein, and therefore beyond the influence of the frost, and of having the moisture falling into drains passing down through the piers of the arches rather than through pipes that emptied outside the walls, had proved successful. This had been put into effect at Fort Henry the previous summer in one section of the works and now should be extended to the rest of the casemates. Upon his inspection of Fort Henry the previous summer, before this work had been done, he had found some of the casemates streaming with water, and the interior of the magazines covered with fungus. If the remainder of the casemates were to be staunched in the manner he had suggested and which had proved successful, it was essential that the work be begun at once. As there was still asphalt available at Kingston he had given orders that the work be continued. Fortunately this was approved by the Board of Ordnance.[9]

When estimates and contract specifications were prepared in 1847 for several Martello towers in Kingston they included the use of asphalt over the arches. The contract specification for the method of staunching the tower at Fort Frederick described the work as follows:

> *The dos d'ânes over arches, which are to be formed of rubble masonry, are to be smoothed off on the upper surface with fine mortar, & covered with a brick pavement laid flat on the slope in cement mortar, leaving the joints open at the surface 1/2 inch deep, and the joints filled with asphalte, on this pavement bricks are to be laid in cement mortar 4 inches apart end to end flatwise (the ends joining) forming gutters in the line of direct descent to the valley, a brick paving to be laid flat in cement on ribs (covering*



12 Sketch enclosed in Holloway's letter of 23 June 1845 to the Board of Ordnance showing the work at Fort Henry, Kingston. (a) Internal drain; (b) Guttering of dos d'âne; (c) Asphalt covering of dos d'âne. *Redrawn by D. Sullivan.*

> *the gutters) and the joints left open at top 1/2 inch deep & then filled with asphalte.*[10]

According to the estimates, the surface of the first course of brick paving was to be covered with one-half inch of asphalt and the water from the gutters was to drain into iron pipes running down inside the tower.[11]

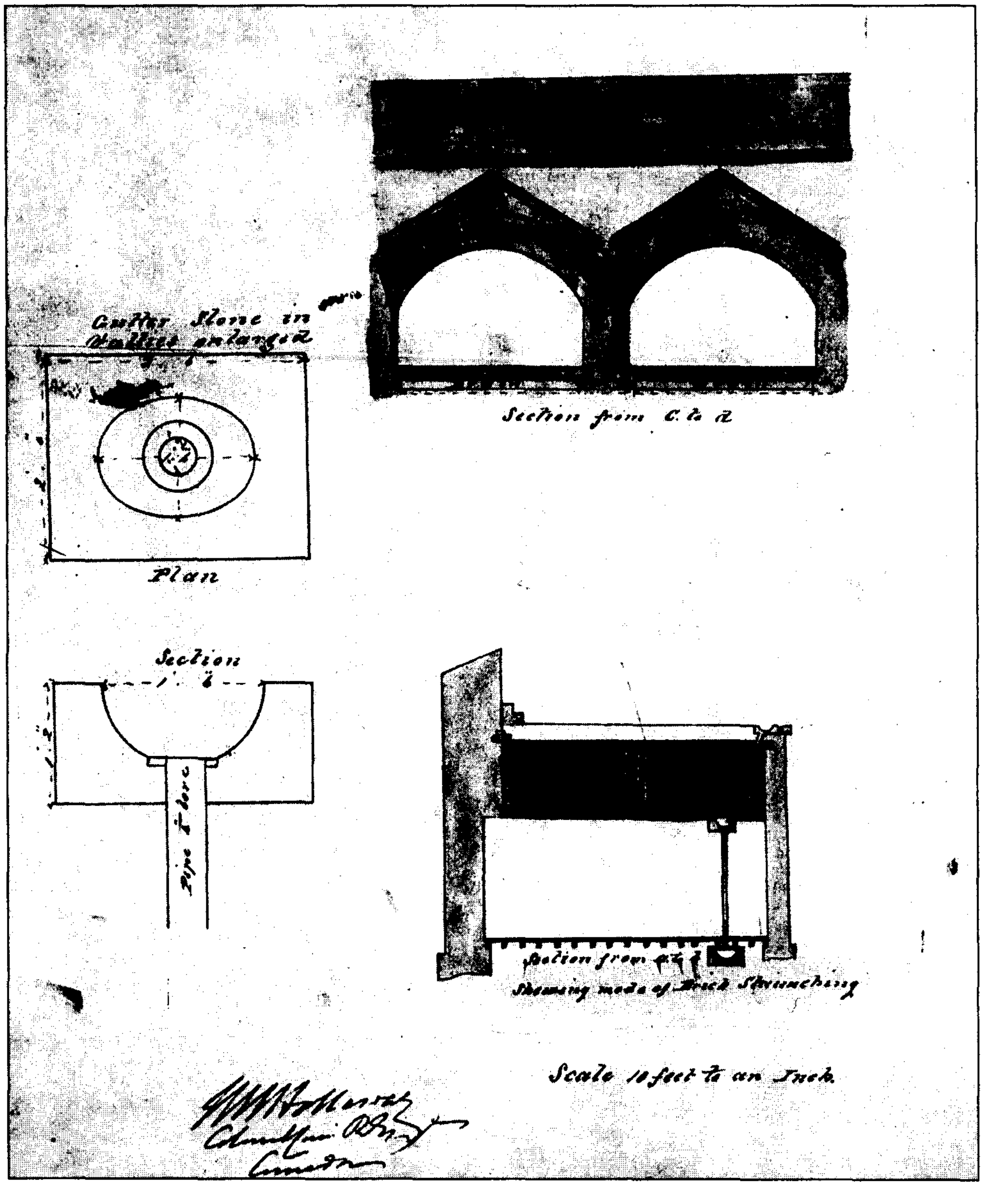
In 1848 another senior engineer officer joined the asphalt debate. Colonel Oldfield, who had become Commanding Royal Engineer at Devonport, England, and so responsible for works at Plymouth Citadel, had been Colonel Holloway's predecessor as Commanding Royal Engineer in Canada. In response to a request from the Inspector General of Fortifications Oldfield drafted a report on his experiences in using asphalt and on the measures he had adopted in trying to remedy the leaky state of the casemates at Plymouth Citadel. According to Oldfield it was he who had originally suggested the use of asphalt at Fort Henry. The asphalt had been supplied from England and a Foreman of Works accustomed to its use had been sent to superintend its application early in the autumn of 1842. Oldfield admitted that the asphalt exposed to the frost at Fort Henry had been a failure, and said that he had intended to try asphalt at Québec in a situation where it would be covered with enough earth to protect it from the frost. He had been transferred from Canada, however, before he was able to try this.

When he arrived at Plymouth to take command there, Oldfield had found the casemates, which were covered with slates bedded in ordinary mortar, uninhabitable because of dampness. He decided to try asphalt in an attempt to stop the leaks. Once the casemates were uncovered, the steep slopes of the dos d'ânes were reduced by filling in with rubble masonry. When this was dry a six-inch coating of concrete made with Aberthaw lime was laid over it, with the top of the concrete worked as smooth as possible. When the concrete was dry the asphalt was laid in two coats about three-eighths of an inch thick. Asphalted brickwork was used to line the walls to a height slightly above the level of the terre-plein, and the asphalt on the dos d'ânes was covered over with "rubbish" to the proper level. The upper slope of the parapet was also covered with asphalt. Every effort was made to ensure that there was no opportunity for moisture to enter. At Plymouth asphalt was also used for flooring the casemates, as a coping to the top of the parapet in the Cumberland Battery and in the construction of an embrasure.

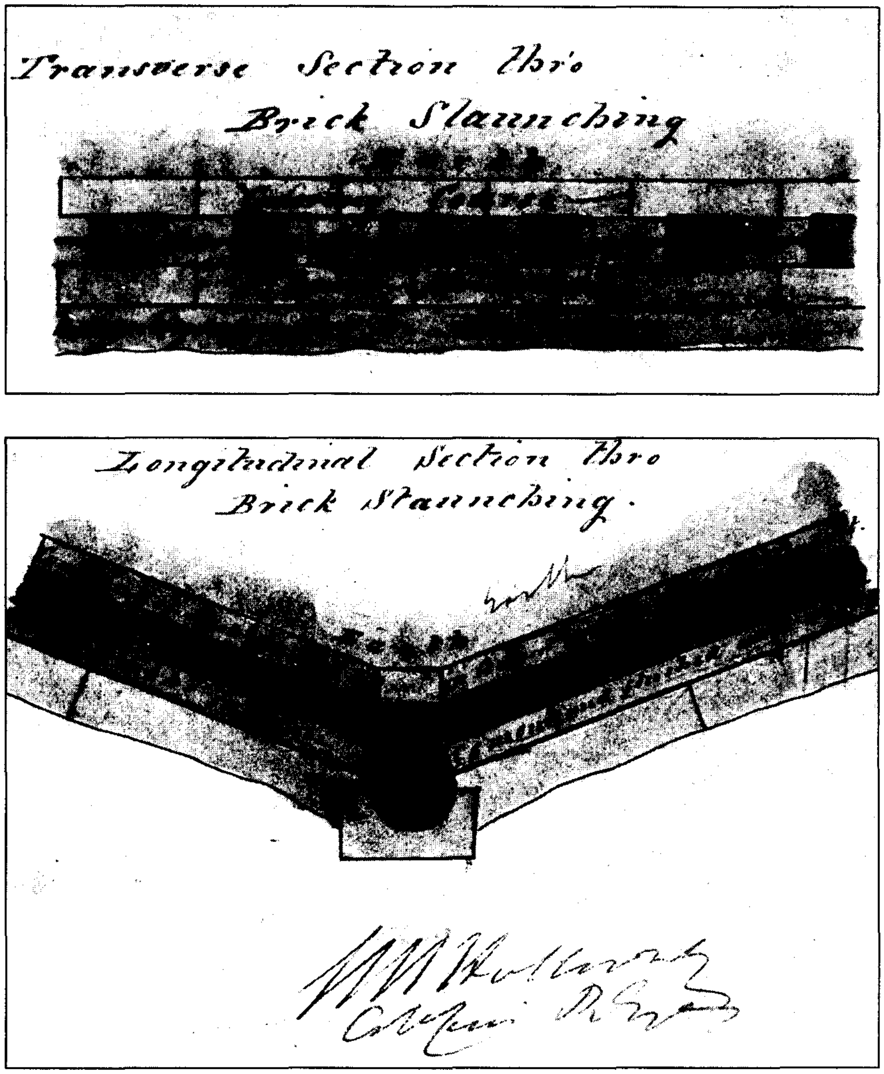
Oldfield was firmly convinced that at Plymouth his use of asphalt had been entirely successful. He stated that "if the *materials and workmanship are unexceptionable*" asphalt was the most effective material for the covering of arches, the floors of tanks, ablution rooms, storerooms and many other barrack buildings. The slightest deficiency in workmanship or materials, however, would cause a failure. Oldfield continued to be convinced of the value of asphalt. In 1855, having heard some complaints about problems with asphalt, he inspected the works where he had used asphalt and found that the casemates in Plymouth Citadel, which before his repairs had been extremely damp, still remained dry and habitable and that in other places where he had used asphalt it was still successful. Oldfield's memorandum of 1848 was soon sent to the Commanding Royal Engineers in the Medway District, in Ireland and in Nova Scotia, as "almost every District having brought forward different methods of staunching arches of Towers etc. ... it appears desirable that a system which has been found to answer should be as far as possible adopted." As well Oldfield's report was published in the *Professional Papers* of the Royal Engineers in 1853 so that his views were widely circulated among engineer officers.[12]

While the authorities in London seemed to take Oldfield's views as the last word on the subject of asphalt, this was not so in British North America. Oldfield had used asphalt to cover the upper surface of the parapet and had relied on asphalted brickwork, covered with a layer of asphalt, joining the asphalt over the dos d'ânes to the front and rear walls, to prevent leakage where the arches met the walls. His methods, particularly the use of asphalt in situations where it was exposed to the external atmosphere, did not appear to engineer officers in Halifax and in Canada to be the most suitable for the North American climate. In the summer of 1848 Lieutenant Colonel Savage at Halifax passed on to the authorities in London the information he had received from Colonel Holloway about the methods used to keep the casemates at Fort Henry from leaking. The important factors in the method, which had seemed to be successful at Fort Henry, were keeping the asphalt covered so that it was not affected by frost, having the drain pipes run inside the walls rather than outside, for the same reason, and having the dos d'ânes hipped, and the slopes provided with a series of brick drains so that all the water would run into the gutters in the valleys of the dos d'ânes and be carried off by the drain pipes (Figs. 13, 14 and 15).[13] While this method appeared to be successful for the time being in curing the problems of dampness in the casemates at Fort Henry, the solution was only temporary and after a few years there were more complaints about wet casemates.[14]

In the late 1840s asphalt was also being used as a waterproofing material at Québec. It was noted on a request for asphalt needed from England for work in 1849-50 that the asphalt already sent for the redoubts in the North Ravelin had been used to staunch the coal vaults. It was suggested as "Asphalte and Tar are so often required in repairs to Casemates etc. at this Station that it is important a certain quantity should be kept in Store for Incidental Services." While this indicates a fairly regular use of asphalt in Québec, in 1850 Colonel Vavasour, Commanding Royal Engineer in the Canadas, requested information on the method used at Plymouth, which had been recommended for use in staunching casemates in Québec. Vavasour died the following year, but his successors continued to struggle with the problems of staunching casemates with asphalt. In August 1851 Lt. Col. Whinyates reported that the casemates in the North Redoubt at Québec were still leaky. When the arches



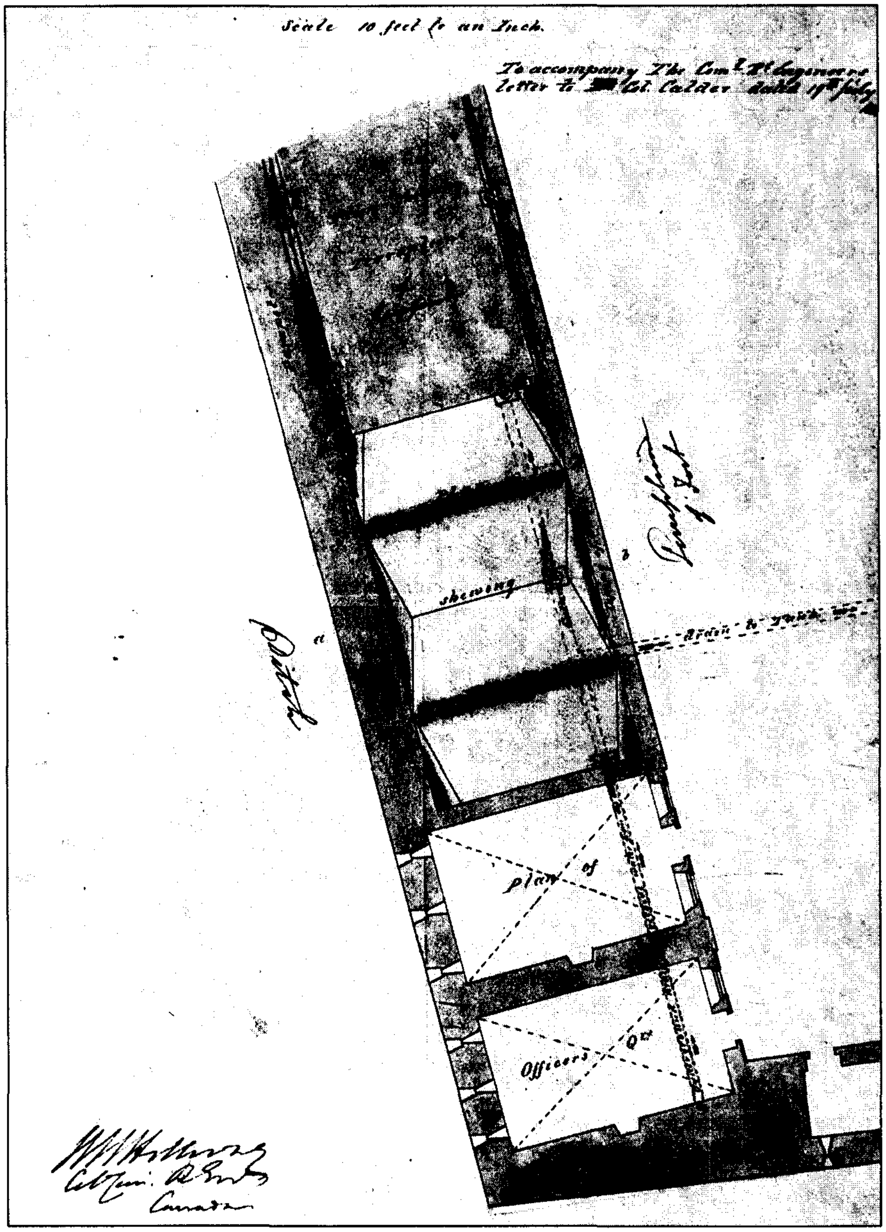
13 The sketches shown in Figures 13, 14 and 15 were enclosed in Holloway's letter to Colonel Calder at Halifax, July 1848, showing the way casemates were being staunched at Kingston. *National Archives of Canada, MG13, WO55/882, f. 516.*



14 There was a layer of asphalt between the bricks and the masonry. *National Archives of Canada, MG13, WO55/882, f. 517.*

were uncovered the asphalt covering was found to be cracked. He stated:

> *Asphalte has never been used in Canada, except by the Engineer Department, and its adoption for the dos d'ânes of the Redoubt, could only be considered as an experiment to test its efficiency,*

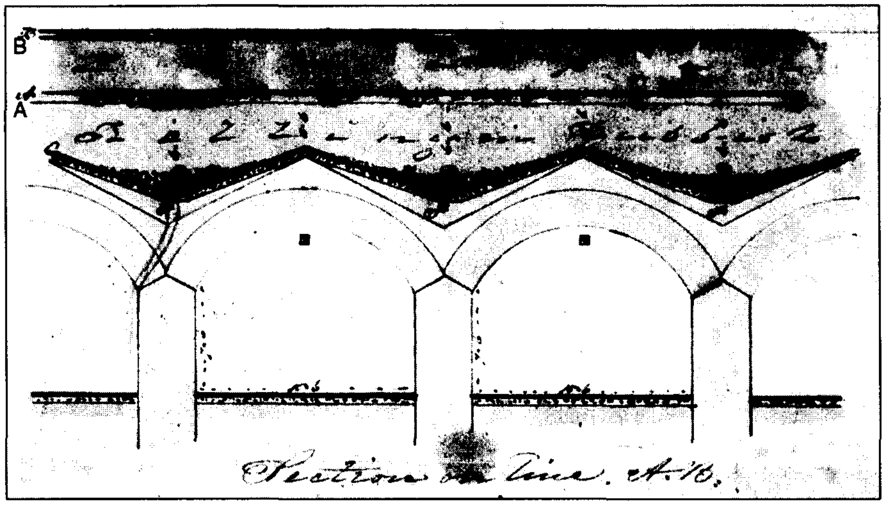


15 Plan view of the casemates at Fort Henry. *National Archives of Canada, MG13, WO55/882, f. 518.*

> *and the present failure clearly shews, that unless perfectly protected from atmospheric action during the winter, by a covering of at least 3' 0" thick it is quite unfit for general use and for the purpose of staunching Bomb-proof Arches especially.*[15]

As far as the engineer officers on the spot were concerned asphalt was not a good material to use in the Canadas.

The question of the use of asphalt at Halifax had arisen, as it had at Fort Henry, with the need to prevent dampness in the casemates. In the original construction of the casemates at Halifax Citadel drainage was provided by lead gutters leading to gargoyles in the retaining wall and an exposed down pipe, which of course became blocked with the first frost each fall. To add to the difficulties, the arches and the dos d'ânes were not carried very far into the end walls of the casemates. As a result the joint between the casemate roofs and the end walls was weak and very likely to leak. At first it had been intended to cover the dos d'ânes with a layer of tiles laid in cement and then, when this began to appear inadequate, with slates. When Colonel Calder took over the command in 1842 he decided that neither tiles nor slates were suitable for this purpose — tiles were porous and were likely to decay and slates were likely to be broken by the weight of the earth over them. Calder felt that granite flagstones would be more durable and more likely to keep out water. He experimented with the use of slates and flagstones and found the latter much more successful.[16] However, problems with leaking in the casemates continued as did the search for a solution to these problems. Calder experimented with hipping the dos d'ânes, to drain water from the end walls to the gutters in the valleys of the dos d'ânes. When he reported to London on the methods he had adopted to combat the dampness of the casemates, authorities there suggested the use of asphalt and sent him a copy of Oldfield's report on the work at Plymouth. Calder was obviously aware of the problems encountered elsewhere with asphalt and was determined that if he were forced to try it himself no one could say he had not warned them. He pointed out that the latest method (he did not specify but presumably he was referring to the use of flagstones and hippng the dos d'ânes) he had tried for staunching the casemates appeared to be successful and added that he considered the efficacy of asphalt in preventing leakage in the casemates in the Halifax Citadel:



16 Oldfield's use of asphalt at Plymouth. (a) Rubble masonry used to reduce slope of dos d'âne; (b) Asphalt covering to dos d'âne. *National Archives of Canada, MG13, WO55/876, f. 278.*

> *extremely doubtful though it may serve in the mild climate of Devonshire, nothing appearing to resist the alternate frost and thaw which is of daily occurrence here for four or five successive months excepting solid materials; and it is doubtful whether what would answer in Canada [Province] where the weather is more steady would in this place.*

If, however, the authorities in London insisted on his trying asphalt it would be necessary to send out with the asphalt someone who knew how to use it.[17]

When Lieutenant Colonel Savage, who had once served in Canada, replaced Calder at Halifax in the summer of 1848 he continued experimenting with possible solutions to the problem of leaky casemates, while fighting a rearguard action against suggestions that he use asphalt. He did not condemn the use of asphalt entirely, but insisted that it was not suitable in Halifax:

> *In a warm climate or even a moderately cold one I am equally an advocate for Asphalte as Mr. Owen the Surveyor, having seen it used in large quantites with great success at Mauritius and Gibraltar, but in severe climates like Canada, Nova Scotia, or New Brunswick, I am of opinion it will never answer except it is well*

> *covered over, and perfectly secured from the influence of the atmosphere ... and as this climate is nearly, if not equally as cold, as Kingston, Upper Canada ... together with the sudden changes of temperature ... I am of opinion Asphalte is more likely to fail in this province than even in Canada.*[18]

The London authorities retorted with the observation that it was not Claridge's Seyssel Asphalte (which they were now advocating) but Bastenne Bitumen which had failed in Kingston and suggested an experiment with Seyssel Asphalte for paving the ground around the powder magazine. They also arranged that an NCO of the Royal Sappers and Miners would be sent to Halifax to superintend the laying of the asphalt. Perhaps some hints of doubt about the value of asphalt did enter their minds as the amount of asphalt sent to Halifax was reduced from 45 tons as originally planned to 21½ tons.[19]

The use of asphalt to pave the ground around the South Magazine in the Halifax Citadel was not a conspicuous success. The asphalt was not delivered to the Ordnance Storekeeper until September 1849. Although the foundation on which the asphalt was to be laid had been prepared in advance, as the work of laying the asphalt itself began so late in the season Lieutenant Colonel Savage decided that it would not be advisable to cover more than half the area around the magazine before stopping the work for the winter. The area around the magazine had been excavated to a depth of 18 inches, drains built and 11 inches of shale laid. Over this were laid two thicknesses of concrete and over this the asphalt, in two thicknesses one-half inch each. The asphalt was laid by an NCO of the Royal Sappers and Miners who had received instructions on this from the Seyssel Asphalte Company. The winter was a mild one. It was not until 6 February that the temperature went below freezing. The following day the asphalt cracked in two places and part of the surface heaved up. In reporting on this the following spring Lieutenant Colonel Savage stated that he intended during the summer to complete asphalting the area around the magazine, but that in his opinion asphalt would never succeed in Nova Scotia where there was any chance of water getting under it and being affected by the frost. He was willing to concede that it might be successful over arches that could not heave from the frost. The authorities in London laid the blame for the failure of the asphalt on the fact that the area had not been completely covered and on the type of foundation built. They considered that the drains should have been deeper and that sand should have been used as a base for the asphalt. Savage replied that sand would not have been suitable and that the drains had not caused problems. He felt that the most important point was to prevent water penetrating through the joints of the masonry in immediate contact with the foundations on which the asphalt was laid. He suggested the use of asphalted bricks to line the footings of the retaining and enclosure walls. Despite Savage's precautions and annual repairs the asphalt pavement around the magazine continued to crack and heave every winter.[20]

Other uses for asphalt were also being tried. In the summer of 1850 asphalt was used to cover the superior slope of the parapet of the Cavalier Barrack in the Citadel. At the same time the interior (vertical) slope of the parapet was lined with asphalted brickwork. This had the same lack of success as had the asphalt paving in the magazine yard and, according to Savage, for the same reason — it was exposed to the action of the frost. In the early 1850s three tanks for holding a supply of water were built under the parade of the Citadel. These were lined with asphalt and asphalted brick. In this case, because the tanks were well below ground level, Savage considered the use of asphalt to have been successful. The tanks were, he reported in 1854, water tight and the water in them did not appear to have been affected by the asphalt.[21]

In his first report on the asphalt paving around the South Magazine Lieutenant Colonel Savage had admitted the possibility that the same problems might not be encountered if the asphalt were laid over arches. As the chief thrust of the instructions from London seem to have been towards the use of asphalt for staunching casemates this opened the way for a renewed effort to ensure the use of asphalt for this purpose at Halifax. Whatever his private feelings on the matter, Savage bowed to the inevitable. During the building seasons of 1851, 1852 and 1853 fifty-four casemates for officers' and soldiers' barracks were covered with asphalt, laid in two coats. According to the instructions from London the work was to be done in the same manner as had been used at Plymouth. Two of the first casemates asphalted and covered with earth were soon found to have leaks where the arches met the interior retaining walls. A lining of asphalted brick up to the first joint in the masonry above the asphalt coating was tried as a remedy. The upper stones of the wall were removed, a coat of asphalt laid over the brickwork and carried well into the thickness of the wall. In 1854 the Royal Engineers at

Halifax considered this method a success. The casemates were reported to be dry and habitable.[22]

The work of asphalting the casemates at Halifax was not without its problems. Although the authorities in London were pressing for the use of asphalt at Halifax, they were unable to ensure the prompt delivery of sufficient asphalt of the right quality to maintain the progress that they hoped for. The late arrival of asphalt in 1849 had prevented completion of the pavement around the magazine in that year. In the summer of 1850 Savage was complaining that most of the work scheduled to be done in the Citadel that year was being delayed because of insufficient asphalt. Complaints about the non-arrival of needed supplies of asphalt continued as long as this work was under way. When the asphalt did reach Halifax it was not always of the quality Savage wanted. In the fall of 1850 he complained that almost half the asphalt supplied was coarse rather than fine and asked whether he should use it. He pointed out that the fine-quality Seyssel Asphalte had been requested because of the order to use the system adopted at Plymouth for staunching the casemates instead of the method he had suggested. Despite claims from the asphalt company that the asphalt sent was of the quality demanded Savage maintained that it was not and sent samples of the substandard materials to London to prove his point. In the meantime Savage received a shipment of half a ton of "Trinidad Bitumen," from the Pitch Lake at La Brea, complete with instructions for its manufacture and use. Savage had been instructed to make a trial of this pitch from Trinidad and compare it with the Seyssel Asphalte, being used by the Royal Engineers at that time. He reported that as soon as the weather permitted he would carry out such experiments with this material as the small amount sent to him would permit and report on this to the Board.[23] What success or otherwise he had with this bitumen is not clear, as it seems to have disappeared from the saga of the Royal Engineers' asphalting mania without any further notice.

Savage was obviously firmly established in the minds of the asphalt enthusiasts as a non-believer. When he requested a supply of Portland Cement for use in staunching casemates someone in the Ordnance office in London immediately jumped to the conclusion that he intended using this in place of asphalt and sent a sharp query requesting clarification of this. Savage replied that the Portland Cement was intended to be substituted for Roman Cement, which had originally appeared in the estimate, and somewhat sourly added that he had no intention of deviating from the method proposed (i.e. asphalt). In his opinion, "where so much expense is about being incurred in the use of Asphalte (a comparative experiment in this severe climate) every part of the work done in combination with it should be of the most permanent character."[24] He obviously wanted to ensure that no one could accuse him of sparing any necessary effort to make the use of asphalt a success.

Suggestions for other uses for asphalt in Halifax continued to be made in the early 1850s. Following the destruction by fire of the North Barracks in 1850 plans and estimates were drawn up for new barracks near Fort Needham. According to the contract specifications Claridge's Patent Seyssel Asphalte was to be used for pavements, covering arches, tanks, some roofing, and floors of ablution rooms, privies and cellars (see App. 4 for an extract from the specifications). The floors of both the powder magazines in the Citadel required renewing at this time because of the decay of the joints. In October 1852 the floor of the North Magazine gave way completely. Once this was repaired it was discovered that the floor of the South Magazine was almost as badly decayed. In the spring of 1853 Savage submitted a special estimate for a new floor. Acting on a suggestion of the Surveyor he proposed to substitute asphalt for joists and planking. For some reason the Inspector General decided against the use of asphalt in this case.[25]

Despite the problems he encountered from lack of sufficient asphalt of the right quality and his doubts about the usefulness of asphalt, by the time he left Halifax in 1854 Savage felt that he had successfully staunched most of the casemates of the Citadel (except for those in the Cavalier Barrack, a building which he considered so poorly built that it could not be made leakproof without major reconstruction).[26] The remedy was short lived. Lieutenant Colonel Stotherd, Savage's successor, reported in January 1855 that the Cavalier Barrack had become completely uninhabitable from the alternating rain storms and frosts. He felt, as had Savage, that the only solution was to take down the walls to the level of the arches and rebuild them properly. He also stated that some of the casemates under the ramparts of the Citadel were showing signs of dampness. He felt that the asphalt covering of the dos d'ânes might have been damaged by the heavy traffic over these ramparts in moving the guns. A marginal note suggested that if asphalt were so bad a covering in Halifax, perhaps flat tiles laid in cement could be tried.[27] Somebody in London was at last beginning to doubt the usefulness of asphalt in Halifax, but this return to the idea of using tiles seems to have received as little attention as it deserved. The asphalt was in place over the casemates and apart from minor repairs over the years there it remained undisturbed.

By the late 1850s the great enthusiasm of officials in London for asphalt had died down, though its use by civilian engineers was increasing. There were, however, recurrences of interest by the Royal Engineers in using asphalt. Interestingly the suggestions that asphalt be employed at Halifax in the late 1850s and early 1860s came from engineer officers in Halifax rather than from officials in London. The estimates drawn up for works and repairs in Nova Scotia for 1859-60 included provision for renewing the basement floor of the Prince of Wales Tower. It was proposed that the new floor be built of asphalt, with a wooden covering on the part used as a magazine. The Surveyor of the Ordnance suggested the work be done in Portland Cement rather than asphalt. This item was not approved for 1859-60 and reappeared in estimates for subsequent years, in that for 1861-62 having been revised in accordance with the Surveyor's remarks. When the work was eventually done the floor was rebuilt in cement rather than asphalt. It seems, however, that some asphalt was shipped to Halifax for this work before the final decision on it was made. The presence of this asphalt in store may have been the reason why an asphalt floor was suggested for the shifting room of one of the magazines in the Citadel in the estimates for 1862-63.[28]

The available records do not reveal any interest in the use of asphalt in the Canadas in the 1850s. There was, however, some revival of interest in asphalt in the 1860s. When the Barracks Annual Estimate for Canada for 1861-62 was forwarded to London the Surveyor suggested that asphalt be used in renewing the flooring of an ablution house at Québec. The Commanding Royal Engineer's reply to this suggestion was that asphalt could not stand the frost. The Fortifications Annual Estimate for the following year included provision for a new expense magazine at Québec. As the space above the arch was to be covered with enough earth that it would be protected from the frost it was decided that the arch could safely be covered with a coating of asphalt.[29] It is interesting that it was felt necessary to state this explicitly in the estimate. When the Commanding Royal Engineer, Major Hassard, was invited in 1863 to comment on a plan prepared by the city corporation to improve the St.

John's Gate in Québec he suggested that the top of the arch should be asphalted to prevent leakage and pointed out that the top of the asphalt should not be less than three feet from the surface of the terreplein. Major Hassard's suggestion was incorporated in the approved plan for this work.[30]

In England asphalt was apparently still considered the standard waterproofing material for casemates. A memorandum, drawn up in February 1865 by the Deputy Director of Works to accompany the design for one of a line of forts proposed for the defence of Montréal, suggested that the caponier and the casemates be covered with a thin layer of concrete and "some impermeable composition analogous to the Asphalte used for the same purpose in England, over which earth will be placed."[31]

When preparations were made to build forts at Lévis to protect Québec, plans included the use of asphalt to protect the casemates from the damp. Although two of the forts were being built by civilian contractors, all of the asphalting was done by the engineers. Men especially trained in the laying of asphalt were sent from England and even the cost of the asphalting was calculated in England. The need to wait for the military to lay asphalt proved frustrating for the contractors. The men sent to lay the asphalt were late in arriving at the port of Québec and by August 1867 the engineer officer in charge of the work had begun to doubt that they would be able to do any work at Fort No. 3 before the onset of winter. The contractors, on the other hand claimed that there should have been no difficulty in laying the asphalt at all the forts in one season. The work on the forts which they were building was sufficiently advanced to keep a large force busy on the asphalting and with the use of a large number of men the work could have been done in time. They refused to take any responsibility for any damage suffered by the work because the War Department had not provided enough trained men or a sufficient quantity of materials.[32] It seems that the Royal Engineers were still the only people using asphalt in Canada.

It was not just that the interest in the use of asphalt was confined to those responsible for military construction. The enthusiasm for this new substance was confined almost exclusively to officials at the Ordnance headquarters in London. Colonel Oldfield was the only officer who had served in North America who continued to be enthusiastic about the value of asphalt, particularly in waterproofing casemates. The officers who followed in Canada, and those stationed at Halifax used asphalt at the insistence of officials in London and continued to urge precautions in its use. The officials in London who were urging the use of asphalt do not appear to have been very knowledgeable about its properties, and despite all the warnings they received from officers on the spot they seem to have been unable to grasp the fact that the North American climate was different from that in southern England. Civilian builders in British North America seem to have shown no interest in the potential uses of asphalt at this time.

The most intriguing question of all, and one which remains unanswered, is why Ordnance officials in England were so anxious to have asphalt widely used in military construction. Although there were large deposits of asphalt in Trinidad, the asphalt which was largely used for military purposes was imported from France. It was often difficult to ensure the shipment of adequate supplies of asphalt to North America when it was needed. Except for the use of "Bastenne Bitumen" in the early 1840s the engineers used Claridge's Patent Seyssel Asphalte almost exclusively, giving this company a virtual monopoly of the supply of asphalt to the Board of Ordnance. It is tempting to wonder if there was some hidden connection between an official in the Board of Ordnance and the management of Claridge's Patent Asphalte Co.

Chapter 6

HARDWARE — LOCKS AND NAILS

"The iron of this country is much Superior..."

Because an examination of the entire range of building hardware would be too lengthy to be included as part of this study, and because there were important developments in the 19th century in the production of both locks and nails, I have concentrated on these in order to determine whether the usage of the Royal Engineers conformed to civilian trends and whether the improvements in technology were reflected in specifications, estimates and contracts drawn up by the Royal Engineers for the construction and repair of various buildings. An interesting note is that to one Royal Engineer officer at least the local iron was "much Superior to the English."[1]

The Manufacture of Iron and Steel to 1860

The chief material used in building hardware was iron, though copper and brass were also used, particularly in fittings for powder magazines. In the period under study there were three main classes of iron in general use — wrought iron, cast iron and steel. The basic difference between these types of iron lies in the amount of carbon they contain. The greater the amount of carbon combined with the iron the harder, less malleable and more brittle is the metal. Wrought iron is smelted in such a way that the greater part of the carbon is burnt off. It is the most easily worked and the most readily welded of the types of iron. Steel is an iron-carbon alloy, with a higher carbon content than wrought iron. The union of carbon and iron is more intimate in steel than in wrought or cast iron. Steel is ductile and malleable when cast. The continuing addition of carbon causes a reduction in ductility, and the metal becomes extremely brittle. Cast iron or "pig iron" (so called because in the early days the output of the blast furnace was cast into moulds which roughly resembled a reclining pig) has a higher carbon content than steel. It can be shaped only by melting and cannot be forged or welded.[2]

Early iron-smelting furnaces produced wrought iron, in relatively small amounts. The blast furnace, which was introduced into Europe in the 15th century, and Britain in the 16th, worked at much higher temperatures, and produced much greater quantities of iron, but it produced cast iron. To produce wrought iron the cast iron pigs had to be remelted and subjected to a decarbonization process. Since the molten iron from the blast furnace could so easily be formed into pigs in sand moulds it became obvious that it could also be cast into other shapes and used without being converted into wrought iron. Cast iron began to be used to produce items such as pots, kettles and stove plates.[3]

The introduction of the blast furnace into Britain and the subsequent development of mechanical means of production resulted in a great increase in the amount of iron produced. In the late 18th century Henry Cort simplified the conversion of cast iron into wrought iron with the invention of the "puddling" process. This process soon became widely used, meaning that wrought iron could be economically produced from cast iron on a large scale. This large-scale production of wrought iron with its malleability and great tensile strength was the basis of British industrial pre-eminence in the first part of the 19th century. Wrought iron was widely used for railway and bridge construction and also for many of the smaller items of building hardware, where the ease with which it could be welded and its malleability made it highly suitable.[4]

Until the 18th century what was known as steel was only a core of wrought iron with a hard outer shell of more intimately fused carbon and iron. In the 1730s Benjamin Hutton developed a process for fusing the two elements through the thickness of the metal. The steel that was available during the first half of the 19th century was extremely costly and was used mainly for the production of tools and smaller precision parts. In the 1850s the Bessemer process for converting pig iron into steel was made public. This process, because it enabled steel to be produced much less expensively and in much greater quantities, led eventually to steel replacing wrought iron as the most commonly used structural material.[5] This last development took place after the period under study.

The Iron and Steel Industry in Canada

Canada has a sizeable proportion of the world's supply of iron ore. Although much of this has only recently become accessible, several attempts were made in the 18th and 19th centuries to use the iron ore deposits known then. The St. Maurice Iron Works, near Trois-Rivières, produced iron from the 1740s to the 1880s. Substantial quantities of iron were produced by the St. Maurice Iron Works, both cast-iron goods such as stoves and pots, and bar iron for smiths. In the 19th century several other iron works came into production in Quebec for varying lengths of time. The Radnor Iron Works, established about 1860, produced wrought iron that was used to make nail rods and scythes and cast-iron wheels for railway cars. The Moisie River Iron Works operated for about ten years. In Montréal rolling mills were established in the late 1850s and early 1860s.[6]

The most important iron works in Upper Canada in the first half of the 19th century was the Normandale Works, on the shore of Lake Erie. In the early 1820s Joseph Van Norman and his associates rebuilt an earlier, unsuccessful furnace and started production of good quality iron from the local bog ore. The Normandale Works continued in operation until 1847, when it was closed because of a shortage of fuel and ore. Van Norman then opened another works at Marmora, but was unable to make a success of this operation, losing in six years at Marmora most of the money he had gained in operating the works at Normandale.[7]

In Nova Scotia the most successful attempt in this era to exploit the local iron ore deposits was made in Londonderry, in Colchester County. There had been earlier, short-lived attempts to smelt iron in Nova Scotia. At Nictaux in Annapolis County a small quantity of iron was produced in the early years of the 19th century. Some years later a blast furnace was brought into operation in Annapolis County, but the works closed within a short time. The Acadian Iron Works of Londonderry used iron from a large vein of local ore. Six Catalan forges were put into operation in 1850 and replaced a few years later by a blast furnace, which operated for 21 years. Steam power was added in 1856 and a rolling mill in 1860. In 1874 a group of English financiers purchased the plant, intending to convert it to the Siemens "open-hearth" process of steelmaking. Because of various problems the operation became so unprofitable that it had to be liquidated in 1883.[8]

The products of these various iron works were available to the Royal Engineers in British North America for construction purposes, if they wished to use locally produced iron. Officers of the Royal Engineers were certainly aware of developments in the iron industry in British North America and took an interest in the potential benefits of purchasing locally produced iron work. In 1830 Colonel Durnford forwarded for the information of the Inspector General of Fortifications some comments by Lt. Col. John By on the iron works near Trois-Rivières:

> *Experience has shown that the Iron of this Country is much Superior to the English which makes me anxious that the Iron required for the various services of the Canal should be procured in Canada, my preference arises from the Metal in this Country being melted with Charcoal, and absorbing a portion of Carbon, renders it tough and more malleable than the English Iron which is melted with Sea Coal.*[9]

By's point about the difference between English and Canadian iron was a valid one, though for building hardware the difference in quality was not of great importance. Because charcoal contains fewer contaminating ingredients than does coke or coal, the iron smelted in furnaces using charcoal tends to have fewer impurities than does that smelted with coke or coal.

In the early years of the 19th century, while items such as lumber and stone were obtained locally, most of the building materials used by the Royal Engineers were purchased in England by the Supply Department of the Board of Ordnance and shipped to British North America as needed. In the period under study the shift to purchasing building materials locally, and the growing tendency to have construction and repair of military buildings carried out by local contractors meant an increased use of locally produced hardware.

Locks

Developments in Lock Production to 1870

A lock is a device which secures an opening of a door or cabinet by means of a bolt or latch that can be released by mechanical, hydraulic or electrical actuation. The bolt or latch may move vertically or horizontally

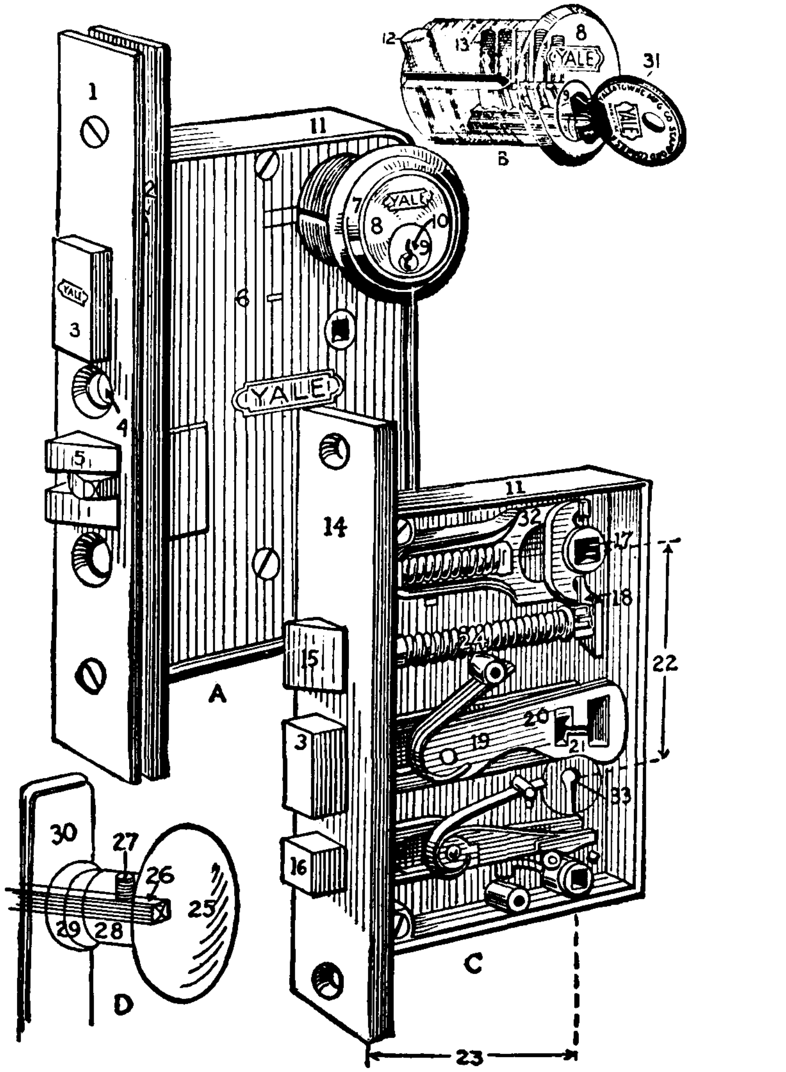


Fig. 556. Parts of Locks*

(A) cylinder lock *(B)* cylinder *(C)* lever tumbler lock *(D)* knob and escutcheon

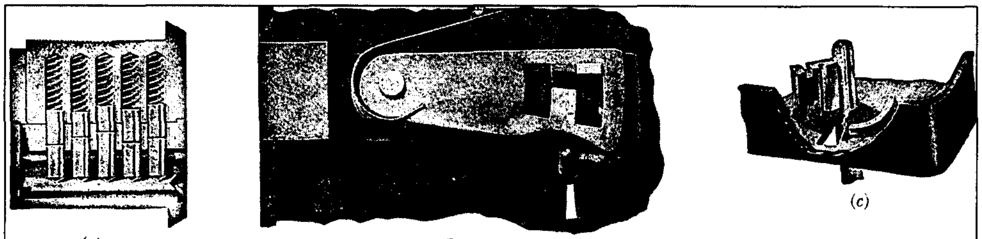
17 Modern mortice locks. The lever tumbler lock is a three-bolt lock. The gating can be seen (21) through which the projection on the bolt can pass when the tumbler is raised the correct amount. *Voss and Henry, Architectural Construction.*

or it may pivot or rotate. Obstructions in the lock case are employed to prevent the use of any but the correct key. These obstructions are either fixed, known as wards, or movable, known as tumblers. Wards are obstructions to the movement of a key; tumblers are obstructions to the movement of a lock bolt. There are three main types of door lock: a) cylinder (pin tumbler), the modern version of which was developed by Linus Yale in the mid-19th century; b) lever tumbler, with a series of one or more flat pivoted tumblers that must be moved to a certain position by the key bits; and c) warded locks (Fig. 18).[10]

In a warded lock, only a key with the proper slots can clear the projections and engage the bolt which can then be released by turning the key. Warded construction, however, does not offer a great deal of security, as it is fairly easy to use a strip of metal to by-pass the wards and actuate the bolt.[11] During the Renaissance a lever tumbler was added to the warded lock for extra security. Besides passing the fixed projections the key raised a lever which released the bolt. The tumbler turned on a pivot and had a projection that dropped into a notch in the bolt.[12]

The increase in security given by the addition of a single-lever tumbler of this type was not great. Robert Barron, seeing the defects in this type of lock devised improvements, which he patented in 1778. Barron's lock had two levers or tumblers with a projection on the end of each. When the tumblers were lifted to the correct height the projections passed through a slot in the bolt. If either tumbler was not lifted to the right height, the bolt would not move because the projection would be in a pocket above or below the central slot or gating in the bolt. In later versions of this lock the projection is fixed to the bolt, with slots in each tumbler.[13]

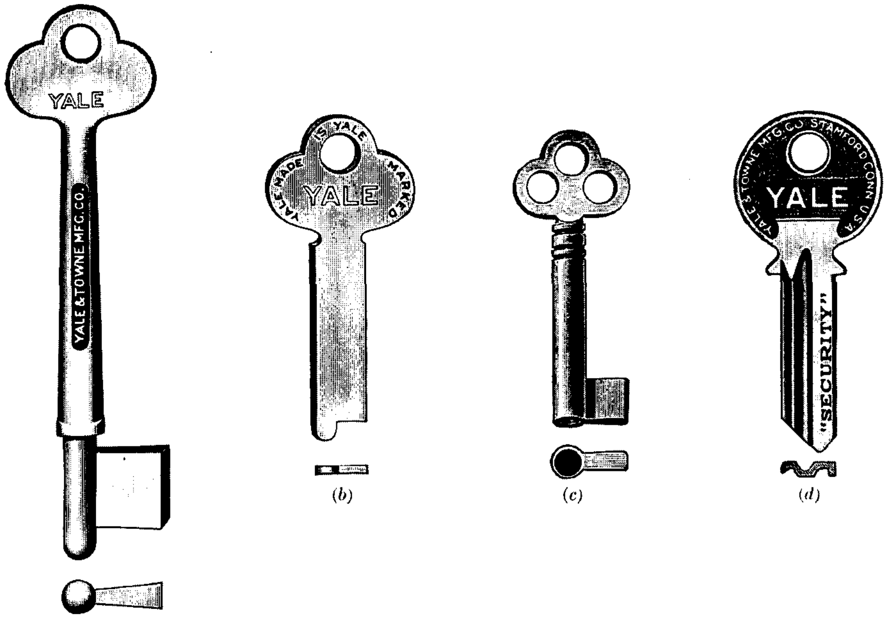
A few years after Barron's patent a Yorkshireman, Joseph Bramah, patented a lock with an extremely high degree of security. Bramah's lock had a cylindrical key with slots of varying depths, which corresponded to notched slides in the lock. When the right key was inserted the notches in the slides were correctly aligned so as to permit the rotation of the key and the movement of the bolt.[14] Bramah's lock never became economically feasible for large-scale production because it required such precision of construction. In 1818 Jeremiah Chubb patented a "detector lock," which indicated when anyone had attempted to open the lock with a false key.[15]



(a) (b)

Fig. 554. Lock Security*

(a) cylinder lock (b) lever tumbler lock (c) warded lock



(a) (b) (c) (d)

Fig. 555. Standard Keys*

18 Types of locks and keys. In the illustrations of the lever tumbler lock and the warded lock, the key is shown in operation. *Voss and Henry, Architectural Construction.*

Another well known patent lock was the Carpenter lock. James Carpenter had been manufacturing locks in Willenhall, Staffordshire, England, for several years before patenting his design in 1830. A Carpenter-type lock can be identified by its distinctive pivoting latch bar. Carpenter's patent incorporated a double set of levers, one set attached to the bolt, the other to the case, in an effort to create additional security, and a latch bar associated with a tumbler which could be operated by a key or by a handle. When James Carpenter died in 1844 his business was transferred to his son-in-law, James Tildesley, who carried it on under the name of "Carpenter and Tildesley." This firm continued to manufacture the same type of lock until late in the 19th century. The Carpenter-type lock was made in large quantities by a number of firms during the second half of the 19th century.[16]

Terms Used to Describe Locks

Before discussing the locks used by the Royal Engineers, it would be helpful to define some terms. A lock can have up to three bolts: a locking bolt, operated by the key; a latching bolt operated by a handle or latch; and a night bolt, operable only from one side of the door. A deadshot lock or a dead lock is a lock having only one bolt, which must be operated by a key. This type of lock was often used in conjunction with a thumb latch. A drawback lock is one in which the latch bolt can be held drawn back by some form of catch, so that the door can be locked, latched or open. Drawback locks seem to have been popular for hall doors. Figure 19 shows a page from a lock company's catalogue. The working parts of most locks were of iron. By the mid-19th century cast iron was being used in the manufacture of locks, particularly lock cases, but wrought iron continued to be used as well.[17] In circumstances where the lock was likely to be exposed to dampness, brass wards were sometimes used, and brass or copper was used to fashion locks intended for powder magazines.

A lock may be attached to a door in a variety of ways. A lock which is let into the edge of a door and thus visible only when the door is open is a mortice lock. A flush lock is one which is let into the door flush with the surface and has only the outer surface of the main plate exposed to view. A lock fastened on the surface of a door is known as a surface-mounted lock. This type of lock may have a metal housing (rim lock), or a wooden housing (stock lock). Stock locks are further subdivided into plate stock locks, in which the mechanism of the lock is attached to a main plate which is then let into the housing, and plain stock locks (called by some writers Banbury locks) in which each part of the mechanism is let into the housing separately. The stock lock was cheaper than the rim lock and in some cases was recommended for damp locations where an iron housing would be more susceptible to corrosion.[18]

HARPER AND CO.'S 2-BOLT HALL DOOR LOCK, No. A 1275.

2, 3, or 5 levers, secure, with neat small key, which acts upon both lock and latch and Rock's patent roller staple.

HARPER AND CO.'S 2-BOLT HALL DOOR OR DRAWBACK LOCK.

Solid ward, key acting upon both bolts from outside of door. No. A 230.

Also a large variety of Hall Door or Drawback Locks, 1, 2, and 3 bolt.

6-in. 2-bolt Rim Lock, No. 60, with "lift up" latch, known as "inclined striker," or "Carpenter's Patent," in every size and quality.

3-bolt Rim Lock, solid brass ward, horizontal movement. No. A 504.

2-bolt Rim Lock, with thin moulded rim. No. 330.

2-bolt Rim Lock, rounded cast case, known as "Bailie's Patent."

19 Page from the catalogue of mid-19th-century British lock manufacturer. The third lock from the top is Carpenter-type lock. *Kauffman, Early American Ironware - Cast and Wrought.*

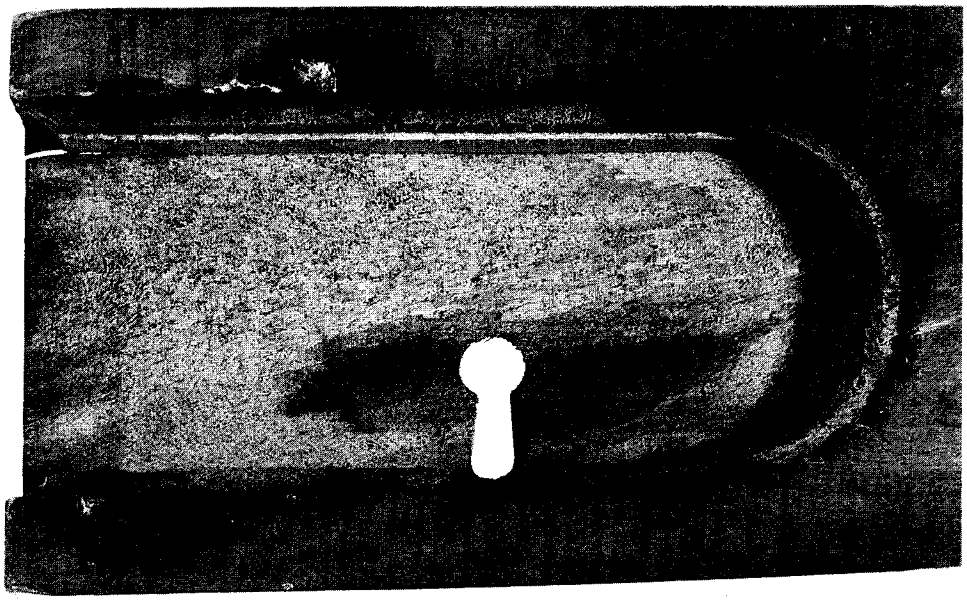
As well as locks, which were permanently attached to doors, estimates for military construction frequently called for padlocks for various uses.

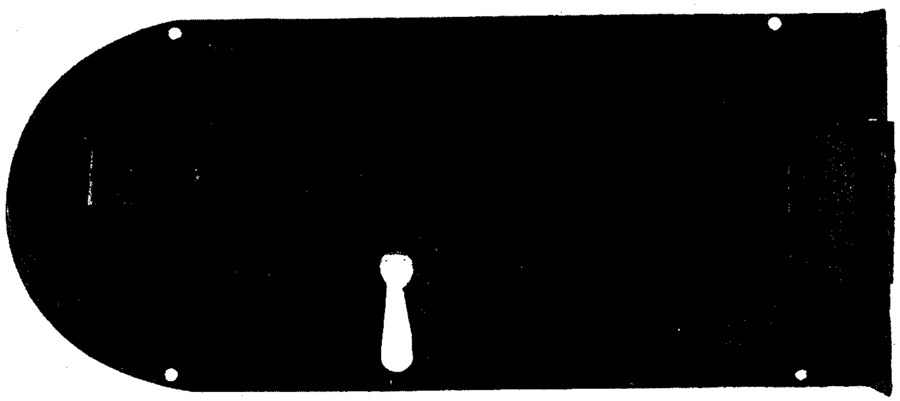
Use of Locks by the Royal Engineers in British North America

There were certain standards laid down for the guidance of the officers of the Royal Engineers in the design and construction of buildings at military posts. The basis of this was, of course, the instruction given them at Chatham. In addition, each engineer officer was supposed to possess a copy of the *Orders and Regulations for the Corps of Royal Engineers*, known as the Engineers' Code, which he was supposed to keep up to date. According to the 1832 edition, mortice locks were only to be used in special and particular instances, and where additional security was required Chubb's Patent Lock was to be used. This was the only mention of the types of locks that the Royal Engineers were expected to use, or not to use. A *Handbook for Military Artificers* published in 1877 described the type of lock in use at that time:

> *Rim Locks are made of iron and are from 5" to 12"; they may be fitted with one or two brass knobs on a spindle, and may have a drawback bolt. They are right or left, and are used for common doors.*[19]

Other instructions were issued from time to time dealing with details of construction for various specific types of building. Figures 20 to 23 show locks from various archaeological sites in Canada, which are of the types used in military construction. Officers quartered in barracks or other accommodation provided by the army often did not consider the standard locks attached to their doors as suitable or adequate. Disputes with Barrack Masters often occurred, particularly when an officer, on being transferred, took with him the locks he had purchased for his doors. For a long time officials in London tried to ensure that only the standard locks were used. An estimate for a barracks at Annapolis Royal in the 1830s included French latches for doors to officers' rooms. (According to a modern encyclopedia of locks the French latch was a type of night latch in use in the 19th century; the key was inserted horizontally and then raised to lift a pivoted latch bar.) The official at headquarters responsible for checking this estimate noted that such extras





20 Plate stock lock showing case and main plate with assembled mechanism. The lock has a cast-iron tumbler pivoted at one end, with a lug at the other end which rests in either of the notches along the top of the tail bolt. The wards are cast as a unit in brass. *Photo by R. Chan.*

were "unnecessary, the locks are sufficient." Finally the Board of Ordnance bowed to the inevitable. In order to obviate this problem it was decided in 1840 that officers wishing to affix a latch lock to their doors should be allowed to do so if they used one of a fixed pattern, thus ensuring uniformity in government quarters. Once attached to the doors these latches would, presumably, remain in place.[20]

Locks and security were particularly important in prisons. In an effort to standardize the type of prison accommodation at various military posts and to bring the design of military prisons into line with contemporary ideas on prison design, a printed memorandum on the provision of barrack cells and prison accommodation was issued by the Board of Ordnance in 1846. It specified that:

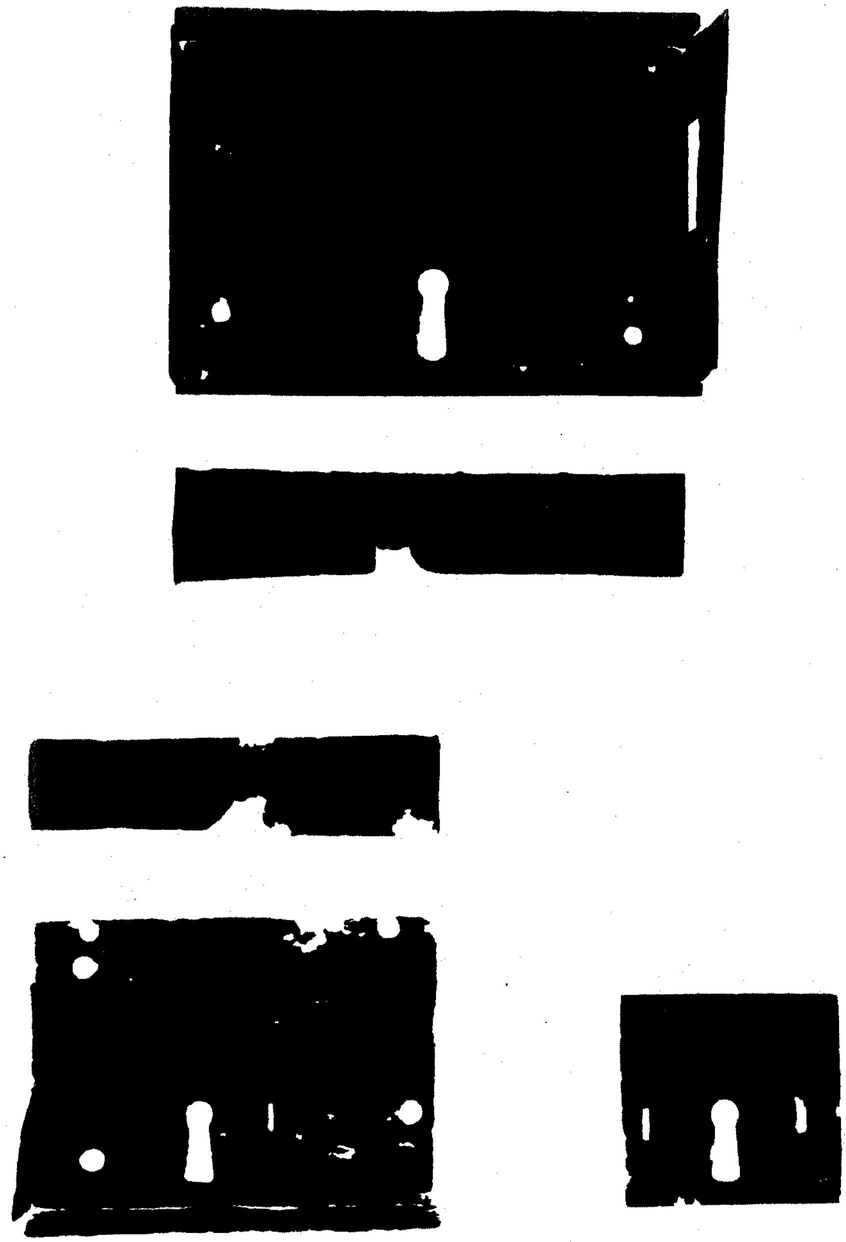
> *Spring Locks will be found very convenient for the Cell Doors, but they should only be used in the larger prisons, where more than one Sergeant would probably be employed. Wherever they are fixed, the Doors and Frames should be double rebated to prevent the possibility of the Bolt being pushed back from the interior of the Cell.*

A spring lock is one which requires a key to open it, but locks automatically. It was noted at the end of the memorandum that items such as locks "will probably be made articles of Store, and may be obtained on demand from the Tower."[21]

In military construction in 19th-century British North America the Royal Engineers made use of the standard types of lock then in use for civilian construction. In accordance with the regulation laid out in the Engineers' Code, estimates and specifications for construction indicate extremely limited use of mortice locks. An 1826 estimate, prepared by the Royal Engineers, for the construction of Government House in St. John's, Newfoundland, called for mortice locks for the principal floor. An estimate for repairs to a house in Halifax which was to be occupied by the Major General commanding the troops in the district included 8-inch mortice locks for the second floor. By this time the use of mortice locks for the principal doors on the better class of house was fairly common. Repairs needed in 1841 to a house in Brockville that had temporarily been taken over by the army included the replacement of several mortice locks. At about this time mortice locks were also being included in estimates for officers' quarters and for the folding doors in the officers' mess in London, Ontario.[22]

The type of lock most commonly specified in estimates for military construction was the iron-rimmed lock. The sizes called for were 6, 7, 8, 9, 10 and 12 inches, with the most widely used being 8, 10 and 7 inches respectively. Descriptions of the locks in the estimates varied, with some being much more specific than others. In some cases the locks were listed merely as iron-rim locks. One-bolt or dead-shot locks were very common. In looking at all the descriptions of locks listed in the available estimates it is difficult to discern any widely applied standards for the type of lock to be used for any specific type of building. Therefore a few estimates for large-scale construction involving more than one type of building, or a multi-use building have been selected in order to ascertain whether there was some pattern in the usage of locks.

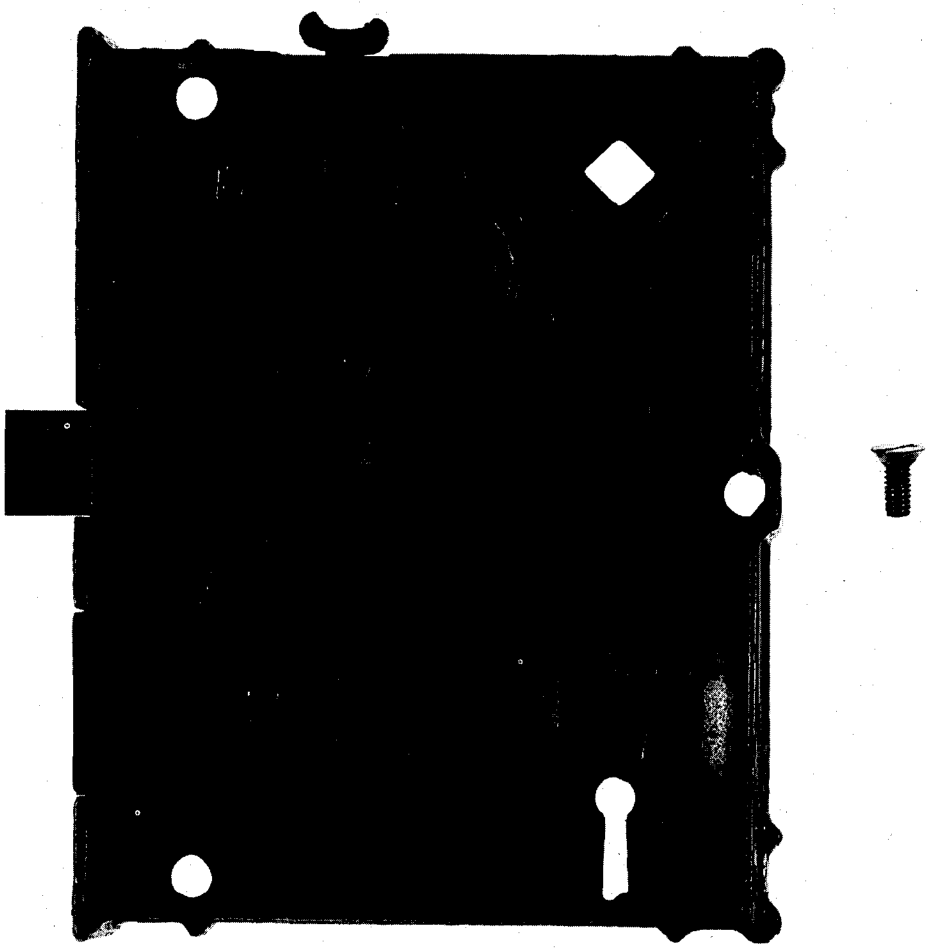
In the first instance the estimates looked at were drawn up in 1839 and 1840 for barracks: a sample estimate drawn up by Thomas Hounslow of Montréal to show his fitness to hold the position of Foreman of Works, and estimates for infantry barracks at Montréal, Toronto and London. The Hounslow estimate is, presumably, closest to the standard as it was not intended for any specific post. This estimate called for stock locks for the men's barracks, cook house and guardhouse and for the outer doors to the officers' barrack and the mess house, with iron-rim, brass-knob locks for the interior doors in the officers' barracks and the mess house and iron-rim dead locks for the officers privies. In the estimate prepared in late 1840 for a proposed barracks for a regiment of infantry at Montréal, stock locks were specified for the soldiers' barracks, commissariat store, stable, washhouse, armourer's store and the outer doors of the canteen and schoolroom, iron-rim, dead-shot locks for the hospital, dead house, officers' privies, inner doors of the canteen and schoolroom, and outer doors for the officers' barracks, and the Barrack Master's quarters, iron-rim, brass-knob locks for the inner doors in the officers' barracks and the Barrack Master's quarters, and iron-rim, three-bolt locks for the barrack cells. The 1839 estimate for a barrack in Toronto made similar use of stock locks, but called for iron-rim drawback locks for hall doors in the officers' barracks and for inner doors in the canteen and stores. An 1839 estimate for an infantry barracks at London is particularly interesting because the locks included in the estimate run the gamut from wood stock locks for stables and sheds through



21 Iron-rim lock. A one-bolt lock. *Photo by R. Chan.*

iron-rim, dead-shot locks for barracks, the hospital, the guardhouse and barrack store to mortice locks for interior doors in the officers' rooms, contrary to the regulation stating that this type of lock was to be used only in unusual circumstances. In all of these estimates a larger size of lock was specified for exterior doors than for interior doors.[23] A few years earlier an extensive estimate was drawn up for buildings which it was proposed to erect at Annapolis Royal, N.S. Unlike the estimates for barracks in the Canadas, stock locks did not appear at all in this estimate, and there was no differentiation by size for exterior and interior doors. Drawback locks were to be used for hall doors in the officers' quarters. French latches were specified for the doors to officers' rooms, and also for some rooms in the men's barracks ("sick rooms" in the estimate, but probably supposed to be for the sergeants' rooms). These French latches were objected to at headquarters as being unnecessary.[24]

In 1852 estimates were drawn up for rebuilding the Ordnance offices and the artillery barracks at Québec, which had been destroyed by fire. In the barracks the use of larger locks for exterior doors continued. The men's barracks were to have dead-shot locks and thumb latches for the interior doors, while the officers were to have iron-rim locks with brass-knob furniture. For the offices all the locks called for were to be the same size (8-inch) with dead-shot locks to be used for exterior doors, a drawback lock for the hall door, and iron-rim locks with brass-knob furniture for the office doors.[25] That same year specifications were prepared for the contract for building new barracks near Fort Needham, Halifax. Locks were mentioned in the specifications for carpenters' work and for ironmongers' work. There are some inconsistencies in the descriptions of the locks in these two parts of the specifications; where descriptions differ that given in the specifications for ironmongers' work has been preferred. The specifications called for "nine inch iron rim dead shot round ward" locks for the exterior doors of the men's barracks and "eight inch iron rim dead shot locks" for the interior doors. The office was to have "nine inch iron rim three bolt brass knob handle strong spring round ward locks," the officers' guard-room a "seven inch iron rim three bolt brass knob handle strong spring, round ward" lock and the doors on the upper floors of the officer quarters were to have "seven inch three bolt brass knob handle strong spring round ward locks." These specifications give a more detailed description of the

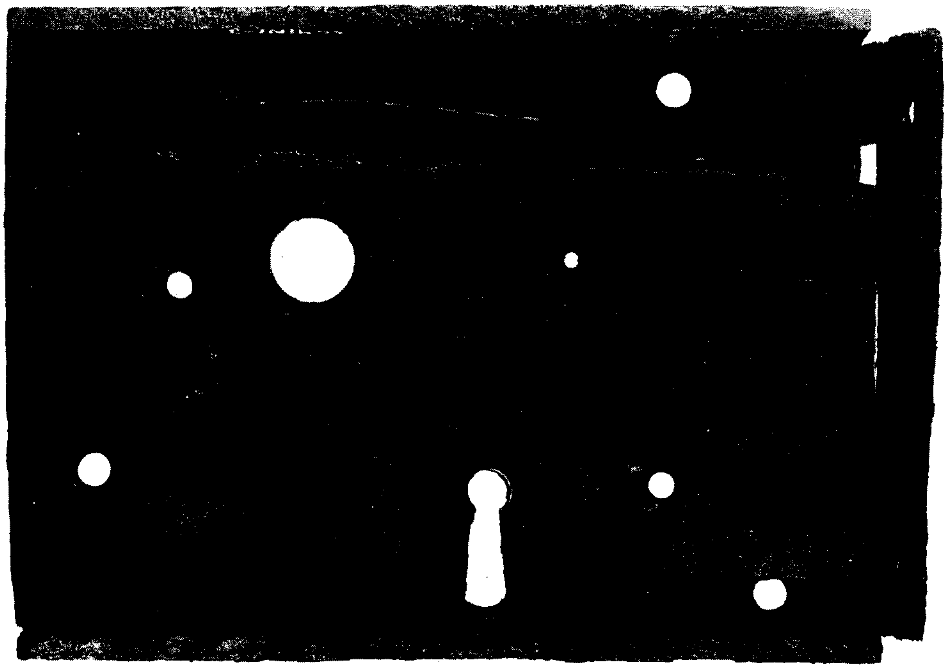


22 Iron-rim lock. A cast-iron, two-bolt lock with a dead-lock bolt and a latch bolt. The tumbler is a flat double-acting one. *Photo by R. Chan.*

locks to be used than do many of the estimates, in keeping with the fact that they were prepared for the guidance of a contractor.[26]

As can be seen from these examples the general tendency was to use more elaborate locks for officers' quarters or for offices than for soldiers' barracks or other buildings such as storehouses or sheds. Exterior doors, which were generally heavier, often had larger locks than interior doors, though this was not always the case. When soldiers' barracks had iron-rim locks, these were almost always dead-shot or one-bolt locks, whereas rooms used by officers generally had locks with knobs. This was presumably more a matter of giving a better appearance to the furniture of doors used by officers as compared to those for privates. It was not reasons of economy that motivated the difference in door furniture, as a dead-shot lock plus thumb latch was often more expensive than a lock with its own knob or handle. There was a further consideration affecting the use of knobs or thumb latches. In reply to a comment from headquarters that knobs would not be needed for a door to an ablution house at Québec, someone in the Royal Engineers Office pointed out that a knob was far easier to catch with a fur-gloved hand than a latch.[27] Stock locks continued in use throughout the period under study, particularly for exterior doors. The advantage of stock locks for outer doors was that they would be less affected by dampness.

In the choice of locks for military structures there seems to have been more concern for the appearance of security than for the reality. Most of the locks which were listed in the various estimates would not have resisted a determined effort to pick them. The estimates and specifications available show very little awareness of the developments in lock technology. It is only in the latter part of the period under study that any of the patent door locks appear in the estimates prepared by the Royal Engineers for works in British North America. An 1850 estimate for a military prison at Montréal called for 9-inch, three-bolt, iron-rim, Carpenter's-patent locks for doors in the prison governor's house.[28] There were also a few other mentions of Carpenter locks for use in officers' quarters in the Canadas. The schedule for the contract for work in the Royal Engineer Department, Montréal, for the period 1850-53 listed various sizes of stock locks, iron-rim locks with brass furniture, drawback locks for hall doors, and dead-shot locks, but did not include any type of patent lock. The analysis of schedule prices which was prepared in order to establish prices for contracts for work from 1853 quoted prices for stock locks, iron-rim, dead-shot locks and Carpenter's-patent locks, with no mention of other types of iron-rim locks. A schedule for contract work at Québec, printed in 1852 and being used in 1856, listed only two kinds of iron-rim locks, Carpenter's patent and dead shot. The contract schedule for work on the canals of Canada East, printed in 1866, and in use for the Chambly Canal at least until the



23 Iron-rim lock. Forged three-bolt Carpenter-type lock. The latch is a pivoting bar with its head permanently projecting outside the case. The head is bevelled so that it rises as it passes a catch on the door frame. *Photo by R. Chan.*

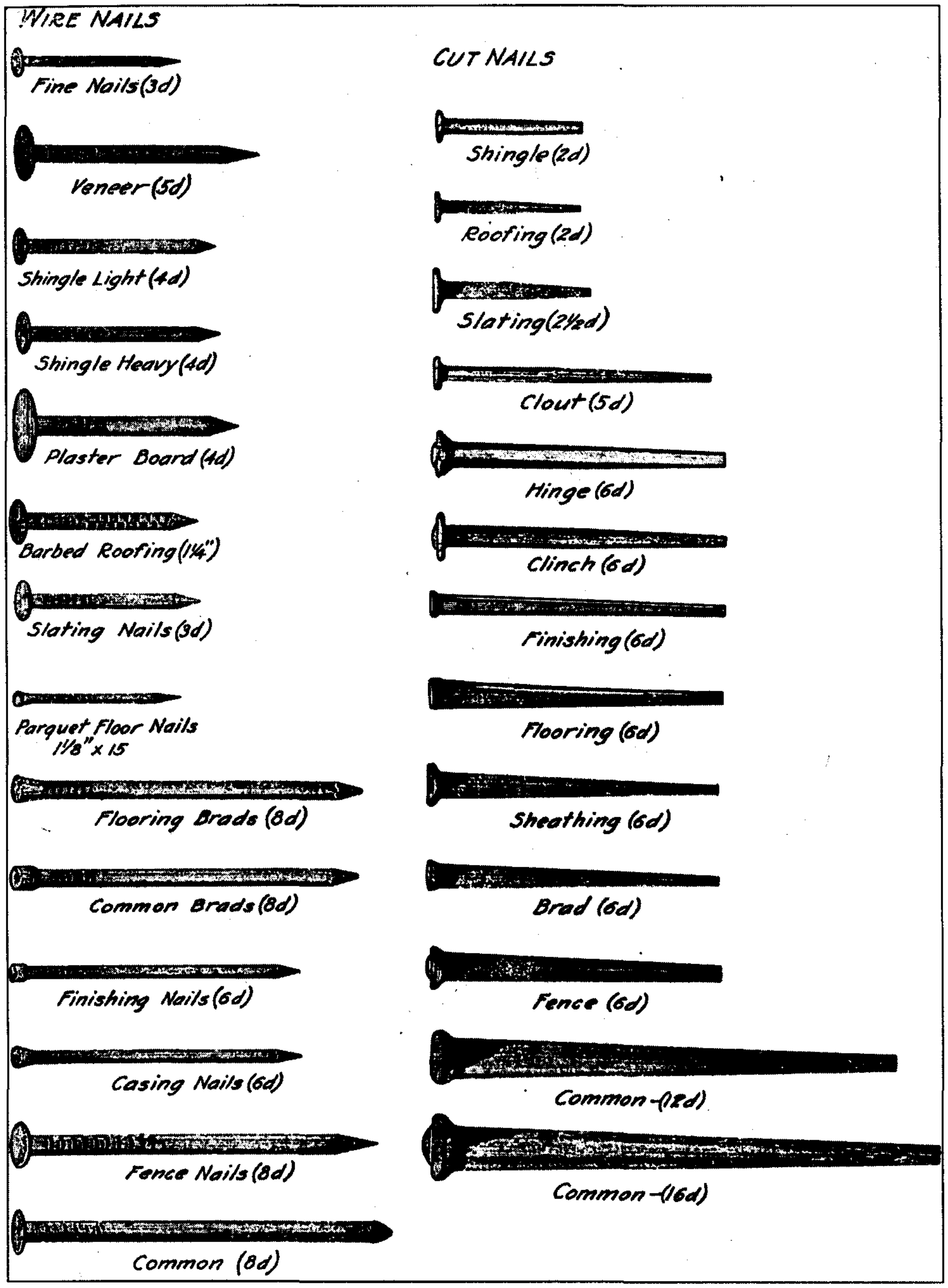
1870s, included Carpenter's patent two- or three-bolt locks and drawback locks, as well as dead-shot locks. The description of the locks specified that none of the parts were to be of cast iron.[29]

One of the 19th-century improvements to the stock lock was Young's patent of 1825. This was apparently intended as an improvement on Barron's lock and also involved a circular cavity in the wooden block, cut on a lathe to improve the appearance.[30] A few references to the use of Young's patent stock locks appear in estimates for work in Nova Scotia in the early 1860s. The printed schedule for work on the canals referred to above included Young's patent stock locks in 8, 9, 10 and 12 inches, at considerably higher prices than ordinary stock locks.

The Engineers' Code suggested the use of Chubb's patent locks in cases where there was a particular need for security. Very little use seems to have been made of Chubb locks by the Royal Engineers in British North America. The only references to Chubb locks in the available estimates are to their use in money vaults in St-Jean, Chambly, and Carillon and for a closet for confidential papers in Montréal. In accordance with the suggestion in the memorandum on the construction of military prisons, which was circulated to officers of the Royal Engineers in the late 1840s, the estimates which were drawn up in 1850 for a military prison at Montréal, and for improving the barrack cells at various posts in the Canadas called for "spring locks of approved pattern" for the cells at many of the posts.[31]

Where spring locks were not used for cells the cell doors were usually secured with padlocks. The 1850 estimate for improvements to the barrack cells at London, Ontario, states that for the cell doors the padlocks currently in use "must be changed for a set one Key of which will answer for all the locks." Padlocks were generally specified for use on cell doors, shutters and gates and occasionally for sheds. The sizes commonly used were 3, 3½ and 4 inches, with the 3-inch padlocks usually required for window fittings. In the various estimates the padlocks were usually described as spring and tumbler padlocks and after the 1840s estimates usually called for patent padlocks. None of these estimates specified whose patent padlock was to be used. Some of the 19th-century lockmakers patented methods of holding the spoon end of the shackle in the lock and providing support against a pull on the shackle. It may have been this type of increased protection the estimates were referring to. Spring shackle padlocks have a shackle which springs open when the key is turned. As well they usually have a spring bolt so that the shackle becomes locked when pushed in.[32]

The extensive use of locks on military buildings shows a desire for at least the appearance of security. Virtually every door, either interior or exterior had a lock. Even privy doors often had key-operated locks. Most of these locks were surface mounted. In their choice of locks for use in military construction the Royal Engineers appear to have been quite conservative. They used the standard type of lock common in civilian construction, but did not take advantage to any great extent of the new developments in security offered particularly by the Chubb Detector Lock. The tendency for officers where possible to use locks which they had purchased themselves indicates that better locks were available.



24 Types of nails. *Voss and Henry, Architectural Construction.*

Nails

Development of Nail Production

Up to the end of the 18th century all nails were made by hand. The nails were forged from nail rods heated in a small blacksmith's hearth, hammered on an anvil, the nail cut off on a chisel and the head formed by dropping the spike into a hole in a "bolster" of steel from which enough of the spike was left projecting to form the head. In the case of clasp nails the head was formed with two strokes of the hammer, while rose nails required four.[33] A great variety of shapes and sizes of nails was produced. In England the making of nails was mainly concentrated in the area around Birmingham. In the United States at the end of the 18th-century nail factories were established to produce large quantities of nails by hand.

A nail-cutting machine was perfected around 1800. The iron was rolled into bars, then cut into strips, which were as wide as the length of nail they were to be used to produce. The strip was then taken to the nail-cutting machine, a table with a guillotine-type of knife at the far end. The strip was fed against the blade and was moved slightly to the left or to the right after each cut, giving the nail a taper on two sides throughout its length. In later versions of the nail-cutting machine the strip was turned over and cut from the opposite side after each cut. Early cut nails were headed by hand, but machines for heading nails were developed too. Despite the rapid proliferation of nail-cutting machinery, especially in the United States, wrought nails were still in use for many years after machine-made nails became readily available. It was for the smaller sizes of nails that the use of nail-cutting machines first became widespread. A large wrought nail was easier to make than a smaller one, whereas the cost of cutting machinery increased greatly with the size of nail to be produced. Early cut nails did not have as great holding power as wrought nails and so wrought nails were often preferred even where cut nails were available and cheaper.

In the latter part of the 19th century machinery for manufacturing wire nails, which are drawn rather than cut, was developed. In 1870 a wire nail manufacturing plant was established in Montréal. By the 1890s wire nails had become the predominant type employed in the building industry.[34]

Use of Nails in Military Construction

As with other building materials, when specifying the types of nails needed for repairs to or construction of military buildings the Royal Engineers were supposed to adhere to certain regulations laid down by the authorities in London. In the case of nails the regulations were quite specific, not so much as to what type or quality were to be used, but in laying down how the nails needed were to be described. In 1813 there was sent to the Commanding Royal Engineer at Halifax a "List of Nails and Spikes required for the Service of the Office of Ordnance." In this all the types and sizes of nails or spikes that might possibly be needed were listed, with an accompanying drawing of each item included in the list. It was ordered that when nails were requested the number in the list, the type, and the weight per thousand nails be specified as well as the number and weight actually required (e.g. "20,000 No. 31 Clasp headed 7 lbs. pr. 1000, 1 cwt., 1 qr."). A copy of this list is in the British Military Records at the National Archives of Canada (see App. 5). In some cases someone has written in the equivalent penny size: for example, No. 7 was a long 20dy nail.[35] A new list of nails was issued in 1826 and probably subsequent revisions were also made. Unfortunately these later lists could not be located.

How closely did engineer officers at the various stations comply with the regulations of the Board of Ordnance concerning the ordering of nails when they were preparing estimates for building work or requesting the supply of building materials? In looking at estimates prepared in the 1820s for work to be done in the Canadas there does not appear to have been a great deal of attention paid to this directive. In these estimates the nails needed were listed as "500 lbs. of 30dy nails" or "7650 of 20dy nails." Further east engineer officers appear to have conformed more closely to Board of Ordnance instructions. For example, an estimate prepared by the Royal Engineers in 1826 for Government House, St. John's, adhered strictly to the 1813 list in stating the nails required: e.g. "Nails B [referring to the number of the Plate in the list] no. 23 Clasp headed 40 lbs. p." (see App. 6). In the spring of 1826 a new printed list of nails was issued in London. By 1829 this list had obviously reached the Royal Engineer Office in St. John's, as the descriptions of the nails included in a demand for stores needed to finish Government House drawn up at the end of 1829, to be sent to the Ordnance officials in London, while conforming to the directions in the 1813 list for ordering nails, do not correspond to the nails in that list.[36] Estimates drawn up at this time in Halifax and in Saint John, described the nails required by number and type: e.g. "112 lbs. of No. 8 rose Nails."[37]

Estimates drawn up for work in the Canadas in the 1830s conformed more closely than those of earlier years to Ordnance regulations in listing nails, but as the numbers used referred to the later list, which has not been located, and as no indication was given of size or weight, this is of little help. In the years between 1837 and 1841 a great deal of military construction was undertaken and a large number of estimates for various types of construction work were drawn up, particularly in the Canadas. In these estimates there was not a great deal of uniformity in describing the nails to be used. Several estimates used more than one method of identifying the nails required. For example, an estimate for a banquette for the loopholed wall of the casemated barracks in the Québec Citadel called for "50 lbs. of No. 122 Nails" and "18 lbs. of 30dy Nails."[38] Several of the estimates specified the various lengths of nails needed. There are a few estimates prepared in the Atlantic area in these years that specify the nails required. These usually specify the type (clasp, rose, etc.) and the number, but seldom give any indication of the size. In the lists of stores required for various projected works in Nova Scotia and New Brunswick sent to London in the 1840s the nails were identified by number and by length or weight. By comparing all these estimates and requisitions and assuming that the numbers given always referred to the same list, one can gain an idea of the size of some of the nails specified (see App. 7).

By the 1850s much of the work of military construction was being contracted out. Estimates described the work to be done, with the type of nails to be used not being specified. Contractors were free to use whatever they considered suitable, provided the work passed the inspection of the supervising engineer officer. A few estimates drawn up in the later period did mention nails: e.g. an 1851 estimate for alterations at the Halifax Hotel, which was to be used to accommodate troops following a fire in the barracks, included rose nails, No. 14, No. 16 and No. 20, and clasp nails, No. 33, and an 1864 estimate for work in Saint John called for the use of 10dy cut nails.[39] For work to be done by contract schedules were used which listed all the types of work or materials that might be required, with a price for each. In these schedules nails were described by type (e.g. rosehead or clout) and length (see App. 8).

As pointed out the official policy of the Board of Ordnance in the early decades of the 19th century was that wherever possible building materials, and particularly items manufactured in England should not be purchased locally. It can be seen from the memorandum explaining the 1813 "List of Nails and Spikes" that the authorities in London certainly expected that the nails needed to build fortifications in British North America would be obtained from England, through the Ordnance Office in London. This was mainly the case in the early part of the period under study, but became less so. Reliance on supplies from England sometimes tended to cause problems. In December 1832 the Commanding Engineer at Halifax informed the Inspector General of Fortifications that because some stores and materials needed for the new works at the Citadel had been struck out of the request sent to England, certain items including nails had to be purchased locally. He stated that these items had been purchased at the contract price, indicating that arrangements already existed for the local purchase of these items.[40] There were also problems with nails which did arrive from England. In the fall of 1831 the Commanding Engineer at Halifax received a complaint from the engineer officer in charge at Saint John, Captain A. Marshall, about the nails sent from England for use in shingling the roof of the soldiers' barrack. The nails sent, No. 82 in the printed list of 20 March 1826, were much stouter than those in common use locally. Because of their coarseness they tended to split the shingles and cause leaks. In one case a contractor who was shingling a barrack disposed of the nails issued to him from the government store and purchased the type in common use locally in order to be able to carry out the work satisfactorily. The nails used by builders in Saint John were 5dy fine and slender Canada rose nails, 3½ pounds per thousand. According to the engineer officer at Saint John the cost of supplying this type of nail from England would be about the same as that of purchasing them locally (eight to nine pence per pound for large quantities). Captain Marshall's report was forwarded to London by the Commanding Royal Engineer at Halifax with the note that No. 82 nails, though the smallest shingle nail in the printed catalogue, were not suitable for use in the area under his command. Despite the precise descriptions of the type of nail used for shingling in the area given by both Captain Marshall and the Commanding Royal Engineer at

Halifax (who added the detail that they should be 1⅜ inches long), shingle nails sent from England continued to cause problems. In 1834 Lieutenant Colonel Rice Jones, then Commanding Royal Engineer at Halifax, complained that of the three types of nails sent from England for shingling — Nos. 53, 54 and 55 — all were unsuitable, and shingle nails had to be purchased locally.[41] This problem of materials sent from England not being suitable was one reason for the increasing tendency to obtain nails locally. Local suppliers were available who could provide most of the types of nails required by the Royal Engineers. Newspaper advertisements show that hardware merchants in most of the larger centres were offering for sale the commonly used sizes of nails and by the late 1820s the smaller sizes of cut nails were specifically listed as being available. In Halifax by the 1830s hardware merchants were able to offer for sale the products of local nail manufacturers as well as nails imported from England and the United States. Nails of various sizes and types were included in a list of stores to be purchased locally for the use of the Royal Engineer Department in Nova Scotia and New Brunswick in the mid-1840s.[42]

Throughout the period covered by this study both wrought and cut nails were in use in civilian construction. Many writers on the subject have stated that by the 1830s cut nails had replaced wrought nails in most uses. The available documentation in military construction shows the Royal Engineers as much slower than civilian builders in accepting the new technology. Even contract schedules printed as late as the 1860s set out prices for both wrought and cut nails. The few early references to the use of cut nails were to their use for shingles or laths, in other words the smaller size of nails. By the 1840s it appears that the use of cut nails was becoming more common. In an 1842 estimate for fitting up a hired building at Drummondville, Ontario, to accommodate troops it was proposed that the floor be covered with one-inch rough pine boards, nailed with wrought nails. The purpose of the covering was to protect the floor so that it would be in good condition when the building was returned to its owner. Wrought nails were to be used because it was considered they would be less injurious to the lower floor than cut nails.[43] The specific mention of the use of wrought nails for this purpose suggests that in this particular area at least, cut nails were in common use for military construction at this time. Even in the 1860s there is an occasional reference to wrought-iron nails in estimates though their use would appear to be the exception rather than the rule.

On the other hand there is an interesting reference to the use of wire nails in the 1860s. In August 1865, a civilian architect in Montréal, William Wagner, submitted to the Royal Engineer Department specimens of asphalt goods for possible use in works being constructed, along with a memorandum describing the goods which he was prepared to supply and install. Included in the list were wire nails to be used for fastening stone paper sheeting or tin to roofs.[44] The military do not at this time appear to have been using wire nails at all.

In general a study of the available documentation relating to the locks and nails used by the Royal Engineers indicates a lack of interest in the technological developments of the early 19th century in the production of locks and nails. The available literature on the history of locks stresses the great improvements in lock design achieved by Barron, Hobbs and Yale and the great interest in developing an "unpickable" lock. The impression given is that most builders made use of the latest lock designs to achieve the maximum security. In military construction, at least, this was not the case. Most of the locks used were of a very basic design and there was generally more interest in the type and appearance of the lock furniture than in the degree of security given by the lock. While locks and nails were generally imported from England by the Ordnance in the early part of the period under study, these items were available locally from hardware merchants. Advertisements in the Kingston papers show that by the 1830s the Commissariat was beginning to call for tenders for the supply of building materials including locks and nails. With the increasing tendency in the 1840s and 1850s to contract out military construction the use of local supplies of these items grew.

Chapter 7

THE WINDOWS

"Free from spots, knots, veins"

The size, style and number of windows in a building are much more noticeable to the observer than the type of foundation or the kind of nail used. This means that in any attempt at restoration or even at creating an impression of age it is important to ensure that the windows are appropriate. The type and number of windows were determined by architectural style; the type of glass used, and to some extent the size of individual panes in the window were determined by technology. In the 19th century there was an increasing awareness of the need for light and ventilation, which led to a desire for more and larger windows in buildings designed for housing, offices or factories. At the same time technological change made it easier to produce comparatively large panes of glass, and in Britain it combined with a restructuring of the tax system to reduce considerably the cost of having more and larger windows in a building. The technological changes in the production of glass in the 19th century also meant an improvement in the quality of the glass available. Thus by the 1850s engineer officers could expect glass that was "free from spots, knots, veins and perfect at each corner"[1] even in the lower quality of glass being ordered for use in soldiers' barracks.

In examining the use of window glass by the Royal Engineers it is important to know what glass was available to them. This requires some understanding of the state of developments of the glass industry at the time, and also of local conditions. What type of glass was being manufactured? What sizes of panes and what thicknesses were readily available? For what purposes was glass used? Was it obtained from local merchants or purchased by the Board of Ordnance in England? How was it shipped? As the glass used in British military buildings on this continent was mainly produced in England, an examination of the glass industry there and of its changing technology and circumstances in the first half of the 19th century is a necessary preliminary to discussion of the window glass used in British North America.

The English Glass Industry

By the 18th century the glass industry had long been established both in England and on the Continent.[2] The location of glasshouses depended initially on the availability of the materials used in the manufacture of glass. Glass is produced by the fusion at very high temperatures of silica with one or more of the basic substances, one of which must be an alkaline metal. The standard form of silica used in the British manufacture of glass was sand. The fine white sand that produced the best glass was obtainable from Lynn in Norfolk, Maidstone in Kent and the western tip of the Isle of Wight.[3] For the finest type of glass pearl ash was used, and for coarser glass the alkali was generally wood ash. Other substances such as lime or chalk and lead oxides (the best of these being litharge) were used to produce various types of glass. Also cullet (waste and broken fragments of the specific kind of glass to be made) was added to the batch before firing.[4]

In modern glass factories the ingredients are mixed mechanically and then melted in a continuous tank furnace in which the raw materials are fed into the back and the molten glass flows steadily from the front end. Most forming is done on automatic machines. The furnace used for making glass must be one in which an intense heat can be maintained for a considerable length of time and uniformly distributed. Up to the late 19th century, glass was manufactured in pots which had to be heated thoroughly before receiving the ingredients for the glass in order to secure uniform melting of the mixture. To produce the intense heat needed in the fusion of the ingredients early glassmakers used wood fires. Until well into the 19th century wood continued to be the main fuel used for the manufacture of glass in most of Europe. By the end of the 16th century wood for fuel in manufacturing processes was becoming scarce in England and a new type of coal-fired furnace that could be used by glassmakers was developed. Newcastle-upon-Tyne, where an abundant supply of coal was readily available, became an important glassmaking centre, particularly for the window glass industry.[5]

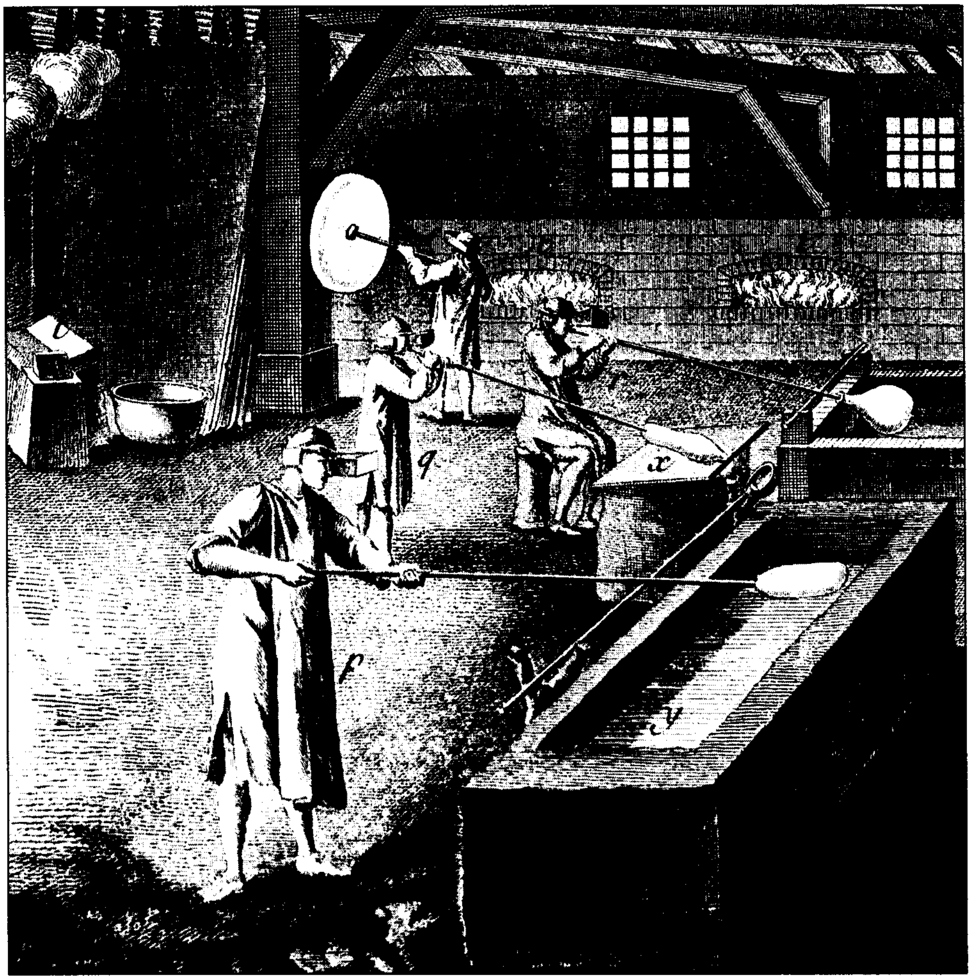
The two major types of window glass were cylinder or sheet glass and crown glass. By the late 18th century crown glass had become the most important form of window glass produced in England. Late 18th-century crown glass was composed of sand, alkali, either potash or soda, and generally a small portion of lime. Other ingredients might be added to correct the colour or facilitate the fusion. The mixture for the composition of good window glass, suggested in an early 19th-century encyclopedia was: white sand, 60 pounds; purified pearl ash, 30 pounds; salt petre, 15 pounds; borax, 1 pound; arsenic ½ pound.[6] Manufacturers, however, varied the mixture to suit their own requirements, and a mixture which produced good glass in one furnace might not be entirely suitable to another.

The technique of making crown glass in its final development in the 19th century has been described as "the perfection of window glass manufacture in the strictly manual field."[7] Figure 25 shows some of the steps in producing crown glass. Once the ingredients were mixed and fused the "gatherer" collected nine or ten pounds of liquid glass on the end of an iron tube. He then blew into the pipe to form the glass into a small hollow vessel. The blower then took over and shaped the glass, producing eventually what appeared to be a large flat-bottomed decanter. The glass was attached to another iron pipe on the point opposite the blow pipe, which was then removed. The second pipe was rotated rapidly, causing the hole where the blow pipe had beeen attached to expand until a thin circular plate was produced. In the centre of this circular plate, called a table, was a lump or bull's eye where the second iron pipe had been attached.[8]

The method generally in use on the Continent at the beginning of the 19th century produced a type of glass known as cylinder glass. When the glass had been blown to the required dimension, the hollow glass was lengthened and the bottom of the cylinder was burst open and the opening widened to the same dimension as the cylinder. The cylinder was then cut open along its length and flattened.[9]

Due to the complexity of the technique used to produce it, crown glass, even from the best glasshouses, was liable to numerous defects. Henry Chance, of the well known 19th-century glassmaking firm of Chance Brothers, after discussing the difficulties of attaining good quality in crown glass, concluded:

> *No wonder that tables of the best quality are few and far between, in some manufactories a forlorn hope never to be realized.*



25 The manufacturing of crown glass. In front of the picture can be seen a blower lengthening the molten glass. Beyond him another blower shapes his glass on the marver. The third blower (r) shapes the glass into a globe while the fourth (s) spins the glass to open it into a table of crown glass. Note the shields worn to protect the faces of the blowers from the heat. *Denis Diderot, Pictorial Encyclopedia of Trades and Industry, Plate 236.*

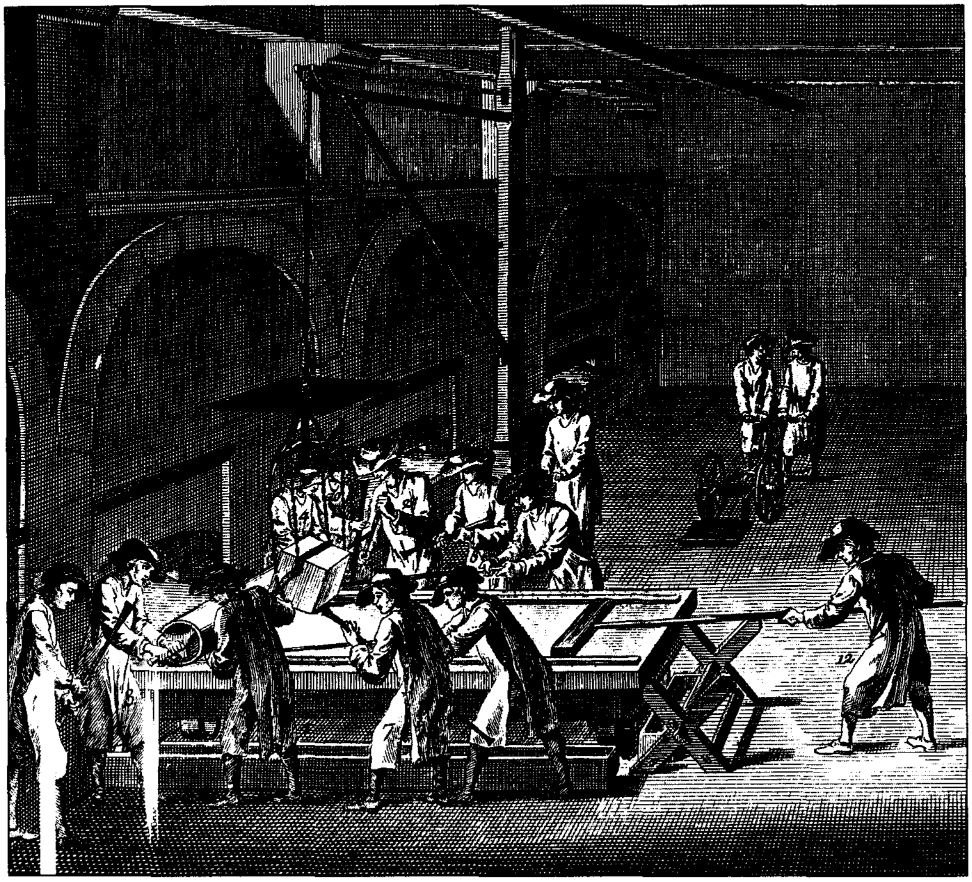
Independently, however, of these defects, there are certain other disadvantages under which even a faultless table of crown glass must unavoidably labour. The cutting of a circle into rectangular sheets must, necessarily, be attended with waste, while the bull's eye confines those sheets to comparatively small sizes. Uniformity

> *of thickness, also, except by the most skilful manipulation, is difficult of attainment.*[10]

Crown glass had, however, many compensating virtues. The chief was its very brilliant surface, due partly to the fact that it came into contact with no other surface during its production. The surface of cylinder glass was not so brilliant because it came into contact with the flattening plate, and the process of turning a rounded sheet into a flat one tended to leave waves and undulations in the glass.[11]

In both methods of making glass there were definite limits to the size of the sheet which could be produced. If, however, the glass was poured onto a flat table and rolled out there could be an increase in the size and thickness of the sheets of glass (Fig. 26). In late 17th-century France the art of making plate glass by casting was sufficiently developed and improved to make it of commercial value. By the late 18th century the demand for large plates of glass was growing rapidly. In 1773 the British Cast Plate Glass Company, having secured workmen and machinery from France, established works at Ravenhead, Lancashire, hoping to win a share in the lucrative market for this type of glass. The prospect of direct communication between Ravenhead and London by canal as well as the availability of coal at a cheap price probably influenced the establishment of this new enterprise in Lancashire rather than the Newcastle area, which was still the traditional manufacturing centre for flat glass. In its first few years the British Cast Plate Glass Company was unsuccessful in its efforts to produce good plate glass which could be sold in the London market. The company eventually overcame its initial difficulties and by the beginning of the 19th century the Ravenhead works were well known for the manufacture of good plate glass.[12]

One problem common to all manufacturers of glass was the heavy taxation on glass in England. There were two classes of tax affecting the glass industry. A tax was charged on all windows above a certain number in houses worth more than £5 per annum. Windows wider than a certain size or lighting more than one room were double taxed. In the 19th century there was growing agitation against the window tax, which was reduced in 1823 and finally abolished in the summer of 1851. The impact of the window tax had been to limit the use of glass in England for more than a century and a half. It was claimed that there were on the Continent twice as many windows in the average building as in England. In 1835 Lucas Chance of Chance Brothers gave it as his opinion that the



26 Plate glass. The molten glass is being poured onto the casting table and rolled. *Denis Diderot, Pictorial Encyclopedia of Trades and Industry, Plate 273.*

tax on windows contributed more than anything else to checking the consumption of glass, because builders aimed at bringing all houses for the lower and middling classes within the limits of seven windows and at keeping their windows small. The window tax, being a direct tax, was felt by, and most obnoxious to, the public.[13]

Falling even more heavily and more restrictively on the glass industry as a whole were the excise taxes levied on the manufacture of glass. Lucas Chance estimated in 1835 that these duties raised the cost of crown glass at least 200 per cent.[14] By the early 19th century the mass of regulations affecting the glass industry became so unwieldy as to be almost impossible to comprehend or to comply with. As manufacturers testifying before the committee investigating the tax on glass in the 1830s complained, the laws contained so many contradictions and did not prevent willful fraud, but they did hinder efforts by law-abiding manufacturers to improve their processes or experiment with new types of glass. The greater the number of regulations and taxes the greater became the temptation to evade some of them and the greater the opportunities.[15]

The restrictions resulting from the various amendments and alterations to the Excise Acts affecting the glass industry not only were irksome to the manufacturers, but also tended to prevent any experiments designed to improve the technology of the industry or to perfect the manufacture of new types of glass. Restrictions limiting the thickness of crown glass, originally imposed to prevent fraud, precluded experiments with the manufacture of lenses. Cookson & Co., prominent manufacturers of crown glass, had been requested by the Northern Lighthouse Board to attempt to make the new French lighthouse apparatus but the excessively high tax on glass of the thickness necessary for this was prohibitive.[16] The well-known optician Dolland found his experiments with lenses so hindered by the Excise Department that he was forced to abandon them.[17]

Because of the differing rates of tax on various types of glass the industry was divided into five water-tight compartments from which no overlapping was allowed. The result of this rigidity was that a glass-house could not turn from making one type of glass to another when conditions warranted. The workings of the excise tax provided one of the most important reasons why Britain clung to crown glass long after the improved cylinder glass had captured the European window-glass market. Because the duty on window glass was levied by weight, while the glass was sold by size and quality, manufacturers had every incentive to make the glass as thin as possible, and crown glass could more easily be made very thin than could cylinder glass. The output of crown glass in Britain rose from 65 000 hundredweight in 1778 to 95 000 hundredweight in 1824, while that of cylinder glass fell in the same period from 22 000 hundredweight to 9000 hundredweight.[18]

While taxes discouraged the manufacture of glass for domestic consumption, rebates or drawbacks were allowed on glass which was exported. The duty on crown glass in 1835 was £3 13s. 6d. a hundredweight. If the glass was exported in squares of not less than 6 by 4 inches a drawback of £4 18s. per hundredweight was allowed. The difference between duty and rebate was intended to compensate for the loss arising from cutting the tables into squares. Cylinder glass, which could be cut into squares without any wastage arising from circular edges or the thick selvage or bullion, was allowed the same drawback as crown glass. This drawback became a bounty on the manufacture of cylinder glass for export. As there was very little domestic consumption of this type of glass, most of that which was made was exported. As the drawback on crown glass exported in tables was only equal to the duty charged, there was comparatively little exportation of tables of crown glass.[19]

Circumstances within the English window-glass industry confined it to a small number of firms. The highly specialized nature of the technology involved and the relatively large amounts of capital required discouraged the multiplication of small enterprises. This concentration of the industry in a relatively small number of large firms made it easier for manufacturers to arrive at understandings on prices and set production quotas. By the early 19th century there was a well-developed system of agreements among window glass manufacturers to fix prices, partition markets and limit output. At the end of the 18th century the main centre of the English window-glass industry was the Newcastle area but in the early 19th century new glasshouses were established in Lancashire, particularly in the St. Helen's area, and around Birmingham. These newer glasshouses were prominent in efforts to improve manufacturing methods and the quality of the glass they produced. With changes in technology and improvements in transportation the Newcastle area gradually lost its pre-eminence, until in 1850 *The Builder* noted that "the Crown Glass trade on the Tyne is said to be now completely paralysed."[20]

Part of the reason for the decline of the window glass trade in the Newcastle area was the adoption by the newer glasshouses of improved methods of producing glass. After visiting a French sheet glasshouse in 1830, Lucas Chance, of the British Crown Glass Company (later Chance Brothers) of Spon Lane near Birmingham, decided to introduce the new methods into England, with the hopes of producing good glass for the export market and taking advantage of the rebates of the excise duties on exported glass. The new process produced clear rectangular sheets ranging in size from 6 to 10 square feet. Throughout the 1830s the amount of sheet glass manufactured at Spon Lane increased as the difficulties involved in the introduction of a new manufacturing process were overcome. A few other large firms began to produce cylinder glass, and by 1841 the manufacturers' assocation had established quotas for the production of sheet glass as well as for crown.[21]

In addition to their introduction of the new European processes to England, Chance Brothers developed a new method of polishing sheet glass, producing what was known as "patent plate." Improvements were also being made in the methods of producing cast plate glass. In 1847 James Hartley took out a patent for a method for making sheets of thin cast plate which were admirably suited for skylights or glass roofing.[22]

The mid-1840s saw a great increase in the demand for window glass. With the industrial expansion of the period a great deal of glass was wanted for buildings such as factories and warehouses which were exempt from the window tax. The same period saw an upswing in the building cycle, with a peak in 1846. That year also marked a recognition on the part of the glass industry of the increased importance of cylinder glass with the manufacturers' association changing its title to "The Crown and Sheet Glass Manufacturers' Association." In the mid-1830s the production of crown glass had begun to diminish and that of sheet glass to grow until by 1844 about a quarter as much sheet glass as crown glass was being made in Britain. In 1841 the glass manufacturers' association had come to an agreement that those who were not at the time manufacturing sheet glass would not embark on that field as long the current quota arrangement was in force. When the excise duties on glass were repealed in 1845 the artificial advantage that they had given crown glass was at an end. Those firms that had managed to establish cylinder glass departments had a great advantage over those who had stuck to crown glass alone. The repeal of the excise duties also meant a considerable drop in the price of glass, helping the market in general.[23]

Before the mid-19th century glass was an expensive luxury, and large windows were possible only in the homes of the well-to-do. The Palladian and Georgian styles fashionable in the 18th century stressed formality and symmetry which affected the placing and design of window apertures. According to classical principles, the breadth of windows should be the same in all stories, and the windows of each story should be placed directly in line with those of the stories above and below; the height might vary to suit the differing heights of each story. A modern architect has criticized English builders of the period for following the rules of Palladianism so slavishly as to stifle a development of the style to suit conditions in England. In particular he faults them for following models more suitable to Mediterranean climates and not increasing the size of the windows in order to let in more light. Peter Nicholson, a well-known architectural writer of the early 19th century, throws a more practical light on the subject:

> *In regulating the dimensions of windows, it may not be superfluous to remind the proprietor, or builder, that, although it may be very pleasant in summer to have the apertures for the windows either very large or very numerous, yet the extraordinary area occupied by them will render the apartments very cold in winter; and to provide against these inconveniences, double glass frames are sometimes deemed indispensably necessary.*[24]

The increasing cheapness of window glass due to the repeal of the taxes on glass, and later of that on windows, combined with the building booms of the mid-19th century to produce a large increase in the demand for glass. At the same time sanitary reformers were arguing that lack of sunlight and ventilation were the chief causes of the high incidence of disease, particularly among the poor, and were encouraging the incorporation of more and bigger windows in new housing. With the technical changes in manufacturing glass, the small glass works which had made crown glass could not successfully compete. The industry became concentrated in three large firms — Chances, Hartleys and Pilkingtons.[25]

The availability of cheap window glass in large sheets suited and stimulated the Victorian taste for large-paned windows and encouraged builders to exaggerate window openings, especially on the ground floor. In working class housing before mid-century the windows tended to be extremely small. With the fall in the price of glass and the removal of the tax on windows this situation began to improve.[26]

English practice differed from that on the Continent not only in the manufacturing process used to produce glass but also in the type of window in common use. The standard type of window in England in the 18th and 19th centuries was the sash window, with vertically sliding frames. In most of Europe the casement window, a hinged window hung vertically and opening either inward or outward, predominated. The architecture of France was typified by the *croissée* window, with a transom, or horizontal bar, above eye level, and two glazed doors opening inward. The sash window had several drawbacks: with the sash, not more than half the window space could be used for ventilation, while sash windows on upper stories were dangerous to clean.[27] In general there was a gradual change in the number of panes of glass used in sash windows. With the increased availability of larger panes of glass, the number of lights per window continued to diminish.[28]

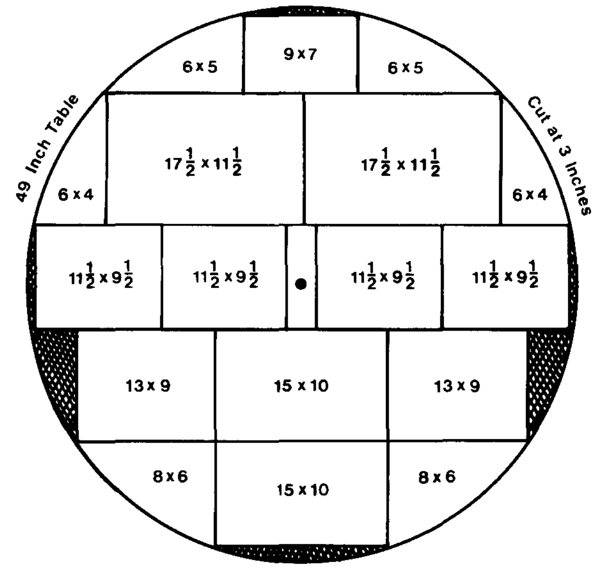
In addition to the use of glass in houses and industrial and commercial structures in the late 18th and early 19th centuries, there was an increasing use of glass for conservatories and greenhouses. The "orangeries" of the early 18th century were more architectural embellishments than greenhouses, with high side walls plentifully supplied with windows, but with opaque roofs. By the end of the 18th century, as recognition of the advantages of a glass roof for a conservatory or greenhouse grew, efforts were made to establish the best design for a conservatory roof. In the early 19th century there was an improvement in the angle of the glass roof, followed by the development of the curvilinear roof. Conservatories and greenhouses were added to many private houses and public gardens not only in England but also on the Continent.

The outstanding example of iron and glass architecture in the 19th century was the Crystal Palace, designed by Joseph Paxton, gardener to the Duke of Devonshire. For the glazing of the Chatsworth Conservatory, Paxton had persuaded Chance Brothers to produce sheets of glass four feet long; for the Crystal Palace slightly longer sheets were produced. Paxton's work, especially at the Crystal Palace, gave a tremendous impetus to the employment of glass and iron construction in many other areas than conservatories and winter gardens, most notably cast-iron commercial buildings with large ground floor show windows.[29]

In a study of the use of window glass, the way in which the glass was used once it was produced must be examined as well as the changes in the manufacturing procedures. Sheets of glass of whatever size produced had to be cut to suit the requirements of the particular window opening, either at the factory or by the glazier. With crown glass it was particularly important that the cutting be skilfully done in order to minimize loss from wastage. The glass had first to be studied for defects so that if possible their inclusion in the panes of glass could be avoided. In the manufacture of cylinder glass the cylinder had to be examined before it was split open. If there were any large defects it was preferable that the slit be made close to one or more of them so that they would be near the edges of the sheet of glass. William Cooper, in his *Crown Glazier's Manual* (1835), described the cutting boards needed in working with crown glass and how these should be marked for measuring the panes of glass, as well as giving diagrams showing the various sizes of panes which might be obtained from a table of crown glass (Figs. 27 and 28).[30]

Once cut into panes the glass had to be carefully packed for shipping to the wholesaler or retail merchant. Care had to be taken to have the boxes in which the panes were to be packed of such a size that no more space was left than necessary for the straw or other packing materials. According to Cooper the best material for packing glass was meadow hay, which should be interleaved with the panes of glass, since putting too many together without some soft substance endangered their safety. After the glass was placed in the box the hay should be firmly stuffed in around it. The boxes were generally in sizes of 50 feet, 100 feet or 200 feet, this measurement referring to the amount of glass contained in the box. Diagrams and charts in Cooper's work showed the sizes of boxes for packing different sizes of glass, where these should be divided, how thick the wood must be, how many panes of glass of any particular size there would be in 100 feet, and how the handles of the boxes should be attached (Fig. 29).[31]

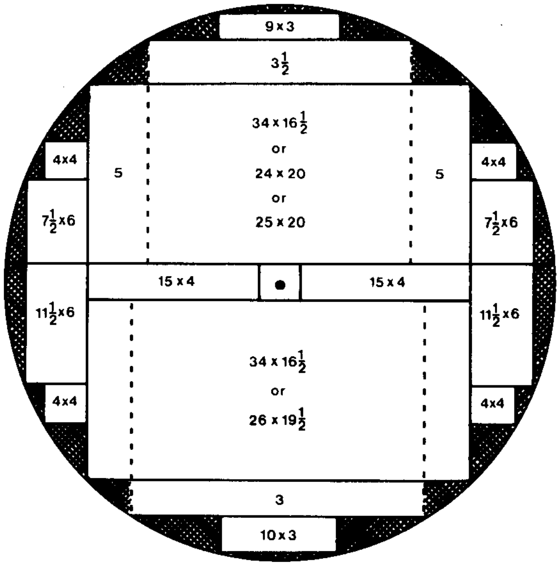
When the glazier was ready to put the glass into the windows he had to measure the sashes and trim the panes to fit, as accurately as possible, leaving about one thirty-second of an inch of space on each side and end of the pane. This space was left to provide for the possible swelling of the wood with moisture or settling of the building. Once the panes were fitted to the sashes they were removed and the checks of the sashes well bedded with putty. The best putty used in the 19th century was composed of whiting and linseed oil. When the checks of the sashes were bedded with putty the panes of glass were returned to their places and gently pressed into the bedding. A properly bedded pane lay quite firmly and did not spring from the putty. When, however, because of some bend in the glass or other cause, it would not go close to the check the glazier had to fill the vacant space carefully and neatly or the window would be apt to admit moisture which would cause deterioration. Where the pane of glass was rounded, the convex side of the pane should be on the outside of the window, as thus placed the pane resisted



Large Half					Ft.	In.
2	panes	17½	x	11½	2	115
4	•	11½	x	9½	3	6
1	•	9	x	7	0	63
2	•	6	x	5	0	60
2	•	6	x	4	0	48
					7	4
Small Half						
2	panes	15	x	10	2	12
2	•	13	x	9	1	90
2	•	8	x	6	0	96
					4	54
Saleable glass cut from a 49 inch table					11	59

27 Diagram and table showing the panes which might be obtained from a 49-inch table of crown glass. *Redrawn by D. Sullivan from illustration in Cooper, Crown Glass Cutter and Glazier's Manual, 1835.*

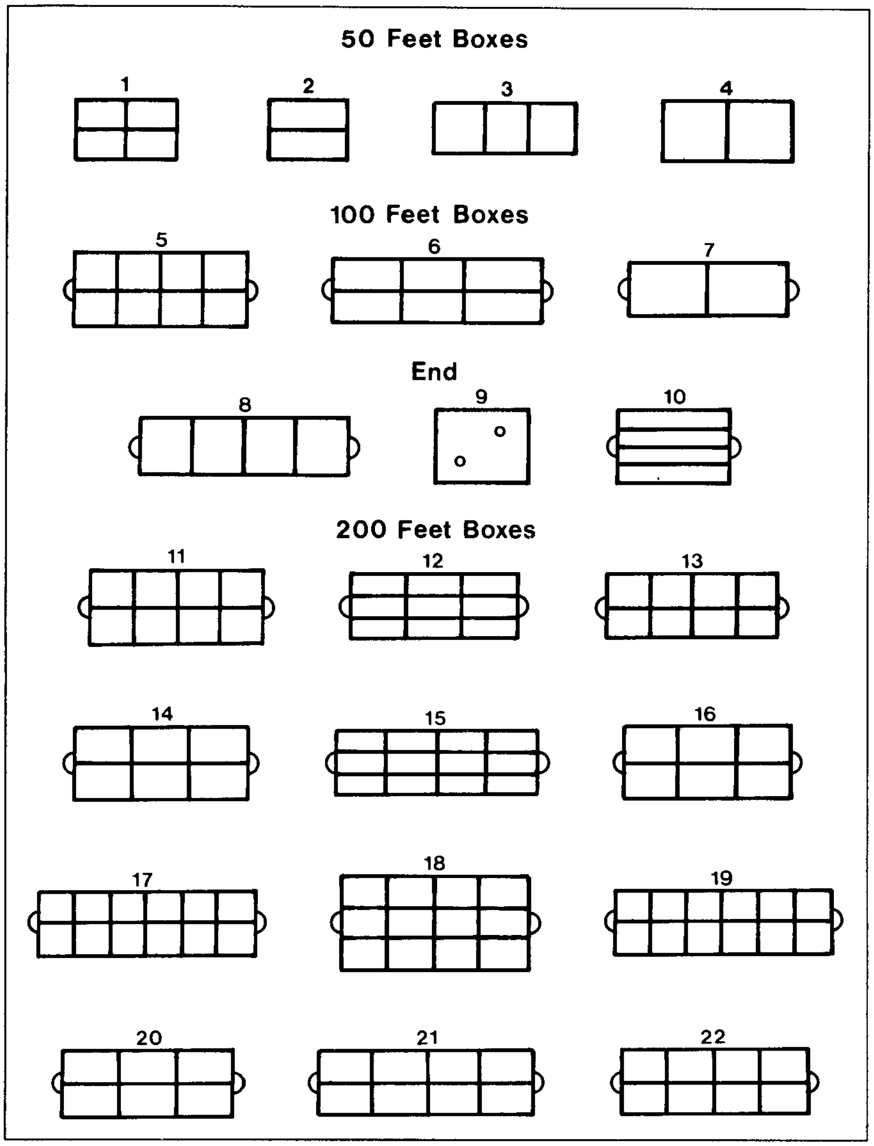
the weather better. After the pane was bedded the next process was the outside puttying. The putty was to be kept in the fore check and slightly below the level of the inside check so that it might not be seen from the inside. It was preferable to wait a few days before finishing off the inside



Large Half	Ft.	In.
1 pane 34 x 16½	3	129
2 • 15 x 4	0	120
1 • 26 x 3	0	78
2 • 11½ x 6	0	138
2 • 4 x 4	0	32
1 • 10 x 3	0	30
	6	95
Or		
1 pane 26 x 19½	3	75
2 • 16 x 4	0	132
2 • 11½ x 6	0	138
2 • 4 x 4	0	32
2 • 15 x 4	0	120
1 • 10 x 3	0	30
	6	95

Small Half	Ft.	In.
1 pane 34 x 16½	3	129
1 • 24 x 3½	0	84
2 • 7½ x 6	0	90
2 • 4 x 4	0	32
1 • 9 x 3	0	27
	5	74
Or		
1 pane 24 x 20	3	48
2 • 16½ x 5	1	21
2 • 7½ x 6	0	90
2 • 4 x 4	0	32
1 • 9 x 3	0	27
	5	74
	12	25
Waste in cutting,	1	66
Round contents of a Table 50 inches diameter	13	91

28 Diagram and table showing the panes which might be obtained from a 50-inch table of crown glass. *Redrawn by D. Sullivan from an illustration in Cooper, Crown Glass Cutter and Glazier's Manual, 1835.*



29 Boxes to contain 50, 100 and 200 feet of glass, showing where the divisions should be in the boxes for various sizes of panes and how the handles should be placed. *Redrawn by D. Sullivan from Cooper, Crown Glass Cutter and Glazier's Manual, 1835.*

puttying, as in this time the putty acquired a certain degree of hardness which allowed a neater finish. The putty should be cut clean off with the putty knife on a level with the moulding.[32] With the developments in the technology of glassmaking which occurred during the 19th century, producing glass which was freer from imperfections and less likely to be curved or bowed, the work of the glazier became less difficult. Little skill was needed by the 1860s and the trade of glazing was usually combined with that of house and sign painter.

During the 19th century improvements in manufacturing processes and the abolition of taxes on glass greatly reduced the cost of window glass and meant that larger quantities of window glass and larger sized panes were available to the public. The literature and the records of the period under study do not reveal any interest by the officers of the Corps of Royal Engineers in the changes in glass technology, but the buildings which they planned and constructed show an awareness of the increasing concern for light and ventilation and the changes in building practice in England. In the second half of the 19th century military engineers were involved in the design and construction of several public buildings in London such as the Victoria and Albert Museum, the Albert Hall and Wormwood Scrubs Prison. The building for the International Exhibition held in London in 1862 was designed by Captain Francis Fowke, RE. Though the building had two glass domes, and the roof and galleries were of iron and glass, the outside walls were of brick, with recessed windows.[33] In their use of glass in architecture the officers of the Royal Engineers followed current building practices and styles rather than experimenting with new methods and designs.

Military Use of Window Glass in 19th-Century British North America

The type of source materials used for this study has been discussed previously. In examining the use of window glass some of these are of particular value. The plans and elevations which usually accompanied the detailed estimates sent to London often indicated such details as the number and size of the windows, type of windows and sometimes details of their construction. Both estimates and contracts give information about the cost of construction, in some cases showing such details as the cost per pane or per foot of glass to be used and in other cases the cost per foot or per opening of windows completely installed. Appendix 9 gives an example of the type of detail concerning the construction of windows included in the specifications which were drawn up to guide contractors working for the Ordnance Department. In the case of surviving buildings, where they have remained in use, the trend to larger apertures and larger panes of glass has sometimes resulted in drastic changes in the windows. Broken panes of glass have often been replaced by a different type of glass. In the case of buildings which have disappeared, archaeological investigations rarely uncover fragments of window glass of any size large enough to indicate the size of the pane or often even the type of glass. A study of flat glass from 19th-century archaeological sites in the Pacific Northwest and the use of this information for dating sites has not proved particularly conclusive.[34] While little usually remains of the original glass, it is often possible to determine the size and spacing of the windows as first built, and in the case of buildings which have not been modernized or too greatly renovated the original frames may still be in use.

During the 19th century, in Canada as in Britain, attitudes to the need for windows changed and the work of the Royal Engineers reflects these changes, though sometimes rather slowly. The lack of a window tax in British North America meant that there was not the same need to limit the number of windows in a building as there was in Britain. The first purpose of a window was to let in light, and as the century progressed a larger proportion of wall space was allotted to windows in new barracks and other buildings. Changes were also made in existing buildings, where windows were added in order to light staircases or passages. In the late 1850s there began an interest in increasing the illumination within the barracks even further by introducing gas lighting. It was considered that the additional lighting would add appreciably to the comfort and convenience of the troops. A report on the possible introduction of gas into the barracks at Halifax blamed the dark and cheerless conditions in the barracks for driving the men to the better lighted drinking shops in the neighbourhood. The cost of gas lighting would be justified if it contributed to keeping the men out of such places.[35]

The most dramatic change in this regard was in the provision of windows in cells. At the beginning of the century the standard guardhouse was provided with one or more "black holes" — windowless cells for the accommodation of prisoners. It was considered that prisoners should be kept in unlighted and unheated cells, this being part of the punishment. In later years, when many of these black holes were converted to solitary cells, windows were added. Windows were also provided in the new military prisons which were built. An 1847 memorandum on the construction of military prisons and barrack cells states that cells should be lighted by a window of sufficient size to enable a prisoner to read.[36]

While windows admitted light, they also frequently admitted a good deal of air, which in a North American winter could be most uncomfortable. Nineteenth-century correspondence relating to military buildings contains numerous requests for window shutters and later for double sashes for winter, justified by such comments as "No one can conceive the discomfort and misery of windows without shutters" and "without such protection it is almost impossible to keep the frost out of the rooms."[37] Such protection from the weather gradually came to be accepted by the authorities in London as necessary, and estimates for new buildings began to provide for the installation of winter sashes.

With the increased concern for light and comfort came also a concern for ventilation. With better fitting windows, winter sashes, and shutters keeping out the air, means of letting in air, in the amount and in the direction desired, were sought. Winter sashes were equipped with tirettes, or ventilating panes, and louvred openings for ventilation were put in gables or under the floor. In summer extra ventilation came to be seen as important, and for special circumstances special methods were adopted: in the barrack master's quarter in St-Jean, the fanlight for the door to the kitchen was to be constructed so that it could be removed in summer; in the clerk's office in the district military prison in Montréal it was decided in 1849 that the hinges should be removed from the window and it should be made to slide so that it would no longer be necessary to move the desk in order to open the window.[38] In many of the buildings, particularly offices and officers' quarters, the double sashes of winter were replaced in summer by louvred blinds, which came to be considered indispensable in the Canadian climate.[39] For officers windows were considered important not only for admitting light and air to the rooms, but also for the view which they provided. When plans were drawn up for the new barracks at Halifax in 1850, the upper passages in the officers' quarters were arranged to run across the width of the building, so that the officers could use them to take exercise in bad weather, and enjoy the view of the harbour and the scenery beyond it to the eastward.[40]

What kind of window glass did the Royal Engineers use in British North America? In England, as earlier discussion has shown, crown glass predominated for use in windows in the earlier part of the 19th century and was increasingly replaced by cylinder glass after repeal of the excise duties on glass in 1845. Because of the encouragement offered by export drawbacks on the excise taxes, most production of cylinder glass before 1845 was destined for export, with some of the glass being shipped to British North America. Estimates and specifications prepared by the Royal Engineers for military buildings in British North America often specified the type of glass to be used. In general the Royal Engineers followed British usage despite the greater availability of cylinder glass in British North America. For ordinary windows they seem to have used crown glass more or less exclusively until the late 1860s. Estimates called for "C glass" or "Crown glass" (the terms most often used), "Newcastle C" or "NC glass," with "C" apparently being used interchangeably with "Crown." Estimates specifying Newcastle glass remained common in the 1850s, even after the window glass industry had shifted from Newcastle to the Midlands. No mention of "cylinder glass" has been found in the estimates and specifications for buildings in British North America in the period before 1865, and the earliest mention of "sheet glass" is in a set of specifications sent from England in 1862. By the late 1860s, however, specifications listed "British, German or Belgian plate or flatted glass."

As well as crown glass, estimates often called for plate, rough plate, ground glass, or muffed glass. These were usually specified for various special purposes such as powder magazines or cells. The specifications for a regimental hospital of 1862 suggested plate glass for most of the outer windows and the accompanying memorandum suggested the use of three-eighths of an inch thick plate in order to obviate the necessity for double sashes.[41]

As well as specifying the type of glass to be used estimates were also supposed to state what quality of glass was required, although this was not always done. The qualitites of crown glass produced were best or first, seconds, thirds, fourths and CC (described as "the worst glass ever made").[42] According to the Engineers' Code, printed in 1832, certain first and second class apartments were to be glazed with first-quality crown glass; other parts of the official residences of civil officers and officers' barracks were to have second-quality crown glass, while soldiers' barracks and store rooms were to be glazed with glass of third quality.[43] On the whole the estimates tended to conform to these regulations, with better quality glass being used for officers' quarters and offices and lower quality glass for the men's barracks and outbuildings.

Frequently, however, estimates called for a higher quality of glass than was specified by the Engineers' Code. This most likely occurred because the engineer officers on the spot recognized that the poorer quality glass available locally was not worth installing in any but the most temporary buildings. In some cases the London authorities substituted a lower quality of glass for that submitted in the estimate. A lengthy correspondence in the early 1840s about the estimates for fitting up a house for the barrack master at Kingston reveals some of the problems such alterations caused. The original estimate called for glazing with best glass, but this was changed to seconds as called for by the Engineers' Code. The contract schedule in force in Kingston at the time, however, named only one quality of glass, best Newcastle. Moreover the engineer officer in Kingston claimed that this was the only kind of glass fit for use, "other qualities sent to this Country being considered unfit for any description of building belonging to Government. The difference in price between best and common glass is 4s.2d. Sterling per 100 superficial foot. The former is clear, even and thick, while the latter is full of flaws, very uneven and thin, consequently much more liable to be broken."[44] It would be more economical, he argued, to use the better quality glass, as the lower future expenditure for repairs would offset the trifling increase in the initial cost. From this correspondence it appears that there were only two qualitities of glass available in Kingston at this time, good and "common." Other references to "common glass" indicate that the term was sometimes used to mean thirds. In Halifax by the 1850s a greater variety of acceptable glass was available, or at least the local engineer officers expected to be able to obtain better quality glass. The estimates for the proposed new barracks at Fort Needham called for "Best or B quality" glass for officers' quarters and C quality glass for soldiers' barracks. Even the latter was expected to be of good quality, "free from spots, knots, veins and perfect at each corner."[45] While the variations in quality in the glass specified in estimates for military buildings can usually be attributed to an adherence to the Engineers'

Code or to restrictions imposed by the local situation, in some cases there is no discernible reason. For example, an estimate for work on the officers' quarters on Signal Hill, St. John's, in 1836 called for thirds Crown glass, while a slightly later estimate for a shed at Kingston called for glazing with best glass.[46]

Where was the glass used in military buildings in British North America obtained? The manufacture of glass required specialized knowledge and the investment of relatively large amounts of capital. Thus it was not until the mid-19th century that glass factories began to appear in British North America and most of these were small and short lived. Therefore all of the glass which was used in British North America in the early years of the 19th century was imported. Despite the stated policy of the Ordnance Department that articles which were manufactured in the United Kingdom should not be purchased at foreign stations the fragility of glass made local purchases attractive at stations where it could be easily obtained. Even though the initial cost was higher in the colonies than in England, the Ordnance Department was spared the cost of shipping while the local merchants bore the risk of breakage. The result was that what was paid for was actually usable. At Halifax there is evidence as early as 1814 of instructions to purchase glass locally. In that year the Board of Ordnance gave directions that the window glass included in a request for stores from Lieutenant Colonel Nicolls at Halifax was to be purchased on the spot by the storekeeper (this was glass in 8-by-10-inch panes, one of the more commonly available sizes).[47] In the early 1820s there are also records of payments to John Merrick of Halifax for glass purchased from him.[48] Similarly in 1817 the Board of Ordnance directed purchase on the spot of certain stores requested for the work of the Royal Engineer Department in Newfoundland including window glass, sizes 8 by 10 inches and 10 by 13 inches.[49] A list prepared at Québec in 1819 of articles needed by the Royal Engineers and to be purchased on the spot included considerable quantities of glass. Almost all the larger-sized panes (from 14 by 11 inches to 18 by 16 inches) were, however, crossed out, possibly because these sizes were difficult to obtain locally and would have to be supplied from England. An estimate, prepared at Québec in the fall of 1822, of articles which should be sent from England included more or less the same list of panes of glass as the 1819 list of materials to be purchased locally, confirming either problems with obtaining a local supply of acceptable glass or efforts to enforce a policy of purchase in England (see App. 10).[50] The Ordnance Office minutes indicate that in the early 1820s glass for stations such as Gibraltar, Malta, and St. Lucia was being purchased in England, mainly from Messrs. Chater and Hayward.[51] As the century progressed the tendency was generally to purchase more and more supplies locally. From the 1840s on any references to the source of window glass for works or repairs for the posts in British North America indicate that it was to be purchased on the spot.

Newspaper advertisements give some indication of the local suppliers of glass and the types of glass available. Among those advertising window glass for sale in early 19th-century Halifax were Hartshorne & Boggs, Lewis E. Piers who was offering crown glass in 1808, John Merrick & Co. who supplied the Ordnance with glass, John Albro whose family was supplying glass to the Ordnance in 1848, Fairbanks & M'Nab who imported glass from Newcastle, W. Barss & Co. who advertised Smethwick Window Glass in 1845, and George Smithers who in 1855 was offering both crown and sheet glass for sale.[52] All of these suppliers were either general hardware merchants or principals in local painting and glazing firms. In 1819 Hart, Logan & Co. of Montréal advertised "a consignment of well assorted Plate Glass ...; besides its peculiar fitness for Mirrors and Picture frames it is now much used in England for Carriage and House Windows ... being very strong and an excellent defence against Cold."[53] Among other firms who advertised glass for sale in Montréal were Francis Wilson & Co., James Miller & Co., John Blackwood, Forsyth Richardson & Co., and Edwin Atwater.[54] Where the type of glass for sale was specified in these advertisements it was, up to the mid-1840s, either crown or plate glass. Hart, Logan & Co.'s advertisement indicates that plate glass was a luxury item, used where particularly strong glass was desired. In the mid-1840s advertisements for Smethwick glass and for sheet glass from Messrs. Hartley & Co. began to appear, as did advertisements for locally produced glass. The first glass factory in Quebec was the Canada Glass Works at St-Jean, which opened in 1845 and closed in the early 1850s. The Ottawa Glass Works at Vaudreuil operated from 1847 until about 1857 and produced sheet glass.[55]

The growing tendency to have work on military buildings done by contract is reflected in changes in the arrangements for glazing. In 1822, after the officers' mess and officers' quarters at the Dauphin Barracks in

Québec had been repaired by contract, glass, shutters and window blinds for these rooms were requisitioned from stores, indicating that the installation of windows and their fittings was being done by military labour rather than by the contractor's men.[56] In 1835, however, tenders were advertised for in Kingston for any glazing which might be needed for the public military buildings there. In this case the contract was specifically for glazing, but by 1840 the Commissariat Department in Kingston was advertising for tenders for building work and for the supply of building materials for up to three years. While tenders for specific trades would be accepted, tenders for the whole service were preferred.[57]

The cost of the glass used by the Royal Engineers varied considerably, depending on the size and type of the glass wanted, transportation costs, local conditions and the price of glass in England. The repeal of the excise tax in 1845 did not occasion the same dramatic fall in prices in British North America in the late 1840s that there was in England, because the drawbacks on exports in the earlier years had greatly lessened the impact of the excise taxes in the colonies. During the first half of the 19th century, rather, there was a gradual but steady decline in the price of window glass in British North America. This did not always mean a lessening of the cost of glazing since while the price of glass was going down, the cost of labour was increasing. A knowledge of these trends, moreover, does not permit comparison between the cost of installing new windows or repairing old ones at various posts and at various times because the basis for stating potential costs differed considerably from one estimate to another. In some cases the probable cost of each window was given; in others the cost was stated per superficial foot of the windows as a whole, that is, frame, sash, glazing and installing complete with fittings. Other estimates gave the cost per foot or per pane of the glass itself, or the cost of glass including glazing. Also the cost of glazing in repairs differed from that of glazing in new sashes. As well, the printed schedules for contracts for repairs and new work in use from the 1850s on show the estimated cost of glazing, but not the rate at which the contractor actually did the work.

An analysis of the schedule of prices proposed for the triennial contracts in Canada commencing 1 April 1853 gives an idea of how the estimates of cost were arrived at. To establish the cost of glazing, the costs of glass, of putty and of hiring a glazier were itemized at eight posts

(Québec, Montréal, St-Jean, Bytown, Kingston, Toronto, Niagara and London). Except that the wages of a glazier were less in Montréal than at Québec, the further west the post the higher the price. A breakdown then followed of the cost of glazing in new sashes with Newcastle C glass, for 50 superficial feet — that is, 52 superficial feet of glass (19s. 6d. at Québec), 15 pounds of oil putty (3s. 9d.) and one day's work by a glazier (5s. 6d.). As was the case for the individual items, the cost per superficial foot of glazing rose as the list progressed westward, from 6¾d. at Québec, Montréal and St-Jean, to 7½d. at Bytown and Kingston, 8¼d. at Toronto and 9d. at Niagara and London.[58] The price most commonly quoted for glazing in estimates for work to be done in the Canadas after 1840 was 7d. per superficial foot. The schedule of a contract for triennial repairs at Montréal from 1850 to 1853 quoted glazing in new sashes at 7d., in repairs at 10d., the cost of a glazier at 5s. 9d. per day, and best Newcastle C glass delivered in such sizes as might be required at 5d. per superficial foot.[59] A schedule for a contract for the Rideau and Ottawa canals for the same period quoted glazing in new sashes at 9d. per superficial foot, in repairs, including painting the putty, at 1s. 3d., the cost of a glazier at 6s. 6d., and the cost of glass at 6d. per superficial foot.[60] In the schedule for work in Quebec from 1859 to 1862 the price for glazing in new sashes with best Newcastle C glass was quoted at 7d. per superficial foot. The contractor in this case agreed to carry out all the work at Montréal and St. Helen's Island as well as the artificers' work at Sorel at four per cent below the prices listed, and the carpenters' and smiths' work at Sorel at one-half per cent above the prices given.[61] Several annual estimates for works and repairs by the Royal Engineer Department in Nova Scotia and New Brunswick, especially for the 1840s, included demands for the stores and materials needed to carry out the work in the estimate. The glass requested ranged from panes 7 by 9 inches at 2½d. per pane, through 12 by 16 inches at 1s. 3d. per pane (1s. 6d. in the estimate for 1843-44) to 18½ inches square at 3s. 6d. per pane.[62] In some cases the price of glass was also quoted per superficial foot, at 9d. In general the price of glass at Halifax appears to have been slightly higher than at Québec, with prices at Fredericton and Saint John somewhat above those at Halifax. Although the analysis of costs prepared for the 1853 contracts showed prices rising as one went inland from Québec, most estimates for work to be done in the 1840s and 1850s showed little recognition of these differences and normally used a standard base figure, presumably based on costs at Québec and Montréal, for all posts in the Canadas.

While one can, to some degree, establish average prices for various posts in various years, other factors, sometimes evident in the estimates and sometimes hidden, affected the cost of glass for any particular building. Estimates for work to be carried out in London, Ontario, in 1863-64, quoted glazing in new sashes for barracks at 8¼d. per superficial foot, for the soldiers' reading room and librarian's quarters at 8d. and for stables at 8½d., and an estimate for the same year for work to be done on the officers' quarters and mess establishment at Toronto quoted glazing in new sashes at 8½d. For Québec the price being quoted at this time was the standard 7d. per superficial foot.[63] The higher cost quoted for similar work at London and Toronto may be due to calculations similar to those in the analysis of prices for 1853, though other estimates for work done in Canada West did not take these factors into account, usually quoting a price of 7d. The differences in price for the various buildings in London may have been caused by the use of different types of glass but this is not evident from the estimate. In some cases it can be established from the estimates that larger than usual panes were being used. A list of stores needed at Québec in 1820 listed 15 sizes of pane, the prices for the larger ones being given per pane (2s. per pane for 18-by-16-inch panes, down to 1s. per pane for 12-by-10-inch panes, with panes 15½ by 10½ inches costing 9¾d.) and for the smaller sizes per superficial foot, running from 11½d. per foot for panes 10 by 9½ inches to 5d. per foot for 7-by-6-inch panes.[64] The quality of glass also affected the price. Specifications made out in 1852 for new barracks in Halifax called for B quality glass at 8d. per superficial foot for the officers's quarters and C quality glass at 7½d. for the men's barracks.[65] It is difficult to trace the relationship between quality and price, as often the quality of glass to be used was not given or was changed, and sometimes different qualities of glass were quoted at the same price, or even at a higher price for a lower quality; for example estimates prepared in 1841 for work to be done at Kingston called in one case for glazing with seconds glass at 8d. and in another case for glazing with best glass at 7d.[66] In some cases it is possible to hypothesize that a higher price was being charged because a different type of glass or a thicker glass was wanted, for instance in the case of glass for cells or for powder magazines. A copy of the schedule for the contract for

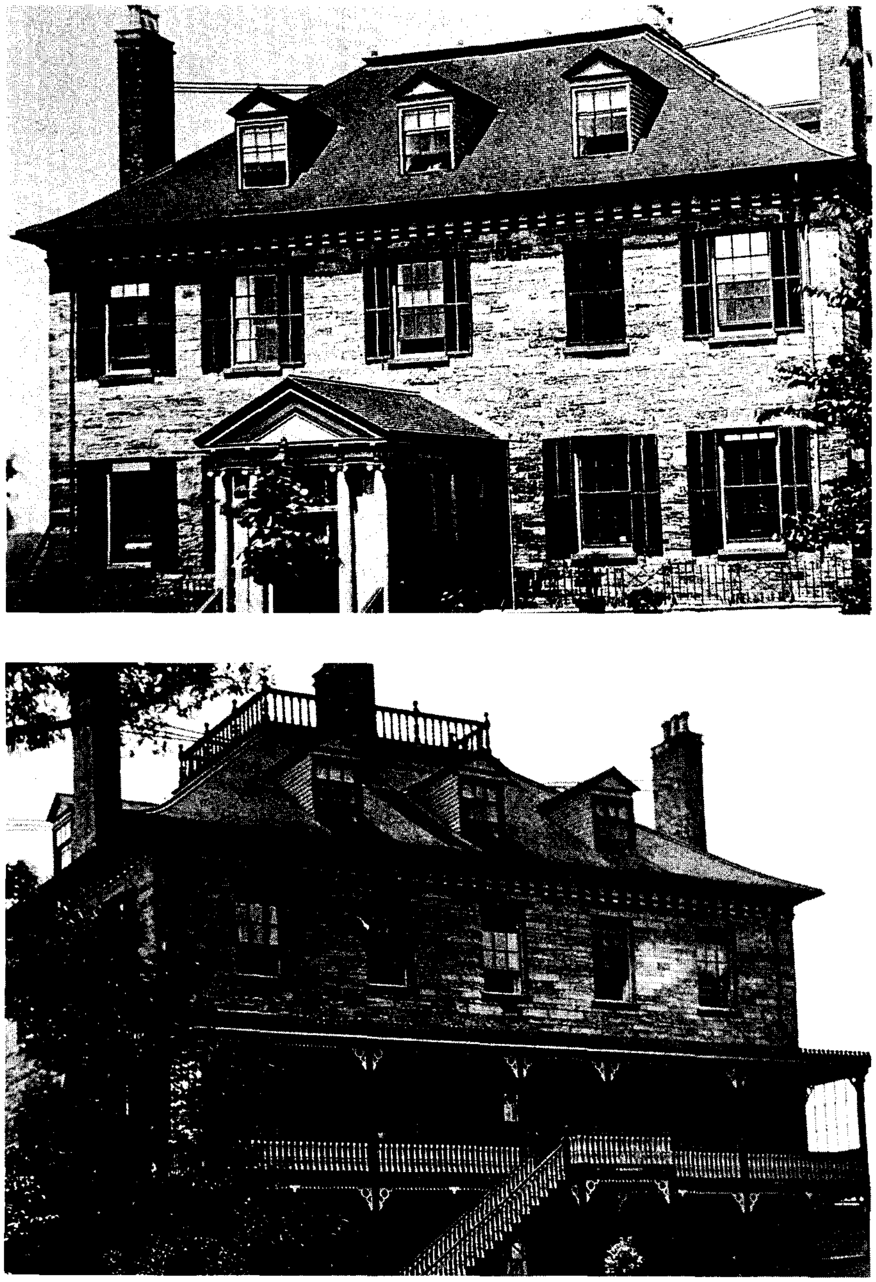
TABLE 1
Specifications for glass from contract for work on Chambly Canal, printed 1866.

	BRITISH, GERMAN OR BELGIAN PLATE AND FLATTED GLASS (Per foot superficial)	Supplied to order: Polished 1st quality, 3/16 in. to ¼ in. thick		Window Glass: Plate, 1st quality, 3/16 in. to ¼ in. thick		Window Glass, Flatted Sheet: 3rd quality, 16 oz. per foot		Window Glass, Flatted Sheet: 4th quality, 16 oz. per foot		Add for stopping into: New sashes, including priming		Add for stopping into: Old sashes, including cutting out the old glass and painting the putty one coat	
		s.	d.	s.	d.	s.	d.	s.	d.	s.	d.	s.	d.
1439	Under 1 foot superficial in one square	5	0	4	6	0	3½	0	3				
1440	One and under 2 feet do. do. do.	5	6	5	0	0	4¼	0	3½				
1441	Two and under 3 feet do. do. do.	6	0	5	6	0	4¾	0	4¼	0	3½	0	5¼
1442	Three and not exceeding 4 feet do. do. do.	6	6	6	0	0	5¼	0	4¾				
1443	Add to prices of item 1439 or 1440 if figured enamelled, any pattern	......		......		1	3	1	3	......		......	
1444	Do. to item 1441 or 1442 if do. do. do.	......		......		1	6	1	6	......		......	
1445	Add to prices of items 1439 to 1442 inclusive, if ordered to be ground, one side	......		0	7½	0	7½	0	7½	......		......	

	ROUGH PLATE GLASS, PLAIN, FLUTED OR RIBBED, AS MAY BE ORDERED	Per foot superficial	Supplied only		Add for stopping into: New sashes, including priming		Add for stopping into: Old sashes, including cutting out the old glass and painting the putty one coat	
			s.	d.	s.	d.	s.	d.
1446	In squares, any size, under 2 feet superficial	⅛ inch thick	1	3				
		3/16 do.	1	6				
		¼ do.	1	9				
		⅜ do.	2	0				
		½ do.	2	3				
1447	Do. do. 2 and not exceeding 4 feet, do.	⅛ do.	1	6	0	6	0	9
		3/16 do.	1	9				
		¼ do.	2	0				
		⅜ do.	2	3				
		½ do.	2	6				

work on the Chambly Canal, printed in 1866, gives an idea of the variations in price of that period according to size and quality (see Table 1).[67] Despite individual variations in price one can often arrive at an estimate of what the glass for a particular building in a particular year might cost, or when a price is known, what type or quality of glass was probably being called for.

The two most common window types in military buildings in British North America were the casement window (sometimes referred to as the Canadian window or the French window) and the sash window (sometimes referred to as the English window), which might be single or double hung. In the eastern provinces the English sash was definitely preferred. While a few instances of hinged or casement windows can be found in estimates for work at posts in Nova Scotia, New Brunswick and Newfoundland they are the exception. For example in the 1836 estimate for alterations to the new officers' quarters at Signal Hill, St. John's, the sashes and frames were to be prepared to hang with hinges, and according to an 1844 estimate the sashes for the windows and loop holes of the new defensive works at Grand Falls, New Brunswick, were to be hung with hinges, though a later plan for the proposed fort at Grand Falls shows a sash window.[68] In the absence of any strong local trend to casement windows, and in keeping with their English experience, the Royal Engineers in Nova Scotia, New Brunswick and Newfoundland preferred the English sash window, as nearly all the estimates for work in this area involving new windows or repairs to old ones included sash pullies, sash weights and sash cord. In some cases the description of the work to be done specified whether the windows were to be single or double hung; in others, it is possible to calculate this from the number of sash pullies called for, if the number of windows is known.[69] From the estimates where window types were specified it appears that double-hung windows were more common, with single-hung windows being used for less important windows, such as those for a basement. The late 19th-century photographs of Admiralty House, Halifax, shown in Figure 30 illustrate double-hung rear windows. In the view of the rear of the house the way in which these windows open at both top and bottom can be seen. The 1852 specifications for new infantry barracks at Fort Needham, Halifax, provided for:



30 Two late 19th-century views of Admiralty House, Halifax. The rear view shows double-hung windows open at both top and bottom. Shutters on front windows add to the imposing aspect of the building. *Naval Historical Library, via Canadian Parks Service, Halifax Defence Complex.*

Soldiers barracks

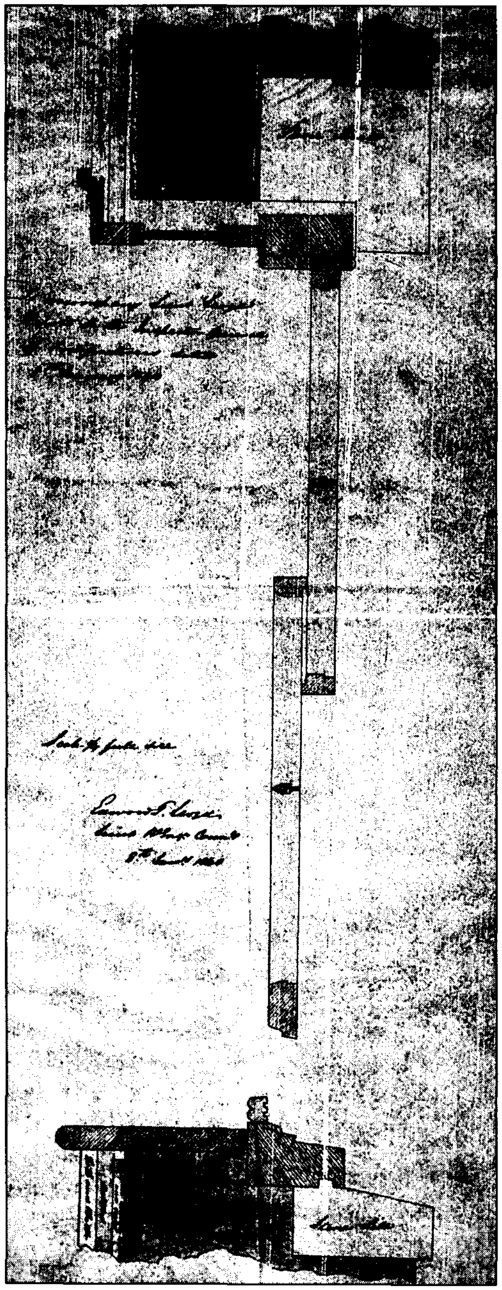
176. *The ground and upper floors, sash frames to be deal cased with oak sunk double rebated and grooved sills, prepared for two inch deal bevel bar sashes, one inch deal outside and inside linings, one and a quarter pulley pieces tongued to inside and outside linings, three-eighth parting beads, half inch back linings, and parting slips, inside beads to be one and a quarter wide, and three quarters thick, double hung with two iron framed pulleys neatly let in and fixed with one inch wrought iron screws, pocket holes twelve by two and a half inches in the clear, to be formed in the pulley styles, etc., pieces of the same thickness to be neatly fitted in and secured with one inch brass screw in each piece. N.B. Three bond timber to be fixed in each jamb.*

177. *Sashes To be 2 inch clean yellow pine deal bevel bar, double hung with best patent flax line, and cast iron weights; the upper sash to be hung with weights half a pound heavier than the sash, and the lower half a pound lighter, with 3 and a half inch brass patent quadrant spring with fastenings, fixed on the sashes with five-eighths iron screws.*[70]

Figure 31 shows how a sash window was constructed.

In the Canadas, in the period before 1835, there are examples of both casement and sash windows. An 1827 estimate for the erection of a stone addition to the Commissariat Office at Québec called for seven pairs of English sashes,[71] while one in the following year for a kitchen and shed in the Rideau Canal district specified ten pairs of folding or French sashes.[72] In the period 1835-55 most military buildings constructed in the Canadas had casement windows. A report and estimate for a barrack establishment in Toronto prepared in early 1839 stated that for the officers' barracks "sashes and sash frames are such as are suitable to the climate" and called for Canadian sashes for all the buildings.[73] An 1852 estimate for rebuilding the Ordnance office and Artillery barracks at Québec, which had been destroyed by fire, described the windows as follows:

The sash frames to be of pine 4 X 4 with oak sunk and rebated sills, wrought, framed, rebated & beaded inside, and chamfered outside. The sashes likewise to be of pine 2" ovolo with rounded and hollowed stiles and throated water boards, put on with white



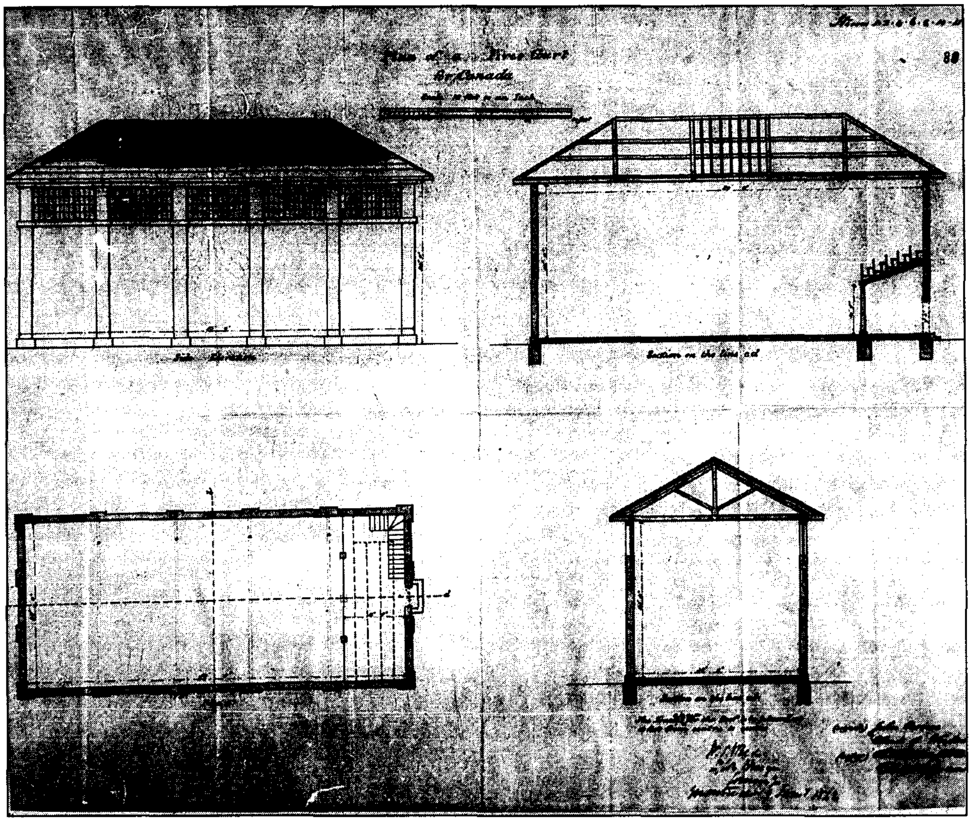
31 Section of a sash and frame, officers' barracks, Signal Hill, St. John's, Nfld., drawn in 1840 to accompany a report on the damp state of the barracks. This shows the construction of a sash window. *National Archives of Canada, MG13, WO55/875, f. 544.*

lead; to be hung with cast iron butts and screws and each sash to be secured by two wrought iron bolts 10 and 20 in. The outer or winter sashes are also to be of 2" pine ovolo fitted and prepared for fixing with 3" wrought iron hooks and eyes. Window seats to be of pine 2 inch.

All the windows to be provided with 15" wrought iron hooks and eyes and wrought iron handles. The sashes to be glazed with N.C. glass.[74]

The major problem with casement windows was a tendency to let in wind and damp. The type of casement window described above, and as built by skilled craftsmen, would be as weather-tight as was possible for this kind of window.

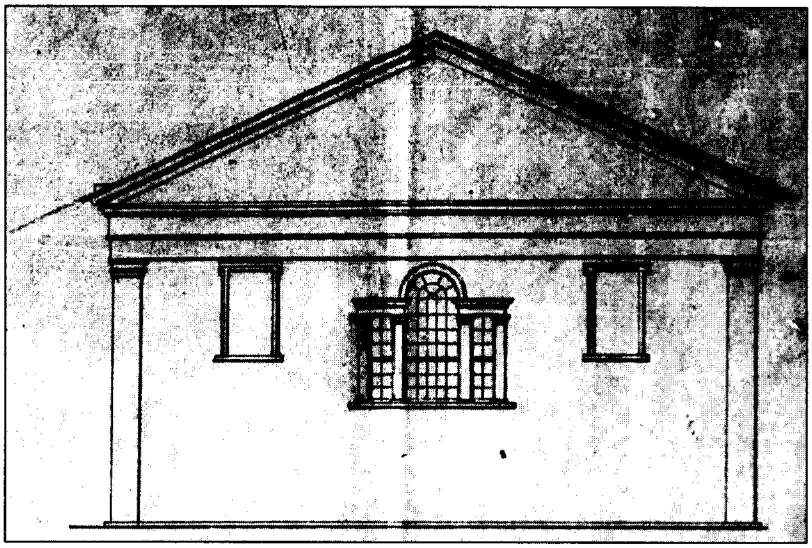
Other types of windows were also used, generally for some specific purpose or special need. Windows hung on pivots were common over doors and were sometimes used in outbuildings such as cookhouses and privies. The 1841 estimate for a hospital at Burlington Heights described transom lights hung on pivots over each window, with spring fastenings with sash lines to shut and open them.[75] According to the 1851 report on school accommodation to be provided for the Royal Canadian Rifle Regiment at various posts, the windows in the rear wall and partition to the school room at Prescott were to be hung on cast-iron pivots with lines and staples for opening them and each was to be secured with two 8-inch sliding bolts fixed on the lower rail of the sashes.[76] In 1842 plans and estimates were drawn up for fives courts to be built at the principal military stations in Canada. In the report on the estimate it was pointed out that enclosed buildings were preferable to open courts because of the climate, and that they could also be used as exercise or parade grounds in bad weather. The plans for these buildings show the windows sliding down inside the walls of the building (Fig. 32). Some buildings merited more elaborate windows than the simple single or double-hung or casement types. The first estimates for a garrison chapel at Halifax called for two "Wyatt windows" in the rear, and a later plan shows a window on the rear of the chapel which is very similar to a window in St. Paul's Church in Halifax.[77] Figure 33 shows the designs for the windows in the front and rear of the chapel. An 1826 estimate for double sashes at Québec mentioned a Venetian window in No. 1 mess room.[78] A drawing accompanying the estimate of works and repairs to be done in Nova Scotia and New Brunswick in 1844-45 shows a window

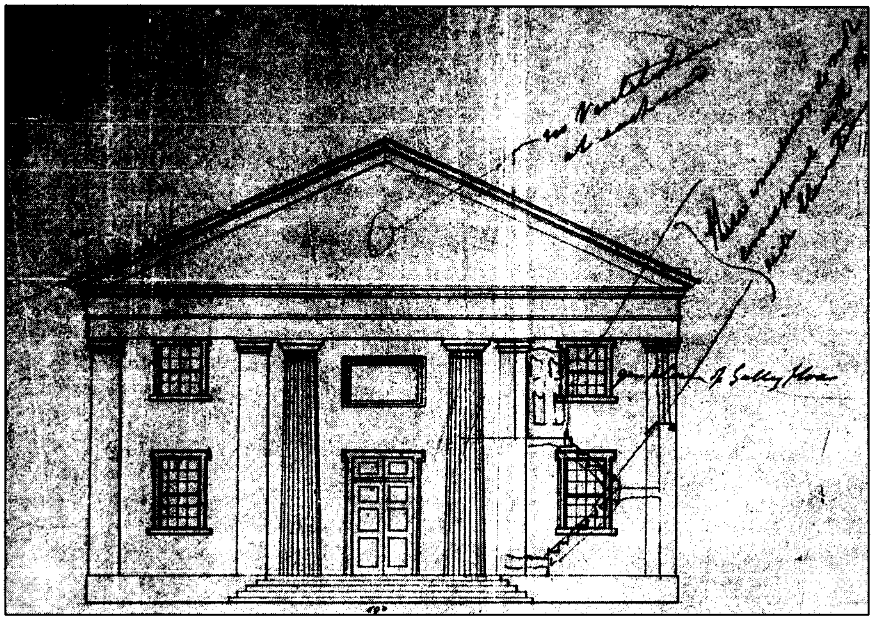


32 Part of a plan drawn up in 1842 for fives courts to provide a sheltered space for recreation which could be used year round. The windows appear to slide down inside the walls. They were fastened by chains which hung down outside the building. *National Archives of Canada, MG13, WO55/877, f. 88.*

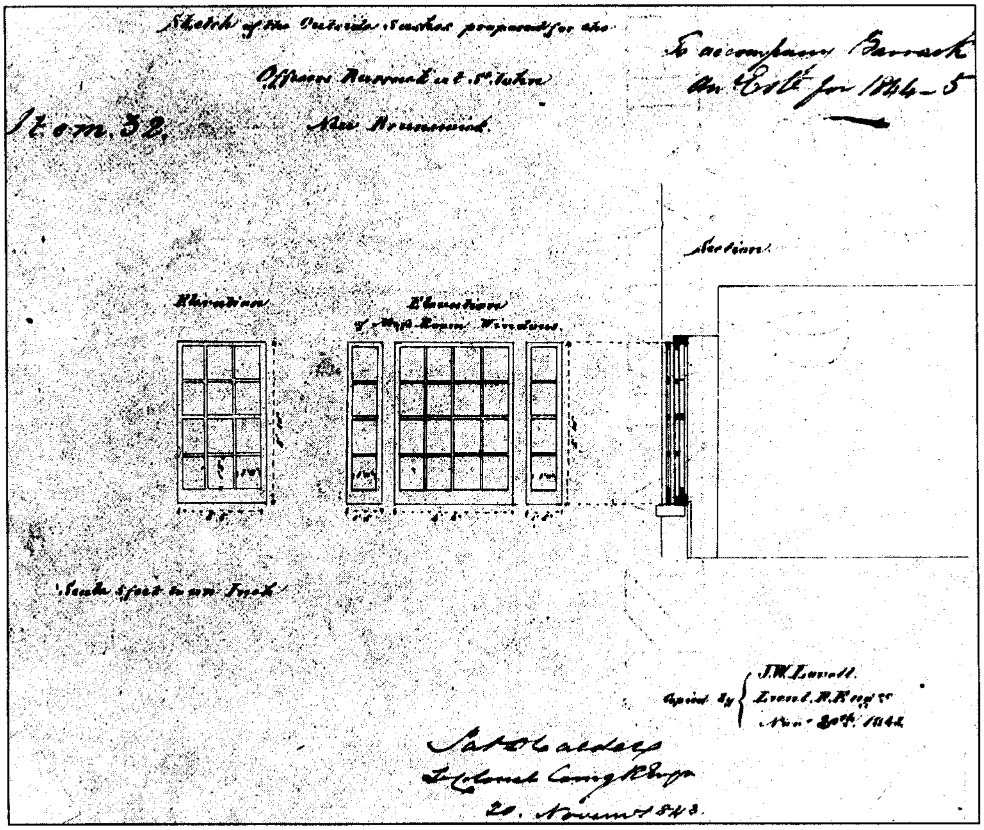
in the officers' mess in Saint John which may be similar to the one in Québec (Fig. 34). Surprisingly, some of the most elaborate windows appear in plans for prisons (Fig. 35). In order to let in additional light, particularly into passages with no windows, external doors frequently had side lights or fanlights or transoms (the latter usually opening on pivots), such as are shown in Figure 36.

The schedules for the triennial contracts for work and repairs in use in Canada from mid-century specified prices for both casement and sash windows. In the schedule for work on the Chambly Canal, printed in 1866, chamfer bar or ovolo sashes 1½ to 2 inches thick, prepared for hanging, were priced at 6½d. per superficial foot. The additional cost





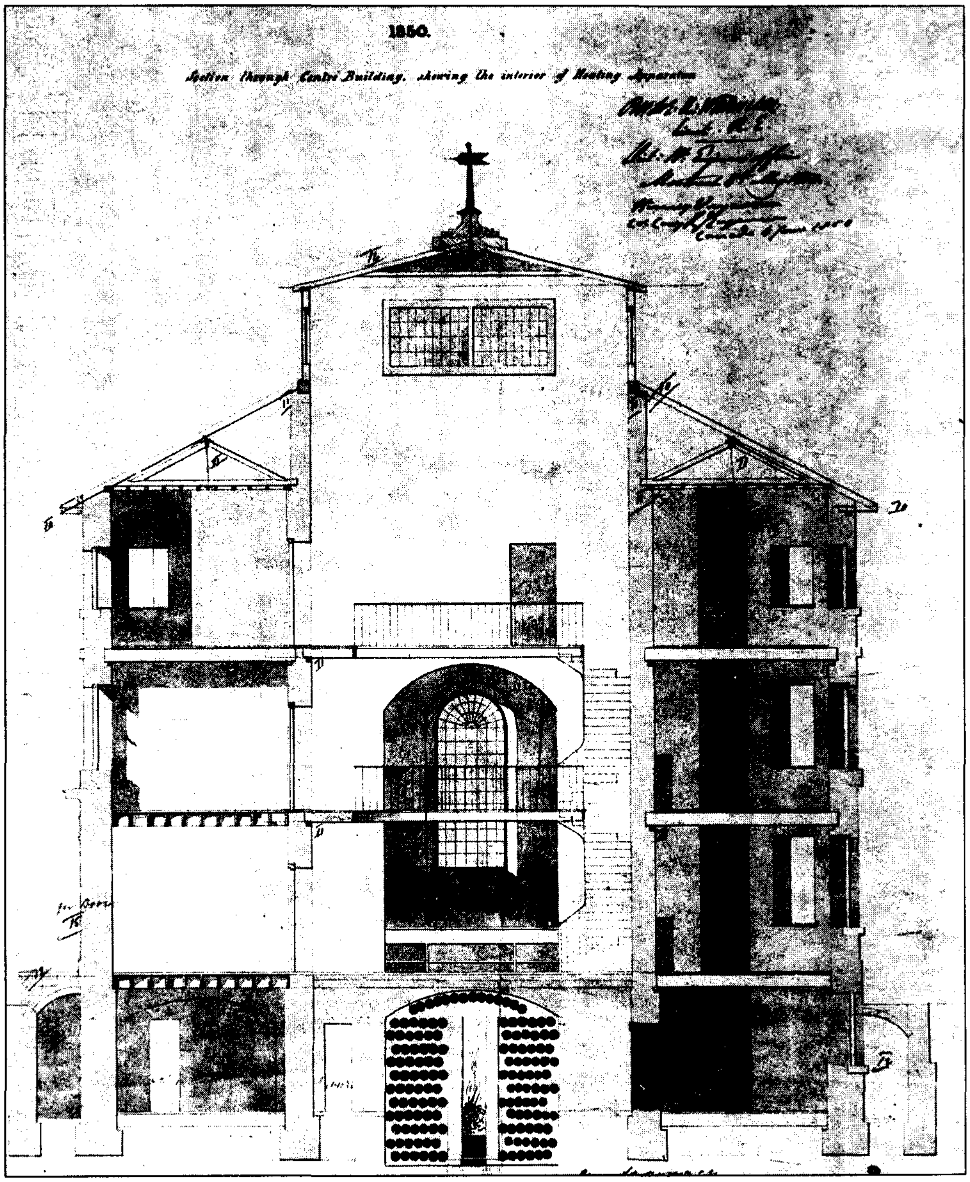
33 These are taken from an 1843 estimate for a garrison chapel in Halifax. The rear elevation (top) shows one Palladian window in the centre. The estimate called for 187-foot linear Wyatt sash frame, a common type of window in churches of the period. The front elevation shows sash windows all of the same width, but with the upper windows shorter. *National Archives of Canada, MG13, WO55/878, ff. 501-2.*



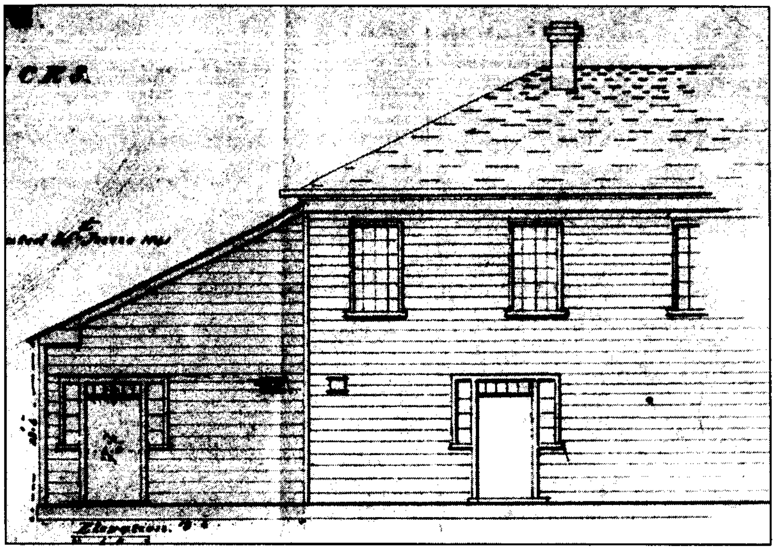
34 This sketch shows the outside sashes which were proposed for the officers' barracks at Saint John, New Brunswick, to be built in 1844-45. The design of the window for the mess room reflects the importance of the room. *National Archives of Canada, RG8, C Series, Vol. 1653, p. 80.*

for single hanging was 4d., and for double hanging 6d. Chamfer bar or ovolo sashes with water boards, hung with cast-iron butt hinges and screws, were priced at 8½d., cheaper than single- or double-hung windows. Ventilating panes, either sliding or hinged, were priced at 2s.[79] Presumably the more elaborate windows, when wanted, were priced individually.

It is difficult from many of the estimates to determine how many panes of glass there were per window, or the number of windows, as often the amount of glass was given in superficial feet rather than numbers of panes. From some estimates and their accompanying drawings one can work out the general pattern of arrangement of panes of glass in



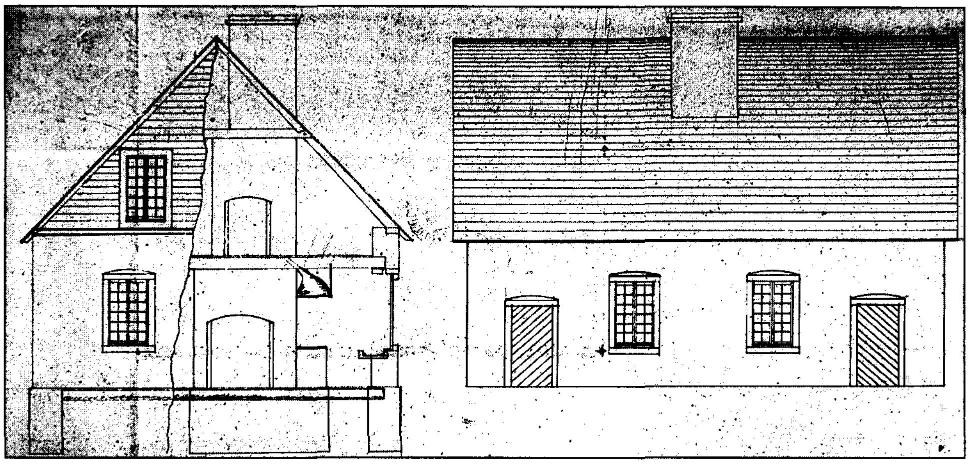
35 Centre Building of the proposed new military prison at Montréal. The long window in the two-storied central corridor is the same as that shown in the printed memorandum on the construction of prisons and barrack cells which was circulated to the various Royal Engineer stations in 1847. The cupola had windows on all sides. The governor's office was in the central portion of the prison. *National Archives of Canada, MG13, WO55/884, f. 201.*



36 Additional stabling for the artillery barracks at London, drawn in 1841. The sashes and fanlights were to be hinged in order to provide ventilation and the inside sashes of the stable area were to have iron bars to prevent the horses from breaking the glass. The doors are surrounded by plain rectangular side lights and transoms. *National Archives of Canada, MG13, WO55/876, f. 278.*

the windows. Where casement windows were used each half generally comprised two panes across and from three to six panes down. In the early 19th century windows of 24 lights were most common. In cases where the more important windows had 24 lights, basement windows or windows of outbuildings frequently had 12 panes, each half being two across by three down. The 1839 estimate for a new barrack establishment at Toronto, for instance, called for Canadian sashes of 24 lights each for the officers' and privates' barracks, hospital, barrack master's store and canteen, and Canadian sashes of 12 lights each for the basement of the officers' barracks, the washhouse and the stable.[80] Windows of 20 lights or 16 lights were also common, particularly from 1840 on, and there were cases where the two arrangements of panes were combined in the same building or group of buildings. Figures 37, 38 and 53 show various arrangements of the panes of glass in casement windows.

For sash windows too, there was generally an equal division of the window, at least for the major apertures of a building, with the dividing line being horizontal rather than vertical. For a few buildings, estimates



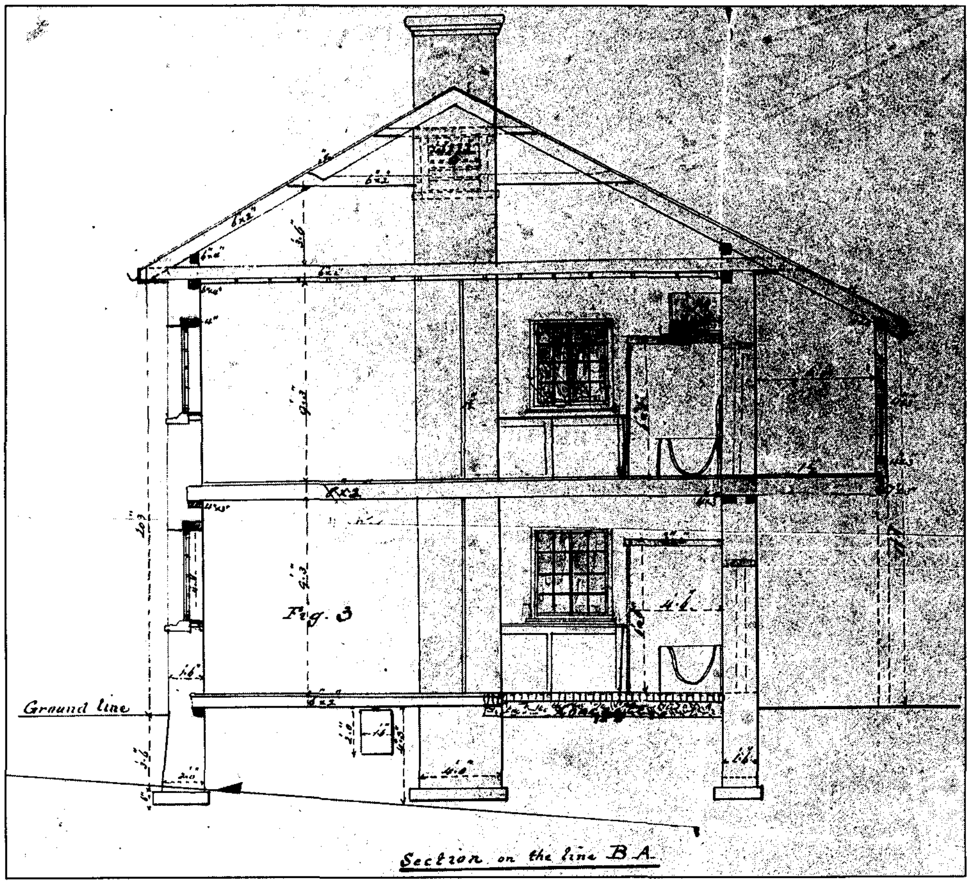
37 Sketch showing a building proposed to be erected as a kitchen for a hospital near the Rideau Canal, drawn in 1828. This building was to have ten pairs of folding or French sashes, 24 panes each with panes of 7½ in. by 8½ in. The elevation and section show the arrangement of the panes of glass in the casements. *National Archives of Canada, MG13, WO55/866, f. 106.*

or drawings indicate windows of 24 panes, each half being four across by three down. Windows of 16 panes were also used sometimes, with each half four panes across by two panes down. The most common arrangement appears to have been six over six, three across by two down in each half, a total of 12 lights. As with casement windows, different stories or sections of a building might have different sizes of windows, with the main floor having larger windows than the basement or attic. An 1839 estimate for repairs to the old engineer quarters at Amherstburg mentioned windows of 12 lights each in the attic and windows of 24 lights each in the principal part of the building.[81] A plan drawn in 1850 showing a barrack in the old fort at Toronto depicts windows of six lights in the attic, 12 lights on the ground floor and nine lights in the basement (Fig. 42). A plan for providing a school room and quarters for a school mistress shows windows of eight panes (two across by four down) for the school mistress's quarters and windows of 12 panes in the school room. Sash windows were not always evenly divided. In some the upper or lower section was only one pane high. For examples of various arrangements of panes in sash windows see Figures 30, 39, 40, 41, 42 and 43.

TABLE 2
Frequency of reference to various sizes of panes of glass 1815-1850

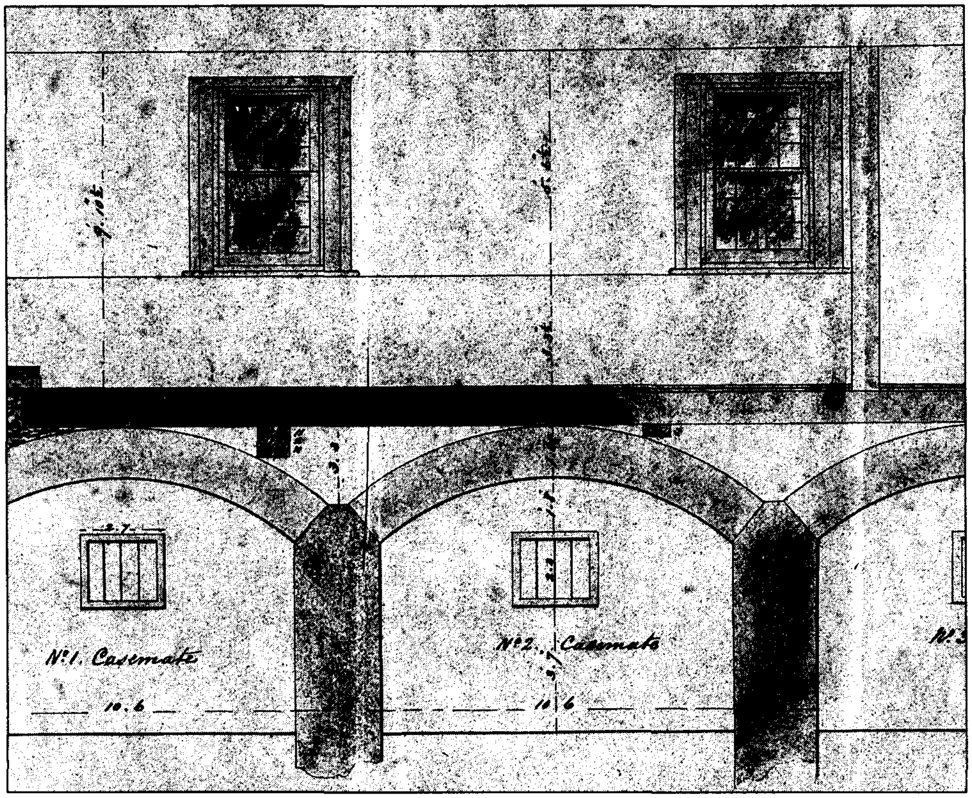
Years / Sizes	1815-1819	1820-1824	1825-1829	1830-1834	1835-1839	1840-1844	1845-1850
6 x 8		1					2
7 x 6	1						1
7½ x 6½	2	5					
7 x 9	6	1			1	3	3
8½ x 7½	37	8	1	1	5	3	
8½ x 9½	4	4			2	1	1
9 x 12	3	2			3	2	
10 x 8	4	4	4		5	5	
10 x 9½	1	2			2	6	
10½ x 9½		2					
11 x 9						3	
12 x 10	3	4	1		1	3	1
13 x 10	1	1					
13½ x 16½						2	
13½ x 18½						3	
14 x 11	1	4					
14 x 12			1			1	1
14½ x 10½	1	1					
15 x 12	1	2				2	
15¼ x 10¼		3					
15½ x 10½	1	5					
16 x 10½		7					
16 x 11	1	5					
16 x 12	1	5	1			4	
16 x 14	2	5					
17 x 12						2	
18 x 16	1	6					

Of the great number of sizes of window glass in use during the 19th century, a few were much more common than the others. Table 2 shows the number of times each size of pane appeared in the estimates, lists of items in store and requests for material found in military records in the National Archives of Canada between 1815 and 1850 (sizes which only appeared once are not included). There is very little evidence available for the sizes of panes of glass in use after 1850, as the overall amount of glass needed rather than number of panes was usually specified in estimates or contracts in the latter half of the century. Lists of panes of glass in store showed a much greater range of sizes of panes than estimates



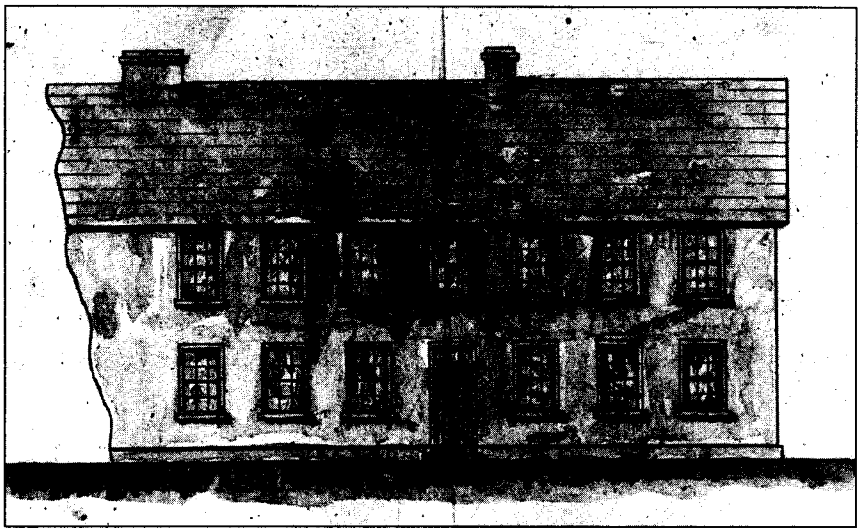
38 Section of labourers' cottages planned for St. Helen's Island, drawn in 1863. These casement windows have fewer panes of glass in them than those in the previous illustration. The panes were probably larger, though their size is not specified in the estimate. The windows were all to have double windows for winter and jalousie blinds for summer. Each gable was to be provided with a louvre frame for ventilation as can be seen in the drawing. *National Archives of Canada, RG8, C Series, Vol. 1423, p. 42.*

for work to be done, but the numbers of each size given reveal to some extent what the most popular sizes were. In the early part of the century the most common size appears to have been 8½ by 7½ inches. In the 1830s and 1840s the favoured size seems to have been 10 by 8 inches, with some use of panes 12-by-10-inch panes. By then the smaller sizes, particularly 7 by 9 inches and 8½ by 7½ inches, were usually needed for repairs to older buildings.



39 Section of the sergeants' mess, Fredericton, drawn in December 1862 to show the cause of a fire in the mess. The windows are sash type, 12 over 12. *National Archives of Canada, RG8, C Series, Vol. 1677, p. 185.*

Early in the century most of the glazing, both in new works and in repairs, was done by military artificers, but by mid-century much of this work was done by contract. From details in estimates and contracts it seems that glazing in British North America followed very much the same procedures described by Cooper in his 1835 *Crown Glazier's Manual.* Estimates specified that glazing was to include priming, bedding and back puttying. The panes of glass were to be bedded flush in putty and back pointed. Where sprigs were required to give additional security to the glass they were to be furnished and fixed without any additional charge in the case of contract work.[82] The specifications for new soldiers' barracks at Fort Needham, Halifax, drawn up in 1852, called for the glass to be "free from spots, knots, veins and perfect at each corner,



40 Front elevation, Royal Artillery Barracks, London, Ont., drawn in 1862. Sash windows in both stories are 6 over 6. Door is surmounted by a plain rectangular transom. *National Archives of Canada, RG8, C Series, Vol. 1420, p. 306.*

41 Married soldiers quarters, George's Island, Halifax, taken ca. 1870. The neatness and elegance of the frames of these windows can be seen here. *Public Archives of Nova Scotia, via Canadian Parks Service, Halifax Defence Complex.*

42 This sketch of the men's barracks, Toronto, 1850, shows windows of 6 lights in the attic, 12 lights in the main story and 9 lights in the basement. *National Archives of Canada, MG13, WO55/884, p. 100B.*

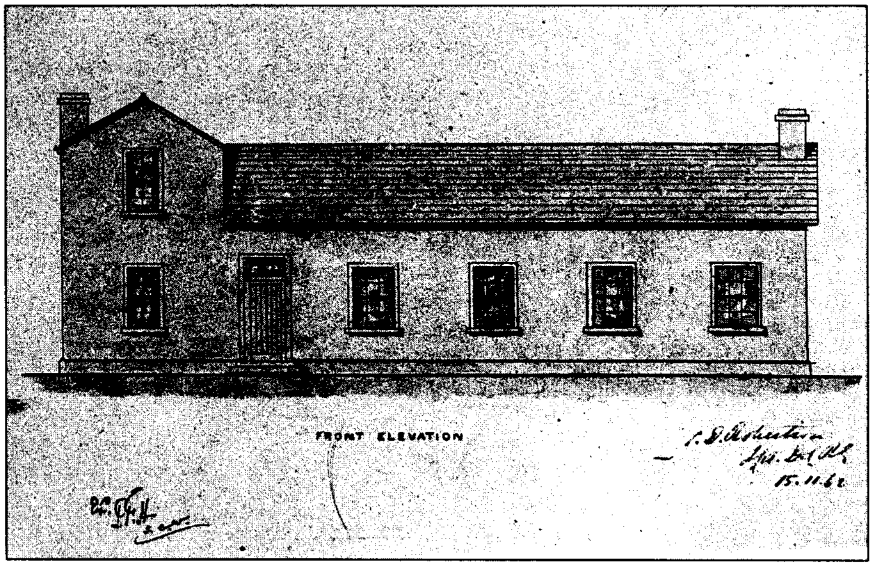
stopped in the full size between the rebates, bedded flush in oil putty ...." It was to be secured with tin sprigs if required and the sashes were to be primed previous to being glazed.[83] Glazing in repairs was more expensive than new work. This included cutting out the old glass (which usually became the property of the contractor, if the work was being done by contract) and painting the putty to correspond with the sash. The triennial contracts also included prices for taking out glass and putting it into other sashes, and for stripping off old putty and reputtying windows. In these cases the putty had to be painted to correspond with the sashes. The amount of putty used in glazing is difficult to judge as estimates varied widely in the proportion of putty to glass.

By mid-century, a growing concern for better living conditions within military buildings led to a recognition of the need for shutters or double sashes to keep the wind, frost, snow and rain out of buildings in the cold North American winters. The comfort provided by double windows or shutters was, however, long seen as a luxury, and they do not seem to have been provided for soldiers' barracks until mid-century. Double sashes first appeared in estimates for officers' quarters and mess rooms, then were gradually added to hospital wards, offices and other such buildings. The 1849 estimate for the district military prison in Montréal called for winter sashes for the associated ward, chapel, chaplain's office, clerk's office, warders' quarters and the guard room. These outside sashes were:

> *to be made of 2" Pine with Chamfered Bars, and each to be fitted with a tirette or Ventilating pane, to be properly glazed with good glass and painted 3 coats white secured to the existing strong pine window frames with wrought iron thumb screws.... As the Iron Guard Bars fixed to the window frames of the Chaplain's office, Surgery and Warders' Quarters project beyond the face of the frames it is proposed to fix to the frames linings ... for the outer sashes to fit against.*[84]

Frequently winter sashes were attached to the window frames with hooks and eyes. An estimate for work to be done at Halifax in 1861-62 provided for outside sashes to the four windows of the Drawing Room in the Royal Engineers' office; they were the only windows in the building not then supplied with such sashes "necessary for the comfort of the room during winter." The report on the work to be done went on to say, "It it not easy to conceive why it has been so long neglected."[85] The memorandum which accompanied specifications for a hospital, sent to Halifax in 1862, suggested that in place of double windows thicker glass (three-eighths inch instead of one-quarter inch) could be substituted, as this would be cleaner and easier to manage.[86] Shutters were also provided to keep out the cold or to ensure greater privacy. Officers' rooms or the lower story of a building frequently had shutters. Winter sashes generally had tirettes, or ventilating panes, in order to allow some air to enter the rooms when desired.

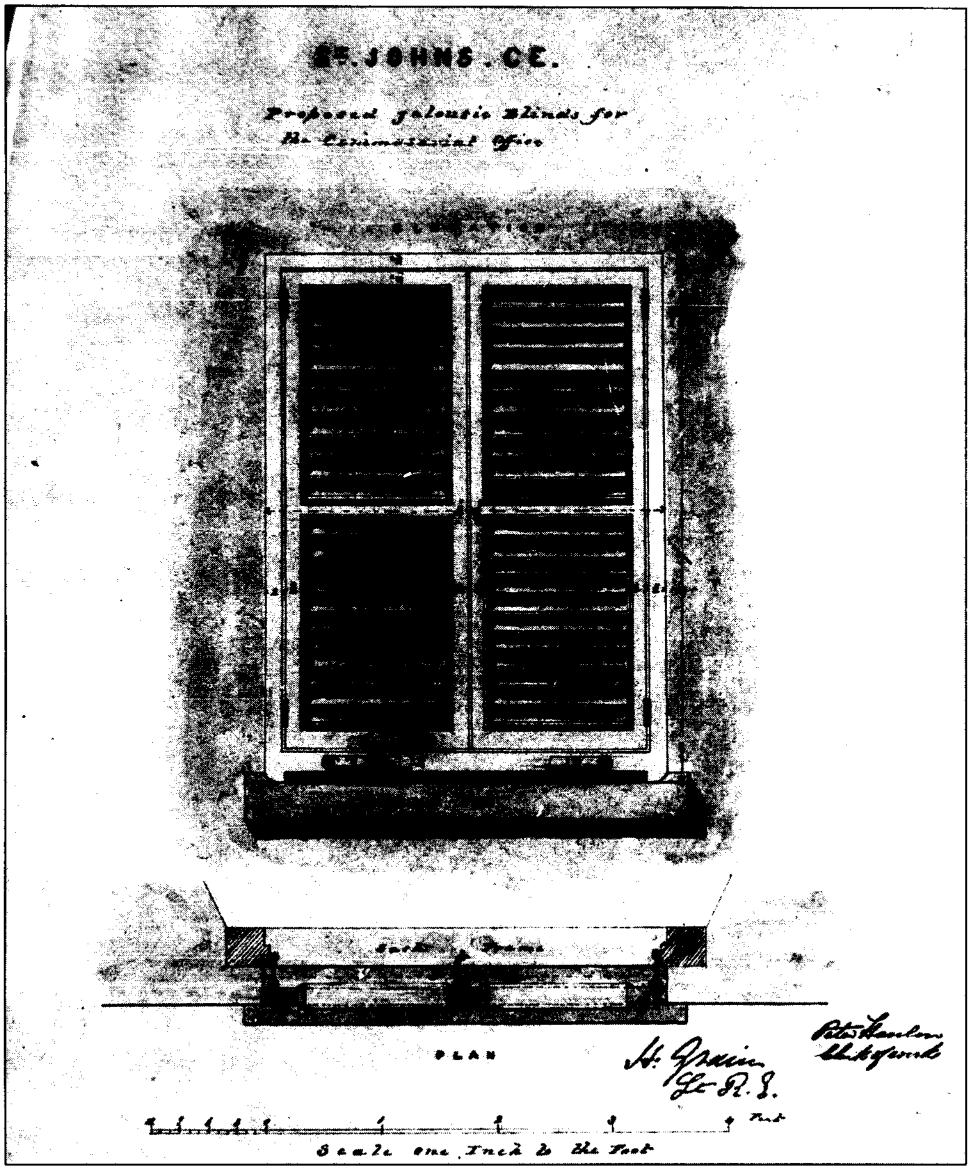
Ventilation was more particularly a concern in summer. An 1841 estimate for stables at London, Ontario, stated that the windows were to be



43 School and quarters for schoolmistress, London, Ont., 1862. The school room has windows of 12 panes (6 over 6) while the windows in the living quarters have 8 panes (4 over 4). *National Archives of Canada, RG8, C Series, Vol. 1420, p. 272.*

hinged "to provide for extra ventilation absolutely necessary in Canada in summer."[87] Windows which were fitted with double windows in winter were often fitted with louvred blinds in summer which would allow the passage of air while keeping the sun out (Fig. 44). The triennial contracts for work to be done included prices for taking down or putting up winter sashes and summer blinds. The 1862 plan for a regimental hospital called for all ward windows to be fitted with spring roller blinds of Green Holland. A demand for stores for work to be carried out in Halifax in 1843-44 included green canvas for blinds.[88] This type of blind may have been used in Nova Scotia more than the louvred type favoured in Canada.

Special situations called for special types of windows. Once the idea that cells for military prisoners should have some sort of lighting had become accepted, it was necessary to construct a type of window suited to the needs of this sort of building. If prisoners had been sentenced to solitary confinement, windows were needed which admitted light but did not allow the prisoners to see out. It was also necessary to ensure that the prisoner could not get out through the window, nor could things

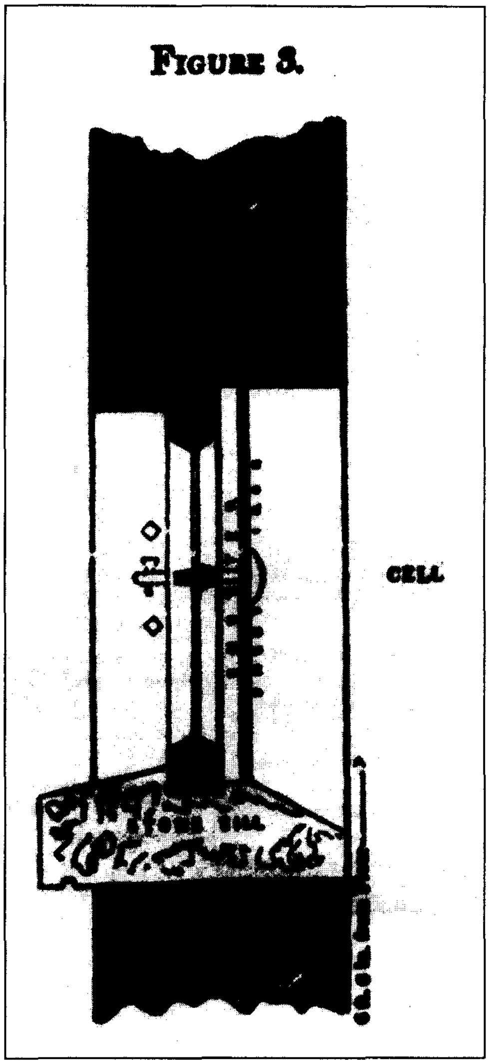


44 Proposed blinds for the commissariat office, St-Jean, 1851. This shows the sort of blinds in use in the Canadas during the summer. *National Archives of Canada, MG13, WO55/885, after f. 404.*

be passed through the window to him. An 1840 estimate for cells in the Citadel at Québec called for rough plate glass, at 2s. 4d. per superficial foot, for the windows.[89] Later estimates for windows for cells or prisons called for ground or "muffed" glass (the latter being cheaper). Where cells already had windows, they were painted over "to prevent persons seeing through." An estimate for work to improve barrack cells at Île-aux-Noix mentioned "muffling sash squares with composition."[90] The "muffed glass" referred to in other estimates may have been glass which had been painted over. A printed memorandum of 1847 on the construction of military prisons and barrack cells described the type of windows considered desirable for such buildings:

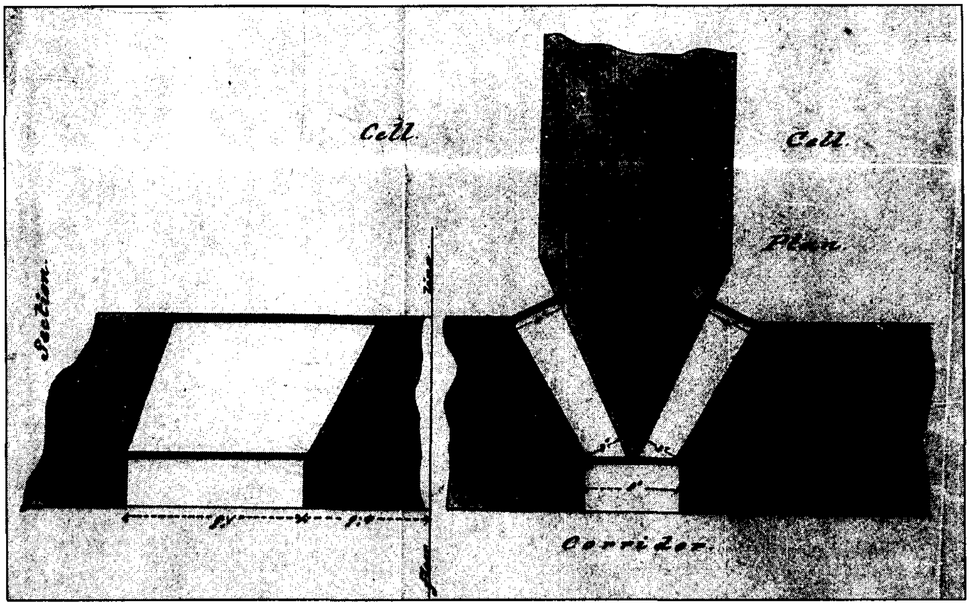
> *7. Cell windows should be fixtures and may be made 2 feet 6 inches wide by 1 foot 3 inches high; the bottom and sides of the Window within the Cell should be splayed. Windows should, when convenient, be made in the centre of a Cell, and the height from the floor to the sill should be about 6 feet 6 inches. The sashes may be of wood, if more convenient than iron. Where wood sashes are adopted, it will be necessary to fix iron guard bars on the outside, not more than 6 inches apart. Figure 3 shows a Cell Window, and Wood Sash fitted with a moveable Shutter covered with sheet iron for darkening a Cell and thereby rendering it available for punishment for a Prison offence. Fluted or ground Glass should be used for glazing the sashes, or common glass may be deadened on the outside by paint.*[91] (Fig. 45)

This memorandum also made suggestions for the improvement of existing cells. If placing a window in the external wall of a cell proved difficult, a glazed frame could be fixed over the door and if necessary the passage lit by a skylight. Where it was difficult to create an opening for ventilation a square of glass might be left out of the window for summer, with the opening being stopped up with perforated zinc. A piece of wood could be attached to the inside of the sash to exclude or admit the air as desired. Stress was laid on special ventilating openings because the cell windows themselves were fixed in their frames and could not be opened. Figures 46 to 50 show sketches of some types of windows and special devices proposed for military prisons and cells. For military prisons cast-iron sashes were preferred and an estimate prepared in 1846 for constructing solitary cells in the military prison on



45 A sketch from the 1847 memorandum on the construction of military prisons and barrack cells. This shows a cell window fitted with a moveable shutter for darkening a cell. *National Archives of Canada, MG13, WO55/882, f. 22.*

St. Helen's Island called for cast-iron inside sashes.[92] Iron bars attached to the windows provided additional security, the number depending on the size of the window. The cells to be built at the Artillery Barracks in Halifax in 1846 were to have windows 2 ft. 2 in. by 1 ft. 1 in., with each window having one inch-square iron bar. An 1847 estimate for cells at Saint John called for five inch-square wrought-iron bars per window and an 1853 estimate for converting the stables at Niagara into cells specified the cell windows be protected with wrought-iron cross bars 2½ inches

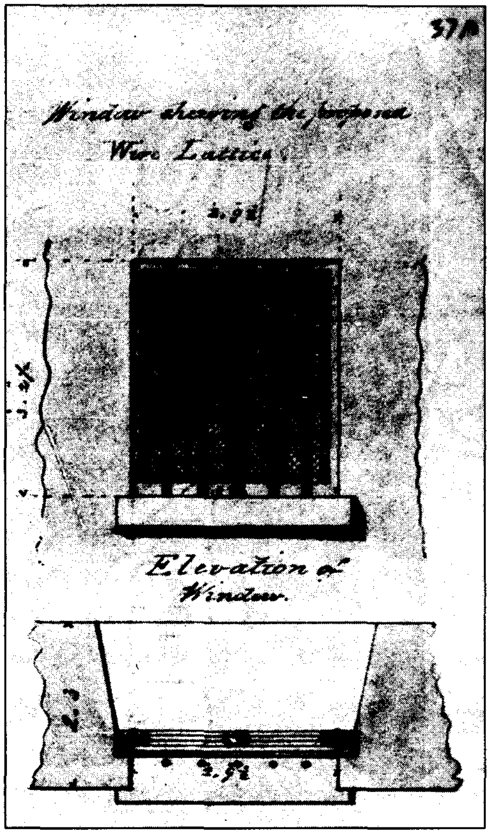


46 Proposed method for lighting cells at St. Helen's Island military prison, 1845. This shows a plan for lighting two cells from one opening in the wall of the corridor. *National Archives of Canada, MG13, WO55/879, before f. 313.*

square and upright bars 2 inches square.[93] As well as iron bars, cell windows were often covered with wire gauze. An estimate for work at the military prison in Québec, drawn up in 1849, called for fixing a wire lattice to the surgery windows "to prevent the introduction of any article by persons outside of the prisons to the prisoners within"[94] (Fig. 47).

Windows of garrison cells and of prisons were not the only ones which were secured with iron bars or wire gauze. An estimate for additional stabling at London, Ontario, suggested that the inside of the sashes have wrought-iron window bars to prevent the horses from breaking the glass. The 1842 estimates for fives courts for the various stations included wire lattice to protect the windows liable to be struck by the balls.[95] Storehouses sometimes also required the additional security provided by iron bars, for example a barrack store at Amherstburg which was to have four wrought-iron bars fixed to each window.[96]

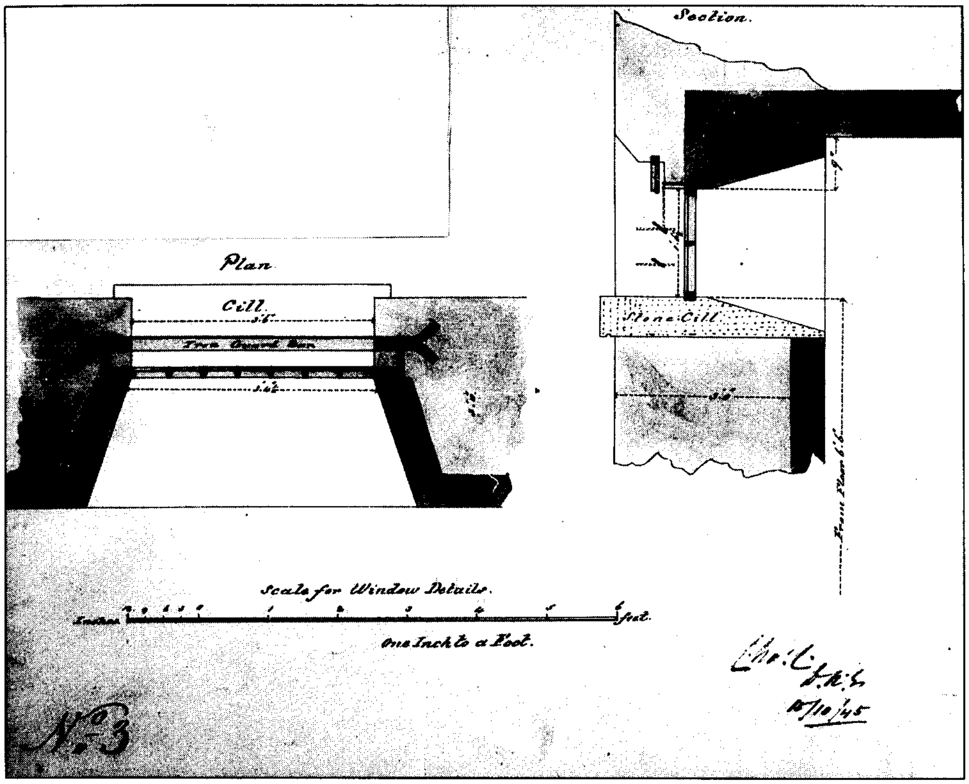
Another special type of window was the light closet or lantern chamber in the wall of a powder magazine. Sometimes the light closet was fixed in the wall between the magazine and shifting room in order to light both. Light closets were usually glazed with thick plate glass. Estimates



47 These drawings accompanied an 1849 estimate for fitting a wire lattice to windows of the surgery, kitchen and storeroom at the military prison in Québec. The purpose of the wire lattice was to prevent the passing of any article to the prisoners through a window. The lattice was to be attached to the windows between the sash frame and the iron bars. *National Archives of Canada, MG 13, WO55/884, f. 37A.*

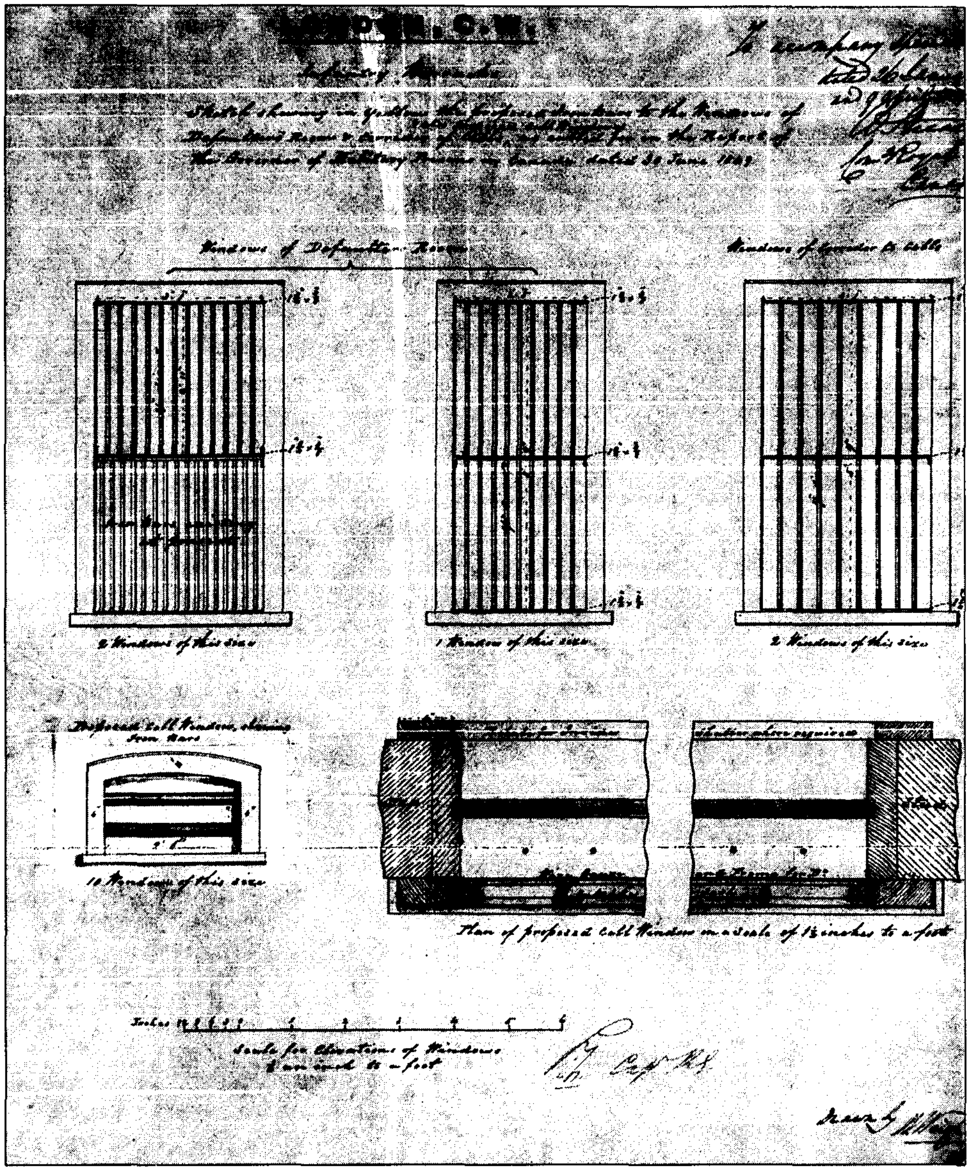
for the various towers built at Kingston in the late 1840s called for one frame of the light closet to be hinged with copper hinges and fastened with a copper turnbuckle, and this was probably typical. Either the light chamber itself or the lantern would be fitted with a reflector. An estimate for work on a magazine at Halifax in 1865 called for "Lamps to Lantern Chambers to be strong copper framed and fitted with silvered reflectors."[97]

Where it was difficult to obtain sufficient light from ordinary windows in the walls skylights were sometimes used. In addition to their use in cell corridors, skylights frequently lit mortuaries of hospitals, presumably to shield the interior from the gaze of passers-by or to protect passers-by from glimpsing what might be happening inside. The 1862 specifications for a regimental hospital included a skylight over the mortuary, which was to have louvre boards for ventilation and to be

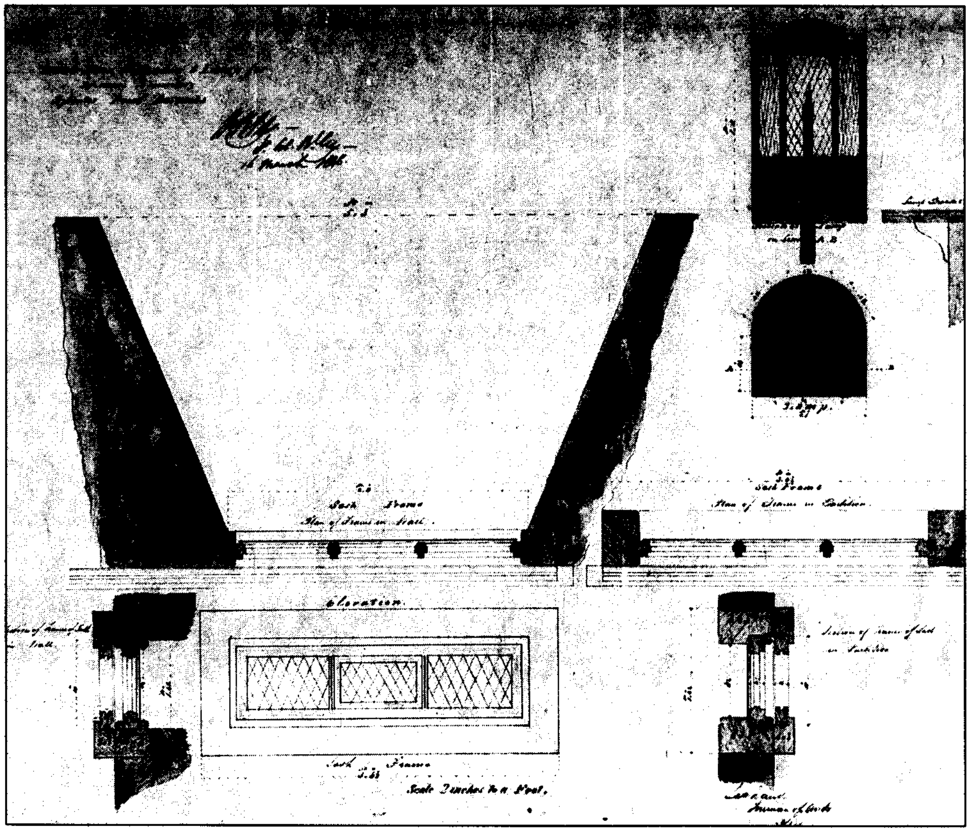


48 This drawing of a prison window is from an 1845 estimate for converting part of the casemated barracks at St. Helen's Island into a military prison. *National Archives of Canada, MG13, WO55/879, follows f. 311.*

grooved for lead flashing in order to weather-proof it.[98] Skylights were not always the preferred method for lighting from above. In 1863 a considerable correspondence occurred over the question of providing additional light for a gunshed at Québec. Lieutenant Colonel Menzies, the Commanding Royal Engineer in the district, stated that "Skylights placed flat on the roof formed of strong rough plate glass have been fitted up in the attic of the stores at St. Helen's Island and answered admirably last winter. They are considerably less expensive than dormer windows." The officer commanding the Royal Artillery, Colonel Benn, however, felt that dormer windows were preferable. If skylights were installed the accumulation of snow in winter would exclude the light, and because the building was so low skylights would be liable to constant breakage when stores were being shifted. Dormer windows would give



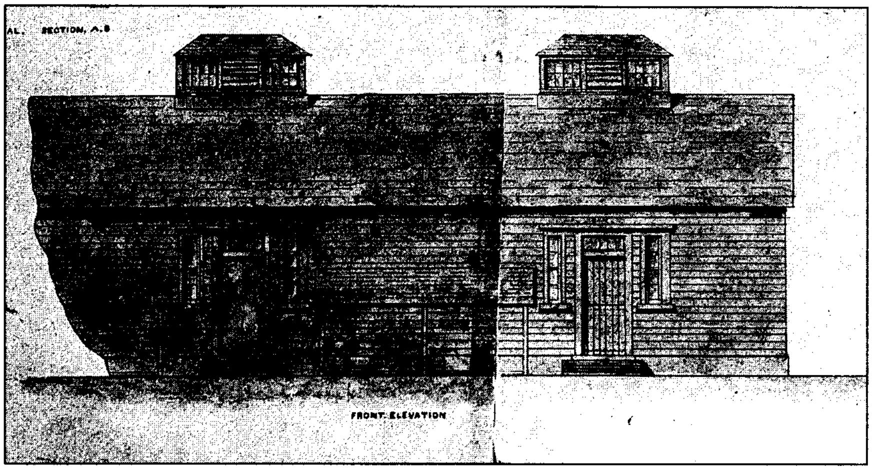
49 Sketch showing windows for cells, defaulters' room and corridors, London, Ont., 1850. This accompanied an estimate for fitting the cells with cast-iron sashes and fixing iron bars and wire guards to windows in the corridor and defaulters' room. *National Archives of Canada, MG13, WO55/885, f. 59A.*



50 Window and lamp for prisoners' dormitory, Québec, 1848. In each of the end walls of the dormitory openings were to be made for a window and a lamp. *National Archives of Canada, WO55/882, follows f. 58.*

additional space and could be used for airing the store room.[99] Figure 53 shows the type of window proposed by Colonel Benn. Skylights did present considerable problems, particularly in winter, in keeping them weather-tight.

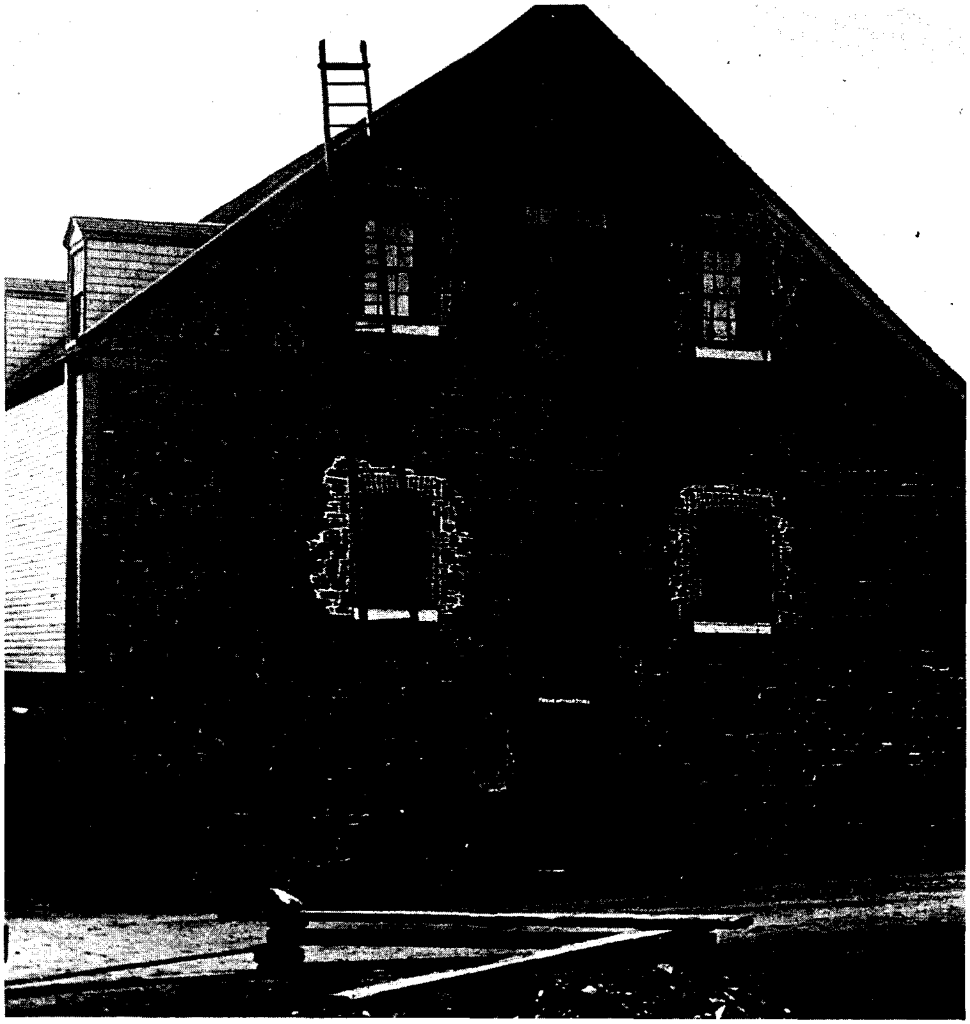
Fanlights and side lights to doors, which were common in the architectural styles of the period, were also used to provide additional light for corridors and passageways. Some of these were fairly plain; for example, the fanlights and side lights for stables at the Royal Artillery barracks in London, Ontario, were simple rectangles (Figs. 36 and 51). Others were more graceful in design with elliptical fanlights and sometimes harmonizing side lights. These, of course, were generally for the



51 Stables, London, Ont., 1863. The doors have very plain rectangular transoms and side lights, with the latter set off from the door itself. Lanterns on the roof provide lighting and ventilation. *National Archives of Canada, RG8, C Series, Vol. 1420, p. 294.*

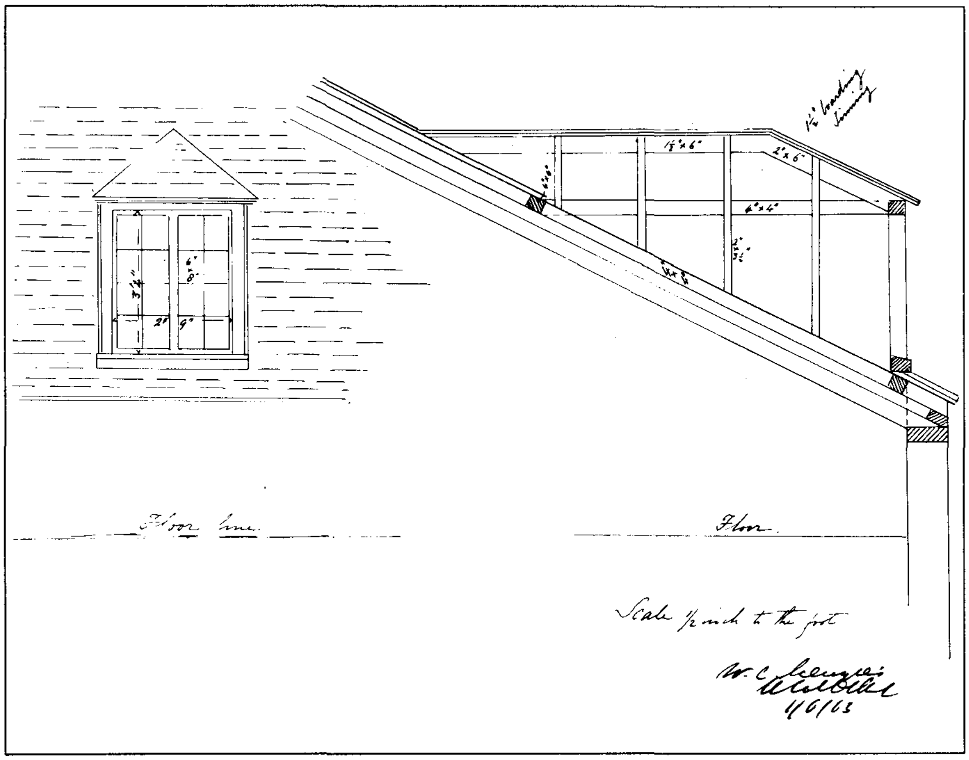
main doorways to major buildings or in such places as officers' quarters (Fig. 54). Outer or inner porches installed in winter also had windows or fanlights. As fanlights were so widely used they could be obtained ready made, as witness the 1833 advertisement of Kingston entrepreneur James Robinson that having purchased a machine for making fanlights, he was ready to carry out all orders.[100]

In the use of fanlights and side lights to light passages and enhance entrances to military buildings, the Royal Engineers were reflecting current architectural practice, both in Britain and in North America. The more severe climate of British North America had produced some differences in building habits from those in use in Britain, and the treatment of windows showed the effects of this. As they grew more conversant with local conditions and local building practices engineer officers began to incorporate some of these practices into their designs for military buildings. The Engineers' Code specified what quality of glass was to be used for each class of room, but at some posts the estimates drawn up for various buildings specified a better quality of glass than that allowed by the Code in response both to the realities of the local supply situation and to the need for stronger glass to withstand the local climate. Windows were designed to be suitable to the climate, and on occasion this was explained in the estimate, perhaps to forestall



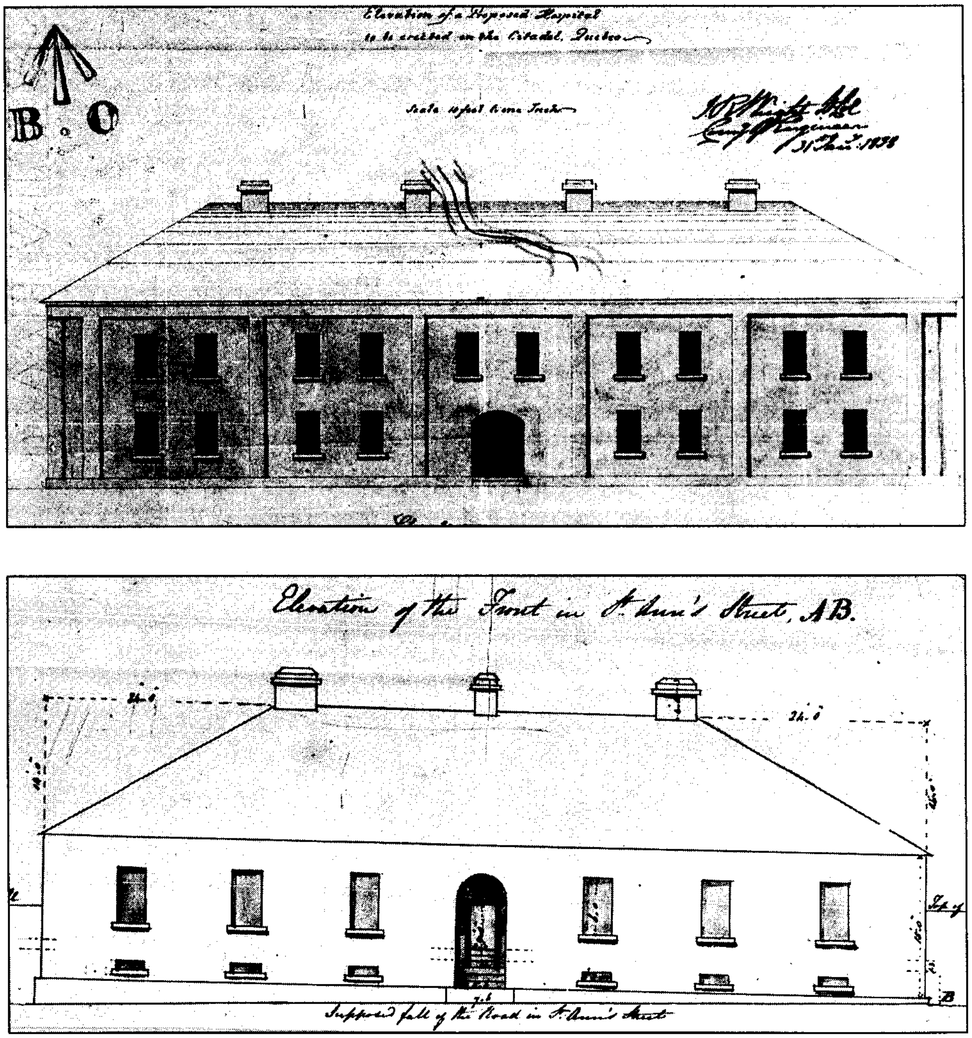
52 Halifax, naval storehouses, taken ca. 1890. Above the doors in the gable wall is a very nice semi-circular window. The main lighting for the upper floor comes from a row of dormer windows. *Naval Historical Library via Canadian Parks Service, Halifax Defence Complex.*

comments by the London authorities. Fanlights and other windows were hinged in order to provide more ventilation in summer. Also the need for double sashes and shutters to keep out the cold in the winter was stressed. The officials in London, being far removed from the severities of the North American winter, often queried the need for the additional



53 Sketch of the type of window proposed for a gunshed at Québec, 1863. The drawing shows how the dormer window was to be constructed. It was to be a casement window, with 8 panes in each half. *National Archives of Canada, RG8, C Series, Vol. 1580, p. 156.*

expense involved in providing such items, which local builders considered a normal part of any building which was to be even moderately comfortable. In some cases the engineer officers, influenced by strictures of economy and by the regulations laid down in London, resisted the requests of those occupying military quarters for such amenities as winter sashes. In reply to complaints made by Lieutenent Colonel Ingalls of the defects which he found in the commanding officer's quarters in the new barracks at Halifax, Colonel Nelson, RE, explained that as many shutters as were permitted by the regulations had been provided for the building; furthermore, while double windows would doubtless add much to the comfort of the quarters, if they were supplied to one part of the barrack buildings, they would be requested for every room in the whole range and for 232 windows this would become a major item



54 Façades of two buildings planned for Québec showing the use of fanlights and side lights adorning main entrances. The design of the doorway in the hospital, top, gives a plainer, more solid effect than the doorway to the kitchen building below. *National Archives of Canada, MG13, WO55/874, ff. 233, 111.*

of expense.[101] On the other hand it was Nelson who, two years earlier, had strongly recommended the introduction of gas lighting for the various barracks in Halifax.[102] Perhaps in view of the difficulties which he was experiencing by 1860 both with the Inspector General of Fortifications and with the General Officer Commanding in Nova Scotia over projects for changes in the Citadel, Nelson was unwilling to incur any expense for adding to the comfort of military quarters without express authorization.

While the use of window glass by the Royal Engineers in British North America reflected mainly practices common in England at the time, it also showed the influence of local conditions. When suggestions were made for deviations from English practice or from the regulations drawn up in London they generally originated with those officers stationed in British North America who had had some experience of the extremes of the climate and who had acquired some knowledge of local construction practices. Although some of the senior officers in the Corps of Royal Engineers had served in North America (for instance, Lieutenant General Gother Mann, Inspector General of Fortifications from 1811 to 1830, had earlier served for several years in Québec), this did not seem to have had any influence on the regulations which were drawn up concerning construction practices. Requests for improvements to windows such as double windows or summer blinds came from the engineers stationed at the various posts who urged that these were not luxuries but were indispensable because of the severities of the climate. It was not until after the middle of the century that the authorities in London began to take into consideration conditions affecting North American construction methods. The change in attitude is revealed in the 1862 plans for a regimental hospital prepared in London which made provision for double windows. This change in attitude is, however, more a reflection of the growing concern for the health and comfort of the ordinary soldier than a response to pressure from officers stationed in British North America.

The engineer officers on the spot were to some extent able to adapt to differing local building conditions. This can be seen in the various types of window in common use in military buildings in the different regions of British North America. In the Maritimes the English or sash window was employed almost exclusively whereas in Canada the casement window, a form more used on the Continent than in England, was much more common. Following architectural trends in England military engineers made a greater use of glass after the middle of the century. There were more windows in most later buildings, and the panes of glass were generally larger, reflecting the improved technology of the glass industry. Buildings designed by the Royal Engineers in British North America did not always reflect current trends in England. Engineer officers continued to specify crown glass in the plans and specifications which they drew up, long after this type of glass had been superseded in popular use by cylinder or sheet glass, probably because crown glass had been the type used when they learned how to draw up specifications. It would be interesting to compare this continuing preference for crown glass with usage in military construction in England and in other foreign stations.

CONCLUSION

"'Tis sport to have the engineer hoist with his own petard"

The purpose of this study has been to examine the work of the Royal Engineers in military construction British North America, 1820-1870, with regard to their use of certain selected building materials and their knowledge of certain aspects of building technology. In the case of some building materials, such as limes and cements, and asphalt, engineer officers in general took an interest in studying new developments and discussing them in papers which were circulated among members of the Corps of Royal Engineers. In the case of the others their interest was limited. For example, while engineer officers showed an interest in the use of cast iron and wrought iron for roof girders they seemed to have none in the more mundane aspects of building hardware, despite the technological developments in some of these items. Some engineer officers stationed in British North America seemed to be able to adapt their ideas on construction techniques to suit local conditions, but the regulations and standards for military construction drawn up in London did not generally reflect any knowledge of North American conditions. As more work on military structures was done by local builders there was more use of materials in common use locally. Construction by local builders did not always mean the use of the methods of construction prevalent locally as contractors worked under the supervision of engineer officers and had to adhere to standards set out in specifications drawn up by the local engineer officers and approved by the authorities in London.

APPENDIX 1

Major military establishments and groups of buildings in British North America, 1820-1870

(This includes many buildings which were built before this period but continued in use after 1820. The locations are spelled as they appear in original documents.)

St. John's, Newfoundland
Fort William
Fort Townshend
Signal Hill
Government House (built under supervision of the Royal Engineers)

Charlottetown, P.E.I.
barracks

Sydney, C.B.
barracks

Annapolis Royal
barracks

Halifax
Citadel
Artillery Park
South Barracks
North Barracks
Wellington Barracks
Fort Clarence
George's Island
McNab's Island
York Redoubt
Melville Island (military prison)
Sherbrooke Tower
Prince of Wales Tower

Garrison Chapel
Garrison Hospital
Fort Ogilvie

St. Andrews
blockhouses

Saint John
Fort Howe
Carleton Tower
Partridge Island
Lower Cove

Fredericton
Artillery Park
stone barracks
wooden barracks

Little Falls of the Madawaska
blockhouse

Dégelé
log barracks

Lake Temiscouata
storehouse
barracks

Quebec City
Citadel
four towers
Jesuit Barracks
Palace Gate Barrack (Artillery Barracks, also Ordnance offices)
Dauphin Barracks
Garrison Hospital
Ordnance storehouses
Engineer Department buildings
King's Wharf storehouse

Point Lévis
Forts 1, 2 and 3

Three Rivers
barracks

Sorel
barracks
Government House (work on this carried out by the military)

Chambly
Fort Chambly
barracks
storehouses

St. Johns
barracks
storehouses
powder magazine

Isle aux Noix
Fort Lennox

Chateauguay
blockhouse

Montreal
Quebec Gate Barracks
Hochelaga Cavalry Barracks (later a military prison)
Queen's Barracks
Garrison Hospital
Artillery Barracks

St. Helen's Island
barracks
storehouses
powder magazine

Longueuil
barracks

LaPrairie
barracks

Cedars
storehouse

Cascades
barracks

Coteau du Lac
barracks

Carillon
commissariat building

Bytown (Ottawa)
barracks
storehouses
Royal Engineer Department building

Prescott
Fort Wellington

Kingston
Fort Henry
Fort Frederick
Martello Towers
Tête de pont barracks
Engineer Yard
Artillery Square

Toronto
Fort York
New Barracks
storehouses

Penetanguishene
barracks
storehouses

Niagara
Fort Mississauga
Fort George
storehouses
barracks

Chatham
barracks

London
infantry barracks
artillery barracks
hospital
storehouses

Windsor
barracks

Amherstburg
Fort Malden
Bois Blanc Island

APPENDIX 2

References to the use of plaster in British North America by the Royal Engineers[1]

St. John's, Newfoundland

1826	estimate for construction of Government House [while not a military building it was constructed under the supervision of the Royal Engineers]; plastering in all stories.
1830	further estimate for finishing eastern wing; plastering rooms and staircases.
1836	estimate for the building of officers' barracks at Signal Hill; walls and ceilings, plaster 2 coats and set.
1837	estimate for repairs required in turning various quarters into soldiers' barracks; plaster needing repairs.
1840	estimate for alterations to officers' barracks, Signal Hill; brick partitions had plaster applied directly to the brick; plaster was to be removed, walls battened, then lath and plaster 2 coats, some set with fine stuff, some floated to receive plaster.
1842	estimate for converting lofts at Fort Townshend into barrack rooms; lath and plaster 2 coats and set with fine stuff.
1853	estimate for completing new hospital, Signal Hill; plastering.

Prince Edward Island

1848-49	estimate for repairs needed to soldiers' barracks and guardhouse; lath and plaster 2 coats.

Sydney, Cape Breton

1822	explanations of the state of the plaster in the barracks.

Halifax

1825	specifications for the storekeeper's house; rooms and passages, first and second floors to have 3 coats lath and plaster, third coat twice floated and well polished; attic and kitchen, lath and plaster 2 coats.

1826	estimate for guardhouse at Fort Massey; includes materials for plaster.
1833	estimate for tower at Wallace's Battery; officer's room; rendering walls 2 coats and set with fine stuff.
1835	estimate for building a garrison chapel; lath and plaster 2 coats, floated, coated.
1836	estimate for completing Citadel; casemates at Redan; 2 coats plaster; men's Cavalier; ceiling of lower rooms; lath and plaster 3 coats.
1840	estimate for repairs to officers' barrack, York Redoubt; plastering.
1841	estimate for repairs to house to be occupied by major general commanding the forces; repairs to plaster in various rooms, and plastering of rooms for servants to be fitted up in attic.
1843	estimate for fitting up rooms for a regimental sergeant major; render and plaster 2 coats.
1844	estimate for building a garrison chapel; lath and plaster 3 coats.
1845-46	estimate for repairs to North Barracks; renewing plaster.
1845-46	estimate for converting cells into orderly room at Royal Artillery Barracks; walls and ceiling, lath and plaster 3 coats, hand finish.
1845-46	estimate for repairs to the General Hospital; walls, lath and plaster 3 coats.
1849	estimate for a mortuary; walls and ceiling, lath and plaster 3 coats.
1849	estimate for repairs to the officers' quarters at the Citadel; ceilings, lath and plaster 2 coats and set with fine stuff; walls, render 2 coats and set with fine stuff.
1852	specifications for new barracks, soldiers' barracks, the ceilings in all the rooms and passages, and the upper part of the partitions in the general reading room and the sergeants' rooms; lath and plaster 2 coats and set with fine stuff.
	— officers' quarters; walls and passages on ground floor, render 2 coats and set with fine stuff; walls and partitions upper floors, render, float and trowel stucco, finish for paper; ceilings to upper floor, lath, plaster 2 coats, float and set with fine stuff; ceiling to ground floor, servants' quarters, lath,

plaster 2 coats, set with fine stuff; walls on ground floor, servants quarters, render 2 coats and set; officers' privies, lath, plaster 2 coat and set with fine stuff.

1864 specifications for new officers' barracks; lath and plaster 3 coats, cornices for sitting rooms.

Annapolis Royal

1833 estimate for proposed barracks; walls and ceilings of officers' quarters, hospital, storeroom, canteen; ceilings of privates' barracks; lath and plaster 2 coats, floated, coated and skimmed with lime putty.

1845-46 estimate for repairs to soldiers' barracks; work on plastering of walls and ceilings.

Saint John, N.B.

1838 estimate for increasing the size of the wooden barrack; walls and ceilings of rooms, lath and plaster 3 coats.

1840 estimate for constructing a stone building to hold Ordnance stores; walls and ceilings of offices and passages, lath and plaster 3 coats.

1840-41 estimate for an Ordnance store of wood; walls and ceilings, plaster 3 coats.

1841 estimate for a brick building for commissariat officers; walls and ceilings, lath and plaster 3 coats.

1845-46 estimate for repairs to soldiers' old barrack; ceiling, plaster 2 coats.

1847 estimate for fitting up Royal Engineers' office; ceilings, sides and partitions, lath and plaster 3 coats.

1847-48 estimate for converting black holes into solitary cells; brick partition plastered; ceiling, lath and plaster 1 coat.

1848-49 estimate for more solitary cells; brick partition plastered; ceiling, lath and plaster 1 coat; walls and ceiling of guardroom, lath and plaster 3 coats.

1850-51 estimate for a new privy; lath and plaster 2 coats.

1859-60 estimate for fitting up a barrack office, lath and plaster needed on partition wall to make the room habitable in winter; lath and plaster 3 coats and hand finish.

Fredericton

1838 estimate for barracks at Artillery Park; walls and ceilings of rooms, lath and plaster 3 coats.

1845-46 estimate for repairs to soldiers' barracks; ceiling, lath and plaster 2 coats.

1847-48 estimate for repairs to soldiers barracks; ceiling, lath and plaster 2 coats and set with fine stuff.

1847-48 estimate for converting black holes into solitary cells; brick partitions, plaster 1 coat.

1848-49 estimate for new guardhouse, and orderly room; ceilings, lath, plaster, float and set; walls, render, float and set.

1848-49 estimate for officers' quarters; walls and ceilings, lath, plaster, float and set.

Woodstock, N.B.

1840 observations, drawn up in London, on the plans for new barracks; the original plan called for 2 coats plaster; suggested 3 coats needed if the walls were to be painted; reply that 3 coats should have been stated; soldiers' rooms to have plaster on upper part of walls.

Grand Falls, N.B.

1844 estimate for a work of defence; tower, walls on first floor, render 2 coats and set with fine stuff; officer's guardroom, render 2 coats and set.

Quebec

1822 estimate for repairs to kitchens at garrison hospital; plaster work required.

1822 estimate for repairs to detachment hospital; boardroom to be plastered.

1822 estimate for fitting up attic in Dauphin Barracks for officers; plastering to be in distemper colours.

1827 estimate for addition to commissariat office; rooms and passage, plaster 3 coats.

1827 estimate for new stone building to contain all the public offices; plaster 3 coats.

1839 estimate for a bombproof hospital; ceilings, lath, plaster, float and set.

1840 estimate for fitting up a hired building as officers quarters; plastering required throughout.

1845 estimate for converting a cavalry barrack into a storeroom; repairs to plaster, 1 coat and set with fine stuff.

1848 estimate for converting a barrack to a prison dormitory; new partition, render 1 coat and set with fine stuff.

1849-50 estimate for an expense magazine; ceiling of porch, lath and plaster 1 coat and set.

1852 estimate for reconstructing Artillery Barracks; officers' quarters, walls, render 2 coats and set with fine stuff, ceilings, lath and plaster 2 coats and set.

1862 estimate for building wards for infectious diseases at the bombproof hospital at the Citadel; lath and plaster 2 coats and set with fine stuff on boarded partitions.

1863-64 estimate for repairs to plaster in officers' quarters, soldiers' barracks at the Citadel.

1864 estimate for building a water closet at the officers' quarters at the Citadel; render 2 coats, float and set.

1866 estimate for fitting up married soldiers' hired quarters; hair mortar, fine stuff, plaster of Paris.

Three Rivers

1838 estimate for repairs to barracks; repairs needed to plastering.

1844 estimate for fitting up a portion of a barracks as a hospital; closing doorways, lath and plaster 2 coats and set with fine stuff.

Sorel

1827 estimate for adding a storey to the Government House; drawing room and four bedrooms; lath and plaster.

1837 estimate for building a wooden barrack; lath and plaster 1 coat.

1840 estimate for a canteen; lath and plaster 2 coats.

1848 estimate to convert part of a building into a hospital; ceilings, lath and plaster 1 coat and set.

Chambly

1838 estimate for repairs to the old fort; lath and plaster 2 coats.

1840 explanation of the issuing of fuel to dry the plaster in the barrack, which was urgently needed.

1840 estimate for fitting up a canteen in a small cottage; lath and plaster 2 coats.

1851 estimate for providing school accommodation for the Royal Canadian Rifle Regiment; fitting up a schoolroom, lath and plaster 2 coats and set with fine stuff.

St. Johns

1840 estimate for a pentagonal redoubt; ceilings of lower rooms, lath, plaster 2 coats, float and set; walls and arches of upper rooms, render 2 coats, float and set.

1841 estimate of repairs needed to fit up quarters for the senior officer of engineers; lath and plaster 2 coats and set.

1841 estimate to build a casemated redoubt; walls and soffits of arches, render 2 coats and set; ceilings and partitions, lath and plaster 2 coats and set.

1848 estimate for partitions to make a quarter for a barrack sergeant; lath and plaster 2 coats and set with fine stuff.

1850 estimate for converting part of commissariat store into office; ceiling and partition, lath and plaster 2 coats and set with fine stuff.

1850 estimate for repairs to Barrack Master's house; servants' room and kitchen; walls, render 2 coats and set with fine stuff.

1851 estimate for school accommodation; ceiling of schoolroom, partition in schoolmaster's quarters, lath and plaster 2 coats and set with fine stuff.

1851 estimate for fitting up quarters for Barrack Master; partition, lath and plaster 2 coats and set with fine stuff.

1863-64 estimate for repairs to south wall of hospital; repairing plaster in interior.

Isle aux Noix

1850 estimate for repairs; cookhouse, walls and ceiling, lath and plaster 2 coats.

1850 estimate for repairs; Provost Sergeant's privy, lath and plaster 2 coats and set with fine stuff.

1851 estimate for school accommodation; walls and ceilings, lath and plaster 2 coats and set with fine stuff.

St. Helen's Island

1825 estimate for repairs at Artillery Barracks; plaster to be repaired.

1845 estimate for converting barrracks into military prison; Provost Sergeant's quarter, hospital, partitions, plaster 1 coat and set.

1848 estimate for repairs to warden's quarters; rendering 2 coats and set with fine stuff.

1864-65 estimate for new cottages for artificers and labourers; lath and plaster 2 coats and set with fine stuff.

Montreal

1834 estimate for a military hospital; walls, render 2 coats and set; ceilings, lath and plaster 2 coats and set.

1837 estimate for alterations to barracks; staff sergeant's quarter; plastering to be done.

1838 estimate to convert jail into a barrack; repair of plaster, walls and ceilings, 2 coats.

1840 estimates for new barracks; there are inconsistencies in these estimates; officers' quarters were to have walls and ceilings lathed and plastered 2 coats; in other buildings ceilings were to be lathed and plastered 2 coats; the later estimate states that the walls were not to be plastered; it is likely the plaster was to have a setting coat though this is sometimes omitted from the description of the work to be done.

1842 estimate for fitting up a guardroom at the military burying ground; lath, plaster, set with fine stuff.

1842 estimate for porches for expense magazines; Quebec Gate Barracks; ceiling, lath, plaster 1 coat and set.

1845 estimate for converting hired quarters into offices; repairs to plaster, 2 coats and set.

1846 estimate for a new barracks establishment; officers' rooms, chapel and offices; walls, plaster 2 coats, finish with fine stuff.

1846 estimate for repairs to house hired from Mr. Tobin; partition, lath, plaster, float and set.

1848 estimate for conversion of attic to accommodation for patients; lath and plaster 2 coats and set.

1849 estimate for proposed new wooden barracks; officers' rooms; walls and ceilings, lath and plaster 2 coats and set with fine stuff; soldiers' rooms, lath and plaster 2 coats.

1849 estimate for proposed military prison; corridors and rooms in centre building, governor's house, wardens' quarters, chapel, workroom; ceilings, lath and plaster 2 coats and set with fine stuff; governor's house, wardens' quarters, chapel; walls, render 2 coats and set with fine stuff.

1850 estimate for fitting up a military prison at the Quebec Gate Barracks; inner side of wall to be made good with rendering 2 coats and set.

Cascades

1848 estimate for repairs needed; renewing ceilings, lath and plaster 2 coats and set with fine stuff.

Coteau du Lac

1842 estimate for repairs to barracks, includes hair mortar and fine stuff.

Carillon

1845 estimate for changes to money vault; render 1 coat and set.

Rideau Canal

1828 estimate for a stone building to serve as a kitchen and a wooden building as a dead house for the hospital; plastering.

Fort Wellington

1822 report on repairs needed to blockhouse, ceiling to be lathed and plastered.

1840 estimate for fitting up a hospital; replastering 2 coats and set with fine stuff.

1851 estimate for providing school accommodation; ceilings and partitions, lath and plaster 2 coats; walls in schoolmaster's quarters; render 2 coats and set with fine stuff.

Kingston

1823 requisition for repairs needed to officers' and men's barracks; plastering needing repairs.

1828 estimate for reconstruction of Fort Henry; guardhouse, orderly room, officers' and men's casemates; plastering.

1832	estimate for casemated barracks at Fort Henry; plastering in officers' and men's casemates.
1841	estimate for Martello towers; walls of officer's room, render 2 coats and set with fine stuff.
1841	estimate for fitting up a residence for Barrack Master; basement, 1 coat, set with fine stuff; main rooms, 2 coats, set with fine stuff.
1846	estimate for tower at Point Frederick; walls of officer's room, render 2 coats and set with fine stuff.
1847	estimates for towers at Murney's Point, Cedar Island and Market Shoal; walls of officer's room, render 2 coats and set with fine stuff.
1847	estimate for guardhouse at Point Frederick; and for guardroom at Market Battery; walls of officer's room, render 2 coats and set; ceilings of officer's and men's room's, lath and plaster 2 coats and set.
1853	estimate for converting buildings in dockyard into quarters for Ordnance personnel; repairs to plaster; render 2 coats and set with fine stuff.
1862-63	estimate for repairs to cottages in dockyard; render 2 coats and set with fine stuff.

Toronto

1837	estimate for quarters for senior commissariat officer; plaster 3 coats; 2 coats in kitchen and privy.
1839	estimate for new barracks of masonry with brick partitions; officers' barracks, walls and ceilings, plaster 2 coats; men's barracks, ceilings, plaster 2 coats; hospital, walls and ceilings, plaster 2 coats; stables, ceilings, plaster 2 coats; Barrack Master's store, offices, ceilings and walls, plaster 2 coats; canteen, ceilings and walls, plaster 2 coats.
1840	estimate for fitting up hired building as a hospital; render 2 coats and set with fine stuff.
1841	estimate for repairs to hired buildings prior to returning them to their owners; repairs to plaster; 2 coats and set with fine stuff.
1841	estimate for an armourer's shop and a stable; ceilings, lath and plaster 2 coats.

1841 estimate for repairs to the Magnetic Observatory; render 2 coats and set with fine stuff.

1850 estimate for a guardhouse, commissariat fuel yard; lath and plaster 2 coats and set with fine stuff.

1850 estimate for converting basement of C barracks into a canteen; new partition, render 2 coats and set with fine stuff.

1852 estimate for fitting up quarters for Assistant Commissary General; partition, lath and plaster 2 coats and set with fine stuff.

1863-64 estimate for repairs to officers' quarters and mess at the old fort; lath and plaster 2 coats and set with fine stuff.

Burlington Heights

1841 estimate for a cantonment; walls and ceiling of officers' rooms, commissariat store, office, bakery, cookhouse, officer's guardroom; ceilings of soldiers' barracks, soldiers' guardroom; plaster 2 coats.

Fort George, Niagara

1822 report that hospital and surgeon's quarters, formerly Indian Department buildings, ready to be plastered.

1839 estimate for repairs to commissary's quarters; plaster to be repaired.

1839 estimate for fitting up commissariat office; lath and plaster 3 coats.

1839 estimate for guardhouse and dead house; inside, lath and plaster 2 coats.

1841 estimate for repairs to engineer quarters; plaster 3 coats; outbuilding, plaster 2 coats.

1851 estimate for providing school accommodation; walls and ceiling, lath and plaster 2 coats and set.

Drummondville

1842 estimate for repairs to Ontario House Barracks; ceiling of verandah, plaster 2 coats.

Chatham

1838 estimate for barrack; ceiling of upper storey and partitions, lath and plaster 2 coats.

1841 estimate for fitting up officers' quarters; sides of rooms, lath and plaster 2 coats.

1842 estimate for fitting up orderly room; partition, plaster 2 coats and set with fine stuff.

London

1838 estimate for stables, rooms for men, cookhouse; ceilings, plaster, 2 coats.

1839 estimate for barracks for a regiment; ceilings of soldiers' barracks, hospital, guardhouse and officers' privies, and walls of hospital, 2 coats; ceilings and walls of officers' barracks, 3 coats.

Amherstburg

1840 estimate for permanent work of defence; ceilings of lower rooms, lath, plaster 2 coats and set; walls and arches of upper rooms, plaster 2 coats, set with putty.

1840 estimate for towers on Bois Blanc Island; officer's room, render 2 coats and set.

1851 estimate for providing school accommodation; partition, lath and plaster 2 coats and set with fine stuff.

APPENDIX 3

Memorandum on the mode of applying the Bastenne Bitumen, 30 April 1841[1]

The quantity of Bastenne Mineral Bitumen or Mastic required to cover 2076 superficial yards is about 35 Tons if laid half an inch in thickness. This thickness is sufficient for foot pavements, terraces &c and may also be sufficient, or at the outside ¾ in., for the proposed purpose of covering the Terreplein of the Redoubt at Point Henry, Kingston, provided it may not be necessary to move heavy guns over it, from one part of the Redoubt to another, in which case a thickness of 1¼ in. or 1½ in. would be necessary.

The Bitumen should be laid on a substratum of concrete varying in thickness according to the nature of the soil or surface which it is proposed to cover; on a hard firm gravelly soil nothing more would be necessary than to loosen and form the surface to the required level or inclination, and to mix with the loosened material a sufficient quantity of lime to form a compact and tolerably smooth surface; in a common earthy soil a firm bed of concrete should be laid 6 or 8 inches in depth; if the ground is alluvial or marshy, it may be necessary to go to a depth of even two or three feet with the concrete. The surface being formed for the reception of the Bitumen and quite dry, rules or Battens of iron or hard wood made of the thickness which it is proposed to lay the material and from three to four inches in width are laid on the concrete forming a square, a rectangle or other convenient figure and which should not exceed in area from 20 to 30 square feet, the hot liquid Bitumen is then poured into the space enclosed by the rules, and the surface brought to a uniform thickness throughout, and for which the rules are a guide, by means of what is termed a "knife," used very hot. Whilst the material is still hot a fine grit or powdered lime or chalk should be sifted evenly over the surface and dressed down with a wooden bat, care being taken to work towards the joints; when the Bitumen is sufficiently firm the rules are removed and three of them laid down to enclose a second area, the fourth side being bounded by the portion already laid; the hot Bitumen is then laid in the second area and finished off as before described, the joints must be completed carefully, and if a complete junction is not at first made, a small quantity of the material is poured into the interstices and neatly smoothed off with the hot "knife."

As the work proceeds two sides of one of the small figures may be bounded by portions already laid, when of course, two only of the rules will be required, at least in a four-sided figure.

The material is manufactured in blocks or cakes and when used requires to be broken into pieces and melted in an Iron pot; whilst heating it must be kept constantly stirred from the bottom to prevent it burning, when it attains the consistency of thick treacle it is fit for use and is then to be ladled out with hot ladles and laid on the spot to be covered.

A common cast Iron Boiler will serve for the purpose of melting the material, which must be fitted with a movable grate for the fuel, but it will be more convenient to have the type of pot used by the Bitumen Company and which they will supply, at a cost of about £10 or £12 together with the few implements required. The pot must be as near as possible to the spot where the material is to be used in order that it may not cool in the transmit.

The price of the Bitumen from the Bastenne Company, and which is here considered the best is, prepared with a certain proportion of grit intermixed and packed in convenient packages for export £4.8.0 per Ton.

Coke is commonly used for melting the Bitumen, but wood will answer the purpose.

APPENDIX 4

Extract from specifications, barracks, Halifax, 1852[1]

61. The whole of the asphalte required to be Seyssel, "Claridge's Patent," Stangate, London, to be laid in all pavements, invariably one inch thick, either in one or two coats, the breadth of each layer not to exceed two feet six inches wide, the joints to be kept perfectly free from dust, &c. and well brushed before the mastic is laid.

62. This work to be performed by the Contractor in the usual manner, as directed by the Royal Engineer Department.

63. Roofing to be finished with a gritted surface, and laid on in two coats each three-eighths of an inch thick, so as to break-joint, and finished with suitable fillets, &c. as will be hereafter described and shown in the Working Drawings.

64. The Asphalte when used to cover arches, &c. to be laid in two coats, each three-eighths of an inch thick, breaking joint in the centre of each layer, properly finished, and laid round all drains pipes, and asphalted brick work, &c. —— and the surface left in the state it is laid in.

65. Asphalte brickwork, bricks to be kiln dried, cut, rubbed, &c. as required, in every respect for use, kept perfectly dry, during the execution of the work, by tarpaulin or other temporary sheds. The bricks to be dried under cover, coated with asphalte at least three-eighths of an inch thick, finished with a gritted surface or otherwise, as may be directed and required for the various works.

66. The Asphalte Brickwork to be executed in English bond, and jointed in fluid asphalte throughout the whole thickness of the work, finished with a neat flush drawn joint, not to exceed three-eighths of an inch on the face of the work.

67. The Asphalte to be used for the covering of all arches, roofing, brickwork, tanks, &c. to be of No. 1 quality.

68. For Floors and Pavements to be of the quality generally prepared and used for that purpose.

69. Specimens of the qualities 67 and 68, will be shown to the persons contracting at the Royal Engineer Office.

APPENDIX 5

"List of Nails and Spikes Required for the Service of the Office of Ordnance. Approved by the Honourable Board's Order of the 29 July 1812"[1]

In ordering nails the number of the nail in the list and the type was to be given. The List of Nails was accompanied by drawings showing all the nails included in the list.

No.	A				Pr 1000
1	Rose headed	Flat-points	Fine drawn	5¼ inches	80 lbs.
2		do	strong	5 inches	91 lbs.
3		do	do	4½ inches	65 lbs.
4		do	do	4 inches	50 lbs.
5	Rose headed	Sharp-points		40d	36 lbs.
6		do		30d	32 lbs.
7		do	long	20d	28 lbs.
8		do		20d	20 lbs.
9		do		18	16 lbs.
10		do		10	12 lbs.
11		do		8	10 lbs.
12		do			7 lbs.
13		30		6	4 lbs.
14		do			3 lbs.
15		do			2 lbs.
16		do			1½ lbs.

No.	B				Pr 1000
17	Best Rose headed	Chisel point flatted Barge		3 inches	32 lbs.
18	Fine drawn Rose headed				45 lbs.
19	Flat points do				45 lbs.
20	Fine shingle do				7 lbs.
21	do do				4 lbs.
22	Clasp headed				40 lbs.
23	do				36 lbs.

No.	B (cont'd)				Pr 1000
24	do				32 lbs.
25	do				26 lbs.
26	do				20 lbs.
27	do				18 lbs.
28	do				14 lbs.
29	do				12 lbs.
30	do				10 lbs.
31	do				7 lbs.

No.	C				Pr 1000
32	Fine Clasp				10 lbs.
33	do				14 lbs.
34	do				18 lbs.
35	do				6 lbs.
36	do				5 lbs.
37	do				4 lbs.
38	do				3 lbs.
39	do				2 lbs.
40	Best Countersunk Clout				45 lbs.
41	do do				36 lbs.
42	do do				24 lbs.
43	do do				20 lbs.
44	do do				18 lbs.
45	do do				12 lbs.
46	do do				10 lbs.
47	do do				7 lbs.

No.	D				Pr 1000
48	Best Countersunk Clout				5 lbs.
49	do do				4 lbs.
50	do do				2½ lbs.
51	do do				2 lbs.
52	do do				1½ lbs.
53	Best Black Tacks				1½ lbs.
54	Best-flatted Dog for Handcrow Levers			3¼ Inches	
55	do	do		2¼ Inches	
56	Fine Clout Best for Coopers				1½ lbs.
57	do				1¼ lbs.
58	do				2 lbs.
59	do				3 lbs.
60	do				4 lbs.

No.	D (cont'd)				Pr 1000
61	do				5 lbs.
62	Trunk				5 lbs.
63	do				2¾ lbs.
64	do				1¾ lbs.
65	do				1¼ lbs.
66	Lathing				7 lbs.
67	do				4 lbs.
68	Long Scupper				4 lbs.
69	Sprigs best fine pointed for Canister Shot Case				16 oz.

No.	E				Pr 1000
70	Slating Broad headed				12 lbs.
71	do Fine broad headed				6 lbs.
72	do do				4 lbs.
73	Best Broad headed Flats				1½ lbs.
74	do do				2 lbs.
75	Round headed Flats			2 Inches	
76	Broad Dog for Bars Brimstone Tubs			2¾ Inches	
77	Chest Large			2⅛ Inches	
78	do Small			2 Inches	
79	Box			1⅝ Inch	
80	Best Slender Boat				16 lbs.
81	do do			2 Inches	11 lbs.
82	do do			1½ Inch	6 lbs.
83	do do				4 lbs.
84	Filling Flat-headed			1 Inch	

No.	F				Pr 1000
85	Fine Drawing			3½ Inches	
86	Best T-headed			1⅝ Inch	
87	Best Back			4 Inches	
88	Best Scarf Fine				1¼ lbs.
89	do Stout				1½ lbs.
90	Best Bellows				9 lbs.
91	Best Dog				84 lbs.
92	do				60 lbs.
93	do				52 lbs.
94	do				28 lbs.
95	do				20 lbs.
96	do				16 lbs.
97	do				9 lbs.

No.	F (cont'd)				Pr 1000
98	do				6 lbs.
99	Tinned Round-headed				1¾ lbs.

No.	G				Pr 1000
100	Spikes Die-headed			14 Inches	
101	do			12 Inches	
102	do			11 Inches	

No.	H				Pr 1000
103	Spikes Die-headed			10½ Inches	
104	do			9 Inches	
105	do			8 Inches	

No.	I				Pr 1000
106	Spikes Die-headed			7 Inches	
107	do			6 Inches	
108	do			5 Inches	
106	Broad Deck			7 Inches	

No.	K				Pr 1000
110	Tacks	Best Flemish			14 oz.
111	do	Round Tinned			11 oz.
112	do	Flat Tinned			13 oz.
113	do	Best Flemish			8 oz.
114	do	do			6 oz.
115	do	do			4 oz.
116	Brads				20 lbs.
117	do				17 lbs.
118	do				12 lbs.
119	do				10 lbs.
120	do				5 lbs.
121	do				4 lbs.
122	do				2¾ lbs.
123	do				1¾ lbs.
124	do				14 oz.
125	do			¾ Inch	12 oz.
126	do			½ Inch	8 oz.
127	Cut Brads			1¼ Inch	
128	do			1 Inch	
129	do			¾ Inch	

No.	K (cont'd)				Pr 1000
130	do			½ Inch	
131	Best Brads	Fine for Modellers			1¾ lbs.
132	do	do			12 oz.
133	Best Clench				8 lbs.

No.	L				Pr 1000
134	Die Dog				16 lbs.
135	do				20 lbs.
136	do				39 lbs.
137	do				56 lbs.
138	do				76 lbs.
139	Clout Chisel Pointed Countersunk				39 lbs.
140	do do				52 lbs.
141	do do				63 lbs.
142	do do				81 lbs.
143	do do				5 lbs.
144	do do				14 lbs.
145	do do				20 lbs.
146	do do				20 lbs.
147	do do				36 lbs.

No.	M				Pr 1000
148	Barge			4 Inches	56 lbs.
149	do			3 Inches	32 lbs.
150	do			2 Inches	18 lbs.
151	Knee			6 Inches	60 lbs.
152	do			4 Inches	40 lbs.
153	Rooves	Large			
154	do	Small			
155	Sprigs	Glaziers			14 oz.
156	do	Sash			4 oz.
157	Brads			3¾ Inches	
158	Broad Dog for Brimstone Tubs			4½ Inches	
159	Rivets				36 lbs.
160	do				24 lbs
161	do				16 lbs.
162	do				8 lbs.
163	do				3 lbs.

APPENDIX 6

Extracts from various estimates listing the nails required

Estimate for building a new Government House and Government Offices, St. John's, Newfoundland, 1826.[1]

Basement Storey							
2,500	Nails	A	No. 3	Rose headed	65 lbs. to M	lbs. 162½
3,334	Nails	B	No. 24	Clasp head	32 lbs. to M	lbs. 106½
450	Spikes	I	No. 108	Die headed	6 to lb.	lbs. 75
Ground Floor							
2,500	Nails	B	No. 23	Clasp headed	40 lbs. to M	lbs. 100
14,167	Nails	B	No. 24	Clasp headed	32 lbs. to M	lbs. 432¼
2,500	Nails	A	No. 3	Rose headed	65 lbs. to M	lbs. 162½
14,167	Brads	K	No. 116	Flooring	20 lbs. to M	lbs. 283¼
500	Spikes	I	No. 106	Die headed	3 to lb.	lbs. 166½
Bed Room Floor							
14,167	Nails	B	No. 23	Clasp headed	40 lbs. to M	lbs. 166½
16,667	Nails	B	No. 24	do	32 lbs. to M	lbs. 533¼
2,500	Nails	A	No. 3	Rose headed	65 lbs. to M	lbs. 162½
14,167	Brads	K	No. 116	Flooring	20 lbs. to M	lbs. 283¼
500	Spikes	I	No. 106	Die headed	3 to lb.	lbs. 166½
Roof							
5,834	Nails	B	No. 23	Clasp headed	40 lbs. to M	lbs. 233¼
25,000	Nails	B	No. 24	do	32 lbs. to M	lbs. 800
5,000	Nails	A	No. 3	Rose headed	65 lbs. to M	lbs. 325
1,750	Spikes	I	No. 106	Die headed	3 to lb.	lbs. 583
1,250	Spikes	I	No. 108	do	6 to lb.	lbs. 208
11,667	Nails	B	No. 20	Rose headed	7 lbs. to M	lbs. 81½

Estimate to build a bakehouse, Quebec, 25 Aug. 1832.[2]

126 lbs. of No. 5 or 9 inch Spikes
136 lbs. of No. 3 or 7 inch Spikes
117 lbs. of No. 17 Nails
54 lbs. of No. 18 Nails
280 lbs. of No. 20 Nails
6 lbs. of No. 32 fine claspheaded Nails
25 lbs. of No. 33 fine claspheaded Nails
18 lbs. of No. 34
60 lbs. of No. 39
50 lbs. of No. 40
330 lbs. of No. 42

Estimate of the expense of constructing two beef stores in the Jesuit Barrack yard, Quebec, 7 Feb. 1838.[3]

½	cwt. of nail rod		
56	lbs. of No.	16	Nails
100	lbs. of No.	17	do
112	lbs. of No.	18	do
12	lbs. of No.	31	do
50	lbs. of No.	38	do
38½	lbs. of No.	68	Tin'd do
240	lbs. of No.	80	do
12	lbs. of No.	96	do
224	lbs. of No.	122	do

Revised demand for stores and materials, Ordnance storehouse, Saint-John, N.B., 1 August 1840[4]

Nails					
Spikes	No.	2	6 inch	lbs.	48
Rose	No.	16	20 lbs. per M	lbs.	272
Rose	No.	20	70 lbs. per M	lbs.	1475
Clasp	No.	33		lbs.	128
Clasp	No.	34		lbs.	10
Clasp	No.	42		lbs.	18
Brads	No.	92		lbs.	2
Brads	No.	95		lbs.	4
Slating	No.	163	6 lbs. per M	lbs.	100

Estimate, fitting up a house at Kingston for a barrack master, 13 Dec. 1841.[5]

½ M	Rose head nails	4 inches
2 M	do do	3¼ inches
⅕ M	do do	2 inches
½ M	Clasp nails	3¼ inches
½ M	Cut brads	2 inches

Estimate for repairs to a house at Halifax to be occupied by the Major General Commanding, 17 June 1841.[6]

Repairing the entrance:	
8 lbs. Rose Nails	No. 16
10 lbs. Rose Nails	No. 20
5 lbs. Clasp Nails	No. 33
1 lb. Brads	No. 95

APPENDIX 7

Sizes of nails used in military construction in British North America. 1835-1850

(Taken from various estimates and requisitions. This indicates the relationship between the official number and size.)

No. 1 1845-46	Spikes, 5 inch
No. 2 1842-43	Spikes, 6 inch
No. 3 1842-43	Spikes, 7 inch
No. 4 1845-46	Spikes, 8 inch
No. 12 1842-43	Clasp, 4 lbs. per thousand
No. 14 1845-46	Rose, 10 lbs. per thousand
No. 15 1844-45	Rose, 16 lbs. per thousand
No. 16 1845-46 1848-49	Rose, 20 lbs. per thousand 20dy
No. 19 1845-46	Rose, 50 lbs. per thousand
No. 20 1845-46	Rose, 70 lbs. per thousand
No. 22 1845-46	Rose, 40 lbs. per thousand
No. 31 1842-43	Clasp, 4 lbs. per thousand
No. 32 1842-43	Clasp, 6 lbs. per thousand
No. 33 1845-46 1846-47	Clasp, 10 lbs. per thousand 10dy

Appendix 7: Size of Nails (cont'd)

No. 34 1845-46	Clasp, 18 lbs. per thousand
No. 40 1842	Clasp, strong
No. 42 1842 1845-46	Clasp, strong Clasp, 40 lbs. per thousand
No. 51 1842-43	Clout, 1½ in. (fine)
No. 62 1842	Clout, strong
No. 68 1841	Tinned, 14 lbs. per thousand
No. 82 1842	Shingle
No. 93 1842-43	Brad, 14 oz. per thousand
No. 94 1842-43	Brad, 1¾ lb. per thousand
No. 95 1844-45	Brad, 2¾ lbs. per thousand
No. 96 1846-47	Brad, 4 lbs. per thousand
No. 98 1846-47	Brad, 15 lbs. per thousand
No. 146 1835-36	Copper, 12 lbs. per thousand
No. 163 1840	Slating, 6 lbs. per thousand
No. 165 1842-43	Brass, high top, 1¾ in.

APPENDIX 8

Extracts from Contract Schedules Listing Nails

Schedule of contract work at Montreal, 1850-53.[1]

Nails	
Rose head	⅞ in., 1¼ in., 1¾ in., 2 in., 2½ in., 2¾ in., 3¼ in., 3¾ in., 4 in., 4½ in., 5 in.
Cut Fine	1¼ in., 1½ in., 2 in., 2½ in., 3¼ in.
Cut Strong	1¾ in., 2¼ in., 2½ in., 2¾ in., 3⅛ in., 3⅜ in.
Clout Fine	¾ in., 1 in., 1¼ in., 1½ in.
Clout Strong	2 in., 2¼ in., 2½ in., 3 in., 3¼ in., 3½ in.
Clasp	1¼ in., 1½ in., 1¾ in., 2 in., 2½ in., 3 in.

Schedule of contract, canals, Canada East, printed 1866.[2]

Nails		
Clasp or Rose, any size that may be ordered		
	under 5 inches	Iron wrought
Clout or slating	do	do
Spikes, 5 inch and	under 8 inch	do
	8 inch and upwards	do
Cut, Rose or Clasp		Iron

APPENDIX 9

Extracts from a schedule of a contract for work for the Ordnance Branch of the War Department at Québec, printed in 1852[1]

General Regulations

4. The Glass to be of best quality specified, and in no instance will glass be admitted in two pieces in a square.

		[shillings/pence] s.	d.
For Store or Day Work			
501.	Painter or Glazier, per day	5	6
502.	Oil Putty, per lb.	0	3
503.	Glass, best Newcastle C, delivered in such sizes as may be ordered, per superficial foot	0	4½
Glaziers' Work			
514.	Glazing in new sashes, with best Newcastle C Glass, per superficial foot	0	7
515.	Ditto in repairs, including cutting out the old Glass, (which is to become the property of the Contractor) and painting the putty to correspond with the Sash, per superficial foot	0	9
516.	Taking out old Glass and stopping into other Sashes, including painting the putty as in Item 515, per superficial foot	0	5
517.	Stripping off old Putty and re-puttying Sash Squares, including painting as in Item 515, per dozen	0	8½

APPENDIX 10

Extracts from two lists of articles regarding glass

Articles needed for the coming year, to be purchased in this country, Quebec, 25 Oct. 1814.[1]

Glass panes
18 x 16*
16 x 14*
16 x 12*
16 x 11
16 x 10½*
15½ x 10½*
15¼ x 10¼*
14 x 11*
12 x 10
10 x 9½
10 x 8
8½ x 9½
8½ x 7½
7½ x 6½
7 x 6

*[crossed out in original]

Articles required to be sent from England, Quebec, 25 Nov. 1822.[2]

Glass panes	No.
18 x 16	60
16 x 14	60
16 x 12	100
16 x 11	60
16 x 10½	60
15½ x 10½	200
15¼ x 10¼	200

Appendix 10 (cont'd)

Glass panes	No.
14 x 11	200
12 x 10	200
10 x 9½	200
10 x 8	200
8½ x 9½	800
8½ x 7½	2500
7 x 9	300
7½ x 6½	300

It can be seen from this list that by far the most popular size at this time was 8½ x 7½.

APPENDIX 11

Extract from an 1862 specification for a regimental hospital, showing the detail of description given by this date[1]

Carpenter and Joiner

Sashes and frames

45. To be of the sizes figured on the several drawings, prepared for 2-inch bevel bar sashes, except for large wards, which are to be 2¼ inches, with oak sunk sills 6½" x 4", rebated, sunk, weathered, and ploughed on the under side for metal tongue, 1½" x 1", to be let into stone sill, and bedded with white lead; inch deal inside and outside linings, 2-inch heads and 1¼-inch pulley stiles, tongued to outside and inside linings and ploughed for ⅜" parting beads; ½-inch back-linings framed to outside and inside linings; ½-inch pendulum slips, leaving ⅛-inch play at each side, nailed to groove on head; pocket pieces 18 inches long and 2 inches wide, undercut and rebated at top, and squared at bottom 6 inches above the sill, and secured with screws; inside beads 1¼" x ¾", pulley stiles grooved and wedged to sills, and railed and grooved into head, prepared for double hanging with 2-inch brass-framed pullies.

Inspection Windows

46. Provide and fix in the nurses' rooms and ward sculleries inspection lights 2 feet by 1 foot 9 inches, to have 1½" deal bevel-bar sashes hung with one pair of 3" wrought butts to 1½-inch framed, rebated, and rounded linings, in width the full thickness of the wall, secured with small brass fastening, and glazed with seconds crown glass in one sheet.

Skylights

47. Construct skylight over dead-house as shown, stiles, head and sill, 3" x 3", wrought and framed. ¾-inch louvre boards 2-inch deal

bevel bar skylights. 1¼" ends, wrought both sides, framed into styles, and grooved for lead flashing.

Casements

49. The casements at end of main wards are to be 2¼" deal bevel-bar in solid frames as shown in detail. To be glazed with polished plate glass ¼" thick, secured as for ward windows, hung with 1½ pairs of 4-inch wrought butts, and secured with espagniolette fastenings let into a socket in oak sill.

Doors to Wards

52. ... the upper panels being filled in with plate glass 1/8" thick, bedded in wash leather, and secured by moveable wainscot beads with brass screws.

Window boards

58. 1½" tongued and rounded window boards, with returned ends on proper bearers, to all windows in central building and kitchen block.

Painter and Glazier

Glazing

126. The ward sashes and casements throughout to be glazed with the best polished plate glass, ¼ inch thick, secured in the manner shown in the drawings. The upper panels of ward doors to be glazed with similar plate. The remainder of the sashes to be glazed with 2nds Newcastle crown glass, 21 oz. to the foot, bedded in good oil putty, and free from flaws and all other defects. The entrance doors and fanlights over to be glazed with British plate, ⅛ inch thick. Rough plate glass ⅜ inch thick to all skylights.

Cleaning

127. The whole of the glazing to be left clean and perfect, and the floors washed, on completion of the works.

ENDNOTES

Introduction

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3 Whitfield, op. cit., pp. 19-26.
4 Porter, op. cit., Vol. 2, pp. 176; Sir Francis Bond Head, *The Royal Engineer* (London: John Murray, 1869), pp. 192-98.
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18 NA, MG13, WO44/202, p. 158.
19 "Engineers' Code," p. 57.
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Chapter 3 — Covering the Walls — Plaster, Render and Stucco

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