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FIRE RESISTANCE RATING (in hours)

CONCRETE MASONRY UNITS		90mm (4 inch)	140mm (6 inch)	190mm (8 inch)	240mm (10 inch)	290mm (12 inch)
HOLLOW	NORMAL (HVY./MED.) WEIGHT (N)	0.8	1.1	1.8	2.4	3.2
	LIGHTWEIGHT ($L_2$20S)	1.1	1.5	2.5	3.5	4.0+
	ULTRA LIGHTWEIGHT (L_2)	1.1	1.6	2.6	4.0+	4.0+
75% SOLID	NORMAL (HVY./MED.) WEIGHT (N)	0.9	1.8	3.0	4.0+	4.0+
	LIGHTWEIGHT ($L_2$20S)	1.1	2.5	4.0+	4.0+	4.0+
	ULTRA LIGHTWEIGHT (L_2)	1.1	2.7	4.0+	4.0+	4.0+
100% SOLID	NORMAL (HVY./MED.) WEIGHT (N)	1.4	3.9	4.0+	4.0+	4.0+
	LIGHTWEIGHT ($L_2$20S)	1.8	4.0+	4.0+	4.0+	4.0+
	ULTRA LIGHTWEIGHT (L_2)	2.0	4.0+	4.0+	4.0+	4.0+
ARCHITECTURAL BLOCK (N)		1.4	1.4	2.0	2.7	3.5

Concrete Type	**Equivalent Thickness**
Type **N** concrete : (symbol **A*** & **B***) Normal Weight in which coarse aggregate is Limestone, course screenings and sand	**$T_e = S_p \times W_d$** Where:
Type **$L_2$20S** concrete: (symbol **C***) class Lightweight in which coarse aggregate is Expanded Slag with less than 20% sand.	T_e = Equivalent Thickness,(mm)
Type **L_2** concrete: (symbol **D***) class Ultra Lightweight in which the coarse aggregate is expanded slag.	S_p = Persent Solid as determined by ASTM C140 - 14b
	W_d = Measured Width, in mm
* defined in **Table 1, Third Facet, CSA A165.1 - 04** (reaffirmed 2014)	

Table 5.1: Minimum Equivalent Thicknesses of Concrete Masonry Walls Loadbearing and Non-loadbearing (Adapted from Table D-2.1.1, NBCC-10)

Wall of Hollow Semi or Solid C.M.U. with Concrete Type	**Minimum Required Equivalent Thickness in millimeters for Fire-Resistance Rating*****					
	30 min.	45 min.	1 hr.	1.5 hr.	2 hr.	3 hr.	4 hr.
Type N concrete**	44	59	73	95	113	142	167
Type $L_2$20S concrete	42	54	64	81	94	116	134
Type L_2 concrete	42	54	63	79	91	111	127

** Hollow concrete masonry units made with Type N concrete must have a minimum specified compressive strength of 15 Mpa, determined in accordance with CSA A165.1

*** Fire-resistance rating between the stated rating periods listed may be determined by linear interpolation.

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Fire Performance

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Fire Performance

5.1 Codes and Standards

Requirements for fire safety and fire protection are provided in Provincial Building Codes and in the National Building Code of Canada (NBCC) from which they are modeled.

For buildings designed in accordance with Part 9, *"Housing and Small Buildings"*, requirements for fire protection and fire safety are, for the most part, stated directly in Part 9. However, for some design issues, Part 9 references the fire requirements within Part 3, *"Fire Protection, Occupant Safety and Accessibility"*. Part 3 contains a comparatively more comprehensive series of design requirements for fire safety and protection. Part 3 of the Building Code is used for the design of buildings other than Part 9 buildings.

Fire safety and fire protection are not within the scope of the CSA standard A165 Series, *"CSA Standards on Concrete Masonry Units"* and therefore fire and fire-related issues, including those specific to concrete masonry, are not addressed by these standards in any manner. Fire requirements specific to concrete masonry are fully contained in the Building Code.

5.2 Fire Protection, General

5.2.1 Objectives of the National Building Code

The scope of the NBCC recognizes two objectives for fire control, these being:

1. **Fire Safety**; to limit the probability that a person in or adjacent to a building will be exposed to an unacceptable risk of injury due to fire; and,
2. **Fire Protection**; to limit the probability that a building or part of a building, or an adjacent building, will be exposed to an unacceptable risk of damage due to fire or structural insufficiency, or will be exposed to an unacceptable risk of loss of use due to structural insufficiency.

Protection of property beyond reducing the risk of structural insufficiency or loss of use resulting from fire, including loss of building contents, is not an objective of the National Building Code of Canada and its requirements for fire safety and protection.

5.2.2 Current Design Strategies and Practice

In order to meet the objectives for fire control, either the ignition of fire must be prevented, or if ignition occurs, the impact of the fire must be managed.

It is acknowledged that a building designer has little control over ignition and moreover, that it is impossible to prevent. Therefore, current fire design strategies and indeed requirements within the Building Code focus on managing fire impact. Inevitably, the most effective means to do so is to include features in the building specifically intended by design to control the intensity of fire and to limit its spread.

Managing the fire by controlling its intensity and limiting spread can be achieved by:

1. Controlling combustion and fire growth;
2. Suppressing the fire;
3. Controlling fire spread by construction;
4. Balanced design.

Controlling combustion

This strategy involves controlling the availability of fuel for the fire within the building, including as sources, the building contents and the included construction materials and components. Whereas the designer can limit the use of combustible building materials and their exposures by appropriately choosing structural materials and finishes that are non-combustible, the designer rarely can control the building contents. Additionally, limiting the contents of buildings is currently beyond the scope of the Building Codes. As a consequence, attempting to control ignition and combustion is not a fully comprehensive strategy for the designer.

Fire suppression

This strategy intends to extinguish or suppress the fire and in most buildings is commonly achieved by installing automatic sprinkler systems. These systems and others which must be activated to perform are known as "Active Fire Protection" systems. Automatic sprinkler systems are known to be highly effective once activated, but there is on-going debate about their reliability, the unintended yet unavoidable damage to the building once activated, and their cost-effectiveness.

Controlling fire spread by construction

The strategic placement and construction of elements within a building that inherently resist fire, such as non-combustible concrete masonry walls, is a form of "Passive Fire Protection". By using these fire-resistant elements, fire control is achieved by suitably retarding or preventing the movement of fire from one area to another such as between adjacent dwellings, compartments, or buildings. The most basic of these fire resistant assemblies are the walls and floors of the building. Once constructed and unlike fire suppression systems, passive protection is always available and requires no active mechanical or electrical operative process or maintenance to function when called-upon to resist fire.

A construction assembly (such as a wall or floor) that acts as a barrier against the spread of fire is defined by the Building Code as a *"fire separation"*. The *"fire-resistance rating"* (FRR), stated in minutes or hours, measures the ability of a material, assembly, or structural member to control the spread of fire and to prevent collapse under exposure to fire. The required locations of fire separations in a building, the required fire-resistance rating for fire separations and the required treatment of fenestration and other penetrations through fire separations are stated within the Building Code and are not a focus of discussion for this Manual. However, of particular interest, is the appropriate selection of concrete masonry materials and assemblies needed to satisfy the fire requirements of the Building Code and to properly control the spread of fire using passive protection.

Balanced Design

Active protection systems such as sprinklers, while effective, are not the entire solution and may fail to perform when needed. This is especially important if construction frame and finish materials have been used that rely on sprinklers to slow their rate of combustion.

Comprehensive fire protection techniques involve a range of strategies. "Balanced Design" combines both active and passive design elements as well as the concept of compartmentalization to enhance fire protection and reliability. Compartmentalization makes use of the passive protection offered by non-combustible floors (such as cast-in-place concrete or concrete plank) and non-combustible walls (such as concrete block masonry) to divide the structure into smaller areas or modules to confine fire to the area of origin and to provide safe egress for occupants and ingress for firefighters.

Balanced Design relies on four complementary life-safety and property protection systems:

(a) automatic detection systems to provide early warning to occupants and the fire department;

(b) compartmentalization to limit fire spread and provide refuge for occupants;

(c) automatic suppression to control or limit fire growth; and

(d) non-combustible construction which:

- does not ignite,
- is not subject to flame spread,
- does not contribute fuel to the fire,
- does not emit toxic gas and smoke under fire,
- absorbs heat and limits temperature rise to prevent new ignition and,
- offers structural integrity under intense and prolonged exposure to heat (maintaining sufficient loadbearing capacity, where required, without collapse).

Balanced Design provides a level of redundancy to help ensure adequate protection even if one system is compromised, impaired or otherwise fails to perform.

Whereas there has been a shift in the approach to fire safety by Building Codes and the built environment in recent decades to a heavier reliance on active fire protection strategies, a Balanced Design is the most reliable of the design strategies.

Concrete block masonry construction is non-combustible and is particularly well-suited to the fire control strategies of "Controlling Combustion", "Passive Fire Protection" and "Balanced Design". The discussions that follow focus on passive fire-safety design strategies and the fire properties and protection offered by concrete block masonry using the requirements of Part 3 of the 2010 edition of the National Building Code of Canada.

5.2.3 Fire Separations

The basic concepts of *"fire separation"* and *"fire-resistance rating"* (FRR) were introduced in Section 5.2.2. As noted previously, a detailed discussion on fire separations is not a focus of this Manual, but some additional information will help to differentiate them from "Firewalls" (discussed in Chapter 5A of this Manual), better describe their use, and further introduce "fire-resistance rating" which is discussed at length in Section 5.3.

The NBCC defines a *"fire separation"* as *"…a construction assembly that acts as a barrier against the spread of fire".* A fire separation may be a wall, partition or floor assembly. Under NBCC-10 Part 3 design, the required locations of fire separations in a building, essentially positioned between adjoining major occupancies and between occupancies and tenancies, are stated in Subsection 3.1.3 and Section 3.3, respectively. Additionally, these sections assign a minimum "fire-resistance rating" (FRR) to each of the required fire separations. These ratings range from 45 min. to 4 hrs.

Requirements specific to fire separations are contained in Subsection 3.1.8 of NBCC-10. The critical characteristic of a fire separation is that it must provide a *continuous* barrier to the spread of fire and thus, with respect to fire, that it be constructed as a continuous element. In order to provide this continuity, large openings such as a door or window must be equipped with a closure and discontinuities and penetrations must be fire stopped. Specific requirements for these materials and assemblies and their installation are also contained in Part 3 of the NBCC.

Although a fire separation may be wall, partition or floor assembly and constructed of a variety of materials and assemblies including steel frame, wood frame, concrete and gypsum board, this manual understandably focuses on walls and partitions constructed using concrete block masonry.

5.3 Fire-Resistance Rating (FRR); the Concept

5.3.1 Definition and Meaning

The National Building Code of Canada defines *"fire-resistance rating"* as *"the time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria".*

The term *"specified conditions of test"* refers to a standard laboratory fire test. Indeed, this standardized test is not representative of all fire conditions and does not simulate an actual fire because actual fire conditions can vary widely. In fact, a laboratory test cannot accurately predict the consequences of a real fire in a structure or for its elements. Specifically, the standard fire test is simply a convenient means, under controlled laboratory conditions, to measure and describe the response of a test specimen to heat and flame and subsequently, to the effects of a water hose stream. It is generally considered to be a reasonable method and basis to provide a relative measure, in this case to determine Building Code compliance, of the fire resistance of an assembly, floor or wall, both loadbearing and non-loadbearing.

However, the standard fire test is not without inconsistency and bias in its means to determine FRR. It does not necessarily establish a ranking of performance among different materials and assemblies. Assemblies having the same fire-resistance rating by this test do not necessarily demonstrate equivalent fire performance. These issues will be subsequently identified and discussed in Section 5.3.2.2.3.

5.3.2 ULC-S101, *"Fire Endurance Tests of Building Construction and Materials"*

5.3.2.1 ULC-S101 and Alternative Standard Test Methods

NBCC-10, by way of Sentence 3.1.7.1.(1), identifies CAN/ULC-S101, *"Fire Endurance Tests of Building Construction and Materials"*, published by Underwriters' Laboratories of Canada, as the standard test in Canada to determine the fire-resistance rating of a material, assembly of materials or a structural member.

The National Building Code of Canada also permits the Authority Having Jurisdiction to accept results of fire tests using other standards. The test method commonly used in the United States to establish fire-resistance rating is ASTM E 119, *"Standard Test Methods for Fire Tests of Building Construction and Materials"*. ASTM E 119 and CAN/ULC-S101 are harmonized and remarkably similar. ASTM E 119 is also known as Underwriters' Laboratories Standard UL 263, *"Fire Tests of Building Construction and Materials"* and National Fire Protection Association NFPA 251, *"Standard Methods of Tests of Fire Resistance of Building Construction and Materials"*.

Fire-resistance ratings determined in accordance with ASTM E 119 are usually acceptable to Canadian building officials. Additionally, requirements in the current editions of these various test standards, including the time-temperature curve, the testing apparatus and the acceptance criteria have changed little from their past editions and test results based upon the various editions are comparable.

5.3.2.2 Testing Walls Under ULC-S101; Test Method and Performance Criteria

5.3.2.2.1 Test Specimen and Method

Wall assemblies are constructed in a test frame to facilitate handling and transport. They are built using the materials, design and workmanship intended to be representative of the field application. Walls are tested by exposing only one side of the test specimen to a standardized fire generated by furnace burners.

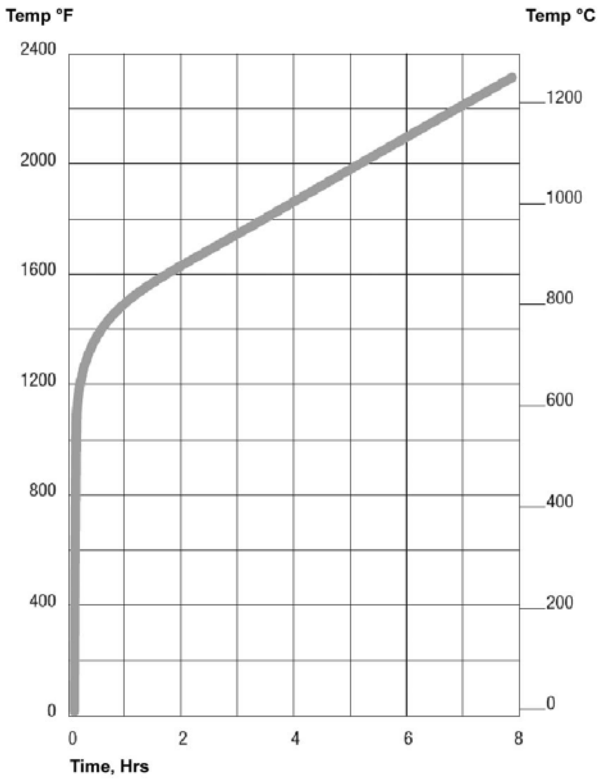
Because loadbearing and non-loadbearing walls serve different functions in a structure, ULC-S101 prescribes different test criteria for each, which include: (a) subjecting loadbearing walls to a superimposed vertical, axial load to simulate service conditions, the magnitude of which is the maximum load condition permitted by the respective national structural design standard (for masonry, this is CSA Standard S304.1-04) and (b) restraining all four edges of a non-loadbearing wall, but providing no side edge restraint for loadbearing walls. The introduction of a vertical load is particularly critical for light-frame wall systems such as wood and steel stud where loss of strength is likely and deflections and deformations under vertical load and elevated temperatures, concurrently, will affect the ability of protective wall membranes, such as gypsum board, to remain integral and contain the fire.

In accordance with Article 3.1.7.3 of NBCC-10:

- Partitions or interior walls must be rated for exposure to fire from both sides since a fire could develop on either side of the fire separation. Consequently, they are normally designed symmetrically. If they are not symmetrical, the fire-resistance rating of the assembly is based on testing from the least fire-resistant side.
- Exterior walls only require rating for fire exposure from inside a building because fire exposure from the building exterior is unlikely to be as severe as from the interior. Consequently, exterior wall assemblies need not be symmetrical when establishing the fire-resistance rating.

For both loadbearing and non-loadbearing walls, the area of the test specimen exposed to the fire must be not less than 9.3 m^2 (100 $ft.^2$), with no side dimension less than 2.7 m (9 ft.). The test specimen is instrumented with thermocouples to measure temperature on both the fire-exposed and non-fire-exposed sides. All thermocouples are positioned at locations prescribed by the standard. Thermocouples on the unexposed fire face are placed in contact with the test specimen. Thermocouples on the exposed face are positioned 152 mm (6 in.) away from the specimen. Furnace burners are monitored and controlled so the temperatures in the furnace closely follow the required time-temperature curve for the standard test fire, shown graphically in Figure 5.1.

Figure 5.1: *Standard Time-Temperature Curve for Fire-Endurance Testing (CAN/ULC-S101)*



Fire endurance testing is continued until failure occurs or until the specified time period has passed.

In addition to the fire endurance testing, constructions having a fire-resistance rating of 1 hour or more must be subjected to the standard hose stream test to determine the effects on the specimen of impact, erosion and cooling. The duration of water application to the fire exposed side of a specimen and nozzle pressure are based on the duration of the specimen's resistance period established by the fire endurance test, that is, the longer the rating, the longer and more severe the hose stream exposure. Section 5.3.2.2.2 provides additional information about the conditions of acceptance by the standard and Section 5.3.2.2.3 provides a more detailed discussion about the hose stream test and equivalent fire performance.

5.3.2.2.2 Conditions of Acceptance

To achieve a desired fire-resistance rating under ULC-S101 or ASTM E 119, the following criteria are applied:

1. For loadbearing walls not subjected to a hose stream test, the wall must sustain the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton material (determined by touching a piece of cotton to various points on the unexposed side of the wall assembly) for a period of time equal to the desired resistance period.
2. For loadbearing walls subjected to a hose stream test, the wall must sustain the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton material for a period of time equal to the desired resistance period and sustain the applied load during the hose stream test without the passage of water for the required duration of application.
3. For non-loadbearing walls not subjected to a hose stream test, the wall must withstand the fire endurance test without passage of flame or gases hot enough to ignite cotton material for a period of time equal to the desired resistance period.
4. For non-loadbearing walls subjected to a hose stream test, the wall must withstand the fire endurance test without passage of flame or gases hot enough to ignite cotton material for a period of time equal to the desired resistance period and the hose stream test without the passage of water for the required duration of application.
5. For all walls subjected to a hose stream test, the assembly is considered to fail the hose stream test if an opening develops that permits a projection of water from the stream beyond the unexposed surface during the time of the hose stream test.
6. For all walls, the assembly is considered to fail the fire endurance test where transmission of heat through the wall raises the average temperature on its unexposed surface more than 139 C° (250 F°)

above its initial temperature, or raises the temperature of a thermocouple on the unexposed face greater than 181 C° (325 F°).

More simply stated, the fire endurance of a wall is determined by the time to reach any of the following conditions: fire penetration through the wall; temperature rise on the unexposed side; collapse; or termination of the test. The fire resistance rating is the fire endurance rounded down to the nearest integral minute (of course, with the requirements of the hose stream test also satisfied, where applicable).

5.3.2.2.3 Significance, Use and Limitations of ULC-S101 (ASTM E 119)

The test standard provides the following information for walls and partitions:

- measurement of the transmission of heat;
- measurement of the transmission of hot gases through the test specimen; and
- measurement of the load carrying ability of the test specimen during the test exposure.

The test standard does *not* provide the following:

- performance of test specimens having components or lengths different from those tested;
- the degree by which the test specimen contributes to the fire hazard by generation of smoke, toxic gases, or other products of combustion;
- the degree to which the assembly controls or limits the passage of smoke or products of combustion;
- simulation of the fire behaviour of junctions between building elements;
- measurement of flame spread over the surface of test specimens; and
- the effect on fire-resistance of common openings in the specimen (electrical receptacles, plumbing penetrations, etc.) unless specifically provided for in the tested construction.

Unlike light frame wall systems, the fire-resistance rating of concrete masonry is typically limited by the heat transmission end-point criteria (temperature rise on the non-fire-exposed side), occurring prior to the passage of flame or gases, or structural failure. Of all possible modes of failure, this is the most preferable with respect to life safety and property protection.

The hose stream test provides some measure of the ability of the construction to endure extreme fire exposure and concurrently resist falling debris, pressure waves due to explosions, actual fire hose streams applied by firefighters and other impacts that oftentimes will occur during a fire.

Interestingly, under ULC-S101 and ASTM E 119 and by way of an optional choice for the test proponent, the hose stream test may be performed in one of two ways:

(a) **The "duplicate specimen" test**: This test allows for the removal of the fire endurance test specimen and its replacement with an identical specimen prior to the initiation of the hose stream test. The first specimen is subjected to the fire endurance test to determine its hourly fire-resistance rating. A second specimen is subjected to the fire endurance test for only one half of the recorded rating period of the first specimen (but not for more than one hour). Subsequently, it is this specimen that is tested under the hose stream.

(b) **The "optional program"**: Under this more rigourous test, the hose stream is applied to the same specimen that has undergone the full fire endurance test.

The "optional program" is commonly used for concrete masonry assemblies. The "duplicate specimen" is typically used for frame wall assemblies, such as wood and steel stud. **The effect of the "duplicate specimen" test is to improve the apparent fire performance of a wall assembly.**

With the optional use by these standards of two profoundly different compliance paths to establish hose stream performance, two distinct levels of durability performance are included and the relative fire performance of different wall assemblies becomes somewhat of an optional measurement. Without differentiation of test means, the hose stream test results should not be equally and uniformly applied to all types of wall construction. It is reasonable to assert that different wall assemblies intended for use in identical applications, yet tested using different test protocols, should not receive the same fire-resistance rating.

As a consequence of the interpretation and use of test results permitted by ULC-S101 and ASTM E 119, wall assemblies that pass the hose stream test are not necessarily equal in their performance. A video showing actual fire endurance and hose stream testing of a concrete block masonry wall and of a gypsum board/steel stud wall in accordance with ASTM E 119 and demonstratively contrasting their fire performances is available from the Canadian Concrete Masonry Producers Association.

In typical Building Code applications, usually no distinction is made between the "duplicate specimen" test and the "optional program" and most designers remain unaware of the profound difference. As a result, assemblies that pass the duplicate specimen test are assumed by users to have the same durability and fire performance as those passing the more rigourous optional hose stream test method and assigned the same fire-resistance rating.

With this awareness, or because of adverse experiences from actual fire events, some jurisdictions have amended their Building Code to require firewalls to pass the hose stream test after meeting the full time required for the fire-resistance period. The Alberta Building Code requires this by way of Building Code Interpretation 06-BCI-005. Further discussion on this is provided under Chapter 5A, "Firewalls".

5.4 Compliant Means to Determine FRR Under NBCC-10

5.4.1 General

For a material, assembly of materials or a structural member used under Part 3 design, Article 3.1.7.1 of NBCC-10 requires fire-resistance ratings to be determined by:

(a) fire testing, using ULC-S101; or,

(b) calculation, on the basis of requirements in Appendix D.

Under Part 9 design, in accordance with Article 9.10.3.1 of NBCC-10, fire-resistance ratings must be determined by:

(a) fire testing, using ULC-S101; or,

(b) assigned rating, in accordance with Appendix C; or,

(c) calculation, on the basis of requirements in Appendix D.

In practical terms, there is little difference in the resulting fire-resistance ratings for concrete masonry assemblies determined by each of these code-recognized methods.

5.4.2 Fire Testing

The means to determine fire-resistance rating by laboratory testing, using standard ULC-S101, *"Fire Endurance Tests of Building Construction and Materials"*, is discussed extensively in Section 5.3.2.

Regardless of the unit or assembly configuration, or the uniqueness of the material types used to produce the masonry units, the fire-resistance rating of virtually any concrete masonry assembly can be determined using physical testing. Additionally, direct testing will provide a more accurate determination of fire-resistance rating and a marginally higher rating than that obtained by other means acceptable to the Building Code. However, because of the associated costs, which are reported to be in the order of $20,000.00 for each tested wall assembly, the fire-resistance rating of most assemblies including those of concrete block masonry is generally determined using the calculation method of Appendix D, NBCC-10, where practicable.

"Fire testing" includes either of the following means to demonstrate fire-resistance:

(a) **Tested Assemblies**, which are "full scale" assemblies that have been tested in accordance with ULC-S101 by a recognized laboratory, with an associated report of the findings that states the fire-resistance rating; or,

(b) **Certified or Listed Assemblies**, which are "full scale" assemblies that have been previously tested in accordance with ULC-S101 by a recognized laboratory, classified, and listed by a recognized certification organization in a published directory of fire-rated assemblies. The most commonly used listing service is Underwriters Laboratory of Canada (ULC), but other agencies are available.

A number of masonry wall assemblies are listed in such directories. Some companies manufacturing concrete block units have submitted their products for evaluation and have received certification reports and listings. The ratings apply only to specific block shipments from certified suppliers. Changes to listed assemblies are only permitted where the certification agency has undertaken an assessment of the impact of the changes.

Some specifiers prefer to select a fire-rated assembly using the listing service option because it offers third-party verification. To verify that the concrete masonry units comply on an on-going basis with appropriate standards, the listing service also monitors the materials and manufacturing procedures used in producing the concrete masonry unit used in a listed assembly. Consequently, concrete masonry units that are so listed may have a cost premium associated with them. Further, listing services offer little flexibility in their application because the units and assembly must be manufactured and constructed as tested. Often, there are supplemental requirements that must be met for ULC listed assemblies, such as those stated in ULC-618, *Concrete Masonry Units*.

Because full-scale testing of representative test specimens is oftentimes not practical in daily practice due to time and financial constraints, the NBCC permits the use of other options to establish fire-resistance ratings.

5.4.3 Assigned Rating

Assigned fire-resistance ratings for a variety of concrete block wall configurations and finishes are tabled in Appendix A of the NBCC-10 (Table A-9.10.3.1.A). The assigned ratings are based on a review of historical fire test data. If a user selects an assembly from the Tables in Appendix A, the assembly is deemed to satisfy the intent of the fire-resistance rating requirements in the NBCC. This option does require justification to the building official that the proposed design is at least equivalent to the prescribed configuration in the Building Code. This prescriptive, deemed-to-comply option is simple to use and has no supplemental cost. However, the range of assemblies offered is limited, the prescribed construction uses standard concrete masonry units only, and the tabled ratings are conservative. The approach is relatively inflexible. Consequently, these tables are seldom used by practitioners or by the masonry industry.

5.4.4 Rating by Calculation

Since before the introduction of the National Building Code of Canada in the early 1940's, literally thousands of small- and full-scale fire tests have been performed on concrete and masonry assemblies. The analyses of the data compiled from these tests have allowed the identification and an understanding of the physical properties of the materials and variables of the assembly that affect fire endurance. As a result of extensive research, analytical calculation methods have been derived that will accurately predict the fire-resistance rating that a concrete masonry assembly would achieve if it were subjected to the ULC-S101/ASTM E 119 fire endurance test.

The primary advantages of using calculation methods to determine fire-resistance ratings of concrete masonry assemblies are (a) ease of use and convenience, (b) significant cost savings compared to the practice of conducting full-scale fire tests and (c) flexibility, since near limitless combinations of masonry unit sizes, configurations and densities can be accounted for, as well as the contribution of various types of finishes added to the surface and of materials placed in the cells of the units.

The National Building Code of Canada (2010), by way of Sentence 3.1.7.1.(2), permits the fire-resistance rating of walls, partitions and columns to be determined by calculation using the requirements and methods stated in *"Appendix D—Fire Performance Ratings"*. The calculation method is the most commonly used method for determining the fire-resistance rating of concrete masonry assemblies.

The calculation method, in accordance with Appendix D of NBCC-10, is the focus of discussion in this Technical Manual.

5.5 Appendix D, NBCC-10, FRR by the Calculation Method

5.5.1 General

To analytically calculate the fire-resistance rating of concrete block masonry it is helpful to be reminded that, of the various terminating or end-point criteria stated in ULC-S101, concrete masonry walls nearly always reach the heat transmission end-point prior to the passage of flame or gases, or structural failure. Therefore, heat transmission is the controlling factor in establishing the fire-resistance rating of a concrete masonry wall.

Since heat transmission is a function of the temperature distribution through the wall and rate of heat transfer through the wall, it follows that those properties of concrete masonry which affect its thermal conductance (or conversely, its thermal resistance) also affect fire-resistance rating. Because the amount of material in a unit and the density of the material used in the manufacture of the unit strongly influence thermal conductivity, it also follows that these properties are those which principally influence the fire-resistance rating of concrete masonry. Consequently, for a standard masonry unit, its “equivalent thickness” (amount of material in a unit) and the “concrete type” (aggregate type, affecting unit density) are the properties upon which the analytical/calculation method is founded. It also follows that the introduction of material into the cells of concrete masonry units also influences the fire-resistance rating. The introduction of materials into the cells of units is also recognized by the calculation method.

Effect of Aggregate on Unit Density and Fire Resistance Rating

As concrete density (which is determined by aggregate type) is reduced, resistance to heat transmission improves. Other properties being equal, concrete masonry walls constructed of units made from lighter-weight aggregate provide higher fire-resistance ratings than walls constructed with units produced from heavier aggregates. Concrete types, aggregates and unit densities of concrete masonry units are discussed in Chapter 4 of this Manual.

Equivalent thickness and Fire-Resistance Rating

As the thickness of a material increases, so too does its thermal resistance. The concept of “equivalent thickness” of a concrete masonry unit, which is a measure of its solid content, was discussed at length in Chapter 4 of this Manual. As the equivalent thickness of a concrete masonry unit increases, so too does its thermal resistance and so too does the fire-resistance rating of the constructed masonry.

Cell Fill and Fire-Resistance Rating

Completely filling the cells of hollow concrete masonry units with mortar, grout, or loose fill material such as perlite or vermiculite increases the thermal resistance of the assembly and thus, the resulting fire-resistance rating. However, if filling of cells is only done intermittently in the wall, for example where construction is partially reinforced and grouted, the rate of heat transfer through the hollow masonry sections of the wall remains unchanged from otherwise fully hollow construction. Thus, the fire-resistance rating for partially grouted or partially filled concrete masonry construction is rationally assigned the same fire-resistance rating as that for hollow concrete masonry construction. Otherwise stated, the equivalent thickness of a partially grouted concrete masonry wall excludes the contribution of the grout; the grout is ignored.

5.5.2 Calculating FRR for Concrete Masonry

5.5.2.1 Concrete Types

5.5.2.1.1 Concrete Types Recognized by NBCC-10

The various “Types of Concretes” recognized by NBCC-10 for use in calculating the fire-resistance rating of concrete masonry elements are identified and described in Appendix D-1.4. Concrete Type is determined by the type of aggregate and their relative volumes used in the material to manufacture the concrete masonry unit. D-1.4 specifically defines the following concretes for masonry:

Type S concrete is the type in which the coarse aggregate is granite, quartzite, siliceous gravel or other dense materials containing at least 30% quartz, chert or flint.

Type N concrete is the type in which the coarse aggregate is cinders, broken brick, blast furnace slag, limestone, calcareous gravel, trap rock, sandstone or similar dense material containing not more than 30% of quartz, chert or flint.

Type L_1 concrete is the type in which all the aggregate is expanded shale.

Type L_2 concrete is the type in which all the aggregate is expanded slag, expanded clay or pumice.

Type $L_1$20S and Type $L_2$20S concretes are the types in which the fine portion of the aggregate is sand and low density aggregate in which the sand does not exceed 20% of the total volume of all aggregates in the concrete.

Although it is not stated in the NBCC-10, the "volume" of aggregate is a "solid" volume and not a "bulk" volume.

Note that the "Types of Concrete" defined in D-1.4 for use in the calculation of fire-resistance rating differ from those identified in CSA standard A165.1 (Discussed in Chapter 4) and although they both relate to masonry unit density and are closely aligned, there are distinctions.

Appendix D-1.4.3 of NBCC-10 requires that:

1. coarse aggregates comply with CAN/CSA-A23.1, *"Concrete Materials and Methods of Concrete Construction";*
2. low-density aggregates comply with ASTM C 330, *"Lightweight Aggregates for Structural Concrete".*

These referenced standards are fully consistent with those referenced by CSA A165 for normal-weight and light-weight aggregate materials (see Chapter 4).

The producers of concrete masonry units can readily provide to designers either:

1. the fire resistance rating of masonry constructed using a specific product; or,
2. the equivalent thickness and concrete type (in accordance with the NBCC definition) of a specific product from which the fire-resistance rating of the constructed masonry element may be calculated.

5.5.2.1.2 Concrete Types Using Blended, Conventional Aggregates

One disadvantage of using the calculation procedure to determine FRR is that the number of Concrete Types recognized by the NBCC is limited. Although not offered by any standard or Building Code in Canada, the U.S.-based consensus standard ACI 216.1/TMS 0216 permits the basic aggregate types (which are conventional aggregates) to be blended together and the corresponding fire-resistance rating to be adjusted in proportion to the relative quantities of the specific aggregate types used. For additional information on this procedure and the determination of the FRR for concrete masonry units manufactured from blended aggregates, refer to ACI 216.1/TMS 0216, *"Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies"*, or NCMA Tek 07-01C, *"Fire Resistance Ratings of Concrete Masonry Assemblies"*.

5.5.2.1.3 Concrete Types Using "Unconventional" Materials

In recent years, manufacturers of concrete masonry products have been exploring the use and potential benefits of alternative materials. Such materials typically include innovative or proprietary aggregates used to partially or fully replace conventional aggregates. Where concrete products are manufactured using aggregates that do not comply with the standards for aggregates referenced by CSA A165.1 and the standards referenced by Appendix D of the NBCC, the fire-resistance ratings for units and assemblies manufactured from concretes containing these aggregates cannot be determined using the tabled FRR baselines and the calculation methods described in Appendix D. This necessitates the use of full-scale ULC-S101 (or ASTM E 119) fire testing to establish the fire-resistance rating.

Although ULC-S101 (and ASTM E 119) defines procedures for evaluating the fire-resistance rating of concrete masonry assemblies, there has historically been no defined procedure for applying the results of the testing to the standardized calculation procedures available in Appendix D of the NBCC. To provide consistency in applying the results of full-scale ULC-S101 testing to established calculation procedures, the National Concrete Masonry Association has developed a guideline, available for download **here**. Within this guideline, reference is made to ACI 216.1/TMS 0216, *"Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies"*. This U.S.-based consensus standard contains design and analytical procedures for determining the fire-resistance of masonry members and assemblies very similar to those provided in Appendix D, NBCC-10.

This guideline stipulates that when applying the fire-resistance calculation procedure of ACI 216.1/TMS 0216 to products manufactured using unlisted aggregate types, at least two full-scale ASTM E 119 (ULC-S101) tests must be conducted on assemblies containing the unconventional material. Based on the results of the full-scale testing, a simple mathematical expression can be developed in accordance with this industry practice that permits the fire-resistance of units produced with such aggregates to be calculated for interpolated values of equivalent thickness and proportion of non-listed aggregate.

5.5.2.2 Calculating the Fire-Resistance Rating of Concrete Masonry Having No Additional Surface Finish Materials

5.5.2.2.1 Single Wythe Concrete Masonry

The "Equivalent Thickness Method" described in Appendix D of NBCC-10 is used to calculate the fire-resistance rating of concrete masonry assemblies constructed of units which satisfy the requirements of CSA A165.1. In addition to the CSA A165.1 requirements, NBCC-10 requires that a masonry unit of Type N or S Concrete has a specified compressive strength of not less than 15MPa.

Concrete block masonry construction used for both fire separations and firewalls does not require "special" masonry mortars. Conventional Type N and Type S mortars, in accordance with CSA A179-04, *"Mortar and Grout for Unit Masonry"*, are suitable.

Appendix D does not assign or limit fire-resistance ratings of concrete masonry based upon bond pattern (running and stack). Therefore, the determination of the fire resistance rating of concrete masonry is independent of bond pattern.

Table 5.1: *Minimum Equivalent Thicknesses of Concrete Masonry Walls Loadbearing and Non-loadbearing (Adapted from Table D-2.1.1, NBCC-10)*

Wall of Solid or Hollow Concrete Masonry, Concrete Type	Minimum Required Equivalent Thickness in millimetres for Fire-Resistance Rating(2)						
	30 min	45 min	1 h	1.5 h	2 h	3 h	4 h
Type S or N concrete(1)	44	59	73	95	113	142	167
Type $L_1$20S concrete	42	54	66	87	102	129	152
Type L_1 concrete	42	54	64	82	97	122	143
Type $L_2$20S concrete	42	54	64	81	94	116	134
Type L_2 concrete	42	54	63	79	91	111	127

(1) Hollow concrete masonry units made with Type S or N concrete must have a minimum specified compressive strength of 15 MPa, determined in accordance with CSA A165.1.
(2) Fire-resistance rating between the stated rating periods listed may be determined by linear interpolation.

NBCC-10 tables (by way of Table D-2.1.1) the fire-resistance rating for concrete block masonry as a function of the equivalent thickness of the unit and the Concrete Type used in its manufacture. Data pertaining to concrete masonry is reproduced in Table 5.1, herein. The data applies to either loadbearing or non-loadbearing walls (see NBCC-10 for some exceptions to loadbearing walls). Linear interpolation of the data is permitted. Appendix D also provides sample calculations illustrating the use of this method.

The equivalent thickness of a masonry unit is defined and discussed in Chapter 4 of this Manual. In addition to the solid content of the unit itself, D-1.6.1.(6) of NBCC-10 allows certain cell fill materials (such as mortar, grout, vermiculite, perlite) to contribute to equivalent thickness of the assembly. Where cell materials are introduced and where all of the cell spaces are filled, the equivalent thickness of the masonry wall is considered to be the same as that of a wall of solid units, or a solid wall of the same concrete type and the same overall thickness. This also applies to partially grouted concrete masonry walls where all ungrouted cells are filled with an approved material. This is true for all cell fill materials listed in D-1.6.1.(6) where applied to a *fire-separation*. However, in accordance with Sentence 3.1.10.2.(3) of NBCC-10, the required fire-resistance rating of a *firewall* must be provided by masonry or concrete only; the consequence of this Sentence is that the inclusion of cell material other than grout/concrete or mortar cannot contribute to the fire-resistance rating of a masonry *firewall* whether all cells are filled or not.

The data in Table 5.1 demonstrate the general trends discussed in Section 5.5.1:

1. increasing fire-resistance rating with an increase in equivalent thickness; and
2. increasing fire-resistance rating with a decrease in concrete density.

Example 1

Calculating the FRR of a Single Wythe Concrete Masonry Wall (Having No Surface Finishes)

A 140 mm concrete block masonry unit manufactured of Type S Concrete has an equivalent thickness of 105 mm and a specified compressive strength of 11 MPa. Determine its fire-resistance rating by calculation methods.

Solution

To use the data in Table D-2.1.1 of NBCC-10, concrete masonry units of Type S or N concrete must have a (specified) compressive strength of not less than 15 MPa (Note 2 to Table D-2.1.1)

The fire-resistance rating of this wall cannot be calculated using the requirements in Appendix D, NBCC-10.

Example 2

Calculating the FRR of a Single Wythe Concrete Masonry Wall (Having No Surface Finishes)

A 140 mm concrete block masonry unit manufactured of Type S Concrete has an equivalent thickness of 105 mm and a specified compressive strength of 19.4 MPa. Determine its fire-resistance rating by calculation methods.

Solution

The specified compressive strength of the unit exceeds the minimum limiting value of 15 MPa for units of Type S concrete; hence, the calculation methods permitted by Appendix D of NBCC-10 may be used to determine the fire-resistance rating.

For Type S Concrete, Table D-2.1.1 lists the following required equivalent thicknesses for a stated fire-resistance rating:

- 95 mm for 1.5 hrs.
- 113 mm for 2 hrs.

Determine the fire-resistance rating using linear interpolation (ratios):

FRR = 1.5 hrs.+[(105 – 95) / (113 – 95)](2 hrs. – 1.5 hrs.) = 1.77 hrs. = 106 min.

Example 3

Calculating the FRR of a Single Wythe Concrete Masonry Wall (Having No Surface Finishes)

The required fire-resistance rating of a concrete masonry wall is 3 hrs. It is desired to use a 190 unit manufactured from $L_2$20S Concrete. Calculate the required equivalent thickness to achieve this fire-resistance rating for a fire-separation. The specified compressive strength is intended to exceed 15 MPa.

Solution

To use Appendix D, there is no minimum compressive strength prescribed by NBCC-10 for units manufactured from $L_2$20S Concrete. The limitation applies only to Type N or S Concrete.

The required equivalent thickness of the unit can be readily determined from the data in Table D-2.1.1, without calculation.

For $L_2$20S Concrete, an equivalent thickness of 116 mm is required for a 190 mm unit.

Example 4

Calculating the FRR of a Single Wythe Concrete Masonry Wall (Having No Surface Finishes)

The solid content of a 250 mm concrete masonry unit is 53%. The unit is manufactured from L_1 Concrete. Determine the FRR for a fire separation of concrete masonry constructed with these units.

Solution

Calculate equivalent thickness = 0.53 x 240 mm = 127.2

For Type L_1 Concrete, Table D-2.1.1 lists the following required equivalent thicknesses for a stated fire-resistance rating:

- 122 mm for 3.0 hrs.
- 143 mm for 4.0 hrs.

Determine the fire-resistance rating using linear interpolation (ratios):

FRR = 3.0 hrs.+[(127.2 – 122) / (143 – 122)](4.0 hrs. – 3.0 hrs.) = 194 min.

Example 5

Calculating the FRR of a Single Wythe Concrete Masonry Wall (Having No Surface Finishes)

The solid content of a 140 mm concrete masonry unit is 58%. The unit is manufactured from L_1 Concrete and will be filled fully solid with grout on-site. Determine the FRR for a fire separation of concrete masonry constructed with these units.

Solution

Calculate equivalent thickness: in accordance with D-1.6.1.(6), the cell fill material (grout) contributes to the equivalent thickness of the wall; the resulting equivalent thickness is the same as that of a wall of solid units because it is fully grouted = 140 mm

For Type L_1 Concrete, Table D-2.1.1 lists the following required equivalent thicknesses for a stated fire-resistance rating:

- 122 mm for 3.0 hrs.
- 143 mm for 4.0 hrs.

Determine the fire-resistance rating using linear interpolation (ratios):

FRR = 3.0 hrs.+[(140 – 122) / (143 – 122)](4.0 hrs. – 3.0 hrs.) = 231 min.

Example 6

Calculating the FRR of a Single Wythe Concrete Masonry Wall (Having No Surface Finishes)

The solid content of a 190 mm concrete masonry unit is 56%. The unit is manufactured from Type $L_2$20S Concrete. A concrete masonry fire separation will be constructed with these units and filled with grout at vertical reinforcement locations having a typical 800 mm spacing. Determine the FRR for this concrete masonry wall.

Solution

Calculate equivalent thickness: all cell spaces have not been filled, hence, the equivalent thickness of the wall is that provided by the units only [D-1.6.(6), NBCC-10]; equivalent thickness = 0.56 x 190 = 106.4 mm.

For Type $L_2$20S Concrete, Table D-2.1.1 lists the following required equivalent thicknesses for a stated fire-resistance rating:

- 94 mm for 2.0 hrs.
- 116 mm for 3.0 hrs.

Determine the fire-resistance rating using linear interpolation (ratios):

FRR = 2.0 hrs.+[(106.4 – 94) / (116 – 94)](3.0 hrs. – 2.0 hrs.) = 153 min.

5.5.2.2.2 Multi-Wythe Concrete Masonry

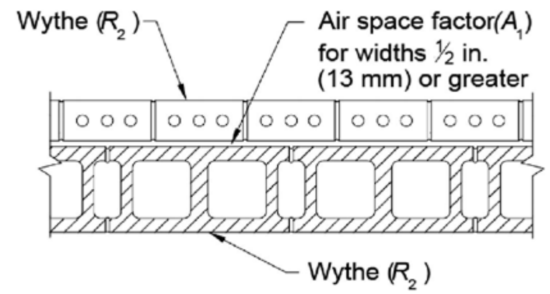
Appendix D-2.1.2, NBCC-10 permits the calculation method to determine the fire-resistance rating of multi-wythe masonry walls, including cavity walls (having two parallel wythes of masonry with an included air space) under the following conditions:

1. D-2.1.2.(4): Masonry cavity walls loaded to a compressive stress exceeding 380 kPa are excluded from the calculation method;
2. D-2.1.2.(3): Masonry cavity walls that are loaded to a compressive strength of not more than 380 kPa have an equivalent thickness equal to the sum of the equivalent thicknesses of the two wythes;
3. D-2.1.2.(5): A multi-wythe masonry wall (including a cavity wall) is considered to have a fire-resistance rating equal to that which would apply if the whole of the wall were of the material that gives the lesser rating.

D-2.1.2.(2) states that a masonry cavity wall (with included air space) will provide a fire-resistance rating at least as great as that of a solid wall of a thickness equal to the sum of the equivalent thicknesses of the two wythes (Figure 5.2). This statement acknowledges that the air space provides fire-resistance.

When multi-wythe walls are constructed of concrete masonry, the endurance period of the composite wall is greater than the summation of the individual fire endurance periods of its component wythes. Unlike NBCC-10, ACI 216.1/TMS 0216 directly acknowledges the contribution of the air space in cavity walls and of each wythe and provides an empirical equation for doing so. For additional information on this procedure, refer directly to ACI 216.1/TMS 0216 or to NCMA Tek 07-01C, *"Fire Resistance Ratings of Concrete Masonry Assemblies"*.

Figure 5.2: *Fire-Resistance Rating of Cavity Walls (Ref 16)*



R_1 = Fire resistance rating of wythe 1
R_2 = Fire resistance rating of wythe 2
A_1 = Air space factor = 0.3

Example 7

Calculating the FRR of a Multi-Wythe Concrete Masonry Wall by NBCC-10

One wythe of a two-wythe concrete masonry cavity wall is constructed of partially grouted, 58% solid, 140 mm units of Type L_2 Concrete (Wythe 1). The second wythe is constructed of 73% hollow units, 90 mm, of Type S Concrete (no cell fill) (Wythe 2). All units are of Type S Concrete and have a (specified) compressive strength of 21 MPa. The fire separation serves as a non-loadbearing partition. Determine the FRR for this concrete masonry wall.

Solution by NBCC-10

Calculate equivalent thickness:

- Non-loadbearing partition, therefore the requirements of Appendix D, NBCC-10 are applicable;
- Two differing Concrete Types; equivalent thickness for the whole of the wall is established using the material providing the lesser rating…use Type S Concrete for both wythes;
- Compressive strength of the Type S units exceeds 15 MPa; hence the calculation method may be used to determine FRR for these units;
- Contribution by partial grouting is ignored;
- Equivalent thickness for the whole of the wall is the sum of the equivalent thicknesses for both walls;

- Hence:
  - o EQ (Wall) = EQ (Wythe 1) + EQ (Wythe 2)
  - o EQ (Wall) = 0.58 x 140 + 0.73 x 90 = 146.9 mm
  - o EQ = 146.9 mm, Type S Concrete

For Type S Concrete, Table D-2.1.1 lists the following required equivalent thicknesses for a stated fire-resistance rating:

- 142 mm for 3.0 hrs.
- 167 mm for 4.0 hrs.

Determine the fire-resistance rating using linear interpolation (ratios):

FRR = 3.0 hrs.+[(146.9 – 142) / (167 – 142)](4.0 hrs. – 3.0 hrs.) = 191 min.

5.5.2.3 Calculating the Fire-Resistance Rating of Concrete Masonry Having Additional Finishes

Gypsum board or plaster is oftentimes applied to concrete block masonry walls either to provide an alternative surface finish, or to improve the fire-resistance rating of the wall. NBCC-10 makes provision for calculating the additional fire-resistance provided by these finishes, whether applied to the fire-exposed or non-fire-exposed side of a concrete masonry wall. To provide the additional fire-resistance rating, these materials and their methods of installation and attachment must satisfy the requirements stated in D-1.7.2 and D-1.7.3. A discussion of these particular requirements is beyond the scope of this Manual.

When these finishes are used to achieve a required fire-resistance rating, certain conditions must be met to ensure structural integrity during a fire:

- the finish must be continuous over the entire face of the masonry wall;
- in accordance with D-1.7.1.(2), the fire-resistance rating of the masonry alone must provide at least half of the total required rating; and
- by D-1.7.1.(4), the contribution of the finish on the non-fire-exposed side cannot be more than one-half of the contribution of the masonry alone.

Certain finishes deteriorate more rapidly when positioned on the fire-exposed face than on the non-fire-exposed face of the masonry and for the same material/assembly, its exposure affects its contribution to the fire-resistance rating of the wall assembly.

For finishes positioned on the non-fire-exposed side of the wall assembly, the contribution of the finish material to fire-resistance is determined as follows:

- the thickness of finish is converted to an adjusted thickness by multiplying the finish thickness by a factor obtained from Table D-1.7.1 of NBCC-10 (Table 5.2, herein), the magnitude of which depends on the type of finish and the Concrete Type of the masonry;
- the adjusted thickness of finish is considered to be an equivalent thickness of concrete masonry for the Concrete Type;
- the adjusted thickness is added to the equivalent thickness of the concrete masonry to yield an equivalent thickness for the entire assembly;
- the fire-resistance rating for the assembly is determined using Table D-2.1.1

For finishes positioned on the fire-exposed side of the wall assembly, the contribution of the finish material to fire-resistance is established as follows:

- the time assigned to the finish material is determined using Table D-2.3.4A (Table 5.3, herein) or D-2.3.4B (Table 5.4, herein) of NBCC-10 (the stated times are essentially the length of time the various finishes will remain integral when exposed directly to fire);
- the time assigned to the finish material is added directly to the fire-resistance rating of the concrete masonry wall determined using Table D-2.1.1;
- where finish materials are applied to both sides of the concrete masonry wall, the time assigned to the finish material on the fire-exposed side is added to the fire-resistance rating determined for the concrete masonry and the non-fire-exposed finish.

Article 3.1.7.3 of NBCC-10 requires partitions and interior walls to be rated for exposure from both sides. If

Table 5.2: *Multiplying Factors for Finishes on Non-Fire-Exposed Side of Concrete Masonry Construction (Adapted from Table D-1.7.1, NBCC-10)*

Type of Surface Protection	Type of Concrete Unit Masonry			
	Type S or N	Type $L_1$20S	Type L_1 or $L_2$20S	Type L_2
Portland cement-sand plaster or lime-sand plaster	1	0.75	0.75	.50
Gypsum/sand plaster, wood fibred gypsum plaster or gypsum wallboard	1.25	1	1	1
Vermiculite or perlite aggregate plaster	1.75	1.5	1.25	1.25

Table 5.3: *Time Assigned to Wallboard Membranes on Fire-Exposed Side of Concrete Masonry Construction, minutes (Adapted from Table D-2.3.4A, NBCC-10*)

Description of Finish	Time, minutes
11.0 mm Douglas Fir plywood phenolic bonded	10 (1)
14.0 mm Douglas Fir plywood phenolic bonded	15 (1)
12.7 mm Type X gypsum wallboard	25
15.9 mm Type X gypsum wallboard	40
Double 12.7 mm Type X gypsum wallboard	80 (2)

Notes to Table D-2.3.4.A:

(1) Non-loadbearing walls only, stud cavities filed with mineral wool conforming to CAN/ULC-S702, *"Mineral Fibre Thermal Insulation for Buildings,"* and having a mass of not less than 2 kg/m^2, with no additional credit for insulation according to Table D-2.3.4.D.

(2) Applies to non-loadbearing steel framed walls only.

Table 5.4: *Time Assigned for Contribution of Lath and Plaster Protection on Fire-Exposed Side of Concrete Masonry Construction, minutes (Adapted from Table D-2.3.4B, NBCC-10)*

Type of Lath	Plaster Thickness, mm	Type of Plaster Finish		
		Portland Cement and Sand(2) or Lime and Sand	Gypsum and Sand or Gypsum Wood Fibre	Gypsum and Perlite or Gypsum and Vermiculite
9.5 mm Gypsum	13	–	35	55
	16	–	40	65
	19	–	50	80(1)
Metal	19	20	50	80(1)
	23	25	65	80(1)
	26	30	80	80(1)

Notes to Table D-2.3.4.B:

(1) Values shown for these membranes have been limited to 80 min because the fire-resistance ratings of framed assemblies derived from these Tables shall not exceed 1.5 hours.

(2) For mixture of Portland cement/sand plaster, see D-1.7.2.(2).

the wall is not symmetrical by design, the fire-resistance rating of the assembly must be based on determination from the least fire-resistant side. Consequently, calculations to determine the fire-resistance rating of walls having finish materials on one side, or finishes of different types and thicknesses on each side, must be performed twice. The lesser of the two calculated values becomes the established fire-resistance rating. For exterior walls, Article 3.1.7.3 only requires rating for exposure from inside a building.

Appendix D-1.7.4, NBCC-10, provides sample calculations to clearly illustrate the use of the calculation procedures for various finishes over concrete block masonry walls.

Example 8

Calculating the FRR of a Concrete Masonry Wall Having Additional Surface Finishes

A concrete block masonry wall is constructed of 190 concrete block units of Type N or Type S Concrete, having a solid content of 56%. The specified compressive strength of the unit exceeds 15 MPa. It is a non-loadbearing partition. This wall is to serve as a fire separation having a fire-resistance rating of 2 hrs. Determine if the application of gypsum board will achieve this FRR.

Solution by NBCC-010

Calculate equivalent thickness of the CM = 0.56 x 190 mm = 106.4 mm.

For Type S or N Concrete, Table D-2.1.1 lists the following required equivalent thicknesses for a stated fire-resistance rating:

- 95 mm for 1.5 hrs.
- 113 mm for 2.0 hrs.

Determine the fire-resistance rating using linear interpolation (ratios):
FRR = 1.5 hrs.+[(106.4 – 95) / (113 – 95)](2.0 hrs. – 1.5 hrs.) = 109 min.

Where the gypsum board is applied to the non-fire-exposed face:

- Place 12.7 mm Type X gypsum board
- Correction factor for PCL plaster over CMU is 1.25 (Table D-1.7.1)
- Added thickness = 1.25 x 12.7 = 15.8 mm
- 106 mm (masonry) + 15.8 (gypsum) = 122 mm > 113, therefore a 2-h FRR is provided
- D-1.7.1.2: $FRR_{assembly} \le 2 \times FRR_{masonry}$?
  - o $FRR_{assembly}$:
    2.0 hrs.+[(122 – 113) / (142 – 113)](3.0 hrs. – 2.0 hrs.) = 138 min.
  - o $FRR_{masonry}$: 109 min (previously calculated)
  - o 138 min. ≤ 2 x 109; therefore, O.K.
- D-1.7.1.4: $FRR_{gypsum\ board} < FRR_{masonry}$?
  - o $FRR_{gypsum\ board}$ = 138 – 109 = 29 min.
  - o $FRR_{masonry}$ = 109 min.
  - o 29 min. < 109 min; therefore, O.K.

Where the gypsum is applied to the fire-exposed face:

- Place 12.7 mm Type X gypsum board
- Added time = 25 min. (Table D-2.3.4.A)
- $FRR_{assembly} = FRR_{masonry} + FRR_{gypsum\ board}$
  $FRR_{assembly}$ = 109 min. + 25 min. = 134 min. > 120 min; therefore, O.K.

The addition of 12.7 Type X gypsum to a 190 mm CMU of Type S or N Concrete will increase the FRR of the wall to above 2-hrs., regardless of the side of the masonry to which the gypsum wallboard is attached.

Example 9

Calculating the FRR of a Concrete Masonry Wall Having Additional Surface Finishes

A concrete block masonry wall is to be constructed of 90 concrete block units. The specified compressive strength of the unit exceeds 15 MPa. At this time, it is not known if the wall will be exposed to fire on both sides. It is to serve as a fire separation having a fire-resistance rating of 2 hrs. Determine if this FRR can be met using an unfinished masonry wall. If finish is required, determine the required equivalent thickness of the CMU, and the various options to be considered with respect to the Concrete Type required of the CMU, and the required thickness of gypsum board.

Solution by NBCC-010

1. Where gypsum is not applied (unfinished CMU):

- the following equivalent thicknesses are required to provide a 2-hr. FRR, as a function of CMU Concrete

Type (Table D-2.1.1):

- o Type N or S: 113 mm
- o Type $L_1$20S: 102 mm
- o Type L_1: 97 mm
- o Type $L_2$20S: 94 mm
- o Type L_2: 91 mm

- a fully solid 90 mm CMU provides an EQ of 90 mm
- for all Concrete Types, the required EQ exceeds 90 mm, and it is not possible to achieve a 2-hr. FRR using an unfinished 90 mm CMU.

2. Applying one layer of Type X GB:

a. where GB is applied to the fire-exposed face:
   i. using 16 mm gypsum board or 12.7 mm GB, the contribution of the GB to the EQ of the CMU wall is (D-1.7.1.5 and Table D-2.3.4.A):
      1. 16 mm GB: 40 min.
      2. 12.7 mm GB: 25 min.
   ii. the FRR required of the CMU is calculated:
      1. using 16 mm GB: 120 – 40 = 80 min.
      2. using 12.7 GB: 120 – 25 = 95 min.
   iii. a fully solid 90 mm CMU provides an EQ of 90 mm
   iv. the FRRs offered by 90 mm masonry construction of various concrete types are as follows (using Table D-2.1.1 and linear interpolation):
      1. where the unit is:
         a. Type N or S: 1 hr. + (90 – 73)/(95 – 73)(0.5 hr) = 1.386 hrs. = 83 min. (> 80 mm required, where 16 mm GB is used)
         b. Type $L_1$20S: 1.5 hr + (90 – 87)/(102 – 87)(0.5 hr) = 1.6 hr. = 96 min. (> 95 mm required, where 12.7 mm GB is used)
         c. Type L_1: 1.5 hr + (90 – 82)/(97 – 82)(0.5 hr) = 1.767 hr. = 106 min. (> 95 mm required, where 12.7 mm GB is used)
         d. Type $L_2$20S: 1.5 hr + (90 – 81)/(94 – 81)(0.5 hr) = 1.846 hr. = 110 min. (> 95 mm required, where 12.7 mm GB is used)
         e. Type L_2: 1.5 hr + (90 – 79)/(91 – 79)(0.5 hr) = 1.958 hr. = 117.5 min. (> 95 mm required, where 12.7 mm GB is used)
   v. the calculated FRR of the assembly must not exceed twice the FRR provided by the masonry (D-1.7.1.2):
      1. for 16 mm GB over CMU of Type N or S concrete:
         i. $FRR_{masonry}$ = 83 min
         ii. $FRR_{16\ GB}$ = 40 min
         iii. $FRR_{assembly}$ = 123 min
         iv. $FRR_{assembly}/FRR_{masonry}$ = 123/83 = 1.48 < 2.0, O.K.
      2. for 12.7 mm GB over CMU of other than Type N or S concrete:
         a. Type $L_1$20S:
            i. $FRR_{masonry}$ = 96 min
            ii. $FRR_{12\ GB}$ = 25 min
            iii. $FRR_{assembly}$ = 121 min
            iv. $FRR_{assembly}/FRR_{masonry}$ = 121/96 = 1.26 < 2.0, O.K.
         b. Type L_1:
            i. $FRR_{masonry}$ = 106 min
            ii. $FRR_{12\ GB}$ = 25 min
            iii. $FRR_{assembly}$ = 131 min
            iv. $FRR_{assembly}/FRR_{masonry}$ = 131/106 = 1.24 < 2.0, O.K.
         c. Type $L_2$20S:
            i. $FRR_{masonry}$ = 110 min
            ii. $FRR_{12\ GB}$ = 25 min
            iii. $FRR_{assembly}$ = 135 min
            iv. $FRR_{assembly}/FRR_{masonry}$ = 135/110 = 1.23 < 2.0, O.K.
         d. Type L_2:
            i. $FRR_{masonry}$ = 117.5 min
            ii. $FRR_{12\ GB}$ = 25 min
            iii. $FRR_{assembly}$ = 142.5 min
            iv. $FRR_{assembly}/FRR_{masonry}$ = 143/118 = 1.21 < 2.0, O.K.
   vi. in summary, where the GB is applied to the fire-exposed face:
      1. where a 90 mm fully solid unit manufac-

tured from Type N or S concrete is used:
   a. application of a single layer of 16 mm GB will provide a 2-hr FRR for the assembly
2. where a 90 mm fully solid unit manufactured *from other* than Type N or S concrete is used:
   a. application of a single layer of 12.7 mm GB will provide a 2-hr. FRR for the assembly.

b. where GB is applied to the non-fire-exposed side:
   i. where the CMU are manufactured form Type N or S concrete:
      1. the EQ required to achieve a 2-hr. FRR is 113 mm (Table D-2.1.1)
      2. the contribution of the GB to the CMU wall is (D-1.7.1.4, D-1.7.1.1, and Table D-1.7.1):
         a. 16 mm GB: 1.25 x 16 = 20 mm
         b. 12.7 mm GB: 1.25 x 12.7 = 16 mm
      3. the EQ required of the Type N or S CMU is:
         a. 16 mm GB: 113 – 20 = 93 mm
         b. 12.7 mm GB: 113 – 16 = 97 mm
      4. a fully solid 90 mm CMU provides an EQ of 90 mm
      5. in summary, where GB is applied to the non-fire-exposed face:
         a. where a 90 mm solid unit of Type N or S Concrete is used:
            i. application of a single layer of 16 mm GB will not provide a 2-hr. FRR for the assembly.
   ii. where the CMU are of *other than* Type N or S concrete:
      1. the following equivalent thicknesses are required to achieve a 2-hr. FRR (Table D-2.1.1):
         a. Type $L_1$20S: 102 mm
         b. Type L_1: 97 mm
         c. Type $L_2$20S: 94 mm
         d. Type L_2: 91 mm
      2. the contribution of the GB to the CMU wall is (D-1.7.1.4, D-1.7.1.1, and Table D-1.7.1):
         a. 16 mm GB: 1.00 x 16 = 16 mm
         b. 12.7 mm GB: 1.00 x 12.7 = 12 mm
      3. the EQ required of the CMU is calculated:
         a. Type $L_1$20S:
            i. 16 mm GB: 102 – 16 = 86 mm
            ii. 12 mm GB: 102 – 12 = 90 mm
         b. Type L_1:
            i. 16 mm GB: 97 – 16 = 81 mm
            ii. 12 mm GB: 97 – 12 = 85 mm
         c. Type $L_2$20S:
            i. 16 mm GB: 94 – 16 = 78 mm
            ii. 12 mm GB: 94 – 12 = 82 mm
         d. Type L_2:
            i. 16 mm GB: 91 – 16 = 75 mm
            ii. 12 mm GB: 91 – 12 = 79 mm
      4. a fully solid 90 mm CMU provides an EQ of 90 mm, which exceeds the thicknesses required for all Concrete Types other than Type N or S
      5. where the GB is applied to the fire-exposed side, the contribution of the GB must not exceed 0.5 times the contribution of the masonry (D-1.7.1.4);
         a. and since the FRR offered by the 90 mm solid masonry is greater than 1 hr, this condition is met
      6. the calculated FRR of the assembly must not exceed twice the FRR provided by the masonry (D-1.7.1.2):
         a. for all 90 mm fully solid units, regardless of Concrete Type, the masonry contributes 90 mm of EQ
         b. 16 mm GB contributes 16 mm of EQ
         c. 12.7 mm GB contributes 12.7 mm of EQ
         d. for 16 mm GB:
            i. $FRR_{assembly}$ = 90 + 16 = 106
            ii. $FRR_{masonry}$ = 90 mm
            iii. $FRR_{assembly}$/ $FRR_{masonry}$ = 106/90 = 1.18 < 2.0, O.K.;

   e. For 12.7 mm GB:
      i. $FRR_{assembly} = 90 + 12 = 102$
      ii. $FRR_{masonry} = 90$ mm
      iii. $FRR_{assembly}/ FRR_{masonry} = 102/90 = 1.13 < 2.0$, O.K.
7. in summary, where the GB is applied to the non-fire-exposed face, the application of a single layer of either 16 mm or 12.7 mm GB is sufficient where masonry units are of *other than* a Type N or S concrete.

3. It is important to reiterate that:
When gypsum board finishes are used to achieve a required fire-resistance rating, certain conditions must be met to ensure structural integrity during a fire:

- the finish must be continuous;
- in accordance with D-1.7.1.(2), the fire-resistance rating of the masonry alone must provide at least half of the total required rating;
- by D-1.7.1.(4), the contribution of the finish on the non-fire-exposed side cannot be more than one-half of the contribution of the masonry alone;
- Article 3.1.7.3 of NBCC-10 requires partitions and interior walls to be rated for exposure from both sides. If the wall is not symmetrical by design, the fire-resistance rating of the assembly must be based on determination from the least fire-resistant side. Consequently, calculations to determine the fire-resistance rating of walls having finish materials on one side, or finishes of different types and thicknesses on each side, must be performed twice. The lesser of the two calculated values becomes the established fire-resistance rating. For exterior walls, Article 3.1.7.3 only requires rating for exposure from inside a building.

5.5.2.4 Masonry Firewalls: Determining FRR

The NBCC defines a distinct difference between a *firewall* and a *fire separation*. A detailed discussion about firewalls is provided in Chapter 5A of this Manual.

Specific to fire-resistance rating for firewalls, Sentence 3.1.10.2.(3) of NBCC-10 prescribes that the fire-resistance rating of a concrete masonry *firewall* be provided by masonry or concrete only. Consequently and strictly-speaking, the inclusion of cell material other than grout/concrete or mortar cannot contribute to the fire-resistance rating of a masonry *firewall* whether all cells are filled or not. Appendix A-3.1.10.(4) explains that inherent in the use of a *firewall* is the intent that the wall construction also provides resistance to physical damage arising out of normal use that would compromise the fire-resistance rating of the assembly. Specific to concrete masonry construction, the use of mortar or grout fill, unlike loose fill materials such as vermiculite or perlite, will not lead to a spill of the cell material and the attendant lose of fire-resistance rating if the face shell of the masonry unit is compromised. This has been a prescriptive requirement for concrete masonry firewalls for many editions of the NBCC.

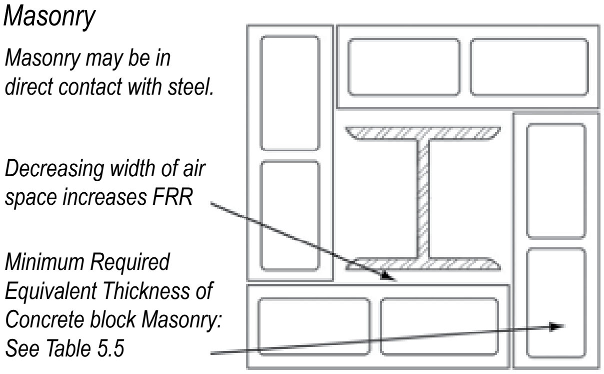
However, new objective-based requirements for firewalls introduced in NBCC-10 opens the possibility for innovative, alternative means to protect masonry firewalls from physical damage while concurrently achieving the required fire-resistance rating using loose fill materials other than mortar/grout. However, the means to demonstrate compliance and the pass/fail criterion can certainly be called into question since neither are stated in the Building Code.

5.5.2.5 Protected Steel Columns

Concrete masonry can be used as a non-loadbearing fire protection covering for structural steel columns (Figure 5.3). The minimum thickness of this covering is stated in Table D-2.6.1.A of NBCC-10 for fire-resistance ratings of 30 min. to 4 hrs. These thicknesses are shown in Table 5.5, herein. The stated thickness is the required “equivalent thickness” of the concrete masonry covering, determined in accordance with the methods described in D-1.6 (that is, in accordance with the requirements described in this Manual).

Decreasing the width of air space between masonry and steel has the effect of increasing the fire resistance

Figure 5.3: *Protecting Steel Columns with Concrete Masonry*



rating. The space between the steel column and the constructed masonry need not be filled. The concrete masonry may be in direct contact with the steel member, however, consideration should be given to the magnitude of differential movement between the two elements to ensure that load transfer does not occur.

NBCC-10 requires that the concrete masonry be reinforced with 5.21 mm dia. wire or wire mesh with 1.19 mm dia. wire and 10 mm x 10 mm openings, laid in every second course. It is interesting to note that this simple prescriptive requirement for 5.21 mm dia. wire is inconsistent with the maximum permissible diameter for wire reinforcement provided in CSA A371, *"Masonry Construction for Buildings"*. CSA A371 limits joint reinforcement to a maximum diameter of one-half the joint thickness, or 5 mm for a standard masonry joint used in today's construction. In order to satisfy both the NBCC-10 and CSA A371 requirements, a rational alternative solution should be used, one which offers an equivalent cross-sectional area of wire reinforcement to that prescribed by the NBCC (5.21 mm dia. wire every second course). This is the approach taken on this issue by the International Building Code in the United States which permits "equivalent reinforcement" to that prescribed. To provide equivalent reinforcement, a single 3.65 mm (9 gauge) diameter wire should be placed in each bed joint of the masonry (each course) (where the masonry unit is a fully solid unit, this wire may be placed along the centerline of the unit), or double wire of 3.65 mm diameter should be placed in every second course (using ladder or truss joint reinforcement) where the unit is hollow or semi-solid (and where each wire is embedded within a face shell of the masonry unit). It is interesting to note that the prescribed requirement for wire mesh by the NBCC does not state a minimum required width of mesh, and thus, the requirement is incomplete, and establishing compliance is strictly not possible. Additionally, note that "failure" of the masonry column protection is established by temperature rise between the exposed and unexposed face (and thus, the basis for equivalent thickness using concrete type), and is fundamentally unrelated to the amount of joint reinforcement in the masonry enclosure.

The concrete masonry can be designed in accordance with CSA S304.1 using either the engineered compliance path or empirical design. Empirical design requirements for a column box-out are provided in Annex F of CSA S304.1-04.

To achieve the same fire resistance rating, note that the requirements for solid content differ for masonry walls and masonry providing column protection because different end-point criteria are used to identify failure. The fire resistance rating for steel column protection is determined as the period of time for the average tem-

Table 5.5: *Minimum Equivalent Thickness of Concrete Masonry Protection to Steel Columns (Adapted from Table D-2.6.1.A, NBCC-10)*

Description of Cover	Fire Resistance Rating						
	30 min	45 min	1 h	1.5 h	2 h	3 h	4 h
Concrete Masonry Units							
Type S concrete (column spaces not filled)	50	50	50	50	64	89	115
Type N or L concrete (column spaces not filled)	50	50	50	50	50	77	102

perature of the steel to exceed 1,000 °F (538°C) or for the temperature at any measured point to exceed 1,200 °F (649°C). For masonry walls, the assembly is considered to fail the fire endurance test where transmission of heat through the wall raises the average temperature on its unexposed surface more than 250 F° (139 C°) above its initial temperature, or raises the temperature of a thermocouple on the unexposed face greater than 325 F° (181 C°).

5.6 Building Services in Fire Rated Assemblies: Fire Stopping of Service Penetrations

5.6.1 Continuity of Fire Separations

Articles 3.1.8.1 and 3.1.8.3 of NBCC-10 require that a fire separation either be constructed as a continuous element or that continuity be provided otherwise at openings, and where it abuts against another separation. And to maintain continuity and ensure integrity of the fire separation, openings in and between them are required to be protected with closures, shafts or “other means”. In accordance with Sentence 3.1.9.1.(1), “other means” is interpreted to be a fire stop system.

A fire stop system is a material, component or assembly of a specific construction and its means of support, used to fill openings and spaces between fire separations, between fire separations and other construction assemblies, or used around items such as electrical, plumbing or mechanical services which wholly or partially penetrate fire separations. Its function is to prevent the passage of flames and gases, and to restore the hourly fire-resistance rating of the fire separation.

For most fire separations, an exception to the use of a fire stop system is provided in Sentence 3.1.9.1.(1) of NBCC-10. For fire separations other than firewalls, a penetration need not be sealed using a fire stop system where it is cast-in-place. The term “cast-in-place”, or grouted-in-place, is interpreted to mean “tightly fitted”, which is the term used in the 1995 edition of the NBCC. The intent is to have no gaps between the penetrating service and the fire separation it penetrates, to ensure that the passage of flames and hot gases are restricted for the required fire-resistance rating period. Additionally, differential movements such as expansion and contraction must be accommodated so that the “seal” is not compromised. For firewalls, the NBCC does not permit penetrating items to be cast-in-place but requires a fire stop system [3.1.9.1.(1) of NBCC-10].

The Appendix Note to Clause 3.1.8.1.(1)(b) provides guidance on the need for fire separations to resist the spread of smoke. Thus, fire stops installed in fire separations must be able to resist the passage of smoke to some extent and for a finite time, however, the NBCC is unclear as to the length of time.

There are some differences between requirements for fire stop systems in Part 3 and Part 9. The discussion in this Manual will focus on requirements pertaining to Part 3. Where a firewall is used to create two Part 9 buildings, the firewall and any penetrations through it must comply with Part 3 requirements.

Detailed discussion on fire stop systems are provided in *References 2 and 14*.

5.6.2 Fire Stop Systems

By Article 3.1.9.1 of NBCC-10, fire stop systems are to be tested to the requirements of ULC-S115, *“Standard Method of Fire Tests of Firestop Systems”.* The test consists of exposure of test samples to a fire of standard time and temperature (the same time-temperature curve used by ULC-S101 and ASTM E 119) and to an application of a hose stream.

Four ratings are established by ULC-S115:

- **“F rating”**: an hourly rating indicating the time period for which the assembly will withstand the passage of flame or the occurrence of flaming on any element of the unexposed side of the assembly; does not provide protection against high temperatures on the unexposed face; does not provide protection against the spread of smoke;
- **“FT rating”**: an hourly rating indicating the time period for which the assembly will withstand the passage of flame as for F rating, and a temperature rise of 181 C° [325 F°] above ambient on the

unexposed face of the assembly during the same period;

- **"FH rating"**: an hourly rating indicating how long the assembly will withstand the passage of flame as for F rating, with successful performance under the application of a hose stream to simulate thermal shock; an "FH rating" is not required by the NBCC;
- **"FTH rating"**: an hourly rating indicating how long the assembly will withstand the passage of flame, temperature rise, and hose stream performance; an "FTH rating" is not required by the NBCC.

The hourly ratings apply only to the complete system. The individual components are not assigned ratings and are not intended to be interchanged between systems.

For the majority of fire stop applications, the NBCC requires an "F rating" [3.1.9.1.(1)], except that an "FT rating" is necessary where a firewall is penetrated [3.1.9.1.(2)]. Application of the hose stream test is therefore not mandatory for fire stop systems under the requirements of NBCC-10. Unless otherwise stated for fire stop systems, the differential pressure between the exposed and unexposed surfaces of the tested assembly measured during the fire test is 2.5 – 10 Pa. The fire stop systems for some types of piping are required by the NBCC to be tested by ULC-S115 under a 50 Pa pressure differential between the exposed and unexposed sides. The user is referred to the NBCC for the specific requirements for the various types of piping and associated fire stop systems.

Where an "F rated" fire stop system is required, the fire stop system must provide an hourly F-rating not less than that stated for closures in NBCC-10 Table 3.1.8.4 (Table 5.6, herein). The required "F rating" is dependent upon the fire resistance rating of the fire separation into which the fire stop system is included, and is "one rating level below" the fire resistance rating required for the fire separation.

Where an "FT rated" fire stop system is required (e.g., firewall), the fire stop system must provide an hourly "FT rating" not less than the required fire-resistance rating of the fire separation (Table 5.6, herein).

Sentence 3.1.8.3.(4) and its Appendix Note identify the need for fire stops to maintain continuity where fire separations abut other assemblies, however, the NBCC does not clearly state how the integrity of a fire separation should be maintained across a joint separating a rated fire separation from a non-rated fire separation.

Fire stop systems used in Canadian construction must be subjected to the ULC-S115 test in order to comply with Canadian building code requirements. "Listed fire stop systems" are systems which have been tested to ULC-S115 by a recognized testing agency, with proof of testing and subsequent follow-up service provided by an independent certification agency. In Canada, fire stop systems achieving these ratings are certified by Underwriters' Laboratories of Canada, Underwriters laboratories Inc. and Intertek Testing Services.

A variety of fire stop materials and products are available on the market, and include:

- caulks and sealants
- putties
- mortars and grouts

Table 5.6: *Required Fire Protection Rating for Fire Stop Systems (Adapted from Table 3.1.8.4, NBCC-10)*

Fire-Resistance Rating of Fire Separation	Fire Stop System	
	F Rating	FT Rating
45 min	45 min	45 min
1 h.	45 min	1 h
1.5 h.	1 h	1.5 h
2 h.	1.5 h	2 h
3 h.	2 h.	3 h
4 h	3 h	4 h

- foams
- coatings and sprays
- wraps
- blocks, pillows and bags
- composite sheets and boards
- fire stop devices
- generic materials (such as mineral wool, gypsum plaster, or Portland cement mortar)

5.6.3 Through-Penetration Fire Stops

Through-penetration fire stop systems are used when a penetrant passes entirely through a fire separation. A through-penetration fire stop system consists of a fire-rated wall, a penetrating item such as a plumbing service, and a fire stop material. When testing these fire stop systems in accordance with ULC-S115, the complete system is tested including the fire separation, penetrating item, and fire stop material, and not simply the fire stop material alone. The type of fire stop system used is dependent upon the penetrating item. An example of a through-penetration fire stop in a hollow masonry wall is shown in Figure 5.4.

Alternatively, an example of a "tightly fitted" fire penetration through a grouted masonry wall, in lieu of use of an "F rated" fire stop material between the masonry and steel sleeve, is shown in Figure 5.5.

5.6.4 Membrane-Penetration Fire Stops

Membrane-penetration fire stop systems are used where a penetrating item does not pass entirely through a fire separation. Typically in construction, and in lieu of a fire stop system, these services are tightly fitted to the masonry unit with mortar.

5.6.5 Joint Systems

Although the NBCC does not specifically address fire stops for construction joints, such fire stop systems are implicitly required by the NBCC in order to maintain the continuity of a fire separation (in accordance with Articles 3.1.8.1 and 3.1.8.3).

Joint fire stop systems are fire stop systems intended to prevent the spread of fire though linear openings between or within fire separations. These openings may run vertically or horizontally, and include wall/floor junctions and wall/wall junctions. These fire stop systems do not incorporate penetrating items. In addition to providing suitable fire performance, they often are designed and installed to accommodate relative movement between the adjacent components caused by temperature and moisture changes, or by structural deflections and deformations. In cases where in-situ movement is

Figure 5.4:
Through-Wall Fire Stop; Hollow Masonry Wall (Ref. 2)

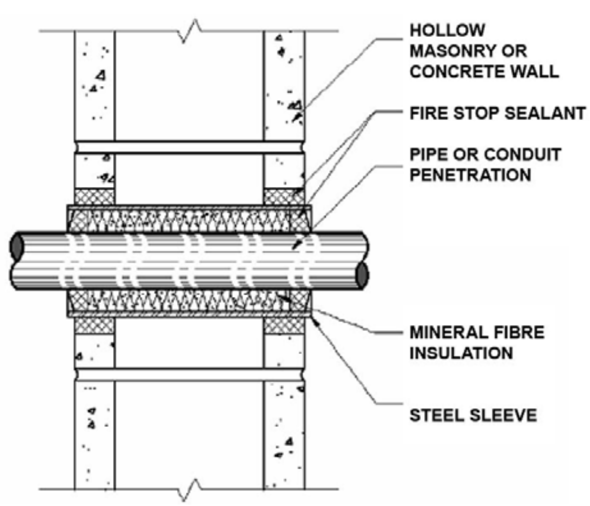
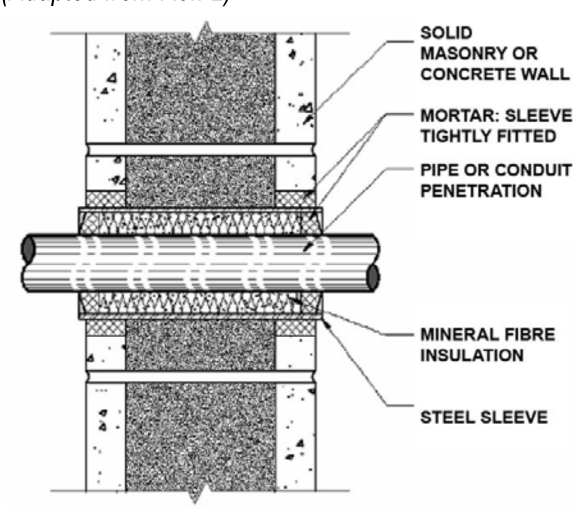


Figure 5.5:
Through-Wall Fire Stop; Grouted Masonry Wall (Adapted from Ref. 2)



anticipated along the joint, a listed joint fire stop system should be specified which is capable of accommodating the movement and maintaining its fire performance characteristics after movement.

Like fire stop systems intended for through-penetrations and membrane-penetrations, construction joint systems are tested and rated in accordance with ULC-S115. Listings for construction joint fire stops include information about whether or not the system has been tested dynamically (and the fire stop system is therefore capable of accommodating a defined amount of movement) or if the fire stop has been tested as a static joint. ULC-S115 contains a requirement to cycle construction joint fire stops through their intended range of movement prior to the fire exposure test. The minimum number of movement cycles is 500. The cycling is intended to demonstrate the capabilities of the fire stop to withstand the typical movements it may encounter during its service life, and to demonstrate its fire performance abilities following cycling.

For construction joint fire stops, F rating is achieved if the fire stop remains in place in the opening during the standard fire test exposure for the required period without the passage of flame or the occurrence of flaming on any element on the unexposed face of the fire stop, and the system must also resist heat to the extent that there is no glowing or flaming of a cotton pad placed on the unexposed side of the system. The FT rating criteria prohibits flame passage through the system and requires the maximum temperature rise of the unexposed surface of the wall assembly and on the fill material not to exceed 181°C (325°F) above ambient. Unless otherwise indicated in the systems, the ratings for joint systems installed in walls apply when either face of the wall is exposed to fire.

By NBCC-10, rating requirements for joint fire stop systems are the same as those for through-penetrations and membrane-penetrations:

- an “F rating” is required for the majority of applications [3.1.9.1.(1)], except that an “FT rating” is necessary for the joints and junctions of a firewall [3.1.9.1.(2)];
- where an “F rated” fire stop system is required, the fire stop system must provide an hourly F-rating not less than that stated for closures in NBCC-10 Table 3.1.8.4 (Table 5.6, herein);
- where an “FT rated” fire stop system is required, the fire stop system must provide an hourly FT-rating not less than the fire-resistance rating for the firewall.

5.6.5.1 Dynamic Joints: Movement Joints

Movement joints (including both control and expansion joints) are oftentimes constructed between two adjacent, abutting concrete masonry elements such as walls, or between a concrete masonry element and an adjacent non-masonry element such as a concrete or steel beam, column, or slab. Movement joints are carefully positioned by design to prevent or relieve stress within a masonry element or between adjacent elements due to displacements, typically caused by temperature and moisture changes, or by structural loading, acting both short-term and long-term, alone or in combination.

CSA S304.1-04 requires the structural designer to appropriately design movement joints to satisfy both structure and serviceability, and to provide on the project drawings and related documents, their locations (frequency of placement, specific location of placement), and details (width, joint type, structural connection for load transfer if any, continuity of reinforcement, and required materials within the joint) . CSA A371 requires the mason to construct the movement joint(s) in accordance with the project drawings and documents.

Movement joints are typically placed in masonry walls that serve as fire separations or as firewalls. For these walls, in addition to satisfying requirements for structure and serviceability, a movement joint must also satisfy requirements for fire performance.

Where a joint is specifically intended to perform as a movement joint, the designer should consider the following:

a. the anticipated in-service and high temperature movement of the joint, and therefore, the maximum and minimum anticipated widths needed for the design and selection of an appropriate listed fire stop system having the required percent compression and extension from the installed width;

b. the required thickness of applied sealant, if any, to ensure movement without debonding or tearing of the sealant;

c. the overlap distance of the sealant to ensure bonding.

Guidance on the use of a listed fire stop system should be provided by the manufacturer.

5.6.5.1.1 Fire Stops at Wall Tops

In many buildings containing non-loadbearing masonry infill walls and partitions, a typical detail requires a 15 to 25 mm horizontally-oriented movement joint between the underside of a floor or deck and the top of a non-loadbearing masonry wall. The intent is to structurally isolate the two elements to ensure that load is not transferred from the floor/deck by vertical deflection to the masonry wall below. In this case, the listed fire stop system must be capable of accommodating the anticipated movement between these elements (Figure 5.6).

Movement joints may not be uniform in width, hence, a variety of shapes of listed fire stop systems are available in order to accommodate irregular contours, such as fluting along the underside of steel decking and the top of a masonry wall (Figure 5.7).

5.6.5.1.2 Fire Stops Between Adjacent Walls

In many buildings, regardless of whether the masonry walls are loadbearing or non-loadbearing, fire-rated masonry walls may abut other fire-rated masonry walls in the same plane or at T- or L-corners, or abut other non-masonry vertical elements to form continuous vertical movement joints. Joints widths are typically 10 mm, the width of a standard mortar joint in masonry metric modular construction. Figure 5.8 illustrates a joint fire stop system in a movement joint between adjacent masonry wall sections.

Prescriptive solutions for joint fire stop systems are provided in the International Building Code (IBC), and ACI 216.1/TMS-0216, *"Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies".* These include provisions for ceramic fibre joint protection for precast panels, which are similar to concrete masonry walls in design and construction, both relying on concrete to achieve fire protection, and for

Figure 5.6: *Joint Fire Stop System Between Underside Concrete Floor and Top of Non-loadbearing Masonry Wall (Ref. 2)*

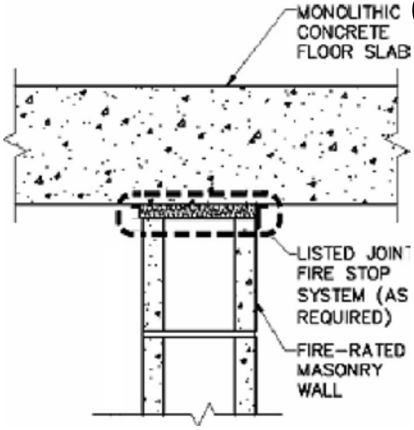


Figure 5.7: *Joint Fire Stop System in Movement Joint Between Underside Steel Decking and Top of Non-loadbearing Masonry Wall (Ref. 2)*

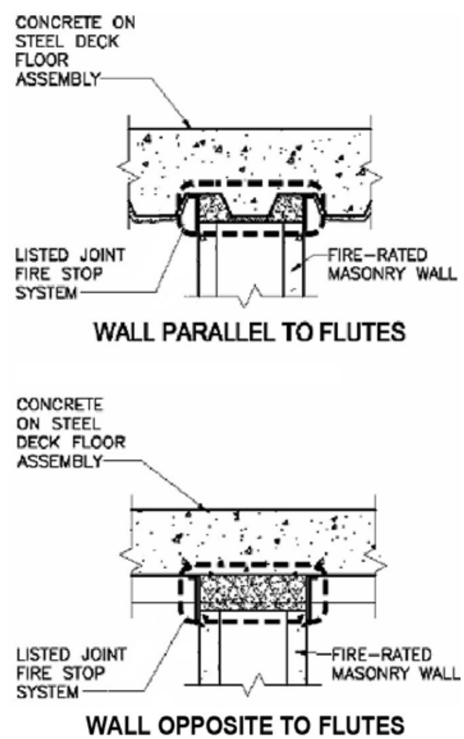
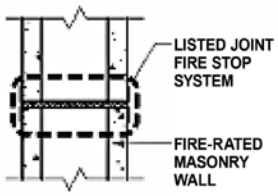


Figure 5.8: *Joint Fire Stop System in Movement Joint Between Adjacent Masonry Walls (Ref. 2)*



both, fire resistance is governed by ULC-S101 heat transmission criteria. Fire tests of wall panel joints in precast assemblies (Ref. 16) have shown that the fire endurance, as determined by a temperature rise of 181 C° over the joint, is influenced by joint type, joint materials, joint width, and panel thickness. When a sufficient thickness of insulating materials is provided within the joint, it is possible to attain a fire resistance equivalent to that of the adjacent panels. Figure 5.9 is based on results of fire tests of panels with butt joints. It can be used to determine the required depth of ceramic fibre felt blanket within a butt joint needed to maintain a required fire resistance rating for the fire separation. The fire stop sealant is required to prevent passage of smoke and hot gases.

Example 10

Calculating a Required Depth of Ceramic Fibre Felt

A concrete block masonry wall is constructed of 140 concrete block units of Type S Concrete, having a solid content of 53%. This wall is to serve as a fire separation having a fire-resistance rating of 2 hrs. Determine the required depth of ceramic fibre felt in a 15 mm wide joint needed to maintain the 2 h FRR in the masonry wall.

Solution using Figure 5.9

CSA masonry standards require that the vertical cell adjacent to movement joints be filled solid with grout. The equivalent thickness of the masonry wall at the joint location is therefore 140 mm.

Using Figure 5.9:

- for a 10 mm joint, the required depth of blanket is about 16 mm.
- for a 25 mm joint, the required depth of blanket is about 56 mm (2.2 in.)

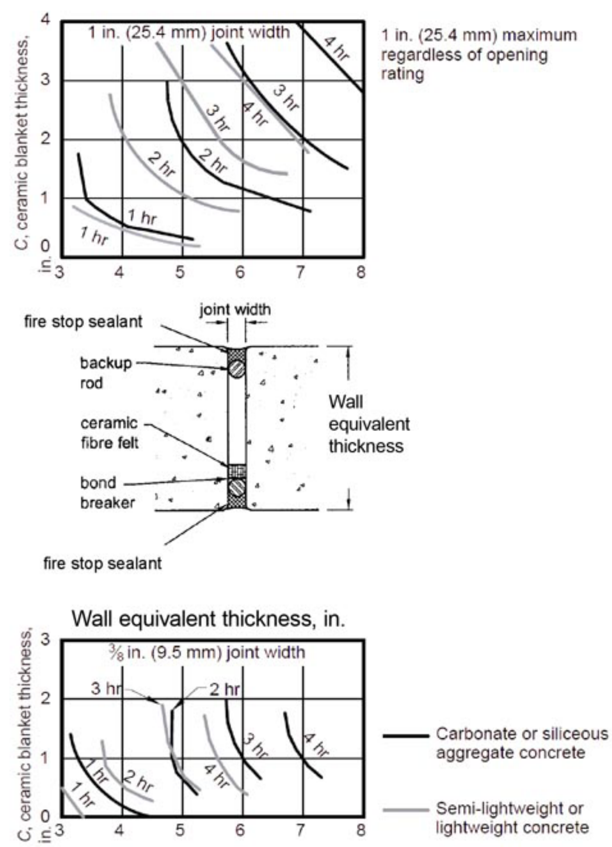
Required depth of blanket for a 15 mm wide joint is:
C_{15} = 16 + [(56 – 16) x (15 – 10)/(25 – 10)] = 30 mm

5.6.5.2 Static Joints and Junctions

In historical masonry construction, masonry walls were typically mortared tightly against, or built integrally with, other masonry walls at joints in T- and L- corners. Similarly, masonry infill wall panels were typically mortared tightly against non-masonry vertical elements such as concrete and steel columns.

It is more common in modern masonry construction to

Figure 5.9: *Thickness of Ceramic Fibre Felt Blanket Required for Wall Joints (Ref. 16)*



Notes:

1. Ceramic felt blanket – a mineral wool insulation material made of alumina-silica fibres and weighing 64 to 160 kg/m^3.
2. 25 mm is the maximum joint width permitted.
3. Linear interpolation is permitted.
4. Types S and N concretes correspond to the “carbonate or siliceous aggregate concrete” curve.
5. Types $L_1$20S and $L_2$20S correspond to the “semi-lightweight or lightweight concrete” curve.

structurally isolate masonry walls at corners, and masonry walls abutting non-masonry vertical elements. Use of open, unobstructed joints, both vertically and horizontally oriented between adjacent elements, help ensure that there is no unintended load transfer that would otherwise exceed the structural capacity of an element. In these cases, the joint or junction is specifically designed and constructed to serve as a movement joint. Where the assemblies are required to have a fire-resistance rating, a joint fire stop system between the adjacent elements is required, and it must offer dynamic capability.

In many cases, however, load transfer between adjacent masonry walls, and between masonry walls and non-masonry horizontal or vertical elements is structurally desirable, and specifically designed for. Cast-in-place concrete and precast concrete slabs and beams oftentimes bear directly on loadbearing concrete block masonry wall systems (Figure 5.10a). Concrete block masonry infill panels may be anchored and mortared tightly against concrete or steel columns specifically to provide the lateral force resistance for a building in lieu of bracing or moment resisting frame. A concrete block loadbearing wall may be rigidly anchored and mortared against an adjacent masonry wall at a T- or L- corner (Figure 5.10b). In these cases, the adjacent elements are rigidly connected, and the joint between them is designed to be static. It is necessarily filled by the mason with mortar or grout so that the elements are tightly fitted. For these cases, where the assemblies are required to have a fire-resistance rating, a joint fire stop system between the adjacent elements is not required. The construction is akin to that identified in Clause 3.1.9.1.(1)(b) of NBCC-10, “cast in place”. This continuous joint or junction, mortared/grouted tightly, is similar to any other head joint within the field of the masonry wall, and remarkably so where the masonry has been constructed in a stack pattern with vertically aligned head joints. In these cases, the construction plans should have the joints and junctions clearly identified as static, mechanically connected, and filled tightly with mortar and grout so that the plan examiner can readily discern that a fire stop system is not required.

Figure 5.10: *“Tightly Fitted” Joint Design and Construction*

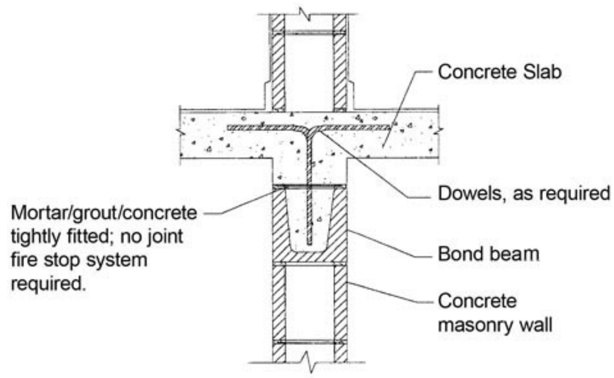


Figure 5.10a: *Rigid connection at wall/floor junction; no joint fire stop system required. (Ref. 20)*

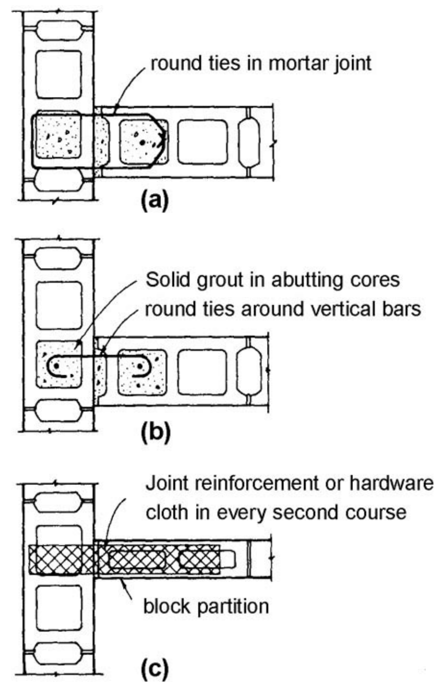


Figure 5.10b: *Rigid connection at intersecting walls; no joint fire stop system required. (Ref. 20)*

5.7 Some Basic Rules of Fire Endurance

A construction consisting of a number of parallel layers, such as a masonry cavity wall, offers better fire endurance than the sum of the fire endurance characteristics of the individual layers.

- The fire endurance of a construction does not decrease with the addition of layers.
- The farther an air gap or cavity is located from the exposed surface of the construction, the more beneficial is its effect on the fire endurance.
- The fire endurance of a construction cannot be increased by increasing the thickness of a completely enclosed air layer.
- The fire endurance of asymmetrical construction depends on the direction of heat flow.
- The presence of moisture, if it does not result in explosive spalling, increases fire endurance.

5.8 Chapter Summary

1. Managing fire by controlling its intensity and limiting spread can be best achieved using a "Balanced Design" strategy.
2. A construction assembly (such as a wall or floor) that acts as a barrier against the spread of fire is defined by the Building Code as a *"fire separation".*
3. The *"fire-resistance rating"* (FRR), stated in minutes or hours, measures the ability of a material, assembly, or structural member to control the spread of fire and to prevent collapse under exposure to fire.
4. CAN/ULC-S101, *"Fire Endurance Tests of Building Construction and Materials"*, published by Underwriters' Laboratories of Canada, is the standard test in Canada to determine the fire-resistance rating of a material, assembly of materials or a structural member.
5. Unlike light frame wall systems, the fire-resistance rating of concrete masonry is typically limited by the heat transmission end-point criteria (temperature rise on the non-fire-exposed side), occurring prior to the passage of flame or gases, or structural failure.
6. By the hose stream test under ULC-S101, the "optional program" is commonly used for concrete masonry assemblies rather than the "duplicate specimen" test which is typically used for frame wall assemblies. The effect of the "duplicate specimen" test is to improve the apparent fire performance of a wall assembly. As a consequence of the interpretation and use of test results permitted by ULC-S101 and ASTM E 119, wall assemblies that pass the hose stream test are not necessarily equal in their performance.
7. Part 3 of the NBCC-10 requires fire-resistance ratings to be determined by:
   a. fire testing, using ULC-S101; or,
   b. calculation, using Appendix D of the NBCC.
8. The fire-resistance rating of most assemblies including those of concrete block masonry is generally determined using the calculation method of Appendix D, NBCC-10.
9. For a standard masonry unit, its "equivalent thickness" (amount of material in a unit) and the "concrete type" (aggregate type, affecting unit density) are the properties upon which the analytical/calculation method of Appendix D is founded.
10. Other properties being equal, concrete masonry walls constructed of units made from lighter-weight aggregate provide higher fire-resistance ratings than walls constructed with units produced from heavier aggregates.
11. As the equivalent thickness of a concrete masonry unit increases, so too does its thermal resistance, and so too does the fire-resistance rating of the constructed masonry.
12. The equivalent thickness of a partially grouted concrete masonry wall excludes the contribution of the grout; the grout is ignored.
13. The producers of concrete masonry units can readily provide to designers either:

   a. the fire resistance rating of masonry constructed using a specific product; or,
   b. the equivalent thickness and concrete type of a specific product from which the fire-resistance rating of the constructed masonry element may be calculated.

14. Where concrete products are manufactured using aggregates that do not comply with the standards for aggregates referenced by CSA A165.1, and the standards referenced by Appendix D of the NBCC, the fire-resistance ratings for units and assemblies manufactured from concretes containing these aggregates cannot be determined using the tabled FRR baselines and the calculation methods described in Appendix D. This necessitates the use of full-scale ULC-S101 (or ASTM E 119) fire testing to establish the fire-resistance rating.
15. NBCC-10 tables (by way of Table D-2.1.1) the fire-resistance rating for concrete block masonry as a function of the equivalent thickness of the unit, and the Concrete Type used in its manufacture (reproduced as Table 5.1, herein).
16. Where cell materials are introduced into concrete block masonry units, and where all of the cell spaces are filled, the equivalent thickness of the masonry wall is considered to be the same as that of a wall of solid units, or a solid wall of the same concrete type and the same overall thickness. For concrete masonry fire separations, a variety of loose fill material will contribute to the equivalent thickness, however, for firewalls, the cell fill material must be only of mortar or grout.
17. The fire-resistance rating for partially grouted or partially filled concrete masonry construction is assigned the same fire-resistance rating as that for hollow concrete masonry construction; the grout or partial fill is ignored.
18. Concrete block masonry construction used for both fire separations and firewalls does not require “special” masonry mortars.
19. The NBCC-10 calculation method does not assign or limit fire-resistance ratings of concrete masonry based upon bond pattern (running and stack). Therefore, the determination of the fire resistance rating of concrete masonry is independent of bond pattern.
20. In addition to providing the means to calculate the fire-resistance rating of single wythe walls constructed of standard concrete block units, the NBCC-10 calculation method may be used to determine the fire-resistance rating of multi-wythe masonry walls, including cavity walls.
21. A masonry cavity wall (with included air space) will provide a fire-resistance rating at least as great as that of a solid wall of a thickness equal to the sum of the equivalent thicknesses of the two wythes. This statement acknowledges that the air space provides fire-resistance.
22. Gypsum board or plaster can be applied to concrete block masonry walls to improve fire-resistance rating. Contribution to fire-resistance rating depends on whether the finish is placed on the fire exposed, or non-fire-exposed face of the wall.
    a. where the finish is placed on the fire-exposed side, the thickness of the finish is converted to an adjusted thickness by multiplying the finish thickness by a factor from Table 5.2; this thickness is added to the equivalent thickness of the supporting masonry wall to establish a total equivalent thickness;
    b. where the finish is placed on the non-fire-exposed side, the time assigned to the finish material is determined using Table 5.3 and Table 5.4, these times being the length of times that the various finishes will remain integral when exposed directly to fire; this time is added directly to the fire-resistance rating of the supporting concrete masonry wall.

23. The minimum required equivalent thickness of concrete masonry used to provide fire protection for structural steel columns is stated in Table 5.5, herein.
24. Fire separations either must be constructed as continuous elements or have fire stop systems placed at openings in, and between them; for fire separations other than firewalls, an opening need not be sealed using a fire stop system where the seal is cast-in-place.
25. Fire stop systems are tested to the requirements of ULC-S115, *"Standard Method of Fire Tests of Firestop Systems".* The fire stop system may receive either an "F-rating" or an "FT-rating, both of which are an hourly rating; the former indicating the time period for which the assembly will withstand the passage of flame, and the latter, additionally, indicating the time period for which the assembly will withstand a temperature rise of 181 C° [325 F°] above ambient on the unexposed face of the assembly during the same period.
26. For the majority of fire stop applications, the NBCC requires an "F rating", except that an "FT rating" is necessary where a firewall is penetrated.
27. Where an "F rated" fire stop system is required, the fire stop system must provide an hourly F-rating not less than that stated in Table 5.6, herein.
28. Where an "FT rated" fire stop system is required (e.g., firewall), the fire stop system must provide an hourly "FT rating" not less than the required fire-resistance rating of the fire separation.
29. Joint fire stop systems often are designed and installed to accommodate relative movement between the adjacent components (a dynamic joint). In such cases, a listed joint fire stop system should be specified which is capable of accommodating the movement and maintaining its fire performance characteristics after movement.
30. A concrete block wall may be rigidly anchored and mortared against an adjacent masonry wall or non-masonry element. The junction/joint between them is specifically designed to be static. It is necessarily filled by the mason with mortar or grout so that the elements are tightly fitted. For these cases, where the assemblies are required to have a fire-resistance rating, a joint fire stop system between the adjacent elements is not required. The construction plans should have the joints and junctions clearly identified as static, mechanically connected, and filled tightly with mortar and grout so that the plan examiner can readily discern that a fire stop system is not required.

5.9 Physical Properties of Concrete Block Masonry; FRR

Table 4.1, Chapter 4, offers physical property data for standard concrete block masonry units, including fire-resistance ratings based upon the calculation procedures of Appendix D, NBCC-10. These data are representative of typical product manufactured by producer members of the Canadian Concrete Masonry Producers Association.

Tables 5.7 to 5.14 herein, provide summaries pertaining to fire-resistance ratings for a variety of concrete block masonry constructions, added surface finishes, and fire stop systems.

Table 5.7: *Minimum Equivalent Thickness of Concrete Masonry Loadbearing and Non-loadbearing, mm (Adapted from Table D-2.1.1, NBCC-10)*

Wall of Solid or Hollow Concrete Masonry, Concrete Type	Minimum Required Equivalent Thickness for Fire Resistance Rating[2]						
	30 min	45 min	1 h	1.5 h	2 h	3 h	4 h
Type S or N concrete [1]	44	59	73	95	113	142	167
Type $L_1$20S concrete	42	54	66	87	102	129	152
Type L_1 concrete	42	54	64	82	97	122	143
Type $L_2$20S concrete	42	54	64	81	94	116	134
Type L_2 concrete	42	54	63	79	91	111	127

(1) Hollow concrete masonry units made with Type S or N concrete must have a minimum specified compressive strength of 15 MPa, determined in accordance with CSA A165.1.

(2) Fire-resistance rating between the stated rating periods listed may be determined by linear interpolation.

Table 5.8: *Calculated Fire-Resistance Ratings for Single Wythe Masonry Walls Constructed of Standard Concrete Block Masonry Units of Typical Solid Contents (Based on Table D-2.1.1, NBCC-10)*

Wall Standard Size Unit	% Solid Content	Concrete Type	Fire Resistance Rating (min.)
90 mm	73% (Hollow)	Type S or N	52
		Type $L_1$20S	59
		Type L_1	63
		Type $L_2$20S	63
		Type L_2	65
	82% (Semi-Solid)	Type S or N	61
		Type $L_1$20S	71
		Type L_1	76
		Type $L_2$20S	77
		Type L_2	80
	100% (Full Solid)	Type S or N	83
		Type $L_1$20S	96
		Type L_1	106
		Type $L_2$20S	110
		Type L_2	117

Table 5.8 (Continued): *Calculated Fire-Resistance Ratings for Single Wythe Masonry Walls Constructed of Standard Concrete Block Masonry Units of Typical Solid Contents (Based on Table D-2.1.1, NBCC-10)*

Wall Standard Size Unit	% Solid Content	Concrete Type	Fire Resistance Rating (min.)
140 mm	58% (Hollow)	Type S or N	71
		Type $L_1$20S	81
		Type L_1	88
		Type $L_2$20S	90
		Type L_2	95
	80% (Semi-Solid)	Type S or N	118
		Type $L_1$20S	142
		Type L_1	156
		Type $L_2$20S	169
		Type L_2	183
	100% (Full Solid)	Type S or N	176
		Type $L_1$20S	208
		Type L_1	231
		Type $L_2$20S	240
		Type L_2	240
190 mm	56% (Hollow)	Type S or N	109
		Type $L_1$20S	129
		Type L_1	142
		Type $L_2$20S	154
		Type L_2	166
	78% (Semi-Solid)	Type S or N	194
		Type $L_1$20S	230
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240
	100% (Full Solid)	Type S or N	240
		Type $L_1$20S	240
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240

Table 5.8 (Continued): *Calculated Fire-Resistance Ratings for Single Wythe Masonry Walls Constructed of Standard Concrete Block Masonry Units of Typical Solid Contents (Based on Table D-2.1.1, NBCC-10)*

Wall Standard Size Unit	% Solid Content	Concrete Type	Fire Resistance Rating (min.)
240 mm	53% (Hollow)	Type S or N	149
		Type $L_1$20S	176
		Type L_1	195
		Type $L_2$20S	217
		Type L_2	240
	78% (Semi-Solid)	Type S or N	240
		Type $L_1$20S	240
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240
	100% (Full Solid)	Type S or N	240
		Type $L_1$20S	240
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240
290 mm	51% (Hollow)	Type S or N	194
		Type $L_1$20S	229
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240
	78% (Semi-Solid)	Type S or N	240
		Type $L_1$20S	240
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240
	100% (Full Solid)	Type S or N	240
		Type $L_1$20S	240
		Type L_1	240
		Type $L_2$20S	240
		Type L_2	240

Table 5.9: *Required Solid Content (%) for Standard Concrete Masonry Units Needed to Achieve Fire-Resistance Rating (Based on Table D-2.1.1, NBCC-10)*

FRR achieved using typical, standard hollow CMU

FRR achieved using typical, semi-solid CMU, or filling cells of hollow units

FRR achieved using full solid CMU, or filling cells of hollow or semi-solid units

Wall of Solid or Hollow Concrete Masonry (mm)	Required Solid Content (%)						
	30 min	45 min	1 h	1.5 h	2 h	3 h	4 h
90 mm Units							
Type S or N concrete	48.8	65.5	81.1	–	–	–	–
Type $L_1$20S concrete	46.7	60.0	73.3	96.7	–	–	–
Type L_1 concrete	46.7	60.0	71.1	91.1	–	–	–
Type $L_2$20S concrete	46.7	60.0	71.1	90.0	–	–	–
Type L_2 concrete	46.7	60.0	70.0	87.8	–	–	–
140 mm Units							
Type S or N concrete	31.4	42.1	52.1	67.9	80.7	–	–
Type $L_1$20S concrete	30.0	38.6	47.1	62.2	72.9	92.2	–
Type L_1 concrete	30.0	38.6	45.7	58.6	69.3	87.2	–
Type $L_2$20S concrete	30.0	38.6	45.7	57.9	67.2	82.9	95.8
Type L_2 concrete	30.0	38.6	45.0	56.5	65.0	79.3	90.8
190 mm Units							
Type S or N concrete	23.2	31.1	38.5	50.0	59.5	74.8	87.9
Type $L_1$20S concrete	22.2	28.5	34.8	45.8	53.7	67.9	80.0
Type L_1 concrete	22.2	28.5	33.7	43.2	51.1	64.3	75.3
Type $L_2$20S concrete	22.2	28.5	33.7	42.7	49.5	61.1	70.6
Type L_2 concrete	22.2	28.5	33.2	41.6	47.9	58.5	66.9
240 mm Units							
Type S or N concrete	18.3	24.6	30.5	39.6	47.1	59.2	69.6
Type $L_1$20S concrete	17.5	22.5	27.5	36.3	42.5	53.8	63.4
Type L_1 concrete	17.5	22.5	26.7	34.2	40.4	50.9	59.6
Type $L_2$20S concrete	17.5	22.5	26.7	33.8	39.2	48.4	55.9
Type L_2 concrete	17.5	22.5	26.3	33.0	38.0	46.3	53.0
290 mm Units							
Type S or N concrete	15.2	20.4	25.2	32.8	39.0	49.0	57.6
Type $L_1$20S concrete	14.5	18.7	22.8	30.0	35.2	44.5	52.5
Type L_1 concrete	14.5	18.7	22.1	28.3	33.5	42.1	49.4
Type $L_2$20S concrete	14.5	18.7	22.1	28.0	32.5	40.0	46.3
Type L_2 concrete	14.5	18.7	21.8	27.3	31.4	38.3	43.8

Table 5.10: *Multiplying Factors for Finishes on Non-Fire-Exposed Side of Concrete Masonry Construction (Adapted from Table D-1.7.1, NBCC-10)*

Type of Surface Protection	Type of Concrete Unit Masonry			
	Type S or N	Type $L_1$20S	Type L_1 or $L_2$20S	Type L_2
Portland cement-sand plaster or lime-sand plaster	1	0.75	0.75	.50
Gypsum/sand plaster, wood fibred gypsum plaster or gypsum wallboard	1.25	1	1	1
Vermiculite or perlite aggregate plaster	1.75	1.5	1.25	1.25

Table 5.11: *Time Assigned to Wallboard Membranes on Fire-Exposed Side of Concrete Masonry Construction, minutes (Adapted from Table D-2.3.4A, NBCC-10)*

Description of Finish	Time, minutes
11.0 mm Douglas Fir plywood phenolic bonded	10 (1)
14.0 mm Douglas Fir plywood phenolic bonded	15 (1)
12.7 mm Type X gypsum wallboard	25
15.9 mm Type X gypsum wallboard	40
Double 12.7 mm Type X gypsum wallboard	80 (2)

Notes to Table D-2.3.4.A:

(1) Non-loadbearing walls only, stud cavities filed with mineral wool conforming to CAN/ULC-S702, *"Mineral Fibre Thermal Insulation for Buildings,"* and having a mass of not less than 2 kg/m^2, with no additional credit for insulation according to Table D-2.3.4.D.

(2) Applies to non-loadbearing steel framed walls only.

Table 5.12: *Time Assigned for Contribution of Lath and Plaster Protection on Fire-Exposed Side of Concrete Masonry Construction, minutes (Adapted from Table D-2.3.4B, NBCC-10)*

Type of Lath	Plaster Thickness, mm	Type of Plaster Finish		
		Portland Cement and Sand[2] or Lime and Sand	Gypsum and Sand or Gypsum Wood Fibred	Gypsum and Perlite or Gypsum and Vermiculite
9.5 mm Gypsum	13	–	35	55
	16	–	40	65
	19	–	50	80 [1]
Metal	19	20	50	80 [1]
	23	25	65	80 [1]
	26	30	80	80 [1]

Notes to Table D-2.3.4.B:

(1) Values shown for these membranes have been limited to 80 min because the fire-resistance ratings of framed assemblies derived from these Tables shall not exceed 1.5 hours.

(2) For mixture of Portland cement/sand plaster, see D-1.7.2.(2).

Table 5.13: *Minimum Equivalent Thickness of Concrete Masonry Protection to Steel Columns (Adapted from Table D-2.6.1.A, NBCC-10)*

Description of Cover	Fire Resistance Rating						
	30 min	45 Min	1 h	1.5 hr	2 h	3 h	4 h
Concrete Masonry Units or precast reinforced concrete units							
Type S concrete (column spaces not filled)	50	50	50	50	64	89	115
Type N or L concrete (column spaces not filled)	50	50	50	50	50	77	102

Table 5.14: *Required Fire Protection Rating for Fire Stop Systems (Adapted from Table 3.1.8.4, NBCC-10)*

Fire-Resistance Rating of Fire Separation	Fire Stop System	
	F Rating	FT Rating
45 min.	45 min.	45 min.
1 h.	45 min.	1 h
1.5 h.	1 h	1.5 h
2 h.	1.5 h	2 h
3 h.	2 h.	3 h
4 h	3 h	4 h

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Firewalls

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Firewalls

This Chapter of the CCMPA Metric Technical Manual has been largely reproduced from "*Firewalls, A Design Guide*", published by the Canadian Concrete and Masonry Codes Council (CCMCC) in 1992. It also includes updates for consistency with NBCC-10, and additional material synthesized from other related documents.

5A.1 What is a *Firewall*?

A *firewall* is the ultimate defense against the spread of fire. It must be able to withstand the onslaught of a fire and prevent further fire spread by containing it to one side of the wall until the fire burns itself out, or is extinguished.

The most stringent provisions in our Building Codes with regard to structural stability and fire performance apply to *firewall*s. *Firewall*s must be suitably designed and constructed to function as a barrier against the spread of fire and smoke. They are subject to very specific requirements regarding use, fire-resistance rating, structural stability, and construction. Requirements for *firewall*s are not typical of any other *fire separation*. The NBCC-10 definition for *firewall* states that it must have the *"structural stability to remain intact under fire conditions for the required fire-rated time"*. If a fire were to occur on one side of a *firewall*, collapse of the building or of a portion of the building on the fire-exposed side of the *firewall* must not cause the *firewall* to collapse or otherwise fail within the code-required, fire-rated time assigned to that *firewall*. This need for structural integrity during the fire event is an important distinction between the Building Code requirements for a *firewall* and for a fire separation. Because of this important distinction, design options and recommendations for compliance with the structural stability requirements for *firewall*s are discussed in the *"Structural Considerations"* section of this chapter.

The term *firewall* is often used when referring to a fire separation. This is incorrect. As noted in Chapter 5 of this Manual, a fire separation is typically a wall or floor assembly that acts as a barrier to the spread of smoke and fire, yet it may or may not be required to have a fire-resistance rating, although most do have some inherent fire-resistance. A required fire-resistance rating for a *fire separation* may be achieved through the use of combustible or noncombustible building materials, provided combustible construction is permitted for the building by the Building Code. A *fire separation* need not satisfy requirements for structural integrity. These are not the case for a *firewall*.

Specific to the design of *firewall*s intended to comply with Part 3 of NBCC-10, code references include the following:

a. requirements pertaining to determining fire-resistance ratings are stated in Subsection 3.1.7, and Appendix D, Division B, *"Fire Performance Ratings"*;

b. requirements for closures are provided in Subsection 3.1.8;

c. requirements for service penetrations are given in Subsection 3.1.9;

d. requirements pertaining to *firewall* connections and their relationship to structural collapse, required fire-resistance ratings, *firewall* continuity, and projection beyond combustible construction are contained in Subsection 3.1.10;

e. requirements related to their structural design are provided in Article 4.1.5.17 and in Commentary "C", *"Structural Integrity of Firewall*s" in the *"User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)"*.

Requirements specific to *firewall*s under Part 9 of the NBCC are contained in Subsection 9.10.11. Notably, by Article 9.10.11.3, where *firewall*s are used they are to be constructed in accordance with the requirements of Part 3.

Until the 2005 edition of the NBCC, all *firewall*s regardless of the required fire-resistance rating were required to be constructed of concrete or masonry. The 2005 edition of the NBCC permitted *firewall*s having a fire-resistance rating of not more than 2 hrs. to be constructed of other than concrete or masonry. This requirement remains unchanged in the 2010 edition. Discussions pertaining to this requirement, the use of alternative *firewall* construction, and the associated inherent risks of using other than concrete or masonry *firewall* construction are provided in Section 5A.7.1 of this chapter.

Chapter 5 *"Fire Performance"*, offers the groundwork for an understanding of fire performance issues, provides discussion fully relevant to *firewall*s, and complements the information specific to *firewall*s provided in this chapter. The reader is therefore urged to review the material presented in Chapter 5.

5A.2 Application of Firewalls

A firewall is designed and constructed with the primary purpose of dividing a building into separate entities or *building areas*, which are considered as separate *building*s under the NBCC for the purposes of fire protection. The wall acts as a barrier against the spread of fire from one area to another to prevent major conflagration, total or partial loss of the building of fire origin, total or partial loss of adjacent buildings, and injury to occupants of the building of origin and to occupants beyond.

In accordance with the assigned and stated *Objectives* of Part 2, Division A , NBCC-10, and the assigned and stated *Functional Statements* of Part 3, Division A, a firewall is intended to:

- limit damage to the building of origin due to fire, explosion, or collapse of physical elements or structural insufficiency, or loss of use due to structural insufficiency;
- limit damage to adjacent buildings, or otherwise beyond the building of origin caused by fire, explosion or collapse of physical elements; and,
- limit exposure of building occupants, and occupants in adjacent buildings to injury due to fire, explosion, structural insufficiency or collapse of physical elements.

The firewall satisfies these objectives by:

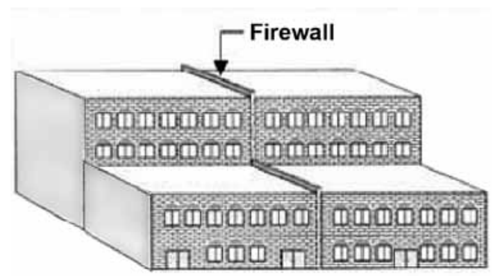
- retarding the effects of fire beyond its point of origin;
- limiting or accommodating expected loads and forces;
- retarding its own failure or collapse due to the effects of fire or explosion; and,
- resisting deterioration expected from service conditions.

5A.2.1 Separation of Buildings

The division or separation of buildings by a firewall can be utilized in a number of situations. Where a wall is jointly owned and used by two parties sharing a building and is erected at or upon a property line, it is called a party wall. Since, in effect, it divides a single building extending across a property line into two buildings, it must be constructed as a firewall (Article 9.10.11.1, NBCC-10).

The use of a firewall in a building under one ownership on a single property can be beneficial. The two areas of a building created by a dividing firewall are each considered by the NBCC as separate areas (Figure 5A.1) (Article 1.3.3.4, Division A, NBCC-10). The fire protection requirements of the NBCC are then applied to each separate area rather than to the building as a whole. Such requirements typically become less stringent with a decrease in building area. Therefore, it is usually more economical to apply the fire protection requirements of each smaller portion of the building than those of the building as a whole. Installation of several firewalls at appropriate intervals will permit a structure to contain a total area many times the maximum permitted for a single building area. Height and area limitations based on the occupancy, type of construction and fire fighter access govern the number of firewalls required within a given building.

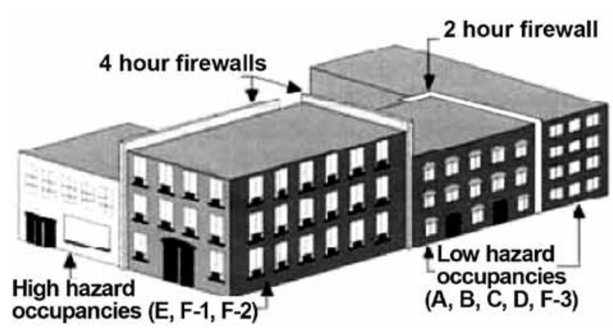
Figure 5A.1: *Example Firewall Location*



5A.2.2 Separation of Major Occupancies

A firewall can also be used for the separation of major occupancies (Figure 5A.2) (Article 3.1.10.2, NBCC-10). Although most different major occupancies can share the same building, a high hazard occupancy (Group F, Division 1) is not permitted in the same building as an assembly, institutional or residential occupancy (Groups A, B, or C) (Article 3.1.3.2, NBCC-10).

Figure 5A.2: *NBCC Minimum Firewall Ratings*



Note: *Group F-1 occupancies are not permitted within the same building as Group A, B or C occupanies (Article 3.1.3.2, NBCC-10).*

5A.2.3 Additions and Renovations

A firewall can also be useful when adding to, or rehabilitating an existing building. A proposed addition may increase a building's area so that more stringent fire protection requirements must then be applied to the entire building, not only to the addition. Placing a firewall at a well-chosen location divides the old and new construction into separate buildings. Thus, the existing building would not require upgrading to the current Building Code. The addition may also then be permitted to comply with less stringent fire protection requirements than would the total building.

Many buildings constructed years ago do not, and cannot, comply with fire protection requirements of today's Building Code because of their construction type. If, because of renovation, such a building would be required to be upgraded to comply with the current Building Code, the use of a firewall to create two smaller buildings that meet current fire protection requirements may be the solution.

5A.2.4 Business Loss Reductions

Many factories and warehouses enclose large areas used for hazardous processes and storage of products. In such buildings, firewalls are the ideal type of fire separation for use in limiting the amount of materials that may be exposed in a fire. Dividing a building into truly isolated fire compartments that will confine a fire to its place of origin and prevent its spread is the most important means of reducing the over-all fire risk in a building. Limiting fire spread will limit the loss of supplies, machinery, and records. Delays incurred in replacing a destroyed building can result in a permanent loss of customers. Saving a portion of a building reduces the amount of reconstruction and material replacement needed, and permits quicker resumption of operations.

5A.3 Fire-Resistance Ratings

5A.3.1 Determination of Ratings

Fire-resistance rating (FRR), its concept, its determination using fire testing, alternative Code compliant means to establish FRR for concrete block masonry, the affects of cell fill, the affects of additional finishes, and a variety of other related topics are discussed in detail in Chapter 5.

Like a masonry fire separation, the equivalent thickness of concrete block masonry is used to calculate the fire-resistance rating of a firewall, and additionally, the grout in partially grouted masonry construction is excluded from the equivalent thickness calculation. However, unlike a masonry fire separation, and in accordance with Sentence 3.1.10.2.(3) of NBCC-10, the required fire-resistance rating of a firewall must be provided by masonry or concrete only. The consequence of this Sentence is that the inclusion of cell material other than grout/concrete or mortar cannot contribute to the fire-resistance rating of a masonry firewall whether all cells are filled or not. Appendix A-3.1.10.(4) explains that inherent in the use of a firewall is the intent that the wall construction also provides resistance to physical damage arising out of normal use that would compromise the fire-resistance rating of the assembly. Specific to concrete masonry construction, the use of mortar or grout fill, unlike loose fill materials such as vermiculite or perlite, will not lead to a spill of the cell material and the attendant lose of fire-resistance rating if the face shell of the masonry unit is compromised. This has been a prescriptive requirement for concrete masonry firewalls for many editions of the NBCC.

Concrete block masonry construction used for firewalls does not require "special" masonry mortars. Conventional Type N and Type S mortars, in accordance with CSA A179-04, *"Mortar and Grout for Unit Masonry"*, are suitable.

NBCC-10 does not assign or limit fire-resistance ratings of concrete masonry based upon bond pattern (running and stack). Therefore, the determination of the fire resistance rating of concrete masonry is independent of bond pattern.

5A.3.2 Fire-Resistance Requirements for Firewalls

A building's fire load is related to the combustible content of the occupancy as well as to its construction materials. The degree of fire-resistance required for a firewall is based on the assumed fire load of a building and the expectation that the firewall will withstand a complete burnout of any portion of a divided building. For a building which will contain highly combustible or hazardous materials, or large amounts of combustibles, a required firewall must have at least a 4 hour fire-resistance rating [3.1.10.2.(1), NBCC-10]. A firewall with not less than a 2 hour rating is deemed to be sufficient by the NBCC for dividing low hazard occupancies [3.1.10.2.(2), NBCC-10]. If a firewall is to separate a high hazard occupancy and a low hazard occupancy into two building areas, it must be constructed in accordance with the firewall requirements for the greater hazard (Table 5A.1 and Figure 5A.2). Notwithstanding these code requirements, a designer should determine if the fire-resistance rating required by the Building Code will be sufficient to provide adequate fire safety based on the proposed use of the building, particularly where a 2 hour firewall is required by the code. Additional fire-resistance rating may be needed. Compared to a 2 hour firewall, constructing a masonry firewall as a 4 hour wall can usually be done for little additional cost because no "special" construction is required. This can be particularly beneficial if possible future occupancy changes may include high hazard uses.

Table 5A.1: *NBCC Fire-Resistance Ratings of Required Firewalls (Constructed from NBCC-2010 requirements, Sentence 3.1.3.2.1 and Article 3.1.10.2)*

Building Area Occupancy	Minimum Required Fire-resistance Rating — Adjoining Building Area Occupancy			
	A, B or C	D or F-3	E or F-2	F-1
A, B or C	2 h	2 h	4 h	N.P.
D or F-3	2 h	2 h	4 h	4 h
E or F-2	4 h	4 h	4 h	4 h
F-1	N.P.	4 h	4 h	4 h

N.P. *Occupancies not permitted within same building*

Due to perceived high risk, there may be situations where a firewall is desired in a building even though it would not be required by the Building Code. Such a wall may have whatever fire-resistance rating that is deemed appropriate for service by the designer. If such a wall is shown on project construction drawings as a firewall having a stated fire-resistance rating, it must meet all of the structural requirements of the Building Code which apply to firewalls. Otherwise, the wall must be termed a fire separation and the building and construction would not qualify for any of the benefits available by using and specifying a firewall.

5A.4 Structural Considerations

5A.4.1 General

Firewalls must possess sufficient strength to remain standing and intact during their specified rating period. To ensure this, NBCC-10 contains requirements in Subsection 3.1.10 dealing with the structural integrity of firewalls. Additionally, loading and support criteria intended to ensure sufficient strength in the firewall are specified in Article 4.1.5.17.

When designing firewalls structurally, it is necessary to recognize the strength reduction that occurs in connections at elevated temperatures. All external anchors and connections used with firewalls must be fire protected for the required fire rating period. Information on the fire protection required for these components is contained in *Reference 18.*

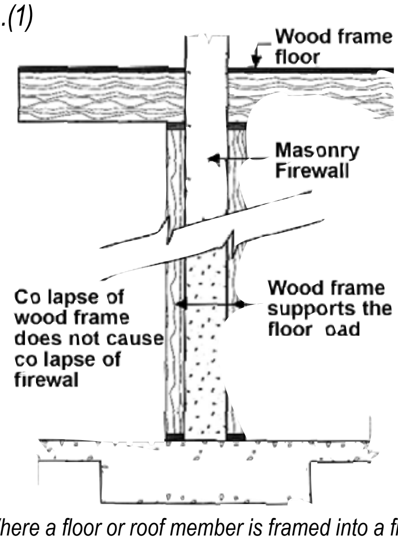
Both steel and concrete strengths diminish with elevated temperatures. The structural resistances of a firewall should be calculated using strength-temperature relationship data for steel and concrete, and information on temperature distributions within concrete/masonry elements during fire exposures. In general, the rate at which heat reaches the reinforcement in a masonry wall, and thus, the loss of strength of the reinforcing steel, is inversely proportional to the masonry cover provided. Designers should be aware that the minimum cover requirements specified in CSA S304.1 and CSA A371 may not be sufficient to meet the needed structural requirements under fire exposure without consideration of effects of elevated temperatures. Elastic modulus and bond between reinforcement and concrete/grout are also known to decrease with increasing, elevated temperatures. *Reference 10* is a treatise on the effects of elevated temperatures on the physical properties of concretes and reinforcing steels, and the behaviour of reinforced concrete members. Additional design data pertaining to the effects of elevated temperatures are available in *Reference 8.* The strength of reinforcement as a function of temperature is provided in Table 5A.3, herein.

Additionally, detailed structural recommendations are provided in *Reference 7.*

5A.4.1.1 Structural Integrity

Commentary “C”, “*Structural Integrity of Firewalls*”, within the *“User’s Guide-NBCC 2010, Structural Commentaries (Part 4 of Division B)”*, expands on the rationale of the firewall structural integrity requirements. Sentence 3.1.10.1.(1) of the NBCC requires that the connections and supports of framing members, which are expected to collapse within the fire rated period of the firewall, be detailed such that the collapse of the framing members will not cause a premature failure of the firewall (Figure 5A.3a).

Figure 5A.3a: *Illustrating NBCC-10 Sentence 3.1.10.1.(1)*



Note*: Where a floor or roof member is framed into a firewall, the remaining masonry must have sufficient equivalent thickness to provide the fire-resistance rating required by the firewall. (See Figure 5A.3b).*

Sentence 3.1.10.1.(2) of NBCC-10 provides an exception to this requirement. Frames otherwise detailed may be tied to a firewall having a higher fire-resistance rating than the frame, provided the firewall is comprised of two

Figure 5A.3b: *Thickness Required at Framed-In Members*

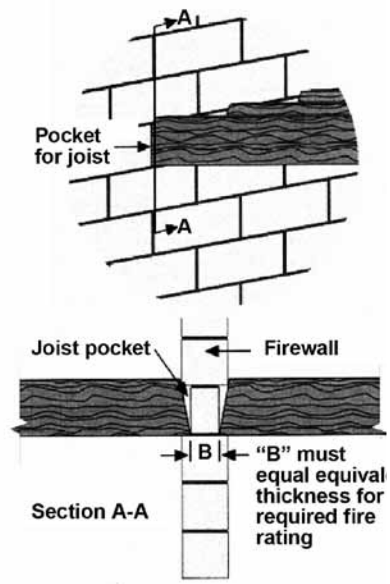
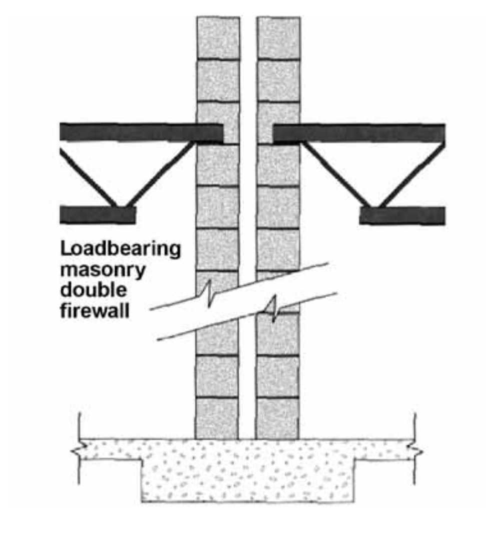


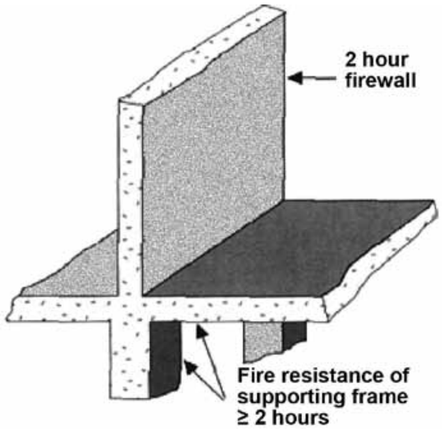
Figure 5A.4: *Illustrating NBCC-10 Sentence 3.1.10.1.(2)*



separate walls that are structurally independent, each having a fire-resistance rating of at least half of that required for the firewall (termed a “Double Firewall”) (Figure 5A.4).

Where a building frame is non-combustible and possesses a fire-resistance rating equal to or greater than that of the firewall to which it is attached, the requirements of

Figure 5A.5: *Illustrating NBCC-10 Sentence 3.1.10.1.(3)*



Sentence 3.1.10.1.(3) are applicable. In such cases, the structural frame may provide support to the firewall and the connection of the frame to the firewall need not meet the requirements of Sentence 3.1.10.1.(1). Figure 5A.5 illustrates the requirements of Sentence 3.1.10.1.(3).

5A.4.1.2 Loading Requirements

The lateral loading requirements for firewalls given in Article 4.1.5.17 of NBCC-10 are intended to insure that in addition to being able to resist normal lateral design loads, the firewall possesses sufficient strength to withstand the accidental loads that can be expected during a fire. Requiring a minimum factored lateral load of 0.5 kPa for firewalls is intended to ensure that the firewall possesses sufficient strength to withstand fire induced loads such as glancing blows from falling debris, the thermal shock and force of a fire-hose stream, and some incident wind pressure. Firewalls must, however, be designed to withstand any loads and forces which reasonably may be expected. Because of this, firewalls are not typically designed to be resistant to a major explosion, as this is a severe requirement. Therefore, in most instances, flammable liquid mixing and storage rooms should be located a remote distance from the firewall, or alternatively, explosion venting should be provided.

Firewalls must be designed for the normal structural requirements relating to walls for wind and earthquake, including that for impact damage, as prescribed by Part 4 of the NBCC. If the firewall is used as part of the structural framing system, the wall should be designed to provide structural integrity in accordance with Commentary “C”, “Structural Integrity of Firewalls” in the *“User’s Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)”*. Thus, a firewall must be designed to resist the “maximum effect” resulting from these otherwise normal loading conditions prescribed by Part 4, or the 0.5 kPa factored load under fire conditions [4.1.5.17.(1), NBCC-10].

5A.4.1.3 Thermal Expansion

Steel building frames exposed to fire may expand significantly towards a firewall. The three main factors that determine the extent of this expansion are temperature rise, coefficient of thermal expansion, and length of frame over which the temperature rise takes place. Commentary “C” suggests that the thermal expansion of the structure be based on an assumed temperature rise of 500°C. Thermal coefficients of expansion are given in Table E-1 of Commentary “E” in the *“User’s Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)”*. Half the fire compartment length, up to a maximum distance of 20 m, is suggested by Commentary “C” as the length of frame over which expansion should be considered for design. These guidelines result in a maximum thermal movement of 120 mm for steel structures. Table 5A.2 lists steel frame thermal movement dimensions for various fire compartment lengths as determined by the NBCC guidelines. These values are the minimum clearances (denoted as “X” in later figures) required between steel framing and the firewall or wythes of a firewall located in a steel structure.

Table 5A.2: *Thermal Movement Values for Steel Frames*

Total Fire Compartment Length(1), (m)	Minimum Clearance X for Steel Frame Expansion, (mm)
10	15
15	30
20	45
25	60
30	75
35	90
≥40	120

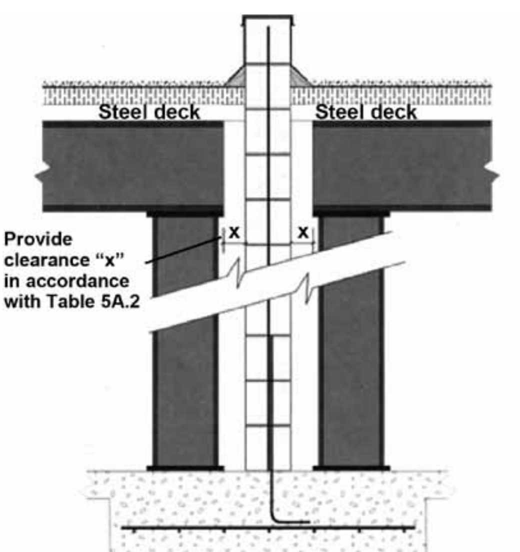
(1) *Dimension perpendicular to the plane of the firewall*

5A.4.2 Designing for Thermal Expansion

5A.4.2.1 Unrestrained Frame Expansion

The design and construction of a firewall should ensure that thermal movements do not cause damage to the wall that would allow fire spread through the wall. This can be accomplished in several ways. The firewall can be detailed so that clearance, in accordance with Table 5A.2, is maintained between the wall and the structural frame to accommodate the expected movement (Figure 5A.6). This approach is required when the structural frames on opposing sides of the firewall are not aligned vertically and horizontally, or where the forces of expansion cannot be resisted by the unexposed frame. In practice, the thermal expansion of flexible metal deck roof systems has not been found to impair the serviceability of firewalls. As a result, it is not considered necessary to provide thermal clearance between the edge of such roof systems and the firewall (Figure 5A.6). However, where the roof system is comprised of a stiff membrane, such as a concrete slab over a steel deck, clearance between the edge of the roof and the firewall should be provided to accommodate the anticipated expansion.

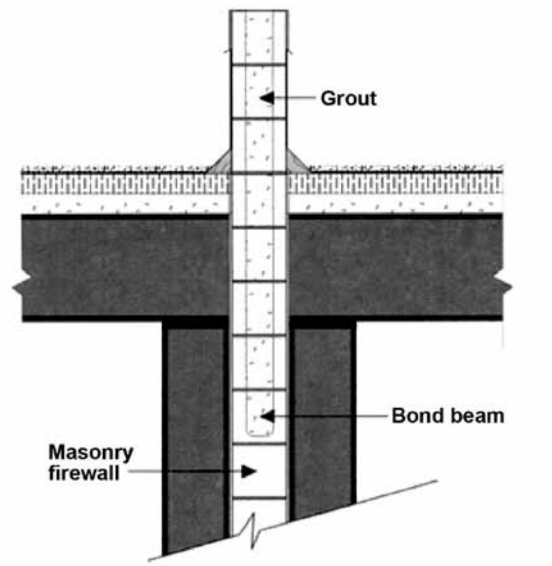
Figure 5A.6: *Detailing for Thermal Expansion*



5A.4.2.2 Restrained Frame Expansion

As an alternative approach, and under certain circumstances, the wall may be constructed in close proximity to the building frames. In this case, the fire-exposed frame is allowed to expand and bear against the firewall which in turn bears against the resisting unexposed frame. Figure 5A.7 illustrates the bearing solution to the thermal expansion condition

Figure 5A.7: *Expanding Frame Bears Against Firewall*

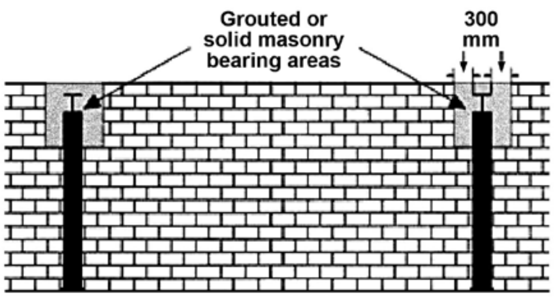


This alternative approach may only be used when:

a. the structural framing members are aligned both vertically and horizontally on both sides of the firewall;
b. the unexposed frame is capable of resisting the loads imposed by the expanding frame, and;
c. a recommended maximum clearance of 20 mm is maintained between the firewall and the frame for walls up to 12.2 m high, with this clearance increased by no more than 6 mm for each additional 3 m of wall height.

If the main framing elements run parallel to the masonry firewall, a continuous bond beam should be installed in the second course below the primary steel framework, and all cells in the blocks units above should be filled with grout. If they run perpendicular to the firewall, fully grouted areas need only be constructed at the column locations between the framing members. This solid bearing area should extend a distance of not less than 300 mm on both sides of the main framing member at the column location. This condition is illustrated in Figure 5A.8.

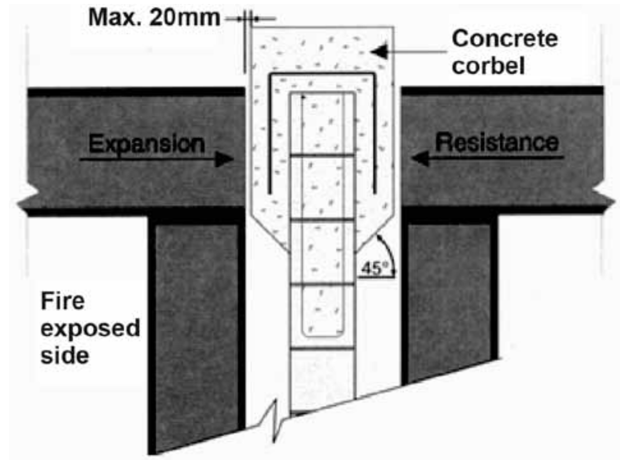
Figure 5A.8: *Thermal Expansion Bearing Areas*



When building frames are allowed to expand and bear against a firewall in this manner, it is important that the recommended maximum clearance of 20 mm be observed. Too much clearance will allow considerable bowing of the firewall between the framing members during the fire. This causes uneven bearing between the wall and the framing elements, which may damage the wall when resistance to expansion begins. Where on-site construction tolerances or other circumstances cause the recommended maximum clearance to be exceeded, corrective measures may include the construction of pilasters or concrete corbels on the wall to reduce the clearance to recommended levels. The pilaster or corbel should be constructed over the same area as that provided for bearing purposes. The configuration of a typical concrete bearing corbel used to reduce the maximum clearance between the wall and the frame is illustrated in Figure 5A.9.

The corbel should be at least as high as the primary structural steel member and, the face abutting the wall should be not less than 600 mm in height.

Figure 5A.9: *Bearing Corbel*



5A.4.2.3 Movement Joints in the Firewall

Masonry firewalls should have construction joints in line with those of the building frame to prevent cracking. The width of these joints is identical to those placed within the building itself.

Masonry firewalls should also have movement joints of sufficient width and frequency of placement to accommodate anticipated in-plane movements caused by short- and long-term shrinkage of the masonry, service temperature changes, anticipated elevated temperatures caused by the fire event itself, and where applicable, in-service structural deformations caused by in-plane loading due to wind and seismic forces.

See Sections 5A.6.2 and 5A.6.5 for discussion regarding joint treatments needed to maintain firewall continuity and integrity.

5A.4.3 Types of Walls

Four basic types of firewalls are used to contain fires in buildings. These are:

1. Double
2. Cantilever
3. Tied
4. Weak Link

The type chosen by the designer will depend on the required fire-resistance rating, building type, scale of the firewall, and the structural design considerations. A detailed description and application of each of these four basic types of firewalls is provided in 5A.4.4.1, 5A.4.4.2, 5A.4.4.3, and 5A.4.4.4, respectively.

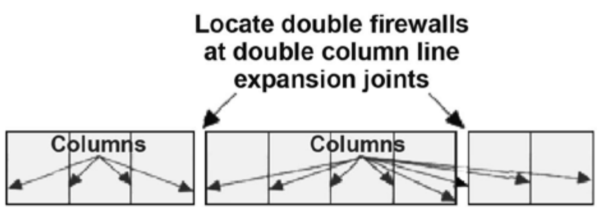
5A.4.4 Design Considerations

5A.4.4.1 Double Firewalls

5A.4.4.1.1 Design Considerations

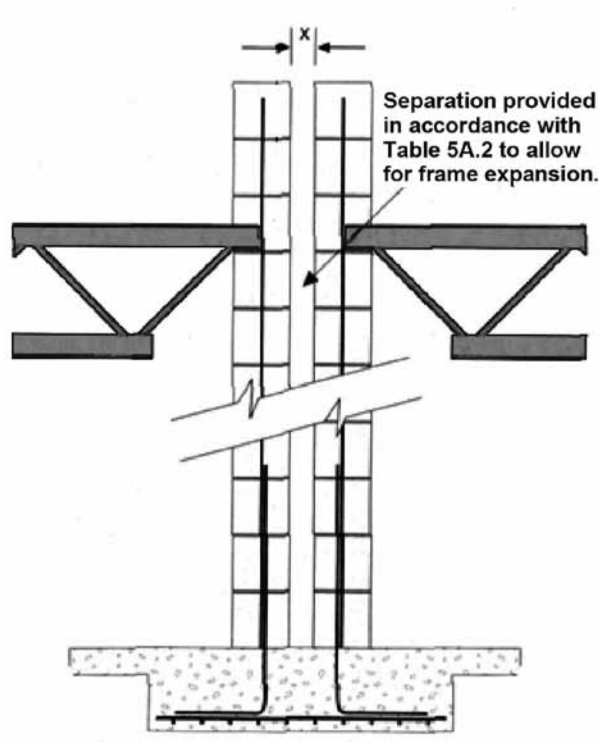
As the name suggests, a double firewall is comprised of two parallel firewalls which are constructed in close proximity to one another, but which are not structurally connected. Double firewalls are used to meet the requirements of Sentence 3.1.10.1.(2) of NBCC-10 and, as such, may or may not be loadbearing. The structural frame on each side of the firewall must be tied to its respective separate wythe such that failure of the exposed structural frame on the fire-side of the wall results only in collapse of the wythe to which it is connected, without damage to the remaining wythe. Double firewalls are ideally used in providing a fire separation between an existing building and new adjoining construction. These walls are also utilized at expansion joints in buildings as illustrated in Figure 5A.10.

Figure 5A.10: *Location of Double Firewalls*



A double firewall is particularly useful with renovations and additions to existing buildings. An existing masonry exterior wall may be modified, if required, to provide an adequate level of fire-resistance. An adjacent masonry wythe may be constructed close to the existing wall and secured to the new building frame. Examples of two types of double firewall assemblies are illustrated in Figures 5A.11a and 5A.11b.

Figure 5A.11a: *Loadbearing Double Firewall*

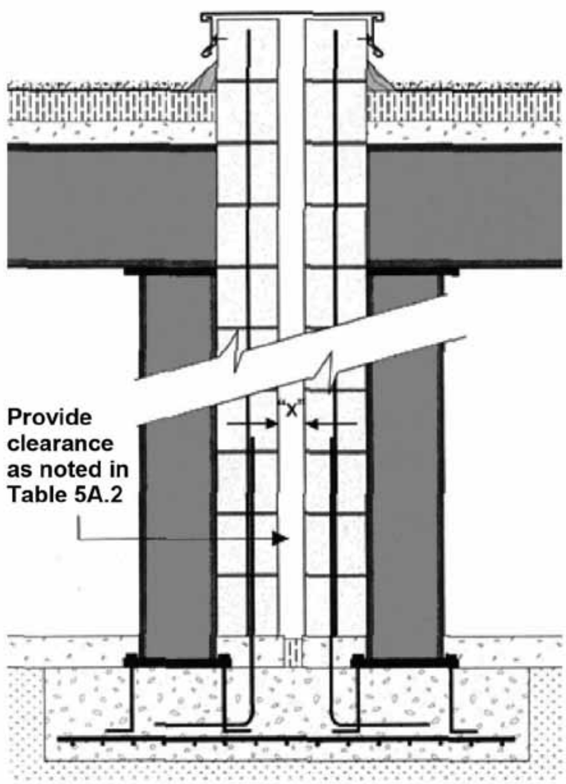


Note: *Where a floor or roof member is framed into a firewall, the remaining masonry must have sufficient equivalent thickness to provide the fire-resistance rating required by the firewall. (See Figure 5A.3b).*

In Figure 5A.11a, the double firewall provides structural support to the roof joists. In Figure 5A.11b, the steel frame is used to support the roof joists, and the firewall is simply tied back to the frame. In both cases, separation between the walls should be provided in accordance with Table 5A.2 to accommodate the thermal movements expected in a steel building frame during a fire. At sites where the seismic hazard index, $I_E F_a S_a(0.2)$, is equal to or greater than 0.35, special consideration should be given to the separation between the double walls so that pounding during a seismic event is avoided.

Where double firewalls support structural loads, thermal expansion of the frame may cause lateral displacements at the wall top. Curvature of the wall caused by fire exposure on one side will tend to exacerbate this effect.

Figure 5A.11b: *Non-loadbearing Double Firewall*



These displacements may induce P-δ effects. The designer must consider these deformations, and their effects on loading, in the structural design of the firewall, otherwise, it is recommended that the wall be designed as non-loadbearing to ensure that premature failure of the framing is not initiated by collapse of the firewall. For very tall firewalls, the self-weight of the wall may be as much or more than the supported roof dead and live load. The structural resistance of the wall must be sufficient to resist the prescribed lateral loads, vertical loads, and P-δ effects resulting from anticipated deformations due to elevated temperatures.

Each wythe of the double firewall should be anchored to its respective building framework at the roof level. This connection must have sufficient strength to support the walls under the lateral loads specified in NBCC Article 4.1.5.17. The only connection between the two wythes of the double firewall should be at the flashing. Typical connection details for double firewalls are shown in Figures 5A.12.a and 5A.12.b.

Figure 5A.12a: *Non-loadbearing Double Firewall Connection*

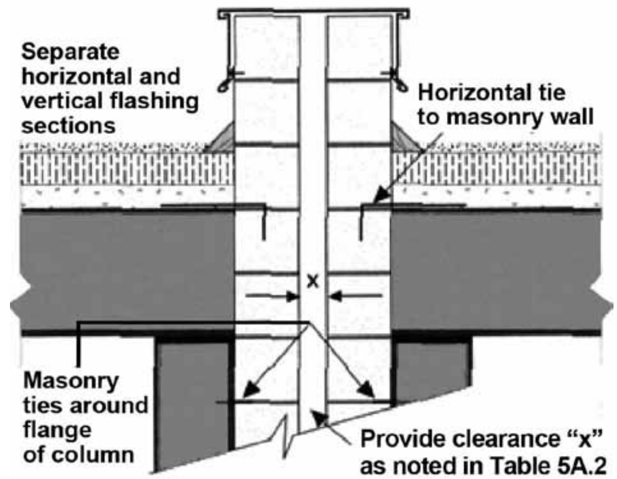
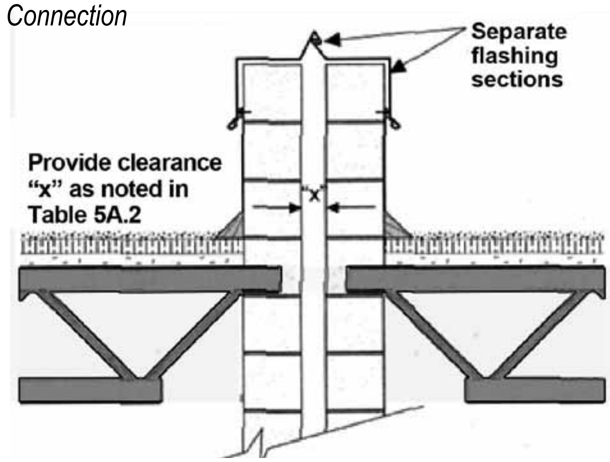


Figure 5A.12b: *Loadbearing Double Firewall Connection*



Note: *Where a floor or roof member is framed into a firewall, the remaining masonry must have sufficient equivalent thickness to provide the fire-resistance rating required by the firewall. (See Figure 5A.3b).*

The NBCC-10 requires that each of the two walls comprising the double wall need only possess one half of the fire-resistance rating required for the entire firewall [3.1.10.1.(2), NBCC-10]. However, this does not appropriately consider the possibility of premature collapse of a fire-exposed frame, and hence, the destruction of one wythe of the firewall before half of the required fire-resistance rating period has expired. In light of this, prudent design will ensure that sufficient fire-resistance is provided by each of the two wythes such that adequate fire-resistance is still provided should one wall be prematurely destroyed. This may be accomplished by adjusting the fire-resistance rating of the double walls or ensuring that the building frame attached to the double wall has a fire-resistance rating at least equivalent to that wythe of the wall to which it is attached.

5A.4.4.1.2 Design Recommendations

1. Each of the two wythes of a double firewall should have a minimum fire-resistance rating equal to the greater of: (a) half the total fire-resistance rating required, or (b) the total fire-resistance required less the lowest fire-resistance rating assigned to the framing system on either side of the firewall, whichever is greater.
2. Sufficiently reinforce each wythe of a double firewall to resist the lateral loadings specified in NBCC-10 Article 4.1.5.17. In the structural design of each wythe, consideration should be given to any eccentric gravity load effects (self-weight, supported floors, etc.) due to thermal bowing or thermal frame displacement (secondary effects). The design strength of the reinforcement, masonry, bond between reinforcement and grout, and the elastic modulus of the assembly should be determined at elevated temperatures using the temperature of these materials at the fire rating time period (Table 5A.3, and *References 10 and 18*).
3. Ensure sufficient separation between the two wythes (in accordance with Table 5A.2) in order to accommodate the thermal expansion of the connected structural framing at elevated temperatures. Consider any seismic requirements that may require the design to exceed the thermal separation requirements of Table 5A.2.
4. Locate double firewalls at expansion joints, or joints between buildings.
5. Each wythe of a double firewall should be anchored to its respective building framework at the roof level. There should be no connection between the two firewalls other than the roof flashing.

5A.4.4.2 Cantilever Firewalls

5A.4.4.2.1 Design Considerations

As the name implies, a cantilever firewall is a free standing wall that is not structurally connected to the building frame. This wall is also ideally located at an expansion joint or at joints in the building framing.

NBCC-10 requires that a minimum lateral load of 0.5kPa be resisted by a firewall under fire conditions [4.1.5.17.(1)]. Reinforced concrete masonry walls provide strong cantilever walls, but usable heights are limited by deflection at the wall tops, which greatly affect serviceability and exacerbate the effects of any eccentric loading on the wall. It is most likely that vertical reinforcement will be required to suitably resist the movement developed at the wall base. It should be noted that, in particular, the

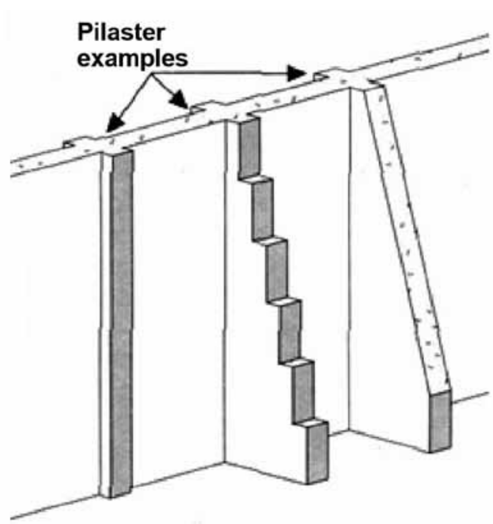
Table 5A.3: *Reinforcement Strength Reduction Values*

Strength remaining in hot rolled reinforcing steel during a standard fire for various concrete types (percent of specified yield strength at 21° C)				
Concrete Cover to Reinforcement (mm)	**at 2 hours**		**at 4 hours**	
	Type N	**Type S**	**Type N**	**Type S**
100	86	85	83	83
76	83	83	79	77
50	79	78	67	61
38	72	71	58	30
25	61	45	36	11
19	42	25	20	–
13	28	18	–	–

stability of a cantilever firewall depends on the capacity of its vertical reinforcement which may have a relatively thinner surface cover (surface covers are prescribed by structural design and construction standards, and typically are based upon design considerations rather than fire performance). In such cases, this reinforcement should be designed for reduced strength at elevated temperatures and with greater coverage if required. For calculating reinforcement requirements, the strength reduction values listed in Table 5A.3 are recommended.

For relatively high cantilever firewalls, masonry pilasters may be used to enhance lateral resistance. In general, due to strength and deflection requirements, the practical height limit for a cantilever firewall is about 10 m. For greater heights, use of a tied firewall (subsequently discussed herein) may be more suitable. Three examples of pilaster types integrated with cantilever firewalls are illustrated in Figure 5A.13.

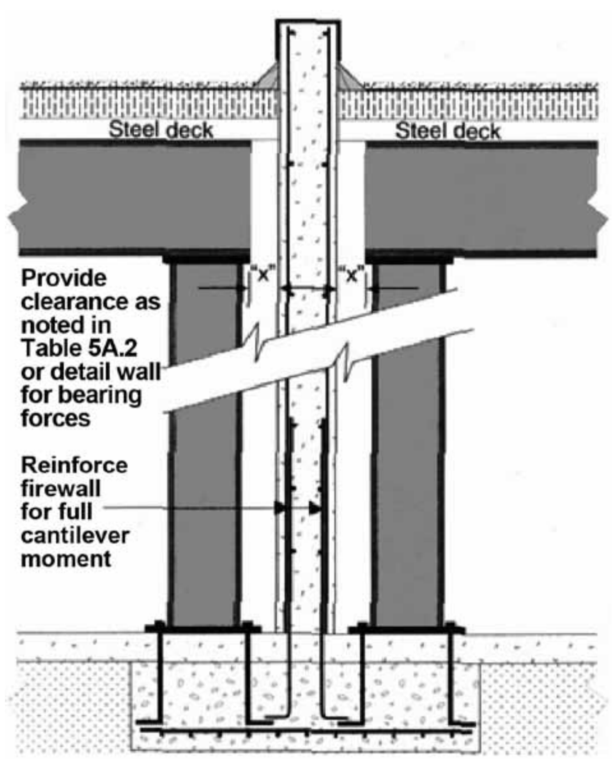
Figure 5A.13: *Cantilever Firewall, Use of Pilasters to Increase Wall Lateral Load Resistance*



If not appropriately accounted for in the design, the thermal expansion of the fire-exposed building frame may exert high lateral forces on a cantilever firewall, possibly causing the wall to fail prematurely. This is especially true if the steel framing does not align horizontally and vertically on each side of the wall (Figure 5A.7). Where adjacent framing does not align, sufficient clearance in accordance with Table 5A.2 should be left between the cantilever firewall and the frame to allow full thermal expansion of the frame without damage to the wall. Figure 5A.14 illustrates proper detailing of such a cantilever firewall at the roof level. Where the building frame is aligned both vertically and horizontally on both sides of the wall, the expansive force may be transferred through the firewall to the unexposed frame on the opposite side of the wall by direct bearing, as illustrated in Figure 5A.8. Where the building frame is allowed to expand and bear against the firewall, as described earlier under “Thermal Expansion” (Section 5A.4.1.3), a maximum clearance of 20 mm between the frame and the firewall should be observed. The framing must be designed to resist the imposed forces caused by frame expansion and bearing.

Cantilever firewalls are not recommended at sites where

Figure 5A.14: *Cantilever Firewall Connections*



the seismic hazard index, $I_E F_a S_a(0.2)$, is equal to or greater than 0.35. Where used, they should be specifically designed to resist the anticipated seismic event and they must not be allowed to bear against the building frame because this would result in pounding damage during a seismic event.

5A.4.4.2.2 Design Recommendations

1. To assure stability during fire events, cantilever firewalls and their foundations should be designed for the lateral loads specified in Article 4.1.5.17 of the NBCC, as well as the eccentric gravity load effects due to thermal bowing of the wall or thermal frame displacement (secondary effects).
2. Cantilever firewalls must be connected to their foundations, sufficient to resist the overturning moment resulting from the lateral loads and secondary effects noted in Recommendation 1, above.
3. The design strength of the reinforcement, concrete, bond between reinforcement and concrete/grout, and the elastic modulus of the assembly should be determined at elevated temperatures using the assumed temperature of these materials at the fire rating time period. Of particular importance is the affect on the strength of cantilever reinforcement (Table 5A.3, and *References 10 and 18*).
4. Clearance should be provided between the steel framing and the firewall in accordance with Table 5A.2, otherwise the framing must be designed to resist the imposed forces caused by frame expansion and bearing.
5. If used as a temporary exterior wall, cantilever firewalls should be tied to the building frame and designed to resist wind and seismic loads as well as the lateral loading requirements noted under Recommendation 1.
6. The use of cantilever firewalls is not recommended at sites where the seismic hazard index, $I_E F_a S_a$ (0.2), is equal to or greater than 0.35.

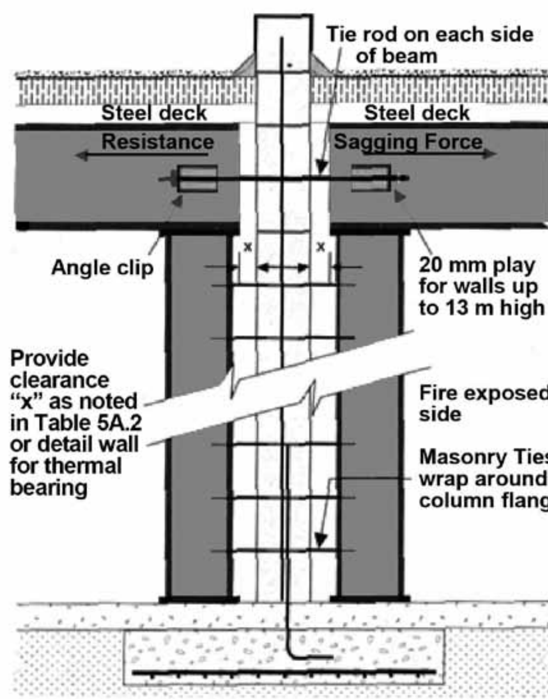
5A.4.4.3 Tied Firewalls
5A.4.4.3.1 Design Considerations

Tied firewalls derive their lateral stability from the stability inherent in the building frame. The general stability requirements for firewalls of NBCC-10 Article 4.1.5.17 must be respected. There are two basic types of tied firewalls, these being single column line, and double column line.

When located at a single column line, the tied firewall will be tied to, and may totally encapsulate, the aligned steel columns in a steel frame structure. The top of the firewall will be tied to the horizontal steel elements which are located directly over the firewall and span in the same direction (Figure 5A.19).

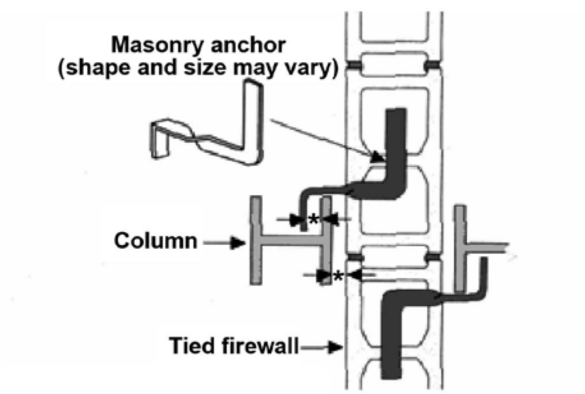
At a double column line, a tied firewall is located between the two adjacent, parallel lines of steel columns and is entirely external to the framework. Tied firewalls should not be loadbearing. In Figure 5A.15a, the structure on each side of the tied firewall provides lateral support to the firewall. The framework is tied together

Figure 5A.15a: *Tied Firewall*



in such a way that lateral forces resulting from collapse of the structure exposed to the fire are adequately resisted by the structural frame of the building on the other side. Flexible masonry anchors (Figure 5A.15b) should be provided for lateral bracing, in addition to the through-wall ties connecting the primary steel. Some free play should be provided between the masonry anchors and the column flange to prevent collapsing steel from pulling on the wall before there is resistance from the unexposed side. To remain stable, the pull of the collapsing steel on the fire side of the wall must be resisted by the strength of the unheated steel frame on the protected side. In a symmetrically framed structure at the building's centre of strength, this will occur naturally.

Figure 5A.15b: *Flexible Masonry Anchors*



* *Maximum space should be 20 mm for walls up to 12.2 m high and an additional 6 mm for every additional 3.0 m of wall height*

In small buildings, the centre of strength is generally at the middle of the building (Figure 5A.16a). In larger structures, the centre of strength may lie between two double column expansion joints (Figure 5A.16b)

Figure 5A.16a: *Tied Firewall Location in a Small Building*

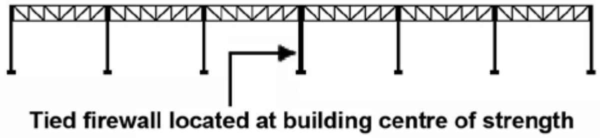
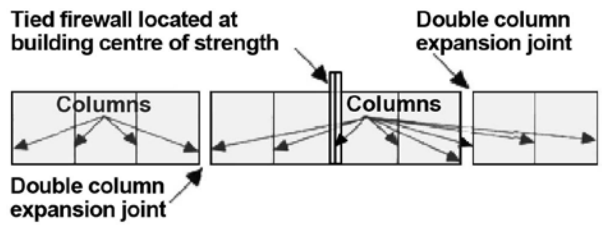


Figure 5A.16b: *Tied Firewall Location in a Large Building*



5A.4.4.3.2 Horizontal Forces from Collapsing Structure

As a steel frame weakens from exposure to elevated temperatures on the fire side, roof loads cause the supporting steel beams to sag and pull the firewall toward the fire. In Commentary "C", *"Structural Integrity of Firewalls"* in the *"User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)"*, guidance is given to determine the force generated by sagging members on the fire-exposed side of a tied firewall. By treating the sagging beam as a cable subjected to a vertical force per unit length, and using a parabolic approximation to a catenary curve, Paragraphs 16 and 17 of Commentary "C" suggest that the sagging force can be calculated as (Figure 5A.17a and 5A.17b):

Sagging Force = $P = wBL^2/(8S)$

Where

- w = dead weight + 25% of specified snow load
- B = the distance between ties
- L = the span of the collapsing structure between columns measured perpendicular to the wall
- S = sag of the member at its mid-point, assumed be 0.07L for steel open-web beams and 0.09L for steel solid-web members.

The supporting structure should be capable of resisting the recommended forces for ties within a 10 m length of the firewall; the other ties are assumed to carry no force (Figure 5A.17a). The factored resistance of the tie should include a reduction factor of 0.5 to account for reduced yield strength at high temperature. Alternatively, if the building frame possesses equal strength on both sides of the firewall (i.e., the firewall is located at the centre of strength of the building), only the tie must be designed for the factored force $wBL^2/(8S)$. A load factor of 1.0 is applied to the sagging force because it is an accidental load.

Figure 5A.17a: *Calculating Sagging Force for Tied Columns*

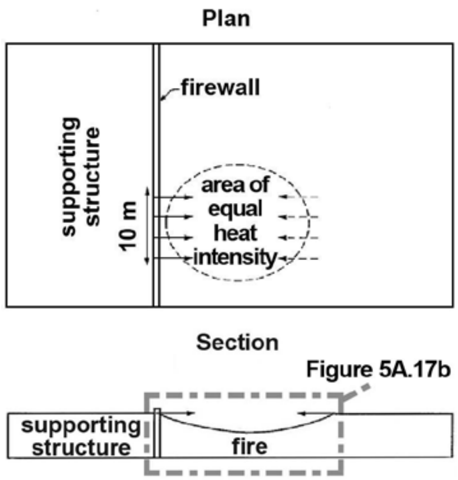
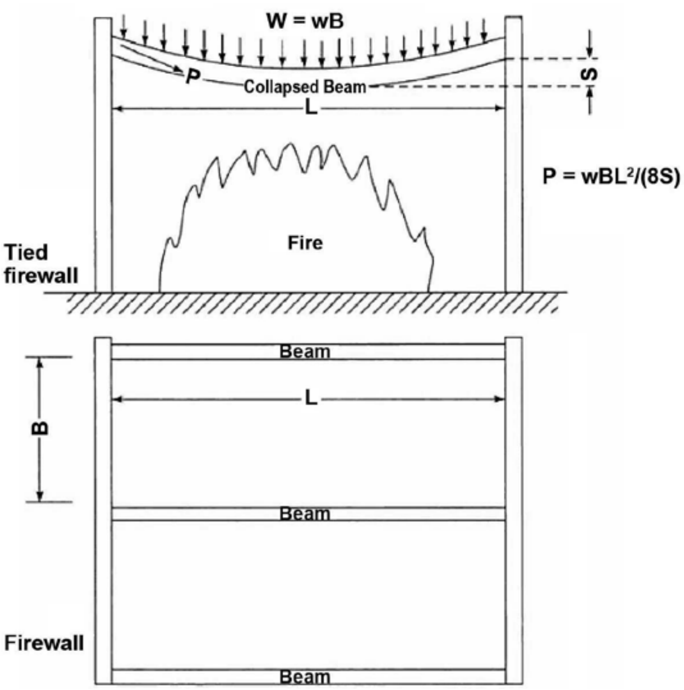


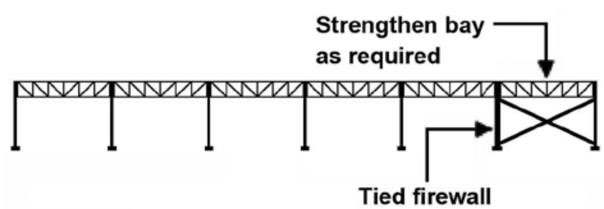
Figure 5A.17b: *Calculating Sagging Force for Tied Columns*



Tied firewalls derive their lateral stability from the building framework. A premature failure of the steel framing in the immediate vicinity of the firewall would jeopardize both the wall and the tie connection. It is therefore essential that the framing members located within, or immediately adjacent to the firewall not fail. These framing members should be fire protected for the required fire rating period or have adequate fire-resistance to ensure they will not collapse during the fire. The columns and steel framework adjacent to tied firewalls should have a fire-resistance rating at least equal to that of the firewall.

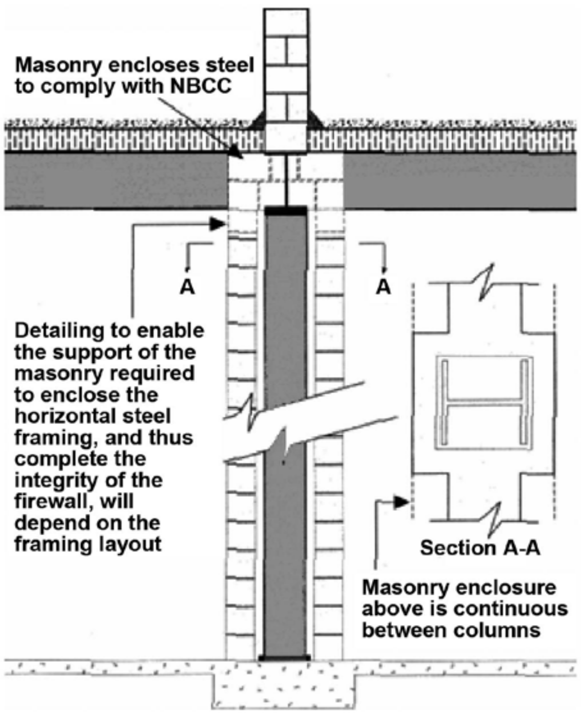
It should be noted that single column line firewalls do not break the continuity of the building frame. Figure 5A.18 illustrates a tied firewall location where additional bracing of the exterior building frame may be needed to accommodate unbalanced sagging forces which may develop during a fire.

Figure 5A.18: *Tied Firewall Located Away From Centre of Resistance*



In situations where tied firewalls encase the structural framework, as shown in Figure 5A.19, it is imperative that the encasement of the framework be properly constructed to ensure that the fire-resistance rating of the firewall is provided. An inadequate level of fire protection would cause a premature failure of the firewall. To meet NBCC-10 requirements, framing members running parallel to, and above the firewall must also be encased. Design of this encasement will depend upon the framing layout selected for the building. A clearance of 20 mm between the steel frame and the encasing firewall is needed to accommodate normal building movements.

Figure 5A.19: *Tied Firewall Encasing Steel Columns*



5A.4.4.3.3 Design Recommendations

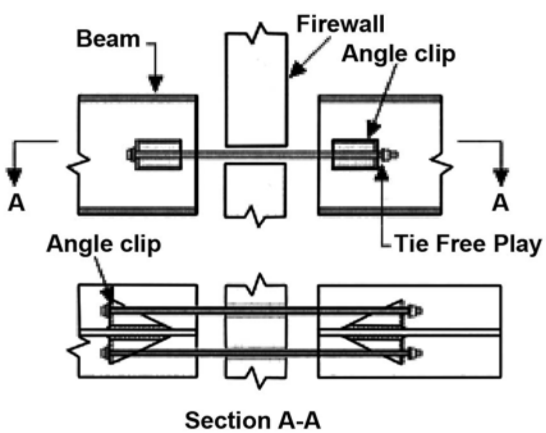
1. A tied firewall should follow a column line to take advantage of the resistance offered by the columns and to minimize twisting forces on the wall. For tied firewalls located at single column lines, both the columns and roof framing members in line with the wall must have a fire-resistance rating, obtained by the masonry, equal to that of the wall. Where the wall is located between columns on a double column line, the columns and beams or trusses parallel to the wall immediately on each side should have a fire-resistance rating at least equal to that of the wall to prevent the steel from buckling and damaging the integrity of the firewall. This generally implies fire protection of the steel.
2. The framing members should be aligned vertically and horizontally on each side of the tied firewall.
3. Where the steel frames on both sides of the tied firewall are not of equivalent strength, the weaker side must be designed to accommodate the forces calculated in accordance with Paragraph 16 of Commentary "C", *"Structural Integrity of Firewalls"* in the *"User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)"*, as well as those of NBCC-10 Article 4.1.5.17.
4. At roof level, the expected horizontal force should be transmitted through the wall with continuous steel framing (for single column line tied walls), or by through-wall ties (for double column line tied walls).
5. Where the wall is constructed between double column lines, the ties should be designed based on the forces calculated in accordance with Paragraph 16 of Commentary "C", *"Structural Integrity of Firewalls"* in the *"User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)"*. Two tie rods per column should be used to reduce torsion on the columns. The ties should be connected to the roof framing steel over the columns. Where the primary steel is parallel to the wall, it may be necessary to install ties more often than every column line. For walls up to 13 m high, 20 mm of free play should be maintained in the through-wall ties to accommodate normal building movement, as illustrated in Figure 5A.20. This dimension should be increased by 6 mm for each additional 3 m of wall height.

   In addition to using through-wall connections to make the framing steel continuous across the firewall, flexible masonry anchors (Figure 5A.15b) should be provided for lateral bracing. And similar to the requirements for the through-wall ties, free play between the masonry anchors and the column flange should be provided to prevent collapsing steel from pulling on the wall before there is resistance from the unexposed side
6. To accommodate initial steel expansion during the fire, clearance between the steel framing and a double column line tied firewall should be provided in accordance with Table 5A.2.

   An alternative approach would be to allow the firewall to act as a bearing pad between the expanding frame and the unexposed frame. This can be achieved by using solid wall sections, as illustrated in Figures 5A.8 and 5A.9.

7. Where tied firewalls encase steel columns, expansion of the steel framing members on the fire side of the wall will be resisted by the framing on the unexposed side of the wall. The connection of the columns to the wall should allow for movements which would occur in the protected frame when resisting the sagging force exerted by the fire-exposed frame. This can be achieved by using flexible masonry anchors or by using concrete block units that loosely key into the re-entrant space of the column.
8. In all cases, the firewall itself must be designed to withstand the lateral loads specified in NBCC-10 Article 4.1.5.17.

Figure 5A.20: *Through-Wall Tie, Primary Steel Perpendicular to Tied Firewall*

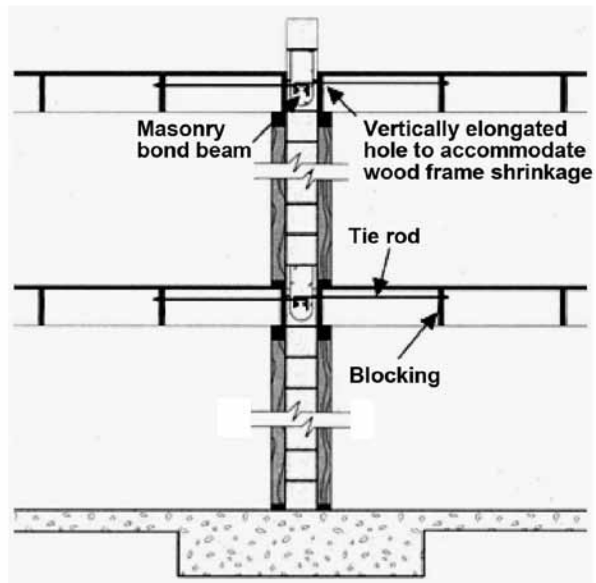


5A.4.4.4 Weak Link Tied Firewalls

5A.4.4.4.1 Design Considerations

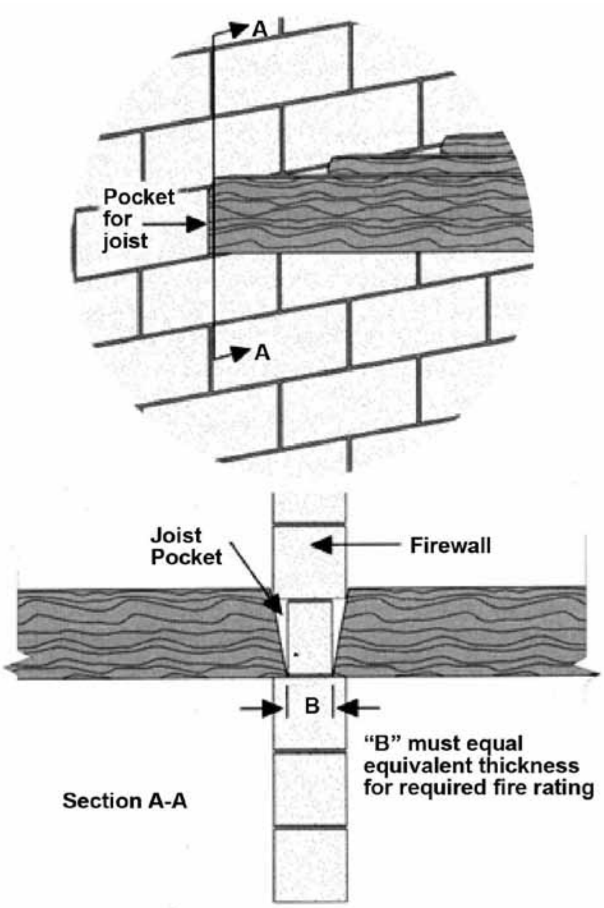
By using weak link tied firewalls, structural components are supported by the firewall in such a way that the failing structure may collapse without damaging the integrity of the firewall. Weak link connections are used with tied firewalls where the wall is braced with wood construction, as illustrated in Figure 5A.21. The blocking connection to the wood frame must be detailed to act as a weak link in accordance with Paragraph 15 of Commentary "C" of *"User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)"*. The firewall itself must be reinforced and detailed in accordance with Paragraphs 8, 9, 14 and 15 of Commentary "C". This form of construction is typically used in wood frame multi-unit residential buildings where firewalls are used to separate dwelling units or building sections.

Figure 5A.21: *Weak Link Connection Firewall*



An alterative form of the weak link connection can be used where wood floor joists run perpendicular to, and are supported on, the firewall. The ends of the joist should be fire cut as shown in Figure 5A.22. This will enable the floor framing exposed to the fire to disengage from its bearing connection on the firewall without pulling the wall down. A minimum thickness necessary to maintain the required fire-resistance rating of the wall must be provided at the joist bearing locations as indicated in Figure 5A.23

Figure 5A.22: *Thickness Required at Framed-in Members; Fire Cutting Wood Joists*



5A.5 Continuity and Terminations

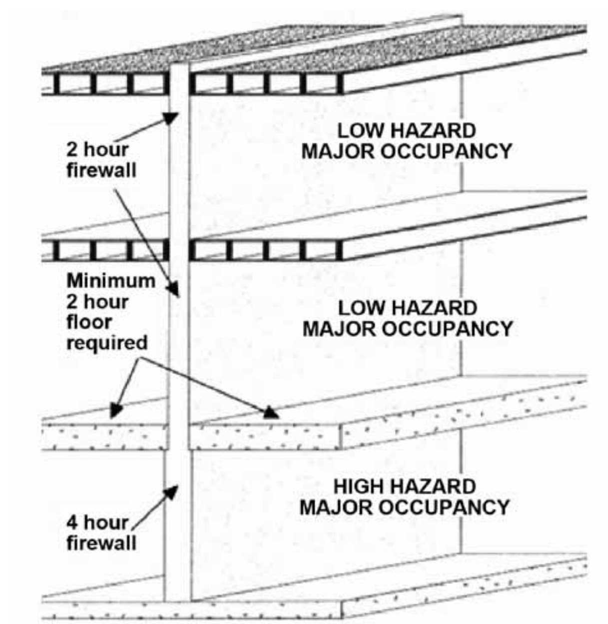
5A.5.1 General

The basic function of a firewall is to prevent the horizontal spread of fire from one area of a building to a neighbouring area. The firewall must completely separate the two areas. To do so, in most cases, it must extend from the foundation through all storeys of the building and through the roof to form a parapet (Articles 3.1.10.3 and 3.1.10.4, NBCC-10).

5A.5.2 Continuity

A firewall must remain in one vertical plane throughout its height. Prior to 1977, the NBCC permitted firewalls to be offset from storey to storey provided the fire separation was continuous bottom to top. This provision was dropped from the 1977 NBCC. Thus, if offsetting of a firewall is desired, a designer must demonstrate to the Authority Having Jurisdiction that the proposed design meets the objectives of the NBCC, as permitted by "alternative solutions" in Division A. Any structural framing supporting a firewall or a portion of it must be noncombustible and have a fire-resistance rating not less than that of the firewall. The framing must remain in place and support the wall for the length of time of the firewall's fire rating.

Figure 5A.23: *Permitted Fire-Resistance Reduction*



Where different floors in a multi-storey building contain occupancies with different fire hazard levels, a firewall may not be required to have the same fire-resistance rating throughout its height [3.1.10.2.(1), NBCC-10]. For example, if the first storey of a building contains high hazard occupancies, a firewall through that storey would require a 4 hr. fire-resistance rating. And although the firewall must extend through all other storeys of the building, where the upper storeys contain only low hazard occupancies, the fire-resistance rating of the firewall through those storeys may be reduced to 2 hours. The fire-resistance rating of the floor between the high and low hazard occupancies, which must have at least a 2 hour rating, combined with the 2 hour firewall in the upper storeys, provides the required 4 hours between high and low hazard occupancies on opposite sides of the firewall (Figure 5A.23).

Where the high hazard occupancy is located above the lesser hazard, the fire-resistance rating of the entire firewall must be at least 4 hours because the supporting firewall or structural frame must have a fire-resistance rating at least equal to the firewall it supports [3.1.10.1.(3), NBCC-10].

5A.5.3 Termination Over Parking Garages

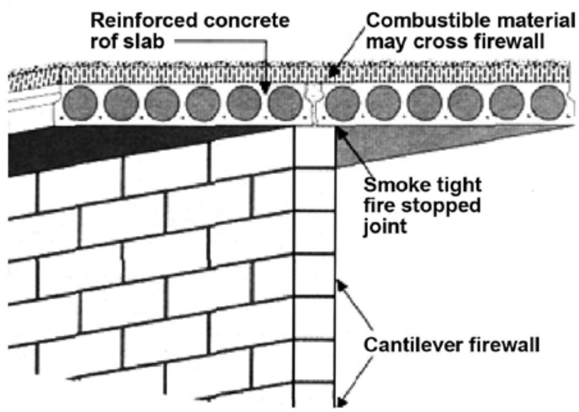
Because of the durability and inherent fire-resistance of concrete construction used for parking garages, and because other fire protection measures must be applied in basement parking garages, there is an exception to having the base of the firewall begin at the foundation. Provided the floor assembly immediately above the parking garage is a fire separation constructed of reinforced concrete having not less than a 2 hour fire-resistance rating, the base of the firewall may terminate on top of that floor [3.1.10.3.(1), NBCC-10]. The floor acts as a horizontal extension of the firewall (Figure 5A.5). If, however, the firewall is required to have a 4 hour rating, its supporting structure must also have a fire-resistance rating of 4 hours.

5A.5.4 Termination at Underside of Roof Slab

Where a building on both sides of the firewall has a reinforced concrete roof with not less than ½ the fire-resistance rating required of the firewall (1 hour for a 2 hour wall, 2 hour for a 4 hour wall), the firewall is permitted to terminate at the underside of the roof slab [3.1.10.3.(2), NBCC-10]. The fire rated concrete slab prevents the fire from spreading over the firewall to the adjacent building area. The roof slab immediately above the firewall must not have any concealed spaces crossing the firewall because they may provide a path for fire to spread over the firewall. Also, the joint between the wall and the roof slab must be properly fire stopped to prohibit the passage of smoke and flame.

Using a fire-rated concrete slab also permits combustible roofing material to extend across the firewall location. A loadbearing cantilever firewall should be considered for use in this situation to ensure that a collapsing roof slab does not cause the wall to fail (Figure 5A.24).

Figure 5A.24: *Termination at Concrete Roof*



5A.5.4 Parapets

Parapets are considered to be an extension of a firewall above the roof line. As with any other part of the firewall, combustible materials may not pass through, over, or around the parapet. Its height is dependent on the expected fire severity, which is related to the fire load of the occupancy. Where the fire hazard is low and only a 2 hour fire-resistance rated wall is required, the NBCC permits the parapet height to be as little as 150 mm [3.1.10.4.(1), NBCC-10]. For a 4 hour firewall, the parapet must be at least 900 mm above the roof [3.1.10.4.(1), NBCC-10]. These parapet heights are considered by the NBCC to be adequate to prevent the ignition of combustible roof elements by wind-driven flames or radiant heat, although greater heights are recommended particularly for 2 hour firewalls (Figures 5A.25a and 5A.25b).

Figure 5A.25a: *Parapet for 2 Hour Firewall*

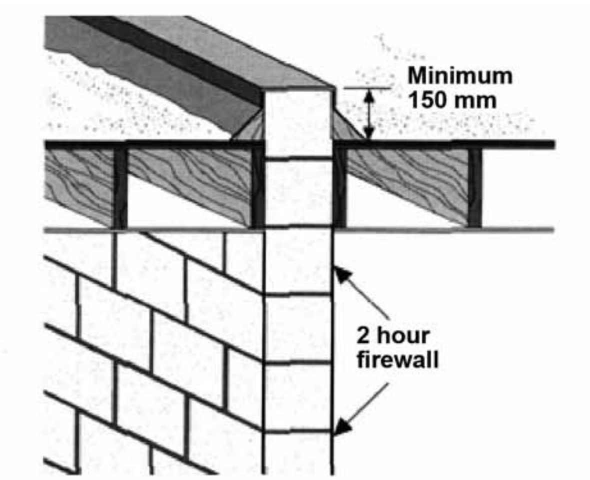
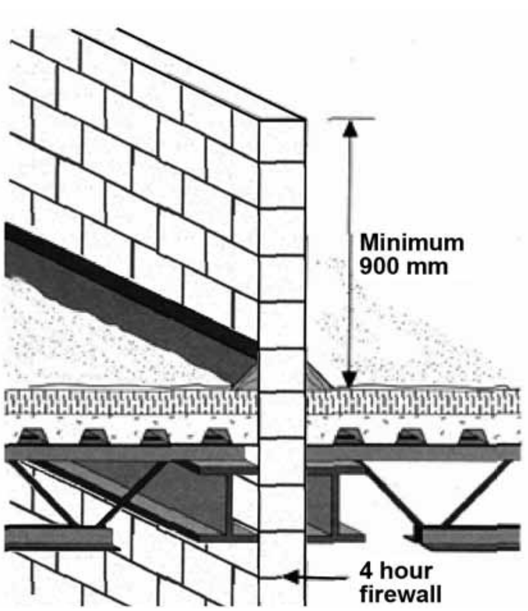
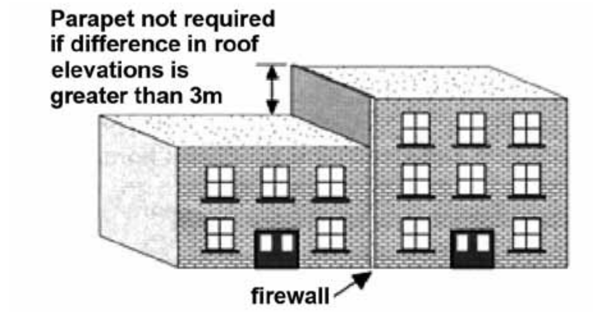


Figure 5A.25b: *Parapet for 4 Hour Firewall*



Where the two building areas separated by a firewall having different roof elevations, the firewall must extend above the upper roof surface and form the required parapet. However, if the difference in roof elevations is greater than 3 m, this is considered to be of sufficient height, and a parapet is not needed on the higher building [3.1.10.4.(2), NBCC-10]. The use of a double firewall is not recommended in this case (Figure 5A.26).

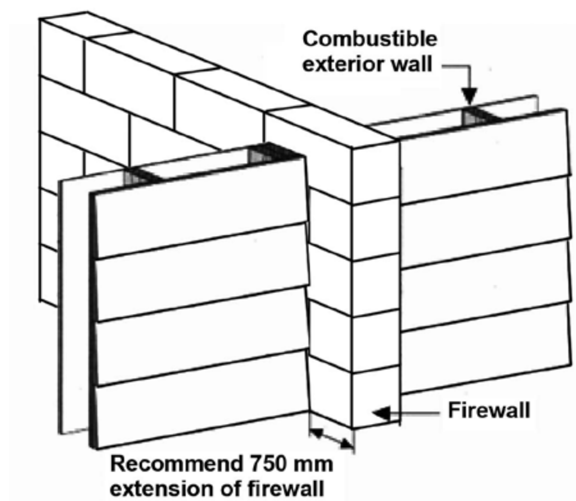
Figure 5A.26: *Firewall at Differing Roof Elevations*



5A.5.6 Horizontal Extensions

A firewall must be designed so that fire will not pass through it or around its perimeter. Like the top of a firewall and the need for parapets, the ends should also extend beyond all combustibles. Although not specifically required by the NBCC, an extension of the firewall beyond the outer surface of a combustible exterior wall of 750 mm or greater is recommended, particularly for 4 hr. firewalls. This projection will help prevent flames jumping around, or radiant heat passing by, the firewall (Figure 5A.27a). The use of masonry exterior walls without combustible exterior finishes will eliminate the need for extensions.

Figure 5A.27a: *Firewall Extension at Combustible Wall*



Where a firewall abuts against a noncombustible exterior wall and does not extend through the exterior wall, the joint between the two walls must be smoke tight (Figure 5A.27b). Where the exterior wall construction is combustible, and has a noncombustible exterior cladding such as concrete masonry veneer, the firewall must extend through to the noncombustible exterior layer [3.1.10.7(1), NBCC-10]. A smoke tight joint is also required here (Figure 5A.27c). Where combustible projections such as eaves are not properly separated (subsequently discussed in 5A.5.7), a firewall must also extend beyond those projections. An extension of 150 mm is recommended (Figure 5A.27d).

Figure 5A.27b: *Firewall Abutting Masonry Wall*

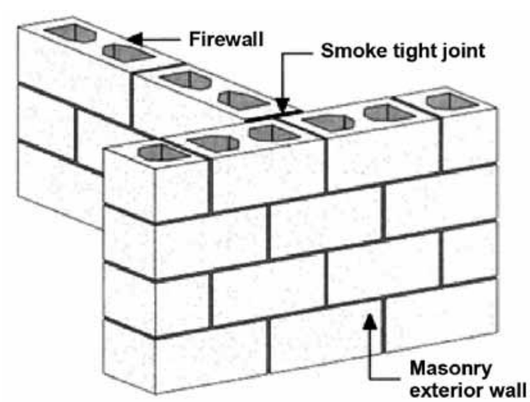


Figure 5A.27c: *Firewall Abutting Masonry Veneer*

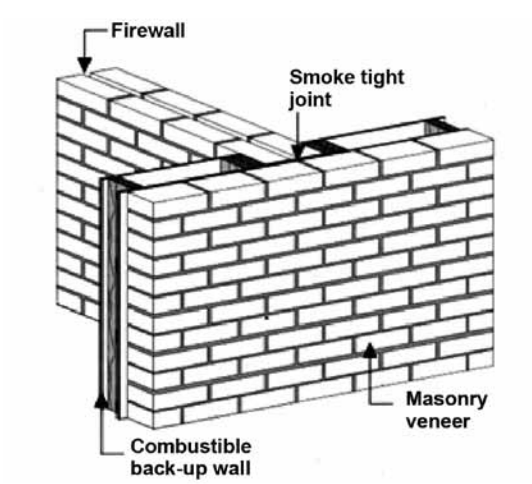
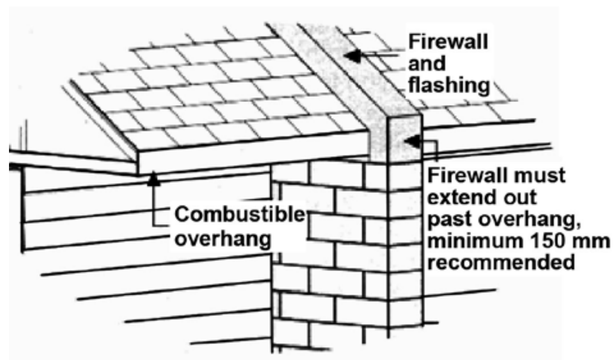


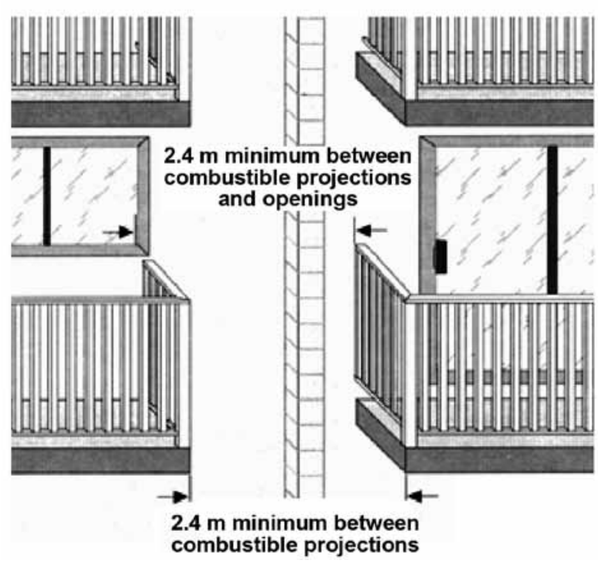
Figure 5A.27d: *Firewall Extension Past Eave*



5A.5.7 Combustible Projections

Combustible projections such as balconies, platforms, stairs and eaves that are located near a firewall can also be ignited by flames or heat that pass around the end of a firewall. Therefore, combustible projections are not permitted within 2.4 m of similar combustible projections, or window or door openings, placed on the opposite side of the firewall. This distance should provide adequate separation to prevent ignition of combustibles [3.1.10.7.(2), NBCC-10] (Figure 5A.28).

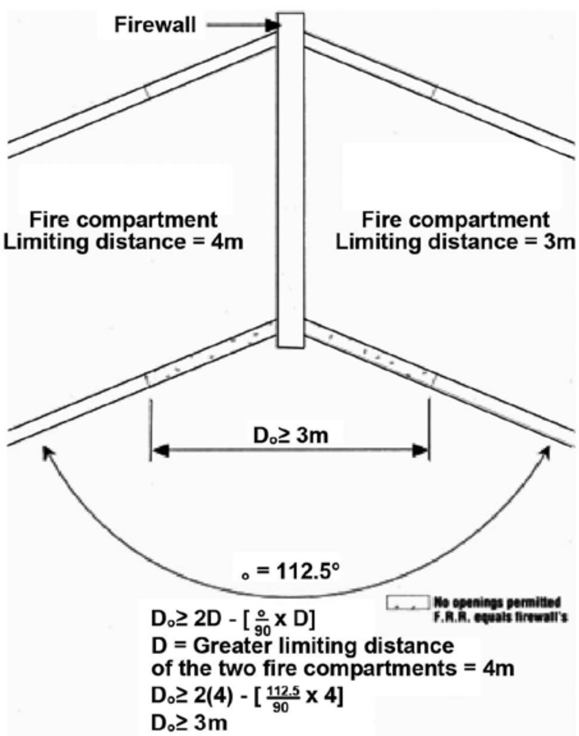
Figure 5A.28: *Combustible Projections*



5A.5.8 Exposure Protection

Where the exterior walls of a building adjacent to a firewall are not both perpendicular to the firewall, there may be potential for the fire spread by flame or radiation across the firewall. Where such exterior walls are at an external angle less than 135°, the exterior walls must be constructed with a fire-resistance rating equal to that of the firewall, and without any openings, within a minimum calculated distance of the firewall [3.1.10.7.(2) and Article 3.2.3.14, NBCC-10]. Figure 5A.29 illustrates this situation, using the equation required by Sentence 3.2.3.14.(1) of NBCC-10.

Figure 5A.29: *Exposure Protection Example*



5A.6 Openings and Penetrations/ Closures and Fire Stopping

A firewall, being a fire separation having a fire-resistance rating, must provide a continuous barrier to the spread of fire, and thus, it must be constructed as a continuous element [3.1.8.1.(1), NBCC-10]. The ultimate firewall, and one that would be the most reliable in performing this intended function, would have no openings or penetrations. However, this is oftentimes not practicable. And regardless of its fire-resistance rating, no firewall will reliably protect against fire spread if unprotected openings, or poorly maintained openings exist, or penetrations are not suitably sealed.

In order for the firewall to provide the required continuity, large openings such as a door or window must be equipped with a closure, and discontinuities and penetrations must be fire stopped.

5A.6.1 Closures

A closure is a device or assembly for closing an opening through a fire separation such as a door, a shutter, wired glass or glass block, including all of the necessary hardware for the device or assembly. Openings in firewalls must be fire-protected by closures. The fire-protection rating of a closure is the time in minutes or hours that a closure will withstand the passage of flame when exposed to fire under specified conditions of test and performance criteria prescribed by the NBCC.
A series of extensive requirements for closures are provided in Subsection 3.1.8 of NBCC-10.

Notwithstanding these minimum fire-protection ratings required by the NBCC for approved closures, openings are the weak points in firewalls. A closure in a firewall requires a fire-protection rating of not less than about ¾ of the required fire-resistance rating of the firewall into which it is included (Table 5A.4). Justification for this reduction is based on the premise that closures are not

Table 5A.4: *Required Fire-Protection Rating for Closures (Adapted from Table 3.1.8.4, NBCC-10)*

Fire Resistance Rating of Fire Separation	Minimum Fire-Protection Rating of Closure
45 min	45 min
1 hr	45 min
1.5 hr	1 hr
2 hr	1.5 hr
3 hr	2 hr
4 hr	3 hr

structural elements, and that the ratio of closure area to firewall area is quite limited.

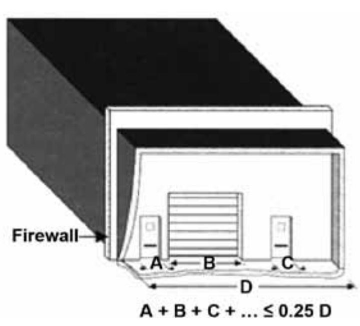
For double firewalls, two closures would be required for each opening, one in each wythe of the wall, with each having half the total required fire-protection rating. For fire dampers, a slip joint should be provided between the dampers.

The NBCC recognizes that closures often rely on fusible links or electronically operated devices to close them during the fire event, which may delay or cause failure of continuity of the fire separation. Thus, although openings in firewalls are protected in the same manner as for other fire separations, there are limits on the aggregate width of firewall openings. As with a fire separation, where a compartment on either side of the firewall is unsprinklered, any one opening in the wall may not be more than 11 m^2 in area or have a width or height greater than 3.7 m [3.1.8.6.(1), NBCC-10]. However, if both compartments are sprinklered, the maximum area may be doubled to 22 m^2, and the width or height may be as much as 6 m [3.1.8.6.(2), NBCC-10]. Additionally, the combined width of all openings cannot exceed 25% of a firewall's length [3.1.10.5.(1), NBCC-10] (Table 5A.5).

Table 5A.5: *NBCC-10 Maximum Permitted Openings*

Protected Opening	Maximum Permitted Dimensions	
	Unsprinklered	Sprinklered
Height	3.7 m	6.0 m
Width (1)	3.7 m	6.0 m
Area	11.0 m (2)	22.0 m (2)

Notes: (1) The sum of the widths of all openings shall not be greater than one-quarter the width of the firewall.
(2) Buildings on each side of the firewall must be sprinklered.



Wired glass and glass block masonry are not approved closures for firewall openings [3.1.8.14.(1), and Table 3.1.8.15, NBCC-10]. Wired glass is also prohibited in doors in 4 hr. firewalls, but may be used in doors in 2 hr. firewalls provided the area of wired glass is not more than 645 cm^2 (Table 3.1.8.15). A door placed in a firewall must comply with maximum temperature rise limits stated in Article 3.1.8.15. These restrictions are due to the critical nature of firewalls and the possible unreliability of such closures.

5A.6.2 Penetrations and Joints

Requirements for service penetrations and joints in fire-rated assemblies are discussed in detail in Section 5.6 of Chapter 5. Pertinent requirements for both fire separations and firewalls are identified therein.

Specific to firewalls:

1. Items penetrating a firewall require a fire stop system, and unlike fire separations, service penetrations through firewalls cannot be sealed by casting-in-place [3.1.9.1.(1), NBCC-10].
2. Penetrant fire stop systems for firewalls require an hourly "FT rating" not less than the required fire-resistance rating of the firewall [3.1.9.1.(2), NBCC-10].
3. Joint fire stop systems for firewalls must provide an hourly FT-rating not less than the fire-resistance rating for the firewall.

In addition to the above, pipes, ducts, totally enclosed noncombustible raceways or other similar service equipment permitted to penetrate a firewall must also be designed so that they will not cause the wall to fail if they collapse [3.1.10.1.(4), NBCC-10]. There are several methods which may be used to accomplish this, for example:

1. Pass raceways, pipes, ducts and other service equipment through the wall at or near the floor. Generally, the recommended height is no more that 1 m above finished floor level. The lower area of a wall is subjected to less heat and is more stable so damage is less likely to occur.

2. Loosely coil (loop) the cables for cable trays right above the floor level on each side of the firewall to prevent them from pulling on the wall during a collapse of part of the building.
3. Where possible, piping, cable trays, conduits, and cables should be passed over, under or around firewalls, rather than through them.
4. For cable trays and ducts, install slip joints on each side of the firewall, as near to the face of the wall as possible, so they can detach from the wall without exerting force on it during a collapse.
5. Feed sprinkler systems on either side of the firewall to avoid penetration of the wall.

5A.7 Firewalls of other than Masonry or Concrete

The 1995 National Building Code of Canada (NBCC-95) prescribed that all firewalls be constructed of masonry or concrete regardless of their required fire-resistance rating. Requirements for fire performance, structural integrity, and durability of firewalls were thereby explicit and implicit, and compliance was comparatively simple to demonstrate. The needed properties and performance of a firewall were assured by the inherent properties, characteristics and behaviours of traditional masonry and concrete systems designed and constructed in accordance with their respective, consensus-based CSA standards.

In marked contrast, and in a radical departure from NBCC-95, the Objective-Based 2005 NBCC introduced requirements that permit a firewall having a fire-resistance rating of not more than 2-hr. to be constructed of non-combustible materials other than concrete or masonry [3.1.10.2.(4), NBCC-05]. This has provided opportunity for the marketing of alternative, proprietary firewalls such as those offered by the gypsum industry. On occasion, the substitution of a masonry firewall with an alternative construction might be considered by an owner, developer, or builder for a perceived construction first-cost benefit. When considering this substitution, caution, prudence and diligence by the structural engineer and other design professionals are essential to avoid specifying and constructing an alternative wall assembly that simply cannot perform the intended functions of a firewall.

Upon closer examination, the new objective-based requirements for 2-hr. firewalls, also permitted in NBCC-10 [3.1.10.2.(4)], are readily found to be deficient because they do not identify all of the required attributes of a firewall needed to ensure its intended function, acceptable minimum and quantified levels of performance for each function, and means to specify the levels of performance, or appropriately define means to determine compliance. These deficiencies are identified and discussed in detail in Section 5A.7, herein.

Note that NBCC-10 requires firewalls having a fire-resistance rating greater than 2 hrs. to be constructed of masonry or concrete. This has not changed from the 1995 edition of the NBCC.

5A.7.1 Compliance with NBCC-10; 2-hr. Firewalls of Other Than Masonry/Concrete

5A.7.1.1 Attributes of a Firewall, Performance, and Verification

The NBCC-95 requirements for firewalls are entirely prescriptive in nature, and code compliance is therefore readily discernable. In contrast, the NBCC-10 requirements for 2-hr. firewalls of other than masonry/concrete are entirely objective-based, and whereas the mandatory requirements of Sentence 3.1.10.2.(4) and Appendix Note A-3.1.10.2.(4) provide objectives as a basis for evaluating solutions, there are obvious deficiencies:

1. They identify only ”fire-resistance rating” (endurance), “protection against damage”, and overall structural stability (by cross-reference to Article 4.1.5.17) as the essential attributes (or functional requirements) of firewall construction. They do not identify other essential properties, characteristics or attributes needed by firewalls to perform satisfactorily including, but not limited to:
   - structural serviceability (movements and deformation)
   - structural and fire resistance to direct/localized

impact from collapsing members and falling construction debris or other objects during a fire event;

- resistance to hose stream for full fire duration;
- resistance to renovation;
- duplicity of construction in the field;
- residual post-test strength; and,
- durability (see subsequent discussion, herein).

These are unstated or unidentified attributes inherent in masonry firewall construction prescribed by the NBCC-95. When a firewall is called upon to stop a spreading fire that is reaching or has attained conflagration proportions, and if it is to serve its purpose, it must have attributes far in excess of the two attributes required by NBCC-10, 3.1.10.2.(4) (a) and (b).

2. They do not make mandatory or identify any test(s), either field or laboratory, to establish a measure of performance related to:
   - "protection against damage";
   - other properties, characteristics or attributes needed by firewalls to perform satisfactorily.
3. They do not make mandatory or identify any minimum levels of performance related to:
   - "protection against damage";
   - other properties, characteristics or attributes needed by firewalls to perform satisfactorily.
4. Although they do caution the user by way of appendix note that:

   "…for the purposes of determining the overall performance of the assembly, it is also necessary to determine by test whether the failure of the damage protection component during a fire affects the performance of the fire-resistive component…",

   they do not provide quantitative criteria or verification methods, that is, useable guidance to building officials or to designers on testing or minimum level of performance related to this attribute to exercise judgment and to determine if the objective "protection against damage" has been met.
5. They do not reference good-practice documents, or more importantly, do not reference related consensus standards or consensus documents.

In summary, with respect to a user's ability to establish compliance for 2-hr. firewalls of other than masonry/concrete construction, the stated requirements in NBCC-10 do not satisfactorily:

- identify (all) the required attributes of a firewall;
- determine acceptable minimum levels of performance;
- identify means to specify the levels of performance;
- define means to determine compliance;

and, consequently, the NBCC-10 requirements for firewalls of other than masonry/concrete are discretionary and not verifiable.

5A.7.1.2 "Durability", and "On-Going Performance" of a Firewall

There is an inherent "resistance" to the use of the term "durability" within the National Building Code of Canada. Notwithstanding, the Canadian Commission on Building and Fire Codes (CCBFC) acknowledges that "durability" is a legitimate issue to address, but only to the extent that it is related to the achievement of the codes' objectives, and that durability is not an objective for its own sake. An illustrative example provided in a CCBFC document titled, *"Appendix A, Objectives Addressed by the National Building Code"*, states:

> *"For example, given that one objective of the National Building Code is safety, the intent of many durability-related requirements is to discourage deterioration of the building's safety features at an unacceptable rate. Therefore these requirements would be linked to the objective of safety."*

Because "firewalls" are fire safety features ("fire safety" being a sub-objective to the objective of "safety"), the issue of "durability" is applicable to them. Rationally, firewalls:

- must be resistant to any mechanisms of deterioration, without maintenance, throughout the design service life of the building, in readiness to satisfactorily perform their intended functions during a fire; and,

- must be resistant to any mechanisms of deterioration during a fire for a stated minimum period of time.

The CCBFC also acknowledges that *"durability is a factor appropriate for codes, provided…any requirements are clear, explicit and enforceable at the time of construction." ("Possible Measures to Implement the Strategic Plan of the CCBFC"*, 1996)

Requirements for the "on-going performance" of firewalls are implicit in the prescriptive requirements of NBCC-95, which demand construction of only masonry or concrete; they are neither implicit nor explicit in the NBCC-10 for alternative firewalls having a fire-resistance rating of 2 hr. or less.

NBCC-10 permits 2-hr. firewalls to be constructed of other than masonry or concrete by way of objective-based requirements, but it does not in any manner identify "durability" or "on-going performance" as requirements or objectives.

Although Part 5 of the NBCC-10 contains requirements for *"compatibility"* and *"resistance to any mechanisms of deterioration which would be reasonably expected", these requirements apply only to "materials that comprise building components and assemblies that separate dissimilar environments"* and firewalls do not necessarily serve this function; moreover, such requirements in Part 5 do not pertain to issues of fire safety.

"One important aspect of enforceable durability requirements is that the criteria used to define the required performance must be clearly stated and conformance to those criteria must be easily determined at the time of construction. Inability to assess and verify conformance in advance of putting the building into use will result in an inoperable regulation that will shift the burden to the legal system." ("The National Building Code: Durability Requirements and their Incorporation into an Objective-Based Structure", Chown and Oleszkiewicz, 1997)

In summary, the NBCC-10 requirements permit the construction of firewalls other than of masonry/concrete that are not required to satisfy any stated or implied criteria for *"on-going performance".*

5A.7.1.3 Technical Requirements for Firewalls, NBCC-10

5A.7.1.3.1 Use of Duplicate Specimen to Provide Fire-Resistance Rating, and Testing to Establish Performance and Evaluate a Firewall

Article 3.1.7.1 of NBCC-10 references CAN/ULC-S101 for the determination of fire-resistance ratings of assemblies, wherein, a duplicate test specimen may be used (if needed) to satisfy resistance to the hose stream test. Use of a duplicate specimen to achieve a stated fire-resistance rating is common for assemblies not of masonry or concrete, for example, gypsum board assemblies. Where a duplicate specimen is used, it is exposed to the effects of the hose stream immediately after being subjected to a fire endurance test for a time period of one-half the fire endurance classification period determined from the fire endurance test on the original specimen. Stated alternatively, a duplicate specimen is exposed to a hose stream after 1 hour when the original specimen is subjected to fire for a 2 hr. period; if it sustains the hose stream, the assembly is given a 2 hr. fire-resistance rating.

Masonry assemblies do not require a duplicate specimen to pass the hose stream test. The fire-resistance rating for masonry assemblies is limited by temperature rise on its unexposed face and not by impact/shock due to hose stream. Hence, the behaviour of a masonry/concrete firewall under the standardized test is radically different from other wall types that achieve the same fire-resistance rating using the duplicate specimen compliance path of the standardized test. For additional discussion, see 5.3.2.2.3 *Significance, Use, and Limitations of ULC-S101 (ASTM E 119)*. For additional discussion about the standardized fire test and use of the duplicate specimen, see 5.3.2 of this Guide.

As a general comment about all "standardized tests", such tests compare materials or assemblies under a given set of conditions which may not represent all conditions under which they are used. Each standardized fire test has some sort of explanatory paragraph in the scope. For example in ASTM E 119, *Standard Test Methods for Fire Tests of Building Construction and Materials,* Sec 1.3 qualifies: *"This standard ... does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products or assemblies under actual fire conditions."*

There exists no standard to test and evaluate the performance of a "firewall", and to differentiate and evaluate the performance of such a wall from a wall having a "fire-resistance" rating. Previous to the NBCC-10, the performance of firewalls could be relied upon in the field because they were prescribed to be constructed of masonry/concrete which inherently offer properties and behaviours under field or test fire conditions that can differ markedly from other walls that receive a fire-resistance rating using a test that (simply) measures fire-resistance rating. And moreover, in the specific cases of ULC-S101 and ASTM E 119, two profoundly different compliance paths can be used to establish hose stream performance, hence two distinct levels of durability performance are included, and the relative fire performance of different wall assemblies becomes somewhat of an optional measurement.

The intent of Article 3.1.7.1, NBCC-10, is not clear. Rationally, firewalls should not rely on a duplicate specimen to pass the hose stream test to receive its fire-resistance rating. If it is not the intent of Article 3.1.7.1 to prohibit the use of a duplicate specimen to establish the fire-resistance rating for a firewall, then effectively, the NBCC-10 permits a 2-hr. firewall constructed of other than masonry/concrete to be penetrated by a standard hose-stream after 1-hr., and this is indeed contrary to the performance needed to maintain integrity throughout full exposure (non-compliance with Sentence 2, Commentary "C", *"Structural Integrity of Firewalls" in the "User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)".*

5A.7.1.3.2 Structural Integrity

The term "integrity" is used in Sentences 3.1.10.1.(1), and 3.1.10.2.(4)(a) of NBCC-10. Although the term "integrity" is not defined by the NBCC-10, in the context of these Sentences and with reference to Commentary "C", *"Structural Integrity of Firewalls"* in the *"User's Guide—NBC 2010, Structural Commentaries (Part 4 of Division B)",* "integrity" implies that the firewall must be designed structurally so *"that the fire not spread between compartments separated by a firewall within the required fire-resistance rating for the wall"*, and further, *"…to achieve this, the wall must not be damaged to the extent that it allows fire spread during this time".* Commentary C further identifies and describes:

- that collapse of the firewall due to explosion, glancing blows from falling debris, force and thermal shock of fire-hose stream and wind pressure can be prevented by designing the system to resist a factored live load of 0.5 kPa (for a firewall located on the building interior);
- that the firewall be designed to resist "normal structural requirements" for interior walls for wind and earthquake, including that for pounding damage;
- that the firewall resist the loads and the effects of loads caused by thermal expansion that would cause damage and allow premature fire spread through the wall; and,
- that the firewall be designed for "structural integrity" in accordance with Part 4 Commentary B.

Part 4 Commentary B, *"Structural Integrity"* describes "structural integrity" as *"the ability of the structure to absorb local failure without wide-spread collapse"*.

Thus, for firewalls, the Part 4 commentary suggests that requirements for "integrity" may be satisfied by a design that:

- resists a factored uniformly distributed live load of 0.5 kPa (interior loading);
- resists normal structural loads otherwise required by Part 4;

- does not collapse (wide-spread, not local) during the fire;
- accommodates thermal effects of a fire event; and,
- resists “pounding”.

In review of this,

- The NBCC-10 uses a 0.5 kPa uniformly distributed load imposed on the firewall to model forces due to explosion, glancing blows from falling debris, impact and thermal shock of a fire-hose stream, all of which are point loads.
- The NBCC-10 does not clarify if the resistance by the wall system to the 0.5 kPa load is determined on the assembly at the time of construction, or, if the resistance must be established using those properties/characteristics/behaviour of the assembly resulting from exposure to the fire (although concrete and masonry firewalls are designed as such).
- In some manner, the firewall must resist “pounding”; “pounding” is neither defined nor described by the NBCC-10…it is not quantified…and no standard test is referenced.
- The text in Commentary C-10 remains unchanged from Commentary M-95. Part 4, NBCC-10, assumes that local penetration of the firewall under fire conditions may not lead to widespread collapse, or otherwise, it assumes that there exists an inherent resistance to local penetration by the wall system, and this assumption has shown to be correct where the firewall is constructed of masonry/concrete. It cannot be assumed, and should be demonstrated where the firewall is constructed of other than masonry/concrete.

In light of these observations, the NBCC-10 can be seen as deficient in its structural requirements for 2-hr. firewalls constructed of other than masonry/concrete, in that:

- The NBCC-10 does not appropriately address requirements for point loading incident upon a firewall during a fire event, needed to ensure that firewall integrity for walls constructed of other than masonry/concrete is maintained throughout the required fire rated time.
- By way of imposing a uniformly distributed load as a means to assess point loading caused by fire events, the NBCC-10 is misleading, with the attendant risk that a firewall constructed of other than masonry/concrete may indeed not be designed to resist point loading and consequently may not maintain its integrity during the fire for the required time of exposure.
- In the move to objective-based codes, and by NBCC-10 acceptance of firewalls constructed of other than masonry/concrete, the structural design requirements in the NBCC-10 do not acknowledge that the resistance to a point loading inherently offered by masonry/concrete systems during fire, inherently may not be offered by alternative systems.

  As such, where this inherent resistance can be relied upon by the designer when using prescriptive requirements (Division B, Acceptable Solutions), it cannot be relied upon and may be absent from alternative systems designed and constructed under the objective-based requirements (Division A).
- Because the NBCC-10, by way of ULC-S101, permits assignment of fire-resistance rating using a duplicate specimen, there is a high risk that a 2-hr. firewall designed and constructed under the objective-based requirements will not maintain its integrity throughout its intended 2-hr. duration.

The requirements related to firewall integrity within the NBCC-10 are unclear and contradictory. Consequently, firewalls of other than masonry/concrete cannot be fully rationally designed for structural integrity using the current requirements of NBCC-10.

5A.7.1.2 Consequences of NBCC-10

5A.7.1.2.1 General

The objective-based path of the NBCC-10 does not fully and clearly identify all of the required attributes of a firewall, acceptable minimum (quantified) levels of performance, means to specify the levels of performance, means to measure, or means to verify compliance. In a strict and real sense, a rational engineering approach to, and verifying compliance of, an alternative solution to 2-hr. firewalls of masonry/concrete is prohibitive because the technical requirements in the Code are incomplete, not clear, and contradictory or absent. And, presently, in the absence of the intelligence needed to undertake a rational design, Building Officials should be compelled to scrutinize and challenge the design process, testing standards, performance baselines, and all design and construction criteria used by any designer or purveyor of a proprietary firewall system to "demonstrate" compliance of an alternative firewall design.

Unfortunately, with this confusion comes some likelihood that assemblies that cannot perform will be constructed and substituted for firewalls of masonry and concrete for a perceived construction first-cost benefit.

Firewalls of masonry and concrete are proven to perform effectively in the field, are forgiving to deficiencies in design and construction, do not require unusual or non-standard construction practices, are inherently resistant to nearly all mechanisms of deterioration occurring in-service both before and during the fire, and are easily duplicated. Using the requirements of NBCC-10, compliance is readily verifiable where the firewalls are designed and constructed of masonry.

5A.7.1.2.2 Ontario Building Code, and Alternative Firewalls

Despite the strong commitment by all provinces to integrate the national and provincial code development systems and harmoniously adopt NBCC requirements for the provincial building codes, the Ontario Building Development Branch chose to move unilaterally and to amend the NBCC-10 on the issue of 2-hr. firewalls constructed of other than masonry/concrete.

The Ontario Building Code does *not* permit 2-hr. firewalls (and "less") to be constructed of other than masonry or concrete where they separate buildings or buildings with floor areas having care or detention occupancies, or where they are used in "high buildings". Therein, is an inherent acknowledgement that 2-hr. firewalls of other than masonry/concrete likely will not offer the same level of fire performance. Additionally, where permitted for other Uses such as for party walls, the OBC requires the level of performance of such alternative firewalls to be not less than that of masonry or concrete in areas of performance during fire conditions, mechanical damage during the normal use of the building, and resistance to damage from moisture.

The OBC requirements maintain an objective-base and are intended to provide assurances that designers, builders, and purveyors of systems alternative to masonry or concrete firewalls must clearly demonstrate, by way of standardized tests and comparison, that such firewalls offer equivalency to masonry/concrete firewalls in all areas of fire performance and related structural performance.

Despite these improvements, the current OBC conspicuously omits a comprehensive list of the functions of firewalls, and the design considerations for each function which must be addressed to demonstrate equivalency to masonry/concrete firewalls and ensure firewall performance. To demonstrate equivalency, areas for consideration must include all of the essential properties, characteristics and attributes needed by firewalls to perform satisfactorily, including those not specifically stated and unidentified by the NBCC-10 and OBC, and inherent in masonry/concrete construction prescribed by the NBCC-95 and OBC-97. Such areas would include, but are not necessarily limited to: resistance to renovation and abuse; duplicity of construction in the field; durability and on-going performance (alternatively stated, resistance to mechanisms of deterioration without maintenance throughout the design service life of the building, in readiness to satisfactorily perform their intended functions during a fire); determination of fire-resistance rating (in its most simple form, requiring resistance to hose-stream after full duration of fire test rather than half-duration as is commonly reported for gypsum systems); structural and fire resistance to direct/localized impact during fire from collapsing members, falling construction debris or other objects, and to explosion; and overall and local structural integrity and serviceability at elevated temperatures.

5A.7.1.2.3 Alberta Building Code, and Alternative Firewalls

Unlike the OBC, the Alberta Building Code adopted the NBCC-05 requirements without change. However, the Alberta Building Technical Council, responsible for the technical content of the Alberta Building Code, identified a concern and need to clarify and interpret the NBCC-05 for both designers and building officials. In February, 2008, the ABTC released STANDATA 06-BCI-005-R1, titled, "Two Hour Firewalls" (http://municipalaffairs.gov.ab.ca/documents/ss/STANDATA/building/bci/06BCI005.pdf)

The STANDATA identifies a number of changes and clarifications to the requirements in the ABC/NBCC-10, including, but not limited to: (a) modifying the ULC-S101 fire test to eliminate the use of duplicate specimens; (b) stating the need to evaluate the damage protection features using the resistance of masonry and concrete as the basis for acceptance, and (c) clearly identifying the design professional as the individual responsible for ensuring that evaluations have been performed.

5A.8 Masonry Firewalls vs. Masonry Fire Separations

There are substantive differences between requirements for masonry firewalls and masonry fire separations within NBCC-10 because these walls perform markedly different functions. Yet, there are many similarities. Their differences are summarized as follows:

Fire-Resistance Rating:

1. The required fire-resistance rating of a firewall must be provided by masonry or concrete only. The inclusion of cell material other than grout/concrete or mortar cannot contribute to the fire-resistance rating of a masonry firewall whether all cells are filled or not.

Structural:

1. A firewall must have structural stability, sufficient to remain intact under fire conditions for the required fire-rated time. Consequently:
    1. a firewall must be designed to resist the "maximum effect" resulting from otherwise normal loading conditions prescribed by Part 4, or a minimum factored lateral load of 0.5 kPa under fire conditions;
    2. the connections and supports of framing members must be detailed such that the collapse of the framing members will not cause a premature failure of the firewall;
    3. pipes, ducts, totally enclosed noncombustible raceways or other similar service equipment which penetrate a firewall must be designed so that they will not cause the wall to fail if they collapse.

Openings/Closures:

1. Openings in firewalls are protected in the same manner as for fire separations. A closure requires a fire-protection rating of not less than about ¾ of the required fire-resistance rating of the wall into which it is included (Table 5A.4).
2. There are limits on the aggregate width of firewall openings:
    1. where a compartment on either side of the firewall is unsprinklered, any one opening may not be more than 11 m^2 in area or have a width or height greater than 3.7 m;
    2. if both compartments are sprinklered, the maximum area may be doubled to 22 m^2, and the width or height may be as much as 6 m;
    3. the combined width of all openings cannot exceed 25% of a firewall's length.
3. Wired glass and glass block masonry cannot be used for firewall openings.

4. Wired glass is prohibited in doors in 4 hr. firewalls, but may be used in doors in 2 hr. firewalls provided the area of wired glass is not more than 645 cm^2.
5. A door placed in a firewall must comply with maximum temperature rise limits.

Penetrations:

1. Unlike fire separations, service penetrations through firewalls cannot be sealed by casting-in-place.
2. Penetrant and joint fire stop systems require an FT-rating for firewalls, and an F-rating for fire separation walls.
3. The required hourly ratings for fire stop systems must be not less than that shown in Table 5.6 of this Manual.

Parapets and Extensions:

1. The primary purpose of a firewall is to divide a building into separate building areas. Consequently, a firewall must provide vertical continuity, and in most cases, a firewall must extend from the foundation through all storeys of the building and through the roof to form a parapet. Additionally, to provide horizontal continuity, an extension of the firewall beyond the outer surface of a combustible exterior wall is recommended, particularly for 4 hr. firewalls.

5A.9 Summary

This Manual explains the provisions within the NBCC-10 for firewalls, and specifically, pertinent to masonry firewalls. The key points can be summarized as follows:

1. The required fire-resistance rating for masonry firewalls must be obtained using masonry (or concrete) materials and assemblies only. Conventional Type N and Type S mortars, in accordance with CSA A179-04, *"Mortar and Grout for Unit Masonry"*, are suitable for the construction of masonry firewalls. NBCC-10 does not assign or limit fire-resistance ratings of concrete masonry based upon bond pattern (running and stack). Therefore, the determination of the fire-resistance rating of concrete masonry is independent of bond pattern.
2. The function of a firewall is to effectively contain the anticipated fire for the time it takes the fire on one side of the firewall to burn itself out.
3. Building areas divided by firewalls are considered separate buildings for structural fire protection purposes.
4. The number of firewalls needed in a building is generally governed by height and area restrictions, which are based on occupancy and construction type.
5. The required fire-resistance rating of a firewall depends on the occupancy of the building: high hazard occupancy requires a 4-hr. rating, other occupancies require a 2-hr. rating.
6. All openings in firewalls must be protected by appropriate fire-rated assemblies.
7. A firewall designed in accordance with the appropriate provisions of the NBCC may be used to support adjoining construction assemblies.
8. A firewall may terminate at the underside of a properly fire-rated concrete roof but must extend through any other roof and form a parapet.
9. A firewall need not extend below a reinforced concrete floor above a parking garage.
10. A firewall must extend through all combustible materials placed in exterior walls, and beyond using suitable length of projections, but is permitted to terminate at the inside face of a noncombustible wall or a noncombustible cladding.
11. The principal difference between a firewall and a fire separation having a fire-resistance rating is its superior fire-resistance and its ability to withstand the collapse of construction on either side of the wall without collapse of the firewall itself.
12. Firewalls having a fire-resistance rating greater than 2-hr. must be constructed of masonry or concrete. Firewalls having a fire-resistance rating of not more than 2 hr. may be constructed of other than masonry or concrete, however, the related objective-based

technical requirements within the NBCC-10 intended to ensure fire performance are incomplete, not clear, contradictory or absent. Consequently, there is a risk that a 2-hr. firewall designed and constructed under these requirements will not perform as expected during the rating period. Designers and Building Officials should be well-aware of the deficiencies of the objective-based firewall requirements of the NBCC-10 where the respective provincial building code is based on this model.

5A.10 References

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