



Canadian Concrete Masonry Producers Association

Metric Technical Manual

Fire Performance

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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 deter-



mine 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

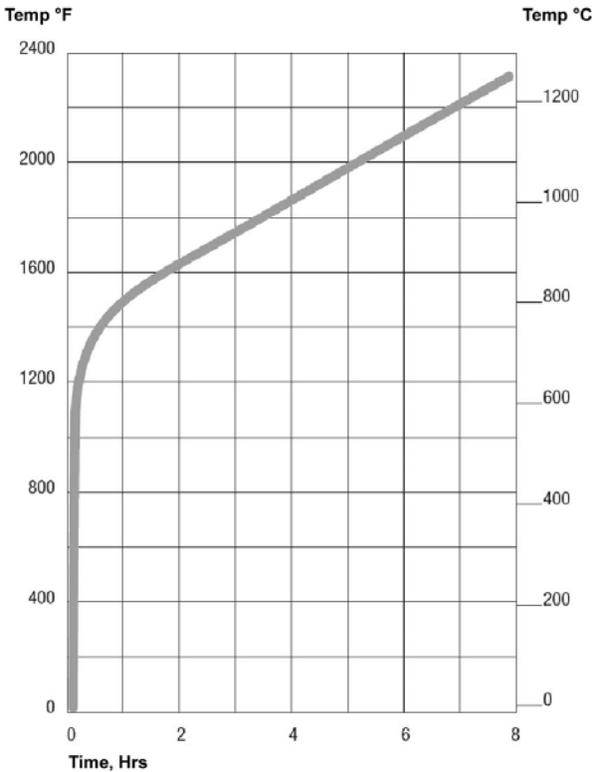
side edge restraint for loadbearing walls. The introduction of a vertical load is particularly critical for light-frame wall systems such as wood and steel stud where loss of strength is likely and deflections and deformations under vertical load and elevated temperatures, concurrently, will affect the 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 m² (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 rigorous 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 rigorous 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 calcula-



tion 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 im-

proves. 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 L₁ concrete is the type in which all the aggregate is expanded shale.

Type L₂ concrete is the type in which all the aggregate is expanded slag, expanded clay or pumice.

Type L₁20S and Type L₂20S 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):

$$\text{FRR} = 1.5 \text{ hrs.} + [(105 - 95) / (113 - 95)](2 \text{ hrs.} - 1.5 \text{ hrs.}) = 1.77 \text{ hrs.} = 106 \text{ min.}$$

Example 3

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

The required fire-resistance rating of a concrete ma-



sonry wall is 3 hrs. It is desired to use a 190 unit manufactured from L₂20S 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 L₂20S 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 L₂20S 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 L₁ Concrete. Determine the FRR for a fire separation of concrete masonry constructed with these units.

Solution

Calculate equivalent thickness = $0.53 \times 240 \text{ mm} = 127.2$

For Type L₁ 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):

$$\text{FRR} = 3.0 \text{ hrs.} + \left[\frac{(127.2 - 122)}{(143 - 122)} \right] (4.0 \text{ hrs.} - 3.0 \text{ hrs.}) = 194 \text{ min.}$$

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 L₁ 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 L₁ 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):

$$\text{FRR} = 3.0 \text{ hrs.} + \left[\frac{(140 - 122)}{(143 - 122)} \right] (4.0 \text{ hrs.} - 3.0 \text{ hrs.}) = 231 \text{ min.}$$

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 L₂20S 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 = $0.56 \times 190 = 106.4 \text{ mm}$.

For Type L₂20S 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):

$$\text{FRR} = 2.0 \text{ hrs.} + [(106.4 - 94) / (116 - 94)](3.0 \text{ hrs.} - 2.0 \text{ hrs.}) = 153 \text{ min.}$$

5.5.2.2.2 Multi-Wythe Concrete Masonry

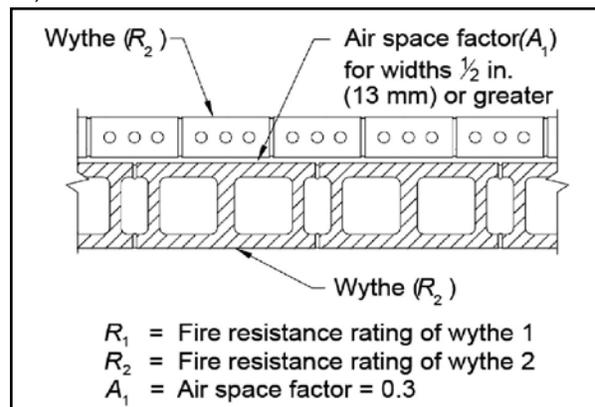
Appendix D-2.1.2, NBCC-10 permits the calculation method to determine the fire-resistance rating of multi-wythe masonry walls, including cavity walls (having two parallel wythes of masonry with an included air space) under the following conditions:

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)



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 L₂ 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-load-bearing 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:
 - EQ (Wall) = EQ (Wythe 1) + EQ (Wythe 2)
 - EQ (Wall) = 0.58 x 140 + 0.73 x 90 = 146.9 mm
 - 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):

$$\text{FRR} = 3.0 \text{ hrs.} + [(146.9 - 142) / (167 - 142)](4.0 \text{ hrs.} - 3.0 \text{ hrs.}) = 191 \text{ min.}$$

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 posi-

tioned 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 filled with mineral wool conforming to CAN/ULC-S702, "Mineral Fibre Thermal Insulation for Buildings," and having a mass of not less than 2 kg/m², 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 = $0.56 \times 190 \text{ mm} = 106.4 \text{ mm}$.

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):

$$\text{FRR} = 1.5 \text{ hrs.} + [(106.4 - 95) / (113 - 95)](2.0 \text{ hrs.} - 1.5 \text{ hrs.}) = 109 \text{ min.}$$

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 = $1.25 \times 12.7 = 15.8 \text{ mm}$
- $106 \text{ mm (masonry)} + 15.8 \text{ (gypsum)} = 122 \text{ mm} > 113$, therefore a 2-h FRR is provided
- D-1.7.1.2: $\text{FRR}_{\text{assembly}} \leq 2 \times \text{FRR}_{\text{masonry}}$
 - $\text{FRR}_{\text{assembly}}$: $2.0 \text{ hrs.} + [(122 - 113) / (142 - 113)](3.0 \text{ hrs.} - 2.0 \text{ hrs.}) = 138 \text{ min.}$
 - $\text{FRR}_{\text{masonry}}$: 109 min (previously calculated)
 - $138 \text{ min.} \leq 2 \times 109$; therefore, O.K.
- D-1.7.1.4: $\text{FRR}_{\text{gypsum board}} < \text{FRR}_{\text{masonry}}$
 - $\text{FRR}_{\text{gypsum board}} = 138 - 109 = 29 \text{ min.}$
 - $\text{FRR}_{\text{masonry}} = 109 \text{ min.}$
 - $29 \text{ min.} < 109 \text{ min.}$; 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)
- $\text{FRR}_{\text{assembly}} = \text{FRR}_{\text{masonry}} + \text{FRR}_{\text{gypsum board}}$
 $\text{FRR}_{\text{assembly}} = 109 \text{ min.} + 25 \text{ min.} = 134 \text{ min.} > 120 \text{ min.}$; 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 L₁20S: 102 mm
- o Type L₁: 97 mm
- o Type L₂20S: 94 mm
- o Type L₂: 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: $1 \text{ hr.} + (90 - 73)/(95 - 73)(0.5 \text{ hr}) = 1.386 \text{ hrs.} = 83 \text{ min.}$ (> 80 mm required, where 16 mm GB is used)
 - b. Type L₁20S: $1.5 \text{ hr} + (90 - 87)/(102 - 87)(0.5 \text{ hr}) = 1.6 \text{ hr.} = 96 \text{ min.}$ (> 95 mm required, where 12.7 mm GB is used)
 - c. Type L₁: $1.5 \text{ hr} + (90 - 82)/(97 - 82)(0.5 \text{ hr}) = 1.767 \text{ hr.} = 106 \text{ min.}$ (> 95 mm required, where 12.7 mm GB is used)
 - d. Type L₂20S: $1.5 \text{ hr} + (90 - 81)/(94 - 81)(0.5 \text{ hr}) = 1.846 \text{ hr.} = 110 \text{ min.}$ (> 95 mm required, where 12.7 mm GB is used)

- e. Type L₂: $1.5 \text{ hr} + (90 - 79)/(91 - 79)(0.5 \text{ hr}) = 1.958 \text{ hr.} = 117.5 \text{ min.}$ (> 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. $FRR_{\text{masonry}} = 83 \text{ min}$
 - ii. $FRR_{16 \text{ GB}} = 40 \text{ min}$
 - iii. $FRR_{\text{assembly}} = 123 \text{ min}$
 - iv. $FRR_{\text{assembly}}/FRR_{\text{masonry}} = 123/83 = 1.48 < 2.0$, O.K.
 - 2. for 12.7 mm GB over CMU of other than Type N or S concrete:
 - a. Type L₁20S:
 - i. $FRR_{\text{masonry}} = 96 \text{ min}$
 - ii. $FRR_{12 \text{ GB}} = 25 \text{ min}$
 - iii. $FRR_{\text{assembly}} = 121 \text{ min}$
 - iv. $FRR_{\text{assembly}}/FRR_{\text{masonry}} = 121/96 = 1.26 < 2.0$, O.K.
 - b. Type L₁:
 - i. $FRR_{\text{masonry}} = 106 \text{ min}$
 - ii. $FRR_{12 \text{ GB}} = 25 \text{ min}$
 - iii. $FRR_{\text{assembly}} = 131 \text{ min}$
 - iv. $FRR_{\text{assembly}}/FRR_{\text{masonry}} = 131/106 = 1.24 < 2.0$, O.K.
 - c. Type L₂20S:
 - i. $FRR_{\text{masonry}} = 110 \text{ min}$
 - ii. $FRR_{12 \text{ GB}} = 25 \text{ min}$
 - iii. $FRR_{\text{assembly}} = 135 \text{ min}$
 - iv. $FRR_{\text{assembly}}/FRR_{\text{masonry}} = 135/110 = 1.23 < 2.0$, O.K.
 - d. Type L₂:
 - i. $FRR_{\text{masonry}} = 117.5 \text{ min}$
 - ii. $FRR_{12 \text{ GB}} = 25 \text{ min}$
 - iii. $FRR_{\text{assembly}} = 142.5 \text{ min}$
 - iv. $FRR_{\text{assembly}}/FRR_{\text{masonry}} = 143/118 = 1.21 < 2.0$, 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 from 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: $1.25 \times 16 = 20$ mm
 - b. 12.7 mm GB: $1.25 \times 12.7 = 16$ 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 L₁20S: 102 mm
 - b. Type L₁: 97 mm
 - c. Type L₂20S: 94 mm
 - d. Type L₂: 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: $1.00 \times 16 = 16$ mm
 - b. 12.7 mm GB: $1.00 \times 12.7 = 12$ mm
 3. the EQ required of the CMU is calculated:
 - a. Type L₁20S:
 - i. 16 mm GB: $102 - 16 = 86$ mm
 - ii. 12 mm GB: $102 - 12 = 90$ mm
 - b. Type L₁:
 - i. 16 mm GB: $97 - 16 = 81$ mm
 - ii. 12 mm GB: $97 - 12 = 85$ mm
 - c. Type L₂20S:
 - i. 16 mm GB: $94 - 16 = 78$ mm
 - ii. 12 mm GB: $94 - 12 = 82$ mm
 - d. Type L₂:
 - 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:
- $FRR_{\text{assembly}} = 90 + 12 = 102$
 - $FRR_{\text{masonry}} = 90 \text{ mm}$
 - $FRR_{\text{assembly}} / FRR_{\text{masonry}} = 102/90 = 1.13 < 2.0$, 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 loss 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).

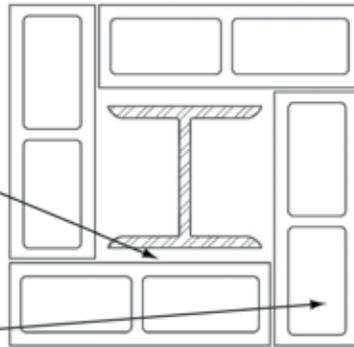
Decreasing the width of air space between masonry and steel has the effect of increasing the fire resistance

Figure 5.3: *Protecting Steel Columns with Concrete Masonry*

Masonry may be in direct contact with steel.

Decreasing width of air space increases FRR

Minimum Required Equivalent Thickness of Concrete block Masonry: See Table 5.5



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 through 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)

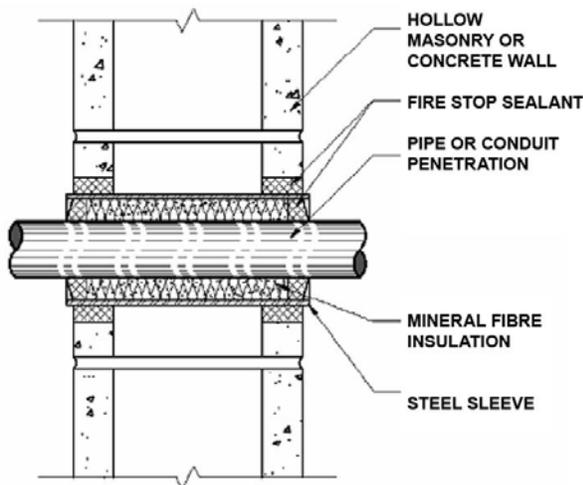
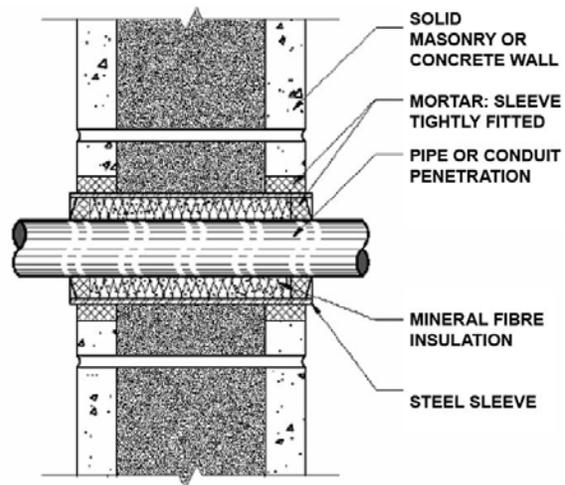


Figure 5.5:
Through-Wall Fire Stop; Grouted Masonry Wall (Adapted from Ref. 2)





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

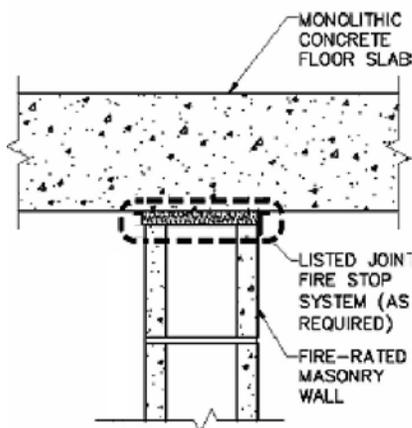
In many buildings containing non-loadbearing masonry infill walls and partitions, a typical detail requires a 15 to 25 mm horizontally-oriented movement joint between the underside of a floor or deck and the top of a non-loadbearing masonry wall. The intent is to structurally isolate the two elements 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

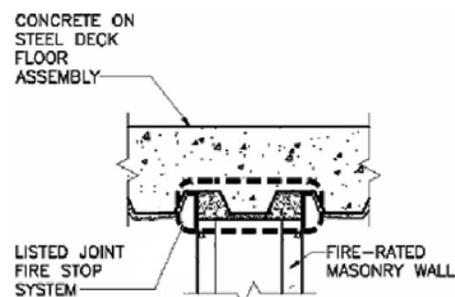
Figure 5.6: Joint Fire Stop System Between Underside Concrete Floor and Top of Non-loadbearing Masonry Wall (Ref. 2)



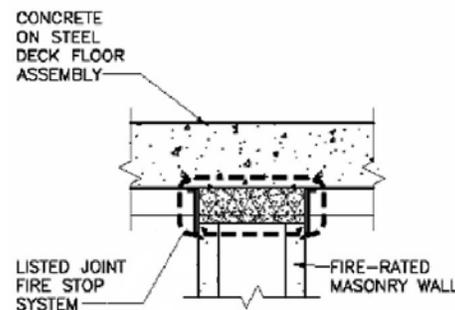
walls are loadbearing or non-loadbearing, fire-rated masonry walls may abut other fire-rated masonry walls in the same plane or at T- or L-corners, or abut other non-masonry vertical elements to form continuous vertical movement joints. Joints widths are typically 10 mm, the width of a standard mortar 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

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



WALL PARALLEL TO FLUTES



WALL OPPOSITE TO FLUTES

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 5.8: 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:

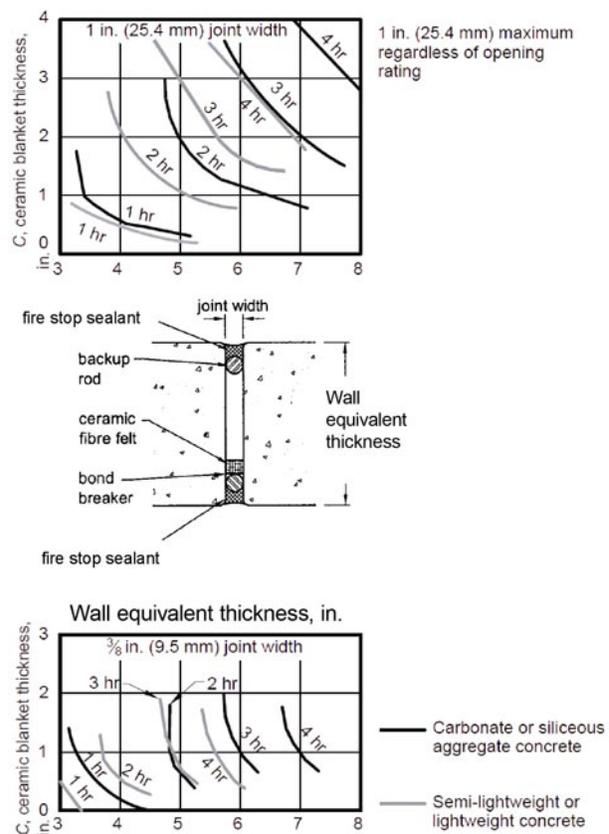
$$C_{15} = 16 + [(56 - 16) \times (15 - 10) / (25 - 10)] = 30 \text{ mm}$$

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/m³.
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 L₁20S and L₂20S 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

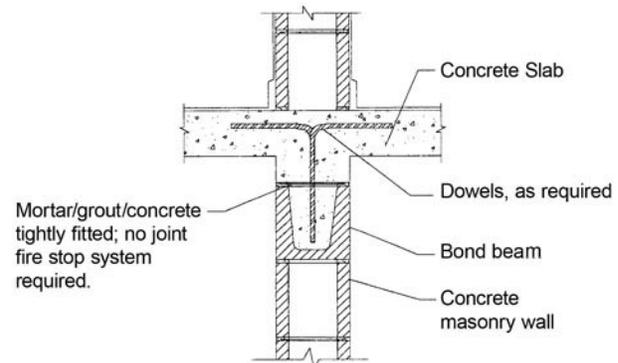


Figure 5.10a: Rigid connection at wall/floor junction; no joint fire stop system required. (Ref. 20)

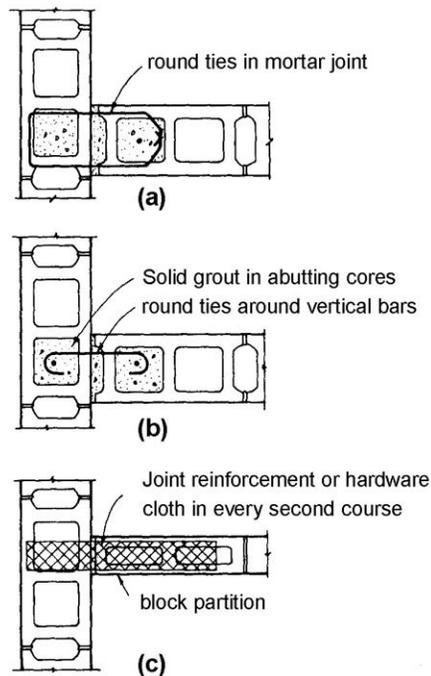


Figure 5.10b: Rigid connection at intersecting walls; no joint fire stop system required. (Ref. 20)



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



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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



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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



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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 filled with mineral wool conforming to CAN/ULC-S702, "Mineral Fibre Thermal Insulation for Buildings," and having a mass of not less than 2 kg/m², 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



5.10 References

1. Balanced Design Fire Protection, TEK 7-2. National Concrete Masonry Association. Herndon, VA, 2008.
2. Best Practice Guide on Fire Stops and Fire Blocks and Their Impact on Sound Transmission. National Research Council of Canada. NRCC-49677. Ottawa, ON, 2007.
3. C. Beall. Masonry Design and Detailing for Architects, Engineers, and Builders. 2nd Ed. McGraw-Hill, 1987.
4. G.E. Brandow, G.E. Chukwuma, G.C. Hart. 2006 Design of Reinforced Masonry Structures. Concrete Masonry Association of California and Nevada, 2007.
5. Canadian Standards Association, CSA A165.1 "Concrete Block Masonry Units", CSA A165 Series, CSA, Mississauga, Ontario, Canada, 2004.
6. Canadian Standards Association, CSA A371, "Masonry Construction for Buildings", CSA, Mississauga, Ontario, Canada, 2004.
7. Canadian Standards Association, CSA S304.1, "Design of Masonry Structures", CSA, Mississauga, Ontario, Canada, 2004.
8. Code Requirements for Determining fire Resistance of Concrete and Masonry Construction Assemblies, ACI 216.1 / TMS-0216-07. American Concrete Institute. Farmington Hills, MI, 2007.
9. Concrete Masonry Fire Resistance. Northwest Concrete Masonry Association. Lynwood, WA, 2005.
10. Design Manual, Precast and Prestressed Concrete. Canadian Precast/Prestressed Concrete Institute. 4th Ed., Ottawa, ON, 2009.
11. R.G. Drysdale and A.A. Hamid. Masonry Structures Behaviour and Design. Canadian Edition. Canada Masonry Design Centre, 2005.
12. Firestopping & Effective Compartmentation Strategies. K. Brebner, M. McClure, B. McHugh.
13. Fire Stopping and Penetration Seals for the Construction Industry. Association for Specialist Fire Protection, Fire Test Study Group. 2nd ed., 2004.
14. Fire Stopping Service Penetrations in Buildings. City of Calgary, Calgary, AB, 2003.
15. Firewalls: A Design Guide. Canadian Concrete and Masonry Codes Council. Ottawa, ON, 1992.
16. Fire Resistance Ratings of Concrete Masonry Assemblies, TEK 7-1C. National Concrete Masonry Association. Herndon, VA, 2009.
17. Guidelines for Calculated Fire Resistance Using Non-Listed Aggregates. National Concrete Masonry Association. National Concrete Masonry Association. Herndon, VA, 2009.
18. Guidelines for Determining Fire Resistance Ratings of Building Elements. Building Officials & Code Administrators International, Inc. Country Club Hills, IL. 2001.
19. Increasing the Fire Resistance of Concrete Masonry, TEK 7-4. National Concrete Masonry Association. Herndon, VA, 2001.
20. W.C. Panarese, S.H. Kosmatka, F.A. Randall. Concrete Masonry Handbook for Architects, Engineers, Builders. Portland Cement Association. 5th Ed., Skokie, IL, 2005.
21. R.R. Schneider, W.L. Dickey. Reinforced Masonry Design. 2nd Ed. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1987.
22. Steel Column Fire Protection, TEK 7-6A. National Concrete Masonry Association. Herndon, VA, 2001.