PART B

Chapter 4

Fire

This chapter provides the design requirements for masonry subject to fire as specified in the National Construction Code (NCC) – Building Code of Australia (BCA)

Contents








4.1 BASIS OF DESIGN

For many years, concrete masonry has proven to be one of our most cost-effective fire-rated building materials. The National Construction Code (NCC) – Building Code of Australia (BCA) and AS 3700 now ensure that both reinforced and unreinforced concrete masonry systems can be designed to provide the required fire resistance of walls.

A severe fire adjacent to a masonry wall will cause the exposed face of the wall to expand while the unexposed face remains near to its original dimensions. This differential expansion causes the wall to bow towards the fire, perhaps cracking and allowing flame or hot gasses to pass through, and possibly causing collapse if the wall is unreinforced. In addition, heat may be transmitted through the wall causing flammable materials touching the unexposed face to ignite.

NCC/BCA specifies that walls must achieve certain FRLs (Fire Resistance Levels) for ***structural adequacy*** (stability against collapse), ***integrity*** (resistance to excessive cracking and passage of hot gasses and flames) and ***insulation*** (resistance to the passage of heat).

The FRL for **structural adequacy** of a particular wall is a measure of its ability to remain stable and depends on the thermal expansion of the material used in the manufacture of the masonry units, reinforcement of the wall and the wall slenderness. Slenderness depends on wall thickness and spacing of vertical and horizontal supports.

The FRL for the **integrity** of a particular wall is a measure of its ability to resist the passage of flames or hot gasses through cracks and fissures. The factors affecting integrity are not well understood but could include the materials used in the manufacture of the masonry units and the thickness of the masonry units.

The FRL for **insulation** of a particular wall is a measure of its ability to resist the passage of heat through the wall. It depends on the density and composition of the masonry units; the material thickness of the masonry units, any renders or other finishes applied to the walls and any grout within the wall.

Fire performance of masonry materials can be determined either by a standard test on a 3.0 metre square panel as set out in AS 1530.4 or by using the deemed-to-comply tables of AS 3700. Once the material behaviour is known, the designer must then provide adequate thicknesses, supports, reinforcement and details to enable the structure to achieve the required FRLs.

4.2 DESIGN REQUIREMENTS

4.2.1 NATIONAL CONSTRUCTION CODE – BUILDING CODE OF AUSTRALIA

The NCC–BCA Volume One Part C requires designers to check three separate fire performance limit states:

- structural adequacy (resistance to collapse),
- integrity (resistance to cracking), and
- insulation (resistance to the passage of heat).

In particular, structural adequacy under fire load must be checked by reference to design rules in AS 3700. No longer can an architect simply match a particular masonry unit to an insulation value. Now, in addition to this insulation requirement, a structural engineer must calculate or check, for each wall in the building, its slenderness, fixity, panel action and robustness.

4.2.2 AS 3700 MASONRY STRUCTURES

AS 3700 gives two options to the designer of masonry walls subject to fire:

- Design the masonry for structural adequacy, integrity and insulation using tabulated (deemed-to-comply) limits on:
  - slenderness (Table 6.1)
  - cover to reinforcement (Table 6.2)
  - material thickness (Table 6.3)

  or
- Design the masonry for structural adequacy, integrity and insulation using data from tests. This may be further subdivided as data from a single test or data from at least two tests.

4.2.3 DEEMED-TO-COMPLY FIRE RESISTANCE LEVELS

During the writing of AS 3700, the masonry unit manufacturers gave Standards Australia the results of a number of fire tests on various masonry units. These tests formed the basis of the deemed-to-comply tables. The tables have been subdivided into different unit types and make provision for units with:

- Over 45% basalt aggregate (improved structural adequacy)
- Density under 1800 kg/m³ (improved insulation).

The deemed-to-comply tables of AS 3700 represent limits which cater for any type of masonry likely to be produced in Australia, including those which have poor structural adequacy or low insulation. The tables are thus very conservative. More cost-effective solutions can be achieved by developing masonry products with mixes designed specifically to give improved structural adequacy or insulation and then testing these to determine their performance.

4.2.4 STANDARD FIRE TEST TO AS 1530.4

AS 3700 makes provision for the determination of material properties from fire tests in accordance with AS 1530.4, and then use this data to predict wall behaviour.

AS 1530.4 sets out the standard method of testing and the failure criteria for building materials (including concrete masonry). Thus AS 1530.4 and the standard test provide the basic fire performance data that can be used by designers in the design of real structures. Masonry panels (3 metres square) are built into one side of a gas-fired furnace. Five thermocouples are located on the external face of the wall to measure the temperature rise, **Figure 4.1**.

A vertical load may be applied by jacks in the top of the furnace to simulate a floor slab loading. The panels may be supported at the top and bottom and subjected to an applied load. This is known as a "loadbearing test". Alternatively, the panels may be supported on four sides and not subjected to any externally applied load. This is known as a "non-loadbearing test". This choice in terminology is perhaps a little misleading, since experience has shown that collapse of a wall (structural adequacy failure) is more influenced by the number of sides supported and the corresponding wall slenderness than by the magnitude of this applied vertical load.

Figure 4.1 *External Face of Typical Fire-Test Panel*

A more informative description would be "test with supports at top and bottom" and "test with supports on four sides". AS 1530.4 uses the three failure criteria of structural adequacy, integrity and insulation.

As heat is applied to the exposed face of the masonry, it expands. The unexposed face remains relatively close to ambient temperature, and therefore does not expand significantly. Thus the wall is induced to bow into the furnace towards the fire. If the wall is supported top and bottom only, the deflection will be considerably greater than for four-sided support. When the deflection approaches the thickness of the wall, the wall will no longer remain stable. Thus collapse occurs (structural adequacy is exceeded). The more slender the panel,

the sooner collapse, **Figure 4.2**. If the panel is supported on four sides, the deflection will be smaller. The use of basalt or similar aggregates with low siliceous content generally leads to a reduction in differential expansion when exposed to fire, and thus enhanced stability or structural adequacy.

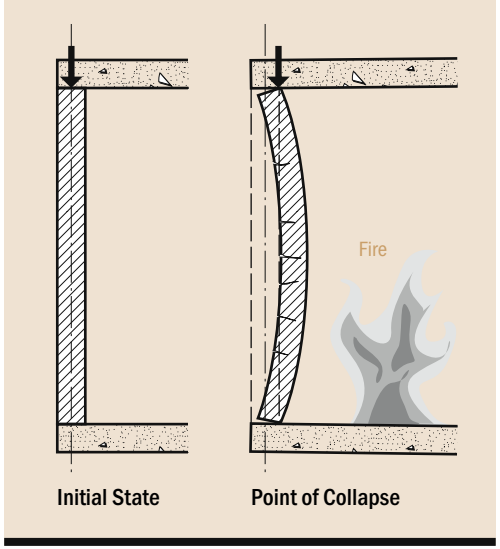


Figure 4.2 *Collapse Mechanism of Concrete Masonry Wall Subject to Fire*

During the test, it is normal for cracks to appear in the masonry. The cracks will commonly be vertical, first appearing near the centre top of the wall and propagating downwards, **Figure 4.3**. The mechanism of cracking is not well understood, although the following factors are known to influence the behaviour. Initial cracking may result from shrinkage of the units as moisture is driven off. As the material expands on the exposed face, it could close the cracks on the exposed face but open them further at the unexposed face. The criterion for measuring cracking (integrity failure) is not defined in AS 1530.4 and the methods used to determine failure during the test include placing a thermocouple over the major cracks, placing a wad of cotton wool in front of the cracks to observe if ignition takes place or visually observing the red glow of the furnace through the cracks.

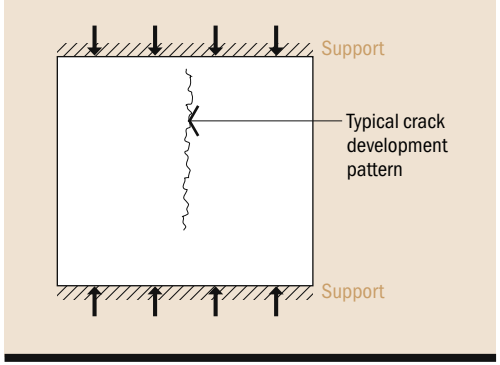


Figure 4.3 *Typical Fire Test Crack Pattern*

The temperature of the unexposed face is recorded by the thermocouples and generally follows the type of curve shown in **Figure 4.4**. As the temperature inside the furnace increases, the temperature of the unexposed face reaches a plateau at approximately 100°C for a lengthy period. During this time, the moisture in the masonry units is absorbing "latent heat" and is evaporating from the surface. Moist patches can be seen on the surface of the wall and water vapour can be seen escaping. When all of the free water has evaporated, the temperature of the unexposed face continues to rise until it reaches the criteria defined in AS 1530.4 as "insulation failure" (average temperature rise of 140°C above ambient or a temperature rise of any of the five thermocouples by 180°C above ambient). The use of lightweight scoria aggregate has been shown to give improved insulation.

While it is reasonable to assume that the insulation performance of a particular material in the standard test will be the same as the insulation performance of the same material in a real building, the structural adequacy of a masonry wall in a real building will be influenced by many additional factors including the position of cross walls, spacing of piers, fixity of the wall to supporting elements, slenderness of the wall and magnitude of the load supported.

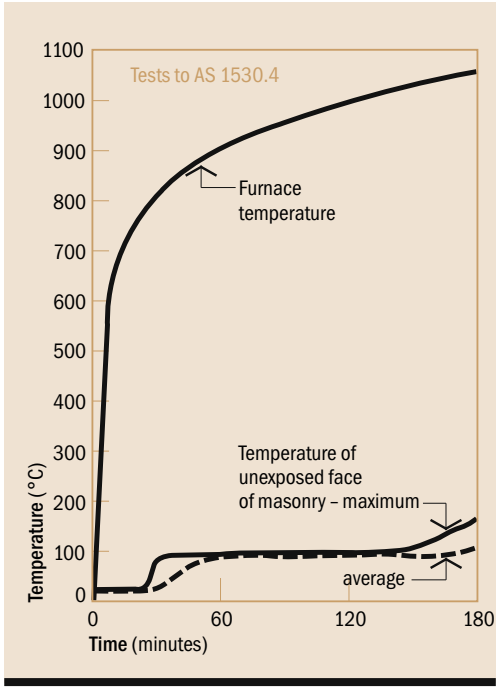


Figure 4.4 *Plot of Typical Fire Test Results*

The results derived from the standard test of AS 1530.4 must therefore be interpreted to give the structural adequacy of real masonry walls in real buildings. This method of interpretation is provided in AS 3700.

4.2.5 MASONRY SYSTEMS

Various concrete masonry wall systems are well suited to particular applications as shown below:

Deemed-to-comply unreinforced masonry

This will provide an economical solution where the required fire resistance levels are low and the walls are relatively small and well supported. The permissible slenderness limits for masonry with 45% or more basalt content are greater than for those with less than 45% basalt. The required material thicknesses for concrete with a density under 1800 kg/m^3 are less than for those of denser materials.

Tested purpose-designed unreinforced masonry

Units with light weight aggregates and/or basalt aggregate can be used to provide enhanced structural adequacy for large wall panels or improved insulation and integrity.

Mixed construction consisting of reinforced bond beams and unreinforced masonry between

If very large wall panels are required (such as in a factory, warehouse, auditorium or shopping centre), a common method of construction is unreinforced masonry panels spanning vertically between horizontal reinforced bond beams supported by portal frames, columns or piers. AS 3700 places a slenderness limit of 36 on reinforced masonry for structural adequacy, and this effectively limits the frame spacing for 190 mm blockwork to 6.84 metres and for 140 mm blockwork to 5.04 metres, **Figure 4.5**. These reinforced bond beams must be designed to withstand a lateral pressure of 0.5 kPa.

Mixed construction consisting of vertical reinforcement and unreinforced masonry between

If the intended frame spacing exceeds 6.84 metres in 190 mm blockwork or 5.04 metres in 140 mm blockwork (or if there are no supporting frames at all), very large wall panels may be designed using unreinforced masonry that spans horizontally between vertical reinforced cores. These reinforced cores must be designed to withstand a lateral pressure 0.5 kPa. If the wall is subject to vertical load, it must be designed for a bending moment equal to the vertical load multiplied by an eccentricity of height divided by 36. Using this system of mixed construction, 190 mm-thick walls up to 6.84 metres high can be constructed, **Figure 4.5**.

Similarly 140 mm mixed construction can be constructed up to 5.04 metres. For many years, it was difficult to achieve 180 minute or 240 minute fire resistance levels in reinforced construction, because the small cores of the then available 140 mm and 190 mm blocks were not appropriate for reinforcement or grout. These levels can, however, now be achieved using purpose-designed blocks with large cores that are quite satisfactory for reinforcing and grouting.

Reinforced masonry with vertical reinforcement

In some cases, the size of walls or the magnitude of the loads requires the use of vertical reinforcement complying with the definitions in AS 3700 Clause 8.6 and spaced at centres not more than 2000 mm. In this case, the wall may be considered to be reinforced masonry rather than mixed construction. This has advantages when considering robustness

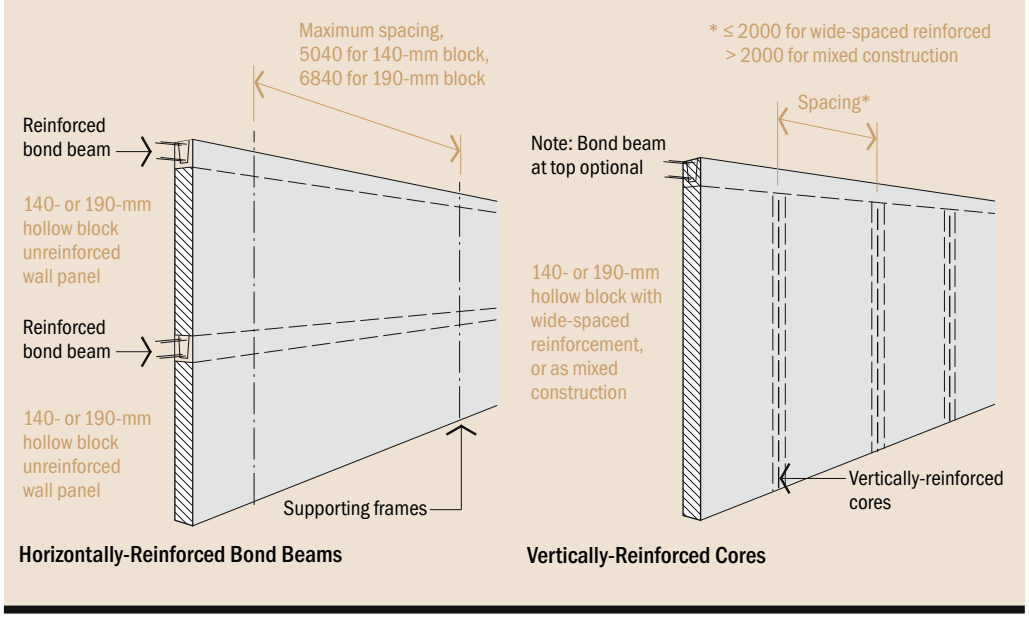


Figure 4.5 *Reinforced and Mixed Construction Arrangements for Concrete Masonry Walls*

4.2.6 HIGH-PERFORMANCE MASONRY

Some specially tested masonry systems developed in Australia have quite low expansion and can therefore remain stable even when used in relatively slender walls. This enables large wall panels to be built, although in some cases robustness and horizontal load considerations may override.

High performance masonry systems have not been included in the standard designs in this manual. Manufacturers are able to provide supplementary design charts and supporting calculations and test certificates for their particular systems.

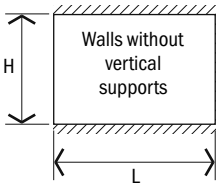
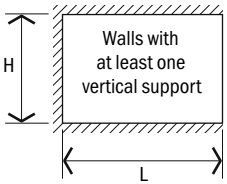
4.2.7 CHASES

Masonry walls are usually cored or hollow. Thus at any one point in the wall, the cross-sectional area could be different from the area at an adjacent section. Small local reductions in area do not diminish the capacity of the wall to insulate against heat transfer, the heat being absorbed into the adjacent material. Therefore, from the aspect of providing insulation, a small number of chases up to 30 mm deep would have little effect.

Of more concern is the effect of chases on structural adequacy. For vertically spanning walls, it is unlikely that a vertical chase would have significant effect, but a long straight horizontal chase near the mid-height of the wall would significantly reduce the structural adequacy. For walls intended to span horizontally in two-way action (panel action), a vertical chase must be treated as a free end.

AS 3700 Clause 6.7 provides rules for chases, which are summarised in **Table 4.1**.

Table 4.1 *Design Requirements for Chases.* [Based on AS 3700 Clause 6.7]

Support details	Chase direction	Chase length	Chase depth (mm)	Design requirements for: Structural adequacy	Integrity	Insulation
 t = thickness of wall before chasing	Vertical(1)	Any	<30	✔	✔	✔
			>30	✔	✘	✘
	Horizontal(2)	≤4t	<30	✔	✔	✔
			>30	✔	✘	✘
		>4t	<30	✘	✔	✔
			>30	✘	✘	✘
	Vertical(1)	≤H/2	<30	✔	✔	✔
			>30	✔	✘	✘
		>H/2	<30	✘	✔	✔
			>30	✘	✘	✘
	Horizontal(2)	≤L/2	<30	✔	✔	✔
			>30	✔	✘	✘
		>L/2	<30	✘	✔	✔
			>30	✘	✘	✘

NOTES:

1 Although not a requirement of AS 3700, it is better to run services through the cores of hollow block masonry rather than to chase it.

2 If horizontal chasing is unavoidable, it is best placed close to the top or bottom of a wall. Although AS 3700 will permit quite long horizontal chases, it is best to ensure that chases are kept short with unchased masonry at regular intervals.

LEGEND:

✔ **Ignore** – for Structural Adequacy, if chase < 30 mm deep; for Integrity and Insulation, as well as chase < 30 mm deep the following must also apply. Any chase cross section shall not exceed 1000 mm^2 (eg 10 mm deep x 100 mm wide, 20 mm deep x 50 mm wide or 30 mm deep x 33 mm wide. The total face area of the chases on both sides of any 5 m^2 section of the wall shall not exceed 100,000 mm^2 (eg two chases 2.5 m long x 20 mm wide)

✘ **Consider** – for purposes of Structural Adequacy, Integrity and Insulation, the thickness of the wall should be measured from the base of the chase to the opposite face (ie the thinnest section). In addition, for Structural Adequacy, the chase should be considered as an unsupported free edge and the wall panel should be considered to consist of a number of smaller sub-panels.

4.2.8 RECESSES

Small local reductions in area of material do not significantly diminish the capacity of the wall to insulate against heat transfer, the heat being absorbed into the adjacent material. AS 3700 Clause 6.6 requires that the total face area of recesses on both sides of any 5 m² section of the wall shall not exceed 10,000 mm² (eg 1 recess 100 x 100 mm, 2 recesses 50 x 100 mm, etc).

4.2.9 DOORS AND WINDOWS

If a door or window is incorporated into a fire-resistant masonry wall, the masonry should be considered to have a free edge at the interface with the door or window, although it must be remembered that any buckling of the door or window under the action of fire could exert a lateral line load on the masonry wall. The magnitude of this line load and means of assessing it is not well understood by researchers and has not been included in AS 3700.

4.2.10 REINFORCEMENT

Steel reinforcement can be incorporated vertically and/or horizontally (**Figure 4.5**) into hollow block walls to provide lateral support. Such reinforcement must comply with AS 3700 Section 5 and, if it is to be considered for structural purposes, it must comply with the relevant requirements of AS 3700 Section 8. AS 3700 Clause 6.3.5 requires that the reinforcement in reinforced masonry walls subject to fire loading be designed to withstand a horizontal pressure of 0.5 kPa or vertical reinforcement must be designed to withstand the bending moment caused be any vertical loads applied at an eccentricity of height/36.

4.2.11 JOINTS

All control joints and expansion joints in a fire resistant masonry wall should be such as to conform with the integrity requirements of AS 3700 and prevent the passage of flames and hot gasses. This can be achieved by:

- omitting the mortar and inserting an intumescent sealing material designed for the purpose, or
- providing a full mortar joint. If the joint is required to be weatherproofed, it may be raked and the surface filled with a flexible jointing compound. Such a detail will not be suitable for expansion.

The NCC–BCA makes provision for the placing of non-combustible mineral fibre insulating material in the gaps between the fire wall and abutting structure or roof.

4.3 STANDARD DESIGNS

4.3.1 GENERAL

Design and detailing
All design and detailing shall comply with the requirements of AS 3700 and, where appropriate, AS/NZS 1170.

It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties. Control joints and openings must be treated as free ends as specified by AS 3700.

Masonry properties
The standard designs in this chapter are based on masonry properties complying with the General Specification set out in **Part C:Chapter 2**, modified as noted on the standard design chart and as noted below. Where units are required to have over 45% basalt content, this is noted on the charts. Many manufacturers have tested units which have performance superior to that indicated in the charts.

Hollow concrete blocks
Width 90 mm, 110 mm, 140 mm and 190 mm

Face-shell bedded

Face-shell thickness as required to produce the material thicknesses given in Design Chart *Fire Resistance Level for Insulation*.

Minimum characteristic lateral modulus of rupture,
f'_{ut} = 0.8 MPa

Solid or cored concrete units
Fully bedded

Minimum characteristic compressive strength,
f'_{uc} =10 MPa

Minimum characteristic lateral modulus of rupture,
f'_{ut} = 0.8 MPa

Mortar joints
Mortar type M3 (or M4)

Joint thickness 10 mm

Concrete grout
Minimum characteristic compressive strength,
f'_c = 20 MPa

Minimum cement content 300 kg/m³

Steel reinforcement
N12, N16 or N20 as noted

4.3.2 STANDARD DESIGN CHARTS

How to Read
The general procedure with most charts is as follows:

- Select the required wall thickness (and, if appropriate, the reinforcement arrangement).
- Select the appropriate support conditions (eg, supported on four sides).
- Project the length of the wall between vertical supports and the height of wall between horizontal supports to determine the design point.
- Select a curve which is above or to the right of the design point. Read off the load capacity corresponding to the selected curve. If necessary, interpolate between curves.
- Check that the masonry wall is adequate for other loadings, design requirements and construction requirements. Some charts have superimposed the robustness requirements for the same conditions.

4.3.3 INDEX OF CHARTS

Fire Resistance Level for Insulation
All units

Fire Resistance Level for Structural Adequacy
Unreinforced Masonry,
< 45% basalt:
90 mm leaf
110 mm leaf
140 mm leaf
190 mm leaf
≥ 45% basalt:
90 mm leaf
110 mm leaf
140 mm leaf
190 mm leaf

Hollow Unreinforced Ungrouted Masonry,
< 45% basalt:
90 mm leaf
110 mm leaf
140 mm leaf
190 mm leaf
≥ 45% basalt:
90 mm leaf
110 mm leaf
140 mm leaf
190 mm leaf

Reinforced and Mixed Construction,
horizontally-reinforced:
140 mm leaf
190 mm leaf
vertically-reinforced cores:
140 mm leaf
190 mm leaf

FIRE RESISTANCE LEVEL FOR INSULLATION

Masonry Unit Thickness (mm) and Type	Material Thickness (mm)	INSULATION FIRE RESISTANCE LEVEL (minutes) Material Density > 1800 kg/m3	Material Density ≤ 1800 kg/m3
90 cored or solid[1]	90	60	90
90 cored or solid[1] + 12 mm cement render each face	102	90	90
110 cored or solid[1]	110	90	120
110 cored or solid[1] + 12 mm cement render each face	122	120	120
140 hollow[2] (ET[3] ≥ 80)	80	60	60
140 hollow (ET[3] ≥ 98)	140	120	180
140 hollow[2] fully grouted	140	120	180
140 hollow[2] (ET[3] ≥ 88) + 12 mm cement render each face	100	90	90
140 hollow[2] (ET[3] ≥ 110) + 12 mm cement render each face	152	180	180
190 hollow[2] (ET[3] ≥ 90)	90	60	90
190 hollow[2] (ET[3] ≥ 100)	100	90	90
190 hollow fully grouted	190	240	240
190 hollow[2] (ET[3] ≥ 90) + 12 mm cement render each face	102	90	90
190 hollow[2] (ET[3] ≥ 100) + 12 mm cement render each face	112	90	120
90 cored or solid + 90 cored or solid[1] cavity wall	180	240	240
90 cored or solid + 110 cored or solid[1] cavity wall	200	240	240
110 cored or solid + 110 cored or solid[1] cavity wall	220	240	240

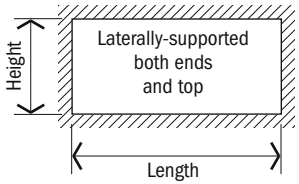
NOTES:

1 Cores less than 30% of the unit volume
(For 90 mm and 110 mm units, material thickness will be 90 mm and 110 mm respectively, irrespective of how the units are bedded)

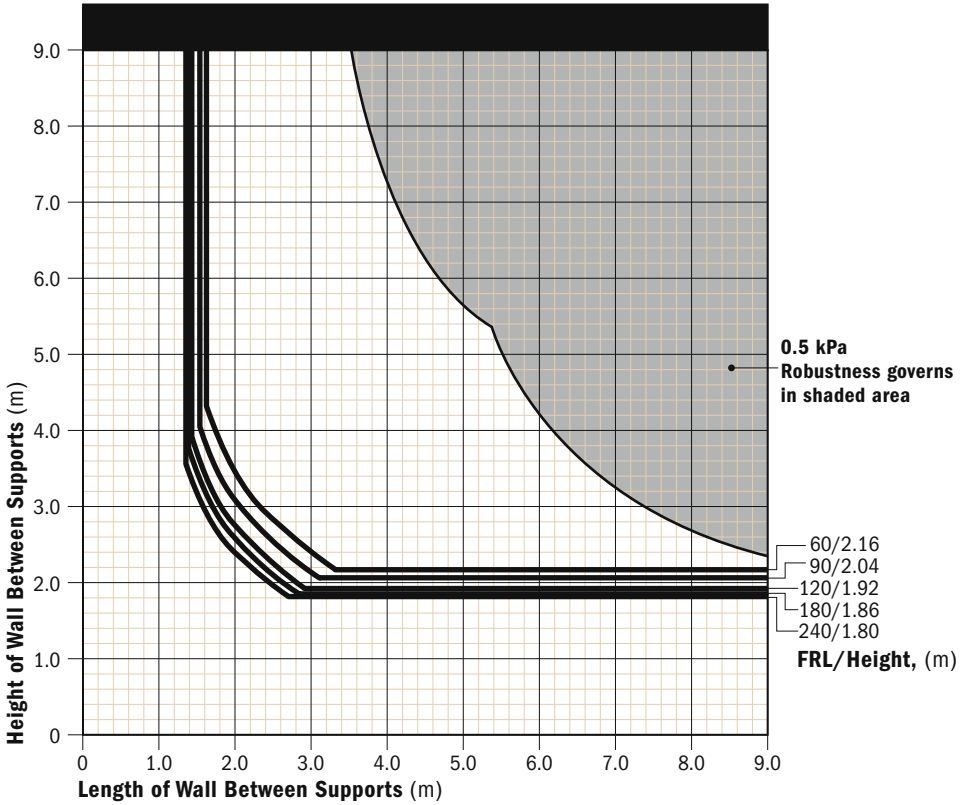
2 Cores greater than 30% of the unit volume

3 Equivalent thickness of the masonry unit (net volume divided by face area)

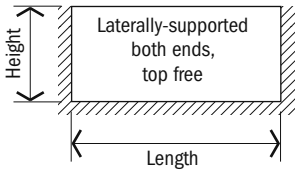
a_{vf} = 0.75, a_h = 1.0



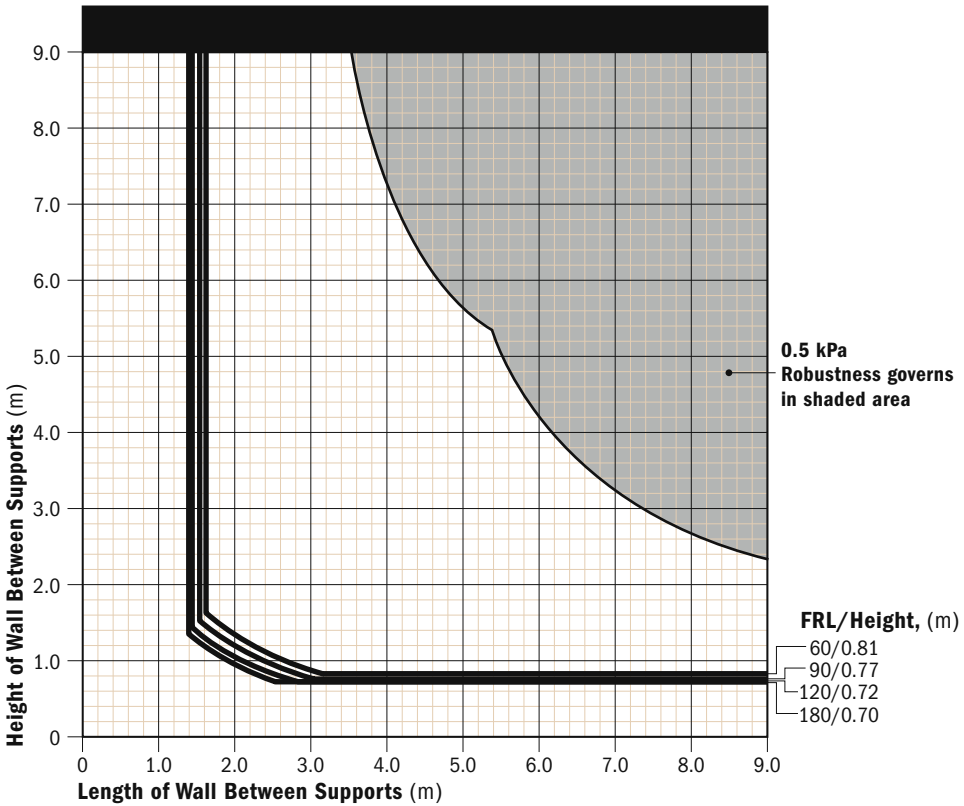
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0

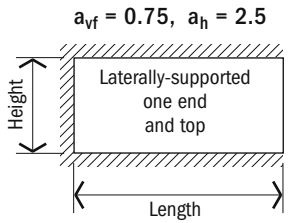


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

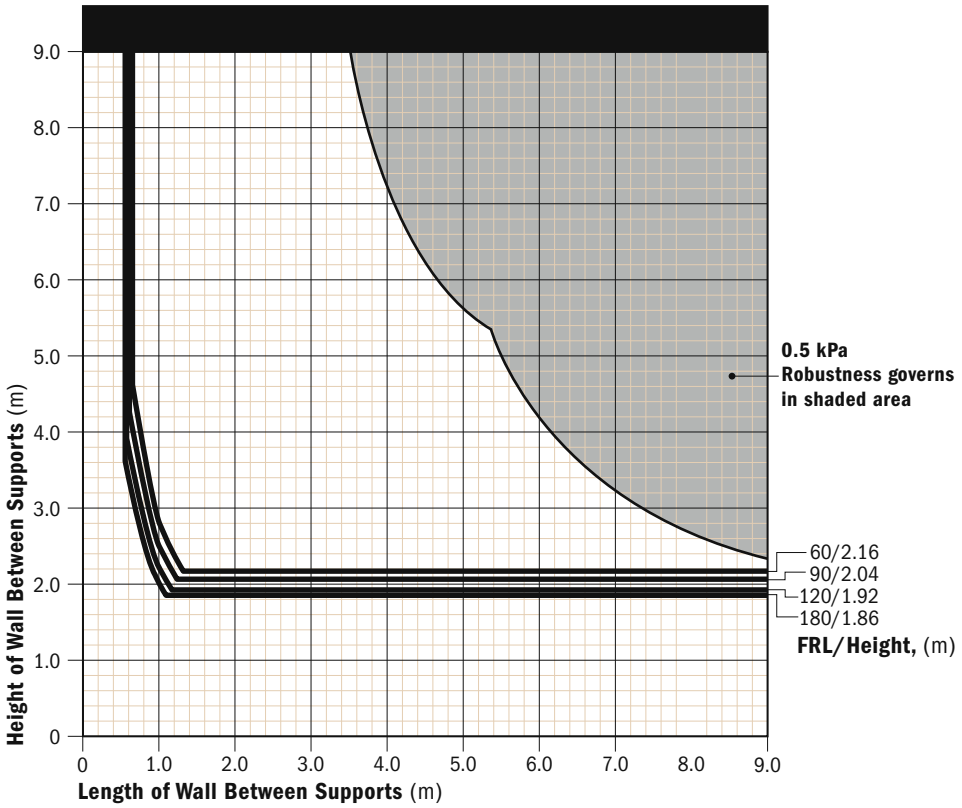


NOTE: It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties

3 of 4



Fire-resistance level, FRL (minutes), **for Structural Adequacy**



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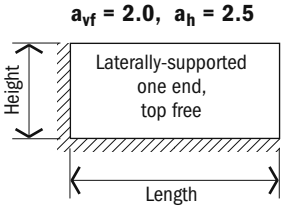
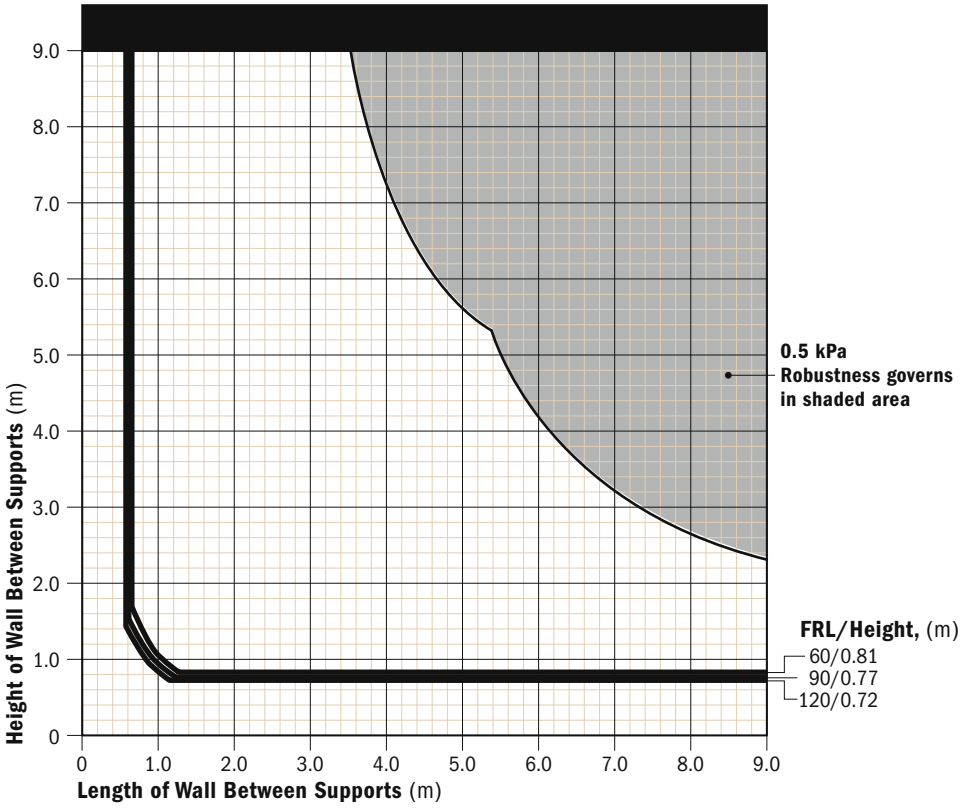
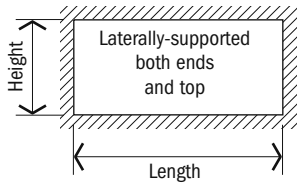


Fire-resistance level, FRL (minutes), **for Structural Adequacy**

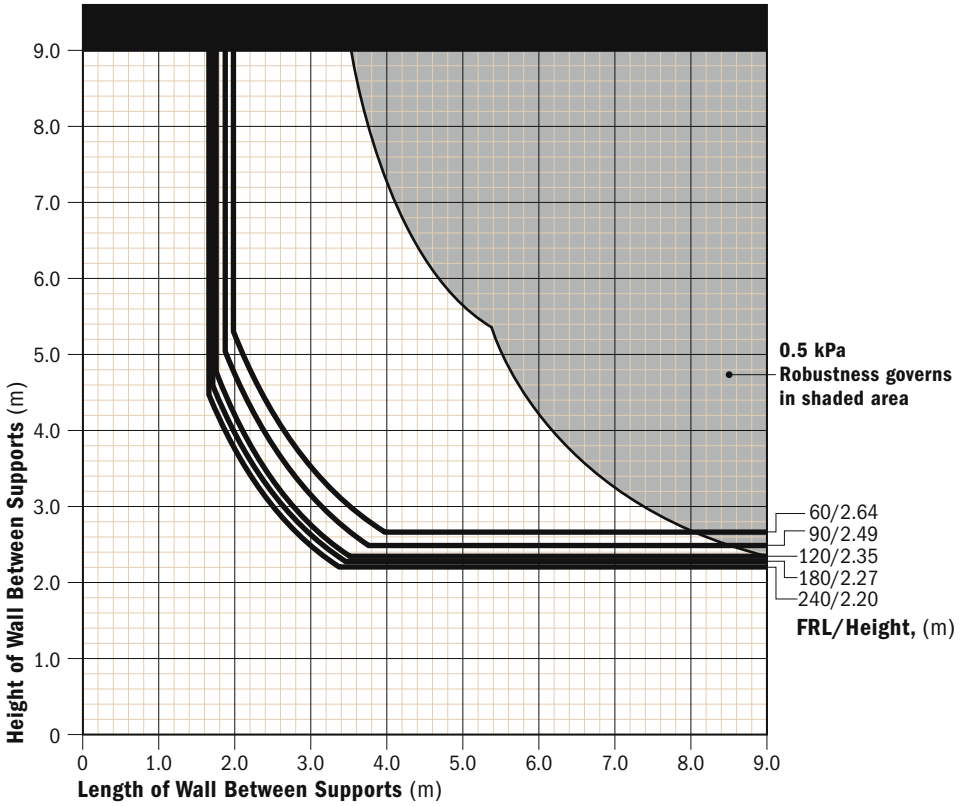


NOTE: It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties

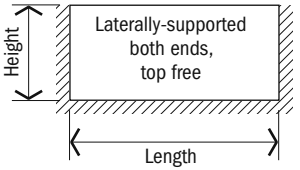
a_{vf} = 0.75, a_h = 1.0



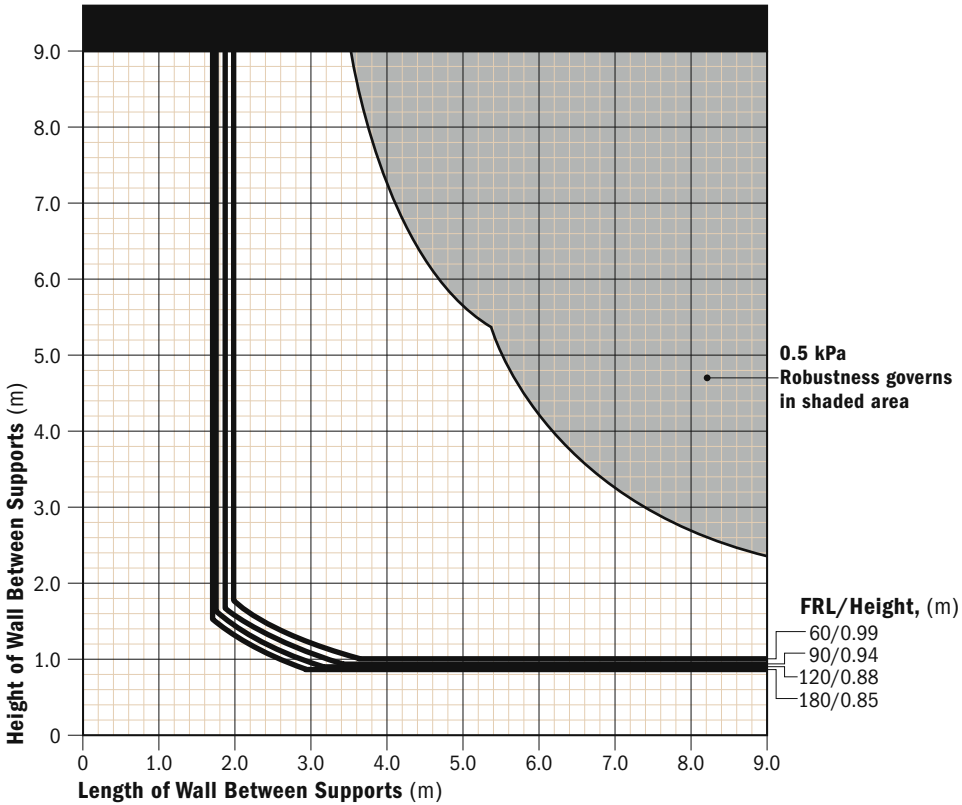
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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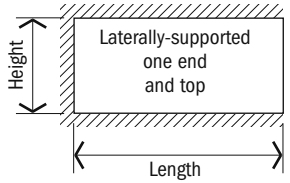
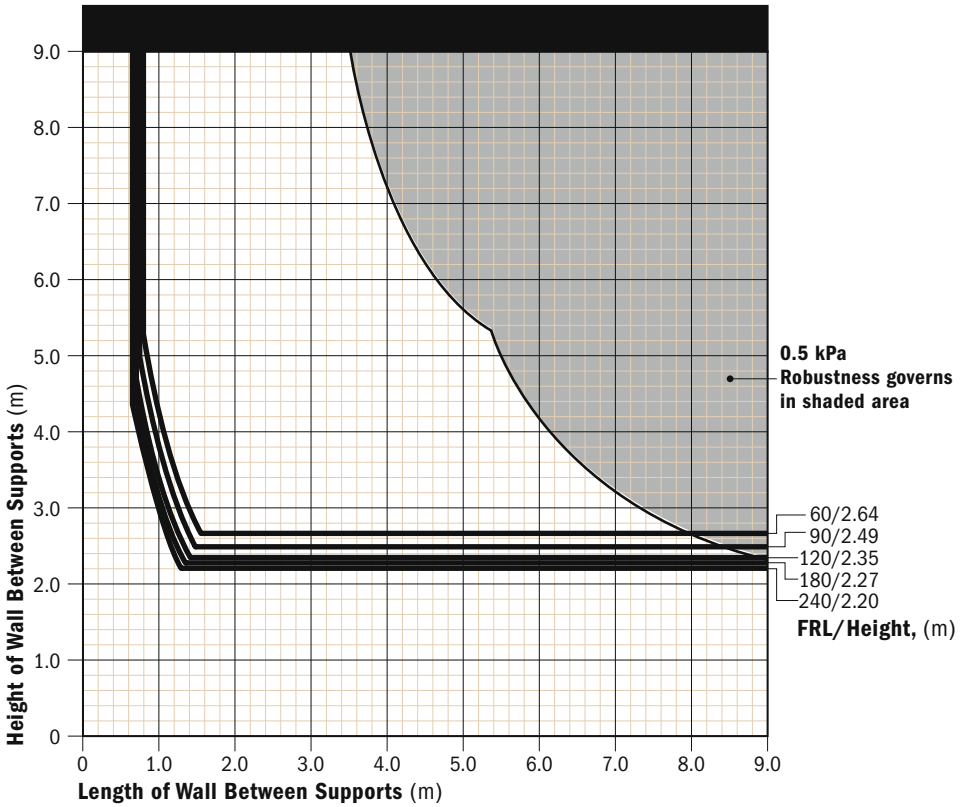
3 of 4

a_{vf} = 0.75, a_h = 2.5

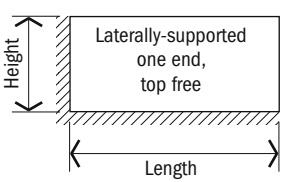


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

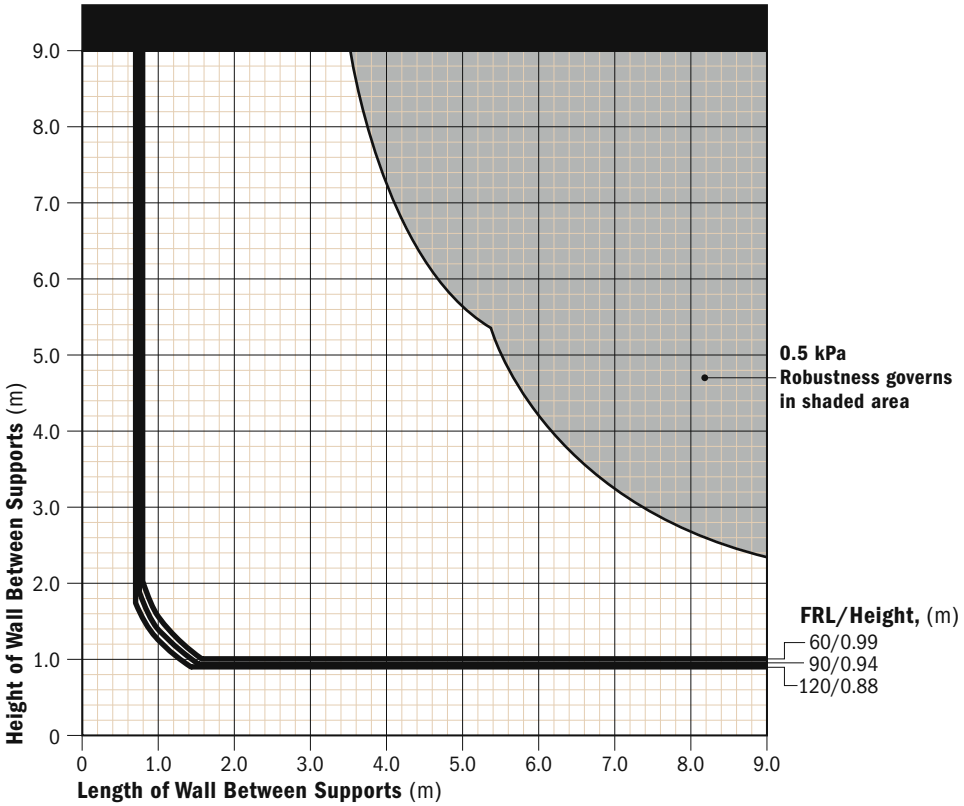


4 of 4

a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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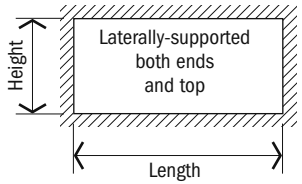
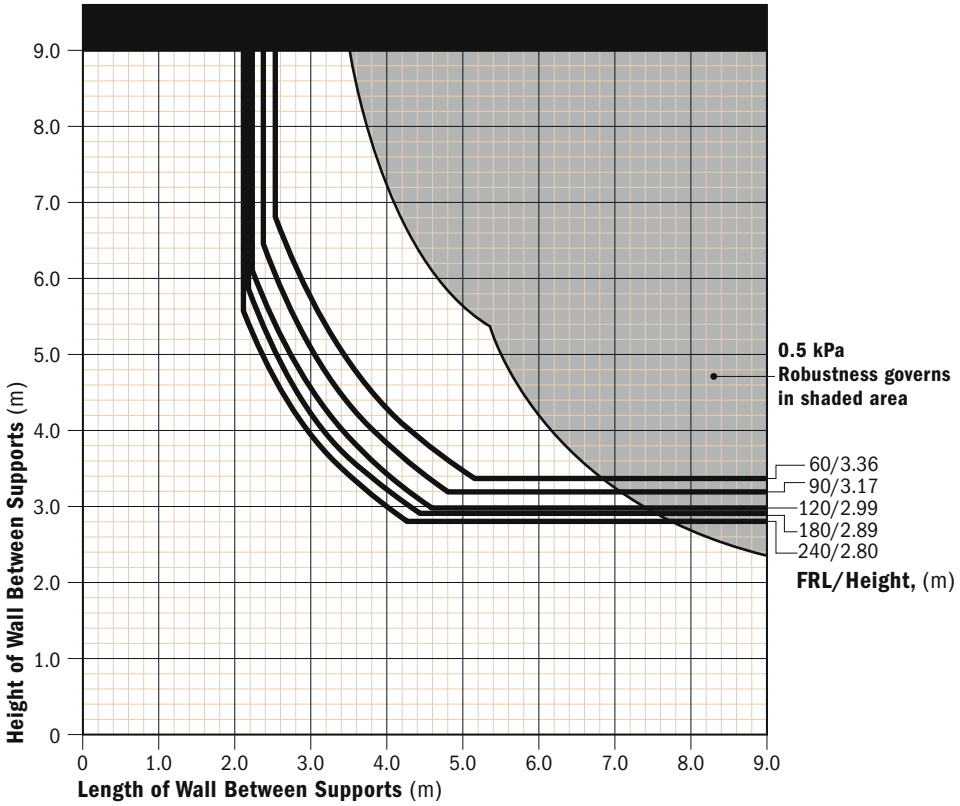
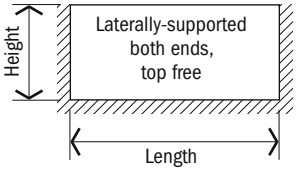
a_{vf} = 0.75, a_h = 1.0



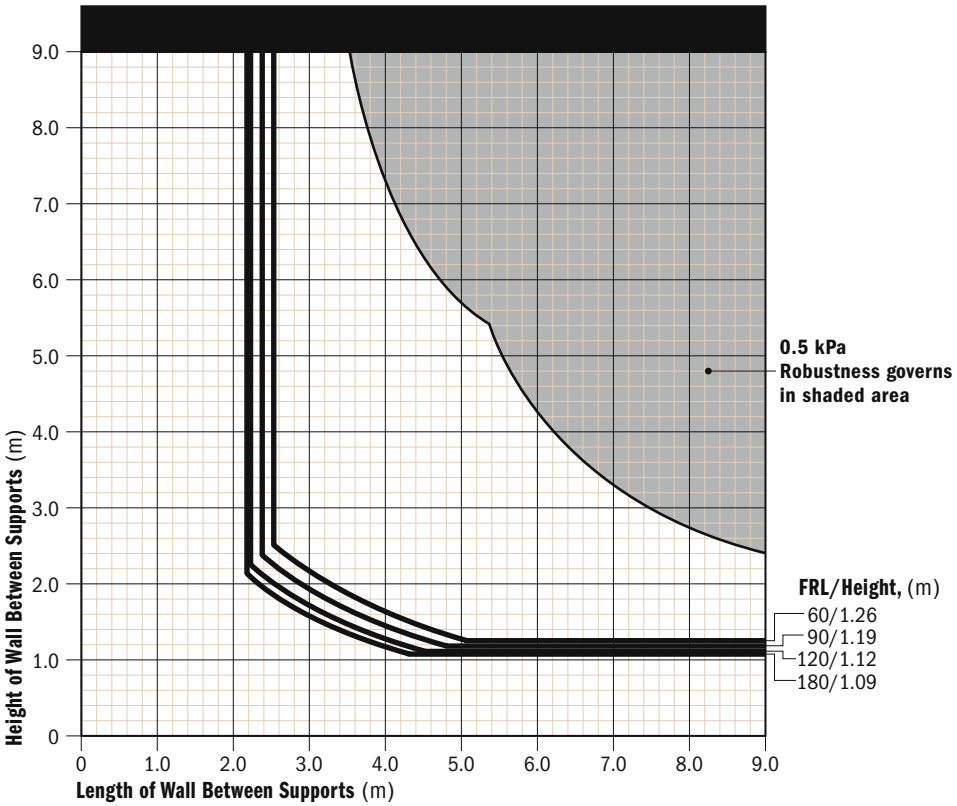
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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140-mm leaf <45% basalt

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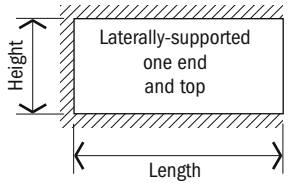
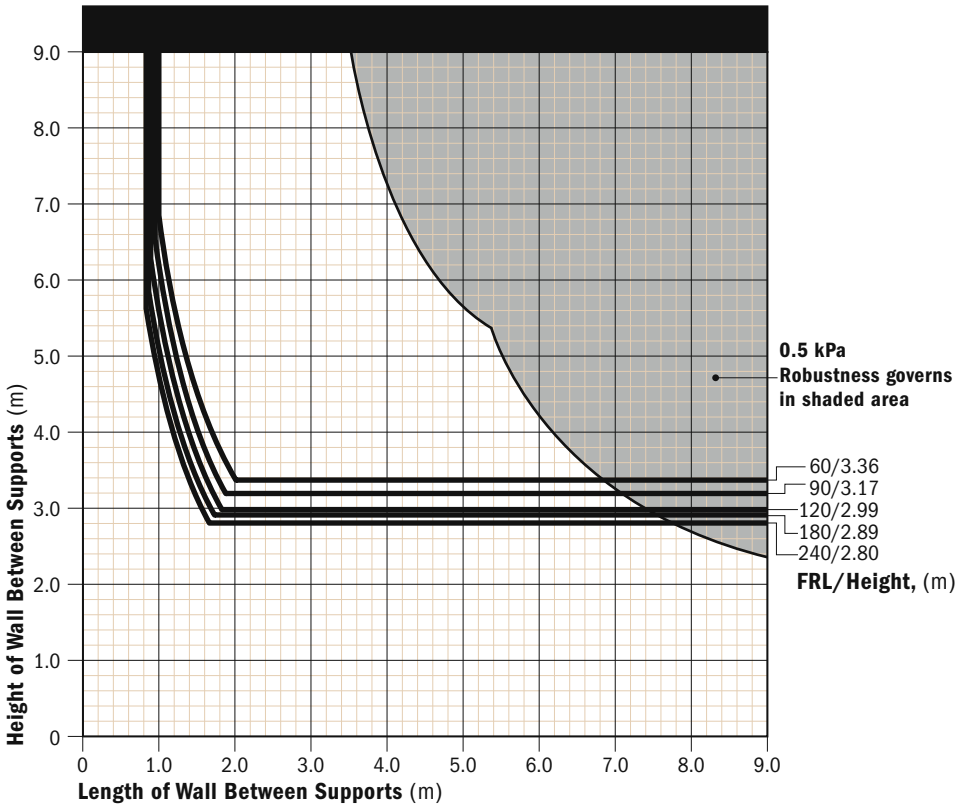
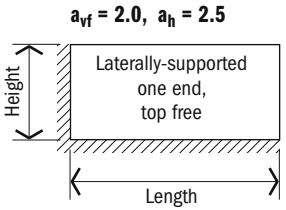


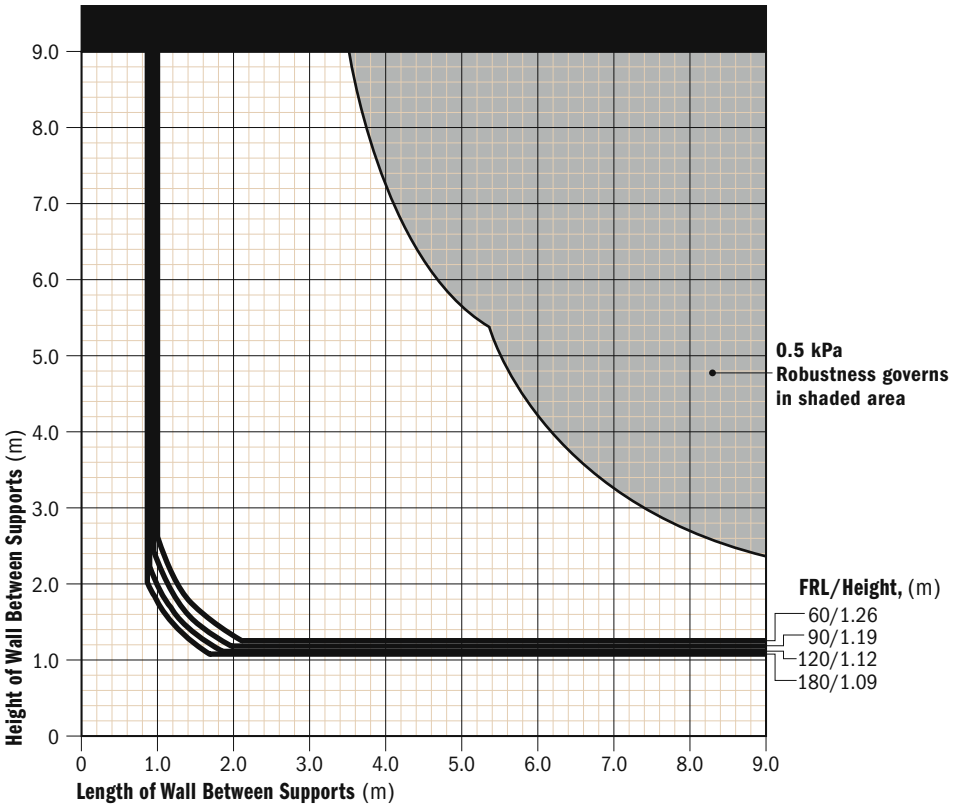
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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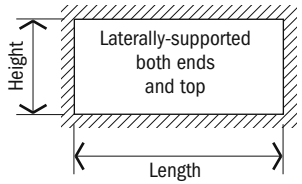
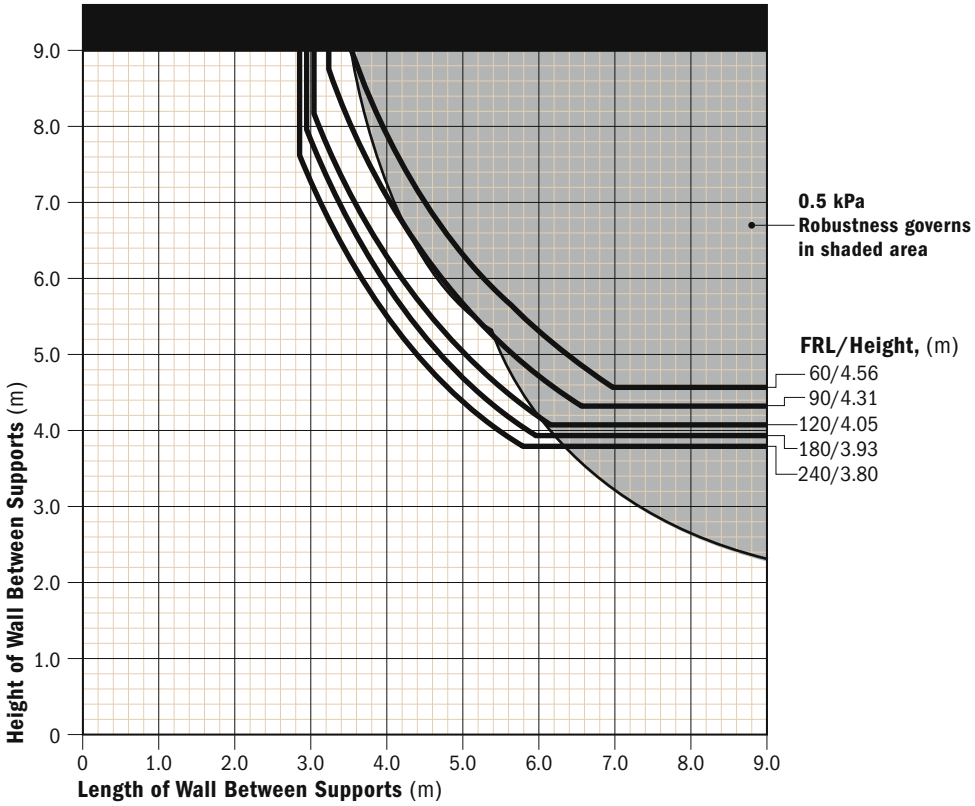
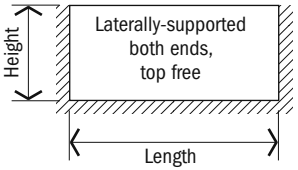
a_{vf} = 0.75, a_h = 1.0



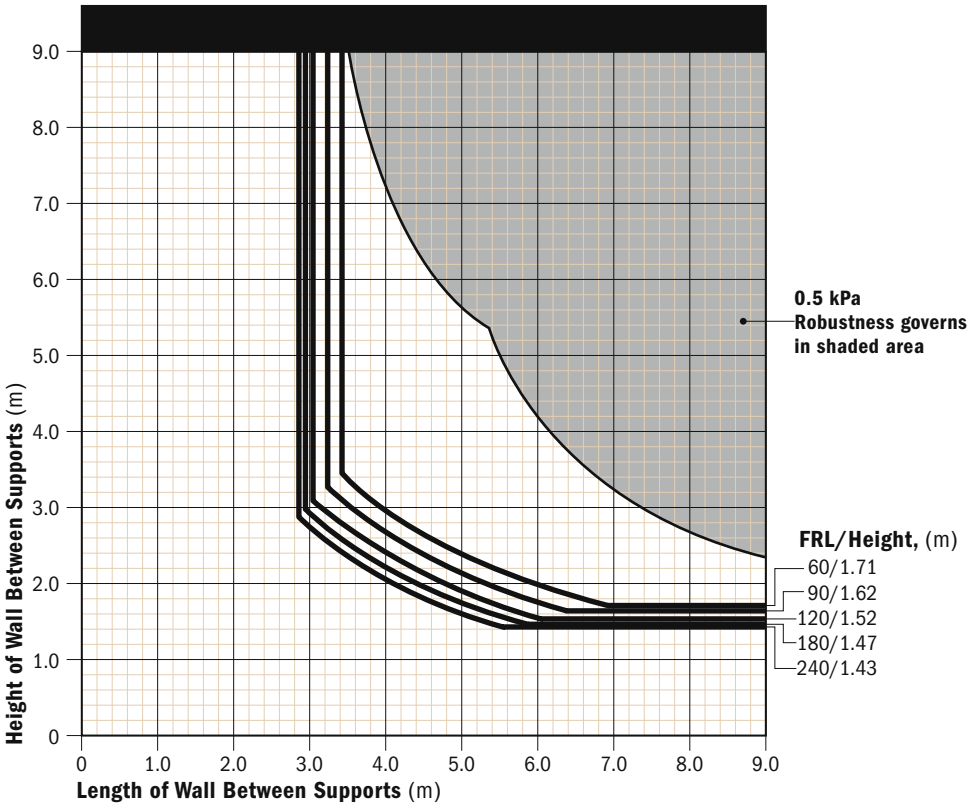
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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3 of 4

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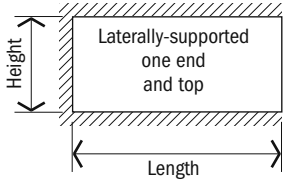
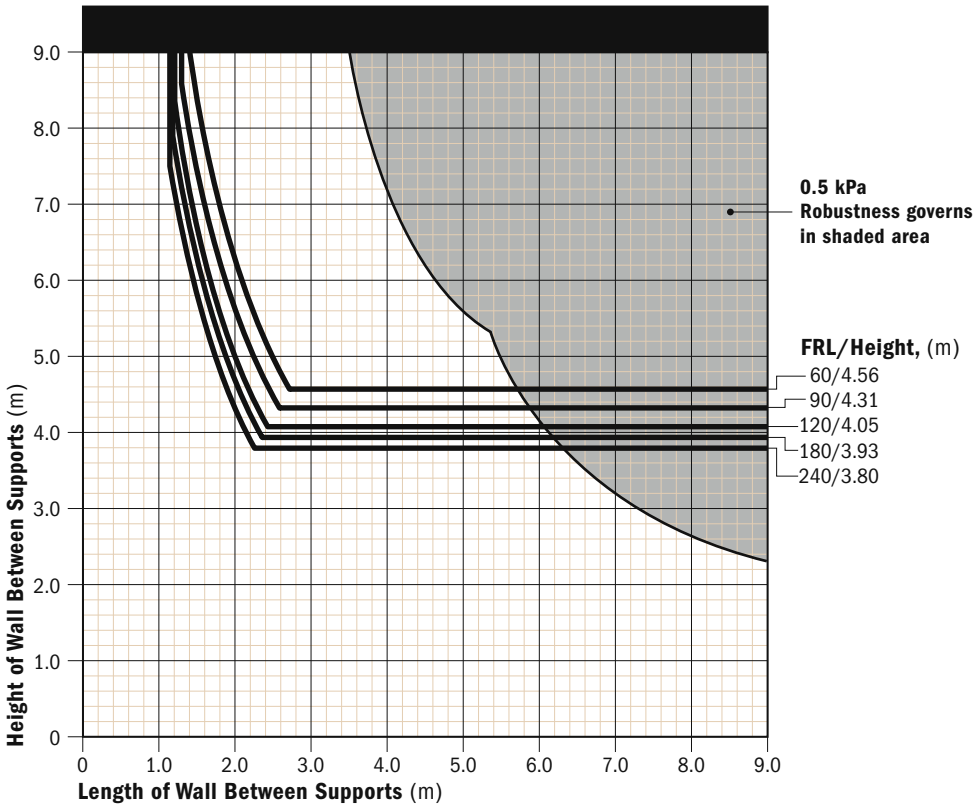
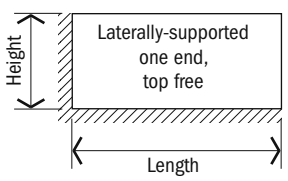


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

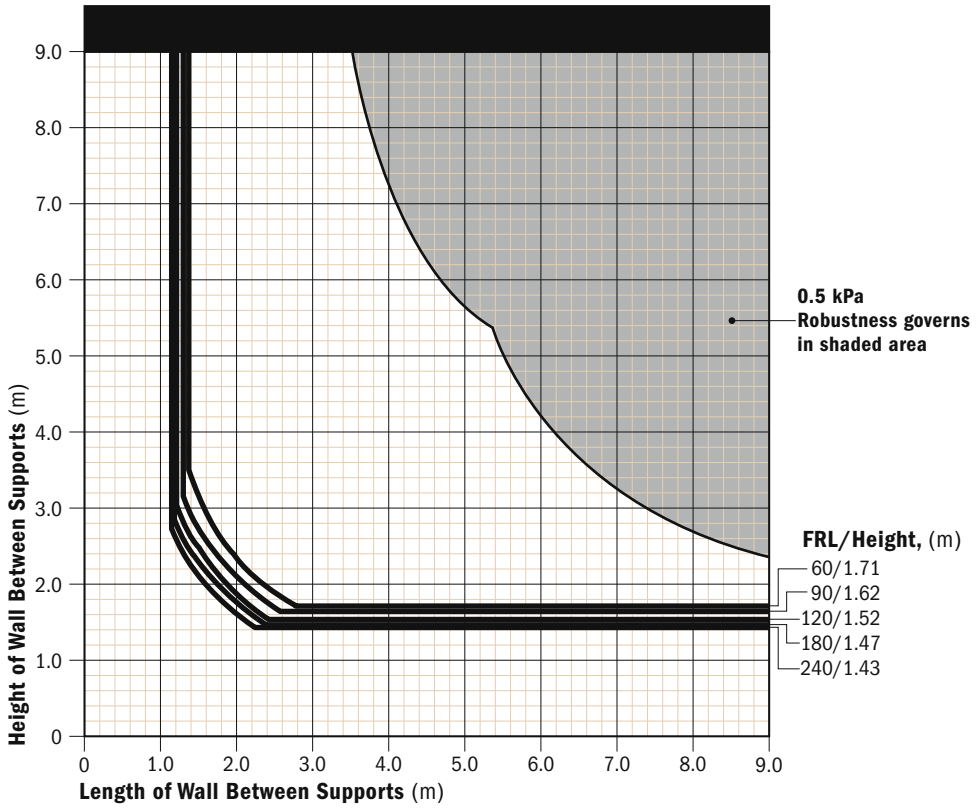


4 of 4

a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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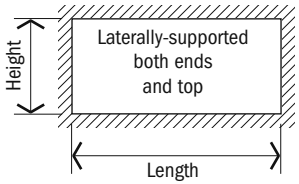
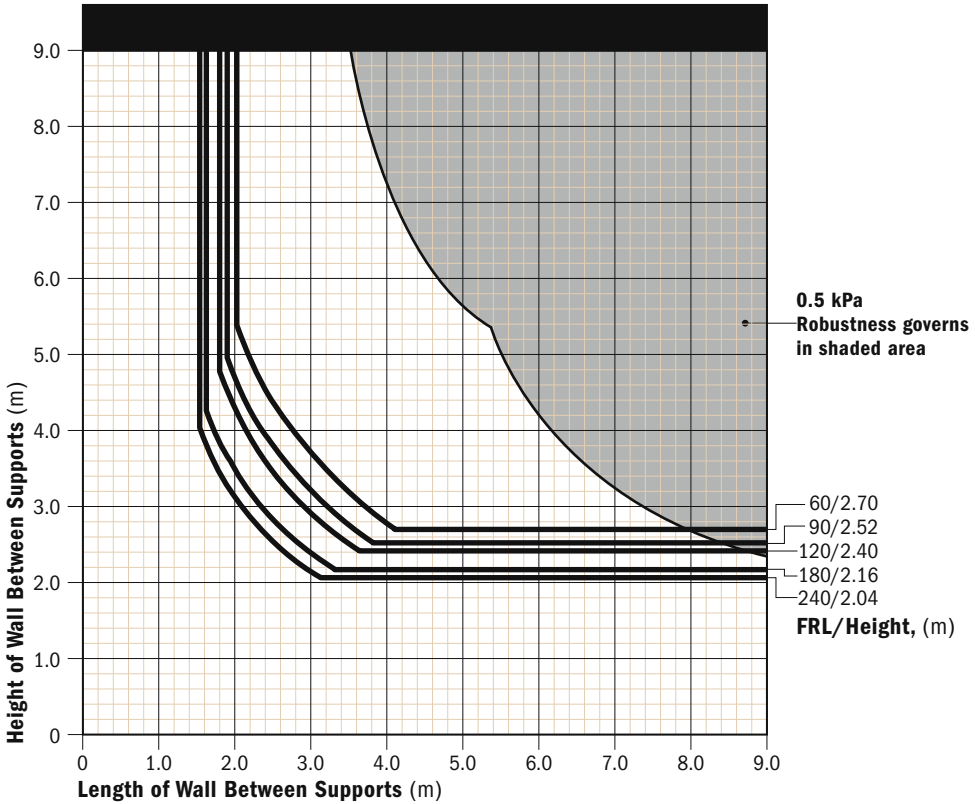
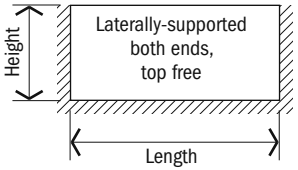


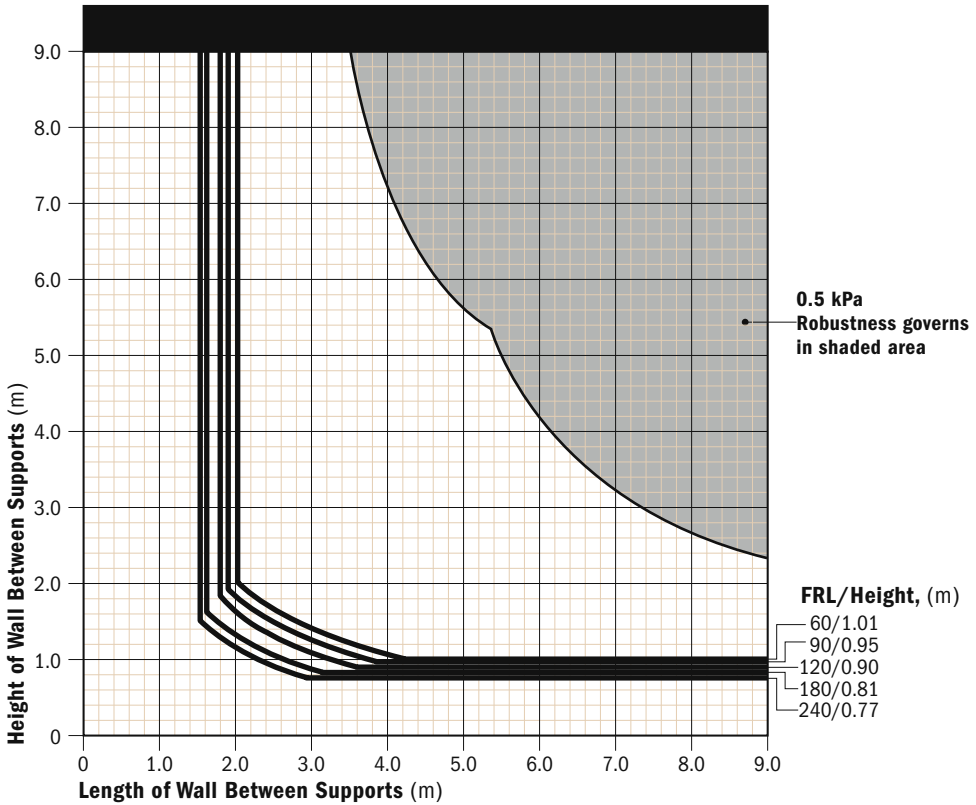
Fire-resistance level, FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level, FRL (minutes), **for Structural Adequacy**



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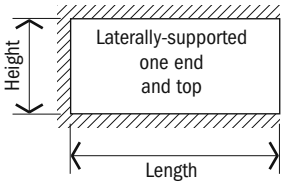
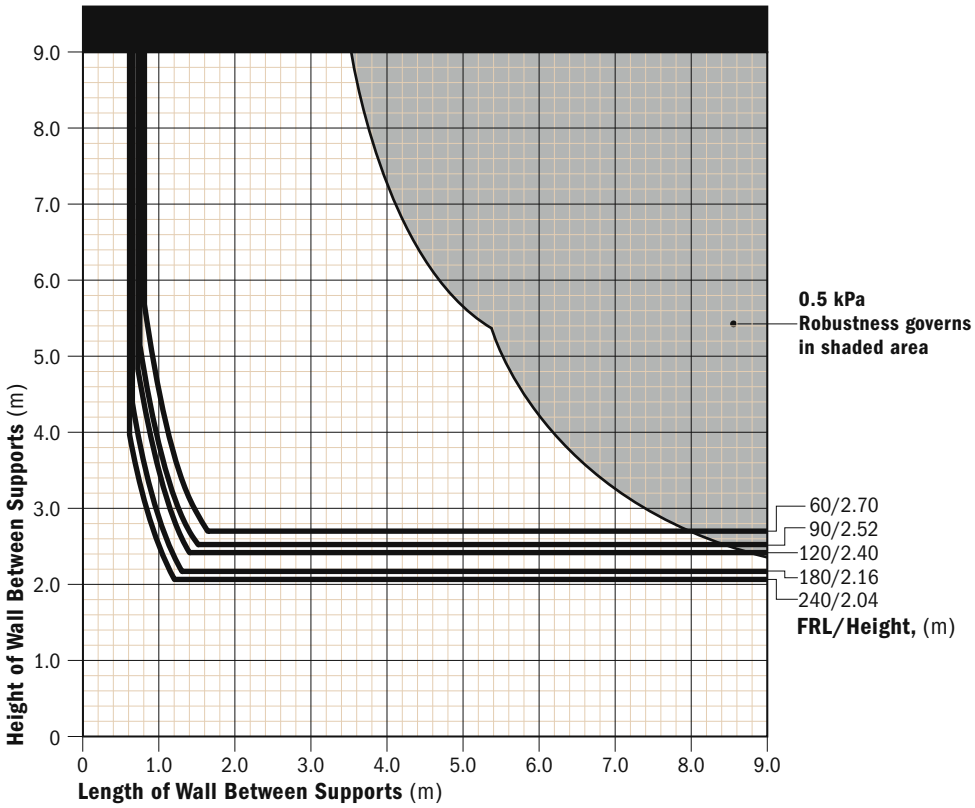


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



4 of 4

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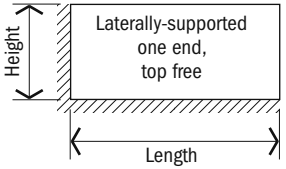
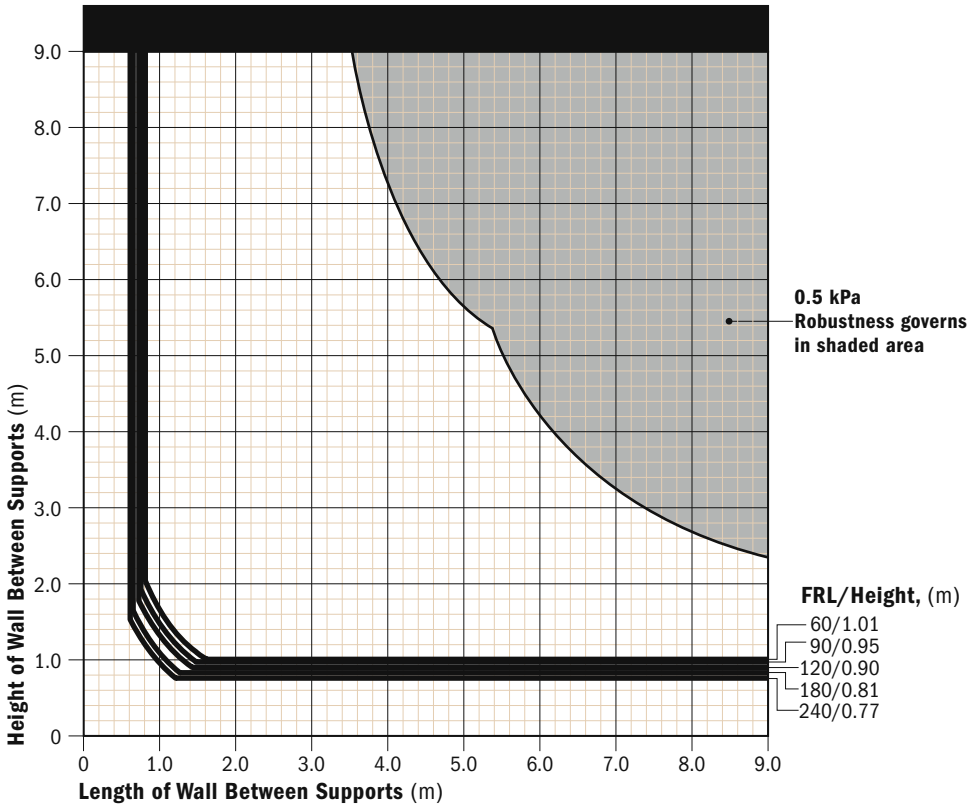


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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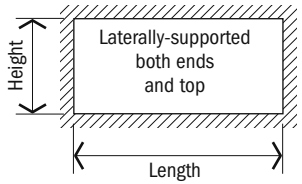
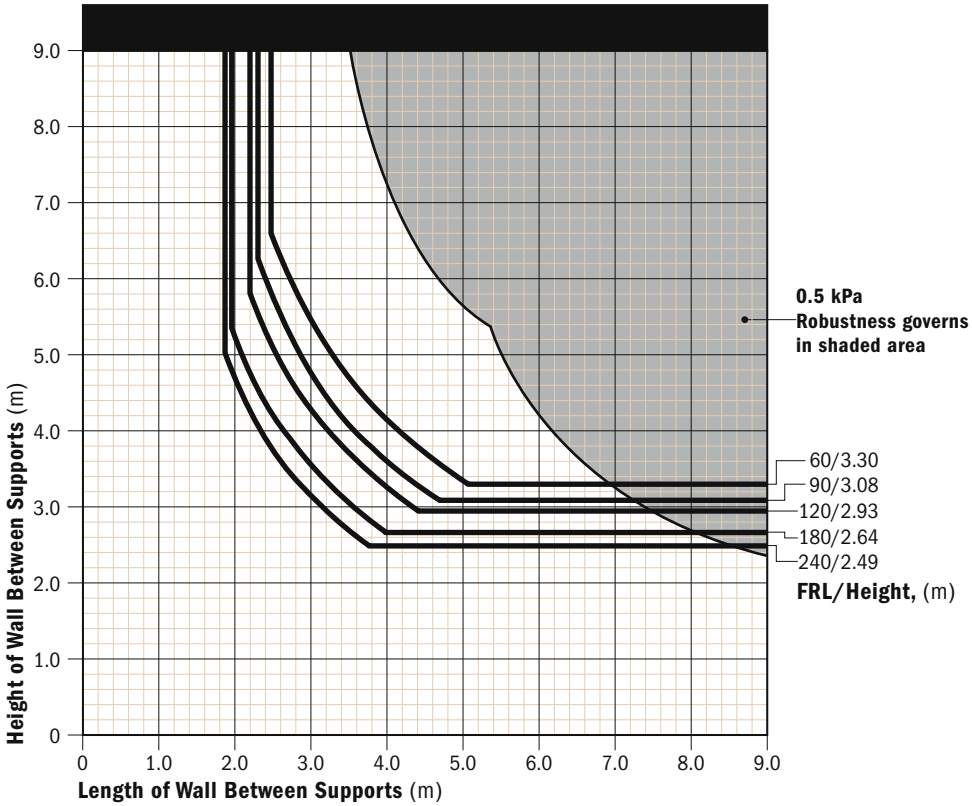
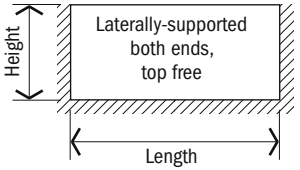


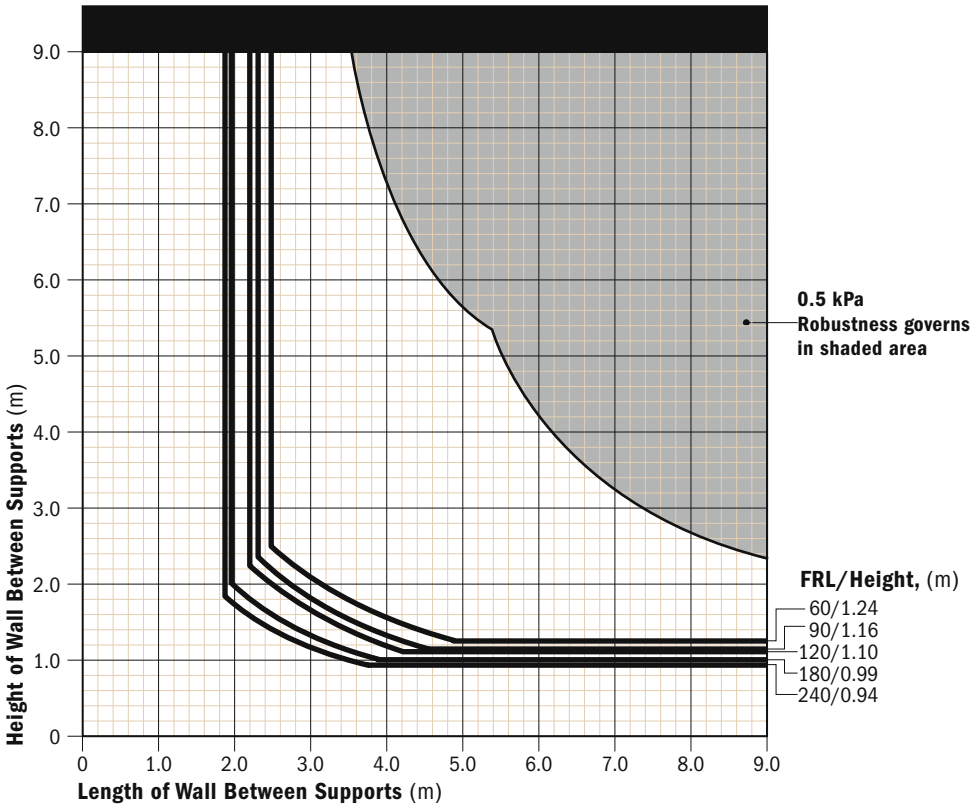
Fire-resistance level, FRL(minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level, FRL (minutes), **for Structural Adequacy**



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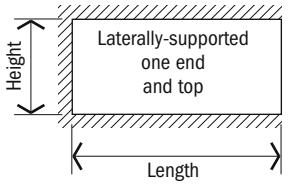
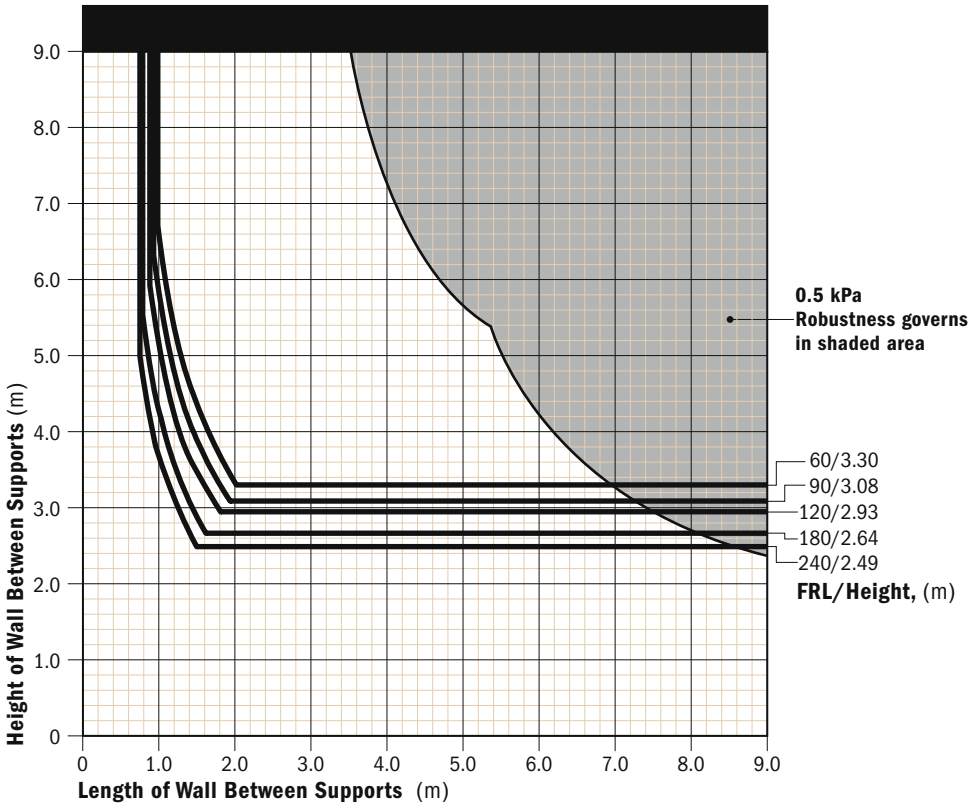


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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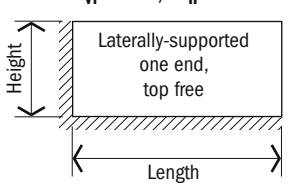
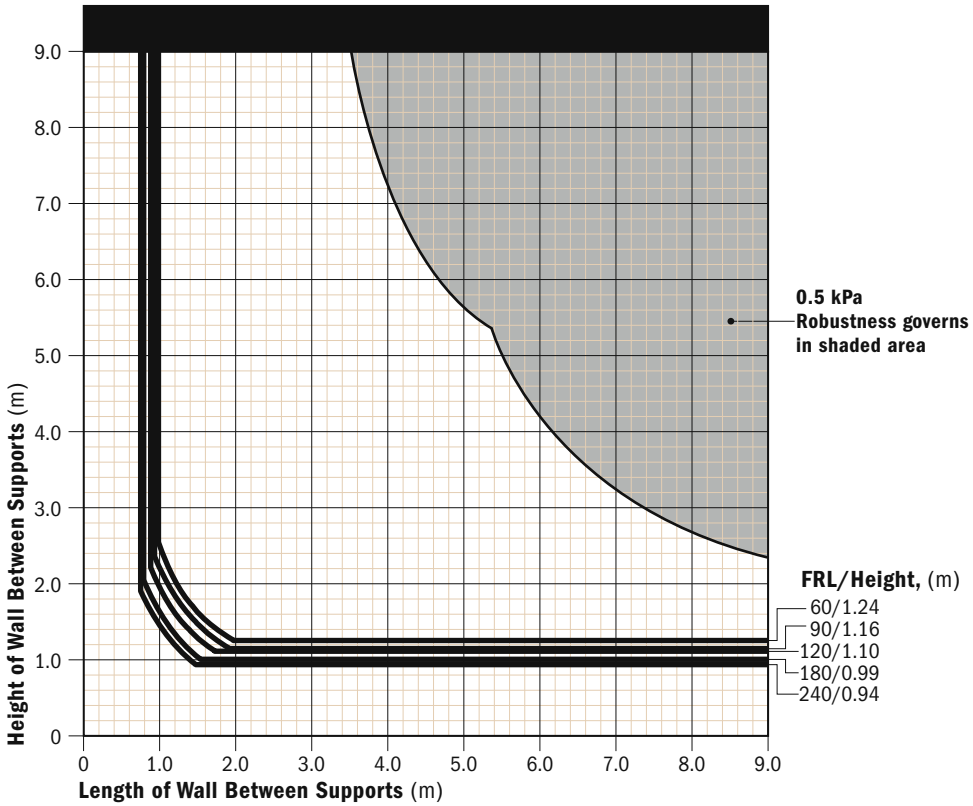


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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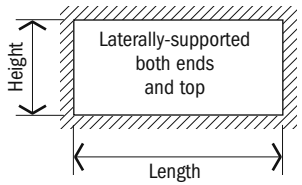

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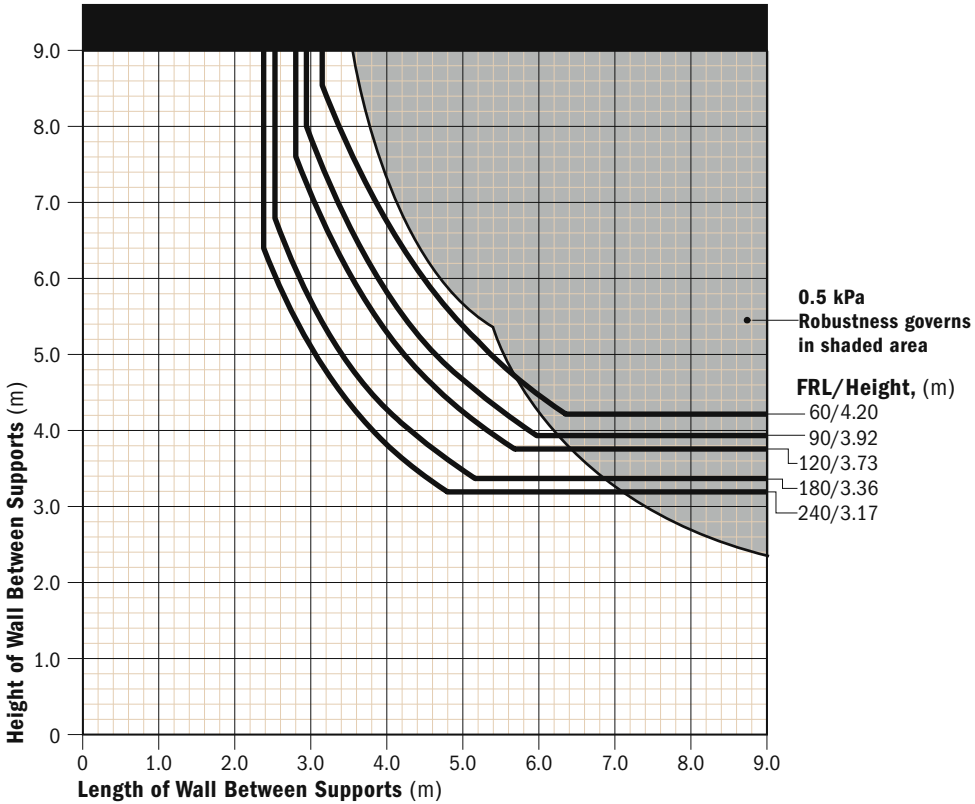

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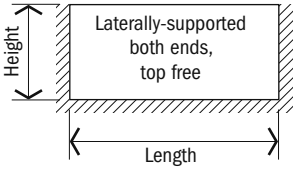

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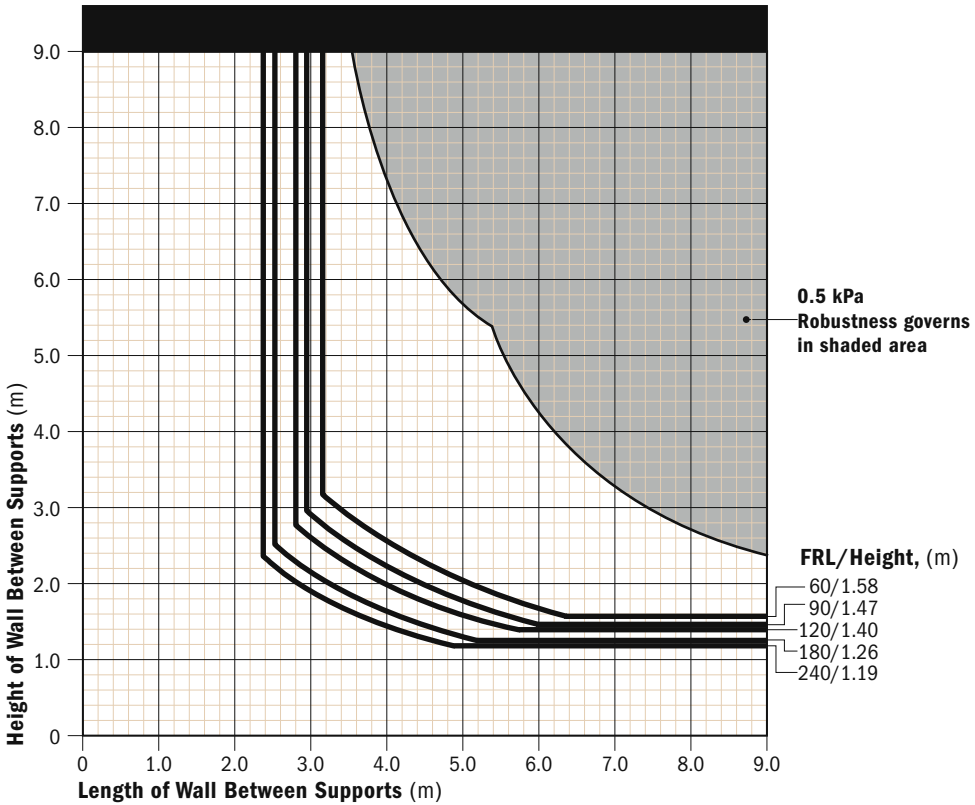

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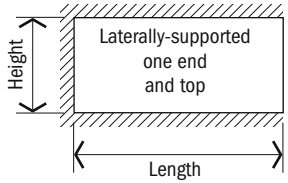

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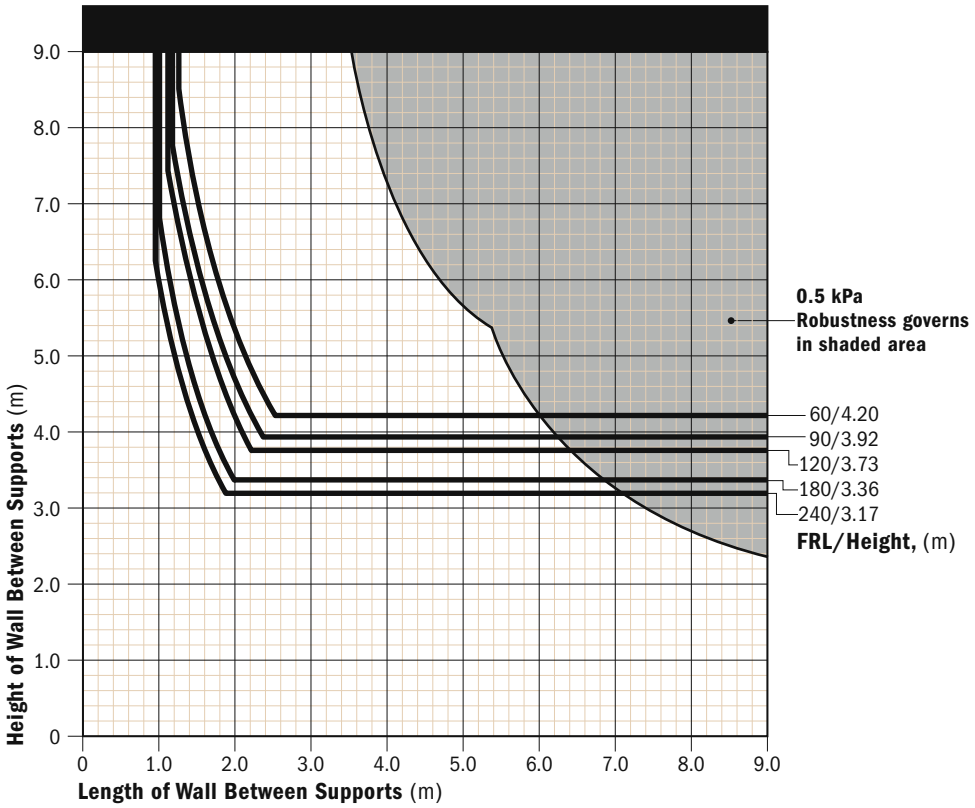
FRL (minutes), **for Structural Adequacy**



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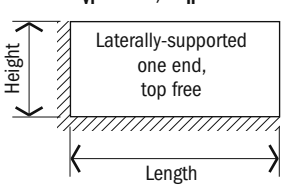

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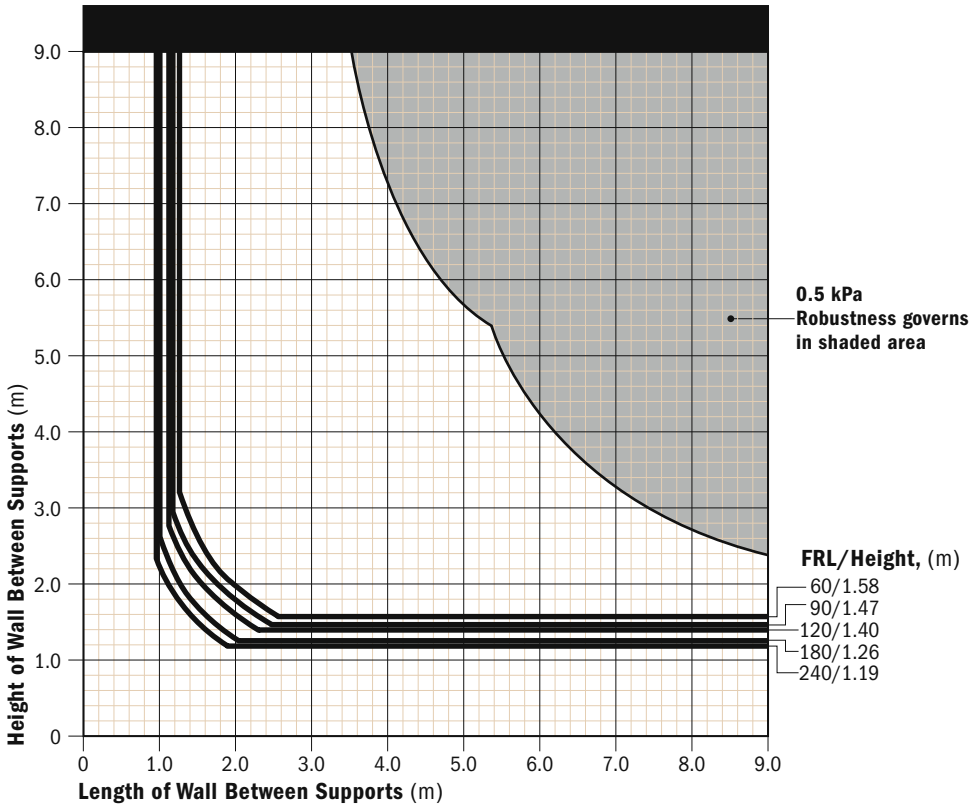

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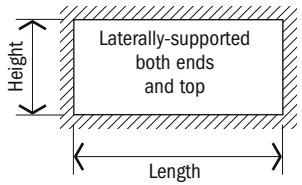
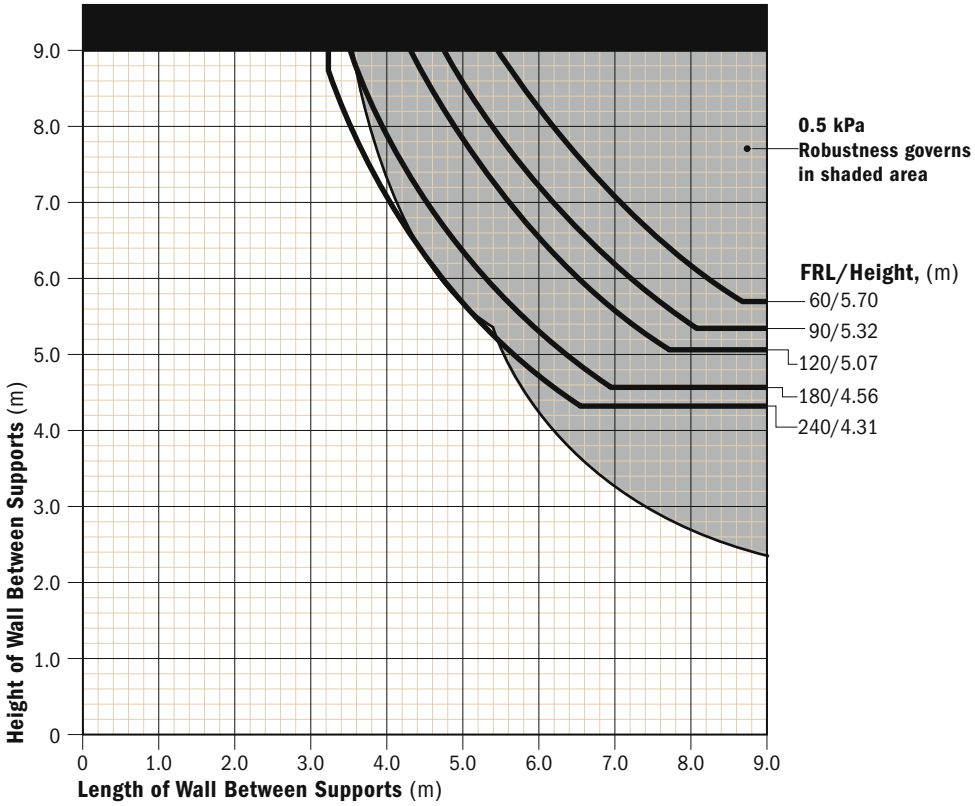


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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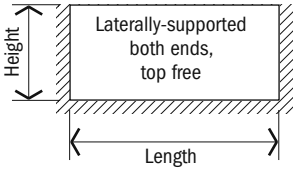

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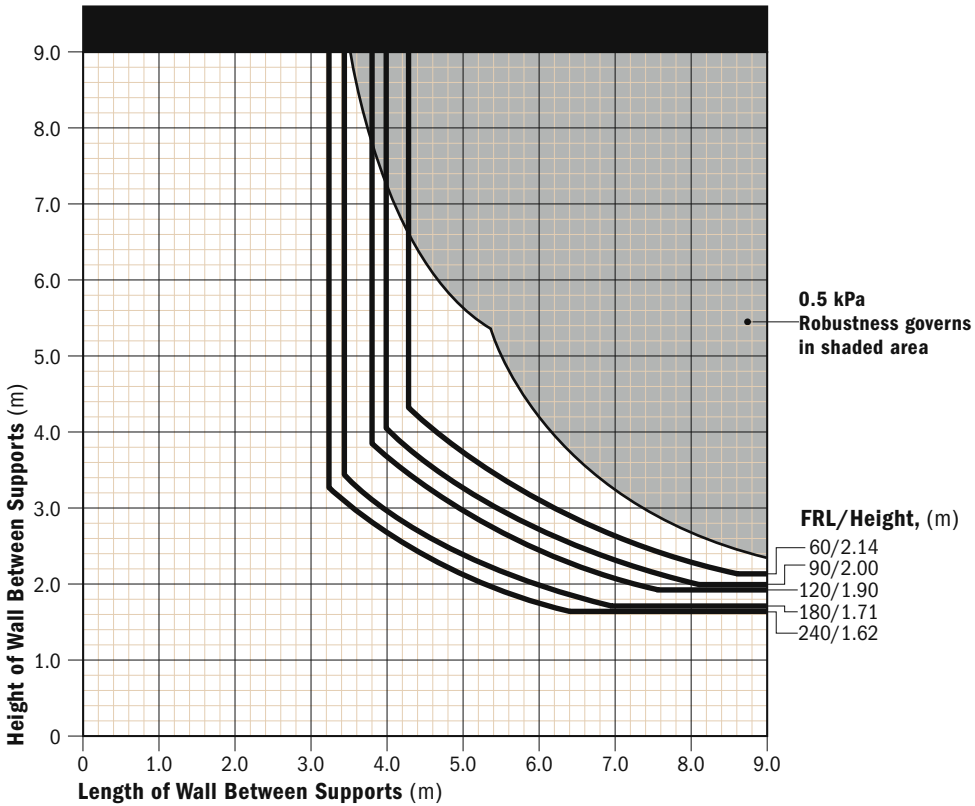

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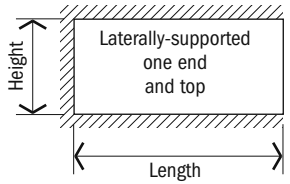
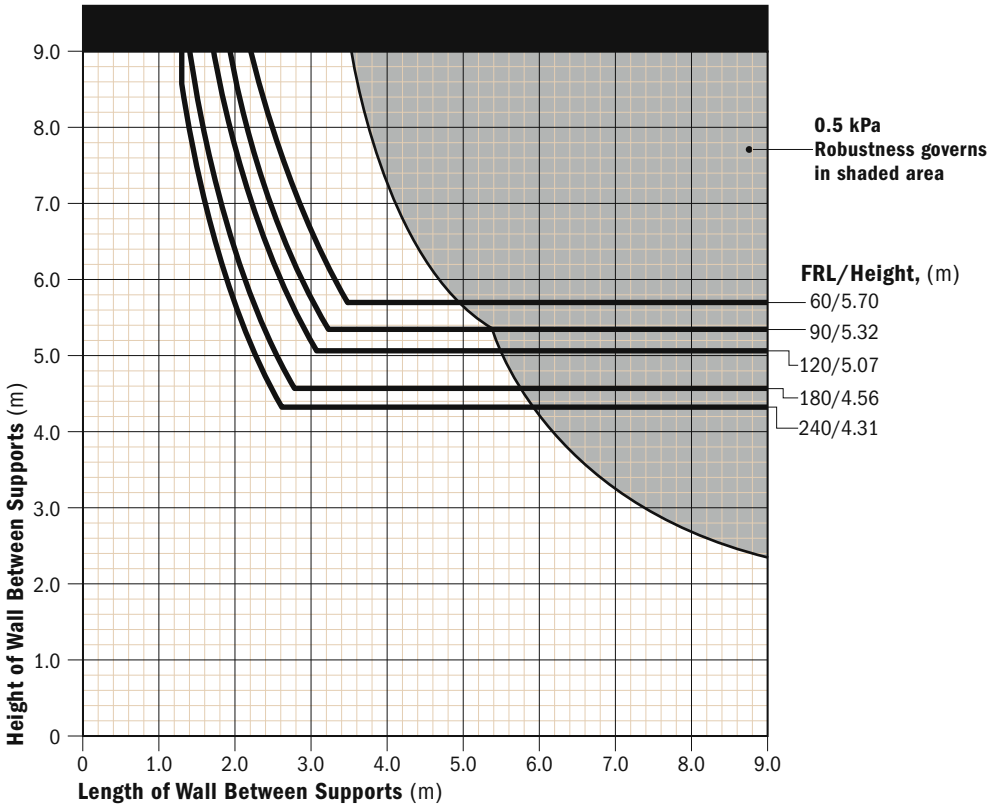
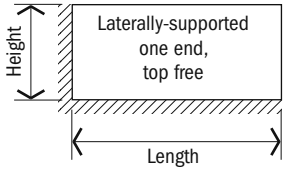


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

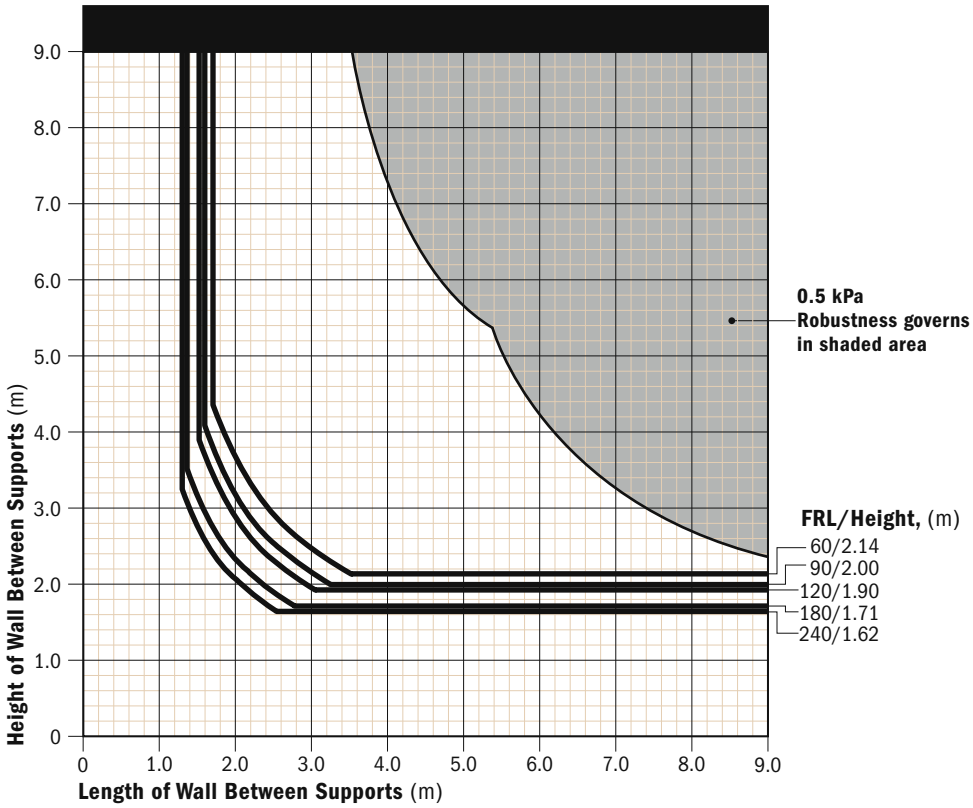


4 of 4

a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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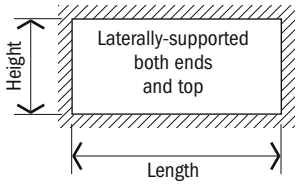
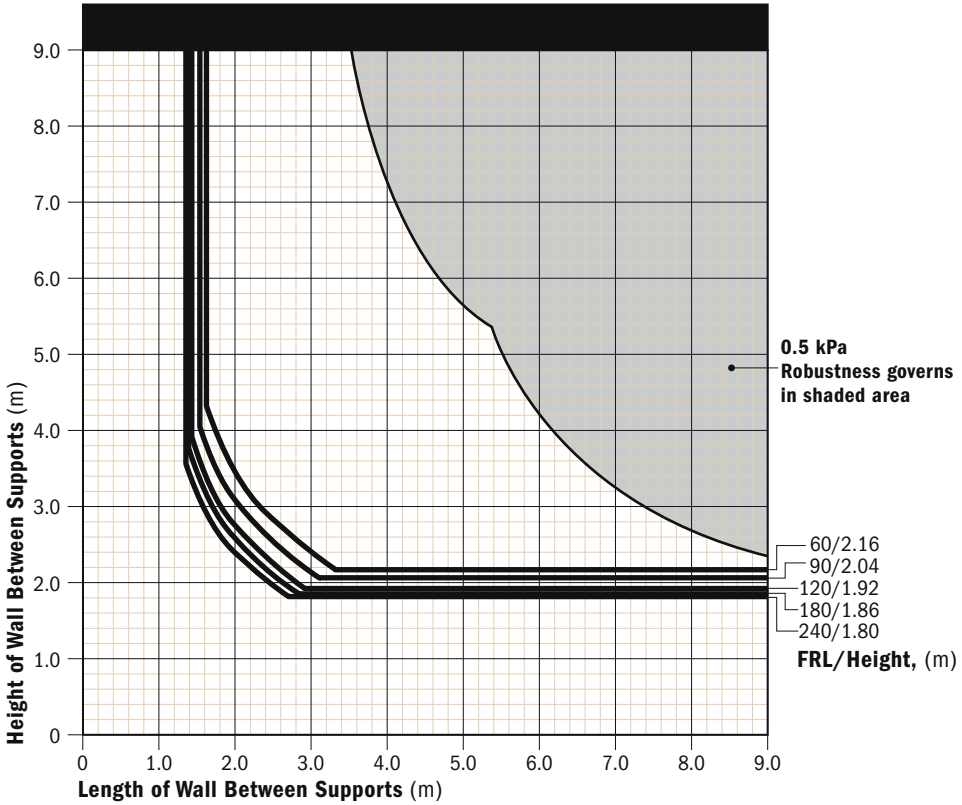
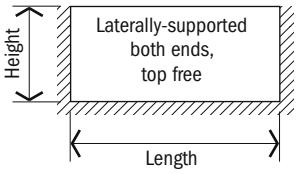
a_{vf} = 0.75, a_h = 1.0



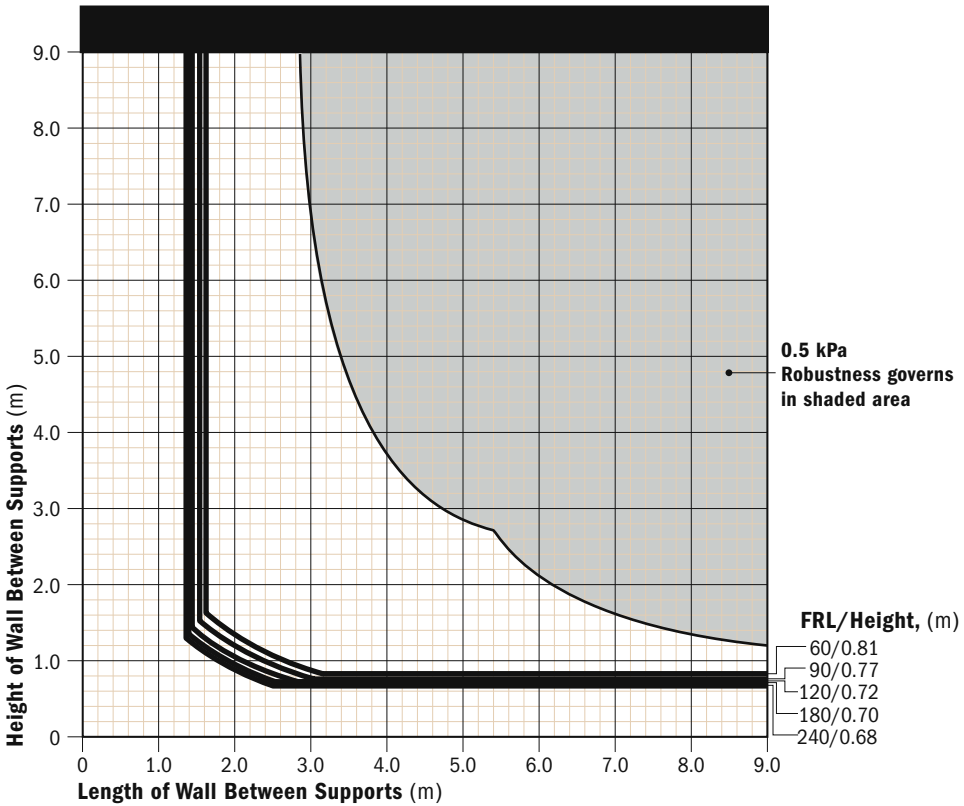
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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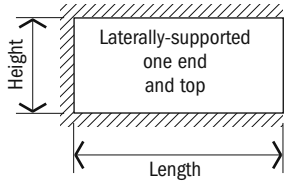
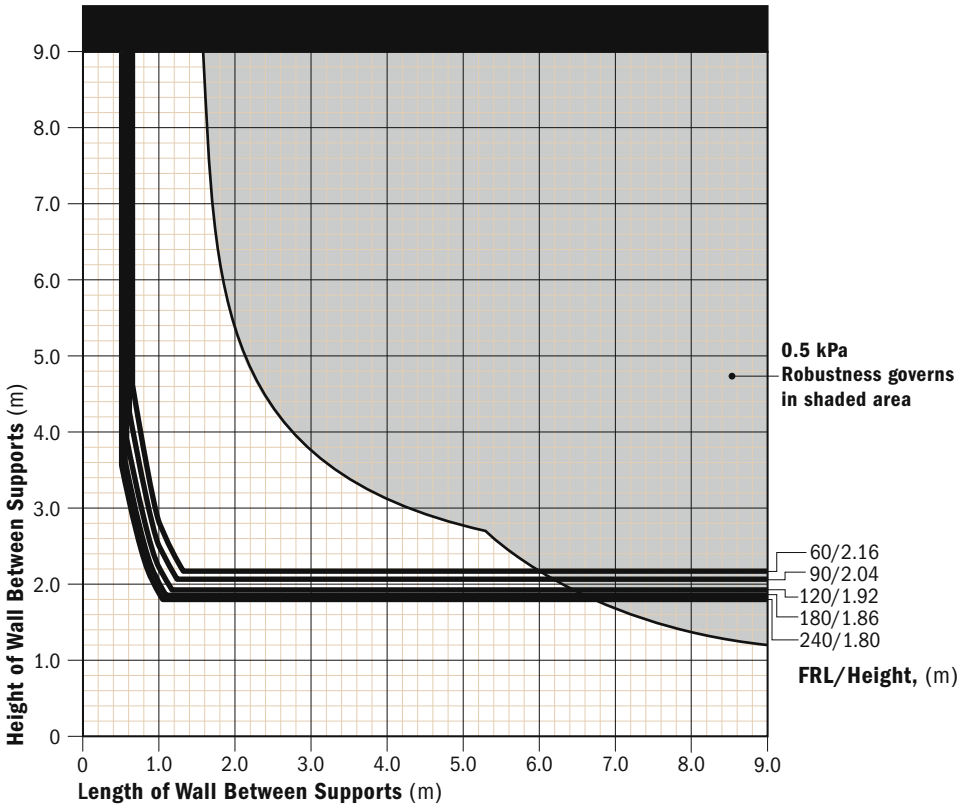
3 of 4

a_{vf} = 0.75, a_h = 2.5

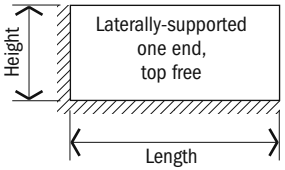


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

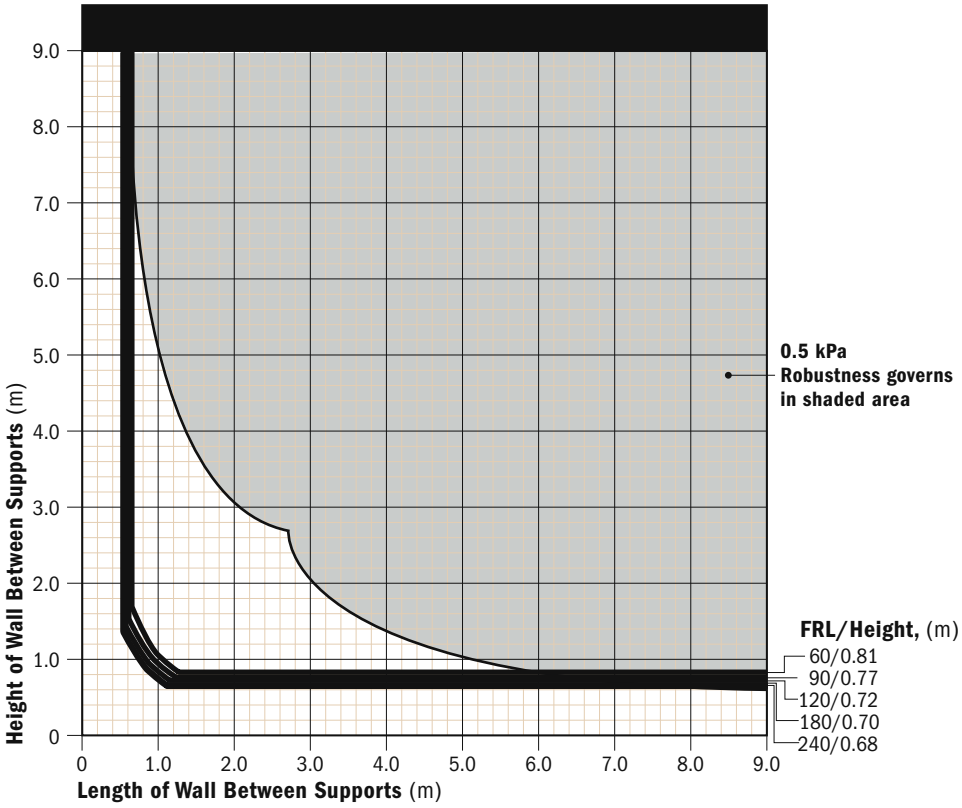


4 of 4

a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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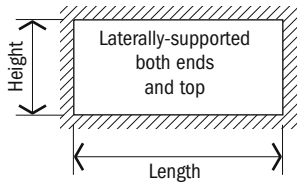
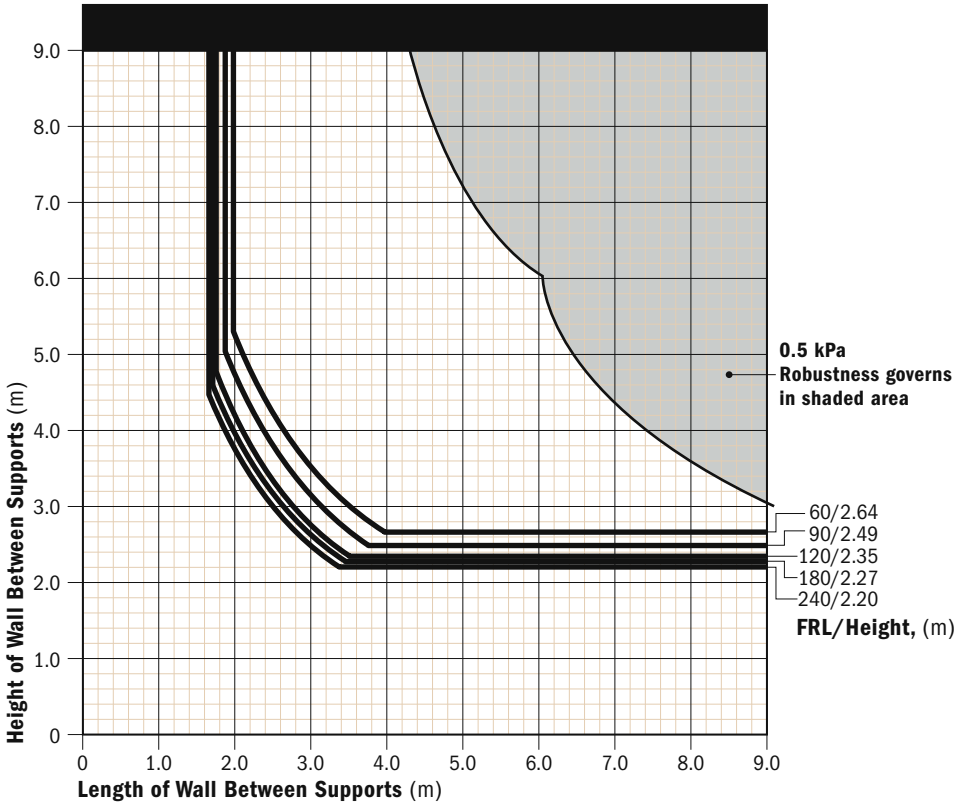
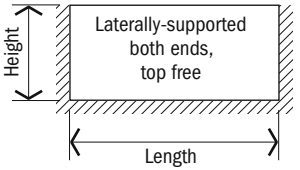


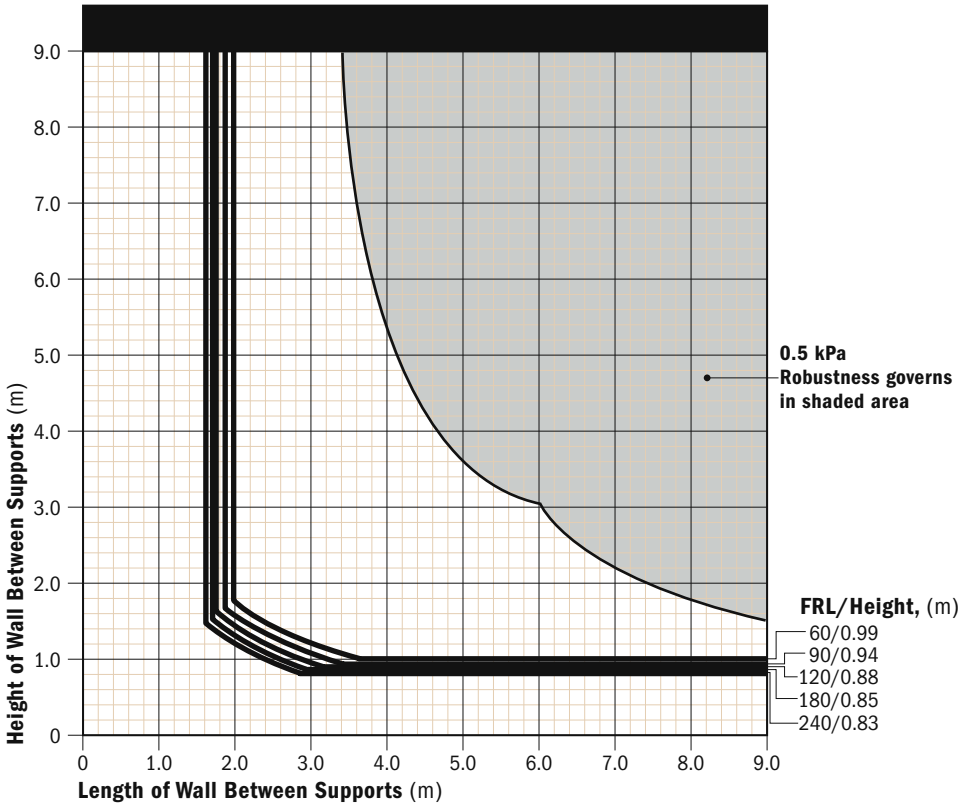
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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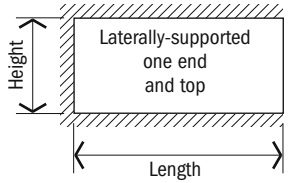
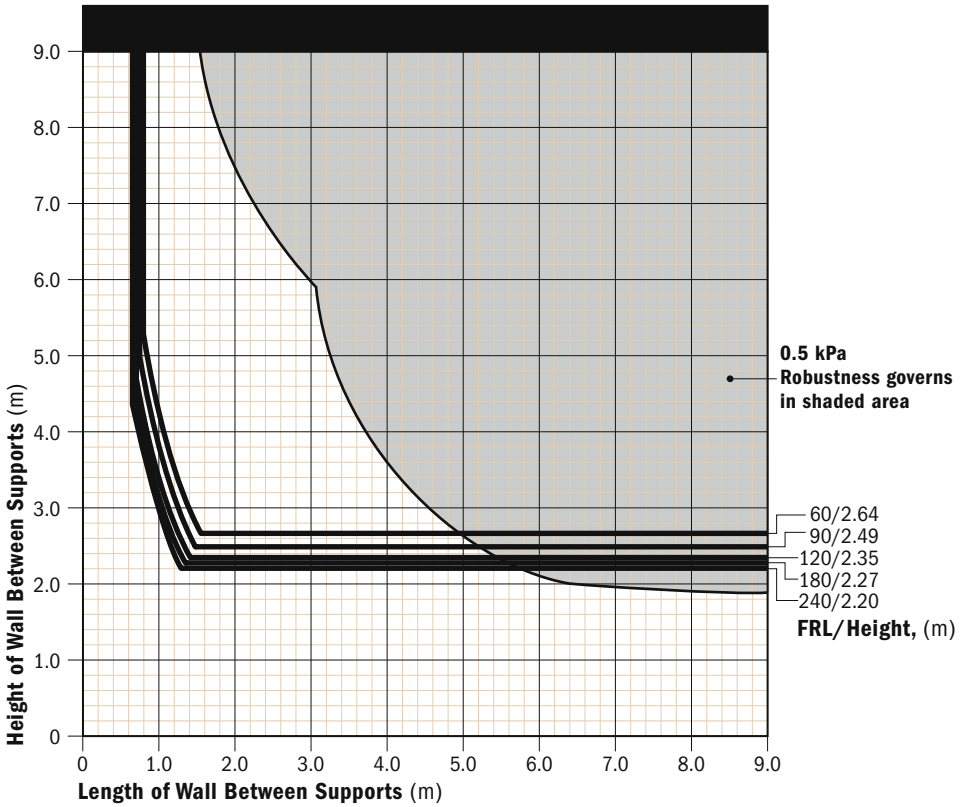


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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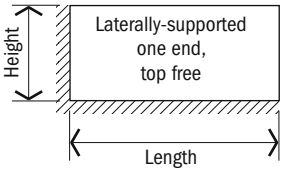
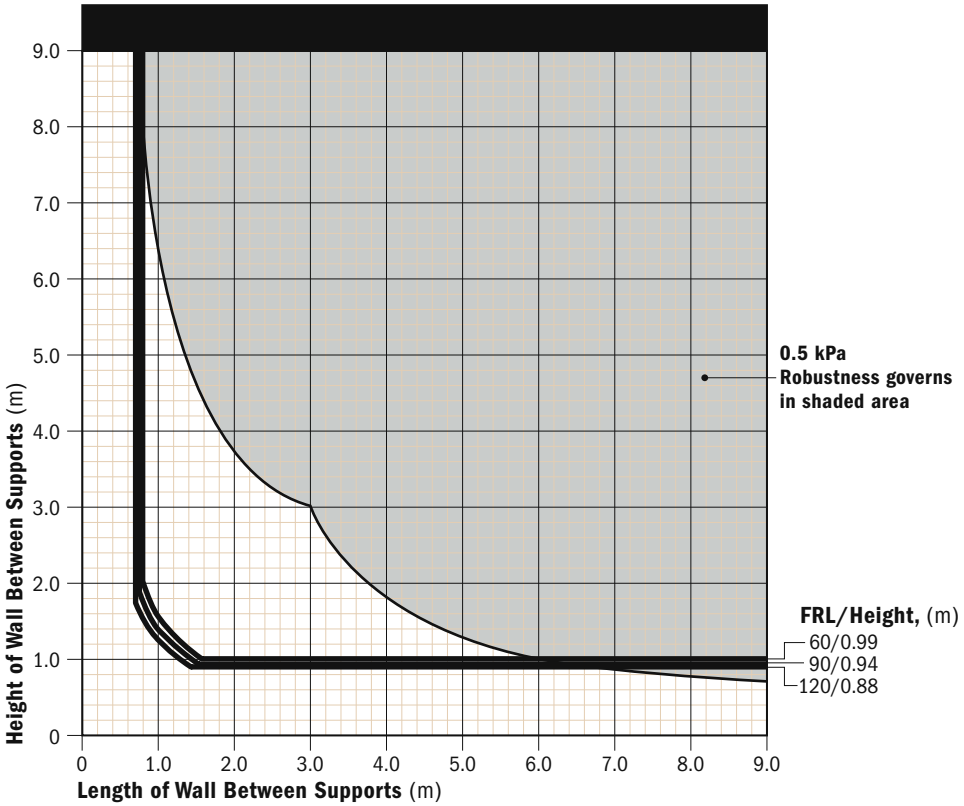


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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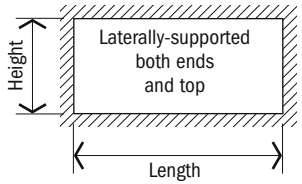
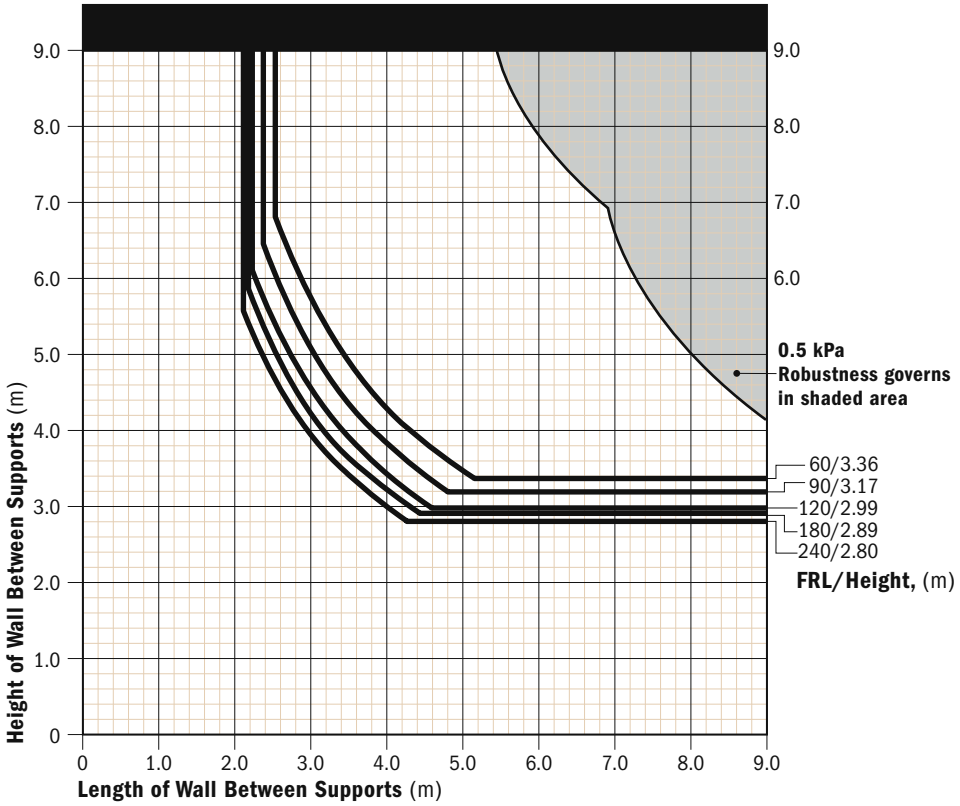
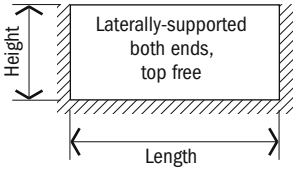


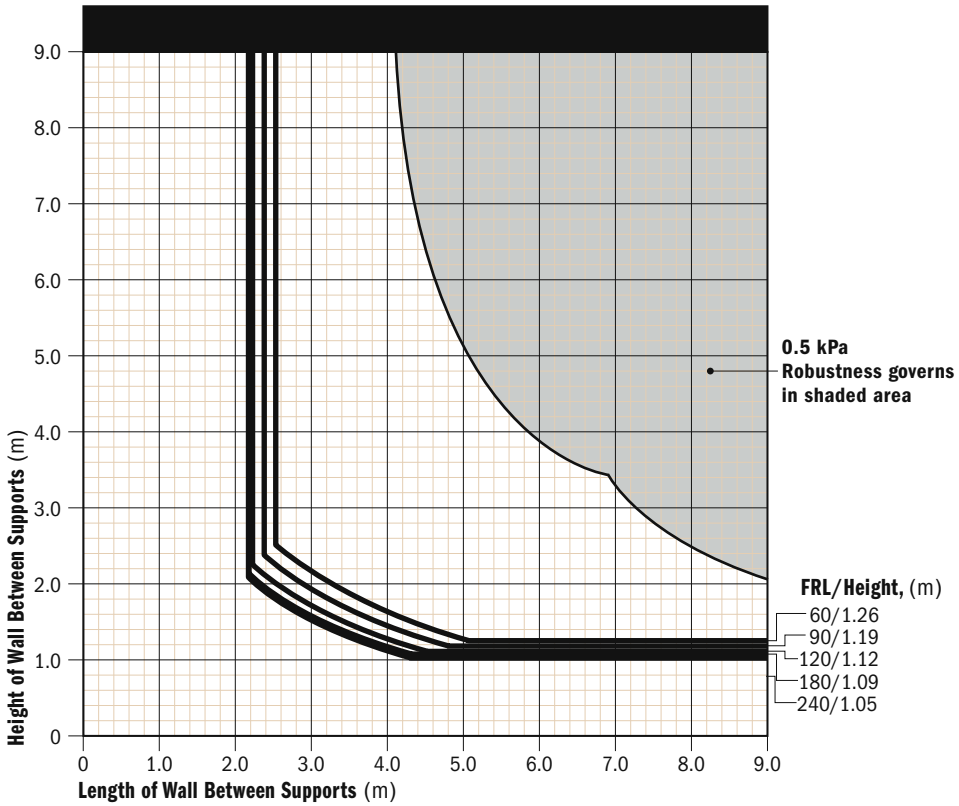
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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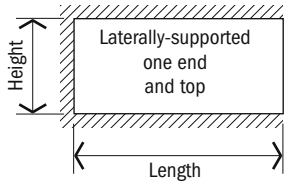
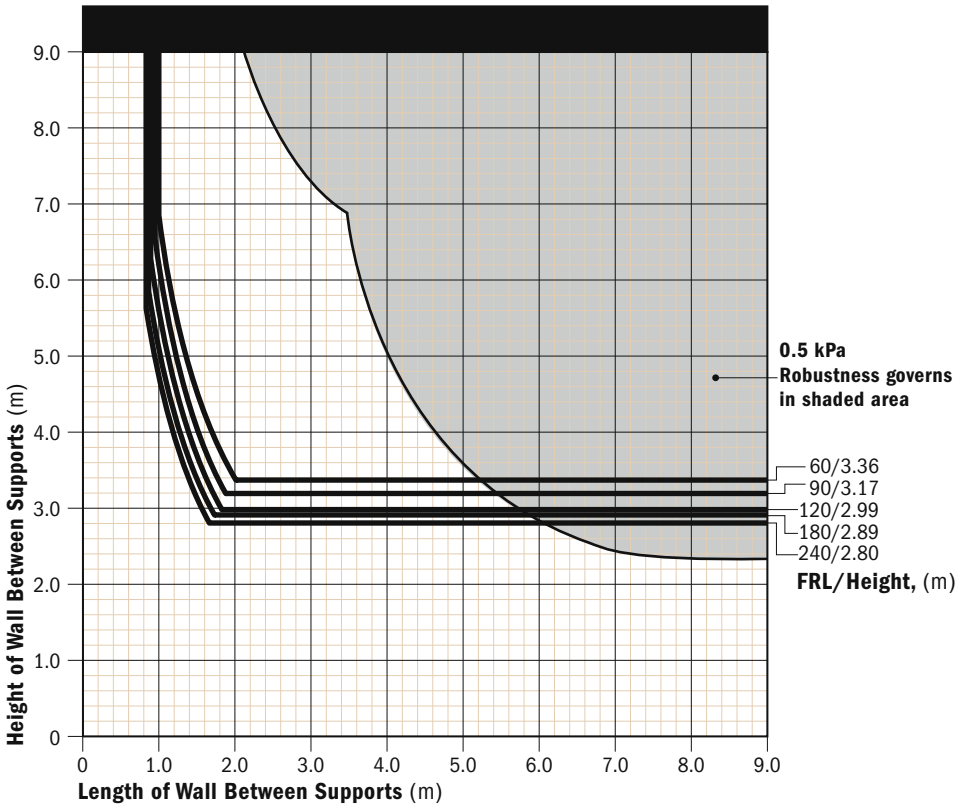


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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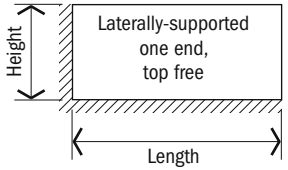
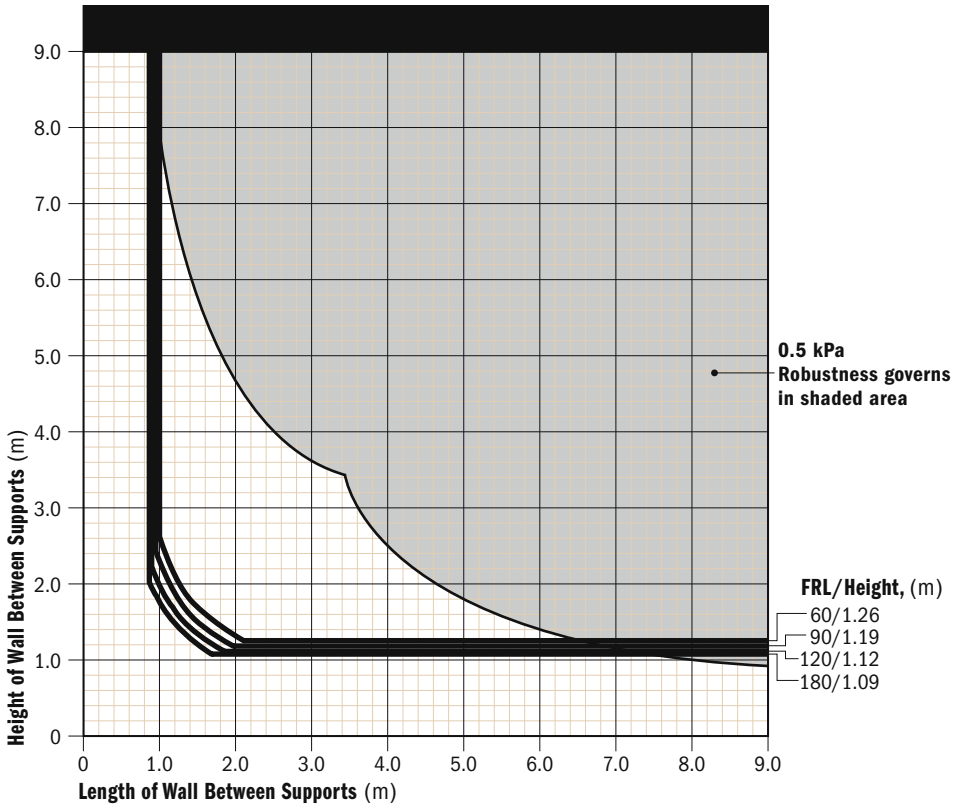


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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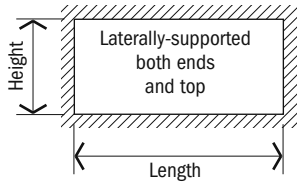
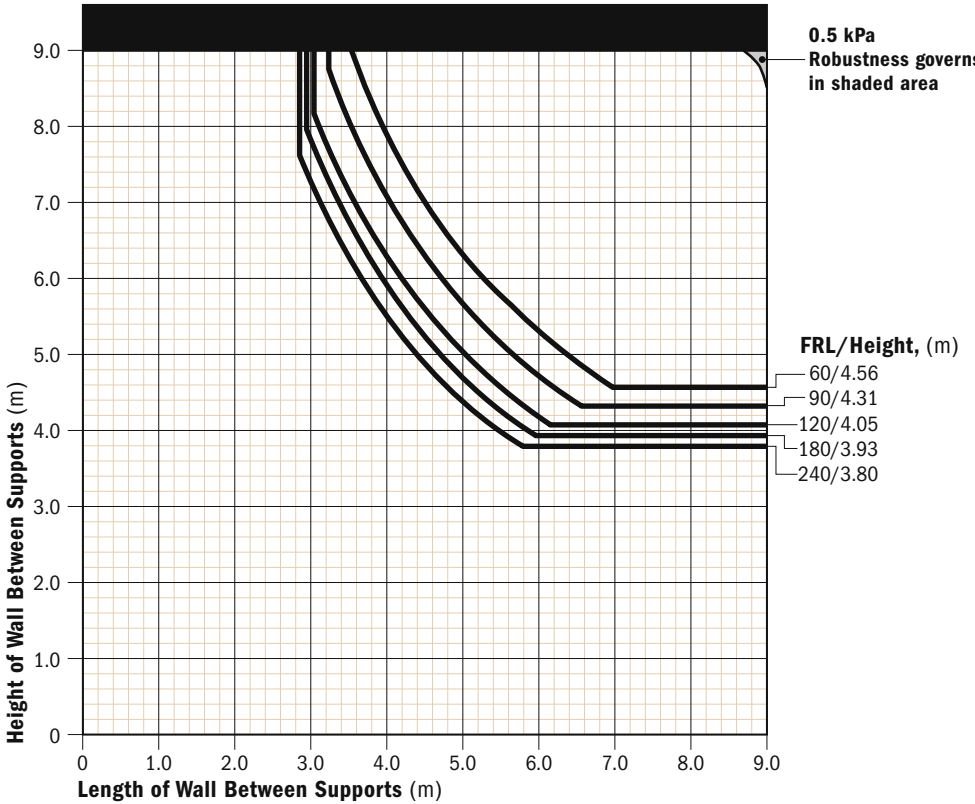
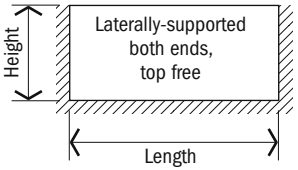


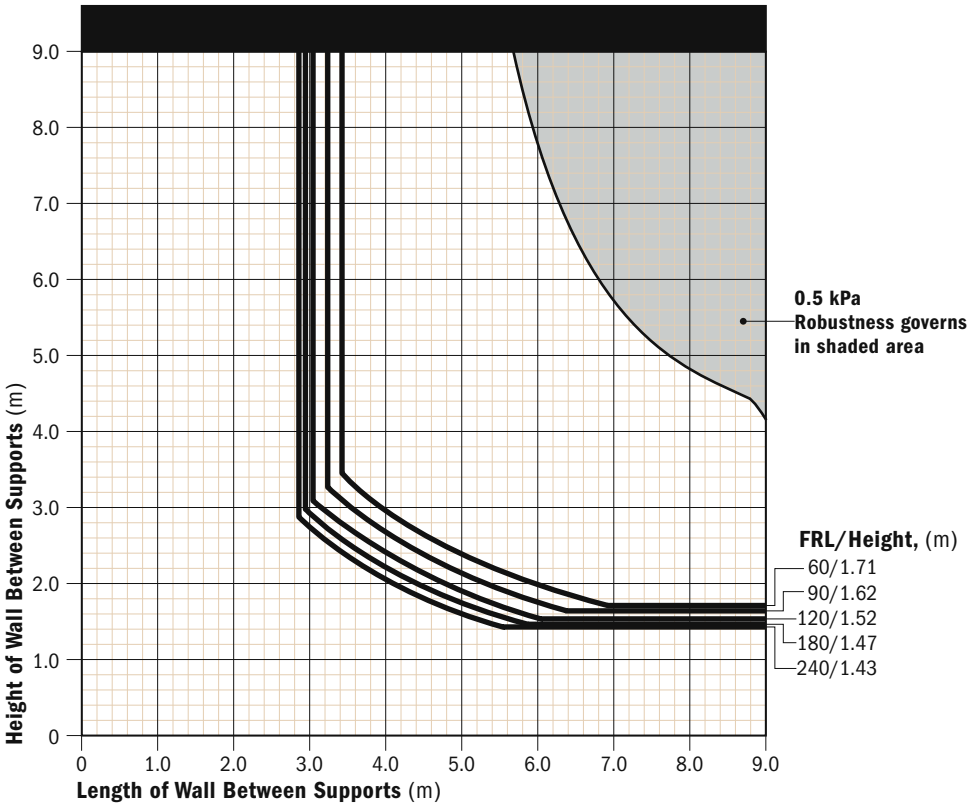
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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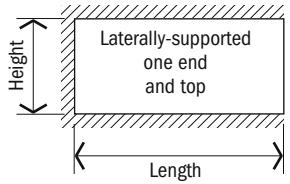
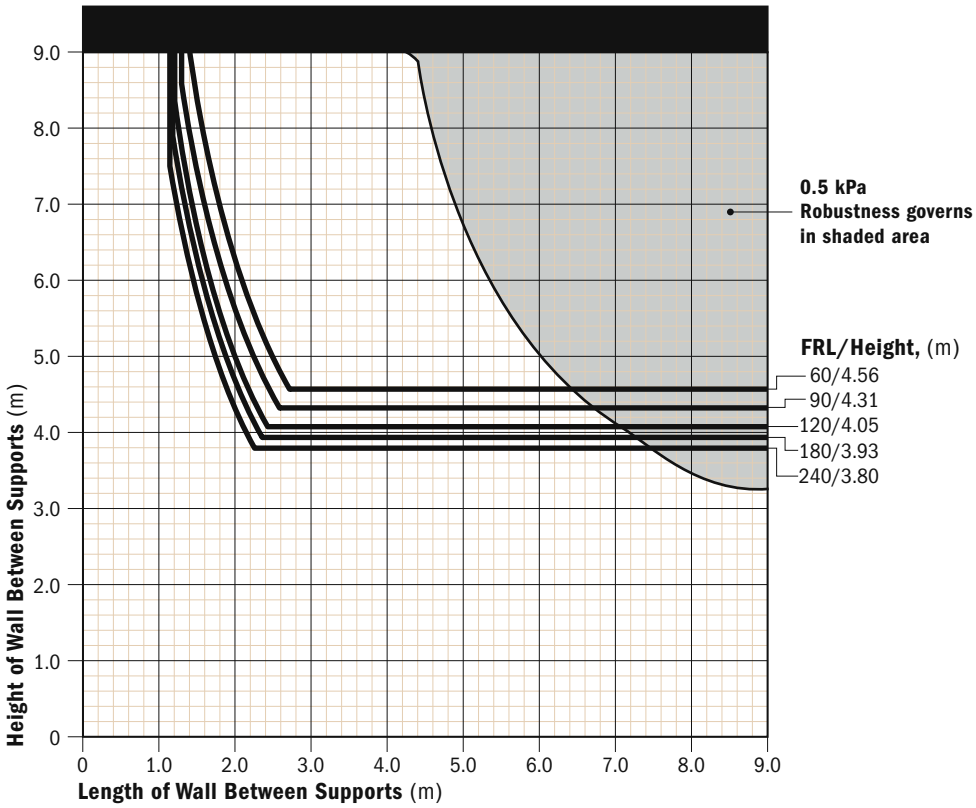


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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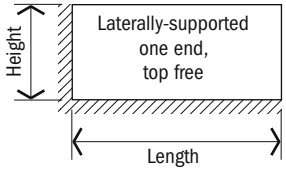
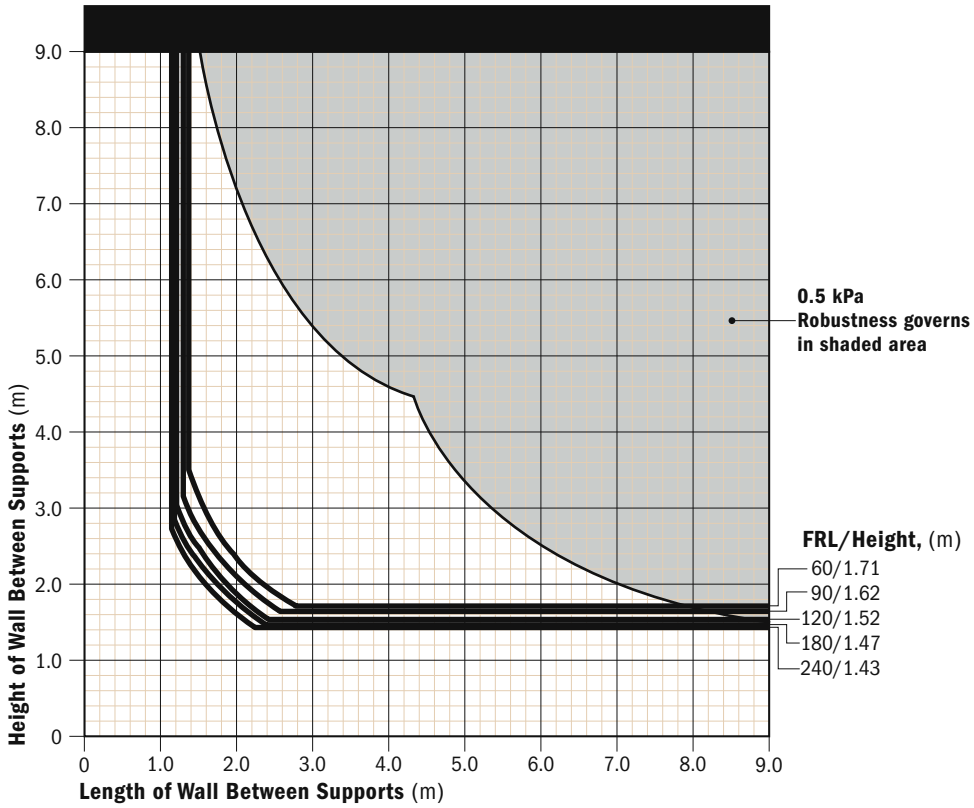


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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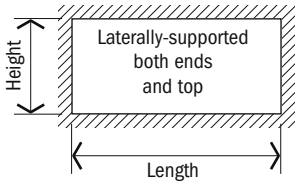
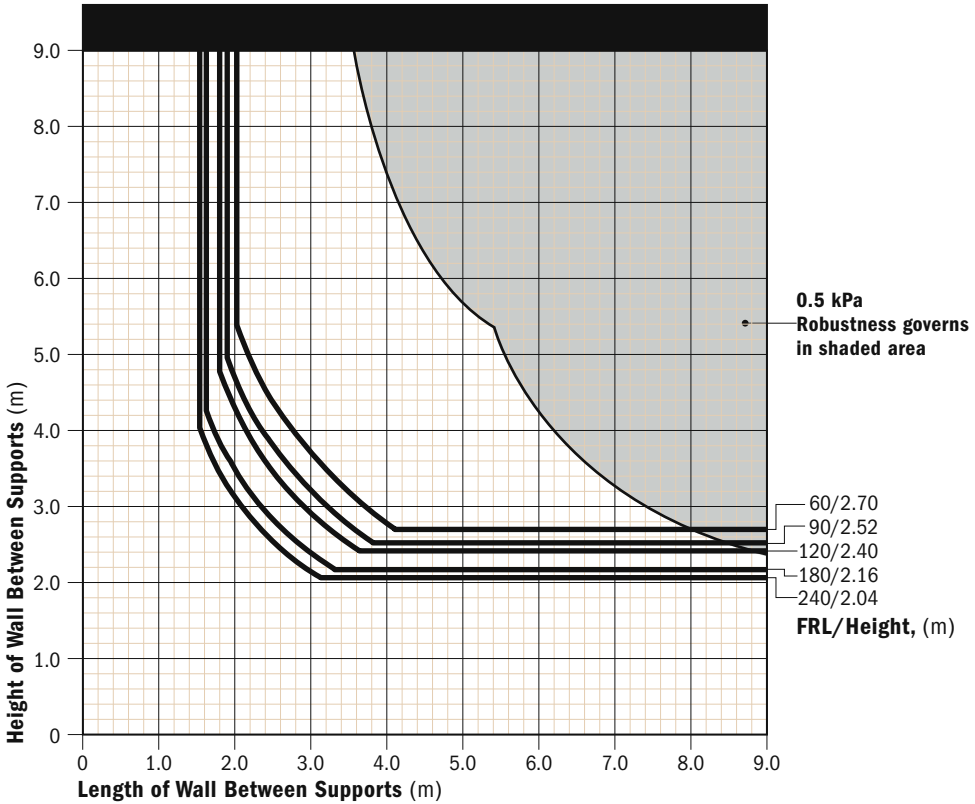


Fire-resistance level, FRL (minutes), **for Structural Adequacy**



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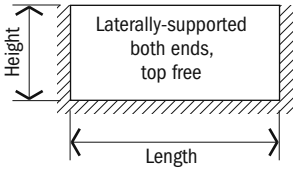
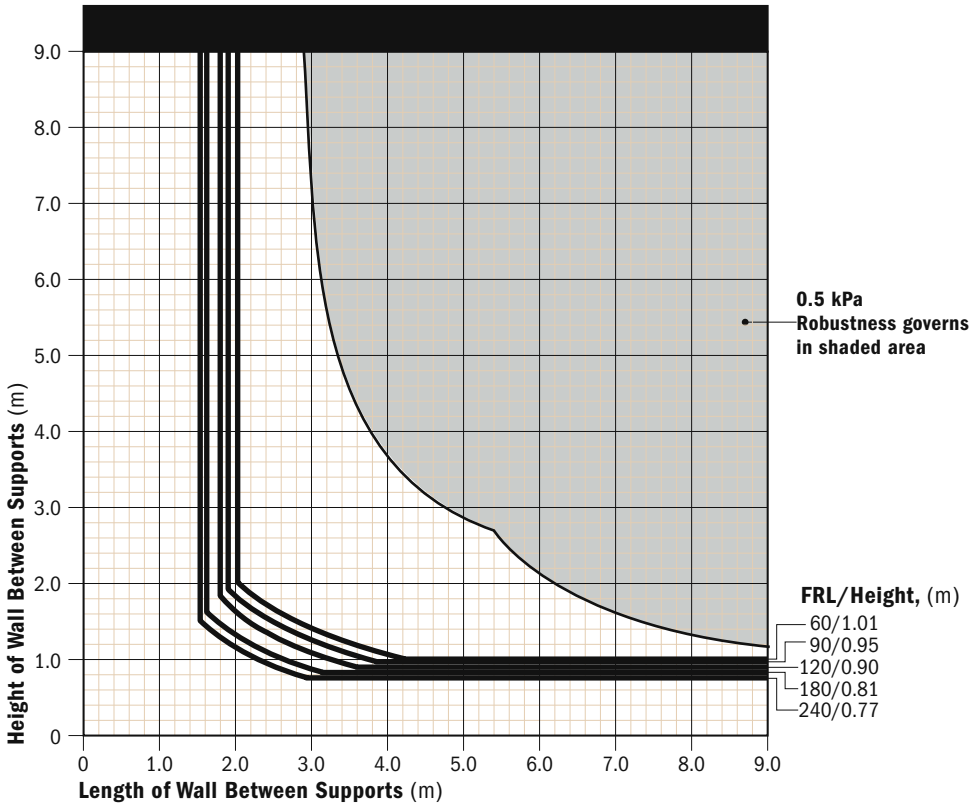


Fire-resistance level, FRL (minutes), **for Structural Adequacy**



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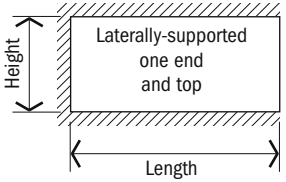

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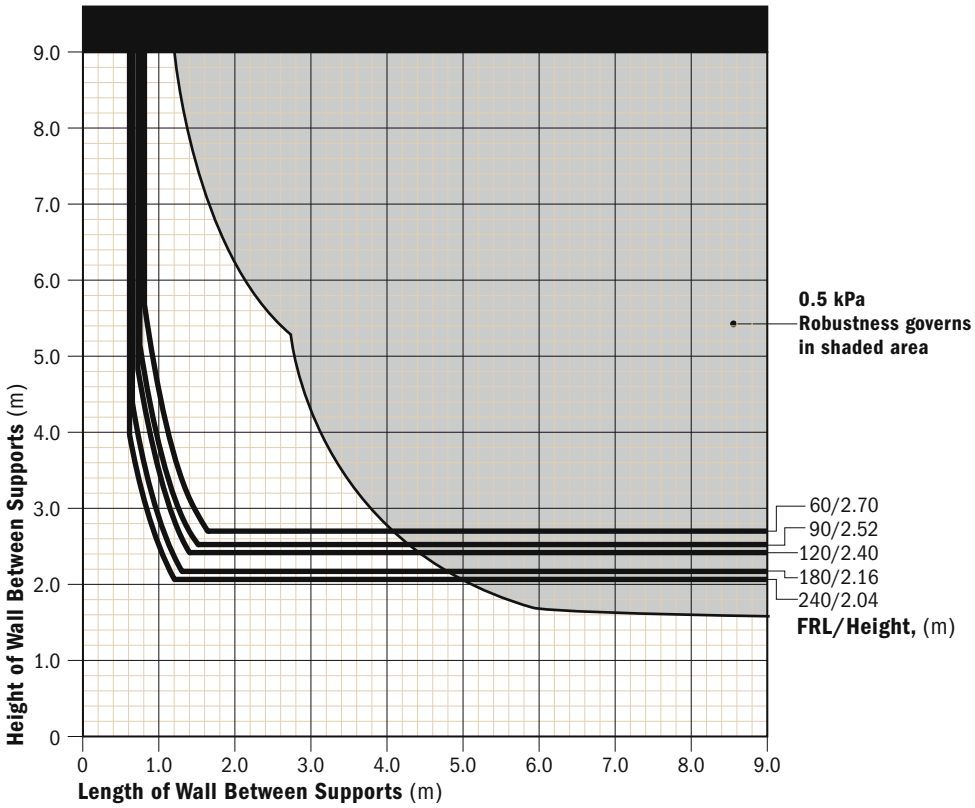

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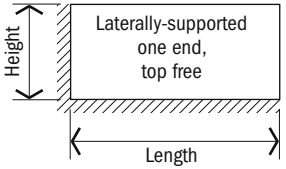

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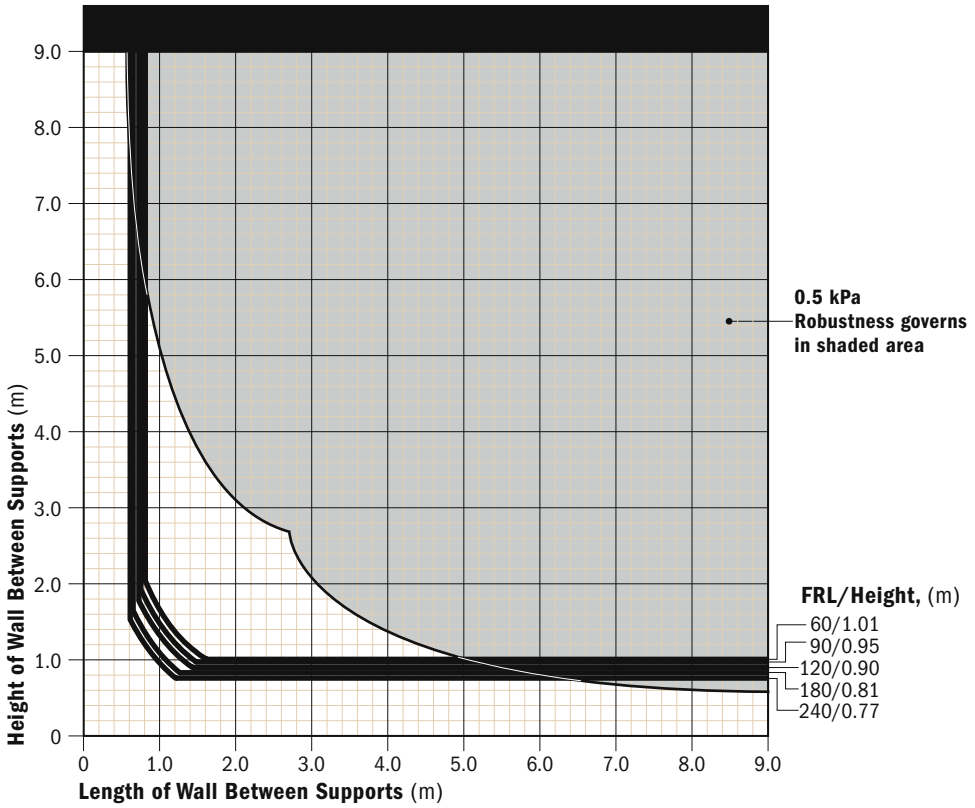
FRL (minutes), **for Structural Adequacy**



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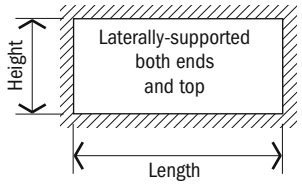
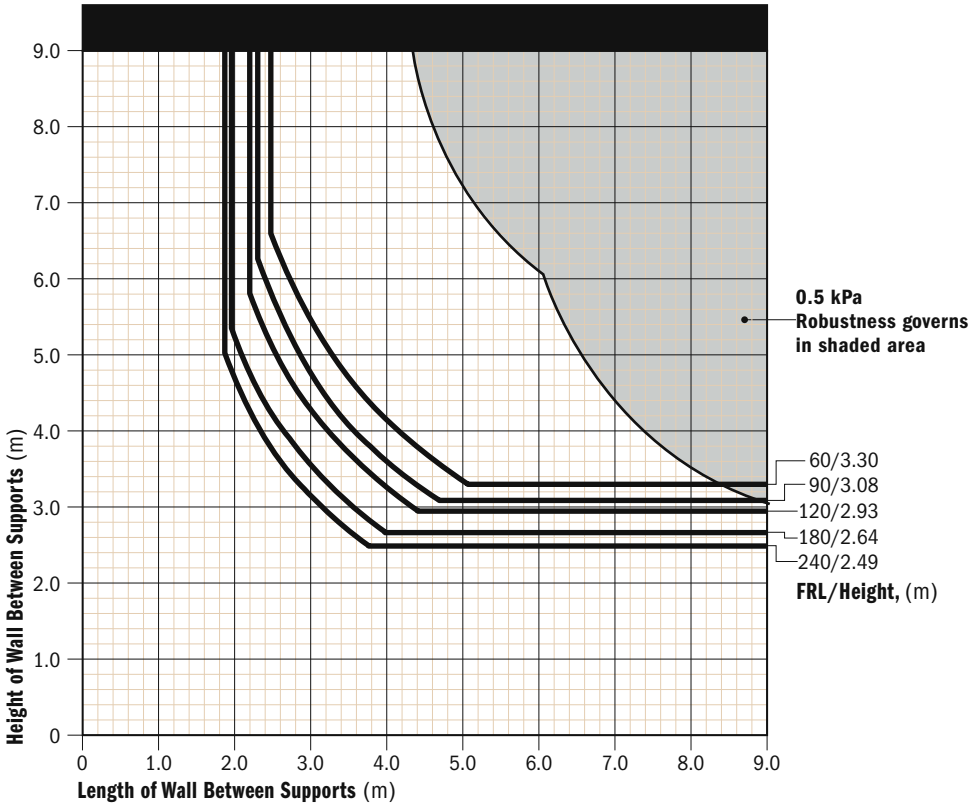


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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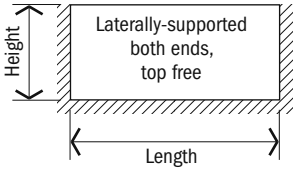

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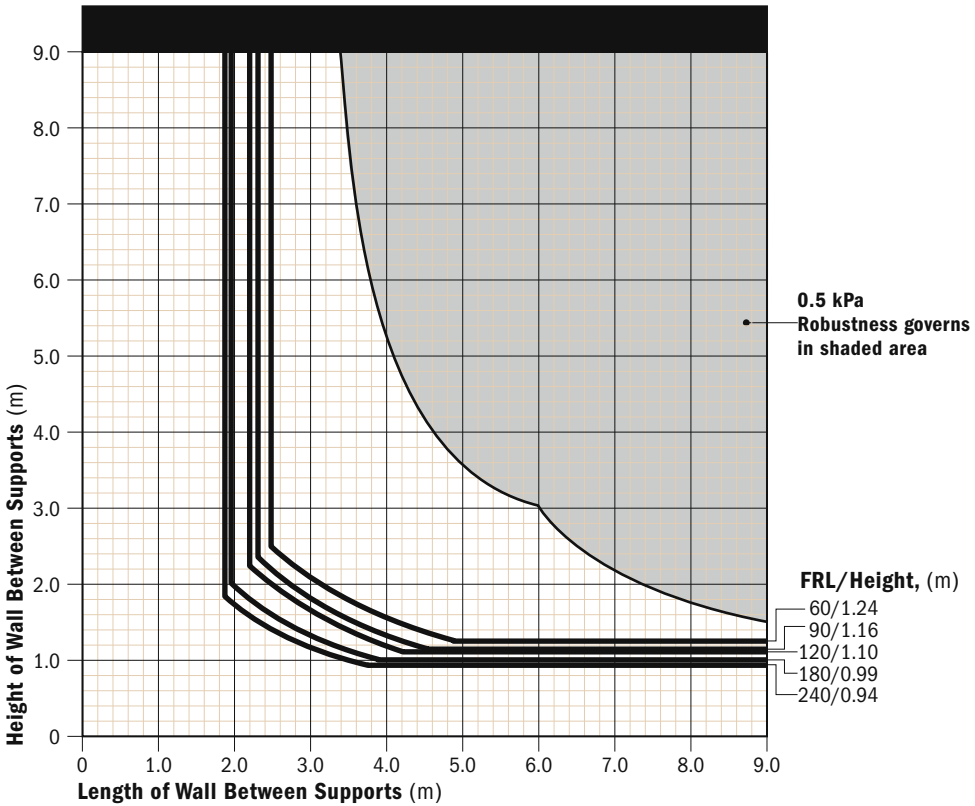

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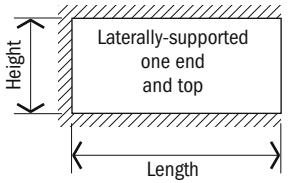

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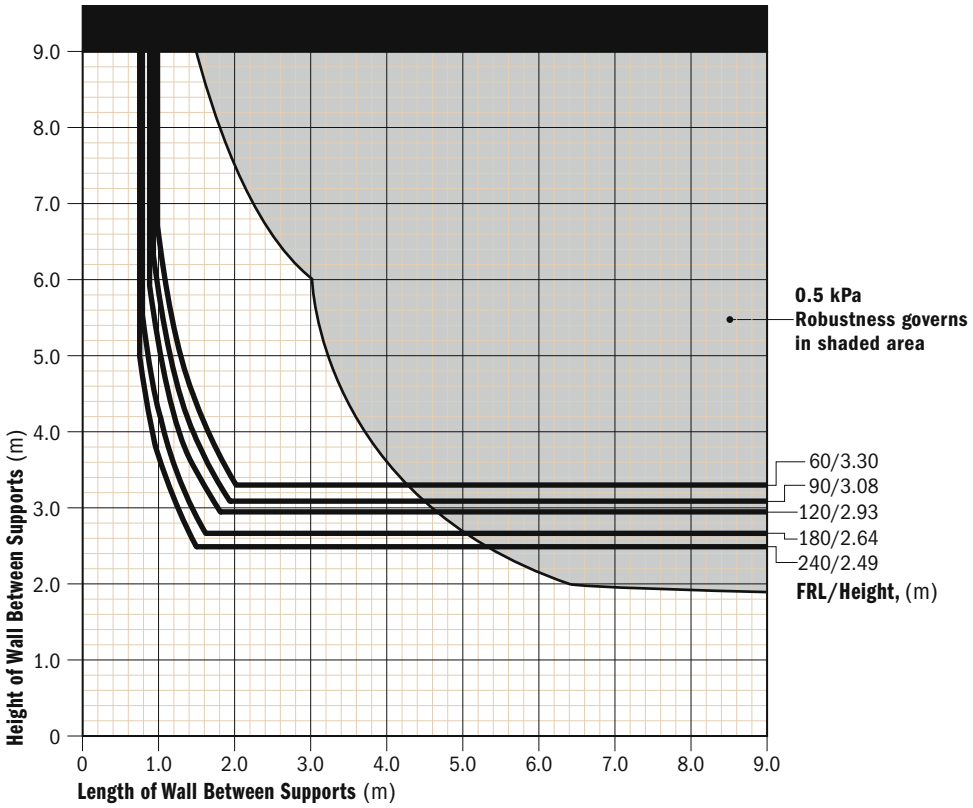
FRL (minutes), **for Structural Adequacy**



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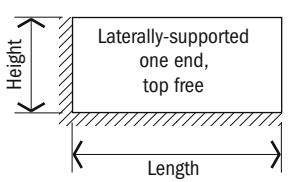
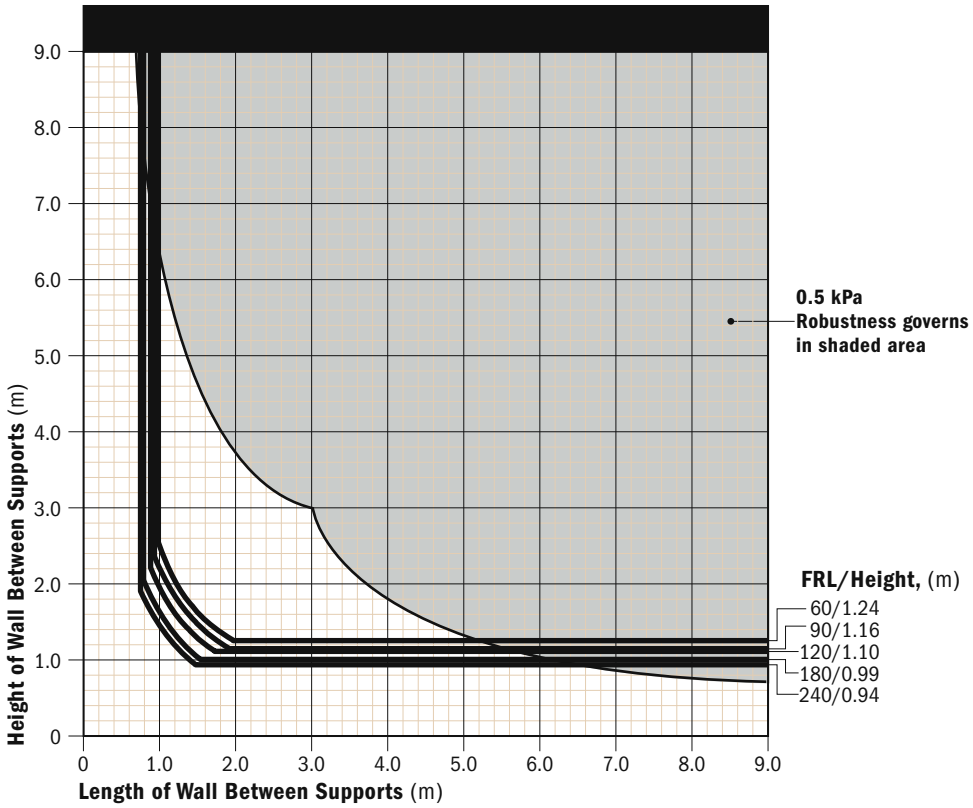
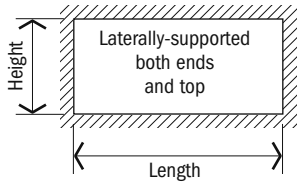


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

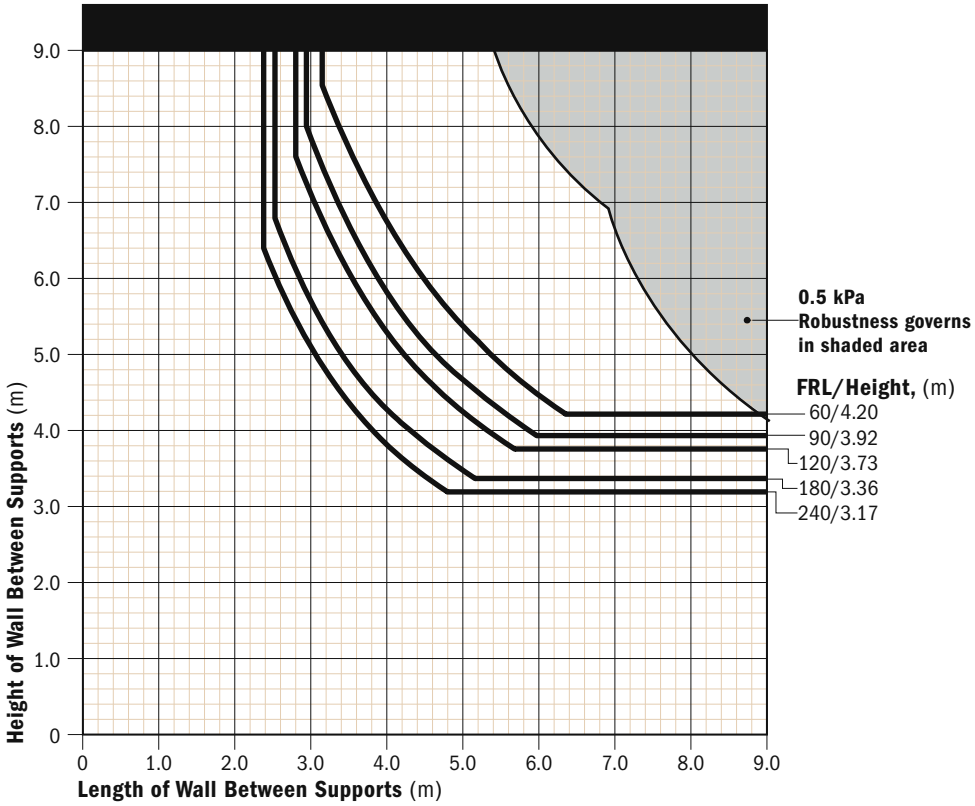


NOTE: It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties

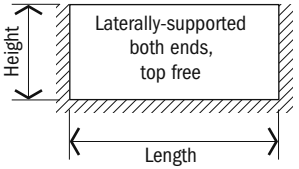
a_{vf} = 0.75, a_h = 1.0



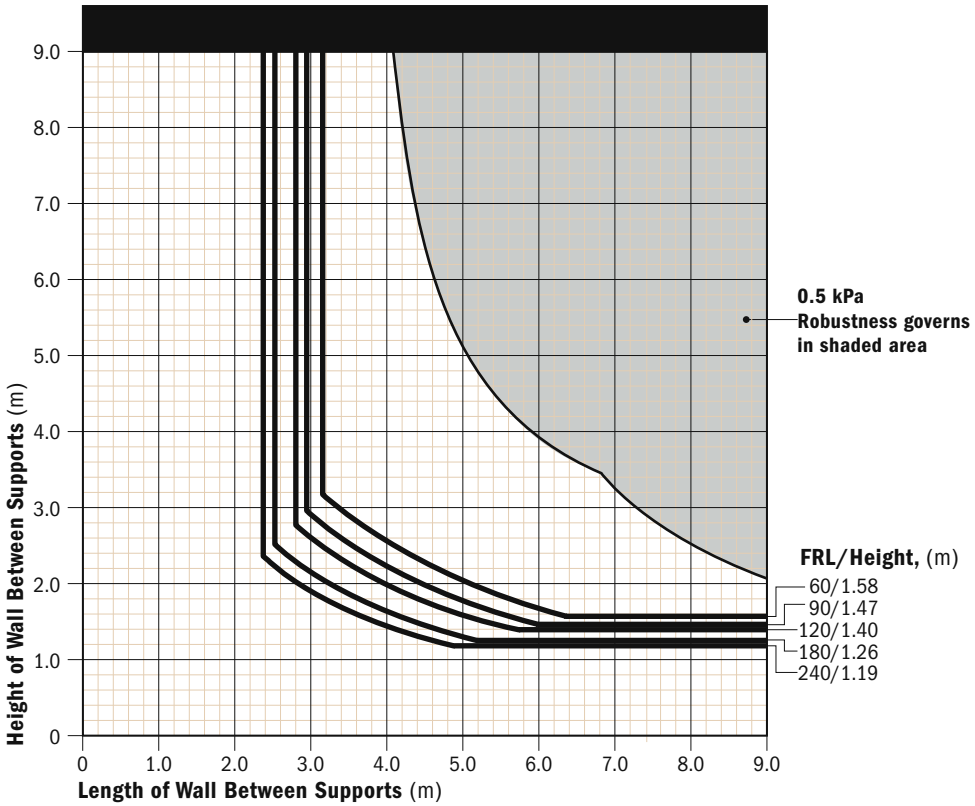
Fire-resistance level, FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level, FRL (minutes), **for Structural Adequacy**



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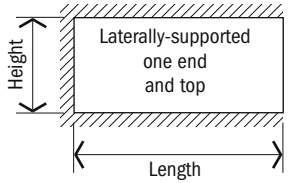
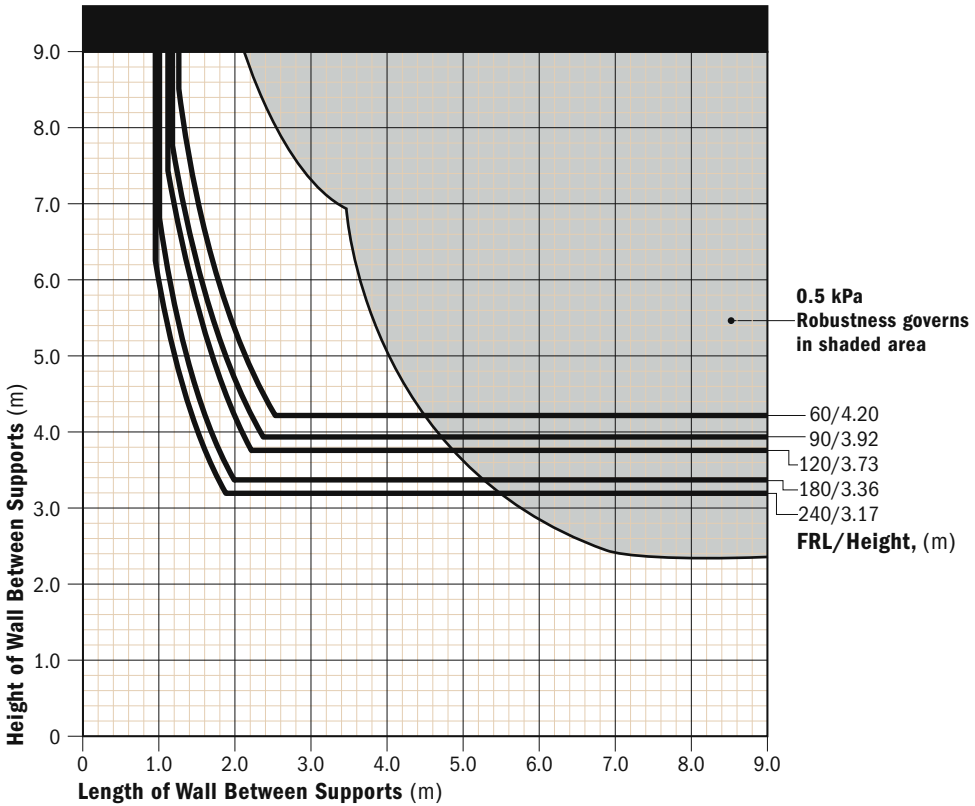
3 of 4

a_{vf} = 0.75, a_h = 2.5

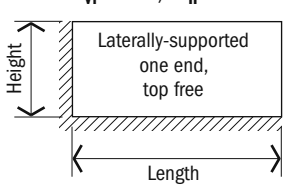


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

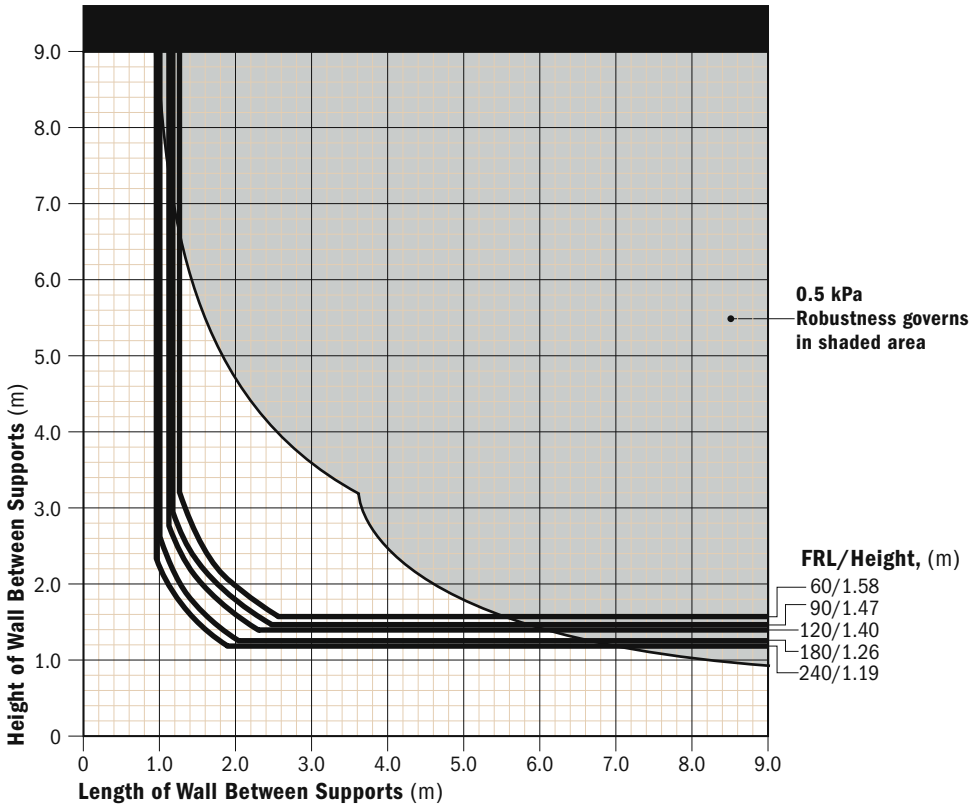


4 of 4

a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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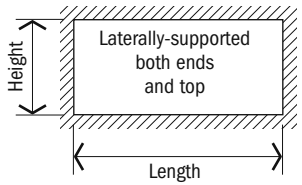
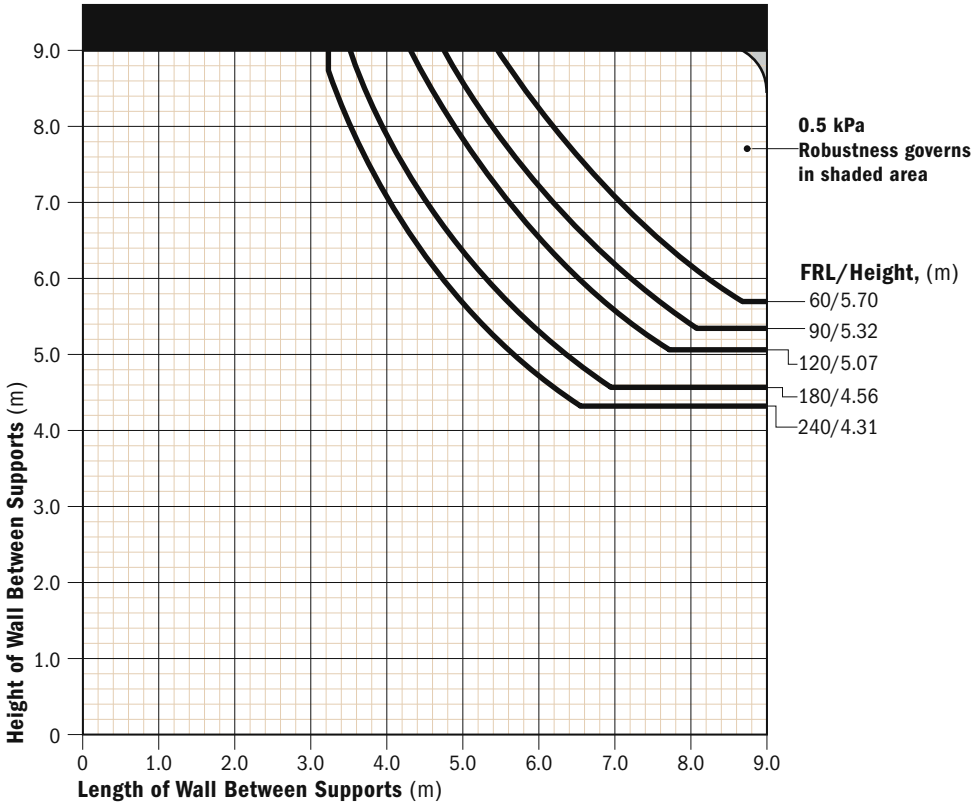
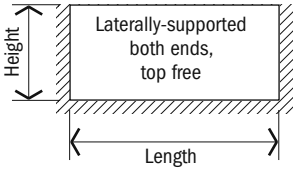
a_{vf} = 0.75, a_h = 1.0



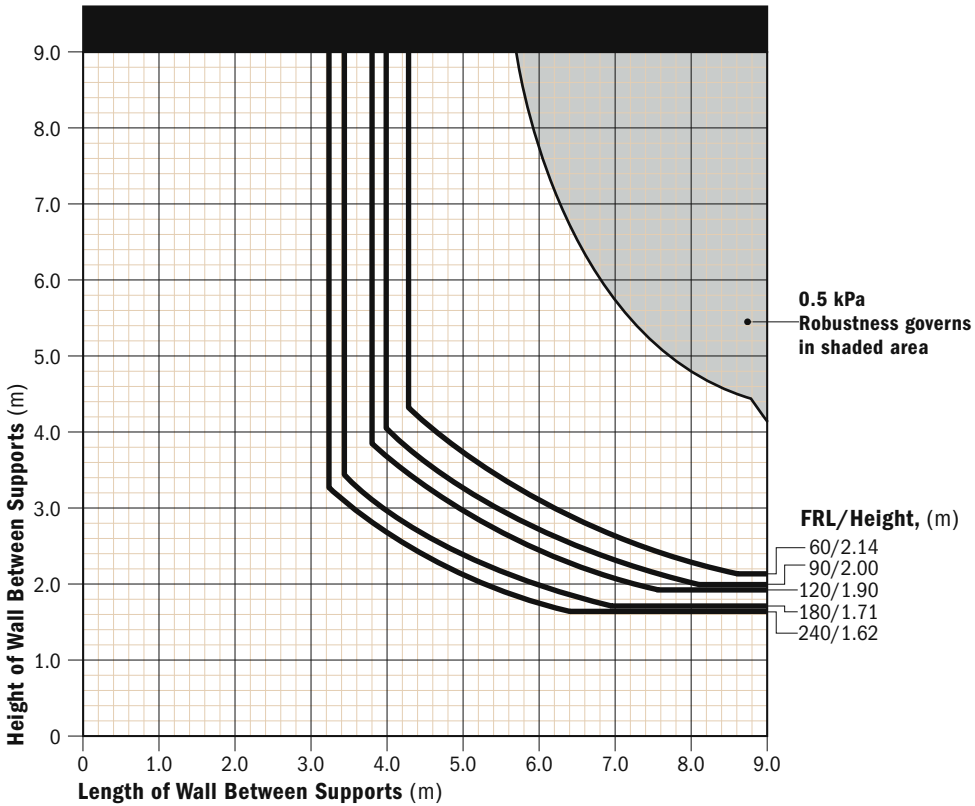
Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



a_{vf} = 2.0, a_h = 1.0



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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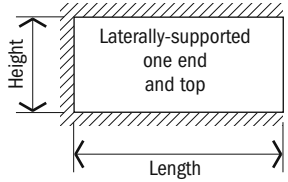
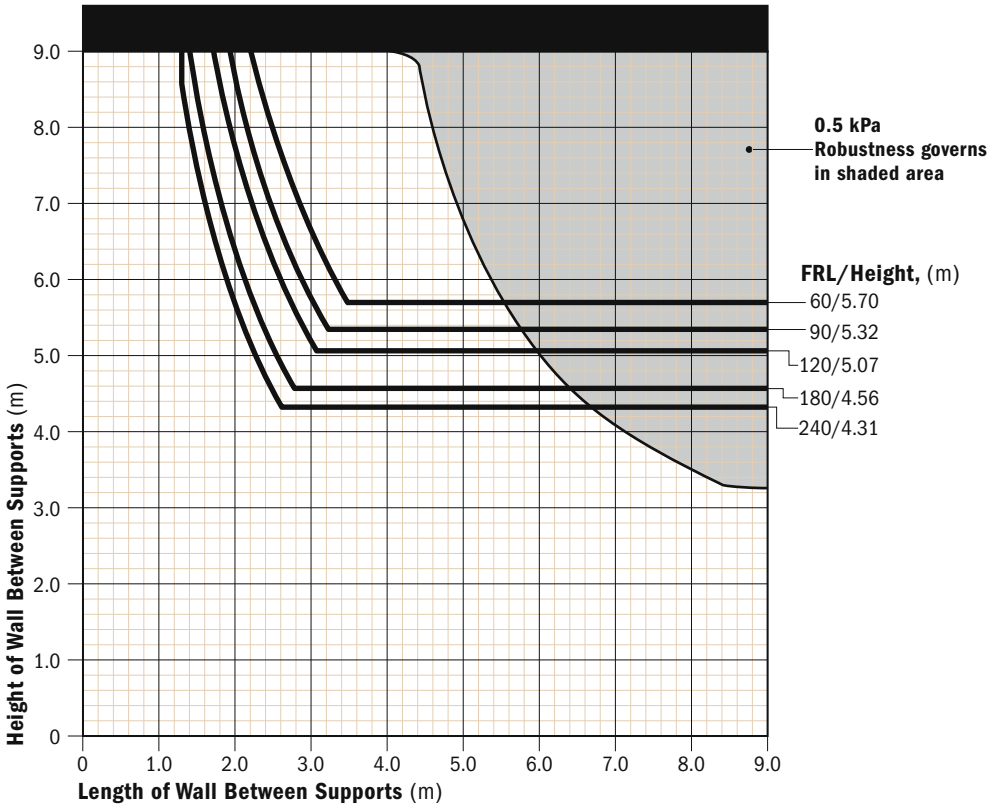
3 of 4

a_{vf} = 0.75, a_h = 2.5

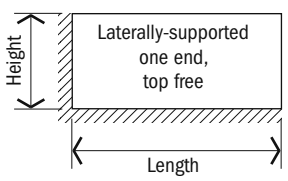


Fire-resistance level,
FRL (minutes), **for Structural Adequacy**

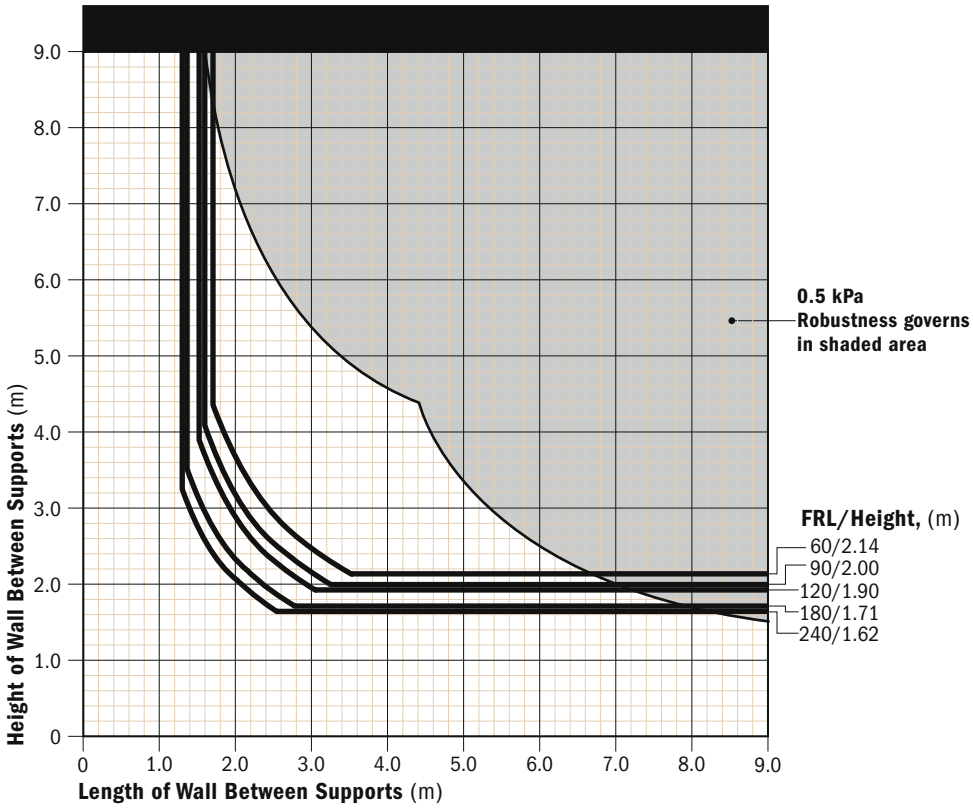


4 of 4

a_{vf} = 2.0, a_h = 2.5



Fire-resistance level,
FRL (minutes), **for Structural Adequacy**



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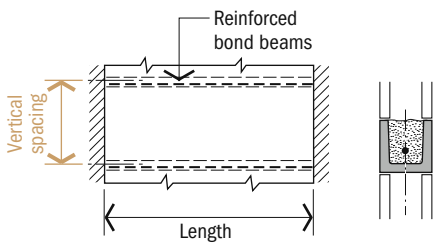
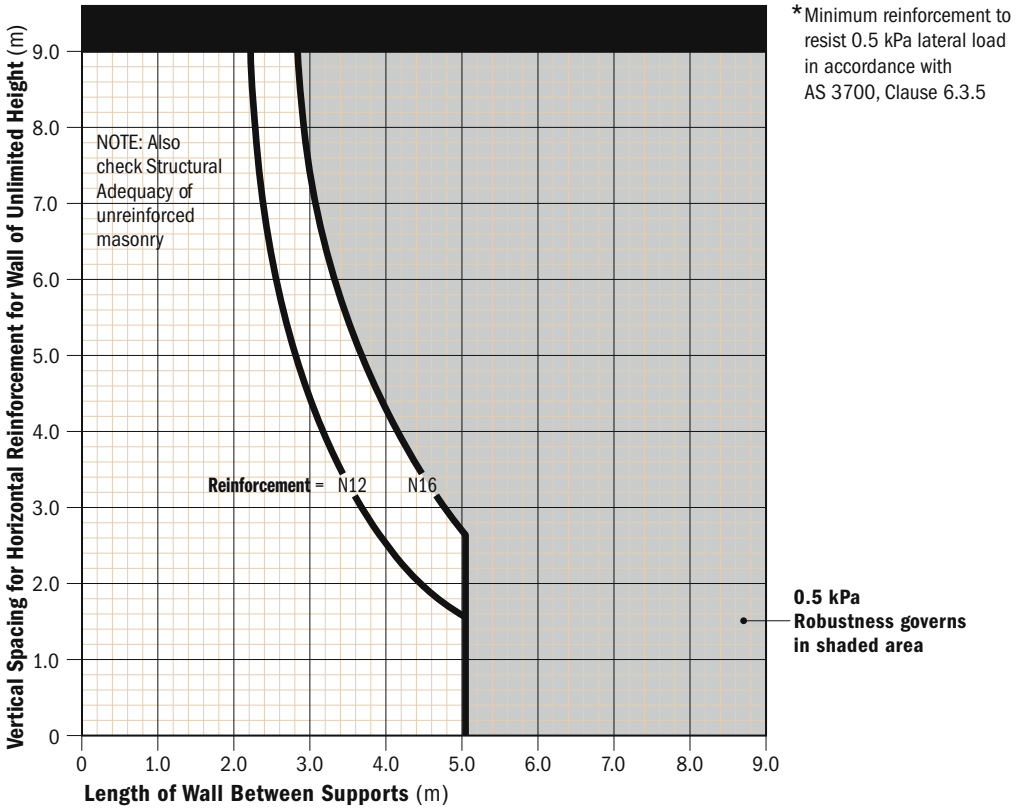
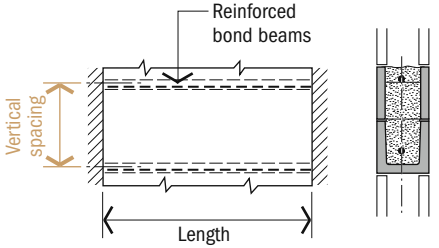
140-mm leaf Horizontally-reinforced bond beams



Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes



*Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5



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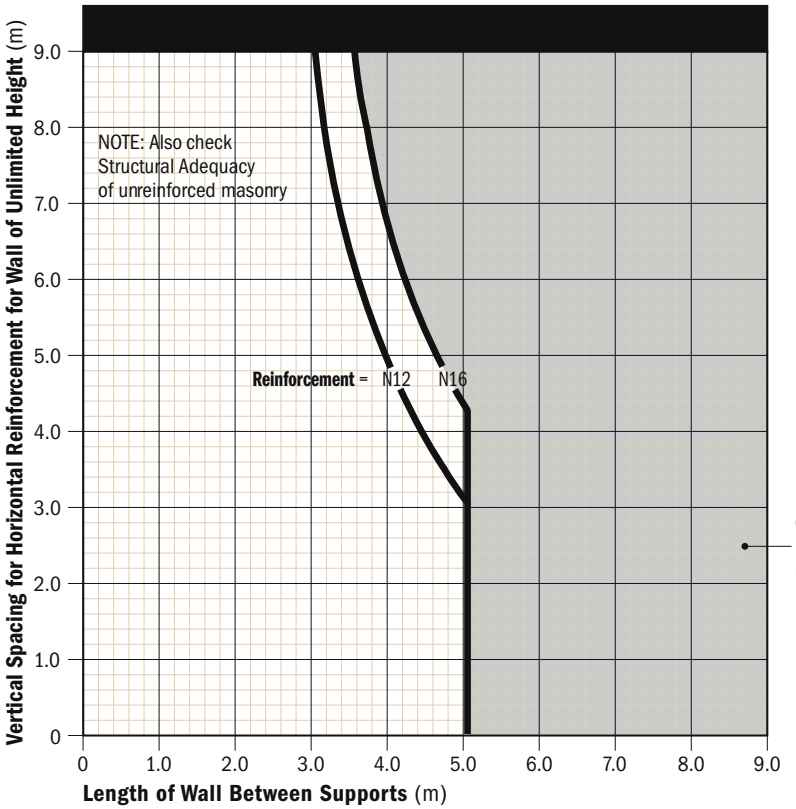
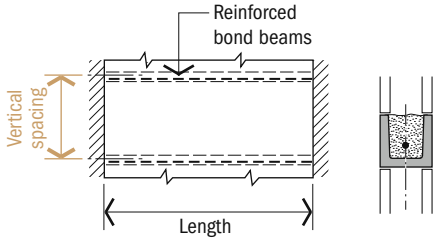


*Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5

NOTE: It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties



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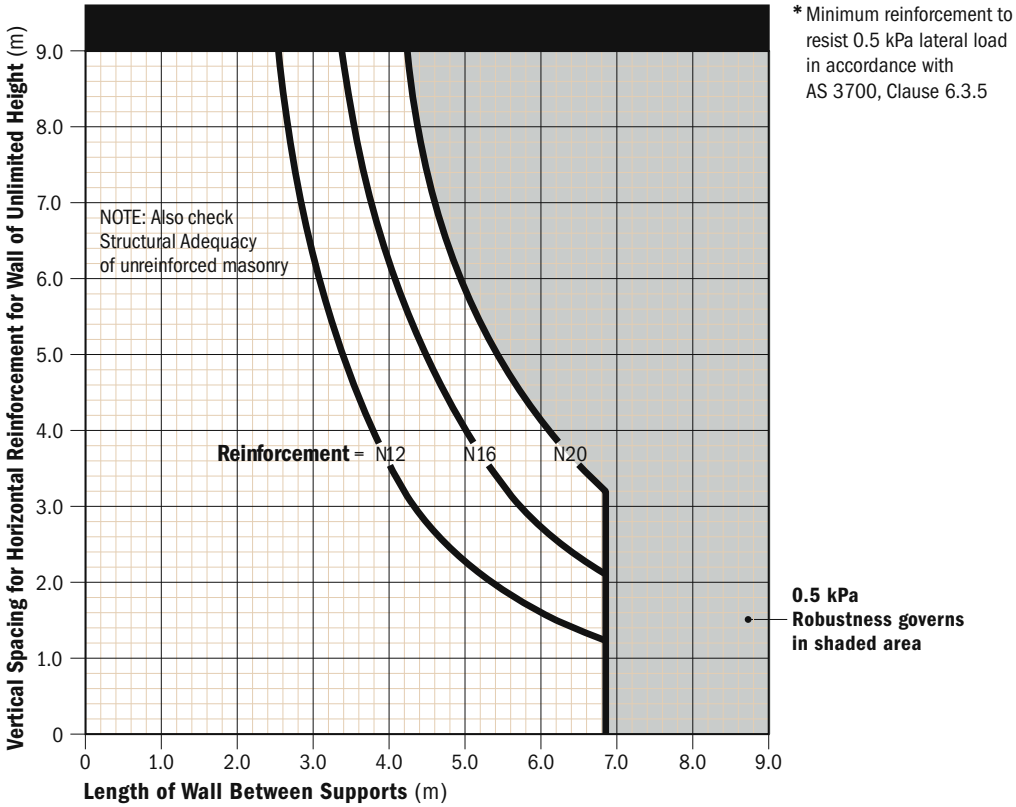
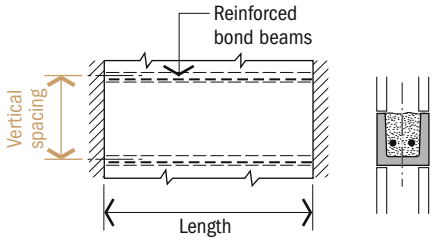
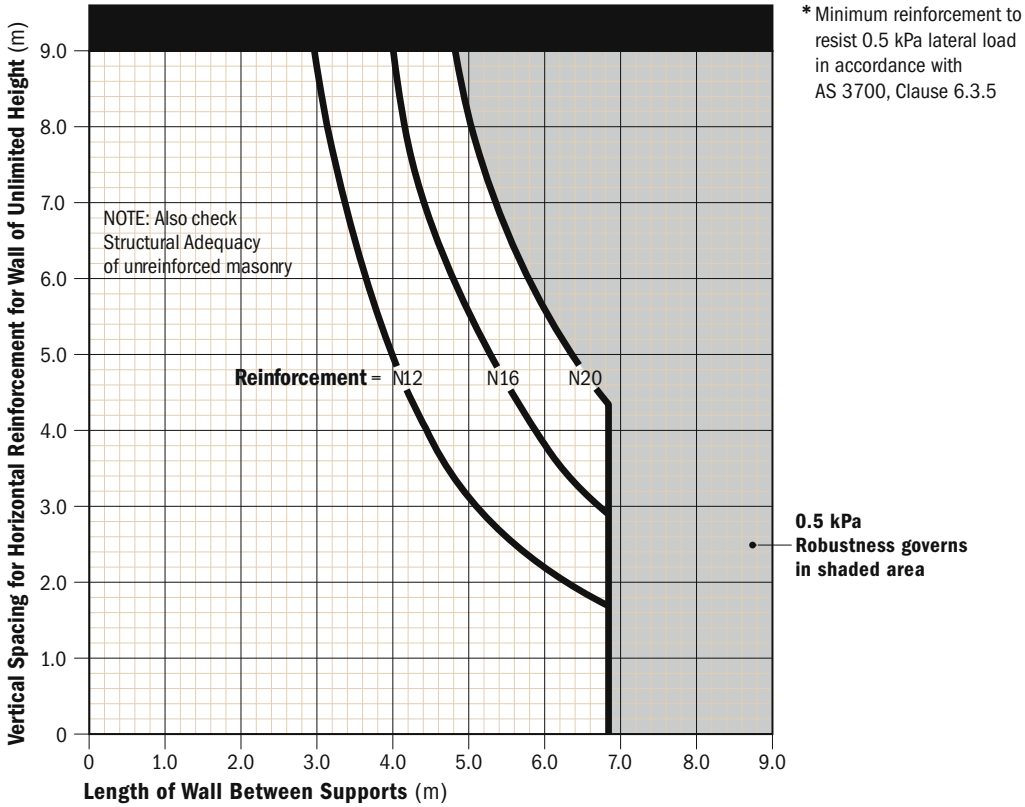


* Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5



Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes



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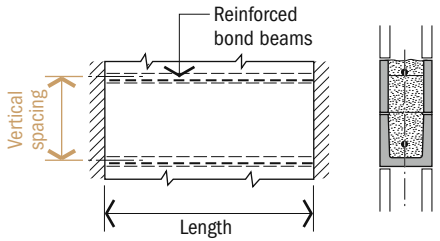
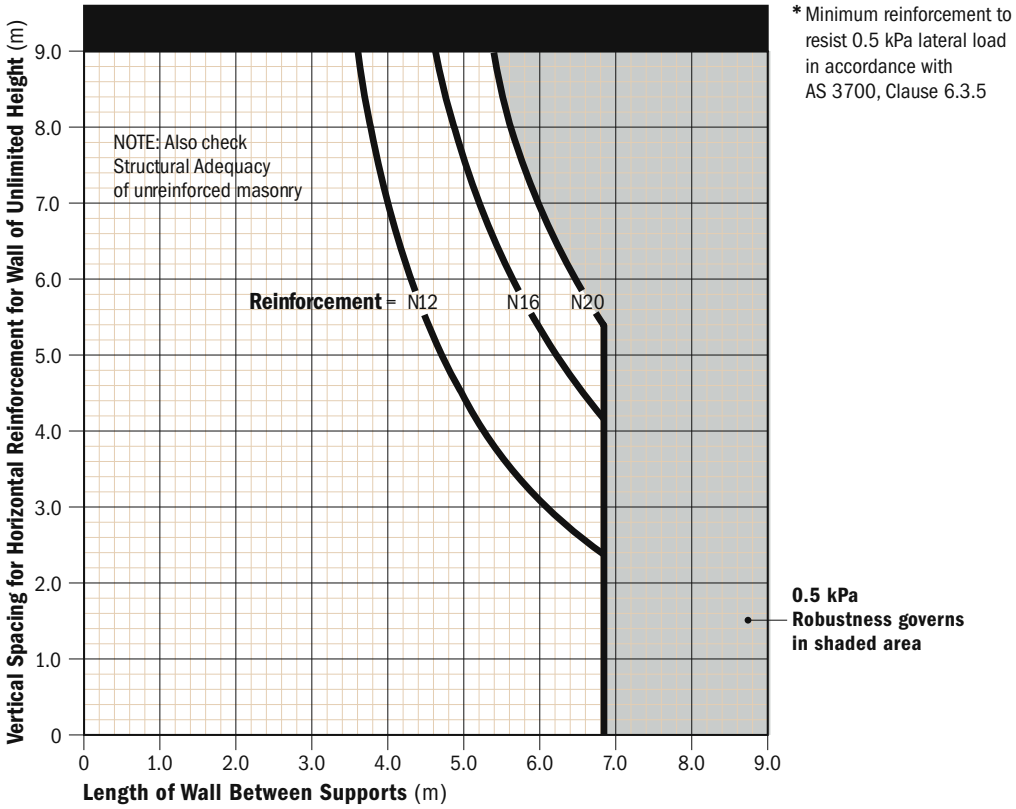
3 of 4

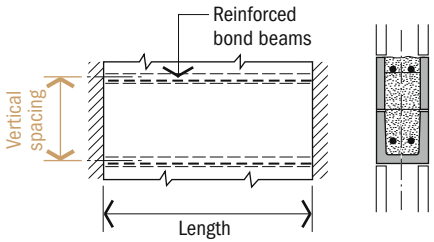


Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes

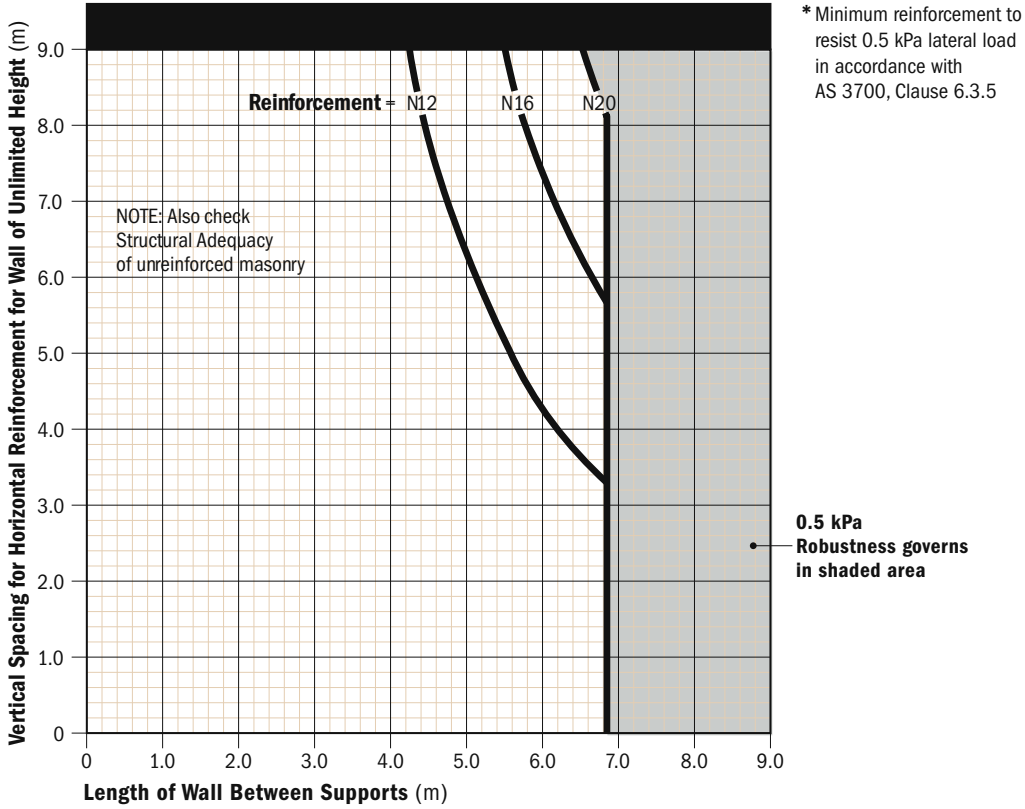


* Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5

4 of 4



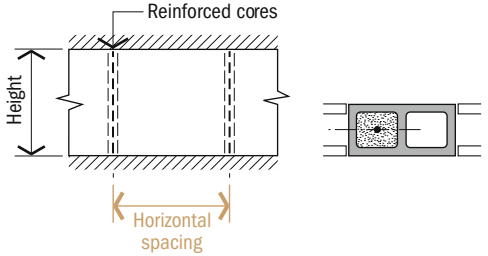
Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes



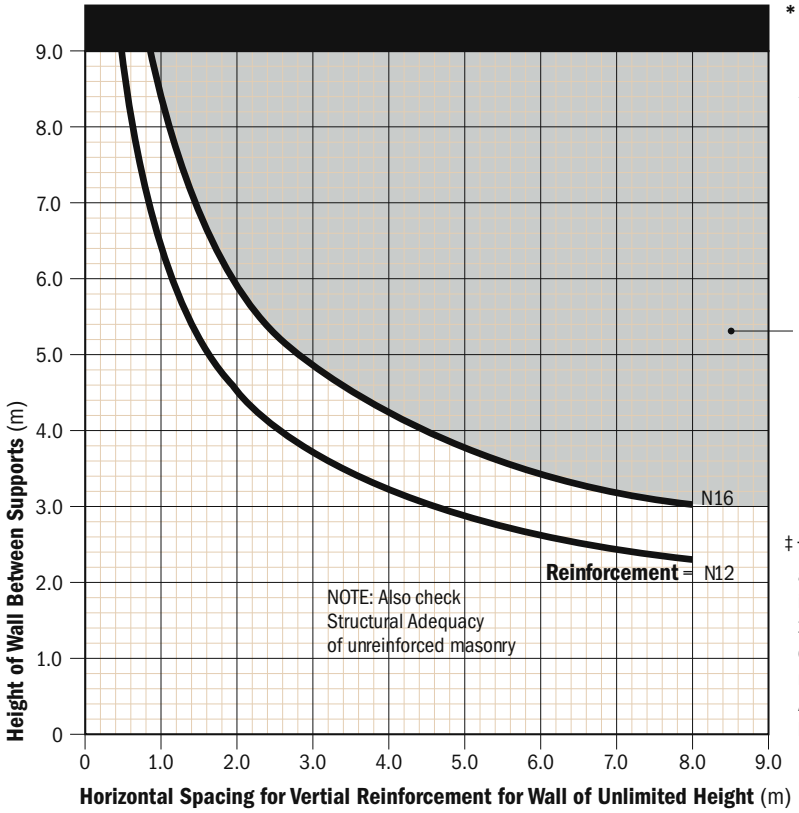
* Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5

NOTE: It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties

REINFORCED AND MIXED CONSTRUCTION where P (kN/m) < 2.25H (m)‡ 140-mm leaf Vertically-reinforced cores



Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes



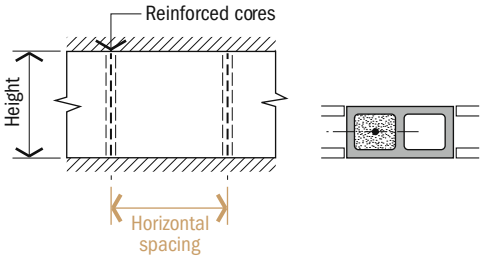
0.5 kPa Robustness governs in shaded area

*Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5

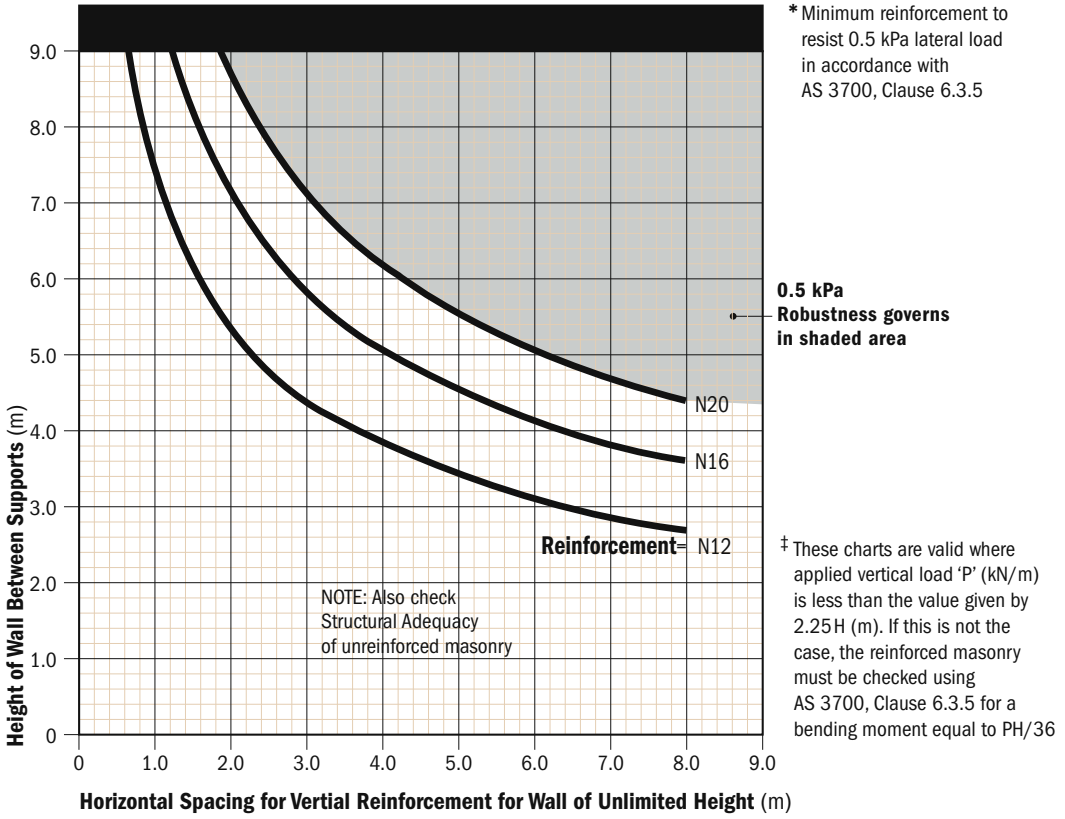
‡These charts are valid where applied vertical load 'P' (kN/m) is less than the value given by 2.25H (m). If this is not the case, the reinforced masonry must be checked using AS 3700, Clause 6.3.5 for a bending moment equal to PH/36

NOTE: It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties

REINFORCED AND MIXED CONSTRUCTION where P (kN/m) < 2.25H (m)‡ 190-mm leaf Vertically-reinforced cores



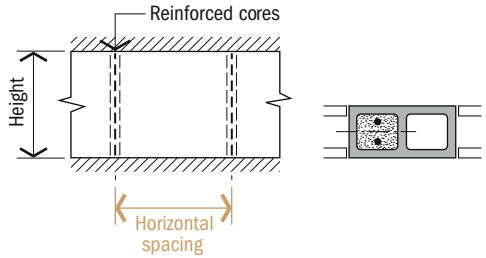
Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes



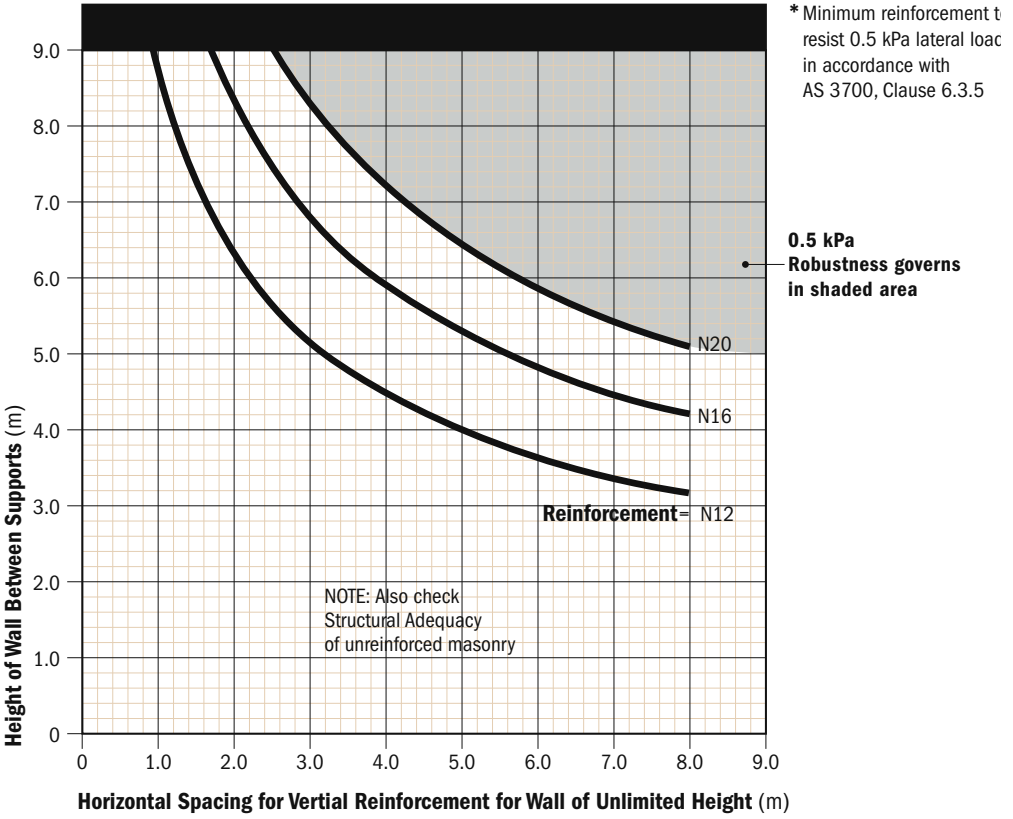
**0.5 kPa Robustness governs in shaded area*

*Minimum reinforcement to resist 0.5 kPa lateral load in accordance with AS 3700, Clause 6.3.5

‡These charts are valid where applied vertical load 'P' (kN/m) is less than the value given by 2.25H (m). If this is not the case, the reinforced masonry must be checked using AS 3700, Clause 6.3.5 for a bending moment equal to PH/36



Reinforcement* required to achieve a Fire Resistance Level (FRL) for Structural Adequacy of up to 240 minutes



**0.5 kPa Robustness governs in shaded area*

*Minimum reinforcement t resist 0.5 kPa lateral loac in accordance with AS 3700, Clause 6.3.5

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4.4 WORKED EXAMPLE

4.4.1 GENERAL

Purpose of the worked examples
The purpose of the following worked examples is to demonstrate the steps to be followed when performing manual calculations or when preparing computer software for the analysis and design of masonry. The worked examples also serve the purpose of demonstrating the origin of the Standard Designs which are based on similar masonry capacity considerations. Although comprehensive in its treatment of AS 3700, the worked examples are not intended to analyze or design all parts of the particular structure. They deal only with enough to demonstrate the design method.

Design and detailing
All design and detailing shall comply with the requirements of AS 3700.

It is the designer's responsibility to allow for the effects of control joints, chases, openings, strength and stiffness of ties and connectors, and strength and stiffness of supports, in addition to normal considerations of loads and masonry properties. Control joints and openings must be treated as free ends as specified by AS 3700.

Masonry Properties
The worked examples in this chapter are based on masonry properties complying with the General Specification set out in Chapter 1 of this manual, modified as noted in the calculations and as noted below.

Hollow concrete blocks
Width 90 mm, 110 mm, 140 mm and 190 mm

Height 190 mm

Length 390 mm

Face-shell bedded

Face-shell thickness as required to produce the material thicknesses.

Minimum characteristic lateral modulus of rupture,
f'_{ut} = 0.8 MPa

Where units are required to consist of over 45% basalt content, this is noted.

Solid or cored concrete bricks
Width 110 mm

Height 76 mm

Length 230 mm

Minimum characteristic compressive strength,
f'_{uc} =10 MPa

Minimum characteristic lateral modulus of rupture,
f'_{ut} = 0.8 MPa

Mortar joints
Mortar type M3 (or M4)

Joint thickness 10 mm

Concrete grout
Minimum characteristic compressive strength,
f'_c = 20 MPa

Minimum cement content 300 kg/m³

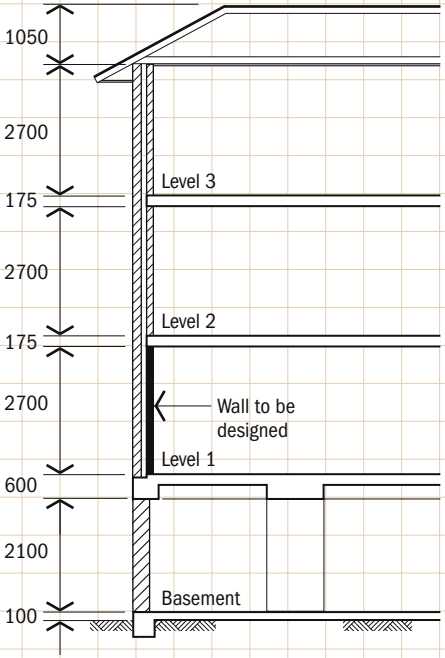
Steel reinforcement
N12, N16 or N20 as noted

4.4.2 INDEX TO WORKED EXAMPLES

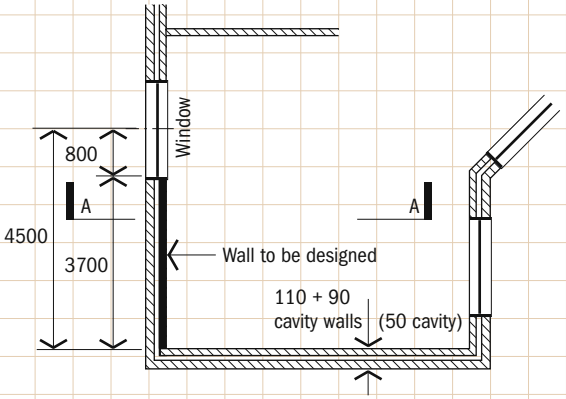
Two examples are provided.

Example 1: Design for fire, a wall in a 4-storey, single-occupancy, block of units (Class 2).

Example 2: Design for fire resistance, the walls of a low-rise industrial building.



SECTION A-A



PART PLAN AT LEVEL 1

DESIGN BRIEF

Design for fire, the wall indicated in the accompanying drawings.

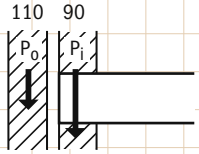
FIRE RESISTANCE LEVELS

4-storey building with single-occupancy units
Class 2
Type A construction *NCC–BCA Vol 1 Table C1.1*
Wall is over 3.0 m from boundary (fire source)

Required FRL: 90/60/30

ie	Structural adequacy	90 mins
	Integrity	60 mins
	Insulation	30 mins

STRUCTURAL ADEQUACY



Loadbearing leaf thickness
t = 90 mm

Load on inner leaf > 1.1 load on outer leaf
$P_i > 1.1P_o$
$\therefore S_{rf}$ for inner leaf only *6.3.2.1*

Clear height (for top supported)
H = 2.70 m

Clear length (for one end supported)
L = 3.70 m

Vertical coefficient (for top supported)
$a_{vf} = 0.75$ *6.3.2.2*

Horizontal coefficient (for one end supported)
$a_h = 2.5$ *6.3.2.2*

Cont…

Slenderness ratio

$$S_{rf} = \frac{a_{vf} H}{t} \qquad 6.3.2.2(2)$$

$$= \frac{0.75 \times 2700}{90}$$

$$= 22.5$$

$$< \frac{0.7}{t}\sqrt{a_{vf}\, H\, a_h\, L} \qquad 6.3.2.2(3)$$

$$= \frac{0.7}{90}\sqrt{0.75 \times 2700 \times 2.5 \times 3700}$$

$$= 33.7 \quad \text{OK}$$

For concrete units < 45% basalt *Table 6.1*

$S_{rf} > 17.0$ Problem

For concrete units > 45% basalt *Table 6.1*

$S_{rf} > 21.0$ Problem

Use tested concrete units with $C_s = 5.6$

Permissible slenderness (for tested units)

$$S_{rf} = C_s\, l_n \left(\frac{720}{t_f}\right) + 13 \qquad 6.3.3$$

$$= 5.6\, l_n \left(\frac{720}{90}\right) + 13$$

$$= 24.6$$

> 22.5 OK

INTEGRITY

For 60 minutes integrity, units must have a material thickness of at least 80 mm for denseweight concrete (> 1800 kg/m3)

6.4.2 Table 6.3

Actual material thickness

$t_m = 90 + 110$

$= 200$ mm

> 80 mm OK

Units must satisfy the slenderness limits for Structural Adequacy FRL of 60 minutes. Tested units are OK for 90 minutes and will therefore be OK for 60 minutes

INSULATION

Units must have a material thickness of at least 55 mm for 30 minutes insulation

6.5.2 Table 6.3

Actual material thickness

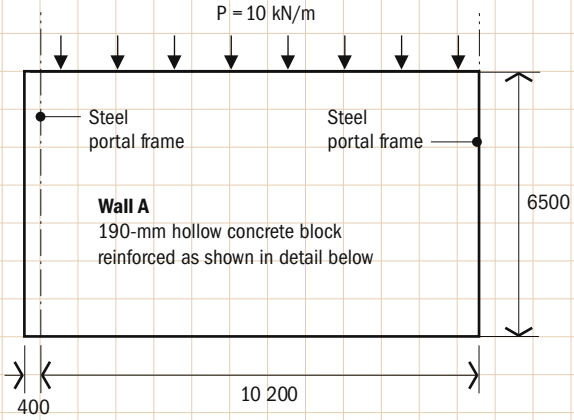
$t_m = 90 + 110$

$= 200$ mm

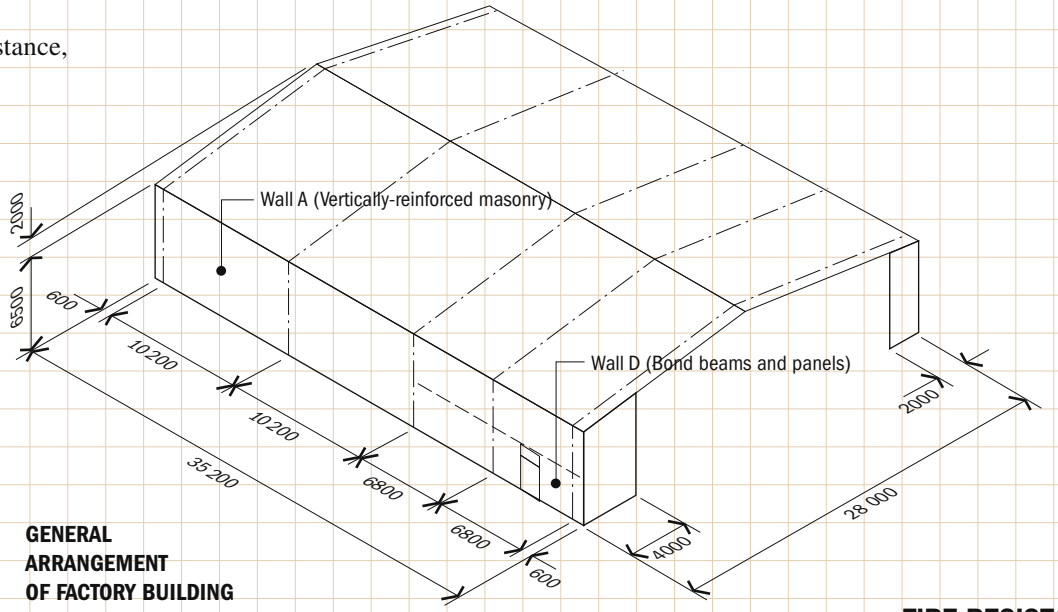
> 55 mm OK

DESIGN BRIEF

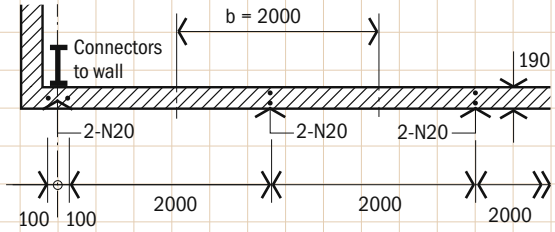
For low-rise industrial building, design for fire resistance, Wall 'A' and Wall 'D' shown below.



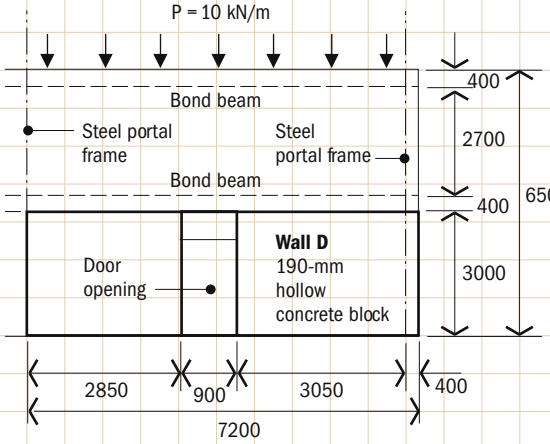
WALL 'A' ARRANGEMENT



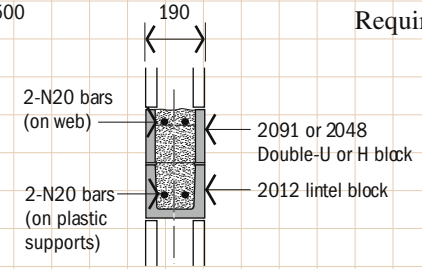
GENERAL ARRANGEMENT OF FACTORY BUILDING



WALL 'A' REINFORCEMENT DETAILS



WALL 'D' ARRANGEMENT



WALL 'D' BOND BEAM DETAILS

FIRE RESISTANCE LEVEL

1-storey building used as a warehouse
Class 7
Type C construction *NCC–BCA Vol 1 Table C1.1*
Wall less than 1.5 m from boundary (fire source)

Required FRL: 90/90/90

ie	Structural adequacy	90 mins
	Integrity	90 mins
	Insulation	90 mins

Cont…

STRUCTURAL ADEQUACY

Wall A – Vertically-reinforced Masonry

Loadbearing leaf thickness

$t = 190$ mm

Clear height (where top support is 100 mm below roof)

$H = 6.50 - 0.10$

$= 6.4$ m

Vertical coefficient (for top supported)

$a_{vf} = 0.75$ *6.3.2.2*

Slenderness ratio (for no vertical supports)

$$S_{rf} = \frac{a_{vf} H}{t} \quad \textit{6.3.2.2}$$

$$= \frac{0.75 \times 6400}{190}$$

$= 25.3$

< 36 OK *Table 6.1*

Shear capacity of vertically-reinforced cores

$V_{cap} = 10.6$ kN/core *Part B:Chapter 6 this manual*

$$> \frac{0.5\ (\text{kPa})\ b\ H}{2} \quad \textit{6.3.5}$$

$$= \frac{0.5 \times 2.0 \times 6.4}{2}$$

$= 3.2$ kN/core OK

Moment capacity of vertically-reinforced cores

$M_{cap} = 13.2$ kN.m/core *Part B:Chapter 6 this manual*

$$> \frac{0.5\ (\text{kPa})\ b\ H^2}{8} \quad \textit{6.3.5}$$

$$= \frac{0.5 \times 2.0 \times 6.4^2}{8}$$

$= 5.1$ kN.m/core OK

$$> \frac{P\ b\ H}{36} \quad \textit{6.3.5}$$

$$= \frac{10 \times 2.0 \times 6.4}{36}$$

$= 3.6$ kN.m/core OK

Cover to reinforcement (from outside block)

$C = 30 + 5 + 15$

$= 50$ mm

> 30 mm OK *Table 6.2*

Wall D – Horizontally-reinforced Bond Beam

Masonry thickness

$t = 190$ mm

Clear length between supports

$L = 6.80$ m

Slenderness ratio

$$S_{rf} = \frac{L}{t}$$

$$= \frac{6800}{190}$$

$= 35.8$ < 36 OK *Table 6.1*

Shear capacity of horizontally-reinforced bond beam

$V_{cap} = 21.3$ kN *Part B:Chapter 6 this manual*

$$> \frac{0.5\ (\text{kPa})\ b\ L}{2} \quad \textit{6.3.5}$$

$$= \frac{0.5 \times (1.5 + 0.4 + 1.35) \times 6.8}{2}$$

$= 5.5$ kN OK

Moment capacity of horizontally-reinforced bond beam

$M_{cap} = 22.6$ kN.m *Part B:Chapter 6 this manual*

$$> \frac{0.5\ (\text{kPa})\ b\ L^2}{8} \quad \textit{6.3.5}$$

$$= \frac{0.5 \times (1.5 + 0.4 + 1.35) \times 6.8^2}{8}$$

$= 9.4$ kN.m OK

Cover to reinforcement

$C = 30 + 5 + 15$

$= 50$ mm

> 30 mm OK *Table 6.2*

Wall D – Unreinforced Masonry

Masonry thickness

$t = 190$ mm

Clear height (for top supported)

$H = 3.0$ m

Clear length to opening (for one end supported)

$L = 3.05$ m

Vertical coefficient (for top supported)

$a_{vf} = 0.75$ *6.3.2.2*

Horizontal coefficient (for one end supported)

$a_h = 2.5$ *6.3.2.2*

Slenderness ratio

$$S_{rf} = \frac{a_{vf} H}{t}$$ *6.3.2.2(2)*

$$= \frac{0.75 \times 3000}{190}$$

$$= 11.8$$

$$< \frac{0.7}{t} \sqrt{a_{vf}\, H\, a_h\, L}$$ *6.3.2.2(3)*

$$= \frac{0.7}{190} \sqrt{0.75 \times 3000 \times 2.5 \times 3050}$$

$$= 15.2 \quad \text{OK}$$

For denseweight concrete units 45% basalt

$S_{rf} < 17.0$ OK *Table 6.1*

INTEGRITY

For 90 minutes integrity, units must have a material thickness of at least 100 mm for denseweight concrete (>1800 kg/m^3) or at least 90 mm for lightweight concrete (<1800 kg/m^3) *Table 6.3*

∴ Use 190-mm hollow concrete units with a material density less than 1800 kg/m^3 and material thickness greater than 90 mm

INSULATION

Similar requirements to integrity *Table 6.3*