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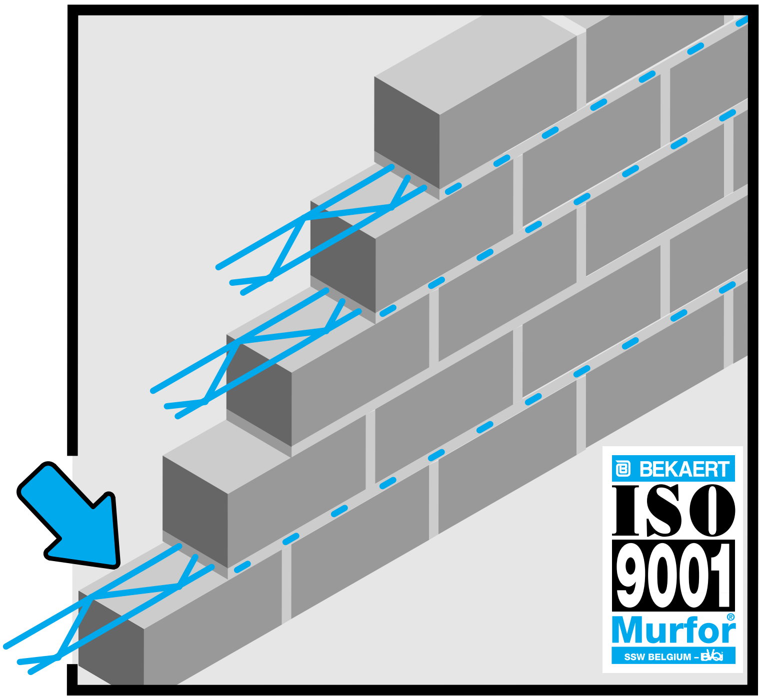
BEKAERT

Murfor®



Reinforcement for masonry

Product identification
range of applications
Installation details
Design principles

Foreword

Clay bricks and natural stone have been used as a building material for thousands of years, and have shown their longevity by the many old examples that can still be seen. In more recent times, calcium silicate and concrete bricks and blocks have been added to the designer's list of masonry materials. Brickwick and block work are, today, essential parts of many buildings and are successfully used throughout the world.

Much masonry is unreinforced, but there has been an increasing interest in adding reinforcement to brickwork and blockwork to increase its efficiency, or to improve its general performance.

As construction has become more competitive, walls have become thinner than they were half a decade ago. This has led to some problems for the designer, contractor and owner; there is less reserve of strength to cater for movement for example. Non-clay walls have a tendency to move due to changes in moisture content, and with certain combinations of shape and size, cracks appear in reinforced walls. Murfor®, incorporates into bed joints, can virtually eliminate the development of unsightly cracks. Thin walls are more difficult to justify for lateral loading, and Murfor® can assist enormously their ability to carry such loading.

Many uses for bed-joint reinforcement are given in this manual which I expect to be of considerable benefit to the Construction Industry.

In this time of international co-operation, materials and design methods are crossing frontiers freely. We can look forward to European Standards and Codes of Practice to assist the specifier and designer to incorporate such materials as Murfor®, in the meantime guidance from the manufacturers and suppliers, as given in this manual, is to be welcomed.

Barry Haseltine
Jenkins and Potter, Consulting Engineers

Contents

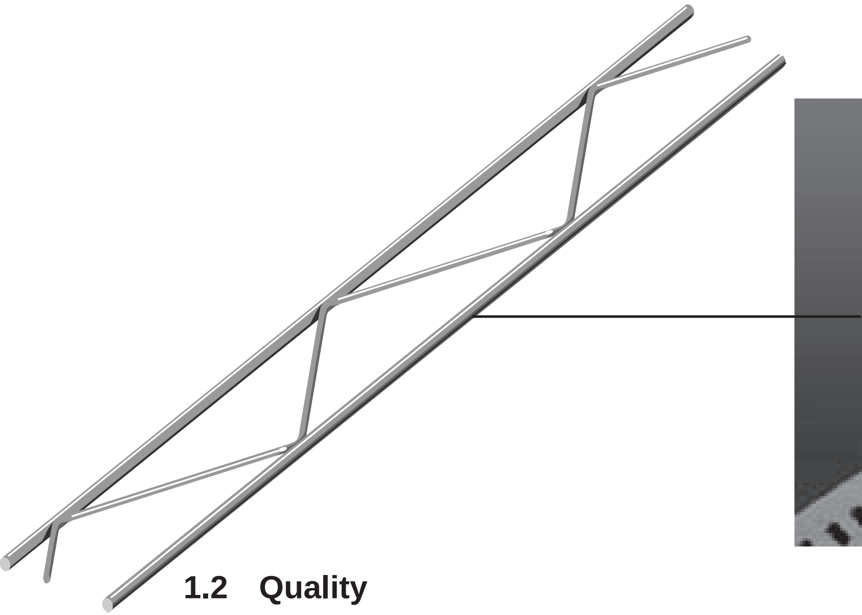
1. Description of Murfor®

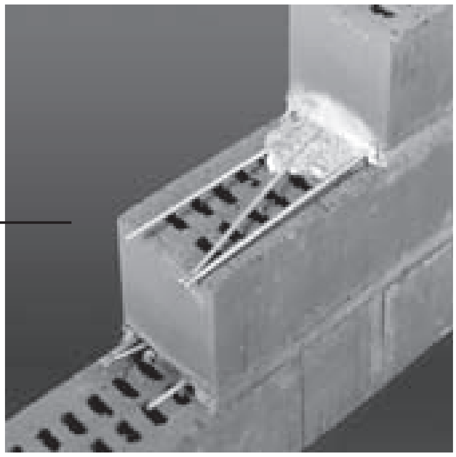
Murfor® is prefabricated wire reinforcement for masonry to be embedded in the horizontal bed joints. Its unique shape combined with its material properties increases the tensile strength of the masonry.

1.1 Description

Murfor® consists of two longitudinal wires which are welded to a continuous zig-zag cross wire to form a lattice truss configuration. The cross wire is welded to the sides of the longitudinal wires so that the overall thickness does not exceed the diameter of the longitudinal wires.

The longitudinal wires are intended to improve the bond with the mortar.





1.2 Quality

The steel used in the manufacture of Murfor® is either high tensile, in accordance with BS4482, or austenitic stainless steel, grade 304, in accordance with BS 970: Part 1: 1983.

The characteristic tensile strength of both the high tensile and stainless steel wires is 500 N/mm^2.

The shear resistance of each weld connecting the cross wire to the longitudinal wires is at least 2.5 kN.

1.3 Standard Types and Dimensions

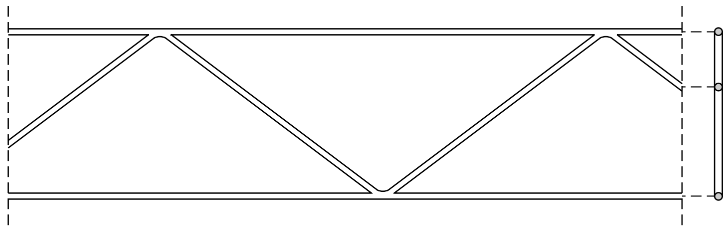
Murfor® reinforcement is manufactured in various widths, shapes and finishes to suit the application.

1.3.1. Standard widths

Murfor® with (mm)	Suitable wall width (mm)
50	90-140
100	140-190
150	190-240
200	over 240

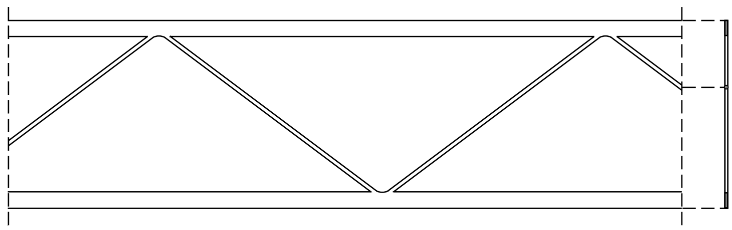
1.3.2. Standard Shapes

Murfor® RND



Round wire, for use with masonry with nominal 10mm thick mortar joints.

Murfor® EFS



Flat wire, 1,5mm thick, for use with masonry with thin bed joints.

1.3.3. Standard Finishes

Hot dipped galvanised wire (ref.../Z) with a zinc coating of at least 70 g/m^2, for masonry exposed to a dry environment.

Stainless steel wire (ref..../S) for masonry exposed to dampness or an aggressive environment.

1.3.4. Standard packaging

Murfor® RND is manufactured in lengths of 3.05 m and packed in bundles of 25 units. A standard pallet consists of 40 bundles of 25 units supported on battens.

Murfor® EFS is manufactured in lengths of 3.05 m and packed in bundles of 25 units. A standard pallet consists of 40 bundles of 25 units supported on battens.

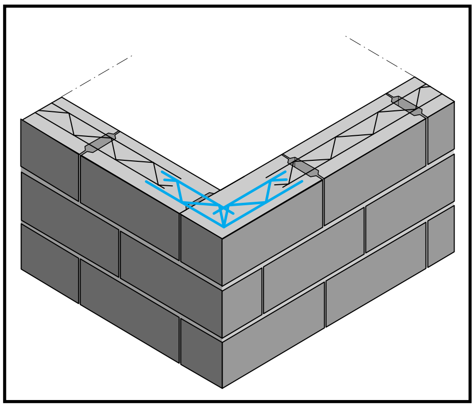
Stainless steel Murfor® (ref..../S) is manufactured in lengths of 3.05 m and packed in bundles of 25 units, for all types.

1.3.5. Table of standard Murfor® Units

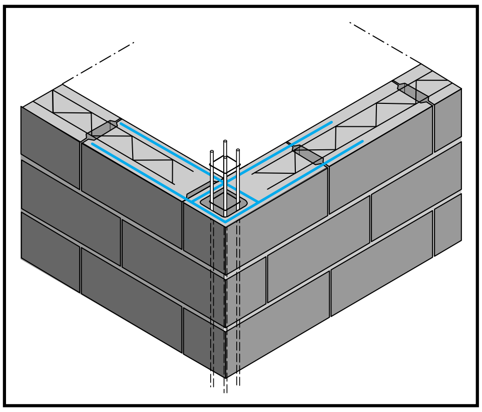
	width mm	diameter longitud-inal wires mm	diameter diagonal wire mm	spacing of diagonals mm	cross-section of two longitud-inal wires mm^2 • + •	weight/ unit kg	length/ unit m	units/ bundle No	units/ pallet No	weight pallet kg
RND/Z Galvanised	50 100 150 200	4 4 4 5	3.75 3.75 3.75 3.75	406 406 406 406	25 25 25 40	0.875 0.897 0.931 1.310	3.05 3.05 3.05 3.05	25 25 25 25	1000 1000 1000 1000	891 913 950 1321
RND/E Epoxy- coated	50 100 150 200	4 4 4 5	3.75 3.75 3.75 3.75	406 406 406 406	25 25 25 40	0.885 0.907 0.942 1.323	3.05 3.05 3.05 3.05	25 25 25 25	1000 1000 1000 750	901 923 958 1053
RND/S Stainless steel	50 100 150 200	4 4 4 5	3.75 3.75 3.75 3.75	406 406 406 406	25 25 25 40	0.887 0.908 0.942 1.334	3.05 3.05 3.05 3.05	25 25 25 25	1000 1000 1000 1000	899 920 954 1346
EFS/Z Galvanised	40 90 140 190	1,5 x 8 1,5 x 8 1,5 x 8 1,5 x 8	1.5 1.5 1.5 1.5	406 406 406 406	25 25 25 25	0.620 0.632 0.650 0.664	3.05 3.05 3.05 3.05	25 25 25 25	1000 1000 1000 750	650 670 682 696

1.3.6. Accessories

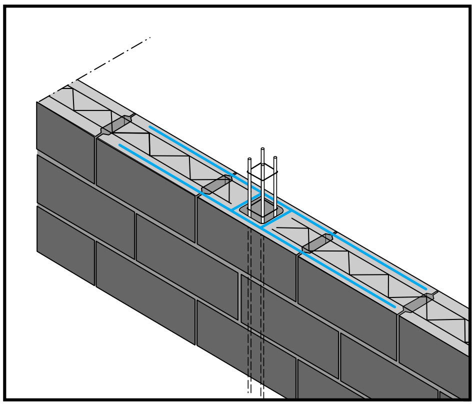
1. Accessories for mortar bed joints



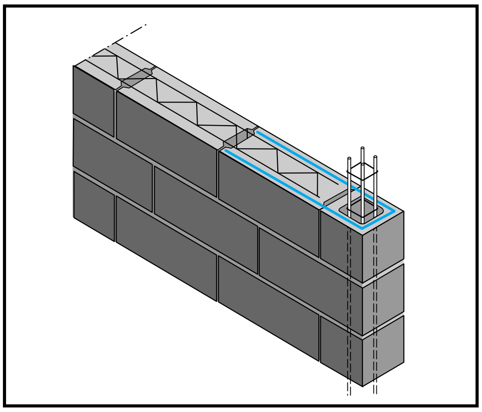
RNC/Z: Fabricated corner unit for Murfor® RND/Z.



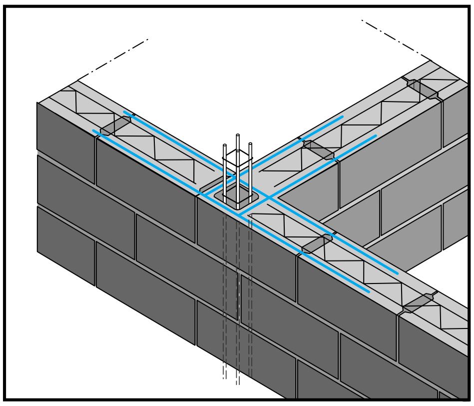
LNC/Z: Fabricated corner unit for Murfor® RND/Z in masonry with vertical reinforcement



LNS/Z: Wall connector for Murfor® RND/Z used in seismic applications

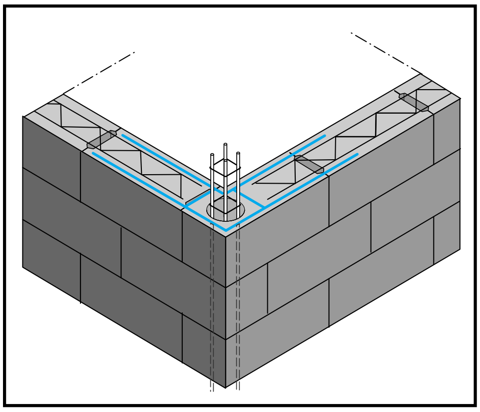


URC/Z: Wall connector for door and window openings

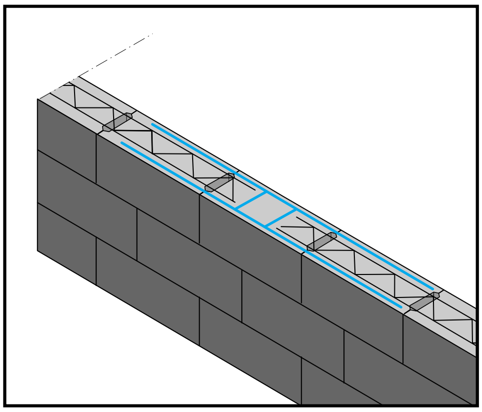


LNT/Z: Fabricated T-unit

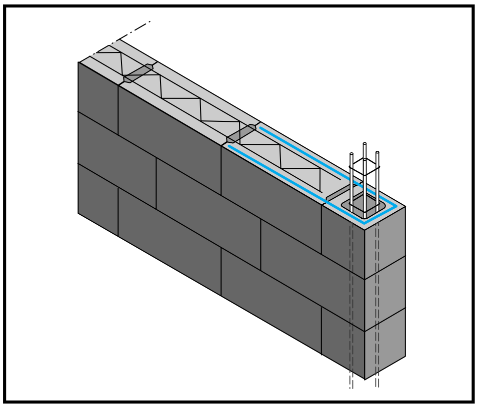
2. Accessories for this bed joints



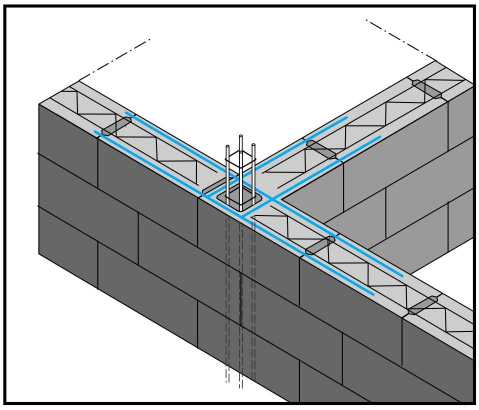
SFC/Z: Fabricated corner for thin bed joints with vertical reinforcement



SFL/Z: Lap connector for Murfor® EFS/Z



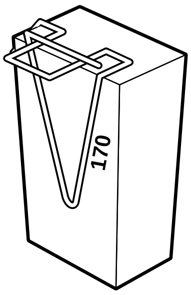
UFC/Z: Wall connector for door and window openings.



SFT/Z: Fabricated T-unit for thin bed joints.

3. Lintel hangers

Soldier course



LHK/S
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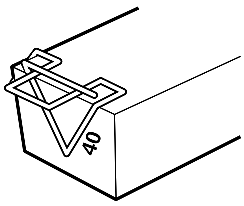
Stretcher course

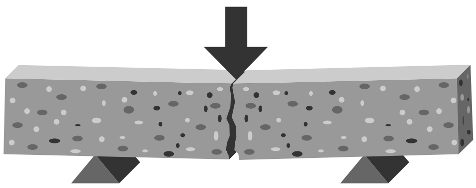


LHK/S
40

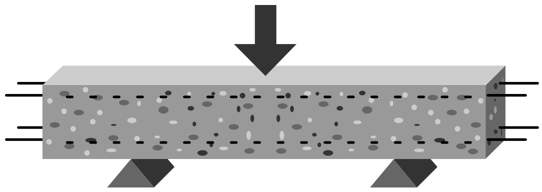
2. Advantages of using Murfor®

2.1. Introduction

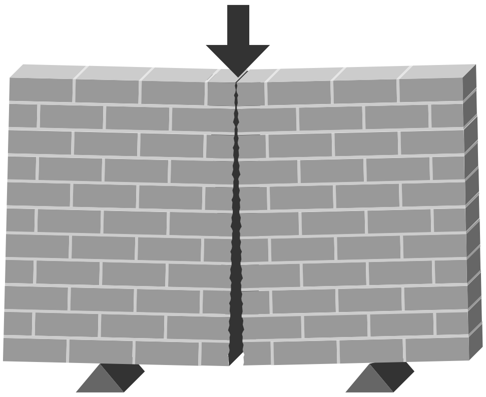
Like concrete, masonry has a high compressive strength but a limited tensile strength. This tends to lead to cracking when tensile and/or shear stresses develop. By providing reinforcement to resist such stresses, the risk of cracking is substantially reduced. Masonry should be reinforced with Murfor®, using general principles similar to those associated with reinforced concrete.



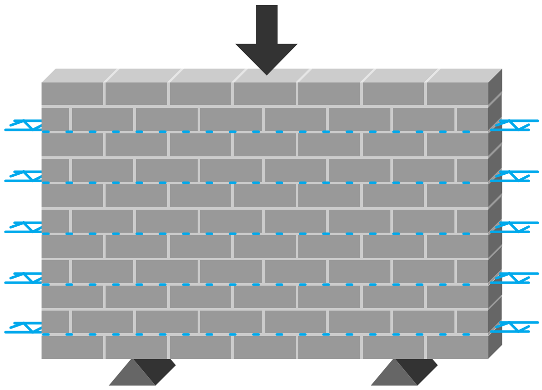
Concrete without reinforcement



Concrete with reinforcement



Masonry without reinforcement



Masonry with Murfor® reinforcement

Murfor® is a convenient, purpose made, reinforcement for masonry for use in the horizontal bed joints. It limits the risk of cracking and increases the tensile and flexural strength of masonry.

Murfor® can be used in conjunction with the masonry to increase the structural strength using design priciples in accordance with BS5628: Part2: 1985"Use of Masonry: Part 2: Structural Use of Reinforced and Prestressed Masonry".

2.2. Crack Control

Murfor® is very effective in reducing cracking in masonry due to a variety of causes, for example:

a. Shrinkage due to drying out
b. Movement due to moisture loss or gain in external situations.
c. Movement due to fluctuating temperatures.
d. Flexural or tensile stresses resulting from loading.
e. Stress concentrations around openings, such as windows or doors.
f. Movement of partition walls due to the deflection of the supporting structure.
g. Long term creep effects

Further examples and details are given in Chapter 3.

2.3. Structural Strength

Murfor® can increase the structural strength of masonry. It can be used to form reinforced masonry lintels to span over openings, and to provide additional resistance to lateral loading from, for example, the wind. Design information is given in Chapter 4.

When used generally throughout masonry construction, Murfor® will improve the overall stiffness of the masonry construction, tying the walls together positively to provide a structural material with a more even distribution of stresses.

Murfor® has been extensively tested by various authorities, including British Ceramic Research Ltd. and its performance investigated in the following respects:

a. Load bearing capacity of masonry lintels.
b. Load capacity of laterally loaded walls.
c. Bond strength.
d. Load transmission across cavities.
e. Corrosion resistance.
f. Shrinkage/expansion control.
g. Thermal conductivity.
h. Fire resistance.

Murfor® meets the design requirements of BS 5628: Part 2: 1985 for bed joint reinforcement.

Technical test data is available on request from Bekaert Building Products.

2.4. Architectural Benefits

Murfor® offers greater flexibility to the architect, for example:

a. Distance between movement joints can be extended.
b. Concrete and steel lintels can be omitted, where Murfor® is used to provide a reinforced masonry lintel.
c. Collar jointed walls can be used with Murfor® tying the two leaves together.
d. Stack bonded walls can be used with Murfor® tying the masonry together.

2.5. Technical advice

Murfor ® has been used in Europe since 1970 and as a result Bekaert have built up considerable technical expertise on the uses of bed joint reinforcement during this time.

This technical knowledge is available to designers and contractors and advice can be obtained by contacting Bekaert's Consulting Engineers.

Jenkins and Potter Consulting Engineers
First Floor, 67-74 Saffron Hill
London, EC1N8QX
Telephone - 0207 242 8711
Fax - 0207 404 0742
E-mail - post@jenkinspotter.co.uk

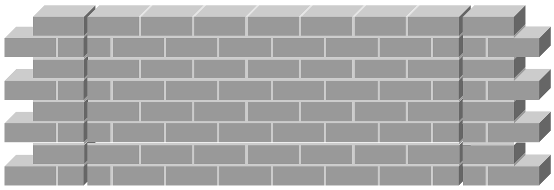
Murfor®:

- **Reduces the risk of cracking**
- **Increases the structural strength**
- **Offers new architectural possibilities**
- **Has full technical support**

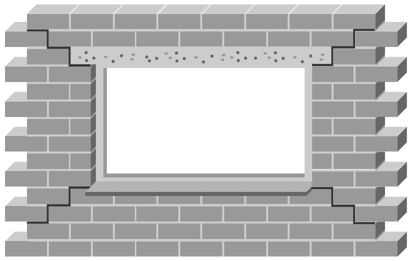
3. Applications of Murfor®

There are many applications for Murfor® which would improve the performance of the masonry. The most important applications are listed on the following pages.

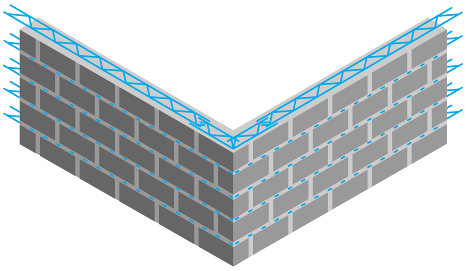
For ease of presentation, block work is shown in the diagrams, illustrating the uses, but the details also apply to brickwork.



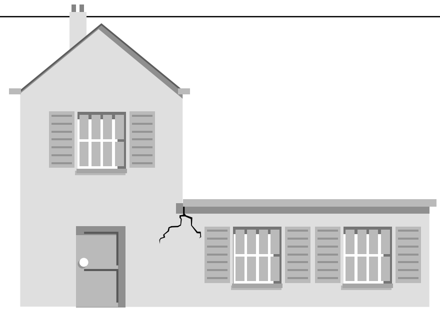
Crack control: spacing of movement joints (Page 16)



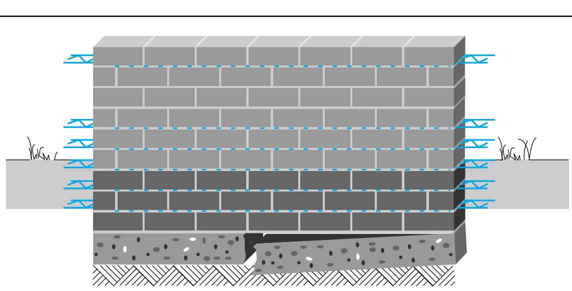
Crack control around openings
(Page 18)



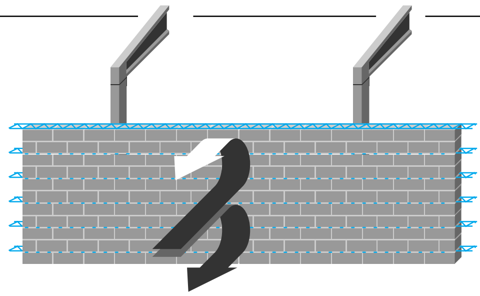
Crack control at wall junctions
(Page 19)



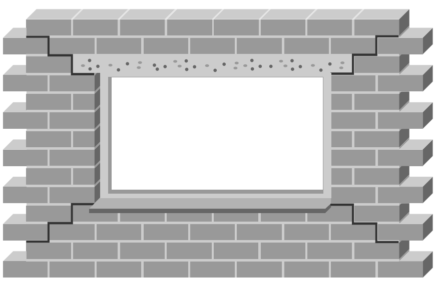
Crack control in irregular elevations
(Page 22)



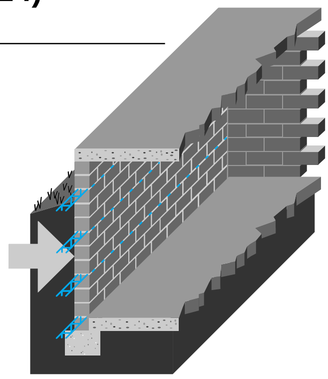
Allowance for differential settlement
(Page 23)



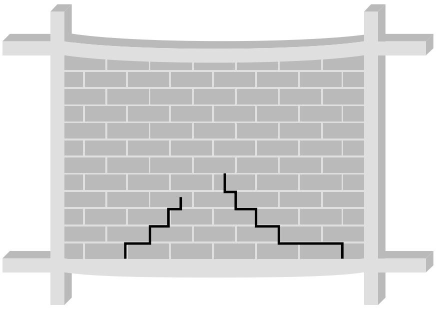
Laterally loaded wall panels
(Page 24)



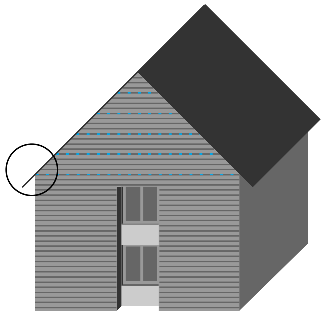
Masonry lintels or beams
(Page 25)



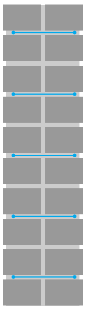
Retaining walls
(Page 26)



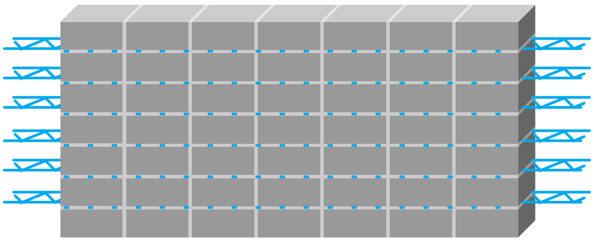
Partition walls **(Page 27)**



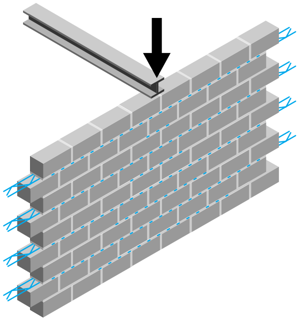
Gables **(Page 28)**



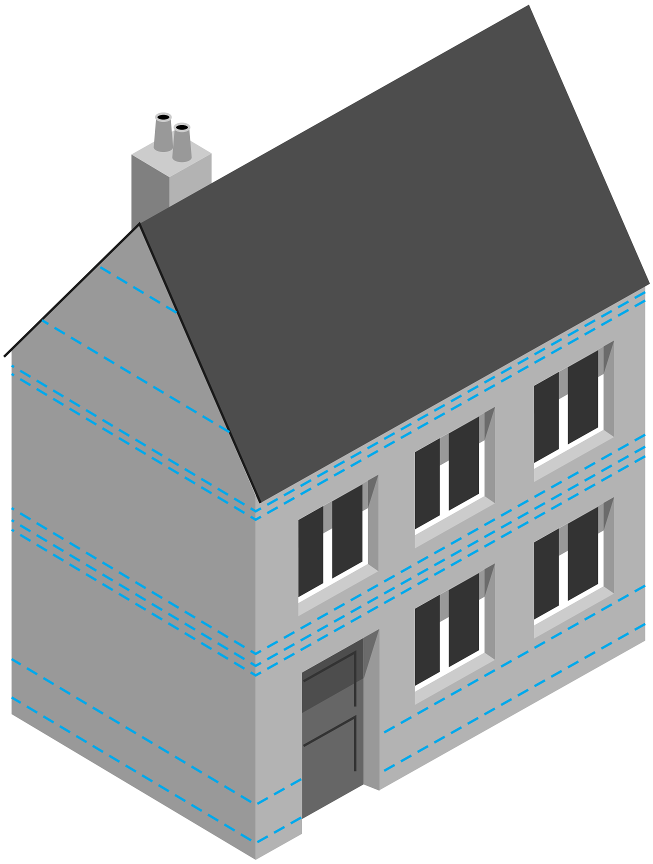
Collar jointed walls **(Page 29)**



Stack bonded and banded masonry
(Page 30)



Beam bearings **(Page 31)**

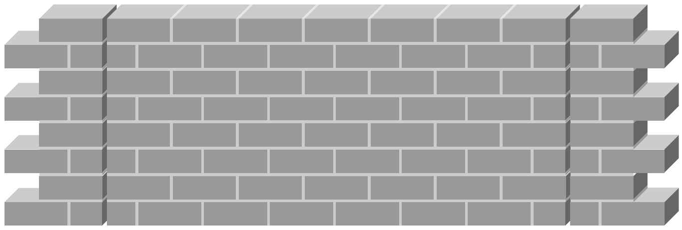


The efficiently reinforced house
(Page 32)

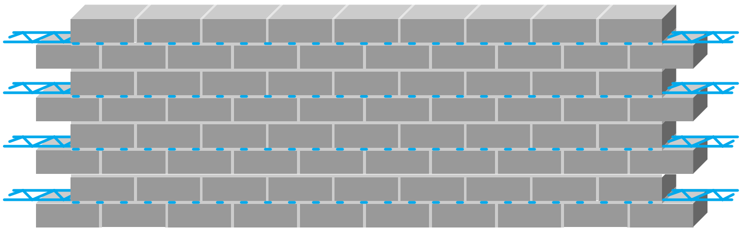
3.1. Crack Control: Spacing of Movement Joints

Movement of masonry due to the shrinkage and/or expansion induces stresses so that cracks may form in the masonry.

Depending on the physical characteristics the chosen brick or block, movement joints should be provided at regular intervals.



No Murfor®: movement joints



Murfor®: less movement joints

Test carried out in the United States and, more recently, in Belgium have shown that, when using Murfor®, the distance between movement joints can be substantially increased, giving greater flexibility of design.

Suitable places for movement joints, provided that the walls are adequately restrained, are:

- at junctions with other materials e.g. concrete columns.
- at changes in section.
- at corners.

The table below gives the required spacing of Murfor® reinforcement for various building materials where:

- the masonry is properly bonded
- the Murfor® reinforcement is lapped and anchored as described in Chapter 5.
- allowance is made for the movement of the masonry by providing suitable joint widths, i.e. wider joints will be required for greater distances between joints.

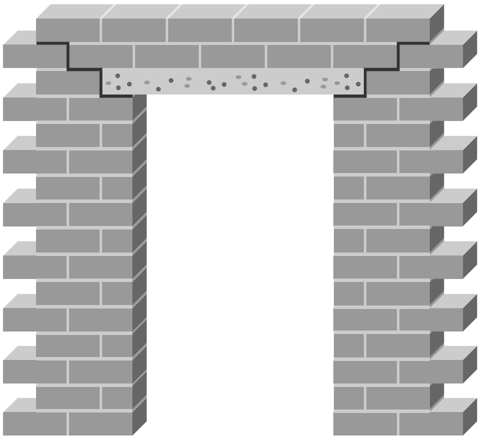
Maximum distance between movement joints

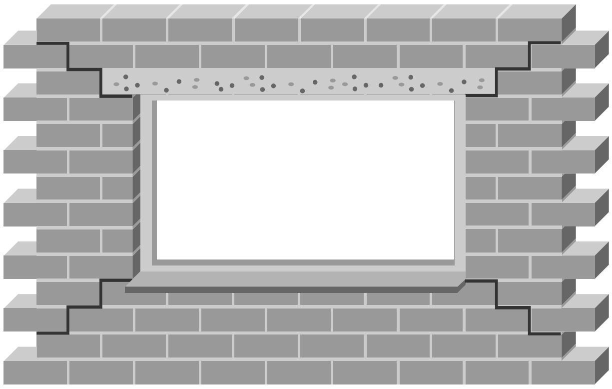
material	wall thickness ≤ 140 mm			wall thickness > 140 mm		
	not reinforced	reinforced every 450mm	reinforced every 225mm	not reinforced	reinforced every 450mm	reinforced every 225mm
clay bricks	15m	20m	>20m	15m	20m	>20m
calcium-silicate bricks **dense concrete blocks**	8m	12m	14m	8m	14m	16m
lightweight concrete blocks **AAC blocks**	6m	10m	12m	6m	12m	14m

3.2. Crack Control around Openings

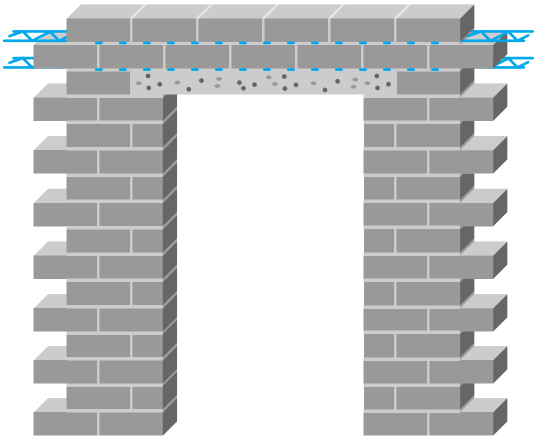
Cracks can form in masonry where there are stress concentrations at the corners of doors and windows. By providing Murfor® reinforcement in the bed joints in these locations, as shown, the tensile stresses which develop can be resisted.

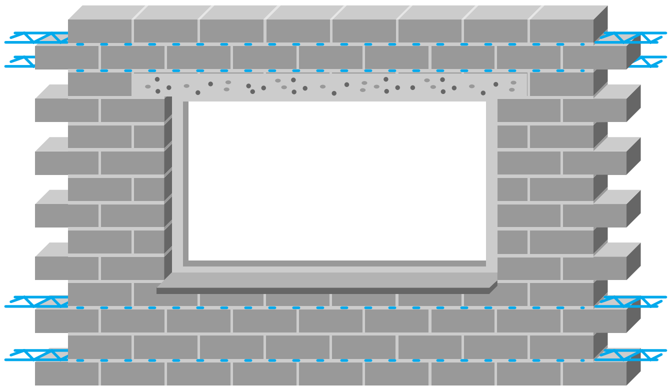
Door opening **Window opening**





No Murfor®: cracks





Murfor®: no cracks

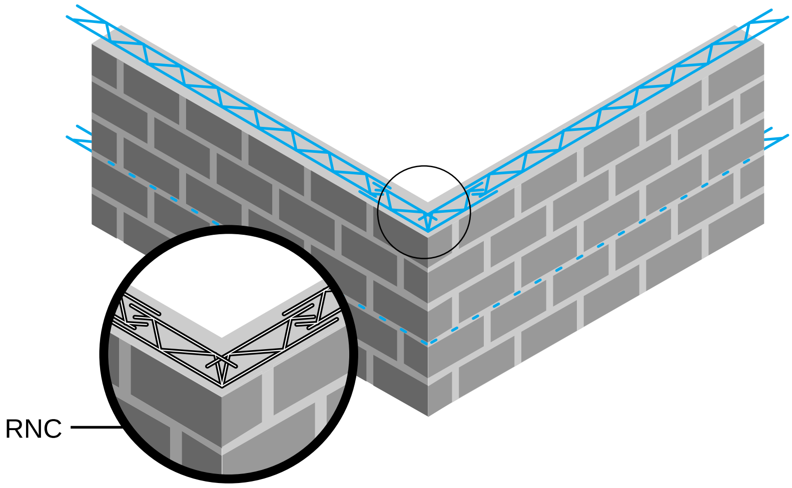
It would be an advantage, where possible, to provide a continuous band of Murfor® reinforcement above door and window openings and below window openings to avoid breaks in the reinforcement which allows stresses to develop (see section 3.14).

3.3. Crack Control at Wall Junctions

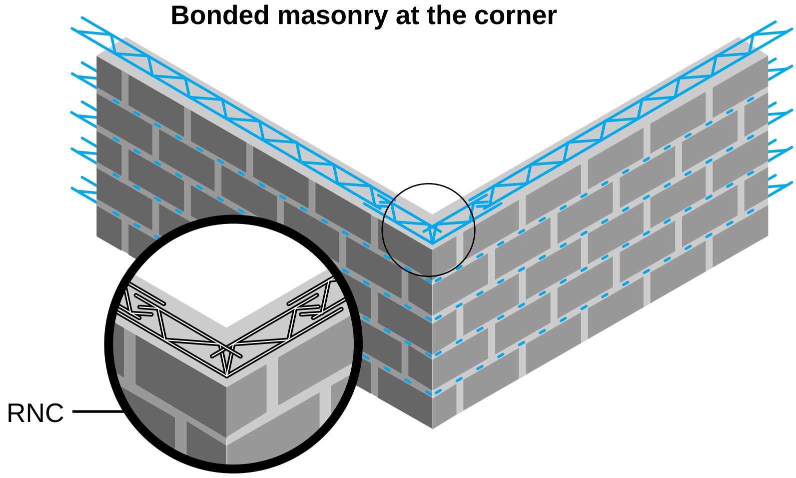
Wall junctions can cause stress concentrations and cracking. By providing Murfor® reinforcement at 450 mm centres throughout the height of the wall, the risk of cracking can be reduced.

Where the masonry is not to be bonded at corners, Murfor® reinforcement can be used to provide the connection between the walls, but is should then be provided at 225 mm centres.

1. Corner junction

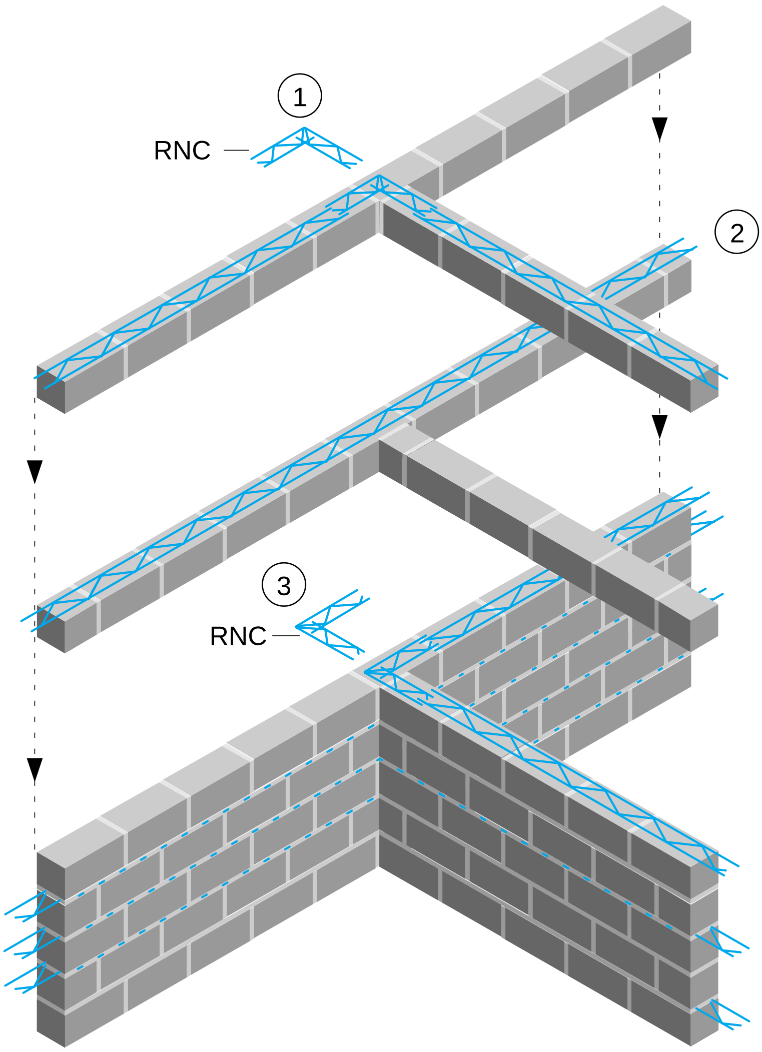


Bonded masonry at the corner

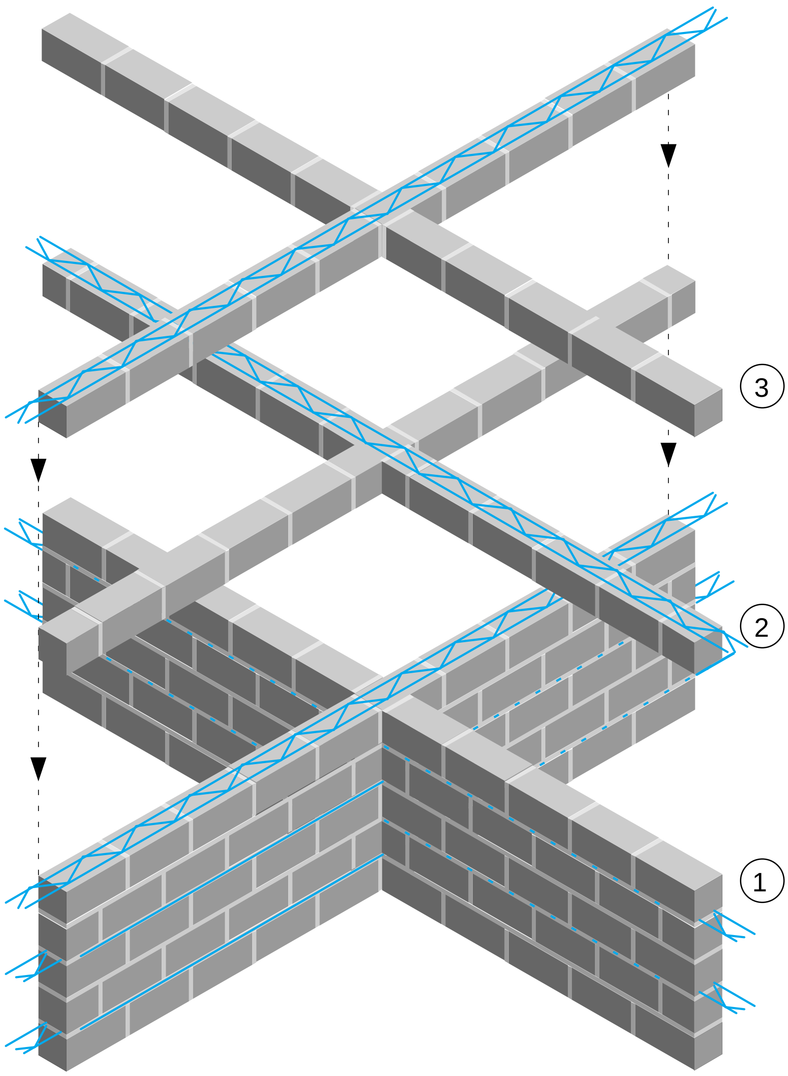


Unbounded masonry at the corner

2. T-junction



3. Cross junction



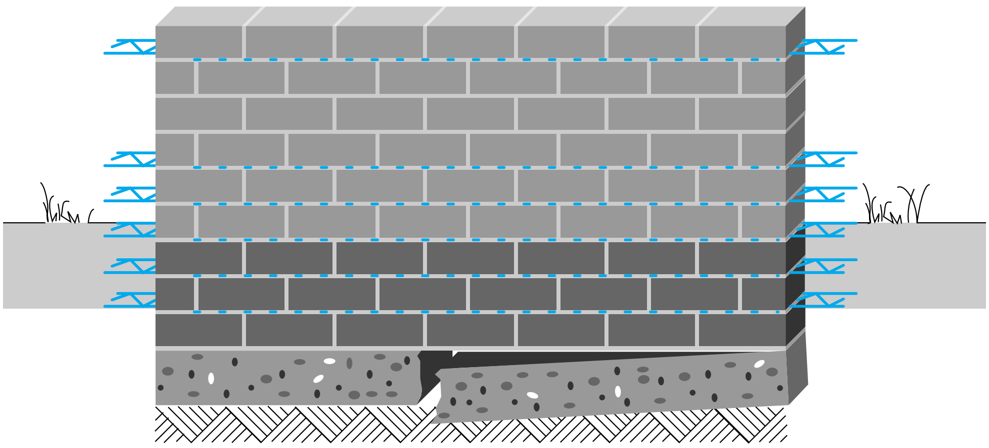
3.4. Crack Control in irregular Elevations

Elevational changes in masonry walls result in different loading condition and concentrations of stresses at the junctions. Where this occurs, Murfor® reinforcement would reduce the risk of cracking.

3.5. Allowance for Differential Settlement

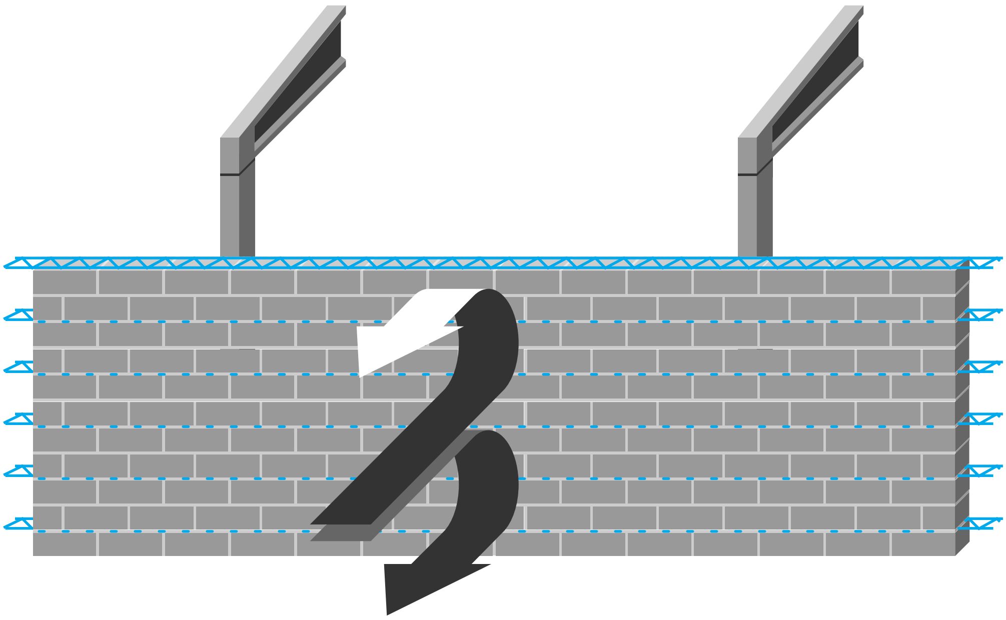
When a building is constructed on soft ground, or when the site is liable to differential settlements, reinforcing the masonry with Murfor® could allow the masonry to span over local problem areas.

Ground movements can result in considerable deformations, causing stresses in the masonry. Providing Murfor® reinforcement in the bottom courses and evenly distributed throughout the height of the walls, at say 450 mm centres, would reduce the risk of resulting cracking.



3.6. Laterally Loaded Wall Panels

Walls subjected to lateral wind pressure can be exposed to considerable stresses. By introducing Murfor® reinforcement in the bed joints, the strength of the wall can be enhanced, allowing greater distance between lateral restraints or, in some cases, the thickness of the wall to be reduced.

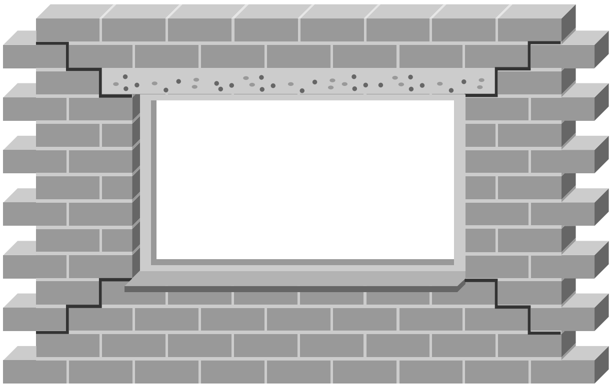


For safe load tables, see tables 1 and 2 in section 4.1., and for typical design calculations, see section 4.3.

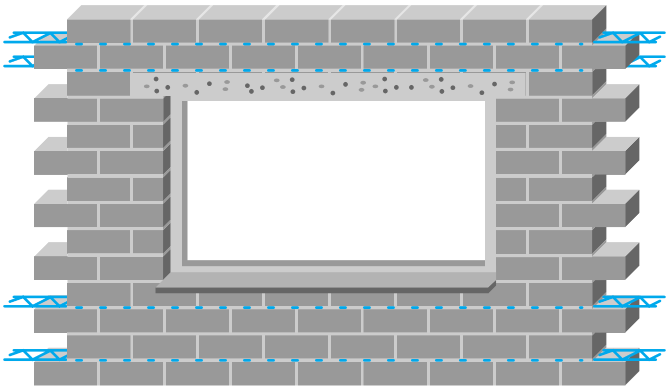
It should be noted that the strength of cavity walls is the sum of the strengths of the two leaves, reinforced separately.

3.7. Masonry Lintels or Beams

Prefabricated lintels made of concrete or steel always tend to affect the masonry aesthetically and physically (e.g. differences in shrinkage and thermal conductivity characteristics resulting in unsightly cracking). Additionally, steel lintels may provide a problem with corrosion in damp conditions.



The use of Murfor® reinforcement to form masonry lintels will reduce these problems, providing an architecturally pleasing finish.



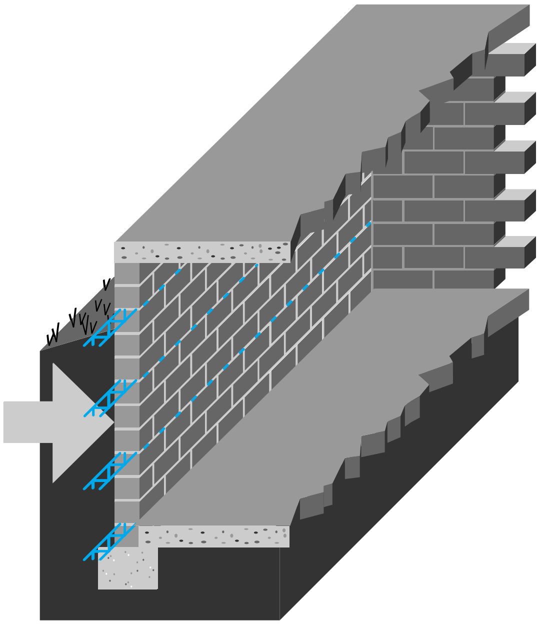
Murfor® reinforcement in the masonry panel below a window will also reduce cracking due to stress concentrations in this location.

The bottom course of masonry lintels should be secured by means of Murfor® Lintel Hangers (ref. LHK), see section 1.3.6. For fixing details see Chapter 5.

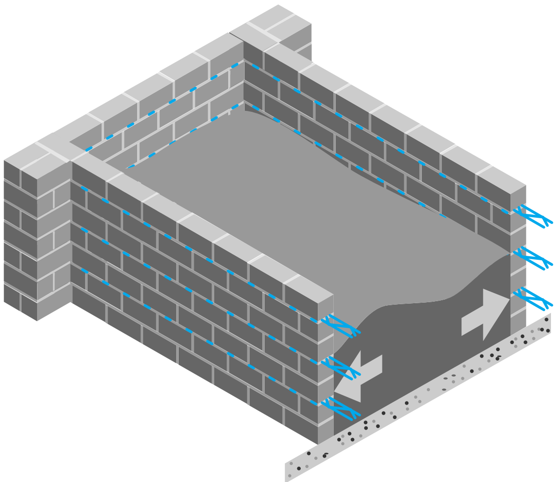
For safe load tables, see tables 3 and 4 in section 4.2., and for typical design calculations, see section 4.4.

3.8. Retaining Walls

Retaining walls, such as for cellars or silos, are often exposed to considerable stresses from lateral loading. Murfor® reinforcement, placed in the bed joints, increases the wall loading capacity to span horizontally between the buttresses. For typical design calculations see section 4.3.



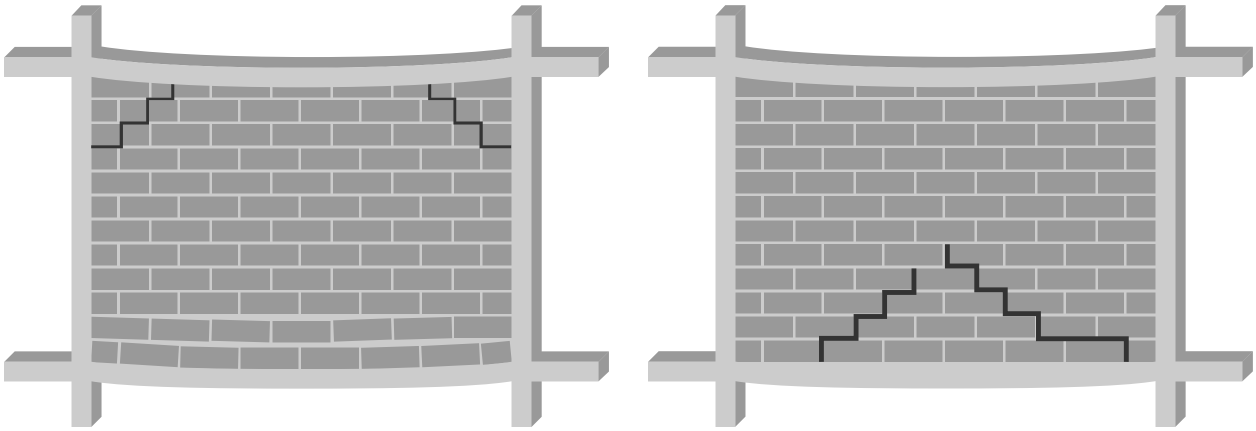
Cellar wall



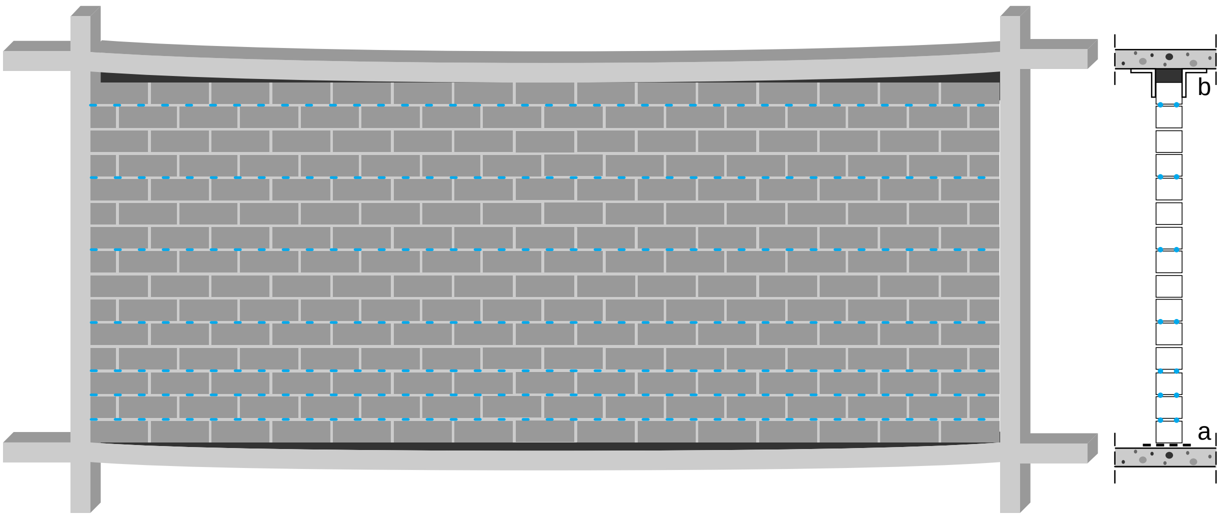
Silo wall

3.9. Partition Walls

When partition walls are built on a supporting floor slab or beam that can deflect, a pattern of cracks can develop.



This can be overcome by separating the partition wall from the supporting floor slab or beam with a damp proof course (dpc) or some other similar material and reinforcing the masonry with Murfor®, to allow it to span over the gap formed as the support deflects, with additional layers in the bottom courses.



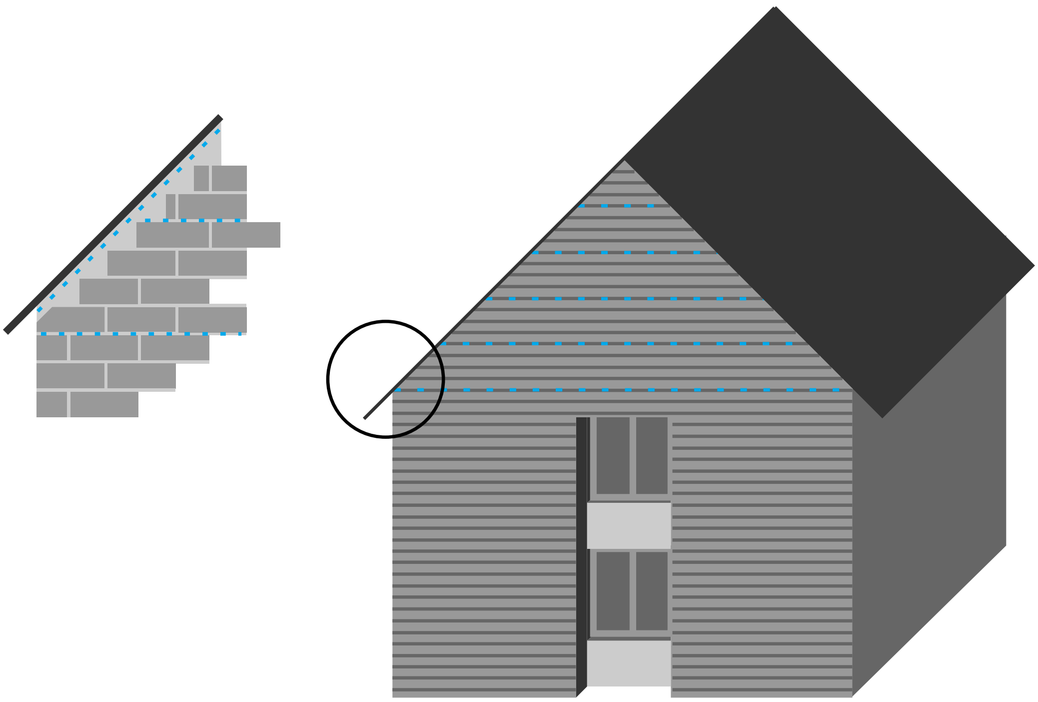
a: bond breaking layer (dpc material)
b: compressible strip

The partition wall can be designed as a deep beam spanning across the width of the floor slab. For typical design calculations see section 4.5.

3.10. Gables

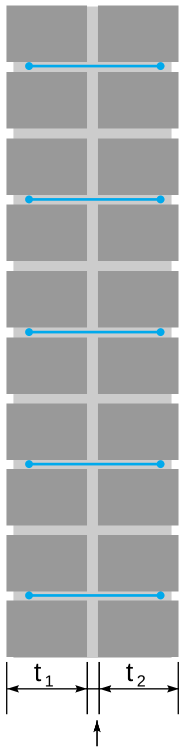
Gables with Murfor® reinforcement placed in the bed joints, can be designed as laterally loaded wall panels spanning between the edges, as section 3.6. Generally, Murfor® reinforcement should be provided at 450 mm centres, but for larger gables than normal in a residential house it would be advisable to provide it at 225 mm centres.

Ties, properly fixed, will be required at the sloping edges to provide the necessary restraint for the wall, in accordance with BS 5628: Part 1: 1978.



3.11. Collar Jointed Walls

Where a wall is constructed of two separate leaves with the vertical mortar filled joint between them not exceeding 25 mm, it is known as a collar jointed wall. Murfor® (ref. RND) can be used to connect the two leaves to improve the stability of the wall.

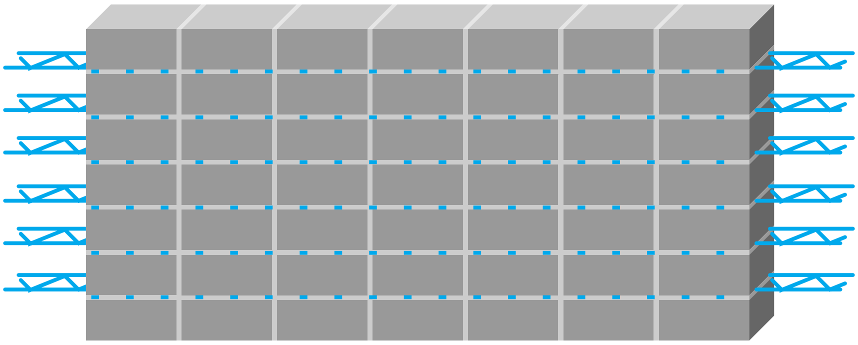


With Murfor® reinforcement provided at 450 mm centres, the wall can be designed as a cavity wall.

With Murfor® reinforcement provided at 225 mm centres, the wall can be designed as a single leaf wall, provided the full requirements of Clause 29.5(b) of BS5628: Part 1: 1992 are met.

3.12. Stack Bonded and Banded Masonry

Unbounded (or stack bonded) masonry allows the Architect to obtain special aesthetic effects. Usually this kind of masonry is used only for small non-loadbearing walls. However, if Murfor® masonry reinforcement is provided in every joint, the wall will act as if it is bonded and would be capable of supporting loads.

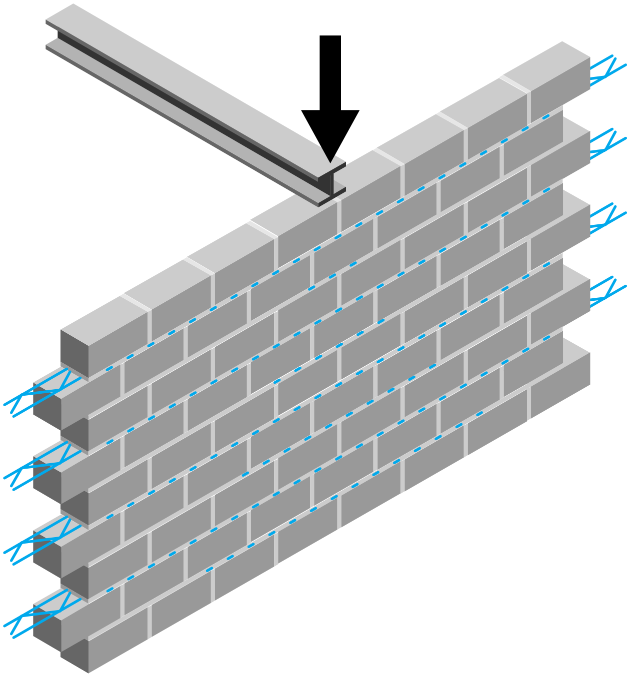


Banded masonry, such as the inclusion of a soldier course in a wall, is often used by architects to provide a pleasing effect in an otherwise large plain area of masonry. Where masonry units of differing properties are used to form the banding or patterns, Murfor® can be used in the bed joints to resist stresses that might be set up due to possible different movement characteristics between the units.

3. 13 Beam Bearings

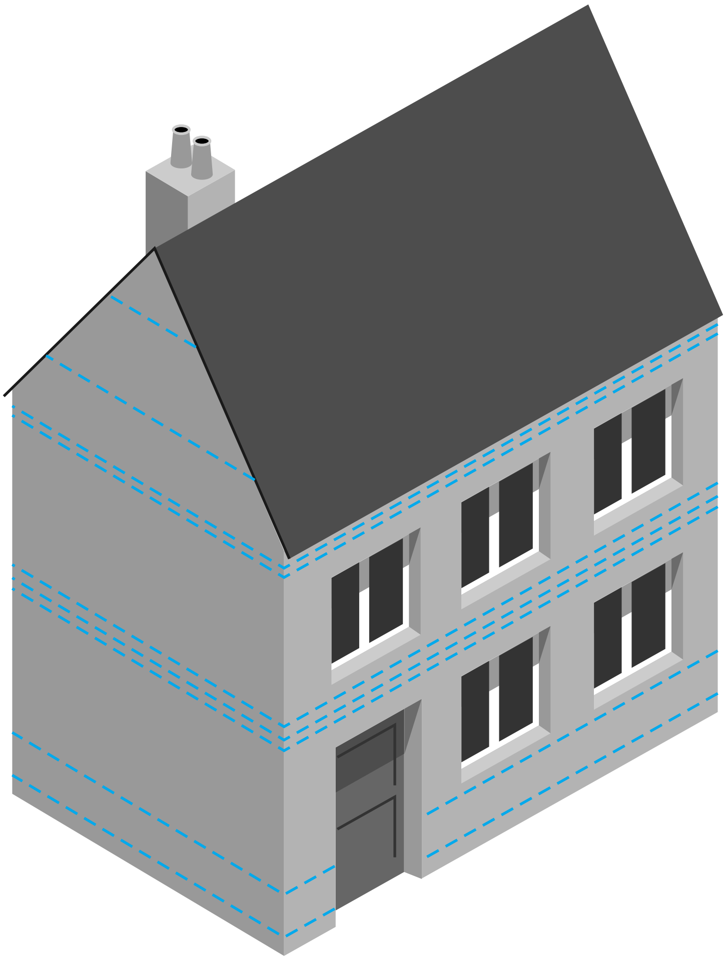
Concentrated loads from beams cause tensile stresses to develop in the zone below the bearing. By providing Murfor® in the courses immediately below the bearing, these stresses can be resisted and the risk of cracking reduced.

Where loads are light and the bearing stresses below the beams are within the capacity of the masonry itself, for example in house construction, it is possible to omit the pad stones below steel beams.



3.14. The Efficiently Reinforced House

So far only the individual applications of Murfor® reinforcement have been considered. However, by providing Murfor® reinforcement at regular intervals throughout the masonry walls, an overall improvement in the structure will be obtained.



The advantages are:

- **the masonry is tied together.**
- **the installation work is easier to monitor and supervise on site.**
- **there is a reserve of strength for unexpected problems that might occur in the future.**

4. Structural Use of Murfor®

In common with concrete, masonry possesses a compressive strength disproportionately larger than its tensile strength and the engineering design of reinforced masonry elements is based on generally similar principles to those with reinforced concrete.

Murfor® can be designed to resist the tensile stresses that develop in masonry subjected to bending. In this chapter, guidance is given on the design of a laterally loaded wall panel (section 4.3.), a simple masonry beam (section 4.4.) and a deep beam (section 4.5.), based on the recommendations given in BS5628: Part 2: 1985, which should be consulted for the full requirements. Safe load tables based on these recommendations, are given in section 4.1., for laterally loaded wall panels, and section 4.2., for masonry lintels or beams.

Further technical advice can be obtained by contacting Bekaert's Consulting Engineers:

Jenkins and Potter Consulting Engineers
First Floor, 67-74 Saffron Hill
London, EC1N8QX
Telephone - 0207 242 8711
Fax - 0207 404 0742
E-mail - post@jenkinspotter.co.uk

4.1. Safe Load Tables for Laterally Loaded Wall Panels

These tables are based on the design as described in section 4.3., using the limitations contained in Appendix A.3 of BS5628: Part 2: 1985.

It is assumed that the minimum strength of the masonry units is as stated and that, in all cases, the mortar grade is not weaker than designation (iii), i.e. 1:1:6.

The design is based on γ_m = 3.5, with normal manufacturing and construction control, and γ_f = 1.4, assuming that the wall affects the stability of the remaining structure.

The wall is assumed to be spanning horizontally between lateral restraints, without edge restraint and simply supported at each end.

The following requirements are also to be met:

- The masonry must be properly bonded ensuring that all mortar joints are filled.
- The Murfor® reinforcement must be lapped and anchored as described in Chapter 5.
- The Murfor® reinforcement is uniformly distributed over the height of the wall.

Table 1 : Clay or Calcium Silicate Bricks
Minimum crushing strength 7 N/mm²

Wall Thickness	Width of Murfor®	Vertical Spacing of Murfor®	Distance between centres of vertical restraints (mm)						
(mm)	(mm)	(mm)	3000	3500	4000	4500	5000	5500	6000
102, 5	50	225 c/c	0.42	0.31	0.24	0.19	0.15	0.13	0.11
		450 c/c	0.42	0.31	0.24	0.19	0.15	0.13	0.11
215	150	225 c/c	1.89	1.38	1.06	0.84	0.68	0.56	0.47
		450 c/c	1.68	1.20	0.94	0.73	0.60	0.49	0.42

Lateral load capacity (kN/m²) for walls spanning horizontally between vertical restraints.

Table 2 : AAC or Concrete Blocks
Minimum crushing strength 3.5 N/mm²

Wall Thickness	Width of Murfor®	Vertical Spacing of Murfor®	Distance between centres of vertical restraints (mm)						
(mm)	(mm)	(mm)	3000	3500	4000	4500	5000	5500	6000
100	50	225 c/c	0.40	0.29	0.22	0.18	0.14	0.12	0.10
		450 c/c	0.40	0.29	0.22	0.18	0.14	0.12	0.10
140	100	225 c/c	0.61	0.45	0.34	0.27	0.22	0.18	0.15
		450 c/c	0.61	0.45	0.34	0.27	0.22	0.18	0.15
190	150	225 c/c	1.17	0.86	0.66	0.52	0.42	0.35	0.29
		450 c/c	1.03	0.76	0.58	0.46	0.37	0.31	0.26
215	150	225 c/c	1.49	1.09	0.83	0.66	0.54	0.44	0.37
		450 c/c	1.31	0.96	0.74	0.58	0.47	0.39	0.33

Lateral load capacity (kN/m²) for walls spanning horizontally between vertical restraints.

4.2. Safe Load Tables for Masonry Lintels or Beams

These tables are based on the design as described in section 4.4 and tests carried out by British Ceramic Research Ltd.

It is assumed that the minimum strength of the masonry units is as stated and that, in all cases, the mortar grade is not weaker than designation (iii), i.e. 1:1:6.

The design is based on γ_m = 3.5 with normal manufacturing and construction control, and γ_f = 1.5, assuming that the imposed load is equal to or less than the dead load. It is assumed that the loading can be considered to be uniformly distributed.

The following requirements are also to be met:

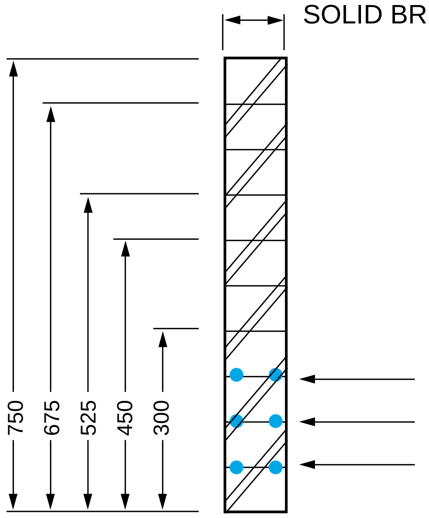
- the masonry must be properly bonded ensuring that all mortar joints are filled.
- imposed loads are applied above the level of the lintel or beam.
- the Murfor® reinforcement must not be lapped within the length of the lintel or beam.
- the Murfor® reinforcement must be anchored on both sides at least 500 mm.
- the bottom course is secured by Murfor® Lintel Hangers (ref. LHK).
- no movement joints are provided within the length of the lintel or beam and its support.
- Murfor® reinforcement is provided at 450 mm centres throughout the height of the lintel or beam.
- the masonry is supported until it has attained adequate strength i.e. for at least 14 days.

Table 3 : Clay or Calcium Silicate Bricks
Minimum crushing strength 7 N/mm²

Clear Depth	lintel	Lintel Width	loading (kg/m) including Self Weight									
(mm)	(mm)	(mm)	100	200	300	400	500	600	700	800	900	1000
up to 600	300	102,5	1	1	1	1	1	1	1	1	-	-
		215	1	1	1	1	1	1	1	1	1	1
601 - 1200	300	102,5	1	1	1	1	-	-	-	-	-	-
		215	1	1	1	1	1	-	-	-	-	-
	450	102,5	1	1	1	1	1	1	1	-	-	-
		215	1	1	1	1	1	1	1	1	1	2
	525	102,5	1	1	1	1	1	1	1	1	-	-
		215	1	1	1	1	1	1	1	1	1	1
1201 - 1800	450	102,5	1	1	1	1	-	-	-	-	-	-
		215	1	1	1	1	2	2	2	-	-	-
	525	102,5	1	1	1	1	1	-	-	-	-	-
		215	1	1	1	1	1	2	2	2	2	2
	675	102,5	1	1	1	1	1	1	1	-	-	-
		215	1	1	1	1	1	1	1	2	2	2
	750	102,5	1	1	1	1	1	1	1	1	-	-
		215	1	1	1	1	1	1	1	1	2	2
1801 - 2400	525	102,5	1	1	1	2	-	-	-	-	-	-
		215	1	1	1	2	2	3	-	-	-	-
	675	102,5	1	1	1	1	2	-	-	-	-	-
		215	1	1	1	1	2	2	2	2	3	3
	750	102,5	1	1	1	1	2	2	-	-	-	-
		215	1	1	1	1	1	2	2	2	2	3

Number of layers of Murfor® reinforcement for various load/span conditions.

SOLID BRICK LINTEL 102.5 or 215



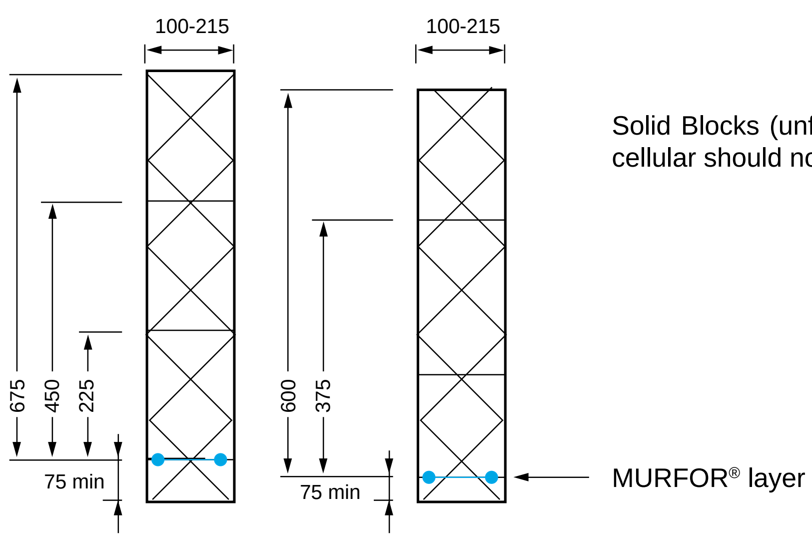
Unfilled cellular and perforated bricks should not be used unless the longitudinal strength is equal to or greater than the strength assumed in the table above.

MURFOR® 3rd layer
MURFOR® 2nd layer
MURFOR® 1st layer

Table 4 : AAC or Concrete Blocks
Minimum crushing strength 3.5 N/mm²

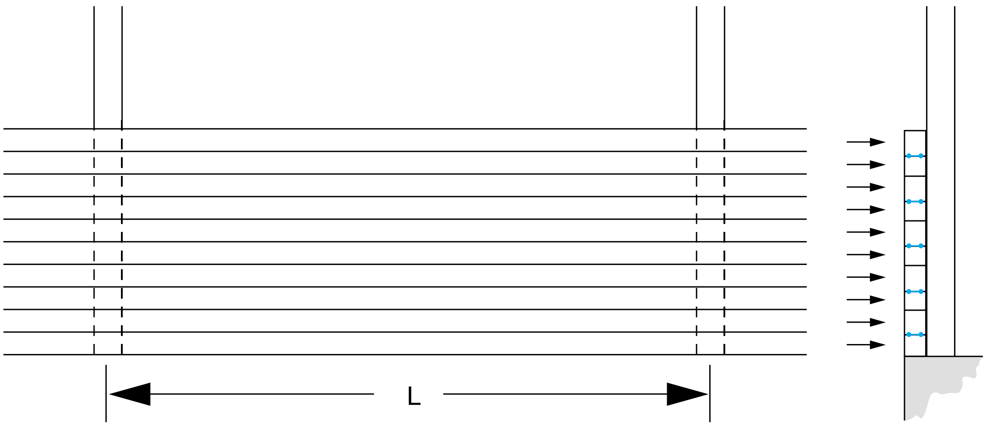
Clear Span	Overall Lintel Depth	Lintel Width	loading (kg/m) including Self Weight						
(mm)	(mm)	(mm)	100	200	300	400	500	600	700
up to 600	300	100	•	•	•	—	—	—	—
		140	•	•	•	•	•	—	—
		190-215	•	•	•	•	•	•	•
	450	100	•	•	•	•	•	•	•
		140	•	•	•	•	•	•	•
		190-215	•	•	•	•	•	•	•
601-1200	450	100	•	•	•	—	—	—	—
		140	•	•	•	•	—	—	—
		190-215	•	•	•	•	•	•	—
	525	100	•	•	•	•	•	—	—
		140	•	•	•	•	•	•	•
		190-215	•	•	•	•	•	•	•
1201-1800	525	100	•	•	—	—	—	—	—
		140	•	•	•	—	—	—	—
		190-215	•	•	•	•	—	—	—
	675	100	•	•	•	•	•	—	—
		140	•	•	•	•	•	—	—
		190-215	•	•	•	•	•	•	—
	750	100	•	•	•	•	•	—	—
		140	•	•	•	•	•	•	—
		190-215	•	•	•	•	•	•	•
1801-2400	675	100	•	•	—	—	—	—	—
		140	•	•	•	—	—	—	—
		190-215	•	•	•	•	—	—	—
	750	100	•	•	•	—	—	—	—
		140	•	•	•	•	—	—	—
		190-215	•	•	•	•	•	—	—

Load capacity for various spans, indicated



Solid Blocks (unfilled hollow and cellular should not be used).

4.3. Laterally Loaded Wall Panel Design



(a) Check panel size limitations

Check that the wall panel is within the limits given in Clause A.2.3 of BS5628: Part 2.

(b) Calculate the applied bending moment, M.

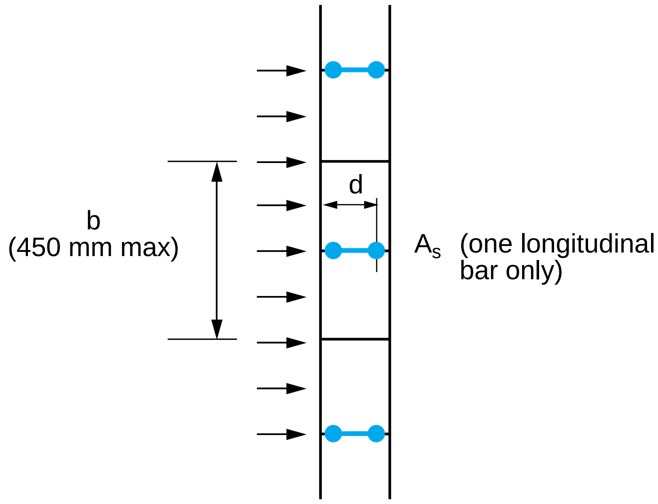
Assess the edge conditions of the wall panel in accordance with Clause 36 of BS5628: Part 1 and determine the relevant bending moment coefficient, α.

Generally the flexural strength of the masonry reinforced with Murfor® will be much greater with the wall panel spanning horizontally rather than vertically. Therefore, it will generally be sufficient to consider the panel spanning horizontally only. If there is a benefit considering the wall spanning in both directions, reference can be made to Table 9 of BS5628: Part 1, using a modified orthogonal ration with the moment of resistance in the horizontal direction based on the strength of the Murfor® reinforcement.

$M = \alpha W_{k\gamma f} L^2$ kN m/m

Where:
α = appropriate bending moment sufficient for the wall panel spanning horizontally
W_k = characteristic lateral load per unit area (kN/m^2)
γ_f = partial safety factor for loads
L = length of panel between supports (m)

(c) Calculate the moment of resistance, M_d.



$$M_d = \frac{A_s f_y z}{\gamma_{ms} b} \text{ N mm/mm}$$

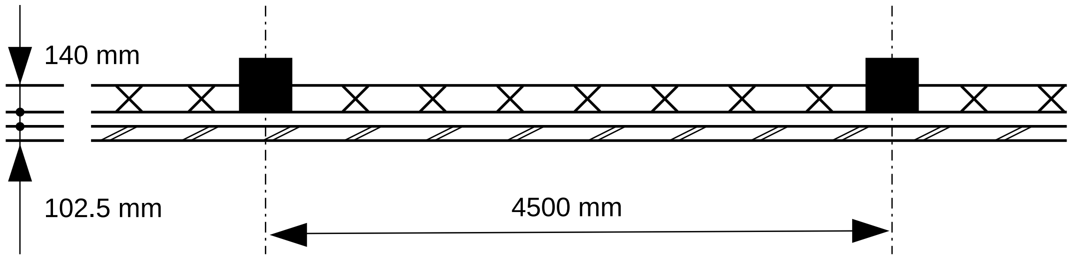
but not greater than $$\frac{0.4 f_y b d^2}{\gamma_{ms} b} \text{ N mm/mm}$$

If M_d is less than M, increase the number of bed joints reinforced with Murfor® and recalculate until M_d exceeds M.

Check that the enhanced lateral load resistance using Murfor® reinforcement is not 50 % greater than that of the unreinforced wall panel, as recommended by Clause A.3 of BS5628: Part 2. For cavity walls, the lateral load resistance should be taken as the sum of the resistance of the two leaves, calculated separately.

(d) Example

Check that a 3.0 m high continuous cavity wall with a brick outer leaf and a 140 block inner leaf can resist a lateral wind load of 0,5 kN/m² over a span of 4,5 m when reinforced with Murfor® at 450 centres.

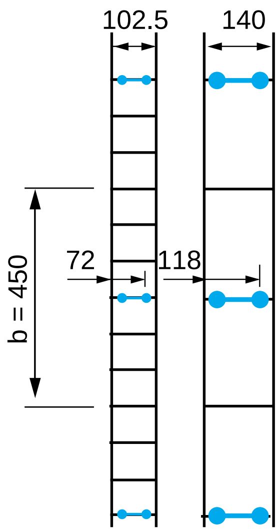


$$t_{ef} = \frac{2}{3}(102.5 + 140) = 161.7 \text{ mm}$$

$$\text{Maximum panel size} = \frac{1800 \times 161.7^2}{10^6} = 47.1 \text{ m}^2 \quad (> 3.0 \times 4.5 = 13.5)$$

Assume that the outer leaf is solid brickwork with f_k = 5.8 N/mm² (20 N/mm² characteristic compressive strength and mortar designation (iii) and f_{kx} = 1.1 N/mm² spanning horizontally, and the inner leaf is solid block work with f_k = 2.9 N/mm² (3.5 N/mm² characteristic compressive strength and mortar designation (iii) and f_{kx} = 0.4 N/mm² spanning horizontally. Assume γ_{mm} = 3.5 with normal manufacturing and construction control.

Provide 50 mm Murfor® in the outer leaf and 100mm Murfor® in the inner leaf, at 450 mm centres.



Outer Leaf :

$$z = 72\left(1 - \frac{0.5 \times 12.5 \times 500 \times 3.5}{450 \times 72 \times 5.8 \times 1.15}\right) = 68.4 \text{ mm}$$

$$M_d = \frac{12.5 \times 500 \times 68.4}{1.15} \times \frac{1}{10^6} \times \frac{1}{0.45} = 0.83 \text{ kN m/m}$$

Moment of resistance of unreinforced wall panel

$$= \frac{1.1 \times 100 \times 102.5^2}{3.5 \times 6 \times 10^6} = 0.55 \text{ kN m/m}$$

maximum allowable resistance of reinforced wall panel

= 0.55 x 1.5 = 0.83 kN m/m

Inner leaf :

$$z = 118\ (1 - \frac{0.5 \times 12.5 \times 500 \times 3.5}{450 \times 118 \times 2.9 \times 1.15}) = 110.7 \text{ mm}$$

$$M_d = \frac{12.5 \times 500 \times 110.7}{1.15} \times \frac{1}{10^6} \times \frac{1}{0.45}) = 1.34 \text{ kN m/m}$$

Moment of resistace of unreinforced wall panel

$$= \frac{0.4 \times 100 \times 140^2}{3.5 \times 6 \times 10^6} = 0.37 \text{ kN m/m}$$

maximum allowable resistance of reinforced wall panel

= 0.37 x 1.5 = 0.56 kN m/m

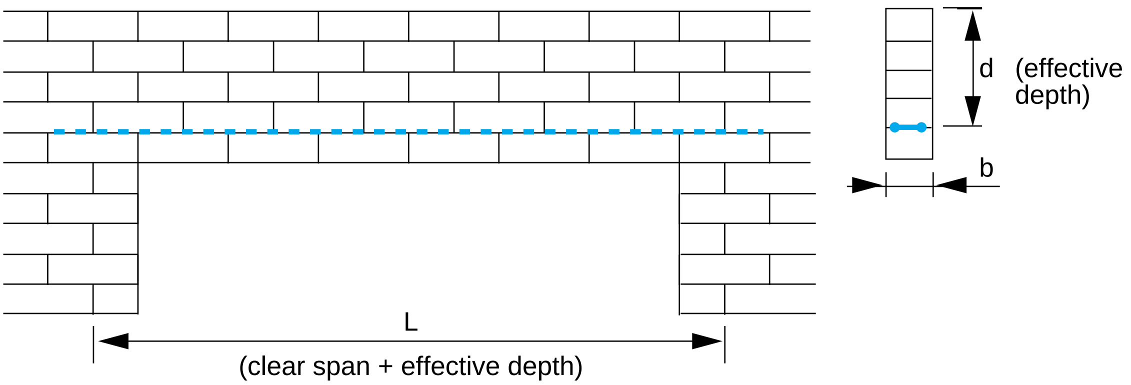
Therefore, combined moment of resistance = 0.83 + 0.56 = 1.39 kN m/m

From Table 9 of BS 5628: Part 1, assume the bending moment coefficient $\alpha = 0.083$ as the wall is continuous and fixity will be provided at supports.

Applied bending moment = 0.083 x 0.5 x 1.4 x 4.5^2 = 1.18 kN m/m

The moment of resistance exceeds the applied moment and, therefore, the wall is adequate.

4.4. Masonry Beam Design



(a) Calculate the applied bending moment.

In the simple case of a uniform distributed load, the applied bending moment, M, will be:

$$M = \frac{\gamma_f W L^2}{8} \text{ kN m}$$

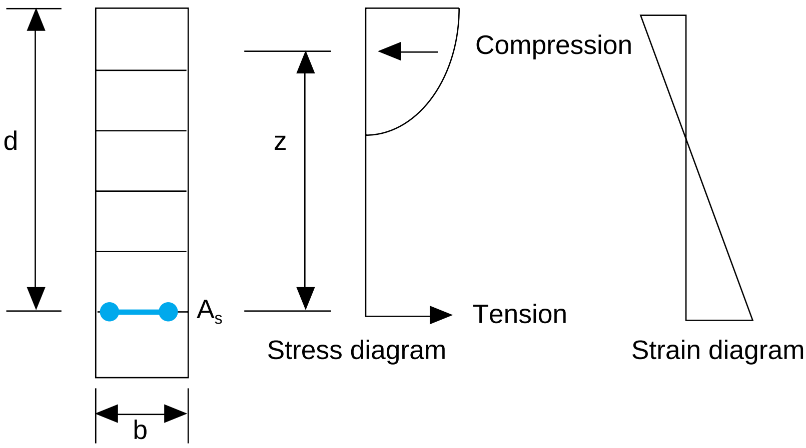
Where W = uniform load per unit length (kN/m)
L = effective span of beam (m)
γ_f = partial safety factor for loads.

For other loading conditions and more detailed information, the designer should consult BS5977: Part 1: 1981, “Lintels. Part. 1. Method of assessment of load”, to calculate the applied bending moment.

The ratio of the span to the effective depth of the beam, d, should be checked against the limits given in Table 9 of BS5628: Part 2. If the ratio is less than 1.5, the beam can be designed as a deep beam in accordance with section 4.5.

The distance between lateral restraints to the wall should be checked to ensure that it is less than 60b or 250 b^2/d whichever is the lesser where b is the width of the beam.

(b) Calculate the moment of resistance M_d



$$M_d = \frac{A_s\, f_y\, z}{\gamma_{ms}} \text{ N mm}$$

$$\left(\text{but not greater than } \frac{0.4\, f_k\, b\, d^2}{\gamma_{mm}} \text{ N mm}\right)$$

where:

A_s = cross-sectional area of Murfor® (mm^2)
f_y = characteristic tensile strength of Murfor® (500 N/mm^2)
z = lever arm (mm) given by:

$$z = d\left(1 - \frac{0.5\, A_s\, f_y\, \gamma_{mm}}{b\, d\, f_k\, \gamma_{ms}}\right) \text{ N mm}$$

But not greater than 0.95d

f_k = characteristic compressive strength of masonry (N/mm^2)
b = width of beam (mm)
d = effective depth of beam (mm)
γ_{ms} = partial safety factor for strength of steel (1.15)
γ_{mm} = partial safety factor for strength of masonry.

If the moment of resistance, M_d, is less than the applied bending moment, M, increase the number of bed joints reinforced with Murfor®, adjusting the effective depth accordingly, and recalculate until M_d exceeds M.

(c) Check that shear reinforcement is not required.

In a simple design case the shear stress, v, should be limited as follows:

$$v < \frac{f_v}{\gamma_{mv}} \text{ N/mm}^2$$

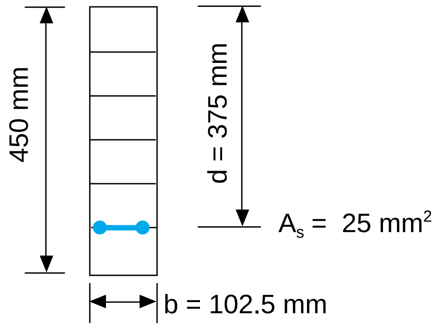
Where:

$$v = \frac{V}{bd} \text{ N/mm}^2$$

V = design shear force (N)
f_v = characteristic shear strength of masonry (0.35 N/mm²)
γ_{mv} = partial safety factor for the shear strength of masonry (2.0)

(d) Example

Determine if one layer of Murfor® reinforcement is adequate in a 450m deep brick beam to carry its self weight over an 1800 mm clear opening.



Assume brickwork has a weight of 20 kN/m³ and f_k = 6.4 N/mm² (solid bricks with a characteristic compressive strength of 20 N/mm² and mortar designation (ii), with γ_{mm} = 3.5 for normal manufacturing and construction control.

As the loading of the beam is dead load only, γ_f =1.4

Design load on beam = 1.4 x 0.1025 x 0.45 x 20 kN/m
= 1.29 kN/m

Effective span = 1.8 + 0.375 = 2.175 m

$$M = \frac{1.29 \times 2.175^2}{8} = 0.76 \text{ kN m}$$

$$\left[\text{check: } \frac{L}{d} = \frac{2175}{375} = 5.8 \ (< 20, > 1.5) \right]$$

$$Z = 375 \left(1 - \frac{0.5 \times 25 \times 500 \times 3.5}{102.5 \times 375 \times 6.4 \times 1.15} \right) = 346 \text{ mm}$$

$$M_d = \frac{25 \times 500 \times 346}{1.15} \times \frac{1}{10^6} = 3.76 \text{ kN m}$$

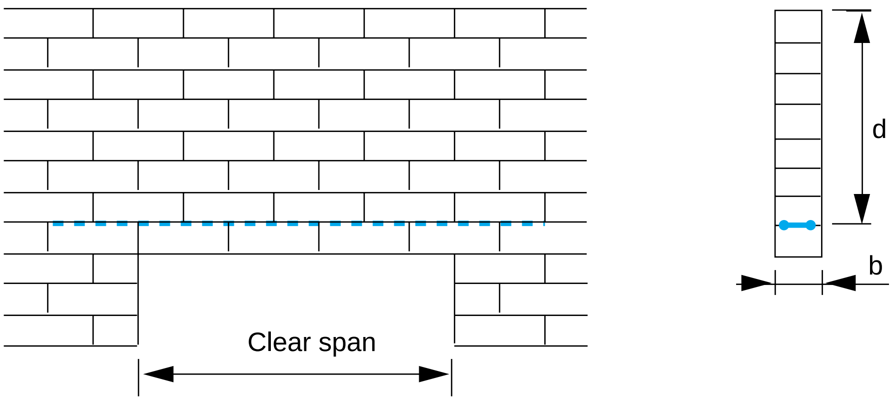
$$\left[\text{check: } \frac{0.4 f_k b d^2}{\gamma_{mm}} = \frac{0.4 \times 6.4 \times 102.5 \times 375^2}{3.5} \times \frac{1}{10^6} = 10.54 \text{ kN m } (>3.76) \right]$$

M_d is greater than M and, therefore, one layer of Murfor® in the bottom bed joint is adequate to carry the load over the opening.

$$\text{Shear stress} = \frac{0.5 \times 1.29 \times 1.8 \times 10^3}{102.5 \times 375} = 0.03 \text{ mm}^2 \ \left(< \frac{0.35}{2.0} = 0.175 \text{ N/mm}^2 \right)$$

Therefore, no shear reinforcement is required.

4.5. Deep Beam Design



(a) Basis of design

Where the ratio of the span to the effective depth of a lintel or beam is less than 1.5, it may be designed as a deep beam.

The general design principles are as for section 4.4 but tension reinforcement should be provided to take the whole of the tensile force, calculated using all the loads supported on the beam and a lever arm equal to two-thirds of the effective depth of the beam, d, with a recommended maximum value equal to 0.5 times the effective span, L.

$$M_d = \frac{A_s\, f_y\, z}{\gamma_{ms}} \text{ N mm}$$

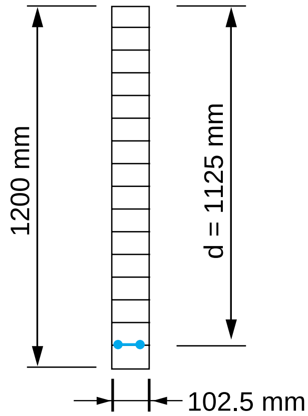
where $z = \frac{2}{3}\,d$ but not greater than 0.5 L

It is recommended that the minimum tensile steel percentage should be taken as 0.05% of the effective area (b d) of the beam, for walls of 100 mm width or more, or 0.075% of the effective area, for walls less than 100 mm wide. It should be noted that it is only necessary to consider the depth of beam required to support the load in calculating the minimum steel percentage, thus keeping the amount of Murfor® to a minimum.

When checking that shear reinforcement is not required, the full effective depth may be used provided that all the loads supported on the wall are taken into account in the design.

(b) Example

Calculate the amount of Murfor® reinforcement in a 1200 mm deep brick beam spanning over an 1100 mm clear opening carrying its self weight plus an imposed load of 10 kN/m.



Assume the brickwork has the same properties as the example in section 4.4.
i.e. f_k = 6.4 N/mm^2 and γ_{mm} = 3.5.

γ_f = 1.4 for dead loads, and γ_f = 1.6 for imposed loads.

Design load on beam = 1.4 x 0.1025 x 1.2 x 20 + 1.6 x 10 = 19.44 kN/m

It is necessary to estimate the effective span of the beam as BS5628: Part 2 does not give adequate guidance for deep beams. Assume the the effective span is say 1.2 x clear span.

Effective span = 1.2 x 1.1 = 1.32 m

$$M = \frac{19.44 \times 1.32^2}{8} = 4.23 \text{ kN m}$$

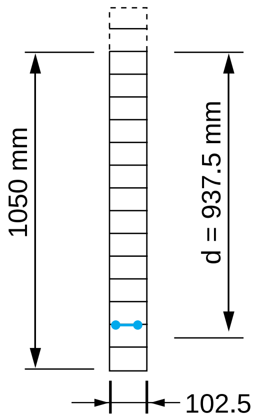
$$\frac{L}{d} = \frac{1320}{1125} = 1.17 \ (< 1.5)$$

$$z = \frac{2}{3} \times 1125 = 750 \text{ mm} \quad (0.5 \times 1320 = 660 \text{ mm})$$

Area of reinforcement required = $\dfrac{4.23 \times 10^6 \times 1.15}{500 \times 660}$ = 14.7 mm^2

minimum area of reinforcement required = $\dfrac{0.05}{100}$ x 102.5 x 1125 = 57.7 mm^2

As the minimum area of reinforcement is excessive, consider a reduced beam depth of 1050 with two layers of Murfor® reinforcement.



$\dfrac{L}{d} = \dfrac{1320}{937.5}$ 1.41 (<1.5)

$z = \dfrac{2}{3}$ x 937.5 = 625 mm (0.5 x 1320 = 660 mm)

Area of reinforcement required = $\dfrac{4.23 \times 10^6 \times 1.15}{500 \times 625}$ = 15.6 mm^2

Minimum area of reinforcement required = $\dfrac{0.05}{100}$ x 102.5 x 937.5 = 48.0 mm^2

[check: $\dfrac{0.4 \times 6.4 \times 102.5 \times 625^2}{3.5} \times \dfrac{1}{10^6}$ = 29.3 kN m (>4.23)]

Therefore, 2 layers of Murfor® reinforcement are adequate

Shear stress = $\dfrac{0.5 \times 19.44 \times 1.1 \times 10^3}{102.5 \times 937.5}$ = 0.11 N/mm^2 (< $\dfrac{0.35}{2.0}$ = 0.175 N/mm^2)

Therefore no shear reinforcement is required.

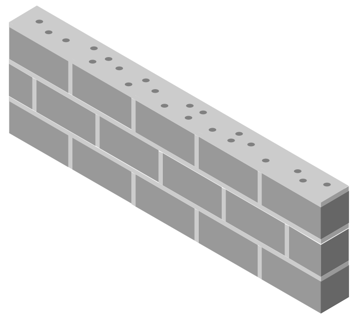
5 Installation of Murfor®

5.1. Mortar bed Joints

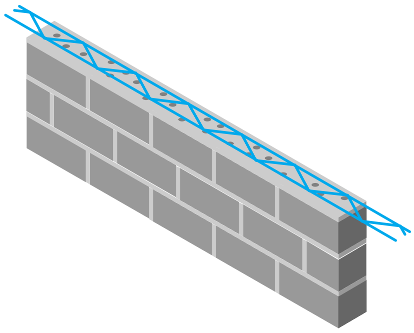
Murfor® (ref. RND) is embedded in the mortar as follows:

- spread out a mortar layer on the bricks or blocks (1).
- press the Murfor® unit into the centre of the mortar layer (2).
- lay the next course of bricks or blocks in the normal way (3).

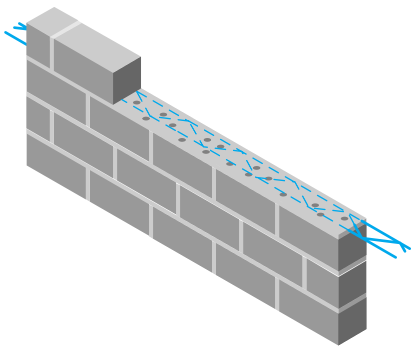
1



2



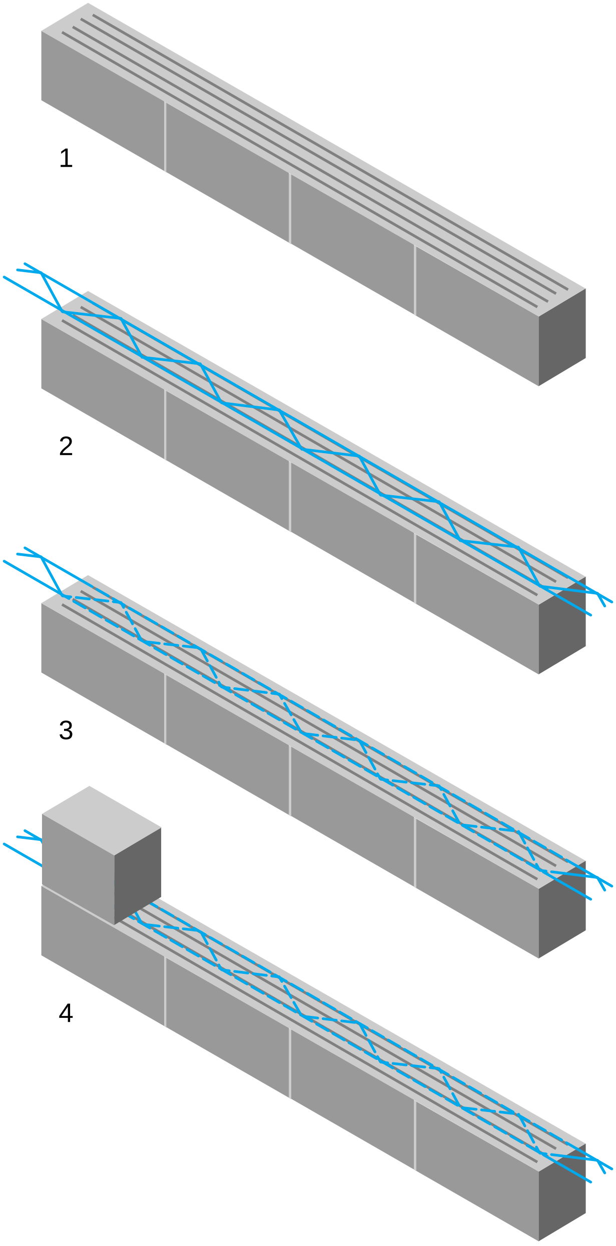
3



5.2. Thin Bed Joints

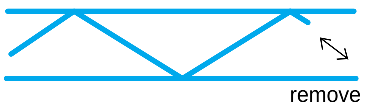
Murfor® (ref. EFS) is embedded in the joints as follows:

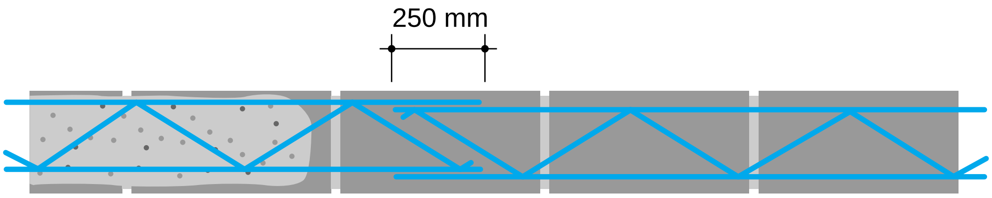
- apply a first layer of the resin mortar to the blocks (1).
- press the Murfor® unit into the resin mortar (2).
- apply a second layer of resin mortar (3).
- lay the next course of block in the normal way (4).



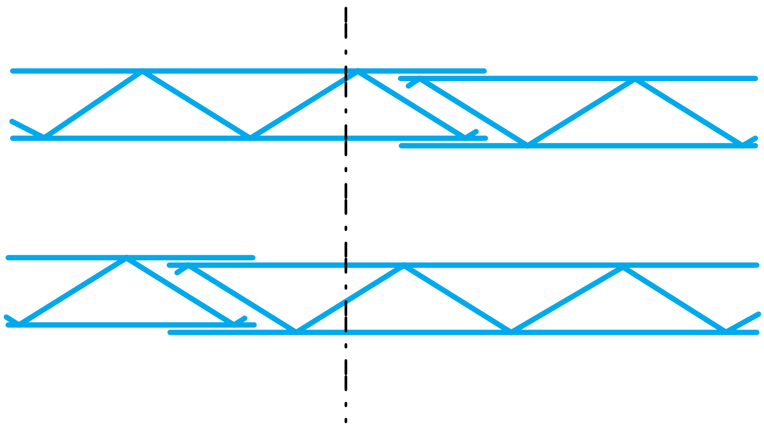
5.3. Laps

When connecting 2 Murfor® units always put them next to each other, and never on top of each other, otherwise the mortar will not cover them sufficiently. The overlap has to be 250 mm. This insures an optimal transfer to the Murfor® units.



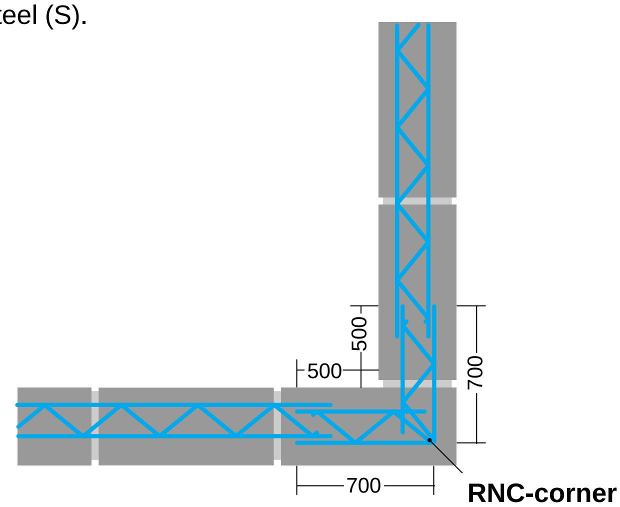


In case overlaps are to be applied in several joints which are situated directly under each other, it must be avoided to position these overlaps in the same vertical plane.

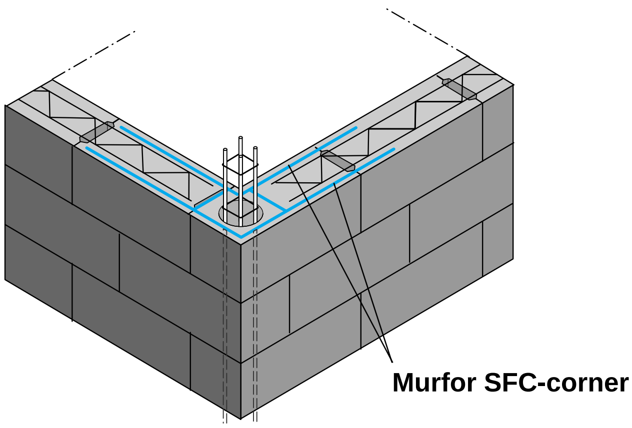


5.4. Corners

To ensure the continuity of the Murfor® reinforcement at the corners, prefabricated corner elements are available (RNC/...). These elements are placed with an overlap of 250 mm. These corner elements exist in galvanised (Z), epoxy-coated (E), and stainless-steel (S).

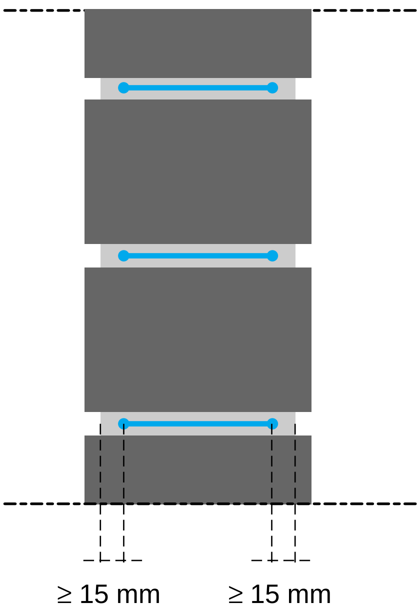


It is very difficult to form corners on the building site when Murfor® EFS is used. Therefore special flat wire Murfor® SFC-corner elements are supplied.



5.5. Mortar Cover and Protection

Murfor® reinforcement should be embedded in such a way that its longitudinal axis lies along the centre line of the wall, with a minimum mortar cover of 20 mm.

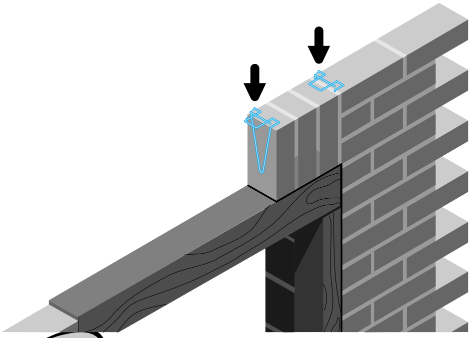


This provides:

- a good transfer of stress between the masonry and the Murfor® reinforcement
- a good protection against corrosion

External cavity walls and walls subjected to dampness or aggressive conditions must be reinforced with stainless steel Murfor® (ref. RND/S).

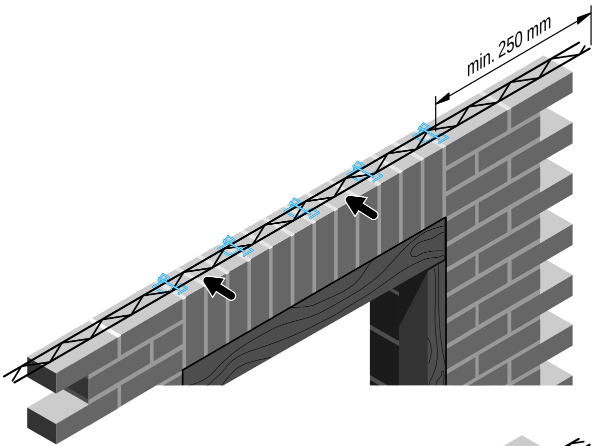
5.6. Masonry Lintels or Beams



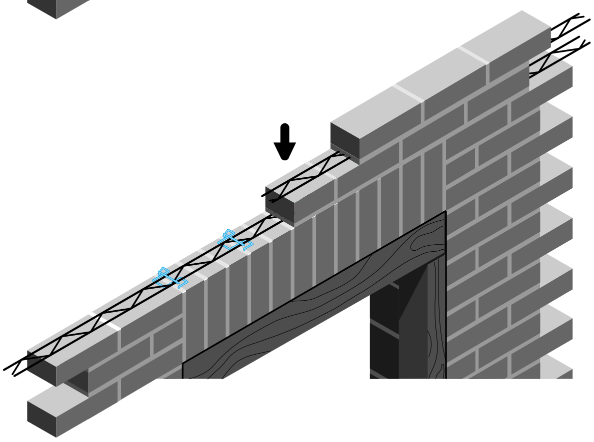
Soldier Course

Every 3rd brick place a lintel hook in the vertical joint.

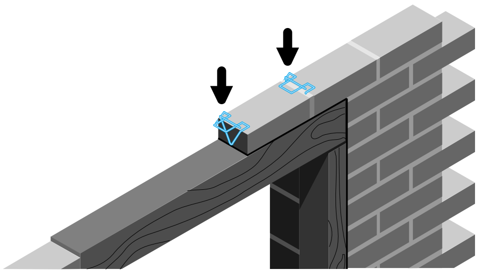
Apply mortar to the brick.
Press the lintel hook in the mortar.



When th soldier course is finished, fix Murfor® RND/S into the lintel hooks.

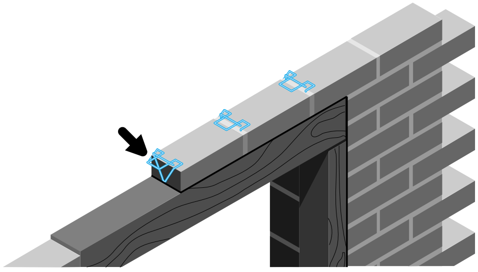


For wider spacing the number of joints to be reinforced must be checked.

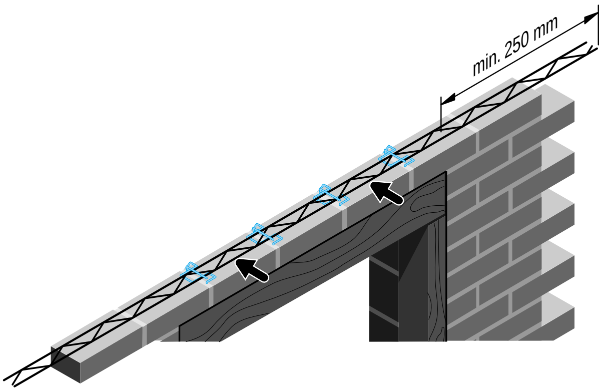


Stretcher course

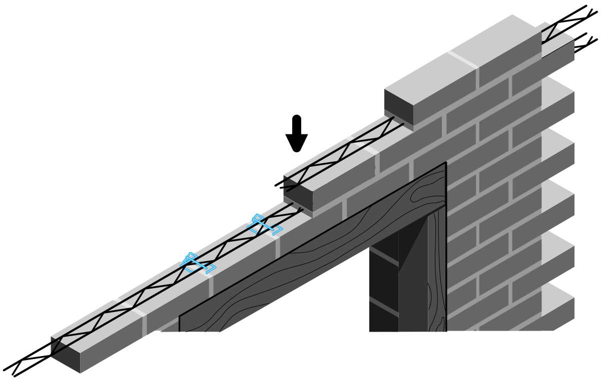
A lintel hook is used in every vertical joint.



The hook ends indicate the position of the lintel hook in the bed joint. This allows for correct positioning of Murfor® reinforcement.



The Murfor® reinforcement is anchored in the arm of the lintel hook.



Wide spans of lintels may require additional Murfor®.

6. Murfor®: Model Specification

Material

Bed joint reinforcement shall be Murfor®, to the sizes specified, supplied by Bekaert Building Products. It shall be a prefabricated lattice manufactured from steel wire with a characteristic tensile strength of 500 N/mm^2, with the cross wire welded to the longitudinal wires within their depth so that the overall depth does not exceed the diameter of the longitudinal wires. The steel shall have a zinc coating of 70 g/m^2 or an additional epoxy coating of 80 microns or be stainless steel.

Workmanship

Murfor® prefabricated bed joint reinforcement, as specified, shall be laid in an even bed of mortar in a continuous strip with 150 mm minimum laps, staggered, and continuous at corners and with a minimum mortar cover of 20 mm from the face.

7. Research reports concerning Murfor® reinforcement

1.[1] "Reinforced Masonry, Final Report", CSTC, January 1979.

2.[2] "Reinforced Masonry", Pfeffermann and P. Baty, June 1981.

3. "The determination of the Performance of Murfor® Reinforcement in Masonry", BCRA, February 1982.

4. "The determination of the Performance of Murfor® Reinforcement in Masonry", BCRA, May 1985.

5. "The resistance to lateral Loading of Cavity Walls with Horizontal Reinforcement", BCRA, October 1978.

6.[1] ".Bond resistance of Murfor® Reinforcement. Papers 1-3", Leuven Research and Development, January-March 1979.

7. Letter from Leuven University reporting the bond characteristics of Murfor® Reinforcement. October 1980.

8. "Report on Tensile Tests on Murfor® Reinforcement in Masonry", BCRA, June 1985.

9.[2] "Investigation into the Corrosion Resistance of Murfor® Reinforcement by means of an Intermittent Submersion Test, TNO Institute, Netherlands, October 1977.

10.[1] "Reinforced Masonry: Study of Corrosion of Reinforcement in Laboratory Wallettes", CSTC, October 1978.

11. "Research on the Physical Behaviour of Reinforced Masonry", Motteu and Pfeffermann, August 1982.

12.[1] "Study of Severe Climatic Conditions on the Shrinkage Behaviour of Concrete Block Masonry with and without Murfor® Reinforcement in the Joints", TNO Institute, Netherlands.

13.[1] "Reinforced Brickwork with Clay and Calcium-Silicate Bricks and Murfor® Bed Joint Reinforcement", Institute of Building and Construction, Zürich, April 1984.

14.[1] "Research in the Coefficient of Thermal Conductivity of a Cavity Wall", A. Nicolaus, September 1976.

15. "Murfor® reinforcement. Research into the use of masonry reinforced with Murfor®", Jenkins & Potter, April 1986.

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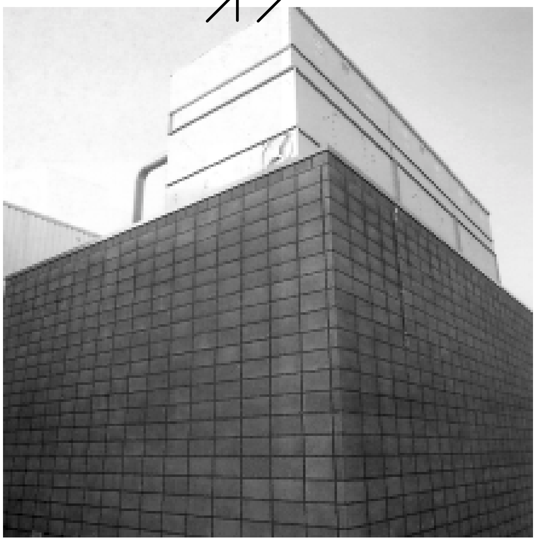
(1) Not available in English
(2) Not in English but translation available from N.V. Bekaert S.A.

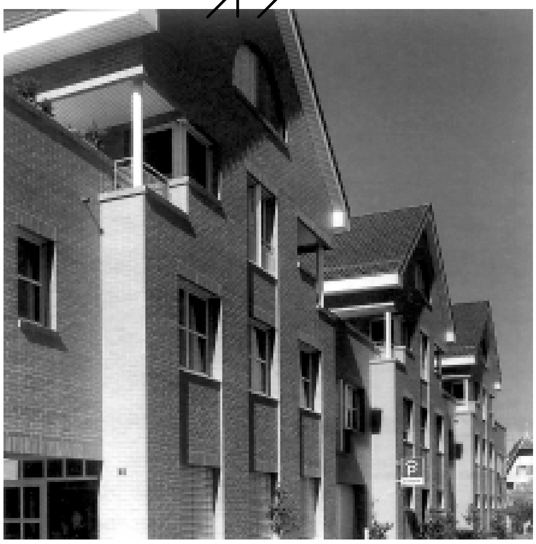
8. Examples of the architectural use of Murfor®



Non stack bonded blockwork
Moen Bekaert
Architect P.Tuts

Lintels in reinforced masonry
Zürich

Fairfaced blockwork
Genève



New architectural possibilities with Murfor®
Switzerland

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