Structural Design - An introduction

Structural information is provided for the design of loadbearing and non-loadbearing walls and includes the following:

- Design of Low Rise Housing
- Designing with higher strength blockwork
- Designing to Eurocode 6 - vertical loading
- Mortar
- Material safety factors and manufacturing control
- Sizing of internal non-loadbearing walls
- Use of cellular and hollow units
- Chasing into blockwork

Design of Low Rise Housing

Simple design guidance for low rise housing can be found in the following documents:

- The Building Regulations Approved Document 'A' for England and Wales
- Small Buildings Structural Guidance document for the Building (Scotland) Regulations
- BS 8103-2 (Structural design of low rise buildings – Part 2 Code of Practice for Masonry Walls for housing).

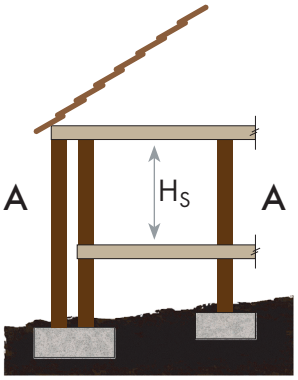
These provide block compressive strength requirements for low-rise buildings as well as for domestic extensions.

The general structural requirements of these documents are summarised in Fig.1:

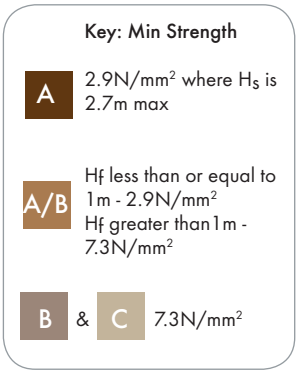
- for two storey housing the minimum strength for blocks is 2.9N/mm^2. In practice 3.6N/mm^2 blocks will usually be specified as these are commonly available products
- for three storey housing, the lowest storey is 7.3N/mm^2, whilst 2.9N/mm^2 (or 3.6N/mm^2) is retained at the two upper levels

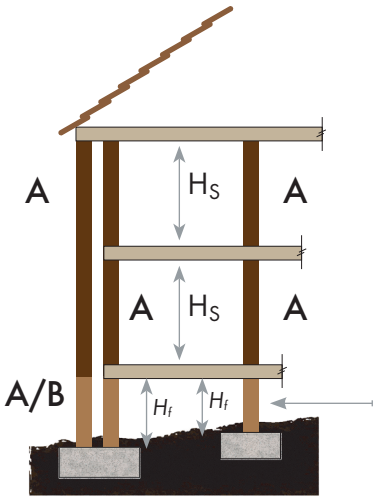
Thus 3.6 and 7.3N/mm^2 products from the Lignacite range can be used to these locations with confidence.

Figure 1 - Blockwork strength requirements

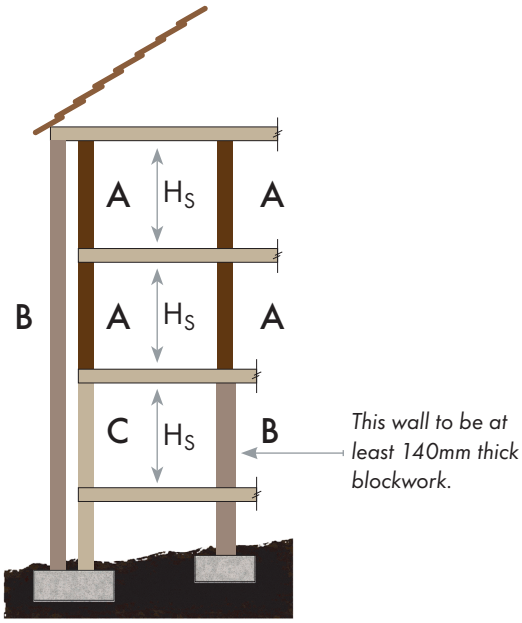


Single Storey





Two Storeys



Three Storeys

Notes:

(1) If H_s is not more than 2.7m, the compressive strength of blocks used int the wall should be as indicated by the key
(2) If H_s is more than 2.7m, the compressive strength of blocsk used int the wall should be at least Condition B, or as indicated by the key whichever is greater
(3) If the external wall is sold construction, the blocks should have a compressive strength of at least that shown for the internal leaf of a cavity wall in the same position.
(4) Timber roof construction,12m max span
(5) Timber or concrete floor,6m max span
(6) Wall lengths,12m max.

This diagram is created from Figure 12 and Table 5 of BS 8103-2.

Where the building layout falls outside the scope of this guidance, or greater than three storeys, a structural design calculation is necessary.

Designing with higher strength blockwork

Normalised Strengths

Highly loaded loadbearing walls can be proven by utilising the higher compressive strength blocks available from Lignacite, with an upper most strength of 30N/mm^2. In such cases the structural design will be in accordance with BS-5628-1 or Eurocode 6. In either case similar factors will need to be taken into account when assessing the loadbearing capability of the wall:

a) The characteristic strength of the masonry (fk), which will depend on the block size, block compressive strength and mortar strength
b) The material safety factor and the quality control of the blocks used as well as the site workmanship
c) The thickness and height of the wall (effective thickness and height)
d) The effects of loading loading that result in an eccentricity at right angles to the wall.

Designing to Eurocode 6 - Vertical Loading

Normalised Strengths

When designing to Eurocode 6, normalised strengths are used, taking into account the shape factor and bringing the unit strength back to a100mm cube equivalent. As the UK quote actual block strengths, as opposed to a cube strength, the Tables 6.1and 6.2) below show the shape factor conversion, and the equivalent normalised strength in accordance with BS EN 772-1, Table A.1.

Table 6.1– Shape Factor correction factor (based on a 215mm height block)

Block width (mm)	100	140	190	215
215mm height blocks	1.38	1.30	1.20	1.16

Table 6.2– Interpolated shape factors for other Lignacite masonry unit sizes.

	Unit widths (mm)		
Unit height	100	140	215
65mm	0.85	0.77	-
100mm eg blocks laid flat [1]	-	-	0.79 [2]

Notes

[1] 100mm high units are units laid flat. Unit strengths are usually given for units laid in their normal aspect and not laid flat. Laid flat unit strengths are usually much greater than the normal aspect strength. The laid flat air dry strength should be multiplied by the appropriate shape factor from Table 6.1.

[2] Shape factor for units 215mm high in normal aspect when laid flat.

Table 6.3– Normalised strengths for 215mm high units.

Unit strength to BS EN 771-3	Normalised strengths for unit widths of			
	100mm	140mm	190mm	215mm
3.6	5.0	4.7	4.3	4.2
7.3	10.1	9.5	8.8	8.5
10.4	14.3	13.5	12.5	12.1
17.5	24.1	22.7	21.0	20.3
22.5	31.0	29.2	27.0	26.1
30.0	41.4	39.0	36.0	34.8

Mortar

For the majority of applications a general-purposes mortar will be specified and is defined as a mortar with a thickness greater than 3mm, although 10mm is commonplace. Such mortars are produced using normal-weight aggregates.

Mortars should be specified according to their compressive strength. An M4 mortar is 4N/mm^2 mortar based on a mean compressive strength at 28 days. Prescribed mortars (described by their constituent materials) are in common use eg. a 1:1:5 cement:lime:sand mix, do not have a corresponding 'M' value although they will have strength properties. A comparison of mortar designations from BS 5628 can be compared in compressive strength terms with those described in Eurocode 6, as shown in Table 6.4.

Table 6.4– Equivalent mortar mixes – BS 5628 and BS EN 1996

Mortar designation - BS 5628	Compressive strength class - BS EN 1996
(i)	M12
(ii)	M6
(iii)	M4
(iv)	M2

When selecting the mortar strength Class/Designation, the following guidance may assist designers:

Above ground - Loadbearing and non-loadbearing walls (of moderate compressive strength).	A mortar strength Class M4 will normally be specified.
Above ground - High strength blockwork >10.4N/mm^2	In most cases a mortar strength Class M4 will be sufficient. Although the maximum permissible stresses in a wall will be gained using a stronger mortar this will need to be balanced with a decreasing ability of the wall to accommodate movement. Loadbearing walls are rarely loaded to their ultimate safe working limit, therefore only in exceptional cases will the use of a stronger mortar be required.

Below ground - Blockwork used with a high risk of saturation with freezing.	A mortar strength Class M6 will normally be specified.
Reinforced blockwork e.g. Hollow blockwork with vertical reinforcement.	A mortar strength Class M12 or M6 will normally be specified

Further information on use of mortar may be found in the following publications:

- *Lignacite Design Guidance - Mortar*
- *Published Document PD 6697 'Recommendations for the design of masonry structures to BS EN 1996-1-1 and BS EN 1996-2*
- *BS EN 1996-2:2006 Eurocode 6. Design of masonry structures. Design considerations, selection of materials and execution of masonry.*

Material safety factors and manufacturing control

For blockwork strengths, the partial safety factor, yM, is subject to the level of manufacturing control of the masonry units and the execution of the work on site.

For manufacturing control, two categories of manufacture are described, with the manufacturer declaring the masonry units to be Category I or Category II. Lignacite Ltd. operate to Category I manufacturing control, supported by certification of its factory production control by an approved body. This allows a lower partial safety to be applied leading to more economic masonry design.

For execution on site, two levels of control are also provided - Class 1 and Class 2, depending on the level of supervision and inspection.

The relevant values of yM can be found in Table NA.1 of the National Annex to Eurocode 6, Part 1-1.

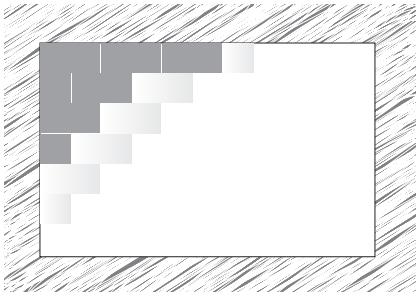
Sizing of internal Non-loadbearing Walls

The following tables provide limiting dimensions for internal non- loadbearing walls for various conditions of lateral restraint. The data has been developed in accordance with EN 1996- 3 (Annex B) for unplastered walls This is applicable to all Lignacite block types.

The data is applicable to walls that are not subject to vertical loads and only limited lateral load.

For practical considerations e.g. the provision of movement joints, the maximum wall length has been limited to 9.0m. Wall lengths above 9.0m are permissible, but designers will need to ensure that adequate precautions are taken to limit the adverse effects of movement.

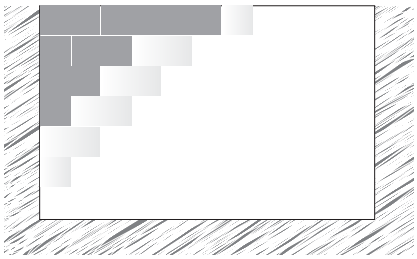
Limiting sizes of internal non-loadbearing walls



Walls restrained at both ends and top

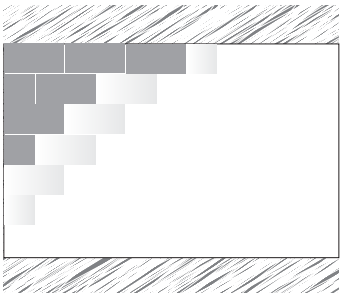
Minimum block thickness (mm)				
	Length (m)			
Height (m)	100	140	190	215
2.4	9.0	9.0	9.0	9.0
2.7	9.0	9.0	9.0	9.0
3.0	9.0	9.0	9.0	9.0
3.3	9.0	9.0	9.0	9.0
4.0	8.0	9.0	9.0	9.0
5.0	4.0	9.0	9.0	9.0
6.0	3.5	9.0	9.0	9.0

Sizing of internal Non-loadbearing Walls (cont)



Walls restrained at both ends

Minimum block thickness (mm)				
	Length (m)			
Height (m)	100	140	190	215
2.4	5.4	9.0	9.0	9.0
2.7	5.2	9.0	9.0	9.0
3.0	5.1	7.5	9.0	9.0
3.3	5.0	6.9	9.0	9.0
4.0	4.7	6.5	9.0	9.0
5.0	4.3	6.0	9.0	9.0
6.0	4.0	5.6	9.0	9.0



Walls with lateral support top and bottom

	Minimum block thickness (mm)			
	100	140	190	215
Maximum wall height (m)	3.0	4.2	5.7	6.4

Notes:

(1) For details of suitable lateral restraints, see EN 1996-1-1.
(2) In determining the appropriate thickness of blockwork walls, consideration should also be given to the accommodation of movement and the effect on stability of openings, chases, etc.
(3) Where upper floors are subject to deflection or thermal movement, suitable precautions should be taken to avoid accidental load transfer or excessive differential movement from taking place.

Use of Cellular and Hollow units

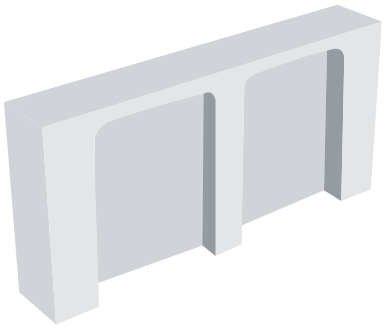
Cellular and hollow units can be used in loadbearing walls. For designs to Eurocode 6, the designer will need to know what configuration the units conform to, i.e. Group 1 or 2. The following diagrams provide this data, together with the dimensions of the wall thicknesses for each size of unit.

Hollow units are particularly suitable where walls require strengthening to withstand high lateral forces, such as basement and freestanding retaining walls. The vertical cores can be reinforced with steel bar and infill concrete. If used on the external leaf of a cavity wall, cellular and hollow units should be protected by a suitable cladding or rendering.

The Concrete Block Association recommends that chasing should be limited as flows:

- The depth of vertical chasing should be restricted to not greater than 1/3 block thickness or 1/6 the thickness for horizontal chases
- The depth of the chase should be restricted to ensure that a minimum shell thickness of 15mm is maintained between the bottom of the chase and the voids.

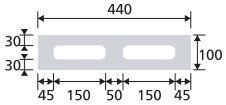
Cellular



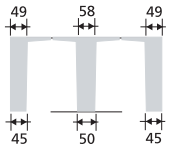
A sectional perspective

100mm width Group 1 unit, to BS EN 1996-1-1

Horizontal section

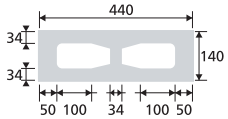


Vertical section

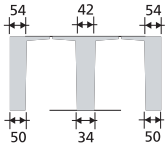


140mm width Group 2 unit, to BS EN 1996-1-1

Horizontal section

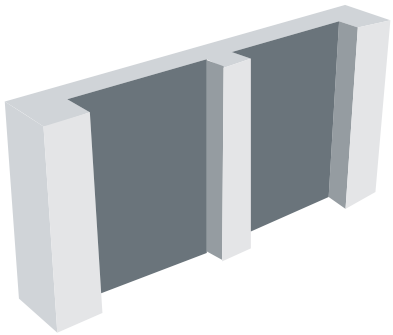


Vertical section



Use of Cellular and Hollow units (cont)

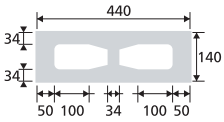
Hollow



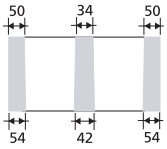
A sectional perspective

140mm Group 2 unit, to BS EN 1996-1-1

Horizontal section

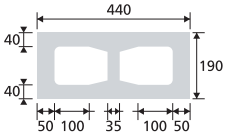


Vertical section

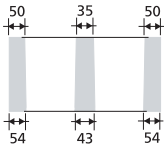


190mm width Group 2 unit, to BS EN 1996-1-1

Horizontal section

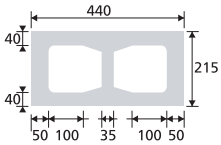


Vertical section

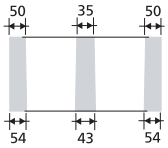


215mm width Group 2 unit, to BS EN 1996-1-1

Horizontal section



Vertical section



Note: 10mm mean base thickness
Core taper of 4mm from top to bottom

Chasing into blockwork

Without calculation

Chases and recesses can be made to masonry walls, providing that they do not impair the stability of the wall. The values for the maximum depth of vertical and horizontal chases allowed without calculation are shown in Tables 6.5 and 6.6.

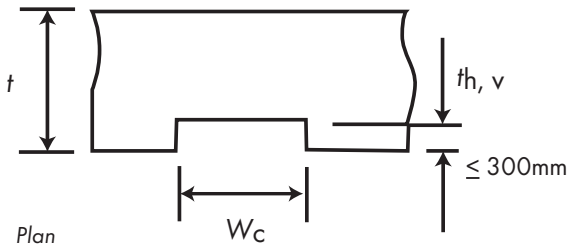
Table 6.5 - sizes of vertical chases and recesses in masonry, allowed without calculation.

	Chases and recesses formed after construction of masonry		Chases and recesses formed during construction of masonry	
Thickness of wall *t* (mm)	Max depth $t_{ch,h}$ (mm)	Max width W_c (mm)	Minimum wall thickness remaining t_r (mm)	Max width W_c (mm)
75 - 89	30	75	60	300
90 - 115	30	100	70	300
116 - 175	30	125	90	300
176 - 225	30	150	140	300
226 - 300	30	175	175	300
> 300	30	200	215	300

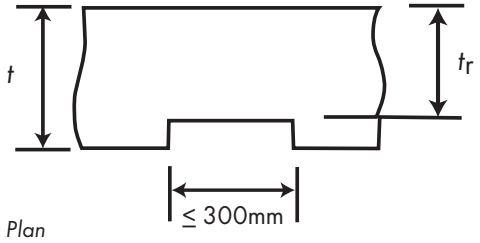
Notes:

(1) The maximum depth of the chase should include the depth of any hole reached when forming the chase.
(2) Vertical chases which do not extend more than one third of the storey height above floor level may have a depth of up to 80mm and a width of up to 120mm, if the thickness of the wall is 225mm or more.
(3) The horizontal distance between adjacent chases or between a chase and recess or an opening should not be less than 225mm.
(4) The horizontal distance between any 2 adjacent recesses, whether they occur on the same side or on opposite sides of the wall, or between a recess and an opening, should not be less than twice the width of the wider of the two recesses.
(5) The cumulative width of vertical chases and recesses should not exceed 0.13 times the length of the wall.
(6) This table is based on the National Annexe to EC6 Part 1-1.

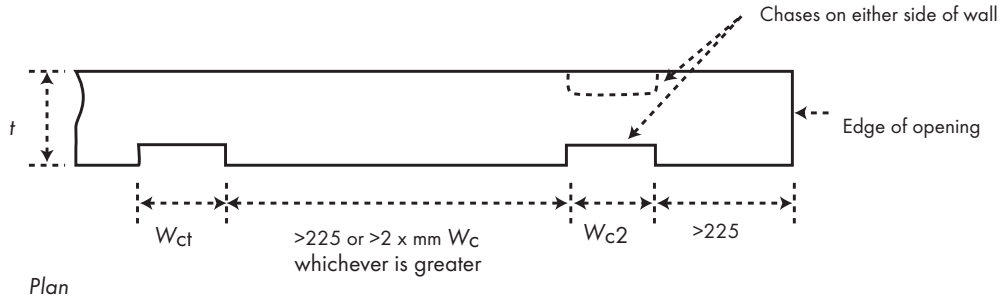
Formed after construction



Formed during construction

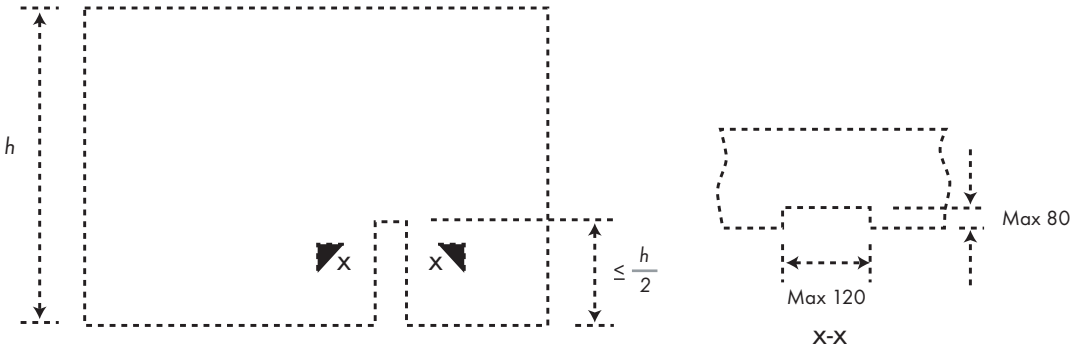


Spacing of chases



Plan

Chases in bottom section of wall, in walls ≥ 225mm thick



Wall elevation

Note: The cumulative width of vertical chases ≤ 0.13 times length of wall.

Table 6.6 - Sizes of horizontal and inclined chases in masonry, allowed without calculation.

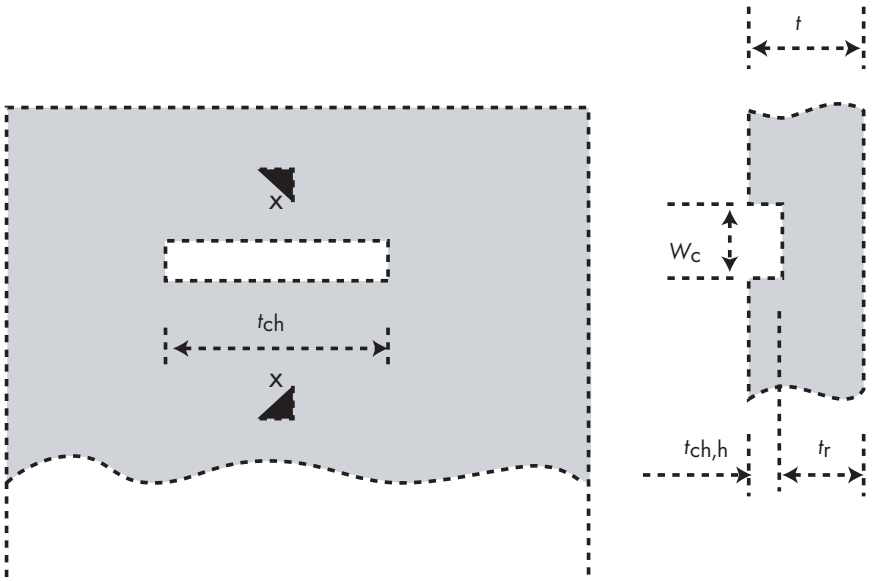
Thickness of wall *t* (mm)	Max depth $t_{ch,h}$ (mm)	
	Unlimited length l_{ch}	length $l_{ch} \leq$ 1250mm
75 - 84	0	0
85 - 115	0	0
116 - 175	0	15
176 - 225	10	20
226 - 300	15	25
over 300	20	30

Notes:

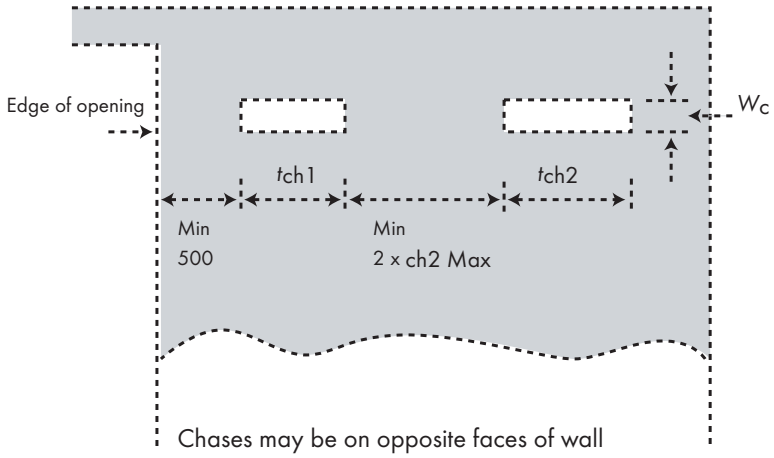
(1) The maximum depth of the chase should include the depth of any hole reached when forming the chase.
(2) The horizontal distance between the end of a chase and an opening should not be less than 500mm.
(3) The horizontal distance between adjacent chases of limited length, whether they occur o the same side or on opposite sides of the wall, should be not less than twice the length of the longest chase.
(4) In walls of thicknesses greater than115mm, the permitted depth of the chase may be increased by 10mm if the chase is machine cut accurately to the required depth. If machine cuts are used, chases up to 10mm deep may be cut in both sides of walls of thickness not less than 225mm.
(5) The width of chase should not exceed the residual thickness of the wall.
(6) This table is based on the National Annexe to EC6 Part 1-1.

Spacing of chases

Wall elevation



Wall elevation



$W_c \leq \frac{t_r}{2}$ (see above)

Notes:

(1) For walls thicker than 175mm, $t_{ch,h}$ may be increased by10mm if accurate machine cutting is used.

(2) Horizontal chases should be positioned within one eight of the clear height of the wall (above or below a floor).

(3) The rules for horizontal chases also apply to inclined chases.