PARTNERS IN WALL BUILDING

Characteristic strengths of masonry

Determination of characteristic compressive strength of masonry, f_k

Currently in the UK, masonry design may be carried out in accordance with Eurocode 6 (EC6) EN1996-1-1 or the withdrawn British Standard BS5628 (withdrawn meaning that it will no longer be maintained or updated by BSI). A basic difference between the EC6 approach and that of BS5628 is that EC6 uses a formula to calculate the characteristic compressive strength of masonry, f_k, whereas BS5628:Pt1 is based on tabulated values.

These tables take into account mortar mixes, different sizes of units (height to thickness ratios) and strength of units. Although previously unit strengths in the UK were based on saturated units (in accordance with BS6073), these have now been replaced by air dry strength values in accordance with the European product standards (EN 771 series) - block strengths in BS5628 were changed to reflect this so that, for example, an old 7.0N/mm² is now 7.3N/mm².

For designs to BS5628, the characteristic compressive strength of masonry, f_k, should be obtained from Tables 2a - 2h (based on mortar strength and size of masonry unit). Given below are values interpolated from BS5628 Table 2 which are relevant to walls constructed with H+H aircrete blocks.

Table 1: Characteristic compressive strength, fk, of masonry (to BS5628:Pt1) for H+H aircrete blocks

			Designation (iii) / M4 mortar					Celfix thin layer mortar			
			Block type (declared compressive strength)					Block type (declared compressive strength)			
Block Height	Block Thickness	H/t	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)	Aggregate block* (10.4)	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)
140	215	0.65	1.5	1.8	3.3	3.7		1.5	1.8	3.5	4.0
	300	0.47	1.3	1.5	2.9	3.3		1.3	1.5	3.1	3.5
	350	0.40	1.2	1.4	2.7	3.1		1.2	1.4	2.9	3.3
215	75	2.87	2.8	3.5	6.4	7.2		2.8	3.5	6.8	7.7
	100	2.15	2.8	3.5	6.4	7.2	8.2	2.8	3.5	6.8	7.7
	140	1.54	2.3	2.9	5.3	6.0	6.8	2.3	2.9	5.7	6.4
	150	1.43	2.2	2.8	5.1	5.8	6.5	2.2	2.8	5.4	6.1
	200	1.08	1.9	2.3	4.3	4.8		1.9	2.3	4.6	5.2
	215	1.00	1.8	2.2	4.1	4.6	5.3	1.8	2.2	4.4	4.9
	275	0.78	1.6	1.9	3.6	4.1		1.6	1.9	3.8	4.3
	300	0.72	1.5	1.8	3.5	3.9		1.5	1.8	3.7	4.2
	325	0.66	1.5	1.8	3.3	3.8		1.5	1.8	3.5	4.0
	350	0.61	1.4	1.7	3.2	3.6		1.4	1.7	3.4	3.9
250	100	2.50						2.8	3.5	6.8	7.7
	140	1.79						2.6	3.2	6.3	7.1
350	100	3.50						2.8	3.5	6.8	7.7

* Aggregate block by others, included for comparison purposes only

All thicknesses shown in each strength for comparison purposes. Please consult H+H Sales Office 01732 886444 for availability of sizes.

Given the vast array of different materials, sizes and shapes of units available across Europe, it was decided when developing EC6 that a single formula approach would be more viable than a tabulated one. However, in order for this to work then the compressive strength of each unit would have to be standardised or "normalised". The normalised mean compressive strength, f_b, used in EC6 is the compressive strength of an air dry 100mm cube of a masonry unit.

Normalised compressive strength, f_b, of blocks

The normalised compressive strength of a masonry unit is a calculated value used to determine the wall strength and should not be confused with the declared mean compressive strength of a block which is a measured property. The values currently declared by manufacturers in the UK are mean air dry strengths for the complete brick or block unit (eg for aircrete 2.9, 3.6, 7.3 and 8.7N/mm²). Compressive strengths are given in N/mm², ie it is the compressive stress of material. The thickness of the blocks are therefore irrelevant (although a 140mm thick block will obviously carry more load than a 100mm block by virtue of its greater area). In order to obtain the normalised strength, the declared mean strengths will need to be multiplied by a shape factor relative to the size of the unit.

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The value of the shape factor is given in Table A.1 of EN 772-1 (relevant values applicable to H+H blocks have been interpolated and are given in the table below).
Although it appears that compressive strength varies with size, it is worth noting that it is not the strength of the masonry unit which alters with its size but merely the effect it has on the overall strength of the wall into which is built.

Table 2: Normalised compressive strengths, f_b, for H+H aircrete blocks in N/mm²

Block			Block type (declared compressive strength, N/mm²)				
Height	Thickness	Shape factor	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)	Aggregate block* (10.4)
140	215	0.95	2.7	3.4	6.9	8.2	
	250 +	0.91	2.6	3.3	6.6	7.9	
215	75	1.43	4.1	5.1	10.4	12.4	
	100	1.38	4.0	5.0	10.1	12.0	14.4
	140	1.30	3.8	4.7	9.5	11.3	13.5
	150	1.28	3.7	4.6	9.3	11.1	13.3
	200	1.18	3.4	4.2	8.6	10.3	
	215	1.16	3.4	4.2	8.5	10.1	12.1
	250 +	1.12	3.2	4.0	8.1	9.7	
250	100	1.45	4.2	5.2	10.6	12.6	
	140	1.37	4.0	4.9	10.0	11.9	
350	100	1.45	4.2	5.2	10.6	12.6	

* Aggregate block by others, included for comparison purposes only

The characteristic compressive strength of masonry designed to BS EN 1996-1-1 is given by

$$f_k = K \cdot f_b^{\alpha} \cdot f_m^{\beta}$$

Clause 5.7.1.3 (1)

Where f_b is the normalised compressive strength of the unit, f_m is the mortar strength (not greater than f_b) and K, α and β are constants taken from the UK National Annex.

Table 3: Characteristic compressive strength, f_k, of masonry (to EC 6) for H+H aircrete blocks in N/mm²

Block		Designation (iii) / M4 mortar (K = 0.75, α = 0.7, β = 0.3, fm = 4N/mm²) — Block type (declared compressive strength, N/mm²)					Celfix thin layer mortar (K = 0.9, α = 0.85, β = 0, fm = 10N/mm²) — Block type (declared compressive strength, N/mm²)			
Height	Thickness	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)	Aggregate block* (10.4)	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)
140	215	2.1	2.6	4.4	5.0		2.1	2.5	4.6	5.4
	250 +	2.0	2.5	4.3	4.8		2.1	2.5	4.5	5.2
215	75	2.9	3.6	5.9	6.6		2.9	3.6	6.6	7.7
	100	2.9	3.5	5.7	6.5	7.3	2.9	3.5	6.4	7.4
	140	2.8	3.3	5.5	6.2	7.0	2.8	3.3	6.1	7.1
	150	2.8	3.3	5.4	6.1	7.0	2.7	3.3	6.0	7.0
	200	2.6	3.1	5.1	5.8		2.6	3.1	5.6	6.5
	215	2.5	3.1	5.1	5.7	6.5	2.5	3.0	5.5	6.4
	250 +	2.4	3.0	4.9	5.6		2.4	2.9	5.3	6.2
250	100						2.9	3.6	6.7	7.8
	140						2.9	3.5	6.4	7.4
350	100						2.9	3.6	6.7	7.8

* Aggregate block by others, included for comparison purposes only

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Determination of vertical load resistance of a wall

It should be noted that it would not be correct to compare f_k values in isolation as the determination of characteristic compressive strength of the masonry is a starting point for determining the load bearing capacity of a wall rather than a final answer. The load resistance of a wall depends not only on its compressive strength but also on its height, length, restraint conditions etc.

For example, the design vertical load resistance of a wall is given in BS5628 as $(\beta.t.f_k)/\gamma_m$ where β is the capacity reduction factor allowing for the effect of slenderness and load eccentricity. Similarly, in EC6 it is given by $Ø.t.(f_k/\gamma_M)$, where Ø is the capacity reduction factor allowing for the effect of slenderness and load eccentricity.

However, the similarity ends there because there are significant differences in the way the two codes calculate slenderness and eccentricities. Consequently, although the comparative f_k values appear different to start with, the final answers in terms of the load resistance of a wall should be fairly similar. It is worth noting, therefore, that specific values obtained whilst working with the two codes are not interchangeable (eg f_k obtained using one code should not be applied to the other).

National Annex

As with the product standards, standardising design codes across Europe has proved to be a complicated and long drawn out process. Whilst the aim was to adopt a single design procedure, it was also equally, if not more, important not to end up with a document which would give significantly different answers to those obtained using existing National Standards in each country - hence the introduction of the National Annexes.

It is therefore important to work with the National Annex to EN1996-1-1 as the figures given therein have been specifically developed to give a final answers which are comparable to design calculations made to BS5628.

Characteristic flexural strength of masonry, f_{kx}

The design for lateral load in EC 6 is based on UK design practice and is similar to BS5628:Pt 1 with the values for characteristic flexural strength in the National Annex being identical to the values BS5628. Interpolated figures relevant to H+H aircrete are given in Table 4 below.

Table 4: Characteristic flexural strength, f_{xk1} and f_{xk2}, of masonry to EC 6 for H+H aircrete blocks in N/mm²

	Values of f_{kx1} Plane of failure parallel to bed joints 				Values of f_{kx2} Plane of failure perpendicular to bed joints 			
Block thickness (mm)	Block type (declared compressive strength, N'mm²)				Block type (declared compressive strength, N'mm²)			
	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)	Solar (2.9)	Standard (3.6)	High Strength (7.3)	Super Strength (8.7)
75	0.25				0.40	0.45	0.60	0.60
100	0.25				0.40	0.45	0.60	0.60
140	0.22				0.36	0.40	0.53	0.53
150	0.22				0.35	0.38	0.52	0.52
200	0.18				0.30	0.32	0.43	0.43
215	0.17				0.29	0.30	0.41	0.41
250 +	0.15				0.25	0.25	0.35	0.35

Values applicable to walls built with both traditional M4 mortar or H+H Celfix thin layer mortar

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Benefits of Celfix thin layer mortar

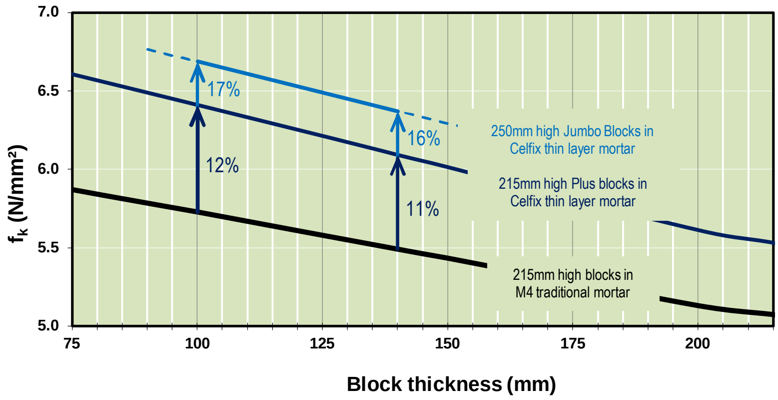
Effect of thin layer mortar on characteristic compressive strength

Although BS5628 recognises the use of thin layer mortars, the benefit in design is limited as the code states that the characteristic wall compressive strengths tabulated for Designation (i), or M12, mortars should be used. Wider European experience of thin layer mortars has meant that the formula derived for EC6 gives more enhanced values for walls built using thin layer mortars when compared to traditional mortars.

Fig 1 below shows the characteristic compressive strength, f_k, to EC6 for a wall built using our Celfix thin layer mortar and a traditional designation (iii) M4 mortar, both with our High Strength (7.3N/mm²) blocks. For a 100mm thick wall, an enhancement of 12% can be achieved by adopting a thin layer mortar in conjunction with High Strength. Similarly, an enhancement of up to 15% can be achieved for Super Strength blockwork. These can be further improved if used in combination with our larger format (250mm high) Jumbo blocks.

The improvement effect of thin layer mortar is less pronounced with Standard grade blocks (3 - 4%) and negligible with Solar due to the fact that the mortar strength is limited to block strengths in the formulae for f_k.

Fig 1: Comparison of EC6 f_k values for High Strength grades of H+H blockwork



Effect of partial safety factors

Both compressive and flexural design strengths incorporate a material partial safety factor in their determination. H+H High Strength (7.3N/mm²) and Super Strength (8.7N/mm²) blocks are manufactured to special category of manufacturing control (ie Category I) which permits a reduced material partial safety factor to be used in design calculations. Furthermore, our Celfix thin layer mortar is factory produced to BS EN 998-2 which enables the utilisation of special category of construction control (Class 1 execution control in EC6).

These two factors combined mean that a reduced partial safety factor, γ_m, of 2.5 (BS 5628:Pt1 Table 4) may be used for both compression and flexure when designing to BS 5628 (see Table 5 below).

This can be equivalent to an additional improvement of at least 20% to wall strength when compared to the safety factors of 3.1 or 3.5 normally assumed.

Standard (3.6N/mm²) and Solar (2.9N/mm²) blocks are normal category (Category II), therefore a slightly higher safety factor of 2.8 applies to compressive strength although 2.5 is still applicable for flexure.

Table 5: Partial Safety factors for material strength γ_m from BS5628:Pt 1 Table 4

	Grade of H+H aircrete		Category of manufacturing control	Category of construction control		
				Traditional mortar		H+H Celfix thin layer mortar *
				Special	Normal	
Compression, γ_m	Super Strength	(8.7N.mm²)	Category I	2.5	3.1	2.5
	High Strength	(7.3N.mm²)				
	Standard	(3.6N.mm²)	Category II	2.8	3.5	2.8
	Solar	(2.9N.mm²)				
Flexure, γ_m	Super Strength	(8.7N.mm²)	Category I	2.5	3.0	2.5
	High Strength	(7.3N.mm²)				
	Standard	(3.6N.mm²)	Category II			
	Solar	(2.9N.mm²)				

* Use of H+H Celfix thin layer mortar would enable Special category of construction control to be assumed

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For designs to EC6, the UK National Annex offers similar, though less pronounced, benefits. Values for γ_M for the ultimate limit state are given in Table NA.1 of the National Annex (see Table 6 below).
In addition, it offers advantages to designers with regards to safety factors where the masonry is an infill panel to a framed structure. Panels within a framed structure can be classified as being in 'laterally loaded wall panel when the removal of the panel would not affect the overall stability of the building'.

Table 6: Partial Safety factors for material strength γ_M from NA to BS EN 1996-1-1, Table NA.1

	Grade of H+H aircrete		Category of manufacturing control	Class of execution control		
				Traditional mortar		H+H Celfix thin layer mortar *
				1	2	
Compression, γ_M	Super Strength	(8.7N.mm²)	Category I	2.3	2.7	2.3
	High Strength	(7.3N.mm²)				
	Standard	(3.6N.mm²)	Category II	2.6	3.0	2.6
	Solar	(2.9N.mm²)				
Flexure, γ_M (when removal of panel would affect overall stability of the building)	Super Strength	(8.7N.mm²)	Category I	2.3	2.7	2.3
	High Strength	(7.3N.mm²)				
	Standard	(3.6N.mm²)	Category II			
	Solar	(2.9N.mm²)				
Flexure, γ_M (when removal of panel would not affect overall stability of the building)	Super Strength	(8.7N.mm²)	Category I	2.0	2.4	2.0
	High Strength	(7.3N.mm²)				
	Standard	(3.6N.mm²)	Category II			
	Solar	(2.9N.mm²)				

* Use of H+H Celfix thin layer mortar would enable Class 1 execution control to be assumed

Note:
References given above refer to the latest version of BS EN1996-1-1 (2022), and its National Annex published in 2024. Notwithstanding, the previous 2013 version is still valid and will not be withdrawn until 30 March 2028.

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