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DETERMINATION OF SHAPE FACTORS FOR MASONRY UNITS

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Abstract

In the testing of masonry units for compressive strength the platen restraint influences the test value of the compressive strength as a function of the test specimen size. This effect is not present in the masonry, the masonry unit format does not directly influence the masonry compressive strength, so that the dependence of the test value on the format has to be taken into account. This can be performed by the so-called shape factors, which were so far specified in Germany on the basis of tests on relatively small unit formats for the reference format 2 DF. In the future specification will be made on another reference format and the shape factors will be regulated in a European Standard, in which the derivation of the values given there is not individually reproducible. Test results are presented below of a Research Project currently in progress, with which it should be possible to fill in the gaps in the knowledge indicated above.

Key Words

Masonry units, compressive strength, shape factor

1 Introduction

Due to the platen restraint occurring in the compression testing of masonry units, as a result of the differential stiffnesses of compression plates and test specimens, the test value of the compressive strength is dependent on the size of the test specimen. This is also known from the concrete sector cf. e.g. (Schickert, 1981), in which the range of test specimen sizes for masonry units is considerably greater. Meanwhile masonry units from 71 to 623 mm high, from 90 to 500 mm wide and from 240 to 1499 mm long are being used.

How great is the influence of the platen restraint depends mainly on the slenderness of the masonry units. The test value of the compressive strength increases with decreasing slenderness. That is, for the same unit material a significantly larger test value of the compressive strength is found for masonry units with a lower slenderness value than for masonry units with greater slenderness. This influence does not occur

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with masonry components, the masonry unit format has practically no influence on the compressive strength of the masonry (Kirtschig and Kasten, 1981). Therefore the influence must be taken into account in the compressive strength testing of the masonry units. This is done with the help of the so-called shape factors. These shape factors were so far specified in Germany for the reference format 2 DF ($l \cdot b \cdot h = 240 \cdot 115 \cdot 113\ mm^3$), as most masonry compression tests were carried out with masonry units of this format. The basis for the specification was constituted by a large number of tests in the 1980s on the commonly used masonry units at that time with maximum height of 238 mm. In order to keep the application of shape factors as simple as possible, these were only specified as a function of certain unit heights and uniformly for all types of masonry unit (see Table 1). The shape factors are a component of the respective masonry unit Standards.

Table 1 Masonry units; German shape factors

Strength class	Unit height (Nominal dimension [mm])	Shape faktor f [-]
2	all heights	1.0
> 2	< 175	1.0
	≥ 175, < 238	1.1
	≥ 238	1.2

Within the scope of the preparation of Eurocode 6 (ENV 1996-1-1, 1996), first of all, because of the corresponding control gaps in the European masonry unit or test Standard, shape factors were derived for masonry units and given there in a Table. These shape factors are obtained on a cube with edge length of 100 mm and depend on the unit height and the smaller value of the unit length or unit width. The shape factors will in future still only be contained in the corresponding European Test Standard EN 772-1. The current values for the shape factors in the Test Standard EN 772-1 (2000) have been compiled in Table 2. As above mentioned, the influence of the greater value of length or width on the shape factor is not considered in EN 772-1.

Table 2 Masonry units, European shape factors δ

Unit height	Smaller value of unit length and unit width [mm]				
[mm]	50	100	150	200	≥ 250
40	0.80	0.70	-	-	-
50	0.85	0.75	0.70	-	-
65	0.95	0.85	0.75	0.70	0.65
100	1.15	1.00	0.90	0.80	0.75
150	1.30	1.20	1.10	1.00	0.95
200	1.45	1.35	1.25	1.15	1.10
≥ 250	1.55	1.45	1.35	1.25	1.15

As is evident from Table 2, the range of values from 0.80 to 1.55 is very large, in which no distinction is made between solid and perforated units. Different values for the shape factors occur for different unit widths with the same slenderness, or different slenderness relationships are produced for the calculation of the shape factors (see Fig. 1). The derivation of the shape factors in EN 772-1 (2000) has not been published and is therefore not simply capable of reproduction. The values over 1.3 appear to be very high, their applicability to perforated units, especially with a high perforation volume, is doubtful. By the application of the high shape factors according to EN 772-1 with very slender masonry units, such as those now produced in Germany for some time, high compressive strengths are found, which may result in less safe design. This also applies to perforated units with a high perforation volume.

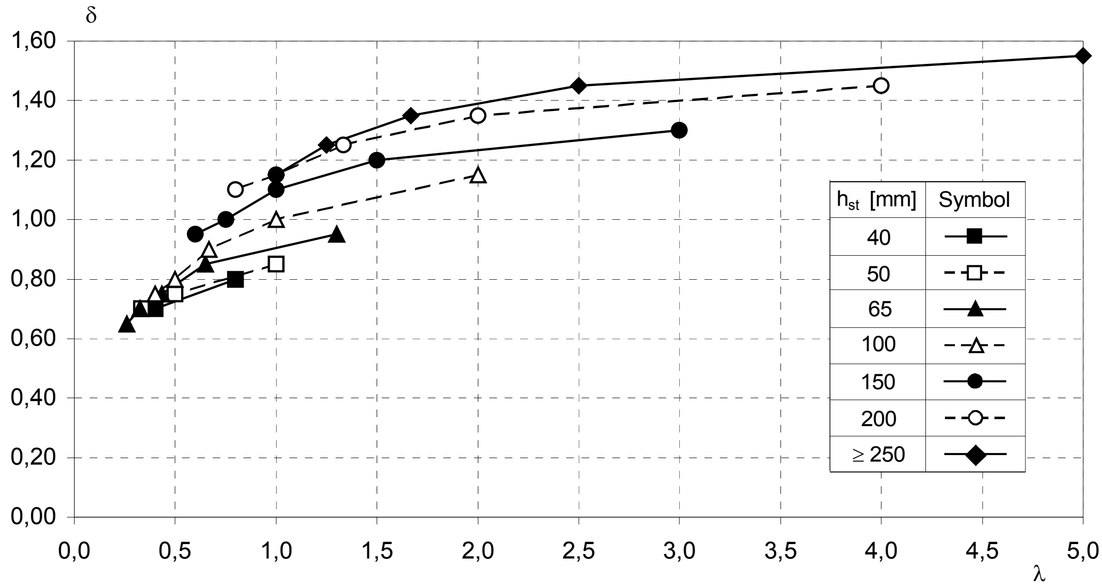

Figure 1 Shape factor δ according to EN 772-1(2000) as a function of the slenderness of the masonry unit λ = h/min (b, l)

By means of a Research Project currently in progress it is intended to complete the above-mentioned gaps in knowledge with the help of theoretical and practical tests on non-perforated and perforated masonry units, in particular those with high slenderness values, and on cubes. The following paragraphs will report on the practical tests finalized some time ago on solid units and on cubes sawn from them. The theoretical tests and also the tests on perforated units (perforated lightweight aggregate concrete units, vertically perforated clay units) have not yet been completed for some time. The Research Project is being kindly sponsored by the “Deutsches Institut für Bautechnik”, Berlin.

2 Practical tests carried out

For the tests forming part of the Research Project solid units were selected of calcium silicate, autoclaved aerated concrete and lightweight aggregate concrete of commonly used masonry unit sizes and compressive strength classes. Tests were carried out in particular on masonry units with high slenderness values (high precision elements), in order especially to obtain reliable information on the influence of slenderness in the field of high masonry unit slenderness values. An overview of the research programme is given in Table 3. Cubes were taken from the masonry units by dry or wet sawing for the determination of the compressive strength and the dry density. The compressive tests were carried out on the masonry units or cubes on the basis of the respective German masonry unit Standards DIN V 105-1 (2003), DIN V 4165 (2003) or DIN V 18152 (2003). Tests on perforated lightweight aggregate concrete units (hollow blocks, solid blocks with small hole content) and vertically perforated clay units are at present still outstanding. Furthermore single tests will be conducted to estimate the influence of the greater value of unit length or width on the shape factor.

Table 3 Test Programme
Unit type, unit length l, unit width b, unit height h, slenderness λ = h/min (b, l), unit compressive strength class $\beta_{N,st}$

Unit type	l	b	h	λ	$\beta_{N,st}$ [N/mm²]				
	[mm]	[mm]	[mm]	[-]	2	4	6	12	20
Calcium silicate unit	240	115	113	0.98	-	-	-	-	X
	248	240	238	0.99	-	-	-	-	X
	248	175	238	1.36	-	-	-	-	X
	998	300	623	2.08	-	-	-	-	X
	998	115	623	5.43	-	-	-	-	X
Autoclaved aerated concrete block	625	365	200	0.55	X	-	X	-	-
	625	365	250	0.68	X	-	X	-	-
	625	240	250	1.04	X	-	X	-	-
	600	300	600	2.00	X	-	X	-	-
	600	175	600	3.43	X	-	X	-	-
	600	115	600	5.22	X	-	X	-	-
Lightweight aggregate concrete block	240	115	113	0.98	X	X	X	X	-
	250	240	249	1.04	-	X	-	X	-
	250	175	249	1.42	-	-	-	X	-
	1000	300	623	2.08	X	X	-	-	-
	1000	240	623	2.60	-	-	-	X	-
	500[1)]	240	623	2.60	-	-	-	X	-
	240[1)]	240	623	2.60	-	-	-	X	-
	1000	115	623	5.42	X	X	-	X	-

1) Sawn from high precision unit with dimensions of 1000 · 240 · 623 mm³

3 Test results

The test results have been compiled in Table 4. In the units of compressive strength class 2 the shape factors f_v for high slenderness values are 1.15 max. for lightweight aggregate concrete. For higher unit compressive strength classes, the influence of the slenderness on the test value of the unit compressive strength is more marked; the shape factors amount for slenderness values of around 5.2 to 5.5 to 1.36 to 1.59 and are therefore very high. The influence of the slenderness appears to be independent of the unit compressive strength class, with few exceptions, already from λ = 2 almost constant (see Fig. 2). This roughly agrees with the test results of Schickert (1981) on concrete or mortar, in which test specimens were tested with square basic surfaces.

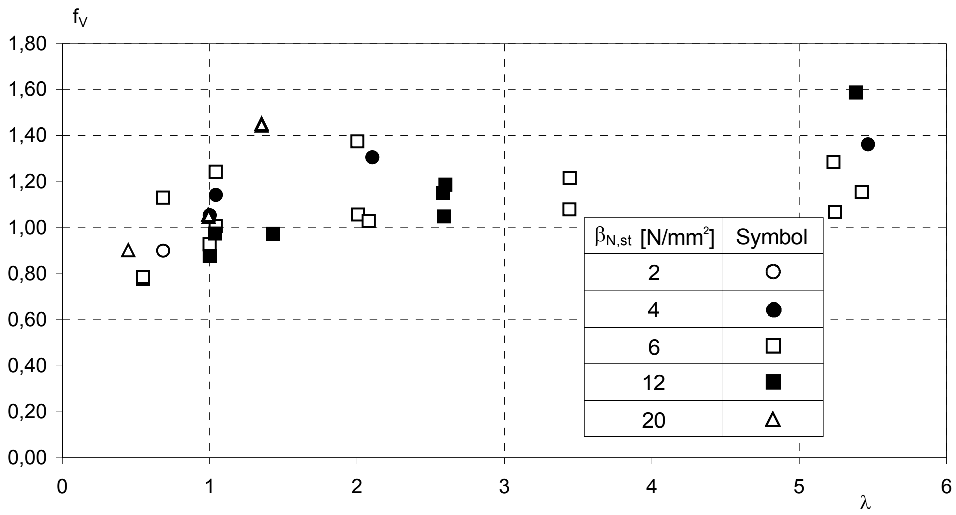

Figure 2 Shape factors f_V as a function of the slenderness of the masonry units λ = h/min (b, l)

Tabelle 4 Results of the tests on solid units and on cubes taken from them
Unit type, compressive strength class $\beta_{N,st}$, unit length l, unit width b
unit height h, slenderness λ = h/min (b, l), test value of the masonry unit compressive strength β_{PR}, cube compressive strength β_W, shape factor $f_V = \beta_W/\beta_{PR}$
shape factor δ according to EN 772-1 (2000), ration value δ/f_V

unit type	$\beta_{N,st}$ [N/mm²]	l [mm]	b [mm]	h [mm]	λ [-]	β_{PR} [N/mm²]	β_W [N/mm²]	f_V [-]	δ [-]	δ/f_V [-]
Calcium silicate unit	20	239,4	114,3	113,2	0,99	39,14	35,29	0,90	1,02	1,14
		248,5	239,3	237,5	0,99	26,52	28,00	1,06	1,16	1,10
		249,4	176,0	238,0	1,35	28,95	30,29	1,05	1,27	1,22
		998,3	299,9	622,7	2,08	16,72	24,29	1,45	1,15	0,79
		998,1	115,1	622,4	5,41	26,20	37,83	1,44	1,42	0,98
Auto-claved aerated concrete unit	2	624,3	364,3	199,4	0,55	2,66	2,07	0,78	1,10	1,41
		624,6	364,1	249,3	0,68	2,85	2,56	0,90	1,15	1,28
		623,5	239,2	249,2	1,04	2,57	2,59	1,01	1,17	1,16
		597,7	298,6	599,1	2,01	2,38	2,52	1,06	1,15	1,09
		598,3	174,0	598,9	3,44	2,53	2,74	1,08	1,30	1,21
		599,8	114,1	598,6	5,24	2,50	2,67	1,07	1,42	1,33
	6	623,7	364,6	199,6	0,55	9,10	7,15	0,79	1,10	1,40
		623,8	364,2	249,1	0,68	6,47	7,31	1,13	1,15	1,02
		624,9	239,8	249,5	1,04	6,06	7,53	1,24	1,17	0,94
		598,1	299,3	599,5	2,00	5,38	7,39	1,38	1,15	0,84
		598,4	173,8	598,6	3,44	6,18	7,51	1,22	1,30	1,07
		599,9	114,4	598,8	5,23	6,15	7,90	1,28	1,42	1,11
Light-weight aggre-gate concrete unit	2	239,6	113,0	113,0	1,00	3,01	2,80	0,93	1,03	1,11
		1000,0	300,3	624,5	2,08	5,56	5,72	1,03	1,15	1,12
		1000,0	114,9	623,4	5,42	3,71	4,28	1,15	1,42	1,23
	4	240,3	113,2	113,4	1,00	3,81	4,01	1,05	1,03	0,97
		250,8	239,2	249,5	1,04	4,71	5,38	1,14	1,17	1,03
		999,8	299,9	630,9	2,10	9,12	11,91	1,31	1,15	0,88
		1000,0	114,0	623,1	5,47	7,51	10,23	1,36	1,42	1,04
	12	239,8	113,0	113,2	1,00	27,71	24,26	0,88	1,03	1,17
		248,6	239,6	248,8	1,04	24,73	24,11	0,97	1,17	1,20
		252,1	174,1	249,2	1,43	26,21	25,51	0,97	1,30	1,34
		1001,2	241,1	624,5	2,59	16,19	16,98	1,05	1,17	1,11
		497,9	241,5	624,6	2,59	14,76	16,98	1,15	1,17	1,01
		240,1	240,2	624,2	2,60	14,30	16,98	1,19	1,17	0,99
		997,9	115,7	623,2	5,38	16,56	26,28	1,59	1,42	0,89

From a comparison of the shape factors determined in the tests and those obtained according to EN 772-1 (2000), it is clearly apparent that in some cases considerable differences exist. The ratio values of the shape factors according to EN 772-1 (2000) and those from the tests are presented in Fig. 3 as a function of the slenderness of the units. The ratio values for low slenderness values (see also Table 4) amount to up to 1.41 and for high slenderness values up to 1.33. Therefore the unit compressive strength would be considerably overestimated in some cases by the use of the European shape factors, leading to lower safety values in the designing of building structures. Only for very few formats the shape factor according to EN 772-1 is smaller than the test value.

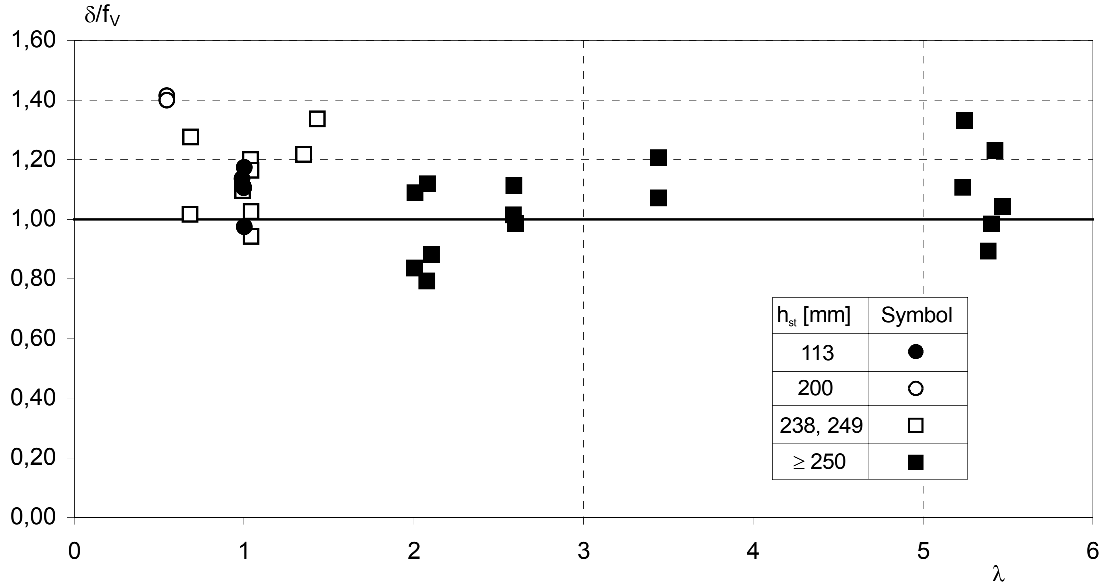

Figure 3 Ratio value δ/f_V as a function of the slenderness of the masonry units
λ = h/min (b, l)

4 Summary

The results of the tests on solid units and on cubes taken from them have shown that a need for adaptation exists for the shape factors according to EN 772-1. The deviations between the actual shape factors determined in the tests and those according to EN 772-1 were very great, up to around 40%. The influence of the platen restraint, with the exception of very few test values, appears to be constant, as from a slenderness value of the test specimens of λ = 2, in which this conforms to the results of tests on concrete. Tests on perforated aggregate lightweight concrete units and vertically perforated clay units are still outstanding.

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