DS/EN 1996-1-1 DK NA:2019

National Annex to

Eurocode 6: Design of masonry structures –
Part 1-1: General rules for reinforced and unreinforced masonry structures

Foreword

This National Annex (NA) is a revision of DS/EN 1996-1-1 DK NA:2014 and replaces the latter as from 2019-12-20. For a transition period until 2019-12-31, this National Annex as well as the previous National Annex will be applicable.

Previous, valid versions of the NAs as well as addenda to these can be found at www.eurocodes.dk.

This NA lays down the conditions for the implementation in Denmark of EN 1996-1-1 for construction works in conformity with the Danish Building Regulations.

This NA applies to construction works covered by section 16(1) of the Danish Building Regulations.

A National Annex contains national provisions, viz. nationally applicable values or selected methods. The Annex may furthermore provide non-contradictory, complementary information.

This NA includes:

- an overview of possible national choices and clauses containing complementary information;
- national choices;
- non-contradictory, complementary information.

This NA applies to construction works covered by section 16(1) of the Danish Building Regulations as well as to construction works covered by sections 24 to 27 of the Danish Building Regulations.

For structures covered by sections 24 to 27 of the Danish Building Regulations BR18, or not covered by the Danish Building Regulations, levels of checking may still be used for the calculation of structures in ultimate limit states.

For structures covered by section 16(1) of the Danish Building Regulations BR18, levels of checking cannot be applied.

Overview of possible national choices

The list below identifies the clauses where national choices are possible and the applicable/not applicable informative annexes. Furthermore, clauses providing complementary information are identified. Complementary information is given at the end of this document.

Clause	**Subject**	**National choice**[1)]
2.4.3(1)P	Ultimate limit states	National choice
2.4.4(1)	Serviceability limit states	Unchanged
3.2.2(1)	Specification for masonry mortar	National choice
3.6.1.2(1)	Characteristic compressive strength of masonry – Characteristic compressive strength of masonry other than shell bedded masonry	National choice
3.6.2(3),(4) and (6)	Characteristic shear strength of masonry	National choice
3.6.4(3)	Characteristic flexural strength of masonry	National choice
3.7.2(2)	Modulus of elasticity	National choice
3.7.4(2)	Creep, moisture expansion or shrinkage and thermal expansion	Unchanged
4.3.3(3) and (4)	Reinforcing steel	Unchanged
5.5.1.3(3)	Effective thickness of masonry walls	Unchanged
6.1.2.2(2)	Verification of unreinforced masonry walls subjected to mainly vertical loading – Reduction factor for slenderness and eccentricity	Unchanged
6.2(2)	Design value of the limiting shear resistance	National choice
8.1.2(2)	Minimum thickness of wall	Unchanged
8.5.2.2(2)	Connection between walls - Cavity and veneer walls	National choice

Clause	Subject	National choice[1)]
8.5.2.3(2)	Connection between walls – Double-leaf walls	National choice
8.6.2(1)	Vertical chases and recesses	Unchanged
8.6.3(1)	Horizontal and inclined chases	Unchanged
Annex A	Consideration of partial factors relating to Execution	Not applicable
Annex B	Method for calculating the eccentricity of a stability core	Applicable
Annex C	A simplified method for calculating the out-of-plane eccentricity of loading on walls	Not applicable
Annex D	Determination of ρ_3 and ρ_4	Applicable
Annex E	Bending moment coefficients, α_2, in single leaf laterally loaded wall panels of thickness less than or equal to 250 mm	Applicable
Annex F	Limiting height and length to thickness ratios for walls under the serviceability limit state	Applicable
Annex G	Reduction factor for slenderness and eccentricity	Applicable
Annex H	Enhancement factor as given in 6.1.3	Applicable
Annex I	Adjustment of lateral load for walls supported on three or four edges subjected to out-of-plane horizontal loading and vertical loading	Applicable
Annex J	Reinforced masonry members subjected to shear loading: enhancement of f_{vd}	Not applicable

National choices

2.4.3(1)P Ultimate limit states

The following partial factors for materials apply in Denmark for the ultimate limit state:

Table 2.4.3a DK NA Assumed types of failure for the determination of the partial factor

Structure (in situ)		
Compressive strength and modulus of elasticity of masonry	$\gamma_c =$	$1{,}60 \cdot\gamma_0\cdot\gamma_3$
Units of Category I	$\gamma_c =$	$1{,}70 \cdot\gamma_0\cdot\gamma_3$
Compressive strength and modulus of elasticity of masonry		
Units of Category II		
Compressive strength and modulus of elasticity of reinforced masonry	$\gamma_c =$	$1{,}45 \cdot\gamma_0\cdot\gamma_3$
Flexural strength of masonry	$\gamma_c =$	$1{,}70 \cdot\gamma_0\cdot\gamma_3$
Strength of reinforcement and modulus of elasticity[1)]	$\gamma_s =$	$1{,}20 \cdot\gamma_0\cdot\gamma_3$
Bond strength of reinforcement[1)]	$\gamma_c =$	$1{,}70 \cdot\gamma_0\cdot\gamma_3$
Cohesion	$\gamma_c =$	$1{,}70 \cdot\gamma_0\cdot\gamma_3$
Friction coefficients	$\gamma_c =$	$1{,}30 \cdot\gamma_0\cdot\gamma_3$
Precast concrete elements, calculation		
Compressive strength and modulus of elasticity of masonry	$\gamma_c =$	$1{,}55 \cdot\gamma_0\cdot\gamma_3$
Units of Category I	$\gamma_c =$	$1{,}65 \cdot\gamma_0\cdot\gamma_3$
Compressive strength and modulus of elasticity of masonry		
Units of Category II		
Compressive strength and modulus of elasticity of reinforced masonry	$\gamma_c =$	$1{,}40 \cdot\gamma_0\cdot\gamma_3$
Flexural strength of masonry	$\gamma_c =$	$1{,}60 \cdot\gamma_0\cdot\gamma_3$
Strength of reinforcement and modulus of elasticity[1)]	$\gamma_s =$	$1{,}20 \cdot\gamma_0\cdot\gamma_3$
Performance testing[4)]		
Ductile failure[2)]	$\gamma_M =$	$1{,}20 \cdot\gamma_0\cdot\gamma_3$
Brittle failure[3)]	$\gamma_M =$	$1{,}40 \cdot\gamma_0\cdot\gamma_3$

1) Reinforcement, wall ties and other embedded, built-in or drilled-in anchors.

2) Elements are assumed to exhibit ductile failure if one of the following conditions is fulfilled:
- it can be demonstrated that the reinforcement yields in the ultimate limit state;
- failure results in an evenly distributed crack pattern in the failure zone expected for the action considered;
- failure due to bending occurs if deflection of the element exceeds 3/200 of the span.

Other failure modes are to be regarded as brittle failures. Failure of components subject to axial forces is always assumed to be brittle failure.

3) The load-bearing capacity of corbels determined by functional testing shall be taken as brittle failure if the failure mode is not known.

4) Where the test result is determined as mean value (R_m) in the test standard, the characteristic 5 % fractile (R_k) may be determined to: $R_k = k_c R_m$, where k_c is given in the table below

Var.coeff [5)] kc

<15%	0,80
<20%	0,75
<30%	0,65

The deflection shall not exceed 3,0 mm for the actual value of R_k.

[5]) The value is the coefficient of variation of the ultimate contact pressure obtained from tests carried out in accordance with the relevant test standard.

The partial factors given in Table 2.4.3a DK NA are based on the guidelines for determining resulting partial factors in the ultimate limit state according to DS/EN 1990 DK NA, where $\gamma_M = \gamma_0 \cdot \gamma_1 \cdot \gamma_2 \cdot \gamma_3 \cdot \gamma_4$.

γ_0: takes into account the consequences class;
γ_1: takes into account the type of failure;
γ_2: takes into account the uncertainty related to the design model;
γ_3: takes into account the inspection level for factory-made mortar and mortar mixed on site (see Table 2.4.3c);
γ_4: takes into account the variation of the strength parameter/measured resistance.

When determining γ_1, the types of failure given in Table 2.4.3b DK NA have been assumed.

Table 2.4.3b DK NA Assumed types of failure for the determination of γ_1

Structures, in situ	
Compressive strength and modulus of elasticity of reinforced masonry	Warning of failure without residual resistance
Compressive strength and modulus of elasticity of unreinforced masonry	No warning of failure
Flexural strength of reinforced and unreinforced masonry	No warning of failure
Strength and modulus of elasticity of reinforcement[1])	Warning of failure without residual resistance
Cohesion	No warning of failure
Friction coefficients	Warning of failure without residual resistance
Anchorage of wall ties	No warning of failure
Precast concrete elements, calculation	
Compressive strength and modulus of elasticity of reinforced masonry	Warning of failure without residual resistance
Compressive strength and modulus of elasticity of unreinforced masonry	No warning of failure
Flexural strength of reinforced and unreinforced masonry	No warning of failure

Strength and modulus of elasticity of reinforcement[1])	Warning of failure without residual resistance
Precast concrete elements, performance testing	
Testing leading to ductile failure[2])	
Testing leading to brittle failure[2])	

1) See 1) in Table 2.4.3a DK NA
2) See 2) in Table 2.4.3a DK NA

Table 2.4.3c DK NA specifies the values of γ_3 depending on the level of checking. For masonry structures, the combinations of consequences classes and levels of checking marked + in Table 2.4.3d DK NA may be used.

Table 2.4.3c DK NA Dependency of level of checking

Level of checking	Reduced	Normal	Extended
γ_3	1,10	1,0	0,95

The factor γ_3 takes into account the level of checking of the product. The reduced level of checking is not used.

Extended level of checking: $\gamma_3 = 0{,}95$
Normal level of checking: $\gamma_3 = 1{,}00$

For structures covered by section 16(1) of the Danish Building Regulations BR18, the extended level of checking cannot be applied, and γ_3 is taken as 1,00.

The partial factors are determined in accordance with the National Annex to EN 1990, Annex F, *Partial factors for resistance*, where $\gamma_M = \gamma_1 \gamma_2 \gamma_3 \gamma_{4,}$, where the values of γ_{Mi} given above include the factor γ_0 .

Table 2.4.3d DK NA Combinations of consequences classes and inspection classes

		Consequences class		
		Low	Normal	Extended
Inspection class	Extended		+	+
	Normal	+	+	+
	Reduced	+	+	

The factor γ_0 takes account of the consequences class, cf. National Annex to EN 1990, Table A1.2(B+C) as stated in Table 2.4.3e DK NA.

Table 2.4.3e DK NA Dependency of design case

Limit state	**STR/GEO**				**STR**
Combination of actions	1	2	3	4	5
γ_0	1,0	1,0	K_{FI}	K_{FI}	$1{,}2 \cdot K_{FI}$

NOTE For structures not subject to geotechnical actions, verification can be achieved solely by applying combinations of actions 1 and 2.

For structures subject to geotechnical actions, verification is to be achieved by applying combinations of actions 1 and 2, combinations of actions 3 and 4 and combination of actions 5.

For structures solely subject to geotechnical actions, verification may be achieved solely by applying combinations of actions 3 and 4 and combination of actions 5.

For K_{FI} = 1,0, combinations of actions 1 and 2 are identical to combinations of actions 3 and 4. For $K_{FI} \neq 1{,}0$, the factor K_{FI} may be applied to the effects of actions (internal forces and moments) instead of to the action, provided that the effects of actions are linearly proportional to the associated action.

Geotechnical actions are actions transmitted to the structure by the ground, fill, standing water or ground water. In addition to the weight, the actions from the ground and fill are determined by the strength and deformation properties of the ground and fill, e.g. expressed as the angle of shearing resistance. Examples of geotechnical actions include earth and water pressures on a wall structure.

For ultimate limit state design, the lower characteristic value is the 5 % fractile and the upper characteristic value the 95 % fractile.

Partial factors for materials are taken as γ_M = 1,0 for serviceability limit states.

3.2.2(1) Specification of masonry mortar

For prescribed mortars, the compressive strengths and flexural strengths specified in Table 3.1 DK NA may be assumed if the constituents of the mortar fulfil the following requirements:

(1) Hydrated lime is to conform to the requirements of EN 459-1 and should not contain slakeable particles;

(2) Cement should at least be of strength class 42,5 and fulfil the requirements specified in EN 197-1;

(3) Aggregates for mortars should fulfil the requirements in EN 13139 and be fractioned in such a way that the grading curve determined as specified in EN 933-1 lies within the limit curves shown in Figure 3.1 DK NA. If the aggregate is polluted with organic substances, the colour reaction when evaluating the humus content according to the test method given in EN 1744-1 should not be darker than 1 proportion of standard colour diluted with 3 proportions of water, unless documented justification is provided.

(4) Admixtures are not to be used. It is permitted, however, that ethanol (methylated spirit) and composite products of ethanol and isopropanol containing up to 40 % isopropanol are used as freezing point depressing agents for KC 60/40/850 and KC 50/50/700, provided that a minimum of 1 litre and a maximum of 4 litres per 100 hl mortar is added. In this case, a reduction of 20% for all mortar strength parameters is to be taken into account.

(5) In the finished mortar the dry mass of the individual constituents should not deviate by more than 5 % from the quantity considered.

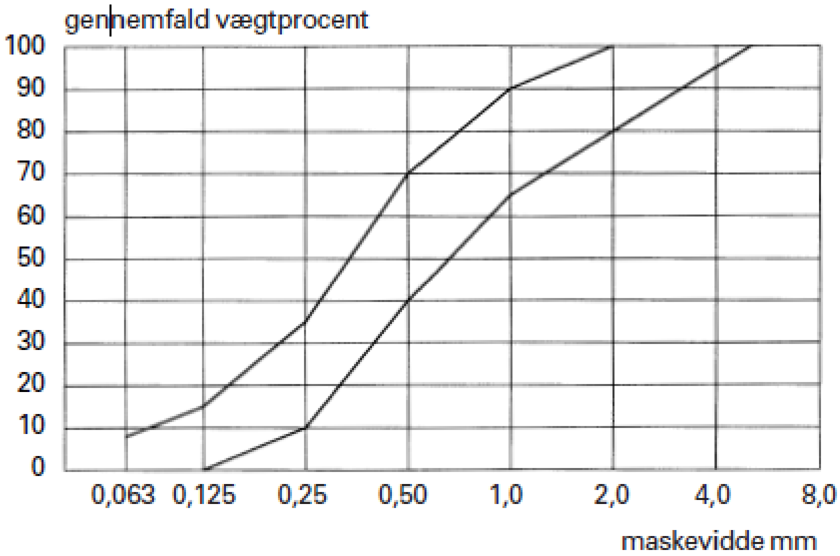

Figure 3.1 DK NA, Limit curves for sand

Table 3.1 DK NA – Ratio between the compressive strength and mix proportion of mortar

Mix proportion	**Minimum compressive strength MC/ML**
KC 60/40/850	ML 0,8 MPa
KC 50/50/700	MC 0,9 MPa/ML 1,8 MPa
KC 35/65/650	MC 2 MPa
KC 20/80/550	MC 4,5 MPa

NOTE 1: If the requirements specified in (1), (2), (3), (4) and (5) are not fulfilled, it is necessary to determine the mortar strength experimentally, and the mortar is to be declared as designed masonry mortar.

NOTE 2: According to the requirements for admixtures given in (4) above, reduced strengths are used for mortars containing freezing point depressing agents.

3.6.1.2(1) Characteristic compressive strength of masonry – Characteristic compressive strength of masonry other than shell bedded masonry

Method (i) in EN 1996-1-1 may be used provided either that documentation of the parameters in equation 3.1 is given or that Table 3.2 DK NA is applied subject to the related conditions. Method (ii) may be used without further documentation.

The compressive strength of the header of the bricks may be determined as $0,5 \cdot f_k$, where f_k is the usual compressive strength perpendicular to the bed joint.

Table 3.2 DK NA specifies characteristic basic compressive strengths for masonry of solid lightweight concrete units of group 1 and solid autoclaved aerated concrete masonry units of height ≥ 185 mm and nominal joints of 10 mm, the compressive strength ML of the mortar corresponding to the basic compressive strength of the masonry and the compressive strength MC corresponding at least to 0,5 times the basic compressive strength of the masonry. Tabulated values apply to category I units with a documented coefficient of variation for the compressive strength of no more than 10 % for compression perpendicular to the bed face.

In the middle of joints in unreinforced masonry of lightweight concrete with a thickness equal to and larger than 190 mm, a 50 mm mortar free zone is permitted e.g. in connection with an embedded thermal insulation strip.

Table 3.2 DK NA - Basic compressive strengths f_k in MPa for solid lightweight aggregate concrete unit masonry and autoclaved aerated concrete unit masonry of a height ≥ 185 mm

Compressive strength of units - f_c 5 % fractile	Basic compressive strength - f_k 5 % fractile
2,0	1,8
2,5	2,2
3,0	2.6
3,5	3,1
4,0	3,5
4,5	3,9
5,0	4,4

Compressive strength of units - f_m [1)] 50 % fractile	Basic compressive strength - f_k 5 % fractile
2,0	1,5
2,5	1,9
3,0	2,3
3,5	2,7
4,0	3,0
4,5	3,4
5,0	3,8

1) In Table 3.2 DK NA, f_m is the mean value of the compressive strength according to EN 771-3. The designation should not be confused with the corresponding designation in EN 1996-1-1 for the compressive strength of masonry mortar.

3.6.2(3), (4) and (6) Characteristic shear strength of masonry

The design shear strength (f_{vd}) may be determined using the following expression:

$$f_{vd} \leq \mu_k/\gamma_m \times \sigma + f_{vk0}/\gamma_m$$

$$\begin{cases} k_m \times f_b \end{cases}$$

but max:

1,5 MPa

where

σ	is the design compressive stress, if any, in sections parallel to the bed joints due to the actual combination of actions for the structure considered;
μ_k	is the characteristic friction coefficient;
f_{vk0}	is the characteristic shear strength;
γ_m	is the partial factor pertaining to the property;
k_m	is 0,07 for clay units;
k_m	is 0,20 for lightweight aggregate units.

Where cohesion and friction coefficients are not known, the values given in Table 3.3 DK NA may be applied.

Table 3.3 DK NA Characteristic friction coefficient and cohesion

Type of joint	μ_k	f_{vk0} MPa
Mortar joint ($f_m < 0{,}5$ MPa)	0,6	f_{xk1} 1)
Mortar joint ($f_m \geq 0{,}5$ MPa)	1,0	f_{xk1} 1)
Mortar joint (adverse)	2,0	$2{,}5 \times f_{xk1}$ 1)
Mortar joint on damp proof course	0,4	0
Mortar joint on damp proof course (adverse)	0,7	0,03

1) f_{xk1} is the characteristic flexural strength having a plane of failure parallel to the bed joint.

3.6.4(3) Characteristic flexural strength of masonry

In cases where the flexural strengths, f_{xk1} and f_{xk2}, or the bond strength, $f_{m,xk1}$, are not specified or determined experimentally, the values given in Tables 3.4 DK NA, 3.5 DK NA, 3.6 DK NA and 3.7 DK NA may be applied.

Table 3.4 DK NA specifies values of the flexural strengths, f_{xk1} and f_{xk2}, for masonry of units of a height ≥ 185 mm. If admixtures have been added to the mortar, either directly or by the binders used, it cannot be assumed that the values apply to the mortar used.

Table 3.4 DK NA Basic flexural strengths, f_{xk1} and f_{xk2}, for masonry of units of a height ≥ 185 mm

Masonry units		Mortar
	Minimum compressive strength	Compressive strength MC ≥ 3,5 MPa Compressive strength ML ≥ 7 MPa

	f_c MPa	f_m MPa[1)]	f_{xk1} MPa	f_{xk2} MPa
	5 % fractile	50 % fractile		
Lightweight concrete	2,4	2,9	0,20	0,45
Aerated concrete	2,4	2,9	0,20	0,45
Clay	10	15	0,20	0,45

1) In Table 3.4 DK NA, f_m is the mean value of the compressive strength according to EN 771-3. The designation should not be confused with the corresponding designation in EN 1996-1-1 for the compressive strength of masonry mortar.

Table 3.5 DK NA specifies values of the bond strength, $f_{m,xk1}$, for clay unit masonry. If admixtures have been added to the mortar, either directly or by the binders used, it cannot be assumed that the values apply to the mortar used.

Table 3.5 DK NA Bond strength, $f_{m,xk1}$, for clay unit masonry

Mortar		
KC50/50/700 (NCI.1) [1)]	compressive strength MC ≥ 1,5 MPa	compressive strength MC ≥ 3,5 MPa
K_h100/400 [2)] KK_h20/80/475 [2)]	compressive strength ML ≥ 3 MPa	compressive strength ML ≥ 7 MPa
$f_{m,xk1}$ MPa	$f_{m,xk1}$ MPa	$f_{m,xk1}$ MPa
0,10	0,15	0,25

1) The mortar is to be produced according to clause 3.2.2(1), Specification for masonry mortar, of this NA.

2) The mortar is to be made from hydraulic lime designated HL5 or NHL5 according to EN 459-1 and to (1), (3), (4) and (5) of clause 3.2.2(1), Specification for masonry mortar, of this NA.

In cases where f_{xk1} for a mortar has been declared on the basis of EN 1052-2, or where the bond strength, $f_{m,xk1}$, has been declared on the basis of EN 1052-5 or is specified in Table 3.5 DK NA, f_{xk1} and f_{xk2} may be determined for clay units of a height lower than 60 mm from Table 3.6 DK NA and Table 3.7 DK NA.

Table 3.6 DK NA Basic flexural strength, f_{xk1}, in MPa determined on the basis of the bond strength, $f_{m,xk1}$, and the normalised compressive strength of masonry units, f_b

$f_{m,xk1}$	Normalised compressive strength of masonry units f_b MPa								
MPa	5	10	15	20	25	30	35	40	45
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,10	0,06	0,08	0,09	0,10	0,10	0,10	0,10	0,10	0,10
0,15	0,08	0,11	0,13	0,14	0,14	0,14	0,14	0,14	0,14
0,20	0,10	0,13	0,16	0,18	0,19	0,19	0,19	0,19	0,19
0,25	0,13	0,16	0,19	0,21	0,23	0,24	0,24	0,24	0,24
0,30	0,15	0,18	0,21	0,24	0,26	0,28	0,28	0,28	0,28
0,35	0,17	0,20	0,23	0,26	0,28	0,31	0,32	0,32	0,32
0,40	0,18	0.22	0,26	0,28	0,31	0,34	0,36	0,38	0,38
0,45	0,18	0,23	0,28	0,31	0,33	0,36	0,38	0,41	0,44
0,50	0,18	0,24	0,29	0,33	0,36	0,39	0,41	0,43	0,46
0,55	0,18	0,24	0,30	0,35	0,38	0,41	0,43	0,46	0,48
0,60	0,18	0,24	0,30	0,35	0,40	0,43	0,45	0,48	0,51
0,65	0,18	0,24	0,30	0,35	0,40	0,45	0,48	0,50	0,53
0,70	0,18	0,24	0,30	0,35	0,40	0,45	0,50	0,53	0,55

Table 3.7 DK NA - Basic flexural strength, f_{xk2}, in MPa determined on the basis of the flexural strength, f_{xk1}, and the normalised compressive strength of masonry units, f_b

f_{xk1}	Normalised compressive strength of masonry units f_b MPa								
MPa	5	10	15	20	25	30	35	40	45
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,06	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21	0,21
0,10	0,29	0,32	0,34	0,34	0,34	0,34	0,34	0,34	0,34
0,15	0,32	0,39	0,44	0,49	0,50	0,50	0,50	0,50	0,50
0,20	0,36	0,43	0,48	0.54	0,60	0,64	0.66	0.66	0.66
0,25	0,40	0.47	0,52	0,59	0,64	0,69	0,74	0,79	0,82
0,30	0,44	0,51	0,57	0,63	0,68	0,73	0,78	0,84	0,89
0,35	0,49	0,56	0,61	0,67	0,73	0,77	0,82	0,88	0,93
≥0,40	0,53	0,60	0,65	0,71	0,77	0,82	0,87	0,92	0,98

In Table 3.6 DK NA and in DK NA Table 3.7 interpolation may be used between values.

3.7.2(2) Modulus of elasticity

Where test data for the short-term secant modules of elasticity are not available, the value of K_E is to be determined as follows:

- for clay unit masonry and/or calcium silicate unit masonry made with lime mortar with no cement content:

$K_E = 150\, f_m$

- for clay unit masonry and/or calcium silicate unit masonry made with mortar using other binder materials (such as cement):

$$K_E = \min \begin{cases} 20 f_b \\ 400 f_m \\ 1000 \end{cases}$$

- for lightweight aggregate concrete unit masonry:

$$K_E = 1000$$

- for autoclaved aerated concrete unit masonry:

$$K_E = 450$$

where

f_k is the characteristic basic compressive strength of masonry in MPa;
f_b is the normalised mean compressive strength of the masonry units in MPa;
f_m is the compressive strength of the mortar in MPa.

6.2(2) Design value of the limiting shear resistance
Expression (6.13) can always be applied.

Expression (6.14) $V_{Rdlt} = f_{vd}\, t\, l$ may be used, provided that it is ensured that no part of the wall is in tension (e.g. by applying a plastic distribution).

8.5.2.2(2) Connection between walls - Cavity and veneer walls
The minimum number of ties connecting the leaves of cavity and veneer walls is taken as n_{min} = 2 pr. m^2 of the wall area considered. If the walls are used as combined walls where wind actions are distributed evenly between the walls depending on the wall stiffness, the number of ties should be at least n_{min} = 4 pr. m^2, and they should be evenly spaced.

8.5.2.3(2) Connection between walls – Double-leaf walls
The minimum number of ties connecting the leaves of double-leaf walls is taken as j = 16 pr. m^2 of the wall area considered.

Complementary (non-contradictory) information

General reference is made to DS/INF 167 *Supplementary guidelines for masonry in connection with the use of Eurocode 6*.