Cladding Annex 1a – Cladding Thickness

The following section has been adapted from the BS 8298 part 2. The calculation for part 4 rainscreen cladding is very similar, please contact the office for more details.

It is important that all calculations are checked by a suitably qualified engineer.

Introduction

The panel thickness should be determined at an early stage of the design, to influence key decisions relating to the facade setting out and wall construction make-up, and to indicate the governing design criteria. The panel thickness should look at a minimum of two calculations, but also consider whether impact (hard or soft body) or point loadings need to be separately accessed for the project. The two calculations are:

- Flexural failure of the stone
- Breakout failure at the fixing point

The thickness of the Portland Stone cladding needs to consider the following:

1. The lateral load on the building
2. The fixing system
3. The panel size
4. The stone's technical properties
    a. The flexural strength
    b. The breaking load at dowel hole
5. The partial load factor and partial material factor

Loading

Ideally the wind loadings should be calculated for each project, but if this cannot be complete then the table from Annex E can be used.

CLASS	***WIND PRESSURE N/m²***	***BRIEF DESCRIPTION***
Low wind load environment	*1500 N·m²⁻*	*Sheltered environment such as the lower floors of a building in a central urban area, e.g. Central Manchester*
Medium wind load environment	*2250 N·m²⁻*	*A more exposed environment such as the higher floors of a tall building or a more exposed location, e.g. Canary Wharf, London*
High wind load environment	*3000 N·m²⁻*	*An exposed environment such as a coastal location*

The Fixing system

There are number of differing fixing systems that can be used including dowel and kerfs for traditional cladding and for rainscreen cladding undercut anchors can also be used, their strength depends on their proximity to the edge and face of the panel and the layout of the fixings should be in accordance with Figure 10 BS 8298 Part 2 and figure 5 in Part 4. The fixing system should be tested at the project thickness in accordance with BSEN 13364 for dowels and Annex C in BS 8298 Part 2 for kerf clips and Annex E, Part 4 for undercut anchors.

The Panel Size

The panel size will obviously affect the lateral loadings but may also need to be consider when completing any impact assessments or point loadings calculations.

Stone Technical Properties

As stated in BS 8298 Part 2 section 5.5.7 –
The selection of the test samples and historical data is vital to understanding the technical properties of the stone. Ideally, the stone would have a good history of use in the local area, historical test data that are incorporated into the latest test results producing a representative mean and LEV characteristic value, in line with a recorded PCT.
All Albion Stone's test data is based on over 5,000 individual tests over 30 years which give us an in depth understanding of the technical properties of our different Portland Stones allowing us to publish a very reliable set of technical data for each of our stones.

Partial and Material load factors, (as set out in BS 8298 Part 2 sections 5.6.2 & 5.6.3)

The **partial load factor** γ_f should be applied to the loading as 1.5 for ultimate limit state design, unless otherwise noted.

The **partial material factors** should be selected based on the amount and nature of relevant test data that are available regarding the strength of the stone. Stones that have less data, of a less representative nature, will lead to the selection of a higher margin of safety, so it is always vital to assess each bed of stone separately.

The following issues should be taken into account when selecting the partial material factor:
a) whether the available test data comprise a mean value or a lower expected value;
b) whether the flexural strength is measured using a constant moment (BS EN 13161) or a concentrated load (BS EN 12372);
c) whether the test data are limited to dry samples, or wet samples were also tested;
d) whether the test data are based on multiple samples or a limited set;
e) whether the stone samples tested are oriented consistent with the project design orientation; and
f) whether any form of freeze-thaw testing has been included in the test programme.

The partial material factor for the design of stone panels should be taken as:

$$\gamma_{\mathrm{m}} = F_0 F_{\mathrm{LEV}} F_{3\text{–}4} F_{\mathrm{H2O}} F_{\mathrm{N}} F_{\alpha} F_{\infty}$$

Component	Description	Range
F_0	F_0 is the basic (minimum) factor of safety that is permissible for ultimate limit state design	3.00
F_{LEV}	F_{LEV} is the component which relates to the use of mean or lower expected values of strength;	1.00 - 1.40

$F_{3\text{-}4}$	$F_{3\text{-}4}$ is the component which relates to constant moment or concentrated load testing (BSEN 13161 or 12372) *Not relevant to strength at fixing calculations*	1.00 - 1.40
F_{H20}	F_{H20} is the component which relates to the use of dry and wet samples for testing;	1.00 - 1.40
F_N	F_N is the component which relates to the number of sets of samples that were tested and the sample selection process;	1.00 - 1.50
F_α	F_α is the component which relates to the orientation of the stone when tested;	1.00 - 1.40
F_∞	F_∞ is the component which relates to the use of freeze-thaw testing.	1.00 - 2.00

Example Calculation

In BS 8298 Annex E is an example calculation of flexural design and fixing breakout.

The worked examples set out below are based on a Jordan Whitbed Portland stone panel size of 900 mm in length × 600 mm in width, supported by dowels in a stack bonded layout with the fixings located in the length one fifth distance from the edges giving a distance along the length of 540 mm between the fixings, so the maximum distance between the fixings is the height at 600 mm. It is assumed that the stone is for a low-rise project in Central London, which is a non-freeze location, but the freeze-thaw results are used as a precaution and the low wind classification is as in Table above in the Loading section.

The technical data was correct at the time the calculation was completed in the summer 2020 and based on the following:

a) LEV results;
b) measurement in accordance with BS EN 13161 (only applicable to the flexural design calculation);
c) test data from dry stone samples;
d) historical data available for over 10 years;
e) sample cut in orientation as intended for project; and
f) freeze-thaw testing shows less than 5% loss after 14 cycles.

Actual results are used for the Portland limestone Jordans Whitbed

1) flexural strength for flexural design calculation (f_k) 2.99 N/mm^2;
2) breakout capacity of fixing for fixing design calculation (R_k) 1 460 N for 50 mm thick

Table 1 – Components of overall factor of safety

	Components of overall factor of safety						
	F_0	F_{LEV}	F_{3-4}	F_{H2O}	F_N	F_α	F_∞
Base factor of safety for flexure/bending (minimum for all stone types)	***3.00***						
Base minimum factor for fixing breakout (minimum for all stone types)	***3.00***						
if using mean strength		1.40					
if using lower expected value (LEV) of strength		***1.00***					
for strength measured using concentrated load to BS EN 12372 (three-point)			1.40				
for strength measured using constant moment to BS EN 13161 (four-point)			***1.00***				
if any included set of test data was derived from dry samples alone				***1.40***			
if each included set of test data was derived from the lower of at least ten dry samples and at least ten wet samples				1.00			
if test data are limited to one set of samples, possibly taken from the same block or panel, or historical data are out of date					1.50		
if test data are available for three or more discrete sets of at least ten samples each, each set taken from blocks extracted at least six months apart or from differing locations in the quarry or mine and are not out of date					1.35		
if test data are available for three or more sets of samples selected by a stone specialist to represent at least the geological range on the agreed reference samples and are not out of date					1.00		
if historical test data are available in line with the BS EN 12372 and BS EN 13161 and BS EN 1469 for over ten years					***1.00***		
if stone subject to variation of properties with orientation, but cut in unknown orientation						1.40	
if stone subject to variation of properties with orientation, but cut in same orientation as intended for use on project						***1.00***	
if stone not subject to variation of properties with orientation						1.00	
if freeze-thaw testing is not carried out							2.00
if, after 14 cycles of freeze-thaw testing to BS EN 12371, the dry flexural strength reduction is less than 40% of that obtained for the reference samples							1.65
if, after 14 cycles of freeze-thaw testing to BS EN 12371, the dry flexural strength reduction is less than 25% of that obtained for the reference samples							1.35
if, after 14 cycles of freeze-thaw testing to BS EN 12371, the dry flexural strength reduction is less than 10% of that obtained for the reference samples							1.10
if, after 14 cycles of freeze-thaw testing to BS EN 12371, the dry flexural strength reduction is less than 5% of that obtained for the reference samples Or if stone is not subject to variation of properties to freeze-thaw testing.							***1.00***
Partial material factor for flexural design of stone panel (see F.1)	**3.00**	**1.00**	**1.00**	**1.40**	**1.00**	**1.00**	**1.00**
Partial material factor for fixing breakout design (see F.2)	**3.00**	**1.00**	**N/A**	**1.40**	**1.00**	**1.00**	**1.00**

.1 Flexural design

1) Design wind pressure:

$$q_d = \frac{\gamma_f q}{10^6}$$

where:

		Values	Calculations
q	is the wind pressure in N/m^2 (see **E.2**);	1 500 N/m^2	–
γ_f	Is the partial load factor (see **5.5.1**); and	1 N/m^2	Taken as 1.0 where wind loading is derived from Table C.1
q_d	is the total design wind load on the stone in N.	0.001 5 N/mm^2	

2) Design moment in panel:

$$M_f = \frac{q_d b L^2}{8}$$

where:

		Values	Calculations
L	is the maximum distance between fixings in mm.	600 mm	–
b	is the width of the panel measured perpendicular to the span, L, in millimetres (mm)	900 mm	
M_f	is the peak flexural design moment in the panel in Nmm; and	–	0.001 5 × 900 × (600^2 / 8) = 60 750 Nmm

3) Design flexural strength of stone

$$f_d = \frac{f_k}{\gamma_m}$$

where:

		Values	Calculations
f_k	is the characteristic flexural strength (LEV) obtained from testing (see **5.4.1**) in N/m^2;	2.99 N/mm^2	–
γ_m	is the partial material factor (see **5.5.2** and Table E.1); and	4.20	–
f_d	is the design flexural strength of the stone	–	2.99/4.20 = 0.71 N/mm^2

4) Required elastic modulus

$$Z_{req} = \frac{M_f}{f_d}$$

where:

		Values	Calculations
Z_{req}	is the required elastic section modulus of the stone in mm^3	–	60 750/0.71 = 85 563 mm^3

5) Required stone thickness

$$t_{\mathrm{req}} = \sqrt{\frac{6Z_{\mathrm{req}}}{b}}$$

where:

b	is the width of the panel measured perpendicular to the span, *L*, in mm;	900 mm	–
t_{req}	is the required thickness of the stone in mm	–	$\sqrt{\frac{6 \times 85\,563}{600}}$ = 23.9 mm

.2 Fixing breakout design – Worked example

1) Total design wind loading:

$$W = \frac{\gamma_{\mathrm{f}} qA}{10^6}$$

where:

		Values	Calculations
A	is the overall face area of the stone (length × width) in mm^2;	540 000 mm^2	(see **E.1**)
q	is the wind pressure (**E.2**) in N/m^2;	1 500 N/m^2	–
γ_f	is the partial load factor (see **5.5.1**); and	1	–
W	is the total design wind load on the stone in N.	810 N	(see **E.1**)

2) Design load supported at each fixing:

$$F_{\mathrm{d}} = \frac{W}{n}$$

where:

n	is the number of restraint fixings engaged.	4	–
F_d	is the design load supported at each fixing in N; and *NOTE It is typically assumed that only three of the four fixings engage.*	–	810/4 = 203 N*

3) Design breakout capacity of fixing

$$R_{\mathrm{d}} = \frac{R_{\mathrm{k}}}{\gamma_{\mathrm{m}}}$$

where:

R_k	is the characteristic breakout capacity of the fixing (LEV) obtained from testing in N 50 mm thick Portland Jordans Whitbed;	1 460 N	–
γ_m	is the partial material factor (see **5.5.2** and Table E.1) in N/mm; and	4.20	–
R_d	is the design breakout capacity of the fixing in N.	–	1 460/4.20 = 347.6 N

4) Design breakout capacity of fixing exceeds design load

$R_d \geq F_d$ –

347.6 ≥ 203*

* *there is an error on the worked example in BS 8298 where the design load was divided by 3 instead of 4. 3 would have been correct if the stone were rainscreen cladding.*