LEADING THE UK EWI INDUSTRY

INCA Technical Guidance Document 03

Wind Load Design Considerations for EWI Systems

September 2021

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Apart from self-weight, wind loads on cladded structures are the most significant loading that a façade is likely to have to withstand. Action by high winds can impose both positive and negative pressures on a façade. Generally, negative suction pressures create the most onerous conditions by ‘pulling’ the system from the wall. This guide contains sample wind load calculations and examines the effect of the results on the design of EWI systems.

The Regulations, Standards and other references given in this document are believed to be correct at the time of issue. These documents remain subject to regular review, amendments, and updates. Whilst INCA will endeavour to review the status of the document, the reader is advised to check the validity and that they reference the latest versions and Regulations.

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Executive Summary

The actual pressures exerted on a building by wind are dependent on many factors including the localised wind speed, the location, and other building specific conditions listed below. Open countryside and coastal regions are likely to be more exposed giving rise to higher wind speeds and therefore higher forces on the structure.

Factors affecting wind loads:

- Building location
- Height above sea level
- Building shape and height
- Topography local to the building
- Surface texture of building
- Permeability of the building (openings)
- Height, shape and proximity of adjacent buildings (existing or planned)

The forces created by wind on a building are very dependent upon the wind direction and the orientation of the building to the wind. Designers should therefore be mindful of the prevailing wind direction for a given site and how they might optimise the building performance by orientating the building accordingly.

High winds are often associated with high buildings, whereas the reality is high wind loads can also be experienced on low rise construction. Tall buildings interrupt air flow at high level, which accelerates as it is forced down towards the ground. This has the effect of increased loads at both higher altitude and ground level. Similarly, where buildings are very close together, the venturi effect (as the wind is compressed) results in very high localised wind speeds and associated high pressures. This effect is known as funnelling and the potential for this effect to occur should be carefully considered on each site.

Like most weather-related issues, it is clear that the prediction of wind forces and their effect on a building is not straightforward nor is it an exact science. Accurate prediction is most likely to be obtained by scale modelling of the building, surrounding buildings and local topography, in a wind tunnel. Whilst this may yield the most reliable results on which to base design, it is time consuming and expensive, therefore likely to be the preserve of only the most prestigious or demanding projects. In practice, most projects will rely on theoretical calculations in accordance with agreed formulae and national / European standards. The relevant standard is now BS EN 1991-1-4:2005, which replaces BS 6399 Pt 2. It is usual that the calculation is carried out by a qualified structural engineer.

The calculation relies upon the input of site / building specific data, wind speed and other standard coefficients to account for variables such as building permeability. Wind behaves similarly to fluid materials in that it creates eddies and currents, which form both positive and negative pressures on the building as it passes through, over and around the building sides. The variability of wind action on the surfaces of the building result in different forces across the building and hence the need to output results in dimensioned ‘zones’, which define the magnitude of the load and the extent of the zone. It is normal to use computer software for calculation as ‘worst case’ conditions require several iterations of the calculation in all wind directions. A typical wind loading calculation example is included in this guide at Appendix 1.

External wall insulation (EWI) systems are typically connected using two fixing types: mechanical (using screws, dowels, rails or specialist insulation fixing units) or adhesive (normally with a proprietary cement-based adhesive). It is the fixing primarily that needs to be checked against failure under wind loading, although the inherent strength of the insulation may also need checking. When using screw or dowel fixings, the failure against ‘pull-out’ from the substrate as well as ‘pull-over’ of the fixing needs to be checked. As with standard engineering design principles, some ‘extra’ allowance has to be made so that systems do not fail under normally applied loads. This is achieved by applying factors of safety into the design which ensures that systems have sufficient ultimate strength to withstand the worst calculated wind load with a comfortable factor of safety.

Ventilated cavities behind insulation systems can create additional problems and consideration must be given to the combination of forces applied (suction on the front face combined with positive pressure) if air is able to enter the cavity from behind the insulation. This combined scenario may result in much higher load demands on the system. The cavity may also allow further movement of the system as it is buffeted under wind gusts. The consequence of this movement should be considered, particularly against fatigue of the components. This is not applicable to a drained cavity system, whereby there is only slight air movement within the cavity.

Each system is required to be checked against the wind loads for the specific zone of the building under consideration. Although wind speeds can be assumed using published data for specific regional areas, the building details, shape, size, height, and positions of surrounding buildings will be unique in every case. For this reason, it is not possible to assume the magnitude of wind loads based on location only i.e., buildings on the same street, in the same town, as all will be subject to uniquely different wind loads.

The strength of cladding systems will vary dependent upon the fixing or adhesive type, the background and the number of fixings used. Inadequate attention to correct fixings, spacing and number can lead to systems being detached from the wall. Standard calculations assume wind gusts on a 50-year return period. As extreme weather events appear to becoming more common place, the need for security of cladding solutions is ever more important.

Advice on the specific strength of a cladding system should always be sought from the system designer. This will be crossed referenced to the project design wind load, taking into account specific geographical locations to ensure that the designed system is compliant.

Modes of Failure

When assessing failure points of ETICS systems there are two modes of approach. The first being a Dynamic Wind Uplift (DWU) test and the second being a structured engineered approach following the principles of EAD 040083-00-0404 / EAD 040914-00-0404 and BS EN 1990 / 1991.

The DWU approach tests a large sample area through repeated changes in air pressure simulating gusts of wind pulling on the façade. After each complete set of cycles, the pressure is increased and the cycle is repeated. This is done until a drop in pressure is recorded or a failure is visible on the sample. The downside to this method is that the data set cannot be extrapolated, and the result is only relevant to the system that is tested including the fixing frequency used and based on the substrate design used.

The structured engineered approach following the principles of EAD 040083-00-0404 / EAD 040914-00-0404 is more common as this allows the system to be designed to the project design wind load using data sets created through testing on each mode of failure. This is completed using safety factors declared in EAD 040083-00-0404 / EAD 040914-00-0404.

Any positive pressure (pushing motion) applied to the system is transferred to the substrate and therefore is not a requirement for it to be considered when designing an ETICS system. For the purpose of designing ETICS systems, only negative pressure (suction) is considered.

When completing a system compliance check to establish if the standard system is suitable or if the system needs to be engineered further, the project design wind load must be known. This is normally completed by the project structural engineer by following the principles outlined in BS EN 1991-1 to obtain the Characteristic Load, then a safety factor, γ_L, is applied in line with BS EN 1990 to obtain the Design Load, also known as Ultimate Wind Load. When being presented with data from the structural engineer, it should be checked to find out what standard this has been created to and if it is the Characteristic or Design Load (i.e., unfactored or factored). Whilst the two methods exist of demonstrating wind load resistance of the system, a testing method and an engineered design method, as the testing method is extremely limited and the combinations within the system are vast, the engineered approach is the most common method used.

Within the engineered methodology there are various methods that can allow an ETICS system to fail under suction and **all** should be considered as each project and structure combination will have its own weaknesses. This section explains what the failure modes are, and the calculations that must be followed to demonstrate compliance to the customer, and also for calculating bespoke fixing patterns should they be required.

Different Types of Modes of Failure

Fixing Pull Out (mechanical fixed systems only)

This is where the mechanical anchors used to secure the system to the substrate fail. For the most common masonry substrates, fixings are classified according to EAD 330196-00-0604 with results declared against each substrate (to a maximum declared value of 1.5kN). Where the substrate is not listed within the EAD, on site testing can be completed in accordance with EOTA TR051 or where lab-based testing is possible this can be done in line with the Construction Fixings Association. Some systems, such as cavity-based systems, may use more than one type of fixing so each fixing type must be accounted for, i.e., fixings for top hat creating the cavity and supporting the insulation fixings. Should ancillary items such as top hats not be supplied by the system designer, it is the responsibility of the project design team to ensure that they are designed correctly, capable of supporting the project load and able to resist the project design loads.

Once the performance of each fixing is known, the number required per m^2 to achieve the Project Design Load can be determined.

Insulation Adhesive Bond Strength (Adhesive fixed systems only)

This is where adhesive is used as the primary attachment for the insulation, in place of mechanical anchors. Failure is deemed to occur when the adhesive fractures and loses its bond strength performance and allows the insulation to detach from the substrate. Adhesive Bond strength is determined from on-site testing in accordance with EAD 040083-00-0404 / EAD 040914-00-0404.

Once the result is known, the percentage of adhesive can be adjusted in line with EAD 040083-00-0404 / EAD 040914-00-0404.

Render Bond Strength

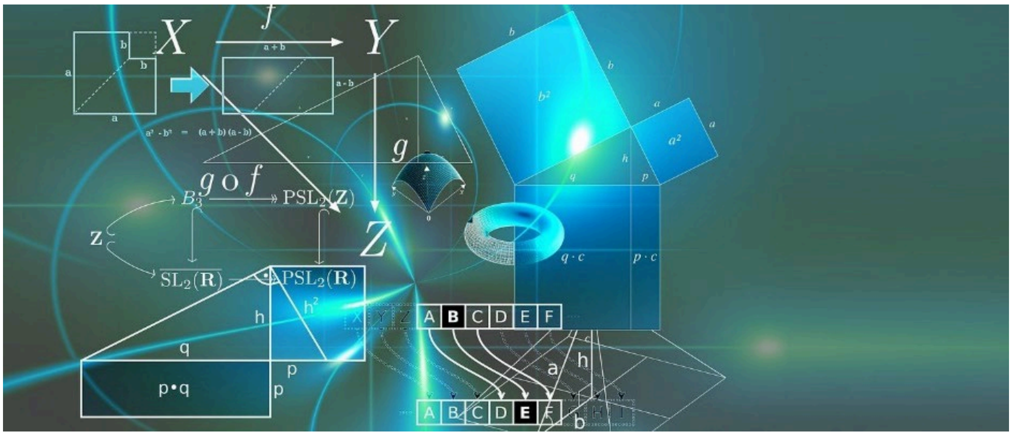
This is where the bonded reinforcing coat detaches away from the insulation. ETICS systems by nature are bonded layered systems and as such, the bond strength between the reinforced base coat and the insulation is a known mode of failure. EPS based systems are less susceptible to this mode of failure, Phenolic systems can be prone to the tissue delaminating from the insulation board causing this mode of failure. MW insulation is more problematic as being fibrous by nature the reinforcing render doesn’t bond as well as it does to closed cell type insulation. In many cases, this is the primary mode of failure for MW systems and can have a low performance limiting the system design before it requires amending. Where the result is lower than the Project Design Load, then **all** mechanical anchors for wind load compliance must be installed through the reinforcing mesh. This may require additional anchors being used as temporary securement of the insulation.

Fixing Pull Through

Pull through is where the insulation anchor remains in the wall but the insulation has been pulled over the fixing head. When considering pull through, it is important to ensure that the fixing washer size and plate stiffness is the same or higher than that tested by the system designer. When moving away from the standard fixing pattern, it is important to consider the rupture method of the insulation to ensure the load displacement of the fixings do not overlap, or interfere with insulation board edges.

When assessing test data for pull through it is important to consider both wet and dry insulation test data sets, as with some insulation types, the performance deteriorates when wet.

APPENDIX 1: EXAMPLE CALCULATION

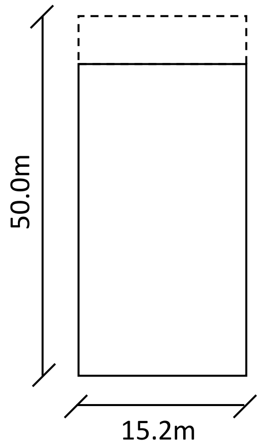


Appendix 1: Example Calculation

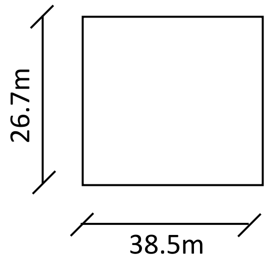
The figures used in the following calculation are for illustrative purposes only.

Building Parameters

i) Building height (50.0m) with 2.0m high parapet.



ii) Assumed example building is assumed to be square on plan.



iii) The building is assumed to be constructed from rendered Clay Brick with a density exceeding 1.8 kg/dm3 and have less than 15% vertical perforations. The render over the bricks is 18mm thick.

iv) Building is to be clad with a 60mm thick phenolic foam ETICS system.

v) Site Location:

Postcode:	**L21 1AU**
OS Grid Ref:	**SJ328972**
Site Level AOD:	**12m**
Upward Distance to Sea:	**0m**
Distance to Edge of Town:	**0m**

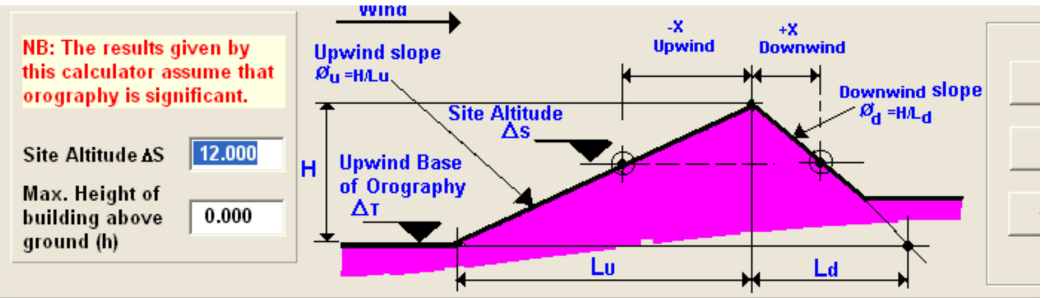
Site Location

i) Site Post code : L21 1AU

ii) Terrain Category : EN 1991-1-4 (4.3.2) Table 4.1

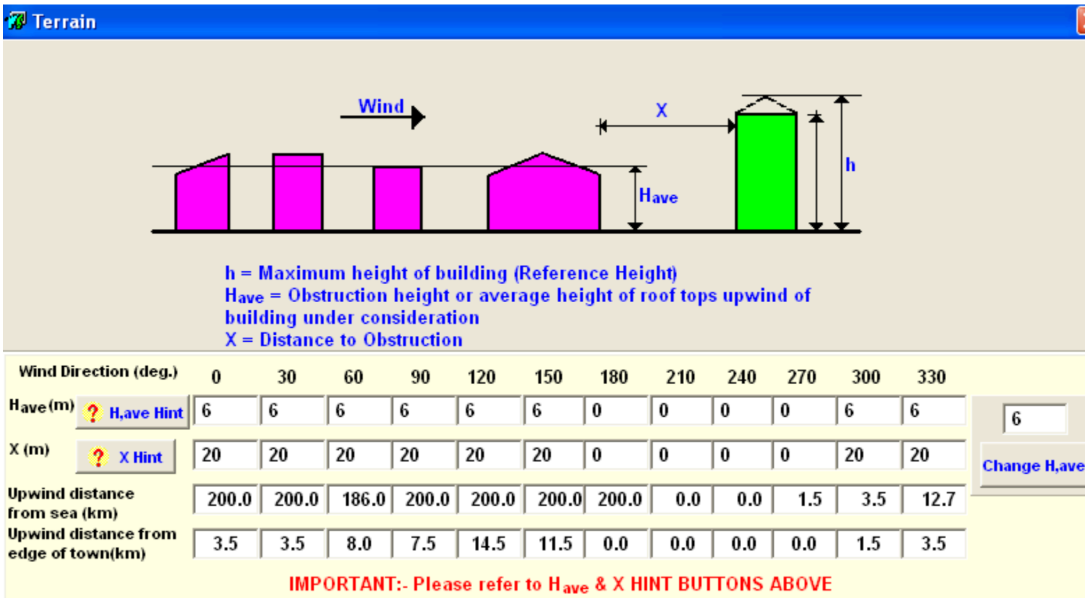
	Terrain category	z_0 m	z_{min} m
0	Sea or coastal area exposed to the open sea	0,003	1
I	Lakes or flat and horizontal area with negligible vegetation and without obstacles	0,01	1
II	Area with low vegetation such as grass and isolated obstacles (trees, buildings) with separations of at least 20 obstacle heights	0,05	2
III	Area with regular cover of vegetation or buildings or with isolated obstacles with separations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest)	0,3	5
IV	Area in which at least 15 % of the surface is covered with buildings and their average height exceeds 15 m	1,0	10
NOTE: The terrain categories are illustrated in A.1.			

iii) Orography Calculator



Wind Direction	0	30	60	90	120	150	180	210	240	270	300	330
H	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
ΔT	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Length of upwind slope Lu	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
Length of downwind slope L_d	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0	300.0
Horizontal distance from crest =X(+ or-)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Orographic location factor (s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Orography factor (Co)	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

iv) Terrain

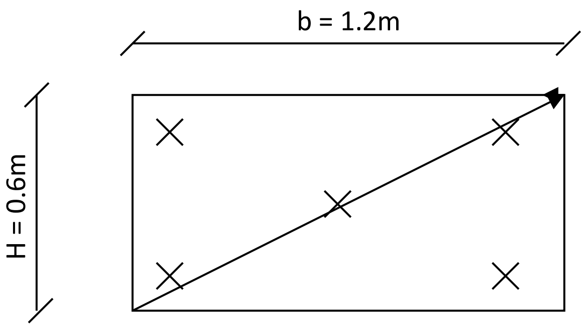


Building Geometry

i) **Reference Height:** $(H_r) = 50m$

ii) **Parapet Height:** $(H_P) = 2.0m$

iii) **Size Effect Factor:** (b+h)



Size effect dimension:

$$b + h = 1.2 + 0.6 = 1.8m$$

The dimensions of the individual cladding panel should be used to determine the size effect. BS 6399 called this the diagonal dimension and used to be set to a minimum of 5m.

Wind Loading

i) Determination of basic wind velocity:

$$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$$ EN 1991-1-4 (4.2)

where:

v_b basic wind velocity

c_{dir} directional factor

c_{season} seasonal factor

$v_{b,0}$ fundamental value of the basic wind velocity

Fundamental value of the basic wind velocity: (see European Wind Map)

$$v_b = 23.5\, m/s$$ (for Sefton – UK)

For simplification the directional factor c_{dir} and the seasonal factor c_{season} are taken to be equal to 1 (conservative)

$$\therefore\ v_b = c_{dir} \cdot c_{season} \cdot v_{b,0} = 23.5\, m/s$$

ii) Basic Velocity Pressure

$$q_b = \frac{1}{2} \cdot \rho_{air} \cdot v_b^2$$ EN 1991-1-4 (eq. 4.10)

where: $\rho_{air} = 1.25\, kg/m^3$

$$\therefore\ q_b = \frac{1}{2} \cdot 1.25 \cdot 23.5^2 = 345.15\, N/m^2$$

iii) Peak Pressure

$$q_p(z) = \left[1 + 7 l_v(z)\right] \cdot \frac{1}{2} \cdot \rho \cdot v_m(z)^2$$ EN 1991-1-4 (eq. 4.8)

Calculation of $v_m(z)$

$v_m(z)$ mean wind velocity

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

where: $c_o(z)$ is the orography factor

$c_r(z)$ is the roughness factor

$$c_0(z) = k_T \cdot \ln\left(\frac{z}{z_o}\right) \qquad \text{for } z_{\min} \le z \le z_{\max}$$

$$c_r(z) = c_r(z_{\min}) \qquad \text{for } z \le z_{\min}$$

where: z_0 is the roughness length

k_T is the terrain factor, depending on the roughness length z_0 calculated using:

$$k_T = 0.19 \cdot \left(\frac{z_0}{z_{0,\mathrm{II}}}\right)^{0.07}$$ EN 1991-1-4 (4.3.2)

where: $z_{0,\mathrm{II}} = 0.05$ (terrain category II) EN 1991-1-4 (Table 4.1)

$z_{\min}$ is the minimum height

$z_{\max}$ is to be taken as 200m

Calculation of $l_v(z)$

$l_v(z)$ turbulence intensity EN 1991-1-4 (eq. 4.7)

$$l_v = \frac{k_\mathrm{I}}{c_o(z) \cdot \ln(z/z_o)} \qquad \text{for} \qquad z_{\min} \le z \le z_{\max}$$

$$l_v = l_v(z_{\min}) \qquad \text{for} \qquad z < z_{\min}$$

where: k_I is the turbulence factor. Recommended value for k_I is 1.0

$z = 50m$

so: $z_{\min} < z < z_{\max}$

$$q_p(z) = \underbrace{\left(1 + \frac{7k_\mathrm{I}}{c_0(z) \cdot \ln(z/z_o)}\right)}_{\text{squared gust factor}} \cdot \underbrace{\frac{1}{2} \cdot \rho \cdot v_b^2}_{\text{basic pressure}} \cdot \underbrace{\left(k_T \cdot \ln(z/z_o)\right)}_{\text{wind profile}}$$

Results

Wind Direction (deg.)		0	30	60	90	120	150	180	210	240	270	300	330
Direction Factor $C_{,dis}$		0.78	0.73	0.73	0.74	0.73	0.80	0.85	0.93	1.00	0.99	0.91	0.82
Orography Factor C_o		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Effective Height (h - hdis) m	Roof	46.800	46.800	46.800	46.800	46.800	46.800	50.000	50.000	50.000	50.000	46.800	46.800
	Sides	46.800	46.800	46.800	46.800	46.800	46.800	50.000	50.000	50.000	50.000	46.800	46.800
	Gable	46.800	46.800	46.800	46.800	46.800	46.800	50.000	50.000	50.000	50.000	46.800	46.800
Altitude Factor $C_{,alt}$	Roof	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009
	Sides	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009
	Gable	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009	1.009
Roughness Factor C_r	Roof	1.127	1.127	1.104	1.105	1.092	1.096	1.288	1.477	1.477	1.403	1.239	1.171
	Sides	1.127	1.127	1.104	1.105	1.092	1.096	1.288	1.477	1.477	1.403	1.239	1.171
	Gable	1.127	1.127	1.104	1.105	1.092	1.096	1.288	1.477	1.477	1.403	1.239	1.171
Exposure Factor C_e	Roof	3.194	3.194	3.051	3.056	2.970	2.997	3.275	3.648	3.648	3.648	3.616	3.456
	Sides	3.194	3.194	3.051	3.056	2.970	2.997	3.275	3.648	3.648	3.648	3.616	3.456
	Gable	3.194	3.194	3.051	3.056	2.970	2.997	3.275	3.648	3.648	3.648	3.616	3.456
Vb,0 (m/s)	Roof	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704
	Sides	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704
	Gable	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704	23.704
Vb (m/s)	Roof	18.489	17.304	17.304	17.541	17.304	18.964	20.149	22.045	23.704	23.467	21.571	19.438
	Sides	18.489	17.304	17.304	17.541	17.304	18.964	20.149	22.045	23.704	23.467	21.571	19.438
	Gable	18.489	17.304	17.304	17.541	17.304	18.964	20.149	22.045	23.704	23.467	21.571	19.438
Vm (m/s)	Roof	20.846	19.510	19.106	19.383	18.894	20.781	25.946	32.551	35.001	32.924	26.731	22.752
	Sides	20.846	19.510	19.106	19.383	18.894	20.781	25.946	32.551	35.001	32.924	26.731	22.752
	Gable	20.846	19.510	19.106	19.383	18.894	20.781	25.946	32.551	35.001	32.924	26.731	22.752
Turbulence Intensity Iv	Roof	0.206	0.206	0.206	0.206	0.206	0.206	0.135	1.477	1.477	0.126	0.189	0.206
	Sides	0.206	0.206	0.206	0.206	0.206	0.206	0.135	1.477	1.477	0.126	0.189	0.206
	Gable	0.206	0.206	0.206	0.206	0.206	0.206	0.135	1.477	1.477	0.126	0.189	0.206
Peak Velocity Pressure q_p (kN/m²)	Roof	0.697	0.611	0.586	0.603	0.573	0.693	0.816	19.149	22.141	1.262	1.076	0.830
	Sides	0.697	0.611	0.586	0.603	0.573	0.693	0.816	19.149	22.141	1.262	1.076	0.830
	Gable	0.697	0.611	0.586	0.603	0.573	0.693	0.816	19.149	22.141	1.262	1.076	0.830

Wind pressure on surfaces:

A positive wind load stands for pressure whereas a negative wind load indicates suction on the surface.

External pressure coefficients:

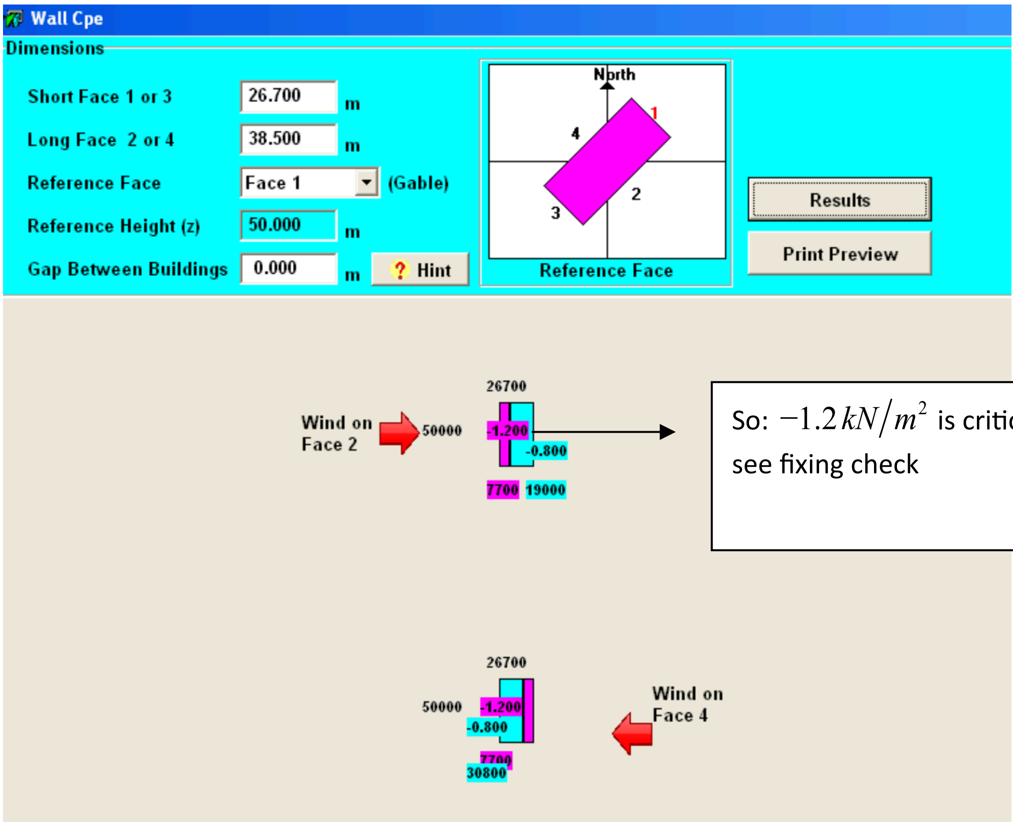
The wind pressure acting on the external surfaces, w_e should be obtained from the following expression:

$$w_e = q_p\left(z_e\right)\cdot\ c_{pe}$$ EN 1991-1-4 (eq. 5.1)

where: z_e is the reference height for the external pressure (50m)

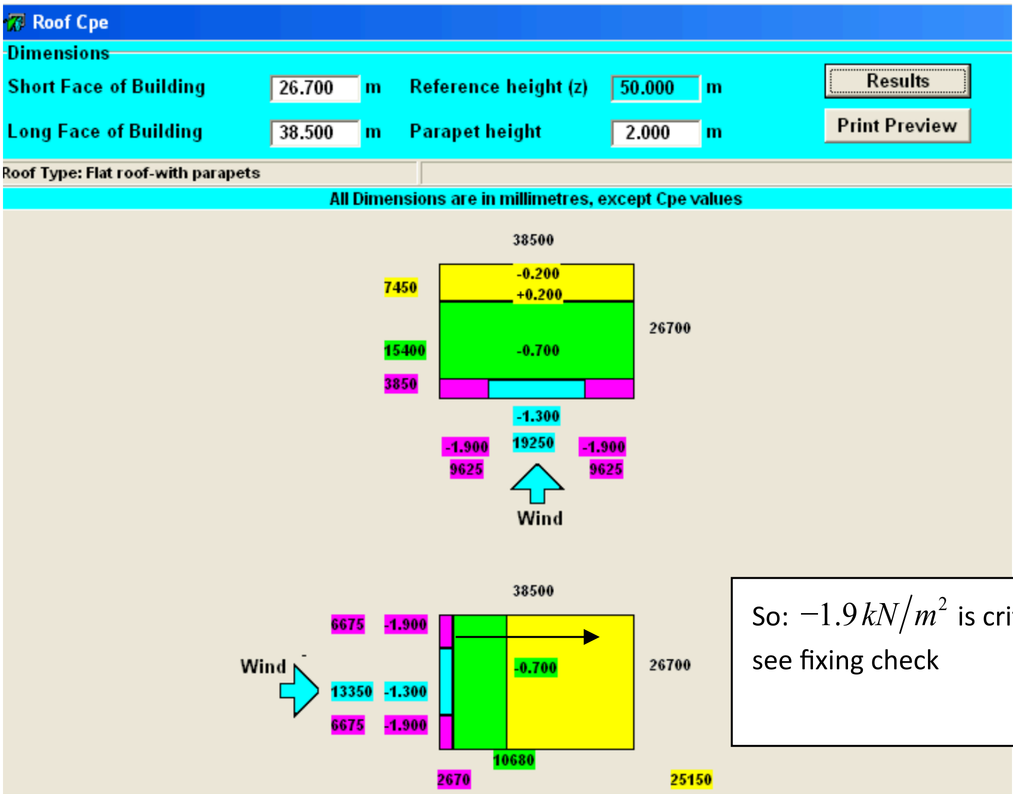
c_{pe} is the pressure coefficient for the external pressure

Walls



So: $-1.2\,kN/m^2$ is critical suction see fixing check

Parapet



So: $-1.9\,kN/m^2$ is critical suction see fixing check

Wind Loading Summary

- Dynamic Pressure: 1.076 kN/m^2
- Maximum Suction Zone A: 1.2 kN/m^2
- Critical Suction on Parapet: 1.9 kN/m^2

Anchor Design Resistance Assessment (Mechanical Fix)

The Construction Fixings Association (CFA) provides detailed guidance when it is necessary to carry out site specific pull-out tests. The CFA guidance notes are available from www.the-cfa.co.uk. Their recommendations are in accordance with BS 8539:2012 *Code of practice for the selection and installation of post-installed anchors in concrete and masonry*.

Testing is not normally required for anchors used in concrete as BS 8539:2012 recommends that only anchors with European Technical Approval (ETA) should be used and full performance will be stated in the ETA. Tests may be required if for some reason no anchors with ETA are available, or if the condition of the concrete gives reason to believe that performance quoted in the ETA is unlikely to be achieved. Site specific testing is normally only required for anchors used in masonry, or other materials as detailed below.

If the anchor type selected is covered by a valid ETA for the category of masonry of the job and that masonry conforms to the qualifications of the ETA then it is allowable to utilise the tabulated values of the Characteristic Resistance N_{rk0} - see appendix 2 for an extract from a typical fixing ETA report.

If the anchor selected is covered by a valid ETA for the category of masonry of the job but that masonry does not conform to the qualifications of the ETA in terms of strength and dimensions, then site specific pull-out tests should be carried out to assess the design resistance of the anchor.

Where there is no anchor on the market which carries a relevant ETA, the tests called for in BS8539:2012 Annex B.2.3 should be carried out provided the proposed anchors are of a type approved by the manufacturer for use in the category of material involved.

The most typical approach is to adopt the recommendations of Annex D of European Technical Approval Guideline (ETAG) 014. These tests shall take account of the most unfavourable conditions of practical execution. At least 15 tests should be undertaken. More tests may be necessary if the substrate is variable in condition or completely different substrates exist in the building i.e., concrete and brickwork areas. Other test regimes are available under BS 8539:2012 and can be used as an alternative. Proof load testing of fixings is highlighted in BS 8539:2012 but is not normally required for ETICS applications and is not deemed practical to undertake.

Extract from Annex D of ETAG 014

D.2. Assembly

The plastic anchor to be tested shall be installed (e.g., preparation of drill hole, drilling tool to be used, drill bit) and, as far as spacing and edge distances are concerned, be distributed in the same way as foreseen for the fixing of the external thermal insulation composite system.
Depending on the drilling tool, hard metal hammer-drill bits or hard metal percussion drill bits, respectively, according to ISO 5468 [17] shall be used the cutting diameter of which is at the upper tolerance limit.

D.3. Execution of test

The test rig used for the pull-out tests shall allow a continuous slow increase of load controlled by a calibrated load cell. The load shall act perpendicularly to the surface of the base material and be transmitted to the plastic anchor via a hinge. The type of test rig bridge needs to be considered in accordance with BS 8539:2012 The load shall be continuously increased so that the ultimate load is achieved after about 1 minute. Recording of load is carried out as the ultimate load (N_{Ru}) is achieved for each anchor.

On site pull-out testing and determination of design loads

Examples of test rigs

The fixing test results should be provided on a test report – see appendix 3 for example of fixing test report.

Product Assessment – Assumptions and Recommendations

This section sets out the assumptions and recommendations for assessment of the product 'fitness for use' according to the ETAG 014 relating to design, installation and execution, packaging, transport and storage, use, maintenance, and repair.

Design Methods for Anchorages

The overall assumption shall be made that the design and dimensioning of anchorages is based on technical considerations and in particular the following:

- The characteristic resistance of single plastic anchors in the different base materials is evaluated according to 6.4.3. Taking a simple approach, the characteristic resistance of single plastic anchors may be used for the different loading directions (shear load and combined tension and shear loads)
- In accordance with UK national regulations (UK Construction and Fixing Association), the partial safety factors for the resistance of the plastic anchor may be taken as: $\gamma_m = 2$ (see above)
- The minimum edge distance (c_{min} = 100mm) and spacing (s_{min} = 100mm) should not fall below these values
- The preparation of verifiable calculation notes and drawings for determining the relevant concrete or masonry in the region of the anchorage, the loads to be transmitted and their transmission to the supports of the structure
- Investigations and evaluations according to ETAG 004 [3] are necessary for the verification of the loading imposed by the ETICS on to the plastic anchor.

Method A (Using ETA Approved Fixings into Standard Substrate)

Assuming that the fixings can be designed using this method, the characteristic resistance of the fixing can be obtained as follows (the N_{Rko} can be taken as 1.5 kN directly from the ETA):

Clay bricks e.g. according to DIN 105, Mz	≥ 1,8	12	Vertically perforation up to 15%	1,5

$$N_{RD0} = 1.5/2 = 0.75kN$$

Method B (Site Testing)

Using the formula given in ETAG 014 Annex D, the characteristic resistance of the anchors can be determined as follows:

D.5. Evaluation of test results

The characteristic resistance N_{RK1} is obtained from the measured values on N_1 as follows:

$N_{RK1} = 0{,}6 \bullet N_1 \leq 1{,}5$ kN

N_1 = the mean value of the five smallest measured values at the ultimate load

Extract from Test Report

On site pull-out tests conducted on the fixings type XYZ.

	Fixings Type	Drill Bit dia (mm)	Penetration (mm)	Location	Material	Load (kN)	Mode of failure
1	XYZ	8	20	Random	K	1.9	Ultimate
2	XYZ	8	20	Random	K	1.8	Ultimate
3	XYZ	8	20	Random	K	2.1	Ultimate
4	XYZ	8	20	Random	K	1.7	Ultimate
5	XYZ	8	20	Random	K	1.7	Ultimate
6	XYZ	8	20	Random	K	**1.6**	Ultimate
7	XYZ	8	20	Random	K	1.8	Ultimate
8	XYZ	8	20	Random	K	**1.7**	Ultimate
9	XYZ	8	20	Random	K	**1.7**	Ultimate
10	XYZ	8	20	Random	K	**1.6**	Ultimate
11	XYZ	8	20	Random	K	1.9	Ultimate
12	XYZ	8	20	Random	K	2.0	Ultimate
13	XYZ	8	20	Random	K	2.2	Ultimate
14	XYZ	8	20	Random	K	**1.5**	Ultimate
15	XYZ	8	20	Random	K	1.8	Ultimate

Material: K = Brickwork

i) Calculate mean N_1 of the lowest 5 results: highlighted in red

N_1 = 1.62 kN

ii) Calculate characteristic resistance

N_{Rk1} = 1.62 x 0.6 = 0.972 kN per fixing

iii) Calculate design resistance

N_{Rd1} = kN $N_{Rd1} = 0.972/2 = 0.486kN$ per fixing

Pull-Through Capacities

The characteristic pull through resistance of the fixings and the specific insulation material should also be examined as this may be the limiting factor, not the actual pull-out resistance of the anchor in the substrate.

The characteristic pull through capacities are assessed as part of the ETAG 004 or BBA approval of ETICS systems. As such, tabulated values of the characteristic pull through values are available. It should be noted that the pull through capacities achieved are highly dependent on the type / thickness of the insulation and the diameter of the fixing head.

Some fixings are designed to be recessed into the insulation. If these fixings are used then it should be noted that the insulation thickness is effectively reduced. Accordingly, the fixing supplier provides recommendations on the minimum thickness of insulation that should be used. These fixings cannot be used with certain types of insulation e.g., dual density mineral fibre.

A typical value of the characteristic pull-through for a 60mm diameter plate fixing with 60mm expanded polystyrene would be circa 530N per anchor (i.e., 0.53 kN); however, with a 140-diameter extension washer the characteristic pull through capacity is typically 1000N.

This characteristic capacity should be factored down by a partial material safety factor. $\gamma_m = 2.5$

Hence the design pull-over value for the fixings with 140mm diameter washers would be / = kN. $1.0/2.5 = 0.400kN$

In this example, this would be the critical design mode of failure and, as such, the limiting design wind pressure would have to be based on this value.

Mechanical Fix – System Design Wind Resistance

Based on 5 fixings per 1.2m x 0.6m board, the wind resistance per board would be:
= kN $5 \cdot 0.40 = 2kN$ /board.

The wind resistance / m2 will therefore be:

$$\frac{2.0}{1.2 \cdot 0.6} = 2.77\,kN/m^2$$

On this basis the design would be safe for the main zone A, B and C areas of the building as wind suction in these areas will not exceed a design wind suction of:

$$1.2 \cdot 1.5 = 1.8\,kN/m^2$$

However, 5 fixings per board would not be sufficient for the parapet areas. The parapet areas would require 6 fixings per board i.e.

$$6 \cdot 0.4 = 2.4kN$$

$$3.33\,kN/m^2 > 1.5 \cdot 1.9 = 2.85\,kN/m^2$$

Adhesive Fix Comparison

To verify the characteristic bond strength for a particular building, five adhesion tests should be undertaken. These tests involve applying adhesive to the wall and allowing it to cure for 1 day per mm of render thickness. The samples are then tested with a pull off meter having bonded a 50mm diameter dolly to the wall. The dolly is normally over cored so that loading is only applied to the surface directly below the dolly and no sharing from surrounding substrate. If the surface strength exceeds 0.08N/mm2 then the adhesion between the adhesive and insulation becomes the weakest link. None of the test results must be lower than 0.08 N/mm^2 – see clause 7.2.1.1 ETAG 004.

The wind suction that can be resisted by a 40% adhesive fixed system with a bond strength of 0.08 N/mm^2 = 80 kN/m^2 is demonstrated by the following calculation:

Design bond strength = characteristic bond strength = 80/9 = 8.8 kN/m^2
Bond area per m^2 = 0.4 m^2
Hence design bond strength = 0.4 x 8.8 = 3.55 kN/m^2
However, the un-factored wind load capacity would be 3.55 / 1.5 = 2.37 kN/m^2

This would therefore be adequate to resist the design load of 1.84 kN/m^2 in zones A, B and C but would not be sufficient for the parapet areas.
For the parapet areas, one of the following would be required:

- Proof that the bond strength exceeded 0.08
- Increase in the adhesive percentage

Extract from ETAG 004

7.2.1.1 Substrate suitable for bonded ETICS

Where the ETICS rely on being bonded, the suitability of the substrate needs to be established as follows:

- New concrete or masonry surfaces may be suitable provided they are not contaminated e.g., by mould, mould oil (concrete) or other pollutants
- Other new substrates will need to be subject to on-site testing
- Old substrates may need surface preparation; for example, removal of paint finishes or existing renders where their load transfer to the wall cannot be confirmed
- Whenever there is doubt about the quality of an existing substrate, on-site testing shall be undertaken
- Where testing is undertaken no result shall be less than 0.08 N/mm^2 for a bonded system to be used.

APPENDIX 2: EXTRACT FROM A TYPICAL ETA FIXING REPORT

Appendix 2: Extract from a Typical ETA Fixing Report

Page 14 of the European Technical Approval ETA-05/0009 issued on 20 January 2010

Table 4: Characteristic resistance to tension loads N_{Rk} in concrete and masonry for a single anchor in kN

Anchor type				XYZ
Base material	Bulk density class ρ [kg/dm³]	minimum compressive strength f_b [N/mm²]	General remarks	N_{Rk} [kN]
Concrete C12/15			EN 206-1	1,2
Concrete C16/20 - C50/60			EN 206-1	1,2
Clay bricks e.g. according to DIN 105, Mz	≥ 1,8	12	Vertically perforation up to 15%	1,5
Sand-lime solid bricks e.g. according to DIN 106, KS	≥ 1,8	12	Vertically perforation up to 15%	1,5
Lightweight concrete solid blocks; e.g. according to DIN 18152, V	≥ 0,9	4	Proportion of hole up to 10% maximum extension of hole: length = 110mm; wide = 45mm	0,5
Vertically perforated clay bricks e.g. according to DIN 105, Hlz	≥ 1,2	12	Vertically perforation more than 15% and less than 50%	0,9
Sand-lime perforated bricks e.g. according to DIN 106, KSL	≥ 1,6	12	Vertically perforation up to 15%	1,5 [1]
Lightweight concrete hollow blocks; e.g. according to DIN 18151, Hbl	≥ 0,5	2	see Annex 6	0,5
Vertically perforated clay bricks Hlz 25x38x23,5			Reference brick advicing ÖNORM B6124 see Annex 6	0,75
partial safety factor		γ_{Mc} =	$2{,}0^{2)}$	

[1] The value applies only for outer web thickness ≥ 20mm; otherwise the characteristic resistance shall be determined by job site pull-out tests.

[2] valid, if no national regulation consists

Characteristic resistance	**Annex 4** of the European Technical Approval XYZ

APPENDIX 3: EXAMPLE OF A FIXING TEST REPORT

Appendix 3: Example of a Fixing Test Report

PULL OUT TEST REPORT

Test date	17th October 2013	Report no.	XXX/XXX/2013
Test carried out for		Site address	
Test location	Front & side elevations	Temperature	14°C
Test equipment	Hydrajaws 0-25kN digital	Calibration date	29th January 2013
Tests carried out by		Witnessed by	
Application details	EWI 90mm GEPS, wet fixed	Characteristic action N_{Sk}	Unknown
Drilling method	Hammer	Hole cleaning method	None
Exact drill bit diameter	8.3mm	Drill hole depth	35mm
Thickness to be fixed	95mm	Materials to be bridged	20mm render/dash
Substrate thickness	100mm	Test objective	Ultimate load test
Fixing name		Test regime	According to ETAG 014 (15 tests)

Test no.	Fixing type/name	Nominal drill diameter (mm)	Embedment depth[1] h_{nom} (mm)	Base material (see below)	Max load applied[2] N_{Ru} (kN)	Mode of failure
1	XXXX-XX-XXX	8	25	B	1.9	Anchor pull out
2	XXXX-XX-XXX	8	25	B	1.8	Anchor pull out
3	XXXX-XX-XXX	8	25	B	2.1	Anchor pull out
4	XXXX-XX-XXX	8	25	B	1.7	Anchor pull out
5	XXXX-XX-XXX	8	25	B	1.7	Anchor pull out
6	XXXX-XX-XXX	8	25	B	1.6	Anchor pull out
7	XXXX-XX-XXX	8	25	B	1.8	Anchor pull out
8	XXXX-XX-XXX	8	25	B	1.7	Anchor pull out
9	XXXX-XX-XXX	8	25	B	1.7	Anchor pull out
10	XXXX-XX-XXX	8	25	B	1.6	Anchor pull out
11	XXXX-XX-XXX	8	25	B	1.9	Anchor pull out
12	XXXX-XX-XXX	8	25	B	2.0	Anchor pull out
13	XXXX-XX-XXX	8	25	B	2.2	Anchor pull out
14	XXXX-XX-XXX	8	25	B	1.5	Anchor pull out
15	XXXX-XX-XXX	8	25	B	1.8	Anchor pull out

[1] Nominal embedment depth in the base material excluding any material to be bridged e.g. old render. [2] Indicated loads are for guidance and indicate performance only in the areas tested.

Base materials (defined ETAG 014):

- **A** Normal weight concrete
- **B** Solid masonry
- **C** Hollow or perforated masonry
- **D** Light weight aggregate concrete
- **E** Autoclaved aerated concrete

Base materials (other):

- **F** No fines concrete
- **G** Steel
- **H** Timber
- **I** Cement particle board
- **J** Other

Characteristic resistance N_{Rk} (ETAG014) = $N_1(0.6)$ <1.5kN **0.972**

Due to the complexity of building materials, tools, fixing and installation techniques, a comprehensive recommendation depends on a full and detailed understanding of specific site conditions. This report is a factual record of results observed and does not constitute an endorsement of suitability of the product tested for the application specified. The results shall only be used as a guide for assessment of suitability in other locations. Any recommendations given by XXXXXXX are dependant on the accuracy of details provided by others, for this reason even when given in good faith they can not be binding. No statement made by us shall be incorporated in any contract unless expressly agreed in writing. It is essential you check all information has been interpreted correctly. To calculate the allowable resistance appropriate safety factors must be applied.

Comments:

1) Building height 50m
2) Assuming 90mm insulation wet fixed, subject to wind loads and fixing pattern, use XXXX-XXX-XXX

Report by: Date: 17th October 2013

Acknowledgements

Wind loads can be calculated using the latest version of Metsec Framing's industry leading panel design software. Metspec14 is Eurocode compatible and provides an invaluable tool to quickly calculate accurate and efficient wind loads in accordance with BS EN 1991-1-4. INCA would like to thank Metsec for the use of their software when calculating wind loads as indicated in Appendix 1. Metspec14 can be downloaded from Metsec's website at www.metsec.com.

All project design wind loads must be completed by a suitably qualified or competent person.

LEADING THE UK EWI INDUSTRY

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