SipsEcoPanels

Structural Design Guide

CATG-SIP-401

SipsEcoPanels

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1. Introduction & Scope of Manual

1.1 This Design Manual has been prepared by Tim Kelly Consulting Engineers Ltd. on behalf of Sips Eco Panels as a design aid to Structural Engineers in the structural design of their Structural Insulated Panels (heretofore known as “SIP panels”). It is expected that the Structural Engineers shall have a good working knowledge of Eurocode 0, Eurocode 1 (parts 1, 3 & 4) and Eurocode 5. It is further assumed that the Structural Engineer is experienced in timber frame / SIP frame design.

1.2 Sips Eco Panels Ltd's SIP panels are a composite, sandwich panel manufactured by gluing outer skins of OSB/3 to expanded polystyrene insulation (of minimum grade EPS90).

1.4 The Sips Eco Panels section depths that form the integral part of this document are 119mm, 144mm, 169mm, 194mm and 219mm. This should not exclude other sizes being added in the future as the calculation methods described within can be readily adapted for any combination of thickness of OSB skins and EPS insulation.

1.5 The SIP panels described within are currently limited to roof and wall elements. Glued SIP lintels are also designed and incorporated as part of the wall design.

The “SIP structure” will also include some or all of the following elements:

1.5.1. Solid timber ceiling ties.

1.5.2 Internal solid timber stud walls (studs typically at 600mm or 400mm crs.) as per structural engineers design and specification.

1.5.3. Solid timber or engineered timber floor joists (engineered timber floor joists are typically proprietary I-joists or open web joists) which are seated on the load-bearing SIP external wall panels and the solid timber internal load-bearing stud wall panels. There is typically a rimbeam running around perimeter of floor.

Joists may also be hung from side of SIP panels using proprietary joist hangers such as Simpson Strong-tie IUQ and HIUQ hangers or similar. The joist hangers must be allowed by the proprietary hanger manufacturer for this purpose.

1.5.4. Solid timber, engineered timber or steel floor beams and purlins which shall be designed to adequately resist the applied loading as per normal structural design principles.

As items described in 1.5.1 to 1.5.4 are not limited to SIP structure and their design is standard and very well described in numerous publications, this document shall, henceforth, limit itself to structural design specifically relating to the SIP panels.

1.6 Previously, Sips Eco Panels Structural Design Guidance was based primarily on test results which were used to produce tables and prescriptive design guides to the principles of BS 5268 and associated British Standards. The previous design guides were, thus, limited to the section sizes tested and to use of BS5268. Therefore the design guide wasn’t “future-proof” as it didn’t allow for differing panel thicknesses or changing of standards to Eurocodes. There is nothing stopping a designer from continuing to use the older design guides as long as designs to British Standards is permitted and assuming that correct design principles are being applied. Principles such as shear deflection and time dependent designs are critical. The use of tables which only state “short-term” loading are confusing for an inexperienced designer.

The main objectives of this design guide are as follows:

1.6.1 To allow for a design methodology based, to a much greater extent, on design from 1st principles. This allows for a greater design flexibility in the use of materials and section depths.

1.6.2 To produce a design guide and accompanying tables to provide a basis for design of the Sips Eco Panels to Eurocode design. Note that all British Standards conflicting with Eurocode have now been withdrawn (although it is understood that until 2016 it is permitted to use either Eurocodes or British Standards. These designs should, as always, be carried out by a Structural Engineer experienced in the design of SIP panels.

1.6.3 To include Glued SIP lintel table to the Structural Design Manual (Annex C).

2. Standards Used and Other References

2.1 BS EN 1990: 2002 + A1: 2006 - Basis for Structural Design.

2.2 BS EN 1991: 2002 + A4: 2004 - Action on Structures: Part 1-1: General actions – densities, self-weight, imposed loads on Buildings.

2.3 BS EN 1991-1-3: 2003 - Actions on Structures: Part 1-3: Snow loads.

2.4 BS EN 1991-1-4:2005 + A1: 2010 - Actions on Structures: Part 1-4: Wind loads.

2.5 BS EN 1995-1-1:2004 + A1:2008 - Design of Timber Structures: Part 1-1: General -Common rules and rules for Buildings.

2.6 BS EN 300: 2006 - Oriented Strand Boards (OSB) – Definitions, Classifications and Specifications.

2.7 BS EN 13163 - Thermal insulation products for buildings. Factory made expanded polystyrene (EPS) products: Specification.

2.8 BS EN 301:2006 - Adhesives, phenolic and aminoplastic, for loading bearing timber structures. Classification and performance requirements

2.9 BS EN 12369-1: 2001 - Wood-based Panels - Characteristic Value for Structural Design - OSB, particleboard and fibreboards.

2.10 BS EN 338: 2009 - Structural Timber: Strength Classes.

2.11 Non-standard References

2.11.1 TR019 - EOTA Technical Report: calculation models for prefabricated wood based loadbearing stressed skin panels for use in roofs.

2.11.2 Manual for the Design of Timber Building Structures to Eurocode 5 by *TRADA and I.Struct.E*.

2.11.3 Structural design to Eurocode 5 by *Jack Porteous and Abdy Kermani*.

2.11.4 Sips Eco Panels 119, 169, 194, 219mm Structural Insulated Panels (SIPs): Design Technical Report for Third Party approval to Eurocode by *Milner Associates*.

2.11.5 Lightweight Sandwich Construction by *JM Davies*.

3. Background - TR019: calculation models for prefabricated wood based loadbearing stressed skin panels for use in roofs.

3.1 There are several types of stressed skin panels presented in TR019. In relation to SIP panel design, there are 2 of relevance:

3.1.1 Type A - Stressed skin panels, closed box type double skin, without wooden ribs, with load-bearing insulation (i.e. SIP panels with SIP splines only at panel / panel connection).

3.1.2 Type B1 - Stressed skin panels, closed box type double skin, with wooden ribs and load-bearing insulation (although the design methodology for SIP panels with splines ignores the effect of the insulation in this case. Longer spans may be possible in the future with clarity on the TR019 design method of sandwich panels with wooden ribs and load-bearing insulation).

3.2 In all cases, it is critical to the design that the grain / strand direction of timber / OSB is parallel to the span direction.

3.3 Although TR019 is primarily for use for roof panels, the principles of TR019 and EN1995-1-1 can be used to design SIP wall panels as will be described in further detail in Section 9.

3.4 Shear deflection: Due to the relatively low shear modulus (G_c) of the expanded polystyrene core (which transfers shear loads within the sandwich panel), the shear deflections in SIP panel design are significant and must be calculated for both the instantaneous deflection and final deflection stages.

3.5 Creep: The deformation modification factor, k_{def} for both OSB and Expanded Polystyrene (EPS) are high and hence the additional deflection due to creep over time is very often critical. The effect of creep must be applied to both bending and shear deflections.

In addition, the ultimate limit state design checks (bending, shear, etc) must be carried out for both the instantaneous response of the material to the applied actions and the final (re-distributed) response. These are based on the reduced moduli of elasticity and shear moduli of the outer skin OSB (typically in Service class (SC) 2), the Inner skin OSB (typically in Service Class (SC) 1) and the EPS core.

Note that the k_{def} value of OSB in SC1 (1.5) and SC2 (2.25) differ. This means that, even when the OSB for inner and outer skins are identical, the neutral axis of the SIP panel at the final (re-distributed) response stage shall not be at mid-depth of the SIP panel.

3.6 TR019 is based on the Kreuzinger model which shall be described in greater detail in Section 7.

4. Material Properties

4.1 Outer and inner wood panel skins - These are both 11mm OSB/3 which shall be in compliance with BS EN 300 and BS EN 12369-1. Both skins are glued to the expanded polystyrene core in a quality controlled factory process (whereby OSB /EPS samples are regularly tested to ensure failure does not occur along adhesive bond-line - samples taken as required to comply with CATG certification).

Material Properties of OSB3 have been used as described in Table 1 below, which represents the minimum permitted strength and stiffness values (based on BS EN 12369-1: 2001). Only values of relevance to the design of SIP roof panels, SIP wall panels and glued SIP lintel have been stated.

Table 1: Properties and Density Values for 11mm OSB outer and inner boards

Strength / Stiffness / Density Property	EC5 notation	Values and units
Characteristic tension stress	$f_{t,0,k}$	9.4N/mm^2
Characteristic compression stress	$F_{c,0,k}$	15.4N/mm^2
Characteristic panel shear stress	$f_{v,0,k}$	6.8N/mm^2
Characteristic rolling shear stress	$f_{r,k}$ (or $f_{v,r,k}$)	1.0N/mm^2
Characteristic flexural stress	$f_{m,0,k}$	16.4N/mm^2
Characteristic density	ρ_k	550kg/m^3
Mean modulus of Elasticity (MOE)	$E_{t,0,mean}$ & $E_{c,0,mean}$	3800N/mm^2
Mean Panel modulus of rigidity (shear modulus)	$G_{v,mean}$	1080N/mm^2

Based on Table 3.2 of EN1995-1-1, the values for k_{def} (permanent load deformation modification factor) is as follows:

4.1.1 OSB/3 in Service Class 1 environment = 1.5.

4.1.2 OSB/3 in Service Class 2 environment = 2.25.

4.2 Properties of the Expanded Polystyrene (EPS) core:

4.2.1 The core material comprises of expanded polystyrene and is assumed to be of Strength Class EPS90 or better. The expanded polystyrene should be laid onto the OSB/3 lower layer (during production) in one piece with a 45mm rebate around the edges to allow for placement of SIP or timber splines as required by the design.

In cases where it is not possible to place the EPS layer in one piece, the pieces must be glued together ensuring full glue spread between the abutting pieces.

It should be verified by tensile testing that failure is away from the bond-line, i.e. the glue has greater strength than the EPS.

Material properties of EPS90 have been used in the design as stated in Table 1 below.

Table 2: Expanded polystyrene EPS90 (min. strength class) Properties

Property	notation	Values and units
Characteristic panel shear stress	$f_{v,k}$	0.0675N/mm^2 (a)
Mean Core modulus of rigidity (shear modulus)	$G_{c,mean}$	2.48N/mm^2 (b)
Deformation modification factor (permanent and long-term loads)	$k_{def,perm}$	3.0 (c)
Deformation modification factor (medium-term loads)	$k_{def,med}$	1.0 (d)
Deformation modification factor (short-term and inst.-term loads)	$k_{def,short}$	0.0 (e)
Characteristic density of core	ρ_k	18.75kg/m^3 (f)

Table Notes:

(a) Characteristic panel shear stress is based on interpolation from table in Section E3.1.1 of TR019.

(b) Mean core modulus of rigidity is based on interpolation from table in Section E3.1.1 of TR019.

(c) Deformation modification factor, $k_{def,perm}$ for permanent and long-term loads is based on previous Sips Eco Panels test data and is the value given in previous quality scheme.

(d) Deformation modification factor, $k_{def.med}$ for medium-term loads is based on calculation ($k_{def,perm}$ * ψ_2), where ψ_2 = 0.3 for floor imposed loading.

(e) Deformation modification factor, $k_{def.short}$ for short and instantaneous-term loads is based on calculation ($k_{def,perm}$ * ψ_2), where ψ_2 = 0.0 for roof imposed, snow and wind loads.

4.3 Properties of the Timber Splines and Rails:

The characteristic strength and stiffness properties and the densities and deformation modification factors for the range of timber grades are as per BS EN 338: 2009 and EN 1995-1-1.

These are widely documented and should be well known to engineers using this guide. Hence it is not considered necessary to repeat them here.

4.4 Adhesives

4.1 The adhesive used for fixing of OSB to EPS90 (or better) shall have greater strength that the EPS. This shall be proven at regular intervals, in accordance with CATG certification requirements, by tensile testing which must demonstrate that failure occurs in the EPS and not within the bond-line.

4.2 The glue used to fix the OSB to the top and bottom timber flanges in the Glued-SIPs-Lintels shall be in accordance with BS EN 301: 2006 and shall be a structural adhesive of Type 1 or 2.

4.3 All gluing shall be done in a factory environment and the glue laid in strict compliance with the glue manufacturers requirements.

5. Loading on structural SIP panel elements and associated deflections (for SLS)

5.1 SIP panels will typically be subjected to some or all of the following loads:

5.1.1 Gravity loading: This is a combination of permanent (G_k) and variable loads (Q_k) applied to the structure based on loads to EN1991 loads (or BS6399 if continuing to use British Standards if / where permitted). There can be several different types of variable loads, each with different load durations.

Uniformly distributed loads for the SIP panels themselves can be calculated from the combined: (thickness of 2 no. outer skins in metres x 550 + thickness of core in metres x 19) to give a self-weight load in kg/m^2. Clearly if timber ribs / splines are used these should be additional to this based on mean timber density for the timber grade used.

5.1.2 Wind Loads perpendicular to plane of SIP panels, i.e. those loads resulting in compressive stresses on one OSB skin and tensile forces on the other skin. This load is also a type of variable load, $q_{k,wind.}$

5.1.3 Wind loads applied in the plane of the SIP panels, i.e. applying racking / shear forces to the SIP panels.

5.2 Load Cases:

5.2.1 The various loads are applied to the structure in the form of a set of load-cases which are separately applied in accordance with EN 1990. There are often several load cases for the ultimate limit state and several load cases for the serviceability limit state.

5.2.2 Ultimate limit state load cases:

The basic equation, from which several load cases can be defined at ultimate limit state is:

$$\sum_{j>=1} \gamma_{G,j}.G_{k,j} + \gamma_{Q,1}.Q_{k,1} + \sum_{i>1} \gamma_{Q,i}.\psi_{0,i}.Q_{k,i}$$

where

G_k and Q_k= Characteristic permanent and variable actions (loads) respectively.

γ_G = ULS partial load factor for permanent loads, i.e. 1.35.

γ_Q = ULS partial load factor for variable loads, i.e. 1.5.

ψ_0 = Factor for combination value of a variable action (See table A1.1 of EN 1990 or table in UK NA if different). For domestic floor load and for imposed roof load, the value of ψ_0 = 0.7, for snow load and for wind load, ψ_0 = 0.5.

On a SIP roof panel, there would be typically 4 load-cases with each case having a different “leading” variable load, i.e. roof imposed load, snow load, man point load and wind load (for the purposes of the Load-span tables within this document, a roof imposed load only has been considered, there will be cases where the snow load is critical and the design engineer must consider the possibility of snow load being more critical than roof imposed load in their design.

On a SIP wall panel, there can be several other load-cases to consider due to the possibility of floor imposed loads, etc.

5.2.3 Serviceability limit state load cases:

In relation to SIP panel design of roof and walls only, limiting deflection to acceptable limits is the sole serviceability limit state criteria (vibration not a consideration for these elements). There are 2 parts to the deflection of a SIP panel, i.e. instantaneous deflection, u_{inst} and creep deflection, u_{creep}. These are added together to obtain the final deflection, u_{fin}.

5.2.3.1 The basic equation, from which several load cases can be defined for instantaneous deflection is:

$$\sum_{j>=1} G_{k,j} + Q_{k,1} + \sum_{i>1} \psi_{0,i}.Q_{k,i} \qquad \text{(instantaneous deflection loadcases)}$$

This is the basis for similar loadcases as set-up for the ultimate limit case, except the partial load factors are omitted for the serviceability limit state cases.

5.2.3.2 The basic equation, from which the load case can be defined for creep deflection is:

$$\sum_{j>=1} G_{k,j} + \sum_{i>0} \psi_{2,i} \, . \, Q_{k,i} \qquad \text{(creep deflection loadcase)}$$

ψ_2 are the factors for the quasi-permanent value of variable actions (Table A1.1 of EN1990).

For all of the common roof applied variable loads, i.e. roof imposed, snow and wind, = 0 and therefore the creep deflection for roof loads is based on permanent (and include long-term loads such as storage also) loads only.

For walls, the main load causing deflection, i.e. wind load normal to the SIPs panel, has a "0" creep associated with it but there will be a creep deflection resulting from axial load induced deflections, i.e. from permanent, long-term and medium-term loads.

N.B. If designing using BS 5268, note that rafter imposed and snow loads are medium-term loads (short-term to Eurocodes) and floor loads are long-term loads (medium-term in Eurocodes). Therefore there may be a creep deflection to consider from roof panels and a larger creep deflection to consider from floor, snow and rafter imposed loads than would be case for Eurocode design.

5.3 Deflections:

5.3.1 Due to the large shear deflections and the large creep deflections, this is often the limiting criteria for SIPs. The final deflections are best calculated as follows for SIP panels:

$u_{fin,} = u_{fin,G} + u_{fin,Q,1} + \sum u_{fin,Qi}$ where i>=1 for final part of equation.

$u_{fin,G} = u_{inst,G} (1 + k_{def})$ (final defl. resulting from perm. action)

$u_{fin,Q,1} = u_{inst,Q,1} (1 + \psi_{2,1.} k_{def})$ (final defl. resulting from lead variable action).

$u_{fin,Q,i} = u_{inst,Q,i} (\psi_{0,i} + \psi_{2,i.} k_{def})$ (final defl. resulting from lead variable action;

i>1 (i.e. secondary variable actions).

For SIP roof panels to Eurocode designs (for sites < 1000m above sea level), this simplifies to:

$$u_{fin} = u_{inst,G} (1 + k_{def}) + u_{inst,Q,1} + u_{inst,Q,i} \, . \, \psi_{0,i}$$

SIP wall panels, on the other hand, will generally require a full deflection derivation as ψ_2 will not be equal to 0 for all wall applied loads.

The instantaneous deflection, u_{inst} is comprised of both bending and shear deflection components. The final deflection equations therefore account for both also being a multiplier of the instantaneous deflection.

Deflection limits are now subject to agreement between the designer and the client (or his representative)

For the load span tables in Annex A, B and C, the following deflection limits have been assumed:

5.3.1.1. Instantaneous deflection: L/350.

5.3.1.2. Final deflection: L/250.

This may be relaxed if there are no brittle finishes to ceiling. The client may also dictate more onerous deflection limits for certain elements.

6. SIP Roof Panels

6.1 Roof of SIP panel buildings can be from loose rafters, ceiling joists, prefabricated roof trusses or SIP roof panels. SIP roof panels are usually supported on a ridge purlin, possibly with intermediate purlins and on wall (or floor member) at eaves level.

6.2 Generally, supports should downstand below SIP roof panels, with the SIP panel supported on triangular wedges which are connected down to supporting structure. The connections from the SIP panel to the wedge and the wedge down to the supports must be able to fully resist the "sliding" force due to the "in-plane component of the gravity roof load (permanent and variable loads) along the slope of the roof, i.e. panel to wedge screws in shear. They must also resist the worst wind load-case which is causing an uplift force on the roof, perpendicular to the plane of the roof, i.e. panel to wedge screws in tension.

6.3 A SIP roof, without additional bracing, will generally provide adequate roof diaphragm action.

6.4 The design of a SIP roof requires the determination of loads perpendicular to the plane of the panel. The length of the span is the slope length.

6.5 The use of SIP panels in flat roofs is permitted, however the designer should be aware of the very significant risk of failure (serviceability limit state and possibly ultimate limit state in extreme cases) if the roof is subjected to water ponding due to inadequate falls. This is particularly high risk for SIP panels due to the additional long-term load from the water, which would not have been accounted for in the creep deflection calculation (as no variable load related creep is accounted for in roofs (see section 5.2.3.2)).

7 Design of SIP roof panels (single span) without timber "spline" reinforcement.

The following steps should be taken to verify the design of a SIP roof panel (the use of a computerised calculation, such as spreadsheet or similar is strongly recommended due to the complexity of the design calculations for these composite panels). The design is based on TR019 and the structural engineer should become familiar with this document before attempting to apply a design to SIPs.

7.1 Calculate the structural span on slope for the SIP panel. This is the span to be used in the design.

7.2. Resolve the dead (G_{DL}) and variable loads (Q_{IL}) in the load diagram shown below so that the vector components of these loads acting perpendicular to the roof are derived. The wind load, Q_{WL} shall already be acting perpendicular to the plane of the roof. See Figure 1 for forces to be resolved.

In figure 1 where: G_{DL} = dead (permanent) load

Q_{IL} = variable gravity loads (various combinations of roof imposed, snow, man point as laid out in section 5.2).

Q_{WL} = variable wind load.

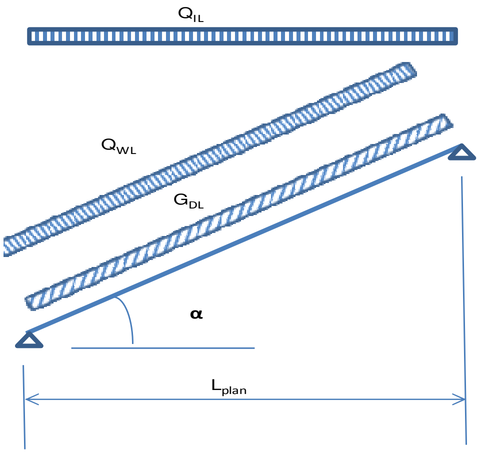


Figure 1

7.3. Calculate the unfactored maximum forces i.e. moment and shear for the various load durations, i.e. permanent (include long-term if applicable), short-term (worst case for man load / roof imposed / snow load) and instantaneous (wind load).

These calculated forces can then be factored using the partial load factors, γ_G and γ_Q in previously stated combinations in which the appropriate ψ_0 factors (as per Section 5.2).

7.4 State the geometric and material properties of the 3 layers (due to differences in k_{def} between inner and outer OSB skins) similar to that shown on the page overleaf

State the relevant material types, thicknesses, service classes and strength and stiffness properties (as well as densities and calculated relevant areas) for each of the 3 layers.

Figure 2

2. Geometric & Material Properties:

	Layer 1 (external)		Layer 2 (core)		Layer 3 (internal)		units
Material type		OSB3		EPS90		OSB3	
depth	d_1 (mm)=	11	d_2 (mm) =	122	d_3 (mm)	11	(mm)
effective width	b_1 (mm)=	1000	b_2 (mm)=	1000	b_3 (mm)=	1000	(mm)
Service Class	SC =	SC2	SC =	SC1	SC =	SC1	

	Layer 1	Layer 2	Layer 3	units
MOE ($E_{t(c),//,0,mean}$) =	3800	5.5	3800	(N/mm^2)
Shear mod. (G_{mean}) =	1080	2.48	1080	(N/mm^2)
Char. comp. strength ($f_{c,//,k}$) =	15.4	0.09	15.4	(N/mm^2)
Char. tens. strength ($f_{t,//,k}$) =	9.4	0.137	9.4	(N/mm^2)
Char. Panel shear strength ($f_{v,0,k}$)=	1	0.067	1	(N/mm^2)
density	550	19	550	(kg/m^3)
Area	11000	122000	11000	(mm^2)

7.5 Determine the Steiner bending stiffness and shear stiffness of virtual beam B for the instantaneous response period:

From EOTA TR 019 for instantaneous response :

(a) Bending stiffness of virtual beam B:

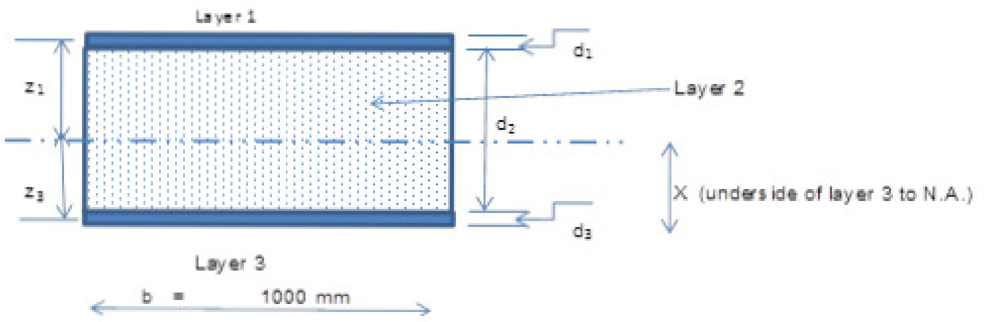
$$(EI)_B = \sum_{i=1}^{3} E_{t(c),//,0mean,i} \cdot A_i \cdot z_i^2 = 3.697E+11 \ Nmm^2$$ (steiner bending stiffness)

NOTE: Layer 2 ignored for bending stiffness.

(b) Shear stiffness of virtual beam B

$$1/(GA)_B = 1/S : (1/a^2) * \left(\frac{d1}{2 \cdot G_{\perp,0,mean,1} \cdot b_1} + \frac{d2}{G_{mean,2} \cdot b_2} + \frac{d3}{2 \cdot G_{\perp,0,mean,3} \cdot b_3} \right.$$

This is based on calculation of the neutral axis position as shown overleaf (diagram is also appropriate for derivation of neutral axis based on final response stiffnesses). Note that the neutral axis will be central at the instantaneous response check where OSB skins are the same but will not be centred at final response check due to the outer skin stiffness being lower than that of the inner skin due to differing k_{def} values (as outer skin in SC2 and inner skin in SC1).



7.6 Ultimate Limit State design checks at the instantaneous response (these checks to be made for all relevant load duration cases).

7.6.1 Calculate the compression stress in the upper OSB layer and the tensile strength in the lower OSB layer resulting from the applied ULS moment on the SIP panel as described in C2.1.3 of TR019. Design to ensure that these are less than the allowable design compression stress (and tension stresses) of the top (and bottom) OSB layers respectively:

i.e. verify that $\sigma_{c,d,1} < f_{c,0,d}$ for compression and

$\sigma_{t,d,1} < f_{t,0,d}$ for tension.

$f_{c,0,d} = f_{c,0,k} \times k_{mod} / \gamma_M$

and $f_{t,0,d} = f_{t,0,k} \times k_{mod} / \gamma_M$

where:

k_{mod} is modification factor for duration of load and moisture content where kmod for various timber members and wood-based panels are defined in Table 3.1 of BS EN 1995.

γ_M = material modification factor as defined Table 2.3 of BS EN 1995.

7.6.2 Carry out shear checks for each layer as well as the interface between the layers as per C2.1.4 and C2.1.5 of TR019. The designer should verify that the maximum applied design shear stress be less than the permissible design shear stress of the EPS90 (or better) core.

7.6.3 The local design compressive stress in the EPS90 core should be checked at each support in accordance with C2.1.6 of TR019.

Verify: $\sigma_{c,d,2} = R_d / A_{eff}$ where the notation is as described in C2.1.6.

7.7 Ultimate limit state design after internal force re-distribution (final response):

At final response stage, the stresses within the layers will be re-distributed due to the changes in relative bending and shear stiffnesses of the 3 layers (primarily due to the fact that the outer OSB layer is in service class 2 environment and is subject to a higher k_{def} than the Service class 1 inner OSB layer). The different stiffnesses of each layer is due to reduced E_{mean} and G_{mean} values for the layer based on the calculation for each layer:

$E_{mean,fin} = E_{mean,i} / (1 + \psi_2 . k_{def})$ and $G_{mean,fin} = G_{mean} / (1 + \psi_2 . k_{def})$.

(for roof loads, $\psi_2 = 1$ for permanent / long-term loads and 0 for short and instantaneous loads. For wall panel designs, derivation may be required for both

$E_{mean,fin,perm}$ and $E_{mean,fin,med}$ as well as $G_{mean,fin,perm}$ and $G_{mean,fin,med}$ to check at medium term response also)

Verify that the design compression, tension and shear stresses, based on the final response re-distribution of stresses are less than the design resistance stresses (similar to checks carried out for instantaneous response as described in 6.4.6.1 and 6.4.6.2 above).

7.8 Verification of serviceability limit states:

7.8.1 The deflection should first be calculated based on instant loading of the panel. This shall be based on the equations stated in Section 5.3 of this document and must include a calculation of shear deflection in addition to bending deflection.

From Annex A (A.2) of TR019, the instantaneous deflection shall be calculated based on the below equation for each of the instantaneous deflections from permanent, lead variable and secondary variable loads:

$$u_{inst} = \frac{5 w L^4}{384 (EI)_{B,inst}} + \frac{w L^2}{8 (GA)_{B,inst}}$$

See equation above and equations in Section 5.3 for calculation of $u_{inst,total}$ and calculation of $u_{fin,total}$.

7.9 For SIP roof panel designs it is critical that the permanent (and long-term if applicable) loads are correctly applied as these will have a significant effect on the critical final deflection calculation.

It is also critical that shear deflections are accounted for and also that the effect of creep is fully calculated. The shear deflection is often much larger than the bending deflection while the creep deflection component is often larger in magnitude to the initial deflection, i.e. the final deflection is > 2 x initial deflection.

7.10 Roof load span tables in Annex A are based on the calculation methodology described in this section (see also load-span table notes in Annex A for guidance on using tables).

7.11 The principles of the design methodology set out above, based on TR019 and EN1995-1-1 could be used to produce a design calculation to BS 5268 if considered appropriate by the designer. This would be based on the working stress principle of timber design to the British Standards.

Alternatively, previously produced design tables based on loading can be used to determine allowable spans for SIP roof panels. These are based on short-term loaded tests and it is critical that due account is taken of creep deflection and also reduced permissible stress resistances for permanent / long-term portion of load.

Using the spans as stated in these test-based tables, without accounting for these items, may yield unsafe designs!

7.12 SIP splines are used to connect adjacent SIP panels together. These should not be considered structurally in the design of the SIP roof panel.

7.13 The designers first preference, where possible, should always be to place purlins, etc at centres to allow for unreinforced splines as this avoids repeat thermal bridges. Due to the constraints of some projects this is not always possible and in these cases a timber spline reinforced SIPs panel is required as described below in section 8.

8. Design of SIP roof panels (single span) with timber "spline" reinforcement.

8.1 Timber splines are used to stiffen / strengthen SIP roof and wall panels. They are placed within the 45mm wide rebate at each end of the 1.2m wide SIP panels. Therefore there are 2 no. 45mm timber splines at 1.2m crs. The depth of the timber splines is: depth of SIP panel – 11mm upper OSB – 11mm lower OSB – 2mm, i.e. a 144mm deep SIP panel will have a 120mm deep timber spline, etc, etc.

The OSB connects to the timber splines with 3.5 x 50mm screws @ 150mm crs. (into each 45mm wide timber member). There are 2 splines within a 1.2m panel so it is appropriate to design for a 1.2m panel with 90mm wide timber splines screwed @ 75mm crs. (2 no. screws @ 150mm crs.).

SIP roof panel with reinforced timber splines achieve longer spans, as demonstrated within load-span table in Annex A. On rare occasions the roof spans may dictate an addition full depth (of SIPs panel) timber spline between the "rebated" timber splines.

8.2 The design of a SIP roof panel with timber splines can be undertaken as follows:

8.2.1 The loads are calculated in the same manner as for the unreinforced SIP roof panel (Section 6.4.2) except that design should allow for a 1200mm wide panel and hence 1200mm wide loading.

8.2.2 Additionally, the moments and shear forces are calculated similarly as described in Section 6.4.3.

8.2.3 As the stiffness of the timber is >> than the stiffness of the EPS core, the core can be ignored for purposes of calculation without significantly effecting the design outcomes. This allows for the design of the reinforced SIP panel as a "mechanically jointed beam" with the upper and lower OSB, the timber spline and the interconnection between the 3 layers as being critical. The design can be based on the method given in *Annex B (Informative): Mechanically jointed beams* in *BS EN 1995-1-1.*

As this Annex lays out clearly the design methodology, a competent design should be readily able to follow the requirements of the ultimate limit state checks for this design. Note that, as in the unreinforced SIP panel design, the effective bending stiffness shall vary between instantaneous response and final response, with a consequent re-distribution of stresses. Ultimate limit state design checks need to be verified for both the instantaneous and final response conditions.

8.2.4 The serviceability limit state design is not explicitly covered and hence some guidance is given here:

The effective bending stiffness as given in equation B.1 of this BS EN 1995 Annex will form the basis of the calculation of the deflections in a similar manner to that described in Section 5.3 and 6.4.7.

In this case, as the shear stress is resisted by the timber "web" members, the shear deflections will be significantly less but nonetheless we recommend that they are calculated. The effect of creep should also be accounted for by calculation of u_{fin} as previously described.

8.3 Load span tables, for SIPs Eco Panel's SIP panels, in Annex A are based on the calculation methodology described in this section (see also load-span table notes in Annex A for guidance on using tables).

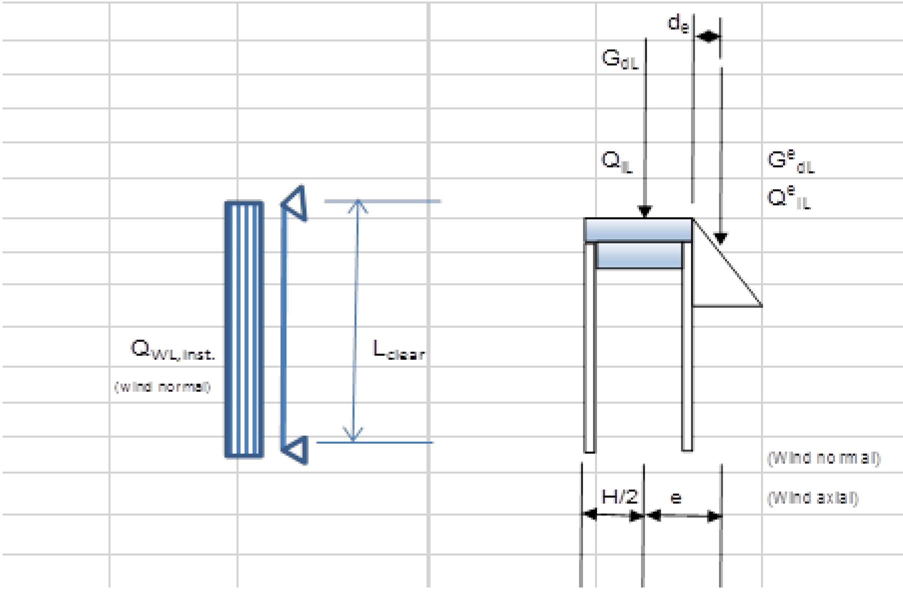
8.4 The principles of the design methodology set out above, based on Annex B of EN1995-1-1 could be used to produce a design calculation to BS 5268 if considered appropriate by the designer. This would be based on the working stress principle of timber design to the British Standards (*The Timber Designer's Manual* by *Ozelton & Baird* has a similar design to BS 5268 Part 2).

9. Design of SIP wall panels (single span) without timber "spline" reinforcement.

9.1 The design methodology for unreinforced SIP wall panel, i.e. SIP splines only connecting adjacent panels, is similar to that for roof panels as outlined in section 7 although there are a number of existing checks to deal with the axial forces.

Although the design methodology in TR019 is for roof stressed skin panels, the principles can also be used for wall panels with, as stated previously, a number of additional checks.

9.2 The loads on a SIP wall panel should be set up as shown in the diagram below where G^{e}_{DL} and Q^{e}_{DL} are the eccentrically applied loads from the floor / roof immediately on the wall under consideration. The worst case is where the joists are hung from the side of the wall with proprietary joist hangers as this results in the largest axial load induced moment.



9.3 Clearly, in the case of wall panels the axial force is significant and this should be included in all applicable calculations.

9.4 Determine the Steiner bending stiffness and shear stiffness of the SIP wall panel for all applicable load durations. In particular permanent (to include long-term), medium term (as floor imposed loading on wall panels) and instantaneous stiffnesses to allow for distribution of the stresses and these can also be used to determine deflections u_{inst} and u_{fin} as applicable.

9.5 The maximum compression forces (or tension if applicable for instantaneous loading) in the OSB skins shall be calculated based on the formulae in C.2.1.3 of TR019 and discussed in Section 7.6.1 of this document for roof panels.

Note that the axial forces are resisted by the OSB skins only although the load-bearing insulation (minimum EPS90) provides lateral restraint to the skins to prevent their buckling.

9.6 Shear checks to be carried out as stated in Section 7.6.2.

9.7 Re-design for final and medium term response re-distributed stresses as per Section 7.7 of this document (based on determination of $(EI)_{B,fin}$ and $(GA)_{B,fin}$ and $((EI)_{B,med}$ and $(GA)_{B,med})$.

9.8 Buckling of Wall under Compression

This issue is specific to wall panels and the methodology used is based on the section "Wall Panel Buckling" from Lightweight Sandwich Construction by JM Davies in which the following formula is presented to determine P_{cr} (the critical axial force re buckling):

$$Pcr = \frac{P_E . P_{EF} - P^2_{EF} + P_E . P_C}{P_E - P_{EF} + P_C}$$

where $PE = \pi^2.(EI)_{B,perm} / L^2$

$P_{EF} = \pi^2.(EI)_{OSB\ flanges} / L^2$

$P_C = A_C.G_C$

A_C = area of core.

G_c = shear modulus of core.

These shall be calculated for each of permanent, medium-term and instantaneous (including short-term) response periods.

The Eurocode 5 instability reduction factor, $k_{c,y}$ is then calculated for the wall panel, for each duration period stated above, by calculation based on Section 6.3.2 of EN1995-1-1 with $\lambda_{rel,y}$ being calculated with the more general formula

$\lambda_{rel,y} = (P_{c,0,k} / P_{CR})^{1/2}$ where $P_{c,0,k}$ is the allowable axial force in the OSB skins.

This replaces formula 6.21 from EN1995-1-1.

9.9 Combined Axial and Bending

The following equations shall be verified to confirm adequacy of wall panels with regard to combined axial compression and bending;

9.9.1

$$\frac{\sigma_{c,axial,perm,\ perm}}{k_{c,y,perm} . f_{c,0,d,perm}} + \frac{\sigma_{c,axial,perm,,med}}{k_{c,y,med} . f_{c,0,d,perm}} + \frac{\sigma_{c,axial,\ perm,\ short / inst}}{k_{c,y,short / inst} . f_{c,0,d,perm}} + \frac{\sum\sigma_{c,bending,0,d}}{f_{c,0,d,perm}} < 1.$$

9.9.2

$$\frac{\sigma_{c,axial,med,\ perm}}{k_{c,y,perm} . f_{c,0,d,med}} + \frac{\sigma_{c,axial,med,,med}}{k_{c,y,med} . f_{c,0,d,med}} + \frac{\sigma_{c,axial,\ med,\ short / inst}}{k_{c,y,short / inst} . f_{c,0,d,med}} + \frac{\sum\sigma_{c,bending,0,d}}{f_{c,0,d,med}} < 1.$$

9.9.3

$$\frac{\sigma_{c,axial,inst,\ perm}}{k_{c,y,perm} . f_{c,0,d,inst}} + \frac{\sigma_{c,axial,inst,,med}}{k_{c,y,med} . f_{c,0,d,inst}} + \frac{\sigma_{c,axial,\ inst,\ short / inst}}{k_{c,y,short / inst} . f_{c,0,d,inst}} + \frac{\sum\sigma_{c,bending,0,d}}{f_{c,0,d,med}} < 1.$$

where the first “perm” or “med” or “inst” term refers to the response period for which the stresses are distributed and the second “perm” or “med” or “inst” refers to the stress from the load (based on its duration type).

9.10. Deflections

Lateral deflections, based on wind loads normal to the SIP wall panel are calculated as per Section 7.8 for roof panels. The only deflection associated with this load is u_{inst} as k_{def} = 0 (as this is an instantaneous load).

Deflections based on axial forces at the top are derived from:

$$U_{axial} = \frac{ML^2}{16\ EI}$$

The deflection due to axial loads is generally small and can be neglected except where joists are side hung from walls in which case the eccentric moment is significant with consequent larger induced deflections.

9.11. A further critical check is bearing at the sole-plate and head-plate. This has been found to be the limiting factor for axial loads in unreinforced SIP wall panels. Therefore, based on standard timber design to EN1995-1-1, check the applied bearing stress against the permissible cross-grain bearing stress of the timber sole-plate / head-binder.

The bearing forces may be reduced by the capacity of the OSB to top-rail or bottom rail screws if deemed appropriate by the designer.

9.12 Load span tables in Annex B are based on the calculation methodology described in this section (see also table notes in Annex B for guidance on using these tables).

The allowable axial loads, and perpendicular allowable wind loads, can be significantly increased by using timber splines (particularly as these significantly increase the bearing area onto the head-binder / sole-plate).

9.13 The principles of the design methodology set out above, based on TR019 and EN1995-1-1 could be used to produce a design calculation to BS 5268 if considered appropriate by the designer. This would be based on the working stress principle of timber design to the British Standards.

Alternatively, previously produced design tables based on loading can be used to determine allowable spans for SIP wall panels. These are based on short-term loaded tests and it is critical that due account is taken of creep deflection and also reduced permissible stress resistances for permanent / long-term portion of load.

Using the spans as stated in these test-based tables, without accounting for these items, will not yield safe designs!

9.14 SIP splines are used to connect adjacent SIP wall panels together. These should not be considered as structural in the design of the SIP wall panels.

9.15 Point Loads on SIP wall panels

Significant point loads will need to be supported by multiple timber studs within the SIP wall panels in accordance with standard design practice using the preferred standard.

Smaller point loads can be supported by the SIP wall panels with the thickness of the head-binder dictating the magnitude of the point load as follows:

$$T = \frac{3}{2} \times \frac{(F_d \times b_{joist})}{28.3}$$

where T = required min. thickness of head-binder.

F_d = design loads on the bearing area (N).

b_{joist} = the width of the joist or beam.

In cases of high loads / small head-binder, the joists may need to be hung from the rimbeam.

10. Lintels

10.1 Lintels may be in the form of solid timber or glulam or engineered timber or steel members. Another option, where permitted by design, is to use a “glued SIP lintel” as a box beam with timber top flange (in line of top-rail and same cross-section as top-rail), bottom flange (rail directly above opening) and OSB webs on each side (outer skins of SIP panels). For very lightly loaded, small span lintels it may be acceptable to screw the OSB to the flanges only.

10.2 The design of “Glued SIP Lintels” is based on design of a glued thin-webbed beam in accordance with Section 9.1.1 of EN 1995-1-1. It is critical that the webs are adequately glued to the timber flanges in order to realise the design strength of a Glued-SIP-Lintel. Use a structural adhesive of Type 1 or 2 in accordance with BS EN 301 (note that the glue used to connect OSB to EPS insulation may not be appropriate for OSB to timber structural adhesion).

The insulation (minimum EPS90) is ignored for purposes of calculation of a glued SIP lintel.

10.3 A comprehensive Table and notes for Glued SIP Lintel is shown in Annex C of this document. For designers who want to do a “first principles" design to EN 1995-1-1, the publication “Structural Design to Eurocode 5” by *Jack Porteous and Abdy Kermani* contains a detailed example.

10.4 As always, if BS 5268 is the chosen standard, a similar design approach can be taken for a glued thin-webbed beam.

11. Racking Resistance

11.1 Applied racking forces are calculated by the designer based on wind loads from EN 1991-1-4 or BS6399-2 as usual for any structure.

11.2 To date, racking resistance values are based on test results in accordance with BS EN 594. A “safe” result is then achieved by applying factors based on section 5.9 of BS 5268-6.1:1996. The basic racking resistance value to BS 5268-6.1:1996 is 2.5KN/m. The racking resistance is reduced for wall sections containing openings based on equation:

R_b = 2.5.exp(-0.0365x)

Where

R_b = test racking resistance per meter run of the wall in KN/m

X = percentage opening in a panel of 2.4m in length.

Where the percentage of openings exceeds 35%, R_b = 0.

The racking resistance is subject to BS5268 Part 6.l factors K104 (panel height factor); K105 (wall length factor) and K108 (interaction factor)

K107 should be modified as follows: $0.004F^2 + 0.025F + 1$ for values up to a maximum of 10.4KN.

11.3 Racking resistance values for EN1995-1-1 designs can be derived as follows:

11.3.1 Unfactored applied wind loads to be derived to provide an applied racking load factor to the level under consideration.

11.3.2 The racking resistance of 2.5KN/m is a safe racking resistance value (as based on racking stiffness which is a serviceability limit state load. Hence use of unfactored wind loads). This can be multiplied by similar equation to K104 for wall heights above 2.4m. No other factors should be applied. Similarly only full height wall panels between openings are permitted (new tests to BS EN 594:2011 may allow higher values to be used for BS EN 1995-1-1 designs).

N.B. Although unfactored wind loads are used for verification of racking resistance, it is critical that factored wind loads are used for the following checks to BS EN 1995-1-1 design:

(a) Overall stability of the SIP frame structure (at each level).

(b) Sliding of the structure at each level.

(c) Overturning and sliding of racking panels.

(d) Uplift of structure at each level.

When checking these to BS 5268:6.1, check for factor of safety requirements within this standard (and BS 5268-3 for roof uplift factor of safety of 1.4).

ANNEX A:

Span Tables

(with and without timber splines)

Annex A Contents

TABLE A.1.1 : 144mm SIP Roof Panels - 0.6KN/m² wind load

			SIP Splines		2 no. 120 x 45 C16 timber splines		2 no. 120 x 45 C24 timber splines		2 no. 120 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.19	2.19	2.6	2.6	2.87	2.87	2.95	2.95
	1.00	0.60	1.52	1.52	2.31	2.31	2.57	2.57	2.65	2.65
15	0.60	0.60	2.17	2.25	2.51	2.60	2.79	2.89	2.88	2.98
	1.00	0.60	1.52	1.57	2.25	2.33	2.50	2.59	2.59	2.68
30	0.60	0.60	2.09	2.41	2.29	2.64	2.56	2.96	2.64	3.05
	1.00	0.60	1.50	1.73	2.07	2.39	2.30	2.66	2.38	2.75
45	0.60	0.30	1.87	2.64	1.99	2.81	2.21	3.13	2.27	3.21
	1.00	0.30	1.42	2.01	1.77	2.50	1.98	2.80	2.04	2.88

TABLE A.1.2 : **144mm SIP Roof Panels - 0.9KN/m² wind load**

			SIP Splines		2 no. 120 x 45 C16 timber splines		2 no. 120 x 45 C24 timber splines		2 no. 120 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.12	2.12	2.4	2.4	2.64	2.64	2.72	2.72
	1.00	0.60	1.52	1.52	2.16	2.16	2.41	2.41	2.49	2.49
15	0.60	0.60	2.08	2.15	2.3	2.38	2.56	2.65	2.64	2.73
	1.00	0.60	1.52	1.57	2.10	2.17	2.34	2.42	2.42	2.51
30	0.60	0.60	1.96	2.26	2.11	2.44	2.34	2.70	2.41	2.78
	1.00	0.60	1.47	1.70	1.93	2.23	2.14	2.47	2.22	2.56
45	0.60	0.30	1.73	2.45	1.74	2.46	1.94	2.74	1.99	2.81
	1.00	0.30	1.34	1.90	1.64	2.32	1.82	2.57	1.88	2.66

SipsEcoPanels

TABLE A.1.3 : 144mm SIP Roof Panels - 1.2KN/m² wind load

			SIP Splines		2 no. 120 x 45 C16 timber splines		2 no. 120 x 45 C24 timber splines		2 no. 120 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	2	2	2.2	2.2	2.46	2.46	2.54	2.54
	1.00	0.60	1.49	1.49	2.04	2.04	2.28	2.28	2.35	2.35
15	0.60	0.60	1.96	2.03	2.14	2.22	2.39	2.47	2.46	2.55
	1.00	0.60	1.47	1.52	1.99	2.06	2.21	2.29	2.29	2.37
30	0.60	0.60	1.84	2.12	1.96	2.26	2.17	2.51	2.24	2.59
	1.00	0.60	1.40	1.62	1.82	2.10	2.02	2.33	2.09	2.41
45	0.60	0.30	1.62	2.29	1.58	2.23	1.75	2.47	1.8	2.55
	1.00	0.30	1.27	1.80	1.53	2.16	1.71	2.42	1.76	2.49

SipsEcoPanels

TABLE A.2.1 : 169mm SIP Roof Panels - 0.6KN/m^2 wind load

			SIP Splines		2 no. 145 x 45 C16 timber splines		2 no. 145 x 45 C24 timber splines		2 no. 145 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.58	2.58	3.1	3.1	3.47	3.47	3.58	3.58
	1.00	0.60	1.81	1.81	2.8	2.8	3.12	3.12	3.22	3.22
15	0.60	0.60	2.55	2.64	3.05	3.16	3.36	3.48	3.49	3.61
	1.00	0.60	1.81	1.87	2.73	2.83	3.04	3.15	3.14	3.25
30	0.60	0.60	2.41	2.78	2.79	3.22	3.1	3.58	3.21	3.71
	1.00	0.60	1.77	2.04	2.51	2.90	2.79	3.22	2.89	3.34
45	0.60	0.30	2.14	3.03	2.38	3.37	2.66	3.76	2.74	3.87
	1.00	0.30	1.65	2.33	2.15	3.04	2.39	3.38	2.48	3.51

TABLE A.2.2 : 169mm SIP Roof Panels - 0.9KN/m^2 wind load

Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	SIP Splines: Clear span on plan L_{plan} (m)	SIP Splines: Clear Span on slope L_{slope} (m)	2 no. 145 x 45 C16 timber splines: Clear span on plan L_{plan} (m)	2 no. 145 x 45 C16 timber splines: Clear Span on slope L_{slope} (m)	2 no. 145 x 45 C24 timber splines: Clear span on plan L_{plan} (m)	2 no. 145 x 45 C24 timber splines: Clear Span on slope L_{slope} (m)	2 no. 145 x 45 C30 timber splines: Clear span on plan L_{plan} (m)	2 no. 145 x 45 C30 timber splines: Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.44	2.44	2.9	2.9	3.21	3.21	3.32	3.32
	1.00	0.60	1.81	1.81	2.63	2.63	2.94	2.94	3.03	3.03
15	0.60	0.60	2.39	2.47	2.84	2.94	3.13	3.24	3.23	3.34
	1.00	0.60	1.79	1.85	2.56	2.65	2.86	2.96	2.95	3.05
30	0.60	0.60	2.25	2.60	2.57	2.97	2.86	3.30	2.94	3.39
	1.00	0.60	1.71	1.97	2.35	2.71	2.61	3.01	2.70	3.12
45	0.60	0.30	2.11	2.98	2.18	3.08	2.42	3.42	2.5	3.54
	1.00	0.30	1.55	2.19	2.01	2.84	2.24	3.17	2.31	3.27

TABLE A.2.3 : **169mm SIP Roof Panels - 1.2KN/m^2 wind load**

Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	SIP Splines: Clear span on plan L_{plan} (m)	SIP Splines: Clear Span on slope L_{slope} (m)	2 no. 145 x 45 C16 timber splines: Clear span on plan L_{plan} (m)	2 no. 145 x 45 C16 timber splines: Clear Span on slope L_{slope} (m)	2 no. 145 x 45 C24 timber splines: Clear span on plan L_{plan} (m)	2 no. 145 x 45 C24 timber splines: Clear Span on slope L_{slope} (m)	2 no. 145 x 45 C30 timber splines: Clear span on plan L_{plan} (m)	2 no. 145 x 45 C30 timber splines: Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.3	2.3	2.7	2.7	3.01	3.01	3.1	3.1
	1.00	0.60	1.74	1.74	2.5	2.5	2.79	2.79	2.87	2.87
15	0.60	0.60	2.26	2.34	2.62	2.71	2.93	3.03	2.98	3.09
	1.00	0.60	1.71	1.77	2.43	2.52	2.71	2.81	2.79	2.89
30	0.60	0.60	2.12	2.45	2.39	2.76	2.65	3.06	2.75	3.18
	1.00	0.60	1.63	1.88	2.22	2.56	2.46	2.84	2.55	2.94
45	0.60	0.30	1.97	2.79	1.98	2.80	2.22	3.14	2.29	3.24
	1.00	0.30	1.47	2.08	1.85	2.62	2.07	2.93	2.15	3.04

TABLE A.3.1 : **194mm SIP Roof Panels - 0.6KN/m² wind load**

			SIP Splines		2 no. 170 x 45 C16 timber splines		2 no. 170 x 45 C24 timber splines		2 no. 170 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.92	2.92	3.7	3.7	4.09	4.09	4.22	4.22
	1.00	0.60	1.86	1.86	3.3	3.3	3.66	3.66	3.77	3.77
15	0.60	0.60	2.87	2.97	3.58	3.71	3.98	4.12	4.11	4.25
	1.00	0.60	2.09	2.16	3.22	3.33	3.57	3.70	3.68	3.81
30	0.60	0.60	2.71	3.13	3.29	3.80	3.65	4.21	3.76	4.34
	1.00	0.60	2.04	2.36	2.96	3.42	3.29	3.80	3.40	3.93
45	0.60	0.30	2.41	3.41	2.86	4.04	3.14	4.44	3.27	4.62
	1.00	0.30	1.86	2.63	2.55	3.61	2.83	4.00	2.92	4.13

TABLE A.3.2 : 194mm SIP Roof Panels - 0.9KN/m^2 wind load

Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	SIP Splines: Clear span on plan L_{plan} (m)	SIP Splines: Clear Span on slope L_{slope} (m)	2 no. 170 x 45 C16 timber splines: Clear span on plan L_{plan} (m)	2 no. 170 x 45 C16 timber splines: Clear Span on slope L_{slope} (m)	2 no. 170 x 45 C24 timber splines: Clear span on plan L_{plan} (m)	2 no. 170 x 45 C24 timber splines: Clear Span on slope L_{slope} (m)	2 no. 170 x 45 C30 timber splines: Clear span on plan L_{plan} (m)	2 no. 170 x 45 C30 timber splines: Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.75	2.75	3.4	3.4	3.78	3.78	3.9	3.9
	1.00	0.60	2.06	2.06	3.1	3.1	3.45	3.45	3.56	3.56
15	0.60	0.60	2.70	2.80	3.3	3.42	3.67	3.80	3.79	3.92
	1.00	0.60	2.03	2.10	3.02	3.13	3.36	3.48	3.46	3.58
30	0.60	0.60	2.54	2.93	3.02	3.49	3.36	3.88	3.46	4.00
	1.00	0.60	1.94	2.24	2.77	3.20	3.07	3.54	3.18	3.67
45	0.60	0.30	2.07	2.93	2.54	3.59	2.85	4.03	2.94	4.16
	1.00	0.30	1.76	2.49	2.37	3.35	2.64	3.73	2.72	3.85

TABLE A.3.3 : 194mm SIP Roof Panels - 1.2KN/m^2 wind load

Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	SIP Splines: Clear span on plan L_{plan} (m)	SIP Splines: Clear Span on slope L_{slope} (m)	2 no. 170 x 45 C16 timber splines: Clear span on plan L_{plan} (m)	2 no. 170 x 45 C16 timber splines: Clear Span on slope L_{slope} (m)	2 no. 170 x 45 C24 timber splines: Clear span on plan L_{plan} (m)	2 no. 170 x 45 C24 timber splines: Clear Span on slope L_{slope} (m)	2 no. 170 x 45 C30 timber splines: Clear span on plan L_{plan} (m)	2 no. 170 x 45 C30 timber splines: Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.6	2.6	3.2	3.2	3.54	3.54	3.65	3.65
	1.00	0.60	1.98	1.98	2.94	2.94	3.28	3.28	3.38	3.38
15	0.60	0.60	2.55	2.64	3.09	3.20	3.44	3.56	3.55	3.68
	1.00	0.60	1.95	2.02	2.86	2.96	3.19	3.30	3.29	3.41
30	0.60	0.60	2.39	2.76	2.82	3.26	3.13	3.61	3.23	3.73
	1.00	0.60	1.85	2.14	2.61	3.01	2.90	3.35	3.00	3.46
45	0.60	0.30	2.09	2.96	2.35	3.32	2.62	3.71	2.7	3.82
	1.00	0.30	1.67	2.36	2.2	3.11	2.46	3.48	2.53	3.58

TABLE A.4.1 : 219mm SIP Roof Panels - 0.6KN/m² wind load

			SIP Splines		2 no. 195 x 45 C16 timber splines		2 no. 195 x 45 C24 timber splines		2 no. 195 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	3.24	3.24	4.2	4.2	4.7	4.7	4.84	4.84
	1.00	0.60	2.38	2.38	3.8	3.8	4.22	4.22	4.35	4.35
15	0.60	0.60	3.18	3.29	4.12	4.27	4.58	4.74	4.71	4.88
	1.00	0.60	2.36	2.44	3.69	3.82	4.11	4.25	4.24	4.39
30	0.60	0.60	3.00	3.46	3.78	4.36	4.21	4.86	4.33	5.00
	1.00	0.60	2.28	2.63	3.41	3.94	3.78	4.36	3.91	4.51
45	0.60	0.30	2.67	3.78	3.29	4.65	3.64	5.15	3.75	5.30
	1.00	0.30	2.07	2.93	2.92	4.13	3.25	4.60	3.35	4.74

TABLE A.4.2 : 219mm SIP Roof Panels - 0.9KN/m² wind load

			SIP Splines		2 no. 195 x 45 C16 timber splines		2 no. 195 x 45 C24 timber splines		2 no. 195 x 45 C30 timber splines	
Pitch (degrees)	Dead Load DL (KN/m^2)	Imposed load DL (KN/m^2)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)	Clear span on plan L_{plan} (m)	Clear Span on slope L_{slope} (m)
0	0.60	0.60	3.05	3.05	3.9	3.9	4.35	4.35	4.48	4.48
	1.00	0.60	2.3	2.3	3.57	3.57	3.97	3.97	4.1	4.1
15	0.60	0.60	3.00	3.11	3.79	3.92	4.23	4.38	4.35	4.50
	1.00	0.60	2.27	2.35	3.47	3.59	3.87	4.01	3.99	4.13
30	0.60	0.60	2.81	3.24	3.47	4.01	3.86	4.46	3.98	4.60
	1.00	0.60	2.16	2.49	3.19	3.68	3.54	4.09	3.65	4.21
45	0.60	0.30	2.48	3.51	2.95	4.17	3.28	4.64	3.38	4.78
	1.00	0.30	1.96	2.77	2.71	3.83	3.03	4.29	3.13	4.43

TABLE A.4.3 : 219mm SIP Roof Panels - 1.2KN/m² wind load

Pitch (degrees)	Dead Load DL (KN/m²)	Imposed load DL (KN/m²)	SIP Splines: Clear span on plan L_{plan} (m)	SIP Splines: Clear Span on slope L_{slope} (m)	2 no. 195 x 45 C16 timber splines: Clear span on plan L_{plan} (m)	2 no. 195 x 45 C16 timber splines: Clear Span on slope L_{slope} (m)	2 no. 195 x 45 C24 timber splines: Clear span on plan L_{plan} (m)	2 no. 195 x 45 C24 timber splines: Clear Span on slope L_{slope} (m)	2 no. 195 x 45 C30 timber splines: Clear span on plan L_{plan} (m)	2 no. 195 x 45 C30 timber splines: Clear Span on slope L_{slope} (m)
0	0.60	0.60	2.89	2.89	3.7	3.7	4.06	4.06	4.2	4.2
	1.00	0.60	2.21	2.21	3.39	3.39	3.77	3.77	3.89	3.89
15	0.60	0.60	2.83	2.93	3.56	3.69	3.95	4.09	4.07	4.21
	1.00	0.60	2.18	2.26	3.29	3.41	3.67	3.80	3.77	3.90
30	0.60	0.60	2.66	3.07	3.24	3.74	3.6	4.16	3.71	4.28
	1.00	0.60	2.08	2.40	3.01	3.48	3.34	3.86	3.46	4.00
45	0.60	0.30	2.32	3.28	2.71	3.83	3.01	4.26	3.11	4.40
	1.00	0.30	1.86	2.63	2.54	3.59	2.83	4.00	2.87	4.06

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Notes Relating to SIP Roof Span Tables

The following notes relate to span tables A.1.1, A.1.2, A.1.3, A.2.1, A.2.2, A.2.3, A.3.1, A.3.2, A.3.3, A.4.1, A.4.2, A.4.3

A.1. General:

1.1 The clear span on plan (L_{plan}) as stated on the tables represents the horizontal span, in metres (m), between internal face of structural support at each side.

1.2. The clear span on slope (L_{slope}) as stated on the tables represents the span along the slope of the roof, in metres (m), between internal face of structural support at each side.

1.3. The spans stated in the tables are based on total bearing width of 90mm at each support.

1.4 The roof panels with SIP splines are designed to EOTA Technical Report: TR019, which is based on design to EN 1995-1-1.

The roof panels with timber splines are based on design to EN1995-1-1 (see section 3 on these notes for important requirements for timber splines and associated connections to the SIP roof panels).

1.5 A 0 degree roof pitch is included in all of the tables. Although stated as 0 degrees it is essential that the final roof finish should be laid to a sufficient fall to avoid any water ponding on the roof. In the absence of any other recommendation, we recommend a minimum fall of 1:40. This is particularly important for SIP roof panels due to the significant and detrimental effect of creep due to accidental long-term or medium-term loading.

1.6 The tables are only applicable to sites in the United Kingdom (below 1000m above sea level)

1.7 Although the Tables are to EN1995-1-1, in order to make them safe for use with BS 5268 structural designs, the k_{def} factor for the EPS90 has been increased from 3.0 to 4.0. Therefore somewhat increased spans can be achieved when designing from 1st principles to EN 1995-1-1 where this value can be set to 3.0 (only effects SIP roof panels without timber reinforcement).

This increase has been found to bring span values into line with previous tables which reflected the use of medium-term k_{def} values for roof imposed and snow loads.

A.2. Loads

2.1 All loads quoted in the accompanying span tables are characteristic (unfactored) loads.

2.2 The dead load quoted in the tables is the load along the roof slope and INCLUDES the following weights of the SIP panels:

2.2.1 119mm, 144mm and 169mm deep panels with SIP splines - 0.15KN/m^2.
2.2.2 119mm, 144mm and 169mm deep panels with timber splines - 0.20KN/m^2.
2.2.3 194mm deep panels with SIP splines - 0.16KN/m^2.
2.2.4 194mm deep panels with timber splines - 0.21KN/m^2.
2.2.5 219mm deep panels with SIP splines - 0.16KN/m^2.
2.2.6 219mm deep panels with timber splines - 0.22KN/m^2.

2.3 The imposed load quoted in the tables is the load on plan. The tables also account for a "man load" of 0.9KN. All roof variable loads are considered to be "short-term" or instantaneous in accordance with UK National Annex to Eurocode 5 (include any long-term loads with permanent loads, if applicable).

2.4 Wind Loads:
2.4.1 Each table is designed for a specific maximum average wind load on the roof panels. Three wind loads are considered in the tables, i.e. 0.6KN/m^2; 0.9KN/m^2: 1.2KN/m^2. The designer must take cognisance of the wind load on the particular site.

2.4.2 As stated, the wind loads referenced are the maximum average wind loads. The tables do NOT take account of different zoning areas on the roof. It is a matter for the designer to ensure that the design moments and shear forces from the actual wind loads do not exceed those derived from the uniform wind loads stated for each table.

2.4.3 Wind load is assumed to act on a plane perpendicular (normal) to the plane of the roof.

2.4.4 Wind loads are considered to be instantaneous loads in accordance with UK National Annex to EN 1995-1-1.

A.3. Splines

3.1 Connect roof panels to SIP splines in accordance with Sips Eco Panels standard details.

3.2 Connect each OSB face to each 45mm wide timber spline with 3.5 x 50mm wood screws at 150mm crs.

3.3 Splines must fit into rebated zones at edge of panels. The tables are only permissible when the OSB facing board (of the panels) can be face fixed to the spline.

3.4 Timber splines to be fixed together in accordance with Sips Eco Panels standard details.

3.5 Alternatively 1 no. 90mm wide spline can be used in lieu of 2 no. 45mm wide timber splines.

ANNEX B:

SIP Wall Panel - Load Span Table

Table B.1 **Lateral Load Capacities for SIP Wall Panels (with SIP splines)**

Vertical Load (KN/m)	**Panel Height** (m)	**119mm thick SIP Panels (Kn/m^2)**	**144mm thick SIP panels** (Kn/m^2)	**169mm thick SIP panels (Kn/m^2)**	**194mm thick SIP panels** (Kn/m^2)	**219mm thick SIP panels (Kn/m^2)**
12	2.40	1.456	1.900	2.365	2.831	3.302
	2.70	1.180	1.570	1.966	2.371	2.781
	3.00	0.960	1.285	1.635	1.991	2.351
	3.60	0.658	0.900	1.159	1.428	1.706
	4.80	0.300	0.483	0.555	0.699	0.851
16	2.40	1.456	1.900	2.365	2.831	3.302
	2.70	1.180	1.570	1.966	2.371	2.781
	3.00	0.960	1.285	1.635	1.991	2.351
	3.60	0.658	0.900	1.159	1.428	1.706
	4.80	N/A!!	0.483	0.555	0.699	0.851

Table B.1 Notes:

1. "N/A!!" means that axial load capacity has been exceeded.

2. In relation to the vertical axial force of 16KN/m, the limiting factor in several cases is the bearing of the OSB facing boards onto the C16 softwood rails. Contact Sips Eco Panels Technical Department for solution where greater vertical loads are imparted onto the SIP wall panel.

3. The lateral loads quoted are intended to be maximum wind loads (instantaneous load duration) and are not applicable for use for the SIP panels acting as a retaining wall for stored material as these would impart a long-term loading onto the panels. Also the values quoted are not suitable for design of SIP roof panels. See separate tables by Sips Eco Panels for allowable roof span tables.

4. Design of walls are to Eurocodes, and in particular Eurocode 5 (design based on principles stated in TR019 "Calculation Models for prefabricated wood-based load-bearing stressed skin panels for use in Roofs" which has been adapted using EN 1995-1-1 for wall panels).

5. The maximum vertical permanent load allowed for in the values stated in the Tables is 8KN/m (the remaining load must be variable load of medium, short or instantaneous duration).

6. The values quoted in Table B.1 assumes that the floor directly above the wall panel considered, bears onto the wall panel with a rimbeam above outer face OSB board of wall panel (and a joist above inner face OSB board of wall panel where joists are parallel to direction of wall panel considered).

   Where joists are hung from face of SIP panel, as by Simpson Strong-tie hanger type IUQ or HIUQ, please contact Sips Eco Panels Technical Department for design of SIP wall panel.

7. The values quoted in Table B.1 are based on vertical axial line loads only, i.e. from trusses / joists @ maximum 600mm crs. Significant point loads must be supported by an appropriate number of timber studs.
   (as per SIP frame Engineer's design).

ANNEX C:

"Glued-SIP-Lintels"

Table C.1: Maximum Spans (mm) for Glued-SIP-Lintels

Permanent & Long-term Loads (KN/m)

		4KN/m	6KN/m	8KN/m	10KN/m	12KN/m	14KN/m
Variable Loads (KN/m)							
	4KN/m	2250	1800	1500	1275	1100	950
	6KN/m	1750	1450	1250	1075	950	850
	8KN/m	1425	1225	1075	950	850	N/A!
	10KN/m	1200	1050	925	850	N/A!	N/A!
	12KN/m	1050	925	825	N/A!	N/A!	N/A!
	14KN/m	900	825	N/A!	N/A!	N/A!	N/A!

<u>Table C.1 Notes:</u>

1. N/A denotes span and/or load exceed capacity.

2. The values have been calculated based on design to EN1995-1-1 and associated standards and National Annexes. Load durations also accord to this standard.

3. The loads stated above are line loads, applied from joists, studs and/or trusses which are spaced at maximum 610mm crs. The loads stated in the table are unfactored loads.

4. The SIP glued lintel design is based on a 270mm deep lintel, extending from underside of 45mm timber rail (directly over opening) to top of rail directly beneath head-binder.

   The depth of 270mm is based on the following: "Wall panel height of 2.4m – opening head height of 2.11m - 20mm head-binder".

   The tables can be used for deeper lintels. Please contact Sips Eco Panels Technical Department for more shallow SIP lintels or alternatively use solid timber, Glulam or steel lintels in lieu.

   The table is applicable for SIP lintel widths of 119mm or greater.

5. Variable Loads are considered to be all imposed loads, except long-term (i.e. storage loads) which have been included with the permanent loads. This table is based on medium-term variable loads, i.e. imposed floor loads, which is the most onerous of the remaining variable loads (as long-term loads not included). Therefore the tables can also safely apply to vertical roof imposed, snow and wind loads.

6. The permanent and dead loads row shall be calculated by adding all applied permanent and long-term loads that apply on the lintel (from all levels above that impart load onto the lintel).

7. The variable loads shall be calculated by adding all applied medium-term, short-term and instantaneous loads that apply on the lintel (from all levels above that impart load onto the lintel). These include, but are not limited to, floor imposed load, roof imposed load, snow load, etc. based on the standard load case rules stated in EN 1990. Ψ factors can be applied to secondary variable loads as usual. Snow load shall not be combined with roof imposed load.

8. The maximum calculated spans (in mm) stated are the clear spans between inside faces of timber stud supports.

9. The design of the lintels is based on the gluing of the OSB webs to the top and bottom timbers (flanges). The glued connection is critical to achieving the required spans under a set of loads. The following criteria must be achieved:

9.1 The glue must conform to BS EN 301 (exposure Type 1 or 2). This may require a different glue to that used to adhere the OSB to the EPS insulation.

9.2 The glue must be applied to ensure full spread between all OSB webs / timber flange connections. To ensure adequate adhesion, the OSB must tightly abut the top and bottom flange timbers. Screwing the OSB to the timber will allow a tighter finish. To ensure acceptable quality control, the gluing must be carried out in the factory.

The top and bottom flange timbers may require timber widths with a tighter tolerance in order to achieve abutting of OSB skins to these timber members.

9.3 The 11mm OSB3 boards, at each side, must be continuous and unbroken for entire length of glued SIP lintel. The OSB3 board must be oriented so that the strands are oriented horizontally!

9.4 At the ends of the lintels there must be at least 1 no. vertical timber member between the 2 timber flanges. Where more that 1 supporting stud is specified, there should be addition vertical timber members within the SIP lintel, i.e. 1 vertical squash block in lintel for very cripple stud specified.

9.5 Timber top and bottom flanges to be continuous and unbroken for full length of glued SIP lintel, including over supports. Timber top flange will be at same level as top-rail for adjacent panels. Head-binder must be continuous across joints between top flange of lintel and adjacent top-rails in order to allow for adequate restraint of lintel.

Signed ________________**Chartered Engineer** Date: 06.01.2015.
TIM KELLY

Qualifications: **BSc.Eng Dip.Eng C.Eng MIEI**