Definition:

A structural sandwich panel is an assembly consisting of a lightweight core securely laminated between two relatively thin, strong facings.

Application:

Sandwich panels are traditionally used as covering and isolating components, thus being secondary structural components of the building. The sandwich panels are mounted on a superstructure and they transfer transverse loads as wind and snow to the superstructure. The panels are subjected to bending moments and transverse forces only.

A new application is to use sandwich panels with flat or lightly profiled faces in smaller buildings – such as cooling chambers, climatic chambers and clean rooms – without any load transferring substructure.

In this new type of application in addition to space enclosure, the sandwich panels have to transfer loads and to stabilise the building. The wall panels have to transfer normal forces arising from the superimposed load from overlying roof or ceiling panels. So the wall panels have to be designed for axial loads or a combination of axial and transverse loads. Furthermore horizontal wind loads have to be transferred to the foundation and the building has to be stabilised. Because of the lack of a superstructure the sandwich panels have to transfer the horizontal loads. For this purpose the high in plane shear stiffness and capacity of the sandwich panels is used.

Load direction:

This paper presents a method for design of sandwich panels for horizontal, vertical or combined loadings. The method may be used for panels with only one type of loading by eliminating the equations which do not apply.

Panel behaviour:

Axial forces in a structural sandwich panel are carried by compression in the facings, stabilized by the core material against buckling; bending moments are resisted by an internal couple composed of forces in the facings; shearing forces are resisted by the core.

Materials:

Metal skins are an ideal material for the facings of sandwich panels, being extremely strong, with excellent finishes and coatings making them the ideal skins. Plywood serves as an ideal material for the facings of sandwich panels. While a variety of core materials may be used with the metal skins to complete the panel. Among these are polystyrene foams, polyurethane foams, and paper honeycombs. Besides resistance to shearing forces, for some applications such as exterior wall panels and roof panels the core should possess high resistance to heat and vapour transmission. The designer should consider the suitability of the core material to his application. Factors to consider include resistance to degradation by heat, age, and moisture; compatibility with glues; etc.

Bond between faces and core:

The bond between the facing and the core is extremely important, since the structural performance of the assembly depends on its integrity. Several types of bond may be acceptable – for instance, glues, and in the case of some of the foam materials, direct adhesion of the foam to the faces during expansion. In exterior wall panels, the bond should be waterproof. The combination of core material and bond should be such as not to creep excessively under the long-term loads and temperatures anticipated.

Panel design for combined loading:

All equations which follow have been adjusted with constants so that substitution of values with dimensions given in the legends will produce answers with the desired dimension.

General:

In general, the structural design of a sandwich panel may be compared to that of an "I" beam. Facings carry the compressive and tensile stresses, and the core resists shear. This core should be thick enough to space the facings so that they provide bending stiffness. The core also supports the facings against buckling. The composite structure must be checked for possible buckling as a column, and for wrinkling or buckling of the skins. Bending stiffness of the core (parallel to facings) is assumed to be insignificant. Tests have proven this assumption correct for panels with facing thicknesses up to 15% of the total panel thickness.

Note: This design method assumes a distribution of stresses based on principles of mechanics and has been verified by testing. Stress distributions around supports should be checked to confirm that stresses in components are within allowable limits. Verification by testing may be advisable in some cases.

Sandwich Stiffness:

Stiffness is a prime consideration for all structural design. The stiffness **D** of a rectangular beam of thickness **h** and width **b** and modulus of elasticity **E** is given by the formula

$$D = E\frac{bh^3}{12}$$

Formula 1

If a sandwich is constructed with the same overall dimensions but with a core of a different material of thickness **c**, the stiffness is given by

$$D = E_f\frac{b(h^3 - c^3)}{12}$$

Formula 2

Where E_f is the modulus of elasticity of the facings and E_c is the modulus of elasticity of the core. For simplicity here, it has been assumed that the facings are of equal thickness. Mathematical formulae have been derived for constructions with facings of different materials and thicknesses. Since the core of the sandwich is extremely lightweight when compared to the facings, it will probably be weak, limber material whose stiffness can be neglected in considering the sandwich thickness.

The above formula can be rewritten as

$$D = \frac{E_f b h^3}{12}\left(1 - \frac{c^3}{h^3}\right)$$

Formula 3

The amount of facing material in a piece of sandwich panel is given by

$$A_f = 2fb$$

Formula 4

Where **f** is the facing material thickness and **b** is the width of the sandwich panel. This may also be expressed by

$$A_f = (h - c)b\ \boldsymbol{OR} = hb(1 - \frac{c}{h})$$

Formula 5

The term $(1 - \frac{c}{h})$ represents the proportion of the facing material in a sandwich compared to the total material in a rectangular section of hb. Similarly the term $(1 - \frac{c^3}{h^3})$ represented in formula 3 represented the proportion of stiffness of the sandwich as compared to the stiffness of a regular section represented in formula 1.

Example: if a sandwich panel as 1/8 of the amount of facing material in the solid section. Then (1-c/h) is 1/8 or c/h is 7/8, thus c^3/h^3 = 2/3 (approximately) and $(1-c^3/h^3)$ = 1/3 (approximately). It thus goes to show that if a sandwich of 1/8th the weight (excluding the light weight core) of a solid core can be made to have 1/3 the stiffness of the solid material. If the sandwich is three times wider than the solid material it will have the same stiffness as the solid material and will still be only 3/8 as heavy.

Obviously therefore, the fain in the stiffness-weight ratio possible with the structural sandwich panel might be offset by the reduction in the shear stiffness and strength and unless the facings are bonded with the core securely, the stiffness will no longer be the sum of the stiffness of each of the sandwich parts.

Shear stiffness of the sandwich panel having thin facings is given by

$$N = \frac{(h + c)b}{2}\ G_c$$

Formula 6

Where G_c is the shear modulus of the core.

Deflection in the sandwich panel is given by

$$y = \frac{k_B P a^3}{D} + \frac{k_s P a}{N}$$

Formula 7

Where **y** is the deflection, **P** is the total load, **a** is the span, **D** is the flexural stiffness, K_B and K_s are constants depending on the beam loading.

Values of K_B and K_s for different loading conditions are given as under

Loading	Beam Ends	Deflections at	K_B	K_s
Uniformly distributed	Both simply supported	Midspan	5/384	1/8
Uniformly distributed	Both clamped	Midspan	1/384	1/8
Concentrated at midspan	Both simply supported	Midspan	1/48	1/4
Concentrated at midspan	Both clamped	Midspan	1/192	1/4
Concentrated at outer quarter points	Both simply supported	Midspan	11/768	1/8
Concentrated at outer quarter points	Both simply supported	Load Point	1/96	1/8
Uniformly distributed	Cantilever, 1 free, 1 clamped	Free end	1/8	1/2
Concentrated at free end	Cantilever, 1 free, 1 clamped	Free end	1/3	1

Strength of a Sandwich Panel:

The strength of a sandwich panel (beam) under bending and shear loads is determined by the ability of the facings to resist compression or tension and that of the core and the bond between the core and skin to resist shear. The stresses produced in the facings by bending moment applied to the sandwich panel are given by

$$F = \frac{2M}{f(h+c)b}$$

Formula 8

Where **F** is the mean compressive or tensile stress, **M** is the bending moment, **f** is the thickness of one facing, **h** is the total sandwich thickness, **c** is the thickness of the core and **b** is the width of the sandwich panel. The shear stress in the core is given by

$$S = \frac{2V}{(h+c)b}$$

Formula 9

Where **S** is the core shear stress and **V** is the shear load on the sandwich.

The stress and the core shear stress formulae can be used for most sandwich panels which have thin facings and moderately rigid and thick cores, for greater accuracy shear load carried by the facings should also be taken into account.

Compressive stress in the facings are given by the formula

$$S = \frac{P}{2fb}$$

Formula 10

If the panel is **simply supported** at its ends, the column **buckling load** is given by

$$P = \frac{\pi^2 D}{a^2\left(1 + \frac{\pi^2 D}{a^2 N}\right)}$$

Formula 11

Where **P** is the total load, **b** is the column width, **a** is the column length, **D** is panel stiffness defined in the formula 3, and **N** is the shear stiffness of the panel.

If the load bearing wall panel is held in line at its vertical edges, the buckling load of the panel is given approximately by

$$P = \frac{4\,\pi^2 D}{b^2\left(1 + \frac{\pi^2 D}{b^2 N}\right)^2}$$

Formula 12

For the panels that are at least as long as they are wide and for the second term in the bracket of the denominator is less than or equal to unity (1).

Where **P** is the total load, **b** is the column width, **a** is the column length, **D** is panel stiffness defined in the formula 3, and **N** is the shear stiffness of the panel.

Note: These design criterions for sandwich panel stiffness and strength are suitable for sandwiches with thin isotropic facings and isotropic cores and are approximate for orthotropic materials. For orthotropic materials and cores as well as for facings which are moderately thick, more exacting calculations are required. 2.79