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Study on Flexural Strength of Double Skin Metal Faced Polyurethane Sandwich Panel for Building

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Abstract: Equivalent elastic modulus of double skin metal faced polyurethane sandwich panel with the same thickness of surface layer was derived. Some numerical simulations were performed to find out the relevance of PUSP (Polyurethane sandwich panel) between its' bending properties and the thickness of material supported on both ends and four edges by ANSYS. The outcome was compared with an experimental investigation on a construction system based on completed in situ sandwich panels subjected to transverse loading. Results show that constraint conditions have significant effect on the flexural bearing capacity of the sandwich panel for walls and roof panels. Thickness of face layers and interlayer affect the bearing capacity by changing the shear force distribution coefficient. It is reasonable to select calculation results as the flexural bearing capacity calculated by the design formula in the standard (GB 23932-2009 - T) when the deflection meet the requirements.

Key words: Polyurethane sandwich panel, equivalent elastic modulus, flexural strength, finite element

INTRODUCTION

Polyurethane sandwich panel(PUSP)are typically constituted by two rigid layers which are separated by an internal insulation layer of rigid polyurethane foam (Qin *et al*., 2008). Because of its lightweight, fire prevention, heat preservation, heat insulation, sound insulation, Sandwich panels are extensively utilized as the floor panels and bulkheads (Wang, 2009; Chen *et al*., 2009). The modified sandwich plate is also used in industrial plant, building adding story, wall panel, roof panel, etc. But the composite sandwich board needs to have enough compressive strength, bending strength as the roof and wall panel as for building. As a retaining structure, the PUSP needs have enough bending strength to resist the wind pressure. However few research on mechanical properties of polyurethane composite sandwich panel carried out. Experimental study related described deformation characteristics of flexural failure process of the color-coated steel sandwich panel through the uniform load test. It also explored the main control factors of its' flexural failure (Zhang and Yu, 2001). But research about the structure thickness of composite Board core material and face layer of confrontation effecting on bent hosted force is rarely. This article studied on flexural strength of double skin metal faced polyurethane sandwich panel for building. According to the existing specification (GB 23932-2009-T) (Standards, 2009), the paper analyzed thickness of different surface layer and the core board effecting on bending properties and compared with test results. Additionally, some

numerical simulations are performed in ANSYS to explore the relationship between the bending force and material thickness in simply-supported at both ends. Under the same conditions, the bending bearing capacity was calculated under four sides clamped condition. This would provide reference for its wider application in engineering.

EQUIVALENT ELASTIC MODULUS

To make sure the material has good flexural performance and moments of inertia centre coincides with the core, some parameters are set as follows. The thickness of the face panels both is h_1. The elastic modulus is E_1. The thickness of core material is h_2 and its' modulus of elasticity is E_2. Its' width is b. Specific section size is shown as Fig. 1.

The external force was calculated by means of:

$$F = \varepsilon bh(2E_1 + E_2) = \varepsilon E \cdot 3bh \quad (1)$$

Tensile modulus of elasticity was

$$E = \frac{2E_1 + E_2}{3} \quad (2)$$

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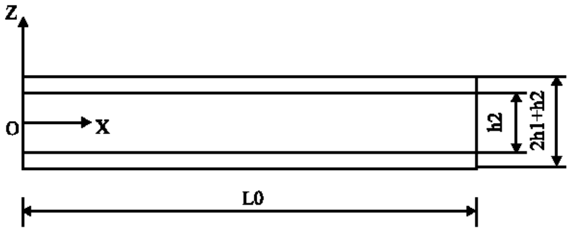

Fig. 1: Specific section size of sandwich panel

When the sandwich panel was bending, its' bending moment is:

$$\int_A y \cdot \sigma dA = M \tag{3}$$

$$\sigma = E\frac{y}{p} \tag{4}$$

That is:

$$\int_A y\frac{Ey}{\rho} \cdot bdy = M \tag{5}$$

Put the parameters into the above formulas, we get:

$$2\int_0^{\frac{h_2}{2}} bE_2\frac{y^2}{\rho}dy + 2\int_{\frac{h^2}{2}}^{\frac{h^2}{2}+h_1} bE_1\frac{y^2}{\rho}dy = M \tag{6}$$

The equivalent bending elastic modulus E is:

$$E = \left(\frac{h_2}{h}\right)^3 E_2 + \left[1-\left(\frac{h^2}{h}\right)^3\right]E_1 \tag{7}$$

BENDING BEARING CAPACITY ANALYSIS OF POLYURETHANE SANDWICH PANEL

The sandwich panels considered in this study are made of double skin metal faced polyurethane sandwich panel for building (Gara *et al.*, 2012). Its' bending bearing capacity was provisioned in the existing specification (GB 23932-2009-T). The role described that the value of flexural strength was determined when the deflection reached 1/200 of roof span and 1/150 of wall panels:

$$f = \frac{5pwL_0^4}{384EI} + \frac{K\beta pwL_0^2}{8GA} \tag{8}$$

$$\beta = R_1\left(\frac{D}{100}\right)^2 + R_2\frac{D}{100} + R_3 \cdot d + R_4 \tag{9}$$

Table 1: The values of R_1, R_2, R_3, R_4

Use of sandwich panel	R_1	R_2	R_3	R_4 EPS, PUR	R_4 RW, SW, GW
Wall panels	0.08	0.021	-0.08	0.72	0.63
Roof panels	-0.20	0.670	-0.20	0.25	0.22

Table 2: Deflection for different thickness of sandwich panel

Dimensions (mm)	Thickness of: Surface layer (mm)	Thickness of: Internal layer (mm)	Load value for: Wall panels (KN/m^2)	Load value for: Roof panels (KN/m^2)
2000×1000	0.5×2	50	2.11	2.12
2000×1000	0.6×2	50	2.35	2.28
2000×1000	0.7×2	50	2.58	2.41
2000×1000	0.5×2	60	2.59	2.68
2000×1000	0.6×2	60	2.86	2.85
2000×1000	0.7×2	60	3.11	3.00
2000×1000	0.5×2	70	3.05	3.23
2000×1000	0.6×2	70	3.33	3.42
2000×1000	0.7×2	70	3.59	3.58

where, f is the deflection in normal use stage, p the load standard values, w and L_0 the wide and the span of the sandwich panel, E the elastic modulus of the surface layers, I the moment of inertia on the surface layers to the neutral axis, K and β the nouniformity coefficient and the distribution coefficient of the shear stress, G and A the shear modulus and the area of internal layer, R_1, R_2, R_3, R_4 the coefficients. Table 1 shows the above values and Table 2 shows all the obtained results.

Result of the Table 2 shows that

- The flexural bearing capacity of the sandwich panel will improve greater under the condition of internal layer thickness increasing 10mm than the panel thickness increasing 1mm. To raise the value of the flexural bearing capacity in design process, it can refer to our calculation
- Thickness of face layers and interlayer affect the bearing capacity by changing the shear force distribution coefficient. The error of flexural bearing capacity is within 5%. It is reasonable to select calculation results as the flexural bearing capacity calculated by the design formula in the standard (GB 23932-2009-T) when the sandwich panel is used for roof panel or wall panel

ANSYS SIMULATION ANALYSIS

To build an accurate structural model, some assumptions are made (Li and Fan, 2006; Zhang and Song, 2011; Boni and de Almeida, 2008).

- The surface layers and core material always work in the linear elastic stage
- To make the surface layer and the internal layer work together, the surface layer have total constraints with the core layer. There is no slip between them

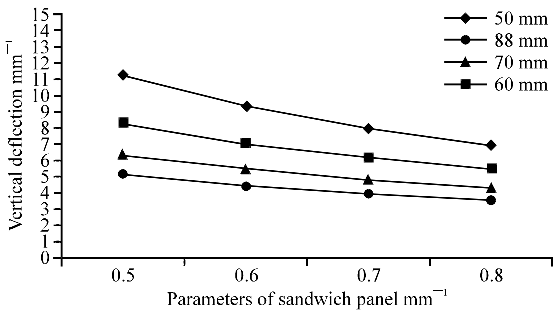

Fig. 2: Influence of panel thickness on vertical deflection under the condition of two edges simply supported

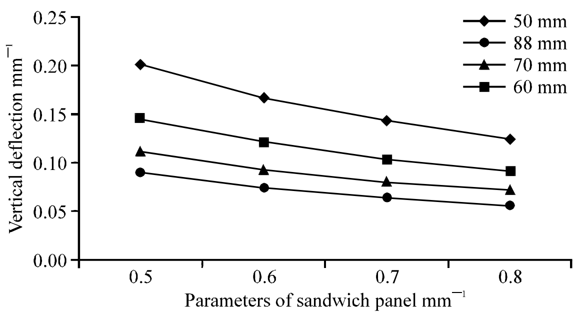

Fig. 3: Influence of panel thickness on vertical deflection under the condition of four sides fixed

- For unit type, the core layer is three-dimensional entity element and the surface layer the 3D shell unit

Uniformly distributed load was applied on the sandwich board. Two edges were simply supported. Some related parameters were set as follows. The elastic modulus of the surface layers is 2.10×105 MPa and its' Poisson ratio is 0.25. For the interlayer, the two above parameters are respectively 8 MPa and 0.4. To receive the effect of material thickness on the bending mechanical properties, sixteen models constituted by different panel thickness were built for numeric simulation. The thickness parameters of interlayer are respectively 50 mm, 60 mm, 70 mm and 80 mm. Accordingly, the thickness parameters of facial layer are respectively 0.5 mm, 0.6 mm, 0.7 mm and 0.8 mm. Imposed by certain load, we get the deflection result shown in Fig. 2. The deflection result is shown in Fig. 3 under the condition of four sides fixed.

From the Fig. 2, it's not difficult to find that the deflection calculated by rule provided is higher than gotten by ANSYS. The reason is that the formulas in current standard are always summarized by practical experience and most of this experience comes from crude operating environment. However numeric simulation in ANSYS provides a perfect environment. Figure 3 describes more practical situation when the sandwich panel used as wall and roof panel for building.

Fig. 4: Test configuration

Fig. 5: Samples failure

EXPERIMENTAL TEST

Three samples with dimension of 2000×1000mm made of two rigid layers and polyurethane interlayer were tested (shown as in Fig. 4 and 5). The thickness of rigid layer is 0.5 mm and the interlayer is 70 mm. The average load measured by test when the deflection reached to 1/200 of the panel span is 4.1 KN and it is 5.0 KN when the deflection reached to 1/150 of the panel span. This proved that it is reasonable to select calculation results as the flexural bearing capacity calculated by the design formula in the standard when the deflection meets the requirements.

CONCLUSIONS

- Changing thickness of interlayer or facial layer has different effect on flexural strength. To raise the value of the flexural bearing capacity in design process, it can refer to our calculation

- Thickness of face layers and interlayer affect the bearing capacity by changing the shear force distribution coefficient. It is reasonable to select calculation results as the flexural bearing capacity calculated by the design formula in the standard when the sandwich panel is used for roof panel or wall panel
- The design value of material strength can be calculated by design formula under the condition of two edges simply supported when the sandwich panel used as wall and roof panel for building. Nevertheless, in this paper description of computing for material strength under the condition of four sides fixed will bring the standard to completion

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