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Structural analysis of sandwich type composites

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Summary

The light structures with sandwich elements have a large use in the civil and industrial buildings. There are a lot of materials that are used to make the sandwich elements, and thus results a large variety of elements. Considering the composition, the structural analysis must have in view the general and local phenomena occurring both in the elements and at the level of the whole , with a view to obtain the standard structural security.

KEYWORDS: sandwich composites, layer, bending stiffness, torsion stiffness, polymers

1. INTRODUCTION

The sandwich-type composites are part of the light but very efficient structures.
The specifically qualities of the sandwich-type composites are:

- The accessibility for design of a large variety of complicated shapes.
- Durability.
- A very good dynamical response (in case of earthquake for example).
- A high capacity of thermo-insulation.
- A reduced cost production for a large variety of in-situ production.
- An independence of environmental condition, [1],[2],[3].

The sandwich-type composites were used for the first time in Aeronautical structure (The Mosquito – 1940) and for the production of some light wood building constructions (in Finland).

From 1960 the sandwich-type composites, started to be used as layered elements, (bonded to each other) having the properties as a combination of all components, [4],[5],[6],[7].

The ASTM C274-53 (US STANDARD) considers the sandwich-type composites as a laminar material including some elementary components bonded to each other in order to accord superior properties to the final item (Fig.1,2,3).

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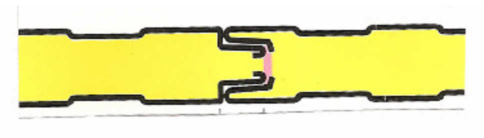

Figure 1

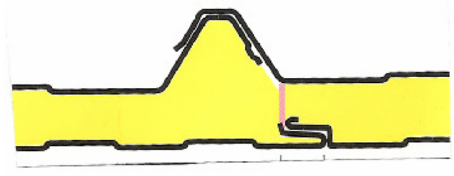

Figure 2

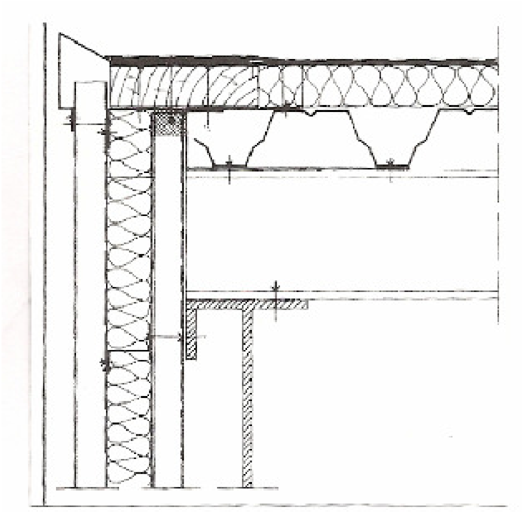

Figure 3

The very first idea of creating sandwich-type composites belongs to Leonardo da Vinci, and the name "sandwich" was used for the first time by Fairbairn in 1849.

Choosing the proper materials, especially the facing layers (with decorative, but particularly high durability properties) involves many pre-conditions as:

- Physical properties – density, color, thermal conductibility, reflection, environmental durability (excessive heat/cold), chemical stability, corrosion, etc.
- Mechanical properties – stress resistance (tension, shear, fatigue) resistance to distortions, impact, etc.

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2. SANDWICH-TYPE COMPOSITES COMPONENTS

Due to diversity of materials used in the sandwich-type composites there are many available products. The most widespread sandwich-type composites consist in two external metallic or concrete (sometimes pre-compressed) layers and, an intermediate layer (usually with a lower elasticity modulus) who connects the two external layers.

The external layers, usually metallic or structurally reinforced concrete may, include local decorative strips. The reinforcement of the lateral layers may vary according to the local requirements such as.

If the external layer is made of steel, the usual thicknesses are $1.5mm$ for a $0.5mm$ span. The bonding (medial) layer is usually made of Polymers with reduced density ($\rho = 10 - 50 daN/m^3$) such as PVC, polyurethanes, polystyrenes or other light materials as porous rubber, wood, fibers, stabilized pulps, etc.

The thickness of the interior layer may vary between $40 - 150mm$ according to the used material.

The external layers are meant to resist to the bending moments (compression /tension) and the inner connecting layer must be capable to resist to the inter-laminar, and torsion forces.

The sandwich-type composites are generally delivered as panels having the dimensions: $(50 - 150cm) * (300 - 1000cm)$.

The sandwich-type panels are a bit more expensive than the classical building materials (200–300 €/m^2 or 30–45 € /m^3).

Considering the thermal insulations it must be mentioned that a sandwich-type panel of $80 - 100mm$ is equivalent with a brick wall of $37.5cm$, for a mass to surface ratio of 13/800 for external layers of steel, and 8/800 for external layers of aluminum.

Apart from steel or concrete, for the external layers may be used wood panels, reinforced gypsum, or other fiber reinforced plastics materials.

The connection among the layers is performed by an adhesive material.

If, from the initial stages of production the three layers were designed to match smoothly each other, this procedure will allow a perfect continuity of the whole structure (Fig.4,5,6).

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Figure 4

Figure 5

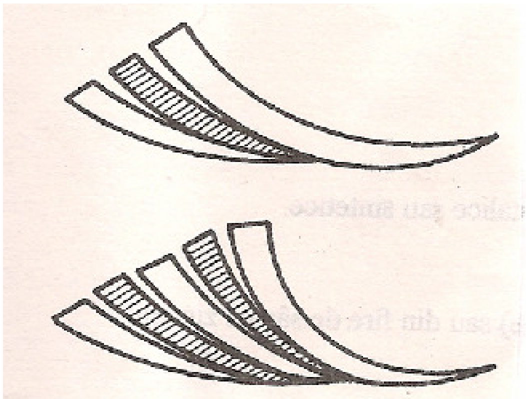

Figure 6

3. EXPERIMENTAL STUDY FOR SANDWICH-TYPE COMPOSITES

The tests were performed both for the individual layers and for the whole structure (sandwich-type composites).

For each layer the tests are the usual ones, such as:

- Tension test for determining the limit of connection loads between the external and internal layers. This test is performed perpendicular on the item's surface.
- The bending test is performed at 4 points and afterwards at 3 points in order to get the direct bending stiffness ratio along with the tangent stiffness ratio. It is very important to consider the sample's dimensions in order to get the precise data about the transversal curvatures.

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- The shear test will be performed on the sandwich product in order to get the shear resistance of the core layer.
- The torsion test is performed on the sandwich product for determining the torsion stiffness ratio.

4. STRUCTURAL ANALYSIS

Considering the basically structure of the sandwich-type composites, the analyses must include the general comportment of the whole structure along with the local influences of each layer including their interaction. Only on this general base, the analysis will be performed according to required standards.

For the smooth external layers the local bending stiffness may be neglected and such, the moment of inertia for the whole section will be:

$$I_{\text{sandwich}} = 2Bt\left(H - \frac{t}{2}\right)^2$$

where:
- B is the panel's width,
- t is the thickness of the external layer,
- H is the high of the whole panel.

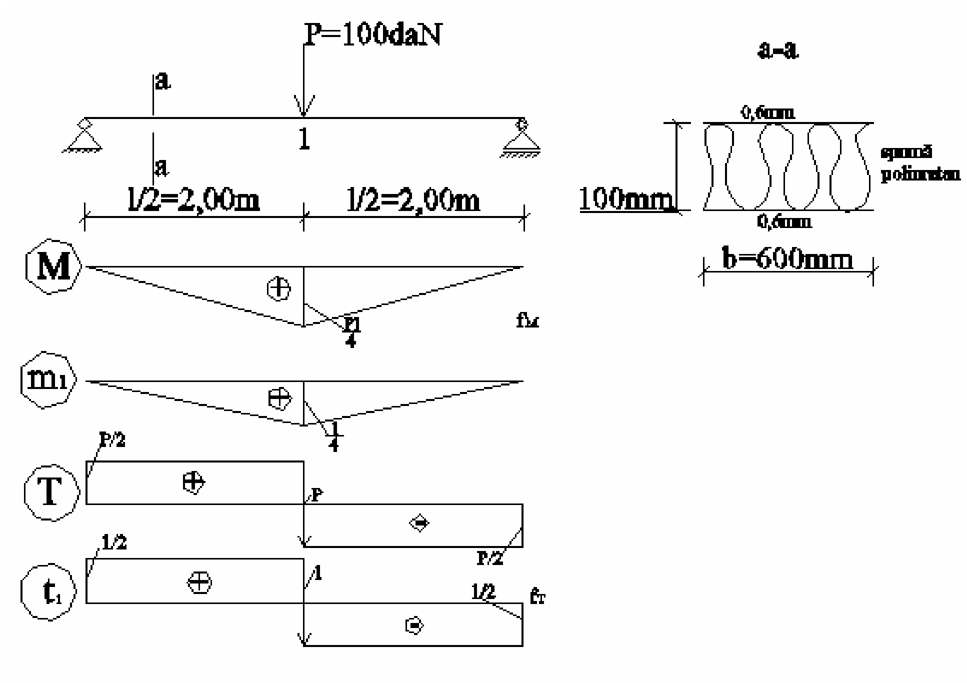
For the deformation calculation, the main task will be performed by the core's shear resistance. The displacements that occur due to the composite's bending or due to shear have similar values. On this ground, the analysis must be performed very attentively considering in each case, the main impact from all load cases, in order to eliminate all the false presumptions.

5. EXAMPLE FOR SANDWICH-TYPE COMPOSITES CALCULATION

How big it will be the displacement in the point 1 for a beam made of a sandwich panel with the following characteristics:

$E_{steel} = 2.1 \cdot 10^6 daN / cm^2$,

$G_{polyurethan\ \ foam} = 50 daN / cm^2$.



Solution

$$f = f_M + f_T$$

$$I_t = 2 \cdot 60 \cdot 0.06 \cdot \left(5 - \frac{0.06}{2}\right)^2 = 177.85 cm^4$$

$$A_{FOAM} = 60 \cdot (10 - 0,06) = 596.4 cm^2$$

$$f_M = \frac{100 \cdot 400^3}{48 \cdot 2.1 \cdot 10^6 \cdot 177.85} = 0.36 cm$$

$$f_T \cong \frac{100 \cdot 400}{4 \cdot 50 \cdot 596.4} = 0.34 cm \cong f_M$$

$$f = 0.36 + 0.34 = 0.7 cm < \frac{l}{300} = 1.33 cm$$

6. CONCLUSIONS

The light sandwich-type composite structures confer the possibilities of an unlimited variety of constructions unattainable by any other building materials.

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With the nowadays ecological conditions, since the beginning of the new Millennia all the classical structures must be up-dated, and consequently the composite materials started to be competitive.

They may be used for a large variety of constructions: in the earthquake areas, in harsh environmental condition on no soil pre-preparations, everywhere. On those premises it might be predicted that the use of composed structure will increase exponentially (Fig.7,8,9,10).

Figure 7

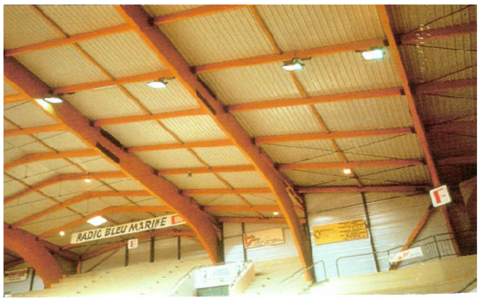

Figure 8

Figure.9

Figure.10

The light sandwich-type composite may be used also for the consolidations of already existing buildings without demolitions simply by replacing the old items with new lighter but stronger non-structural items.

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