Flexural Rigidity Evaluation of a New Sandwich Structure With Nonwoven Polyester Mat

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Abstract: - The paper presents the evaluation of flexural rigidity in case of a new sandwich structure with thin nonwoven polyester mat as core. The structure is seen as an open beam with dissimilar skins from which one is EWR-300 glass fabric reinforced polyester. Three-point bend tests have been carried out to determine the most important features of this structure.

Key-Words: - Flexural rigidity, Sandwich, Nonwoven polyster, Core, Open beam, Three-point bend.

1 Introduction

In general, a sandwich structure is manufactured of three layers: two cover layers called “skins” – that form the carrying structure, layers composed of stiff and resistant material, and an intermediate layer named “core” – which has the main purpose to sustain the skins and to give stiffness to whole structure [1-6].

This stiffness is obtained actually through “thickenning” the composite structure with a low density core material. This leads to a substantial increase of flexural rigidity of the structure, on the whole, without a significant increasing in its entire weight [7-13]. Sandwich structures are more and more used in various applications due to their high stiffness at bending. Nowadays, there are a great variety of cores such as rigid foams, hexagonal structures made from thermplastics, metallic and non-metallic materials, expandable and fireproof materials, balsa wood, etc., [8-16].

2 Problem Formulation

In general, composite laminates are formed by thin layers called laminae. These laminates present a quite low flexural rigidity. A solution could be their stiffening using ribs [17], [18].

However, there are constructive situations when these ribs can not be used [19], [20]. Another solution could be the increase of layers number that compose the structure. But this solution presents the disadvantage of the increase of resin and reinforcement consumption with economic and environmental consequences.

3 The Structure

The structure that can avoid the previously presented disadvantages is composed from the following layers:

- An EWR-300 glass fabric reinforced polyester resin;
- A nonwoven polyester mat as core;
- A pure polyester resin layer which can be pigmentated (“gelcoat”).

The structure can be seen as an open beam with dissimilar skins. The core presents the most important influence in the overall structure’s flexural rigidity.

The core material is a random oriented noncontinuous nonwoven polyester mat contains microspheres that prevent excessive resin consumption. The most important features of the whole structure using this kind of core are:

- Stiffness increase;
- Weight saving;
- Resin and reinforcement saving;
- Fast build of the structure’s thickness;
- Superior surface finish.

The nonwoven polyester mat is soft, present excellent resin impregnation and high drapeability when it is wet and therefore is suitable for complex shapes. It is most often applied against the “gelcoat” to create a superior surface finish for instance on hull sides. The applying of the nonwoven polyester mat against the “gelcoat” layer is more important when dark “gelcoats” are used, to prevent the appearance of the glass fibers reinforcement.

This material has a good compatibility with the polyster, vinylester and epoxy resins and is suitable for hand lay-up and spray-up processes.

4 Structure’s flexural rigidity

According to the ordinary beam theory, the flexural rigidity, here denoted R, of a beam is the product between Young modulus of elasticity *E* and the moment of inertia *I* (that depends on structure’s cross-section). The flexural rigidity of an open sandwich beam assumed to have thin skins of equal thickness represents the sum between the flexural rigidities of the skins and core determined about the centroidal axis of the whole cross section (fig. 1) [1]:

$$R = E_s \cdot \frac{b \cdot t^3}{6} + E_s \cdot \frac{b \cdot t \cdot d^2}{2} + E_c \cdot \frac{b \cdot c^3}{12}, \qquad (1)$$

where E_s and E_c represent the Young moduli of elasticity for skins and core respectively.

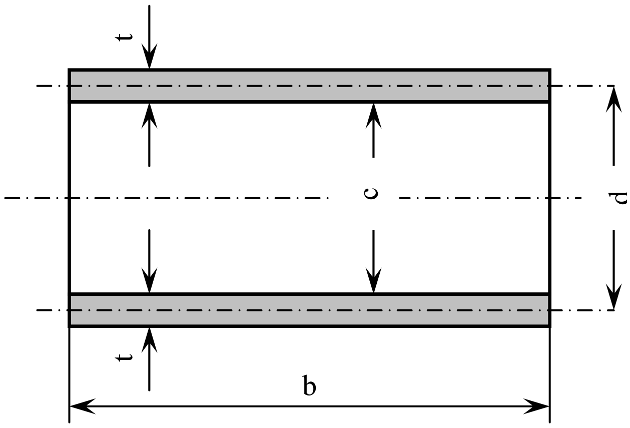

Fig. 1. Dimensions in a cross section of an open sandwich beam with equal thickness skins

If the skins present different materials and unequal thickness, like our structure with dissimilar skins (fig. 2) and taking into consideration that the local flexural rigidities for the skins can not be neglected, which means that [1]:

$$\frac{d}{t} > 5.77, \qquad (2)$$

the sandwich flexural rigidity can be written according to reference [1] as:

$$R = \frac{b \cdot d^2 \cdot E_{s1} \cdot E_{s2} \cdot t_1 \cdot t_2}{\left(E_{s1} \cdot t_1 + E_{s2} \cdot t_2\right)} + \frac{b}{12} \cdot \left(E_{s1} \cdot t_1^3 + E_{s2} \cdot t_2^3\right). \qquad (3)$$

Considering the beam as a wide one, the authors propose that the structure’s flexural rigidity can be computed as follows:

$$R = \frac{b \cdot d^2 \cdot E_{s1} \cdot E_{s2} \cdot t_1 \cdot t_2}{\left[E_{s1} \cdot t_1 \cdot (1-\upsilon_{s2}^2) + E_{s2} \cdot t_2 \cdot (1-\upsilon_{s1}^2)\right]} +$$

$$+ \frac{b}{12} \cdot \left(\frac{E_{s1} \cdot t_1^3}{1-\upsilon_{s1}^2} + \frac{E_{s2} \cdot t_2^3}{1-\upsilon_{s2}^2} \right). \qquad (4)$$

where the suffixes 1 and 2 refer to the upper and lower skins respectively, *b* represent the width of the beam cross section, *d* is the distance between centrelines of opposite skins, *t* is the skin thickness, *c* is the core thickness, υ_{s1} and υ_{s2} represent the upper respective the lower skin Poisson ratio .

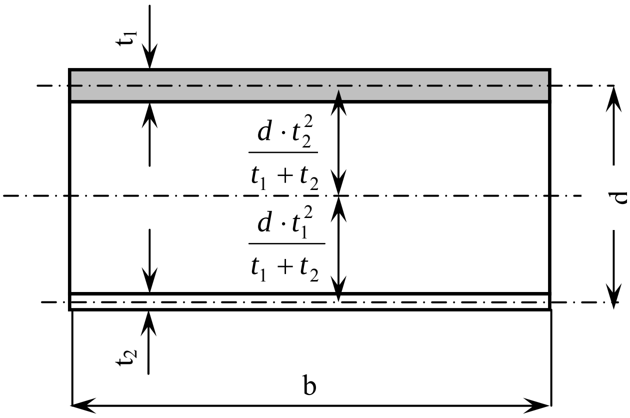

Fig. 2. Dimensions in a cross section of an open sandwich beam with dissimilar skins

In case that we consider the structure as a sandwich panel supported on two sides, this panel can be seen as a wide open beam. Condition (2) remains the same but in flexural rigidity analysis, due to the fact that each skin is considered a thin plate, the ratio between stress and strain is $\frac{E}{1-\upsilon^2}$ [1].

5 Experimental approach

The three-point bend test has been used to determine the most important features of this test. Twelve specimens have been cut from a sandwich panel and subjected to bending until break occurs. Some specimens characteristics are presented in table 1. The test features are presented in table 2.

The tests have been carried out on a LR5K-type testing machine (5kN maximum load) produced by Lloyd's Instruments.

Table 1. Specimens features

Average dimensions	Value
Width, b (mm)	15
Length (mm)	150
Sandwich thickness (mm)	8.27
Core thickness, c (mm)	4
Cross-section area (mm^2)	124.05
Thickness of the upper skin, t_1 (mm)	3.1
Thickness of the lower skin, t_2 (mm)	1.1
Distance, d (mm)	6.17

Table 2. Test characteristics

	Value
Test type: three-point bend	-
Test speed (mm/min)	4
Span (mm)	130
Test limit (mm)	100

The following features have been determined using the software NEXYGEN-plus:

- Stiffness (N/m);
- Young modulus of bending (MPa);
- Flexural rigidity (Nm^2);
- Load at maximum load (kN);
- Maximum bending stress at maximum load (MPa);
- Machine extension at maximum load (mm);
- Extension at maximum load (mm);
- Maximum bending strain at maximum load (-);
- Work at maximum load (Nmm);
- Load at maximum extension (kN);
- Maximum bending stress at maximum extension (MPa);
- Machine extension at maximum extension (mm);
- Extension at maximum extension (mm);
- Maximum bending strain at maximum extension (-);
- Work to maximum extension (Nmm);
- Load at minimum load (kN);
- Maximum bending stress at minimum load (MPa);
- Machine extension at minimum load (mm);
- Extension at minimum load (mm);
- Maximum bending strain at minimum load (-);
- Work to minimum load (Nmm);
- Load at minimum extension (kN);
- Maximum bending stress at minimum extension (MPa);
- Machine extension at minimum extension (mm);
- Extension at minimum extension (mm);
- Maximum bending strain at minimum extension (-);
- Work to minimum extension (Nmm);
- Load at break (kN);
- Maximum bending stress at break (MPa);
- Machine extension at break (mm);
- Extension at break (mm);
- Maximum bending strain at break (-);
- Work to break (Nmm).

6 Results

The input data for the theoretical approach are presented in table 3.

Table 3. Input data

	Value
Young modulus of bending, E_{s1} (MPa)	6118.6
Young modulus of bending, E_{s2} (MPa)	7172.6
Upper skin Poisson ratio, υ_{s1} (-)	0.25
Lower skin Poisson ratio, υ_{s2} (-)	0.35

Some experimental results obtained on twelve sandwich specimens are presented in figs. 3 – 8.

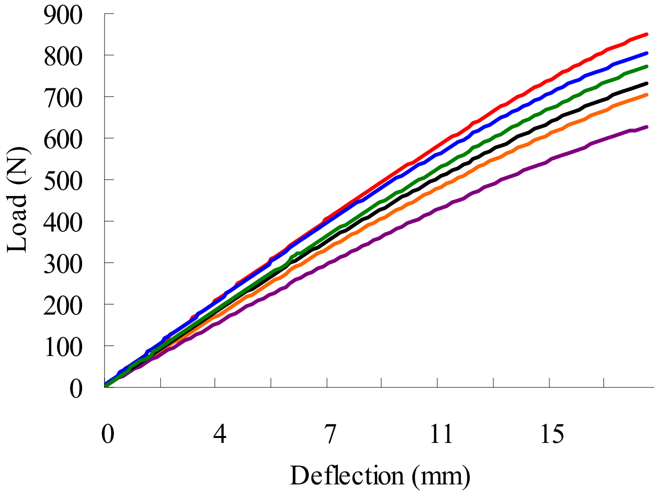

Fig. 3. Load at bending distribution for six sandwich specimens with unequal skins of two different materials

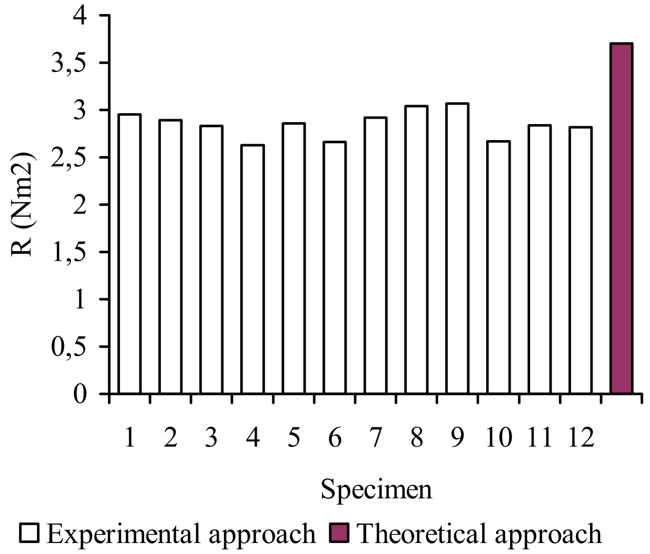

Fig. 4. Flexural rigidity distribution of twelve sandwich specimens with unequal skins of two different materials. Comparison with theoretical approach

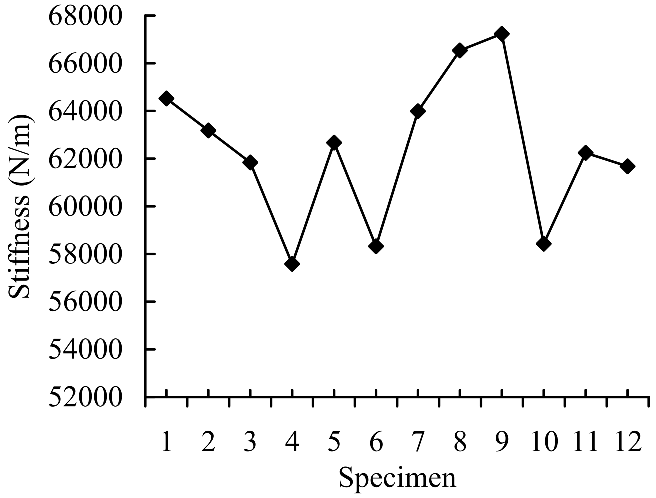

Fig. 5. Stiffness distribution of twelve sandwich specimens with unequal skins of two different materials

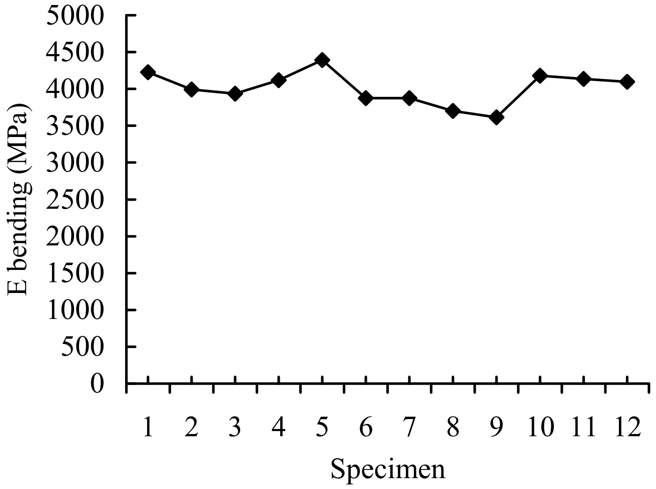

Fig. 6. Distribution of Young modulus of bending

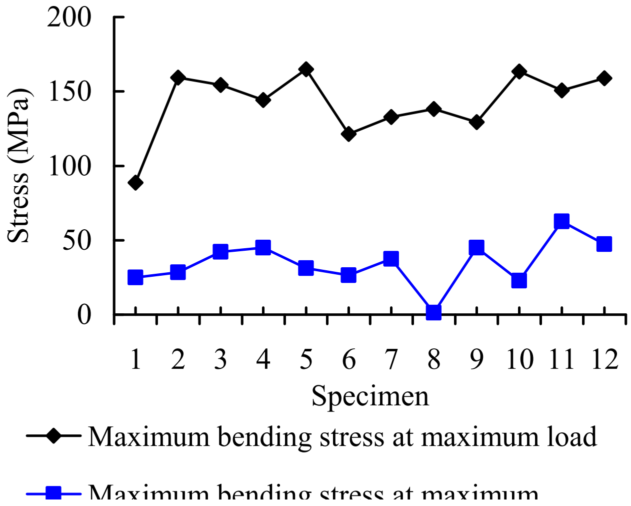

Fig. 7. Distribution of maximum bending stress

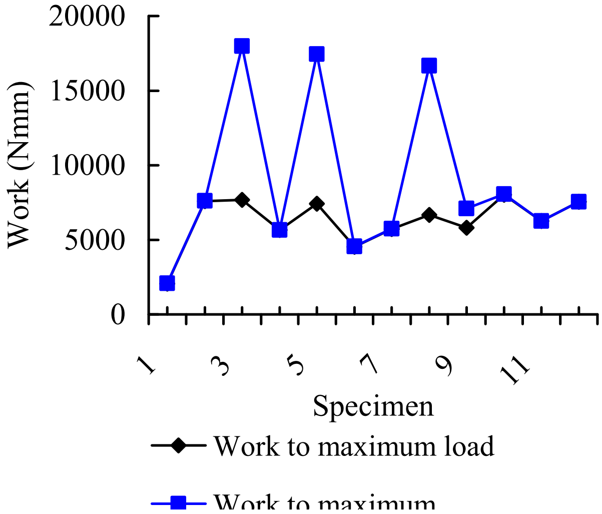

Fig. 8. Distribution of work of twelve sandwich specimens with unequal skins of two different materials

Failure modes of specimens are presented in figs. 9-15.

Fig. 9.

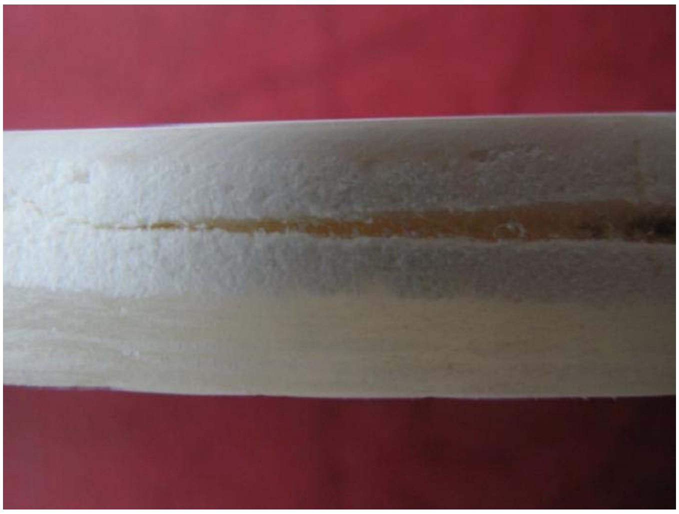

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14

Fig. 15.

7 Conclusions

The sandwich structure with thin nonwoven polyester mat as core presents an excellent bond between skins and core. This has been noticed during the three-point bend tests.

The sandwich structure's flexural rigidity determined experimentally is 12 times grater than the upper skin's one, 57 times grater than the core's one and more than 237 times grater than the lower skin's flexural rigidity (fig. 16). The 30% difference in structure's flexural rigidity determined theoretically and the experimental approach can be a little bit reduced by a better estimation of the upper and lower skin's Poisson ratios.

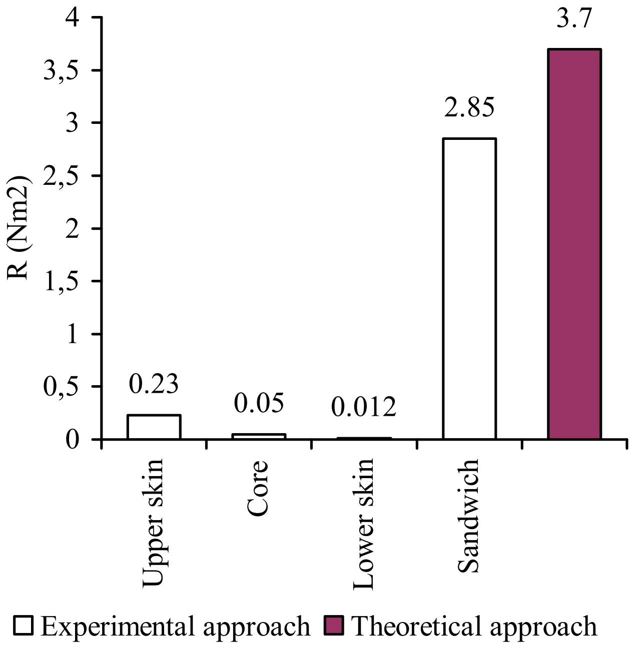

Fig. 16. Sandwich structure's flexural rigidity evaluation

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