CASE STUDY ON STRUCTURAL PERFORMANCE OF NEW TYPES OF LIGHTWEIGHT STRUCTURES MADE OF WOOD AND POLYURETHANE

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ABSTRACT: The paper aims to introduce an innovative wood panel, using various modern materials from the construction domain. The purpose of the experimental study is to highlight the mechanical properties and to show the advantages of such element usable as building panels. Analyses are made both practical and numerical results validating the values obtained. Laboratory tests were conducted on prefabricated panels having the dimensions commonly used in civil engineering.
Tests were conducted with the support of "National Institute of Research - Development in Construction and Construction Economy" INCERC Cluj-Napoca.

KEY WORDS : mechanical properties, composites, laboratory, tests.

1. INTRODUCTION

This paper presents the results of research on bearing capacity of a wood multilayered composite panels for use in houses as walls and slabs. The loads where applied parallel and perpendicular with the faces of the studied panel according to the civil requirements.
This issue is outlined in the global energy problems. The Increasing energy and environmental demand on buildings has led to the development of new research directions on how the house envelopes are made.

Technologies for the opaque building envelope used in passive houses know two trends of development:
a) Increase the level of prefabrication of the building envelope;
b) The usage of wood as a resistance component or as an insulation material.
These specific trends are complemented by a general goal encountered in civil engineering domain, one that attempts to achieve a higher rigidity using a minimum of material.
Based on these considerations we tried to achieve a geometric structure composed of a web of triangles, resembling a crystalline-like structure (see fig. 1).

Figure 1. The composite structure analyzed [5]

2. EXPERIMENTAL

2.1 Materials and specimens

According to the crystal structure mentioned, strips of fiberboard with 3 mm thickness and a height of 10 cm or 15 cm, were made and assembled. The panels faces were made from oriented strand boards (OSB) with different thicknesses. In order to stiffen the panels it was necessary to bond these components with polyurethane adhesives.

According to the desired rigidity were made two different types of panels:

a) Panels with middle layer consisting of simple cell structure;

b) Panels with middle layer consisting of cell structure filled with foam.

a)

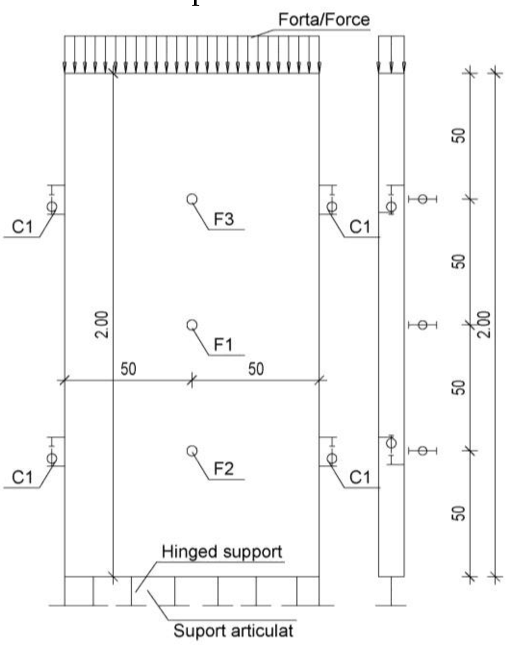
b)

b)

Figure 2. Analyzed composite panels. a) strips of fiberboard in crystal structure bonded with polyurethane adhesives; b) Panels with middle layer consisting of simple cell structure; c) Panels with middle layer consisting of cell structure filled with foam.

2.2 Test methods and equipment used for testing

In order to determine the structural behavior to vertical static load parallel and erpendicular to the faces of the panel there was been made two types of stands. Supports position, measurement and control instrumentation and loads position are represented in figures 3 and 4.



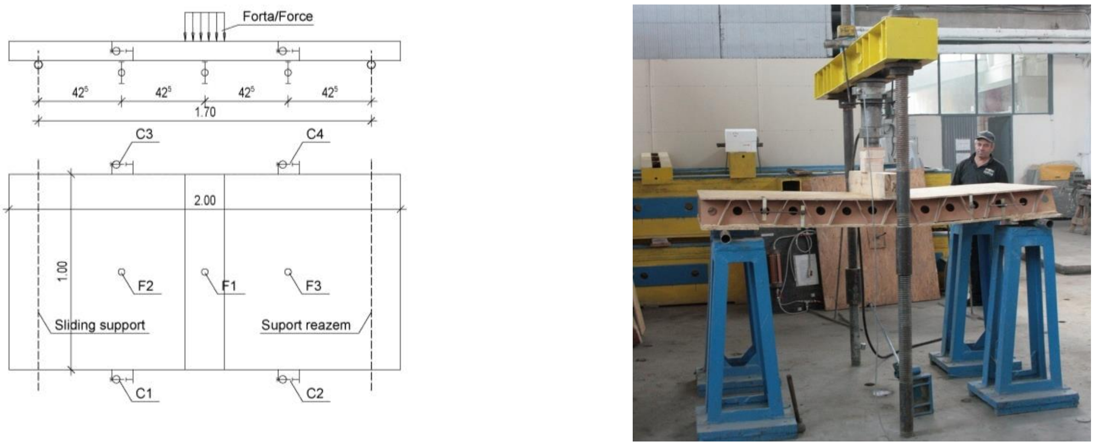
a)

b)

Figure 3. The stand with parallel load to the face of the panel. a) Scheme b) The testing stand

The positions of the measurement instruments were determined by the deformation of the panel. The behavior of the panels was recorded for increments of loads necessary to draw the load-deformation graph for each position of precision dial indicators.

All the information was necessary to calibrate the theoretical model.



a) b)

Figure 4. The stand with parallel load to the face of the panel. a) Scheme b) The testing stand

The measurement and control instrumentation used are: precision dial indicators (denoted F&C), used for measuring deflections, measuring amplifier "hottinger baldwin messtechnik scout 55" coupled with force transducer C6A (see fig. 5). The load was provided with a hydraulic pump.

Figure 5. Measurement and control instrumentation. a) precision dial indicator b) measuring amplifier "Scout 55", c) force transducer C6A

3. THEORETICAL STUDIES

The mathematical model and the numerical analyzes were performed using Solid Works Simulation software. Newton-Raphson method for nonlinear systems was chose for the accuracy and fast convergence. This method analyses elastic behavior, but because of the internal structure, the overall results generate an post elastic response.

According to the experimental model, displacement sensors (see fig. 6) were positioned in strategic locations to verify the panel response to applied loads and to calibrate the model according to the experimental results.

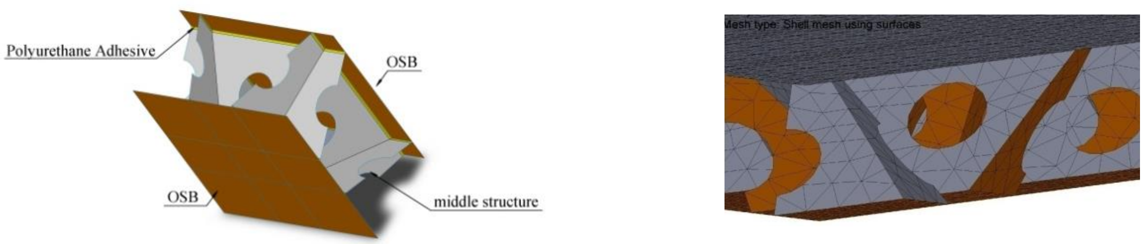


Figure 6. Basic module for building the mathematical model and the generated mesh

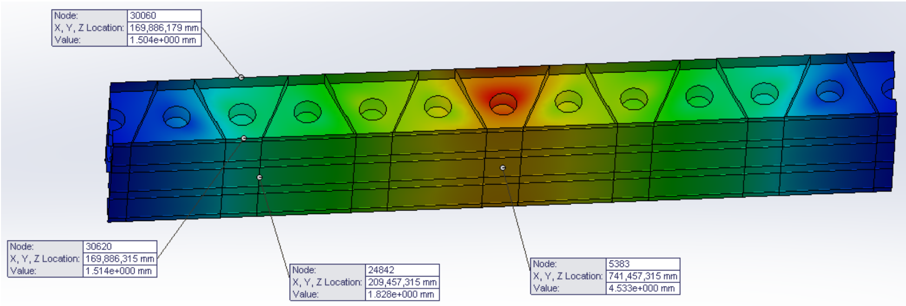


Figure 7. Sensors positions on the numerical model

4. EXPERIMENTAL ANALYSIS RESULTS ON LAMINATED COMPOSITE PANELS

Test purposes were to determine bending and compressive behavior of the panels, because this kind of stresses is related to prefabricated elements used in construction industry. The obtained results prove the hypothesis of rigidity on the three main axes of the structure; thereby it is possible to use this approach on load-bearing panels in civil building.

In experimental case the limit criteria was set by the breaking point were the panel can no longer take loads (see fig. 8), and for the numerical analyses the criteria for determining the breaking limit was when one of the parameters, stress or strain reached the limit state (see fig. 9).

According to the simulation, the bearing capacity of the panels varies depending to the thickness of the faces and the effective thickness of the composite panel.

Figure 8. Strain at the breaking point for perpendicular to the faces of the panels load

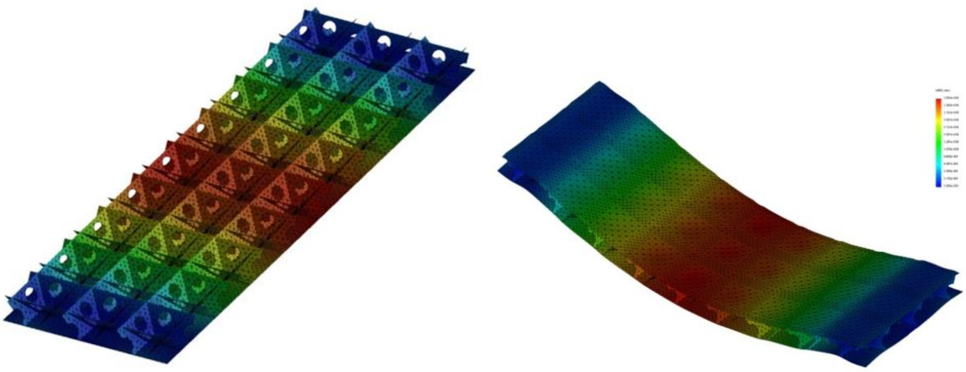


Figure 9. Displacement diagram and the deformed shape of the composite panel loaded with perpendicular to the faces forces

To compensate for the imperfections of the material, according to the experimental measurements, the mathematical model was calibrated.

After the model calibration it can be used afterwards for different kind of checks.

5. RESULTS VALUES FROM THE TESTS

In figure 10 and 11 are plotted the values obtained for different sections of the panels. The names of the probe are presented in tab 1.

- Incerc - experimental values;
- Numeric - theoretical values.

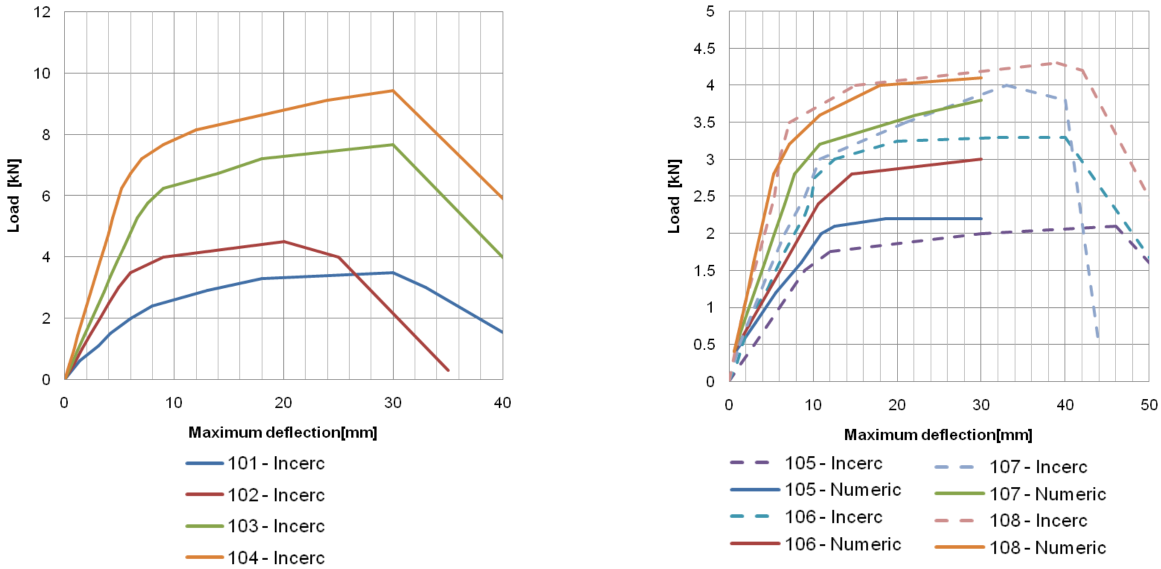


Figure 10. Simply supported panel behavior on static loads applied perpendicular to faces

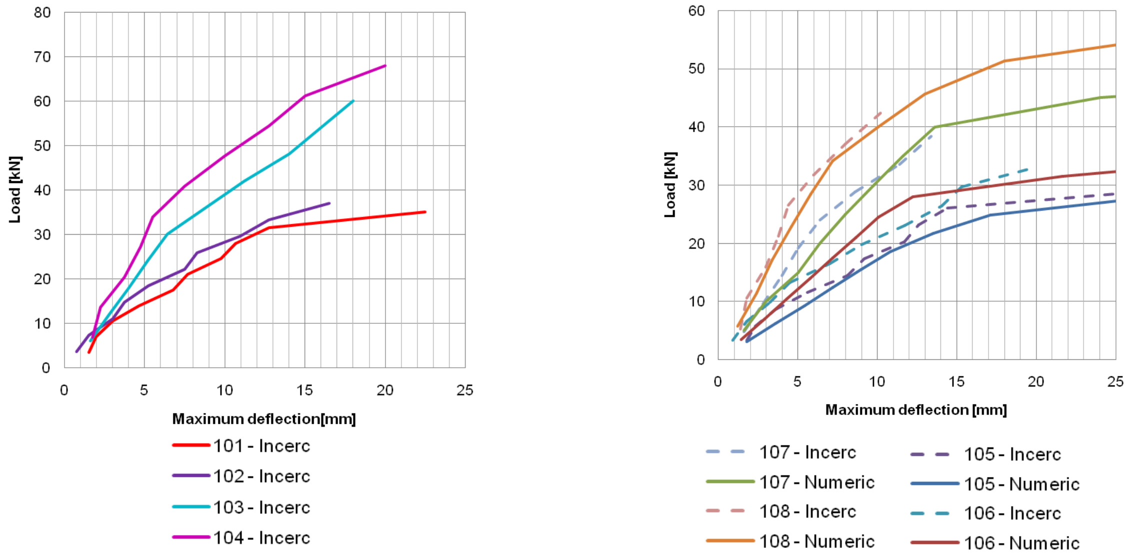


Figure 11. Simply supported panel behavior on static loads applied parallel to faces

Abbreviations and notes for table 1:

* Values extracted for structural insulated panels from "Technical Approvals 06-01/211-2010", made by ICECON S.A Bucharest

• PUR45 - rigid polyurethane foam, polyisocyanate based bicomponent product with a density of 40 - 45 kg/m3;

• OSB3 - moisture resistance oriented strand boards, according to EN13986:2004 norm;

• CEL+PUR30 - 3mm thick fiberboard cellular structure filled with rigid polyurethane foam;

• CEL - 3mm thick fiberboard cellular structure

Table 1. Maximum loads of prefabricated wood-based panels corresponding service limit state (SLS), maximum strain L/250. L = 2800mm, L/250 = 11.2 mm

Panel code	Panel type and components	Panel weight	Uniform distributed load intensity	
			Wall element	Slab element
SIP	Structural Insulated Panel (SIP)* 15mm OSB3 + 90mm PUR45+ 15mm OSB3	39.5 kg/m^2	5000 daN/m*	285 daN/m^2*
Panel 101	10mm OSB3 + 90.5mm CEL+PUR30+ 10mm OSB3	16.32 kg/m^2	1750 daN/m	130 daN/m^2
Panel 102	12mm OSB3 + 90.5mm CEL+PUR30+ 12mm OSB3	18.60 kg/m^2	2000 daN/m	220 daN/m^2
Panel 103	10mm OSB3 + 13.6mm CEL+PUR30+ 10mm OSB3	24.61 kg/m^2	3000 daN/m	300 daN/m^2
Panel 104	12mm OSB3 + 13.6mm CEL+PUR30+ 12mm OSB3	26.99 kg/m^2	3800 daN/m	430 daN/m^2
Panel 105	10mm OSB3 + 90.5mm CEL+ 10mm OSB3	17.42 kg/m^2	1400 daN/m	60 daN/m^2
Panel 106	12mm OSB3 + 90.5mm CEL+ 12mm OSB3	19.44 kg/m^2	1800 daN/m	100 daN/m^2
Panel 107	10mm OSB3 + 13.6mm CEL+ 10mm OSB3	17.05 kg/m^2	2300 daN/m	120 daN/m^2
Panel 108	12mm OSB3 + 13.6mm CEL+ 12mm OSB3	19.32 kg/m^2	3200 daN/m	180 daN/m^2

6. CONCLUSIONS

Thanks to smart design layout of the cellular structure, bearing capacity of the studied composite panel exceeds the performance of structural insulating panel (SIP). Although, for a complete technical approval of such a product, there must be other types of inspections.

The main observations that can be made after performing this experimental study on the composites panels under loads are the following ones:

- For a better compression performance of the composites panels it is necessary that the thickness of the faces to be larger;
- The ductile behavior of the panels is advantageous because it generates a warned breaking.

In the space between the OSB faces can be introduce with injection insulating unconventional materials like cellulose.

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