INTERSECTII
INTERSECTIONS
http://www.intersections.ro

FEM Analysis of a Platform Framing Timber Structure

Ion Florenţa[1], Marian Pruteanu[1] and Ciprian-Ionuț Zub[2]

[1]*Department of Civil and Industrial Engineering, "Gheorghe Asachi" Technical University, Iaşi, Zip code: 700050, Romania*

[2] *Department of Steel Structures and Structural Mechanics, "Politehnica" University, Timişoara, Zip code: 300224, Romania*

Summary

Due to climate changes of the last years, in Europe, there is a tendency of using ecological materials in building constructions. Therefore, timber structures represent a very good solution in reducing the negative environment impacts.

The Platform Framing structural system offers the possibility of constructing new multi-storey buildings. In order to increase the quality of execution and to reduce the time of constructing the building, it can be used prefabricated wood panels as structural walls.

This paper presents a numerical analysis of a multi-storey Platform Framing timber structure by using finite element method. The structure consisting of prefabricated panels is located in Iaşi City and it has 3 levels: Ground floor Level + 2 Levels. The numerical analysis of the structure was done by using the commercial structural program Axis VM 12.

KEYWORDS: timber, platform framing, prefabricated panels, Finite Element Method, Axis VM 12.

1. INTRODUCTION

Climate changes are already happening and their effects becoming more and more obvious. The humanity efforts to reduce them have resulted in a set of principles of sustainable development, which aims to put the society on a trajectory required to maintain a favourable climate for life on Earth. In addition to social and political components of these principles, the environmental component is also very important [1-2].

The latest norms from environmental and construction sector reduced both the amount of energy consumed during operation of the building and the one embedded in them. Therefore, in recent years, timber structures were imposed, the energy embedded in this material being inferior to the one embodied in the materials of classic structures, like concrete, metal or masonry [3]. The structure of the building is cover in various materials to meet the essential performance requirements. To this purpose, the most often are used thermal and acoustic

INTERSECTII
http://www.intersections.ro

insulations made from mineral wool [4], but recently began to use low embedded energy materials as straw bales, cellulose, sheep wool insulation and hemp or flax insulation. Also, it is desired that the buildings to be more economical from the point of view of material consumption and also to have a cost as low as possible [5].

In order to fulfils these requirements, the best solution can be the timber framing structures. This system can be classified in two different structures: Balloon Framing and Platform Framing. The main advantages of this system when comparing with other systems made of reinforced concrete or masonry are the following [6]:

- 30 % cost reduction;
- fast and not season dependent execution;
- reduced weight;
- good seismic behaviour;
- height thermal comfort;
- ecological, with a positive environment impact.

The proposed building for the case study is a Platform Framing system. This system offers the possibility of constructing multi-storey buildings. The recommended maximum height regime for constructions located in seismic areas with peak ground accelerations values greater than 0.15 g is 7.00 m. The height is considered from the ±0.00 level of the building to the cornice (eaves). It can be allowed buildings with regime height greater than 10.00 m, but it is necessary that the structural capacity to be evaluated on 1/1, 1/2 or 1/4 scale models [7].

So, the paper presents the study of the structural behaviour of a multi-storey Platform Framing building, located in Iaşi City (a_g = 0.25 g), having a height regime G + 2 L (8.40 m). The building's layout is 18.60 m by 10.80 m. The analysis is performed on a 3D model, represented in Axis VM 12, with the scale of 1/1.

2. CASE STUDY

2.1. Description of the structural system

The Platform Framing structural system is specific for one-family houses. This structural system consists of structural walls (vertical and horizontal load-bearing elements), bearing walls (carrying only vertical loads), light frames (also carrying only vertical loads) and of rigid floors and roof, which have the role of transmitting the vertical and horizontal loads to the structural walls.

Within this paper a different approach was proposed, because the structure is a multi-family building, it was proposed that all the walls to be structural walls. In order to increase the quality of execution and to considerably decrease the time for erecting the building, prefabricated structural panels were used. The connection of the panels to the foundation is done by using anchors: bolt type anchors for shear connections and hold-down anchors for moment connections. The connection of the panels to the slabs is done by using straps and hold-down anchors [6].

The structure of the prefabricated panel is presented in Figure 1.

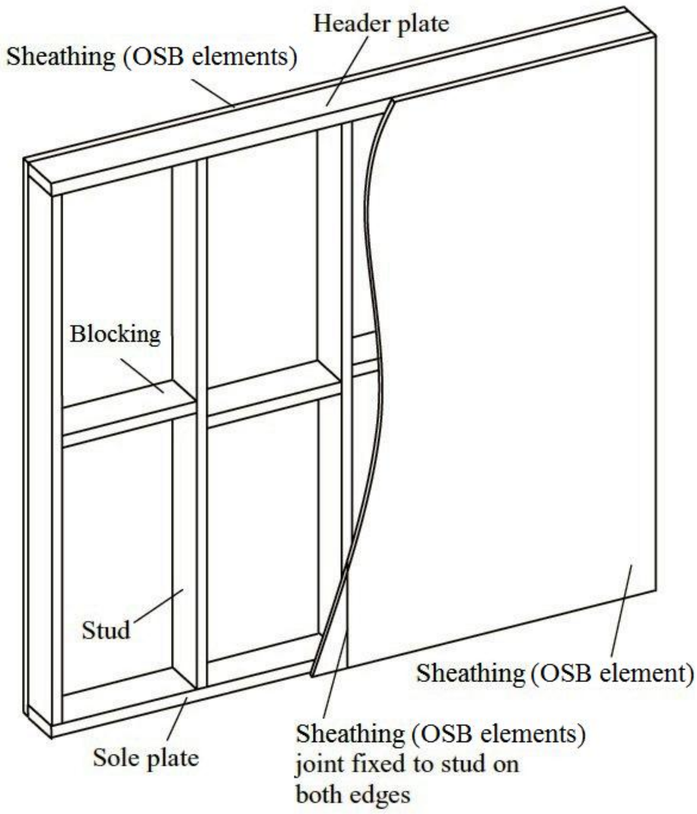

Figure 1. The structure of a prefabricated panel (insulation, breather membrane, etc. not shown) [8]

The studs of the prefabricated panel are placed at 600 mm (between the axes) and are made of fir, timber class C24. The exterior walls consist of 50 x 250 mm studs and they are boarded on the exterior face with 18 mm thick Oriented Strand Boards (OSB) which have a stiffening role. The interior walls consist of 50 x 200 mm studs and are boarded on both faces with 18 mm thick OSB elements. The OSB elements are nailed to the studs and to the blocking of the prefabricated panel.

The framing type slab (Figure 2) consists of timber joists of C24 class with the cross-section of 50 x 250 mm. On top of the slab, sheathings of 22 mm thick OSB elements are provided. The OSB elements are nailed to the joists and to the blocking. This structure of the slab provides a diaphragm effect with respect to the lateral stiffness of the vertical elements.

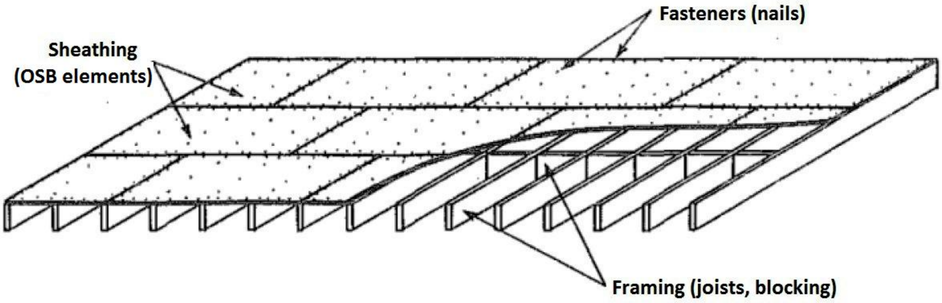

Figure 2. The structure of the framing type slab [9]

The framing type roof is a terrace and it is made by timber joists of C24 class, with the cross-section of 50 x 250 mm, covered with 44 mm thick OSB elements.

For thermal and acoustical isolation, straw bales were used for the exterior walls and the mineral wool is used for the interior walls and for the slabs.

Several hypotheses were used in order to define the structural model for the numerical analysis:

- the studs of the prefabricated panel were modelled using rib finite elements
- the structural OSB elements were modelled with shell elements;
- the connection between the studs and the structural board is rigid connection;
- the connection between the panels and the foundation is a rigid connection;
- the connection between the panels is continuous and assures both vertical and horizontal continuity of the walls;
- the slabs and the roof provide a diaphragm effect.

The loads acting on the structure are computed according to the norms for the specific site location (Iaşi City, Romania). After establishing the hypotheses and the load combinations, the structure will be meshed using a triangular finite element type (Figure 3).

INTERSECTIONS
INTERSECTII
http://www.intersections.ro

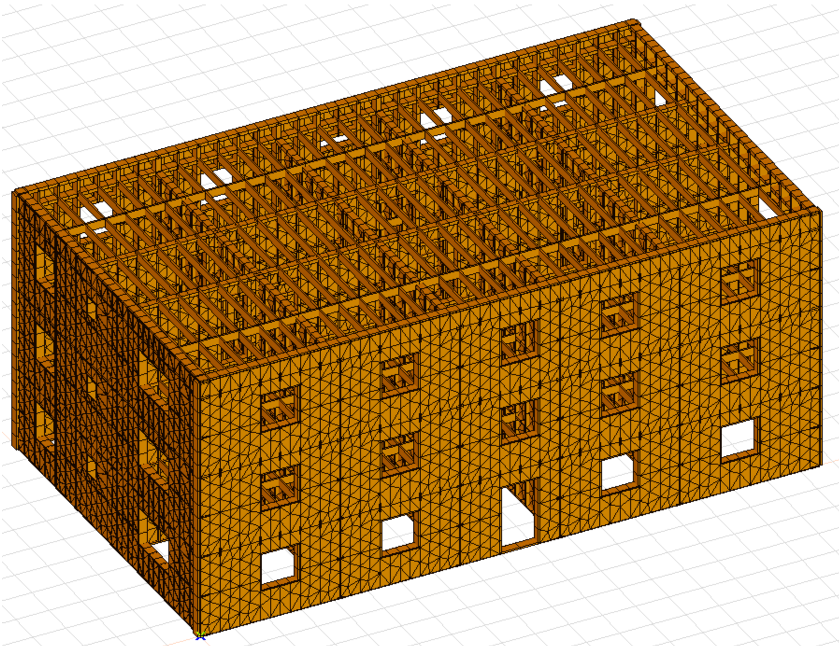

Figure 3. The mesh of the structure with triangular shell

2.2. Analysis results and discussion

From the modal analysis the next results can be observed (Table 1):

Table 1. Modal Analysis Results

Natural modes of vibration	Period [s]	Frequency [Hz]
Mode 1 of vibration	0.178	5.63
Mode 2 of vibration	0.157	6.38
Mode 3 of vibration	0.156	6.40

The first mode of vibration is a translation on X direction, the second mode is a translation on Y direction and the third one is torsion about Z axis.

After running the modal analysis, the seismic action can be computed according to P100-1/2013 for the site location (Iaşi City).

The main results obtained from static linear analysis are presented below. These results were used to design the structure.

ISSN 1582-3024

INTERSECTII
INTERSECTIONS
http://www.intersections.ro

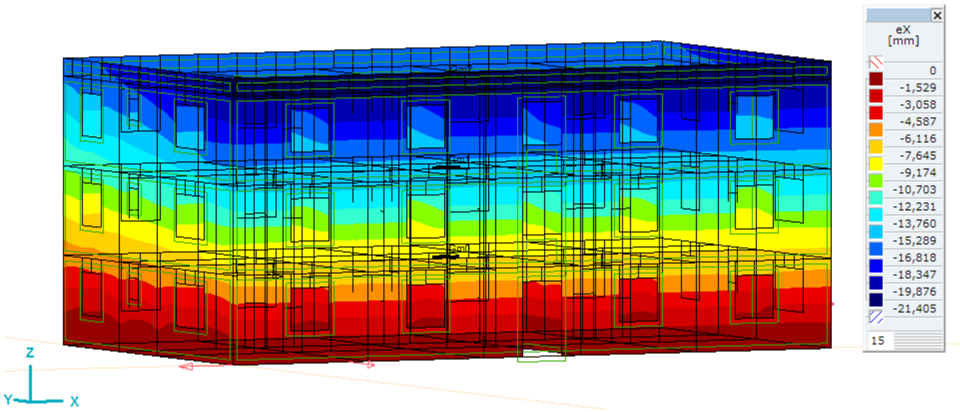

Figure 4. Maximum values of displacements on X direction

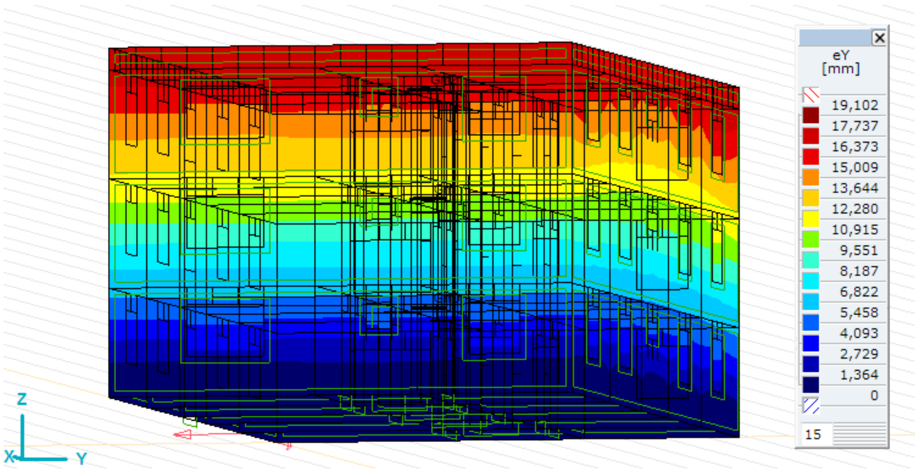

Figure 5. Maximum values of displacements on Y direction

The inter-storey drift check is done according to P100-1/2013, Annex E:

$$d_r^{SLS} = \nu \cdot q \cdot d_{re} < d_{r,a}^{SLS} \tag{1}$$

where: d_r^{SLS} is the inter-storey drift under the seismic action associated with SLS; d_{re} is the inter-storey drift, computed by elastic analysis under seismic design actions; ν is the reduction factor accounting for the reduced recurrence interval of the seismic action associated with the SLS checks (v = 0,5); q is the behaviour

ISSN 1582-3024

factor depending on the type of structure used for computing the seismic design forces $d_{r,a}^{SLS}$ is the admissible inter-storey drift.

Table 2. Inter-storey drift checks, X direction

Storey	d_r^{SLS} [mm]	$d_{r,a}^{SLS}$ [mm]	$d_r^{SLS} < d_{r,a}^{SLS}$ [mm]
Ground	10.4	21	OK
Level 1	10.9	21	OK
Level 2	8.9	21	OK

Table 3. Inter-storey drift checks, Y direction

Storey	d_r^{SLS} [mm]	$d_{r,a}^{SLS}$ [mm]	$d_r^{SLS} < d_{r,a}^{SLS}$ [mm]
Ground	8.9	21	OK
Level 1	9.2	21	OK
Level 2	7.4	21	OK

3. CONCLUSIONS

In this paper, it was numerically analysed the behaviour of a Platform Framing timber structure consisting of prefabricated panels, located in Iaşi City, having a regime height greater than the maximum recommended one.

The displacement results obtained from the numerical FEM analysis were checked according to P100-1/2013 [7]. It was concluded that the maximum value of the inter-storey drift is smaller than the admissible one.

References

1. MacKay, D.J.C., *Sustainable Energy — without the hot air*, UIT Cambridge Ltd., United Kingdom, 2009.
2. Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M., *Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Climate Change 2013: The Physical Science Basis, IPCC, Cambridge University Press, United Kingdom and U.S.A., 2013.
3. Dodoo, A., Gustavsson, L., Sathre, R., *Lifecycle primary energy analysis of low-energy timber buildingsystems for multi-storey residential buildings*, Energy and Buildings, Vol. 81, Pp. 84–97, 2014.
4. Kubba, S., *Green Building Materials and Products*, Handbook of Green Building Design and Construction, Chapter 6, Pp. 227-311, 2012.

ISSN 1582-3024

INTERSECTII
INTERSECTIONS
http://www.intersections.ro

5. Mattila, T., Grönroos, J., Judl, J., Korhonen, M.R., *Is biochar or straw-bale construction a better carbon storage from a life cycle perspective?*, Process Safety and Environmental Protection, Vol. 90, Pp. 452–458, 2012.
6. Breyer, D.E., Fridley, K.J., Cobeen, K.E., Pollock, D.G., *Design of Wood Structures – ASD/LRFD*, Sixth Edition, McGraw-Hill, U.S.A., 2007.
7. P 100-1/2013, *Cod de proiectare seismică, Partea I: Prevederi de proiectare pentru clădiri,* Monitorul official al României, Bucureşti, 2013. (in Romanian)
8. Porteous, J., Kermani, A., *Structural Timber Design to Eurocode 5,* Blackwell Publishing Ltd., United Kingdom, 2007.
9. Hoekstra, T., *Multi-storey Timber-Frame Building - modelling the racking stiffness of timber-frame shear-walls,* MSc Thesis, Delft University of Technology, Munchen, 2012.

ISSN 1582-3024