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STRUCTURAL BEHAVIOUR OF MASONRY WALLS MADE WITH ECOLOGICAL BRICKS

BY

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Abstract. The aim of this research is to obtain an environment friendly construction product as a brick unit based on wooden waste incorporated in concrete used for structural elements in case of low-rise building.

This paper presents the structural behaviour of masonry walls made from hollow blocks with recycled wood chips.

The influence of the percentage of wood chips variation, as well as of the length of the structural wall, on the load-bearing capacity of the masonry made with blocks that include wooden waste was analysed.

The study highlights that the variation, from 4 to 6 m, of the wall length significantly influences the load-bearing capacity of the analysed masonry, while the variation of the percentage of wooden waste as wood chips relative to the volume of aggregates, 25% and 50%, causes small changes in achieving the bending or shear capacity of the masonry made with ecological blocks.

Keywords: ecological block; wooden waste; environment friendly; light aggregate; bearing capacity.

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1. Introduction

The increasing demand for construction materials and the expansion of residue from various industries require waste recycling strategies in order to obtain new building products (Ahmed *et al.*, 2018). Wood recycled and reused as a component of masonry blocks for achieving engineered products with performant qualities is a way of construction waste recycling as well as to reduce of the environmental effects of pollution.

The recent research highlights the main applications for embedding of wooden waste in concrete as a light aggregate for the purpose of sustainable building design (Aigbomian and Fan, 2014).

Construction products as a concrete brick or ecological brick, made of wooden waste incorporated in concrete as partial replacement of different components (Fapohunda *et al.*, 2018; Chowdhury *et al.*, 2015; Thandavamoorthy 2016; Sasah and Kankam, 2017; Ganga *et al*., 2014), could be realised in different shapes. The influence of the percentage variation or sizes of wooden waste as light aggregate is also noticeable in the new materials characteristics as convenient mechanical, good thermal properties and low density.

Masonry structures are used, commonly, for housing or low-rise residential building. Usually, masonry units have to fulfil thermal requirements, partitioning and load bearing. At these buildings, with reduced loading states comparative with multi-storey buildings, the strength requirements for structural materials are not so high. Thus, it can be used blocks made with light aggregate generated by industrial waste embedded in concrete or cement without affecting the structural strength and stability.

In case of residential low-rise buildings such as single-family homes, masonry can have both a closing and partitioning role, as well as a load-bearing one. Therefore, the total cost of the structural system with load-bearing masonry walls is lower than that of a supplementary reinforced concrete frames structure. On the other hand, a masonry structure imposes a fixed functional with walls that cannot be moved or removed in the future. From the architectural point of view, masonry structure implies a limitation in the further functionality changes. This limitation is inappropriate on office buildings (when the partitioning walls are frequently changed according to business requirements), but it is easily accepted on residential buildings.

The using of masonry with hollow blocks made with different types of industrial wastes is more efficient than conventional units, due to their performances and skills (Zhou *et al.*, 2019). In the bricks' core, concrete columns can be embedded with various types of reinforcement, in order to increase the bearing capacity of the structure.

In this study, a structural behaviour of masonry made with hollow core ecological bricks has been analysed, in order to point out the advantages of this

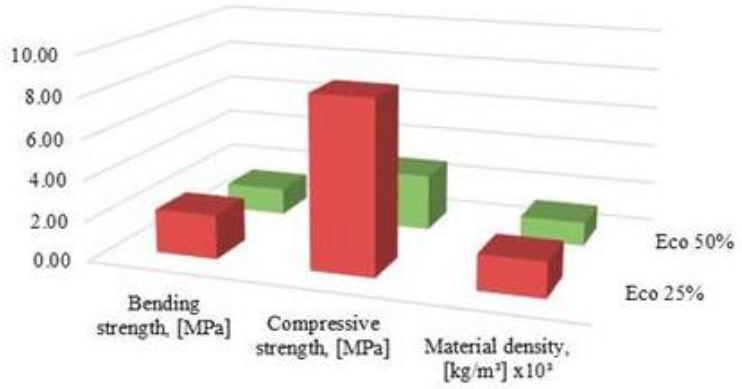
solution in comparison with a conventional masonry structure. The study includes bricks with two different percentages of wood chips incorporated in concrete: 25% and 50%.

In order to provide a suitable architectural plan, the dimension of the walls is imposed according with the functional demands. Hence, the masonry structure consists of walls with various lengths. In order to highlight the influence of the size on the bearing capacity, three different lengths (4, 5 and 6 meters) where considered in the study.

2. Characteristics of Materials with Waste Wood Chips Incorporated in Concrete

The strengths and density of the brick made with incorporated wooden waste were established by an experimental programme at Faculty of Civil Engineering and Building Services Iasi (Fig. 1). The study involves two proposed recipes based on the initial C20/25 concrete grade.

The contents for those two mixes are based on the 25% and 50% wood chips reported to the total volume of aggregate, included in the mixture with cement and water (Enţuc *et al*., 2019) and are noted with Eco 25% and Eco 50%.



	Bending strength, [MPa]	Compressive strength, [MPa]	Material density, [kg/m³] x10³
Eco 25%	2.17	8.50	1.74
Eco 50%	1.34	2.81	1.18

Fig. 1 – The strengths and densities of the ecological bricks with incorporated wooden waste in different percentage.

The results presented in Fig. 1 are important for establishing the bearing capacity of the structural walls.

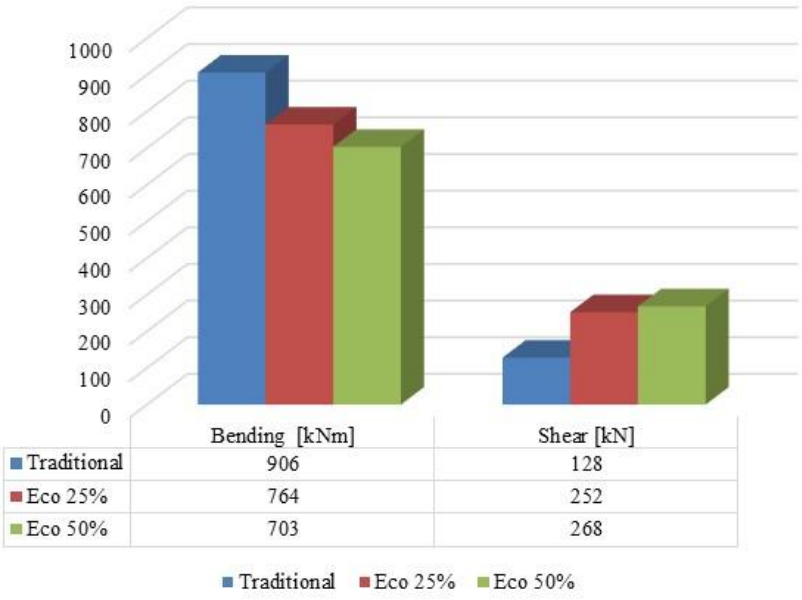
3. Behaviour of Masonry Walls with Incorporated Wooden Waste

In order to determine the bearing capacity, the hight of the structural elements was considered 2.8 m, a common value for unifamilial residential buildings. Also, for the evaluation of loads, the thickness of 13 cm of the reinforced concrete floor, a framework type roof with sheet metal cover, 1.5 kPa live loads related to the residential buildings and 2.5 kPa snow load for an eastern Romanian geographical location were taken into consideration.

The analytical evaluation is based on the Romanian standard for the design of masonry structures (CR6/2013), with respect of the already determined strength of the ecological brick (Fig. 1).

The hollows of the ecological bricks are filled with reinforced concrete which are essential in the evaluation process and therefore the results show a convenient bending and shear capacity for the studied walls.

In Fig. 2 are shown the values for bearing and shear capacity of a masonry wall with 4 m length regarding to percentages of wooden waste embedded in concrete, 764 kNm and 703 kNm. In this case, the bending capacity of the traditional masonry, 906 kNm, is bigger than both alternatives with wood chips while the shear capacity is lower.

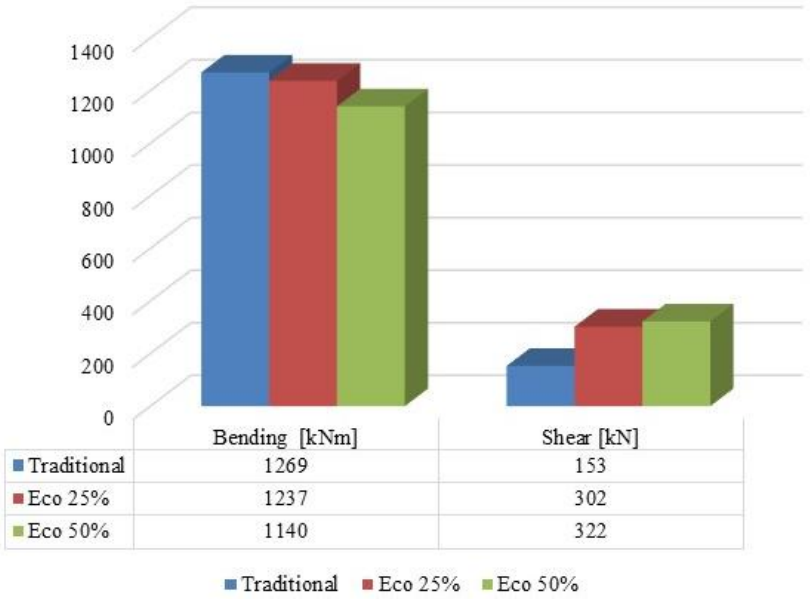


	Bending [kNm]	Shear [kN]
Traditional	906	128
Eco 25%	764	252
Eco 50%	703	268

Fig. 2 – Bearing capacity of 4 m structural wall for different types of bricks.

The values of bearing capacity of a 5 m masonry wall for the three cases (traditional, eco 25% and 50%) are illustrated in Fig. 3. The bending capacity of

walls with ecological bricks are lower, with 1237 kNm and 1140 kNm values than 1269 kNm in case of traditional masonry. Nevertheless, the differences between the peaks are smaller than the 4 m wall case. The shear capacity of the ecological masonries, 302 kN respectively 322 kN are bigger than the traditional one, 153kN.



	Bending [kNm]	Shear [kN]
Traditional	1269	153
Eco 25%	1237	302
Eco 50%	1140	322

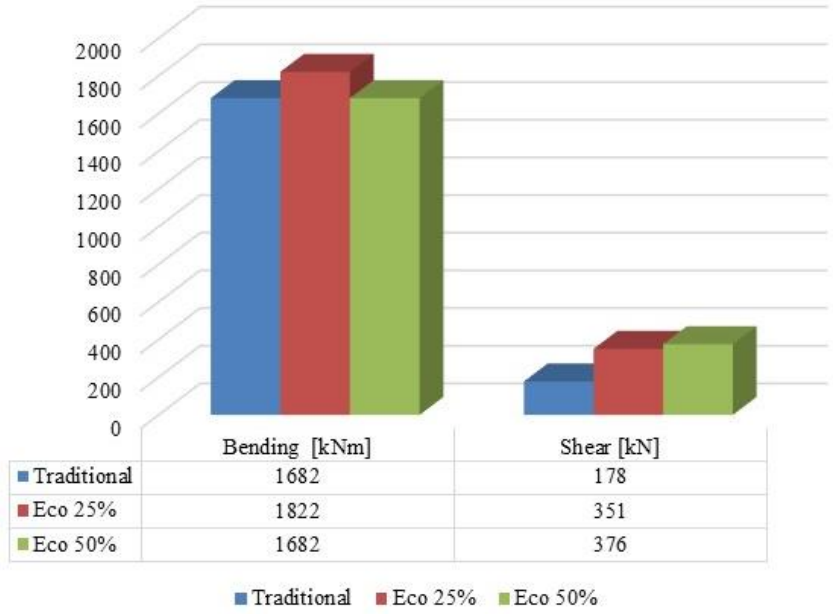
Fig. 3 – Bearing capacity of 5 m structural wall for different types of bricks.

For the 6 m length, Fig. 4 presents an increase of the Eco 25% bending capacity value, 1822 kNm, comparative with the traditional one, 1682 kNm and higher values for Eco 25% and Eco 50% shear capacity, 351 kN and 376 kN related to the regular masonry with 178 kN value.

Thus, the increasing of the bearing capacity according to walls length is related to uniform distribution of reinforced concrete in the analysed masonry walls (Figs. 5, 6). In Fig. 5 is illustrated percentage change of the bending capacity related to length of the wall and the content of wood chips in comparison with traditional masonry.

The masonry walls made of ecological bricks present a weaker behaviour in bending, and the difference is more noticeable in case of walls with short length. On the other hand, for lengths bigger than 6 m, the proposed eco material provides better results than the traditional solution.

The differences appear due to different position of the reinforcement. In traditional solution, the reinforcements are provided at the edges of the wall while in the new eco bricks, the reinforcements were uniformly distributed on the entire length of the wall.



	Bending [kNm]	Shear [kN]
Traditional	1682	178
Eco 25%	1822	351
Eco 50%	1682	376

Fig. 4 – Bearing capacity of 6 m structural wall for different types of bricks.

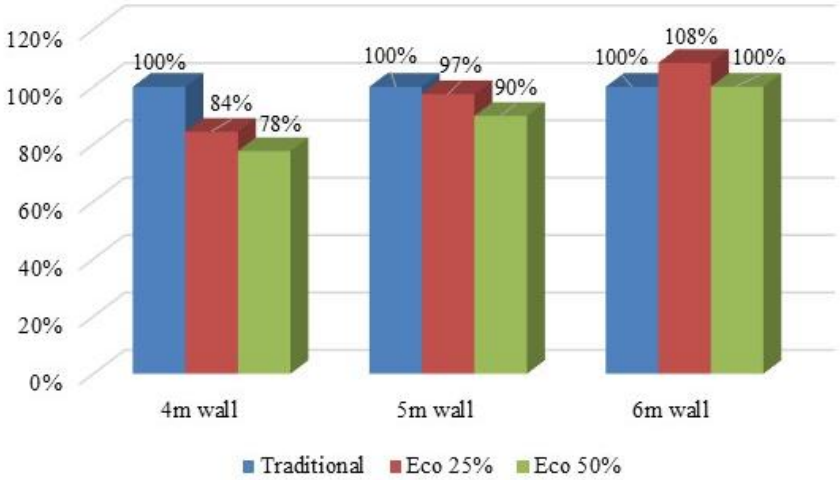


Fig. 5 – Variation of bending capacity due to wall's length and percentage of wooden waste.

Additionally, it has been noticed a significant rise, up to two times, of the shear strength for the walls made with ecological bricks due to the uniformly distribution of the longitudinal steel bars comparative to conventional masonry for all analysed cases (Fig. 6).

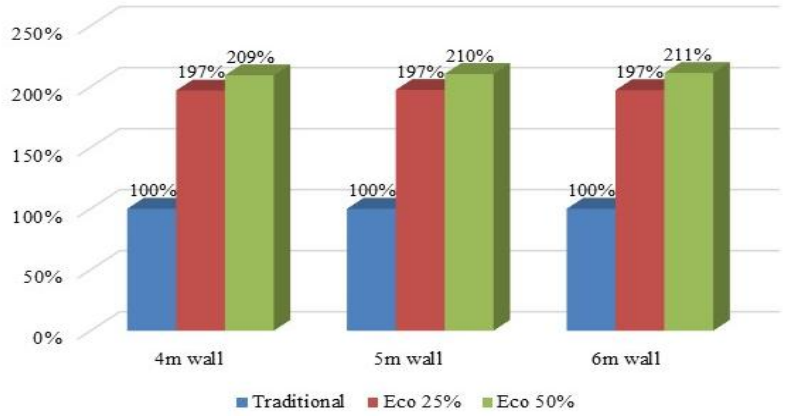


Fig. 6 – Variation of shear capacity due to wall's length and percentage of wooden waste.

Thus, the different distribution of the reinforcement at the ecological masonry leads to a decrease of the bending capacity, while the shear capacity is higher due to the more uniform positioning of the reinforcement, along the entire length of the wall, not only at wall intersections.

3. Conclusions

The ecological brick consists in an adequate solution for individual houses and structures with small high and loads. The behaviour of structural walls made of ecological brick with incorporated wood waste is satisfactory and similar with traditional solution.

The biggest difference appears in bending where eco-materials provide a smaller bearing capacity. To overcome this inconvenience, the length of the wall has to be increased in order to obtain better results. Shear behaviour was two times more favourable compared with traditional solutions, mainly due to presence of the reinforced concrete in the core of the wall.

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REFERENCES

Ahmed W., Khushnood R.A, Memon S.A., Ahmad S., Baloch W.L., Usman M., *Effective Use of Sawdust for the Production of Eco-Friendly and Thermal-Energy Efficient Normal Weight and Lightweight Concretes with Tailored Fracture Properties*, Journal of Cleaner Production, **184**, 1016-1027 (2018).

Aigbomian E.P., Fan M., *Development of Wood-Crete from Treated Wood*, Construction and Building Materials, **52**, 353-360 (2014).

Chowdhury S., Mishra M., Suganya O., *The Incorporation of Wood Waste Ash as a Partial Cement Replacement Material for Making Structural Grade Concrete: An Overview*, Ain Shams Engineering Journal, **6**, 429-437 (2015).

Enţuc I.S., Isopescu D.N., Bagdasar L.C., Oprişan G., Zapodeanu I., Maxineasa S.G., *Performances of the Concrete Masonry with Recycled Wood Chips (II)*, Bul. Inst. Polit. Iaşi, s. Construction. Architecture, **65 (69)**, *1*, 9-16 (2019).

Fapohunda C., Akinbile B., Oyelade A, *A Review of the Properties, Structural Characteristics and Application Potentials of Concrete Containing Wood Waste as Partial Replacement of one of its Constituents Material*, YBL Journal of Built Environment, **6**, *1* (2018).

Ganga G., Nsongo T., Elenga H., Mabiala B., Tatsiete T.T., Nzonzolo, *Effect of Incorporation of Chips and Wood Dust Mahogany on Mechanical and Acoustic Behavior of Brick Clay*, Journal of Building Construction and Planning Research, **2**, 198-208 (2014), http://dx.doi.org/10.4236/jbcpr.2014.23018.

Sasah J., Kankam C.K., *Study of Brick Mortar Using Sawdust as Partial Replacement for Sand*, Journal of Civil Engineering and Construction Technology, **8**, *6*, 59-66, July 2017 (2017), DOI: 10.5897/JCECT2017.0450.

Thandavamoorthy T.S., *Wood Waste as Coarse Aggregate in the Production of Concrete*, European Journal of Environmental and Civil Engineering, **20**, *2*, 125-141 (2016), DOI: 10.1080/19648189.2015.1016631.

Zhou Xiaojie, Du Jingeng, Peng Quanmin, Chen Peiqi, *Hollow Block Masonry Wall Reinforced by Built-In Structural Configuration: Seismic Behavior Analysis*, Soil Dynamics and Earthquake Engineering, **126**, November 2019 (2019).

*** CR 6 – 2013, *Cod de proiectare pentru structuri din zidarie*.

COMPORTAREA STRUCTURILOR DIN ZIDĂRIE REALIZATE CU BLOCURI ECOLOGICE

(Rezumat)

Scopul acestui studiu este de a obține un produs de construcții prietenos cu mediul prin înglobarea deșeurilor lemnoase în beton, produs ce poate fi utilizat la realizarea elementelor structurale pentru clădiri cu număr redus de niveluri.

Lucrarea prezintă comportarea structurală a zidăriilor realizate din blocuri prefabricate cu goluri, ce conțin așchii din lemn provenite din reciclarea deșeurilor lemnoase. Astfel, s-a analizat influența variației conținutului de așchii, precum și a lungimii peretelui asupra capacității portante a zidăriilor realizate cu blocuri ce înglobează așchii din lemn. Studiul evidențiază faptul că variația lungimii pereților din zidărie este importantă în atingerea capacității portante a zidăriilor analizate, în timp ce variația procentului de așchii lemnoase raportat la volumul de agregate, 25% și 50%, nu influențează semnificativ capacitatea portantă la încovoiere sau forfecare a zidăriilor realizate cu blocuri cu agregate ușoare din așchii din lemn.