UNIVERSITY "UNION - NIKOLA TESLA"

Nikola Tesla

# THE FIRST INTERNATIONAL CONFERENCE ON SUSTAINABLE ENVIRONMENT AND TECHNOLOGIES

# PROCEEDINGS


24-25 SEPTEMBER 2021
CARA DUŠANA 62-64, BELGRADE, SERBIA

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### LECTURES

# INFLUENCE OF HEMP PARTICLE SIZE AND MASS RATIO OF COMPONENTS ON MECHANICAL PROPERTIES OF HEMP BLOCKS

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## Abstract

The aim of the present study is to investigate the performances of hemp block made of hemp shives and CaO binder (lime). In order to improve the performances of cono block, a selection of particle size from 1 mm to 40 mm of hemp shiv was made. The optimization of the mass ratios of the components was also done. The results show that there is a positive effect of reducing the dimensions of the hemp shiv particles on the mechanical properties of the formed cono block. Also, there is a significant influence of the mass ratio of the components on the mechanical properties of the obtained cono blocks.

**Keywords:** hemp shive, hemp block, lime, CaO, mechanical properties

## INTRODUCTION

One of the biggest concerns of building construction in the context of sustainable development, is the choice of environmentally friendly materials. In fact, it has some effects on the depletion of natural resources, energy consumption, pollution emissions, etc.... The use of different fibres, woods and byproducts issued from plants have been investigated by numerous studies in building materials. Plant co-products in general, and hemp shives in particular, have been used to fabricate new materials, which provide good thermal insulation, limited impact on the environment and a low cost. In the process of hemp fiber extraction as a co-product hemp shives are produced from hemp stems, in form of ligneous particles. Hemp concrete (mix of hemp shives and CaO or other mineral binder) is a relatively new material that has been increasingly studied (Samri 2008). There is a need for some improvements to allow the large scale development of these kinds of materials. In fact, due to the high water absorption rate of hemp shive, hemp blocks requires an excessive amount of water, which leads to a very long drying time, and decrease in mechanical strength. Pretreatment of the hemp shiv could be a solution to reduce its water absorption rate. Finally, with regard to binder, hemp concrete using CaO has been successfully studied by several authors (Nguyen, 2010). The mechanical and thermal properties of hemp concrete using this binder are comparable to those found in the literatures (Arnaud, 2012). In order to predict the mechanical properties of hemp blocks, a cooperative project with industrial partners was studied, and experimental tests and numerical studies were carried out. The main purpose of this article is to relate the influence of hemp particle size and mass ratio of components on mechanical properties of hemp blocks.

## MATERIAL AND METHODS

### Binder

In this study, a commercial binder CaO, was used. Chemical composition of used binders are presented in Table 1.

*Table 1. Chemical composition of binder*

| CaO | | | | | | | |
|---|---|---|---|---|---|---|---|
| Components | | | | | | | |
| | CaO | MgO | $Fe_2O_3$ | $SiO_2$ | $Al_2O_3$ | $CaCO_3$ | Impurities |
| Content by weight (%) | 94.5 | 0.4 | 0.1 | 0.13 | 0.87 | 3.8 | 1.2 |

The structural properties of the used calcium oxide were determined by XRD technique. The results of the structural properties of the used calcium oxide (CaO) adhesive / binder are presented in Figure 1.

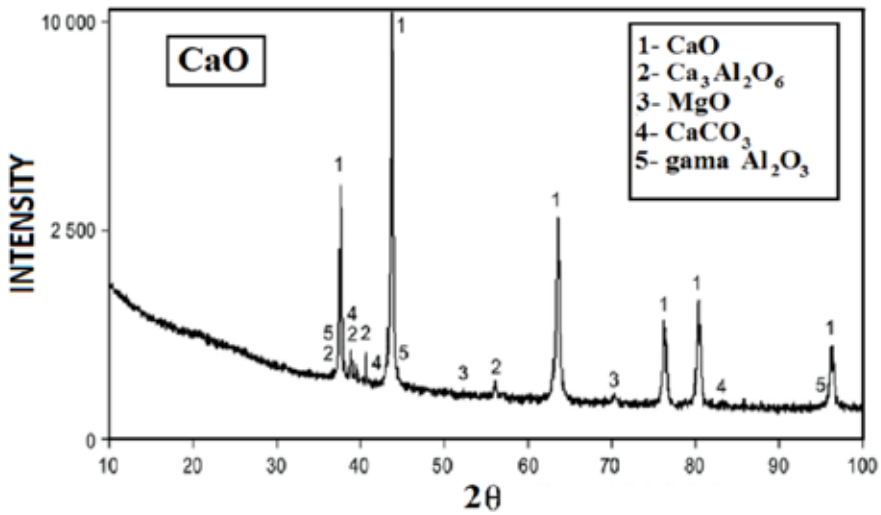


*Figure 1. The XRD of the used calcium oxide CaO*

As can be seen in Figure 1, the XRD results confirm the presence of crystalline phases of all components found in the chemical composition of the binder used. It can also be noticed that this is a material with a high degree of crystallinity based on the intensity of the obtained peaks and their sharpness.

## Plant aggregates

The plant aggregate used in this study was hemp shiv, the ligneous particles extracted from hemp stems as a co-product of the process of hemp fiber extraction. Hemp shiv is obtained through an industrial defibration process by mechanical breaking, after which particles are dusted and calibrated. Table 2. shows the results of testing the chemical composition of the hemp used to form the cono block.

*Table 2. Chemical composition of hemp*

| | Hemp | | | | | | |
|---|---|---|---|---|---|---|---|
| | Chemical composition | | | | | | |
| | Celulose | Hemicelulose | Lignin | Ash | Waxes | Proteins | Pectin |
| Content by weight (%) | 48 | 12 | 28 | 2 | 1 | 3 | 6 |

Particle size distribution of the used plant aggregate (hemp shiv) was examined by vibrating shaker with sieves of different pore dimensions, and also with digital scanning software. The results of particle size distribution are presented in figure 2.

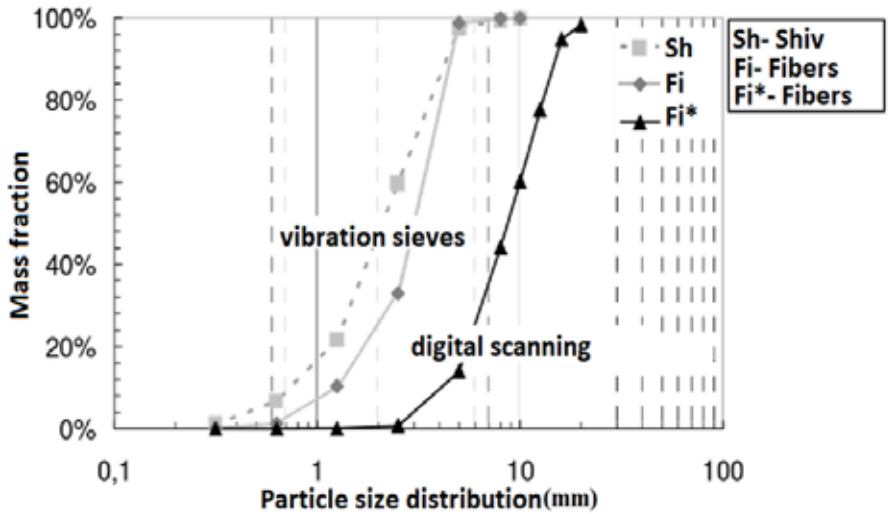


*Figure 2. Particle size distribution of used hemp*

As can be seen from Figure 2. less than 7% of the particles have a dimension below 1mm, 90% of the particles are in dimensions from 1mm to 10mm, and 3% of the particles have a dimension larger than 10mm.

**Composites**

First of all, the selection of the granulate fraction with particles from 1 mm to 40 mm was performed based on the test of the compressive strength of the cylindrical block formed by the hemp shiv (results are not presented in this work). It was concluded that there is a positive effect of reducing the dimensions of the hemp shiv particles on the mechanical properties of the formed cono block. Three mixing ratios of industrial hemp (hemp shiv), CaO (binder) and water were defined in the function of forming a hemp block with excellent performance, and also in order to determine the influence of mass ratios of components on the mechanical properties of the formed hemp blocks. Table 3. shows the mass ratio of the components at which the cono blocks were formed.

*Table 3. Mass ratio of the components used for composite material*

| | Mass ratio of components of cono block | Low binder content (A) | Medium binder content (B) | High binder content (C) |
|---|---|---|---|---|
| 1 | Binder to hemp (CaO / hemp shiv) | 1.0 | 2.0 | 3.0 |
| 2 | Initial density (kg/m$^3$) | 635 | 839 | 913 |
| 3 | Water to binder (Water / CaO) | 0.55 | 0.85 | 0.95 |

**Compressive test**

The compressive tests were realized on the cylindrical samples at 14 and 28 days of age. The device used was the HOUNSFIELD H50KS machine (load cell capacity: 50 kN) with a constant displacement rate of 5 mm/minute.

## RESULTS AND DISCUSSION

Based on the selection of the fraction fraction in terms of particle size in the range from 1mm to 40mm and previously defined mixing ratios of cono block components, three different cono blocks with different binder proportions were formed (Low binder content (A), Medium binder content) (B) and high binder content (C)), and they are tested in terms of mechanical properties, ie. the following properties: strength, elasticity, toughness and hardness. Table 4 shows the

results of compaction and bending tests of formed cono blocks, according to the mass ratio of weights and binders as well as in the function of block aging.

*Table 4. Results of compaction and bending tests of formed cono blocks*

| Low binder content (A) | Bending strength (range) (N/mm$^2$) | Compression force (range) (N/mm$^2$) | Bending / Compression ratio |
|---|---|---|---|
| 14 Days | 2.6 (2.4 – 2.7) | 5.1 (4.8 – 5.6) | 1.96 |
| 28 Days | 3.6 (3.4 – 3.9) | 9.4 (8.9 – 10.1) | 2.61 |
| Medium binder content (B) | | | |
| 14 Days | 5.3 (5.2 – 5.5) | 25.1 (24.6 – 25.8) | 4.73 |
| 28 Days | 7.3 (7.0 – 7.6) | 31.1 (29.6 – 32.8) | 4.26 |
| High binder content (C) | | | |
| 14 Days | 3.7 (3.5 – 3.8) | 11.8 (11.5 – 12.2) | 3.18 |
| 28 Days | 4.6 (4.5 – 4.8) | 14.9 (13.8 – 15.3) | 3.23 |

Based on the results shown in Table 4, and as it was also found in literature (Woolley, 2008), it can be concluded that the proportion of binder in the cono block is of great importance for the mechanical properties of the formed cono blocks. According to the test of resistance to compression and bending, it can be noticed that the ratio of binder to hemp shiv (CaO / hemp shiv) of 2.0 with medium binder content (B) is significantly better than the ratio with low and high binder content, in terms of mechanical properties of the obtained cono block. The trend of hardening of the obtained cono blocks as a function of aging can also be noticed, which is in accordance with literature findings (Jonaitienė et al., 2016).

## CONCLUSION

In terms of environmental acceptability when using industrial hemp weights to form kono blocks-ie composite material, the conclusion is that the material is completely Eco-friendly due to the unknown content of pollutants in the sample. The mechanical and physical properties of the obtained composite

materials largely depend on the mutual relations of the mass fraction of hemp shiv and CaO. Based on the measurements, it was concluded that the best ratio is 2: 1-binder to hemp shiv.

The mechanical and physical properties are influenced by the granulate fraction, ie. the size of the hemp shiv particles that enter the formation of cono blocks. It was shown on the basis of measurements that the most suitable fractions of granules are 1-40 mm. According to our assumptions and literature, there is an additional possibility of improving the cono blocks, which would be based on the introduction of various additional components such as pozzolan, $Al_2O_3$, MgO, cellulose acetate etc., which would further improve all characteristics of the cono block.

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