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### THE USE OF FIBROUS PLANTS IN THE PRODUCTION OF BUILDING MATERIALS

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Concrete development has gone so far since the revolution of human kind. Climate change, energy conservation, and life cycle examination problems are majors that have accorded to the quick augmentation of plant-based materials for buildings, which can be entitled as environmental and eco friendly, enduring and efficient multidisciplinary materials. Recently, several approaches are in action in order to develop concrete materials that are environmentally friendly. The aim of this work is to estimate the suitability of Hemp, Nettle, *Artemisia vulgaris* and *Sida hermaphrodite* plants for production of building materials. The tasks of this research are to calculate density, compressive and bending strength and insulation of the concrete with Hemp, Nettle, and *Artemisia vulgaris* and *Sida hermaphrodite* fibres. The main objective of this research is to check the possibility of replacing the concrete that has been in use till date now with the major focus on decreasing the emission of the carbon dioxide and developing environmental friendly concrete for future. The results of the research carve the path for further research in future. *Artemisia vulgaris* concrete is strongest but not enough for structural material. Further research on these plants is highly essential as they can be the base for the replacement of cement concrete and making world a better place by developing the eco-friendly concrete.

**Keywords:** building materials, hemp plants, nettle fibres, *Sida hermaphrodite*, *Artemisia vulgaris*, concrete, compressive strength, bending strength, density

#### INTRODUCTION

The awareness of the environmental impact of building has guide to a focus on alternative materials that are environmentally friendly, creating a circumstances in which concrete made from Hemp, Nettle, *Artemisia vulgaris* and *Sida hermaphrodite* has significant properties and can be proved valuable assets for development of ecological and environmental friendly building components. As compared to the existing Portland cement in use in traditional building, the concrete made of plant fibres have greater energy balance, emits less amount of CO<sub>2</sub> and other harmful pollutants which fulfilled energy produced demand stated by OECD i.e. 25-40% (Boutin et al., 2006). Concrete and building industries produce the third highest amount of CO<sub>2</sub> that emits to atmosphere. The plant shives used in the production of plant concrete have low density and high porosity. The combination of these plant shives with binder creates a building material that has different properties than the conventional concrete in use. The plant concrete developed in this way has a lower density and lower thermal conductivity but have low compressive strength of less than 2 MPa (Butschi, 2004). The materials in current state with the low compressive strength and low Young's modulus cannot be used as a prompt replacement of conventional concrete because of its low load bearing capacity.

Currently, Hemp concrete and nettle blocks are mainly used as layers in the conventional load bearing wall to provide thermal and acoustic insulation. Depending on its composition, it can also be used in floors and roofs (Cerezo, 2005). Moreover, most of the research that has been conducted in this field is focused on thermal and hydrothermal properties than strength of the hemp, nettle and other environmental friendly plant. In the pursue of the main goals of sustainable with a aim of development of cities and communities that are sustainable to the environment by using affordable materials, many studies were made since last 5-10 years to decrease the extraction of raw materials. After the years of research and studies, it is found that the extract of the raw materials are derived from agricultural sector such as hemp, nettle and so on proving it might be the materials that is alternative to conventional concrete. As most of these shives plant shows promising result in past, this

research is focused on chosen plant fibrous. These plants when proper composition is made to enhance the impacts to reduce sound (acoustic phenomenon), decrease extraction and decrease energy consumption can be proved revolutionary. The aim of the work is to estimate the suitability of Hemp, Nettle, *Artemisia vulgaris* and *Sida hermaphrodite* plants for production of building materials. The tasks of this research are to estimate density, compressive and bending strength and insulation of the concrete with Hemp, Nettle, and *Artemisia vulgaris* and *Sida hermaphrodite* fibres.

## TEST MATERIALS

**Hemp plant (*Cannabis Sativa*).** There is a history of shiv of hemp plants for bedding industries but after 1990 it was started to be used in building industry. Recently, more than 25000 products worldwide have been composed of hemp components. Generally in one hectare of land 6-15 kg hemp can be grown which consists of 75% of hemp shives, 20% long strain fibres and 5% dust. In 2018 Delannoy provides a scientific literature study of Guillaume regarding the building materials that is composed of hemp and cement as a binder in different composition and find out the acoustic, thermal and the hydro properties are similar to the traditional concrete (Delannoy, 2018). Similarly, Balciunas (2013) analyzed the characteristics of hemp fabric reinforced nano-clay cement nano-composites and studied the impact of hemp shives aggregate mineralization on the physical-mechanical properties and structure of composite with cementitious binding material (Balciunas, 2013). He analyzed that the characteristics of the hemp fibres cement based mortars affects the mechanical, physical properties and structural composition of the hemp concrete.

**Nettle (*Girardinia diversifolia*).** Nettle fibres do not have any recent history to be used in the building industries but numerous research are in process to evaluate its use in building industry. The fibers from the plant are usually used to make nets for fishing, ropes, clothing materials etc. In general very less amount of the fibers can be achieved from the plants comparing to other natural fibers. Nettles are tall plants of 1.5-3.0 m high and are found in altitude at 1000–2500 m above sea level. They are strong, erect and require favorable environmental condition such as good moisture, high air velocity and low temperatures to grow. The processes for fiber extraction can be done naturally as well as by chemical treatment. Natural extraction can be done by using hand retting process, and chemical treatment can be done by caustic soda treatment for fiber extraction which is not used currently (shrestha, 1994). Himalayan Wild Fibers LLC has already embarked on the industrial scale-up of *G. diversifolia* fiber production in Nepal.

**Mugwort (*Artemisia vulgaris*).** *Artemisia* is commonly used as a source of food and in production of the pharmaceuticals products. They are generally found in the northern hemisphere (DiTommaso, 2003). The substantial *Artemisia* genus attribute is its insensitivity to moisture regime and can tolerate the pH of 4.8-8.2. The research on the *Artemisia* genus plant biomass increases because the biomass utilization for bio fuel production increases at the initial stage ((Kryževičienė et al., 2010). The essential oil and the plant extracts of *Artemisia* have been used for the treatment of several diseases, and sample scientific evidence supports its function as anti-epileptic, anti-hysterical, diuretic, digestive and stimulant. *Artemisia Vulgaris* has never been tested as possible building materials before this research. This research can be proven pivotal if necessary results can be achieved.

***Sida hermaphrodite* (*Virginia mallow*).** *Virginia mallow* (*Sida hermaphrodite rusby*) is the species of the plant that have very high crop yielding potential. None of the NPK mineral fertilization have no influence in the growing of leaves, stems and roots of *Virginia mallow*. *Sida hermaphrodite* has never been tested as possible building materials before this research. This research can be proven pivotal if necessary results can be achieved.

## SAMPLE PREPARATION

The test sample was prepared in accordance of EN 12390-2. Each batch for three test specimens consist of  $1100 \pm 2$  g of Lime,  $145 \pm 5$  g of unburned lime,  $220 \pm 1$  g of metakaolin and  $2650 \pm 1$  g of water (water/binder ratio = 0,50) for the preparation of three 100x100x100 mm cubes and three prismatic rectangular sample of 16x40 mm respectively. The estimated materials are mixed by using remixing container and shovel. Once the mixture is properly mixed, the inner surface of the mould is covered with a thin film of non-reactive materials to prevent the adhering. The mould of volume equivalent to 100x100x100 mm is then with the prepared mixture of fibrous concrete. During the filling the manual compaction was done regularly by compaction rod into layers. Once the compaction was done, the excess mixture was removed from the upper surface of the mould by making the smooth surface. As a curing method the prepared sample is left into the mould for 7 days and as a post curing the prepared specimens were removed from mould leaving them in the open air and the binder used in the mixture were air binder. The samples were left in the open dry air for 28 days before the tests were carried out (Fig.1).



Figure 1. Curing of the specimen in the open air.

## TEST METHODOLOGY

**Compressive strength.** Specimens to be tested are loaded to failure in compressive testing machine accordance to the euro code EN 12390-4. The maximum load that a material can bear is recorded and the compressive strength of the prepared concrete is calculated. The cube test specimen of the sample is prepared accordingly to EN 12390-2 with the tolerance size as given in the standard. Compressive strength of the tested specimen was calculated by using the equation.

$$f_c = \frac{F}{A_c} \quad (1.1)$$

where,  $f_c$ - compressive strength of specimen (MPa);  $F$ -maximum load at the failure (N);  $A_c$ - Cross sectional area of the specimen in which the load is applied (mm<sup>2</sup>)

**Density of the hardened concrete.** Densities of the prepared specimens were calculated in accordance to EN 12390-7. The as-received specimen was weighted to the maximum permissible error of 1g of the mass of the specimen and the values of the mass of the each specimen were recorded in kg. The volume of the specimen was calculated from the measurement by the help of calipers on the specimen in accordance with EN 12390-1 in m<sup>3</sup>. The density of the hardened specimen was calculated by using the formula:

$$D = \frac{M}{V} \quad (1.2)$$

where,  $D$ - density of the specimen related to the condition (kg/m<sup>3</sup>),  $M$ -mass of the specimen in kg,  $V$ -volume of the specimen in m<sup>3</sup>

**Flexural strength.** The flexural test was carried out using the testing machine in accordance with EN 12390-4. The Prepared prismatic samples are subjected to a bending moment by the application flexural strength testing machine. The maximum load bear by the specimen was recorded and the flexural strength of the material is calculated. The flexural strength of the tested specimen was calculated by using the equation.

$$f_{ct,fl} = \frac{3 \cdot F \cdot l}{2 \cdot d_1 \cdot d_2^2} \quad (1.3)$$

where,  $f_{ct,fl}$ - Flexural strength (N/mm<sup>2</sup>),  $F$ - Maximum load (N),  $l$ - Length between the two supports (mm),  $d_1$  and  $d_2$  - Lateral dimension of the cross section (mm)

## RESULT AND ANALYSIS

**Compressive strength test result.** Among the four different tested specimens with different fibers *Artemisia vulgaris* has the maximum compressive strength of 0.26 MPa gradually decreasing in the order of Hemp 0.20 MPa, Nettle 0.16MPa and *Sida hermaphrodita* 0.15MPa respectively. Our result for the Hemp which has been tested severally before has same amount of compressive strength as achieved by Sutton (Sutton et al, 2011). The rest of the materials have been subjected to any compressive strength test before but the results shows that the Artemisia Vulgaris has the highest compressive strength amount the tested materials.

**Density test result.** Among all the tested concrete blocks with specific fibers *Artemisia vulgaris* is the densest concrete specimen prepared with the density of 648.55 kg m<sup>-3</sup>. Additionally the density of Hemp, Nettle and *Sida hermaphrodita* concrete block was obtained to be 379 kg m<sup>-3</sup>, 492.22 kg m<sup>-3</sup> and 544.20 kg m<sup>-3</sup> respectively. Hemp concrete has the highest compressive strength as compared to other tested materials with least density which might make it reliable to use as a building materials where light weight concrete with desirable compressive strength is required.

**Thermal conductivity of tested materials.** According to dependency of the values of the densities with thermal conductivity, the thermal conductivity of Hemp, Nettle, *Sida hermaphrodita* and *Artemisia vulgaris* concrete block was obtained to be 0.073 W/mK, 0.096 W/mK, 0.107 W/mK and 0.1315 W/mK respectively.

**Flexural test result.** Among the four different tested specimens with different fibers *Artemisia vulgaris* has the maximum Flexural strength of 0.0405 MPa gradually decreasing in the order of *Sida hermaphrodita* 0.0261MPa, Nettle 0.0195MPa and Hemp 0.0070 MPa respectively. Our result for the Hemp which has been tested severally before has significant difference in compressive strength as achieved by Murphy in 2010 (Murphy et al., 2010) as 0.3-0.4 MPa. The rest of the materials have been subjected to any compressive strength test before but the results shows that the *Sida hermaphrodita* has the highest flexural strength amount the tested materials.

**Comparison of all tested properties of the specimens.** From the graph (Fig. 2) it can be seen that the flexural and compressive strength of the materials is directly proportional to the density of the materials. As *Artemisia vulgaris* has the highest density so do the compressive and flexural strength of the material.

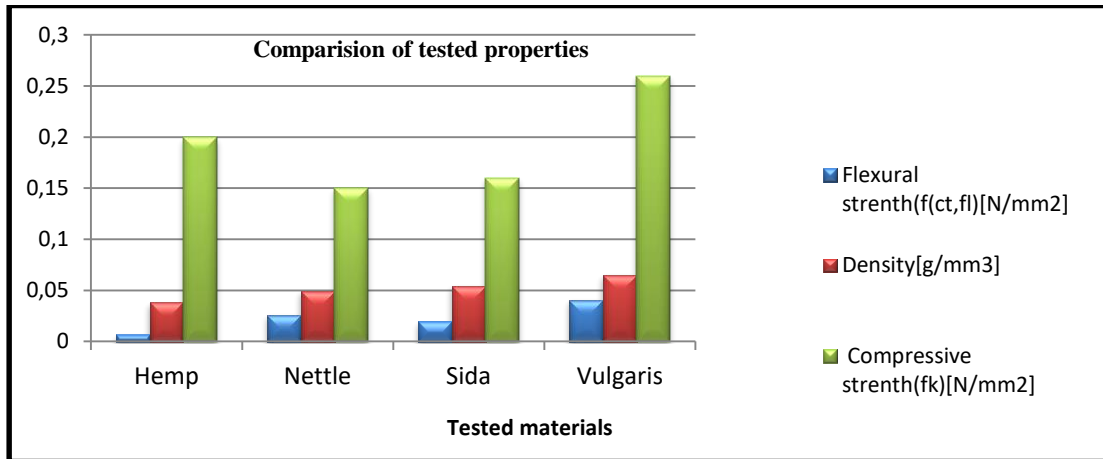


Figure 2. Comparison of all properties

It is always great challenge to develop materials that are environment friendly. This study proves tested fibers have very interesting and satisfactory tensile properties and could also be suitable as reinforcing components in composite materials that can be used in building development. Among the tested ecological fibrous concrete prepared in the laboratory it is seen that *Artemisia vulgaris* (mugwort) which has never been tested before as a building materials and hemp concrete is very close to being mature enough to be adopted by the mainstream construction industry and that all nations must include bio-aggregate basedconcretes in their building standards. The reviewed literature shows that *Artemisia vulgaris* and Hemp concrete has the potential to positively affectenvironments by reducing their carbon footprint. It is suggested that the materials can be used in the form of lightweight concrete such assandwich panels, modular systems, fillers for filler slabs, and so onmay be explored. The final product obtained after the concrete mixing and the curing process has adequate mechanical strength and good environmental credentials, and adequate durability. Similarly, Nettle concrete and Sida concrete has also shown the considerable compressive and flexural strength near to those of hemp and *Artemisia vulgaris* which opens up door even for this material to be use in the field of construction. With references to the several reviews, mechanical properties of the concrete with fibers can be increased with increase of better binder which can broad up the possibility to use all of the material as a construction materials. It is also suggested that this concrete are not reliable and good to use it as a structural concrete as they do not have significant amount of properties to use as a structural member. Additionally all of the materials are very light so they can be categorized as a light-weight or medium-weight concrete. Artemisia fibers are more porous as compared to other fibers. Density of these materials has considerable affect on the mechanical properties of the materials.

## CONCLUSION

- The densest concrete is with *Artemisia vulgaris* fibers. Comparing with other fibers it is denser from 15 to 40 %.
- Artemisia vulgaris concrete have the best strength properties. The compression strength of this concrete is greater than Hemp, Sida and Nettle concretes by 23, 38 and 42 % respectively. All the prepared sample were tested in compressive and flexural testing machine that shows *Artemisia vulgaris* has the maximum compressive strength of 0.26 MPa gradually decreasing in the order of Hemp 0.20 MPa, Nettle 0.16MPa and Sidahermaphrodita 0.15MPa respectively. Flexural strength of *Artemisia vulgaris* has the maximum Flexural strength of 0.0405 MPa and Hemp has the minimum of 0.0070 MPa. The density test of the prepared specimen shows that the hemp is the lightest and *Artemisia vulgaris* is the densest among the tested specimen.

- Hemp concrete has the best thermal properties and the worst is for *Artemisia vulgaris* concrete. According to dependency of the values of the densities with thermal conductivity, the thermal conductivity of Hemp, Nettle, *Sida hermaphrodita* and *Artemisia vulgaris* concrete block was obtained to be 0.073 W/mK, 0.096 W/mK, 0.107 W/mK and 0.1315 W/mK respectively. According to dependency of the values of thermal conductivity and thickness of the wall, the thickness of the internal wall to be used with the heat transfer coefficient equivalent to 0.11 W/m<sup>2</sup>·K (For A+ class buildings) for Hemp, Nettle, *Sida hermaphrodita* and *Artemisia vulgaris* concrete block was obtained to be 66cm, 87 cm, 97 cm and 120 cm respectively excluding any thermal insulation materials that can be used during the construction of wall.
- Hemp is more economical than any of the tested materials because of its thermal conductivity properties as the thickness of the wall to be constructed for hemp is least.
- According to all results the most suitable organic fibres for production of building materials is Hemp due to best results in thermal properties. *Artemisia vulgaris* concrete is strongest but not enough for structural material.

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