Characterization of polymer concrete with natural fibers

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Abstract. In the study are presented the experimental results obtained for polymer concrete prepared with epoxy resin, aggregates, fly ash as filler and two types of fibers: wool and hemp. The influence of type and dosage of fibers were studied. The density and mechanical characteristics were determined: compressive strength, flexural strength and split tensile strength. For both types of fibers, with increasing the fiber dosage the density decreases. The studied dosages had not an important influence on mechanical strengths. The fibers improved especially the tensile strength and the compressive strength presented generally smaller values than the control mix.

1. Introduction
In the domain of sustainable building materials a lot of wastes are used for obtaining new materials, for improving the characteristics or as addition in the mix [1,2]. The wastes are used for obtaining cement concrete, polymer concrete, cement, plaster, composites which are used in civil engineering, bridges, building services, highways, hydraulic constructions, etc. [3-7]. Generally concrete is sensitive to cracking and in tension it presents a brittle failure. The fibers help to a better behavior of concrete in tension by stopping the cracking processes and improving ductility at failure. Several types of fibers are used in building materials such as: synthetic fibers (glass, carbon, metallic, etc.), natural fibers (cellulose, sisal, rice husk, etc.). [8-14]. Polymer concrete presents some advantages in comparison with cement concrete related to higher mechanical strengths, low permeability, a better resistance to aggressive agents, etc. Although the costs of polymer concrete are higher than cement concrete it is very useful for using in severe conditions from industry, public buildings, transport, etc.[15-22]. Natural materials like wool or hemp are abundantly available materials in many countries. And when they are not used they are dumped in landfills with high costs or are burned polluting the environment. Their use in building materials industry can be a possibility of consuming these natural materials [23-25].

The present study analyses the influence of fibers from wool or hemp on the mechanical characteristics of polymer concrete with fly ash as a possibility of obtaining new eco-friendly concrete.

2. Experimental program
The polymer concrete used as control sample was obtained with epoxy resin type Ropoxid, a Romanian product which in combination with hardener type Romamid was the binder of the mix. Epoxy resin was in a dosage of 12.4% from the mix, minimum quantity that could be used from the condition of workability. Two sorts of aggregates were used: sort I (sand) and sort II-river gravel (4-8
mm) both in the same dosage of 37.4% from the total volume of the mix. A dosage of 12.8% from the total volume mix was fly ash used as filler. The experimental mixes with fibers type wool, noted PCW1 to PCW5, and hemp, noted PCH1 to PCH5, were prepared with the same components as the control mix and the fibers were added in dosages of 1%, 2%, 4%, 5% and 6% from the resin weight.

2.1. Samples
According the European standards for determining the mechanical characteristics such as compressive strength \((f_c)\), flexural strength \((f_{ti})\) and split tensile strength \((f_{td})\) [26-28] of both type of polymer concrete, the following types of samples were poured: cubes of 70 mm sizes and prisms of 70x70x210 mm sizes. The experimental tests on samples were effectuated at 14 days according to standards [26-28].

3. Results and discussions

3.1. Physical characteristic
The density of polymer concrete with fiber varied between 1996 kg/m\(^3\) for PCW5 (with 6% wool fibers) and 2218 kg/m\(^3\) for PCH1 (with 1% hemp fibers), Figure 1. The mixes with wool fibers presented the majority of densities under the control mix. For both types of fibers, with increasing the fiber dosage the density decreases.

![Figure 1. Density of polymer concrete with fibers](image1)

3.2. Mechanical strengths
The experimental results were determined for compressive strength \((f_c)\), flexural strength \((f_{ti})\) and split tensile strength \((f_{td})\).

Compressive strength obtained on polymer concrete with wool fiber waste was with values between 31.7 MPa and 57.1 MPa and with hemp fibers was with values between 27.8 MPa and 53.1 MPa, Figure 2.

![Figure 2. Compressive strength of polymer concrete with fibers](image2)
Comparing the both types of fibers with control polymer concrete it can observe that:

- The polymer concrete with 1% wool fiber presented the highest value of compressive strength, an increase with 19.2% in comparison with control mix (PC) and that with 6% wool fibers presented a decrease of compressive strength of about 33.8%.
- The concrete with 6% hemp fiber presented the highest value of compressive strength, an increase with 10.8% in comparison with the control mix (PC) and that with 2% hemp fibers presented a decrease of compressive strength of about 42%.

As conclusion, the influence of wool and hemp fiber on compressive strength of polymer concrete is that of decreasing this characteristic.

Comparing the influence of type of fiber on the compressive strength it can observe that polymer concrete with wool fiber presented higher values that polymer concrete with hemp fibers for dosages of 1%, 2% and 5%, Figure 3.

![Figure 3. Influence of fiber type on compressive strength](image)

Flexural strength obtained on polymer concrete with wool fiber waste was with values between 14.4 MPa and 19.3 MPa, and with hemp fibers was between 8.6 MPa and 17.8 MPa, Figure 4. The polymer concrete with 2% wool fiber presented the highest value of flexural strength, an increase with 19.1% in comparison with the control mix (PC) and that with 5% wood fibers presented a decrease of flexural strength of about 42%.

![Figure 4. Flexural strength of polymer concrete with fibers](image)

The concrete with 4% hemp fiber presented the highest value of flexural strength, an increase with 9.8% in comparison with the control mix (PC) and that with 2% hemp fibers presented a decrease of flexural strength of about 46%.

Comparing the influence of type of fiber on the flexural strength it can observe that polymer concrete with hemp fiber presented higher values that polymer concrete with wool fibers for dosages of 1%, 4% and 6%, Figure 5.
Split tensile strength obtained on polymer concrete with wool fiber waste was with values between 4.87 MPa and 7.7 MPa, all values are bigger than that of control mix (PC). The maximum increase was for mix PCW2 that had an increase of about 60% in comparison with the control mix (PC). The polymer concrete with hemp fibers presented values of split tensile strength between 3.5 MPa and 6.9 MPa, Figure 6. The polymer concrete with 4% hemp fiber presented the highest value of split tensile strength, an increase with 43.4% in comparison with the control mix (PC) and that with 2% hemp fibers presented a decrease of split tensile strength of about 27.3%. The polymer concrete with hemp fibers presented also higher values of \( f_{ti} \) than the control mix, with an exception in the case of mix PCH2.

Comparing the influence of type of fiber on the split tensile strength it can observe that polymer concrete with hemp fiber presented higher values that polymer concrete with wool fibers for dosages of 1%, 4% and 6%, Figure 7.

The mix PCW4 (with 5% wool fiber) presented the highest value of \( f_c \) and the mix PCW2 (with 2% wool fibers) presented highest values of \( f_{ti} \) and \( f_{tdr} \) in comparison with all mixes.
4. Conclusions

In the study are presented the experimental results obtained for polymer concrete prepared with epoxy resin, aggregates, fly ash as filler and two types of fibers: wool and hemp. For both types of fibers, with increasing the fiber dosage the density decreases.

The values of mechanical strengths were influenced by the fiber type and dosage. The studied dosages between 1% and 6% had not an important influence on mechanical strengths and higher dosages must be studied. The compressive strength obtained with wool and hemp fiber was generally smaller than that of control mix. Comparing the influence of type of fiber on the compressive strength it can observe that polymer concrete with wool fiber generally presented higher values that polymer concrete with hemp fibers. In the case of flexural strength the hemp fiber presented generally higher values in comparison with wool fibers. In the case of split tensile strength only the polymer concrete with wool fiber presented all values bigger than that of control mix, but for hemp fibers only some values of split tensile strength were bigger than that of control mix.

From the experimental researches was observed that a better influence of wool and hemp fibers is beneficial on the tensile strengths and density. Function other characteristics such as thermal conductivity, acoustic properties, etc. the polymer concrete can be used in obtaining eco-friendly lightweight concrete, concrete with improved thermal properties, etc.

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