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# Influence of Plasma Treatment on Polypropylene Microfibers in Foamed Cement Paste Containing Recycled Concrete

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**Abstract.** This article deals the effect of oxygen plasma modification on mechanical properties of lightweight cement matrix. There is also described the process of plasma modification. Test specimens contain polypropylene microfibers, cement, recycled concrete, foaming agent and mixing water. Two sets of lightweight test samples with different density and a set of non-lightweight samples were made. To determine the effect of the plasma modification on the mechanical properties of the resulting cementitious composite, the samples were divided into two groups. Half of the samples contain oxygen plasma treated microfibers; the other half of the samples have the same composition but contain microfibers without plasma treatment. The mechanical properties of the test specimens were measured and the compressive strength of samples containing plasma modified fibers were compared with samples containing fibers without plasma modification.

## Introduction

The cohesion of the cement matrix with the fibers depends on the interfacial transition zone (ITZ). The properties of the ITZ depend on the processing and properties of the cement matrix and the fiber surface. Appropriate processing of the matrix with fine fillers and the use of microfibers can cause a significant reduction of the transition layer, resulting in a much higher bonding of the fiber with the matrix [1,2]. The surface of the polypropylene fibers can be mechanically or chemically modified to increase the cohesion with the cement matrix [3,4]. Plasma treatment can modify the surface both mechanically and chemically. The effect of plasma modification on the fiber surface depends on many parameters - for example, on the pressure during modification (low or atmospheric) or on the gas used. The resulting effect also depends on the type of used device and its settings [5,6]. Polypropylene fibers are poorly wettable in water, oxygen plasma modification can be used to increase their wettability. During plasma modification, free electrons and ions impinge on the surface of the material, disrupt the surface bonds and form various functional chemical groups improving adhesion with the matrix. The mechanical effect of the plasma modification on fibers surface is caused by ions which, due to their mass about 2000 times greater than electrons, can disrupt the surface of the modified material. The energy that the ion strikes the fibre, can cause releasing particles from the fibre surface or disrupt its surface structure. [7,8].

## Materials and Samples

Polypropylene microfibers are poorly wettable in water, to increase coherence with cement matrix it is advisable to increase their wettability in water. In order to increase the wettability, the fiber surface was modified by oxygen plasma. Based on previous measurements, the modification by low-pressure oxygen plasma for 60 seconds was chosen [9]. Plasma modifications were performed by Tesla VT 214. First, the fibers were placed in the chamber of the Tesla VT 214 and then almost vacuum was created. The air pressure in the chamber was about 22 Pa. Next, the chamber was filled by oxygen, the pressure in the chamber increased to 60 Pa. After that, the plasma modification process was initiated. The plasma was generated by a radio frequency source with 100 W input power. Finally, after plasma modification process, the chamber was filled by air to atmospheric pressure and the fibers were removed.

Pordtland cement CEM 42.5R (Radotin) was used as a binder. Micronized concrete recyclate was used as a filler. The foaming agent SIKA Lightcrete 400 was used to light-weight the cement matrix. The water ratio was determined to be 0.32 based on previous measurements. To determine the effect of plasma modification, specimens containing plasma modified fibers and fibers without plasma modification were made. The composition of the samples is given in Table 1.

Table 1: Composition of the samples

| Set | Cement [g] | Recyclate [g] | Water [ml] | Foaming agent [ml] | W/C+R | Fibers [g] | Plasma treatment |
|---|---|---|---|---|---|---|---|
| X | 750 | 750 | 480 | 0 | 0.32 | 0.75 | NO |
| P | 750 | 750 | 480 | 0 | 0.32 | 0.75 | YES |
| VX | 750 | 750 | 480 | 1.5 | 0.32 | 1.43 | NO |
| VP | 750 | 750 | 480 | 1.5 | 0.32 | 1.43 | YES |
| VVX | 750 | 750 | 480 | 3 | 0.32 | 1.875 | NO |
| VVP | 750 | 750 | 480 | 3 | 0.32 | 1.875 | YES |

## Experimental Methods and Results

A total of 6 sets of test samples were made, each set containing 6 samples. Half of the samples contain oxygen plasma treated microfibers (*P*), the other half of samples have the same composition, but contain microfibers without plasma treatment (*X*). There are three groups of samples with different density - very lightweight samples with a density of about 1250 $kg \cdot m^{-3}$ (*VV*), lightweight samples with a density of about 1400 $kg \cdot m^{-3}$ (*V*) and non-lightweight samples with a density of about 1800 $kg \cdot m^{-3}$.

The dimensions of the test samples were 40 × 40 × 160 mm. The samples were stored for 28 days under water in a laboratory environment at 22 ± 1 ° C. Subsequently, the specimens were halved during bending tests. After that, compression-testing were performed by hydraulic press. Samples were loaded by a controlled displacement in a hydraulic press Heckert FP100. The loading speed during compression-testing was set to 0.8 mm per second. The measured compressive strength of samples is given in Fig. 1. The percent comparison of compressive strength between samples containing plasma treated fibers and samples containing fibers without plasma treatment is shown in Fig. 2.

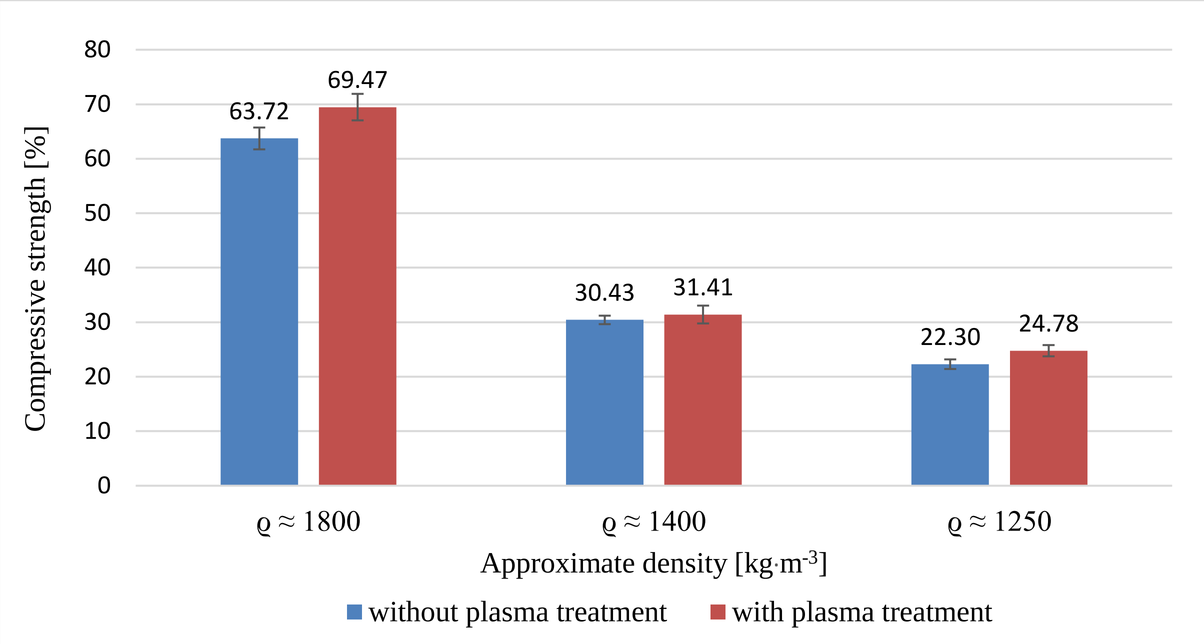


Fig. 1: Compressive strength of samples

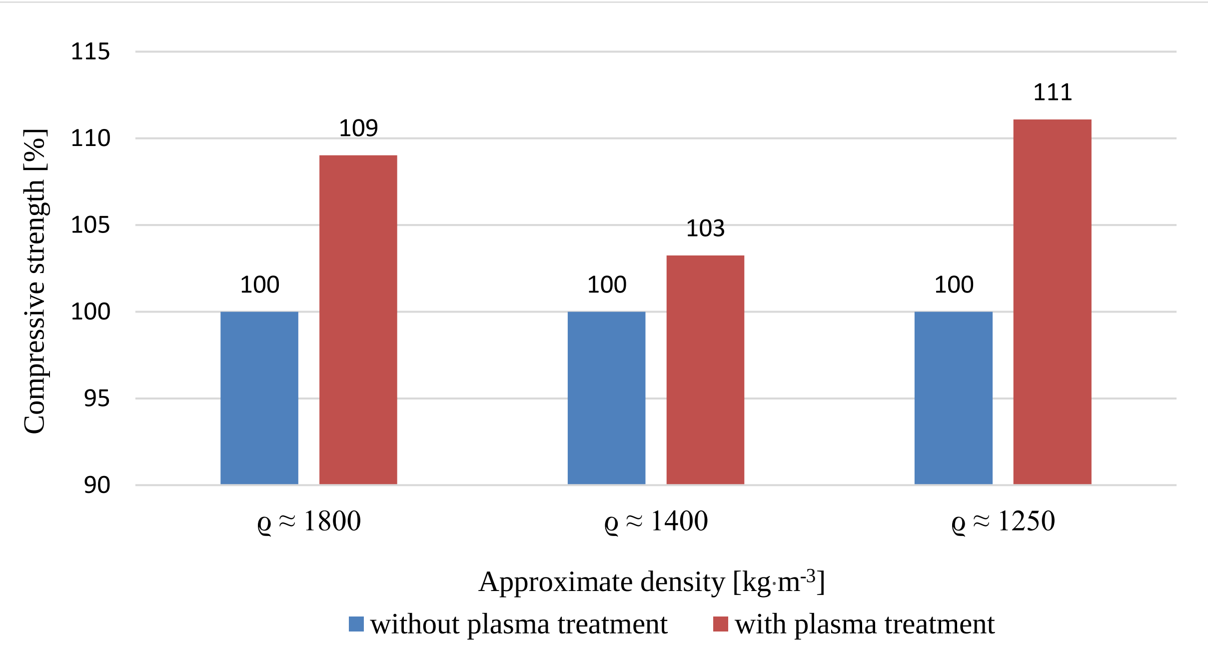


Fig. 2: The percent comparison of compressive strength between samples containing plasma treated fibers and samples containing fibers without plasma treatment

## Conclusions

Based on the performed experiment, the positive effect of oxygen plasma on the surface of PP fibers, which were applied to a sufficiently lightweight cement matrix containing recycled concrete, was proved. Compressive strength of samples with a density of about 1250 kg · $m^{-3}$ increased for samples containing plasma modified fibers by approximately 10 % compared to samples containing fibers without plasma modification. Furthermore, the positive effect of plasma treatment of PP fibers applied to non-lightweight cement composite materials was confirmed.

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