International Journal of Advance Research in Science and Engineering
Vol. No.4, Special Issue No. (02), September 2015
www.ijarse.com
IJARSE
ISSN 2319 - 8354

# EFFECT OF MICRONIZED RECYCLED MATERIALS ON MECHANICAL PROPERTIES OF CEMENT MORTAR WITH CRUSHED BRICKS

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## ABSTRACT

*The article presents the result of mechanical tests on cement mortar with crushed bricks and micronized recycled materials. Mixtures with 2 different micronized materials (recycled concrete prefabricated at the factory and marble powder) were tested. Micronized materials were produced in the company Lavaris Ltd. (Czech Republic) by use of high speed grinding. The investigated parameters were compressive and flexural strength and bulk density of the samples. Flexural strength and compressive strength were determined for the 28 days old specimens. Testing was performed on beams of dimensions 40 × 40 × 160 mm. The mechanism behind the increase of mechanical strength and elastic stiffness is explained by means of microscopic analysis, which was carried out by electron microscope. Electron microscopy was performed using a ZEISS merlin at the UCEEB CTU in Prague The aim of this article was to determine the influence of type recycled material on the resulting mechanical properties.*

***Keywords: Compressive Strength, Electron Microscopy, Flexural Strength, Recycled Materials, X-Ray Spectrometry***

## I. INTRODUCTION

Mortar is one of the most popular building materials and it has been extensively used since the antiquity times. Romans people successfully built structures made of lime mortar with crushed brick before 1st century BC. Mortar consisting of lime and crushed bricks was called cocciopesto [1]. When designing historic mortars of cocciopesto type, it has been found that the presence of crushed bricks increased to mortar strength [2]. Mixtures of modern cocciopesto were designed with Portland cement as binder and micronized recycled materials as microfiller. Two variants of recycled material were used to increase the content of recycled material in mixtures.

First micronized recycled material was waste concrete prefabricated at the factory (in our case railway sleepers). In the work [3, 4, 5, 6] micronized recycled concrete was used to compensate natural filler in the mortar. The result was that the replacement of the recycled material has reduced the workability of mixture, all of the modified mixture showed higher compressive and tensile strength of the bending and all mixtures showed the same adhesion, shrinkage and water absorption.

Second micronized recycled material was marble powder (in our case from west bank of the Jordan). The marble solid and sludge wastes were used in many applications such as the construction industry [7], paper industry [8] and cement manufacture [9]. Marble dust in mortar has resulted in increase of mechanical properties [10].

## II. TESTED MATERIALS AND SPECIMENS

All of the tested mixtures were composed of natural sand (from Zálezlice with a fractions 2-4 mm) and crushed bricks (from Bratronice with a fraction 2-5 mm). Mixtures A and B contained Portland cement CEM I 42.5R (Radotín) and microfiller. Mixture C contained only microfiller without Portland cement. Recycled railway sleepers (pulverized by Company Lavaris) of a fraction 0-0.1 mm was used as microfiller for mixtures A and C. Marble powder pulverized by Company Lavaris) of a fraction 0-0.04 mm was used as microfiller for mixtures B. The weights of individual components in the mixtures presents Table 1.

Amount of water was designed to maintain the same workability of fresh mixture. Consistency of the mixtures was determined using slump-flow test. Table 2 presents specifications for individual sets. Six specimens were made for each mixture and their dimensions were equal to 40 × 40 × 160 mm. Samples were demoulded the day after production, and the samples were stored loosely in a laboratory environment at 22 ± 1 ° C and relative humidity 50 ± 2 %.

**Table 1. Composition of the tested materials**

| Set | Mass [kg] | | | | |
|---|---|---|---|---|---|
| | **CEM I** | **Sand** (0-4 mm) | **Brick** (2-5 mm) | **Marble powder** (< 0.04 mm) | **Recycled concrete** (0-0.1 mm) |
| A | 0.07 | 1.75 | 1.05 | 0 | 0.63 |
| B | 0.07 | 1.75 | 1.05 | 0.63 | 0 |
| C | 0 | 1.75 | 1.05 | 0 | 0.7 |

## III. EXPERIMENTAL METHODS AND RESULTS

All samples were weighed and measured their dimensions, before was used destructive methods. These values were used to calculate bulk density of individual samples / materials, which can be used to compare the effects of individual materials on the monitored parameters (Table 2). The values of bulk density were similarly for each sample.

**Table 2. Water ratio, workability and bulk density of the tested materials**

| Set | Water Ratio | Spillage (after 10 impulses) [mm] | Spillage (after 20 impulses) [mm] | Bulk density [kg/m$^3$] |
|---|---|---|---|---|
| A | 0.512 | 105 | 120 | 1749 |
| B | 0.518 | 111.5 | 118.5 | 1724 |
| C | 0.568 | 109.5 | 118 | 1777 |

The flexural and compressive strength were determined using the Heckert device, model FP100 on the 28 days old specimens. The testing was displacement controlled at a constant rate of 0.1 mm/s in the case of three-point bending and 0.3 mm/s for the compressive test. The distance between supports for three-point bending test was equal to 100 mm. The uniaxial compressive test was performed on the broken halves of the specimens with effective dimensions of 40 × 40 × 80 mm.

Value of compressive strength of the mixture with micronized recycled concrete (A) was higher about 1 MPa than the compressive strength of the mixture with micronized marble powder (B) and the mixture without Portland cement (C) had similarly value of compressive strength as the mixture with a micronized marble powder.

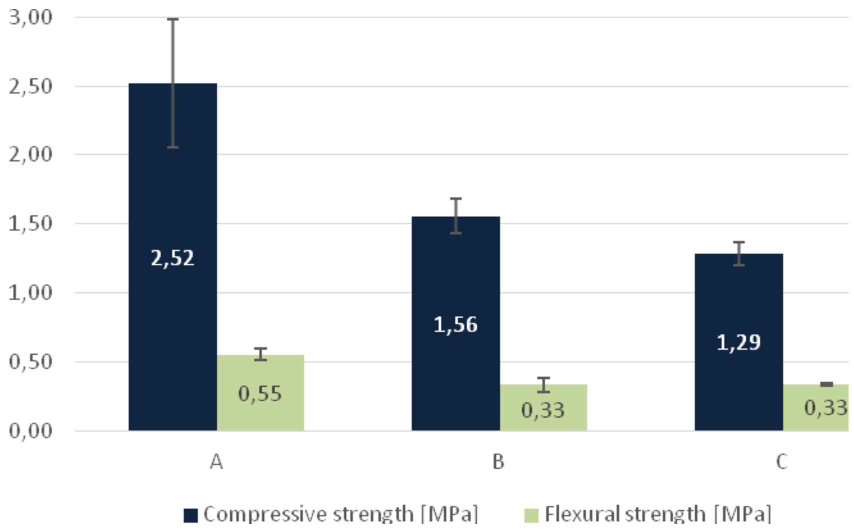
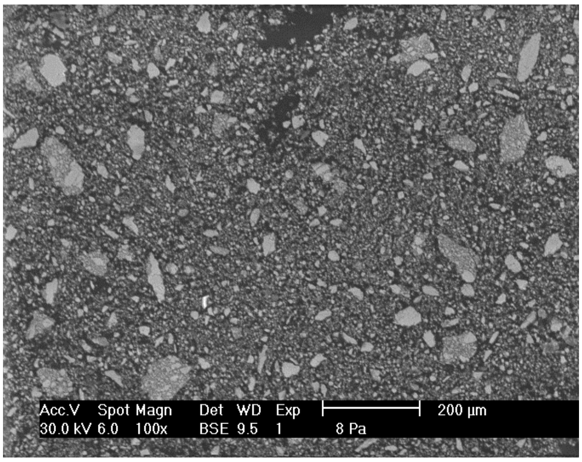
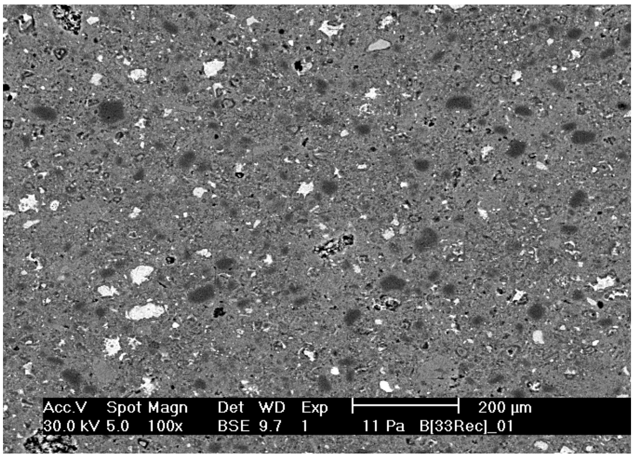



**Figure 1: Comparison of compressive and flexural strength (with standard deviation)**

In the next step, electron microanalysis (Fig. 2) was used for determine the effect of microfiller on the resulting mechanical properties of the samples. The recycled railway sleepers and marble powder samples were analysed chemically to determine the percentages of their different constituents. Energy-dispersive (EDS) and wavelength-dispersive (WDS) X-ray spectrometry was used. $CaCO_3$ content marble powder samples (Fig. 2a) was 99 % and $MgCO_3$ wasn't dominant with a content of less than 1 %. Marble powder samples was completely inert. The recycled railway sleepers samples (Fig. 2b) contained 10 % of clinker minerals, which joined to hydration of the cement.




a) Marble powder samples




b) Mixture with micronized recycled concrete (A)

**Figure 2: The image from Environmental scanning electron microscope, magnification 100×**

## IV. CONCLUSION

The tested materials seem very promising for the use as a microfiller and binder. Micronized recycled concrete seems most advantageous from the viewpoint of the mechanical properties of the tested materials. Micronized recycled railway sleepers (A, C) contained 10 % non-hydrated or milling activated clinker minerals which had influence on the development of mechanical properties. Marble powder samples (B) was completely inert and had only function of microfiller. In the future, work will deal with micromechanical study of recycled railway sleepers and marble powder as presented e.g. in [11, 12].

## V. ACKNOWLEDGEMENT

This work was financially supported by Czech Technical University in Prague – SGS projects SGS14/122/OHK1/2T/11 and by the European Union, OP RDI project No. CZ.1.05/2.1.00/03.0091 – University Centre for Energy Efficient Buildings. The authors also thank the Center for Nanotechnology in Civil Engineering at the Faculty of Civil Engineering of CTU in Prague.

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