

LABORATORY VERIFICATION OF THE PROPERTIES OF RECYCLED FINE AGGREGATES AND THE EFFECT OF DIFFERENT REPLACEMENT PERCENTAGES ON CONCRETE PROPERTIES

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ABSTRACT. This research work deals with the issue of laboratory testing of commonly available recycled fine aggregates, namely concrete recyclate, mixed recyclate and brick recyclate. Their geometrical properties: granulometric composition and fine particle content, including physical properties: bulk density and water absorption are investigated. The tests themselves are carried out according to available standards, which are currently mainly standards for testing natural aggregates, and it is necessary to assess the suitability of these tests for recycled aggregates as well. The results found for concrete recyclates confirm the use of these standards to obtain the properties mentioned, but the bulk density and absorption tests are inconclusive in the case of mixed and brick recyclates. Subsequently, test concrete specimens were produced in which natural fine aggregate and concrete recyclate were substituted at 33, 66 and 100 %. A series of tests were performed on the hardened concrete: bulk density, absorption, porosity and compressive strength. From the results obtained, the use of concrete recyclate in concretes with the replacement of natural fine aggregate at 33 % is suitable, without a significant reduction in the observed properties.

KEYWORDS: Recycled fine aggregate, concrete recyclate, mixed recyclate, brick recyclate, utility properties.

1. INTRODUCTION

Nowadays, the use of recycled materials is becoming more and more popular and recycling itself is taking its place in various areas of our lives. For this reason, it is an ideal time to expand public awareness of recycled materials that can also be used in construction. The construction industry itself is a major producer of raw materials that are generated by recycling construction and demolition waste. The recycling of this waste most often results in recycled aggregates, for which it is now necessary to find a place in modern construction, where we can see, for example, concrete structures for which recycled aggregates could serve as an alternative to natural aggregates. This aggregate can be divided into a fine fraction and a coarse fraction. The coarse fraction is now often used in the production of new concrete and is supported by standards [1]. The use of recycled fine aggregate is also possible in the production of new concrete. According to the available literature, concrete [2], brick [3] or mixed recyclate from brick and concrete [4] can be used as recycled fine aggregate.

An important process in this replacement is to define the properties of the recyclate itself, which include its granulometric composition, content of washable particles, bulk density and water absorption, as it

is necessary to know the material that enters the concrete production process. For this reason, CSN standards that specify test procedures for natural aggregates in concrete are used in this paper and it is necessary to evaluate the suitability of these standards for these recyclates.

Scientific studies [5, 6] have addressed the effect of concrete recyclates on concrete properties, specifically porosity, water absorption and compressive strength were tested. Another study led by Jagan Sivamani [7] investigated the effect of concrete recyclate on concrete properties. The results of this study indicated deteriorating properties with increasing percentage of replacement.

2. MATERIALS AND SAMPLES

The recycled aggregates were supplied by Moravostav a.s., which used RESTA jaw crushers for crushing construction and demolition waste. Three basic recyclates are investigated in this paper. Concrete recyclate (REC1) came from highly segregated concrete waste, Mixed recyclate (REC2) consisted of a mixture of concrete, brick waste combined with soil and Brick recyclate (REC3) consisted of pure brick waste. REC1 was selected to replace the natural fine aggregate in 33, 66 and 100 weight percent replacements for the

Set	Cement	Fine natural aggregate 0/4	Coarse natural aggregate 4/8	Coarse natural aggregate 8/16	REC1	Water
REF	300	700	538	601	0	165
R1_33	300	466	538	601	233	165
R1_66	300	233	538	601	466	165
R1_100	300	0	538	601	700	165

TABLE 1. Summary of concrete mix design in kg m^{-3} .

impact of the recycled fine aggregate, and reference concrete (REF) was produced at the same time. Three test specimens were produced for each test set. The detailed compositions of the concretes are described in Table 1. Concrete cubes with an edge of 150 mm were used as test specimens. The concrete itself contained Portland cement with the designation CEM I 42.5 R, which came from the Mokra plant. In addition, natural fine aggregate, defined by the 0/4 fraction, from the Dobrın gravel pit, managed by Cemex, was used. The coarse aggregate came from the Zbraslav quarry with fractions 4/8 and 8/16 used.

3. TESTING RECYCLED AGGREGATES

The dried recyclates were weighed and then soaked in water for 24 hours. After this time, this aggregate was placed on a set of sieves where the smallest sieve was 0.063 mm and with the vibration on, the aggregate was sieved while continuously adding water. The test itself is described by EN 933-1[8] and the desired result was the percentage of washable particles. The aggregate was then dried again in an oven at 110 °C, ready for the next stage of the test described in the previously mentioned standard. In this case, this involved the determination of the granulometric composition, which resulted in a grain size curve. Furthermore, it was necessary to carry out a test to determine the bulk density and water absorption of the recycled fine aggregates, for which the standard EN 1097-6 [9] was used. The standard described the procedure for carrying out the pycnometric method to obtain several types of bulk weights (apparent, surface dried and fully saturated) and percentage of absorption of the recyclates.

4. TESTING OF CONCRETE SAMPLES

The produced test specimens were unmolded after solidification and stored in containers with water. They were subsequently tested after 7 and 28 days. The first test carried out on the test specimens was the bulk density, which was measured on the fully water-saturated solids according to EN 12390-7 [10], and it was necessary to measure the dimensions of the solids themselves to obtain their volume. This was followed by a test to determine the compressive strength of the concrete, which was based on EN 12390-3 [11]. The individual specimens were surface dried and placed in a test press. The loading was carried out by a constant

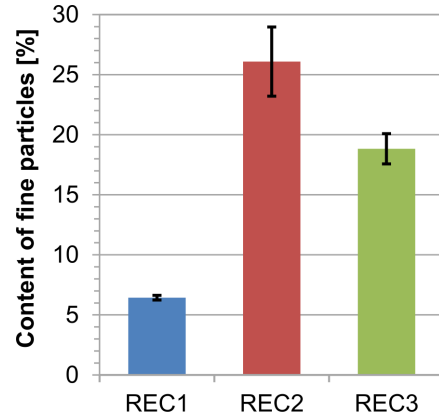


FIGURE 1. Content of fine particles.

increase in force until the resulting failure. The compressive strength was calculated from the maximum force achieved during the test $F_{c,\max}$ as:

$$f_c = \frac{F_{c,\max}}{ab}, \quad (1)$$

where

f_c is the compressive strength [Pa],

$F_{c,\max}$ is the maximum force [N],

a is the width of the sample [m],

b is the height of the sample [m].

5. RESULTS AND DISCUSSION

The results of the amount of fine particles can be seen in Figure 1 and, as expected, the lowest percentage of contamination came out for REC1. In the case of REC2 and REC3, the percentage of contamination already reaches significant values, indicating that these recyclates are very contaminated and their use is all the more complicated. In Figure 2 we can observe the resulting grain size curves for the tested recyclates. REC1 shows uniform gradients of the different fractions, but contains the smallest proportion of finer aggregates compared to the other two recyclates. In the case of REC2 and REC3, a more pronounced representation of grain sizes of 0.063–0.25 mm can be seen, which may be due to the higher content of fines.

In Figure 3, the results of the bulk weights can be observed. In the case of REC1, the resulting values are conclusive and very similar to, for example, the study by Cheng-Chih Fan [2]. For the other two recyclates

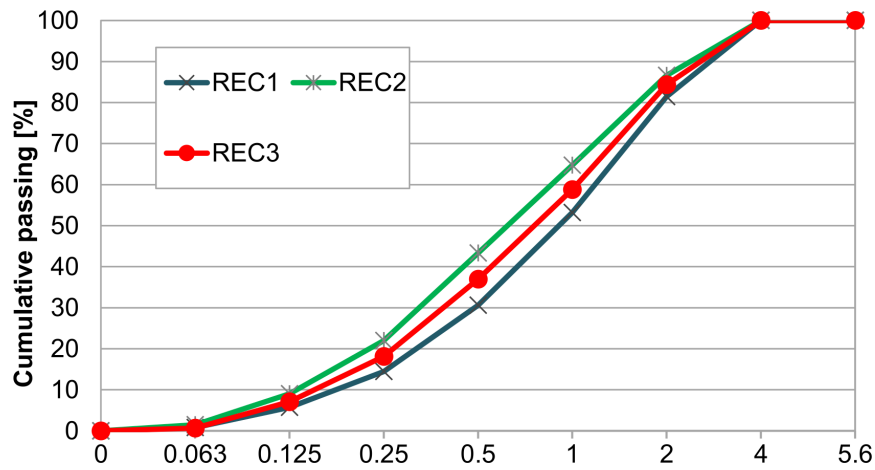


FIGURE 2. Particle size distribution.

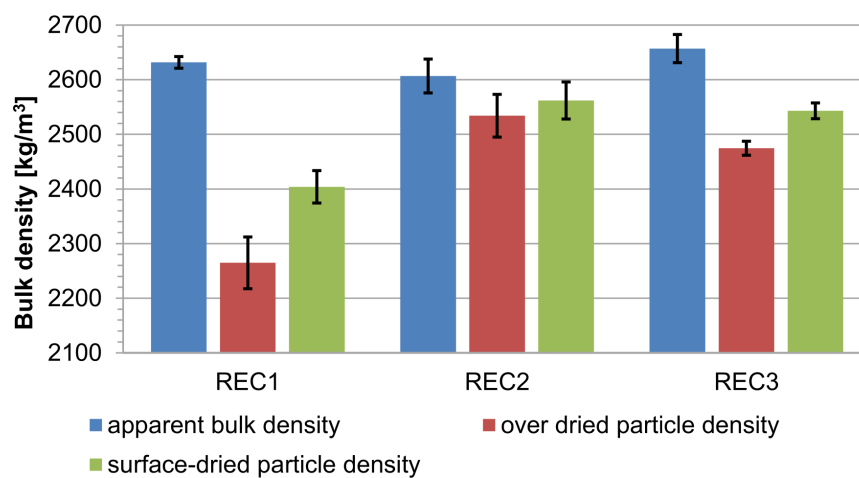


FIGURE 3. Bulk density of testing fine recycled aggregate.

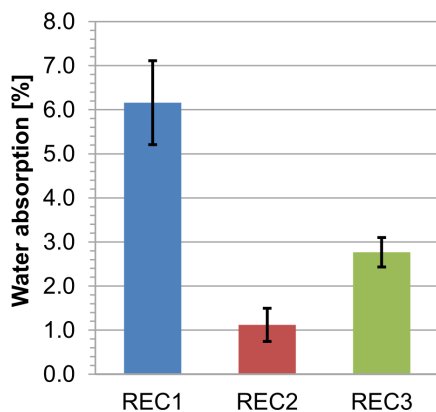


FIGURE 4. Water absorption of testing fine recycled aggregate.

REC2 and REC3, the results are considerably high, indicating the unsuitability of this test for these types of aggregates. The problem itself may be due to the difficulty in achieving the surface dried condition of the aggregate, which is the main variable of this test. Also related to the results of the bulk weights are the results of the absorption of the recyclates, which are shown in Figure 4. In relation to the previously

mentioned problem, the results for REC2 and REC3 are completely inconclusive as their absorption rates are very low compared to reality. In the case of REC1, the absorption is assumed and is based on a similar basis as in the study by Gómez-Soberón [12] and therefore this recyclate can theoretically be tested according to the existing CSN standards for aggregates for concrete.

The results of the bulk weights of hardened concrete in the saturated state are shown in Figure 5. It is possible to observe a significant reduction in the bulk weights of the R1 set concretes compared to REF, and there is a linear relationship between the replacement and the bulk weight reduction itself. The same conclusion was also reached by Cheng-Chih Fan [2].

In Figure 6, the results of the compression test after 7 and 28 days can be seen. The resulting strength of REF concrete at 7 days shows lower strengths than the concrete with 33% replacement. This may have been due to the small number of test specimens or to indiscipline in production. After 7 and 28 days, there is a rule of thumb which indicates that the compressive strength of concrete decreases as a function of replacement size, which is also confirmed by Jagan Sivamani [7].

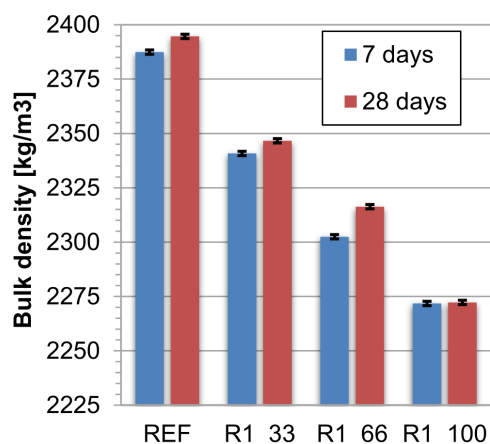


FIGURE 5. Bulk density of concrete specimens.

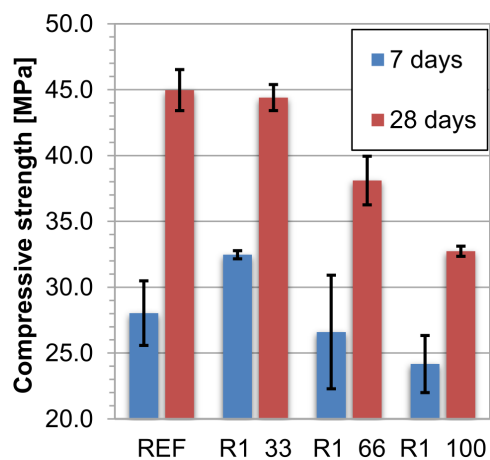


FIGURE 6. Compressive strength of concrete specimens.

6. CONCLUSION

This work was concerned with the determination of the basic properties of recycled fine aggregates, according to the available standards that apply to natural fine aggregates. At the same time, REC1 was selected, for which test bodies with 33, 66 and 100% substitutions for natural fine aggregate were produced and the effect of these substitutions on the properties of the concrete itself was investigated. In the case of fine aggregates, it can be said that REC1 (concrete recycle) can be tested according to current standards for aggregates in concrete. However, REC2 and REC3 are unsuitable for the application of these standards as it is difficult to achieve a surface dried condition of aggregates which affects the determination of their bulk density and water absorption. Concretes with a higher proportion of recycled fine aggregates have been shown to reduce the bulk density of concrete, which is also related to the resulting strength of the concrete. Concrete using 33% recycled aggregate replacement is the closest approximation to the properties of the reference concrete. The 66% and 100% replacements are already far from the reference concrete in terms of properties.

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