

PROPERTIES OF CEMENT SCREEDS USING RECYCLED FINE AGGREGATES WITH RESPECT TO CEMENT PERCENTAGE

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ABSTRACT. This article deals with the effect of 100 % replacement of natural aggregate by recycled aggregate and at the same time the effect of cement percentage on the observed properties of cement screeds. For these purposes, concrete and brick recycled aggregate is used in combination with CEM I 42.5R Portland cement, constituting 10 %, 15 %, 20 % and 25 % of the mixtures weight. To determine the properties of the cement screeds, test intervals of 3, 7, 14, 21 and 28 days are set, during which changes in bulk density are monitored. Simultaneously, destructive tests are carried out on test beams of $4 \times 4 \times 16$ cm in size. The results found that the use of recycled fine aggregates allows the production of lighter cement screeds, for example, for reconstruction. Potentially usable mixes appear to be those containing 15 %, 20 % and 25 % cement compared to recycled aggregate. For the contaminated recycle fine fraction, the flexural strength has been shown to improve. However, this improvement is not reflected in an increase in compressive strength.

KEYWORDS: Recycled aggregate, cement screed, concrete recycle, brick recycle, Portland cement.

1. INTRODUCTION

Over the last few years, people's attitudes towards recycling have changed significantly. The same applies to using recycled materials and products that are becoming part of everyday life. Unfortunately, in the construction sector, the use of it is problematic. This may be due to a lack of knowledge, insufficient standards, financial disadvantages, deteriorated properties, and people's attitudes towards building materials made from recycled materials. These barriers need to be overcome as the amount of construction waste is increasing every year. At the same time, landfill space is diminishing, and the storage of recyclable waste should be banned in the Czech Republic from 2030 [1]. On the other hand, it is very problematic to meet the high demand with the existing quarries and natural aggregate deposits. Thus, the pressure to find efficient uses for construction waste is increasing. Concrete, brick, and mixed recyclates are the most commonly encountered and can be further divided into coarse (> 4 mm) and fine (0.063–4.0 mm) recycled aggregates (RFA). Coarse aggregates are already starting to be used for recycled concrete and the number of researches looking into this application is increasing [2]. However, there is very little research on the fine fraction, even though its representation in the construction waste recycling process is significant. For this reason, this article focuses specifically on the use of the fine recycled fraction for use in cement screeds, where there is some hidden potential. These screeds currently use natural sand as a filler and are used

as leveling and spreading layers for floors in hall and apartment buildings. They are applied in small thicknesses, reaching a maximum thickness of 50 mm [2]. They can be distributed as dry bagged mix, wet mix, or as liquid cement screed [2]. Many manufacturers modify the properties of these screeds with various additives and admixtures to achieve faster strength increases and better workability [3].

Cement screeds are defined by ČSN EN 13318 [4]. Production is governed by EN 13892-1 [5] and the most common tests are described in ČSN EN 13892-2 [6]. In their studies of fresh mixtures using RFA, researchers also look at the following properties: air content, consistency of the mixture, and onset and end of solidification. In the case of hardened mortars, the most commonly monitored properties are: bulk density, flexural strength, compressive strength, and water absorption [7]. For the use of cement screed, a minimum safe flexural strength of 2 MPa is defined [3], and standard ČSN EN 13813 [8] separates cement screeds from 1 MPa. In the case of compressive strength, the lowest compressive strength is specified by the standard from 5 MPa [8]. For the use of cement screed as a contact leveling layer with the use of an additional floor covering, the minimum compressive strength is set at 12 MPa. For use in residential construction as a floating layer, the strength is set at 20 MPa, and for heavy use up to 30 MPa [9].

Existing research in the investigation of the fine recycled fraction uses the term cement screeds and mortars. The mixtures themselves in these investigations tend to be very similar and consist of aggregate,

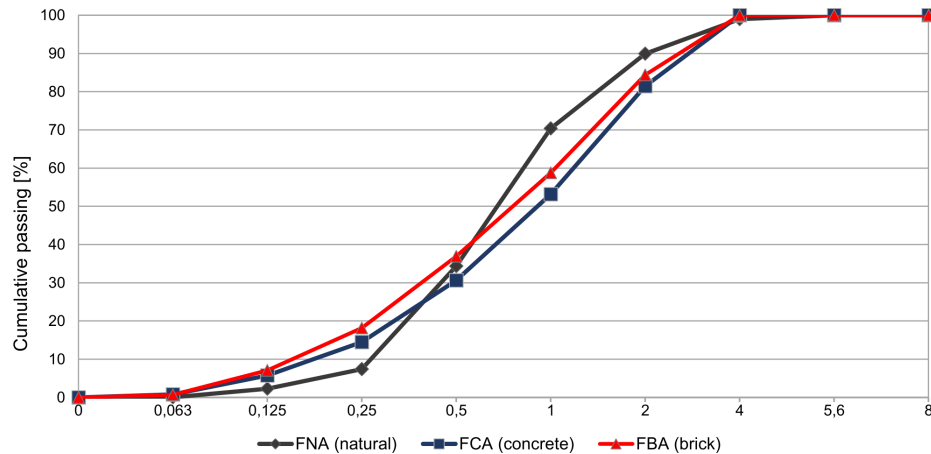


FIGURE 1. Cumulative passing.

cement, and water. For this reason, the properties of the two also agree in many respects on similar conclusions and are presented in this article. In the research carried out by Katz [7] focusing on the effect of FRA on mortars, it was found that FRA is more absorbent and therefore affects the amount of water added and thus workability. Furthermore, the quality and purity of FRA also affects the final properties, as it may contain clays, glass, and other impurities [2, 7]. More research points to deteriorating tensile and compressive strengths when using RFA [2, 7, 10, 11].

Further, some researchers agree on the conflicting results, with some studies saying that fine recycled aggregates affect the resulting mix positively and others negatively. This may be due, for example, to different approaches to incorporating absorbed water into the recycled aggregate [2, 7, 12], production process [2, 7], and the method of crushing [11].

2. MATERIALS

The recycled aggregates used in this research were supplied by company Moravostav. These are concrete recyclate (FCA) and brick recyclate (FBA). FCA was produced from clean concrete waste that was delivered from a separate demolition site and crushed using a RESTA jaw crusher. The FBA came from crushing brick rubble that was obtained from separate demolition. All these recyclates were supplied with a maximum grain size of 4 mm for production. For the reference mix, natural fine aggregate (NFA) was used, which came from the Dobříň gravel pit. For all these aggregates, their grain size curve was known (Figure 1) and also the content of pollution by washable particles (< 0.063 mm) (Figure 2). Portland cement with the designation CEM I 42.5 R from the Radotín plant was used as a binder.

3. SAMPLE PRODUCTION

Based on the mixture knowledge for cement screeds with NFA, the production ratios for mixtures using recycled fillers are shown in Table 1. This is a volume

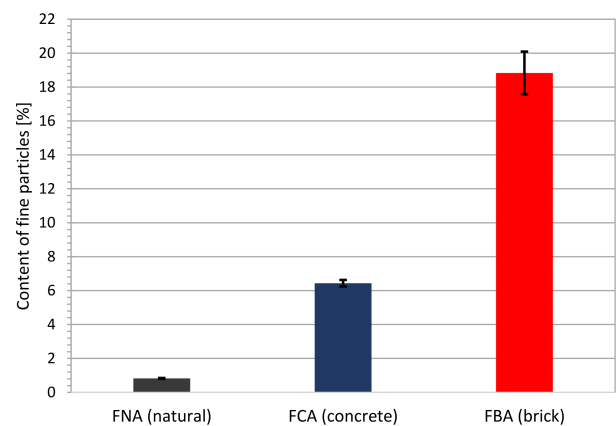


FIGURE 2. Content of fine particles.

replacement of the filler and the effect of the different percentages of cement in the mix, which was set at 10%, 15%, 20% and 25% by volume of the filler. The amount of water contained in each mixture was individually adjusted to achieve a similar consistency, which was set at $170 \text{ mm} \pm 5 \text{ mm}$. For this purpose, a shaking table was used which complies with the standard ČSN EN 1015-3.

The forms used for the test beams were $40 \times 40 \times 160$ mm in size. A total of 108 beams were produced, so 3 of each mix were allocated for each test. The test dates were set at 3, 7, and 28 days for destructive tests. The actual manufacture was carried out in accordance with the procedures described in the ČSN EN 13892-1 [5]. After fabrication, the test beams were stored for 7 days in containers of water at 20°C . They were then left in the air at 21°C and 65% humidity to ensure that the curing conditions were suitable for use on site.

4. EXPERIMENTAL METHODS

4.1. BULK DENSITY

Before each non-destructive and destructive test, the test beams were weighed, and their dimensions measured. From this knowledge, the wet and dry bulk

Set	Cement [kg m ⁻³]	Fine natural aggregate [kg m ⁻³]	Fine concrete aggregate [kg m ⁻³]	Fine brick aggregate [kg m ⁻³]	Water [kg m ⁻³]
REF 10	210	1 890			331
REF 15	315	1 785			307
REF 20	420	1 680			284
REF 25	525	1 575			272
C 10	210		1 531		301
C 15	315		1 446		293
C 20	420		1 361		305
C 25	525		1 276		310
B 10	210			1 531	396
B 15	315			1 446	390
B 20	420			1 361	399
B 25	525			1 276	399

TABLE 1. Overview of mixtures.

weights were calculated according to the scheduled test dates using the formula:

$$D = \frac{m}{V}, \quad (1)$$

where

D bulk density of saturated sample [kg m⁻³],

m mass of the fully saturated test body [kg],

V volume of the test body [m³].

4.2. FLEXURAL STRENGTH

This test is based on the ČSN EN 196-1. Laboratory hydraulic press from STRASSENTTEST was used for this test. The beams were placed on 2 supports spaced 140 mm apart and loaded at a speed of 3 mm min⁻¹ using a non-moving part located above the center of the beam until they broke. From the force required to break the beam, flexural strength was calculated according to the formula:

$$f_t = \frac{3F_{b,\max}L_s}{2ab^2}, \quad (2)$$

where

f_t flexural strength [MPa],

$F_{b,\max}$ maximum breaking force [N],

L_s distance of supports [mm],

a beam width [mm],

b beam height [mm].

A total of 108 beams were tested in this way, from which 216 halves were created for the next test.

4.3. COMPRESSIVE STRENGTH

The broken beams from the previous test were further used for the compressive strength test, which was also performed according to ČSN EN 196-1. For this test, a test press was used, which was supplemented with an insert that defined 2 areas of 40 × 40 mm. The 216 beam halves were inserted between these

sections until final failure. After deduction of the maximum achieved force, the compressive strength was calculated according to equation:

$$f_c = \frac{F_{c,\max}}{A_c}, \quad (3)$$

where

f_c compressive strength [MPa],

$F_{c,\max}$ force at the moment of breakage [N],

A_c loaded area [mm²].

5. RESULTS AND DISCUSSION

The bulk density results (Figure 3) show a gradual decrease in the bulk density of the cement mortar over time. The significant differences between the initial and final measurements are due to the decreasing amount of water in the mortar due to drying and hydration of the cement. Linear increases in the bulk weights of the mixtures with increasing cement percentage can be observed. This is due to the higher bulk density of cement, which proportionally replaces the lighter filler. The decreasing bulk density of cement mortar when substituting filler is also confirmed by Hubáček [2] in his research at FCA and also Mora-Ortiz [12], who researched the FBA.

When comparing REF, C and B mixtures, we can conclude the suitability of mixtures with recycled fine aggregate, as the differences reach values up to 300 kg m⁻³. This is due to the higher porosity and lower bulk density of the recyclates used compared to the natural aggregate. This could be used, for example, in the reconstruction of old buildings where overloading of the structure is undesirable.

From the results on Figure 4, there is a linear increase in flexural strength for all mixes with increasing time and percentage of cement, which is the expected result. For short-term strengths, mixes using C and B with 10 and 15 % cement are even more resistant to failure compared to mixes with FNA filler. From the

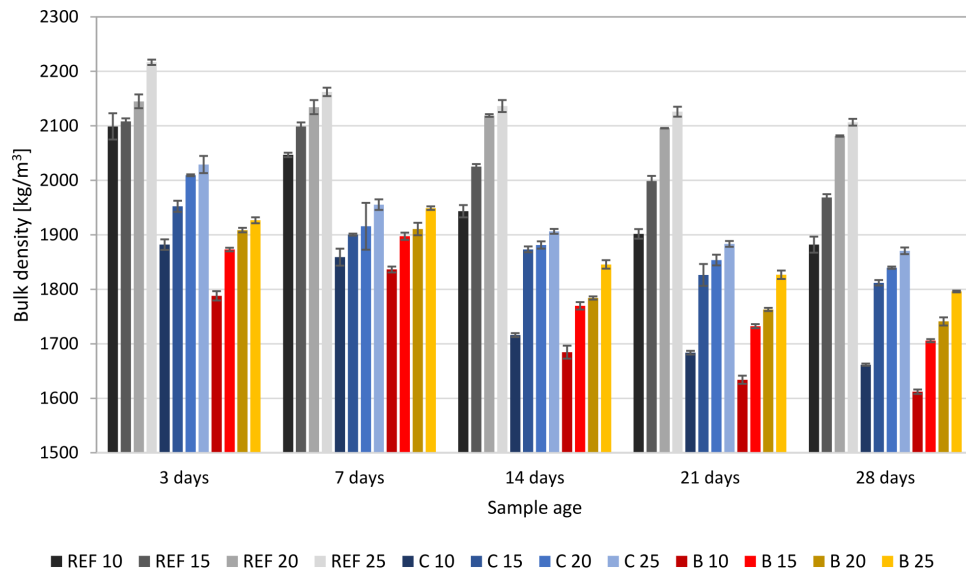


FIGURE 3. Bulk density.

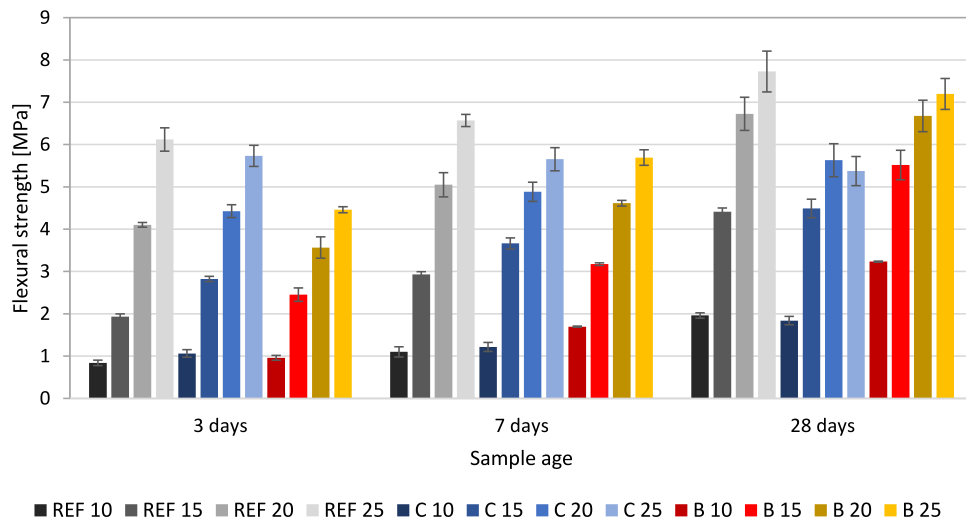


FIGURE 4. Flexural strength.

point of view of allowing light loads, mixes with B 20, B 25, C 20, and C 25 appear to be suitable after only 3 days. Looking at the strengths after 28 days, there is a more significant increase in strength for C 15, C 20, and C 25 compared to B mixes. This may be due to the higher proportion of finer grains in the delivered FBA, which is evident from Figure 2. Similar trends in the use of FCA have been achieved by Katz [7] and Hubáček [2], who also describe decreasing flexural strengths compared to reference mixtures.

Figure 5 shows the compressive strength results after 3, 7, and 28 days. The results show a linear increase in strength over time for all aggregates used. During the first 3 days, the C 15 and C 20 mixes achieve higher or equal strengths compared to the reference mixes. Mixture B achieves noticeably poorer strengths during the first 7 days compared to the others. Of note are mixes B 15 and B 25 at 28 days, which have comparable strengths to mixes C 15 and C 25. One possible explanation also according to

Hubáček [2] is the effect of a higher proportion of washable particles on the filling of the space between the individual grains in the cement mortar. The effect of 100% replacement of aggregate with fine recyclates on the inferior strengths compared to the reference mixes is also consistent with research conducted by Katz [7] and Fan [11] for concrete recycle and Mora-Ortiz [12] for brick recycle.

6. CONCLUSION

This article investigated the effect of fine recycled aggregate (concrete and brick) on the performance of cement screeds at 10, 15, 20, and 25% cement content in the mix with full replacement of natural fine aggregate. Cement screeds with recycled fine aggregates have the great advantage of a lower bulk density compared to natural aggregates and can therefore be used in applications requiring low weight.

For the flexural strength, the concrete recycle has worse strengths after 28 days compared to brick with

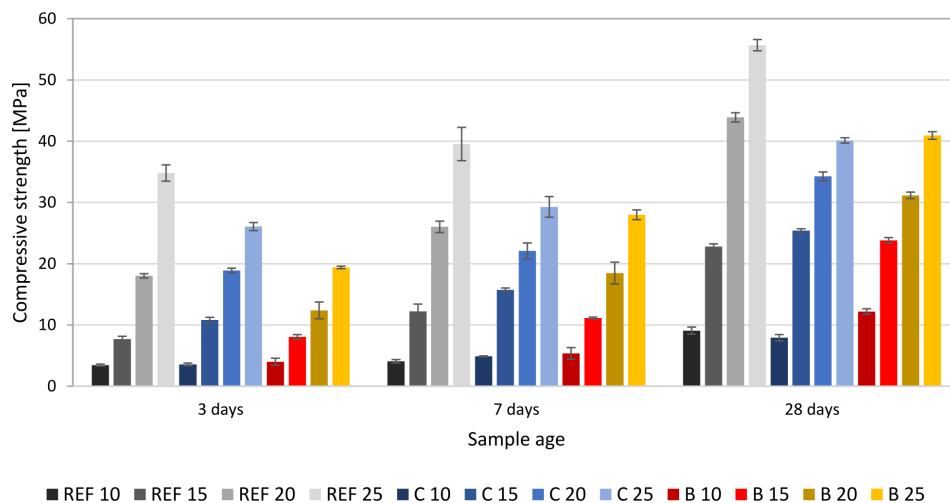


FIGURE 5. Compressive strength.

the same cement content. Furthermore, mixes with recyclates and at least 20 % cement content appear to be suitable for light loads within 3 days of placement. The flexural strength itself is positively influenced by the higher fraction < 0.063 mm.

The compressive strength has a negative effect when using the recycled fines fraction and the resulting strength compared to the reference mixes. Mixes containing concrete and brick recycle and at least 25 % cement and achieving approximately the same strengths, but not the strengths of the reference mixes. Mixtures C 15, C 20, C 25, B 15, B 20, and B 25 meet the requirements for use as leveling and base layers for residential construction, as they reach compressive strengths higher than 20 MPa and flexural strength higher than 2 MPa.

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