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MECHANICAL PROPERTIES OF SELF–COMPACTING CONCRETE WITH COARSE RECYCLED AGGREGATE

Summary

Use of recycled aggregates, obtained by crushing old concrete, presents one of the solutions offered by the concept of sustainable development. This paper includes an overview of available literature regarding the application of recycled aggregates in the production of self–compacting concrete and its aim is to determine the impact of changes in some properties of self–compacting concrete, according to the percentage content of coarse recycled aggregate. On the basis of the analysis results in the presented scientific papers, we established the changes in flow diameter and compressive strenght, depending on the amount of the applied recycled aggregates.

Key words

Self–Compacting Concrete – SCC, recycled concrete aggregate, compressive strenght

MEHANICKE KARAKTERISTIKA SAMOUGRAĐUJUCEG BETONA SA KRUPNIM RECIKLIRANIM AGREGATOM

Rezime

Upotreba recikliranog agregata, dobijenog drobljenjem starog betona predstavlja jedno od rešenja koje nudi koncept održivog razvoja. Ovaj rad obuhvata pregled dostupne literature u vezi primene recikliranog agregata za izradu samougrađujućeg betona i ima za cilj da odredi uticaj promene nekih mehaničkih karakteristika samougrađujućeg betona u zavisnosti od procenta sadržaja krupnog recikliranog agregata. Na osnovu analize rezultata u prikazanim naučnim radovima ustanovljena je promena prečnika rasprostiranja i čvrstoće pri pritisku u zavisnosti od količine primenjenog recikliranog agregata.

Ključne riječi

Samougrađujući beton, reciklirani betonski agregat, čvrstoća pri pritisku

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1. INTRODUCTION

The concept of sustainable development, which besides social and economic aspects includes energy–saving, environmental protection and the conservation of exhaustible natural resources, impose the use of recycled aggregates as a solution of two significant problems in the in civil engineering. There is a lack of natural aggregates in urban areas and increasing of the distance between the sources of natural aggregates and construction sites, as well as the problem of removal and disposal of large quantities of concrete waste. The construction industry uses vast amounts of natural resources, simultaneously producing significant amounts of debris, which has a large impact on the environment. Annual production of concrete in the world has reached 10 billion tons, which classifying it as the most widely used construction material. Regards to the fact that about 70 % of concrete is actually an aggregate, it is clear the how much of the quantities of natural and crushed aggregates is required. The uncontrolled exploitation of aggregates from rivers seriously disrupts aquatic ecosystems and habitats, while production of crushed natural aggregates increases emission of harmful gases, primarily CO_2, responsible for the greenhouse effect. On the other hand, the amount of construction waste generated during construction and demolition process is growing rapidly, deepening problem of waste disposal, which is usually resolves by established (which are occupying large areas and waste disposal is expensive) or "wild" – illegal dumps [1]. From these reasons, the use of recycled concrete aggregate in concrete is very important.

2. RECYCLED CONCRETE AGGREGATE

Recycled aggregate consists of the original aggregate and cement mortar layer remaining of the old concrete. Physical and mechanical properties of recycled aggregate dependent on the properties, as well as on the quantity of remaining mortar, which range is from 25 % to 65 % (given in volume percentages) and varies by individual fractions – a smaller fraction, the greater the amount of cement mortar so that some authors restrict the use of recycled first fraction [2]. Regardless of the certain minor differences in respect of recycled concrete aggregate properties, recycled aggregate has generally, in relation to the natural aggregate, the following properties: higher water absorption, lower density, higher abrasion, higher crushing, a greater amount of powder percentage, higher content of organic substances and possible content of harmful chemical substances, which imply previous detailed testing. In order to remove the hardened cement paste from aggregate grain, it has been developed several advanced recycling technology primarily in Japan, One of them is the so–called "method of heating and scraping." With this is possible to made 35 % to 45 % of pure coarse aggregate, 30 % to 35 % of pure and 18 % to 35 % of fine powder of the cement mortar, accordingly to the heating temperature (300°–700° C) [2]. Another technology is chemical treatment of classically produced recycled aggregates. By previous soaking of recycled aggregate in a mild solutions of hydrochloric, sulfuric or phosphoric acids, it is possible to remove part of cement mortar and to improve the properties of aggregate, without a significant increase of chloride and sulfate in it. This procedure includes soaking of the recycled aggregate in an acidic environment for a period of 24 hours at a temperature of about 20° C, and further rinsing with distilled water in order to eliminate the maximum of possible applied acids. Prior to actual concrete mixing,

aggregate should be in the water for 24 hours. In order not to reduce the quality of aggregate (pH value), the concentration of acid in the solution should be about 0,1 mol [3,4].

3. REVIEW OF THE LITERATURE

Recycling of waste concrete is important from the viewpoint of preventing environmental pollution and reducing the consumption of natural aggregates. With the increasing interest in the use of self–compacting concrete, the possibility of using recycled aggregates to make self–compacting concrete, has also been examined.

One of the first studies dealing with the application of recycled aggregates for making self–compacting concrete, is the test performed by S. C. Kou and C. S. Poon [5]. They tested the properties of self–compacting concrete made using fine and coarse recycled aggregates, whereby the replacement of coarse aggregate was done 100 %, while the replacement of fine aggregate was done by 25 %, 50%, 75 %, and 100 %.

Properties of self–compacting concrete, made with coarse recycled aggregate of crushed old concrete, were presented in the paper by Z. J. Grdić, G. A. Topličić–Ćurcić, I. M. Despotović, N. S. Ristić [6]. For concrete mixes with natural and coarse recycled aggregate, the requirement was to achieve the same consistency of fresh concrete mixes, wherein the replacement of coarse recycled aggregate was 50% and 100%.

Properties of self–compacting concrete in the fresh state, made with coarse recycled aggregate, were tested by M. D. Safuddin, M. A. Salam, M. Z. Jumaat [7]. Mixes in which coarse aggregate was partly or completely replaced by recycled aggregates (30 %, 50 %, 70 %, 100 %) were examined in terms of mobility, passing ability, and resistance to segregation.

Properties of self-compacting concrete, made with coarse recycled aggregate, were tested by K. C. Panda, P. K. Bal [8]. They compared mechanical properties, in the fresh and in the hardened state, of conventional vibrated concrete and self–compacting concrete with 100 % natural aggregate, to self–compacting concrete in which 10 %, 20 %, 30 %, and 40 % of coarse aggregate was replaced by recycled aggregate.

Possible application of coarse aggregate and evaluation of mechanical properties of self–compacting concrete were examined by P. O. Modani, V. M. Mohitkar [9]. Replacement of coarse aggregate by recycled aggregate was done from 20 % to 100 %, gradually by 20 %. Mechanical properties of self–compacting concrete with coarse recycled aggregate were treated in accordance with the recommendations of EFNARC.

L. A. Pereira–de–Oliveria and others, in their papers [10,11], examined the possibility of using coarse recycled aggregate for making self–compacting concrete. Results of testing mechanical properties of self–compacting concrete with 10 %, 20 %, 30 %, and 40 % of coarse aggregate are presented in the paper [10], while the properties with the replacement of 20 %, 40 %, and 100 % are shown in the paper [11].

The application of recycled aggregates in making self–compacting concrete was examined by M. Seethapathi, S. R. R. Senthilkumar, K. Chinnaraju [12]. In this investigation, they made self–compacting mix by replacing natural coarse aggregate with recycled aggregate of 10 %, 20 %, 30 %, and 40 %, wherein the quantity of cement was constant in all the mixes.

Aggregates made by recycling prefabricated elements, damaged in the production process, were applied in the investigation by B. Milošević, M. Mijalković, Ž. Petrović, S. Ranković [13]. Based on the condition of equal consistency, they defined mechanical properties of the mix, in the hardened and fresh state, in which 50 % and 100 % of coarse recycled aggregate was replaced.

Based on the condition that the projected compressive strength is 30 MPa, S. K. Sam, D. Varkey, E. John [14] examined mechanical properties of self–compacting concrete with recycled aggregate. In their investigation, they compared the properties of self–compacting concrete with 10 %, 20 %, and 30 % of recycled aggregate, to self–compacting concrete with natural aggregate, as well as to conventional vibrated concrete.

In their research, B. Ajrun, M. R. Gowda [15] tried to make self–compacting concrete mix with recycled aggregate meet the criteria of Nan Su method, as well as of the guidelines defined by EFNARC. Coarse aggregate was replaced from 25 – 60 %, gradually by 5 %, by recycled aggregate, wherein mechanical properties in the fresh and hardened state were determined.

Based on the review of research conducted so far, it can be noted that the replacement of coarse aggregate by recycled aggregate up to 50 % is more prevalent as compared to the tests dealing with replacing of more than 50 % of coarse aggregates, while only one of the analyzed papers examines the application of fine recycled aggregate.

3.1. ANALYSIS OF THE RESULTS OF PREVIOUS RESEARCH

The analysis of the results for all designed mixes presented in the researches conducted so far, shows inconsistency of determining the mechanical properties, both in the fresh and in the hardened state. Mechanical properties of self–compacting concrete in the fresh state actually define this concrete and they are regulated by EFNARC [16] and based on EN 206–9–2010 [17]. In all the papers, Slump–flow test results are shown, while the results of T 500, L–box, and V–funnel tests are in many papers omitted. On the basis of the analysis results of Slump–flow test, Figure 1 shows the correlation between percentage change of coarse recycled aggregates and flow diameter.

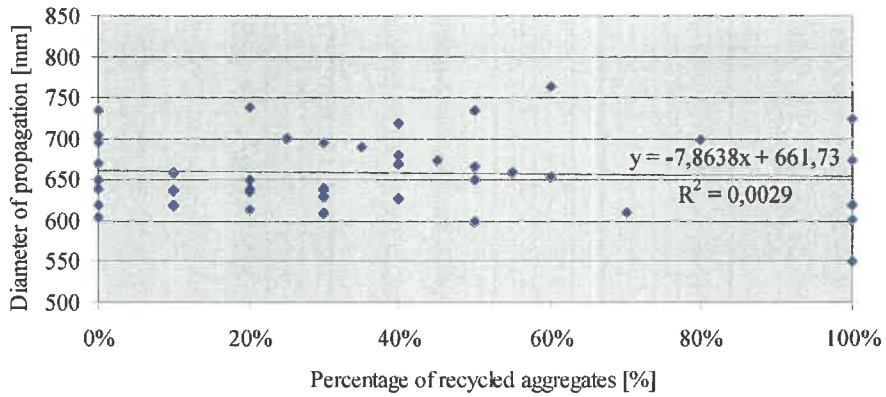

Figure 1. Correlation between percentage of recycled aggregates and diameter of propagation

Changes in flow diameter of fresh concrete slab, using Slump–flow test, depending on the amount of recycled aggregate, can be noticed on the basis of the analysis results presented in studies. Using linear approximation, the average change of flow diameter of fresh self–compacting concrete slab with 100 % of the coarse recycled aggregate, as compared to the mix with natural aggregates, is 7,8 cm.

In the analyzed papers, the results of presented tests of mechanical properties of self–compacting concrete with recycled aggregates in the hardened state, are not mutually adjusted. All the analyzed papers present the determination of compressive strength; determination of tensile strength was performed both by splitting and bending, while determination of modulus of elasticity is shown only in two papers. On the basis of the test results shown in the analyzed papers, Figure 2 shows the correlation between percentage of coarse recycled aggregates and compressive strength.

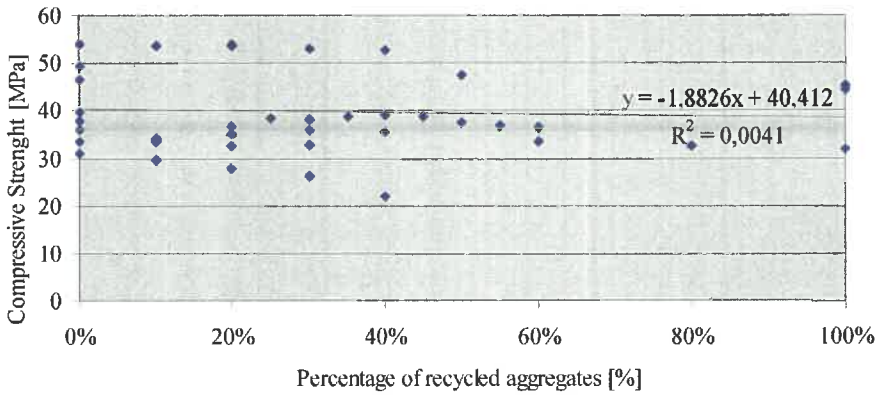

Figure 2. Correlation between percentage of recycled aggregates and compressive strenght

Using linear approximation, it can be seen that decrease of compressive strength of self–compacting concrete with 100 % of recycled aggregates in relation to the mix with 0 % recycled aggregates, is 1,88 MPa. It can be said that the influence of the quantity of recycled aggregate on the decrease of concrete compressive strength is insignificant.

4. CONCLUSION

Based on the analysis of the results of research so far conducted, related to the possible use of recycled aggregates to make self–compacting concrete, the following conclusion can be drawn: although the guidelines for testing the mechanical properties of self–compacting concrete are given in EFNARC and EN 206–9: 2010 regulations, in the analyzed papers, presented examinations are not coordinated, and presentation of results is arbitrary. In their papers, the authors suggest that the optimal replacement of coarse natural aggregates by recycled aggregates is up to 50 %. Changes in flow diameter of fresh concrete slab, as well as in concrete compressive strength, is less than 10 % in relation to the properties of self–compacting concrete with natural aggregate, so that the use of recycled aggregates is fully justified.

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