EVALUATION OF SCC MIXTURES WITH THE COMBINED USE OF CRUMB RUBBER AND RECYCLED CONCRETE AGGREGATE

Marko Popovic[1], Marina Latinovic Krndija[2], Aleksandar Savic[1]
[1]University of Belgrade, Faculty of Civil Engineering, Belgrade, Serbia
[2]University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy, Bosnia and Herzegovina

ABSTRACT: *Adopting sustainability in the construction industry emerged as crucial to achieving the United Nations Global Goals for Sustainable Development (SDGs). Rapid growth in the construction sector strains raw material resources such as natural aggregates (NA), possibly leading to their depletion. Furthermore, the growth of construction and demolition waste (CDW) intensifies the global issue of waste management as one of the largest waste streams worldwide. Since concrete is the main constituent of CDW, its recycling as aggregate (RCA) emerges as a prominent solution to the above-mentioned problems. On the other hand, potentially hazardous disposal of end-of-life tyres (ELTs) is another increasing waste problem. Incorporating recycled tyre rubber in concrete mixtures as a substitute for natural aggregates is one possible solution. This paper aims to give some insights into the possibility of using crumb rubber (CR) and recycled concrete aggregate (RCA) as alternative aggregates in self-compacting concrete (SCC) mixtures. For that purpose, the physical and mechanical properties of prepared SCC mixtures with CR and RCA were evaluated by tests performed on fresh and hardened concrete.*

Key words: *Self-Compacting Concrete; crumb rubber; recycled concrete aggregate;*

1. INTRODUCTION

Concrete is the most widely used construction material around the world with a comparable environmental footprint. Cement and concrete production is energy and emissions intensive process with a high demand for natural resources such as aggregates. In addition to that concrete is among the major contributors to one of the largest waste streams known as construction and demolition waste (CDW). On the other side, the enormous growth in the volume of end-of-life tyres (ELTs) and waste management of this "black pollution" is a global sustainability issue.

A promising and sustainable solution to the over-exploitation of natural aggregate (NA) and CDW and ELTs disposal problem is the use of recycled concrete and crumb rubber as aggregate. In this paper, the previously mentioned sustainable solution is combined with the benefits of self-compacting concrete (SCC) – untreated crumb rubber (CR) was used as a substitute for fine NA, while coarse NA was replaced by recycled concrete aggregate (RCA) in prepared SCC mixtures.

2. EXPERIMENTAL CAMPAIGN

To estimate the possibilities and limitations of using the SCC mixtures with RCA and untreated CR in structural elements, fresh and hardened state tests were performed. In the fresh state, bulk density was measured, and filling and passing ability were assessed based on the results of the slump flow test and L-box test. In the hardened state, compressive and flexural tensile strength, ultrasonic pulse velocity (UPV), water permeability and pull-off bond strength tests were conducted. Three SCC mixtures were prepared – the reference mixture ("REF"), mixture with 100% coarse RCA (R_0C_{100}) and mixture with 20% CR (by volume of fine NA) and 100% coarse RCA ($R_{20}C_{100}$).

Figure 1: SCC components used in this research – NA fractions I, II and III, untreated CR and RCA fractions II and III, limestone powder (LP), portland-composite cement CEM II/A-M(S-L)42,5R, superplasticizer (SP) and water from the city water-works

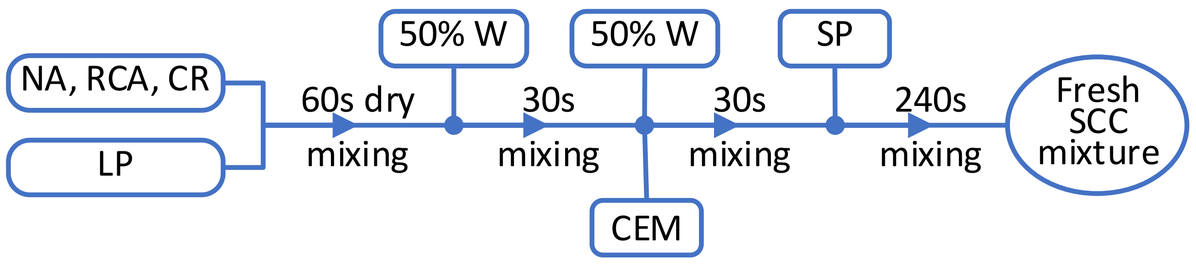

Figure 2: Two-stage mixing approach (TSMA) – to overcome the impact of RCA's high water absorption on fresh and hardened state performance, mixtures were prepared by TSMA procedure and with equal effective water-cement ratio – w/ceff = 0.45.

3. RESULTS AND DISCUSSION

Table 2: Properties of SCC mixtures in fresh state

Mixture label	Slump flow diameter		Slump flow t500		L-box PA (3 bars)		Bulk density
	[mm]	flowability class	[s]	viscosity class	[/]	PA class	[kg/m³]
REF	840	SF3	2,2	VS2	0,99	PA2	2405
R_0C_{100}	790	SF3	2,4	VS2	0,88	PA2	2353
$R_{20}C_{100}$	770	SF3	3,1	VS2	0,88	PA2	2244

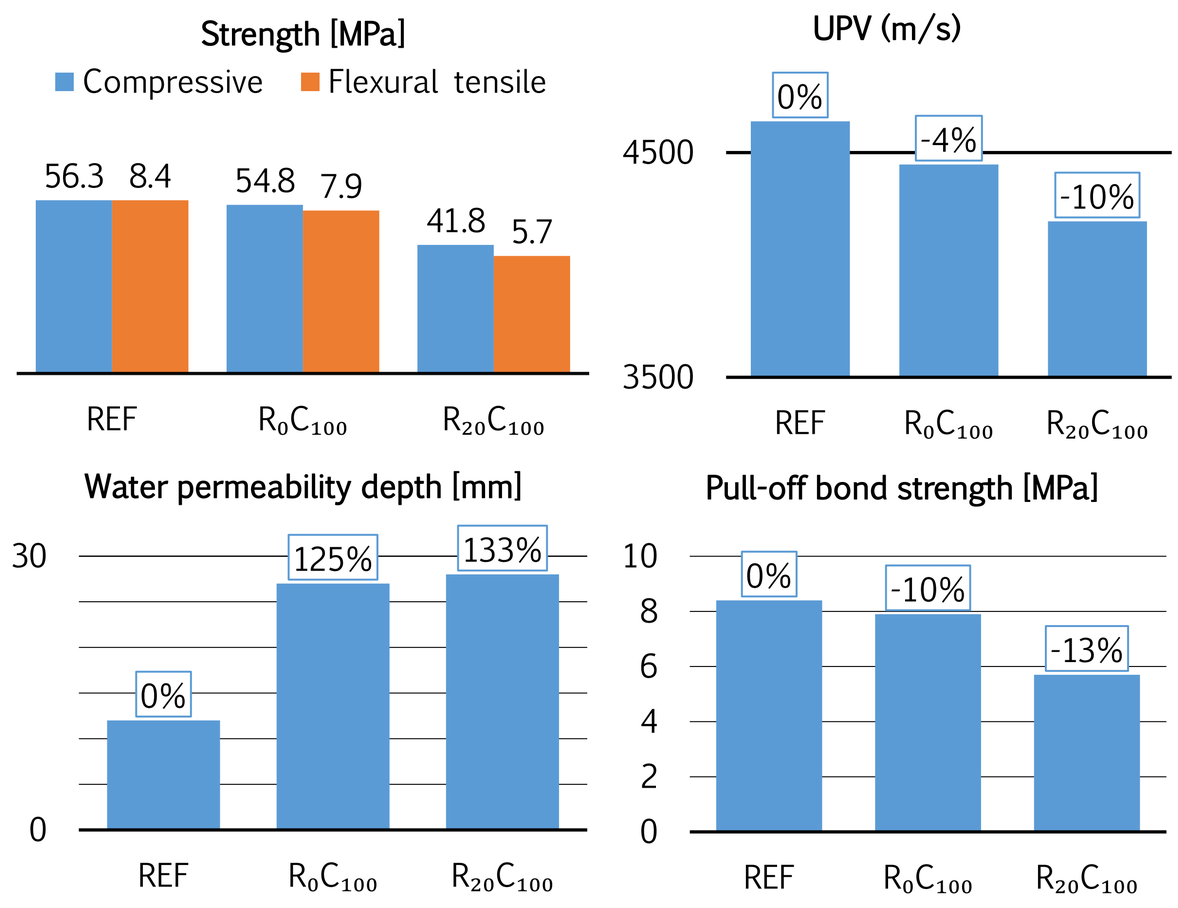

Figure 3: Hardened state properties of SCC mixtures

4. SUMMARY AND CONCLUSIONS

Fresh and hardened SCC test results that are presented and discussed in this paper were used to form the following conclusions:

- Both filling and passing ability decreased by replacing the NA with coarse RCA and CR as fine aggregate. However, the mixtures with RCA and CR intrusion satisfied the workability requirements for SCC and reached the same classification as the reference mixture. All three mixtures were classified as SF3 for flowability, VS2 for viscosity and PA2 in terms of passing ability.
- The usage of coarse RCA had a negligible effect on strength values, while the incorporation of CR decreased compressive and flexural tensile strength values by 26% and 32%, respectively.
- The mixtures with replacement aggregates had up to 10% smaller values of UPV, but far above the lower limit for concrete homogeneity and quality to be classified as "good".
- The pull-off test results showed that bond strength decreased up to 13% for mixtures with RCA and CR intrusion.
- The water tightness of prepared SCC mixtures was tested as a durability indicator – the usage of RCA and CR increased the penetration depth by 133%, but still had values under 30 mm, meaning that mixtures can be classified as "impermeable under aggressive conditions".