INFLUENCE OF SUPERPLASTICIZER TYPE AND DOSAGE ON RETENTION OF CONSISTENCY OF RUBBERIZED CONCRETE

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ABSTRACT

Concrete with recycled rubber as a partial replacement of fine natural aggregate, intended for use in load-bearing structural elements, requires specific fresh concrete properties such as a particular slump and flow classes. These specific requirements can be caused by increased water or superplasticizer content. Therefore, concrete mixtures with different percentages of two types of superplasticizers A1 and A2, i.e. 0.2, 0.4 and 0.6% by cement mass, were prepared. Furthermore, the effect of retention of consistency after 15, 30, 45, 60, and 90 minutes, was also studied. Slump and flow table tests were performed at 15-minute intervals to determine the fresh performance of each concrete mixture and retention of consistency. Test results indicate that mixtures with superplasticizer A2 show a more uniform workability range during the measurement period and at the end of the measurement, remain within the same consistency classes, as in the initial measurement.
Keywords: recycled rubber aggregate, superplasticizer, slump, workability, retention of consistency.

1 INTRODUCTION

Due to a large number of unusable waste tires from different types of vehicles, common disposal methods such as landfilling and incineration can cause serious ecological problems, either because of rapid site depletion or air pollution [1]–[3]. Various associations around the world are promoting a circular economy and sustainable development, recycling of scrap tires, and reuse of tires by adding new value to the recycled material. One of the ways to reuse waste rubber is to add it to concrete as a replacement for natural aggregates. The use of recycled rubber as a partial aggregate replacement has the following effects on concrete: reduction of water content, reduction of workability, and may affect mechanical properties due to insufficient bonds between cement paste and rubber [4]–[7]. Concrete with recycled rubber as a partial replacement for fine natural aggregate intended for use in load-bearing structural elements requires specific fresh concrete properties such as a particular slump and flow class. These specific requirements can be caused by increased water or superplasticizer content. Superplasticizer is a type of water reducer. Superplasticizer significantly reduces the amount of water required when mixing the concrete [8]. The effects of superplasticizer are obvious, that is, producing concrete with very high workability or concrete with very high strength. The mechanism of a superplasticizer is through giving the cement particles a highly negative charge so that they repel each other due to the same electrostatic charge. By deflocculating the cement particles, more water is provided for concrete mixing [9]. Although numerous studies have been conducted with different types of chemical admixtures, very few of them addressed the effect of chemical admixtures on the properties of prolonged mixed concrete [10]–[16]. The objective of this study was to determine the effects of two commercially available superplasticizers on rubberized concrete, focusing on how dosage and type affect the properties of fresh rubberized concrete and retention of concrete consistency during the 90 min period.

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2 MATERIAL CHARACTERISTICS AND PREPARATION

2.1 Materials

Concrete mixtures were prepared using recycled rubber 0–4 mm as a partial replacement for fine natural aggregate. Normal Portland cement CEM I 42.5R (characteristic values of mechanical, physical, technical properties, and requirements according to the standard HRN EN 197-1:2011), 5% silica fume (RW-Fuller, properties and requirements according to the standard HRN EN 13263-1:2009), crushed dolomite as coarse aggregate, natural sand from the river Drava as fine aggregate. Two types of the mix were prepared, all with a w/c ratio of 0.45. Mixtures R10-0.2-A1 to R10-0.6-A1 are mixtures corresponding to concrete class C30/37, 160–210 mm slump, 490–550 mm and 1.5% air content, with 10% of crumb rubber and different percentages of superplasticizer A1 (0.2% to 0.6%). Mixtures R10-0.2A2 to R10-0.6-A2 are mixtures in the same ratio as before, but with different percentages of superplasticizer A2 (0.2% to 0.6%). Two different types of superplasticizers were used. Both superplasticizers are based on modified polycarboxylate ethers, which have a strong plasticizing effect of homogenizing concrete. The differences between superplasticizer Energy FM 500 marked as A, and Energy FM 500NX marked as A2 are listed in Table 1.

Table 1: Differences between superplasticizers A1 and A2.

A1	Influence on rheological properties	■	■	■		
	Maintaining level of consistency	■	■	■	■	
	Early strength	■	■			
A2	Influence on rheological properties	■	■	■	■	■
	Maintaining level of consistency	■	■	■		
	Early strength	■	■	■		

2.2 Mixture design and testing method

Table 2 shows the mixture proportions in this experiment. The influence of two types of polycarboxylate superplasticizers A1 and A2 on workability, i.e. slump and flow, was tested.

Table 2: Mixture proportions.

Mark	Weight per unit volume (kg/m^3)							Admixture (%)	
	C	SF	FA	FR	CA	S	W*	A1	A2
R10-CEM-I	427.5	22.5	437.5	65.8	812.9	323.6	212.6	0	0
R10-CEM-I-0.2-A1	427.5	22.5	437.0	65.8	811.9	323.3	212.6	0.2	0
R10-CEM-I-0.4-A1	427.5	22.5	436.4	65.8	810.9	322.8	212.6	0.4	0
R10-CEM-I-0.6-A1	427.5	22.5	435.9	65.8	809.8	322.4	212.6	0.6	0
R10-CEM-I-0.2-A2	427.5	22.5	437.0	65.8	811.9	323.3	212.6	0	0.2
R10-CEM-I-0.4-A2	427.5	22.5	436.4	65.8	810.9	322.8	212.6	0	0.4
R10-CEM-I-0.6-A2	427.5	22.5	435.9	65.8	809.8	322.4	212.6	0	0.6

* k-concept, (w/c = w/(c+k×a))

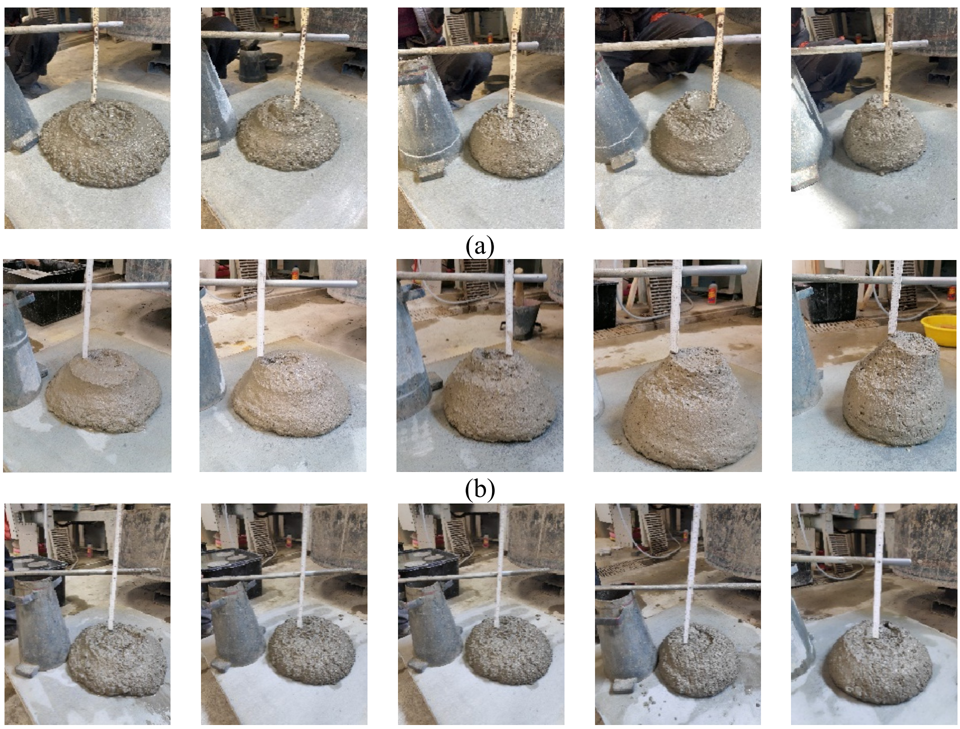
The ambient temperature was 25°C ± 2°C when the mixtures were prepared. The consistency of the fresh concrete was determined with slump-test in accordance with HRN

EN 12350-2:2019 and flow of fresh concrete in accordance with flow table test HRN EN 12350-5:2019. A total of seven concrete mixtures, with 10% crumb rubber as a partial replacement for fine aggregate and with different admixtures (A1 and A2), were subjected to a mixing period during 90 minutes. Slump and flow tests were carried out for concrete mixtures subjected to prolonged mixing at 15-minute intervals. The concrete was mixed in a pan mixer with a capacity of 120 litres. Each mixture was initially mixed for 8 minutes to ensure its homogeneity. The mixer was stopped at 15-minute intervals to conduct slump and flow tests. The mixing process of each concrete mixture was continued for 90 minutes.

3 RESULTS OF EXPERIMENTAL TESTING

3.1 Influence of superplasticizer type and dosage on concrete workability

Fig. 1 shows examples of slump-tests after 0 minutes, 15 minutes, 30 minutes, 45 minutes, and 60 minutes. It can be seen how the workability of the mixtures decreases with time. As the amount of A1 and A2 adsorbed on the cement particles continues to increase, the slump loss of paste fluidity is slowed. Figs 2 and 3 show the test results of slump-tests of the rubberized concrete mixtures. The data are recorded and shown to observe the relationship between superplasticizer dosage and slump loss.



(a)

(b)

(c)

Figure 1: Examples of measured slump-test on mixtures. (a) R10-CEM-I; (b) R10-CEM-I-0.2-A1; and (c) R10-CEM-I-0.2-A2.

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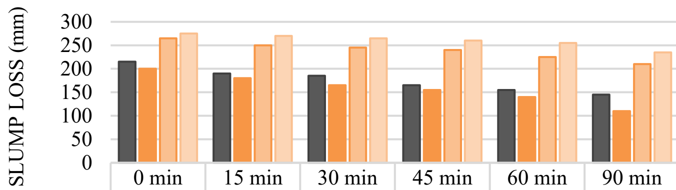
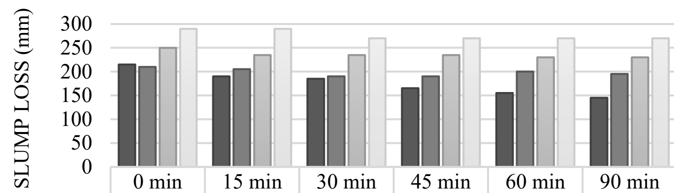


	0 min	15 min	30 min	45 min	60 min	90 min
R10-CEM-I	215	190	185	165	155	145
R10-CEM-I-0.2-A1	200	180	165	155	140	110
R10-CEM-I-0.4-A1	265	250	245	240	225	210
R10-CEM-I-0.6-A1	275	270	265	260	255	235

Figure 2: Results of the slump-test for mixtures with A1.



	0 min	15 min	30 min	45 min	60 min	90 min
R10-CEM-I	215	190	185	165	155	145
R10-CEM-I-0.2-A2	210	205	190	190	200	195
R10-CEM-I-0.4-A2	250	235	235	235	230	230
R10-CEM-I-0.6-A2	290	290	270	270	270	270

Figure 3: Results of the slump-test for mixtures with A2.

Fig. 4 shows the plot between slump loss and superplasticizer dosage at a w/c ratio of 0.45. It can be seen that the minimum slump loss occurs at a dosage of 0.2% and that the optimum superplasticizer dosage for the workability criteria after 90 minutes is 0.4% for A1 and 0.2% for A2 superplasticizer. Fig. 4 shows the change in slump over time for different dosages of superplasticizer. From Fig. 4 it can be seen that the slump decreases with time. This behaviour is acceptable because the continuous hydration process produces calcium silicate hydrate, which fills the pores between the cement particles and the aggregate. As a result, the setting of the concrete will reduce the fluidity of concrete and, consequently, the slump.

Since superplasticizer helps to retain the concrete in liquid state for a longer time, a higher admixture dosage decelerates the setting rate of the concrete. This potentially reduces slump loss during transport of the concrete to the construction site. An overdose of the admixture (0.6% of A1 and A2) leads to a high slump loss, which does not lead to the expected and desired behaviour. On the other hand, it can be concluded that superplasticizer A2 is more effective in maintaining the slump of the concrete with the recycled rubber than superplasticizer A1 or the reference concrete without admixture.

The workability of each mixture was also determined with the flow table. Flow table test was performed according to HRN EN 12350-5:2019. Figs 5 and 6 show the test results of the

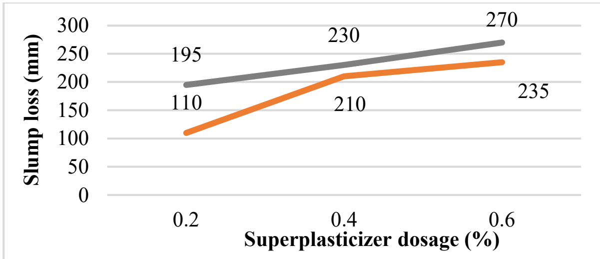
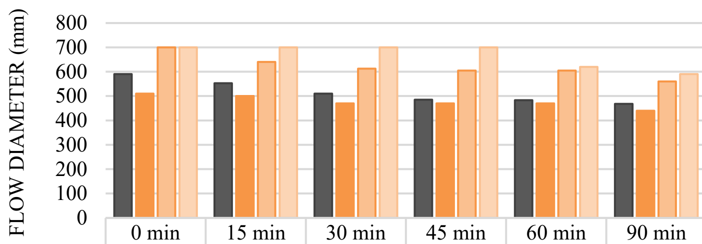
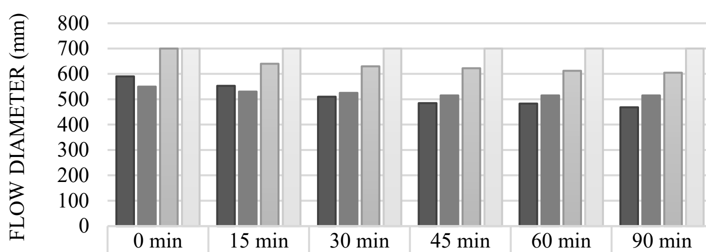


Figure 4: Slump loss vs dosage of superplasticizer.



	0 min	15 min	30 min	45 min	60 min	90 min
R10-CEM-I	590	553	510	485	483	468
R10-CEM-I-0.2-A1	510	500	470	470	470	440
R10-CEM-I-0.4-A1	700	640	612.5	605	605	560
R10-CEM-I-0.6-A1	700	700	700	700	620	590

Figure 5: Results of the flow-test for mixtures with A1.



	0 min	15 min	30 min	45 min	60 min	90 min
R10-CEM-I	590	553	510	485	483	468
R10-CEM-I-0.2-A2	550	530	525	515	515	515
R10-CEM-I-0.4-A2	700	640	630	622.5	612.5	605
R10-CEM-I-0.6-A2	700	700	700	700	700	700

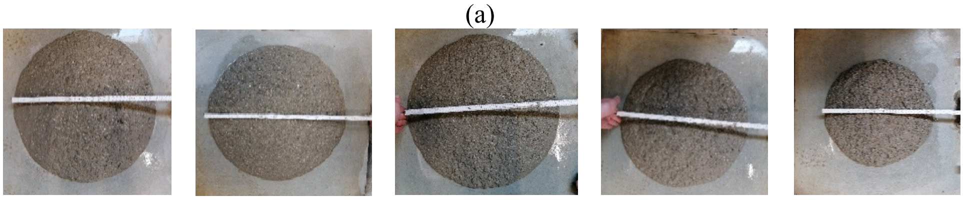
Figure 6: Results of the flow-test for mixtures with A2.

tested mixtures. The average of the two measured values of the concrete diameter was recorded, as shown in Figs 5 and 6. There is no visible bleeding or segregation of concrete mixtures, and the use of stabilizing agents was not required. Compared to superplasticizer

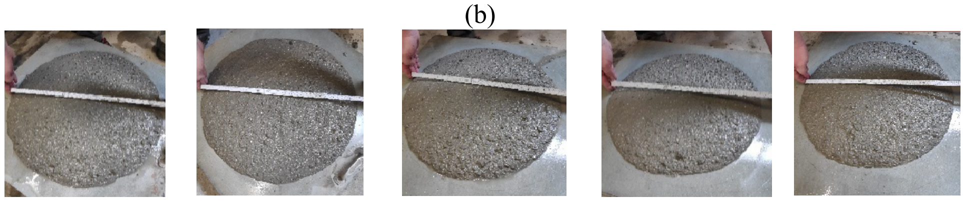
A2, a higher dosage of superplasticizer A1 was required to make the paste flow. Concrete mixes with 0.6% A1 and A2 admixtures flow continuously when the cone is removed and topples or shear off before the measurement can be made.

Fig. 7 shows the examples of the measured flow table tests after 0 min, 15 min, 30 min, 45 min and 60 min. The test results shown in Figs 5 to 8 indicate that the flowability of the rubber concrete mix containing superplasticizer A2 is better than that of the concrete containing superplasticizer A1. Superplasticizer A2 keeps the flowability of rubber concrete constant over time, and superplasticizer A1 reduces flowability over time. The presence of superplasticizer A2 with a dosage 0.2% by weight of the cement leads to an increase in the flowability of the concrete mixture compared to that without superplasticizer A2.

(a)



(b)



(c)

Figure 7: Examples of measured flow table test on mixtures. (a) R10-CEM-I; (b) R10-CEM-I-0.2-A1; and (c) R10-CEM-I-0.2-A2.

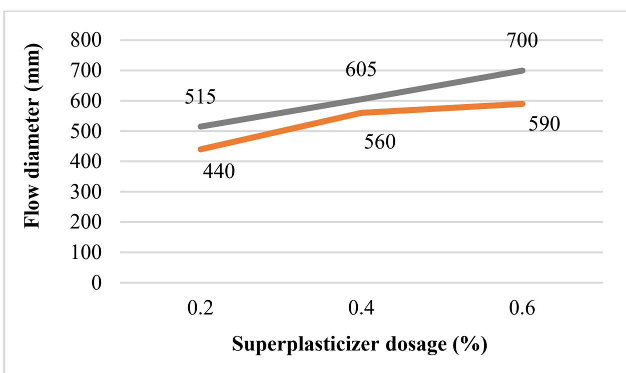


Figure 8: Flow vs dosage of superplasticizer.

3.2 Influence of type and dosage of superplasticizer on retention of concrete consistency

Figs 9 and 10 show the influence of different types and dosages of superplasticizers on retention of the consistency by measuring the slump and flow of each concrete, respectively. The slump behaviour and flowability of concrete mixtures with recycled rubber and superplasticizer A1 are quite changed in the measured periods of the concrete. Mixtures with superplasticizer A2 show a much smaller difference in the change of slump and flow value within the measured time. Moreover, during the measurement period and at the end of the measurement (after 90 minutes), they show a more uniform workability range, within the same consistency classes expressed by slump and flow diameter, as in the initial measurement.

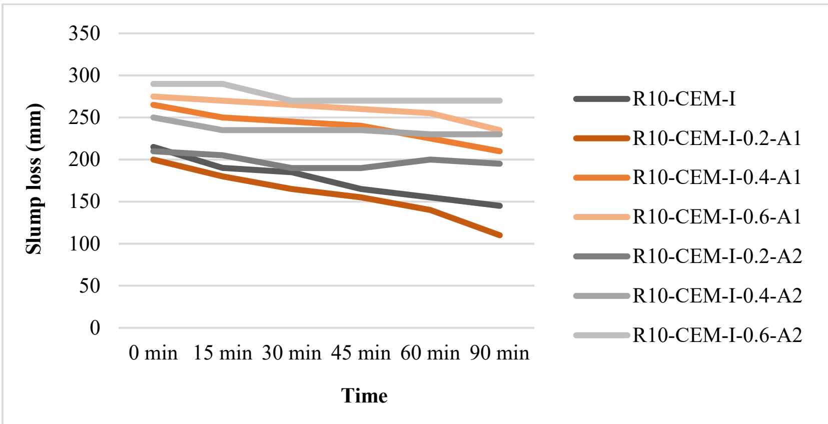


Figure 9: Retention of consistency measured by slump test.

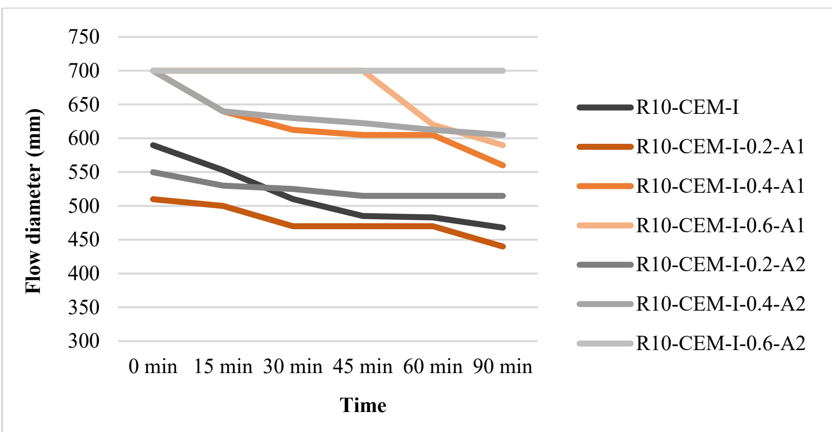


Figure 10: Retention of consistency measured by flow table test.

3.3 Compressive strength

Fig. 11 shows the plot between the strength and dosage of superplasticizer at a 0.45 water–cement ratio. It is evident that the compressive strength of concrete is maximum at 0.4% of superplasticizer dosage and it is obtained as 28.11 and 27.72 MPa. Thus, it can be concluded that there is no significant difference in the compressive strengths between mixtures with superplasticizer A1 and A2.

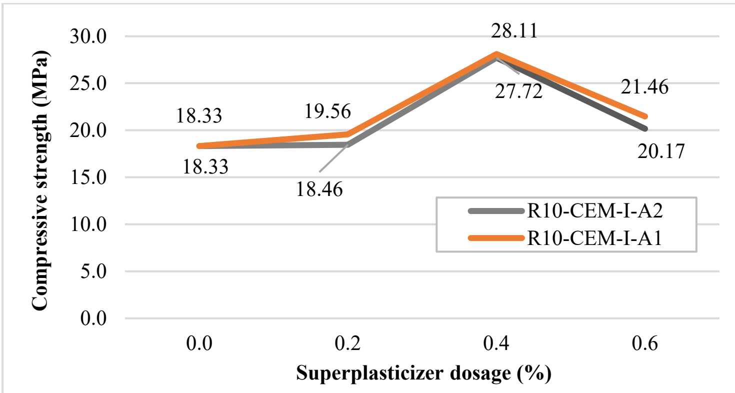


Figure 11: Compressive strength vs superplasticizer dosage.

4 CONCLUSION

With the usage of crumb rubber in concrete, a reduction in workability occurs which can be increased by adding a superplasticizer. However, very high superplasticizer dosages (more than 0.4%) affect the cohesion of the concrete. Slump loss can be reduced by using A1 and A2 superplasticizers. Slump loss and flow diameter test results have shown that the A2 superplasticizer used in this experiment allows concrete containing recycled rubber to be transported over a distance in the range of 90 minutes without the need for delayed or interrupted addition of admixtures. Mixtures with superplasticizer A2 should be highlighted because they show a more uniform workability range during the measurement period and at the end of the measurement (after 90 minutes), remain within the same consistency classes, expressed by slump and flow diameter, as in the initial measurement. Compressive strength is improved by superplasticizer, and there is no significant difference between the usage of superplasticizer A1 and A2. Based on this experimental work, the following recommendations can be proposed to further enhance the utility of the experiment. Different types of admixtures react differently in contact with cement, even if they are classified in the same category. Therefore, a study should be conducted to determine which admixture performs better under specific exposure conditions. In addition, only three different dosages of two different admixtures were used in this experiment. Therefore, it is difficult to determine the exact optimal dosage of the studied admixtures. For this reason, more concrete mixtures should be made with recycled rubber containing different dosages of admixtures to obtain the optimal dosage of the admixture.

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