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Investigation of rubber waste in self-compacting concrete during hardening and its performance in the civil and environmental industry

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Abstract

In order to used and worn out tires and a better understanding of the commercial potential of used tires as rock molders in the concrete industry and the performance of this type of concrete in structural and non-structural applications, the study of the properties of new and complex concrete has to be necessary to contain these lesions. Testing fresh concrete such as slump, since reaching a diameter of 50 cm (T50) Hopper V, Box L, ring J and hardened concrete include compressive strength on samples cube 28 and 56 days to dimensions of 10 x 10 cm and bending strength on samples prismatic dimensions of 75 x 15 x 15 cm by 28 days were done. In this research, used tires, as in the 5 designs mixed with 0, 5, 10, 15 and 20 percent replacement of coarse aggregate were used for the volume. Results showed that by increasing the amount of gum paste viscosity and increase the ability to pass, dispersion and filling, reduced. The compressive and flexural strength of the samples also decreased with increasing rubber content, the lowest drop, at 5%, and the highest drop in the 20% rubber replacement compared to the control plan, and we are witnessing with dropped by 5% and 20% in the maximum and minimum in the replacement.

Keywords: self-compacting concrete, rubber, fresh concrete, flexural strength, compressive strength, environment, tensile stress.

1. Introduction

In recent years, in many developed countries, discarding deprecated tires has been banned, so their re-use in the manufacture of other products has grown rapidly. One of the ways to consume and recycle these materials is to use them in concrete and other building materials Which is in the environmental process aimed at limiting the use of natural materials in the field of building materials and

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hence increasing interest in the use of alternative materials (waste) from industrial activities, which has significant economic benefits, energy and environmental conditions. The worn-out tires of vehicles are inseparable materials, and their recovery can be of great help to the environment. In some areas, they burn burners to eliminate worn tires, which cause global warming and contaminate the smoke from the environment [1].

On the other hand, in recent decades, the global growth of the car industry and increased use of cars as the main means of transportation have led to a significant increase in tire production. For example, every year in Iran more than 10 million worn tire exits from the consumption circle. The use of waste tires in concrete, in addition to reducing environmental damage, saves the consumption of raw materials for the preparation of concrete. [3]In Figure 1, could see a wide range of tires used in the environment and how to dispose of these wastes.

Construction of this type of concrete is possible with the use of chemical additives (new generation super lubricants) and minerals. The advantages of this concrete, the minimum difference between laboratory concrete and workshop can be mentioned. The advantages of using self-compacting concrete include: ensuring condensation, especially in areas where vibration application is difficult, easier to fit in molds, better finished surfaces, lower manpower, faster execution, especially for wall and column sections, more freedom to operate, in design (the possibility of creating thinner sections such as a sewage pipe) and reducing the noise pollution caused by the vibration operation. Regarding the possibility of accepting recycled concrete, including rubber-containing concrete in various uses of this material, this paper tries to investigate the behavioral and mechanical properties of self-compacting concrete containing rubber. Due to the concrete construction and attention to the durability and lack of skilled workers, the expansion of prefabricated concrete industry has caused the concrete to be designed to work in consolidation and compacting in practice, concreting and trembling better than other concrete.

Figure 1 - An overview of the accumulation and disposal of rubber`s waste

2. History

In 2004, Nabil presented an article titled "Properties of Mortar" containing tire rubber ash. In this paper, tire rubber ash is replaced by 2.5, 5, 7.5 and 10% by weight of the tire. Based on the results obtained in this paper, increasing the amount of tire rubber ash in the mixture reduces air percentages, increases stroke time, increases compressive strength and tensile strength, as well as 5% and 10% ash of tire tires, resistance to damage to the web and Ice and chlorine ion penetration has increased [6].

The first works in this area include Eldin and Sanoki in 1993, which replaced particles of three different types of rubber, replacing part of the aggregate, as well as Topco in 1995, the Auculer in 1997, and Khatib and his colleague Boyami in the year 1999 [4].

In 2002, hernandez-olivares and colleagues used 12.5 mm long elastomeric fibers and 12 to 19 mm polypropylene fibers with replacement percentages of 5 and 7% in concrete, and found that the use of this fiber in static and concrete hardness does not cause a significant reduction [5].

Self-compacting concrete theory, a revolution in the field of concrete technology, was first introduced by Professor Echomura of the University of Koji, Japan in 1986. In 1988, this comment was completed and for the first time self-compacting concrete was constructed. In 1989, the first paper on self-compacting concrete was presented at the 2nd Conference on Structural Engineering and Building of East Asia [3].

In 2006, Mr. Bignozzi and his colleagues conducted studies on the use of rubber in self-compacting concrete, which in this experiment was conducted on samples with alternatives 22.2 and 33.3% instead of aggregates with water to cement ratio 0.53 fresh and hard concrete tests that the results showed with increasing rubber the compressive strength decreased [7].

In 2017, in Iran, Shokri Andi, a study was conducted on the mechanical properties of conventional rubber-containing concrete, which showed that the concrete and concrete strength and specific gravity decreased with the addition of rubber [1].

Hall and Najim re-examined the mechanical and mechanical properties of self-tight concrete in 2012. In this research, the crude rubber was used in three ways: fine-grained, coarse-grained and mixed in weight ratio of 5%, 10% and 15% instead of stone materials. They found that, despite the fact that the rubber composition in concrete generally has a negative effect on mechanical strength, as shown in Fig. 2.13, according to Fig. 14.2; it improves the strain capacity and thus significantly reduces the bending cracks relative to the control concrete [8].

In 2012, Ganesan and his colleagues Conducted extensive laboratory studies on self-compacting concrete, which tested fresh concrete, hardened concrete, durability and corrosion tests [9].

Wang Her Yung and et al. recently completed a thorough study on the self-compacting properties of tire wear tires in 2013. In this study, rubber with a grain size of 30 and 50 sieves with replacement percentages of 5, 10, 15 and 20 with a water-to-cement ratio of 0.7 was used for making samples. 28-day resistance showed a decrease in resistance with the addition of rubber [10].

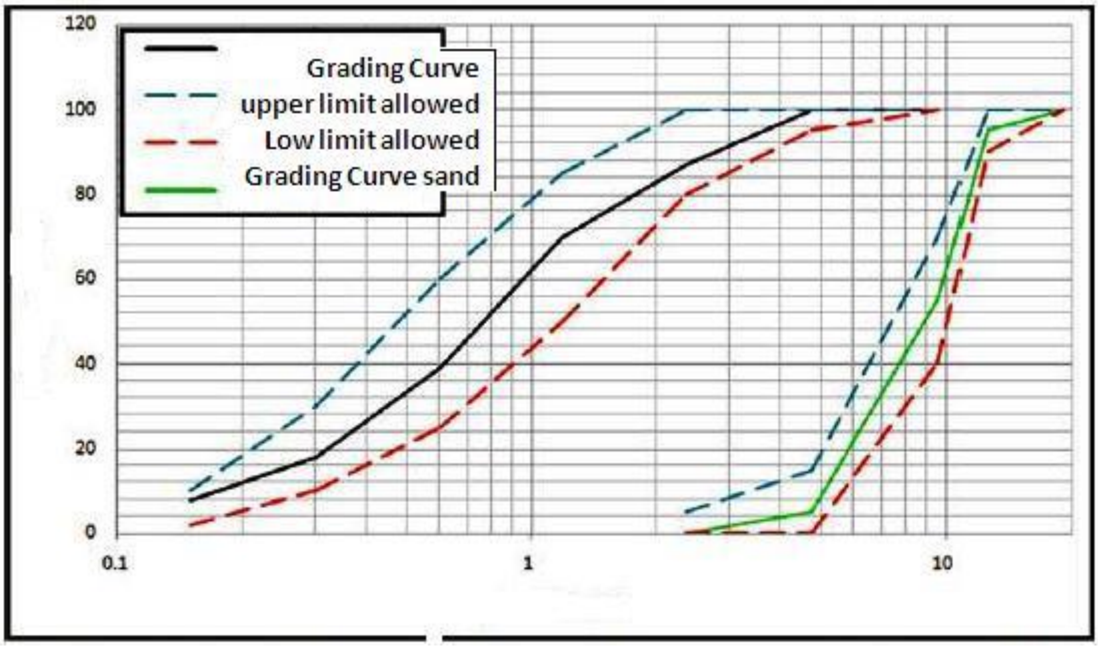
Mohammad Reza Shokri Andi, in 2017, studied and interpreted the effect of the amount of super-lubricant on the properties of self-compacting concrete contained in the rubber paste in the dough phase. As the rubber increases in concrete, the density of fluidity, filling and permeability increases and the ductility increases. [2]

3. Laboratory program

4.1. Consumer materials

In this research, Portland cement type 2 of Sistan was used. One of the most commonly used additives in self-compacting concrete (SCC) is powder from the material used to adjust the mucilage of fresh concrete. In this research, Qom stone powder has been used due to its high quality and uniformity in its grading. The chemical characteristics of cement and stone powder are presented in Table 1. The specific gravity of this powder is about 2700 kg / m 3 and its particle size is about 500-550 m 2 / kg. Coarse grains In this study, broken grains with a specific gravity of 2.7 g / cm are in accordance with ASTM C 127 and a water absorption of 0.84% (in accordance with ASTM C 127) [15].

The grain grading results according to ASTM C 33 standard are shown in Figure 2. The gravel is sand broken and has a specific gravity of 2.6 g / cm3 and an absorption rate of 1.57% in accordance with ASTM C 128. [12] The sand graining results used in accordance with the ASTM C33 standard are shown in Fig. 3. [13]The water needed to make all mixing designs is water available in the Babolsar area.



Sieve size (cm)

Figure 2 - Granular curve of used stone materials. (A) Coarse grains and (b) fine grained according to ASTM C 33

Table 1 Chemical composition of cement type 2 Sistan and Qom powder

SiO2	A12O3	Fe2O3	MgO	CaO	Na2O	K2O	SO3	Lo.I	Kind of materials
21.04	5.12	3.6	1.75	63.04	0.6	0.43	2.36	1.08	Sistan Cement type 2
0.81	0.23	0.08	0.88	-	0.14	-	0.26	-	Stone powder

Table 2. Self-compacting concrete designs containing rubber

w/c	Super lubricant (kg/m3)	Crumb rubber (kg/m3)	Stone powder (kg/m3)	Cement (kg/m3)	water (kg/m3)	sand (kg/m3)	Gravel (kg/m3)	Design name
0.42	9	-	150	450	189	890	730	SCC
0.42	9	16	150	450	189	890	693.5	SRC5
0.42	9	32	150	450	189	890	657	SRC10
042	9	48	150	450	189	890	620.5	SRC15
0.42	9	64	150	450	189	890	584	SRC20

3.1. Used tires

The tires used in this study were manufactured from a waste compactor from a recycled rubber Safarlou in Qom, which was larger than 4.75 mm in accordance with Fig. 3.

Figure 3 - Rubber used

4. Lubricant

Super-lubricant based on modified polythene polycarboxylate (PCE) brand Super Viscose 1 is a product of the Namikaran product factory. This super lubricant is in accordance with the standard (1989) SIA 162 prEN 934-2 and Table 3 and Table 4 of the 2930 standard without chlorine ion and corrosive materials and has a specific gravity of 1.07 + -0.02 kg per cubic meter. [14]

5. Mixing pattern

In this laboratory program, 5 mix designs were designed to investigate the effect of substratum substituting with coarse aggregate aggregates on self-compacting concrete. Substrates with 5%, 10%, 15% and 20% replaced the coarse grains and 2% extra lubricant was used. The ratio of water to cement was fixed at 0.42 for all designs. The full specifications of the mixing plan are given in Table 2.

6. Hardened concrete results

The results of compressive strength of 28 and 56 days and the 28-day bending strength are presented in Table 4. The results showed that the addition of rubber reduced the compressive strength of self-compacting concrete at all replacement rates at the age of 28 and 56 days. The reduction of 28-day compressive strength for 5, 10, 15, and 20 percent substitute rubber substitutes is 3.87, 25.81, 35.7 and 43.01 percent, respectively. The highest compressive strength loss is observed at 28 and 56 days at 20% replacement, and the compressive strength drop in the 5% rubber replacement is compared with the control plot.

The results of compressive strength of 28 and 56 days are shown in Fig. 4. An overview of how the samples are placed under the jaw of the device and how it is broken is shown in Figure 5.

Table 3. Results of mechanical properties tests

28-day bending strength (Mpa)	*56-day compressive strength* (Mpa)	*28-day compressive strength* (Mpa)	Design name	No.
6.8	49.8	46.50	SCC	1
6.29	48	46.70	SRC5	2
5.75	37	34.50	SRC10	3
5.46	34	29.9	SRC15	4
4.41	29	26.5	SRC20	5

7. Fresh concrete results

The results of fresh concrete experiments are shown in Table 3. The results show a decrease in the slip diameter distribution, a lack of blockage in the L box, and an increase in the drain time of the funnel V, T50, the difference between the inside and outside height of the J ring in fresh concrete experiments.

Table 4. The results of fresh concrete tests

J-RING		V-Funnl (s)	L-BOX			Stump Flow		Design name	No.
(h2-h1)	D(mm)		h2/h1	T400(s)	T200(S)	T50cm(s)	D(mm)		
7	710	8.64	0.9	2.3	1.1	3.1	720	SCC	1
7.3	700	7.74	0.84	2.7	1.12	3.74	715	SRC5	2
8.4	660	8.8	0.82	3.34	1.3	4.12	700	SRC10	3
9	640	10.32	0.8	4.1	1.9	4.35	675	SRC15	4
10.25	605	13.04	0.78	4.6	2.9	5.1	630	SRC20	5

8. The method of research

The experiments carried out in this study included two sections of new concrete: Slump Flow, Flow Time (T50), J Ring, L Box and Funnel V, according to European Standard (EFNARC), and Concrete Incorporated including compressive strength according to ASTM C39 and The flexural strength is according to the ASTM C78 standard. For each mixing plan, 3 100 mm cube test specimens were designed to determine the compressive strength and three flexural beam test specimens of 150 * 150 * 750 mm in order to determine the bending strength and the mean values were recorded as the final result of each mixing plan.

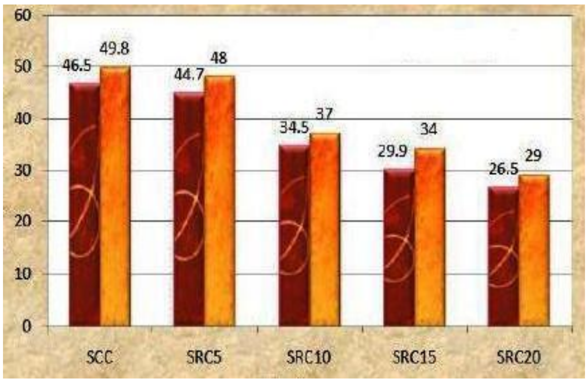


Figure 4 - Compressive strength of samples of 28 and 56 days

Figure 5 - Sample containing 20% crude rubber after rupture

In Fig. 6, the compressive strength of a 28-day self-compacting compact rubber is presented. The results show that the addition of small rubber in self-compacting concrete at the age of 28 days reduces the flexural strength in all percentages of replacement. The bending strength for the 5, 10, 15, and 20 percent substitute rubber substitutes was 7.4, 15.32, 19.6 and 35.1 percent, respectively, compared to the control plot. In Figure 7, the distribution of seeds and crumb rubber in the example of incoherent beam is visible.

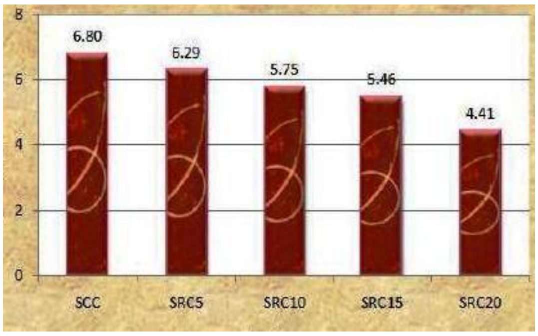


Figure 6 - Flexural strength of 28-day samples

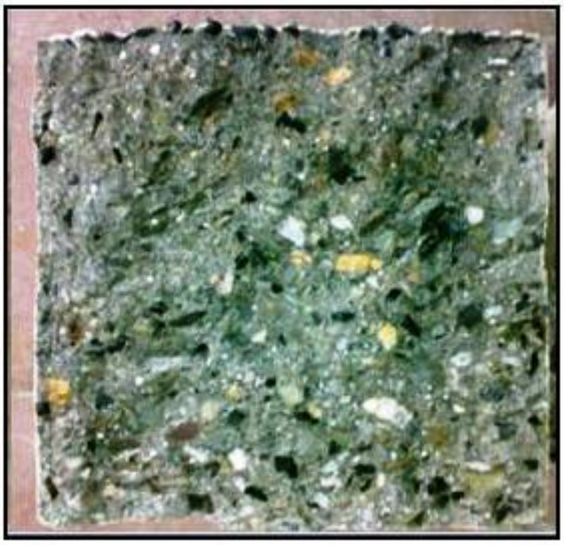


Figure 7. Distribution of sub-rubber in self-compacting concrete

9. Conclusion

The bending strength has decreased in all subclass substitutions. This reduction is due to the lower strength of rubber parts against the application of tensile stresses and accelerates the onset and crack cracking due to the low adhesion of the rubber parts to the concrete mix. Due to the structural results of waste concrete containing rubber, rubber concrete with low replacement rates can be used up to about 15% in structural applications and higher percentages in non-stick applications such as road paving and elastic pavement. By increasing the amount of rubber in self-compacting concrete, the spreading diameter of the slam dome and the ratio of blockage in the L box decrease, and the time of the funnel V, the time reached to 50 cm in diameter (T50), the increase in the interior and exterior of the J loop increases. This change in the behavior of fresh concrete results from a decrease in the fluidity and fluidity and an increase in the shear viscosity of self-compacting concrete, due to the lower specific gravity of the rubber substrate than to the rocky materials and the increased friction between the irregular surfaces of the rubber and the concrete mixture. The compressive strength of 28 and 56 days decreased with increasing the amount of rubber in all replacement percentages, due to the low adhesion of rubber parts to the concrete mixture on one side and the elasticity of rubber parts and softness of the samples on the other.

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