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Influence of polypropylene-fiber on the mechanical properties of self-compacting-concrete with recycled aggregates

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Abstract. In this study, the properties of self-compacting concrete (SCC) produced with different percentages of recycled aggregates (RAs) and polypropylene fibers is investigated in comparison with natural aggregates. The effect of using different percentages of 0 %, 25 %, 50 %, 75 % and 100 % RAs instead of natural aggregates (NAs) and polypropylene fibers of 0.1 %, 0.2 % and 0.3 % by volume of concrete in a fresh and hard state, consisting of a total 20 mixture composition, was investigated in SCC. SCC tests in the fresh state, including Slump Flow, J Ring, V Funnel, and L Box and hard concrete tests include compressive, tensile, and flexural and impact tests performed at the age of 28 days. Increasing the use of RAs does not significantly reduce the SCC tests in the fresh state while increasing the fibers causes a significant decrease in tests. In hardened concrete tests, with the increasing use of RAs of concrete, decreasing in compressive strength, tensile strength, flexural strength, and impact resistance were observed. While increasing the percentage of polypropylene fibers in recycled concrete, there was an increase in impact resistance and tensile strength and more energy absorption in the flexural test.

1. Introduction

One of the most important parameters for reaching proper durable concrete is the compact of the concrete. To achieve this target, usually needs to shake or vibrating to reduce the porosity of concrete air, the required strength has been obtained is increasing and prevent the formation of defective concrete. But vibrating is one of the most problems in this industry. Therefore, concrete manufacturing without vibrating was an important goal of industry experts. This issue has been discussed for several years until after major studies and experiments, were first produced by this specimen of concrete in Japan in 1980 [1]. The stability of self-compacting concrete (SCC) in the fresh state can be defined by various properties: Filling ability, passing ability and resistance to segregation. The mixture composition of concrete will be classified as a self-compacting if all the mentioned properties are present [2–4].The Building industry is one of the largest pickup and consumers' natural materials and at the same time, it is the largest group of producers and construction wastes that damage to the environment. The appearance of numerous environmental issues caused by the increase of construction and destruction, the engineering community has pushed forward towards sustainable development. One of the suitable ways to reduce the consumption of natural materials is to recycle and reuse concrete materials. Because of the recycling, these materials can result in less environmental degradation in both disposal and dumping and in terms of harvesting less than natural primary materials [5]. In the last two decades, were extensively studied about the properties of normal concrete with recycled aggregates (RAs) [6–11]. Many Researchers from different countries study this issue: L. Solomon and H. Paulo (Brazil), and C. Poon, S. Kou and L. Lam (China) in their papers [8, 12] showed an aggregate which is got from demolished masonry and concrete structures as potentially use in new concrete. The quality of recycled aggregates (RAs) of concrete is usually lower than the quality of natural aggregates (NAs) [13]. Safiuddin et al. [14] stated that the maximum decrease in the 28-day compressive strength due to the incorporation of RAs was only 12.2 %. According to the research by Tabsh and Abdelfatah the compressive strength and tensile strength in concrete

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containing recycled coarse aggregates (RCAs) depends on the proportion use of the RCAs in the mixture composition and they reach to this result of overall strength of recycled concrete is about 10 to 25 percentages lower than strength the normal concrete made with NAs [15]. Etxeberria et al. [16] recorded when 100 % replacement of coarse recycled aggregate in compressive strength of concrete test at 28 days decreased to 20–25 %; when 25 % of the aggregates were replaced, there were no significant changes to the compressive strength. In the article by Farzam et al. [17] in 2014, which investigate the affection of RAs from demolished concrete on the performance of new concrete, therefore the affection of RAs 5, 25, 50, 75, 100 percent respectively on compressive strength, tensile strength and Slump Flow two types of concrete with strength 25 and 35 MPa were tested and the results showed the use of these aggregates with low percentage of participation does not have negative effect on the concrete performance and in the high rate of participating up to 26 % decrease in compressive and maximum decrease 15 % in tensile strength. These results were supported by Solyman [18] who found a decrease in tensile strength test up to 18.8 % in concrete with 70 % recycled fine aggregates (RFAs) compared with reference concrete. In comparison with NAs, recycled concrete aggregates are weaker, more porous and exhibit higher values of water absorption [19]. A piece of evidence which is important for the mix of SCC with (RCAs) is the quantity of water absorbed by the recycled aggregate (RA), which is always higher in comparison to the same type of the natural coarse aggregate (NCA). The amount of water absorption by RA was taken into account separately by some researchers [20], in addition to its wetness before mixing and the free water that formed part of the mixture. Other researchers [21–22] consider the total water content for W/C ratio because it is impossible to separate the effective water content (water absorption by RA and mixing water) from the total water content in the concrete fresh state, especially in RA. On the other hand, SCC has disadvantages in terms of it, like Low ductility and high Fragility and for compensating these disadvantages using the different methods like using various fibers that are equally spread in concrete volume and it can improve the concrete performance. The idea of this work goes back to the centuries ago the use of straw and horse hair in mud bricks. In fiber concrete, thousands of small fibers are spread on concrete and improve the concrete virtues in all directions. The fibers help to improve the ductility concrete, tensile strength of concrete, fatigue strength, impact resistance and Contraction cracks. Some researchers have been presented the Use of fibers into SCC mixes [23–25]. However, the performance of fibers as reinforcing materials in cementations' composites is needed for more research into the study [26–28]. Previous studies have clearly shown the advantages of concrete containing steel and polypropylene fibers under impact tests, and in some cases, the results of the impact test were subjected to statistical analysis [29–32]. In the United States of America in 1960 researching was about the use of steel fibers in the mixture of concrete and it was shown that the Tension concentration on the place of the cracks considerably decreased. In England in 1975 Walton and Majumdar in their research found that the addition of polymer fibers Such as nylon and polypropylene, even at the lowest proportion, it improves the impact resistance mixture of concrete [33]. Ghernouti et al in 2015 assessed the properties of self-compacting concrete containing plastic bag waste fibers (WFSCC). The Effects of length and fiber contents, Stress–strain behavior and Load–deflection behavior of the WFSCC were evaluated [34]. Hesami et al in 2016 studied the behavior of SCC pavements incorporating recycled tire rubber crumb and reinforced with polypropylene fiber. Adding this material result in increases in compressive, tensile, flexural and abrasion strength, but had no considerable effect on the modulus of elasticity of these specimens. The presence of fiber in rubberized SCC decreased water absorption based on evaluation of ultrasonic wave's velocity [35]. fathi et al in 2017 focused on the effects of fiber and glass on the mechanical properties of self-compacting concrete. The results showed that substitution of glass for aggregates in concrete reduces compressive strength. Addition of fibers to glass-containing concrete increases compressive strength and finally addition of glass to concrete reduces the tensile strength of concrete [36]. Mohseni et al in 2017 studied the fibre-reinforced self-compacting concrete containing recycled coarse aggregate. Based on the obtained results in significant improvement in tensile strength showed with increasing fiber content [37]. Aslani et al in 2018 investigated the effects of rubber granules on the fresh and hardened properties of self-compacting concrete. Based on the experiments, the optimum crumb rubber aggregate replacement percentage in SCC and optimum crumb rubber aggregate size in the SCC are provided [38]. Mahdikhani and safikhani in 2018 investigated rheological properties of self-consolidating concrete made by crushed waste tile aggregates. Based on the result of the experiments the percentage of fine aggregates have a significant impact on the properties of self-consolidating concrete [39]. Pan et al in 2019 evaluated the effects of steel slag powder on the properties of self-compacting concrete with recycled aggregates. The result showed that the 10 % replacement ratio of SSP result in superior mechanical properties and better durability [40]. Sasanipour et al in 2019 focused on the Effect of silica fume on durability of self-compacting concrete made with waste recycled concrete aggregates. Due to the results, it observed that Silica fume plays an important role to improve durability performance. Also, it made be decreased water absorption according to BS and ASTM standards [41]. Sadeghi-Nik et al in 2019 studied the effect of Recycled Concrete Aggregates and Metakaolin on the Mechanical Properties of Self-Compacting Concrete Containing Nanoparticle. They concluded that the construction of self-compacting concrete with complete replacement of recycled aggregates is possible [42].The purpose of this study the using of recycled aggregate as fine and coarse aggregate with different percentages of replacement 0 %, 25 %, 50 %, 75 % and 100 % than to the natural aggregates, which this work, using less than natural resources as far as possible could produce the environmentally friendly concrete. Therefore, in this research, we try to improve the properties of concrete containing RAs; the effect of polypropylene fibers with various percentages of 0.1 %, 0.2 % and 0.3 % by volume on this type of concrete is investigated. In this study investigating the fresh state tests include Slump Flow, J Ring, V Funnel, and L Box and hard concrete state includes compressive, tensile, and flexural and impact tests.

2. Methods

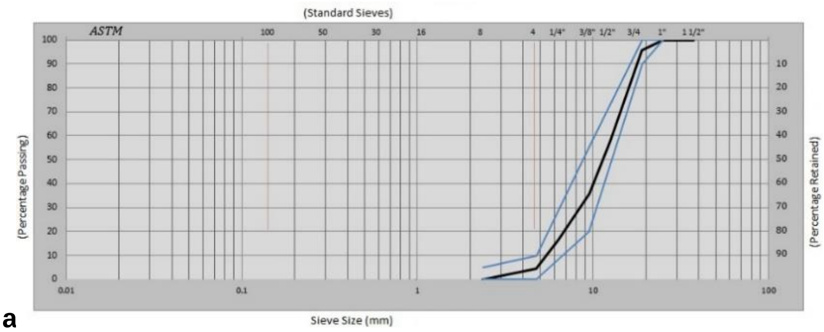
2.1. Materials

From among of variety standard cement, use the typical cement which one of that is used popularly in the normal conditions. For this reason, was used Portland cement type 2. Therefore, the chemical properties of this cement are given in Table 1.

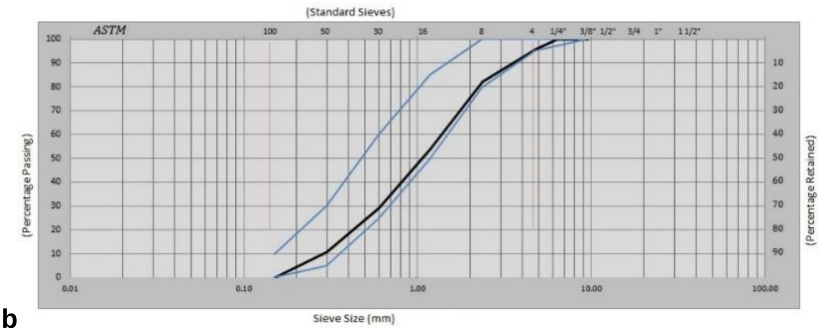
Table 1. Chemical properties of cement.

Composition	(%)
CaO	62.28
SiO_2	20.79
Al_2O_3	4.76
Fe_2O_3	3.86
MgO	3.22
SO_3	1.89
K_2O	0.68
Na_2O	0.37
CaO.f	0.82

In this research, the Zhikava Company superplasticizer (SP) with that model zp-pf4 was used. This product is in harmony with various types of cement and in accordance with the ASTM C-494 standard. This material was a brown color and has a specific gravity 1.1 g/cm^3. Polypropylene fibers consumed by NSG Company and at 12 mm length, which has a specific gravity 0.9–0.91 g/cm^3 and tensile strength 350 Mpa. In this study, to make a concrete mixture of natural coarse aggregate (NCA), which has a uniform grain maximum; size of 19 mm and the water absorption 2.36 % were used. Natural fine aggregate (NFA) consumed from the type of river sand was washed twice without any clay and the particle size of fine aggregate was between 0–4.75 mm with softness modulus 3.28 and water absorption was used 3.38 %. RCAs were used in the 15 cm cubic specimens of a concrete company with a compressive strength less than 25 MPa. Operation crushing and separating of specimens was done by a sledgehammer and then bypassing the RAs, the related sieves of the two groups of sand and gravel were divided. RCA was used has a uniform grain and maximum size of grains 19 mm and water absorption of 8.53 percent. Recycled fine aggregate (RFA) was used in this study, 0–4.75 mm. Also, the percentage of water absorption was 9.94 %, softness modulus 3.39 and has a uniform grain. Natural and recycle coarse aggregate and Natural and recycle fine aggregate Grading used in this research are based on the ASTMC33 standard. The grain size distribution of natural and recycle coarse aggregate, natural and recycle fine aggregate is shown in Fig. 1.



a



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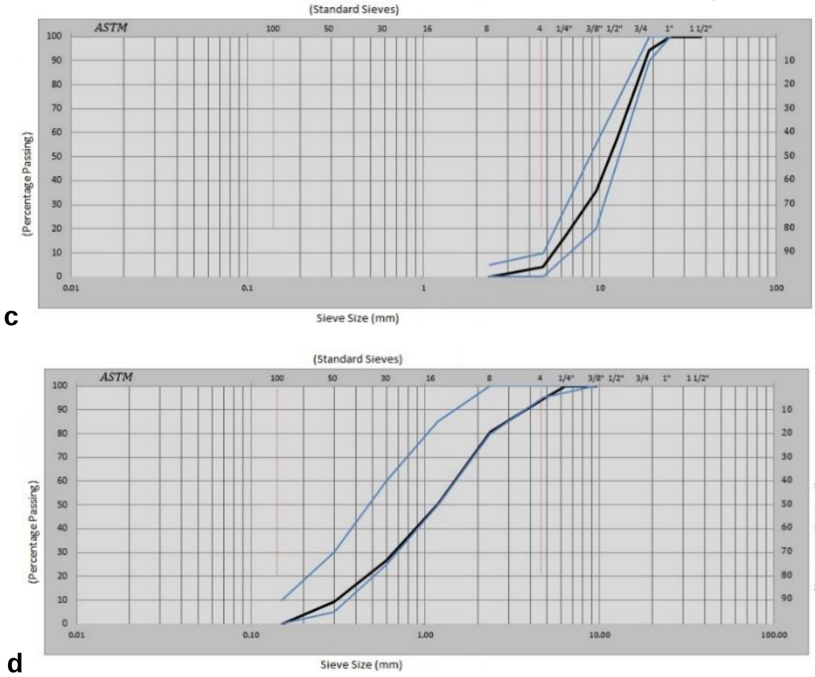

Figure 1. aggregate size distribution; a) natural coarse aggregate; b) natural fine aggregate; c) recycle coarse aggregate; d) recycle fine aggregate.

Due to the high absorption percentages of RAs compared to NAs, to compensate for the effect of reducing the concrete properties in fresh state of recycled aggregate mixes, after calculating the percentage of water absorption of natural and recycled aggregates, the difference in the water absorption percentages of these two types of aggregates is as extra water, to the final mixes contain of RA were added. The used material of natural and recycle coarse aggregate, natural and recycle fine aggregate, Cement, superplasticizer (SP) and fiber can be viewed in the Fig. 2.

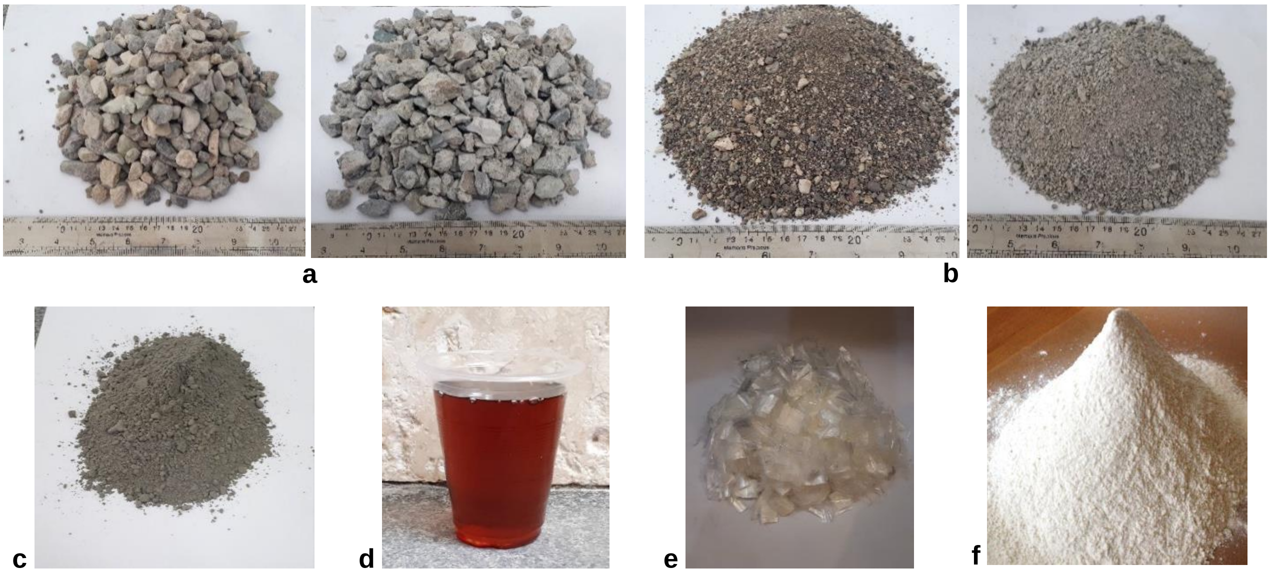

Figure 2. Materials; a) natural and recycle coarse aggregate; b) natural and recycle fine aggregate; c) cement; d) superplasticizer (SP); e) fiber; f) limestone.

2.2. Mixing ratios and specimen preparation

First of all, according to the concrete properties target, a mix for starting the work is chosen. Reference concrete is completely made with natural material. The acceptance criteria of final mixture composition are firstly the compressive strength and also the proper performance by checking the slump flow. Finally, the reference concrete mixture composition was selected and then, according to this mix, the other mixes were made and tested. In the manufacture of specimens, use 0 %, 25 %, 50 %, 75 %, and 100 % RAs are replaced by NAs and also were used 0.1 %, 0.2 %, and 0.3 % by volumes of concrete of fiber. Overall 20 mixture compositions to investigate the effect of RA and polypropylene fibers were made in SCC, finally fresh and hardened concrete tests on them. Details of concrete mixes are given in Table 2.

Table 2. Proportions of mix compositions (kg.m^3).

Mix No.	Mix code	Cement	w/b	extra water	Natural aggregate		Recycled aggregate		Limestone	Fiber	SP
					Coarse aggregate	Fine aggregate	Coarse aggregate	Fine aggregate			
1	100NA	450	0.43	-	501.9	1075.5	-	-	215.1	-	4.05
2	100NA-0.1PP	450	0.43	-	501.9	1075.5	-	-	215.1	0.91	4.05
3	100NA-0.2PP	450	0.43	-	501.9	1075.5	-	-	215.1	1.82	4.05
4	100NA-0.3PP	450	0.43	-	501.9	1075.5	-	-	215.1	2.73	4.05
5	75NA-0.1PP-25RA	450	0.43	24.7	376.425	806.625	125.475	268.875	215.1	0.91	4.05
6	75NA-0.2PP-25RA	450	0.43	24.7	376.425	806.625	125.475	268.875	215.1	1.82	4.05
7	75NA-0.3PP-25RA	450	0.43	24.7	376.425	806.625	125.475	268.875	215.1	2.73	4.05
8	50NA-0.1PP-50RA	450	0.43	49.4	250.95	537.75	250.95	537.75	215.1	0.91	4.05
9	50NA-0.2PP-50RA	450	0.43	49.4	250.95	537.75	250.95	537.75	215.1	1.82	4.05
10	50NA-0.3PP-50RA	450	0.43	49.4	250.95	537.75	250.95	537.75	215.1	2.73	4.05
11	25NA-0.1PP-75RA	450	0.43	74.2	125.475	268.875	376.425	806.625	215.1	0.91	4.05
12	25NA-0.2PP-75RA	450	0.43	74.2	125.475	268.875	376.425	806.625	215.1	1.82	4.05
13	25NA-0.3PP-75RA	450	0.43	74.2	125.475	268.875	376.425	806.625	215.1	2.73	4.05
14	0.1PP-100RA	450	0.43	98.9	-	-	501.9	1075.5	215.1	0.91	4.05
15	0.2PP-100RA	450	0.43	98.9	-	-	501.9	1075.5	215.1	1.82	4.05
16	0.3PP-100RA	450	0.43	98.9	-	-	501.9	1075.5	215.1	2.73	4.05
17	75NA-25RA	450	0.43	24.7	376.425	806.625	125.475	268.875	215.1	-	4.05
18	50NA-50RA	450	0.43	49.4	250.95	537.75	250.95	537.75	215.1	-	4.05
19	25NA-75RA	450	0.43	74.2	125.475	268.875	376.425	806.625	215.1	-	4.05
20	100RA	450	0.43	98.9	-	-	501.9	1075.5	215.1	-	4.05

How to name the mixes as follows:

NA: Natural aggregate, RA: Recycle aggregate, PP: Polypropylene fibers

The numbers behind each of the signs represent the percentage of each of them in the mixture composition. For example, this mix code 75NA-0.3PP-25RA means it contains 75 percent natural aggregates, 0.3 percent polypropylene fibers, and 25 percent recycled aggregate.After completion of the manufacturing of mixes, specimens are cured in the laboratory conditions for about 24 hours, after that keeps them in water with a temperature from 18 to 23 centigrade for about 28 days. In this study, the compressive strength test was performed on cubic specimens of 100×100×100 mm, Tensile strength test on cylindrical specimens with dimensions of 150×300 mm, Flexural strength test on prismatic beams specimens in the dimensions of 100×100×500 mm and for doing the impact test first concrete shape disks to diameter 152 mm and a height 63.5 mm or cylindrical specimens 150×300 mm were cut which was used the second method in this experiment. The behavior of SCC in the fresh state, including the Slump Flow test, J Ring test, V Funnel test, and L Box test was evaluated.

2.3. Setting and test methods

2.3.1. Compressive strength test

According to the structure mentioned in Table 2, each mixing design with different percentages of RAs and polypropylene fibers three cube specimens with dimensions of 100×100×100 mm were used in accordance with standard BS 1881-116 [43] for the evaluation of compressive strength and depicted in Fig. 3a. In total sixty cubic specimens were manufactured and the effect of different percentages of RA (0 %, 25 %, 50 %, 75 %, and 100 %) and polypropylene fibers (0.1 %, 0.2 %, and 0.3 %) was investigated.

2.3.2. Tensile strength test

For doing this test, an indirect method was used to do splitting tensile strength of the cylindrical specimen of 150×300 mm in accordance with the ASTM C 496 [44] standard, which is horizontally along its axis in accordance with Fig. 3b in the test device the compressive strength is placed. From each mixture composition, two specimens and a total of forty cylindrical specimens were made. Then, the load is continuous with steadily speeding within the concrete tensile stress range and between 0.66 to 1.38 MPa/min it applies until to the failure of the specimen.

2.3.3. Flexural strength test

For the analyses of the performance of SCC were made of RAs and polypropylene fibers, a number of forty prismatic beams (100×100×500 mm) were tested in accordance with ASTM C 293 [45] standard under the three point bending test. The test setup used to evaluate flexural assesses is depicted in Fig. 3c. The flexural loading on the beams was applied with a loading rate of 0.3 mm/min.

For the calculating modulus of rupture, using the below equation:

$$R = \frac{3PL}{2bd^2}, \quad (1)$$

where R is modulus of rupture, psi, or MPa;

P is maximum applied load indicated by the testing machine, lbf, or N;

L is span length, in., or mm;

b is average width of specimen, at the fracture, in., or mm;

d is average depth of specimen, at the fracture, in., or mm.

For each mixture composition, the two numbers of the specimen’s prismatic beam were manufactured.

2.3.4. Impact drop weight test

The drop weight Impact test was conducted based on ACI Committee 544 [29]. This device is depicted in Fig. 3d. A steel hammer with 4.45 kg weight from 457 mm height on the steel ball with 63.5 mm diameter is fall. This steel ball is in contact with the central surface specimens. In total, sixty concrete disks with 150 mm diameter and 65 mm height from cylindrical specimens of 150×300 mm at the age of 28 days in accordance with Fig. 3d are cut.

For the calculating absorption energy, using the below equation:

$$\text{Impact energy } (EN) = N \times W \times H \quad (2)$$

While N is the number of blows, *W* is the weight of the steel hammer with a mass of 4.45 kg, H is the height of fall.

To evaluated disks, resistance under drop weight impact load, while for each group of mixture composition three specimens were tested.

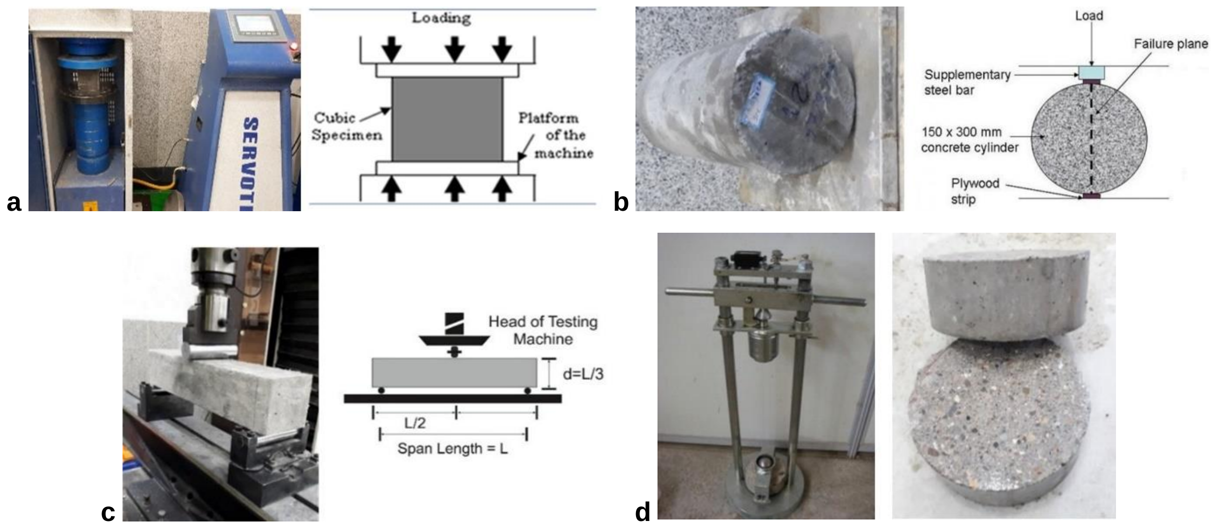

Figure 3. a) Cylindrical specimen and how to place the specimens; b) cubic specimens and apparatus of compressive test; c) Prismatic beams and test setup for the execution of three point bending test; d) Disks and apparatus of impact test.

3. Results and Discussion

3.1. Fresh mix properties

In order to measure the performance of SCC containing fiber and RAs, SCC measurement parameters have been used in accordance with European EFNARC [2] regulation. Fresh state concrete test results are depicted in Table 3.

Table 3. The test results obtained by measurement of fresh concrete.

Mix No.	Mix code	Slump-flow test		J-ring test	V-funnel test		L-box test
		cm	T_{50} (sec)	∆h (mm)	T (sec)	T (5min)	$H_2.H_1$
1	100NA	78	1.6	3.75	4.1	6.6	0.92
2	100NA-0.1PP	69	2.2	6.75	5	8	0.82
3	100 NA-0.2PP	62	3.1	7.5	5.7	9.8	0.72
4	100 NA-0.3PP	53	9.8	9.5	6.5	11.3	0.6
5	75 NA-0.1PP-25RA	68	2.4	6.75	6	8.2	0.79
6	75 NA-0.2PP-25RA	62	4.7	8	6.7	10.1	0.68
7	75 NA-0.3PP-25RA	51	12.4	13.75	7.5	12.3	0.59
8	50 NA-0.1PP-50RA	68	2.5	7	6.7	8.3	0.77
9	50 NA-0.2PP-50RA	61	5.1	7.5	7.1	10.6	0.65
10	50 NA-0.3PP-50RA	51	15.3	15.5	7.7	12.5	0.57
11	25 NA-0.1PP-75RA	65	2	7.5	6.8	8.6	0.73
12	25 NA-0.2PP-75RA	59	5.1	9.5	7.1	11.3	0.64
13	25 NA-0.3PP-75RA	49	-	16.5	8	13.1	0.55
14	0.1PP-100RA	64	2.9	8.5	7.1	8.9	0.72
15	0.2PP-100RA	59	4.1	9.25	7.6	11.6	0.64
16	0.3PP-100RA	45	-	19.75	8	13.6	0.52
17	75 NA-25RA	76	1.9	4	4	6.8	0.9
18	50 NA-50RA	75	1.9	5	4.3	6.9	0.89
19	25 NA-75RA	73	2	5.5	4.4	6.9	0.86
20	100RA	73	2.2	7.25	4.6	7	0.85

The slump flow test is one of the widely used to measure the SCC properties to evaluate the flow ability of the SCC and resistance to segregation. This test accordance to EFNARC does and the average diameter of spread concrete in two directions perpendicular and also the time of reaching to 50 cm in diameter, is recorded based on the marking on the surface of the slump flow test. Test results are present in Fig. 4a and Fig. 4b.

As shown in the Fig. 4a it can be seen, mixes the number of 3, 6, 9, 11, 12, 14 and 15 in the category of SF1 concrete for unreinforced concrete structures or less rebar such as concrete slabs and also in small sections it does not need a long horizontal flow of concrete like piles is applicable. Mixes number 2, 5, 8, 18, 19 and 20 in the category of SF2 concrete it is suitable for many commonly use concrete applications. Number designs 1 and 17 in the category of SF3 concrete for vertical sections concreting, full rebar structures and complex structures are applicable. Finally, mixes numbers 4, 7, 10, 13 and 16 were not included in the SCC category because of a sharp drop in the slump flow. The maximum reduction in the slump flow occurred when 100 percent RA and 0.3 by volume percentages polypropylene fibers were used at the same time and resulting in a 42.31 % decrease in the slump flow. As can be seen, increasing the percentage of recycled aggregates decrease the slump flow This result agrees with the results of the reference of [39].

J Ring test based on EFNARC regulation was used, in order to determine the attribute to passing ability fresh state concrete through the rebars. The height difference between inside concrete and outside the J ring was a dimension in four points and averaging which expresses the ability to pass the concrete. Test results are depicted in Table 3 and Fig. 4c.

According to Fig. 4c, the height difference between inside and outside of the J ring with increased by consuming the amount of fiber and RA was increased. Generally, it can be said most of the mixes are included within the allowed range (Δh mm ≤10) and only the mixes containing 0.3 % polypropylene fibers are not included within the allowed range of this test.

According to EFNARC regulation, the L box test was designed to investigate the capability of the fresh concrete flow and blocking phenomenon due to the presence of the rebars. In this test, the first and end of the height of the L box after that passing through the fresh SCC between rebars was dimension and according to the results of the passing ability and blockage that is estimated. Test results are present in the Table 3 and Fig. 4d.

The charts from the L box test, when an increase of fibers and RA in each mixture composition, the rate of flow concrete on the horizontal surface of L box was decreased. In other words, it is possible to mention reduce the ability of concrete to passing through from the rebars network of L box. While the mix contained 100 % RA and 0.3 % fibers, concrete was hardly reached the bottom of L box.

According to EFNARC regulation, V funnel the time of the concrete release from the funnel is measured and is used as a criterion in determining the filling ability and viscosity of concrete. Test results of the V funnel are depicted in Table 3 and Fig. 4e. It can clearly be seen, increase in the percentage of RA will increase the time of concrete releases from the V funnel, therefore, increase of fibers cause of the higher the viscosity while the amount of fiber consumed increases and this led to longer passing times of concrete from the V funnel. In the mixes contain 0.3 % fiber, the concrete release time increases sharply after 5 minutes from V funnel. But in general, most of the mixes based on the EFNARC regulation range. The notable drawback lack of water throwing of all the mixture's composition of including the fiber was in the V funnel after five minutes, this indicates shows that the fibers can prevent water thrown in concrete. In Fig. 4e, the concrete release times from the V funnel are shown on the graph after 10 seconds and 5 minutes. It is observed that in the mixed number 1, it contains 100 % NA and the lack of fiber, the difference of the concrete release times from the V funnels after 10 seconds and release time after 5 minutes is equal 2.5 seconds. While in the mixed number 16 contain 100 % of RA and 0.3 % is fibers this difference is reached in 5.6 seconds.

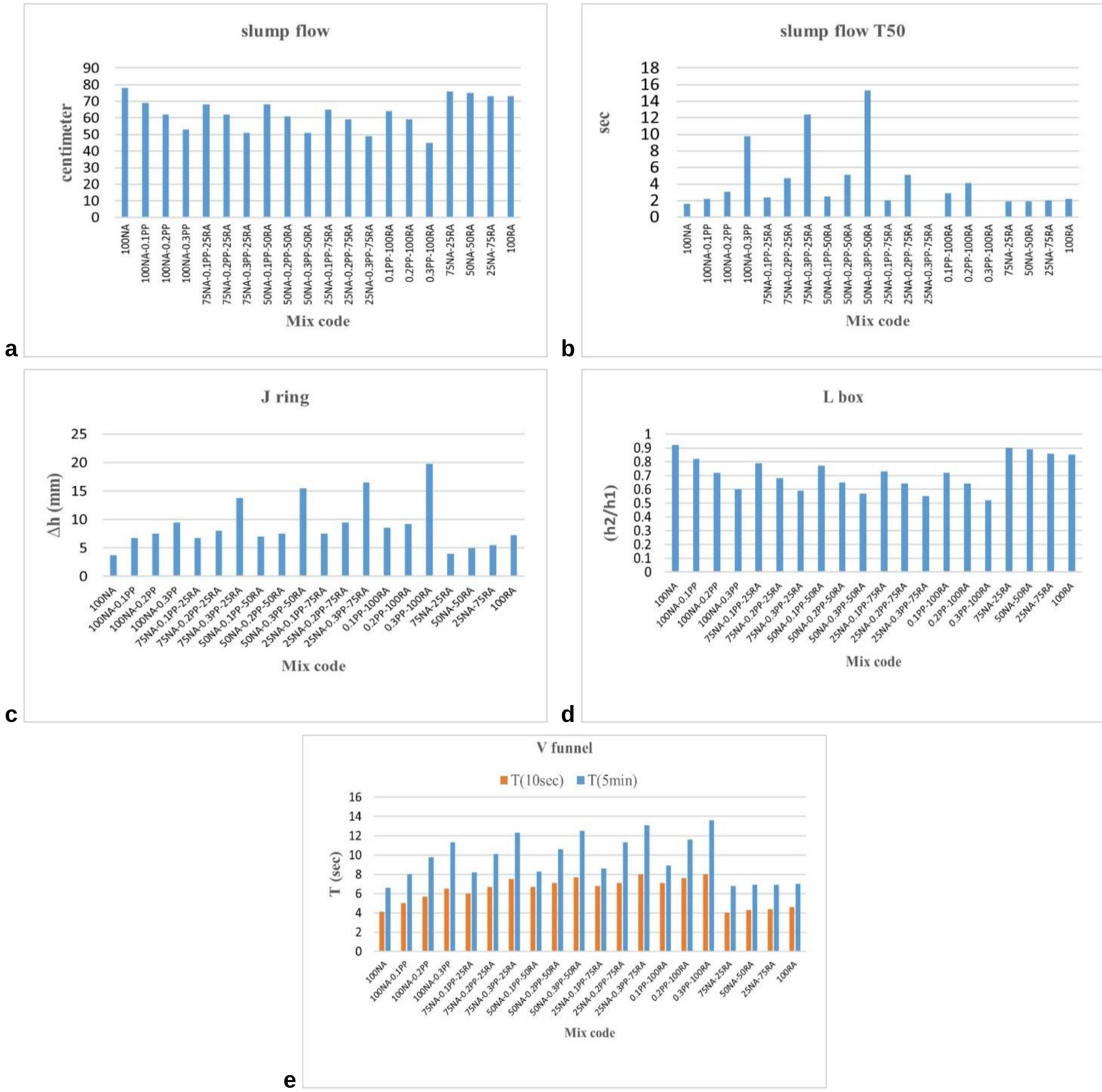

Figure 4. Effect of different fiber and recycled aggregate percentages contents on: a) slump flow; b) slump flow T50; c) J ring; d) L box; e) V funnel.

3.2. Properties of hardened concrete

All test results of hardened concrete are present in Table 4.

Table 4. Results of compressive strength, tensile and flexural strength tests.

Mix No.	Mix code	Compressive strength (MPa)	Tensile strength (MPa)	Flexural strength			Blow number		Impact energy (En)	
				N	(MPa)	Energy absorption (J)	First crack	Ultimate crack	First crack	Ultimate crack
1	100NA	51.5	3.17	10126.42	7.59	2585.64	143	146	2910.56	2971.62
2	100NA-0.1PP	52.3	3.74	9933.2	7.44	3733.53	160	167	3256.57	3399.04
3	100NA-0.2PP	53.67	3.99	11537.89	8.65	5458.23	172	186	3500.81	3785.76
4	100NA-0.3PP	48.63	3.94	8861.61	6.64	5845.8	187	198	3806.12	4030.01
5	75NA-0.1PP-25RA	49	3.81	6309.02	4.73	2465.29	137	144	2788.44	2930.91
6	75NA-0.2PP-25RA	50.2	4.02	5575.93	4.18	3032.77	148	159	3012.33	3236.22
7	75NA-0.3PP-25RA	48.27	3.56	6476.60	4.85	4275	159	171	3236.22	3480.46
8	50NA-0.1PP-50RA	40.1	3.66	5855.21	4.39	2302.31	122	128	2483.13	2605.25
9	50NA-0.2PP-50RA	42.2	3.01	5735.17	4.30	2886.6	128	141	2605.25	2869.85
10	50NA-0.3PP-50RA	42.73	3.45	9795.63	7.34	5223.28	133	141	2707.02	2869.85
11	25NA-0.1PP-75RA	33.4	2.88	6987.29	5.24	2110.45	90	97	1831.82	1974.29
12	25NA-0.2PP-75RA	35	2.92	7692.6	5.76	2876.89	103	114	2096.41	2320.30
13	25NA-0.3PP-75RA	36.73	2.70	8867.92	6.65	4429.78	115	128	2340.66	2605.25
14	0.1PP-100RA	22.03	1.98	6081.38	4.56	1695.68	75	81	1526.51	1648.64
15	0.2PP-100RA	28.7	2.55	5636.55	4.22	1548	89	101	1811.46	2055.71
16	0.3PP-100RA	35.57	3.19	6769.78	5.07	1627.65	108	122	2198.18	2483.13
17	75NA-25RA	46.75	3.76	8697.55	6.52	2529.28	116	126	2361.01	2564.55
18	50NA-50RA	41.33	3.15	8731.11	6.54	1975.75	101	108	2055.71	2198.18
19	25NA-75RA	34.65	2.62	6977.26	5.23	1866.68	88	92	1791.11	1872.53
20	100RA	26.72	1.84	5588.99	4.19	1661.01	52	55	1058.38	1119.44

3.2.1. Compressive strength

As previously mentioned, Compressive strength test for different ratios 0, 25, 50, 75 and 100 percent replacement of recycled coarse and fine aggregate with natural coarse and fine aggregate and polypropylene fibers with proportions 0.1, 0.2 and 0.3 by volume percent of concrete was applied to 100×100×100 mm cube specimens. This device is compressive the type of hydraulic and has a capacity of 300 tons. The results are presented in Table 4 and Fig. 5a.

Similar to the results of the reference of [36], in this study can also be said In general, increasing the percentage of RAs are causing reduce the compressive strength of concrete. Also, using the fibers in SCC to a certain amount can improve the compressive strength. The reason for this increase could be the reduction of fine-grained concrete in the concrete transfer area. Adding a lot of polypropylene fibers in SCC cause reduce the strength of specimens because were many fibers efficiencies and the flow of SCC was reduced and causing the remaining amount of air in the concrete to increase. So this reason will reduce the strength of the concrete.

According to the Table 4 and Fig. 5a, increasing the use of recycled aggregates as coarse and fine in new concrete, decreasing in the compressive strength of the specimens is observed. So that in the mixes number 17 to 20 containing 0 %, 25 %, 50 %, 75 % and 100 % RA respectively, causing reduced of the strength 9.22 %, 19.75 %, 32.72 % and 48.12 % to comparing with mix number 1 which contain 100 % NA. The reason for this reduce less resistance RAs than to NAs, first of all, is in during mixing the weakest parts of concrete into smaller pieces, to this case increases the fine aggregate (FA) in the concrete mixture, finally the concrete strength to drop. The other one, old mortars stick to RAs that have less resistance than to NAs, to this issue reduces the compressive strength of concrete containing RAs. This result indicates that if choosing reference concrete with high resistance, the possibility of manufacturing recycled concrete with a complete replacement of RA in a way resistance is a desirable level, so it is easily accessible. The results in Table 4 and Fig. 5a, are shown in mixes are contains 100 % and 75 % NA (mixes number 1 to 7) presence of fibers until 0.2 % can improve the compressive strength of concrete. While the percentage of fibers reached to 0.3 %, we are confronted to drop of the resistance which reason of this drop of the resistance can reduce efficiency and flow of SCC due to a lot of addition the polypropylene fibers can increase the remaining amount of air into the concrete and causes the drop of the resistance. In the mixes that include NAs less than 50 %

(mixes number 8 to 20) their compressive strength in mixes containing 0.1 % polypropylene fibers (mixes number 8, 11 and 14) than to mix lack of fibers with that corresponding (mixes number 18, 19 and 20) are lower. While in the mixes containing 0.2 % and 0.3 % polypropylene fibers (mixes number 9, 10, 12, 13, 15 and 16) than to the mix lack of fibers with that corresponding (mixes number 18, 19 and 20) polypropylene fibers compensate for the lost compressive strength by RAs.

3.2.2. Tensile strength

The Tensile strength results of mixtures composition, manufacturing with different percentages of recycled fine and coarse aggregate and polypropylene fiber are depicted in Table 4 and Fig. 5b.

The results are shown as totally in all mixes using fiber can cause improve the tensile strength of specimens and tensile strength of all mixes include fiber are higher than the other mixes lack of fiber. This finding is consistent with the results of the reference of [37]. Although, the increasing of the RA causes the decrease of tensile strength, which has the highest drop is relatives to the mixed number 20 it is containing 100 % RA and this drop than to mix number 1 which contains 100 % NA it is equal to 41.96 %. As can be seen, the best tensile strength was when used fiber 0.2 % by volume of concrete, but in the presence of 0.3 %, fiber has little effect on the tensile strength and cause slightly reduced in tensile strength. So, in the mixed number 3, which contains 100 % NA and 0.2 % by volume of concrete is fiber it can improve the tensile strength about 21 % than to mix number 1 which has only NA. What can happen, when the increase the tensile strength is due to the use of polypropylene fibers can be explained the fiber when spread between the split sections of the concrete matrix, can withstand a greater tensile strain through the transfer of tensions from a concrete matrix to the fiber. As a result, an increase in tensile strength is observed. The appropriate spread of polypropylene fiber in the concrete matrix can be another reason for more load tolerance.

3.2.3. Flexural strength

A flexural strength test was performed to determine the rupture modulus of concrete in three point bending method on prismatic beams specimens of 100×100×500 mm. The results on the flexural strength of the mixture composition made with different percentages of replacement of the recycled fine and coarse aggregate and polypropylene fibers are shown in Table 4 and Fig. 5c.

The results of the flexural strength are shown with increasing the proportion of RAs in new concrete the flexural strength concrete up to 45 % decrease. Similar to the results of the reference of [34], when adding fiber to the concrete, it is possible to achieve the concrete with a higher flexural strength than reference concrete .Therefore, the effect of these fibers will be investigated by adding different percentages of polypropylene fibers. The presence of fibers in mixes containing 100 % NAs until to 0.2 % by volume of concrete respectively, causing increases the flexural strength up to 12.25 % compared to non-fibers. However, the presence of 0.3 %, by volume, of fiber cause the flexural strength is reduced 12.52 % than to the mix lack of fiber.

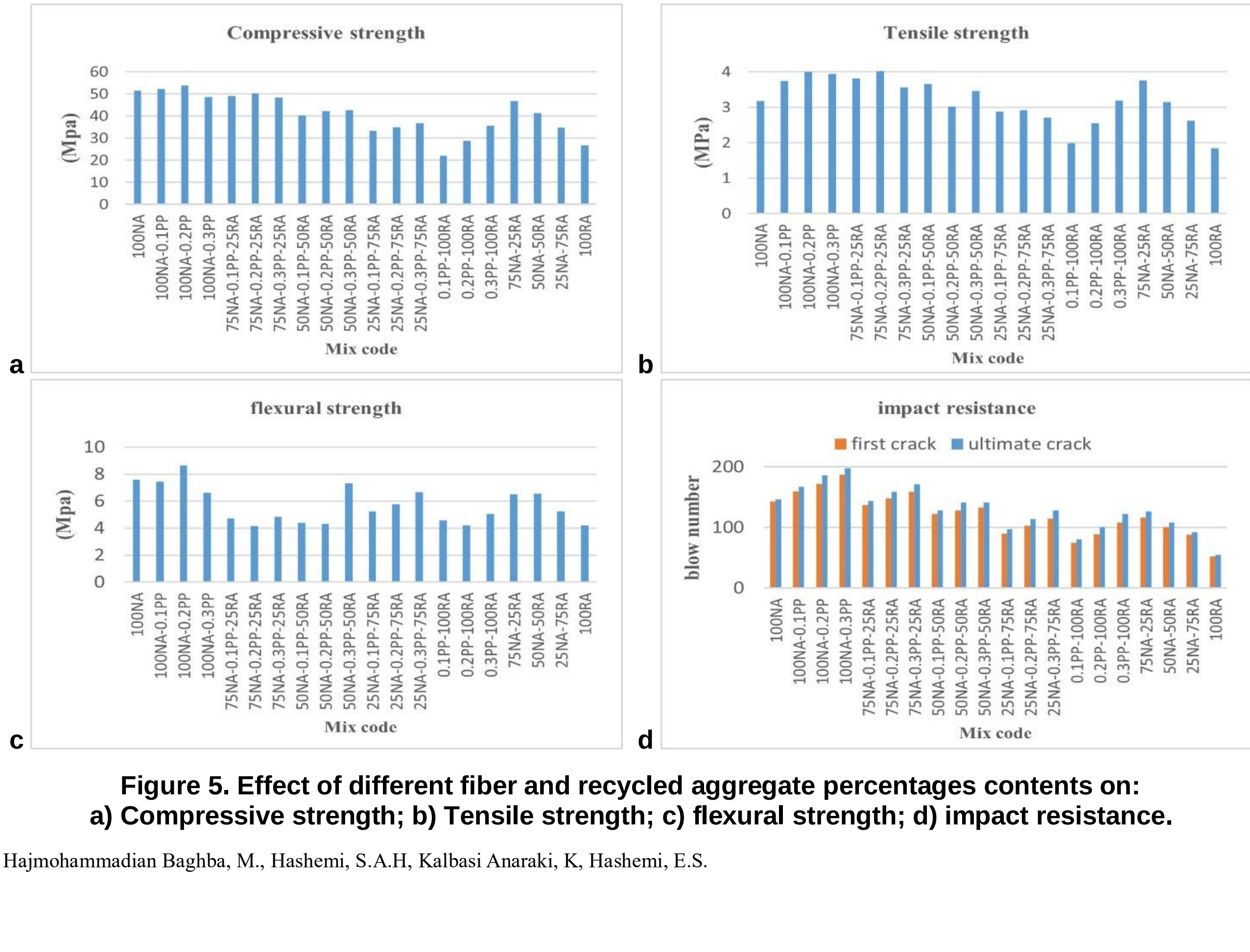

Figure 5. Effect of different fiber and recycled aggregate percentages contents on:
a) Compressive strength; b) Tensile strength; c) flexural strength; d) impact resistance.

Unlike the concrete lack of fiber, concrete containing fiber is not broken immediately after the first crack and its tolerance the load of the fiber and can cause energy absorption. This point is confirmed in the results of the flexural strength test of this study. Even in cases, flexural strength was reduced than to concrete lack of fiber, the amount of specimen energy absorption was more after the first crack. The flexural durability is shown below the surface curved of load-displacement. The other hand the most important effect of the fiber in the concrete is the increase in the ductility and energy absorption, it is necessary to measure flexural durability. For this purpose, in this study concrete prismatic beams specimens with dimensions of 100×100×500 mm at the age of 28 days were tested for flexural and load–displacement chart was drawn for them. Fig. 6 Show the results of the flexural test for mixture's containing 0, 25, 50, 75 and 100 percent replacement of RAs with NAs along with 0.1 %, 0.2 % and 0.3 % by volume of polypropylene fiber.

The total stored and released energy in the element can be obtained by calculating the area under the load-displacement charts. The total energy absorption by each of the beams is presented inTable 4.

Overall, the use of fibers has increased the energy absorption of the beam. So, using 0.1 %, 0.2 % and 0.3 % polypropylene fibers in mixes containing 100 % NA (mixes number 2, 3 and 4), the energy absorption than the lack of fibers mix (mix number 1), respectively 44.4 %, 111.1 %, and 126.1 % are increasing. The percentage of energy absorption with the presence of the percentage of different fiber and RAs is variable so that the presence of RA is increasing; the percentage of energy absorption is decreasing.

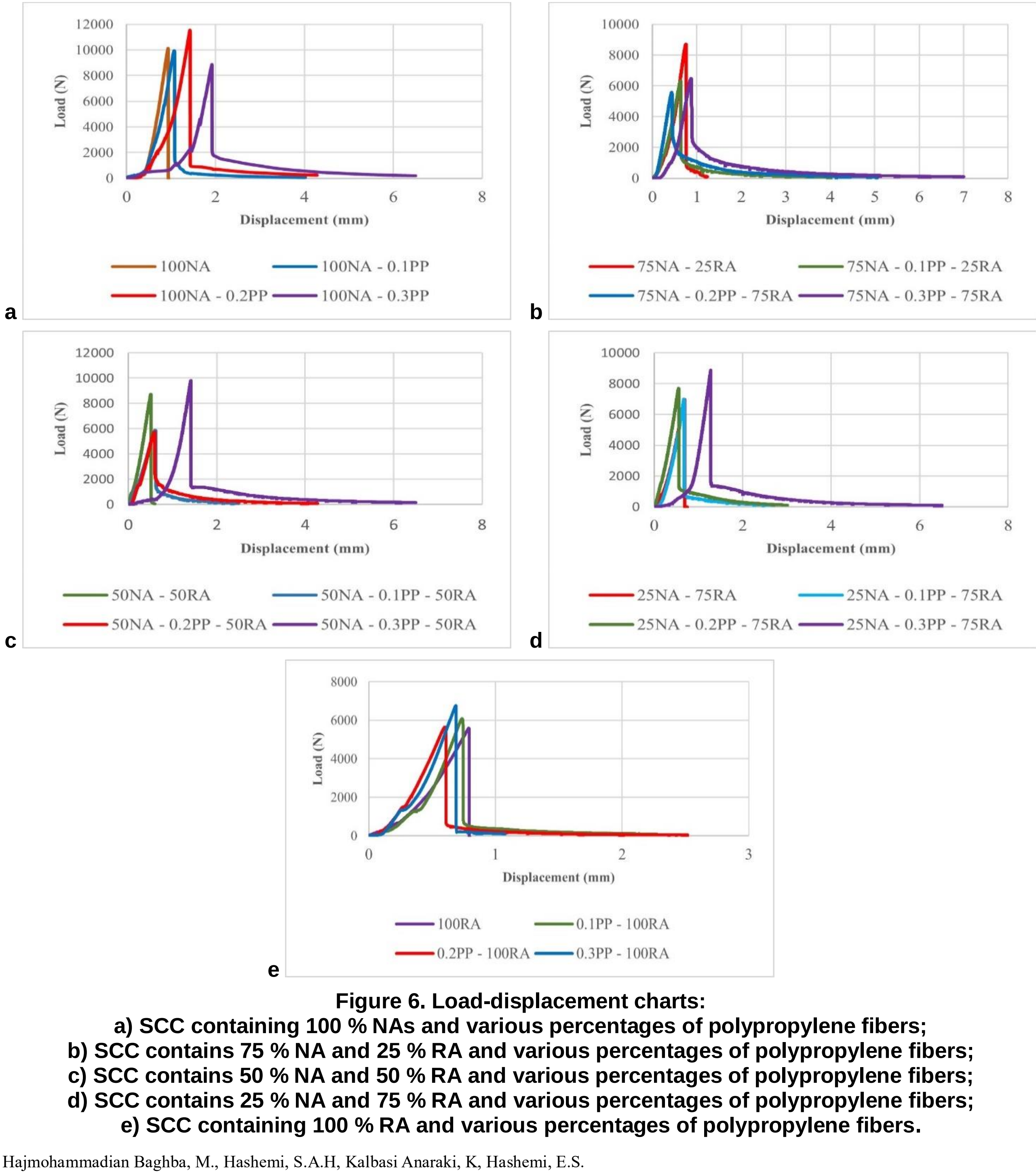

Figure 6. Load-displacement charts:
a) SCC containing 100 % NAs and various percentages of polypropylene fibers;
b) SCC contains 75 % NA and 25 % RA and various percentages of polypropylene fibers;
c) SCC contains 50 % NA and 50 % RA and various percentages of polypropylene fibers;
d) SCC contains 25 % NA and 75 % RA and various percentages of polypropylene fibers;
e) SCC containing 100 % RA and various percentages of polypropylene fibers.

According to the load-displacement diagrams, it is observed in all designs with increasing polypropylene fibers, surface below the curve and hence the energy absorption capacities of the specimens are increasing. Specimens lack of fiber, have more fragility behavior and effect of applied load and after reaching the final resistance specimen completely cracked and the resistance reaching to zero. But, in the specimens containing fiber, when the applied load reaches to the maximum value (load tolerance by section) the load capacity is not reached zero and the specimen will still be able to load tolerance. It should be noted that the higher presence of the percentage of fiber, the more energy absorption in specimens is observed.

3.2.4. Impact resistance

This test was done on the concrete shape disks specimens to diameter 150 and a height 65mm at the age of 28 days. The results test for the manufacturing of mixture composition with different percentages of recycled aggregate and polypropylene fiber is shown in Table 4 and Fig. 5d. As shown in Fig. 5d the effect of different percentages fiber and RA. Fiber improves the performance of concrete in this test. This is consistent with the results stated the reference of [30–33]. According to increasing 0.1 %, 0.2 % and 0.3 % polypropylene fiber in mixes include 100 % NA (mixes number 2, 3 and 4) compared to mix number 1 the lack of fiber increased by 11.88 %, 20.28 %, and 30.77 % respectively of the impact resistance against the first crack. While recycled aggregate causing reduces the concrete impact resistance against to the first crack. So that replaced by 25 %, 50 %, 75 % and 100 % RA (mixes number 17, 18, 19 and 20) instead of NA (mix number 1) in the mixes lack of fiber, respectively 18.88 %, 29.37 %, 38.46 %, and 63.63 % were decreased impact resistance against the first crack.

4. Conclusion

1. The test results of the flow slump are shown, with the increase of recycled aggregate, flow slump is decreased slightly while adding the fibers causing to the flow slump decreased rapidly.

2. The presence of the 0.3 % polypropylene fibers in mixes has to lead the steep drop of the flow slump, so it can be said that none of them not including in the categories of self-compacting concrete. Hence, the presence of polypropylene fibers until to 0.2 % in the mixes is allowed (for cement consumption: 450 kg/cm^3).

3. The processing of decreasing the passing ability and filling ability self-compacting concrete in the other concrete fresh state test is slightly change confirmed.

4. By increasing the use of recycled aggregate in new concrete, it can be seen compressive strength, Tensile strength, flexural strength and impact resistance of the specimens are decreasing.

5. The using of the polypropylene fibers up to 0.2 % in the mixes containing 100 % natural aggregate causes to the slight increase of the compressive strength. While increasing 0.3 % of the fibers in the mixes, causing a decrease in the compressive strength of concrete.

6. Using 0.1 % of polypropylene fibers have not more effect on the compressive strength in different percentages of recycled aggregate. While in the mixes including 0.2 % and 0.3 % polypropylene fibers with the presence of 25, 50, 75 and 100 % recycled aggregate causes to increase the compressive strength. In other words, the fibers can to some extent compensate the drop of strength from the presence of recycled aggregates.

7. Totally, the presence of the polypropylene fibers causes the increase in the tensile strength of concrete. With the increase, the polypropylene fibers up to 0.2 % are significantly increased.

8. With the increasing by volume of percentage the polypropylene fibers in the mixes including recycled aggregates, the flexural strength of concrete were decreased. The specimens that have a lack of the fibers are fragile behavior and in the effect of applied load and after reaching the maximum resistance and the whole section are surrendered. While in the specimens containing polypropylene fibers after the applied load reaches to the maximum value load tolerance by section suddenly not surrender and the specimen will still be able to load tolerance.

9. By investigation, the load-displacement charts, it can be seen the presence of polypropylene fibers generally improves the energy absorption.

10. Using the polypropylene fibers has changed the specimen failure from Fragile to gradual failure.

11. Generally, it can be said that the presence of 25 % recycled aggregate; there was no significant drop in tests. It can easily good replacement for natural aggregate and at the same time causes less environmental degradation.

12. As the results of this study show, the presence of fibers improves the mechanical properties of concrete. This is similar to the results of other researchers.

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