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Properties of Normal and High Strength Fiber Reinforced Concrete using Recycled Aggregate and Different Fibers

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Abstract: In Egypt, the efficient use of the construction and demolishing wastes by recycling would reduce the costs and definitely lead to conservation of the invaluable non-renewable sources of energy and hence it should be given considerable importance. This investigation was carried out on forty mixes divided into two phases: phase-I of cement content 400 kg/m^3 for normal strength concrete and phase-II of cement content 600 kg/m^3 for high strength concrete. Four recycled aggregate replacement percentages of (0%, 25%, 50% and100%) with different types and volume fractions of synthetic fibers of (0.05%, 0.1% and 0.2% Fibermesh 300 and 0.1% polypropylene fiber) are used in the both phases. The experimental program included assessment of fresh and hardened concrete properties using tests of workability, air content, compressive strength, indirect tensile (splitting tensile) strength, flexural strength, static modulus of elasticity, impact resistance, abrasion resistance and drying shrinkage. Based on the findings, it was found that both normal and high strength recycled aggregate concretes, as the replacement percentage of recycled aggregate increases, the mechanical properties of concrete with and without fibers decrease. Also, the used synthetic fibers with volume fraction up to 0.2% enhanced the mechanical properties of both types of normal and high strength concrete mixes. However, research results indicate that the Fibermesh 300 performs better than polypropylene fibers in flexure strength, impact strength and controlling drying shrinkage of concrete at the same volume of content.

Key words: Recycled aggregate · Normal strength · High strength · Synthetic fibers · Concrete properties

INTRODUCTION

Utilization of recycled aggregates from construction and demolition wastes is considered to have prospective application in construction as alternative to primary (natural) aggregates. Usually, the old cement paste or mortar attached to the Recycled Concrete Aggregate (RCA) particles ranges between 30-60%, depending on the aggregate size. This may have a great influence on the bond between the new cement paste and the aggregate [1, 2]. Also, it is the main reason for the higher absorption of RCA referred by many researches [3]. The compressive strength of concrete is a vital parameter as it decides the other parameters like tension, flexure etc. It was observed that the compressive strength of Recycled Aggregate Concrete (RAC) is about 80% or more than that of the control concrete with Natural Aggregates (NA) when the relative water absorption of aggregate is below 1.8%. However, when the relative water absorption of aggregate is above 5.5%, the compressive strength of RAC drops significantly about 40% as compared with the control concrete mix with NA. The poor development of the RAC compressive strength can be due to the large amount of old cement paste on the surface of recycled aggregates because it causes insufficient hydration and weak interface-zone formed between different components of the concrete matrix [4]. However, El-Karmoty [5] indicated that test results of the compressive strength of concrete using replacement of natural aggregates by up to 100% RCA in mixtures with 250 kg/m^3 cement content produced plain concrete with 15MPa characteristic strength which is suitable for most

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plain concrete applications in Egypt. Rana Mtasher *et al.* [6] observed that compressive strengths increase for fibrous concrete with polypropylene fiber compared to non-fiberous concrete is 11%, 24.35%, 46.0% and 56.4% for 0.4%, 0.8%, 1.0% and 1.5% fiber content, respectively. With respect to durability, it was clearly seen throughout experiment that the measured drying shrinkage of RAC mix is obviously greater than the control mix (incorporating NA) with an increase about 25% average at 112 day. Test results in the same research also indicated that the addition of fly ash as a partial cement replacement in RAC mix reduces drying shrinkage [7]. The shrinkage contraction rate of fibrous concrete decreased significantly with the addition of polypropylene fibers (PPF). At the 45th day, the shrinkage contraction rate has reduced by 43.03%, 51.93% and 68.25% for fiber contents of 0.45, 0.90 and 1.35kg/m^3 mixtures compared to reference mixture C1, respectively [8].

The main objectives of the current research are to determine the influence of using RCA on the properties of both normal and high-strength concrete and to investigate the effect of adding synthetic fibers to recycled aggregate concrete to provide a solution for current application requirements and better performance.

Research Program: The experimental test program was designed to achieve the research objectives of the study. The program consists of two phases: phase-I of cement content 400 kg/m^3 for normal strength concrete and phase-II of cement content 600 kg/m^3 for high strength concrete. Forty mixes were made with RCA replacement percentages of (0%, 25%, 50% and 100%) and percentages of synthetic fibers of (0.05%, 0.1% and 0.2% of Fibermesh® 300 and 0.1% polypropylene fiber). The experimental program included assessment of fresh and hardened concrete properties using tests of workability, air content, compressive strength, indirect tensile (splitting tensile) strength, flexural strength, static modulus of elasticity, impact resistance, abrasion resistance and drying shrinkage. The hardened concrete properties were measured at age 28 days, except for compressive strength that was measured at 7, 28 and 90 days.

Materials Properties: Test specimens in this study were prepared using three types of aggregates which include natural sand as fine aggregate, coarse aggregates with grading 5-10 mm were natural crushed stone aggregate and recycled coarse aggregate. The recycled coarse aggregate was produced by crushing waste ready-mix concrete by Jaw crusher type (BB300) machine. The type of cement used was CEM I 42.5N. Clean tap drinking water was used for concrete mixing all through the study. Silica fume was used only in phase-II for high strength concrete mixes. A superplasticizer namely (ADDICRETE BVF) was used in phase-I, while ViscoCrete®-20HE was chosen to be used in phase-II. Testing of these materials was carried out according to Egyptian standard specifications and the ASTM standards. Two types of synthetic fibers were used in this study namely: CMB polypropylene fiber and Fibermesh® 300 synthetic fiber. Both types of fibers have the same density of 0.9 g/cm^3 but with different geometry. These synthetic fibers have been chosen because of their performance in concrete behavior according to previous investigations.

Concrete Mix: Mixing was done in a standard drum-type mixer. Coarse and fine aggregates were first mixed in dry state until the mixture became homogeneous. All binder materials (cement and silica fume) were added to the dry mixture and mixing continued until the mixture became homogeneous. Fibres were then dispersed manually into the rotating mixer. Finally, the mixing water containing the superplasticizer admixture was added to the rotating mixer and mixing continued to assure complete homogeneity. Different water/binder ratio and superplasticizer content were used in this work to achieve constant slump (8 -10 cm) for phases I and II.

Details of Specimen: Compression test at 7, 28 and 90 days was carried out on 150 x 150 x 150 mm cubes. Splitting test and static modulus of elasticity at 28 days were carried out on 150 x 300 mm cylinders. Flexural strength and impact resistance tests at 28 days were carried out on 100 x 100 x 500 mm beams. Molds of 70 × 70 × 30 mm were used for abrasion tests at 28 days, while prisms of 70 × 70 × 300 mm were used for drying shrinkage tests. The tests were carried out according to the Third Appendix of Egyptian Code ECP 203-2007 [9], Egyptian Stander Specifications ESS 1658-2008 [10], ESS No. 269-2/2006 [11] for abrasion tests and ASTM C 157 [12] for drying shrinkage. All the test specimens were demoded after 24h and then stored under water in curing tanks with room temperature (25± 2°C).

RESULTS AND DISCUSSION

Workability: For phase I, the dosage of (ADDICRETE BVF) superplasticizer added to different concrete mixes to maintain a constant slump of 8-10 cm was ranged between 0.425% and 0.5% of cement content, for all the concrete

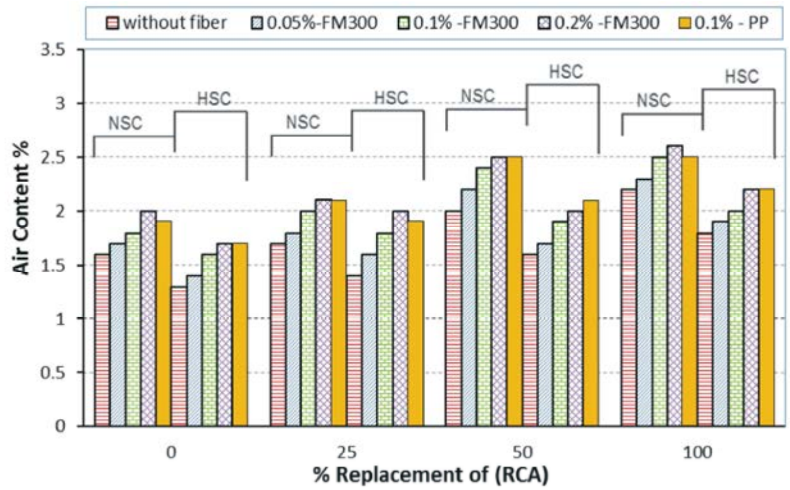

Fig. 1: Effect of RCA replacement percentage and different fiber content on air content % phase I and phase II

mixes using different replacement percentages of RCA of 25%, 50% and 100% with different amounts and types of polypropylene fibres. It can be noticed that the dosage of superplasticizer increased around (6% to 18%) compared to the control mix by increasing the percentage of replacement ratio of RCA. This can be due to more angularity in shape and rough surface of RCA as well as the adhering mortar attached to the aggregates. In addition, the fibrous concrete mixes needed more water mix than the normal concrete mixes. Full replacement of natural aggregate with RCA requires about 12% increase in the dosage of superplasticizer to achieve the same workability without using change in w/c ratio. This percentage increased to about 18% at concrete mix containing 0.2% Fibremesh 300.

For phase II, The dosage of (ViscoCrete® -20HE) superplasticizer added to different concrete mixes was at constant rate of 2% of cement weight. Superplasticizer (SP) was used to lower the water/ binder ratio and increase the slump for all the concrete mixes resulting in higher concrete strengths. The free water/binder ratio was ranged from 0.2 to 0.227 for NAC and RAC mixes to obtain a slump value of 8 -10 cm. It can be noticed that it is required to increase water by 2.5–14 % to achieve the same level of workability when using different percentage replacement of RCA. Full replacement of natural aggregate with RCA requires about 6% increase in mixing free water to achieve the same workability without using change in SP/b%. This percentage increased to about 14% at concrete mix containing 0.2% Fibremesh 300.

Air Content: The air contents of concrete mixtures with coarse RCA are higher than those with only NA for both phases. This may be attributed to greater porosity of the RCA due to the adhered mortar. Also, results presented in Fig. 1 show that the air content percentage increases due to presence of fibers. For phase I, using 25%, 50% and 100% replacement percentages of RCA, the air content percentage of recycled aggregate concrete increased about 6%, 25% and 38%, respectively. While, for phase II, the air content percentage increased about 8%, 23% and 38.5%, respectively as compared to control concrete mixes with natural aggregates in both phases. Similar trend was observed for fibrous concrete mixes with different RCA content. In phase I, the maximum air content percentage was 2.6% for concrete mix with 100% RCA and 0.2% Fibermesh 300. While, in phase II, the maximum air content percentage was 2.2% for concrete mix with 100% RCA and 0.2% Fibermesh 300. These values are considered acceptable as they didn't exceed the maximum allowable air content percentage mentioned in the Egyptian code which is (3%) [13].

Compressive Strength: The increase in the compressive strength for each type of concrete with age as recorded during the test is shown in Tables 1 and 2. It can be noticed that, the compressive strength of NAC is always greater than that of RAC at 7, 28 and 90 days. This may be attributed to the weak interfaces bond in recycled aggregate concrete, as there are two different Interfacial Zones (ITZ), the old ITZ between the original aggregate and the adhering mortar and a new ITZ between the new cement paste and the old mortar adhering to the RCA and this is mainly the factor that contributes to the decrease in strength of the RCA concrete mixes. In Fig. 2, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the compressive strength of recycled aggregate concrete decreased about 3.8%, 6%

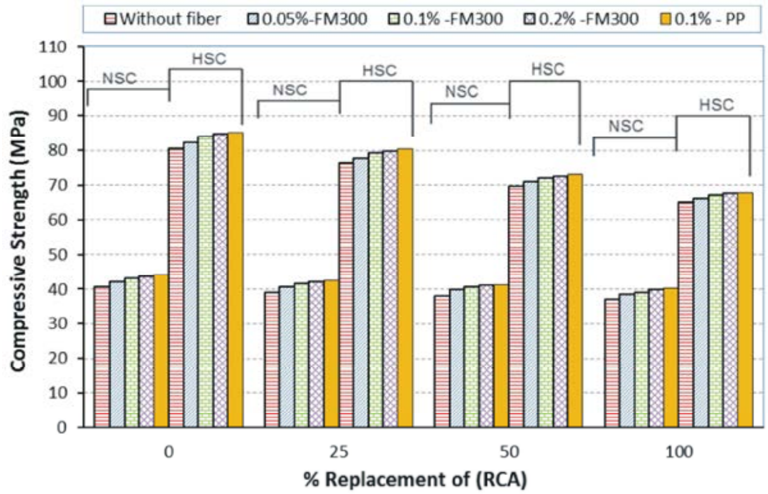

Fig. 2: Effect of RCA replacement percentage and different fiber content on compressive strength at 28 days, phase I and phase II

Table 1: Compressive strength test results forconcrete mixes, phase I

Mix symbol	(RCA) %	(FM 300) %	(PP) %	Compressive strength (MPa)		
				7days	28 days	90 days
N*0	0	0	0	30.71	40.6	47.15
N*25	25	0	0	29.86	39.06	45.05
N*50	50	0	0	29.6	38.21	44.27
N*100	100	0	0	28.65	37.2	43.17
N1	0	0.05	0	32.35	42.32	48.93
N2	0	0.1	0	33.18	43.33	49.93
N3	0	0.2	0	33.83	43.91	50.44
N4	0	0	0.1	33.92	44.14	50.6
N5	25	0.05	0	31.33	40.85	46.75
N6	25	0.1	0	32.34	41.78	47.74
N7	25	0.2	0	32.89	42.24	48.12
N8	25	0	0.1	33.09	42.45	48.51
N9	50	0.05	0	30.86	39.89	45.42
N10	50	0.1	0	31.86	40.78	46.77
N11	50	0.2	0	32.58	41.24	47.25
N12	50	0	0.1	32.38	41.3	47.26
N13	100	0.05	0	29.94	38.57	44.46
N14	100	0.1	0	30.78	39.23	45.6
N15	100	0.2	0	31.48	39.98	45.84
N16	100	0	0.1	31.27	40.09	45.84

and 8.4%, respectively at 28 days. While, for phase II, the compressive strength decreased about 5.3%, 13.4% and 19.2%, respectively as compared to NAC control concrete mixes in both phases. The results also show that by using synthetic fibers of Volume Fraction (V_f) up to 0.2%, the compressive strength increases for the tested concrete mixes in this research that were designed to obtain a slump value of 8 -10cm. The improvements of compressive strength with small content of the used polypropylene fibre and Fibremesh came principally from the fibers interacting with the advancing cracks. The presence of polypropylene fibers reinforce the concrete matrix by delaying the initial cracks and disallowing the micro cracks from growing into macro cracks [14]. By using Fibremesh 300 of V_f= 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the compressive strength for phase I increased about 3.6 %, 5.5%, 7.4%, respectively and 7.8 % when using 0.1% of polypropylene fiber. For phase II, the compressive strength increased about 1.4%, 3%, 4%, respectively and 4% when using 0.1% of polypropylene fiber, as compared to corresponding RAC mixes without fiber content in both phases.

Table 2: Compressive strength test results for concrete mixes, phase II

Mix symbol	(RCA) %	(FM 300) %	(PP) %	Compressive strength (MPa)		
				7 days	28 days	90 days
H*0	0	0	0	71	80.68	88.72
H*25	25	0	0	68.12	76.4	83.8
H*50	50	0	0	62.25	69.87	76.62
H*100	100	0	0	57.88	65.19	71.47
H1	0	0.05	0	73.13	82.45	90.49
H2	0	0.1	0	74.48	83.91	92.04
H3	0	0.2	0	75.54	84.71	93.05
H4	0	0	0.1	75.97	85.03	93.33
H5	25	0.05	0	69.67	77.93	85.61
H6	25	0.1	0	70.89	79.23	87.04
H7	25	0.2	0	71.77	79.84	87.63
H8	25	0	0.1	72.11	80.3	88.13
H9	50	0.05	0	63.59	71.12	78.21
H10	50	0.1	0	64.39	72.24	79.29
H11	50	0.2	0	65.26	72.66	79.82
H12	50	0	0.1	65.57	73.08	80.21
H13	100	0.05	0	59.04	66.1	72.54
H14	100	0.1	0	59.85	67.14	73.62
H15	100	0.2	0	60.6	67.66	74.26
H16	100	0	0.1	60.83	67.8	74.33

Table 3: Hardened concrete test results forconcrete mixes, phase I

Mix symbol	(RCA) %	(FM300) %	(PP) %	Tensile strength (MPa)	Flexure strength (MPa)	Elastic modulus (GPa)	Impact energy (kNmm)	Drying shrinkage (με)	Loss of thickness (mm)
N*0	0	0	0	3.70	6.05	28.88	121	460	0.81
N*25	25	0	0	3.46	5.74	28.24	115	524	0.86
N*50	50	0	0	3.33	5.51	28.01	112.6	552	0.90
N*100	100	0	0	2.81	5.01	25.70	106.5	566	0.96
N1	0	0.05	0	3.81	6.33	29.59	217.8	382	0.71
N2	0	0.1	0	3.90	6.82	29.93	278.4	340	0.69
N3	0	0.2	0	3.99	7.15	29.97	363.1	267	0.61
N4	0	0	0.1	4.00	6.61	30.06	254.2	354	0.61
N5	25	0.05	0	3.54	5.98	28.94	205.6	433	0.76
N6	25	0.1	0	3.63	6.42	29.23	260.8	389	0.73
N7	25	0.2	0	3.71	6.75	29.29	336.9	303	0.65
N8	25	0	0.1	3.71	6.15	29.36	234.6	399	0.65
N9	50	0.05	0	3.41	5.70	28.68	199.1	447	0.79
N10	50	0.1	0	3.49	6.01	28.88	252.6	403	0.77
N11	50	0.2	0	3.56	6.36	28.88	329.2	315	0.68
N12	50	0	0.1	3.55	5.85	28.96	230.2	421	0.68
N13	100	0.05	0	2.86	5.16	26.27	190.9	452	0.85
N14	100	0.1	0	2.94	5.46	26.42	243.1	410	0.82
N15	100	0.2	0	2.98	5.70	26.45	317.4	315	0.73
N16	100	0	0.1	2.98	5.31	26.50	221	427	0.72

Tensile Strength: Results in Tables 3 and 4 show the reduction in splitting tensile strength of concrete mixes by increasing the percentage of RA content. In Fig. 3, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the average splitting tensile strength of recycled aggregate concrete decreased about 6.6 %, 10% and 24%, respectively. While, for phase II, the tensile strength decreased about 7.8 %, 15% and 29%, respectively as compared to NAC control concrete mixes in both phases. This trend is observed to be the same for all concrete mixes containing different fiber volumes as the usage of recycled aggregates contributed lower tensile strengths. The results also show that by using Fibremesh 300 of V_f = 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the tensile strength for phase I increased about 1.8 %, 4.5%, 5.8%, respectively and 6% when using 0.1% of polypropylene fiber. For phase II, the tensile strength increased slightly about 0.7%, 1% and 1.7%, respectively and increased to 2 % when using 0.1% of polypropylene fiber, as compared to corresponding RAC mixes without fiber content in both phases.

Table 4: Hardened concrete test results forconcrete mixes, phase II

Mix symbol	(RCA) %	(FM300) %	(PP) %	Tensile strength (MPa)	Flexure strength (MPa)	Elastic modulus (GPa)	Impact energy (kNmm)	Drying shrinkage (με)	Loss of thickness (mm)
H*0	0	0	0	5.39	10.78	37.55	302.6	685	0.68
H*25	25	0	0	4.97	9.78	36.87	293.2	760	0.71
H*50	50	0	0	4.58	9.25	36.42	279.9	795	0.73
H*100	100	0	0	3.83	8.07	33.98	254.2	829	0.76
H1	0	0.05	0	5.47	11.08	37.88	496.2	596	0.6
H2	0	0.1	0	5.51	11.39	38.13	617.2	541	0.56
H3	0	0.2	0	5.6	12.22	38.18	786.7	438	0.5
H4	0	0	0.1	5.62	11.22	38.24	568.8	562	0.5
H5	25	0.05	0	5.02	10	37.16	475.5	652	0.62
H6	25	0.1	0	5.05	10.31	37.39	589.8	595	0.59
H7	25	0.2	0	5.13	11.03	37.48	751.2	484	0.52
H8	25	0	0.1	5.15	10.16	37.53	548.9	628	0.52
H9	50	0.05	0	4.62	9.41	36.62	451.6	660	0.64
H10	50	0.1	0	4.63	9.55	36.87	563.9	604	0.61
H11	50	0.2	0	4.7	10.19	36.95	723.1	488	0.54
H12	50	0	0.1	4.73	9.52	37.06	519.1	651	0.53
H13	100	0.05	0	3.85	8.19	34.12	411.4	674	0.68
H14	100	0.1	0	3.86	8.29	34.27	515.8	611	0.64
H15	100	0.2	0	3.89	8.84	34.28	653.7	492	0.57
H16	100	0	0.1	3.91	8.21	34.35	466	655	0.56

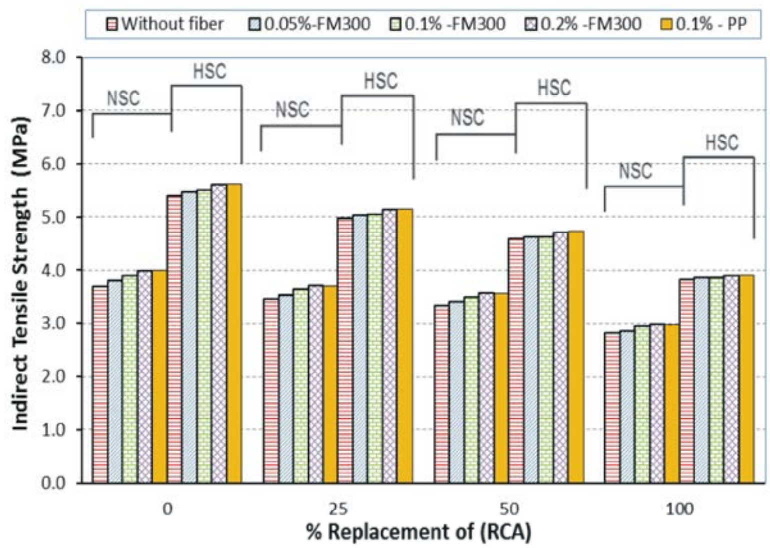

Fig. 3: Effect of RCA replacement percentage and different fiber content on tensile strength, phase I and phase II.

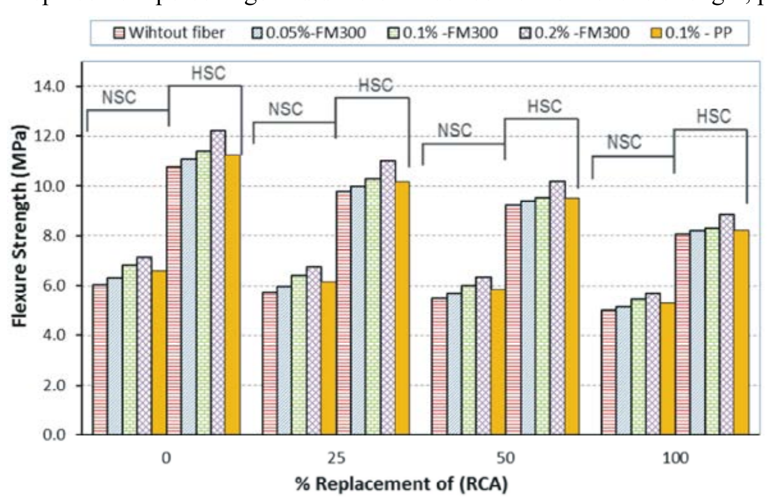

Fig. 4: Effect of RCA replacement percentage and different fiber content on flexure strength, phase I and phase II.

Flexural Strength: Results in Tables 3 and 4 show the reduction in flexure strength of concrete mixes by increasing the percentage of RA content. In Fig.4, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the average flexure strength of recycled aggregate concrete decreased about 5 %, 9% and 17%, respectively. While, for phase II, the Flexure Strength decreased about 9.3%, 14.2% and 25%, respectively as compared with control concrete mixes with natural aggregates in both phases. The results in Fig. 4 show that by using Fibremesh 300 of V_f = 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the flexure strength for phase I increased about 3%, 9%, 13.8%, respectively and 6% when using 0.1% of polypropylene fiber. For phase II, the flexure strength increased about 1.5%, 2.7% and 9.5%, respectively and increased to 1.7% when using 0.1% of polypropylene fiber as compared to corresponding RAC mixes without fiber content in both phases. The enhancement in flexural strength results can be explained by the ability of fibers to improve load bearing capacity in post cracking zone [15]. Mu and Meyer [16] mentioned that for fiber mesh-reinforced specimens, different loading directions lead to different mechanical response because of different crimped yarn and wavy yarn structures of the fabric. This is mainly could be the reason that Fibermesh 300 can perform better than polypropylene fibers depending on the test loading type.

Modulus of Elasticity: Results in Tables 3 and 4 show the reduction in modulus of elasticity of concrete mixes by increasing the percentage of RA content. In Fig. 5, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the average modulus of elasticity of recycled aggregate concrete decreased about 2%, 3% and 11%, respectively. While, for phase II, the modulus of elasticity decreased about 1.8%, 3% and 9.5%, respectively as compared to NAC control concrete mixes in both phases. This may be attributed to the presence of more micro cracks and weaker interfaces in recycled aggregate concretes. The results also show that by using Fibremesh 300 of V_f= 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the modulus of elasticity for phase I increased about 2.2%, 2.8% and 3%, respectively. For phase II, the modulus of elasticity increased slightly about 0.4 %, 0.8% and 1%, respectively as compared to corresponding RAC mixes without fiber content in both phases.

Impact Resistance: The impact resistance of concrete mixes reduced by increasing the percentage of RA content as shown Tables 3 and 4. In Fig. 6, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the impact resistance of recycled aggregate concrete decreased about 5%, 7% and 12%, respectively. While, for phase II, the impact resistance decreased about 3%, 7.5% and 16% respectively as compared to NAC control concrete mixes in both phases. The reason of that reduction may be because of the weak interface between the recycled aggregates and the cement paste that contribute to fracture propagation in the concrete. By using Fibremesh 300 of V_f= 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the impact resistance for phase I, increased significantly about 79.3%, 128.3%, 198%, respectively and 107.5% when using 0.1% of polypropylene fiber. For phase II, the impact resistance increased about 62%, 103% and 157.2%, respectively and increased to 83.3% when using 0.1% of polypropylene fiber compared to corresponding RAC mixes without fiber content in both phases. These results can be due to the fact that polypropylene fibers improve ductility and it would retard the appearance of the first cracking and resist crack development.

Abrasion Resistance: The abrasion resistance of concrete mixes reduced by increasing the percentage of RA content as shown in Tables 3 and 4. In Fig. 7, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the abrasion resistance of recycled aggregate concrete decreased about 6%, 11% and 18%, respectively. While, for phase II, the abrasion resistance decreased about 4%, 7% and 12%, respectively as compared to NAC control concrete mixes in both phases. These results could be due to the higher amount of cement matrix, attached to the recycled concrete aggregate which abraded more easily than the grains of natural aggregates [17]. By using Fibremesh 300 of V_f= 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the abrasion resistance for phase I, increased significantly about 11.5%, 14.2% and 23.7%, respectively and 24.5 % when using 0.1% of polypropylene fiber. For phase II, the abrasion resistance increased about 11%, 16%, 25.8%, respectively and 26.7% when using 0.1% of Polypropylene fiber, as compared to corresponding RAC mixes without fiber content in both phases. These results could be the bonding between the PP fibers and the concrete matrix that might have not allowed the particles to move away during the testing.

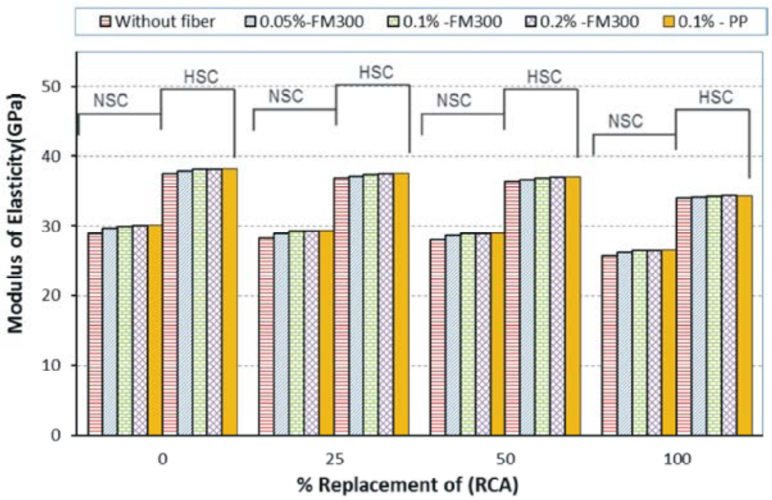

Fig. 5: Effect of RCA replacement percentage and different fiber content on modulus of elasticity, phase I and phase II

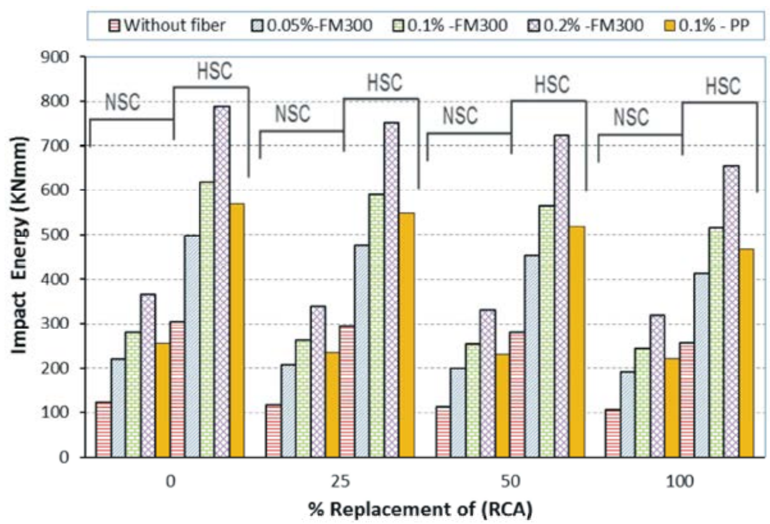

Fig. 6: Effect of RCA replacement percentage and different fiber content on impact resistance, phase I and phase II

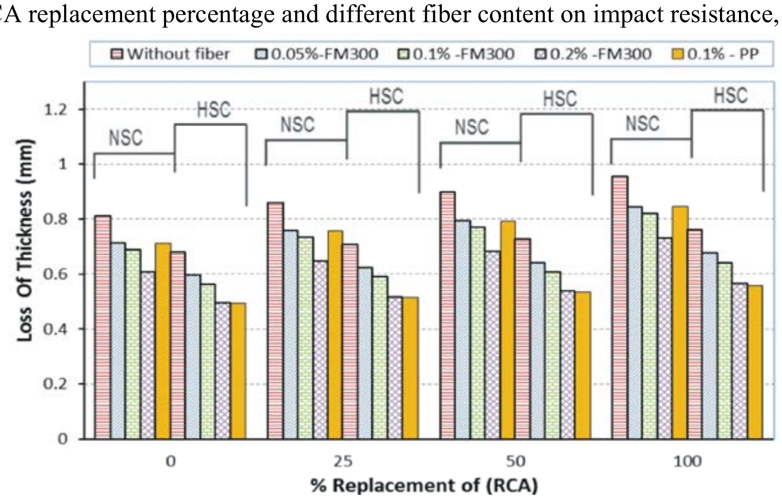

Fig. 7: Effect of RCA replacement percentage and different fiber content on loss of thickness (mm), phase I and phase II

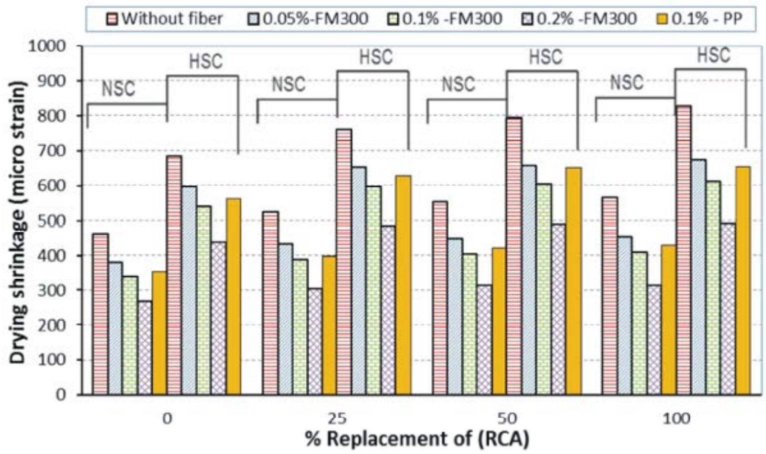

Fig. 8: Effect of RCA replacement percentage and different fiber content on drying shrinkage, phase I and phase II

Drying Shrinkage: Tables 3 and Table 4 show that the drying shrinkage of RAC is significantly greater than that of NAC. In Fig. 8, for phase I, using 25%, 50% and 100% replacement percentages of RCA, the drying shrinkage of recycled aggregate concrete increased about 14%, 20% and 23%, respectively. While, for phase II, the drying shrinkage increased about 11%, 16% and 21%, respectively as compared to NAC control concrete mixes in both phases. These results are expected due to the high water absorption of the RCA particles. The reduction of drying shrinkage of NAC and RAC mixes is observed when the percentage of Polypropylene fibers increased. This reduction in shrinkage can be explained as the early age volume changes in concrete cause weakened planes and micro shrinkage to form, the growth of these cracks is inhibited by mechanical blocking action of the fibers [15]. By using Fibremesh300 of V_f= 0.05%, 0.1% and 0.2% in RCA concrete mixes with 100% replacement percentages, the drying shrinkage for phase I decreased about 20.2%, 27.6%, 44.3%, respectively and 24.5 % when using 0.1% of Polypropylene fiber. For phase II, the Drying shrinkage decreased about 18.7%, 26.3%, 40.6%, respectively and 21% when using 0.1% of polypropylene fiber, as compared to corresponding RAC mixes without fiber content in both phases.

CONCLUSION

The use of recycled aggregates in concrete proves to be a valuable building. In accordance with the experimental phases carried out in this research, the following conclusions are drawn:

- The two types of fibers used in this study have almost the same effect on the reduction of slump. This is because the mix becomes fibrous which results in difficulty in handling. Also, the decrease in slump becomes higher at greater RCA content. Full replacement of natural aggregates by RCA in phase I requires about 12% increase in the dosage of superplasticizer to achieve a constant slump of 8-10 cm.
- The maximum air content percentages for concrete mix with 100% RCA and 0.2% Fibermesh 300 was 2.6% and 2.2% for phase I and II, respectively. These values are considered acceptable as they didn't exceed the maximum allowable air content percentage mentioned in the Egyptian code (3%).
- For all the concrete grades, as the replacement percentage of recycled aggregate increases, the mechanical properties of concrete with and without fibers decrease.
- By increasing the cement content and reducing w/c ratio in phase II, the compressive strength of 100% RCA concrete mix at 28 days was about 75% higher than corresponding mix in phase I. Also, most of the mechanical properties of RCA concrete mixes were significantly improved.
- The reduction in compressive strength of RCA concrete mixes with 100% replacement percentages in phase II was 20% instead of 9% for corresponding RCA concrete mix in phase I. Thus, recycled aggregate concrete is found to be more suitable for lower grade concretes.
- The tensile strength, impact resistance and drying shrinkage for concrete mixes with 100% RCA and PP fiber of V_f= 0.1% improved about 6%, 108% and 25% as compared to corresponding RAC mixes without fiber content in phase I, which provide a solution to

current application requirements and gives better performance.

- Fibermesh 300 performs better than polypropylene fibers in flexure strength, impact strength and controlling drying shrinkage of concrete in both phases. As the impact resistance of NA concrete mix in phase I using 0.1% Fibermesh 300 was about 9.5% higher than corresponding concrete mix using polypropylene fiber by the same volume fraction.

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