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MECHANICAL PROPERTIES OF CONCRETE CONTAINING RECYCLED CONCRETE AGGREGATES SUBJECTED TO DIFFERENT FIRE DURATIONS

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The amount of construction and demolition waste has increased considerably over the last few years. Crushing concrete to produce coarse aggregate for the production of new concrete is one common means for achieving a more environment-friendly concrete. This experimental study demonstrates the mechanical properties of concrete containing recycled concrete aggregate (RCA) subjected to different fire durations. In the experimental work, the fresh concrete properties (slump test) and the hardened concrete properties, (compressive strength, splitting tensile strength, flexural strength and modulus of elasticity) were carried out. A total of thirty concrete mixes with different cement contents (300, 350, and 400 Kg/m3) at w/c ratio (0.5) were made and the percentage of substitution of natural concrete coarse aggregate by the recycled concrete coarse aggregate subjected to fire durations (1,2 and 3 hours) at fire temperature (600ºC) was (0%, 25%, 50% and 100%). In the process of mixing, equal consistence among all concrete mixes was achieved. The obtained results indicate that the recycled coarse aggregate subjected to fire can successfully be used for making structural concrete.

KEYWORDS: *Recycled concrete aggregate, fire duration, Compressive strength. Tensile strength, Flexural strength and Modulus of elasticity*

1. INTRODUCTION

Shortage of natural aggregate in urban environments and increasing distance between the sources of quality natural aggregate and construction sites compelled the constructors to consider substituting the natural aggregate by recycled material (construction ceramics, slag, concrete). On the other hand, large quantities of old concrete often occur in urban environments, whose removal and disposal presents an environmental problem. Many authors from different countries study this point. Solomon et al, [1] Marked an aggregate which is brought from demolished masonry and concrete structures as potentially good for use in new concrete. Scope of usage of recycled materials is determined by their quality. In general, the quality of recycled aggregate depends on the quality of the original concrete it was obtained from, so prior to the design of mixture; aggregates must be examined in detail. Tabsh and Abdelfatah, [2] Conclude that the percentage loss in compressive or tensile strength due to the use of recycled aggregate is more significant in a weak concrete than in stronger one. The use of coarse aggregate made from recycled concrete with strength equal to 50 MPa will result in concrete compressive and tensile strengths comparable with that achieved when using natural coarse aggregate. Recycled concrete mixes require more water than conventional concrete to maintain the same slump without the use of admixtures, regarding that it is a relatively new material [3].

Concrete is a composite material consisting of aggregates and matrix as its basic components. The effect of heating on both these components individually as well as their interaction control the behavior of concrete at high temperatures. Purkiss, [4] Concrete is a porous material with its pores filled with water and air. Surface heating of the concrete at elevated temperatures during fire not only results in deterioration of its properties like elastic modulus, tensile and compressive strength, but also in moisture migration in the presence of liquid water, heat evolved from fire to the concrete, causes the evaporation of liquid water. With the rise in temperature, the aggregate expands, the expansion of the matrix, on the other hand, is substantially offset of sometimes completely negated by shrinkage due to the evaporation of water. The resultant expansion differential causes internal cracking in the concrete and reduction in its stiffness. The extent of this phenomenon differs considerably with the type of aggregate and is most pronounced in the case of concrete with siliceous aggregate which at very high temperatures (575 ºC or above) also undergoes physical changes accompanied by a sudden expansion in volume, thus sometimes causing aggregate splitting and / or spalling. Concrete is a poor conductor of heat, but can suffer considerable damage when exposed to fire. Unraveling the heating history of concrete is important to forensic research or to determine whether a fire-exposed concrete structure and its components are still structurally sound, [5]. At temperatures of 70–80 °C ettringite dissociates and at about 100 °C the water physically bound in both the aggregates and the cement matrix starts to evaporate, increasing capillary porosity and microcracking at these relatively low temperatures, concrete may only experience a minor loss of strength. At temperatures ranging from 250 to 300 °C the loss of bound water in the cement matrix becomes more prominent a significant loss of strength is often observed. Up to 600 °C, most aggregates undergo thermal expansion and the consequent internal stresses give rise to extensive cracking at 600 °C the mechanical performance of concrete is already severely affected. From 600 to 800 °C, carbonates suffer decarbonation for calcareous aggregates, a considerable contraction may occur (due to the release of carbon dioxide) causing severe microcracking of the cement matrix. Finally, from 800 to 1200 °C, calcareous constituents suffer complete disintegration concrete becomes a calcinated material [6]. Producing concrete with recycled aggregate subjected to fire has still been inadequately researched field. So the effect of using aggregate obtained from demolished concrete has been studied previously in several researchers, while in the current study the recycled aggregate resulting from concrete subjected to fire will be used and its effect on the properties of concrete will be studied.

2. EXPERIMENTAL PROGRAM

2.1 Materials

2.1.1Cement

The cement used in this investigation was CEM I 42.5 N. Testing of cement was carried out as per the Egyptian Standard Specifications ESS 2421/2005 [7]. Mechanical and physical properties and the chemical analysis of the used cement are given in Tables (1) and (2) respectively.

Table (1): Mechanical and Physical Properties of Cement

Property		Results	Specifications Limits*
Compressive Strength of Standard Mortar (MPa)	2 days	21.4	Not less than 10
	28 days	47.7	Not less than 42.50 Not more than 62.5
Soundness (La Chatelier) (mm)		1	Not more than 10
Setting Time (min)	Initial	135	Not less than 60
	Final	180	----------

*Limits of ESS 4756-1 / 2007 [7]

Table (2): Chemical Properties of Cement

Property	Results
Silicon Oxide SiO2	21.0
Aluminum Oxide Al2O3	6.10
Ferric Oxide Fe2O3	3.00
Calcium Oxide CaO	61.5
Magnesium Oxide MgO	3.8
Sulfur Oxide SO3	2.5
Sodium Oxide Na 2O	0.4
Potassium Oxide K2O	0.3
Loss on Ignition (L.O.I)	1.6
Insoluble Residue	0.9

2.1.2 Fine Aggregates

Natural sand composed of siliceous materials was used as Fine Aggregate (FA) in this study. Testing of sand was carried out according to the ESS 1109/2002 [8]. Table (3) shows the physical properties of the sand.

Table (3): Physical Properties of Fine Aggregate

Property	Results	Limits*
Specific Weight	2.63	-----
Bulk Density (t/m3)	1.78	-----
Clay and Fine Dust Content (% By Volume)	1.4	Not more Than 3

*Limits of ESS 1109 /2002 [8]

2.1.3 Coarse aggregates

2.1.3.1 Natural coarse aggregates

Natural crushed stone (dolomite) was used in this study. Testing of natural coarse aggregate (NCA) was carried out according to the ESS 1109/2002 [8]. Mechanical and physical properties of the NCA comply with both ESS 1109/2002 [8] and the Egyptian Code ECCS203-2007 [9]. Table (4) shows the physical and mechanical properties of the Natural crushed stone (dolomite).

Table (4): Physical and Mechanical Properties of Natural Coarse Aggregate

Property	Results	Limits
Specific Weight	2.61	-----
Bulk Density (t/m3)	1.56	-----
Water Absorption %	2.05	Not more than 2.5**
Clay and Fine Dust Content	2.4	Not more than 4*
Flakiness Index %	36.8	Not more than 40*
Elongation Index %	9.6	Not more than 25**
Abrasion Index %	17.8	Not more than 30*
Impact Value %	12.60	Not more than 45*

*Limits of ESS 1109/2002 [8]
**Limits of ECCS203-2007 [9]

2.1.3.2 Fired Recycled coarse aggregates

The recycled coarse aggregate used in this study were produced by crushing the concrete elements subjected to fire. Jaw crusher type (BB300) was used to gash the fined elements into wise recycled aggregate with fraction size 10 mm.

Testing of (RCA) was carried out according to the ESS 1109/2002 [8]. The physical and mechanical properties of the RCA are shown in Table (5).

Table (5): Physical and Mechanical Properties of Recycled Coarse Aggregates

Property	Results			Limits
	600°C - 1hr	600°C - 2hrs	600°C - 3hrs	
Specific Weight	2.18	2.20	2.15	-----
Bulk Density (t/m3)	1.25	1.51	1.31	-----
Water Absorption %	4.95	6.65	7.65	Not more than 2.5**
Clay and Fine Dust Content %	7	10	13	Not more than 4*

*Limits of ESS 1109/2002 [8]

2.1.4 Mixing water

Drinking water was used for mixing.

2.1.5 Superplasticizer

In this study, In order to obtain same workability without increased water, super plasticizer admixture ADDICRETE BV was used. ADDICRETE BV is a superplasticizer and flowing concrete admixture. (Complies with ASTM C 494 – 80 type A, DIN 10045, BS 5075PART1). Following properties, base material was lingo sulphonates, density was 1.18± 0.01/1 at 25°C and it was combatable with types of Portland cement.

2.2 Test setup of fire furnace and the Jaw crusher type BB300

The fire furnace was designed for the purposes of fire; the fire furnace system consists of three main components the fire chamber the fire lighter, and temperature control system as shown in Figure (1).The crusher used in this study was jaw crusher (type BB300) was shown in Figure (2).

2.3 Concrete mixes

The concrete mixes were prepared in the laboratory of Housing and Building National Research Center. A total of thirty concrete mixtures were made with different cement contents (300,350, and 400 kg/m^3) at w/c = (0.5), the superplasticizer dosage varied from 0.6% to 2.9% of cement content to achieve the required level of workability defined by a slump value of 10± 2cm. The percentage of substitution of natural concrete coarse aggregate by the recycled concrete coarse aggregate subjected to fire temperature 600°C for fire durations (1, 2, and 3hours) was (0%, 25%, 50% and 100%). Control mixes made with the natural aggregate, and the other concrete mixes were made using a recycled concrete aggregates subjected to fire, the ratio of fine to coarse aggregate was about 1:2 .Composition of designed mixtures has been shown in Table (6).

Fig (1) Test setup of fire furnace

Fig (2) Jaw crusher BB300

Table (6): Concrete Mixes Proportions at Fire Temperature 600°C for Fire Durations (1, 2, and 3 Hours)

Mix NO.	Designation	W	SP			C	FA	NCA	FRCA
			1hr	2hrs	3hrs				
Control	M1 (M-0% -300)	150	1	1	1	300	659	1317	-
G1 (1,2 and 3 hrs) 9 mixes	M2 (M-25%-300)	150	1.15	1.2	1.3	300	638	957	319
	M3 (M-50%-300)	150	1.7	1.9	1.95	300	618	618	618
	M4 (M-100%-300)	150	2.6	2.8	2.9	300	582	-	1164
Control	M5 (M-0%-350)	175	0.8	0.8	0.8	350	623	1246	-
G2 (1,2 and 3 hrs) 9 mixes	M6 (M-25%-350)	175	1	1.1	1.2	350	604	906	302
	M7 (M-50%-350)	175	1.35	1.45	1.6	350	585	585	585
	M8 (M-100%-350)	175	2.3	2.45	2.55	350	550	-	1100
Control	M9 (M-0% - 400)	200	0.6	0.6	0.6	400	588	1176	-
G3 (1,2 and 3 hrs) 9 mixes	M10 (M-25%-400)	200	0.9	1	1.1	400	569	854	285
	M11 (M-50%-400)	200	1.25	1.3	1.45	400	551	551	551
	M12 (M-100%-400)	200	1.7	1.9	2	400	519	-	1038

W= Water (Litre/m^3)
SP%; Superplasticizer percentage of cement content
C (kg/m^3) = Cement content
FA (kg/m^3) = Fine aggregates (sand)
NCA (kg/m^3) = Natural coarse aggregates
FRCA (kg/m^3) = Fired Recycled coarse aggregates

2.4 Concrete Tests

All the concrete mixes were mixed in the laboratory of Housing and Building National Research Center (HBRC). The slump test was conducted on fresh concrete to determine the slump value. For each concrete mix, six 150*150*150 mm cubes were cast for the determination of compressive strength at 7 and 28 days. Three 150 mm * 300 mm cylinders were cast for the determination of indirect tensile strength at 28 days. Three beams of dimensions 100 * 100 * 500 mm were cast for the determination of flexural strength at 28days. Two 150 mm * 300 mm cylinders were cast for the determination of static modulus of elasticity at 28 days. After casting, all the cast specimens were covered by plastic sheets and water saturated burlap and left in the laboratory at 20 ± 3 °c for 24 h. the specimens were then demoulded and transferred to a saturated water curing tank at 25°c until the age of testing.

3. RESULTS AND DISCUSSION

3.1 Properties of Fired Recycled Coarse Aggregate

Water absorption

The water absorption of fired recycled coarse aggregates is much higher than that of the natural coarse aggregates due to the large amounts of old mortar and cement paste attached to fired recycled coarse aggregates and dehydration. The water absorption of fired recycled coarse aggregates is ranged from 4.95% to 7.65%.

Specific gravity

The large amount of old mortar and cement paste adhering to fired recycled coarse aggregates, their specific gravity will be 15% to 17% lower than that of the natural coarse aggregates. The specific gravity of fired recycled coarse aggregates is ranged from 2.15 to 2.20.

Bulk Density

The bulk density of fired recycled coarse aggregates obtained from fired concrete at 600°C temperature for fire durations (1, 2, and 3 hours) are 19%, 3% and 16% respectively lower than that of natural coarse aggregate.

3.2 Fresh concrete properties

The dosage of superplasticizer added to different concrete mixes to maintain a constant slump of 10 ± 2 cm was shown in figure (3).

Figure (3) shows the comparison between concrete groups (600°C - 1hr, 600°C -2hrs, and 600°C -3hrs), it can be noticed that the dosage of superplasticizer was increased significantly by increasing the percentage of replacement of FRCA and fire duration.

In general, recycled concrete needed more superplasticizer dose than the control concrete (without recycled materials) regardless of fire duration, and this agree with D. M. Sadek [10] who found that the recycled concrete needed more superplasticizer dosage than the control concrete (without recycled materials) regardless of w/c ratio or type of recycled materials.

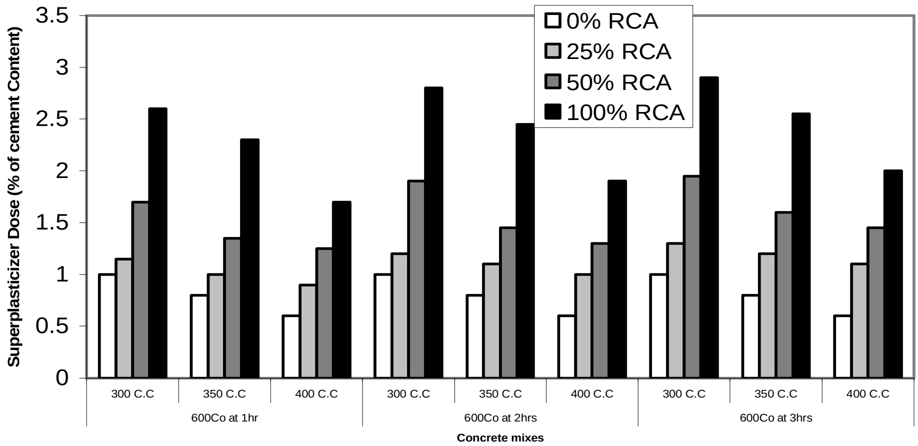


Fig (3): Superplasticizer Dosage for Concrete Mixes

3.2 Hardened concrete properties Compressive strength

The compressive strength results at 7 and 28 days of concrete mixtures subjected to fire temperature 600°C for fire durations (1, 2, and 3 hours) were presented in Table (7).

It was observed that the compressive strength of concrete mixtures with percentage of replacement ratios of FRCA (0% , 25% ,50 % and 100%)were increased by (26%,35%,25% and 30 %) , (28%,31%,22%and 20%) and (34%, 36%, 29 and 25%) at cement contents 300,350 and 400 kg/m^3 from 7 to 28 days, respectively, at fire duration 1hour.

Figure (4-a) shows the concrete mixtures subjected to fire temperature 600°C for 1hour, it can be noticed that at replacement ratio 25% FRCA, there is a slight increase in the compressive strength by (2% and 1%) at cement contents of (300 and 350kg/m^3) respectively, the compressive strength at cement content 400kg/m^3 decreased by 1% comparing to control mixtures at 28 days. This agree with Etxeberria et al, [11].Who found that the results up to 25% RCA has no major effect on compressive strength, and also with F.A. El-Latif, [12].Who reported that there is an increase in the compressive strength at replacement ratio 25% by (4% and 2%) for cement contents (350 and 400kg/m^3) respectively, comparing to control mixtures at 28 days. (Notice that the RCA used in the previous studies was not exposed to fire). While at replacement ratios (50% and 100%) FRCA, there is a reduction in the compressive strength by (10% and 17%), (13% and 21%) and (13% and 20%) at cement contents 300,350 and 400kg/m^3 respectively, comparing to control mixtures at 28 days. This may be attributed to the weak bond between the fresh mortar and the old mortar adhering to the fired recycled coarse aggregates in addition to the low resistance of the fired recycled coarse aggregates to the mechanical action compared with the natural aggregates.

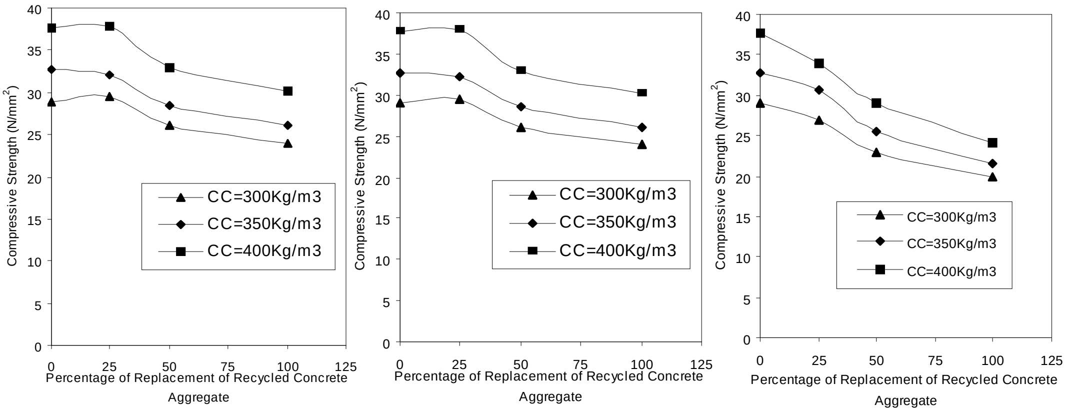
Figure (4-b) shows the concrete mixtures subjected to fire temperature 600°C for 2hours, it can be demonstrated that at replacement ratio 25%FRCA, there is a slight decrease in the compressive strength of concrete by 3% at cement contents (300 and 350 kg/m^3), while the compressive strength decreased by 4% at cement content 400 kg/m^3. At replacement ratios (50% and 100%) FRCA, there is a reduction in the compressive strength by (18% and 24%), (19% and 30%) and (18% and 28%) at cement contents 300,350 and 400 kg/m^3 respectively, comparing with control mixes.

Also, figure (4-c) shows the concrete mixtures subjected to fire temperature 600°C for 3hours, it can be noticed that as fire temperature and fire duration increased there is a significant disintegration of the calcium silicate hydrate as well as partial disintegration occurs in the aggregate. Where at replacement ratio 25%FRCA, there is a reduction in the compressive strength of concrete by 7% at cement contents (300 and 350 kg/m^3) and decreased by 10% at cement content 400 kg/m^3, while at replacement ratios (50% and 100%) FRCA, there is a reduction in the compressive strength by (20% and 34%), (23% and 34%) and (23% and 36%) at cement contents 300,350 and 400kg/m^3, respectively, comparing with control concrete. So as the fire duration increase the cohesion between the cement matrix and aggregate is starting to release, leads to the predominance of microcracks where the space between the cement matrix and aggregate increased intermingled with voids due to increase in porosity, the dehydration of calcium hydroxide is take place Ca(OH)2, and C-S-H gel. So we can concluded that as the duration of recycled concrete aggregate exposed to fire increased the loss in compressive strength increased at different cement contents and different percentage of replacements.

Table (7) Compressive Strength of Concrete Mixtures at Fire Temperature 600°C for Fire Durations (1, 2, and 3 Hours) at 7 and 28 days

Group	Designation	Compressive strength at 7 days (N/mm^2)			Compressive strength at 28 days (N/mm^2)		
		1-hr	2-hrs	3-hrs	1-hr	2-hrs	3-hrs
G1	M1(M-0%-300)	22.9	22.9	22.9	28.95	28.95	28.95
	M2(M-25%-300)	21.8	20.05	19.5	29.45	28	27
	M3(M-50%-300)	20.90	19.05	17.15	26.15	23.95	23
	M4(M-100%-300)	18.4	16.5	14.65	24	22.05	19.5
G2	M5(M-0%-350)	25.55	25.55	25.55	32.8	32.8	32.8
	M6(M-25%-350)	24.5	22.05	22	32.15	31.7	30.6
	M7(M-50%-350)	23.3	20.90	19.2	28.5	26.5	25.5
	M8(M-100%-350)	21.6	19.15	17.45	26	23	21.5
G3	M9(M-0%-400)	28	28	28	37.75	37.75	37.75
	M10(M-25%-400)	27.7	23.1	23.5	37.9	36.4	33.9
	M11(M-50%-400)	25.4	22.65	20.45	33	31	29
	M12(M-100%-400)	24.1	21.35	19.2	30.2	27.2	24.1

(M-%–C-G)
Where
M, refers to mix
% refers to fire recycled coarse aggregates
C, refers to cement content (kg/m^3)
G, refers to group number



a- Duration – 1hr b- Duration – 2hrs c- Duration – 3 hrs

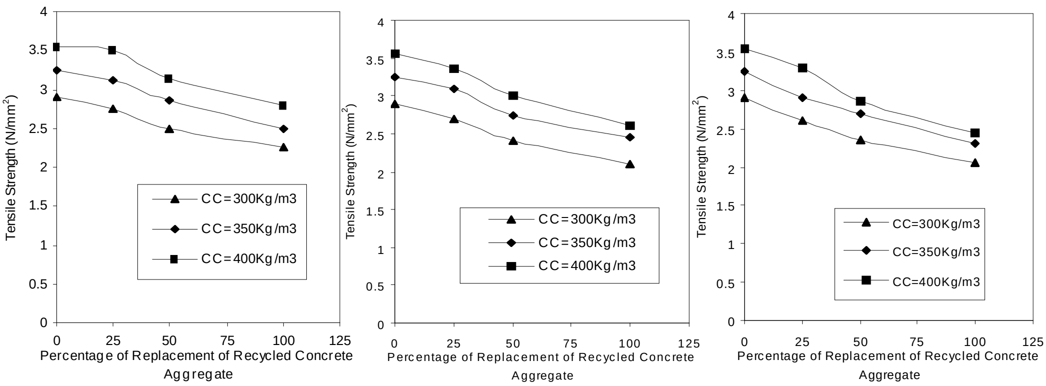
Fig. (4) Relationship between Compressive Strength and Percentage of Replacement of (RCA) for Different Cement Contents at Fire Temperature 600°C at 28 Days

Tensile Strength

It can be noticed from Fig (5-a) that at replacement ratio 25%FRCA, there is decrease in the tensile strength by (5%, 4%and 2%) at cement contents (300,350 and 400kg/m^3) when subjecting to fire temperature 600°C for fire duration 1 hour respectively, comparing to control mixtures . While at replacement ratios (50% and 100%) FRCA, there is a reduction in the tensile strength by (14% and 22%), (12% and 23%) and (12% and 21%) at cement contents 300,350 and 400 kg/m^{3}respectively, comparing to control mixtures.

It can be noticed from Fig (5-b) that at replacement ratio 25% FRCA, there is decrease in the tensile strength by (7%,5% and 5%) at cement contents (300,350 and 400kg/m^3) when subjecting to fire temperature 600°C for 2 hours respectively, comparing to control mixtures. While at replacement ratios (50% and 100%) FRCA, there is a reduction in the tensile strength by (17% and 27%), (15% and 25%) and (15% and 26%) at cement contents 300,350 and 400 kg/m^3 respectively, comparing to control mixtures.

Also, it can be noticed from Fig (5-c) that at replacement ratio 25% FRCA, there is high decrease in the tensile strength by (10%,10% and 7%) at cement contents (300,350 and 400kg/m^3)when subjecting to fire temperature 600°C for 3 hours respectively, comparing to control mixtures. While at replacement ratios (50% and 100%) FRCA, there is a reduction in the tensile strength by (19% and 30%), (17% and 29%) and (19% and 31%) at cement contents 300,350 and 400 kg/m^3 respectively, comparing to control mixtures. This agree with Hansen [13] Who stated that the full replacement of RCA, the tensile strength of recycled aggregate concretes produced with both fine and coarse aggregate to be reduced by 35%. (Notice that that the RCA used in the previous studies was not exposed to fire).



a- Duration – 1hr b- Duration – 2hrs c- Duration – 3 hrs

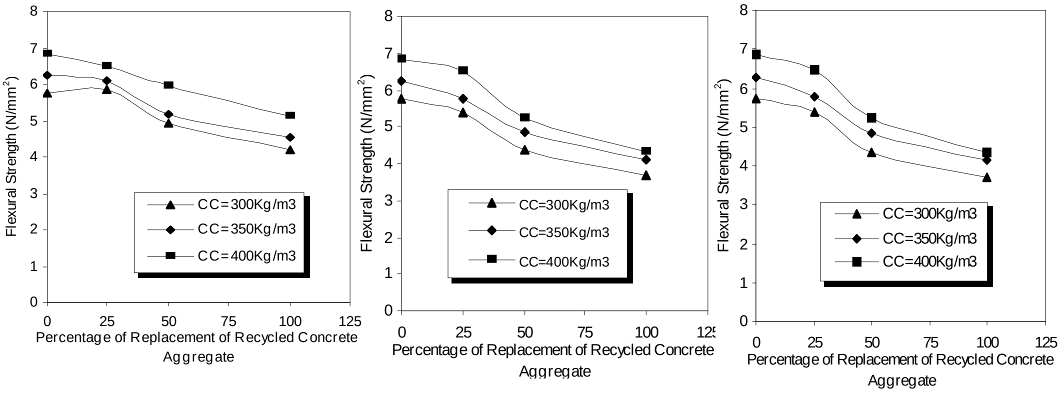
Fig. (5) Relationship between Tensile Strength and Percentage of Replacement of (RCA) for Different Cement Contents at Fire Temperature 600°C at 28 Days

Flexural strength

Figure (6-a) shows the concrete mixtures subjected to fire temperature 600°C for 1hour, it can be noticed that at replacement ratio 25%FRCA, there is a slight increase in the flexural strength by 1% at cement content 300 kg/m^3 and decreased by (1% and 6%) at cement contents (350 and 400kg/m^3) respectively, comparing to control mixtures, while at replacement ratios (50% and 100%) FRCA, there is a reduction in the flexural strength by (13% and 27%), (18% and 27%) and (14% and 25%) at cement contents 300,350 and 400kg/m^{3}respectively, comparing with control concrete. This agree with A. Rao et al, [14] Who stated in his literature that the full replacement of RCA, the flexural strength produced with both fine and coarse aggregate reduced by 26 %.(Notice that the RCA used in the previous studies was not exposed to fire).

Figure (6-b) shows the concrete mixtures subjected to fire temperature 600°C for 2hours, It can be noticed that at replacement ratio 25%FRCA, there is a decrease in the flexural strength by (5%, 4% and 9%) at cement contents (300,350 and 400 kg/m^3) respectively, comparing to control mixtures, while at replacement ratios (50% and 100%) FRCA, there is a reduction in the flexural strength by (18% and 30%), (20% and 31%) and (18% and 30%) at cement contents 300,350 and 400kg/m^3 respectively, comparing with control concrete.

Also, figure (6-c) shows the concrete mixtures subjected to fire temperature 600°C for 3hours, It can be noticed that replacement ratio 25%FRCA, there is decrease in the flexural strength by (6%, 8% and 5%) at cement contents (300,350 and 400kg/m^3) respectively, comparing to control mixtures, while at replacement ratios (50% and 100%) FRCA there is a reduction in the flexural strength by (24% and 36%), (22% and 34%) and (24% and 37%) at cement contents 300,350 and 400 kg/m^3 respectively, comparing with control concrete.



a- Duration – 1hr b- Duration – 2hrs c- Duration – 3 hrs

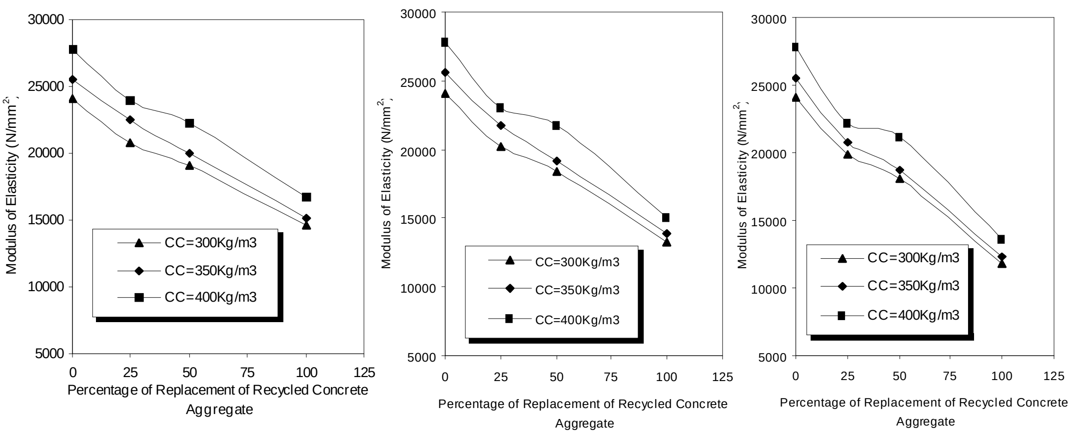
Fig. (6) Relationship between Flexural Strength and Percentage of Replacement of (RCA) for Different Cement Contents at Fire Temperature 600°C at 28 Days

Modulus of Elasticity

Figure (7-a) shows the concrete mixtures subjected to fire temperature 600°C for 1hour, It can be noticed that at replacement ratio 25%FRCA, there is a reduction in the modulus of elasticity by (14%, 12% and 14%) at cement contents (300,350and 400kg/m^3) respectively, comparing to control mixtures, while at replacement ratios (50% and 100%) FRCA, there is a reduction in modulus of elasticity by (21% and 39%), (22% and 41%) and (20% and 40%) at cement contents 300,350 and 400kg/m^{3}respectively, comparing to control mixtures. This may be attributed the presence of more micro cracks and weaker interfaces in recycled aggregate concretes. In addition to large amount of old mortar which is attached to original aggregate particles in recycled aggregates. This agree with Juan and Gutiérrez, [15] Who found out that the elasticity modulus is one of the most affected properties of recycled concretes, for percentages of RCA 20%, 50% and 100% the values of modulus of elasticity were 10%, 20% and 40% lower than the corresponding natural aggregate concretes. (Notice that RCA used in the previous studies was not exposed to fire).

Figure (7-b) shows the concrete mixtures subjected to fire temperature 600°C for 2hours, It can be noticed that at replacement ratio 25%FRCA, there is a reduction in the modulus of elasticity by (16%,15% and 17%) at cement contents (300,350and 400kg/m^3) respectively comparing to control mixtures, while at replacement ratios (50% and 100%) FRCA, there is a reduction in modulus of elasticity by (24% and 45%), (25% and 46%) and (22% and 46%) at cement contents 300,350 and 400kg/m^3 respectively, comparing with control concrete .

Also, figure (7-c) shows the concrete mixtures subjected to fire temperature 600°C for 3hours, It can be noticed that replacement ratio 25%FRCA, there is a reduction in the modulus of elasticity by (18%,19% and 20%) at cement contents (300,350and 400kg/m^3) respectively, comparing to control mixtures, while at replacement ratios (50% and 100%) FRCA, there is a reduction in modulus of elasticity by (25% and 51%), (27% and 52%) and (24% and 51%) at cement contents 300,350 and 400 kg/m^3 respectively, for different cement content when compared with the control concrete.



a- Duration – 1hr b- Duration – 2hrs c- Duration – 3 hrs

Fig. (7) Relationship between Modulus of Elasticity and Percentage of Replacement of (RCA) for Different Cement Contents at Fire Temperature 600°C at 28 Days

4. CONCLUSIONS

1- The variation in density and water absorption ratio of fired recycled concrete aggregates are much higher than those of natural aggregates. The variations are mainly due to the adhered mortar as reported by many other researchers. This may cause a quality control problem.

2- The dosage of superplasticizer was increased significantly by increasing percentage of replacement ratio of recycled concrete aggregates in the concrete mixtures to achieve acceptable workability of concrete.

3- The high strength relative observed in mixtures with 300 kg/m^3 cement content , so it can be concluded that it could be more useful to use recycled concrete aggregates in lower strength concrete.

4- Replacement of natural aggregate by 25% recycled concrete aggregates subjected to fire temperature 600°C for fire durations (1, 2 and 3hours) has a very minor effect on both of compressive, tensile strength and flexural strength.

5- The compressive strength of concretes containing full replacement of natural aggregate by recycled aggregates subjected to fire temperature 600°C for fire durations (1, 2 and 3hours) decreased with range (18% to 36%), comparing to control mixtures.

6- The tensile strength of concretes made with 100% recycled concrete aggregate subjected to fire temperature 600°C for fire durations (1, 2 and 3hours) decreased with range (23% to 30%), comparing to control mixtures.

7- The modulus of elasticity of concretes made with 100% recycled concrete aggregate subjected to fire temperature 600°C for fire durations (1, 2 and 3hours) decreased with range (40% to 50%), comparing to control mixtures.

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الخواص الميكانيكية للخرسانة التي تحتوي على ركام الخرسانة المعاد تدويره والمعرض للحريق لفترات زمنية مختلفة

تلاحظ في الآونة الأخيرة الزيادة المطردة في المخلفات الناتجة عن هدم الخرسانة حيث يتم التخلص منها عن طريق تجميعها في مدافن صحية خاصة مما يمثل ضررا بيئياً من حيث إهدار الموارد الطبيعية و المتمثلة في الركام الطبيعي ومن ثم بدأ التفكير في أنحاء متفرقة من العالم في استغلال هذه المخلفات عن طريق إعادة استخدامها في إنتاج الخرسانة بحيث تحل محل الركام بنسب مختلفة و ذلك بعد تكسير مخلفات الخرسانة باستخدام الكسارات للوصول الى المقاسات المطلوبة. و رغم وجود العديد من الأبحاث التي تم من خلالها دراسة الخواص الميكانيكية للخرسانة المحتوية على كسر الخرسانة كنسبة من الركام ألا أنه حتى الآن لم يتم دراسة تأثير استخدام مخلفات هدم الخرسانة الناتجة من انهيار المنشآت بسب الحريق عند استخدمها كنسب من الركام في الخرسانة .

ولذلك فان هذه الدراسة تعتني بدراسة تأثير زمن تعرض ركام الخرسانة المعاد تدويره والمعرض للحريق علي خواص الخرسانة التي يشكل فيها كسر الخرسانة نسبة من الركام حيث تم دراسة تأثير تعرض ركام الخرسانة المعاد تدويره والمعرض للحريق عند درجة حرارة 600 درجة مئوية لفترات زمنية متغيرة لمدة ساعة و ساعتين وثلاث ساعات و ذلك لعدد من الخلطات الخرسانية المختلفة (30 خلطة خراسانية) من حيث محتوي الأسمنت (300 و 350 و 400 كجم/م3) وكذلك تم الأخذ في الاعتبار نسبة استبدال الركام الطبيعي الكبير بناتج كسر الخرسانة (0% و 25% و 50% و 100%) وتستعرض نتائج الدراسة الخواص المختلفة للخرسانة مثل الخواص الطازجة (اختبار الهبوط) والخواص المتصلده مثل (مقاومة الضغط – مقاومة الشد – مقاومة الانحناء– معامل المرونة).