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FRESH AND HARDENED PROPERTIES OF RECYCLED CONCRETE AGGREGATE MODIFIED BY IRON POWDER AND SILICA

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ABSTRACT: In recent years, significant attention has been given by researchers to use recycled concrete aggregate (RCA) instead of natural aggregate (NA) in concrete mixes to decrease the demand on the natural aggregate resources and to reduce its environmental effects. This research work was carried out to investigate the efficiency of using RCA in concrete mixes in place of natural coarse aggregate. 90 cubes of (100 x 100 x 100 mm) with different percentages of RCA (0%, 30%, 45%, and 60%) at water to cement ratio of 0.4 and using 0% and 2.5% super plasticizer were casted. For that mix which was prepared with 45% of RCA 54 cubes of (100 x 100 x 100 mm) were casted with different percentages of iron powder in place of fine aggregate (10%, 15%, and 20 %). Hardened test was examined to measure the compressive strength after 7, 14 and 28 days of curing. Fresh property test was conducted (Slump test) to study the efficiency of using RCA on workability. The results of the study showed that the fresh property was decreased by increasing the RCA replacement. The compressive strength of the RCA was deceased by increasing the RCA replacement. For specimens casted using 45% of the RCA the compressive strength was increased by increasing iron powder replacement.

Keywords: Recycled Concrete Aggregate, Natural Aggregates, Iron Powder, Super Plasticizer

1. INTRODUCTION

Recycled concrete aggregates (RCA) largely vary from natural aggregate (NA) where RCA comprise of NA and cement mortar that coated NA. RCA has high water absorption, irregular texture and angular shape than NA, these factors affect the concrete properties [14]. RCA can be defined as the concrete mixes in which NA (fine and coarse aggregates) replace partially or entirely with recycled aggregate (RA). The RA was used in 1945 in concrete mixes, the constructing of concrete mix started after World War II to rebuild and rehabilitation of the residential buildings, roads, and infrastructures [28]. The housing buildings, roads, concrete bridges, concrete dams, and sometimes from a catastrophes (fire, floods and earthquake) are considered the main source of RCA that may be used in the construction processes [12]. Generally, the overall demolition construction waste from demolished facilities comprises about 40% concrete, 5% metal, 10% wood, 5% plastics, 30% ceramics and 10% other mixtures [30]. A great demand of cement and NA is expected in the world [Dabhade and others in 2014]. In the US approximately 2 billion tons of NA are used in construction each year, this NA consumption is anticipated to risein excess of 2.5 billion tons per year by the year 2020 [19]. The recent investigates have been mentioned to that quantities of demolished construction in the EU about 850 million tons per year, this represent about 31% of the overall waste generation [17].The European Union, 500 kg of rubble, construction and demolition waste per year correspond to every citizen [22]. The demand on the natural aggregate is in increasing, it's expected to increase to approximately 18 billion tons a year by 2050, which means in future we need approximately 14.4 billion tons of natural aggregate for concreting [24]. In general, engineering properties of the RCA is smaller than NA due to high porosity and low density as a result covered mortar paste around the aggregates [32]. On the other hand, the over 50% of RC have adhered mortar paste, this property is produced poor quality (highly porous mortar) than the new paste of NA [Preeti Saini, Deepakar Kr. Ashish]. Using of the RCA can solve several environmental problems such as decrease disposal areas by removing the increased waste concrete, decreasing of the energy consumption (production and transportation of aggregates), conserve of NA, transport costs of disposal concrete are reduced, and reduce harmful gas emissions. Otherwise, the ground excavation to remove rocks for preparation of virgin aggregates cause unrecoverable ecological destruction such as the change of landscape [27]. As well the NA production of 1 ton, 0.0046 million ton of carbon may be emitted whereas 1 ton RA only 0.0024 million ton carbon is emitted [30].

One of the most effective methods for growing environmental problems is usage of RCA in the different construction process (concert mix or asphalt mix) [13].So most of researches attendance in this century is to reuse the recycled aggregate in construction the structural elements.

2. LITERATURE REVIEW

In this century a lot of researches are focusing on using recycled concrete aggregate (RCA) as a replacement with natural aggregate (NA) in concrete buildings. Researchers examined many tests using different percentages' replacement of RCA instead of NA to investigate their properties. Ghand [9] replaced 10%, 20%, 30% and 40% of recycled aggregate in place of natural aggregate to study the compressive strength, splitting tensile strength, flexural strength, water absorption and bond strength for different concrete mixes prepared with different percentages of waste recycled aggregate at 7, 14 and 28 days curing period, they concluded that when they replaced 30% crushed aggregate in place of coarse aggregate and 10% of granite powder in place of fine aggregate the tests results after 7 and 28 days curing period of compressive strength, splitting tensile strength, flexural strength and bond strength got the optimum increment in comparison with the conventional concrete mixes. Yehia and other [27] studied the physical and mechanical properties of several concrete mixes prepared with 100 % RCA using four grades of RCA, grade 1 (maximum size of 10 mm), grade 2 (maximum size of 25 mm), grade 4 (mixture of course and fine aggregate along with impurities) and grade 5 (fine sand), it was seen that mix that prepared of RCA of grades 1,2 and 5 performed acceptable values of compressive, flexural, splitting tensile strength, and modulus of elasticity due to high packing density of the mix. Tiwari and Nateriya [29] used Indian standard codes to prepare concrete cubes with 0%, 50% and 100% of recycled aggregate (RA). Compressive test was performed for each percentage at 7, 14 and 28 days curing period, the test showed that the compressive strength of concrete cubes was decreased by increasing RA replacement without adding any type of filler. Etxeberria and other [11] investigated compressive strength and modulus of elasticity in wet condition for specimens casted with 0%, 25%, 50% and 100% of recycled coarse aggregates, the experimental investigation showed that the compressive strength of concrete mixes prepared with 25% of recycled coarse aggregates was medium strength in comparison with the other percentage and got the same mechanical properties as that of conventional concrete at specific w/c ratio, otherwise mixes prepared with 50% and 100% of RA need high amount of cement to achieve a high compressive strength, the results showed that it was not economic to use those percentages. Ngwenya and Franklin [21] examined slump test and compressive strength to five mixes prepared with different contents of recycled aggregate (RA); 0%, 25%, 50%, 75%, and 100% at water to cement ratio (w/c) of 0.45 and 0.5.According to test results compressive strength and slump test were decreased by increasing the percentage of replacement of RA from 0% to 100% and by increasing w/c. Adnan and other [2] performed compressive strength test to specimens prepared by (0%, 25%, 50%, 75%, and 100%) of recycled aggregate (RA) at different water-cement ratio (0.4, 0.5, and 0.6). It was found that recycled aggregate concrete (RAC) had lower compressive strength compared to Natural Aggregate Concrete (NAC).

Recycled concrete aggregate (RCA) can be developed to produce sustainable mixes. RCA can be prepared by crushing concrete aggregate into different sizes and then adding filler to RCA mixes to improve its properties since the RCA has high porosity and low specific gravity in comparison with conventional one. Concrete mixes which containing recycled aggregate were improved by adding different types of filler to increase the mixes strength. Junak and Sicakova [15] prepared 24 standard cubes (100*100*100 mm) for different percentage of coating filler; coal fly ash, liquid glass and 8M NaOH solution to improve the mechanical properties of recycled concrete aggregate (RCA), for each type of coating filler 12 specimens were tested to examine the density and the compressive strength of RCA and the other 12 specimens were used to examine the total absorption. The coating of RCA during the mixing of concrete showed higher value of compressive strength in comparison with those without coating". "Kou SC and other [16] presented an experimental study on the behavior of recycled concrete aggregate (RCA) by adding different types of filler, silica fumes (SF), metakaolin (MK), fly ash (FA) and ground granulated blast slag(GGBS) to study compressive strength, splitting tensile strength, ultrasonic pulse velocity, drying shrinkage and iron penetration to show the incorporation of those fillers in improving the RCA behavior, the results illustrated that the contributions of the filler admixtures to performance of concrete mixes of the recycled aggregate concrete mixes were higher than that to the natural aggregate concrete mixes.

Concrete compressive strength can be developed by adding iron filler to the mixes, Alzaed [5] prepared 144 standard cubes and cylinders using 0%, 10%, 20% and 30% of iron filing in concrete mix to study effects of iron powder filler on compressive strength and tensile strength after 28 days of casting, he performed that, concrete compressive strength increased gradually when iron filing added to the concrete mix where the tensile strength had a minor effect if the percentage of iron filing used more than 10%. Olutoge and other [23] investigated an experimental study on compressive strength of concrete after 28 days of casting prepared by adding different percentage of iron filler of 0%, 10%, 20% and 30%, their study investigated that the compressive strength of concrete mixes contained 10% and 20% increased by 3.5% and 13.5% while at 20% there was a decrease of 8% of compressive strength.

Chemical admixtures can be added to concrete mixes to improve their behaviors, super plasticizer has been used in many researches to increase the concrete strength and workability. Davoudi [10] used different dosage of super plasticizer in his research (5-20) litters per cubic meter of the concrete to study the effects of the super plasticizer on concrete mixes strength using the tree-classification decision algorithm analyzing, he concluded that by increasing the super plasticizer dosage the compressive strength was increased. Alsadey [4] performed an investigation to study effects of super plasticizer dosage on concrete and to get the best dose of super plasticizer that achieve the better strength and workability, in his investigation different percentages of super plasticizer were used 0.6, 0.8, 1.2, 1.8 and 2.5. he noticed by increasing the dose of super plasticizer the compressive strength for the different dosage of super plasticizer was higher for concrete mixes than the normal concrete mixes until reached to optimum value then beyond this value increasing the dose of super plasticizer reduced the compressive strength since over dosage of super plasticizer caused bleeding and segregation that affected the cohesiveness and uniformity of the concrete. Ngo and other [20] investigated the effect of type of admixture on fresh and hardened properties of concrete mixes that prepared with recycled aggregate(RA) with different proportions (15, 30, 70, and 100%), cubic specimens of (70*70*250)mm and cylindrical specimens of 150*300 mm were casted to measure compressive strength after 1,7 and 28 days of curing and to measure splitting tensile strength after 28 days of curing respectively, two types of chemical admixture (Polycarboxylate and Ether polycarboxyliquie) were used to increase the mixes workability, the result showed that mixes casted using superplasticizer had higher compressive strength than those not contained superplasticizer, and for the two types of superplasticizer Ether polycarboxylique performed higher compressive strength and splitting tensile strength than that casted using Polycarboxylate.

Recently, Al Tijani [3] tested modified RCA with specific replacements of micro-silica (0%, 5%, 15%, 20% by weight of cement) and artificial macro fiber, the results indicated to50% of RCA is in line standard limits, as shown that add the micro-silica additives with 15% increase the compressive strength of concrete greater than 26.2 % related to the conventional mix. The engineering properties of RCA mixes decreased after 15 % micro-silica additives and 50 % RCA replacement. Saini and Goel [18] added silica-fume (SF) to RCA and NA as additives. They stated that replace (RA) with (NA) declines the compressive strength value 7.5% at 50% replacement. This decrease was 16% for 100% replacement of RCA. The upper value of the compressive strength concrete was for 50% RAC with 10% of silica-fume (SF) at 28 days, where exceeded about 3% of corresponded value of the conventional NA mixes.

3. OBJECTIVES

Unexpected growth of waste concrete materials resulting from harsh conditions in the Arab region of the demolition of infrastructures and residential buildings as well as consumption of raw aggregates as a result modern urban developments are one of the motivating future tasks facing construction engineers and designers today. The main objective of this research is to determine the fresh and hardened concrete properties of RCA depend on replacing natural coarse aggregate (NCA) with different percentage of RCA (0%, 30%, 45% and 60% by total weight of NA). In addition, use the iron powder and silica with 10%, 15% and 20% as a replacement to fine aggregate to improve quality of the concrete mixture, and then comparative study between modified concrete mixes with conventional concrete mixes that prepared by natural aggregate.

4. MATERIAL AND METHODOLOGY OF THE STUDY

To achieve the objectives of the study, 90 cubes of (100 x 100 x 100 mm) with different percentages of RCA (0%, 30%, 45%, and 60%, three samples for percent) at w/c of 0.4 and using 0% and 2.5% super plasticizer were casted. Iron powder and silica were added as a filler in place of fine aggregate for the mix that was prepared with 45% of RCA. Two another mixes were prepared with 45% of RCA, 54 cubes were casted with different percentages of iron powder and silica in place of fine aggregate (10%, 15%, and 20 %, three samples for percent). Hardened test was examined to measure the compressive strength after 7, 14 and 28 days of curing. Fresh property test was conducted (Slump test) to study the efficiency of using RCA on workability.

4.1 Concrete Mixture

Concrete mixtures were prepared using:
Type I ordinary Portland cement, from Alshamalea Cement Company, Jordan, which uses in a general construction.

Natural Aggregate (fine and coarse) (NA): These aggregate were selected according to the standard specifications such as granular gradation, durability and free of any impurities that weaken the properties (good physical and chemical properties), NA were brought from Wadi Alkarak, Jordan. The gradation for NA was taken as a standard by sieve analysis and ASTM C33, Table1.

Table1: Gradation for coarse aggregate using sieve analysis.

Sieve size	% Passing Coarse Aggregate	% Passing Fine Aggregate
1 (25mm)	100	100
3/4 (19mm)	97.24	100
1/2 (12.5mm)	60.65	100
3/8 (9.5mm)	33.59	100
#4 (4.75mm)	2.88	99
#8 (2.36mm)	0.57	86
#16 (1.18mm)	0	50
#30 (600mc)	0	30
#50 (300mc)	0	16
Fine > #200 (75mc)	0	7

Recycled coarse aggregate (RA): RA used in this research was taken from a demolished building which is a residential building as shown in the figure1. It was manually crushed using hummer until it became small enough to be used in concrete mixtures.

Fig.1 Demolished residential building

The properties of NA and RA were defined. Los Angeles abrasion value, specific gravity of the coarse and water absorption, all of these values don't compatible with standard specifications as shown in the table 2,3. Higher water absorption can be due to old mortar cement which coated coarse aggregate where the old mortar involve high porosity.

Table 2: Aggregate properties of RA and NA

Test	NA	RA
L. A. Abrasion Test Mass Loss (ASTM C131 – 81)	26.78 %	42.3 %
Specific Gravity (ASTM C127 (2012a))	2.53	2.31
Water Absorption ASTM C127 (2012a)	1.57 %	7.3 %

Table 3: Standard specifications of aggregate properties

Test	standard Specifications
L. A. Abrasion Test Mass Loss	15 - 30 % Max MORTH (IV Revision) [31]
Specific Gravity	2.4 - 2.9 WSDOT (2009) [12]
Water Absorption	0.8 – 3.7% Max WSDOT (2009) [12]

Admixture: A chemical admixture of Superplasticizer (AdCon SP 500) was used to increase the workability retention of the concrete mixtures, properties of AdCon SP 500 was presented below in Table 3."Super plasticizer is an extra-effective water-reducing admixture with a very great plasticizing effect on concrete". It isreduce the water content required for concrete mixtures without influencing its consistency. Addition of Super plasticizer have several benefits for instance higher workability that enhance in placing and compaction of concrete mixes (increase the concrete fluidity); Decreasing w/c ratio of the mixes leads to rise strength concrete with the same level of workability; Improve consistency, durability, quality of concrete; cost-effective mix design; finally, speeding of construction process [3]. For normal concrete a dosage among 0.75% to 2.2% by weight of cement may be used, and for high strength concrete, a dosage of up to 3% by of cementations material can be used [4] performed an investigation to study effects of superplasticizer dosage on concrete and to get the best dose of superplasticizer that achieve the better strength and workability, in his investigation different percentages of superplasticizer were used 0.6, 0.8, 1.2, 1.8 and 2.5, he noticed by increasing the dose of superplasticizer the compressive strength for the different dosage of superplasticizer was higher for concrete mixes than the normal concrete mixes until reached to optimum value then beyond this value increasing the dose of superplasticizer reduced the compressive strength since over dosage of superplasticizer caused bleeding and segregation that affected the cohesiveness and uniformity of the concrete [33].

Table3: Superplasticizer (AdCon SP 500) properties, [Concrete Technology Company].

Appeara -nce	Specific gravity	PH	Chloride content	Air entrai -ment
Brown liquid	1.195± 0.01@25 ^{O}C	7-8	Almost nil to BS5075	Less than 2%

Iron filing: Iron filing is a very small granular material that was obtained by crushing iron into small pieces. It was used in concrete mixtures as a replacement of sand used in certain proportions to increase the density of the RCA mixtures.
Silica: Virgin silica were brought from the AL-Qawirah quarry, Jordan. Its purity was about 98%. The silica was added to mixtures of NA and RCA as a modifier in place of fines aggregate larger than 0.1 mm and less than 1 mm. The silica percentage used was 0%, 10%, and 15% of the total fines.

4.2 Experimental Investigations

4.2.1 Workability Test: fresh properties of concrete mixture was presented by slump test, usually slump test for concrete mixture appears in three different types; shear, collapse and true slump. Concrete mixtures with different degree of workability can be used in different cases [26].

4.2.2 Compressive Strength Test: Compressive strength of the concrete mixture was measured in accordance with ASTM C39-05 after 7, 14 and 28 days of curing.

5. EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Slump Test

The fresh properties of concrete mixture were presented by slump test; the results were compared with ASTM C143-78 standards. The relation between slump values and the RCA content using 0% and 2.5% super plasticizer was presented in Figure 2 below.

The results showed that by increasing the RCA content the slump values decrease, the slump values were 190mm, 160mm, 140 mm, 40 mm and zero slump for 0%, 15%, 30%, 45% and 60% respectively. The reduction in slump values because of RCA has high porosity and water absorption that lead to reduce the workability of the mixture. The same estimations were proved by [21]. As for the addition of Super plasticizer at 2.5%, the test results state that the workability increased for 0%, 15%, 30%, and 45% of RCA content, these test results are similar to those attained by [10] and [4]. The slump values at 45% of RCA was 40 mm are recommended for foundations with light reinforcement or can be used for road vibrated by hand operated machine according to standards revealed by [26] (Table 10.6; Building Materials).

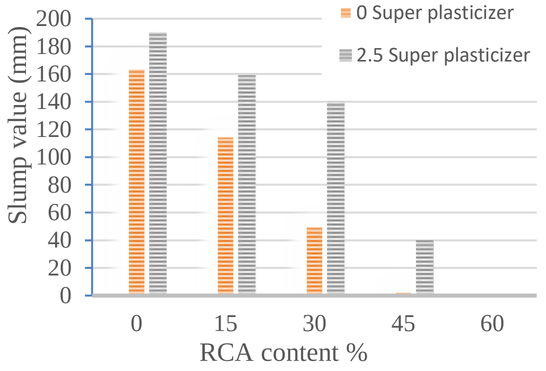

Fig. 2 Slump test values

5.2 Compressive Strength of Recycled Concrete Mixtures

The compressive strength of hardened concrete was tested for 72 cubes using Universal testing machine in accordance with **ASTM C39 (2005)** on cubical specimens after 7,14 and 28 days of curing with 0% and 2.5% of super plasticizer for a recycled aggregate replacement of 0%, 30%, 45% and 60%. Figure 3, 4 and 5 showed the results of compressive strength after 7, 14 and 28 days of curing.

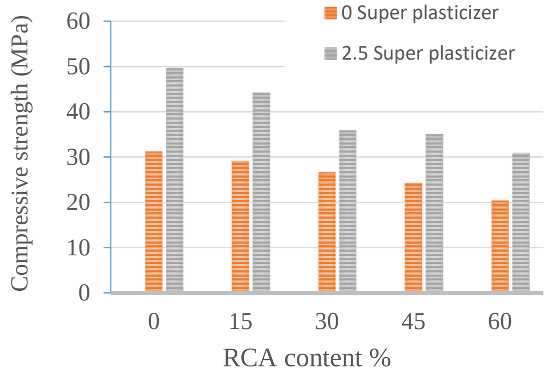

Fig. 3 Compressive strength of concrete after 7 days of curing

As shown in the figure 4 the compressive strength of concrete decreased as the recycled aggregate replacement (RCA content %) increased for 0% and 2.5 % of SP. The compressive strength after 7 days of curing was higher for 2.5% SP in comparison with 0% SP, a significant difference was observed after 7 days of curing between mixtures that contained 2.5% SP and 0% SP. The percent difference was 59.1, 35, 45, and 52 MPa for 0%, 30%, 45% and 60% of RCA, also the compressive strength of concrete was decreased by increasing the RCA content respectively. Results are well-matched with the results of many researches, [4], [20], and [10]. Experimental results indicated that the super plasticizer has a significant effect on the early strength stage of concrete. Therefore, such as behavior is useful to construct of rigid pavement.

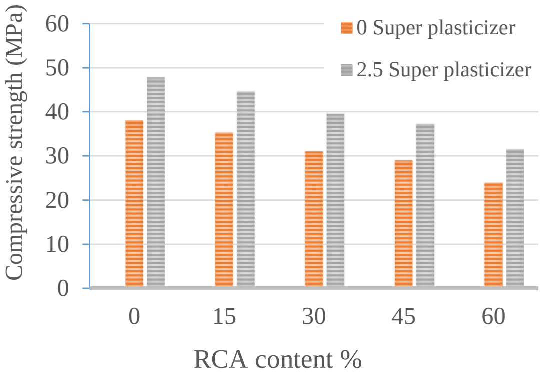

Fig. 4 Compressive strength after 14 days of curing

The compressive strength of concrete after 14 days of curing was higher at 2.5% SP in comparison with 0% SP for all replacement RCA content as presented in the figure 5. As shown in the previous figure the compressive strength of concrete was decreased by increasing the replacement RCA content. Oppositely, small difference of compressive strength of concrete was observed after 28 days of curing between mixtures that contained 2.5% SP and 0% SP in comparison with mixtures that tested after 7, 14 days of curing as illustrated in the figure 6. The percent difference between 2.5% SP and 0% SP was only 4% for 0% of RCA while was 59.1% for 7 days of curing, and at 45% of RCA the difference of compressive strength at 28 days was 0.025% between 0%, 2.5% of SP while 45% for 7 days, which indicated that the super plasticizer had a significant effects on the early strength stage of concrete, also the compressive strength of concrete was decreased by increasing the RCA contend. Therefore, such as behavior is useful to construction of rigid pavement.

Based on the previous results, the compressive strength of concrete decrease as the RCA content % increase, this performance may be as a result of the high water absorption of RCA related to NCA, the same results were obtained by [29] and [2]. A concrete mixtures of 45% was taken according to standard strength and economy, which has 40.5 MPa compressive strength. The recommended standards for compressive strength of concrete are categorized as low strength concrete smaller than 20 N/mm2, medium strength concrete from 20 to 40 N/mm2 and high strength concrete greater than 40 N/mm2 [26]. Off course, a 45% of RCA is more economic than 30% to add to concrete mixes as well more workability. This replacement percentage (45 % of RCA) was greater than value (30%) that was reached [9] as shown in the literature review.

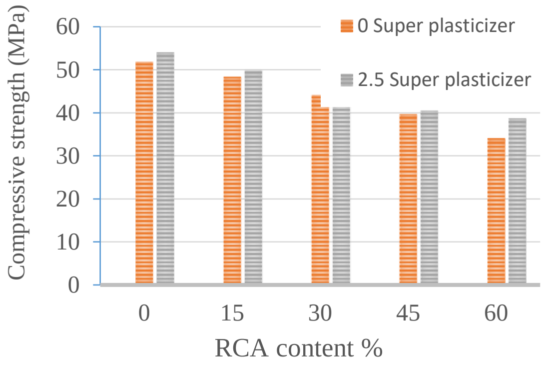

Fig. 5 Compressive strength after 28 days of curing

5.3 Compressive Strength of Modified Recycled Concrete Mixtures

5.3.1 Adding of Iron Powder to 45%-RCA Mixtures

Iron powder and silica was added to 45%-RCA as a replacement of fine aggregate in different percentage (10%, 15%and 20%). The figure 6 shows the investigational results achieved from the compressive test for the 45%-RCA mixes with iron powder.

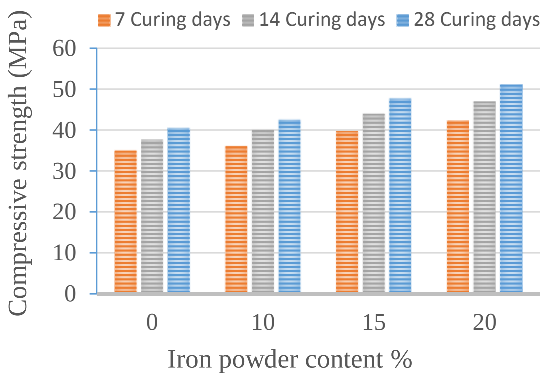

Fig. 6 Compressive strength for 45% RCA with iron filler after 7, 14 and 28 days of curing

The results showed that a considerable enhancement of the compressive strength of 45%-RCA can be accomplished with the addition of iron powder as additive. In addition, it is obviously that the compressive strength of 45%-RCA is affected by the days of curing. It was founded that as the curing time is increased the compressive strength is increased. The highest value of compressive strength was at 20% iron powder replacement at any curing days. By comparing the compressive strength of 45%-RCA mixtures that contain20%

and 0% of iron powder, the compressive strength increase of 26% at 20% of iron powder after 28 days of curing since iron filling has high strength and high toughness which leaded to increase the mixture strength [23].Examination results are compatible with various investigates, [5] and [23].

5.3.2 Adding of silica to 45%-RCA mixtures

The compressive strength of 45%-RCA mixes with 0, 10, 15, and 20% of Silica after 7, 14 and 28 days of curing are revealed in figure 7.

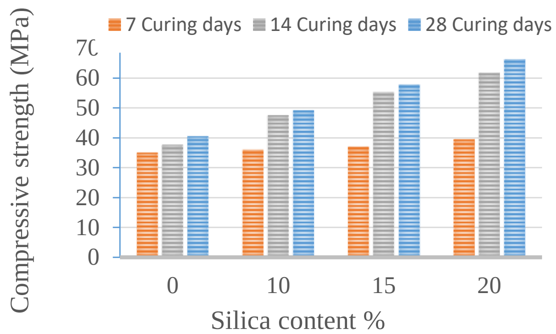

Fig. 7 Compressive strength for 45%-RCA with Silica after 7, 14 and 28 days of curing

Analysis also proved that there is an enhancement in the compressive strength of 45%-RCA with the use of silica as shown in the figure 7, where addition of the silica leaded to effective increase of the hydration consequently the ratio of pozzalonic reaction (PR)would be increased, therefore increasing of the compressive strength of concrete. The results were approved with investigates in literature review, [3], [18]. The compressive strength of 45%-RCA and 20% - silica at 28 days of curing were higher values comparable to those with 10 and 15% of silica, where were the increase of 68% at 20 of silica related to 0% of silica. And almost the same is true for 14 curing days, as for 7 of curing days there are no a significant effect on the compressive strength of 45%-RCA for all silica percent.

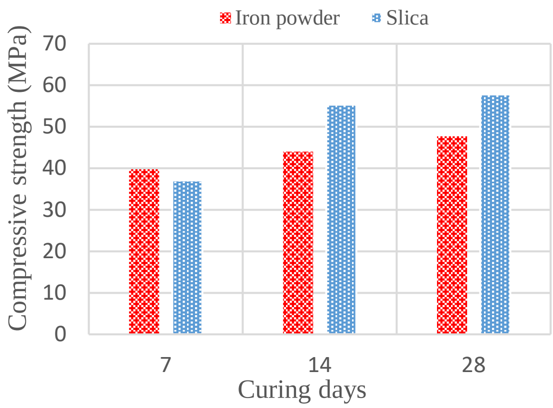

Fig. 8 comparative analysis between iron powder and silica at 10% of both silica and iron

5.3.3 A comparative analysis between iron powder and silica as additives for 45%- RCA after 28 days of curing

The compressive strength of 45%-RCA with iron powder and silica after 7, 14, and 28 days of curing shown in the figure 8, 9, and 10.

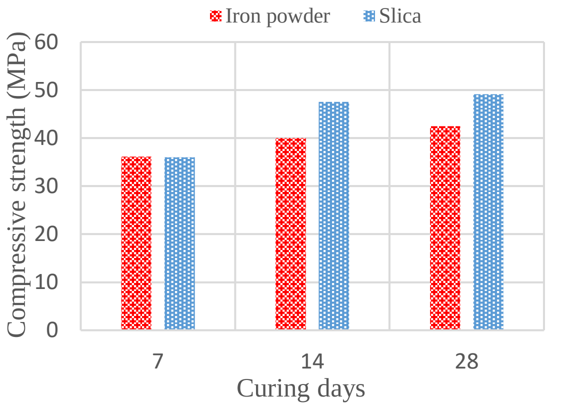

Fig. 9 Comparative analysis between iron powder and silica at 15% of both silica and iron

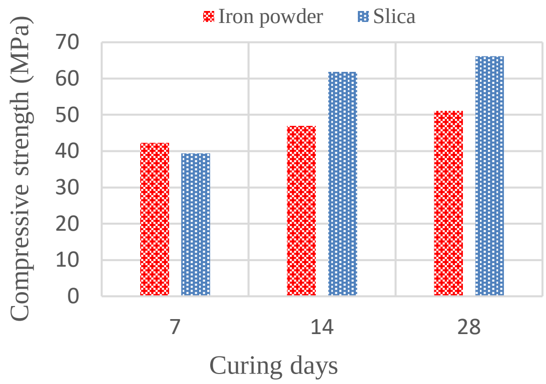

Fig. 10 Comparative analysis between iron powder and silica at 20% of both silica and iron

On the basis of the experiment results available from the figure (8), (9) and (10) they concluded that compressive strengths of 45%- RCA with iron powder at early stage after casting (7 curing days) a little higher than to those with silica for 10%, 15%, and 20% of both silica and Iron. Oppositely, at 14 and 28 curing days, the compressive strengths of 45%- RCA with silica is higher than iron powder, where the increase in the compressive strengths after 28 curing days were about 30% for silica, and at 14 curing days were about 31% at 20% of both silica and iron. The results showed that adding of iron and silica affected the concrete compressive strength.

6. CONCLUSIONS

Based on the results of previous experiments, the following conclusions were obtained as shown:

1. The workability of RCA mixtures decreased by increasing the RCA replacement, where slump values was 0 mm at 60% of RCA for 0 and 2.5% of Super plasticizer.
2. The compressive strength of recycled concrete mixtures decreased gradually by increasing the replacement percentage of RCA for 0 and 2.5% of Superplasticizer.
3. Adding Super plasticizer to concrete mixtures resulted in increasing in workability of the RCA mixtures, were slump value at 45%-RCA with 2.5% of super plasticizer was 40 mm and 3 mm at 0% of Super plasticizer.
4. The super plasticizer had a significant effect on the early compressive strength (at 7 days) of concrete from 10 to18MPa according to RCA replacement, while this effect decreases at curing days increase (14 and 28 days). Therefore, such behavior is useful to construction of rigid pavement.
5. Adding iron powder to RCA mixes filled the pores in those mixtures which increased the compressive strength of 26% at 20% of iron powder after 28 days of curing.
6. The compressive strength of 45%-RCA increased with increasing quantity of silica in concrete mixes with the same effective w/c ratio. However, The compressive strength of 45%-RCA and 20% silica at 28 days of curing were higher value comparable to those with 10% and 15% of silica, where were the increase of 68% at 20% of silica related to 0% of Silica.
7. Compared to the addition of iron powder and silica to 45%-RCA mixes, at 7 curing days iron powder has a slight increase of compressive strength of 45%-RCA compared with silica. After 14 and 28 curing days, there are a considered increase of compressive strength of 45%-RCA in the addition of silica compared to iron powder.

8. RECOMMENDATIONS

Although the compressive strength of RCA is increased by increasing iron and silica content. Other laboratory tests such as tensile strength of concrete, resilient modulus, flexural strength and durability must be conducted.

7. ACKNOWLEDGEMENTS

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