Behavior of Green Beams Using Industrial Waste as Partial Coarse Aggregate Replacement

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Abstract

Recycling of waste concreteis one of the sustainable solutions for the growing waste disposal crisis and depletion of natural aggregate sources.As a result, recycled concrete aggregate (RCA) is produced, and so far it has mostly been used inlow-value applications such as for the pavement base. But, from the stand point of promoting are source and energy savings and environmentalpreservation, it is essential to study, whether concrete made of recycled aggregates. Recycled concrete aggregate (RCA) can be used as a structural material. The experimental research presented in this paper is performed in order to investigate the flexural behavior and shear behavior of RCA and SS beams when compared to the behavior of natural aggregate concrete (NAC) beam. Steel slag is a byproduct from either the conversion of iron to steel at 1500-1650 °c .Amount of slag deposited in storage yard adds up to 30 m.t, leading to serious pollution to the environment., the optimum usage of slag and RCA in concrete beams mixtures (40%).full scale tests were performed on six simply supported beams unite the failure load had been reached. Comparison of load deflection behavior,crack patterns, deflection, and the proposed model is verified through experimental results of concrete beams with steel slag and crushed concrete with w/c 0.5.

Index Terms—recycled aggregate concrete, reinforcing concret beams, slag, Pullout, optimum usage, compressive strengh.

1 Introduction

The shortage of area for construction and demolition waste disposal and increasing renting costs of landfills is becoming a famous problem in urban areas [1]. One of the solutions to the problems related to disposal of bulding and demolition waste and depletion of natural resources of aggregates is recycling of deposited building materials, primarily concrete .It can be processed so as to obtain the recycled concrete. Slag is a by-product obtained during steel manufacturing and is commonly used in concrete because it improves durability and decrease porosity. Economic and ecologic benefits in the form of energy-savings and resource-conserving properties can also be achieved using slag blende [2, 3].Compressive strength is the most important engineering property of concrete. To ensure progress in construction and safety in engineering practices, we aim to develop understanding on the stern development of concrete. Some of experimental investigations have been conducted on the strength development of slag blended concrete. The strength development of slag blended concrete closely relates to the water-to-binder ratio, slag replacement ratio, and curing conditions. Beushausen et al. [4] found that, under moist curing conditions and when the slag replacement ratio is less than 50%, the1-day early-age strength of concrete almost linearly reduse with the increase in the slag replacement ratio. At the ages of 28 and 56 days, due to the formation of calcium silicate hydrate (CSH) from the slag reaction, the compressive strength of slag-blended concrete can exceeds that of control Portland cement concrete. Shariq et al. [5] found that, for concrete quantity larger slag content (higher than 60% of the binder content), until the age of 180 days, the compressive strength for slag-blended concrete is still lower than that of Portland cement concrete. Oner and Akyuz [6] systematically investigated the effect of slag inclusions on the compressive strength increased in concrete. They found that at alate age of 365 days, compressive strength of concrete mixtures containing slag development as the amount of slag increases. After an optimum point of slag, a further increase in slag little improves the compressive strength using. The aim of this work is to provide additional experimental data on the behavior of reinforced RAC and S.S beams in favor of the idea of using RCA and S.S in structural concrete elements (beams).The methodology of experimental research is based on the comparison of the performance of reinforced concrete beams made of natural aggregate concrete (NAC), RAC and S.S.

2 Experimental Program

2.1 Material

One kinds of coarse aggregate was used to produce concrete

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mixtures— RCA. RCA was obtained from one different source: waste laboratory concrete samples, where the properties of original concrete, was UN known.

The steel slag used here is a slag and collected from melting steel from delta factory. Both physical and mechanical properties of a coarse natural and recycled aggregate were tested in accordance with the national standards.

2.2 Concrete Mixture and Proportions

The mixtures are prepared with replacement coarse aggregate by percentage of RCA and S.S (40%), and 100% natural coarse aggregate. mixes (NAC, RAC and S.S) were designed to have the different compressive strength and workability. Although some new mixture proportioning methods for RAC and S.S can be found in the literature e.g., equivalent mortar volume method (EMV) [7], the authors decided to apply the usual mixture design for the conventional concrete. The water absorption after 30 min is the only additional property of RCA which had to be determined prior to mixture design, compared to procedure with entirely natural aggregate. The target values for RAC concrete properties were: 15 cm cube compressive strength of 40 MPa (at28 days) and the slump of 6.5cm measured 30min. after mixing. And the value of compressive strength for S.S 39MPa(at 28days), but NAC have compressive strength 45MPa at 28 days In order to obtain these properties, laboratory tests with series of trail mixtures of NAC, S.S and RAC were performed. Several NAC, RAC40, andS.S40 mixes of the same water-to-cement ratios were designed for target slump [8]. The total volume of aggregate was derived from the sum of the Absolute volumes of component materials (water, cement, aggregate S.S or RAC) in 1m^{3}of fresh concrete.six15 cm cube samples were cast for each type of concrete for the purpose of compressive strength testing (fc), whilst the additional three cylinders (base diameter 15 cm, height 15 cm) were made for the purpose of testing the splitting tensile strength (ft). Properties were tested in accordance with the national standards [9, 10, and 11]. Besides the samples, three 15 cm cube samples were made foreach type of concrete, which were cured under the same conditions as beams, and tested for compressive strength. The properties of both fresh and hardened concrete mixtures are presented in Table 3, 4 based on average values for three tested specimens. It can be seen from Table 5. 28day compressive strength of all concrete types is somewhatover39MPa, with negligible difference of 1 and 6 % when compared to S.S40%, for RAC40% and NAC100, restively.

Table1 Composition of concrete mixtures in (kg/m^3).

Mix	cement	Coarse agg.	sand	water	slag	RCA	%
NA	315	1114	556	157	-	-	
NA1	315	1114	556	157	-	-	agg
RCA	315	643.4	536	157	-	428.7	40%
RCA1	315	643.4	536	157	-	428.7	40%
SS	315	707.6	589.7	157	471.7	-	40%
SS1	315	707.6	589.7	157	471.7	-	40%

TABLE 1: MIXTURE PROPORTIONOF BEAMS (300*150*2000mm)

Type	Specific Gravity	Volumetric weight	Absorption
RCA	2.6	1.6	4-5%
SS	2.9	1.168	2.93%

TABLE 2: PROPERTIES OF MATARIAL

RCA	0%	20%	40%	60%	100%
Slum	7	6.5	3.5	2	3

TABLE 3: SLUMP TEST RECYCLED AGGREGATE

The slump decreased by increasing percentage of RAC, but after curing RAC, slump increasing (6.5%) by percentage 40%from RAC and 60%dolomite.

SS	0	20%	40%	50%	100%
slump	7	4.5	8.5	3.723	0.23

TABLE 4: SLUMP TEST OF STEEL SLAG

The slump decreased by increasing percentage of RAC, but after curing RAC, slump increasing (6.5%) by percentage 40%from RAC and 60%dolomite.

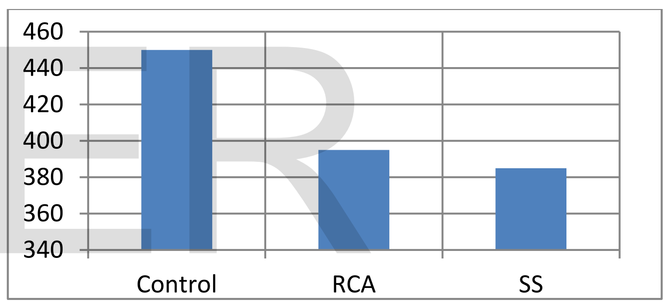

FIGURE 1: COMPRESSIVE STRENGTH AT 28 DAYS

However the average of compressive strength of RCA and SS was lower than NA, but max load of them, ductility and stain more than NA.

2.3Description of beamspecimens

Two kind of beam of different longitudinal reinforcement were made from each type of concrete. (NAC, RAC and S.S)-beams. Six beams were tested all together. All beam specimens were designed to fail in (cracks, flexure, strain in concrete and stain in steel). Three are two types of reinforcement of all beams. Three of beams reinforced with steel bars to prevent shear failure and anther beams to prevent moment.The minimum reinforcement ratio was calculated according to Eurocode 2 [12] provisions for NAC. The details of beams reinforcement for all beam specimens are shown. Allthe beams had rectangular cross section of 15 cm width and 30 cm depth and a tot l length of 2 m.

2.4 Test set-up and instrumentation

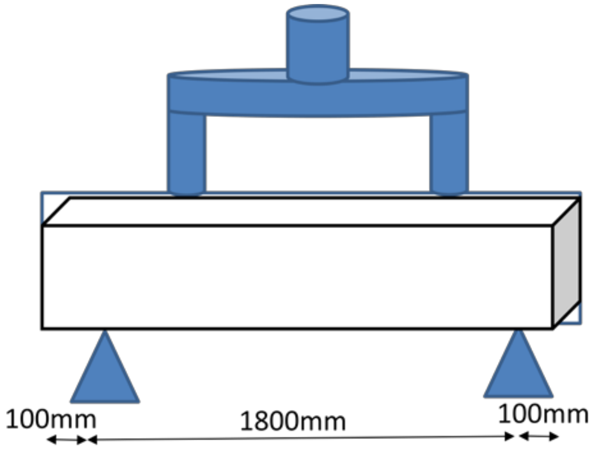

FIGURE 2: TEST SET-UP

2-4-1The Reinforcement as we mentioned before there is two different reinforcement detail:

A- Type (1) consists of:

4Ø12 (bottom steel)
2Ø10 (top steel)
5Ø8/m (stirrups)- (NAC1, RAC1 and S.S1).

FIGURE 3: BEAM SHEAR FAIURE

(This reinforcement makes the beam safe for moment because of the bottom steel, so it will break down due to shear force).

B- Type (2) consists of:

2Ø12 (bottom steel)
2Ø10 (top steel)
8Ø8/m (stirrups)- (NAC, RAC and S.S).

FIGURE 4: BEAMCOMPRESIONFAIURE

(This Reinforcement Makes the Beam BreakDown due to Moment)

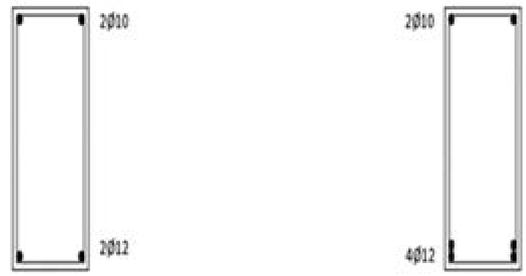

FIGURE 5: REINFORCEMENTDETATAILS

2-4-Strain gauge:

A strain gage (sometimes referred to as a Strain gauge) is a sensor whose resistance varies with applied force; it converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured. When external forces are applied to a stationary object, stress and strain are the result. Stress is defined as the object's internal resisting forces, and strain is defined as the displacement and deformation that occur.

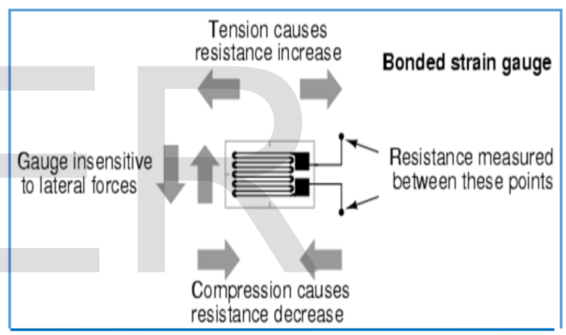

FIGURE 6: STRAIN GAUGE

3. Results and Discussion

The summarized results of beam's testing The ultimate load (P_u),the yielding load(P_y) and corresponding deflections (d_y, d_u),as well as the cracking load (P_{cr}) as well as concrete strains in top of beam's mid-span.

3-1 moment group

No deferent more in loads between (NA, RCA, SS), but NA resist more than (SS and RCA)in loads with little value ,NA resist at 15t,RCAresist at 12.5t and SS resist at 14.3t.

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SS reinforced beams no resist more than (NA, RCA), because it have little yct and increasing in cover.
Comparison between (NA, RCA, and SS) in max deflection, SS have max deflection more than (NA, RCA).
The max Concrete strain for reinforced beams is beam (NA).
The max Steel strain in of beams is beam (RCA and SS).

3-2 shear group

Comparison between (NA1, RCA1, and SS1) in maximum Loads, SS1 have max load more than (NA1, RCA1).
Comparison between (NA1, RCA1, and SS1) in maximum deflection, SS1 has max deflection more than (NA1, RCA1).
The max Concrete strain for reinforced beams is beam (RCA).
The max Steel strain of reinforced beams is beam (SS).
The compressive strength at (7days and 28days) for control beams(NA) is the best.

4. Behavior at Failure

There are six beams; three of them resist moment and the anther resist shear. failure load at NAC at 15t and deflection failure18mm.t, RAC at 12,5t and deflection15.9mm, S.S at 14,5T and deflection 31.3mm, but the failure load at anther beams NAC1 at 16t and deflection10.25mm, and RCA1 at 17tand deflection 8.5mm, S.S1 at 21t and deflection 16.1mm.the beam (S.S) has height ductility because yct of it very little for this failure load at 14.5t, but S.S1 failure load 21.5t because $y_{ct}$of it very long.

4-1 Moment group (NA, RCA, SS)

4-1-1 NA beam

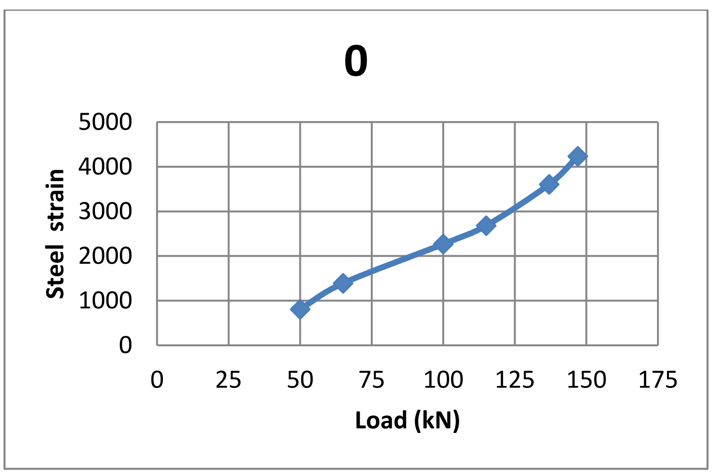

FIGURE7: LOAD-STRAIN IN STEEL CURVE FOR NA BEAM

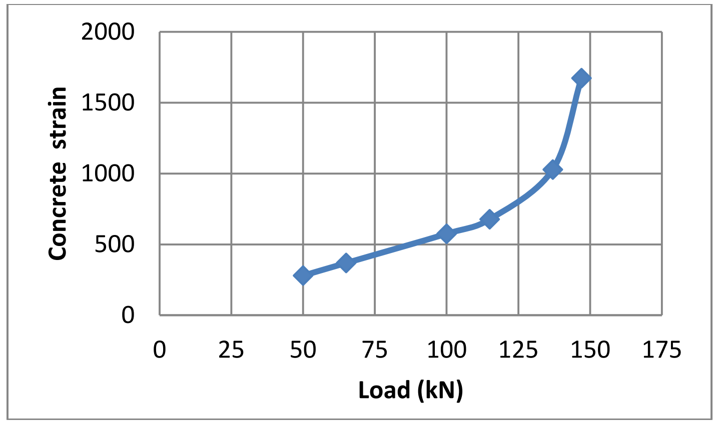

FIGURE 8: LOAD-STRAIN IN CONCRETE CURVE FOR NA BEAM

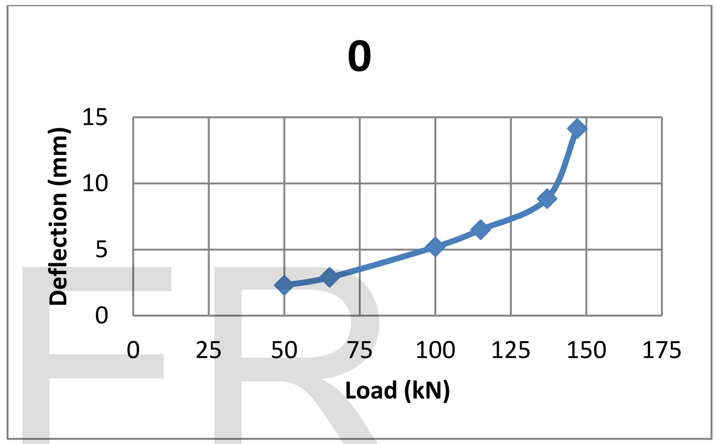

FIGURE 9: LOAD-DEFLECTION CURVE FOR NA BEAM

Observation(NA)	Applied load(ton)	Deflection(mm)
First crack	5	2.3
Yield	10	5.2
Failure	15	18
Mode of failure	Compression failure	

TABLE 5: MODE OF FAILURE FOR NA BEAM

4-1-2RCA beam

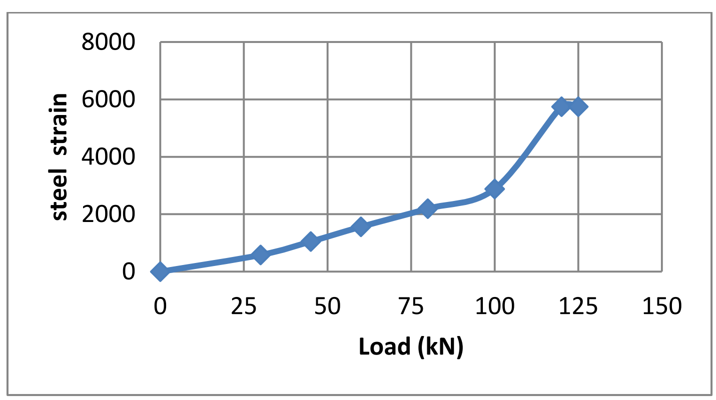

FIGURE 10: LOAD- STRAIN IN STEEL CURVE FORRCA BEAM

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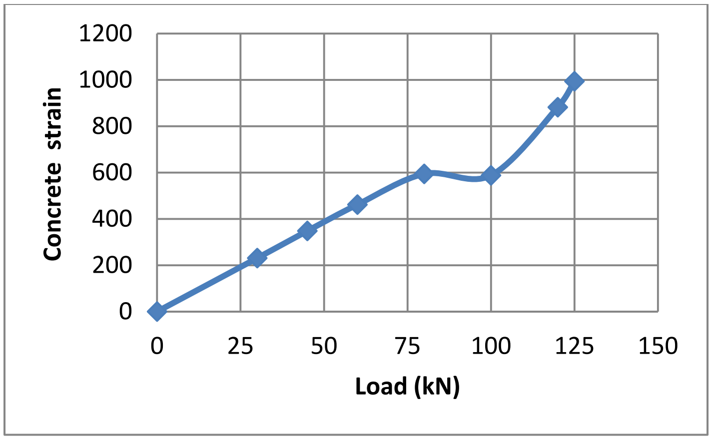

FIGURE 11: LOAD-STRAIN IN CONCRETE CURVE FOR RCA BEAM

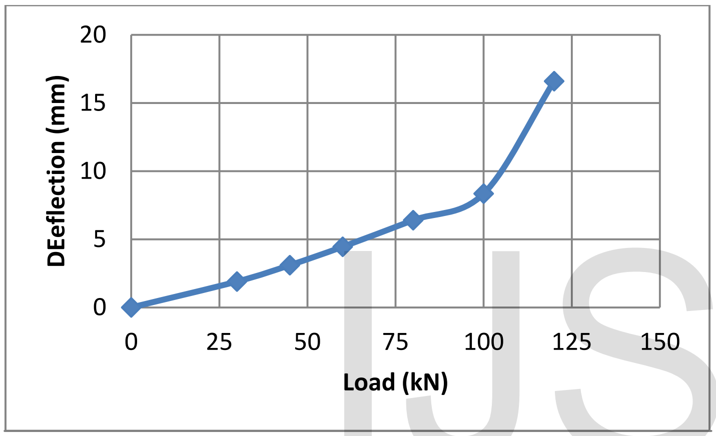

FIGURE 12: LOAD- DEFLECTION CURVE FOR RCA BEAM

Observation(NA)	Applied load(ton)	Deflection(mm)
First crack	3	1.85
Yield	10	8.3
Failure	12.5	15.95
Mode of failure	Compression failure	

TABLE 6: MODE OF FAILURE FOR RCA BEAM

4-1-3 SS beam

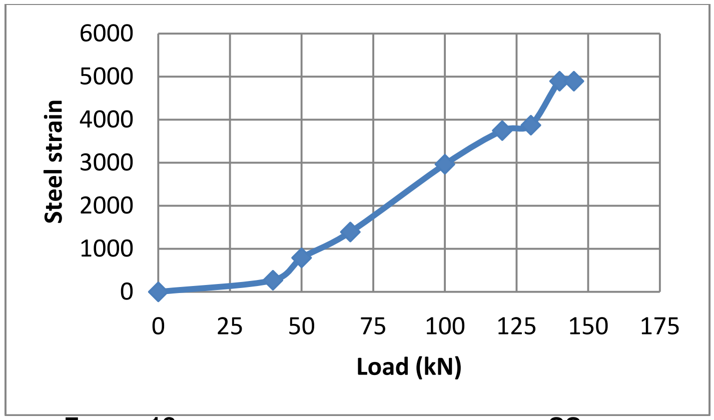

FIGURE 13:LOAD- STRAIN IN STEEL CURVE FOR SS BEAM.

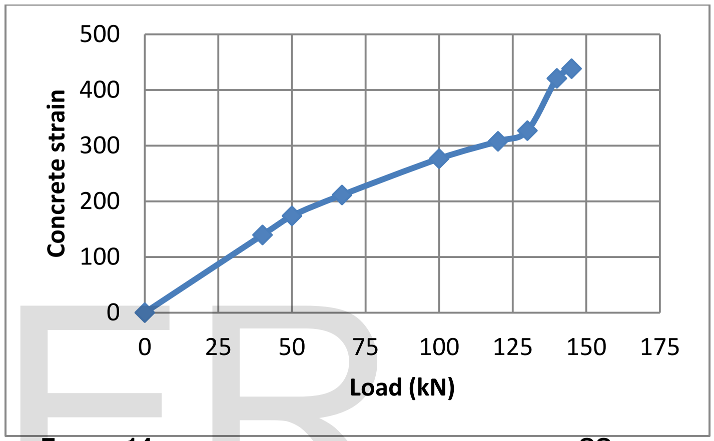

FIGURE 14: LOAD- STRAIN IN CONCRETE CURVE FOR SS BEAM

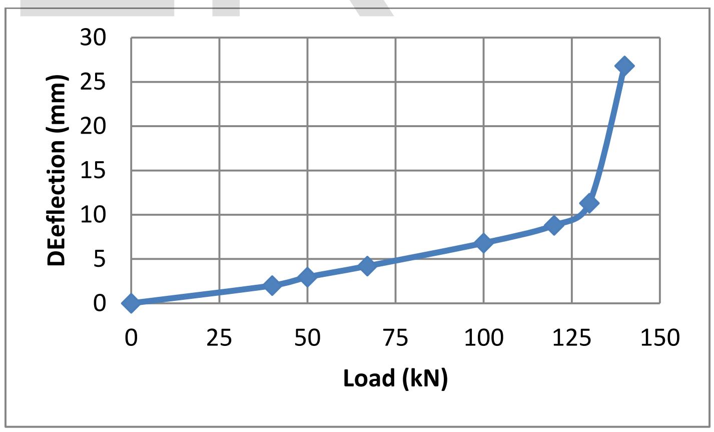

FIGURE15: LOAD- DEFLECTION CURVE FOR SS BEAM

Observation(NA)	Applied load(ton)	Deflection(mm)
First crack	4	2
Yield	10	6.8
Failure	14.3	40.45
Mode of failure	Moment failure	

TABLE 7: MODE OF FAILURE FORSS BEAM

4-2 Shear group (NA1, RCA1, SS1)

4-2-1NA1 beam

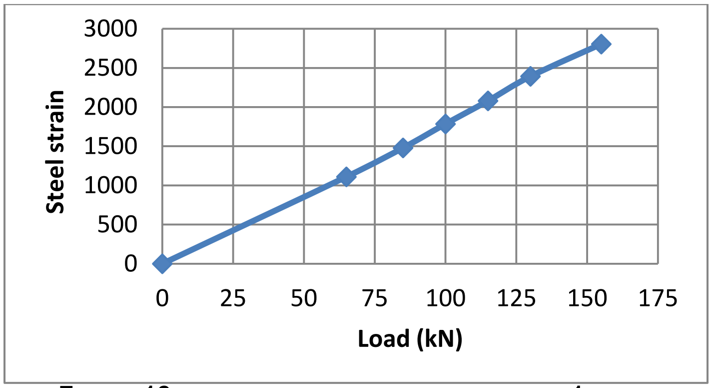

FIGURE 16:LOAD- STRAIN IN STEEL CURVE FOR NA1 BEAM.

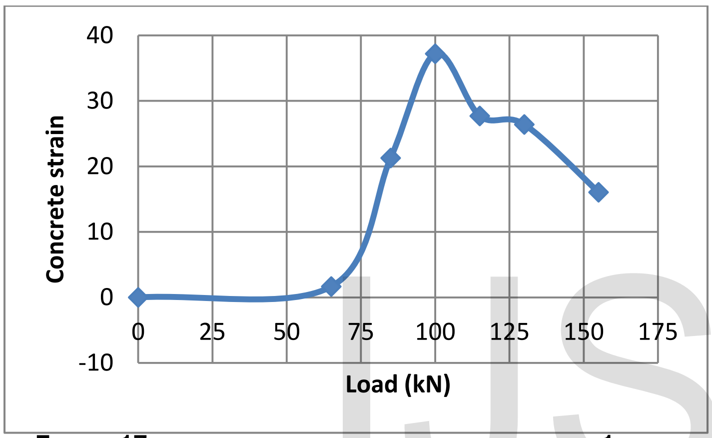

FIGURE 17: LOAD- STRAIN IN CONCRETE CURVE FOR NA1 BEAM

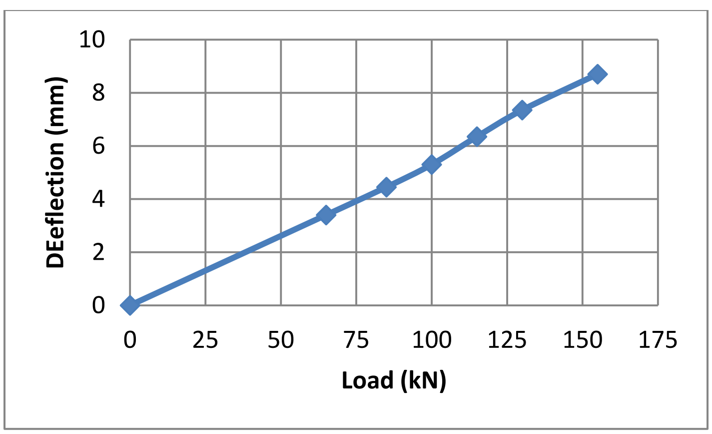

FIGURE18: LOAD- DEFLECTION CURVE FOR NA1 BEAM

Observation(NA)	Applied load(ton)	Deflection(mm)
First crack	6.5	3.35
Yield	10	5.3
Failure	16	10.25
Mode of failure	Shear failure	

TABLE 8: MODE OF FAILURE FORNA1 BEAM

4-2-2 RCA1 beam

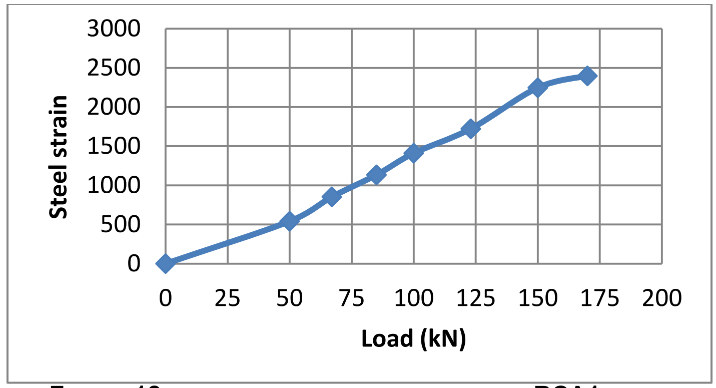

FIGURE 19:LOAD- STRAIN IN STEEL CURVE FOR RCA1 BEAM.

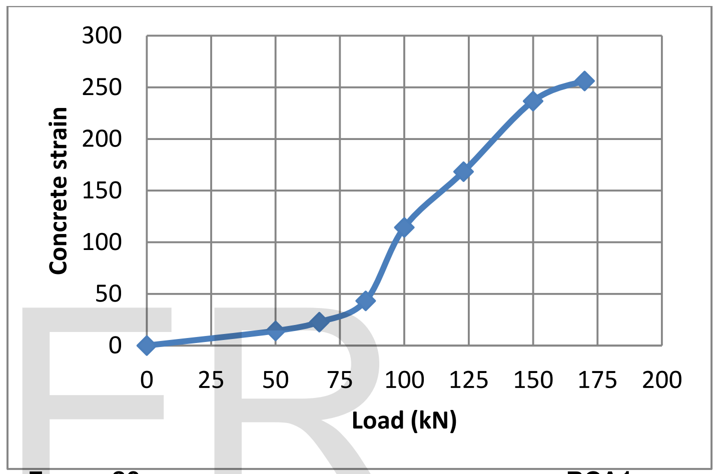

FIGURE 20: LOAD- STRAIN IN CONCRETE CURVE FOR RCA1 BEAM

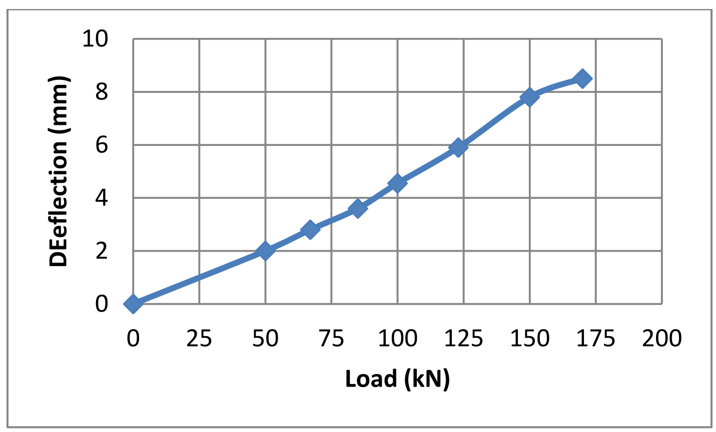

FIGURE21: LOAD- DEFLECTION CURVE FOR RCA1 BEAM

Observation(NA)	Applied load(ton)	Deflection(mm)
First crack	5	1.9
Yield	15	7.8
Failure	17	8.5
Mode of failure	Shear failure	

TABLE 9: MODE OF FAILURE FORRCA1 BEAM

4-2-3 SS1 beam

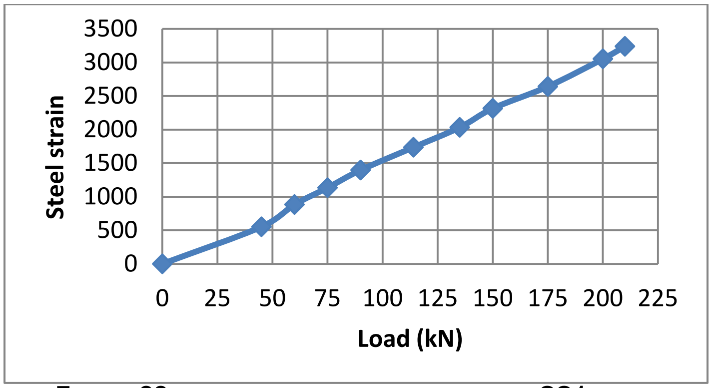

FIGURE 22:LOAD- STRAIN IN STEEL CURVE FOR SS1 BEAM.

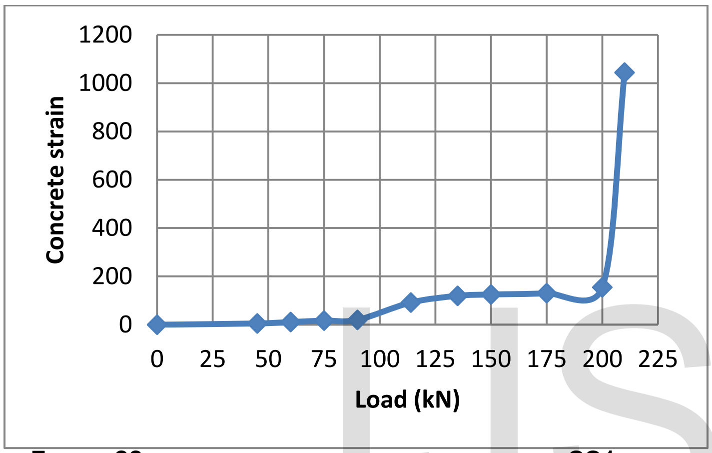

FIGURE 23: LOAD- STRAIN IN CONCRETE CURVE FOR SS1 BEAM.

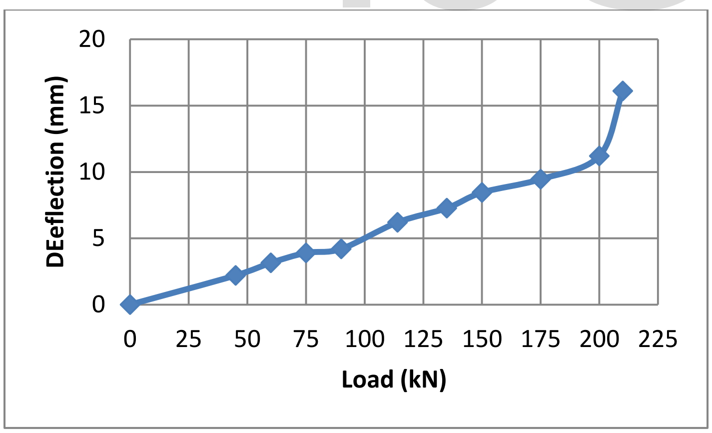

FIGURE24: LOAD- DEFLECTION CURVE FOR SS1 BEAM.

Observation(NA)	Applied load(ton)	Deflection(mm)
First crack	4.5	2.2
Yield	15	8.45
Failure	21	16.1
Mode of failure	Shear failure	

TABLE 10: MODE OF FAILURE FORSS1 BEAM

5. Cracks Patten

5 -1 Crack patterns at failure load in the middle third of the span, for beams resisted shear shown in figures (25,26,and27).

FIGURE25: CRACK DISTRIBUTION FOR RAC BEAM

FIGURE26: CRACK DISTRIBUTION FOR SS BEAM

FIGURE26: CRACK DISTRIBUTION FOR NA BEAM

5 -2 Crack patterns at failure load in the middle third of the span, for beams resisted moment shown in figures (28, 29, and 30).

FIGURE28: CRACK DISTRIBUTION FORNAC1 BEAM

FIGURE29: CRACK DISTRIBUTION FORRAC1 BEAM

FIGURE30: CRACK DISTRIBUTION FOR S.S1 BEAM

5 -3 Compresion failures for beams resisted moment shown in figures (31, 32, and 33).

FIGURE31: COMPRESSION FAILURE FOR NA BEAM

FIGURE32: COMPRESSION FAILURE FOR RAC BEAM

FIGURE33: COMPRESSION FAILURE FORS.S BEAM

5 -3 Shear failures for beams resisted moment shown in figures (34, 35, and 36).

FIGURE34: SHEAR FAILURE FORNAC1 BEAM

FIGURE35: SHEAR FAILURE FORRAC1 BEAM

FIGURE36: SHEAR FAILURE FORS.S1 BEAM

6. COMPARATIVE analysis of test results

In this chapter, the analysis of our own and other authors' test results [13, 14, and 3] were performed on all behavior of RAC reinforced concrete beams and S.S steel slag concrete beams. In the analyzed experimental research, tests were performed on beams made of RAC and slag with replacement ratios of natural course with coarse RCA and S.S (40%) and on control beams made of NAC. Natural sand was used as afine aggregate in all analyzed tests. The NAC of control beams was made with the same water-to-cement ratio as RAC and S.S. In order to compare data from different in vestigations, the analysis of all mixtures proportions had been performed, all tested beams were simply supported.

7. CONCLUSIONS

Based on tests performed on material properties and based on comparison made in terms of all behavior of NAC, RAC and S.S reinforced beams with replacement (40%) RAC and S.S is sustainable solution to reduced environmental impact by reducing the amount that must be disposed and it reduced the demand for natural aggregate.

1. in this study, RAC and SS was designed to have compressive strength and workability near of NAC. Due to the good quality of coarse RCA and S.S when using compared to NA mixt.

2. t is not recommended to predict RAC and SS beams behavior based only on knowing the material properties of both RAC and corresponding NAC. Comparison of load-deflection behavior, crack patterns, service deflections, failure modes,strain in concrete ,strain in steel and ultimate flexural capacity of NAC beams , RAC and S.S beams with 40 % replacement ratio of NAC, based on our own and other researchers'

Test results, showed that the flexural behavior of RAC and S.S Beams are satisfactory when compared to the behavior of NAC beams.

3-shear strength for beams made with RAC is much better than beams made with NAC by (5-6) %.

4- Moment strength for beams RAC better than beams NAC by (14-15) %.

5- Flexural strength of RAC is lower than NAC.
6- Despite one of beam that contain slag composed before the NAC, but beams continuing S.S better than NAC and RAC.
7- Comparison NAC and S.S we find that NAC was completed more S.S but, y_{ct} of S.S was few and cover was great.
8- Comparison NAC1 and S.S1 we find that S.S1 was completed up to (21.5) t and completed for (S.S, NAC and NAC1) because carver of it more little than S S.
9-maximum deflection at NAC 27.8 mm but deflection in failure 18mm., maximum deflection at NAC1 15.25mm but deflection in fulair10.25mm, maximum deflection at RAC 41.7mm but deflection in failure 15.9mm, maximum deflection at RAC 15.85mm but deflection in fulair8.5mm,maximum deflection at SS 48.48mm but deflection in failure 40.45mm,-maximum deflection at SS1 25mmbut deflection in fulair16mm.

Acknowledgments The work reported in this paper is a part of the investigation within the research project by-products and

recycled waste materials in concrete composites and steel slag beams to study the behavior of beams and compreditis with NA in the scope of sustainable construction development,: investigation and environmental.

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