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Structural Behavior of R.C Beams Cast with Recycled Concrete

Randa Elsayed [1], Alaa Gamal [2], Ata El-Kareim [3], Anwar Mahmoud [4]

1sM.Sc. student, Department of Civil Engineering, Helwan University, Egypt
2 Professor of Reinforced Concrete, Faculty of Engineering, Helwan University
3 Professor of Reinforced Concrete, Faculty of Engineering, Helwan University
4 Associate Professor of Properties and Resistance of Material, Housing and Building, National Research Center

ملخص البحث:-

يعتبر التخلص من مخلفات الهدم والبناء من المشاكل البيئيه التي تعاني منها مناطق عديده ولقد قامت ابحاث ودراسات كثيره لاستخدام هذه المخلفات واعاده تدويرها كركام في عمليات الردم ورصف الطرق وعدم استخدامها في الاعمال الانشائيه ولذلك فكره هذا البحث هو دراسه السلوك للكمرات المصنعه من الخرسانه المحتويه علي هذا النوع من الركام لمعرفه هل يصلح للاعمال الانشائيه ام لا وتشمل الدراسة تنفيذ 9 كمرة مسلحة بسيطة الارتكاز بنفس القطاع ونفس التسليح في الشد والكانات وتم عمل ثلاث مجموعات كل مجموعه تحتوي علي ثلاث كمرات وذلك لدراسه السلوك الانشائي للكمرات المصنعه من الركام المعاد تدويره بنسبه 100%ومحتوي علي نسبه من الاضافات 10%من الركام المتطاير او 1%من الياف الصلب وقد اشتملت دراسه السلوك علي سلوك التشرخ وطبيعه الانهيار وسلوك الحمل- الترخيم للكمرات. ولقد تبين من نتائج الاختبارات أن استخدام الركام المعاد تدويره أدى للحصول على مقاومة قص اعلي من الكمرات التى تحتوى على ركام من مصادر طبيعية

Abstract:

This study focused on the recycled construction materials to use in R.C. elements. An experimental program was designed to study the behavior of reinforced concrete (RC) Beams cast with 100% recycled concrete aggregate (RCA) and admixture 10%flyash(FA) or 1% steel fiber(SF) was carried out to test nine simply supported reinforced concrete beams subjected to two concentered loads, with different of span to depth ratio is a\d=1.1,1.6 and 2.32 . All tested specimens are 150 mm wide, 300mm depth with a length of 1700mm centered in span, and have a clear span between supports equal to 1500 mm; all tested beams have the same flexural longitudinal reinforcement (2Ø16 at the bottom, and 2 Ø8 at the top). All specimens were designed to fail due to shear. Specimens divided into three groups (A, B, and C), with different applied load location apart from edge support as a ratio of the depth of the beam to (a/d) equal to 1.1, 1.6, and 2.32 with group A, B and C respectively. Each group contains three tested beams, one as a control beam with normal concrete strength without any admixture in the mix, and the other two beams specimens' have100%RCA and different admixture (10%fly ash or 1%steel fiber) added to the concrete mix. The failure load, cracking pattern, load-deflection, and load-stirrups strain were recorded in the test results. From the analysis of the tested results obtained it was observed that the of 100%RCA and 10%fly ash ,1%steel fiber is an effective technique to enhance the shear capacity of the used recycling materials.

The maximum shear strength of tested beams contains RCA is higher than those with natural aggregates indicating the possibility of using admixture (fly ash or steel fiber) with RCA to produce concrete.

Keywords: recycled aggregates و shear behavior ,fly ash ,steel fiber

1. INTRODUCTION :

The use of recycled aggregates in concrete opens a new range of possibilities in the reuse of materials in the building industry. The utilization of recycled aggregates is a good solution to the problem of an excess of waste material. Concrete recycling gains importance because it protects natural resources and eliminates the need for disposal by using the readily available concrete as an aggregate source for new concrete[1]. The recycled coarse aggregate was produced by crushing the old concrete elements tested specimens that were used in the previous laboratory test. the compressive strength generally decreased when the percentage of recycled aggregate increased in all tested ages this is maybe due to the higher values of water absorption of RA [2]. **Ashraf Wagih[3]** studied the Recycled construction and demolition, concrete Replacing 25% of natural course aggregate with recycled concrete aggregate had no significant adverse effect on structural concrete performance. When the replacement ratio increased to 50%, the compressive strength reduction ranged from 7 to 13%. **Kou, S. C., Poon, C. S., & Chan, D [4]** studied The effects of the use of Class F fly ash as a cement addition on the hardened properties of recycled aggregate concrete were determined it was found that the addition of fly ash was able to mitigate this detrimental effect. Also, the addition of flyash reduced the drying shrinkage and enhanced the resistance to chloride ion penetration of concrete prepared with recycled aggregate **Arezoumandi, M., Smith[5]** paper presents the results of an experimental investigation of the flexural strength of full-scale reinforced concrete beams constructed with both 100% recycled concrete aggregate (RCA) Results of this study show that the RCA beams have comparable ultimate flexural strength and approximately 13% higher deflection corresponding to the ultimate flexural strength of the CC beams. **Wardeh, G., Ghorbel, E[6]** an experimental study on the shear behavior of concrete made with natural aggregates (NAC) and 100% recycled aggregates (RAC) are presented in this study .The beams were tested under 4 points bending for a shear span-to-depth ratio (a/d) equal to 1.5 and 3.0. The experimental results show that, for the same class of compressive strength, the shear failure mechanisms in recycled aggregate concretes are the same compared to the natural aggregate concretes while the shear strength is lower. The decrease in the shear strength is consistent with the decrease in the splitting tensile strength of the RAC mixtures compared to the NAC mixtures **Sadati, S., Arezoumandi, [7]** The study reported in this paper investigates the shear capacity of full-scale reinforced concrete beams fabricated with high volume fly ash and coarse recycled concrete aggregate (RCA). The beams were fabricated with three different longitudinal reinforcement ratios of 1.27%, 2.03%, and 2.71%. Four concrete mixtures were employed for casting the beams: conventional concrete (CC) without any fly ash or RCA as the reference; fly ash concrete with 50% of Class C fly ash replacement (FA50 beams); RCA concrete with 50% coarse RCA the SC beams had a 10% lower shear capacity than the CC beams. The average shear capacity of the SC beams was 18% and 16% lower than those of the FA50 and RCA50 beams, respectively .**Nasr Z. Hassan[8]** Increase of shear span-depth ratio (a/d) increases the number of cracks formed and as result more cantilever force applied at the cracked concrete, reducing the shear strength of concrete to greater extent.

2. Experimental work

An experimental test program was planned to achieve the research objectives presented in the previous section. The program test considered nine beams that were cast to investigate the effect of the span to depth ratios and effect of the different percentage of admixture on the structural behavior. We used fly ash and steel fiber additional in the mix.

2.1 materials:

The materials used in this research work are Portland cement (CEM I 42.5 N) from El-Suez Cement Company (El Suez Plant), natural coarse aggregate from Ataka Quarry,natural sand from Beni-Suef, drinking water, Recycled Coarse Aggregate (Crushed Concrete) from HBRC previous study and three variable additions (% Fly ash, % Steel fiber and % Admixture " Sikament 163m ") Physical properties of fly ash and steel fiber as listed in the table (2,3)

Testing of these materials was carried out according to the Egyptian code (ECP 203-2018) [9], and the ASTM standards. Constant contents of cement, water, and aggregate were adjusted, as listed in the table (1)

Table -1: Mix design

	Cement Kg	Sand Kg	Gravel Kg	Water Liter	Flay ash Kg	Steel fiber kg	Sikement Kg
1m3					10%	1%	2%
	350	595	1190	175	35	3.5	7

Table -2: Physical properties of fly ash

Properties	Fly ash
Density (g/cm3)	2.31
Specific surface area (cm2/g)	3960

Table -3: Physical properties of steel fiber

Average Thickness	0.75
Length.mm	40
Density	7850 kg / m3
Tensile strength	8500 kg / cm2
Specific gravity	7.85

Table -4: Results of Cubes for Strength Concrete Specimens compressive strength

Specimen	Cube Strength (N/mm2) When the specimen was tested (after 28 days)
Normal concrete	28
100%RACand 10%FA	34
100%RAC and 1%sf	31.24

2.2 Set- up- test:

The test set-up as shown in figure1. The specimens were located under the crosshead of the testing machine such that the centreline of the specimen was oriented perpendicular to the centreline of the crosshead. The specimen was supported over two steel rods (hinge support). The beams were tested using two concentrated loads. The locations of loading points were variable, depending on the shear span of each group of the tested beams. The load and location of the first crack were recorded and the propagation of crack was traced until failure.

Figure (1): The test set up

2.3 Description of Test Specimens :

Nine beams specimens forming three groups of beams were tested. Each group involve three beams with the same reinforcement and, two mix families (0% coarse RCA and 100% coarse RCA) were produced, both with superplasticizers (SP). The coarse natural aggregates (NA) were replaced with coarse RCA at 0% and 100%, respectively. For each of the mentioned families, different percentage of admixtures (0%, 10%FA and,1%SF), as mentioned in table 5. The dimensions of beams, supports and loading systems were the same in all members but with variable shear span. all the tested beams had rectangular cross section of 150 mm width and 300 mm thickness, a total length of 1700 mm and were simply supported with a span length of 1500 mm. The reinforcement was designed in groups of beams to obtain different mode of failure

Table -5: description of test specimens

Group No.	Spec.	a/d	%admaxture	Vertical Stirrups	Main Steel	Compression Steel
A	A-0	1.1	0%-0%-1.1	5 Ø 8 / m	2 Ø 16	2 Ø 8
	A-1		100% RcA-10%FA-1.1	5 Ø 8 / m	2 Ø 16	2 Ø 8
	A-2		100%RcA-1%SF-1.1	5 Ø 8 / m	2 Ø 16	2 Ø 8
B	B-0	1.6	0%-0%-1.6	5Ø 8 / m	2 Ø 16	2 Ø 8
	B-1		100% RcA-10%FA-1.6	5 Ø 8 / m	2 Ø 16	2 Ø 8
	B-2		100%RcA-1%SF-1.6	5Ø 8 / m	2 Ø 16	2 Ø 8
C	C-0	2.3	0%-0%-2.3	5Ø 8 / m	2 Ø 16	2 Ø 8
	C-1		100% RcA-10%FA-2.3	5 Ø 8 / m	2 Ø 16	2 Ø 8
	C-2		100%RcA-1%SF-2.3	5 Ø 8 / m	2 Ø 16	2 Ø 8

Aslong, Longitudinal steel
Ast, Transversal steel
a, Shear span.
d, Beam depth
FA, Flyash
SF,steel fiber
RcA;recycled aggregate concret

3- Test results and analysis

All the tested beams failed in shear as it was expected. The values of ultimate shear loads, failure modes, and percentage of load increase based on the ultimate load of control beam are given in Table 6. As shown in this table, the addition fly ash and steel fiber on 100%RCA increased the ultimate capacity of the tested beams.

3.1. Crack pattern and mode of failure:

The failure load and final deflection of all beams listed in Table (6), then the mode of failure listed for each beam according to final shape at failure which is shear mode failure of flexure mode failure, (see Figure (2,3,4))
Referring to Table (6) verify the tested beams; it can be noticed that the measured deflection of all beams with different admixture in the mix is smaller than or bigger than that of the control beams (A-0), (B-0) and (C-0). This means that using steel fiber and fly ash in the mix changed the behaviour.

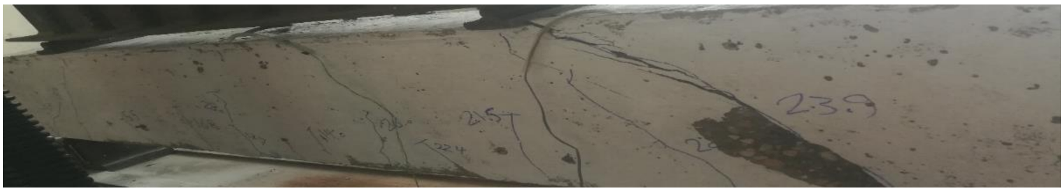
Table -6: Test Results

<table>
<tr><th>Group No.</th><th>Spec.</th><th>a/d</th><th>Admixture Content</th><th>Max Load (kN)</th><th>Final Deflection (mm)</th><th>Mode of Failure</th></tr>
<tr><td rowspan="3">GA</td><td>A-0</td><td rowspan="3">1.1</td><td>0%-0%-1.1</td><td>240</td><td>12.52</td><td>Flexure shear failure</td></tr>
<tr><td>A-1</td><td>100% RcA-10%FA-1.1</td><td>320</td><td>13.79</td><td>Flexure shear failure</td></tr>
<tr><td>A-2</td><td>100%RcA-1%SF-1.1</td><td>280</td><td>9.4</td><td>Flexure shear failure</td></tr>
<tr><td rowspan="3">GB</td><td>B-0</td><td rowspan="3">1.6</td><td>0%-0%-1.6</td><td>210</td><td>65.94</td><td>Shear flexture failure</td></tr>
<tr><td>B-1</td><td>100% RcA-10%FA-1.6</td><td>230</td><td>63.05</td><td>Shear flexture failure</td></tr>
<tr><td>B-2</td><td>100%RcA-1%SF-1.6</td><td>240</td><td>43.15</td><td>Shear flexture failure</td></tr>
<tr><td rowspan="3">GC</td><td>C-0</td><td rowspan="3">2.23</td><td>0%-0%-2.3</td><td>140</td><td>14.64</td><td>Flexure shear failure</td></tr>
<tr><td>C-1</td><td>100% RcA-10%FA-2.3</td><td>148</td><td>19</td><td>Flexure shear failure</td></tr>
<tr><td>C-2</td><td>100%RcA-1%SF-2.3</td><td>160</td><td>40.19</td><td>Flexure shear failure</td></tr>
</table>

As shown in Figure (2) all tested beams in this group have almost the same cracking pattern. The main cracking pattern consisted of a diagonal crack with some flexural cracks. After that, additional diagonal shear cracks appeared and the crack continued propagating just underneath the flange towards the loadings points. It was found that beams content 10%FA and 1%SFand 100%RCA did not change the failure type-casted with normal at the same span to depth ratio but with the change to depth ratio had different the mode of failure for group two shear-flexure and also group three.

a) Beam content normal concrete at span to depth ratio 1.1(A-0)

b) Beam content 100%RAC and 10%fly ash at depth ratio 1.1(A-1)



c) Beam content 100%RAC and 1%steel fiber at depth ratio 1.1(A-2)

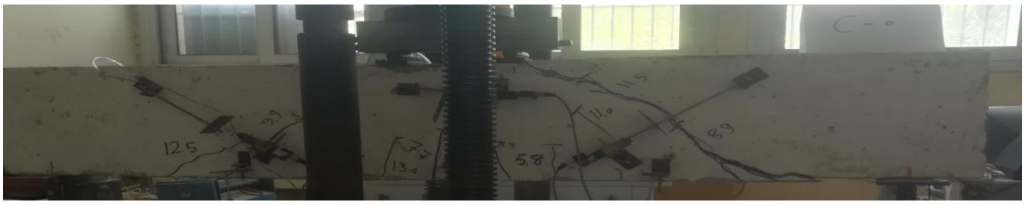
Fig -2: Crack Pattern of Specimens Group (A)

a) Beam content normal concrete at span to depth ratio 1.6(B-0)

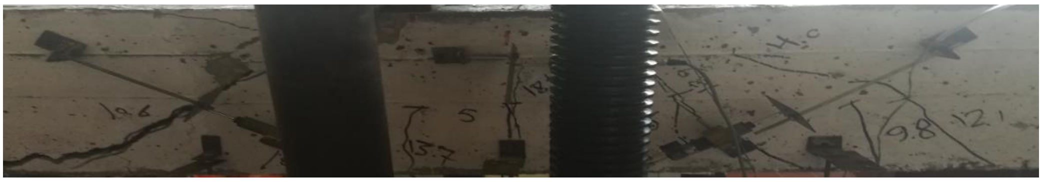
b)Beam content 100%RAC and 10%fly ash at depth ratio 1.6(B-1)

c) Beam content 100%RAC and 1%steel fiber at depth ratio 1.6(B-2)

Fig -3: Crack Pattern of Specimens Group (B)



a) Beam content normal concrete at span to depth ratio 2.32(C-0)



b) Beam content 100%RAC and 10%fly ash at depth ratio 2.32(C-1)

c) Beam content 100%RAC and 1%steel fiber at depth ratio 2.32(C-2)

Fig -4: Crack Pattern of Specimens Group (C)

3.2. Load Deflection Curves

Referring to Table (6) verify the tested beams; it can be noticed that the measured deflection of all beams with different admixture and different span to depth ratio is smaller than that of the control beams (A-0), (B-0) and (C-0). This means that the using 100%RCA and 10%fly ash or 1%steel fiber in mix enhances the stiffness of all beams.

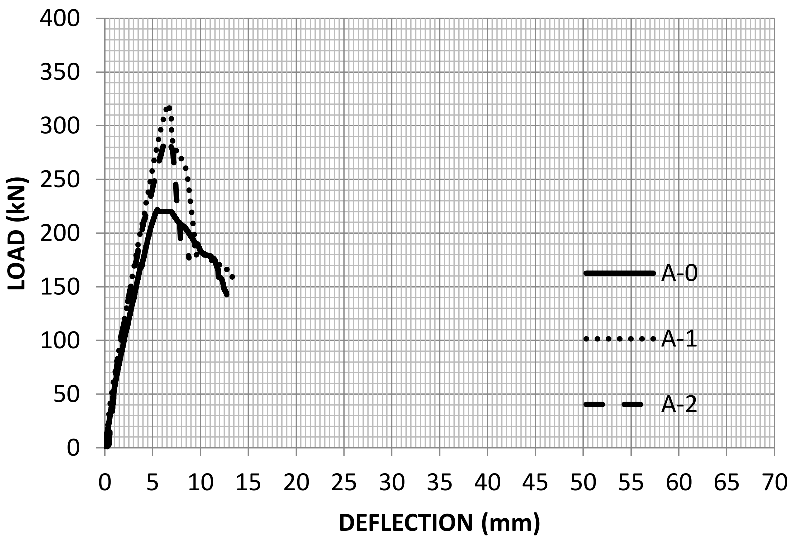


Fig -5: the effect of different material on the load-deflection curves at a\d=1.1 group A

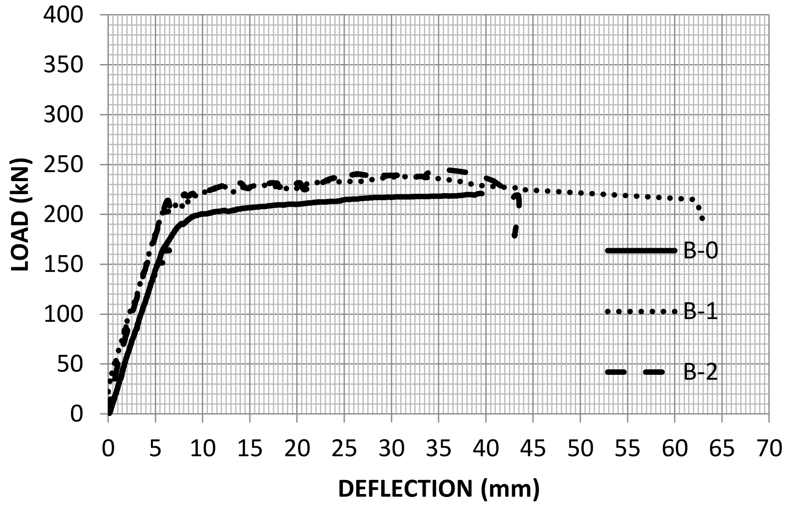


Fig -6: the effect of different material on the load-deflection curves at a\d=1.6 group B

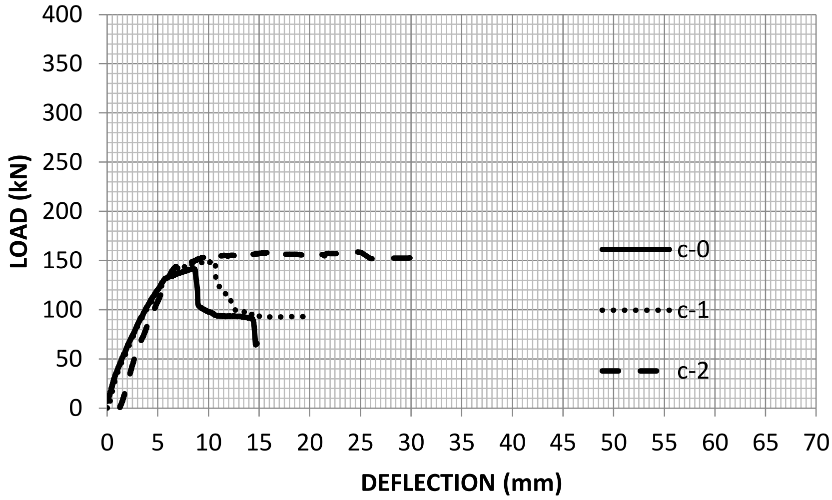


Fig -7 the effect of different material on the load-deflection curves at a\d=2.32 group C

3.3. Measure of electrical strain gauges

Fig. 8,9,10 shows the relationship between the applied load and strain of main steel (group A) and different shear span-to-depth ratio respectively. Increased span to depth ratio had changed mod of failure for all beams and strain of main steel.

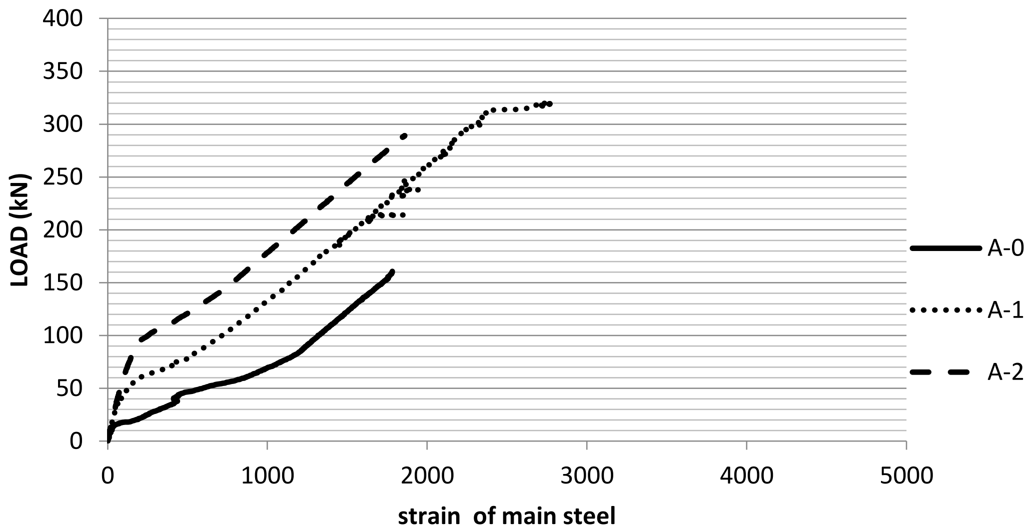


Fig -8: The Load-strain of main steel for group A at a\d=1.1

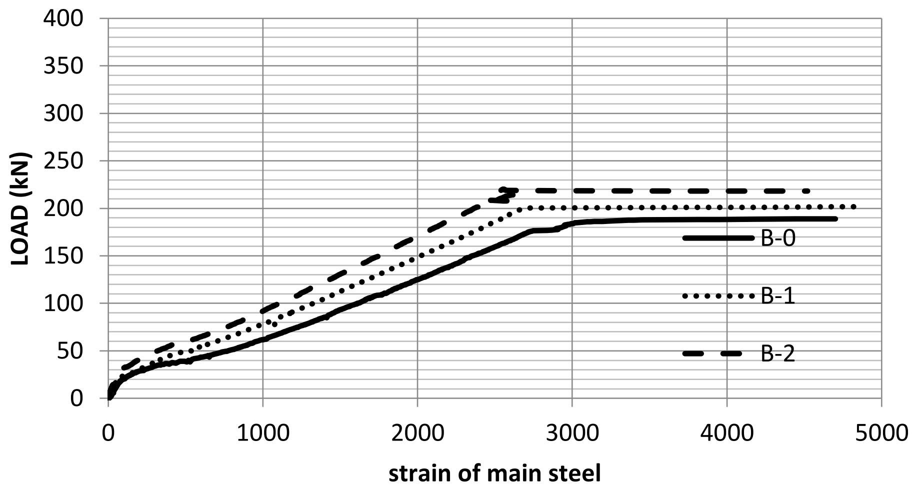


Fig -9: The Load-strain of main steel for group A at a\d=1.6

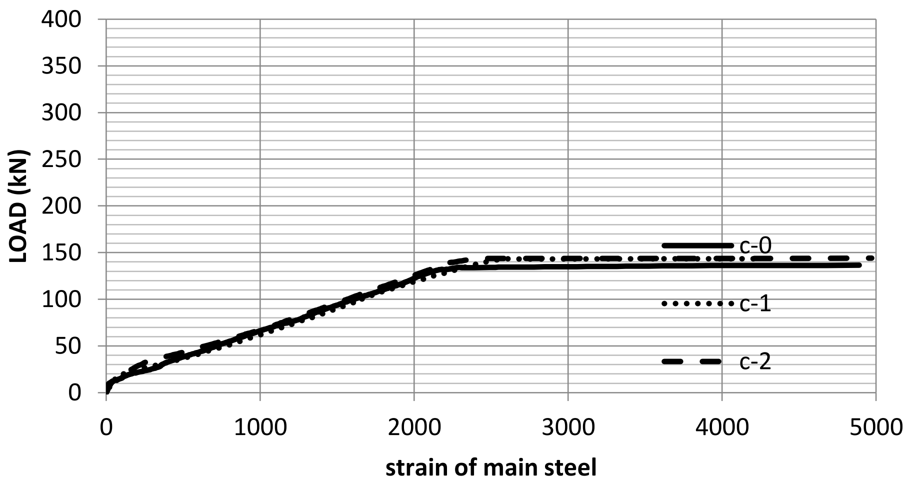


Fig -10: The Load-strain of main steel for group A at a\d=2.32

4. The effect of span to depth ratio
4.1. Ultimate load

In this part, comparing the ultimate loads with different span to depth ratio (1.1, 1.6and.2.32) for different materials was done. Figure (3) indicated the effect of shear span to depth ratio and change of percentage admixture (10%fly ash, 1%steel fiber) in the mix contents of (0,100%) recycled aggregate concrete respectively on failure load for all specimens.

- Using 10%fly ash or 1%steel fiber increase the ultimate load by about 33.3%to 16.66 respectively at span to depth ratio 1.1.
- Using 10%fly ash or 1%steel fiber increase the ultimate load by about 9.5% to 14.28% respectively at span to depth ratio 1.6.
- Using 10%fly ash or 1%steel fiber increase the ultimate load by about 5.7%to 13.5% respectively at span to depth ratio 2.32.

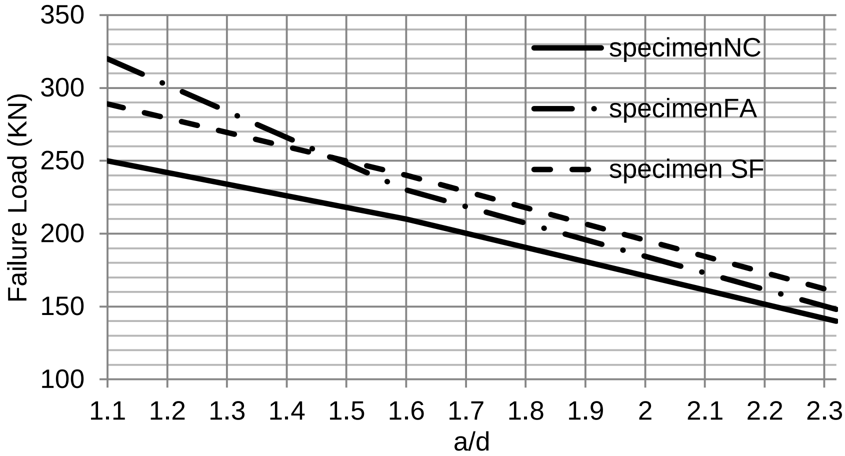


Fig -11: Effect of Shear-Span Depth on Failure Load

8. CONCLUSIONS

- Using 100%RCA with 10%FA increasing the ultimate capacity of beam 33%for group one at a\d equal 1.1 and 9. 52 %for group two at a\d equal 1.6 and 5.7 %for group three at a\d equal 2.32.
- Using 100%RCA with 1%SF increasing the ultimate capacity of beam 16.6%for group one at a\d equal 1.1 and 14.26 %for group two at a\d equal 1.6 and 14.3 %for group three at a\d equal 2.32.
- change shear span to depth ratio (a/d) from 1.1 to 2.32 decreasing the ultimate load of beam 12.5%,41.66% for specimen NC and 28.125%,53.75% for specimen FA and 14.28 %,42.87% for specimen SF.
- Change the additional material when RAC(100%) not have a significant effect on the crack pattern of the specimen Using 100%RCA with 10%fly ash increase the stiffness of beams.

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