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EFFECT OFRECYCLED AGGREGATES AND STEEL FIBERS ON FLEXURAL AND SHEAR BEHAVIOR OF REINFORCED NORMAL CONCRETE BEAMS

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Abstract: Concrete wastes are generally delivered to the landfill sites for disposal. Due to increase charges of landfill and shortage of natural coarse aggregate (NA), recycled coarse aggregate (RA) (resulting from concrete wastes) is growing interest in Building Engineering. It is sustainable to use recycled construction materials to preserve the natural resources and maintain the environmental of cities.In the present study, RA was used as a full replacement of NA in some specimens of beams to produce normal concrete (NC).The experimental work consists of casting and testing eight rectangular simply supported reinforced concrete beams of (1200*180*250) mm with concentric point load as well as tests for control specimens to determine the mechanical properties of NC. Four of each eight beams for flexural and the other four beams for shear behavior. The present research also includes the following main variables: transverse reinforcement (stirrups spacing, 50 mm and 100 mm), coarse aggregate (RA and NA) and steel fibers of (V_f = 0.5%). All beams have constant longitudinal steel reinforcement ratio=0.008.Experimental results have generally showed that ultimate loads (Pu) of beams made with RA are approximately close to the results of beams made with NA by percentages (6.2% and 10.1%) for flexural and shear behavior respectively. RA can be used as a full replacement in the future construction industry. The presence of steel fibers increases the maximum deflection of beams by 38.55% for flexural and 31.70% for shear

Keywords: *Normal concrete, Recycled aggregate*

تأثير الركام المعاد والألياف الحديدية على سلوك الأنثناء والقص للعتبات الخرسانية المسلحة الاعتيادية

الخلاصة: غالبا مايتم التخلص من الخرسانة القديمة (انقاض خرسانية) في مواقع ذات أرض مفتوحة. ونظرا لزيادة وثقل التحميل لهذه المواقع وندرة (قلة) المصادر الطبيعية لانتاج الركام الخشن الطبيعي, يتم استخدام الركام المعاد تدويره (المشتق من الخرسانة القديمة). وهذا الركام زاد الاهتمام به في الصناعات الانشائية. لذلك في الهندسة المستدامة يتم استخدام الركام المعاد تدويره من اجل المحافظة على الموارد الطبيعية واصلاح بيئة المدن. في هذا البحث, استخدم الركام المعاد (RA) كبديل كلي عن الركام الطبيعي (NA) وذلك لانتاج خرسانة تقليدية اعتيادية. تضمن العمل المختبري طريقة الصب والفحص (تحت تأثير الانثناء والقص) لثمان عتبات خرسانية مستطيلة المقطع وبسيطة الاسناد بأبعاد (1200*180*250) ملم ذات تحميل مركزي احادي, بالاضافة الى فحوص للنماذج الخرسانية في مرحلة الخرسانة المتصلبة لتحديد الخواص الميكانيكية للخرسانة التقليدية. تم اختيار اربع عتبات من اصل ثمانية لدراسة سلوك الانثناء والاربعة الاخرى لدراسة سلوك القص. تضمن البحث المتغيرات الرئيسية التالية: التسليح الثانوي (المسافة بين الاطواق50 ملم و 100 ملم), الركام الخشن (RA و NA) والياف التسليح ذات النسبة الحجمية الثابتة (0,5 %). علما ان نسبة حديد تسليح طولي ثابته ρ =0,008. اظهرت النتائج العملية عموما ان الاحمال القصوى للعتبات المصبوبة بأستخدام الركام المعاد تدويره مقاربة جدا الى الاحمال القصوى للعتبات المصبوبة بأستخدام الركام الطبيعي وبنسبة تغاير بسيطة لذلك من الممكن استخدامه كبديل عن الركام الطبيعي في الصناعة الانشائية المستقبلية حيث ان نسبة الزيادة (6,2% و 10,1%) لسلوكي الانثناء والقص على التوالي . ان وجود الياف الحديد زاد من قيمة الهطول للعتبات الخرسانية بنسبة زيادة (38,55%) لسلوك الانثناء و (31,70%) لسلوك القص.

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1. Introduction:

Concrete is the main building material that is widely used in all kinds of civil engineering works like substructure, short and tall buildings, and installations of defense work, environs defense and local-domestic improvements. However, recently the perception of the continued extensive abstraction and use of natural resources aggregates is questioned at a worldwide level (Lawson et al, 2001). This is chiefly because of natural aggregates quality depletion and the greater awareness of protection of environmental. Considering this, the obtainability of natural resources to the future had also been recognized (CSIR, 2000).

Today, there are severe lacks of natural resources in current situation. Concrete production and use are rapidly increased, which result in increased natural aggregate consumption as they are the largest component of concrete (Wai et al, 2012). Building materials are progressively featured by their sustainable features; a solution of these problems is recycling damaged concrete and producing a substitute aggregate for concrete structures (Valeria et al, 2009). Recycled concrete aggregate (RCA) lessens impact on landfills, reduces energy depletion and provides cost reserves (Huang et al, 2002).

On the other hand, there is the beneficial use of RA in concrete building (Eguchi et al, 2006). Recycled aggregate is made of crumpled, arranged, inorganic subdivisions treated from material that is used in structure and destruction rubbles (Ravi, et. al, 2013). Recycled concrete aggregate (RCA) is defined in (BS 8500-1, 2006) as the general word for aggregate result from the reusing of inorganic material before used in building.

- Construction materials recycling advantages: (Tushar, 2006)
  1- Used in construction of precast and cast in situation gutters and Krebs**.**
  2- Cost saving**.**
  3- Save environment**.**
  4- Save time**.**

- Recycling construction materials limitations or disadvantages: (Tushar, 2006)
  1- Fewer features such as strength of compression**.**
  2- High water absorption.
  3- Higher drying shrinkage and creep**.**

2. Objective of this paper

The main objective of this research is to investigate both flexural and shear behavior of recycled reinforced normal concrete beams by using new type of coarse aggregate of (10 mm) maximum size which is recycled from an old concrete barrier.

3. Research Significance

It is widely known that there is an important potential reason for demolished debris recycling, and to be used in value added uses to get the most out of cost-effective and environmental profits (Hirokazu et al, 2005). As a result of that, reusing engineering in many parts of world counting South Africa, convert low-value trashes into subordinate building materials such as a variability of aggregate fines (dust), aggregate grades, and road materials, and These materials are often used in road manufacture, low-grade production of concrete, backfill for retaining walls, brickwork, drainage, and block work for low-cost frame (CSIR, 2000).Asian countries should seriously think about RCA applications due to the growing of concrete discharge for every year (Mulheron, 1988). Hong Kong, Japan and China have turn into discoverer counties inAsia which actively directed studies on RCA requests in building industry (Poon and Chan, 2006).

The crushers which are used recently for the recycling of rubble were not designed or developed specifically for the purpose. The majority of crushers originated from coal and ore processing from natural stone crushing plants (Lindsell and Mulheron, 1985). Modifications have been made to these crushers to alter the degree of size reduction and the particle size distribution (Boesman, 1985). They included an impact crusher, a con crusher and a jaw crusher as shown in "Fig. 1".

A jaw crusher consists of two plants fixed at one angle plate, remains stationary while the other plate oscillates back and forth relative to the fixed plate. This action crushes material passing between the two plates.

An Impact crushers: use heavy steel “blow bars” mounted on a horizontal or vertical rotor to repeatedly impact concrete fragments and hurl them against steel anvils or “break plates” in the crusher housing. The rotor continues to throw particles that are larger than the desired top size

A cone crushers: use an eccentric rotating cone to trap and crush concrete fragments against the inner crusher housing walls when the material becomes small enough.

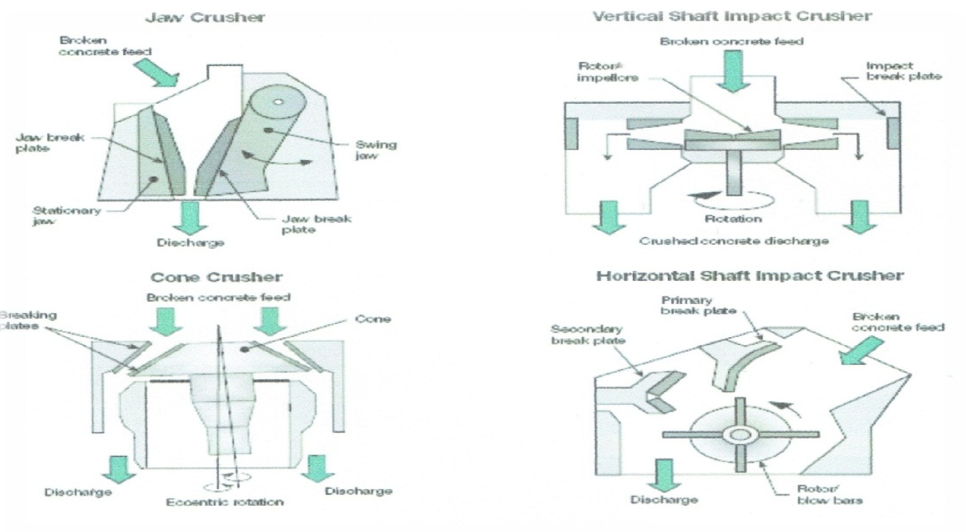


Figure 1: Sketch of crushing equipment types (Boesman, 1985)

4. Materials and experimental work

Normal concrete beam of (1200*180*250) mm has been made using confident proportions of cement, fine aggregate, coarse aggregate (natural and recycled) and water. In the program of testing, the compressive strength of concrete was kept constant which it is 30 MPa. The mix proportion was (1:2:3:0.45) by weight for cement, sand, gravel and water respectively. OPC type I with 350kg/m^{3}content.

AL-Ukhaider natural sand with fineness modulus (2.6) and specific gravity 2.63 was used. Natural and recycled gravel with maximum size (10mm) and specific gravity 2.62 and 2.58 respectively was used. Hooked steel fiber with aspect ratio (80) was used. All beams and control specimens are totally vibrated on a vibrating table. The vibration time to reach full compaction is certain upon by the end of air bubbles passage from concrete fresh state. The specimens are then cast into three layers, in which 25-30 seconds are required for compaction per layer. For each concrete mix, three cube specimens (150*150) mm, three cylinders (150*300) mm and one prism (100*100*500) mm have been taken and tested at 28 days.

5. Test results

As mentioned before, the main aim of this research is to study the flexural and shear behavior for the properties of normal concrete (NC) containing recycled coarse aggregate (RA) as full replacement of natural coarse aggregate (NA) in some specimens in addition to the specimens of (NA).

According to the test program of this study, the investigation involves 8 beam specimens tested under incrementally increasing load until failure. Cracking moment, ultimate moment, deflection at the center and quadrant of the beams.

Also this research presents and discusses crack patterns and modes of failure for all beams.

5.1. Mechanical properties results of NC

The properties of NC in the hardened state are important to understand the behavior of reinforced concrete beams. The mechanical properties that were studied in this investigation are as follows:

5.1.1 Compressive strength (f'_c)

The most important properties of all tests is the compressive strength test because it describes the concrete features that are associated with the strength and the essential importance of the compressive strength of concrete in structural design. Table 1 shows the measured values of compressive strength.

Table 1: Measured values of compressive strength

Mix	*f'c (cube), MPa*	*f'c (cylinder), MPa*	$f'c_{cylinder} / f'c_{cube}$
N50/1	31.3	24.6	0.79
N50/2	31.08	24.2	0.78
N50/3	31.1	23.9	0.77
N50/4	30.4	23.4	0.76
N100/1	31.23	25.9	0.82
N100/2	31.2	24.9	0.8
N100/3	30.8	25.5	0.82
N100/4	30.5	24.3	0.8

where:

N50/1	Specimen of beam with (N) normal concrete/ (50) stirrups spacing/ (1) natural aggregate with steel fiber
N50/2	Specimen of beam with (N) normal concrete/ (50) stirrups spacing/ (2) natural aggregate without steel fiber
N50/3	Specimen of beam with (N) normal concrete/ (50) stirrups spacing/ (3) recycled aggregate with steel fiber
N50/4	Specimen of beam with (N) normal concrete/ (50) stirrups spacing/ (4) recycled aggregate without steel fiber
N100/1	Specimen of beam with (N) normal concrete/ (100) stirrups spacing/ (1) natural aggregate with steel fiber
N100/2	Specimen of beam with (N) normal concrete/ (100) stirrups spacing/ (2) natural aggregate without steel fiber
N100/3	Specimen of beam with (N) normal concrete/ (100) stirrups spacing/ (3) recycled aggregate with steel fiber
N100/4	Specimen of beam with (N) normal concrete/ (100) stirrups spacing/ (4) recycled aggregate without steel fiber

The table above shows that the results of compressive strength of mixes made with recycled aggregate (RA) have slight decrease than the mixes made with natural aggregate (NA) by (1.5%) because the recycled aggregate was reacted previously. Also, "Fig. 2" shows the relationship between compressive strength and volumetric ratio of steel fibers. It is obvious from this figure that there are only marginal improvements in compressive strength due to addition of steel fibers because the fibers act as aggregate of special shape in view of their small percentages in practical material (Aliewi, 2006). The mixes made with steel fiber of V_f (0.5%) have slight increase than the mixes of non-fibrous concrete by percentages of (2.5%) for flexural behavior and (2%) for shear behavior.

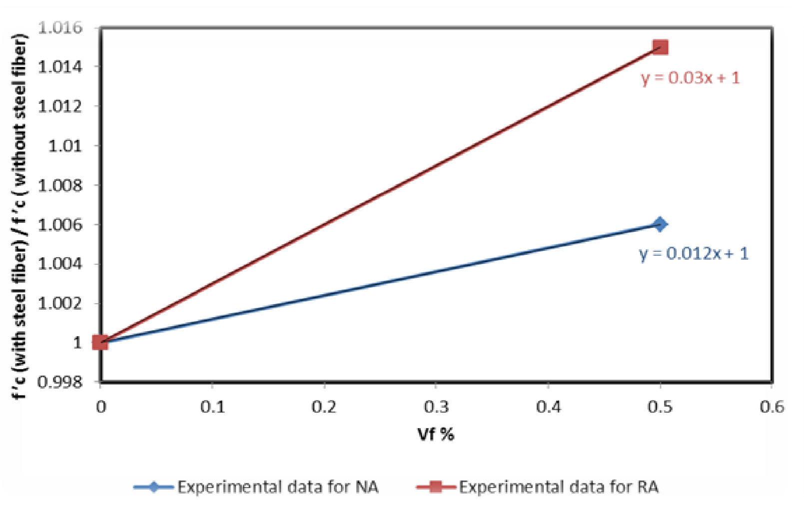


Figure 2: Effect of steel fibers content on the compressive strength for NC mixes

5.1.2 Splitting tensile strength (f_t)

It is a significant property of hardened concrete which the cracking of concretes is almost commonly refers to tension stress that accrued. Table 2 and "Fig. 3" below show the measured values of splitting tensile strength test of all mixes and the predicated values calculated from the equations 1 and 2.

$$\text{(ACI 363R-1992)}, \quad f_t(\text{ theoretical}) = 0.59(f'c)^{0.55} \quad (1)$$

$$\text{(ACI 318M-2011)}, \quad f_t(\text{ theoretical}) = 0.56\sqrt{f'c} \quad (2)$$

where : $f'c$ and f_t in MPa.

Table 2: Measured values of splitting tensile strength

Mix	*f_t (experimental), MPa*	*f_t (theoretical), MPa ACI 363R-1992*	*f_t (theoretical), MPa ACI 318M-2011*
N50/1	2.97	3.43	2.78
N50/2	2.65	3.40	2.75
N50/3	2.9	3.38	2.74
N50/4	2.62	3.34	2.73
N100/1	2.91	3.53	2.85
N100/2	2.69	3.46	2.79
N100/3	2.84	3.50	2.83
N100/4	2.54	3.41	2.76

Table 2 shows the following below:

- The values of experimental and theoretical (f_t) of the mixes with steel fibers are greater than the same mixes but without steel fibers because the presence of steel fibers will increase the ductility of concrete.
- Both (RA) and (NA) have the same effect on the values of (f_t).
- The values of experimental (f_t) are approximately close to equation 2.

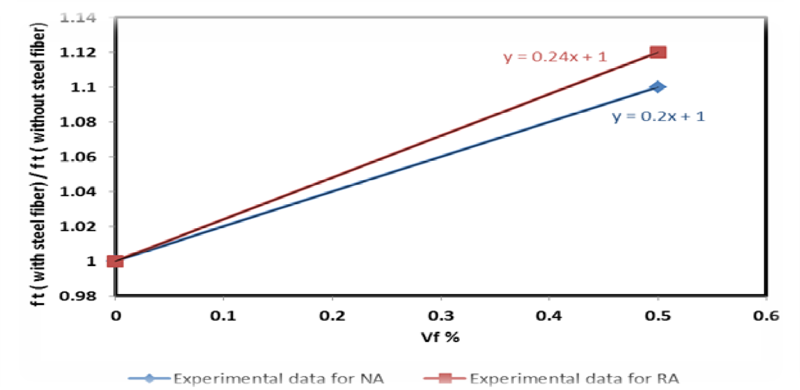


Figure 3: Effect of steel fibers content on the splitting tensile strength for NC mixes

5.1.3 Flexural strength (f_r):

Flexural strength (modulus of rupture) is the maximum tensile stress of concrete tested in flexural, and can be calculated from the formula used for elastic materials, ($f_r = MC/I$), (where M is bending moment, C is the distance from the neutral axis to the outermost fiber of concrete and I is the moment of inertia) by testing a plain concrete beam. Experimental results of this work are compared with the equation adopted by (ACI 318M-2011) code as shown in Table 3, "Fig. 4" and the equation is as below:

$$f_r = 0.62\sqrt{f'c} \quad (3)$$

where: $f'c$ and f_r in MPa.

Table 3: Measured values of flexural strength

Mix	*f_r (experimental), MPa*	*f_r (theoretical), MPa ACI 318 M-2011*
N50/1	4.2	3.1
N50/2	3.35	3.05
N50/3	3.6	3.03
N50/4	3.15	3.02
N100/1	3.9	3.16
N100/2	3.15	3.1
N100/3	3.8	3.13
N100/4	3.11	3.06

Table 3 shows that the mixes with steel fibers give values of (f_r) greater than the mixes without steel fibers because the presence of steel fibers will increase the ductility of concrete.

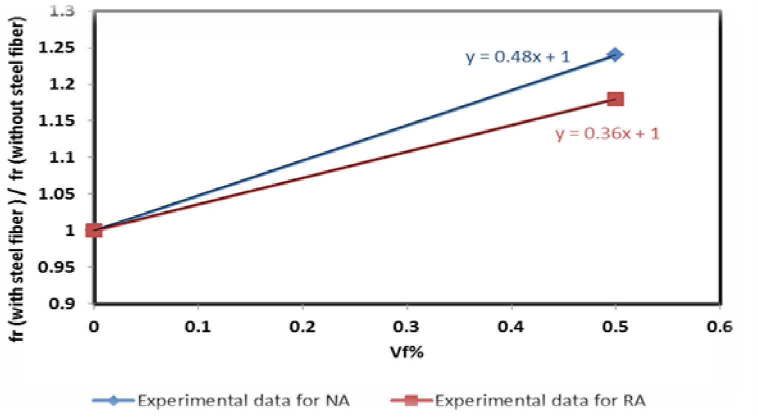


Figure 4: Effect of steel fibers content on the flexural strength for NC mixes

5.1.4 Elastic Modulus (E_C)

It is the most significant elastic property of concrete. It can be obtained by carrying a compressive test on concrete cylinders. Table (4) and "Fig.5" explain values of elastic modulus for various strength and the theoretical values adopted the following equations:

(ACI 363R-1992), $Ec = 3320\sqrt{f'c} + 6900$ (4)

(ACI 318M-2011), $Ec = 4700\sqrt{f'c}$ (5)

where: $f'c$ and E_c in MPa.

Table 4: Measured values of modulus of elasticity

Mix	*E_C (experimental), MPa*	*E_C (theoretical), MPa ACI 363R-1992*	*E_C (theoretical), MPa ACI 318M-2011*
N50/1	29114.5	23366.70	23311.24
N50/2	26764.71	23232.24	23120.94
N50/3	27477.03	23130.70	22977.18
N50/4	24763.64	22960.02	22929.1
N100/1	27903.48	23796.16	23919.26
N100/2	24465.41	23466.77	23452.95
N100/3	25614.03	23665.2	23733.84
N100/4	22883.88	23265.95	23168.66

Table 4 shows that the mixes with steel fibers give values of (E_c) greater than the mixes without steel fibers because the presence of steel fibers will increase the ductility of concrete.

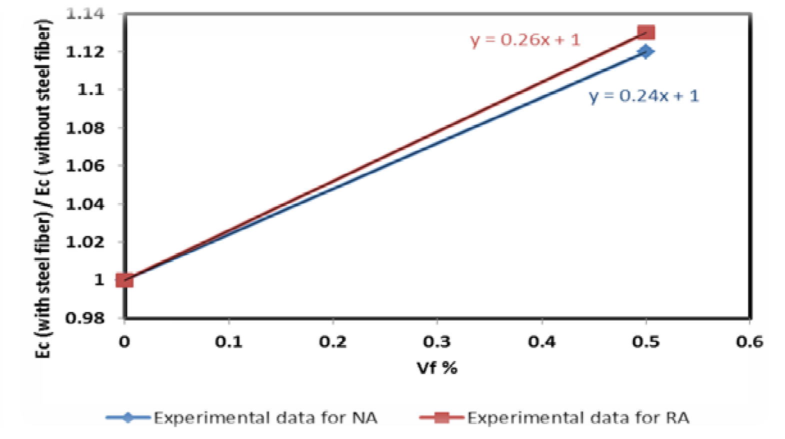


Figure 5: Effect of steel fibers content on the elastic modulus for NC mixes

5.2 Cracking moment (M_{cr})

Cracking moment is defined as the moment at which the first visible surface cracks on the surfaces of the member. Table 5 and "Fig. 6" show the results of cracking load and ultimate load. It is clearly shown that the cracking load increases when the ultimate load increased. The cracking load to the final load ratio (P_{cr} / P_u) was generally between (10 – 17) %.

Table 5: Cracking loads of the tested beams

Beam	*P_{cr} (kN)*	*P_u (kN)*	*P_{cr} / P_u (%)*	*M_{cr}*(kN.m)*
N50/1	20	120	16.67	5.25
N50/2	17.5	112.5	15.55	4.60

N50/3	18	114	15.78	4.73
N50/4	14	105	13.33	3.68
N100/1	15	100	15	3.94
N100/2	12.5	87.5	14.28	3.28
N100/3	14	92.5	15.13	3.68
N100/4	10	78	12.82	3.63

*$M_{cr} = P_{cr} . L /4$

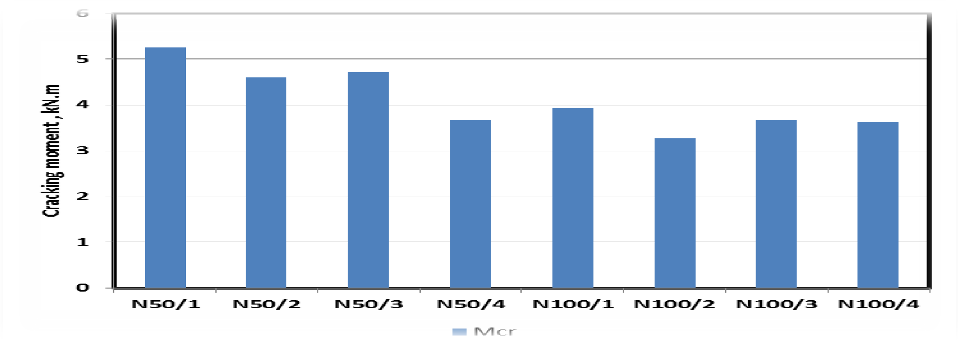


Figure 6: Cracking moment for the tested beams

Table (5) and "Fig. 6" show the following results:

The effect of coarse aggregate: the cracking moment values of the beams mixed with (NA) were larger than the beams mixed with (RA) when the other parameters are kept fixed because the shape of recycled aggregate is angular. It was already reacting and exposed to tensile stress, so the bonding with the rest of concrete component would be little so the cracking moment (M_{cr}) would be lesser. The percentage of these increments is about (10-25)% for flexural behavior and between (7-38)% for shear behavior.

5.3 Ultimate moment (M_u)

It is the maximum moment which can be carried out by the beams that are tested. Table (6) and "Fig. 7" show the results of experimental and theoretical ultimate moments as follows:

Table 6: Ultimate moment of the tested beams

Beam	*P_u (kN)*	*M_u *(experimental) kN.m*	*M_u **(theoretical) kN.m*
N50/1	120	31.50	25.35
N50/2	112.5	29.53	25.34
N50/3	114	29.93	25.343
N50/4	105	27.56	25.30
N100/1	100	26.25	25.35
N100/2	87.5	22.97	25.348

N100/3	92.5	24.28	25.33
N100/4	78	20.50	25.31

$*M_u = P_u \cdot L/4$, $** M_u = \varphi \{A_s f_y (d - \frac{a}{2})\}$, $a = \frac{As\,fy}{0.85 f'c\, b}$

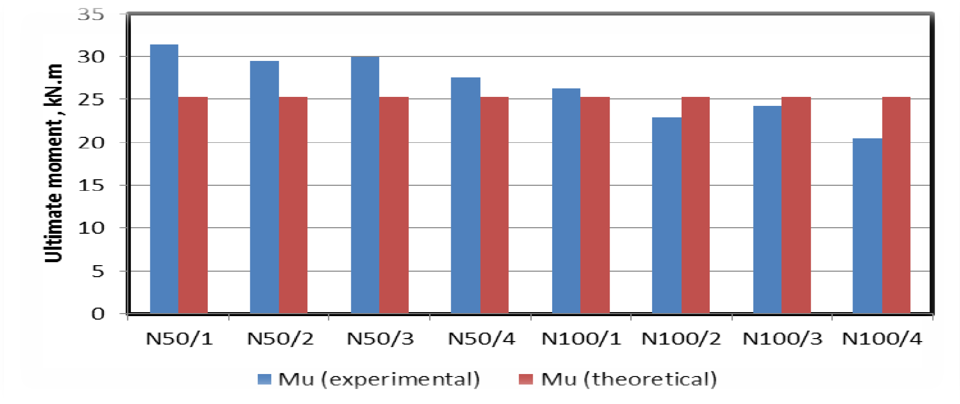


Figure 7: Theoretical and experimental Ultimate moments (M_u) for the tested beams

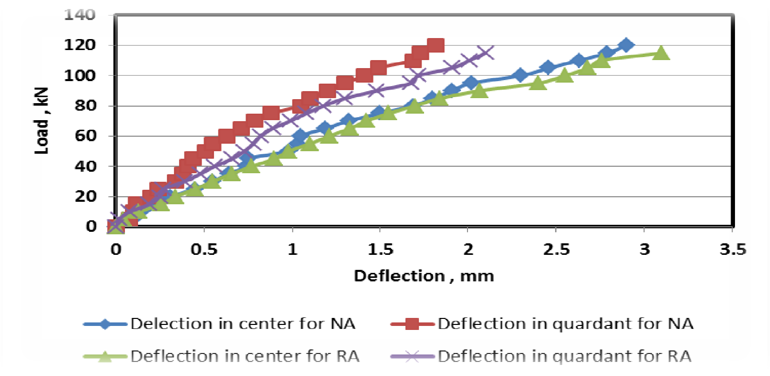
It is obvious that the theoretical moment values vary between (25.30-25.35) kN.m for flexural behavior and between (25.31-25.35) kN.m for shear behavior, while the experimental moment results vary between (27.56-31.50) kN.m for flexural behavior and between (20.50-26.25) kN.m for shear behavior.

5.4. Load deflection behavior

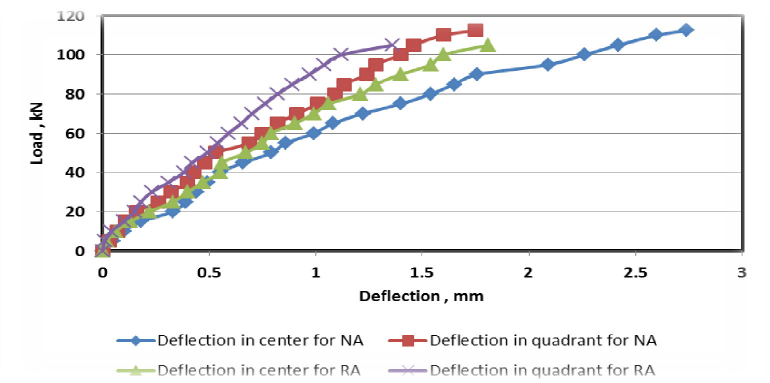
The structural behavior is normally explained using load versus deflection curves. The load-deflection curves in this work are taken at center and quadrant of all the tested beams. Table 7 illustrates the maximum deflection in center and quadrant of the beam with maximum load, and "Fig. 8" shows the load-deflection curves of normal concrete.

Table 7: Maximum deflection in center and quadrant of the beams

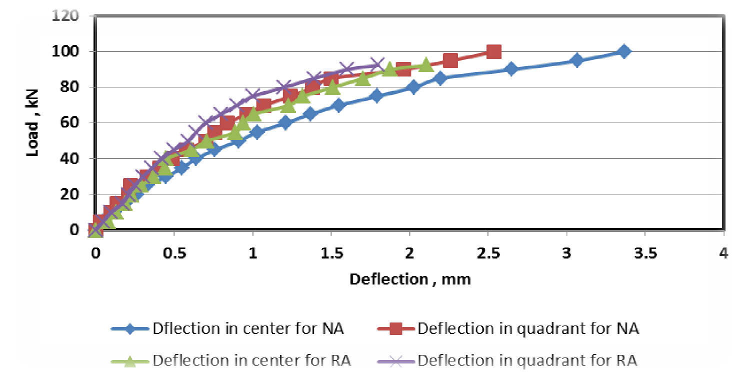
Beam	*Ultimate load, kN*	*Maximum deflection at center, mm*	*Maximum deflection at quadrant, mm*
N50/1	120	2.9	1.82
N50/2	112.5	2.74	1.75
N50/3	114	3.1	2.1
N50/4	105	1.81	1.36
N100/1	100	3.37	2.54
N100/2	87.5	1.71	1.2
N100/3	92.5	2.11	1.8
N100/4	78	3.18	2.24



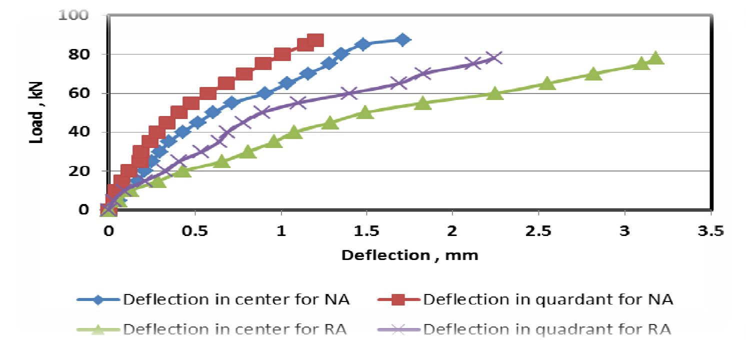
(a) Comparison between (NA) and (RA) with steel fiber addition for normal concrete (flexural cop



(b) Comparison between (NA) and (RA) without steel fiber addition for normal concrete flexural behavior)



(c) Comparison between (NA) and (RA) with steel fiber addition for normal concrete (shear behavior)



(d) Comparison between (NA) and (RA) without steel fiber addition for normal concrete (shear behavior)

Figure 8: Load - deflection curves for specimens containing natural aggregate (NA) and recycled aggregate (RA)

5.4 Crack patterns and modes of failure

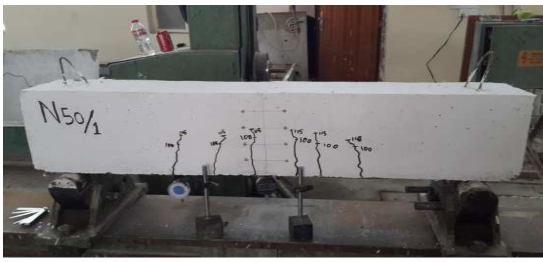
In this study, four of 8 beams are designed with Φ6@50 mm spacing for stirrups. This group of beams fails in flexure by yielding of tension steel bars. The other four beams are designed with Φ6@100 mm spacing for stirrups and fail in shear by diagonal tension cracking. Longitudinal steel bars (3Φ12 mm) for the 16 beams were hooked at their ends by about 90° to ensure that no bond failure between steel bars and surrounding concrete can take place. Table 8 and "Fig.11 and 12" show maximum crack width and modes of failure of the tested beams**.** Crack width is measured by a simple gauge (knives) as shown in "Fig. 9"which is used to give an approximate crack size during visual surveys, this simple gauge has been designed to provide inspectors with a low cost alternative for determining the width of cracks in a concrete. While the measuring of crack depth by a Digital Caliper,8" (200mm) as shown in "Fig. 10", this instrument (provide an accurate depth of cracks) is easy to read LCD digits, rolling thump wheel, plus control buttons for zero, on/off and inch/mm functions. Range 0-8" (200mm) with accuracy 0.001mm.

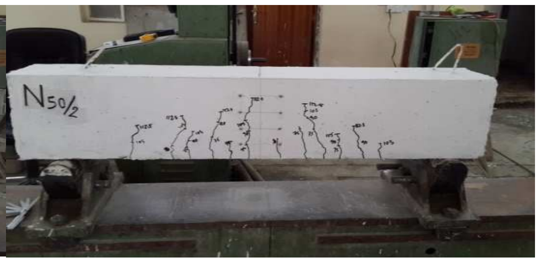
Table 8 : Maximum crack width and modes of failure of the tested beams

Beam	P_u *, kN*	*Crack width, mm*	*Crack depth, mm*	*No. of cracks*	*Mode of failure*
N50/1	120	0.2	1.1	6	Flexure
N50/2	112.5	0.25	1.5	12	Flexure
N50/3	114	0.35	1.2	8	Flexure
N50/4	105	0.4	1.82	9	Flexure
N100/1	100	0.25	1.8	4	Shear
N100/2	87.5	0.35	2.1	4	Shear
N100/3	92.5	0.3	0.94	4	Shear
N100/4	78	0.4	3.5	4	Shear

Figure 9: Crack width measurement

Figure 10: Digital Caliper





(a) Natural aggregate with steel fiber

(b) Natural aggregate without steel fiber

(c)Recycled aggregate with steel fiber (d) Recycled aggregate without steel fiber

Figure 11: Crack patterns and Modes of failure for normal concrete/ flexural behavior

(e) Natural aggregate with steel fiber (f) Natural aggregate without steel fiber

(g) Recycled aggregate with steel fiber (h) Recycled aggregate without steel fiber

Figure 12: Crack patterns and Modes of failure for normal concrete/ shear behavior

6. Conclusions

Based on the results obtained from experimental work for eight rectangular reinforced concrete beams which are made from normal concrete with (NA) and (RA), besides to their corresponding cubes, cylinders and prisms specimens, the conclusions can be illustrated below:

6.1 Mechanical properties of normal concrete

1- The results of mechanical properties of normal concrete with RA mixes have slight decrease than NA mixes by (1.5%, 2.88%, 8.5% and 5.63%) for compressive strength, tensile strength, flexural strength and elastic modulus respectively.
2- The effect of steel fibers on mechanical properties of concrete gives larger values than the non-fibrous concrete by (2.25%, 19%, 17.5% and 8.75%) for compressive strength, tensile strength, flexural strength and elastic modulus respectively.

6.2 Cracking moment (M_{cr})

1- The mixes of RA give cracking moment values smaller than NA mixes by 21% and 23.5% for flexural and shear behavior.
2- The cracking moment of steel fiber mixes is greater than mixes without steel fiber by 16% and 20.25% for flexural and shear behavior.

6.3 ltimate moment (M_u)

1- The mixes of RA give ultimate moment values smaller than NA mixes by 6.5% and 10.5% for flexural and shear behavior.
2- The ultimate moment of steel fiber mixes is greater than mixes without steel fiber by 9.5% and 14%for flexural and shear behavior.

6.4 Load-Deflection curves

1- The maximum deflection of RA mixes is the same as NA mixes for the same parameters.
2- The maximum deflection of steel fiber mixes has values greater than the non-fibrous mixes.

6.5 Crack patterns and modes of failure

1- The presence of recycled aggregate (RA) in the mixes gives the first crack loads and ultimate loads come earlier than the other mixes that used natural aggregate (NA).
2- The presence of steel fiber in the mixes made the concrete more ductile to resist first crack and ultimate loads.

7. Brief Conclusions

It can be used this type of aggregate (recycled aggregate) in the future projects as a substitute of natural aggregate because the recycling process services to decrease energy usages, reduces raw aggregate depletion, reduces water and air pollution by reducing requirements for conventional waste discarding, reduces emissions of greenhouse gases, protects and saves environment. It is sustainable using of resources so it can preserve the natural resources.

This can be obtained by some reservations as follows:

1- Some researches must be made as it mentioned in the recommendations below in order to contain all the branches of this subject which include increase safety factor for applied load and decrease factors for strength for bending and shear.
2- The reaching and obtaining the above advantages of the recycling program need support and help from the government and companies in order to preserve the environment and save money by giving contribution for this project to construct a mass crushing planets for breaking the concrete barriers to produce the substitute raw materials in future which is acceptable and high quality from one side and economic from the other side. And that entire conclusion had done in this work to have a good quality control in order to let this project to success and to be accepted by constructed companies and engineers.

8. Recommendations

1- This work can be further extended with other different types of concrete beams such as (high strength concrete, reactive powder concrete and hybrid concrete beams of normal concrete and Self-compacting concrete).
2- The use of other types of fibers such as plastic fiber instead of steel fiber.
3- The effect of using other members such as columns or other variables such as (with or without stirrups, shear span to depth ratio and beam size) can be studies.

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