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Improvement of Performance for R.C. Beams Made from Recycled Aggregate by Using Non-Traditional Admixture

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***Abstract*—**The aim of this work is to use an environmental, cheap; organic non-traditional admixture to improve the structural behavior of sustainable reinforced concrete beams contains different ratios of recycled concrete aggregate. The used admixture prepared by using wastes from vegetable oil industry. Under and over reinforced concrete beams made from natural aggregate and different ratios of recycled concrete aggregate were tested under static load until failure. Eight beams were tested to investigate the performance and mechanism effect of admixture on improving deformation characteristics, modulus of elasticity and toughness of tested beams. Test results show efficiency of organic admixture on improving flexural behavior of beams contains 20% recycled concrete aggregate more over the other ratios.

***Keywords*—**Deflection, modulus of elasticity, non-traditional admixture, recycled concrete aggregate, strain, toughness, under and over reinforcement.

I. Introduction

THE amount of construction and demolition waste has increased considerably over the last few years. Nowadays, almost all demolished concrete has been mostly dumped to landfills. From the viewpoint of environmental preservation and effective utilization of resources, the interest in using recycled materials derived from construction and demolition waste is growing all over the world [2]-[4], [15]. Previous works concluded that using different ratios of recycled concrete aggregate has a harmful effect on fresh and hardened concrete properties [7]-[9], [13].

Also modern production of plain and reinforced concrete is closely connected with wide using of different types of chemical traditional admixture to improve fresh and hardened concrete properties, almost of the traditional admixtures in the market are expensive, [1], [5]. In 2014, Y. A. Hassanean et al. [16] prepared an organic non-traditional admixture depending on wastes from vegetable oil industry (soap-stock) to improve fresh and hardened concrete properties made from different ratios of recycled concrete aggregate, they determined the optimum doses of each concrete mix. Slump and compacting factor measured to study fresh concrete properties, while compressive, tensile, bond and flexural strength measured to study hardened concrete properties. Test results show that the organic non-traditional admixture have a good and clear effect on improving fresh and hardened concrete properties made from of recycled concrete aggregate.

In 2002, M. M. Rashawn and K. A. Assaf [10] used two types of non-traditional admixtures, SM-C1 and SM-C2 to cast six beams with different amount of tensile steel to study the improvement of deformation for R.C. beams made using these admixtures. They compared results with six beams made using another non-admixture SMP and control beams without admixtures. They found the effectiveness of admixtures on improving the deformation characteristics of under and balanced reinforced sections. Otherwise, these admixtures have a bad effect on the deformation characteristics of over reinforced sections.

In 2009, Fatma el Zahra et al. [11] tested eighteen beams to evaluate the structural behavior of simply supported reinforced concrete beams made from recycled concrete aggregate, with different sizes of recycled concrete aggregate and replacing ratios of recycled aggregate, in comparison with beams made from natural aggregates. She concluded that all recycled aggregate concrete beams subjected to flexural loading showed the same cracking behavior as the natural aggregate concrete beams. Also recycled aggregate concrete beams showed good ductility behavior more than beams made from natural aggregate. While shear strength showed considerable enhancement by increasing the amount of shear reinforcement more than recycled concrete beams.

II. Experimental Work

A. Test Specimens

Eight reinforced concrete beams with a cross section 12×30cm and length of 280cm were fabricated and tested under four-points of loading. The design of the flexural and shear steel reinforcement ensured a flexural failure of the beams. The tested beams made from different ratios of RCA (0%, 20%, 30% and 40%), organic non-traditional admixture used to improve the properties of concrete contains RCA. The tested beams divided into two groups according to the amount of tension steel, the first group of beams consists of four under reinforced beams reinforced with 2Φ12 as tension steel bars, 2Φ10 as stirrups hunger and 8Φ8/m\ closed stirrups, the second group of beams consists of four over reinforced beams reinforced with 4Φ16 as tension steel bars, 2Φ10 as stirrups

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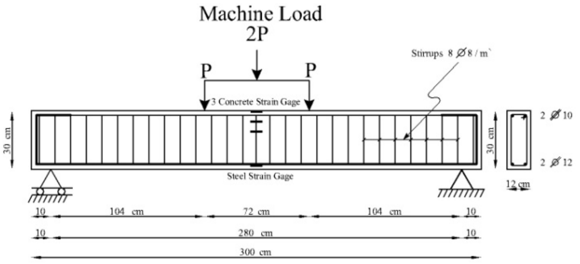
hunger and 10Φ8/m\ closed stirrups. Slump of mixes ranged from 7 to 8cm, the optimum dose of the suggested admixture according to compressive strength for all types of mixes were obtained and explained by [15] and [16]. Complete details of beams presented in Table I and Fig. 1.

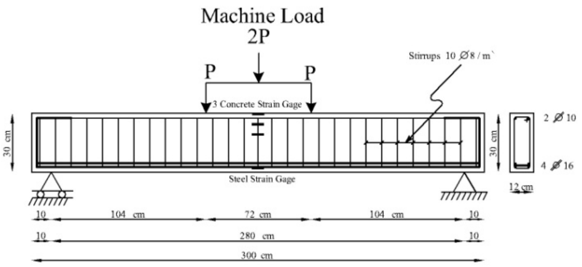
TABLE I
DETAILS OF TESTED BEAMS

Beam	w/c	Add %	RCA %	A_s	stirrups	$\frac{a}{d}$	μ
A1	0.61	0	0	2Φ12	8Φ8/m\	4	0.7
A2	0.47	0.88	20	2Φ12	8Φ8/m\	4	0.7
A3	0.49	0.91	30	2Φ12	8Φ8/m\	4	0.7
A4	0.5	0.95	40	2Φ12	8Φ8/m\	4	0.7
B1	0.61	0	0	4Φ16	10Φ8/m\	4	2.65
B2	0.47	0.88	20	4Φ16	10Φ8/m\	4	2.65
B3	0.49	0.91	30	4Φ16	10Φ8/m\	4	2.65
B4	0.5	0.95	40	4Φ16	10Φ8/m\	4	2.65

RCA % = Recycled Concrete Aggregate Ratio, Add % = Admixture dose by weight of cement, $\frac{a}{d}$ = Shear span to depth ratio, A_s = Main bars of steel reinforcement, μ= Reinforcement steel ratio on concrete section



(a) Details of beams group A



(b) Details of beams group B

Fig. 1 Details of tested beams

B. Materials

1. Cement

Ordinary Portland cement with CEM I 42.5 N was used. Mechanical, physical and chemical properties of the used cement agree with the requirements of the Egyptian code (ECP 203-2007), [6].

2. Natural Aggregate

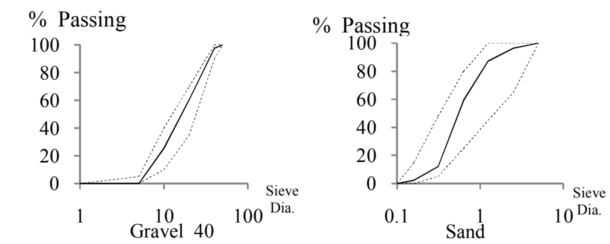
Natural aggregate used from Assiut quarries, and its physical, chemical and mechanical properties are presented in Table II as well as the grading of aggregate is shown in Fig. 2.

3. Recycled Aggregate

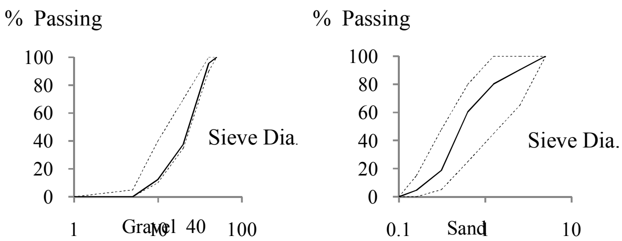
Recycled aggregates used in this work were produced by crushing the demolitions of a building in Sohag zone. The crushed concrete was from the upper skeleton has been screened using sieve analysis. Physical, mechanical and chemical properties of the RCA are determined according to ECP 203-2010, [6]. It was observed that the density and water absorption ratio of RCA are higher than that of NA. The differences observed in these properties are mainly due to the adhered cement mortar as reported by many other researchers [2], [3], [13], and its physical, chemical and mechanical properties are presented in Table II, also the grading of aggregate is shown in Fig. 2.

TABLE II
PROPERTIES OF USED AGGREGATE

Property	*Natural Aggregate*		*Recycled Aggregate*	
	Sand	*Gravel*	*Sand*	*Gravel*
Specific Weight	2.58	2.53	2.5	2.44
Bulk Density (t/m^3)	1.68	1.63	1.58	1.46
Water Absorption %	-------	0.93	--------	3.8
Clay and Fine Dust Content %	1.13	-------	0.42	-------
Crushing Value %	-------	10.13	--------	29
Fineness modulus	3.58	6.2	3.55	6.6
chloride content CL- %	0.034	0.025	0.07	0.062
Sulfates content SO3 %	0.093	0.0116	0.226	0.223
Degree of alkalinity (PH)	7.5	8	9.5	9



a) Grading of Natural Aggregate



b) Grading of Recycled Aggregate

Aggregate Grading. Limits of ECP 203,

Fig. 2 Grading curve of used Aggregate

4. Admixtures

Organic non-traditional admixture, was used to improve fresh and hardened concrete properties, the admixture was prepared using wastes of vegetable oil industries. Technique of preparing and producing the admixture is given in [16]. The admixture components by weight were:

1- Soap-stock. …………………................ 30 %
2- Calcium Oxide “CaO”….………………1 %
3- Plasticizer “PVF”………… ………....... 5 %

4- Water…………………………….......... 64 %

C. Concrete Mixes

The concrete mixes were designed to achieve target strength 250kg/cm^2, using 20%, 30% and 40% RCA using 40 mm M.N.S. aggregate. The concrete mixes proportions by weight presented in Table III.

TABLE III
MIXES' PROPORTIONS

Cement (Kg)	Gravel (Kg)		Sand (Kg)		Water (liter)	Add %	W/C
	NA	RCA	NA	RCA			
350	1193.8	0.00	633.2	0.00	192.5	0	0.61
350	898.56	224.65	499.2	124.8	164.5	0.88	0.47
350	786.2	337	436.8	187.2	171.5	0.91	0.49
350	674	449.3	374.4	249.6	175	0.95	0.5

III. Results and Discussion

A. Pattern of Cracks and Mode of Failure

Investigation of Fig. 3 and Table IV shows that each group has the same mode of failure. The mode of failure of the under reinforcement beams was flexure tension, while it was flexural compression in over reinforcement beams. Also it can be observed that, at the same level of loading the width of cracks and its propagation were small in beams made from RCA using admixture comparing with control beam.

B. Cracking and Ultimate Loads

The cracking and ultimate loads of the tested beams are presented in Table IV. The effect of using the suggested admixture on improving cracking and ultimate loads of the tested beams can be observed from Fig. 4. The figure shows increasing in cracking load of under reinforcement beams by 13.6%, 9% and 2.40% for beams A2, A3 and A4 respectively compared with the control beam A1. Cracking load increases for over reinforcement beams by about 10 % for beams B2 and B3. Also there is an increasing in ultimate load of under reinforcement beams by 16.7%, 8.3 % and 3.3 % for beams A2, A3 and A4 respectively, compared with the control beam A1. Also the ultimate load increases for over reinforcement beams by about 8.7%, 6.5% and 1.4% for beams B2, B3 and B4 respectively.

C. Deflection

The vertical deflection of the tested beams compared at both cracking and ultimate loads, the values of deflection at both cracking and ultimate loads are presented in Table V. The used admixture has a significant effect on reducing deflection of under reinforcement beams at cracking load. The reduction on deflection of the under reinforcement beams were 61.5%, 42.3% and 27% for beams A2, A3 and A4 respectively, compared with the control beam A1, despite these beams contains different ratios of RCA. Also it reduces the vertical deflection at failure by about 18.75%, 6.25% and 6.52% for beams A2, A3 and A4 respectively, compared with the control beam A1, as shown in Fig. 5. For over reinforced beams it is necessary to notice that the difference between deflection values beams until cracking load is small, after this level of load the influence of non-traditional admixture on reducing vertical deflection started to appear. This is because at load equal to 30 % of the ultimate load, there are no cracks; the beams still elastic and the compression zone of the beams are nearly equal at the initial levels of loading. While the used admixture reduces the maximum deflection at failure by about 33%, 6.1% and 7.3% for beams B2, B3 and B4 respectively, comparing with the control beam B1, as shown in Fig. 5.

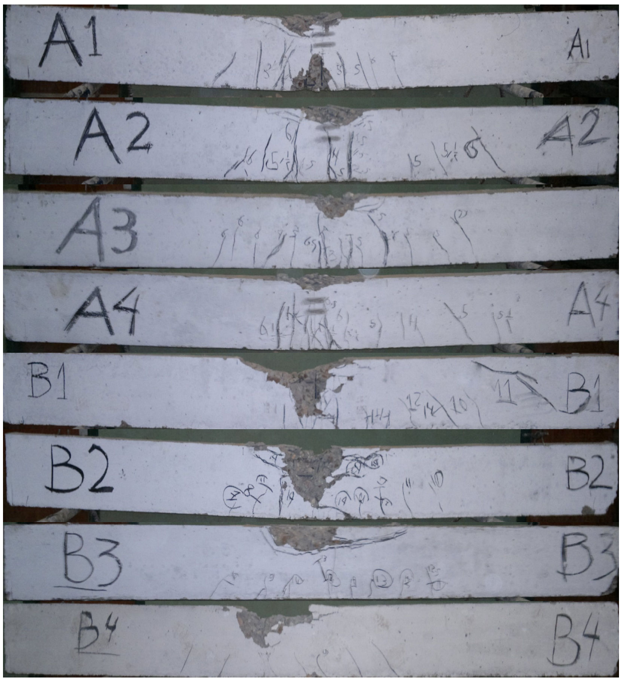


Fig. 3 Pattern of cracks and mode of failure of the tested beams

D. Main Steel Strain

The induced steel strain of the tested beams compared at the same load equal to 3 tons for beams group A and 6.9 tons for beams group B. the used admixture decrease steel strain induced up to failure in both under and over reinforced beams in spite of using RCA with different ratios. The reducing of steel strain for under reinforced beams was 60.8%, 39.45% and 27% for beams A2, A3 and A4 respectively, comparing with the control beam A1 while it was 51%, 33.3% and 41.3% for beams B2, B3 and B4 respectively, comparing with the control beam B1, for over reinforced beams, as shown in Fig. 6. This explained by the positive effect of admixture on increasing the compression zone of these beams and also increasing the tensile and bond strength of concrete, [16], which leads to decreasing on the tension force on steel bars.

TABLE IV
TEST RESULTS

Beam No.	F_{C28}	P_{cr}	P_U	Mode of failure.
A1	220	1.1	3	F.T.
A2	300	1.25	3.5	F.T.
A3	285	1.2	3.25	F.T.
A4	280	1.1	3.1	F.T.
B1	220	4.1	6.9	F.C.
B2	300	4.5	7.5	F.C.
B3	285	4.5	7.35	F.C.
B4	280	4	7	F.C.

F_{C28} = cube compressive strength after 28 days in kg/cm^2, F.T.= Flexural tension failure, F.C.= Flexural compression failure, Pcr & P_U = Cracking and Ultimate loads in tons.

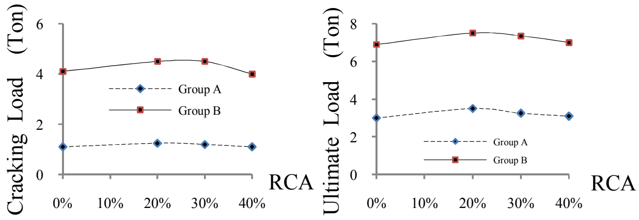


Fig. 4 Effect of the Suggests Admixture on Cracking and Ultimate Loads of the Tested Beams

TABLE V
CONT. TEST RESULTS

Beam No.	δ cr	δ u	E_S	T	1/ρ
A1	5.2	16	198253	20.2	$1.41x10^{-5}$
A2	2	13	236582	32.2	$1.17x10^{-5}$
A3	3	15	218342	28.2	$1.28x10^{-5}$
A4	3.8	15	212527	24.1	$1.31x10^{-5}$
B1	8.2	19	252457	40.4	$2.36x10^{-5}$
B2	5.5	14	565733	58.7	$1.07x10^{-5}$
B3	7.7	17	399182	48.2	$1.51x10^{-5}$
B4	7.6	16.8	347535	45.7	$1.72x10^{-5}$

δ cr & δ u = Deflection at Cracking and Ultimate loads in mm, E_S = Modulus of Elasticity in kg/cm^2, T = Toughness in ton.mm, 1/ρ = Radius of Curvature in cm^{-1}.

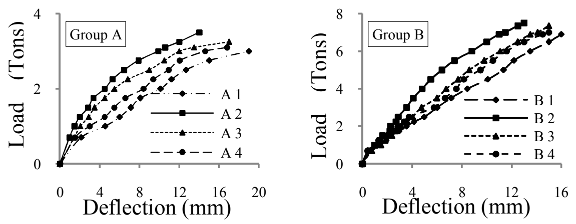


Fig. 5 Load-Deflection of the tested beams

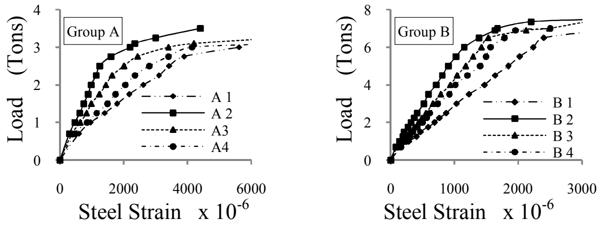


Fig. 6 Load-Steel strain diagram for tested beams

E. Concrete Strain

Fig. 7 show the effect of the used admixture on reducing the induced concrete strain, by comparing the induced concrete strain of the tested beams with the control one at load equal to 95% of the failure load. The percentage of reduction was 52.8%, 26% and 36.6% for under reinforced beams A2, A3 and A4 respectively comparing with the control beam A1. Also it was 56.7%, 43.2% and 44.6% for over reinforced beams B2, B3 and B4 respectively, comparing with the control beam B1. This is because of the effect of the non-traditional admixture on improving the microstructure formation of the hardened concrete, which produce more dense and homogenous material. This consequently increases strength and decreases maximum strain of concrete under different rates of loading until failure.

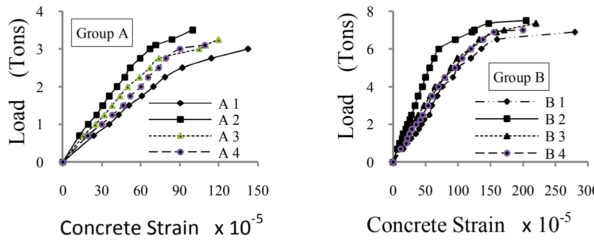


Fig. 7 Load-Concrete strain diagram for tested beams

F. Modulus of Elasticity

Modulus of elasticity of tested beams was evaluated by calculating the neutral axes depth z, at load level equals to 0.25 P_U, by using the three strain gages that attached at the compression zone, as shown in Fig. 1. Modulus of elasticity for all tested beams was presented in Table V. It can be observed from Table V and Fig. 8 that the used admixture increases the modulus of elasticity for both under and over reinforced beams in spite of containing different ratios of RCA, comparing by the control beam. The percentage of increasing was 19%, 10% and 7% for under reinforced beams A2, A3 and A4 respectively comparing with the control beam A1. Also it was 124%, 58% and 37.6% for over reinforced beams B2, B3 and B4 respectively, comparing with the control beam B1. This explained by the positive effect of admixture on improvement of concrete strength and homogeneity of the used concrete.

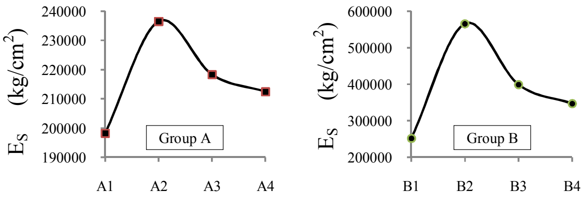


Fig. 8 Modulus of elasticity for tested beams.

G.Toughness

Flexural toughness can define as the energy equivalent to the area under the load-deflection curve up to define or a specified deflection. [12] and [14]. Toughness of the tested beams was calculated as the area under the load-deflection curve up to failure, at the same deflection of all tested beams equal to 14mm for beams group A and 13 mm for beams group B. Table V presents toughness values of the tested beams. Table V and Fig. 9, show the effect of the used non-traditional admixture on improving toughness for both under and over reinforcement beams in spite of containing different ratios of RCA, comparing by the control beam. Toughness for under reinforced beams increases by about 59.4%, 39.6% and 19.3% for beams A2, A3 and A4 respectively, while it was 45.3%, 19.3% and 13.1% for beams B2, B3 and B4 respectively.

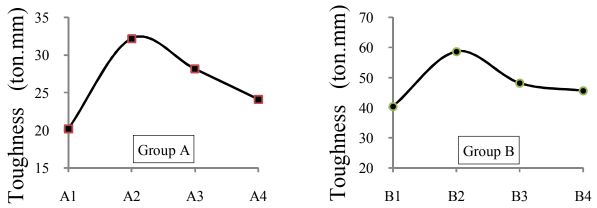


Fig. 9 Toughness of tested beams

H.Radius of Curvature

Radius of curvature (1/ρ) can express the stiffness of the tested beams. As radius of curvature (1/ρ) increases, both of induced strain and vertical deflection increases. Therefore, stiffness of beams increases as radius of curvature (1/ρ) decreases. Radius of curvature (1/ρ) for tested beams calculated at the elastic stage as the elastic line deformed to avoid cracks effect on deflection or strains. Therefore it calculated at the same elastic load which modulus of elasticity calculated at it, by dividing the elastic strain ε_{el} by compression zone depth (z - 2cm) as the location of upper strain gage. Table V presents the radius of curvature values of the tested beams. Table V and Fig. 10, show the effect of the used non-traditional admixture on improving radius of curvature (1/ρ) for both under and over reinforcement beams in spite of containing different ratios of RCA, comparing by the control beam. Radius of curvature (1/ρ) for under reinforced beams decreases by about 16.6%, 9.4% and 6.8% for beams A2, A3 and A4 respectively, while it was 54.5%, 36.1% and 26.9% for beams B2, B3 and B4 respectively.

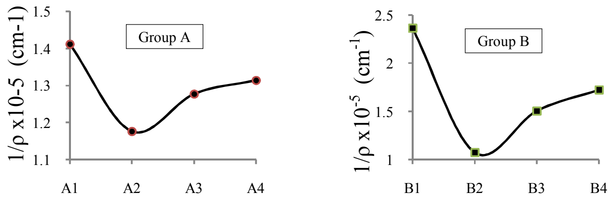


Fig. 10 Radius of curvature of tested beams

IV. Conclusions

Based on the experimental results carried out on reinforced concrete beams made from RCA and NA using non-traditional admixture the following conclusions can be drawn:

1. The suggested non-traditional admixture reduces the induced deformations like as vertical deflection, strains in both steel and concrete of reinforced concrete beams made from RCA.
2. The suggested non-traditional admixture improving and modifying the modulus of elasticity, toughness and radius of curvature of reinforced concrete beams made from RCA.
3. The optimum level of using recycled concrete aggregate on structural elements must not exceed than 20% of the used aggregate.

References

[1] Abo Elfadl Mohammed Megahed. (2002), “High impermeable mortar for surface of water tanks”, Master Thesis, Faculty of Engineering, Assiut University, Egypt.
[2] A.K. Padmini, K.Ramamurthy and M.S .Mathews. (2009) “Influence of parent concrete on the properties of recycled aggregate concrete” Journal of Construction and Building Materials, Vol. 23, pp 829–836.
[3] A.Rahman, H.Hamdam and A. M. A. Zaidi. (2009) “Assessment of Recycled Aggregate Concrete” Journal of Modern applied science, Vol. 3, NO.10.
[4] A .Rao, K. N.Jha and S.Misra. (2007) “Use of aggregates from recycled construction and demolition waste in concrete” Journal of Resources Conservation and Recycling, Vol. 50, pp 71–81.
[5] A. Megahed Ahmed, M.M. Rashwan and Mostafa A.Razek.(2012), “Performance of a local economical additive on the cement mortar properties affected by aggressive environmental conditions”, Journal of Engineering Sciences, Assiut University.
[6] Egyptian Code of Practice for Design and Construction of Concrete Structures ECCS (203-2007).
[7] I.B. Topqu. (1997) “Physical and Mechanical Properties of Concretes Produced With Waste Concrete”, Journal of Cement and Concrete Research, Vol.27 NO .12, pp 1817-1823.
[8] K. H .Yang, H. S Chung and F. A. Ashour. (2008) “Influence of Type and Replacement Level of Recycled Aggregate on Concrete Properties” Journal of ACL Materials, Vol. 105 NO 3.
[9] L.Butter, J.S.West, S.L. Tighe (2011) “The effect of recycled concrete aggregate properties on the bond strength between RCA concrete and steel reinforcement”, Cement and Concrete Research Vol 41 (2011) pages 1037–1049.
[10] M.M. Rashwan and K.A. Assaf (2002) “ Deformation performance for reinforced concrete beams using non-traditional Additions” , Journal of Engineering Sciences, Assiut University.
[11] Fatma Al Zahraa Ibrahim Abd El-Latif (2009) “Structural behavior of reinforced concrete beams with recycled concrete aggregate” Master Thesis, Faculty of Engineering, Cairo University, Egypt.
[12] Scancem Materials, Products for engineered concrete “Scanfiber-Flexural Toughness Testing”, Page 2, Japanese Standard (JSCE-SF4).
[13] Wai Hoe Kwan, Mahyuddin Ramli, Kenn Jhun Kam, Mohd Zailan Sulieman (2011) “Influence of the amount of recycled coarse aggregate

in concrete design and durability properties", Construction and Building Materials.
[14] www.nationmaster.com / encyclopedia.
[15] Yehia A. Hassanean, M.M. Rashwan, Kamal A. Assaf, Khaled A.A.(2013)," Influence of size and eplacement ratio of recycled concrete aggregate on concrete properties", Journal of Engineering Sciences, Assiut University. Vol. 42 NO .1
[16] Yehia A. Hassanean, M.M. Rashwan, Kamal A. Assaf , Khaled A.A. (2014) " Improvement of concrete properties made from recycled concrete aggregate using Non-Traditional admixture" Journal of Engineering Sciences, Assiut University.