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Repair and Strengthening of Reinforced Concrete Beams With Concrete Strength(C350) Failed in Shear Zone.

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I. Introduction

Repaired by internally Injected of epoxy and externally strengthened by carbon fibre sheets(CFRP)has been investigated recently through this research. The aim of this research is to evaluate and analyses the behaviour of tested concrete specimen and reinforced concrete beams repaired by using internally injection of epoxy with strengthened externally by carbon fibre sheets(CFRP). The internal injection method in present time became very important method especially for treatment not only visible cracks but also micro cracks internally reinforced concrete beams in structures.

A concrete flexure and shear cracks varies according to its constituents, concrete manufacturing, curing and type of loadings producing acting flexure and shear stress. Flexure and Shear stresses developed from applied loads might be higher than the limit tension and shear strength of concrete, therefore, web reinforcement should be added to resist quick higher values of acting shear stress. However, the ability resistance of concrete to flexure and shear stresses in the reinforced concrete beams does not have a fixed value, but it is affected by concrete compressive strength, cross section of beam, tension steel percent, and layout of tension steel, shear span to the effective depth ratio (a/d) as well as kind and distribution of web reinforcement [1-5].

Cracks in concrete have many causes. They may affect appearance only, or they may indicate significant structural distress or a lack of durability [1-8]. The proper repair of cracks depends on knowing the causes and selecting the repair procedures take these causes into account; otherwise, the repair may only be temporary. Successful long-term repair procedures must attack the causes of the cracks as well as the cracks themselves [3-5].

This work presented an experimental program aimed to develop internal injection technique that is utilized to re-strengthen the existing cracked reinforced concrete member. The proposed technique consists of internal injection of epoxy resin adhesive in a flexural and shear cracks of beams to increase its stiffness and flexural strength. Also strengthening of damaged reinforced-concrete beams by using externally carbon fiber sheets (CFRP) at shear-span zone (a) of beams with tensile reinforcement and U stirrup.

Keywords: Cracks, epoxy injection, carbon fiber sheets (CFRP), repair, and strengthening procedure.

In this study, it is planned to consider the effect of a variables on the repaired strengthened of concrete specimen and reinforced concrete beams by internally injected of epoxy and externally strengthened by carbon fibre sheets (CFRP).The following variable was considered in this study are:-

1. Theconcrete samples (cylinder - prisms) internally repaired by epoxy and externally strengthened by carbon fibre sheets (CFRP).
2. References reinforced concrete beams (Ref) with shear span –depth ratio (a/d=1.0‹2.0&3.0).
3. Reinforced concrete beams internally injected by epoxy and externally Strengthened by carbon fibre sheets (CFRP).
4. Effect of shear –span depth ratio (a / d=1.0, 2.0 &3.0).
5. Effect of concrete compressive strength (Fcu= 250kg/cm^2-350kg/cm^2-450kg/cm^2**).**

II. Experimental Programmer:

The main objective is to describe the test specimens, used materials, instrumentation and test procedure for the tested beams. This work presented an experimental program aimed to develop injection technique that is utilized to re-strengthen the existing cracked reinforced concrete member. The proposed technique consists of injection of epoxy resin adhesive in a flexural and shear cracked beams to increase its stiffness and flexural strength. Also strengthening of damaged reinforced-concrete beams by using a carbon fiber sheets (CFRP) with beam tensile reinforcement and U stirrup.

Experimental program was carried out to investigate the influence and the effect of using internal injection by epoxy materials in vents (4MM), as a new technical method to repair and strengthening of concrete specimens and reinforced concrete beams.

The materials used, mixture proportions, specimen preparation and curing regimes in this research are discussed in details. Testing procedures to evaluate the compressive strength, modulus of elasticity, indirect tension strength and the flexural strength of the specimens. Also the repairand strengthening the casted beams were also presented Fig. (1).

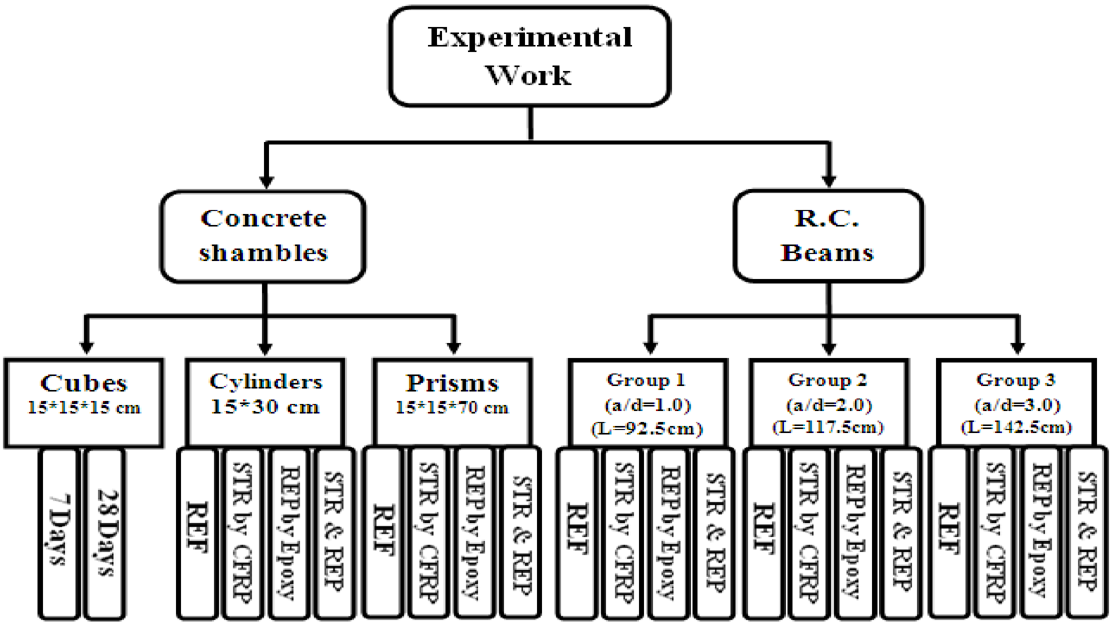


Fig. (1): The Experimental Work Program.

2.1. Materials Used:

Ordinary Portland cement, which was produced by the BENI SUEF Cement Factory. The used cement has a grade of 52.5 N/mm2. The chemical and physical characteristics of the used cement satisfy the Egyptian Standard Specification (E.S.S. 4756-1/2013) (CEM I 52.5N). Fine and coarse aggregates were used from local sources in Egypt. Sieve analysis of the aggregates was carried out according to ASTM C 136. The fineness modulus of sand was 2.7, thereby, indicating medium coarse sand. The absorption value was 0.65%, and its relative density at the saturated surface dry (SSD) condition was 2.55 t/m3. The coarse aggregates were crushed gravels with maximum nominal size of 10mm. Its absorption value was 0.85%, whereas relative density (SSD) was 2.64 and 1.567 t/m3 volume weight. Tap water was used in manufacturing concrete. Wood form-work (molds) was used for casting beams.Deformed steel Grade 60 for # 10mm bars and Grade 35 for # 8mm bars were used in the test beams. After two days, forms were removed. Curing was done for the next 14 days. Beams were left for the next 28days to achieve the desired strength.

Twelve reinforced concrete beams with constant cross-section (10x 15 cm) and length(L=92.5 cm) and effective span (L0=62.5 cm) for a/d=1.0, (L=117.5 cm) and effective span (L0=87.5 cm) for a/d=2.0, (L=142.5 cm) and effective span (L0=112.5 cm) for a/d=3.0, The beams having reinforcement 2 #10 mm bars of grade 60 (6000kg/cm2) on tension side, and compression face but #8 @ 12.5 C/C stirrups for shear throughout the lengths were prepared while remaining of grade 35 (3500 kg/cm2). All the beams were tested till cracks appeared to be width of 1 mm and comparison was made. The beams were repaired by using epoxy injection technique. Procedure for construction, repairing and strengthening of beams was as under:

2.2 Mix proportions:

The proportions of the concrete mixes were 1:2.4 by mass of cement, sand and gravel respectively. Water cement ratio (w/c) was kept 0.50. Workability of concrete was measured in terms of slump, which was determined for each batch. A slump (5-7 cm) was noted. Average compressive strength at 28 days was achieved as 250 kg/cm2. (Table 2).

2.3. Injection by epoxy materials:

There are two important variables effect on the condition of the used structure with high quality. To keep all the elements of structure at the high quality mean repair and strengthening all of them continuously. The internal injection method in present study became very important method especially for treatment cracks of concrete specimens and reinforced concrete beams. The concrete beams structure is important structures need continuous check for all members to be at good efficiency to do the demand job, which required.

Three cases of study for the 3 reinforced concrete beams, after internal injection by epoxy resin materials for every (a/d) ratio equal to1.0, 2.0 &3.0. Also 3 reinforced concrete beams with the same grade of concrete (fcu =250 kg/cm2)study after internal injection by epoxy resin materials and strengthening externally the reinforced concrete beams by carbon fiber sheets (CFRP)in shear zone for every (a/d)ratio equal to 1.0 ,2.0 &3.0.

Epoxy resin is a process in which in liquid form is pumped into the voids and cracks to fill the fine fissures in concrete and then hardens. The internal injection operations are very difficult and new operations in the whole world and needs specialists to do. The subsequent steps have to be made to give successfully internal injection operation: Fig. (2).

Fig (2): The **Epoxy (KEMA-EPOXY103)** used as internal injected material**.**

2.3.1. Piping works: Boreholes along the total length of the concrete Specimens (cylinders - prisms) and reinforced concrete beams made with a suitable diameter to allow the internal injection mixing to penetrate through the cracks and the fissures. The common diameters of the boreholes are (4 mms.).The used piping works operation is butting a tube inside the concrete works by using a plastic tube with diameter 4 mm, and by using the pushing from concrete before hardened to take out the hole or pipe vents with sufficient condition to carry out the required tests to be done for the structure member, which needs to be repaired.

2.3.2. Specific discharge: Specific discharge, the density and consistency of the injection mix are the important operations have to be determined. Permeability test were done after the boreholes reached the total required test and cleaned. The borehole length is totally effective.-The right and the left side of interval have to be completely closed to prevent any seepage (make packer) Fig. (3).

2.3.3.-Injection operation: The injection of holes is performed in intervals by fluid under specified pressures. The injection operation was done through the concrete specimens special boreholes by pressuring the injection mixture to fill the voids, and cracks in the concrete Specimens body. The mixture, which goes through long path in the voids and cracks, depends on many variables. This raft rubber should be soft enough to work under the maximum pressure for grouting. Fig. (3) Shows the injection system components.

1-Mixer 2-Agitator 3-Pump 4-Recorder 5-Packers 6-Measuringtank 7-Mixer hose 8-Delivery hose 9-Nipple10-Ballvalve11-T-coupling12-Presure gauge

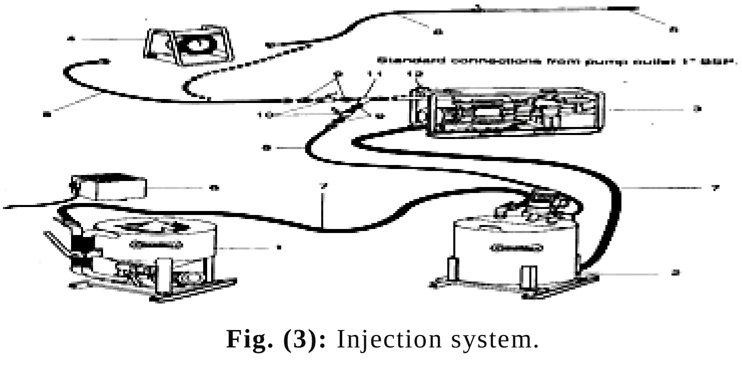


Fig. (3): Injection system.

2.3.4. Principles of application

Epoxy injection is a highly technical work and need highest level of care in executing it, although it’s based on a very simple procedure. It is important that all cracks visible by naked eye must be properly recorded and indicating its approximate length, width and location in particular.

The step-by-step method is explained below.

- The crack will be visually inspected and any weak area around it will be chipped off.
- The longitudinal pipe vents will be cleaned with wire and compressed air brush on the concrete vents to remove any dust or dirt.
- The surface of the longitudinal pipe vents is then grinded to make a good bonding surface for epoxy adhesive.
- Injection longitudinal pipe vents will be fixed on the specimens and beams prepared crack surface with mixed epoxy at specified locations.
- The remaining cracks surface will be sealed off with epoxy adhesive with the help of scrapper to make the crack leakage free.
- After at least 72 hours of longitudinal pipe vents fixing, injection procedure will be initiated.
- Out let pipe of the injection pump will be inserted into one longitudinal pipe vents, preferably the lowest one.
- Compressed air (without moisture) will be pumped into the injection pump via inlet.
- The epoxy will be injected against the gravity into the longitudinal pipe vents, until it seeps out of the crack above. The lower crack will be corked.
- Now injection outlet pipe vents will be inserted into the seeped out longitudinal pipe vents, and epoxy will be injected again. All the longitudinal pipe vents will be fed with epoxy unless these are filled completely.
- In case of through cracks in a structural component, the longitudinal pipe vents will be fixed on both sides, and if epoxy seeps from other side it will also be corked.
- Whole length of the crack will be injected in this manner. The injected cracks will be left to cure for 72 hours.
- The longitudinal pipe vents will be flushed off, and the sealed crack surface will be grinded again, to make a uniform surface.
- All the cracks will be injected in the same manner.

2.3.4.1. Epoxy InjectionTechnique.

Filling cracks by internal injection is necessary to join the de-bonded concrete, and bring the structure to stronger state. Injection epoxy is widely used and recommended procedure for structural strengthening. Epoxy injection consists of mainly two components.

a. Chemical epoxy for sealing the crack: The material should be of low viscosity with sufficient compressive strength, even more than concrete. It should be with good bond and tensile strength so that the repair crack could not reappear. High strength epoxy for sealing cracks inside of concrete elements and crack surface.

2.2.4.2. Carbon Fiber Reinforced Polymer (CFRP).

The CFRP reinforcement applied in this experiment consisted of carbon fiber reinforced polymer (CFRP) sheets bonded to concrete with 4500 epoxy matrix BASEF. The CFRP sheets are commercially available with unidirectional plain weave. They were cut into strips 400 mm long and 50 mm wide. The thickness of each layer of carbon fibre was 0.13 mm .Fig. (4) And table (1).

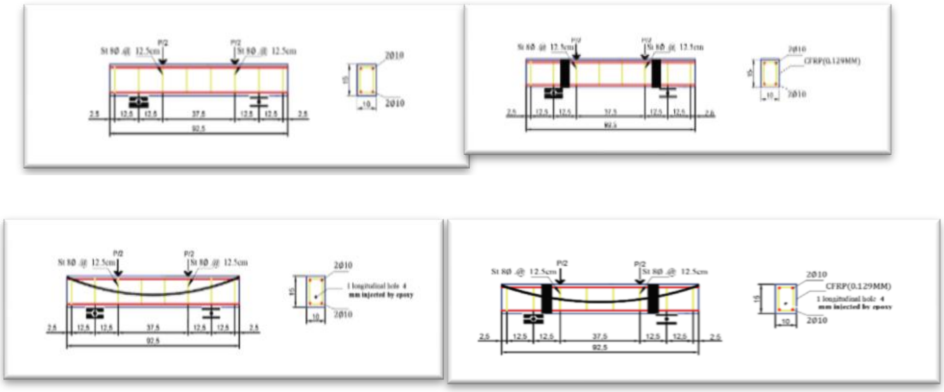
Figure (4): CFRP sheets and Master Brace SAT 4500 Part A&B, BASFE

Table (1): Description of CFRP/fibre BASEF 4500 and mater Brace Sat4500 part A&B

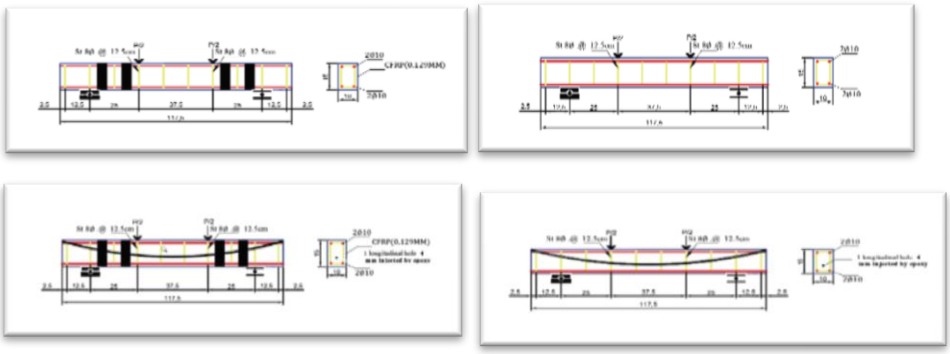
Material	Modulus of elasticity GPa	Tensile strength MPa	Fibre orientation	Thickness mm	Elongation at failure	Surface mass g/m^2
CFRP/fiber BASEF4500	238	3650	Unidirectional	0.13	1.5%	225

2.4. Beams preparation.

Group (1) a/d=1.0



Group (2) a/d=2.0



Group (3) a/d=3.0

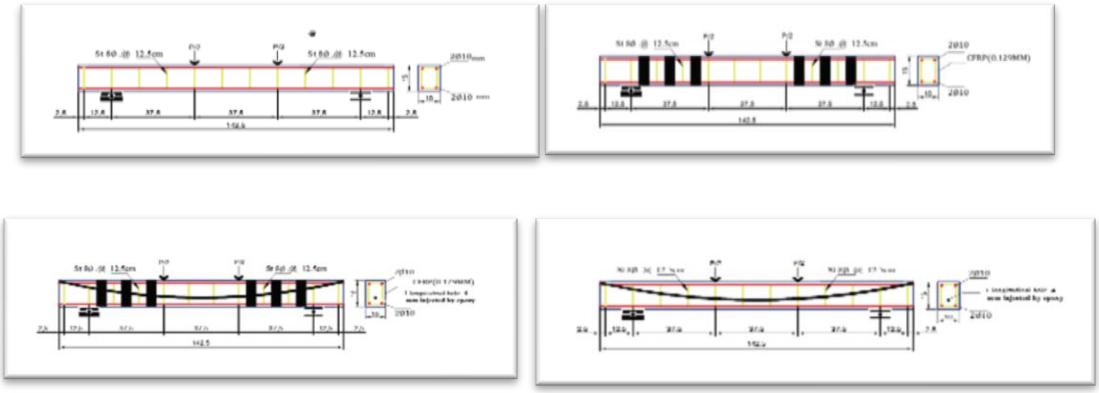


Fig. (5).Details of Beams

Group (1) - **B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, (a/d=1.0).**
Group (2) **-B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP., (a/d=2.0).**
Group (3) **-B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. (a/d=3.0).**

Table. (2) Details of the tested beams.

rou p	Beam Name	L (cm)	L0 (cm)	Shear span (a)	D (cm)	Shear span-depth ratio a/d	As& As' (Ø) mm	INJECTED By Epoxy	STRENGTHENED. (CFRP)	Fcu. Kg/cm 2
G1	B1-1 C350 (REF)	92.5	62.5	12.5	12.5	1.0	2Ø10	WITHOUT	WITHOUT	350
	B2-1 C350 (STR)	92.5	62.5	12.5	12.5	1.0	2Ø10	WITHOUT	WITH	350
	B3-1 C350 (REP)	92.5	62.5	12.5	12.5	1.0	2Ø10	WITH	WITHOUT	350
	B4-1 C350 (STR&REP)	92.5	62.5	12.5	12.5	1.0	2Ø10	WITH	WITH	350
G2	B5-2 C350 (REF)	117.5	87.5	25.0	12.5	2.0	2Ø10	WITHOUT	WITHOUT	350
	B6-2 C350 (STR)	117.5	87.5	25.0	12.5	2.0	2Ø10	WITHOUT	WITH	350
	B7-2 C350 (REP)	117.5	87.5	25.0	12.5	2.0	2Ø10	WITH	WITHOUT	350
	B8-2 C350 (STR&REP)	117.5	87.5	25.0	12.5	2.0	2Ø10	WITH	WITH	350
G3	B9-.3 C350 (REF)	142.5	112.5	37.5	12.5	3.0	2Ø10	WITHOUT	WITHOUT	350
	B10- 3 C350 (STR)	142.5	112.5	37.5	12.5	3.0	2Ø10	WITHOUT	WITH	350
	B11- 3 C350 (REP)	142.5	112.5	37.5	12.5	3.0	2Ø10	WITH	WITHOUT	350
	B12-3 C350 (STR&REP)	142.5	112.5	37.5	12.5	3.0	2Ø10	WITH	WITH	350

L= the total length of beam Ĺ0= the effective length of beam
a= Shear span d= effective depth of beam b= the breadth of beam
Fc = concrete compressive strength No. of A_{st} = Area of steel No. of
$A_{st'}$ = Area of stirrups e= the spacing between stirrups

III. Results & Discussions

The effect of internal injection of epoxy resin in the plain concrete is very clear. The results of indirect tensile strength indicate the positive effect of the injection .This effect is reflected on the concrete tensile strength .The concrete cylinder tensile strength increased by about 12.67 % .This is show that the internal injection of epoxy is suitable in cracked concrete to give concrete the ability to withstand the tensile load which causes the harmful cracks in concrete elements.

Closing the cracks in concrete elements prevents the CO2 and the water steam to penetrate into the concrete element and causes the corrosion of reinforced steel.

The effect of external strengthening by (CFRP) in the plain concrete cylinder is very clear. The results of indirect tensile strength indicate the positive effect of external strengthening by (CFRP) by increased by about 21.00%. Whiletheeffect of internal injection of epoxy resin with external strengthening by (CFRP) in the plain concrete cylinder is very clear. The concrete cylinder tensile strength increased by about 31.6 %. This is show that the internal injection of epoxy with external strengthening by (CFRP) is very suitable in cracked concrete to give concrete the ability to withstand the tensile load which causes the harmful cracks in concrete elements**.** Fig. (6).

Fig.(6) Plainconcretecylinderswith internalinjectionbyepoxy.

To show the effect of internal injection of the epoxy resin on the modules of rupture of concrete, the 15*15*70 cm plain concrete prisms were casted and tested under 4 point loads. The modulus of rupture was calculated for both the plain concrete specimens after internal injected epoxy resin throw 1 holes. The modulus of rupture of the concrete prisms after internal injection of epoxy resin was determined Fig. (7).

The modulus of rupture of concrete was increased by about 13 % due to theinternal injection.

In plain concrete the internal injection improve the tensile strength of concrete it is should using the minimum number of holes in P.C. to internal inject the epoxy resin.

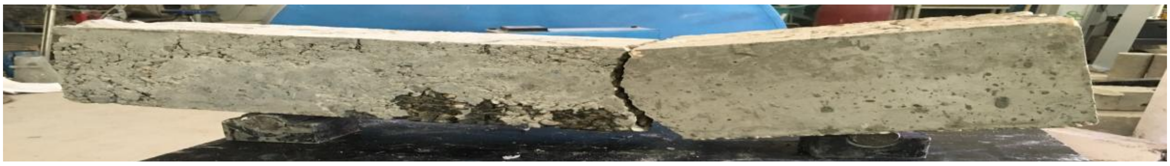


Fig. (7) Plainconcreteprismsflexuralstrengthwith internal injection by epoxy.

The initiation and propagation of the first crack for all beams observed in the bottom side of pure moment zone at mid span. Increasing the applied load gradually the formed cracks propagated upward and several new cracks observed in the tension zone, these started also from the bottom of concrete surface and propagated up to comp-zone.

During testing, the fine flexural cracks were initiated in the pure bending region and with further increase of load, new flexural-shear cracks formed in the shear span. Also several cracks were observed in the shear zone (which initiated at the area between the support and near loadingpoint) these cracks started from bottom surface to top surface as flexural- shear crack and subsequently, curved toward the loading points from the bottom near to the top load poin

The flexural-shear crack was observed at load more than (3.0) ton. The height and width of crack increased with increase of the load up to failure with two vertical main cracks and several secondary cracks. Infactas applied load increases, principal tensile stress increases.When principal tensile stress exceeded the tensile strength of concrete, flexural crack occurred in the direction perpendicular to the direction of principal tensile stress. The major cracks were formed under the loads points and mid - span in flexural zone and the pattern of cracks is shown in Fig. (8). the final mode of failure of all beams was noticed to be flexural - shear failure

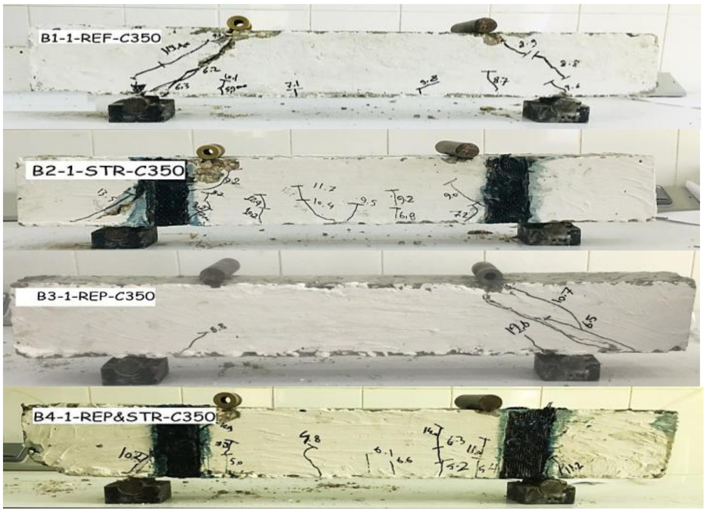


Fig:(8) Pattern of crack of beams

B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. ($\frac{a}{d}$ = 1.0).L=92.5CM.

B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. ($\frac{a}{d}$ = 2.0). -L=117.5CM.

B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. ($\frac{a}{d}$ = 3.0).)-L=142.5CM.

Table. (3) Values of cracking load (pcr.), injected load (pinj.) and ultimate load (pu.) for tested beams:
The values of cracking, injection and ultimate loads (Pcr, Pinj. &Pu) for the beams:

G No	Beam Name	a/d	As &As (Ø) mm	INJECTED BY EPOXY	STRENGTHENED (CFRP)	Fcu Kg/cm^2	Pcr. (exp) (ton)	PINJ (exp) (ton)	Pu. (exp) (ton)	Pcr/ Pcr(R)	Pu/ Pu.(R)	Pcr (th)	Pu (th)	Pcr (exp)/ pcr(th)	Pu (exp)/ Pu(th)	Mode Of Failure
G1	B1-1 (REF) C350	1	2 ø10	WITHOUT	WITHOUT	335.7	6.0		12.9	1.0	1.0	4.20	11.61	1.43	1.11	SHEAR-FAILURE
	B2-1 (STR) C350	1	2ø10	WITHOUT	WITH		6.3		13.9	1.05	1.07			1.50	1.19	SHEAR-FAILURE
	B3-1-(REP) C350	1	2 ø10	WITH	WITHOUT		6.2	9.7	13.2	1.03	1.02			1.47	1.13	SHEAR-FAILURE
	B4-1 (STR& REP) C350	1	2ø10	WITH	WITH		6.4	9.7	15.4	1.06	1.19			1.52	1.32	SHEAR-FAILURE
G2	B5-2 (REF) C350	2	2 ø10	WITHOUT	WITHOUT	351.3	3.0		8.50	1.0	1.0	2.10	5.80	1.42	1.46	FLEXURAL SHEAR - FAILURE
	B6-2 (STR) C350	2	2ø10	WITHOUT	WITH		3.5		9.50	1.16	1.12			1.66	1.63	FLEXURAL SHEAR - FAILURE
	B7-2 (REP) C350	2	2 ø10	WITH	WITHOUT		3.0	6.4	9.00	1.0	1.05			1.42	1.55	FLEXURAL SHEAR - FAILURE
	B8-2 (STR& REP) C350	2	2 ø10	WITH	WITH		3.5	6.4	10.0	1.16	1.17			1.66	1.72	FLEXURAL SHEAR - FAILURE
G3	B9-3 (REF) C350	3	2 ø10	WITHOUT	WITHOUT	329.5	3.0		5.84	1.0	1.0	1.40	3.87	2.14	1.50	FLEXURALCOMPRESSION -FAILURE
	B10-3 (STR) C350	3	2ø10	WITHOUT	WITH		3.2		7.70	1.06	1.31			2.28	1.98	FLEXURALCOMPRESSION -FAILURE
	B11-3 (REP) C350	3	2 ø10	WITH	WITHOUT		3.0	4.4	7.37	1.0	1.26			2.14	1.90	FLEXURALCOMPRESSION -FAILURE
	B12-3 (STR& REP) C350	3	2 ø10	WITH	WITH		3.6	4.4	8.40	1.2	1.43			2.57	2.17	FLEXURALCOMPRESSION -FAILURE

B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, (a/d=1.0).B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP., (a/d=2.0). B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. (a/d=3.0).

3.1 Cracking and Injection loads.

For shear span depth ratio (a/d=1.0) the values of cracking loads (Pcr) increase with repairing and the strengthening of beams in shear zone. The beams (B2-1-STR) strengthening by carbon fiber (CFRP), (B3-1-REP) repairing by internal injection by epoxy & (B4-1-STR&REP) strengthening by carbon fiber (CFRP) with repairing by internal injection by epoxy, were tested to study the effect of these parameters respectively .The beam (B1-1-REF) had a solid cross section used as reference beam. The percentage increase of ultimate load for (B2-1) (5.0 %), (B3-1) (3.0%) and for (B4-1) (6.0%) than that the ultimate load of reference beam (B1-1®).

The beams (B3-1) and (B4-1), had many parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm approximately injected at loads equal to (9.7 ton) for mentioned beams respectively Fig.(9).

For shear span - depth ratio (a/d=2.0) the values of cracking loads (Pcr) increase with repairing and the strengthening of beams in shear zone. The beams (B6-2-STR) strengthening by carbon fiber (CFRP), (B7-2-REP) repairing by internal injection by epoxy & (B8-2-STR&REP) strengthening by carbon fiber (CFRP) with repairing by internal injection by epoxy, were tested to study the effect of these parameters respectively .The beam (B5-2-REF) had a solid cross section used as reference beam. The percentage increase of ultimate load for (B6-2) (16.0 %), (B7-2) (0.0%) and for (B8-2) (16.0%) than that the ultimate load of reference beam (B5-2®).

The beams (B7-2) and (B8-2),hadmany parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm (6.4 ton) for mentioned beams respectively Fig. (9).

For shear span - depth ratio (a/d=3.0) the values of cracking loads (Pcr) increase with repairing and the strengthening of beams in shear zone. The beams (B10-3-STR) strengthening by carbon fiber (CFRP), (B11-3-REP) repairing by internal injection by epoxy & (B12-3-STR&REP) strengthening by carbon fiber (CFRP) with repairing by internal injection by epoxy, were tested to study the effect of these parameters respectively .The beam (B9-3-R) had a solid cross section used as reference beam. The percentage increase of ultimate load for (B10-3) (6.0 %), (B11-3) (0.0%) and for (B12-3) (20.0%) than that the ultimate load of reference beam (B9-3®).

The beams (B11-3),and (B12-3),had many parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm approximately injected at loads equal to (4.4 ton) for mentioned beams respectively Fig.(9).

3.2. Ultimate loads (Pu.).

The beams (B1-1®) (B5-2®) (B9-3®) were tested to study the effect of shear span depth ratio (a/d=1.0, 2.0&3.0) these beams had a solid cross section and without injection. The beam (B1-1®) used as reference beam.

For shear span - depth ratio (a/d=1.0) the values of ultimate loads (Pu) increase with repairing and the strengthening of beams in shear zone. The beams (B2-1-STR) strengthening by carbon fiber (CFRP), (B3-1-REP) repairing by internal injection by epoxy & (B4-1-STR&REP) strengthening by carbon fiber (CFRP) with repairing by internal injection by epoxy, were tested to study the effect of these parameters respectively .The beam (B1-1-R) had a solid cross section used as reference beam. The percentage increase of ultimate load for (B2-1) (7.0 %), (B3-1) (2.0%) and for (B4-1) (19.0%) than that the ultimate load of reference beam (B1-1®).

The beams (B3-1),and (B4-1),had many parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm approximately failed at loads equal to (13.2 ton)and (15.4ton)for mentioned beams respectively Fig.(9).

For shear span - depth ratio (a/d=2.0) the values of ultimate loads (Pu) increase with repairing and the strengthening of beams in shear zone. The beams (B6-2-STR) strengthening by carbon fiber (CFRP), (B7-2-REP) repairing by internal injection by epoxy & (B8-2-STR&REP) strengthening by carbon fiber (CFRP) with repairing by internal injection by epoxy, were tested to study the effect of these parameters respectively .The beam (B5-2-R) had a solid cross section used as reference beam. The percentage increase of ultimate load for (B6-2) (12.0 %), (B7-2) (5.0%) and for (B8-2) (17.0%) than that the ultimate load of reference beam (B5-2®).

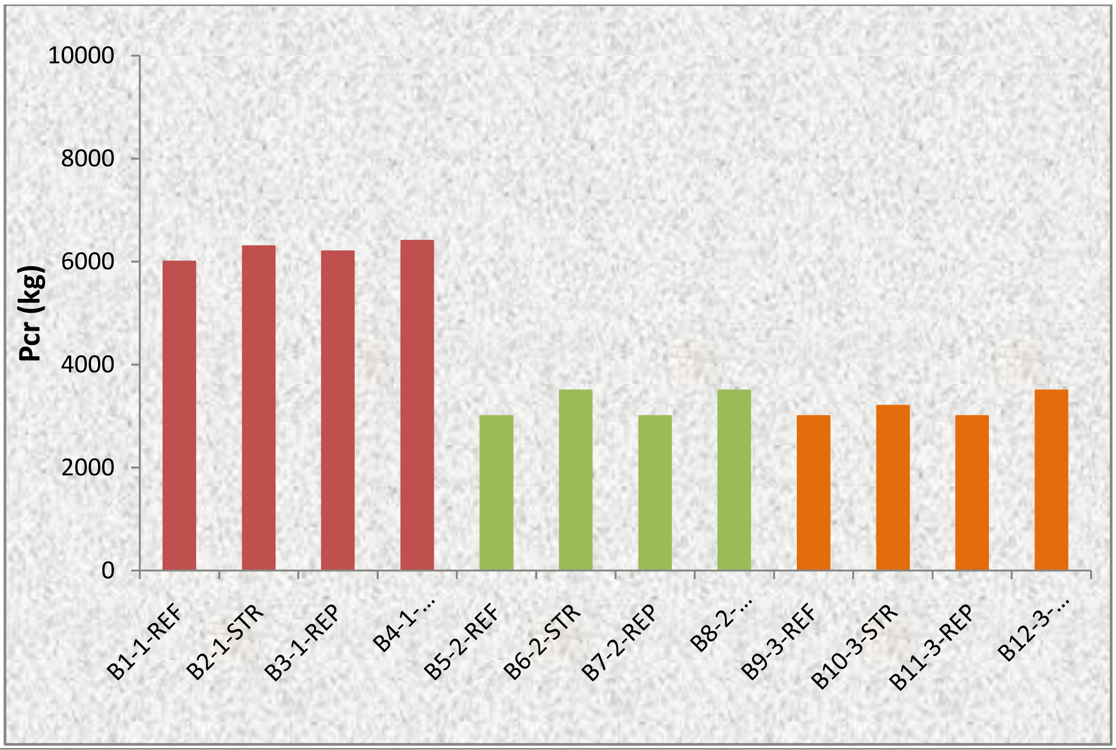
The beams (B7-2),and (B8-2),had many parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm approximately failed at loads equal to (9.0 ton) and (10.0ton) for mentioned beams respectively Fig.(9).

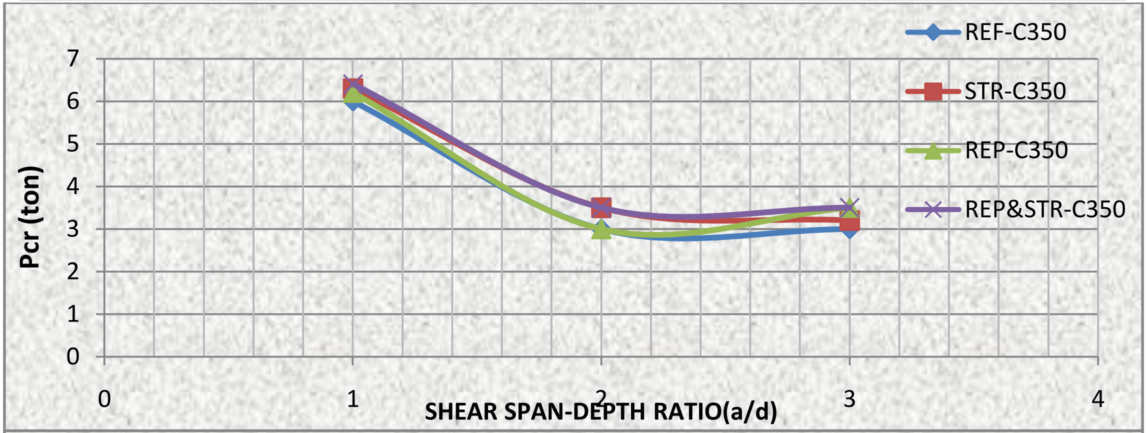
For shear span - depth ratio (a/d=3.0) the values of ultimate loads (Pu) increase with repairing and the strengthening of beams in shear zone. The beams (B10-3-STR) strengthening by carbon fiber (CFRP), (B11-3-REP) repairing by internal injection by epoxy & (B12-3-STR&REP) strengthening by carbon fiber (CFRP) with repairing by internal injection by epoxy, were tested to study the effect of these parameters respectively .The beam (B9-3-R) had a solid cross section used as reference beam. The percentage increase of ultimate load for (B10-3) (31.0 %), (B11-3) (26.0%) and for (B12-3) (43.0%) than that the ultimate load of reference beam (B9-3®).

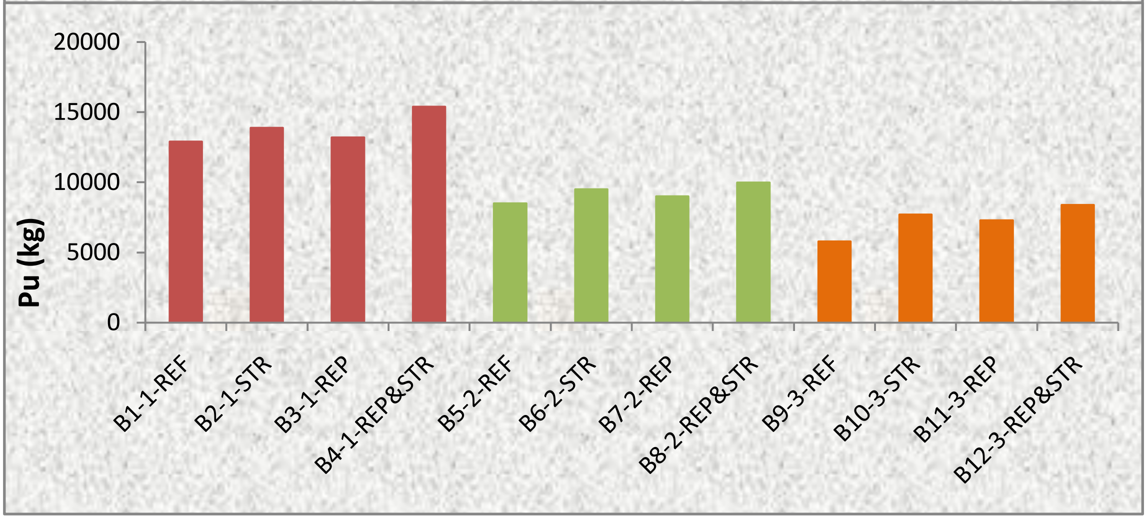
The beams (B11-3),and (B12-3),had many parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm approximately failed at loads equal to (7.73 ton) and (8.40ton) for mentioned beams respectively Fig.(9).

Lab experiments were undertaken to determine whether common proprietary epoxy resins reinstate the equivalent tensile capacity of concrete. This was done by comparing the failure load of undamaged concrete beams with the failure load of crack repaired concrete beams under flexural tensile loading.

The results showed that the performance of the repaired beams even though the epoxy material may have a greater tensile strength than concrete, they cannot reinstate the full capacity of cracked concrete if full bonding or penetration is not achieved due to high viscosity or improper application.


Pcr (kg)
10000
8000
6000
4000
2000
0
B1-1-REF
B2-1-STR
B3-1-REP
B4-1-...
B5-2-REF
B6-2-STR
B7-2-REP
B8-2-...
B9-3-REF
B10-3-STR
B11-3-REP
B12-3-...


Pcr (ton)
7
6
5
4
3
2
1
0
0
1
2
3
4
SHEAR SPAN-DEPTH RATIO(a/d)
REF-C350
STR-C350
REP-C350
REP&STR-C350


Pu (kg)
20000
15000
10000
5000
0
B1-1-REF
B2-1-STR
B3-1-REP
B4-1-REP&STR
B5-2-REF
B6-2-STR
B7-2-REP
B8-2-REP&STR
B9-3-REF
B10-3-STR
B11-3-REP
B12-3-REP&STR

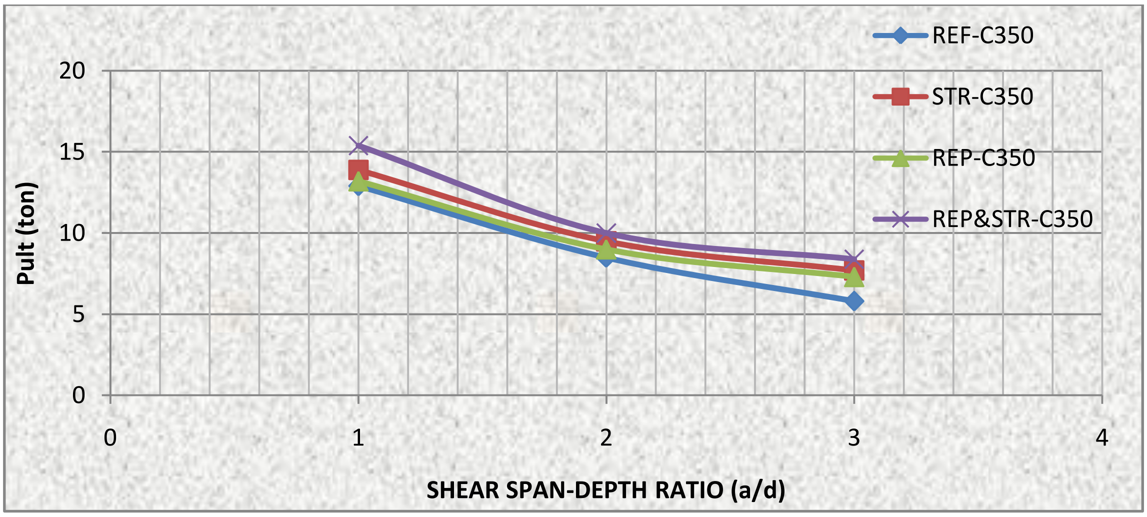
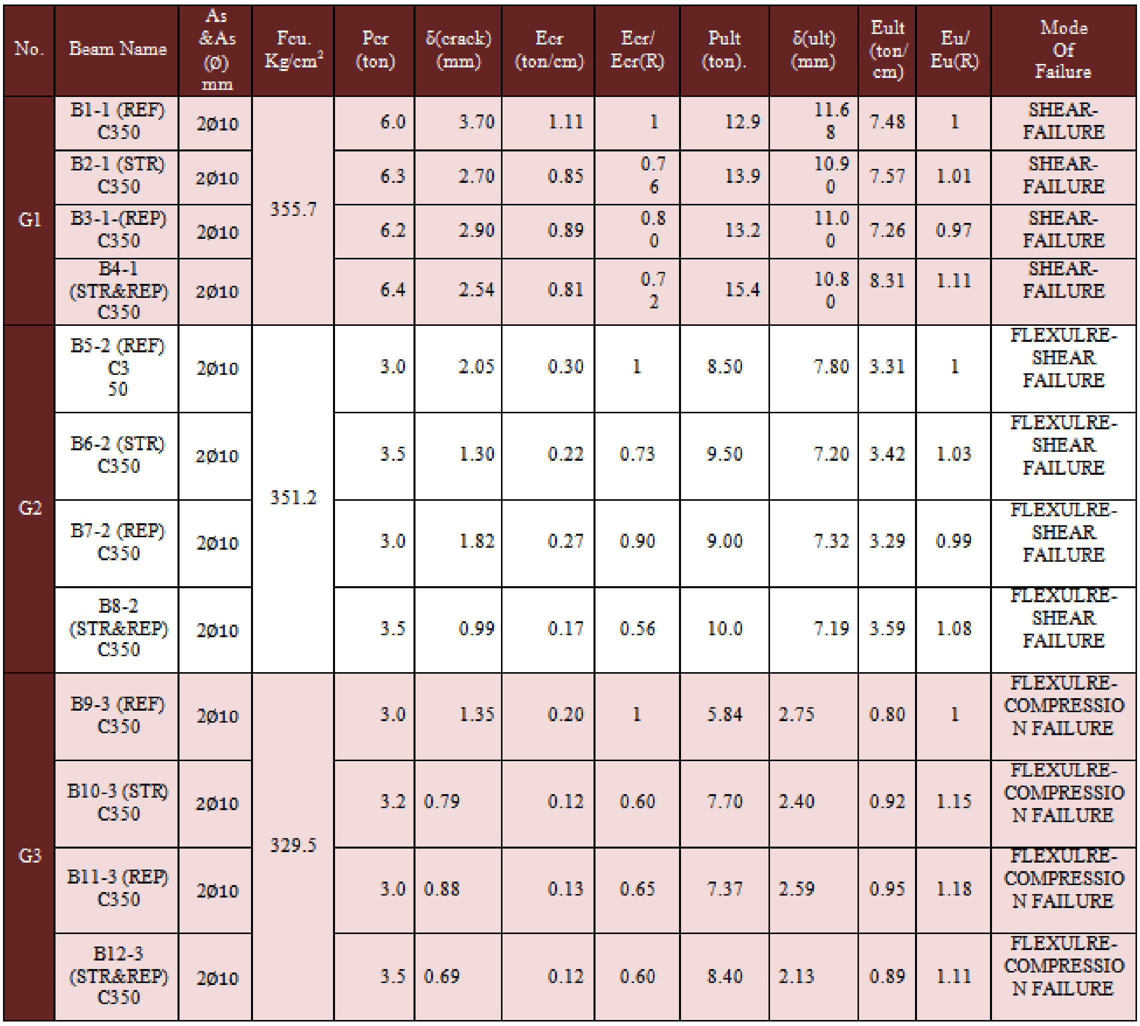


Fig: (9) Cracking and Ultimate Loads for beams
B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. $(\frac{a}{d} = 1.0)$.L=92.5CM.
B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. $(\frac{a}{d} = 2.0)$. -L=117.5CM.
B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. $(\frac{a}{d} = 3.0)$.)-L=142.5CM.

Table (4): Values of cracking deflection (δcr), and ultimate deflection (δu)- absorbed energy at cracking (Ecr) and at ultimate loads (Eu) for tested beams.



No.	Beam Name	As &As (Ø) mm	Fcu. Kg/cm²	Pcr (ton)	δ(crack) (mm)	Ecr (ton/cm)	Ecr/ Ecr(R)	Pult (ton).	δ(ult) (mm)	Eult (ton/ cm)	Eu/ Eu(R)	Mode Of Failure
G1	B1-1 (REF) C350	2Ø10	355.7	6.0	3.70	1.11	1	12.9	11.68	7.48	1	SHEAR-FAILURE
	B2-1 (STR) C350	2Ø10		6.3	2.70	0.85	0.76	13.9	10.90	7.57	1.01	SHEAR-FAILURE
	B3-1-(REP) C350	2Ø10		6.2	2.90	0.89	0.80	13.2	11.00	7.26	0.97	SHEAR-FAILURE
	B4-1 (STR&REP) C350	2Ø10		6.4	2.54	0.81	0.72	15.4	10.80	8.31	1.11	SHEAR-FAILURE
G2	B5-2 (REF) C350	2Ø10	351.2	3.0	2.05	0.30	1	8.50	7.80	3.31	1	FLEXULRE-SHEAR FAILURE
	B6-2 (STR) C350	2Ø10		3.5	1.30	0.22	0.73	9.50	7.20	3.42	1.03	FLEXULRE-SHEAR FAILURE
	B7-2 (REP) C350	2Ø10		3.0	1.82	0.27	0.90	9.00	7.32	3.29	0.99	FLEXULRE-SHEAR FAILURE
	B8-2 (STR&REP) C350	2Ø10		3.5	0.99	0.17	0.56	10.0	7.19	3.59	1.08	FLEXULRE-SHEAR FAILURE
G3	B9-3 (REF) C350	2Ø10	329.5	3.0	1.35	0.20	1	5.84	2.75	0.80	1	FLEXULRE-COMPRESSION FAILURE
	B10-3 (STR) C350	2Ø10		3.2	0.79	0.12	0.60	7.70	2.40	0.92	1.15	FLEXULRE-COMPRESSION FAILURE
	B11-3 (REP) C350	2Ø10		3.0	0.88	0.13	0.65	7.37	2.59	0.95	1.18	FLEXULRE-COMPRESSION FAILURE
	B12-3 (STR&REP) C350	2Ø10		3.5	0.69	0.12	0.60	8.40	2.13	0.89	1.11	FLEXULRE-COMPRESSION FAILURE

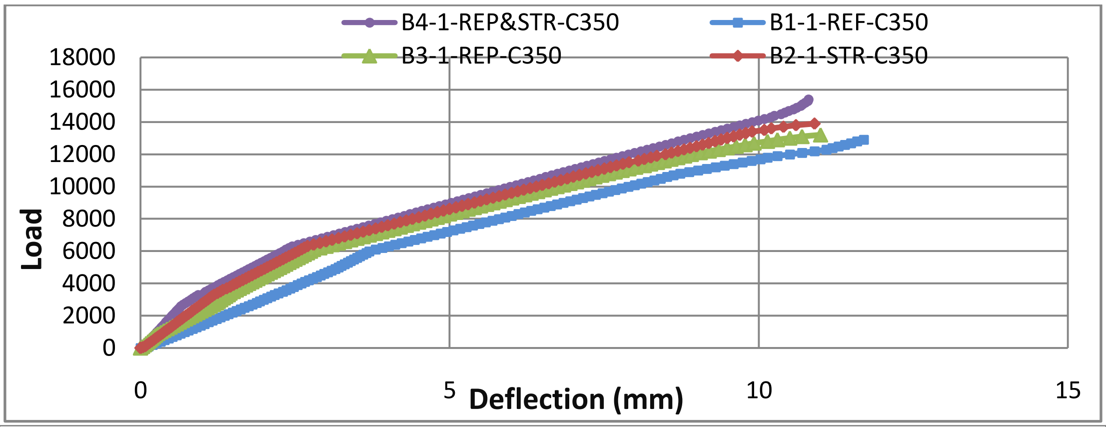
3.3. Cracking, Injected and Ultimate deflection:

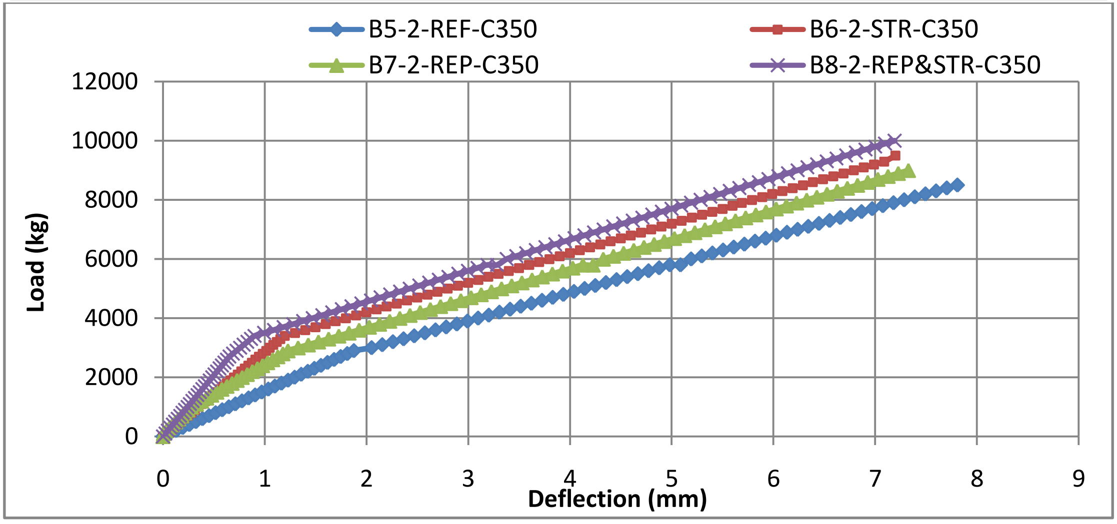
In both of the analysis cases all the relationship between the applied load (P) and mid span deflection (δ), for the tested beams with various a/dratio or internal injection and also strengthened by carbon fiber sheets (CFRP). The analysis will include also the crack load (Pcr.), injected load (Pinj.), ultimate load (Pu.) with their mid span deflections (δ), and absorbed energy (E) Tables(3).

The cracking deflection of beams (B1-1®), (B5-2®) and (B9-3®)equal to (3.70), (2.05) and (1.35) mm. And the cracking deflection of beams (B2-1), (B6-2) and (B10-3) Strengthened by carbon fiber sheets (CFRP) equal to (2.70), (1.30), (0.79) mm. And also the cracking deflection of beams (B3-1), (B7-2) and (B11-3) withInjected of (Epoxy) with equal to (2.90), (1.82) and (0.88) mm. And also the cracking deflection of beams (B4-1), (B8-2) and (12-3) with Injected of (Epoxy) and Strengthened by carbon fiber sheets (CFRP) equal to (2.54), (0.99) and (0.69) mm. Fig (10&11).

The Injection deflection of beams (B3-1), (B4-1), (B7-2), (B8-2), (B11-3) and (B12-3) equal to (4.94), (6.4), (5.90), (3.70), (1.44) and (0.91) mm. Fig (10&11).

The Ultimate deflection of beams (B1-1®), (B5-2®) and (B9-3®) equal to (11.68), (5.58) and (2.75) mm.And the ultimate deflection of beams (B2-1), (B6-2), (B10-3) Strengthened by carbon fiber sheets (CFRP) equal to (10.90), (4.63) and (2.40) mm. And also the ultimate deflection of beams (B3-1), (B7-2) and (B11-3) with Injected of (Epoxy) equal to (11.0), (5.19) and (2.59) mm. And also the ultimate deflection of beams (B4-1), (B8-2) and (B12-3) with Injected of (Epoxy) and STRENGTHENED BY CARBON FIBER SHEETS (CFRP) equal to (10.80), (3.86) and (2.13) mm. Fig (10&11).





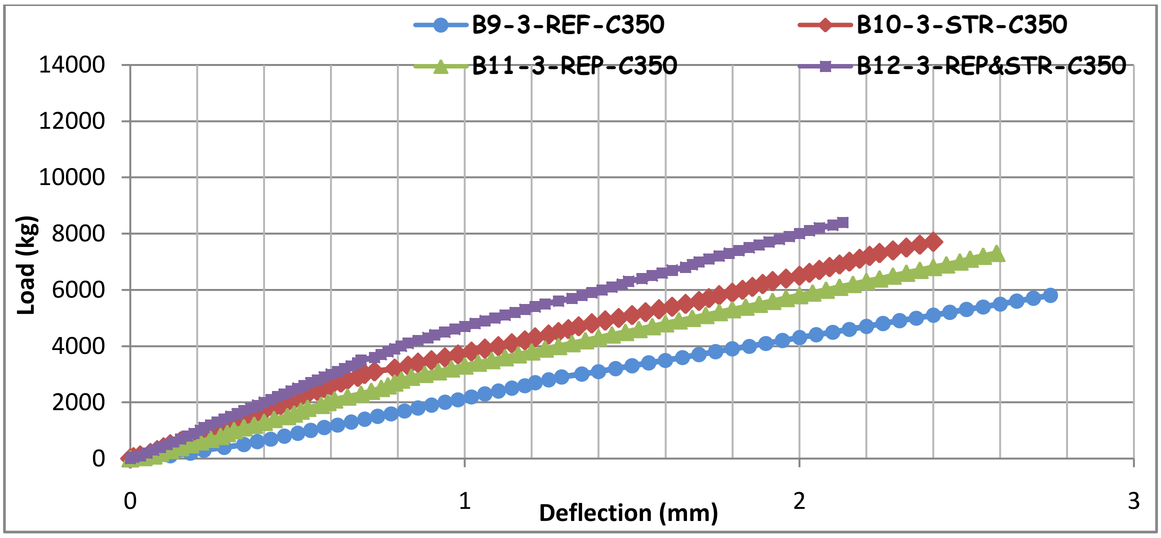
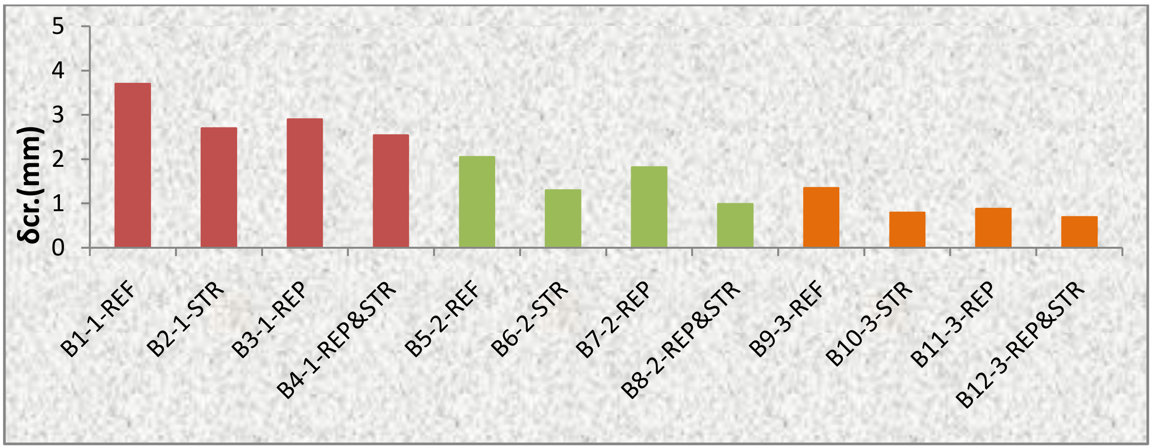


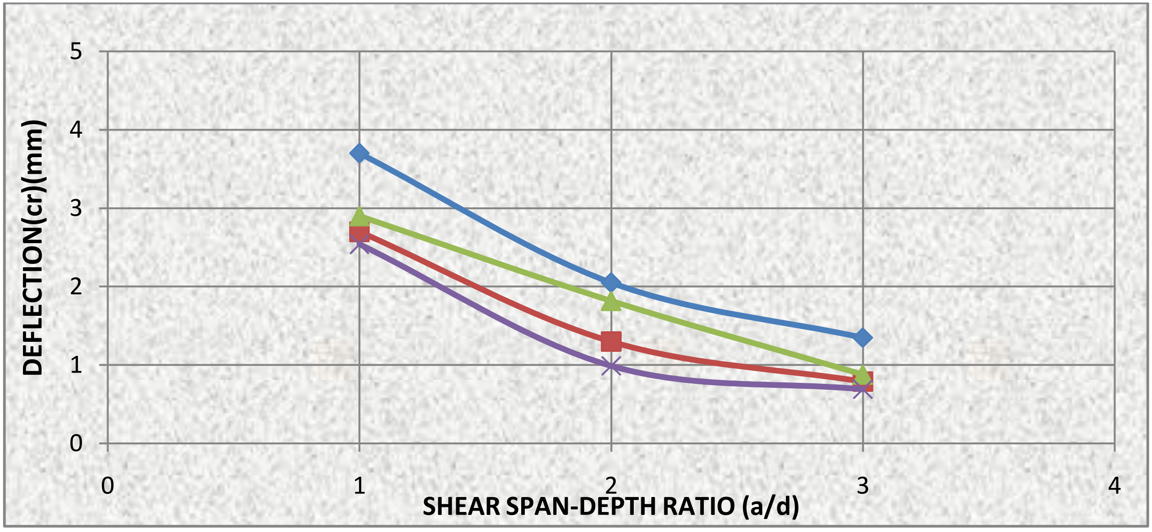
Fig: (10) Load- deflection for beams

B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. $(\frac{a}{d}=1.0)$.L=92.5CM.

B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. $(\frac{a}{d}=2.0)$.L=117.5CM

.B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. $(\frac{a}{d}=3.0)$.)-L=142.5CM**.**





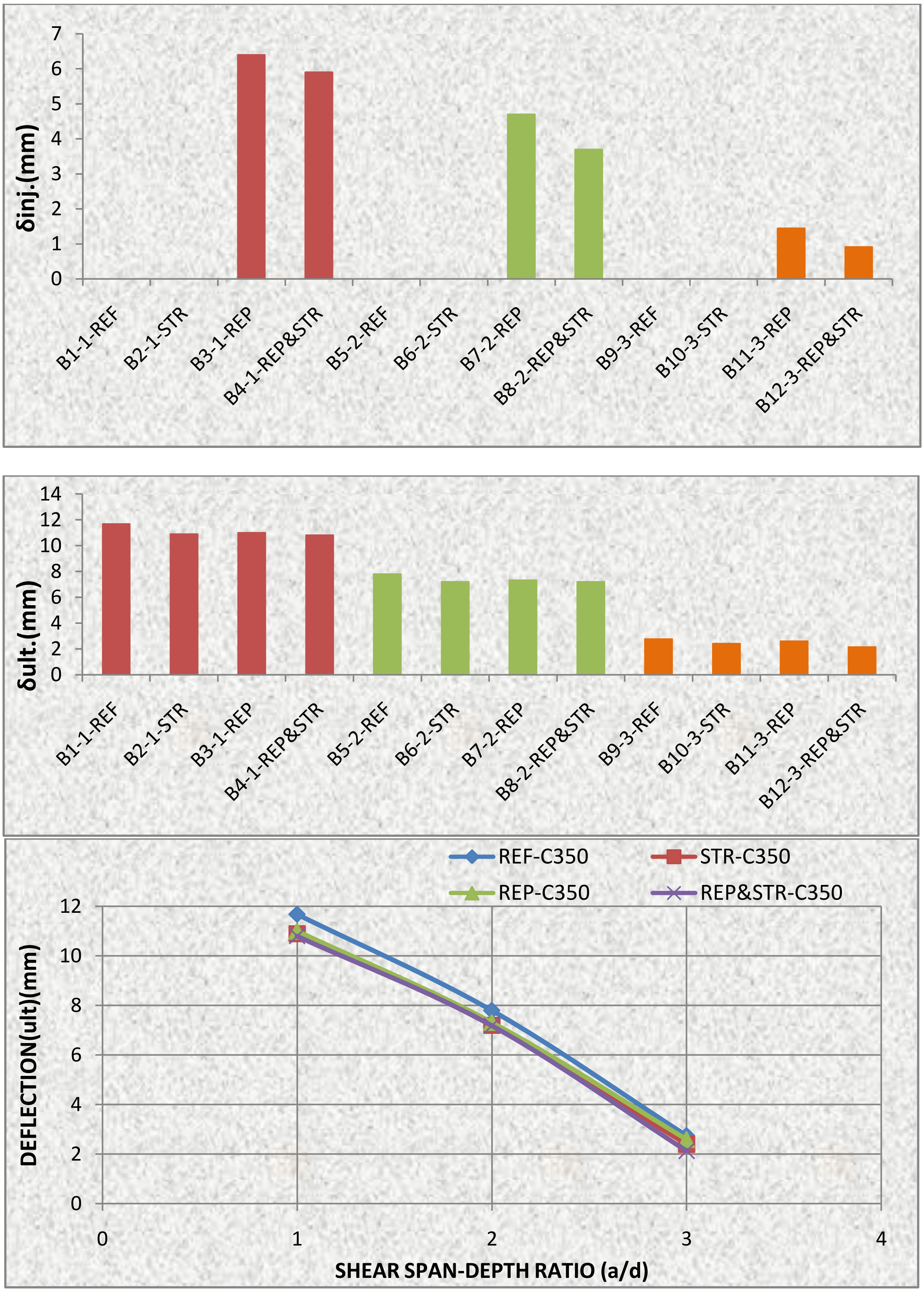


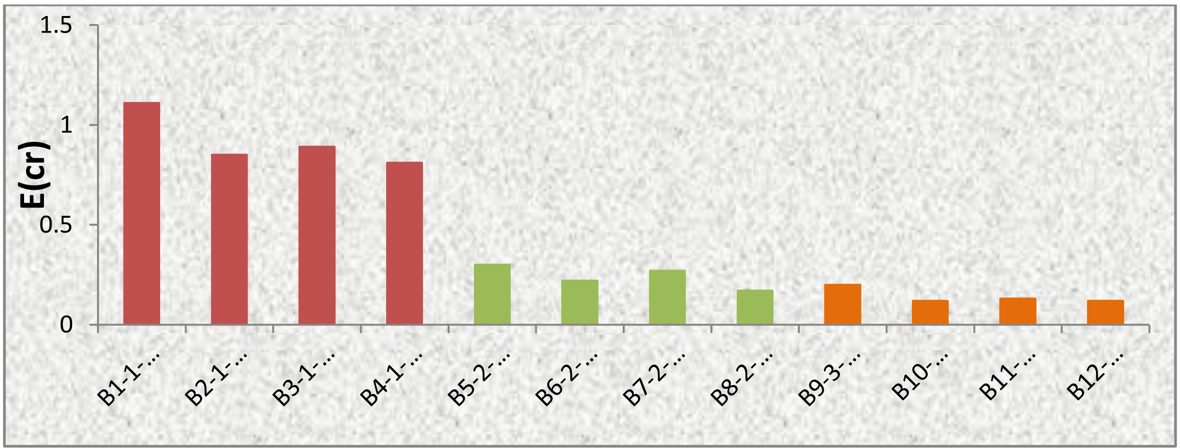
Fig (11).Deflection at cracking loads (δcr.mm) and Ultimate loads (**δu.exp.) for beams B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. ($\frac{a}{d} = 1.0$).L=92.5CM. B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. ($\frac{a}{d} = 2.0$).-L=117.5CM. B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. ($\frac{a}{d} = 3.0$).)-L=142.5CM.**

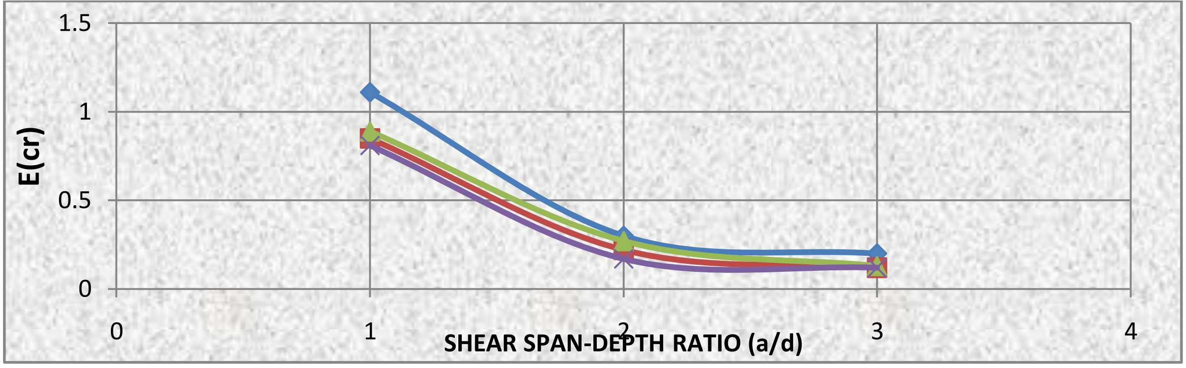
3.4. Cracking, Injected and Ultimate energy absorbed:

The area under the load-deformation curve represents the amount of energy absorbed by a specimen .The increase in energy absorption both at crack load and beyond this are reported in Table (3.) In addition values of absorbed energy for repaired beams up to a crack load have been 76%(B2-1-STR), 80%(B3-1-REP), and 72%(B4-1-REP&STR) along with total energy absorption capacity by reference beam (B1-1®). And the values of absorbed energy for repaired beams up to a ultimate load have been 101%(B2-1-STR), 97%(B3-1-REP), and 111%(B4-1-REP&STR) along with total energy absorption capacity by reference beam (B1-1®). Fig (12).

The area under the load-deformation curve represents the amount of energy absorbed by a specimen .The increase in energy absorption both at crack load and beyond this are reported in Table (4.3.) In addition values of absorbed energy for repaired beams up to a crack load have been 73%(B6-2-STR), 90%(B7-2-REP), and 56%(B8-2-REP&STR) along with total energy absorption capacity by reference beam (B5-2®). And the values of absorbed energy for repaired beams up to a ultimate load have been 103%(B6-2-STR), 99%(B7-2-REP), and 108%(B8-2-REP&STR) along with total energy absorption capacity by reference beam (B1-1®)Fig (12).

The area under the load-deformation curve represents the amount of energy absorbed by a specimen .The increase in energy absorption both at crack load and beyond this are reported in Table (4.3.) In addition values of absorbed energy for repaired beams up to a crack load have been 60%(B2-1-STR), 65%(B3-1-REP), and 600%(B4-1-REP&STR) along with total energy absorption capacity by reference beam (B9-3®). And the values of absorbed energy for repaired beams up to a ultimate load have been 115%(B10-3-STR), 118%(B11-3-REP), and 111%(B12-3-REP&STR) along with total energy absorption capacity by reference beam (B1-1®)Fig (12).





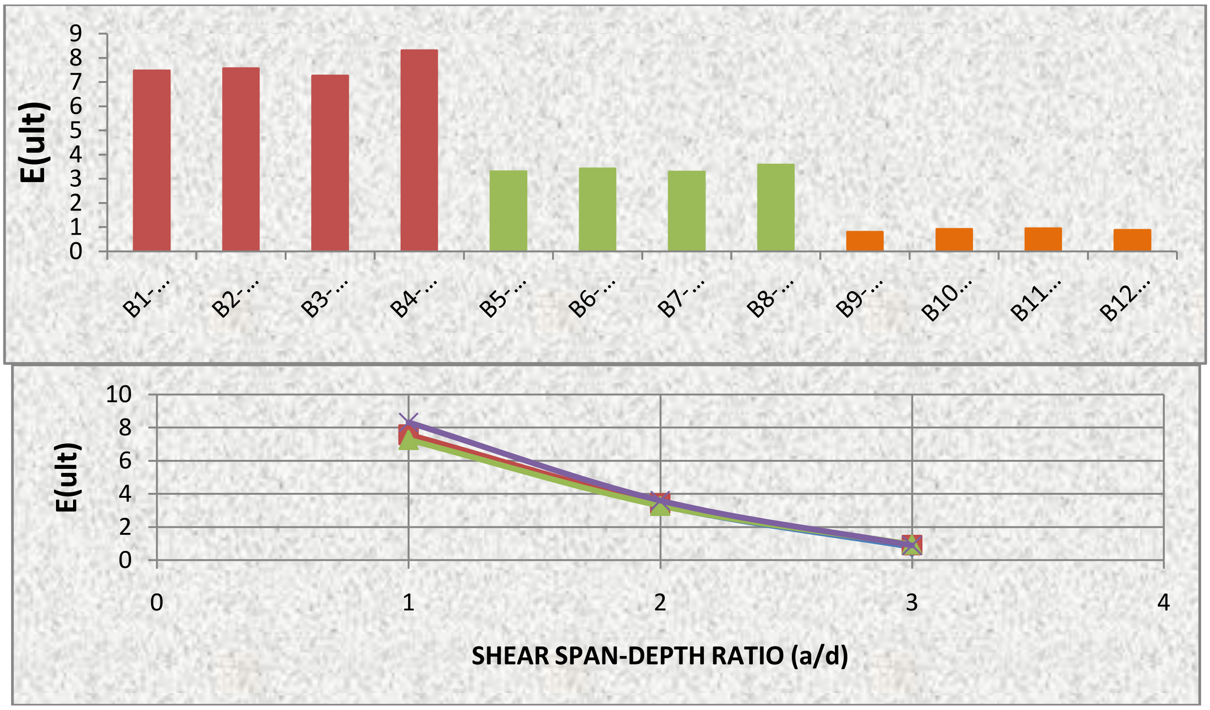


Fig (12). Absorbed energy at cracking loads (Ecr.) and at Ultimate loads (Eu) for:
B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. ($\frac{a}{d} = 1.0$).L=92.5CM.
B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. ($\frac{a}{d} = 2.0$).-L=117.5CM.
B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. ($\frac{a}{d} = 3.0$).)-L=142.5CM.

3.5. Cracking, Injected and Ultimate slip.

The cracking slip of beams (B1-1®), (B5-2®) and (B9-3®) equal to (0.63), (0.47) and (0.42) mm. And the cracking slip of beams (B2-1), (B6-2) and (B10-3) Strengthened by carbon fiber sheets (CFRP) equal to (0.36), (0.38), (0.21) mm. And also the cracking slip of beams (B3-1), (B7-2) and (B11-3) withInjected of (Epoxy) equal to (0.50), (0.38) and (0.30) mm. And also the cracking deflection of beams (B4-1), (B8-2) and (12-3) with Injected of (Epoxy) and Strengthened by carbon fiber sheets (CFRP) equal to (0.34), (0.32) and (0.14) mm. Fig (13&14).

The slip of beams at injected loads (B3-1), (B4-1), (B7-2), (B8-2), (B11-3) and (B12-3) equal to (0.61), (0.43), (1.2), (0.88), (0.44) and (0.18) mm. Fig (13&14).

The Ultimate slip of beams (B1-1®), (B5-2®) and (B9-3®) equal to (0.96), (2.7) and (0.69) mm. And the ultimate slip of beams (B2-1), (B6-2), (B10-3) Strengthened by carbon fiber sheets(CFRP) equal to (0.66), (2.0) and (0.45) mm. And also the ultimate slip of beams (B3-1), (B7-2) and (B11-3) with Injected of (Epoxy) equal to (0.93), (2.4) and (0.64) mm. And also the ultimate slip of beams (B4-1), (B8-2) and (B12-3) with Injected of (Epoxy) and Strengthened by carbon fiber sheets (CFRP) equal to (0.68), (1.7) and (0.34) mm. Fig (13&14).

Table. (5) .Values of slip at cracking and ultimate loads (Δ slip.cr and ultimate (Δ slip.u) for tested beams.

G No.	Beam Name	As &As (Ø) mm	Fcu. Kg/cm2	Pcr (ton)	Δ slip.cr. (mm)	Pinj. (ton)	Δ slip.inj. (mm)	Pu. (ton)	Δ slip.u. (mm)	Mode Of Failure
G1	B1-1 (REF) C350	2Ø10	355.7	6.1	0.63			12.9	0.96	SHEAR-FAILURE
	B2-1 (STR) C350	2Ø10		6.3	0.36			13.9	0.66	SHEAR-FAILURE
	B3-1-(REP) C350	2Ø10		6.2	0.5	9.7	0.61	13.2	0.93	SHEAR-FAILURE
	B4-1 (STR&REP) C350	2Ø10		6.4	0.34	9.7	0.43	15.4	0.68	SHEAR-FAILURE
G2	B5-2 (REF) C350	2Ø10	351.2	3.0	0.47			8.50	2.70	FLEXULRE- SHEAR FAILURE
	B6-2 (STR) C350	2Ø10		3.5	0.38			9.50	2.00	FLEXULRE- SHEAR FAILURE
	B7-2 (REP) C350	2Ø10		3.0	0.38	6.4	1.20	9.00	2.40	FLEXULRE- SHEAR FAILURE
	B8-2 (STR&REP) C350	2Ø10		3.5	0.32	6.4	0.88	10.0	1.70	FLEXULRE- SHEAR FAILURE
G3	B9-3 (REF) C350	2Ø10	329.5	3.0	0.42			5.84	0.69	FLEXULRE- COMPRESSION FAILURE
	B10-3 (STR) C350	2Ø10		3.2	0.21			7.70	0.45	FLEXULRE- COMPRESSION FAILURE
	B11-3 (REP) C350	2Ø10		3.0	0.30	4.4	0.44	7.37	0.64	FLEXULRE- COMPRESSION FAILURE
	B12-3 (STR&REP) C350	2Ø10		3.5	0.14	4.4	0.18	8.40	0.34	FLEXULRE- COMPRESSION FAILURE

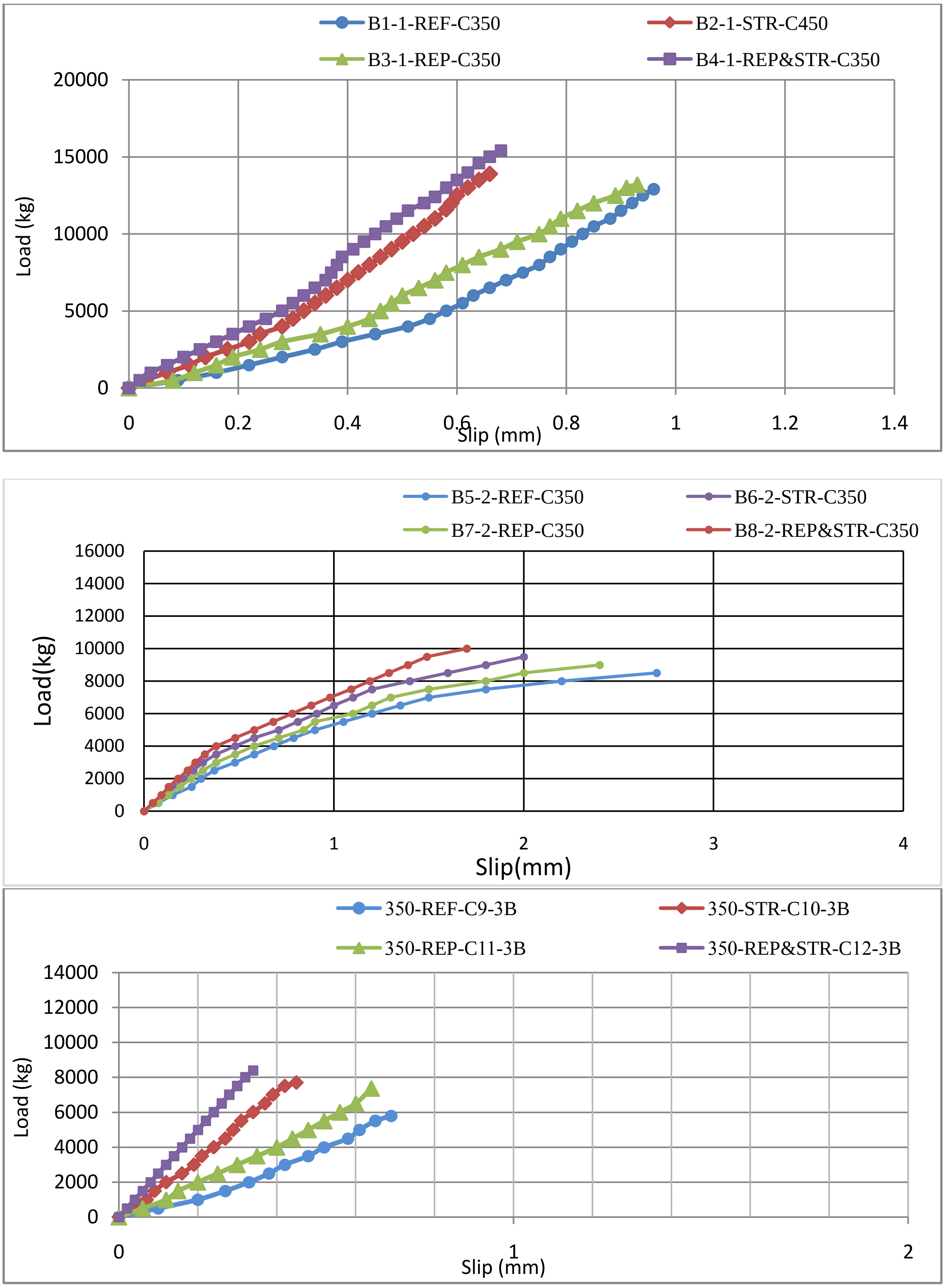


Fig (13).Load –Slip Relationship at cracking loads (Δ cr.mm) and at Ultimate loads (Δu.exp.) for tested beams B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. $(\frac{a}{d} = 1.0)$.L=92.5CM.

B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. $(\frac{a}{d} = 2.0)$. -L=117.5CM.

B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. $(\frac{a}{d} = 3.0)$.)-L=142.5CM.

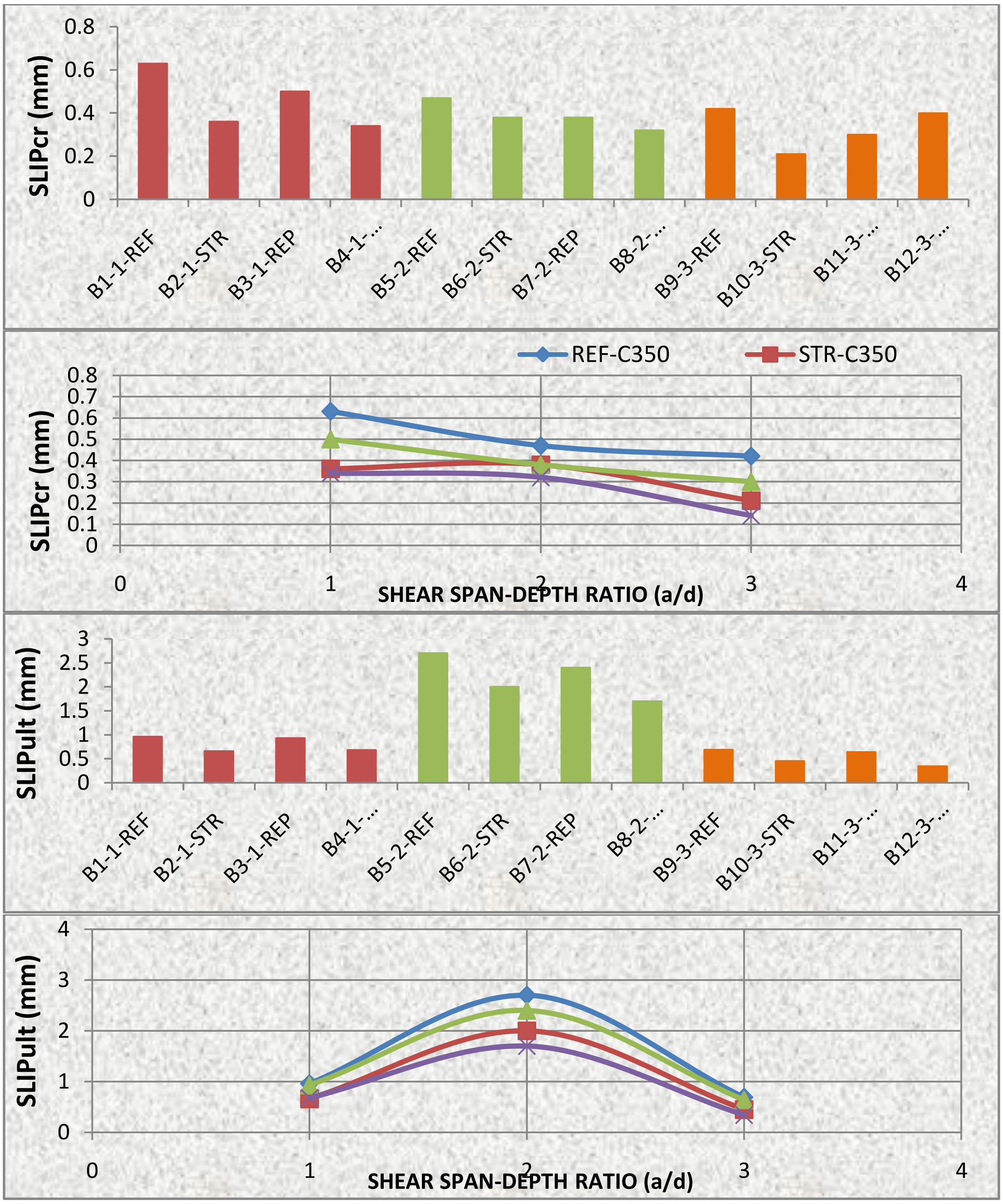


Fig (14).Slip at cracking loads (Δ cr.mm) and Ultimate loads (Δu.exp.) for beams
B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP, group 1. ($\frac{a}{d} = 1.0$).L=92.5CM.
B5-2®-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2. ($\frac{a}{d} = 2.0$). -L=117.5CM.
B9-3®. B10-3- STR., &B11 -3-REP&B12-3-STR&REP. group 3. ($\frac{a}{d} = 3.0$).)-L=142.5CM.

VI. Conclusion

The study concluded that to evaluate the ultimate shear strength and to identify the modes of failure of tested R.C.beams. The research presented herein was conducted to investigate the durability performance and behavior of crack internally injected by epoxy resin in R.C. beams with and without (CFRP) strengthening. Epoxy internally injected and strengthening by (CFRP) does not increase the weight of beams very much and decrease the deflections of repaired beams, so it can be used to successfully repair the cracked of R.C. beams based on the research performed, following conclusions can be drawn:

1. In plain concrete cylinder the internal injection improve the tensile strength of concrete. The concrete tensile strength increased by about 15 % .This is show that the internal injection of epoxy is suitable to give concrete the ability to withstand the tensile load which causes the harmful cracks in concrete elements. Closing the cracks in concrete elements prevents the CO2 and the water steam to penetrate into the concrete element and causes the corrosion of reinforced steel.

2 .The effect of external strengthening by (CFRP) in the plain concrete cylinder is very clear. The results of indirect tensile strength by about 22% indicate that the positive effect of external strengthening by (CFRP).

3. The concrete tensile strength increased by about 37.6 %. This is show that the internal injection of epoxy with external strengthening by (CFRP) is very suitable to give concrete the ability to withstand the tensile load which causes the harmful cracks in concrete elements.

4. The modulus of rupture of concrete was increased by about 15 % due to the internal injection. This indicated that internal injection through holes may be disturbed internal structure of concrete which is the main in the bond of concrete materials.

5. Repair of R.C. beams with epoxy by internal injection technique is effective for control the cracks and leads to increase crack load carrying capacity for beams by(4.76%), and also leads to increase the ultimate load carrying capacity for beams by(9.33%)for a/d=1.0, 2.0 and 3.0 respectively. An increase in the ultimate strength of all beams was observed in the testing this is likely due to the stronger epoxy to concrete bond-line strength compared to the tensile strength of concrete.

6. In reinforced concrete the internal injection of the epoxy resin is auseful method to close the concretecrakes and achieve the protection to the reinforcement. The internal injection way for repairing the R.C. structures is very effective ways due to the depression of the epoxy through the body is enough.

7. Strengthened of R.C. beams by (CFRP) is more effective for control the cracks and leads to increase load carrying capacity by(7.33%), and also leads to increase the ultimate load carrying capacity for beams by(11.33%)for a/d=1.0, 2.0 and 3.0 respectively. The beams strengthened with (CFRP) achieved higher ultimate load than the reference beams. This is due to the high utilization of the tensile strength of the (CFRP). RC beams with (CFRP) sheets were less likely to fail by rupture of the (CFRP) sheet. Loading affect the ultimate load capacity of RC beams by the formation of micro-cracks in concrete and weakening of the bonding layer between the concrete and the external (CFRP) sheets.

8. Repair of R.C. beams with epoxy by internal injection technique and strengthened by CFRP is more effective for control the cracks and leads to increase load carrying capacity by(8.67 %) , and also leads to increase the ultimate load carrying capacity for beams by(33.33%)for (a/d=1.0, 2.0 and 3.0) respectively. Whether to achieve ductile or brittle behavior of RC beams with repaired epoxy injection and external (CFRP) sheets is highly dependent of the scheme and type of the attached (CFRP).

9. Beams failed due to opening of repaired cracked which strongly recommended that epoxy by internal injection technique is efficient in the repair of cracked concrete structure.

10. Crack injection provided an increase in stiffness in the linear region of the load–displacement curves for all of the RC beams without CFRP strengthening; the increase was as high as 3.5 times the control specimens. However, no increase in flexural capacity was observed.

11. In this experimental work one thing was observed that when load on the beams was kept constant at 75% of ultimate load of reference beam crack width remain opening to a certain value due to which more epoxy was internally injected to cracks. Also in practical field when the member will remain under permanent loading condition, more epoxy will be injected internally in the cracks and more efficient results will be obtained.

12. An increase in ultimate strength and initial stiffness of load versus deflection curves is achieved by (CFRP) strengthened R.C. beams with crack injection as compared to (CFRP) strengthened beams without crack injection. Injected cracks with (CFRP) strengthened beams showed minimal crack opening displacement; beams without crack injection showed crack opening displacements to some extend but not as high as the un-strengthened beams. This can be explained by (CFRP) application, which caused a reduction of stress in the reinforcement steel and reduced crack propagation. Hence crack injection prior to (CFRP) strengthening is recommended in cases where severe cracking has occurred and durability is a major concern.

13. Principal tensile stress at failure was not to be increase more for repaired , strengthen by (CFRB) and repaired with strengthened by (CFRB) beams respectively of (groups 1,2 and3) as compared with reference beam B1-1®, B2-5®& B3-9®. Further decrease in the deflection was observed for these repaired beams as compared with the reference beam B1-1®, B2-5®& B3-9®.

14. Up to crack, repaired beams showed average increased in energy absorptionby73% (STR) and 61.67% for(REP) and 76 % (REP&STR) as compared with reference beams B1-1®, B2-5®& B3-9®. Up to failure, repaired beams showed average increased in energy absorption by 103 % for (STR) and 103.33 % for (REP) and 114.67 % for (REP&STR) as compared with reference beams B1-1®, B2-5®&B3-9®.
15. All beams strengthened with (CFRP) strips failure was dominated by the high shear stresses by de-bonding between the (CFRP) and the concrete. In general, the behavior of the (CFRP) strengthened beams indicated significant increase in the stiffness and strength in comparison with the un-strengthened beam.In summary, the (CFRP) strengthening technique could be considered as a valid strengthening technique.

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