

Repair and Strengthening of Reinforced Concrete Beams With Concrete Strength (C450) 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:-

- The concrete samples (cylinder - prisms) internally repaired by epoxy and externally strengthened by carbon fibre sheets (CFRP).
- References reinforced concrete beams (Ref) with shear span –depth ratio ($a/d=1.0, 2.0 & 3.0$).
- Reinforced concrete beams internally injected by epoxy and externally Strengthened by carbon fibre sheets (CFRP).
- Effect of shear –span depth ratio ($a / d=1.0, 2.0 & 3.0$).
- Effect of concrete compressive strength ($F_{cu}= 250\text{kg/cm}^2\text{-}350\text{kg/cm}^2\text{-}450\text{kg/cm}^2$).

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 repair and strengthening the casted beams were also presented Fig. (1).

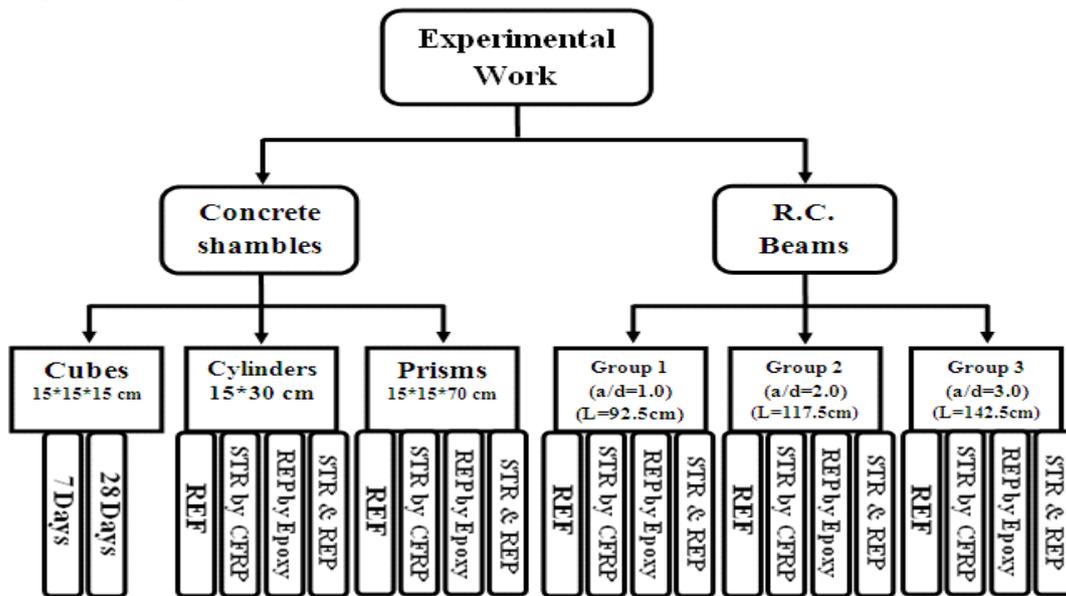


Fig. (1): The Experimental Work Program.

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 to 1.0, 2.0 & 3.0. Also 3 reinforced concrete beams with the same grade of concrete (f_{cu} =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).

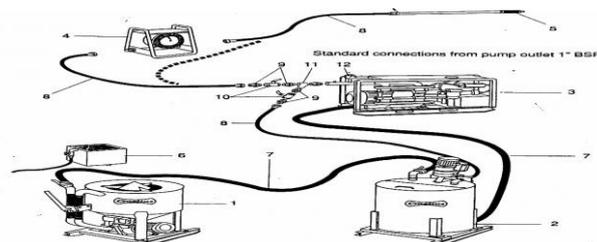


Fig (2) :(The Epoxy (KEMA-EPOXY (103 used as internal injected material.

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-Pressure 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 Injection Technique.

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.

- 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 0.1 3mm .Fig. (4) And table (1. (



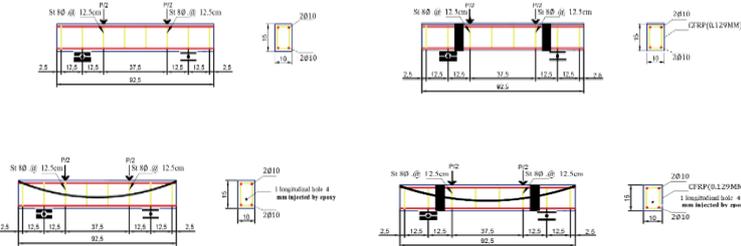
B, BASFE&Master Brace SAT 4500 Part A and Figure (4): CFRP sheets

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

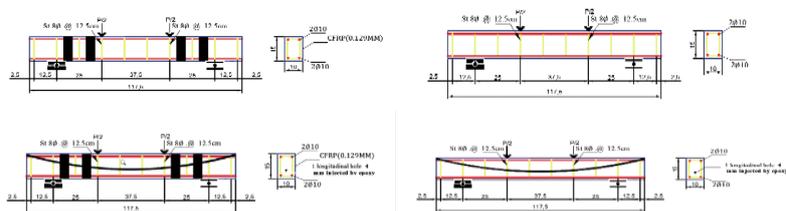
Table (1): Description of CFRP/fiber BASEF 4500 and mater Brace Sat4500 part A&B

2.4. Beams preparation.

Group (1) a/d=1.0



Group (2) a/d=2.0



Group (3) a/d=3.0

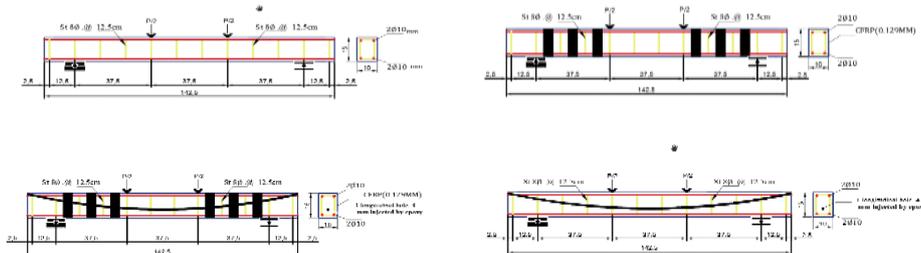


Fig. (5).Details of Beams

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

Table. (2) Details of the tested beams.

Groups	Beam Name	L (cm)	L0 (cm)	Shear span (a)	D (cm)	Shear span-depth ratio a/d	As& As' (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	2	WITHOUT	WITHOUT	450
	B2-1 C350)STR(	92.5	62.5	12.5	12.5	1.0		WITHOUT	WITH	450
	B3-1 C350)REP(	92.5	62.5	12.5	12.5	1.0	2	WITH	WITHOUT	450
	B4-1C350) STR & REP (	92.5	62.5	12.5	12.5	1.0		WITH	WITH	450
G2	B5-2C350)REF(	117.5	87.5	25.0	12.5	2.0	2	WITHOUT	WITHOUT	450
	B6-2 C350)STR(	117.5	87.5	25.0	12.5	2.0		WITHOUT	WITH	450
	B7-2C350) REP(	117.5	87.5	25.0	12.5	2.0	2	WITH	WITHOUT	450
	B8-2C350)STR& REP (	117.5	87.5	25.0	12.5	2.0	2	WITH	WITH	450
	B9-3 C350)REF(	142.5	112.5	37.5	12.5	3.0	2	WITHOUT	WITHOUT	450

G3	B10-3C350)STR(	142.5	112.5	37.5	12.5	3.0		WITHOUT	WITH	450
	B11-3C350)REP(	142.5	112.5	37.5	12.5	3.0	2	WITH	WITHOUT	450
	B12-3C350) STR &REP(	142.5	112.5	37.5	12.5	3.0	2	WITH	WITH	450

L= the total length of beam =0Lthe effective length of beam a= Shear span d =effective depth of beam
 b= the breadth of beam Fc = concrete compressive strength No. of Ast = Area of steel No. of
 Ast = '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 16.60 % .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 26.56%.

While the effect 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 32.3 % . 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) .Plain concrete cylinders with internal injection by epoxy.

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 13.0 % due to the internal 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) Plain concrete prisms flexural strength with 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 loading point) 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 point.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.Infact as 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

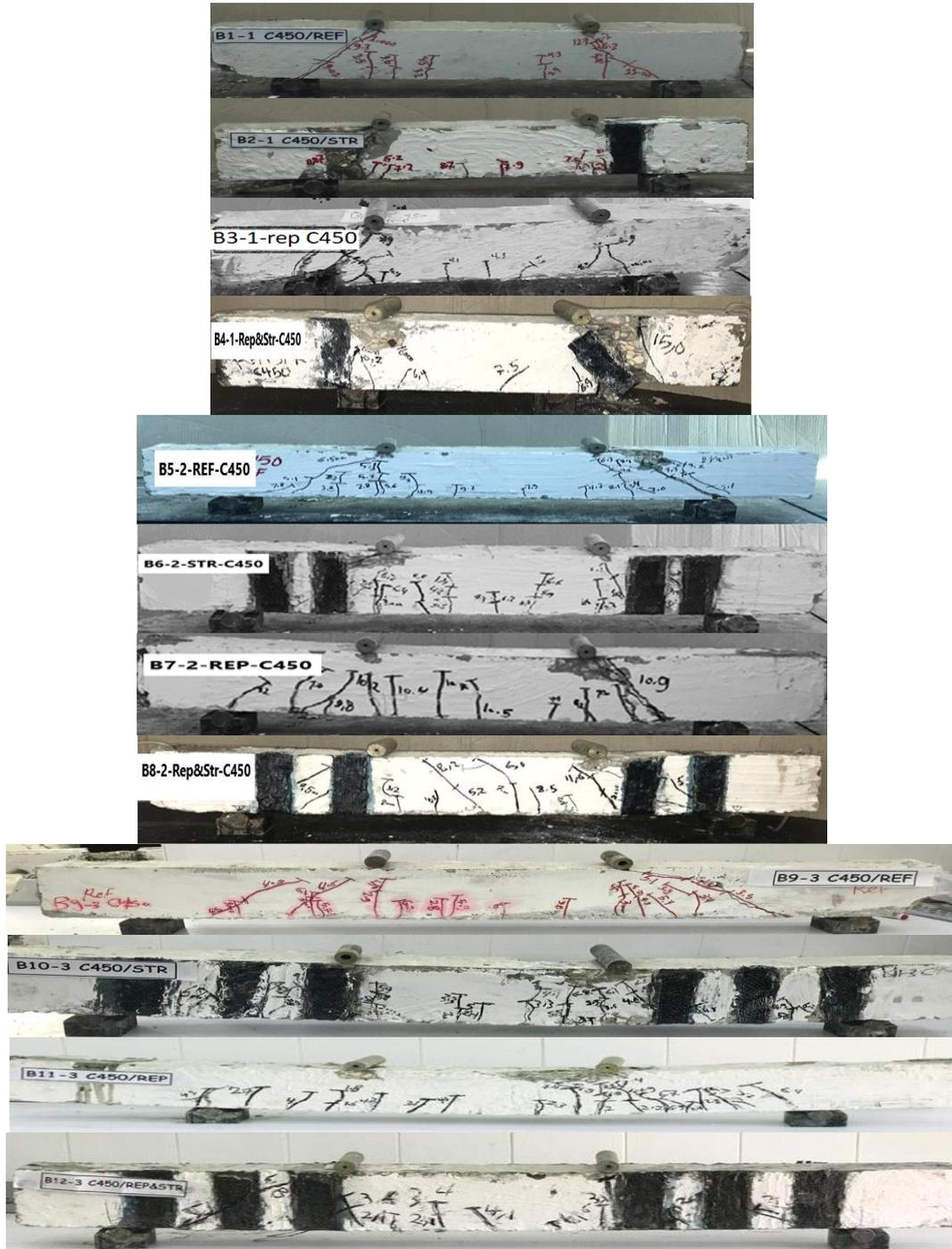


Fig: (8) Pattern of crack of beams

B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP ,group 1.) .L=92.5CM.
B5-2-®, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2-) .L=117.5CM.
B9 .®3-B10-3- STR& ,.B11 -3-REP&B12-3-STR&REP .group 3-() .L=142.5CM.

Table (3) .Values of cracking load) pcr.(injected load) pinj (.and ultimate load) pu (.for tested beams:

Group	Beam Name	As&)As Mm	a/d	INJE CTE D BY EPO XY	STR ENG THE NED. (CFR (P	Fcu . Kg/ cm 2	P cr .(ex p) (t o n)	PI N J.) ex p) (t o n)	Pu.(exp) (ton) .(	Pc r.(th) (to n) .(	Pu. (th) (to n)	Pcr .(ex p) /Pc r.R (ex .(p	Pu. (ex p) /Pu .R(exp .(	Pcr. (exp) /Pcr .(th	Pu. (ex p) /Pu .th	Mode Of Failure
G1	B1-1- REF-C450. ((R	2	1, 0	WIT HOU T	WIT HOU T	442	6. 1	-	13.0 6	4. 8	11. 8	1.0	1.0	1.27	1.1 0	SHEAR-FAILURE
	B2-1- STR-C450		1, 0	WIT HOU T	WIT H		6. 3	-	14.2			1.0 3	1.0 8	1.31	1.2 0	SHEAR-FAILURE
	B3-1- REP-C450	2	1, 0	WIT H	WIT HOU T		6. 2	9. 8	13.4			1.0 1	1.0 2	1.29	1.1 3	SHEAR-FAILURE
	B4-1- STR &RE P-C450		1. 0	WIT H	WIT H		6. 4	9. 8	15.6			1.0 4	1.1 9	1.30	1.3 2	SHEAR-FAILURE
G2	B5-2- REF-450-(R	2	2, 0	WIT HOU T	WIT HOU T	451	3. 0	-	9.33	2. 4	9.5	1.0	1.0	1.25	1.5 7	SHEAR-FAILURE
	B6-2- STR-450		2, 0	WIT HOU T	WIT H		3. 3	-	11.2			1.1 1	1.1 1	1.37 5	1.8 9	SHEAR-FAILURE
	B7-2- REP-450	2	2, 0	WIT H	WIT HOU T		3. 0	7. 0	10.9			1.0 1	1.0 1	1.25	1.8 4	SHEAR-FAILURE
	B8-2- STR &RE P-C450	2	2. 0	WIT H	WIT H		3. 6	7. 0	11.6			1.2	1.1 2	1.5	1.9 6	SHEAR-FAILURE
G3	B9- .3- REF-C450-((R	2	3, 0	WIT HOU T	WIT HOU T	439 1.	3. 0		5.8	1. 6	3.9 3	1.0	1.0	1.87 5	1.4 7	SHEAR-FAILURE
	B10- -3 STR-C450		3, 0	WIT HOU T	WIT H		3. 3		7.5			1.1	1.3 2	2.06	1.9 5	SHEAR-FAILURE
	B11- -3 REP-C450	2	3, 0	WIT H	WIT HOU T		3. 0	4. 5	7.0			1.0	1.2 5	1.87 5	1.7 8	SHEAR-FAILURE
	B12- -3 STR &RE P-C450	2	3, 0	WIT H	WIT H		3. 6	4. 5	8.3			1.2	1.4 4	2.25	2.1 1	SHEAR-FAILURE

The values of cracking, injection and ultimate loads) Pcr ,Pinj& .Pu (for the beams 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.(

3.1Cracking and Injection and ultimate 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 fibre) 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 cracking load for (B2-1) (3.0 %), (B3-1) (1.0%) and for (B4-1) (4.0%) than that the cracking 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 9.8(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 fibres) CFRP), (B7-2-REP) repairing by internal injection by epoxy) & B8-2-STR&REP) strengthening by carbon fibre) 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 cracking load for (B6-2) (10%), (B7-2) (0%) and for (B8-2) (20%) than that the cracking 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 injected at loads equal to (7.0) 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 fibres) CFRP), (B11-3-REP) repairing by internal injection by epoxy) & B12-3-STR&REP) strengthening by carbon fibres) 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 cracking load for (B10-3) (10 %), (B11-3) (0%) and for (B12-3) (20.0%) than that the racking 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 4.5(ton) for mentioned beams respectively Fig. (9.(

The beams (B1-1^(®)) (B5-2^(®)) (B9-3^(®)) reference beams were tested to study the effect of shear span-depth ratio and these beams had a solid beams cross sections and without injected and strengthening materials.

The beams (B3-1) (B7-2) (B11-3) and (B4-1) (B8-3) (B12-3) had many parameters for internal injection and strengthening technique, the beams was injection by (Epoxy (at 75% of the) Pu (of the reference beam approximately at loads equal to (9.8, 7.0 and 4.5 ton) respectively Fig. (9.(

For shear span - depth ratio ($a/d=1.0$) the values of ultimate loads) Pcr (increase with repairing and the strengthening of beams in shear zone. The beams (B2-1-STR) strengthening by carbon fibre) CFRP), (B3-1-REP) repairing by internal injection by epoxy) & B4-1-STR&REP) strengthening by carbon fibres) 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) (8.0 %), (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 ultimate reached a width equal to 1.0 mm approximately failed at loads equal to

13.4(ton) (and 15.6) ton) for mentioned beams respectively Fig. (9.(

For shear span - depth ratio ($a/d=2.0$) the values of ultimate 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 fibres) 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) (11%), (B7-2) (10%) and for (B8-2) (12%) 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 (10.9 ton)and(11.6 ton) for mentioned beams respectively Fig. (9.(

For shear span - depth ratio ($a/d=3.0$) the values of ultimate loads) Pcr (increase with repairing and the strengthening of beams in shear zone. The beams (B10-3-STR) strengthening by carbon fibres) CFRP), (B11-3-REP) repairing by internal injection by epoxy) & B12-3-STR&REP) strengthening by carbon fibres) 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) (10 %), (B11-3) (0%) and for (B12-3) (20.0%) than that the racking 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 (4.5 ton) 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

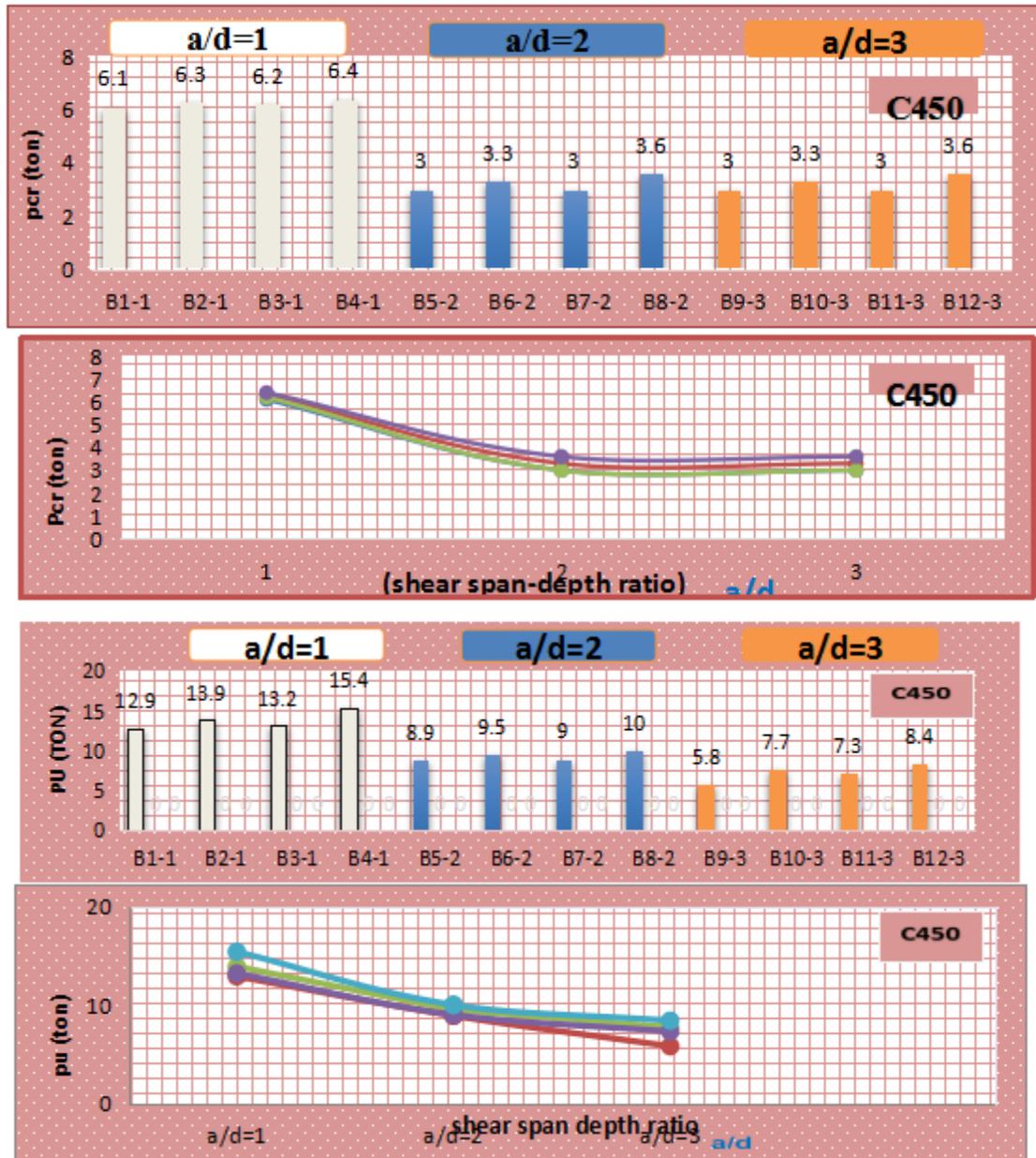


Fig: (9) Cracking and Ultimate Loads for beams

.B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP ,group 1.) .L=92.5CM.

B5-2@-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2-) .L=117.5CM.

B9 .®3-B10-3- STR& ,.B11 -3-REP&B12-3-STR&REP .group 3-) .L=142.5CM

.3.2Cracking, Injected and Ultimate deflection

In both of the analysis cases all the relationship between the applied load (P) and mid span deflection (δ) (suoirav htiw smaeb detset eht rof (δ a/d ratio or internal injection and also strengthened by carbon fibre 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 (1.68), (2.06) and (1.0) .(And the cracking deflection of beams (B2-1), (B6-2) and (B10-3) Strengthened by carbon fibres sheets (CFRP) equal

to (1.45), (1.22), (0.63) mm .And also the cracking deflection of beams (B3-1), (B7-2) and (B11-3) with Injected of (Epoxy (with equal to (1.5), (1.52) and (0.89) mm .And also the cracking deflection of beams (B4-1), (B8-2) and (B12-3) with Injected of (Epoxy (and Strengthened by carbon fibres sheets (CFRP (equal to (1.06), (1.01) and (0.54) mm. Fig (10.(11&

The deflection of beams at injected load)B3-1), (B4-1), (B7-2), (B8-2), (B11-3) and (B12-3) equal to (1.5), (1.06), (1.52), (1.01), (0.89) and (0.54) mm. Fig (10.(11&

The Ultimate deflection of beams (B1-1®), (B5-2®) and (B9-3®) equal to (3.4), (5.4) and (2.3(

mm .And the ultimate deflection of beams (B2-1), (B6-2), (B10-3 (Strengthened by carbon fibres sheets) CFRP) equal to (2.75), (4.6) and (2.15) mm .And also the ultimate deflection of beams (B3-1), (B7-2) and (B11-3) with Injected of (Epoxy (equal to (2.85), (5.09) and (2.24) mm. And also the ultimate deflection of beams (B4-1), (B8-2) and (B12-3) with Injected of (Epoxy (and Strengthened by carbon fibres sheets) CFRP) equal to (2.5), (4.05) . (And (2.13) mm. Fig (10(11&

Table (4): Values of cracking deflection) δ_{cr} ,(and ultimate deflection) δ_u -(absorbed energy at cracking) E_{cr} (and ultimate loads) E_u (for tested beams.

Group	Beam Name	As & A's (mm)	a/d	INJECTION BY EPOXY	STRENGTHENED BY CFRP	Failure Load (kN)	Cracking Load (kN)	Cracking Deflection (mm)	Ultimate Deflection (mm)	Cracking Deflection (mm)	Ultimate Deflection (mm)	Cracking Energy (kJ)	Cracking Energy (kJ)	Ultimate Energy (kJ)	Ultimate Energy (kJ)	Mode Of Failure
G1	B1-1-REF-C450 (Control)	2	1.0	WITHOUT	WITHOUT	42.2	6.1	13.06	2.46	5.52	6	1	20	1	SHEAR-FAILURE	
	B2-1-STR-C450		1.0	WITHOUT	WITH		6.3	14.02	1.26	2.6	3.96	0.66	25.39	1.27	SHEAR-FAILURE	
	B3-1-REP-C450	2	1.0	WITH	WITHOUT		6.2	13.4	1.69	2.46	5.239	0.87	25.46	1.723	SHEAR-FAILURE	
	B4-1-STR&REP-C450		1.0	WITH	WITH		6.4	15.6	0.7	1.32	2.24	0.37	21.95	1.1	SHEAR-FAILURE	
G2	B5-2-REF-C450 (Control)	2	2.0	WITHOUT	WITHOUT	45.1	3.0	9.33	2.06	5.4	8.1	1	20	1	SHEAR-FAILURE	
	B6-2-STR-C450		2.0	WITHOUT	WITH		3.3	11.2	1.22	4.6	7.59	0.93	25.76	1.29	SHEAR-FAILURE	
	B7-2-REP-C450	2	2.0	WITH	WITHOUT		3.0	10.9	1.52	3.26	7.64	0.94	27.75	1.36	SHEAR-FAILURE	
	B8-2-STR&REP-C450	2	2.0	WITH	WITH		3.6	11.6	1.01	2.11	7.3	0.9	23.49	1.17	SHEAR-FAILURE	
G3	B9-3-REF-C450 (Control)	2	3.0	WITHOUT	WITHOUT	43.9	3.0	5.8	1	2.3	3.45	1	6.67	1	SHEAR-FAILURE	
	B10-3-STR-C450		3.0	WITHOUT	WITH		3.3	7.5	0.63	2.15	2.48	0.72	8.06	1.2	SHEAR-FAILURE	

B11-3-REP-C450	2	3.0	WITH	WITHOUT	3.0	4.5	7	0.89	1.3	2.24	3.36	0.97	9	1.35	SHEAR-FAILURE
B12-3-STR&REP-C450	2	3.0	WITH	WITH	3.6	4.5	8.3	0.54	0.684	2.13	2	0.85	7.5	1.12	SHEAR-FAILURE

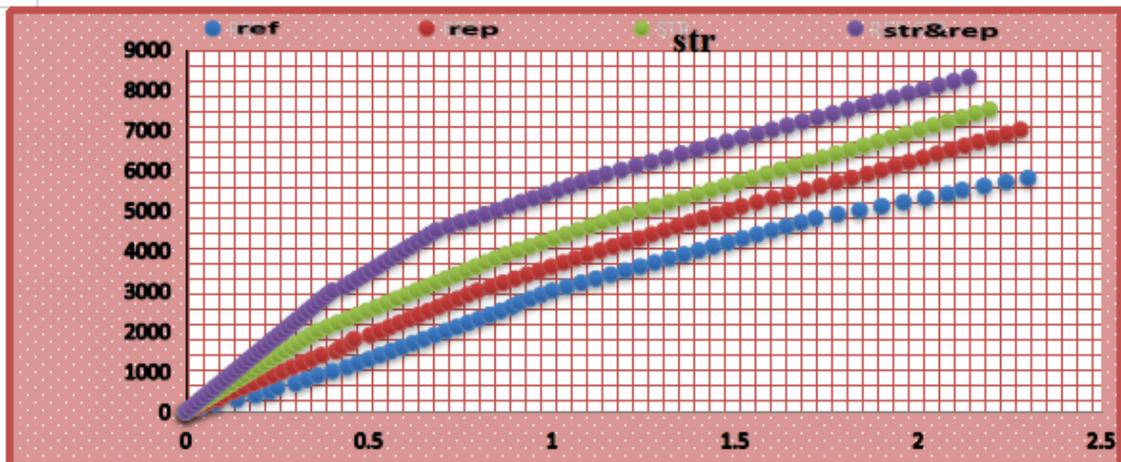
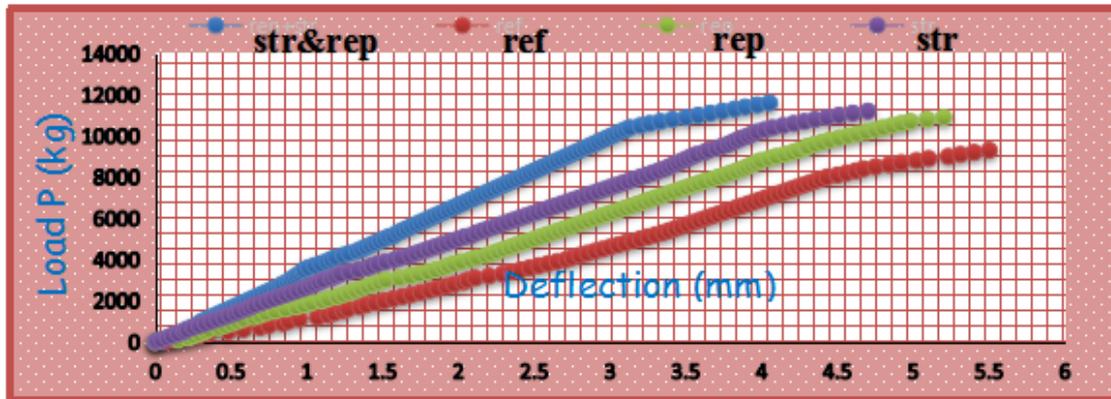
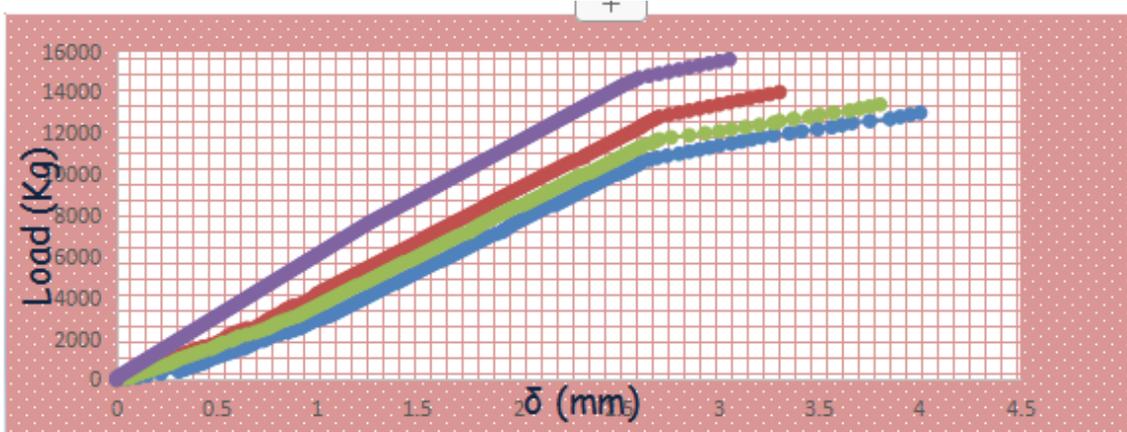


Fig: (10) Load- deflection for beams B1-1-@, B2-1-STR, B3-1-REP, B4-1-STR&REP ,group 1 .
 .)L=92.5CM.B5-2@-, B6-2- STR, B7-2-REP., B8-2-STR&REP group) .2 L=117.5CM.
 B9 .@3-B10-3- STR& ,.B11 -3-REP&B12-3-STR&REP .group 3-() .L=142.5CM.

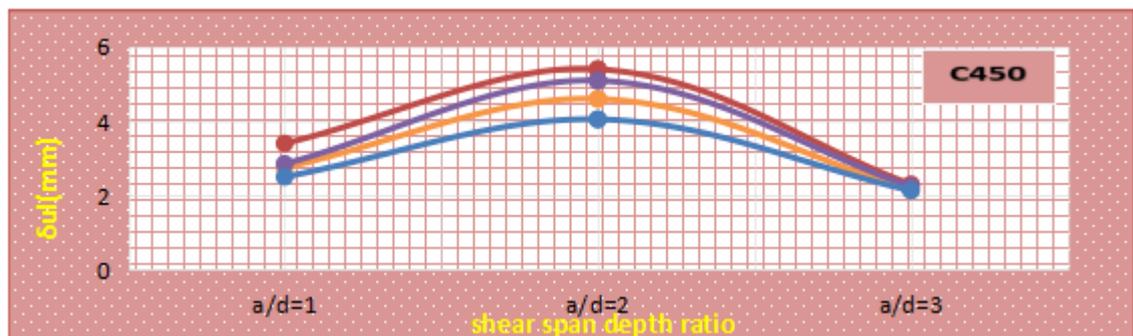
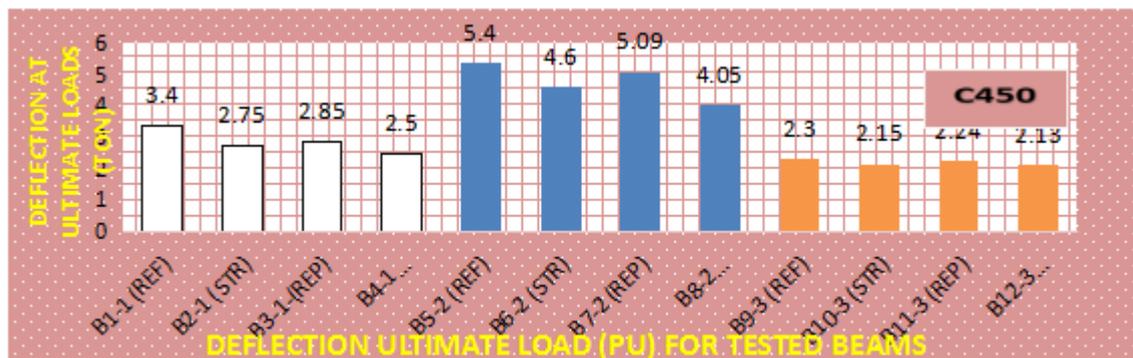
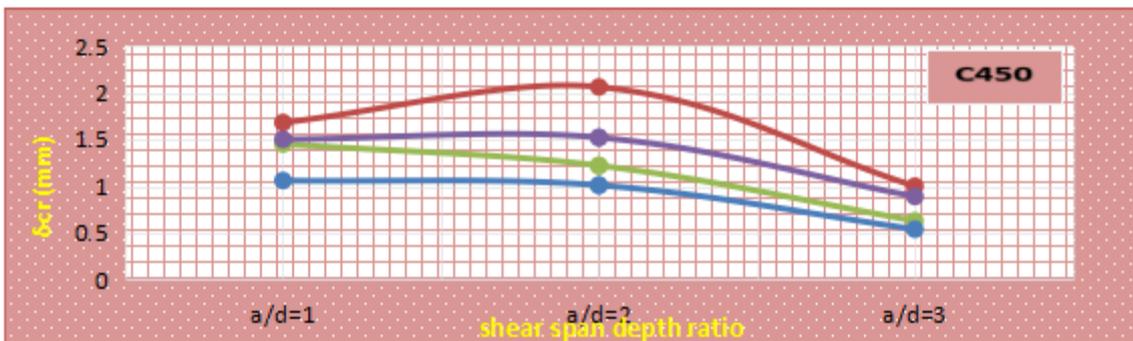
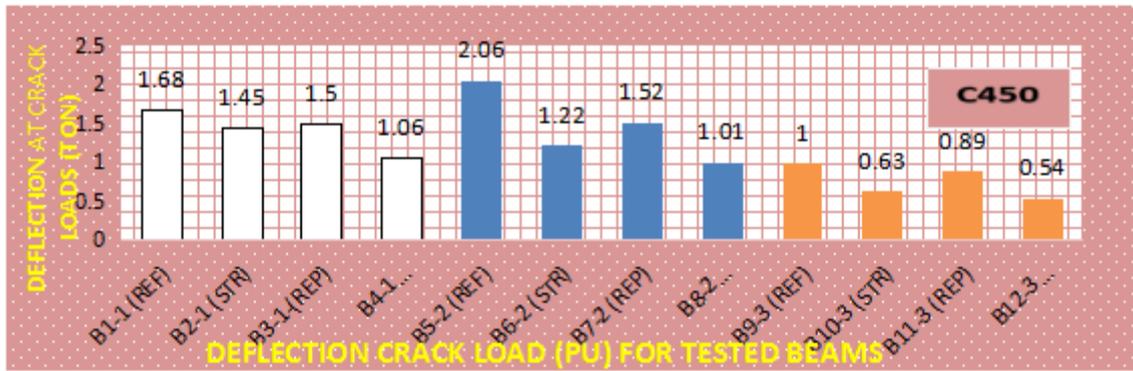


Fig (11). Deflection at cracking loads (δ_{cr} (mm) & Ultimate loads (δ_{ult} (mm)) for beams B1-1 (REF), B2-1 (STR), B3-1 (REP), B4-1 (STR), B5-2 (REF), B6-2 (STR), B7-2 (REP), B8-2 (STR), B9-3 (REF), B10-3 (STR), B11-3 (REP), B12-3 (STR). L=92.5CM, L=117.5CM, L=142.5CM

.3.3Cracking, 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 .(The 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.®

The values of absorbed energy for repaired beams up to a crack load have been 73 % (B2-1-STR), 90 % (B3-1-REP), and 56 % (B4-1-REP&STR (along with the energy absorption capacity by reference beam (B5-2.®

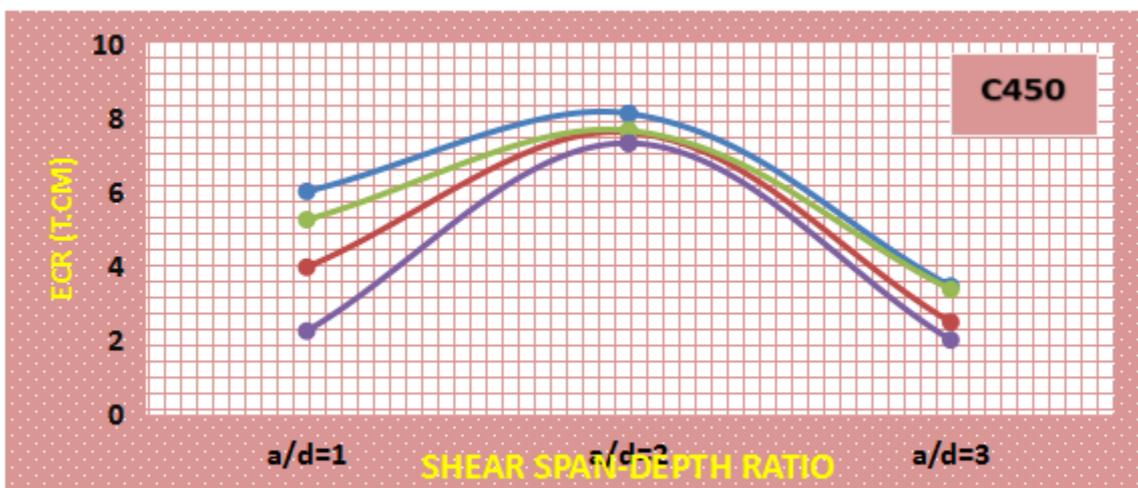
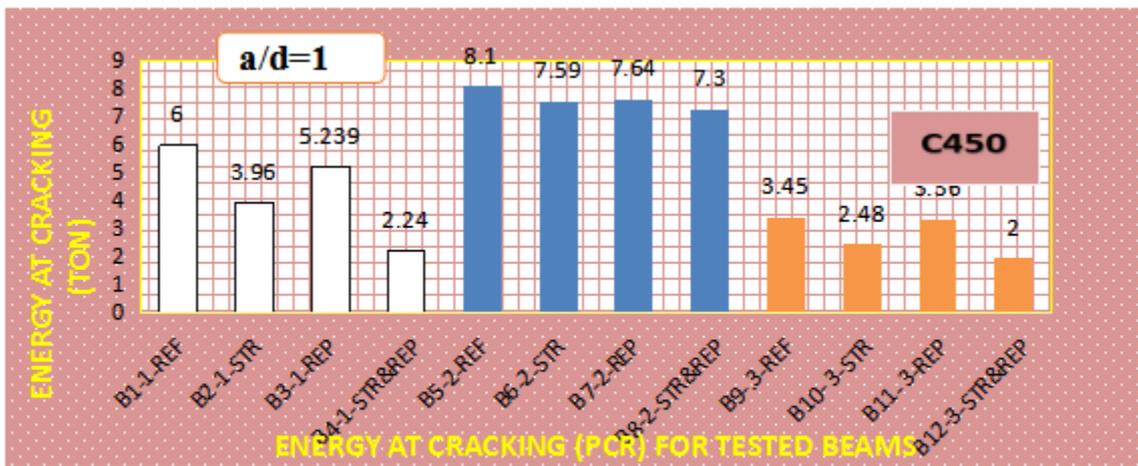
The values of absorbed energy for repaired beams up to a crack load have been 60 % (B2-1-STR), 65 % (B3-1-REP), and 60 % (B4-1-REP&STR (along with the energy absorption capacity by reference beam (B9-3.®

The values of absorbed energy for repaired beams up to failure 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.®

The values of absorbed energy for repaired beams up to a failure load have been 103 % (B2-1-STR), 99 % (B3-1-REP), and 108 % (B4-1-REP&STR (along with the energy absorption capacity by reference beam (B5-2.®

The values of absorbed energy for repaired beams up to a failure load have been 115 % (B2-1-STR), 118 % (B3-1-REP), and 111 % (B4-1-REP&STR (along with the energy absorption capacity by reference beam (B9-3.®

These results concluded that epoxy by internal injection along the holes and strengthening by carbon fiber sheets (CFRP) is capable of substantially increasing the load capacity, ductility and energy absorbing capacity Fig (12. (



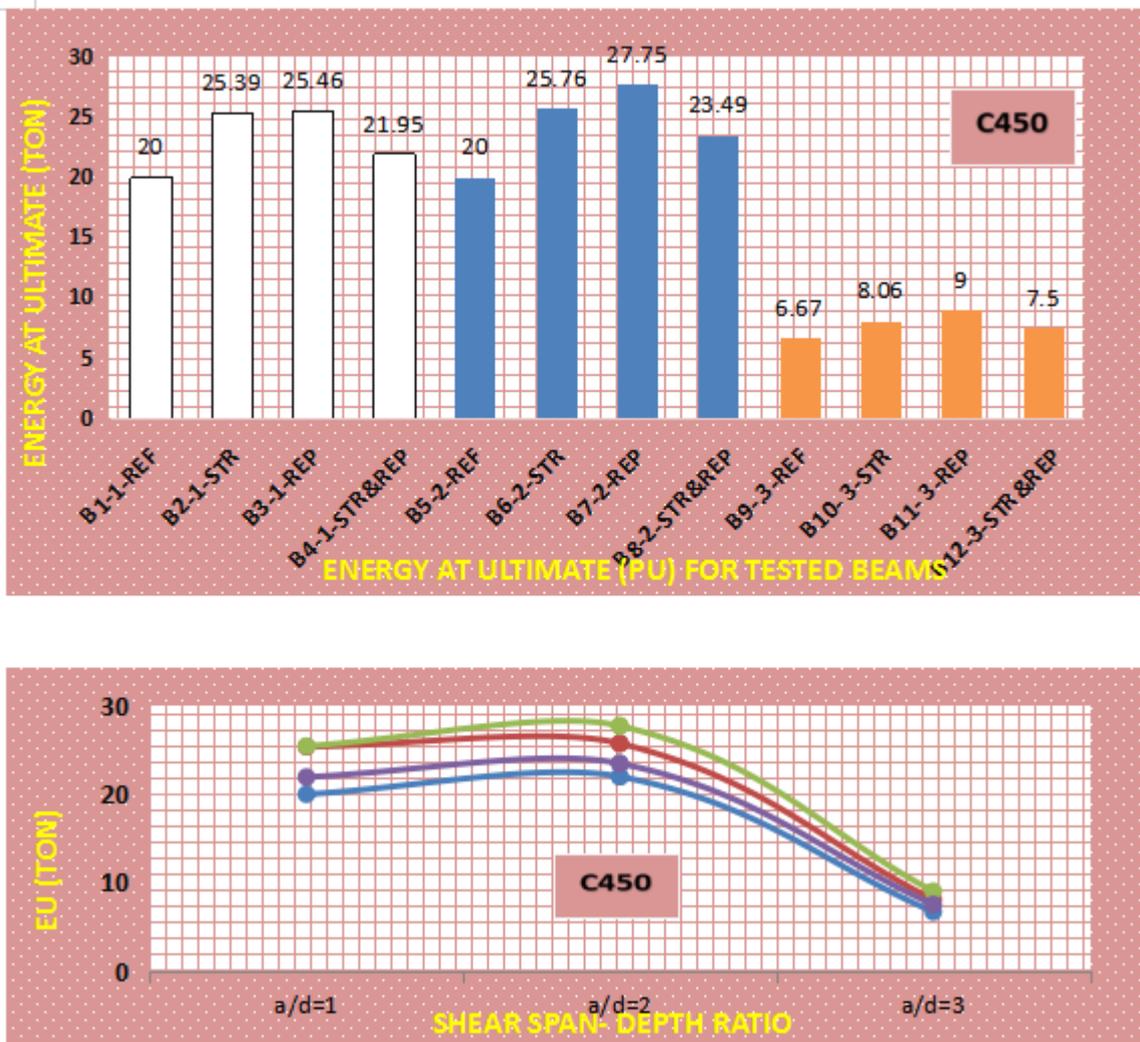


Fig (12). Absorbed energy at cracking loads) E_{cr} (and at Ultimate loads) E_u (for beams B1-1-®, B2-1-STR, B3-1-REP, B4-1-STR&REP ,group 1.) .L=92.5CM. B5-2-®, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2-) .L=117.5CM. B9 .®B10-3- STR& ,B11 -3-REP&B12-3-STR&REP .group 3-() .L=142.5CM.

.3.4Cracking, Injected and Ultimate slip.

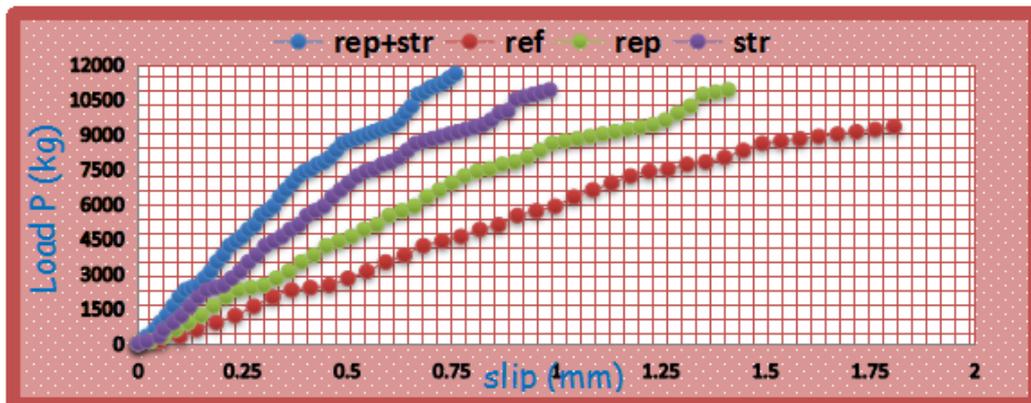
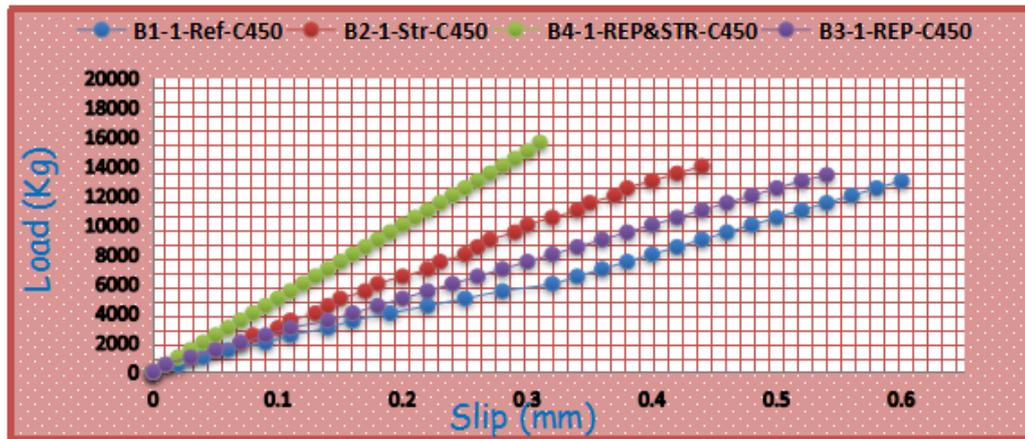
The cracking slip of beams (B1-1®), (B5-2®) and (B9-3®) equal to (0.63), (0.47) and (0.42) mm .And the cracking slip of beams (B2-1), (B6-2) and (B10-3 (Strengthened by carbon fibres sheets) CFRP) equal to (0.36), (0.38), (0.21) mm .And also the cracking slip of beams (B3-1), (B7-2) and (B11-3) with Injected 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 fibres 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 fibres 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 fibres 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) mm	Fcu. Kg/cm2	Pcr (ton(	Δ slip.cr.)mm) *0.01	Pinj. (ton(	Δ slip.inj.)mm) *0.01	Pu.)ton(	Δ slip.u.)mm(0.01*	Mode Of Failure
G1	B1-1)REF) C350	2	422	6.1	0.32	-	-	13.06	0.64	SHEAR-FAILURE
	B2-1)STR) C350			6.3	0.2	-	-	14.02	0.46	SHEAR-FAILURE
	B3-1-(REP) C350	2		6.2	0.25	9.8	0.29	13.4	0.54	SHEAR-FAILURE
	B4-1)STR&REP) C350	2		6.4	0.13	9.8	0.19	15.6	0.31	SHEAR-FAILURE
B5-2)REF) C350	3.0		0.45	-	-	9.33	1.76	COMPRESSION-FAILURE		
B6-2)STR) C350	3.3		0.3	-	-	11.2	1.1	COMPRESSION-FAILURE		
B7-2 (REP) C350	2		3.0	0.35	7.0	0.75	10.9	1.4	COMPRESSION-FAILURE	
G2	B8-2)STR&REP) C350	2	451	3.6	0.25	7.0	0.36	11.6	0.9	COMPRESSION-FAILURE
	B9-3)REF) C350	2		3.0	0.38	-	-	5.8	0.6	COMPRESSION-FAILURE
G3	B10-3)STR) C350		439.1	3.3	0.27	-	-	7.5	0.52	COMPRESSION-FAILURE
	B11-3)REP) C350	2		3.0	0.3	4.5	0.42	7	0.55	COMPRESSION-FAILURE
	B12-3)STR&REP) C350	2		3.6	0.2	4.5	0.29	8.3	0.46	COMPRESSION-FAILURE



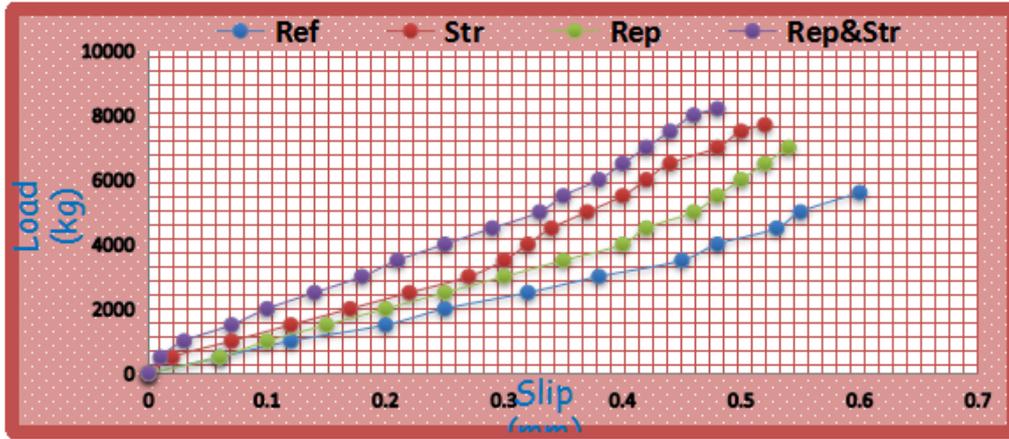
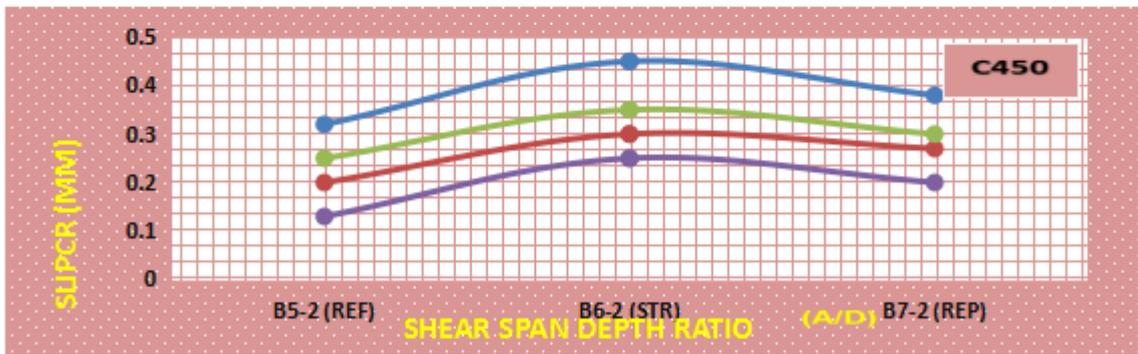
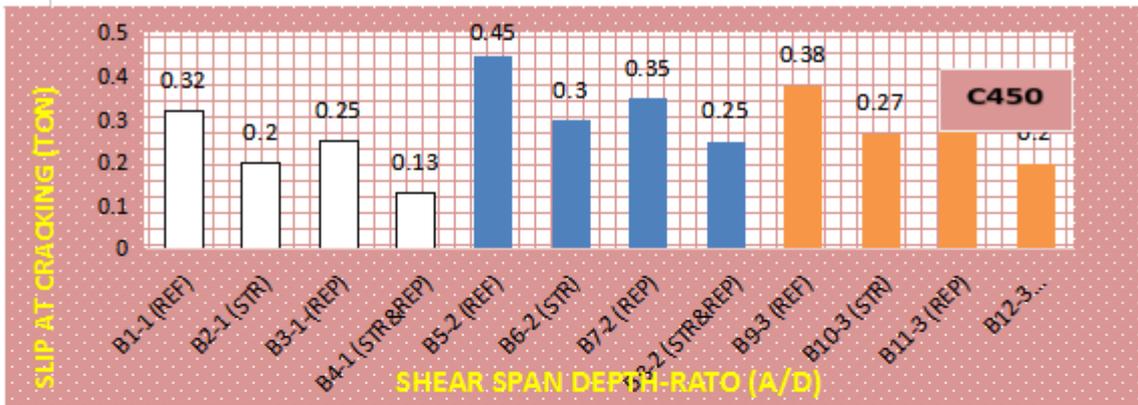


Fig (13).Load –Slip Relationship at cracking loads (Δ cr.mm) and at Ultimate loads (Δ u.exp (for tested beams B1-1-@, B2-1-STR, B3-1-REP, B4-1-STR&REP ,group.) .1 L=92.5CM. B5-2@-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2-) .L=117.5CM. B9 .@3-B10-3- STR& ,B11 -3-REP&B12-3-STR&REP .group 3-() .L=142.5CM.



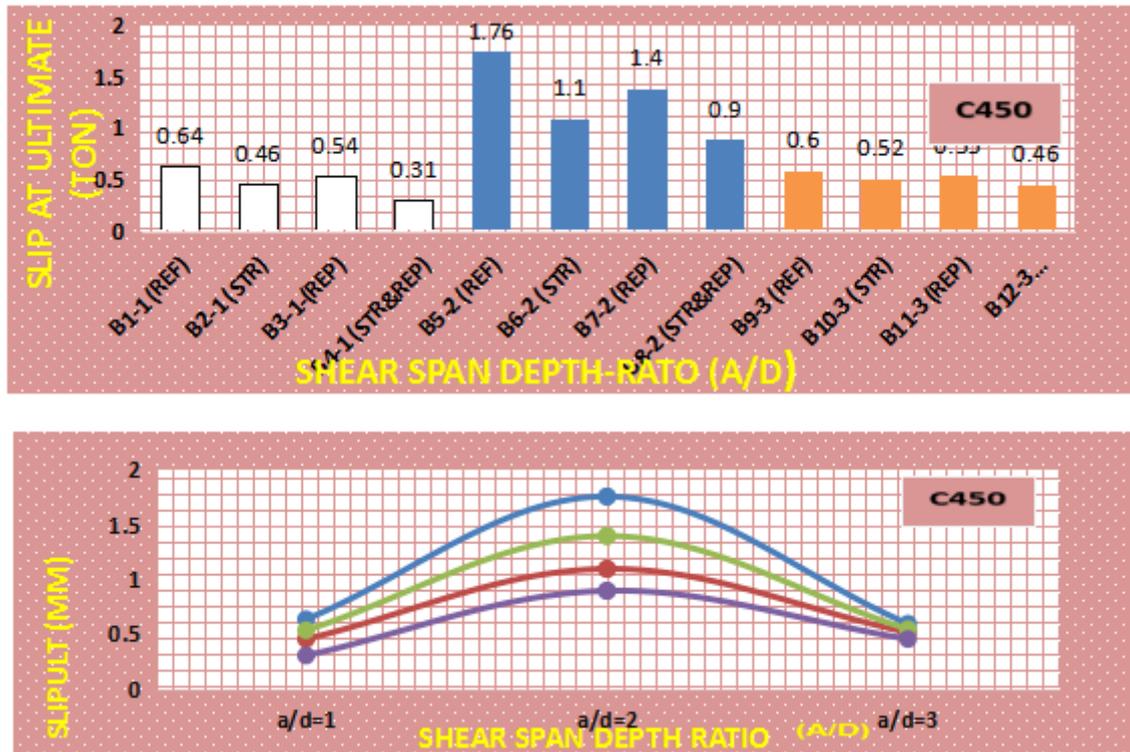


Fig (14).Slip at cracking loads (Δ cr.mm) and Ultimate loads ($\Delta u.exp$.for beams B1-1-@, B2-1-STR, B3-1-REP, B4-1-STR&REP ,group 1.) .L=92.5CM. B5-2@-, B6-2- STR, B7-2-REP., B8-2-STR&REP group 2-) .L=117.5CM. B9 .@3-B10-3- STR& .B11 -3-REP&B12-3-STR&REP .group 3-() .L=142.5CM

IV. Conclusions

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 behaviour 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

.1In plain concrete cylinder the internal injection improve the tensile strength of concrete. The concrete tensile strength increased by about .% 16.6 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 CO 2and the water steam to penetrate into the concrete element and causes the corrosion of reinforced steel.

. 2The effect of external strengthening by) CFRP (in the plain concrete cylinder is very clear. The results of indirect tensile strength by about %26.6 indicate that the positive effect of external strengthening by)CFRP.(

.3The concrete tensile strength increased by about .% 32.3 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.

.4The modulus of rupture of concrete was increased by about % 16 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.

.5Repair 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 ,(%)0.66)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.

.6In reinforced concrete the internal injection of the epoxy resin is a useful method to close the concrete crakes 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 7.66%) and also leads to increase the ultimate load carrying capacity for beams by 17% 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 14.66%)

And also leads to increase the ultimate load carrying capacity for beams by 25% for $a/d=1.0, 2.0$ and 3.0 respectively. Whether to achieve ductile or brittle behaviour 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 minima crack opening displacement; beams without crack injection showed crack opening displacements to some extent 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 noted to be increases more for repaired, strengthened by CFRP (and repaired with strengthened by CFRP (beams respectively of (groups 1, 2 (3 & as compared with reference beams B1-1, B2-5 & B3-9. Further, a decrease in the deflection was observed for these repaired beams as compared with the reference beam B1-1, B2-5 & B3-9. Crack repaired by internal injection using low viscosity epoxy strengthened by CFRP. (And repaired with strengthened by CFRP (provided an increase of stiffness in the linear region of the load–displacement curves of all repaired RC beams.

14. Up to crack, repaired beams showed average increased in energy absorption by 77% for STR (and 70.66% for REP) and 92.66% for (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 bonding between the CFRP (and the concrete. In general, the behaviour 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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