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Repair and Strengthening of Reinforced Concrete Beams by Internal Injection Different Types of Materials.

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I. Introduction

Repair and strengthening by injection materials has been widely investigated recently through many research. The aim of this research is to evaluate and analyses the behavior of tested concrete specimen and reinforced concrete beams by using different types of internal injection materials with strengthening by internal steel wires (S.W.4mm). The internal injection method in present time became very important method especially for treatment cracks in structures.

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].

Concrete flexure and shear crack varies according to its constituent's materials, concretemanufacturing, 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 elements does not have a fixed value, but it is affected by concrete compressive strength, cross section of beam, tension steel per cent, and layout of tension steel, shear span to the effective depth ratio as well as kind and distribution of web reinforcement [1-5].

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 a longitudinal wire as internal reinforcement in the longitudinal internal pipe - vents with beams tensile reinforcement and U stirrup.

In this study, it is planned to consider the effect of a variables on the repair and strengthening of concrete specimen and reinforced concrete beams by internal injection different types of materials. Three different procedures of repairing and strengthening the damaged beams are examined experimentally.

The first study with different area of main longitudinal reinforcement. The second study is repairing and strengthening includes full internal injection the longitudinal pipe-vents with different types of injected materials (Epoxy resin- Cement mortar). While the third is fixing and strengthening by uses a longitudinal wires (s.w.4mm) as internal reinforcement in the longitudinal internal pipe - vents with beams tensile reinforcement and U stirrup.

1. The concrete samples (cylinder - prisms) and reference reinforced concrete beams and steel reinforcement %.
2. The number of longitudinal holes(2 holes-4 holes-6 holes) with (8mm diameter) at different height levels for internal injection of the concrete samples (cylinder- prisms) and reinforced concrete beams.
3. The types of internal injection materials (1- Epoxy103 2-Cement mortar-3-BASF1315) for the concrete samples (cylinder- prisms) and reinforced concrete beams.
4. Internal Strengthening by steel wires (S.W. 4mm) of reinforced concrete beams with internal injection by different types of materials.

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 longitudinal wire as internal reinforcement in the longitudinal internal pipe - vents with beam tensile reinforcement and U stirrup.

Keywords: Cracks, epoxy injection, cement mortar injection, repair, and strengthening procedure.

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).

Experimental program was carried out to investigate the influence and the effect of using internal different types of internal injection materials with steel wires (S.W.4MM), as a new technical method to repair and strengthening of concrete specimens and reinforced concrete beams.

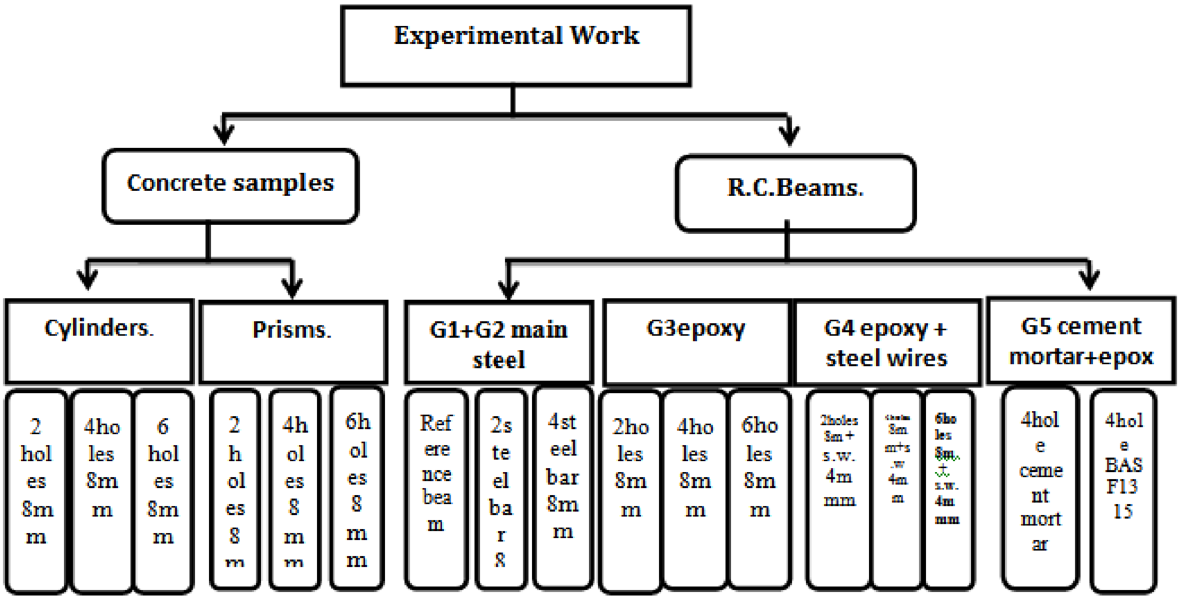


Fig. (1): The Experimental Work Program.

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 (moulds) 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.

Eleven reinforced concrete beams with constant cross-section (15x 15 cm) and length (L=135.5 cm) and effective span (L0=112.5 cm), 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 and cement - mortar 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 300 kg/cm2. (Table 1).

2.3.Injection by different types of 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 beam structure is important structures need continuous check for all members to be at good efficiency to do the demand job, which required.

Two cases of study for the 3 reinforced concrete beams, after internal injection by different types of materials and also 3 reinforced concrete beams by adding internal steel wires 4mm with internal injection type. Also 2 reinforced concrete beams with the same grade of concrete (fcu=300 kg/cm2)study after internal injection by another type of materials(cement-mortar) and the second reinforced concrete beams by adding internal steel wires 4mm with the another type of internal injection materials.

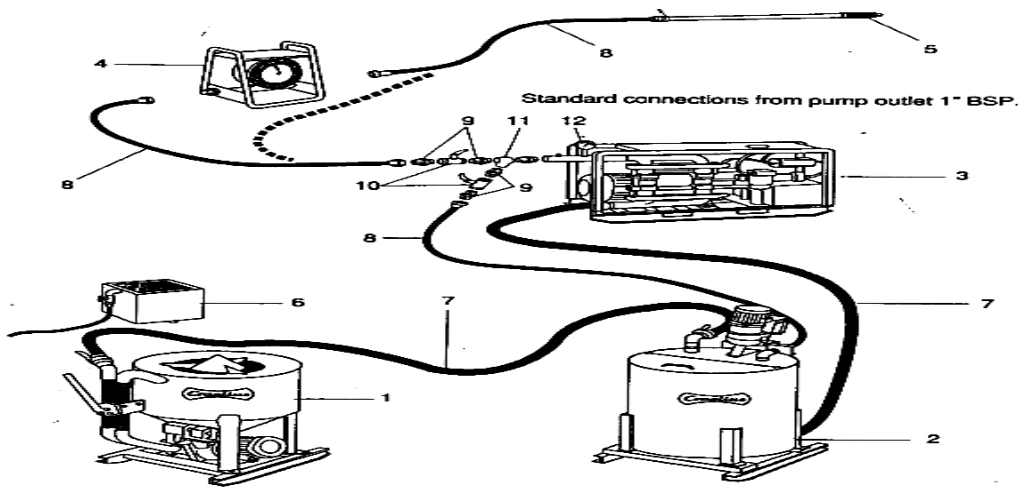
Grouting is a process in which grout in liquid form is pumped into the voids and cracks to fill the fine fissures in concrete and then hardens. The internal injection operations are very difficult and new operations in the whole world and needs specialists to do. The subsequent steps have to be made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

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 thefissures. The common diameters of the boreholes are (8 mms.).The used piping works operation is butting a bar inside the concrete works by using a steel bar with diameter 8 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. (2).

2.3.3.-Grouting operation: The grouting line, pump and the mixture with known volume tank should be prepared after the specific discharge and the (W/C) were determined.

The injection of holes is performed in intervals by fluid under specified pressures. The injection operation was done through theconcrete specimens special boreholes by pressuring the injection mixture to fill the voids, and cracks in the concreteSpecimensbody. 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.(2) shows the injection system components.



1-Mixer 2-Agitator 3-Pump 4-Recorder 5-Packers 6-Measuringtank 7-Mixer hose 8-Delivery hose 9-Nipple 10-Ballvalve 11-T-coupling 12-Presure gauge Fig. (2): 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 24 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.
b. High strength epoxy for sealing cracks inside of concrete elements and crack surface.

2.3.4.2. The cement mortar used as injected material:

Cement-mortar:Cement mortar is an intact combination of cement and sand mixed with ample amounts of water to create synthetic paste. Its adhesive characteristics vary, depending on the amount of water added the mixture. It has four basic types. "Lean" mortar has a minimal amount of cement content while the "rich" type contains a high volume of cement. "Neat" cement, on the other hand, is pure cement, meaning it has no sand content. The "aggregate" type has coarser materials, usually gravel or fragmented rock.

Beams preparation.

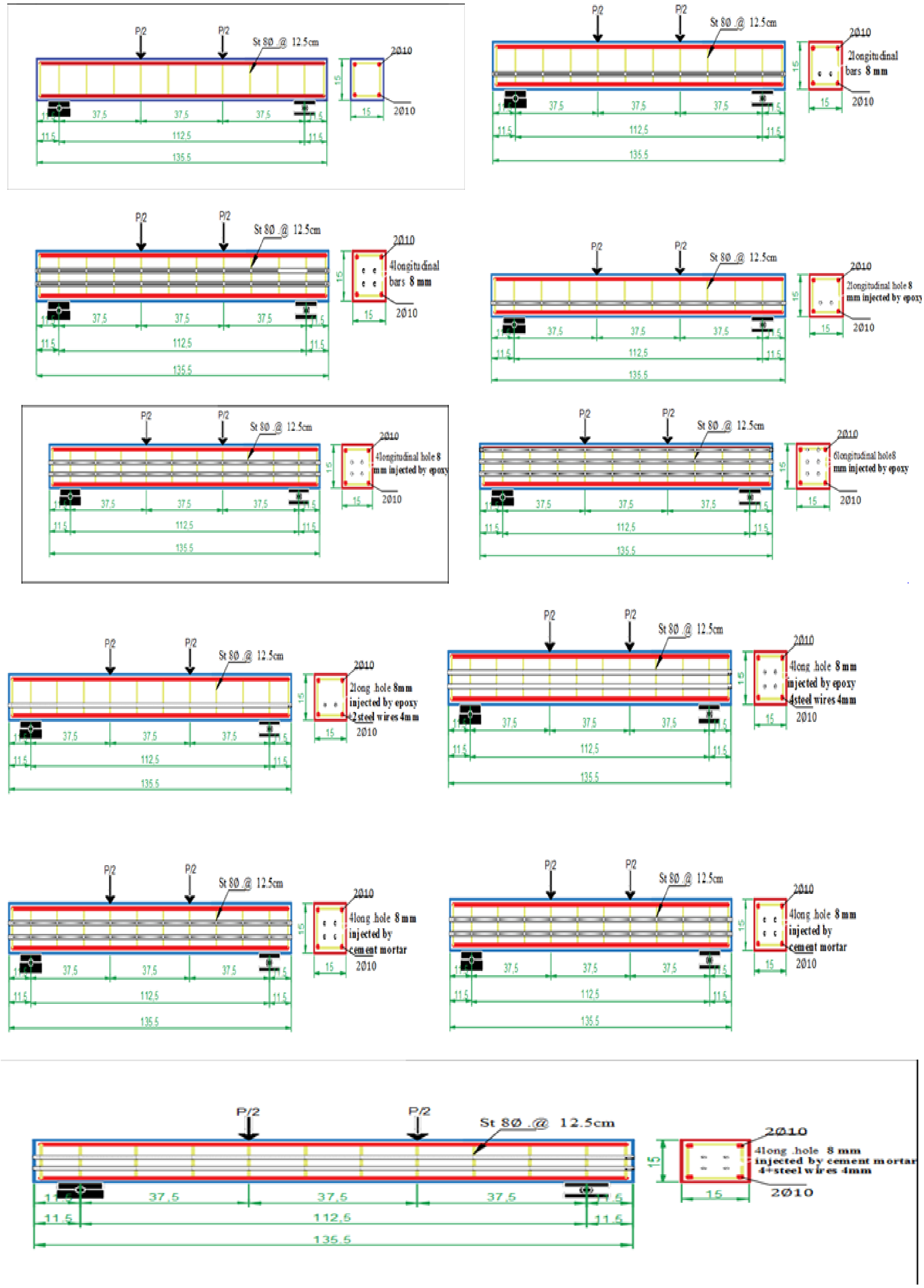


Fig.(2).Details of beams B1®,B2,B3,B4,B5,B6,B7.,B8.,B9.,B10.,&B11.

Table. (1) Details of the tested beams

Group	Beam Name	L(cm)	L0 (cm)	Shear-span (a)	d(cm)	a/d	As (∅) mm	INJECTION TYPE	STRENGTHENING	As'(∅) mm	Fcu. Kg/cm2
G1	B1®	135.5	112.5	37.5	12.5	3,0	2∅10	WITHOUT	WITHOUT	2∅10	300
G2	B2.	135.5	112.5	37.5	12.5	3,0	2∅10+2 ∅8mm	WITHOUT	WITHOUT	2∅10	300
	B3.	135.5	112.5	37.5	12.5	3,0	2∅10 + 4 ∅8mm	WITHOUT	WITHOUT	2∅10	
G3	B4.	135.5	112.5	37.5	12.5	3,0	2∅10	2∅8 holes Inj. epoxy	WITHOUT	2∅10	300
	B5.	135.5	112.5	37.5	12.5	3,0	2∅10	4∅8 holes Inj. epoxy	WITHOUT	2∅10	
	B6.	135.5	112.5	37.5	12.5	3,0	2∅10	6∅8 holes Inj. epoxy	WITHOUT	2∅10	
G4	B7.	135.5	112.5	37.5	12.5	3,0	2∅10	2∅8 holes Inj. epoxy	2∅4 mm S.W	2∅10	300
	B8.	135.5	112.5	37.5	12.5	3,0	2∅10	4∅8 holes Inj. epoxy	4∅4 mm S.W.	2∅10	
	B9.	135.5	112.5	37.5	12.5	3,0	2∅10	6∅8 holes Inj. epoxy	6∅4 mm S.W.	2∅10	
G5	B10.	135.5	112.5	37.5	12.5	3,0	2∅10	4∅8 Iholes Inj. cement M.	WITHOUT	2∅10	300
	B11.	135.5	112.5	37.5	12.5	3,0	2∅10	4∅8 holes Inj. Basf 1315.	4∅4 MMsw	2∅10	

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 tensile strength increased by about 25 % .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 CO_2 and the water steam to penetrate into the concrete element and causes the corrosion of reinforced steel Fig.(4)**.**

Fig.(4)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 2, 4 and 6 holes. The modulus of rupture of the concrete prisms after internal injection of epoxy resin was determined Fig.(5).

Fig.(5)Plainconcreteprismsflexuralstrengthwith internalinjectionbyepoxy.

The modulus of rupture of concrete was increased by about 46 % due to theinternal injection. The internal injection throw 2 holes increase the modulus of rupture by about 48.5% .The internal injection throw 4and 6 holes caused an increase of 45 % and 47 % respectively, this that indicated that internal injection throw lesser holes is best than using more holes because the more holes may be disturbed the internal structure of concrete which is the main in the bond of concrete materials.

In reinforced concrete the internal injection of the epoxy resin is auseful method to close the concrete crakes and achieve the protection to the reinforcement.

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.

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. In fact 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. (6). the final mode of failure of all beams was noticed to be flexural - compression failure.

The values of cracking, injection and ultimate loads (Pcr, Pinj. &Pu) for the beams (B1®), (B2),& (B3), were tested to study the effect of steel reinforcement ratio as % and these beams had a solid beams cross sections and without injected materials .The beam (B1®)used as reference beam.

The beams (B4), (B5), (B6), (B7, (B8), (B9), (B10). and (B11) had many parameters for internal injection and strengthening technique after cracks reached a width equal to 1.0 mm approximately at loads equal to 5.8,4.5,4.5,5.8,5.2,5.5,4.95,&4.4 ton respectively.

The values of ultimate loads (Pu.) increase with the increase of the beam steel reinforcement ratio. The beams (B1®), (B2),& (B3), were tested to study the effect of steel reinforcement ratio as % .These beams had a solid cross section and without injection .The beam (B1®)used as reference beam. The percentage increase of ultimate load for B2 (27 %), and for B3 (26%) than that the ultimate load of reference beam B1®.

The values of ultimate loads (Pu.) increase for the reinforced concrete beam B4 (2Ø 10 mm+2Ø longitudinal holes 8 mm)with small number of holes internally injected by epoxy than that for the reinforced concrete beam B5 by (2Ø 10+4 longitudinal holes Ø 8 mm)&B6 (2Ø 10 mm+6 longitudinal holes Ø 8 mm). The percentage increase of ultimate loads (Pu.) for beams B4(24%), forB5 (23%) and for B6 (22%) than the reference beam B1® in Table (2).

The values of ultimate loads (Pu.) increase for the beam(B7)reinforced by (2Ø 10 mm+2 longitudinal holes Ø 8 mm +2 Ø 4 mm s.w.) with small number of holes internal injected by epoxy than that for the beams(B8) reinforced by(2Ø 10+4 longitudinal holes Ø 8 mm +4 Ø 4 mm s.w.).& beam (B9) reinforced with (2Ø10+6 longitudinal holes Ø 8 mm +6 Ø 4 mm s.w.). The percentage increase for ultimate loads (Pu.) of beams B7 (32.5%), for B8 (29.7%) and for B9 (27%) than the reference beam B1®.

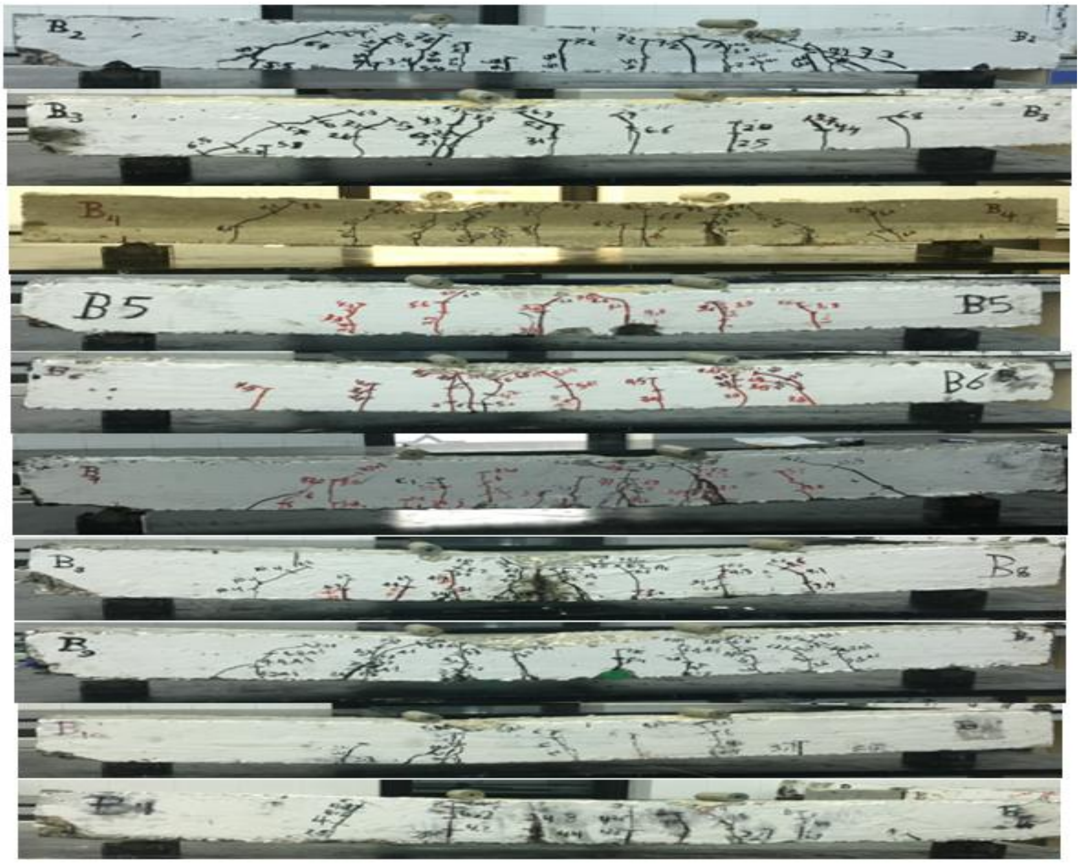


Fig: (6) Pattern of crack of beams B1®,B2,B3,B4,B5,B6,B7,B8,B9,B10 &B11.

The values of ultimate loads (Pu.) for the beams reinforced with (2∅ 10 mm+4 longitudinal holes∅ 8 mm.)with the same number of 4 holes the percentage increase for B10 (18 %), and for B11 (20 %) than the reference beam B1®.

Lab experiments were under-taken 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 varies depending on the epoxy type and application methods. If suitable epoxy resin is used and applied properly, the structural strength and continuity of the concrete beams can be fully reinstated. It was also found that most likely the viscosity of epoxy is more important than its tensile or compressive strength. In other words, 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.

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 reinforcement ratio or internal injected materials types and also internal strengthening by 2,4and 6 steel wires (S.W. 4mm) in one, two and three rose were studied. 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).

By applying epoxy by internal injection technique, an increase in mid-span deflection at crack load was noted to be 70 %, 96 %, and 138% for repaired beams (B4, B5 and B6) respectively. Mid span deflection at failure was observed to be 53 %, 69.4 % and 82.2 % more for repaired beams (B4, B5 and B7) as compared with reference beam B1®. Increase in beam capacity along with enhancement in deflection is an indication of comparatively ductile behaviour of R.C. beams.

Also by applying epoxy by internal injection technique with adding steel wires 4 mm, an increase in mid-span deflection at crack load was noted to be 0.0 %,45 %, and 68% for repaired beams (B4, B5 and B7) respectively. Mid span deflection at failure was observed to be 65.9 %, 81.8 % and 102 % more for repaired beams (B7, B8 and B9) as compared with reference beam of B1®. Increase in beam capacity along with enhancement in deflection is an indication of comparatively ductile behaviour of R.C. beams Fig. (7&8).

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 been70%, 68%, and 138 % along with total energy absorption capacity by reference beam (B1®). It can be seen that beams of (group 3) showed an increase in energy absorption up to a crack load as well as up to failure as compared to the reference beam (B1®). Up to a crack load, this increase in average energy absorption repaired beams for was found to be 91 %, 97% and 83%for reference beam respectively. As an average, repaired R.C. beams of (group 3. (B4, B5 and B6)) exhibited 90.33% more energy absorption capacity as compared with reference beam (B1®) up to failure. This enhancement in energy absorption could be due to the presence of internal injection provided in beams of (group 3. (B4, B5 and B6))which resulted in bridging across the crack surface. These very low values recorded for beams of B1® are responsible of their relatively low ductility and comparatively in adequate warning prior to failure observed during testingup to cracking load, repaired beams (group 4) showed increased energy absorption (0.0 % for B7, 45% for B8 and 68% for B9) as compared with reference beams (B1®). This is due to effectiveness of epoxy injection technique used in repairing the beams. Repaired beams exhibited more energy absorption even beyond the development of cracking load. This increase in energy absorption beyond the development of cracking load in (group 4) 154 % for B7, 159 for B8 and 178% for B9) respectively.

Beams of (group 4) absorbed high total energy as compared with beams of repaired beams (group 3). In essence, the ability of R.C. beams to absorb total energy before failure is due to its performance during which the included steel wires (4mm S.W.) and with epoxy materials internal injected in longitudinal holes serve to prevent concrete failure and separation. It is well known that the higher the absorbed energy, the higher the capacity to resist load. Since the energy absorbed is a function of the applied load and ultimate displacements, it is affected by factors that affect load carrying capacity in beams such as the number of longitudinal vents internally injected .It, therefore, follows that beams with steel wires (4mmS.W.) will absorb higher energy compared with those of similar characteristics but without injection. These results concluded that epoxy by internal injection along the holes is capable of substantially increasing the load capacity, ductility and energy absorbing capacity Fig(9&10).

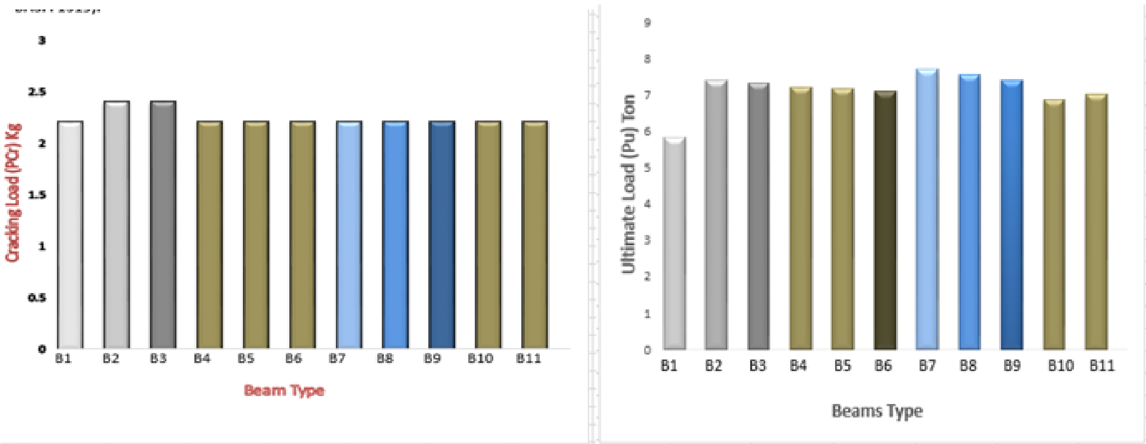


Fig: (7) Cracking and Ultimate Loads for beams B1®,B2,B3,B4,B5,B6,B7,B8,B9,B10 &B11.

IV. Conclusion

The study concluded the effect of internal injection and strengthening by different types of materials on the several variables, which were studied. On the basis of the results obtained from this research work the experimental results indicated that sealing the existing cracks by epoxy internal injection is an effective method to repair the cracked of R.C. beams since it reduced the deflection under allowable value (5 mm).

Epoxy injection does not increase the weight of beams very much and effectively increase the deflections of repaired beams, so it can be used to successfully repair the cracked of R.C. beams and the following conclusions can be drawn:

1. In plain concrete the internal injection improve the tensile strength of concrete. The concrete tensile strength increased by about 25 % .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.
2. The modulus of rupture of concrete was increased by about 46 % due to the internal injection. The internal injection throw 2 holes increase the modulus of rupture by about 48.5% & throw 4and 6 holes caused an increase of 45 % and 47 % respectively, this indicated that internal injection throw lesser holes is best than using

more holes because the more holes may be disturbed the internal structure of concrete which is the main in the bond of concrete materials.
3.The internal injection by different types of materials through the cracked reinforced concrete beams needs check from all the variables of injection like the path of internal injection mixture, the pressure used, viscosity of mixture and so on.
4. Repair of R.C. beams with epoxy by internal injection technique is effective for control the cracks and leads to increase load carrying capacity by 22.0 %.to 24.0 %.
5. Repair of R.C. beams with epoxy by internal injection technique and strengthening by 4 mm S.W. is more effective for control the cracks and leads to increase load carrying capacity by 27.0% to 32.5%.
6. The repaired beams were observed more ductile as compared to the control beams. This is a result of the increased of deflection values for repaired beams as compared to the control beam.
7. Beams failed due to opening of repaired cracked which strongly recommended that epoxy by internal injection technique is very efficient in the repair of cracked concrete structure.
8. In this experimental work one thing was observed that when load from the beams was removed, crack width decreases to a certain value due to which less epoxy was internally injected to crack. 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.
9. The results showed that the performance of the repaired beams varies depending on the epoxy type and application methods. If suitable epoxy resin is used and applied properly, the structural strength and continuity of the concrete beams can be fully reinstated.
10. It was also found that most likely the viscosity of epoxy is more important than its tensile or compressive strength. In other words, 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.

11. Principal tensile stress at failure was noted to be 23 %, 30 % and 19% more for repaired beams of (groups 3, 4 and 5) as compared with reference beam B1®. Further, a continuous increase in the deflection was observed for these repaired beams of groups 3&4&5 as compared with the reference beam B1®.
12. Up to crack width of 1 mm, repaired beams showed average increased in energy absorption by 101% for (group3), and 37.67 % 34.5% for (group4& 5) as compared with reference beams B1®.Also up to failure repaired beams showed average increased in energy absorption by 90.33% for (group 3), 163.67 % for (group4) and 80.5% for (group 5) as compared with reference beams B1®.
13. In 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 by different types of materials for repairing the R.C. structures is very effective ways due to the depression of the epoxy and grouting mix through the body is enough.
14. For successfully internal injection operation by different types of materials it is required to following the suitable system and must design suitable program with successive study steps for repairing.

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