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"REPAIR OF CRACK IN CONCRETE STRUCTURE BY EPOXY RESIN"

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Abstract- Cracks in building are a common occurrence. It affects the stability and appearance of buildings. So, it is important to understand the cause of cracks and the effective measures should be taken for prevention. Though cracks in concrete cannot be prevented entirely but they can be prevented by using proper material and technique of construction and considering criteria. Sometimes water penetrates through cracks in building and cause severe damage to building. There are many reason of occurrence of cracks like moisture, thermal movement, elastic deformation, chemical reaction, foundation movement, vegetation and earthquake. We all dream of a house structurally safe and aesthetically beautiful but it is not so easy. So, timely identification of such cracks and adopting preventive measures is essential. In this work, we will discuss about the methodology for prevention and repair of cracks in building. Strength of concrete is also an influencing factor for repairing cracks in building. Epoxy repair methods for concrete are becoming widely popular in Malaysia. The current assessment for repair is not accurate and lack of accumulative research data. Moreover, most of the repair methods for concrete is done based on deemed- to-satisfy method based on readily available proprietary repair systems. The work presented provides additional information on the assessment and repair of cracks for concrete. Upon 28 days and 56 days of curing, the cubes, beams, and cylinders undergoes the compression test, flexural strength, and split tensile strength however, the compression test, flexural test, and split tensile test will be timed and monitored only until obvious cracks appears from the author's naked eyes. At this juncture the universal Testing Machine's (UTM) power will be killed immediately and the sample removed thereafter. The samples will be repaired by applying epoxy at cracks and will be left for drying at ambient temperature in the laboratory. The repaired sample will be once again tested under compression, flexural, and split tensile test using UTM, however, at this pointthe sample will be tested until failure and the strength recorded. The outcome suggests that the repair method using epoxy wasable to sustain at least 80% to 85% of total strength achieved when cracks appeared during testing.

Keywords: Concrete, cracks, and epoxy

1. INTRODUCTION –

Concrete inherits certain type of cracks in pre-hardening stage and also develops some other types of cracks in post hardening stage in due course of time due to various reasons, despite our utmost care in prevention of cracks. While concrete becomes older, these cracks become sources, of leakages and see pages and give easy access to the moisture, oxygen, chloride, carbon dioxide, and other aggressive chemicals and gases into the concrete leading to serious degradation of the structure and causing corrosion of steel and damage in the concrete in the form of spalling etc. and subsequently causing structural failure of the member. Cracking is the initial sign of distress of the structure baring other forms of distress and deterioration like deformation, surface deposits and construction defects etc. causing damage to structural strength, durability and serviceability. Cracks are some of the problem that always occurs at the building.

Cracks can be seen easily because it is physical properties of the building, but sometime cracks can also occur inside the concrete and cannot be seen. This is more dangerous because we do not know whether the building is safe or not. It is very common of concrete to sustain cracks.There is no perfect mixture of concrete. There are several reasons that cause concrete cracks. Firstly, the excess waterin the mixture. Concrete does not need too much water inside the mixture. Nowadays, the concrete used in site has too much water added in the mixture. The more wateradded inside, the higher the shrinkage happen. When the concrete dried and harden, the shrinkage will happen due to the evaporation of the excess water and can cause the early age of crack on the concrete. The excess of water canreduce the concrete strength. Secondly, concrete cracks due to improper strength concrete mixture. Cracks can be divided into two types which are non-structural cracks and structural cracks. A structural crack means it crack due to the incorrect design and faulty in construction or overloading

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This type of crack may endangered the safety of the building itself. While a non-structural crack means crack due to induced stresses inside the concrete but it is generally do not affect the weakness of the building. Moreover, non-structural cracks may because of theenvironmental value such as weathering, corrosion of reinforcement and shrinkage. Crack often happen in concrete building. Cracks happen due to temperature, volume change, drying shrinkage, thermal contraction and many more. The crack needs to be repaired in order to maintain our reputation, aesthetic value, and even to decrease the amount of fatal accident such as collapse's of building. This study used epoxy resin for concrete repair. Epoxy resin used was in the form of sticky-liquid form Conbextra EP10(M) . Conbextra EP10(M) is a solvent free that also contain epoxy. This Conbextra EP10(M) have a lot of advantages which are harden without shrinkage, easy to apply, high strength, and high humidity could not be affected by the hardening. In present work used 1:3 ratio of compartment of Conbextra EP10(M) A and Conbextra EP10(M) B. Epoxy resins are also known as poly epoxides, there are in a class of reactive pre-polymers and polymers which include epoxide groups.

2. CRACK CATEGORIZATION:

Cracks develop due to deterioration of concrete or corrosion or reinforcement bars due to poor construction or inappropriate selection of constituent material and by temperature and shrinkage effects. Internally induced stresses in building components lead to dimensional changes and whenever there is a restraint to movement as is generally the case cracking occurs. Depending on width of crack, these are classified as follows:

Table 1.1 Classification of cracks based on width

Types of Crack	Crack width
Thin	<1mm
Medium	1mm to 2mm
Wide	> 2mm wide

According to IS: 456 2000, the surface width of crack should not exceed 0.3mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel, nor upon the durability of the structures. In the members where cracking in tensile zone is harmful either because they are exposed to moisture or in contact of soil or ground water, an upper limit of 0.2mm is suggested for maximum width of crack. For particularly aggressive environment such as the 'severe' category, the assessed surface width of crack should not in exceed 0.1mm.

Cracking in reinforced concrete structures of various types can be divided into two main groups:

A. Non-structural Cracks

These type of crack occur mostly due to internally induced stresses in building material and normally do not endanger safety but may look unsightly, create impression of faulty work or give feeling of instability. Crack on wall, parapet wall, driveway are called non-structural cracks.

B. Structural Cracks

Structural cracks results from incorrect design, faulty construction or overloading and may endanger the safety of a building. The cracks in beam, column, slab and footing are considered as structural cracks.

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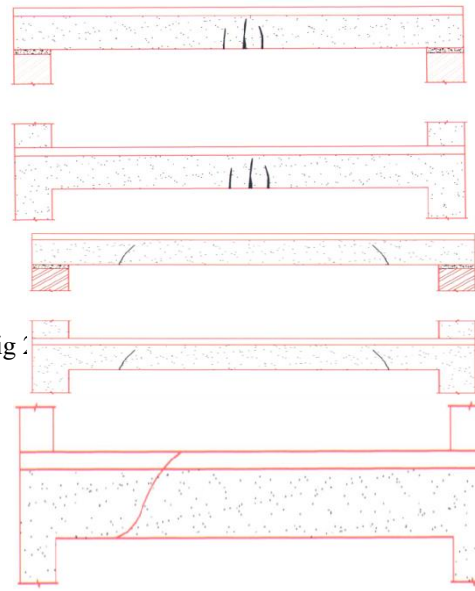

[13]

Fig 2.4 Flexural c

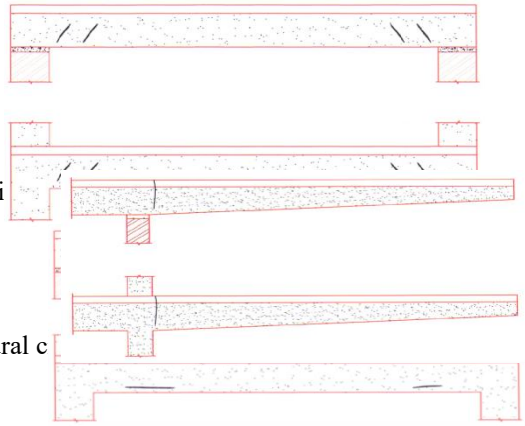

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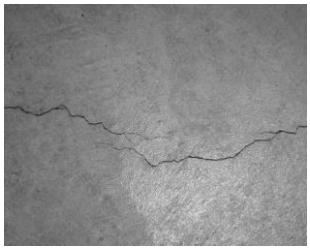
Fig 2.6 Bond cracks in beams[13]

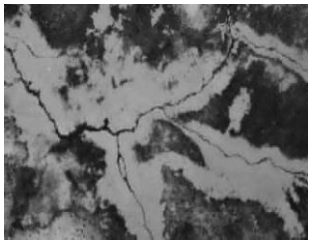
Structural cracks



Non-Structural cracks

Heaving concrete cracks

Creep movement

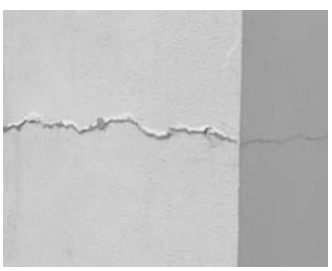


Moisture movement

Settling concrete cracks

Plastic shrinkage concrete cracks

Expansion concrete cracks



Thermal Movement

Fig 2.7 structural and nonstructural cracks [13]

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3. EPOXY RESIN:

Epoxy is the family of basic components or cured end products of epoxy resins. Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. The epoxide functional group is also collectively called epoxy. The IUPAC name for an epoxide group is an oxirane.

Concrete cracks are repaired using different techniques and methods, such as epoxy injection depending on how wide, long, and/or deep the crack is. Most of the concrete cracks are related to shrinkage, heat, wrong joint placements, over stress and loading conditions and movements caused by external factors. Some of these repairs are completed by using epoxy injections applied directly to the crack. The procedure is different and varies depending on the crack location and whether the concrete cracks are horizontal or vertical.

Some cracks might require additional steps, but this article will focus on concrete cracks repaired using epoxy. The recommended process of injecting epoxy into cracks might vary but here are some general recommendations to follow when repairing concrete cracks.

Epoxy is known as polyepoxide, is a thermosetting polymer formed from reaction of an epoxide "resin" with polyamine"hardener". Epoxy is a co-polymer, means that it is formed from two different chemicals. These are referred to as the "resin" or "compound" and the "hardener" or "activator". Epoxy resin is a kind of thermosetting (solid) resin. When main agent is blended with the hardener of appropriate ratio, after cross linkage for hardening, a network structure of three-dimensional space is formed. Therefore, this product has equipped with a special physical property, mechanical property, and chemicals-resistant, etc. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols (usually called mercaptans). These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing.

4. REPAIR AND REHABILITATION:

Concrete is the most widely used and versatile construction material possessing several advantages over steel and other construction material. Very often one comes across with some defects in concrete they are in the form of cracks, spelling of concrete, exposure of reinforcement, excessive deflections or other signs of distress. Corrosion of reinforcement may trigger off cracking and spelling of concrete, coupled with deterioration in the strength of the structure such situations call for repairs of affected zones and sometimes for replacements of entire structure.

Repair is the process of restoring something that is damaged or deteriorated or broken to good condition. Repairs are performed on damaged buildings to restore the strength after disaster. Rehabilitation is the process of restoring the structure to service level, once it involves the upgrading or changing of a building's foundation in support of changes desired, its use, design goals or regulatory requirements. Assessing the existing condition of the structure and deciding which component of the structure should be repaired or restored based on all future requirement of the structure. Need for repair and rehabilitation of structures:

- Faulty design of the structure
- Improper execution and bad workmanship
- Extreme weathering and environmental conditions
- High degree of chemical attack
- Ageing of structures

5. CAUSES OF CRACK ON CONCRETE:

Principal causes of the incidence of cracks in the buildings are as follows:-

a) Moisture variant:

Building materials majorly have pores in their burnt clay bricks, mortar, some stones and many others. These substances enlarge on soaking up moisture and settlement or reduce on drying.

The diverse outcomes of moisture adjustments are:-

a) Initial shrinkage.

b) Reversible motion.

This is one of the most important causes of cracking in building. Thermal movement largely depends on several factors such as variation in temperature, co-efficient of thermal expansion and other physical properties of the components. Thermal variation in the internal walls and internal floors of the building are not much and thus do not cause much cracking. It is majorly the external walls and the roofs which are exposed to several physical factors and are subjected to substantial thermal variation that are liable to cracking.

b) Excess water in the mix:

Concrete does not require much water to achieve maximum strength. But a wide majority of concrete used in residential work has too much water added to the concrete on the job site. This water is added to make the concrete easier to install. This excess water also greatly reduces the strength of the concrete.

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Shrinkage is a main cause of cracking. As concrete hardens and dries it shrinks. This is due to the evaporation of excess mixing water. The wetter or soupier the concrete mix, the greater the shrinkage will be. Concrete slabs can shrink as much as 1/2 inch per 100 feet. This shrinkage causes forces in the concrete which literally pull the slab apart. Cracks are the end result of these forces.

The bottom line is a low water to cement ratio is the number one issue effecting concrete quality- and excess water reduces this ratio.

c) Rapid drying of the concrete:

Also, rapid drying of the slab will significantly increase the possibility of cracking. The chemical reaction, which causes concrete to go from the liquid or plastic state to a solid state, requires water. This chemical reaction, or hydration, continues to occur for days and weeks after you pour the concrete. You can make sure that the necessary water is available for this reaction by adequately curing the slab.

d) Improper strength concrete poured on the job:

Concrete is available in many different strengths. Verify what strength of the concrete you are pouring on job should be poured as per design strength.

e) Lack of control joints:

Control joints help concrete crack where you want it to. The joints should be of the depth of the slab and no more than 2-3 times (in feet) of the thickness of the concrete (in inches).

6. THE PURPOSE OF THE PRESENT STUDY

The purpose of this study is to analyze cracks in concrete structure and to repair the different types of cracks produced on concrete surface by using an epoxy resin, including suggesting the remedial measures required if any

LITERATURE REVIEW

1 **Camille A. Issa et.al. [2007]**

The main purpose of this study is to experiment with the use of epoxy compounds to restore the integrity of a cracked member by gravity filling of the crack, emphasizing on the physical characteristics of epoxies as well as the importance of surface preparation, temperature conditioning of the substrate and epoxy compound, and alterations of the hardening rate of epoxies. Furthermore, all lab tests and results on concrete cubes will be fully documented and interpreted.

From the experimental results, it was proved that a crack reduces strength; a reduction in strength of 40.93% was obtained due to D1 cracks and 32.71% due to D2 cracks. Consequently, cracks in concrete structures should not be taken for granted, but on the contrary, they must be inspected and repaired. Several methods are used in crack repair. Based on the careful evaluation of the extent and cause of cracking and depending on the nature of the damage, one or more repair methods may be selected. If repair is required to restore structural integrity of a crack, it should be repaired with epoxy. Epoxy adhesives are the most common adhesives used for crack either by injection (Epoxy injection method) or by gravity flow (Gravity filling method). The use of epoxy in repairing the cracks of cubes D1 and D2 by the gravity filling method was a success. The percent reduction in compressive strength of cube D1 + E (i.e., cube D1 filled with epoxy) was 11.25% compared with 40.93% reduction for cube D1, whereas the percent reduction in compressive strength of cube D2 + E (i.e., cube D2 repaired with epoxy) was 8.23% compared with 32.71% reduction for cube D2. Thus, the use of epoxy can increase tensile and compressive strengths across a crack, if further cracking is not anticipated. However, the use of epoxy alone might not be sufficient sometimes to restore the damage in a structure, but it will be necessary to use other repair methods in addition such as additional reinforcement or using post-tensioning. Finally, proper preparation of a given surface is an art and a science and must be given careful attention because irreversible damage can be done to the bond with the substrate or the epoxy itself, resulting in lower strength

2 Saeed Ahmad et.al. [2013]

The research reported in this paper is a contribution in understanding the epoxy injection retrofitting technique to strengthen the existing RC cracked members. This technique consists of injecting epoxy resin adhesive in a cracked beam to increase the stiffness and the strength. A considerable enhancement in the load carrying capacity was observed in the beams after the retrofitting. A reduction in deflection was also observed due to the injection of epoxy. On the basis of the results obtained from this research work, the following conclusions can be drawn: RC beams can be strengthened by repairing the existing flexural and shear cracks with epoxy injection and this can lead to a considerable (49 %) increase in the load carrying capacity. Up to crack width of 1 mm, repaired beams showed increased energy absorption as compared with control beams.

3 Renga Rao Krishnamoorthy et al. [2013]

From this researches, the conclusion that can be made based on the test results that obtained from the test are the maximum strength achieved at crack initiation for different water cement ratio was observed. The higher the water cement ratio, the lower the maximum strength achieved. For example, for 0.60 water cement ratio, it only achieved 30.42 KN, while for

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0.45 water cement ratio, it achieved at about 46.19 KN whereas the failure limit of 0.60 and 0.45 water cement ratio are at 36.78 KN and 53.21 KN. This is because the water content inside the concrete affect the strength itself. In order to have good quality of concrete, water cement ratio is very important to be considered to have strong and safe building. Moreover, this research shows the repairing of concrete cracks using epoxy. The used of epoxy as a crack sealant can save the cost of maintenance of a building. In addition, epoxy was applied at the crack in order to combine back the concrete by using injection method. Furthermore, the cracks had been injected with the epoxy and had been tested using the compressive strength test machine. From this research, the strength of repaired concrete after applying epoxy are quite relevent. As in the result above, the percentages reduction of concrete strength before and after applying epoxy is only at range of 14 to 21%.

4 R. K. GHOS [2014]

For outdoor works in tropical countries such as India, the amount of curing agent are required to be admixed with epoxy resin was found to be 4 to 5 hr instead of the 9 hr used in colder climates and for indoor works. In the case of polyester resin, the quantity of accelerator necessary was 0.5 ml per 100 ml of the resin. Higher amounts of curing agent or accelerator not only decreased the pot life of the formulation considerably thus making its use uneconomical, but also resulted in increased void content and only inconsiderable gain in strength. For high early strength, polyester resin mortar was found to be preferable. Mortar mixes leaner than 1:4 were found to be unsuitable for repair work. Curing at temperatures up to 1000 C was beneficial but higher temperatures affected the strengths adversely. With dry surfaces of concrete, both resin mortars gave good bond. These mortars were, however, susceptible to alternate heating and cooling, alternate freezing and thawing, and continued contact with moisture, although the effect on polyester resin mortar was more severe. In rigid overlay construction involving laying of green concrete over the old concrete surface, only epoxy resin formulation could come in question as bonding media In repair of cracks and low spots, both types of resin mortars could be used

5 David de Almeida Araújo [2017]

The use of epoxy resins by injection or just by sealing constitutes the most common solution for cracks repair. However, epoxy resins products are not able to fix properly all cracking problems, such as active cracking or in the presence of moisture. For this purpose, the existence of polyurethane and acrylic resins is a good solution to solve these problems. This paper describes, briefly, the reinforced concrete structures behavior towards the most common anomaly, cracking, detailing cracks causes and characteristics. Then, a review of standard EN 1504 is presented, concerning products performance requirements, conformity assessment and test methods. Further, injection materials, equipment, methods and procedures are also described. Lastly, a case study is presented: a project that involved the repair of cracks in a reinforced concrete tunnel, using different techniques and materials. Injection systems with resins are the most common technology for cracks repair, because the injection process is simple and expeditious and resin materials characteristics provide solutions with quality assurance. Among the injection resin products, the most used over the past years are the epoxy ones. If it is necessary to restore structural rigidity, the use of epoxy resins is generally the most suitable. However, epoxies cannot effectively repair all cracking problems, depending on cracks characteristics and structure conditions. That is why the injection products development like polyurethane and acrylic resins was very important, providing solutions with materials with different properties and characteristics, to solve many problems which epoxy resin cannot solve..

6 Nur Farhayu Ariffin [2017]

Formation of cracks due to the shrinkage effects during curing and mechanical loading can deteriorate the concrete performance especially in terms of durability aspect. Chemical and harsh solutions will easily penetrate into the concrete and cause damage to the concrete. In order to solve this problem, researchers have introduced a selfhealing concrete; the mechanism of automatically repairing concrete cracks without external intervention. Nowadays, the self-healing concrete by using bacteria as a healing agent had gained interest among researchers. In contrast, this paper presents the study on performance of epoxy resin without hardener as a self-healing agent in concrete. Mortar specimens were prepared with mass ratio of 1:3 (cement: fine aggregates), water-cement ratio of 0.48 and 5 to 20% epoxy resin of cement content. All tested specimens were subjected to wet-dry curing; where compressive strength, apparent porosity and self-healing evaluation were measured. Result shows that, the compressive strength of mortar with addition of epoxy resin by 10% increased significantly compared to normal mortar. Epoxy resin as a healing agent was found to be functioned well as the compressive strength and ultrasonic pulse velocity regain the initial reading with prolonged curing time. These results together with microstructure test indicate that epoxy resin can be used as a self healing agent.

7 Nalini.Set.al [2017]

The main aim of the present investigation is to increase the strength of Concrete cubes when it is subjected to heavy loads by using injection technique. In the Project work, we use epoxy resin in repair works. Epoxy resin is the bonding material. The use of epoxy is to seal the cracks, Bolt anchoring, Base plate levelling and Acidic environments. The epoxy resins are widely used in repairing of cracks, Patching and grouting of concrete, Industrial Flooring, of concrete, Structural adhesives, Anticorrosive linings, etc. In this study, eighteen concrete cubes were casted and tested after proper on curing of concrete cubes at 21 days. Nine cubes were normal testing cubes, Nine cubes were three cubes were epoxy resin injected cubes for 7, 14 and 21 days. After curing took place the cubes were tested for compressive strength and the results

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obtained have been compared. From this paper we have concluded following points 1. Epoxy materials achieved the objective of increasing strength with a negligible change of global mass. 2. External confinement of concrete specimen with Epoxy resulted in an increase in the strength and ductility. 3. Epoxy strengthening of concrete cubes improves the strength than that of the conventional concrete cubes. So it can be used as an alternative strengthening method 4. The provision of injection resulted in a substantial reduction in the measurement of cracked concrete specimens. 5. Epoxy Resin is the best material to give more strength compared to other injecting materials.

8 Abdul Rahman Mohd. Sam et.al. [2017]

Formation of cracks due to the shrinkage effects during curing and mechanical loading can deteriorate the concrete performance especially in terms of durability aspect. Chemical and harsh solutions will easily penetrate into the concrete and cause damage to the concrete. In order to solve this problem, researchers have introduced a selfhealing concrete; the mechanism of automatically repairing concrete cracks without external intervention. Nowadays, the self-healing concrete by using bacteria as a healing agent had gained interest among researchers. In contrast, this paper presents the study on performance of epoxy resin without hardener as a self-healing agent in concrete. Mortar specimens were prepared with mass ratio of 1:3 (cement: fine aggregates), water-cement ratio of 0.48 and 5 to 20% epoxy resin of cement content. All tested specimens were subjected to wet-dry curing; where compressive strength, apparent porosity and self-healing evaluation were measured. Result shows that, the compressive strength of mortar with addition of epoxy resin by 10% increased significantly compared to normal mortar. Epoxy resin as a healing agent was found to be functioned well as the compressive strength and ultrasonic pulse velocity regain the initial reading with prolonged curing time. These results together with microstructure test indicate that epoxy resin can be used as a self-healing agent.

9 Dr Hossein Askarinejad et. al. [2017]

The use of epoxy resins for repairing concrete cracks is a common method to restore cracked concrete structures. In this paper, the effectiveness of three chosen brands of epoxy which are commonly used in industry in New Zealand to repair cracked concrete beams are investigated. Multiple unreinforced concrete beams were tested before and after epoxy repair under vertical loads (flexural load) to determine the effectiveness of the epoxy to restore the structural strength or continuity of the beams. The tests were conducted using the third-point loading method applying a constant bending moment to the middle segment of the beam span. The results showed that the performance of the repaired beams varies depending on the epoxy type and application methods. It is demonstrated that the viscosity of epoxy is critical to ensure full bonding and in turn reinstating the capacity of the cracked sections. 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.

10 Mr. Shyam Doshi et.al.[2018]

In this paper, they have discuss about the methodology for prevention and repair of cracks in building. This research paper also gives information about result of Rebound Hammer Test and Ultrasonic Pulse Velocity Test for determining strength of concrete. Because strength of concrete is also an influencing factor for repairing cracks in building. So, we can say if crack repair is assumed to be building of structure then this paper can be assumed as foundation of it. This research work concludes that though it is impossible to guarantee against cracking yet attempts can be made to minimize development of crack. Some prevention could be taken care of during the construction process itself. Any lack of attentiveness can lead to a cause for damage in the building in its future, which can also lead to the failure of structure. And also, not all type of crack requires same level of attention. Cracks may occur due to various reasons, as earlier. The occurrence of cracks cannot be stopped but particular measures can be taken to restrict them to reduce the level and degree of consequences. The potential causes of crack can be controlled if proper consideration is given to construction material and technique to be used. Generally speaking, for causes and prevention of cracks in particular case it is necessary to make careful observations. In case of existing cracks, after detail study and analysis of crack parameters, most appropriate method of correction should be adopted for effective and efficient repair of crack is epoxy resign.

11 Hussam Ali Mohammed [2019]

Depending on the opening of the cracks on the surface, cracks can be described (as tiny as hairline, or cracks with a few millimeters opening); however, this procedure does not provide enough information about the depth of these cracks. Different techniques have been developed and used over time for the purpose of crack depth measurement in concrete. The effectiveness of repair methods such as epoxy injection relies on accurate prediction of crack depth. Different methods have been developed over years to evaluate the depth of cracks in concrete.

12 Rathod Ravinder [2019]

The purpose of the project is to gain fundamental and practical understanding on concrete repair and rehabilitation of the structures. Large number of reinforced concrete (RC) structure are deteriorating, often prematurely, and need remedial measures to reinstate their safety and/or serviceability. Consequently, the need for repair and protection has grown considerably in recent years. While costs associated with repair of deteriorating concrete structures can be substantial,

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costs resulting from poorly designed or executed repairs may be even higher. Repair methods need to be designed with consideration for the anticipated or desired remaining service life of the structure. A distinction must be made between repairs intended to stop deterioration fully and those merely aimed at slowing down deterioration processes for a limited period of time. During the research for our project relevant repair methods for damaged concrete structures will be discussed, focusing on design methods. The project will be initiated with various sites nearby Nizampet inspection and repairs will examined. Then the respective repairs will be studied and classified into cracks, corrosion of concrete reinforcement, seepage and deterioration of surface coating.

With the help of journals and publications a detailed study will be done on the causes for each repair and a suitable rehabilitation method will be suggested for each repair site by comparing various methods. This paper will consist of studies of various repairs along with pictures, referred case studies and other references. Every building has some life span after time passes certain problems arises like paint deuteriation, corrosion, seepage problems, deflections in beams etc. Buildings will become unstable due to all these problems. So, repair works should be done in order to gain the strength of the structure. Repair and Rehabilitation is necessary to save hazardous failure of structures. It is recommended for old buildings which have some signs like cracks, corrosion of embedded materials, etc. Therefore, timely maintenance of structures is required. Most of the olden structures are given strength by doing process of repair and rehabilitation like Charminar. The selection of technique is used as per cost, location of site and other factors. Thus, for proper maintenance, the techniques likewise.

13 Soofian Noor Mat Saliah [2021]

This paper explores and analyses how reinforced concrete beams, can be restored and repaired after sustaining damage from monotonic loading. Epoxy resin was used to repair the beams. By employing a technique known as the “acoustic emission (AE)” technique, the damage sustained by the beams under monotonic loading can be evaluated. The reference beam, and the repaired beam, were both prepared. The load, the acoustic emission parameters, and the crack modes were investigated and analysed. The signal strength, rise angle value, and average frequency were analysed and discussed. The S4B was found to produce a maximum load that measured higher than the S1C. However, the AE analyses indicated a different result where the S4B produced a lower value than S1C. The average frequency and rise angle value with the patterns of cracks on the beams are directly correlated. Hence, two cracks were identified i.e. tensile and shear cracks. It is safe to deduce that to assess the soundness of the epoxy injected concrete beams, the AE technique can be applied.

14 Tae-Kyun Kim and Jong-Sup Park [2021]

In this study, epoxy, impregnating, and epoxy/impregnating methods were used to repair concrete cracks. Epoxy was used for crack injection, and a supernatant was used for surface protection. The epoxy/impregnating method was used to protect both cracked areas and surfaces. Activated cracks were induced using flexural strength tests, and the stiffness of the specimens according to the repair method was compared to examine the structural performance. For concrete design strengths of 20 and 30 MPa, the compressive strengths of the epoxy and impregnating repair methods exceeded the design strengths, and the epoxy/impregnating repair method recovered performance as much as the control specimens. In the case of the design strength of 40 MPa, none of the repair methods could recover performance as much as the control specimen. Approximately 90% recovery was achieved.

15 Agu Ransford Tetteh et.al. [2018]

Cracks are a typical defect that are unavoidable in concrete. If cracks exceed the allowable widths defined in the codes of practice, they considerably reduce the strength, stiffness and durability of the concrete structure and therefore need to be repaired. However, many components are often needed, such as reinforced concrete structures need repair to restore structural integrity and protect the reinforcement Weather conditions. Different types of materials and methods are available. Repair of protruding cracks in concrete structures. In this paper, causes of cracks, repair materials and the repair method are been discussed. Successful long-term repair procedures must attack the causes of the cracks as well as the cracks themselves. The following provides detailed conclusions from our research. Proper construction methods should be used during construction to prevent formation of cracks.

1. However if there are any cracks, visual inspection should be done first.
2. Cause of the cracks should be done with first before repairing.
3. Evaluation of cracks can be done by different technique like crack compactor and ultrasonic testing.
4. Epoxy injection can be used for narrow cracks (0.002 in 0.05mm).
5. Stitching can be used across major cracks.
6. In case of bridge girder, provision of pre-stressing steel is useful.

Algorithm/Methodology/Workflow:-

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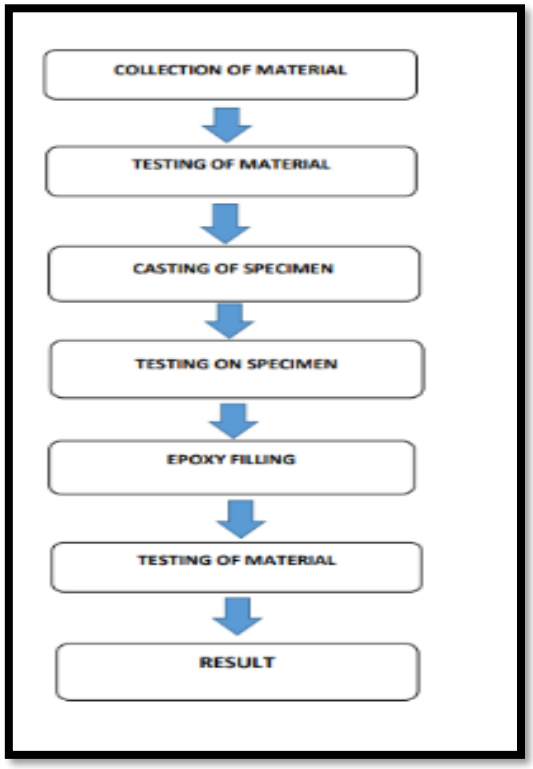

1. COLLECTION OF MATERIAL:

1.1. CEMENT: -

Cement is a material that acts as a binder to bind the aggregates and sand together in the concrete mixture. It is grey and very fine material that bind only after it mixed with water. Ordinary Portland cement is best Portland cement and is best suited for use in general concrete construction where there is no exposure to sulphate in the ground water. This cement primarily consist of silicates and aluminates of lime obtained from stone and clay. This mixture is grounded, blended, fused in kiln at high temperatures of 1400 degree Celsius and a product called clinker is obtained. The clinker is cooled and grinded to cement. The cement is cement produced in maximum quantity than the other cements because of its durability and resistance to atmosphere and other attacks. It is produced by grinding Portland clinker with possible quantity of gypsum, water or both less than 1% of air entraining elements. AMBUJA CEMENT OPC 53 GRADE cement is required to conform to BIS specification IS:12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/sqcm. 53 Grade OPC provides high strength and durability to structures because of its optimum particle size distribution and superior crystallized structure.

1.2. SAND: - Sand is the most popular material that being used for mix design also known as standard of sand. Standard of sand should be quartz, light grey and whitish color. Sand is one of the fine aggregates. Sand is made up from a granular form of silica. Sand is free from clay or silt, organic matter, can pass through 850 µm and less than ten percent of 600µm sieve. In order to use sand in the manufacturing of concrete or building constructions, sand should possess at least 85% of the strength of standard sand. Sand also has its own function which is to strike the economy by its own use as materials in concrete.

1.3. AGGREGATE: - Aggregate that left for about 4.75 mm sieve can be classified as coarse aggregates. The coarse aggregate can be obtained from the artificial crushing of rocks. The size can be classified through their thickness, spacing of reinforcement, cover, and many more. The maximum size for coarse aggregate is at about 80 mm, but that maximum size should not be as large as possible and not more than 5 mm less than spacing of the reinforcement. Coarse aggregate with size 20 mm are commonly used in the making of concrete.

EPOXY RESIGN Conbextra EP10(M) is a two part epoxy resin system for grouting gaps ranging from 0.25mm to 10mm. It is an all liquid system consisting of a base and hardener.

2. TESTING OF MATERIAL PROPERTIES:

Material properties consist of properties of all the materials required for the work. Following are the materials and its properties. A) Cement: Cement consists of four major compounds tricalcium silicate (C3S), Dicalciumsilicate (C2S), Tricalcium Aluminates (C3A) and Tetra Calcium Aluminum ferrite. (C4AF). Tricalcium Silicate (C38) and Declaim silicate (C2S) is the most important |a compound responsible for strength. Together they constitute 70-80 percent of cement. The average C3S content in modern cement is about 45 percent and that of C2S is about 25 percent. During the

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course of reaction of C3S and C2S with water, calcium silicate hydrate (C-S-H) and calcium hydroxide (Ca (OH) 2) are formed. Calcium silicate hydrates are the most important products and determines the good properties of concrete. C3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete. C2S hydrates rather slowly produces less heat of hydration. It is responsible for later strength of concrete. After reviewing all above requirements Shree Jung Rodhak Ordinary Portland Cement (OPC) cement is used be throughout the experimental work. Cement is tested in laboratory and is as follows:

B) Aggregate:

Aggregate is a collective term for the mineral materials such as sand, gravel and crushed stone that are used with a binding medium (such as water, bitumen, Portland cement, lime, etc.) to form compound materials (such as asphalt concrete and Portland cement concrete). Aggregate is also used for base and sub base courses for both flexible and rigid pavements. Aggregates can either be natural or manufactured. Natural aggregates are generally extracted from larger rock formations through an open excavation (quarry) Extracted rock is typically reduced to usable sizes by mechanical crushing, The importance of using the right type and quality of aggregates cannot Sr. No. Description of Test As per IS 12629-1989 Results 01 Fineness of cement(residue on IS sieve No.9) 10% 2% 02 Specific gravity 3.15 3.15g/cc 03 Standard consistency of cement 35mm from top 35mm from top 04 Setting time of cement a) Initial setting time b)Final setting time 30 min. 600 min. 105 min. 350min. 05 Soundness test of cement (with Le-chatelier's mould) 10.0 Max 3mm 06 Compressive strength of cement: a)7 day b) 28 days 37 MPa 53 MPa 38N/nm2 55N/nm2 be overemphasized. The fine and coarse aggregates generally occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete's freshly mixed and hardened properties, mixture proportions, and economy.

Table 4.1: Cement Properties

Sr. No.	Description of Test	As per IS 12629-1989	Results
01	Fineness of cement(residue on IS sieve No.9)	10%	2%
02	Specific gravity	3.15	3.15g/cc
03	Standard consistency of cement	35mm from top	35mm from top
04	Setting time of cement a) Initial setting time b)Final setting time	 30 min. 600 min.	 105 min. 350min.
05	Soundness test of cement (with Le-chatelier's mould)	10.0 Max	3mm
06	Compressive strength of cement: a)7 day b) 28 days	 37 MPa 53 MPa	 38N/nm^2 55N/nm^2

3. Crack Depth Measurement in Concrete:

Why crack depth measurement in concrete matters? Cracks can ease the access for aggressive agents (i.e. chloride ion) to reach to steel reinforcement, which will eventually cause corrosion. It is important to evaluate the depth of cracks, to make sure if surface cracking is well propagated into concrete or not. The effectiveness of repair methods such as epoxy injection relies on accurate prediction of crack depth. Different methods have been developed over years to evaluate the depth of cracks in concrete.

I) Steel Ruler:

Steel ruler is simple instrument used to monitor crack width variation. The width of the crack can be measured to the nearest 0.5mm provided that great care is practiced. It should be bear in mind that steel rule measurements are subjective because it is not possible to measure

crack width from the same point each time the measurement is taken. That is why steel ruler measurements are used for assessing state of damage at the beginning of investigation.

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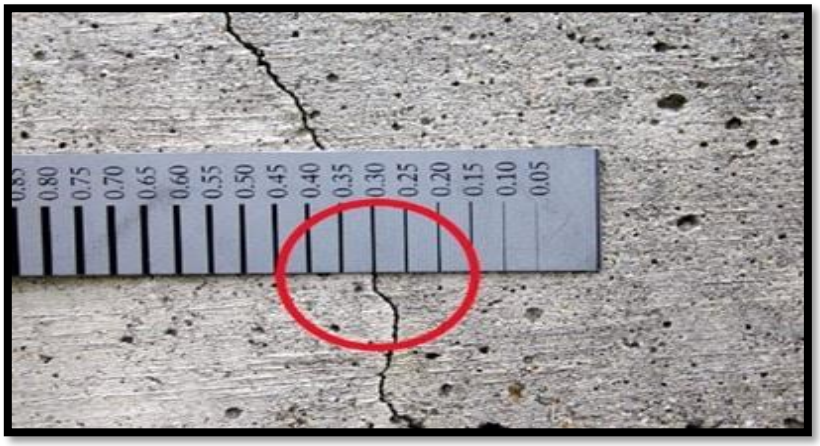

Fig.3.1: Steel Ruler

II) Visual Examination of Concrete Cores:

In this method, dye is injected (using pressure) into surface cracks. Later, concrete cores will be taken from the area under investigation. The sample is studied under microscope for determining the depth of cracks in concrete. Photo adapted from Kevic C Arne (2014). "Crack depth measurement in reinforced concrete using ultrasonic techniques" MSc. Thesis.

Fig. 3.2: Visual Examination

4. REPAIR OF CRACKS:

The repair of cracks can be achieved with the following techniques:

1) By epoxy-injection grouting
2) By routing and sealing
3) By flexible sealing
4) By stitching
5) By drilling and plugging
6) By grouting
8) Dry packing
9) Surface coatings

Here we will discuss about most popular repair technique of cracks such as epoxy-injection method and grouting.

i.Crack Repair By Epoxy-injection Method

Epoxy compounds are having very well compressive, tensile and bond strength. They can be used for preparing repair mortars but if used as bonding/binding materials for concrete i.e. epoxy concrete, the cost is prohibitic. Cracks as narrow as 0.05 mm can be bonded by the injections of epoxy. It is excellent material for repairing cracks because they have very good properties such as resistant against water penetration, resistant to crack formation and their very good adhesive properties. This method has been successfully used in the repair of cracks in building, bridges, and other types of concrete structures. The repair process by this method is as follow:

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[A] Clean the cracks The very first step is to clean the cracks that have Contaminants such as oil, grease, dirt or fine particles. Because such contaminants prevent epoxy penetration in the cracks to be repaired. For this reason cleaning is required.

[B] Sealing of the surfaces Surface cracks should be sealed. It is used to keep the epoxy from leaking out before it has gelled. This can be done by applying an epoxy, polyester or other appropriate sealing material to the surface of the crack and allowing it to harden.

[C] Install the entry and venting ports When the cracks are v-grooved, drill holes are made in the groove of about 20mm diameter below the apex of the v-grooved section. Fittings such as pipe nipples are inserted in to the holes. But when the cracks are not v-grooved, an entry port is to be bond a fitting flush with the concrete face over the crack.

[D] Mixing of epoxy it is done either by batch or continuous methods. In batch mixing, the adhesive components are premixed according to the manufacturer's instructions, usually with the use of mechanical stirrer, like a paint mixing paddle. In the continuous method, the two liquid adhesive components pass through metering and driving pumps prior to passing through an automatic mixing head.

[E] Inject the epoxy the equipment's used for injecting the epoxy are hydraulic pumps, air actuated caulking guns or paint pressure pots. The pressure used for injection must be selected carefully. The use of excessive pressure can cause additional damage. If the crack is vertical or inclined the injection process should begin by pumping epoxy in to the entry port at the lowest level until the epoxy level reaches the entry port above. For horizontal cracks, the injection should start from one end of the crack to the other in the same manner.

[F] Remove the surface seal once the injected epoxy has cured, the surface seal should be removed by draining or other means as appropriate.

ii. Crack Repair by Grouting

Based on the grouting material used, there are three methods:

1) Portland cement grouting Wide cracks in gravity dams and thick concrete walls can be repaired by filling the Portland cement grout in cracks. This method is proved effective in preventing water leakage, but will not structurally bond cracked sections. In this method the very first step is cleaning the concrete along the crack by using air jetting or water jetting, then grout nipples at suitable intervals is installed, then sealing is done between the seats with sealant, then the crack should be flushed to clean it and test the seal and then grouting the whole area. To improve the properties of the grout, water reducers or admixtures may be used.

2) Chemical Grouting Chemicals used for grouting are silicates, urethanes and acrylomides. Two or more chemicals are combined to form a gel, a solid precipitate or foam as opposed to cement grouts that consists of suspensions of solid particles in a fluid. Chemical grouts can be used in moist environments and in very fine fractures. But with some limits of control of gel time.

5. EPOXY:

Epoxy is known as polyepoxide, is a thermosetting polymer formed from reaction of an epoxide "resin" with polyamine" hardener". Epoxy is a co-polymer, means that it is formed from two different chemicals. These are referred to as the "resin" or "compound" and the "hardener" or "activator".

Epoxy resin is a kind of thermosetting (solid) resin. When main agent is blended with the hardener of appropriate ratio, after cross linkage for hardening, a network structure of three dimensional space is formed. Therefore, this product has equipped with a special physical property, mechanical property, and chemicals-resistant, etc.

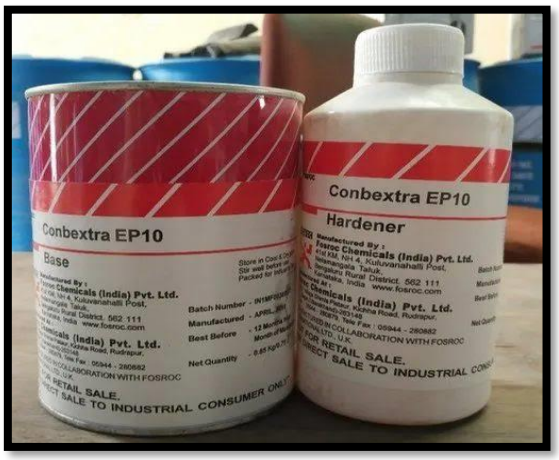

Fig.5.3: Conbextra EP10 (M) EPOXY

Advantages of epoxy resin:

1. Viscosity.
2. ν Moisture insensitive

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3. Low creep characteristics

Test method	Typical result
Density (Kg/m^3)	1060
Compressive strength (N/mm^2) ASTM D695	60
Tensile strength (N/mm^2) ASTM C307 - 94	20
Flexural strength (N/mm^2) BS6319 Part 3	45

4. High compressive, tensile and flexural strengths
5. Fast, convenient pumping with early strength gain
6. Withstands a wide range of chemicals

Properties

The following results are typical for the hardener grout at 30 deg. C.

6 EPOXY FILLING:

[A]Test Method:

To study the compressive strength, flexural strength, and split tensile strength of different fibers used before and after applying epoxy. The cement, coarse aggregate, fine aggregate and the water were mix together. Forty two no of concrete cubes, beams, and cylinders was to show the effect of compressive strength, flexural strength, and split tensile strength before and after applying epoxy on cracks. In this study, the concrete cube, beam, and cylinder will be divided into forty two forty two no of concrete cubes, beams, and cylinders for every each normal. All these samples will be cured in water up to 28 days and 56 days as shown in the figure below. Thus, after 28 days and 56 days, all the cubes, beams, and cylinders will be tested by using the universal testing machine to create cracks. Once the cracks seen, the stop button will be immediately pushed before it achieved to failed cubes, beams and cylinders. The cracks on the cube, beam, and cylinders are shown in the figure below. The compressive strength, flexural strength, and split tensile strength for every cube, beam, and cylinder was recorded. Next, the epoxy or Concentra EP10 (M) were used. The component A and B will be mixed together in order to get grey in color by using 1 to 3 ratio. After being mixed together, the cracks that occurred before will be injected with epoxy inside to act as glued as shown in the figure below. Although the cracks are hair line cracks, the epoxy are forcedly injected in the small cracks and then being apply around the surface of the cube, beam, and cylinder. Once the cracks are done being injected and covered, those cubes will be left for 1 day to dry up. The next day, those cubes, beams, and cylinders were tested again in order to get the strength after applying epoxy.

[B] Injecting the Epoxy Crack:

Conbextra EP10 (M) has to be mixed with clean graded quartz sand from 1:3 to 1:6 parts by weight depending on the consistency required. You might want to close the second port as this might help to accommodate the epoxy below the concrete surface. Repeat the process until no more epoxy is flowing and then remove the cartridge. Move to the next open port or to the one that has epoxy coming out of it, and inject more epoxy.

If the epoxy is hardened, move one port forward and repeat the process. It is important to apply constant pressure so the epoxy can flow adequately without leaving voids below the surface. Once the injection process is complete, remove the ports and the top seal from the crack.

EPOXY FILLING :-

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RESULT AND CONCLUSION

This chapter will discuss about all the results from testing and laboratory works that had been done. Compressive strength, flexural strength, split tensile strength, epoxy Conbextra EP10 (M) and percentages of increasing strength had been discussed in this chapter. There are use in epoxy resins. In present work epoxy resins had eighteen no of samples of concrete cubes 150 x 150 x 150 in size, eighteen no of samples of concrete beams 700 x 150 x 150 in size, and eighteen no of samples of concrete cylinders 300 mm x 150 in size. Regarding to the place of the experiment had been done; the only machine that was very suitable to be used was universal testing machine. The only problem of using this machine was the crack occurred only a small crack before it achieved the failure limit. Epoxy resin used was in the form of sticky-liquid form. Epoxy resins are also known as polyepoxides, there are in a class of reactive pre-polymers and polymers which include epoxide groups. In this research, Conbextra EP10(M) had been used. Conbextra EP10(M) has many different types of grade. This Conbextra has high modulus, high strength, structural epoxy paste and to harden concrete. The surface must be cleaned before applying the epoxy at the concrete. Conbextra EP10(M) have two components which are component A and component B. Component A is black in color

CONCLUSION

1. From this Project Work, the conclusion that has been made based on the test results that obtained from the test are, the maximum strength achieved at crack initiation for expoy resins.
2. After the compressive strength, flexural strength, and split tensile test crack width is obtained in between 0.1mm to 0.3mm.
3. The maximum compressive strength of epoxy filled concrete cubes value is 28.59 N/mm2 and 29.57 N/mm2 for 28 days and 56 days respectively obtained by volume of concrete.
4. The maximum flexural strength of epoxy filled concrete beams is 7.4 N/mm2 and 8.56 N/mm2 for 28 days and 56 days respectively obtained by volume of concrete.
5. The maximum split tensile strength of epoxy filled concrete beams is 5.43 N/mm2 and 5.97 N/mm2 for 28 days and 56 days respectively obtained by volume of concrete.

Also some general conclusions were made as follow:

1. Epoxy materials achieved the objective of increasing strength with a negligible change of global mass.
2. External confinement of concrete specimen with Epoxy resulted in an increase in the strength and ductility.
3. The provision of injection resulted in a substantial reduction in the measurement of cracked concrete specimens.
4. Epoxy Resin is the best material to give more strength compared to other injecting materials.
5. Epoxy adhesives are the most common adhesives used for repair crack by Injection Technique.

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