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EFFECT OF ACID ON MECHANICAL PROPERTIES OF EPOXY REPAIRED CONCRETE

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Abstract - *Nowadays in all concrete structures, various types of problems occurs due to different reasons such as lower quality of materials used, exposure condition, volume instability ingress of moisture, chemical, and thermal effects etc. These problems lead to crack and further to failure condition, if not repaired or replaced. Replacement of structural members is not feasible and is also quite expensive. Instead of replacing the structural members, there are various techniques by which it can be repaired. Epoxy is the one of them, which is used to repair the cracks by injection techniques or seal the cracks by coating. In this project, different concrete cubes have been tested against acid (H_2SO_4). Also the efficiency of concrete has been tested against repairing, where the repairing has been done using epoxy. The parameters such as acid concentration, grade of concrete, other materials have been kept same. The purpose of thesis to determine the efficiency of repaired concrete and its reactiveness towards acids. From experiment, it has been observed that the repairing material i.e. epoxy {Sikadur-31(IN)} helps to regain the strength upto 80-85% and is also not much reactive towards acid.*

Key Words: **Epoxy, Sulphuric Acid, Repair, Concrete, Strength, Cracks**

1. INTRODUCTION

The world is developing fast and modern construction plays an important role in it. The modern construction consists of large and innovative buildings, bridges, etc. Concrete is one of the most common building material and is now widely used in industrial and civil construction, water conservancy, city construction, agriculture and forestry, transport and Harbor Engineering. The biggest disadvantage of concrete, however, is that it cracks easily, which lead to the decline of the durability of concrete and causes structural damage, thus bringing huge losses. Cracks are mostly developed due to deterioration of concrete and due to corrosion of reinforcement provided due to faulty design and poor construction or by many other factors like temperature and shrinkage properties.

Cracks can be primarily of many types. Active cracks are the ones which keep on growing over in a particular direction. Other types of cracks called as Inactive cracks also called as dormant cracks which are initially not so dangerous but if left unrepaired can cause damage in the long-run.

1.1 Repair & Maintenance

Repair is the technical aspect of rehabilitation which refers to modification of a structure, partly or wholly, which is damaged in appearance or serviceability. To repair the damaged concrete portion we have to prepare the concrete surface. After the concrete surface has been prepared, a bonding coat ought to be applied to the complete cleaned exposed surface. The bonding coat could carry with it bonding agents such as cement suspension, cement sand mortar, epoxy, epoxy mortar, resin materials etc.

Maintenance is preventive in nature. Activities embrace examination and works necessary to fulfil the supposed function or to sustain original level of service. The upkeep of structure is done to satisfy the assorted issue like bar damages because of natural agencies and to keep them in sensible look and dealing condition.

1.2 Epoxy

Epoxy is a co-polymer, which means it is formed from two different chemicals. This is referred to as a resin or compound & hardener and activator. Epoxy resins are low molecular weight of pre–polymers & higher molecular weight of polymers. Nowadays epoxy resins are largely petroleum derived although some may be plant derived. Epoxy resin used was in the form of sticky liquid. It's also known as polyepoxides.

In this research epoxy resin is used for concrete repair. Epoxy resin used was in the form of sticky-liquid form {Sikadur-31(IN)}. Sikadur-31(IN) is a solvent free that also contain epoxy. This sikadur 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. This research used 1 to 3 ratio of part A and B. Epoxy resins are also known as polyepoxides, there are in a class of reactive pre-polymers and polymers which include epoxide groups. Epoxy is in a family of thermosetting resin which has the characteristic unique to them. Thermosetting is in a polymer that is irreversible, once cured and harden, it cannot melt back because of the cross linking. Cross linking from the epoxy itself and epoxy molecule cross-linked with each other that make them become strong enough and harder, indirectly the strength increase. In this research use epoxy to seal the crack.

2. OBJECTIVES OF STUDY

The work has been undertaken with the following objectives:

- To repair the cracks of concrete using epoxy resin.
- To check the efficiency of epoxy in repairing work.
- Compare the compressive strength of controlled and epoxy repaired concrete.
- To review the literature, covering various types of repairing materials and their efficiency.
- To check the reactiveness of epoxy in presence of sulfuric acid.
- To check the reactiveness of concrete in presence of sulfuric acid.
- Compare the compressive strength of controlled and epoxy repaired concrete after acid test.
- Compare the compressive strength of controlled concrete with and without effect of acid.
- Compare the compressive strength of epoxy repaired concrete with and without effect of acid.

3. MIX DESIGN

STEP 1. Test data required for materials

S No	Characteristic properties	Values
1	Grade of concrete	M -20
2	Maximum nominal size of aggregates	20 mm
3	Grade of cement	OPC 53 grade
4	Specific gravity of fine aggregate	2.65
5	Maximum water-cement ratio	0.5
6	Workability (for slump test)	100 mm
7	Grading Zone of fine aggregate	Zone-II
8	Specific gravity of cement	3.15
9	Specific gravity of coarse aggregate	2.786
10	Aggregate shape	Angular
11	Entrapped air	2.00%
12	Admixture used	-
13	Maximum temperature of concrete at the time of pouring	27 +/-2℃
14	Maximum cement content	450 kg/m³
15	Minimum cement content	250 kg/m³
16	Surface moisture - A. In fine aggregates B. In coarse aggregates	Nil
17	Method of transporting & placing	Manual
18	Exposure conditions IS-456:2009 Table no 4	Moderate

STEP 2. Calculation of target mean strength = 26.6 N/mm²

STEP 3. Calculation or selection of water cement ratio = 0.5

STEP 4. Calculation of water content = 197.16 litre

STEP 5. Calculation of cement content = 394.32 kg/m³

STEP 6. Calculation of proportion of volume of coarse aggregate and fine aggregate = 0.38

STEP 7. Calculation of mix proportion

Mass of coarse aggregate = 1171.33 kg/m³

Mass of fine aggregate = 682.74 kg/m³

STEP 8. Final Mix proportion by weight for trial mix

Water	Cement	Fine aggregate	Coarse aggregate
197.16	394.32 kg	682.74 kg	1171.33 kg
0.5	1	1.73	2.97

4. TEST ON CONTROLLED CONCRETE

4.1 Compressive Strength Test

Compressive strength test are most common test conducted on hardened concrete. Strength of concrete is defined as the ability of a material to resist stress without failure. For compressive strength test the cubical sample are cast. Strength of concrete depends on different factors such as water-cement-ratio, cement strength, quality of concrete material and quality control during production of concrete, etc.The compressive strength test are conducted in universal testing machine. The cubical sample of size 150 mm x 150 mm x 150 mm is made for testing.

In this test we had prepared three cubes of control concrete specimen as per mix proportion which is calculated in mix design. For the testing of specimen place the cube on UTM and load will be applied at a rate of 4 KN/Sec. at a certain period specimen occurs failure. And finally we get the compressive strength of controlled concrete cube.

Fig 4.1 Compressive strength Test on UTM before & after failure

4.2 Acid Test

This test is done to check the durability of concrete against adverse environment. In these study acid test has been conducted against sulfuric acid. By the help of sulfuric acid which dilute in distilled water sulphate attack has been tested. For the acid test take 5% concentration of sulfuric acid and dilute in distilled water and make a solution where concrete cubes to be immersed for 28 days. All cubes weighted before immerse in solution. After 28 days remove it from solution and weigh it again. We see weight of cube has been decrease at a certain amount. Again these cubes are test it in UTM for compressive strength test.

Fig 4.2 Acid test on concrete

Fig 4.3 Compressive strength test of specimen after acid test

5. PROVIDING HAIR CRACKS AND REPAIRING WITH EPOXY

For repairing of concrete we have to provide cracks on specimen that would be repaired. For providing cracks on specimen first of all weigh the concrete cube and place it in CTM for application of load. After some time crack will be seen then stop the CTM load application. For providing hair cracks we have to pay attention at crack point and before failure we have to stop the loading mechanism.

Fig 5.1 Cracks occur in specimen

After coating of epoxy sikadur-31(IN) in cracked portion of concrete cubes surface of these cubes are plane by the help of proper use of scraper. These repaired cubes are placed in a room at ambient temperature for 24 hours for the setting of epoxy coated cubes.

Fig 5.2 Repairing the cracked concrete cubes with epoxy

6. RESULTS

6.1 Before Acid Effect

Table 6.1.1 Compressive strength test data of controlled concrete after 28 days:

S.no.	Weight of specimen (gm)	Ultimate strength (N/mm^2)	Ultimate load (KN)	Breaking point (KN)
	8460	21.16	476.28	352.17
	8900	28.56	642.75	324.89
	8540	24.89	560.19	294.81

Average ultimate strength of controlled concrete cubes:-

$$= \frac{21.16 + 24.89 + 28.56}{3}$$

$= 24.87\ N/mm^2$

Table 6.1.2 Compressive strength test data of repaired concrete

S.no	Weight of specimen (gm)	Ultimate strength (N/mm²)	Ultimate load (KN)	Breaking point (KN)
	8860	17.42	392.02	203.58
	8931	21.186	476.69	265.62
	8952	23.25	523.22	353.83

Average ultimate strength of repaired concrete cubes:-

$$=\frac{17.42 + 21.86 + 23.25}{3}$$

= 20.61 N/mm²

6.2 After Acid Effect

6.2.1 Compressive strength test data of controlled concrete after immersing in acid for 28 days:

Average ultimate strength of controlled concrete cubes:-

$$=\frac{13.55+15.12+14.99}{3}$$

= 14.53 N/mm²

6.2.2 Compressive strength test data of repaired concrete after immersing in acid for 28 days:

S.no	Weight of specimen (gm)	Ultimate strength (N/mm²)	Ultimate load (KN)	Breaking point (KN)
	7540	13.55	305.06	166.59
	7740	14.92	335.89	176.60
	8240	15.12	340.38	177.95

S.no	Weight of specimen (gm)	Ultimate strength (N/mm²)	Ultimate load (KN)	Breaking point (KN)
	8700	11.47	285.27	140.94
	8820	12.23	275.32	161.27
	8840	12.80	288.11	175

Average ultimate strength of repaired concrete cubes:-

$$=\frac{11.47+12.23+12.80}{3}$$

= 12.16 N/mm²

7. CONCLUSIONS

1. The average efficiency of repaired concrete cubes which were repaired by epoxy {sikadur-31(IN)} is about 83%. So for the repairing work of concrete epoxy {sikadur-31(IN)} can be used.
2. After effect of acid {Sulfuric acid (H_2SO_4)} at the concentration of 5% on concrete cubes about 42% strength decreases, which shows impact of sulphate attack on cement concrete.
3. The efficiency of epoxy repaired concrete cubes still remains 83% of controlled concrete cubes after acid effect, which shows that in sulfuric acid solution, sulphate is not much effective on epoxy.

8. FUTURE SCOPE FOR STUDY

1. In this project epoxy has been used as a repairing material, due to its good adhesive property it can also be used in mortar mix.
2. In this project, research has been done by keeping the concentration of acid as 5%, it can also be tested for higher concentration.
3. Research can also be done by repairing 'concrete mixed with fibers' using epoxy which is further carried out in acid test.
4. In this project, I have done the repairing work with epoxy as a coating, it can also be carried out by the injection technique.

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