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Research Article

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Crack Repair for Construction Material using Polymeric Composite

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Abstract The need to repair concrete cracks has increased dramatically at present, as there are a large number of concrete structures that have been particularly affected by excessive loads and earthquakes, causing cracks that require more than one surface treatment. In recent pots, epoxy resin has been used to repair concrete cracks, restore the strength of concrete and increase its durability. It is the only option for preserving the concrete. Crack repair is required if it reduces the strength of the structure, the rigidity or durability of the structure, and the function of the structure may be very weak [1]. The repair of cracks in concrete is done by using different methods, using polymer-based materials [2] or methods of epoxy resin injection [3-4]. The properties and advantages of epoxy were developed by adding fillers, as the discovery of the epoxy binding function led to a new concept in adhesives [5]. This research aimed to add fillers without reducing the properties of the epoxy, choosing (alumina, silicon carbide, pumice, silica smoke) To add them to the epoxy with different proportions (5, 10 and 15%) to create a new compound. The experiment tried to find the best mixing ratio for the components and on this basis tests were conducted to prove the composite result, as among these physical tests, including the hardness of the composite and mechanical materials, including bending and testing The tensile strength, to reach the best compound material, improves the characteristics of the epoxy material to make it a higher durability material for concrete crack injection.

Keywords Micropile, Lateral Load, Displacement, Moving Rate

1. Introduction

Often the most used material is epoxy, as it is one of the most popular engineering techniques used in many applications including electrical, electronic, packaging, textiles and consumption due to its unique mechanical properties. Epoxy belongs to the group of materials used for repair. Repair materials can be of two types: stiffeners and resin-based materials [1]. Cement materials sometimes alternate between plaster and traditional mortar that has high properties when using additives. With the addition of gaskets, the strength is increased, shrinkage decreases and workability is increased [1]. Epoxy contains resins that are used in several applications, including those used for injection, gravity, mortar and pastes for manual use because its nature has less elasticity and higher creep compared to reinforcing materials [1]. This was one of the reasons for using epoxy as a matrix in composites to form a compound with new properties [2] as the fillers in them are inorganic like alumina, fly ash, clay, mica, silica, kaolin, etc. [3]. The new compound has high strength, as well as many improved epoxy properties, among them low viscosity and higher adhesion strength, High elasticity and resistance to penetration of water and impurities.

2. Experimental Procedure

2.1. Materials System

2.1.1 Epoxy

The epoxy used in this research works on treating and repairing concrete cracks and was from the well-known company (DCP) that has products for more than 90 years of experience in developing, manufacturing and marketing innovative building materials. DCP has operations in several countries including North America, Europe, Africa, the Middle East and Asia with 15 manufacturing sites and a distribution network to more than 35 countries. The epoxy material consists of two components: a liquid and solid amine resin produced in Switzerland, and the required ratio (2.72 bases in one reinforcer).

2.1.2 Alumina

It is naturally occurring in its polycrystalline phase and its gemstones are formed, including sapphire. Alumina is a white crystalline powder that is insoluble in water. Chemically usually consisting of aluminium and oxygen with the chemical formula Al_2O_3. The alpha type, with a granular size of 90 µm, was used to spread it inside the epoxy matrix regularly to avoid Precipitation occurrence due to the large granular size. One of the most important properties of this material is considered to be very solid and is used as an abrasive material, in addition to its high temperature tolerance due to its high melting point [6].

2.1.3 Silicon Carbide

A very hard crystalline compound made of silicon and carbon. Its chemical formula is SiC. Since the nineteenth century, silicon carbide has become an important material as it was first used in sandpaper, grinding wheels, and cutting tools. Therefore, it has continued to be used today, in a variety of applications including heat-resistant linings and heating elements for industrial furnaces, and in important parts such as corrosion resistance of pumps and rocket engines [4]. This type of material is not soluble in water but soluble in hot alkali. (Passes through 220 networks): min. 95.0% Molecular Weight: 40.10.

2.1.4 Silica Fume

Fumed silica is an extremely compact particle size with enormous surface area, high purity and tendency to form chains in the chemical manufacturing process. The particle is formed by injecting chlorosilanite, such as silicon tetrachloride, into a flame of hydrogen and air. A reaction is produced that leads to the production of fumigated silica and hydrogen chloride. The chemical formula for fumigated silica is SiO_2 and the chemical name for it is amorphous synthetic silicon dioxide, devoid of crystals. Fumigated silica has two primary functions. Reinforcement increases the strength of various materials, allowing them to be used in a greater number of applications depending on the exact requirements of the user. The rheology control allows customers to adapt the system viscosity to their specific requirements. It is used as a mild abrasive in products like toothpaste. Other uses include elastomer fillings and viscosity modification in paints, coatings and other applications as well as in construction applications due to its softness [5].

2.1.4 Pumice

It is a light vitreous rock ceramic type, a porous type that is filled with holes, i.e. the pores resulting from gas retention during its solidification from the volcanic eruption and often there are many pores, most of the pores are very small and not connected, and therefore oil, water, or gas cannot flow Through this rock, it makes the pumice so light that it floats on the water, as it is included in many paint preparations [7]. The most important place in the islands of Liberia on the shores of Italy, it is also called: artichoke, the stone is crushed through a jaw crusher to obtain a granular size of 50 microns to be used as an epoxy filler in this experiment.

2.1.5 Cement

In this research he used cement AL-Mass Portland Cement. To ensure the preservation of the material from weather conditions, the package was stored in a dry place. According to the results of the examination, there is a conformity with the Iraqi Standard No. 5/1984 [8]. The test was conducted by Progress Engineering Construction Lab in Iraq.

2.1.6 Fine Aggregate

The size and fineness of the sand was (4.75 mm) and (2.35), respectively. The test results conform with the Iraqi Standard No. (45/1984) [9]. The tests were also conducted at the Building Materials Laboratory of the Progress Engineering Company's Building Laboratory in Iraq.

2.1.7 Coarse Aggregate

For experiment purposes, crushed river gravel from the spring area was used for normal concrete with a maximum size of 5 mm. The test results comply with the limit of Iraqi Standard No. 45/1984 [9].

2.1.8 Water

Tap water was used at its normal temperature for mixing tested samples cubes and prisms.

2.2 Experimental Work

Work was done with a horizontal rotary mixer 0.19 m3 in the construction plant of the Progress Engineering Company in Iraq. Dry sand is first loaded into a mixer, then 0.5 liters of tap water is added. After that, gravel is added and mixed for 30 seconds with sand. Then the appropriate amount of cement is placed in the mixer and all the dry materials are mixed for one minute to obtain the homogeneity of the mixture. The amount of water is added three times and mixed for three minutes. After that, it is mixed by hand to homogenize the mixture, and continue to mix for another (3) minutes, and subsequently the thread is poured into the pre-prepared molds (150 * 150 * 150 mm cubes) according to BS 1881-116 [10] and Prism 400 * 100 * 100mm) according to ASTM C1314-18 [11], the mixture is placed in the molds and then the molds are placed on the vibrator to remove the bubbles and make sure that there are no gaps inside the mixture and the concrete is compressed, then the surface of the mold is modified and the excess parts removed and each mold is placed with its symbol and the molds are left to dry For 24 hours an hour. After 24 hours has passed on the mixture to dry, it is removed from the molds and placed in a high-efficiency curing bath and completely immersed in water for 28 days at 25 ° C. During the preparation of the cubes 72 samples of epoxy reinforced with different materials and 6 samples of epoxy were prepared. Without adding any epoxy resin and hardener. The base material was mixed with a solidification ratio (2.72 bases in one hardener) and well mixed for 3 to 5 minutes. After 5 minutes, the fillings were added. With different weight ratios and different particle sizes ranging from (65-90), mixing continued for 2 to 3 minutes after being poured into the original molds. The 72 samples were divided into 4 main groups (P, SF, Sic, Al2O3), and each group was divided into two subgroups, a tensile test group and a bending test group (1, 2) and the reinforced materials were added in different proportions (5, 10, 15).)%. Molds are made of various materials (silicone rubber mold, acrylic). After conducting the necessary tests for samples of reinforced epoxy with different proportions of filler and knowing the effective ratio of each material, these ratios were selected to be applied to concrete samples and to know their effectiveness in treating damaged concrete. The resulting material was applied to concrete samples (cube, sawn) after breaking the cube by the fission method to ensure that the cube was not fragmented, by placing a steel column with a length of 10 mm below and above the concrete cube in the middle of the cube, and also the concrete prism was used in the same way for crushing. After that, the samples that were crushed are treated by filling the cracks with cement and water paste on three sides to prevent the curing material from leaking through and leaving one side through which the reinforced epoxy is applied by the method of gravity. Treated samples are re-examined for results and efficacy of the treated material.

2.3 Taste

The tests were for samples of composite materials to choose the best ratio of injection into concrete, and for cubes and prisms to see which of the materials gave the highest efficiency compared to the others.

2.3.1 Tests of Composite Material

Several tests were performed for particle compounds, including the physical test for hardness, and the mechanical test consisted of the bending strength.

2.3.1.1 Hardness Test

Hardness tests were performed on polymer samples by recording an average of three readings of samples from a single mixture. A portable digital durometer was used to test Shore D hardness in accordance with ASTM D2240 [12].

2.3.1.2 Flexural strength Test

Flexural strength is the pressure that a material is subjected to at the moment of rupture and is measured in terms of stress. The mechanical parameter of brittle materials is defined as the ability of the material to resist deformation under load. The transverse bending test is used frequently, in which a specimen having a rectangular cross section is bent until a fracture occurs. The test method was performed in accordance with ASTM D790 [13]. The rectangular cross-section (200 × 10 × 4) mm is placed on two supports and loaded by loading the nose at the midpoint of the distance between the struts (single-point loading), and the test speed was chosen to be 2 mm / min, using a calibration test machine. (Sercomp, Controls Co. Italy) at a load rate of 1.8 kN / s see figure (1).

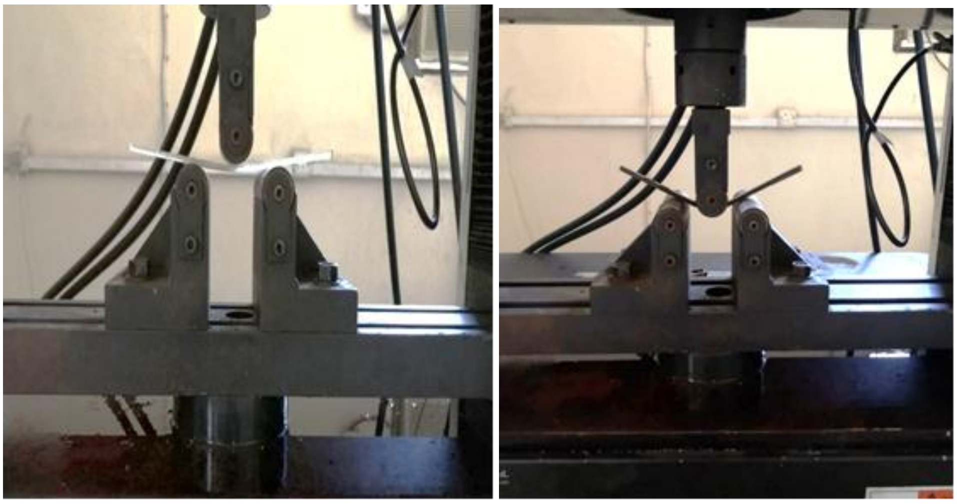

Figure 1: Concrete Flexural Machine

2.3.2 Tests of the Concrete Mixture

There are several types of tests for concrete that are tested after injection, including tensile strength and ultrasonic to ensure that the strength and homogeneity of concrete are known after filling the crack with composite materials.

2.3.2.1 Compression Test

Figure 2: Method of bisection of a cube

Pressure tested according to BS 1881-116. (Using 150 mm cube samples) [14]. Single samples were loaded by a compacting machine (2000 kN Automatic Concrete Compactor, Liya Corporation) with a capacity of 2000 kN with a loading rate of 2.5 kN / s. All samples were tested at the same loading rate, and the rate was taken for every three cubes examined each time.

2.3.2.2 Ultrasonic Pulse Velocity Test

This test was in accordance with British Standard BS1881: Part 203 [15] using a non-destructive portable ultrasound signal tester (PUNDIT Lab PROCEQ) Switzerland. Two power transformers were installed on the device's cables, one of them acted as an ultrasound transmitter, and the second as a receiver. Both transformers were mounted to the sample surface with a coupling agent to ensure good pulse permeability. Grease or

Vaseline was applied between the tested surfaces of the sample and the contact faces of the transducer to ensure good contact. In this test, a linear vibration pulse with resonant frequencies of 54 kHz was produced by an electroacoustic transducer and then converted into an electrical signal by the transducer of the receiver. The pulse transit time is applied by an electronic timing circuit. Pulse velocity (V) in (m / s) was calculated as follows:

V = L / t ……………………………………………………….………..(1) [16]

Where L = distance between centers of transducer faces (m)

t = transit time (micro sec.)

2.4 Results & Discussion

A discussion of the effect of filler materials in the new compound on the properties of epoxy was included, and this study was completed by applying the best filler material to concrete after conducting several tests on it to prove the quality of the material and its effect on improving the properties of epoxy.

2.4.1 Composite Tests

2.4.2.1 Hardness Test

Hardness tester is mainly used to evaluate the indentation of materials. These methods include indentation of samples using steel indentation with specific strength and geometry. It is evident from the hardness test results that an increase in the filler content of the composite leads to an increase in the stiffness values, and the results from the figures are:

The addition of (S IC, AL_2 O_3 , SF, Pumice) to the epoxy improved the hardness due to the nature of the additives having high hardness, in addition to that the highest hardness value was obtained when adding 15% of the filler materials in general. The hardness values were increased due to the addition of fillers to the epoxy, due to increased crosslinking and stacking (which reduces the movement of the polymer particles), which increased the scratch resistance of the material. Then the stiffness of the material depends on the type of forces between the atoms or molecules present in the material. The strength of the bond increases from the value of the stiffness [15].

Table (1) the hardness results with filler percentage in the epoxy and epoxy separately

	Hardness, shore D			
Filler %	**SIC**	**Al_2O_3**	**SF**	**Pumice**
5	95.9	96.6	96	96.7
10	96.4	97.3	96.8	97.1
15	97.1	98.1	97.4	98.4
Epoxy	**95**			

2.4.2.2 Flexural strength Test

The following points can be concluded as a result of the bending test:

• The test results show the effect of the filler content on the bending. The bending resistance increases when the filler is added, due to the high degree of adhesion between the polymer and the filler particles. The filler acts as a binder that improves the bending resistance of the epoxy [9], while the bending resistance decreases at a high percentage of the filler because the distance between the chain of polymers increases and the filler particles prevent contact between them. In addition, at a high content of fillers, the particles act as pressure concentrators [17].

• A compound containing 5% pumice with a higher flexural strength of 85.5 MPa. This is because of the good adhesion between the particles and the matrix material (epoxy), and because the powder is well distributed in the matrix.

• The compound with a SIC content of 15% showed a decrease in bending resistance (13 MPa) as a result of the lower bond strength between the polymer and filler molecules.

• Pumice is a better reinforcing compound than other materials, due to the pumice as a filler behavior for good bending resistance and good workability.

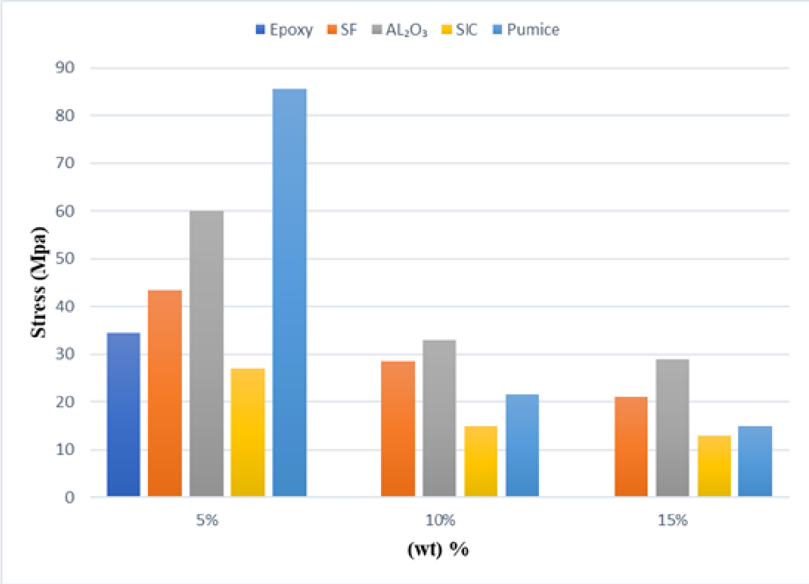

Figure 3: Comparison between the flexural strength of different percentage of polymer composites and epoxy without reinforcing

When comparing bending strength and packing (SIC, AL, SF, pumice) the compound reinforced with 5% pumice powder has higher bending strength, and the compound reinforced with 10% sic powder has lower bending strength. We conclude from this that additives at rates higher than 5% make the material brittle and vulnerable to impact loads.

2.4.2 Concrete Testes

2.4.2.1 Compression Test

The pressure behavior of composite materials is one of the important mechanical properties that has been carefully studied by scientists and researchers. In general, it is the main distinguishing value of evaluating composite quality in national and international laws. For this reason, it is especially important to check whether changes in the mixture composition will affect early and late compressive strength. All results are an average of three samples to obtain its last result. It can be concluded that the treatment of concrete cubes was effective in varying proportions, as the results showed that the treatment with epoxy only gave less results than the treatment with concrete cubes. Other composites and the results also showed that the highest result was obtained when treated with a compound (5% epoxy + pumice), and the reason for this was that the pumice powder did not significantly affect the bonding strength with epoxy. Molecules and also led to the development of their mechanical properties.

$\sigma = P/A$ ……..…………….…………………………………………..… (2)

- σ is the compressive strength (Mpa)
- P is the load (force) (N)
- A is the area (mm)

Table 2: The Compressive strength of Cube after Rehabilitation

No.	Compressive strength Mpa	Curing ratio %	
1	33	—	Stander
2	25	75.7	Rehabilitation with (Epoxy)
3	26.71	80.9	Rehabilitation with (Epoxy + 5% SIC)
4	25.8	78.1	Rehabilitation with (Epoxy + 5% A)
5	27.3	82.7	Rehabilitation with (Epoxy + 5% P)
6	26.5	80.3	Rehabilitation with (Epoxy + 5% SF)

2.4.2.2 Ultrasonic Pulse Velocity Test

The purpose of this type of test is to evaluate the consistency of the particle compounds as well as calculate the wave travel time. Useful data on the internal composition of the composite particle samples were obtained using this assay. This test was performed to find the homogeneity of the two parts of the treated cube. The following observations were obtained from the test results:

1. The addition of fillers of all proportions to the epoxy increased the density of the compound, indicating the homogeneity of the compound, resulting in an ultrasonic pulse velocity between 2350 m / s and 2810 m / s.

2. It should be noted that there is a slight difference in the results of this examination, and that the highest percentage was obtained for using the compound (epoxy + sic).

2

.5 Conclusions

The empirical results of the current tests are:

1- The main objectives of the current study are to develop compounds used in construction applications by strengthening the properties of the epoxy with different materials (SIC, AL, SF, PUMICE) as fillers.

2- Epoxy plays an important role in treating the bonding strength by reducing the brittle nature of the filling material, to fix adhesion between concrete cracks, a key factor in bonding to repair cracks, as it achieved the highest bending strength (5%) of the pumice compound (2.85 MPa).

3- The result of the compound containing pumice particles by (15%) gave the highest hardness test (98.4). The hardness of alumina is also high (98.1) by 15%, which is higher than the hardness given by the rest of the materials. The final results showed improvement in all general properties of the compound when adding (SIC, AL, SF, PUMICE).

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