Journal of Engineering and Sustainable Development
http://jeasd.uomustansiriyah.edu.iq/index.php
https://doi.org/10.31272/jeasd.25.3.8

Vol. 25, No. 03, May 2021
ISSN 2520-0917

STUDY THE EFFECT OF DIFFERENT ADDITIVES ON CRACK REPAIR

*Baraa M. Kadhim[1] Khalid M. Oweed[1]

1) Department of Materials Engineering, College of Engineering, Mustansiriyah University, Baghdad, Iraq

Received 14/10/2020 ***Accepted in revised form 20/12/2020*** ***Published 1/5/2021***

Abstract: Using epoxy to repair concrete crack is widely used for restoring concrete structure. Epoxy is used as a base material in composite materials with fillers to improve mechanical and physical properties. The study aims to modify the properties of the epoxy by adding (alumina, silicon carbide, silica fume, pumice) and using This compound is for repairing concrete cracks.
Each of the materials (alumina, silicon carbide, silica fume, pumice) were used to harden the epoxy in different proportions (5, 10, 15) by weight. It has particle sizes (45 - 65 µm), to prepare composite particles that can be used in construction applications. Further tests are performed to verify whether or not composites are suitable for applications. For the crack repair application, the resulting composites were tested for compression and bending.
The resulting compound was applied to treat cracks in previously prepared concrete samples and several tests were performed (compression, bending, and UPV) to determine the effectiveness of this compound in treating cracks in the structural elements.

Keywords: *(alumina), (pumice), (silicon carbide), (silica fume), epoxy resin, composite materials*

1.Introduction

Epoxy was one of the most often engineering techniques used by thermosetting widely in all electrical, electronic, packaging, packaging, textile and consumer applications due to its exceptional mechanical properties that fulfil this purpose. It refers to a wide variety of materials for use in the repair field. Repair materials can be of two types: reinforcing materials and based on resin[1]. Cement materials can alternate between traditional plaster and mortar, and materials with higher properties, i.e. fully improved, which are achieved through the use of additives. The additives used can lead to higher strength gain rates, become higher strength, reduce bleeding and shrinkage, and increase workability and tenacity[1].

These resin-containing materials are generally based on epoxy resins and include resins that are used for injection, gravity, and mortars and pastes of hand application. Epoxy resins are characterized by having a lower modulus of elasticity and higher creep compared to reinforcing materials[1]. For this reason, great effort was made to use matrix epoxy resin in composites[2] by adding inorganic fillers such as alumina, fly ash, clay, mica, silica, kaolin.[3]

A filler was added to the epoxy to enhance and develop the compound properties to obtain better double-edged material. The addition was demonstrated by improving the compatibility with the structure. This improvement was in terms of an increase in the modulus of elasticity and became non-sagging. The most prominent advantages of resin-based fillers as a fixing material over fixatives include the following:

**Corresponding Author*: baraa.makki90@gmail.com

- It has a very low viscosity for injection into microcracks,
- It has a high adhesion strength,
- It has high flexibility to accommodate movement,
- The gain rate is high, and
- It has a very high resistance to salt and water penetration.

The aim of the present work is to show the Utilization of polymer composites with fillers material as used as repairing cracks material for concrete.

2. Materials

2.1. Epoxy

The epoxy material used in this research works on treating the concrete cracks, which has two parts of the components: liquid and solid amine resin. Product Switzerland, and required ratio (2.72 bases in one booster).

2.2. Alumina

Naturally occurring in its α-Al_2O_3 polycrystalline phase, it is like the mineral corundum and its gemstones from sapphire and sapphire. The compound is chemically made of aluminum and oxygen with the chemical formula Al_2O_3. It is more common in many aluminum oxides and is a white crystalline powder that is odorless and insoluble in water. Alumina Particle size used 90 microns has been used to make sure that the epoxy has a fair distribution without precipitation, Coarse particles (more incredible 90 microns) in the epoxy because of gravity. It is identified explicitly as aluminum oxide (Al_2O_3) important in Because of its high hardness, it is used to produce aluminum metal as an abrasive, and it is resistant to heat due to its high melting point.

2.3. Silica Carbide

Also known as carborundum, it contains silicon and carbon. It is insoluble in water but soluble in hot alkali. It occurs very rarely in nature as the mineral moissanite. Industrial Sic this substance has been manufactured since 1893 in powder form for use as a bulk and much-needed abrasive. By sintering its particles, some applications require several characteristics where the use of ceramics is widespread because it is tough and also has high durability. Among these applications are car brakes, clutches, and ceramic plates in bulletproof vests. [4] Working with mesh grain size (passing through 220 mesh): min. 95.0% Molecular Weight: 40.10.

2.4. Silica fume

It has many names, including micro silica, which is an amorphous form of silicon dioxide and silica. Its particles are spherical and very soft because they are about 100 times softer than the cement used in construction.[5] Therefore, a portion of the cement used in the concrete mixture can be replaced with micro silica at a rate of 7-15 wt %. It is in the main field of application as high-performance concrete pozzolan material. The production process, particle properties, and application areas of fumigated silica differ from those of silica fumes. The main chemical and physical properties of silica fumes meeting American standards ASTM C 1240-04[6].

2.5 Pumice

It is a highly porous form of glazed igneous rocks, usually of a very light colon, and its actual density, that is, the density of crushed materials, is between 2000 and 3000 kg / m3 The bulk density, that is, the density of loose material accumulation, ranges between 300 and 800 kg/m_3.[7] The pumice particles are either round or angled and have a diameter of 65 mm. In addition to light-colored pumice, many dark-colored shapes were referred to as lava and can be also used as building materials. The powder was obtained by crushing jaw using a HERZOG HSM mill before sieving using an automatic sieve to enable particles of 50 microns in size. The particle size in this work was selected at (50 μm) for the pumice stone, which was then sieved through stages to obtain this particle size. The reason for choosing this particular size to ensure adequate distribution stability in the epoxy without precipitation was that coarse particles (greater than 50 microns) had settled in the epoxy due to gravity.

2.6 Cement

The type of cement used to form concrete in this paper is AL-Mass Portland Cement. The cement package was stored in a dry place to prevent it from being affected by weather conditions. According to the results of the examination, there is a conformity with the Iraqi Standard No. 5/1984[8]. Progress Engineering's construction lab conducted the test in Iraq.

2.7. Fine Aggregate

The maximum size and fineness modulus of natural green sand were 4.75 mm and 2.35, respectively. The test results are in conformity with the Iraqi Standard No. (45/1984)[9]. The tests were also conducted in the building materials laboratory of the Construction Laboratory of the Progress Engineering Company in Iraq.

2.8. Coarse Aggregate

Crushed river gravel obtained from Nabaie area was used for standard concrete with a maximum size of 5 mm. The test results comply with the limit of the Iraqi Standard IQS No. 45/1984 [9].

2.9. Water

Tap water was utilized for curing and mixing of the tested cubes and prisms specimens.

3. Experimental Work

Epoxy was manufactured with filler particles (Al2o3, Sic, Fumigated Silica, Pumice) with particle sizes 45-65 micron as a hardener. Various mixtures of composite particles were prepared to study their properties. Each substance was added in proportions (5, 10, 15) by weight%. Where samples were divided into 4 main groups for the composite material in addition to the additive-free epoxy showed in figure (1). 72 samples of reinforced epoxy were prepared with different materials and 6 samples of epoxy without addition. As the base material was mixed with the solidification ratio (2.72 bases with 1 hardener) with good mixing for 3 to 5 minutes, after which the fillings were added with different weight ratios, and mixed for 2 to 3 minutes after that they are poured into the moulds. 72 samples were divided into 4 main groups (P, F, C, A), and each group was divided into two subgroups, the tensile test group and the bending test group, supported materials were added in different proportions (5, 10, 15) %. The moulds are made of different materials (Silicone rubber mould), where the tensile moulds are manufactured according to (ASTM D638-TIPO I) [10] and the bending moulds according to American standards (ASTM D790-02) [11].as shown in figure (2)

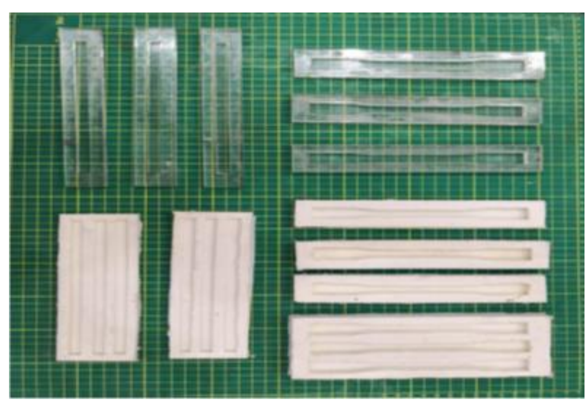

Figure 1. Molds.

Figure 2. Simples

4. Tests

Two parts of the tests are carried out, the first part was for samples of composite materials to choose the best percentage for injection into concrete, and the other part was for cubes and prisms to notice which of the materials gave higher efficiency compared to others.

4.1. Tests of Composite Material

Several tests were carried out for the particle compounds, including a mechanical and physical test. Physical test includes density and mechanical test consist of bending strength.

4.1.1. Density Test

Based on the standard procedure (ASTM C138) [12] for weighing samples and dividing these values (mass in kilograms) by the sample sizes, the density of the composites was selected for each epoxy filler in kg/m^3. Table 1 shows the results of the density tests for all ratios. Epoxy with additives as a strengthening material.

Table 1. The density of particulate composite specimens for Fillers.

Filler %	Density (Kg/m^3)			
	SCI	**Al_2O_3**	**SF**	**Pumice**
5	1180.924	1186.575	1186.575	1192.225
10	1214.827	1209.179	1220.477	1231.778
15	1265.68	1243.078	1248.729	1271.33
Epoxy	1100			

4.1.2. Tensile tests

Tensile tests were performed in the laboratories of the University of Technology, at 27 ° C on a universal testing machine WDW-200E, the Chinese manufacturer of the tensile strength of 200 kN. Dog bone shape samples (ASTM D638 I) were used for testing, see Figure 3. The test speed was chosen to be 5 mm/min. All samples were tested with the same load.

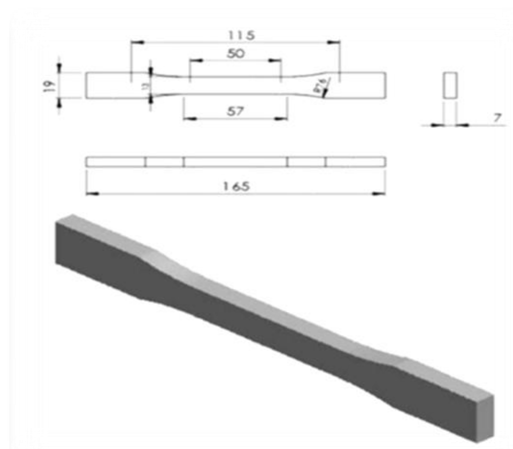

Figure ٣. Dog bone shape sample

4.2. Tests of The Concrete Mixture

There are several types of tests for concrete after injection, including tensile testing, bending and ultrasound to find out the strength and homogeneity of the concrete after filling the crack with composite materials.

4.2.1. Flexural Strength Test

The test method carried out following ASTM C1314-18[13].The specimen having a rectangular cross-section was bent to fracture or surrender as the sample was of rectangular cross-section (400×100×100 mm) using the machine calibration test machine for bending strength of concrete 150 KN, Liya co) with a loading rate of

1.8 kN / s. The rate was taken for three samples each time a test, see Figure ٤.

Figure ٤. Flexural Strength Test.

5. Results & Discussion

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

5.1 Composite Tests

5.1.1. Density Test

The increased densities of the additives improved and increased the density of the compound compared to the epoxy itself. It is showed that the density of the compound particles varies according to the amount of fine filler. This increase is a function of the proportion of materials and the amount of air that is or intentionally retained. Table (4-1) shows the results of density tests for all epoxy ratios with additives as stiffeners. The following observations can be obtained:

- A compound containing 15% achieved the highest density.
- The density of pumice in the compound was higher than that of the other additives in all proportions.
- However, it has been shown that adding fillers to epoxy increases the density of the epoxy.

5.1.2. Tensile Strength Test

The following observations can be concluded from above Figure results:

The effect of the filler content on the tensile strength of the epoxy. It is noticed that the highest tensile strength (33.62 and 33.4 MPa) was obtained when adding pumice and SIC at a rate of 5%.

Through the apparent experimental results, it is noticed that increasing the filler content at 15% weakens the material to resist tensile strength, and the reason for this condition is attributed to the fact that the distance between the chain of polymers increases and the filler particles prevent contact between them. In polymer/filler composites system, when agglomerations of filler occur, it leads to inhomogeneous distribution and consequently weakening the interaction between the filler and polymer matrix. Hence, this diminishes the mechanical properties of the composite. It is well-known that agglomerates are acting as a weak point in the composite materials, which result in undesirable material properties [14].

The reduction in tensile strength with filler addition may be due to the chemical bond strength between filler particles and the matrix is too weak to than silica fume the tensile load or the sharp corners of irregularly shaped filler particles result in stress concentration zones in the matrix body during tensile loading or due to the increase in void percentage in the composites with an increase in filler content [15].

5.2. Concrete Testes

5.2.1 Density

The density of concrete is a function of the scale of concrete hardness. Depending on the work need, the concrete mixing process can be modified to form a higher or lower density of the final product. Table 1 shows the density of concrete cubes used in this research.

Table 2. Density of Concrete Simples

No.	Weight (Kg)	Volume (m^3)	Density (Kg/m^3)	Description
1	7.68	0.003375	2275	Stander
2	7.65	0.003375	2266	Reh by (E)
3	7.65	0.003375	2266	Reh by (C)
4	7.7	0.003375	2281	Reh by (A)
5	7.69	0.003375	2278	Reh by (F)
6	7.71	0.003375	2284	Reh by (P)

5.2.2. Flexural Test

The results that all the materials used in the treatment were effective, as it was noticed that all samples that were treated and re-examined were noticed that failure does not occur in the treated area, and this indicates that the treatment materials that were manufactured for it Better mechanical properties than concrete, and has higher cohesion [16].

It is noticed that there is a slight difference in the results, and the reason for this is due to the fact that the samples were not poured from one mixture only, but from several mixtures, and it is not possible to obtain the same mixture all the time due to the conditions that are difficult to control, see table 2 [17].

Table 3. The Flexural strength of Cube after Rehabilitation

No.	Flexural Strength (MPa)	Curing Ratio (%)	Description
1	11.25	-	Stander
2	11	97.7	Reh. with (Epoxy)
3	11.1	98.6	Reh. with (Epoxy+5%SIC)
4	10.8	96	Reh. with (Epoxy+5%A)
5	11.3	100	Reh. with (Epoxy+5%P)
6	10.9	96.8	Reh. with (Epoxy+5%SF)

6. Conclusions

The following conclusions were reached through experience of the present study:

1. Adding fillers to epoxy has an effect on its properties and makes its nature brittle.
2. Interestingly, the wad filler can improve the tensile strength of epoxy to a certain extent.
3. The increase in the addition of epoxy fillers can significantly increase the density.
4. The best mechanical properties can be obtained using 5% pumice.
5. In terms of crack treatment, the treatment with composite consisting of epoxy and pumice of concrete samples that contain cracks was better than other materials.

Acknowledgements

Sincere debtors to the Materials Department of the College of Engineering / Al-Mustansiriya University for all the help, advice and facilities they provided us. Besides, I want to thank the Engineering Technical College / Production and Minerals Department. I want to thank the technicians and engineers of the Laboratory and Engineering AL-Taqadum Center Building research and concrete works which have the most examinations Experiments were conducted.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

References

1. Md Daniyal, Shakeel Ahmad, “Application of Waste Ceramic Tile Aggregates in Concrete”, International Journal of Innovative Research in Science, Engineering and Technology, vol. 4, Issue 12, 2015.
2. Andrew Mc Eish, Underwater Concreting and Repair. New York, USA: John Wiley and Sons, Inc. (1994).
3. H. V. Rama Krishna, S. Padma Priya, S. K. Rai, A. Varada Rajulu "Tensile, Impact, and Chemical Resistance Properties of Granite Powder-Epoxy Composites", Journal of Reinforced Plastics and Composites, Vol. 24, no. 5, pp. 451-455, 2005.
4. Poornima Vijayan P, Debora Puglia, Agnieszka Dąbrowska, Pournami Vijayan P, Andrzej Huczko, Jose M. Kenny, Sabu Thomas "Mechanical and thermal properties of epoxy/silicon carbide nanofiber composites", Polymers for Advanced Technologies, Vol. 26, no. 2, pp. 142-146, 2015.
5. Abhinav Shyam, Abdullah Anwa, Syed Aqeel Ahmad "Study of Silica fume as Partial Replacement of Cement in Concrete", nternational Journal of Advanced Engineering, Management and Science (IJAEMS) Vol. 3, no. 3, 2017.
6. "ASTM C1240-04, "Standard Specification for the Use of Silica Fume as a Mineral Admixture in Hydraulic Cement Concrete, Mortar and Grout"", ASTM International, West Conshohocken, PA,2004, Vol., 2004.
7. R. Muralitharan, V. Ramasamy "Basic Properties of Pumice Aggregate", International Journal of Earth Sciences and Engineering, Vol. 08, pp. 256-258, 2015.
8. IQS No.5/1984,"Portland Cement”, Central Agency for Standardization and Quality Control, Planning Council, Baghdad, Iraq, Translated from Arabic Edition.
9. "Iraqi Specification Limit, "Aggregate from Natural Sources for Concrete and Construction", Central Agency for Standardization and Quality Control, Baghdad, IQS No.45 , Vol., 1984.
10. Sarah Griffin, Hossein Askarinejad and Brian Farrant “Evaluation of Epoxy Injection Method for Concrete Crack Repair” P. O. Box 540, Christchurch 8140, New Zealand.
11. ASTM D 790 – 02, “Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials”, 2002.

12 "ASTM C138/C138M Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete", Vol., 2010.

13. "ASTM D 790 – 02, “Standard Test Methods for Flexural Properties of 121Unreinforced and Reinforced Plastics and Electrical Insulating Materials”", Vol., 2002.
14. Edward M. Petrie.,” Handbook of adhesives and sealants”, The McGraw-Hill Companies, Inc., 2000.
15. George O., “Principles of Polymerization”, Fourth edition, John Wiley & Sons, Inc., New York, 2004.
16. Shrivastava, Anshuman and William Andrew “Introduction to Plastics Engineering ,2018.
17. Carraher’s S., “Polymer Chemistry”, Seventh edition, Charles E. Carraher J., CRC press Taylor and Francis Group, New York, 2006.