Sulfate Resistance Of Polymer Light-Weight Concrete With Variation Of Epoxy Resin

Aidil Fitra Bowo, Saloma, Siti Aisyah Nurjannah, Ika Juliantina

Abstract: Sulfate attacks that occur naturally in soil and groundwater where structures are located, to minimize damage to concrete structures due to external influences. Immersion carried out based on ASTM 1012 Concrete soaked for 28 days with 2 types of sulfate solution is aluminum sulfate $Al_2(SO_4)_3$ and sodium sulfate (Na_2SO_4) with a concentration of 10%. The test results show that compared to polymer light-weight concrete under normal conditions and polymer light-weight concrete under sulfate immersed conditions, the compressive strength of concrete with epoxy resin substitution is higher than the compressive strength of concrete that has been immersed in sulfate solution. The test results show that the compressive strength of 28 days of age under normal conditions produces maximum compressive strength compared to concrete in conditions that have been immersed for 28 days experiencing a decrease in compressive strength due to sulfate attack.

Index Terms: Sulfate attack, aluminum sulfate, sodium sulfate, sulfate solution, compressive strength, epoxy resin, polymer light-weight concrete.

1 INTRODUCTION

Concrete is one material that is widely used as the main material for building civil infrastructure systems such as waste facilities. In sewage facilities, there are bacteria that react with hydrogen sulfate to produce sulfuric acid which causes concrete to break down quickly [1]. The addition of polymers to concrete without cement aims to improve concrete properties and shorten the manufacturing process time. To improve the durability of concrete structures, a lot of research has been done in the last few decades polymer modification is one of the most effective methods to improve concrete performance [2]. The mechanism of sulfuric acid corrosion on concrete will affect the performance of concrete which will reduce concrete's resistance to corrosive sulfuric acid. The physical and chemical reaction between sulfuric acid and cement products is a major cause of failure in the durability of concrete structures [2]. The mechanism of sulfuric acid corrosion on concrete is the result of a combination of corrosion and subsequent corrosion reactions caused by sulfuric ion (SO_4^{2-}) [3]. Immersion in sulfuric solution with 70 x 70 x 70 mm specimens carried out a concentration of 7% volume of sulfuric acid pH 3 and concentration of 3% volume of sulfuric acid pH 6. 7% concentration is the maximum concentration produced by thiobacillus bacteria [4]. Testing fine aggregate particles used in sizes 0.3 to 5.0 mm immersed in sulfate solution. The material is prepared in a dry state, then the material is immersed in a sulfate solution with a concentration of 5% for each test for 14 days [4]. The cycle of material damage due to sulfuric acid attack can be seen in Fig 1.

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In reinforced concrete construction, corrosion actually not only occurs in reinforcing steel, but also occurs in the concrete material itself, especially in aggressive environments, in environments that contain many elements of sulfuric salt, chloride or other acids [5].

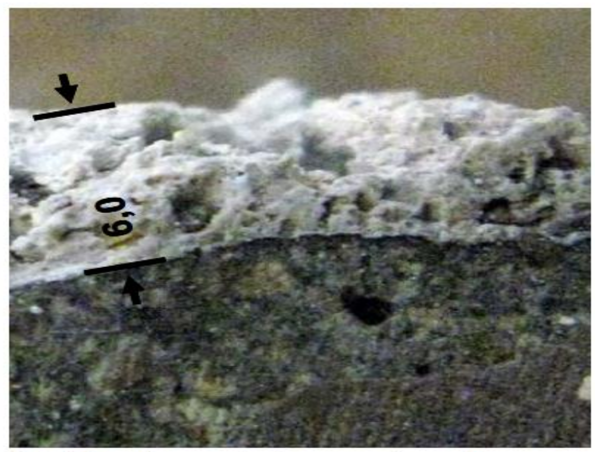

***Fig 1**. Sulfuric acid immersion concrete test results*

Sulfate sources that can cause damage to concrete are as follows:

a. Internal Sources

Although rarely found, but sulfate can come from within the concrete itself, which is derived from concrete materials such as hydraulic cement, fly ash, aggregates, and other materials.

b. External Sources

Sulfate is indeed common in soil or ground water, or also comes from industrial waste that is around the concrete structure [6].

Concrete construction that is built underground or at sea, the environment can contain sodium, calcium, magnesium chloride and magnesium sulfate. Calcium hydroxide or lime contained in cement will react with sulfate and water, then produce calcium sulfate. The formation of calcium sulfate when it is dry then, the cast will form a needle-like crystal and expand, pressing on the surrounding side so that damage occurs on the side around it and can be seen the paste or mortar is brittle [6]. If after the cast is wet or damp, the cast will react with C_3A or calcium aluminate hydrate in concrete to form calcium sulfat aluminate salt or often called ettringite, which has fluffy properties. Because the development of a larger volume that is beyond the original volume, this chemical process will cause bubbles, cracks, and concrete peeling. With such concrete conditions, the compressive strength of its destruction will decrease. Furthermore, the damage spreads to the inside so that the corrosion attacks the reinforcement [7]. The severity of the sulfate attack depends on a number of factors including the following.

1 Type sulfate, magnesium and ammonium sulfate are the most damaging to concrete.
2 Sulfate concentration, the greater the sulfate content, the more damaging the concrete.
3 Way of contact between sulfate and concrete. In the case of running water, the severity of the sulfate attack increases. More intensive attacks occur on concrete that is subjected to a cycle of wetting and drying than concrete that continues to sink in sulfate solution.
4 Pressure. The pressure from outside the concrete tends to force the sulfate solution into the concrete resulting in increased severity of the sulfate attack.
5 Temperature. Like most chemical reactions, the reaction rate increases with temperature.
6 The presence of other ions. Other ions present in the sulfate solution affect the severity of the attack.

For example sodium hydroxide can reduce sulfate expansion, sodium chloride can slow the formation of ettringite, and magnesium chloride can prevent the formation of ettringite completely [8]. Sulfate attack on concrete will occur when sulfate solution penetrates and reacts with concrete, especially with cement. Thus, the factors that influence concrete's resistance to sulfate are not only what affects the chemical reaction with the compound in cement, but also what influences the permeability and overall quality of the concrete [8]. According to Cement Concrete and Aggregates Australia (2002) [8], these factors include the following:

1 The type of cement used in a concrete mixture is a factor that affects the resistance of concrete to sulfate. Portland cement which contains less than 5% tricalcium aluminate is classified as sulfate-resistant cement.
2 The level of cement, the level of damage to sulfate decreases with increasing levels of cement, even in concrete made from ordinary Portland cement. To produce sulfate resistant concrete, the use of sulfate resistant cement must be combined with the use of minimum cement content.
3 Water factor semen, if all the other factors in the concrete are the same, good quality material, the right proportion of mixtures and good workmanship, resistance to sulfate increases with decreasing value of the cement water factor.
4 Material in addition, the use of additives that have an effect on reducing the cement water factor or increasing the workability of concrete can increase the resistance of concrete to sulfate, as long as it is not used to reduce cement content. The use of additives containing calcium chloride also affects the resistance of concrete to sulfate.
5. The construction, casting, compaction and maintenance of concrete is an important factor for producing concrete with low permeability. Adding water during casting to reduce the value of the slump or to assist during the final finishing process will disrupt the concrete's resistance to sulfate.
6 Design and detail, a structure designed in detail that provides for adequate reinforcement to minimize cracking or to minimize inundation is important to reduce the intensity of sulfate attack, thereby increasing concrete's resistance to sulfate.

2 EXPERIMENTAL PROCEDURES

2.1 Material

The materials used in this study include the following:

a. The epoxy resin
b. Aggregate
c. The water
d. Foaming agent
e. Sodium sulfate and aluminum sulfate

TABLE 1

COMPOSITIONS OF LIGHTWEIGHT POLYMER CONCRETE

Mixed Code	Epoxy (kg/m^3)		aggregate (kg/m^3)	Foam (L)
	Resin (kg/m^3)	Hardener (kg/m^3)		
BP 1: 3.00 - 1:30	187	93	840	500
BP 1: 2.75 - 1:30	199	100	821	500
BP 1: 2.50 - 1:30	213	107	800	500
BP 1: 2.00 - 1:30	249	124	747	500
BP 1: 3.00 - 1:40	187	93	840	500
BP 1: 2.75 - 1:40	199	100	821	500
BP 1: 2.50 - 1:50	213	107	800	500
BP 1: 2.00 - 1:50	249	124	747	500
BP 1: 3.00 - 1:50	187	93	840	500
BP 1: 2.75 - 1:50	199	100	821	500
BP 1: 2.50 - 1:50	213	107	800	500
BP 1: 2.00 - 1:50	249	124	747	500

Information:
BP = lightweight polymer concrete
1: 2-1: 3 = epoxy ratio: fine aggregate
1: 30-1: 50 = ratio of foaming agent: water

To determine the proportion of mixtures the ACI Standard 211.1-91 method is used [8]. Cube-shaped specimens measuring 50 x 50 x 50 mm. The test is limited to 28-day old specimens with the distribution of samples in each variation of the epoxy resin mixture as shown in table 1. Test specimens that have been made in accordance with the proportion of the mixture, removed from the mold, carried out maintenance and soaked sulfate solution for normal concrete or concrete with epoxy resin according to the age specified. After that, the weight of the test object is weighed and a compressive strength test is performed [9].

3 RESULTS AND DISCUSSION

3.1. AGGREGATE TEST RESULTS

Based on ASTM C40 [10] the results of aggregate test showed a light yellow color in the test and compare it with the number of organic plates. The result of aggregate testing shows organic plate standard No.2. So that the fine aggregate in this test meets the eligibility standard under organic plate no.3 and is suitable for concrete mixtures. Based on ASTM C 40 [10] the results of the testing of fine aggregate sludge content meet the percentage of sludge content below 5%. Data on the results of aggregate testing can be seen in table.

TABLE 2

THE RESULTS OF AGGREGATE TESTING

No.	Description	Results
1	Sand + mud height (cm)	10
2	Sand height (cm)	9.7
3	Sludge levels (%)	3
4	Pan Weight (gr)	63.5
5	Wet aggregate weight (gr)	1,063.5
6	Dry aggregate weight (gr)	1,048
7	Water content (%)	1.57

3.2. FLOW TABLE

Flow table test results obtained range from 16-25 cm with the diameter of the mortar the most flow is found in a mixture of BP 1: 3-1: 30 of 25.73 cm (Fig. 2 and 3). Percentage of maximum flow table diameter found in the mixture of BP-1: 3-1: 30 obtained an optimum diameter of 25.73 cm, the percentage of mixture of BP-1: 3-1: 40 obtained a diameter of 20.65 cm and the minimum diameter percentage found in the mixture of BP 1: 3-1: 50 obtained at 16.98 cm. This shows the higher the percentage of foam agent, the smaller the diameter of the concrete mixture [11].

3.3. DENSITY

Density testing is done by weighing the weight of the cube volume cube 0.000125 m^3. Based on Fig. 4 the maximum percentage specific gravity mixture of BP 1: 3-1: 30 mixture is 1,768 kg/m^3 and the minimum percentage specific gravity in a mixture of BP 1: 2-1: 50 is 1,564 kg/m^3. The average specific gravity of the test object at a percentage of water is 30% greater than the specific gravity of the test object percentage of 40% and 50% [12]. This shows that concrete is included in the criteria for lightweight concrete with a specific gravity range of 300-1,850 kg / m^3 [13].

3.4. COMPRESSIVE STRENGTH TEST RESULTS

The optimum compressive strength of lightweight concrete polymers at 28 days was obtained in a mixture of BP 1: 3-1: 30 of 15.89 MPa. The optimum compressive strength of lightweight concrete polymers at 28 days was obtained in a mixture of 1: 2-1: 50 of 11.34 MPa (Fig. 6 and 7).

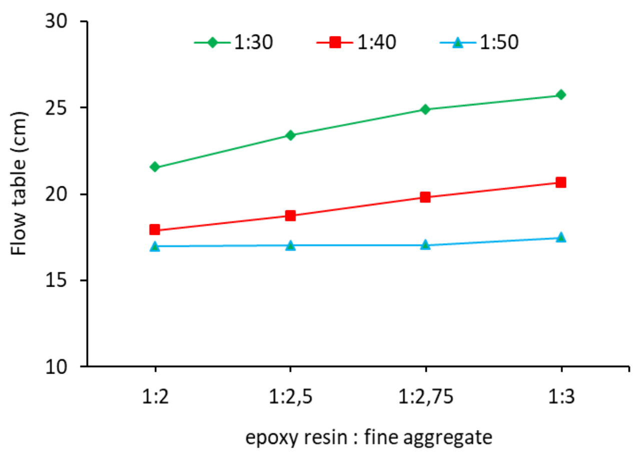

***Fig 2**. Effect of percentage of epoxy and fine aggregate on the flow table*

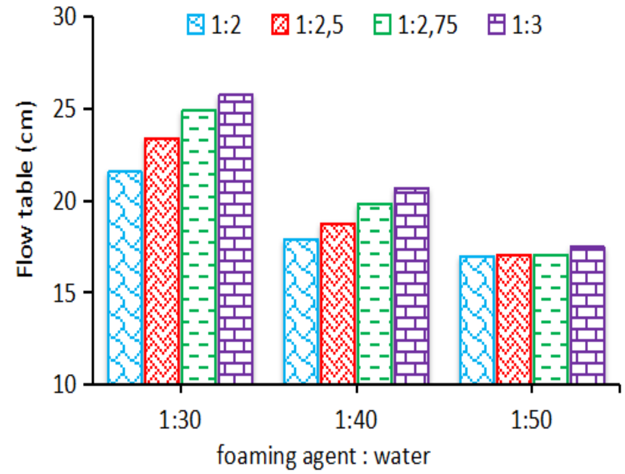

***Fig 3.** Effect of foam percentage on the flow table*

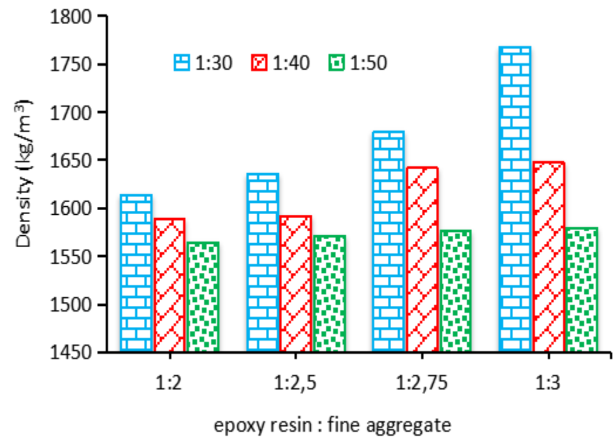

***Fig 4.** Effect of percentage of epoxy and fine aggregate on the density*

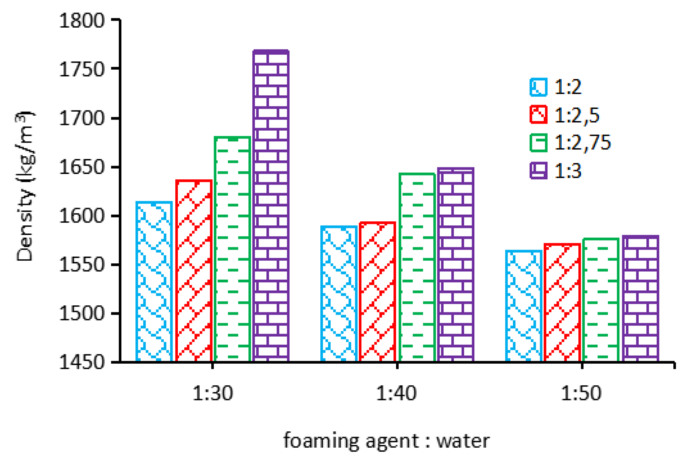

***Fig 5**. Effect of percentage foaming agent and water on specific gravity*

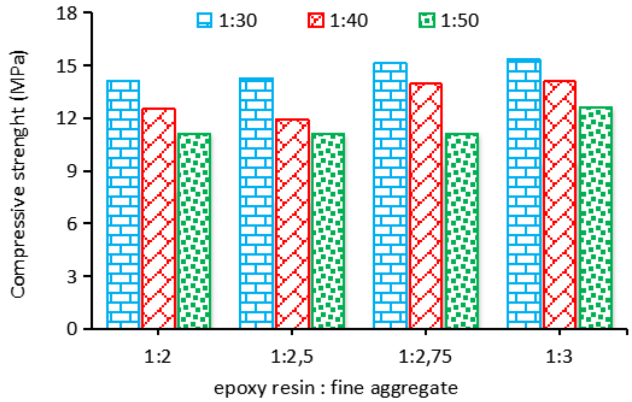

Fig 6. The effect of percentage of epoxy resin and fine aggregate on compressive strength

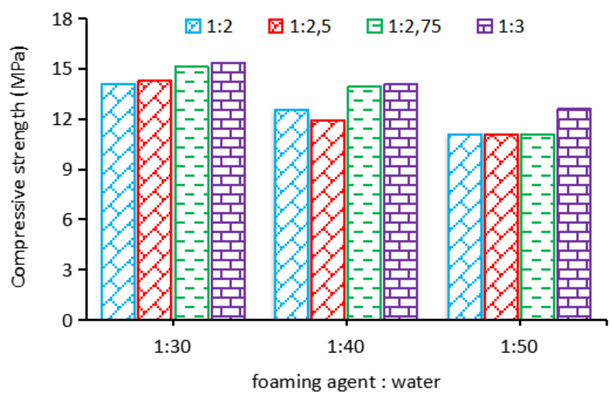

Fig 7. The effect of the percentage of foaming agent and water on compressive strength

3.5. MICROSTRUCTURE TESTING RESULTS

Regarding lightweight concrete polymers using foaming agents, SEM test results were obtained. These particles are usually hollow, contain other smaller particles on the inside, the surface texture of the particles looks smooth, and has no form of quartz particlesLightweight polymer concrete which was tested by microstructure with 2000x magnification produced uniform pores of 0.5-10 µm (Fig. 8 and 9). The results of the 2000x magnification microstructure test on polymer lightweight concrete that was immersed using a sulfate solution namely sodium sulfate (Na_2SO_4) and aluminum sulfate $Al_2(SO_4)_3$ for 28 days shows that lightweight polymer concrete has larger pores and a non-dense matrix at the ratio of foaming agents and water causes high levels of concrete dehydration. Pores are seen a lot in the mixture with the addition of epoxy resin, thus contributing to the reduction in compressive strength of concrete [14].

Fig 8. Microstructure test results in immersion Al_2SO_4

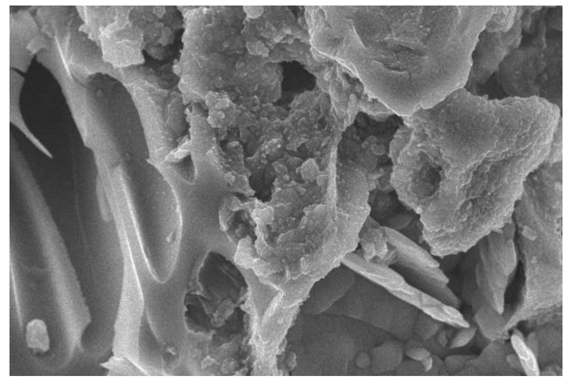

Fig 9. Microstructure test results in immersion Na_2SO_4

4. CONCLUSION

Considering the results of this experimental research, the authors conclude as follows:

1. The value of concrete slump with epoxy resin substitution is greater than the value of normal concrete slump. The value of the concrete slump continues to increase with the addition of the amount of foam in the concrete. This means that the pores produced by foam on the concrete will contribute to the reduced compressive strength of the concrete.
2. There are more pores in the concrete and damage to the concrete during the attack of sulfate solution causes a decrease in weight of the concrete and a decrease in the compressive strength of the concrete.
3. The results of compressive strength test of lightweight concrete polymers have maximum compressive strength in a mixture of BP 1: 3.00 - 1:30 for 1,768 kg/m^3. While the minimum compressive strength is found in a mixture of BP 1: 2.00 - 1:50 for 1,564 kg/m^3.
4. The effect of sulfate on lightweight concrete polymers was seen in microstructure testing of concrete immersed with aluminum sulfate $Al_2(SO_4)_3$ and sodium sulfate (Na_2SO_4) with a concentration of 10% show pores of 10 µm which contributes to reducing the compressive strength of concrete.
5. The increasing amount of concentration of sulfate solution and duration of soaking. The decreasing value of concrete compressive strength.

5 ACKNOWLEDGMENT

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