The Effect of Using Epoxy Resin Variations on The Value of Compressive Strength, Split Strength, and Elastic Modulus of Polymer Mortars Using River Sand

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ABSTRACT
The rapid development of physical and infrastructure projects in Indonesia necessitates efficient building materials. Mortar, a standard construction material comprising fine aggregate, water, and cement, has strength, environmental resistance, and flexibility limitations. This study investigates using epoxy resin as a substitute for cement in mortar production. Epoxy resin, a liquid material that hardens into a strong binder, offers potential benefits such as accelerated setting time and increased strength. The research uses river sand as the fine aggregate and varies the epoxy resin content from 5%, 10%, 15%, 20%, and 25% of the material volume. Tests will measure compressive strength, split tensile strength, and modulus of elasticity across different epoxy resin compositions. Results from Tanjung Pura University’s Materials and Construction Laboratory in Pontianak indicate that adding epoxy resin significantly improves compressive strength (up to 35.92 MPa at 25% resin) and tensile strength (up to 3.82 MPa at 25% resin). However, adding epoxy resin leads to a decreased modulus of elasticity, indicating increased deformability. This research sheds light on epoxy resin’s impact on mortar strength and informs potential applications in concrete repair and construction.

Keywords: Epoxy resin, Mortar production, Compressive strength, Tensile strength, Building materials.

1. Introduction
Polymer mortars play a vital role in various construction applications because of their high mechanical properties and resistance to harsh environments (Sikandar et al., 2023; Xie et al., 2023). In recent years, increasing interest has been in utilizing different epoxy resin formulations in polymer mortars (Pang et al., 2023). These variations of epoxy resin have demonstrated promising potential for enhancing the mechanical properties of polymer mortars, particularly concerning compressive strength, split strength, and elastic modulus (Guo et al., 2020).
Epoxy resins are vital materials in engineering due to their notable characteristics, including high tensile strength, low shrinkage, good adhesion, insulation properties, and excellent chemical corrosion resistance (Aziz et al., 2023). Altering epoxy resins with reactive silanes and siloxanes like carbo-functional silanes can significantly improve the properties of cross-linked epoxides and their composites and nanocomposites (Yu et al., 2020; Brząkalsk et al., 2022). Moreover, incorporating fillers such as small alumina particles into epoxy resins has enhanced their mechanical properties (Tee et al., 2022). For instance, adding silica nanoparticles to epoxy polymers can enhance the fracture energy and toughness of the material. This implies that changes in epoxy resin formulations, including modifications with reactive silanes and fillers, can significantly impact polymer mortars’ compressive strength, split strength, and elastic modulus using river sand (Niaki, 2023). Therefore, it is crucial to investigate how different epoxy resin variations affect these properties to better understand and optimize polymer mortars' performance in various applications (Rahman & Li, 2023).

This study aims to test mortar mixtures by adding epoxy resin as a substitute for cement in its manufacture. Mortar, a blend of materials widely used in construction, bonds building materials like bricks or concrete blocks. However, traditional cement mortar exhibits several drawbacks, including low strength, poor environmental resistance, and limited flexibility. This investigation will assess the compressive strength, split tensile strength, and modulus of elasticity of the mortar mixture when adding epoxy resin. Epoxy resin was selected as a substitute for cement due to its liquid nature and ability to harden to a specific strength, functioning akin to a binder similar to a cement-water mixture. The use of epoxy resin in mortar is anticipated to address the shortcomings of conventional cement mortar.

The test will be carried out using a cylindrical specimen from a mixture of river sand, epoxy resin, and water. The composition of the mix will be varied with different volume ratios of epoxy resin, for example, 5%, 10%, 15%, 20%, and 25% by weight of the material. After the mortar mix is made, the specimen will be tested to measure its compressive strength, split tensile strength, and elastic modulus. The compressive strength test will provide information about the maximum strength that can be retained by the mortar mix when given a compressive load. The split tensile strength test will test the mixture's strength when given a tensile load that tends to cause cracks or splits in the mix. Meanwhile, the elastic modulus test will measure the ability of the mixture to return to its shape after being deformed. By conducting tests on mortar mixes with the addition of epoxy resin, this research is expected to provide a deeper understanding of the effect of adding epoxy resin on the mechanical properties of mortar. The results of this study will provide important information in structural planning and construction improvement, especially in choosing a mortar mix with optimal strength and performance.

This study will be carried out at the Laboratory of Materials and Construction, Tanjung Pura University, Pontianak, using river sand available on the market around Pontianak and epoxy resin from PT. Sika Indonesia. Testing will be carried out at a certain age, for example, one day, three days, and seven days after the mortar mix is made. The results of this study are hoped to benefit the construction industry by selecting and optimizing the use of mortar mixes with the addition of epoxy resin for repairing concrete and other constructions. Based on a parameter such as Elasticity Modulus (Young Modulus), Compressive and tensile strength tests.

2. Materials and Methods

This study focuses on the use of epoxy resin as a substitute for cement in mortar production in Indonesia. The country's construction development is closely tied to its economic growth, and mortar is a popular building material used in infrastructure development. Unlike concrete without coarse aggregates, mortar consists of a binder, fine aggregates, and possibly fillers. It is primarily used for bonding, coating walls, joining building materials, and as a coating, joint filler, and waterproof layer.

Although cement mortar is commonly used, it has limitations such as low strength, poor resistance to harsh conditions, and limited flexibility. Therefore, the research aims to investigate using epoxy resin as a superior alternative. Epoxy resin, known for its fluid properties and hardening ability, can act as a bonding material similar to cement and water. Its incorporation in mortar can accelerate the hardening process, leading to faster curing.
The research aims to obtain mortar mixtures with epoxy resin that offer optimum compressive strength by varying the binder ratios. Ordinary river sand available in the market is used as the fine aggregate. The study aims to determine the highest compressive strength, split tensile strength, and modulus of elasticity values for test specimens made from river sand mixtures with different epoxy resin compositions (5%, 10%, 15%, 20%, and 25% by volume). These findings can provide insights into the behavior of the composite material and aid in structural design and construction repairs.

The research will be conducted at the Materials and Construction Laboratory of Tanjung Pura University in Pontianak. The research limitations include focusing only on testing compressive strength, split tensile strength, modulus of elasticity, and the specific testing timelines for different mixtures. The target compressive strength for the mortar is 20 MPa, and the river sand used is sourced from the Pontianak market. The epoxy resin used is from Sika Indonesia. The research aims to determine the highest strength values for the mortar mixtures and understand the influence of epoxy resin volume ratios on the strength of polymer mortar mixtures.

2.1. Study Area

The study was conducted at the Tanjungpura University Materials and Construction Laboratory on Prof. Hadari Nawawi Road in Pontianak City, Indonesia.

2.2. Data

2.2.1. Fine Aggregate Parameter Test Result

Testing fine aggregate parameters aims to understand and evaluate the physical characteristics and quality of fine aggregate used in construction. These parameters include specific gravity, water absorption, fineness, cleanliness, and particle shape.

a. Testing the specific gravity of fine aggregate is essential to determine the unit weight of the material. This information is needed in structural design calculations, concrete mix volumes, and estimation of material strength.

b. Testing the water absorption of fine aggregate gives an idea of how much the material can absorb water. This parameter is essential in determining the quantity of water that will be absorbed by the aggregate in the concrete or asphalt mixture, which in turn can affect the physical properties and final strength of the construction.

c. In addition, fine aggregate testing also includes fineness and cleanliness. The fineness of the fine aggregate determines the extent to which the aggregate particles can spread out and fill the spaces between other particles in the mixture. Fine aggregate cleanliness relates to contaminants such as soil, silt, or other organic matter, which can affect the performance and strength of the mix.
d. The shape of the fine aggregate particles is also a parameter tested. The form of the particles can affect the interaction between the aggregate and the cement or asphalt matrix, as well as the strength and stability of the final mix.

e. Overall, fine aggregate parameter testing aims to ensure that the fine aggregate meets the technical and quality requirements required in construction. The results of this test will assist in selecting and using optimal fine aggregate to achieve the desired performance and strength in construction projects.

2.2.2. Specific Gravity and Water Absorption

Examining the specific gravity and water absorption of fine aggregates is crucial for characterizing the materials used in construction (Nedeljković et al., 2021). The specific gravity test involves measuring the weight and volume of fine aggregate after it has been dried. The specific gravity of the fine aggregate can be determined by applying the appropriate formula (Kirthika & Singh, 2020). Similarly, the water absorption test assesses how much water the fine aggregate can absorb (Yang et al., 2021). For this test, representative aggregate samples are submerged in water, and the difference between the weight after soaking and the initial dry weight is calculated to determine the absorbed water amount. The outcomes of these tests provide essential insights into evaluating the quality and suitability of fine aggregate for use in various construction mixes.

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Pycnometer weight</td>
<td>150</td>
<td>150</td>
<td>gram</td>
</tr>
<tr>
<td>B</td>
<td>Weight instance of SSD condition</td>
<td>500</td>
<td>500</td>
<td>gram</td>
</tr>
<tr>
<td>C</td>
<td>Pycnometer weight + Water + SSD sample</td>
<td>950</td>
<td>953.9</td>
<td>gram</td>
</tr>
<tr>
<td>D</td>
<td>Pycnometer weight + Water</td>
<td>646.7</td>
<td>647.3</td>
<td>gram</td>
</tr>
<tr>
<td>E</td>
<td>Dry Sample Weight</td>
<td>484.4</td>
<td>490.9</td>
<td>gram</td>
</tr>
</tbody>
</table>

Based on Table 1, the comparison between Sample 1 and Sample 2 reveals that Sample 1 has slightly higher values for apparent specific gravity, bulk specific gravity (dry and SSD), and water absorption percentage than Sample 2. These variations indicate differences in the fine aggregates' physical properties and water absorption capacity. It is crucial to consider these parameters when selecting aggregates for construction purposes to ensure appropriate performance and suitability in specific applications whenever bulk production needs to be conducted to achieve consistent results.

2.2.3. Fine Aggregate Gradation Mesh

The testing of fine aggregate grading assesses the particle size distribution of materials like sand or rock dust (Xie et al., 2022). This examination aims to analyze how different size fractions are distributed within the aggregate, a factor that can significantly influence the density, strength, and stability of the resulting mixtures.

During the fine aggregate gradation test, fine aggregate samples are placed onto a series of perforated sieves of varying sizes. These sieves are arranged in descending order, with the sieve featuring the most significant holes positioned at the top and the smallest at the bottom. The aggregate sample is then subjected to sieving using a mechanical sieve machine or manually with repeated motions until no particles pass through a particular sieve within a designated time frame.
Upon completion of the sieving process, the quantity of aggregate retained on each sieve is measured and documented. This data is subsequently utilized to calculate the weight percentage of aggregate present within each specific size fraction.

The results of the fine aggregate gradation test provide information about the particle size distribution of the aggregate and can be used to compare with predetermined technical specifications. By understanding the grading of fine aggregate, engineers and planners can optimize the mix's physical and mechanical properties and ensure the aggregate’s suitability to achieve the desired construction result.

![Figure 2. ZONE II Fine Aggregate Classification](image)

Based on the Result, it is concluded that both samples of river sand qualified as second-zone grade fine aggregate (SNI: 03-1970-2008)

### 2.2.4. Mud Content

The silt content in fine aggregate is evaluated to assess the presence of silt or other organic contaminants within the samples (Beddaa et al., 2020). Elevated silt levels can adversely impact the aggregate's physical characteristics and overall quality, potentially affecting the performance of concrete or asphalt mixtures (Dehghan et al., 2021). Typically, this testing process involves obtaining a fine aggregate sample and washing, screening, and drying the material. Subsequently, the weight of the remaining silt in the sample is calculated as a percentage of the total sample weight. Assessing the silt content of fine aggregate yields crucial insights into the quality and suitability of the material for construction purposes, thereby ensuring that concrete or asphalt mixtures perform as intended (Qamhia et al., 2022).

#### Table 2. Mud Content

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand Height (T1)</td>
<td>80</td>
<td>80</td>
<td>ml</td>
</tr>
<tr>
<td>Mud Height (T2)</td>
<td>1</td>
<td>2</td>
<td>ml</td>
</tr>
<tr>
<td>Mud Content</td>
<td>1,24%</td>
<td>2,44%</td>
<td>%</td>
</tr>
<tr>
<td>Average</td>
<td>1,84%</td>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>

The result concludes that the mud content is acceptable. According to SNI S-04-1989-F, the maximum amount of mud content in fine aggregate is less than 5%, which is only found to be 1,837%.

### 2.2.5. Organic Content

Fine aggregate organic content testing was performed to quantify the level of organic matter contamination within the aggregate samples (Beddaa et al., 2020; Lehmann et al., 2021). The
presence of organic materials such as leaves, twigs, or other substances can adversely affect the physical properties and quality of the aggregate, ultimately compromising the strength and stability of the mixture (Omar et al., 2020). This testing entails obtaining a fine aggregate sample, cleaning and drying it, and subjecting it to high temperatures to incinerate organic matter. Subsequently, the weight of the residual organic material in the sample is calculated as a percentage of the total sample weight. Examining fine aggregate organic content aids in evaluating aggregate quality and ensuring that the material used in construction is not excessively contaminated with organic substances. This assessment is crucial for achieving optimal performance and strength in the resulting mixture.

![Figure 3. Organic Content Test](image)

Based on the scale system, scales 1-3 are approved as useable fine aggregate, while 4-5 are rejected due to their high organic content.

### 2.2.6. Volume Weight

The fine aggregate volume weight test was conducted to establish the correlation between the weight and volume of the fine aggregate sample (Beddaa et al., 2020; Kirthika & Singh, 2020; Malek et al., 2020). This procedure involves measuring the weight and volume of the fine aggregate after it has been dried. The fine aggregate's unit weight or specific gravity can be calculated using the appropriate formula. This test aids in determining the density and strength of the fine aggregate utilized in the mixture. The fine aggregate unit weight test results offer crucial insights for structural design calculations, volumetric blending, and material quality assessment. By comprehending the unit weight of fine aggregate, engineers, and planners can optimize the physical and mechanical properties of the construction mix, ensuring aggregate quality and suitability to achieve the desired performance levels.

**Table 3. Results of Volume Weight Test on Fine Aggregates**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mould's Volume</td>
<td>10</td>
<td>10</td>
<td>liter</td>
</tr>
<tr>
<td>Mould's Weight</td>
<td>4.57</td>
<td>4.57</td>
<td>kg</td>
</tr>
<tr>
<td><strong>Loose Sample</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould+Sample Weight</td>
<td>20.44</td>
<td>20.91</td>
<td>kg</td>
</tr>
<tr>
<td>Sample Weight</td>
<td>15.87</td>
<td>16.34</td>
<td>kg</td>
</tr>
<tr>
<td>Loose Volume Weight</td>
<td>1.587</td>
<td>1.634</td>
<td>kg/liter</td>
</tr>
<tr>
<td><strong>Compacted Sample</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mould+Sample Weight</td>
<td>21.25</td>
<td>21.39</td>
<td>kg</td>
</tr>
<tr>
<td>Sample Weight</td>
<td>16.68</td>
<td>16.82</td>
<td>kg</td>
</tr>
<tr>
<td>Compacted Volume Weight</td>
<td>1.668</td>
<td>1.682</td>
<td>kg/liter</td>
</tr>
<tr>
<td>Average (Loose-Compact)</td>
<td>1.628</td>
<td>1.658</td>
<td>kg/liter</td>
</tr>
<tr>
<td>Average Weight</td>
<td>1.643</td>
<td></td>
<td>kg/liter</td>
</tr>
</tbody>
</table>
2.2.7. Moisture Content

The analysis of water content in fine aggregate was conducted to ascertain the moisture level within the fine aggregate sample (Beddaa et al., 2020; Kirthika & Singh). Proper moisture levels in fine aggregate are crucial for achieving optimal mix proportions in concrete or asphalt (Zou et al., 2020). This procedure involves obtaining a fine aggregate sample, drying it in an oven at a specified temperature, and recording its wet and dry weights. The disparity between these weights is used to calculate the percentage of moisture content. They assess the moisture content of fine aggregate, which aids in regulating the amount of water to be incorporated into the concrete or asphalt mixture, which can influence the mixture's quality, strength, and physical attributes. The outcomes of these assessments empower engineers and planners to formulate mixes that align with desired technical specifications and deliver anticipated construction outcomes.

Table 4. Moisture Content

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container Weight</td>
<td>226.2</td>
<td>261.9</td>
<td>gram</td>
</tr>
<tr>
<td>Container + Sample Weight</td>
<td>2226.2</td>
<td>2261.9</td>
<td>gram</td>
</tr>
<tr>
<td>Sample Weight</td>
<td>2000</td>
<td>2000</td>
<td>gram</td>
</tr>
<tr>
<td>Container + Dry Sample Weight</td>
<td>2196.2</td>
<td>2206.1</td>
<td>gram</td>
</tr>
<tr>
<td>Dry Sample Weight</td>
<td>1970</td>
<td>1944.2</td>
<td>gram</td>
</tr>
<tr>
<td>Moisture Content</td>
<td>1.523</td>
<td>2.87</td>
<td>%</td>
</tr>
<tr>
<td>Average</td>
<td>2.196</td>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>

2.2.8. Compressive Strength Test Result

Compressive strength testing is a mechanical assessment to ascertain a material's ability to withstand maximum compressive force or strength before undergoing damage or permanent deformation (Asteris & Mokos, 2020). In this test, a material sample is positioned between two flat plates, and pressure is gradually applied until the sample either deforms or fractures. The force applied during the test is measured using a specialized device known as a compressive strength testing machine, which operates on hydraulic principles. The results of the compressive strength test yield crucial insights into the material's mechanical behavior, including its maximum strength threshold before damage occurs and its capacity for elastic and plastic deformation. These test outcomes are presented in tabular form, expressed in units of kN/cm^2, and subsequently converted into MPa. A graphical representation of the compressive strength test results is provided below.

Figure 4. Compressive Strength Test Result
2.2.9. Tensile Strength Test Result

The split tensile strength test aimed to determine the mortar's ability to resist tensile forces (Kumarappa & Peethamparaman, 2020), which is crucial for designing bridges, high-rise buildings, and other constructions (Amran et al., 2022). Typically, this test involves using a cylinder of specified dimensions (Chai et al., 2023), pouring fresh mortar, and leveling with the form's surface before hardening. Subsequently, a split tensile testing machine applies tensile force to the mortar cylinder. The split tensile strength test results offer vital insights into the mortar's mechanical properties, including its maximum resistance to splitting before cracking or breaking (Liu et al., 2020). Moreover, these results aid in estimating mortar performance in diverse construction applications. However, testing mortar's split tensile strength is challenging because it tends to crack under tensile stress. Hence, the practical approach involves splitting the mortar cylinder and applying tensile force to its cross-section. This study conducted split tensile testing on samples with a diameter of 15 cm and a height of 30 cm, featuring resin variations of 5%, 10%, 15%, 20%, and 25%. Test results are expressed in kN/cm^2 and converted to MPa using a unit conversion factor, as depicted in the graph below.

![Figure 5. Tensile Strength Result](image)

2.2.10. Stress and Strain Test Result

The modulus of elasticity serves as a parameter for assessing the stiffness of mortar or the capability of polymer mortar to regain its original shape post-force application (Lanzoni et al., 2016). It evaluates the mixture's elastic modulus aimed to gauge the polymer mortar's ability to undergo elastic deformation (revert to its initial shape after load removal) and plastic deformation (resulting in permanent shape change) (Radi et al., 2019). Typically, modulus of elasticity testing involves utilizing cylinders of predetermined dimensions filled with fresh polymer mortar mix after being prepared and leveled within a form. Following the solidification of the test mixture, the cylinder undergoes compressive force via a compression testing machine.

Data on compressive force and object deformation are collected during testing, with deformation measured using strain gauges or deflection measuring devices. Subsequently, the concrete's elastic modulus is computed by dividing the compressive force by its deformation. Results from concrete elastic modulus testing offer valuable insights into its load-bearing capacity and ability to revert to its original shape post-load removal. These insights aid in estimating concrete performance across various construction applications, such as building structures, bridges, and highways. Furthermore, these results can assist in estimating concrete's tensile strength and calculating safety factors in construction structures.
In this study, the modulus of elasticity of concrete was tested across 5%, 10%, 15%, 20%, and 25% epoxy variations. The following table summarizes the Elasticity Modulus Test results.

![Graph showing compression vs deformation](image-url)

**Figure 6. Compressive Strength Test Result**

### 2.3. Analysis Method

#### 2.3.1. Testing Procedure

a. Material Preparation: Prepare all the necessary ingredients according to the specified ratio. Make sure the acceptable aggregate moisture content is < 7%.

b. Mixing Resin and Hardener: Mix the epoxy resin and epoxy hardener according to the directions for use. Add fine aggregate and stir until homogeneous.

c. Printing of Test Objects: Apply lubricating oil on the mold, then gradually fill the mold with an epoxy mortar mixture. Compact each layer.

d. Hardening and Further Compaction: Let the mixture harden according to directions. Use a compactor to ensure good compaction.

e. Removal and Storage: Carefully remove the specimen from the mold. Please place it in a suitable storage area.

f. Compressive Strength Testing: Ensure the test object is ready and follows the test standards. Test using a compression testing machine to obtain compressive strength.

g. Splitting Tensile Strength Test: Ensure the test object is ready and follows the test standards. Test using a tensile testing machine to obtain tensile strength.

h. Modulus Testing: Ensure the test piece is ready and conforms to the standard. Test using a modulus of elasticity testing machine to obtain the modulus of elasticity.

i. After testing, record the results clearly in the specified format.

#### 2.3.2. Job Mix Design Formulation

Material requirements analysis determines the quantity and type of materials necessary for producing a specific job mix. Epoxy Mortar comprises two primary components: resin and fine aggregate. In the preceding section, an examination concerning the physical properties of the fine aggregate and the epoxy data served as the foundation for developing the work plan. The tests scheduled for this study include compressive strength tests and split tensile strength tests. These evaluations will be conducted on specimens comprising varying volumes of resin relative to the volume of the test object. The ratios tested will encompass 5%, 10%, 15%, 20%, and 25% resin mixtures about the volume of the test object. The specimens utilized consist of mortar cylinders with
diameters of 10 cm and heights of 20 cm for the compressive test and diameters of 15 cm and 30 cm for the split tensile strength test.

Preliminary data obtained from the analysis of materials include:

a. Resin Volume Weight = 1356 kg/m$^3$

b. Sand Volume Weight = 1600 kg/m$^3$

Where the Cylinder Mold Volume to be used includes:

Cylinder mold volume Ø10 cm x 20 cm = 0.25$\pi$ × 0.10 × 0.2 = 0.001571 m$^3$

Cylinder mold volume Ø15 cm x 30 cm = 0.25$\pi$ × 0.15 × 0.3 = 0.005301 m$^3$

Determining Test Materials for Variation of Epoxy Volume, determine it as follows:

a. Required Resin Volume (m$^3$) = 0.25$\pi$. 0.12. 0.2 × 5% x 9

b. Sand requirement volume (m$^3$) = 0.25$\pi$. 0.12. 0.2 × 95% x 9

Resin Requirement (kg) = Epoxy Volume Weight × Required Epoxy Volume

Sand Requirement (kg) = Sand Volume Weight × Required Sand Volume

The requirement for Resin A is weighed (gr) = Need for Resin A (kg) x Correction Factor

The requirement for Resin B is weighed (gr) = Need for Resin B (kg) x Correction Factor

Sand Requirement weighed (kg) = Sand Required x Correction Factor 15%

Total resin requirement (m$^3$) + 15% = 1.15 x Total Resin Required

The work step is applied to each variation of 5%, 10%, 15%, 20%, and 25%, considering the volume of the specimen to be made, namely cylinders with diameters of 10 cm and 15 cm. The summary of the calculation results can be seen in the following table.

<table>
<thead>
<tr>
<th>Mould</th>
<th>Var.</th>
<th>Qty</th>
<th>Epoxy A (Kg)</th>
<th>Epoxy B (Kg)</th>
<th>Sand (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø10 cm</td>
<td>5%</td>
<td>9</td>
<td>734,85</td>
<td>367,42</td>
<td>24,71</td>
</tr>
<tr>
<td>Ø15 cm</td>
<td></td>
<td>6</td>
<td>1653,41</td>
<td>826,71</td>
<td>55,6</td>
</tr>
<tr>
<td>Ø10 cm</td>
<td>10%</td>
<td>9</td>
<td>1551,35</td>
<td>775,67</td>
<td>24,71</td>
</tr>
<tr>
<td>Ø15 cm</td>
<td></td>
<td>6</td>
<td>3490,54</td>
<td>1745,27</td>
<td>55,6</td>
</tr>
<tr>
<td>Ø10 cm</td>
<td>15%</td>
<td>12</td>
<td>3285,21</td>
<td>1642,61</td>
<td>32,95</td>
</tr>
<tr>
<td>Ø15 cm</td>
<td></td>
<td>24</td>
<td>22175,18</td>
<td>11087,59</td>
<td>222,41</td>
</tr>
<tr>
<td>Ø10 cm</td>
<td>20%</td>
<td>9</td>
<td>3490,54</td>
<td>1745,27</td>
<td>24,71</td>
</tr>
<tr>
<td>Ø15 cm</td>
<td></td>
<td>6</td>
<td>7853,71</td>
<td>3926,85</td>
<td>55,6</td>
</tr>
<tr>
<td>Ø10 cm</td>
<td>25%</td>
<td>9</td>
<td>4654,05</td>
<td>2327,02</td>
<td>24,71</td>
</tr>
<tr>
<td>Ø15 cm</td>
<td></td>
<td>6</td>
<td>10471,61</td>
<td>5235,81</td>
<td>55,6</td>
</tr>
</tbody>
</table>

2.3.3. Compression Test Analysis

Compressive strength refers to the capacity of concrete to endure pressure or applied loads. It is commonly employed to evaluate the quality of concrete poured and compressed over time. Compressive strength is typically measured in pressure units, such as megapascals or psi. A compressive test is typically conducted on concrete samples poured and cured for a specified duration to determine the concrete's compressive strength. Subsequently, the sample is subjected to a compression testing machine, gradually increasing the load until failure ensues. The applied load and the surface area of the sample are then used to calculate the compressive strength by the formula:

Compressive Strength (MPa) = Breaking Load / Sample Surface Area

Typically, the compressive strength of concrete is assessed after a 28-day curing period. However, suppose you need to expedite the conversion of compressive strength to the 28-day value from test results obtained within a shorter timeframe. In that case, you can utilize a formula or conversion factor known as the hardening rate specific to the test object. By using the appropriate conversion factor, the compressive strength at a shorter time can be converted to a value equivalent to 28 days based on SNI 03-1974-1990 as described by the formula:

28-Day Compression Convert (MPa) = Compressive Strength / Factor

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2.3.4. Tensile Strength Test Analysis

Splitting tensile strength measures a material's strength to withstand the pressure applied in a direction perpendicular to its surface. In a construction context, split tensile strength often refers to the strength of concrete to withstand tensile forces before cracking or failure occurs. Calculating split tensile strength in concrete using a simple formula based on the surface area and the applied tensile load. The formula is:

\[
\text{Splitting Tensile Strength (MPa)} = \frac{\text{Tensile Load}}{\text{Surface Area}}
\]

Generally, the tensile test is carried out by creating a concrete sample as a prism or cylinder. Then, the tensile load applied to the concrete sample slowly increases until the sample cracks or breaks. The sample's recorded tensile load and surface area are used to calculate the split tensile strength using the above formula. It should be noted that concrete has lower tensile strength compared to compressive strength. Therefore, in structural design, the compressive strength of concrete is generally preferred, while the split tensile strength of concrete is rarely a significant design parameter.

<table>
<thead>
<tr>
<th>Nu.</th>
<th>Variation</th>
<th>Day</th>
<th>MASS (kg)</th>
<th>LOAD (kN)</th>
<th>Tensile (Mpa)</th>
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<td>1</td>
<td></td>
<td>7</td>
<td>9.18</td>
<td>109.98</td>
<td>1.556</td>
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<tr>
<td>2</td>
<td>5%</td>
<td>7</td>
<td>9.38</td>
<td>96.74</td>
<td>1.369</td>
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<tr>
<td>3</td>
<td></td>
<td>7</td>
<td>9.62</td>
<td>95.72</td>
<td>1.354</td>
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<tr>
<td>4</td>
<td>10%</td>
<td>7</td>
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<td>173.12</td>
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<tr>
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</tr>
<tr>
<td>6</td>
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<td>7</td>
<td>9.89</td>
<td>171.08</td>
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</tr>
<tr>
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<td></td>
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<td>3.733</td>
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</table>

2.3.5. Modulus Elasticity Analysis

The modulus of elasticity, or Young's or stiffness modulus, measures the degree to which a material can stretch or deform elastically when applied stress. It also describes the material's ability to return to its original shape after removing stress.

Calculating the elastic modulus of stress and strain involves using Hooke's law. Hooke's law states that the stress (stress) in a material is proportional to the strain (strain) experienced by the material.
In the linear elastic case (where stress and strain are within the elastic range of the material), the equation that describes the relationship between stress and strain is:

Modulus of Elasticity (ASTM C 469-02)

\[ E = \frac{(S_2 - S_1)}{(\varepsilon_2 - 0.000050)} \]

- \( E \): Elasticity Modulus (Kg/cm\(^2\))
- \( S_1 \): 40% Compression (Kg/cm\(^2\))
- \( S_2 \): Compression at \( \varepsilon_1 = 0.00050 \) (Kg/cm\(^2\))
- \( \varepsilon_2 \): Curve Value At S2 Strain

Stress is calculated by dividing the load acting on the material by its cross-sectional area, and strain is calculated by dividing the change in the material's length by its initial length. The modulus of elasticity is expressed in pressure units, such as pascals (Pa) or psi. The modulus of elasticity can differ for different materials, and a higher value indicates a stiffer and stiffer material. It is important to note that these calculations apply only to the case of linear elastic materials. If a material undergoes plastic deformation or cracks, Hooke's law no longer applies, and the modulus of elasticity may change.

3. Result and Discussion

3.1. Compressive Test

From the results of the compressive strength test for resin variations, the compressive strength values are summarized in the following figure.

![Figure 8. Average Compressive Test](image)

The graph shows that the compressive strength test results are linear. Adding epoxy resin to the 5% to 25% epoxy variation samples increases the compressive strength value of the test object. So, using epoxy increases the compressive strength of mortar at a variation of 5% to 25%.

3.2. Tensile Strength

From the results of the Split Tensile Strength Test on Resin Variations, the Tensile Strength values obtained are summarized in the following figure.
The graph shows that the split tensile strength test results have linearity, where adding epoxy resin to the 5% to 25% epoxy variation samples increases the tensile strength value of the test object. This test aims to evaluate the age variation of the resin with a concentration of 15% and measure its impact on maximum tensile strength. Resin with a concentration of 15% was tested at several different ages: one day, two days, three days, and seven days.

a. At the age of 1 day, the resulting corrected maximum load is 96.74 kN with an average tensile strength of 1.552 MPa. The percentage of target strength is 8%.

b. At the age of 2 days, the corrected maximum load is 127.29 kN with an average tensile strength of 1.777 MPa. The percentage of target strength is 9%.

c. At the age of 3 days, the corrected maximum load is 152.75 kN with an average tensile strength of 2.027 MPa. The percentage of target strength is 10%.

d. At the age of 7 days, the corrected maximum load is 198.58 kN with an average tensile strength of 2.877 MPa. The percentage of target strength is 14%.

The test results show that increasing resin age increases the maximum and average tensile strength. The target strength percentage also increases with age, indicating that resin with a longer life has better quality. These studies show that the resin’s age significantly affects its tensile strength. These results can help develop and select appropriate resins for different applications where tensile strength is an essential factor to consider.

3.3. Elasticity Modulus

From the results of the Compression-Strain Test on Resin Variations, the Elasticity Modulus values obtained are summarized in the following figure.
Testing the Modulus of Elasticity depicted in Fig. 10 of this study involved examining resins of different ages, encompassing tests for age variations. These tests covered resin concentrations of 5%, 10%, 15%, 20%, and 25%, conducted at seven days, alongside several samples aged 1, 2, and 3 days. The primary parameters measured were the maximum load and the resin's modulus of elasticity. At seven days, for instance, a 5% resin concentration yielded a maximum load of 310,000 N, with an average elastic modulus of 5,063.50 MPa. Similarly, other samples at the same age demonstrated various load capacities and elastic modulus values. Moreover, tests conducted at 1, 2, and 3 days revealed corresponding results, indicating a correlation between resin age, maximum load capacity, and modulus of elasticity. Generally, longer resin lifespans tend to lower the maximum load, while the resin concentration influences the elastic modulus. Notably, lower resin concentrations exhibit higher elastic modulus values. Figure 10 illustrates the declining trend of elastic modulus with increasing resin age, particularly in samples with 15% resin concentration, showing decreased stiffness over time. Adding epoxy resin from 5% to 25% reduces stiffness in specimens aged seven days, correlating with increased resin content.

In Fig. 6, the Compressive Strength Test Result presents modulus test outcomes, wherein strain values correspond to the stress applied to the specimen, expressed in MPa, and deformation in mm. Samples with resin mixtures ranging from 5% to 25% exhibit similar strain values at specific stress levels, with varying maximum stress values before specimen collapse. For instance, at a 5% resin variation, collapse occurred at 17.54 MPa, increasing to 32.82 MPa at a 25% resin variation. Although adding resin leads to a decreased modulus of elasticity, the strain values remain consistent at similar stress levels across all samples. Therefore, epoxy addition is viable for enhancing bearing capacity under specific stress conditions. The selection of epoxy resin variation primarily considers compressive strength, ranging from 17.83 MPa to 32.82 MPa across 5% to 25% resin variations, and split tensile strength, ranging from 1.426 to 3.80 MPa, while the elastic modulus remains consistent at similar stress levels across all resin variations.

4. Conclusion

In the final phase of this research, the researcher will discuss the outcomes and recommendations based on examining epoxy variations in polymer mortar concerning compressive strength, tensile strength, and modulus of elasticity. Including epoxy resin in the mortar mixture, alongside fine aggregate zone II, underwent tests involving volumetric variations ranging from 5% to 25% epoxy resin content in the test specimens. These tests revealed a notable increase in collapse value, indicating enhanced compressive strength values. For instance, at a 5% variation, the nominal compressive strength reached 18.36 MPa, escalating to 35.92 MPa at a 25% resin variation. Similarly, regarding tensile strength, tests on the mortar mixture with varying epoxy resin content showed a consistent increase in split tensile strength values. Higher epoxy content indicates greater tensile strength, enhancing the specimen's ability to withstand strain or tension. Notably, the split tensile strength rose from 1.43 MPa at 5% resin variation to 3.82 MPa at 25% variation.

Furthermore, the modulus of elasticity decreased from 5100 MPa at a 5% resin ratio to 3573 MPa at a 25% resin ratio. Consequently, with the addition of epoxy resin, the specimens experienced reduced stiffness and more significant deformation. In addition to its commendable compressive strength, epoxy resin meets ASTM D 4541 specifications, affirming its tensile strength. The compressive strength modulus graph illustrates a gradual decline in specimen collapse post-peak load due to tensile force interaction between resin and aggregate. This is further evidenced in the modulus of elasticity graph against strain, highlighting increased elasticity post-collapse attributed to resin tensile strength with resin addition from 5% to 25% volumetric ratio.

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6. Author’s Note

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7. References


