# Study of Mechanical Properties of *Vinyl Ester Composite* with Glass Powder Filler

**Diaz Muhammad Irham Dailami [1] , Sulaiman Talib[1*] , Husni [1]**

[1] *Department of Mechanical and Industrial Engineering, Faculty of Engineering, Syiah Kuala University. Jalan Mr. Syech Abdur Rauf No. 7 Darussalam, Banda Aceh 23111, Indonesia*

E-mail: sulaimanthalib@usk.ac.id

**Abstract**

This research, study aims to investigate the influence of particle composition on the mechanical properties of vinyl ester composites with glass powder as a filler. The composites were fabricated using the stir casting method to mix vinyl ester and glass powder particles with a 200-mesh size. The compound in compositions of wt% vinyl ester as matrix and wt% glass powder as fillera as follows: 100/0, 90/10, 80/20, 70/30, and 60/40. Mechanical properties testing encompasses Tensile Testing, Compression Testing, and Bending Testing. The specimens and mechanical testing procedures adhere to ASTM standards: ASTM D638-I for Tensile Testing, ASTM D695 for Compression Testing, and ASTM D790 for Bending Testing. Based on the test results, the following data was obtained: The highest tensile strength was 39.15 MPa with a 10% particle content, while the lowest tensile strength was 9.19 MPa with a 40% particle content. The highest compressive strength was 80.04 MPa with a 40% particle content, while the lowest compressive strength was 42.21 MPa with a 0% particle content. The highest bending strength was 93.74 MPa with a 20% particle content, while the lowest bending strength was 69.84 MPa with a 30% particle content. The addition of the filler reduces the tensile strength, increases the compressive strength, and has a relatively minor impact on bending strength.

**Keywords**: Composite, Vinyl Ester, Glass Powder, Tensile Strength, Compression Strength, Bending Strength.

## 1. Introduction

Various types of composite materials are widely used in everyday life, such as those used for household equipment and other uses for vehicles. Composite materials are also alternative materials for use in superior products in various industries, such as the aircraft industry, automotive industry, sports, shipping and in the oil and natural gas industry[1]. This industry requires materials that have high strength but light weight or that require a Strength to Weight ratio better. Composite materials have advantages compared to metal materials which lie in better mechanical properties, light material weights, lower density, resistance to corrosion, and have properties that can be adjusted according to the needs and use. Composite materials consist of two materials, namely reinforcement or filler and a matrix which functions as a binder. Meanwhile, the particle composite material is used as a filler are particles that are evenly distributed and dispersed in the matrix[2, 3, 4].

Glass material is an industrial product that is often found in everyday use. Glass used for building construction or for household purposes is increasing, resulting in an increase in glass waste spreading everywhere. Glass is classified as inorganic waste and has not been used in the recycling process. Generally, glass waste itself is considered dangerous if thrown away carelessly. This glass waste is also very difficult to decompose in the soil, requiring thousands or even millions of years to decompose completely and if not utilized it will pollute the environment [5,6] . For this, innovative alternative measures are needed to enable glass waste to be returned to nature safely or reprocessed into useful products.

To date the particles produced from glass have not been utilized optimally by society even though their potential is quite large. Glass, whose constituent material is mostly silica oxide ($SiO_2$) has superior pozzolan properties, glass when combined with cement can increase the quality of concrete. Glass also has superior properties in the form of a high melting point and very strong mechanical properties. This makes glass waste have good potential as a base material for strong composites. Glass also has the property of not absorbing water [7,8] .

Vinyl ester is a material for making pipe, tank and channel structures. Vinyl ester is also one of the main choice materials used for transportation or infrastructure. This use includes the manufacture of vehicle parts such as cars and motorbikes, building materials, bridges, and several other infrastructure. The choice of vinyl ester is because vinyl ester has

good chemical properties and is also slightly soluble in water compared to polyester. Vinyl ester material can also cure at room temperature which has almost the same properties as epoxy. Vinyl ester also has specific properties, namely it is resistant to most chemicals, has good thermal stability, has excellent fatigue resistance and has good corrosive resistance. This property is the advantage of vinyl ester [9,10] .

Based on the explanation above, this article discusses a study of the use of glass powder as a composite filler with a *vinyl ester matrix* and examine its mechanical properties.

## 2. Methodology

### *2.1. Composite Mechanical Properties*

Mechanical tests were carried out to determine the mechanical properties of the vinyl ester composite material filled with powder, namely tensile testing, compressive testing and bending testing.

#### *2.1.1. Tensile Strength*

Tensile testing is carried out to get an idea of the strength of the material by slowly adding a tensile load at the end of the rod so that it results in an increase in the length of the material in proportion to the tensile force obtained by the material [11]. The tensile test used refers to the ASTM D 638-I standard as in Figure 1.

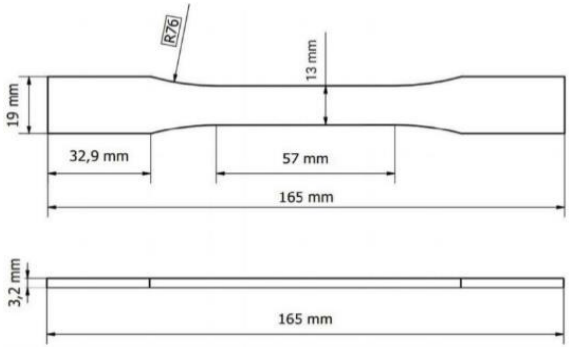


Figure 1. ASTM D-638-I Tensile Test Specimen

#### *2.1.2. Compressive Strength*

Compressive testing is carried out to obtain the maximum compressive strength value that can be achieved by a material until the material cannot withstand the compressive load that has been given, by applying a compressive force in the same direction to the material [12]. The compression test used refers to the ASTM D-695 standard as in Figure 2.

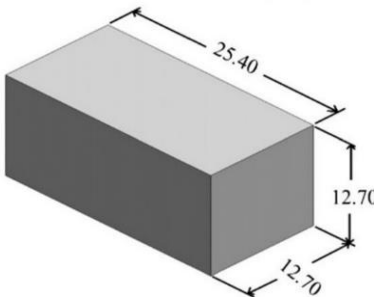


Figure 2. ASTM D-695 Compression Test Specimen

#### *2.1.3. Bending Strength*

Bending testing is carried out to determine the bending strength of a material against loading at the bending point and the elasticity of a material using the three point bending test method[13]. Bending tests carried out refer to the ASTM D-790 standard as in Figure 3.

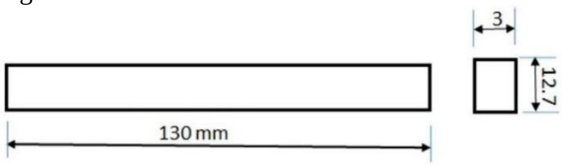


Figure 3. ASTM D-790 *Bending* Test Specimen

#### *2.1.4. Materials*

The material used in this research is glass powder as a filler which can be obtained on the market in various particle sizes. The resin as a matrix uses vinyl ester resin as a matrix and a MEPOXE type catalyst as a hardener. vinyl ester resin and catalyst can be obtained in the market or through online stores.

#### *2.1.5. Composite Manufacturing*

The composite manufacturing process is carried out by mixing glass particles and vinyl ester resin manually in a mixed composition of glass powder particles and resin as listed in Table 1. After the mixing process it is then poured into a mold that has been prepared previously. The size and composition of the particles used are according to the desired size. The resulting mixture of particles and resin is inserted into a mold in the form of a tensile test compression test and bending test sample as in Figure 3, while the mold results are as in Figure 4 .

Table 1. Composition of resin vinyl ester and glass powder

| No. | Vinyl Ester weight composition (%) | Weight composition of Glass Powder (%) |
|---|---|---|
| 1 | 100 | 0 |
| 2 | 90 | 10 |
| 3 | 80 | 20 |
| 4 | 70 | 30 |
| 5 | 60 | 40 |

Figure 4 . Mold ASTM D638-I Tensile Test, ASTM D790 Bending Test and ASTM D695 Compression Test.

The results of composite material molds in the form of tensile test samples and compression test samples are as shown in Figure 5, while compression test samples are as shown in Figure 6

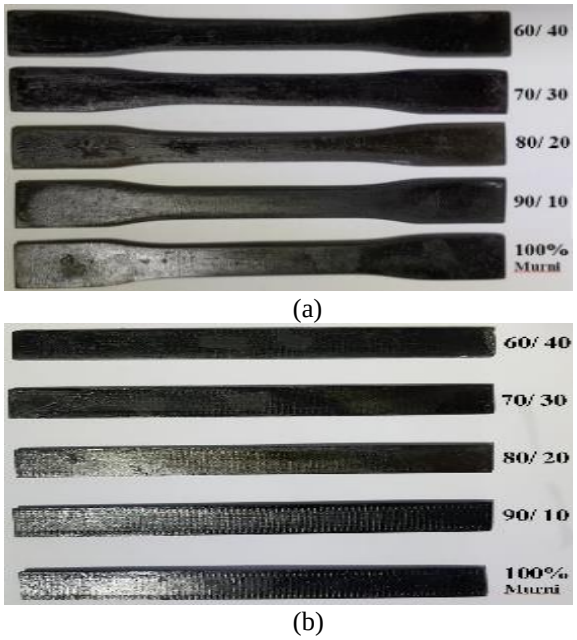


Figure 5. (a) Tensile test samples, (b) bending test test samples

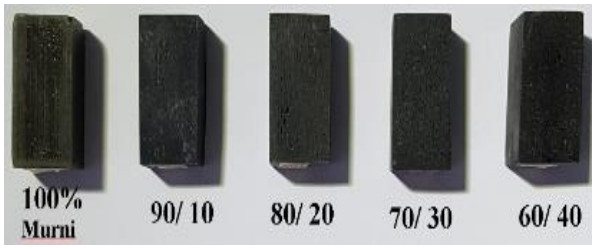


Figure 6. Bending test sample

## 3. Results And Discussion

Results testing pull , compression testing and bending testing can be done seen on Table 2, Table 3 and Table 4. The graph plots for tensile testing, compression testing and bending testing can be seen in Figure 7, Figure 8 and Figure 9 respectively.

Table 2. Tensile strenght test result

| No. | Composition (%) | | Tensile Strength (MPa) |
|---|---|---|---|
| | Powder | Resin | |
| 1 | 0 | 100 | 33.21 |
| 2 | 10 | 90 | 39.15 |
| 3 | 20 | 80 | 21.48 |
| 4 | 30 | 70 | 10.75 |
| 5 | 40 | 60 | 9.10 |

Based on the test results data contained in Table 2, a graph can be created the relationship between tensile strength and glass powder composition as shown in the following graph;

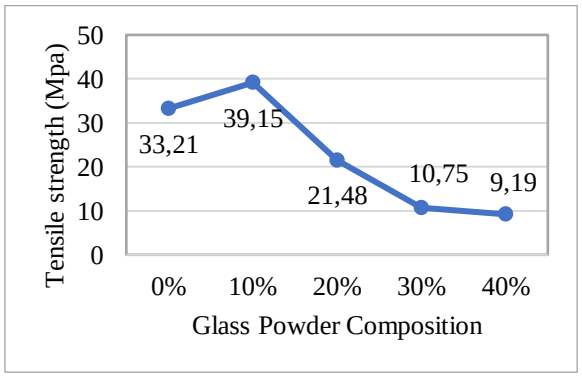


Figure 7. Relation of tensile strength with glass powder composition

From connection strength pull _ on show strength pull _ the more decreases with increasing glass powder composition [14] , mark highest strength pull _ that is 39.15 MPa, on fraction heavy 1 0 % and the lowest value is in the 40% fraction, namely 9.19 MPa. This decrease in tensile strength is due to the influence of the filler in the form of particles, where the hard particles in the matrix, when

subjected to a tensile load on the particles, will cause a stress concentration that can exceed the yield strength of the matrix material so that cracks begin to open around the particles. The greater the powder composition, the greater the crack opening that occurs, this results in a decrease in the strength of the composite material reinforced with pasteicles.

Data from the results of compression tests carried out on samples of vinyl ester composite material as a matrix filled with glass powder seen on Table 3. From this data it is plotted to become graph relation of compressive strenght with glass powder composition can be seen on Figure 5. The result from the compression test, shows an increase in compression strength according to reference [15]. Compression strength highest obtained at composition 40% glass powder that is 80.04 MPa, while lowest compresion strenght is 42.21 MPa on composition 0 % glass powder. which shows a tendency for compressive strength to increase with increasing glass powder composition.

Table 3. Compression Test result

| No | Composition (%) | | Tensile Strength (MPa) |
|---|---|---|---|
| | Glass powder | Resin | |
| 1 | 0 | 100 | 40,.21 |
| 2 | 10 | 90 | 47.84 |
| 3 | 20 | 80 | 53.59 |
| 4 | 30 | 70 | 59.57 |
| 5 | 40 | 60 | 80.04 |

The compressive load received by the composite material during testing will close all cleaved between the matrix and the glass powder particles so that the composite material becomes continuous without any initial cracks. This compressive load can also close the matrix porosity that forms when the composite material hardens. Besides that, hard glass particles can accept a greater load transmitted by the vinyl ester matrix so that the larger the particle composition shows increasing strength as long as the matrix is still able to bind the particles before the bonds are released and destroyed.

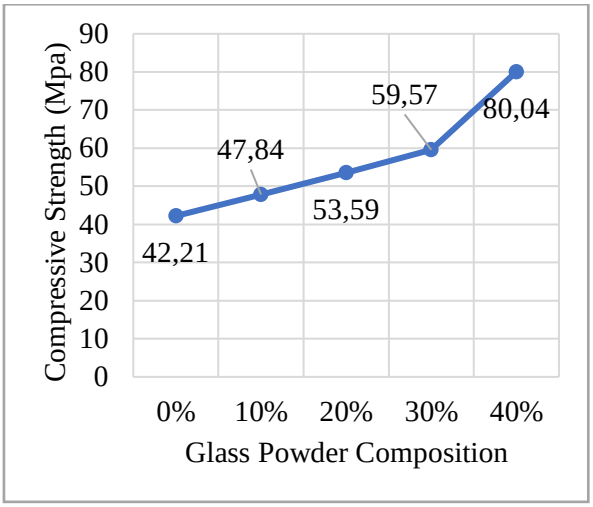


Figure 8 . Relation of compressive strenght with glass powder composition

The bending test results for composite materials are listed in Table 4, this data is plotted in graphical form.

Table 4 Data testing bending

| No | Composition (%) | | Bending Strength (MPa) |
|---|---|---|---|
| | Powder | Resin | |
| 1 | 0 | 100 | 89.78 |
| 2 | 10 | 90 | 87.89 |
| 3 | 20 | 80 | 98.74 |
| 4 | 30 | 70 | 69.84 |
| 5 | 40 | 60 | 74.85 |

Graphics bending strength relationship with a composite powder composition vinyl ester as a matrix can be seen on Figure 9. From the bending test graph above, it shows that The strength of the composite material is highest in the composition 20% powder is 93.74 MPa, the lowest strength is 30% compositions, namely 69.84 MPa. The bending strength of the composite shows a decrease with increasing glass powder composition. As is known, bending of the material will receive two types of load simultaneously, namely tensile load and compressive load, while the axis line is neutral. The largest tensile load is on the outer side of the sample in the tensile direction, and the largest compressive load is also on the other outer side which is in the compressive direction. In the tensile position the material is not strong enough to accept the tensile load because of the possibility of opening cracks in the particles. The opening of these cracks causes the strength of the material to decrease so that the neutral axis can shift towards compression. This causes the remaining strength of the material to decrease, resulting in final fracture.

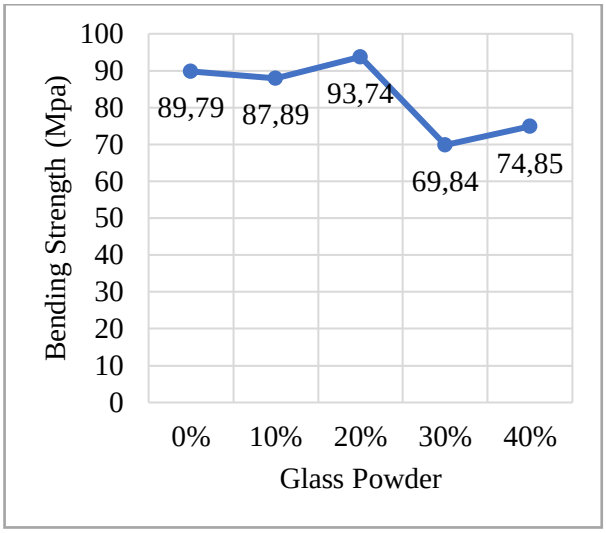


Figure 9. Relation of bending strength with glass powder compositions

## 4. Conclusion

Based on the discussion carried out in the previous section, the results of tensile testing, compression testing and bending testing can be concluded as follows ;

1. The increasing composition of the particle filler causes a decrease in tensile strength, because hard glass particles can become a place for opening initial cracks when receiving tensile loads. The highest tensile strength occurred at 10% particle composition, namely 39.15 MPa.
2. The compressive load received by the composite material will close the cleave between the matrix and particles and can close the porosity in the matrix. Material composites compressive strength increased with increasing glass powder composition, the highest compressive strength occurred at 40% particle composition, namely 80.04 MPa.
2. The decrease in the strength of the composite material under bending loads is caused by the tensile load acting on the tension side, allowing initial cracks to occur which results in a shift of the neutral axis towards compression, resulting in a decrease in the residual strength of the composite material. The strength of the composite material decreases with increasing glass powder composition, although the decrease is not as sharp as in pure tensile loading.

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