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RESEARCH ARTICLE

FABRICATION AND CHARACTERIZATION OF GFRP-POLYURETHANE COMPOSITE SANDWICH PANELS FOR EARTHQUAKE-RESISTANT BUILDINGS

S. Rohman, E. Kalembang, M.E. Harahap, S. Roseno, D. Budiyanto and Wahyudin
Center Research for Advanced Material, National Research and Innovation Agency, Building 224, PUSPIPTEK, South Tangerang 15314 Indonesia.

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Abstract

Today's modern house walls use a lot of fabric panels that have good insulating properties, are energy-saving, and are easy to clean and sterilize so the room becomes healthier. These insulator panels are also widely used for earthquake-resistant houses because these materials are light and do not break easily. These panels are often also referred to as composite sandwich panels. The properties of this composite sandwich panel depend on the behavior of the two face layers of the composite material and the lightweight core material as the filler component. This research focuses on fabricating and characterizing sandwich structure glass fiber reinforced polymer (GFRP) composites filled with rigid polyurethane foam. The main objective of this study is to observe the effect of the amount of epoxy resin as a binder between the GFRP face layer and the polyurethane core material on mechanical strength, such as tensile strength, flexural strength, and compressive strength. The test results showed that the maximum mechanical strength was in sandwich panels with the epoxy composition of 2.5 kg/m2 panels, with a flexural strength of 3.68 MPa, compressive strength of 15.53 MPa, and tensile strength of 0.175 MPa. The polyurethane core material is the most fragile part of the composite sandwich panel.

Introduction:-

The application of composite sandwich panels is increasingly widespread, not only for insulating rooms but also for building construction. Composite materials are defined as materials consisting of two or more different parts that have special properties or are often referred to as materials consisting of two different phases, where each constituent phase has different physical properties to form high-performance materials [1]. Composite material research is growing with the development of the application of composite panel materials and the construction industry manufacturing sector, especially for GFRP composite materials because they have advantages in strength and lightweight [2].

Most of the victims of natural disasters from earthquakes are caused by falling debris from the building materials that make them up, such as walls and concrete tiles. Therefore, to prevent more victims in the event of an earthquake, it is necessary to develop building materials that are resistant to earthquakes, so that they can protect the residents from the ruins of the building material itself [3].

Corresponding Author:- S. Rohman
Address:- Center Research for Advanced Material, National Research and Innovation Agency, Building 224, PUSPIPTEK, South Tangerang 15314 Indonesia.

This research aims to optimize the formulation of the use of epoxy resin as a binder for the GFRP face layer with rigid foam polyurethane core material in the manufacture of composite panels. The application of this panel is for earthquake-resistant building walls. Composite sandwich panel formulation results were then characterized using various tests including mechanical tests such as tensile tests [4], compression tests, and bending tests [5][6][7].

Materials and Method:-

In this research, the material used for the face layer (skin) was glass woven. As a matrix, unsaturated polyester resin was used. As for the core material, rigid polyurethane foam was used with a thickness of 50 mm.

Making composite panels consists of two process steps, namely the manufacture of a glass fiber reinforced polymer (GFRP) face layer and a polyurethane core material. The GFRP face coating is formulated with catalytically activated unsaturated polyester resin with a wt% (100:1) ratio of glass fiber woven unsaturated polyester resin reinforced. The resin was spread over the glass mold, then 4 pieces of glass fiber woven (100 x 100) cm^2 were placed sheet by sheet while the resin was given in a closed-hand lay-up combined. After the hand lay-up process is complete, proceed with the vacuum bagging process. The vacuum pump is set at a pressure of 0.1 - 0.2 bar for one hour. The next step is the manufacture of a GFRP-Polyurethane composite sandwich panel, in which two layers of GFRP faces are glued together using an epoxy resin adhesive and hardener with a ratio of wt% (1:1) to rigid polyurethane foam. In this research, 4 formulas were made, namely F1, F2, F3, and F4. where each panel requires 1.0 kg, 1.5 kg, 2.0 kg, and 2.5 kg of epoxy resin for each m^2 panel [7].

Observation of mechanical properties is carried out through testing, flexural bending, compressive strength in position flatwise, and tensile strength using a 250 kN Shimadzu AG-Xplus Universal Testing Machine (UTM). Flexural bending specimens were analyzed using the three-point bending method according to ASTM C393, load is applied to the panel specimen at a constant rate of 5 mm/min for 10 minutes [6][7]. In the compressive test, the panel specimen is tested according to ASTM 365 standards to obtain an average compressive strength. The load at a rate of 1.5 mm/minute presses the specimen in the normal direction to the plane of the structural sandwich construction. The number of test objects is 5 cubic pieces with dimensions of 100 x 100 x 50 mm^3.

The tensile test was carried out to determine the bond strength between the core material and the face sheet of the sandwich composite panel. This test uses the flatwise tensile test method which refers to the ASTM C 297 standard. The test consists of loading the sandwich construction with a normal tensile load to the sandwich plane, so that the load is transmitted to the thickness of the sandwich and the interfacial bonds are subjected to a tensile force. Based on ASTM C 297 standard the dimensions for the test specimen are 100×100 mm^2. To determine the tensile strength value of the sandwich composite structure, you can use the Equation:

$$\sigma = P / (L \times W)$$

where σ is the tensile strength of the composite sandwich (MPa), P is the maximum force that can be accepted by the composite sandwich panel specimen (N), L is the length of the sample tested (mm), and W is the width of the sample tested (mm) [8].

Results:-

The resulting composite sandwich panel is shown in **Figure 1. Figure 1(a)** shows that cracks due to mechanical testing almost all occurred in the polyurethane core material. This occurred because the adhesive effect of the epoxy resin on the GFRP face layer was very strong compared to the cohesive bond of the polyurethane core material. However, cracks can also occur at the interfacial bond between the epoxy resin and the polyurethane core material, or the epoxy resin with the GFRP face layer as shown in **Figure 1(b).**

Shown in **Figure 1(a)** is the cross-sectional layer of the composite sandwich panel, where the GFRP face layer, epoxy resin adhesive, and the polyurethane core material bond well, while cracks form in the polyurethane core material. Cracks occurred in almost all tensile test specimens in a flat direction, whereas in the flexural bending test, specimen cracks occurred in two locations, namely cracks in the polyurethane core material and in the epoxy resin bond with the polyurethane core material as shown in Figure 1(b). From morphological observations, it can be concluded that the main weakness of the mechanical properties of composite sandwich panels is the polyurethane core material [9].

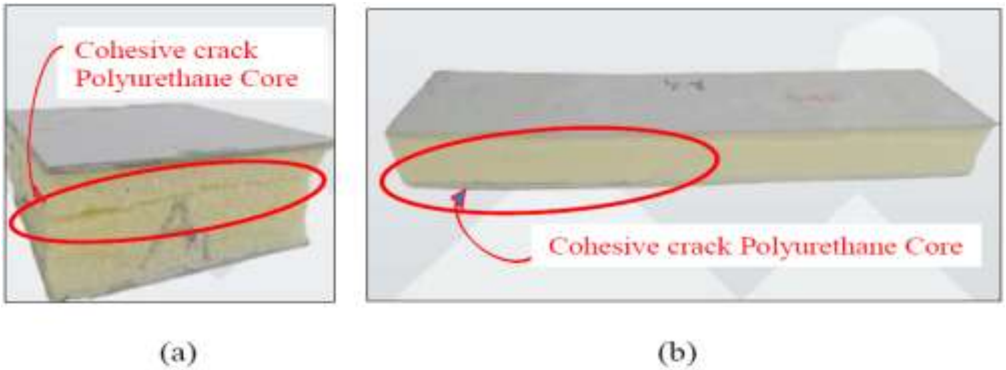

Figure 1:- Cracks in a composite sandwich panel; a). Cracks in the polyurethane core material. b). Cracks in the polyurethane core material and cracks in the epoxy resin adhesive between the GFRP face and the polyurethane core material.

The flexural specimens were analyzed using a three-point bending mode according to ASTM C393. The load was applied to the panel specimens at a constant rate of 5 mm/min for 10 min. The panel specimens were tested regarding ASTM 365 to obtain the flexural strength results shown in **Table 1.** From this test we can see that the amount of resin composition added is directly proportional to the flexural strength possessed by the composite panel [10][11].

Table 1:- Flexural strength of the composite sandwich panel GFRP-Polyurethane.

Resin Panel Formula	F1	F2	F3	F4
Flexural Strength (MPa)	2,66	2,85	3,35	3,68

It can be seen from the flexural strength test results of the GFRP-Polyurethane composite sandwich panel shown in the form of flexural stress to the flexural strain curve of the composite sandwich panel in **Figure 2**. The flexural strength of the composite sandwich panel formula F4 has a greater value of flexural strength compared to other formulas such as formula F1, F2 and F3 The flexural strength values of each of these methods are shown in **Table 1.**

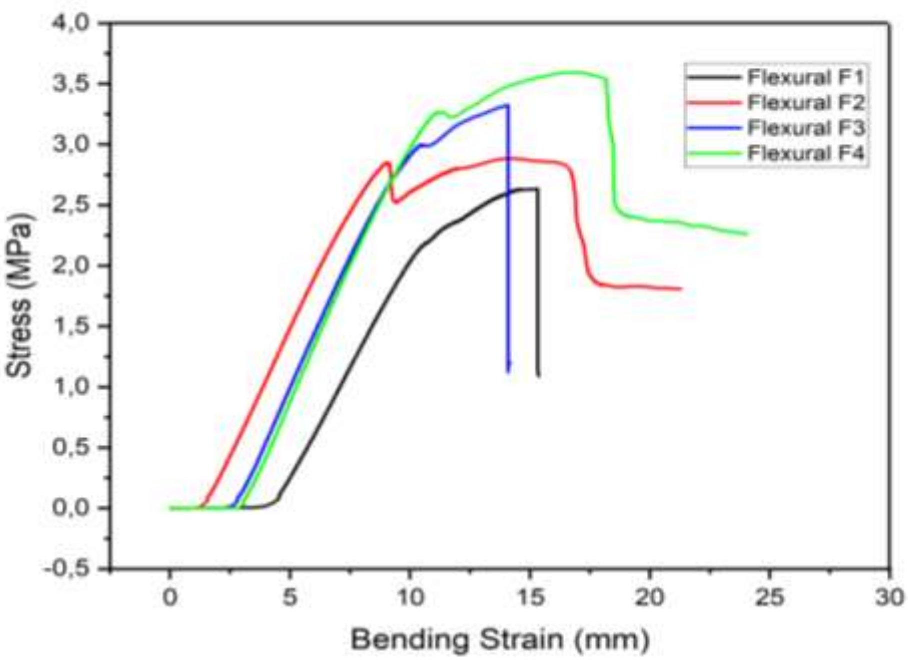

Figure2:-Stress-Strain ofbending flexural test of the composite sandwich panel.

The flexural strength values shown in **Table 1** and the curve in Figure 2 show that the flexural strength of GFRP-PU panels is equivalent to the amount of epoxy resin added as a binder for the GRFP front layer with polyurethane core material. It can be seen that the flexural strength value is 2.66 MPa on the use of 1.0 kg of epoxy resin (F1) and increased to 2.85; 3.35; and 3.68 MPa when the use of epoxy resin is added to 1.5 kg (F2); 2.0 kg (F3); and 2.5 kg (F4). From this research, the optimal amount of epoxy resin has not been seen, because the value of flexural strength is still increasing with the addition of the amount of epoxy resin in the panel area. The strain value also continues to increase with the increasing use of epoxy resin as an adhesive.

The results of the flat direction compressive strength of composite sandwich panels that have been carried out according to ASTM C 297 standards are shown in **Table 2**. The flat direction compressive strength values trend increases in line with the increase in the amount of epoxy resin used. The highest flat compressive strength values are in formula 4 (F4) composite sandwich panels which is 15.53 MPa with a strain of 1.73 mm. The rigid polyurethane used as the core material for this panel cracks easily when subjected to high enough pressure. The rigid foam polyurethane core material used is a manufactured product as a temperature insulator grade [12].

Table 2:-Compressive strength of the composite sandwich panel GFRP-Polyurethane.

Resin Panel Formula	F1	F2	F3	F4
Compressive strength (MPa)	7,86	8,37	13,65	15,53

The brittle nature of this rigid polyurethane core material is shown in **Figure 3.**, in which the compressive curve is sharp or steep with very short strains. The highest compressive value is the composite sandwich panel formula 4 (F4), in which the compressive strength value is 15.53 MPa. while the strain is only 1.73 mm. This shows that the polyurethane rigid core in this panel is taught, but is brittle because this research we use the low-density type, it is better if we use the high-density polyurethane rigid [12].

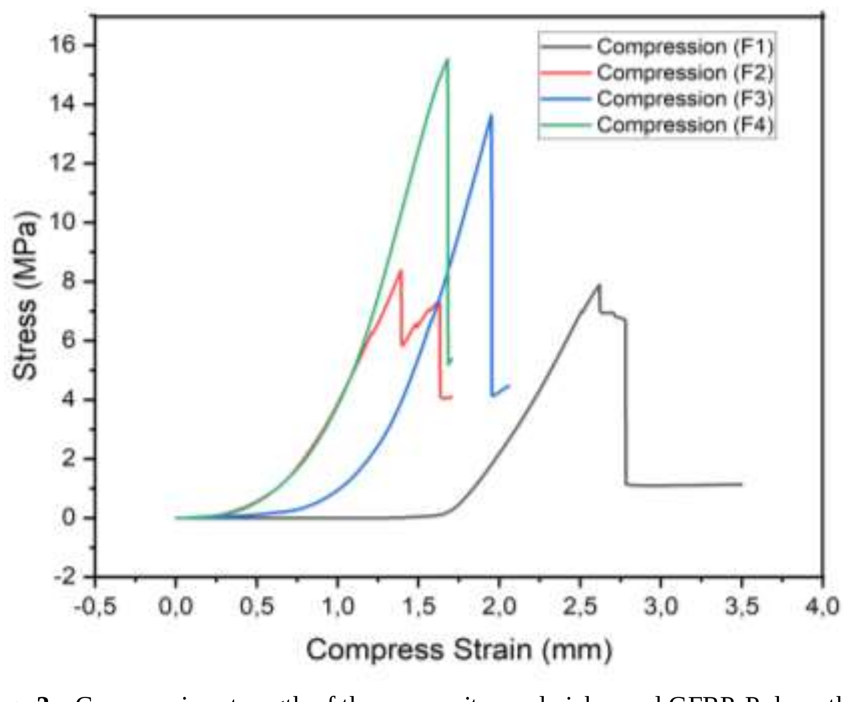

Figure 3:- Compressive strength of the composite sandwich panel GFRP-Polyurethane.

Tensile test results for composite sandwich panels with a polyurethane core material and an outer layer of GFRP are shown in **Table 3** and **Figure 4**. The tensile strength value increases as the amount of epoxy resin added as an adhesive between the outer layer of GFRP and the rigidpolyurethane core material increases.

The highest value of the tensile strength of this composite sandwich panel is 0.175 MPa with a strain of 1.64%, namely the panel formula 4 (F4), namely, the panel formula uses 2.5 kg epoxy resin per 1 m^2 panel, while the lowest tensile strength value is in panels with formula 1 (F1).

Table 3:-Tensile strength of the composite sandwich panel GFRP-Polyurethane.

Resin Panel Formula	F1	F2	F3	F4
Tensile Strength (MPa)	0,134	0,137	0,152	0,175

The tensile test of the flat direction panel is highly dependent on several material factors for the composite sandwich panels being tested, including; cohesive properties of the polyurethane core material, cohesive properties of the epoxy resin adhesive, and cohesive properties of the GFRP-facing material. Apart from the cohesion factor, the adhesive factor includes; the adhesive between the GFRP coating material and the epoxy resin adhesive and the adhesion between the epoxy resin adhesive and the polyurethane core material. The cracks that occur in the composite sandwich panel when tested in tension can be observed in **Figure 4.** From this figure, we can improve the tensile strength properties of the composite sandwich panel.

Tensile testing of the composite sandwich panel has been carried out previously by Herranen et al. (2012), this test was also carried out later by Prayoga (2018), the results of the tensile test sought obtained the maximum tensile strength value of the composite sandwich panel was 51.486 MPa, this result is very large when compared to the results obtained in **Table 3**., which only reached 0.173 MPa. contrary to the research conducted by Tuwair et al. (2015) the value obtained from the flat direction tensile test of this composite sandwich panel is very small, which is only 1.04 MPa. This can happen due to the 5 factors of adhesive-cohesion between the materials making up the composite sandwich panel as described above [13][14].

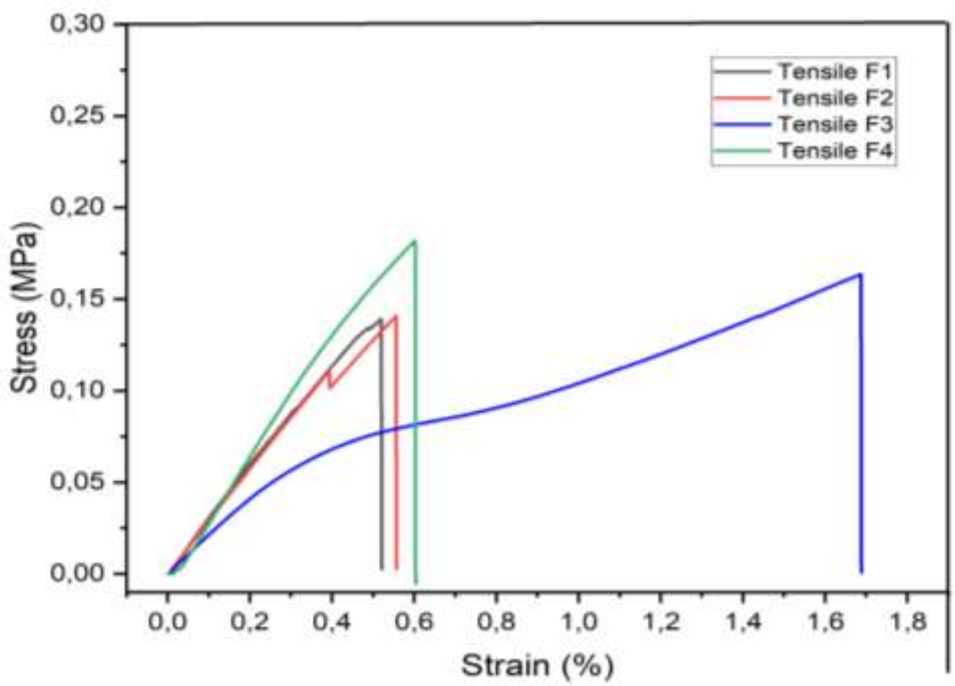

Figure 4:- Stress-Strain curve of Tensile test of the composites sandwich panel GFRP-Polyurethane.

Conclusion:-

Composite sandwich panels made from polymeric materials have a light mass making them suitable for earthquake-resistant building wall or partition applications. These panels do not endanger residents when a disaster occurs. From the results of mechanical testing, F4 is the best, this panel has a flexural strength of 2.66 MPa, a compressive strength of 15.53 MPa, and a tensile strength of 0.175 MPa. Rigid foam polyurethane used as the core material for this panel is very fragile when compared to other core materials in composing this panel, therefore it is not recommended for application in permanent buildings, but can still be used for temporary housing as disaster mitigation.

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