EFFECT OF PARTICULATE SIZE OF FLY ASH AND FLY-ASH WEIGHT FRACTION TO FLEXURAL PROPERTIES OF FLY ASH–POLYESTER COMPOSITE

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ABSTRACT

In Indonesia, there is a big number of the fly ash powder waste resulted by industries producing batubara. The fly ash can be used as particulate reinforcement of composite material design. The objective of this research is to investigate the effect of particulate size and content of fly ash to flexural properties of the fly ash - polyester composite. The materials in this research are fly ash particulate, unsaturated polyester resin (UPRs) and MEKPO hardener. The MEKPO hardener content is 1% (v/v) of the polyester. The variables in this research are particulate grain size of fly ash and fly-ash weight fraction (Wf). The composites were made by using a press mold method. The specimens were produced according to ASTM D 790 standard, and they were tested by using a universal testing machine. According to the result, the fly ash powder can be used as reinforcement material to increases flexural properties of composite materials. The smaller particulate grain size of fly ash, the higher flexural stress and flexural strain of the fly ash – UPRs composite. However, the flexural modulus of the composite has the similar values for some size of fly ash. For 40% of fly ash content, the composite reinforced by 0.10 mm of particulate grain size of fly ash has 127.24 MPa in flexural strength and 4.11 GPa in flexural modulus. The increasing of fly-ash content can increase the flexural strength and modulus of the composite. The composite has the maximum flexural strength for 40% of fly-ash weight fraction, and the flexural modulus of the composite increases linearly with the increasing of Wf. In contrast, the flexural strain of the composite decreases when the fly ash content increases. The increasing of fly ash content decreases the elasticity of the composite and increases the brittleness.

Keywords: fly ash, polyester, particulate grain size, weight fraction, flexural properties

INTRODUCTION

Background

Disposal of this fly ash (FA) powder waste, like in PLTU Payton East Java and PLTU Suralaya West Java, has always been a problem. A lot of the waste has been used in other industry, like cement industry. The fly ash can be categorized into small size powder, containing about 50% of silicon (Si) and other materials. The powder can cause environment pollution case and danger the health of people. When dry season, the powder can fly free carried by wind, and when rainy season, it can cause soil pollution carried by the water. As the powder is produced in big number, the negative effect caused by waste is difficult to be protected. According to the problem, engineers and scientists have a responsible to study the useful of the fly ash powder waste for making other engineering product.

Many researchers have improved the useful of the fly ash for designing a new materials, like composite. [1] Weis et. al have combined fly ash and aluminum for designing metal matrix composite (MMC) for making automotive component. [2] The composites, synthesized conducting polyaniline/fly ash (PANI/FA) composites by in situ polymerization in the presence of FA, may become promising candidates for advanced materials to be used in the high-technology industries in the future. These materials can also reduce the cost due to usage of FA. [3] The strength of the sintered compacts decreased with increasing weight per cent of fly ash under the present experimental conditions; however, the hardness was found to increase slightly up to 10 wt% fly ash, beyond which it decreased.

In India, more than 100 million tonnes of fly ash produced, use of fly ash for the preparation of polypyrrole–fly ash composites will in no way help in its bulk utilization. [4] Murugendrappa et. al have made an effort towards the better utility of fly ash by synthesizing polypyrrole–fly ash composites. The results shows a strong dependence on the weight per cent of fly ash in polypyrrole. [5] The larger the fly ash content in the polymer, the higher the extent of moisture ingestion. Whereas strength in dry condition increases with initial addition of ash particles, those for the medium ingressed show a decrement. Interface debonding occurring around ash particles has been traced to be the cause for such changes in response in the wet samples vis-a-vis the dry ones. [6] The impact strength increases linearly on increasing the fly ash content up to 50 wt% and then decreases for further increment. This decrease in impact strength when the fly ash content increases from 50 to 60 wt% can be attributed
to the immobilization of the macromolecular chains by
the fillers, which limit their ability to adopt to the
deformations and hence makes the material more brittle
[7] and each particle or aggregate of particles is the site
of stress concentration and can act as a microcrack
initiator [8].

In other side, the composite technology demanded
to improve the composite panels, which have high fire
 retardant. It is needed because almost all transportation
cars applied the panels as car body panels. The
experiences show that the fire follows transportation car
accidents. For example, when the Garuda Indonesia
Aircraft had an accident caused by hard landing on
International Adisucipto Air Port Yogyakarta in 2007, the
fire burned all interior composite panels in 5 minutes.
Whereas, the panels had been made from the glass
fiber as reinforcement and resin containing fire retardant
material as bonding material. Other accident of train also
shows that the fire, caused by short circuit of the electric
system, burn the interior car body panels. Refer to the
accident case; it is very important to develop the
composite panel, which has high fire retardant.

According to the statements above, the increasing
of the fire retardant of the composite panel can be
designed by using fly ash as reinforcement. It is
reasonable because the fly ash includes the very high
fire retardant material. In spite of the composite panel
should have high fire retardant, the panel also should
have high mechanical properties. The load occurred on
the car body composite panels consist of combination
loads, including flexural load. The purpose of this paper
is to investigate the effect of particulate grain size of fly
ash and fly-ash weight fraction to flexural properties of
fly ash – polyester composite.

**Flexural Properties**

The strength of composite material is influenced by
many factors, like type, geometry, orientation,
distribution, and content of reinforcement material. The
reinforcement content factor includes a dominant factor
usually used as variable in the research. The factor can
be calculated as follow [9-11]:

\[
\gamma_f = \frac{W_f}{W_r + W_m} \quad \cdots (1)
\]

\[
W_f = \frac{\rho_f \gamma_f}{\rho_f \gamma_f + \rho_m \gamma_m} \quad \cdots (2)
\]

\[
w_f = \frac{W_f}{W_C} \quad \cdots (3)
\]

\[
\frac{P_L h}{2 \rho h^3} \Rightarrow \sigma_b = \frac{12 P L h}{8 b h^3} \Rightarrow \sigma_b = \frac{3 P L}{2 b h^2} \quad \cdots (4)
\]

Notes; \( P = \) load (N), \( L = \) support span (mm), \( b = \) width
of beam (mm), dan \( h = \) depth of beam (mm). If the
maximum deflection is more than 10% of span (L), the
flexural strength of the beam should be calculated as
follow [13]:

\[
\frac{3PL}{2bh^3} \left[ 1 + \frac{6}{L} \left( \frac{\delta}{L} \right)^2 - \frac{4d}{L} \frac{\delta}{L} \right] \quad \cdots (5)
\]

Notes; \( \delta = \) midspan deflection (mm). The flexural
modulus and strain can be calculated as follow [13]:

\[
E_b = \frac{L m}{4bh^3} \quad \cdots (6)
\]

\[
r = \frac{6 \delta h}{L^2} \quad \cdots (7)
\]

Note; \( m = \) slope of the tangent to the initial straight-line
portion of the load-deflection curve.

**METHOD**

The materials used in this research are fly ash
(FA) powder waste, unsaturated polyester resin (UPRs)
157 BQTN EX and hardener MEKPO (methyl ethyl
keton peroxide). The fly ash was obtained from PLTU
Payton East Java, and the chemical materials (UPRs
and MEKPO) were obtained from PT. Justus Kimia
Raya Jakarta.

First, the fly ash powder was dried to evaporate
the water content using an oven at 100 °C for 1 hour.
And then, it was tested using a sieving machine to
classify the particulate grain size of FA. The sieving
machine has 5 mesh sizes (50, 100, 140, 200 and 250
mesh size) for 0.5 mm, 0.25 mm, 0.17 mm, 0.12 mm,
and 0.10 mm of grain size, respectively. There are two
group specimens in this research. First, the specimens
were varied in the particulate grain size for 40% of FA
weight fraction, and second, the specimens were varied in FA weight fraction (20, 30, 40, 50 and 60 % of fly ash content) for mixed particulate sizes of fly ash.

The composites were made by using a press mold, and all specimens were produced by according to ASTM D-790. Each specimen has 3 mm in thickness and 12.7 mm in width. They were tested by flatwise flexural test and the depth of the specimens should be the thickness of the material. For all tests, the support span shall be 16 (tolerance ± 1) times the depth of the beam. The specimen shall be long enough to allow for overhanging on each end of at least 10 % of the support span, but in no case less than 6.4 mm (1/4 in.) on each end. Overhang shall be sufficient to prevent the specimen from slipping through the supports.

When the specimens were tested, the load data could be seen on a monitor. The data for calculating the flexural properties was taken for every 0.25 mm of deflection.

RESULT AND DISCUSSION

Effect of Particulate Size to Flexural Properties of Fly Ash – UPRS Composite

According to the basic theory of the composite, the smaller size of reinforcement results the higher strength of composite material. As shown in figure 2a and figure 2b, the maximum moment and flexural strength of the composite reinforced by the smaller particulate grain size of FA is higher than that of composite reinforced by the greater particulate size of FA. For 40% of FA weight fraction, the composites reinforced by 0.10 mm, 0.12 mm, 0.17 mm, 0.25 mm and 0.50 mm of particulate grain size of FA have 127.24 MPa, 126.77 MPa, 92.47 MPa, 94.33 MPa and 48.19 MPa in flexural strength, respectively. As shown in figure 2d, the flexural strain curve has the similar characteristic with the flexural strength curve. The smaller particulate grain size of FA, the higher flexural strain of the composite.

However, the particulate grain size of FA has no effect to the flexural modulus of the composite, as shown in figure 2c. For 0.10 mm, 0.12 mm, 0.17 mm, 0.25 mm, and 0.50 mm in grain size of FA, the composites at 40% of FA weight fraction have 4.11 GPa, 4.71 GPa, 4.20 GPa, 4.37 GPa and 4.23 GPa in flexural modulus, respectively. The values show that the modulus has the same value for all particulate grain sizes of FA.

Based on the result above, it can be concluded that the smaller particulate grain size of FA increase the moment, flexural strength, and flexural strain of FA-UPRs composite. For the same FA weight fraction, the composite reinforced by smaller particulate grain size of FA has the greater contact surface between the reinforcement (FA) and the bonding material (UPRs). When the composite is loaded, the load is transferred by shear load between the both materials. The greater contact surface of them results the higher strength of the composite.

Effect of Fly-Ash Weight Fraction to Flexural Properties of Fly Ash – UPRS Composite

Theoretically, the increasing of the reinforcement material content increases the mechanical properties of the composite material. However, the increasing properties of the composite will decrease at a number of reinforcement materials content, whenever the materials are not bonded perfectly by the matrix. Here, the FA is as reinforcement material and the UPRs is as bonding material (matrix). According to the theory, this result shows that the composites have the optimum strength for 40% of FA weight fraction. As shown in figure 3a and figure 3b, the composites have the maximum moment and flexural strength for 40% of FA weight fraction. For 20%, 30%, 40%, 50% and 60% of FA weight fraction, the composites have the maximum moment 941 Nmm, 1038 Nmm, 1104 Nmm, 996 Nmm, and 861 Nmm, respectively. For the same FA weight fraction
fraction, the flexural strength of the composites is 49.39 MPa, 54.49 MPa, 57.95 MPa, 52.28 MPa, and 45.20 MPa, respectively. The strength is influenced by two factors, the increasing of reinforcement (FA) and the greater contact surface between FA and UPRs. They result the higher shear strength for transferring load.

In contrast, the increasing of FA weight fraction decreases the flexural properties of the composite. The FA, containing more than 50% Si, has high modulus, but it has low elasticity and plasticity. In other side, the UPRs (matrix) has high elasticity and plasticity. As consequence, the flexural strain decreases with the increasing of FA weight fraction, as shown in figure 3d. The composites containing 20%, 30%, 40%, 50% and 60% of FA have 1.52%, 1.37%, 1.17%, 0.83%, and 0.59% of flexural strain, respectively. It also shows that the composite has higher rigidity when the composite has higher FA weight fraction. The increasing of FA decreases the elasticity of the composite and increases the brittleness.

Refer to the general formula; the modulus is comparison of the flexural strength and flexural strain. The decreasing of the flexural strength increases the flexural modulus, and the modulus will increase significantly when the flexural strength increases. As result, the bending modulus of the FA – UPRs composite increases linearly with the increasing of FA weight fraction, as shown in figure 3c. This result shows that the composites have 3.45 GPa, 4.19 GPa, 4.97 GPa, 6.76 GPa, and 7.83 GPa in bending modulus for 20%, 30%, 40%, 50% and 60% of FA content, respectively.

Fracture Characterization

The fracture surface identification shows that all specimens have the same characteristic, as shown in figure 4. The fracture surface can be classified as single fracture, and the line fracture of all specimens makes a straight line. The fly ash – UPRs composite can classified into brittle material. It is reasonable because the reinforcement material is powder.

CONCLUSION

According to the result, the fly ash powder can be used as reinforcement material to increases properties of composite material. The smaller particulate grain size of fly ash, the higher flexural strength and flexural strain of the fly ash - UPRs composite. However, the flexural modulus of the composite has the similar values for some size of fly ash. For 40% of fly ash weight fraction, the composite reinforced by 0.10 mm of particulate grain size of fly ash has 127.24 MPa in flexural strength and 4.11 GPa in flexural modulus.

The increasing of fly-ash weight fraction can increase the flexural strength and modulus of the composite. The composite has the maximum flexural strength for 40% of fly-ash weight fraction, and the flexural modulus of the composite increases linearly with the increasing of fly-ash weight fraction. In contrast, the flexural strain of the composite decreases when the fly ash fly-ash weight fraction increases. The increasing of fly ash fly-ash weight fraction decreases the elasticity and increases the brittleness of the composite.

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