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Tensile Test of Fly-Ash-HDPE Hybrid Composite Via Finite Element Analysis

Intan Syaqirah Mohd Zulkifli[1*], Sharwinder Singh Sukadevh Singh[1], Kugenraj A/L Shankar[1], Freddawati Rashiddy Wong[2], Muhammad Izzat Nor Ma'arof[1].
[1]Faculty of Engineering and Quantity Surveying (FEQS), INTI International University, Persiaran Perdana BBN, Putra Nilai, 71800 Nilai, Negeri Sembilan, Malaysia
[2]Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

[*]**Email:** syaqirah.zulkifli@newinti.edu.my

Abstract

Fly-ash is one of the major wastes resulted from the power plant that generates electricity. In ensuring environmental sustainability, this waste should be properly disposed or utilized for other possible purposes. The goal of this study was to investigate the tensile strength of a newly developed fly-ash-high-density polyethylene (HDPE) hybrid composite via Finite Element Analysis (FEA) simulation. Four (4) types of hybrid composite were simulated in this study which were: (i) 100% HDPE with 0% fly-ash, (ii) 90% HDPE with 10% fly-ash, (iii) 80% HDPE with 20% fly-ash, and (iv) 70% HDPE with 30% fly-ash. The properties of the composite for four (4) different samples were obtained from the literature and via calculations. It was observed that the maximum stresses for samples 1, 2, 3 and 4 were 19.21MPa, 16.95MPa, 23.45MPa and 24.57MPa, respectively. The yield strengths were 26.1 MPa, 16.3 MPa, 22.5 MPa, and 23.7 MPa. It can be deduced that the tensile strength of the composite is increasing but the yielding strength is fluctuating. Furthermore, only sample 1 managed to record the factor of safety to be above 1.0. Non-homogeneity might be the cause of the values to fluctuate. For future studies, other types of mechanical properties assessment are recommended to be conducted on the fly-ash-HDPE hybrid composite.

Keywords

fly-ash-HDPE hybrid composite, tensile test, renewable material

Introduction

Composites are widely utilized in automobiles, aviation, transportation and many more industries due to its lightweight material. Fly-ash is now being introduced to reinforce the material due to its enhanced mechanical properties such as improved ultimate tensile strength, toughness, low density, compressive strength, impact strength, hardness and low ductility. Fly-ash is also noted to be abundantly available in Malaysia from various industries such as from the coal power stations. Thus, a composite can be formed with the combination of these two materials.

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An experiment was conducted by Shah. S et. al., (2014) to study the effects of fly-ash as a filler on mechanical properties of glass fiber reinforced material. Three (3) different types of specimens were prepared for the study. Specimen A is fibre-reinforced plastic (FRP) without filler material (0% fly-ash). Specimen B consist of FRP with 10% of fly-ash as filler material and specimen C with 5% of fly-ash as filler material. Specimen A shows that its tensile strength is 110 MPa while specimen B shows its tensile strength is 65 MPa when 10% of fly-ash is added to it. Specimen C shows that it has a tensile strength of 74 MPa. There is an increase in tensile strength for specimen C than specimen B but specimen A has the highest tensile strength among all specimens. By adding 10% of fly-ash as filler material increases the brittleness of the material. At the same time, by adding only 5% filler material shows that there is a reduction in the brittleness of the material. It can be observed that specimen A elongates by 6% while specimen B elongates by 4% due to the 10% of fly-ash addition. Specimen C elongates by 5% due to the 5% addition of fly-ash in the glass fibre reinforced plastic material. The elongation of the material depends on the percentage of fly-ash present in the material. Hence, this indicates the positive benefits in the introduction of fly-ash into the development of a composite.

In 2019, a study was conducted to test the composite containing fly-ash, recycled plastic (PP) and banana fibre treated with Maleic Anhydride and NaOH (Kulkarni. M. B et. al., 2019). Various composition of the composite were compounded with an extruder. The composition of treated and untreated fly-ash used are 0%, 10%, 20%, 30% and 40% while 0%, 1.5%, 3%, 5%, and 7% of banana fibre were used with 10% of PP. The exudates were left to dry for about 2 to 3 hours at 80°C after pelletizing. Then, the pellets were injected molded to form specimen for tensile and impact testing. Based on the results obtained, when 20% of fly-ash is added together with PP and natural banana fibre, the impact strength and flexural modulus improved. The composite mechanical properties improved with the addition of fly-ash due to the crystalline structural transformation.

Similarly, P. Doddipatla and S. Agrawal conducted an experiment on PP and fly-ash in the year 2018. PP was mixed with fly-ash to check the mixture composition. 3-Amino propyl trimethoxy Silane (APTMS) and Trimethoxy (propyl) Silane (TMPS) were used as an agent to treat the fly-ash to form treated fly-ash. They were mixed together based on different compositions of 5%, 10%, 20%, 30% and 50% of fly-ash in the mixture. Testing were conducted and the obtained results did not show a major difference in tensile of treated and untreated fly-ash. When the average tensile strength is taken, the results improved when the composite consist of treated fly-ash. The treated fly-ash also have a better tensile modulus. In a nutshell, treated fly-ash gives and also improves the mechanical properties of a material.

Next, in 2010, a study was conducted by Ahmad. I., and Mahanwar. P. between HDPE and fly-ash. The fly-ash acts as a filler in the composite. The study was conducted to check the mechanical properties of the composite. A maximum percentage of fly-ash used in the experiment is 40%. From the study, the results showed that moduli, tensile strength and flexural increases with the increment of fly-ash percentage. The tensile elongation shows a reduction when more than 10% of fly-ash is added to the composite. The material/composite strength and elongation increases when a smaller size of fly-ash is used. However, the small size particles of fly-ash did not improve the impact resistance and composite modulus according to the research.

In short, generally, all of these study illustrates the general positive result given by the addition of fly-ash in the development of new composite. Therefore, the utilization of fly-ash in increasing the performance of composite is indeed promising. Nonetheless, the mechanical properties test for a fly-ash-high-density polyethylene (HDPE) hybrid composite via Finite Element Analysis (FEA) simulation has yet to be conducted.

Methodology

Finite element analysis (FEA) simulation was performed via ANSYS software. The aim for the FEA simulation was to perform the tensile test according to ASTM D638 standard onto the specimens in order to determine the deformation, strain, stress, yield strength and the factor of safety (FS) for each of the specimens due to the weight percentage variations of HDPE and fly-ash. The maximum number of substeps applied in ANSYS is 150. The shape and dimension of the specimen as conducted in the FEA is as shown in Figure 1.

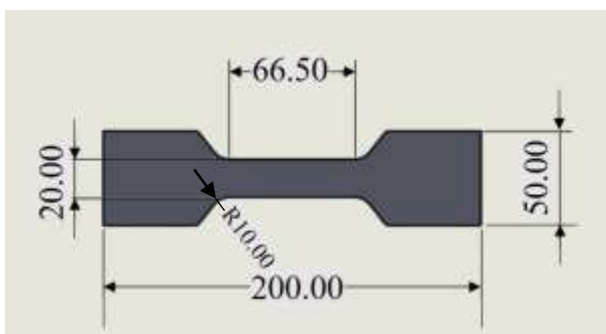

Figure 1. Dimensions of the specimen for tensile test

Table 1. Composite Composition for FEA

SAMPLE	HDPE	FLY-ASH
1	100 %	0 %
2	90 %	10 %
3	80 %	20 %
4	70 %	30 %

Result and Discussion

From the simulation, Sample 1 shows the characteristic of cold drawing polymer. It develops a necking develops upon stretching (Figure 2). Hence, the yielding process is followed immediately with the necking process. For Sample 2, the highest stress is 17.36MPa. The specimen experiences fracture at 16.95MPa. Next, Sample 3 highest stress is 23.45MPa. The specimen begins to fail at 23.22 MPa. Finally, Sample 4, has a characteristic of cold drawing polymer similar to sample 1. It develops a necking develops upon stretching. Hence, the yielding process is followed immediately with the necking process. The sample begins to fail at 24.4MPa.

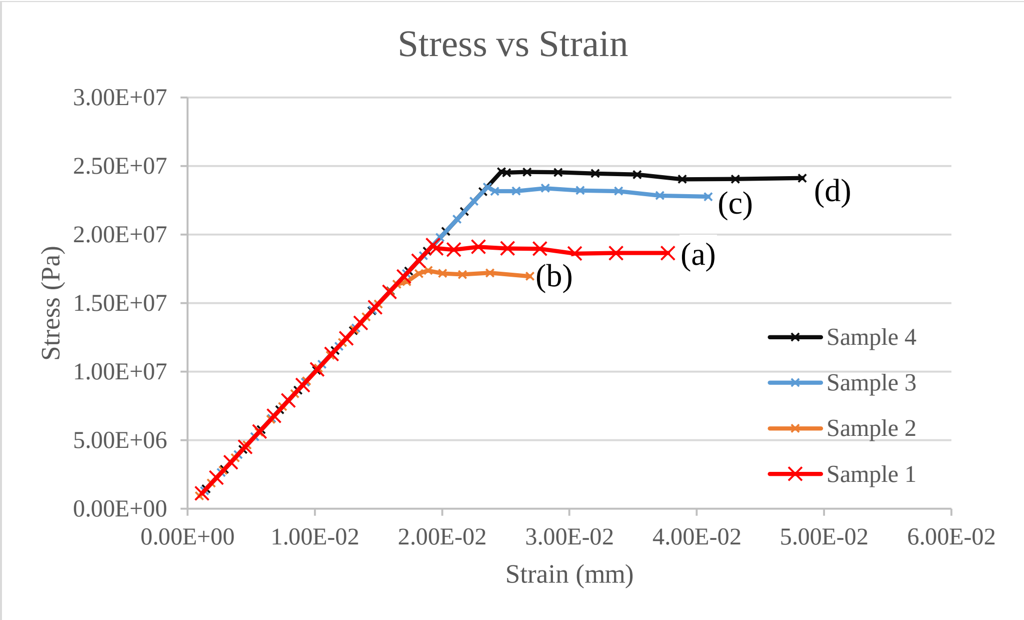

Figure 2. Stress vs. Strain graph for sample (a) Sample 1, (b) Sample 2, (c) Sample 3 and (d) Sample 4

Table 2. Results for Tensile Testing Simulation

Sample	Deformation (m)	Strain	Stress (MPa)	Yield Strength (MPa)	Factor of Safety
1	0.0025763	0.037742	19.21	26.1	1.36
2	0.0022861	0.02688	16.95	16.3	0.96
3	0.0029961	0.04091	23.45	22.5	0.96
4	0.0033055	0.04829	24.57	23.7	0.96

Based on the data in Table 2 the highest deformation, highest strain and highest stress occurs in sample 4. There is a weak bonding in sample 4. The bonding could be improved by introducing a coupling agent. This will improve the mechanical property. Besides, the addition of fly-ash does increase the material strength but when compared to yield strength, the factor of safety for Sample 1 is more than one which indicates it is safe. For sample 2, sample 3 and sample 4 the factor of safety is less than one which is not safe. The graphs were plotted with sub-steps of ranging from 20 to 150 to get more data. A non-linear effect was selected in the simulation in order to get yielding point in the graph. Besides, in order to get a more accurate results, the data were all collected with the convergence tool. A simple tensile test is conducted for this simulation to study the mechanical properties of the composite. The tensile test is performed by applying a force at the end of the specimen with the other end of the specimen is fixed (one-end fixed). The highest force acts at the middle of the sample where it will break (weak point). From the stress-strain graph, the graph shows a linear deformation trend. After the yielding point, the graph moves towards the tensile point. If the material is unable to endure the stress, the, material will fracture. The tensile strength value could be same, lower or higher than yield strength. The maximum stress for sample 1, 2, 3 and 4 is 19.21MPa, 16.95MPa, 23.45MPa and 24.57MPa respectively. The tensile strength of the composite is increasing but the yielding strength is fluctuating. Hence, this causes the factor of safety for the sample 1 to be 1 (safe) and other samples to be less than 1 (unsafe). Non-homogeneity might be the cause of the values to fluctuate. By comparing, Sample 1 has factor of safety more than 1.

Conclusion

Based on the result of the FEA simulation of this study, it can be concluded that the tensile strength of the fly-ash-high-density polyethylene (HDPE) hybrid composite is indeed increasing upon the increase of the fly-ash percentage in the composite. However, it is important to note that the yielding strength is unfortunately fluctuating. Hence, this causes in the discrepancies with respect to the obtained factor of safety with only sample 1 is noted to be safe, whilst, the rest of the samples has the factor of safety to be less than 1.0. Non-homogeneity might be the cause of the values to fluctuate. For future studies, other types of mechanical properties assessment are recommended to be conducted on the fly-ash-HDPE hybrid composite.

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