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by I Nyoman Suamir

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Experimental Investigation of Making a Composite Material from Plastic (LDPE) Waste

Made Ery Arsana[1,a*], I Nyoman Suamir[2,b], Sudirman[3,c], I Wayan Temaja[4,d] and Ida Bagus Gde Widiantara[5,e]

[1,2,3,4,5]Mechanical Engineering Department, Politeknik Negeri Bali,
Bukit Jimbaran, Badung, Bali 80364, Indonesia

[a*]eryarsana@pnb.ac.id, [b]nyomansuamir@pnb.ac.id, [c]dirmansdr@pnb.ac.id,
[d]wayantemaja@pnb.ac.id, [e]bgsgdewidiantara@pnb.ac.id

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Abstract. Plastic waste has been a major issue regarding waste in the world today. Plastic production in the world has reached 8300 million metric tons (Mt) from 1950 to 2015 and of about 6,300 Mt turned into waste. The development of industry and technology is often accompanied by the emergence of environmental impact issue. Encompassed plastic waste in nature causes problems, as it can drift from the land and fill the oceans around the world. Various plastic waste processing technologies have been introduced. Recycling plastic waste into goods, fuel oils and asphalt mixtures are things that have been done enormously. This research aims to make composite materials from used plastics, clay materials, and charcoal. A qualitative experimental method by heating the plastic waste below 270°C. Then, it is mixed with additional materials and casted the composite into a mold to form test specimens. Mechanical testing has been carried out to evaluate the composite. The results show that a composite material comprises plastic waste, clay and charcoal can provide maximum tensile strength of 14.59 N. The tested composite material is found to be 34.20% stronger than the material made of only plastic waste.

Introduction

Plastic was introduced in the early 20th century and beginning to expand its use after the second world war. Because it is strong and not easily degraded, plastic is used for various applications replacing metal. It also transforms packaging from production to disposable. Geyer et al. [1] estimated that 8300 million metric tons (Mt) have been produced from 1950 to 2015, and there are approximately 6,300 Mt of plastic waste produced, about 9% of which has been recycled, 12% burned, and 79% accumulated in landfills or our surroundings. If the production trend continues and waste management continues, as it is today then by 2050 it is estimated that there will be about 12,000 Mt of plastic waste in landfills or our surroundings.

Indonesia is the third largest contributors of plastic waste in the world. There has to be a real effort to mitigate it. Various plastic waste processing technologies have been introduced. Such as the usage of plastic recycling activities to remake recycled goods and research activities such as stone replacement aggregators for concrete mixtures [2], replacing cement on concrete [3, 4] and the usage plastic composite materials and desert sand [5]. Application of plastic composite materials and river sand and for concrete or bricks have been reported in [6-8]. Even plastic asphalt began to be used to make roads as reported in [9]. However, much more development is needed to get the new composite material. Opportunities for the usage of plastic waste are still extensive. Plastic waste, especially low-density polyethylene (LDPE) type, can be recycled to become plastic bags, food garbage wraps and beverage pipettes.

This research aims to make composite materials from low-density polyethylene plastic waste such as plastic bags, crepe bags, and PP (polypropylene), such as straws that are still rarely used for recycling. Composite material based on plastic waste to be mixed with Styrofoam, local clay and wood charcoal has never been made. Clay and charcoal materials is commonly used for ceramic materials that can improve the strength of ceramics [10]. This study is also aimed to investigate method of producing composite materials based on plastic waste that can be used for tile materials and wallboards of the room. Appropriate compositions have been tested and evaluated. This paper presents development of new composite materials from plastic waste and additive materials such as local clay and wood charcoal. The investigated composite materials are expected to be alternative materials for roof and wall materials.

Materials and Methods

The experimental program is focus on: (i) investigation that the composite material can be made with different composition; (ii) studying the tensile strength of the new composite material; (iii) comparing the results obtained with specimen without clay-wood charcoal and with the standard. Materials to be used include clay, wood charcoal, LDPE and Styrofoam waste, and used palm oil.

Mixtures preparation. To facilitate the production of the test specimen in the form of roof tile, mold of size 200 (mm) x 200 (mm), a mixer, oven, compression machine and a specimen maker tool were prepared. While the composite tiles were fabricated according to the process described below:

- Weighing the required quantity of Clay and LDPE;
- Mixing and melting the LDPE with the clay in the mixer for few minutes;
- Placing the mixture in the oven for 10 minutes than removing it;
- Putting the composite in the mold and;
- Applying the tensile strength testing.

Controlled composite material of four mixture compositions were made and investigated. The compositions of the composite which are characterized by their proportion of 200 (g) in weight of plastic waste LDPE and mixed with additive materials: fine clay, Styrofoam and used palm oil. The first composition category which based on mixture of plastic waste, Styrofoam and used palm oil is listed in Table 1.

Table 1. The first composition category by weight of composite materials

Test specimen code	Plastic waste (g)	Fine Clay (g)	Wood charcoal (g)	Styrofoam (g)	Used palm oil (g)
Test piece 1a	200	0	0	80	200
Test piece 1b	200	0	0	80	400
Test piece 1c	200	0	0	80	600
Test piece 1d	200	0	0	80	800

The second composition category comprises two composite materials as shown in Table 2. The characteristic of the composite is a combination between the first composition category and additional fine-clay with mixed composition as presented in Table 2.

Table 2. The second composition category by weight of the composite materials

Test specimen code	Plastic waste (g)	Fine Clay (g)	Wood charcoal (g)	Styrofoam (g)	Used palm oil (g)
Test piece 2a	200	120	0	80	200
Test piece 2b	200	240	0	80	200

The third composition category has also two composite materials as can be seen in Table 3. Characteristic of the composite is a combination between wood charcoal of the two proportions by 200 (g) of plastic waste LDPE, 200 (g) of used palm oil, 80 (g) Styrofoam and mix with fine wood charcoal 120 (g) for test piece 3a and 240 (g) for test piece 3b. In the third composition category no fine clay is added.

Table 3. The third composition category by weight of the composite materials

Test specimen code	Plastic waste (g)	Fine Clay (g)	Wood charcoal (g)	Styrofoam (g)	Used palm oil (g)
Test piece 3a	200	0	120	80	200
Test piece 3b	200	0	240	80	200

Table 4 shows the fourth composition category. Characteristic of composite is a mixture of 200 (g) of plastic waste LDPE, 200 (g) of used palm oil, 80 (g) Styrofoam, fine clay 240 (g) and wood charcoal 240 (g).

Table 4. The fourth composition category by weight of the composite materials

Test specimen code	Plastic waste (g)	Fine Clay (g)	Wood charcoal (g)	Styrofoam (g)	Used palm oil (g)
Test piece 4a	200	240	240	80	200

Fig. 1 shows a sample of test specimen for composite material in fourth composition category. The composite comprises plastic waste, fine clay, Styrofoam and used palm oil. A tool (test piece maker) for making standard test piece is also shown in the figure.

Fig. 1 A sample of test specimen for composite material in fourth composition category

Test equipment and method. Electric melting furnace was used to melt plastic waste is shown in Fig. 2. The furnace is completed with digital temperature control to regulate the furnace temperature in accordance with test requirement. The process includes preheating plastic waste, heating plastic waste at temperature below 270 °C and mixing with materials such as Styrofoam, used palm oil, clay and wood charcoal. The next step is heating the composite materials to a temperature setting below 270 °C for 10 minutes. The composites are then poured into a mold. A test piece for tensile test can be made by using a test piece maker tool (Fig. 1).

Fig. 2 Electric melting furnace completed with digital temperature controller

A tensile testing machine for non-metal materials were used to perform the strength of the composite. The capability of the machine ranging from 0 to 100 (kg_f) or 981 (N). Fig. 3 illustrates the tensile testing machine applied in this investigation. The tests were conducted in the laboratory of materials and testing of Politeknik Negeri Bali.

Fig. 3 Tensile testing machine with test pieces

Results and Discussion

Nine types of test pieces of the composite for tensile test have been prepared which include 4 test pieces for the first composition category, 2 test pieces each for the second and the third composition categories and 1 test piece for the fourth composition category. For accuracy, testing for each test piece was performed by using 10 up to 15 samples.

Results of the tensile test conducted for the first composition category of the composite materials are shown in Fig. 4. The testing used 10 samples for each test piece. Compositions of the test pieces (1a), (1b), (1c) and (1d) can be seen in Table 1. From the figure it can be seen that test piece (1a) can withstand the highest load with average maximum load of 10.52 (N). The results also show that the higher the composition of used-palm oil the lower the maximum load can be withstood by the composite material.

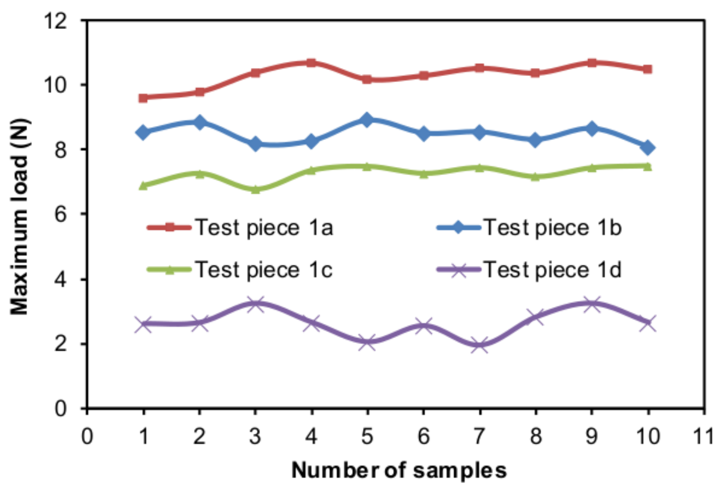

Fig. 4 Maximum tensile load variation of the first composition category using 10 test samples

Fig. 5 illustrates yield point of each composite material in the first composition category. A yield point describes the starting point of material's elasticity changing into tensile load during the tensile test. From the figure, it can be identified transformation of the composite material elasticity increases with the composition of the used-palm oil from test piece (1a) of 200 (g) up to test piece (1c) of 600 (g). Then, it sharply decreases when the composition reaches 800 (g) used-palm oil in plastic waste as contained by test piece (1d).

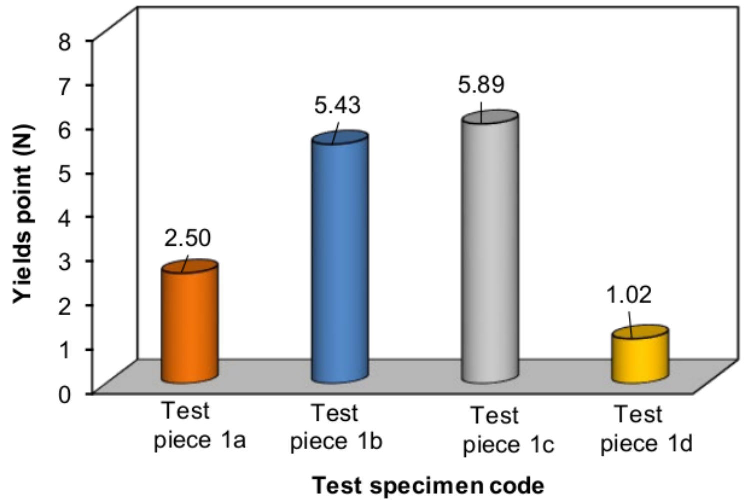

Fig. 5 Yields point value of the composite materials with various content of used-palm oil in the first composition category

Fig. 6 shows the change in the composition of the composite mixture, where the content of clay in the composition is varied from 120 (g) to 240 (g). The complete composition of the composite is shown in Table 2. A heavy fraction of clay can decrease tensile strength of the composite material. If the composition of the clay is increased two times from 120 (g) to be 240 (g), it can cause an increase in the tensile strength from 8.49 (N) to 9.60 (N) and accounted for an increase of 13.1%.

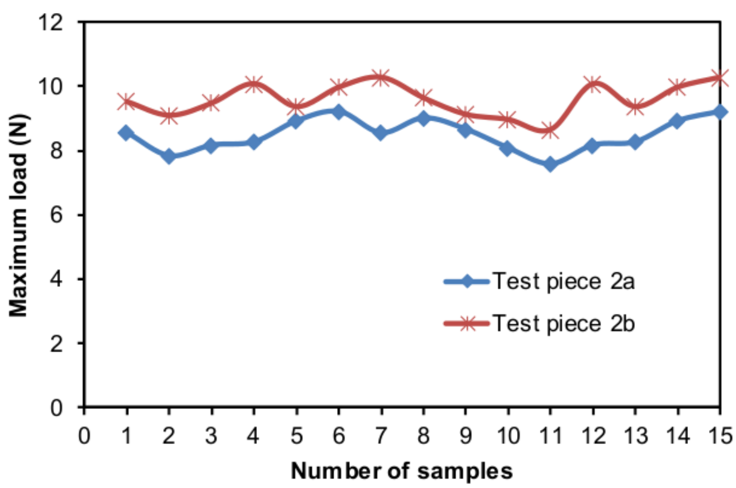

Fig. 6 Variation of maximum tensile load of the second composition category with 15 test samples

Fig. 7 illustrates the change in the composition of the composite materials as in the third composition category (Table 3). Addition of wood charcoal two folds of the initial composition causes a decrease in the tensile strength of the composite material from 13.66 (N) down to 12.32 (N). It indicates a reduction of tensile strength of about 9.5 %. However, the average tensile strength of the composite materials with wood charcoal mixture is higher 29 % than those with clay mixture. When they are compared with the strength of pure plastic material the value of their tensile strength increases for about 31 %.

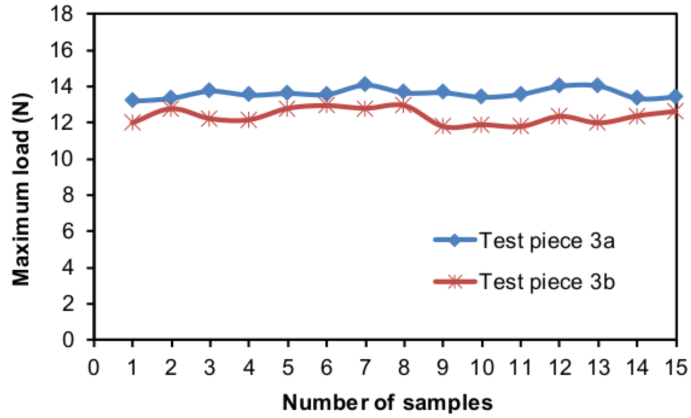

Fig. 7 Maximum tensile load of the third composition category with 15 test samples

Maximum tensile load comparison of the composite materials in the second, third and fourth composition categories can be seen in Fig. 8. The figure clearly shows that the test piece (4a) has the highest attractiveness with tensile strength reaching 14.9 (N). The test piece is group into the fourth composition category which contains fine clay and wood charcoal. Its tensile strength increases in the range between 6% and 40% when compared with that of the composite in the third and the second composition categories. The increase can reach 42% when it is compared with the tensile strength of the composite in the first composition category without the addition of fine clay and wood charcoal.

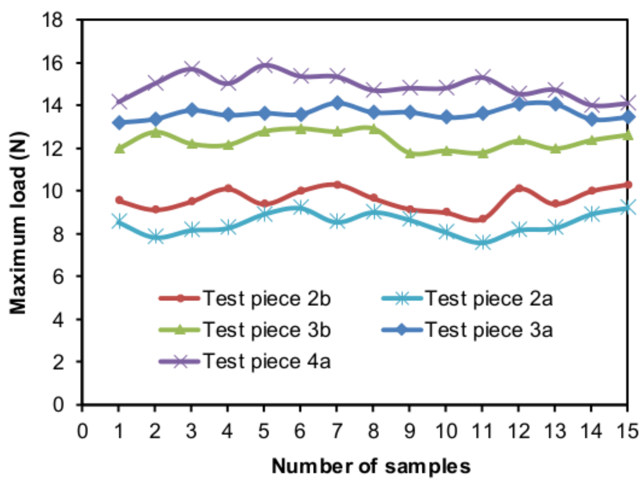

Fig. 8 Maximum tensile load comparison between the second, third and fourth composition categories

Test results also show yield points of various composite materials in the second, third and fourth categories. Fig. 9 shows a decrease in the start of elastic changes occurring from the clay mixture material in the second composition category (test pieces 2a and 2b). There is also an increase with the addition of wood charcoal material in the third composition category (test pieces 3a and 3b) and reaching the highest yield point of 6.09 (N). The shift of the yield point decreases down to half that of the load of 3.14 N occurs when the composite material using the fourth composition category with addition of clay and wood charcoal materials of the same comparison.

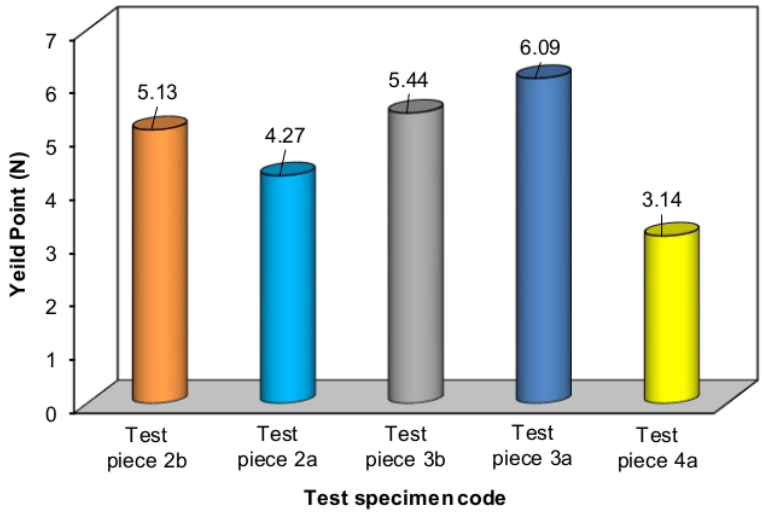

Fig. 9 Yields point value of the composite materials with various content of fine clay and/or wood charcoal in the second, third and fourth composition categories

Summary

The addition of more clay fraction above 60% can decrease the strength of the composite material. On the other hand, when the charcoal fraction is added, it can significantly improve the strength of the composite. The tensile strength of the composite material has been found to increase with the increase of wood charcoal above 60%. Composite material (test piece 4a) comprises plastic waste and Styrofoam to be mixed with clay and wood charcoal in powder form with the same ratio to the base materials can provide the best material tensile strength, with tensile strength reaching 14.9 (N).

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