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Study of strength and hardness of plastic waste from polypropylene and low-density polyethylene for speedbump material

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Abstract

The increase in human population causes the demand for food to always increase, as well as the increase in plastic that is no longer used and becomes waste that is just thrown away. Plastic waste is classified as waste that is difficult to decompose but can be recycled, one of which is by becoming the basic material for making speed bumps. Polypropylene (PP) and Low-Density Polyethylene (LDPE) plastics which will be recycled as speed bump materials. PP has strong properties and LDPE has elastic properties. The combination of a mixture of PP and LDPE has the potential to produce properties that are in accordance with the characteristics of the speed bump needs. The research method used was experimental. The stages of research activities were preliminary studies, preparation of material samples, material testing, analysis and conclusions. The research variable used was the test carried out by comparing the mixture of PP and LDPE compositions. Material testing carried out is a tensile and hardness test. The results obtained were the best composition of 80% PP and 20% LDPE with a tensile strength value of 7 N/mm^2 and a hardness of 62 Shore-D.

Keywords

Plastic waste, polypropylene, speed bump

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Introduction

The increase in human population causes food demand to always increase. Apart from that, the complexity of needs and improvements in people's lifestyles have spurred the development of various industries. However, from these activities, the resulting effects are also increasingly worrying, one of which is the enormous amount of waste produced. Waste in environmental health science is actually just a portion of objects or things that are considered unused, unused, disliked, or must be thrown away, in such a way that they do not interfere with the survival of life. From this perspective, it can be concluded that what is meant by waste is part of something that is not used, is not liked, or something that must be thrown away, which generally comes from human activities

(including industrial activities), which is generally solid (because of used water is not included). The increasing demand for plastic has resulted in a lot of plastic waste being thrown away or burned. Large volumes of waste cause problems in society and waste that is removed by burning causes adverse effects due to the combustion gases being released into the environment. There needs to be a wiser solution by utilizing and transforming plastic waste into useful goods. Therefore, conducting research on waste or plastic waste so that it can be reused into a speed bump product is a relevant thing to do. A speed bump is a mound made across the road to limit the speed of vehicles when passing in order to reduce accidents during traffic.

Figure 1. Speed bump.

In Indonesia, speed bumps mostly use a mixture of cement and asphalt because of their hardness and resistance to water. In this case, plastic waste can potentially be used as a substitute for cement and asphalt (Figure 1). The non-corrosive nature of plastic and types of plastic that have high strength can be a solution. Plus, the flexible nature of the plastic adds an advantage to the speed bump so that it does not endanger the driver at high speeds. The properties of the plastic used must have strong properties and high elasticity, such as LDPE (Low Density Polyethylene) plastic and PP (Polypropylene) plastic to reduce hard impacts on vehicles. LDPE tends to be more elastic while PP tends to be stronger. The combination of a mixture of PP and LDPE can produce material properties that are suitable for use as base materials for speed bumps. A speed bump is basically a surface profile 3-5 inches high that is placed on the road [1]. Usually installed in residential areas with relatively high interaction between humans and motorized vehicles to reduce the risk of accidents [2]. Various efforts have been made to improve driver/passenger comfort when passing speed bumps by optimizing the shape and height of speed bumps [3–5]. Vehicles that pass this speed bump have a vehicle speed of approximately 8 km/hour (5 mph). Apart from that, speed bumps can control and reduce vehicle speed. This is to anticipate undesirable events related to uncontrolled vehicle speed. In making speed bumps, there are regulations regarding their use that are regulated by the government. There are also regulations related to speed bumps, although they do not explain in detail what a speed bump is, namely Decree of the Minister of Transportation Number KM. 3 of 1994 concerning Road User Control and Safety Devices [6] is said to be a speed limiting device, namely in Article 3 paragraph (1)

"a speed limiting device is additional equipment on a road which functions to make motorized vehicle drivers reduce the speed of their vehicle" Paragraph (2) "Additional equipment as referred to in paragraph (1), may take the form of raising part of the road body across the road axis to a certain width, height and slope." The following is a picture of the standard design of a speed bump (vehicle speed limiter) which complies with government regulations in Figure 2. Standard Design of Speed Bump (vehicle speed limiter). Speed Bumps will be useful if they are placed and designed according to regulations, for example on roads in dense residential areas, local roads that have class IIIC roads, and [3–5] on roads where construction work is being carried out. then the rule is that the maximum height cannot be more than 15 cm, also the slope is 15%. If it is made according to the conditions above it will be useful. Speed bumps that do not meet standards not only damage the vehicle, but also endanger the driver. Inappropriate height and tilt angle result in excessive vehicle shock and shaking loads. Speed bumps are placed on (1) Roads in dense residential areas; (2) Local roads that have road class IIIC; and (3) On roads where construction work is being carried out.

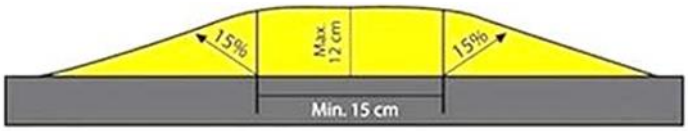

Figure 2. Standard speed bump design.

Plastic is a hydrocarbon whose chain is almost entirely composed of hydrogen and carbon atoms. This polymer is designed to inhibit the entry and exit of oxygen, so that the product or food stored in it is preserved from natural biodegradation or putrefaction processes [7]. Plastics are composed of organic solids or additional polymers called non-plastic components in the form of inorganic compounds that have a low molecular weight and can contain other substances to increase economic value. About a third of this material is used in the production of single-use materials including wrappers, bags and other packaging materials, glasses and plates for fast food and agricultural purposes [8]. Plastic polymers are considered one of the characteristics of the emergence of the modern era, which is characterized by a practical and comfortable life. Low Density Polyethylene (LDPE) is obtained from several items such as bags and containers [9]. Items with this code can be recycled and are good for items that require flexibility but are strong. Items with this code can be said to be indestructible but are still good for food containers and trash bags. LDPE has the advantages of (1) stable ability at high temperatures; (2) low price; and (3) easy to obtain [10]. LDPE is more suitable for use as modified asphalt because it has a low density and can improve the mechanical properties of the bond with asphalt [11,12]. LDPE has a melting point of 160-240 oC [13] Polypropylene (PP), PP has good resistance to chemicals, is strong, and has a high melting point so it is suitable for products related to food and drinks such as food storage containers, bottles drinking bottles, medicine containers and drinking bottles for babies. Usually recycled into battery casings, brooms, brushes, etc. PP has a melting point of 200-300 oC [13]. Tensile testing is carried out by pulling the specimen until it

breaks to determine the stress, strain and modulus of elasticity using an Insrton tensile machine. The shape and dimensions of the Tensile test specimen refer to the ASTM D638-14 standard with dimensions in millimeters (mm) for tensile testing on plastics [14]. Hardness testing aims to determine the material's ability to withstand pressure on the surface. The hardness testing standard refers to ASTM D785-08 for Rockwell hardness testing of plastics and electrical insulation materials [15]. The speed bump material that is widely used today is concrete, while the speed bumps sold on the market are made from rubber. Similar research that has been carried out is making speed bumps using concrete foam reinforced with empty oil palm fruit bunches. The test results showed that the speed bump cracked after an average of five times being stepped on the road by the weight of the Honda Freed car. Variable variations were made in the composition of cement, sand and empty oil palm fruit bunch fiber [16]. Another similar study conducted research using natural rubber composite materials with fly ash. Mechanical testing was carried out on the material and no cracks were found on the surface which was carried out at the laboratory stage. Variation of research variables was carried out on five formulations of Natural Rubber (NR) and Styrene Butadiene Rubber (SBR) [17]. Meanwhile, this research uses unused and uneconomical materials such as LDPE and PP which come from bottle waste, plastic, etc. Which is not used as material for making speed bumps. Apart from utilizing waste that is not useful, the success of this research can also reduce the volume of waste which continues to increase.

Methods

Research method and Model

The research method used is research and development. First, experiments were carried out on the variable composition of LDPE and PP alloy materials. Next, the best material composition was used as material for making speed bumps. The research model that would be carried out with these variables. This research model is explained in the research model flowchart in Figure 3 below. Plastic waste material came from LDPE and PP materials from bottles, plastic bags were collected. Next, the plastic waste was selected and cleaned from various impurities by washing it until it is clean. Preparation of tools and materials for melting plastic and molding plastic into molds in the form of tensile test and compression test specimens. Making samples was printed from test sample molds that had been provided with a number of specimens based on five types of variations in composition variables tested for tensile and hardness test specimens. Tensile and hardness testing samples were taken to a certified tensile and hardness testing institution for testing. The test data received was analyzed whether it corresponds to good test data or not. If the test data contained error, then the test containing certain samples would be retested. After the test data was considered good, an analysis process was carried out to answer the potential use of plastic waste as speed bump material so that conclusions could be drawn.

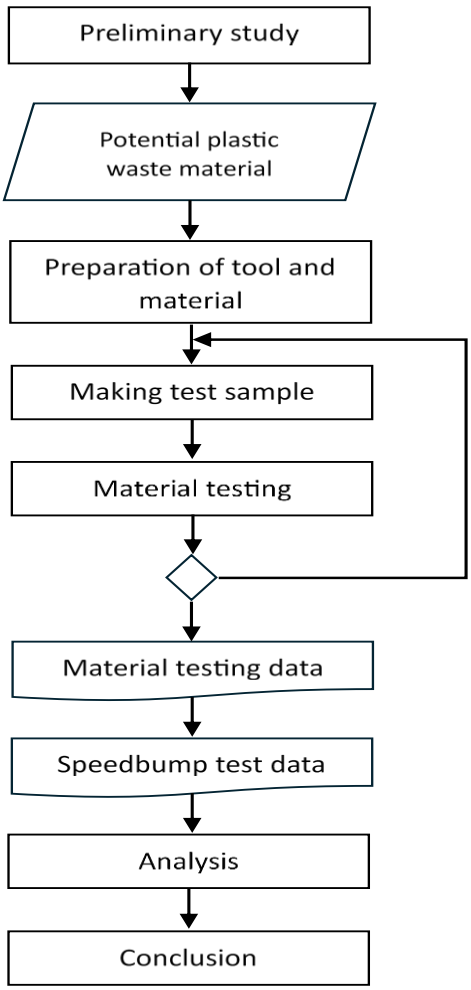

Figure 3. Research flow

Research variable, data collection technique and data analysis

This research had variables, namely the composition of the LDPE and PP alloy material. A more detailed explanation could be seen in Table 1. variable testing below.

Table 1. Test variables

No.	Mass Fraction
1	LDPE 20 % + PP 80 %
2	LDPE 35 % + PP 65 %
3	LDPE 50 % + PP 50 %
4	LDPE 65 % + PP 35 %
5	LDPE 80 % + PP 20 %

The data collection technique used was ASTM D638-14 standard tensile testing and ASTM D785-08 standard hardness testing. The data obtained from standardized testing was then processed and analyzed to draw conclusions about the composition of the best LDPE and PP alloy materials. The best LDPE and PP alloy composition was used as the material composition for making speed bumps. The test result data was processed and analyzed to obtain final conclusions.

Results and Discussion

LDPE and PP plastic mixture specimens were made according to specimens for testing the tensile strength and hardness of plastic materials. The testing standards used were ASTM D638-14 standard tensile testing and ASTM D785-08 standard hardness testing. The specimen results for testing are shown in Figure 4.

Figure 4. Test specimen.

The tensile test results of the mixed LDPE and PP plastic material show that the tensile strength increased with decreasing mass fraction of LDPE and increasing mass fraction of PP. The highest tensile strength results for a mixture of LDPE 20% and PP 80% were 7.00 N/mm^2 and the lowest tensile strength was for a mixture of LDPE 80% and PP 20% plastic at 3.34 N/mm^2. The tensile strength of a mixture of 80% LDPE and 20% PP is 3.34 N/mm^2, a mixture of 65% LDPE and PP 35% is 3.91 N/mm^2, a mixture of 50% LDPE and PP 50% is 4.50 N/mm^2, a mixture of 35% LDPE and PP 65% is 6.09 N/mm^2 and a mixture of 20% LDPE and PP 80% is 7.00 N/mm^2. The tensile strength test results are shown in Figure 5.

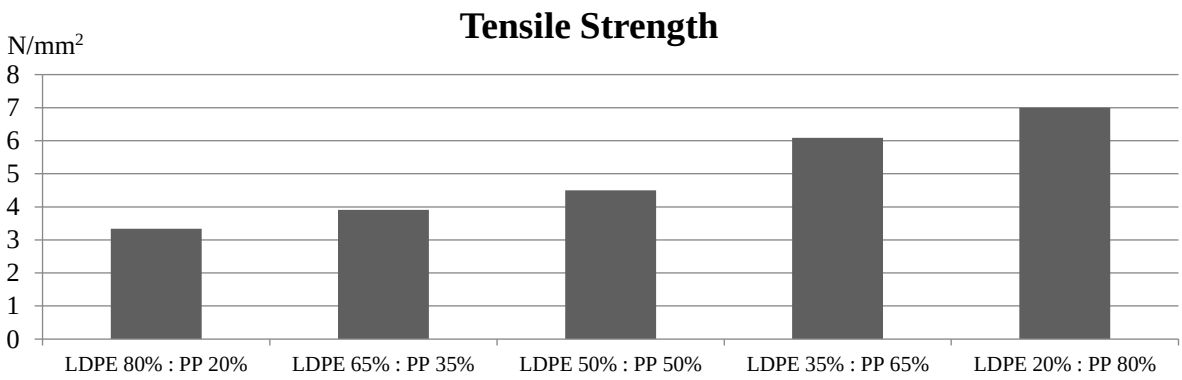

Figure 5. Tensile strength of LDPE and PP mixture.

The hardness test results of the mixed LDPE and PP plastic material show that the hardness increases with decreasing mass fraction of LDPE and increasing mass fraction of PP. The highest hardness result in a mixture of LDPE 20% and PP 80% was 62 Shore-D and the lowest tensile strength in a mixture of LDPE 80% and PP 20% plastic was 50 Shore-D. The hardness of a mixture of LDPE 80% and PP 20% was 50 Shore-D, a mixture of LDPE 65% and PP 35% is 52 Shore-D, a mixture of LDPE 50% and PP 50% is 57 Shore-D, a

mixture of LDPE 35% and PP is 65 % of 61 Shore-D and a mixture of 20% LDPE and PP 80% of 62 Shore-D. The results of the hardness test are shown in Figure 6.

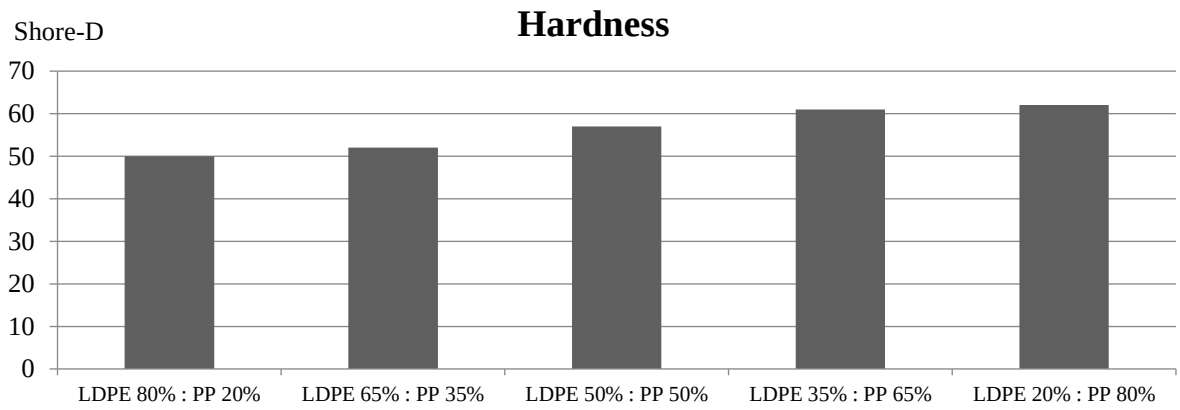

Figure 6. Hardness of LDPE and PP mixture.

The tensile strength and hardness test results show that both increase with decreasing LDPE composition and increasing PP composition. Increased tensile strength of LDPE 65% and PP 35% compared with LDPE 80% and PP 20% increased 17%, LDPE 50% and PP 50% compared with LDPE 80% and PP 20% increased 35%, LDPE 35% and PP 65% compared with LDPE 80% and PP 20% increased 82%, and LDPE 20% and PP 80% compared with LDPE 80% and PP 20% increased 110%. Increased hardness of LDPE 65% and PP 35% compared with LDPE 80% and PP 20% increased 4%, LDPE 50% and PP 50% compared with LDPE 80% and PP 20% increased 14%, LDPE 35% and PP 65% compared with LDPE 80% and PP 20% increased 22%, and LDPE 20% and PP 80% compared with LDPE 80% and PP 20% increased 24%. The percentage results of differences in tensile strength and hardness of LDPE and PP mixtures are shown in Table 2.

Table 2. Test variables.

Composition	Tensile strength (N/mm^2)	Increment tensile strength (%)	Hardness (Shore-D)	Increment hardness (%)
LDPE 80% : PP 20%	3.34	-	50	-
LDPE 65% : PP 35%	3.91	17	52	4
LDPE 50% : PP 50%	4.5	35	57	14
LDPE 35% : PP 65%	6.09	82	61	22
LDPE 20% : PP 80%	7	110	62	24

Conclusion

Based on the results of this research, conclusions can be drawn that the best test sample material for speedbump material was LDPE 20% and PP 80% with a tensile strength of 7 N/mm^2 and a hardness of 62 D-Shore, increasing the PP content causes an increase in the tensile strength of the material mixture and decreasing the LDPE content causes an increase in the tensile hardness of the material mixture.

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