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Characterization of Foam Materials Based on HDPE Plastic Waste for Automotive Seat Application

Muhammad Yazid Rahman[1], **Noraini Marsi**[1]*

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

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Abstract: The NVH (Noise, vibration and harshness) problem is one of the main worries of car manufacturers. Moreover, the problems of seeking alternate methods for the disposal of large quantities of packaging are rising for organizations. This study therefore suggests a method of solid-state recycling to incorporate direct recycling of polyethylene as the green engineering shaping technology. This study aims to determine optimum composition of high-density polyethylene (HDPE) plastic waste reinforced PU foam for automotive seat application. Using HDPE reuse can offer new options for a smoother, quieter driving experience, and it will address the problem with materials that compromise overall vehicle weight. Plastic wastes of high-density polyethylene (HDPE) are prepared for various ratios of 0.2, 0.4, 0.6 and 0.8. The mechanical test was carried out using tests of Tensile strength test (ASTM D3574), Impact strength test (ASTM D256), Sound absorption test (ASTM E105-95) and Bending strength test (ASTM C293). For physical test Optical Microscopic test (ASTM F728-81) and porosity testing was performed. The result show that the highest strength of the tensile and bending strength is 0.08 MPa respectively and 0.10 MPa. Moreover, data have shown that in the O.2:1:1, 0.4:1:1 and 0.8:1:1 ratio of the study, the maximum impact intensity test used was same at 1.06 kJ/m^2. Sample a obtained the highest sound absorption coefficient of between 1200 Hz and 1400 Hz with a ratio of 0.2:1:1 with the highest sound absorption coefficient (SAC) of 0.61. Insulation foams were also examined in an optical microscope and found to be changed according to an increasing ratio from plastic to PUF in white, uniform morphological shape and cellular form.

Keywords: NVH, PU Foam, HDPE, Car Seat, Automotive

1. Introduction

Automobiles are one of the main means of transport worldwide and have to give drivers and passengers a high degree of comfort and protection. Car seats constructed from nonlinear polyurethane

*Corresponding author: mnoraini@uthm.edu.my

foam cushions and the passenger seated body are also known to exhibit nonlinear mechanical behaviour. Vibration is the most important factor in deciding the degree of comfort and protection, and spontaneous vibration is the main factor in generating high stress inside the vehicle bodies through harmonic excitation and large deformation. The dynamic interaction between the seat of the automobile and the human body is a very complex phenomenon which needs an overall assessment based on this.[1].

Polymer materials are considered the highest growth zone in building materials. Polyurethane (PU) takes a leading position among polymer materials because of its exceptional mechanical properties. These include high elongation capacity, high energy absorption capacity, high tolerance in hostile conditions, thermal stability, chemical resistance, flexibility in their products and applications, ease of use, cost efficiency, and their contribution to the overall durability and sustainability of the final products. PU foam has been used with other materials in the last few decades to obtain composites with low density , high toughness and ductility, high impact resistance, efficient sound insulation and excellent mechanical properties[2].

In addition, plastic pollution is considered to be a planetary boundary threat, as it is irreversible, low degradation, impossible to recover all plastics on a planetary scale, and likely to disrupt the processes of the Earth system, either by having negative effects on ecosystems or by altering the physicochemical properties of the environment. The life cycle of plastics and plastic pollution directly contributes to climate change and has negative impacts on loss of biodiversity[3]. The HDPE is the third largest material in urban solid waste, contributing about 17.6 per cent of the various applications of plastic waste grades. Additionally, studies demonstrate that polymer foams can be reinforced with waste material to reinforce their mechanical, thermal and acoustic properties.

Plastic waste recycling has benefits because it is commonly used and has a long service life which ensures that the waste is eliminated from the waste stream for a long time. In addition, the use of post-consumer plastic waste is not only the safe disposal process but can also boost properties such as tensile strength, chemical resistance, drying shrinkage and short- and long-term shrinkage[4]. Throughout this study, HPDE plastic waste combined with polyurethane foam for sound absorption properties also reduced vibration, which then enhanced the mechanical properties and reliability of the material throughout automated use.

The international automotive industry has put forward a new standard referred to by the NVH standard, namely Noise, Vibration, and Harshness. In general, the NVH problem applies to both sensory and auditory experiences of car occupants. The more serious the vibration and noise issues of the car, the more irritable and unpleasant it will become for the passenger. From the NVH point of view, a vehicle is a device that consists of an exciter engine, a suspension-like actuator and a vibration noise generator. Today, the NVH problem is one of the main concerns that car manufacturers have been most concerned about, from the NVH standard analysis procedure for large system-level vehicles to the limited NVH component-level problems. According to statistics, most major car manufacturers have invested more than 20 percent of R&D funding to solve the NVH problem with vehicles[5]. The NVH problem can be solved particularly in the seat application by reinforced HDPE plastic with PU foam.

Therefore, given the suitability of plastic for a wide range of applications, companies face the increasing problem of seeking alternate methods for disposing of a large amount of waste packaging. Because of its very low biodegradability and presence in large quantities, disposal of plastic waste in the environment is considered a big problem[4]. Many countries have their different levels of waste generation, based on their level of income, becoming a serious issue for PSW disposal and management. Waste management is a complex process due to the requirement of different sources of information, such as influencing factors in waste generation, vast quantity forecasts and reliable data. The waste generated in Eastern and Central Asia is at least 93 million tons per annum. The production of waste per capita ranges from 0.29 to 2.1 kg per person per day, with an average of 1.1 kg per capita per day [6].

Hence, in this research, a solid-state recycling process is proposed to realize the direct recycling of polyethylene as the forming technology for green engineering. It will also be used to manufacture plastic cement directly from solid state in order to enhance the mechanical properties and processability of products[4]. Putting plastic waste mitigation to the forefront of the global policy agenda. 6.3 billion tons of plastic waste were produced as of 2015, 79 per cent of which ended up in landfills or the natural environment. This enormous amount of plastic pollution endangers our marine, freshwater and soil environment and potentially the safety of our entire food system [7]. The 80.00 % of post-consumer plastic will be sent to landfill, 8.00 % will be incinerated and 7.00 % will be recycled. Land filling with HDPE has serious repercussions as Green House gas production. By strengthening different particles the recycled plastic application area can be increased [6].

HDPE plastic waste is filled with PU foam, and then added to the interior of the vehicle. This solution will reduce the useless plastic HDPE and, especially in reducing the NVH, can improve the aspect in automated application. The improved insulation of this foam characteristics which enabled sound absorption in the car will give the consumer a good benefit.

2. Materials and Methods

This chapter outlined the experimental method of sampling reinforced polyurethane foam with HDPE plastic waste. The main aim is to determine the optimal ratio of plastic waste mix with polyurethane foams as vibration absorption properties for application of car seats. Through carrying out the technique, all the activities and preparations can be carried out in a timely and smooth manner, which can also avoid any errors occurring during the activities, especially in preparing samples and procedures.

2.1 Materials

Polyol and diphenyl-methane diisocyanate are the two primary components used to produce polyurethane foam. The mixture ratio is 1:1 such chemical substances by weight. HDPE plastic waste has been combined with polyurethane moisture to enhance the mechanical properties of the polyurethane moisture. Food container and syringe was used in fabrication process.

In order to prevent all deficiencies in car seat samples manufacturing process, it is necessary in the first step of plastic waste preparation that HDPE plastic waste is cleaned of all other pollutants, such as oils and detergents fluids. The dry plastic waste was cut until its small length using a small scissor as shown in the figure 1. The small sizes of HDPE plastic waste should be grinded using the grinding machine in the Packaging Laboratory, but the machine was broken and cannot be used an at the end the plastic waste was cut using scissor only.

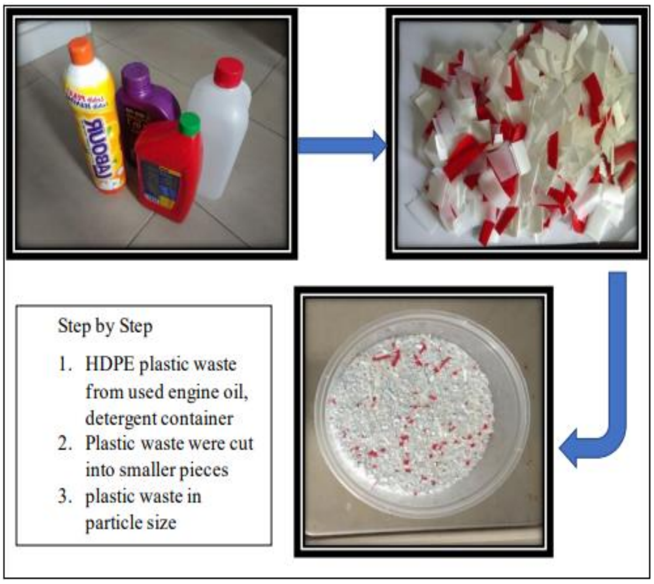

Figure 1: preparation of raw material

2.2 Fabrication Process

As shown in Figure 2 below, the 50 ml syringe contains a chemical solution of at a rate of 1:1, the polyurethane foam and polyurethane hardener were measured. 50 ml of polyurethane mixed solution scale was used to produce the sample at a ratio of 1. The polyol and isocyanate components are then ready for polyurethane foam chemical mixing. First, the chemical polyurethane solution was prepared, the method is to blend the chemical solution with plastic waste. As a manual mixing machine for mixing the solution, plastic food containers and wooden stirring rods were used. The process begins with the mixing process of polyurethane solution and polyurethane hardener plastic waste. The fume cupboard undergoes the polyurethane mixing process. Initially, the polyurethane solution was combined with plastic waste into the plastic food container and then mixed thoroughly with the polyurethane before mixing. The polyurethane hardener was then added to the polyurethane foam blend as it is thoroughly mixed until the blend expands into the polyurethane and plastic waste blend foam.

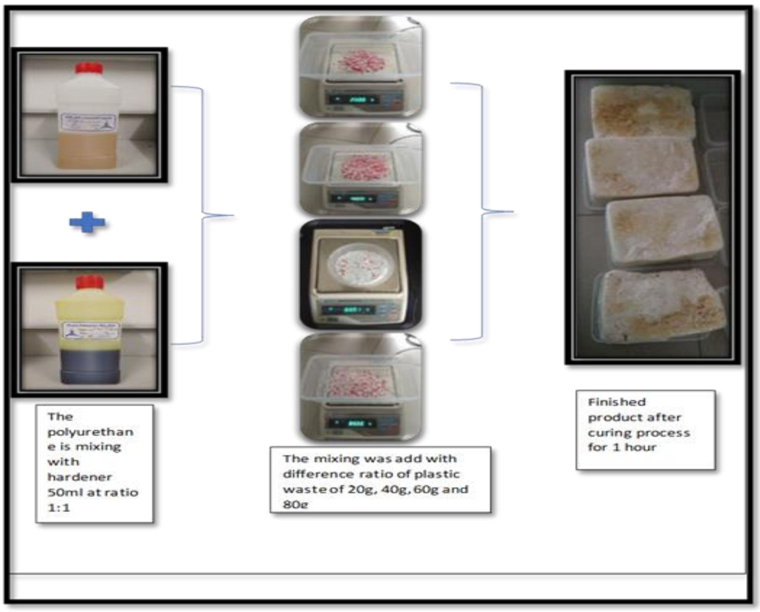

Figure 2: Fabrication process

The four samples were fitted with 100 mm diameter and 35 mm thickness. The sample was prepared in Figure 3 with 4 different plastic to-polyurethane foam to-material hardener ratios in 0.2.1.1, 0.4.1.1, 0.6.1.1 and 0.8.1.1. for sound absorption test (ASTM E1050- 95).

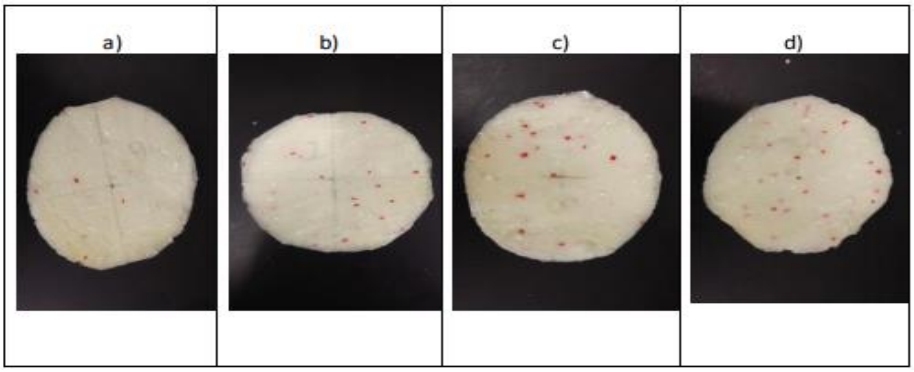

Figure 3: Four samples for Sound Absorption Test (a) 0.2.1.1, (b) 0.4.1.1, (c) 0.6.1.1, and (d) 0.8.1.1

3. Results and Discussion

3.1 Impact Test

The distinct ratio between HDPE plastic waste and plastic waste was shown in Figure 4. Polyurethane foam as a result of the impact test. The ratio of 0.2, 0.4 0.8 of HDPE plastic waste is clearly known to withstand the maximum impact strength value of 1.06 kJ/m^2. The ratio of 0.6 is the lowest with the maximum impact strength value 1.00 kJ/m^2. All the result shows a decrease value of impact test from the result of impact test of foam without reinforcement.

The effect parameters such as peak load, absorbed energy/impact energy ratio and contact period increased with impact energy were shown to decrease with the size of the impactor. With the thickness of the face layer, the impact energy and contact length also decrease, while the peak load increases. Furthermore, with the impact energy, both the planar damage diameter and indentation depth increase, while decreasing with face sheet thickness. In addition, the energy dissipation properties of composite structures without foam core were higher than the other, based on the falling weight effect outcomes. The content and thickness of foam and the structure arrangement were significantly affected by this property.[8]

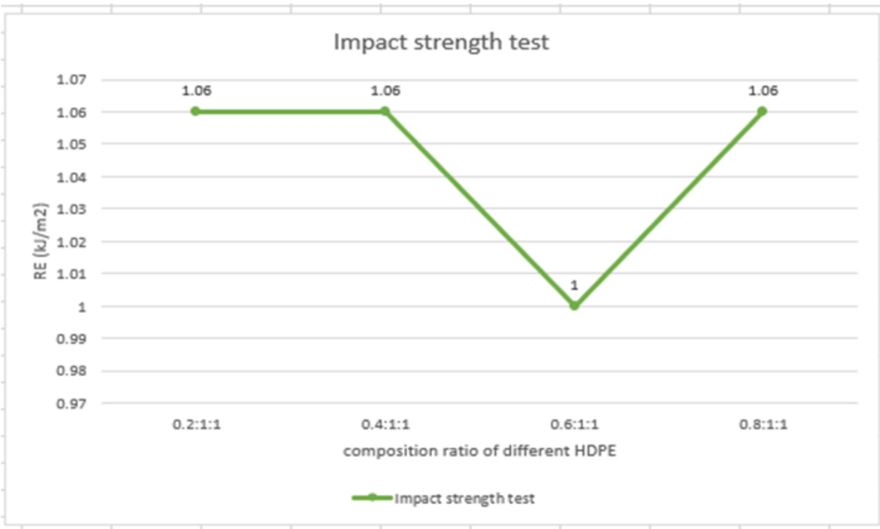

Figure 4: Impact strength test Result

3.2 Tensile Test

Figure 5 shows the tensile strength results of the sample. It is being shown to the maximum tensile strength value is 0.08 MPa at a ratio of 0.4:1:1, followed by a ratio of 0.6:1:1 with a tensile strength value of 0.06 MPa, same with ratio of 0.8:1:1 with a tensile strength value of 0.06 MPa and ultimately a ratio of 0.2:1:1 with a lowest tensile strength value of 0.03 MPa respectively.

The non-uniform dispersion of particles and polyol mixtures can also be related to the explanation for the decreasing mechanical strength at a high filling rate. A strong tendency, visible in the structure, to aggregate filler particles leads to a weakened interfacial adhesion between the filler and the productive active surface. As a result, RPUFs are characterized by microphase structure separation, which leads to an unintended failure of the samples at random locations in the samples.[9]

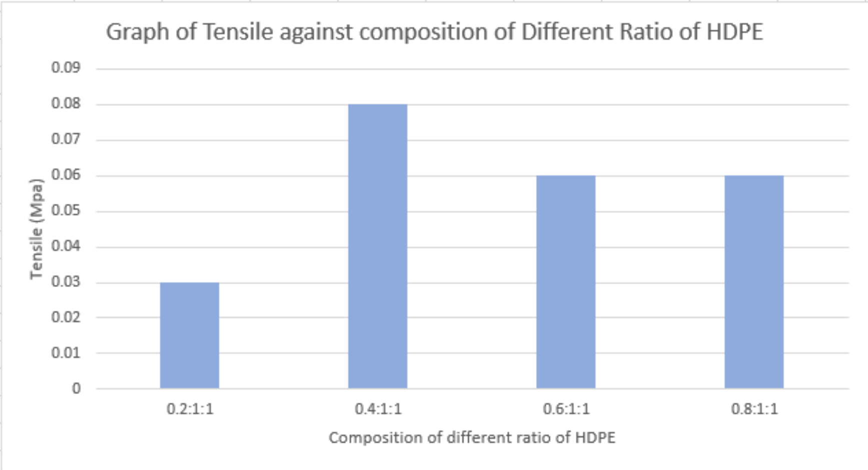

Figure 5: Tensile Test Strength result

3.3 Bending Test

Based on Figure 6, the sample bending strength increases as the matrix ratio grows. The highest bending strength of the sample bending strength of the 0.4:1:1 ratio is 0.10 MPa, and the lowest bending strength of the 0.2:1:1 matrix ratio is 0.02 MPa. The value of the bending power of the sample increases as the ratio of plastic waste particles in the mixture increases. The mechanical strength of the sample thus increases as the quantity of plastic waste increases in the polyurethane foam mix from 0.2:1:1 to 0.4:1:1 and starting decrease at ratio 0.6:1:1 with the value of 0.04 MPa same with ratio 0.8:1:1. By increasing the HDPE content, the adverse effects of the filler, such as disruption of the formation of hydrogen bonds and stoichiometry of the reaction, the risk of agglomeration of nanoparticles due to increased viscosity and improper distribution of nanoparticles, are substantially increase. The interaction of the particles with PU macromolecules is thus reduced and the mechanical characteristics are weakened.[9]

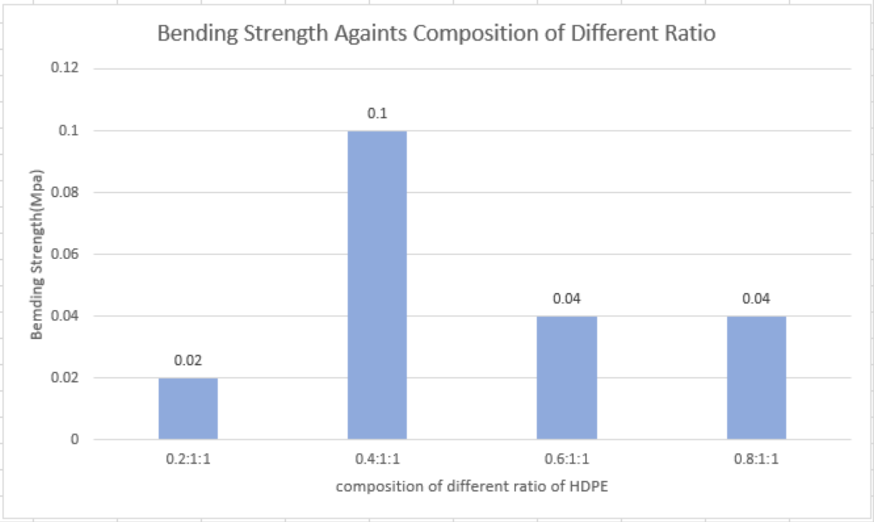

Figure 6: Bending Strength Test Result

3.4 sound absorption

The effect of sound absorption in the samples is shown in Figure 7 using the Impedance tube machine with samples that contain polyurethane foam with various ratios of plastic waste. The graph shows that the higher the sound absorption coefficient of the polyurethane foam can be increased in the polyurethane foams by more plastic waste particle fillers. Sample a obtained the highest sound absorption coefficient of between 1200 Hz and 1400 Hz with a ratio of 0.2:1:1 with the highest sound absorption coefficient (SAC) of 0.61. Although Sample b, with a 0.4:1:1 ratio, has the lowest SAC with a peak value of just 0.35.

This is probably due to the high content of the other elements, increasing porosity, lower overall density. This leads to a drastic decrease in the absorption of sound. When the other component content is regulated within a certain range, the efficiency of sound absorption is enhanced by increasing the content of other components. However, as the content of the other components continued to increase, the efficiency of sound absorption decreased. The average porosity of foams increases, and the density decreases with an increase in the ratio of foams. A fair regulation of the particle size is therefore important in order to improve the sound absorption properties of foams.[10]

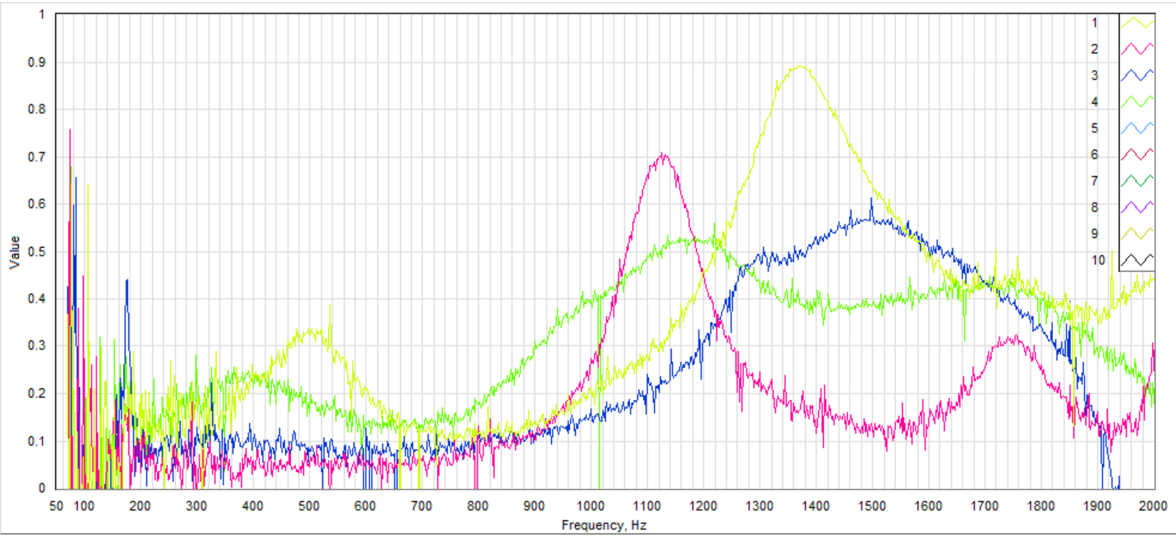

Figure 7: Sound Absorption Test Result

3.2 Discussions

Sample a obtained the highest sound absorption coefficient of between 1200 Hz and 1400 Hz with a ratio of 0.2:1:1 with the highest sound absorption coefficient (SAC) of 0.61. At a ratio of 0.2:1:1, 0.4:1:1 and 0.8:1:1 HDPE plastic waste to polyurethane foam mixture with an effect of 1.06 kJ/m^2, the highest impact strength test was calculated. Furthermore, with a ratio of 0.8:1:1, with a forced value of 41.19 N and a tensile strength of 0.08 MPa, the maximum tensile strength was calculated. Therefore, a variation in the matrix of the waste plastic particle increases the mechanical strength of the sample. Furthermore, with a highest bending strength of 0.4:1:1 in plastic to the polyurethane mixture, the sample has a peak bending strength of 0.10 MPa. Consequently, the ratio from polyurethane reinforced with plastic waste showed that 0.4:1:1 is ideal composition of mixture.

The outcome of the polyurethanes in the sample region is influenced by the mixture of different plastic waste into the polyurethane foam and thus give effect to the mechanical characteristics of the sample.

4. Conclusion

The experimental data have shown that in the 0.2:1:1, 0.4:1:1 and 0.8:1:1 ratio of the study, the maximum impact intensity test used was 1.06 kJ/m^2. In comparison, the strength of the tensile and bending strength is 0.08 MPa respectively and 0.10 MPa. But the tensile strength and bending data were decreased at their strength when 0.6:1:1 to 0.8:1:1 ratio. Moreover, insulation foams were also examined in an optical microscope and found to be changed according to an increasing ratio from plastic to PUF in white, uniform morphological shape and cellular form. Sample a obtained the highest sound absorption coefficient of between 1200 Hz and 1400 Hz with a ratio of 0.2:1:1 with the highest sound absorption coefficient (SAC) of 0.61. It can be concluded on the basis of the mechanical and physical test of the sample that the ideal and optimal ratio of mixed polyurethane foam plastic waste is 0.4: 1: 1. The ratios suggest that as the proportions of plastic waste particles increase, the proportions of foam particles increase. The mechanical and physical properties of the sample increase but decrease the product of the ratio 0.6:1:1 and 0.8:1:1:1 due to a defect in the curing phase or because the ratio is not suitable for the mixture

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