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Lightweight By-Product Block for Road Construction Application

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Abstract

The road construction industry in Malaysia and numerous other nations has encountered formidable challenges, chiefly emanating from soft soils. Lightweight block technology has garnered significant interest in addressing such challenges owing to its reduced weight, which minimizes pressure on the underlying soil, ameliorates differential settlement, facilitates ease of handling and installation, and aligns with sustainable construction practices. Therefore, this research was carried out to explore the feasibility of local by-product wastes in developing an alternative lightweight block for road construction applications. In this research, palm kernel shells (PKS) and rice husk (RH) were used as alternative lightweight aggregates (LWA) in the development of lightweight by-product blocks to reduce their density. The mix design ratio for the lightweight by-product block is 2:1:1 (cement:sand:aggregate). In this research, RH is partially replaced with sand by 0%,25%,50%,75%, and 100%, while PKS is replaced with coarse aggregate. The mixture was poured into a cube mould 50X50X50mm and underwent 7, 14, and 28 days of air-dry curing. The performance of the lightweight by-product block was evaluated based on density, water absorption, compressive strength, and Young's modulus. The results have shown that the higher the proportion of RH is, the lower its compressive strength, lighter its density, and the high in water absorption. RH proportions of 25% and 50% show a good result before dropping dramatically; the compressive strength is 4 MPa and 2.64 MPa, respectively. The density achieved is 1642.37 kg/m^3 and 1460.03 kg/m^3 respectively.The benefits of this research is reduction of by-product waste by repurpose it for block application. The introduction of new block can lead to new innovation for local to use in road construction for additional method to reduce the selfweight of fill materials. This parallels the Sustainable Development Goal developed by the United Nations Development Programme specifically SDGs 9,12, and 13.

1. Introduction

Soft soil covered a significant number of lands in southeast Asia like Malaysia it covered a portion of the west and east coasts of the Peninsular and East Malaysia [1], [2], [3]. In Malaysia, quaternary sediments comprising organic, or peat soils and alluvial deposits are generally called soft soil [2], [3]. [1] reported that peat soil covers about 2.6 million hectares and constitutes about 15% of peninsular Malaysia, over 80% in Sarawak, and in Sabah, it is 5%. In recent years, many cases of embankment settlement and deformation have been reported from high compressibility and low shear strength of soft soil. It poses a challenge for engineers to implement the structure on soft soil without any soil stabilization because of its poor properties with high water content, which varies between 230% and 500%. Poor shear strength, notably within 2kPa to 8Kpa. Inadequate permeability, high compressibility, and weak shear strength are typical characteristics of soft soil. These properties will lead to settlement and can result in structure and road failure which is hazardous and uncomfortable for road users [4].

Recently, many by-product materials have been produced significantly more due to the industrial economy. Rice husk, the outer shell removed from paddy rice during processing, becomes agricultural waste. Its high silica content makes it resistant to breaking down in the environment, posing ecological challenges. Globally, rice husk accounts for about 20% of the 500 million tons of paddy produced yearly [5]. In 2018, Indonesia alone produced nearly 11.3 million tons of rice husk annually. Malaysia generates about 770,000 tons annually, and Brazil around 7 million tons [6]. This equates to roughly 200 kg of rice husk for every ton of rice produced. The Malaysian government aims to cut rice husk waste by 50% by 2025 by promoting its use as a renewable resource [7]. Thus, an innovation that promotes sustainability and is environmentally friendly is compulsory to protect the next generation. In every development, by-product waste is generated. Several researchers use RH as a partial material replacement; the most studied is cement replacement using rice husk ash (RHA), while shallow studies are aggregate replacements.

Rice husk (RH) is an excellent lightweight material due to its high porosity and interconnected structure, making it lighter than sand. RH has a density of about 108 kg/m^3, compared to sand's 1,850 kg/m^3 [5]. The rice husk particles are 2 to 4 mm wide, about 10 mm long, and evenly distributed. This even distribution in the concrete mixture helps create uniform air voids in the hardened concrete. As a result, concrete blocks made with rice husk are less dense than regular concrete blocks [5].

Lightweight blocks have recently become prevalent in many applications [8]. The lightweight block can be classified as a low density block. For example, it is expanded polystyrene (EPS) geofoam tire bales and cellular concrete [8], [9]. One of the applications of lightweight blocks is as lightweight fill material in road embankments [10], [11]. The use of lightweight blocks can reduce the settlement because it is lighter than conventional fill materials, which alleviates the pressure on the underlying soils [8], [11]. The use of lightweight blocks can reduce the use of soil as fill materials [11]. However, in Malaysia, the adaptation of lightweight blocks in road applications is very low. Furthermore, using EPS and tire bales can be expensive because of non-local products [8].

Several lightweight blocks have been used in road construction, such as EPS geofoam and tire bales, which are used in road construction applications as embankment fill materials. The density of EPS and tire bales reached 12-35 kg/m^3 and 420 kg/m^3, respectively [8],[9],[10],[11]. The water absorption of both lightweight blocks was close to 0%. The compressive strength for EPS is 40-276kPa, while tire bales can reach 815kPa. The Young's modulus of tire bales obtained was 713-904kPa [10],[11].

Thus, this study aims to research the optimum ratio of RH proportion in lightweight blocks as partial sand replacement and use other by-product waste to promote sustainable and eco-friendly concrete blocks. The research focuses on replacing the RH with sand with percentages of 0%, 25%, 50%, 75%, and 100%. Meanwhile, the PKS fully replaces the coarse aggregate in all block batches. The method begins with material preparation, a sieve to the desired size for PKS and RH. Next is the standard concrete mix procedure used in this study with mold size 50x50x50 mm. Then, set for dry curing for 7, 14, and 28 days before conducting testing. The study examined the performance of the lightweight by-product block in terms of density, water absorption, compressive strength, and Young's modulus.

2. Materials and Methods

2.1 Materials

The main materials used in the fabrication of the lightweight by-product fill blocks are Ordinary Portland Cement (OPC), Palm Kernel Shell (PKS), Rice Husk (RH), Sand, Water, and Super Plasticizer (SP).

2.1.1 Cement

The binder used is Ordinary Portland Cement (OPC). The decision to use OPC complies with the MS EN 197-1:2007 CEM I 52.5N standards. Portland cement will be used when mixed with water due to its binding properties and hardening ability.

2.1.2 Palm Kernel Shell (PKS)

The Palm Kernel Shell (PKS) was sourced from a nearby Bukit Pasir, Muar oil palm mill. The PKS was dried in an oven at the temperature of 105 °C ± 5 °C for at least 24 hours to remove the moisture in it. The OPS will be sieved through a 12mm to act as coarse aggregates replacement.

2.1.3 Rice Husk (RH)

The rice husk (RH) used in this study was collected at a nearby Pagoh Jaya, Johor nursery. The rice husk is grind and sieved, passing 4.75mm.

2.1.4 Sand

Natural river sand is used as fine aggregate, and the nominal size of sand passes through a 4.75 mm sieve. The sand is sourced from the Technology Concrete Laboratory at Universiti Tun Hussein Onn, Malaysia.

2.1.5 Water

Water is a pivotal component in concrete mixing, significantly impacting the workability and strength of the concrete. The quantity and quality of water added to the mix are determining factors. It initiates a chemical reaction with cement, facilitating its setting and hardening.

2.1.6 Super Plasticizer (SP)

Master Glenium®SKY 8808 manufactured by BASF was included in all mixes in a small amount to enhance the workability of fresh concrete mortar. The SP dosage used is 2 % of the weight of cement used.

2.2 Lightweight By-Product Block Mix Design Ratio

The main materials used are ordinary Portland cement, rice husk waste (RH), sand, and palm kernel shells (PKS) as aggregate, collectively forming the lightweight block. The By-Product Lightweight Block primary element is Cement:Sand:Aggregate with a ratio of 2:1:1. In this batch, the compressive strength of By-Product Lightweight Block samples was evaluated at 7 days, 14 days, and 28 days of dry curing. The development of the By-Product Lightweight Block involved employing five (5) different ratios of rice husk, which he rice husk was used as a partial substitute for sand with an RH:sand proportion of 1:0, 75:25, 50:50, 25:75, and 0:1. Moreover, the PKS was used as a 100% aggregate replacement to create lighter blocks, with a density 50% lower than the conventional aggregate. The procedure for fabricating this product is shown in Figure 1. Table 1 outlines the experimental mix design ratios of the by-product lightweight block, and its sample codes are listed in Figure 2.

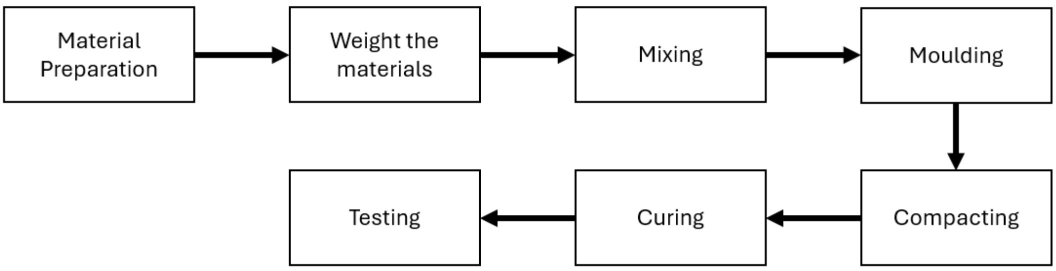


Figure 1: Procedure of fabrication

Table 1: Mix design of Lightweight By-product Block

Sample Code	Ratio (2:1:1)			Curing Time (Day)	Total Sample
	Cement	RH:Sand	PKS		
R-PS100(7)		(1:0)			
R-PS75(7)		(75:25)			
R-PS50(7)	2	(50:50)	1	7,14,28	45
R-PS25(7)		(25:75)			
R-PS0(7)		(0:1)			

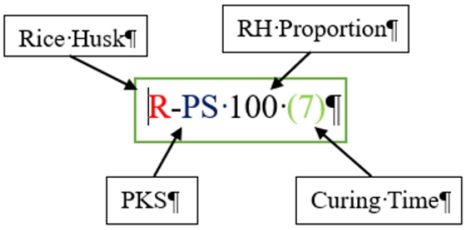


Figure 2: Sample Code

2.3 Product casting

The preparation of concrete was performed after hand mixing was done. The list of apparatus, material, and procedure of concrete is based on BS 12390-1:2012 (BS EN-12390-1:2012, 2012). The apparatus used is a tamping rod, shovel, cylinder container (50mm x 50mm x 50mm) mold, bucket, and aluminum tray. Based on the procedure from Figure 1, the procedure started with material preparation which is to prepare the material before mixing. The materials used are sand, rice husk (RH), palm kernel shell (PKS), ordinary Portland cement (OPC), water, and superplasticizer (SP). The RH and PKS was sieved to desired size. After cleaning the mould, oil was applied to the inner mould to remove the sample easily. The cement, water, sand, and PKS were weighed before mix. The sand, cement, RH and PKS were mixed first before water is added, as shown in Figure 3. After sufficient mixing and enough water, the SP was added and thoroughly mixed into the concrete mix. Next, the mixture was added layer by layer into the mould in 3 layers and compacted 25 times for each layer using tamping rod. All the mixes were compacted by hand tamping to minimize segregation and avoid vibration compaction. The concrete is set to cure for 24 hours before opening, as shown in Figure 4. Every concrete sample was labeled with the ratio containing RH with 3 samples in each ratio, as shown in Figure 5.

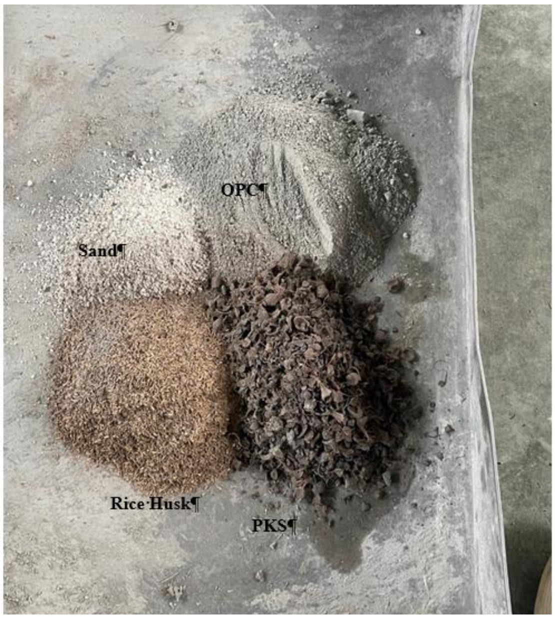


Figure 3:Materials before mixing

Figure 4: Moulded sample 50x50x50mm

Figure 5: Sample labelled

2.4 Laboratory Testing

2.4.1 Density

BS EN 12390-7:2009 is used to determine the density of hardened concrete. Following the EN standard, the determination of mass is as received. The determination of volume is by calculation using actual measurements. The dimensions of each block were measured in centimeters and rounded to the nearest millimeter after the blocks had cooled to room temperature. The total volume was then calculated in cubic meters.

2.4.2 Compression Strength Test and Young's Modulus

The compression test was conducted to measure the compressive strength of each cube composition using the compression test machine. The compressive strength test determines the maximum load a material can withstand before fracturing. This test method follows BS 12390-3:2002 (BS EN 12390-3, 2002). The maximum load and compressive strength for each sample are recorded.

The modulus of elasticity or Young's Modulus represents the capacity of the material to resist deformation under applied load. It is determined by computing a stress-strain diagram by finding the linear portion of the curve representing the elastic deformation region. Data obtained from the compression strength test is needed to calculate the strain and stress from compressive strength machine data to determine the Young's Modulus value. The EN1992-1-1 standard is used as a reference.

2.4.3 Water Absorption Test

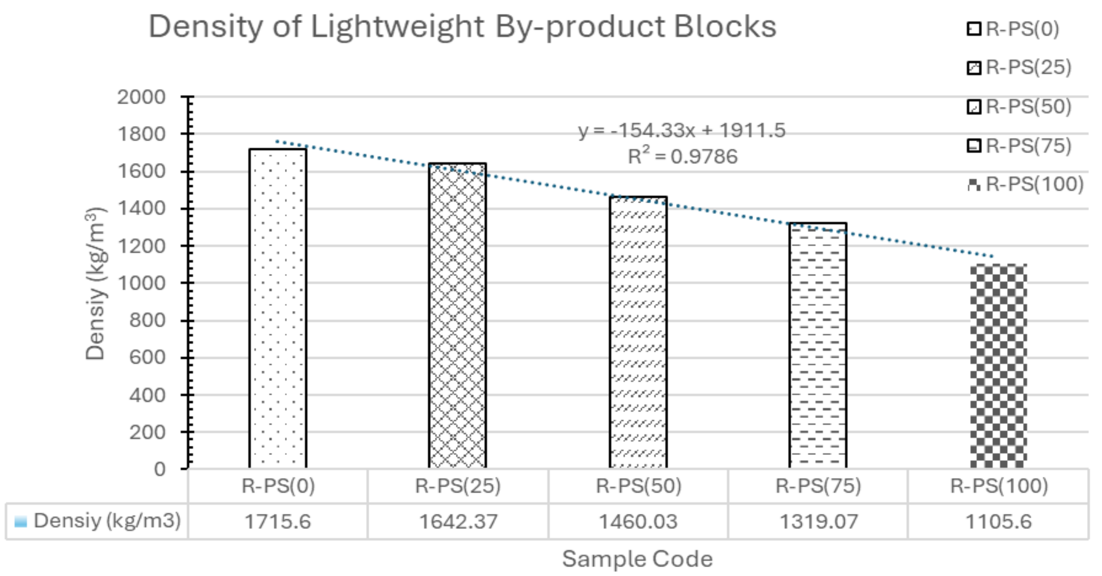
The water absorption test is carried out to determine the quantity of water absorbed. The lower the absorption rate, the better the block is. The water absorption test procedure is based on BS1881-122 (BS1881-122, 2011). After being oven-dried for 24 hours at 105 ± 5°C, the specimen was cooled and weighed. The specimen was then submerged in room temperature water for 30 ± 0.5 minutes. The specimen was taken out after 30 ± 0.5 minutes and dried with a cloth until no more free water was on the surface. Every sample was measured as a wet mass. The weighted dry and weighted wet was needed to calculate the water absorption. This test was done after the samples were cured for 7, 14, and 28 days.

3. Result and Discussion

This section briefly discusses the results and conclusions obtained from the test results. There are several laboratory tests performed on lightweight by-product blocks, which are density test, water absorption, compressive strength test, and Young's modulus.

3.1 Density

The results show that as the rice husk content increases up to 100%, the density of the lightweight blocks decreases from 1715.6 kg/m^3 (R-PS(0)) to 1105.6 kg/m^3 (R-PS(100)). Figure 6 illustrates this consistent trend of the density decrease with increased rice husk content, resulting in lightweight blocks. This demonstrates how varying amounts of rice husk significantly affect the density, making the blocks lighter.



	R-PS(0)	R-PS(25)	R-PS(50)	R-PS(75)	R-PS(100)
Densiy (kg/m3)	1715.6	1642.37	1460.03	1319.07	1105.6

Figure 6: Average density of lightweight by-product block

The RH content in the lightweight by-product blocks is the reason for the drop in density. Because RH has a lower density 108 kg/m^3, compared to sand's 1,850 kg/m^3, adding RH to the mixture may cause its density to decrease [5]. For instance, a study on using RH in place of some of the sand in the production of concrete blocks discovered that the RH content increased as the blocks' dry density decreased [5].

The lowest density for lightweight by-product block density is 1105.6 kg/m^3, way higher than EPS (35 kg/m3) and tire bales (420 kg/m3); in terms of density, the compacted conventional fill materials (2000 kg/m3) are higher than lightweight by-product block.

3.2 Water Absorption

Figure 7 shows the average water absorption influence by RH:S proportion. The finding shows that the water absorption increases as the percentage of RH content increases from 21.53% (R-PS(0)) to 54.77% R-PS(100). Water absorption increases by 6.82% when the RH content is up to 25% (R-PS(25)). As the rice husk (RH) content rises, this increase becomes more noticeable: R-PS(50) shows a 14.49% increase, R-PS(75) a 19.80% increase, and R-PS(100) the highest increase at 25.44%. The equation y=8.6112x+8.7987 describes the relationship between water absorption and the rice husk (RH) content in the lightweight by-product block. With an R^2 value of 0.9408, close to 1, the equation accurately fits the data. Thus, using RH will increase the water absorption of the sample. The high water absorption can cause a reduction in strength, which makes the block less resistant to the load above. Other than that, water absorption does not have a high impact on road applications.

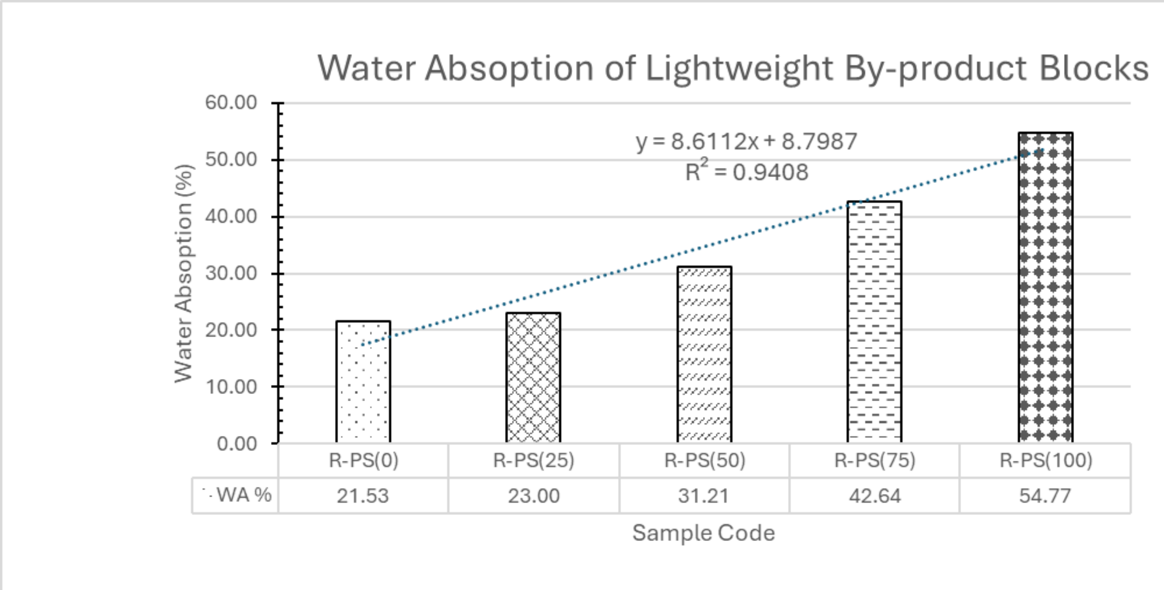


Figure 7: Average Water Absorption Of Lightweight By-Product Block

A number of studies using concrete obtained the same case. According to [12], RH content increases water absorption. This rise in water absorption is due to RH's high water absorption capacity, which can reach 100% by weight [13]. Additionally, using RH increases the porosity of the concrete, further contributing to higher water absorption [14].

The water absorption of EPS and tire bales which is close to zero is better than lightweight by-product block, the use of agriculture materials and cement as binder facilitate the water absorption abilities. Thus, water proofing is recommended to reduce the water absorption in lightweight by-product block.

3.3 Compressive Strength of lightweight by-product block

3.3.1 Effect of rice husk proportion on compressive strength

Figures 8 show the compressive strength of lightweight by-product blocks with various RH:S proportions at 28 days. It aligned with 5 sample codes of R-PS(0), R-PS(25), R-PS(50), R-PS(75), and R-PS(100). Specifically, the results show that adding RH content as partial sand replacement has decreased the sample's compressive strength.

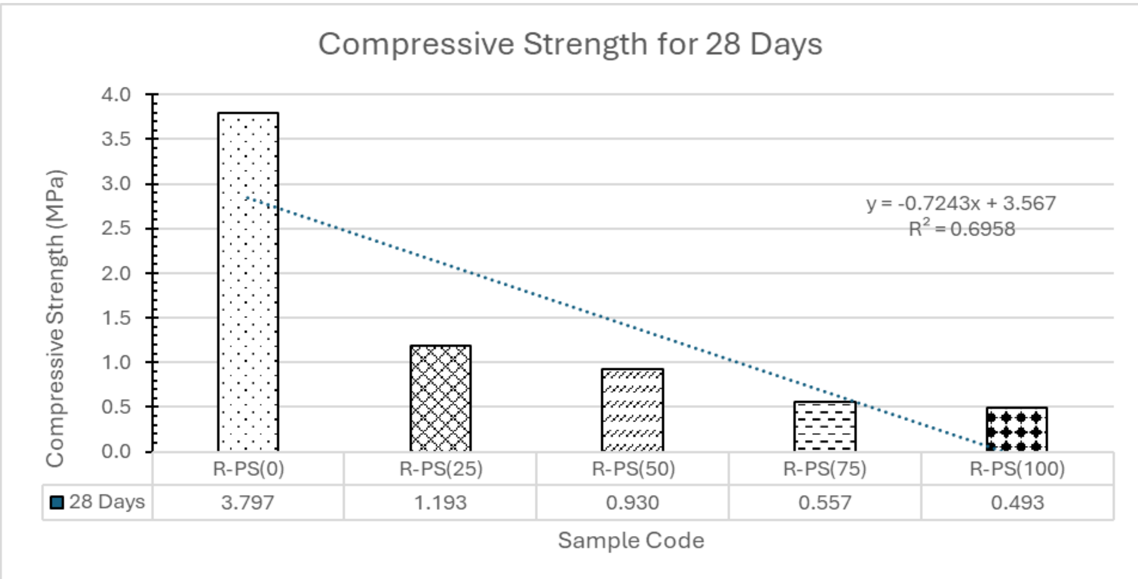


Figure 8: Compressive Strength of lightweight by-product block for 28 Days

Several factors can cause the fall in compressive strength; the reduction of density and higher water absorption are the main factors because they increase the porosity and void in the blocks [12][15][16]. The increase in these is because of the properties of RH, which are light in weight and high in water absorption. The compressive strength of lightweight by-product block is higher than EPS geofoam and Tire bales, which are 0.276 MPa and 0.815 MPa, respectively. The RH proportion of 25% and 50% pass the compressive strength for both lightweight blocks.

3.3.2 Effect of curing time on the compressive strength

Figure 9 compares samples R-PS(0) and R-PS(25) regarding the effect of curing time on compressive strength. It is observed that with the increase in curing time, the compressive strength of the block decreases in both samples. This shows that the materials are unsuitable for concrete mixtures without any adjustment. It may be that the RH sizes and shapes need to be finer to be included in the mixture [13]. Moreover, many studies use RH in ash as a pozzolanic material to replace concrete rather than as a sand replacement. No study has shown the effect of curing time when incorporating the RH content into the mixture. S. Winarno [5] and Kumar [14] conducted a study using RH as sand replacement for concrete for 28 days of curing; thus, the effect of curing time needs to be investigated. A study from [16] burns the RH before use in the concrete mixture to activate its pozzolanic properties in RH. The RH without incinerating has disadvantages in its porosity, hygroscopy and organic content [16]. It can be one of the reasons why the compressive strength is low.

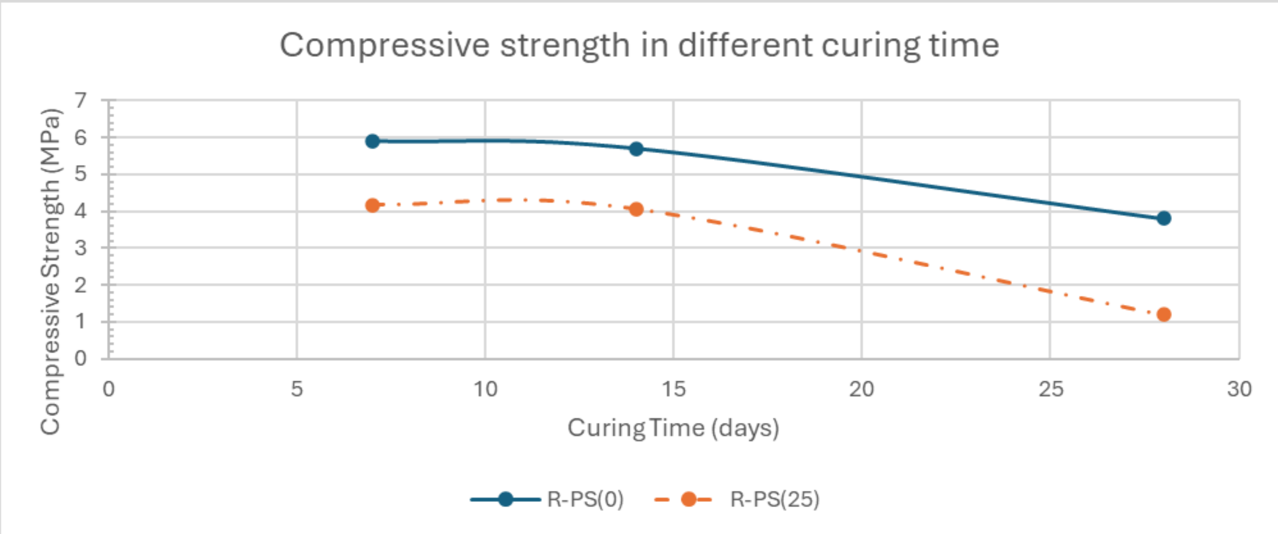


Figure 9: Effect of curing time in compressive strength for R-PS(0) and R-PS(25)

3.4 Young Modulus

Figure 10 illustrates Young's Modulus values for lightweight by-product blocks incorporating different rice husk (RH) ratios at 7, 14, and 28 days respectively. By observing the figures, Young's Modulus decreases as the RH:S proportion increases for 3 curing times. 7 days results show that the E decreased from 22.872 kg/cm2 R-PS(0) to 2.722 kg/cm2 R-PS(100). Furthermore, 22.97 kg/cm2 R-PS(0) fall to 0.815 kg/cm2 R-PS(100) for 14 days of curing time. Lastly, 28 days of curing show a decrease of about 7.596 kg/cm2 R-PS(0) to 0.887 kg/cm2 R-PS(100).

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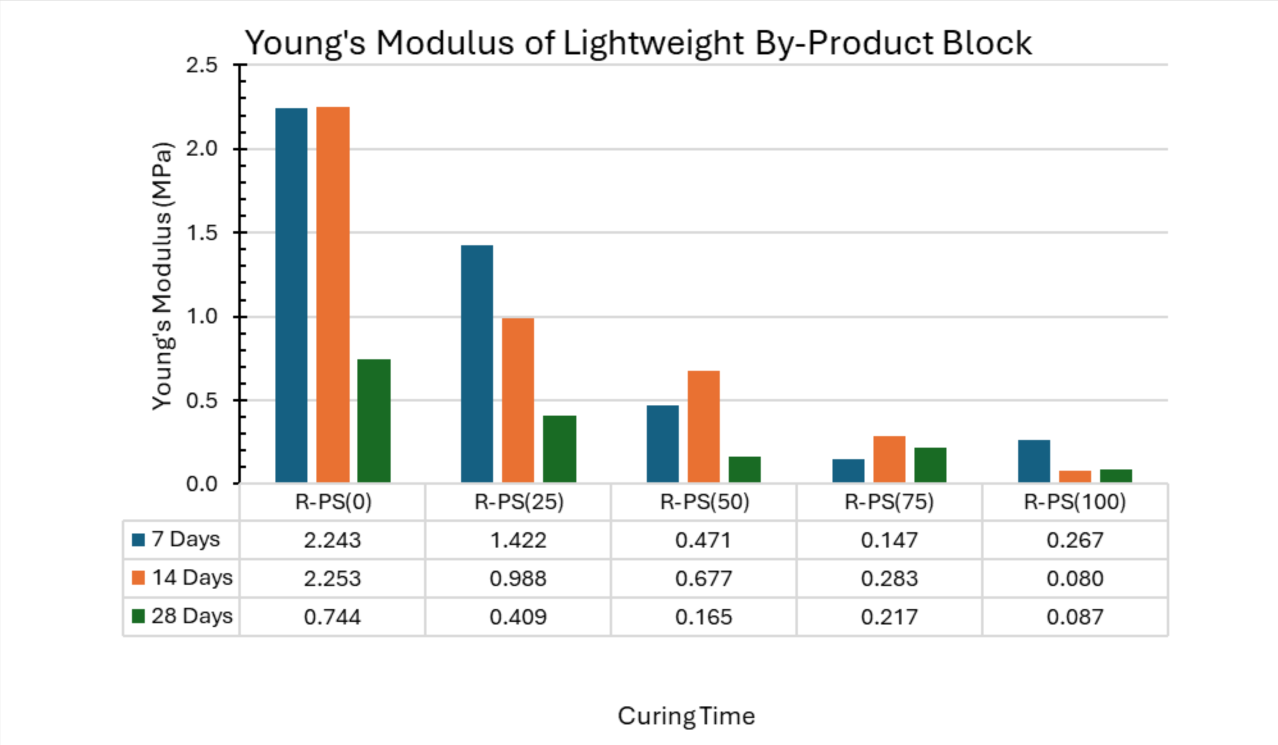

Figure 10: Young's Modulus for 7,14 and 28 Days

Young's Modulus represents the capacity of the material to resist deformation under applied load; it is important because of the application of lightweight by-product blocks in road construction over soft soil, many uneven settlements and deformation could occur on the road. The Young's modulus obtained is from 0.409Mpa to 0.087MPa, which is lower than tire bale Young's modulus value of 0.904MPa. The high in Young's modulus can withstand the uneven load that occurs on the road. Tire bales have a high Young's modulus (800-100 MPa) which good in withstand the settlement.

3.5 Relationship Density and Compressive Strength of lightweight by-product block

Figure 11 depicts the relationship between density and compressive strength in lightweight by-product blocks with varying RH content tested at 14 days. The density decreases incrementally as RH content increases from 25% to 100%. The R-PS(0) with the highest density has the highest compressive strength, while blocks with lower densities R-PS(25) to R-PS(100) have progressively decreasing compressive strengths. R-PS(0) shows the density is 1715.60 kg/m^3, and the compressive strength is 5.68 MPa, while for 100% RH content R-PS(100) was 0.29 MPa of compressive strength to 1105.6 kg/m^3 of density.

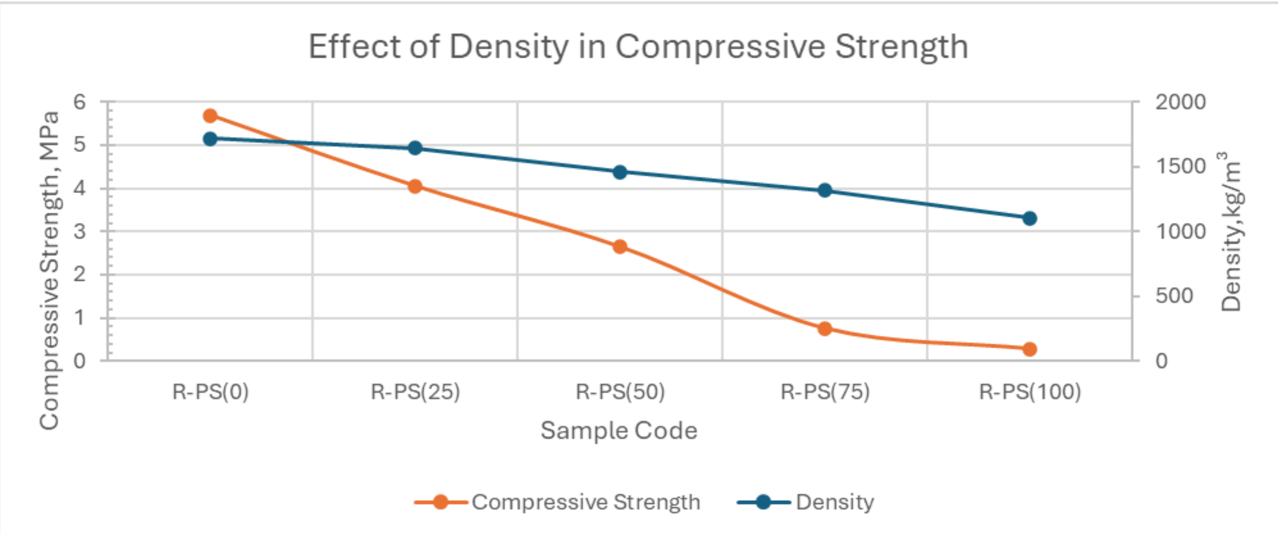

Figure 11: Relation of Density with Compressive Strength

3.6 Relationship Density and Water Absorption

Figure 12 shows the correlation between density and water absorption of lightweight by-product blocks. From the observation, the higher RH content in the mixture resulted in higher water absorption but decreased density. The water absorption and density can be observed from 1715.6 kg/cm^2 density with 21.53% water absorption R-PS(0) to a density of 1105.6 kg/cm^2 with 54.77% water absorption.

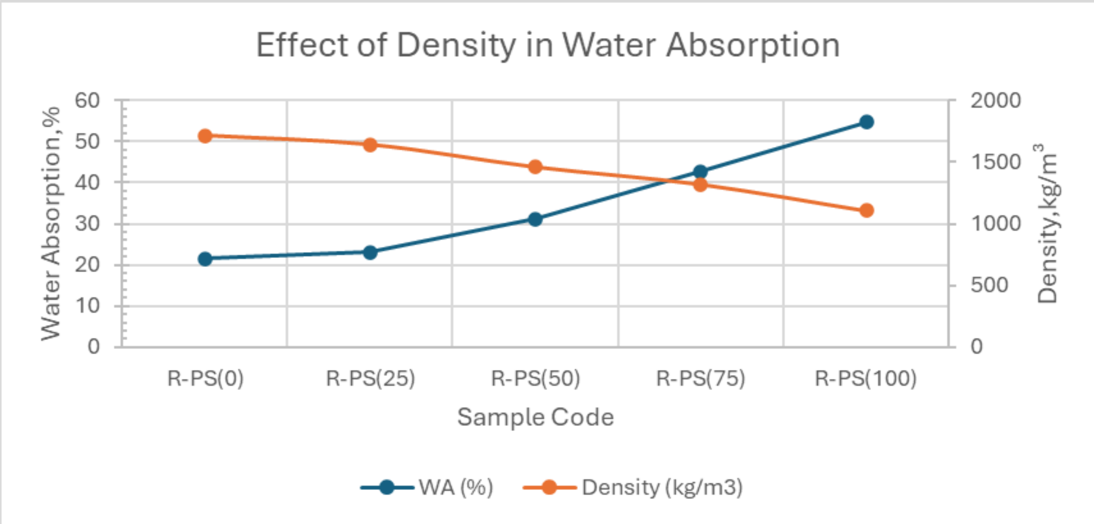

Figure 12: Relation of Density and Water Absorption

The increase in water absorption of lightweight by-product block is because of the content of RH in the lightweight by-product block, the use of RH significantly reduces the density of the block by replacing the sands which is heavier than RH. The RH properties that absorb up to 100% of water is the reason why the water absorption is high.

4. Conclusion

Using RH in lightweight by-product blocks can significantly reduce the density and increase water absorption of the blocks; however, it results in a loss of strength. The decrease in strength can be caused by the RH properties, which differ from those of conventional materials such as sand in shape and properties. This study identified that the maximum proportion of RH use is 50% before drastically reducing strength. The best ratio from the examination is 25% and 50% of the RH proportion.Overall, the study of RH shows that it is possible to use RH as lightweight material for road construction however interms of strength it low to handle the load. The product could be improve by using different ratios, adding other materials to close the pores or process the materials by burned the materials before included it into the batch.

The use of agricultural waste, such as RH and PKS, can significantly help in reducing the waste produced from dumping into landfills that can produce harmful effects on the environment. This followed the United Nations Goal 13, which is to combat climate change and its impacts, and SDG 12. Furthermore, It helps promote sustainability and uses local by-product materials to create innovative products that help construction industries in which the same as SDG 9 to build resilient infrastructure using innovative methods.

A few recommendations can be listed to help fabricate the block. RH could be soaked in the water before being added to the mixture to prevent any water loss that RH will absorb. Furthermore, the rice husk should burn before being used to enhance the silica properties in RH.

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References

[1] R. Adon, I. Bakar, D. C. Wijeyesekera, and A. Zainorabidin, "Overview of the Sustainable Uses of Peat Soil in Malaysia with Some Relevant Geotechnical Assessments," 2012.

[2] Jabatan Mineral dan Geosains Malaysia, *Garis Panduan Pemetaan Geologi Kejuruteraan Kawasan Gambut danTanih Lembut*. 2010.
[3] N. O. Mohamad *et al.*, “Challenges in Construction over Soft Soil - Case Studies in Malaysia,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Jul. 2016. doi: 10.1088/1757-899X/136/1/012002.
[4] R. Ganasan, A. J. M. S. Lim, and D. C. Wijeyesekera, “Use of Lightweight Cellular Mats to Reduce the Settlement of Structure on Soft Soil,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Jul. 2016. doi: 10.1088/1757-899X/136/1/012006.
[5] S. Winarno, “Preliminary Study on Hand-cast Lightweight Concrete Block using Raw Rice Husk as Aggregate,” in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing Ltd, Dec. 2021. doi: 10.1088/1755-1315/933/1/012005.
[6] E. C. Pachla, D. B. Silva, K. J. Stein, E. Marangon, and W. Chong, “Sustainable application of rice husk and rice straw in cellular concrete composites,” *Constr Build Mater*, vol. 283, May 2021, doi: 10.1016/j.conbuildmat.2021.122770.
[7] J. Bao *et al.*, “fermentation Underutilized Malaysian Agro-Industrial Wastes as Sustainable Carbon Sources for Lactic Acid Production,” 2023, doi: 10.3390/fermentation.
[8] A. J. Puppala, P. Ruttanaporamakul, and S. S. C. Congress, “Design and construction of lightweight EPS geofoam embedded geomaterial embankment system for control of settlements,” *Geotextiles and Geomembranes*, vol. 47, no. 3, pp. 295–305, Jun. 2019, doi: 10.1016/j.geotexmem.2019.01.015.
[9] S. N. Moghaddas Tafreshi, S. M. A. Ghotbi Siabil, and A. R. Dawson, “Expanded polystyrene geofoam,” in *New Materials in Civil Engineering*, Elsevier, 2020, pp. 117–153. doi: 10.1016/B978-0-12-818961-0.00004-1.
[10] A. Duda and T. W. Siwowski, “Stability and Settlement Analysis of a Lightweight Embankment Filled with Waste Tyre Bales over Soft Ground,” *Transportation Infrastructure Geotechnology*, vol. 9, no. 4, pp. 467–491, Aug. 2022, doi: 10.1007/s40515-021-00184-5.
[11] A. Duda and T. Siwowski, “Experimental determination of mechanical properties of waste tyre bales used for geotechnical applications,” *Materials*, vol. 14, no. 12, Jun. 2021, doi: 10.3390/ma14123310.
[12] J. Sutas, A. Mana, and L. Pitak, “Effect of rice husk and rice husk ash to properties of bricks,” in *Procedia Engineering*, Elsevier Ltd, 2012, pp. 1061–1067. doi: 10.1016/j.proeng.2012.02.055.
[13] N. Yuzer *et al.*, “Influence of raw rice husk addition on structure and properties of concrete,” *Constr Build Mater*, vol. 44, pp. 54–62, 2013, doi: 10.1016/j.conbuildmat.2013.02.070.
[14] A. Kumar Jha and P. Poudyal, “Experimental Study on the Properties of Concrete with the Partial Replacement of Sand by Rice Husk,” 2016. [Online]. Available: https://www.researchgate.net/publication/319650242
[15] S. Anggraeni, A. Bayu Dani Nandiyanto, A. Restu Pribadi, and M. Ghiyats Al-kadzim, “THE EFFECT OF RICE HUSK COMPOSITION ON POROUS CONCRETE PERFORMANCE,” 2022.
[16] A. M. Portillo-Rodríguez, “Characterization of materials formed by rice husk for construction,” in *Journal of Physics: Conference Series*, Institute of Physics Publishing, 2013. doi: 10.1088/1742-6596/466/1/012038.