Experimental study on the utilization of raw rice husks as a partial replacement of sand in the production of paver blocks

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Article Info
***Article history*:**
Received:
July 14, 2024
Revised:
June 10, 2025
Accepted:
June 11, 2025
Available online:
June 12, 2025

***Keywords*:**
Compressive strength
Water absorption
Skid resistance
Abrasion resistance

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Abstract

This study explores the potential use of raw rice husks as a partial substitute for sand in the production of paver blocks, addressing the increasing demand for concrete and the overuse of natural resources like aggregates. Rice husks, an abundant waste material in Indonesia, were incorporated into paver blocks made from Portland cement, sand, and raw rice husks. The initial mix ratio was 1 part cement to 8 parts sand, with subsequent mixes gradually replacing sand with rice husks in proportions ranging from 0.5 to 2 parts. The paver blocks were mixed, molded, and compacted, and their properties were tested for compressive strength, water absorption, skid resistance, and abrasion resistance. Five different mix variations were tested, and the production costs were analyzed. The findings revealed that increasing the rice husk content reduced compressive strength but improved water absorption, skid resistance, and abrasion resistance. Additionally, higher rice husk content resulted in lower production costs. The optimal mix, consisting of 1 part cement, 7.5 parts sand, and 0.5 parts rice husks, met all Indonesian standards and demonstrated the best performance. Further research is recommended to assess freeze-thaw resistance and enhance the cost-effectiveness and quality of paver production.

Introduction

Concrete is one of the mostly used manmade materials as it plays a crucial role in the construction of buildings which are an essential need for human being (Yuzer et al., 2013). Concrete is a mixture of cement, aggregates and water (Lawal et al., 2019). There has been a huge demand for concrete in the past years due to the rapid development that is happening across different parts of the world which has led to the over exploitation of natural resources such as aggregates (Chabannes et al., 2014). This leads to a need to innovate new technologies that ensure sustainable production of concrete without imposing a huge burden on the existing few natural resources available as this helps in the conservation of the environment (Rahman et al., 2014).

Previous researches have utilized agricultural and industrial wastes that are one of the major causes of waste management and pollution problems in order to incorporate the wastes in the production of concrete. These wastes can act as a concrete aggregate substitution for some of the conventional materials in which this substitution is one of the solutions to counteract the scarce over exploited natural resources as well as cost reduction (Sisman et al., 2014). Various agricultural wastes have been used in these matters, such as sugarcane bagasse, groundnut husks, hemp, rice corn husks and others (Son et al., 2017).

Rice husk is abundant in Indonesia since rice is the mostly consumed food in Indonesia hence leading to huge numbers of rice plantations in the country where in 2022 the country produced over 54 million tons of rice (Statistik, 2023). Rice husks form the biggest proportion of agricultural waste products that are obtained during the husking process of rice hence becoming an agricultural waste where each manufacturing of 1000 kg of rice generates 220 kg (22 %) of rice husks as waste (Arpit-Chawda, 2018). Over 500 million tons of paddy are produced every year around the world and 22% of these tons are rice husks which exhibits the availability of the material to be utilized other than being wasted (Winarno, 2021). Rice husks are usually dumped or burnt leading to environmental degradation (Rahman et al., 2014).

Various researches have been made for the utilization of rice husks in concrete but have been mainly focusing on its usage as rice husk ash in cement replacement. Production of rice husk ash requires the rice husks to undergo husks a controlled burning process which is very complex as well as leads to production of gases that pollute the atmosphere (Yuzer et al., 2013). Instead of rice husk ash, the availability of rice husks provides opportunity to the usage of raw rice husks as aggregate replacements in the production of several concrete products such as paver blocks. Paver blocks are one of the materials made from concrete that are some of the products usually used in construction of roads, parking yards as well as compounds and have exhibited good strength and durability qualities for the past years of their usage (Ahmad et al., 2022).

According to previous research, there is proof that raw rice husks can be used as aggregate replacements in concrete and concrete blocks. There is no research yet that uses raw rice husks as aggregate replacements in pavers. Therefore, it is urgent to conduct an experimental study in relation to the utilization of rice husks for paver block production.

The purpose of this research is to study the utilization of raw rice husks as partial replacement of sand in the production of paver blocks as well as determining their mechanical properties such as compressive strength, water absorption, skid resistance, and abrasion resistance coupled with the cost efficiency of the production of these paver blocks.

Method

The rice husks were obtained from a rice farmer in Sleman Region, Yogyakarta, Indonesia. The paver production was carried out at the Innovation Centre of Universitas Islam Indonesia, Yogyakarta. The paver block ingredients included ordinary Portland cement, sand and raw rice husks as a partial replacement of sand.

Five variations of pavers were produced in which the mix proportion was in a volumetric ratio of 1 cement constant, 8 sand which kept on varying with partial replacement of raw rice husks in proportions of 0.5, 1.0, 1.5, 2.0 of the volume of the batch box. The paver blocks were produced by a machine after which were laid in a curing place to set and harden. Tests carried out on the paver blocks were compressive strength, water absorption, skid resistance, and abrasion resistance.

Paver blocks

Paver blocks are categorized as one of the concrete masonry products used in the construction of roads and parking yards.The common ingredients of paver blocks are a blend of Portland cement, sand, and water. Portland cement is a bonding agent when mixed with water produces a cementing paste through a chemical reaction or hydration.the cement paste further fills the voids inside concrete as well as converting the mixture of concrete ingredients into plastic and workable form.Hardened concrete gains strength with time and testing this hardened concrete for quality is vital for structures.

Water liable for drinking is the most suitable to mix the concrete and its amount for mixing depends on the types and mix ratio of cement aggregate, expected strength and the method of production. The amount of water should be sufficient enough to facilitate production without imparing shape or slumping of blocks after demolding.

The production of paver blocks consists of three basic stages; mixing,molding and curing.The paver block is 20cm long,10cm wide and 6cm high.The pavers are produced by a hydraulic press machine.

Raw rice husk

Raw rice husk are the hard protecting coverings of rice.Rice being the staple food in Indonesia is grown by many farmers thus the rice husks are easily collected everywhere and cheaply. These rice husks are oftenly dumped or burned hence the need to utillise these rice husks to avoid environmental degradation.

Rice husk is formed from hard materials including silica, lignin and it is resistant to natural decomposition. Based on its physical properties, raw rice husk is in loose form that can replace sand for paver block production.

Rice husk has 2 to 4 mm in width, its length is roughly 10 mm and it is distributed homogenously. Due to its homogenous size, the use of raw rice husks in a concrete mixture can initiate a uniform distribution of air voids within hardened concrete sample thoroughly.

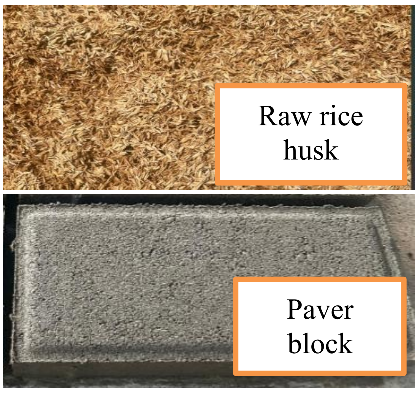

Figure 1. Raw rice husks and paver block

Results

Calculation of mixture requirements as well as variation of each paver
The materials used included cement, sand and rice husks. The mix proportion by volume was used which involved the use of a batch box which was a bucket to determine the required quantities of materials. The cement to sand ratio used was obtained from a predetermined mix ratio of 1:8 with varying percentage replacement of sand with rice husks as shown in Table 1.

Table 1. Material proportion

ID	Mix Proportion	Cement (kg)	Sand (kg)	Rice Husks (kg)
P0	0.5:4:0	7,62	81,56	0
P1	0.5:3.75:0.25	7,62	76,46	0.61
P2	0.5:3.5:0.5	7,62	71,37	1.22
P3	0.5:3.25:0.75	7,62	66,27	1.83
P4	0.5:3:1	7,62	61.17	2.44
	Total	38,1	356.83	6.1

Compressive Strength test

The test was carried out after 28 days of curing out at Universitas Islam Indonesia Construction Materials Technology Laboratory. Ten samples were picked from each of the 5 paver variations leading to 50 samples that were tested for compressive strength. The average compressive strength is calculated from each of the variations as this will determine the quality of the pavers in reference to SNI-03-0961-1996 paver blocks. This is illustrated in Table 2 below.

Table 2 Classification of paver block quality based on compressive strength

ID	Compressive strength (MPa)	Paver Block Quality	Paver Block Function	Results
P0	14.05	C	Pedestrian	Accepted
P1	12.75	C	Pedestrian	Accepted
P2	9.80	D	Park	Accepted
P3	8.61	D	Park	Accepted
P4	7.42	N/A	N/A	Not Accepted

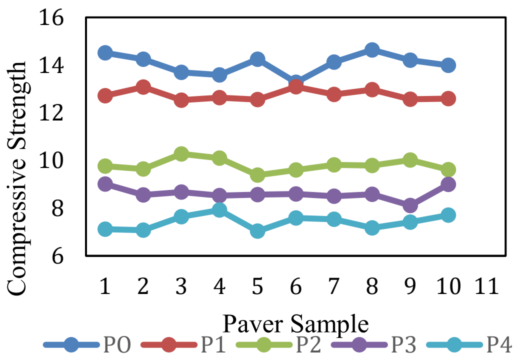

Figure 2. Compressive strength results graph

The compressive strength of the paver blocks decreased with an increase in the rice husks replacement with sand. This is attributed to the fact that rice husks make the pavers hollow thus the higher the rice husks in the paver block the lower the compressive strength of the pavers because the pavers are not well bonded as the cement paste does not fully fill the pavers very well. The partial replacement of sand with rice husks in P1 pavers had a slight impact on the overall compressive strength of the paver blocks hence yielding the best results as it was in the same class of paver quality C as per SNI-03-0961-1996 as the control pavers P0 which had no rice husks. This makes it the most efficient partial replacement proportion of sand with rice husks compared to other paver samples that had partial replacements of sand with rice husks.

Water Absorption test for paver blocks

10 samples were picked from each of the 5 paver variations leading to 50 samples that were tested for water absorption and the results are presented in Table 3.

Table 3. Classification of paver block quality based on water absorption

ID	Water absorption (%)	Paver block quality	Paver block function	Results
P0	7.67	C	Pedestrian	Accepted
P1	8.26	C	Pedestrian	Accepted
P2	10.24	D	Park	Accepted
P3	12.35	N/A	N/A	Not Accepted
P4	14.38	N/A	N/A	Not Accepted

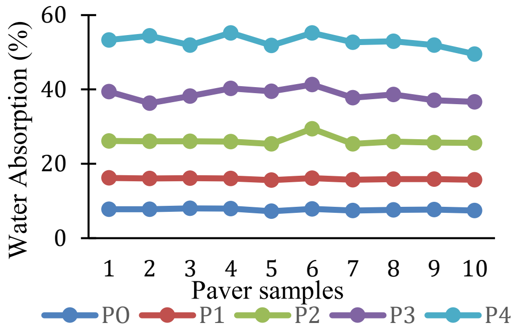

Figure 3. Water absorption results

The higher the amount of rice husks in the pavers, the higher the value of water absorption. This is attributed to the fact that the addition of rice husks in the pavers creates voids which paves way for more water to be absorbed by the pavers thus increasing the amount of water absorption. The partial replacement of sand with rice husks in P1 pavers had a slight impact on the overall water absorption of the paver blocks hence yielding the best results as it was in the same class of paver quality as per SNI-03-0961-1996 as the control pavers P0 which had no rice husks. This makes it the most efficient partial replacement proportion of sand with rice husks compared to other paver samples that had partial replacements of sand with rice husks.

Skid Resistance test for paver blocks

The skid resistance test was carried out at Universitas Islam Indonesia Transport laboratory. 3 samples were picked from each of the 5 paver variations leading to 15 samples that were tested for skid resistance.

Table 4. Classification of paver block quality based on skid resistance

ID	Skid resistance	Minimum skid resistance	Paver block function	Results
P0	69.33	65	Difficult sites such as	Accepted
P1	67.13	65	round about	Accepted
P2	68.53	65	bends with radius less than 150 m on unrestricted roads	Accepted
P3	81.60	65	Gradients, 1 in 20 or steeper, of lengths >100m	Accepted
P4	85.33	65	Approaches to traffic lights on unrestricted roads	Accepted

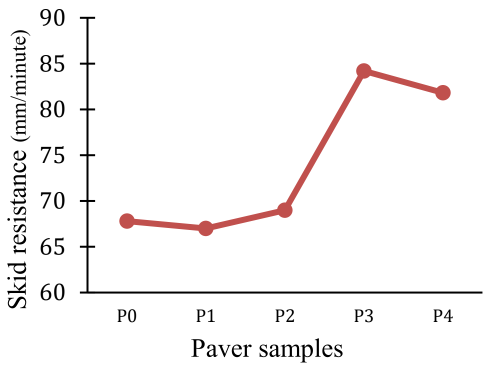

Figure 4. Skid resistance of wet pavers results

All the paver blocks met the standards of skid resistance for paver blocks. The higher the amount of rice husks in the paver blocks, the higher the value of skid resistance and the lower the amount of rice husks in the paver blocks, the lower the value of skid resistance. This is attributed to the fact that rice husks have a natural rough texture which makes the surface of the pavers rougher leading to a high skid resistance value.

Abrasion resistance test for pavers

The test was carried out using an abrasion resistance testing machine at Universitas Islam Indonesia Construction Materials Technology laboratory. Ten samples of paver blocks were selected for each mix proportion hence 50 samples were tested.

Table 5. Classification of paver block quality based on abrasion resistance

ID	Abrasion resistance (mm/minute)	Paver block quality	Paver block function	Results
P0	0.163	C	Pedestrian	Accepted
P1	0.239	D	Garden	Accepted
P2	0.424	N/A	N/A	Not Accepted
P3	0.644	N/A	N/A	Not Accepted
P4	0.867	N/A	N/A	Not Accepted

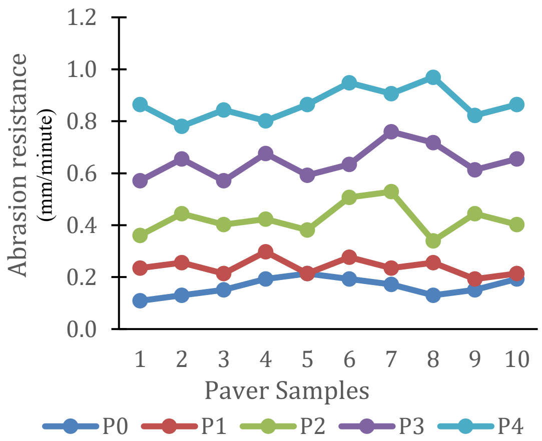

Figure 5. Abrasion resistance results

The higher the value of abrasion resistance, the lower the quality of the paver blocks as they are fragile and prone to damage while the lower the value of abrasion resistance, the higher the quality of the paver blocks as they are strong and resistant to damage. The higher the amount of rice husks, the higher value of abrasion resistance thus the lower the quality of the paver blocks. This is attributed to the fact that rice husks create voids and weak bonds of the aggregates in the pavers which makes the pavers weak and easily damaged once subjected to a given load. The partial replacement of sand with rice husks in P1pavers had a slight impact on the overall abrasion resistance of the paver blocks hence yielding the best results as they met the minimum standards of paver quality as per SNI-03-0961-1996. This makes it the most efficient partial replacement proportion of sand with rice husks compared to other paver samples that had partial replacements of sand with raw rice husks.

Calculation of the cost of production for the paver blocks

The cost of production for the pavers was estimated through carrying out interviews with the workers at Pusat Innovasi Universitas Islam Indonesia to determine the prices of the tools, materials, wages of workers and other items related to costs. The cost of production of each paver sample is shown in Table 6.

The higher the amount of rice husks in the pavers, the lower the cost of production of the pavers hence integration of rice husks in the production of pavers lowers the cost of production. After carrying out a survey in Sleman area, Yogyakarta obtained the price range of pavers was between Rp. 1,500 – Rp 2,500 depending on the quality of the pavers which indicates that the rice husk paver blocks are within the price ranges of the paver blocks thus being feasible to produce.

Discussion

After analysis of the data on the several tests carried out on the paver blocks, it was observed that some paver blocks were able to meet the minimum standards for paver blocks in reference to SNI – 03 – 0961 - 1996 paver blocks while other paver blocks failed to meet the minimum standards for paver blocks. For compressive strength test, pavers P0 and P1 met the standards for quality C, pavers P2 and P3 met the standards for quality D, Pavers P4 did not meet the minimum standards of compressive strength for paver blocks. Some pavers did not meet the minimum standards of compressive strength because raw rice husks are convex in shape which affects their bonding with the aggregates leading to weak bonds and low strength pavers.

For the water absorption test, pavers P0 and P1 met the standards for quality C, pavers P2 met the standards for quality D, Pavers P3 and P4 did not meet the minimum standards of water absorption for paver blocks. Some pavers did not meet the minimum standards of water absorption given the convex shape of the raw rice husks that create pores within the pavers which increases the water absorption rate of the pavers.

For the skid resistance test, all paver samples were able to meet the minimum standards. For the abrasion resistance test, paver P0 met the standards for quality C, paver P1 met the standards for quality D, paver P2, P3 and P4 failed to meet the minimum standards of abrasion resistance. Most of the pavers failed to meet the minimum standards of abrasion resistance because raw rice husks create voids and weak bonds of the aggregates in the pavers which makes the pavers fragile and easily damaged once subjected to a given load. For the cost of production, all the paver samples were within the range of production costs as other pavers. The integration of raw rice husks lowered the cost of production.

Table 6. Paver cost of production

ID	Mix proportion	Cost of production (Rp)
P1	0.5:3.75:0.25	1,341.95 /paver
P2	0.5:3.5:0.5	1,327.21 /paver
P3	0.5:3.25:0.75	1,312.44 /paver
P4	0.5:3:1	1,297.66 /paver

Conclusion

Pavers P0, P1, P2, and P3 met the standards of compressive strength for quality paver blocks while P4 pavers did not meet the standards of compressive strength for quality paver blocks because raw rice husks affect the bonding of the aggregates. Paver P1 had the same standard quality C as the control pavers P0 which made it the most efficient partial replacement proportion of sand with rice husks compared to other paver samples that had partial replacements of sand with rice husks.

Pavers P0, P1 and P2 met the standards of water absorption for quality paver blocks while P3 and P4 pavers did not meet the standards of water absorption for quality paver blocks because raw rice husks create voids within the pavers leading to higher water absorption rates. Paver P1 had the same standard quality C as the control pavers P0 which made it the most efficient partial replacement proportion of sand with rice husks compared to other pavers. samples that had partial replacements of sand with rice husks.

All the paver blocks met the standards of skid resistance for paver blocks. Pavers P0 and P1 met the standards of abrasion resistance for quality paver blocks while P2, P3 and P4 pavers did not meet the standards of abrasion resistance for quality paver blocks because raw rice husks create weak bonds that make the pavers fragile and easily damaged. Paver P1 met the standards which made it the most efficient partial replacement proportion of sand with rice husks compared to other paver samples that had partial replacements of sand with rice husks.

The higher the amount of rice husks in the pavers, the lower the cost of production of the pavers hence integration of rice husks in the production of pavers lowers the cost of production. The price of the rice husk paver blocks was within the price range of the paver blocks manufactured around Sleman thus being feasible to produce.

References

Aguinis, H., Ramani, R. S., & Alabduljader, N. (2023). Best-Practice Recommendations for Producers, Evaluators, and Users of Methodological Literature Reviews. Organizational Research Methods, 26(1). https://doi.org/10.1177/1094428120943281

Agyeman, S., Obeng-Ahenkora, N. K., Assiamah, S., & Twumasi, G. (2019). Exploiting recycled plastic waste as an alternative binder for paving blocks production. Case Studies in Construction Materials, 11(2019), e00246. https://doi.org/10.1016/j.cscm.2019.e00246

Ahmad, S., Dawood, O., Lashin, M. M. A., Khattak, S. U., Javed, M. F., Aslam, F., Khan, M. I., Elkotb, M. A., & Alaboud, T. M. (2022). Effect of coconut fiber on low-density polyethylene plastic-sand paver blocks. Ain Shams Engineering Journal. https://doi.org/10.1016/j.asej.2022.101982

Belhajjame, K., Zhao, J., Garijo, D., Gamble, M., Hettne, K., Palma, R., Mina, E., Corcho, O., Gómez-Pérez, J. M., Bechhofer, S., Klyne, G., & Goble, C. (2015). Using a suite of ontologies for preserving workflow-centric research objects. Journal of Web Semantics, 32. https://doi.org/10.1016/j.websem.2015.01.003

Bohn, B. P., Von Mühlen, C., Pedrotti, M. F., & Zimmer, A. (2021). A novel method to produce a ceramic paver recycling waste glass. Cleaner Engineering and Technology, 2(January). https://doi.org/10.1016/j.clet.2021.100043

Breslin, D., & Gatrell, C. (2023). Theorizing Through Literature Reviews: The Miner-Prospector Continuum. Organizational Research Methods, 26(1). https://doi.org/10.1177/1094428120943288

Chabannes, M., Bénézet, J. C., Clerc, L., & Garcia-Diaz, E. (2014). Use of raw rice husk as natural aggregate in a lightweight insulating concrete: An innovative application. Construction and Building Materials, 70, 428–438. https://doi.org/10.1016/j.conbuildmat.2014.07.025

Chabannes, M., Garcia-Diaz, E., Clerc, L., & Bénézet, J. C. (2016). Effect of curing conditions and Ca(OH)2-treated aggregates on mechanical properties of rice husk and hemp concretes using a lime-based binder. Construction and Building Materials, 102, 821–833. https://doi.org/10.1016/j.conbuildmat.2015.10.206

Chawda, A., & Ansari, S. (2018). Substitution of Base Materials Rice Husk of Concrete. Journal of Innovative Engineering and Research, 1(1), 25–27.

Gungat, L., Anthony, F., Mirasa, A. K., Asrah, H., Bolong, N., Ispal, N. A., & Matlan, S. J. (2021). Development of Paver Block Containing Recycled Plastic. IOP Conference Series: Materials Science and Engineering, 1144(1), 012094. https://doi.org/10.1088/1757-899x/1144/1/012094

Lawal, A. Q. T., Ninsiima, E., Odebiyi, O. S., Hassan, A. S., Oyagbola, I. A., Onu, P., Yusuf, D. A., & Japyem, E. (2019). Effect of unburnt rice husk on the properties of concrete. Procedia Manufacturing, 35, 635–640. https://doi.org/10.1016/j.promfg.2019.06.006

Patel, A. J., Patel, D. V. M., & Patel, D. M. A. (2019). Review on Partial Replacement of Cement in Concrete. International Research Journal of Multidisciplinary Technovation, November.

Rahman, M. E., Muntohar, A. S., Pakrashi, V., Nagaratnam, B. H., & Sujan, D. (2014). Self compacting concrete from uncontrolled burning of rice husk and blended fine aggregate. Materials and Design, 55, 410–415. https://doi.org/10.1016/j.matdes.2013.10.007

Sastrawidana, D. K., Sukarta, I. N., Saraswati, L. P. A., Maryam, S., & Putra, G. A. (2022). Plastic waste reinforced with inorganic pigment from red stone in manufacturing paving block for pedestrian application. Journal of Achievements in Materials and Manufacturing Engineering, 110(2), 49–58. https://doi.org/10.5604/01.3001.0015.7042

Setiawan, A. A., Philip, F. J., Permanasari, E., & Resdiansyah. (2019). Skid resistance and micro-structure of concrete containing waste plastic fiber for rigid pavement. Journal of Applied Science and Engineering, 22(4), 597–606. https://doi.org/10.6180/jase.201912_22(4).0001

Sisman, C. B., Gezer, E., & Comert Kurc, H. (2014). Effects of Rice Husk on the Lightweight Concrete Properties Produced by Natural Zeolite for Agricultural Buildings. In Asian Journal of Applied Sciences. www.ajouronline.com

Son, N. K., Toan, N. P. A., Dung, T. T. T., & Huynh, N. N. T. (2017). Investigation of Agro-concrete using by-products of Rice Husk in Mekong Delta of Vietnam. Procedia Engineering, 171, 725–733. https://doi.org/10.1016/j.proeng.2017.01.421

Statistik, B. P. (2023). Badan Pustaka Statistik. www.freepik.com

Tamanna, N., Tuladhar, R., & Sivakugan, N. (2020). Performance of recycled waste glass sand as partial replacement of sand in concrete. Construction and Building Materials, 239. https://doi.org/10.1016/j.conbuildmat.2019.117804

Ugheoke, I. B., & Mamat, O. (2012). A critical assessment and new research directions of rice husk silica processing methods and properties. Maejo International Journal of Science and Technology, 6(3), 430–448. https://doi.org/10.14456/mijst.2012.31

Velumani, P., & Senthilkumar, S. (2018). Production of sludge-incorporated paver blocks for efficient waste management. Journal of the Air and Waste Management Association, 68(6), 626–636. https://doi.org/10.1080/10962247.2017.1395373

Watson, R. (2015). Quantitative research. Nursing Standard (Royal College of Nursing (Great Britain) : 1987), 29(31). https://doi.org/10.7748/ns.29.31.44.e8681

White, M. G. (2020). Why human subjects research protection is important. Ochsner Journal, 20(1). https://doi.org/10.31486/toj.20.5012

Winarno, S. (2021). Preliminary Study on Hand-cast Lightweight Concrete Block using Raw Rice Husk as Aggregate. IOP Conference Series: Earth and Environmental Science, 933(1). https://doi.org/10.1088/1755-1315/933/1/012005

Yuzer, N., Cinar, Z., Akoz, F., Biricik, H., Gurkan, Y. Y., Kabay, N., & Kizilkanat, A. B. (2013). Influence of raw rice husk addition on structure and properties of concrete. Construction and Building Materials, 44, 54–62. https://doi.org/10.1016/j.conbuildmat.2013.02.070