AN EXPERIMENTAL STUDY ON THE PERFORMANCE OF PAVER BLOCKS CONTAINING ARECANU SHEATH ASH

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Abstract

The construction industry faces increasing pressure to adopt sustainable practices to mitigate environmental impact. Ordinary Portland Cement (OPC), renowned for its high compression strength, is widely used, leading to heightened demand and environmental concerns. This study investigates the potential of utilizing waste material from arecanut sheath as ash, partially replacing cement in paver blocks. Chemical composition and physical properties of the ash are compared with cement. Various mix proportions substituting ash at 0%, 5%, 15%, and 25% are tested for compressive strength, flexural strength, tensile strength, water absorption, and efflorescence at 7, 14, and 28 days of curing. Results demonstrate that paver blocks containing 25% arecanut sheath ash exhibit superior mechanical properties and durability, suggesting the effectiveness of ash as a cement substitute to improve paver block performance while reducing cement demand.

Key words - Cement, Arecanut sheath ash, Paver block

1.INTRODUCTION

Paver blocks are a popular and versatile option for paving roads, sidewalks, driveways and patios. Traditionally, the manufacturing process of paver blocks involves the use of cement as a primary binding material. However, with growing environmental concerns and the construction industry's push towards sustainable practices, there is an increasing interest in replacing cement with more eco-friendly alternatives. One such alternative that has gained attention is the use of ash in the place of cement. The use of ash in paver blocks not only helps in reducing the environmental footprint associated with cement production but also addresses the issue of waste management. Cement production is energy-intensive and releases a significant amount of carbon dioxide, a greenhouse gas, into the atmosphere. On the other hand, arecanut sheath ash is a waste product from Areca leaf plate manufacturing industries and can be used without the need for additional resources or processes that harm the environment. Incorporating arecanut sheath ash into the manufacturing process of paver blocks can improve the properties of the blocks. This can lead to the production of blocks with enhanced mechanical and durability properties, such as increased compressive strength, flexural strength, tensile strength and reduced water absorption. Moreover, the fine particle size of arecanut sheath ash contributes to a denser matrix, offering a smoother finish to the paver blocks. However, replacing cement with arecanut sheath ash partially in the production of paver blocks requires careful consideration of the mix design. Furthermore, the adoption of arecanut sheath ash in paver block manufacturing also depends on regulatory acceptance and market readiness to embrace alternative materials.

The incorporation of alternative materials in the manufacture of concrete has garnered considerable interest in recent times, primarily driven by the urgent demand for sustainable construction methodologies. Numerous scholarly investigations have been conducted to explore the feasibility of integrating diverse waste materials as partial substitutes for traditional cement in concrete compositions. This literature review presents a comprehensive summary of significant findings derived from pertinent research investigations that center on the application of alternative materials, with a specific emphasis on Arecanut Sheath Ash (ASA), in the manufacturing of concrete.

2. LITERATURE SURVEY

The study conducted by Al-Rawas and Goosen (2005) investigated the potential application of date palm ash as a substitute for cement in concrete. Their research showed that date palm ash can improve concrete qualities and decrease the need for cement, indicating its potential as an eco-friendly substitute. In their study, Mehta and Siddique (2017) undertook a comprehensive examination of the utilization of Arecanut Husk Ash (AHA) as an adjunct cementitious substance in concrete. According to their review, AHA has the potential to enhance the performance of concrete and promote sustainability by decreasing the carbon emissions linked to cement manufacturing.

Drawing upon the aforementioned research, Datta and Roy (2018) conducted an investigation on the application of areca husk ash as a partial substitute for cement in the composition of concrete. Their research shown that the use of areca husk ash resulted in enhancements in the strength and longevity of concrete, highlighting its potential as an environmentally friendly remedy in the field of building. In a similar vein, Hassan et al. (2019) investigated the utilization of arecanut sheath ash as a partial substitute for cement in the manufacturing of concrete. Their study showcased the efficacy of arecanut sheath ash in improving the characteristics of concrete, thereby decreasing the need for cement and mitigating environmental consequences.

The study conducted by Vijay and Reddy (2020) centered on examining the impact of incorporating areca nut ash as a partial substitute for cement on the mechanical characteristics of concrete. The research conducted by the authors emphasized the beneficial impacts of integrating areca nut ash into concrete mixtures, resulting in enhanced compressive strength and endurance. In addition, an experimental investigation was carried out by Suresh et al. (2020) to examine the strength characteristics of geopolymer concrete including arecanut sheath ash. Their study showcased the capacity of geopolymer concrete made from arecanut sheath ash as a viable and environmentally friendly substitute for traditional concrete.

The utilization of arecanut sheath ash as a partial substitute for cement in concrete has been further examined in recent research conducted by Aswathy and Jayasree (2021) and Prabhu and Narayana (2021). Both experiments have shown confirmation of the advantageous impacts associated with the inclusion of arecanut sheath ash in concrete mixtures, resulting in enhanced mechanical characteristics and increased longevity. In their study, Saha and Das (2022) investigated the use of areca nut husk ash as a substitute for cement in concrete, emphasizing its capacity to improve sustainability in construction methods.

Kumar and Shukla (2022) conducted a study to investigate the impact of incorporating arecanut husk ash as a partial substitute for cement in concrete. According to their study, the addition of arecanut husk ash to concrete resulted in improved compressive strength, flexural strength, and durability, hence promoting sustainability in the building industry.

In summary, the literature study shows that alternative materials, specifically Arecanut Sheath Ash, have the potential to be sustainable substitutes for traditional cement in the manufacturing of concrete. These research offer vital insights into the efficacy of integrating alternative materials to improve the properties of concrete while simultaneously mitigating environmental consequences, hence facilitating the adoption of more sustainable construction methodologies.

3. MATERIALS

3.1 Cement

Cement is an important ingredient which acts as a binding agent in the production of paver blocks. Ordinary Portland Cement (OPC) is the most commonly used cement due to its durability and strength. When OPC is used in paver blocks, it provides the necessary binding properties that hold the aggregate materials together creating a solid and stable surface.

3.2 Arecanut Sheath Ash

Arecanut sheath ash is derived from the uncontrollable burning of sheath of arecanut palm and is sieved in the sieve of 600 microns. Due to its high silica content, it exhibits pozzolanic properties which can be partially replaced for cement. When it is mixed with cement it enhances the hydration process which leads to strength and durability of paver block.

3.3 Fine Aggregate

Fine Aggregates used in the paver blocks are composed of sand with particle size not greater than 4.75 mm. These fine aggregates fill the voids between coarse aggregates and bind together with cement paste to form a cohesive mixture. They contribute to the smooth surface finish of the paver blocks and help to achieve tight interlock between units, improving overall stability and load distribution.

3.4 Coarse Aggregate

Crushed stone or gravel with particle sizes ranging from 6 mm to 10 mm are the coarse aggregates utilized in paver blocks. The aggregates play a crucial role in enhancing the load-bearing capacity and longevity of the paver blocks by providing structural support and stability. Table 1(a) and 1(b) depicted the properties all materials utilized in this study.

Table 1(a) Physical Properties of cementitious materials

Material	Consistency test	Initial setting time	Final setting time
Cement	25%	45 mins	356 mins
Arecanut Sheath Ash	27%	67 mins	390 mins

Table 1(b) Physical Properties of aggregates

Material	Specific gravity	Bulk density (kg/m³)	Fineness modulus
Coarse aggregate	2.37	1514	
Fine aggregate	2.46		

4. MIX DESIGN AND METHODOLOGY

The preparation of the M30 grade concrete mix utilizing Arecanut Sheath Ash (ASA) as a partial substitute for cement will adhere to the guidelines outlined in the Indian Standard (IS) standards. The mix proportions will be calculated according to the intended replacement percentages of ASA, which will range from 0% to 25% in increments of 5%. In order to uphold the desired strength of M30 grade concrete, the cement content shall be appropriately modified in accordance with the specifications given in IS 10262:2019. Consistency and uniformity in the concrete mix will be ensured by calculating the mix proportions for each replacement %. The proposed methodology entails the dry mixing of cement, ASA, fine aggregate, and coarse aggregate within a concrete mixer, following the guidelines outlined in IS 456:2000. The addition of water will be done gradually in order to attain the desired consistency, while also guaranteeing adherence to the water-cement ratio indicated in IS 456:2000. Following a comprehensive mixing process, the concrete mixture will be poured into molds designed for paver block specimens, in accordance with the dimensions prescribed in IS 15658:2006.

5. TESTING OF SPECIMENS

5.1 Compressive Strength Test

The compressive strength test of paver blocks is a crucial assessment to determine their ability to withstand loads without failure. This test is essential for ensuring the durability and safety of pavements made from these blocks. The paver block is placed in the compression testing machine. The size of paver block is used as 200mmx200mmx75 mm in size. The orientation of the block should be such that the load is applied to the face as it would be in actual use (usually the top surface as laid in pavements). The load is applied gradually at a uniform rate (usually specified by the relevant standard, such as ASTM, IS, or EN). The rate can vary but is often in the range of 0.5 MPa/s to 2.0 MPa/s. The compressive strength is calculated by dividing the maximum load by the surface area of the paver block. The unit of measure is typically MegaPascals (MPa) or pounds per square inch (psi).

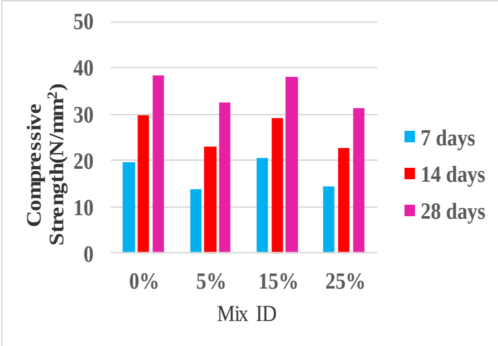

Fig.1 Test findings on compressive strength

5.2 Flexural Strength Test

The flexural strength test of paver blocks, also known as the modulus of rupture test, measures the ability of a paver block to resist deformation under load. This test is crucial for assessing the tensile strength of the block along its weakest plane, which is vital for understanding how it will perform when subjected to bending forces in real-world applications, such as pedestrian or vehicular traffic. Place the paver block on the machine so that it spans horizontally between two supports. The distance between the supports (span length) is crucial and is defined by the testing standard or protocol. A load is applied at a uniform rate at the midpoint of the block (for a simple beam test) or at two points equidistant from the supports and the center (for a third-point loading test). The rate of loading should be consistent with the relevant standards. Increase the load gradually until the paver block fails by cracking. Record the maximum load at the point of failure. The flexural strength (modulus of rupture) is calculated using the formula that corresponds to the loading configuration (simple beam or third-point). The formula is:

Flexural Strength = $3PL/2BD^2$

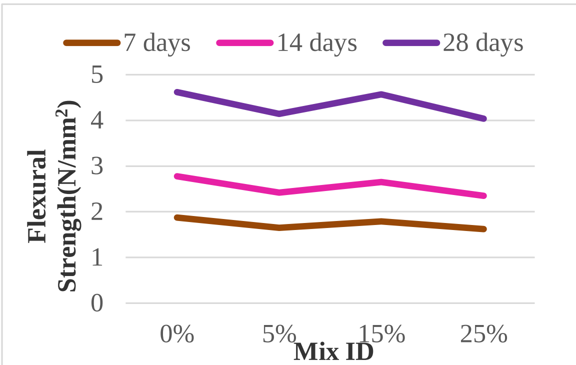

Fig 2 Test findings on flexural strength

5.3 Split Tensile Strength Test

The split tensile strength test of paver blocks, also known as the splitting tensile strength test, is a method to determine the tensile strength of the paver. Unlike concrete, which is strong in compression but weak in tension, this test provides insight into how well a paver block can perform under tensile stress. It's particularly useful because it's a more straightforward and less expensive method compared to direct tension tests.

The split tensile strength is calculated using the formula:

split tensile strength = 2P/ЛLD

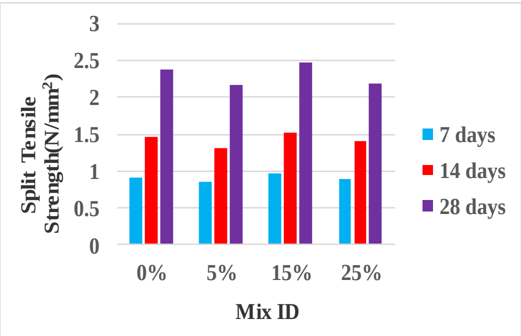

Fig 3 Test findings on split tensile strength

5.4 Water Absorption Test

The water absorption test of paver blocks is a crucial assessment that measures the porosity of the paving blocks, indicating how much water they can absorb. This test is significant for evaluating the durability and performance of paver blocks, especially in environments where freeze-thaw cycles, de-icing salts, and other weathering processes are of concern.

Water Absorption = {W2 – W1}/{W1} × 100

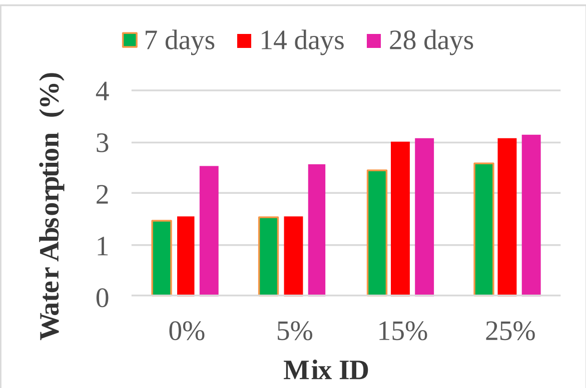

Fig 4. Test findings on water Absorption test

5.5 Efflorescence Test

The efflorescence test for paver blocks is designed to assess the potential of these blocks to exhibit efflorescence, a condition where soluble salts are brought to the surface of concrete and masonry products by water, which then evaporates and leaves a white, powdery residue behind. This phenomenon can affect the aesthetic appeal of paving blocks but does not typically impact their structural integrity.It is calculated that there is minimum amount of silts released on the surface of paver blocks with 25% of arecanut sheath ash.

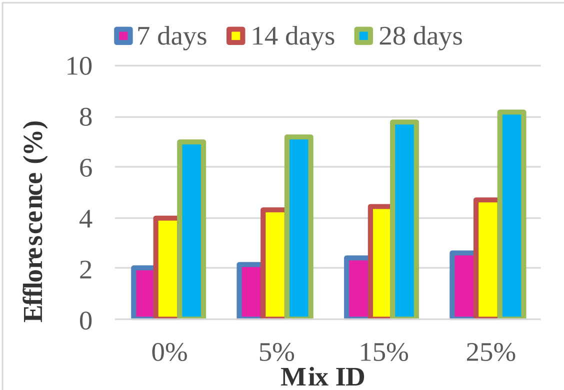

Fig 5. Test findings on efflorescence test

6. DISCUSSION ON TEST RESULTS

6.1 Results and Discussion:

The experimental investigation conducted on paver blocks with varying percentages of Arecanut Sheath Ash (ASA) replacement in cement revealed several noteworthy findings, as summarized below:

i. Compressive Strength:

The maximum compressive strength was observed at 15% ASA replacement, reaching 38.20 N/mm² after 28 days of curing. This suggests that incorporating ASA up to this percentage enhances the compressive strength of paver blocks, indicating the potential for optimizing the mix design to achieve desired strength requirements.

ii. Flexural Strength:

Similarly, the maximum flexural strength was recorded at 15% ASA replacement, measuring 4.57 N/mm² after 28 days of curing. This indicates that the addition of ASA up to 15% contributes positively to the flexural strength of paver blocks, which is crucial for withstanding bending stresses in real-world applications.

iii. Split Tensile Strength:

The highest split tensile strength was also attained at 15% ASA replacement, measuring 2.48 N/mm^2 after 28 days of curing. This further supports the notion that incorporating ASA up to this percentage enhances the tensile strength properties of paver blocks, which is essential for resisting cracking and deformation under tensile forces.

iv. Water Absorption:

According to industry standards, the water absorption rate of paver blocks should be greater than 8%. It was observed that all mixes, including those with up to 25% ASA replacement, fell within this acceptable range. This indicates that the incorporation of ASA did not adversely affect the water absorption properties of the paver blocks, ensuring their durability and resistance to moisture ingress.

v. Efflorescence Test:

The results of the efflorescence test for all mixes remained within the range of slight (less than 10%). This indicates that the paver blocks, regardless of the percentage of ASA replacement, exhibited minimal efflorescence, which is crucial for maintaining their aesthetic appeal and structural integrity over time.

Overall, the findings suggest that incorporating Arecanut Sheath Ash as a partial replacement for cement in paver block production can lead to improvements in mechanical properties such as compressive strength, flexural strength, and split tensile strength. Additionally, the paver blocks remained within acceptable ranges for water absorption and efflorescence, indicating their suitability for use in construction applications. Further optimization of mix proportions and additional durability testing may provide valuable insights for maximizing the benefits of ASA incorporation while ensuring the long-term performance and sustainability of paver blocks.

7. CONCLUSIONS

The experimental work of this project involves the conversion of arecanut sheath into ash, ash replaced for cement in the block and their engineering properties were assessed in terms of water absorption, efflorescence, compressive strength, flexural strength and split tensile strength.

i. The maximum compressive strength is attained at 15% of arecanut sheath ash replacement i.e, 38.20N/mm^2 for 28 days of curing.

ii. The maximum flexural strength is attained at 15% of arecanut sheath ash replacement i.e, 4.57N/mm^2 for 28 days of curing.

iii. The maximum split tensile strength is attained at 15% of arecanut sheath ash replacement i.e, 2.48N/mm^2 for 28 days of curing.

iv. The water absorbtion by the paver block should be greater than 8%. It is noted that all the mixes the (upto 25% of arecant sheath ash replacement ia with in the range.

v. The efflorescence test results for all the mixes are within the range of slight (less than 10%).

Based on these result, the production of concrete paver blocks with cement replaced by arecanut sheath ash upto 15% is the optimum result.

8. REFERENCES

1. A A Raheem, S I Adedokun, E A Adeynika and B V Adewole (2017) 'Application of corn stalk ash as partial replacement for cement in the production of interlocking paving stones', International Journal of Engineering Research in Africa, ISSN: 1663-4144, Vol. 30, pp 85-93.

2. Abdul Rachman Djamaluddin, Muhammad Akbar Caronge, M W Tjaronje, Asiyanthi T Lando and Rita Irmawaty (2019) 'Evaluation of sustainable concrete paving blocks incorporating processed waste tea ash' Case Studies in Construction Materials, e00325.

3. Deepak Kumar Singh and Shri Ram Chaurasia (2016) 'International Journal of Science Technology and Engineering' Volume 2, Issue 11, ISSN: 2349-784X.

4. Fuat Koksal, Osman Gencel, Yusa Sahin and Osman Okur (2021) 'Recycling bottom ash in production of eco-friendly interlocking concrete paving blocks', Journal of Material Cycles and Waste Management 23:1985-1001.

5. Hanafi Yusop, Meldi Suhatril, Mohamad Amirul Hafiz Abdul Hamid, Fetri Zainal, Md. Fauzan Kamal Md. Yapandi and Nor Aishah Abbas (2022) 'Usage of Coal Fly Ash and Bottom Ash from Ash Ponds for Bricks and Precast Concrete Blocks – A Review', Journal of Sustainable Civil Engineering and Technology, e-ISSN:2948-4294 Vol 1 Issue 2 , 50-62.

6. Hanafi Yusop, Meldi Suhatril, Mohamad Amirul Hafiz Abdul Hamid, Fetri Zainal, Md. Fauzan Kamal Md. Yapandi and Nor Aishah Abbas (2022) 'Usage of Coal Fly Ash and Bottom Ash from Ash Ponds for Bricks and Precast Concrete Blocks – A Review', Journal of Sustainable Civil Engineering and Technology, e-ISSN:2948-4294 Vol 1 Issue 2 , 50-62.

7. M K Musau, D Shitanda, M Githinji and C Mwende (2021) 'Use of rice husk ash as partial replacement of cement in concrete paving blocks', Journal of Engineering in Agriculture and the Environment, Vol 7, No 1.

8. P M Shanmugavadivu, Hima Hemant , P JeevaRekha and D P Preeti (2021) 'A Study on Paver block using Rice Husk Ash', International Conference on Science and Engineering (ICSE 2011), ISBN: 978-981-08-7931-0.

9. Priscilla M, Vinaya Shyam D, Harikrishna R Chavalagi, Kavya P Naik H L Shreeharsha Dombale and R Manish Kumar (2018) 'An Experimental Study on Recycled Aggregate Concrete by Partial Replacement for Cement by Arecanut Husk Ash', International Journal of Innovative Research in Technology,Volume 5 Issue 1 , ISSN: 2349-6002.

10. Raheem Akeem Ayinde, Adedokun Solomon Idowu, Ajayi Babatunde Raphael, Adedoyin Olakunle Adedapo and Adegboyega Biliki Olayemi (2017) 'International Journal of Sustainable Construction Engineering & Technology' (ISSN: 2180-3242) Vol 8, No 1, 2017.

11. Al-Rawas, A. A., & Goosen, M. F. (2005). Utilization of date palm ash in concrete as cement replacement material. Cement and Concrete Research, 35(5), 900-904.

12. Mehta, P. K., & Siddique, R. (2017). Arecanut husk ash (AHA) as a supplementary cementitious material in concrete: A review. Construction and Building Materials, 147, 500-508.

13. Datta, S., & Roy, P. (2018). Utilization of areca husk ash as partial replacement of cement in concrete. Materials Today: Proceedings, 5(1), 1434-1441.

14. Hassan, S., Babu, K. G., & Ravikumar, R. (2019). Arecanut sheath ash as partial replacement for cement in concrete. Materials Today: Proceedings, 15, 531-535.

15. Vijay, V. G., & Reddy, K. (2020). Influence of areca nut ash as a partial replacement of cement on strength properties of concrete. Materials Today: Proceedings, 28, 1162-1167.

16. Suresh, S., Prasad, R. K., & Subramani, T. (2020). An experimental study on the strength properties of arecanut sheath ash based geopolymer concrete. Materials Today: Proceedings, 22, 41-46.

17. Aswathy, K. J., & Jayasree, C. (2021). Arecanut Sheath Ash as Partial Replacement of Cement in Concrete. Materials Today: Proceedings, 45, 4379-4383.

18. Prabhu, V. B., & Narayana, T. S. (2021). Experimental Investigation on Partial Replacement of Cement with Arecanut Sheath Ash in Concrete. Materials Today: Proceedings, 45, 4414-4418.

19. Saha, S., & Das, S. (2022). Utilization of areca nut husk ash as partial replacement of cement in concrete. Sustainable Structures and Materials, 3(1), 45-51.

20. Kumar, V., & Shukla, A. (2022). Influence of Arecanut Husk Ash as Partial Replacement of Cement in Concrete. Journal of Cleaner Production, 332, 130134.

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