Engineering Research Unit
University of Moratuwa
Sri Lanka

Development and Performance Evaluation of Polymer Cement Hybrid Bricks Incorporating Polymeric Waste for Sustainable Construction

A.A.M. Yasir
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
ent1920137@tec.rjt.ac.lk

A.N. Liyanage
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri lanka
ent1920065@tec.rjt.ac.lk

W.A.H.I. Jayaweera
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
ent1920047@tec.rjt.ac.lk

A.L. Maduwanthi
Department of Materials Technology
Rajarata University of Sri lanka
Mihintale, Sri lanka
mliyanage@tec.rjt.ac.lk

H.M.I.K. Herath
Department of Materials Technology
Rajarata University of Sri Lanka
Mihintale, Sri Lanka
ikherath@tec.rjt.ac.lk

Keywords—Pyrolysis Char, Rice Husk Ash, Sustainable Construction, Eco-friendly Materials, Polymer Bricks

I. INTRODUCTION

The sudden emergence of the production of non biodegradable waste such as plastic and used tires is a grave environmental concern, with millions of tons being produced annually. Conventional methods of disposal such as landfilling, open dumping, and burning are leading to serious environmental effects [1]. Pyrolysis is a exciting waste to resource technology that produces oil, syngas, and a solid product pyrolysis char [2]. While oil and syngas are widely used as fuel, pyrolysis char finds limited application in Sri Lanka, where most of the plants are for fuel recovery. Pyrolysis yields about 30% to 40% of char material, which contains value added material like carbon black and silica and possesses properties like porosity, high percentage of carbon, and thermal stability and is thus usable in lightweight construction bricks [3]. Char must be bound by materials like cement or other substances to impart strength and endurance.

Despite global attention on green construction materials, few studies have been conducted on using tire and plastic based pyrolysis char in bricks, particularly in Sri Lanka. This work reduces this gap by developing eco friendly bricks with locally manufactured pyrolysis char and silica Rich Husk Ash (RHA) [4]. The research seeks to optimize mix ratio, mechanical and heat testing, and compare performance to conventional clay and cement bricks. The outcomes are expected to promote circular economy practice and offer a sustainable alternative for Sri Lankan construction.

II. LITERATURE REVIEW

Non biodegradable wastes such as used tires and plastics continue to accumulate globally, creating severe environmental challenges [1]. Pyrolysis offers a sustainable waste to resource route, generating oil, syngas, and a solid carbon rich residue known as pyrolysis char. Although locally unused, studies show that char possesses high fixed carbon, silica content, and a porous morphology, making it suitable for lightweight composite and brick applications. RHA, an agricultural by product rich in amorphous silica, functions as a supplementary cement based material. Its silica reacts with calcium hydroxide ($Ca(OH)_2$) from cement hydration through a pozzolanic reaction to form additional calcium silicate hydrate (C-S-H), improving strength and reducing porosity. Previous research indicates that combining carbon based fillers with pozzolanic ashes enhances mechanical and thermal performance in alternative bricks. However, the combined use of polymer derived pyrolysis char with RHA has not been explored in Sri Lanka. The selected material proportions in this study were based on maintaining enough carbon content for lightweight structure while ensuring sufficient reactive silica from RHA for C-S-H formation. This gap in scientific evaluation highlights the need to assess the mechanical, physical, and thermal behaviour of char, RHA hybrid bricks compared with conventional clay and cement bricks.

III. MATERIALS AND METHODS

The study utilized a sequential approach, raw material preparation, binder mix design, molding, curing, surface coating, and performance testing to achieve the research objectives.

A. Raw Material Preparation

Pyrolysis char was received from local tire and plastic industries, dried, and sieved to 150-300 µm and rubbery residues extracted. Char morphology will be analyzed through a scanning electron microscope to examine particle structure and porosity [3]. RHA was produced by heating rice husk char at 900 °C, then sieved to 75-150 µm [5], and its silica content was analyzed using X-ray fluorescence. Commercial cement was the primary binder.

B. Binder Mix Development and Mixing

A three stage mix optimization was performed. First, RHA was varied with constant cement and char to establish workable and strength compatible limits. Next, char was adjusted at the optimum RHA level to study effects on density and strength. Finally, cement was varied to refine mechanical performance and cost.

Initial proportion ranges were determined based on preliminary trials using higher char contents. Three sequential mix sets (A, B, and C) were prepared and evaluated through compressive strength and water absorption tests, with results from each stage guiding the next. This stepwise approach enabled the identification of 2-3 promising

ERU Symposium 2025 - DOI 10.31705/ERU.2025.25

TABLE I. MIXING RATIOS

B. No	RHA (Volume)			Char (Volume)			Cement (Volume)		
	A	*B*	*C*	*A*	*B*	*C*	*A*	*B*	*C*
01	1	2	2	10	10	19	5	5	1
02	2	2	2	10	11	19	5	5	2
03	3	2	2	10	12	19	5	5	3
04	4	2	2	10	13	19	5	5	4
05	5	2	2	10	14	19	5	5	5
06	6	2	2	10	15	19	5	5	6
07	7	2	2	10	16	19	5	5	7
08	8	2	2	10	17	19	5	5	8
09	9	2	2	10	18	19	5	5	9
10	10	2	2	10	19	19	5	5	10

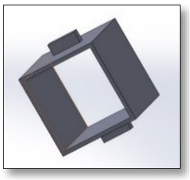

Fig. 1. Mould Design

Fig. 2. Bricks

formulations. Table 1 presents the three mix sets in the order they were developed.

C. *Molding and Curing*

The prepared mix was poured into molds, vibrated to remove entrapped air bubbles, pressed, and then demolded carefully. Cubic samples following ASTM D695 standards were prepared [6], approximately half the length of a standard Sri Lankan engineering brick. The molded samples were cured under shaded and well ventilated conditions for 7, 14, and 28 days to observe strength development over time [5].

D. *Surface Coating*

Upon curing, bricks were treated with Moringa (Drumstick tree) resin in water solution. This natural sealant minimizes surface dusting, increases durability, and provides safe handling without using synthetic chemicals.

E. *Testing and Evaluation*

All three stage mix variations were evaluated using compressive strength (ASTM D695) and water absorption tests to shortlist optimal formulations, which will undergo extended mechanical, thermal, and environmental characterization.

IV. RESULTS AND DISCUSSION

Three sequential mix variation stages were evaluated through compressive strength and water absorption testing to identify workable pyrolysis char/RHA/cement brick formulations. In the first set, compressive strengths ranged from 0.70-5.36 MPa, from which mix A2 (5.36 MPa) was selected for the second stage optimization. The second set produced strengths of 3.92-5.80 MPa, and the best performing mix, B10 (5.80 MPa), was advanced to the third stage. Final stage mixes compressive strengths of 5.94-10.51 MPa, though the first four mixes were rejected due to excessive water absorption. Among all samples, mixes C7 (7.83 MPa), C8 (9.07 MPa), and C9 (10.51 MPa) demonstrated the best balance of strength and durability, with water absorption values of 10.61%, 10.06%, and 11.08%, respectively. These values fall within acceptable limits for non fired composite bricks and confirm improved performance as mix proportions were improved. When compared with Sri Lankan standards, the best performing mixtures exceed the minimum requirement for cement solid blocks (≥1.2 MPa) and meet or surpass the compressive strength ranges of clay engineering bricks (2.8 MPa, 4.8 MPa, and 10.0 MPa classes). This progression confirms that pyrolysis char blended with RHA and cement can achieve structural grade performance, demonstrating strong potential for sustainable brick production pending further thermal and durability testing.

V. CONCLUSION

This study demonstrates that pyrolysis char and RHA, combined with cement, can be formulated into eco friendly hybrid bricks suitable for green construction. Through a three stage proportioning process, several mixes achieved compressive strengths exceeding Sri Lankan clay and cement brick requirements, while selected compositions showed moderate water absorption consistent with porous carbon based materials. The use of natural Moringa resin as a surface coating further supports sustainable finishing. Overall, the findings highlight the potential for converting local industrial and agricultural waste into viable construction materials, with future work focusing on performance optimization and advanced durability testing.

REFERENCES

[1] M. G. Kibria, N. I. Masuk, R. Safayet, H. Q. Nguyen, and M. Mourshed, "Plastic Waste: Challenges and Opportunities to Mitigate Pollution and Effective Management," *Int. J. Environ. Res.*, vol. 17, no. 20, pp. 1-37, Jan. 2023, doi: 10.1007/s41742-023-00507-z.

[2] P. Talwar, M. A. Agudelo, and S. Nanda, "Pyrolysis Process, Reactors, Products, and Applications: A Review," *Energies*, vol. 18, no. 11, p. 2979, Jun. 2025, doi: 10.3390/en18112979.

[3] N. Gao, F. Wang, C. Quan, L. Santamaria, G. Lopez, and P. T. Williams, "Tire Pyrolysis Char: Processes, Properties, Upgrading and Applications," *Progress in Energy and Combustion Science*, vol. 93, p. 101022, 2022, doi: 10.1016/j.pecs.2022.101022.

[4] N. M. S. Hasan, M. H. R. Sobuz, M. M. H. Khan, N. J. Mim, M. M. Meraz, S. D. Datta, M. J. Rana, A. Saha, A. S. M. Akid, M. T. Mehedi, M. Houda, and N. M. Sutan, "Integration of rice husk ash as supplementary cementitious material in the production of sustainable high-strength concrete," *Materials*, vol. 15, no. 22, p. 8171, Nov. 2022, doi: https://doi.org/10.3390/ma15228171.

[5] M. A. Noaman, M. R. Karim, M. N. Islam, and M. S. Mia, "Strength and durability parameters of brick aggregate concrete incorporating rice husk ash as a partial replacement of cement," *Adv. Mater. Sci. Eng.*, vol. 2022, Art. no. 8541276, May 2022, doi: 10.1155/2022/8541276.

[6] S. S. Raj, K. A. Mikhailovich, K. Subramanian, S. Sathiamoorthyi, and K. T. Kandasamy, "Philosophy of selecting ASTM standards for mechanical characterization of polymers and polymer composites," *Mater. Plast.*, vol. 58, no. 3, pp. 247-256, 2021, doi: 10.37358/MP.21.3.5523.