

Experimental Investigation on Mechanical Properties of Interlocking Structural Masonry Using Plastic Fiber and Ceramic Aggregates as a Replacement

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Abstract: Masonry in general is the construction of structure by using individual units which are laid and mortar is used for binding those units. One of the high durable types of construction is masonry. The common masonry materials are burnt clay bricks, stones such as marble, granite, concrete blocks, stabilized earth blocks, etc. The most commonly used masonry units are burnt clay brick (conventional brick) and concrete blocks. The research focuses on evaluating compressive strength and shear strength, two critical parameters for structural performance. While previous studies have examined natural and recycled aggregates, limited data exist on ceramic aggregates in interlocking blocks. This study investigates the mechanical properties of Plastic fiber interlocking structural masonry by replacing coarse aggregates with ceramic. The research focuses on evaluating the compressive strength, flexural strength, density, and water absorption characteristics of plastic fiber interlocking masonry blocks incorporating varying proportions of ceramic aggregates.

Keywords: Ceramic aggregate, Polyethylene (PE), water absorption test, compressive strength and Shear Strength.

I. LPG INTRODUCTION

The construction industry is constantly evolving to incorporate sustainable and cost-effective materials that enhance structural performance while reducing environmental impact. One such innovation is interlocking structural masonry, a technique that eliminates the need for mortar and improves construction efficiency. By integrating alternative materials such as plastic fiber and ceramic aggregates, interlocking masonry blocks can be optimized for strength, durability, and sustainability. Plastic waste is

a major environmental issue, and its use in construction materials provides a sustainable solution. Incorporating plastic fibres from waste polymers like PP, PE, and PET enhances the mechanical properties of masonry by improving tensile strength, impact resistance, and flexibility. These fibres help bridge microcracks, increasing the durability and structural integrity of interlocking blocks. Similarly, ceramic aggregates, sourced from recycled ceramic waste, provide an effective replacement for traditional aggregates. Ceramic materials exhibit high compressive strength, low water absorption, and excellent thermal insulation properties, making them ideal for sustainable masonry applications.



Figure 1: Polyethylene fibers and Ceramic aggregates

II. LPG LITERATURE REVIEW

Muhammad Nadeem et.al (2023) stated that the masonry construction is widely used for its durability and cost-effectiveness, but traditional methods require mortar, leading to high energy consumption and emissions. To address these issues, cored 6" Eco Blocks (CEBs) were developed as self-interlocking, stabilized earth blocks that eliminate the need for mortar, reducing construction time and environmental

impact. This study evaluates the mechanical properties of CEBs, including compressive strength, flexural strength, shear strength, and diagonal tensile strength. The blocks were prepared using cement (6%), clayey soil (35%), sand (50%), and water (9%). Various tests assessed their density, water absorption, load-bearing capacity, and shear resistance. Results showed compressive strength between 5.60 MPa and 6.61 MPa, meeting international standards for load-bearing walls. Flexural strength averaged 1.66 MPa, and water absorption ranged from 8.98% to 12.50%, ensuring durability. The interlocking shear keys improved stability and resistance to slippage. The study concludes that CEBs offer a sustainable and cost-effective alternative to conventional masonry. Their interlocking mechanism enhances structural stability, making them suitable for affordable housing and eco-friendly construction.

Bashar S. Mohammed et.al (2022) stated that the demand for efficient construction methods has driven the development of mortarless interlocking bricks, which simplify assembly and reduce construction time. Rubberized concrete interlocking bricks (RCIBs) are an innovative solution that integrates waste materials such as crumb rubber and fly ash, promoting sustainability and reducing environmental impact. These bricks eliminate the need for mortar while maintaining structural integrity. This study investigates the mechanical performance and sustainability of RCIB masonry prisms by replacing 56% of ordinary Portland cement with fly ash and 20% of sand with crumb rubber. The research evaluates compressive strength, failure mechanisms, stress-strain behavior, energy absorption, and thermal resistance. Additionally, fuel consumption, CO₂ emissions, and cost savings compared to conventional concrete bricks (CCB) are analyzed. By utilizing waste materials, RCIBs contribute to resource conservation and eco-friendly construction practices. The findings of this study could help optimize interlocking brick technology for sustainable and cost-effective applications in the construction industry.

Paul O. Awoyera et.al (2021) stated that sustainable concrete production using waste materials is gaining attention as an eco-friendly approach. This study examines the use of shredded plastic fibers and waste

ceramic powder in interlocking concrete blocks (ICBs) to enhance strength, water resistance, and durability. Materials used include Ordinary Portland Cement, waste ceramic powder, shredded PET plastic fibers, and river sand. A concrete mix ratio of 1:2 was used, with 20% sand replaced by ceramic waste, and plastic fibers added in varying amounts (0% to 2%). Tests on water absorption, compressive strength, and splitting tensile strength were conducted after 7, 28, and 90 days of curing. Results showed that increasing plastic fiber content reduced water absorption, with the lowest absorption at 0.5%. Strength improved with higher plastic fiber content, with 2% fiber yielding the best performance. Microstructural analysis confirmed better compactness and bonding in fiber-reinforced ICBs. The study concludes that incorporating plastic fibers and ceramic waste in ICBs is a sustainable and effective alternative for pavement construction.

G. Ghadvir et.al (2021) stated that it is always a big challenge for researchers to make interlocking blocks lightweight, cost-effective, and capable of performing well under different environmental conditions. This paper presents the results of various experimental studies on compressive strength, density, and water absorption by altering the percentage of stone dust, sand, and fly ash in different proportions of mix. Glass Fiber Reinforced Polymer (GFRP) was used in this study, and the results were discussed in detail. These experimental results were compared with burnt clay brick masonry. The findings indicate that interlocking block masonry is durable and has sufficient strength.

K. B. Anand et.al (2000) stated that mortarless masonry have been used in different countries with lack of research studies. This paper deals with the features of interlocking block masonry and also deals with LPG development of interlocking block masonry with respect to shape and easiness in manufacture. In this paper different tests were performed. Wallet tests under axial compression and eccentric compression is carried. Flexural test both perpendicular and parallel to bed joints is carried on dry-stacked specimen. Interlocking block masonry results that is dry stacked mortarless masonry results were compared with mortar bed masonry results and dry stacked masonry found to be high in efficiency. Also, this paper states that channel shaped interlocking blocks when compared to I-shape interlocking blocks

have high flexural capacity This paper proved that the solid interlocking block masonry is good alternative to mortar bed masonry which accelerates construction and also results in better structural performance.

III. GAP ANALYSIS

Various experimental studies are conducted on interlocking blocks and conventional bricks like compressive strength on prisms, wallet tests to determine the shear stress, compressive strength tests on conventional bricks an interlocking block, dimensional tests on bricks and blocks, water absorption tests on conventional bricks and blocks, modulus of elasticity.

1. Most studies focus on traditional concrete interlocking blocks with natural aggregates and incorporate recycled aggregate but lacks data on ceramic aggregate.
2. The influence of different percentage of plastic fiber used in interlocking blocks on the mechanical properties has not been studied.
3. Most existing studies focus on either plastic fibers or ceramic waste separately, with limited research on combining both in interlocking block systems.

IV. OBJECTIVES

1. To determine the mechanical properties of interlocking concrete masonry block with plastic fibres by replacing coarse aggregate with ceramic aggregate.
2. To compare the mechanical properties of plastic fibre interlocking concrete blocks made with ceramic aggregates to conventional concrete blocks and to determine the optimum percentage of replacement.
3. To evaluate the effect of optimum percentage of plastic fibres and ceramic aggregates on the shear strength of interlocking concrete structural masonry prism.

V. MATERIAL

- [1] **Cement:** OPC 53 grade cement served as a binding agent in this mix. The relative density of the tests revealed the cement to be 3.12.

- [2] **LPGFine Aggregate:** Crushed sand was employed as fine aggregate material. It passed through the 4.75 mm sieve and was retained on the 60-micron sieve. Sand exhibited a specific gravity of 2.58 as well as its ability to absorb water was 1%.
- [3] **Coarse Aggregate:** The coarse aggregate's maximum grain size used was 12 mm. It had a relative density of 2.68 and 0.72% water absorption.
- [4] **Ceramic Aggregate:** Typically derived from crushed waste ceramic materials such as tiles and sanitary ware, are a sustainable alternative to natural coarse aggregates in construction. Part of the coarse aggregate was replaced using ceramic aggregate in different proportions such as ranging from 5% to 30%. Specific gravity of ceramic waste is 2.44 and water absorption is 2.51%
- [5] **Polyethylene fiber (PE):** A synthetic fiber derived from recycled plastic waste, known for its high toughness, flexibility, and resistance to moisture and chemicals.
- [6] **Water:** Mixing was done using potable water. It met the IS 456:2000 standards. The water-cement ratio used in this mix was 0.6.

VI. METHODOLOGY

The Design mix for M15 grade of concrete is done with IS 10262: 2019. The Mix ratio was 1:2.27:3.43 with the water cement ratio of 0.6. Then the cube samples are casted only with the partial replacement of cement with the polyethylene fiber was done and the optimum percentage was derived. Then with the optimum percentage replacement of polyethylene fiber, the Ceramic aggregate is replaced for Coarse aggregate and the compressive strength was calculated and the optimum percentage replacement is determined. Finally, the Interlocking Blocks are casted with the optimum percentage replacement obtained with the replacement of both the polyethylene fiber and ceramic aggregates, and the compressive strength was determined for the Interlocking Block.

VII. RESULTS AND DISCUSSIONS

The Concrete Cube Mold of size 150 x 150 x 150 mm used for casting the specimens. Totally 48 cubes samples and 40 Interlocking Block samples were casted and tested. In this study, a total of four sample

of interlocking masonry prism and two interlocking masonry walls were tested. The specimens were classified as follows: two sample of three interlocking block masonry prisms of dimension 470 (height) x 300 (length) x 150 (width) mm, two sample of five interlocking block masonry prisms of dimension 790 (height) x 300 (length) x 150 (width) mm, and two sample of interlocking block masonry wall of size 910 (length) x 810 (height) x 150 (width) mm. Masonry prisms specimens are tested under static load conditions within a 100-ton LPG capacity loading frame, and wall specimens are tested under lateral load condition by using the hydraulic jack of 50-ton capacity.

VII.1 Compressive Strength Test for polyethylene fiber

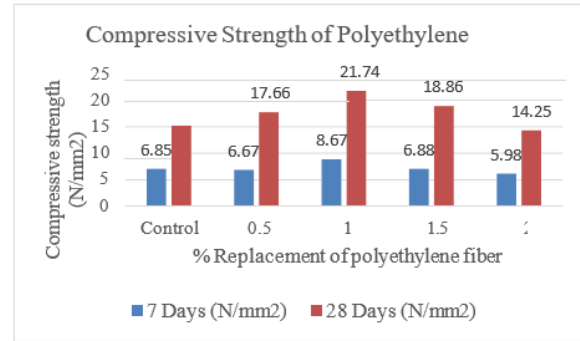
The compressive strength test of concrete cubes was conducted on three samples after curing periods at 7 and 28 days, concrete cubes incorporating partial replacement of cement were prepared polyethylene fiber (PF) at 0.5%, 1%, 1.5%, and 2% by volume. As per the guidelines of IS 516 (Part 1: Sec 1:2021), the compressive strength should not fall below 4 N/mm². The observed mode of failure is illustrated in chart-1.

Table-1 Compression strength test of polyethylene fiber

Sl No	Percentage of polyethylene fiber	Compressive Strength (N/mm ²)	
		7 Days	28 Days
1	Control	6.85	15.14
2	0.5	6.67	17.66
3	1	8.67	21.74
4	1.5	6.88	18.86
5	2	5.98	14.25

From the table-1 the compression strength of concrete cube with varying proportions of polyethylene fiber was tested and the test results are compared with the conventional concrete. Results indicate that compressive strength peaked with a 1% replacement of cement by polyethylene fiber at both 7 and 28 days. Thus the 1% sample was considered as the optimum percentage of polyethylene fiber replacement.

Chart-1 Compressive strength of polyethylene fiber graph for 7 & 28 days



From the above graph results, the compressive strength increased with the addition of polyethylene fibers, reaching an optimum value of 21.74 MPa at 1% replacement. Beyond this dosage, strength reduced (18.86 MPa at 1.5% and 14.25 MPa at 2%) due to fiber balling and poor workability, confirming 1% as the optimum level.

VII.2 Evaluation of Compressive Strength in Concrete with Polyethylene Fiber and Ceramic Aggregate

The experimental design involved replacing natural coarse aggregate with ceramic aggregate at four levels, namely 5%, 10%, 20%, and 30% by volume. In all mixes, 1% polyethylene fiber (by volume of cement) was included, as this proportion had already been identified as the optimum in the preliminary stage.

Table-2 Compression strength test of polyethylene fiber and ceramic aggregate

Sl No	Percentage of Ceramic aggregate	Compressive Strength (N/mm ²)	
		7 Days	28 Days
1	Control	13.58	15.56
2	5	10.22	17.55
3	10	15.77	20.88
4	15	11.55	16.44
5	20	11.11	17.331

From the table-2 the compressive strength of concrete cube with varying replacement of Ceramic aggregate with optimum percentage of polyethylene fiber which was determined from table-1 was casted then they were tested. which showed that, in comparison to the control sample, the compressive strength peaked at 10% (1% replacement of polyethylene fiber and 10% replacement of ceramic aggregate) in both the 7- and 28-day compressive strength tests. Therefore, the 10%

sample was thought to be the ideal proportion for replacing cubes with ceramic aggregate and polyethylene fiber.

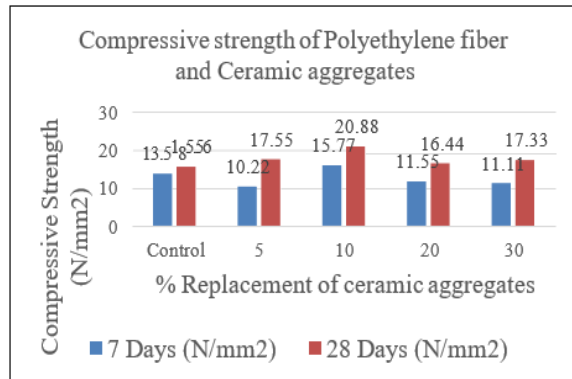


Chart-2 Compressive strength of polyethylene fiber and ceramic aggregate graph for 7 & 28 days

VII.3 LPG Compression Strength test of Interlocking Blocks

The compression test of interlocking blocks was done after 28 days of curing for three samples. The interlocking blocks are made with the final optimum percentage obtained from the compressive strength of Polyethylene fiber and Ceramic Aggregate i.e., 1% of Polyethylene fiber and 10% of Ceramic aggregate. The interlocking blocks dimension is 300mm length, 150mm height, 150mm width and 20mm of shear key was casted. The results of the compressive strength are tabulated in table 2. According to the specifications given in IS:2185 (Part 1)-2005.

Table-3 Compression test of Interlocking Blocks

Sl No	Load (KN)	Area (mm²)	Compressive Strength (N/mm²)
1	690	45000	15.33
2	684	45000	15.2
3	670	45000	14.88



Figure 2. Compression failure of Interlocking Blocks

VII.4 Water Absorption test of Interlocking Blocks

The water absorption test was performed on interlocking blocks to assess their porosity, density, and durability, in accordance with IS 2185 (Part 1): 1979, which specifies that the interlocking concrete blocks should not absorb more than 10% of water. The results obtained are satisfied according to this code. The blocks were first dried in an oven at 105 °C–110 °C until their weight remained constant, which was noted as the dry weight. After that, they were kept in water for 24 hours and then weighed again to get the wet weight. The obtained results are tabulated in table 4

Table-4 Water absorption of Interlocking Block

Sl No	Dry weight of interlocking block	Wet weight of interlocking block	Water absorption (%) by mass
	M1(gms)	M2 (gms)	$\frac{(M2 - M1)}{M1} \times 100$
1	15960	16140	1.12
2	15360	15660	1.95
3	15870	16080	1.32



Figure 3. water absorption of interlocking blocks
The average water absorption of interlocking blocks is

found to be 1.46%, which is satisfied as per IS: 2185(part1)-1979 which specifies the solid interlocking blocks should not absorb more than 10% of water.

VII.5 Compressive strength of interlocking block masonry prisms

Prism tests were conducted to evaluate the structural behavior of interlocking block masonry beyond the level of individual blocks. While cube tests provide insight into the compressive strength of the material itself, prism specimens simulate masonry elements under axial loading, making them more representative of real wall performance. In this study, prisms were constructed using the optimum mix proportion of blocks containing 1% polyethylene fiber and 10% ceramic aggregate.

Table- 5 Compression test of interlocking Block masonry prisms

Sl No	Specimen Size h x l x h (mm)	Load (N)	Compressive stress (N/mm ²)	Mode of failure
1	790 x 300 x 150	356000	7.911	Crushing
2	790 x 300 x 150	310000	6.88	Crushing



Figure 4. Mode of failure of interlocking block masonry prism

Observations during testing revealed that prisms made with modified blocks displayed a more gradual failure mode compared to conventional blocks. Instead of sudden brittle crushing, the presence of plastic fibers restrained the rapid propagation of cracks, resulting in finer and distributed cracks across the height of the specimen. The average compressive strength of interlocking blocks is found to be 7.45 MPa, which is

satisfied as per IS: 1905-1987 which specifies the minimum compressive strength should be 4 MPa.

VII.6 Triplet strength test of interlocking block masonry prisms

In this investigation, interlocking block masonry prisms of size 470 (height) x 300 (length) x 150 (width) mm were selected, consisting of three blocks stacked vertically with two mortar joints of 10 mm thickness. The choice of three-block prisms provides a balanced configuration, ensuring that the middle block transfers load through both top and bottom joints, thereby simulating realistic stress conditions similar to those in actual walls. After 28 days of curing, the specimens were tested under axial load in a 100-ton Universal Testing Machine (UTM). The compressive load applied vertically induces a shear stress along the plane of the mortar joints, which continues to increase until bond failure occurs.

Table- 6 Shear strength test of interlocking Block masonry prisms LPG

Sl No	Specimen Size h x l x h (mm)	Load (KN)	Shear strength (N/mm ²)
1	470 x 300 x 150	19.230	0.429
2	470 x 300 x 150	17.820	0.396

LPG



Figure 5. Mode of failure of mortar joint in masonry prism

The triplet test conducted on interlocking block masonry prisms containing 1% polyethylene fibers and 10% ceramic aggregates yielded shear strengths of 0.396 N/mm² and 0.429 N/mm², corresponding to ultimate loads of 17.82 KN and 19.23 KN. These values are well above the 0.03 N/mm² minimum limit specified in RILEM recommendations and also surpass the 0.1–0.3 N/mm² range prescribed in IS

1905:1987 for conventional mortar joints. In addition, the measured strengths align with the 0.3–0.5 N/mm² range commonly reported in ASTM C1531 as well as in international research findings on masonry shear behavior.

VII.7 Shear stress test on wall panel

To evaluate the overall shear performance of an interlocking block masonry system, a moderately sized wall specimen was constructed and tested under lateral loading. The wall dimensions were 910 mm in length, 810 mm in height, and 150 mm in thickness, representing a realistic portion of a structural wall. Construction was carried out in a Flemish bond arrangement, with mortar of 1:4 mix ratio used to maintain 10 mm thick joints. Proper curing for 28 days ensured adequate strength development before testing.

Sl No	Specimen size l x h x t (mm)	Ultimate Load (KN)	Shear stress strength (N/mm ²)
1	910 x 810 x 150	82	1.82
2	910 x 810 x 150	78	1.73

Table -7 Shear stress of interlocking Block masonry wall LPG



Figure 6. Mode of failure of interlocking block masonry wall

The interlocking masonry wall specimens were tested under lateral loading to assess their in-plane shear performance. The walls, constructed with blocks containing 1% polyethylene fiber and 10% ceramic aggregates, recorded ultimate loads of 82 kN and 78 kN, corresponding to shear stresses of 1.82 N/mm² and 1.73 N/mm². According to IS 1905–1987 standards and ASTM standards, the minimum shear strength requirements for unreinforced masonry walls is 0.9 N/mm² which is lower than the obtained value, confirming that the interlocking block masonry walls

tested are structurally adequate for low-rise to medium-rise buildings. Failure was primarily characterized by diagonal cracking across the panel, a typical shear failure mode in masonry walls.

VIII. CONCLUSION

1. The compressive strength results of cube specimens showed that 1% polyethylene fiber replacement delivered the optimum performance, indicating that a small percentage of fibers is effective in enhancing strength, while higher dosages reduce workability and strength.
2. Incorporating 10% ceramic aggregate along with 1% fiber gave the best compressive strength among modified mixes, proving that ceramic waste can successfully replace natural coarse aggregates up to a certain limit.
3. The interlocking blocks cast with the optimum mix reached an average compressive strength of 15.13 MPa, which is far above the minimum requirement of 4 MPa specified in IS 1905–1987, confirming their suitability for structural applications.
4. The water absorption of 1.46% recorded for interlocking blocks was significantly below the permissible limit of 10% (IS:2185 Part 1–1979), showing that the blocks are highly durable and less prone to moisture damage.
5. LPGPrism tests indicated an average compressive strength of 7.45 MPa, where the observed failure was primarily crushing at mid-height, suggesting a uniform stress distribution across the masonry units.
6. Triplet tests on masonry prisms yielded an average shear strength of 0.413 MPa, highlighting that mortar joints remain the weakest link in interlocking masonry.
7. The wall panel tests recorded shear stresses of 1.82 N/mm² and 1.73 N/mm², with diagonal cracking identified as the primary mode of failure. Since both values are well above the minimum shear strength requirement of 0.9 N/mm² specified in IS 1905:1987 and ASTM standards, it can be concluded that interlocking block walls provide adequate lateral load resistance and are structurally suitable for low- to medium-rise construction.

8. The combined use of plastic fibers and ceramic aggregates not only improved the mechanical performance of the blocks but also addressed waste management and sustainability challenges, offering an eco-friendly alternative to traditional masonry.
9. Despite the improvements, the brittle nature of failure indicates that additional reinforcement or design modifications are necessary in seismic-prone zones to improve ductility.
10. The findings support the idea that interlocking masonry with waste-based materials can be adopted as a cost-effective, sustainable, and durable construction method for future building projects.

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