

Experimental Investigation on Mechanical Properties of Cement-Free Composite Blocks Using Multilayer Plastic Waste and Brick Waste Powder.

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Abstract

The rapid increase in plastic waste and construction demolition waste has created serious environmental concerns worldwide. The present study investigates the utilization of multilayer plastic (MLP) waste and brick waste powder in the development of sustainable cement-free composite blocks. Multilayer plastic waste was melted using a controlled heating arrangement and mixed with brick waste powder and coarse aggregate in different proportions. Cube specimens of size $75 \times 75 \times 75$ mm³ were prepared and tested for compressive strength using a Compression Testing Machine (CTM). The results showed that compressive strength increased with increase in multilayer plastic content and incorporation of brick waste powder. Among all mixes, specimen M4 having proportion 80:10:10 (MLP: Brick Waste Powder: Coarse Aggregate) achieved the highest compressive strength of 12.11 MPa. The developed blocks exhibited comparatively ductile behavior and reduced brittle failure. The study demonstrates that multilayer plastic waste and brick waste powder can be effectively utilized in the production of sustainable cement-free composite blocks for lightweight and non-structural construction applications.

Keywords: Multilayer plastic waste, Brick waste powder, Composite blocks, Sustainable construction materials, Plastic waste recycling...

INTRODUCTION

India is one of the largest producers of plastic waste in the world due to rapid urbanization, industrial growth, and the increasing consumption of packaged products. According to reports published by the Central Pollution Control Board (CPCB), millions of tonnes of plastic waste are generated annually in India, creating serious environmental and waste management challenges [1,2]. A considerable portion of this waste consists of single-use and multilayer plastic packaging materials, which are widely used in food packets, milk pouches household products, and commercial packaging applications. According to government datasets and CPCB records, plastic waste generation in India has continuously increased over recent years due to population growth, urbanization, and increased consumption of packaged products [4].

Plastic waste generated in India mainly includes polyethylene terephthalate (PET), high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polyvinyl chloride (PVC), polystyrene (PS), and multilayer plastic (MLP). Among these, polyethylene-based plastics contribute a major share of the total plastic waste. Recent studies and CPCB reports indicate that LDPE accounts for a significant percentage of plastic waste generation, followed by HDPE and multilayer plastic waste [2,3]. Multilayer plastic waste is especially difficult to recycle because it consists of multiple layers of polymers and metallic coatings bonded together, making separation and conventional recycling processes complex and uneconomical [7]. Due to the absence of economical recycling techniques, large quantities of multilayer plastic waste are disposed of in landfills or openly dumped into the environment.

Improper disposal and ineffective recycling of plastic waste result in severe environmental problems such as soil contamination, blockage of drainage systems, groundwater pollution, and harm to aquatic ecosystems. Since

plastic materials are non-biodegradable in nature, they remain in the environment for several decades [6]. Therefore, the utilization of plastic waste in construction materials has emerged as a sustainable approach for reducing environmental pollution and conserving natural resources [8]. Recycling and reusing plastic waste in construction applications can also reduce landfill burden and promote sustainable waste management practices. Simultaneously, the construction industry is facing increasing demand for sustainable and eco-friendly materials due to rapid infrastructure development. Conventional construction materials consume significant quantities of natural resources and energy during production. In addition, demolition activities and construction processes generate large quantities of brick waste, which are commonly disposed of in open landfills. Brick waste powder possesses suitable physical properties and can be effectively

MATERIALS AND METHODOLOGY

Materials

The materials used in the present experimental investigation were multilayer plastic (MLP) waste, coarse aggregate, and brick waste powder. Multilayer plastic waste having a density of 960 kg/m^3 was collected from college campus dustbins and nearby waste collection areas. The collected waste mainly consisted of chips packets, snack wrappers, chocolate wrappers, and other multilayer packaging materials shown in Figure 1(a). The plastic waste was manually segregated, washed thoroughly with water to remove impurities, dried under sunlight, and cut into small strips of approximately 2–3 cm size to ensure uniform melting during heating utilized as a replacement material in construction applications, thereby reducing waste disposal problems and the consumption of natural aggregates.

Several researchers have investigated the use of plastic waste in the production of bricks, paver blocks, concrete composites, and pavement materials [8,9]. Different types of plastics such as PET, HDPE, LDPE, and PP have been utilized either as binder replacements or aggregate replacements to improve certain mechanical and durability properties [10]. Previous studies on multilayer plastic composite blocks demonstrated that multilayer plastic waste can be effectively utilized in construction materials to improve waste management and sustainability in the construction sector [5]. However, comparatively fewer studies have focused on the utilization of multilayer plastic waste because of its complex composition and recycling difficulties [7]. Moreover, limited research has been conducted on the combined utilization of multilayer plastic waste and brick waste powder in paver block manufacturing.

The present study aims to investigate the mechanical properties of paver blocks prepared using multilayer plastic waste and brick waste powder. The research focuses on evaluating properties such as compressive strength and water absorption for different mix proportions. The utilization of these waste materials in paver block production can provide an environmentally sustainable solution for plastic and construction waste management while producing economical and durable construction materials suitable for practical applications. The study also aims to promote sustainable construction practices by reducing environmental pollution and minimizing the use of conventional construction materials.

Coarse aggregate of size ranging from 4.75 mm to 10 mm was used for the preparation of composite blocks. The coarse aggregate possessed a specific gravity of 2.80 and water absorption of 0.4%. The aggregates were oven dried before use to remove moisture content and improve bonding with molten plastic.

Brick waste used in the study was obtained from demolished brick masonry and construction waste. The broken brick pieces were crushed manually and sieved through a 600-micron IS sieve to obtain fine brick waste powder. The brick waste powder possessed a density of 2850 kg/m^3 , specific gravity of 2.85, and water absorption of 15.67%. The obtained powder was used as filler material in the preparation of composite blocks

Methodology

The present study was conducted to investigate the utilization of multilayer plastic waste and brick waste powder in the production of composite plastic blocks. The experimental work mainly focused on evaluating the mechanical properties of the developed specimens through density and compressive strength testing. Different mix combinations containing multilayer plastic waste, brick waste powder, and coarse aggregate were selected to study the influence of varying material proportions on the performance of the composite blocks.

The experimental setup mainly consisted of an electric induction heating system, a closed metal cooker used as a melting chamber, a steel pipe connected to a water-cooled container for gas cooling shown in Figure 1 (b), steel

cube moulds of size $75 \times 75 \times 75$ mm, and a Compression Testing Machine (CTM). The closed cooker arrangement helped in controlling and cooling the gases emitted during melting of plastic waste, thereby reducing direct release into the environment.

Initially, the prepared multilayer plastic strips were tightly packed inside the closed metal cooker and heated using an electric induction heater at an approximate temperature of 160°C . At this temperature, the multilayer plastic gradually softened and transformed into a molten state. The melting process adopted in the present study was designed to be comparatively environmentally safer than open burning methods. During heating, the gases emitted from the molten plastic were passed through a steel pipe connected to a water-cooled container. This arrangement worked on the principle of controlled pyrolysis, where the emitted gases were cooled before release into the atmosphere. After cooling, the by-products obtained were mainly gaseous substances, which reduced direct smoke emission and minimized environmental impact during the melting process.

After complete melting of the multilayer plastic waste, the required quantities of coarse aggregate and brick waste powder were added according to the selected mix proportions shown in Figure 1 (c). Continuous manual mixing was carried out until a homogeneous mixture was obtained and proper coating of aggregates and filler material by molten plastic was achieved

Table 1 Mix Proportions of Composite Blocks

Test Sample	Mix Proportion (MLP: Brick Waste Powder: Coarse Aggregate)
M1	20: 0: 80
M2	60: 20: 20
M3	70: 20: 10
M4	80: 10: 10

The density of each mix was calculated using the densities and proportions of the individual constituent materials. Approximately 15% air voids were considered during the calculations. For sample M1 to M4, the density of MLP and coarse aggregate was taken as 960 kg/m^3 and 2800 kg/m^3 respectively. Assuming the total mass as 1 kg, the density was calculated using the ratio of total mass to total absolute volume of constituent materials.

Similarly, the density for all mixes were calculated and are presented in Table 2

Table 2 Density of Test Sample

Test Sample	Density (kg/m^3)
M1	1640.29
M2	1118.41
M3	1045.33
M4	952.88

Cube specimens of size $75 \times 75 \times 75$ mm were used for casting. The quantity of materials required for each cube specimen was estimated based on density and volume of cube moulds. The calculated quantities of multilayer plastic waste, brick waste powder, and coarse aggregate used for different mixes are presented in Table 3.

Table 3 Quantity Estimation for Different Test Sample

Test Sample	Mix Proportion (MLP: Brick: Coarse Aggregate)	MLP (gm)	Brick Powder (gm)	Coarse Aggregate (gm)
M1	20: 0: 80	145	0	575
M2	60: 20: 20	330	110	110
M3	70: 20: 10	355	100	100

M4	80: 10: 10	375	50	50
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The prepared hot mixture was poured into steel cube moulds and compacted using tamping rods and mechanical vibration to minimize entrapped air voids and ensure proper compaction shown in Figure 1 (e). After casting, the specimens were kept undisturbed at room temperature for cooling and solidification. Since multilayer plastic acted as the binding material, no water curing process was required. After 24–48 hours, the specimens were demoulded and prepared for testing.

The actual density of each cube specimen was determined by measuring its mass using a digital weighing balance and dividing it by the volume of the cube specimen. Since all specimens had identical dimensions, the volume remained constant at 0.000421875 m³.

Compressive strength testing was carried out using a Compression Testing Machine (CTM). The cube specimens were placed centrally on the loading platform, and compressive load was applied gradually at a loading rate of approximately 1.3 kN/sec until failure occurred shown in Figure 1 (f). The maximum load sustained by each specimen was recorded, and the corresponding compressive strength values were calculated. The compressive strength test was conducted to evaluate the load-bearing capacity and mechanical performance of the developed composite blocks for potential construction applications





M1

M2

M3

M4

Figure 1(e) Cube casted by different mix



Figure 1 (f) Testing of Cube

RESULTS AND ANALYSIS

Compressive Strength Results

The compressive strength of the cube specimens was determined using a Compression Testing Machine (CTM). The specimens were tested under gradually applied compressive loading until failure, and the maximum load sustained by each specimen was recorded. The compressive strength values obtained for different mix proportions are presented in Table 4.

Table 4 Compressive Strength of Different Test Samples

Test Samples	Proportion (MLP: Brick: Coarse Aggregate)	Compressive Strength (MPa)
M1	20: 0: 80	1.63
M2	60: 20: 20	9.83
M3	70: 20: 10	8.43
M4	80: 10: 10	12.11

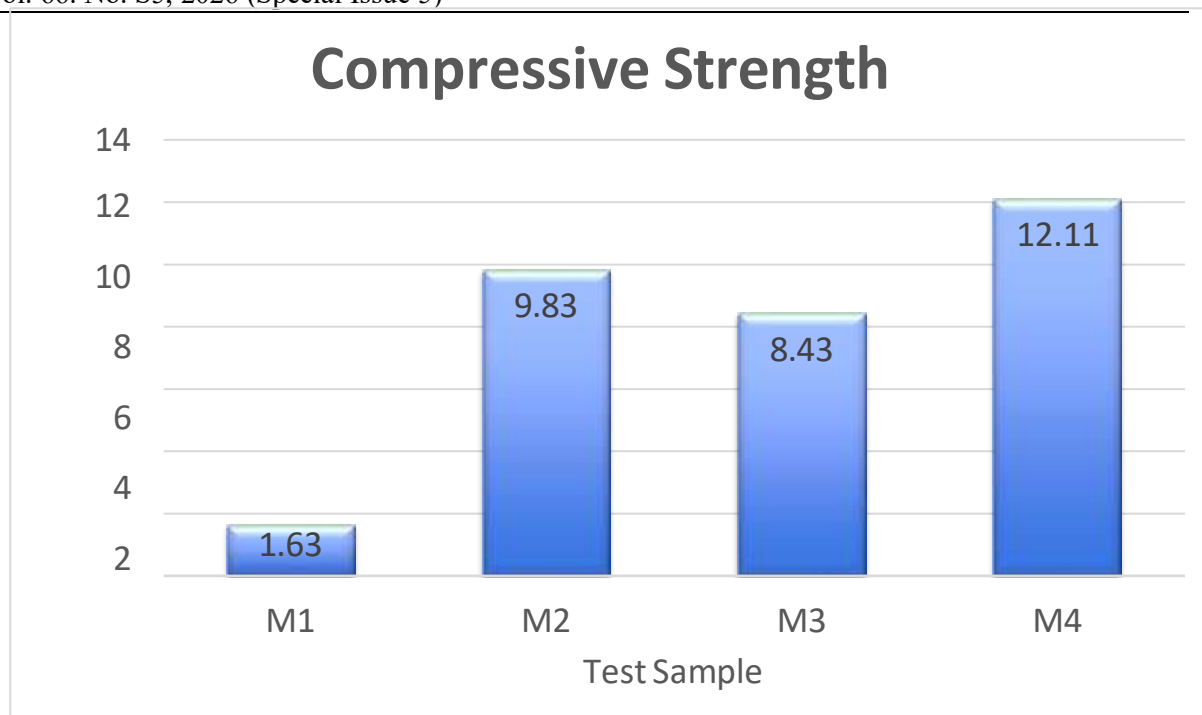


Figure 2 Compressive Strength Results of MLP Composite Cubes

The compressive strength results indicate that the strength of composite blocks increased significantly with an increase in multilayer plastic content and the incorporation of brick waste powder. Among all the specimens, sample M4 exhibited the highest compressive strength of 12.11 MPa. This improvement in strength may be attributed to better bonding and interlocking between molten multilayer plastic and filler materials, resulting in a denser composite structure.

Sample M1 exhibited the lowest compressive strength of 1.63 MPa due to the absence of brick waste powder and higher percentage of coarse aggregate. The lower plastic content in M1 was insufficient to form an effective binding matrix around the aggregates, leading to poor load transfer and weak internal bonding. In comparison, specimens M2 and M3 showed considerable improvement in compressive strength due to the presence of brick waste powder, which acted as a filler material and enhanced the packing density of the composite mixture.

The results further indicate that the addition of brick waste powder contributed positively to the mechanical performance of the developed blocks. Brick waste powder filled the internal voids within the composite structure and improved bonding between plastic and aggregate particles. However, variation in the proportion of coarse aggregate and brick waste powder influenced the final strength values. Although M3 contained higher plastic content than M2, a slight reduction in compressive strength was observed, possibly due to lower coarse aggregate content and non-uniform distribution of internal voids.

During compressive loading, the specimens did not exhibit brittle failure behavior similar to conventional cement concrete cubes. Instead, the developed composite blocks showed comparatively ductile behavior, especially in mixes containing higher plastic content. Failure mainly occurred through internal cracking, deformation, and gradual yielding of the plastic matrix rather than sudden aggregate crushing. This behavior confirms that the multilayer plastic acted as the primary binding matrix governing the failure mechanism of the composite blocks.

The experimental results demonstrate that multilayer plastic waste and brick waste powder can be effectively utilized in the development of composite construction blocks with satisfactory compressive strength characteristics. The developed blocks also exhibited reduced brittleness and improved deformation capacity compared to conventional cement-based materials, indicating their potential suitability for lightweight and non-structural construction applications.

Reason for Variation in Compressive Strength
The variation in compressive strength of the composite blocks mainly occurred due to changes in the proportion of multilayer plastic (MLP), brick waste powder, and coarse aggregate. These materials directly influenced the bonding characteristics, density, internal void formation, and load transfer mechanism within the composite structure.

Sample M1 exhibited the lowest compressive strength because it contained a high percentage of coarse aggregate (80%) and a comparatively low amount of multilayer plastic (20%). The lower plastic content was insufficient to form an effective binding matrix around the aggregate particles. As a result, weak bonding, poor compaction, and higher internal voids were observed within the specimen, leading to very low compressive strength.

In sample M2, the increase in multilayer plastic content significantly improved the binding characteristics and particle packing within the composite matrix. The addition of brick waste powder acted as a filler material, reducing internal voids and increasing the density of the specimen. Improved interlocking between particles and better

CONCLUSION

The present study investigated the utilization of multilayer plastic (MLP) waste and brick waste powder in the preparation of composite construction blocks. Different mix proportions containing multilayer plastic waste, brick waste powder, and coarse aggregate were prepared and experimentally evaluated for compressive strength characteristics, through internal cracking, deformation, and gradual yielding of the plastic matrix rather than sudden aggregate crushing. This behavior confirms that the multilayer plastic acted as the primary binding matrix governing the failure mechanism of the composite blocks.

The experimental results demonstrate that multilayer plastic waste and brick waste powder can be effectively utilized in the development of composite construction blocks with satisfactory compressive strength characteristics. The developed blocks also exhibited reduced brittleness and improved deformation capacity compared to conventional cement-based materials, indicating their potential suitability for lightweight and non-structural construction applications. compaction contributed to a considerable increase in compressive strength.

Sample M3 showed a slight reduction in compressive strength compared to M2 despite having higher multilayer plastic content. This reduction may be attributed to the decrease in coarse aggregate content, which reduced the load-carrying skeleton of the composite structure. In addition, the higher proportion of fine materials possibly created weak zones and microcracks within the specimen, resulting in a slight decrease in strength.

Sample M4 exhibited the highest compressive strength among all the mixes. The optimum combination of high multilayer plastic content with controlled proportions of brick waste powder and coarse aggregate resulted in better particle packing and a denser internal structure. Reduced void formation and improved interfacial bonding between materials enhanced stress distribution throughout the specimen, thereby producing maximum compressive strength.

Therefore, the developed composite blocks demonstrated promising mechanical performance and potential for sustainable non-structural construction applications.

Based on the experimental investigation, the following conclusions were drawn:

The compressive strength of composite blocks increased significantly with increase in multilayer plastic content and incorporation of brick waste powder. The molten multilayer plastic effectively acted as a binding material and improved the bonding between aggregate particles.

The addition of brick waste powder improved particle packing and reduced internal voids within the composite structure, thereby enhancing density and compressive strength.

Sample M1 containing lower multilayer plastic content and higher coarse aggregate proportion exhibited the lowest compressive strength of 1.63 MPa due to insufficient binding and poor compaction.

Sample M4 with mix proportion 80:10:10 (MLP: Brick Waste Powder: Coarse Aggregate) achieved the maximum compressive strength of 12.11 MPa due to optimum particle packing, improved interfacial bonding, and reduced void formation.

The developed composite blocks exhibited comparatively ductile behavior during compressive loading and did not show sudden brittle failure similar to conventional cement concrete specimens. Failure mainly occurred through gradual

The present study confirms the potential of multilayer plastic waste and brick waste powder as alternative materials for sustainable construction practices. Further studies may be carried out to

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5. The controlled heating arrangement adopted in the study helped in reducing direct emission of gases during melting of plastic waste. The emitted gases were cooled using a water-cooled arrangement based on the principle of controlled pyrolysis, making the process comparatively environmentally safer than open burning methods.
6. The experimental results demonstrate that multilayer plastic waste and brick waste powder can be effectively utilized for the production of sustainable composite construction blocks suitable for lightweight and non-structural construction applications.
7. The utilization of waste materials in construction applications can significantly contribute towards plastic waste management, reduction of landfill disposal, conservation of natural resources, and development of eco-friendly construction materials.
8. investigate durability characteristics, long-term performance, thermal behavior, and large-scale field applications of the developed composite blocks
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