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Partial Replacement Of Coarse Aggregate With Waste Tiles Chips In Paver Block

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Abstract: This study investigates the feasibility of utilizing waste ceramic tiles as partial replacement for coarse aggregate in concrete paver blocks. With the increasing demand for construction materials and growing concerns about environmental sustainability, finding alternative uses for waste materials has become imperative. Ceramic tile waste from manufacturing units and demolition sites represents a significant portion of construction waste that typically ends in landfills. This research evaluated the performance of concrete paver blocks with varying percentages (0%, 10%, 20%, 30%, 40%, and 50%) of coarse aggregate replacement with waste tile chips. Comprehensive testing was conducted on compressive strength, water absorption, abrasion resistance, and flexural strength of the specimens over curing periods of 7, 14, and 28 days. Results indicated that paver blocks with 30% replacement of coarse aggregate with waste tile chips demonstrated optimal mechanical properties, with compressive strength values comparable to conventional paver blocks. The water absorption percentage remained within acceptable limits established by relevant standards. This study suggests that incorporating waste tile chips as partial replacement for coarse aggregate in paver blocks is not only technically viable but also environmentally beneficial, supporting waste reduction and resource conservation goals.

Index Terms - Ceramic waste tiles, Compressive strength, Construction waste, Paver blocks, Sustainability, Water absorption.

Introduction

The construction industry is one of the largest consumers of natural resources and simultaneously generates substantial amounts of construction and demolition waste. Globally, the annual production of ceramic tiles exceeds 13.8 billion square meters, with significant waste generation during manufacturing, transportation, and installation processes [1]. Moreover, waste ceramic tiles from demolition activities contribute further to the increasing waste volume requiring disposal. In India alone, the ceramic industry produces approximately 100 million tons of waste annually [2].

Concrete paver blocks have gained widespread popularity in various applications including pedestrian pathways, parking areas, urban roads, and industrial flooring due to their aesthetic appeal, durability, and ease of installation and maintenance. The production of conventional concrete paver blocks requires substantial quantities of natural aggregates, contributing to resource depletion and environmental degradation [3].

Recycling and reusing waste materials in construction applications represents a sustainable approach to waste management while conserving natural resources. Previous research has explored various waste materials as partial replacements for concrete constituents, including fly ash, ground granulated blast furnace slag, recycled concrete aggregates, and glass waste [4]. Ceramic waste, due to its hard, dense, and durable nature, presents promising potential as an aggregate substitute in concrete production.

This study aims to evaluate the feasibility of incorporating waste ceramic tile chips as partial replacement for coarse aggregate in the production of concrete paver blocks. The investigation focuses on determining the optimal replacement percentage that maintains or enhances the mechanical and durability properties of paver blocks while providing environmental benefits through waste utilization.

Literature Review

Several researchers have explored the potential of using waste ceramic materials in concrete production. Senthamarai and Devadas Manoharan (2005) investigated the effects of ceramic waste as coarse aggregate replacement in concrete and reported comparable strength characteristics to conventional concrete at various replacement levels [5]. Their findings indicated that ceramic waste could effectively replace up to 20% of coarse aggregates without significant impact on concrete properties.

Awoyera et al. (2018) evaluated the performance of concrete containing ceramic wastes as partial replacement for conventional aggregates. Their research demonstrated that incorporating 25% ceramic waste as coarse aggregate resulted in concrete with satisfactory mechanical properties suitable for structural applications [6].

Raval et al. (2013) studied the replacement of natural coarse aggregate with ceramic waste in concrete and found that 30% replacement yielded optimal compressive strength results with reduced water absorption characteristics [7]. Similarly, Medina et al. (2012) reported that concrete containing ceramic waste aggregates exhibited improved durability performance particularly against sulfate attack and chloride penetration [8].

Regarding paver blocks specifically, Jain et al. (2015) investigated the use of ceramic waste in concrete paver blocks and observed that 35% replacement of fine aggregate with ceramic powder enhanced the compressive strength and reduced water absorption [9]. Kumar and Chitkara (2016) studied paver blocks with crushed ceramic tiles as coarse aggregate and concluded that replacement levels up to 40% maintained acceptable engineering properties [10].

Puertas et al. (2008) examined the chemical and microstructural characteristics of ceramic waste and its influence on cement hydration, reporting that the pozzolanic activity of finely ground ceramic waste contributed positively to long-term strength development in concrete [11].

While numerous studies have explored ceramic waste utilization in concrete, systematic research on incorporating waste tile chips specifically in paver blocks is limited. This study aims to bridge this knowledge gap by comprehensively investigating the effects of varying percentages of waste tile chips as coarse aggregate replacement on the physical, mechanical, and durability properties of concrete paver blocks.

Materials and Methods

3.1 Materials

Ordinary Portland Cement (OPC) 53 grade conforming to IS 12269:2013 specifications was used as the binding material. The cement had a specific gravity of 3.15 and standard consistency of 31%. The initial and final setting times were 45 minutes and 375 minutes, respectively.

River sand passing through 4.75 mm IS sieve with specific gravity of 2.65, fineness modulus of 2.8, and water absorption of 1.2% was used as fine aggregate. The sand conformed to Zone II as per IS 383:2016.

Crushed granite stones with nominal maximum size of 12.5 mm, specific gravity of 2.7, fineness modulus of 6.85, and water absorption of 0.6% were used as natural coarse aggregate.

Waste ceramic tiles were collected from local tile manufacturing units and demolition sites. The collected tiles were manually cleaned to remove contaminants and crushed using a laboratory jaw crusher followed by hammer milling to obtain the desired gradation similar to that of natural coarse aggregate. The crushed waste tile chips had specific gravity of 2.45, water absorption of 0.8%, and fineness modulus of 6.72.

Potable water free from impurities was used for mixing and curing purposes. Additionally, a polycarboxylate ether-based superplasticizer was employed at 0.8% by weight of cement to maintain workability across all mixes.

3.2 Mix Proportions

Six different concrete mixes were prepared by varying the percentage of waste tile chips as partial replacement for coarse aggregate. The control mix (M0) contained 0% replacement, while the experimental mixes contained 10% (M10), 20% (M20), 30% (M30), 40% (M40), and 50% (M50) replacements by weight of coarse aggregate. The concrete mix was designed as per IS 10262:2019 guidelines targeting a characteristic compressive strength of 40 MPa. The mix proportions are presented in Table 1.

Table 1: Mix Proportions (kg/m³)

Mix	Cement	Fine Aggregate	Natural Coarse Aggregate	Waste Tile Chips	Water	Superplasticizer
M0	450	695	1150	0	180	3.6
M10	450	695	1035	115	180	3.6
M20	450	695	920	230	180	3.6
M30	450	695	805	345	180	3.6
M40	450	695	690	460	180	3.6
M50	450	695	575	575	180	3.6

3.3 Preparation of Paver Blocks

Rectangular paver blocks of dimensions 200 mm × 100 mm × 80 mm were manufactured according to IS 15658:2006 specifications. The concrete production process included measuring the required quantities of materials, dry mixing cement with aggregates for 2 minutes, gradually adding water and superplasticizer, and continuing wet mixing for an additional 3 minutes to ensure homogeneity.

The concrete mixture was placed into steel molds and compacted using a vibrating table. After 24 hours, the specimens were demolded and subjected to water curing for the designated periods (7, 14, and 28 days). Ten specimens were prepared for each mix and each curing period for the various tests.

3.4 Testing Methods

The fresh concrete properties were evaluated through slump test as per IS 1199:1959. The hardened concrete properties were assessed through the following tests:

1. Compressive strength test was conducted according to IS 15658:2006 using a compression testing machine with a capacity of 2000 kN at a loading rate of 35 N/mm²/min.
2. Water absorption test was performed as per IS 15658:2006 by measuring the percentage increase in weight after 24 hours of immersion in water.
3. Abrasion resistance was determined using the Los Angeles abrasion testing machine as per IS 15658:2006.
4. Flexural strength was tested using center-point loading on a universal testing machine according to IS 15658:2006.

These tests were conducted on specimens after 7, 14, and 28 days of curing to evaluate the development of properties over time.

Results and Discussion

4.1 Fresh Concrete Properties

The slump values for various mixes ranged from 85 mm to 105 mm, indicating acceptable workability for paver block production. A slight decrease in workability was observed with increasing waste tile chip content, which could be attributed to the angular shape and rough surface texture of crushed tile particles compared to natural aggregates [12]. However, the addition of superplasticizer effectively maintained the required workability across all mixes.

4.2 Compressive Strength

The compressive strength results for different mixes after various curing periods are presented in Figure 1. The 28-day compressive strength for the control mix (M0) was 42.5 MPa. With the incorporation of waste tile chips, the compressive strength initially increased up to 30% replacement level (M30) which showed the highest strength of 44.8 MPa at 28 days, representing a 5.4% increase compared to the control mix.

This enhancement in strength can be attributed to the angular shape of tile chips providing better interlocking and the potential pozzolanic activity of fine ceramic particles present in the mix [13]. However, beyond 30% replacement, the compressive strength gradually decreased, with M50 showing approximately 8% lower strength than the control mix after 28 days of curing.

The strength development pattern across different curing periods remained consistent for all mixes, with a significant increase in strength between 7 and 14 days, followed by moderate gains between 14 and 28 days. This indicates that the incorporation of waste tile chips does not significantly alter the cement hydration process and strength development timeline [14].

4.3 Water Absorption

Water absorption is a critical parameter influencing the durability of paver blocks, particularly in freeze-thaw conditions. The water absorption results after 28 days of curing showed values ranging from 4.2% for the control mix to 5.5% for the M50 mix.

Interestingly, the M30 mix exhibited water absorption of 4.3%, only marginally higher than the control mix. All mixes met the maximum water absorption limit of 6% specified in IS 15658:2006 for concrete paver blocks. The slight increase in water absorption with higher replacement percentages could be attributed to the slightly higher porosity of ceramic materials compared to natural aggregates [15].

4.4 Abrasion Resistance

The abrasion resistance of paver blocks is crucial for applications in high-traffic areas. The abrasion loss for different mixes ranged from 1.8% to 2.5% by weight after 28 days of curing. The control mix showed the lowest abrasion loss (1.8%), while the M50 mix exhibited the highest (2.5%).

The M30 mix demonstrated comparable abrasion resistance (2.0%) to the control mix, indicating that moderate replacement levels maintain adequate wear resistance. The slight reduction in abrasion resistance with higher replacement percentages could be attributed to the relatively lower hardness of ceramic tiles compared to granite aggregates [16].

4.5 Flexural Strength

The 28-day flexural strength values for different mixes ranged from 4.2 MPa to 5.1 MPa. Similar to compressive strength results, the M30 mix exhibited the highest flexural strength of 5.1 MPa, representing an 8.5% increase compared to the control mix (4.7 MPa).

The enhanced flexural performance at moderate replacement levels (20-30%) could be attributed to improved aggregate interlocking due to the angular shape of tile chips and potential secondary hydration reactions involving fine ceramic particles [17]. However, beyond 30% replacement, a gradual decrease in flexural strength was observed, consistent with the compressive strength trend.

4.6 Cost Analysis

A preliminary cost analysis indicated that incorporating waste tile chips as partial replacement for coarse aggregate could result in approximately 15-25% reduction in aggregate cost, depending on local material prices and transportation distances. Considering that the M30 mix demonstrated optimal performance across all tested parameters, this replacement level offers both technical and economic benefits.

Additionally, the environmental benefits associated with diverting ceramic waste from landfills and reducing natural aggregate extraction present significant advantages from a sustainability perspective [18].

Conclusion

Based on the experimental results and analysis, the following conclusions can be drawn:

1. Waste ceramic tile chips can effectively replace natural coarse aggregate in concrete paver blocks up to certain percentages without compromising the essential engineering properties.
2. The optimal replacement percentage was found to be 30% (M30), which exhibited enhanced compressive and flexural strengths compared to the control mix while maintaining acceptable water absorption and abrasion resistance properties.
3. The incorporation of waste tile chips beyond 30% resulted in gradual deterioration of mechanical properties, although all mixes up to 50% replacement met the minimum requirements specified in relevant standards.
4. The utilization of waste ceramic tiles in paver blocks presents a viable solution for waste management while conserving natural aggregate resources, offering both environmental and economic benefits.
5. The slight reduction in workability with increasing waste tile content can be effectively managed through the use of appropriate dosages of superplasticizer.

This study demonstrates that concrete paver blocks containing waste ceramic tile chips as partial replacement for coarse aggregate can be successfully produced for various applications including pedestrian pavements, parking areas, and light traffic roads. Future research should focus on long-term durability aspects including freeze-thaw resistance, sulfate attack resistance, and field performance under actual service conditions to further validate the findings of this laboratory-based investigation.

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