

OPTIMIZATION OF ROAD PAVEMENT MATERIALS: THE EFFECT OF TILE REPLACEMENT IN WET MIX MACADAM

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Abstract: Road construction activities require large quantities of natural aggregates, leading to rapid depletion of natural resources and increased environmental concerns. At the same time, ceramic tile waste generated from construction and demolition activities creates serious disposal problems. This study investigates the feasibility of using ceramic tile waste as a partial replacement for natural coarse aggregates in Wet Mix Macadam (WMM). Ceramic tile waste was crushed into suitable sizes and tested for engineering properties such as Aggregate Crushing Value, Aggregate Impact Value, Water Absorption, and Los Angeles Abrasion Value. The experimental results showed that tile waste aggregates exhibited slightly higher crushing, impact, abrasion, and water absorption values compared to natural aggregates. However, all values remained within IRC permissible limits for pavement construction. The study concludes that ceramic tile waste can be effectively utilized in WMM as a sustainable and cost-effective alternative material. Its use helps reduce environmental pollution, minimizes landfill disposal, and conserves natural aggregate resources, thereby promoting sustainable pavement construction practices.

Keywords: Ceramic Tile Waste, Wet Mix Macadam, Sustainable Pavement, Aggregate Replacement, Road Construction, Waste Management.

INTRODUCTION

The rapid growth of infrastructure and transportation networks has significantly increased the demand for construction materials, particularly natural aggregates used in road pavement construction. Aggregates form the major component in pavement layers such as Wet Mix Macadam (WMM), base courses, and sub-base layers. Continuous extraction of natural aggregates from quarries and riverbeds has resulted in depletion of natural resources, environmental degradation, ecological imbalance, and increased construction costs. Therefore, the need for sustainable and eco-friendly alternative materials has become highly important in modern pavement engineering. Simultaneously, the construction industry generates a huge quantity of construction and demolition (C&D) waste every year. Ceramic tile waste is one of the major constituents of this waste generated from tile manufacturing industries, building construction, renovation works, and demolition activities. Large quantities of broken and rejected ceramic tiles are disposed into landfills, causing serious environmental concerns such as land pollution and waste management problems. Since ceramic materials are non-biodegradable in nature, their disposal occupies valuable landfill space and adversely affects the environment.

In recent years, researchers and engineers have focused on recycling waste materials in civil engineering applications to promote sustainable development. Utilization of industrial and construction waste materials in pavement construction not only reduces environmental pollution but also minimizes dependency on natural resources. Among the various waste materials, ceramic tile waste has shown considerable potential because of its hardness, durability, and resistance to chemical attack. Crushed ceramic tiles possess physical properties similar to natural aggregates and can therefore be used as a substitute material in pavement layers. Wet Mix Macadam (WMM) is an important layer in flexible pavement construction and serves as a load-distributing layer between the sub-base and bituminous layers. It consists of graded aggregates mixed with water at optimum moisture content and compacted to achieve maximum density. The quality of aggregates used in WMM directly affects pavement strength, stability, durability, and service life. Hence, evaluating alternative aggregates such as ceramic tile waste becomes essential before their implementation in road construction.

The use of ceramic tile waste in WMM offers several advantages. It reduces the disposal problems associated with construction waste and promotes sustainable waste management practices. It also conserves natural aggregate resources and decreases the environmental impact caused by quarrying operations. Additionally, the use of recycled materials can reduce overall construction costs, making pavement projects more economical. Several studies conducted by researchers have shown that ceramic tile waste exhibits satisfactory engineering properties when used as a replacement for natural aggregates. Properties such as crushing strength, abrasion resistance, impact resistance, and water absorption are found to be within acceptable limits for pavement applications. However, due to the brittle nature of ceramic materials, certain mechanical properties may slightly differ from conventional aggregates. Therefore, detailed laboratory investigations are necessary to evaluate their suitability for WMM applications.

The present study aims to investigate the feasibility of using ceramic tile waste as a partial replacement for natural coarse aggregates in Wet Mix Macadam. Laboratory tests including Aggregate Crushing Value Test, Aggregate Impact Value Test, Water Absorption Test, and Los Angeles Abrasion Test were conducted on both natural aggregates and ceramic tile waste aggregates. The obtained results were compared to determine the engineering performance and suitability of tile waste in pavement construction. This study

contributes toward sustainable pavement engineering by promoting the reuse of construction waste materials in road infrastructure. The successful utilization of ceramic tile waste in WMM can reduce environmental pollution, conserve natural resources, and encourage the development of eco-friendly construction practices.

NEED OF THE STUDY.

The increasing demand for natural aggregates in road construction has resulted in depletion of natural resources and environmental degradation. Simultaneously, large quantities of ceramic tile waste generated from construction and demolition activities create serious disposal and landfill problems. Utilizing ceramic tile waste in Wet Mix Macadam (WMM) can reduce environmental pollution, conserve natural resources, and promote sustainable construction practices. Since WMM requires large quantities of aggregates, partial replacement with ceramic tile waste can provide an economical and eco-friendly alternative. Therefore, this study is necessary to evaluate the engineering properties and suitability of ceramic tile waste for sustainable pavement construction.

LITERATURE REVIEW

1. Ram Vilas Meena et al. (2025)

Ram Vilas Meena and associates examined the effect of crushed ceramic waste tiles on self-compacting concrete. The study focused on replacing fine aggregates with ceramic tile waste in varying proportions. Mechanical tests and durability tests under wetting and drying cycles were conducted. The results showed improved compressive strength, enhanced durability, and satisfactory workability characteristics. The study recommended ceramic tile waste as an environmentally sustainable material for concrete applications.

2. Rabehi Bahia et al. (2025)

Rabehi Bahia and co-authors investigated the recycling of ceramic tile waste in self-compacting concrete. Natural aggregates were replaced with ceramic tile waste in proportions of 25%, 50%, 75%, and 100%. Experimental investigations included slump flow tests, compressive strength tests, and flexural strength tests. The study concluded that replacement levels up to 75% maintained satisfactory mechanical performance and workability. The researchers highlighted the importance of ceramic waste recycling in minimizing landfill disposal and conserving natural resources.

3. Xi Yi Lim et al. (2025)

Xi Yi Lim and researchers studied the utilization of ceramic tile waste in normal concrete by replacing conventional coarse aggregates. Tests such as compressive strength and flexural strength were performed. The results indicated that approximately 20% replacement improved strength characteristics while maintaining durability. The study emphasized that ceramic tile waste can serve as an effective alternative aggregate material in sustainable construction.

4. Sumit Basak et al. (2024)

Sumit Basak and colleagues evaluated the performance of ceramic tile waste as a partial replacement for brick aggregates in concrete. Different replacement percentages including 0%, 25%, 50%, and 75% were studied. Tests on water absorption, compressive strength, and durability were carried out. The results showed improved strength up to 50% replacement and acceptable durability characteristics. The researchers concluded that ceramic tile waste can be effectively used as an economical and sustainable construction material.

5. Ghasan F. Huseien et al. (2025)

Ghasan F. Huseien presented a comprehensive review on recycling waste ceramic tiles in green concrete. The review summarized the findings of several experimental studies related to ceramic waste utilization in construction. The study reported that ceramic tile waste enhances durability, reduces environmental pollution, and minimizes landfill disposal. The authors concluded that ceramic waste has strong potential for sustainable infrastructure development.

6. Anoop Narain Singh et al. (2021)

Anoop Narain Singh and co-authors studied the use of ceramic tile waste as a replacement for cement and aggregates in construction materials. Mechanical tests conducted in the study showed satisfactory compressive and tensile strength properties. The researchers observed that ceramic waste can effectively improve sustainability when used within permissible replacement limits.

7. Poon and Chan (2006)

Poon and Chan investigated the use of recycled aggregates in construction applications. Their research focused on the mechanical behavior and durability performance of recycled aggregate concrete. The study highlighted that recycled materials can reduce environmental degradation and conserve natural resources while maintaining satisfactory engineering performance.

8. Medina et al. (2012)

Medina and co-researchers examined the influence of ceramic waste on the mechanical properties of concrete. Their study revealed that ceramic waste aggregates improve compressive strength and exhibit acceptable water absorption characteristics. The authors concluded that ceramic waste can be effectively utilized in structural and pavement applications.

9. Sharma and Gupta (2018)

Sharma and Gupta conducted a study on the sustainable use of ceramic waste in construction materials. The research emphasized environmental benefits such as reduction in landfill disposal and conservation of natural aggregates. Experimental results indicated that ceramic tile waste possesses suitable physical and mechanical properties for pavement applications.

10. Reddy and Rao (2020)

Reddy and Rao specifically studied the utilization of tile waste in Wet Mix Macadam. Their research focused on evaluating crushing value, impact value, and abrasion resistance of tile waste aggregates. The study concluded that ceramic tile waste can be safely used in WMM layers within permissible IRC limits.

11. Patel and Desai (2021) Patel and Desai evaluated the performance of ceramic waste as aggregate replacement material in pavement construction. Laboratory investigations indicated that ceramic waste aggregates possess adequate abrasion resistance and load-bearing capacity. The authors recommended the use of ceramic waste in low-volume roads and sustainable pavement systems.

OVERALL SUMMARY OF LITERATURE REVIEW

From the literature reviewed, it is evident that ceramic tile waste possesses acceptable engineering properties and significant environmental benefits when used as a replacement for natural aggregates. Most researchers reported satisfactory compressive strength, durability, abrasion resistance, and sustainability performance. The studies collectively indicate that ceramic tile waste

can be effectively utilized in pavement and concrete applications while reducing environmental pollution and conserving natural resources. However, limited research is available regarding the application of ceramic tile waste specifically in Wet Mix Macadam layers. Therefore, the present study focuses on evaluating the suitability of ceramic tile waste in WMM through detailed laboratory investigations.

III. MATERIALS AND METHODOLOGY

The methodology involved collection of ceramic tile waste, crushing into required sizes, and preparation of WMM mixes with varying replacement percentages. The following materials were used:

- Natural Coarse Aggregates
- Ceramic Tile Waste
- Fine Aggregates (Stone Dust)
- Water

The experimental program included the following tests:

1. Aggregate Crushing Value Test
2. Aggregate Impact Value Test
3. Water Absorption Test
4. Los Angeles Abrasion Test

The present study investigates the feasibility of using ceramic tile waste as a partial replacement for natural coarse aggregates in Wet Mix Macadam (WMM) for sustainable pavement construction. The methodology adopted in this study includes collection of materials, preparation of tile waste aggregates, laboratory testing, and analysis of engineering properties according to IRC specifications.

Table 1: Environmental Benefits of Tile Waste Utilization

Benefit	Description
Reduction in landfill waste	Ceramic tile waste disposal problem is minimized.
Conservation of natural resources	Less quarrying of natural aggregates is required.
Cost effectiveness	Reduced material procurement costs in road projects.
Sustainable construction	Promotes eco-friendly pavement construction practices.
Lower environmental pollution	Reduces dust, mining, and waste accumulation.

The materials used in the study were natural coarse aggregates, ceramic tile waste, fine aggregates (stone dust), and water. Natural coarse aggregates were collected from a local quarry and used as conventional aggregates in the WMM mix. These aggregates possess good strength, durability, and load-bearing capacity required for pavement construction. Ceramic tile waste was collected from construction and demolition sites, tile shops, and renovation activities. The waste tiles were cleaned to remove impurities such as dust and cement mortar, and then crushed into suitable sizes using mechanical crushing methods. The crushed tile waste was sieved and graded according to WMM requirements. Fine aggregates in the form of stone dust were used to fill the voids between coarse aggregates and improve the density and stability of the mix. Clean potable water was used for mixing and compaction purposes.

The experimental methodology involved several stages. Initially, the collected materials were prepared and graded according to IRC standards for Wet Mix Macadam. Ceramic tile waste aggregates were partially substituted in place of natural coarse aggregates. Laboratory tests were then conducted on both natural aggregates and tile waste aggregates to determine their engineering properties and suitability for pavement applications.

The Aggregate Crushing Value Test was conducted to determine the resistance of aggregates against compressive loads. The test results showed a crushing value of 22% for natural aggregates and 26% for ceramic tile waste aggregates. The Aggregate Impact Value Test was carried out to evaluate the toughness of aggregates under sudden impact loads. The impact value obtained for natural aggregates was 18%, whereas tile waste aggregates showed 23%. Water Absorption Test was performed to determine the porosity characteristics of aggregates. The results indicated water absorption values of 0.8% for natural aggregates and 1.9% for ceramic tile waste aggregates. Los Angeles Abrasion Test was conducted to determine the resistance of aggregates against wear and abrasion caused by traffic movement. The abrasion values obtained were 30% for natural aggregates and 37% for tile waste aggregates.

The experimental results indicate that ceramic tile waste aggregates exhibit slightly lower strength characteristics and higher water absorption compared to natural aggregates due to their brittle and porous nature. However, all the obtained values were found to be within IRC permissible limits for Wet Mix Macadam applications. Therefore, ceramic tile waste can be effectively utilized as a sustainable and economical alternative material in pavement construction while reducing environmental pollution and conserving natural resources.

IV. RESULTS AND DISCUSSION

The experimental results obtained from laboratory testing are presented below. Tile waste aggregates showed slightly higher crushing, impact, water absorption, and abrasion values compared to natural aggregates. However, all values remained within IRC permissible limits.

Table 2: Comparison of Aggregate Properties

Test	Natural Aggregate	Tile Waste Aggregate	IRC Limit	Status
Crushing Value	22	26	30	Within Limit
Impact Value	18	23	30	Within Limit

Water Absorption	0.8	1.9	2	Within Limit
LA Abrasion	30	37	40	Within Limit

Table 3: Percentage Increase in Tile Waste Aggregate Values

Property	Increase (%)	Inference
Crushing Value	18.18	Minor variation
Impact Value	27.78	Moderate increase
Water Absorption	137.5	Significant increase
LA Abrasion	23.33	Moderate increase

Graphical Representation of Results

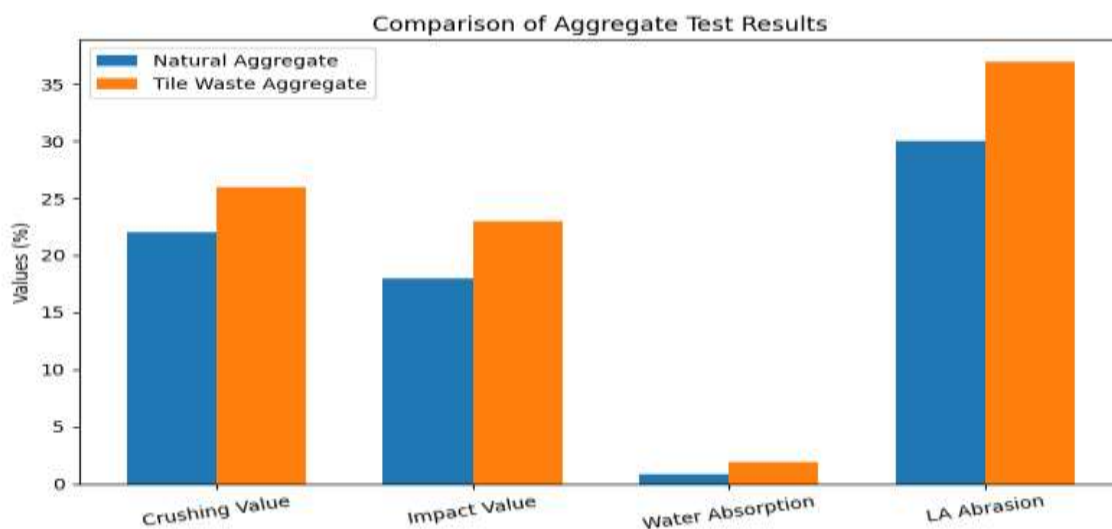


Figure 1: Bar Graph Showing Comparison of Aggregate Test Results

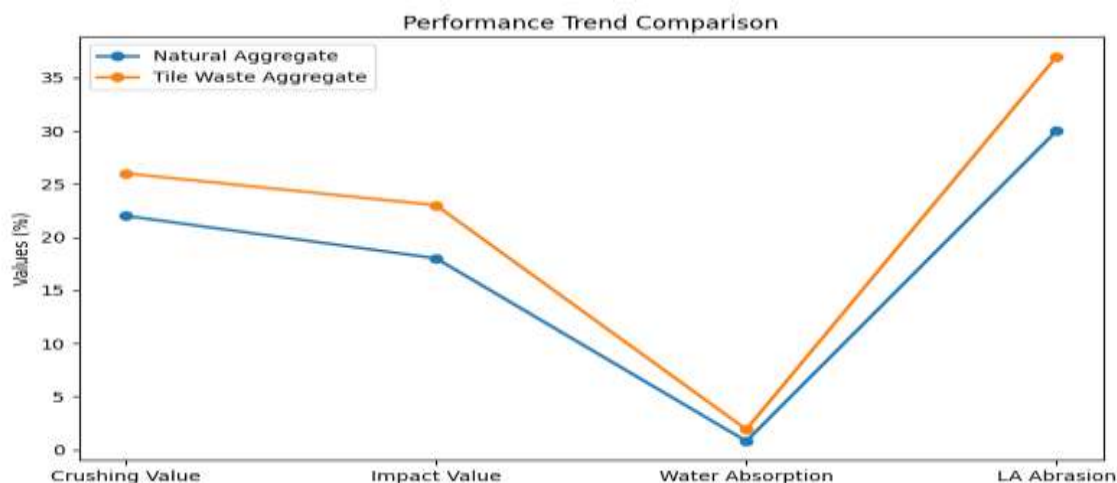


Figure 2: Line Graph Showing Performance Trends

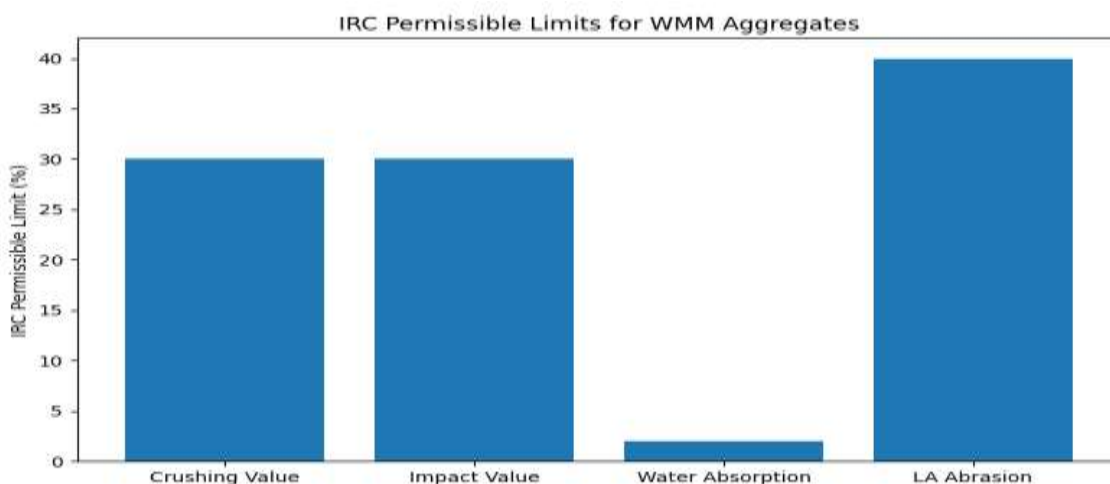


Figure 3: IRC Permissible Limits for WMM Aggregates

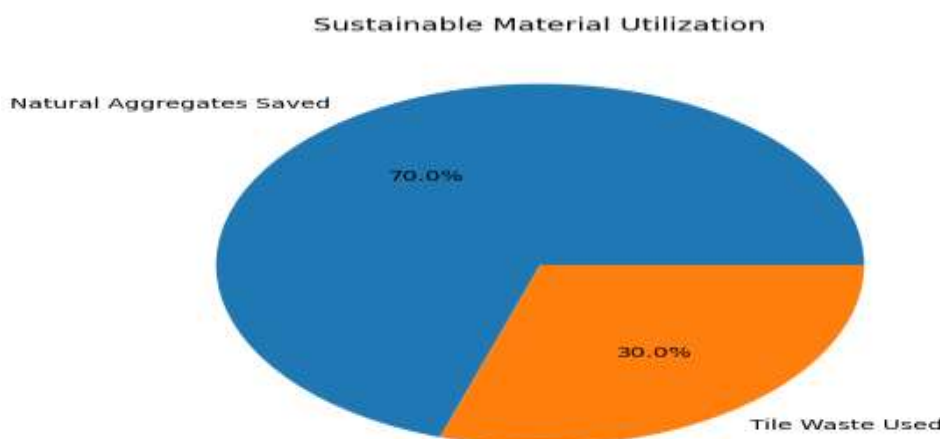


Figure 4: Sustainability Contribution of Tile Waste

V. INTERPRETATION OF RESULTS

The experimental investigation clearly indicates that ceramic tile waste aggregates can be effectively utilized in Wet Mix Macadam applications. Although the tile waste aggregates showed slightly higher crushing value, impact value, water absorption and abrasion value compared to conventional natural aggregates, all obtained results were found to be within IRC permissible limits. The crushing value of tile waste aggregate was observed to be 26%, which indicates acceptable resistance against compressive loading. Similarly, the impact value of 23% demonstrates sufficient toughness for pavement applications. The water absorption value was slightly higher because ceramic materials possess porous characteristics. However, the value remained within permissible standards. The Los Angeles abrasion value of 37% also confirms that the material has adequate wear resistance under traffic loading. The environmental analysis further confirms that utilization of ceramic tile waste reduces landfill disposal problems and minimizes depletion of natural aggregate resources. Hence, the use of ceramic tile waste contributes significantly toward sustainable pavement engineering.

The results indicate that natural aggregates perform better in terms of strength and durability compared to ceramic tile waste aggregates. Tile waste aggregates exhibited higher crushing and impact values, indicating slightly lower resistance to compressive and impact loads. Water absorption values were also higher due to the porous nature of ceramic materials. Despite these differences, the properties of ceramic tile waste aggregates remained within acceptable IRC limits, making them suitable for use in WMM layers.

VI. CONCLUSION

Based on the laboratory investigation and analytical interpretation, ceramic tile waste can be safely recommended as a partial replacement material in Wet Mix Macadam construction. The study confirms that tile waste aggregates satisfy IRC requirements and provide environmental as well as economic benefits. Therefore, ceramic tile waste can be considered a sustainable alternative material for modern pavement construction.

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