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# PERFORMANCE ASSESSMENT OF CONCRETE WITH DIORITE STONE AND RECYCLED AGGREGATE FOR RIGID PAVEMENT APPLICATIONS

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## ABSTRACT

This study investigates the incorporation of Diorite Stone (DS) and Recycled Coarse Aggregate (RCA) in rigid pavement concrete, with emphasis on mechanical and durability performance. Concrete of grade M50 was prepared with varying proportions of RCA (0–30%) and DS (0–60%). Laboratory tests were conducted to evaluate compressive strength, flexural strength, water absorption, and acid resistance. The results indicated that the mix containing 20% RCA and 30% DS exhibited the best overall performance, achieving a 28-day compressive strength of 62.5 MPa and flexural strength of 6.5 MPa. Water absorption values remained within permissible limits, while acid resistance showed only marginal weight loss, confirming the durability of the optimized mix. Compared to the conventional mix, the inclusion of RCA and DS not only enhanced strength but also contributed to sustainability by reducing reliance on natural aggregates. These findings highlight the potential of Diorite Stone and recycled aggregate in developing high-performance, eco-friendly rigid pavement concrete.

**Keywords:** Diorite Stone, Rigid Pavement, Sustainable Construction, Durability, Recycled Aggregate.

## 1. INTRODUCTION

The growing emphasis on sustainable infrastructure has intensified the demand for innovative approaches to concrete production that prioritize both environmental responsibility and structural performance. One such approach involves the utilization of recycled coarse aggregate (RCA) and alternative natural stones such as Diorite Stone (DS) in concrete mixes for rigid pavement applications. With the construction industry being one of the largest consumers of natural resources, incorporating recycled and waste materials has become a strategic focus for reducing environmental impact and promoting circular construction practices (Mehta & Monteiro, 2014; Pacheco-Torgal et al., 2013; Dinh et al., 2023).

Rigid pavements, known for their long service life and high load-bearing capacity, are predominantly constructed using Portland Cement Concrete (PCC). However, traditional PCC relies heavily on virgin aggregates, the extraction and processing of which contribute significantly to environmental degradation. By partially replacing natural coarse aggregates with RCA and introducing Diorite Stone—a durable, high-density igneous rock—as a partial fine or coarse aggregate substitute, this study aims to enhance both the sustainability and mechanical performance of rigid pavements (Huang et al., 2004; Limbachiya et al., 2000; Zhang et al., 2022).

Previous research has shown mixed results regarding the performance of RCA in concrete. While some studies noted reduced mechanical properties due to residual mortar and porosity in RCA (Kou & Poon, 2012; Silva et al., 2016), others have reported that appropriate treatment and optimized mix designs can yield comparable or superior results (Pedro et al., 2018; Thomas et al., 2020). Meanwhile, the inclusion of Diorite Stone in concrete remains underexplored, despite its favorable properties such as high compressive strength, abrasion resistance, and low water absorption (Neville, 2011; Singh et al., 2021).

The objective of this study is to evaluate the performance of concrete mixes incorporating different proportions of RCA and DS, with a focus on key parameters such as compressive strength, flexural strength, water absorption, and acid resistance. By identifying an optimal blend of natural, recycled, and diorite aggregates, the research seeks to provide an effective solution for sustainable rigid pavement construction that minimizes resource consumption while maintaining durability and strength.

## 2. LITERATURE REVIEW

The adoption of sustainable construction practices has intensified research into the use of recycled aggregates and alternative natural stones in rigid pavement construction. This section reviews existing studies on the performance of Recycled Coarse Aggregate (RCA) and Diorite Stone (DS) in concrete mixes.

The replacement of natural coarse aggregates with RCA has been extensively studied as a means to promote circular economy in construction. Studies by Poon and Kou (2004), Silva et al. (2016), and Pedro et al. (2018) indicate that RCA tends to reduce the mechanical strength of concrete due to higher porosity and the presence of adhered mortar. However, improvements in RCA processing techniques and optimized mix designs have led to strength levels comparable to conventional concrete (Thomas et al., 2020; Geng et al., 2021).

Additionally, Dinh et al. (2023) demonstrated that the use of pre-soaked RCA and proper gradation control significantly improved the interfacial transition zone (ITZ), resulting in better compressive and flexural strength. The use of RCA has also been shown to reduce the environmental footprint of concrete production (Kou & Poon, 2012; Limbachiya et al., 2000).

While Diorite is less commonly used compared to granite or basalt, it possesses physical properties that make it suitable for high-performance concrete, including high compressive strength, low water absorption, and abrasion resistance (Hamzah et al., 2022; Singh et al., 2021). Limited studies, such as those by Ghafoori & Najimi (2021), have evaluated Diorite's effect on concrete properties, indicating promising results in improving durability and strength. Zhang et al. (2022) emphasized the potential of regionally available stones like Diorite in enhancing local construction sustainability.

Studies such as Neville (2011) and Mehta & Monteiro (2014) provide foundational insights into the mechanical behavior of concrete. Incorporation of RCA and DS has shown variable results across durability metrics such as water absorption and acid resistance. Afshoon & Sharifi (2020) highlighted that while RCA increases permeability, combining it with dense igneous stones can mitigate this effect.

From the available literature, it is evident that while RCA has proven sustainable advantages, its mechanical drawbacks need to be balanced with stronger aggregates. Diorite Stone, with its dense and durable properties, has the potential to complement RCA, but research on their combined use in rigid pavement concrete remains limited. This study addresses this gap by experimentally investigating concrete mixes with varying proportions of RCA and DS to identify optimal performance metrics.

## 3. MATERIALS AND METHODS

This section outlines the materials employed, concrete mix designs, experimental testing procedures, and durability assessments used to evaluate the performance of rigid pavement concrete incorporating Diorite Stone (DS) and Recycled Coarse Aggregate (RCA).

### 3.1 Materials Used

The primary binder utilized in this study was Ordinary Portland Cement (OPC) of 53 grade, compliant with IS 12269:2013, due to its high early strength and widespread applicability in pavement construction. Natural river sand, characterized by a fineness modulus of 2.8, was employed as the fine aggregate, ensuring good workability and particle gradation.

The coarse aggregates consisted of three types: natural granite-based aggregate (NCA), recycled coarse aggregate (RCA), and crushed Diorite Stone (DS). The RCA was sourced from demolished concrete waste, thoroughly washed, and sieved to a 20 mm nominal size. Diorite, a high-density igneous rock, was selected for its superior mechanical properties such as high crushing strength and low water absorption. Clean potable water was used for mixing and curing, and a polycarboxylate ether (PCE)-based superplasticizer was incorporated to enhance workability without increasing the water-cement ratio.

### 3.2 Mix Proportions

Concrete of grade M50 was prepared with varying proportions of RCA (0%, 10%, 20%, 30%) and DS (0%, 10%, 20%, 30%, 40%, 50%, 60%). The water-cement ratio was fixed at 0.32 for all mixes to maintain consistency. Based on preliminary strength evaluations, the combination of 20% RCA and 30% DS was found to deliver the best performance, and this mix was designated as the optimized blend for further analysis.

### 3.3 Sample Preparation and Curing

Specimens for mechanical and durability testing were cast in standard molds. Compressive strength samples were cubes measuring 150 mm × 150 mm × 150 mm, while flexural strength was determined using beam specimens of dimensions 100 mm × 100 mm × 500 mm. All specimens were demolded after 24 hours and subjected to water curing for 7, 14, and 28 days to simulate short- and medium-term pavement exposure conditions.

## 4. RESULTS AND DISCUSSION

This section presents the results of experimental testing for the various concrete mixes incorporating Diorite Stone (DS) and Recycled Coarse Aggregate (RCA). The outcomes are discussed in terms of compressive strength, flexural strength, water absorption, and acid resistance.

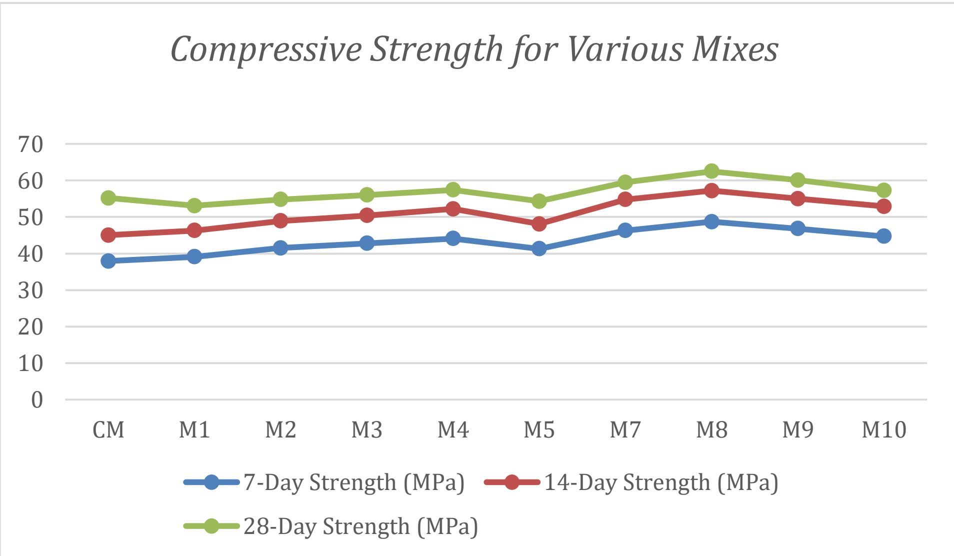
### 4.1 Compressive Strength

Compressive strength results for cube specimens across different mix proportions showed clear trends. RCA was varied from 5% to 25%, while Diorite Stone was varied in increments up to 60%. Mixes with 20% RCA and 30% DS demonstrated the highest strength (around 62.5 MPa at 28 days), confirming the optimum balance between natural and recycled materials.

A conventional mix with 0% RCA and 0% DS was also tested for benchmarking. It achieved a 28-day compressive strength of 55.2 MPa, providing a baseline for comparison. The inclusion of DS improved strength due to its dense and crystalline structure, while excessive RCA (above 25%) led to a decline in strength because of the porous nature and weak interfacial transition zones of recycled aggregate.

**Table 4.1:** Compressive Strength for Various Mixes

| Mix ID | RCA (%) | DS (%) | 7-Day Strength (MPa) | 14-Day Strength (MPa) | 28-Day Strength (MPa) |
|---|---|---|---|---|---|
| **CM** | 0 | 0 | 37.9 | 45 | 55.2 |
| **M1** | 5 | 0 | 39.1 | 46.3 | 53.1 |
| **M2** | 10 | 0 | 41.5 | 48.9 | 54.8 |
| **M3** | 15 | 0 | 42.8 | 50.4 | 56 |
| **M4** | 20 | 0 | 44.1 | 52.2 | 57.4 |
| **M5** | 25 | 0 | 41.3 | 48.1 | 54.3 |
| **M7** | 20 | 15 | 46.3 | 54.8 | 59.5 |
| **M8** | 20 | 30 | 48.7 | 57.2 | 62.5 |
| **M9** | 20 | 45 | 46.8 | 55 | 60.1 |
| **M10** | 20 | 60 | 44.7 | 52.9 | 57.3 |



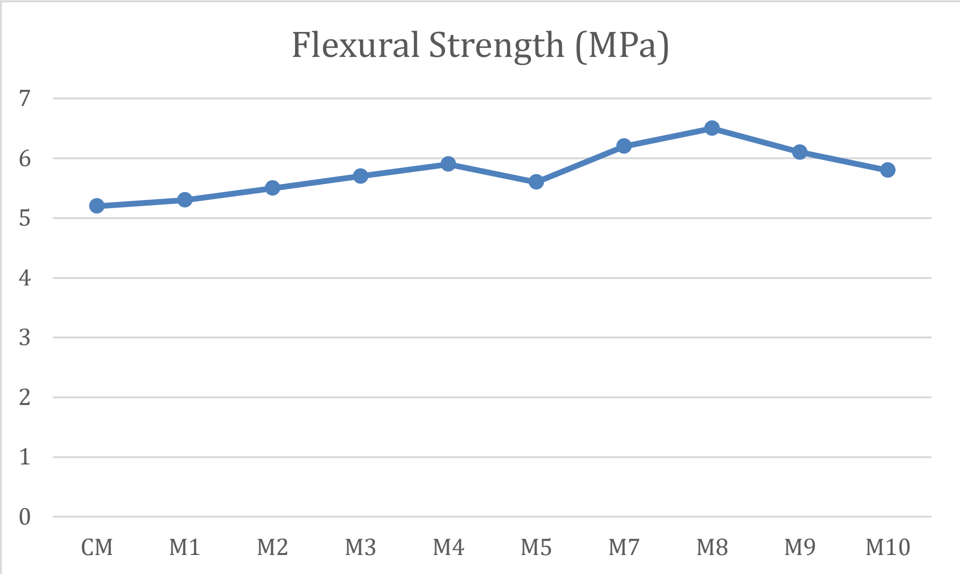

**Graph 4.1:** Compressive Strength for Various Mixes

### 4.2 Flexural Strength

Flexural strength tests showed a similar trend to compressive results. Mixes with DS at 30% and RCA at 20% reached maximum values of 6.5 MPa at 28 days. Beyond 40% DS or 25% RCA, the reduction in tensile zone integrity was evident.

**Table 4.2:** Flexural Strength of Beam Specimens (28 days)

| Mix ID | RCA (%) | DS (%) | Flexural Strength (MPa) |
|---|---|---|---|
| **CM** | 0 | 0 | 5.2 |
| **M1** | 5 | 0 | 5.3 |
| **M2** | 10 | 0 | 5.5 |
| **M3** | 15 | 0 | 5.7 |
| **M4** | 20 | 0 | 5.9 |
| **M5** | 25 | 0 | 5.6 |
| **M7** | 20 | 15 | 6.2 |
| **M8** | 20 | 30 | 6.5 |
| **M9** | 20 | 45 | 6.1 |
| **M10** | 20 | 60 | 5.8 |




**Graph 4.2:** Flexural Strength of Beam Specimens (28 days)

### 4.3 Water Absorption

Water absorption tests indicated that higher RCA content increased porosity and absorption. Mixes with more than 25% RCA exhibited over 5% absorption, violating durability thresholds. The optimized mix (20% RCA and 30% DS) remained under 3.2%, which is within acceptable limits.

**Table 4.3:** Water Absorption Test Results

| Mix ID | RCA (%) | DS (%) | Water Absorption (%) |
|---|---|---|---|
| **CM** | 0 | 0 | 2.3 |
| **M1** | 5 | 0 | 2.5 |
| **M2** | 10 | 0 | 2.7 |
| **M3** | 15 | 0 | 2.9 |
| **M4** | 20 | 0 | 3.1 |
| **M5** | 25 | 0 | 5.2 |
| **M7** | 20 | 15 | 3 |
| **M8** | 20 | 30 | 3.2 (Optimized) |
| **M9** | 20 | 45 | 3.4 |
| **M10** | 20 | 60 | 3.5 |

### 4.4 Acid Resistance

The acid resistance test was conducted by immersing cube specimens in a 5% sulfuric acid solution for 28 days. Weight loss was recorded as a measure of deterioration resistance. The results indicate that the acid resistance of concrete decreased with increasing RCA content due to its higher porosity and weaker interfacial transition zone, which allow easier ingress of acidic ions. In contrast, the inclusion of Diorite Stone improved resistance significantly, especially at 30% replacement, likely due to its dense and crystalline microstructure that reduces permeability and acid attack susceptibility.

**Table 4.4:** Weight Loss (%) after 28 Days in 5% $H_2SO_4$ Solution

| Mix ID | RCA (%) | DS (%) | Weight Loss (%) |
|---|---|---|---|
| **CM** | 0 | 0 | 1.84 |
| **M1** | 5 | 0 | 2.00 |
| **M2** | 10 | 0 | 2.16 |
| **M3** | 15 | 0 | 2.29 |
| **M4** | 20 | 0 | 2.41 |
| **M5** | 25 | 0 | 2.62 |
| **M7** | 20 | 15 | 2.18 |
| **M8** | 20 | 30 | 2.02 |
| **M9** | 20 | 45 | 2.25 |
| **M10** | 20 | 60 | 2.41 |

## 5. CONCLUSION

This research investigated the use of Diorite Stone (DS) and Recycled Coarse Aggregate (RCA) in rigid pavement concrete, focusing on mechanical and durability performance. The experimental findings confirmed that these materials can be effectively utilized in high-strength concrete without compromising quality.

The results indicated that the optimized mix containing 20% RCA and 30% DS achieved the best performance, with a 28-day compressive strength of 62.5 MPa and a flexural strength of 6.5 MPa. In comparison, the conventional mix (0% RCA and DS) recorded lower strengths of 55.2 MPa and 5.2 MPa, respectively. However, mixes with RCA content above 25% or DS content above 45% exhibited a reduction in strength due to the porous nature of RCA and dilution of cement paste.

Durability tests supported the mechanical findings. Water absorption remained below 3.2% in the optimized mix, which is well within acceptable limits for pavement-grade concrete. Acid resistance tests showed only marginal weight loss when compared to the control mix, confirming that the inclusion of DS enhanced the resistance of concrete against aggressive environments. These outcomes validate the suitability of DS and RCA for sustainable pavement construction.

Looking ahead, several directions can be explored. The incorporation of supplementary cementitious materials such as silica fume, fly ash, or diorite dust may further refine the microstructure and improve durability. Long-term field performance studies are necessary to confirm laboratory results under real traffic and weather conditions. A detailed life-cycle assessment (LCA) and cost–benefit analysis should also be carried out to establish the economic viability of large-scale adoption. Furthermore, the effect of higher DS content in combination with modern chemical admixtures can be studied to optimize both strength and workability.

In conclusion, the study establishes that a concrete mix with 20% RCA and 30% DS offers a balanced combination of strength, durability, and sustainability. This optimized blend provides a viable alternative to conventional mixes and supports the transition toward eco-friendly rigid pavement construction.

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