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Evaluating the Performance of Concrete Containing Reclaimed Asphalt Pavement as Coarse Aggregate

Matsyapuri Bhagya Lakshmi[1], Kunamineni Vijay[2] and M. Ashok Kumar[3]
[1]UG Student, Vishnu Institute of Technology/ Civil Engg. Department, Bhimavaram, India
Email: 22PA5AO111@vishnu.edu.in
[2]Assistant Professor, CVR College of Engineering/ Civil Engg. Department, Hyderabad, India
Email: vijay.k@vishnu.edu.in
[3]Assistant Professor, CVR College of Engineering/ Civil Engg. Department, Hyderabad, India
Email: m.ashokkumar@cvr.ac.in

Abstract: **Reclaimed asphalt pavement is a recycled pavement material consisting of asphalt and aggregate that has been treated. The majority of RAP is recycled back into pavements; hence there is a general dearth of data on the properties of RAP in other prospective uses such as Portland cement concrete. In this work, the characteristics of Portland cement concrete with coarse RAP were examined in the laboratory. Further, basalt fibers have been employed in the concrete mix to enhance the properties of concrete. The different proportions of RAP have been added into the concrete as a replacement to coarse aggregate for finding the optimum dosage for enhancing strength and durability. All samples were tested for workability, compressive strength, flexural strength, and acid attack tests to investigate the impact of RAP as coarse aggregate on concrete performance. The test results indicate that the inclusion of RAP makes concrete more workable while decreasing its strength. The reason for this is the inadequate adhesion between the cement matrix and RAP aggregate. Additionally, the durability and strength of RAP concrete are improved by the incorporation of basalt fibers. In addition to RAP as a partial substitute for coarse aggregate, the investigation suggests employing basalt fibers.**

Index Terms: **Reclaimed asphalt pavement, workability, Strength, Durability, Replacement, Fly ash, Sustainability**

I. Introduction

The utilization of concrete has been increasing day-by-day due to its strength, durability, and easy availability of raw materials [1]. Building with a wide variety of structures is made up of concrete, requires the use of a substantial quantity of aggregates. The earth is the source of these aggregates, and the extraction of such large quantities is detrimental to the ecology. As a result of the advantages that rigid pavements have over flexible pavements, the building of rigid pavements has seen a significant increase in recent years. Furthermore, rigid pavements have a far lower life cycle maintenance cost than flexible pavements. The India Ministry of Road Transport and roads predicts that the conventional building technique for national roads will progressively shift to rigid pavement. Bitumen roads degrade more rapidly, therefore concrete roads eventually replace them [2]. The removal of the road produces a significant quantity of waste materials. Worldwide, road and highway maintenance produces millions of tonnes of reclaimed asphalt pavement (RAP) in this scenario. In the United States alone, the expected annual quantities for milled asphalt exceed 100 million tonnes [3]. Previous studies have demonstrated that improper RAP disposal is one factor that has led to environmental deterioration, particularly when RAP comes into contact with water [4]. A significant amount of hazardous contaminants, including heavy metals, polycyclic aromatic hydrocarbons, and volatile organic compounds, cause damage to the environment after they have been washed off of RAP material and are subjected to temperature [5], [6]. Therefore researchers are utilizing RAP as a replacement for natural aggregates to minimize the problem of availability of natural aggregates [7]–[9]. It decreases aggregate consumption and diminishes greenhouse gas emissions, therefore preserving valuable land and generating sustainable concrete [10], [11]. The performance of concrete may be adversely affected by the use of RAP aggregates [12]–[14]. To understand the causes behind the decrease in the overall strength of RAP concrete, it was found that the presence of an asphalt layer and agglomerated particles caused the decline [10], [14], [15]. Several studies have proposed diverse methodologies to eliminate the bitumen layer surrounding the aggregates to enhance the properties of RAP aggregates and fortify the bond between cement mortar and RAP aggregates [16], [17]. The efficient bonding of RAP aggregates and cement mortar is enhanced by the Abrasion and Attrition (AB&AT) procedure [18]. There is a need to further improve the bond between the cement and mortar. In this investigation, an attempt has been made to enhance the properties of RAP concrete by incorporating basalt fibers in it.

II. Materials

Ordinary Portland cement of grade 43, which possesses a specific gravity of 3.15, was obtained from a nearby supplier to employ it as a binder. As fine aggregate, sand that was readily accessible in the area and confirmed zone II with a specific gravity of 2.6 was employed. In this investigation, coarse aggregate with a specific gravity of 2.7 has been used. The National Highway 16 route is where the RAP aggregates are collected and utilized in this study.

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III. Methodology

A. Concrete Mix Details

The mix details of M20 grade concrete are prepared by IS:10262-2019 standards and depicted in Table 1. The work involves casting and testing concrete using RAP as a partial substitute for coarse aggregate and basalt fibers. The mix designations of various mixes are depicted in Table I. In Table II, the control mix is denoted as CM. Further R20, R40, and R60 denote the mixes containing 10%, 20%, and 30% of RAP as a substitute for coarse aggregate. Also, the mixes FCM, FR20, FR40, and FR60 denote the mixes with 1% of basalt fibers along with 0%, 10%, 20%, and 30% of RAP as coarse aggregate replacement.

TABLE I.
MIX PROPORTIONS (kg/m^3)

Cement	Fine Aggregate	Coarse Aggregate	Water
315	749	1300	197

TABLE II.
MIX DESIGNATIONS

Mix Details	RAP (%)	Fibers (%)
CM	0	0
R10	20	0
R20	40	0
R30	60	0
FCM	0	1
FR10	20	1
FR20	40	1
FR30	60	1

B. Test Procedure

In the current study, the workability of concrete was examined utilizing a slump cone test according to IS 1199-2018 [19]. The compressive and flexural strength tests are employed to assess the strength characteristics of concrete following IS:516-2021 [20]. The durability of concrete was examined by executing a water absorption test and an acid attack test on the surface of hardened concrete using cubes measuring 150 x 150 x 150 mm. The acid attack test on concrete was done using the ASTM C267 standards [21]. The water absorption test was performed on all mixes, to determine the increase in resistance towards water penetration in concrete.

IV. Results And Analysis

A. Workability of Concrete

The test results are depicted in Figure 1. From Figure 1, it is seen that the inclusion of RAP aggregate enhances the workability. The workability is directly related to the dosage of RAP. The inclusion of 20% RAP as a replacement for aggregate shows a 5.5% enhancement in the workability in contraction with the control mix. Similarly, the addition of 40% and 60% of RAP aggregate shows 11% and 18.8% enhancement in the workability in contraction with the control mix. The improvement is because of the presence of asphalt in the pores of the aggregate it decreases the water absorption of concrete and increases the workability [22], [23].

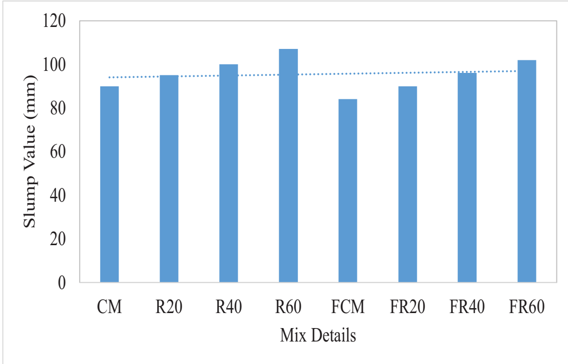

Figure 1. Slump test results of different mixes

Further, the inclusion of basalt fibers reduces workability. It reduces the workability of concrete containing RAP aggregate also. This is mostly due to the development of a fiber network inside the concrete mixture, which obstructs the movement of large particles and enhances resistance to flow [24].

B. Compressive Strength

All concrete mixes were tested in triplicate for a 7- and 28-day curing time. The test results are depicted in Figure 2. The inclusion of 20% RAP as a replacement for coarse aggregate reduces the compressive strength by 5.4% and 6.9%, respectively, in contraction with the control mix after 7 and 28 days of curing. The inclusion of 40% RAP as a replacement for coarse aggregate reduces the compressive strength by 10.4% and 13.1%, respectively, in contraction with the control mix after 7 and 28 days of curing. Similarly, adding 60% RAP reduces the compressive strength by 18.6% and 20.7% in contraction with the control mix after 7 and 28 days of curing, respectively. The loss in strength is due to improper bonding [23]. The strength of concrete decreases as asphalt builds up over aggregate, creating a smooth surface and a weak bond with mortar and cement paste.

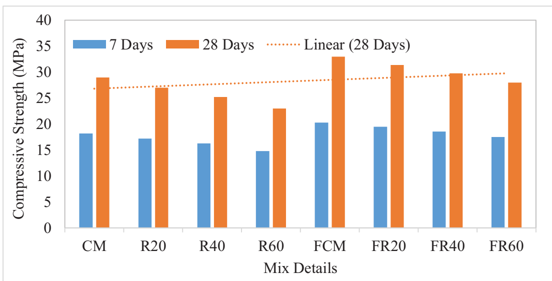

Figure 2. Compressive strength test results

Furthermore, to increase the strength characteristics of RAP concrete, basalt fibers are used to strengthen the bonding between the aggregate, mortar, and cement paste. The inclusion of fibers in the control mix increases the strength by 11.5% and 13.8% for curing periods of 7 and 28 days, respectively. The addition of fibers in the concrete with 10% RAP increases the strength by 7.1% and 8.3%, respectively, from the control mix. The inclusion of fibers in the RAP concrete mix increases the strength of the concrete by improving bonding between particles and acting as bridges between cracks, allowing the concrete to carry further loading before failing.

C. Flexural Strength

Figure 3 shows the test results for each concrete mix. It is evident from Figure. 3 that the flexural strength test results and the compression strength test results for the concrete were similar. The flexural strength is adversely affected when RAP is added in place of coarse aggregate. Concrete's flexural strength is reduced when the RAP dose is increased in place of coarse aggregate. This demonstrates that, in contraction with the control mix, the bonding between the aggregate and mortar is poor. It was also confirmed by the visual observation of the failure pattern of the concrete.

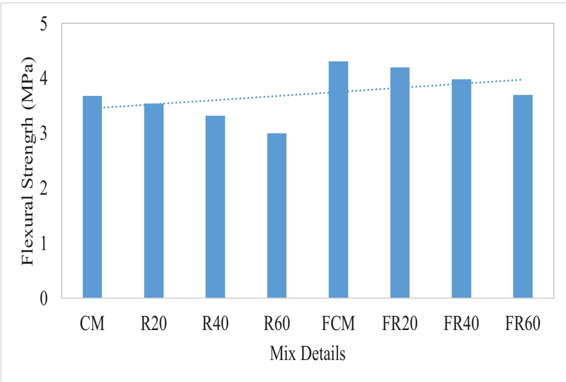

Figure 3. Flexural strength test results

The inclusion of basalt fibers in the concrete mix increases flexural strength when compared to the control mix. The fibers improve the connection between the aggregate and mortar by bridging action [25], [26]. The RAP concrete flexural strength is also enhanced by the addition of basalt fibers in it.

C. Acid Attack Test

This test was employed using 28-day water-cured concrete cubes measuring 100 x 100 x 100 mm. These cubes were removed from the curing chamber and soaked in water containing 5% H2SO4 solution for 28 days in plastic tubs. The percentage of weight loss was recorded to determine the effect of acid on the surface of the concrete. The test results are displayed in Figure. 4. Figure. 4 shows that using RAP as a substitute for coarse material improves the weight loss % of concrete. This is due to a poor connection between the aggregate and mortar. Because of this, H_2SO_4 can enter the concrete mix and increase the weight loss percentage.

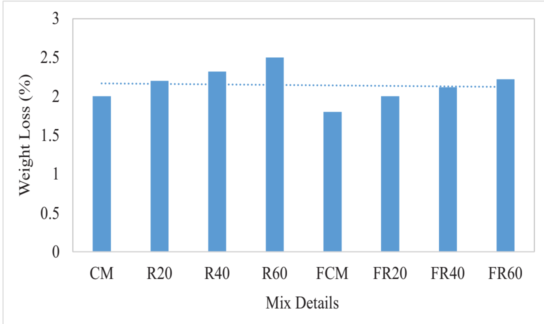

Figure 4. Acid attack test results

The addition of basalt fibers to the control mixture lowers the weight loss of concrete. Furthermore, the inclusion of basalt fibers in RAP concrete has comparable outcomes in terms of reducing concrete weight loss. Basalt fibers offer a higher resilience to acid harm [27]. The inclusion of basalt fibers in RAP concrete strengthens the material's resistance against acid degradation.

C. Water Absorption of Concrete

The test has been performed on all concrete mixes using cubes cured at 28 days. The test results are shown in Figure. 5. From Figure 5 it was observed that the inclusion of RAP in concrete shows increased water absorption values. It is confirmed that the increase in dosage of RAP as aggregate increases the water absorption of concrete.

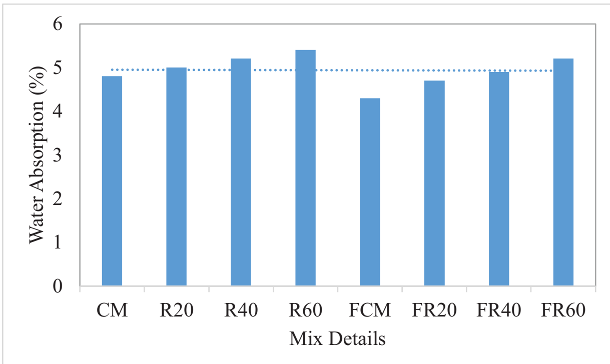

Figure 5. Water absorption test results

The inclusion of 20% of RAP as aggregate exhibits a 4% increase in water absorption in contraction with the control mix. The inclusion of 40% of RAP as aggregate exhibits an 8% increase in water absorption in contraction with the control mix. Similarly, the inclusion of 60% of RAP as aggregate exhibits a 13% increase in water absorption in contraction with the control mix. This is because of the poor bonding between the aggregates and mortar. It allows water to enter into the concrete. Further, the inclusion of basalt fibers minimizes the water absorption of concrete. The inclusion of fibers exhibits a 10% reduction in the water absorption in contraction with the control mix. The inclusion fibers in 20% of RAP aggregate concrete exhibit a 3% reduction in the water absorption in contraction with the control mix. The inclusion of fibers in 40% of RAP aggregate concrete exhibits a 2% increase in water absorption in contraction with the control mix. The inclusion of fibers enhances the bonding between the aggregates and mortar by bridging action. Thus water absorption capacity diminishes.

V. Conclusions

In this work, the influence of RAP combined with basalt fibers on concrete performance was examined.

1. The use of RAP as a substitute for coarse aggregate has significantly improved the workability. This is due to decreased particle friction and less water absorption.
2. The presence of RAP in concrete reduces its mechanical characteristics. As the RAP dose increases, the concrete's strength declines.
3. The acid attack test findings showed a similar pattern of results. This is due to the development of a weak connection between coarse aggregate and mortar.
4. Furthermore, adding basalt fibers to the concrete matrix improves the overall performance of the concrete.
5. The utilization of basalt fibers reduces the workability of concrete. The addition of basalt fibers to concrete significantly increases its strength and durability.
6. The study suggests employing RAP as a partial replacement for coarse aggregate, combined with basalt fibers.

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