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Experimental Exploration of High Strength Concrete (HSC) Properties Using Mineral Admixtures and Superplasticizers

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Abstract: High Strength Concrete (HSC) has garnered increasing interest due to its applications in modern construction, where enhanced strength, durability, and long-term performance are required. This study investigates the impact of mineral admixtures (such as fly ash, silica fume, and ground granulated blast-furnace slag) combined with superplasticizers on the properties of HSC. By systematically incorporating these admixtures at varying dosages and evaluating the mechanical and rheological properties of the resulting concrete, this study aims to optimize HSC formulation to enhance compressive strength, workability, and durability. Experimental results reveal significant improvements in concrete performance, suggesting that mineral admixtures and superplasticizers can synergistically improve HSC properties. These findings can inform mix design strategies for applications requiring high-performance concrete

Keywords: High Strength Concrete (HSC), Mineral Admixtures, Superplasticizers, Concrete Properties, Compressive Strength, Durability of HSC

I. INTRODUCTION

In recent years, significant advances have been made in developing High Strength Concrete (HSC). Although the main application of High Strength Concrete is in high rise buildings, it is receiving more attention in other areas such as bridge constructions, precast and prestressed concrete, etc. due to its high modulus of elasticity, high tensile strength, early strength development, low creep and low shrinkage. In high rise buildings, it offers considerable advantages such as reduction in column size and higher stiffness. High Strength Concrete (HSC) was coined in the 1980s which resulted in improved durability with compressive strength ranging from 48MPa to 117MPa.

The High Strength Concrete is generally defined as concrete above M50. Probably concrete of strength more than 35Mpa was used in large scale in Konkan Railway during early 90's and concretisation of Mumbai Municipal Corporation Roads. The demands of modern civil engineering projects necessitate the development of materials that possess high strength, durability, and workability. High Strength Concrete (HSC) has been a prominent solution due to its enhanced structural characteristics, achieved by a refined microstructure and reduced porosity.

However, achieving these properties requires more than just high cement content. Incorporating mineral admixtures and superplasticizers has shown promise in enhancing the performance of HSC.

This paper aims to explore how various mineral admixtures, in combination with super plasticizers, influence the physical and mechanical properties of HSC. The primary focus is on analyzing compressive strength, workability, durability, and micro structural properties to provide insight into optimal HSC formulations.

II. OBJECTIVES

1) To study the functions of Admixtures.
2) To achieve the concrete mix of strength greater than 50 MPa.
3) To achieve high strength concrete at lower cost with good workability and durability.

III. LITERATURE REVIEW

Jitsangiam et al., 2023 The environmental issue of plastic waste and proposes a modified mix design framework for hot-mix asphalt concrete (ACP) that incorporates recycled plastic. The study introduces the concept of dry mixing, where plastic is directly mixed with the hot aggregate, and evaluates the performance of ACP compared to conventional asphalt concrete (AC) through laboratory tests. The results indicate that ACP exhibits superior performance, highlighting its potential as an alternative solution for recycling plastic waste in road construction.

Oreskovic et al., 2023 This study investigates the feasibility of incorporating copper slag (CS) into asphalt mixtures for both the surface and base layers of road pavements. Two sets of asphalt mixtures with different CS content and fraction sizes were prepared, and their performance was evaluated. The results showed that adding CS to the surface layer improved stiffness and rutting resistance without significant negative impacts on other properties, while adding CS to the base layer improved cracking resistance but negatively affected stiffness, rutting, and fatigue resistance. Overall, CS has the potential to be a suitable substitute for virgin aggregates in asphalt mixtures for both surface and base layers.

Rivera et al., 2023 The use of polymer-based household waste in the wearing course of flexible pavements has been analysed, either as an asphalt bitumen modifier or as a dry additive. However, there are not enough records in which this waste is used to make up the aggregate to be used in an asphalt mix. This article presents the development carried out at LEMaC, consisting of pieces made from the mixture of household waste polymers and soils, which has been called Polymeric Stone. This material is used to design a cold-mix asphalt, and its use has been validated after evaluating a series of properties.

Khan et al., 2023 This research evaluated the use of marble dust (MD) as a substitute for mineral filler in hot mixed asphalt (HMA). The Marshall stability test results showed that an optimum filler content of 4% MD improved the Marshall stability, rutting resistance, and permanent deformation of the asphalt mixtures, while reducing the fatigue life. Increasing the percentage of MD increased rutting resistance and stiffness at high temperatures, but decreased the fatigue life. MD can be used as a partial substitute for stone dust (SD) to enhance rut resistance in HMA mixtures, particularly in areas with significant MD waste.

Upadhya et al., 2023 In this study, the researchers aimed to find the most suitable prediction model for Marshall Stability and Bitumen Content in carbon fiber reinforced asphalt concrete for flexible pavements. They used Marshall Stability tests and considered published research articles to analyze and select the optimal model. By applying various input parameters and machine learning techniques, they found that the Random Forest-based model performed the best, with high accuracy and low error metrics, indicating that a binder content of approximately 5.0% significantly influences the Marshall Stability in carbon fiber-reinforced asphalt mixes.

Ozel et al., 2023 This study examined the potential use of olive pomace (OP) waste, a type of biomass waste, in modifying bitumen for asphalt. The performance and cost of OP-modified bitumen were compared to styrene butadiene styrene (SBS) modified bitumen, commonly used in asphalt modification. The results showed that OP-modified bitumen, particularly with a 19% OP addition, exhibited similar performance to 4% SBS modified bitumen, improving properties such as rutting resistance, fatigue, and thermal crack resistance. This suggests that OP can be a viable alternative to SBS in terms of performance and cost, while also reducing environmental damage caused by waste materials.

Naser at al., 2022 This research evaluated the performance of hot mix asphalt (HMA) mixes with recycled asphalt pavement (RAP) and recycled concrete aggregate (RCA) as replacements for natural aggregate in flexible pavement surface layers. The study involved two phases, investigating different aggregate materials and studying the replacement of crushed limestone with RAP and RCA at varying asphalt cement contents. The experimental results showed that using RCA violated air voids limits and increased the optimum asphalt content, while adding RAP improved the Marshall stability of the HMA mixes.

IV. METHODOLOGY

Apart from conventional ingredients of concrete, chemical and mineral admixtures are used.
Ingredient materials are as follows:

Table No. 1 Ingredient materials

Ingredient	Size/Grade
Cement	OPC 53 Grade
Fly Ash	Class-F
Fine Aggregates	2.36mm

Coarse Aggregates	10mm
Coarse Aggregates	20mm
Water	Potable
Superplasticizer	Procrete LP20
Marble Dust	2.36mm

A. *Design Mix:-1*

DESIGN OF M50 GRAGE OF CONCRETE AS PER IS-10262

Design Stipulation

a) Grade Designation = M-50
b) Characteristic compressive Strength = 50 N/mm^2 required in field at 28 days
c) Maximum size of aggregate = 20 mm
d) Minimum Cement Content = 300 kg/m^2 (IS 456:2000)
e) Maximum water-cement ratio = 0.50 (Table 5 of IS 456:2000)
f) Exposure Condition = Moderate (for Reinforced concrete)
g) Workability (Slump) = 150 mm
h) Method of Concrete Placing = Manually
i) Degree of quality control = Fair
j) Types of exposure = Moderate
k) Degree of supervision = Good
l) Types of Fine Aggregate = Natural Sand

1) *Test Data For Material*

A. Cement
1) Ordinary Portland Cement = 53 Grade
2) Specific gravity of cement = 3.15

B. Fine aggregate
1) Specific gravity of fine aggregate = 2.74
2) Water absorption of fine aggregate = 1%

C. Coarse aggregate
1) Specific gravity of Coarse aggregate = 2.74
2) Water Absorption of Coarse aggregate = 0.5%

D. Free surface moisture
1) Coarse aggregate = Nil
2) Fine aggregate = Nil

a) *Fine aggregate: Conforming to Grading Zone III of Table 4 of IS 383*

Total Weight of sample taken =1000 gm

Table No. 2 Seive Analysis

Sr. No	IS Sieve sizes	Weight of aggregate retained in gm	Percentage retained	Cumulative% retained	Cumulative % passing
1.	10 mm	-	-	-	-
2.	4.75 mm	36	3.6	3.6	96.4
3.	2.36 mm	171	17.1	20.7	79.3
4.	1.18 mm	308	30.8	51.5	48.5
5.	600 micron	217	21.7	73.2	26.8
6.	300 micron	114	11.4	84.6	15.4
7.	150 micron	123	12.3	96.9	3.5
8.	Pan	22	2.2	99.1	0.9
	Total			330.5 F.M=3.305	

The sample given above nearly confirms to the grading zone III. Hence, it is suitable for concrete as well as reinforced works.

2) Selection Of Water Cement Ratio

From fig. 1, the free water-cement ratio required for the target strength of 58.25 N/mm^2 is 0.34 OPC53 grade curve. This is lower than the maximum value of 0.50 prescribed for 'moderate' exposure for reinforced concrete as per Table 5 IS 456.

0.34<0.50, hence OK

3) Determination Of Water Content

For 20mm nominal maximum size aggregate and sand conforming to **Grading zone-III** water content per cubic meter of concrete =186 litre for 25mm to 50mm Slump. Water content increase by about 3% for every additional 25mm slump.

$=186+\frac{12}{100}\times186$

$=208.32$ kg.

4) Determination Of Cement Content

Water-cementratio =0.34

Cement content = 186 /0.34

Cement content = 612.71 kg/m^3> 300 kg/m^3 ok

5) Determination Of Volume Of Coarse & Fine Aggregate

From Table 3 of (IS 10262:2009) Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone III) for water-cement ratio of 0.50 =0.64 .

In present case water cement ratio is 0.34.

Therefore, the correct proportion of volume is coarse aggregate for the water cement ratio 0.34=0.64+0.032

=0.67

For pumpable concrete proportion the value may be reduced by 10%

Therefore, the volume of coarse aggregate =0.672 -10/100 x 0.672

=0.605m^3

Volume of fine aggregate = 1-0.605 = 0.395m^3

6) MIX Calculation For 1 m^3

a) Volume of concrete = 1m^3

b) Volume of cement $= \frac{\text{Mass of Cement}}{\text{Specific gravity of cement X1000}}$

c) Volume of water $= \frac{\text{Mass of water}}{\text{Specific gravity of water X1000}}$

= 208.32/1x1000

= 0.208m^3

d) Volume of all in Aggregate (Coarse Aggregate and Fine aggregate)

Volume of all in aggregate = [Volume of concrete] - [Volume of cement + Volume of water +Volume of entrapped air]

= 1-[0.194+0.208+0.01]

= 0.588 m^3

e) Mass of coarse aggregate = [Volume of all in aggregate x Volume of coarse aggregate x Specific gravity of coarse aggregate x 1000]

= 0.588 x 0.605 x2.74 x 1000

= 974.73 kg

f) Mass of fine aggregate = [Volume of all in aggregate x Volume of fine aggregate x Specific gravity of fine aggregate x 1000]

= 0.588 x 0.605 x 2.74 x 1000

= 639.39 kg

V. RESULT AND DISCUSSION

A. Analysis : Design Mix-1
1) Water to cement ratio : 0.34
2) Superplasticizer and Mineral Admixture were not used.
3) 28 days compressive Strength: 58.01 MPa.
4) Cube test: 3 for each test.
5) 80% strength gained after 7 days.

B. Analysis : Design Mix-2
1) Water to cement ratio : 0.34
2) Only Superplasticizer was used.
3) 28 days compressive Strength: 59.85 MPa.
4) Cube test: 3 for each test.
5) 75% strength gained after 7 days.

C. Analysis : Design Mix-3
1) Water to cement ratio : 0.309
2) Only Mineral Admixtures wereused.
3) 28 days compressive Strength: 51.64MPa.
4) Cube test: 3 for each test.
5) 70%strength gained after 7 days.

D. Analysis : Design Mix-4
1) Water to cement ratio : 0.309
2) Superplasticizer and 5% Mineral Admixtures were used.
3) 28 days compressive Strength: 54.09MPa.
4) Cube test: 3 for each test.

VI. CONCLUSION

After performing the experiment the results come in the way that:
1. High Strength Concrete can be achieved through use of certain Admixtures.
2. Fly ash and marble dust can be used as a partial replacement of cement.
3. Superplasticizer allows reduction of water content.
4. Reduction in w/c ratio resulted in increased compressive strength.
5. Replacement of cement by 10% Mineral Admixtures gives early High Strength. About 65% strength is gained after 7 days only.
6. After addition of certain Admixtures, High Strength Concrete requires less material to achieve the same structural integrity as a conventional concrete.
7. This result in cost saving up to 15%-20% which also have good durability.
8. Formworks will be removed earlier and member can be loaded earlier.
9. More paste volume requires achieving high strength. Rich mix should be used, i.e. more binder content and fine aggregates.
10. Good surface finishing occurs due to high paste volume.

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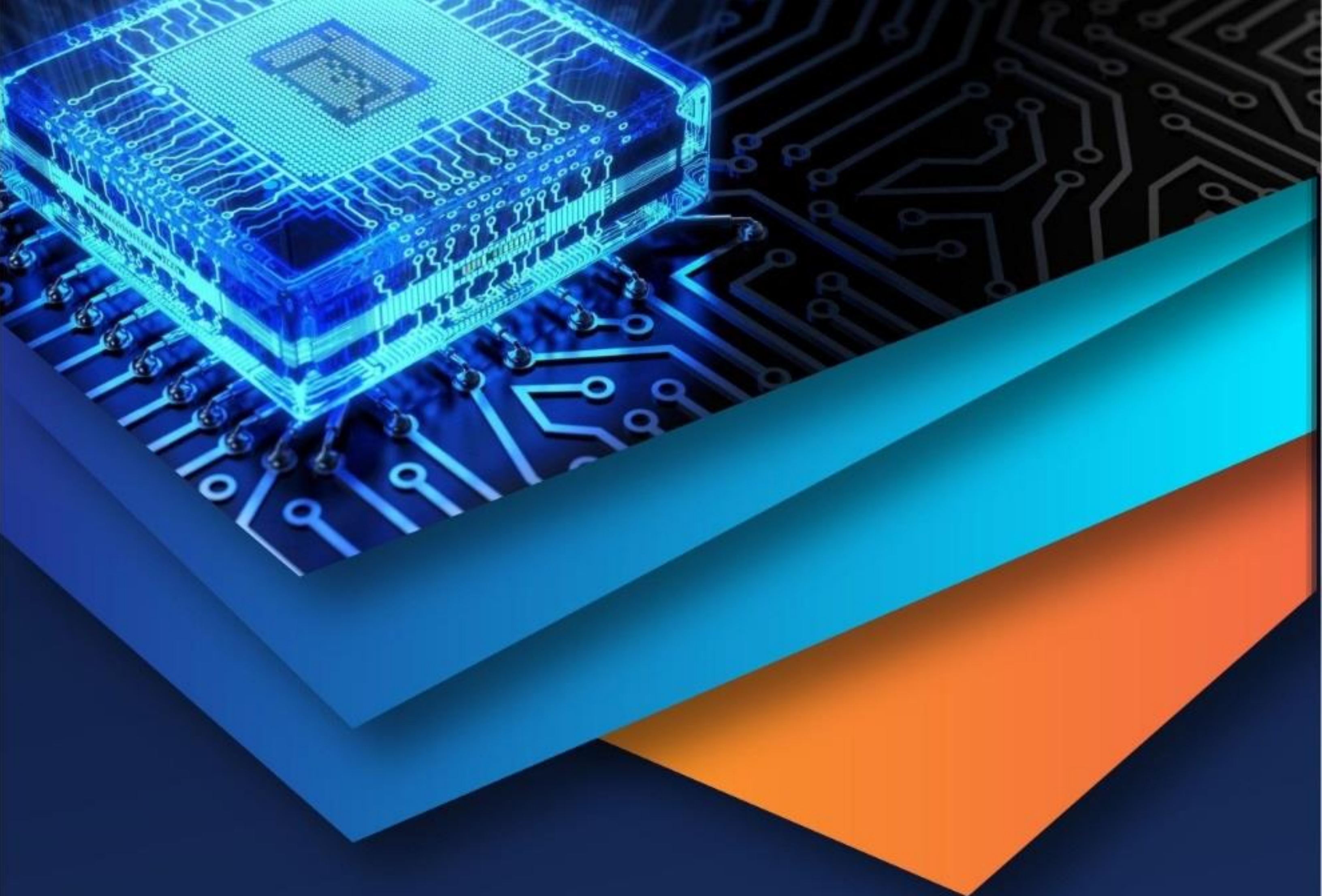

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