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MECHANICAL CHARACTERISTICS OF RECYCLED AGGREGATE AND MINERALS ADMIXED HIGH-PERFORMANCE CONCRETE

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Abstract - *In this research paper, we have studied the effect of recycled aggregates and minerals in physical characteristics on high-performance concrete (HPC) when mixed in it. The present study consists of and considered the effect of many properties of concrete components which are not taken into account by the traditional mix design method. The suggested mix design process follows the rule and regulations of the (BIS) Bureau of Indian Standards as well as the American Concrete Institute (ACI).*

The analysis of recycled aggregate (mostly demolished concrete) as a substitute for natural aggregates admixed with minerals, "silica fume" has been done based on an experiment conducted on HPC. M60 mix design is used in this study. At first, different materials used for making HPC are identified and later then with the help of mix design code, proportional quantities of materials are to be found. The proportions of silica fume in HPC are taken as 0, 10, 12, 15, 17.5, and 20 percent with cement content as 0, 0.5, 0.75, 1, 1, 1.25, and 1.5 percent fume silica. Two different minerals silica fume and fumed silica were used in experiment.

Cube compressive strength test at different (w/b) ratios 0.28, 0.3, 0.32 at different ages, such as 3, 7, 14, 28, 56, and 90 days.

***Key Words*: High-Performance concrete, recycled aggregate, plasticizers, silica fume, fumed silica**

1.INTRODUCTION:

Concrete is the main component used for infrastructure development, most of the structures are made by reinforced concrete in India. In modern times when high rise structures are in trend as well as in need, to provide more living room for the increasing world population, especially in India. High rise and heavy-duty structures can't be constructed with standard concrete mix, for which design of HPC is required, high performance concrete have a compressive strength of 55MPa or more. More construction work requires more construction materials, and construction land for that purpose. In the nowadays skyscraper buildings and heavy transportation bridges, and high-rise water retaining structures like dams are been constructed, because of that there is considerable focus on research and development of high-performance concrete. Furthermore, there is a need to find new sources of aggregates due to the increased demand and reduction in natural resources. Sustainable building development principles and maximizing the recycling of construction waste through research and development is necessary. One potential outlet is the use of recycled aggregates in concrete construction.

Concrete is typically made by using alluvial river sand and chorused crushed gravel, which are abundant and relatively inexpensive to process. These materials produce high-quality concrete due to their physical properties such as size and shape. However, these deposits were formed over millions of years and are not easily replenished. There is currently a shortage of sand and over-mining can cause environmental problems and damage to groundwater reserves. As a result, some state governments have banned sand mining due to concerns such as the danger of excessive digging from the riverbed, the impact on groundwater levels caused by deep pits, and erosion of surrounding land due to excessive sand lifting. It is generally believed that excessive lifting of sand around sub-constructions endangers the safety of bridges, especially the well foundation.

1.1 NEED OF HPC:

Since ancient times, cement materials have been used in construction works. During past fifty - forty years, materials have aged significantly and In present times, because of recurring natural disasters and structure failures, a modern solution is needed to be found. To fulfill the purpose of improving the strength and durability of structures, High-performance concrete was invented by use of water-reducing admixture, which leads to high strength. High-performance concrete (HPC) is designed to have superior chemical and physical characteristics compared to traditional design mix concrete.

High-performance concrete not only has high compressive strength but also has excellent flexural and tensile strength, it has a high modulus of elasticity which means less deformation under stress application. HPC structures are less susceptible to liquid-like "chemical and water" penetration due to their low permeability.

1.2 ROLE OF MINERALS AND ADMIXTURES:

1. Mineral mix like calcium hydroxide (CH) of silica fume and fumed silica are used to alleviate the unwanted negative effects during the cement

hydration in concrete. These minerals produced a negligible amount more calcium hydroxide than ordinary Portland cement (OPC) and produced a high amount of additional compressive strength comparatively.

2. In 1952 first experimental testing of silica fume in OPC based concrete was carried out. In early times researchers used fumed silica made from silicon tetrachloride combustion in hydrogen oxygen flames, while silica fume was a by-product of elemental ferrosilicon/silicon alloys in electric arc furnace production.

3. Fresh HPC has more cohesion means less prone to segregation, and less concrete bleeding, it can be used at high fluidity compared to other concrete mixes with no silica fume.

4. Using silica fume in HPC enhance its durability by three mechanisms: by increasing compressive strength, by reducing its permeability, and by its pozzolanic activity.

5. As for chemical admixtures in concrete like superplasticizers when added to an almost solid mixture, dispersion occurs and the mixture becomes more workable, more liquid as a result. Superplasticizers are high range water reducers (HRWR) of "ASTM C494 type F and Type G" and are used to reduce the moisture content by 12- 30 %.

2. NEED OF THE STUDY

1. Older buildings and structures are being demolished more frequently in metropolitan areas in construction industry because they are hazardous, required maintenance, and remodeling, or need to be demolished in order to make new, bigger, higher constructions. As a result, they produced, a whole lot of inorganic waste by demolishing concrete, and this demolished concrete is damped in landfill or used to restore land.

2. In present days natural resources are been reducing fast as a result of urbanization, As we know both construction materials (such as aggregates, and sand) and land comes from nature which means the scarcity of both became an issue for construction societies.

3. In order to overcome the depletion and shortage of natural course and fine aggregates there are many ongoing research and development works are taking place, is one of. them is to use recycled aggregates for the concrete mix design. Recycled aggregate contains inorganic concrete waste like processed and crush concrete blocks, brick-bats, and recycled steel fiber.

Objective of study:

We have six main objectives for this study.

1. To study the effect of fumed silica on HPC cube compressive strength.

2. To study the effect of fumed silica on HPC split tensile strength.

3. To study the effect of fumed silica on HPC flexural strength.

4. To study the effect of silica fume on HPC cube compressive strength

5. To study the effect of silica fume on HPC split tensile strength.

6.To study the effect of silica fume on HPC flexural strength.

3. LITERATURE REVIEW:

1. Viatceslav Konkov et. al (2013)[1]

The author has done his study on the principle approaches to HPC concrete applications in construction field. In his article, he has discussed the specific requirement of HPC in present times for different types of structures. Optimization of HPC production and its application, design of HPC concrete compositions. And conclude that HPC is becoming a necessity of modern time structures application.

2. H. Van Damme (2018) [2]

The author studied the past, present and future innovations of the concrete industry and possibility of using different concrete materials to produce in terms of quality and strength-wise enhanced concrete, and conclude In long term use of structures admixing Ingredients that can be used as cement and concrete additives include fly ash, slag, pozzolana cement, and silica fume. Mineral mixes may provide advantages like enhanced rheological characteristics.

3. Mohamed Amin, Yara Elsakhawy, Khaled Abu el-Hassan, Bassam Abdelsalam Abdelsalam (2022) [3]

"Behavior evaluation of sustainable high strength geopolymer concrete based on fly ash, metakaolin, and slag"

In this study, High Strength Geopolymer Concrete (HSGC) was made using industrial wastes such fly ash, metakaolin, and granulated blast furnace slag. In order to compare four geopolymer concrete mixes with fifteen different high strength concrete (HSC) mixes, four HSC mixes comprising Portland cement were created. The mixtures are all poured, cured, and tested. sag measurements are taken for the fresh qualities of HSC and HSGC blends, as well as air content. The mechanical parameters of the material were also tested and analysed, including its compressive strength, ultimate tensile strength, flexural strength, and elastic modulus at 3, 7, 28, and 91 days. Concrete combinations made of cement and geopolymer were examined for water permeability coefficient, and durability during 3, 7, 14, 21, 28, 56, and 91 days, and tests temperature was kept between 100° and 700°.

4. Y.N. Chana et . al (2000) [4].

After being exposed to high temperatures of up to 80 °C, the author evaluated the compressive strength and pore structure of high-performance concrete. High-performance concrete (HPC) and normal-strength concrete were subjected to an experimental program to investigate the mechanical characteristics and pore water of concrete element following exposure to high temperature. After the concrete samples had undergone a specific temperature. Their residual compressive strength was calculated at an 80°C temperature. Mercury intrusion porosimetry was used to examine the concrete's porosity and pore size distribution. According to test results, HPC exhibited more residual strength, after being exposed to high temperatures, its strength declined more quickly than that of normal-strength concrete. Changes in pore size could be utilised to show how HPC's mechanical properties have degraded as a result of exposure.

5 J. J. Chena et. al. (2017) [5].

The production of high-performance concrete using fly ash microspheres and condensed silica fume was the subject of the author's research. Regarding the concrete materials' packing model, the addition of fly ash microspheres (FAM) to fill the spaces between cement grains,

In order to obtain the desired flowability, the water content would be reduced, then condensed silica fume (CSF) would be added to further fill the spaces between the FAM. This might make it possible to use less water to make High-Performance Concrete (HPC) by reducing the W/CM ratio. The purpose of this study was to assess how FAM and CSF affected cementitious material packing density as well as cement paste flowability and strength. The outcomes demonstrated that FAM and CSF can considerably improve 2019 JETIR June 2019, Volume.

6. Ali Mohd (2018)[6]

This paper aims to assess the information gathered from overview, 70% of respondents have given the reasons why they do not support reusing construction waste, and from this examination it is very likely to be assumed that 25% RCA square having more quality than regular, yet half RCA square quality too adequate. (3) This paper compares the performance of recycled aggregate in concrete.

4. Osama Zaid, Faisal M. Mukhtar, Rebeca M-García, Mohammad G. El Sherbiny, Abdeliazim M. Mohamed,(2022).[7]

"Characteristics of high-performance steel fiber reinforced recycled aggregate concrete utilizing mineral filler"Nowadays, a lot of buildings are demolished to make room for new ones. As this trash is useless, recycled aggregates are employed in this paper along with mineral filler for construction purposes. Using recycled materials can help reduce pollution because demolished structures produce garbage and the amount of pollutants in the globe is rising. This study intends to make use of and assess the utilisation of steel fibres and recycled aggregates to improve the performance of high performance concrete. In this study, 15 distinct geopolymer concrete mixes were used to create four high strength mixes using Portland cement. Mechanical properties such as compressive strength, tensile strength, flexural strength, and elastic modulus at 3, 7, 28, and 91 days were measured and examined, and the durability and water permeability coefficient also.

5. Prashant Dodiya, Varsha Yadav (2023) [8].

The author studied the performance analysis of HPC using Metakaolin and silica fume effect on HPC concrete strength and conclude the result compressive strength of mix having 10% silica and 10% metakaolin has its highest strength achieved by day 28 of casting.

4. METHODOLOGY OF STUDY:

To Understand the interactions of different materials with respect to the selection of appropriate ingredients, evaluation of their properties and Optimal use is essential for the develop a high performance concrete mix by using the right Cement material for this test, such as fine aggregate (FA), recycled concrete aggregate (RCA), coarse aggregate (CA), water, chemical, and mineral mix.

For Effective production carefully select all the ingredients of HPC, which should be controlled, and used proportionally obtained. To achieve HPC, cement content, overall quality, and copy ratio, given the mixed paste interaction, mixing type, dose, and characteristics of meticulous care in mixing and handling, the optimum ratio should be selected.

4.1 Ingredients Used:

List of ingredients used in study is given below

1. OPC, conforming to BIS 53 grade : 12269-1987.
2. Dry dense form of silica fume obtained from ELKEM India (P) Ltd. Properties are given in table 2.1.
3. Dry dense form of fumed silica from CABOT SANMAR LMT. Properties are given in table 2.2.

4. Superplasticizer (chemical admixture) CONPLAST SP 430 compliant with BPS: 9103-1999 and ASTM C494-1992 the properties are given in table 2.3.
5. Recycled aggregate with a specific gravity of 2.5 and a fineness modulus of 6.45.
6. Nominal size, locally available based on BIS table 2 12.5MM correspond to graded aggregate:383-1970 with s.p of 2.65 and 6.7 coarse aggregate.

Table -4.1: Physical properties of silica fume

S,no	Component	Result (%)
1.	Specific gravity	2.2
2.	Surface area ,(m2/kg)	190000
3	Size, (μm)	< 1

Table -4.2: Physical properties of fumed silica

S,no	Component	Result (%)
1.	Specific gravity	2.5
2.	Surface area ,(m2/kg)	190000
3	Size, (μm)	14

Table -4.2: properties of superplasticizer

S, no	Properties	Result obtained
1	type	Sulphonated naphthalene formaldehyde Condensate
2	Specific gravity	1.22
3	Recommended dose	00.6-01.5 lit/100kg of cement
4	Solid content	40.0%
5	Comp. strength	Upto 46.0% to 50.0%

4.2 Mix design Calculation for HPC:

Grade Designation: M60 as HPC concrete.

In this case 40% partial replacement of natural fine aggregate by recycled aggregate is taken.
Step1 . Target main strength fck

$$fck = fck + (t \times s) \quad ..... (1.1)$$

$$= 60 \times 1.4 \quad =84 \text{ MPa}$$

Step 2. For M60 Grade of concrete design mean target strength at 28 days for calculations.

Design mean target strength for M60=60+1.65*5=68.25MPa

But revised mean target strength for 40% RCA replacement of natural aggregates for M60 grade of concrete to calculate Quantities:

84+1.65*5=92.25 MPa

Step 3. With the obtained set of materials by various trials it has concluded that OPC 440kg /m^3, silica fume 44kg /m^3 and w/c + SF ratio of .28 gives 28 days average compressive strength as 71.27 MPa.

Step 4. The calculated density of concrete mix ;

=10 X 2.65 (100-1.5) + {440[1-(2.65/3.15)] + 44[1-(2.65/2.20)]}-120(2.65-1) = 2610.25 + 57.842-198
= 2470.1 kg/m^3

step 5. Quantity of aggregates = 2470.1-440-44-118= 1868.1 kg/ m^3

step 6. Recycled Aggregates= 1868.1 x 0.4=7747.2 kg/m^3
Sand =1868.1 x 0.25=467 kg/m^3
12.5 mm aggregates =1868.1 x 0.35=653.8 kg/m^3

Now we have the estimated quantity of mix design as follows:

- Water required =118 kg/m^3
- Cement required =440 kg/m^3
- Silica fume = 44 kg/m^3
- Recycled aggregate=378 kg/m^3
- Sand =661.5 kg/m^3
- 12.5 mm aggregate =850.5 kg/m^3
- Superplasticizer = 4.41 kg/m^3

5. RESULTS AND DISCUSSION

5.1Cube Comp. Str.

Cube compressive strength results in water-binder ratios such as 0.28 for different ages, such as 3, 7, 14, 28, 56, and 90 days, and at replacement levels such as 0%, 10%, 12.5%, and 15% of silica fume and 0.%, 0.5%, 0.75% ,1%, fumed silica are presented in Tables 5.1.1 to 5.1.2 and plotted in the graph.

Table -5.1.1: cube compressive strength result mixes with silica fume at w/b ratio of 0.28

Silica fume % days	Average cube compressive str. in MPa					
	3	7	14	28	56	90
0.0	21.65	39.54	55.61	65.44	69.41	71.71
10.0	36.81	48.02	58.02	67.27	71.35	75.38
12.5	38.25	50.49	59.44	68.96	75.02	81.36
15.0	43.08	56.48	67.36	72.50	82.26	88.00

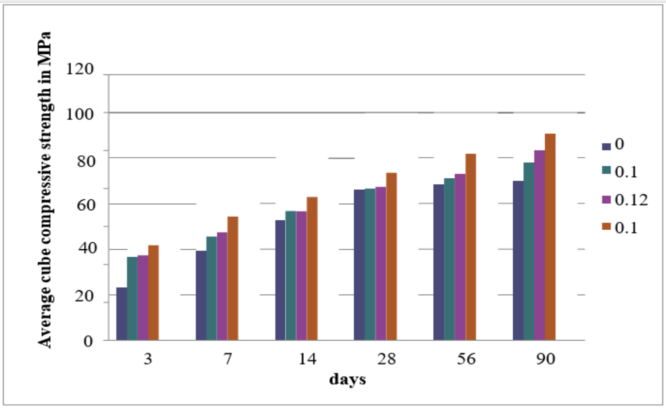

Fig.5.1.1 effect of Silica Fume on the comp. str. Of HPC when mixed in w / b ratio of 0.28

Table -5.1.1: cube compressive strength result mixes with fumed silica at w/b ratio of 0.28

Fumed silica % days	Average cube compressive str. in MPa					
	3	7	14	28	56	90
0.0	22.71	41.82	58.69	68.70	72.19	72.53
0.5	37.84	47.11	58.74	68.97	73.04	76.41
0.75	39.69	50.52	60.37	71.77	77.17	79.82
1.0	44.41	58.44	67.07	78.43	86.55	89.52

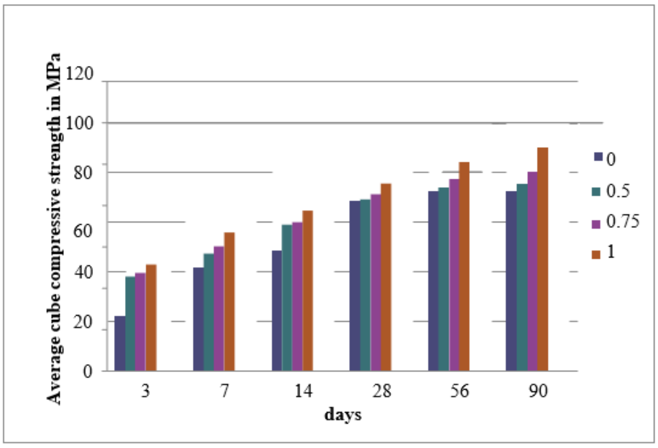

Fig.5.1.2 effect of Fumed Silica on the comp. str. Of HPC when mixed in w / b ratio of 0.28

5.2 Flexural Strength

It is previously known that compression is directly related to the flexural strength of concrete and depends on the compressive strength. But for HPC there is a low rate of increase in the flexural strength, which is approximately 9 to 10% of its compression strength.

Table 5.21 Flexural strength results of HPC mixes with silica fume at 28 days at w/b 0.28

Silica fume %	Flexural strength (MPa) w/b = 0.28
0.0	6.89
10.0	7.09
12.5	7.27
15.0	8.01

Table 5.21 Flexural strength results of HPC mixes with fumed silica at 28 days at w/b 0.28

Fumed Silica %	Flexural strength (MPa) w/b = 0.28
0.0	6.83
0.50	6.85
0.75	7.14
1	7.79

5.3 Splitting Tensile Strength

The spilt tensile strength result of HPC are taken for w/b ratio of 0.28 at different substitution level of silica fume such as 0%, 10%, 12.5%, 15% and for fumed silica substitution level are kept as 0%, 0.5%, 0.75%, 1% at 28 days of age are given in the tables 5.3.1 and 5.3.2 below.

Table 5.21 split tensile strength results of HPC mixes with silica fume at 28 days at w/b 0.28

Silica fume %	Split tensile strength (MPa) w/b = 0.28
0.0	4.15
10.0	4.27
12.5	4.38
15.0	5.07

Table 5.21 Flexural strength results of HPC mixes with fumed silica at 28 days at w/b 0.28

Silica fume %	Split tensile strength (MPa) w/b = 0.28
0.0	4.12
0.50	4.14
0.75	4.37
1	4.86

3. CONCLUSIONS

The concrete mix design procedure outlined here is more logical since it takes into account the effects of numerous concrete component qualities, which are often overlooked in standard mix design techniques. Superplasticizer and a mineral mixture are coupled to create a straightforward mix design procedure for HPC that complies with BIS and ACI code requirements. To create affordable HPC mixtures, this proposed method of mix design, proportionally uses superplasticizers and concrete components along with RCA in place of natural aggregates. Target strength is applied to the design mix after casting the trial mix. Therefore, HPC can be designed employing mineral combinations such as silica fume and fume silica using the indicated mix design process.

The HPC Mix's compressive strength at 7 and 14 days was 60 to 78 and 85 to 92 percent, respective, of the strength at 28 days. This shows that silica fume and fumed silica gain early strength when cement is partially substituted.

The optimal replacement of silica fume and fumed silica were found to be 15 and 1 present.

On the other hand the optimal amount of recycled concrete to be replaced by natural aggregates was found to be 40 % maximum.

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