iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 **Issue:** VII **Month of publication:** July 2024

DOI: https://doi.org/10.22214/ijraset.2024.63704

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VII July 2024- Available at www.ijraset.com

Development of Ultra-High-Performance Concrete Using GGBS and Alccofine

Prerna Kumari[1], Gautam Kumar[2]
KK Universty, India

Abstract: ***Ultra-high-performance concrete, or UHPC, is a cementitious mixture that is distinguished by its exceptionally high compressive strength—more than 120 MPa as well as its remarkable toughness, tensile ductility, and longevity. Ground Granulated Blast Furnace Slag (GGBS) and Alccofine (AF) are commonly used in the matrix composition to increase the particle system's packing density and subsequently enhance the matrix's strength in order to guarantee that UHPC has the proper strength. To investigate the engineering properties of ternary blended UHPC with GGBS, AF, a comparative study was conducted. In comparison to the control UHPC mix, the ternary blended UHPC mix's mechanical and durability qualities were improved by the percentage variation of AF within specific bounds. In this study, the experimental work included mix proportioning and preparation of ternary blended UHPC specimens and various tests like Compressive Strength, Split Tensile Strength, Flexure Strength and RCPT (Rapid Chloride Penetration Test) were performed in the laboratory. The results show that under normal water curing conditions, the strength qualities of UHPC based on GGBS are considerable, up to a cement replacement level of 40%. In addition, compared to the binary counterpart, the mixture of 20 Percent AF and 40 Percent GGBS showed better mechanical and durability properties.***

Keywords: ***Alccofine, Ground Granulated Blast Furnace Slag, Ultra-High-Performance Concrete, Rapid Chloride Ion Resistance. Water – Binder Ratio***

I. INTRODUCTION

A cementitious blend with extraordinary mechanical strength and performance is known as ultra-high-performance concrete, or UHPC. UHPC has the capacity to offer superior strength and performance since the world's population is expanding quickly and there is a demand for building materials. Following 15 years of research and development on new UHPC, multiple researchers have determined the ratio of strength to serviceability that characterizes high-performance concrete. This concrete can be used for heavy construction projects like road pavement, flyovers, bridges, dams, and multistory buildings. Its performance could revolutionize buildings. Due to high costing the use of UHPC is limited and the design codes which provide information regarding designing of UHPC are also limited. To reduce the initial cost of UHPC, microfine mineral admixture as Alccofine (AF) and Ground Granulated Blast Furnace Slag (GGBS) have been incorporated. Basically, GGBS is the waste by product of Steel Manufacture industry. The binding properties of GGBS and AF will reduce the water content in concrete mix to enhance the properties of concrete. These are capable enough to enhance the strength and durability of concrete. It may be possible to significantly reduce the amount of greenhouse gases produced by including supplementary cementitious materials (SCMs). Researchers have found that industrial by-products such as fly ash (FA), silica fume (SF), and GGBS are pozzolanic and cementitious, which makes them a good option to use with cement to lower carbon emissions.

II. RESEARCH SIGNIFICANCE

Larrard first coined the term UHPC in 1994 [1]. These days, it is more precisely defined as a cementitious composite with a compressive strength more than 120 MPa [2]. Together with superior durability, tensile ductility, toughness, and compressive strength exceeding 120 MPa [3]–[5]. In addition to its exceptional endurance qualities, UHPC possesses incredibly low porosity and low permeability [6], [7].Replacement of certain amount of cement with Supplementary Cementitious Materials (SCMs) such as AF and GGBS in the production of UHPC itself leads to lesser consumption of cement. Both AF and GGBS, when added to cement, alter its hydration rate and volume. Similar to AF, adding GGBS to concrete can decrease the amount of porosity and Ca $(OH)_2$ in the interfacial transition zone (ITZ) between the aggregate and the cement paste as well as the breadth of the ITZ relative to the control sample [8]

©IJRASET: All Rights are Reserved

III. METHODOLOGY

A. *Material Properties*

In the present experimental investigation, Ordinary Portland cement (OPC) of 53 Grade corresponding to Bureau of Indian Standard (BIS) IS: 12269:2013 [9]. The other cementitious materials included GGBS and AF was used in the densified form in this research. The GGBS and AF sample satisfied the requirements of IS 15388-2003 [94] and IS 12089–1987 [10]. W/b ratio is taken as 0.20 for all mixes. As fine aggregate, common riverbed sand with a Fineness modulus of 2.60 was used. Specific gravity and water absorption were found to be 1.1% and 2.51, respectively. As coarse aggregate 12.5mm-sized crushed Pakur stone that was readily available locally was used. Specific gravity and Water absorption were found to be 0.4% and 2.82, respectively. Polycarboxylic ether-based water-reducing superplasticizer Structuro 203 (FOSROC) [11] was used in preparing UHPC mixes.

B. *Mixture Proportion*

Mix proportions were taken from previous research work [12].The mix proportions for UHPC mixes are shown in Table 1.

Table 1. Mix Proportions for UHPC mixes (Kg/m^3)

Mix	Cement	AF	GGBS	SP	CA	FA	Water
Control Mix	740	0	0	8.88	1102	519	158
G10	666	0	74	8.88	1098	518	158
G20	592	0	148	8.88	1095	516	158
G30	518	0	222	8.88	1091	514	158
G40	444	0	296	8.88	1088	513	158
G50	370	0	370	8.88	1084	511	158
AF5	703	37	0	8.88	1093	515	158
AF10	666	74	0	8.88	1083	511	158
AF15	629	111	0	8.88	1074	506	158
AF20	592	148	0	8.88	1065	502	158
AF25	555	185	0	8.88	1056	498	158
G40/AF5	407	37	296	8.88	1079	508	158
G40/AF10	370	74	296	8.88	1069	504	158
G40/AF15	333	111	296	8.88	1060	500	158
G40/AF20	296	148	296	8.88	1051	495	158
G40/AF25	259	185	296	8.88	1042	491	158

IV. RESULTS

A. *Compressive Strength Test Results*

The uniaxial compressive strength of the concrete was determined by crushing three cube samples of size 150mm after 1, 7 and 28 days of curing, as per Bureau of Indian Standard (BIS) [13] equivalent to ASTM C39-18[14]. For each age, the average compressive strength of three specimens was calculated. Figure 1. Illustrate the compressive strength results obtain from experimental work.

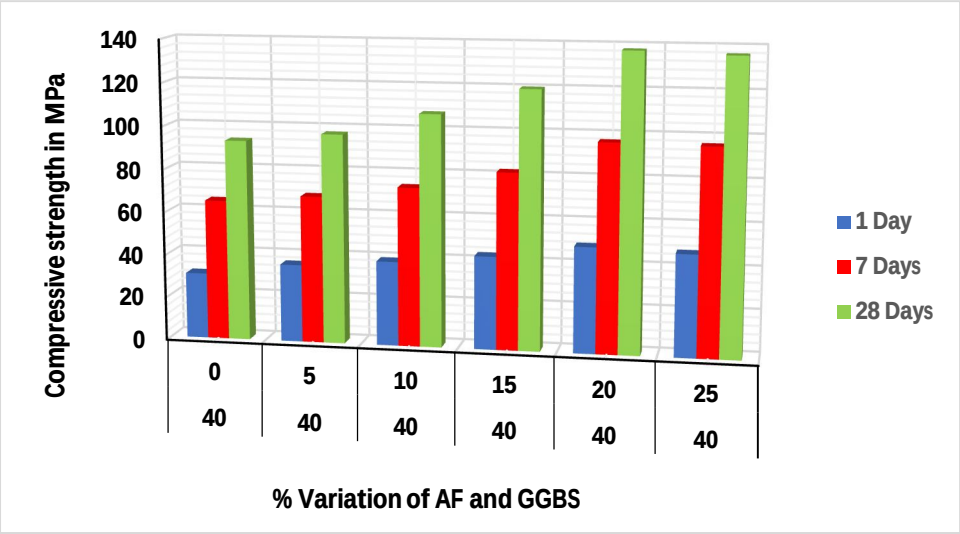


Figure 1. Compressive Strength Test Results

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue VII July 2024- Available at www.ijraset.com

As can be seen in Figure 1.1, the test results indicate that the optimal strength was attained at 40% GGBS and 20% AF variation in the mix. Accepting the literature review that shows better outcomes are obtained with 40% GGBS and 20% AF replacement; further increases in GGBS or AF percentage may not demonstrate an increase, as was also observed in a downward trend after 20% AF proportion. The water content in this concrete mix was maintained at 0.25 and the water reduction agent was assumed to be 1.2%. The result presented here are consistent with those of a previous researcher [15].

B. Flexure Strength Test Results

Specimens were cast in 50 x 10 x 10 cm moulds for the flexural strength test. Following a standard 28-day water curing period, the test was carried out. To determine their flexural strength, concrete beam samples were center-point loaded according to the ASTM C-293-02 [16] method. The ASTM C-293-compliant modulus of rupture is given by Equation 1.

$$R = \frac{3PL}{2bd^2} \qquad \text{……..(1)}$$

Where, P denotes the maximum force applied in Newtons, R the rupture modulus in MPa, b the prism width in millimetres, d the prism depth in millimetres, and L the span length in millimetres. Figure 2 displays the results of the flexural strength test after 28 days.

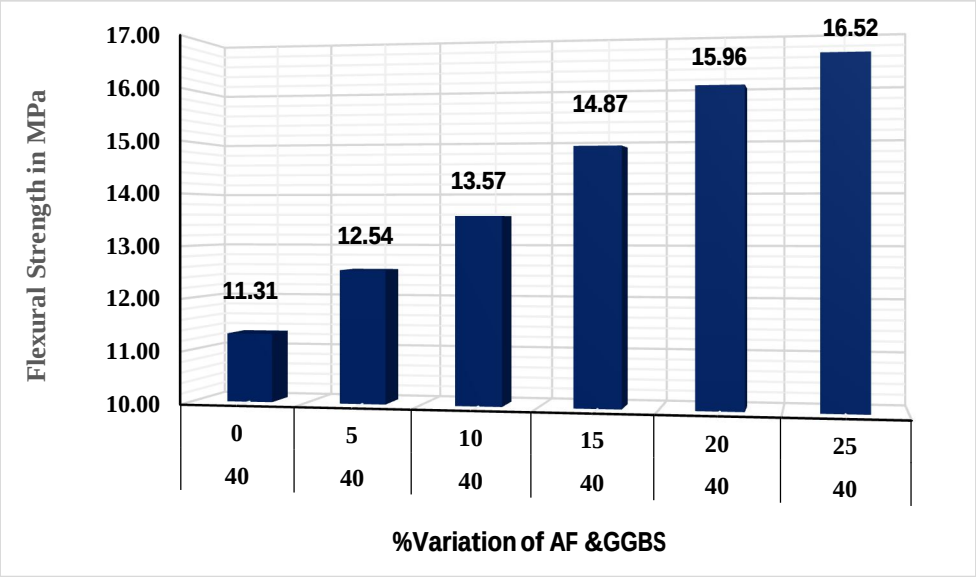


Figure 2. Flexure Strength Test Results

It can be seen clearly from Figure 2. that at 20% AF variation maximum flexure strength is obtained. Further variation of AF does not improve flexure strength much. At 20% AF and 40% GGBS, the optimal flexure strength was found to be 15.96 MPa. Furthermore, compared to binary blended UHPC mixes with GGBS, the ternary blended mixes with GGBS and AF demonstrated a 30% increase in flexural strength. The outcome demonstrates the identical pattern of findings from earlier studies. [15]

C. Split Tensile Strength Test Results

Split tensile strength comes under the indirect tension test method as the failure of the cylindrical test specimens occurs by indirect tension. Cylindrical specimens of size 150mm × 300mm were cast to measure the 28 days splitting tensile strength as per BIS[17]. Three cylinders were tested at the age of 28 days, and average values were obtained. The horizontal tensile stress is expressed as Equation 2.

$$\text{Horizontal Tensile Stress} = \frac{2P}{\pi DL} \qquad \text{……..……..(2)}$$

Where, P = compressive load on cylinder in Newtons, L = Length of cylinder in millimetres and D = Diameter of cylinder in millimetres .

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |

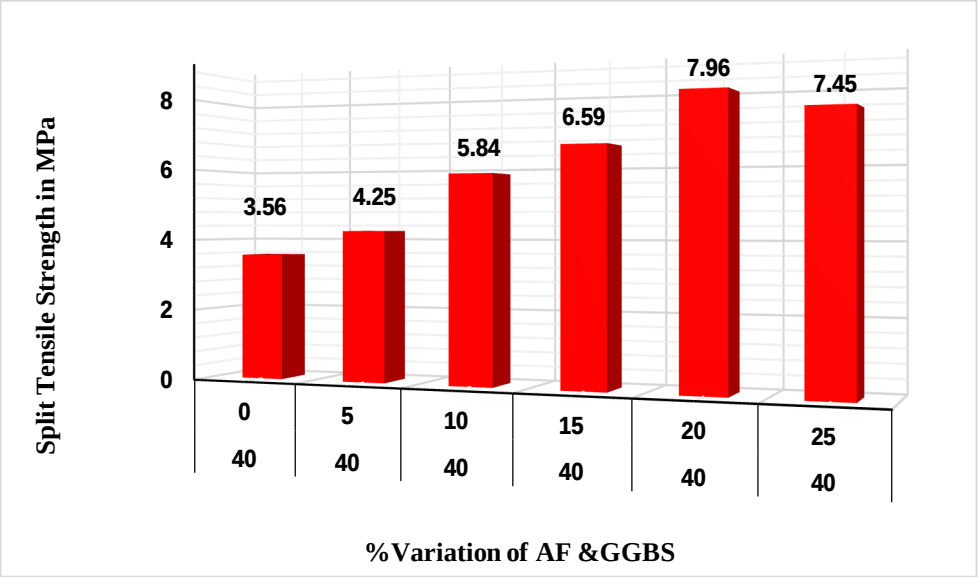


Figure 3. Splitting Tensile Strength

The results indicate that splitting tensile strength values followed the almost similar pattern as compressive strength. UHPC mixture containing AF + GGBS has produced a maximum splitting tensile strength of 7.96 MPa, which is 75 % more than the splitting tensile strength of GGBS based UHPC. Figure 3 shows that the UHPC mixture containing AF performed well with the combination of GGBS rather than with the only GGBS. The results here are in line with the findings of previous researcher [15]

D. Rapid Chloride Permeability test (RCPT)

The RCPT test was used to evaluate the resistance of chloride ion penetration. This test determines the electric conductivity of different classes of concrete mixes and provides a prompt indication of the ions' resistance to entering. The total electrical charge transported over a 6-hour period, expressed in Coulombs and pertaining to the penetration of chloride ions, was used to calculate the chloride permeability index. The test consists of inserting a 100 mm-diameter concrete block into a sample cell that is filled with 3.0% salt solutions and 0.3N sodium hydroxide solutions. By using the code IS:6925-1973, the test has been carried out [18].

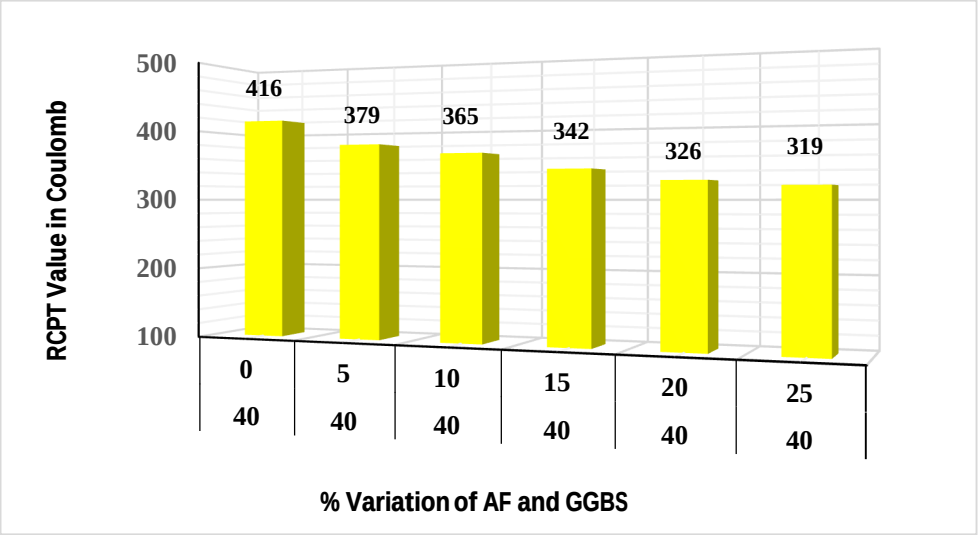


Figure 4. RCPT Test Results

From, Figure 4. it can be observed that when AF percentages variation increases, the RCPT values is decreasing. Since AF is fine materials hence percentage variation of increase in AF causes decrease in the chloride ion penetration, results in decrement of the RCPT value.

The results show that the resistance to chloride ion penetration increases as the dosage of AF in the UHPC mix increases. As a result of AF replacement, UHPC's pore structure physically densifies, which in turn raises chloride resistance. The results here are in line with the findings of previous researcher [12].

V. CONCLUSION

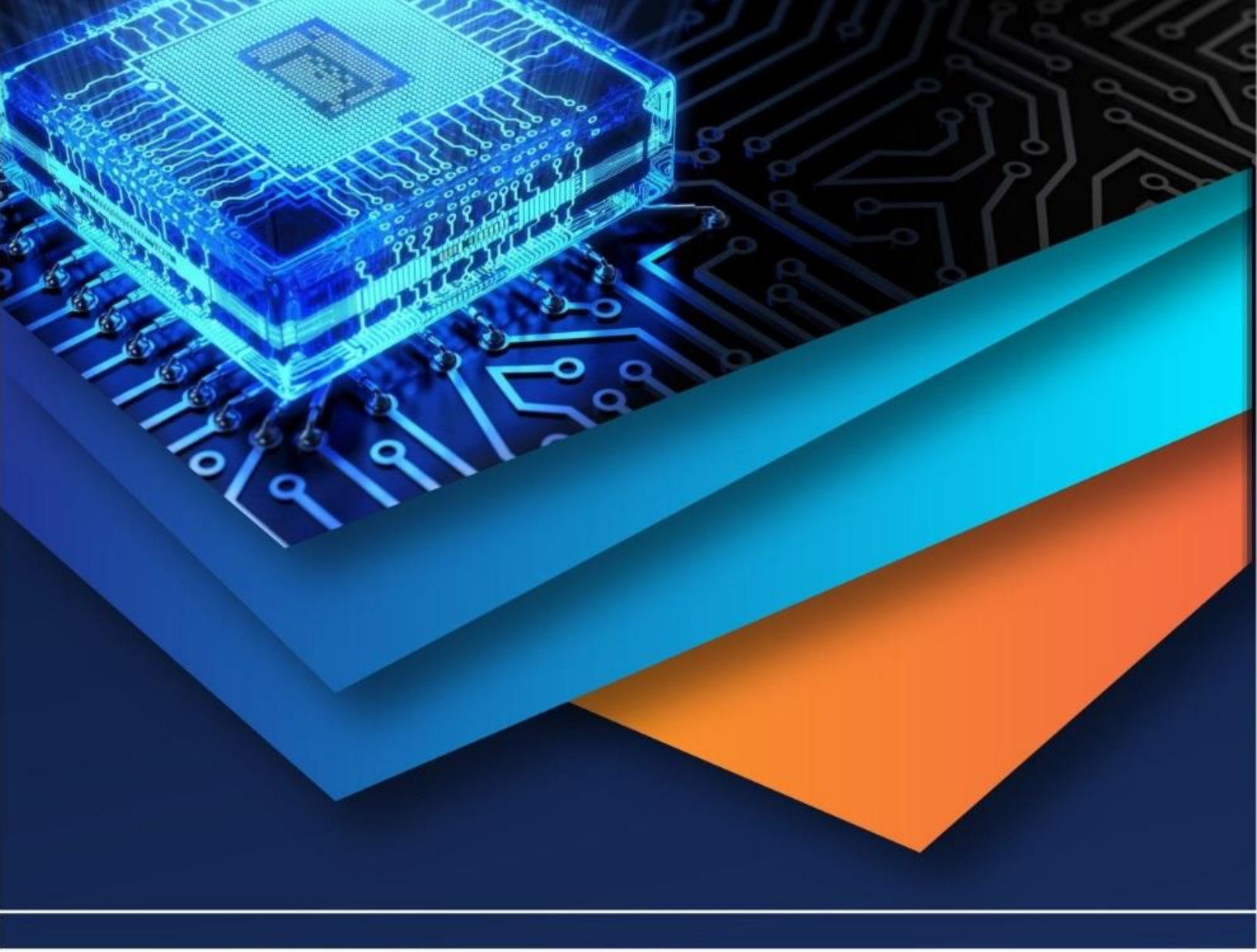
1) The optimum level of compressive strength was seen when 40% GGBS was mixed the 20% of AF with UHPC mix compared to normal plane concrete.
2) Around 17% enhancement in compressive strength result was observed at the optimum quantity of mineral admixture used as compared to GGBS based UHPC.
3) Early strength was also achieved in ternary blended UHPC mix because of its ultrafine materials. Around 36% of ultimate compressive strength was achieved in one day after casting.
4) In comparison to binary blended UHPC with GGBS, ternary blended UHPC shows a flexural strength improvement of about 30% after 28 days. Similarly, compared to binary blended UHPC, there was an improvement of about 73% in split tensile strength.
5) Addition of mineral admixture also gave improved results for RCPT. It tends to fill all the void present in the concrete mix hence increasing the resisting power of the mix against chloride ions.

Conflict of Interest: The author declares that they have no conflict of interest

REFERENCES

[1] F. De Larrard and T. Sedran, “Optimization of ultra-high-performance concrete by the use of a packing model,” Cem. Concr. Res., vol. 24, no. 6, pp. 997–1009, 1994.
[2] K. Wille, A. E. Naaman, and G. J. Parra-Montesinos, “Ultra-high performance Concrete with compressive strength exceeding 150 MPa (22 ksi): A simpler way,” ACI Mater. J., 2011, doi: 10.14359/51664215.
[3] J. Liu, H. Jin, X. Zhao, and C. Wang, “Effect of Multi-Walled Carbon Nanotubes on Improving the Toughness of Reactive Powder Concrete.,” Mater. (Basel, Switzerland), vol. 12, no. 16, Aug. 2019, doi: 10.3390/ma12162625.
[4] K.-Q. Yu, Z.-D. Lu, J.-G. Dai, and S. P. Shah, “Direct Tensile Properties and Stress–Strain Model of UHP-ECC,” J. Mater. Civ. Eng., vol. 32, no. 1, p. 04019334, 2020, doi: 10.1061/(asce)mt.1943-5533.0002975.
[5] R. Sharma and P. P. Bansal, “Efficacy of supplementary cementitious material and hybrid fiber to develop the ultra high performance hybrid fiber reinforced concrete,” Adv. Concr. Constr., vol. 8, no. 1, pp. 21–31, 2019, doi: 10.12989/acc.2019.8.1.021.
[6] N. K. Lee, K. T. Koh, S. H. Park, and G. S. Ryu, “Microstructural investigation of calcium aluminate cement-based ultra-high performance concrete (UHPC) exposed to high temperatures,” Cem. Concr. Res., vol. 102, pp. 109–118, 2017.
[7] J. Y. R. Liew, Design guide for concrete filled tubular members with high strength materials to Eurocode 4. Research publishing, 2015.
[8] RILEM, “Advances in Science and Technology of Concrete,” in 3rd R. N. Raikar Memorial International Conference & Gettu-Kodur International Symposium, 2018, vol. 14-15 Dec.
[9] IS 12269: 2013, “Ordinary Portland Cement , 53 grade specification,” Bur. Indian Stand., no. March, pp. 1–14, 2013.
[10] IS:12089-1987, “Specification for granulated slag for the manufacture of Portland slag cement,” Bur. Indian Stand. New Delhi, pp. 1–14, 1987.
[11] C. Should, “Structuro 203,” pp. 1–2.
[12] S. Prakash, S. Kumar, R. Biswas, and B. Rai, “Influence of silica fume and ground granulated blast furnace slag on the engineering properties of ultra-high-performance concrete,” Innov. Infrastruct. Solut., vol. 7, no. 1, 2022, doi: 10.1007/s41062-021-00714-7.
[13] IS:516, “Method of Tests for Strength of Concrete,” Bur. Indian Stand. New Delhi,India, 2004.
[14] ASTM C39-18, “Compressive Strength of Cylindrical Concrete Specimen.,” ASTM Stand., 2011, doi: DOI: 10.1520/C0150_C0150M-12.
[15] S. Kavitha and T. F. Kala, “Evaluation of Strength Behavior of Self-Compacting Concrete using Alccofine and GGBS as Partial Replacement of Cement,” vol. 9, no. June, pp. 1–5, 2016, doi: 10.17485/ijst/2016/v9i22/93276
[16] ASTM C293-02, “Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading),” Annu. B. ASTM Stand., pp. 1–3, 2002, doi: 10.1520/D1635.
[17] IS:5816, “Specification for splitting tensile strength of concrete -Method of Test,” Bur. Indian Stand. New Delhi, India, pp. 1–8, 1999.
[18] M. Kisan, S. Sangathan, J. Nehru, and S. G. Pitroda, “IS:6925-1973,” 1973.

©IJRASET: All Rights are Reserved | SJ Impact Factor 7.538 | ISRA Journal Impact Factor 7.894 |



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)