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Comparative Study on Ultra High Performance Concrete with and Without Coarse Aggregate by Particle Packing Method

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A B S T R A C T

This study focuses on the comparative examination of ultra high-performance concrete with and without coarse aggregate using the particle filling method. This research study examines the rheological and mechanical properties of two high-performance concrete construction mixtures, one containing no coarse aggregate and the other containing coarse aggregate below 12.5 mm. The behavior of each mixture in its new state was examined by changing the water cement ratio as 0.26, 0.28 and 0.3. The two minerals used in the mixture are 10% micro silica and 5% metakaolin by weight instead of cement, and sand (M-Sand) and quartz sand produced as quality materials were used. Quartz sand 60 mesh, 100 mesh, 200 mesh etc. Available in colors. In order to prevent cracks in the concrete mixture and increase the ductility of the concrete, 1% steel fiber was used in both mixtures. Some properties of new ultra high-performance concrete (UHPC) were examined using a test rig frequently used to determine the properties of self-compacting concrete. Measure sufficient capacity, excess capacity and capacity of new functional concrete (UHPC). The samples are then cast and tested for compressive strength. It has been observed that the compressive strength of the composite material without coarse aggregate is 5% to 10% higher than that of the composite material with coarse aggregate.

1. INTRODUCTION

A particular kind of concrete called ultra-high-performance concrete is made for a particular need. UHPC is referred to as "concrete that meets extraordinary execution and consistency requirements that cannot be met by using standard materials, blending techniques, or curing processes." Compressive strength, high workability—which encourages resistance to compound or mechanical stresses—low penetrability, and extended durability are the minimum characteristics that set UHPC apart.

To enhance the strength and durability of concrete, certain mineral root materials are also added. These materials include fly ash and silica fume, which are typically fine—possibly even finer than cement—and when added to cement in the proper proportion, can enhance the strength and durability of concrete. In this way, UHPC is obtained. Because of this, modern concrete can have more than the four fixings listed above. Additionally, concrete's properties can be suitably tailored for particular construction-related tasks, just like those of many other composites.

The physical, chemical, and morphological characteristics of the materials used to make concrete are crucial to its workability, mechanical strength, and longevity. The characteristics of the materials, which include mild steel fibers, cement, metakaolin, and micro silica as cementitious materials, M-Sand and quartz sand as fine aggregate, and cement, are evaluated using methods in accordance with conventional codes of practice and standards.

2. MIX DESIGN

There are codal references for the mix design of higher-grade concrete. Mix designs for higher grade concrete can be done by using particle packing density method. This is a new concept of mix design.

Particle Packing Density Mix Design

The particle packing density approach method is used to carry out the mix design. The bulk densities of M-sand and coarse aggregates, both loose and roded, are assessed independently. The processes listed below are used to determine the design mix for the remaining tasks.

1. Determination of packing density.
2. Estimation of voids content and voids ratio.
3. Calculation of packing factor.
4. Evaluate the mass of fine aggregate and coarse aggregate.
5. Determining the mass of total aggregates.
6. Finding out the required cement paste and by selected the W/C.
7. Estimation of cement content and also the quantity of water required.

Design of mix with coarse aggregate

Determination of packing density.

Manufactured Sand conforms to Zone-II as per specifications of IS: 383-1970

Specific gravity =2.63

Loose Bulk Density =1356.16 kg/m3

Roded Bulk Density =1469.36kg/m3

Coarse Aggregates of 12.5 mm maximum size Confirms to graded requirements as per specifications of IS: 383-1970

Specific gravity =2.65

Loose Bulk Density =1443.4 kg/m3

Roded Bulk Density =1563.3 kg/m3

Optimum Combined bulk density of total (Coarse and fine combined in the ratio of 45:55 respectively) aggregates:

Packing density for fine aggregates

(Bulk density x weight fraction)/ specific gravity = (1356.16*0.55)/ 2.63 = 281.47 kg/ m3

Volume = 0.281 m3

Packing density for Coarse aggregates

(Bulk density x weight fraction)/ specific gravity = (1443.4*0.45)/ 2.65=245.763 kg/ m3

volume= 0.246 m3

Total packing density = 0.282+0.246 = 0.53

Estimation of voids content and voids ratio.

Void Content (1-Total packing density) = 0.47

10% excess in void content = 0.47 x 1.1

Paste content = 0.517

Total volume of aggregate (1-Paste Content) = 0.483

Calculation of packing factor.

Packing factor (PF) is defined as the ratio of roded bulk density to lose bulk density.

PF = R B D / L B D = 1.1

Vfa = Volume of fine aggregates, Vca = Volume of coarse aggregates

Pfa= Density of fine aggregate, Pca= Density of coarse aggregate

Substituting the values ρfa = 1356.16kg/m3, ρca = 1443.4 kg/m3 and Rfa/ca = 1

Vfa = 0.55 and Vca = 0.45 we get Rfa/ta = 1

Evaluate the mass of fine aggregate and coarse aggregate.

Loose Mass of fine aggregates mfa = Vfa x ρfa = 745.80kg

Loose Mass of coarse aggregates mca=Vca x ρca = 649.35 kg

Mass of total aggregate = PF (mfa + mca) =1.1 (745.8 + 649.35) = 1534.52kg

Determining the mass of total aggregates.

Final mass of fine aggregates PF x mfa = 1.1 x 745.8 = 810.17 kg

Final mass of coarse aggregates PF x mca = 1.1 x 649.60 = 713.87 kg

Finding out the required cement paste and by selected the W/C.

Water cement ratio= w/c = 0.3

Total paste C+W = C/3.15 +0.30C/1 = 0.6174C

Estimation of cement content and also the quantity of water required.

Cement content (0.517/0.6174) *1000 = 833.6 kg

Quantity of water (cement*0.3) = 249.9L.

B. Design of mix without coarse aggregate

Manufactured Sand conforms to Zone-II as per specifications of IS: 383-1970

Specific gravity = 2.63

Loose Bulk Density (LBD) 1356.16 kg/m3

Roded Bulk Density (RBD) 1469.36kg/m3

Packing factor: Aggregate packing factor (PF) is defined as the ratio of roded bulk density to loose bulk density.

PF = R B D / L B D = 1.08, say =1.1

Vfa + Vca = 1

Vfa x pfa / ((Vfa x pfa) + Vca x pca = Ratio of fa/ta

ρfa = 1356.16 kg/m3, Vfa = 1, Vca=0

Substituting the values in the above equations we get R fa/Ta = 1

Loose Mass of fine aggregates mfa = Vfa x ρfa = 1356.16 kg

Mass of total aggregate PF (mfa + mca) = 1.1 (1356.16 + 0) = 1464.48 kg

Volume of voids = 1-(Magg / (1000xSp.Gr) = 0.453

Past content 10% excess in void content

Past content 1.1x0.427= 0.495

Water cement ratio= w/c 0.3

Total paste C + W= C/3.15) + (0.3C/1) =0.6174C

Cement content = (0.495/0.6174) *1000 = 802.26 kg

2.1 Results and Discussion

The test procedures used to determine new UHPC qualities including resistance to segregation, fallibility, and passing ability are described first, and then each test's outcomes and discussions are presented. As a result, the V funnel test and the slump flow test are used to evaluate the behaviour of UHPC in its fresh form.

V-Funnel Test

Table 1. Results of V Funnel Test at w/c ratio of 0.26 for Mix1 and Mix2.

Trials	Admixture Dosage in %	V- funnel – Mix1		V- funnel – Mix2	
		(T r) Flow(sec)	Flow at T_5 min (sec)	(Tr) Flow (sec)	Flow at T_5 min (sec)
1	1	30	36	28	33
2	1.05	25	29	22	28
3	1.1	21	24	16	20
4	1.15	18	21	12	13
5	1.2	15	19	12	
6	1.25	13	14		
7	1.3	12	15		

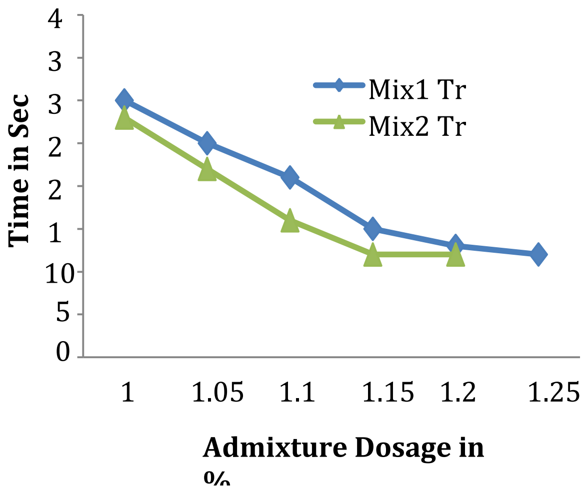

Fig. 1. Typical Graph for V Funnel Time in Sec – Tr and T5 for Different Dosages of Admixture.

1. The amount of time needed to empty the V funnel decreases when the admixture dosage is increased. The time of flow decreases as the w/c ratio increases. This indicates that an increased weight-to-cement ratio results in a higher admixture dosage and less emptying time.

2. For mixes 1 and 2, which have a higher cementitious composition, the V-Funnel time required is greater at lower additive dosages. The amount of time needed decreases with increasing dosage, and at 1.2% to 1.3% of admixture, the time needed approaches the maximum V-Funnel time.
3. Mixes with a larger paste volume may become more cohesive and have less flowability. This could be the result of the mixtures' inter-particle friction.

Slump Flow Test

Table 2. Results of Slump Flow Test.

Water Cement Ratio		0.3	0.28	0.26	Specifications
Mix 1	Paste Content in %	49.5	48	46.4	
	Admixture Dosage in %	0.65	0.7	0.85	
	Horizontal Flow in mm	780	750	710	600to 800
	T50 cm Flow Time in sec	2	3	3	5
Mix 2	Paste content in %	51.7	49.7	48	
	Admixture Dosage in %	0.55	0.65	0.75	
	Horizontal Flow in mm	760	720	680	600to 800
	T50 cm flow Time in sec	3	3	4	5

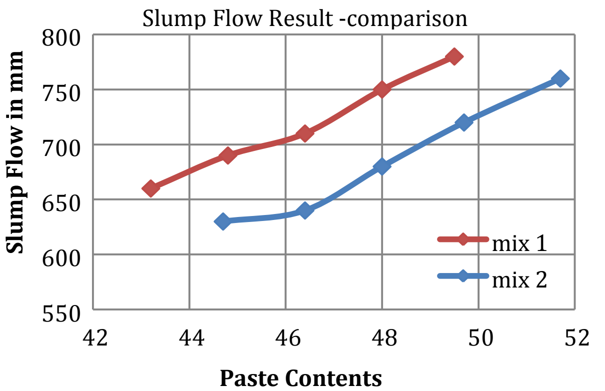

Fig. 2. Comparison of Slump Flow of Mix 1 and Mix 2 with paste content.

1. Slump flow diameter is measured at three distinct locations, and the average is noted as Mix-1's slump flow. If the flow characteristics are not met, the admixture dosage is raised to 1.05.
2. For the whole water cement ratio, mix 1's admixture required is about the same. This suggests that similar and equivalent admixtures are needed for UHPC mixes without coarse aggregates and with varying Cementous concentrations. When the water cement ratio is lowered, there is a greater need for admixture in mixes without coarse particles than in mixes that do.

Compressive Strength Test

The mixes that meet the rheological specifications are followed by 100 x 100 x 100 mm specimens for the compressive strength test. After a day, the specimens are demoulded and submerged in water to cure in accordance with code standards. According to IS 516, the Ultra High-Performance Concrete's compressive strength is assessed. After 3 and 28 days of curing, the strength is evaluated.

Table 3. Compressive Strength Test Results.

Water Cement Ratio		0.3	0.28	0.26
Mix 1	Paste Content %	49.5	48	46.4
	3days Strength in MPa	43.12	46.7	49.87
	28days strength in Mpa	121.76	126.76	130.11
Mix 2	Paste Content %	51.7	49.7	48
	3days Strength in MPa	37.45	41.31	44.78
	28days strength in Mpa	115.15	119.27	123.15

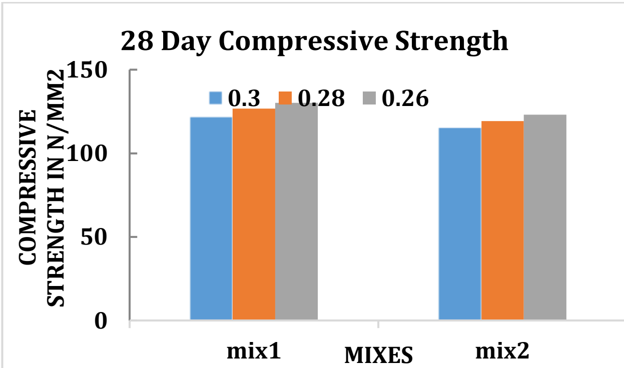

Fig. 3. Strength of Mix 1 and 2 with and without Coarse Aggregates at Different w/c ratio.

3. CONCLUSION

As per the result and observations made in this experimental study, the followingconclusions are drawn.

- From the above results it can be concluded that mixes without coarse aggregate have higher strengths than mixes with coarse aggregate because the powdered form has higher strengths; therefore, finer particles play the role of coarse aggregate because the powdered concrete is very densely packed into tiny silt-sized particles, increasing the surface area for the binder and enhancing the strength of the concrete.

- The paste content of the mixes decreases by 3.25% with reduction in w/c ratio from 0.3,0.28, & 0.26 this explains us that the less w/c ratio will form less paste content and will give more strength. the mix-2(with coarse aggregate) showed higher paste content of 51.7% for w/c of 0.3 and minimum paste content was for mix-1 with w/c ratio of 0.26.
- As the w/c ratio is increased, the time of flow is reduced. This shows that at higher w/c ratio, dosage of admixture required is more and time of emptying is less.

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REFERENCES

[1] M. S. Shetty, *Concrete Technology Theory and Practice*, New Delhi, 1982

[2] A. R. Santhakumar, *Concrete Technology*, Oxford 2006

[3] N. Krishna Raju, *Design of Concrete Mixes*, CBS Publishers, 2017

[4] M. A. Kadry and A. A. A. Ali, "Comparative study of UHPC and traditional concrete," *International Journal of Civil Engineering and Construction*, vol. 3, 2024.

[5] S. Wang, B. Wang, H. Zhu, G. Chen, Z. Li, L. Yang, Y. Zhang, and X. Zhou, "Ultra-high performance concrete: Mix design, raw materials and curing regimes—A review," *ScienceDirect*, vol. 35, 2023.

[6] M. Amran, S.-S. Huang, and A. M. Onaizi, "Recent trends in ultra high-performance concrete (UHPC): Current status, challenges, and future prospects," *Elsevier*, vol. 352, 2022.

[7] O. A. Mayhoub, E.-S. A. R. Nasr, Y. A. Ali, and M. Kohail, "The influence of ingredients on the properties of reactive powder concrete: A review," *Ain Shams Engineering Journal*, vol. 12, no. 1, pp. 145-158, Mar. 2021.

[8] M. M. S. Ridhaa, K. F. Sarsama, and I. A. S. Al-Shaarbafb, "Experimental Study and Shear Strength Prediction for Reactive Powder Concrete Beams," *Elsevier Case Studies in Construction Materials*, vol. 8, pp. 434-446, Jun. 2018.

[9] X. Hou, S. Cao, Q. Rong, W. Zheng, and G. Li, "Effects of steel fiber and strain rate on the dynamic compressive stress-strain relationship in reactive powder concrete," *Elsevier Construction and Building Materials*, vol. 170, pp. 570-581, May 2018.

[10] M. Sujan, "Effect of compressive strength with and without coarse aggregate using flyash and silica fume on high strength concrete," *International Journal of Engineering and Technology*, vol. 4, no. 8, 2017.

[11] M. Bandukwala and H. G. Sonkusare, "Study of Reactive Powder Concrete and its Characteristics," *International Journal of Science Technology & Engineering*, vol. 2, no. 7, Jan. 2016.

[12] D. Mostofinejad, M. R. Nikoo Seyed, and A. Hosseini, "Determination of optimized mix design and curing conditions of reactive powder concrete (RPC)," *Elsevier Construction and Building Materials*, vol. 123, pp. 754-767, Oct. 2016.

[13] L. Jaya, S. Doodala, and T. S. Babu, "A Comparative Study between Reactive Powder Concrete and High Performance Concrete," *International Journal of Emerging Technologies in Engineering Research (IJETER)*, vol. 4, no. 8, 2016.

[14] S. Sarika and E. John, "A Study on Properties of Reactive Powder Concrete," *International Journal of Engineering Research & Technology (IJERT)*, vol. 4, no. 11, Nov. 2015.

[15] R. Yu, P. Spiesz, and H. J. H. Brouwers, "Mix design and properties assessment of Ultra-High Performance Fibre Reinforced Concrete," *Elsevier Cement and Concrete Composites*, vol. 55, pp. 383-394, Jan. 2015.

[16] N. Raj, S. G. Patil, and B. Bhattacharjee, "Concrete Mix Design By Packing Density Method," *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, vol. 11, no. 2, pp. 34-46, Mar.-Apr. 2014.