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Development of High Strength Concrete using Artificial Sand as Fine Aggregate

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Abstract – *About 30-35 percentage volume of concrete is occupied by sand. But the natural sand resources depleting day by day and disturbing nature of ecosystem of our country. Also, government had restricted quarrying of sand from natural resources. It is necessary to find another substitute to river sand. For the fulfilment of high strength requirement, efforts are contributed to overcome above challenges. In the present study, we developed M80 grade of high strength concrete using fully replacement of artificial sand as fine aggregate and fly ash, silica fume as supplementary cementaneous material with incorporation of super plasticizer by Indian standard method. Trial mixes are designed with water cement ratio 0.26, poly carboxylate ether based super plasticizer and various percentage addition of silica fume (2.5,5.0,7.5,10.5,12.5), fly ash (5.0,10.0,15.0,20.0) for to obtain optimum mix proportion of M80 grade concrete. Target compressive strength is achieved at 1% dosage of super plasticizer, 5% addition silica fume and artificial sand below 300 micron which is replaced by fly ash, with well graded coarse aggregate. Therefore, it is possible to achieve high grade concrete using silica fume mineral admixture and artificial sand without dust. Fly ash not give much more strength in 28 days.*

***Key Words*: High Strength Concrete, Artificial Sand, Silica Fume, Fly ash, Superplasticizer.**

1. INTRODUCTION

Concrete is most used construction material in construction industry for infrastructure development. It has ability to develop required and form any shape after hardening. The world scenario, in last 10-15 year, very high strength concrete (HSC) entered in the construction field, in particular construction of long span bridges and flyover, high rise building, atomic power plant, prestressed concrete, metro rail project. Hence, consumption of concrete in huge amount. Concrete is made up of various ingredients, which help to develop good matrix of it. A good quality and required strength of concrete is formed by properly mixing ingredients at standard temperature (27±2 ^{0}C) and humidity (50-60%).

Current scenario of construction industry for development of concrete natural sand is commonly used as fine aggregate. Due to an infrastructure development, the natural sand resources depleting day by day. It is expected that fine aggregates suitable for use in concrete will become scarce and significant increase in its cost. Sand mining from our rivers becomes objectionable, also disturb nature of ecosystem of our country. Also, government had restricted quarrying of sand from natural resources, resulted in the need to identify new source of fine aggregate.

Fine aggregate is a paramount constitute of concrete, which control the property of fresh concrete and hardened concrete. They not only improve the cohesiveness but also responsible for strength of concrete matrix. Therefore, it is necessary to select new material as fine aggregate in concrete, considering all aspect of HSC. Manufactured sand (M-sand) offer a viable alternative to natural sand. M-sand has to satisfy the technical requisites like workability and strength of concrete. Since the data on this aspect of concrete using manufactured sand is scarce, it is necessary to investigate the concrete produced with manufactured sand (1).

In the present paper, the endeavour is made to develop optimum mix proportion for HSC of M80 grade concrete using artificial sand, supplementary cementaneous material, superplasticizer with required workability.

2. METHODOLOGY

To find suitability of artificial sand over river sand for development of HSC, various trial mix design of M80 grade concrete was carried out based on IS 10262:2019 guideline. The target slump was decided 100 and water cement ratio kept constant as 0.26. Various trial mix proportioning of ingredients, with varying percentage addition of special mineral and chemical admixture have to be attempted for about 120 days to achieve optimum mix proportion of M80 grade concrete. Therefore, research is experimental oriented.

3. MATERIAL USED FOR HSC

3.1 Cement

Sagar brand (Hyderabad, Telangana) of 53 grade cement confirming to IS 12269-1987 was used in present study, important physical properties of cement are shown in table1.

Table 1. Physical properties of cement

Properties	Investigated value of Sagar OPC cement
Specific gravity	3.10
Consistency (%)	33
Initial setting time (min)	140
Final setting time (min)	235
Soundness (mm)	1.5
Comp. Strength (28days)	68.5 MPa

3.2 Fine aggregate (FA)

Artificial sand of grading zone-II as per IS 383:1987 was used. Physical properties of river and artificial are shown in table 2. Details of sieve analysis for natural and artificial sand carried out, shown in table 3.

Table 2. Physical properties of river and artificial sand.

Properties	Krishana river sand	Artificial sand Walawa, Sangli.
Fineness Modulus	2.5	4.46
Specific Gravity	2.69	2.74
Water Absorption (%)	2.80	1.6

Table 3. Details of sieve analysis for natural and artificial sand.

Sieve designation	% passing of zone-II sand		Grading limit for zone-II
	Natural sand	Artificial sand	
4.75 mm	92.7	94.3	90-100
2.36 mm	84.1	82.4	75-100
1.18 mm	76.1	69.9	55-90
600 μ	42.7	47.2	35-59
300 μ	14.3	9.9	08-30
150 μ	7.7	5.3	0-20

3.3 Coarse aggregate (CA)

First, we used maximum 12.5 mm size of coarse aggregate for M80 and above grade as per IS 10262:2019. But, fractions of CA and FA of obtained mix proportion of M80 was used to be discussed in further section. Physical properties of CA as shown in table 4.

Table 4. Physical properties of CA.

Physical properties	Average value
Fineness modulus	5.60
Specific gravity	2.78
Water absorption (%)	1.4

3.4 Water

Water which is fit for drinking was considered for making concrete.

3.5 Silica fume (SF)

Silica fume used was confirming to ASTM C 1240-2000 of specific gravity 2.2. Elkem micro silica of 920D was used in present study which was supplied by "ELKEM industry, Mumbai.

3.5 Fly ash

The fly ash we used of type C, in that the Cao present is more than 12%. Properties of fly ash shown in table 5.

Table 5. Properties of fly ash.

Specific gravity	2.20
Bulk density (Kg/m^3)	540-860
Shape	spherical
Size	5μ-300μ

3.6 Chemical admixture

In the present research study, poly carboxylate ether (PCE) based "Master Glenium Sky 8521" was used, which is supplied by BASF private limited, Mumbai. Properties of superplasticizer shown in table 6.

Table 6. Properties of superplasticizer.

Aspect	Light brown liquid
Relative density	1.10 at 25^{0}C
Ph	>6 at 25^{0}C
Chloride ion content	<0.2%

4. MIX PROPORTION OF INGRADIENT

As per IS 10262:2019 guideline various trial mix proportion are made as shown in table 7. Details of aggregate gradation of Trial mix 10 as shown in table 8. Fig.1 shows the image of ingredients of proposed concrete grade.

Table 7. Various mix design is made at different trial combination.

Trial mix No. / Material	Control Mix	TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8	TM9	TM10
Cement (kg/ m^3)	573	573	573	573	573	573	573	573	573	573	573
Water (kg/ m^3)	149	149	149	149	149	149	149	149	149	149	142
FA (kg/ m^3)	802.1	790	770	769	760	755	760	732.5	646.9	624.5	770
CA (kg/m^3)	1020.9	1011	1003	978.8	968	960	968	955	843.6	814.5	1002
SP (%)	0.75	0.9	1.0	1.1	1.15	1.2	1	1	1	1	1
SF (kg/ m^3)	0	14.32 (2.5%)	28.65 (5%)	42.97 (7.5%)	57.3 (10%)	71.62 (12.5%)	28.65 (5%)	28.65 (5%)	28.65 (5%)	28.65 (5%)	28.65 (5%)
Fly ash (kg/ m^3)	0	0	0	0	0	0	28.65 (5%)	57.3 (10%)	85.95 (15%)	114.6 (20%)	-

5. TEST ON CONCRETE AND RESULT

5.1 Slump Test

After proper mixing of all ingredient at standard temperature and humidity slump test is must to be carried out for to measure workability of concrete mix. The strength of concrete is depending on water-cement ratio, higher the strength lower will be water-cement ratio. But, due to lower water-cement workability of concrete is reduce. For very low w/c ratio (i.e., 0.26) here, we use PCE base super plasticizer and optimum dosage of super plasticizer find out to fix slump of 100mm as shown below in table 9 and graphical form in chart 1.

Table 8. Detailed gradation of CA and FA for TM10

CA	Fraction I -20% [20 mm-12.5 mm size] Fraction II -60% [12.5 mm-10 mm size] Fraction III -20% [below 10 mm size]
FA	Fraction I -90% [4.75 mm- 300μ size] Fraction I -10% [fly ash]

Fig 1: Ingredients of Trial Mix.

Fig- 2: Slump test

Table 9: super plasticizer dosage for various addition of silica fume for 100mm slump**.**

Silica Fume (%)	Superplasticizer (%)
0	0.75
2.5	0.9
5	1
7.5	1.1
10	1.15
12.5	1.2

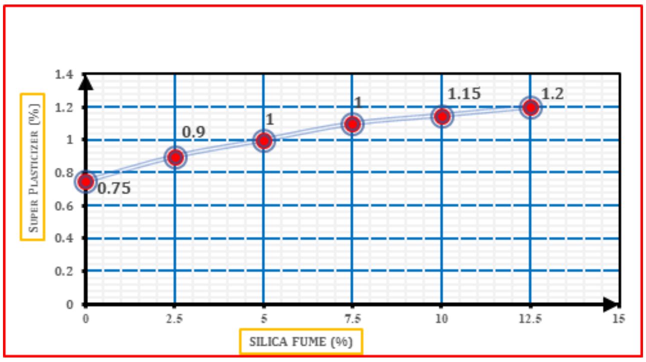

Chart -1: Silica fume and super plasticizer percentage for 100m slump

Fig-3: Compressive Strength Test

Fig-4: Break behavior of tested cubes**.**

5.2 Compression strength test

After 28 days curing period, the specimens were taken out of curing tank and were tested under a compression testing machine of 300-tonne capacity. The crushing loads were noted and the average compressive strength of three specimens is determined. The compression failure pattern of hardened concrete cube is due to crushing of coarse aggregate and not due to bond failure. Figure 3 and 4 shows the compressive strength test setup and break behavior of tested cube respectively.

The 7 Days and 28 Days results of compressive strength of various trial mix for M80 are expressed in tabular and graphical form shown below in Table 10 and chart 2 respectively.

Table 10. Compressive strength result after 7 Days and 28 Days

Trial Mixes	Silica Fume (%)	Fly ash (%)	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
CM	0.0	0.0	67.33	76.44
TM1	2.5	0.0	74.00	83.33
TM2	5.0	0.0	77.70	87.95
TM3	7.5	0.0	73.33	84.66
TM4	10.0	0.0	70.66	82.00
TM5	12.5	0.0	66.66	78.66
TM6	5.0	5.0	75.75	83.33
TM7	5.0	10.0	74.00	82.00
TM8	5.0	15.0	70.66	79.33
TM9	5.0	20.0	66.66	75.77
TM10	5.0	-	78.66	90.22

6. DISCUSSION ON RESULT

By referring IS 10262:2019 guidelines, trial mix combinations are designed for M80 grade concrete having w/c ratio as 0.26 kept constant with or without addition of cementaneous materials (CMS).Concrete work was carried out for M80 grade concrete, without addition of CMS named as control mix (CM) and others trial mixes (TM) are with addition of cementaneous materials like silica fume (SF) and fly ash (FA). The result of compressive strength was obtained at 7 Days and 28 Days curing period.

We casted cube conventionally like normal concrete but compressive strength at 28 Days result obtained less (i.e. 76.44 N/mm²) than the target strength (89.9 N/mm²). Therefore, it is not possible to achieve target strength of such high grade (M80). Concrete using cement as binder material which strength is restricted up to 53 Grade. Also, cement content goes to 573 kg/m³ which is greater than 450 kg/m³ suggested by IS 456 :2000, leads to shrinkage and cracking problem due to high heat of hydration. From past literature studied and suggestion of IS 10262:2019, it is necessary to use additional cementaneous material for high strength and durability view point.

Firstly, we consider SF as cementaneous material in various percentage addition (2.5%,5%,7.5%,10%,12.5) for making such high-grade strength (i.e. M_{80} concrete) which is suggested by IS 10262:2019 and decided optimum percentage to achieve target strength.

The Compressive strength of concrete showed gradual increase as the percentage of SF is increased up to 5% after which decreases the strength for further addition of SF. From graphical representation, considering only silica fume (TM2) 5% gives maximum compressive strength (87.95 N/mm²) which is nearly equal to target strength (89.9 N/mm²). But there is whole problem in hardened concrete at surface and interior also, shown in fig 5. It affects durability aspect.

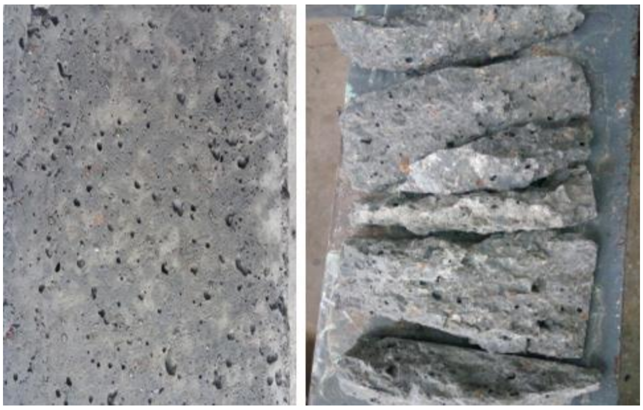

Fig-5: Whole problem in hardened concrete cube.

To overcome above problem and additional more strength with optimized 5% SF we added another popular material fly ash which is used to develop HPC, in various percentage addition (5%,10%,15%,20%) and with respective trail mixes (TM6-TM9) are carried out and compressive strength result shown in same graph chart 2. It is found that, when addition of fly ash from 5% to 20% results are goes decreasing sequentially from 83.33 N/mm² to 75.77 N/mm². But wholes in harden concrete cube is negligible.

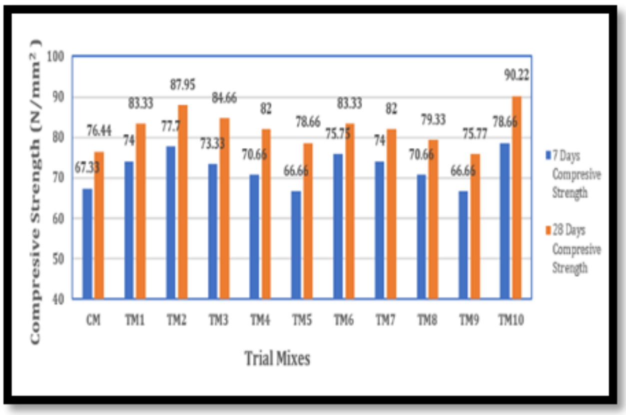

Chart-2: Trial mix verses compressive strength

Finally, we observed that, with minimum fly ash content and after removing dust in artificial sand we get well finished concrete surface and compressive strength up to 90 N/mm² which is greater than target strength (89.9 N/mm²). Therefore, we replace artificial sand below 300 micron which is nearly equal to 10%, is replaced by fly ash with well gradation of coarse aggregate sizes named as TM10 and it gives maximum compressive strength (90.22 N/mm²) result.

Hence, TM10 is optimum mix proportion of M80 grade concrete.

7. CONCLUSIONS

After completion of research work following conclusion are drawn:

- The Compressive strength result of concrete gradual increase as the percentage of SF is increased up to 5% after which decreases the strength for further addition of SF.
- As per 28 days curing, optimum mix proportion of M80 grade concrete is TM10 with SF (5%) and artificial sand below 300 micron which is nearly equal to 10%, is replaced by fly ash with well gradation of coarse aggregate of 20mm maximum sizes.
- It gives maximum compressive strength (90.22 N/mm²) result. Which is more than control mix (without mineral admixture) and target strength (89.9 N/mm²), have compressive strength (76.44 N/mm²).
- The ratio of 7days compressive strength to 28days compressive strength is up to 87%.
- The specific gravity of manufactured sand with dust and without dust is 2.25 and 2.74 respectively, which is responsible for compressive strength of concrete.

- Therefore, it is possible to achieve higher grade concrete using silica fume as mineral admixture and artificial sand without dust. Fly ash not gives much more strength in 28 days curing period.

- Use of SF in concrete reduces the workability. Therefore, by using PCE base superplasticizer (HRWR), it is possible to increase workability and high earlier strength at lower w/c ratio.

- The compression failure pattern of hardened concrete cube is due to crushing of coarse aggregate and not due to bond failure.

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BIOGRAPHIES

Prashant U. Narale received his BE in Civil Engineering and pursuing his MTech in Civil-Structural Engineering, at RIT, Sangli, Maharashtra.

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