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# Mix Design and Cost Analysis of High Performance Concrete M70 using SCMs and Superplasticizer

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**ABSTRACT:** The demand for sustainable and high-performance construction materials has led to the development of High-Performance Concrete (HPC). M70 grade HPC is widely used in structural applications, particularly where high strength and durability are required, such as in marine environments and high-rise buildings. This paper presents the mix design and cost analysis of M70 grade HPC incorporating Supplementary Cementitious Materials (SCMs) such as Ground Granulated Blast Furnace Slag (GGBS), Fly Ash, and Silica Fume. Additionally, Polycarboxylate Ether (PCE) superplasticizer is used to improve workability and reduce water-cement ratio. The mix design is developed following IS 10262:2019 guidelines, targeting a compressive strength of 70 MPa. Various proportions of SCMs are incorporated to optimize the performance of the concrete in terms of strength, durability, and cost. The use of SCMs helps to reduce the cement content, leading to a decrease in carbon footprint and cost. A detailed cost analysis is conducted by comparing the cost of raw materials such as cement, SCMs, aggregates, and admixtures. The results demonstrate that the inclusion of SCMs not only enhances the mechanical properties and durability of the concrete but also reduces the overall cost, making it an economically viable solution for high-performance applications. The findings indicate that with the optimal blend of materials, M70 grade HPC can be designed to meet both performance and economic requirements.

**KEYWORDS:** SCMs, High Performance Concrete, Mix Design, Ground Granulated Blast Furnace Slag (GGBS), Fly Ash, and Silica Fume, Polycarboxylate Ether (PCE)

## I. INTRODUCTION

In recent years, there has been a growing emphasis on sustainability in the construction industry, which has led to the increased use of Supplementary Cementitious Materials (SCMs) in concrete mix designs. SCMs such as Ground Granulated Blast Furnace Slag (GGBS), Fly Ash, and Silica Fume offer several advantages, including reduced environmental impact by lowering cement content, improved mechanical properties, and enhanced durability. The incorporation of SCMs in the mix design not only enhances the performance of concrete but also contributes to lower carbon emissions. To achieve the desired workability and strength of M70 grade concrete, the use of chemical admixtures, particularly Polycarboxylate Ether (PCE)-based superplasticizers, is essential. These superplasticizers significantly reduce water content while maintaining flowability, enabling the production of highly workable concrete with superior compressive strength. The mix design of M70 concrete must strike a balance between strength, durability, and cost-effectiveness. This involves selecting appropriate proportions of cement, aggregates, water, SCMs, and chemical admixtures. A well-optimized mix design not only ensures that the concrete meets structural and durability requirements but also minimizes the overall material costs. Cost analysis plays a vital role in determining the feasibility of M70 grade concrete in construction projects. The inclusion of SCMs can help reduce the reliance on costly cement while maintaining or improving the performance of the concrete. However, the use of high-quality superplasticizers and fine materials like silica fume may raise the overall cost. Therefore, a thorough cost analysis is necessary to evaluate the economic viability of producing M70 HPC, considering both material costs and long-term benefits such as reduced maintenance and extended service life. This study aims to develop a mix design for M70 grade HPC using SCMs and superplasticizers and to conduct a cost analysis to evaluate the economic impact of different mix designs. The study

will provide insights into the optimization of concrete mixes for high strength, sustainability, and cost-effectiveness, contributing to better decision-making in construction projects.

## II. OBJECTIVE

1. To design a mix for M70 grade concrete using GGBS, Fly Ash, Silica Fume, and PCE Superplasticizer to produce durable concrete.
2. To analyze Cost-effectiveness.

## III. MIX DESIGN

The right use of different proportion of mineral admixture like GGBS, fly ash, silica fume in the high-performance concrete increases the mechanical properties of high-performance concrete and reduces the consumption of natural resources and energy sources and lesser the burden of pollutants on environment. Therefore, it is proposed to have look into the effect of 30%, 40%, 50%, replacement of cement with mineral admixture like GGBS, fly ash, silica fume in the high performance concrete M70 Grade by performing an experiment with three type of mix, Mix1 Mix2, Mix3. The Concrete mix of M70 was used to cast the samples. The details of the concrete mix proportion are shown. The mix proportion shown is surface saturated dry (SSD) before moisture correction. The concrete mix was identified as Mix 1, Mix 2, Mix 3. the codes IS 456, IS 383, IS 10262:2009 were followed.

Concrete Mix-1 (With 30%SCMs.) SSD Weights details are as follows,  
Proportion of SCMs- GGBS-14%; Fly Ash-10%; Silica Fume-6%  
Trial Mix 1 as per IS 10262:2019

### TARGET STRENGTH FOR MIX PROPORTIONING

$f'_{ck} = f_{ck} + 1.65 S$  or  $f'_{ck} = f_{ck} + X$  whichever is higher.

where  $f'_{ck}$  = target average compressive strength at 28 days,

$f_{ck}$  = characteristic compressive strength at 28 days,

S = standard deviation, and X = factor based on grade of concrete.

From Table 2 of IS 10262:2019, standard deviation, S = 6.0 N/mm<sup>2</sup>.

Therefore, target strength using both equations, that is,

a)  $f'_{ck} = f_{ck} + 1.65 S$

= 70 + 1.65 × 6.0 = 79.9 N/mm<sup>2</sup>

b)  $f'_{ck} = f_{ck} + 8.0$  (The value of X for M 70 grade as per Table 1 is 8.0 N/mm<sup>2</sup>)

= 70 + 8.0 = 78.0 N/mm<sup>2</sup>

The higher value is to be adopted. Therefore, target strength will be 79.9 N/mm<sup>2</sup> as 79.9 N/mm<sup>2</sup> > 78.0 N/mm<sup>2</sup>

### APPROXIMATE AIR CONTENT

From Table 6 of IS 10262:2019, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1% for 20.0 mm nominal maximum size of aggregate

### SELECTION OF WATER-CEMENTIOUS MATERIALS RATIO

The free w/c ratio required for the target strength of design concrete as per IS 10262 is 0.00

The value of w/c prescribed IS 456 for said exposure for concrete design 0.40

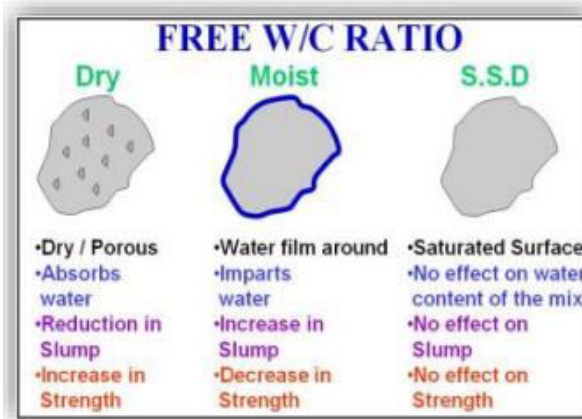
(Severe - exposure)

w/c ratio adopted for this concrete mix design is 0.21

0.21 < 0.40

Hence, O.K.





(1) Free W/c Ratio

**SELECTION OF WATER CONTENT**

From Table 7 IS 10262:2019,

Water content for 20 mm aggregate = 186 kg/m<sup>3</sup> (for 50 mm slump without using superplasticiser).

Now estimated water content for required slump, we adopted water content 208.32 Kg

Since High Range Water reducing admixture is used, the water content may be reduced based on trial data, water content reduction percent is considered, while using at the rate of added percent by the weight of total cementitious per cum.

Hence the water content reduction percentage considered 38%

Hence the water content for design mix is 130 kg

**CALCULATION OF CEMENT CONTENT**

Water–cement ratio = 0.21

Water content = 130 kg/m<sup>3</sup>

Cement content = 1130 / 0.21 = 615 kg/m<sup>3</sup>

From IS 456, minimum cement content for given exposure condition Severe 360 Kg/cum

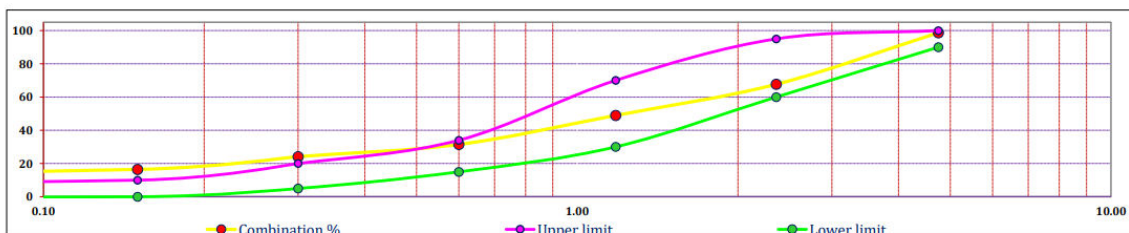
615 kg/cum > 360 Kg/cum

Hence O. K.

**Fine Aggregate Sieve Analysis**

Sieve Size	% Passing		0%		100%		% Passing Combined 100%
	R Sand	C Sand	R Sand	C Sand			
4.75mm	0.00	98.70	0.00	98.70			98.70
2.36mm	0.00	67.68	0.00	67.68			67.68
1.18mm	0.00	48.94	0.00	48.94			48.94
0.600mm	0.00	31.48	0.00	31.48			31.48
0.300mm	0.00	24.13	0.00	24.13			24.13
0.150mm	0.00	16.46	0.00	16.46			16.46

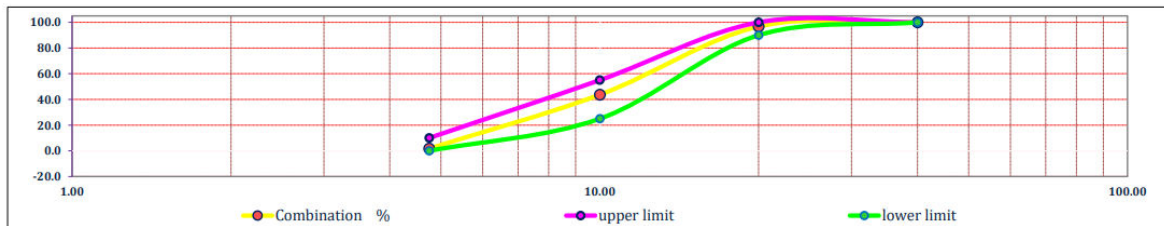
Fine aggregate sieve analysis confirming to grading Zone I reference IS 383



Coarse aggregate Sieve Analysis

Sieve Size	% Passing		55%	45%	% Passing
	20mm	12.5 mm	20mm	12.5mm	Combined 100%
40.00 mm	100.00	100.00	55.00	45.00	100.00
20.00 mm	94.06	100.00	51.74	45.00	96.74
10.00 mm	4.35	91.64	2.39	41.24	43.63
4.75 mm	0.54	3.20	0.30	1.44	1.74

Reference Indian Standard 383



(2) Blending gradation of aggregate in SSD condition.

PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT

Table 5 & 10 of IS 10262:2019 shows volume of coarse aggregate per unit volume of Total aggregate for different zones of fine aggregate for different w/c ratio

Note: - Volumes are based on aggregates in saturated surface dry condition

Suitable adjustment may also be made for aggregates; volume of coarse & fine aggregate may be increased or decreased suitably.

For pumpable concrete the volume of coarse aggregate should be reduced by 10%.

Volume of Coarse aggregate is required to be increased or decreased to decrease or increased the fine aggregate with respect to w/c ratio at the rate of + - 0.01 for every - + 0.05 change in w/c

20 mm size of aggregate & Zone-I, fine aggregate & adopted w/c ratio = 0.21

Proportion of volume of C. Aggregate ratio with reference to w/c given in Indian standard 0.3 = 0.64

Having difference in w/c 0.09

Corrected proportion of vol. of coarse aggregate for the water cement ratio of 0.21 = 0.66

Method of Concrete Placing is Pumping However based on to obtain cohesive concrete mix, we adopted CA aggregate percentage 67% and FA aggregate percentage 33%

Note: This percentage of aggregate is obtained after confirmatory trials done to ensure that mix does not look over fines. Also check percentage of Fine aggregate and Coarse aggregate by conducting sieve analysis and combined grading. Proper balance is maintained to avoid the mix being underhanded or over cohesive.

MIX CALCULATIONS

The mix calculation per unit volume of concrete.

Volume of Concrete	1 m <sup>3</sup>	
Volume of Cement	0.138	
Volume mineral admixture JSW GGBS	0.030	
Volume mineral admixture Fly Ash	0.023	
Volume mineral admixture Silica Flume	0.017	
Volume of Water	0.130	
Volume of Chemical Admixture	0.007	1.20%
Mass of coarse aggregate	1198	
CA. 20 MM	664	
CA. 12.5 MM	534	
Mass of fine aggregate	566	
FA. River Sand	0	
FA. CRF Sand	566	
FA. GBS Sand	0	

Concrete Mix-1 (With 30% SCMs) SSD Weights details are as follows,  
Proportion of SCMs- GGBS-14%; Fly Ash-10%; Silica Fume-6%

**Table 1. Concrete Mix Proportion for Mix-1 (Kg/m<sup>3</sup>) (With 30% SCMs)**

Ingredients	CMD-1 (SSD Weights in Kgs/Cum)
Cement	431
GGBS	86
Fly Ash	62
Silica Fume	37
20mm	664
12.5mm	534
Crushed Sand	566
Water	130
Admixture (1.2%)	7.38 kg
W/C ratio	0.21

Similarly, we did for Mix-2 and Mix-3  
Concrete Mix-2 (With 40% SCMs) SSD Weights details are as follows,  
Proportion of SCMs- GGBS-20%; Fly Ash-14%; Silica Fume-6%

**Table 2. Concrete Mix Proportion for Mix-2 (Kg/m<sup>3</sup>) (With 40% SCMs)**

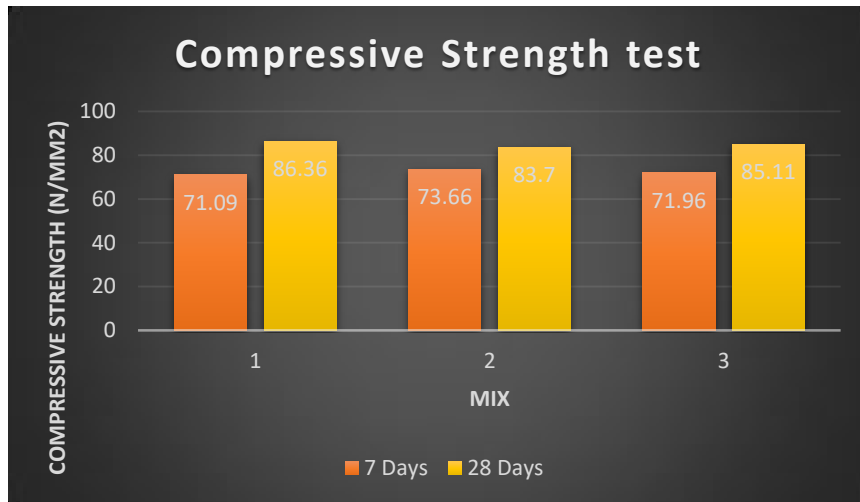
Ingredients	CMD-1 (SSD Weights in Kgs/Cum)
Cement	384
GGBS	128
Fly Ash	90
Silica Fume	38
20mm	607
12.5mm	596
Crushed Sand	534
Water	129
Admixture (1.2%)	7.68 kg
W/C ratio	0.20

Concrete Mix-3 (With 50% SCMs) SSD Weights details are as follows,  
Proportion of SCMs- GGBS-30%; Fly Ash-14%; Silica Fume-6%

**Table 3. Concrete Mix Proportion for Mix-3 (Kg/m<sup>3</sup>) (With 50% SCMs)**

Ingredients	CMD-1 (SSD Weights in Kgs/Cum)
Cement	335
GGBS	201
Fly Ash	94
Silica Fume	40
20mm	608
12.5mm	597
Crushed Sand	501
Water	129
Admixture (1.2%)	8.04 kg
W/C ratio	0.19

IV. RESULTS AND DISCUSSION



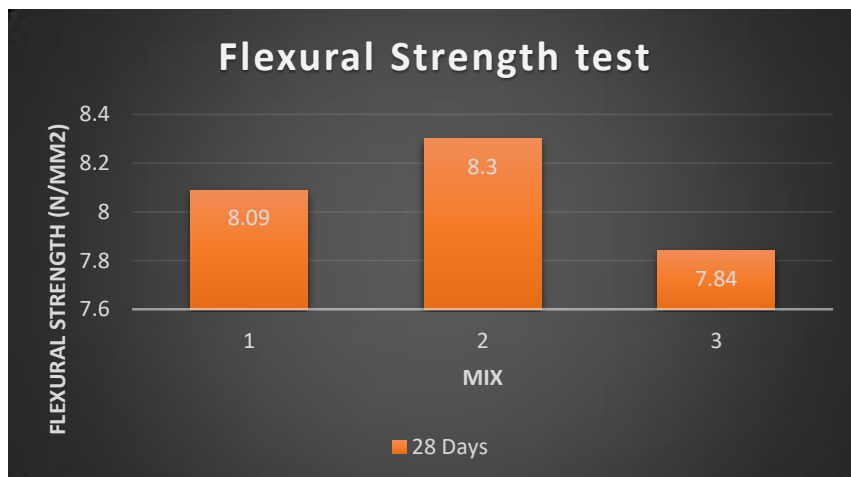
(3) Compressive strength test @7 Days & 28 Days

Test must be performed in compliance with IS: 516-1959.

Mix-1, Mix-2, and Mix-3 all exhibit early strength gain at the 7-day test, with Mix-2, which contains 40% SCMs, aving the highest compressive strength in comparison to the other two.

Similar to Mix-1 with 30% SCMs, Mix-3 with 50% SCMs exhibits 85.11 MPa more than Mix-2 with 40% SCMs, which shows 83.7 MPa, at the 28-day test.

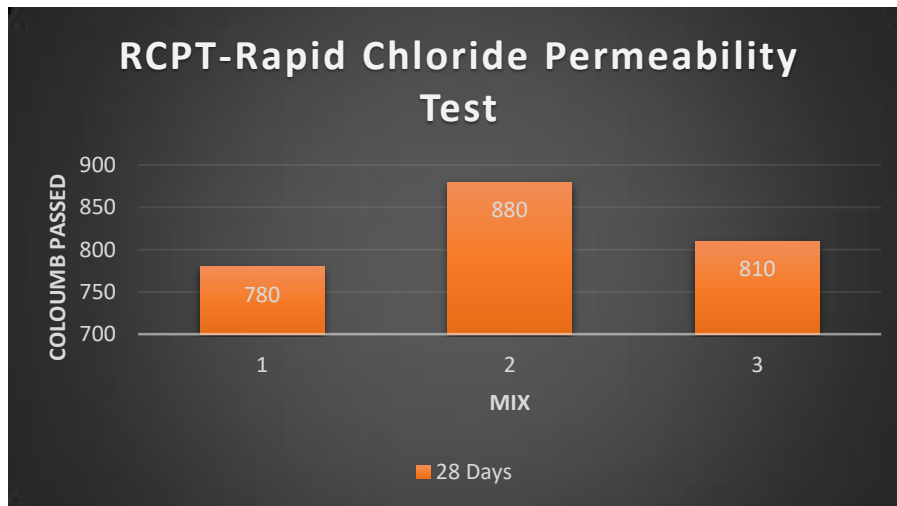
As a result, Mix-2 exhibits early strength growth.



(4) Flexural Strength Test.

28-Day Flexural Strength Test: Must be conducted in compliance with IS: 516-1959. One indicator of concrete’s tensile strength its flexural strength. It is a measure of how resistant an unreinforced concrete slab or beam is to bending failure. Concrete beams measuring 150 x 150 mm and loaded with a span length at least three times the depth are used to measure it.

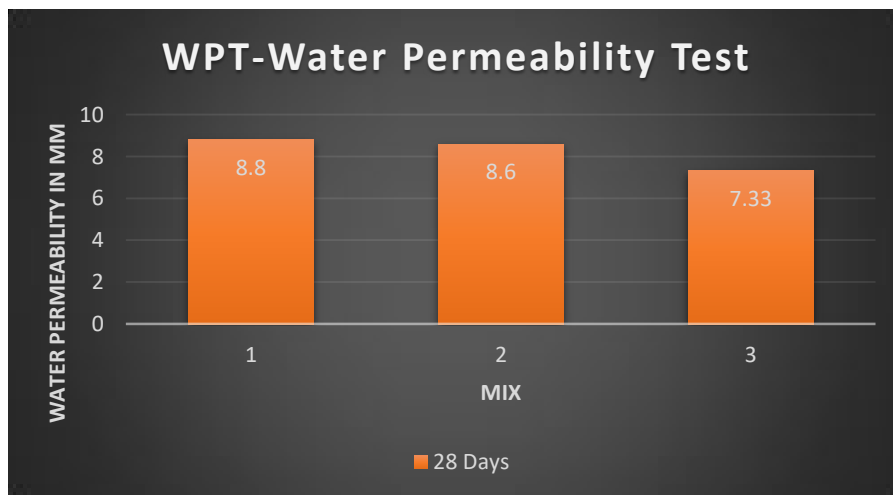
It was shown that Mix-2, which contains 40% SCMs, exhibits a maximum flexural strength of 8.3 MPa after 28 days.



(5) Rapid Chloride Penetration Test

**RCPT Rapid Chloride Penetration Test** at 28 Days; AASHTO T277 and ASTM C 1202 must be followed when conducting the test. The Rapid Chloride Permeability Test (RCPT) measures how resistant material is to chloride ion penetration. Because it is quick and easy to perform, the rapid chloride permeability test (RCPT) is frequently used to assess how resistant concrete is to the entry of chloride ions.

More chloride ion penetration is reduced in concrete Mix-1 with 30% SCMs than in the other two mixes. This demonstrates that the desired requirements of sites can be met by using SCMs in the right proportion.



(6) Water Permeability Test

**WPT- Water Permeability Test** @ 28 Days. Test to be carried out in accordance with BS EN 12390-8:2000 /DIN1048 Part 5:1996. WPT- The water permeability test determines the true resistance of concrete against the penetration of water under hydrostatic pressure.

Mix-3 with 50% SCMs has an average water penetration depth of 7.33 mm, which is better than the other two. Results indicate that using SCMs in concrete mixes greatly reduces water penetration, extending the life of structures.



V. COST ANALYSIS

We calculated cost for 1 m<sup>3</sup> for all three Mix.  
For Mix-1 cost difference is negligible and for Mix-2 cost difference is 61 Rs per m<sup>3</sup>.

Table 4: Cost Analysis

Rate of Materials		Per Kg.	Cost Difference	0	-61	-53
			Cost/Cum	6435	6375	6392
OPC JSW Cement (50 KG)	300	6.00				
JSW GGBS (50 KG)	150	3.00				
Fly Ash (50 KG)	100	2.00				
Silica Fumes (50 KG)	1500	30.00				
CA. 20mm M2 (MT)	795	0.80				
FA. I CRF Sand (MT)	915	0.92				
Admixture (Kg)	120	120.00				
Material (Kg)	M70(Mix1)	M70(Mix2)	M70(Mix3)			
JSW Cement OPC	431	384	335			
JSW GGBS	86	128	201			
FLY ASH	62	90	94			
Silica Fume	37	38	40			
CA 20mm M2	664	607	608			
CA 10mm M1	534	596	597			
FA I CRF Sand	566	534	501			
Admixture	7.39	7.68	8.04			
Total Water	135	129	129			
Free Water	217	208	208			
W/C	0.31	0.34	0.39			
<b>Theo. Density</b>	<b>2522</b>	<b>2514</b>	<b>2513</b>			

As per cost analysis the Mix-2 contains GGBS-20%; Fly Ash-14%; Silica Fume-6% gives more reduction in cost. Similarly, for Mix-3 cost difference is 53 Rs per m<sup>3</sup>. Mix-3 contains GGBS-30%; Fly Ash-14%; Silica Fume-6%. This test conducted on trial basics and outcomes has shown a good result as sustainable and economical.

VI. CONCLUSION

In conclusion, study highlights how adding SCMs to concrete mixtures provides advantages for technology, cost, and the environment. Optimizing blending combinations to successfully replace Ordinary Portland Cement (OPC) requires more research. According to the findings, SCMs are a sustainable and advised choice for the construction sector, meeting both industry expectations for improved concrete performance and environmental concerns.

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