



ECONOMICAL SELF COMPACTING CONCRETE WITH VARIABLE WATER-CEMENT RATIO

Engineering

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ABSTRACT

Self Compacting Concrete (SCC) has brought a great revolution in the field of construction industry since its invention. This happened due to its copious advantages over the conventional concrete. However, drawbacks like relative high cost, bleeding and adverse affects on environment have been hindering the wide usage of self compacting concrete. Therefore this paper investigates different approaches to tackle the disadvantages of SCC. In this experiment, we have framed 3 different mix designs of M20 grade according to European Guidelines for SCC and replaced the cement with high fly ash content by 45% and 50%. We also have taken two different water-cement ratios (0.38 and 0.33) according to which the proportion of the admixture (superplasticizer) used also changes. After that, we have carried out various characteristic tests like flow table test, O funnel test, U Box and L Box test to measure its workability and have casted cubes of 15 cm x 15 cm x 15 cm each to check its compressive strength in 3, 7 and 28 days. At the end, we have done cost analysis for each mix design to find out the optimum and economical mix design.

KEYWORDS

self compacting concrete, high fly ash content, variation in water-cement ratio, economical SCC

INTRODUCTION

As the name suggests, Self Compacting Concrete is a highly flowable concrete which gets compacted under its own weight and doesn't need any external source of vibration, thus reduces noise. It is highly workable concrete which can be placed easily in onerous conditions like underwater concreting and sections with thinner cross section or with congested reinforcement providing faster construction, better finishing and greater freedom in design. Due to its high flowability, it can be pumped easily and thus reduces manpower.

When the construction industry in Japan experienced a decline in the availability of skilled labour in the 1980's, a need was felt for a concrete that could overcome the problems of deficient workmanship. This led to the development of self-compacting concrete, primarily through the work by Okamura. Since then it has gained international popularity and is now a focus of interest. It has been successfully used in many countries like Sweden, Thailand, France, Denmark, the Netherlands and UK, apart from Japan. Research and development of SCC is widespread in these countries and the knowledge of SCC has moved from domain of research to application. But in India, the goal of uniformity and acceptance for practical use has not yet been fully realized.

However, drawbacks like relative high cost, bleeding and adverse affects on environment have been hindering the wide usage of self compacting concrete. Thus, this paper intends to find an economical and eco-friendly SCC mix design. In the experiment, we have taken fly ash content replacing cement content by 45% and 50%. We have also changed the water-cement ratio to study its effect on the economy of the SCC.

EXPERIMENTAL PROGRAM

SCOPE OF EXPERIMENT

- Study of use of fly ash as the replacement of cement
- Framing of mix design of SCC using fly ash
- Casting of SCC cubes and beam as per the mix design
- Testing of SCC's property to know whether it fulfills its criteria
- Costing of SCC
- Providing optimum mix design with respect to Strength, Durability and Workability & Economy.

OBJECTIVES OF EXPERIMENT

- To make SCC economical
- To make SCC eco-friendly
- To lessen the use of admixtures

MATERIALS USED

Cement: Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together. Cement used in this experiment was Ordinary Portland Cement (Grade 53). The minimum cement content taken was 300 kg/m³. Cement had specific gravity of 3.15 and other physical properties were according to the IS 12269 (2013)

Aggregate: Aggregates are inert granular materials such as sand, gravel or crushed stone that are an end product in their own right. Aggregates constitute the bulk of a concrete mixture, and give dimensional stability to concrete.

Aggregates used in the experiment

- Coarse Aggregate: Locally available natural river sand with 4.75 mm maximum size was used as fine aggregate and have specific gravity and zone as per Table 1.
- Fine Aggregate: Crushed stone with 10mm maximum size and have specific gravity and zone as per Table 1.

Both fine aggregate and coarse aggregate conformed to Indian Standard Specifications IS: 383-1970 [6]. Table 1 gives the physical properties of the coarse and fine aggregates.

TABLE – 1 COARSE AND FINE AGGREGATE PHYSICAL PROPERTIES

Physical Properties	Coarse Aggregates	Fine Aggregates
Specific Gravity	2.66	2.65
Zone	Zone 1	Zone 4

Admixtures: Material added during the mixing process of concrete in small quantities related to the mass of cement or water to modify the properties of fresh or hardened concrete.

There are two types of admixture used

- Chemical Admixture (Superplasticizer)
- Mineral Admixture (Fly Ash)

Superplasticizer: Superplasticizers, also known as high range water reducers, are chemical admixtures are used as dispersants to avoid particle segregation (gravel, coarse and fine sands) and to improve the flow characteristics.

A polycarboxylic ether based superplasticizer named 'CHRYSO Fluid Optima 380' was used in this experiment.

Fly Ash: Mineral admixtures such as fly ash, are fine inorganic materials with pozzolanic properties which are commonly used to improve and maintain the workability, as well as to regulate the cement content and so reduce the heat of hydration.

Here, Class F fly ash conforming ASTM C618, was used in the testing. The physical properties and chemical contents of the fly ash are given in table 2 and 3 respectively.

TABLE – 2 FLY ASH PHYSICAL PROPERTIES

Physical Properties	Results
Color	Grey
Specific Gravity	2.30

TABLE – 3 FLY ASH CHEMICAL PROPERTIES

Chemical Contents	Weight (%)
Silica (SiO ₂)	55
Alumina (Al ₂ O ₃)	26
Calcium Oxide (CaO)	9
Ferric Oxide (Fe ₂ O ₃)	7
Loss Of Ignition	6
Magnesium Oxide (MgO)	2
Sulfate Oxide (SO ₃)	1

FRAMED MIX DESIGNS

The mix design of Self Compacting Concrete can be done by using 'The European Guidelines of Self Compacting Concrete'. Thus with the help of European Guidelines and other various references, we were successful in framing 3 mixed designs of SCC of M20 grade with fly ash replacing cement. The mix designs are given below

TABLE – 4 MIX DESIGN CONTENTS

Material	Weight in kg/m ³ (Trial Mix 1)	Weight in kg/m ³ (Trial Mix 2)	Weight in kg/m ³ (Trial Mix 3)
Cement	337.17	306.49	388.03
Fly Ash (Filtered)	275.77 (45%)	306.36 (50%)	317.65 (45%)
Coarse Sand	318.37	316.49	297.96
Fine Sand (River Sand)	383.60	381.35	359.03
Aggregate (10mm)	784.85	780.24	749.38
Water	257.71	257.57	256.19
Admixture (Superplasticizer)	1.283	0.856	1.478
W/C Ratio	0.38	0.38	0.33



Image 1: Flow Table Test



Image 2: L-Box Test



Image 3: U-Box Test



Image 4: O Funnel Test

TABLE – 5 WORKABILITY TEST RESULTS

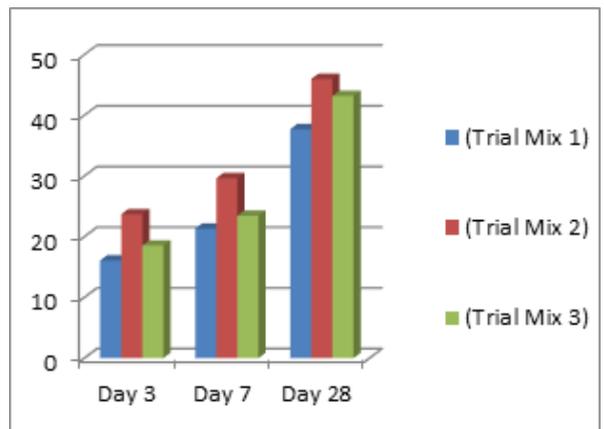
Test	Unit	Typical ranges (Min)	Typical ranges (Max)	Value Obtained		
				Trial Mix 1	Trial Mix 2	Trial Mix 3
Flow Table	mm	650	800	760	730	780
L-box	mm	0.8	1	0.89	0.85	0.84
U-box	mm	0	1	0	0	0
O- Funnel	sec	8	12	9	12	11

COMPRESSIVE STRENGTH RESULTS

TABLE – 6 COMPRESSIVE STRENGTH RESULTS

Specimen	Average Peak Stress (MPa)		
	3 rd day	7 th day	28 th day
SCC (Trial Mix 1)	16.05	21.35	37.7
SCC (Trial Mix 2)	23.70	29.7	46
SCC (Trial Mix 3)	18.55	23.45	43.1

GRAPH 1 COMPRESSIVE STRENGTH



COST ANALYSIS

In order to know the economic aspect, we have done the cost analysis of mix designs. The following table shows the details of cost of each component (cost of each component may vary according to time and location) and also the overall cost of per cubic metre.

TABLE – 7 COST ANALYSIS TABLE

Content	Trial Mix 1	Trial Mix 2	Trial Mix 3
W/C Ratio	0.38	0.38	0.33
Cement	Rs 1854.44	Rs 1685.70	Rs 2134.17
Fly Ash	Rs 330.92 (45%)	Rs 367.63 (50%)	Rs 387.18 (45%)
Coarse Sand	Rs 191.02	Rs 189.90	Rs 178.78
Fine Sand	Rs 191.8	Rs 190.68	Rs 179.52
Aggregate	Rs 549.40	Rs 546.17	Rs 524.57
Admixture	Rs 153.96	Rs 102.72	Rs 177.36
Total Cost	Rs 3271.54	Rs 3082.80	Rs 3581.58

CONCLUSION

The following conclusions can be drawn on the basis of SCC mix design

- By increasing the fly ash, the compressive strength is drastically increased. This can be concluded by comparing trial mix 1 and 2.
- Increase in the fly ash increases the homogeneity and thus less admixture is required.
- The reduction in cement content and increase in the materials finer than 80 µm like fly ash, increase packing density and can reduce the water-cement ratio and also the high-range water reducer (HRWR) demand.
- Moreover, by replacing the cement with fly ash by 50%, the heat of hydration is minimized and thus the concrete becomes eco friendly to a great extent.
- As we decrease the water-cement ratio, the compressive strength is undoubtedly increased but on other hand, the amount of water reducer has to be increased in order to maintain the flowability and workability of the concrete which increases the overall cost as seen in trial mix 3.
- Overall we can conclude, the trial mix 2 with 50% of fly ash and 0.38 water-cement ratio, has durability, workability, homogeneity and is also eco-friendly with adequate compressive strength.

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