A Case Study of the Self Compacting Concrete for M70 Grade for Residential Building

[1]Valvi Tejas Ramsing, [2]Sable Trupti Panditrao, [3]Valvi Sakshi Hemant
[4]Gangurde Hemant Devidas, [5]Prof. Puneet Jain

Department of Civil Engineering,
Sandip Institute of Engineering and Management Nashik, India

Abstract— **Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in different conditions and in sections with congested reinforcement. Use of SCC can also help to minimize hearing related damages on the worksite that are induced by vibration of concrete. The main object of this paper is to design mix for self-compacting concrete (SCC) of M70 grade concrete for water-cementitious ratio, air content, water content, admixture and aggregate content. The ingredients of concrete affect its various characteristics like strength, durability etc. it isn't easy to compact the reinforced concrete without voids. This can be overcome by using self-compacting concrete. This type of concrete does not required compaction. Concrete mix design of M70 grade was done according to Indian standard code. Concrete cube specimens were tested for evaluation of compressive strength. Also, for design mix of HSC the silica fume and fly ash used at various percentage replacement levels with cement whereas superplasticizer is used. This review paper explains self-compacting concrete and its material and mix design of self-compacting concrete (SCC).**

Keywords— **Self compacting concrete, M70 grade, water-cementitious ratio, air content, admixture, strength, durability, silica fume, fly ash, superplasticizer.**

I.INTRODUCTION

The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura, but it was first developed in 1988 in Japan by Professor Ozawa (1989) at the University of Tokyo. Self-compacting concrete (SCC) does not require any vibration and compaction for placing. It is able to flow under self-weight and achieving full compaction between congested steel reinforcement. as comparable to conventional concrete SCC has a strength and durability. the use of self-compacting concrete (SCC) has gained wide acceptance in the precast industry as well as in-situ constructions on account of reduction in the time of construction, noise of construction by eliminating vibration and good possibility of usage of complex formworks and members with highly congested reinforcement etc leading to achievement of a better final product in terms of finish and durability. As per IS: 456–2000 [Code of Practice for Plain and Reinforced Concrete], concretes ranging 25 – 55 MPa are called standard concretes and above 55 MPa called high strength concrete and above 120/150 MPa are called ultra high strength concrete. The applications of High strength concrete has numerous in buildings, bridges with long span and buildings in aggressive environments. Building elements made of high strength concrete are usually densely reinforced. At concreting time congested reinforcement creates a problems in placing the concrete. Densely reinforced concrete problems can be solved by using concrete that can be easily placed and spread in between the congested reinforced concrete elements. A highly homogeneous and well spread and dense concrete can be ensured using such a type of concrete. Usually range of compressive strengths of SCC is 60-100 N/mm2. However, as per requirements grades of concrete can be used. SCC was developed at the University of Tokyo in Japan in 1980 for used of congested reinforcement structures in an highly Earthquake regions. Durability of the structures is a very important lesson in Japan and skilled labor required for the compaction of concrete for durability of the structures. The SCC first reported in 1989. This requirement led to the development of SCC. The development of SCC was first reported in 1989. SCC is a new kind of High Performance Concrete (HPC) which has an excellent deformability and segregation resistance and flow through self weight in a congested reinforcement. Study on self compacting concrete is made for M70 grade of polycarboxylate ether based super plasticizers. The material is to be used this study are cement (53 grade), aggregate (having size 20 mm), chemical admixture (polycarboxylate ether PCE) to improve workability. It is beneficial for faster construction, reduction in site manpower, thinner concrete sections and self working environment. Self compacting concrete (SCC) to fulfill all these requirement. The research to develop new type concrete named self compacting concrete (SCC).

OBJECTIVES: -

- To achieve ultra-high strength self- compacting concrete of M70 grade using PCE and by performing trial and error method for the mix design.
- To achieve the fresh properties like flowability, possibility, resistance to segregation, segregation to bleeding, etc. of self-compacting concrete.
- To achieve the hardened properties of self- compacting concrete.

II. LITERATURE REVIEW

Prof. Shriram H. Mahure. The fresh and hardened properties of self compacting concrete using Fly ash 2014. The author had studied about the fresh and hardened properties of self compacting concrete using Fly ash as partial replacement of cement in different percentages in addition to filler. The fresh properties have been determined by computing the Slump value, V-funnel value and L-box value and the hardened properties are determined by computing the Compressive strength, Flexural strength and Split tensile strength of the specimens. It is observed that the fresh properties of concrete shows an acceptable value upto 30% replacement of fly ash and also the hardened properties of concrete is significantly improved when compared to the conventional mix.

J. Guru Jawahar. The properties of self compacting concrete by replacing the aggregate with crushed granite stones, 2012. The paper presents the properties of self compacting concrete by replacing the aggregate with crushed granite stones of size 20mm and 1Omm. The concrete is obtained by replacing the cement with the class F fly ash by 35% and 0.36 water/cementitious ratio by weight. The fresh properties of the concrete were obtained by conducting workability test, V-funnel and L-box test. The test is conducted for different type of mixes. The test reveals that some mixes are successful in slump flow test they were failed in V-funnel and L-box test. He also concluded about the range of coarse aggregate content suitable for particular coarse aggregate blending in self Compacting concrete.

Payal Painuly, Itika Uniyal “Self Compacting Concrete” International Journal of Technical Research and Applications e-ISSN, 2320-8163, 2016. Making concrete structure without compaction has been done in the past. Like placement of concrete underwater by the use of termie without compaction. Inaccessible areas were concreted using such techniques. The production of such mixes often used expensive admixtures and very large quantity of cement. But such concrete was generally of lower strength and difficult to obtain. This lead to the development of Self Compacting Concrete (SCC) The workability properties of SCC such as filling ability, ability and segregation resistance are evaluated using workability tests such as slump flow, V- funnel and L-Box tests.

S.Santos, PR Da Silva, Jorge De Brito . “Self-compacting concrete with recycled aggregates” Journal of Building Engineering 22, 349-371, 2019. This paper presents a complete and updated literature review on the properties of self-compacting concrete with fine and coarse recycled aggregates. The subject of self compacting concrete with recycled aggregates (RASCC) is greatly relevant to Society, since there is an increasing demand from the construction industry to adopt new processes to minimize its negative impacts on the environment. The use of recycled aggregates in concrete production presents a great environmental benefit through savings from the extraction of natural aggregates and the reduction of dumped material.

Rafat Siddique. Strength and durability properties of self compacting concrete, 2013. This paper presents investigation about the strength and durability properties of Self-Compacting. Concrete which is obtained by partially replacing natural sand with waste foundry sand (WFS). He replaced the Natural sand with WFS by 0%, 10%, 15% and 20% in terms of weight. He studied the fresh properties of concrete before computing the strength parameters. Compressive strength and split tensile strength test were obtained at the age of 7, 28, and 56 days and to determine the durability of the concrete, sulphate resistance was evaluated at the age of 7, 28 and 56 days and Rapid Chloride Permeability test was conducted at age of 28 days. Test results have shown that there is increase incompressive strength and split tensile strength of self-compacting concrete and also the durability properties have been improved by incorporating waste foundry sand as a replacement of Natural sand.

III. MATERIALS: -

Cement :-

Ordinary Portland cement of 53 grade [IS 12269-1987,specifications for 53 grade ordinary Portland cement] has been used in the study.the cement content can be 350 – 450 kg/m^3. The usage of cement more than 500 kg/m3 may increase the shrinkage in the hardened state of concrete whereas the quantity less than 350 kg/m^3 may decrease the durability of SCC.

Aggregate:-

Fine aggregate :-

The fine aggregate used was locally available river sand without any organic impurities and conforming to IS 383 – 1970 [method of physical tests for hydraulic cement]. The finr aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS 2386 – 1963 [Methods of test for aggregate for concrete]. The amount of fines has a very significant effect on SCC mix proportions. Fine sand requires more water and superplasticizer but less filler than coarse sand.

Coarse aggregate :-

The coarse aggregate chosen for SCC was typically crushed angular in shape, well graded smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self compacting concrete was between 16mm to 20mm.these were tested as per IS 383 – 1970[Methods of physical tests for hydraulic cement]. The physical properties like, bulk density, flakiness index, elongation index and fineness modulus.

Water:-

Water is used for mixing and curing potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS : 3025-1964 part 22, part 23 and IS : 456-2000 [code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS:456-2000.

Mineral admixture :-

Fly ash :-

Fly ash is one of the most extensively used supplementary cementitious material in the construction field resembling Portland cement. It conforms with grade I of IS 3812-1981 [specifications for fly ash for use as pozzolana and admixture]. It was tested in accordance with IS 1727-1967 [Methods of test for pozzolana material].

Silica fume :-

Silica fume is an amorphous (non crystalline) polymorphous of silicon dioxide, silica, silica fume is added to Portland cement concrete to improve its properties in particular its compressive strength, bond strength and abrasion resistance.

Chemical admixture :-

Superplasticizer:-

High range water reducing admixture called as superplasticizer are used for improving the flow or workability for lower water cement ratios without sacrifice in the compressive strength. Water reducing admixture Glenium conforming to IS 9103:1999 [specification for admixtures for concrete].

IV. MIX DESIGN AND PROPORTION MIX DESIGN OF M70 GRADE

Step-1 :- Stipulations for proportioning

Grade designation :- M70
Type of cement :- OPC 53 grade conforming to IS 269
Silica fume :- Conforming to IS 15388
Maximum nominal size of aggregate :- 20 mm
Exposure condition as per table 3 and table 5 of IS 456 :- Severe (for reinforced concrete)
Workability :- 120 mm slump
Method of concrete placing :- Pumping
Degree of supervision :- Good
Type of aggregate :- Crushed angular aggregate
Maximum cement (OPC) content :- 450 kg/m^3
Chemical admixture type :- Superplasticizers (polycarboxylate ether based)

Step-2 :- Test data for materials

Cement used :- OPC 53 grade conforming to IS 269
Specific gravity of cement :- 3.15
Specific gravity of
Coarse aggregate (at SSD condition) :- 2.74
Fine aggregate (at SSD condition) :- 2.65
Fly ash :- 2.20
Silica fume :- 2.20
Chemical admixture :- 1.08
Water absorption
Coarse aggregate :- 0.5%
Fine aggregate :- 1.0%
Moisture content
Coarse aggregate :- Nil
Fine aggregate :- Nil
Sieve analysis
Coarse aggregate :- conforming to table 7 of IS 383
Fine aggregate :- conforming to grading zone 2 of table 9 of IS 383
Type of aggregate :- Coarse aggregate :- Crushed angular
Fine aggregate :- Zone 2

Step-3 :- Target strength for mix design

F'ck = fck + 1.65 S
OR
F'ck = fck + X
Whichever is higher.
Where,
F'ck = Target average compressive strength at 28 days
Fck = Characteristics compressive strength at 28 days
S = Standard deviation
X = Factor based on grade of concrete
From table 2 of IS 10262 : 2019, Standard deviation, S = 6.0 N/mm^2 therefore, target strength using both equations that is,
F'ck = fck + 1.65 S
= 70 + 1.65 x 6.0
= 79.9 N/mm^2
F'ck = fck + 8.0 (The value of x for M70 grade as per table 1 is 0.8 N/mm^2)
= 70 + 8.0
= 78.0 N/mm^2

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

Step-4 :- Approximate air content
As per clause 6.2.3 of IS 10262 : 2019 (section 3) from table 6, the approximate amount of entrapped air is to be expected in normal (non-air-entrained) concrete is 0.5% for 20 mm nominal maximum size of aggregate.

Step-5 :- Selection of water-cementitious material ratio
As per clause 6.2.5 of 10262 : 2019 (section 3) from table 8, the water-cementitious materials ratio required for the target strength of 79.9 N/mm^2 is 0.29 for 20 mm aggregate. This is lower than the maximum value of 0.45.
The maximum W/C ratio for severe exposure condition is 0.45 (from table 5)
0.29 < 0.45 hence O.K

Step-6 :- Selection of water content
As per clause 6.2.4 of 10262 : 2019 from table 7, water content for 20 mm aggregate is 186 kg/m^3 (for 50 mm slump without using superplasticiser)
Estimated water content for 120 mm slump.

$WCx = WC_{50} + X\text{-}50/25 \times 3/100 \times WC_{50}$

$WC_{120} = 18.6 + 120 – 50/ 25 \times 3/100 \times 186$

$= 201.62$ kg/m^3 of concrete

As superplasticiser (polycarboxylate ether based) is used, the water content can be reduced by 30 percent.
Hence, the reduced water content.
= 202 x 30/100
= 202 – 60.6

Step-7 :- Calculation of cementitious content
From table 5 of IS 456 : 2000, the minimum cementitious content is
Water-cementitious ratio = 0.29
Water content = 141 kg/m^3
Cement content = 141/0.29 = 486 kg/m^3
The cementitious material content = 486 x 1.10 = 535 kg/m^3
Fly ash @ 15% by weight of cementitious material = 535 x 15% = 80.25 kg/m^3
Silica fume content @ 5% by weight of revised cementitious material = 535 x 5%
= 26.75 kg/m^3
Cement content = 535 – 26.75 – 80.25 = 428 kg/m^3
Revised W/C ratio = 141/535 = 0.264
Check for minimum cementitious material content 320 kg/m^3 < 535 kg/m^3 (428 kg/m^3 OPC + 26.75 kg/m^3 silica fume + 80.25 kg/m^3 fly ash) Hence O.K

Step-8 :- Proportion of volume of coarse aggregate and fine aggregate content
As per cl
ause 6.2.7 of IS 10262 : 2019 from table 10, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate grading zone 2 = 0.66 per unit volume of total aggregate. This is valid for water-cementitious materials ratio of 0.30. As water-cementitious material ratio is actually 0.264, the ratio is taken as 0.667.
We cannot use table 10, because it is used when W/C ratio is 0.3
Volume of coarse aggregate / unit volume of any W/C ratio
= Vca@ 0.3 + 0.3-w/0.05 x 0.01 (clause 6.2.7)
For 20 mm maximum nominal size aggregate and for zone 2 grading for W/C ratio of 0.3 it is 0.66.
Volume of coarse aggregate / unit volume of any W/C ratio = 0.66 + 0.3-0.264/0.05 x 0.01 = 0.6672.
As per clause 6.2.7 of IS 10262 : 2019, since pumping is the method of placing of concrete
Revised volume of coarse aggregate / unit volume @ 264 W/C ratio
= 0.6637 x 0.95 = 0.634 i.e Coarse aggregate is 63.4% of total aggregate.
Similarly, revised volume of fine aggregate / unit volume @ 0.264 W/C ratio = 1-0.634 = 0.366 i.e fine aggregate content is 36.6% of total aggregate.

Step-9 :- Mix calculations
Total volume = 1 m^3
Volume of entrapped air in wet concrete = 0.005 m^3
Volume of cement = Mass of cement/specific gravity of cement x 1/1000
= 428/3.15 x 1/1000
= 0.136 m^3
Volume of water = mass of water / specific gravity of water x 1/1000

= 141/1 x 1/1000
= 0.141 m^3
Volume of silica fume = mass of silica fume / specific gravity of silica fume x 1/1000
= 26.75/2.2 x 1/1000
= 0.0121m^3
Volume of fly ash = mass of fly ash / specific gravity of fly ash x 1/1000
= 80.25/2.2 x 1/1000
= 1.1365 m^3
Volume of chemical admixture (superplasticizer @ 0.5% by mass of cementitious materials)
= mass of chemical admixture/ specific gravity of admixture x 1/100
= 535 x 0.5%/1.08 x 1/1000
= 0.0025 m^3

Volume of all aggregate
= {(a-b)–(c+d+e+f+g)}
={(1-0.005) –(0.136+0.14+0.0122+0.0365+0.0025)}
= 0.667 m^3

Mass of coarse aggregate = h x volume of coarse aggregate x specific gravity of coarse aggregate x 1000
= 0.667 x 0.634 x 2.74 x 1000
= 1159.03 kg
Mass of fine aggregate = h x volume of fine aggregate x specific gravity of fine aggregate x 1000
= 0.667 x 0.366 x 2.65 x 1000
= 647.11 kg

Step-10 :- Mix properties for trial number 1 on aggregate in SSD condition
Cement = 428 kg/m^3
Fly ash = 80.25 kg/m^3
Silica fume = 26.75 kg/m^3
Water = 141 kg/m^3
Fine aggregate = 647.11 kg/m^3
Coarse aggregate = 1159.03 kg/m^3
Chemical admixture = 2.675 kg/m^3
W/C ratio = 0.264

Step-11 : Adjustments in mix design
Fine aggregate (dry) = mass of FA in SSD condition/1+(% of water absorption /100) – (% of moisture content / 100)
= 647.11/1+(0.5/100) – (0/100)
= 643.89 kg/m^3
Extra water required for FA to simulate a SSD condition
A = (mass of FA in SSD condition) – (mass of FA in dry condition)
= 647.11 – 643.89
= 3.22 kg/m^3
The interference from above is, if we add more 3.22 kg/m^3 of water, then it will saturate FA such that it will not absorb more water, hence, it will have a SSD condition.
Coarse aggregate (dry) = mass of CA in SSD condition / 1+(% of water absorption/100) – (% of moisture content / 100)
=1159.03/1+(0.5/100) – (0/100)
= 1153.26 kg/m^3
Extra water required for FA to simulate a SSD condition
B = (mass of CA in SSD condition) – (mass of CA in dry condition)
= 1159.03 – 1153.26
= 5.77 kg/m^3
Total water required = water required + A+ B
= 149.99 kg/m^3
= 150 kg/m^3

Step-12 :- Mix proportion after the adjustments
Required quantities after revised Material
Cement = 428 kg/m^3
Water = 150 kg/m^3
W/C ratio = 0.264
Fly ash = 80.25 kg/m^3

Silica fume = 26.75 kg/m^3
Superplasticizer = 2.675kg/m^3
Coarse aggregate = 1159.03 kg/m^3
Fine aggregate = 647. 11 kg/m^3
Water : Cement : F.A : C.A
0.35 : 1 : 1.511 : 2.708

V. RESULT AND DISCUSSION: -

Fresh and Hardened state properties of SCC :-

Test results on fresh concrete the workability test i.e. Slump flow test, V-funnel test, L-box test results to obtained for different fly ash replacement with cement i.e. (0%, 5%, 10%, & 15%) with constant water cement ratio (0.25).

For w/c 0.25, slump flow increases from 665mm to 668mm (0.45%).V-funnel values are increasing with fly ash replacement increases. V-funnel time increases from 8.20 sec to 8.32 sec (1.46%). It is observed that workability value increases in fly ash content 0 to 15%. L-box value increases 0.968 to 0.969 as the fly ash value increases in 0 to 15%. 7 days compressive strength increases from 53.10Mpa to 53.87 (1.45%). Whereas 28 days compressive strength increases from 81.65 Mpa to 82.87 Mpa (1.49%). 7 days split tensile strength increases from 3.44 Mpa to 3.45 Mpa (0.29%). Whereas 28 days split tensile strength increases from 4.06 Mpa to 4.07 (0.24%). 7 days flexural strength decreases from 5.72 Mpa to 5.73 Mpa (0.174%). Whereas 28 days flexural strength decreases from 6.20 Mpa to 6.30 Mpa (1.62%).

It is observed that compressive strength and split tensile strength decreases at higher rate for 7 days strength when compared to 28 days strength, whereas the flexural strength increases at a higher rate for 28 days strength when compared to 7 days strength.

Fig. Slump Flow Test apparatus

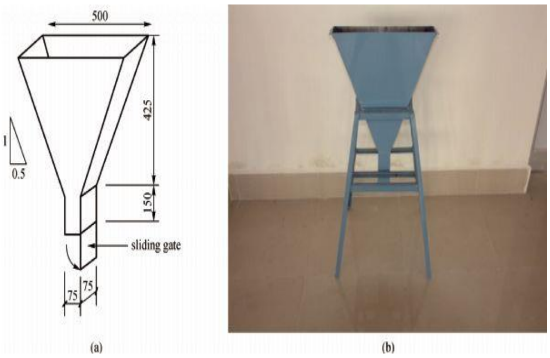

Fig. V – Funnel Test apparatus

Fig. L - Box Test apparatus

VI. CONCLUSIONS:

Based on the systematic and detailed experimental study conducted on SCC mixes with an aim to develop performance mixes, the following are the conclusions arrived in Residential Building:-

- Mix proportion should consist of maximum amount of powder content (fines materials) for achieving ultra-high strength.
- Use of standard chemical admixtures (PCE) plays an important in achieving the fresh properties of SCC.
- For achieving the desired strength only fine aggregate must be used, as coarse aggregate fail above 80Mpa strength.
- To achieve properties of fresh concrete i.e. flowability and workability, an optimum amount of water and PCE has to be used which can be decided by trial and error.
- Higher the strength higher is the cement content leading to problems like shrinkage and creep which is avoided by adding steel and polymer fibres.
- High powder content and low water content is the main criteria for mix design.

REFERENCES:

1. Prof. Shriram H. Mahure. The fresh and hardened properties of self compacting concrete using Fly ash 2014.
2. J. Guru Jawahar. The properties of self compacting concrete by replacing the aggregate with crushed granite stones, 2012.
3. Payal Painuly, Itika Uniyal "Self Compacting Concrete" International Journal of Technical Research and Applications e-ISSN, 2320-8163, 2016.
4. S.Santos, PR Da Silva, Jorge De Brito . "Self-compacting concrete with recycled aggregates" Journal of Building Engineering 22, 349-371, 2019.
5. Rafat Siddique. Strength and durability properties of self compacting concrete, 2013.
6. Puneet Jain, Auwal Alhassan Musa, Lasmar Garba, 2020, Application of Nanomaterials in Transportation Engineering, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 09, Issue 02 (February 2020).
7. Puneet Jain, Murala Giridhar Sai 1, May-June 2020,Assessment of Fiber Reinforced Concrete (FRC) with Industrial Wastage Material for Rigid Pavements, TEST Management Journal, Article Info Volume 83 Page Number: 13446-13451 Publication Issue: May-June 20.
8. Jain P. (2017), Partial Replacement of Fine Aggregate with Glass using DIC using Technique with Waste Materials for Investigation of Crack Propagation. INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH AND APPLICATION, 7(11), 5, https://doi.org/DOI:10.9790/9622-0711056165.
9. Jain P. (2017). Determining Mix Proportion for the Marble Slurry Powder Recovered from Marble Slurry Replacing Fine Aggregate of Concrete used in Residential Construction Project in Udaipur, India. IJERA, 7 (10), 30-35, https://doi.org/DOI;10.9790/9622-0710.