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# STUDY ON MIX DESIGN OF SELF COMPACTING CONCRETE OF M30

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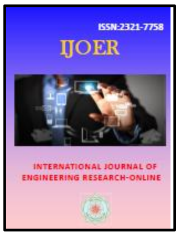

**ABSTRACT**

Concrete occupies unique position among the modern construction materials, Concrete is a material used in building construction, consisting of a hard, chemically inert particulate substance, known as a aggregate (usually made for different types of sand and gravel), that is bond by cement and water. Self – compacting concrete (SCC) is a high – performance concrete that can flow under its own weight to completely fill the form work and self consolidates without any mechanical vibration. Such concrete accelerate the placement, reduce the labor requirements needed for consolidation, finishing and eliminate environmental pollution. The so called first generation SCC is used mainly for repair application and for casting concrete in restricted areas, including sections that present limited access to vibrate. Such value added construction material has been used in applications justifying the higher material and quality control cost when considering the simplified placement and handling requirements of the concrete. The successful production of self – compacting concrete (SCC) for use, is depended on arriving at an appropriate balance between the yield stress and the viscosity of the paste. Specially formulated high range water reducers are used to reduce the yield stress to point to allow the designed free flowing characteristics of the concrete. However, this alone may result in segregation if the viscosity of the paste is not sufficient to support the aggregate particles in suspension. The process of selecting suitable ingredients of concrete and determining their relative amounts with an objective of producing a concrete of required strength, durability, and workability as economically as possible is termed as concrete mix design.

The Mix Design for concrete M30 grade is being done as per the Indian Standard Code IS: 10262-1982.

## 1. INTRODUCTION

**1.1 SELF–COMPACTING CONCRETE (SCC)** is a fluid mixture, which is suitable for placing difficult conditions and also in congested reinforcement, without vibration. In principle, a self – compacting or self – consolidating concrete must:

- Have a fluidity that allows self – compaction without external energy
- Remain homogeneous in a form during and after the placing process and
- Flow easily through reinforcement

Self – consolidating concrete has recently been used in the pre – cast industry and in some commercial applications, however the relatively high material cost still hinders the wide spread use of such specialty concrete in various segments of the construction industry, including commercial and residential construction.

Compared with conventional concrete of similar mechanical properties, the material cost of SCC is more due to the relatively high demand of cementation materials and chemical admixtures including high – range water reducing admixtures (HRWRA) and viscosity enhancing admixtures (VEA). Typically, the content in Cementation materials can vary between 450 and 525 Kg/m3 for SCC targeted for the filling of highly restricted areas and for repair applications. Such applications require low aggregate volume to facilitate flow among restricted spacing without blockage and ensure the filling of the formwork without consolidation. The incorporation of high volumes of finely ground powder materials is necessary to enhance cohesiveness and increase the paste volume required for successful casting of SCC.

**1.2 BENEFITS AND ADVANTAGES** At present self – compacting concrete (SCC) can be classified as an advanced construction material. The SCC as the name suggests, does not require to be vibrated to achieve full compaction. This offers benefits and advantages over conventional concrete.

- Improved quality of concrete and reduction of onsite repairs.
- Faster construction times.
- Lower overall costs.
- Facilitation of introduction of automation into concrete construction.
- Improvement of health and safety is also achieved through elimination of handling of vibrators.
- Substantial reduction of environmental noise loading on and around a site.
- Possibilities for utilization of "dusts", which are currently waste products and which are costly to dispose of.
- Better surface finishes.
- Easier placing.
- Thinner concrete sections.
- Greater Freedom in Design.
- Improved durability, and reliability of concrete structures.
- Ease of placement results in cost savings through reduced equipment and labor requirement.
- SCC makes the level of durability and reliability of the structure independent from the existing on – site conditions relate to the quality of labor, casting and compacting systems available.
- The high resistance to external segregation and the mixture self – compacting ability allow the elimination of macro – defects, air bubbles, and honey combs responsible for penalizing mechanical performance and structure durability.

**1.3 DEVELOPMENTS OF SELF – COMPACTING CONCRETE:** The prototype of SCC was first completed in 1988 using materials already on the market. The proto type performed satisfactorily with regard to drying and hardening shrinkage, heat of hydration, denseness after hardening, and other properties. This concrete was named "High Performance Concrete" and was defined as follows at the three stages of concrete:

1. Fresh : Self – Compactable.
2. Early age : Avoidance of initial defects
3. After hardening: Protection against external factors.

"High Performance Concrete" was defined as a concrete with high durability due to a low water-cement ratio by professor Aitcin et al (Gangneetal 1989). Since then, the term high performance concrete has been used around world to refer to high durability concrete. Therefore, H.Okamura and M.Ouchi, the authors, of an invited paper on SCC for JACT 2003 have changed the term for the proposed concrete, for their work, to "Self – compacting High performance Concrete".

**1.4 MECHANICAL CHARACTERSTICS:**

Characteristic compressive strength at 28 days shall be 25 – 60 Mpa.

Early age compressive strength shall be 5 – 20 Mpa at 12 – 15 hours (Equivalent age at$20^0$ C)

"Normal" creep and shrinkage

**1.5 APPLICATIONS**

1. To shorten construction period
2. To assure compaction in the structure: especially in confined zones where vibrating compaction is difficult.
3. To eliminate noise due to vibration: especially at concrete products plants.

**2. MATERIALS OF SCC**

**2.1.1. Aggregates** The coarse aggregate chosen for SCC is typically round in shape, is well graded, and smaller in maximum size than that used for conventional concrete typical conventional concrete could have a maximum aggregate size of 40 mm or more. In general, a rounded aggregate and smaller aggregate particles aid in the flow ability and deformability of the concrete as well as aiding in the prevention of segregation and deformability of the concrete as well as aiding in the prevention of segregation. Gradation is an important factor in choosing a coarse aggregate, especially in typical uses of SCC where reinforcement may be highly congested or the formwork has small dimensions. Gap – graded coarse aggregate promotes segregation to a greater degree than well-graded coarse aggregate. As with conventional concrete construction, the maximum size of the coarse aggregate for SCC depends upon the type of construction. Typically, the maximum size of coarse aggregate used in SCC ranges from approximately 10 mm to 20 mm. All normal concreting sands are suitable for SCC. Both crushed and rounded sands can be used. Siliceous or calcareous sands can be used. The amount of fines less than 0.125 mm is to be considered as powder and is very important for the rheology of the SCC. A minimum amount of fines (arising from the binders and the sand) must be achieved to avoid segregation.

**2.1.2. Cement** The most common cement currently used in construction is type I/II Portland cement. This cement conforms to the strength requirement of a Type I and the C3A content restriction of a Type II. This type of cement is typically used in construction and is readily available from a variety of sources. The Blaine fineness is used to quantify the surface area of cement. The surface area provides a direct indication of the cement fineness. The typical fineness of cement ranges from 350 to 500m2/kg for Type I and Type III cements, respectively.

**2.1.3. Fly ash:** Fly ash (or) pulverized fly ash is a residue from the combustion of pulverized coal collected by mechanical separators, from the fuel gases of thermal plants. The composition varies with type of fuel burnt, load on the boiler and type of separation. The fly ash consists of spherical glassy particles ranging from 1 to 150 micron in diameter and also passes through a 45-micron sieve. The constituents of fly ash are mentioned below.

Silicon dioxide-----$SiO_2$---30 – 60 %
Aluminum oxide-----$Al_2O_3$---15 - 30 %
Unburnt fuel-----(Carbon)---up to 30 %
Calcium oxide-----CaO--1-7%
Magnesium oxide-----(MgO)---small amounts
Sulpher trioxide-----($SO_3$)---small amounts.

**2.1.4. Ground Granulated Blast Furnace Slag (GGBS):**Ground granulated blast-furnace slag is a non metallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form glassy sand like material. The granulated material when further ground to less than 45 micron will have specific surface about 400 to 600m2/kg. the chemical composition of blast furnace slag is similar to that of cement clinker.

| | |
|---|---|
| CaO | 30-45% |
| $SiO_2$ | 17-38% |
| $Al_2O_3$ | 15-25% |
| $Fe_2O_3$ | 0.5-2.0% |
| MgO | 4.0-17.0% |
| $MnO_2$ | 1.0-5.0% |
| Glass | 85-98% |
| Specific gravity | 2.9 |

The performance of slag largely depends on the chemical composition. Glass content and fineness of grinding. The quality of slag is governed by IS 12089 of 1987.

**2.1.5. Micro Silica:** Silica fume also referred to as micro silica or condensed silica fume, is another material that is used as an artificial pozzolonic admixture. It is a product resulting from reduction of high purity quartz with coal in an electric and furnace in the manufacture of silicon or ferro silicon alloy. Silica fume rises as oxidized vapors. It cools, condenses and is collected in cloth bags. It is further processed to remove impurities and to control particle size. Condensed silica fume is essentially silicon dioxide (more than 90%) in non crystalline form. Since it an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than I micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000m2/kg, as against 230 to 300 m2/kg that of cement.

**2.1.6. Super plasticizer:** Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation.

Conplast SP 430 is utilized in this project, which is a product of FOSROC Company having a specific gravity of 1.222. Super plasticizer is a chemical compound used to increase the workability without adding more water i.e. spreads the given water in the concrete throughout the concrete mix resulting to form a uniform mix. SP improves better surface expose of aggregates to the cement gel. Super plasticizer acts as a lubricant among the materials. Generally in order to increase the workability the water content is to be increased provided a corresponding quantity of cement is also added to keep the water cement ratio constant, so that the strength remains the same.

**2.1.7. Water:** Potable water is used for mixing and curing.

**3. MIX PROPORTION:** The ingredients for SCC are similar to other plasticized concrete. It consists of cement, coarse aggregate, fine aggregate, water, and mineral and chemical admixtures. No standard or all-encapsulating method for determining mixture proportions currently exists for SCC. However, many different proportion limits have been listed in various publications. Multiple guidelines and "rules of thumb" about mixture proportions for SCC were found. The table summarizes this information.

**Table 1: Limits on SCC material proportions**

| | HIGH FINES | VMA | COMBINATION |
|---|---|---|---|
| **Cementations lb/ yd$^3$** | 750-1000 | 650 – 750 | 650 – 750 |
| **(kg/m3)** | (450-600) | (385 – 450) | (385 – 450) |
| **Water/ Cementations material** | 0.28 – 0.45 | 0.28 – 0.45 | 0.28 – 0.45 |
| **Fine aggregate/ Mortar (%)** | 35 - 45 | 40 | 40 |
| **Fine aggregate/ Total Aggregate (%)** | 50 - 58 | -- | -- |
| **Coarse aggregate/ Total mix (%)** | 28 - 48 | 45 - 48 | 28 – 48 |

**3.1 EFNARC-PROPOSALS**

**3.1.1. Initial mix composition**

In designing the mix it is most useful to consider the relative proportions of the key components by volume rather than by mass.

- Water / Powder ratio by volume of 0.80 to 1.10
- Total powder content – 160 to 240 liters (400 – 600 Kg) per cubic meter.
- Coarse aggregate content normally 28 to 35 percent by volume of the mix.
- Water cement ratio is selected based on requirements in EN 206. Typically water content does not exceed 200 liter/m3 .
- The sand content balance the volume of the other constituents.

Generally, it is advisable to design conservatively to ensure that the concrete is capable of maintaining its specific fresh properties despite anticipated variations in raw material quality. Some variation in aggregate moisture content should also be expected and allowed for at mix design stage. Normally viscosity-modifying admixtures are a useful tool for compensating for the fluctuations due to any variations of the sand grading and the moisture content of the aggregates.

**3.2 GENERAL REQUIREMENTS IN THE MIX DESIGN:**

**3.2.1. A high volume of paste:** The friction between the aggregates limits the spreading and the filling ability of SCC. This is why SCC contains a high volume of paste (cement + additions + sufficient water + air), typically 330 to 400 1/m3 , the role of which is to maintain aggregate separation.

**3.2.2. A high volume of the fine particles (<80 µm):** In order to ensure sufficient workability, while limiting the risk of segregation or bleeding. SCC contains a large amount of fine particles (around 500 kg/m3). Nevertheless, in order to avoid excessive heat generation, the Portland cement is generally partially replaced by mineral admixtures like limestone filler or fly ash or GGBS (Cement should not be used as a filler). The nature and the amount of filler added are chosen in order to comply with the strength and durability requirements.

**3.2.3. A high dosage of plasticizer**

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Super plasticizers are introduced in SCC to obtain the fluidity. Nevertheless, a high dosage near the saturation amount can increase the proneness of the concrete to segregate.

**3.2.4. The possible use of a viscosity agent (water retainer):** These products are generally cellulose derivatives, polysaccharides or colloidal suspensions. These products have the same role as the fine particles, minimizing bleeding and coarse aggregate segregation by thickening the paste and retaining the water in the skeleton. The introduction of such products in SCC seems to be justified in the case of SCC with high water to binder ratio. On the other hand, they may be less useful for high performance SCC (strength higher than 50Mpa) with low water to binder ratio. For intermediate SCC, the introduction of viscosity agent has to be studied for each case. Viscosity agents are assumed to make SCC less sensitive to water variations in water content of aggregate occurring in concrete plants. Because of the small quantities of viscosity agents required, however, it may be difficult to achieve accuracy of dosage.

**3.2.5. A low volume coarse aggregate:** It is possible to use natural rounded, semi-crushed or crushed aggregates to produce SCC. Nevertheless, as the coarse aggregate plays an important role on the passing ability of SCC in congested areas, the volume has to be limited. Generally speaking, the maximum aggregate size, D max, is between 10 and 20 mm. The passing ability decreases when D max increases, which leads to a decrease of the coarse aggregate content. The choice of a higher D max is thus leads to a decrease of the coarse aggregate content. The choice of a higher D max is thus possible but is only justified with low reinforcement content.

Admixture added to SCC can have a resulting effect on strength and the temperature development in the fresh concrete, and this will have to be borne in mind in the construction process.

## 4. PROPERTIES OF MATERIALS

### 4.1. CEMENT

Ordinary Portland cement of 53 grade from the local market was used and tested for physical and chemical properties as per IS: 4031 – 1988and found to be conforming to various specifications as per IS: 12269-1987.

**Tests on cement**

1. Normal consistency : 30%
2. Initial setting time : 35 min
3. Compressive strength

7 days : 37 N/mm$^2$
14 days : 47 N/mm$^2$
28 days : 53 N/mm$^2$

4. Specific gravity : 3.01

### 4.2. TESTS ON AGGREGATE

**4.2.1. Fine aggregate :**In the present investigation fine aggregate is natural sand from local market is used. The physical properties of fine aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS :2386.

**Fig 1: Fine Aggregate**

**Table 2: Fineness modulus of fine aggregate**

| I.S.Seive | Weight of aggregate retained in gms | Cumulative weight retained in gms | Cumulative % of weight retained | % of passing | Remarks |
|---|---|---|---|---|---|
| 10 mm | 0 | 0 | 0 | 100 | |
| 4.75 mm | 0 | 0 | 0 | 100 | |
| 2.36 mm | 10 | 10 | 1 | 99 | |
| 1.18 mm | 197.5 | 207.5 | 20.75 | 79.25 | Zone - II |
| 600 µ | 371 | 578.5 | 57.85 | 42.15 | |
| 300 µ | 353 | 931.5 | 93.15 | 6.85 | |
| 150 µ | 68.5 | 1000 | 100 | 0 | |

Fineness modulus of fine aggregate = 272.75/100 = 2.7275 = 2.72

**Table 3: Physical properties of fine aggregate**

| PROPERTY | RESULT |
|---|---|
| **Fineness modulus** | 2.72 |
| **Specific Gravity** | 2.613 |
| **Bulk Density (Kg/M$^3$)**<br>**Loose**<br>**Compact** | <br>1585<br>1690 |

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**4.2.2 Coarse aggregate :** The crushed coarse aggregate of 12.5 mm maximum size rounded obtained from the local crushing plant, Robo silicon, keesera gutta; Hyderabad is used in the present study. The physical properties of coarse aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with IS ; 2386.

**Fig 2:Coarse Aggregate**

**Table 4: Fineness modulus of coarse aggregate**

| I.S.Seive | Weight of aggregate retained in gms | Cumulative weight retained in gms | Cumulative % of weight retained | % of passing |
|---|---|---|---|---|
| 40mm | 0 | 0 | 0 | 100 |
| 20mm | 0 | 0 | 0 | 100 |
| 10 mm | 270 | 750 | 15 | 85 |
| 4.75 mm | 4250 | 5000 | 100 | 0 |
| 2.36 mm | 0 | 5000 | 100 | 0 |
| 1.18 mm | 0 | 5000 | 100 | 0 |
| 600 µ | 0 | 5000 | 100 | 0 |
| 300 µ | 0 | 5000 | 100 | 0 |
| 150 µ | 0 | 5000 | 100 | 0 |

Fineness modulus of coarse aggregate = 615/100 = 6.15

**Table 5: Physical properties of Coarse aggregate**

| PROPERTY | RESULT |
|---|---|
| **Fineness modulus** | 6.15 |
| **Specific Gravity** | 2.625 |
| **Bulk Density (Kg/M3)** | |
| **Loose** | 1475 |
| **Compact** | 1690 |

**4.3. FLY ASH:** In the present investigation work, the fly ash used is obtained from Vijayawada thermal power station in Andhra Pradesh. The specific surface of fly ash is found to be 4250cm2/gm. by blaines permeability apparatus and its specific gravity is 2.3.

**Table 6: Chemical composition of fly ash.**

| S.NO | CHARACTERISTIC | PERCENTAGE |
|---|---|---|
| 1 | Silica, $SiO_2$ | 49-67 |
| 2 | Alumina | 26-28 |
| 3 | Iron Oxide | 10-Apr |
| 4 | Lime | 0.7-3.6 |
| 5 | Magnesia | 0.3-2.6 |
| 6 | Sul | 0.1-2.6 |
| 7 | Surface area $m^2$ /kg | 230-600 |

**4.4 GROUND GRANULATED BLAST FURNANCE SLAG:**

**TABLE 7: PHYSICAL PROPERTIES OF GGBS**

| S.NO | Characteristics | Properties of slag used |
|---|---|---|
| 1 | Specific gravity | 2.91 |
| 2 | Fineness (Blaine's) $m^2$/Kg | 330 |
| 3 | Glass content percent | 93 |
| 4 | Bulk density | 1100 |
| 5 | Colour | Dull white |

**Table 8: CHEMICAL COMPOSITION OF GGBS**

| S.No | Characteristics | Requirement (BS: 6699) | % contents |
|---|---|---|---|
| 1 | $SiO_2$ | 32-42 | 33.12 |
| 2 | $Al_2O_3$ | 7.16 | 18.3 |
| 3 | CaO | 32-45 | 41 |
| 4 | $Fe_2O_3$ | 0.1-1.5 | 1.3 |
| 5 | MgO | 14 Max | 11.6 |
| 6 | $SO_3$ | 2.5 Max | 1 |
| 7 | Cao / $SiO_2$ | 1.4 Max | 1.23 |
| 8 | Loss on ignition | 3 Max | 0.5 |

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**4.5 MICRO SILICA OR SILICA FUME**: Micro silica is a highly efficient pozzolanic material and as considerable potential for use in concrete. Micro silica is obtained from elkem metallurgy(p) ltd, 66/77 , mahavir centre , sector 17 , vashi , navi mumbai-400703 is used.

**4.6 SUPERPLASTICIZER**: The super plasticizer used in concrete mix makes it highly workable for more time with much lesser water quantity. It is observant that with the use of large quantities of finer material (fine aggregate + cement + fly ash ) the concrete is much stiff and requires more water for required workability hence, in the present investigation SP430 is used as water reducing admixture.

**4.7 WATER:** This is the least expensive but most important ingredient of concrete. The water, which is used for making concrete , should be clean and free from harmful impurities such as oil, alkali, acid, etc., in general, the water, which is fit for drinking should be used for making concrete.

## 5. MIX DESIGN

Mix design can be defined as the process of selecting suitable ingredients of concrete and determining with the object of producing concrete of certain minimum strength and durability as economically as possible.

**5.1Mix design forM30 grade concrete according to BIS method.**

**TABLE 9: RATIOS OF MIX PROPORTIONS BY WEIGHT:**

| Mix | Grade of Cement | Cement | F.A | C.A | Fly ash | GGBS | Micro Silica | SP 430 Dosage | VMA Dosage |
|---|---|---|---|---|---|---|---|---|---|
| SCC | M30 | 1 | 3.81 | 3 | 0.55 | 0.4 | 0.01 | 0.05 | 0.007 |

**5.2 FRESH CONCRETE PROPERTIES:**

**TABLE 10: PROPERTIES OF FRESH CONCRETE (SCC)**

| Trail Mix | Slump Flow | | V-Funnel | | L - Box |
|---|---|---|---|---|---|
| | Mm | T 50 (Sec) | T 0 (Sec) | T 5 (Sec) | H2/ H1 |
| 1 | 670 | 5 | 11 | 13 | 0.8 |
| 2 | 675 | 4.5 | 10 | 12 | 0.82 |
| 3 | 685 | 3.5 | 8 | 9 | 0.84 |
| 4 | 680 | 4 | 9 | 11 | 0.83 |

**5.3 HARDENED CONCRETE PROPERTIES:**

**TABLE 11: PROPERTIES OF HARDENED CONCRETE (SCC)**

| Trail Mix | Compressive Strength ($N/mm^2$) | | | | Tensile Strength ($N/mm^2$) | |
|---|---|---|---|---|---|---|
| | 1 day | 3 days | 7 days | 28 days | 7 days | 28 days |
| 1 | 18.5 | 22 | 30.5 | 42 | 2.542 | 3.108 |
| 2 | 18 | 22 | 30 | 41 | 2.386 | 3.264 |
| 3 | 16 | 20.5 | 28.5 | 39 | 2.392 | 2.929 |
| Final Mix | 17 | 20 | 26.5 | 40 | 2.312 | 3.607 |

## 6. CONCLUSION

Based on the investigation conducted for the study of behavior of self compacting concrete the following conclusions are arrived.

1. As no specific mix design procedures for SCC are available mix design can be done with conventional BIS method and suitable adjustments can be done as per the guidelines provided by different agencies.
2. Trail mixes have to be made for maintaining flow ability, self compatibility and obstruction clearance.

**For Final Mix**

Compressive Strength of hardened concrete after 1 day = 17.0 $N/mm^2$

Compressive Strength of hardened concrete after 3 days = 20.0 $N/mm^2$

Compressive Strength of hardened concrete after 7 days = 26.5 $N/mm^2$

Compressive Strength of hardened concrete after 28 days = 40.0 $N/mm^2$

Tensile Strength of hardened concrete after 7 days = 2.312 $N/mm^2$

Tensile Strength of hardened concrete after 28 days = 3.607 $N/mm^2$

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