

Effect of Water to Cement Ratio on Self-Compacting Concrete Contain GGBS for Fresh State and Harden State Mechanical Properties

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Abstract: This paper presents an experimental investigation on Self-compacting concrete (SCC) of M50 for different water to cement ratio on fresh state and harden state mechanical property. SCC is runny fluid mix which does not require any external vibration. It gains its fluidity from the fine aggregate, cementitious material and super plasticizer. The cost of SCC is high due to high amount of cement and chemical admixture use in it. To overcome this issue ground granulated blast furnace slag (GGBS) can be used as an alternative to cement, which acquires the same cementitious properties as that of cement. The utilization of GGBS in SCC is indirectly aiding waste reduction and maintaining ecological balance in the environment. When SCC is in fresh state its properties are measured in terms of workability such as flow value, V-funnel, J-ring, L-box and plastic density are measured. The Harden state properties namely compressive and split tension test are measured at 3, 7, 14 and 28 days of moist curing for water to cement ratio 0.25, 0.3, 0.35. Substitution level of GGBS in the concrete is kept at 50%. It is found that maximum compressive and split tensile strength obtained for water cement ratio of 0.35 and similarly fresh properties.

Keyword: Ground Granulated Blast Furnace Slag, Self-Compacting Concrete, fresh, mechanical properties, V-funnel, J-ring and L-box.

Introductions:

Self-compacting concrete (SCC) is a highly fluid mix concrete which does not require any vibration. Low yield stress, high deformability, segregation resistance and reasonable viscosity are the advantages of SCC. It also possesses setting, curing and strength gaining characteristics as that of conventional concrete. Supplementary cementitious materials such as fly ash (FA), ground granulated blast furnace slag (GGBS) and silica fume (SF) brings deformability, cohesiveness and strength. It is characterized by its filling, passing ability and segregation resistance. Partial replacement of supplementary cementitious materials produce an eco-friendly concrete. The introduction of GGBS as a partial replacement of cement reduces the heat of hydration and decrease the manufacturing cost as it is a by-product of steel industry. The emission of greenhouse gases reduces by replacing it with cement. SCC is less acceptable to abrupt changes in aggregate moisture content, use of chemical admixture and water content (Alireza et al., 2020).

Due to these properties SCC get affected by the type of concrete mixer, transportation time and the method of concrete placement. Applications of SCC are easy to the construction industry because of its characteristics namely movement ability, filling ability, resistance to bleeding and segregation over the normal concrete (Mehrddad et al., 2021). It is suitable to employ in congested reinforcement areas where normal concrete has the compaction problem. The working efficiency and productivity get enhanced by using SCC. Its free flowability under the gravity due to self-weight without any bleeding, it is marked as one of the most beneficial structural materials (Ali et al., 2019; Nuruddin et al., 2014).

Factors affecting the performance of SCC are water to cement ratio, binder to filler ratio, fine aggregate size, dose of super-plasticizer and viscosity modifying agents (Arsala et al., 2020; Pathak and Siddique, 2012). Polycarboxylate Ether (PCE) based super-plasticizer are generally employed to reduce the water content in SCC. The internal chemical structure of PCE affects the

workability, retention and rheological performance of SCC (Felekoglu and Sarikahy et al., 2008). Hemalatha et al. (2015) observed that the homogeneousness and consistency of SCC are exaggerated because of constituents and mixing time. Normally, SCC possesses lower yield stress and higher plastic viscosity to that of normal concert. The concrete mixture for SCC contains higher amount of cement and fines which can disturb the mixingquality of SCC. Also GGBS can impart more resistance to sulphate attacks and corrosion of reinforcement steel in concrete (Osamaetal., 2016).

At present the construction industries are incorporating the sustainable mineral materials such as GGBS, FA, Metakaolite (MK), Bagasse Ash (BA) etc. in the manufacturing of concrete. These materials impose the delay in hydration process. They can achieve compressive strength later period of time. Hanneson et al.(2012) reported that full replacement of cement with minerals admixture gives very lowstrength; it need some quantity cement to produce SCC due to calcium deficiency. The optimum use of GGBS in the concrete can made upto 55% for gaining maximum compressive strength (Oner et al., 2007).

Research Significance:

The main objective of this paper is to use GGBS replacement at 50%andobtaining fresh and harden state properties of SCC for different w/c ratios.. The fresh property of this concrete is measured in term of slumpflow, V-funnel, plastic density and L-box. The mechanical property of SCC is evaluated through compressive strength test which is conducted at the curing ages of 3,7,14 and 28days and split tensile strength at 28 days.

Materialsandmethods:

Materials:

Ordinary Portland cement (OPC-53Grade) of different brand namely Birla Super with specific gravity of 3.10 is used throughout the investigation. The chemical composition ofcement and GGBS as received from the manufacturer is shown in Table 1. The physicalproperties of GGBS are described in Table 2. Table 3 describes physical properties of fineaggregates and coarse aggregates. Coarse aggregates of size ranging from 4.75 mm to 20 mmare used in this study. Potable water is used to mix the concrete. GGBS of M/s. Jindal SouthWest (JSW) – India brand is used as partial replacement of OPC.Artificial sand is used as fineaggregate from Pune, Maharashtra, India quarry. All the tests are conducted at M/s Durocrete Engineering Services Pvt. Ltd. Pune.

Table1: Chemical composition of GGBS

Elements	SiO2	Al2O3	Fe2O3	CaO	MgO	Na2O	K2O	SO3	LOI	MnO	Cl
GGBS	34.81	17.92	0.66	37.63	7.8	-	-	0.2	-	0.21	0.004
Birla OPC53	20.59	3.66	6.10	63.78	0.95	0.26	0.48	2.13	2.05	-	-

Table2: Physical properties of GGBS

Property	GGBS	Birla OPC-53
Grade	-	53
Colour	Off-white	Grey
Soundness (Le-chatterer’s method)	2.5mm	1.5mm
Specific gravity	2.87	3.10
Initial setting time	48min	33min
Consistency	29.5%	28%

Fineness (Blaine's air Permeability Method)	386 m ² /kg	313m ² /kg
Final Setting time	318min	660min
Glass content	96.85%	NA
7days slag activity index	71.32%	NA
28days slag activity index	91.82%	NA

Table3: Properties of fine aggregate

Property	Fine Aggregates	Standard method as per BIS
Water absorption	2%	IS:2386(PartIII)
Bulk density	1638kg/m ³	IS:2386(PartIII)
Specific gravity	2.65	IS:2386(PartIII)

Methods:

Mix design:

Total two sets of SCC mixes are designed with two types of cement. As per Bureau of Indian Standard

(BIS) 10262:2019 guidelines, the SCC mixes are prepared with water-binder ratio of 0.34. Table4 describes about mix design for different types of cement.

Table4: Composition of concrete mixes of M50

Material	Quantity used Kg/m ³	Quantity used Kg/m ³	Quantity used Kg/m ³
Cement quantity	380 kg	380 kg	380 kg
GGBS quantity	180 kg	180 kg	180 kg
Water quantity	196 lit	168 lit	140 lit
Admixture quantity	5.500 lit	5.500 lit	5.500 lit
Fine Aggregate	711 kg	711 kg	711 kg
Coarse Aggregate (up to 10mm)	393 kg	393 kg	393 kg
W/Cratio	0.35	0.30	0.25
Admixture type	Mapei Dynamax SX 542M (B-VA190723-04)	Mapei Dynamax SX 542M (B-VA190723-04)	Mapei Dynamax SX 542M (B-VA190723-04)

Test methods:

Various tests are conducted on the fresh SCC mixes to determine slump flow plasticity density, spread, J-ring, V-funnel flow time and passing ratio (from L-box). In the present experimental study the flow ability of the SCC mixes is assessed by slump flow test. V-funnel flow time tests are conducted to evaluate the flow rate, it is closely related to plastic viscosity of the SCC mixes. Passing ability and segregation resistance of SCC mixes are

evaluated by L-box test respectively.

Tests on hardened state of SCC concrete are cubes test as per BIS 516-2004 of two different mixes with water cured at the ages of 3,7,14 and 28 days from the day of preparation. The three replicate cubes of each are determined at the curing ages on compression testing machine. The average value of the three replicate cube specimens are reported as the compressive strength of SCC mix at a given curing age.

Fig.1 Free flow measurement, J-ring test and casting cubes in the laboratory



Results and discussion:

The filling ability is one of the important properties of SCC, which is examined by the slump flow test. As per guidelines of (BIS 1199: 2018), the slump flow spread values varies in the range of 660 mm to 750 mm is suitable for normal application work, in both type of cement vales are in the prescribed range. The Vfunnel flow time values are closely related to the viscosity of fresh SCC mix. These results indicate that two SCC mixes satisfied the criteria of moderate to high flow-rate as demonstrated in (EFNARC-2002) guidelines

(minimum 8 s for V-funnel flow time) in both cement. Passing ability is also a key property of self-compacting concrete, which is evaluated in this investigation by L-box test with three bar arrangement for the SCC mixes get varied from 0.78 to 0.85, results indicate that L-box test value are higher than the minimum value as per (EFNARC-2002) guidelines. The plastic density in fresh state of SCC is measured by bucket. Table 5, 6 and 7 describe about fresh and hardened state properties of SCC for different w/c ratio.

Table 5: Fresh test on SCC

Type test	Experimental values for w/c=0.35	Experimental values for w/c=0.30	Experimental values for w/c=0.25
Free flow value	740(mm)	728 (mm)	710(mm)
J-Ring	760(mm)	751(mm)	742(mm)
V-funnel	12.6(Sec)	12.2(Sec)	12(Sec)
L-box(H2/H1)	0.81	0.81	0.8
Plastic density	2562kg/m ³	2568kg/m ³	2576kg/m ³

Table 6: Mechanical property (Compressive strength of SCC in MPa)

Days	As per BIS requirement	w/c=0.35	w/c=0.3	w/c=0.25
3days	17.3	20.18	22.3	20.18
7days	30.27	43.2	49.6	43.2
14days	38.92	54.3	58.2	54.3
28days	43.25	60.8	62.4	60.8

Table 7: Mechanical property (Split tensile strength of SCC in MPa)

Days	w/c=0.35	w/c=0.3	w/c=0.25
28 days	2.1	2.32	2.51

As w/c ratio decrease there is increase in compressive strength and split tensile strength. In fresh state higher w/c ratio increases flow, J-ring and V-funnel time. The super plasticizer may provide desired fresh properties. Maximum plastic density is obtained in lower w/c ratio. It may increase compressive strength due to homogenous, compact and less void.

Conclusions:

Based on the experimental investigations following key points conclusions are drawn

- Workability of GGBS get improved for higher w/c ratio in fresh state
- In harden state for lower w/c ratio impart higher split tensile strength is achieved
- Maximum compressive strength gain at w/c of 0.3 on 28 days of curing, it is an optimum w/c ratio
- At 50% replacement level of GGBS cement higher mechanical properties obtained at lower w/c ratio
- More early strength is obtained in lower w/c ratio value
- All mixes attained desire strength on 28 days

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Role of authors

R A Joshi and Sunny Joshi- Experimental programme

S G Joshi and R S Apte- Critical review

Conflict of Interest

Authors have no conflict of interest