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A Compressive Strength Model for Proportioning Self-Compacting Concrete

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Abstract

Self-compacting concrete flows nearly uniformly at the level of gravity and does not divide, where the structure function and the gaps between the reinforcement is deaerated and completely filled. This fresh property of SCC improves overall construction quality and avoids human errors, till now there is no simple method that makes the SCC mixtures feasible to use in small scale construction industry. This study aims to validate a mixture design procedure for Self-compacting concrete proposed by Ghazi & Al Jadiri with the local materials available at Vijayawada city, Andhra Pradesh India. The proposed method is capable of proportioning Self-compacting concrete mixtures with the previous methods which primarily considers fresh properties rather than the strength requirements. This method covers a wide range of strength (15 to75MPa) covering standard and high strength concretes. Three grades of concrete mixtures 30, 40 & 60MPa were design using the proposed method and the mixtures are varied until the fresh as well as hardened properties are satisfactory. Standard concrete mixtures showed good agreement in both fresh, hardened state whereas high strength concrete requires slight changes in the design assumptions.

Keywords: Self-compacting concrete, fresh and hardened properties, Concrete Mixtures, Compressive strength.

1. Introduction

Self-compacting concrete (SCC) was first produced in Japan in 1986, a new type of high-performance HPC with excellent deformity and separation resistance. This type of concrete can flow through and fill reinforcement gaps and corners during the placing process without requiring any friction and compaction. Although showing good results, SCC is different from the highest level of hard wear and durability established in North America and Europe. HPC merely enhances the fluidity of the concrete in order to facilitate positioning, but cannot fluidly pack each corner of the molds and any distance between reinforcement. In terms of workability. In other words, in the building phase HPC also requires vibration and compaction [1]. In contrast, SCC has more desirable characteristics, including high fluidity, strong segregation resistance and distinctive ability to self-compact without any vibration requirement during the placement process. Though SCC has moved from the research stage to field applications, its mixture proportioning does not include systematic standards or requirements [2].

2. Proposed Mixture Design Method for SCC

From the review of research on Mix Design methods proposed for SCC, the method suggested by Ghazi et.al.[3]-[7] is experimentally validated for the present study. This method is formulated to give a clear and straight forward procedure for the design of SCC mixtures that primarily depends on the required compressive strength without compromising the fresh properties of the SCC mix.

3. EFNARC Recommendations

The EFNARC method gives the following guidelines for proportioning SCC: An Absolute coarse aggregate volume (VG) = 28 to 35% by the concrete mixture volume.

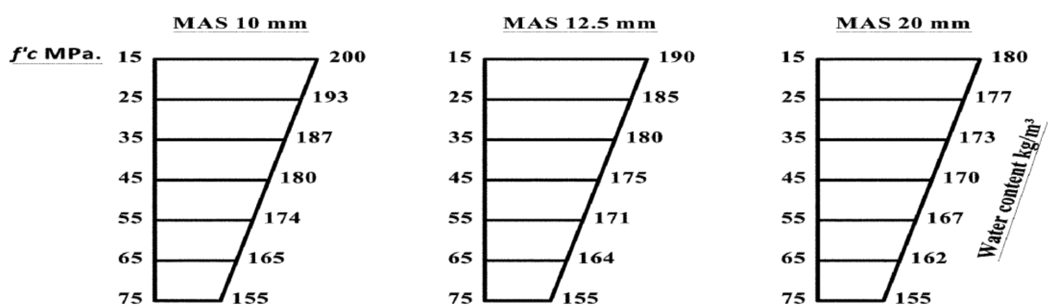
- Total powder'sabsolute volume (VC + VL) = 0.16 to 0.24 m3 (0.209 to 0.314 yd3);
- VW/VC + VL volumetric ratio = 0.80 to 1.10;
- 400 ≤ WC + WL ≤ 600 kg/m3 (675 ≤ WC + WL ≤ 1011 lb/yd3);
- VW ≤ 200 L/m3, that is, WW ≤ 200 kg/m3 (337 lb/yd3); and
- Sand quantity is the rest of the mixture volume.

3.1 Recommended Procedure of Proportioning SCC Mix Design

The steps to be followed for proportioning SCC according to the proposed method are as follows:

- Maximum water weight and air content (a) are derived from Table 2 in the mixture according to the overall rough aggregate scale (MAS).
- Receive water weight (WW) from Fig. 1. The w / c is obtained from Table 3 in accordance with the necessary SCC compressive power.
- The cement content (WC) is determined and the cement (VC) volume measured.
- The gravel volume (VG) is obtained from Table 3.
- Calculate a dry gravel weight (WGD) by multiplying (VG) by a sealed gravel device.
- Calculate gravel weight of the Saturated Dry Surface (SSD.
- Calculate VW/WC + VL, and for a specified f_c and maximum size, the powder volume(VL) should then be measured.
- Calculate Powder weight.
- Determine the total powder content weight (WC + WL) and total powder volume (VC + VL) and check with the results of the EFNARC[11] method.
- Determine the value of the fine added by absolute volume

1 m^3 = Ww /1 × 1000 + Wc /3.15 × 1000 + WL/SGL × 1000+ Ws/SGS × 1000 +Wg/SGG × 1000 + a%.



1kg/m^3=1.68 lb/yd^3, 1 mm=0.0393in, 1 MPa= 145 psi.

Fig. 1. Water quantities for different concrete strengths and maximum aggregate sizes by proposed method.[5 , 9]

Table 1: Maximum water requirements for modified SCC

	Maximum aggregate size (MAS), mm		
	9.5	12.5	19.0
Water content, kg/m^3	200	190	180
Air content, %	3.0	2.5	2.0

Table 2: W/b versus SCC compressive strength relationship

fc, MPa	15	20	25	30	35	40	45	50	55	60	65	70	75
w/c	0.8	0.7	0.62	0.55	0.48	0.43	0.38	0.35	0.34	0.33	0.32	0.31	0.29

Table 3: Bulk volume of coarse aggregate per unit volume of SCC

MAS, mm	FM			
	2.40	2.60	2.80	3.00
9.5	0.50	0.48	0.46	0.44
12.5	0.53	0.51	0.49	0.46
19.0	0.56	0.54	0.52	0.50

Table 4: Proposed water volume to total powder volume for different compressive strength of SCC mixtures

fc, MPa	$V_W/V_C + V_L$
15	1.10
25	1.05
35	1.00
45	0.95
55	0.90
65	0.85
75	0.80

4. Experimental Validation of Proposed Method

The study aims to validate the suggested method by Ghazi et.al. [8]. This method has a compressive strength range of 15 to 75 MPa. In many papers or reports reviewed, the SCC compressive strength was divided into two categories of concrete- housing or civil engineering – with characteristic strengths in the range of 30 to 60 MPa.[9][10]. The present study consisted of testing SCC mixtures for its properties in fresh and hardened state. Three compressive strengths 30, 40 and 60 MPa with coarse aggregate size less than 12mm available in the local market and nearby Krishna river sand as fine aggregate is examined for validating the suggested method.

4.1 Materials

- The binding material used for experimental work is Ordinary Portland Cement (OPC) of grade 53with specific gravity of 3.1.
- River sand with a specific gravity and fineness modulus of 2.67 and 2.4 respectively are used as fine aggregate.
- Coarse aggregate 10mm size with a specific gravity of 2.81
- GGBS with a specific gravity of 2.8 is used as filler material for increasing the surface area of the mix.
- A PCE (Poly Carboxylic Ether) based High-range water-reducing admixture with specific gravity of 1.065 and solids content of 45% is used.

4.2 Design of SCC Mixture

Several SCC mixtures were designed according to the proposed method. They were tested to determine their fresh and hardened properties. Table 5 gives the mixture proportions of these 30, 40 & 60 MPa of SCC mixtures.

4.3 Testing of Concrete

The slump flow test and V-funnel test[11][12] are used to determine the fresh properties of the mixtures . These tests were chosen for their efficient use at construction sites.SCC cube specimens 150 X 150 X 150mm were cast without any external vibration. The moulds are covered with wet gunny bags for 24 hours, then stripped of and placed in water for 28 days of curing. The cubes were then tested to evaluate the compressive strength of the mixtures according to IS - 456 – 2000.

Table 5(a): Proportions of M30 SCC Mixture.

S.No	% SP	Cement Kg/m³	Fine aggregate Kg/m³	Coarse aggregate Kg/m³	GGBS Kg/m³	SP in Lt/m³	Water Lt/m³
1	0.2	346	836.86	800	210	1.11	190
2	0.3	346	835.49	800	210	1.67	190
3	0.4	346	834.12	800	210	2.22	190
4	**0.5**	**346**	**832.63**	**800**	**210**	**2.78**	**190**
5	0.6	346	831.39	800	210	3.33	190

Table 5(b): Proportions of M40 SCC Mixture

S.No	% SP	Cement Kg/m³	Fine aggregate Kg/m³	Coarse aggregate Kg/m³	GGBS Kg/m³	SP in Lt/m³	Water Lt/m³
1	0.4	427	845.92	799	148.4	2.30	183.5
2	0.5	427	845.41	799	148.4	2.87	183.5
3	**0.6**	**427**	**839.31**	**799**	**148.4**	**3.45**	**183.5**
4	0.7	427	834.39	799	148.4	4.02	183.5

Table 5(c): Proportions of M60 SCC Mixture

S.No	% SP	Cement Kg/m³	Fine aggregate Kg/m³	Coarse aggregate Kg/m³	GGBS Kg/m³	SP in Lt/m³	Water Lt/m³
1	1	514	855.13	800	86	6	169.5
2	1.2	514	852.12	800	86	7.2	169.5
3	1.4	514	849.11	800	86	8.4	169.5
4	1.5	514	847.61	800	86	9	169.5
5	1.6	514	846.11	800	86	9.6	169.5
6	1.8	514	843.10	800	86	10.8	169.5
7	2	514	840.09	800	86	12	169.5
8	2.2	514	837.08	800	86	13.2	169.5
9	2.4	514	834.07	800	86	14.4	169.5

Table 6: Minimum and maximum values of slump and v-funnel test [13]-[15]

S.No	Workability Test	Minimum (sec)	Maximum (sec)
1	T_{50} slump	2	5
2	Slump flow	65	80
3	V- funnel	8	12

Table 7 (a): Fresh and Hardened properties of M30 SCC Mixture

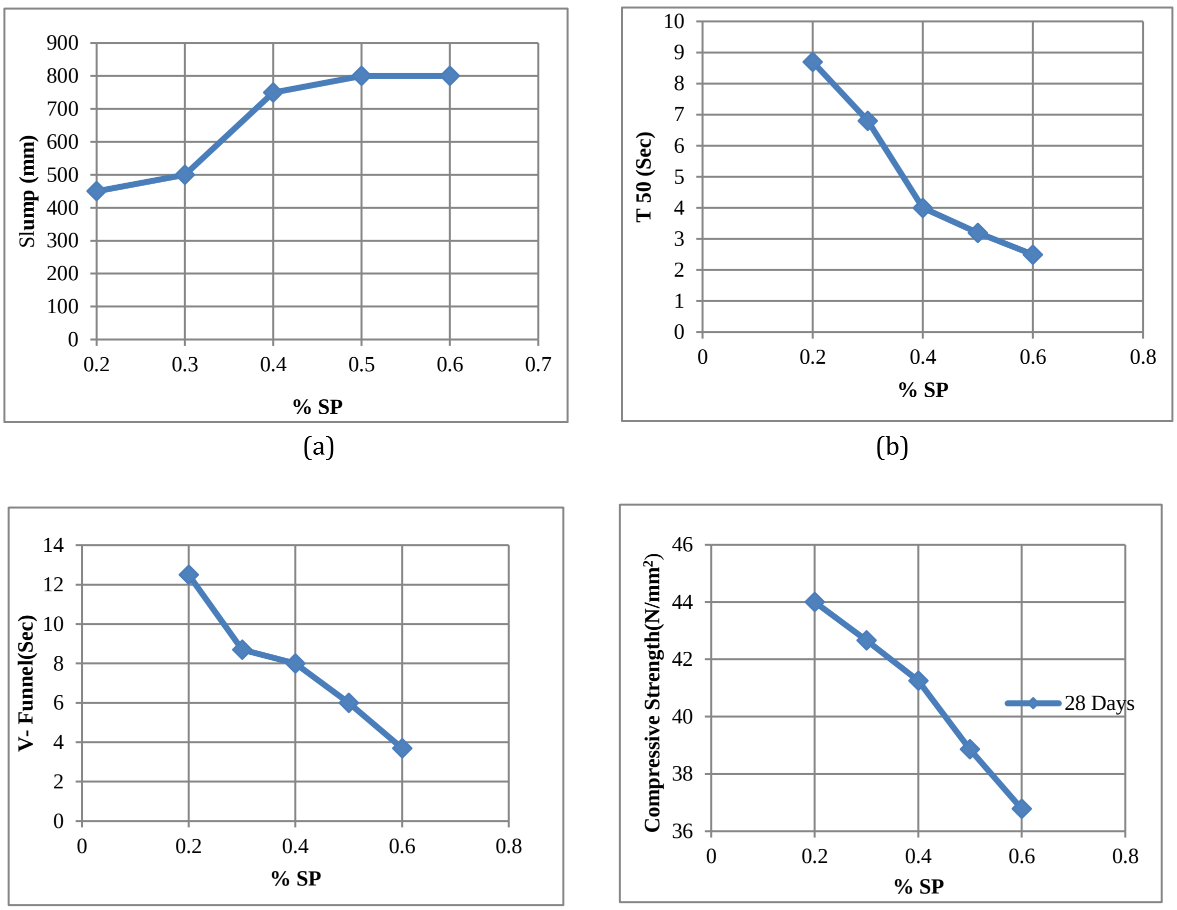
S.No	% SP	Slump Flow (mm)	T50 sec	V Funnel(sec)	f_c (N/mm²)
1	0.2	450	8.7	12.5	44
2	0.3	500	6.8	8.7	42.66
3	0.4	750	4	8	41.25
4	**0.5**	**800**	**2.2**	**6**	**38.86**
5	0.6	800	2.0	3.7	36.78

Table7 (b): Fresh and Hardened properties of M40 SCC Mixture

S.No	% SP	Slump Flow (mm)	T50 sec	V Funnel(sec)	f_c (N/mm²)
1	0.4	620	4.2	10	51.23
2	0.5	680	2.8	8	48.63
3	**0.6**	**760**	**2.6**	**6.7**	**46.84**
4	0.7	800	2	4.7	43.23

Table 7(c): Fresh and Hardened properties of M60 SCC Mixture

S.No	% SP	Slump Flow (mm)	T50 sec	V Funnel(sec)	f_c (N/mm²)
1	1	550	6	12.5	61.488
2	1.2	580	4.9	11.6	61.8
3	1.4	650	4.1	9.7	66.08
4	1.5	660	3.5	7.5	56.3
5	1.6	680	3.1	7.6	57.7
6	1.8	730	3.2	6.7	61.8
7	2	700	2.3	5.45	56.8
8	2.2	750	2.2	4.8	50
9	2.4	780	2	4.2	51.505



(c) (d)

Fig. 2. (a),(b),(c)&(d) shows the relation between the fresh & hardened properties of M30 SCC Mixture with various percentages of Superplasticizer.

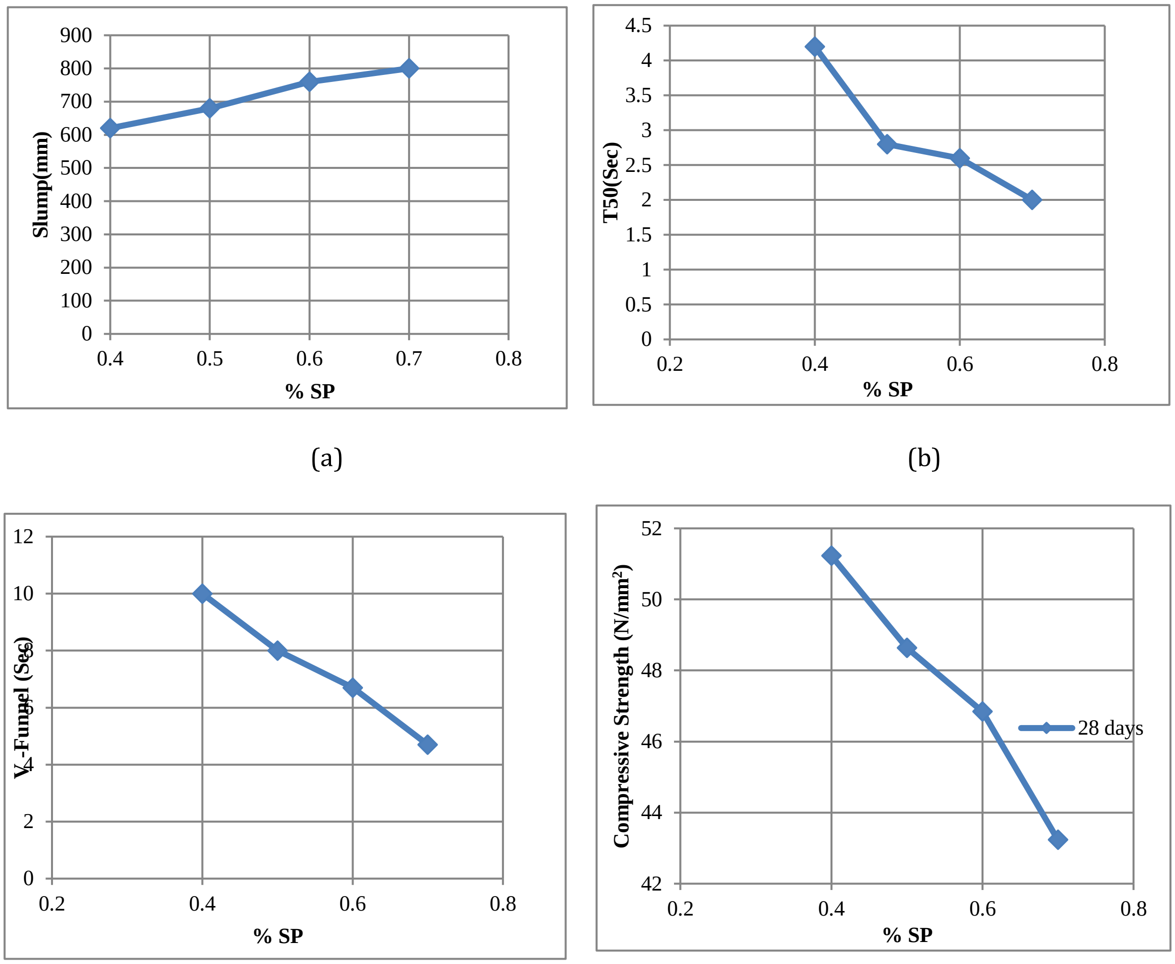
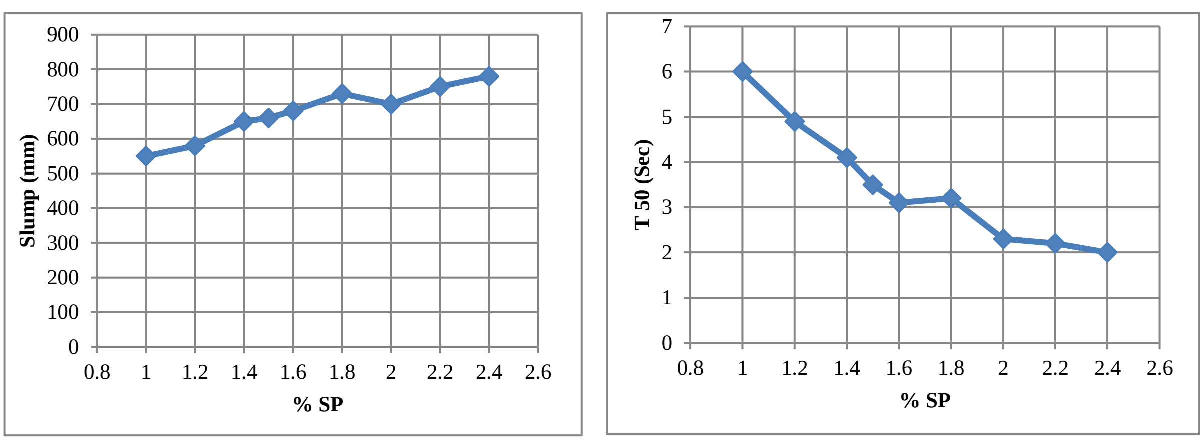
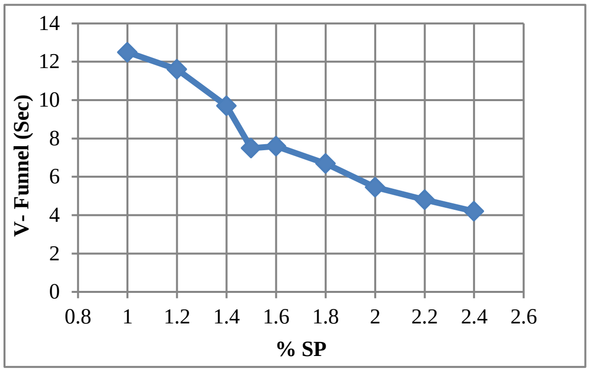


Fig. 3. (a),(b), (c)&(d) shows the relation between the fresh & hardened properties of M40 SCC Mixture with various percentages of Superplasticizer.

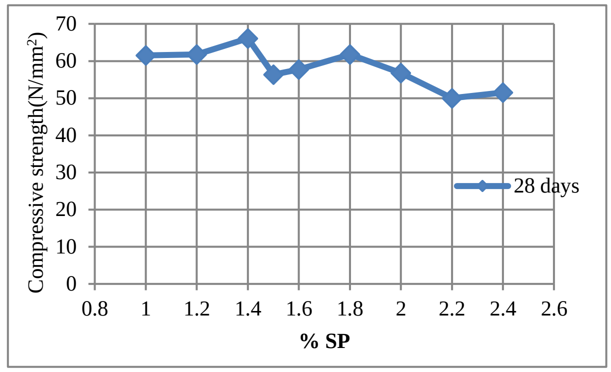


(a)

(b)



(c)



(d)

Fig. 4. (a),(b),(c)&(d) shows the relation between the fresh & hardened properties of M60 SCC Mixture with various percentages of Superplasticizer.

5. Conclusion

1. The mixtures M30 and M40 showed good agreement in both fresh and hardened state.
2. The compressive strength of M30 & M40 yielded a better value which is good to apply at site conditions.
3. Small modifications should be made to the mix design when used for proportioning high strength concrete.
4. The demoulding period for high strength concrete has taken more than 24 hours as the setting of concrete is delayed due to high dosage of superplasticizer. The cubes are crushed while demoulding at 24 hours after casting and when immersed in water.
5. A decrement in strength is observed when super plasticizer is added in high range.
6. This mix design proposed is valid and suggested for use with concrete strength range between 20 to 60MPa and necessary modifications need to be made for high strength concrete greater than 60MPa.

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