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ASSESSMENT OF CHARACTERISTICS OF VARIOUS SELF-COMPACTING CONCRETE AND NORMAL CONCRETE AT GREEN AND HARDENED STATE

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ABSTRACT

Self compacting concrete consolidates under its own weight and do not requires any external efforts. As mix composition of self compacting concrete is different than normal vibrated concrete, the characteristics at fresh and hardened state are different. Three mixes of powder type self compacting concrete with variable binder, one mix of viscosity modifying agent type self compacting concrete and one normal vibrated concrete mixes with identical water to binder ratio are studied and compared. At green state, the powder type self compacting concrete with higher binder content found to be more stable. Compressive strength increasing with increases in binder content. Tensile strength enhances with increase in compressive strength while ratio of tensile strength to compressive strength ratio found to be decreasing with increase in compressive strength.

Keywords: self compacting concrete, compressive strength, splitting tensile strength, elastic modulus.

1. INTRODUCTION

Concrete is being used from many years and compaction is invariable part of concrete making. It is important to compact the concrete in order to completely pass through reinforcement and fill all the space in the form for meeting strength and durability requirement. If compaction is not adequate, it will lead to loss of strength and affect performance of the structure [1]. In case of dense reinforcement, it is very difficult to compact the concrete because vibrator cannot be inserted properly within the reinforcement. Noise creation of vibration is also a problem. Self-compacting concrete (SCC) may provide solution to these problems [2].

Self-Compacting Concrete is a type of concrete with admirable deformability and segregation resistance. It also improves the durability and speed of construction in mass concreting [3]. According to way of providing stability to mix, SCC may classify as viscosity modifying agent (VMA) type and powder type self-compacting concrete. For powder type SCC, filler materials like fly ash, GGBS, lime powder and quarry dust can be used as partial replacement of cement [4]. Researches have been carried out for studying properties of powder and VMA types self-compacting concrete. The mix proportion for SCC is different than normally vibrated concrete (NVC). Also VMA type and powder type SCC are having different mix proportions which change their behavior at fresh and hardened state [5]-[8]. If fly ash is used as partial replacement of cement, it will save environment, cost and energy consumed in cement production [9].

At fresh state, workability and segregation resistance are important properties and at hardened state, properties like compressive strength, tensile strength, modulus of elasticity are important.

An experimental program is undertaken with VMA type, powder type of self-compacting concrete and normal vibrated concrete. The properties at green state such as workability and segregation resistance and at hardened state such as compressive strength, tensile strength and elastic modulus are determine and compared.

2. EXPERIMENTAL PROGRAM

In powder type self-compacting concrete, three mixes with binder content 550 kg/m^3,600 kg/m^3 650 kg/m^3 (designated as Mix 1, Mix 2, Mix 3) are casted. Fly ash is used in amount of 40 % of binding material. The quantity of binder content in VMA Mix and NVC Mix is kept 400 kg/m^3 (designated as Mix 4 and Mix 5). Natural river sand is use as fine aggregates. It is confirming to zone II as per IS 383 specifications. Basalt crushed stone coarse aggregates of 20 mm and 10 mm nominal sizes are used. The properties of these are as given in Table-1. Cement used is OPC 53 Grade confirming to IS 12269 - 1987. The properties of cement are as given in Table-2.Fly ash confirming to Class F, which is locally available is used. Polycarboxylic Ether based super plasticiser is used as high range water reducing admixture. Unlike normal vibrated concrete, less data is available on mix design of SCC. Few guidelines for mix design of self-compacting concrete like EFNARC [10] are available, along with mix design used in various researches [11]-[13].After conducting preliminary trials, appropriate changes are made in mix design. The mix proportion adopted for study is given in Table-3. Water/binder ratio is kept constant for all mixes.

Flowing ability of self compacting concrete is asses by slump flow test, L-box T_{20} and T_{40} tests. Passing ability is tested by L-box blocking ratio test and segregation resistance is tested by V-funnel $T_{5minutes}$ test and visual assessment of slump flow. The properties determine at hardened state of concrete are compressive strength, spiting tensile strength and modulus of elasticity. To find compressive strength of concrete, cubes of size 150 mm are prepared. The compressive strength of concrete is taken at the age of 7, 28 and 56 days. For

determination of modulus of elasticity and splitting tensile strength, cylinders of 150 mm diameter are prepared.

Table-1. Properties of fine and coarse aggregates.

Test	Sand	Coarse aggregates	
		10 mm	**20 mm**
Specific Gravity	2.79	2.9	2.9
Water Absorption	0.18%	1 %	0 %
Fineness Modulus	2.93	6.09	8.11

Table-2. Properties of cement.

Fineness Test	1.5 gm
Soundness Test	3mm
Initial Setting Time	45 minutes
Final Setting Time	230 minutes
Compressive Strength (7 days)	42 N/mm^2
Specific Gravity	3.15
Specific Surface Area (cm^2/gm)	3250

Table-3. Mix proportion.

		Mix				
		Mix 1	**Mix 2**	**Mix 3**	**Mix 4**	**Mix 5**
Cement in kg		330	360	390	400	400
Fly Ash in kg		220	240	260	0	0
Natural Sand in kg		1130	1090	1060	1114	688
Coarse Aggregates in kg	10mm	321	308	359	401	412
	20 mm	137	136	154	172	619
Water/ Binder Ratio		0.33	0.33	0.33	0.33	0.33
Superplasticiser%		1.30	0.95	0.85	1.60	0. 5
VMA %		-	-	-	0.20	-

3. RESULTS AND DISCUSSIONS

3.1 Fresh properties of concrete

The results of workability for all SCC mixes are given in Table-4. It is seen that all parameters are within permissible limits and hence the requirement of self compacting ability is satisfied. V-funnel five minute tests show segregation resistance of the concrete. A uniform flow of coarse aggregates in slump flow test is noted which is indication of stability of concrete (Figure-1). Powder type SCC mixes are observed more stable as compared to VMA type mix. The amount of paste available provides stability to mix. It is found that the stability of mix is better with increase in binder content. For NVCin Mix 5, the workability is observed as 79mm slump.

By observation of Table-3, it is seen that superplasticiser requirement goes on decreasing with raise in binding material. Requirement of superplasticizer is 1.3% for Mix 1 which reduces to 0.95% for Mix 2 and further reduces to 0.85% for Mix 3. Higher amount of paste available in these mixes is reducing friction between ingredients which in turn resultsin reducing demand of superplasticiser. This will reduce cost of superplasticiser by adding cheaper filler material like fly ash.

Table-4. Workability of various mixes.

S. No.	Test	Results for Various mixes				Acceptable limits
		Mix 1	Mix 2	Mix 3	Mix 4	
1	V-Funnel Time T_0 (Sec)	8.2	7.20	7.42	11.2	6 - 12
2	V-Funnel at $T_{5minute}$ (Sec)	10.9	9.9	10.25	13.8	$\leq T_0+3$
3	Slump Flow diameter (mm)	680	710	690	690	650 - 800
4	L-Box T_{20cm} (Sec)	0.89	0.9	0.92	1.2	1 ± 0.5
5	L –Box T_{40cm} (Sec)	2.34	2.2	2.09	2.3	2 ± 0.5
6	L-Box Blocking Ratio (H_2/H_1)	0.86	0.9	0.85	0.8	– 1.0

Figure-1. Flow of self compacting concrete.

3.2 Hardened properties of concrete

a) Compressive strength of concrete

Figure-2 shows variation of compressive strength of all mixes with time. For powder type SCC, it is observed that the compressive strength goes on increasing with increase in binder material. Observation of graphs of Mix 1, Mix 2 and Mix 3 shows that the rate of gaining strength is higher in first 28 days which found to be declining after that. Percentage increases in strength from 28 days to 56 days are 12.1%, 5.02% and 8.47% respectively for Mix 1, Mix 2 and Mix3. Compressive strengths of VMA type SCC Mix 4 and NVC Mix 5 are observed identical. No substantial increase in strength from 28 days to 56 days is observed in these mixes. This is due tonon availability of fly ash in these mixes which has delayed hydration properties [14].

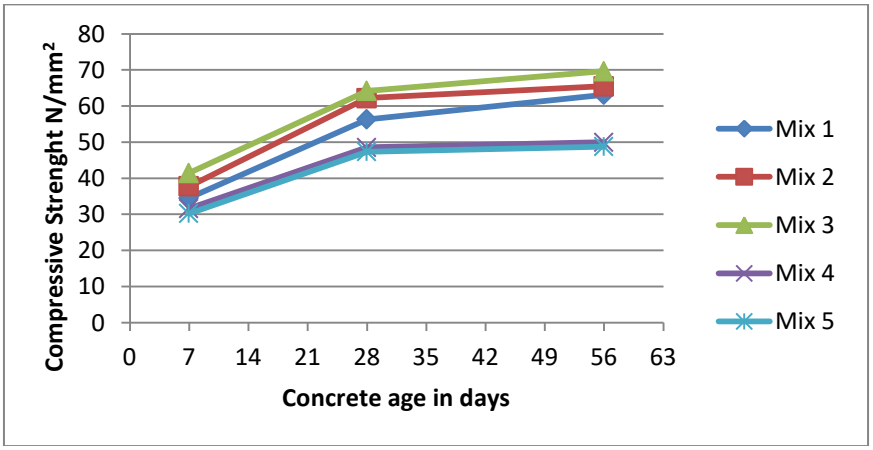


Figure-2. Compressive strength of all mixes.

b) Tensile strength of concrete

Splitting tensile strength of SCC mixes against compressive strength is shown in Figure-3. It is observed that tensile strength increases with compressive strength. Figure-4 shows ratio of tensile strength to compressive strength verses compressive strength of SCC mixes. The trend shows that with increase in compressive strength, the ratio of tensile strength to compressive strength decreases. Although there is raise in tensile strength with compressive strength, the rate of increase of tensile strength goes on decreasing [15].

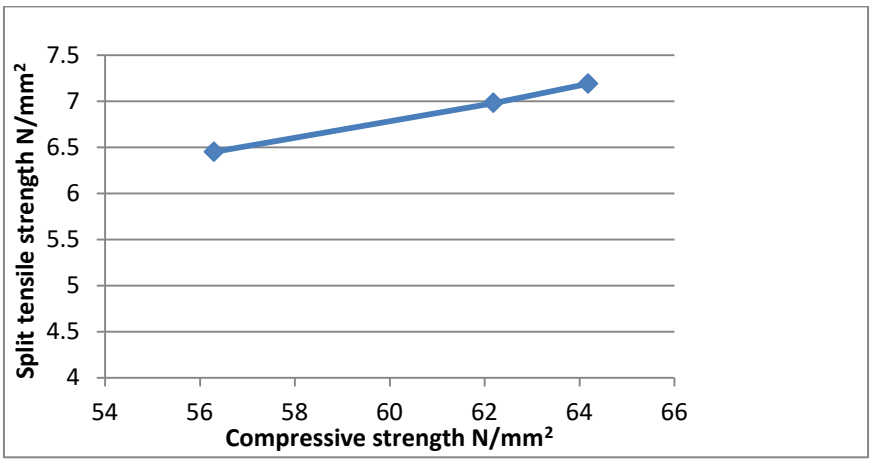
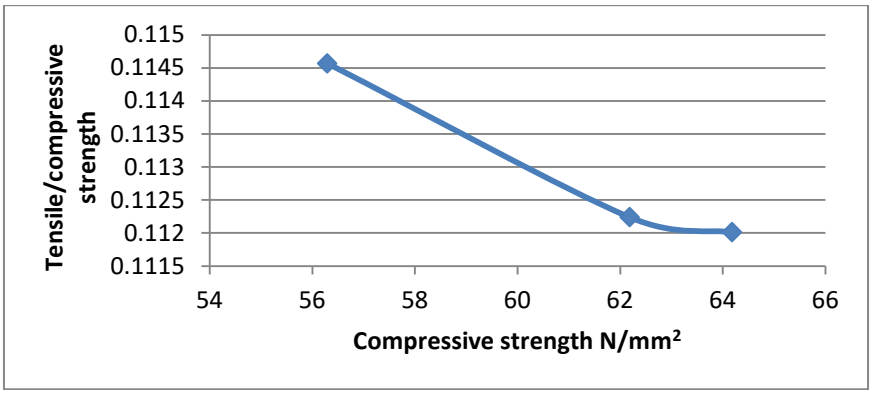


Figure-3. Compressive strength and tensile strength for SCC mixes.



Figurte-4. Compressive strength and ratio of tensile and compressive strength for SCC mixes.

c) Modulus of elasticity of concrete

Figure-5 shows modulus of elasticity of all mixes after 28 days. The predicted values using codes ACI 363R-84[16] and ACI 318-89 [17] are also shown. It is observed that predictions by code ACI 318-89 are in close agreement with experimental values obtained. ACI 318-89 code makes use ofequation $4700\sqrt{f_{ck}}$ for predicting modulus of elasticity of concrete. Table 5 gives values of multiplying constant with $\sqrt{f_{ck}}$ to obtain modulus of elasticity for experimental results. For powder type SCC mixes (Mix 1 to Mix 3), it is observed that the value of multiplying constant goes on decreasing. It is higher for VMA SCC (Mix 4) than all powder type mixes while for NVC mix (Mix 5) it is maximum. From Mix 1 to Mix 3, quantity of coarse aggregates goes on decreasing (Table-3) which leads in decreasing this constant.Course aggregates are more in NVC and hence multiplying constant is highest for Mix 5.

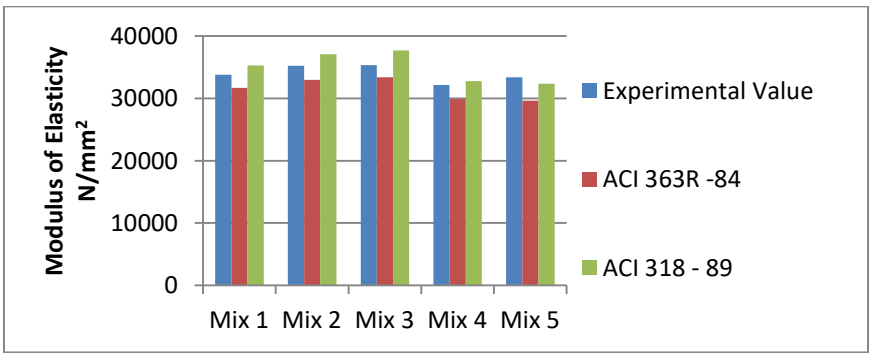


Figure-5. Modulus of elasticity for all mixes.

Table-5. Multiplying constant to obtain modulus of elasticity.

Mix 1	4503
Mix 2	4464
Mix 3	4410
Mix 4	4604
Mix 5	4844

4. CONCLUSIONS

Three powder type self compacting concrete mixes with increasing binder content, VMA type self compacting concrete and normal vibrated concrete mix are tested at fresh and hardened state for properties such as compressive strength, tensile strength and elastic modulus.

- Mixes with higher binder content are found more stable and cohesive. Quantity of superplasticizer requires is also less for higher binder mixes and hence can be recommended using.
- Compressive strength increases with increase in binder content. After 56 days, strength increases in powder type self compacting concrete while there is no significant rise in strength if VMA type self compacting concrete and normal vibrated concrete.
- Tensile strength of concrete increases with increase in compressive strength, however ratio of tensile strength to compressive strength is found decreasing with increase in compressive strength.
- Elastic modulus predictions by code ACI 318-89 are more close to experimental values. Multiplying factor found to be least in mix with highest binder and maximum in normal vibrated concrete.

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