IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 6, Dec-Jan, 2015
ISSN: 2320 – 8791 (Impact Factor: 1.479)
www.ijreat.org

Effect of Size and Volume of Coarse Aggregate on the Properties of Self-Compacting Concrete

Vageesh H.P[1], Reena K.[2]

[1]Assistant Professor, Dept. of Civil and Architectural Engineering, Axum University, Axum, zipcode-1010, Ethiopia.

[2]Assistant Professor, Dept .of Civil Engineering, ACS College of Engineering, Bangalore, zip code- 560074, India

Abstract

In The present investigation a simple mix design procedure proposed by Nan Su was used and aims to study the change in the strength of concrete when the variation of coarse aggregate size and volume take place. And also to check all the properties of SCC, to check compressive strength, flexural strength, & split tensile strength of SCC Specimens after 7 and 28 days curing. In this study the different sizes of aggregate used are 12.5, 10, & 6mm in a two different way combination by varying the proportions of each. And in this study a 10 different mixes were investigated with a different size and different proportions of each. And the water to cement ratio and the superplasticizer dosage is kept constant throughout the experiment. And all the fresh state properties (i. e, slump, V- funnel flow, L – box) are checked to achieve a SCC. And in the hardened state, Compressive strength, split tensile strength, flexural strength of the concrete after 7 and 28 days curing were also investigated. From the above experimental investigation.the results show how the SCC properties achieved with a different sizes of coarse aggregate. And the fresh property of SCC reduces with the increase in the size of coarse aggregate but it gives a higher strength in the hardened state. We can say that the increase in strength is directly proportional to the size of the aggregate.

Keywords *– Compressive Strength, Flexural strength, Fly Ash, Nan-Su Method, Split tensile Strength, Water Cement Ratio*

1. Introduction

Self-compacting concrete is a concrete which can be placed and compacted under its own weight with little or no vibration effort. SCC is the modified concrete with the use of chemical and mineral admixtures in the concrete. It is designed generally with high content of powder/fine material. To facilitate flow and penetration through congested reinforcement zones, it is desirable to avoid 20mm aggregate. If more coarse aggregate is used, flow rate will be diminished due to frictional loss and stresses.

SCC is still not widely used in India in spite of its many advantages including reduction in labour and fast track construction etc. This is because of lack of sufficient data and information on SCC made of materials available in the different parts of the country and hence insufficient confidence of engineers in producing this materials**.** India has abundant supply of flyash, with its sources well distributed across the country. SCC generally possesses a high powder content which keeps the concrete cohesive with high flow ability. This high powder content is required to maintain a sufficient yield value of the fresh mix and cement cannot be the only powder material in SCC. For achieving economy, a substantial part of this powder could also contain flyash. SCC can accommodate more than 200 kg/m^3 of fly ash which is regarded as a high volume addition. Hence it is considered worthwhile to investigate the influence of flyash in SCC.

An extremely important aspect of the durability of concrete is its permeability. Fly ash concrete is less permeable because fly ash reduces the amount of water needed to produce a given slump, and through pozzolanic activity, creates more durable CSH (calcium-silicate-hydrate) as it fills capillaries and bleeds water channels occupied by water-soluble lime (calcium hydroxide). Fly ash improves corrosion protection. By decreasing concrete permeability, fly ash can reduce the rate of ingress of water, corrosive chemicals and oxygen- thus protecting steel reinforcement from corrosion and its subsequent expansive result. Fly ash also increase sulphate resistance and reduces alkali-silica reactivity. At this point a distinction between Class C and F fly ashes needs to be made. While both improve the permeability and general durability of concrete, the chemistry of Class has proven to be more effective in mitigating sulphate and alkali-silica expansion and deterioration in concrete. Some Class C fly ashes have been used to mitigate these reactions, but must be used at higher rates of cement replacement. Fly ash has been shown to be an effective addition for SCC providing increased cohesion and reduced sensitivity to changes in water content. However, high levels of fly ash may produce a paste fraction which is so cohesive that it can be resistant to flow

Requirements for SCC

SCC exhibits following properties in its plastic state.

➢ **Filling Ability:** It is the ability of SCC to flow into and fill completely all spaces in the formwork and encapsulate reinforcement while maintaining homogeneity.

➢ **Passing Ability:** It is the ability of concrete mix to pass through obstacles like narrow sections in form work, closely spaced reinforcement bars without getting blocked by interlocking of aggregate particles.

➢ **Resistance to segregation:** Segregation resistance of self-compacting concrete is its capability to retain homogeneity in the distribution of ingredient in fresh state during both static and moving condition i.e., during mixing, transportation and placing. It is dependent on viscosity of mix in fresh state.

Experimental Objectives:

The specific objectives of this experimental work are as follows:

1. To design a suitable SCC mix by Nan-Su's method and utilizing varies sizes of coarse aggregates with different proportions and locally available normal sand and by fixing W/P ratio and super plasticizer dosage and without incorporating VMA.

2. To determine compressive, split tensile, flexural strength of such concrete for 7 and 28 days

There are varieties of strengthening measures available for the coarse aggregate size effect on the properties of self-compacting concrete. The detailed explanation is given for the effect of concrete mix in both fresh and hardened state with a various sizes of coarse aggregate. And the suggestion is obtained on finding the optimization of coarse aggregate proportion in a given coarse aggregate volume of self-compacting concrete. The varies codes are used to study the properties of the constituent materials. The various mix design procedure were explained with details. By going through all the designs the Nan-Su method of mix designing calculation is adopted in this particular study.

2. Materials Used

- ➢ Cement
- ➢ Fine Aggregates
- ➢ Water
- ➢ Coarse aggregate
- ➢ Filler (Flyash)
- ➢ Super plasticizer

Cement -Cement is such a material that has cohesive and adhesive properties in the presence of water such cement is called hydraulic cement. These consist preliminary of silicates and aluminates of lime obtained from limestone and clay. In this experiment 53 grade ordinary Portland cement (OPC) with brand name Ultra tech was used for all SCC mixes. The cement used was fresh and without any lumps, the testing of cement was done as per IS: 12269-1987.

Fine Aggregates - The sand used in this present study is collected from the bed of river Tungabhadra The sand passing through 4.75 mm size sieve is used in the preparation of concrete mix. The sand confirms to grading Zone III as per IS: 383-1970 (Reaffirmed 1997). The properties of sand such as fineness modulus and specific gravity were determined as per IS: 2386-1963. The physical properties of the Fine aggregate (sand) are mentioned in table 1.

Sl no	Physical properties	Fine aggregate (sand)
1	Specific gravity	2.67
2	Fineness modulus	3.47
3	Bulk density(kg/m^3)	1600
4	Packing factor	1.078
5	Water absorption	1.3%

Table 1: Physical Properties of the Fine Aggregate

\

Coarse aggregate: The coarse aggregate used in this present study is 12.5,10,6 mm down size graded confirm to IS 383-1970 (Reaffirmed 1997) locally available crushed stone obtained from local quarries. The physical properties of coarse aggregates have been mentioned in table 2.

Table 2: Physical Properties of Coarse Aggregates

Sl no	Physical properties	Coarse aggregate		
		(12.5 + 10 + 6) mm	(10 + 12.5) mm	(10 + 6) mm
1	Specific gravity	2.91	2.98	2.92
2	Fineness modulus	7	6	5
3	Bulk density(kg/m^3)	1515	1528	1500
4	Packing factor	1.09	1.08	1.081
5	Water absorption	0.6	1	0.8

Water -The water used in the mixing of concrete was potable water and its free from organic content , turbidity and salts confirms to IS 456-2000 was used for mixing and for curing throughout the experiment program.

Filler (Flyash)- Filler Materials such as flyash, blast furnace slag, etc. are commonly used as filler for producing SCC. An extremely important aspect of the durability of concrete is its permeability. Fly ash concrete is less permeable because fly ash reduces the amount of water needed to produce a given slump, and through pozzolanic activity, creates more durable CSH as it fills capillaries and bleed water channels occupied by water-soluble lime Fly ash improves corrosion protection. By decreasing concrete permeability, fly ash can reduce corrosive chemicals and oxygen- thus protecting steel reinforcement from corrosion and its subsequent expansive results. in this research Flyash is used as a filler material. Fly ash from Raichur thermal power station, Karnataka was used.

Super plasticizer- As the locally available PCE based super plasticizers proved to be very effective in SCC; this study is carried out using such type of super plasticizers. GLENIUM B233Commercially available poly-carboxylic ether based super plasticizer it is an admixture of a new generation based on modified polycarboxylic ether. GLENIUM B233 is a super plasticizer manufactured by BASF chemicals; Hubli was used in this experimentation. Its use emhances the workability of the mix and strength aspect, helps in producing a better compaction and finishing. It also permits reduction in water content

3. Experimental Work

Design mix for SCC by Nan Su method [8]

Details of selecting a suitable SCC mix for evaluating its performance in terms of strength and durability are described. For selecting a suitable mix using local aggregates, by using the Nan-Su method a mix proportion A Number of trial mixes were prepared and the slump test has been carried out by varying the superplasticizer content and water to powder ratio. By keeping all other parameter constant to fix the superplasticizer dosage. And also to obtain a proper mix. Proportioning of the trial mixes was carried out using the absolute volume method. Each mix was tested for self-compatibility. Finally, a suitable mix was selected based on the self-compatibility and strength test results.

Data's are obtained from experimental program

- Packing factor (PF) =1.09
- Sp gravity of Cement (Gc) = 3.15
- Sp gravity of FA (Gs) = 2.67
- Sp gravity of CA (Gg) = 2.91, 2.98, 2.92
- Sp gravity of Flyash (Gf) = 2.13
- Sp gravity of water (Gw) = 1.0
- Bulk density of FA (Wsl) = 1600 Kg / m3
- Bulk density of CA (Wgl) = 1515, 1528, 1500 Kg / m3
- Max size of aggregate = 12.5,10,6 mm
- Super Plasticizer (SP) = GLENIUM B233
- Air content (Va) = 1.5 %
- Designed compressive strength (psi) f^1c = 40 MPa

Mix Proportions:

Cement: Fly ash: Fine Aggregate: Coarse Aggregate: Water

1: 0.75: 3.3: 2.7: 0.68

Sl No.	Combination of aggregate	Mix proportion
1	(12.5 + 10 + 6)	1 : 0.75 : 3.3 : 2.7 : 0.68
2	(10 + 12.5)	1 : 0.755 : 3.32 : 2.7 : 0.68
3	(10 + 6)	1 : 0.75 : 3.50 : 2.77 : 0.68

Table 3: Mix Proportion of Different Sizes

Mix	Cement kg/m^3	Flyash kg/m^3	Water %	12.5mm kg/m^3	10mm kg/m^3	6mm kg/m^3	Sand kg/m^3	SP %
A-1	280	211.45	0.4	250.4	250.4	250.4	931.39	0.8
A-2	280	211.45	0.4	375.6	187.8	187.8	931.39	0.8
A-3	280	211.45	0.4	187.8	375.6	187.8	931.39	0.8
A-4	280	211.45	0.4	187.8	187.8	375.6	931.39	0.8
B-1	280	211.45	0.4	375.6	375.6	_	931.39	0.8
B-2	280	211.45	0.4	225.36	525.84	_	931.39	0.8
B-3	280	211.45	0.4	525.84	225.36	_	931.39	0.8
C-1	280	211.45	0.4	_	375.6	375.6	931.39	0.8
C-2	280	211.45	0.4	_	525.84	225.36	931.39	0.8
C-3	280	211.45	0.4	_	225.36	525.84	931.39	0.8

Table 4: Mix proportion of constituent materials

In this study SCC specimens were casted with compressive strength, Split tensile and Flexural strength respectively. 48 compressive strength test specimens of cube size (150mm x150mmx150mm). Likewise 48 Cylinders (dia-150mm, height 300mm) for Split tensile and 48 Beams (100mmx100mmx500mm) for Flexural strength Which consist of Cement, sand, aggregate, filler (Fly Ash), super plasticizer were taken in mix proportion **1: 0.75: 3.3: 2.7: 0.68**: **0.8**. Which correspond to M40 grade of concrete the ingredients of concrete were thoroughly mixed in concrete mixer machine. Before casting oil was smeared to the inner surface of the moulds. Concrete was poured in to the moulds without any hand compaction and vibration. The specimens were given finished smooth with trowel. After 24 hours, the specimens were demoulded and transferred to curing tanks where they were allowed to cure for 7and 28 days. Then they were tested for compressive, Split tensile and Flexural strength.

4. EXPERIMENTAL RESULTS

The Workability test results with recommended limits are tabulated in table 2 and variation of compressive strength, Split tensile strength and flexural strength of different SCC mixes with varying size of coarse aggregates corresponds to M_{40} grade of SCC from the experimental investigations are tabulated in tables 6 to table 8 and Figure 1 to Figure 3 respectively.

Mix name	W/P ratio	SP in %	Slump flow(mm)	V-funnel flow at Tf(s)	L-box Ratio (h2/h1)
A-1	0.4	0.8	680	9	0.91
A-2	0.4	0.8	630	11	0.86
A-3	0.4	0.8	650	10	0.92
A-4	0.4	0.8	690	8	1
B-1	0.4	0.8	630	11	0.91
B-2	0.4	0.8	710	9	0.96
B-3	0.4	0.8	620	11.2	0.81
C-1	0.4	0.8	690	9	0.96
C-2	0.4	0.8	680	9	0.94
C-3	0.4	0.8	725	8	1
Recommended limits	–	–	**600 – 800 mm**	**8 – 12 sec**	**0.8 – 1**

Table 5: Workability test results with recommended limits

4.1Compressive Strength Results

Mix Name	7 days strength in Mpa	28 days strength in Mpa
A-1	29.77	49.77
A-2	26.66	44.44
A-3	23.11	43.55
A-4	23.11	44
B-1	27.11	48
B-2	26.66	44
B-3	24	41.33
C-1	30.22	52.44
C-2	24	43.11
C-3	23.11	40.88

Table 6: Compressive strength results for 7 and 28 days

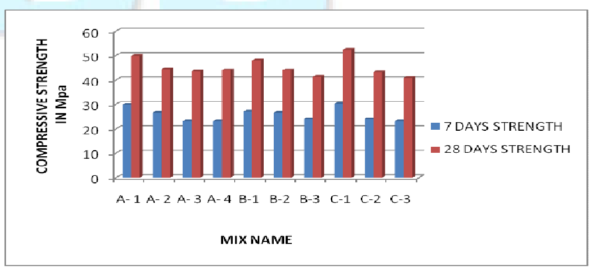

Figure 1: Compressive strength results for 7 and 28 days

It has been observed from the fig 5.2 that the 7 days compressive strength is less compared to that of 28 days, this is due to delayed hydration process because of the presence of flyash. The average 28-days compressive strength varied in 43 to 52 Mpa. The ratio of 7days compressive strength to the 28 days compressive strength varied from 48.7 percent to 59.9 percent. This strength ratio for normal concrete is usually taken as 67 percent. In earlier stages, it is observed that when larger size coarse aggregate with a higher proportion, it has given a very less fresh state properties values (i.e. slump, V-funnel flow) but higher compressive strength is obtained compared to few mixes with a lower size aggregate with higher proportion. The mix A – 1(with a equal proportion of 12.5, 10, 6 mm size aggregate) and the mix C – 1 (with a equal proportion of 10, 6 mm size coarse aggregate) gives a very high compressive strength compare to other mixes.

The mix A – 3 (with 50% of 10mm & 25% of 12.5, 6mm size coarse aggregate) and mix A – 4 (with 50% of 6 mm & 25% of 12.5, 10 mm size aggregate) and mix C – 3 (with 70% of 6mm & 30% of 10mm size aggregate) gives a very low compressive strength compare to other mixes but obtained a higher slump for the same mix. The mixes A-3 (50% of 10mm and 25% of 12.5 & 6 mm size coarse aggregate) and A-4(50% of 6mm and 25% of 12.5 & 10 mm size coarse aggregate) give almost the same compressive strength. By above observation it can be state that, the compressive strength increases with increase in the size and volume of coarse aggregate.

4.2 Split Tensile Strength Result

Mix Name	7 days strength in Mpa	28 days strength in Mpa
A-1	2.69	3.97
A-2	1.68	3.67
A-3	1.98	3.53
A-4	2.23	3.67
B-1	2.19	3.39
B-2	1.69	3.53
B-3	1.98	2.97
C-1	2.26	3.81
C-2	2.07	3.25
C-3	1.84	3.11

Table 7: Split tensile strength result of 7 and 28 days

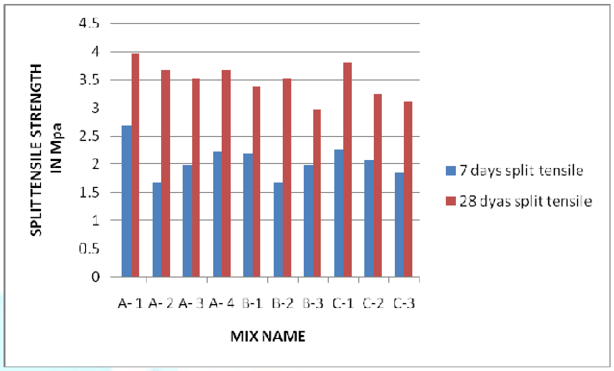

Figure 2: Split tensile strength result of 7 and 28 days

It as been observed from the fig 5.3 that, all the mixes resulted in the lower split tensile srength for mix A – 2 (with 50% of 12.5 mm, & 25% of 10, 6 mm size aggregate) and mix B – 2 (with 70% of 10 mm & 30% 6mm size aggregate) at a early age i. e, at 7 days stage, but the strength incresed in the 28 days stage due to higher proportion of lower size aggregate and also for low pozzolonic activity of fly ash. The mix A – 1(equal amount of coarse aggregate 12.5, 10, 6 mm size), and the mixC – 1 (with equal amount of 10, 6mm size aggregate) give a very high split tensile srength compare to other mixes. The mix C – 3 (with 70% of 6mm & 30% of 10mm size aggregate) gives a very low split tensile strength compare to other mixes. It is observed that split tensile srength is maximum at maximum size aggregate and go on reducing when we consider a lower size aggregate.

4.3 Flexural Strength Results

Mix Name	7 days flexural strength in Mpa	28 days flexural strength in Mpa
A-1	6.25	7.25
A-2	5.25	6.75
A-3	5.75	6.75
A-4	6	6.5
B-1	6.5	6.75
B-2	5.5	6.25
B-3	5.25	6.5
C-1	6.25	7
C-2	5.25	6.25
C-3	5.75	6

Table 8: Flexural strength results of 7 and 28 days

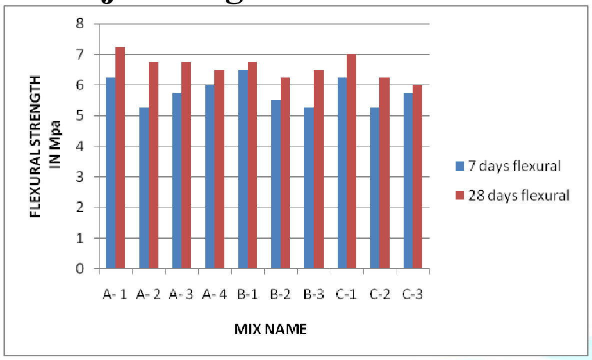

Figure 3: Flexural strength results of 7 and 28 days

By observing the graph 5.4 it can straightly stated that, the increase in flexural strength due to the increase in the size and volume of coarse aggregate. It obtain a higher flexural strength for all the mixes with a equal proportion of all three combination(i. e, 12.5 + 10 + 6 mm) and equal proportion of all two combination (i. e, 10 + 12.5mm, & 10 + 6mm) in both 7 and 28 days strength.The mixes with the 70% of 10mm size aggregate in both mixes B – 2, and C – 2, gives a very low flexural strength compare to other mixes. And also compare to the mix prepared by a 70% of the 6mm size aggregate. It is observed that self compacting concrete shows higher performance in attaining strength on longer duration.

CONCLUSIONS

Based on the present investigation the following conclusions can be drawn

- The fresh properties of SCC reduce with increase in the size and volume of coarse aggregate.
- Both coarse aggregate size and volume are influential in obtaining the successful SCC mix.
- As the size of coarse aggregate increases the tendency of the mix to segregate increases.
- Higher sizes aggregate with a greater proportion leads to the collision and internal friction within the coarse aggregate particles.
- Increase in size and volume both influential in obtaining the passing ability of SCC.
- The aggregate size effect have direct effect on the physical properties of materials like, density, voids, strength, workability.
- The compressive strength, split tensile strength, and flexural strength are maximum at the higher size of coarse aggregate with higher proportion.
- The mixes with the 70% of 10mm size aggregate gives a very low flexural strength compare to other mixes. And also compared to the mix prepared by a 70% of the 6mm and 12.5mm size coarse aggregate.
- SCC can be obtained for widely differing flyash content or cement contents as long as the paste volume constituted by the water cement ratio is kept constant.
- The higher size aggregate gives less values in fresh properties compare to the lower size aggregate, but at the hardened state higher size aggregate give a better strength than the smaller sizes.
- The increase in strength is directly proportion to the size of coarse aggregate

AKNOWLEDGEMENT

The authors wish to thank the authorities of Axum University, Axum (Ethiopia) and Visvesvaraya Technological University, Belgaum for giving an opportunity to conduct the experiments in the concern Concrete and Highway Engineering Laboratories of Axum university, Axum, Ethiopia and ACS college of engineering Bangalore, India.

REFERENCES

1) Hajime Okamura and Masahiro Ouchi,“Self compacting concrete” Journal of advanced concrete technology Vol. 1, No 1, April 2003.

2) H.J.H. Brouwers, H.J. Radix, Self-compacting concrete : Theoretical and experimental study

3) Hui Zhao, Wei Sun, Xiaming Wu, Effect of coarse aggregate gradation on the properties of self compacting concrete, Material & science volume 40 sep 2012

4) Debashis Das, V.K. Gupta & S.K. Kaushik, “Effect of maximum size & volume of coarse aggregate on the properties of SCC”, The Indian concrete journal, march 2006

5) A. V. Krishna, B. Krishna Rao, A. Rajagopal, “Effect of different sizes of coarse aggregate on the

properties of NCC and SCC." ByInternational journal of engineering science and technology Vol. 2(10), 2010,

7) J. Guru jawahar, M.M. Premchand, C. Sashidhar, "Effect of coarse aggregate blending on fresh properties of self compacting concrete." By, International Journal of Advances in Engineering & Technology, May 2012.

8) Jagdish Vengala and R.V.Ranganath, Mixture proportioning procedures for Self Compacting Concrete, The Indian concrete Journal, august 2004.

9)Subramaniam.SandChattopadhyay(2002)"Experiment for Mix proportioning of SCC" Indian Concrete Journal",Janaury vol pp 12-30.

10) Das, et,al " Experimental investigation on self compacting conrete.Indian concrete journal , 2006.

11) Specifications and guidelines for self compacting concrete, EFNARC, www.efnarc.org

12) Shetty M.S., 'ConcreteTechnology', S. Chand publishers, 7th revised edition 2013.

13) IS: 383-1970, "Specification for coarse and fine aggregates from natural sources for concrete (2nd revision)", Indian standards bureau, New Delhi, India.

14) IS: 3812-2003, "Specification for flyash for use as pozzolana & admixture".

15) IS: 516-1959, "Methods of tests for strength of concrete", Indian standards bureau, New Delhi, India.

16) IS: 456-2000, "Plain and reinforced concrete code of practice", Indian standards bureau, New Delhi, India.

17) IS: 10262-2009"Recommended guidelines for concrete mix design", Indian standards bureau, New Delhi, India.

18) IS: 12269-1987, "Specification for 53 grade ordinary Portland cement". Indian standards bureau, New Delhi, India.