FLY ASH AS PARTIAL REPLACEMENT FOR CEMENT IN SELF COMPACTING CONCRETE- A STUDY ON COMPRESSIVE, TENSILE AND FLEXURAL STRENGTH

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

[1] *Assistant Professor, Dept. Of Civil and Architectural Engineering,*

Axum University, Axum (Ethiopia)

[2] *Assistant Professor, Dept .Of Civil Engineering, ACS College Of Engineering, Bangalore (India)*

ABSTRACT

In the present investigation a simple mix design procedure proposed by Okamura (Japanese method) was used. . In the present work a wide range of SCC mix were developed using fly ash as a partial replacement along with Portland cement of 43 grade. The scope of this work is limited to the development of a suitable mix design to satisfy the requirements of Self Compacting Concrete with Flyash as partial replacement in plastic stage using local aggregates and then to determine the Compressive, Split tensile and Flexural strengths. To qualify Self-Compacting Concrete mixes Slump flow, V-funnel, L-Box, U-Box tests were conducted and the fresh properties obtained are checked against the specifications given by EFNARC guidelines. Compressive, Split tensile and Flexural strength tests were conducted by the replacement of Fly ash in 10%, 20% and 30% by the weight of cement was done, Self Compacting concrete containing flyash was compared with Normal SCC. And to know the strength properties of the mixes at the age of 7, 14, 21 and 28 days of curing. It was observed that Fly ash can be replaced in SCC up to 10% to obtain a reasonable good mix as that of SCC without Fly ash. SCC with 10% Fly ash replacement has same Compressive strength and as good as Normal SCC without Fly ash.

Keywords – Compressive Strength, Flexural Strength, Fly Ash, Okamura Method (Japanese Method), Split Tensile Strength, Water Cement Ratio.

I. 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 flowability. 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 sulfate 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 sulfate 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.

II. MATERIALS AND METHODOLOGY

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 43 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: 8112-1989.

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 II 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 specific gravity of fine aggregate is found to be 2.7 and having fineness modulus 3.47. The water absorption is 1.5%.

Coarse aggregate: The coarse aggregate used in this present study is 12.5 mm down size graded confirm to IS 383-1970 (Reaffirmed 1997) locally available crushed stone obtained from local quarries. The physical properties have been determined. The specific gravity of coarse aggregate is found to be 2.65. The water absorption is 0.5%..

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.Fly ash also increase sulfate resistance and reduces alkali-silica reactivity 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

2.1 Experimental Work

2.1.1 Design Mix for SCC by Okamura (Japanese Method) [7]

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, 10 trail mixes were carried out by replacing of Fly ash in 10%, 20% and 30% by the weight of cement, by varying water powder ratio and remaining parameters were kept constant. Proportioning of the trial mixes was carried out using the absolute volume method. Each mix was tested for self compatibility and compressive strength. Finally, a suitable mix was selected based on the self-compatibility and strength test results.

2.1.2 Data's Are Obtained From Experimental Program

- Sp gravity of Cement (G_c) = 3.0
- Sp gravity of FA (G_s) = 2.7
- Sp gravity of CA (G_g) = 2.65
- Sp gravity of Flyash (G_f) = 2.5
- Sp gravity of water (G_w) = 1.0

- Max size of aggregate = 10 mm
- Bulk density of coarse aggregate = 1.62
- Assume air content = 2%
- Coarse aggregate by volume = 50%
- fine aggregate by volume of mortar = 50%
- Water/Powder ratio = 1.05

- Super Plasticizer (SP) = GLENIUM B233(by BASF chemicals, Hubli)

2.1.3 Mix Proporations

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

384: 1010.47: 873.18: 136.92: 214.78: 3.065

1: 2.63: 2.27: 0.356: 0.559

In this study SCC specimens were casted with Flyash replacements as 10%,20%and 30% by mass of cement for 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: 2.63: 2.27: 0.356: 0.559. 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 7, 14, 21 and 28 days. Then they were tested for compressive, Split tensile and Flexural strength.

III EXPERIMENTAL RESULTS

The Workability test results with recommended limits of different trail mixes i.e. TR1, TR2 up to TR10 are tabulated in table 1 and compressive strength, Split tensile and Flexural strength. Corresponds to SCC with different percentages of flyash are tabulated in table 2, 3 and 4 respectively.

Table 1 Workability Test Results with Recommended Limits

Mix	**W/P ratio**	**SP in %**	**Slump flow(mm)**	**V-funnel flow (sec)**	**U-Box test Results(mm)**	**L-box Ratio (h2/h1)**
TR1	0.85	0.9	708	9	24	0.9
TR2	0.9	0.9	718	10	18	0.86
TR3	0.95	0.9	726	8	20	0.94
TR4	0.9	0.9	731	9	21	0.92
TR5	0.95	0.9	739	11	19	0.89
TR6	1	0.9	742	9	20	0.91
TR7	0.95	0.9	745	8	25	0.93
TR8	1	0.9	757	9	17	0.86
TR9	1	0.9	765	12	23	0.85
TR10	1.05	0.9	777	11	18	0.88
Recommended limits		**–**	**600 – 800 mm**	**8 – 12 sec**	**0-30 mm**	**0.8 – 1**

TABLE 2 Compressive Strength of SCC for Different Percentage of Flyash with W/P Ratio 1 (TR8)

Curing period, days	PERCENTAGE OF FLYASH USED F0R REPLACEMENT			
	0	10	20	30
7	19.1	20.7	23.4	22.6
14	24.9	30.3	24.2	26.3
21	31.6	32.4	26	28.6
28	35.7	35.7	25.7	29.6

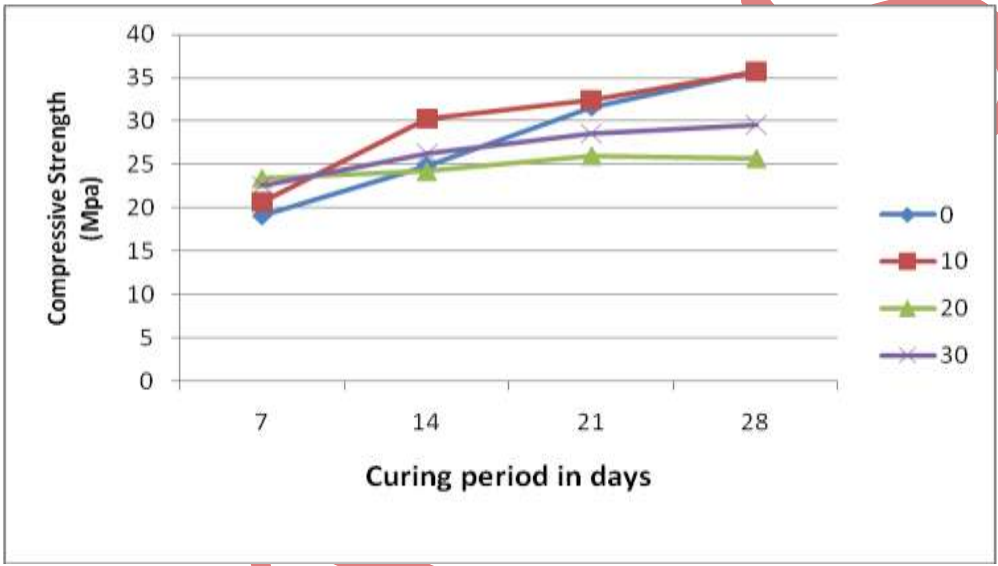

Fig 1: Showing Comparison Between Different Percentages Of Flyash On Compressive Strength

Normal concrete though has lesser initial Compressive strength at 7 days, it has about 35.7 Mpa at 28 days. Among SCC samples specimen with 10% replacement is showing a higher compressive strength when compared to 20% and 30% replacement.

10% replaced specimen is showing a steady increase in the strength gain at an uniform rate.

Table 3 Split Tensile Of SCC for Different Percentage of Flyash with W/P Ratio 1 (Tr8)

curing period, days	PERCENTAGE OF FLYASH USED F0R REPLACEMENT			
	0	10	20	30
7	5.6	5.5	4.7	4.9
14	7.3	8.35	6.45	6.4
21	8.7	8.65	6.9	6.9
28	12.4	10.2	9.1	7.8

The Tensile strength taking capacity of 10% replaced SCC is much higher than 20% and 30% replaced specimens.

20% and 30% replaced specimens have almost the same strength till 28days, with a marginal variation thereafter.

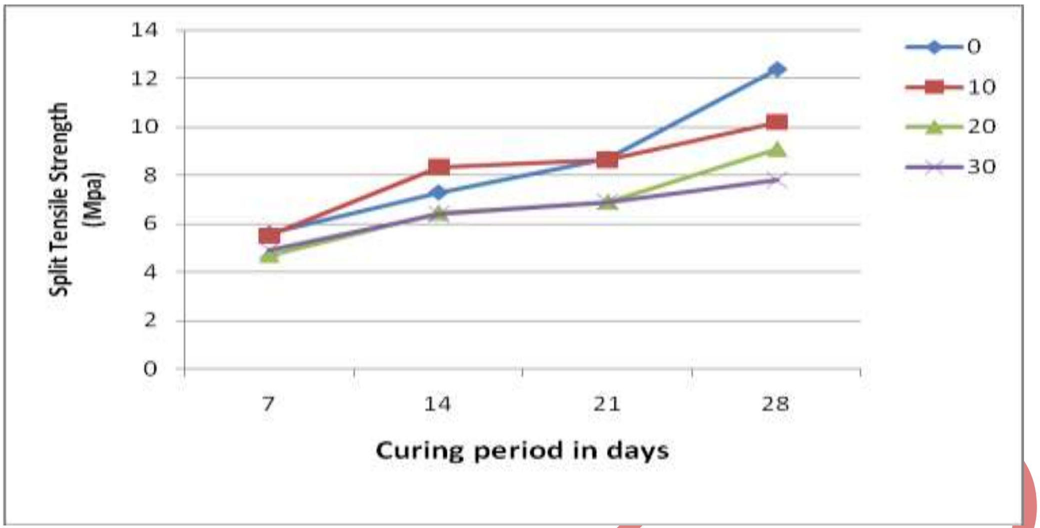

Fig 2: Showing Comparison Between Different Percentages Of Flyash On Split Tensile Strength

TABLE 4 Flexural Strength of SCC for Different Percentage of Flyash with W/P Ratio 1 (TR8)

curing period, days	PERCENTAGE OF FLYASH USED F0R REPLACEMENT			
	0	10	20	30
7	7.4	6.7	5.49	4.4
14	7.7	7.3	6.5	5.6
21	8.8	7.6	6.9	5.8
28	9.25	8.75	6.8	6.1

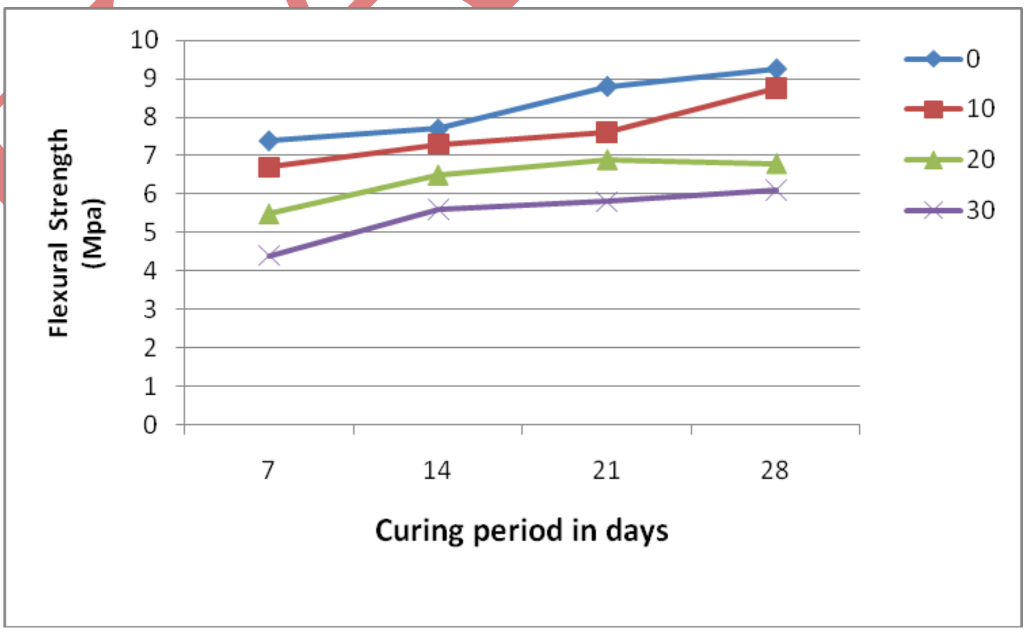

Fig 3:Showing Comparison Between Different Percentages Of Flyash On Flexural Strength

The flexural strength of Fly ash mixed SCC is lower than Normal concrete SCC without Fly ash, but as seen from the graph SCC with 10% Fly ash is showing much higher strength than the other two replacements. As the 28 days strength of 10% replaced SCC is on par with the Normal SCC without Fly ash, which indicates that Fly ash can be used in SCC up to 10% replacement without affecting the characteristic strength. As seen from table 1 and 2 the compression strength of 10% replaced SCC specimen is 0.99 that is equal to the strength of Normal SCC, where as the Tensile and Flexural strength is 0.8 times the corresponding values of Normal SCC. But 20% and 30% replaced specimens are in the range of 0.6 to 0.7 times the strength in Normal SCC, with respect to Split tensile and Flexural strength. The variation in Tensile and Flexural strength with respect to Compression in Normal SCC is 0.24 and 0.27. The same in 10% replaced SCC, the Tensile and Flexural strength is also varying in the range of 0.25 to 0.28.This indicates SCC with 10% Fly ash replacement has the same properties as that of Normal SCC.

3.1 Recommonded Design Mix

TABLE 5 Recommended Design Mix Test Results

Trail	W/P ratio	SP in %	Slump flow(mm)	V-funnel flow	U-Box test	L-box Ratio (h2/h1)
TR8	1	0.9	757	9	17	0.86
Recommended limits		**–**	**600 – 800 mm**	**8 – 12 sec**	**0-30 mm**	**0.8 – 1**

IV. CONCLUSIONS

On the basis of results the following conclusions can be drawn

1) SCC with 10% Fly ash replacement has same Compressive strength and as good as Normal SCC without Fly ash. At 14 days the strength is much higher than Normal strength concrete.
2) 10% replaced SCC has much higher Tensile strength than 20% and 30% replaced specimens.
3) 10% replaced SCC has Tensile strength lower than Normal SCC by about 17.75% ($f_{t-}= 0.81f_{t-NSCC}$)
4) SCC with 10% replacement gains about 80% of the strength than compared to Normal SCC under Tensile loading.
5) In Flexure SCC with 10% replacement has higher strength compared to 20% and 30% replaced specimens.
6) SCC with 10% replacement is about 11% lower in Flexure strength than Normal SCC. ($f_f = 0.89f_{ck-NSCC}$)
7) It is understood that Flyash can be replaced in SCC upto 10% to obtain a reasonable good mix as that of SCC without Flyash.

V. 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 and ACS college of engineering Bangalore.

REFERENCES

[1] Subramaniam.S and Chattopadhyaya (2002),Experiment for Mix proportioning of SCC, Indian Concrete Journal",Janaury vol pp 12-30

[2] H.Okamura, Self Compacting High Performance Concrete, Gihoudou Publications, Tokyo 1993.

[3] Jagadish Vengala Sudarsan,M.S., and Raghanath,R.V. , Mixture Proportioning procedures for Self Compacting Concrete, Indian Concrete journal, August 2004.

[4] Bouzoubaa N and Lachemi M ,Self-compacting concrete incorporating high volumes of class F fly ash - Preliminary results, cement and concrete research,31(3), 2001, pp. 413-420

[5] Dr. Hemant Sood, Dr.R.K.Khitoliya and S. S. Pathak, Incorporating European Standards for Self Compacting Concrete in Indian Conditions, International Journal of Recent Trends in Engineering, Vol. 1, No. 6, May 2009.

[6] T.Seshadri Sekhar and P.Srinivas Roa, Relationship between Compressive, Split Tensile, Flexural Strength of Self Compacting Concrete, International Journal of Mechanics and Solids, 2008, pp 157-168.

[7] Jagadish Vengala Sudarsan,M.S., and Raghanath,R.V.(2003), Experimental Study for obtaining Self Compacting Concrete, Indian Concrete Journal, August, pp 1261-1266.

[8] Specifications and guidelines for self compacting concrete, EFNARC, www.efnarc.org

[9] Shetty M.S., 'ConcreteTechnology', S. Chand publishers, 7th revised edition 2013.

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

[11] IS: 3812-2003, "Specification for flyash for use as pozzolana & admixture".

[12] IS: 8112-1989, "Specification for 43 grade ordinary Portland cement (1st revision)", Indian standards bureau, New Delhi, India.

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

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

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