Study on Structural Properties of Concrete by Partial Replacement of Fly Ash - A Study

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ABSTRACT
A basic mix design process described by Okamura (Japanese method) was applied in the current study. In this study, a variety of SCC mixes were created utilising fly ash as a partial replacement for Portland cement of grade 43. The purpose of this study is to construct a viable mix design to meet the criteria of Self Compacting Concrete with Flyash as a partial replacement in the plastic stage utilising local aggregates, and then to determine the compressive, split tensile, and flexural strengths. To determine the suitability of self-compacting concrete mixtures Slump flow, V-funnel, L-Box, and U-Box tests were carried out, and the results were compared to the EFNARC guidelines' criteria. Fly ash was replaced in 10%, 20%, and 30% by the weight of cement. Also, to determine the strength attributes of the mixtures after 7, 14, 21, and 28 days after curing. It was discovered that Fly ash may be substituted up to 10% in SCC to provide a satisfactory mix similar to SCC without Fly ash. The Compressive strength of SCC with 10% Fly ash substitution is the same 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

Concrete that can be put and compacted by its own weight with little or no physical effort is known as self-compacting concrete. SCC refers to concrete that has been changed by the addition of chemical and mineral admixtures. It's usually made up of a lot of powder or fine stuff. It is preferable to avoid 20mm aggregate in crowded reinforcing zones to allow flow and penetration. Because of frictional loss and strains, the flow rate will be reduced if more coarse material is employed. Despite its many advantages, including as labour savings and faster construction, SCC is still not commonly employed in India. This is due to a lack of appropriate data and knowledge on SCC made of materials accessible in various sections of the nation, as well as engineers' lack of faith in their ability to produce these materials. India has a plentiful amount of flyash, with sources located throughout the country. SCC typically has a high powder concentration, which helps to keep the concrete cohesive and flowable. Cement cannot be the only powder ingredient in SCC, hence a high powder concentration is necessary to ensure an acceptable yield value of the new mix. That would save money, a large amount of this powder may also include flyash. SCC can handle above 200 kg/m3 of fly ash, which is considered a large volume addition. As a result, it's thought to be beneficial to look at the impact of flyash on SCC. The permeability of concrete is an incredibly significant feature of its long-term durability. Fly ash concrete is less permeable because it decreases the quantity of water required to achieve a certain slump and forms more lasting CSH (calciumsilicate-hydrate) through pozzolanic activity as it fills capillaries and bleeds water channels formerly held by water-soluble lime (calcium hydroxide). Corrosion resistance is improved by using fly ash. Fly ash can lower the rate of entry of water, corrosive chemicals, and oxygen into concrete, preserving steel reinforcement from corrosion and the resulting expansive consequence. Sulfate resistivity and alkali-silica reactivity are also improved by fly ash. A difference between Class C and F fly ashes must be made at this time. While both increase concrete's permeability and overall durability, Class's chemistry has been shown to be more successful in preventing sulphate and alkali-silica expansion and degradation. To counteract these reactions, some Class C fly ashes have been employed, although they must be used at greater cement replacement rates. SCC has been proven to benefit from the addition of fly ash, which increases cohesiveness and reduces susceptibility to changes in water content. High quantities of fly ash, on the other hand, may result in a paste fraction that is so solid that it resists flow.

Requirements for SCC

In its plastic form, SCC has the following characteristics.

- **Filling Ability:** SCC's capacity to flow into and completely fill all voids in the formwork, encapsulating reinforcement while retaining uniformity, is known as encapsulation.
- **Passing Ability:** It is the capacity of a concrete mix to move through impediments such as narrow formwork sections and closely spaced reinforcing bars without being obstructed by aggregate particle interlock.
- **Resistance to segregation:** Self-compacting concrete's segregation resistance refers to its capacity to maintain homogeneity in the distribution of ingredients in a fresh state throughout both static and moving conditions, such as mixing, transportation, and placement. It is determined by the viscosity of the mixture in its fresh form.

II. MATERIALS AND METHODOLOGY

Cement- Hydraulic cement is a type of cement that possesses cohesive and adhesive capabilities in the presence of water. These are made up of silicates and aluminates of lime that are extracted from limestone and clay. All SCC mixes in this experiment were made using 43 grade ordinary Portland cement (OPC) from the Ultra tech brand. The cement used was new and lump-free, and the cement was tested according to IS: 8112-1989.

Fine Aggregates - The sand utilised in this investigation was gathered from the Tungabhadra River's bed. Sand that passes through a sieve with a size of 4.75 mm is utilised to make concrete mix. The sand conforms to IS: 383-1970 grading Zone II (Reaffirmed 1997). The fineness modulus and specific gravity of sand were calculated according to IS: 2386-1963. The fine aggregate has a specific gravity of 2.7 and a fineness modulus of 3.47. 1.5 percent of the water is absorbed.

Coarse aggregate: The coarse aggregate used in this investigation was crushed stone with a size of 12.5 mm that was obtained from local quarries and graded according to IS 383-1970. (Reaffirmed 1997). The object's physical features have been determined. The specific gravity of coarse aggregate is determined to be 2.65. Water is absorbed at a rate of 0.5 percent.

Water - The water utilised in the concrete mixing was potable water that met IS 456-2000 standards for organic content, turbidity, and salts. It was used for mixing and curing throughout the trial programme.

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. Because fly ash decreases the quantity of water required to achieve a given slump, and because of its pozzolanic activity, it generates more lasting CSH by filling capillaries and bleed water channels filled by water-soluble lime, fly ash concrete is less permeable. Corrosion resistance is improved by using fly ash. Fly ash reduces corrosive chemicals and oxygen in concrete, preserving steel reinforcement from corrosion and subsequent expansion. In this study, fly ash also increased sulphate resistance and decreased alkali-silica reactivity. Flyash is a filler material that is used in construction. The fly ash came from the Raichur thermal power plant in Karnataka.

Super plasticizer- This investigation is carried out utilising locally available PCE based super plasticizers since they have proven to be particularly successful in SCC. GLENIUM B233 is a commercially produced superplasticizer based on polycarboxylic ethers. It's a new generation of admixture based on modified polycarboxylic ether. GLENIUM B233 is a superplasticizer made by BASF chemicals and utilised in this experiment at Hubli. Its usage improves the mix's workability and strength, as well as helping to achieve better compaction and finishing. It also allows for a decrease in water content.

2.1 Experimental Work

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

The process of selecting a suitable SCC mix and testing its strength and durability is detailed in detail. For the purpose of choosing an appropriate mix utilising local aggregates, 10 trail mixes were created by substituting Fly ash in 10%, 20%, and 30% of the weight of cement, altering the water powder ratio, and keeping the remaining parameters constant. The absolute volume approach was used to measure the proportions of the experimental mixtures. Each blend was put through its paces in terms of self-compatibility and compressive strength. Finally, based on the results of the self-compatibility and strength tests, an acceptable blend was chosen.

2.1.2 Data's Are Obtained From Experimental Program

- Sp gravity of Cement (Gc) = 3.0
- Sp gravity of FA (Gs) = 2.7
- Sp gravity of CA (Gg) = 2.65
- Sp gravity of Flyash (Gf) = 2.5
- Sp gravity of water (Gw) = 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

For compressive strength, split tensile strength, and flexural strength, SCC specimens were cast with Flyash replacements of 10%, 20%, and 30% by mass of cement, respectively. 48 cube-sized compressive strength test specimens (150mm x150mmx150mm). Similarly, 48 Cylinders (dia-150mm, height 300mm) for Split tensile and 48 Beams (100mmx100mmx500mm) for Flexural strength were made with Cement, sand, aggregate, filler (Fly Ash), and super plasticizer in the proportions of 1: 2.63: 2.27: 0.356: 0.559. In a concrete mixer machine, the concrete materials were fully combined. The interior surface of the moulds were coated with casting oil before casting. Without any manual compaction or vibration, concrete was poured into the moulds. With a trowel, the specimens were smoothed out. The specimens were demoulded and moved to curing tanks after 24 hours, where they were allowed to cure for 7, 14, 21, and 28 days, respectively. They were then put through a series of tests to determine their 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

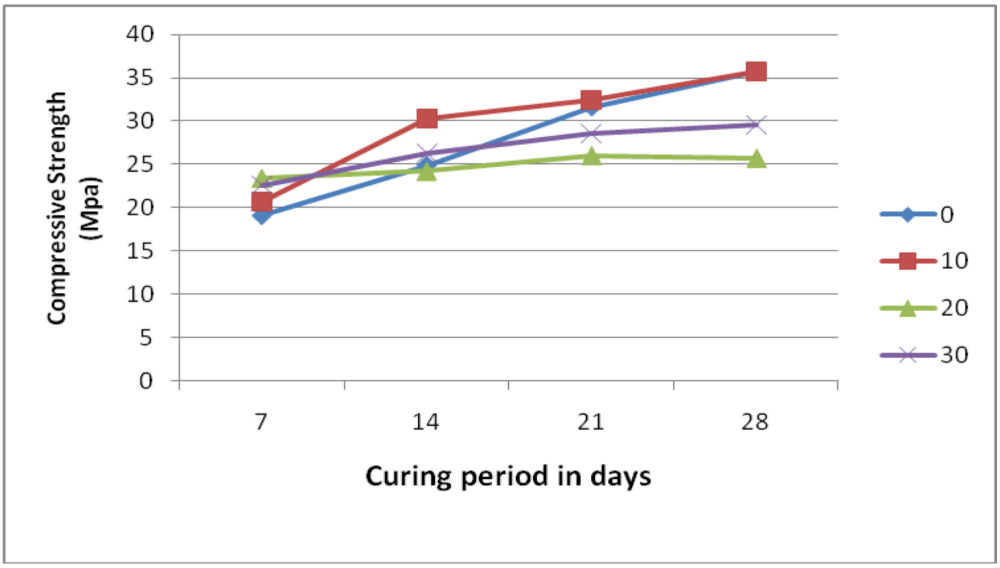

Fig 1: Showing Comparison Between Different Percentages Of Flyash On Compressive Strength

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.

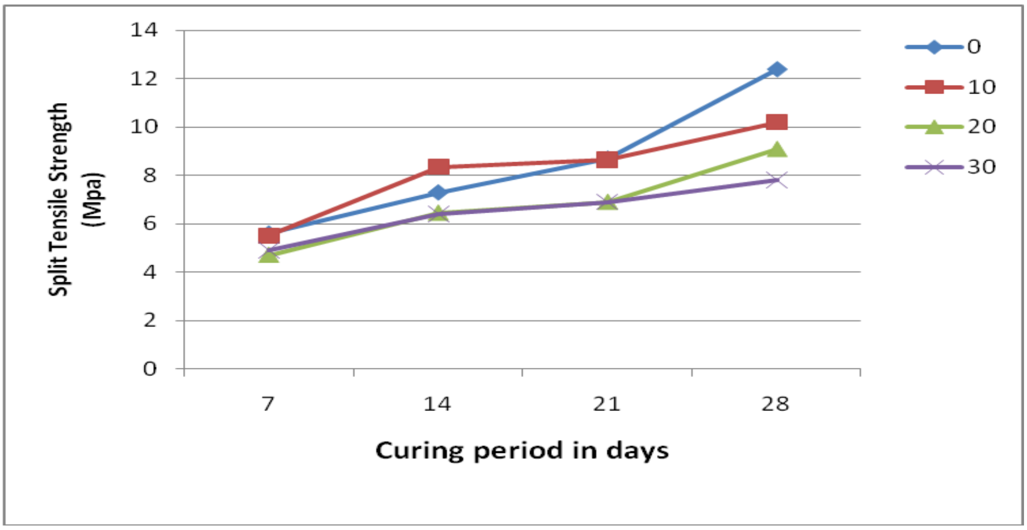

Fig 2: Showing Comparison Between Different Percentages Of Flyash On Split Tensile Strength

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

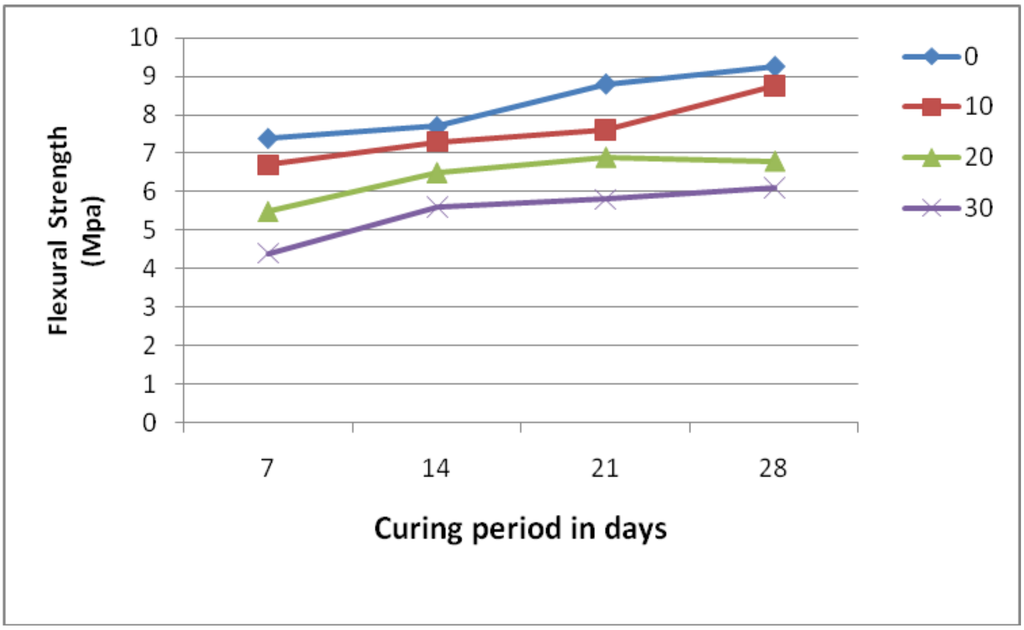

Fig 3:Showing Comparison Between Different Percentages Of Flyash On Flexural Strength

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 Recommended 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) 1) SCC with 10% Fly ash substitution has the same compressive strength as normal SCC without Fly ash and is as excellent as normal SCC without Fly ash. The strength of the concrete after 14 days is significantly higher than that of normal strength concrete.
2) 2) SCC with 10% replacement has a substantially better tensile strength than specimens with 20% and 30% replacement.
3) 3) Tensile strength of 10% substituted SCC is roughly 17.75 percent lower than normal SCC (ft = 0.81ft-NSCC).
4) 4) When compared to Normal SCC under Tensile stress, SCC with 10% replacement adds around 80% of the strength.

5) Flexure SCC specimens with 10% replacement had stronger strength than specimens with 20% and 30% replacement.

6) SCC with 10% replacement has a flexure strength that is around 11% lower than normal SCC. (NSCC ff = 0.89fck)

7) It is thought that up to 10% of Flyash can be substituted in SCC to provide a fairly decent mix similar to SCC without Flyash.

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