IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Experimental Investigation On Optimization Of Sustainable Materials & Mechanical Properties In M20 Grade Self Compacting Cocrete

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Abstract:

Self-Compacting Concrete (SCC) is an innovative concrete that possesses the ability to flow under its own weight and completely fill form work without the need for mechanical vibration. This project investigates the development of Self-Compacting Concrete of M20 grade by partially replacing cement with fly ash, an industrial by-product, to improve work-ability and promote sustainable construction practices. Fly ash was used as a partial replacement of cement in different proportions, and its influence on the fresh and hardened properties of SCC was studied. The fresh properties of SCC were evaluated using standard tests such as slump flow test, T50 time, V-funnel test, and L-box test to ensure conformity with SCC guidelines. The hardened properties were assessed by conducting compressive strength tests at 7 and 28 days. The experimental results indicate that the inclusion of fly ash enhances the flow-ability, filling ability, and passing ability of SCC while achieving the required strength for M20 grade concrete. An optimum percentage of fly ash replacement was observed to provide a good balance between strength and work-ability. The study concludes that fly ash can be effectively utilized as a partial replacement of cement in Self-Compacting Concrete, resulting in economical, durable, and environmentally friendly concrete suitable for structural applications.

KEYWORDS: Self-Compacting Concrete (SCC), Fly Ash, PPC based Cement, Flowability, Superplasticizer

1.INTRODUCTION:

Concrete is a widely used construction material composed of cement, fine aggregate, coarse aggregate, and water. It gains strength through the hydration process of cement and develops high compressive strength and durability over time. Due to its versatility, concrete can be molded into various shapes and sizes, making it suitable for structural elements such as beams, slabs, columns, and foundations. However, conventional concrete requires proper compaction using mechanical vibration to eliminate air voids and achieve the desired strength and durability.

Self-Compacting Concrete (SCC) is a special type of concrete that can flow and compact under its own weight without the need for external vibration. The development of SCC is essential to overcome the limitations of conventional concrete, especially in heavily reinforced and complex structural sections. SCC ensures complete filling of form-work, reduces construction time and labor cost, and improves surface finish. It also minimizes noise pollution and health hazards associated with vibration, leading to better quality control and enhanced durability of concrete structures.

Fly ash is a fine powder obtained as a by-product from coal-based thermal power plants and is widely used as a supplementary cementation material in concrete. It exhibits polarization properties and reacts with calcium hydroxide released during cement hydration to form additional calcium silicate hydrate (C-S-H) gel, which improves the strength and durability of concrete. The incorporation of fly ash enhances work-ability, reduces heat of hydration, and minimizes thermal cracking. Moreover, partial replacement of cement with fly ash contributes to sustainable construction by reducing cement consumption, lowering carbon emissions, and utilizing industrial waste effectively.

1.1 Material used

- **Cement**: OPC grade 43
- **Coarse aggregate**: 16mm &12mm
- **Fine aggregate**
- **Fly-ash**
- **Superplasticizer**

2. METHODOLOGY

Self- Compacting Concrete is characterized by filling ability, passing ability and resistance to segregation. Many different methods have been developed to characterize the properties of SCC. In the experiment we use M20grade of concrete for the cube casting and to perform compressive strength test. No single method has been found until date, which characterizes all the relevant workability aspects, and hence, each mix has been tested by more than one test method for the different workability parameters. Table 1 gives the recommended values for different tests given by different researchers for mix to be characterized as SCC mix

2.1Table Recommended Limits for Different Properties

Sr. No.	Property	Range
1.	Slump Flow Diameter	500-700 mm
2.	L-Box H2/H1	≥ 0.8
3.	V-Funnel Test	8-12sec

TABLE NO: 1 Range of slump

The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. On lifting the slump cone, filled with concrete, the concrete flows. The average diameter of the concrete circle is a measure for the filling ability of the concrete. The time T50cm is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the instant when horizontal flow reaches diameter of 600mm.

FIGURE NO :1 Measuring Flowability of SCC

The passing ability is determined using the L- box test [10] as shown in Fig 3. The vertical section of the L-Box is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1). This is an indication of passing ability. The specified requisite is the ratio between the heights of the concrete at each end or blocking ratio to be ≥ 0.8.

FIGURE NO:2 Flowability test of SCC concrete through Reinforcement bars using L-Box Setup

The V-funnel test is a workability test used mainly for self-compacting concrete (SCC) to evaluate its flowability and viscosity. In this test, fresh concrete is poured into a V-shaped funnel, and the time it takes to completely flow out through a narrow opening at the bottom is measured in seconds (called the V-funnel flow time). A shorter flow time indicates better flowability and lower viscosity, while a longer time suggests higher internal resistance or possible blockage due to poor mix design. It is a simple and effective method to assess the filling ability and segregation resistance of SCC.

FIGURE NO: 3 Measuring time duration for flowability of SCC using V-funnel

The cube compression test is conducted to determine the compressive strength of hardened concrete. Compressive strength is the most important property of concrete, as it indicates its ability to withstand loads without failure. The test is performed as per **IS 516**. Concrete cubes of size 150 mm × 150 mm × 150 mm are cast and cured in water for 7 and 28 days. After curing, the specimen is placed in a Compression Testing Machine (CTM) and load is applied gradually until failure occurs. The maximum load at failure is recorded

FIGURE NO: 4 Compressive strength test of the specimens

Split tensile strength of concrete is an indirect method used to determine the tensile capacity of hardened concrete. Since concrete is weak in tension, this test helps in evaluating its resistance to cracking. The test is conducted on cylindrical specimens (150 mm diameter and 300 mm length) by applying a compressive load along the diameter until failure occurs.

FIGURE NO:5 Concrete Specimen Placed In a Compression Testing Machine To Measure Compressive Strength

2.1 Experimental procedures

- The **M20** grade of concrete is used in this experiment and the mix design is prepared for M20.
- The materials are firstly mix by properly weigh batching process.
- The materials the mixed as by hand mixing process
- SCC1 is normal mix prepared as without any superplasticizer additional or nor any fly-ash mix. The SCC1 mix is to prepare the self-compacting concrete without any additional superplasticizer.
- Thereafter SCC2, SCC3, SCC4 mix is prepared at 5%, 10%, 15%, 20%,25%,30%&40% addition of fly-ash and also superplasticizer is used as per mix design.
- The slump flow test performed on the mixes to the check the filling ability of the mixes.
- The L-box test is performed on the mix to check the passing ability of the mixes.
- The v- funnel test is performed on the mix to check the passing ability of the mixes.
- 9 Cubes/mixes are casted to check the compressive strength of the concrete. 3 cubes are for 7day test, 3 cube for 7 days and 3 cubes for 28 days test. Whole 36 cubes are casted to check the compressive strength of the cube.
- Average compressive strength are taken as a comprehensive strength at the day.
- Comparison b/w normal concrete and self-compacting concrete are performed to get the conclusion.

2.2 Mix Proportions

Mix	Cement (Kg/m^3)	Fly Ash (Kg/m^3)	CA 16mm (Kg/m^3)	CA 12mm (Kg/m^3)	FA (Kg/m^3)	Superplasticizer (%)	Water
Trial Mix No.1*	300	0	627.440	513.36	826.09	3	160
Trial Mix No.2	285	5	627.440	513.36	826.09	3	160
Trial Mix No.3	270	10	627.440	513.36	826.09	3	160.
Trial Mix No.1*	255	15	627.440	513.36	826.09	3	160
Trial Mix No.5	240	20	627.44	513.36	826.09	3	160
Trial Mix No.2	225	25	627.440	513.36	826.09	3	160
Trial Mix No.7	210	30	627.44	513.36	826.09	3	160
Trial Mix No.3	195	35	627.440	513.36	826.09	3	160
Trial Mix No.9	180	40	627.44	513.36	826.09	3	160

3.TEST RESULTS

3.1 SLUMP CONE TEST:

3.1 TABLE NO – 2

SLUMP CONE TEST		
S.No	**Trail Mix**	**SLUMP VALUE (mm)**
1	CC-1	75
2	CC-2	80
3	CC-3	85

3.2 FLOW TABLE:

3.2 TABLE NO - 3

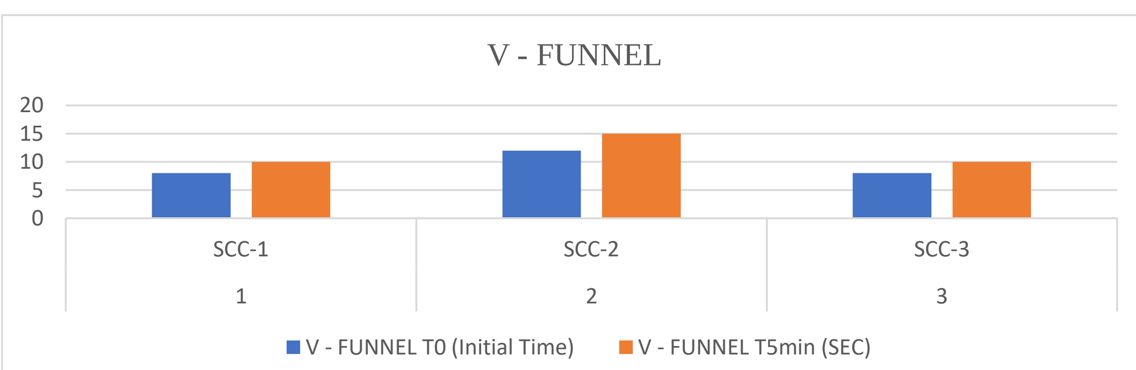
FLOW TABLE TEST		
S.No	**Trail Mix**	**Diameter (mm)**
1	SCC-1	600
2	SCC-2	650
3	SCC-3	550

3.3 V- FUNNEL TEST:

3.3 TABLE NO – 4

V - FUNNEL			
S.No	**Trail Mix**	**T0 (Initial Time)**	**T5min (SEC)**
1	SCC-1	8	10
2	SCC-2	12	15
3	SCC-3	8	10

Graph 3: V-Funnel Test Results (T_0 and T_5min) for SCC-1, SCC-2 and SCC-3 Mix



3.4 L-BOX TEST:

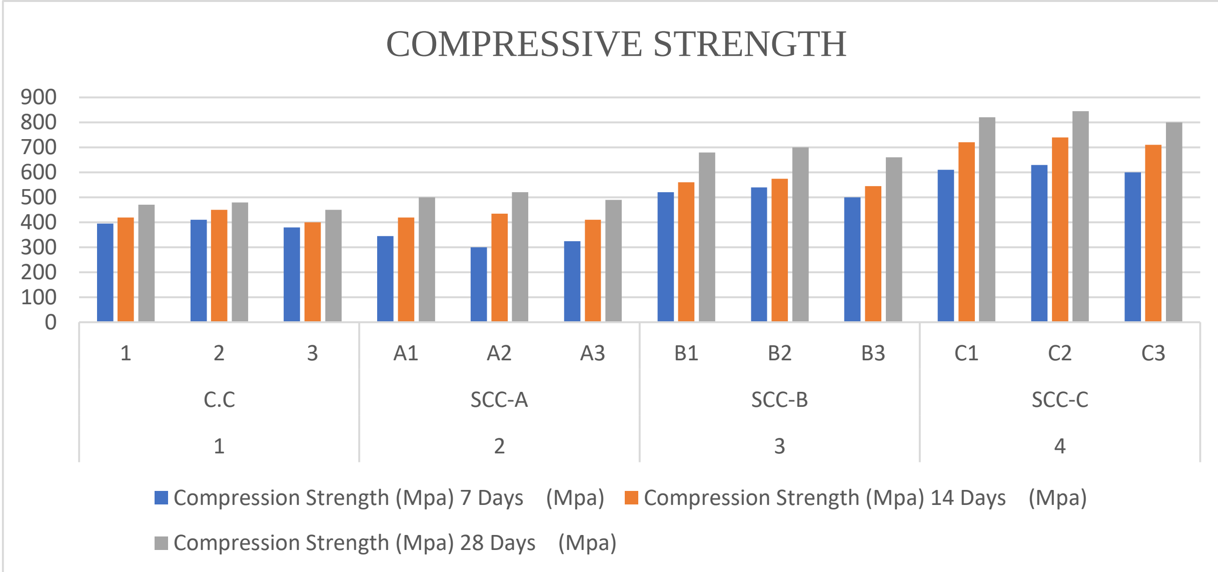
3.4 TABLE NO – 5

L-BOX TEST				
S.No	**Trail Mix**	**H1(mm)**	**H2(mm)**	**BLOCK RATIO**
1	CC-1	600	75	0.125
2	CC-2	600	80	0.138
3	CC-3	600	70	0.116

3.5 COMPRESSIVE STRENGTH TEST:

3.5 TABLE NO - 6

S.No	**Trail Mix**	**No of Specimens**	**Compression Strength (Mpa)**			
			7 Days (Mpa)	**14 Days (Mpa)**	**28 Days (Mpa)**	**Avg of 28 days**
1	**C.C**	1	395	420	470	466.6
		2	410	450	480	
		3	380	400	450	
2	**SCC-A**	A1	345	420	500	503.3
		A2	300	435	520	
		A3	325	410	490	
3	**SCC-B**	B1	520	560	680	680
		B2	540	575	700	
		B3	500	545	660	
4	**SCC-C**	C1	610	720	820	821.6
		C2	630	740	845	
		C3	600	710	800	



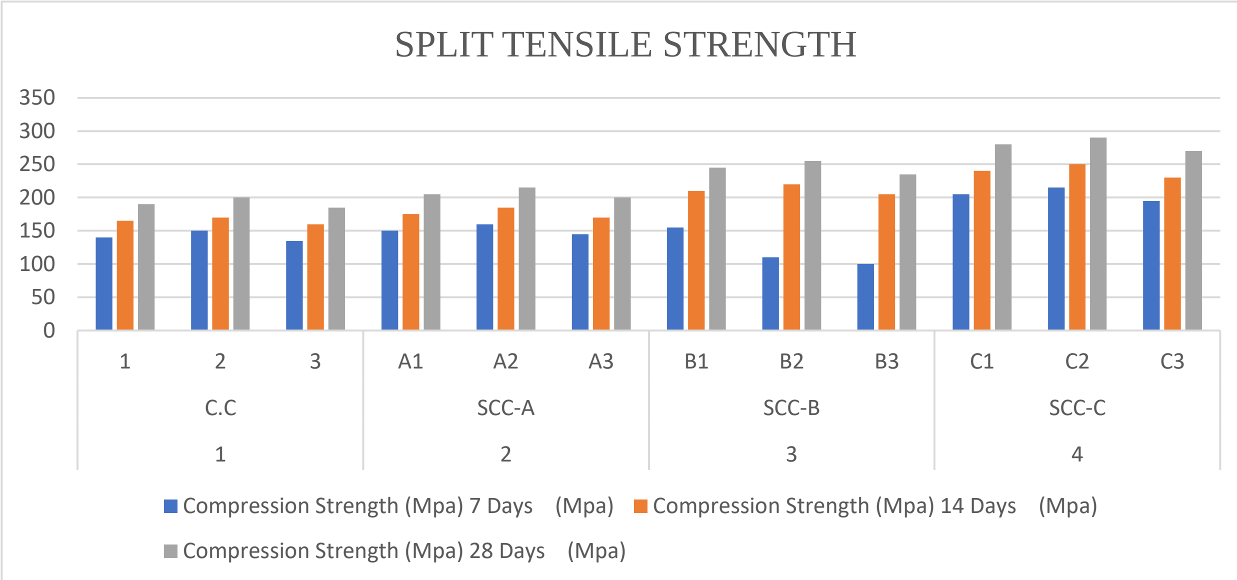
Graph 5: Compressive Strength of Concrete Mixes at 7, 14 and 28 Days

3.6 SPLIT TENSILE STRENGTH TEST:

3.6 TABLE NO - 7

S.No	Trail Mix	No of Specimens	Compression Strength(Mpa)			
			7 Days (Mpa)	14 Days (Mpa)	28 Days (Mpa)	Avg of 28 days
1	**C.C**	1	140	165	190	191.6
		2	150	170	200	
		3	135	160	185	
2	**SCC-A**	A1	150	175	205	206.6
		A2	160	185	215	
		A3	145	170	200	
3	**SCC-B**	B1	155	210	245	245
		B2	110	220	255	
		B3	100	205	235	
4	**SCC-C**	C1	205	240	280	280
		C2	215	250	290	
		C3	195	230	270	

Graph 6: Split Tensile Strength of Concrete Mixes at 7, 14 and 28 Days



4. CONCLUSION

1. The experimental study confirmed that Self-Compacting Concrete (SCC) of M20 grade can be successfully developed using fly ash as a partial replacement of cement. The mixes satisfied the required fresh and hardened property criteria as per SCC guidelines.
2. The slump flow, L-box, and V-funnel test results indicated that the inclusion of fly ash significantly improved the flowability, filling ability, and passing ability of concrete. This demonstrates better self-compaction without the need for mechanical vibration.
3. The use of superplasticizer played a vital role in achieving the desired workability and maintaining uniform consistency in all trial mixes. Proper dosage ensured resistance to segregation and improved overall performance.
4. Compressive strength results at 7 and 28 days showed that SCC with fly ash achieved the required strength for M20 grade concrete. An optimum replacement percentage provided a balanced improvement in both strength and workability.
5. Higher percentages of fly ash beyond the optimum level showed a gradual reduction in early strength gain. However, long-term strength development remained satisfactory due to pozzolanic reactions.
6. The partial replacement of cement with fly ash reduces cement consumption and promotes sustainable construction practices. It also lowers carbon emissions and effectively utilizes industrial waste materials.
7. Overall, the study concludes that fly ash-based SCC is economical, durable, and environmentally friendly. It is suitable for structural applications, especially in heavily reinforced and complex sections where conventional compaction is difficult.

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