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A Study on Workability and Strength Properties of Flyash Based Self Compacting Concrete of Grade M20

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ABSTRACT: - Admixtures of minerals and chemicals are mostly used in concrete as a means of achieving complete compaction, especially in cases of reinforcing congestion and a labour scarcity. Previous studies have emphasised that adding chemical and mineral admixtures to concrete gives it the desired characteristics while it's both fresh and hardened. The purpose of this research is to investigate the performance of self-compacting concrete with cement contents of 0%, 5%, 10%, 15%, and 20% fly ash. Five mixes of M20 grade self-compacting concrete were tested experimentally for both fresh and hardened qualities; the findings are compared with those of regular vibrated concrete. The following tests are taken into consideration for the study: the compressive strength, unit weight, compaction factor, and slump tests. The findings demonstrate that, while the water cement ratio is constant, adding more superplasticizer to self-compacting concrete improves its capacity to self-compact while also somewhat lowering its unit weight. Additionally, the compressive strength is somewhat higher than with a typical concrete mix.

Key words: unit weight, workability, superplasticizer, fly ash, normal concrete, and self-compacting concrete.

I. INTRODUCTION

1.1 General:

Self-consolidating concrete (SCC) or Self Compacting concrete, as it’s sometimes known, arrived as a revolution in the field of concrete technology. Even if there is still no official definition of SCC, the concept could be defined as follows:

A self-consolidating concrete must:

Have a fluidity that allows self-consolidation without external energy

- Remain homogeneous in a form during and after the placing process, and
- Flow easily through reinforcement.

Self Compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened

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concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

Self Compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design method and self compact ability testing methods have been carried out from the viewpoint of making it a standard concrete. Self Compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like “honey” and has a very smooth surface level after placing. With regard to its composition, Self Compacting concrete consists of the same components as conventionally vibrated concrete, which are cement, aggregates, and water, with the addition of chemical and mineral admixtures in different proportions.

1.2 Historical Development of Self Compacting Concrete:

Self Compacting concrete, in principle, is not new. Special applications such as underwater concreting have always required concrete, which could be placed without the need for compaction. In such circumstances vibration was simply impossible. Early Self Compacting concretes relied on very high contents of cement paste and, once super plasticizers became available, they were added in the concrete mixes. The mixes required specialized and well-controlled placing methods in order to avoid segregation, and the high contents of cement paste made them prone to shrinkage. The overall costs were very high and applications remained very limited.

1.3 Motive for Development of Self Compacting Concrete:

For several years beginning in 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. To make durable concrete structures, sufficient compaction by skilled workers is required. However, the gradual reduction in the number of skilled workers in Japan's

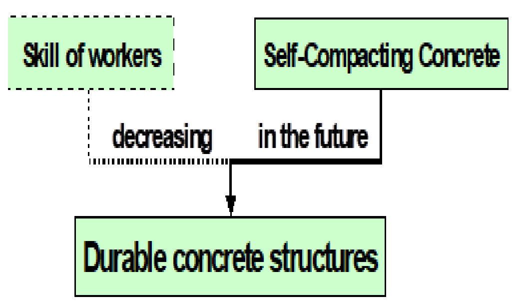

Fig. 1. Necessity of Self-

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II. LITERATURE REVIEW

2.1 General

Present-day self Compacting concrete can be classified as an advanced construction material. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete. These include an improved quality of concrete and reduction of on-site repairs, faster construction times, lower overall costs, facilitation of introduction of automation into concrete construction. An important improvement of health and safety is also achieved through elimination of handling of vibrators and a substantial reduction of environmental noise loading on and around a site. The composition of SCC mixes includes substantial proportions of fine-grained inorganic materials and this gives possibilities for utilization of mineral admixtures, which are currently waste products with no practical applications and are costly to dispose of (St John, 1998).

2.2 Previous Research Work on Self Compacting Concrete:

Self Compacting concrete extends the possibility of use of various mineral by-products in its manufacturing and with the densification of the matrix, mechanical behavior, as measured by compressive, tensile and shear strength, is increased. On the other hand, the use super plasticizers or high range water reducers, improves the stiffening, unwanted air entrainment, and flowing ability of the concrete. Practically, all types of structural constructions are possible with this concrete. The use of SCC not only shortens the construction period but also ensures quality and durability of concrete. This non-vibrated concrete allows faster placement and less finishing time, leading to improved productivity.

In the following, a summary of the articles and papers found in the literature, about the self Compacting concrete and some of the projects carried out with this type of concrete, is presented.

Hajime Okamura: A new type of concrete, which can be compacted into every corner of a formwork purely by means of its own weight, was proposed by Okamura (1997). In 1986, he started a research project on the flowing ability and workability of this special type of concrete, later called self-compacting concrete. The self-compactability of this concrete can be largely affected by the characteristics of materials and the mix proportions. In his study, Okamura (1997) has fixed the coarse aggregate content to 50% of the solid volume and the fine aggregate content to 40% of the mortar volume, so that self-compactability could be achieved easily by adjusting the water to cement ratio and super plasticizers dosage only.

A model formwork, comprised of two vertical sections (towers) at each end of a horizontal trough, was used by professor Okamura to observe how well self compacting concrete could flow through obstacles. Figure 2.1 shows the ends of small pipes mounted across the horizontal trough and used as obstacles. The concrete was placed into a right-hand tower, flowed through the obstacles, and rose in the left-hand tower.

Fig 2.Small pipes used as obstacles in formwork (Okamura, 1997).

The obstacles were chosen to simulate the confined zones of an actual structure. The concrete in the left-hand tower rose to almost the same level as in the right-hand tower. Similar experiments of this type were carried out over a period of about one year and the applicability of Self Compacting concrete for practical structures was verified. This research was started at the suggestion of professor Kokubu (Okamura, 1997) from Kobe University, Japan, one of the advisors of Hajime Okamura. They thought that it would be easy to create this new concrete because anti washout underwater concrete was already in practical use. Anti washout underwater concrete is cast underwater and segregation is strictly inhibited by adding a large amount of a viscous agent (anti washout admixture), which prevents the cement particles from dispersing in the surrounding water. With a super plasticizer, the paste can be made more flow able with little concomitant decrease in viscosity, compared to the drastic effect of the water, when the cohesion between the aggregate and the paste is weakened (Figure 2.2).

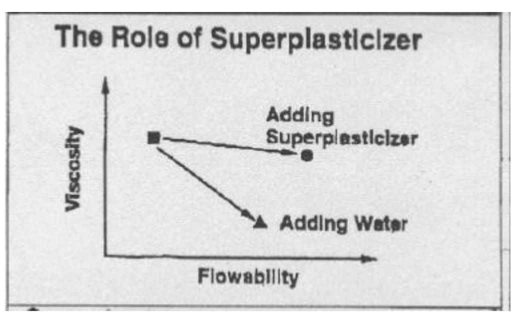

Fig 3. Effect of super plasticizer on viscosity (Okamura, 1997)

The water-cement ratio was taken between 0.4 and 0.6 depending on the properties of the cement. The super plasticizer dosage and the final water-cement ratio were determined so, as to ensure the self-compactability, evaluated subsequently by using the U-type test (Ouchi and Hibino, 2000) described in the previous chapter.

III. COMPOSITION MIX DESIGN AND TESTING PROCEDURES OF SELF COMPACTING CONCRETE

3.1 Materials used for Self-Compacting Concrete:

The materials used in Self-Compacting concrete are:

1. Portland Cement
2. Aggregates

Coarse aggregate

Fine aggregate

3. Mineral admixtures

Fly Ash

4. Chemical admixtures

Super-plasticizers

5. Water

Portland Cement:

In principle, the manufacture of Portland cement is very simple and relies on the use of abundant raw materials. An intimate mixture, usually of limestone and clay, is heated in a kiln to 1400 to 1600°C (2550 to 2900°F), which is the temperature range in which the two materials interact chemically to form the calcium silicates. High-quality cements require raw materials of adequate purity and uniform composition.

A typical chemical composition of an ordinary Portland cement is given in Table 3.1. It can be noted that the quantities do not add up to 100%, the missing percentages being accounted for by impurities.

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Chemical Name	Chemical Formula	Shorth and Notation	Weight Percentage
Tricalcium Silicate	3CaO-SiO2	C3 S	55
Dicalcium Silicate	2CaO-SiO2	C2 S	18
Tricalcium aluminate	3CaO-Al2O3	C3 A	10
Tetracalcium aluminoferrite	4CaO-Al2O3. Fe2O3	C3 AF	08
Calcium Sulfate dehydrate (Gypsum)	CaSO4 . 2H2O	CS H2	06

Table .1 Typical composition of ordinary Portland cement.

Super plasticizers:

Ozkul and Dogan (1999) studied the effect of an N-vinyl copolymer super plasticizer on the properties of fresh and hardened concretes. Workability of concrete was measured by slump flow test and in situ tests were undertaken to find out the pumping ability of super plasticized concrete. The coarse aggregate was crushed stone with the maximum size of 25 mm. By using this chemical admixture, which was a little bit different from the conventional ones, the ability of water reduction was increased along with the retention of high workability for a longer time.

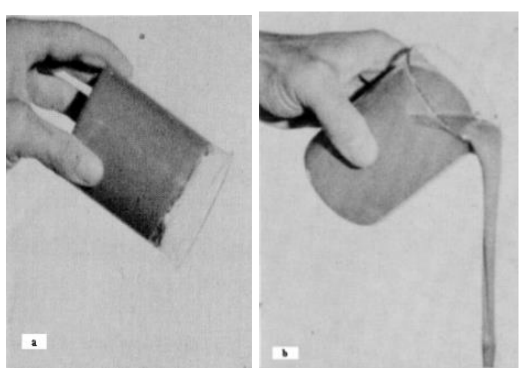

Fig 4. Effect of super plasticizer on cement: (a) Cement and water; (b) Cement, water, and super plasticizer

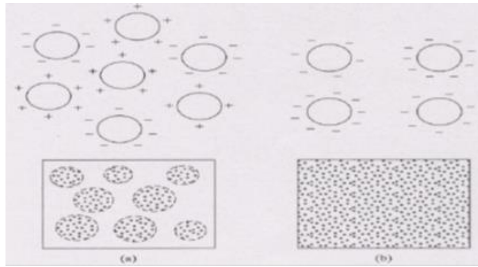

Fig 5. Dispersing action of water-reducing admixtures: (a) flocculated paste; (b) dispersed paste (Mindess et al., 2003).

Some high-range water-reducing admixtures can retard final set by one to almost four hours and if prolonged setting times are not convenient, the admixture can be combined with an accelerating admixture to counteract the retarding tendencies or even to provide some net acceleration of setting. When water-reducing admixtures are used in concrete mixtures, some increases in compressive strength can be anticipated and these increases can be observed in as early as one day if excessive retardation does not occur.

3.2 Mix Design of Self-Compacting Concrete:

Till now there is no specified method for the proportioning of Self-Compacting Concrete. Different people followed different methods. Some of the methods are discussed here.

The European Guidelines for Mix design of Self-Compacting Concrete

Mix design principles

To achieve the required combination of properties in fresh SCC mixes:

• The fluidity and viscosity of the paste is adjusted and balanced by careful selection and proportioning of the cement and additions, by limiting the water/powder ratio and then by adding a superplasticiser and (optionally) a viscosity modifying admixture. Correctly controlling these components of SCC, their compatibility and interaction is the key to achieving good filling ability, passing ability and resistance to segregation.

• In order to control temperature rise and thermal shrinkage cracking as well as strength, the fine powder content may contain a significant proportion of type l or ll additions to keep the cement content at an acceptable level.

• The paste is the vehicle for the transport of the aggregate; therefore the volume of the paste must be greater than the void volume in the aggregate so that all individual aggregate particles are fully coated and lubricated by a layer of paste. This increases fluidity and reduces aggregate friction.

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• The coarse to fine aggregate ratio in the mix is reduced so that individual coarse aggregate particles are fully surrounded by a layer of mortar. This reduces aggregate interlock and bridging when the concrete passes through narrow openings or gaps between reinforcement and increases the passing ability of the SCC.

These mix design principles result in concrete that, compared to traditional vibrated concrete, normally contains:

- Lower coarse aggregate content
- Increased paste content
- Low water/powder ratio
- Increased superplasticiser
- Sometimes a viscosity modifying admixture.

Test methods

A wide range of test methods have been developed to measure and assess the fresh properties of SCC. Table 3.3 lists the most common tests grouped according to the property assessed.

Characteristic	Test method	Measured value
Flowability/ filling ability	Slump-flow	total spread
	Kajima box	visual filling
Viscosity/ flowability	T_{500}	flow time
	V-funnel	flow time
	O-funnel	flow time
	Orimet	flow time
Passing ability	L-box	passing ratio
	U-box	height difference
	J-ring	step height, total flow
	Kajima box	visual passing ability
Segregation resistance	penetration	depth
	sieve segregation	percent laitance
	settlement column	segregation ratio

Table .2 Testing methods according to the property assessed

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3.3 EFNARC guide lines for Mix design of Self-Compacting Concrete

Requirements of S.C.C.

SCC can be designed to fulfill the requirements of EN 206 regarding density, strength development, final strength and durability. Due to the high content of powder, SCC may show more plastic shrinkage or creep than ordinary concrete mixes. These aspects should therefore be considered during designing and specifying SCC. Current knowledge of these aspects is limited and this is an area requiring further research. Special care should also be taken to begin curing the concrete as early as possible. The workability of SCC is higher than the highest class of consistence described within EN 206 and can be characterized by the following properties:

- Filling ability
- Passing ability
- Segregation resistance

A concrete mix can only be classified as Self-compacting Concrete if the requirements for all three characteristics are fulfilled.

Test methods

Many different test methods have been developed in attempts to characterize the properties of SCC. So far no single method or combination of methods has achieved universal approval and most of them have their adherents. Similarly no single method has been found which characterizes all the relevant workability aspects so each mix design should be tested by more than one test method for the different workability parameters.

Method	Property
1 Slump-flow by Abrams cone	Filling ability
2 T50cmslumpflow	Filling ability
3 J-ring	Passing ability
4 V-funnel	Filling ability
5 V-funnel at T5minutes	Segregation resistance
6 L-box	Passing ability
7 U-box	Passing ability
8 Fill-box	Passing ability
9 GTM screen stability test	Segregation resistance
10 Orimet	Filling

Table 3. List of test methods for workability properties of SCC

Adjustment of the mix

Laboratory trials should be used to verify properties of the initial mix composition. If necessary, adjustments to the mix composition should then be made. Once all requirements are fulfilled, the

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mix should be tested at full scale at the concrete plant or at site. In the event that satisfactory performance cannot be obtained, then consideration should be given to fundamental redesign of the mix. Depending on the apparent problem, the following courses of action might be appropriate:

- Using additional or different types of filler, (if available);
- Modifying the proportions of the sand or the coarse aggregate;
- Adjusting the dosage of the superplasticiser;
- Using alternative types of superplasticiser(and/or VMA),more compatible with local materials;
- Adjusting the dosage of admixture to modify the water content, and hence the water/powder ratio.

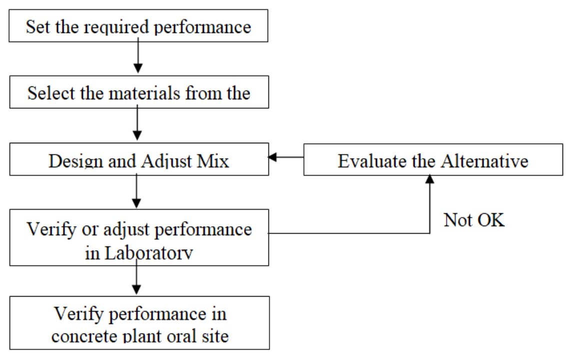

Fig: 6. Flow chart of the mix

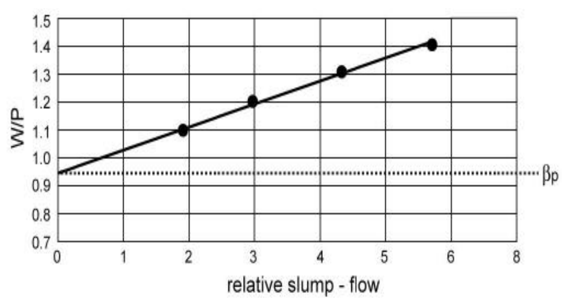

Figure 7. Determination of water powder ratio β p

Slump flow test:

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. The slump cone, filled with concrete is lifted and concrete flows; the horizontal diameter of the flowed material is measured, as shown in Fig 3.4. The average diameter of concrete circle is a measure for the filling ability for the concrete. The time T50 is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the

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instant when horizontal flow diameter reaches 500mm. According to Khayat and Manail, a slump flow ranging from 500mm to 700mm is necessary tor a concrete to be self compacted. At more than 700mm the concrete might segregate and at less than 500mm the concrete may not have sufficient flow to pass through highly congested reinforcement. This is simple, rapid test procedure, though two people are needed if T5o time is to *be* measured, it can be used on site, though the size of the plate is somewhat unwieldy and a level ground is essential.

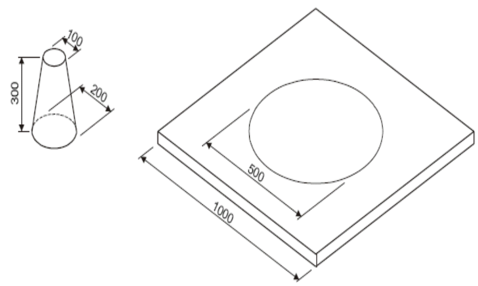

Fig 8. Slump-flow test.

V- Funnel test:

The ability of flow of fresh concrete can be tested with V-funnel test, where by the flow time is measured. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Further, $T_{5minutes}$, is, also measured with V-funnel, which indicates the tendency for segregation, wherein the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation, the flow time will increase significantly. According to Khayat and Manai, a funnel test flow time less than 6s is recommended for a concrete to qualify for a sec.

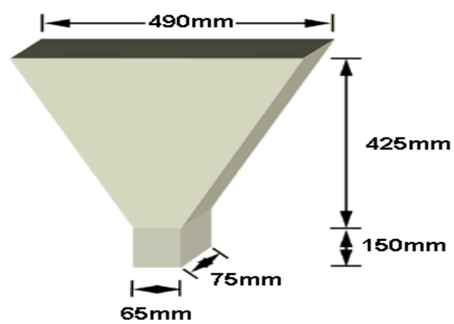

Fig 9. V-Funnel

L-Box test:

The passing ability is determined using L-Box test, Fig 2.11. The vertical section of L.box is filled with concrete, the gate lifted to let the concrete flow into the horizontal section.

The height of the concrete at the end of horizontal section is expressed as a proportion that remained in the vertical section (H2/Hl). This is an indication of passing ability. The T20 and T40 are the times taken for concrete to reach the 20cm and 40cm marks of horizontal section of L-Box. These are indications of the ease of flow of concrete. The specified requisites are the time needed to flow up to 20cm (T20) = 1±0.5 see, the time needed to flow up to 40cm(T40) = 2 ± 0.5sec and a ratio between the height of the concrete at each end (or) blocking ratio less than 0.80.

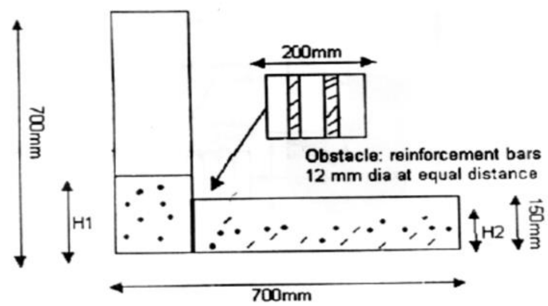

Fig 10. L-Box Test

IV. MATERIALS USED IN THIS INVESTIGATION

4.1 Scope of Investigation:

The proposed study is being carried out to develop Self Compacting concrete of different grades with Fly ash as admixture for use in the Indian conditions satisfying European Standards for rheological properties of concrete in fresh state.

4.2 Materials Used:

The different materials used in this investigation are

- 53 grade Ordinary Portland Cement
- Coarse Aggregate
- Fine Aggregate
- Fly Ash
- Superplasticizer
- Water

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4.2.1 Cement:

The cement used in all mixtures was commercially available Ordinary Portland cement (OPC) of 53 grade manufactured by Ultratech Company confirming to IS: 12269-1987.

S. No	Property	Experimental Values	Suggested value as per IS: 12269-1987 code
1.	Specific gravity	3.15	**3.00 to 3.20**
2.	Normal Consistency	34%	- -
3.	Initial Setting Time	121min	Min 30 minutes
4.	Final Setting Time	320min	Max 10 Hours

Table 3. Physical properties of cement

4.2.2 Coarse Aggregates:

The coarse aggregate from a local crushing unit having 20mm normal size well-graded aggregate according to IS-383 is used in this investigation. The coarse aggregate procured from quarry was sieved through 20mm, 16mm, 12.5mm, 10mm and 4.75mm sieves. The material retained on 12.5mm, 10mm and 4.75mm sieves was filled in bags and stacked separately and used in the production of Self Compacting Concrete.

S. No	Property	Value
1.	Specific gravity	2.70
2.	Bulk density	1479 Kg/m3
3.	Water Absorption	0.1%
4.	Fineness modulus	7.01

Table 4. Physical properties of coarse aggregate

4.2.3 Fine Aggregates:

The fine aggregate that falls in zone-II was obtained from a nearby river course. The sand obtained was sieved through all the sieves (i.e.4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ). To obtain zone-II sand correctly, sand retained on each sieve is mixed in appropriate proportion.

S. No	Property	Value
1.	Specific gravity	2.63
2.	Fineness modulus	2.53
3.	Bulk Density	1551 Kg/m3
4.	Grading	Zone-II

Table 5. Physical properties of fine aggregate:

Sieve Size (mm)	Weight retained (gms)	% weight retained	Cumulative (%) weight Retained(F)	Cumulative % weight passing	Specification as per IS 383 -1970 for Zone II
4.75	27	2.7	2.7	97.30	90-100
2.36	38	3.8	6.50	93.50	75-100
1.18	132	13.2	19.70	80.3	55-90
600	260	26.0	45.70	54.30	35-59
300	420	42.0	87.70	12.30	8-30
150	105	10.5	98.20	1.80	0-10
75	10	1.00	99.20	0.80	--

Table 6. Sieve analysis of fine aggregate:

Safety precautions:

As with all chemical products, care should be taken during use and storage to avoid contact with eyes, mouth, skin and foodstuffs (which can also be tainted with vapour until product fully cured or dried). Treat splashes to eyes and skin immediately. If accidentally ingested, seek immediate medical attention. Keep away from children and animals. Reseal containers after use. Do not reuse containers for storage of consumable item.

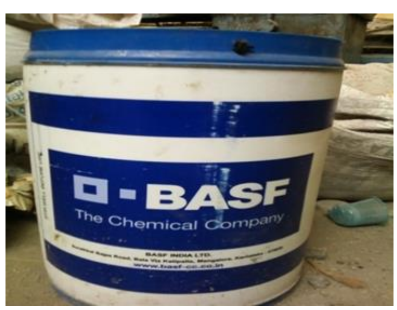

FIG.11 Chemical admixtures Used in the Present Investigation

V. EXPERIMENTAL INVESTIGATIONS

5.1 General

This experimental program has been carried out for designing S.C.C. mixes by partly replacing cement with Fly ash (Percentages of replacement are 0, 5, 10,15 and 20%).

The test program consists of

1. Preparing Self Compacting Concrete mixes with various percentages of super Plasticizer, and water/Powder ratio for each percentage replacement of cement with Fly ash (0%, 5%, 10% , 15% and 20%) and carrying out standard flow tests of SCC (Slump test, V-Funnel test, L- Box test) on these mixes.
2. Casting specimens and conducting Compressive strength test on cubes and split tensile strength test on cylinders, for those mixes which satisfy the requirements of SCC.
3. In this work a total of 5 mixes were prepared, out of which are satisfied the properties of Self compaction concrete. For the satisfied Self Compacting concrete mixes, a total of 75 specimens which consist of 45 cubes (150X150X150mm size) and 30 cylinders (150X300 size) were cast and tested.

5.2 Mix Proportioning:

To produce SCC, the major challenge is designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained. In practice, SCC in its fresh state show high fluidity, self-compacting ability and segregation resistance, all of which contribute to reducing the risk of honey combing of concrete. With these good properties, the SCC produced can greatly improve the reliability and durability of the reinforced concrete structures.

S.N	Mix	Mix Details
1	TR1 **(SCC 1)**	Plain SCC with 0% replacement of Fly ash and with SP=1.8% (9.0 kg/m^3), Cementitious Material : 500Kg, W/P=0.4
2	TR2 **(SCC 2)**	Plain SCC with 5% replacement of Fly ash and with SP= 1.80% (9.0 kg/m^3) and W/P = 0.40, Cementitious Material :500Kg
3	TR3 **(SCC 3)**	Plain SCC with 10% replacement of Fly ash and with SP=2.20% (11.0 kg/m3) and W/P = 0.40, Cementitious Material :500Kg
4	TR4 **(SCC 4)**	Plain SCC with 15% replacement of Fly ash and with SP= 2.40% (12.0 kg/m3) and W/P = 0.40, Cementitious Material :500Kg
5	TR5 **(SCC5)**	Plain SCC with 20% replacement of Fly ash and with SP= 2.60% (13.0 kg/m3) and W/P = 0.45, Cementitious Material :500Kg

Table-7: Nomenclature of Fly ash based SCC mixes

Tr.no	Mix	% Replacement of PG	Cement (Kg)	PG (Kg)	FA (Kg)	CA (Kg)	w/p	Water (Li)	SP (Kg)
1	TR1	0	500	0	642	659	0.4	200	9
2	TR2	5	475	25	642	659	0.4	200	9
3	TR3	10	450	50	642	659	0.4	200	11
4	TR4	15	425	75	642	659	0.4	200	12
5	TR5	20	400	100	642	659	0.4	200	13

Table 8- Details of mix proportions for Self Compacting Concrete

For each grade mix

FS=Fly ash,

FA=Fine aggregate,

CA=coarse aggregate,

SP= Super Plasticizer (GleniumB233),

Fresh Properties of SCC:

Slump flow test and t_{50cm} test:

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete. The test also indicates the resistance to segregation.

Equipment:

Mould in the shape of a truncated cone with the internal dimensions 200mm diameter at the base, 100mm diameter at the top and a height of 300mm.

- Base plate of a stiff non-absorbing material, at least 1000mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500mm diameter.
- Trowel
- Scoop
- Ruler

- Stopwatch

Fig 12 Slump Diameter measurement

L - Box test method:

This test is based on a Japanese design for underwater concrete, has been described by Peterson the test assesses the flow of the concrete, and also the extent to which it is subjected to blocking by reinforcement. The apparatus is shown in the Fig. 4.1 below.

Equipment:

- L-Box
- Bucket
- Trowel
- Scoop
- Stopwatch

Fig 13. L-Box

V– Funnel test and V-Funnel test at 5 minutes:

The test was developed in Japan and used by Ozawa et al. The equipment consists of a V-shaped funnel. The described V-funnel, test is used to determine the filling ability (Flow ability) of the concrete with maximum aggregate size of 20mm. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. After this the

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funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.

Assessment of test:

Though the test is designed to measure Flowability; the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result 0 if, for example there is too much coarse aggregate. High flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction.

Equipment:

- V-funnel
- Bucket
- Trowel
- Scoop
- Stopwatch

Fig 14. V-Funnel

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Fig 15.V-Funnel with SCC

Procedure flow time at T_5 minutes:

- Do not clean or moisten the inside surfaces of the funnel again.
- Close the trap door and refill the V-funnel immediately after measuring the flow time.
- Place a bucket underneath.
- Fill the apparatus completely with concrete without compacting or tapping, simply strike off the concrete level at the top with trowel.
- Open the trap door 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity.
- Simultaneously start the stopwatch when the trap door is opened, and record the time for discharge to complete (flow times at T_5 minutes). This is taken to be when the Light is seen from above through the funnel.

Testing of Specimens:

Compressive strength test on cubes:

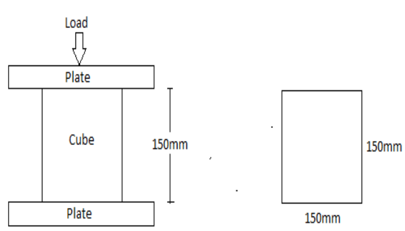

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Fig. 16. Testing of Cubes for Compressive strength

The specimens were loaded gradually to the possible extent up to failure and the ultimate load was noted. After switching off the machine the pressure valve was released. The plates were cleaned. The procedure was repeated for testing all the cubes specimens and results are presented in Table 5.4.

Cube compressive strength fck = P/A N/mm^2

Where P= Ultimate load in N.

A= Area of cube specimen under loading.

Fig 17.Compressive strength test on cubes

5.5.2 Split tensile strength test on cylinders:

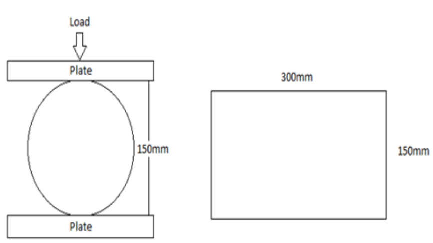

Fig.18. Testing of Cylinders for Split Tensile strength

Fig 19. Split tensile strength test on cylinders

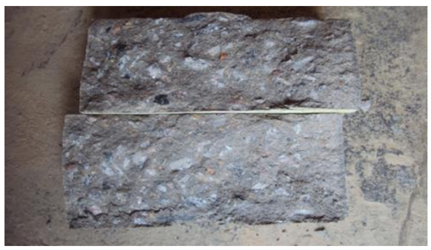

Fig 20. Specimens after Split tensile strength test

VI. TEST RESULTS AND DISCUSSIONS

6.1 General:

This chapter presents the results of the tests conducted for ascertaining Self Compacting concrete properties such as workability, passing ability, filling ability for different mix proportions and also presents the results of compressive strength, split tensile strength and flexural strength tests.

6.2 Self Compactability Tests:

The results of workability tests conducted to achieve self compaction concrete are presented. The trials started at 50% volume of total concrete as content of coarse aggregate and 50% by the volume of mortar in concrete as content of fine aggregate and variation in cement, Fly Ash, water powder ratio, Superplasticizer and viscosity modifying agent were carried out to achieve the Self Compacting concrete mixes. Similarly different trials were carried out for different mix proportions until all properties of Self Compacting concrete obtained. The results of these tests are represented in table 6.2 and the graphs are drawn for these tests comparing for

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different mixes. The properties of Self Compacting Concrete as recommended by EFNARC are presented in Table 6.1.

S.No.	Test Method	Property	Unit	Min	Max
1	Slump flow	Filling ability / Flow ability	mm	650	800
2	Slump flow at T_{50}cm	Flow ability	Sec	2	5
3	V-Funnel	Filling ability / flow ability	Sec	6	12
4	Time increase, V-funnel at T5minutes	Segregation	Sec	0	+3
5	L-Box	Passing ability	Ratio	0.8	1.0

Table-9: Properties of SCC as per EFNARC guidelines:

S NO	Mix	Slump Dia (mm)	V-Funnel (sec)	V-Funnel at T5 min(sec)	L-Box (h2/h1)
1	TR1 **(SCC1)**	690	7.0	--	.85
2	TR2 **(SCC2)**	750	8.0	--	.90
3	TR3 **(SCC3)**	730	8.0	--	.95
4	TR4 **(SCC4)**	760	9.0	--	.90
5	TR5 **(SCC5)**	670	11.0	--	0.85

Table – 10. Fresh Concrete Properties of SCC

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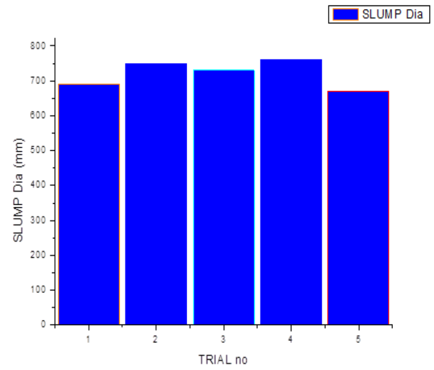

Fig 21. Trial No V/S Slump in Dia (mm)

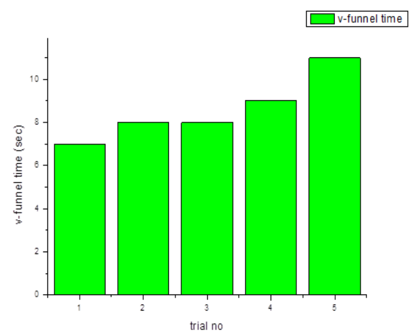

Fig 22 Trial No V/S V Funnel Time in Sec

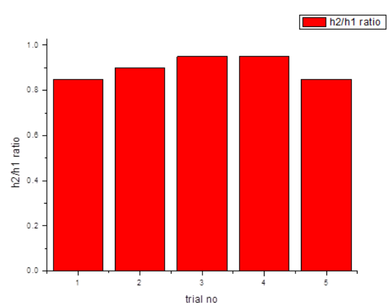

Fig 23 Trial No V/S h2/h1 Ratio

As per filling ability of the mixes was concerned the test results of V-funnel test satisfied the standard requirements.

In the total investigation, 5 trails (TR1 to TR5) were done to satisfy the Self compaction concrete characteristics. These trail mix proportions satisfy all the properties of self compaction concrete. For these mix proportions, specimens were prepared and tested to know compressive

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strength and split tensile strength. The results of these tests are shown in tables and the graphs are drawn for different replacement percentages of Fly ash.

6.3. Hardened concrete properties

S.NO	MIX	% OF FLYASH	COMPRESSIVE STRENGTH N/mm^2		
			7 DAYS	14 DAYS	28 DAYS
1.	M-1	0	17	22.59	25.09
2.	M-2	5	18.74	24.81	27.57
3.	M-3	10	19.85	25.55	28.39
4.	M-4	15	19.25	24.66	27.8
5.	M-5	20	16.54	21.23	24.38

Table -11: Average Compressive strengths of cubes

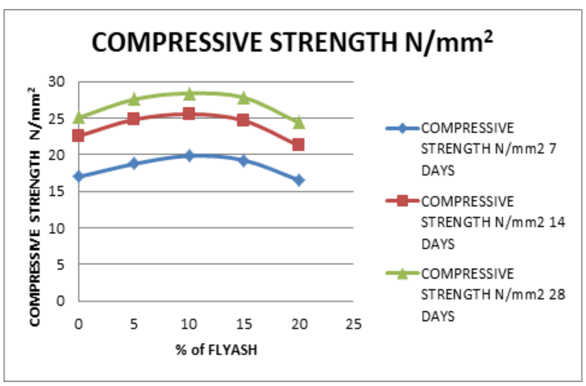

Fig. 24. Compressive Strength in N/mm V/S % of Fly Ash

S NO	MIX	% of Fly ash	Split tensile strength in N/mm2 for 28 days
1	SCC1	0	3.20
2	SCC2	5	3.51
3	SCC3	10	3.95
4	SCC4	15	3.68
5.	SCC5	20	3.12

Table – 12. Average Split Tensile Strength in N/mm2

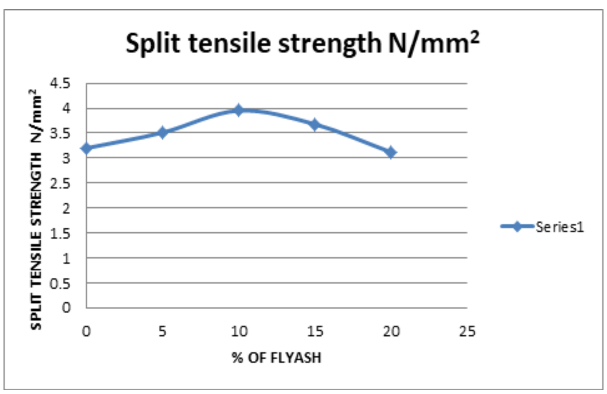

Fig.24. Split Tensile Strength V/S % of Fly Ash

VII. CONCLUSIONS

The findings of this investigation appear to support the following conclusions.

1. For seven days, fourteen days, and twenty-eight days of curing, respectively, the compressive strength of concrete increases from 17.00 MPa to 19.85 MPa, from 22.59 MPa to 25.55, and from 25.09 MPa to 28.39 MPa when the percentage substitution of cement with fly ash is increased from 0% to 10%. The concrete's compressive strength decreases from 19.85 MPa to 16.54 MPa, from 25.55 MPa to 21.23 MPa, and from 28.39

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MPa to 24.38 MPa after 7 days, 14 days, and 28 days of curing, respectively, when the proportion of fly ash replacement is increased from 10% to 20%.

2. After 7 days and 28 days of curing, respectively, the split tensile strength of concrete increases from 2.08 MPa to 2.57 MPa and from 3.20 MPa to 3.95 MPa when the percentage of cement replaced with fly ash is increased from 0% to 10%. The Split Tensile strength of concrete decreases with increasing percentage of fly ash substitution from 10% to 20%, and with 7 days and 28 days of curing, it goes from 2.57 MPa to 2.2.03 MPa and 3.95 MPa to 3.12 MPa, respectively.

3. For the SCC mix to provide stability and fluidity to the concrete mix, a higher powder content, less coarse aggregate, and a higher range Superplasticizer are needed.

4. As long as the paste volume made up of the water cement ratio is maintained constant, SCC may be produced for significantly different fly ash or cement concentrations.

5. The balance of fluidity, deformability, filling ability, and resistance to segregation determines the workability of SCC. It is necessary to maintain this balance long enough to allow transportation, placement, and completion.

6. An industrial waste product such as fly ash Combines the strength-building properties of calcined goods, making it suitable for use in the construction sector to prepare concrete in place of some cement—a crucial component of concrete that helps achieve economy.

7. When fly ash was substituted for 10% of the cement, there was a considerable increase in both the split tensile strength at day 28 and the compressive strength with age. However, if fly ash is added to cement further, the compressive strength would drastically decrease.

8. The following mix proportions are advised for various grades of self-compacting concrete.

Suggestions for future work

1. Fly ash may be added to concrete to create fiber-reinforced self-compacting concrete via experimentation.
2. Glass fibre reinforced self-compacting concrete may be made by experimentation using fly ash as an additive.
3. Fly ash-based self-compacting concrete may undergo durability tests, such as permeability, resistance to acid assault, resistance to fire attack at high temperatures, etc.

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