Durability Properties of Self Compacting Concrete: A Review

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***Abstract*—The Self Compacting Concrete (SCC) was to be the future in the construction industry. To reduce the amount of cement in the concrete mix, fly ash was replaced in the self-compacting concrete mix. The study deals with reducing the cement content in the self-compacting concretemixwith replacement of 15%, 20% and 25% of fly ash. The concrete mix includes four mixes with one conventional mix and three mixes with replacement of fly ash instead of cement with different percentage. With the addition of Superplasticizers and Viscosity modifying agent the concrete mix enriches the quality of workability in this study. The self-compacting concrete thus generated was subjected for testing the mechanical and durability properties of the concrete. The testing includes compressive strength, split tensile test, flexural testing and rapid chloride penetration test. The result concludes, compared to the replacement of fly ash with the percentage of 25% and 20% the concrete mix with replacement of fly ash with 15% gives greater strength and more durable. When the concrete structure is completed, the owner should further be provided with a proper service manual for the future operation of the structure.**

***Keywords*—Fly ash, Construction, Self-Compacting Concrete, Super plasticizer,**

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I. INTRODUCTION

A. General

The use of Self Compacting Concrete (SCC) was enriched nowadays. Due to the voids present in the conventional concrete there may have chances in forming cracks on the structural member due to high autogenous shrinkage values. Since SCC was homogeneous, therefore due to the presence of micro particles the voids in the concrete get minimized and therefore the shrinkage gets neglected. SCC gets compacted by its own weight majorly used in congested reinforcement. In our study fly ash was to be used for the replacement of cement. Fly ash is the byproduct of coal combustion process for energy generation and is recognized as an environmental pollutant.

In India, thermal power plants are majorly reliant on the combustion of high- ash bituminous coal in pulverized fuel fired systems. The fly ash was going to be replacing the construction industry soon.

By means of using SCC, problems like detachment, bleeding, water absorption and permeability can be avoided. SCC mix design and structure are not significantly different from the normal concrete. In addition, special precautions regarding aggregate gradation used in this type of concrete considered. Since, the aggressive compounds play a major role in the mix. Dense fly ash concrete enhances the aggressive compound on the surface; thereby the destructive action is reduced. Fly ash is highly resistant to sulfate attack, milk acid and sea water.

Usage of super plasticizer is a key factor for SCC, which leads to reduction of water content up to 30% without affecting the workability. The viscosity modifying agent was used to improve the cohesiveness and stability of SCC.

For a long time, concrete was very durable material requiring little or no maintenance. Emphasis was mostly on compressive strength of concrete. Exposure conditions also have been found to play a vital role on the durability of concrete. Accordingly, IS 456: 2000 has been amended.

B. Objectives of Study

Following are the objectives of this study.

1) To study the mechanical and durable properties of SCC with replacement of fly ash instead of cement.
2) Replacement includes about 15%, 20% and 25% of fly ash.
3) Comparative study for the replacement of fly ash in the mix.

C. Factors Affecting of Durability

Durability: As per IS 456: 2000, durable concrete is one that performs satisfactorily in the working environment during the anticipated exposure conditions and during its service life. It is the ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration which will alter the original form and quality. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

Durability to a great extent is influenced by its permeability to ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is greatly governed by the constituents, workmanship in making concrete.

Factors influencing durability:
1) The environment (Rain, heat, cold, fire, snow)
2) The cover to the embedded steel
3) The type and quality of constituent materials
4) The cement content and water/cement ratio of the concrete
5) Workmanship, to obtain full compaction and efficient curing
6) The shape and size of the members
7) Permeability, and abrasion

D. Materials Used

1) *Cement:*
The colour of cement is fine gray powder. It was made from crushed rock with burnt lime as binder.
2) *Aggregate:*
Aggregates is naturally aninert granular material and it is a form of sand and crushed stone. The aggregates are free from absorbed chemicals and also other finer materials to prevent from deterioration of concrete.
3) *Fine Aggregate:*
Sand is naturally obtained as a seashore and desert. The mass of rock can be crushed into fine like material is known as sand.
4) *Coarse Aggregate:*
Aggregates is mainly used filler for concrete and also used to reduce the weight of cement added in concrete. Aggregates are obtained from crushed angular material like limestone or granite.
5) *Specific Gravity:*
The specific gravity of the materials used in this study was tabulated below in the table 1.

TABLE 1: SPECIFIC GRAVITY OF MATERIAL TO BE USED IN THE CONCRETE MIX

Materials	Specific Gravity
Coarse Aggregate	2.765
Fine Aggregate	2.7
Cement	3.12
Fly ash	2.20

6) *Fly Ash:*
The study is in fond of pozzolanic material, thereby using fly ash we enrich the concrete behaviour. The structure of fly ash was spherical which makes them free flow on concrete mixtures. The durability of the concrete gets increased due to the addition of fly ash through control of high thermal gradients.

II. LITERATURE REVIEW

Following are the detailed literature review based on factors that affect in durability of High-Performance Concrete.

New City Development, Oslo (2005)project ("Tjuvholmen") was started in the harbor region of Oslo City. Thisproject includes a number of concrete substructures located in seawater with various depths of up to 20 m, ontop of which a number of business and apartment buildings would be constructed as shown in Fig. 1. [17]

Fig. 1. A new city development currently under construction in the harbor region of Oslo City[17]

Mostof these concrete substructures, which are still under construction, include large, submerged parking areas. Inthe shallower water, these substructures include a solid concrete bottom slab on the seabed surrounded by concrete walls partly protected by riprap and partly freely exposed to the tidal zone. In the deeper water, some of the structures include an open concrete deck on top of solid columns consisting of driven steel pipes filled with concrete. For the deepest water, four large concrete caissons were constructed in a dry dock of a nearby shipyard. Upon completion, these prefabricated concrete units were moved into position and submerged in water to depths of up to 20m. These structures provide large, submerged parking areas in four levels as shownin Fig. 2.

Fig. 2.A model section showing how the prefabricated concrete caissons provide large submerged parking areas in four levels [17]

Saiful M. et al. (2010) reported the results of an experimental investigation carried out to study the effects of fly ash. The strength increases with the increase of fly ash up to an optimum value, beyond which, strength values started decreasing.[3]

KartieyTiwari et al. (2012) cement has been replaced by fly ash accordingly in the range of 0% 10%, 20%,30% and 40% by weight of cement for M25 and M40mix. As fly ash percentage increases compressive strength and split strength decreases.[5]

J. R. Pitroda et al. (2016) studied that the replacement of cement with fly ash in the proportion of 10%, 20%, 30% and 40% by weight for the grade of M25 and M40. As fly ash percentages increased compressive strength and split tensile strength decreases. [8]

B.P Hudson et al. (2016) replaced 20% cement by weight with 27.5% fly ash by weight. The quality of sand was reduced, and coarse aggregate increased by an amount equal to the weight of fly ash added.[16]

III. MATERIAL, MIX DESIGN OF CONCRETE AND DURABILITY TESTS OF CONCRETE

A. Materials

1) Cement:

In this study, Ordinary Portland Cement (OPC) of 53 Grade confirming to I S specification is used. Properties of the cement are presented in Table 2.

TABLE 2 PROPERTIES OF OPC 53 GRADE CEMENT

Properties	Test Results	Technical Reference
Specific gravity	3.15	IS4031(PART 11): 1988
Consistency (%)	33	IS4031(PART 4): 1988
Fineness of cement (%)	8	IS4031(PART 2): 1996
Initial setting time (minutes)	75	IS4031(PART 5): 1988

2) Fine Aggregate:

Manufactured sand (M-Sand) is an alternative to river sand for construction. M-sand is a product obtained from crushing of hard granite stone. The size of M-Sand is less than 4.75mm. Due to the scarcity of river sand, another alternate material manufactured sand has been used for construction purposes. Another reason for use of M-Sand is its ease of availability and less transportation cost. Also, it is a dust free material, causing very less pollution. Properties of fine aggregate are presented in table 3.

TABLE 3 PROPERTIES OF FINE AGGREGATE

Properties	Test Results
Specific gravity	2.74
Water absorption (%)	0.4
Free surface moisture	Nil

3) Coarse Aggregate:

Aggregates having particle size distribution greater than 4.75 mm, but generally ranges between10 mm to 40 mm in size. Coarse aggregate provides strength, toughness, and hardness properties to concrete and provides resistance to abrasion. Coarse aggregate used in the experimental study was confirming to IS 383:1970. Properties of coarse aggregate are listed in table 4.

TABLE 4.PROPERTIES OF COARSE AGGREGATE

Properties	Test Results	Technical Reference
Specific gravity	2.63	IS2386(PART 3): Clause 2.4.2
Water absorption (%)	1.2	IS383(PART 3): 1970
Free surface moisture	Nil	IS383(PART 3): 1970
Fineness modulus	2.6	IS383(PART 3): 1970

4) Fly ash:

Fly ash is a by-product of combustion of coal, composed of fine particles that are escaped out of the boiler along with the flue gases. Fly ash is generally captured by electrostatic precipitators and the bottom ash is removed from the bottom of the boiler. Fly ash is generally stored at coal power plant or dumped in landfills. Flyash which are recycled is often used as pozzolan to produce hydraulic cement and as a replacement or partial replacement for Portland cement in production of concrete. Fly ash particles are commonly spherical in shape and size ranges from 0.5 μm to 300 μm. This study involves the use of fly ash as a partial replacement of cement with the 30% addition. A property of Fly Ash is listed in table 5.

TABLE 5. PROPERTIES OF FLY ASH

Properties	Results	Technical Reference
Specific gravity	2.2	IS 3812(Part I):2013
Moisture content (%)	0.12	IS 3812(Part I):2013 Clause 6.2
Particles retained on 45μ sieve	0.31	IS 3812(PART I):2013 Table 2

5) Chemical Admixture

The homogeneity of concrete will be affected when cement mixes with water. Therefore, a chemical admixture was used, the superplasticizers or plasticizers are used for reducing the water content and it is termed as water reducing agents. To reduce the coarse content and to increase the fine content in the concrete mix there needs a proper workability and henceforth superplasticizers are used. The amount of super plasticizer to be added was based on the weight of cement and varying water cement ratio which ranges from 0%, 2%, 2.5%, 3.5% and 0.4, 0.45, 0.5, 0.55 respectively.

B. Mix Proportion:

The mix consists of replacement of fly ash instead of cement with a percentage of 15%, 20% and 25%. A total of four mixes were prepared for this study. A conventional concrete without the addition of fly ash and the remaining three mixes includes the replacement of fly ash. The mix followed throughout the project was M40 grade of concrete. The concrete mix that to be followed in this study were calculated and tabulated in the Table 6.

TABLE 6 CONCRETE MIXES

Materials	Conventional Concrete (Mix 1)	Replacement of Fly Ash		
		15 %(Mix 15%)	20% (Mix 20%)	25 % (Mix 25%)
Cement	450	442	416	390
Fly Ash	-	78	104	130
Water/ Binder	0.45	0.45	0.45	0.45
Fine aggregate	870	870	870	870
Coarse aggregate	890	890	890	890
Super Plasticizer	0.26	0.26	0.26	0.26
VMA	0.053	0.53	0.53	0.54

C. Tests of Concrete

Tests on Fresh Concrete

In fresh concrete test is require because fresh concrete is more essential than harder concrete. Any concrete test mix design is most required because concrete mix design is more effect of durability concrete. If there obtained a satisfactory mix design the test to be conducted using fresh concrete should have been done. An SCC mix gets satisfied whenever it has the following characteristics.

1) Filling ability
2) Passing ability and
3) Segregation Resistance

For the above characteristics there are several test methods which was followed widely. In our study we used L- box test, V- funnel test, V- funnel test at T5 minutes, slump flow and T50 cm slump flow. L- box test was used to determine the passing ability of the concrete, V-funnel and V-funnel test at T5 minutes were used to determine the segregation resistance of the concrete mix, Slump flow and T50 Slump test were conducted to determine the filling ability of the concrete mix. Results of Tests conducted on Fresh Concrete were tabled in the table 7.

TABLE 7. RESULTS OF TESTS CONDUCTED ON FRESH CONCRETE

Tests	Tests Values
Slump Flow	750mm
T50 cm Slump Flow	3sec
V- funnel	9sec
V- funnel at T5 minutes	2sec
L- box	0.9 (h2/h1)

Preparation of Test Specimen

A total of 36 cubes (150 mm), 4 cylinders (50 mm diameter and 200mm height), 8 cylinders (70mm diameter and 150 mm height) and 8 beams (100*100*400mm) were casted in this study. After the specimen was filled with concrete mix and later it was subjected to curing.

Tests on Hardened Concrete

a) Compressive Tests on Cubes

The compression test was carried out on standard 150*150*150mm cubic specimens. All the cubes were tested in surface dried condition for each mix combination, three cubes were tested at the age of 14-, 28- and 56-days using compression testing machine of 100 ton capacity. The tests were carried out at a uniform stress rate, after the specimen was centred in the testing machine. The loading was continued till the specimen reaches its ultimate load. The ultimate load divided by the cross-sectional area of the specimen is equal to the ultimate compressive strength. Figure 3and Figure4 shows the tested specimens.

Fig. 3. Compressive Test on Specimen

Fig. 4. Tested Specimen

TABLE 8. RESULT OF COMPRESSIVE STRENGTH ON 14TH DAY

No	Mix	Compressive Strength after 14 Days Mpa	Average Compressive Strength after 14 Days Mpa
1	Mix 1	37.4	31.17
		26.5	
		29.61	
2	Mix 15%	51.42	43.61
		48.49	
		30.92	
3	Mix 20%	40.25	34.12
		30.95	
		31.15	
4	Mix 25%	33.26	31.53
		37.01	
		24.32	

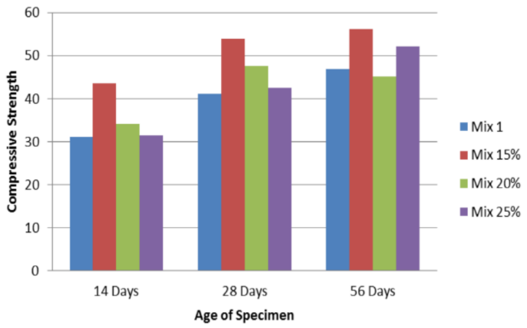

Fig. 5. Comparison of Compressive strength of Concrete specimen on different days

In figure 5Simplies the comparison between all the test cube concrete specimens which undergoes for compression testing.in concrete compressive strength is check or conclude life of concrete. The graph implies that the concrete mix which was subjected to 15% replacement of fly ash instead of cement shows greater compressive strength of concrete than the concrete mix of conventional concrete, 20% replacement of fly ash and 25% replacement of fly ash. And 15% of replacement of fly ash strength is more strength of 20% and 25% replacement of fly ash.

b) Split Tensile Strength

The cylinders were tested in saturated surface dried condition. For each mix combination, two cylinders were tested at the age of 56 days using compression testing machine of 100-ton capacity. The tests were carried out at a uniform stress rate, after the specimen was centered in the testing machine. The loading was continued till the specimen reaches its ultimate load. Figure 6 imply the split tensile strength that tested. The results of split tensile strength test were tabled in the table 9.

TABLE 9. RESULT OF SPLIT TENSILE STRENGTH

Testing time	**Mix**	**Average Split Tensile Strength of two samples (N/ mm2)**
56 days	Mix 1	6.08
56 days	Mix 15%	6.51
56 days	Mix 20%	6.05
56 days	Mix 25%	5.43

Fig. 6. Split Tensile strength test

The split tensile strength of the concrete specimen cylinder. In this graph 15% replacement of fly ash instead of cement shows superior strength compared to other mixes.

c) Flexural Test

Flexural test was carried out on a beam specimen with dimension 400*100*100mm at the age of 56 days. Two point loading was given to the specimens and the flexural load was recorded at time of failure.

TABLE 10. RESULT OF FLEXURAL BEAM STRENGTH TEST

Testing time	**Mix**	**Average Flexural Beam Strength of two samples (N/ mm2)**
56 days	Mix 1	6.68
56 days	Mix 15%	6.66
56 days	Mix 20%	7.96
56 days	Mix 25%	8.97

The result concludes that concrete mix replacement of 25% of fly ash instead of cement shows greater flexural quality when compared to other concrete mixes.

Fig. 7. Flexural Testing

D. Effect of Some Materials on Concrete

1) Mineral oils – Petrol do not attack hardened concrete. Creosotes have some effect on concrete. Lubricating oils do not attack concrete.

2) Organic Acids – Acetic acid, formic acid, tannic acid and phenols are mildly corrosive. Fresh milk does not harm concrete.

3) Vegetable oils - have slow corrosive effect. Animal oils are corrosive.

4) Sugar – It may gradually corrode concrete. However, storage of molasses has been done with satisfactory results

5) Sewage – Domestic sewage is not detrimental on good concrete. Septic sewage in sewage sludge digestion tanks/ industrial wastes may promote formation of sulphuric acid which can attack concrete.

E. Surface Treatment to Concrete:

1) Aqueous solution of sodium silicate
2) Magnesium or zinc silico fluoride
3) Drying oils like linseed oil or tung oil
4) Chlorinated rubber paint
5) Neoprene paint
6) Epoxy paint or coal tar epoxy paint
7) Silicon fluoride treatment

IV. CASE STUDY

A. Case Study- 1

a) Project Name:Effect and optimization of plastic waste for enhancing mechanical parameters of concrete
b) Location: G H Patel College of Engineering &Technology,V.V. Nagar,Gujarat,
c) Overview

Today entire world is facing problems due to environmental pollution.Plastic is the biggest hazard to nature. Plastic is also very harmful to animals and aquatic life. As we know, we can't destroy plastic completely. So by reusing waste plastic in our daily life we can reduce hazard from plastic to the nature. By looking at the current scenario we are going to use plastic waste in concrete. Plastic waste can be a good alternative to the natural filling material. By using plastic waste, we can reduce hazard to the nature. It will be environment friendly concrete.

d) *MATERIALS*

1) Cement:
Brand Name: Ultra techsuper
Grade of cement: 53 Grades (IS12269:1987)
Type of cement: Ordinary Portland cement
2) Fine aggregate
3) Coarse aggregate
4) Plastic material

i. Material should be high density plastic which should be melted and grinded to the required size.
ii. Material should be ground to the size of 10mm to 20mm.
iii. Material should not have more rounded edges for proper bonding with other material in concrete.
iv. Material should be free from any other reactive chemicals.

Fig.8 Waste plastic material

e) *MIX DESIGN*

As per IS10262:2009 concrete mix proportioning – guidelines trial mix design with different proportion of ingredients has been designed. Table 11 presents the design mix proportion for M25 grade.

TABLE 11. CONCRETE MIX DESIGN

Mix	Water (lit)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)
M25	209.46	438	666.27	1140.27
	0.478	1	1.52	2.60

f) *RESULT AND ANALYSIS*

1) Slump test:

Slump test is most commonly used method to measure consistency of concrete which can be use either in laboratory or at site of work.

TABLE 12. SLUMP TEST

% plastic waste (kg)	Slump(mm)
0	70
5	75
10	77
15	80

2) Compression test:

The cube specimen is of the size 15cm x 15cm x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm to 100mm size cubes may also be used as an alternative.

Fig.9 Compression test

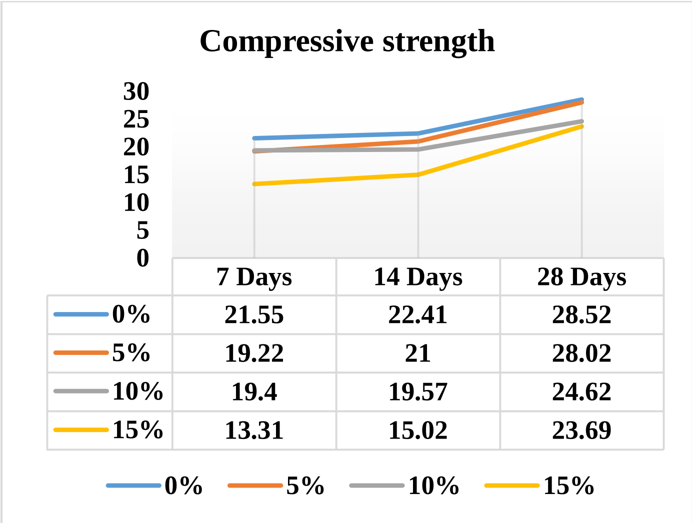

Fig .10 Compression test results

3) *Flexural test:*

Concrete as we know is relatively strong in compression and weak in tension force. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces.

V. CONCLUSIONS

The following conclusion based on test results.

1) The addition of fly ash to the mixture containing hydraulic lime is quite beneficial, bringing a substantial improvement of the behaviour of SCC.
2) SCC with 15% replacement of cement with fly ash showed good results both in compression and split tensile.
3) In terms of tension the values vary at micro level but in terms of compressive strength, 15% replacement of fly ash considerably shows greater strength when compared to other mix.
4) Since concrete should be good in compression therefore it was preferred.
5) From the experimental investigation it is clear that cement can be replaced with 15% of fly ash effectively in self-compacting concrete, thereby reducing the consumption of cement, which in turn reduces the cost.
6) In terms of rapid chloride penetration test results 15% replacement of fly ash suffers from chloride penetration.
7) In this research paper i have conclude in Self-compacting concrete 10 to 15 % replace of fly ash concrete durability result is same as the normal

Fig. 11.Flexural test

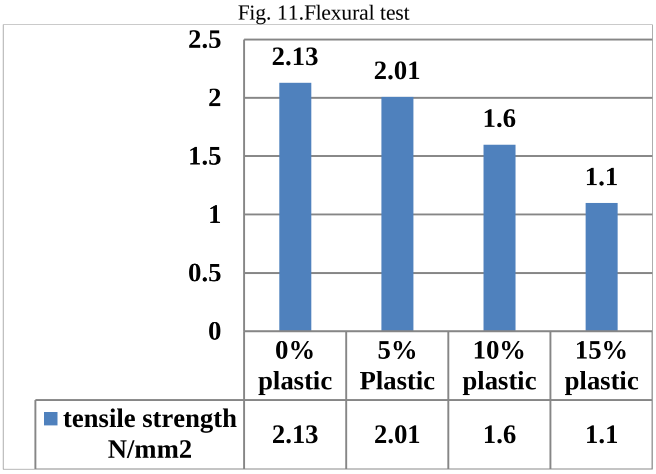

Fig.12. Flexural test results

8) concrete but overall cost is lesser then normal concrete.

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