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RESEARCH ARTICLE OPEN ACCESS

Mechanical Properties of M45 Grade Self Compacting Concrete with and without Confinement

G Ramesh*, P Anusha(Asst Professor) **

**(Amrita Sai Institute of Science and Technology, Paritala, Andhra Pradesh
Email: gollamandala116@gmail.com)
** *(Amrita Sai Institute of Science and Technology, Paritala, Andhra Pradesh
Email :piratlaanusha832@gmail.com)

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Abstract:

The present experimental work is carried out to investigate the utilization of cement, coarse aggregate, and fine aggregate and water, mineral and chemical admixtures as the material for making self-compacting concrete of grade M45 as per EFNARC specifications. The objective of present work is to study the mechanical properties i.e., compressive strength, flexural strength and split tensile strength of optimum self-compacting concrete of M45 grade and compared with the conventional concrete. The program involved casting and testing of different cubes and cylinders. The specimens were casting using standard cubes of size 150 mmX150mmX150 mm, standard cylinders of size 150mm diameter X 300mm height with and without confinement. All of the specimens were tested using a universal testing machine. As a result, the results reveal that increasing the volume of transverse reinforcement enhances restricted concrete's strength and ductility. At 0.827 percent volume of transverse steel, the percentage increase in strength was 24 percent, and at 1.091 percent volume of transverse steel, it was 42 percent.

Keywords **—M45 Grade, Self-compacting concrete, Compressive Strength.**

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I. INTRODUCTION

The problem of concrete construction durability has been a prominent topic of interest in Japan for several years, commencing in 1983. Sufficient compaction by competent workers is essential to create enduring concrete buildings. However, as the quantity of competent workers in Japan's construction industry declines, so does the quality of the job. The use of self-compacting concrete, which can be compacted into every corner of a formwork merely by its own weight and without the need for vibrating compaction, is one approach for achieving long-lasting concrete buildings regardless of the quality of construction work. Okamura, in 1986, proposed the need for this form of concrete. Ozawa and Maekawa of the University of Tokyo conducted research on the development of self-compacting concrete, including a fundamental study on concrete workability.

Many academic institutions, Admixture, ready-mixed, pre-cast, and contracting organisations have developed their own mixed proportioning procedures because there is no standard approach for SCC mix creation. Because of the necessity of overfilling the spaces between the aggregate particles, volume is frequently used as a significant component in mix designs. Some methods attempt to fit available elements into a grading envelope that is optimised. Another way is to test the flow and stability of the paste and then the mortar fraction before adding the coarse aggregate and testing the entire SCC mix. The basic materials are identical to those used in typical vibrated concrete in any event.

A. *Benefits of SCC*

Both the designer and the builder can profit economically and technologically from properly sized and cast SCC. SCC has a number of advantages, including noise reduction on the job site.

- Reduce labour costs and improve resource management.
- Vibration-related issues are no longer an issue.
- There is less work involved.
- The features of the surface finish can be improved.
- Quality and durability have been improved.
- Construction is completed more quickly.
- Environmental advantages for the community.
- In architectural applications, improved look and uniformity.
- Concrete construction with a lower risk.
- Equipment and power expenditures are reduced.
- Low permeability, excellent bond to steel reinforcement, and elimination of macro-defects, air bubbles, and honeycombs.

B. *Limitations of SCC*

When compared to normal concrete, it initially proves to be more expensive because the mix requires more cement. In addition, admixture costs must be covered.

Plastic shrinkage and creep are more prevalent in SCC than in ordinary concrete due to the considerable amount of fines in the mix. There are no established test procedures for assessing segregation on the job.

The more individuals who are aware of this material's properties, the more they will be able to use it to their own unique applications. The drilled shaft sector can use SCC Technology to reduce or eliminate concrete installation issues in tough situations. Contractors should no longer experience headaches or heartburn due to underwater pile placement, dense rebar, or other challenging installation conditions. Those afflictions should, as usual, be left to Mother Nature to deal with.

II. OBJECTIVES OF THE PROJECT

The objectives of the present work are

1. To develop the self compacting concrete of M45 grade and which can be adjusted as per EFNARC guide specifications.
2. To study the mechanical properties viz. compressive strength, flexural strength and split tensile strength of optimum self compacting Concrete of M45 grade and compare with the conventional concrete.

A. *Scope of the work*

The present experimental work is carried out to investigate the utilization of cement, coarse aggregate, and fine aggregate and water, mineral and chemical admixtures as the material for making selfcompacting concrete of grade M45 as per EFNARC specifications. The concrete properties studied included the compressive strength, flexural strength, split tensile strength and bond strengths.

III. LITERATURE REVIEW

N. Bouzouba and M. Lachemi (2001) describe and explain their experimental programme aiming at manufacturing and evaluating SCC built with high amounts of fly ash. This study looked at nine SCC combinations and one control concrete. The cementitious material composition was kept constant (400 kg/m3), while the water/cementitious material ratios varied between 0.35 and 0.45. Class F fly ash replaced 40 percent, 50 percent, and 60 percent of the cement in the self-compacting mixtures. All combinations were tested to determine the qualities of fresh concrete in terms of viscosity and stability. Hardened concrete's mechanical properties, such as compressive strength and drying shrinkage, were also studied. The SCC achieved compressive values of 26 to 48 MPa after 28 days. The findings suggest that combining large amounts of Class F fly ash into a cost-effective SCC may be done successfully.

IV. TEST METHODS ON SELF COMPACTING CONCRETE

The following tests were conducted in this research

- Slump flow test/T 50 cm test

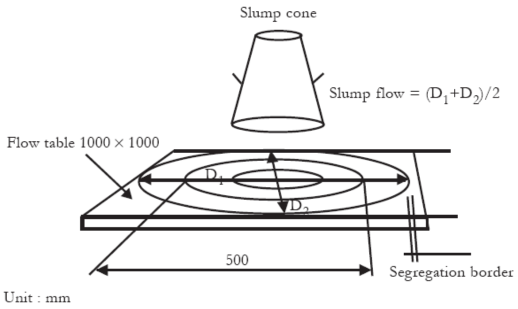

Fig. 1 Slump Cone Test

- J-Ring Test

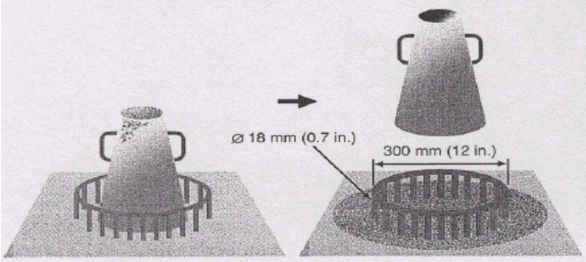

Fig. 2 The J Ring used in conjunction with the slump Equipment

- V-Funnel Test and V-Funnel Test at T 5 min

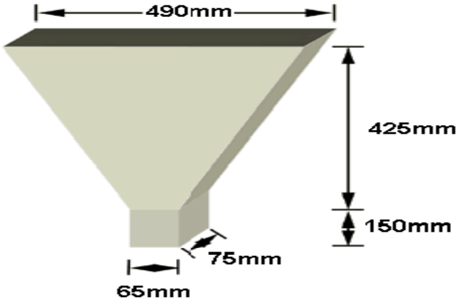

Fig. 3 V-Funnel test equipment (rectangular section)

- L-Box Test

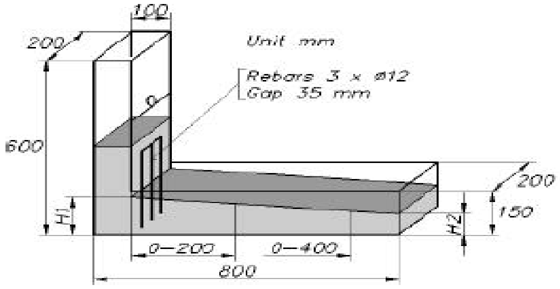

Fig. 4 L-Box Test

- U-Box Test

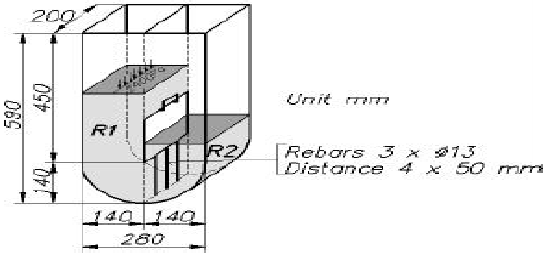

Fig. 5 U-Box Test

- GTM Screen Stability
- Orimet Test

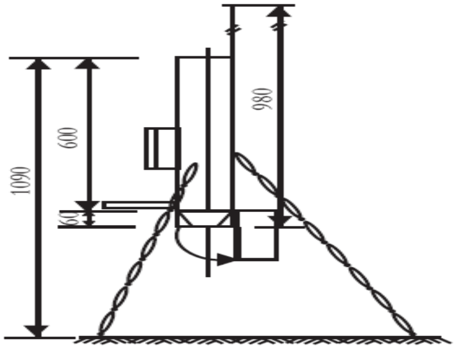

Fig. 6 Orimet Test

TABLE I
LIST OF METHODS FOR WORKABLE PROPERTIES OF SCC

S.no	Method	Property
1	Slump-flow by Abrams cone	Filling Ability
2	T_{50} Slump	Filling Ability
3	J-Ring	Passing Ability
4	V-Funnel	Filling Ability
5	L-Box test	Passing Ability
6	U-Box test	Passing Ability

7	Fill Box	Passing Ability
8	GTM Screen Stability Test	Segregation Resistance
9	Orimet	Filling Ability

TABLE II
ACCEPTANCE CRITERIA FOR SCC

S.No	Method	Unit	Typical Range of Values	
			Minimum	Maximum
1	Slump Flow by Abrams Cone	Mm	650	800
2	T_{50} Slump-Flow	Sec	2	5
3	J-Ring	Mm	0	10
4	V-Funnel	Sec	6	12
5	L-Box	H_2/H_1	0.8	1.0
6	U-Box	(h_2-h_1)mm	0	30
7	Fill Box	%	90	100
8	GTM Screen Stability test	%	0	15
9	Orimet	Sec	0	5

V. EXPERIMENTAL INVESTIGATION

TABLE III
MATERIAL QUANTITIES OBTAINED AS PER DESIGN METHOD

S no	Materials	Quantities (kg/m^3)
1	Cement	550
2	Fine Aggregate	533.37
3	Coarse Aggregate	1085.8
4	Water	190

The above mixes are further adjusted using EFNARC guidelines

The Fine aggregate content as per EFNARC specification has to be in the range of 40% to 50% of the total aggregate. Based on this the Fine aggregate content was taken as 50% of the total aggregate, the coarse aggregate was taken as 50% of the total aggregate.

Free water content has to be less than 200 kg/m3 which is also satisfied as our water content is 190 kg/m3

TABLE IV
MATERIAL QUANTITIES AFTER ADJUSTMENTS AS PER EFNARC GUIDELINES

S no.	Material	Quantity (kg/m^3)
1	Cement	412.5
2	Fine Aggregate	809.5
3	Coarse Aggregate	809.5
4	Water	190
5	Fly ash	137.5
6	Super plasticiser	5.07 litre
7	Viscosity Modifying Agent	0.17 litre

After casting, the moulded specimens are stored in the laboratory at room temperature for 24 hours. After these periods the specimens are removed from the moulds and immediately submerged in clean, fresh water of curing tank and specimens are cured for 28 days in the present investigation work.

VI. TEST RESULTS AND DISCUSSIONS

Results obtained from experimental investigations are the mechanical properties of M45 Grade of self-compacting concrete with and without confinement. They are compared with the mechanical properties of the plane concrete.

TABLE V
ACCEPTED MIX PROPORTION

Cement	Fine Aggregate	Coarse Aggregate	Water
1	1.47	1.47	0.345

A. Compressive Strength for M45 Grade Concrete

Compressive Strength at different ages are shown in Table 6.

TABLE VI
COMPRESSIVE STRENGTH AT DIFFERENT AGES

S.No	*Mix*	Compressive Strength (MPa)			
		Day 3	Day 7	Day 14	Day 28
1	M_{45}	22.21	35.13	47.90	63.74
2	M_{45}	21.98	36.89	48.63	62.42
3	M_{45}	23.10	36.32	47.52	62.83
4	M_{45}	22.58	36.52	48.29	63.90

Average	M_{45}	22.46	36.21	48.08	63.22

TABLE VII
SCC MIX PROPORTIONS ARRIVED FOR M45 MIX

Mix	Cement (kg/m^3)	Fine Agg (kg/m^3)	Coarse Agg (Kg/m^3) 12mm	Coarse Agg (Kg/m^3) 20mm	Fly ash (Kg/m^3)	Water (litres)	Super plasticizer (litres)	V.M.A (lit/m^3)
Mix-1	413	807	605	210	135	181	5.13	0.29
Mix-2	416	806	585	211	138	190	5.39	0.28
Mix-3	415	809	585	211	138	190	5.08	0.45
Mix-4	415	809	585	211	138	190	5.08	0.17

TABLE VIII
FRESH SCC TEST RESULTS

S.No	Property	Limits	Mix 1	Mix 2	Mix 3	Mix 4
1	**Slump flow in mm**	650-800 mm	680	790	790	730
2	**T_{50cm} slump in sec**	2-5 sec	4	2.42	3	3
3	**V-Funnel time for concrete**	6-12 sec	10	7	7.3	7.54
4	***V-Funnel*** **T_5 min in sec**	6-15 sec	17	13	13.5	12.2
5	**L-Box H_2/H_1 ratio**	0.8-1	0.44	0.98	0.97	0.97
6	**U-Box (H_2-H_1)mm**	0-30 mm	2.5	2	2	1.5
Remarks			Low workability due to less water content	Segregation of concrete showed a less continuous flow	Rapid settlement of aggregate it leads to segregation	Passed and the values are within the allowable limits

In this experiment our aim is to arrive at the mix proportions for M45 Grade Self Compacting Concrete. Here mix 1 to mix 4 is the trial mixes for evaluating the self compactability of the concrete.

In Mix 1 all material quantities used which are obtained according to BIS method of mix design without any modifications. During the mix preparation, it is found that the water content is not sufficient to produce SCC. Therefore it's failed in V-funnel T5 test and the mix is not fit for SCC.

In the mix 2 the water content increased to increase the flowability of concrete mix, according to this change powder content is increased in the mix design and considering the dosage of superplasticizer as 0.85% of cementitious material. Here it is observed that the mix passed and the values are within the allowable limits, but in V-funnel T5 test segregation occurred and mix is not fit for SCC.

In mix 3 the material quantities are same as used in the above mix but the quantity of superplasticizer is decreased and VMA dosage is slightly increased accordingly resulting in the blocking of coarse aggregate due to rapid settlement coarse aggregate. Hence and in the mix 3 the segregation of concrete showed a less continuous flow. So this mix is not fit for SCC.

In mix 4 the material quantities are same as used in the above mix including the quantity of superplasticizer, only reducing the dosage of VMA is changed. Here the mix passed and the values are within the allowable limits. Thus the mix 4 is considered as the final mix.

B. Comparision of SCC with and without confinement

TABLE IIX
STRESS-STRAIN CALCULATIONS FOR 0% STEEL AT 28 DAYS

SL.NO.	STRAIN	STRESS	NORMALIZED SRAIN	NORMALIZED SRESS
1	0.000006	1.1371	0.003	0.0322
2	0.000029	2.2636	0.0145	0.064
3	0.000044	3.3953	0.022	0.096
4	0.0000595	4.527	0.029	0.129
5	0.0000755	5.658	0.037	0.161
6	0.0001025	6.790	0.051	0.193
7	0.0001235	7.922	0.061	0.225
8	0.0001425	9.054	0.071	0.258
9	0.0001645	10.185	0.082	0.290
10	0.000193	11.317	0.096	0.322
11	0.000205	12.449	0.102	0.354
12	0.000225	13.581	0.112	0.387
13	0.00027855	14.712	0.139	0.419
14	0.00031208	15.844	0.156	0.451
15	0.00033858	16.976	0.169	0.483
16	0.00037791	18.108	0.188	0.516
17	0.00039245	19.240	0.196	0.548
18	0.00042066	20.371	0.210	0.580
19	0.00044546	21.503	0.222	0.612
20	0.00047536	22.635	0.237	0.645
21	0.00048	23.767	0.24	0.677
22	0.000505	24.898	0.253	0.709
23	0.000555	26.030	0.277	0.742
24	0.000605	27.162	0.302	0.774
25	0.00069935	28.294	0.349	0.806
26	0.000795	29.425	0.397	0.838
27	0.0009	30.557	0.45	0.870
28	0.0010078	31.689	0.503	0.903
29	0.0011145	32.821	0.557	0.935
30	0.00134	33.953	0.67	0.967
31	0.002	35.084	1	1
32	0.0021	28.294	1.05	0.806
33	0.0023	20.371	1.15	0.580

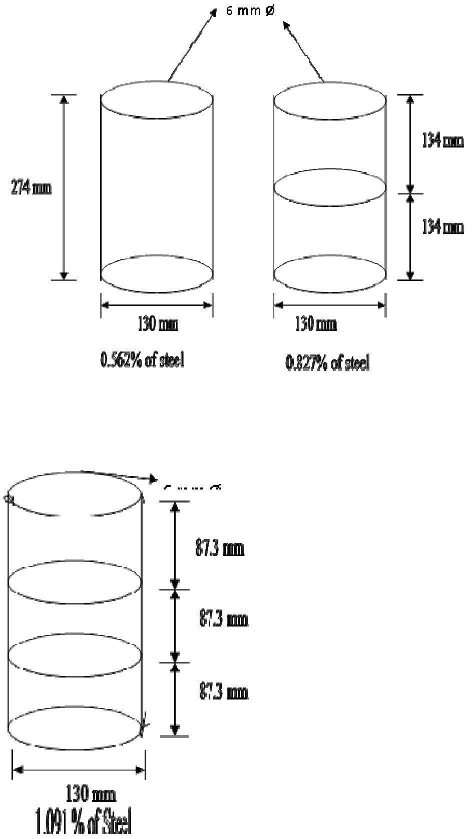

Fig. 7 Different Arrangements Of Lateral Confindment

The test was continued until the peak load dropped to about 0.5 times of peak load.eyond that strain increased at a rapid rate and was accompanied with a decrease load carrying capacity of specimen. Yielding is observed at 0.66455% of confinement steel.

CONCLUSIONS

The following conclusions are formed based on the experimental findings.

- Concrete confinement boosted strength from 21.1 percent to 50.78 percent after 28 days.
- As the compressive strength grows, the ascending component of the stress-strain curve becomes more linear and steeper. As the concrete strength increases, the discrepancy between the analytical and experimental values becomes larger and

larger in the Carriera and Chu models. As a result, the falling component of the curve is not effectively represented by this model.

- The strength and ductility of restricted SCC are directly improved by increasing the volume of transverse reinforcement. For circular sections, the increase in strength was determined to be 24 percent at 0.827 percent transverse steel volume and 42 percent at 1.091 percent transverse steel volume.
- The ductility of confined concrete, defined as the ratio of the strain at peak stress of confined concrete to the strain at peak stress of matching unconfined concrete, ranged from 21% to 51% for volumetric ratios of 0.827 percent to 1.091 percent for circular specimens.
- More effective than square parts with rectilinear confinement are circular sections with circular hoops as confinement. At 1.091 percent volume of transversal steel, the percentage improvement in strength was 42 percent and 30 percent for circular and square sections, respectively.
- At 1.091 percent volume of transversal steel, the percentage improvement in ductility was 51 percent and 46 percent for circular and square sections, respectively. As a result, square sections require a higher volumetric ratio of transverse steel than circular sections in order to achieve the same percentage improvement in ductility.

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