AN EXPERIMENTAL STUDY ON MIX PROPORTIONING OF SELF COMPACTING CONCRETE BY DIFFERENT MIX PROCEDURES

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ABSTRACT

Self-compacting concrete (SCC) has become more popular in building industry in recent years, due to its superior performance over conventional concrete mix. The main drawback in adopting self-compacting concrete is that there is no proper design mix standard throughout world. The aim of this study is to find out an optimum mix proportioning of high strength self-compacted concrete for different grades (30MPa – 80MPa). Numerous trial mixes have to be adopted including mineral admixtures like Fly Ash. The strength can be increased by reducing the water-Cement ration and adding sufficient quantity of mineral admixture. Also chemical admixtures are used to improve the workability and to minimize segregation. Tests such as Slump flow test, L-box test V-funnel test, etc., will be conducted in fresh state to estimate the quality of mix. After casting the specimens are tested for three basic strengths such as Compressive strength, Split tensile strength and Flexural strength at 1, 7, 14, 28, 56 and 90th days respectively. With the assumed mix proportion and the tested results, empirical relationship shall be obtained using SYSTAT. Hence for any assumed mix proportion, it is not necessary to cast an SCC specimen, not necessary to wait until the curing period to determine the strength parameter of the specimen by using the established relationships, the strength parameter can be determined. The accuracy of the relationships may be in the order of about 90% to 95%

Keywords- self-compacting concrete, Fly ash, Super plasticizer, Viscosity Modifying Agent, development of self-compatibility of fresh concrete, mix design, tests methods for self-compacting concrete, Slump flow test, L-Box test, V-Funnel test, U-Box test, SYSTAT.

1. INTRODUCTION

Self compacting concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of form work under its self weight only (Okamura 1997). Thus SCC eliminates the needs of vibration either external or internal for the compaction of the concrete without compromising its engineering properties.

This concrete was first developed in Japan in late 80's to combat the deterioration of concrete quality due to lack of skilled labours, along with problems at the corners regarding the homogeneity and compaction of cast in place concrete mainly with intricate structures so as to improve the durability of concrete and structures. After the development of SCC in Japan

1988, whole Europe started working on this unique noise free revolution in the field of construction industry.

ADVANTAGE OF SCC:

- Improved Concrete Quality
- Environmental & Human Health Protection
- Economy & Time Reducing
- Construction with SCC is not affected by the skill of the workers, and shape and arrangement of reinforcing bars of the structures.
- SCC use at construction sites reduces the chance of accident by reducing number of cables needed for the operation of compacting equipment, hence, reduces the workers compensation premiums.

DISADVANTAGES OF SCC

- The production of SCC places more stringent requirements on the selection of materials in comparison with conventional concrete.
- An uncontrolled variation of even 1% moisture content in the fine aggregated will have a much bigger impact on the rheology of SCC at very low W/C (~0.3) ratio. Proper stock pilling of aggregate, uniformity of moisture in the batching process, and good sampling practice are essential for SCC mixture,
- A change in the characteristics of a SCC mixture could be a warning sign for quality control and while a subjective judgment, may some times be more important than the quantitative parameters.
- The development of a SCC requires a large number of a trial batches. In addition to the laboratory trial batches, field size trial batches should be used to simulate the typical production conditions. Once a promising mixture has been established, further laboratory trial batches are required to quantify the characteristics of the mixture

2. INGRADIENTS OF SCC

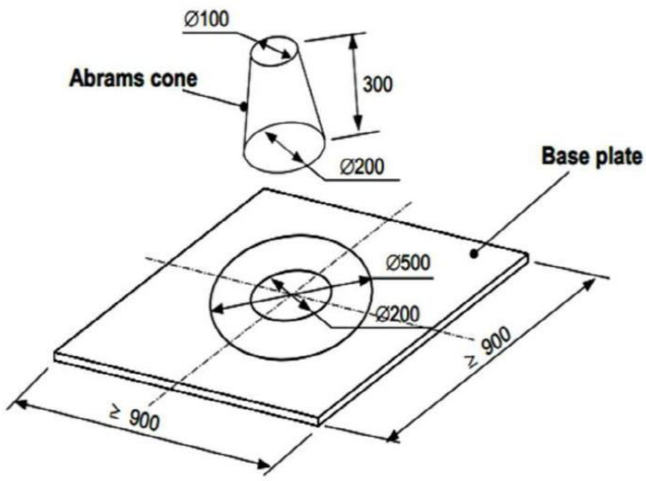
- SCC is something different than the conventional concrete or modification of conventional concrete it has similar ingredients such as Aggregate binder, however there blending is changed so as to get the advantage of self compactness:
  - Cement
  - **Aggregates:-** The maximum size of aggregate is generally limited to 20mm . Aggregate of size 10 mm is desirable for structures having congested reinforcement. Wherever possible size of aggregate higher than 20 mm could also be used. Well graded cubical or rounded aggregate are desirable. Aggregates should be of uniform quality with respect to shape and grading.
  - **Mixing water: -** Ordinary potable water of normally pH 7 is used for mixing and curing the concrete specimen.
  - **Chemical Admixtures:** Superplasticizer, Viscosity Modifying Agent (VMA)
  - **Mineral Admixtures:** Fly Ash, Foundry waste sand

High Resistance to Segregation:
Self compacting concrete must meet the requirements of 1 and 2 while its original composition remains uniform. The key properties must be maintained at adequate levels for the required period of time (e.g.20 min) after completion of mixing. It is property 2 the passing ability and property 3 resistance to segregation that constitute the major advance, form a merely super plasticized fresh mix which may be more fluid than self compacting concrete mix.

3. SCC AND MEASUREMENT OF IT'S FLOW PROPERTIES

TEST METHODS

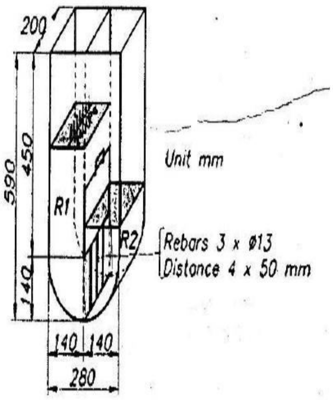
3.1 SLUMP FLOW TEST: The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.
Assessment of test: This is simple, rapid test procedure, though two people are needed if the T50 time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. It can be argued that the completely free flow, unrestrained by any boundaries, is not representative of what happens in practice in concrete construction, but the test can be profitably be used to assess the consistency of supply of ready-mixed concrete to a site from load to load.



3.2 U box test method: The test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometimes the apparatus is called a "box shaped" test. The test is used to measure the filling ability of self-compacting concrete. An operating with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13mm are installed at the gate with center-to-centre spacing of 50mm.This creates a clear spacing of 35mm between the bars. The left hand section is filled with about 20 liter of concrete then the gate lifted and concrete flows upward into the other section. The height of the concrete in both sections is measured.

Assessment of test.

This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability-this is literally what the concrete has to do-modified by an unmeasured requirement for passing ability. The 35 mm gap between the sections of reinforcement may be considered too close.



3.3 L box test method: This test, 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 consists of a rectangular section box in the shape of an 'L', with a vertical and horizontal section, separated by a moveable gate, in front of which vertical lengths of reinforcement bars are fitted.
The vertical section is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, 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 in the diagram). It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted.

Assessment of test.

This is widely is used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately there is no agreement on materials, dimensions, or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork.

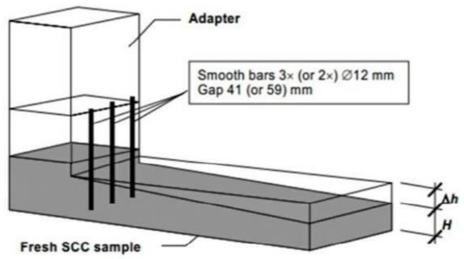


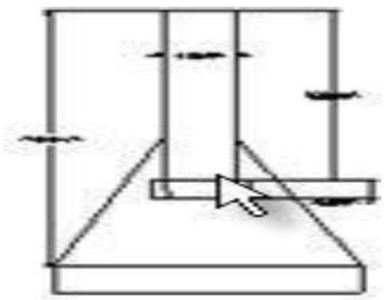
Fig 5.2.1 L BOX APPARATUS

3.4 Orimet Test: The Orimet was developed at the University of Paisley as a method for assessment of highly workable, flowing fresh concrete mixes on construction sites. The test is based on the principle of an orifice rheometer. The Orimet consists of a vertical casting pipe fitted with a changeable inverted cone shaped orifice at its lower, discharge, end, with a quick – release trap door to close the orifice. Usually the orifice has an 80 mm internal diameter which is appropriate for assessment of concrete mixes of aggregate size not exceeding 20 mm. Orifices of other sizes, usually from 70 mm to 90 mm in diameter, can be fitted instead. Operation consists simply of filling the Orimet with concrete then opening the trap door and measuring the time taken for light to appear at the bottom of the pipe(when viewed from above).

Assessment of test.

This test is able to simulate the flow of fresh concrete during actual placing on sites. It is rapid test, and the equipment is simple and easily maintained. The test has the useful characteristic of being capable of differentiation between highly workable, flowing mixes, and might therefore useful for compliance testing of successive loads on site. The timing procedure, however, may be subjected to error, and ideally requires two people**.**

5.4 Orimet Test



3.5 V Funnel Test and V Funnel test at T5 minutes

The test was developed in Japan and used Ozawa et al. The equipment consists of a V-shaped tunnel, shown in fig. An alternative type of V-funnel, the O funnel, with a circular section is also used in Japan.

The described V-funnel test is used to determine the filling ability (flow ability) of the concrete with a maximum aggregate size of 20mm.The funnel is filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the 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 flow ability, 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 – if, for example there is too much coarse aggregate. High flow time can also be associated with low deformability due to high paste viscosity, and with high inter-particle friction.

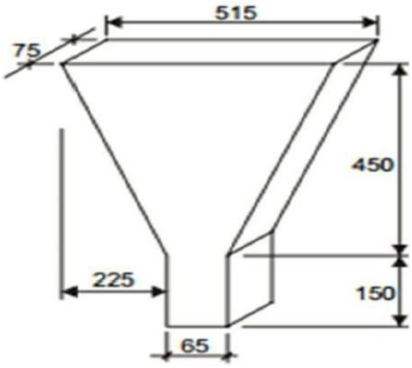


Fig- 5.3.2 The V Funnel Apparatus

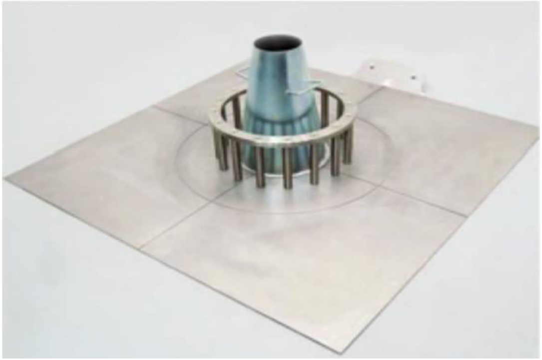
3.6 J-RING TEST: The principle of J Ring test may be Japanese, but no references are known. The J Ring test itself has been developed at the University of Paisley. The test is used to determine the passing ability of the concrete. The equipment consists of a rectangular section (30mmx25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sections of bar can be of different diameters and spaced at different intervals in accordance with normal reinforcement consideration, 3x the maximum aggregate size might be appropriate. The diameter of the ring of vertical bars is 300mm, and the height 100mm.

The J Ring can be used in conjunction with the slump flow, the Orimet test or even with the V-funnel. These combinations test the flowing ability and (the contribution of J ring) the passing ability of the concrete. The Orimet time and/or slump flow spread are measured are usual to assess flow characteristics. The J ring bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the J ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

Assessment of test:

These combinations of tests are considered to have great potential, though there is no general view on exactly how results should be interpreted. There are number of options- for instance it may be instructive to compare the slump-flow/J Ring spread with the unrestricted slump flow: to what extent is it reduced?

Like the slump flow test, these combinations have the disadvantage of being unconfined, and therefore do not reflect the way concrete is placed and moves in practice. The Orimet option has the advantage of being dynamic test, also reflecting placement in practice, though it suffers from requiring two operators.



Tests to be fulfilled to qualify as SCC:

Though there are many test methods to confirm the qualification to SCC, as mentioned above, no single method or combination of methods have obtained universal acceptance. One cannot declare a mix of SCC by only looking at the slump flow. For example, a mix with slump of even 650mm or more may not be an SCC, as it may, some times be susceptible to blocking and segregation as well. For example [6], in japan, the slump flow test, V-funnel test, and the box shaped test (or U-box test) are used for the purpose of SCC acceptance. In Sweden slump flow and L-box test are used.

So any mix aimed to be SCC must be tested for at least three workability tests. These can be a combination of any of the following, in addition to slump flow test, V-funnel test, L-box blocking ratio test etc.

TEST RESULTS AND DISCUSSION

FRESH CONCRETE

Test methods used to study the characteristics of fresh concrete include slump test, U – tube, V – funnel and L – Box. These tests had been conducted to determine the filling ability, passing ability and resistance to segregation of the SCC mix.

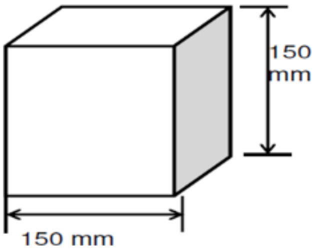
Table 4.1 Test results of fresh concrete properties of SCC

S.No	Detail	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
1	Slump flow	673 mm	675 mm	682 mm	684 mm	688 mm	690 mm	698 mm	699 mm	700 mm	700 mm
2	T50cm Slump flow	5 Sec	4 Sec	3 Sec	3 Sec	2 Sec	2 Sec	2 Sec	2 Sec	2 Sec	2 Sec
3	V funnel Test	10 Sec	10 Sec	10 Sec	8 Sec	8 Sec	7 Sec	7 Sec	7 Sec	7 Sec	7 Sec
4	V funnel at T5 minutes	13 Sec	13 Sec	12 Sec	11 Sec	10 Sec	9 Sec	9 Sec	9 Sec	9 Sec	9 Sec
5	L Box Test	0.84	0.83	0.87	0.89	0.9	0.91	0.91	0.91	0.91	0.91
6	U Box Test	26	26	24	24	23	21	21	21	21	21

Hardened concrete

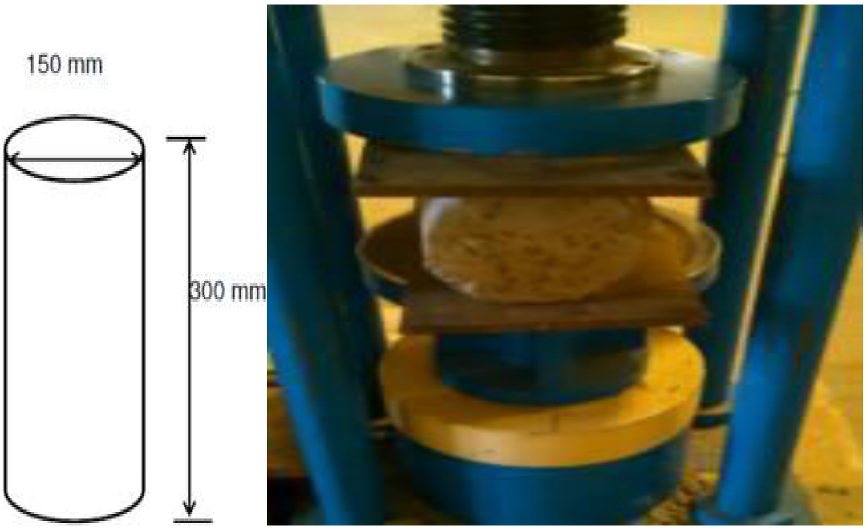
Compressive strength

Each measuring 150 x 150 x 150 mm cubes had been tested for each mix to determine the compressive strength on 3, 7, 14, 28 56 and 90 days.



MIX	3rd Day	7th Day	14th Day	28th Day	56th Day	90th Day
	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²	N/mm²
M30	15.10	21.30	23.45	24.15	25.60	27.60
M35	17.60	24.80	25.10	26.60	29.40	31.85
M40	20.10	25.45	28.40	30.40	34.40	37.20
M45	22.60	28.90	31.50	36.90	39.15	41.40
M50	26.32	37.57	40.5	42.75	43.50	46.50
M55	27.60	39.00	41.25	42.90	47.85	49.50
M60	30.43	42.51	44.55	46.80	49.20	54.65
M65	32.60	45.10	46.75	50.70	53.30	58.55
M70	34.25	46.80	48.25	52.50	57.40	63
M75	39.50	47.20	51.75	56.25	61.50	67.50
M80	44.25	51.10	56.50	62.75	69.25	73.65

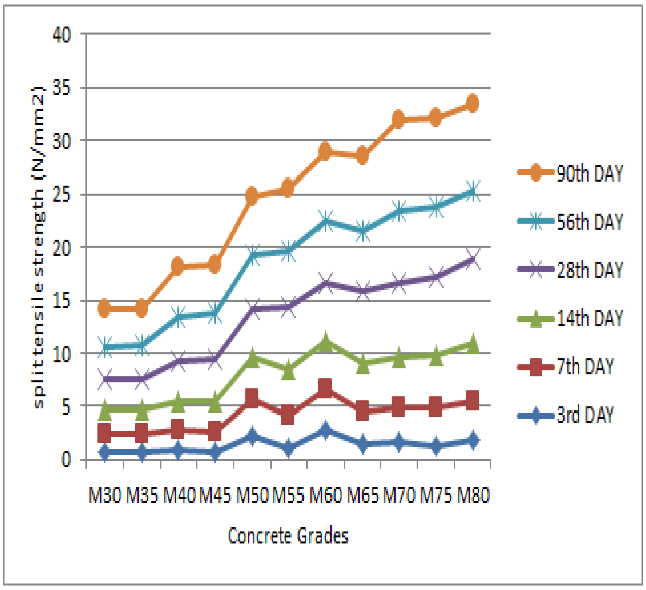
Test results **for Compressive Strength**



Compressive Testing **Machine**

Split Tensile Strength:

Each measuring 150 mm diameter and 300 mm height cylinders had been tested for each mix to determine the compressive strength on 3, 7, 14, 28,56 and 90 days



Compressive Testing Machine

MIX	3rd Day	7th Day	14th Day	28th Day	56th Day	90th Day
	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
M30	0.72	1.65	2.24	2.94	3.06	3.53
M35	0.78	1.71	2.20	2.89	3.11	3.47
M40	0.97	1.91	2.52	3.82	4.24	4.59
M45	0.73	1.94	2.78	4.00	4.30	4.60
M50	2.33	3.27	3.94	4.58	5.17	5.46
M55	1.16	2.96	4.41	5.81	5.27	5.97
M60	2.81	3.80	4.57	5.41	5.89	6.37
M65	1.55	3.04	4.43	6.83	5.66	7.00
M70	1.63	3.30	4.61	7.11	6.76	8.54
M75	1.37	3.58	4.93	7.31	6.63	8.37
M80	1.91	3.51	5.51	7.94	6.53	8.13

Test results for Split Tensile Strength

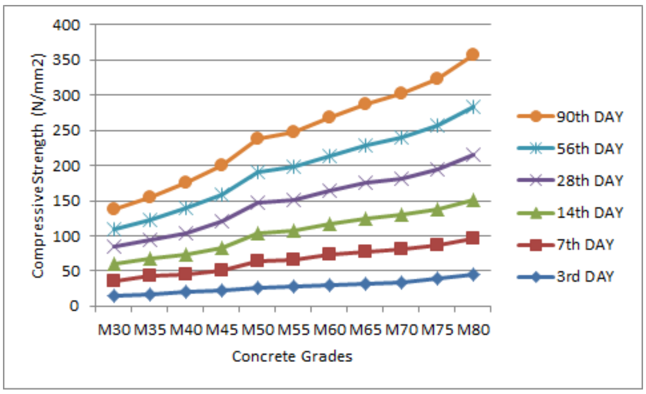
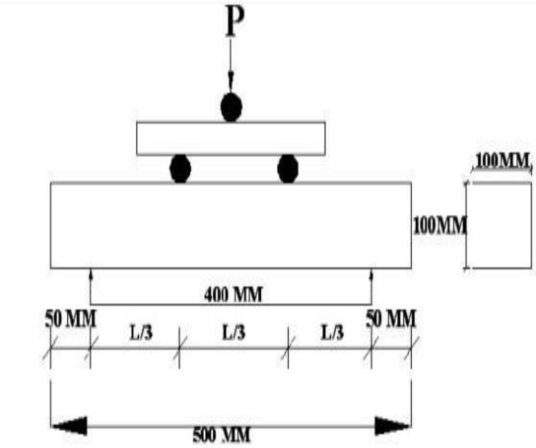


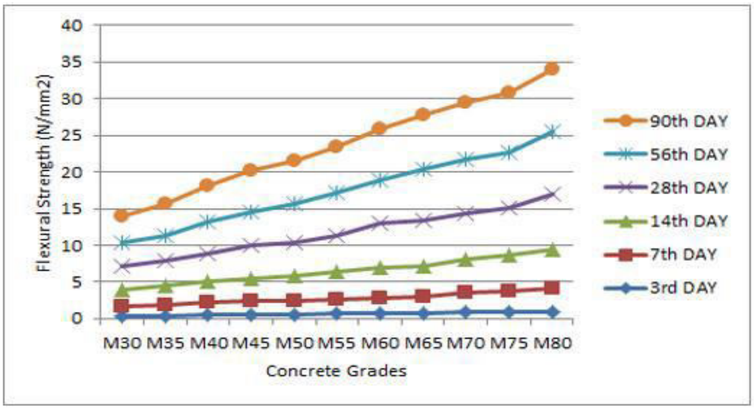
Chart for Split Tensile Strength

Flexural Strength:

Each measuring 150 x 150 x 150 mm cubes had been tested for each mix to determine the compressive strength on 3, 7, 14, 28, 56 and 90 days.



Flexural Loading Device



Graph of split tensile strength

MIX	3rd Day	7th Day	14th Day	28th Day	56th Day	90th Day
	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
M30	0.36	1.234	2.40	3.11	3.17	3.75
M35	0.43	1.48	2.56	3.46	3.29	4.45
M40	0.46	1.71	2.91	3.78	4.37	4.81
M45	0.526	1.88	3.06	4.61	4.54	5.56
M50	0.59	1.91	3.40	4.41	5.30	5.96
M55	0.67	2.01	3.70	5.00	5.84	6.11
M60	0.70	2.07	4.21	6.02	5.91	7.01
M65	0.76	2.21	4.26	6.22	6.90	7.46
M70	0.83	2.67	4.58	6.20	7.41	7.69
M75	0.89	2.90	4.91	6.48	7.56	8.08
M80	0.94	3.11	5.37	7.60	8.46	8.56

CONCLUSION

Based on the experimental investigation, the following conclusions are drawn within the limitations of the test results.

- The test results of fresh concrete are within the limits of SCC i.e., flow ability, passing ability and resistance against segregation.
- In Experimental Investigation, the concrete have been casted for M30 to M80 in order to check the Compressive strength, Split tensile strength and Flexural strength
- Statistical experimental design can be used to systematically investigate the selected range of combination of ingredients for the desired characteristics.
- The mathematical models furnished in this investigation can be used to predict the proportions of various constituents of concrete, by substituting the value, in coded form, of respective factors.
- The five level factorial techniques can be employed easily for developing mathematical model for predicting the strength and workability within the workable region of control parameters for required characteristics.
- Optimum binder composition concrete mixtures for the designed strength can be identified from the proposed models.
- RSM can be used effectively in analyzing the cause and effect of the process parameters on response.

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