Experimental Study On The Behavior Of Self Compacting Self Cured Concrete Using Chemical Admixtures And Metakaolin

Najitha Naushad, G. Vasudhevan

Abstract—Self-consolidating concrete or self-compacting concrete (SCC) is characterized by a low yield stress, high deformability, and moderate viscosity necessary to ensure uniform suspension of solid particles during transportation, placement (without external compaction), and thereafter until the concrete sets. Such concrete can be used for casting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface than conventional concrete. SCC was conceptualized in 1986 by Prof. Okamura at Ouchi University, Japan.The incorporation of powder, including supplementary cementitious materials and filler, can increase the volume of the paste, hence enhancing deformability, and can also increase the cohesiveness of the paste and stability of the concrete.

The main constituents of self-compacting concrete are cement, fine aggregate, coarse aggregate, water and admixtures.The admixtures increase workability without increasing water content or decrease the water content at the same workability. Conplast SP 430 and PEG 400 are used as chemical admixtures. Cement is replaced with a mineral metakaolin. Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The strength of SCC using only with chemical admixtures, and with chemical admixtures and mineral are analysed to find outwhich one makes SCC more perfect. Different test specimens are casted and tested in laboratory condition. The different tests for SCC are also carried out in lab

Keywords— SCC,metakaolin,chemical admixtures

I. INTRODUCTION

Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Use of SCC can also help minimize hearing-related damages on the worksite that are induced by vibration of concrete. Another advantage of SCC is that the -time required to place large sections is considerably reduced.

When the construction industry in Japan experienced a decline in the availability of skilled labour in the 1980s, a need was felt for a concrete that could overcome the problems of defective workmanship.

This led to the development of self-compacting concrete, primarily through the work by Okamura. A committee was formed to study the properties of self-compacting concrete, including a fundamental investigation on workability of concrete, which was carried out by Ozawa et al at the University of Tokyo. The first usable version of self-compacting concrete was completed in 1988 and was named “High Performance Concrete”, and later proposed as “Self Compacting High Performance Concrete”.

In Japan, the volume of SCC in construction has risen steadily over the years. Data indicate that the share of application of SCC in precast concrete industry is more than three times higher than that in the ready-mixed concrete industry. This is attributable to the higher cost of SCC. The estimated average price of SCC supplied by the RMC industry in Japan was 1.5 times that of the conventional concrete in the year 2002. Research studies in Japan are also promoting new types of applications with SCC, such as in lattice type structures, casting without pump, and tunnel linings.

Since the development of SCC in Japan, many organizations across the world have carried out research on properties of SCC. The Brite-Euram SCC projectwas set up to promote the use of SCC in some of the European countries. A state-of-the-art report on SCC was compiled by Skarendahl and Peterssonsummarizing the conclusions from the research studies sponsored by the Brite-Euram project on SCC. A recent initiative in Europe is the formation of the project – Testing SCC– involving a number of institutes in research studies on various test methods for SCC. In addition, an organization with the participation from the speciality concrete product industry – EFNARC– has developed specifications and guidelines for the use of SCC that covers a number of topics, ranging from materials selection and mixture design to the significance of testing methods.

II. PROPERTIES OF SELF COMPACTING CONCRETE

- This concrete is able to flow and to fill the most restacted places of theform work without vibration.
- The concrete mix of SCC must be placed at a relatively higher velocity than that of regular concrete. It has been placed from heights taller than 5 meters without aggregate segregation.
- Self-compacting concrete produces resistance to segregation by using mineral fillers or fines, and using special admixtures.
- SCC is required to flow and fill special forms under its own weight, it shall be flowable enough to pass through highly reinforced areas, and must be able to avoid aggregate segregation.
- This type of concrete must meet special project requirements in terms of placement and flow.

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- SCC with a similar water content or cement binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to lack of vibration giving an improved interface between the aggregate and hardened paste.
- It can also be used in areas with normal and congested reinforcement, with aggregates as large as 2 inches.

III. BENEFITS OF SELF COMPACTING CONCRETE

- SCC improves the construction and reduces the labour.
- Provides good bond to reinforcing steel and improves structural integrity.
- SCC not requires skilled labour and it accelerates project schedules.
- It can flow into complex forms and minimizes voids on highly reinforced areas.
- It can produce superior surface finishes and reduce equipment wear.
- SCC provides superior strength and durability.
- Allows for easier pumping procedure, fast placement without vibration or mechanical consolidation and produces a uniform surface.
- Lowering noise levels produced by mechanical vibrators and produces a wider variety of placement techniques.
- Allows for innovative architectural features.

IV. OBJECTIVE AND SCOPE OF THE STUDY

The objective of the study was

- To find the hardened concrete properties of self-compacting self-cured concrete with metakaolin.
- To have an idea about self-compacting self-curing concrete.
- To find the hardened concrete properties using SP, SAP and mineral separately.
- To find the hardened concrete properties with best proportion of SP, SAP and mineral.
- To compare the results of above two and find out which one makes the SCC much better.
- To have an idea about making procedure of self-compacted self-cured concrete.
- To find the two key fresh properties of SCC – filling ability and passing ability - for mix design purposes in the lab.
- Conduct suitable tests to identify suitable SCC.
- To find the behaviour of SCC with different percentages of cement replacement by metakaolin.

The scope of the study was

- This concrete having self-compact ability with which it can be placed in the every corner of formwork without vibration causing no segregation.
- The performance evaluation method of fresh Self-Compacting Concrete widely differs depending on whether vibration is given to the concrete during placing.
- Self-Compacting Concrete that can be placed without any external forces other than gravity.
- Due to less vibration is needed, SCC can be used in precast product plants.
- It helps to reduce the number of workers required at the construction site.
- In precast product plants as well, SCC is highly effective in reducing the noise as it requires no vibration.
- To find out that how effectively we can use the metakaolin mineral as a replacement of cement.

V.METHODOLOGY

This section briefly explains the methodology adopted in this. The following methodology has been adopted to achieve above objective.

In the first phase, physical, chemical and mechanical properties of all ingredient of concrete were found out. In the second phase, initially compressive strength of cubes and cylinders, split tensile strength will be found out. Finally Reinforced beams will be subjected under two-point loading to study the flexural behaviour and other salient features of concrete beams. The experimental investigation is conducted as detailed below. All the materials tests were conducted in the laboratory as per relevant Indian Standard codes. Basic tests were conducted on fine aggregate, coarse aggregate, and cement to check their suitability for concrete making. The properties of fine and coarse aggregates, sieve analysis of fine and coarse aggregates, tests on cement are to be found.

The study aims to investigate the strength related properties of concrete of M_{30} grade with self compacting concrete. The proportions of ingredients of the control concrete of grade M_{30} had to be determined by mix design with reference of ocamura and EFNARC.The cubes will be casted as per the M_{30} grade of concrete. Cube specimens having 150x150x150mm, cylinder specimens of 100mm diameter and 200 mm height would be casted. Beam specimens of size 100x100x500mm will cast, cured and subjected under two- point loading to study their flexural behaviour and other salient parameters.

VI. MATERIALS USED

Ordinary Portland Cement (43 grade) cement conforming to IS 8112 was used. The different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time as per IS 4031 and IS 269-1967. Here metakaolin is used for cement replacement. Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) byproducts produced during cement hydration.

Shape and particle size distribution of the aggregate is very important as it affects the packing and voids content. The moisture content, water absorption, grading and variations in fines content of all aggregates should be closely and continuously monitored and must be taken into account in order to produce SCC of constant quality. Superlasticizers or high range water reducing admitures are an essential components of SCC . Coneplast SP 430 was used as a chemical admixture. A superabsorbent polymer, SAP, is a polymeric material which is able to absorb a significant amount of liquid from the surroundings and to retain the liquid within its structure without dissolving. Here PEG 400 is used as super absorbent polymer.

VII. EXPERIMENTAL INVESTIGATION

Table 1 - TEST RESULTS OF CEMENT

Sl.no	Name of the test	Result
1	Standard consistency	32%
2	Specific gravity	3.14
3	Fineness modulus	2.67%
4	Initial setting time	215 minutes
5	Final setting time	495 minutes

Table 2 - PHYSICAL TEST RESULTS OF FINE AGGREGATE

Physical tests	Fine aggregate
Fineness modulus	4.79
Specific gravity	2.66
Water absorption	0.92
Bulk density	1.84 g/cc

Table 3 - PHYSICAL TEST RESULTS OF COARSE AGGREGATE

Physical tests	Coarse aggregate
Fineness modulus	4.71
Specific gravity	2.67
Water absorption	0.45
Bulk density	1.66g/cc

VIII. MIX DESIGN OF SCC

Generally, it is advisable to design conservatively to ensure that the concrete is capable of maintaining its specific fresh properties despite anticipated variations in raw material quality. Some variation in aggregate moisture content should also be expected and allowed for at mix design stage. Normally viscosity-modifying admixtures are a useful tool for compensating for the fluctuations due to any variations of the sand grading and the moisture content of the aggregates.

The initial mix proportions were calculated using mix design method of conventional concrete given by Indian Standard method instead of simply assuming the contents of Cement, Coarse Aggregate and Fine Aggregate as given by the literature. These contents were compared with the EFNARC Specifications and small modifications were done to the contents that arrived in the Indian Standard method to satisfy the SCC mix composition criteria.

The conventional mix proportion using BIS method is given in the table below:

Table 4 - CONVENTIONAL MIX

Cement	Sand	Coarse aggregate	Water
474.38 kg	485.55 kg	1169.22 kg	199.24
1	1.02	2.46	0.42

It is then modified into SCC mix as

Table 5 - SCC MIX

Cement	Sand	Coarse aggregate	Water
474.38 kg	893.58 kg	756.19 kg	190
1	1.88	1.59	0.40

IX. CASTING AND TEST RESULTS FOR TWO TRIAL MIXES

The strength parameters of normal M30 mix compared withstrength parameters of SCC mix at 7days and 28 days.

1. Cubes, cylinders and beam specimens are casted according to two mix proportions.
2. Cube specimen has a size of 150x150x150mm, cylinder specimen is 100 mm diameter and 200mm length, beam is 100x100x500mm.

Table 6 - TEST RESULTS FOR TWO TRIAL MIXES

	Days	Mix1 (1:1.02:2.46)			Mix2 (1:1.88:1.59)		
		S1	S2	Avg	S1	S2	Avg
Compressive stress in N/mm^2	7	21.48	17.8	19.64	24	20	22
	28	31.3	30.56	30.93	33.8	31.9	32.84
Split tensile strength in N/mm^2	7	1.8	1.6	1.7	1.72	2.12	1.91
	28	2.4	2.8	2.6	3.1	2.7	2.9
Flexural strength in N/mm^2	7	2.1	2.3	2.2	2.5	2.1	2.3
	28	3.5	2.9	3.2	3.5	4.1	3.8

X. CASTING AND TEST RESULTS FOR SAP

The strength parameters of self cured concrete were found out for 7days and 28 days.

1. Concrete specimens cast using SAP for 0.5%, 1%, 1.5%.

2. The optimum dosage of SAP for self cured concrete was found out to be 1% by weight of cement.

PEG 400 was used as self-curing agent. M30 grade of concrete is adopted for the investigation. The conclusions of the test are

1. The optimum dosage is 1%.Addition of SAP leads to a significant increase of mechanical strength (Compressive and Splitting tensile).
2. Compressive strength of self-cured concrete for dosage of 1% was higher than SCC.
3. Split tensile strength of self-cured concrete for dosage of 1% was higher than SCC.
4. Flexural Strength of self-cured concrete for dosage of 1% was higher than SCC.

Table 7 - TEST RESULT FOR SAP

Percentage	Days	Compressive strength in N/mm²			Split tensile strength in N/mm²		
		S1	S2	Avg	S1	S2	Avg
0.5%	7	18.8	20.0	19.4	2.2	2.65	2.43
	28	29.6	33.3	31.4	4.1	3.48	3.82
1%	7	24.2	26	25.01	2.5	2.95	2.75
	28	36.5	38.4	37.44	4.0	4.36	4.18
1.5%	7	24.5	20.9	22.68	2.28	2.52	2.4
	28	32.4	35	33.7	3.4	3.92	3.66

Percentage	Days	Flexural strength in N/mm²		
		S1	S2	Avg
0.5%	7	2.4	2.6	2.51
	28	3.52	3.78	3.65
1%	7	3.2	2.4	2.8
	28	3.9	4.3	4.1
1.5%	7	1.9	2.3	2.1
	28	3	3.1	3.05

Percentage	Days	Flexural strength in N/mm²		
		S1	S2	Avg
3	7	1.61	1.51	1.56
	28	2.24	2.76	2.5
6	7	2.2	1.8	2.0
	28	3.1	3.5	3.3
9	7	2.57	2.23	2.4
	28	3.7	3.5	3.6
12	7	3	2.8	2.9
	28	4.6	4.2	4.4
15	7	1.8	1.94	1.87
	28	2.84	3.16	3.0

XI. CASTING AND TEST RESULTS FOR METAKAOLIN MINERAL

The strength parameters of SCC by replacing particular amount of cement were found out for 7days and 28 days.

1. Concrete specimens cast for 3%, 6%, 9%, 12%, 15% by weight of cement.
2. The optimum of mineral for SCC was found out to be 12% by weight of cement

Table 8 - TEST RESULTS FOR METAKAOLIN

Percentage	Days	Compressive strength in N/mm²			Split tensile strength in N/mm²		
		S1	S2	Avg	S1	S2	Avg
3	7	21.1	19.06	20.08	1.38	1.46	1.42
	28	31.3	30.56	30.93	2.0	2.26	2.13
6	7	20.8	24.06	22.43	1.64	1.3	1.47
	28	33.7	31.36	32.53	2.1	2.34	2.22
9	7	21.2	24.5	22.8	1.5	1.54	1.52
	28	32.8	36.34	34.57	2.46	2.3	2.38
12	7	23	25.8	24.2	1.79	1.59	1.69
	28	38.4	34.5	36.44	2.1	2.9	2.5
15	7	19.2	20.82	20.01	1.37	1.21	1.29
	28	31.4	29.04	30.22	1.85	2.21	2.03

From the experimental investigation it was observed that the replacement of cement with metakaolin powder in SCC show improves workability and mechanical properties. So from all the tests conducted, the final mix obtainedfor one cubic meter of concrete is given below.

Table 9 - FINAL MIX

CEMENT	474.38 KG
FINE AGGREGATE	488.55 KG
COARSE AGGREGATE	1169.22 KG
WATER	199.24 LITRE
SAP (PEG 400)	1% OF WEIGHT OF CEMENT
CONPLAST SP 430	0.5 LITRE /100 KG OF CEMENT
METAKAOLIN POWDER	REPLACING 12% BY WEIGHT OF CEMENT

XII. CASTING AND TEST RESULTS FOR CHEMICAL AND MINERAL,AND WITH CHEMICAL ADMIXTURES ONLY

Table 10 - TEST RESULT FOR TWO MIXES

	Days	Chemical and mineral admixtures (Mix A)		
		S1	S2	Avg
Compressive stress in N/mm^2	7	20.2	24.2	22.2
	28	34.8	32.1	33.45
Split tensile strength in N/mm^2	7	2.1	1.76	1.93
	28	2.71	3.17	2.94
Flexural strength in N/mm^2	7	2.9	2.5	2.72
	28	3.6	4.2	3.9
	Days	Chemical and mineral admixtures (Mix B)		
		S1	S2	Avg
Compressive stress in N/mm^2	7	21	25	23
	28	34.1	35.9	35
Split tensile strength in N/mm^2	7	1.91	2.15	2.03
	28	3.2	3.05	3.12
Flexural strength in N/mm^2	7	3.3	2.54	2.92
	28	4.0	4.3	4.15

The strength parameters of SCC by using both chemical and mineral were found out for 7days and 28 days.

Comparing these, MixB was found to be more efficient

XIII. TEST RESULTS ON FRESH STATE

Slump test, V-funnel test, U-box and L-box tests were conducted in the lab.

Table 11 - TEST RESULTS IN FRESH STATE

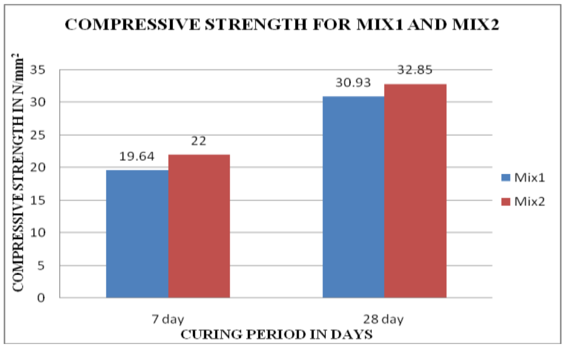
S. No.	Test Conducted	Unit	RESULT	
			Chemical and mineral admixtures	Chemical admixtures only
1	Slump-flow	mm	691	682
4	V-funnel	Sec	10	11
6	L-Box	(h_2/h_1)	0.93	0.98
7	U-Box	(h_1-h_2)	17	14

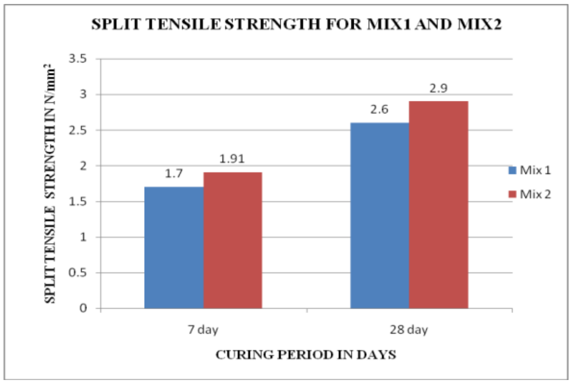
XIV. CONCLUSIONS

Based on the investigation conducted for the study of behavior of self -compacted self -cured concrete the following conclusions are arrived.

1. The optimum value of SAP obtained as 1% by weight of cement.
2. The optimum value of metakaolin obtained as 12% by weight of cement.
3. As no specific mix design procedures for SCC are available mix design can be done with conventional BIS method and suitable adjustments can be done as per the guidelines provided by different agencies.
4. Tests done in fresh properties showed results is within the specified limits.
5. The result found out for specimen contains both chemical and mineral shows better strength than normal SCC in compressive, split tensile, and flexural strengths.
6. But the SCC mix with chemical admixtures only shows slightly better strength than the mix contain both chemical and mineral.
7. So the mix with chemical only is the best strength giving mix.

APPENDIX


COMPRESSIVE STRENGTH FOR MIX1 AND MIX2
COMPRESSIVE STRENGTH IN N/mm²
19.64
22
30.93
32.85
7 day
28 day
CURING PERIOD IN DAYS
Mix1
Mix2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SPLIT TENSILE STRENGTH IN N/mm²
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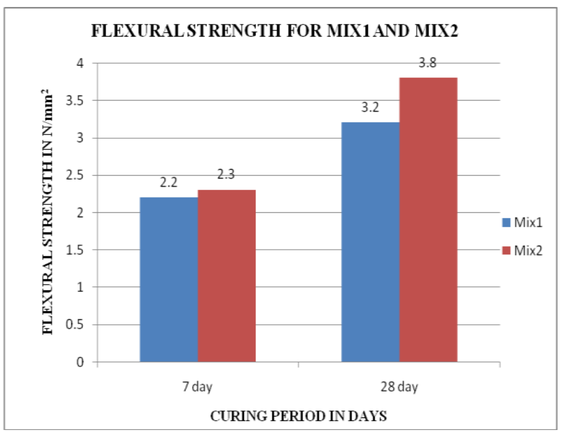
2.9
7 day
28 day
CURING PERIOD IN DAYS
Mix 1
Mix 2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FLEXURAL STRENGTH IN N/mm²
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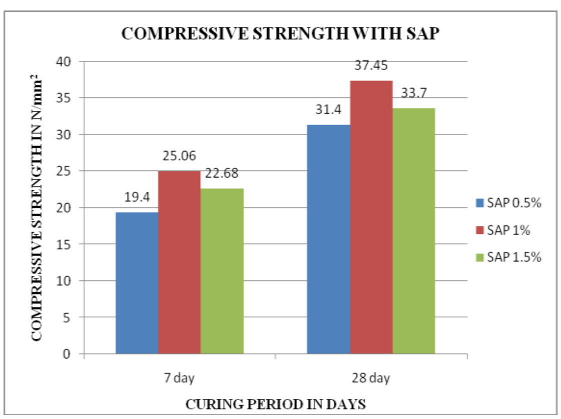
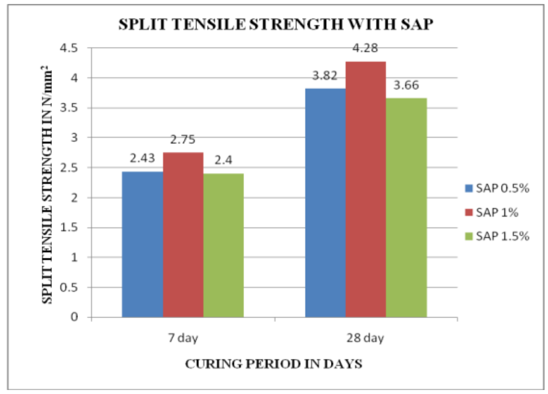
3.2
3.8
7 day
28 day
CURING PERIOD IN DAYS
Mix1
Mix2


COMPRESSIVE STRENGTH WITH SAP
COMPRESSIVE STRENGTH IN N/mm²
19.4
25.06
22.68
31.4
37.45
33.7
7 day
28 day
CURING PERIOD IN DAYS
SAP 0.5%
SAP 1%
SAP 1.5%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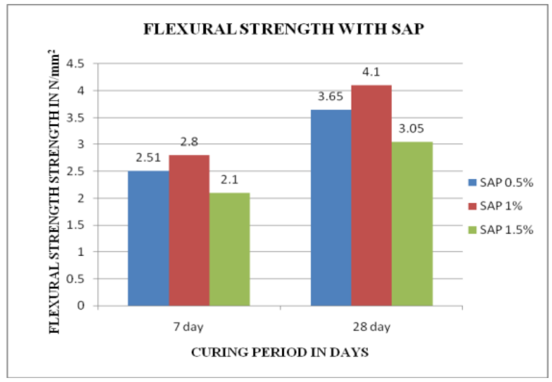
SPLIT TENSILE STRENGTH IN N/mm²
2.43
2.75
2.4
3.82
4.28
3.66
7 day
28 day
CURING PERIOD IN DAYS
SAP 0.5%
SAP 1%
SAP 1.5%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4.1
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28 day
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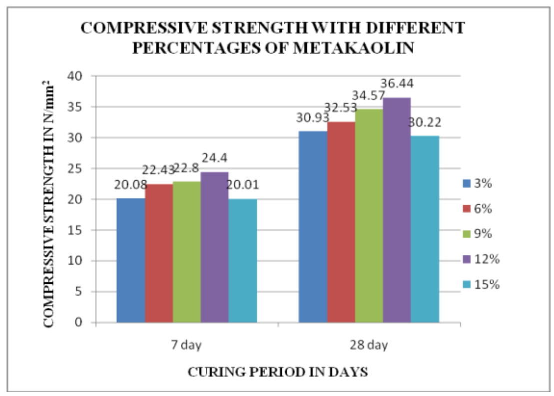
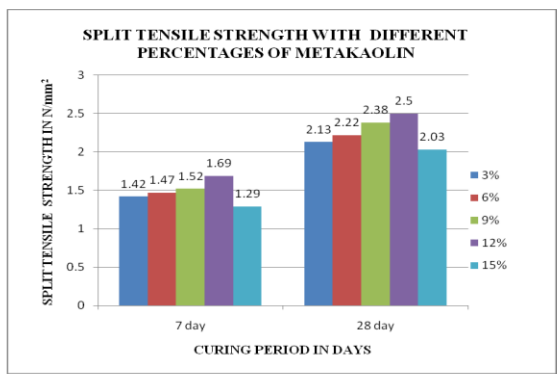
SAP 0.5%
SAP 1%
SAP 1.5%


COMPRESSIVE STRENGTH WITH DIFFERENT PERCENTAGES OF METAKAOLIN
COMPRESSIVE STRENGTH IN N/mm²
20.08
22.43
22.8
24.4
20.01
30.93
32.53
34.57
36.44
30.22
7 day
28 day
CURING PERIOD IN DAYS
3%
6%
9%
12%
15%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SPLIT TENSILE STRENGTH IN N/mm²
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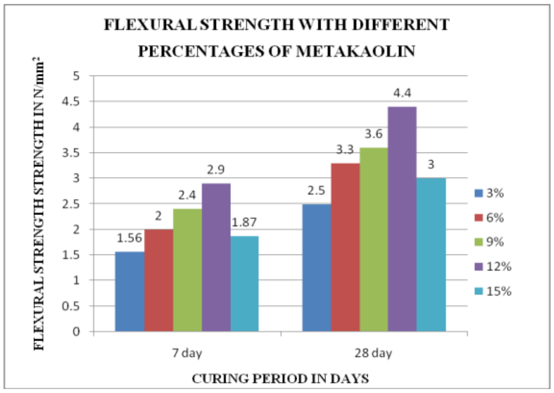
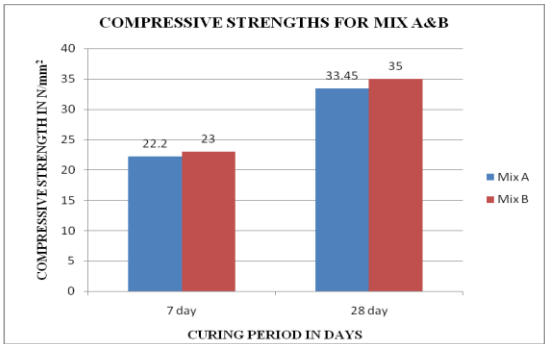
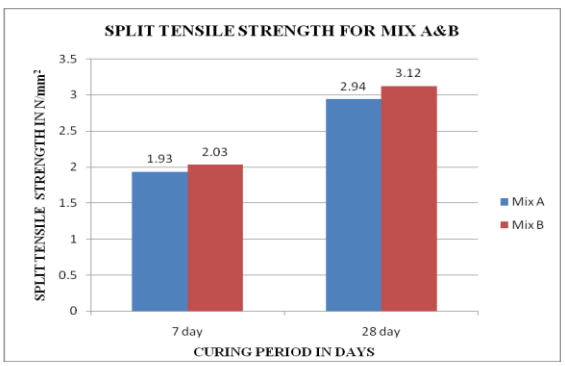
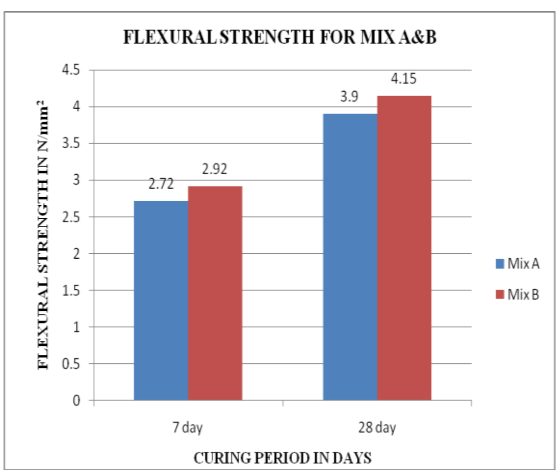
1.47
1.52
1.69
1.29
2.13
2.22
2.38
2.5
2.03
7 day
28 day
CURING PERIOD IN DAYS
3%
6%
9%
12%
15%









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