

EFFECT OF ELEVATED TEMPERATURE ON COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE USING FLY ASH, SILICA FUME, METAKAOLIN AND ALCCOFINE

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Abstract— Self-Compacting Concrete (SCC) is defined as category of high performance concrete that has excellent deformability in the fresh state as well as high resistance to segregation and can be placed and compacted under its self-weight without applying vibration. In this paper flow properties of SCC with fix ratios of mineral admixture as well as water to cement, and ViscoCrete to cement determined by experimental investigation. The flow properties such as filling ability, passing ability and segregation resistance were found using the Slump Flow, J-Ring and V-Funnel test setups respectively. Self-compacting concrete (SCC) may be used in buildings subjected to high temperatures during operation or in case of an accidental fire. The proper understanding of the effects of elevated temperatures on the properties of SCC is necessary. An experiment has been made to study the effect of elevated temperature on compressive strength of SCC specimens heated from 200°C, 300°C, and 400°C respectively.

Keywords— Self-Compacting Concrete, Elevated temperature, ViscoCrete, Fly ash, Silica Fume, Alccofine, Metakaolin, Compressive strength

1. INTRODUCTION

In past years there has been substantial improvement in concrete technology and this lead to development of self-compacting concrete. Self-compacting concrete was developed in Japan. It has some important properties such as great filling capacity better flow and resistant to segregation it can easily flow through narrow opening and cover the reinforcement. As the use of self-compacting concrete become common, its risk to exposing to the fire also increases. Fire is the severe environment condition which a structure may be subjected. Although concrete is known for its excellent thermal resistant over other construction materials. Deterioration of concrete is observed when it is exposed to high temperature such as in case of fire. Concrete damage as exposed to fire includes reduction in strength and weight loss. Fire causes damage structure as well as human lives. Due to fire accident, it may lead to building collapse. It has become a major issue to make structure fire resistant for long duration.

2. LITERATURE REVIEW

M. S. Al-Lami(2017)[1] studied the effect of high temperature on compressive strength of self-compacting concrete samples heated from 25°C to 700°C. the result show that self-compacting concrete has better resistance to high temperature upto 200°C than normal concrete. But at 300°C and 400°C the resistance was less and decreased with increase in percentage of chemical admixture and water cement ratio.

Patrick Bamonteet. Al(2012)[2].proposed three self-compacting “limestone” concretes (target strength $f_c = 50, 80$ and 95 MPa). The objective is to synthesize the test results available in the literature and to make systematic comparisons, something that is not as simple as one may expect, because of the different heating rates, specimen types, and procedures in data treatment and presentation. The agreement, however, is more than satisfactory and confirms what has been more or less overtly indicated in previous studies, that the thermal and mechanical behaviour of SCC at high temperature is hardly different from that of VC, at least in quasi-static thermal conditions and uniaxial loading.

V.K.R. Koduret. al.(1998) [3]presented experimental program on the conduct of high strength concrete-filled steel hollow structural section (HSS) columns for three sorts of concrete filling. A correlation will be made of the fire-resistance performance of HSS columns filled with NSM, HSC, and steel fibre-reinforced HSC. The different components that affect the structural behaviour of high strength concrete-filled HSC columns under fire conditions are talked about. The addition of steel fibres into high strength concrete enhance the fire resistance and offers an efficient answer for flame safe development. Noumoweet. al. (2006) [4]displayed the consequences of exploratory work on the high-temperature behaviour of vibrated high-strength concrete and high strength self-compacting concrete. Concrete cylindrical specimens and prismatic specimens were subjected to a low heating rate of 0.5°C/min up to 400°C and a high heating rate indicated to International Standard Organization 834 fire curve up to 600°C. The test come about show the residual mechanical properties in reference to initial mechanical properties of self-compacting high-strength concretes were similar to that of conventional high-strength concrete. The risk of spalling for self-compacting high-strength concrete was noteworthy than that of high-strength concrete. As for the ordinary vibrated high-strength concrete, the use of polypropylene fibre enhance the thermal stability of high-strength self-compacting concrete. Including polypropylene fibre modified thermal gradient in consequence thermal stresses in the investigated concrete specimens throughout the heating cooling cycles. This may contribute to explaining the difference in thermal stability

Michael Stegmaier et. al.(2006)[5] examinations on self-consolidating concrete (SCC) have been done over in the past recent years and the mechanical behaviour of this sort of concrete is well surely knew at this point. The fire conduct of this particular cement, be that as it may, isn't completely comprehended, and conflicting outcomes on the fire behavior of SCC were presented in the literature. Along these lines, diverse sort of SCCs with compressive strengths between 25 and 65 MPa (3.6 and 9.4 ksi) were designed, and specimens with an edge length of 300 mm were subjected to fire as indicated by ISO 834 at an age of 180 days. The compressive strength at 28 days, the weight reduction because of drying, the spalling of the specimens, and the residual compressive strength of the concretes after fire testing were measured and identified with the execution of reference vibrated concrete.

Hanaa Fares et. al.(2010)[6] experimental study on the properties of self-compacting concrete (SCC) subjected to high temperature. Two SCC mixtures and one vibrated concrete mixture were tried. These mixtures originate from the French National Project B@P. The specimens of each concrete mixture were heated at a rate of 1 °C/min up to various temperatures (150, 300, 450 and 600 °C). In order to guarantee a uniform temperature all through the specimens, the temperature was held steady at the extreme temperature for 1 hour before cooling. Mechanical properties at ambient temperature and residual mechanical properties after heating have just been resolved. In this paper, the physicochemical properties and the microstructural attributes are exhibited. Thermogravimetric investigation, thermo differential examination, X-ray diffraction and SEM perceptions were used. The point of these examinations was specifically to clarify the residual compressive strength increase between 150 and 300 °C.

Jin Tao et. al.(2010)[7] reports the consequences of laboratory examination carried out to ponder the impact of high temperatures extending from room temperature to 800°C on the compressive strength of different water-cement ratio SCC and high-strength concrete. It is discovered that the hot compressive strength of SCC decreases at elevation temperature. Contrasted with normal-strength SCC, high-strength SCC possesses a larger compressive strength exposed to high temperature. Another tests result is addition of polypropylene fibers decreased the strength and probability of explosive spalling.

3. EXPERIMENTAL WORK

Mix design of M35 grade of self-compacting concrete is done as per EFNARC/BIS[8] guidelines. Material selection and testing of basic ingredients like cement, coarse aggregates and fine aggregates. Testing of rheological properties of SCC as per EFNARC/BIS. Preparation of test samples to govern hardened properties of SCC. Firstly 15 cubes of reference mix cube were casted. These was tested at 7 and 28 days, at 28 day 3 reference mix cubes were tested on normal temperature and remaining 12 were heated for 2 hours at elevated temperature of 200°C,300°C, and 400°C respectively. Compressive strength test were conducted at 7 days and 28 days. After that 60 cubes were cast with fix proportion of mineral admixtures i.e. 10% of powder content (Fly Ash, Silica fumes, Metakaolin, Alccofine), chemical admixture @ 1.5%, and water 0.40. It was tested at 7 days and 28 days at ambient temperature and parallelly at elevated temperature for 2 hours at 200°C,300°C, and 400°C

respectively and compressive strength was tested. Testing of hardened properties of SCC as per BIS guidelines. Analysis of results from various experiments.

Table 3.1 Compressive Strength (N/mm²) Tested on 100*100*100 mm Cubes

Mix	Mineral admixture %	Cement kg/m ³	Fine aggregate kg/m ³	Coarse aggregate kg/m ³	w/c %	Water kg/m ³	Chemical Admixture (ViscoCrete 5101 NS) %
Reference mix	0	450	1097.70	691	0.40	180	1.5
SCC with Fly Ash	10	405	1071.98	674.70			
SCC with Silica Fume			1071.98	674.70			
SCC with Metakaolin			1075.20	676.70			
SCC with Alccofine			1080.04	679.78			

4. MIXING MATERIAL

Ultra Tech Ordinary Portland Cement (OPC) 43 Grade confirming to (IS 269:2015) was used. Coarse aggregate of size 12.5 mm sieve and 20mm collected from local area. Testing of coarse aggregate for specific gravity, water absorption, crushing value and impact value confirms to IS 383:2016 [9] was carried out in the laboratory.

Fine aggregate of size ranging 4.75mm to 75 microns collected from local area. Physical Properties of the fine aggregates and sieve analysis confirming to IS 383:2016.

Table 4.1 Sieve Analysis of Fine Aggregates

IS Sieve Size	Weight of F.A. Retained (gm)	% Weight Retained	Cumulative % Weight Retained	% Passing	Grading Zone
4.75mm	58	5.80	5.80	94.20	Conforming to Grading Zone III of Table 4 of IS 383-2016
2.36mm	76	7.60	13.40	86.60	
1.18mm	82	8.2	21.60	78.40	
600mic	104	10.40	32	68.0	
300mic	282	28.20	60.20	39.80	
150mic	370	37	97.20	2.80	
75mic	20	2	99.20	0.80	
Pan	8	0.80	100	0	

Table 4.2 Sieve Analysis of Coarse Aggregate 20mm:12.5mm Graded Aggregate
Weight of sample = 3000 gm (20 mm & 12.5 mm graded size by 1:1)

IS Sieve Size	Weight of coarse Aggregate Retained(gm)	Percentage Weight Retained	Cumulative Percent Weight Retained	Percent Passing
20	52	1.73	1.73	98.27
10 mm	2068	68.93	70.66	29.34 (25-55)
4.75 mm	856	28.54	99.20	0.80
Pan	24	0.80	100	0

5. FRESH CONCRETE TEST

Concrete is normally classified as self-compacting, if it fulfills the necessities of filling ability, passing ability and resistance to segregation. For this reason, a detailed experimental investigate on the designed mixes is carried out. SCC characteristics in fresh state of mix proportion with varying dosages, slump flow test (slump flow diameter and T50cm time), U-Box, V-Funnel and L-Box test were performed according to the procedure proposed by EFNARC. The results of these tests are given:

Table 5.1 Fresh properties of SCC Mixtures (observed values)

Mix	Slump Flow (mm)	T-50 (sec)	L-Box (H2/H1)	U-Box (H2-H1)	V-Funnel (sec)
Reference mix	700	2.95	0.85	27	10
SCC with Fly Ash	650	4.6	0.81	29	13
SCC with Silica Fume	675	4.35	0.82	28	12
SCC with Metakaolin	700	2.90	0.85	28	11
SCC with Alccofine	675	4.42	0.83	28	12

6. RESULT AND DISCUSSION

The reference mix of SCC, with Fly ash, Silica fume, Metakaolin and SCC Alccofine are tested respectively for compressive strength on a CTM machine of capacity 3000 KN at curing age of 7 and 28 days at normal temperature and at 28 days at elevated temperature (200°C, 300°C, 400°C). All the results of compressive strength (N/mm²) have been shown as under:



Figure 6.1 furnace used to heat the specimens

Mix	Compressive Strength at		Compressive Strength at Elevated		
	Normal Temperature (N/mm ²)		Temperature at 28 Days (N/mm ²)		
	7 days	28 days	200°	300°	400°
Reference mix	37.30	44.20	37.70	32.50	28.70
SCC with Fly Ash	34.70	46.00	50.40	62.50	55.70
SCC with Silica Fume	34.00	43.80	50.20	57.50	64.00
SCC with Metakaolin	32.50	39.50	43.00	50.00	58.00
SCC with Alccofine	38.50	43.50	48.50	62.50	60.00

The comparison of Compressive Strength of SCC at 7 days at normal temperature is shown in the Figure 6.2, which clearly indicates that the maximum compressive strength of 38.5 N/mm² is achieved by the SCC mix with Alccofine.

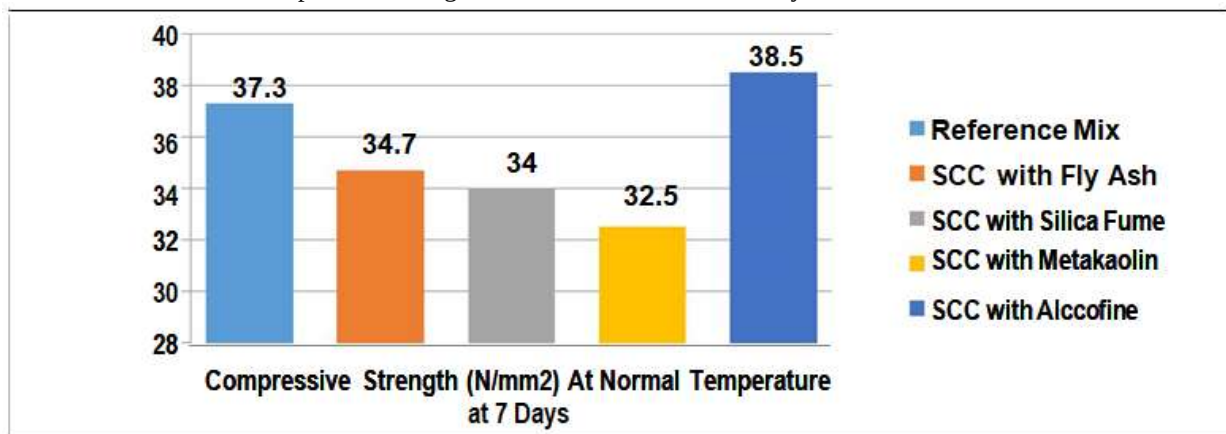


Figure 6.2 Compressive Strength of Different Mixes at 7 days

The comparison of Compressive Strength of SCC at 28 days at normal temperature is shown in the Figure 6.3, which clearly indicates that the maximum compressive strength of 46 N/mm² is achieved by the SCC with Fly Ash.

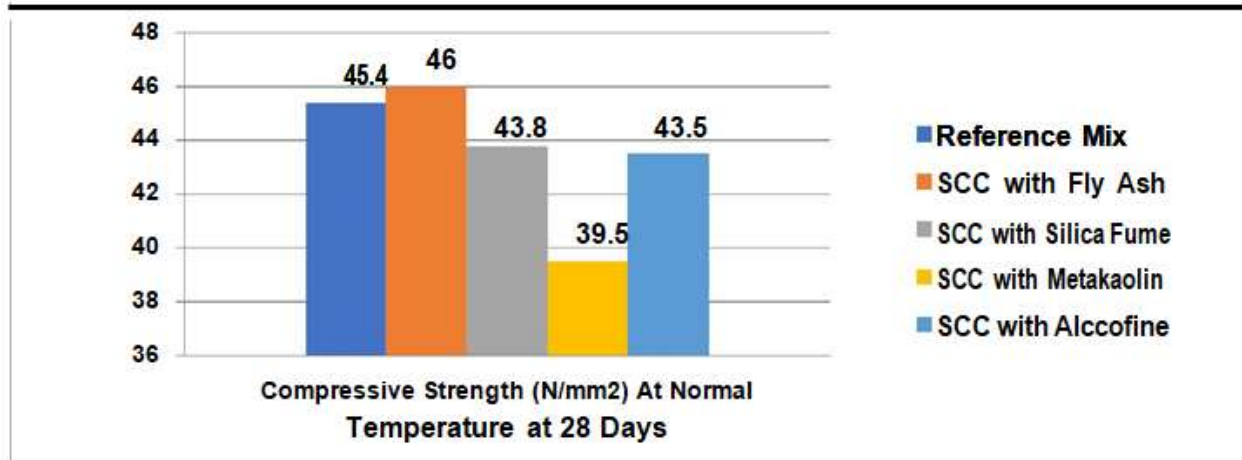


Figure 6.3 Compressive Strength of Different Mixes at 28 days

The comparison of Compressive Strength of SCC at 28 days at elevated temperature (200°C) is shown in the Figure 6.4, which clearly indicates that the maximum compressive strength of 50.4 N/mm² is achieved by the SCC with fly ash.

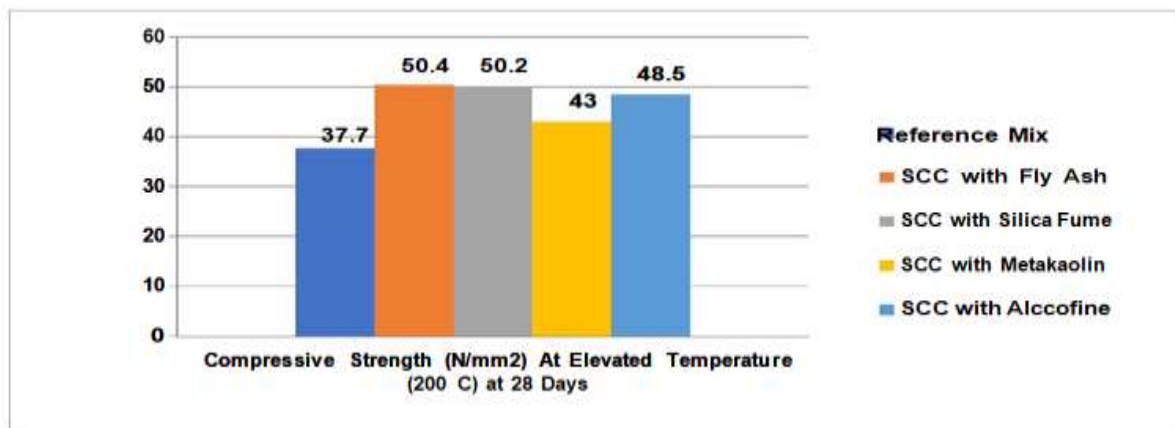


Figure 6.4 Compressive Strength of Different Mixes at Elevated Temperature (200°C) at 28 days

The comparison of Compressive Strength of SCC at 28 days at elevated temperature (300°C) is shown in the Figure 6.5, which clearly indicates that the maximum compressive strength of 62.5 N/mm² is achieved by the two mixes i.e. SCC with fly ash and SCC with Alccofine.

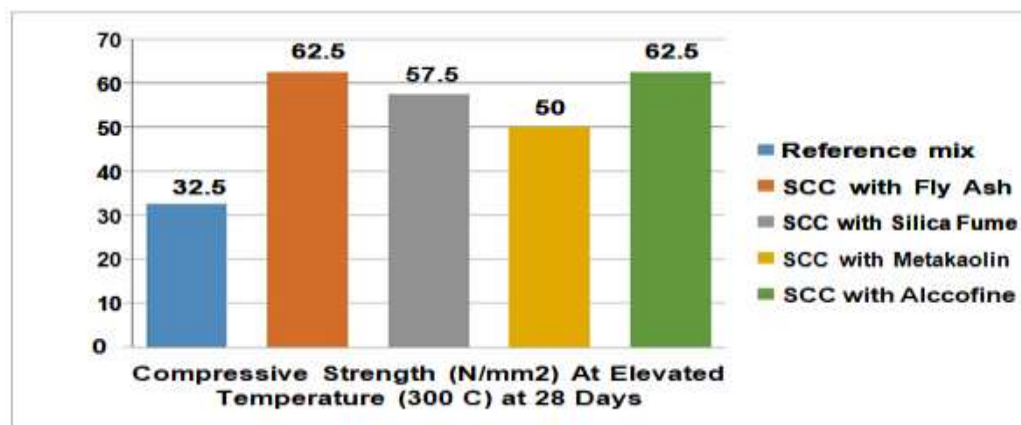


Figure 6.5 Compressive Strength of Different Mixes at Elevated Temperature (300°C) at 28 days

The comparison of Compressive Strength of SCC at 28 days at elevated temperature (400°C) is shown in the Figure 6.6, which clearly indicates that the maximum compressive strength of 64 N/mm² is achieved by SCC with silica fume.

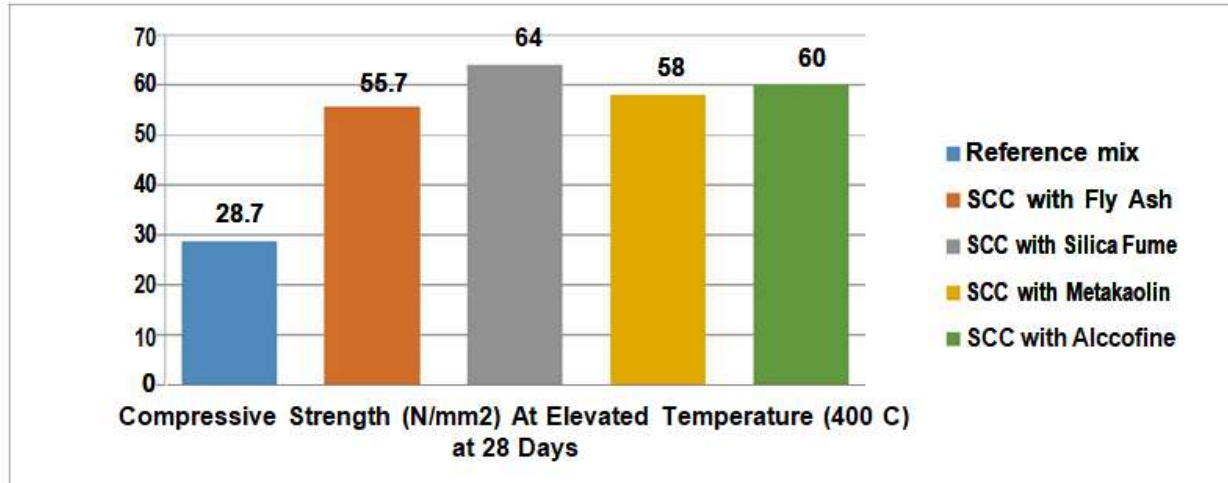


Figure 6.6 Compressive Strength of Different Mixes at Elevated Temperature (400°C) at 28 days

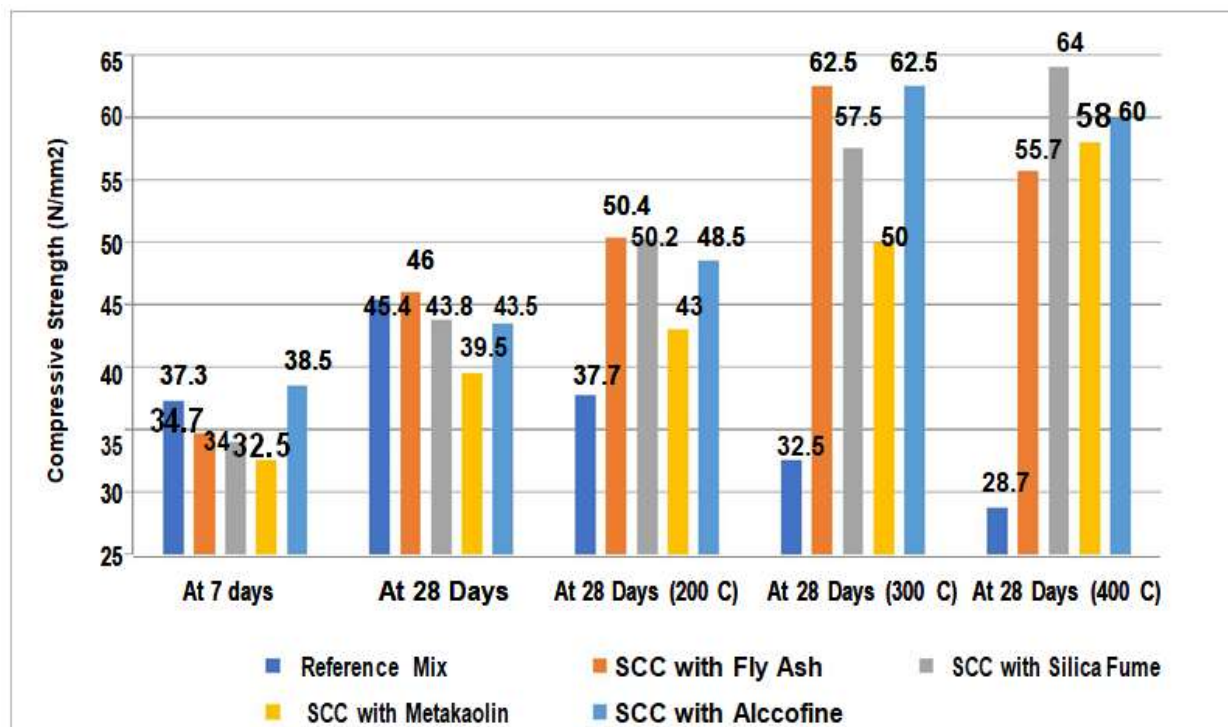


Figure 6.7 Comparison of Compressive Strength of all the SCC.

It demonstrates the correlation of compressive strength of SCC at 7days, 28 days (at normal temperature) and 28 days (at elevated temperature of 200°C, 300°C and 400°C). SCC with Fly ash show maximum compressive strength on 28 days curing at normal temperature, but on elevated temperature its compressive strength loss as the temperature **increased**. SCC with silica fume have maximum resistance toward elevated temperature up to 400°C.

I. CONCLUSIONS

Generally, it was noticed from results that most SCC mixtures had a higher resistance to elevated temperature up to 200°C than reference mx, while at 300°C and 400°C only the mix with silica fume resist the most against the high temperature. SCC with Silica fume compressive strength increase as the temperature rise up to 400°C. Thus, it is the best mixture which gave high resistance to elevated temperature.

7. REFERENCES

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