SELF COMPACTING CONCRETE

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ABSTRACT :-*Concrete is one of the most versatile and widely used construction materials. With the demand increasing for reinforced concrete structures in the modern society to meet the needs of new developments, increasing population and new ambitious structural design ideas, the reinforcement in concrete structures is becoming more dense and clustered.*

During the last decade, concrete technology has made an enormous advance through the introduction of self-compacting concrete (SCC). Self-compacting or self-consolidating concrete is a relatively new generation of high-performance concrete that is able to achieve impressive deformability and homogeneity in its fresh state, filling all the space around the reinforcement, passing through dense reinforcing steel bars while compacting under its own weight without any external vibration.

SCC with its outstanding properties, impressive deformability, gives designers and architects more freedom of creativity that was not possible previously. Lighter and slender members can be made from SCC, larger span bridges can be developed, and underwater structures can be built, making SCC a highly promising material for the future of the in-situ and pre-cast construction industries. Since its early use in Japan, SCC has now started to be an alternative to vibrated concrete across the world in such areas where normal vibrated concrete is difficult or impossible to pour and vibrate. However those applications are still few and vibrated concrete is still considered as the standard concrete. As more and more investigations are done into SCC, it is likely to move from being a fringe technology to becoming a concrete of choice for construction because of reduced health concerns, i.e. no vibration-induced noise.

Key words: Concrete, self-compacting, SCC, fibers, construction, vibration-induced noise.

1.INTRODUCTION

Concrete is one of the most versatile and widely used construction materials. With the demand increasing for reinforced concrete structures in the modern society to meet the needs of new developments, increasing population and new ambitious structural design ideas, the reinforcement in concrete structures is becoming more dense and clustered. The heavy and dense reinforcement can raise problems of pouring and compacting the concrete. The concrete must be able to pass the dense rebar arrangement without blocking or segregating. The design of such concrete is very challenging because poor placement and the lack of good vibratory compaction can lead to the inclusion of voids and loss of long term durability of concrete structures. This has been a concern for engineers for many years.

Depending on its composition, SCC can have a wide range of different properties; from a normal to an ultra-high compressive strength, from a poor to an extremely high durability. The mixture of SCC is strongly dependent on the composition and characteristics of its constituents in its fresh state. The properties of SCC in its fresh state have a great influence on its properties in the hardened state. Therefore it is critical to understand its flow behavior in the fresh state. Since the SCC mix is essentially defined in terms of its flow-ability, the characterization and control of its rheology is crucial for its successful production.

Compared with conventional concrete of similar mechanical properties, the greater material cost of SCC is due to the relatively high demand of cementitious materials and chemical admixtures, including high-range water reducing admixtures (HRWRS) and viscosity enhancing admixtures (VEAs). Typically, the content in cementitious materials can vary between 450 and 525Kg/m^{3}for SCC targeted for the filling of highly restricted areas and repair applications. Such applications require low aggregate volume to facilitate flow among restricted spacing without blockage and ensure the filling of the form work without consolidation. The incorporation of high volumes of finely ground powder materials is necessary to enhance cohesiveness and increase the paste volume required for successful casting of SCC. Concrete containing mineral admixtures is used extensively throughout the world for their good performance and for ecological and economic reason. The most common cementitious materials that are used as concrete constituents, in addition to Portland cement are flyash, ground granulated blast furnace slag (GGBS), silica fume and rice husk ash. They save energy, conserve resources and have many technical benefits. Metakaolin is a recent addition in the list of pozzolanic materials.

Fire resistance of concrete is highly dependent on its constituent materials, particularly the pozzolans. The effect of high temperature on concrete containing flyash or natural pozzolans has not been investigated in detail. When the concrete is subjected to a temperature of above 300 ^{o}C there is uniformity in opinion concerning a decrease in mechanical characteristics. However, strength reductions which have been reported in the literature reveal significant quantitative differences due to the variety of high temperature condition tested, and the variety of constituent materials of concrete used. It is recognized that the behavior of concrete subjected to high temperature is a result of many factors such as heating range, peak temperatures, dehydration of C-S-H gel, phase transformations, and thermal incompatibility between aggregates and cement paste. On the other hand, quality control of concrete, by means of non-destructive methods, in structures subjected to fire or not so high temperature exposure conditions, is not particularly easy o be carried out. Since human safety in case of fire is one of the major considerations in the design of buildings, it is extremely necessary to have a complete knowledge about the behavior of all construction materials before using them in the structural elements.

In this study, a general overview of the thermal properties and applications of SCC will be given, highlighting the influence of materials used on its characteristics in the fresh and hardened states. Finally, the testing methods of SCC in its fresh state will be summarized.

1.2 HISTORY OF DEVELOPMENT

In the mid-1980s, research undertaken into underwater placement technology within the UK, North America and Japan led to the development of concrete mixes with a high degree of washout resistance. However, the creation of durable structures from such mixes required adequate compaction by skilled workers. At the same time in Japan, a gradual reduction in the number of skilled workers in the construction industry was leading to a reduction in the quality of construction work, with subsequent knock-on effects on concrete durability (Okamura et al., 1998). One solution to overcome the durability problems in concrete structures independently of the quality of construction work was to use self-compacting concrete (SCC) (Okamura and Ouchi, 2003).

Its use was first proposed by Okamura (1986) who also conducted a fundamental study on the workability of SCC. The first prototype SCC was completed in 1988 at Tokyo University, using constituent materials readily used in conventional vibrated concrete (Ozawa et al., 1989). The main reasons for the employment of SCC were to shorten the construction time, to avoid vibrating the confined zones which are rather difficult to reach and to eliminate noise caused by vibration (Okamura and Ouchi, 2003).

“High Performance Concrete” and was defined as follows at three stages of concrete:

- ➢ Fresh: Self-Compactable
- ➢ Early age: avoidance of initial defects
- ➢ After hardening: Protection against external factors.

1.3 SELF-COMPACTING CONCRETE DEFINITION

The British Standard (BS EN 206-9, 2010) defines “SCC is the concrete that is able to flow and compact under its own weight; fill the formwork with its reinforcement, ducts, box outsect, whilst maintaining homogeneity”.

1.4 ADVANTAGES AND DISADVANTAGES OF USING SCC

- ✓ Simple inclusion even in complicated formwork and tight reinforcement.
- ✓ Higher installation performance since no compaction work is necessary which leads to reduced construction times, especially at large construction sites.
- ✓ Reduced noise pollution since vibrators are not necessary.
- ✓ Higher and more homogenous concrete quality across the entire concrete cross- section, especially around the reinforcement.
- ✓ Improved concrete surfaces (visible concrete quality)
- ✓ Typically higher early strength of the concrete so that formwork removal can be performed more quickly.
- ✓ SCC ensures a uniform architectural surface finish with little to no remedial surface work.
- ✓ Improved quality of concrete and reduction of onsite repairs.
- ✓ Faster construction times.
- ✓ Possibilities for utilization of “dusts”, which are currently waste products demanding with no practical applications and which are costly to dispose of.

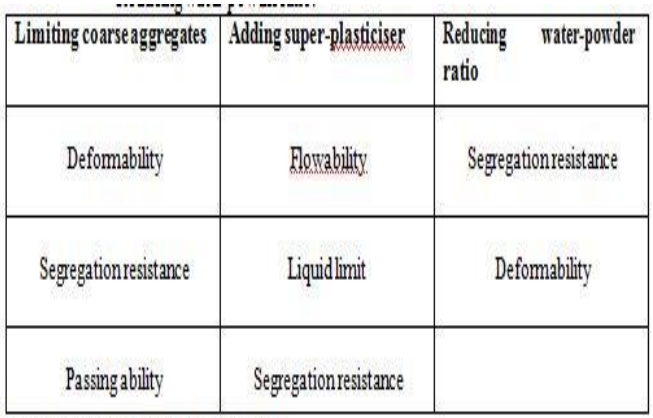
1.5 THE DISADVANTAGES OF SCC MAY INCLUDE:

- ✓ Increased material costs, especially for admixtures and cementitious materials (Which can be subsequently overcome by the low cost of labour)
- ✓ Increased formwork costs due to possibly higher formwork pressures. ü Increased technical expertise required to develop and control mixtures. ü Increased variability in properties, especially workability.
- ✓ Increased quality control requirements.
- ✓ Reduced hardened properties—possibly including modulus of elasticity and dimensional stability—due to factors such as high paste volumes or low coarse aggregate contents.
- ✓ Delayed setting time in some cases due to the use of admixtures.

2) MECHANISMS OF ACHIEVING SCC

In the fresh state, SCC should achieve high flow-ability as well as rheological stability which means it must be as fluid as possible in the fresh state to fill under its own weight all the far reaching corners in the form work and pass through heavy reinforcement without segregation. The methodology of selecting the right amount of materials and admixtures is crucial to achieve this goal. The following three main rules have been suggested by Okamura and Ouchi (2003):

- ✓ Limiting aggregate content.
- ✓ Using super-plasticizer.
- ✓ Reducing water-powder ratio.



Limiting coarse aggregates	Adding super-plasticiser	Reducing water-powder ratio
Deformability	Flowability	Segregation resistance
Segregation resistance	Liquid limit	Deformability
Passing ability	Segregation resistance	

Mechanisms of achieving self-compactability

2.1HIGH AMOUNT OF SUPER-PLASTICIZER:

Achieving a highly flowable mix would conflict with keeping the homogeneity at an acceptable level. The mechanism of achieving this is by the dispersion effects of super- plasticizer on flocculated cement particles, by reducing the attractive forces among them. An optimum amount is necessary as a high amount would result in segregation and a low amount would compromise the fluidity.

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It is consumed by those increased internal stresses, resulting in blockage. Also, paste with high viscosity prevents localized increases in internal stresses due to the approach of coarse aggregate particles. A high amount of fine particles increases the workability and cohesiveness while simultaneously reducing the interlocking of coarse particles which could result in a blocking behaviour (Khayat, 2000). The necessity of including this large amount of fines requires that there should be cement replacement.

3. USING VISCOSITY MODIFYING AGENTS (VMA):

These products are generally cellulose derivatives, polysaccharides or colloidal suspensions. The use of VMA gives the same effect as the fine particles in minimizing bleeding and coarse aggregate segregation by thickening the paste and retaining the water in the skeleton. For normal strength SCC with high water to binder content, the introduction of such products seems to be justified. On the other hand, they may be less useful for high performance SCC with low water to binder ratio. Viscosity agents are assumed to make SCC less sensitive to water variations. Because of the small quantities of viscosity agents required, however, it may be difficult to achieve accuracy of dosage (Tviksta, 2000).

3.1 APPLICATION OF SELF COMPACTING CONCRETE BURJ DUBAI:

The Burj Dubai structure represents the state- of-the-art in super high-rise buildings. During its construction the most recent accomplishments in all fields have been united, including concrete production technology. Several different concrete mixes tower, podium and office annex excluding foundations.

The designed concretes were obtained using Portland cement combined with silica fume, fly ash or ground slag. As a result, different materials having high density and high final strength were obtained (concrete C50 was built-in into floor structures and C60 and C80 into vertical load-bearing members).

2.5 EFFECTS OF SUPER-PLASTICIZERS (SP) ON SCC

The hardened properties of self-compacting concrete are affected by its fresh behavior which is dominated primarily by the dispersing of its components. With conventional concrete the cement particles group together to form flocs and therefore internal friction occurs within the mix, hindering its flow-ability as the particles will not be able to flow past each other with ease.

Super-plasticizers or high-range water-reducing admixtures (HRWRAs) contribute to the achievement of denser packing and lower porosity in concrete by increasing the flow-ability and improving the hydration through greater dispersion of the cement particles, and thus assisting in producing SCCs of high strength and good durability.

4. EXPERIMENTALINVESTIGATION

Compressive Strength Test

To know the reduction of the compressive strength the following procedure to be adopted.

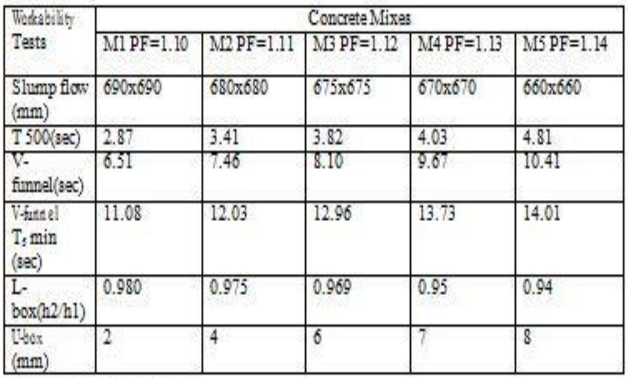
Apparatus:

Pan Mixer, Muffle furnace of capacity 1100oC, Compression testing machine, Stop watch and Weigh balance were used.

Procedure:

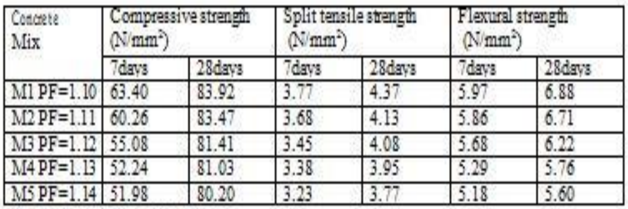
Prepare the cubes of 100X100mm in size as per standard methods for the above mentioned mix proportions in Table. 3.4. Remove he specimens from moulds after 48 hours for HSSCC and after 24 hours for HSVC. Place the specimens in submerged water for curing submerged in clear fresh water about 28 days. Remove the specimen from water after specified curing time and wipe out excess water from the surface. Take the dimension of the specimen to the nearest 0.2m & Weigh each specimen before heating and after heating .Heat the specimens in muffle furnace to the testing temperatures of 1000C, 2000C, 4000C& 6000C and maintain constant temperature to required testing duration hours (i.e., 1hr, 2hrs, 3hrs, 4hrs& 6hrs).Allow to cool the specimens under normal conditions until they gains to room temperature. Clean the bearing surface of the testing machine. Place the specimen in the compressive testing machine in such a manner that the load shall be applied to the opposite sides of the cube cast. Align the specimen centrally on the base plate of the machine. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load gradually without shock and continuously at the rate of 140kg/cm2/minute till the specimen fails. Record the maximum load and note any unusual features in the type of failure. For each set test at least three Specimens are to be tested under normal temperature and as well as after heating to required temperature (i.e., at 1000C, 2000C, 4000C and 6000C) also. Compressive strength of the specimen can be calculated by using following expression:

$$\text{Compressive strength} = \frac{\text{Load at failure (N)}}{\text{area of the specimen(mm2)}} = \text{(MPa)}$$



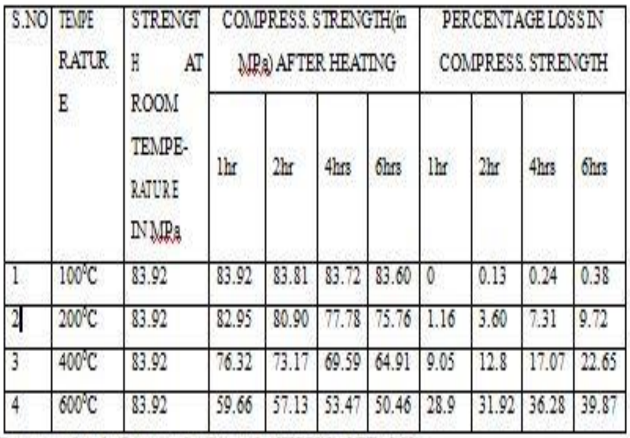
Workability Tests	Concrete Mixes				
	M1 PF=1.10	M2 PF=1.11	M3 PF=1.12	M4 PF=1.13	M5 PF=1.14
Slump flow (mm)	690x690	680x680	675x675	670x670	660x660
T 500(sec)	2.87	3.41	3.82	4.03	4.81
V-funnel(sec)	6.51	7.46	8.10	9.67	10.41
V-funnel T_5 min (sec)	11.08	12.03	12.96	13.73	14.01
L-box(h2/h1)	0.980	0.975	0.969	0.95	0.94
U-box (mm)	2	4	6	7	8

Fresh state properties of HSSCC



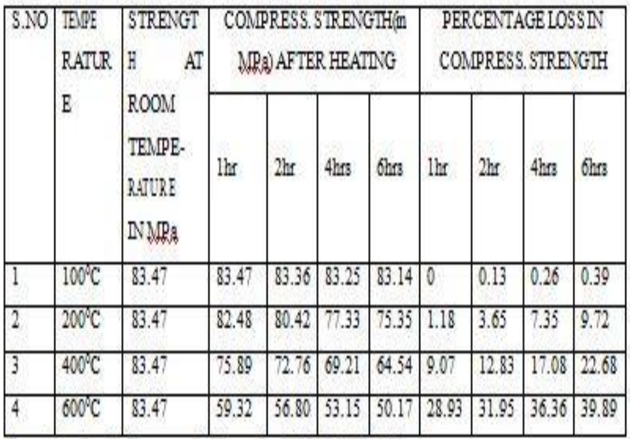
Concrete Mix	Compressive strength (N/mm^2)		Split tensile strength (N/mm^2)		Flexural strength (N/mm^2)	
	7days	28days	7days	28days	7days	28days
M1 PF=1.10	63.40	83.92	3.77	4.37	5.97	6.88
M2 PF=1.11	60.26	83.47	3.68	4.13	5.86	6.71
M3 PF=1.12	55.08	81.41	3.45	4.08	5.68	6.22
M4 PF=1.13	52.24	81.03	3.38	3.95	5.29	5.76
M5 PF=1.14	51.98	80.20	3.23	3.77	5.18	5.60

Mechanical Properties of HSSCC



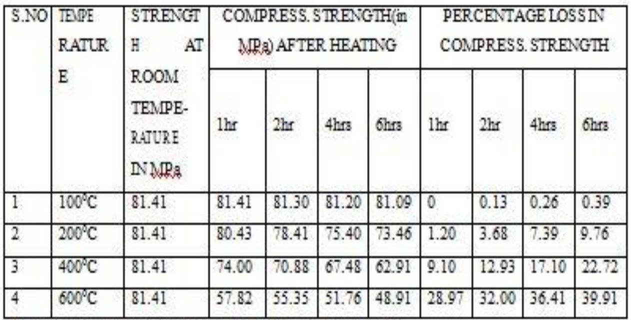
S.NO	TEMPERATURE	STRENGTH AT ROOM TEMPERATURE IN MPa	COMPRESS. STRENGTH(in MPa) AFTER HEATING				PERCENTAGE LOSS IN COMPRESS. STRENGTH			
			1hr	2hr	4hrs	6hrs	1hr	2hr	4hrs	6hrs
1	100°C	83.92	83.92	83.81	83.72	83.60	0	0.13	0.24	0.38
2	200°C	83.92	82.95	80.90	77.78	75.76	1.16	3.60	7.31	9.72
3	400°C	83.92	76.32	73.17	69.59	64.91	9.05	12.8	17.07	22.65
4	600°C	83.92	59.66	57.13	53.47	50.46	28.9	31.92	36.28	39.87

Percentage loss in Compressive Strength of HSSCC of (PF =1.10)



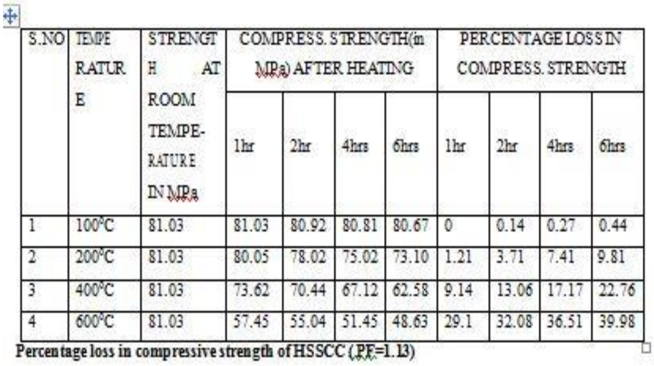
S.NO	TEMPERATURE	STRENGTH AT ROOM TEMPERATURE IN MPa	COMPRESS. STRENGTH(in MPa) AFTER HEATING				PERCENTAGE LOSS IN COMPRESS. STRENGTH			
			1hr	2hr	4hrs	6hrs	1hr	2hr	4hrs	6hrs
1	100°C	83.47	83.47	83.36	83.25	83.14	0	0.13	0.26	0.39
2	200°C	83.47	82.48	80.42	77.33	75.35	1.18	3.65	7.35	9.72
3	400°C	83.47	75.89	72.76	69.21	64.54	9.07	12.83	17.08	22.68
4	600°C	83.47	59.32	56.80	53.15	50.17	28.93	31.95	36.36	39.89

. Percentage loss in Compressive Strength of HSSCC(PF=1.11)



S.NO	TEMPERATURE	STRENGTH AT ROOM TEMPE-RATURE IN MPa	COMPRESS. STRENGTH(in MPa) AFTER HEATING				PERCENTAGE LOSS IN COMPRESS. STRENGTH			
			1hr	2hr	4hrs	6hrs	1hr	2hr	4hrs	6hrs
1	100⁰C	81.41	81.41	81.30	81.20	81.09	0	0.13	0.26	0.39
2	200⁰C	81.41	80.43	78.41	75.40	73.46	1.20	3.68	7.39	9.76
3	400⁰C	81.41	74.00	70.88	67.48	62.91	9.10	12.93	17.10	22.72
4	600⁰C	81.41	57.82	55.35	51.76	48.91	28.97	32.00	36.41	39.91

Percentage loss in Compressive Strength of HSSCC(PF=1.12)



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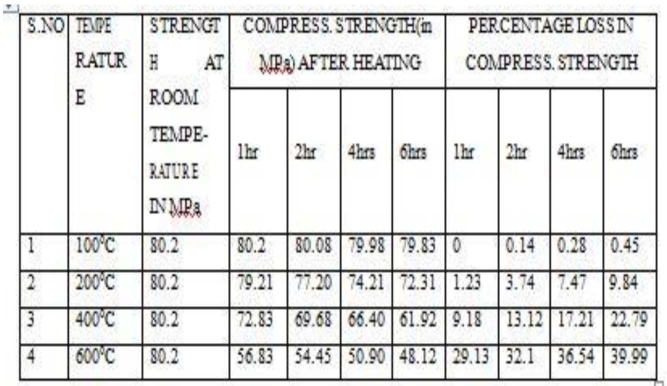
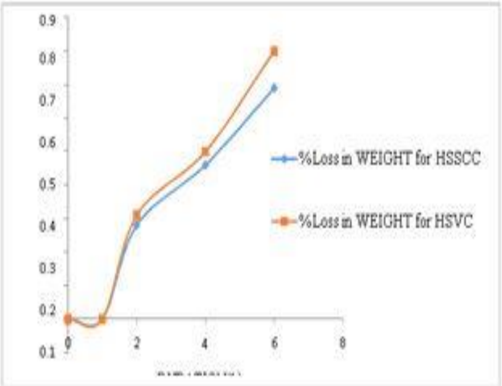
			1hr	2hr	4hrs	6hrs	1hr	2hr	4hrs	6hrs
1	100⁰C	81.03	81.03	80.92	80.81	80.67	0	0.14	0.27	0.44
2	200⁰C	81.03	80.05	78.02	75.02	73.10	1.21	3.71	7.41	9.81
3	400⁰C	81.03	73.62	70.44	67.12	62.58	9.14	13.06	17.17	22.76
4	600⁰C	81.03	57.45	55.04	51.45	48.63	29.1	32.08	36.51	39.98

Percentage loss in compressive strength of HSSCC (PF=1.13)



S.NO	TEMPERATURE	STRENGTH AT ROOM TEMPE-RATURE IN MPa	COMPRESS. STRENGTH(in MPa) AFTER HEATING				PERCENTAGE LOSS IN COMPRESS. STRENGTH			
			1hr	2hr	4hrs	6hrs	1hr	2hr	4hrs	6hrs
1	100⁰C	80.2	80.2	80.08	79.98	79.83	0	0.14	0.28	0.45
2	200⁰C	80.2	79.21	77.20	74.21	72.31	1.23	3.74	7.47	9.84
3	400⁰C	80.2	72.83	69.68	66.40	61.92	9.18	13.12	17.21	22.79
4	600⁰C	80.2	56.83	54.45	50.90	48.12	29.13	32.1	36.54	39.99

Percentage loss in compressive strength of HSSCC (PF=1.14)



Comparative Graphical Representation of Percentage Weight loss of HSSCC (at PF=1.14) and HSVC (at 0.30w/c).

DISCUSSIONS

During the last decade, concrete technology has made an enormous advance through the introduction of self-compacting concrete (SCC). Self-compacting or self-consolidating concrete is a relatively new generation of high-performance concrete that is able to achieve impressive deformability and homogeneity in its fresh state, filling all the space around the reinforcement, passing through dense reinforcing steel bars while compacting under its own weight without any external vibration.

Concrete at elevated temperatures, undergoes significant physicochemical changes. These changes cause properties to deteriorate at elevated temperatures and influence additional complexities such as spalling in HSSCC. Thus thermal, mechanical and deformation properties of concrete change substantially within the temperature range associated with building fires.

In this present study attempt has been made to study the effect of elevated temperature on the performance of high strength self- compacting concrete at different temperatures for different durations. To achieve the objective different mix proportions with constant water cement Ratio (0.25) and different Packing Factors of 1.10 to 1.14 were considered. For the above mixes investigations done on residual compressive strength and weight loss test at different temperatures (from room temperature to 600^{0}) for different durations (i.e., from 1hour to 6hours).

CONCLUSIONS

- ✓ From the results presented in this paper using M70 self- compacting concrete with different Packing Factors for constant water cement ratio, the main conclusions are Required minimum slump is achieved for a Packing Factor of 1.14 with minimum strength for M70 grade high strength self- compacting concrete.
- ✓ Maximum strengths are achieved for a Packing Factor of 1.10 with optimum slump for M70 grade high strength self -compacting concrete.
- ✓ These values are obtained for a Water Cement ratio of 0.25 with addition of 7% micro silica.
- ✓ It is observed that when Packing Factor is less than 1.10 the mix requires more binders there by affecting the workability. Whereas when Packing Factor is more than 1.14 the required strengths and workability are not achieved.
- ✓ There is an increase in compressive strength with decrease in packing factor.

All the workability factors for SCC are improved with decrease in packing factor from 1.14 to 1.10.

Scope for further work

- Based on the present study, the following aspects have been suggested for further study.
- The present study was conducted by using Fly ash and Micro silica as mineral admixtures. Further study can be extended for HSSCC with, Rice husk ash, Metakolin and Micro silica as mineral admixtures.
- Further the study can be extended by designing the concrete with different types of aggregates as the retention in mass of concrete at elevated temperatures is highly influenced by the type of aggregate.
- Further the study can be extended on study of micro structure by using SEM and X-ray analysis.

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