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Investigational Study on Strength of SCC by adding Nano Silica with Metakaolin as Replacement for Cement

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Abstract
In the past few years, the use of Self Compacting Concrete (SCC) is growing tremendously and much research and modification have been done to produce self-compacting concrete which has the desired characteristics. There is a current trend in all over the world to utilize treated and untreated industrial by-products, domestic wastes, etc. as raw materials in concrete. These not only help in the reuse of the waste materials but also create a cleaner and greener environment. The present study focuses on the utilization of metakaolin and nano-silica in SCC. Reinforced concrete construction exposed to harsh environments such as chloride-bound air causes deterioration in concrete through its pore structure by corroding the steel bar. The use of pozzolanic material i.e. metakaolin (MK), nano-silica (NS) can be used as a partial cement replacing material that not only reduces the pores in concrete but improves the mechanical, durability properties, and microstructure of concrete. In this project, work was done on an experimental study on fresh and hardened properties such as flowability, passing ability, compressive strength, split tensile, flexural strength of SCC. In this work, SCC was made by partially replacing cement with both metakaolin and nano-silica. Five mixes with different percentages of Metakaolin (0%, 5%, 10%, 15% and 20%) and nano-silica (0%, 0.5%, 1.0% and 1.5%) as partial replacement for cement is considered. For each mix workability and hardened tests are carried and the test results for hardened properties are carried out at 7, 28, and 91 days respectively. The obtained results are discussed and finally, conclusions are made accordingly

Keywords: Self Compacting-Concrete, Nano silica, Metakaolin, Rheological characteristics, Mechanical properties, Pore Structures.

1.1 History of SCC

SCC was developed in Japan, beginning in 1983, has been focused on theelimination of poor compaction which was identified as a major cause of poor durabilityof concrete structures by Ouchi, (1998). Motivated by a lack of skilled workers and asubstantial number of durability damages due to insufficient compaction, Okamuraannounced in 1986 the necessity to employ SCC, which can be compacted into everycorner of a formwork, purely employing its weight and without the need forvibrating compaction by Okamura and Ozawa.

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1.2 Introduction: The advance of new technology in material science is progressing rapidly, In the last three decades, a lot ofstudies was carried out all around the globe to improve the performance of concrete in terms of strength and durability qualities. Concrete technology has undergone from macro to micro-level study in the enhancement of strength and durability properties from the 1980"s onwards. Till 1980 the research study was focused only on to flowability of concrete, to enhance the strengths however, durability did not draw a lot of attention of the concrete technologists. This type of study has resulted in the development of SCC, a much-needed revolution in the concrete industries. SCC is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of formwork under its self-weight by Okamura (1997). Thus SCC eliminates the need for vibration either external or internal for the compaction of the concrete without compromising its engineering properties. SCC is a fluid mixture, which is suitable for placing difficultconditions and also in congested reinforcement, without vibration. In principle, a self–compacting or self – consolidating concrete must have the following properties.

2.0 Literature review:

A literature review has been done to get an over review of the project of the subject and analysis the research gap for the research. The objective for the study has been framed by considering the research gap from the literature review.

Prof. R.V.R.K. PRASAD et.al(2012) In the present investigation on "Experimental investigation of the use of micro silica in self-compacting concrete" This paper is described the Project in detail and presents laboratory observation. Microsilica is used as a 10% replacement of cement by weight. Various tests were conducted on fine aggregate & coarse aggregate, to determine specific gravity, bulk density, fineness modulus of aggregate, concrete mix proportion design using this parameter.

B. KARTHIKEYAN et.al (2014) In the present investigation on "Microstructural analysis of strength properties of concrete with nano-silica" the study reports part of the experimental investigations on using nano-sized mineral admixtures in concrete as a partial replacement of cement. Mechanical properties were obtained by performing strength tests for specimens cast with different percentages of ground and unground micro-silica in partial replacements such as 5%, 10% and 15% by weight of cement. From the results, it is understood that cubes cast with 10% replacement of nano-silica for cement by weight are showing better strength performance.

M.IYAPPAN.et.al(2014)present an investigation report on "high strength self-compacting concrete with nano-silica" This article presents the benefits of SCC with Nano silica, nano-silica used as partial replacement of Portland cement in Self-compacting concrete with different percentage, fresh and hardened properties of SCC are established. There are three different replacement percentages of Nanosilica (0%,2%,4%,6%) is used in this study. The Hardened Properties like compressive strength, splitting tensile strength, Flexural strength were evaluated at 28 days.

Dr. D .V. PRASADA RAO et.al(2014) In the present experimental investigation "A study on the influence of fly ash and nano-silica on strength properties of SCC"the cement is partially replaced by 20% and 30% of Fly Ash and Nano-Silica 1.5%, 3% and 4.5% by weight. The influence of the combined application of Fly Ash and Nano-Silica on compressive strength, split tensile strength, flexural strength, and modulus of elasticity of M25 grade of concrete is established.

A.HEIDARI et.al(2015)study on "Properties of Self-compacting concrete incorporating alginate and nano-silica" This paper presents an experimental study on the properties and the durability of self-compacting concrete (SCC) containing alginate in variety values with artificial stone resin, micro, and nano-silica. The values of 0.5 and 1% alginate, 10% micro silica, 0.5% nano-silica and 0.5% artificial stone resin are used. . Properties of hardened SCC such as compressive, split tensile, flexural strength and water absorption are assessed and represented graphically.

SANGA KRANTHI KUMAR et.al (2015) In the present investigation on "Influence of nano-silica on strength and durability of self-compacting concrete" In this work 40Mpa self-compacting concrete is developed using modified Nan-Su method of mix design. Specimens of dimensions 150x150x150mm were cast without nano-silica and with two different grades of nano-silica which is in a colloidal state with 16% and 30% nano, content is added in different percentages(1%, 1.5%, and 2% by weight of cement) to SCC.

2.1 Main objectives of present investigation:

Based on exhaust relevant literature review, the main objectives derived is as follows,

1. Development of SCC mixes using metakaolin with nano-silica
2. Study of fresh and hardened properties of developed SCC mixes in the laboratory.

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3. Comparison of results of developed mixes with Control Mix.

3.0 Methodology

The present investigation is to design M40 grade SCC by using relevant guidelines (EFNARC). Further developed mixes are studied both for rheology as well as hardened properties, both for normal SCC and replacement of cement by metakaolin with nano-silica. The Methodology consists of three phases; the first phase covers the design of SCC mixes by using a suitable mix design method as per the literature review. The second phase covers the achievement of desired design SCC mix by doing a trial and error procedure by satisfying all the rheological characteristics. The third phase covers the study of hardened properties of developed SCC mixes in the laboratory. Further, it is planned to chalk out the program for casting several cubes and cylinders. The mix design planned is a modified Nan-us method because it is flexible when compared to other methods of mix design. The percentage replacement of metakaolin is chosen in the range from 10% and three different additive percentages of Nanosilica (0%, 0.5%, 1.0%, 1 .5%).

3.1 Different test were conducted for OPC 53 grade cement,metakaolin, Nanao silica, fine aggregate, coarse aggregate, water as specified by relevant IS Codes

3.1.1 Cement: The cement used for the investigation was Ordinary Portland cement (OPC) 43grade with specific gravity 3.13 and fineness 4% was used. It confirmed the requirements of Indian Standard Specification IS: 269 2015.

3.1.2 Fine aggregate:M.sand was used as fine aggregate and tests were conducted on fine aggregate to determine physical properties a per IS 383-2.16. The specific gravity of fine aggregate 2.65and belongs to zone II. The fineness modulus was found to be 2.85.

3.1.3 Coarse Aggregates: The maximum size of aggregate is generally limited to 20mm. The aggregate of size 12 mm is desirable for structures having congested reinforcement. The properties of coarse aggregate are specific gravity 2.80, fineness modules 7.06 and water absorption was 0.48%

3.1.4 Water: Ordinary potable water of normally pH 7 is used for mixing and curing the concrete specimen.

3.1.5 Superplasticizer: In the present study by using **CONPLAST SP430** is used because it is an essential component of SCC to provide necessary workability. The specific gravity -1.25

3.1.6 Nano Silica: The specific gravity of nano-silica is 1.03, and they are silica particles with a maximum size of 10 nm, In addition, nano-silica is a water emulsion with 50 % dry solid and PH of 10. The control mix was excluding nano-silica. It is obtained from Astro chemicals, Chennai.

Table 2.1: Properties of Nano silica

Solid content (SiO2-content)	50 wt %
Density	1.4 g/cm3
Ph	9.5
Viscosity	<15cPS
Specific surface Area m^2/gm	650

3.1.7 Metakaoline:-Metakaolin is an artificial pozzolana produced by burning selected kaolinite clay within a specific temperature range (between 650 and 800 C). When heated to 700–900 C, kaolin becomes calcined, losing up to 14% hydroxyl water and changing into MK.The specific gravity of 2.5 and lime reactivity 780mg$Ca(OH)_2$. It is obtained fromAstro chemicals, Chennai.

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Table 2.2: Chemical properties of metakaolin.

Constituents	Percent
CaO	0.78
SiO_2	52.68
Al_2O_3	36.34
Fe_2O_3	2.14
MgO	0.16
SO_3	-
K_2O	0.62
Na_2O	0.26
LOI	0.98
Specific Gravity	2.5
BET Fineness (m^2/kg)	12000

3.2 Mix proportion

Ten different mixes were employed to examine the influence of incorporation of both MK and NS in SCC on compressive strength and splitting tensile strength .the mix was designed for 40MPa and water-cement ratio 0.40. The design mix ratio found by the Nan-Su method is then used to develop SCC by trial mixes. The developed mixes should satisfy the fresh property as per EFNARC guidelines. The ratio which satisfies all criteria of EFNARC is a final developed ratio which the cement is replaced with Metakaolin by (5%,10%&15%) and Nano Silica is an additive by weight of cement is90.5-1.5%) at the interval of 0.5% for the optimum mix and further fresh and hardened properties are to be studied.

For Conventional mix and allSCC mixes the cement content is (400 kg/m^3 varies replacement MK and additive of NS) with a quantity of fine aggregate, coarse aggregate, water content, and water to binder ratio will remain constant (fine aggregate 910Kg/m^3, coarse aggregate,910Kg/m^3, water 160 ka/m^3). The optimum dosage of superplasticizer is found out by conducting marsh cone test and found as 1%.detials are given in Table.3.1

Table 3.1:Cementitious Materials of SCC

Mix proportions	Cement replacement and additive		
	Cement (kg)	Metakaolin (gms)	Nano silica (gms)
NOMINAL MIX	400	-	-
5%MK+0.5%NS	380	20	2
5%MK+1.0%NS	380	20	2
5%MK+1.5%NS	380	20	2
10%MK+0.5%NS	360	40	4
10%MK+1.0%NS	360	40	4
10%MK+1.5%NS	360	40	4
15%MK+0.5%NS	340	60	6
15%MK+1.0%NS	340	60	6
15%MK+1.5%NS	340	60	6

3.3 Casting, Curing, and Testing of Specimens

All the mixes are tested for workability. The workability of various SCC mixes was assessed by determining the fresh properties as per EFNARC guidelines (Slump Flow, T_{50} slump flow, V-funnel, and J-ring tests) as well as the hardened concrete properties such as compressive strength and splitting tensile strength test. In case of strength

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study, A 90 each specimen were demoulded after 24 hours of a castin and then kept in a curing tank for water curing till test ages are reached.

4.0 Results and Discussion: The results are evaluated in the present investigation are reported in the form of tables and Graphs. The test results of materials, trial mixes arrived, fresh properties of SCC, hardened properties of SCC for various percentages of MK as a partial replacement to cement ranging from 5 to 15% at an interval of 5% and additive of NS (0.5%- 1.5%) are worked out.

4.1 Fresh properties of SCC: The fresh self-compacting concrete properties were observed using a filling ability, passing ability, and segregation resistance of different mixes in the laboratory .as given in table 4.1

(i) Filling ability: SCC must flow into forms and around obstacles such as reinforcing steel under only the force of gravity. This does not mean that all SCC is self-leveling.

(ii) Passing ability (resistance to blocking): SCC must pass through various obstacles and fill open spaces in the formwork without blockage due to aggregates being restricted from passing through narrow openings.

(iii) Stability (segregation resistance): SCC must have dynamic stability by remaininghomogenous throughout mixing, transportation, placing, and have static stability during finishing and curing.

Table 4.1: Fresh properties of SCC

Mix Notions	Slump flow	T50 Slump	v-funnel	J ring
Range of Suggested Valve	**(650-800mm)**	**(2-5 sec)**	**(6-12 sec)**	**(0-10 sec)**
NOMINAL MIX	675	3.45	9.47	6
5%MK+0.5%NS	673	3.34	8	7
5%MK+1.0%NS	670	3.12	7.5	5
5%MK+1.5%NS	699	3.04	9	6
10%MK+0.5%NS	696	2.97	10	7
10%MK+1.0%NS	693	2.90	11	8
10%MK+1.5%NS	692	2.82	12	6
15%MK+0.5%NS	687	3.45	10	4
15%MK+1.0%NS	683	3.34	8	5
15%MK+1.5%NS	678	3.12	9	6

4.2 Cube Compressive Strength

The concrete cube specimen of size 150mm×150mm×150mm was tested for each mix with replacement and without replacement, The test was according to IS Specifications and done on the 7^{th},28^{th}, and 90^{th} days of casting. Table 4.2 shows the compressive strength gained with age. [4] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller.This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased

Table 4.2: Comparisons between 7, 28 & 91 days Compressive Strength

Mix Proportions	**Compressive strength (MPa)**		
	7 days	**28 days**	**91 days**
NOMINAL MIX	18.05	41.98	50.35
5%MK+0.5%NS	19.32	43.25	51.99
5%MK+1.0%NS	20.32	45.23	52.08
5%MK+1.5%NS	20.98	47.63	52.17
10%MK+0.5%NS	25.58	47.98	52.27
10%MK+1.0%NS	26.76	48.20	52.48

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10%MK+1.5%NS	27.27	48.83	52.58
15%MK+0.5%NS	28.15	49.59	53.26
15%MK+1.0%NS	28.74	49.71	53.49
15%MK+1.5%NS	29.35	50.03	53.94

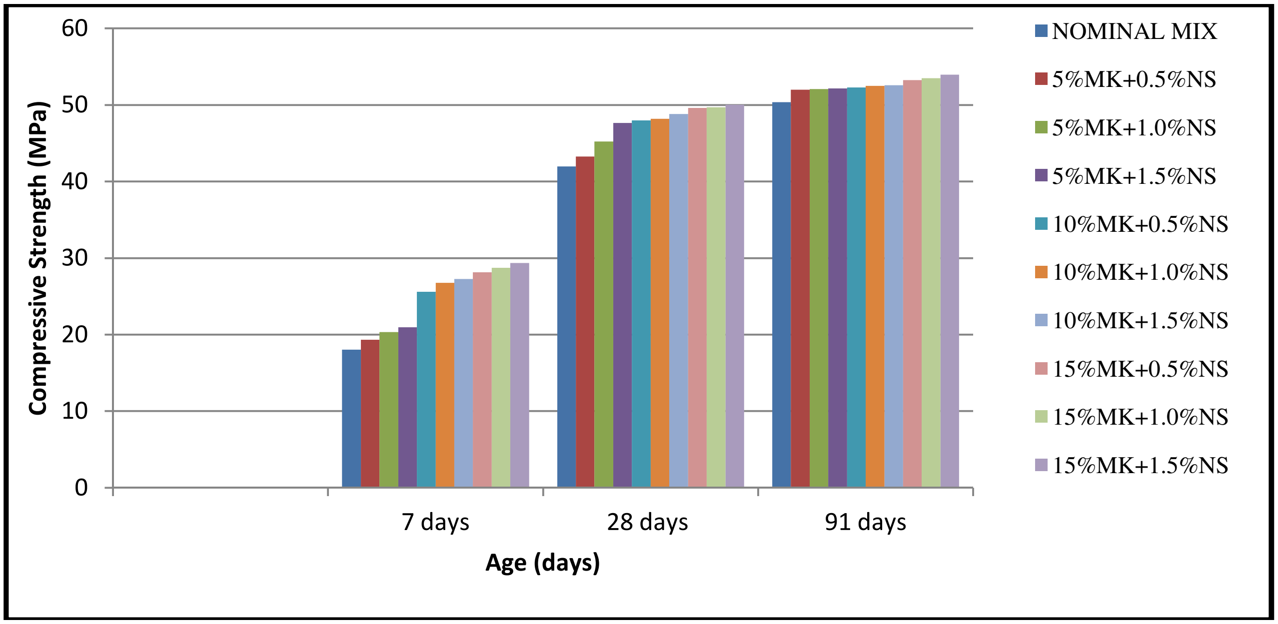

Fig.4.1 Graph of variation of compressive strength versus age in days.

Observations: From **Fig.4.1,** it is observed that acomparison of 7, 28 &90 dayscompressive strength versus age, the control SCC mixes compared to MK and NS based mixes with replacement levels of MK and NS by weight of cement respectively. Further replacement levels of MK and NS in the ranges of 5-15% and 0.5%-1.5% for various ages are presented in the form of bar charts. Hence it is observed that the variation of compressive strength is lower in the case of Nominal mixes and marginally higher in the case of MK and NS-based mixes in all cases. Also, it is noted that there is a marginally increase in strength15%MK+1.5%NS at a higher age than compared to lowerages.

4.3 Split Tensile Strength

The split tensile strength is the tensile strength of concrete determined indirectly bysplitting a concrete cylinder specimen across its vertical diameter. Table 4.3 shows the variation of split tensile strength with replacement of metakaolin and addition of nano-silica content at 7, 28, and 91 days respectively.

Table 4.3: Comparisons between 7, 28 & 91 days Split Tensile Strength

Mix Proportions	Split Tensile Strength (MPa)		
	7days	**28days**	**91 days**
NOMINAL MIX	2.69	3.46	4.60
5%MK+0.5%NS	2.95	3.47	4.64
5%MK+1.0%NS	3.20	3.51	4.68
5%MK+1.5%NS	3.37	3.54	4.70
10%MK+0.5%NS	3.40	3.57	4.73
10%MK+1.0%NS	3.41	3.58	4.74
10%MK+1.5%NS	3.42	3.70	4.76
15%MK+0.5%NS	3.43	3.96	4.78
15%MK+1.0%NS	3.44	4.15	4.89

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15%MK+1.5%NS	3.45	4.52	5.01

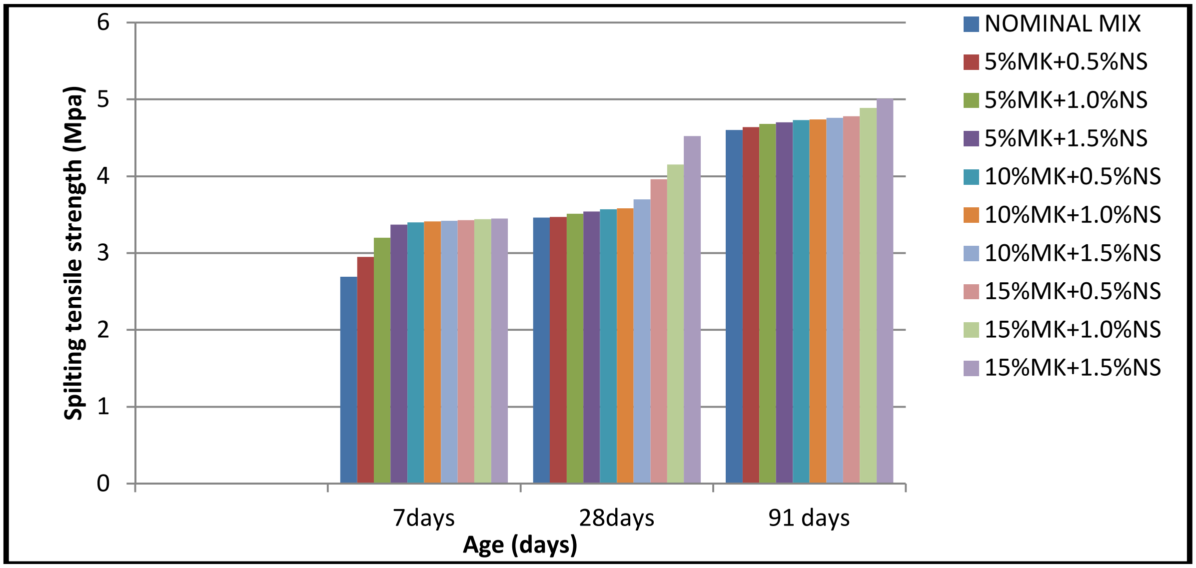

Fig.4.2 Graph of variation of splitting tensile strength versus age in days.

Observations: From Fig.4.2,it is observed that a comparison of 7, 28 &90 dayssplitting tensile strength versus age in days, the control SCC mixes compared to MK and NS based mixes with replacement levels of MK and NS by weight of cement respectively. Further replacement levels of MK and NS in the ranges of 5-15% and 0.5%-1.5% for various ages are presented in the form of bar charts. Hence it is observed that the variation of compressive strength is lower in the case of Nominal mixes and marginally higher in the case of MK and NS-based mixes in all cases. Also, it is noted that there is a marginally increase in strength 15%MK+1.5%NS at a higher age than compared to lowerages.

5.1 Conclusions

Based on the laboratory investigation the following important conclusions have arrived.

- SCC mixes require high powder content and a high range of superplasticizer dosage to achieve good rheological properties of SCC.
- The time of addition of superplasticizer is very important and it is generally added after the addition of 50-70% of water.
- SCC fills the formwork and encapsulates the reinforcements without vibration, to achieve compaction by its own weight and gives an excellent surface finish.
- Based on test results, cement can be replaced by the blend of NS and MK up to 15% without affecting the strength of the mixes.
- It is observed that compressive strength increases up by increasing the replacement of cement by adding 1.5% NanoSilica and 15% Metakoline.
- It is experimental observations have been made by using NanoSilica to improve the porosity of the developed concrete mix.
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References

[1]. M .Iyappan. “high strength self compacting concrete with nano silica”International Journal of Emerging Trends in civil engg.

[2]. Sanga kranthi kumar “Influence of nano silica on strength and durability of self compacting concrete” International Journal of Advanced and Applied Sciences

[3].B. H. Venkataram Pai, Maitreyee Nandy, A. Krishnamurthy, Pradip Kumar Sarkar,C. Pramukh Ganapathy,

Philip George "Development of self compacting concrete with various mineral admixtures",

[4]. Christo Ananth, M.A.Fathima, M.Gnana Soundarya, M.L.Jothi Alphonsa Sundari, B.Gayathri, Praghash.K, "Fully Automatic Vehicle for Multipurpose Applications", International Journal Of Advanced Research in Biology, Engineering, Science and Technology (IJARBEST), Volume 1,Special Issue 2 - November 2015, pp.8-12.

[5]. Dr. D .V. Prasada rao (2014) "A study on influence of fly ash and nano silica on strength properties of SCC".IJART,Issn 0976 - 6480 (Print) ,ISSN 0976 - 6499 (Online)Volume 5, Issue 7, July (2014), pp. 94-102

[6]. B. Karthikeyan et.al (2014) "Microstructural analysis of strength properties of concrete with nano silica" International Journal of ChemTech Research CODEN (USA): IJCRGG, Vol.6, No.5, pp 3004-3013

[7]. Prof. R.V.R.K. Prasad et.al(2012) "Experimental investigation of use of microsilica in self compacting concrete" Indian Streams Research Journal Vol.2,Issue.IV/May; 12 pp.1-4.

[8]. Ozawa K., and Maekawa, K, (1989), "Development of high performance concrete based on durability design of concrete structure," Proceeding of the Second East- Asia and Pacific Conference (EASEC-2), Vol.1, pp.445-450.

[9]. Rame Gowda, Narasimhan.M.C; and Karisiddappa, (2011), "Development and study of the strength of self-compacting mortar mixes using local materials", 526 / Journal of Materials in Civil Engineering ,ASCE / May, pp.526-532.

[10]. IS 269-2015 Indian Standard Specification for 43 Grade Ordinary Portland cement, First revision, BIS, New Delhi,1989.

[11]. IS 383-2016, Specification for coarse and fine aggregate for natural sources for concrete, second revision, 9th reprint,1993.

[12]. http://www.efnarc.org/pdf/SCCGuidelinesMay2005.pd