JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

EXPERIMENTAL INVESTIGATION ON RHEOLOGICAL AND HARDENED PROPERTIES OF SCC WITH PARTIAL REPLACEMENT OF STEEL SLAG AGGREGATES

Ashwin K, Bharath S, Swathi M, Aravinthan Raju E
1-4 Students B.E Civil Engineering
Department of Civil Engineering, Sri Shakthi Institute Engineering & Technology, L&T Bypass,Coimbatore, Tamil nadu, India.
Prof. SreAdetya V
Department of Civil Engineering, Sri Shakthi Institute Engineering & Technology, L&T Bypass,Coimbatore, Tamil nadu, India.

Abstract :
Self compacting concrete (SCC) gained wide use for the placement in the congested reinforced structure with difficulty in casting condition. For, such applications fresh concrete must possess high fluidity and good cohesiveness. One alternative to reduce the cost of self compacting concrete is by adding mineral admixture such as super plasticizer and Viscosity Modifying Agents replacement cement by 0%, 5%, 10%, 15% and 20% . Moreover, by the addition of mineral admixture in the manufacturing of self compacting concrete not only it reduces the cost but also reduces the heat of hydration, also parameters like environmental consciousness, sustainable development plays important role in future. So keeping that in mind the research is made with partial replacement of foundry sand with fine aggregate by 50%. Knowing that concrete is weak in tension, Glass fibers are added by 1% to improve the tensile property. The initial results of experimental programs aimed at producing and evaluating SCC made with Glass fibers are presented and discussed. The mix design of SCC was arrived as per guidelines of European Federations of National Associations Representing for Concrete (EFRNAC).Based on the results obtained from the comparison study of SCC with the results have concluded that the use of Super Plasticizer and Viscosity Modifying Agents increases the early age strength of the concerte.

I. INTRODUCTION

Self-compacting concrete (SCC) was first developed in Japan (in the mid to late 1980s) as a means to create uniformity in the quality of concrete by controlling the ever present problem of insufficient compaction by a workforce that was losing skilled labour and by the increased complexity of designs and reinforcement details in modern structural members. Durability was the main concern and the purpose was to develop a concrete mix that would reduce or eliminate the need for vibration to achieve consolidation. Self-compacting concrete achieves this by its unique fresh state properties.In the plastic state, it flows under its own weight and maintain homogeneity while completely filling any formwork and passing around congested reinforcement. In the hardened state, it equals or excels standard concrete with respect to strength and durability.The use of SCC concrete has been increasing in the United States also during the last 5 years. Currently the technology is being primarily applied to the precast industry. Other segments being targeted are flatwork, columns and wall construction.The applications of SCC are many, limited only by the industry's knowledge of it, ability to produce it and acceptance of it. The usual self-compacting concretes have compressive strengths in the range of 60-100N/mm². However Ultra High Performance

Self-Compacting Concrete (UHPSCC) with strength about 150 N/mm² have also been successfully developed .The durability of cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion or any other process of deterioration. Durable concrete will remain its original form, quality and serviceability when exposed to its environment.

II. LITERATURE REVIEW

Kosmas,et.al (2015) replaced ladle furnace slag, a by-product of steel making process as filler material for the production of self compacting concrete mixtures of different classes. Seven different self-compacting concrete mixtures SCC 25-30 LF,SCC 25-30 LFS 15%, SCC 25-30 LFS 25%, SCC 30-37 LF, SCC 30-37 LFS 15%,SCC 30-37 LFS 25% and SCC 35-45 were produced. Ladle furnace slag was used as an alternative filler material replacing aggregates in four SCC mixtures at percentages of 15% and 25% per weight of cement. Ladle furnace slag is a fine material with 100% passing the 96 μm sieve and 95% passing the 45 μ m sieve. High range water reducing carboxylic ether polymer admixture was added at different dosages in order to achieve self compatibility in the case of SCCs. It was observed that addition of LFS improved the fresh properties of SCC mixtures. Resulting this way to reduction of the super plasticizer amount needed in C25/30 SCC mixtures, compressive strength of SCC25/30 mixtures was slightly increased at later ages when LFS was used. The effect on strength increase was more significant in SCC30/37mixtures where higher dosages of LFS were added. Durability properties of LFS SCCs were improved especially in mixtures produced with higher amount of LFS and lower w/c ratio. Both carbonation and chloride resistance were increased. This increase was more essential in SCC30/37 mixture produced with 25%LFS where both durability indicators found to be equal with the values measured on SCC35 /45 mixture.

Divya chopra,et.al (2015) carried out a study on strength, permeability and micro structure of self compacting concrete containing Rice Husk Ash. The cement is replaced by Rice husk ash (RHA) as supplementary cementitious material. SCC was tested for fresh and hardened state for four different mixes. The rice husk ash is replaced by cement by varying percentages from 0, 10, 15 and 20. To improve the workability high range water reducer super plasticizer is used up to 25% without loss of workability. By the replacement of 15% RHA shows good workability and up to 33% of strength increased. The replacement increased to 20% the strength decreased but 20% RHA mix shows increase in porosity, but it is still less than the control mix. In this study porosity decreased with increases in age. This is basically due to large formation of C-S-H gel, dense structure is formed, so porosity decreased. From XRD and SEM analysis shows the formation of C-S-H gel at the replacement of 15% RHA concrete helps increase in compressive strength. Pores and cracking were at maximum for the control mix. The most dense structure was observed for 15% replacement with RHA which resulted in the highest compressive strength for the mix.

Nageswararao,et.al (2015) replaced the fine aggregate by crushed stone dust (CSD) and marble sludge powder (MSP) in various proportions in combination. Six mix deigns were prepared by partial replacement of CSD and MSP at 0%, 20%, 40%, 60%, 80% and 100%. Super plasticizer is added in various ratios 0.35, 0.3 and 0.25 to obtain the flow properties.

The fresh and hardened concrete (Compressive Strength Split tensile strength and Flexural strength) properties show good results at a partial replacement of MSP (60%) and CSD (40%) with lower water content. However, the durability results are not comparable with normal self compacting concrete. Self compacting concrete can be achieved by low water cement ratio with addition of super plasticizer.

Nileena,et.al(2014) replaced the Ground Granulated Blast Furnace Slag as filler material by the water cement ratio of 0.45.Six different mix proportions were prepared with a partial replacement of cement by GGBS at 30%, 40% and 50% and GBS at 30%,40%and50% as partial replacement of fine aggregate. Super plasticizer is used to achieve the self compatibility.The standard tests for fresh and hardened concrete was carried out and it was observed that only a small increase in compressive strength was achieved for 20% partial replacement of GGBS and GBS. But, ultrasonic pulse velocity shows an excellent result that there is no crack or undulations inside the specimen.

Edwin Fernando,et.al (2014) carried out an experimental investigation on self compacting concrete by replacing the fly ash as a filler material and copper slag as fine aggregate at a percentage of 5%,10%, 15%, 20% and 25%. Mix design is done as per EFNARC specification by keeping water cement ratio of 0.40 all mix and super plasticizer was used to increase the flow properties. The fresh and hardened properties of concrete was tested as per the standards and compared for normal SCC and SCC with partial replacement of fly ash and copper slag. The result shows a marginal improvement in the replacement of cement by fly ash up to 40%.

Kannan,et.al (2013) carried out an experiment of chloride and chemical resistance of self compacting concrete using Rice Husk Ash (RHA) and Metakaolin (MK) as filler materials and replacement of cement. Seventeen different mixes for various proportions were designed including ordinary SCC and tested for suitability. The percentage replacement of RHA and MK adopted in this study were 5%,10% 15%, 20%, 25% and 30% in separate and combined percentage replacement of RHA and MK were 5%, 10%, 15% and 20% with the addition of super plasticizer (SP). The fresh state is tested for all mix and the flow properties are observed. From the results it was observed that compressive strength increased at a replacement of 15% (RHA), 20% and 30% (MK) in combination of both. The durability test to determine the acid resistance is carried out by immersing the cube in H2SO4 solution, the result shows that there is a better improvement during individual replacement of RHA and MK at 25% and 5% respectively and 40% of combination of RHA and MK. The SEM analysis clearly states that there were no pores while RHA and MK are combined together. **Siddique,et.al (2013)** carried an experiment of foundry sand in SCC by the partial replacement of natural sand. To identify various mix proportions of partial replacement of fine aggregate by foundry sand at 0%, 10%, 15% and 20% is calculating using mix design by considering water powder ratio as 0.47 and that of 0.8% of super plasticizer. From the results it was observed that, compressive strength increases by 35.14% (28 days) and 24.94% (56 days) for a partial replacement of 15% when compared to control mix. Rapid chloride permeability result shows 15% replacement of foundry sand gives better effect to internal pore structure of concrete as filler material.

Ali Abd-Elhakam Aliabdo ,et.al (2012) carried out an experimental study on polymer modified concrete self compacting concrete (PMSCC). Two different polymers, styrene butadiene rubber (SBR) and polyvinyl acetate (PVC)are used in this experiment in different dosage from 0%, 5%,10% and 15% in the production PMSCC and was compared with traditional concrete and self compacting concrete. The filler material used in this experiment is Lime powder and Silica fume. To increase the flow properties superplasticizer namely, naphthalene and modified polycarboxylic either were used for the production of SCC.

The flow test is conducted on a constant 70cm diameter of concrete for 12 different mix designs. The comparison is tested between SBR and PVC in PMSCC and SCC. From the results it was observed that, at 90 days compressive strength of PMSCC is 25% higher than the self compacting concrete. Lime powder and Naphthalene based chemical admixture shows marginal improvement in compressive strength, mechanical properties and bond strength. The use of polymer decrease the degree of hydration of cement.

Srivastava,et.al (2012) carried an experiment of addition of silica fume as a filler material to concrete in various stages. Cement is partially replaced by silica fume in varying proportions as per the mix design. The addition of silica fume increases workability, strength and durability, as well as resistance to cracks are improved. It was observed that there is an increase in compressive strength from 6% to 57% during partial replacement of cement by silica fume. Addition of silica fume improves the bond strength of concrete. However, modulus of elasticity of silica fume in concrete shows a similar result to that of conventional self compacting concrete.

A. **S.E. Belaidi ,et.al (2012)** has studied the effect of substitution of cement with natural pozzolana and marble powder on the rheological and mechanical properties of self-compacting mortar (SCM) and self compacting concrete (SCC). Ordinary Portland cement (OPC) was partially replaced by different percentages of pozzolana and marble powder (10–40%). The workability of fresh SCC was measured using slump test-funnel flow Time test, j-ring l-box and sieve stability test .Compressive strength was determined on prisms at the ages of 7,28,56 and 90days. The results indicate an improvement in the workability of SCC with the use of pozzolana and marble powder. Compressive strength of binary and ternary SCC decreased with the increase in natural pozzolana and marble dust content, but strength at 28 and 90 days indicate that even with 40% (natural pozzolana + marble powder), suitable strength could be achieved.

Esraa Emam Ali , et.al (2012) has studied the effect of using recycled glass wase as a partial replacement of fine aggregate, on the fresh and hardened properties of Self-Compacting Concrete (SCC). A total of 18 concrete mixes were produced with different cement contents (350, 400 and 450 kg/m3) at W/C ratio of 0.4. Recycled glass was used to replace fine aggregate in proportions of 0%, 10%, 20%, 30%, 40% and 50%. The experimental results showed that the slump flow increased with the increase of recycled glass content. On the other hand, the compressive strength, splitting tensile strength, flexural strength and static modulus of elasticity of recycled glass (SCC) mixtures were decreased with the increase in the recycled glass content. The results showed that recycled glass aggregate can successfully be used for producing self-compacting concrete.

Heba,et.al (2011) presented an experimental study on SCC with two cement contents; the work involved three types of mixes, the first considered different percentages of fly ash, the seconds used different percentages of silica fumes and the third used mixtures of fly ash and silica fume. It was concluded that higher the percentages of fly ash the higher the values of concrete compressive strength until 30% of FA, however the higher values of concrete compact.

Mohamed (2010) carried out an experiment of self compacting concrete with the addition of micro-cellulose fibres in SCC. It is obtained from the recycled paperboard. It is used in the production of SCC with six different fibre volumes VF 14%, 21%, 28%, 41%, 83% and 138% and a normal SCC is designed and tested. Limestone is used as a filler material and to improve the fresh state of concrete super plasticizer are added in it. The packing factor of solid component mixture is prepared without fibre and with fibre is tested. The compressive strength increases due to addition of fibre content by volume of about 21%, due to homogeneity and high compaction between the fibres and the cement matrix.

If fibre content exceeds to 41% the compressive strength and the density are remarkably reduced. Concrete Equivalent Mortar (CEM) method of design is induced and addition of fibre content of about 21% by volume of cement shows good result in compressive strength up to 25%.At the addition of 41% fibre content showed a reduction of about 5%compressive strength compare to the non-fibered one incorporation of cellulose micro fibre decreases super plasticizer dosage reduce the density of the concrete. **Attar (2010)** carried out an experiment on replacement of natural sand by foundry sand in self compacting concrete. The scarcity of natural sand diverted the researchers for a better alternative; in this view foundry sand is replaced as fine aggregate. Foundry sand is partially replaced from 5% to 60% for natural sand and tested for various fresh and hardened properties of concrete.The silica content in the foundry sand was observed to be more than 90%.The compressive strength result shows a marginal increase at partial replacement of 20% to 60%, however, the strength decreases if replacement percentage exceeds 60%.

Erdogan Ozbay (2008) carried out an investigating mix proportion of high strength self compacting concrete (HSSCC) by using Taguchi Method. The experiment shows the HSSCC by replacing the cement by fly ash in various stage by15%, 30% and 45%. It is used as a filler material and coarse aggregate is replaced by crushed lime stone and crushed sand. To improve the fresh property super plasticizer is used. For this experiment Eighteen (18) different mixes were designed and tested for fresh and hardened properties of concrete. HSSCC is analysed by using the Taguchi's experiment design. In this method level of mix proportions are determined by Ultra Pulse Velocity (UPV). Various test are carried out for fresh and hardened concrete were Slump flow and V funnel test; UPV, compressive strength and split tensile tests. It was observed that design mix M10 (1:1.5:1.9) show better improvement in compressive strength and M18 (1:2.1:1.8) in split tensile strength. The design mix confirming to M10 and M18 satisfies the high strength self compaction concrete.

Andreas Leemann (2007) carried out a study on the effect of Viscosity modifying agent (VMA) on mortar and concrete used to obtain the flow properties and the rheology is studied. Mainly VMA is used in the SCC to obtain the free flow without any segregation. Inorganic VMA micro silica (MS) and nano silica slurry (NA) and organic VMA high molecular ethylenoxide derivate (EO), Natural Polysaccharide (PS),starch derivate (ST) are used. These are combined with Super plasticizer (SP) for varying water binder ratios (w/b) are tested. While addition of VMA and SP shows the marginal difference in flow properties and rheology. The organic VMA MS and NS and the organic VMA to show a bigger gradient and VMA PS (0.4% and 0.8%) and ST a smaller gradient than the mix without VMA.PS causes the strongest increase of yield stress and MS the lowest. Combination of VMA and SP shows the improvement in compressive strength at the age of 28 days. Variation of w/b, the addition of SP and VMA all change flow properties and rheological properties in a different way. The in organic VMA cause an acceleration of hydration and higher compressive strength.

Kumar (2006) reported the history of SCC development and its basic principle, different testing methods to test high flowability, resistance against segregation, and passing ability. Different mix design methods using a variety of materials has been discussed in this paper, as the characteristics of materials and the mix proportion influences self-compact ability to a great extent, also its applications and its practical acceptance at the job site and its future prospects have also been discussed.Orimet test was performed, the more dynamic flow of concrete in this test simulates better the behaviour of a SCC mix when placed in practice compared with the Slump-flow variation. The Orimet/J-ring combination test shows great promise as a method of assessing filling ability, passing ability and resistance to segregation.

Lachemi and Hossain,et.al (2004) presented the research on the suitability of four types of Viscosity Modifying Agent (VMA) in producing SCC. Fresh and hardened properties of SCC were studied by adding different VMA to SCC. The deformability through restricted areas can be evaluated using v-funnel test. In this test, the funnel was filled completely with concrete and the bottom outlet was opened, allowing the concrete to flow out. The time of flow from the opening of outlet to the seizure of flow was recorded. Flow time can be associated with a low deformability due to high paste viscosity, higher inter particle friction or blockage of flow. Flow time should be below 6 sec for the concrete to be considered as SCC. All the mix performed well with no significant segregation and jamming of aggregate was noticed.

Bertil (2001) carried out an experimental and numerical study on mechanical properties such as strength, elastic modulus, creep and shrinkage of SCC and the corresponding properties of normal compacting concrete. The study includes eight mix proportions of sealed or air-cured specimens with water binder ratio (w/b) varying between 0.24 and 0.80.Fifty percent of mixes were self compacting concrete and rest were normal cement concrete. The result indicates that elastic modulus, creep and shrinkage of SCC did not differ significantly from the corresponding properties of normal cement concrete.

III. METHODOLOGY :

The methodology for Normal Aggregate concrete (NAC) with partial replacement of Slag Aggregate Concrete (SAC) involves several steps. The following outlines the general methodology used in this study:

1. Material selection: The materials used in this study included cement,Viscosity modifying agent, natural coarse aggregate, and Slag aggregate . The proportions of each material were selected based on previous studies and laboratory tests.
2. Preparation of NAC: The Aggregate , sand , water and cement are cleaned to remove any contaminants, such as dirt or debris.to create the desired coarse aggregate blend.
3. Preparation of Slag aggregate paste: The cement,sand and Slag aggregate, followed by the addition of water. The mixture was then blended until a homogeneous paste was formed.
4. Proportioning: Different percentages of Slag aggregate were used as a partial replacement for natural coarse aggregate in the SCC. The proportions were selected based on previous studies and laboratory tests.
5. Casting of specimens: The SCC With slag aggregates was cast into molds to create specimens for testing. The specimenswere cured for 28 days under controlled conditions.
6. Mechanical testing: The mechanical properties of the specimens were evaluated using compressive strength, splitting tensile strength, and flexural strength tests. The results of the tests were analyzed to determine the effect of SCC on the mechanical properties of Slag aggregates.
7.

Overall, the methodology used in this study involved a combination of laboratory testing, material selection and analysis to evaluate the feasibility of using Slag aggregate as a partial replacement for natural coarse aggregate in RPC. The results of the study provide valuable insights into the potential benefits of using Slag aggregate in SCC and could inform future research and construction practices.

IV. RESULTS AND DISCUSSION

Introduction

The Normal coarse aggregate concrete and Slag aggregate concrete are mixed at various proportions and aremade into concrete blocks. These specimens are tested and the results of the respective proportions are compared and the better composition that is obtained are discussed.

Compressive strength test

Compressive strength of concrete is tested using Compression testing machine (CTM). Where the force is applied by the help of compression testing machine till the concrete block of dimension 150mm ×150mm × 150mm fails. Then the strength is found when the applied force is divided by cross sectional area of concrete block. Compressive strength of respective mixes are given in the table below.

Table 4.1 Compressive strength test results

Mix Type	7 Days	14 Days	28 Days
	Compression Strength (N/mm^2)	Compression Strength(N/mm^2)	Compression Strength (N/mm^2)
NC	16	23.5	25.1
SCC 1	17.7	17.7	33.11
SCC 2	18	20	35.07
SCC 3	18.2	21.7	38.87
SCC 4	17.3	20	39.1

Table 4.1 shows that the compressive strength of the specimen shows greater strength at 20% replacement of SCC that is mix M3 and decreasing after. The conventional mix M1 shows results approximately similar to M3.

Table 4.2 Split tensile strength test results

Mix Type	7 Days	14 Days	28 Days
	Split tensileStrength (N/mm^2)	Split tensile Strength(N/mm^2)	Split tensileStrength (N/mm^2)
NC	2.73	2.4	2.8
SCC 1	3.11	3.5	3.7
SCC 2	3.24	3.3	3.5
SCC 3	3.13	4.1	4
SCC 4	2.8	4.2	3.77

Table 4.2 shows that the tensile strength of the specimen undergoes an gradual decrease with increase in content of Recycled aggregate concrete. The conventional mix M0 shows greater strength at the end of thetest.

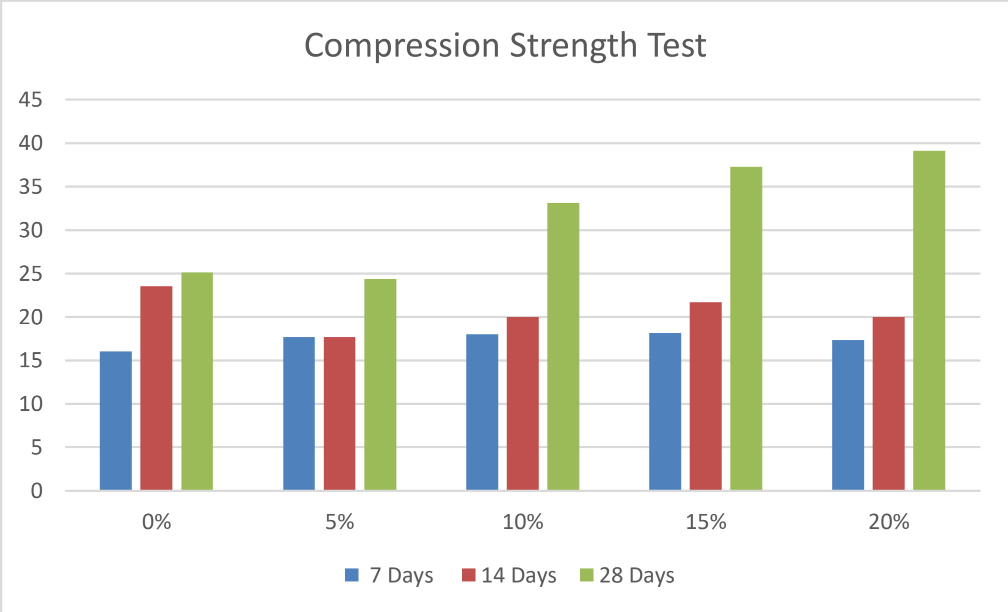

Fig 4.1 Graph showing Compressive strength of specimen

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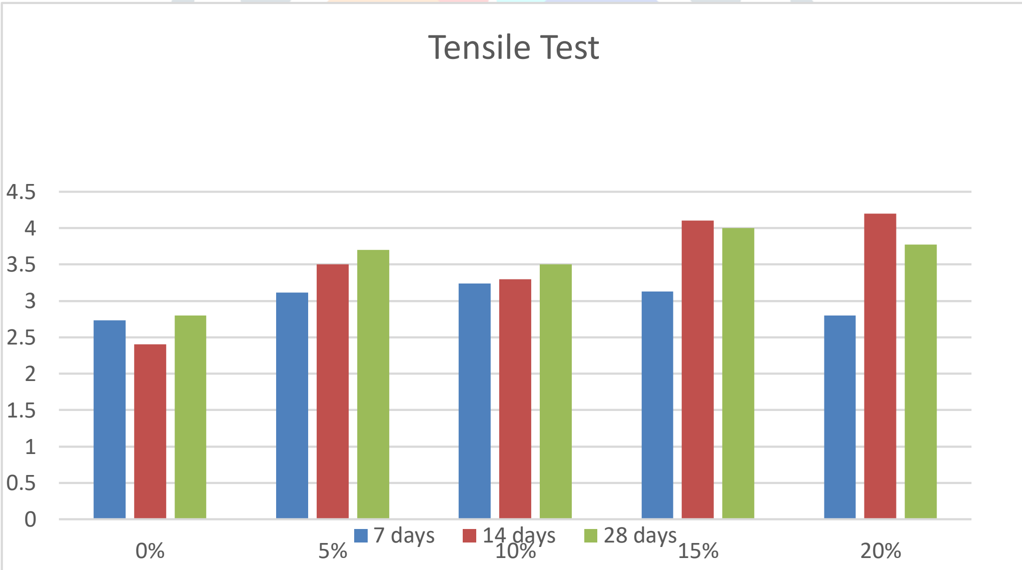

Fig 4.2 Graph showing Split tensile strength of specimen

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V. CONCLUSION:

The reason of this project is to design a suitable SCC mix and evaluate it by 4 tests which are slump flow, V-Funnel, L-Box, and then determine the strength of it by casting the concrete in cubes and then put it in the compression machine and measure the strength after 7,14, 28 -days curing.

The main conclusions of this project are:

- SCC is recommended in complicated frameworks which have narrow places and congested steel bars, because it can flow throw this places very smoothly and without vibration and give the best compaction and surface finishes.
- Trial and error method was been used to design the SCC mix because the is no standard method for SCC in any institutes and concrete mix plants.
- SCC is recommended in high rise building because by using SCC the time for construction will be shorter and also the cost will be cheaper than using ordinary concrete.
- Fourteen trails have been done for SCC and the critical ingredients were the superplastisizer, VMA and fine materials which play a big role in the SCC properties.
- SCC do not depend in a single test, but it depends in all of the four tests and it must pass all of them to be called Self-compacting concrete.

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