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A REVIEW ON PERFORMANCE OF SELF COMPACTING CONCRETE USING MINERAL AND CHEMICAL ADMIXTURE

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Abstract:

Self-Compacting Concrete Originally developed in Japan, SCC technology was made possible by the much earlier development of Superplasticisers for concrete. The self-compacting concrete (SCC), has been used in precast constructions like bridge, building and tunnel construction since the early 1990's. In the last five years, a number of SCC bridges have been constructed in Europe. The application of SCC in highway bridge construction is very limited at this time. However, the U.S. precast concrete industry is beginning to apply the technology to architectural concrete. SCC has high potential for wider structural applications in highway bridge construction. This paper covers the Review of SCC using various admixtures. The main objective of this paper is to make use of SCC in precast elements and to understand cost implication. Applications of SCC results in a large payoff in not requiring vibration to achieve consolidation and the low noise level to meet stringent environmental requirements in urban and suburban construction sites. Less labour and speedier construction will result in substantial cost savings, less traffic disruption and risk reduction. Better durability and high strength will allow the engineers to design and build bridges to last a century and beyond. To Study the workability and mechanical properties of Self-Compacting Concrete & Compare to Conventional Self-Compacting Concrete.

Key Words: Self-Compacting Concrete, Super Plasticizer, Material Testing, Precast Elements & Conplast

1. Introduction:

Self-compacting Concrete (SCC) that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, while maintaining homogeneity and without the need for any additional compaction. In principle, a self – compacting or self – consolidating concrete must:

- ✓ Have a fluidity that allows self – compaction without external energy
- ✓ Remain homogeneous in a form during and after the placing process and
- ✓ Flow easily through reinforcement

Self – consolidating concrete has recently been used in the pre – cast industry and in some commercial applications, however the relatively high material cost still hinders the wide spread use of such specialty concrete in various segments of the construction industry, including commercial and residential construction. The history of self-compacting concrete (SCC) dates back to late 1980s. It was proposed for construction by Okamura [1] in Japan to offset a growing shortage of labour. Though the concept originally was thought to be a tool to enhance long-term durability of structures having members with congested reinforcements, the excellent user-friendly characteristics of SCC are of great attraction today in traditional construction industry also. SCC has a big role to play because of its substantial benefits in construction both qualitatively and quantitatively. A concrete that is capable of self consolidating, occupies all the space in the form without any external effort (in the form of mechanical vibration, floating, poking etc.) is termed as self-compacting concrete. The guiding principle behind the self-compacting concrete is that "the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists". For a concrete to be self-compacting, to occupy the full space, flowing through the form, without any external efforts, it has to have an acceptable level of passing ability, filling ability and stability. As concrete is a heterogeneous product of materials with various specific gravities, it is very difficult to keep its constituents in a cohesive form. Specially, when concrete has a consistency of a fluid, materials of higher mass tend to settle down. This problem however can be tackled by adding more amount of finer material (passing 100 microns) in unit content of concrete and super-plasticizers. Super-plasticizers are instrumental in reducing the water demand of a highly fluid mix, and producing optimally high-fluidity concrete while using the least possible amount of water is key to produce high-density, and consequently high-strength concrete.

2. Literature Review:

Josef Hegger, Sebastian Bülte, Boris Kommer (2007) were described Structural Behavior of Prestressed Beams Made With Self-consolidating Concrete Self-consolidating concrete (5CC) offers ecological and economic advantages over conventional concrete, especially for the precast concrete industry. Besides proper mixture proportioning and manufacturing procedures, the mechanical characteristics of 5CC and its effects on a member's structural behavior are of particular interest to ensure efficient application. Numerous material models for the fresh and hardened 5CC are available, but its structural behavior has not been fully described. Although previous investigations 1showed that the characteristics of 5CC do not affect a member's bending capacity, SCC's influence on bond strength and shear capacity is not completely understood. Therefore, tests on the bond strength and shear capacity of members made with 5CC have been performed. The target was to collect missing information on the structural behavior of members made from 5CC and to allow an economical and reliable design of prestressed concrete beams.

Hajime Okamura & Masahiro Ouchi (2003) were described "Self-Compacting Concrete" Journal of Advanced concrete technology volume 1.Self-Compacting Concrete was first developed in 1988to achieve Durable concrete structures. In early 1983, the problem of the durability of concrete structures was a major topic of interest in Japan. The creation of durable concrete structures requires adequate compaction by skilled workers. Okamura solved the issue of degrading quality of concrete construction due to lack of compaction by the employment of SCC which is independent of the quality of construction work. The prototype of SCC was completed in 1988.This concrete was named as "High performance concrete" as follows at 3stage

Early age : Avoidance of initial defect
Fresh state : Self-compactable
After hardening: Protection against external factors

The method for achieving self-compatibility involves not only high deformability of paste (or) mortar, but also resistance to segregation between coarse aggregate & mortar when the concrete flows through the confined zone of reinforcing bars. When self-compacting concrete become so widely used that it is seen as the "Standard Concrete" rather than a "Special Concrete", we will have succeeded in creating durable &reliable concrete structures that require very little maintenance work.

N R Gaywala& D B Raijiwala (2006) was done on "Self-Compacting Concrete: A Concrete of Next Decade" Journal of Engineering Research and Studies. The specimens were casted by M25 grade of concrete. They studied the effect of different proportion of Fly Ash (15%, 25%, 35%, 45%, and 55%) in concrete. The maximum compressive strength, split tensile strength, flexural strength & pull out strength for self-compacting concrete can be obtained by addition of 15% of fly ash in mix as compared to addition of 25%, 35%, 45% and 55% cement replacement by fly ash.SCC gives good durability properties as compared to the ordinary concrete

Gopala Krishna Sastry& Asha Deepthi. Deva (2015) was done on "A Comparative Study on Mechanical Properties of Normal Vibrated Concrete and Self-Compacting Concrete" International Journal of Civil and Structural Engineering Research. The specimens were casted by M30 grade of concrete. They studied the effect of different proportion of Fly Ash 30 % & Silica Fume 10% in concrete.NVC of M30 grade is designed as per IS code - 10262:2009 and attained compressive strength 39.52 N/mm2 at 28 days.SCC with 30% FA addition gives nearly same strength of NVC of same grade.SCC with 10% SF addition gives nearly same strength of NVC of same grade.SCC containing 30% FA & 10% SF obtained maximum compressive strength , split tensile strength & flexural strength .The percentage increase in compressive strength, split tensile strength and flexural strength at 30% FA & 10% SF for SCC M30 grade is 23.89%, 18.77%, 20.31% more than that of SCC without mineral admixture.

Mayur B. Vanjare & Shriram H. Mahure (2012) were described "Experimental Investigation on Self-Compacting Concrete Using Glass Powder" International Journal of Engineering Research and Applications. The specimens were casted by M20, M25, and M30 grade of concrete. They studied the effect of different proportion of Glass Powder (5%, 10%, and 15%) in concrete. The flow value decreases by an average of 1.3%, 2.5% and 5.36% for glass powder replacements of 5%, 10% and 15% respectively. The average reduction in compressive strength for all grades was around 6%, 15% and 20% for glass powder contents of 5%, 10% and 15% respectively. The average reduction in flexural strengths for all grades was around 2%, 3.7% and 6.75% for glass powder contents of 5%, 10% and 15% respectively.

Selvamony Cet al (2009) was done on "Development of High Strength Self-Compacted Self-Curing Concrete With Mineral admixtures" International Journal on Design and Manufacturing Technologies. In this study, the effect of replacing the cement, coarse aggregate and fine aggregate by limestone powder (LP) with silica fume, quarry dust and clinkers respectively and their combinations of various proportions on the properties of SCC has been compared. Silica fume was observed to improve the mechanical properties of SCC, while lime stone powder along with quarry dust affected mechanical properties of SCC adversely. From the test result a maximum of 8% of lime stone powder with silica fume, 30% of quarry dust and 14 % of clinkers was able to be used as a mineral admixture without affecting the self compact ability.

Ramanathan P et al (2013) was done on "Study on Durability Characteristics of Self-Compacting Concrete with Fly Ash" Jordan Journal of Civil Engineering. They studied the effect of different proportion of Fly Ash (10%, 20%, 30%, 40% and 50%).The durability of concrete is tested by acid resistance, sulphate attack and saturated water absorption at the age of 28, 56 and 90 days. From the test result 30% replacement of fly ash, the fresh properties observed were good as compared to 10%, 20%, 40% and 50% fly ash replacement. Saturated water absorption percentage decreases with the increase in fly ash. For 30%replacement of fly ash, the lower water absorption level is a good. Compressive strength loss decrease with the increase in fly ash in concrete.

Chandra Mohan G (2015) was done on "A Study on Properties of Self-Compacting and Self-Curing Concrete" International Journal of Advanced Research Trends in Engineering and Technology. The specimens were casted by M40 grade of concrete. The SCC were cured under three different curing conditions being normal curing (NC), membrane curing (MC) and self-curing (SC).The compressive strength of the self-compacted self-curing concrete is more than other curing methods like normal and membrane curing types. The compressive strength of self-compacting concrete is getting more than the conventional concrete. It is found that the ratio of gain in strength is almost same or even better than that of conventionally vibrated concrete.

Deepa Balakrishnan S et al (2013) were described "Workability and strength characteristics of self-compacting concrete containing fly ash and dolomite powder" American Journal of Engineering Research (AJER). The specimens were casted by M20 grade of concrete. In this paper, high volume fly ash self-compacting concrete was produced with 12.5% , 18.75% , 25% , and 37.5% of the cement (by mass) replaced by fly ash and 6.25% , 12.5% and 25% of the cement replaced by dolomite powder. Better mechanical and physical properties of concrete can be obtained with the replacement of cement with fly ash from 12.5 percent to 18.75 percent. Better fresh properties of SCC can be obtained with the replacement of cement with dolomite powder

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from 6.25 percent to 12.5 percent. From this experimental study it can be inferred that fly ash and dolomite powder blend well to improve the overall workability, which is the prime characteristics of SCC.

Mr. Bharath E et al (2015) was done on "Effect of Partial Replacement of Cement in Self-Compacting Concrete by Fly Ash and Metakaolin" International Journal of Engineering Research & Technology (IJERT). The specimens were casted by M40 grade of concrete. They studied the effect of different proportion of Fly Ash (5%, 15%, and 25%) & metakaolin (3%, 6%, and 9%).Replacement of cement by a combination of fly ash and metakaolin in the range of 8 to 34 percent has no adverse effect on the workability properties of SCC. As the percentage of cement replacement increases, the 7 days and 28 days compressive strength of SCC cubes increase up to 24 % and later decrease .The maximum splitting tensile strength of SCC cylinders at 28 days occurs for a percentage of cement replacement = 14 in the considered range. The minimum splitting tensile strength at 28 days occurs for a percentage of cement replacement = 28 in the considered range. The initial tangent modulus of SCC is a function of the 28 days compressive strength. As the strength increases the modulus also increases.

Ahmed Fathi et al (2013) was done on "Study The Effectiveness of the Different Pozzolanic Material on Self-Compacting Concrete" ARPN Journal of Engineering and Applied Sciences. This paper presents the study on the effect of fly ash (FA), silica fume (SF) and microwave incinerated Fly Ash (MIRHA) as cement replacement material (CRM) on the mechanical and fresh properties of self-compacting Concrete (SCC). The result showed that the MIRHA needed more water as compared to SF to achieve the similar fresh properties, similarly concrete with 5% SF showed about 9.70% higher compressive strength after 90 days, 5.10 MPa high tensile strength and 10.12 MPa flexural strength when compared with other mixes. 5% SF and 30% FA mixes showed highest compressive strength as compared to the control mix. Whereas all CRM mixes resulted in high flexural strength, which was due to the negligible bleeding and high cohesiveness. Silica fume requires less water demand as compared to MIRHA for achieving the similar fresh properties.

3. Material Study and Test Methods:

General: The self-compacting considered here is prepared by the following ingredients ASTM Type II Portland cement, fine sand (approximately 150-500 μm), and Naphthalene super plasticizer 553.

Cement: Ordinary Portland Cement 53 grade cement can be used.

Super-Plasticizer: Super-Plasticizer Super plasticizer is essential for the creation of SCC. The job of SP is to impart a high degree of flow ability and deformability, however the high dosages generally associate with SCC can lead to a high degree of segregation. Conplast SP 430 is utilized in this project, which is a product of FOSROC Company having a specific gravity of 1.222. Super plasticizer is a chemical compound used to increase the workability without adding more water i.e. spreads the given water in the concrete throughout the concrete mix resulting to form a uniform mix. SP improves better surface expose of aggregates to the cement gel. Super plasticizer acts as a lubricant among the materials.

Properties of CONPLAST SP 430	
Appearance	Brown liquid
Specific gravity	1.20 at 20°C
Chloride content	Nil to BS 5075
Air Entrainment	Less than 2% additional air entrained at Normal dosages
Alkali content	Less than 72.0 g. Na_2O equivalent / litre of admixture.

Table 1: Properties of Conplast Sp 430 Chandra Mohan G (2015)

Fly Ash: SCC is produced with high quantity of powder or fine materials. In majority of cases SCC is used with Fly Ash. Where Class-F Fly ash normally produced burning anthracite or bituminous coal, usually has less than 5% CaO. Class F fly ash has pozzolanic properties only. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO).

Silica Fume (SF): Silica fumes also referred to as micro silica or condensed silica fume, is another material that is used as a pozzolonic admixture. It is a product obtained from reduction of high purity quartz with coal in an electric furnace in the manufacture of silicon or ferrosilicon alloy. The use of silica fume in conjunction with super plasticizer has been the backbone of modern high performance concrete. For higher strengths, the use of silica fume is essential. Highly reactive pozzolan used to improve mortar and concrete.

Rice Husk Ash (RHA): Rice husk Ash, is obtained by burning rice husk in controlled manner without causing environmental pollution. Rice husk Ash exhibits high pozzolanic characteristics and contribute to high strength and high impermeability of concrete. Rice husk Ash essentially consist of amorphous silica (90%SiO_2).India produces about 122 million ton of paddy every year .Each ton of paddy producers about 40Kg of RHA.

Fine Aggregate: Fine aggregate should be properly graded to give minimum void ratio and be free from deleterious materials like clay, silt content and chloride contamination etc. It can be natural or manufactured. The grading must be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes. Particles smaller than 0.125mm (125μ) size are considered as fine which contribute to the powder content. Fine aggregates shall conform to the required of IS 383. The sand was washed and screened at site to remove deleterious materials and tested as per the procedure given in IS: 2386-1968 and the results were tabulated.

Coarse Aggregate: The coarse aggregate chosen for SCC is typically round in shape, is well graded, and smaller in maximum size than that used for conventional concrete typical conventional concrete could have a maximum aggregate size of 40 mm or more. In general, a rounded aggregate and smaller aggregate particles aid in the flow ability and deformability of the concrete as well as aiding in the prevention of segregation and deformability of the concrete as well as aiding in the prevention of segregation.

Gradation is an important factor in choosing a coarse aggregate, especially in typical uses of SCC where reinforcement may be highly congested or the formwork has small dimensions. Gap – graded coarse aggregate promotes segregation to a greater degree than swell-graded coarse aggregate. As with conventional concrete construction, the maximum size of the coarse aggregate for SCC depends upon the type of construction. Typically, the maximum size of coarse aggregate used in SCC ranges from approximately 10 mm to 20 mm.

Chemical Admixture: Admixtures may be defined as the materials other than the basic ingredients of concrete i.e. cement, aggregates and water added to the concrete mix immediately before and during the mixing process to modify one or more specific properties of concrete in fresh and hardened state. Super plasticisers are an essential component of SCC to provide necessary workability. To improve the workability of self-compacting concrete we have to add some plasticizers (water reducers) as a chemical admixture. While naphthalene based super plasticiser are popularly used in conventional concrete, SCC is associated more with polycarboxylic ether based super plasticiser. These have been most recently developed, and are sometimes referred to as “new generation” super plasticizers. The difference in functional mechanism between these two types and general compatibility of the latter with major types of cement could be reasons for this trend. In my project, I am going to use polycarboxylic ether based super plasticizer Naphthalene Super Flow complying with ASTM C-494 type F.

Compressive Strength of Concrete: Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen. (Ex 150 mm cube according to ISI) divided by the area of cross section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 150mm size cubes. Place the cube in the compression-testing machine. The green button is pressed to start the electric motor. When the load is applied gradually, the piston is lifted up along with the lower plate and thus the specimen application of the load should be 300 KN per minute and can be controlled by load rate control knob. Ultimate load is noted for each specimen. The release valve is operated and the piston is allowed to go down. The values are tabulated and calculations are done.

Split Tensile Strength: A concrete cylinder of size 150mm dia×200mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner .The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress.

Test Setup and Methods: Slump Flow Test and T50 Slump (EFNARC) Flow Test This test is used to measure the free horizontal flow of SCC on a plain surface without any obstruction. Concrete poured in slump cone without external compaction is made to flow on flow table. Time required for the concrete to cover 50 cm diameter spread circle (T50 cm time) from the time the slump cone is lifted is noted. Average flow of concrete after concrete stops flowing is measured to ascertain the slump flow value. It is most commonly used test and gives a good assessment of filling ability and indications on stability of the mix. In case of unstable mix, most of the coarse aggregate particles remain in the center of the flow table and only cement mortar flows. Absences of uniform distribution of larger particles across the spread indicate the poor viscosity of the mix. Intentional depressions created by finger, if not melded after removal of finger, indicate that the mix is segregated.

V-Funnel Test: This test is conducted to assess the fluidity and segregation resistance of SCC. Inverted cone shaped equipment with 75 mm square opening at the bottom is used to assess the properties of mix such as unacceptable viscosity, undesirable volume of coarse aggregate, stability etc. (EFNARC) V-funnel test is an important tool to assess the consistency of the mix. Uniformity in flow properties of fresh concrete during the production and before placement of concrete into the form can well be measured using Vfunnel test. To assess the consistency/fluidity of the mix, measurement of T 0 i.e., the time required for emptying the concrete filled V-funnel completely in seconds is measured by filling the funnel up to top with concrete without any external efforts and emptying immediately thereafter. A stable mix having T 0 in between 6 to12 seconds is considered to be satisfactory. Stability of the mix is ascertained by measuring the time (in seconds) required to empty the V-funnel completely 5 minutes after filling the funnel completely. This time is referred to as T 5. If the mix is segregated, T 5 time will be abnormally high as T 0 time.

L-Box Test Method: This test is conducted to assess the filling and passing ability of SCC. Uniformity of the mix is also examined by inspecting sections of the concrete in the horizontal section of ‘L’ box. (EFNARC) Concrete is made to pass through the obstructions of known clearances. The vertical section is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section through vertically placed reinforcements. When the flow is stabilized, the height of concrete h1 (at obstructions) and h2 (at the end of horizontal section of ‘L’) with respect to base are measured. The ratio of h2 and h1 referred to as blocking value, a measure of passing ability of SCC, is calculated. Blocking value of a stable concrete between 0.8 to 1.0 indicates better passing ability.

5. Conclusion:

- ✓ Optimum dose of chemical admixture varies with the type of the chemical admixtures as well as type of cement and w/c ratio-Durgesh Jadhav (2016)
- ✓ As w/c ratio decreases, the optimum dose of admixture expressed as percentage of cement in concrete mix increases.
- ✓ Mostly optimum admixture dose expressed as percentage of cement in concrete mix decreases with increase in retention time
- ✓ Use of supplementary cementious materials that is, fly ash with an aim to achieve better workability with the saving in cementious material.
- ✓ From the slump and compaction factor tests, it is observed that concrete containing fly ash and super plasticizer yields good workable mix in addition to increase in compressive strength marginally.

- ✓ Addition of super plasticizer along with 10% fly ash of cement content accelerates the compressive strength of Self-Compacting.
- ✓ Self-Compacting Concrete not only establishes the uniform and homogenous mix but also gives marginal reduction in weight of hardened mix of concrete (S. M. Dumne (AJER) 2014) From the present study, one can support to the comments made by previous researchers about saving of time in construction and also environment friendly user because of no compaction and vibrations resulting to no noise creation.
- ✓ The scope of study in future is to assess the workability of mix using L-box test for the requirement of properties like passing, filling and flow ability whereas V-funnel test employed to know the property of viscosity. Further, hardened properties of SCC could be assessed for other test like flexural strength, split tensile strength , water absorption test as per Indian standards and suitably applied for pre-cast units to reduce the thickness without reducing the strength simultaneously optimization of cost can be achieved.

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