Comparative Studies on Durability and Mechanical Properties of M50 Grade Steel Fibre Reinforced Conventional and Self-Compacting Concretes

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Abstract- Durability of concrete structures has been a topic of research for a long time. Many modifications and various attempts are being made by Engineers and scientists have been proposed in conventional concrete in order to improve its overall performance, including strength and durability. An attempt has been made to study the comparison between M50 grade SCC and CVC with steel fibers dosage of 30 Kg/m³, 60 Kg/m³, and 90 Kg/m³ with aspect ratio of 35 and subjected to durability and mechanical strengths. In this experimental work, the SCC concrete was designed using different available methods. From those, by trial and error, quantities for mix were obtained with satisfied properties of SCC. Trials have been made based on NAN SU method and finally arrived at the quantities, which satisfied the properties of SCC i.e., slump flow test, L-Box test, U-Box test and V-Funnel test. To this mix, steel fibers of different aspect ratios and varied quantities of 30, 60 and 75kg/m3 were added. The following parameters were studied under the durability aspect viz., weight loss, strength and consumption of solutions. The durability studies were carried out by conducting the tests viz., Water Absorption, Marine Water Attack, Magnesium Sulphate Attack, Sodium Sulphate Attack and Hydrochloric Acid.

Keywords: conventional concrete, self-compacting concrete, steel fiber, mix design.

I. INTRODUCTION

Concrete technology has made a tremendous stride in the past decade. Concrete is now no longer a material consisting of cement, aggregates, water and admixtures but it is an engineered material with several new constituents performing satisfactorily under different exposure conditions. Concrete today can be tailor made for specific applications and it contains different materials like micro silica, colloidal silica and many other binders, filler and pozzolanic materials. The development of specifying a concrete according to its performance requirements rather than the constituents and ingredients has opened innumerable opportunities for producers and users to design concrete to suit to their specific requirements. The type of concrete that is designed to a specific application is known as high performance concrete. ACI defines high performance concrete [HPC] as “Concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients, normal mixing procedure and typical curing practices.” HPC should have at least one outstanding property viz. compressive strength, high workability enhance resistance to chemical or mechanical stresses, lower permeability, high durability etc..

1.1 Conventional concrete (CVC)

For a long time, Concrete was considered to be very durable material requiring a little or no maintenance. The assumption is largely true, except when it is subjected to highly aggressive environment. We build concrete structures in highly polluted urban and industrial areas, aggressive marine environment, and harmful subsoil water in coastal area and many other hostile conditions where other materials of construction are found to be non-durable. Since the use of concrete in recent years, have spread to highly harsh and hostile conditions, the early impression that concrete is very durable material is being threatened, particularly on account of premature failures of number of structures in the recent past.

In the past, only strength of the concrete was considered in the concrete mix design procedure assuming strength of concrete is an all pervading...
factor for all other desirable properties of concrete including durability. For the first time, the pious option was proved wrong in late 1930’s when they found that series of failures of concrete pavements have taken place due to frost attack. Although the compressive strength is a measure of durability to a great extent it is not entirely true that the strong concrete is always a durable concrete. In addition to strength of concrete another factor, environmental condition or what we generally call exposure condition has become an important consideration of durability.

In the recent revision of IS: 456-2000, one of the major points discussed, deliberated and revised is the durability aspects for concrete.

One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength. The degree of hardness of the environmental condition to which concrete is exposed over its entire life is equally important. Therefore strength and durability have to be considered explicitly at the design stage. Generally, construction industry needs faster development of strength in concrete so that the projects can be completed in time or before time. This demand is catered by high early strength cement, use of very low Water-Cement ratio through the use of increased cement content and reduced water content. The above steps result in higher thermal shrinkage, drying shrinkage, modulus of elasticity and lower creep coefficients. With higher quality of cement content concrete exhibits greater cracking tendencies because of increased thermal and drying shrinkage. As the creep coefficient is low in such concrete, there will not be much scope for relaxation of stresses. Therefore, high early strength concretes are more prone to cracking than moderate or low strength concrete. The structural cracks in high strength concrete can be controlled by the use of sufficient steel reinforcements. But this practice does not help concrete durability, as provision of more steel reinforcement will only results in conversion of bigger cracks into smaller cracks.

1.2 Self-Compacting Concrete (SCC)

Self-Compacting concrete is specific part of high performance concrete which distinguishes itself with self-consolidation properties with high flow ability. HPC finds very useful application in the precast industry because of its requirements for high early strength flow ability. The introduction of plasticizers, super plasticizers and pozzolanic materials had a tremendous influence on the concrete technology and its benefits subsequently filtered down to precast industry. Many technological developments have provided incremental advances in the design and placement of concrete in structures. In this, the most important development is self-compacting concrete [SCC]. Hence, SCC will be the future of concrete technology. The principle of self-compacting concrete is not new. Specific applications such as under-water concreting always require fresh concrete, which could be placed without the need for compaction, since vibration is simply impossible. Early self-compacting concretes relied on very high contents of cement paste the mixes require specialized and well-controlled placing methods in order to avoid segregation. The high contents of cement paste made them prone to shrinkage and high heat of generation. The overall costs were varied and its applications remained more. This led to the development of admixtures, which served the purpose of producing SCC as easy one. The admixtures consist of high range Water Reducing Admixture (WRA) and Viscosity Modifying Agents (VMA).

II. MATERIALS USED

1. Cement:

Ordinary Portland cement of 53 grade conforming to Bureau of Indian Standards was used in the present investigation. The cement was tested for various properties as per IS 12269-1987.

2. Silica fume:

The high level of fineness and practically spherical shape of silica fume results in good cohesion and improved resistance to segregation. However, silica fume is also very effective in reducing or eliminating bleed and this can give rise to problems of rapid surface crusting. This can result in cold joints or surface defects if there are any breaks in concrete delivery and also to difficulty in finishing the top surface. The silica fume used in the present work was obtained from M/S. Fosroc chemicals, Navy-Mumbai.

3. Fly ash:

Fly ash used in the test was obtained from Thermal Power Station at Vijayawada.

4. High Range Water Reducing Admixture (HRWA)/Super plasticizers:

As the Water-Cement ratio is very less, to achieve the required workability, a high range water reducer, Conplast SP430 A2 was used in mix proportioning. The Conplast SP430 A2 is sulphonated Naphthalene Polymer obtained from FORSOC CHEMICALS was used. Dosage of chemical was 0.80% and 1.1% for CVC and SCC respectively.

5. Water:

Potable water from local resources was used for mixing and curing of concrete cubes.
6. Fine aggregate:
The river sand, passing through 4.75 mm sieve and retained on 600 μm sieve, conforming to Zone II as per IS 383-1970 was used as fine aggregate in the present study. It is clean, inert and free from organic matter, silt and clay.

7. Coarse aggregate:
Broken hard Granite was used as coarse aggregate. The combination of 12.5 mm and 10 mm size coarse aggregates were used for all mixes.

8. Steel:
The steel reinforcement was tested in the laboratory for its strength and ductility. High yield strength deformed bars (HYSD) are used.

9. Steel Fibres:
The Steel Fibres used for the present experimental work were:

   Length of the fibre: 35 mm
   Diameter of the Fibre: 0.9 mm
   Aspect Ratio: 38
   Volume Fractions: 30 Kg/m$^3$, 60 Kg/m$^3$ & 90 Kg/m$^3$ to volume of the concrete was used for the present study.

10. Marine Water:
The marine Water is obtained from natural sea water near Visakhapatnam. The marine water consists 34.8% salinity at the time of testing.

11. Magnesium Sulphate (MgSO$\textsubscript{4}$):
The magnesium Sulphate is obtained from locally and is manufactured in Molychem, Mumbai with minimum assay of 99.8%.

12. Sodium Sulphate (Na$_2$SO$\textsubscript{4}$):
The sodium Sulphate was procured locally and is manufactured in Universal laboratories Pvt. Ltd., Mumbai with minimum assay of 99.0%.

III. TESTS OF SCC

The concrete composition is now determined and the super plasticizer dosage is finally selected on the basis of concrete tests are as following:

Filling Ability:-
1. Slump Flow Test
2. V-Funnel Test
3. T50 slump flow

Passing Ability:-
4. L-Box test
5. U-Box test

Segregation Resistance:-

1. V-Funnel T5min

The following is a brief summary of the most common tests currently used for the present assessment of fresh SCC:

3.1 Slump Flow Test:
The basic equipment used is the same for the conventional concrete slump test i.e., slump cone, Tampering Rod and a smooth surface table. But the test method differs from the conventional one, the concrete sample placed into the mould is not rodded and when the slump cone has been removed and the sample has collapsed. The diameter of the spread sample is then measured horizontally on the top of the surface of the concrete but not vertically as in the conventional slump test. Also measuring the diameter of the spread, the time that it takes for the collapsed sample to spread diameter of 500 mm is measured in T50 seconds. This method gives the FILLING ABILITY of the fresh SCC.

3.2 V-Funnel Test:
Though the test is designed to measure flow ability, the result is affected by concrete properties other than flow. The inverted cone shape will cause any liability of the concrete to block to be reflected in the result – if, for example there is too much coarse aggregate. High flow time can also be associated with low deformability due to a high paste viscosity, and with high inter-particle friction.

While the apparatus is simple, the effect of the angle of the funnel and the wall effect on the flow of concrete is not clear.
3.3 L-Box Test:

This method uses a test apparatus consisting of a vertical section and a horizontal section, which the concrete is allowed to flow on the release of a trap door from the vertical section passing through reinforcing bars placed at the intersection of the two areas of the apparatus. The time is also taken for the passing of concrete for 200 mm from the gate which is made by the steel rods kept at a distance of 35 mm centre to centre is T20 seconds. Then measure the heights on each side i.e., H1 & H2. This test gives the PASSING ABILITY of the fresh SCC as well as FILLING ABILITY.

3.4 U-Box Test:

This is the method of conducting to observe the FILLING ABILITY as well as PASSING ABILITY of the fresh SCC. This apparatus is made in the shape of U with steel rods of spacing 35 mm centre to centre. So, allow the concrete to pass from vertical wing through this gate to other wing for measure the height of each wing of the U-Box.

IV. MIX DESIGN

The Japanese concept for design of SCC is based on a method proposed by Okamura and Ozawa7. The authors have proposed a simple mix-proportioning system assuming general supply from ready-mixed concrete plants. The coarse and fine aggregate contents are fixed so that self-compactability can be achieved easily by adjusting the water to powder volume ratio and superplasticizer dosage only. The mixed design as proposed is: • Coarse aggregate content is fixed at 50% of the solid volume; • Fine aggregate content is fixed at 40% of the mortar volume; • Water-powder ratio in volume is assumed as 0.9 to 1.0 depending on the properties of the powder; and • Superplasticizer dosage and the final water-powder ratio are determined so as to ensure the self-compactability. The value of water to powder volume ratio (Vw/Vp) is optimized by mortar flow test and Mortar Funnel Test. Takada8 considered the slump flow value of 650±30 mm and the V-funnel time of 11±2 s as adequate value for the workable SCC. Further to increase the viscosity and thereby reduce the deformity an organic stabilizer ‘welan gum’9 was used. In organic stabilizer, there is a polymer formation of 3-dimensional framework which increases the viscosity and water adsorption.

V. CONCLUSION

1. The modified NAN SU method provides required mix proportion, for concrete grades up to M50 while satisfying the flow characteristics of SCC.
2. The required strength and durability of the concrete mixes were obtained by some modifications made in the available NAN SU method.
3. Addition of steel fibres improved the durability aspects of Self compacting concrete up to 0.75% volume fraction.
4. The loss in weight and compressive strengths of SCC and CVC were negligible under marine and sulphate attacks due to less percentage reduction of loss.
5. SFRSCC resist the acid and marine attacks within tolerable limits and the optimum dosage of fibres for better performance was found to be at 0.5 percent.
6. NAN SU method provides less quantity of cement in normal grades of concrete that is not sufficient to bind all the ingredients in the mix.
7. Ultimate load carrying capacity of FCVC and SFRSCC beams are same for the fibre dosage of 0.75% volume fraction.
8. The SCC is not economical due to increasing the powder content with rarely available powders, but it is most suitable for constructions without any damages and is done with sufficient less skilled labor.

VI. SCOPE FOR FUTHER STUDIES

1. Optimization of powder content and super plasticizer to achieve economy in construction.
2. Studies may be conducted with increasing cement content for the Nan-Su method to achieve strength and durability characteristics.
3. Further studies are made on specimens at different ages under different environmental conditions.
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