ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Evaluating the Bond Characteristics of Fiber Based Self Compacting Concrete

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ABSTRACT

Self compacting concrete (SCC) is a development of ordinary concrete, in which the use of vibrator for compaction is no more needed/demanded. Self-compacting concrete was first developed in 1988 to (accomplish or gain with effort) (able to last through tough conditions) concrete structures. Since then, different (acts of asking questions and trying to find the truth about something) have been carried out and this type of concrete has been used in practical structures in Japan mainly by large construction companies. The use of self compacting concrete (SCC) can help the placement of concrete in crowded and blocked (strengthening item/reward/supplies) in the (related to what holds something together and makes it strong) members. This is especially important in deep (related to what holds something together and makes it strong) members and wall elements where concrete can separate (because of race, religion, etc.) and show bleeding and settlement which can result in local (related to what holds something together and makes it strong) defects that can reduce mechanical properties. (acts of asking questions and trying to find the truth about something) for beginning and building on a clear and sensible mix-design method and self-compactability testing methods have been carried out from the viewpoint of making self-compacting concrete a standard concrete.

Several studies in the past have showed/told about the usefulness of fibers to improve the properties of concrete like (the ability to be flattened or drawn into wire), post crack resistance, energy (mental concentration/picking up of a liquid) ability (to hold or do something) etc. Fiber reinforced self compacting concreting combines the benefits of self compacting concrete in fresh state and shows an improved performance in the hardened state due to the addition of fibers. Fibers bridge cracks and retard their spread, they add/give to an increased energy (mental concentration/picking up of a liquid) compared with plain concrete. In this Cem-FIL anti-crack high breaking up/spreading out glass fibers and steel fibers were added to self compacting concrete and Fiber Reinforced Self Compacting Concrete was developed by using (press or force into a smaller space)ible packing model. Several tests, such as slump flow, L-box, J-ring, V-funnel tests were carried out to get the properties for flowability and workability of fresh concrete. An experimental (act of asking questions and trying to find the truth about something) was performed to study the bond between (not formed or appearing correctly) bars, plain and fiber reinforced SCC with different embedment lengths (100mm, 150mm, 300mm.) for 16mm Î¦ bar. The results shows that bond stress was decreased with an increased embedment length of a grade of self compacting concrete and also bond stress was increased by the addition of steel fibers for all grades of SCC and corresponding slip increases for same (distance or line from one edge of something, through its center, to the other edge) of bar with constant embedment length.

Cite this article as: G.Harinarayana & Dr.K.Rajasekhar, "Evaluating the Bond Characteristics of Fiber Based Self Compacting Concrete", International Journal & Magazine of Engineering, Technology, Management and Research, Volume 6 Issue 12, 2019, Page 38-47.

INTRODUCTION

Background of self compacting concrete

Self compacting concrete (SCC) [1-4] represents one of the most significant advances in concrete technology for decades. In recent years, self-compacting concrete (SCC) has gained wide use for placement in congested reinforced concrete structures with difficult casting conditions. For such applications, the fresh concrete must possess high fluidity and good cohesiveness. Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its self-weight with little or no vibration effort, and which is at the same time, cohesive enough to be handled without segregation or bleeding. It is used to facilitate and ensure proper filling and good structural performance of heavily reinforced structural members.

Development of self-compacting concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self-compacting concrete is not affected by the skills of workers, the shape and amount of reinforcing bars or the arrangement of a structure and, due to its high-fluidity and resistance to segregation it can be pumped longer distances. The concept of self-compacting concrete was proposed in 1986 by Professor Hajime Okamura [1], but the prototype was first developed in 1988 in Japan, by Professor Ozawa [2] at the University of Tokyo. Self-compacting concrete was developed at that time to improve the durability of concrete structures. Since then, various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational mix-design method and Self-Compactability testing methods have been carried out from the viewpoint of making it a standard concrete. Self-compacting concrete is cast so that no additional inner or outer vibration is necessary for the compaction. With regard to its composition, self-compacting concrete consists of the same components as conventionally vibrated concrete, which are cement, aggregates, and water, with the addition of chemical and mineral admixtures in different proportions. Usually, these concretes have higher workability, superior mechanical properties and greater resistance to chemical attack as compared to traditional concrete [7].

It can also be regarded as "the most revolutionary development in concrete construction for several decades". Originally developed to offset a growing shortage of skilled labor, it is now taken up with enthusiasm across all countries for both site and precast concrete work. It has proved beneficial economically because of a number of factors as noted below (Krieg [15], 2003 and ENFARC, 2005):

1. Faster construction,
2. Reduction in site manpower,
3. Easier placing,
4. Uniform and complete consolidation,
5. Better surface finishes,
6. Improved durability,
7. Increased bond strength,
8. Greater freedom in design,
9. Reduced noise levels, due to absence of vibration, and
10. Safe working environment.

Mechanism for achieving SCC

The method for achieving self-compacting concrete involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when concrete flows through the confined zones of reinforcing bars. Okamura [1] and Ozawa [2] have employed the following methods to achieve self-compactability (Fig. 1.1 & 1.2)

(1) Limited aggregate content.
(2) Low water-powder ratio
(3) Use of super plasticizer

The frequency of collision and contact between aggregate particles can increase as the relative distance between the particles decreases and then internal stress can increase when concrete is deformed, particularly near obstacles. Research has found that the energy required for flowing is consumed by the increased internal stress, resulting in blockage of aggregate particles [3]. Limiting the coarse aggregate content, whose energy consumption is particularly intense, to a level lower than normal is effective in avoiding this kind of blockage.

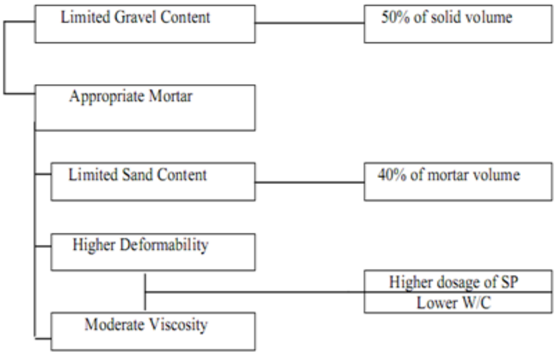

Fig.1.1 Method for achieving self-compactability

Highly Viscous paste is also required to avoid the blockage of coarse aggregate when concrete flows through obstacles. When concrete is deformed, the paste with a high viscosity also prevents localized increase in internal stress due to the approach of coarse aggregate particles. High deformability can be achieved only by the employment of a superplasticizer, keeping the water-powder ratio to a very low value.

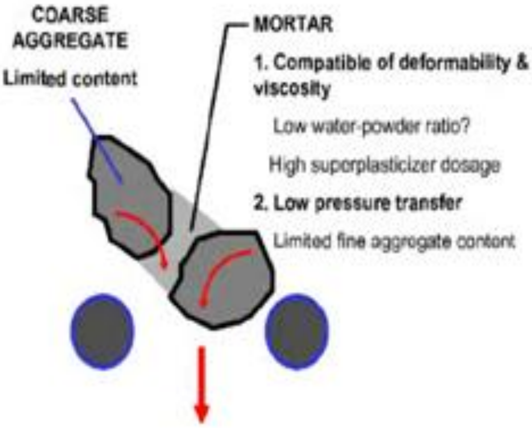

Fig.1.2 Mechanism for achieving self-compactability

Since the development of the prototype of self-compacting concrete in 1988, the use of self-compacting concrete in actual structures has gradually increased. The main reasons for the employment of self-compacting concrete can be:

- To shorten construction period
- To assure compaction in the structure - especially in confined zones where vibrating compaction is difficult
- To eliminate noise due to vibration - effective especially at concrete products plants

By employing self-compacting concrete, the cost of chemical and mineral admixtures is compensated by the elimination of vibrating compaction and work done to level the surface in case of the normal concrete. SCC can greatly improve construction systems previously based on conventional concrete requiring vibrating compaction. Vibration compaction [5], which can easily cause segregation, has been an obstacle to the rationalization of construction work. Once this obstacle has been eliminated, concrete construction could be rationalized and a new construction system, including formwork, reinforcement, support and structural design, could be developed (Figure 1.3)

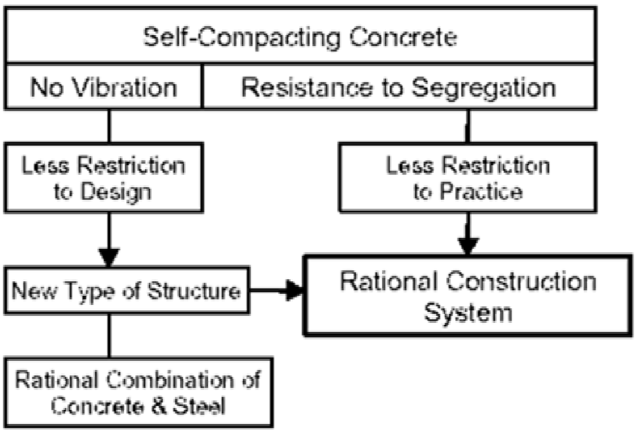

Figure 1.3 Rational construction system proposed by Ozawa

Self-Compacting Concrete composition

Self-compacting concrete (SCC) is a fluid mixture, which is suitable for placing in difficult conditions and in structures with congested reinforcement, without vibration. 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

The technology of SCC is based on adding or partially replacing Portland cement with amounts of fine material such as fly ash, blast furnace slag, and silica fume without modifying the water content compared to common concrete. This process changes the rheological behavior of the concrete [6].

World-wide Current Situation of Self-Compacting Concrete

Self-compacting concrete has already been used in several countries. In Japan, major construction projects included the use of SCC in the late ’90s. Today, in Japan, efforts are being made to SCC of the “special concrete” label and integrate it into day-to-day concrete industry production. Currently, the percentage of self-compacting concrete in annual product of ready-mixed concrete (RMC), as well as precast concrete (PC), in Japan is around 1.2% and 0.5% of concrete products respectively.

In the United States, the precast industry is also implementing SCC technology through the Precast/Prestressed Concrete Institute (PCI) which has done some research on the use of SCC in precast/prestressed concretes starting with 1999. It is estimated that the daily production of SCC in the precast/prestressed industry in the United States will be 8000 m3 in the first quarter of 2003 (around 1% of the annual ready-mix concrete). Furthermore, several state departments of transportation in the United States (23 according to a recent survey) are already involved in the study of SCC. With such a high level of interest from the construction industry, as well as manufacturers of this new concrete, the use of SCC should grow at a tremendous rate in the next few years in the United States. However, even if it is made from the same constituents the industry has used for years, the whole process, from mix design to placing practices, including quality control procedures, needs to be reviewed and adapted in order for this new technology to be applied properly.

Development of Self-Compacting Concrete in India

Development of Self-compacting concrete (SCC) is considered as the most sought development in construction industry due to its numerous inherited benefits. In India, this technology is yet to realize its full potential. Central Road Research Institute (CRRI) [8] New Delhi, has been working on SCC technology since the year 2000 and carried out significant research work on various aspects of SCC starting from selection of suitable ingredients including superplasticizer, viscosity modifying agent, mineral admixtures, mix proportion optimization, evaluation of the characteristic properties at fresh stage and hardened properties such as compressive strength, splitting tensile strength, flexural strength, Young’s modulus of elasticity.

Further, in-situ performance evaluation of the structural element cast by using SCC in comparison with conventional plasticized concrete of similar strength i.e. 50 MPa at 28 days were carried out by using semi-destructive and non-destructive test methods. Structural behavior of SCC in heavily reinforced T beams was conducted to study cracking pattern, deflection and ultimate load bearing capacity. On the basis of manufacturing cost, SCC is about 20% costlier than the conventional concrete of similar compressive strength which is compensated by several benefits of using it such as saving in electricity, saving in labor cost related to compaction work, increase in productivity etc. SCC technology is considered as an energy conservation technique in construction industry as it eliminates electricity requirement for compaction of concrete and providing ample opportunity to use by product materials such as fly ash, quarry dust etc. With a wide knowledge and experience on the technology, CRRI [9] can provide technical advices related to the manufacturing of SCC.

Bond-Slip Mechanism

Considering the economy and the durability of our present concrete structures, the quality and the density of the concrete cover, as well as the compaction of the concrete are main parameters. For this SCC offers new possibilities and prospects as a result of the mix design. Some properties of the hardened concrete can be different for SCC in comparison to the normal concrete (NC) [10].Therefore, it is important to verify the mechanical properties of SCC before using it for practical applications, especially if the present design rules are applicable or if they need some modifications.

Hence the load bearing capacity of a reinforced concrete structure is considerably influenced by the bond behavior between the reinforcing bars and the concrete.

The bond between concrete and reinforcement bars is very important to develop the composite behavior of reinforced concrete. Bond strength is influenced by several factors such as bar diameter, cover of concrete over the bar, spacing of bars, grade and confinement of concrete, aggregate, type of bars and coating applied on bars, if any, for corrosion prevention.

Bond in reinforced concrete refers to the adhesion between the reinforcing steel and the surrounding concrete. The bond between steel and concrete ensures strain compatibility (the strain at any point in the steel is equal to that in the adjoining concrete) and thus composite action of concrete and steel.

Bond in reinforced concrete is achieved through the following mechanisms:

- Chemical adhesion due to the products of hydration.
- Frictional resistance due to the surface roughness of the reinforcement and the grip exerted by the concrete shrinkage.
- Mechanical interlock due to the ribs provided in deformed bars.

Objective of the research

To produce SCC, the major work involves designing an appropriate mix proportion and evaluating the properties of the concrete thus obtained. A simple mix design procedure based on compressible packing model (CPM) and NANSU mix design model [11] was used with some modifications to arrive at the mix proportions.

Hence the main objective of the research is to arrive at the CA/FA proportions in a systematic approach using the CPM method after conducting number of trails and getting the SCC mixes by satisfying EFNAC specifications [12]. For higher strength concrete, a higher degree of elastic and stiffer bond behavior is expected due to the improved strength and the higher modulus of elasticity. The average bond strength is increased in Self compacting concrete as the porosity is reduced due to the addition of much finer material such as fly ash.

Though the bond characteristics of the normal concrete are reasonably well established, the bond characteristics of self compacting concrete using supplementary cementitious materials like GGBS [9], fly ash and silica fume have not been studied in detail. So the investigations are carried out to evaluate the bond strength of steel reinforcements for M40, and M60 grade of self compacting concrete with and without glass and steel fibers. Fiber reinforcement in the region of the splice/development length played a role similar to ordinary transverse reinforcement in that it restricted the growth of the splitting cracks and increased the splitting bond strength.

EXPERIMENTAL PROGRAM

Introduction of Experimental study

The experimental program was designed to study the comparison of bond behavior and bond strengths of M40, and M60 grade of SCC with and without steel and glass fibers.

The program consisted of casting and testing a total number of 54 cylinders of size 150mm diameter and 300mm height with 16 mm Φ Tor steel bars and 9 cubes of 150x150x150 mm size, were casted in 3 batches. Of these 54 cylinders 27 cylinders for M40 grade [11] of self compacting specimens and 27 cylinders of M60 grade of self compacting specimens, and their corresponding 9 cubes for compressive strength.

The specimens were cast with the steel rebar in perfect vertical position with help of fasteners at the top end of mould in order to avoid secondary stresses in the bar. The steel bars were rust free and perfectly straight. For each concrete batch, the cube compressive strength was determined on three 150 x 150 x150 mm3 Cubes. The mix proportion for M40, and M60 grade of Self compacting concrete was designed by using CPM model. The fly ash was incorporated in the above mix proportion by replacing 26.82% for M40 and 19.38% for M60 respectively [10].

This optimum content of fly ash was obtained by casting trail mixes and from previous studies. Water reducing admixtures are added into mixes on requirement, till the desired fresh properties are exhibited by them. The details of the specimen's cast are shown in Table 3.1.

Table 3.1 Details of specimens cast

S. No	Grade of concrete	Type of concrete	Embedment Length(mm)	No of cylinders cast(pullout test) 150 D x300 mm^3 for 16mm Φ	No of cubes for (comp. strength) 150X150X150 mm^3
1	M40	Without fibers	100	3	3
			150	3	
			300	3	
		With steel fibers	100	3	3
			150	3	
			300	3	
		With glass fibers	100	3	3
			150	3	
			300	3	
2	M60	Without fibers	100	3	3
			150	3	
			300	3	
		With steel fibers	100	3	3
			150	3	
			300	3	
		With glass fiber	100	3	3
			150	3	
			300	3	

MATERIALS USED

The different materials used in this investigation are

- 53 Grade Ordinary Portland cement.
- Fine Aggregate and Coarse Aggregate
- Super Plasticizer (CONPLAST SP430).
- Fly ash.
- Deformed Steel Bars
- Water
- Steel fibers and Glass fibers

Cement

Cement used in the investigation was 53 Grade Ordinary Portland cement confirming to IS: 12269. The cement was obtained from a single consignment and of the same grade and same source. Procuring the cement it was stored properly. The Specific gravity of the cement is found to be 3.11.

Fine Aggregate

The fine aggregate conforming to Zone-2 according to IS: 383[28] was used. The fine aggregate used was obtained from a nearby river source. The bulk density, specific gravity of the sand used were 1.56g/cc, and 2.42.The sand obtained was sieved as per IS sieves (i.e.2.36, 1.18, 600,300 and 150m). Sand retained on each sieve was filled in different bags and stacked separately for use. To obtain zone-2 sand correctly, sand retained on each sieve is mixed in appropriate proportion according to the mix design and required quantity in which each size fraction is mixed is shown in Table 3.2.

Table 3.2 Proportions of Different Size Fractions of Sand to Obtain Zone-2 Sand

Sieve size (mm)	% Passing recommended by IS: 383[36]	Adopted grading	%Weight retained	Cumulative % Weight retained	Weight retained in gms.
10-4.75	100	100	-	-	-
4.75-2.36	90-100	100	-	-	-
2.36-1.18	75-100	90	10	10	100
1.18-0.60	55-90	65	25	35	250
0.60-0.30	35-59	40	25	60	250
0.30-0.15	8-30	10	30	90	300
0.15	0-10	0	10	100	100

Tests for Fresh Properties of Self-Compacting Concrete

At the stage before solidification, self-compacting concrete is required to have three qualities: high-flowability, resistance against segregation and possibility, i.e. ability that is necessary to pass the space between reinforcing bars. Therefore, it is important to test whether the concrete is self-compactable or not and also to evaluate deformability or viscosity for estimating proper mix proportioning if the concrete does not have sufficient self-compactability.

Moulds and Equipment

Cubes: Standard cube moulds of150X150X150mm are made of cast iron were used for M20 ,M40 and M60 grades for obtaining compressive strength of each specimen type.

Cylinders: Standard cast iron moulds of size 150mm diameter X 300mm height were used for casting specimen for pullout tests to obtain pullout strength.

Mixing:

It was found that the fresh fly ash-based concrete was dark in color (due to the dark color of the fly ash), and was cohesive. The amount of water in the mixture played an important role on the behavior of fresh concrete. When the mixing time was long, mixtures with high water content bleed and segregation of aggregates and the paste occurred. This phenomenon was usually followed by low compressive strength of hardened concrete.

The effects of water content in the mixture and the mixing time were critical parameters which decide the concrete strength. From the preliminary work, it was observed that the mixing period of concrete should be within five to seven minutes as for the concrete and while mixing the following steps should be followed.

- First Mix all dry materials in the pan mixer.
- Add the liquid component of the mixture at the end of dry mixing, and continue the wet mixing for another four minutes.

Casting

The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there are small gaps they were filled with plaster of Paris. The moulds then oiled and kept ready for casting. The entire casting was done in three stages one each corresponding to M40 and M60 grades. A pan mixer of having 100kg capacity was used for mixing concrete. In case of M40 and M60 concretes the super plasticizer was used for workability purpose as per the specifications and calculations. This was dispersed in water in required proportion before mixing the water with the ingredients coarse, fine aggregates, cement and fly ash.

Deformed Steel bars of 16 mm diameter are used. Bars with calculated length have been put in the cylindrical specimens for pull out tests and fastened properly so as to keep the bars perfectly straight and concentric in the moulds during casting. The Embedded length has been controlled carefully such that the calculated amount of length will only get inserted in the specimen at casting time. The general details of bar length have been shown below in the fig(3.1.). A grip length of 100 mm for fixing, and lower platen coverage of 350mm, 250 mm free length for extensometer provision has been considered as the projected bar length excluding embedded length for all the specimens. An embedded lengths of 100mm, 150mm and 300mm for M40 and M60 grade concretes has been adopted.

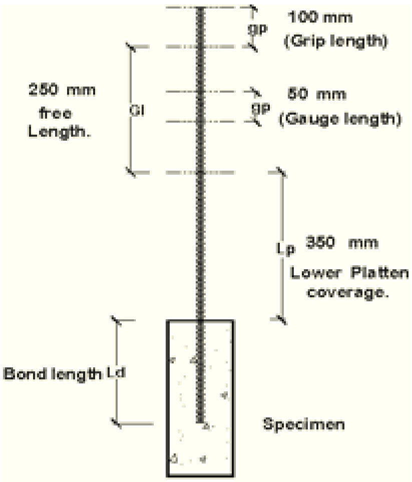

Fig 3.6 General details of free bar in the specimens.

At the end of casting the top surface was made plane using trowel and a hacksaw blade to ensure a top uniform surface. After 24 hrs of a casting the moulds were kept for wet curing for the required number of days before testing.

Curing

After the completion of casting all the specimens were kept to maintain the ambient conditions viz. temperature of 27±2 C and 90% relative humidity for 24hours. The specimens were removed from the mould and submerged in clean fresh water until just prior to testing. The temperature of water in which the cubes were submerged was maintained at 27± 2 C. The specimens were cured for 60days.Care was taken to see that the reinforcement steel was entirely out of water to prevent it from rusting.

RESULTS & DISCUSSIONS

General

As explained earlier in chapter 3, the experimental investigations were done on Slip-Bond behaviour of M40 and M60 grade of SCC mixes without fiber, with steel fiber and with glass. In the present work the idea is to study the bond behaviour of self compacting concrete for M40 & M60 for various parameters like effect of fiber (steel and glass) and different embedded lengths (100mm, 150mm, 300mm.).

The results of 54 cylindrical specimens with 16 mm Φ deformed bar embedded in them for Bond studies and 9 cubes for compressive strength have been presented in this chapter. Flow Chart showing the Experimental programme details is presented below.

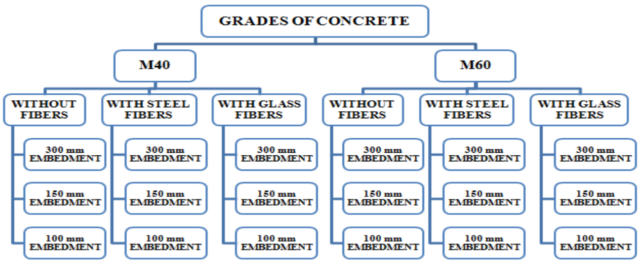

Fig 4.1 Flow Chart showing the Experimental programme details

Effect of Compressive Strength for self compacting concrete

Table 4.1, Table 4.2 and Table 4.3 shows the compressive strength for M40 and M60 grade self compacting concrete with 300mm, 150mm and 100mm embedment lengths without fibers, with steel and glass fibers.

Table 4.1 Details of Average compressive strengths without fibers

Specimen designation M40	Avg. comp. Strength. fck (N/mm^2)	Specimen designation M60	Avg. comp. Strength. fck (N/mm^2)
M40-1	48.67	M60-1	69.12
M40-2		M60-2	
M40-3		M60-3	

Table 4.2 Details of Average compressive strengths with Steel fibers

Specimen designation S40	Avg. comp. Strength. fck (N/mm^2)	Specimen designation S60	Avg. comp. Strength. fck (N/mm^2)
S40-1	51.65	S60-1	71.92
S40-2		S60-2	
S40-3		S60-3	

Table 4.3 Details of Average compressive strengths with Glass fibers

Specimen designation G40	Avg. comp. Strength. fck (N/mm^2)	Specimen designation G60	Avg. comp. Strength. fck (N/mm^2)
G40-1	50.13	G60-1	70.94
G40-2		G60-2	
G40-3		G60-3	

CONCLUSIONS

A detailed experimental program was taken up to understand the role of embedment length on the bond stress of self compacting concrete. Based on the study, the following conclusions can be drawn regarding the bond behavior of self compacting concrete.

1) There is an increase in ultimate slip with increase in embedment length for all grades Self Compacting Concrete (M40 and M60) without fibers, with glass and steel fibers.

2) There is an increase in bond strength with increase in grade of Self Compacting Concrete (M40 and M60) without fiber, with steel and glass fiber.

3) There is an increase in the ultimate slip with the addition of fibers (steel and glass) to Self Compacting Concrete, this is due to crack arresting property of the fibers

4) The bond strength increases with decrease in embedment length for all grades Self Compacting Concrete (M40 and M60) with (steel and glass) and without fiber.

5) The bond strength and ultimate slip increases with the addition of fibers for grade of self compacting concrete. This increment is predominant in case of addition of Steel fibers and there is marginal increase in the case of addition of Glass fibers for all grades (M40 and M60) of self compacting concrete.

6) There is an increase in fracture energy with increase in embedment length for all grades (M40 and M60) of SCC. This further increase as the grade of SCC increases.

7) Fracture energy increases with the addition of fibers for grade of self compacting concrete. This increment is predominant in case of addition of steel fibers and there is marginal increase in the case of addition of glass fibers for all grades of SCC.

REFERENCES

[1]. Hajime Okamura and Masahiro Ouchi (2003), “Self-Compacting Concrete”, Journal of Advanced Concrete Technology Vol.1, No.1, 5-15, April 2003.

[2]. Ozawa K., Kunishima, M., Maekawa, K. and Ozawa, K, “Development of High Performance Concrete Based on the Durability Design of Concrete Structures”. Proceedings of the second East-Asia and Pacific Conference on Structural Engineering and Construction (EASEC-2), Vol. 1, pp. 445-450, January 1989.

[3]. Subramanian, S. and D. Chattopadhyay, “Experiments for mix proportioning of self-compacting concrete”, The Indian Concrete Journal, pp.13-20 (2002).

[4]. Khayat, K.H., M.Vachon, and M. C. Lanctot, “Use of Blended Silica Fume Cement in Commercial Concrete Mixtures”, ACI Materials Journal, pp.183-192 (1997).

[5]. Nan Su, Kung-Chung Hsu, His-Wen Chai, “A simple mix design method for self-compacting concrete”, Cement and Concrete Research, 6 June 2001, pp1799-1807.

[6]. H.J.H. Brouwers, H.J. Radix, Self-Compacting Concrete: Theoretical and experimental study Cement and Concrete Research 35 (2005) 2116– 2136.

[7]. S. VenkateswaraRao, M.V. SeshagiriRao, P. Rathish Kumar, “Effect of Size of Aggregate and Fines on Standard and High Strength Self compacting Concrete”, Journal of Applied Sciences Research, 6(5): 433-442, 2010.

[8]. T. Suresh Babu, M.V. SeshagiriRao and D. Rama Seshu, “Mechanical properties and stress strain behavior of self compacting concrete with and without glass fibers”, Asian journal of civil engineering (Building and Housing) Vol. 9, No. 5 (2008) Pages 457-472.

[9]. T. Suresh Babu, M.V. SeshagiriRao and D. Rama Seshu, “Mechanical properties and stress strain behavior of self compacting concrete with and without glass fibers” Asian journal of civil engineering (Building and Housing) Vol. 9, No. 5 (2008) Pages 457-472.

[10]. N. Subramanian, “Development length of reinforcing bars –need to revise Indian codal provisions”,Theindian concrete journal,August 2005.

[11]. A. Foroughi-Asl, S. Dilmaghani, H. Famili, "Bond strength of reinforcement steel in self-compacting concrete" International Journal of Civil Engineering, Vol. 6, No. 1, March 2008.

[12]. W. Zhu, M. Sonebi and P. J. M. Bartos, "Bond and interfacial properties of reinforcement in self compacting concrete Materials and Structures / Matdriaux et Constructions", Vol. 37, August-September 2004, pp 442-448.