A Thesis on

A STUDY ON LATEX MODIFIED GLASS FIBER REINFORCED SELF COMPACTING CONCRETE

Submitted for partial fulfillment of the requirement for the award of degree

MASTER OF TECHNOLOGY

In

STRUCTURAL ENGINEERING

By

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DECLARATION

I declare that the research thesis entitled "**A Study on Latex Modified Glass Fiber Reinforced Self Compacting Concrete**" is the bonafide research work carried out by me, under the guidance of **Mr. Muddassir Umer Rizvi (Assistant Professor), Department of Civil Engineering, Integral University, Lucknow**. Further I declare that this has not previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

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CERTIFICATE

It is Certified that the thesis entitled **“A Study on Latex Modified Glass Fiber Reinforced Self Compacting Concrete”** is being submitted by **Mr. Satish Kumar (Roll no.: 1901432006)** in partial fulfillment of the requirement for the award of degree of Master of Technology (Structural Engineering) of Integral University, Lucknow, is a record of candidate’s own work carried out by him/her under my supervision and guidance.

The results presented in this thesis have not been submitted to any other university or institute for the award of any other degree or diploma.

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Chapter 01
INTRODUCTION

1.1 Introduction

Self-compacting concrete technology was originally developed in Japan, this technology was also being made possibly easier and earlier development of super-plasticizers for concrete as in Japan, the SCC is used due to the fact that the cement content of SCC is more than conventional concrete so making the concrete costlier but when view the whole costing the use of SCC gets decreased as in the use of SCC, the labour involved in casting and placement is much decreased due to no compaction of SCC and reduced use of machines. Self-Compacting Concrete is a special type of concrete which can be consolidated and compacted under its dead weight without the use of any type of vibrations from any external sources due to its deformation and it can cohesive so as to be handled without any segregation and bleeding. Yield stress is also a rheological parameter of fresh concrete and it is defined as a minimum stress required to make the concrete flow, SCC requires a low yield stress and it inversely related to slump flow.

Slump flow describes the flowability of fresh SCC in unconfined conditions and it is a sensitive test and checks that the fresh SCC meets the specifications of it. The slump classes are as: Slump flow (SF1) 550-650mm slump flow is suitable for unreinforced or less reinforced structures (as in housing slabs, tunnel-linings, pile & deep foundations).

Slump flow (SF2) 650-750mm slump is used for walls and columns where reinforcement is slightly balanced in the structure.

Slump flow (SF3) 750-850mm is produced with nominal aggregate size less than 16mm and it is produced for vertical application in congested structures but here segregation resistance is difficult to control as compared to SF2.

Viscosity is also a parameter rheological and it is the resistance of SCC, when the flow has started. Viscosity can be accessed by the T_{500} time test and V-funnel flow time. The time calculated in V-funnel test does not measures the viscosity of SCC but it describes the rate of flow. Viscosity is calculated in two ways: Viscosity VS1 has best filling ability within the congested reinforcement and it is a capability of self-levelling and good surface finish. Viscosity VS2 has increasing flow time and is also likely to exhibit thixotropic effects.

It has already been found that the main differences between the recycled concrete and conventional fresh concrete is the water absorption of the recycled-aggregate that is used in the production of recycled concrete and water absorption of recycled aggregate is calculated and the amount of variation of water is then calculated and found in increase in the water absorption of recycled concrete more as compared to conventional concrete. It is originally developed to manage the growing shortage of skilled-labour, it is already has been proven that self-compacting concrete is economical in a number of ways including:

- Easier placement of concrete
- Improved durability of concrete
- Greater freedom in designing structures
- Thinner concrete sections can easily be casted
- Reduced noise pollution due to no use of vibrators
- Safer working environment with less machinery and electric motors
- Easier, durable and faster construction
- Reduction in skilled labour and site man-power
- Better surface finishes
- Improved quality of construction

Self-compacting concrete and conventional concrete of same strength have very comparable strength as therefore SCC can be used where normal is used. The compressive strength test of concrete is the most vital test in engineering properties. SCC with a similar water cement ratio as in conventional concrete, it will usually have a slightly higher compressive strength as in comparison to conventional concrete as it is due to the reason that an improved interference between the aggregate and hardened paste due to absence of any external vibrations. So, the compressive strength of SCC developed is comparatively higher. For SCC of any strength, the tensile strength of SCC may be assumed to be same as compared to the normal conventional concrete as the volume of paste (fines + cement + water) which is much more in SCC and it has no significant effect on tensile strength. Infact due to the improvement of denser microstructure, less porous structure, mechanical properties and homogeneity, the tensile strength becomes slightly higher as compared to conventional concrete.

VMA is particularly adopted for the production of self-compacting concrete as it provides hydraulic binder-based material with excellent stability and results in a high level of fluidity and high quality without the use of any external vibrations, etc. Viscosity Modifying Admixture (**V.M.A.)** is a water-based and non-flammable admixture and VMA has a life span of 24 months period provided the temperature is maintained in a range of 2^0 C to 50^0 C. When VMA is used, the application of self-compacting concrete shall be such that it is not poured from a great height into the casting area and the use of sleeves for filling the casting structure is highly recommended.

1.2 Definitions of SCC

The Self compacting concrete has been defined by many and some of the definitions are as below:

i) EFNARC, May 2005, Guidelines for SCC defines it as "Concrete that is able to flow and consolidate under its own weight, completely fill the formwork even in the presence of dense reinforcement, whilst maintaining homogeneity and without the need for any additional compaction".

ii) Technical Bulletin TB-1501 defines SCC as "Self-Consolidating Concrete (SCC) also known as self-compacting concrete, a highly workable concrete that can flow through densely reinforced or complex structural elements under its own weight and adequately fill voids without segregation or excessive bleeding, and without the need for vibration.

iii) Khayat K. H. defines SCC as: "A highly flowable, yet stable concrete is one that can spread readily into place and fill the formwork without any consolidation and undergoing any significant segregation".

iv) As per N.V.Nayak et.al: "A concrete that is capable of Self compacting (self consolidating), occupies all space in the form without any external efforts (in the form of mechanical vibration ,floating, poking etc.) is termed as self compacting concrete".

v) As per report # 1, SCC of CE241, Concrete technology (2004): "SCC is in want of a standard definition, but may be nominally considered a concrete mix of exceptional deformability during casting, which still meets resistance to segregation and bleeding."

vi) Japan Concrete Institute defines SCC as "A concrete having self compatibility, self compactability of concrete is its ability related to the placeability, with which it can be uniformly filled and compacted in the every corner of formwork by its own weight without vibration during placing".

1.3 Necessity To Choose SCC

SCC is considered as a preferred option due to its well known properties of flowability, passing ability and compatibility.
SCC is an excellent repair material for concrete encasement because of its ability to flow through narrow openings.
Care shall be taken to avoid shrinkage of concrete by adding shrinkage compensating admixtures since bonding of new concrete with the old concrete is a requirement in repair works.
Congested reinforcements, secondary concreting of gate slots, complicated shapes of concrete elements necessitates the use of SCC.

1.4 Advantages of Self Compacting Concrete

i) Self compacting concrete (SCC) is a concrete which is able to flow under its own weight, completely filling formwork & achieving full compaction, even in the congested places. The SCC mixes have these attributes because of their good deformability enabling them to maintain homogeneity at fresh state. It can be placed & compacted under its self weight with little or no vibration effort & which is at the same time is cohesive enough to be handled without segregation & bleeding.
ii) Self compacting concrete offers a rapid rate of concrete placement with faster construction times & ease of flow around congested reinforcement. The fluidity & segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids & uniform concrete strength in situ, providing the potential for a superior level of finish & durability to the structure.
iii) Use of fly ash in SCC is an eco friendly option and is useful in controlling the excess heat of hydration in concreting. It also improves to the qualities like homogeneity, permeability and durability of the concrete.
iv) Use of flyash is mostly necessary to provide higher quantity of powdery material required in SSC. SCC has got a property of self compacting which removes one of the main reasons of discrepancy between the performance of laboratory concrete specimens and that of the concrete structures at site, namely the degree of compaction of the fresh concrete; as SCC mixture does not depend on the degree of compaction of the fresh concrete.

v) SCC enables reduction in noise at site and so it ensures improved health and safety at site. The use of SCC reduces the exposure of the workers to sound intensities that are as low as one tenth of those produced when placing traditional vibrated concrete; introduction of SCC is truly a quiet revolution in concrete.

vi) SCC requires reduced manpower over conventional concrete placing of SCC is much less strenuous activity than placing traditional vibrated concrete.

vii) More innovative designs, more complex shapes, more thinner sections are possible with use of SCC.

viii) SCC exhibit greater stability than traditional concrete.

ix) Reduced internal bleeding when SCC is used is responsible for a denser and stronger ITZ with respect to that of CC. The positive role of SCC in decreasing microcracking and porosity of interfacial transition zone (ITZ) is also responsible for a more durable concrete.

x) Large amount of fly ash or limestone filler in SCC favors formation of a less porous and, hence, a stronger transition zone due to a limited amount of microcracking in the vicinity of the ITZ.

xi) The denser microstructure of the ITZ in SCC may contribute for a lower plastic settlement, higher bond between steel and concrete matrix, lower permeability to oxygen and lower chloride diffusion coefficient with respect to corresponding values for conventional concretes.

xii) Higher tensile strength for SCC is due to improvement in the homogeneity and denser microstructure of the ITZ.

xiii) SCC allows rapid pumping of concrete.

xiv) SCC has uniform, even surface with less surface defects, voids honeycombs etc. by virtue of good filling ability.

xv) SCC has improved aesthetics of final product with improved surface finish due to its good fluidity and deformability making SCC a competitive option vis-a-vas traditional concrete.

xvi) When placing a new layer of SCC on old SCC, the bond between the old and new SCC is equal to or better than in the case of conventional vibrated concrete.

xvii) A review of technical literature shows that SCC can flow (in formwork) horizontally a distance of 15-20m without segregation. A well designed SCC may have a free fall of as much as 8 m without segregation. However, from practical considerations height of free fall shall be restricted to 3 m and horizontal flow be as small as possible but restricted to 10 m.

1.4 Limitations of SCC

i) Self compacting Concrete is a new technology and hence, requires well maintained and high degree of quality control & quality assurance methods. Production and placing of SCC need to be carried out by trained personnel only.

ii) Absence of internal and external bleeding in SCC, however is one of the causes for their higher plastic shrinkage compared to traditional vibrated concrete. Hence, SCC should be cured as soon as practicable after placement to prevent surface shrinkage cracking.

iii) The lower MSA (nominal maximum size of aggregate) and reduction in % of coarse aggregate in volume of SCC are responsible for lower modulus of elasticity compared to the conventional concrete. For this reason, the total shrinkage of SSC is also slightly higher.

iv) SCC requires good and leak proof formwork due to presence of more fines and flowable concrete. Special attention is needed in design of the formwork for pressures based on the flowability, cohesiveness, rate and method of placing or pumping (from top/from bottom) etc.

v) Before any SCC is produced at the plant and used at the job site, the mix must be properly proportioned and tested to assure compliance with the functional requirements and the project specifications. The ingredients and the equipment used in developing the mix and testing should be the same ingredients and equipment to be used in the final mix for the project.

vi) Most common concrete mixers can be used for producing SCC. However, the mixing time may be longer than that for the conventional vibrated concrete.

vii) SCC is more sensitive to the total water content in the mix. It is necessary to take into account the moisture/water content in the aggregates and the admixtures before adding the remaining water in the mix. The mixer must be clean and moist, and contains no free water.

viii) The truck drivers (transit mixer) should be given oral and written instructions for handling SCC. He must check the concrete drum before filling with SCC to make sure that the drum is clean and moist, but with no free water. Extra care must be taken for long deliveries. The truck driver shall also be given training in regional languages about the effects of wrong handling, adding extra water etc. This training will help them to know the importance so that the instructions given to them can be implemented effectively.

ix) The truck drivers should not be allowed to add water and/or admixtures during transit.

x) SCC is more sensitive to temperature during the hardening process than the conventional vibrated concrete hence extra care shall be taken about the handling and keeping the concrete cool.

1.5 Scope

This Chapter is an effort to represent a document addressed to those specifiers, designers, producers and users who wish to enhance their expertise and use of SCC. It will serve as a useful guide to the engineers and contractors working in Water resources department & Public works department. The Guidelines in this chapter cover information that is common to SCC for the ready mixed, site mixed concrete industry.

The Guidelines are drafted with an emphasis on ready-mixed, site mixed SCC where there are requirements in relation to the specification of the hardened state. In addition, the Guidelines cover specific and important requirements for user of SCC regarding the site preparation over traditional vibrated concrete. The document describes the properties of SCC in its fresh and hardened state, and givesadvice to user of ready-mixed, site mixed concrete, on how SCC should be specified in relation. Advice is given to the producer on constituent materials, their control and interaction. Since there are number of different approaches to the design of SCC mixes, no specific method is recommended. However, approaches to mix design are given. Advice is given to the contractor/user of ready-mixed, site mixed SCC on delivery and placing.

Chapter 02

LITERATURE REVIEW

2.1 Review of Literatures

1. **Mohsen A. Issa, Mohammad A. Alhassan, Jill C. Ramos**

The fiber feeder system is simple to use and can be used to produce LMC mixtures with very uniform fiber distribution. Although the addition of 0.6 and 1.2 kg/m^3 (1 and 2 lb/yd^3) of glass fibers to LMC apparently has a small effect on compressive and flexural strength, the addition of glass fibers does appear to reduce shrinkage.

2. **Mohammed Kareem Abed**

The result of concrete workability test, showed that the adding of glass fiber would reduce the value of slump flow, t50cm, blocking ratio of L-Box test and time flow of V-funnel test, but these results would remain within the standard classification. Hardened concrete inspection results show the increasing of compressive and splitting strength and modulus of rupture (MOR) when using of glass fibers and this increment is proportionate directly with volume of fibers which are used. It is recommended to use glassy fibers in the self compacting concrete (SCC) for the reason of it has a positive affect in the improvement of concrete properties.

3. **Byung Jae Lere, Yun Yong Kim.**

Mixing with the shrinkage agent had insignificant effect on the properties of fresh concrete, but when concrete was mixed with over 5% shrinkage reducing agent, excessive air content and slump loss occurred. In terms of compressive strength and bond strength, SRA 3 mixing showed the highest compressive strength and bond strength and the compressive strength and bond strength decreased in other mixing conditions. Through evaluating the shrinkage properties of LMC mixed with the shrinkage reducing agent, the SRA 3 mixing showed the lowest length change. In terms of crack occurrence, there was no crack resistance test for 56 days. In the durability performance evaluation it was confirmed that the high strength LMC showed high resistance to chloride ions penetration. In terms of the scaling resistance an excellent result was also achieved when the shrinkage reducing agent was used.

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4. **N. Dhivyabharathi, Dr. E.K.Mohanraj**

This study carries out an experiment to separate steel reinforcement from concrete as completely as possible through indirect heating using high-frequency induction heating, especially of the steel reinforcement inside the reinforced concrete.

5. **Abdulkader Ismail Al-Hadithi, Nahla Naji Hilal.**

The slump flow diameters ranging from 650 to 780 mm were obtained for the self compacting concrete. The reference mixture was in the SF1 class while the self compacting rubberized concrete with WPF were in the SF3 class according to EFNARC. Although the increasing in WPF content which led to reduce the slump flow diameters of concrete, the result were acceptable for many normal application of self compacting concrete. The addition of WPF leaders to increase in both T50 slump flow and V-funnel flow times. All the mixture can be categorized as VS2/VF2 viscosity class due to the fact that using the WPF in production of self compacting concrete requirements according to EFNARC. As waste plastic fibers WPF were added, wet density values of all mixtures generally became lower. The reason for this reduction attributed to the fact that the plastic has low specific gravity.

6. **A. Deepak raj, M. Mergin Benize, J. Esther Daisy, M. Sri Nikhil**

The test results concluded that the addition on S-glass fibers does not affect the filling ability, passing ability and segregation resistance of the SCC. It is observed that the flow ability of GFRSCC is directly proportional to the length and quantity of glass fiber added. 1% of S-glass fiber in all size (|G1, G2 AND G3) is more flow able than 0.25% of S-glass fiber in all sizes.

7. **Noor Ahmed Memon, Muneeb Ayoub Memon, Nawab Ali Lakho, Fareed Ahmed Memon, Manthar Ali Keerio, Ammaar Noor Memon**

A wide variety of waste materials is used as cement replacement in SCC. The fresh properties are significantly affected by the addition of cementitious materials. However, the effect depends upon the type, dosage and combination of adopted cementitious materials. Mechanical properties were also remarkably affected by the cementitious materials used. The effect is significant on certain types of waste materials such as silica fume and fly ash. Different fibers added as fiber reinforcement in SCC were used. Fibers exhibit pronounced effect on both fresh and hardened properties of SCC. The waste materials obtained from different resources are also used as replacement of fine aggregates but the discussion in this regard is beyond the scope of this paper.

8. Guneyisi, Yahya R. Atewi, Mustafa F. Hasan

The results showed that the CDW could be transformed into recycled concrete aggregate leading to reduction in the concrete compressive strength ranged from 37% to 62% depending on the type of the CDW constituents.) Construction and demolition waste can be recycled to be used as concrete aggregate with properties suitable for infrastructure applications (e.g. pavement and sidewalk border).

9. Osman GENCEL, Cengiz OZEL, Fuat KOKSAL, Gonzalo MARTINEZ-BARREA, Witold BROSTOW, Hasan POLAT

The combination of SCC+ fibers + FA has provided sufficient strength characteristics of concrete and improved workability. Inclusion of fly ash, an industrial waste material, lowers environmental pollution and has a positive effect on economy. Used fuzzy logic approach to predict fresh concrete properties from variables representing the concrete mixture, to predict similarly hardened concrete properties and finally hardened concrete properties from fresh concrete properties. The advance of the proposed approach is that the behavior of concrete can be predicted without lengthy trial and error experiments that increase material waste and also increase production costs. Thus predicted from fuzzy logic approach several properties quite successfully: slump flow, V-funnel, J-ring and slump diameter, all non the basis of fly ash content (%), cement content (kg/mcub) and fiber content (kg/mcub).

10. Pedro J.D. Mendes, Joaquim A.O. Barrtos, Jose M. Sena-Cruz, Mahsa Taheri

In this work a composite solution for a pedestrian bridge of 12 m span is proposed, composed by a deck made by steel fiber reinforced self compacted concrete (SFRCC) of 40 mm thickness and 2 m wide and GFRP “I” shape profiles. To fix the GFRP profiles to the concrete deck, epoxy adhesive and metallic anchor (M10) were used. Several; studies were performed, experimental and numerical, including creep effect, stress analyses, serviceability and ultimate limit analyses and cross section optimization. From the numerical and experimental research it was concluded that the connection between the deck and the profile can be made exclusively by epoxy adhesives but the long term behaviour of these adhesive when subjected to real weathering and to fatigue load conditions should be investigated along with the dynamic response of the proposed concept.

11. Debalina Ghosh, Ammar Abd-Elssamd, Zhongguo John Ma, Diana Hun

A high early strength FRSCC concrete mix was developed that achieved a compressive and flexural strength of 40.4 and 4.33 Mpa, respectively , at 6 h with only air curing. This concrete mixture maintained its workability for at least 30 min to allow casting an finishing. The developed high early strength FESCC mix will allow the precast concrete industry to double production capacity (i.e. use casting beds twice per day) without expanding facilities. Analysis of concrete batches revealed that strength gain rate and early compressive strength of the concrete mix are highly dependent on powder composition and w/b ratio. Despite allow friction of 0.3 vol%, the fiber type significantly influenced concrete slump flow diameter, flow time and workability.

12. M. Mastali, A. Davand, A.R. Sattarifard

Increasing GFRP fiber content resulted in linearly reduced slump flow while T500 and Tv increased linearly. Adding GFRP fiber improves mechanical properties and the impact resistance so that the maximum compressive strength, flexural strength and impact resistance were recorded for specimen GFRP1.25. The maximum rate of gaining flexural strength was recorded for GFRC0.75 and best performance in terms of the first crack and the ultimate impact resistance was recorded for specimens GFRC1.25 and GFRC0.75 respectively. The highest rate of gaining the numbers of post initial crack blows to failure was obtained for GFRC0.75. Flexural strength, INBP the first and ultimate impact resistance linearly correlated to compressive strength to the coefficient of determination (R^2) of more than 0.86.

13. Tahir Kibriya, Leena Tahir

Concrete with stone dust induced higher workability thereby satisfying the selfcompacting concrete performance with higher slump flows. Due to the pozzolanic and filling effects of the rock dust, there is more cementitious material formed with a dense structure with highly impermeable concrete formed through pore refinement. SCC with blended cement and containing 10% and 20% sand replacement with stone dust can be designed for compressive strengths of 60 & 80 MPa like high strength concrete with ordinary Portland blended cement.

14. Jin Ran, Jinxi Zhang

The flowability of fresh mixture increases with the increase of water-tosolid (W/So) ratio, while the bleeding rate increases also with the increase of flowability. Rapid hardening Controlled Low Strength Material needs to have the higher flow ability, whereas the higher bleeding rate has probably an adverse influence on the normal condensation and hardening of material, the internal structure and properties of hardened mixture.

15. Tahir Kibriya, Leena Tahir.:

The rate of development of strength of mixed aggregate concrete was observed to be similar to that of normal aggregate concrete. Mixed aggregates concrete developed satisfactory compressive strengths as compared to concrete with gravel aggregate. Flexural strengths were higher by about 5%, the average static modulus of elasticity was observed to decrease by 35% to 40%, and average dynamic modulus for concrete with brick aggregate plus gravel was 20% to 23% lower than the value for concrete.

16. Tahir Kibriya, Leena Tahir.:

The performance of concrete with partial replacement of sand with limestone dust proved to be satisfactory with improved performance. Compressive strengths of 60/80/100 N/mm2 can be attained with up to 20% sand replaced with limestone dust in normal concrete mixes. Better packing, reduced voids, improved workability and better hydration due to fines dispersal in the mix resulted into better performance.

17.El Hadji Leye Gueye,Seni Tamba,Karim Limam:

The study of sand concrete that we conducted has shown that prestressed beams of sand concrete can replace those of conventional concrete; also we noted that the hollow bricks can also be made with sand concrete; on the other hand dune sands can replace beach sands in this production of prefabricated elements because they have comparable characteristics and are less expansive.

18. Hongzhu Quan, Hideo Kasam

Self-compacting concrete with recycled fine powder, granulated blast furnace slag and granulated limestone were tested for slump flow, compressive strength, modulus of elasticity and drying shrinkage. Reduction in super plasticizing effect of high range water reducer was found for concrete with recycled powder. Compressive strength of concrete with recycled fine powder was the same as those with granulated limestone, and lower than those with granulated blast furnace slag.

19. Shrividya M.Nair, Dr Geetha K.Jayaraj

It is observed that Self Compacting Concrete (SCC) by using recycled aggregate achieves workability requirements as per EFNARC guidelines. The results obtained from various studies apparently indicate that Compressive, Flexural and Split tensile strength decrease with increasing amount of recycled aggregate.

20.Rebecca Belay Kassa, Christopher Kanali, Nathaniel Ambassah

This paper looked at the cost and environmental advantages of incorporating PET bottle fibres and fly ash to a conventional concrete mix. From the resultsaddition of PET bottle fibres and fly ash as a partial replacement of cement showed positive cost implications, reducing the production cost for one cubic meter of concrete by 19%.

21.Shrividya M. Nair, Dr. Geetha K. Jayaraj

As compared to normal aggregate, recycled coarse aggregate has lower specific gravity, fineness modulus, bulk density and higher water absorption, impact value. Fresh state properties of self compacting concrete has shown negligible effect with incorporation of recycled coarse aggregate. Self compacting concrete with 50% replacement of coarse recycled aggregate shows higher water absorption than other two mixes. Compressive strength of self compacting concrete with normal aggregate is less as compared to self compacting concrete with recycled aggregate.

22.Shrividya M. Nair ,Dr. Geetha K. Jayaraj

As compared to normal aggregate, recycled coarse aggregate has lower specific gravity, fineness modulus, bulk density and higher water absorption, impact value. Fresh state properties of self-compacting concrete has shown negligible effect with incorporation of recycled coarse aggregate. Self-compacting concrete with 50% replacement of coarse recycled aggregate shows higher water absorption than other two mixes. Compressive strength of self -compacting concrete with normal aggregate is less as compared to self-compacting concrete with recycled aggregate.

23. S.Girish, N. Ajay, Sasha Azmi.

Results showed increase in compressive strength as paste volume is increased for the same w/c ratio and higher compressive strength when compared to normal concrete. The enhancement in compressive strength can be factored in the mix design. SCC can be the preferred choice when recycled coarse aggregate are used.

24. Monica Batista Leite, Marcela Crusoe Figueiredo

The results indicated that all SCC produced with CDW filler met the limits established at any level of substitution without changes of the w/c ratio or superplasticizer content. It was possible to verify that the presence of CDW filler, in substitution of cement, by volume, improves the resistance to segregation and up to 5% of CDW filler decreases the loss of fluidity with time.

25. Mohammed Abed, Rita Nemes

This research primarily aims to investigate the mechanical properties of SCHSC using RCA as a partial replacement of NA and three types of unprocessed waste powder materials as CRMs, namely, WFA, WCC and WPP, in short- and long term investigations.

2.2 INFERENCE

From several studies, it was observed that the addition of admixture and fibers improves the split tensile strength and modulus of rapture (MOR) properties of SCC.

The flexural strength of the concrete generally increases with the addition of fibers. Several researches highlighted that the usage of hooked steel and long fibers provide better flexural strength compared to other forms of steel fibers such as micro fibers.

Most commonly the addition of fibers improves the ductility of the concrete and in particular long fibers usually provide higher strength and ductility for the Fiber reinforced Self Compacting Concrete

The shrinkage induced in the concrete is higher when the long fibers are used and is less under short fibers.

Addition of glass fibers reduces shrinkage of concrete.

Adding of glass fibers reduce the workability.

Flow ability of Glass Fiber Reinforced Self Compacting Concrete is directly proportional to the length and quantity of glass fibers.

Adding glass fiber reinforcement polymer fiber improves mechanical properties and impact resistance of self compacting concrete.

The addition of steel and polypropylene fibers in High strength concrete can improve the ductility of HSC columns and increase higher resistance and reduce spalling.

Flexural strength of polymer modified self compacting concrete directly proportional to polymer to cement weight ratio.

Workability of fresh concrete is inversely proportional to the quantity of fiber.

The compressive strength of SBR Latex modified polypropylene fiber concrete decreases and flexural strength increases as compared to plain concrete.

A the compressive strength, split tensile strength and flexural strength of SBR- latex modified Steel Fiber Reinforced Concrete increases as compared to plain concrete.

There is improvement in compressive and flexural strength is observed with the addition of SBR latex cement concrete mixes as the SBR latex content increased and maximum improvement is at 15% of SBR latex content.

2.3 RESEARCH GAP

Enormous research has been done, especially on the usage steel fiber and glass fiber self compaction concrete in concrete structures. However, use of different polymers along with glass fiber in self compacting concrete are still to be explored. The usage of polymers and glass fiber reinforcement in self compacting concrete i.e. latex modified glass fiber reinforcement self compacting concrete may help in increasing the tensile strength, flexural strength, toughness, anti crack properties and water proofing properties up to some extent.

2.4OBJECTIVE

1.To determine workability of latex modified glass fiber reinforced self compacted concrete and plain self compacting concrete by V-Funnel test , L-Box test , J-Ring test & Slump Flow test .

2.To determine the compressive strength of latex modified glass fiber reinforced self compacting concrete and plain self compacting concrete.

3.To determine the flexural strength of latex modified glass fiber reinforced self compacted concrete and plain self compacted concrete.

Chapter 03

MATERIALS USED

3.1 Cement

Portland Pozzolana Cement as per IS 1489(1991) part 1 with using fly ash and a carboxylate super-plasticizer was used with viscosity modifying agent (VMA) that gives more outcomes of controlling segregation when the powder content is limited. In this research work Ultra Tech cement is used with a compressive strength of 37.20 Mpa at 7days, initial setting time of 170 minutes, final setting time 250 minutes & standard consistency of 31.75%.

Properties of OPC Cement Used	
Properties	Test Results
Fineness	330
Standard Consistency (%)	31.75
Initial Setting Time (minutes)	65
Final Setting Time (minutes)	275

Properties of PPC Cement used

Table No. 1

3.2 Fine Aggregate

All common concrete sands are suitable for SCC. Crushed or round sand can be used. Either siliceous or calcareous sand can be used. The amount of fine powder should be less than 0.125 mm are considered powder for the study of rheology of SCC. It must contain a minimum quantity of fines (from binder and sand) to avoid segregation/isolation. The fine aggregate take here is Zone-II.

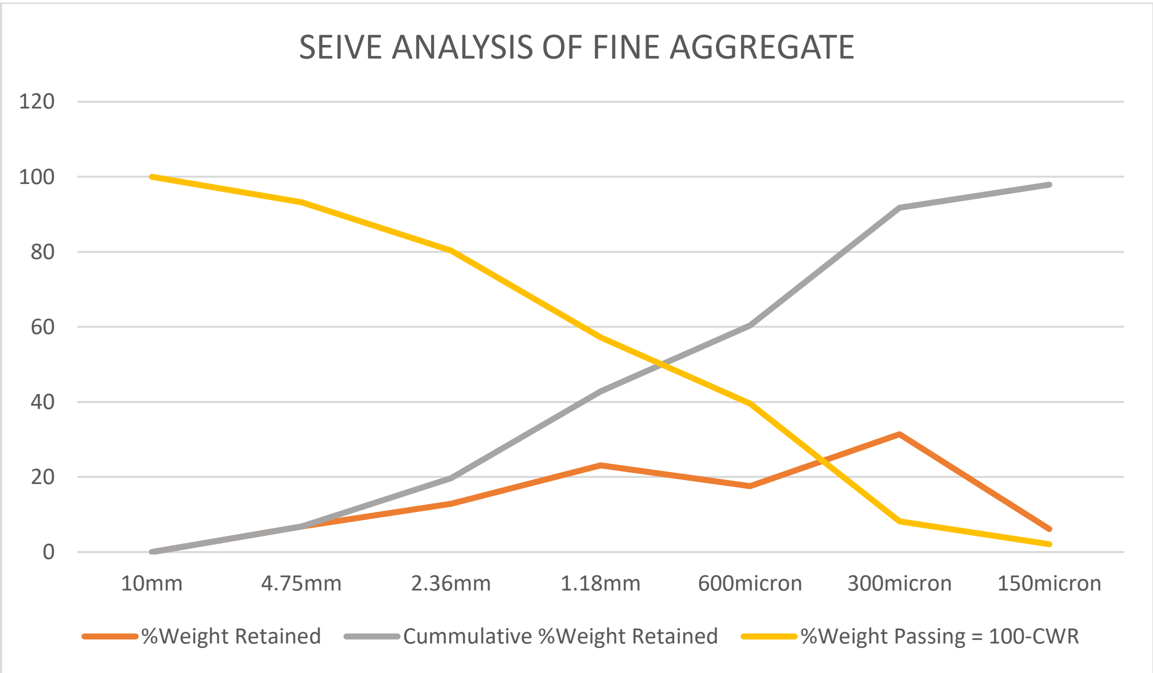
Weight of sample = 1.0 Kg.

IS Sieve Size	Weight Retained (grams)	%Weight Retained	Cummulative %Weight Retained	%Weight Passing = 100-CWR
10mm	0	0	0	100
4.75mm	68	6.8	6.8	93.2
2.36mm	129	12.9	19.7	80.3
1.18mm	231	23.1	42.8	57.2
600micron	176	17.6	60.4	39.6
300micron	314	31.4	91.8	8.2
150micron	61	6.1	97.9	2.1

IS Sieve Analysis results of fine aggregates

Table No. 2

The sample taken is found to be zone II.



Sieve Analysis of Fine Aggregate

Fig. No. 1

3.3 Coarse Aggregate

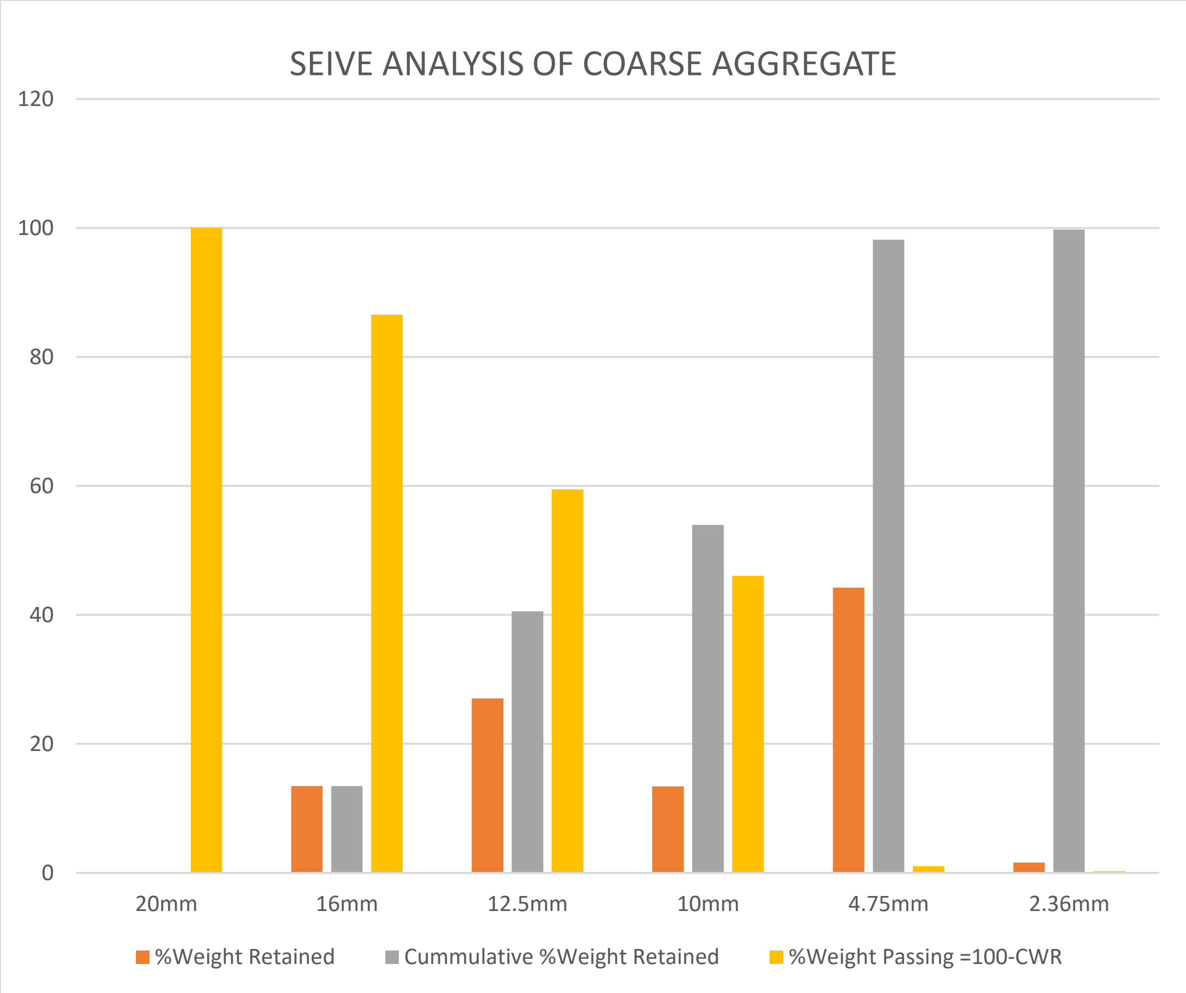
All types of aggregates are suitable. The normal maximum size is generally 10 mm. However, the particle sizes up to 20 mm is used in SCC. According to the characteristics of different types of aggregates, crushed aggregates tend to improve strength due to interlocking of angular particles, while circular aggregates improve flow because of lower internal friction. Gap graded aggregates are generally better than continuously graded aggregates, which may experience greater internal friction and reduced flow. The fine in the coarse aggregate taken is 0.8%.

IS Sieve Size	Weight Retained 1(grams)	Weight Retained 2(grams)	Weight Retained 3(grams)	Average	%Weight Retained	Cummulative %Weight Retained	%Weight Passing =100-CWR
20mm	-	-	-	-	-	-	100
16mm	659	680	682	673	13.46	13.46	86.54
12.5mm	1325	1347	1363	1354	27.08	40.54	59.46
10mm	671	666	674	670	13.4	53.94	46.06
4.75mm	2209	2205	2220	2211	44.22	98.16	1.04
2.36mm	88	76	75	79	1.58	99.74	0.26

IS Sieve Analysis results of coarse aggregates

Table No. 3

The coarse sand taken is found to be graded aggregate.



Sieve Analysis results of coarse aggregates

Fig. No. 2

3.4 Admixture

The most important admixtures are superplasticizers (high range water reducers), used with water reduction by more than 20%. The use of viscosity modifying agents (VMA) offers more segregation control possibilities, when the amount of powder is limited. This mixture helps to provide very good homogeneity and the tendency to separate (segregation) is reduced. The VMA used in this research work is Forsoc Auramix V100 and it’s appearance is opaque liquid with a specific gravity of 1.01 Kg/m^3 at 20^{o}C. The chloride io content in VMA is nil as per IS: 456

3.5 Fly Ash

When fly ash is added in SCC, it starts providing an increment in the cohesion and reduced sensitivity as due to the change in water content. The fly ash used in this work has a specific gravity of 2.43 as it relevant to IS 3812 2007.

CHAPTER 4
EXPERIMENTAL SETUP

2.5 Introduction

Many different types of test methods have been developed in attempts to characterise working the properties of SCC. So, no single method or combination has achieved its approval and most of them have different adherents. Similarly, none of the methods have been found which characterises all the relevant workability aspects so each mix design should be tsted by more than one test method for the different workability parameters. For the initial mix design of SCC, all the three workability parameters need to be assessed to ensure that all the aspects are fulfilled. A full test should be used to verify the self-compacting characteristics of the chosen design for a particular application of concrete. For site quality assurance and quality control, two testing methods are generally sufficient to monitor the production and quality of SCC. The typical combinations are Slump-Flow, V-Funnel, J-Ring. With a consistent raw material quality, a single test method is operated by a trained and experienced technician may be sufficient.

Here we have discussed about the testing methodologies for calculating the passing-abilities, filling-abilities and viscosity of SCC.

TESTS FOR FILLING ABILITY

The most used common type of tests using for finding the filling ability of SCC are slump-flow, T500 slump-flow & V-funnel test.

2.5.1 SLUMP FLOW

The slump flow is used to determine the free flow properties of SCC without any obstructions. The ASTMC1611/C1611M (2009) describes the working procedure of the slump flow test. This test method is based on determining the slump of SCC and diameter of concrete circle is the measure the filling ability of concrete.

2.5.2 T500 SLUMP FLOW

The T500 slump flow is the time taken by slump flow to reach 500mm (20 inches) diameter circle on the flow table, after we have raised the slump cone. Its value must be between 2-5 seconds. The longer the time (T500), the longer will be the passing-ability. A truncated cone with a height of 300mm, internal diameter a bottom is 200mm and at the top is 100mm.

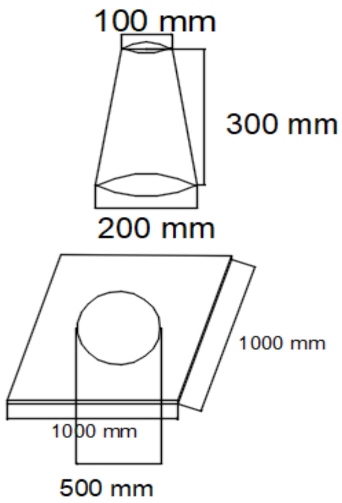


Fig. No. 3

Equipments

The apparatus is shown in fig. no. 5

- mould in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100 mm diameter at the top and a height of 300 mm.
- base plate of a stiff non absorbing material, at least 700mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500mm diameter.
- Trowel
- Scoop
- Ruler
- stopwatch

Procedure

- About 6 litre of concrete is needed to perform the test, sampled normally.
- Moisten the base plate and inside of slump cone,
- Place baseplate on level stable ground and the slumpcone centrally on the base plate and hold down firmly.
- Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel.
- Remove any surplus concrete from around the base of the cone.
- Raise the cone vertically and allow the concrete to flow out freely.
- Simultaneously, start the stopwatch and record the time taken for the concrete to reach the 500mm spread circle. (This is the T50 time).
- Measure the final diameter of the concrete in two perpendicular directions.
- Calculate the average of the two measured diameters. (This is the slumpflow in mm).

Note any border of mortar or cement paste without coarse aggregate at the edge of the pool of concrete.

Interpretation of result

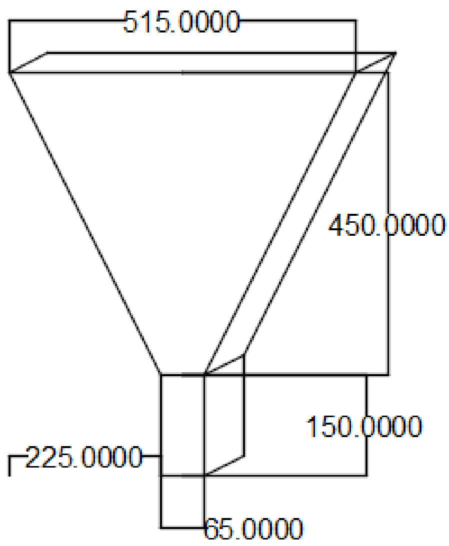
The higher the slump flow (SF) value, the greater its ability to fill formwork under its own weight. A value of at least 650mm is required for SCC. There is no generally accepted advice on what are reasonable tolerances about a specified value, though ± 50mm, as with the related flowtable test, might be appropriate.

The T50 time is a secondary indication of flow. A lower time indicates greater flowability. The Brite EuRam research suggested that a time of 3-7 seconds is acceptable for civil engineering applications, and 2-5 seconds for housing applications.

In case of severe segregation most coarse aggregate will remain in the centre of the pool of concrete and mortar and cement paste at the concrete periphery. In case of minor segregation a border of mortar without coarse aggregate can occur at the edge of the pool of concrete. If none of these phenomena appear it is no assurance that segregation will not occur since this is a time related aspect that can occur after a longer period.

4.1.3 V-FUNNEL

The V-funnel test is used to determine the flow time (filling ability) of the self -compacting concrete with a maximum aggregate size of 20mm. The test was developed in Japan. The working apparatus consists of a v shaped funnel and it is filled with 20 litres of concrete and the total time taken by the concrete to flow through the apparatus is measured. The V-funnel flow should be less than 8 Sec.(reference)



V-FUNNEL TEST APPARATUS

Fig. No. 4

Equipment

- V-funnel
- bucket (±12 litre)
- trowel
- scoop
- stopwatch

Procedure flow time

- About 12 litre of concrete is needed to perform the test, sampled normally.
- Set the V-funnel on firm ground.
- Moisten the inside surfaces of the funnel.
- Keep the trap door open to allow any surplus water to drain.
- Close the trap door and place a bucket underneath.
- Fill the apparatus completely with concrete without compacting or tamping, simply strike off the concrete level with the top with the trowel.

Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity. Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (**the flow time**). This is taken to be when light is seen from above through the funnel. The whole test has to be performed within 5 minutes.

Procedure flow time at T 5 minutes

- Do not clean or moisten the inside surfaces of the funnel again.
- Close the trap door and refill the V-funnel immediately after measuring the flow time.
- Place a bucket underneath.
- Fill the apparatus completely with concrete without compacting or tapping, simply strike off the concrete level with the top with the trowel.
- Open the trap door 5 minutes after the second fill of the funnel and allow the concrete to flow out under gravity.

Simultaneously start the stopwatch when the trap door is opened, and record the time for the discharge to complete (**the flow time at T 5 minutes**). This is taken to be when light is seen from above through the funnel.

Interpretation of result

This test measures the ease of flow of the concrete; shorter flow times indicate greater flowability. For, SCC a flow time of 10 seconds is considered appropriate. The inverted cone shape restricts flow, and prolonged flow times may give some indication of the susceptibility of the mix to blocking. After 5 minutes of settling, segregation of concrete will show a less continuous flow with an increase in flow time.

TESTS FOR PASSING ABILITY

The mostly used common type of tests using for finding the passing ability of SCC are J-Ring & L-Box test.

4.1.4 L-BOX TEST

This test is based on under-water concrete developed in Japan designed by Peterson. The test assesses the flow of the concrete and extent to which it is subject to blocking by reinforcement. The apparatus consists of a rectangular section box in the shape of an “L” with a vertical horizontal section separated by a moveable gate, in front of which vertical lengths of reinforcement bar are fitted. The vertical section is filled with concrete then the gate lifted to let the concrete flow into the horizontal section. When the flow stops, the height of the concrete at the end of horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1) and it represents the slope of concrete at rest. This is an indication of passing ability. The equipment used are L-Box, Trowel, Scoop, Stop-watch.

INTERPRETATION OF RESULT

If the self-compacting concrete flows through the L-box, the SCC passes the vertical section then it enters the horizontal section through the trapped gate and both the heights are measured as H1 & H2.

So, H2/H1 = 0.9

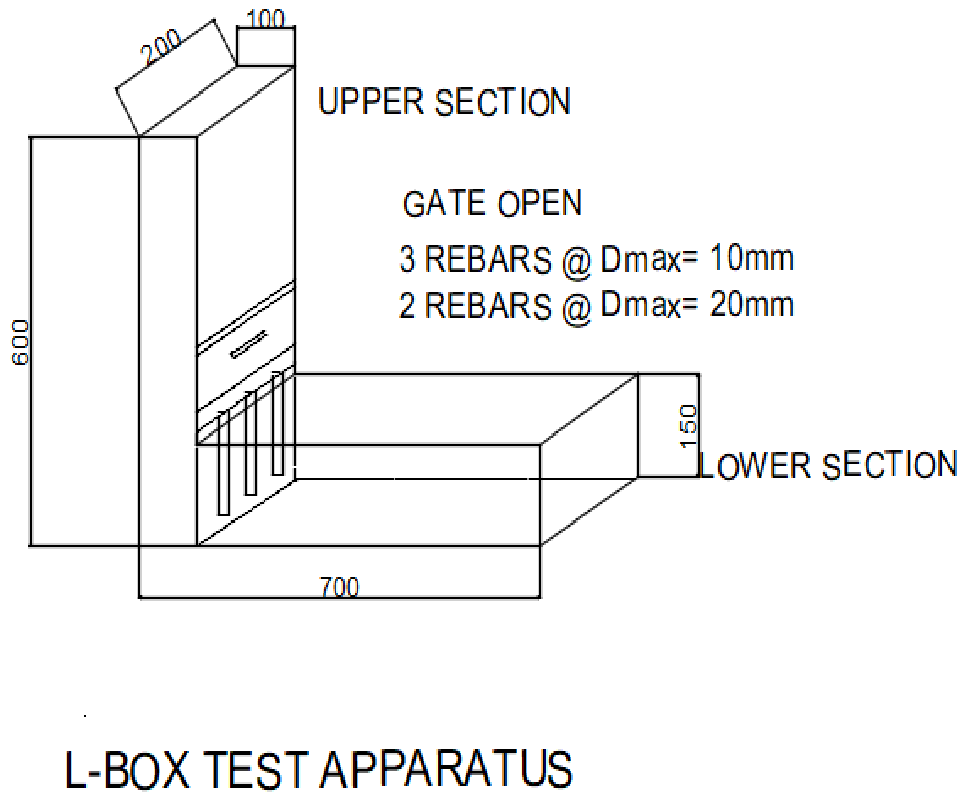


Fig. No. 5

Assessment of test

This is a widely used test, suitable for laboratory, and perhaps site use. It assesses filling and passing ability of SCC, and serious lack of stability (segregation) can be detected visually. Segregation may also be detected by subsequently sawing and inspecting sections of the concrete in the horizontal section. Unfortunately, there is no agreement on materials, dimensions, or reinforcing bar arrangement, so it is difficult to compare test results. There is no evidence of what effect the wall of the apparatus and the consequent 'wall effect' might have on the concrete flow, but this arrangement does, to some extent, replicate what happens to concrete on site when it is confined within formwork. Two operators are required if times are measured, and a degree of operator error is inevitable.

Equipments

- L box of a stiff non absorbing material
- Trowel
- Scoop
- stopwatch

Procedure

- About 14 litre of concrete is needed to perform the test, sampled normally.
- Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it.
- Moisten the inside surfaces of the apparatus, remove any surplus water
- Fill the vertical section of the apparatus with the concrete sample.
- Leave it to stand for 1 minute.
- Lift the sliding gate and allow the concrete to flow out into the horizontal section.

Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200 and 400 mm marks.

When the concrete stops flowing, the distances “H1” and “H2” are measured.

Calculate H2/H1, **the blocking ratio.**

The whole test has to be performed within 5 minutes.

Interpretation of result

If the concrete flows as freely as water, at rest it will be horizontal, so H2/H1 = 1. Therefore, the nearer this test value, the ‘blocking ratio’, is to unity, the better the flow of the concrete. The EU research team suggested a minimum acceptable value of 0.8. T20 and T40 times can give some indication of ease of flow, but no suitable values have been generally agreed. Obvious blocking of coarse aggregate behind the reinforcing bars can be detected visually.

4.1.5 J-RING TEST

J-ring test is a method of testing which determines the passing ability of self-compacting concrete under its own weight by spreading and filling completely the complicated formwork with complex reinforcement. The J-ring test is developed by the University if Paisley. The equipment consists of a section rectangular in shape (30mm X25 mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. The diameter of the ring provided with the vertical bars is 00mm and with a height of 100 mm.

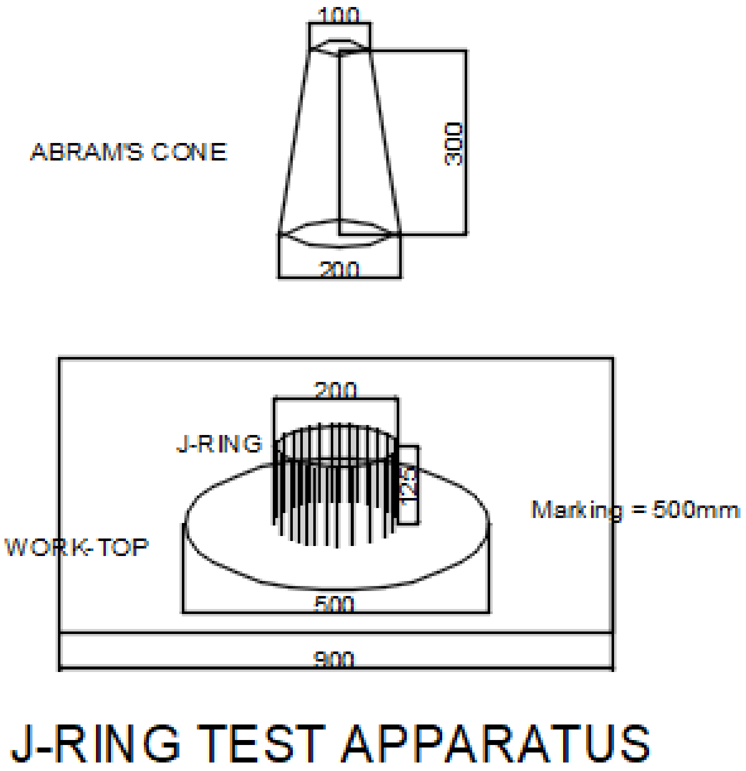


Fig. No. 6

The principle of the J-Ring test may be Japanese, but no references are known. The J-Ring test itself has been developed at the University of Paisley. The test is used to determine the passing ability of the concrete. The equipment consists of a rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes to accept threaded sections of reinforcement bar. These sections of bar can be of different diameters and spaced at different intervals: in accordance with normal reinforcement considerations, 3x the maximum aggregate size might be appropriate. The diameter of the ring of vertical bars is 300mm, and the height 100 mm. The J-Ring can be used in conjunction with the Slump flow or eventually even the Vfunnel. These combinations test the flowing ability and (the contribution of the JRing) the passing ability of the concrete. The slump flow spread are measured as usual to assess flow characteristics. The

J-Ring bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete. After the test, the difference in height between the concrete inside and that just outside the JRing is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

Assessment of test

These combinations of tests are considered to have great potential, though there is no general view on exactly how results should be interpreted. There are a number of options – for instance it may be instructive to compare the slump-flow/J-Ring spread with the unrestricted slump-flow: to what extent is it reduced. Like the slump-flow test, these combinations have the disadvantage of being unconfined, and therefore do not reflect the way concrete is placed and moves in practice. The Orimet option has the advantage of being a dynamic test, also reflecting placement in practice, though it suffers from requiring two operators.

Equipments

- mould, WITHOUT foot pieces, in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100 mm diameter at the top and a height of 300 mm.
- base plate of a stiff non absorbing material, at least 700mm square, marked with a circle showing the central location for the slump cone, and a further concentric circle of 500mm diameter
- trowel
- scoop
- ruler
- J-Ring a rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes. In the holes can be screwed threaded sections of reinforcement bar (length 100mm, diameter 10mm, spacing 48 +/- 2mm).

Procedure

- About 6 litre of concrete is needed to perform the test, sampled normally.
- Moisten the base plate and inside of slump cone,
- Place base-plate on level stable ground.
- Place the J-Ring centrally on the base-plate and the and the slump-cone centrally inside it and hold down firmly.
- Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel.
- Remove any surplus concrete from around the base of the cone.
- Raise the cone vertically and allow the concrete to flow out freely.
- Measure the final diameter of the concrete in two perpendicular directions.
- Calculate the average of the two measured diameters. (in mm).
- Measure the difference in height between the concrete just inside the bars and that just outside the bars.
- Calculate the average of the difference in height at four locations (in mm).

Note any border of mortar or cement paste without coarse aggregate at the edge of the pool of concrete.

Recommended limits of Flow Test as per IS Code and EFNARC Specifications and guide lines for Self-Compacting Concrete	
Test on Fresh Concrete	**Recommended Limits**
V-Funnel (sec)	Less than 8.0 sec.
L-Box Test (h2/h1)	Between 0.8 to 1.0
J-Ring Test (mm)	Between 0-10
T500 time (sec)	Between 2sec – 5sec
Slump Flow (cm)	760mm – 850mm (SF-3)

Conformity criteria for Fresh Concrete Testing of SCC

Table No. 4

4.2 Mix Design Trials Compression Results

Trial No.	Trial 01	Trial 02	Trial 03	Trial 04	Avg. Strength	Remarks
Compressive Strength at 7 Day (N/mm^2)	19.9	13.8	17.6	-	17.1	**Passed**
Compressive Strength at 28 Day (N/mm^2)	27	30	19.2	-	28.5	**Passed**

Mix-Design Trial Mix Results

Table No. 5

Chapter 05

SCC FLOW TEST RESULTS

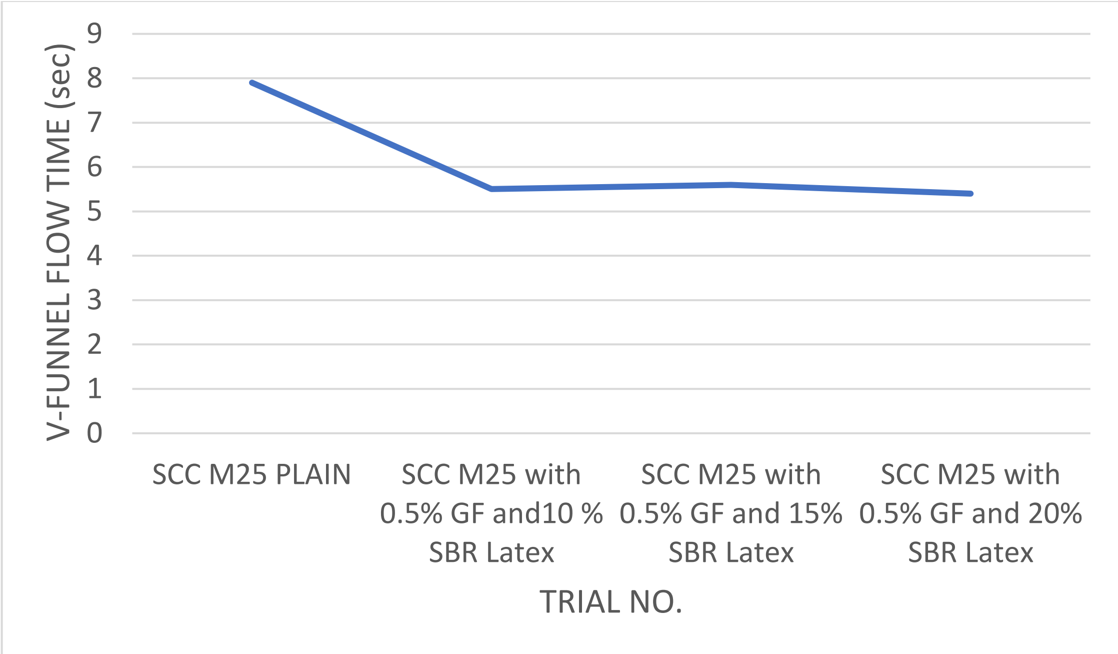
5.1 DETAILING OF TRIAL MIX USED IN MULTIPLE TRIALS/SAMPLES

When, we have analysed the flow tests for SCC with making variations in the percentage of admixture, the flow test results obtained are given below:

Trial No.	Mix Design Trial	V-Funnel (sec)	L-Box (h2/h1)	J-Ring (mm)	T50cm (sec)	Slump Flow (cm)	Remarks
SAMPLE 01	SCC M25 PLAIN	7.9	0.96	3.0	3.5	670	**FAILED**
SAMPLE 02	SCC M25 with 0.5% GF and10 % SBR Latex	5.5	0.85	4.5	4.0	750	**PASSED**
SAMPLE 03	SCC M25 with 0.5% GF and 15% SBR Latex	5.6	0.93	5.4	4.8	820	**PASSED**
SAMPLE 04	SCC M25 with 0.5% GF and 20% SBR Latex	5.4	.89	6.7	4.0	780	**PASSED**

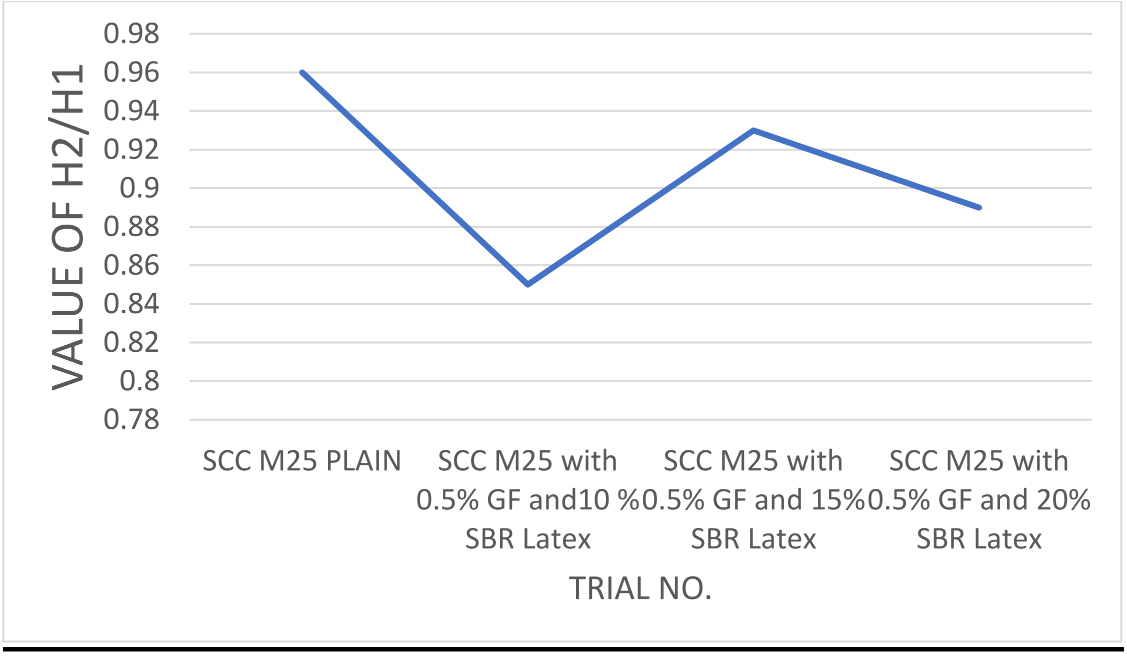
Results of multiple trials mixes done with their experimental results

Table No. 6



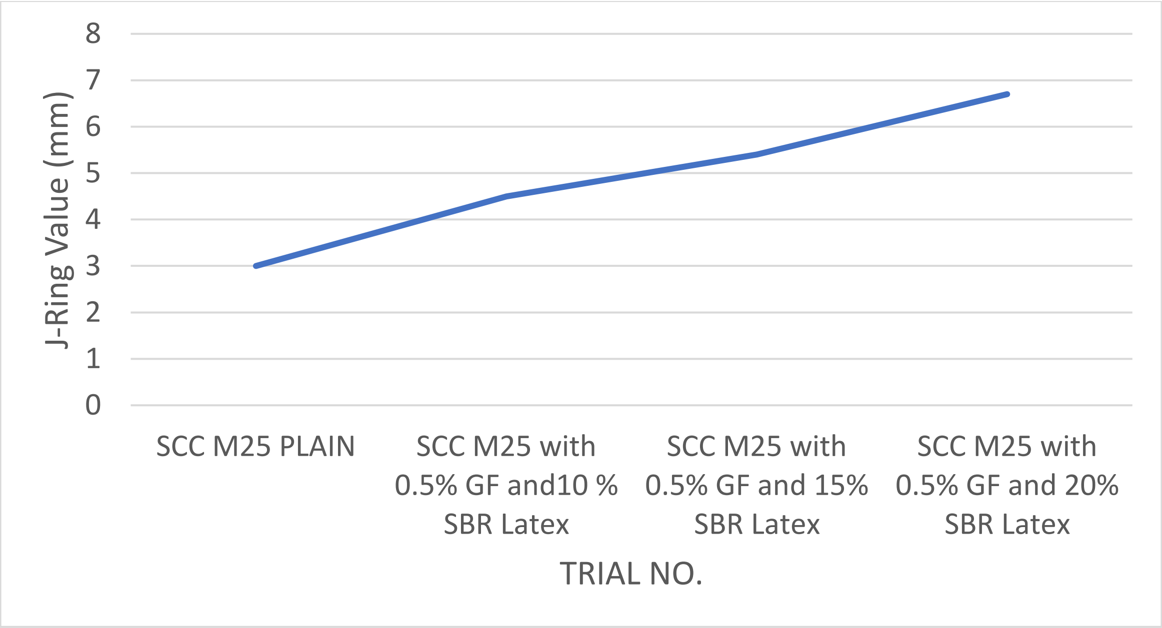
V-Funnel Flow Data

Fig. No. 7



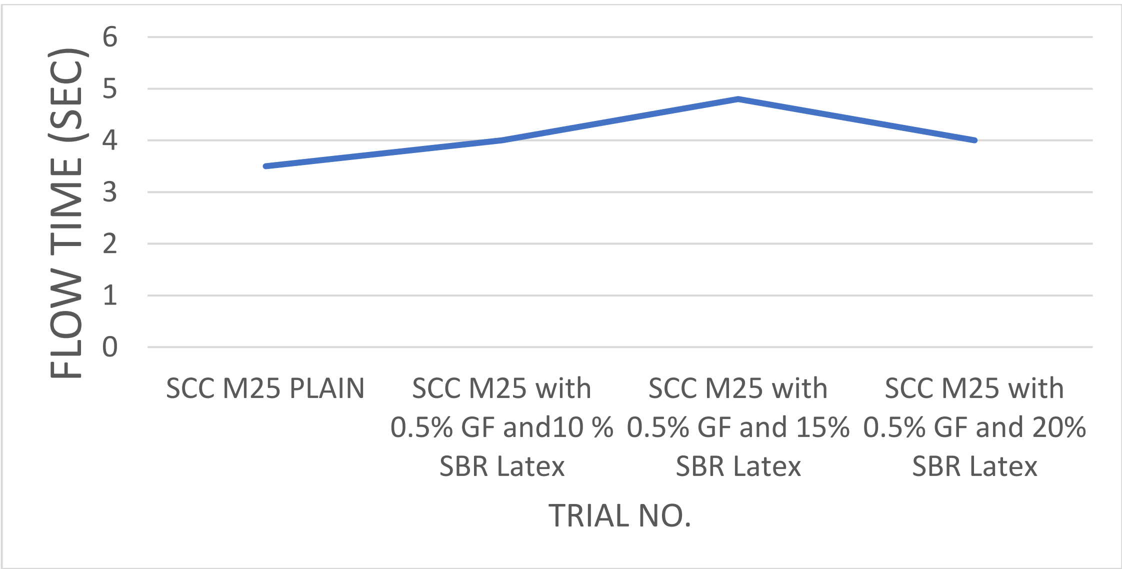
L-Box Test Data (H2/H1)

Fig. No. 8



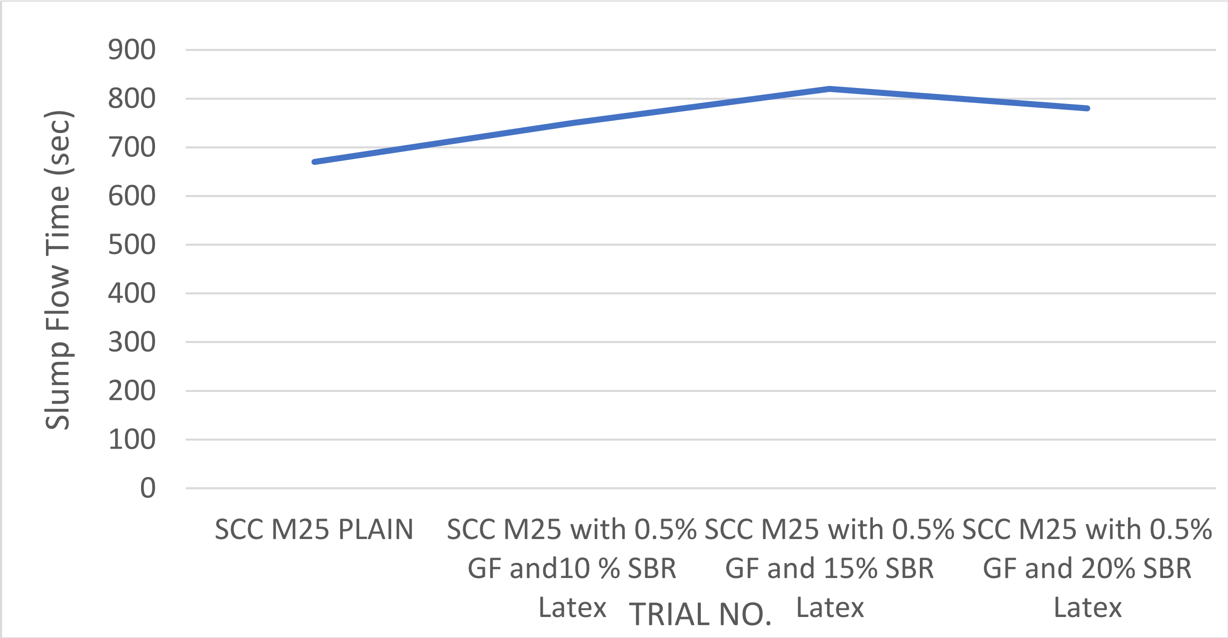
J-Ring Test Data

Fig. No. 9



T50cm Test Data

Fig. No. 10



Slump Flow Data

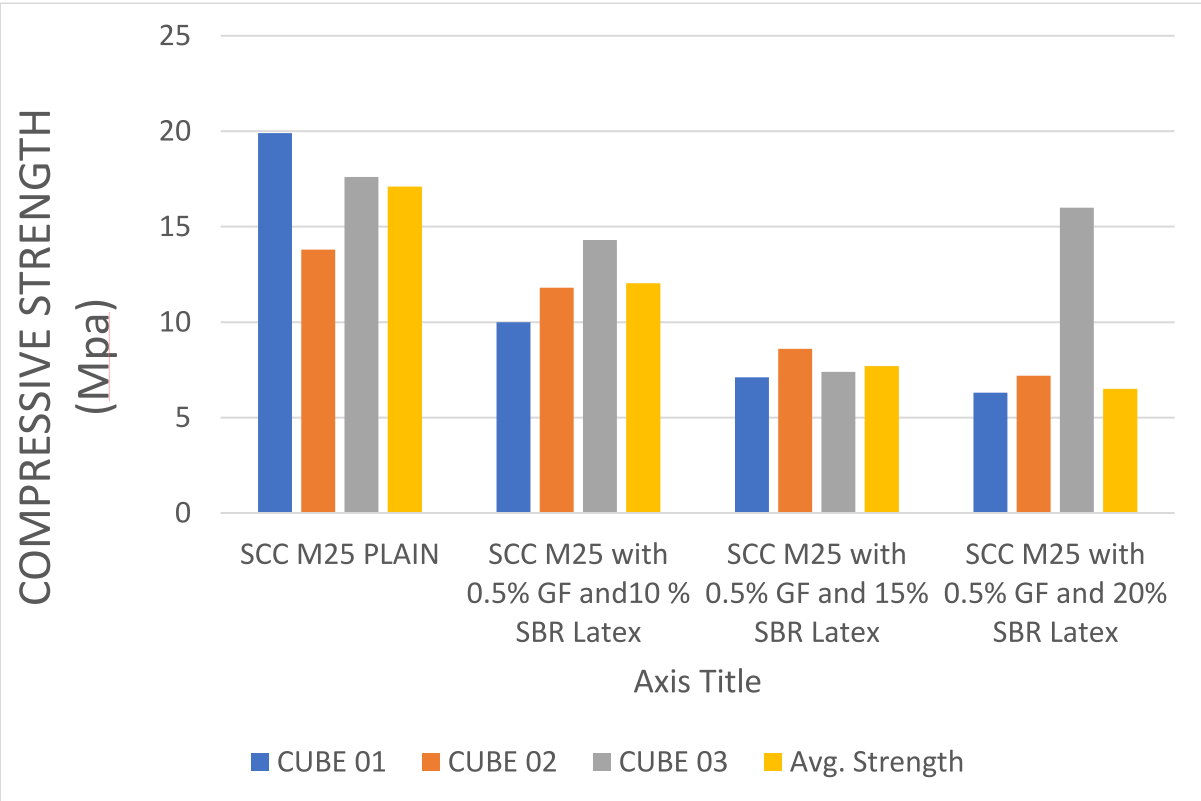
Fig. No. 11

5.2 COMPRESSION TEST RESULTS AT 7th DAY & 28th DAY

TYPE OF CONCRETE	CUBE 01	CUBE 02	CUBE 03	Avg. Strength
SCC M25 PLAIN	19.9	13.8	17.6	17.1
SCC M25 with 0.5% GF and10 % SBR Latex	10	11.8	14.3	12.03
SCC M25 with 0.5% GF and 15% SBR Latex	7.1	8.6	7.4	7.7
SCC M25 with 0.5% GF and 20% SBR Latex	6.3	7.2	16.0	6.5

Average Compressive Strength at 7th day (in N/mm2) of all the trial mixes

Table No. 7



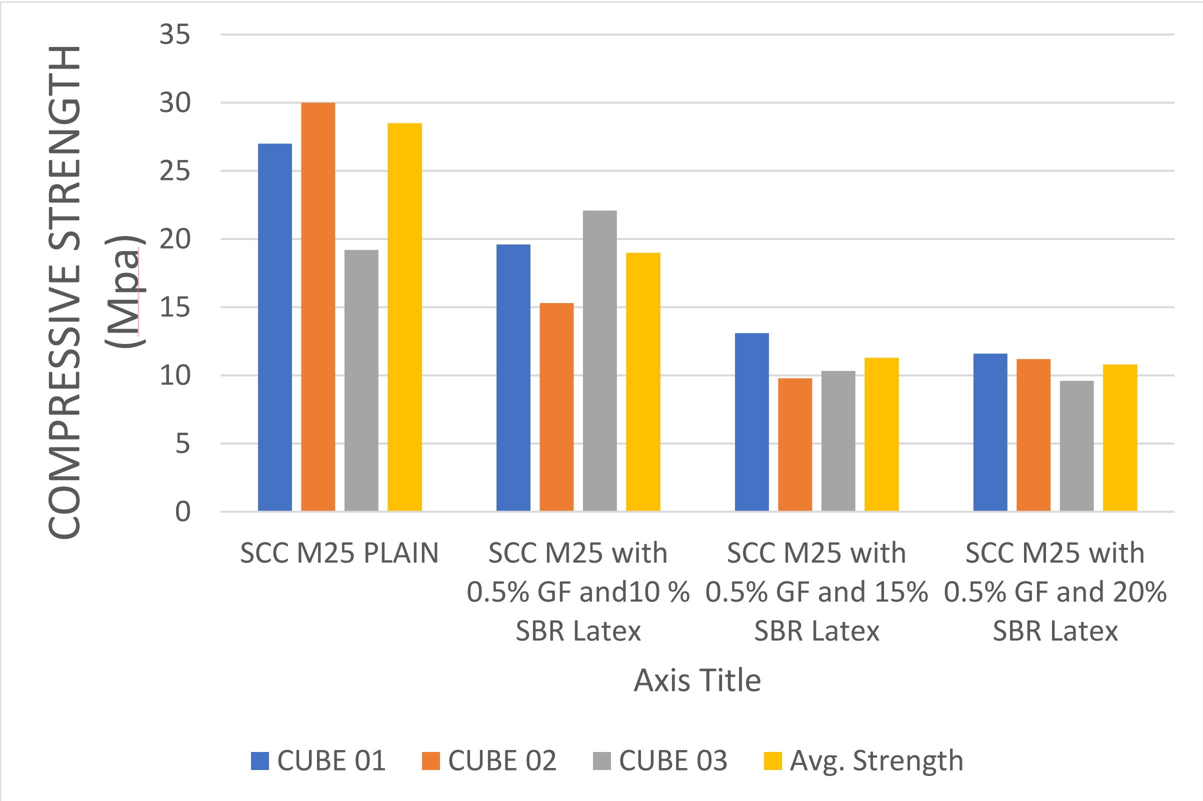
TEST RESULTS COMPRESSIVE STRENGTH 7 DAYS

Fig No. 12

TYPE OF CONCRETE	CUBE 01	CUBE 02	CUBE 03	Avg. Strength
SCC M25 PLAIN	27	30	19.2	28.5
SCC M25 with 0.5% GF and10 % SBR Latex	19.6	15.3	22.1	19
SCC M25 with 0.5% GF and 15% SBR Latex	13.1	9.8	10.32	11.3
SCC M25 with 0.5% GF and 20% SBR Latex	11.6	11.2	9.6	10.8

TEST RESULTS COMPRESSIVE STRENGTH 28DAYS

Table No. 8



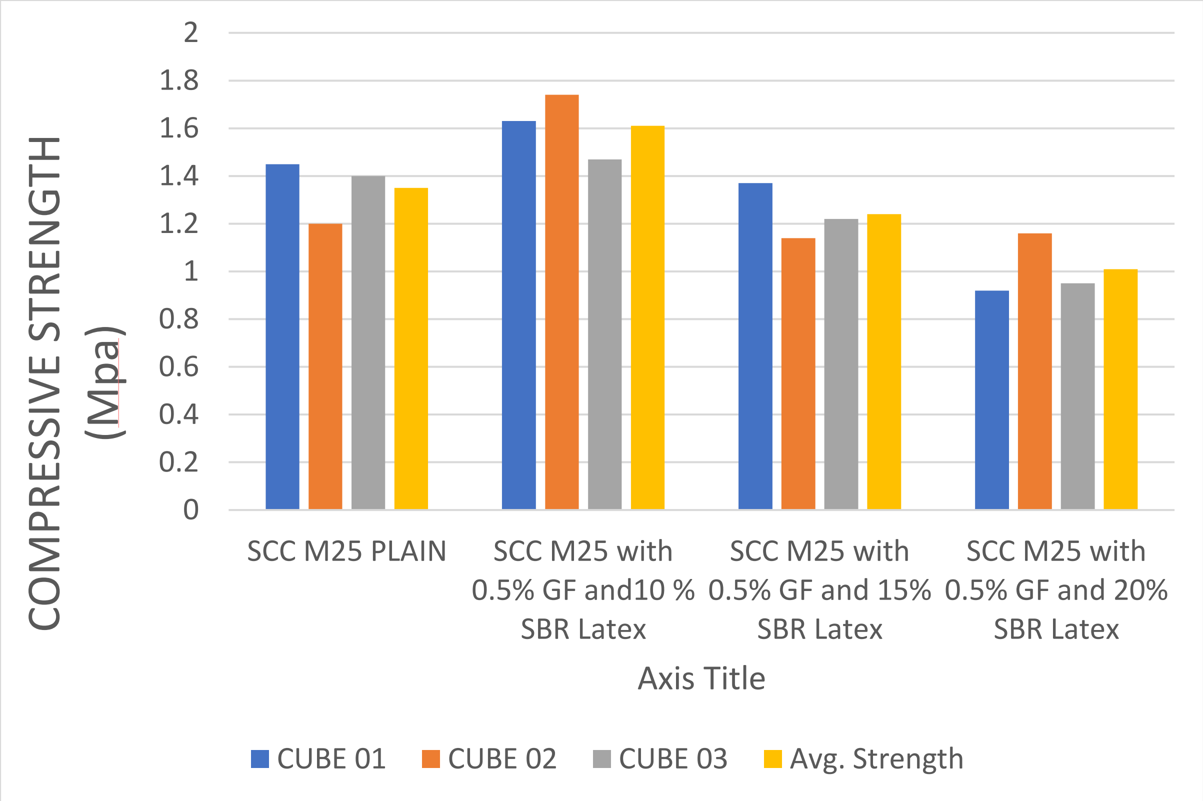
Graph for compressive strength test results at 28th day

Fig. No. 13

TYPE OF CONCRETE	CUBE 01	CUBE 02	CUBE 03	Avg. Strength
SCC M25 PLAIN	1.45	1.2	1.4	1.35
SCC M25 with 0.5% GF and10 % SBR Latex	1.63	1.74	1.47	1.61
SCC M25 with 0.5% GF and 15% SBR Latex	1.37	1.14	1.22	1.24
SCC M25 with 0.5% GF and 20% SBR Latex	0.92	1.16	0.95	1.01

TEST RESULTS OF FLEXURAL STRENGTH 28 DAYS

Table No. 9



TEST RESULTS FLEXURAL STRENGTH 28 DAYS

Fig. No. 14

Chapter 06
CONCLUSION
6.1 Conclusion

From all the experimental work we have done in our research work, we got to a conclusion that when we are adding glass fibre in a quantity of 0.5% with SBR latex 10% , 15% & 20%.

The flexural strength of concrete is increasing and maximum with 10% SBR Latex in the designed concrete and as a result it can be adapted in practice in the concrete of road pavements, as the PQC used in the pavements require higher value of flexural strength.

So, it can be adopted.

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