Design And Development Of High Strength Self Compacting Concrete

A Project Report

Submitted by

R.Anbarasu - 0720101001

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(An Autonomous Institution Affiliated to Anna University, Coimbatore.)

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BONAFIDE CERTIFICATE

Certified that this project report titled **"Design And Development Of High Strength Self Compacting Concrete"** is the bonafide work of

Mr. R.Anbarasu - Reg No: 0720101001

Dr.S.L.Narasimhan	Mr.R.Elangovan
Head of the Department	Thesis Supervisor
Department of Civil Engineering	Department of Civil Engineering
Kumaraguru College of Technology	Kumaraguru College of Technology
Coimbatore-641 006	Coimbatore-641 006

Certified that the candidate with university Register No. 0720101001 was examined in project viva voce Examination held on 04.05.2009

Internal Examiner **External Examiner**

DEPARTMENT OF CIVIL ENGINEERING
KUMARAGURU COLLEGE OF TECHNOLOGY, COIMBATORE 641 006

(An Autonomous Institution Affiliated to Anna University, Coimbatore.)

KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE , TAMILNADU

DEPARTMENT OF CIVIL ENGINEERING

INNOVATIONS IN CIVIL ENGINEERING - ICE'09

CERTIFICATE

This is to certify that Mr/Ms R. Anbarasu - PG student

of Kumaraguru College of Technology, Coimbatore

has participated and presented a paper in the National Conference on "INNOVATIONS IN CIVIL ENGINEERING - ICE'09" during 21st, April 2009.

Title Design and development of high strength self compacting concrete.

Dr.P.ESWARAMOORTHI & Mrs.K.RAMADEVI
CO-ORDINATORS

Dr.S.L.NARASIMHAN
CONVENOR

Prof.R.ANNAMALAI
VICE PRINCIPAL

ABSTRACT

This paper presents an experimental investigation on the properties like workability and strength of Self-Compacting Concrete (SCC). Self Compacting Concrete gets compacted under its own self-weight. Several series of tests involving various binder combinations, water-binder ratio and high range water reducing admixtures and set retarding admixtures were used to optimize the mixture proportions of SCC. Test methods used to study the characteristics of fresh concrete were slump test, U – tube, V – funnel and L – Box. The properties like compressive, tensile and flexural strength of SCC were also investigated.

For compressive strength of studies the cube size of 100mmX100mmX100mm were used. The specimens were cured and tested for 7 and 28 days for high compressive strength.

The split tensile strength was studied for the same concrete mix using cylinders size 100mmX200mm. The specimens were cured and tested for 7 and 28 days.

The flexural strength was studied for the same concrete mix using beam of size 100mmX100mmX200mm. The specimens were cured and tested for 7 and 28 days.

The stress-strain relationship was studied for the same concrete mix using cylindersof size 150mmX300mm. The specimens were cured and tested for 7 and 28 days.

Test Results shows that the workability characteristics of SCC are within the limiting constraints of SCC. The maximum compressive strength of SCC for M4 mix at 28 days age of curing was 52.1 MPa.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM - American Standard for Testing Materials

CA - Coarse Aggregate

FA - Fine Aggregate

SCC - Self Compacting Concrete

ACI - American Concrete Institute

HRWR - High Range Water Reducer

VMA - Viscosity Modifying Agent

CTM - Compression Testing Machine

CHAPTER-1

INTRODUCTION

1.1 SELF COMPACTING CONCRETE

The history of self compacting concrete dates back to 1980's .It was first proposed for construction by Okamura in Japan to offset to growing shortage of construction labour. Though the concept originally was thought to be a tool to enhance long term durability of structures having members with congested reinforcement, the excellent user friendly characteristics of SCC are of great attraction today in traditional construction industries also. SCC has a big role to play because of its substantial benefit in construction both qualitatively and quantitatively.

A concrete that is self compacting occupies all the space in the form without any external effort (in the form of mechanical vibration, floating, poking etc.,). The guiding principle behind the self compaction is that "the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exits".

For a concrete to be self compacting, to occupy the full space, flowing through the congestion in the form, without any external efforts, it has to have an acceptable level of passing ability, filling ability and stability.

As concrete is a heterogeneous product of materials with various specific gravities, it is very difficult to keep its constituents in cohesive form. Specially, when concrete has a consistency of a fluid, materials of higher mass tend to settle down. This problem, however, can be tackled by adding more amount of finer material (passing 100 microns) in unit content and super plasticizers. Super plasticizers are instrumental in reducing the water demand of a highly fluid mix, and producing optimally high fluidity concrete while using the least possible amount of water is key to producing high density, and consequently high strength concrete.

In ideal conditions, it is observed that for a given set of parameters, SCC can be produced with ingredients (with super plasticizer)
that is used for conventional concrete. But small variation in the parameter of ingredients such as grading, moisture content and absorption, batching tolerance etc., can change the characteristic of the SCC, there by rendering the mix unstable or sticky (high viscous). This problem is overcome by varying viscosity of the mix by

the addition of stabilizing agent called “Viscosity Modifying Agent (VMA). VMA is the pseudo-plastic agent that thickens the paste and keeps the ingredients under suspension, providing segregation resistance to the concrete under static condition.

Concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement, without the need of any vibration, while maintaining homogeneity is Self Compacting Concrete. SCC incorporates several chemical admixtures, in particular a High Range Water Reducing admixture [HRWR] and a Viscosity Modifying Agent [VMA]. High powder content is required to enhance the deformability and stability of concrete. The HRWR helps in achieving excellent flow at low water to cementitious materials ratios and the VMA helps in reducing bleeding and improving stability of the concrete mixture.

1.2 ADVANTAGES OF SCC:

- Faster progress, as more amount of concrete free fall is possible
- Quality of construction is enhanced, as a manual variable in the form of mechanical compaction is eliminated
- Better surface finishes because of more fines and better fluidity
- Safe working environment is possible due to the elimination of manual labour (vibrating operator, mason etc.,) for compaction and finishing works
- Better molding ability, there by easy to shape the concrete for aesthetics
- Enviro
- nmental-friendly, as industrial waste (fly ash) are used and concreting is noise-free
- Economic, where source of supplementary materials are available locally

1.3 EFFECT OF ADMIXTURES ON THE PROPERTIES OF SCC:

1.3.1 Effect of mineral Admixtures on the performance of SCC:

SCC often incorporates mineral and chemical admixtures. A high powder content is required for SCC. As the whole of this powder content cannot be cement alone, a part of the powder has to be one of the mineral admixtures. These mineral admixtures are either inert fillers or reactive in nature. Inert fillers include quartz powder and limestone while the reactive fillers are fly ash, silica fumes, ground blast furnace slag, etc.

These reactive mineral admixtures affect the concrete properties in many ways. Addition of fly ash generally improves the workability but the main problem with the fly ash is slow pozzolanic activity that leads to a low initial strength gain.

Blast furnace slag is also used as filler in SCC. It has been reported that the use of slag results in better early strength of concrete when compare to fly ash.

Silica fume is another mineral admixture that is used in concrete to produce high strength concrete. The use of 8% silica fume as a cement replacement is reported to reduce washout loss and improves segregation resistance when compared with concrete with 100% cement content.

Limestone is inert filler, but the use of limestone powder of a suitable fineness and quantity has been reported to have a reduced drying shrinkage.

1.3.2 Effect of chemical Admixtures on the performance of SCC:

The most commonly used chemical admixtures in SCC are a HRWR and a VMA. The traditional HRWRs were melamine or naphthalene based sulphonates. They wrap around the cement granules at a very early stage of the concrete mixing process. The sulphonic groups of the polymer chains increase the negative charge of the cement particle surface and disperse these particles by electrostatic repulsion. The electrostatic mechanism cause the cement paste to disperse and has the positive consequences of requiring less mixing water for a given concrete or making it more flowable.

Viscosity modifying agents are water-soluble polymers that increase the viscosity of mixing water and enhance the ability of concrete to retain its constituents in suspension. These admixtures are also known as anti-washout admixtures or anti bleeding admixtures. Kawai classified such water-soluble polymers as given below.

i. Natural polymers that include starch and natural gums
ii. Semi synthetic polymers that include decomposed starch and its derivatives; cellulose, ether derivatives, hydroxyl ethyl cellulose and carboy ethyl cellulose and electrolytes as sodium alginate.
iii. Synthetic polymers including those based on ethylene, such as polyethylene oxide, and those based on vinyl, such as polyvinyl alcohol.

1.4 SCOPE OF THE PROJECT

In the nuclear power plants, all the structures should be constructed with high quality material to safeguard the structures and thereby preventing the detrimental effects to the environment. Even if we provide good quality material to the structures, the accidents such as fires, blast, etc., which may happen under unavoidable situations, may cause the structure to be unsafe.

- If a fire broke out, severely it causes damage to both man and material. The personal hazard depends mainly to that person concerned but the material loss can be minimized by the effects of conducting experiment on thermo shock and properly applying this experiment to field. Recently the fire accident occurred in WTC, Trichy marriage hall and Tuticorin film theatre and Kumbakonam tragedy are few examples to quote for the disastrous effect of fire.

- The scope of this project lies in selecting a suitable admixture compatible with fly ash added SCC for compressive strength of concrete.

SCC is costlier than ordinary concrete by 50% because of the high fines content, use of new generation HRWR and VMA. Welan gum is the widely used VMA; we have tried with Gelinium 51, the cost of which is significantly high. Hence alternate VMA's which are available in India at low cost is to be tried and their compatibility also needs to be evaluated.

1.5 OBJECTIVE:

1. To select proper materials and arrive at the optimum mixture proportion for making high performance Self Compacting Concrete.
2. To evaluate the performance of VMA (i.e.,Glenium stream2) in modifying the properties of SCC and their compatibility with the chosen HRWR.
3. To produce Self Compacting Concrete economically.

1.6 METHODOLOGY:

- Mix design for Normal concrete (M40).
- Fixing water to cementitious material ratio for Self Compacting Concrete with various flyash content through slump flow test.
- Carrying out tests to determine the properties of Self Compacting Concrete in fresh state through V-funnel, slump flow, U-box and L-box.
- Determining the compressive strength , split tensile strength , flexture strength and stress-strain relationship of hardened concrete.

CHAPTER-2

LITERATURE REVIEW

Lars-Goran Tviksta (2000) concluded that the use of self-compacting concrete (SCC) , will improve the quality of concrete structures by eliminating some of the potential for human error. It will replace manual compaction of fresh concrete with a modern semi-automatic placing technology. However, this type of concrete needs a more advanced mix design than conventional concrete and a more careful quality assurance with more testing and checking, at least during the start-up period. Before SCC is produced and used the mix has to be designed and tested to be sure that the mix fulfils the demands regarding among others workability, segregation and passing ability. Suitable test methods and criteria are presented.

R. Khurana and R. Saccone (2000) concluded that the importance of low water cement ratio for enhancing durability of a concrete has long been accepted. Low water content leads to a low workability of the fresh concrete and if this concrete is not properly compacted, the durability of the structure will be impaired. In the mid seventies, super plasticizers were introduced to the market to produce rheoplastic concretes. These concretes had a high workability, slump of over 200mm, but were at the same time cohesive and none segregating. Millions of cubic meters of such concretes have been used all over the world during this decade. Recently self compacting concrete was developed in Japan and its use is spreading very rapidly to other countries. A proper design of self compacting concrete requires considerably more fines content as compared to that traditional concrete. Therefore, large volumes of fly ash, partially substitution cement, and partially as filler, can be employed in producing self compacting concrete. Compares the properties of fresh and hardened normal concrete and a self compacting concrete with large volume of fly ash.

Britil Persson (2000) concluded that the experimental studies of the mechanical performance of Self-Compacting Concrete, SCC, under compressive loading at fire temperatures. The SCC contains different amounts of polypropylene fibre, different types of cement and air content, preconditioned either in the air or in water. The result of the studies was compared with the corresponding properties of

normal concrete, with the same w/c and air content. Half a year's or one year's age applied at the time of testing. The strength development of the concrete was followed in parallel. Seven SCCs with w/c = 0.40, 0.55 or 0.70 and one normal concrete, NC, with w/c = 0.40 were studied for compressive strength in a fire temperature oven. The temperatures were200 °C, 400 °C and 800 °C. Both testing at elevated temperature and after cooling took place. Elastic modulus, ultimate strain at maximum strength, dynamic modulus and relative humidity, RH, were studied in parallel. Supplementary tests of were performed, after cooling from 600 °C, of strength, elastic modulus, ultimate strain at maximum strength. Supplementary tests were also performed on capillary suction, porosity and resistance to water penetration at water suction.
The results of the laboratory tests were compared with results of full-scale tests on twelve SCCs with w/c = 0.40, 0.55 or 0.70 and 4 NCs with w/c= 0.40, 0.55 or 0.70 on fire spalling carried out in a high-temperature oven. The same concrete was studied in the laboratory and in full-scale tests. The concrete was air-cured at an ambient RH =60%, or water-cured from demoulding until testing. The effects of increased amount of polypropylene fibres, age, different types of cement and air content, capillary suction, porosity, moisture content, hydration losses, preconditioning either in the air or in water, were studied.

S.G. Oh, T. Noguchi and F. Tomosawa ,Japan concluded that High Strength concrete has become one of the hottest topic since 1980s, and it is now possible to have structures that are built with concrete over 100 MPa compressive strength, something we would not have even thought of before. This kind of excitement has also triggered further development on the construction techniques and materials used for such concrete. At the same time, there were concerns on the maintenance of concrete structure. How is it possible to minimize the cost of maintenance, and to prolong the life of concrete. Thus, a lot of the research shifts to the development on the durability of concrete.

Praveen Kumar et al, concluded that Self-compacting concrete generally possesses a high powder content which keeps the concrete cohesive with high flowability. For achieving economy, a substantial part of this powder could contain fly ash. In such cases, early age strength development may prove to be a decisive factor, particularly when the formwork has to be reused. Test results of an experimental study are presented, which involved fly ash contents of more than 50 percent of the total powdered material. Compressive strength and split tensile strength test results are reported at the ages of 3, 7, 28 and 56 days. Compressive strengths of the order of 20 and 30 MPa are obtained with SCC at the ages of 3 and 7 days, respectively.

S G Bapat, S B Kulkarni and K S Bandekar, Nuclear Power Corporation of India Ltd. (NPCIL) intends to adopt the technology of self-compacting concrete (SCC) for various structures in nuclear power plants (NPPs), especially for those having congested reinforcement. The paper describes the efforts in developing SCC mixtures, full-scale mock-ups and actual use of SCC at the NPP at Kaiga in Karnataka. The authors conclude that an economical SCC mixture can be developed incorporating low powder and water contents (450 kg/m3 and 165 l/m3, respectively) with fly ash content being as high as 50 percent of the total powder content and manufactured sand being 70 percent of the total fine aggregate content.

J Annie Peter et al, concluded that, Self-compacting concrete (SCC) is made from almost the same ingredients as that of conventionally-vibrated concrete (CVC) except that relative proportions of these ingredients are to be carefully selected to impart self-leveling and self-compacting property to fresh concrete without a need for any external compacting and vibrating equipment. SCCs have generally higher content of fines (cement, fine aggregate) and chemical admixtures so that enhanced cohesiveness with no tendency for segregation is achieved. Thus, CVCs and SCCs are designed to have different characteristics when the concrete is fresh. In order to understand the structural behavior of these two concretes in hardened stage, reinforced concrete (RC) beams of size 150 mm ´ 400 mm ´ 3000 mm with similar concrete strength and identical reinforcement were cast and tested in flexure.

B V B Pai discussed with the cost of the ingredients of NSC/HSC and SCC differs marginally – SCC materials cost just about 10-15 percent higher. If an in-depth analysis of the other components of costs like the cost of consolidation, finishing, etc is carried out, then one would realize that SCC is certainly not a costly concrete. Further, the other advantages of SCC far out-weigh those of NSC/HSC.

CHAPTER-3

TEST METHODS FOR SELF COMPACTING CONCRETE

Assessing the fresh concrete properties of SCC has been a challenging problem for researchers. Conventional workability test methods cannot be adopted to judge the properties of SCC as they are not very sensitive for highly workable concrete, and do not say anything about the segregation resistance. Thus new test methods were designed to study the properties of SCC.

Self-Compactability is the ability of concrete to flow and compact under its own self-weight. The concrete is said to be Self-compacting concrete only when it satisfies the following three characteristics,

i. Filling ability:

The ability of SCC to flow in to and fill completely all spaces within the form work, under its own weight.

ii. Passing ability:

The ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking.

iii. Segregation resistance:

The ability of SCC to remain homogenous in composition during transport and placing.

Table 3.1: List Of Test Methods For Scc

S.NO	Method	Property
1	Slump-flow by Abrams cone	Filling ability
2	T_{50cm} slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel at $T_{5minutes}$	Segregation resistance
6	L-box	Passing ability
7	U-box	Passing ability

A concrete mix can only be classified as self compacting concrete if the requirements for all the above three characteristics are fulfilled.

Table 3.2 Test Method for Workability Properties Of SCC

S.No.	METHODS	PROPERTY	RECOMMENDED VALUES
1	Slump flow by Abrams Cone	Filling Ability	650 to 800 mm average flow diameter
2	T50 cm slump flow	Filling Ability	2 to 5 sec time to flow 500 mm
3	V - funnel	Filling Ability	6 to 12 sec time for emptying of funnel
4	V - funnel @ T5 min	Segregation Resistance	0 to +3 time for emptying of funnel after retaining of funnel for 5 min.
5	L - Box	Passing Ability	0.8 to 1 ratio of heights at beginning and end of flow
6	U - Box	Passing Ability	0 to 30 mm difference in heights in two limbs

3. 1. SLUMP FLOW TEST and T_{50}cm TEST:

3.1.1 Introduction:

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The test method is based on the test method for determining the slump. The diameter of the concrete circle is a measure for the filling ability of the concrete.

3.1.2 Assessment of test:

This is a simple, rapid test procedure, though two people are needed if the T50 time is to be measured. It can be used on site, though the size of the base plate is somewhat unwieldy and level ground is essential. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without blocking, but may give some indication of resistance to segregation. It can be argued that the completely free flow, unrestrained by any boundaries, is not representative of what happens in practice in concrete construction, but the test can be profitably be used to assess the consistency of supply of ready-mixed concrete to a site from load to load.

3. 1.3 Equipment:

The figure is shown in 3.1.

- Mould in the shape of a truncated cone with the internal dimensions 200mm diameter at the base, 100mm diameter at the top and a height of 300mm
- 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
- Stop watch

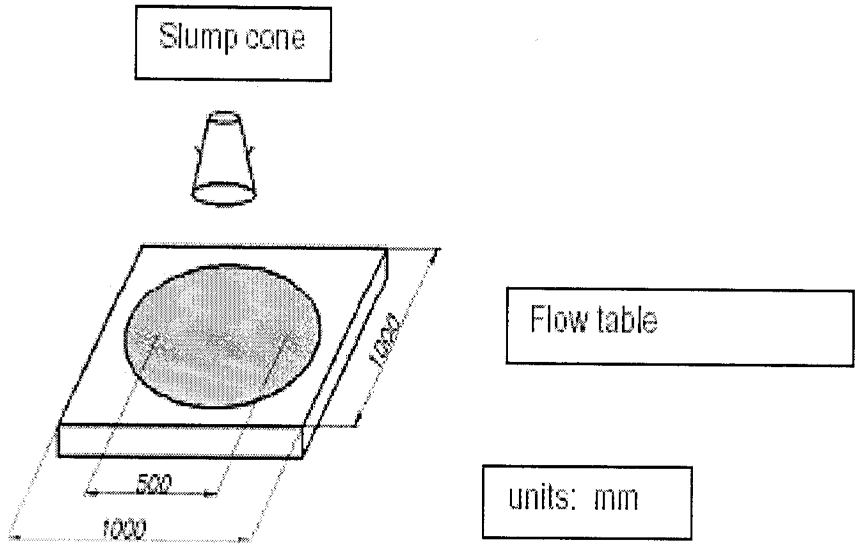


Fig.3.1 Slump flow test

Procedure:

- About 6 litre of concrete is needed to perform the test
- Initially the base plate and inside of slump cone is moistened
- The base plate is placed on a level ground and the slump cone centrally on the base plate
- The concrete is filled on the cone and it is leveled with the top of the cone with the trowel
- The surplus concrete around the concrete is removed
- The cone is raised vertically and the concrete is allowed to flow out freely
- Simultaneously, stopwatch is started and the time taken for the concrete to reach the 500mm spread circle is to be noted. [This is the T_{50} time]
- The final diameter of the concrete in two perpendicular directions are measured
- The average of the two measured diameters will give the slump flow in mm.

3. 1.5 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 flow table test, might be appropriate.

The T_{50} 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.

3.2 V Funnel test and V Funnel test at $T_{5minutes}$:

3.2. 1 Introduction:

The test was developed in Japan and used by Ozawa et al. The equipment consists of a V-shaped funnel, shown in Fig.3.2 An alternative type of V-funnel, the O funnel, with a circular section is also used in Japan.

The described V-funnel test is used to determine the filling ability (flowability) of the concrete with a maximum aggregate size of 20mm. The funnel is filled with about 12 litre of concrete and the time taken for it to flow through the apparatus measured.

After this the funnel can be refilled concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time will increase significantly.

3.2. 2 Assessment of test:

Though the test is designed to measure flowability, 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.

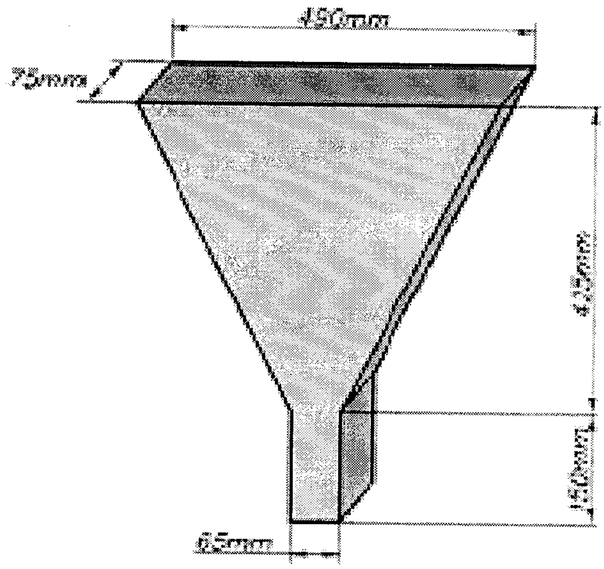


Fig 3.2 V-funnel test

3.2. 3 Equipment:

- V-funnel
- Bucket
- Trowel
- Scoop
- Stopwatch.

3.2. 4 Procedure: [flow time]

- About 12 litre of concrete is needed to perform the test
- V-funnel is placed on the firm ground and inside surfaces of the funnel are moistened
- Trap door is open to allow any surplus water to drain and then it is closed

- The apparatus is completely filled with concrete without compaction and leveled at the top with trowel
- The trap door is opened and simultaneously stopwatch is started and the time taken for the discharge to complete is noted.

Procedure flow time at $T_{5\ minutes}$:

- The trap door is closed and it is refilled with concrete in V-funnel after measuring flow time
- The trap door is opened after 5 minutes after the second fill of the funnel simultaneously the stop watch is started and the time taken for the discharge of concrete is noted.

3.2. 5 Interpretation of result:

This test measures the ease of flow of the concrete; shorter flow times indicate greater flow ability. 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.

3.3. L box test method:

3.3.1 Introduction:

This test, based on a Japanese design for underwater concrete, has been described by Petersson. The test assesses the flow of the concrete, and also the extent to which it is subject to blocking by reinforcement. The apparatus is shown in fig 3.3

The apparatus consists of a rectangular-section box in the shape of an 'L', with a vertical and 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, and then the gate lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1in the diagram). It indicates the slope of the concrete when at rest. This is an indication passing ability, or the degree to which the passage of concrete through the bars is restricted. The horizontal section of the box can be marked at 200mm and 400mm from the gate and the times taken to reach these points measured. These are known as the T20 and T40 times and are an indication for the filling ability. The 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 bars can principally be set at any spacing to impose a more or less severe test of the passing ability of the concrete.

3.3. 2 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.

3.3. 3 Equipment:

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

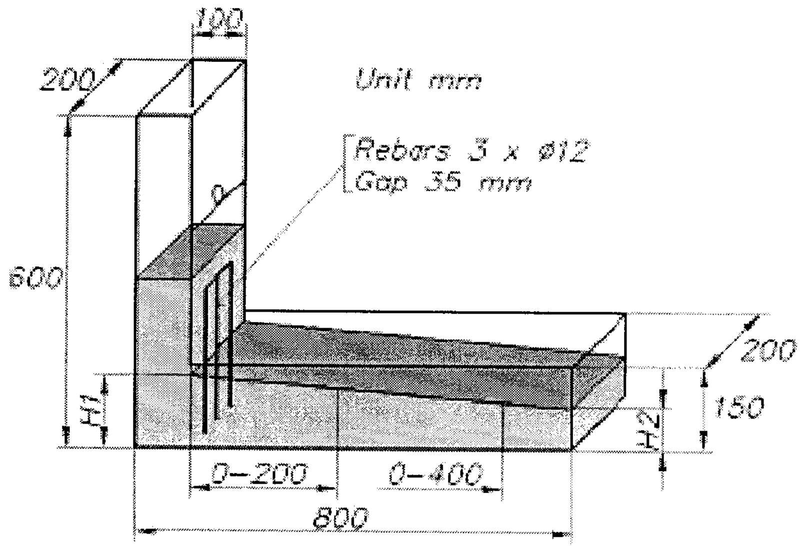


Fig 3.3 L-box

3.3.4 Procedure:

- About 14 litres of concrete is needed to perform this test
- Initially the inside portion of the apparatus is moistened
- Concrete is filled in the vertical section of the apparatus and it is allowed to stand it for 1minute
- Then the sliding gate is lifted and the concrete is allowed to flow out in the horizontal section. Simultaneously the stopwatch is started and time taken for the concrete to reach the 200 and 400mm marks are noted
- The height "H_I" and "H_2" are measured
- H_2/H_l is Calculated. This is known as the blocking ratio.

3.3.5 Interpretation of result:

If the concrete flows as freely as water, at rest it will be orizontal, so $H_2/H_l = 1$. 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. T_{20} and T_{40} 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.

3.4. U box test method:

3.4. 1 Introduction:

The Technology Research Centre of the Taisei Corporation in Japan developed the test. Sometimes the apparatus is called a "box-shaped" test. The test is used to measure the filling ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments, shown by R1 and R2 in Fig.3.4. An opening with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with centre-to-centre spacings of 50 mm. This creates a clear spacing of 35 mm between the bars. The left hand section is filled with about 20 litre of concrete then the gate lifted and concrete flows upwards into the other section. The height of the concrete in both sections is measured.

3.4. 2 Assessment of test:

This is a simple test to conduct, but the equipment may be difficult to construct. It provides a good direct assessment of filling ability – this is literally what the concrete has to do – modified by an unmeasured requirement for passing ability. The 35mm gap between the sections of reinforcement may be considered too close. The question remains open of what filling height less than 30 cm. is still acceptable.

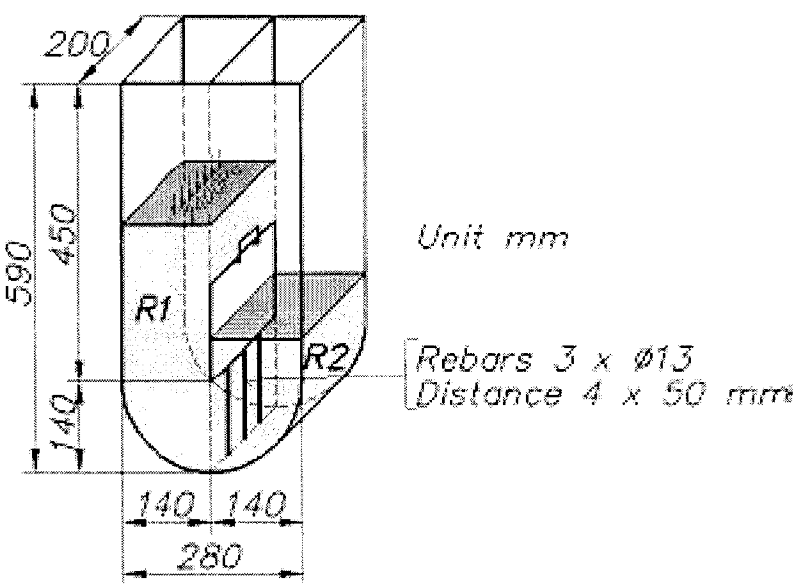


Fig 3.4 U-box

3.4. 3 Equipment:

- U-box of a stiff non absorbing material
- Trowel
- Scoop
- Stopwatch.

3.4. 4 Procedure:

- About 20 litres of concrete is needed to perform this test
- Initially the inside portion of the apparatus is moistened
- Concrete is filled in one compartment of the apparatus and it is allowed to stand for 1 minute
- Then the sliding gate is opened and the concrete is allowed to flow in to other compartment
- The heights [H_1 and H_2]after the concrete comes to rest
- $H_1 - H_2$ is calculated

3.4. 5 Interpretation of result:

If the concrete flows as freely as water, at rest it will be horizontal, so $H_1 - H_2 = 0$. Therefore the nearer this test value, the 'filling height', is to zero, the better the flow and passing ability of the concrete.

CHAPTER- 4

MATERIALS

4.1 MATERIALS USED AND THEIR PROPERTIES

The materials used in this study were ordinary Portland cement of 43 grade conforming to IS: 8112, natural river sand conforming to zone II, locally available crushed siliceous stone coarse aggregate of maximum size 12.5mm, fly ash from Mettur thermal power plant station, high range water reducing admixture of type Glenium B233, viscosity modifying agent of type Glenium stream2,portable tap water available in the laboratory. The properties of these materials used in this project are explained below.

4.1.1 Cement

The Portland pozzolana cement of conforming to IS: 8112 1989 was used for the present experimental study. The important properties of this cement have been tested and given below:

Specific gravity of Cement	=	3.16.
Normal Consistency Of Cement	=	34%.
Initial Setting Time Of Cement	=	35 minutes.
Fineness modulus cement	=	1.75

4.1.2 Fly Ash

4.1.2.1 Physical Properties of Fly Ash

Table No: 4.1 physical properties of fly ash

Sl.No.	Properties	Values
1	Fineness modules (passing through 45µ),%	78.60
2	Specific Gravity	2.10

4.1.2.2 Chemical Properties of Fly Ash:

Table No: 4.2 chemical properties of fly ash

Sl.No.	Properties	Values in %
1	Silica	59.62
2	Alumina	26.43
3	Iron oxide	6.61
4.	Calcium oxide	1.2
5.	Magnesium oxide	0.76
6.	Sulphur tri oxide	0.58
7.	Titanium oxide	1.56
8.	Loss of ignition	1.76

Natural river sand with fraction passing through 4.75mm sieve and on 150μm sieve was used and tested as per IS:2386 - 1983. The important properties tested for fine aggregate are given below:

Specific gravity of fine aggregate = 2.72.

fineness modulus of fine aggregate = 2.85.

bulk density of fine aggregate = 1487.6 kg/m^3.

4.1.3 Fine Aggregate

Natural river sand with fraction passing through 4.75mm sieve and on 150μm sieve was used and tested as per IS:2386 - 1983. The important properties tested for fine aggregate are given below:

Specific gravity of fine aggregate = 2.72.

fineness modulus of fine aggregate = 2.85.

bulk density of fine aggregate = 1487.6 kg/m^3.

4.1.4 Coarse Aggregate

Crushed granite coarse aggregate of size 12.5mm was used and tested as per IS: 2386 - 1983. The important properties tested for coarse aggregate are given below:

Specific gravity of coarse aggregate = 3.02.

Bulk density of fine aggregate = 1652.89 kg/m^3.

4.1.5 Water

Portable tap water available in laboratory with pH value of 7.0 ± 1 and confirming to the requirement of IS: 456-2000 was used for mixing concrete and curing the specimens as well.

4.2 ADMIXTURES:

4.2.1 High Range Water Reducers

Glenium B233 has been primarily developed for application in the ready mixed precast concrete industries and high performance concrete where the highest durability and performance is required.

Colour	: brown free flowing liquid
Relative density	: 1.08-0.10
pH	: 7 to 8
Chloride content	: Nil to EN934-2

4.2.2 Viscosity Modifying Agent (VMA)

The VMA used was Glenium stream2. It is a premier ready-to-use liquid, organic, viscosity-modifying admixture(VMA) specially developed for producing concrete with enhanced viscosity and controlled rheological properties.

Aspect	: colourless free flowing liquid
Relative density	: 1.01(+ or -) 0.01 at 25C
pH	: 8 (+ or -) 1
Chloride ion content	: <0.2%

CHAPTER-5

EXPERIMENTAL INVESTIGATION

5.1 INTRODUCTION

The experimental investigations were carried in which material properties required for the mix designs were determined and the mix for Normal concrete (M40) was designed. "Trial mixes" were made, tested and final mix proportion arrived and appropriate w/cm ratio by slump flow test for Self Compacting Concrete with various Fly ash contents by total binder were determined. Also, fresh properties and hardened properties were determined for Self Compacting Concrete.

5.2 MIXING

The required quantities of Cement, Sand, and Coarse aggregate, flyash, Viscosity Modifying Agent and Water were weighed accurately and kept separately for each mix. Cement and flyash , which were in powder form, were blended together and dry mixed thoroughly to get uniform color. VMA in the liquid form was mixed to the gauged water. This blended mix was kept aside. Initially coarse aggregate and sand was mixed. Then the blended mix was added to the coarse aggregate and sand mix.

5.3 CASTING OF TEST SPECIMENS

Cast Iron cube , cylinders and prism moulds were used for casting the test specimens. The concrete mixture prepared as described above was poured into the mould and the top surface was finished smooth.

5.3.1 Size of the specimens

Cubes size	: 100mm X 100mm X 100mm
Prisum size	: 100mm X 100mm X 500mm
Small cylinders size	: 100mm dia X 200mm
Cylinders size	: 150mm dia X 300mm

5.4 CURING OF TEST SPECIMENS

The specimens were left in the moulds for 24 hours. Identifications were marked on the exposed face of the specimen. The specimens were demoulded and they were immersed in the water in the curing tank. The specimens were allowed to cure in water for periods of 7and 28 days.

5.5 PREPARATION OF SPECIMEN FOR TESTING

The main objective of this study is to find the Compressive strength ,split tensile strength , flexural strength and stress-strain relationship of hardened concrete after subjecting to very high temperature for longer duration and a sudden cooling the after.

The specimens were taken out of the curing tank after the completion of the curing period. The surface was cleaned for removing any salt deposit. They were allowed to dry at room temperature for about 3 hours. The actual dimensions of the specimens were accurately measured. The compressive strength of cube specimens was found out and the values are tabulated.

5.5.1 COMPRESSIVE STRENGTH

$$f_c = P/A,$$

Where,

f_c = compressive strength (N/mm^2)

P = ultimate load (N) and

A = loaded area (100mm X 100mm)

5.5.2 FLEXURAL STRENGTH

= PL/BD^2

Where,

P=failure load in N,

L=length of span in mm

B=width of specimen in mm

D=depth of specimen in mm

5.5.3 SPLIT TENSILE STRENGTH

=2P/pLD

Where, P=failure load on the cylinder,

L=length of cylinder,

D=diameter of the cylinder.

5.6 MIX DESIGN BY ACI METHOD

The mix design of M40 grade of concrete is done by using the ACI method by using the test results of the materials known.

Design stipulations:

Characteristic strength required at 28^{th} day	:	40MPa.
Standard deviation	:	4MPa.
Maximum size of aggregate	:	12.5mm

Test data of materials:

Specific gravity of fine aggregate	:	2.72
Specific gravity of coarse aggregate	:	3.05
Dry rodded bulk density of CA	:	1487.6 kg/m^3.
Fineness modulus of fine aggregate	:	2.85.

Design:

Target mean strength

Target mean strength = f_{ck} + 1.64S

= 40 + (1.64 x 4)

= 46.56 N/mm^2.

Water cement ratio

Estimated W/C ratio = 0.38 (from exposure condition Table 11.6)

Cement content

A Slump of 150 to 180 mm is necessary. For 12.5mm maximum size of aggregate and for non air entrained concrete. The mixing water content is 166.7 kg/m^3 of concrete. Approximate entrapped air content is 2%.

The required cement content = 166.7/0.38

= 436.6 kg/m^3.

Coarse aggregate

From the table 11.4, for 12.5mm CA, for Fineness Modulus of Fine aggregate 2.85, Bulk volume of dry rounded coarse aggregate per unit volume of concrete = 0.6

Weight of Coarse Aggregate = 0.6 * 1487.6

= 892.56 kg/m^3.

Fine aggregate:

From Table 11.9, the first estimate of density of fresh concrete for 12.5mm maximum size of aggregate and for non air entrained concrete =2315 kg/m^3.

Weight of Fine aggregate	=	2196- (166.7+436.6+892.56)
	=	819.14 kg/m^3.

Mix ratio obtained by ACI method is:

Water	Cement	Fine aggregate	Coarse aggregate
166.7l/m^3 :	436.6kg/m^3 :	819.14kg/m^3 :	892.56kg/m^3
0.38 :	1 :	1.87 :	2.04

5.7 METHODOLOGY ADOPTED IN THIS STUDY

The sequential procedure adopted in this experimental study is as follows:

- Initially, a nominal mix with 80 to 100mm is targeted without the use of super plasticizers.
- A vertical slump of 180 mm is then aimed by adding super plasticizer to the mix obtained in previous mix. If any segregation especially bleeding takes place at this stage, as judged visually, a part of coarse aggregate is replaced by fine aggregate. The percentage of replacement is chosen to be small.
- To proceed towards achieving SCC the coarse aggregate is then replaced with fly ash, by various percentages of 10, 15, 20%, until a horizontal slump for SCC is achieved. And also the other tests like U –box, V- funnel test also reached with the limits of SCC.
- Finally, after achieving the appropriate SCC mix, specimens are casted and tested for the hardened properties.
-

5.8 TRIAL MIX PROPORTIONS TO OBTAIN SCC

The various trial mix proportions of different ratios are conducted in the laboratory to achieve the Self Compacting Concrete. By the addition of the HRWR of various ratio of 1.0%, 1.5% and the VMA of various ratio of 0.25%,0.5% to achieve the Self Compacting Concrete. In this stage the segregation of aggregates are found. So the coarse aggregate is replaced by fine aggregate by 5% and then the bleeding was not seen. To achieve the SCC mix the coarse aggregate is replaced by the fly ash by various percentages of 10, 15 and 20%. The finally the SCC mix was achieved in

20% replacement of coarse aggregate by fly ash. The mix proportion of achieved SCC is shown in the below:

Mix Ratio for SCC obtained from various trials is

Water	:	Cement	:	FA	:	CA	:	Fly ash	:	HRWR	:	VMA
166.7	:	436.6	:	858	:	685	:	262	:	10.48	:	3.493
0.38	:	1	:	1.97	:	1.57	:	0.6	:	0.024	:	0.008

This mix ratio is taken as the Conventional SCC ratio. This ratio satisfies all the fresh properties tests for SCC such as the slump flow test for the filling ability of the SCC, U – box test for the flow ability and also the segregation property of the SCC, V – funnel test for the filling ability of the SCC. Thus it satisfying all the requirements of SCC this mix proportion is taken as control mix of SCC.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 GENERAL

The Results of fixing of Optimum Mix Proportions, Test for Fresh properties and Hardened property (Compressive Strength, split tensile strength , flexture strength and stress-strain relationship) effect of VMA are discussed.

6.2 MIX PROPORTIONS OF SCC

The mix proportions were arrived based on the following guidelines. The mix design details of self compacting concrete are given in Table 1

Course aggregate content	-	46% of solid volume
Fine aggregate content	-	40% of mortar fraction volume
Paste volume	-	60% of mortar volume
Powder volume	-	50% of paste volume
Water content	-	50% of paste volume
Set retarder	-	2.2 liters / m^3

Table:6.1 Mix Design Of SCC

Mix	Cement (kg/m^3)	Flyash (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (kg/m^3)	Gleniun B233(kg/m^3)	Glenium stream2(kg/m^3)
1	436.6	262.0	858	685	166.7	10.48	3.49
2	414.6	290.2	853	685	162.5	10.57	3.52
3	424.5	297.1	821	672	184.8	10.82	3.61
4	434.4	304.1	829	661	181.7	11.08	3.69

6.2.1 SCC MIX 1

VMA namely Gleniun B233 as Water Reducer were used in this trial. Water content was changed so as to achieve the flow ability. The dosage of VMA and water reducer were optimized from preliminary investigations and other ingredients were adopted as suggested and mix proportions adopted in this trial is given in Table 6.1.

Table 6.2 Mix Proportions of SCC For Mix 1

Materials	Quantity taken
Water	166.7 Kg/m^3.
Cement	436.6 Kg/m^3.
Fly Ash	262.0 Kg/m^3.
Fa/c	0.6 Kg/m^3
w/cm	0.38 Kg/m^3.
Fine aggregate	858 Kg/m^3.
Coarse aggregate	685 Kg/m^3.
Glenium B233	10.48 Kg/m^3.
Glenium stream2	3.49 Kg/m^3.

Table 6.3 Fresh Concrete Properties of SCC In Mix 1

Tests	Value
Slump flow T50	3 sec.
Spreaded diameter	660 mm
V funnel	6 sec.
V funnel @ T5 min.	10 sec.
L box	
H1	100 mm
H2	90 mm
H2/H1	0.90 mm
T20	3 sec.
T40	5 sec.
U box	
H2 - H1	40 mm
(left) H2	250 mm
(right) H1	290 mm

6.3.2 SCC MIX 2

VMA namely Glenium stream2 and Super plasticizer namely Glenium B233 as Water Reducer were used in this trial. Water content was changed so as to achieve the flow ability. The dosage of VMA and water reducer were optimized from preliminary investigations and other ingredients were adopted as suggested and mix proportions adopted in this trial is given in Table 6.3. The performance in fresh state and Compressive Strength are presented in Table 6.5 and 6.6.

Table 6.4 Mix Proportions of SCC For Mix 2

Materials	Quantity taken	
Water	162.5	Kg/m^3.
Cement	414.6	Kg/m^3.
Fly Ash	290.2	Kg/m^3.
Fa/c	0.69	Kg/m^3.
w/cm	0.39	Kg/m^3.
Fine aggregate	853	Kg/m^3.
Coarse aggregate	685	Kg/m^3.
Glenium B233	10.57	Kg/m^3.
Glenium stream2	3.52	Kg/m^3.

Table 6.5 Fresh Concrete Properties of SCC In Mix 2

Tests	Value
Slump flow T50	3 Sec.
Spreaded diameter	680 mm
V funnel	6 Sec.
V funnel @ T5 min.	10 Sec.
L box	
H1	95 Mm
H2	85 Mm
H2/H1	0.89 Mm
T20	3 Sec.
T40	5 Sec.
U box	
H2 - H1	35 Mm
(left) H2	250 Mm
(right) H1	285 Mm

6.3.3 SCC MIX 3

By observing the performance of the first trial mix concrete in the fresh stage, 31% of fly Ash and 69% of cement was tried in the second trial and other ingredients were adopted as suggested, given in Table 6.7.

Table 6.6 Mix Proportions of SCC For Mix 3

Materials	Quantity taken
Water	184.8 Kg/m^3
Cement	424.5 Kg/m^3.
Fly Ash	297.1 Kg/m^3.
Fa/c	0.69 Kg/m^3
w/cm	0.42 Kg/m^3.
Fine aggregate	821 Kg/m^3.
Coarse aggregate	672 Kg/m^3.
Glenium B233	10.82 Kg/m^3.
Glenium stream2	3.61 Kg/m^3.

Table 6.7 Fresh Concrete Properties of SCC In Mix 3

Tests	Value
Slump flow T50	5 sec.
Spreaded diameter	640 Mm
V funnel	8 sec.
V funnel @ T5 min.	12 sec.
L box	
H1	98 Mm
H2	85 Mm
H2/H1	0.87 Mm
T20	3 sec.
T40	5 sec.
U box	
H2 - H1	50 Mm
(left) H2	250 Mm
(right) H1	300 Mm

6.3.5 SCC MIX 4

By observing the performance of the first trial mix concrete in the fresh stage, fly Ash and cement was tried and other ingredients were adopted as suggested, given in Table 6.7. The performance in fresh state and Compressive Strength ,split tensile strength, flexural strength and stress-strain relationship were given in table.

Table 6.8 Mix Proportions of SCC For Mix 4

Materials	Quantity taken
Water	181.7 Kg/m^3
Cement	434.4 Kg/m^3.
Fly Ash	304.1 Kg/m^3.
w/cm	0.41 Kg/m^3.
Fa/c	0.70 Kg/m^3.
Fine aggregate	829 Kg/m^3.
Coarse aggregate	661 Kg/m^3.
Glenium B233	11.08 Kg/m^3.
Glenium stream2	3.69 Kg/m^3.

Table 6.9 Fresh Concrete Properties of SCC In Mix 4

Tests	Value
Slump flow T50	5 sec.
Spreaded diameter	690 mm
V funnel	4 sec.
V funnel @ T5 min.	10 sec.
L box	
H1	89 Mm
H2	77 Mm
H2/H1	0.87
T20	2 sec.
T40	4 sec.
U box	
H2 - H1	30 Mm
(left) H2	250 Mm
(right) H1	280 Mm

Fig: 6.1 Slump Flow Test

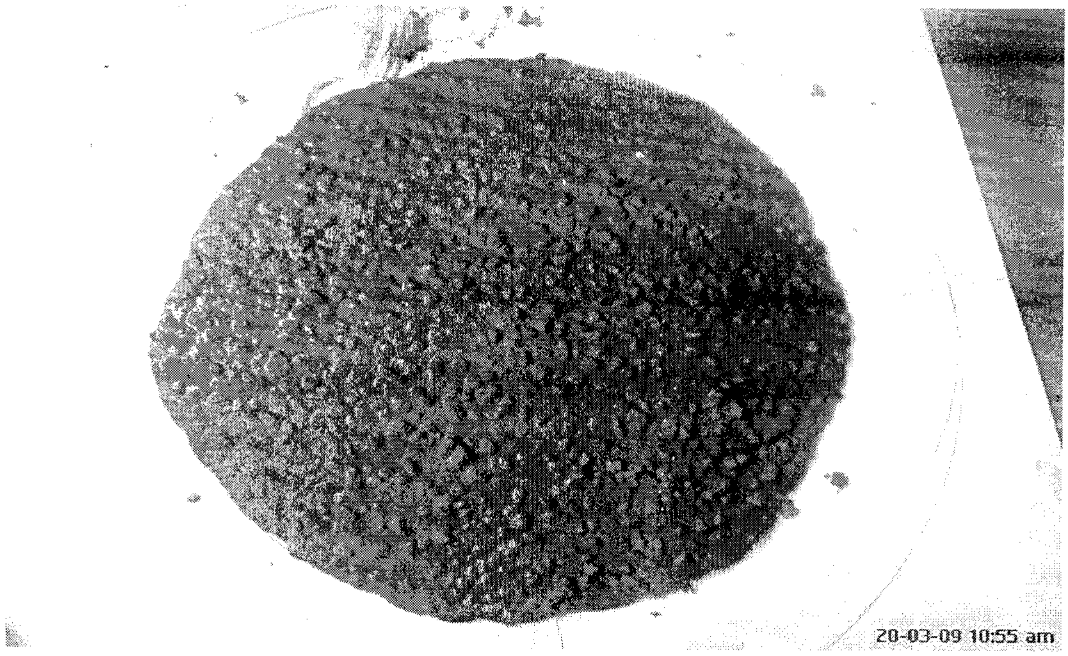


Fig: 6.2 U- Tube Test

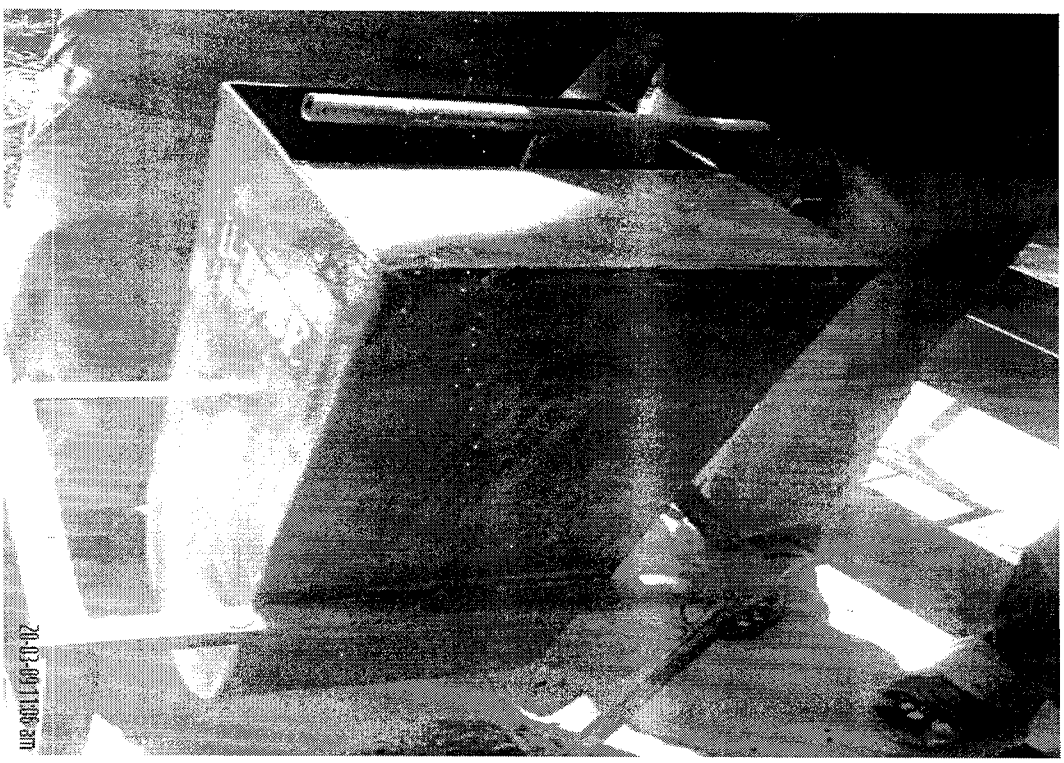
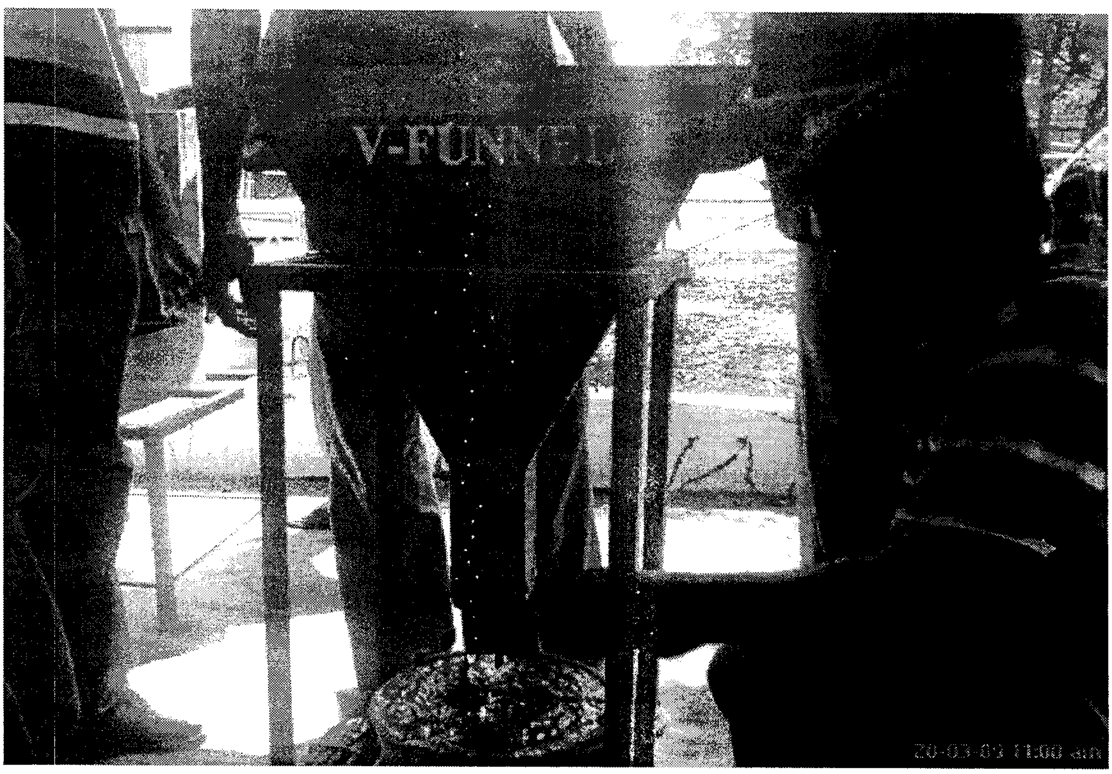


Fig: 6.3 L-Box test

Fig: 6.4 V-Funnel Test



6.4 HARDENED PROPERTY RESULTS

6.4.1 RELATIONSHIP BETWEEN AVERAGE COMPRESIVE STRENGTH OF VARIOUS MIX

Table: 6. 10 compressive strength of cubes

Type of Mix	Compressive Strength of Cube at 7th day(N/mm^2)	Compressive Strength of Cube at 28th day (N/mm^2)
1	30.3	43.3
2	32.6	46.6
3	34.6	49.3
4	37.6	53.3

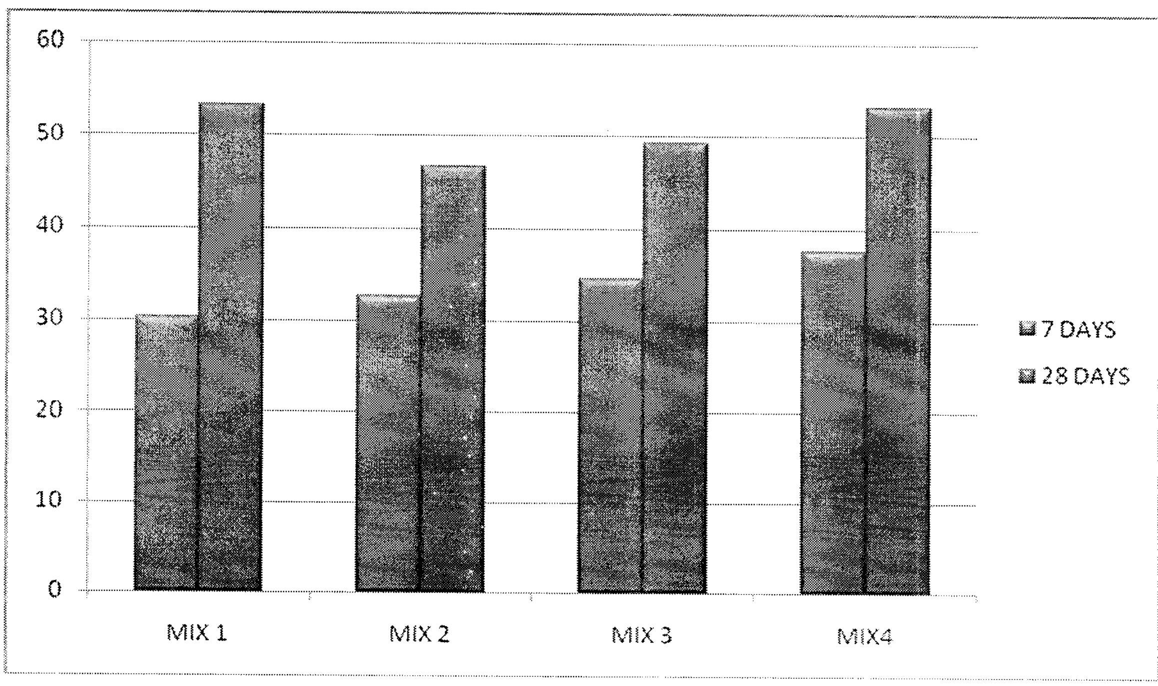


Fig :6.5 Compressive strength

6.4.2 RELATIONSHIP BETWEEN AVERAGE SPLIT TENSILE STRENGTH OF VARIOUS MIX

Table 6.11 Split tensile Strength of Cylinders

Type of Mix	Split Tensile Strength of Cylinders at 7^{th} day (N/mm^2)	Split Tensile Strength of Cylinders at 28^{th} day (N/mm^2)
1	2.36	4.16
2	2.61	4.33
3	2.99	4.64
4	3.41	4.91

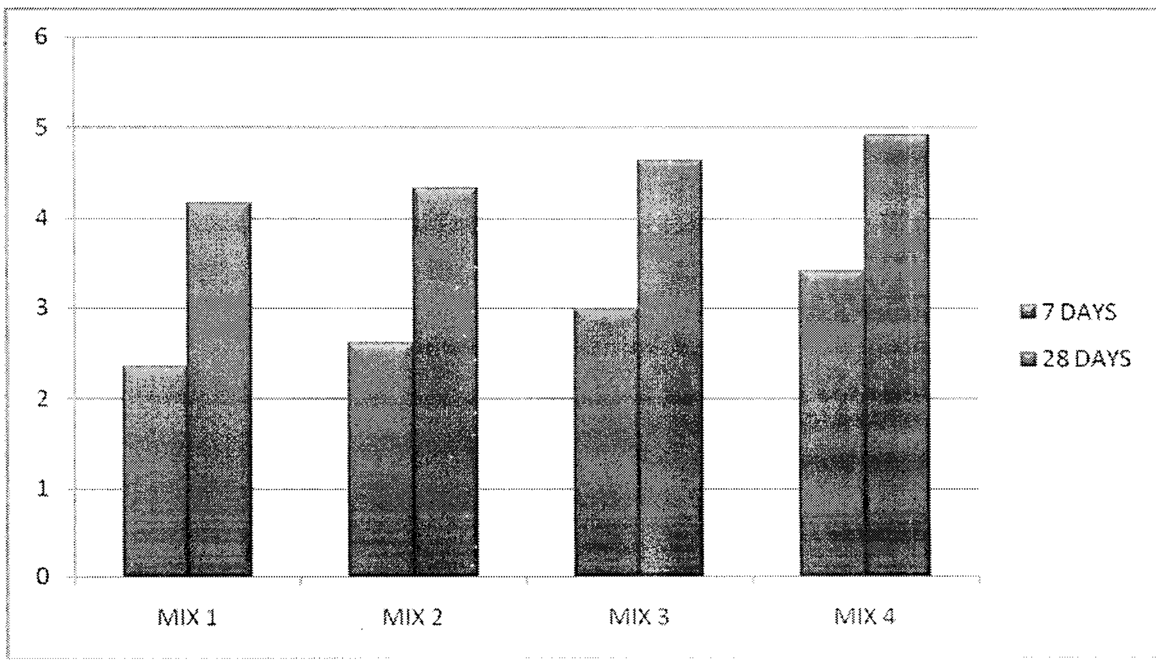


Fig :6.6 Split tensile strength

6.4.3 RELATIONSHIP BETWEEN AVERAGE FLEXURAL STRENGTH OF VARIOUS MIX

Table 6.12 Flexural strength of Prisms

Type of Mix	Flexural Strength of prism at 7th day (N/mm^2)	Flexural Strength of prism at 28th day (N/mm^2)
1	3.85	4.92
2	4.17	5.31
3	4.35	5.67
4	4.65	6.21

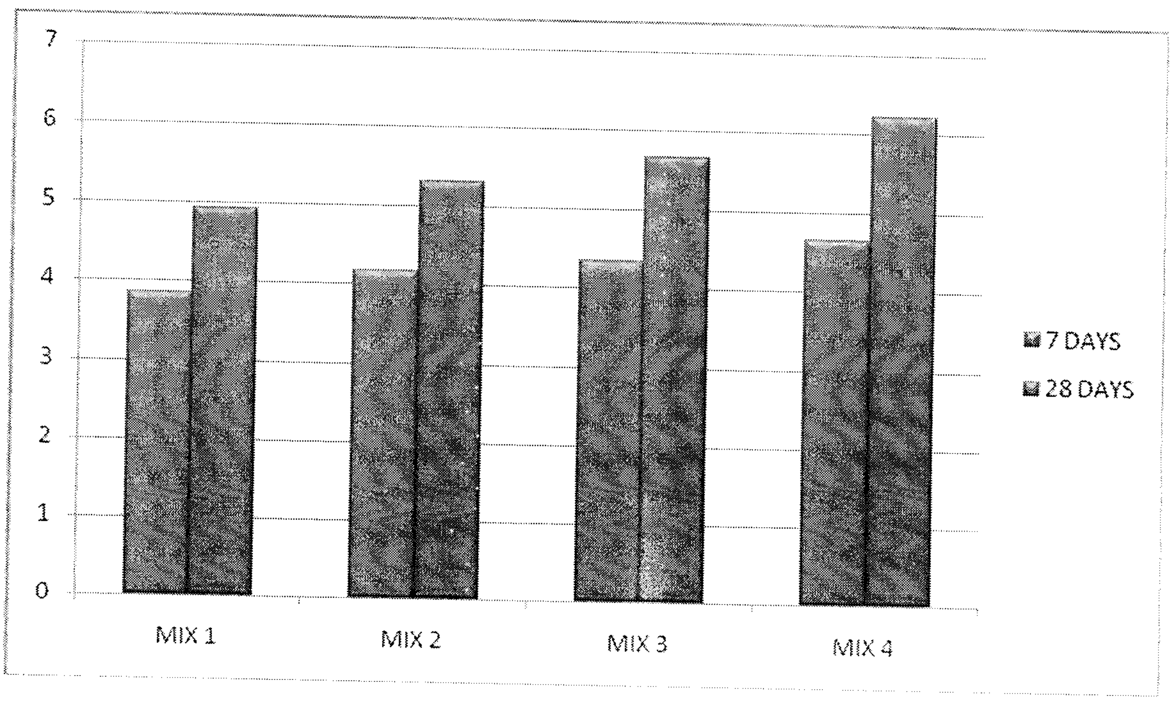


Fig :6.7 Flexural strength

6.4.4 STRESS-STRAIN RELATIONSHIP

Table No: 6.13 stress-strain results of various mixes

Type of mix	Youngs modulus of cylinders at 7th day (N/mm^2)	Youngs modulus of cylinders at 28th day (N/mm^2)
M1	26621.79	31390.93
M2	27143.61	34517.61
M3	32899.04	38034.76
M4	29739.38	33965.31

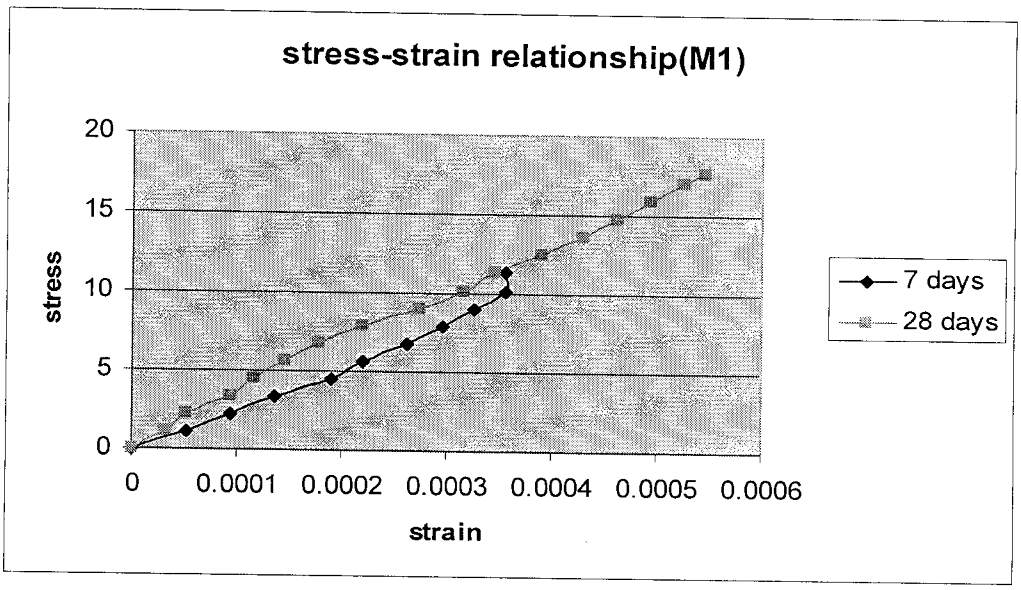


Fig : 6.8 Stress-strain Relationship Mix 1

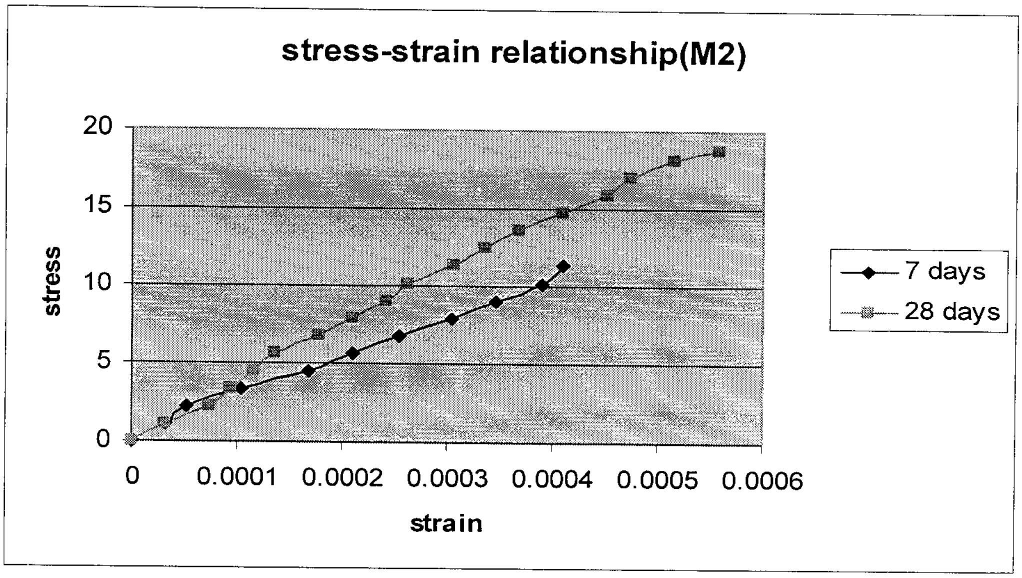


Fig :6.9 Stress-strain Relationship Mix 2

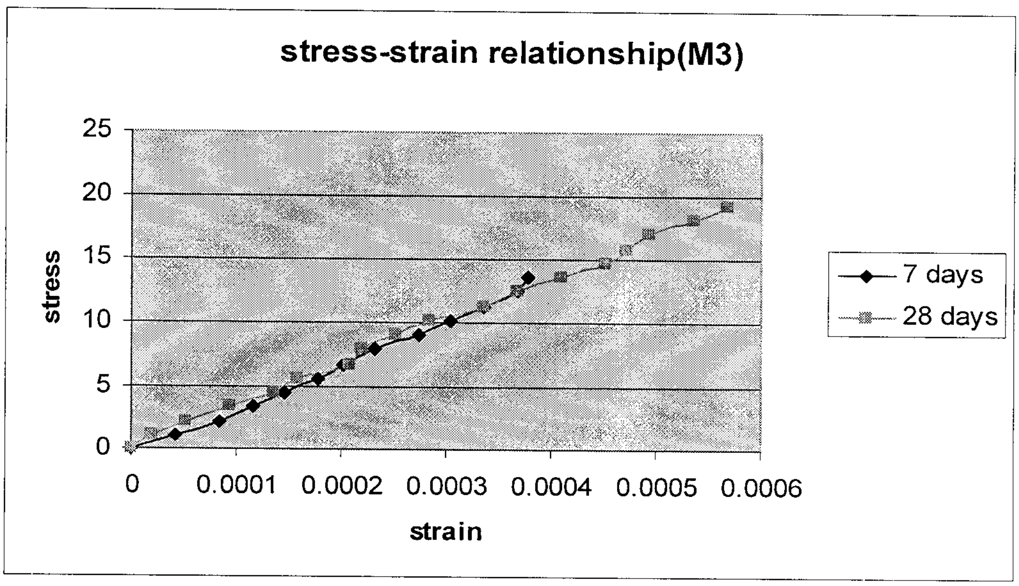


Fig :6.10 Stress-strain Relationship Mix 3

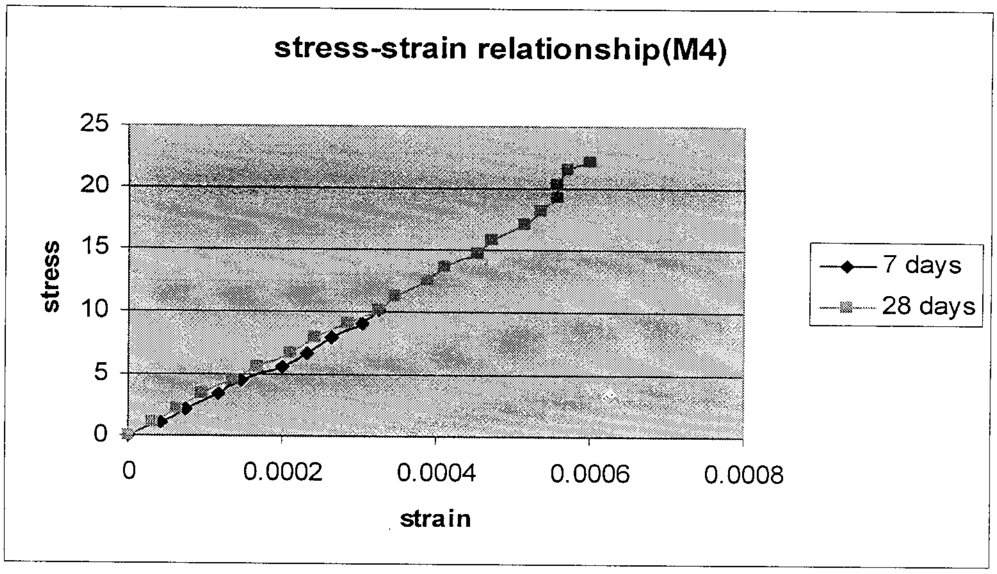


Fig :6.11 Stress-strain Relationship Mix 4

FIG: 6.12 COMPRESION TESTING OF CUBES

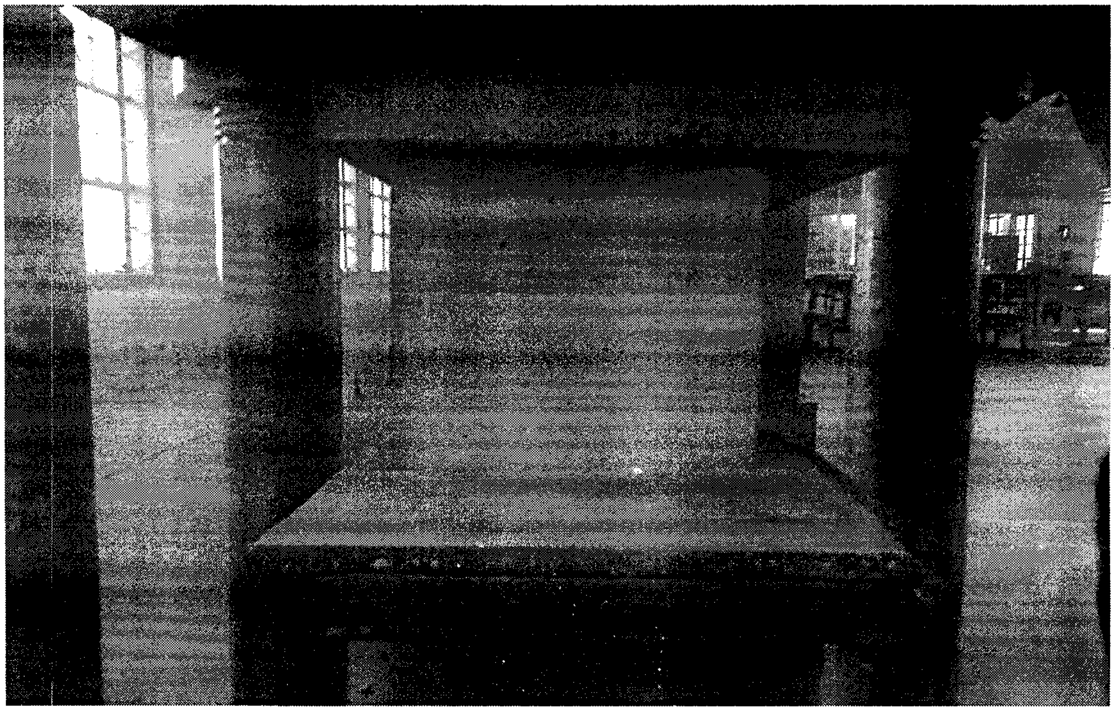


FIG: 6.13 SPLIT TESTING OF CYLINDERS

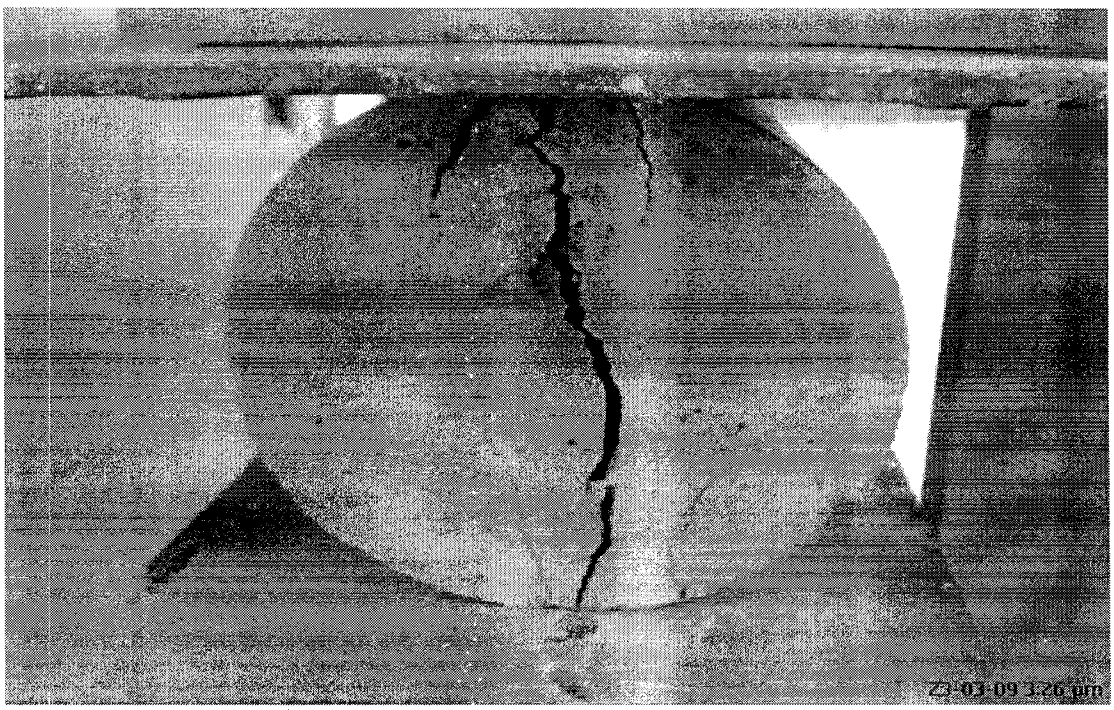
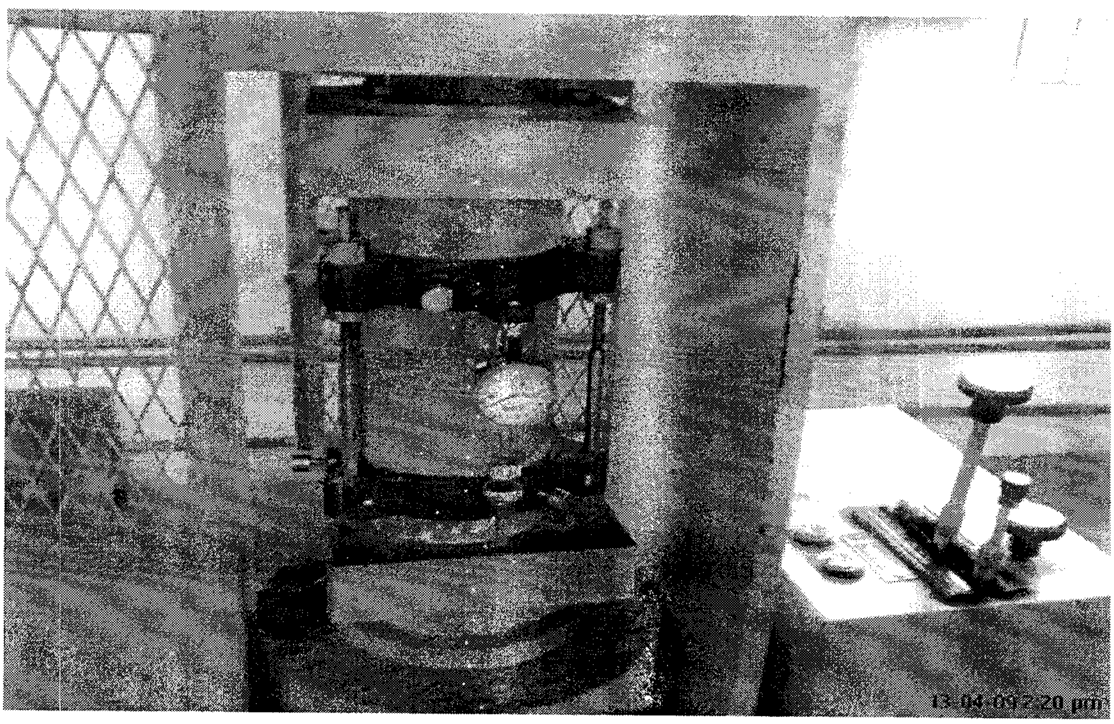


FIG: 6.14 FLEXURAL TESTING OF PRISMS

FIG:6.15 STRESS-STRAIN RELATIONSHIP TEST



6.5 SUMMARY OF TRAIL MIX RESULTS

Aim of this part of the investigation was to compare the performance of SCC with Ordinary Mix proportions as detailed in the following table, which was adopted for carrying out tests on fresh and hardened concretes.

TABLE 6.14 INGREDIENTS OF VARIOUS MIX PROPORTIONS

Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (kg/m^3)	W/C	Glenium B233(kg/m^3)	Glenium stream2(kg/m^3)
1	436.6	262.0	858	685	166.7	0.38	10.48	3.49
2	414.6	290.2	853	685	162.5	0.39	10.57	3.52
3	424.5	297.1	821	672	184.8	0.42	10.82	3.61
4	434.4	304.1	829	661	181.7	0.41	11.08	3.69

For each mix, tests such as V funnel, slump flow, L-box, U-box were conducted to determine the filling ability, passing ability and segregation resistance in fresh state .

TABLE 6.15 ABSTRACT FOR FRESH CONCRETE PROPERTIES

TESTS	Unit	Recom. Values	SCC1	SCC 2	SCC 3	SCC 4
Slump flow T50	*sec*	2 - 5	3	5	5	5
Spreaded diameter	*mm*	650 - 800	660	680	640	690
V funnel	*sec*	6 – 12	8	6	8	6
V funnel @ T5 min.	*Sec*	+ 0 - 3	10	10	12	10
L box						
H1	*mm*	....	100	95	98	96
H2	*mm*	....	90	85	85	82
H2/H1	*mm*	0.8 – 1	0.9	0.89	0.86	0.85
T20	*sec*		2	2	3	3
T40	*sec*		4	4	5	4
U box						
H2 - H1	*mm*	0 - 30	40	30	50	40
(left) H2	*mm*		250	250	250	250
(right) H1	*mm*		290	280	300	290

From the above table it is observed that the workability results of SCC 4 is very close to the permissible Values.

6.6 DISCUSSION:

Performance of Self Compacting Concrete with fly ash in fresh and hardened state s compared to that of normal concrete and the following important points are taken for discussion.

6.6.1 PROPERTIES OF SELF COMPACTING CONCRETE IN FRESH STATE

6.6.1.1 FILLING ABILITY

The recommended values of V-funnel value is 6to 12 seconds, slump flow is 650 to 800 mm and T50 cm time of 2-5 secs indicates the filling ability of Self Compacting Concrete. Mix SCC1 (FA30) was found to give values less than the recommended value of V funnel 4sec, 5sec. Also Mix SCC5 (FA50) was found to give more value of slump flow of 802mm. All the other mixes satisfied the above requirement uniformly as observed from Table 5.19.

6.6.1.2 PASSING ABILITY

For L-box, the desirable value of blocking ratio (H2/H1) should be 0.8 to 1. The desirable value for the height difference (R1-R2) in U-box should be 0 to 30 mm. All the mixes satisfied the above requirements as seen from table 5.19 and have got good passing ability.

6.6.1.3 SEGREGATION RESISTANCE

The time required in V-funnel for T5 min indicating segregation resistance should be 0 to +3 sec. All the mixes satisfied the requirement.

From the above discussion it is clear that all the mixes, FA60, FA69, FA69, and FA70 satisfied the requirements of Self Compacting Concrete in the fresh state indicating that increase in flyash content beyond certain limit (ie) more than 235Kg/m^3 do not affect the self compatibility of concrete. This is because the water to cementitious material ratios adopted for the final mixes were chosen based on the slump flow, which is a clear indication of flow ability of concrete.

CHAPTER 7
CONCLUSIONS

From the present experimental investigation of self compacting concrete with various percentage of cement replacement by fly ash, the following conclusions are arrived at:

1. The compressive strength was conducted for all percentage of mixes, it was found from the results that mix 4 gives better strength.

2. For split tensile strength it was found from the results that mix 4 gives better strength.

3. SCC designed and produced with proposed mix design method contains more sand but less coarse aggregates. Thus passing ability through gaps of reinforcement can be enhanced.

4. The above replacement of cement by fly ash was found to give good compressive strength. In order cases the compressive strength was found to be decrease.

5. The entire rehological test can be concurrently used to predict the flow behavior of the concrete made with different composition.

6. Adequately proportioned SCC can be used to cast highly reinforced structure, which can be successfully made with out internal or external vibration there by simplifying and accelerating the construction process

CHAPTER 8

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