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EXPERIMENTAL STUDY ON HIGH PERFORMANCE SELF COMPACTING CONCRETE USING RECYCLED AGGREGATE

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Abstract: Conventionally concrete is a mixture of cement, sand and aggregate. The large variation in the strength of concrete is due to the variation in the quality of aggregates used. Recycled aggregate concrete use is necessary in order to decrease the environmental impact of the construction industry. In general, there is a scarcity of sand throughout the world. Consumption of large amount of sand affects the environment. For the purpose of reducing the consumption of sand there is a need for an alternative fine aggregate arises. Recycled aggregates are obtained from the demolition of buildings, culverts, also as by product from the industries. Hence, partial or full replacement of fine aggregates and coarse aggregate by Recycled aggregate is researched in this project, in view of conserving the ecological balance. In this investigation, the coarse aggregate is partially replaced with 10%, 20% and 30% of recycled aggregate. The strength tests namely compressive strength test., split tensile strength test and flexural strength tests are carried out in this investigation. It is found that the replacement of replacement of coarse aggregate with recycled aggregate gives the better results and hence it can be used in construction industry maintaining ecological balance.

1. INTRODUCTION

Concrete is a composite construction material that is composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water, and chemical admixtures. The word concrete comes from the Latin word "concretus" (meaning compact or condensed), the past participle of "concresco", from "com-" (together) and "cresco" (to grow).Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together, eventually creating a robust stone-like material. Concrete is used to make pavements, pipe, architectural structures, foundations, motorways/roads, bridges/overpasses, parking structures, brick/block walls and footings for gates, fences and poles. Concrete is used more than any other man-made material in the world. As of 2006, about 7.5 cubic kilometers of concrete are made each year—more than one cubic meter for every person on Earth.

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is

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inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

Concrete is a relatively brittle material, when subjected to normal stresses and impact loads. Tensile strength of concrete is approximately one tenth of its compressive strength. As a result for these characteristics, plain concrete members could not support loads and tensile stresses that occurred, on concrete beams and slabs. Concrete members are reinforced with continuous reinforcing bars to withstand tensile stresses and compensate for the lack of ductility and strength. The addition of steel reinforcement significantly increases the strength of concrete, and results in concrete with homogenous tensile properties; however the development of micro cracks in concrete structures must be checked. The introduction of fibers is generally taken as a solution to develop concrete in view of enhancing its flexural and tensile strength. . [4] discussed about amplifier power relation, impedance , T π and microstripline matching networks.

Concrete shrinks when it is subjected to a drying environment. The extent of shrinkage depends on many factors, including the properties of materials, temperature and relative humidity of the environment, and the size of the structure. If concrete is restrained from shrinkage, tensile stresses develop and concrete may crack. Cracking due to restrained plastic shrinkage can be of critical concern in concrete construction such as highway pavements, slab cast on grade, and floors for parking garages. One possible method to reduce these adverse effects of cracking due to restrained shrinkage is addition of short and randomly distributed fibres. Addition of fibres is known to considerably reduce the crack width resulting from restrained shrinkage.

Now a day the construction industry turning towards pre-cast elements and requirement of post-tensioning has made the requirement of the high strength of concrete invariable and the engineers had to overcome these drawbacks, which to a great extent we have been able to do. The construction today is to achieve savings in construction work. This has now turned into one of the basic requirement of concreting process.

2. Self-compacting concrete

SCC is highly workable concrete that can flow under its own weight through highly congested reinforcement sections without segregation and bleeding. Self-compacting concrete should also have properties of theology such as relatively low yield value to ensure high flow ability, a moderate viscosity to resist segregation and bleeding, and must maintain its homogeneity during transportation, placing and curing to ensure adequate structural performance and long term durability. The successful development of SCC offers beneficial of economically and wide engineering varieties. The two main purposes of SCC during the plastic stage are flow ability which can be achieved using the high dosage of super plasticizer and stability or resistance to segregation of the plastic stage mixture that is attained by increasing the total quantity of the fines or otherwise using the viscosity agent admixture.

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2.1 BASIC PRINCIPLES AND REQUIRE MENTS OF SCC

With regard to its composition, SCC consists of the same components as conventionally vibrated normal concrete, which are cement, aggregates, water, additives and admixtures.However,high volume of super plasticizer for reduction of the liquid limitand for better workability, the high powder contentas "lubricant" for the coarse aggregates, as well as the use of viscosity-agentstoincrease the viscosity of the concrete have to be taken in to account (Dehnetal.,2000).Figure1.shows the basic principles for the production of SCC.

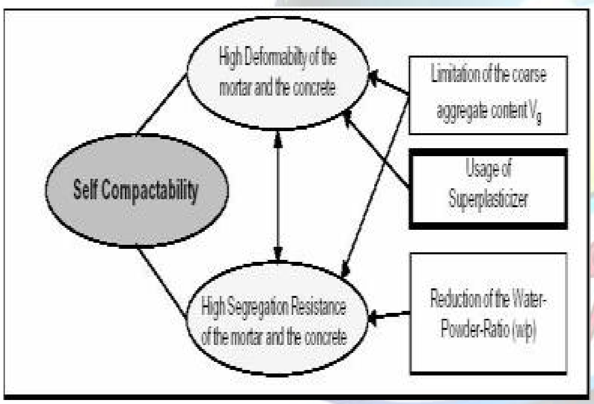

Figure-2.1. Basic principles for the production of SCC

Okamura and Ozawa (1995) have employed the following methods to achieve self-compact ability of SCC:

1. Limited aggregate content (coarse aggregate 50% of the concrete volume and sand 40% of the mortar volume),
2. Low water/powder ratio, and
3. Use of higher dosage of superplastcizer

A concrete mix can only be classified as SCC if the requirements for all the following three workability properties are fulfilled (EFNARC, 2002):

1. Filling ability,
2. Passing ability, and
3. Segregation resistance.

Filling ability: It is the ability of SCC to flow into all spaces within the formwork under its own weight. Tests, such as slump flow, V-funnel etc, are used to determine the filling ability of fresh concrete.

Passing ability: It is the ability of SCC to flow through tight openings, such as spaces between steel reinforcing bars, under its own weight. Passing ability can be determined by using U-box, L-box, Fill-box, and J-ring test methods.

Segregation resistance: The SCC must meet the filling ability and passing ability with uniform composition throughout the process of

2.2. DEVELOPMENT OF SCC

Origination of self compacting concrete is in 1983 from Japan as a solution for the shortage of the skilled labour who is required for the compaction purposes which is adequately required for constructing of durable concrete structures. However, one solution for the achievement of durable concrete structures is the employment of the self-compacting 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, whilst maintaining homogeneity. The necessity of this kind of concrete was proposed by Okamura in 1986.

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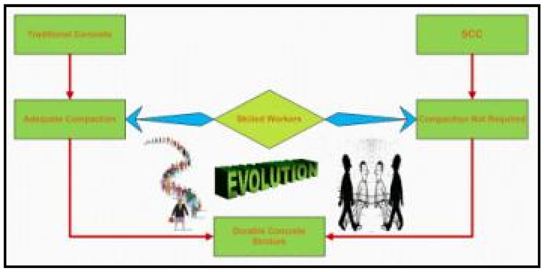

Fig.2.2.Development of SCC

2.3. MECHANISM FOR ACHIEVING SELF - COMPACTABILITY

The method for achieving self-compact ability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. Okamura and Ozawa have employecompactabilityd the following methods to achieve self- compact ability (1995):

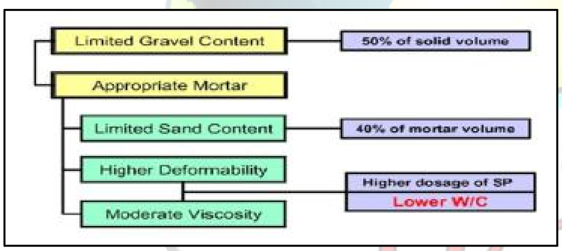

Fig-2.3. Methods for achieving self compatability

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

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

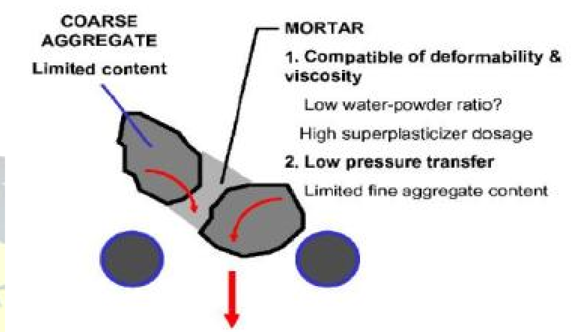

Fig.2.4. Mechanism for achieving self compatibility

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

The mix proportioning of self-compacting concrete is shown and compared with those of normal concrete and RCD (Roller Compacted concrete for Dams) .The aggregate content is smaller than conventional concrete that requires vibrating compaction. The ratios of the coarse aggregate volume to its solid volume (G/Glim) of each type of concrete. The degree of packing of coarse aggregate in SCC is approximately 50% to reduce the interaction between coarse aggregate particles when the concrete deforms.

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In addition, the ratios of fine aggregate volume to solid volume (S/Slim) in the mortar are shown in the same figure. The degree of packing of fine aggregate in SCC mortar is approximately 60% so that shear deformability when the concrete deforms may be limited. On the other hand, the viscosity of the paste in SCC is the highest among the various types of concrete due to its lowest water-powder ratio. This characteristic is effective in inhibiting segregation.

2.4. STATE OF THE ART ON SELF-COMPACTING CONCRETE

2.4.1 Current status of Self-Compacting Concrete

Self-compacting concrete has been used as a "special concrete" only in large general construction companies in Japan. In order for self-compacting concrete to be used as a standard concrete rather than a special one, new system for its design, manufacturing and construction of self-compacting concrete need to be established. Various committee activities on self-compacting concrete have been carried out as a result. Among them, a system by which the ready-mixed concrete industry can produce self-compacting concrete as a normal concrete would seem the most effective since, in Japan, as much as 70% of all concrete is produced by the ready-mixed concrete industry. Assuming a general supply from ready-mixed concrete plants, investigations to establish the following items have been carried out mainly at the University of Tokyo since the development of the prototype.

(1) Self-compatibility testing method
(2) Mix-design method
(3) Acceptance testing method at job site
(4) New type of powder or admixture suitable for self-compacting concrete.

2.5. SCC MIXES

There are three ways in which SCC can be made

1. Powder type
2. VMA type.
3. Combined type.

In Powdered type SCC is made by increasing the powdered content.in VMA type.It is made by using Viscosity Modifying Admixture. In combined type it is made by increasing powdered content and using the VMA. The above three methods are made depending upon the structural conditions, constructional conditions, available material and restrictions in concrete production plant etc….

2.6. Properties of SCC

The main characteristics of SCC are its properties in fresh state.The mix design is based on the ability to flow under its own weight without vibration,the ability to flow through congested reinforcement, under its own weight and ability to retain homogeneity without segregation

A concrete mix can only be classified as self compacting if it has following characteristics.

- Filling ability
- Passing ability
- Segregation resistance

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Table-2.1 List of test methods for workability properties of SCC

SI.NO	Method	Property
1	Slump flow by Abrams Cone	Filling ability
2	T50cm slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel at T5 minutes	Segregation resistance
6	L-Box	Passing ability
7	U-box	Passing ability
8	Fill-box	Passing ability
9	GTM Screen stability Test	Segregation resistance
10	Cement	Filling ability

3.1. RECYCLED AGGREGATES

Recycled aggregates are aggregates derived from the processing of materials previously used in a product and/or in construction. Examples include recycled concrete from construction and demolition waste material (C&D), reclaimed aggregate from asphalt pavement and scrap types.

3.2. SCOPE OF THE PROJECT:

- To minimize the need of cement by replacing cement with fly ash.
- To utilize the waste and locally available materials i.e. fly ash and recycled aggregate
- To produce the concrete with enhanced workability and strength thereby reducing repair cost and labours work.

4. FRESH CONCRETE PROPERTIES AND TEST RESULTS

4.1. CHARACTERISTICS OF FRESH SCC

The main characteristics of SCC are the properties in the fresh state. In order to flow, fill through the dense reinforcement the SCC must pose certain properties like flow ability, fill ability, resistance for segregation.

The major properties of SCC are:

- Passing ability (confined flow ability).
- Filling ability (unconfined flow ability).
- Resistance to segregation (segregation resistance).

4.1.1 PASSING ABILITY

- The ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking.
- The flow ability of the mix is tested by the slump flow, T_{50} slump flow, V funnel.
- The flow ability of the mix is increased by having a suitable water/powder ratio.
- The use of super plasticizers helps to increase the workability of the concrete.

4.1.2 FILLING ABILITY

- This property of fresh concrete is related entirely to the mobility of the concrete.
- The ability of SCC to flow into and fill completely all spaces within the formwork, under its own weight.
- This property is achieved by addition of super plasticizers and by optimizing the

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packing of fine particles by adding fillers.

- This property is tested by the Slump flow test and V – funnel test.

4.1.3 RESISTANCE TO SEGREGATION

- The mix has to maintain its stability under high flow conditions i.e. it should not segregate and should remain homogenous in composition during transport and homogeneity.
- The normal concrete mix when it shows signs of segregation, a percentage of coarse aggregate is replaced by fine aggregate.
- This property of the Self Compacting Concrete is tested by V – funnel test and V – funnel at T_5 minutes test.

4.2. TESTING METHODS FOR SCC

The guideline for testing the fresh Self Compacting Concrete has not been standardized to date. So far no single method or combination of methods has achieved universal approval and most of them have their adherents. The constant search for finding more appropriate field testing methods has led to the emergence of few empirical methods in the past few years. The filling ability, passing ability and resistance to segregation are the distinguished properties of SCC which is not common to conventional concrete and, therefore the tests for SCC are handled through special tests. EFNARC, making use of broad practical experiences of all members of European federation with SCC, has drawn up specification and guidelines for testing the SCC and also specified the limiting values to obtain SCC. It also provides a framework for design and use of high quality SCC. Some of the important tests that have to be carried out in order to satisfy the requirements of Self Compacting Concrete are listed below.

In these tests only three tests are executed in this project. Those tests are slump flow by Abram's cone, L-box and J –ring Test. Their test procedure and test results are as follows

Table-4.1 List of test methods for workability properties

SI.NO	Method	Property
1	Slump flow by Abrams Cone	Filling ability
2	T50cm slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-funnel at T5 minutes	Segregation resistance
6	L-Box	Passing ability
7	U-box	Passing ability
8	Fill-box	Passing ability

.

4.2.1 L-BOX TEST

Principle

The method aims at investigating the passing ability of SCC. It measures the reached height of fresh SCC after passing through the specified gaps of steel bars and flowing within a defined flow distance. With

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this reached height, the passing or blocking behaviour of SCC can be estimated.

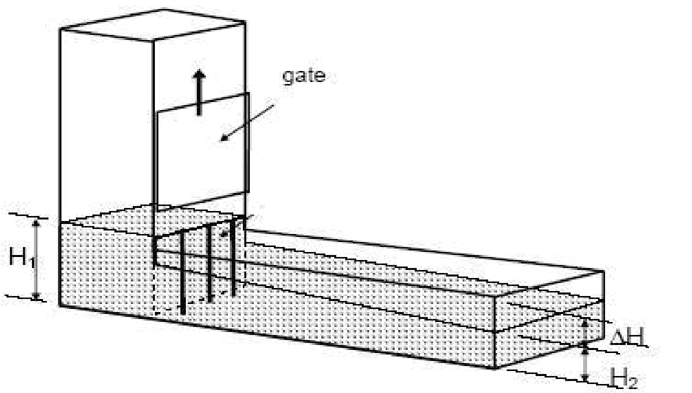

Figure-4.1 L-BOX

4.2.2 J- RING TEST

Principle;-

The J-ring test device can be used with the slump flow test. The J-ring, is a rectangular section (30 mm by 25 mm) open steel ring with a 300 mm diameter. Vertical holes drilled in the ring allow standard reinforcing bars to be attached to the ring. Each reinforcing bar is 100 mm long. The spacing of the bars is adjustable, although 3 times the maximum aggregate size is typically recommended. For fiber-reinforced concrete, the bars should be placed 1 to 3 times the maximum fiber length.

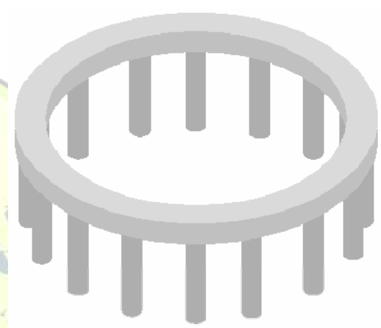

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Figure-4.2 J-ring Test

Table 4.2 Test results for workability

MIX	Slump flow (mm)	L-Box	J-Ring (secs)
SCC	695	0.89	9.8
RA 10%	704	0.96	10.5
RA 20%	690	0.88	10.3
RA 30%	713	0.92	10.7

5. HARDENED CONCRETE PROPERTIES AND TEST RESULTS

5.1. GENERAL

Even though the SCC is characterized by the fresh concrete properties especially workability, it also equally important in the properties of the hardened concrete and it do not vary much from the normal concrete. It is very important that the SCC possesses all the hardened concrete properties, such as the compressive strength, the tensile strength and the flexural strength. For measuring the compressive strength, cubes and cylinders are cast and used. The tensile strength is determined indirectly by performing split-tensile tests on cylindrical specimens. The Indian standard of testing the hardened concrete is given below.

5.2. COMPRESSIVE STRENGTH OF CONCRETE:

Cube test:

Concrete is strong in compression and in construction also concrete is mainly used in compression. Higher the compressive strength, better is the durability and bond strength. Resistance to abrasion and volume stability improve with the compressive strength which is very important in quality control of concrete.15cm,cube size is normally used. But 10cm size can also be used if the aggregate size is not greater than 20mm . The apparatus used are Cube moulds 15cm size, trowels, tamping rod 16mm diameter and 60cm long , compression testing machine.

Compressive strength,

$C = P/A$

Where,

P= load in Newton

A= area of cross section of cube in mm^2

5.3. SPLIT TENSILE STRENGTH ON CONCRETE:

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure.

The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consist of applying a compressive line load along the opposite generators of concrete cylinder placed with its axis horizontal between the compressive platens . Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis.

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The magnitude of this tensile stress σ_{sp} is given by the formula

$$\sigma_{sp} = 2p/\pi dl$$

Where,

p is the applied load,

d and l are the diameter and the length of the specimen

Due to the tensile stress, the specimen fails by splitting vertically into two halves; this test is also called the split test. The test has been standardised for concrete specimens with diameter larger than four times the maximum size of the coarse aggregate or 150mm whichever is greater. The length of the specimens shall not be less than the diameter and not more than twice the diameter. For the routine testing, the specimens shall be cylinders 150mm diameter and 300mm in length. The apparatus used are Cylinder mould , compression testing machine.

5.4. FLEXURAL STRENGTH OF CONCRETE:

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the 'pull' applied to the concrete. While a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure the flexural strength property of concrete. The value of the modulus of rupture (extreme fibre stress in bending) depends on the dimension of the beam and manner of loading. The systems of loading used in finding out the flexural tension are central point loading and third point loading.

There are three types of loading namely

1. Central point loading
2. Two point loading
3. Three point loading

In the central point loading, maximum stress will come below the point of loading where the bending moment is maximum. In the symmetrical two point loading, the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending moment is maximum. It can be expected that the two point loading will yield a lower value of modulus of rupture than the centre point loading

Flexural strength, $F = Pl/bh^2$

Where, P= load in Newton shown in dial gauge

l= length of rectangular prism in mm i.e 700 mm

b= breadth of rectangular prism i.e 150 mm

h= height of rectangular prism i.e 150 m

5.5. Compressive Strength Test

Table-5.1 Compressive Strength Test

SI. NO	Recycled Aggregate	Compressive Strength N/mm²		
		7 Days	14 Days	28 Days
1	0%	22.14	29.76	33.34
2	10%	26.66	29.8	33.95
3	20%	27.31	30.57	34.89
4	30%	28.03	31.31	35.82

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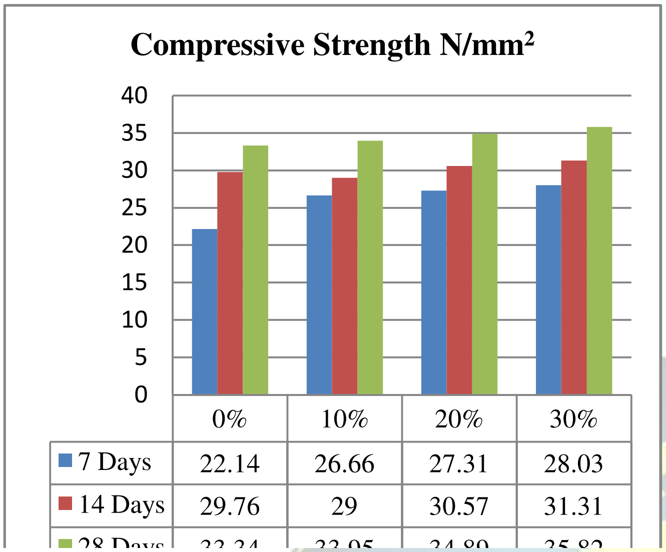

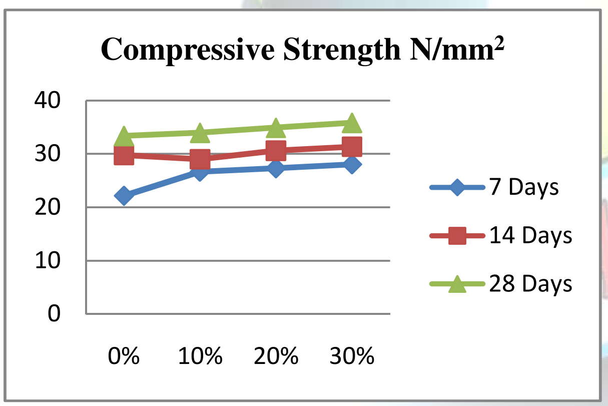

Figure-5.1 Compressive Strength

Discussion

In this investigation, the compressive strength test of self compacting concrete is carried out with 10%, 20% and 30 % replacement of recycled aggregate with coarse aggregate. The tests are carried at 7 days, 14 days and 28 days. It is found that the compressive strength at 28 days has increased up to 7% with 30% 0f recycled aggregate

5.6 Split Tensile strength.

Table-5.2 Split Tensile strength

SI.NO	Recycled Aggregate	Split Tensile Strength N/mm²		
		7 Days	14 Days	28 Days
1	0%	0.69	0.9	1.32
2	10%	0.71	0.92	1.38
3	20%	0.88	1.24	1.43
4	30%	1.07	1.29	1.46

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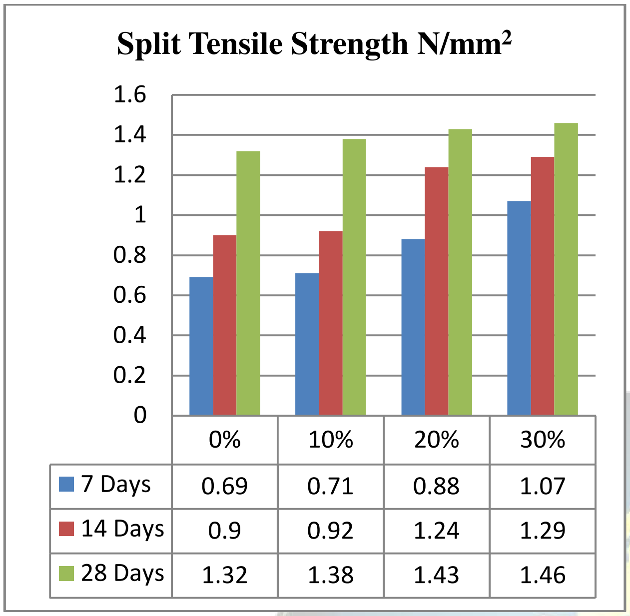

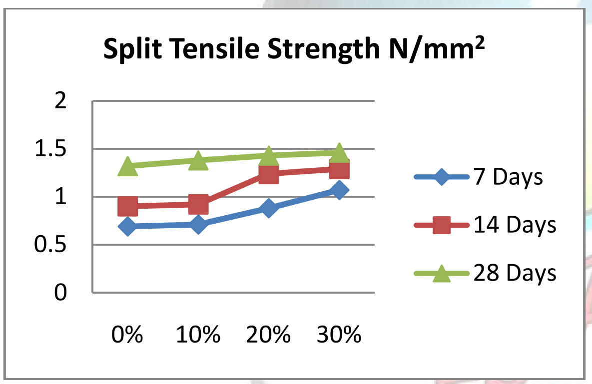

Figure-5.2 Split Tensile strength

Discussion

In this investigation, the split tensile strength test of self compacting concrete is carried out with 10%, 20% and 30 % replacement of recycled aggregate with coarse aggregate. The tests are carried at 7 days, 14 days and 28 days. It is found that the split tensile strength at 28 days has increased upto 9.5% of recycled aggregate

5.7 Flexural strength

Table- 5.3 Flexural strength

SI.NO	Recycled Aggregate	Flexural Strength N/mm^2
		28 Days
1	0%	5.25
2	10%	5.71
3	20%	6.74

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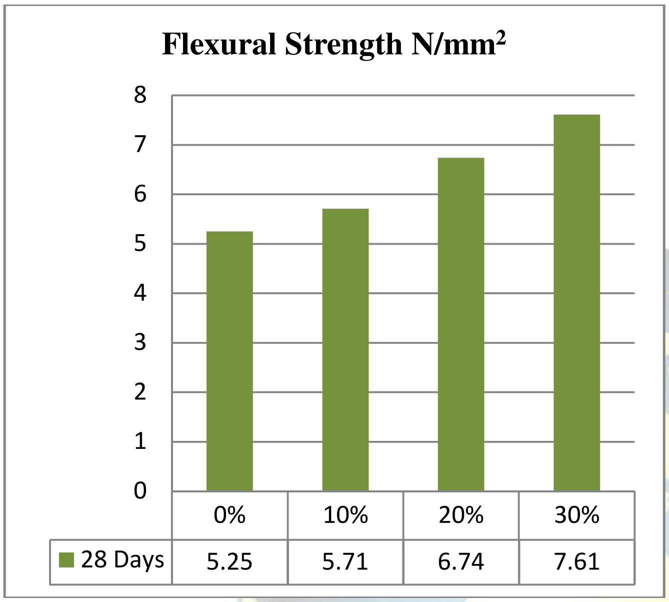
4	30%	7.61



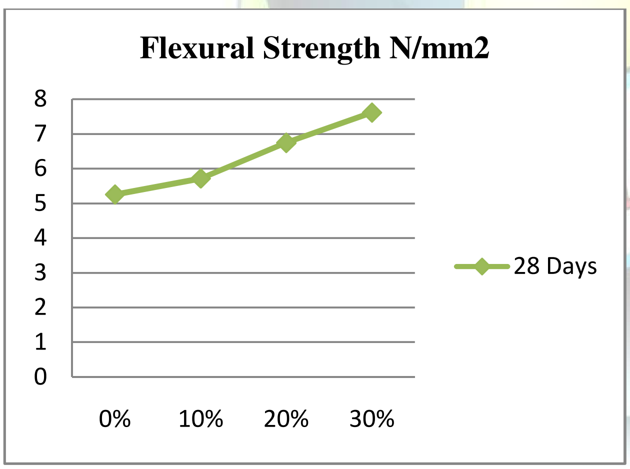


Figure-5.3 Flexural strength Test

Discussion

In this investigation, the split tensile strength test of self compacting concrete is carried out with 10% ,20% and 30 % replacement of recycled aggregate with coarse aggregate. The tests are carried at 7 days, 14 days and 28 days. It is found that the split tensile strength at 28 days has increased upto 31% of recycled aggregate

6. CONCLUSION

In this experimental study on high performing self compacting concrete using recycled

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aggregate, the following conclusions have been made.

- SCC with 30% replacement of coarse aggregate with recycled aggregate has given the best results
- The recycled aggregate has high water absorption compared to natural aggregate.
- Difficulties observed in this project are quick initial setting of concrete due to the effect of Poly Carboxylic Ether (PCE) based super plasticizer
- Based on Marsh cone test the effect of super plasticizer dosage find out. The result reducing while, increasing percentage of super plasticizer.
- The tests namely L-Box, J-ring and slump cone were used to find out the workability properties of self compacting concrete.
- The addition of VMA Glenium stream -2 , (.1%) give exact workability

Finally the replacement of 30 % coarse aggregate with recycled aggregate has given the better results in all aspects.

7. REFERENCE

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