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EXPERIMENTAL ANALYSIS OF FIBER-REINFORCED RECYCLED AGGREGATE SELF-COMPACTING CONCRETE USING WASTE RECYCLED CONCRETE AGGREGATES, POLYPROPYLENE AND CARBON FIBERS

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Abstract: Self-compacting concrete (SCC) is a cementitious composite which serves complex formworks without mechanical vibrations with superior deformability and high resistance to segregation. Besides, the recycled aggregate concrete (RAC) is also developing rapidly and along with the ever-increasing sustainable demand for infrastructure. The utilization of recycled concrete aggregate in Self-Compacting Concrete (SCC) has the potential to reduce both the environmental impact and financial cost associated with this increasingly popular concrete type. The combination of the fibers, RAC, and SCC may create advantages for the construction industry. In this study, the polypropylene (PP) fiber at 0.1, 0.15,0.2 and 0.25% volume fractions and carbon fibers at 0.4, 0.6, 0.8 and 1% volume fractions are introduced into fiber-reinforced Natural aggregate &recycled aggregate self-compacting concrete. Both fresh property and hardened mechanical performance, compressive strength, split tensile test are analyze and results compared.

INTRODUCTION

The increasing demand for infrastructure and construction projects are rapidly increasing, resulting in a high interest on efficient, economical, and optimal design for concrete mixes. However, corresponding environmental issues are raised and it releases 1,183 million tonnes, construction waste annually worldwide. This poses the challenge and demand for a more sustainable approach to preserve the environment through resource conservation and reduce the amount of landfill required.Self-compacting concrete (SCC) is a concrete, which flows and compacts only under gravity. It fills the mould completely without any defects. Usually self-compacting concretes have compressive strengths in the range of 60-100 N/mm^2. However, lower grades can also be obtained and used depending on the requirement. SCC was originally developed at the University of Tokyo in Japan with the help of leading concrete contractors during 1980's to be mainly used for highly congested reinforced structures in seismic regions. As durability of concrete structures was an important issue in Japan, an adequate compaction by skilled labors was required to obtain durable concrete structures. This requirement led to the development of SCC. The development of SCC was first reported in 1989.SCC is a new kind of High-Performance Concrete (HPC) which has an excellent deformability and segregation resistance. By name it can be defined as a concrete, which can flow through and fill the gaps of reinforcement and corners of the moulds without any need for external vibration. SCC compacts itself due to its self-weight and de-aerates almost completely while flowing in the formwork. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete, such as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flowability of SCC makes it possible to fill the formwork without vibration Since its inception, it has been widely used in large construction works or projects in Japan. Recently, this concrete has gained wide use for different applications and structural configurations across the world. Concrete (HPC) which has an excellent deformability and segregation resistance. By name it can be defined as a concrete, which can flow through and fill the gaps of reinforcement and corners of the moulds without any need for external vibration. SCC compacts itself due to its self-weight and de-aerates almost completely while flowing in the formwork. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete, such as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flowability of SCC makes it possible to fill the formwork without vibration. Since its inception, it has been widely used in large construction works or projects in Japan. Recently, this concrete has gained wide use for different applications and structural configurations across the world.

High strength concrete can be produced with normal concrete. But these concretes cannot flow freely by themselves, to pack every corner of moulds and all gaps of reinforcement. High strength concrete-based elements require thorough compaction and vibration in the construction process. SCC has more favorable characteristics such as high fluidity, good segregation resistance and distinctive self-compacting ability without any need for external or internal vibration during the placing process. It can be compacted into every corner of formwork purely by means of its own weight without any segregation. Hence, it reduces the risk of honey combing of concrete.

Development of SCC is a very desirable achievement in the construction industry for overcoming the problems associated with cast-in place concrete. It is not affected by the skill of workers, shape and amount of reinforcing bar arrangement of a structure. Due to its high fluidity and resisting power to segregation, The use of SCC not only shortens the construction period but also ensures quality and durability of concrete. It replaces manual compaction of fresh concrete with a modern semi-automatic placing technology.

The utilization of recycled concrete aggregate in Self-Compacting Concrete (SCC) has the potential to reduce both the environmental impact and financial cost associated with this increasingly popular concrete type. The combination of the fibers, RAC, and SCC may create advantages for the construction industry.

1. LITERATURE REVIEW

S.C. Kou, et al, studied the fresh and hardened properties of SCC using RCA as both fine and coarse aggregate states. For investigation prepared with 100% recycled coarse aggregates Three SCC mixes and different levels of recycled fine aggregates were used to replacement of river sand and natural Coarse aggregate. The cement content was kept constant for all SCC mixtures. W/B ratios of 0.35, 0.40 and 0.44 were used. The experimental results indicate that the properties of the SCCs with river sand and crushed fine recycled aggregates showed only slight differences. The feasibility of max. utilizing fine and coarse recycled aggregates with rejected fly ash and Class F fly ash for SCC.

Grdic, et al, studied on the potential usage of RCA obtained from crushed concrete for production of SCC, and additionally emphasizing its ecological value. They concluded that RCA showed high water absorption compared with conventional Natural Aggregates due to old mortar attached with previous concrete and has relatively lower specific gravity.

Venkataram Pai et al, have experimentally aimed at producing SCC mixes of M25 grade by using the Modified Nan Su method, incorporating five mineral admixtures. They have concluded that in the modified Nan Su method of developing SCC, the quantity of the powder mainly depends on the specific gravity and consistency of the powder itself. The SCC mix containing GGBS exhibiting greater strength could be because of the high pozzolonic activity of GGBS.

Debashis Das, V.K Gupta et al. have carried out experimental investigation on production of self-compaction concrete (SCC) using Micro-silica and flyash from Dadari, Thermal Power Plant, Delhi. Vengala et al. [9] developed SCC using flyash from Silchar, Thermal Power Station, Karnataka. Naveen Kumar et al. [10] developed SCC using blend of flyash and metakaolin. Praveen Kumar et al. [11]used stone crusher dust partially replacing aggregates to obtain SCC.

Jose A., Albert De La Fuente et al., in this paper six different mixes where produced in two different conditions- In concrete plant in order to verify the adaptability of the existing equipment to produce and pour this material under real boundary conditions. In laboratory-controlled conditions, a physical and chemical characterization including 1100 specimens was carried out. The conclusion was, if the aggregates are properly pre-saturated, these do not alter the consistency of fresh concrete, and a more fluid consistency can even be achieved if recycled aggregates are introduced in the saturated state with dry surface.

3. MATERIALS

3.1General

Widespread applications of fiber-reinforced self-compacting concrete have been restricted due to lack of standard mix design procedure and testing methods. It is pertinent to mention that only features of fiber-reinforced self-compacting concrete have been included in Indian Standard Code of practice for plain and reinforced concrete fourth revision, year of 2000. Slump flow test, L-box test, V-funnel test, U-box test, Orimet test & GTM Screen test are recommended by EFNARC [European Federation of Producers and Applicators of Specialist Products for Structures, May 2005] for determining the properties of fiber-reinforced self-compacting concrete in fresh state.

carbon fibers. Full details of the specimen's configuration are shown in Table 3.1.

SI.No	Specimen Designation	Mix Name
1	NA, PP, CF,0.1,0.4	Mix-1
2	NA, PP, CF,0.15,0.6	Mix-2
3	NA, PP, CF,0.2,0.8	Mix-3
4	NA, PP, CF,0.25,0.1	Mix-4
5	RCA, PP, CF,0.1,0.4	Mix-5
6	RCA, PP, CF,0.15,0.6	Mix-6
7	RCA, PP, CF,0.2,0.8	Mix-7
8	RCA, PP, CF,0.25,0.1	Mix-8
Note: NA -Normal Aggregate, RCA -Recycled Aggregate		

Table 3.1.Specimen's Configuration

3.2 Objective

To identify the three key properties of fiber-reinforced self-compacting concrete i.e. filling ability, passing ability and segregation resistance.

To determine the workability of fiber-reinforced self-compacting concrete using Slump Cone Test, U Tube Test, L Box Test and V Funnel Test.

To study the Strength and behavior of using different type of aggregate with fiber-reinforced self-compacting concrete.

3.3 Scope

To determine the workability of fiber-reinforced self-compacting concrete using slump come test, U-tube test, L-box test, V-funnel test.

To study the strength characters of fiber-reinforced self-compacting concrete like compressive strength and split tension strength and flexural strength.

To study the strength and behavior of fiber-reinforced self-compacting concrete while using normal aggregate and recycled aggregate.

To study the mix proportion for fiber-reinforced self-compacting concrete material with steel fibers using standard codes of practice.

3.4Materials

The materials used in the experimental investigation are locally available cement, sand, coarse aggregate, Recycled aggregate, mineral and chemical admixtures. The chemicals used in the present investigation are of commercial grade.

3.4.1 Cement

Ordinary Portland cement of 53 grade [IS: 12269-1987, Specifications for 53 Grade Ordinary Portland cement] has been used in the study. It was procured from a single source and stored as per IS: 4032 – 1977. Care has been taken to ensure that the cement of same company and same grade is used throughout the investigation. The cement thus procured was tested for physical properties in accordance with the IS: 12269 – 1987.

3.4.2Fine Aggregates

The fine aggregate used was locally available river sand without any organic impurities and conforming to IS: 383 – 1970 [Methods of physical tests for hydraulic cement]. The fine aggregate was tested for its physical requirements such as gradation, fineness modulus, specific gravity and bulk density in accordance with IS: 2386 – 1963 [Methods of test for aggregate for concrete] and is shown in Table 3.3. The sand was surface dried before use.

Fig2. Fine Aggregate

3.4.3 Coarse Aggregate

The coarse aggregate chosen for fiber-reinforced self-compacting concrete was typically round in shape, well graded and smaller in maximum size than that used for conventional concrete. The size of coarse aggregate used in self compacting concrete was between 10mm to 16mm. The rounded and smaller aggregate particles provide better flowability and deformability of concrete and also prevent segregation. Graded aggregate is also important particularly to cast concrete in highly congested reinforcement or formwork having small dimensions. Recycled aggregate of sizes 16 mm to 10 mm graded obtained from the locally available demolished building waste was used in the present investigation. Recycled aggregate acquired from crushed concrete waste is normally different from Normal aggregate since the original aggregate particles are surrounded by old cement mortar. The presence of the adhered cement mortar makes Recycled aggregate to yield different physical and mechanical properties than the Normal aggregate. The performance of Recycled aggregate is also varying depending on the quality of the concrete waste in which they are produced from. These were tested as per IS 383-1970 [Methods of physical tests for hydraulic cement]. The physical properties like specific gravity, bulk density, flakiness index, and elongation index and fineness modulus

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Fig3. Coarse Aggregate

3.4.4 Water

Water used for mixing and curing was potable water, which was free from any amounts of oils, acids, alkalis, sugar, salts and organic materials or other substances that may be deleterious to concrete or steel confirming to IS : 3025 – 1964 part22, part 23 and IS : 456 – 2000 [Code of practice for plain and reinforced concrete]. The pH value should not be less than 6. The solids present were within the permissible limits as per clause 5.4 of IS: 456 – 2000.

3.4.5 Fly Ash

Fly ash is one of the most extensively used supplementary cementitious materials in the construction field resembling Portland cement. It is an inorganic, noncombustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace. Most of the fly ash particles are solid spheres and some particles, called cenospheres, are hollow and some are the plerospheres, which are spheres containing smaller spheres inside. The particle sizes in fly ash vary from less than 1 µm to more than 100 µm with the typical particle size measuring less than 20 µm. Their surface area is typically 300 to 500 m2/kg, although some fly ashes can have surface areas as low as 200 m2/kg and as high as 700 m2/kg. Fly ash is primarily silicate glass containing silica, alumina, iron and calcium. The relative density or specific gravity of fly ash generally ranges between 1.9 and 2.8 and the color is generally grey.

Super Plasticizer

High range water reducing admixture called as super plasticizers are used for improving the flow or workability for lower water-cement ratios without sacrifice in the compressive strength. These admixtures when they disperse in cement agglomerates significantly decrease the viscosity of the paste by forming a thin film around the cement particles. In the present work, water-reducing admixture Glenium conforming to IS 9103: 1999 [Specification for admixtures for concrete], ASTM C – 494 [Standard Specification for Chemical Admixturesfor Concrete] types F, G and BS 5075 part.3 [British Standards Institution] was used. The details of the super plasticizer

Viscosity Modifying Agent

These admixtures enhance the viscosity of water and eliminate the bleeding and segregation phenomena in the fresh concrete as much as possible. VMA is a neutral, biodegradable, liquid chemical additive designed to reduce the bleeding, segregation, shrinkage and cracking that occur in high water/cement ratio concrete mixes. VMA also contribute to stabilization for fiber-reinforced self-compacting concrete mixes that are susceptible to segregation at high slump ranges. The VMA used in this investigation was Glenium stream-2 which is a product of BASF construction chemicals.

Polypropylene fiber

The properties of the Polypropylene fiber used

Fig 3.1 Polypropylene fiber

Carbon Fiber

The properties of the carbon fiber used

Fig 3.2 Carbon fiber

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3.7.3Test Methods

It was observed that none of the test methods for fiber-reinforced self-compacting concrete has yet been standardized, and neither the tests described are yet perfected or definitive. A brief description of the tests has been presented below. They are mainly ad-hoc methods, which have been devised specifically for fiber-reinforced self-compacting concrete.

3.7.3.1 Slump flow test and T_{50} cm test

The slump flow is used to assess the horizontal free flow of fiber-reinforced self-compacting concrete in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete. The diameter of the concrete circle is a measure of the filling ability of concrete.

Slump Flow is definitely one of the most commonly used fiber-reinforced self-compacting concrete tests at present. This test involves the use of slump cone with conventional concretes as described in ASTM C 143 [Standard Test Method for Slump of Hydraulic-Cement Concrete]. The main difference between Slump Flow Test and ASTM C 143 [Standard Test Method for Slump of Hydraulic-Cement Concrete] is that the Slump Flow Test measures the spread or flow of concrete sample, once the cone is lifted rather than the traditional slump (drop in height) of the concrete sample. The T50 test is also determined during the Slump Flow Test. It is simply the amount of time that the concrete takes to flow to a diameter of 50 centimeters. The slump flow test procedure is as shown in Fig.3.3.

Fig. 3.3 Slump flow test

a. Slump flow apparatus

The mould used is in the shape of a truncated cone with internal dimensions 200mm diameter at the base, 100mm diameter at the top and a height of 300mm. The base plate is of a stiff non- absorbing material of at least 700mm square, marked with center location for the slump cone, and further concentric circle of 500mm diameter. The other apparatus required are trowel, scoop, ruler, and a stopwatch.

b. Procedure

About 6 liter of concrete is needed to perform the test. The base plate and the inside of the slump cone were moistened. The base plate was placed on level stable ground and the slump cone was placed centrally on the base plate and hold down firmly. The concrete was filled into the cone with the scoop without tamping. The excess material on the top of slump cone was removed and leveled with a trowel. The surplus concrete around the base of the cone was removed. The slump cone was raised vertically upwards allowing the concrete to flow out freely. The time taken for concrete to reach the 500 mm spread circle was recorded by using the stopwatch. This is the T50 time. After the flow of concrete was stopped, the final diameter of concrete in two perpendicular directions was measured. The average of the two measured diameters is called as slump flow in mm.

3.7.3.2 L – Box test

This test, based on a Japanese design for underwater concrete, has been described by Petersson, 1999. This test assesses the flow of concrete, and also the extent to which it is subjected to blocking by reinforcement. The apparatus is shown in Fig.3.4.

Fig.3.4 L – Box test apparatus

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 bars are fitted. The vertical section is filled with concrete, and then the gate is 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 called as H2/H1 ratio or blocking ratio. It indicates the slope of the concrete when the concrete is at rest. This is an indication of 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 time taken to reach these points measured. These are known as the T20 and T40 times and are indicators of the filling ability.

a. Procedure

About 14 liters of concrete is needed to perform the test. The apparatus was placed on the level ground. It was ensured that the sliding gate can open and close freely. The inside surfaces of the apparatus were moistened, and surplus water was removed. The vertical section of the apparatus was filled with the concrete sample. The sliding gate of the vertical section was lifted and concrete has allowed flowing out into the horizontal section. The time taken for concrete to reach the 200- and 400-mm marks in the horizontal section was measured simultaneously by using the stopwatch. The distances H1 and H2 were measured when the concrete stops flowing and the blocking ratio H2/H1 is calculated. The maximum time required for performing this L – box test is 5 minutes.

3.7.3.3 V- funnel test and V-funnel test at T_5 minutes

This test was developed in Japan and used by Ozawa et al, the equipment consists of a V-shaped funnel, shown in Fig.3.5. The V-funnel test is used to determine the filling ability of the concrete with a maximum aggregate size of 20mm. The funnel was filled with about 12 liter of concrete and the time taken for it to flow through the apparatus measured. After this the funnel was refilled concrete and left for 5 minutes to settle. If the concrete shows segregation, then the flow time increases significantly.

Fig.3.5 V – funnel test apparatus

a. Procedure for flow time

About 12 liters of concrete was needed to perform this test. The V-funnel apparatus was placed on the firm ground. The inside surfaces of the V – funnel was moistened and the surplus water in funnel was drained through trap door by opening it. Before starting the test, the trap door was closed and a bucket was placed underneath. The V – funnel apparatus was completely filled with concrete without any compaction. The top surface was leveled with the trowel. The trap door was opened and concrete was allowed to flow out under gravity. By using the stopwatch, the time taken for the complete discharge of concrete from the funnel was measured. The whole test has to be performed within 5 minutes.

b. Procedure for flow time at T_5 minutes

After measuring the flow time, the trap door of the V-funnel was closed, and a bucket was placed underneath. Again, the concrete was filled into the apparatus completely without any compaction. The top surface was leveled with the trowel. The trap door was opened after 5 minutes and the concrete was allowed to flow out under gravity. The time for the complete discharge of concrete from the funnel was recovered.

3.7.3.4 J – Ring test

The J – Ring test 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. 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 test. These combinations judge the flowing ability and the passing ability of the concrete. The slump flow spread was measured to assess flow characteristics. The J – Ring bars can 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 J – Ring is measured. This is an indication of passing ability, or the degree to which the passage of concrete through the bars is restricted.

a. Equipment

The mould used is 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. The base plate is of a stiff non- absorbing material, at least 700mm square, marked with center location for the slump cone, and further concentric circle of 500mm diameter. A rectangular section (30mm x 25mm) open steel ring, drilled vertically with holes is called as J - ring. The holes can be screwed threaded sections of reinforcement bar. The other apparatus required are trowel, scoop, ruler, and a stopwatch.

b. Procedure

About 6 liters of concrete is needed to perform this test. Moisten the base plate and inside of slump cone, place the baseplate on level stable ground. The slump cone was placed on the level ground and the J – ring was placed centrally inside the slump cone and was held down firmly. The concrete was filled into the cone with the scoop without any compaction. The top surface of the cone was leveled with the trowel. The surplus concrete around the base of the cone was removed. The slump cone is raised vertically upwards to allow the concrete to flow out freely through the rings. The difference in height between the concrete just inside the bars and that just outside the bars was measured. The average of the difference in height at four locations (in mm) was measured.

3.7.3.5 U – Box test

This test was developed by the Technology Research Centre of the Taisei Corporation in Japan. This test is also called as box-shaped test. It 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.3.6. An opening with a sliding gate was fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with center-to-center spacings of 50 mm. This creates a clear spacing of 35 mm between the bars. The left-hand section was filled with about 20 liters of concrete. The gate was lifted and the concrete flows upwards in the other section. The height of the concrete in both sections is measured.

Fig.3.6 U – Box apparatus

3.8 Size of test specimen used

The Self Compacting Concrete mixes, after having checked for the satisfaction of the fresh properties of self-compacting specifications as per EFNARC [2002] was cast into cube moulds of size 150 mm x 150 mm, beam moulds of size 100mm x 100mm x 500 mm and cylindrical moulds of 300 mm height x 150mm diameter. The moulds were fabricated with steel sheets. It is easy for assembling and removing the mould specimen without damage. Moulds were provided with base plates, having smooth surface to support. The mould is filled without leakage. Care was taken to ensure that there were no leakages.

3.9 Curing of test specimens

After 24 hours of casting, the specimens were removed from the moulds and immediately dipped in clean fresh water. The specimens were cured for 3 days, 7 days and 28 days respectively depending on the requirement of age of curing. The freshwater tanks used for the curing of the specimens were emptied and cleaned once in every fifteen days and were filled once again. All the specimens under immersion were always kept well under water and it was seen that at least about 15 cm of water was above the top of the specimens as shown in Fig.3.7.

Fig.3.7 Specimen Casting

3.10 Tests on hardened concrete

Testing of hardened concrete plays an important role in controlling and confirming the quality of self-compacting concrete.

3.10.1 Compressive Strength

Compressive strength of a material is defined as the value of uniaxial compressive stress reached when the material fails completely. In this investigation, the cube specimens of size 150 mm x 150 mm x 150 mm are tested in accordance with IS: 516 – 1969 [Method of test for strength of concrete]. The testing was done on a compression testing machine of 300 tons capacity. The machine has the facility to control the rate of loading with a control valve. The machine has been calibrated to the required standards. The plates are cleaned; oil level was checked and kept ready in all respects for testing.

After 28 days of curing, cube specimens were removed from the curing tank and cleaned to wipe off the surface water. The specimens were transferred on to the swiveling head of the machine such that the load was applied centrally. The smooth surfaces of the specimen are placed on the bearing surfaces. The top plate was brought in contact with the specimen by rotating the handle. The oil pressure valve was closed and the machine was switched on. A uniform rate of loading 140 kg/cm^2/min was maintained. The maximum load to failure at which the specimen breaks and the pointer starts moving back was noted. The test was repeated for the three specimens and the average value was taken as the mean strength. The test set up is shown in Fig.3.8.

Fig.3.8 Compressive strength test setup

In the present investigation, the compressive strength test has been conducted on concretes with different type of coarse aggregate. M 30 grade of fiber-reinforced self-compacting concrete at 7, 21 and 28 day were tested.

EXPERIMENTAL RESULTS

5.1 General

In chapter – 3, a detailed experimental investigation covering the various mechanical properties viz. compressive strength, split tensile strength and flexural strength have been studied. The present chapter highlights the results obtained from the above experimental investigation

5.2 Fresh properties of fiber-reinforced self-compacting concrete

The details of the fresh properties are shown in Table 4.1, M30 grade of concrete.

S. No	Specimen Designation	Slump Flow value	T_{50}	V-Funnel	V-Funnel at T5 Minutes	L-Box H_2/H_1 (blocking ratio)
1.	Mix-1	720 mm	5 Sec	9 Sec	12 Sec	1.00
2.	Mix-2	725 mm	5 Sec	6 Sec	8 Sec	1.00
3.	Mix-3	735 mm	5 Sec	7 Sec	9 Sec	1.00
4.	Mix-4	740 mm	5 Sec	9 Sec	11 Sec	1.00
5.	Mix-5	765 mm	5 Sec	8 Sec	13 Sec	1.00
6.	Mix-6	770 mm	5 Sec	7 Sec	11 Sec	1.00
7.	Mix-7	775 mm	5 Sec	8 Sec	12 Sec	1.00
8.	Mix-8	780 mm	5 Sec	6 Sec	9 Sec	1.00

Table 5.1 Fresh properties of fiber-reinforced self-compacting concrete

5.3. Mechanical properties of fiber-reinforced self-compacting concrete with different type of aggregate

5.3.1 Compressive strength

The results of the mechanical properties obtained based on the specimens tested as per Indian standard test procedures (as per IS: 516) are discussed. M30 grade of concrete, casted Normal aggregate and Recycled aggregate with their three different ages of curing are the variables of investigation. The details of the compressive strengths of M30 grade are shown in Table 4.2.

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Mix Type	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
Mix-1	26.00	36.40	41.86
Mix-2	26.65	37.31	42.91
Mix-3	27.30	38.22	43.95
Mix-4	27.95	39.13	45.00
Mix-5	23.40	32.76	37.67
Mix-6	23.99	33.58	38.62
Mix-7	24.57	34.40	39.56
Mix-8	25.16	35.22	40.50

Table: 5.2 Compressive strength of M 30 grade FRSCC

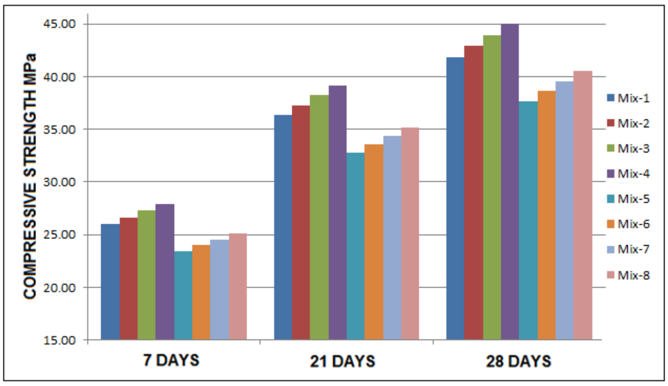

Fig 5.1. Compressive strength of concrete mixes at 7,21&28 days

From the figure it is observed that rate of gain in Compressive strength is more at 28 days compared to 21 days.

From the below figure it is observed that rate of increment in compressive strength of the natural aggregate mix is higher percentage at age of 7,21&28 days respectively compared to Recycled aggregate mixes.

From the graph it is clear that there is an improvement in compressive strength of the Mix - 4 is higher at age of 7,21 &28 days respectively compared to all other mixes.

The highest compressive strength was achieved by Mix-4 (Table 4.2) with natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers, which was found about 45 N/mm^2 compared with other mix.

The compressive strength for natural aggregate addition of 0.25% of polypropylene and 0.1% carbon fibers the load carrying capacity is increased to 11.1% compared with the recycled aggregate specimen.

The results indicated that the compressive strengths of concrete made with natural aggregate specimen are higher than the recycled aggregate concrete specimen.

5.3.2 Split tensile strength

The splitting tensile strength are presented in Fig. 5.2. For each mix three cylinders were tested for split tensile strength. The results from the tensile test are presented in Table 4.3.

Mix Type	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
Mix-1	3.65	5.11	5.88
Mix-2	3.85	5.39	6.20
Mix-3	4.05	5.67	6.52
Mix-4	4.20	5.88	6.76
Mix-5	3.10	4.34	5.00
Mix-6	3.27	4.58	5.27
Mix-7	3.44	4.82	5.54
Mix-8	3.57	5.00	5.75

Table: 5.3 splitting tensile strength of M 30 grade FRSCC

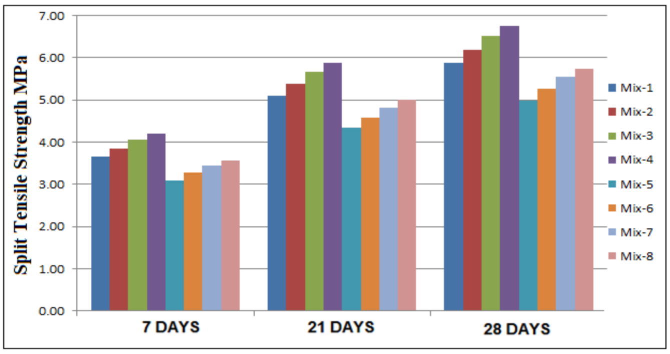

Fig 5.2 Splitting tensile strength of concrete mixes at 7,21&28 days

From the figure it is observed that rate of gain in splitting tensile strength is more at 28 days compared to 21 days.

From the below figure it is observed that rate of increment in splitting tensile strength of the natural aggregate mix is higher percentage at age of 7,21&28 days respectively compared to Recycled aggregate mixes.

From the graph it is clear that there is an improvement in splitting tensile strength of the Mix - 4 is higher at age of 7,21 &28 days respectively compared to all other mixes.

The highest splitting tensile strength was achieved by Mix-4 (Table 4.3) with natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers, which was found about 6.76 N/mm^2 compared with other mix.

The splitting tensile strength for natural aggregate addition of 0.25% of polypropylene and 0.1% carbon fibers the load carrying capacity is increased to 17.65% compared with the recycled aggregate specimen.

The results indicated that the splitting tensile strengths of concrete made with natural aggregate specimen are higher than the recycled aggregate concrete specimen.

5.3.3 Flexural strength

The Flexural strength are presented in Fig. 5.3. For each mix three cylinders were tested for split tensile strength. The results from the tensile test are presented in Table 4.4.

Mix Type	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
Mix-1	3.40	4.76	5.47
Mix-2	3.50	4.90	5.64
Mix-3	3.80	5.32	6.12
Mix-4	4.10	5.74	6.60
Mix-5	2.79	3.90	4.49
Mix-6	2.87	4.02	4.62
Mix-7	3.12	4.36	5.02
Mix-8	3.36	4.71	5.41

Table: 5.4 Flexural strength of M 30 grade FRSCC

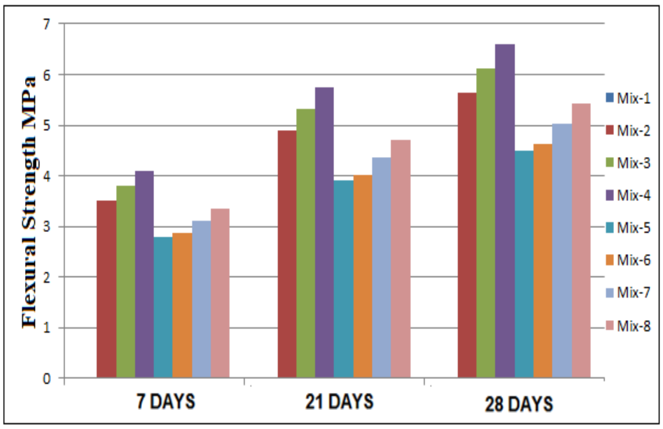

Fig 5.3Flexural strength of concrete mixes at 7,21&28 days

From the figure it is observed that rate of gain in Flexural strength is more at 28 days compared to 21 days.

From the below figure it is observed that rate of increment in Flexural strength of the natural aggregate mix is higher percentage at age of 7,21&28 days respectively compared to Recycled aggregate mixes.

From the graph it is clear that there is an improvement in Flexural strength of the Mix - 4 is higher at age of 7,21 &28 days respectively compared to all other mixes.

The highest Flexural strength was achieved by Mix-4 (Table 8.1) with natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers, which was found about 6.6 N/mm^2 compared with other mix.

The Flexural strength for natural aggregate addition of 0.25% of polypropylene and 0.1% carbon fibers the load carrying capacity is increased to 22% compared with the recycled aggregate specimen.

The results indicated that the Flexural strength of concrete made with natural aggregate specimen are higher than the recycled aggregate concrete specimen.

5.3.4 Summary

An overview of experimental results has been discussed brief in this chapter

CONCLUSIONS

The following conclusions could be made from the various experimental work conducted on the structural behavior of Normal aggregate and Recycled aggregate with various percentage of polypropylene and carbon fibers. Based on the experimental investigation carried out on Normal aggregate with various percentage of polypropylene and carbon fibers the following conclusions are arrived,

On experimentation it was found that natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers gave most promising results (i.e.) better compressive strength was observed on comparison with the all recycled aggregate specimen.

The compressive strength for natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers the load carrying capacity is increased to 11.1% compared with the recycled aggregate specimen.

The results of the splitting tensile strength tests show that, there is a increase in strength by increasing fiber with natural aggregate mix. it was found that highest splitting tensile strength was achieved by Mix-4 with natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers, which was found about 6.76 N/mm^2 compared with other mix. The load carrying capacity is increased to 17.65% compared with the recycled aggregate specimen.

Based on the experimental test result there is an improvement in Flexural strength of the Mix - 4 is higher at age of 7,21 &28 days respectively compared to all other mixes.

The Flexural strength for natural aggregate addition of 0.25%of polypropylene and 0.1% carbon fibers the load carrying capacity is increased to 22% compared with the recycled aggregate specimen.

There is a marginal decrease (<12%) in 7, 21and 28-day compressive strength, splitting tensile strength and flexural strength of fiber-reinforced self-compacting concrete with recycled aggregate compared to natural aggregate fiber-reinforced self-compacting concrete.

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