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BEHAVIOR OF CONCRETE BY PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH RECYCLED PLASTIC GRANULES.

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Abstract: Concrete is the most widely utilized "manmade" material globally for construction in many developing countries in all types of civil engineering works. Also, concrete is an environmental - friendly material and in areas of growing environment – related awareness that is of prime importance. Many of investigations were attempted by the researchers to improve the quality, strength and durability against adverse exposures, since decades. Portland cement concrete is considered to be a relatively brittle material. When subjected to tensile stresses, unreinforced concrete will crack and fail. Since the mid 1800's steel reinforcing has been used to overcome this problem. As a composite system, the reinforcing steel is assumed to carry all tensile loads.

When plastics are added to the concrete mix, it too can add to the tensile loading capacity of the composite system. In fact, research has shown that the ultimate strength of concrete can be increased by adding plastics reinforcing. In this research paper, an attempt is made to use recycled plastics only .The experimental investigation consisting of casting and testing of compression tests were conducted on 150x150x150mm cube and 150mmx300mm, cylindrical specimens using test method that gave the complete compressive strength, split tensile test using partial replacement of coarse aggregate using Recycled Plastic Granules of volume coarse aggregate fractions 0, 5, 10, 15, 20 and 25% of ordinary Portland cement concrete. Based on the results will find the superior crack resistance, improved tensile strength. The proposed sample will be tested at 7 days, 21 days and 28 days age of curing. These results will show whether the recycled plastic granules is suitable for proper confinement or not for structures subject to extreme load conditions such as seismic loading and impact loading.

Keywords: **Plastics Reinforced Concrete, Recycle Material, concrete test**

1. INTRODUCTION

Concrete is weak in tension. Microcracks begin to generate in the matrix of a structural element at about 10 to 15% of the ultimate load, propagating into macrocracks at 25 to 30% of the ultimate load. Consequently, plain concrete members cannot be expected to sustain large transverse loading without the addition of continuous bar reinforcing elements in the tensile zone of supported members such as beams or slabs. The developing microcracking and macrocracking, however, still cannot be arrested or slowed by the sole use of continuous reinforcement. The function of such reinforcement is to replace the function of the tensile zone of a section and assume the tension equilibrium force in the section. The addition of randomly spaced discontinuous fiber elements should aid in arresting the development or propagation of the microcracks that are known to generate at the early stages of loading history. Although fibers have been used to reinforce brittle materials such as concrete since time immemorial, newly developed fibers have been used extensively worldwide in the past three decades. Different types are commercially available, such as steel, glass, polypropylene, or graphite. They have proven that they can improve the mechanical properties of the concrete, both as a structure and a material, not as a replacement for continuous-bar reinforcement when it is needed but in addition to it. Concrete fiber composites are concrete elements made from a mixture comprised of hydraulic cements, fine and coarse aggregates, pozzolanic cementitious materials, admixtures commonly used with conventional concrete, and a dispersion of discontinuous, small fibers made from steel, glass, organic polymers, or graphite. The fibers could also be vegetable fibers such as sisal or jute. Generally, if the fibers are made from steel, the fiber length varies from 0.5 to 2.5 in. (12.7 to 63.5 mm). They can be round, produced by cutting or chopping wire, or they can be flat, typically having cross-sections 0.006 to 0.016 in. (0.15 to 0.41 mm) in thickness and 0.01 to 0.035 in. (0.25–0.90 mm) in width and produced by shearing sheets or flattening wire. The most common diameters of the round wires are in the range of 0.017 to 0.040 in. (0.45 to 1.0 mm) (ACI Committee 544, 1988, 1993, 1996).

2. LITERATURE REVIEW

Raghtate (2020), A. carried out the research work and studied the effect of using plastic in concrete on its properties namely compressive strength and split tensile strength. The study was carried out by adding varying percentages of pieces of polyethylene bags in 0.2%, 0.4%, 0.6%, 0.8% and 1%. Increase in the percentage of plastic impacted the compressive strength, but the rate of reduction of strength was found to be lowered. A reduction of 20% compressive strength with 1% plastic was observed. Furthermore, split tensile strength was found to be increased to a little extent, when plastic was added to the concrete. The researcher concluded that, increase in percentage of plastic in concrete improves its tensile strength but affects the compressive strength.

Mahesh M. et al (2019), carried out investigation on utilizing polyethylene plastic in the form of fibers in the concrete. The study was carried out with varying percentages of plastic fibers in the concrete as 2%, 4% and 6%. The concrete specimens were cured for 7, 14 and 28 days and tested for compressive strength and split tensile strength. The test results found that there was reduction in the compressive strength and split tensile strength of concrete as the percentage of plastic fibers increased, but the rate of reduction of strength was low. Reduction in the self-weight of concrete was observed. It has been concluded that using plastic fibers in concrete can cause 5%-10% effect on mechanical properties of the concrete.

Chien C. et al (2018), the research was based on the study of properties of concrete using HDPE plastic fine aggregate. In the workability test, results showed that increase in the percentage of HDPE plastic fine aggregate in concrete reduces its workability. The split tensile strength test and compressive strength test performed on cylindrical specimens of 100mm (diameter) x 200mm (height) and slab of 305mmX305mmX25mm found that beyond 10% replacement of fine aggregate with HDPE plastic aggregate, the workability reduced significantly but the compressive strength and heat absorption of the concrete improved.

Mathews P. et al (2018), the researchers carried out investigation of effects on the mechanical properties of concrete when natural coarse aggregate (NCA) was replaced with plastic coarse aggregate (PCA). The workability test results have shown that the workability of concrete with 20% PCA is higher than that of nominal concrete, due to absence of water absorption by the PCA. The concrete specimens with varying percentages of replacement of NCA with PCA tested for compressive strength found that a 22% percentage replacement of NCA with PCA gave significant improvement in the compressive strength of the concrete.

M. Sudhakar et.al (2014), carried out the experimental investigation to study the behaviour of ESFRC by varying the volume percentage content of steel fiber. Four rectangular reinforced concrete beams, with the steel fiber reinforced concrete in critical sections along with the stirrup confinement, have been tested. The findings of the investigation indicate that up to about 80 percent of ultimate strength, the behaviour of ESFRC beams was similar to that of beams with rectangular tie confinement. The effect of the steel fiber was felt prominently beyond the post ultimate stage. The ductility is increased due to increase in percentage of fiber content.

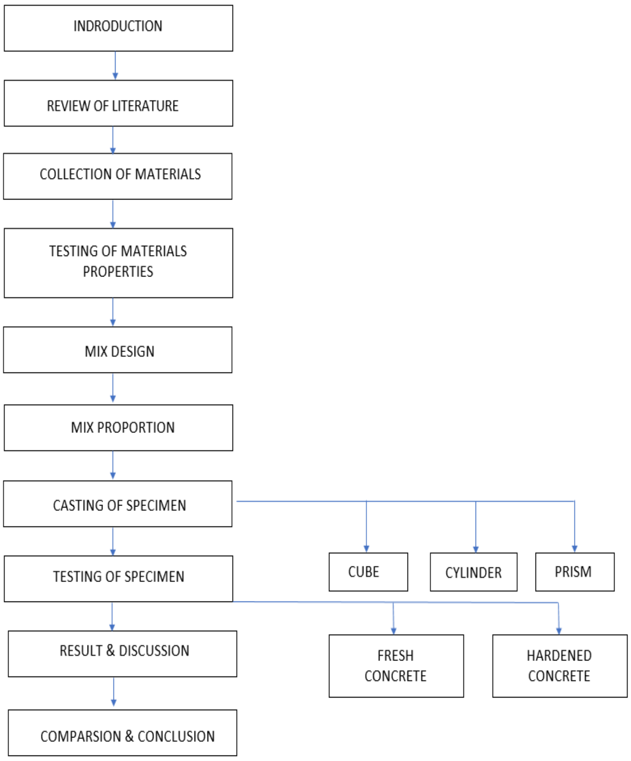
Job Thomas et.al (2007), carried out the experimental program and an analytical assessment of the

influence of addition of fibers on mechanical properties of concrete. Models derived based on the regression analysis of 60 test data for various mechanical properties of steel fiber-reinforced concrete have been presented. The various strength properties studied are cube and cylinder compressive strength, split tensile strength, modulus of rupture and post cracking performance, modulus of elasticity, Poisson's ratio, and strain corresponding to peak compressive stress. The variables considered are grade of concrete, namely, normal strength (35MPa), moderately high strength (65MPa), and high-strength concrete (85MPa), and the volume fraction of the fiber (Vf=0.0, 0.5, 1.0, and 1.5%). The strength of steel fiber-reinforced concrete predicted using the proposed models have been compared with the test data from the present study and with various other test data reported in the literature. The study indicates that the fiber matrix interaction contributes significantly to enhancement of mechanical properties caused by the introduction of fibers, which is at variance with both existing models and formulations based on the law of mixtures.

Vikas Srivastava (2018), investigated the effects of silica fume on fresh and hardened concrete. Materials used were Ordinary Portland cement and Silica fume. Tests conducted were workability, Compressive Strength, Tensile Strength, Bond Strength and Modulus of Elasticity. Based on the results obtained it was concluded that (i) Workability reduced with the addition of silica fume. However, workability improved in some cases. (ii) Compressive strength of concrete was significantly increased (6-57%) with inclusion of silicafume. The increase depended upon the replacement level. (iii) Flexural and tensile strength of silica fume concrete was almost like the referral concrete. (iv) Bond strength was improved with the addition of silica fume (v) Modulus of elasticity of silica fume concrete was almost like the referral concrete.

Naveen Prasad (2016), Crushed waste tiles and Granite powder were used as a replacement to the coarse aggregates and fine aggregate. The combustion of waste crushed tiles was replaced in place of coarse aggregates by 10%, 20%, 30% and 40% and Granite powder was replaced in place of fine aggregate by 10%, 20%, 30% and 40% without changing the mix design. M25 grade of concrete was designed to prepare the conventional mix. Without changing the mix design different types of mixes were prepared by replacing the coarse aggregates and fine aggregate at different percentages of crushed tiles and granite powder. Experimental investigation is carried out. The workability of concrete increased with increase in granite powder and it has been observed that the compressive strength is maximum at 30% of coarse aggregate replacement.

3. METHODOLOGY



4. MATERIALS USED

The concrete is a composite mass containing coarse aggregate, fine aggregate, water and cement. The strength and durability of concrete depends mainly on the materials used in it. The behavior of materials would be different based on its nature.

1. CEMENT

CEMENT OPC 53 Chettinad cement is used in this investigation. The quantity required for this work is assessed and the entire quantity is purchased and stored properly in the casting yard. The following tests are conducted in accordance with IS standards

To determine the fineness of cement, follow these steps:

- Take a sample of cement and ensure that it is free of lumps.
- Weigh 100g of cement and record it as W1.
- Pour the 100g of cement into a 90 µm sieve and cover it with the lid.
- Place the sieve in a sieve shaking machine, or shake it manually by agitating the sieve in both planetary and linear movements for 15 minutes.
- Weigh the residue retained on the 90 µm sieve and record it as W2.

Fig 3.1 Fineness Test

2. FINE AGGREGATE

Manufactured sand (M-Sand) is a substitute of river sand for concrete construction. M- Sand is produced from hard granite stone by crushing. Due to fast growing construction industry, the demand for sand has increased tremendously, causing deficiency of suitable river sand in most part of the word. Due to the depletion of good quality river sand for the use of construction, the use of M-Sand has been increased. M-Sand is used for availability and transportation cost. The properties of sand will affect the strength of concrete in great manner. The fine aggregates should not have high clay and silt content, since clay will affect the behavior of cement and reduces the strength of concrete. The fine aggregate should also be free from any organic contents. Fineness modulus of sand should be between 2.5 to 3.2.

Fig2. Fine Aggregate

3. COARSE AGGREGATE

Aggregates are the most mined materials in the world. Aggregates are a component of composite material such as concrete. The aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in drainage applications such as foundation and French drains, septic drain field, retaining wall drains and road side edge drains. Aggregates are also used as base material under foundations, roads and railroad. In other words aggregates are used as a stable foundation or road/rail base with predictable, uniform properties (e.g. to help prevent differential settling under the road or building). The coarse aggregate is collected from local area. The nominal coarse aggregate size is 20 mm. the texture of the aggregate will have significant effect on properties of concrete.

Fig3. Coarse Aggregate

3.4.3

Procedure for Specific Gravity Test of Coarse Aggregates:

- Take at least 2000 grams of aggregate from the sample and mix thoroughly. Wash the aggregate to remove any fine particles on the surface and allow it to drain for 5 minutes.
- Place the aggregate in a wire basket that is already submerged in water. Remove any entrapped air bubbles on the surface of the aggregates by lifting the wire basket approximately 25mm and dropping it. Repeat this operation 25 times within 25 seconds, at a rate of one drop per second.
- Leave the aggregates in water for 24 +/- 0.5 hours. After 24 hours, weigh the wire basket with the aggregate. (Weight a1)

Fig 3.2 Specific Gravity Test

Procedure for Determining the Fineness Modulus of Coarse Aggregates:

- Arrange the sieves in descending order and place them on a mechanical shaker. It is recommended to use a mechanical shaker for obtaining accurate values of fineness modulus for coarse aggregates as it has more number of sieves and can handle heavy-sized particles efficiently.

Fig 3.3 Sieves

Water Absorption Test Procedure:

Water absorption is defined as the increase in the mass of aggregate due to the penetration of water into the pores of the particles during a specific period. It is expressed as a percentage of the dry mass and excludes the water adhering to the surface of the particles.

Apparatus:

- Weighing Balance Wire mesh bucket (4000-7000 cm^3 capacity and not more than 6.3mm mesh) as sample container.
- Suitable arrangement for suspending the container in water from the center of the balance Container for filling water and suspending the wire mesh bucket Shallow Tray and Absorbent Cloth Oven Sample of Aggregate

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Procedure:

- Dry the sample to a constant weight at 100 ± 5°C.
- Cool the sample at room temperature for about 1-3 hours and immerse it in water at room temperature for 24± 4 hours.
- Remove the sample from water and wipe the particles using an absorbent cloth until all surface films are removed.
- Weigh the sample in this saturated surface dry condition to the nearest 0.5 g. Immediately after weighing, place the sample in a wire basket, suspend it in water at 23±1.7°C, and obtain the buoyant weight.
- Take care to remove all entrapped air before weighing by shaking the container while immersed.

Fig 3.7 Water Absorption Water

In the present investigation, portable water is used as per IS 10500 (2012).

Recyclable Plastics

Recyclable Plastics is an inorganic, noncombustible, finely divided residue collected. Most of the Recyclable Plastics 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 Recyclable Plastics vary from less than 4.5 mm to not more than 20 mm with the typical particle size measuring less than 20 mm. Their surface area is typically 300 to 500 m^2/kg, although some Recyclable Plastics can have surface areas as low as 200 m^2/kg and as high as 700 m^2/kg. Recyclable Plastics is primarily silicate glass containing silica, alumina, iron and calcium. The relative density or specific gravity of Recyclable Plastics generally ranges between 1.9 and 2.8.

Figure 3.10: Recyclable Plastics Granules

5.EXPERINMENTAL INVESTIGATION

5.1 INTRODUCTION

This chapter presents the details of experimental investigations carried out on the test specimens to study the strength characteristics of Plastics granules in different combinations. The experiment is conducted on test specimens to ascertain the strength related properties such as cube compressive strength, cylinder split tensile strength and prism flexural strength. Three specimens are tested, and the average is reported for each mix for each test. All the tests are conducted as per Indian standards. Based on the strength test results of cube and cylinders the optimum percentage is arrived. Then the concrete specimens are casted. After 7, 21&28 days curing, the specimens are tested for compressive, Tensile and flexural strength.

5.2 SIZE OF TEST SPECIMEN USED

The Concrete mix, after having checked for the satisfaction of the fresh properties 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.

5.3 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 7 days, 21days 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. Specimen casting as shown in Fig.5.1

Fig.5.1 Specimen Casting

5.4 TESTS ON HARDENED CONCRETE

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

5.4.1 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/cm2/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.5.2.

Fig.5.2 Compressive strength test setup

Fig.5.3 Schematic diagram for flexure test setup

In the present investigation, the compressive strength test has been conducted on concretes with different type of coarse aggregate. M25 grade of fiber-reinforced self-compacting concrete at 7, 21 and 28 day were tested.

5.4.2 FLEXURAL STRENGTH

Standard beam test (Modulus of rupture) was carried out on the beams of size 100 mm x 100 mm x 500 mm as per IS: 516 [Method of test for strength of concrete], by considering that material is homogeneous. The beams were tested on a span of 400 mm for 100 mm specimen by applying two equal loads placed at third points. To get these loads, a central point load has applied on a beam supported on steel rollers placed at third point as shown in Fig.6.4. The rate of loading is 1.8 kN/minute for 100 mm specimens and the load was increased until the beam failed.

Depending on the type of failure, appearance of fracture and fracture load, the flexural tensile strength of the sample was estimated.

As explained earlier, in the present investigation, the flexural strength test has been conducted on concretes with different type of coarse aggregate M25 grade of fiber-reinforced self-compacting concrete at 7,21 and 28 days.

If ‘a’ be the distance between the line of fracture and the nearer support, then for finding the modulus of rupture, these cases should be considered.

i) When a > 133 mm for 100 mm specimen
fcr = PL/bd2, where P = total load applied on the beam

ii. When 110 mm < a < 133 mm, fcr = 3Pa/bd2

iii. When a < 110 mm, the result should be discarded.

6. RESULT AND DISCUSSION

This chapter deals with the presentation of test result, and discussion on compressive strength, tensile strength and flexural strength development of partial replacement of coarse aggregate with Plastics granules reinforced concrete over ordinary concrete at different percentage and different curing period.

6.1 SLUMP CONE TEST RESULT

Specimen	Slump Result
Conv	100 mm
Mix-1	49 mm
Mix-2	100 mm
Mix-3	48 mm
Mix-4	44 mm
Mix-5	50 mm

Table 6.1 Slump Value

The workability of concrete on Conv, Mix-3, Mix-4 and Mix-5 was is lower since plastics granules has a low moisture absorption.

6.2 EXPERIMENTAL RESULTS:

6.2.1 COMPRESSIVE STRENGTH

Compressive strength of concrete is defined as the load, which causes the failure of a standard specimen. Divided by the area of cross-section in uniaxial compression under a given rate of loading. The test of compressive strength should be made on 150mm size cubes. Place the cube in the compression-testing machine. The green button is pressed to start the electric motor. When the load is applied gradually, the piston is lifted up along with the lower plate and thus the specimen application of the load should be 300 KN per minute and can be controlled by load rate control knob. Ultimate load is noted for each specimen. The release valve is operated and the piston is allowed to go down. The values are tabulated and calculations are done.

The results of the mechanical properties obtained based on the specimens tested as per Indian standard test procedures are discussed. M25 grade of concrete, casted using lightweight aggregate with their three different ages of curing are the variables of investigation. The details of the compressive strengths of M25 grade are shown in Table 6.5.

Mix	7 Days N/mm^2	21 Days N/mm^2	28 Days N/mm^2
Conv	22.25	26.41	32.14
Mix-1	23.21	30.11	37.14
Mix-2	23.91	30.91	37.09
Mix-3	24.85	32.01	39.98
Mix-4	23.10	28.14	35.77
Mix-5	22.29	27.64	32.27

Table 6.2:7, 21&28 days Compressive Strength

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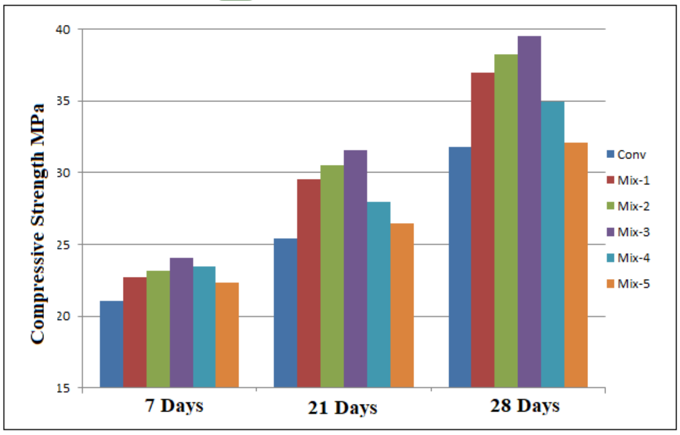

Fig 6.1. Compressive strength of concrete mixes at 7, 21&28 days

From the figure it is observed that rate of gain in Compressive strength is more at 28 days compared to 21 days.The results of Compressive Strength show that addition of Mix-3 influence the strength parameters. Also the replacement of Coarse aggregate up to 15% by weight of aggregate volume has increased the compressive strength.From the graph it is clear that there is an improvement in compressive strength of the Mix - 3 is higher at age of 7, 21 &28 days respectively compared to all other mixes.

Mix	7 Days N/mm2	21 Days N/mm2	28 Days N/mm2
Conv	3.24	3.41	4.31
Mix-1	3.39	3.52	4.42
Mix-2	3.61	3.76	4.54
Mix-3	3.91	3.99	4.79
Mix-4	4.41	4.62	5.23
Mix-5	4.5	4.99	5.52

Mix	7 Days N/mm2	21 Days N/mm2	28 Days N/mm2
Conv	3.24	3.41	4.31
Mix-1	3.39	3.52	4.42
Mix-2	3.61	3.76	4.54
Mix-3	3.91	3.99	4.79
Mix-4	4.41	4.62	5.23
Mix-5	4.5	4.99	5.52

Table 6.3:7, 21&28 days Split Tensile Strength

6.2.2 SPLIT TENSILE STRENGTH

A concrete cylinder of size 150mm dia×300mm height is subjected to the action of the compressive force along two opposite edges, by applying the force in this manner .The cylinder is subjected to compression near the loaded region and the length of the cylinder is subjected to uniform tensile stress. The splitting tensile strength are presented in Fig. 6.2. For each mix three cylinders were tested for split tensile strength. The results from the tensile test are presented in Table 6.9.

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

The results of Split Tensile Strength show that addition of Mix-5 influence the strength parameters. Also the replacement of Coarse aggregate up to 25% by weight of aggregate volume has increased the compressive strength.

From the graph it is clear that there is an improvement in splitting tensile strength of the Mix - 5 is higher at age of 7,21 &28 days respectively compared to all other mixes.

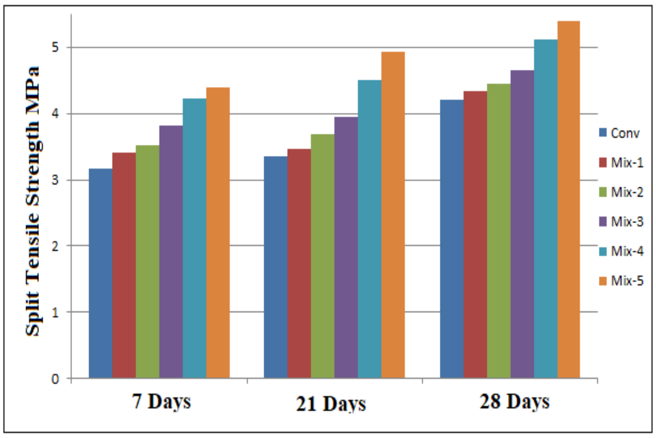

Figure 6.2.: 7, 21&28Day Split Tensile Strength

7. CONCLUSION

In the light of the preceding results and discussion, the following can be concluded: -

- The partial replacement of recycled plastic granules addition of Mix-3 influence the strength parameters. Also the replacement of Coarse aggregate up to 15% by weight of aggregate volume has increased the compressive strength.
- The increase in recycled plastic granules an increase in compressive strength to the normal mix. But in case of carbon showed a decrease to the normal mix.
- The results of Split Tensile Strength show that addition of Mix-5 influence the strength parameters. Also the replacement of Coarse aggregate up to 25% by weight of aggregate volume has increased the compressive strength.
- The results of Flexural Strength show that addition of Mix-5 influence the strength parameters. Also the replacement of

Coarse aggregate up to 25% by weight of aggregate volume has increased the compressive strength.

- Sulphate attack, the compressive strength reduces the most, up to 8.9%, at Mix-3. Following Mix-3, the compressive strength continues to decrease and reaches a low of 12.5% at Mix-4. As per the observations the weight of the specimen decreases the most, up to 11.25%, at Mix-2 after sulphate attack.
- After conducting the acid attack, it was observed that the compressive strength decreased the most, up to 9.11%, at Mix-1, and continued to decrease further, reaching 5.9% at Mix-3. Similarly, the weight of the specimen decreased the most, up to 7.55%, at Mix-2, and continued to decrease further, reaching 7.59% at Mix-4.
- The findings in chloride attack indicate that the compressive strength decreases the most, up to 11.5%, at Mix-3 after chloride attack. Subsequently, at Mix-5, it decreases further to a maximum of 12%. Similarly, that after chloride attack, the weight of the specimen decreases the most, up to 6.19%, at Mix-3. After Mix-3, the weight continues to decrease, reaching a minimum of 5.83% at Mix-1.
- That improve the tensile and cohesion of concrete.
- The recycled plastic granules concrete fails in more ductile mode opposite the plain concrete that shattering into pieces.
- This mix can be used advantageously over normal concrete pavement. Recycled plastic granules are being used due to their cost effective as well as corrosion resistance. Recycled plastic granules requires specific design considerations and construction procedures to obtain optimum performance.
- Resistance to change though however small disturbs our society, hence we are always reluctant to accept even the best. It's high time that we overcome the resistance and reach for the peaks. Recycled plastic granules opens a new hope to developing and globalizing the quality and reshaping the face of the "True Indian Structures".

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