Study on Crumb Rubber Concrete using GGBS & Nano- TiO_2

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Abstract: **Nowadays there is one of the major environmental challenges is to dispose waste rubber tyres. To sort with this concern several studies and tests are being carried out on the waste rubber tyres. The tests are done on the rubber granulates and crumb rubber in partial replacements or additions in the concrete. These waste rubber tyres acquire landfill spaces, so scientist and engineers are carrying out study on the use of crumb rubber in construction building materials. Cement Concrete in one of the main material in building construction which consists of cement, coarse aggregate, fine aggregate and water. The use of crumb rubber in partial replacement with fine aggregate in concrete can reduce the cost and enhance the performance of concrete. Ground granulated blast furnace slag (GGBS) is highly cementitious material high in calcium silicate hydrate which is strength enhancing compound which improves durability and appearance of concrete. Replacement of maximum 50% of concrete with GGBS provides high durability and strength of concrete. Nano- TiO_2, a nano material which in powder form used in the concrete for increasing the rate of hydration due to which the porosity in the concrete decreases and becomes more denser and durable. In this experimental approach Crumb rubber and GGBS is partial replaced with Fine Aggregate and Cement. Nano- TiO_2 is used for better performance of the concrete. Customized Concrete is studied with mechanical properties of concrete and Workability of concrete. The Partial Replacement are carried with replacement of Crumb Rubber (5%, 10%, 15%, 25%) with fine aggregates, GGBS (30%) and Fly-Ash (25%) with cement and TiO_2 as a additional to improve the quality of prepared concrete. The main aspect of this study is to waste management of rubber tyres and proper use of the same in improvement in quality of cement. This study concludes that the strength of concrete gradually increases after 28 days of curing under water with comparison to conventional concrete.**

Keywords- Fine aggregate, GGBSS, Crumb rubber, TiO_2, Mechanical Properties, Partial Replacement.

I. INTRODUCTION

Concrete is one of the most widely used construction today. More than 90% of the structures ranging from buildings, bridges, roads, dams, retaining walls etc. utilise the concrete for their construction. The versality and mould ability of this material, its high compressive strength and discovery of reinforcing and prestressing technique has gained its widespread use, strength, durability and workability may be considered as the main properties of concrete. In addition good concrete is able to resist wear and corrosion and it should be water- tight and economical. The Concrete must be strong enough to withstand without injury all the imposed stresses with required factor of safety. To develop a given strength longer time of moisture curing is required at lower temperature than is necessary while curing is done at higher temperature.

Crumb Rubber Concrete is the concrete made out of piece elastic tyre chips and scrap elastic where utilized to supplant mineral today in cement. The common use of waste rubber specifically tyre chips have been in highway asphalt mixes. Material characterization experiments have been conducted to determine the practicality of using rubber in Concrete. Research has shown that replacement of conventional aggregates with rubber results in a decrease in compressive strength and tensile strength and stiffness. Eldin and senouci (1993) performed tension and compression test on two types of cylinders, with potions of the coarse or fine aggregate replaced with rubber. They observed tensile strength decreases of 50% and compressive strength reduction of up to 85% however noted that the rubberized concrete absorbed a great amount of plastic energy.

Based on the published literature on crumb rubber concrete (CRC) it is apparent that the ductility and energy absorption is enhanced over that of the conventional concrete. These characteristics may prove beneficial for applications where dynamic blast pressure demands are a concern. Concrete can be made cheaper by replacing a fixed percentage of fine aggregate with crumb rubbers from rubber waste. These rubber crumbs can be achieved through the process called continuous shredding, which is done to create crumbs small enough to replace aggregates as fine as sand effectively. Such kind of concrete can be used in manufacturing process of reinforced pavement and bridge structures because this behaviour resistance to frost and ice thawing.
In Present scenario, the disposal of waste tyre rubber is a major concern in waste management throughout the world. It is estimated that around 1.2 billion of waste tyre rubber is produced per year around the world. It is also estimated that around 11% of tyres are exported post consumption and 27% are piled as landfill, stockpiled or dumped illegally and only 4% of it is utilized for civil engineering works. Hence, efforts have been made to identify the potential of this waste tyre rubber in civil engineering projects. Our present study aims to investigate in the same context i.e. the optimal use of crumb rubber as fine aggregate in concrete composite. With the increase in urbanization in countries like India the environmental threat. This study shows us an alternative way of recycling tyres by incorporating them into the concrete. The Concept that if problem emerges from urbanization and

the solution must go along with it should also be appreciated. Therefore, the aim of this study is to introduced an environmental friendly technology, which will benefit the society and the nation.

II. MATERIALS AND METHODS

A. Cement:

Cement used in this study is ordinary Portland cement obtained from local supplier and of 53 grade as per IS 11269 it has a specific gravity of 3.15 with fineness (IS:4031-PART 1-1996) is less than 5% and have good specific surface area of more than 600 m^2/ kg. The cement obtained is stored in airtight environment without moisture entry and formation of lumps is avoided.

B. Fine aggregate:

Fine aggregate used in this study is obtained from nearby source and its clean river sand adhering to the norms prescribed in IS:383 and it confirms to Zone-II with a specific gravity of 2.68 and free from any foreign particles. Sand obtained is stored in large containers without moisture entry and its managed as clean and dry to manage the water content in the mix design.

C. Coarse aggregate:

Coarse aggregate adopted in this work is obtained from nearby crusher unit which is derived from basalt rock and it is non flaky with clear edges. The aggregates are sieved on crusher end with nominal size of 20 mm as per IS 383 it adheres strictly to the protocols. The coarse aggregate has a specific gravity of 2.65 and abrasion value of less than 6% with good impact crushing strength of less than 3% which shows that it can be even used for highway pur- pose. The obtained material is stored in a concrete tank with shelter to avoid water entry and clean, dried aggregate only is used throughout the study.

D. Water:

The water used in the entire process is tap water and the density is taken as 1000 kg/m^3 and a pH of 6.2 with TDS of less than 500 ppm with clear and no color. The water is stored in plastic containers and closed with a cap to avoid dust or foreign particles entry before mixing with concrete.

According to IS: 2386 (Part I 1963) the fineness modulus range for medium sand the value is 2.6 to 2.9, Thus we can replace the fine aggregate with crumb rubber as medium sand. For casting of cubes, moulds of size (150X150X150) mm made of cast iron are used. These Cubes are used to obtain compressive strength. For casting beam moulds of (150X150X700) mm made of cast iron. These Beams specimens are used to obtain flexure strength of concrete.

E. Crumb Rubber:

Crumb Rubber is recycled rubber produced from automotive and truck scrap tyres. During the recycling process steel and tyre cord are removed, leaving the rubber with a granular consistency. Continued processing with a granulator or cracker mill, possibly with the aid of cryogenics or mechanical means, reduces the size of particles further. The particles are sized and classified based on the various criteria including color. The granulate is sized by passing through a screen, the size based on a dimension (1/4 inch) or mesh (holes per inch: 10 20).

When dealing with asphalt overlays, reflection cracks can arise and cause an unwanted cracks pattern beneath the pavement. Rubber modified asphalt uses the stress absorbing membranes that reduces the reflective cracking because of its elastic properties. With fewer cracks, there are fewer repairs, so crumb rubber assists in reducing maintenance costs. The pavement has an increased lifespan because after multiple uses and exposures to different elements, regular asphalts losses elasticity over time. The use of the artificial rubber resists the formation of cracks and has an anti-aging effect that keeps the asphalt in a better condition. The tyre crumbs are poured in between the artificial grass blades, giving the artificial fields more cushion and support.

Component	Content
Ash content	4.98
Acetone extract	10.59
Natural rubber content	25.79
Rubber hydrocarbon content	36.91
Carbon black content	21.193
Relative density	1.192

Table no. 1 Content of Crumb Rubber

F. Ground granulated blast furnace slag (GGBS):

Ground-granulated blast furnace slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. From structural point of view, GGBS replacement enhances lower heat of hydration, higher durability and higher resistance to sulphate and chloride attack when compared with normal ordinary concrete. On the other hand, it also contributes to environmental protection because it minimizes the use of cement during the production of concrete. The chemical compositions vary as per composition of raw material. It is use to make durable concrete structures in combination of OPC/PPC. Concrete with GGBS sets slowly than ordinary but simultaneously gains strength over long period. Replacement level vary from 30% up to 85%. Strength increases over the time.

Advantages of GGBS:

- It lowers heat of hydration
- Avoids cold joints.
- Better workability
- Reduce thermal cracking.
- Higher resistance to acid attack, reducing risk of corrosion
- Sustainable

G. Nano- Titanium dioxide (TiO_2):

Incorporation of Nano- Titanium dioxide in cement exhibits significant improvement in properties of cement composites. Increased research in the use of nano- titanium dioxide in

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construction industry is attributed to its nano size that accelerates hydration of cement, reduces setting time and enhances the mechanical properties. The dimensional stability if cement mix affected by excess addition of nano-titanium dioxide is mitigated by optimal selection of size of nano- titanium dioxide. The focus is on effect nano- titanium dioxide on heat of hydration, workability, setting time, mechanical strength, microstructure and permeability of cement blended mixes. About an optimum replacement percentage of around 2.0- 3.0% exhibits notable impacts in improving the quality of cement matrix.

Photocatalytic concrete is a formulation of concrete used as pavers and other structural concrete that includes titanium dioxide as an admixture or superficial layer. Titanium dioxide is a heterogenous photo catalyst that uses sunlight and moisture to absorb and renders oxides of nitrogen in to nitrates ions. Which are then either washed away by rain or soaked in to the concrete to form stable compounds.

Parameter	Value
Size	35 mm
Size Range	30- 50 mm
Chemical Composition	Titanium- 59.91% & Oxygen-40.06%
Density	4.22 gm/cm^3
Moral Mass	79.9373 gm/mol
Melting Point	1.841^{o}C
Boiling Point	2,969^{o}C

Table no. 2 Properties of TiO_2

H. Fly-ash:

Fly ash, also known as "pulverized fuel ash", is one of the residues generated by coal combustion, and is composed of the fine particles that are driven out of the boiler with the flue gases. fly ash includes substantial amounts of silico dioxide (SiO_2)
(both amorphous and crystalline), aluminium oxide (Al_2O_3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata . fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm. Two classes of fly ash are defined by Class F fly ash and Class C fly ash. The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the boiler is known as coal ash.

Advantages of Fly Ash:

- Reduction in heat of hydration and thus reduction of thermal cracks improves soundness of concrete mass.
- Improved workability of concrete.
- Converting released lime from hydration of OPC into additional binding material contributing additional strength to concrete mass.

III. MIXING, CASTING, CURING AND TESTING

Concrete is a composite material which is prepared using mixing of various admixtures and placing it properly in the prepared mould, curing it for the required period, it may be in laboratory or in field this process has impact on the concrete strength. In this research we had taken careful attempt in preparing the concrete, it is prepared in a levelled watertight steel platform which does not absorb the water added in the concrete. The surface is levelled and cleaned properly the mixing is done for this work in a cleaned tiltable concrete mixer (electric operated). Before casting of the specimen, the surface is cleaned, watered, the ingredients are measured in weight batching and kept ready near the mixer. Moulds are properly oiled and bolted to avoid cement and water escape, the vibration is done by using table vibrator for cube mould and electric operated need vibrator without segregation. Ingredients are mixed in the mixer machine using standard mixing protocols by placing aggregate first, then fine aggregate with adding half of required water, allowed to mix properly. Then cement is added in the mix with crumped rubber being added slowly and allowed to mix duly with the addition of remaining water required. Then the concrete is poured to steel buckets after which the flowability tests were conducted, then they are placed in the mould using standard placing procedures through which care is taken to avoid segregation and escape of water. The whole mixing and placing platform are free from direct sunlight and also moisture, the room temperature during mixing is 29°c. Once the concrete is placed in the mould and vibration is done properly the surface is leveled and the mould with concrete is covered with polythene sheets to avoid water escape. The setup is kept for 24 h for proper setting and ready for de-moulding, it is done after ensuring the setting of concrete. De-moulded specimens were kept in clear and adulterant free water which has a pH of 6.9 and no other material is present. keeping idle for 1h, surface cleaning is also done with cotton cloth.

The specimens are then painted with white cement to note the crack propagation and marked as per the specimen number. Testing is done in pre-calibrated testing equipment including compressive strength testing machine which is digitally controlled with 2000 KN capacity. The prepared specimens are tested as per Indian standard code provisions with the required loading pattern and timing of load applications. Flexure testing is done in an electrically operated Universal testing machine with 1000 KN capacity which contains strain controlling mechanism.

IV. RESULTS AND DISCUSSIONS

The cubes, cylinders and beam specimens were casted for M_{40} grade of concrete with 5%, 10%, 15% and 20% replacement of fine aggregate with crumb rubber by volume fraction, GGBS & Fly Ash to be replaced partially with cement with proportion of 30% & 25% respectively with inclusion of TiO_2 5%. Above specimens were tested to obtain the optimum replacement of crumb rubber with fine aggregate in the concrete for Compressive strength, Workability and Flexural strength.

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Combinations	
Conventional concrete	M40 Grade of Normal Concrete
Combination 1	GGBS 30% TiO2 5% Crumb Rubber 5%, 10%, 15%, 20%
Combination 2	Fly Ash 25% TiO2 5% Crumb Rubber 5%, 10%, 15%, 20%
Combination 3	Fly Ash 25% GGBS 30% TiO2 5% Crumb Rubber 5%, 10%, 15%, 20%

Table no. 3 Combinations of Testing Concrete

Materials	Partial replacement with
Crumb Rubber	Fine Aggregate
Ground Granulated Blast Furnace Slag (GGBS)	Cement
Fly Ash	Cement
Nano- Titanium Dioxide (TiO_2)	Cement

Table no. 4 Partial replacements

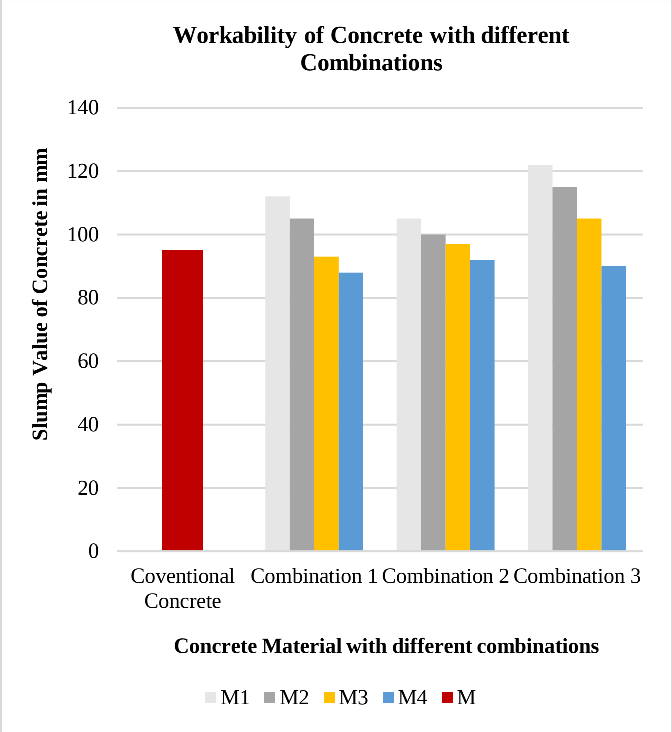
A. Workability of concrete:

Concrete slump test is to determine the workability or consistency of concrete mix prepared at the laboratory or the construction site during the progress of the work. Concrete slump test is carried out from batch to batch to check the uniform quality of concrete during construction. concrete slump value is used to find the workability, which indicates water-cement ratio, but there are various factors including properties of materials, mixing methods, dosage, admixtures etc. also affect the concrete slump value. Keeping water to cement ratio constant that is 0.3 for all combinations it is been observed that the workability of concrete for each combination increased by 16 % and further gradually decreased for all the combinations. The highest slump was found for the combination 3 was 122 mm with respect to conventional concrete 95 mm.

For each combination the fresh concrete is been prepared with constant M_{40} grade of concrete.

Concrete Material	Slump Value (mm)
Water-Cement Ratio- 0.35	
Conventional Concrete	95
Combination 1	
M1	112
M2	105
M3	93
M4	88
Combination 2	
M1	105
M2	100
M3	97
M4	92
Combination 3	
M1	122
M2	115
M3	105
M4	90

Table no. 5 Workability Test on Concrete

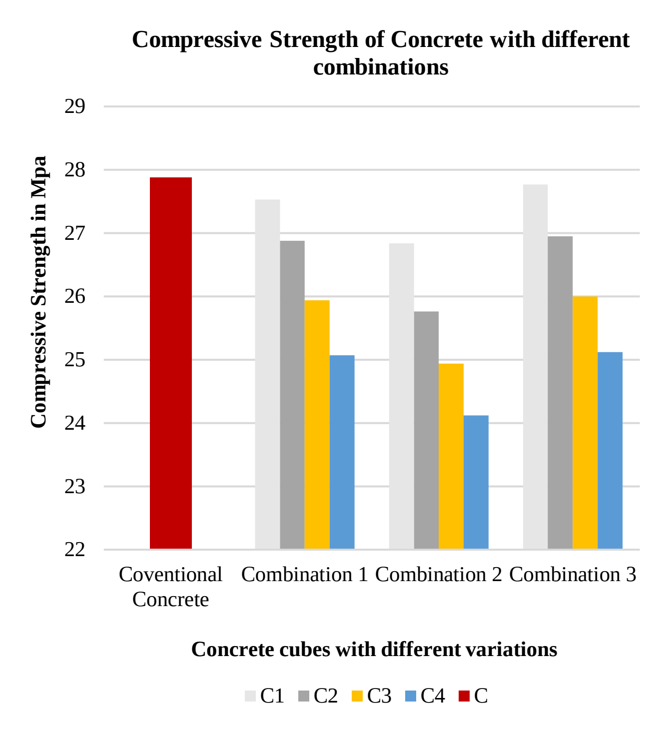


B. Compressive strength of concrete:

The compressive strength of concrete was observed on (150X150X150) mm cubes under the compression testing machine with constant loading. M_{40} grade of concrete was kept constant for each cube casted. Compressive strength is observed after the water curing period of 7 days and 28 days. It is been observed that the compressive strength for all the combinations was low with respect to the conventional concrete tested at the 7^{th} day of curing. It is been observed that the compressive strength was gradually decreasing with increase in replacement of crumb rubber with fine aggregate. The highest compressive strength was observed 27.77 Mpa with respect to conventional concrete 27.88 Mpa with loss of 0.4 % of strength at 7^{th} day of curing.

Concrete Specimen	Compressive Strength (N/mm^2)
Conventional Concrete	27.88
Combination 1	
C1	27.53
C2	26.88
C3	25.94
C4	25.07
Combination 2	
C1	26.84
C2	25.76
C3	24.98
C4	24.12
Combination 3	
C1	27.77
C2	26.95
C3	26
C4	25.12

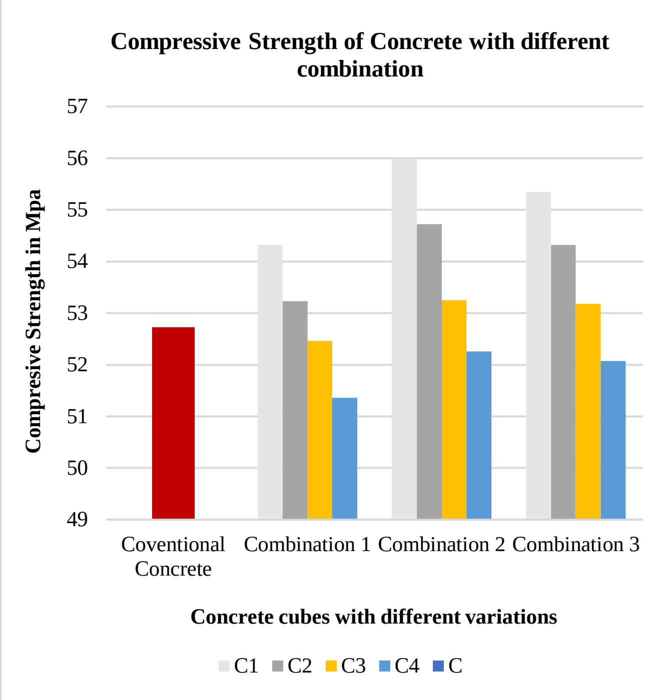
Table no. 6 Compressive Strength of Concrete (7 Days)



At 28th day of water curing it is been observed that the compressive strength of concrete specimen gradually increased compared with the conventional concrete. The compressive strength firstly increased and then gradually decreased with increase in addition of crumb rubber. The highest compressive strength was observed at 28th day of curing was 55.98 Mpa with respect to the conventional concrete 52.72 Mpa with increase in 5.9 % of Strength of concrete. It is also been observed that up to 10% to 15% of replacement of crumb rubber with fine aggregate is acceptable.

Concrete Specimen	Compressive Strength (N/mm^2)
Conventional Concrete	52.72
Combination 1	
C1	54.32
C2	53.23
C3	52.46
C4	51.36
Combination 2	
C1	55.98
C2	54.72
C3	53.25
C4	52.26
Combination 3	
C1	55.35
C2	54.32
C3	53.18
C4	52.07

Table no. 7 Compressive Strength of Concrete (28 Days)

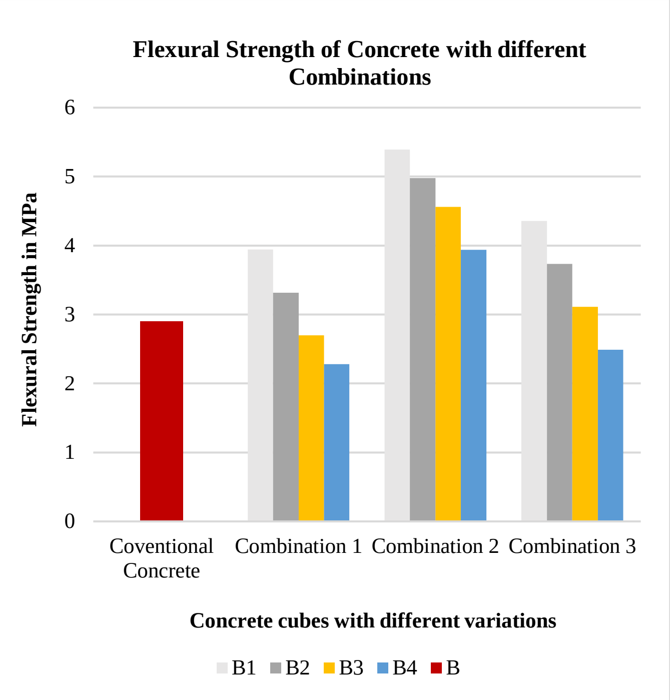


C. Flexural strength of concrete:

The compressive strength of concrete was observed on (150X150X700) mm beams under the universal testing machine with constant loading. M_{40} grade of concrete was kept constant for each cube casted. Flexural strength is observed after the water curing period of 7 days and 28 days. It is been observed that the Flexural strength for all the combinations was high with respect to the conventional concrete tested at the 7th day of curing. It is been observed that the flexural strength was gradually decreasing with increase in replacement of crumb rubber with fine aggregate. The highest flexural strength was observed 5.392 Mpa with respect to conventional concrete 2.903 Mpa with increase of 46.15 % of strength at 7th day of curing.

Concrete Specimen	Flexural Strength (N/mm^2)
Conventional Concrete	2.903
Combination 1	
B1	3.942
B2	3.318
B3	2.696
B4	2.281
Combination 2	
B1	3.942
B2	3.318
B3	2.696
B4	2.281
Combination 3	
B1	4.355
B2	3.733
B3	3.111
B4	2.488

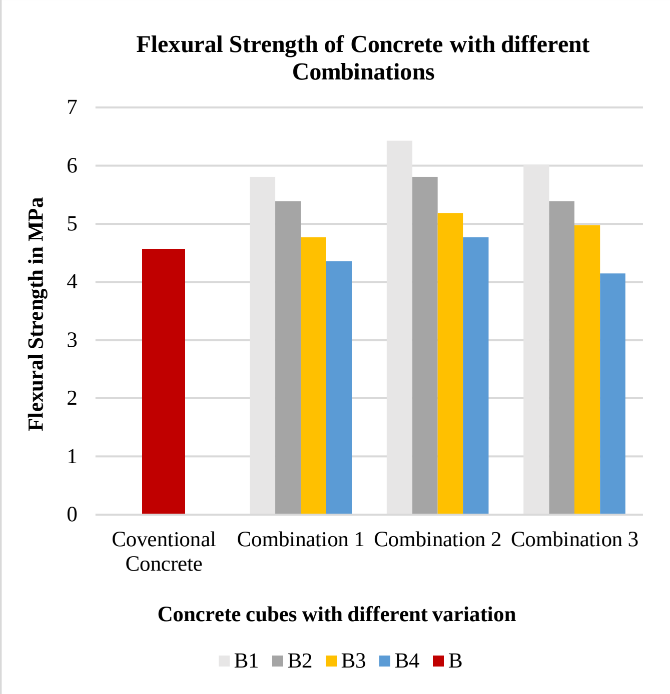
Table no. 8 Flexural Strength of Concrete (7 Days)



At 28th day of water curing it is been observed that the flexural strength of concrete specimen gradually increased compared with the conventional concrete. The flexural strength firstly increased and then gradually decreased with increase in addition of crumb rubber. The highest flexural strength was observed at 28th day of curing was 4.562 Mpa with respect to the conventional concrete 6.429 Mpa with increase in 29.01 % of Strength of concrete. It is also been observed that up to 10% to 15% of replacement of crumb rubber with fine aggregate is acceptable.

Concrete Specimen	Flexural Strength (N/mm^2)
Conventional Concrete	4.562
Combination 1	
B1	5.807
B2	5.392
B3	4.77
B4	4.355
Combination 2	
B1	6.429
B2	5.807
B3	5.185
B4	4.77
Combination 3	
B1	6.014
B2	5.3925
B3	4.977
B4	4.148

Table no. 9 Flexural Strength of Concrete (28 Days)



V. CONCLUSION

With the outcome of experimental results authors are highly confident that usage of crump rubber is viable considering the need of improvement in concrete focusing on specific criteria. With the results obtained via design of experiments we had added crump rubber from 5 to 20% with reference to the weight batching and conducted experiments in M_{40} grade concrete. Strength of concrete specimen was gradually increased first and with addition of crumb rubber the strength gradually decreased after one limit. The compressive strength was increased up to 6 % with addition of 10% to 15% of crumb rubber. The flexural strength was increased up to 46% with addition of 10% to 15% of crumb rubber and the after it started decreasing below 15%. It is concluded that 5% to 15% of crumb rubber is acceptable in concrete to avoid the waste tyre rubber in environment. With this its very evident that:

- Usage of crump rubber is prescribed but only at an optimal level above which the strength will start dropping,
- An optimal value of 20 percentage addition is suggested which will increase the strength values considerably.
- Effect of crump rubber on one type of strength (compressive/tensile/flexural) is not reciprocating in other strength which should be studied further.

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