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Experimental Investigation on Bead Rubber Cement Concrete (BRCC)

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Abstract: ***Due to huge production in automobile industry the country having huge disposal from rubber tyre as waste also increased and is directly disposes to the earth. The reason for selecting tyre rubber is having more elastic nature, durable, and having high ductile nature. To reduce the cost of construction – partially replace the coarse aggregate with ordinary tyre rubber and steel with tyre bead wire in concrete. The main aim of this project is to study the mechanical properties of rubberized (Rubber-Reinforced) concrete, which is partially replacement of coarse aggregate and tyre bead wire and compare with M_{20} ordinary mix. At the same time comparing on reducing steel reinforcement by adding bead rubber as reinforcement. At present, the cost of construction increases because of using regular /traditional materials in concrete. From these studies we can use waste materials like tyre rubber from auto mobiles, and silica fume from industry. Utilization of silica fume is to make concrete more durable, economical at usage and increase in strength parameters.***
The crumbled rubber percentage should be not more than 0.15 ratio of 20% replacement and Bead wire position should be placed in two layers, 2 strips at top and top strips at bottom. By increasing the percentage in silica fume the strength increases comparing to the rubber cubes, cylinders and in prims.
Keywords: Tyre rubber, Tyre bead wire, silica fume, Cement, Aggregates etc.

I. INTRODUCTION

A. Concrete

The word concrete is derived from the Latin word “concretes” (meaning compact and condensed), the perfect passive participle of “concessive”, from “con” (together) and “crescive” (to grow). Concrete is a mixed material which can be molded into desired shape. The relative quantities of cement, aggregates and mixed water control the concrete properties. Concrete contains an amount of entrapped air and may also contain the entrapped air.

B. Rubber Concrete

The main difference between normal concrete and rubber concrete is usage of rubber in concrete in addition to all the materials used in normal concrete.
The usage of rubber in concrete is done in two ways:

- Chipped rubber
- Crumbed rubber

II. MATERIALS

The materials used in the construction are

- Cement
- Fine aggregates or sand
- Coarse aggregates
- Water
- Rubber
- Bead wire
- Silica fume Cement

Cement is a binding material made by burning a mixture of calcareous, siliceous, and argillaceous materials in specific proportions at high temperatures. The resulting product, called clinker, is then ground into a fine powder. Even though cement makes up only about 10% of the volume in concrete, it has a major impact on the workability, strength, durability, and cost-effectiveness of the concrete.

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Fine aggregate should be free from dust, silt, and organic impurities. According to IS: 383 – 1970, the fine aggregates are divided into four grading zones as shown in table 4. The grading zones become progressively finer from zone 1 to zone 4. When high strength and good durability are required in concrete, fine aggregates conforming to any of the four grading zones can be used, but the concrete mix should be properly designed. As the fine aggregate grading becomes progressively finer, moving from zone 1 to zone 4, this affects the overall properties of the concrete.

Coarse aggregate is made up of bigger granular materials like crushed stone or gravel, usually larger than 4.75 mm. It plays an important role in concrete and asphalt. It helps give construction materials volume, strength, and durability by filling spaces and affecting qualities such as strength, ease of working with the material, and how compact it becomes. The size, shape, and quality of the aggregate are very important for making sure a project goes well.

Water plays an important role in the chemical reaction that happens when cement hydrates and when concrete cures. Therefore, the water used for mixing and curing concrete needs to be clean and free from harmful substances like oils, acids, alkalis, salts, and organic materials, which can damage concrete and steel. These impurities can affect how quickly the cement sets, reduce the strength of the concrete, and lead to corrosion of reinforcing steel. Drinking water is usually a good choice for mixing concrete. Sea water should not be used because it contains harmful salts. The pH level of the water should be at least 6. The physical and chemical tests for water should be carried out according to IS: 3025.

The main reason for using tyre rubber as a substitute is because it is a readily available and waste material. It can be used in two forms:



Figure 1: chipped and crumbed rubber

1) Chipped rubber: These are rubber pieces that come in various shapes and sizes. They are used as a substitute for coarse aggregates in concrete. This helps to use tyre rubber in a more economical way and reduces the need for natural aggregates.
2) Crumbed rubber: Crumb refers to powdered rubber. The rubber is processed into a fine powder and used as a replacement for sand. Using crumbled rubber makes the concrete lighter. It is made by grinding used tyres into small particles similar to sand. This helps to replace some of the sand in concrete, reducing the need for natural sand and making use of waste tyre rubber.

Bead wire is an essential part of a tyre that transfers the vehicle's weight from the rim to the tyre and helps to prevent vibrations during driving.

It significantly affects the safety, strength, and durability of tyres. Bead wire is a thin steel wire made from high-carbon steel rods. The surface is coated with copper or bronze to help it bond properly with the rubber.

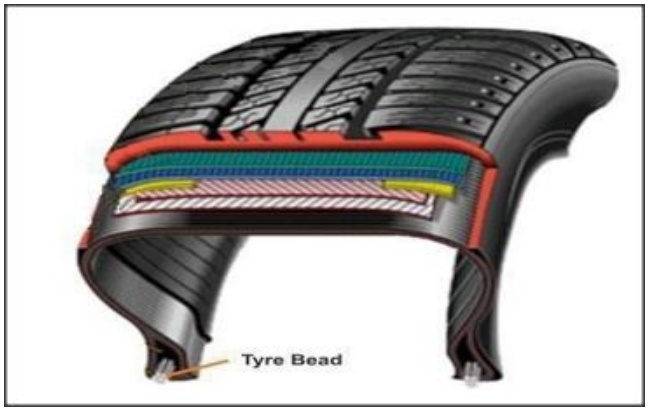
The primary role of tyre bead wire is to act as reinforcement and give the tyre a firm grip on the rim.

It is used in almost all types of pneumatic tyres, such as those on trucks, buses, cars, jeeps, heavy machinery, farm equipment, motorbikes, scooters, and bicycles. The type of tyre and the design of the bead ring determine the appropriate size of bead wire, which ranges in diameter from 0.78 to 2.00 mm for normal and high tensile bronze-coated wires.

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The wire must be made from steel that qualifies under ISO 16120-1.

- For Normal Tin (NT), it also meets ISO 16120-2
- For High Tin (HT), it also meets ISO 16120-4



Tensile strength	% (mass fraction)				
	Carbon	Silicon	Manganese	Sulphur Max	Zinc Max
NT	0.60 – 0.76	0.15 – 0.30	0.40 – 0.70	0.035	0.035
HT	0.77 – 0.90	0.15 – 0.30	0.40 – 0.60	0.025	0.020

Table: chemical composition of Bead wire

Diameter (mm)	Tensile strength NT N/mm^2	Tensile strength HT N/mm^2	Minimum elongation at rupture A_t %
$0{,}80 \leq d < 0{,}95$	1900 to 2300	2150 to 2500	5,0
$0{,}95 \leq d < 1{,}25$	1850 to 2250	2050 to 2400	5,0
$1{,}25 \leq d < 1{,}70$	1750 to 2150	2050 to 2400	5,0
$1{,}70 \leq d < 2{,}10$	1500 to 1800	2050 to 2400	5,0
Fill plat 3 × 1,50	1650 to 1950		2,0

Table: Tensile properties of bead wire with elongation details

Concrete is strong when it's under compression, but it's weak when it's under tension. To fix this, we use steel as reinforcement. Steel is used because it has a high thermal expansion coefficient and a much higher modulus of elasticity compared to concrete.
The reinforcement can be any of the following:

1) Mild steel and medium tensile steel bars according to IS: 432 (part 1)
2) High strength deformed steel bars according to IS: 1786
3) Hard drawn steel wire fabric according to IS: 1556
4) Structural steel according to grade A of IS: 2062

Functions of reinforcement in RCC:

- To handle the tension that occurs in flexural elements such as slabs, beams etc.,
- To deal with diagonal tension caused by shear forces.
- To minimize the shrinking of concrete.
- To prevent spiral cracking that happens due to tension.
- To enhance the ability of compression elements like columns to carry more load.
- To counteract secondary stresses such as those from temperature changes.
- To stop the formation of large cracks in concrete due to tension strains.

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S. no	Constituent	Percentage		
		Mild steel	High tensile steel	Hard drawn steel
1	Carbon	-	0.3	-
2	Sulphur	0.06	0.05	0.06
3	Phosphorus	0.065	0.06	0.06

III. TESTS ON MATERIALS

A. *Test on Cement*

The cement was delivered in one single batch and kept in proper storage.

1) Ordinary Portland cement of 53 grade was used.

2) The field tests include the following:

- The cement should have a greenish-grey colour and should not contain any lumps.
- When rubbed between the fingers, it should feel smooth.
- When a hand is put into a cement bag, it should feel cool.
- If a handful of cement is thrown into water, it should float for a few minutes before sinking.

3) The laboratory tests that were done are:

- Fineness test
- Specific gravity test

B. *Tests on Fine Aggregates and Coarse Aggregates*

Locally available natural sand was used. The following tests were made on sand:

- Sieve analysis
- Specific gravity
- Bulk density

C. *Tests on Bead Wire*

The following tests are conducted on the bead wire:

1) Tensile test

The tensile test is done following ISO 6892 using samples that have the full cross-section of the wire.

His test helps determine the tensile strength, elongation at the moment of break, and the yield strength at 0.2% proof stress (Rp0.2).

The reference length for measuring elongation is 200 mm ± 2 mm.

Other gauge lengths can be agreed upon by the involved parties.

2) Torsion test

The torsion test is carried out according to ISO 7800.

3) Diameter and out-of-roundness

The diameter is measured using a micrometre that has a precision of ±0.001 mm.

IV. BATCHING, MIXING, CASTING AND CURING

A. *Batching*

Batching is when you measure the right amounts of cement, coarse aggregate, fine aggregate, and water for each time you mix concrete.

Methods of batching

- Volume batching
- Weigh batching

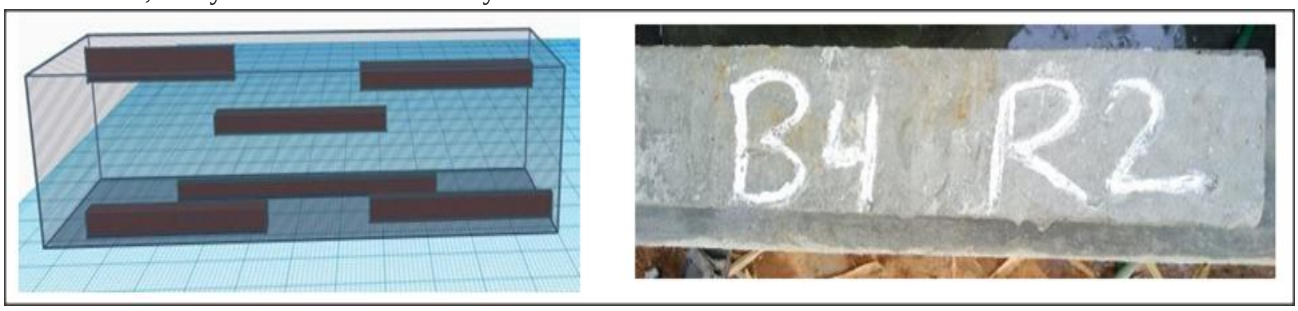
B. *Mixing*

Mixing concrete means thoroughly combining all the materials needed to make a uniform concrete mixture. This can be done by hand or with machines, but using machines is the usual method.

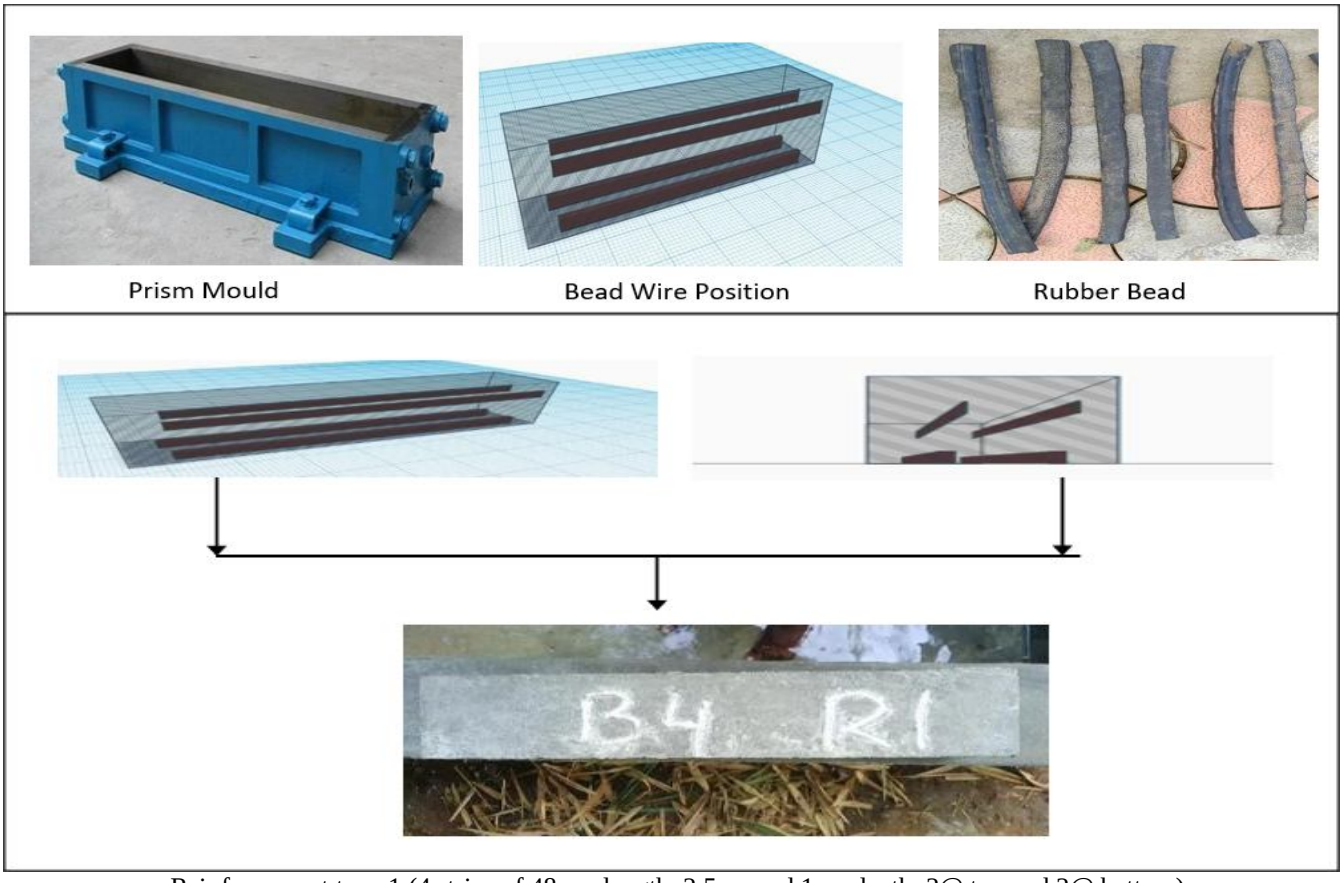
The mixing of concrete is very important because it helps create high-quality fresh concrete.
When you mix the ingredients properly, the surface of every bit of aggregate gets covered with cement paste. Good mixing is essential for the right consistency and performance of the concrete, both when it's still wet and after it has hardened. If the mixing isn't done well, the concrete can separate or lose water from the surface, which affects its strength and quality.

C. Casting of Prisms

- A mould measuring 10 cm by 10 cm in width and 50 cm in length is used to cast the prisms.
- All the ingredients must be measured accurately, and the materials should be weighed carefully, whether using volume or weight measurements.
- Then, mix all the ingredients either by hand or using a machine.
- Next, pour the concrete into the mould in layers. While doing this, place bead wire strips in both the compression and tension areas and compact the concrete with a tamping rod.
- After 24 hours, the cylinder should be carefully taken out of the mould.



Reinforcement type 2 (2 strips of 48cm length, 2.5cm width and 1 cm deep at bottom layer 3 strips of 18cm length, 2.5cm width and 1cm deep at middle layer and top layer)



Reinforcement type 1 (4 strips of 48 cm length, 2.5cm and 1cm depth, 2@ top and 2@ bottom)

D. Curing

Concrete curing is the method of keeping fresh concrete moist and at the right temperature so the cement can fully hydrate, which helps it gain maximum strength and durability. It stops the surface from losing moisture too quickly and stops the concrete from drying out, which can cause problems like cracking or shrinking. This leads to a stronger, more durable, and longer-lasting structure.

V. TESTS ON SPECIMENS

A. Compressive Strength

The compressive strength test of a concrete cube gives an idea about all the qualities of concrete. With just this one test, you can tell if the concrete was properly mixed and poured. For regular construction, the compressive strength of concrete usually ranges from 15 MPa (2200 psi) to 30 MPa (4400 psi), and it's even higher in commercial and industrial buildings. The strength of concrete depends on several factors like the water-cement ratio, the strength of the cement used, the quality of the materials, and how well the concrete is made and controlled during production.

Compressive Strength = Load / Cross-sectional Area

B. Split Tensile Test

Age at Test – Tests should be conducted at standard ages for the test specimens, with the most common being 7 and 28 days. If early strength measurements are needed, tests can also be done at 24 hours ± half an hour and 72 hours ± 2 hours. The ages are calculated from the moment water is added to the dry materials. Split tensile strength as 0.7√EckEck which is the flexural strength given by IS: 456-2000

Strength T = $2P/\boldsymbol{\pi LD}$

Where,

T = split tensile strength in N/mm^2
P = maximum load applied in KN
L = length of the specimen in mm
D = diameter of the specimen in mm

C. Flexural Strength Test

Tests should be conducted at standard ages for the test samples, with the most common being 7 and 28 days. If early strength measurements are needed, tests can be done at 24 hours plus or minus half an hour and 72 hours plus or minus two hours. The age of the samples is calculated from the moment water is added to the dry materials.

Flexural strength = P x L/bd^2

Where,

b = measured width in cm of the specimen,
d = measured depth in cm of the specimen at the point of failure,
l = length in cm of the span on which the specimen was supported, and
p = maximum load in kg applied to the specimen

VI. RESULTS AND OBSERVATIONS

D. Results and Observations of Cubes

- For Normal Cubles

Sl No	Age of the specimen	Identification of specimen	Specimen Area mm^2	Load kN	compressive strength N/mm^2	Average compressive strength N/mm^2
1	7 days	1	22500	305	13.56	13.48 N/mm^2
2		2	22500	290	12.89	
3		3	22500	315	14	
1	28 days	1	22500	465	20.67	20.51 N/mm^2
2		2	22500	440	19.55	
3		3	22500	480	21.33	

- For Rubber 20% replacement with 0.1 ratio

Sl No	Age of the specimen	Identification of specimen	Specimen Area mm^2	Load kN	compressive strength N/mm^2	Average compressive strength N/mm^2
1	7 days	1	22500	285	12.67	13.03 N/mm^2
2		2	22500	295	13.11	
3		3	22500	300	13.33	
1	28 days	1	22500	435	19.33	19.77 N/mm^2
2		2	22500	445	19.77	
3		3	22500	455	20.22	

- Rubber 20 % replacement with 0.15 ratio

Sl No	Age of the specimen	Identification of specimen	Specimen Area mm^2	Load kN	compressive strength N/mm^2	Average compressive strength N/mm^2
1	7 days	1	22500	355	15.77	17.99 N/mm^2
2		2	22500	425	18.88	
3		3	22500	435	19.33	
1	28 days	1	22500	540	24	27.47 N/mm^2
2		2	22500	650	28.88	
3		3	22500	665	29.55	

- Rubber 20 % replacement with 0.17 ratio

Sl No	Age of the specimen	Identification of specimen	Specimen Area mm^2	Load kN	compressive strength N/mm^2	Average compressive strength N/mm^2
1	7 days	1	22500	350	15.55	15.03 N/mm^2
2		2	22500	325	14.44	
3		3	22500	340	15.11	
1	28 days	1	22500	535	23.77	22.88 N/mm^2
2		2	22500	495	22	
3		3	22500	515	22.88	

- Rubber 20 % replacement with 0.19 ratio

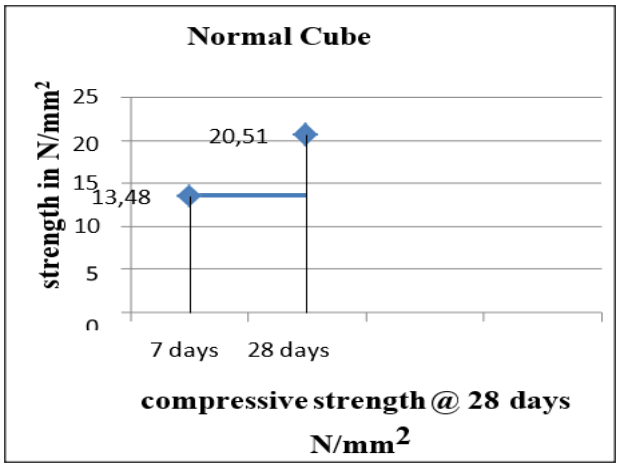
Sl No	Age of the specimen	Identification of specimen	Specimen Area mm^2	Load kN	compressive strength N/mm^2	Average compressive strength N/mm^2
1	7 days	1	22500	325	14.44	12.66 N/mm^2
2		2	22500	245	10.88	
3		3	22500	285	12.66	
1	28 days	1	22500	495	22	19.33 N/mm^2
2		2	22500	375	16.66	
3		3	22500	435	19.33	

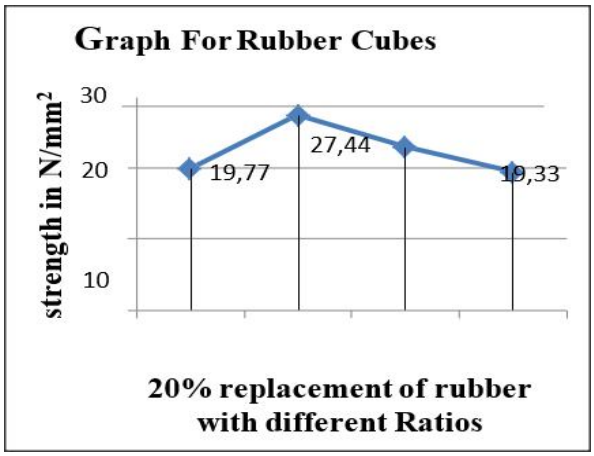
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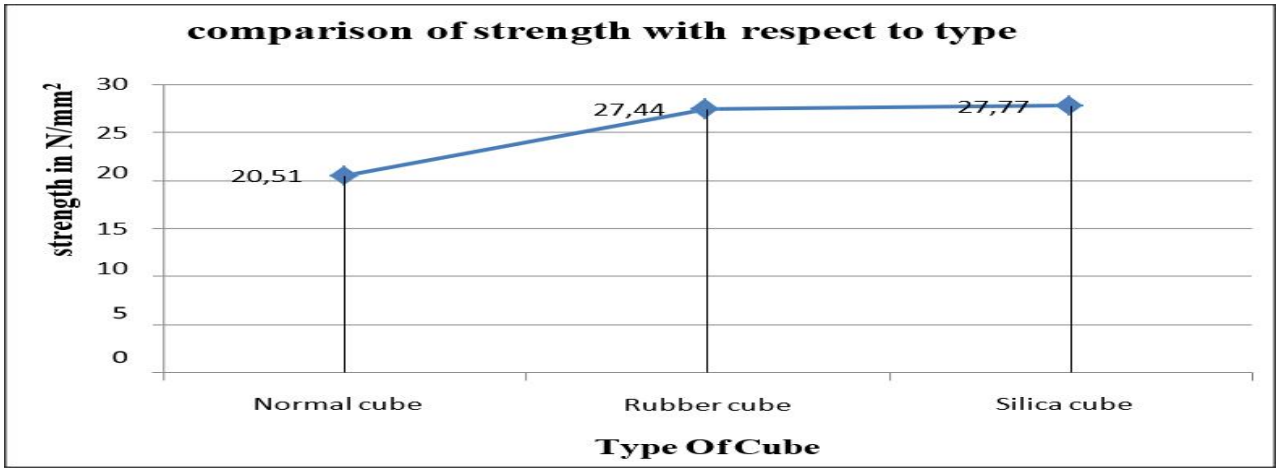
- Silica cubes (5%) with 0.15 ratio rubber

Sl No	Age of the specimen	Identification of specimen	Specimen Area mm^2	Load kN	compressive strength N/mm^2	Average compressive strength N/mm^2
1	7 days	1	22500	420	18.66	18.12 N/mm^2
2		2	22500	375	16.66	
3		3	22500	435	19.33	
1	28 days	1	22500	640	28.44	27.77 N/mm^2
2		2	22500	570	25.33	
3		3	22500	665	29.55	

E. Graphs for Results







F. Results and Observations of cylinders

- Normal Cylinders

Sl No	Age of the specimen	Identification of Specimen	Dia of specimen mm	height of specimen mm	Load kN	Tensile strength N/mm^2	Average tensile strength N/mm^2
1	7 days	1	150	300	100	1.41	1.41 N/mm^2
2		2	150	300	105	1.48	
3		3	150	300	95	1.34	
1	28 days	1	150	300	155	2.19	2.19 N/mm^2
2		2	150	300	160	2.263	
3		3	150	300	150	2.12	

- Rubber 20 % replacement with 0.1 ratio

Sl No	Age of the specimen	Identification of Specimen	Dia of specimen mm	height of specimen mm	Load kN	Tensile strength N/mm^2	Average tensile strength N/mm^2
1	7days	1	150	300	95	1.34	1.31N/mm^2
2		2	150	300	95	1.34	
3		3	150	300	90	1.27	
1	28days	1	150	300	145	2.04	2.04 N/mm^2
2		2	150	300	150	2.12	
3		3	150	300	140	1.98	

- Rubber 20 % replacement with 0.15 ratio

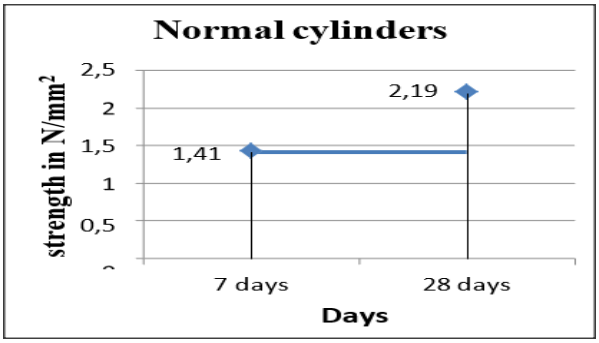
Sl No	Age of the specimen	Identification of Specimen	Dia of specimen mm	height of specimen mm	Load kN	Tensile strength N/mm^2	Average tensile strength N/mm^2
1	7 days	1	150	300	110	1.55	1.59 N/mm^2
2		2	150	300	105	1.48	
3		3	150	300	125	1.76	
1	28 days	1	150	300	170	2.42	2.478 N/mm^2
2		2	150	300	165	2.334	
3		3	150	300	190	2.68	

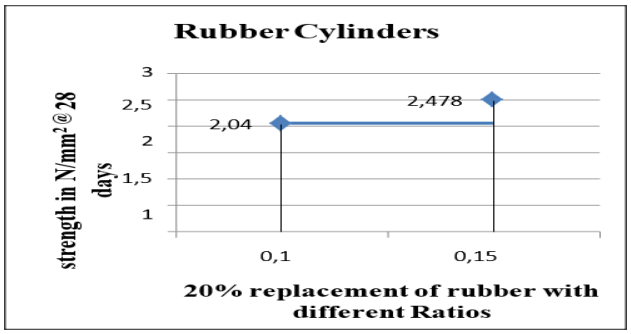
- Silica cylinders (5 %) with 0.15 ratio rubber

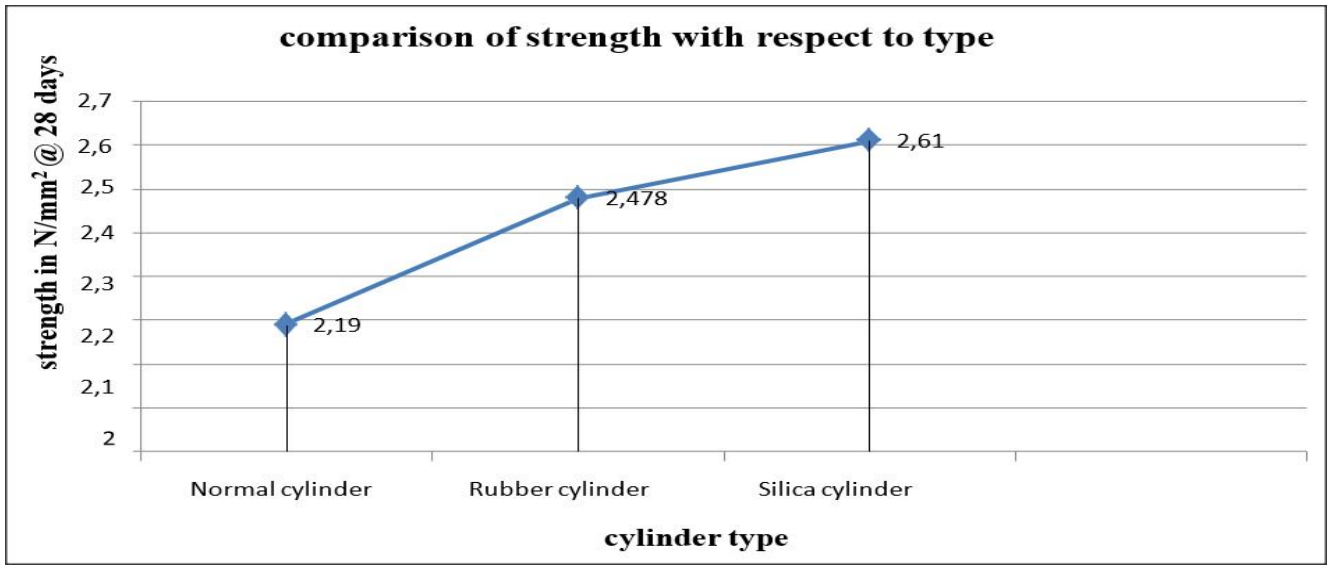
Sl No	Age of the specimen	Identification of Specimen	Dia of specimen mm	height of specimen mm	Load kN	Tensile strength N/mm^2	Average tensile strength N/mm^2
1	7 days	1	150	300	115	1.62	1.71 N/mm^2
2		2	150	300	130	1.83	
3		3	150	300	120	1.69	
1	28 days	1	150	300	175	2.47	2.61 N/mm^2
2		2	150	300	195	2.75	
3		3	150	300	185	2.61	

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G. Graphs for Results







H. Results And Observations of Prism

- Prisms without Reinforcement

Sl No	Age of the specimen	Identification of specimen	Mould size mm x mm	length of specimen mm	Load kN	Flexural strength N/mm^2	Average flexural strength N/mm^2
1	7 days	1	100 x 100	500	11	1.87	1.87 N/mm^2
2		2	100 x 100	500	10	1.7	
3		3	100 x 100	500	12	2.04	
1	28 days	1	100 x 100	500	17	3.89	3.1N/mm^2
2		2	100 x 100	500	15	2.55	
3		3	100 x 100	500	18	3.06	

- Prisms with Reinforcement Type1 (4 strips of 48 cm length, 2.5cm and 1cm depth, 2@ top and 2@ bottom)

Sl No	Age of the specimen	Identification of specimen	Mould size mm x mm	length of specimen mm	Load kN	Flexural strength N/mm^2	Average flexural strength N/mm^2
1	7 days	1	100 x 100	500	28	4.76	4.47 N/mm^2
2		2	100 x 100	500	25	4.25	
3		3	100 x 100	500	26	4.42	
1	28 days	1	100 x 100	500	42	7.14	6.85 N/mm^2
2		2	100 x 100	500	39	6.63	
3		3	100 x 100	500	40	6.8	

- Prisms with Reinforcement Type2 2 strips of 48cm length, 2.5cm width and 1 cm deep at bottom layer 3 strips of 18cm length, 2.5cm width and 1cm deep at middle layer and top layer

Sl No	Age of the specimen	Identification of specimen	Mould size mm x mm	length of specimen mm	Load kN	Flexural strength N/mm^2	Average flexural strength N/mm^2
1	7 days	1	100 x 100	500	14	2.38	2.21 N/mm^2
2		2	100 x 100	500	12	2.04	
3		3	100 x 100	500	13	2.21	
1	28 days	1	100 x 100	500	21	3.57	3.4 N/mm^2
2		2	100 x 100	500	19	3.23	
3		3	100 x 100	500	20	3.4	

- Prisms with Steel Reinforcement (4 bars of 10 mm dia 2@ top and 2@ bottom 6 mm dia stirrups @ 50mm C/C)

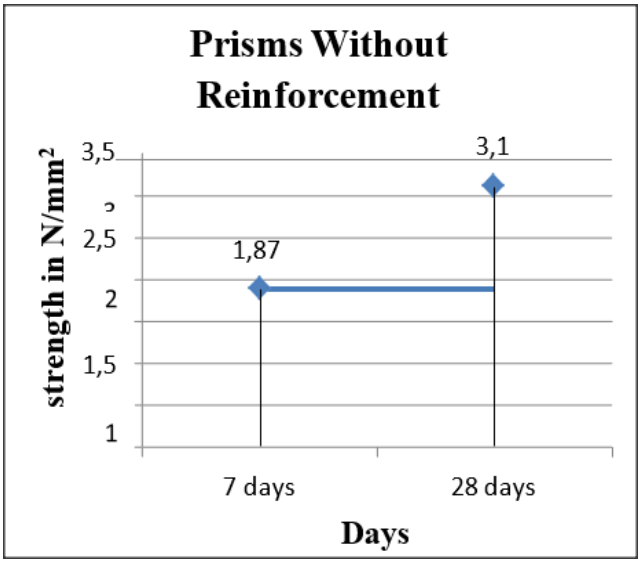
Sl No	Age of the specimen	Identification of specimen	Mould size mm x mm	length of specimen mm	Load kN	Flexural strength N/mm^2	Average flexural strength N/mm^2
1	7 days	1	100 x 100	500	35	5.95	5.83 N/mm^2
2		2	100 x 100	500	36	6.12	
3		3	100 x 100	500	32	5.44	
1	28 days	1	100 x 100	500	51	8.67	8.67 N/mm^2
2		2	100 x 100	500	53	9.01	
3		3	100 x 100	500	49	8.33	

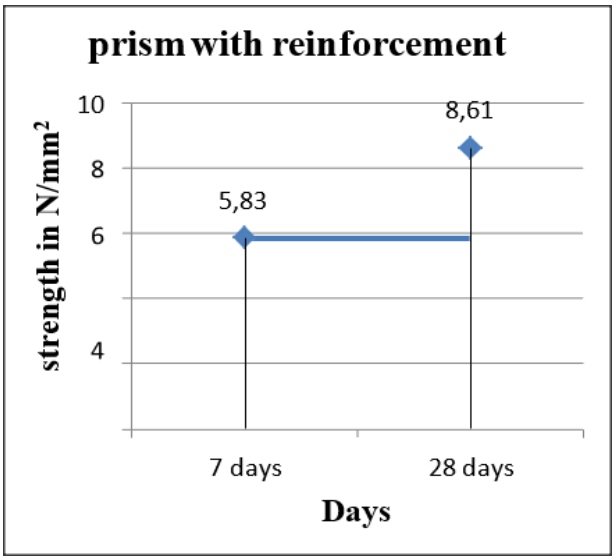
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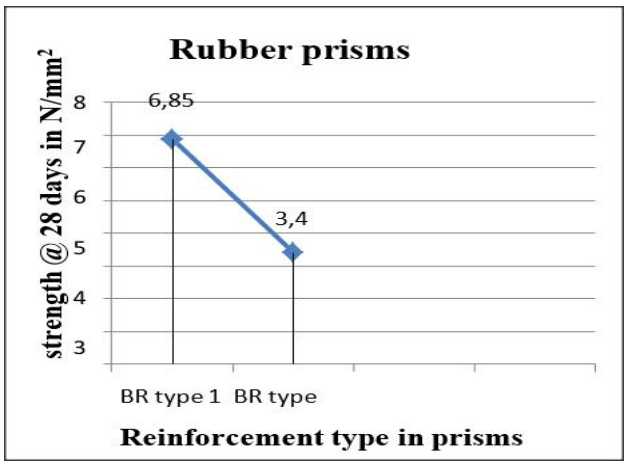
- Silica Prisms with Reinforcement Type 1 (5 %)

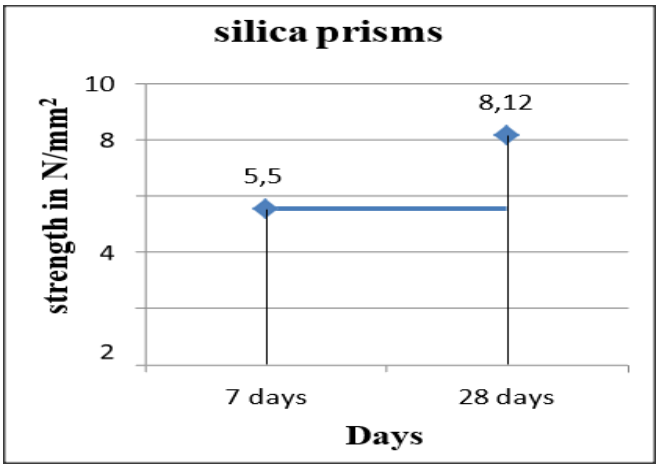
Sl No	Age of the specimen	Identification of specimen	Mould size mm x mm	length of specimen mm	Load kN	Flexural strength N/mm^2	Average flexural strength N/mm^2
1	7 days	1	100 x 100	500	32	5.44	5.5 N/mm^2
2		2	100 x 100	500	34	5.78	
3		3	100 x 100	500	31	5.27	
1	28 days	1	100 x 100	500	48	8.16	8.12 N/mm^2
2		2	100 x 100	500	50	8.5	
3		3	100 x 100	500	47	7.99	

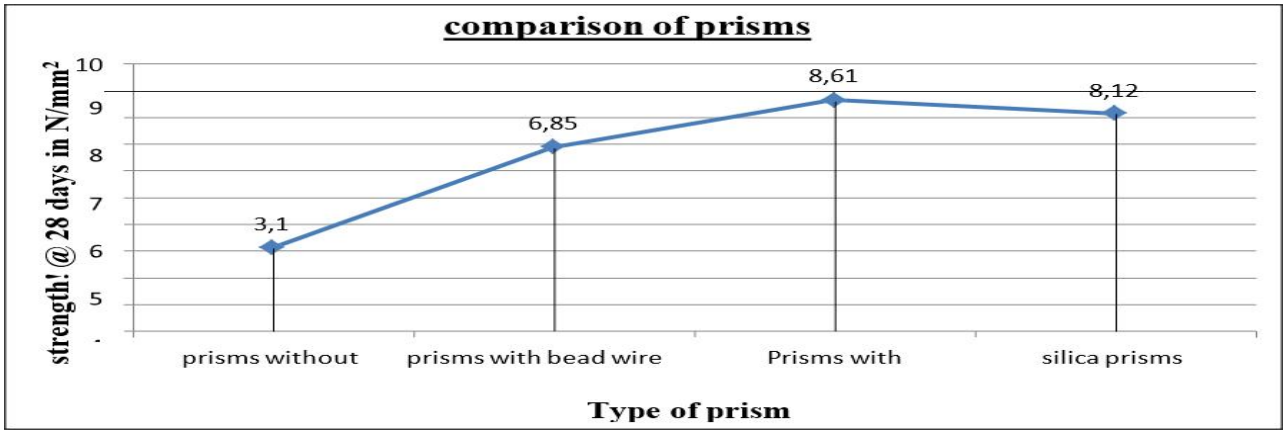
I. Graphs for Results









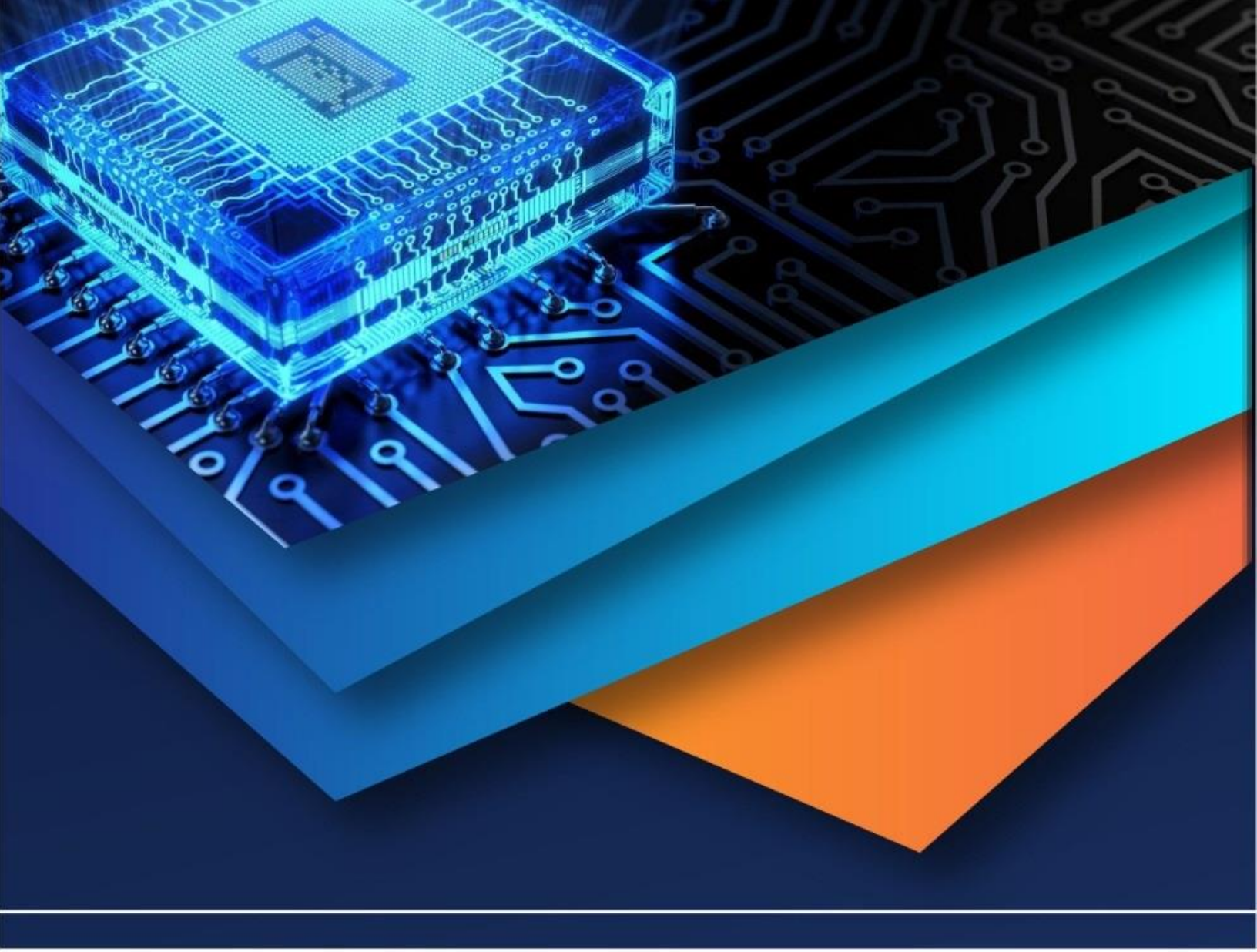


VII. CONCLUSION

1) The addition of chipped rubber to concrete results in better performance compared to regular concrete.
2) The chipped rubber with a 20% replacement and a 0.15 ratio performs better than the 20% replacement with 0.10, 0.17, and 0.19 ratios, causing less confusion and frustration.
3) Adding 5% silica fume enhances the strength of concrete, whether it contains chipped rubber or not.
4) When chipped rubber is added to cubes, it increases compressive strength by 34% compared to normal cubes.
5) Similarly, adding chipped rubber to cylinders increases tensile strength by 13% compared to normal cylinders.
6) Including 5% silica fume in cubes boosts compressive strength by 1% compared to rubber cubes, while in cylinders, it increases tensile strength by 5% compared to rubber cylinders.
7) Bead rubber strips should be placed along the entire length of the prisms, similar to reinforced type 1.
8) Prisms reinforced with bead type 1 show greater strength than plain prisms and other types of prisms using rubber as reinforcement.
9) Prisms with bead reinforced type 1 have 25.6% less flexural strength compared to prisms with steel reinforcement. Prisms made with silica cubes have 6% less flexural strength than steel-reinforced prisms, but 18% more flexural strength than prisms with bead reinforced type 1.

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