



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 10, October 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.524

9940 572 462

6381 907 438

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Performance and Evaluation of Rubber as a Construction Material in Concrete

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ABSTRACT: Globally, the use of rubber products is growing annually. Tire waste is a significant environmental issue in many Indian cities. In India, more than 1 billion scrap tires are produced annually, or roughly one tire for every person. This poses a serious threat to life as we know it on Earth. Burning the rubber is the quickest and least expensive way to break it down in this situation. As a result, there is smoke pollution, other harmful emissions, and global warming. Roughly 75–80% of used tires are currently buried in landfills. Disposing of used tires in landfills is not only expensive but wasteful as well. Council Directive 1999/31/EC, a recent EU policy on waste land filling, outlawed the land filling of whole or shredded

KEYWORDS: Rubber, Compressive strength, efficiency

I. INTRODUCTION

Rubber is a hard, elastic polymeric material that can be synthetically or from the latex of tropical plants. There are two types of rubber: synthetic and natural. When it was first produced, natural rubber, also known as India rubber or caoutchouc, was made up of polymers of the organic compound isoprene along with trace amounts of other organic compounds and water from the rubber tree. It is therefore known as natural rubber. Rubber substitute: Any synthetic elastomer is a synthetic rubber. The majority of these are polymers made from petroleum byproducts. Different polymers are synthesized to create synthetic rubber. Thus, it goes by the name "artificial rubber."

Properties of Rubber

Rubber's elasticity, water resistance, and electrical insulating qualities are its most well-known qualities. Similar to the synthetic variety, raw rubber tends to break in colder temperatures and becomes sticky when heated. Rubber bands are a good example of how elastic rubber is. Rubber is used as a seal around waterproof cell phone cases and is also water-resistant. According to the Hindu, insulated rubber coatings are applied to wires that could come into contact with one another in order to prevent short circuits. Vulcanization is a process used to improve the qualities of rubber. How It Works explains that rubber is treated with sulfur during the vulcanization process while

Because it increases the rubber's elasticity and resistance to the damaging effects of higher or lower temperatures, sulfur is essential to the process. The advantages of synthetic rubber over natural rubber are discussed on InfoPlease.com. Rubber made of synthetic materials is more resilient to weather, oils, acids, and other chemicals, and it lasts a lot longer. Natural rubber does not absorb as much heat as synthetic rubber, thus it is less likely to tear when heated.

Significance

Wastes are separated into three categories: gaseous waste, liquid waste, and solid waste. Both liquid and gaseous waste materials can be disposed of in a variety of ways. Certain solid waste items, like steel, paper, plastic bottles, and other materials, can be recycled without harming the environment. However, there is no way to get rid of solid wastes like used tires. The tire's toxic byproduct will harm the environment and cause air pollution if it is burned. The soil and vegetation's

fertility may be impacted by this material's inability to biodegrade. They could occasionally start an uncontrollable fire. Similarly, greenhouse gas emissions and carbon dioxide emissions present another threat to human society.

Objective.

To check the physical, chemical, and mechanical properties for both standard and modification concrete mix. Replacement a fine and coarse aggregate of standard concrete mix with different weight ratios of scrap tires (both crumb and chipped rubber) as (0%, 10%, 20%, and 25%) respectively. To calculate what will be optimum range for rubber that can be replaced with aggregates. Cost analysis for different pavement.

II. LITERATURE REVIEW

Biel & Lee(1994), In this paper authors have published that used recycled tire rubber in concrete mixes made with magnesium oxychloride cement, where the aggregate was replaced by fine crumb rubber up to 25% by volume. The results of compressive and tensile strength tests indicated that there is better bonding when magnesium oxychloride cement is used. The researchers discovered that structural applications could be possible if the rubber content is limited to 17% by volume of the aggregate. [1]

Ilker Bekir Topcu (1995), the properties of rubberized concretes, proposed the concrete was modified by mixing with crumb rubber in coarse aggregate in the ratio of 15%, 30% and 45%. In this study the changes of the properties of rubberized concrete were investigated according to the terms of both size and amount of rubber chips added. In this the physical and mechanical properties were determined according to that the stress strain diagram were developed from that the toughness value and the plastic and elastic energy capacities were determined.[2]

Guoqiang Li (2004), conducted investigation on chips and fibre's. The tyre surfaces are treated by saturated NaOH solution and physical anchorage by drilling hole at the centre of the chips were also investigated and they concluded that fibre's perform better than chips: NaOH surface treatment does not work for larger sized tire chips: using physical anchorage has some effect. Further efforts will be geared toward the enlarging the holes size and insuring that the hole be through the chip thickness entirely. Fibre length restricted to less than 50mm to avoid entangle: steel belt wires provide positive effect on increasing the strength of concrete.[3]

Fattuhi in, proposed that, the cement paste, mortar, and concrete (containing OPC or grade rubber obtained from shredding scrap tyres. Properties examined for the 32 mixes prepared included density, compressive strength, impact and fire resistances, and nail ability. Results showed that density and compressive strength of various mixes were reduced by the addition of rubber. (Rubber type had only marginal effect.) Density varied between about 1300 and 2300 kg/m³. Compressive strength reduced by 70% when the proportion of rubber to total solid content by mass of concrete reached about 13%.

III. METHODOLOGY

$f'_{ck} = 33.25 \text{ Mpa}$

Selection of w/c ratio (IS 456:2000):

Water Cement Ratio = 0.45

1) Selection of water content:

Maximum water content depends upon maximum nominal size of aggregate. For 20mm size of aggregate,

Maximum Water content = 186 litre

2) Calculation of cement content:

Water Cement Ratio = 0.45

Cement Content = Water content/water cement ratio

= $186/0.45$

= 413.33 kg/m^3

Minimum cement content for severe exposure condition = 320 kg/m^3

∴ $413.33 > 320\text{kg/m}^3$ ∴ OK

- 3) Proportion of volume of coarse aggregate and fine aggregate content: From (IS 10262:2009)
For nominal maximum size of aggregate 20mm and zone of coarse aggregate and fine aggregate of zone II = 0.624

Volume of coarse aggregate per unit volume of total aggregate = 0.64
Volume of fine aggregate per unit volume of total aggregate = $1 - 0.64 = 0.36$

- 4) Mix calculations

The mix calculations per unit volume of concrete shall be as follows

- a) Volume of concrete :

$$1 \text{ m}^3$$

- b) Volume of cement :

$$\text{Mass of cement} / \text{specific gravity of cement} \times 1/1000$$

$$= 413.33 \div 2.3 \times 1000$$

$$= 0.179\text{m}^3$$

- c) Volume of water :

$$\text{Mass of water} / \text{mass density of water}$$

$$= 186/1 \times 1000$$

$$= 0.186\text{m}^3$$

- d) Volume of all in aggregates (e) = a – (b + c)

$$= 1 - (0.179 + 0.186)$$

$$= 0.635\text{m}^3$$

- e) Mass of coarse aggregate :

$$= \text{Volume of all in aggregate} \times \text{Sp. Gravity of coarse aggregate} \times \text{Volume of Coarse aggregate} \times 1000$$

$$= 0.635 \times 2.910 \times 0.64 \times 1000$$

$$= 1182.62\text{kg}$$

- f) Mass of fine aggregate :

$$= \text{Volume of all in aggregate} \times \text{Sp. Gravity of coarse aggregate} \times \text{Volume of Fine aggregate} \times 1000$$

$$= 0.635 \times 2.910 \times 0.36 \times 1000$$

$$= 665.22\text{kg}$$

- 5) Mix proportions for trial number:

Cement = 413.33 kg/m^3

Water = 186 kg/m^3

Fine aggregate =

665.22kg/m^3 Coarse aggregates =
 1182.62kg/m^3 Water cement ratio =
 0.45
Mix Proportion = 1:1.60:2.86

Cement	Water (w/c=0.45)	Fine Agg.	Coarse Agg.	Chipped Rubber	Crumb Rubber	Admix- ture
413.33	186	665.22	1182.62	-	-	4.13
Mix Proportion - 1:1.60:2.86						

Table 3.1 Trial 1 Mix proportion for trial mix 1 (Control Sample) for 1m^3 in kg (weight batching)

For 10% of Replacement

A. Coarse Aggregate Replacement

Volume of all in aggregate =
 0.635m^3 Volume of CA = 0.64
 $\times 0.635$
 $= 0.406\text{m}^3$
 10% of CA = $10/100 \times 0.406 = 0.0406\text{m}^3$

B. 10% of replacement of chipped rubber

$= 0.0406 \times 1000 \times 1.1$
 $= 44.66 \text{ kg}$
 Weight of CA to be reduced = $0.0406 \times 1000 \times 2.91$
 $= 118.146\text{kg}$

Table 3.2 Trial 2 Mix proportion for trial mix 2 (10% replacement of coarse aggregate by chipped rubber) for 1m^3 in kg (weight batching)

Cement	Water (w/c=0.45)	Fine Agg.	Coarse Agg.	Chipped Rubber	Crumb Rubber	Admix- ture
413.33	186	665.22	1064.474	118.146	-	4.13

C. Fine Aggregate Replacement

Volume of all in aggregate = 0.635m^3
 Volume of FA = 0.36×0.635
 $= 0.2286\text{m}^3$
 10% of FA = $10/100 \times 0.2286 = 0.0228\text{m}^3$

D. 10% of replacement of crumbed rubber

Weight of FA to be reduced = $0.024 \times 1000 \times 2.90$
 $= 66.12\text{kg}$

Table 3.3: Trial 3 Mix proportion for trial mix 3 (10% replacement of fine aggregate by crumb rubber) for 1m³ in kg (weigh batching)

Cement	Water (w/c=0.45)	Fine Agg.	Coarse Agg.	Chipped Rubber	Crumb Rubber	Admixture
413.33	186	599.1	1182.62	-	66.12	4.13

Table:- 3.4 Mix proportion for different trials with different replacement

S. No	Replacement %	Trial No.	Cement	Water w/c=0.45	Fine Agg.	Coarse Agg.	Chipped rubber	Crumb rubber
1.	10%	Trial2	413.33	186	665.22	1064.47	118.146	-
		Trial3	413.33	186	599.10	1182.62	-	66.12
2.	20%	Trial4	413.33	186	665.22	946.32	236.292	-
		Trial5	413.33	186	532.20	1182.62	-	132.98
3.	25%	Trial6	413.33	186	665.22	887.25	295.361	-
		Trial7	413.33	186	499.05	1182.62	-	166.16

Casting of Cubes

To guarantee homogeneity, the binder, sand, and aggregates were first premixed dry for one minute. Next, wet mixing for a total of four and a half minutes.

Pour the concrete into steel molds that measure 150 by 150 by 150 millimeters. After a day, demold the concrete specimens and store the cubes in an open container to cure with water. After 3, 7, and 28, test the three cubes to determine their compressive strength.



Fig 3.3.1 Material prepared for sample



Fig 3.3.2 Dry mixing of materials



Fig. 3.3.3 Filled and finished cubes



Fig. 3.3.4 Curing in Curing tank



Figure 3.3.5 Compressive testing in CTM.

IV. RESULTS AND CONCLUSION

4.1 Results

1. Compressive Strength Test (3rd Day)

Table No-4.1 Trial 1 (Control Sample) M25

Cube	3 rd Day Strength(MPa)	Weight(Kg)
1	14.3	9.2
2	16.2	9.1
3	15.3	8.8

Table No-4.2 Trial 2 (10% replacement of coarse aggregate by chipped rubber)

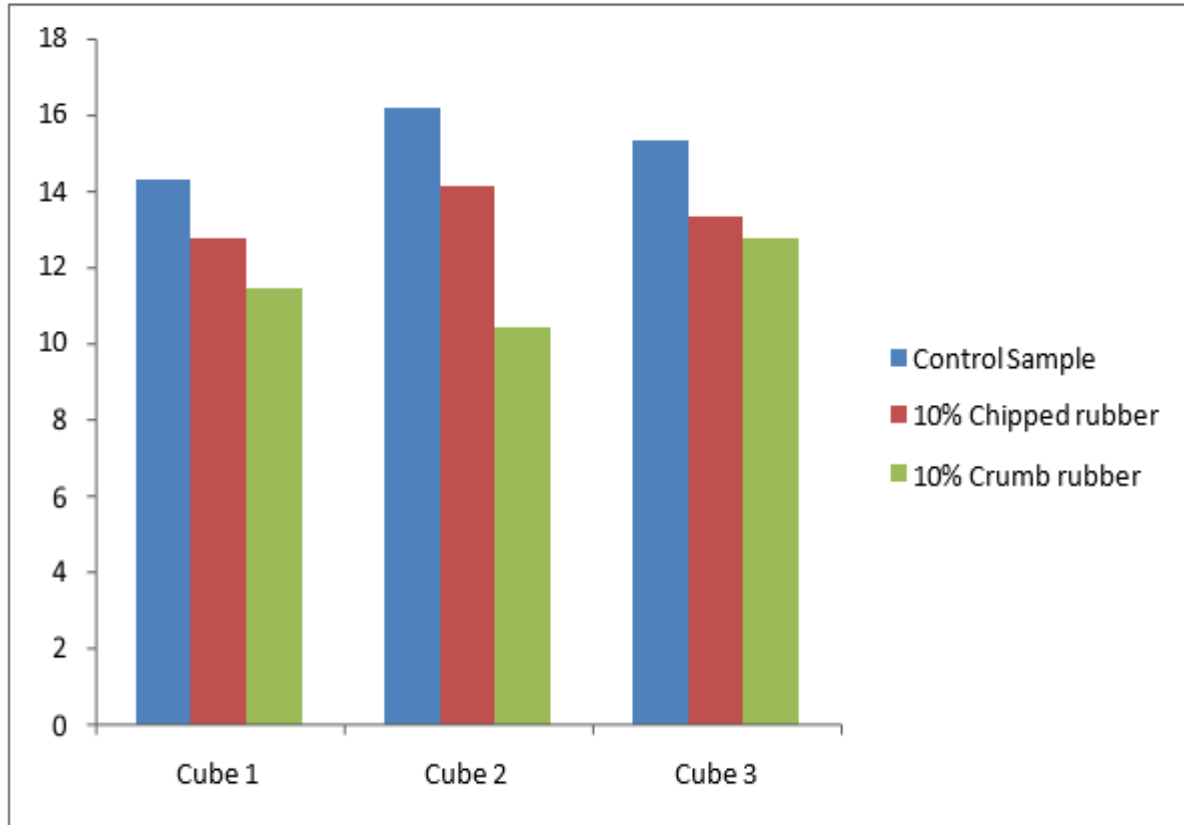
Cube	3 rd Day Strength(MPa)	Weight(kg)
1	12.77	8.63
2	14.11	8.47
3	13.33	8.41

Table No-4.3 Trial 3 (10% replacement of fine aggregate by crumb rubber)

Cube	3 rd Day Strength(MPa)	Weight(kg)
1	11.44	8.28
2	10.88	8.27
3	12.77	8.34

Table No-4.4 Overall 10% replacement (3rd day)

S.No.	Trial	Cube	Strength	Weight
1.	Control Sample	Cube 1	14.3	9.2
		Cube 2	16.2	9.1
		Cube 3	15.3	8.8
2.	10% Chipped Rubber	Cube 1	12.77	8.63
		Cube 2	14.11	8.47
		Cube 3	13.33	8.41
3.	10% Crumb Rubber	Cube 1	11.44	8.28
		Cube 2	10.88	8.27
		Cube 3	12.77	8.34



Graph No-4.1 Compressive strength of 10% replacement (3rd day)

2. Compressive Strength Test (28thDay)

Table No-4.5 Trial 1 (Control Sample) M25

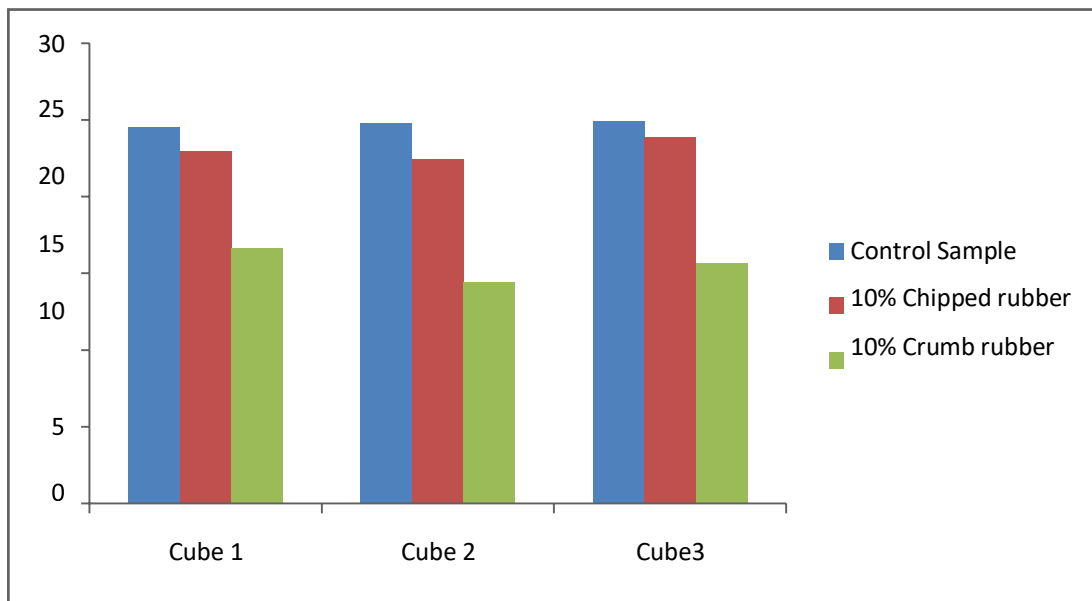
Cube	28 th Day Strength(MPa)	Weight(kg)
1	24.55	9.0
2	24.77	9.1
3	24.90	8.9

Table No-4.6 Trial 2 (10% replacement of coarse aggregate by chipped rubber)

Cube	28 th Day Strength(MPa)	Weight(kg)
1	23	8.3
2	22.44	8.2
3	23.90	8.1

Table No-4.7 Trial 3 (10% replacement of fine aggregate by crumb rubber)

Cube	28 th Day Strength (MPa)	Weight(kg)
1	16.66	7.01
2	14.44	7.00
3	15.66	7.05



Graph No-4.2 Compressive strength of 10% replacement (28th Day)

Table No-4.8 Trial 1 (Control Sample) M25

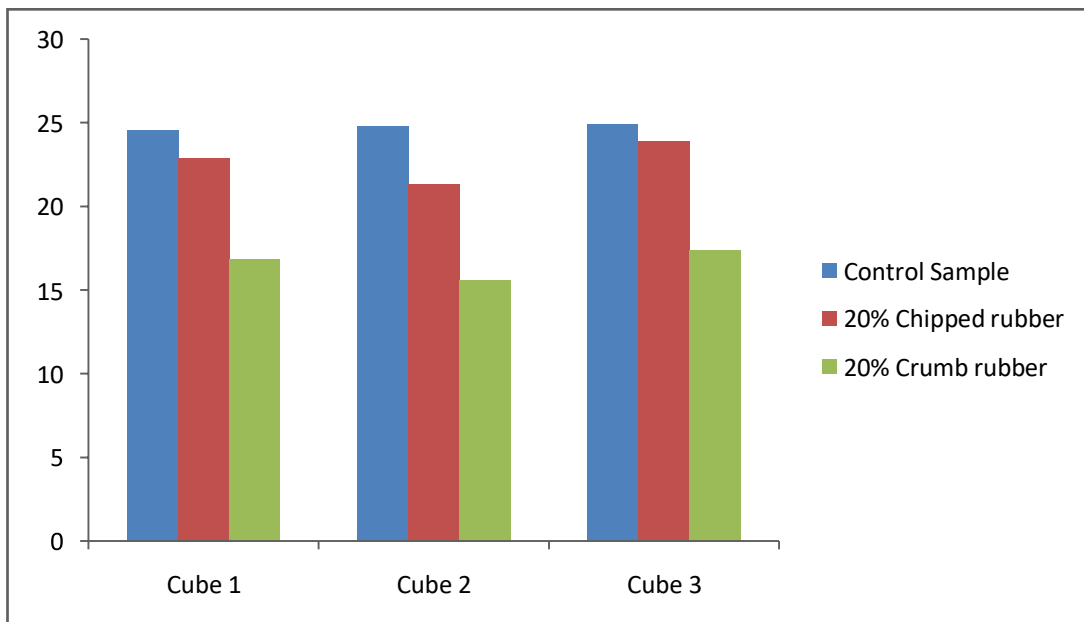
Cube	28 th Day Strength(MPa)	Weight(kg)
1	24.55	9.0
2	24.77	9.1
3	24.90	8.9

Table No-4.9 Trial 4 (20% replacement of coarse aggregate by chipped rubber)

Cube	28 th Day Strength(MPa)	Weight(kg)
1	22.91	8.1
2	21.30	7.9
3	23.98	8.0

Table No-4.10 Trial 5 (20% replacement of fine aggregate by crumb rubber)

Cube	28 th Day Strength(MPa)	Weight(kg)
1	16.82	6.70
2	15.58	6.72
3	17.36	6.65



Graph No-4.3 Compressive strength of 20% replacement (28th Day)

Table No-4.11 Trial 1 (Control Sample) M25

Cube	28 th Day Strength(MPa)	Weight(kg)
1	24.55	9.0
2	24.74	9.1
3	25.00	8.9

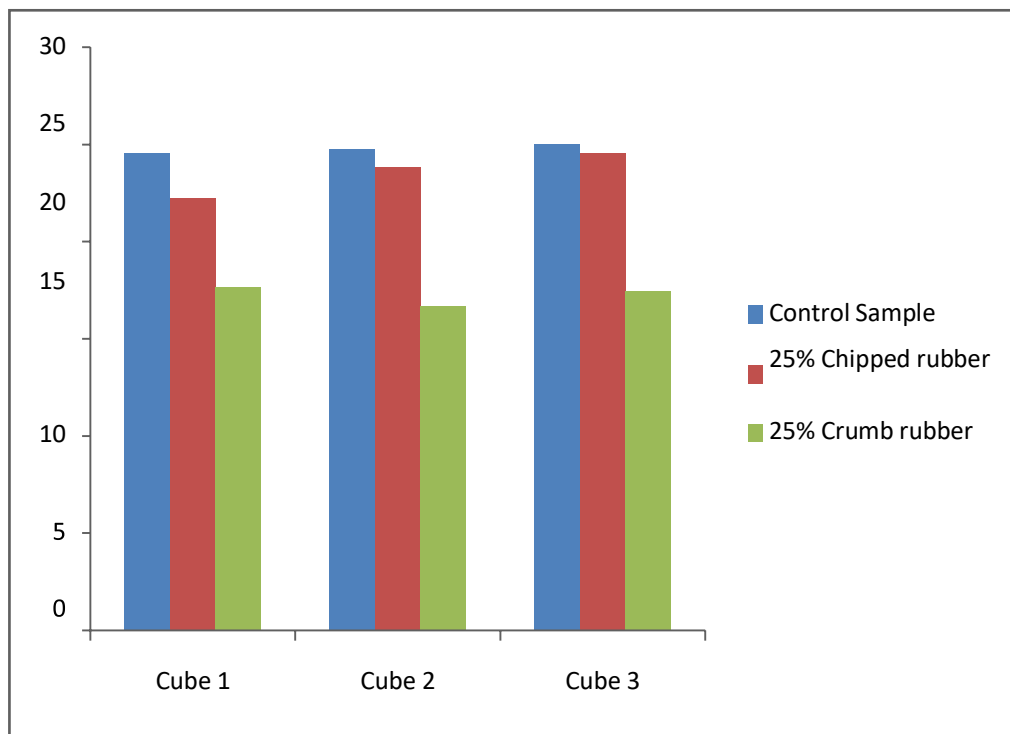
Table No-4.12 Trial 6 (25% replacement of coarse aggregate by chipped rubber)

Cube	28 th Day Strength(MPa)	Weight(kg)
1	22.24	8.0

2	23.84	8.4
3	24.53	8.2

Table No-4.13 Trial 7 (25% replacement of fine aggregate by crumb rubber)

Cube	28 th Day Strength(MPa)	Weight(kg)
1	17.66	6.56
2	16.66	6.55
3	17.44	6.62



Graph No-4.4 Compressive strength of 25% replacement (28th Day)

V. DISCUSSION OF RESULTS

As a result, we finished our project, and throughout the process, we noticed several things about our sample. On the third day, we discovered that the cubes' weight had decreased and their compressive strength had increased by 20% when compared to the typical control sample of M25, following a 10% substitution of coarse aggregate with chipped rubber. Additionally, the compressive strength of the cubes decreased when 10% fine aggregate was substituted with crumb rubber. After adding chipped rubber to replace 10% of the coarse aggregate, it was observed on day 28 that the cubes' compressive strength had increased by 4% and their weight had decreased in comparison to the normal M25 sample. Additionally, the compressive strength dropped after 28 days when 10% of the fine aggregate was substituted with crumb rubber.

5.1 Cost Estimate:-

1. Initial Cost of Flexible Pavement = Rs. 21 lakh per km

2. Initial Cost of Rigid Pavement = Rs. 27 lakh per km

3. Initial Cost of Rigid Pavement

(using 25% chipped rubber replacement

of coarse aggregate) = Rs. 23 lakh per km

4. Strengthening with WBM

(every 10th year-10th, 20th year)

WBM 100mm = $0.10 \times 3.75 \times 1000 \times 800$ = Rs.3,00,000 PC

20mm = $90 \times 3.75 \times 1000$ = Rs.

3,37,500

Total Cost = Rs. 6,37,500 Say Rs. 6.50 lakh

5. Average maintenance cost of rigid pavement = Rs.10,000 per year[11]

5.2 Summary of initial and life cycle

Table No- 4.2

Sr.No	Pavement Type	InitialCost	Life Cycle Construction/Maintenance cost
1.	Flexible/Bituminous	21	33.60
2.	Rigid/Concrete	27	28.30
3.	Rigid/Concrete with25% chipped rubber	23	24.50

VI. CONCLUSION

1. According to the findings, replacing 25% of the crumpled and chipped rubber results in a higher compressive strength than replacing 10% or 20% of the rubber with crumpled and chipped rubber.
2. It has occasionally been noted that adding more rubber to concrete reduces its compressive strength. However, adding rubber aggregate to concrete can improve its properties in a number of ways.
3. Rigid pavement, including rubber embedded in concrete, can be built by selecting an appropriate replacement percentage range.
4. Cost analysis conducted after construction revealed that the initial investment cost of rigid rubber pavement was lower than that of conventional rigid pavement.

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