PARTIAL REPLACEMENT OF AGGREGATES IN CONCRETE WITH TREATED AND UNTREATED WASTE TYRE RUBBER

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by

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DECLARATION

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Place:

CERTIFICATE

This is to certify that **SHAHID RASOOL TARRY** under Registration No. **11507294** has prepared the dissertation report titled entitled **"Partial replacement of aggregates in concrete by treated and untreated Waste Tyre Rubber"** under my direction. This is a bonafide work of the above competitor and has been submitted to me in fractional satisfaction of the prerequisite for the honour of Masters of Technology in Civil Engineering.

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ACKNOWLEDGEMENT

The fulfillment and elation that go with the effective finishing of any errand would be fragmented without specifying the people whose steady direction and support made it conceivable.

I express my profound feeling of appreciation towards my guide **Mr. Waseem Akram, Assistant Professor** for his steady direction, consolation, proposals, support and profitable sources of info. Without his help and tolerance it would not have been conceivable.

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Signature of Student

SHAHID RASOOL TARRY

ABSTRACT

Our present study intends to explore the most effective use of the waste tyre rubber as a constituent of concrete mix replacing the coarse aggregate partially. In this research work, emphasis is given on the pre-treating of the rubber particles and then using them as the partial replacement of the conventional rock aggregates. To get the best results, the rubber aggregates used are surface treated by sodium hydroxide and cement paste before using them in the concrete.M20 grade concrete is used. Using untreated rubber aggregates, the compressive strength of the resultant concrete reduced rapidly, but when treated rubber aggregates were introduced, it resulted in the regaining of more than 90% of the 28 day compressive strength of normal concrete which can be considered quite satisfactory considering the easy and cheap availability of the used tyres and the negative impacts it can have on the environment if left unused. This much compressive strength is enough for treated-rubberized concrete for its use in different areas where compressive strength is not much important like in floors and concrete road pavements. Flexural and split tensile strength is found to be higher than that of the normal concrete but only when treatment is given to the rubber aggregates before using them. Workability is decreased. Flexibility gets increased and due to the lower unit weight of the rubber particles, it is also lighter than the normal concrete. These enhanced properties can be helpful in using this concrete in flexible slabs and as light weight concretes. Appreciable compressive strength, more flexural and split tensile strength, light weight, higher impact and toughness resistance which means prolonged and better resistance to formation of cracks, upgraded ductility, etc

Keywords: *rubber aggregates, rubberized concrete, sodium hydroxide (NaOH), cement paste, tread.*

TABLE OF CONTENTS

CHAPTER	DESCRIPTION	PAGE NO
DECLARATION		**i**
CERTIFICATE		**ii**
ACKNOLEDGEMENT		**iii**
ABSTRACT		**iv**
CONTENT		**v**
LIST OF FIGURES		**vii**
LIST OF TABLES		**viii**
CHAPTER 1	**INTRODUCTION**	**01-02**
	1.1 General	01
CHAPTER 2	**REVIEW OF LITERATURE**	**03-08**
	2.1 Literature Review	03
CHAPTER 3	**RATIONALE AND SCOPE OF THE STUDY**	**09-10**
	3.1 Scope of the Study	09
	3.2 Problem Definition	09
	3.2.1 Need for partial replacement of aggregates with rubber	09
	3.2.2 Need for light weight concrete	10
CHAPTER 4	**OBJECTIVES OF THE STUDY**	**11-11**
	4.1 Objectives	11
CHAPTER 5	**EQUIPMENT AND MATERIALS**	**12-23**
	5.1 Collection of raw material	12
	5.2 Material testing	12
	5.2.1 Cement tests	12
	5.2.2 Aggregate tests	14

	5.3 Classification of waste tyre rubber	21
CHAPTER 6	**RESEARCH METHODOLOGY**	**24-27**
	6.1 Experimental Setup	24
	6.2 Mix proportion	24
	6.3 Treatments	25
	6.4 Work layout plan	27
CHAPTER 7	**RESULTS AND DISCUSSION**	**28-35**
	7.1 Workability	28
	7.2 Compressive strength	30
	7.3 Flexural strength	32
	7.4 Split tensile strength	34
CHAPTER 8	**CONCLUSION AND FUTURE SCOPE**	**36-36**
	8.1 Conclusion	36
	8.2 Future Scope	36
	REFRENCES	**37-38**

LIST OF FIGURES

FIGURE NO.	DESCRIPTION	PAGE NO.
5.1	Setup for crushing test	14
5.2	Setup for Los Angeles abrasion test	16
5.3	Setup for impact test	17
5.4	Flakiness gauge	18
5.5	Elongation gauge	18
5.6	Manual cutting of tyre rubber to size of coarse aggregates	21
6.1	NaOH-Treated Rubber	26
6.2	Cement-paste treated rubber	26
7.1	Rubberized concrete sample for workability test	29
7.2	Slump vs. percent replacement by rubber	29
7.3	Cube under compression	31
7.4	Variation of 28 day compressive strength vs percent replacement by rubber	31
7.5	Comparison between 7 and 28 day compressive strength on varying percentages of rubber	32
7.6	Two point flexural loading on beam	33
7.7	Variation of 28 day flexural strength vs. percent replacement by rubber	34
7.8	Cylinder under split tensile load	35
7.9	Variation of 28 day split tensile strength vs. percent replacement by rubber	35

LIST OF TABLES

TABLE NO.	DESCRIPTION	PAGE NO.
5.1	Consistency test results of cement	13
5.2	Grading Limit of Fine Aggregate	20
5.3	Grading Limit of Coarse Aggregate	20
5.4	Results for coarse aggregates	21
5.5	Composition by weight	22
5.6	Materials used in tyre	22
6.1	Mix proportion	25
7.1	Slump values of different samples	28
7.2	Compressive strength of different samples	30
7.3	Flexural strength test results	32
7.4	Split tensile strength of different samples	34

CHAPTER 1

INTRODUCTION

1.1 General

Use of Waste tyres or used tyres has been an inveterate environmental issue in western countries but now due to the modernization and industrialization, this problem has slowly been felt in different Asian countries especially India and china. India has at a very slow pace started to work against this menace, but not effectively when compared to its western counterparts. As India is on its way from being a developing country to a developed country, rate of vehicles hitting the road per year is increasing very fast and so is the number of tyres. Increasing number of tyres produced or used per year means more number of waste tyres being produced at the end of that year which in turn produces more number of landfills that are hazardous to the environment. Burning of these tyres has also not been recommended due to the production of a variety of poisonous gases which is again a big environmental problem.

In the last five fiscal years i.e. 2010 to 2015, the tyre industry in India has shown a growth of about 12%. This growth is considered to be very good for the nation's economy and from industrialization point of view but taking into consideration the environmental aspect; it has been seen as a challenge and an emerging threat.

Different areas for the use of recycled tyre rubber have been identified from time to time and a lot of research is being carried out for its better use but due to the unique physical and chemical properties of rubber, and the quantity in which it is produced, it is very difficult to use it wholly in a particular area or field. The different applications of waste tyre rubber where it has been successfully used are:

- Sports surfaces
- Automotive industry
- construction
- geo-technical/asphalt applications
- adhesives and sealants

- shock absorption and safety products
- rubber and plastic products

One such application of waste tyre rubber to overcome its environmental problem is in the field of construction. It has shown great potential in the construction industry where it can be used with cement concrete and asphalt pavements. Different researches have been conducted to successfully incorporate waste rubber in concrete and appreciable results have been found. Certain properties of rubber like better flexibility and light weight are considered to be the main reason for its more and more use in the construction industry. Waste rubber has been successfully used as the replacement of the aggregates in the cement concrete. With a great environmental concern and in saving the natural rock aggregates, we have replaced a part of the conventional coarse aggregates by shredded rubber aggregates resulted from cutting worn tyres.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Literature Review

Concretes which have been incorporated with tyre rubber aggregates have in general been found to exhibit low compressive and tensile strengths as compared to the normal concretes using conventional aggregates. Tyre chips or shredded rubber has been used as the replacement of the coarse aggregates and the crumb rubber which is almost a powdered form of rubber has been used as the replacement of fine aggregates. But the results by far have been found to be not so satisfactory but still appreciable. Some properties of concrete other than compressive strength and tensile strength get enhanced by the addition of rubber. Rubberized concretes possess ductile characteristics better than the normal conventional concretes. This property of rubberized concrete is useful in the construction of overlaying fatigued or cracked pavements. It can also be used as a durable crack resistant asphalt surface in new construction.

More than 6 million tyres get dumped to landfills per year. Recovering this much rubber which is a main source of environmental pollution if left as such, is of national importance and a key priority. Over the years, a lot of research has been carried out on the possible use of this waste rubber as the conventional aggregate replacement. The summary of few such researches is given below:

1. **Akinwonmi, Seckley et al. (2013).** They separately replaced the natural aggregates by both shredded rubber as well as by crumb rubber. After testing the specimen which contained different percentages of the crumb rubber and others which contained the different percentage of shredded rubber, it was observed that up to the replacement level of 2.5% by shredded tyre, the compressive strength slightly increased but when the replacement level goes beyond 2.5%, there is a massive decrease in the compressive strength of the concrete. On the other hand the replacement by crumb rubber totally showed negative results and thus was not recommended.

2. **Amjad A. Yasin et al. (2012).** They partially replaced the natural aggregates with the shredded tyre rubber aggregates. The results showed that the compressive strength gets

significantly reduced as compared to the compressive strength of the concrete with natural aggregates. They recommended that the shredded tyre rubber as the replacement of natural rock aggregates should not be preferred for structural uses and should only be used in non load bearing places.

3. **Blessen Skariah Thomas et al. (2016).** Rubberized concrete shows high resistance to freeze thaw, acid attacks, and chlorine ion penetration.

4. **El-Gammal et al. (2010).** They replaced natural aggregates in the concrete by tyre rubber aggregates and then studied its effect on the resultant concrete mix. It was observed that a good percentage of compressive strength is reduced. On the other hand, when the testing of the rubber aggregate concrete specimen was done, it was observed that a good amount of compressibility allowed the specimen to absorb a greater amount of energy under compressive loads. After the failure of the specimen, it remained partially intact even after it failed under the ultimate load. Thus it can be concluded that ductility of the concrete is increased.

5. **Ishtiaq alam, Umer Ammar Mahmood, Nouman Khattak (2015).** Like other research works, they also replaced the natural aggregates in concrete with rubber aggregates and found that the compressive strength of the resultant concrete gets drastically reduced. To increase it, surface treatment of rubber particles just before use, by silica fume was recommended. This review paper also contains some positive effects on the resultant concrete like development of ductile behavior in concrete before it fails. They also found that the density of normal concrete was more than the concrete containing rubber aggregates and it was found that density gets decreased when percentage of rubber is increased in the concrete. It is because of the fact that the specific weight of the rubber is lesser than that of the natural rock aggregates.

The other part of this research which compared the results of chipped rubber aggregates used as coarse aggregates with that of the crumb rubber used as the fine aggregates suggested that the chipped rubber aggregates showed appreciable strength. The use of shredded rubber as partial replacement of natural aggregates was not recommended.

6. **Krunal N. Patel and Prof. M.A.Jamnu (2014).** Enhancement of mechanical properties of rubber crumb concrete using pretreated rubber crumbs and alccofine**.** This paper has gone one step further than other papers mentioned above. They also partially replaced the conventional aggregates with waste tyre rubber aggregates but what they did was to pre treat the rubber aggregates by NaOH and adding of silane coupling agent incorporating the use of alccofine (GGBS) to improve the bonding between the aggregates and the cement paste. Their main aim was to overcome the problem of poor bonding between cement paste and untreated rubber aggregates which was evident in almost all the previous research works. The results depicted that if some bonding material is used and pre treatment is given to the rubber aggregates, the strength is sure to improve. The influence of different gradations of the rubber aggregate on concrete properties is not evaluated in this study.

7. **Lee et al. (1998).** They studied the crumb rubber filled concrete and observed its impact and flexural strength. It was found that the flexural and impact strength of the crumb rubber filled concrete is more as compared to the latex modified concrete as well as portland cement concrete. It was concluded that due to the formation of styrene-butadiene rubber (SBR) latex, the interfacial bond between the crumb rubber particles and cement paste becomes much stronger as compared to the conventional bond when there is no SBR latex.

8. **More, Tushar R., Pradip D. Jadhao, and S. M. Dumne (2015).** In this research work of strength appraisal of concrete containing waste tyre crumb rubber, there was a continuous decrease in the flexural strength as they went on to increase the percentage of crumb rubber as the replacement of sand as fine aggregate in the concrete. The value of flexural strength was found out to be a mere 40% of the normal concrete when the replacement level was just 3% and it went on decreasing when the replacement percentage was further increased. For various mix samples, it was found out that the workability decreased as we added the crumb rubber into it. Like flexural strength, the split tensile strength of the rubberized concrete was also found out less than the normal concrete and its value corresponding to the replacement level 3% was found to be only 30% of the split tensile strength of the normal concrete, which is very poor. The decrease in the strength can be attributed to the poor bonding between the rubber aggregates and the

cement paste. It was thus recommended that rubberized concrete be used in such places where strength is not the prime requirement like in non load bearing members.

9. **N. J. Azmi B. S. Mohammed, H. M. A. Al-Mattarneh (2008).** This research work mainly focused on the mechanical properties of the concrete containing crumb rubber as partial replacement of natural fine aggregates with the replacement levels of 10, 15, 20 and 30% by volume. Different water cement ratios of 0.68, 0.57 and 0.41 were used and the testing of specimen was carried for compressive strength, split tensile strength, flexural strength and also for modulus of elasticity. As in other research works, the results depicted that there is a reduction in the compressive strength of the concrete. They also found out that when the crumb rubber content was increased from 0-30%, there was a clear increase in the workability as well. Crumb rubber being more workable than the conventional/normal concrete can thus be very use full in certain conditions where less workability is needed. The replacement of aggregates by crumb rubber also reduced the static modulus of elasticity and increased the deformability. American Concrete Institute mix design methods were used in this research work.

10. **Obinna Onuaguluchi et al. (2014).** Surface treatment by lime stone powder is given to the crumb rubber with varying percentages of replacement levels by volume. The increase in strength was very less but when the same surface modification of crumb rubber was applied in combination with the silica fume as cement replacement, the mechanical properties enhanced significantly. It was also concluded that the rubber incorporated acted as electrical insulator which increased the surface resistivity and resistance to chlorine permeability.

11. **Qingli Dai, Guo et al. (2017).** In this research work different surface treatments were given to the rubber particles before using them in the mix. they were treated with sodium hydroxide and silane coupling agent were used. The rubber particles were also treated with cement, silica fume and blended cement with sodium silicate. these all treatments were given in order to increase the bonding between the cement paste and the rubber particles. the tests revealed that the best results were shown by the concrete which contained NaOH treated rubber particles. it was concluded that the up to the 25% replacement by rubber, the resultant rubberized

concrete is good enough for the fulfilling the strength requirements of a rigid pavement concrete. Mechanical performance and durability also increased.

12. **Sunil N. Shah, Pradip D. Jadhao et al. (2014).** The different tests performed in this study showed that the workability decreased upon the increase in chipped rubber aggregate content. The unit weight of the resultant rubberized concrete samples was found less as compared to the normal concrete. This led to the conclusion that rubberized concrete can be used as light weight concrete though it showed less strength than the normal concrete. Thus its application is restricted and can only be used in certain predefined conditions where strength is not the priority or where light weight concrete is need to be used. Other important observation made by them was the crack pattern seen at the time of ultimate load application. The rubberized concrete showed better ductility and flexibility than normal concrete which is very use full at the time of earth quakes.

13. Taha et al. (2003). They added various percentages of rubber aggregates having the size range of 5mm to 20 mm. When 100% of aggregates were replaced by the rubber aggregate, a huge reduction of 75% in the compressive strength of resultant concrete was found which is considered to be extremely poor.

14. **Yu Ma, Liang He et al. (2016).** In order to strengthen the chemical bond between the crumb rubber particles and the cement paste, the surface modification method was adopted. The surface modification included the oxidation with KMnO4 solution and sulphonation with NaHSO3. It was found that this treatment increased the interfacial bonding strength between the rubber and cement paste. The adhesion strength increased by 41.1%. tests revealed that the compressive and the impact strength also increased by the surface modification. The compressive strength was found to be about 48.7% higher than that of the untreated rubberized concrete at 4% replacement level.

15. **Zeineddine Boudaoud, Miloud Beddar. (2012).** As in other research works, this piece also led to the conclusion that there is a reduction in the mechanical characteristics of the

concrete when rubber is added to it. However, even after the reduction in the strength, it still has the potential to be used in many places where not much strength is required like in the road construction industry. It was observed to be more economical, ecological and lighter than the normal concrete.

CHAPTER 3

RATIONALE AND SCOPE OF THE STUDY

3.1 Scope of the Study

In our country India, a large quantity of waste materials produced from industries is polluting the environment. Keeping in view the points already mentioned in the above section, this study is focused on the recycling of one such waste material i.e. used tyre rubber. The management of waste tyres will not only have beneficial effects on the environment, but due to its abundant and free availability, it will also contribute to the economy of the structure, when it replaces a material that is costlier than it. Rubber aggregates being more flexible and lighter than the natural rock aggregates, has great potential to be used in earthquake prone areas. Rubberized concrete has the ability to dissipate the vibration shocks at the time of earthquakes better than the normal concrete. Lighter weight of the rubber aggregates than the conventional aggregates shows that it is a new and viable source of structural aggregate material.

At present the disposal of waste tyres is becoming a major waste management problem in the world. Around 1.2 billion tons of waste tyre rubber is produced all around the world per year. About 11% of these tyres are exported and 27% are sent to landfill, dumped illegally and only 4% is used for civil engineering projects. In the context, different research works have been carried out to identify the potential application of these used tyres in civil engineering projects. Our present study aims to investigate the optimal use of waste tyre rubber as coarse aggregate in concrete.

3.2 Problem Definition

3.2.1 Need for partial replacement of aggregates with rubber

The increase in the demand of the concrete construction or concrete manufacturing has resulted in the draining out of the natural resources where from natural aggregates are obtained. The preservation of these natural resources is required. Also in the process of extracting these aggregates, there is a lot of labor required. The fine aggregates used in concrete are mostly obtained from riverbed mining. But, due to non-scientific and non-technical methods adopted during mining, lowering of the water table level and bridge pier failures are becoming common.

These all factors lead us to the conclusion that an alternative for aggregates should be found which can replace them whenever and wherever required.

Keeping in view the above problems faced by the concrete industry and to make it more sustainable, the use of waste materials such as tyre rubber as the replacement of natural rubber has been adopted with great success over past few years. It not only helps in replacing a better and costly material, but also helps in reducing the landfill pile ups, thus saving the environment as well.

Use of the waste materials not only helps in getting them utilized in cement, concrete and other construction materials, but also has numerous indirect benefits such as reduction in land fill cost, saving in energy, and protecting environment from possible pollution effect. It also helps in reducing the cost of concrete manufacturing.

3.2.2 Need for light weight concrete

Light weight concrete has gained much importance due to its ability to considerably reduce the dead load of the structure. So, where ever the dead load is required to have a low value, keeping the dimensions same we can use light weight concrete and get a lesser value of dead load.

Incorporating rubber aggregates into the concrete results in a lighter concrete which can be easily used in place of light weight concrete.

CHAPTER 4

OBJECTIVES OF THE STUDY

4.1 Objectives

The objective of this study is to use the waste tyre rubber as a partial replacement of natural coarse aggregate for the positive variations in the properties of the mix and then in order to further improve those properties, we give surface treatments to the rubber aggregates before their use, in order to improve their bond strength with the cement paste. The effect of rubber aggregates used as the replacement of coarse aggregate and its surface treatment is to be determined by testing workability, tensile strength, compressive strength, durability, etc. of cement mortar. These tests will enable a complete characterization and an evaluation of application possibilities. The main objectives of the study are given below;

- The main purpose of this study is to examine the effect of addition of shredded rubber aggregates into the Portland cement concrete in three different proportions i.e. 5%, 10% and 15% by mass of coarse aggregates and evaluate the fresh and hardened rubberized concrete properties.
- Another objective of this experimental study is to investigate the effect of surface treatment of rubber on various properties of rubberized concrete. Two different treatments will be given to the rubber aggregates.

  A) Treatment by coating the rubber aggregates with cement paste.

  B) Treatment by washing the rubber aggregates with NaOH solution.
- To prepare lightweight concrete by using waste rubber as partial replacement of course aggregate.
- Utilization of waste rubber in the concrete construction sector, hence eliminating the need of land fill disposal of this non bio-degradable waste.

CHAPTER 5
EQUIPMENT AND MATERIALS

5.1 Collection of Raw Material

The material used in the project is cement, sand, tyre rubber and sodium hydroxide. The cement, sand and sodium hydroxide are easily available in the market while the tyre rubber is available at very few sources. For this Project the tyre rubber was collected from a local garage and the sodium hydroxide was obtained from the market. Cement is a dispersed solid whose particle size is ranging from 0.1 to 250 micron-meter. The rubber thus obtained was brought down to a size comparable to the size of coarse aggregate. For this purpose the rubber obtained was cut down manually to get the desired size of particles in the workshop.

5.2 Material Testing

Below mentioned tests were conducted on the materials used:

- **Cement tests:** Consistency test, determination of initial and final setting time, compressive strength test, fineness test (sieve analysis), soundness test.
- **Tests For fine and coarse aggregate:** crushing test, impact test, abrasion test, water absorption test, soundness test, Shape test, Specific gravity and water absorption test, Sieve analysis (gradation).

5.2.1 Cement Tests

a) Consistency test for cement

Consistency of cement is its ability to flow. It depends up on the compound composition and fineness of the cement. Standard consistency of the cement paste is defined as that consistency which permits vicat's plunger to penetrate through a depth of 33-35 mm from top of the mould. In other words, we can also define it as the consistency at which vicat's plunger penetrates up to a point which is 5-7 mm from the bottom of the vicat's mould. The vicat's plunger has a needle with diameter of 10 mm and length of 50 mm.

Procedure: In this project we weighed approximately 400 gm of cement and mixed it with a weighed quantity of water keeping water cement ratio equal to 0.25. The water quantity comes out to be equal to 100 gm. The mixing is done for a time between 3 to 5 minutes, also called as Gauging time. Fill the vicat's mould, with this cement paste and smoothen it. The mould should rest on a plain, clean and dry plate. Glass plates are mostly used and recommended. Release the needle and let it penetrate through the paste in the mould. The depth of the penetration is measured and the procedure is repeated with the change in water cement ratio value. This value is varied in order to bring the penetration value of the needle near 33- 35 mm when measured from top. The particular percentage of water at which the penetration value comes between 33-35 mm, is known as the percentage required producing a cement paste of standard consistency. The results carried out on three different samples are given below:

Table 5.1: Consistency test results of cement

Sample number	Consistency value	Weight of water(gm)
1	28.9	115.6
2	28.5	114
3	29.3	117.2

We consider that the average of above three sample result as the consistency value of the cement. Therefore, consistency value (P) is 28.9 %.

b) Initial and final setting time

Procedure: We take the cement sample of about 400 gm and, mix it with the water quantity of about 0.85 times the water required to give a paste of standard consistency i.e. (0.85P). Like in the determination of standard consistency, the gauging time here should also be between 3-5 minutes. The gauging should be over by the time there is any sign of setting in the paste. The time period between the time of adding of water and the time we start to fill the mould is recorded. The mould is filled with the cement paste and the top surface is leveled with the mould. A very minute vibration may be given to get rid of any possible voids.

Water added = 0.85 * P = 0.85 *115.6 = 98.26 gm.

Initial setting time: Initial setting time is defined as the time period measured from when the water is added to the cement up to the time when it starts to lose its plasticity. For calculating the initial setting time, the needle used has 1 mm square section. This needle is lowered and then quickly released which allows it to penetrate into the mould. In the initial minutes, it will completely get pierced through the 40 mm of the mould. We repeatedly continue to let the needle pierce through the cement paste in the mould until it fails to pierce the test block to a depth of 5-7 mm from the bottom of the mould. The time elapsed between the time when water is added to the cement and the time at which the needle fails to go through the paste in the mould to a depth of 5-7 mm from the bottom. The initial setting time for the ordinary Portland cement (OPC) is generally taken as 30 minutes.

Initial test observed on stopwatch was 40 minutes.

Final setting time: The procedure is almost same as that of calculating the initial setting time with the difference of the type of needle used. For calculating final setting time, the needle used for initial setting time is replaced with a needle having an angular ring at bottom. The needle is released which makes an impression on the cement paste. The same procedure is again repeated up to the time when the needle fails to make an impression on the paste. Final setting time is thus calculated as the time period elapsed between when water is added to the cement at the start up to the time when the needle fails to make an impression on it. It is generally taken as 4 hours.

Final setting time for our sample was observed as 3 hours and 35 minutes.

5.2.2 Aggregate Tests

a) **Crushing test**

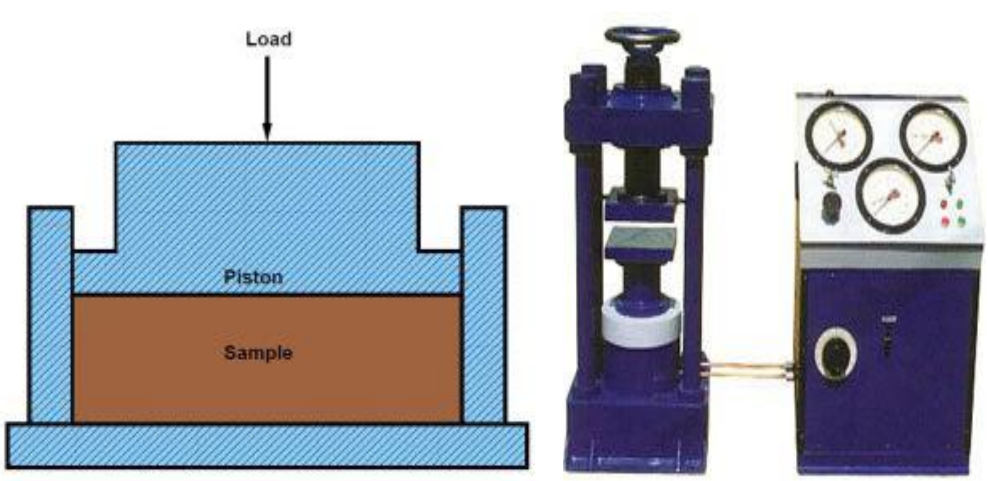


Figure 5.1: Setup for Crushing Test

The crushing strength of aggregates is determined by crushing test which is done in order to find the load under which it fails when compressive stress is applied on it. This test is standardized by IS: 2386 part- IV. This value gives us the relative measure of resistance of the aggregates to crushing when load is applied gradually. In other words, it is the resistance to crushing under severe stress.

The test is carried out using the aggregates of size between 10-12.5 mm. The setup contains a mould of 115mm diameter and 180 mm depth. The load which is applied on the aggregates in the mould is 40 tones and the load is applied for 10 minutes.

The aggregate crushing value of the aggregates is calculated as the material passing through 2.36 mm sieve expressed as the percentage of total aggregate.

Aggregate crushing value = (B/A)*100 %

Where,

B = weight of fraction passing through 2.36 mm sieve = 1.5 kg

A = weight of surface dry sample taken in mould = 6.5 kg

Crushing value = (1.5/6.5)*100 = 23.07 %

b) Abrasion test

Hardness feature of the aggregates is found out by performing abrasion test on them and then depending upon the test results, decision is taken if the aggregates are suitable for the various construction works. There are three types of abrasion tests:

- Los Angeles abrasion test.
- Deval abrasion test.
- Dory abrasion test.

In general, out of the above the types of abrasion tests, Los Angeles test is preferred and most widely used. It also has been standardized in India **(**IS: 2386 part-IV).

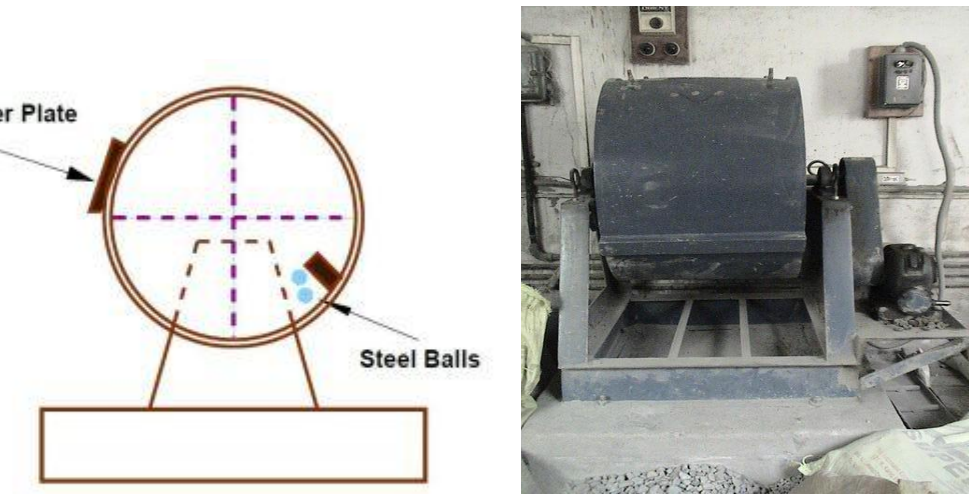


Figure 5.2: Setup for Los Angeles abrasion test

Abrasion test is used to find out the percentage wear. The wear in the test is caused due to the relative rubbing action between steel balls used as abrasive charge in the steel drum and the aggregates.

Aggregates are placed in the rotating steel drum which is attached with a shelf plate attached to its outer wall. The steel drum has a diameter of 700 mm and is 500 mm long. The steel balls used are 48 mm diameter spheres with a weight of 390-455 gm. The rotation of the drum at the time of testing takes place at 30-33 rpm. The number of the steel balls used in the drum varies with the gradation of the aggregates used.

The Los Angeles abrasion value of the aggregates is calculated as the material passing through 1.7 mm sieve expressed as the percentage of total aggregate.

Los Angeles abrasion value = (B/A)*100 %

Where,

B = weight of material passing through 1.7 mm sieve = 0.67 kg

A = weight of total aggregates = 2.1 kg

Abrasion value = (0.67/2.1)*100 = 30.90 %.

c) **Impact test**

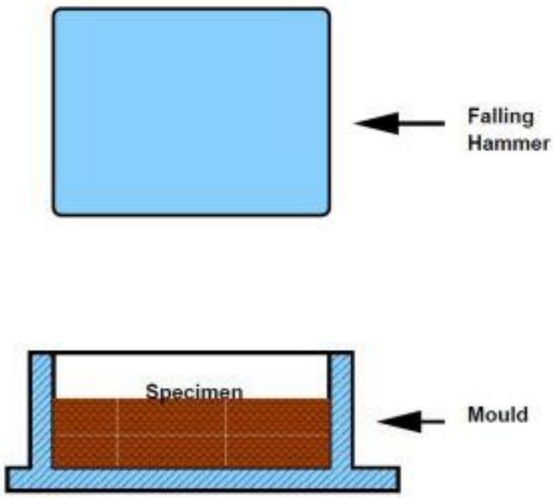


Figure 5.3: Setup for impact test

The aggregate impact test is performed in order to find out the resistance of aggregates to impact or sudden load. The size of the aggregates used for the test should be 10-12.5 mm. the mould which is used to carry out this test is 50 mm deep and has a diameter of 102 mm. the hammer which is used to impart the impact load to the aggregates is 13.5-14 kg and has a fall of about 380 mm. A total of 15 blows are given to the aggregates.

The impact value of the aggregates is calculated as the material passing through 2.36 mm sieve expressed as the percentage of total aggregate.

Aggregate Impact value = (B/A)*100 %

Where,

B = weight of fraction passing through 2.36 mm sieve = 325 g

A = weight of surface dry sample taken in mould = 1.55 kg

Crushing value = (0.325/1.55)*100 = 21 %

d) **Soundness test**

Freezing and thawing causes some aggregates to disintegrate at a very fast rate. This test is conducted to check the durability of such kind of aggregates. This test is meant to investigate the resistance of aggregates against the weathering action. This is done by repeatedly submerging the aggregate sample to be tested in some chemicals. In India, this test is specified in IS: 2386 part-V.

In this test, we soak the aggregate sample in a saturated solution of sodium or magnesium sulphate for 16-18 hours. After the soaking, the sample is dried and heated at a temperature of 105 degree to constant weight. The same procedure is again adopted and a total of 5 cycles is completed. After that, the loss in weight for each fraction of aggregates is observed. The soundness value is the weighted average percent loss for the entire sample. This loss in weight is obtained by sieving out all undersized particles and then weighed.

The loss in weight should be less than 12 % when sodium sulphate is used and is case of magnesium, the limiting value of soundness is 18%.

e) Shape test

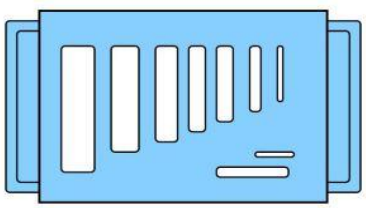


Figure 5.4: Flakiness gauge

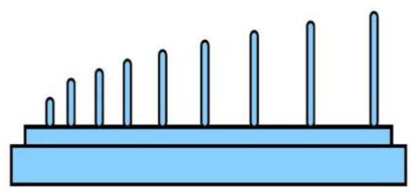


Figure 5.5: Elongation gauge

This test is very important for compaction, workability in PCC and binder requirement in bituminous mixes. Cubic angular aggregates which possess rough texture are considered better in terms of strength but the workability is affected. Rounded aggregates are easier to compact but impart less strength to the concrete. Flat and elongated aggregates often break when compaction is done and result in the decreasing of the strength. The procedure adopted for performing this test has been standardized in India (IS: 2386 part-I)

Flakiness index is the percent by weight of the aggregate particles whose least dimension is less than 0.6 times the average size of the aggregate fraction. It is applicable for the sizes larger than 6.3 mm. Thickness gauge is used.

Elongation index is the percent by weight of the aggregate particles having maximum dimension greater than 1.8 times the average dimension. Length gauge is used.

f) Specific gravity and water absorption test

These two properties of aggregates i.e. specific gravity and water absorption which are very important are used in the design of concrete and bituminous mixes.

Two kilograms of dry aggregates are kept in water for 24 hours. The aggregate sample weight is found in water and thus we get the buoyant weight. Then the same aggregates are placed in oven with a temperature of 100- 110^{o}C for about 24 hours and then weighed.

The specific gravity is calculated by dividing dry weight of aggregates by weight of equal volume of water at a specified temperature. Value of specific gravity of aggregates lies between 2.6 and 2.9.

Water absorption can be expressed as the percent water absorbed in terms of oven dried weight of aggregates. The value of the water absorption should be less than 0.6 % of the weight of aggregates.

g) Sieve analysis

In order to check the gradation of aggregates, sieve analysis is performed on them. The aggregate sample is sieved through a mesh with a standard size and the cumulative percentage of the aggregates passing is plotted against the sieve sizes. It generally done in logarithmic scale and a curve is plotted. The curve thus formed is called as aggregate gradation or particle distribution curve. The procedure adopted is given below:

Take about 2.5 kilograms of aggregates for coarse aggregates as the sample for testing and 0.5 kilograms for fine aggregates. The required number of sieves is taken and then arranged in descending order. This means that the sieve with the smallest opening will be at the bottom and the sieve with the largest opening will be at the top of all of them. The aggregates are poured on the top sieve and the whole arrangement is shaken or vibrated for at least two minutes. Then the measure of weight of aggregates present on each sieve after the vibration is taken and expressed as the percentage of passing. These values of percent passing are compared with the recommended values to check if it lies within that recommended range of gradation or not. If it lies outside that range, then necessary action is needed to fix the problem.

For reference, grading limit of both kinds of aggregates i.e. coarse aggregates and fine aggregates is given below;

Table 5.2: Grading Limit of Fine Aggregate

IS Sieve	Equivalent BS sieve	Percentage passing for			
		Zone 1	Zone 2	Zone 3	Zone 4
10 mm	3/8 –in	100	100	100	100
4.75 mm	3/16 –in	90-100	90-100	90-100	95-100
2.36 mm	N0. 7	60-95	75-100	85-100	95-100
1.18 mm	No. 14	30-70	55-90	75-100	90-100
600 micron	No. 25	15-34	35-59	60-79	80-100
300 micron	No. 52	5-20	8-30	12-40	15-50
150 micron	No. 100	0-10	0-10	0-10	0-15

Table 5.3: Grading Limit of Coarse Aggregate

I.S. Sieve Designation	% passing for graded aggregate of nominal size			
	40 mm	20 mm	16 mm	12.5 mm
80 mm	100	-	-	-
63 mm	-	-	-	-
40 mm	95-100	100	-	-
20 mm	30-70	95-100	100	100
16 mm	-	-	90-100	-
12.5 mm	-	-	-	90-100
10 mm	10-35	25-55	30-70	40-85
4.75 mm	0-5	0-10	0-10	0-10
2.36 mm	-	-	-	-

Table 5.4: Results for coarse aggregates

IS sieve size	Percent retained	Cumulative percent retained	Percent passing
40 mm	0.00	0.00	100
20 mm	3.55	3.55	96.45
10 mm	61.20	64.75	35.25
4.75 mm	31.25	96.00	4.00

5.3 Classification of Waste Tyre Rubber

There is not any specific or defined classification of the waste rubber tyres which are used in the construction industry. Depending up on the size they are cut down after they retire from serving their primary requirement of supporting a vehicle in moving, they have been classified into following types. This is not a very specific or strict classification as at certain points, they are used simultaneously as only one type.

Figure 5.6: Manual cutting of tyre rubber to the size of coarse aggregates

a) Scrap tyres

These can be referred to as a complete waste tyre in its full form with no cutting or shredding being done on it. A typical automobile tyre has a weight of about 9.07 kilograms. Similarly the weight of a truck tyre in general is taken to be about 45.35 kilograms. Table below gives the typical composition by weight of automobile and truck tyres.

Table 5.5: Composition by weight

Composition by percent weight	Automobile tyre	Truck tyre
Natural rubber	14	27
Synthetic rubber	27	14
Carbon black	28	28
Steal	14-15	14-15
Fabric, filler, accelerators	16-17	16-17

Table below gives different the materials used in the manufacture of tyres

Table 5.6: Materials used in tyre

Synthetic Rubber
Natural Rubber
Sulfur and Sulfur compounds
Phenolic resin
Oil (Aromatic, naphthenic, paraffinic)
Fabric (Polyester, Nylon etc)
Petroleum Waxes
Pigments (Zinc oxide, Titanium Dioxide etc)
Carbon black
Fatty acids
Steel wires

b) Slit tyres

This can be referred to as the waste tyre rubber which results when a full tyre is cut down into two or three parts. Different tyre cutting machines are used to carry out this work. These are produced in tyre cutting machines. These machines cut these tyres into pieces and also can also separate the side walls of the tyre from its tread.

c) Shredded and chipped tyres

Shredded or chipped tyres result after the primary and the secondary shredding has been done on the tyre. This simply means that the tyre is cut down into much smaller pieces. The size of these shredded or chipped rubber particles is generally taken as 0.5- 3 inches.

d) Ground rubber

It is a much smaller sized rubber whose size varies with the intended application. Its size also depends upon the type of instrument used to bring it down to this smaller size. At first, these particles are subjected to a dual cycle of magnetic separation. After this they get screened and are recovered in various desirable sizes.

e) Crumb rubber

These are the rubber particles which are the smallest in size when compared to other tyes. These are the powdered form of rubber and can be used as a replacement of the fine aggregates in the concrete. Their size ranges from 0.075- 4.55 mm. There are different methods by which a scrap tyre is converted into crumb rubber. These methods are enlisted below;

- Cracker mill process
- Granular process
- Micro mill process.

CHAPTER 6
RESEARCH METHODOLOGY

6.1 Experimental Setup

The moulds used for the preparation of samples were cubes of size (15cm x15cm x 15cm) for compressive strength testing, the beams of size (50cm x 10cm x 10cm) for flexural testing and the cylinders of size (10cm x 20cm) for split tensile strength testing.

Treatment of rubber wastes involves its surface modification to improve the bond between rubber and the concrete components like cement paste and aggregates and it was done by soaking rubber particles in 0.1 molar solution of NaOH and in cemented suspension for about 20 minutes just before using them in concrete.

A total of 20 cubes, 10 beams and 10 prisms are casted of M20 grade by replacing 5, 10 and 15 percent of natural coarse aggregate with untreated and treated waste tyre aggregate and compared with regular M20 grade concrete

6.2 Mix Proportion

The cement: sand: aggregate ratio of 1:1.5:3 is taken and the calculations of each constituent were done by weight analysis .For replacements, the aggregate replacement %age is taken as in Table 6.1. Water/cement ratio is kept as 0.45 for all samples. The cement with which the mix design is done is OPC 53 grade.

Table 6.1: Mix proportion

S.No	Mix ID	Cement(Kg/m^3)	Fine aggregate(Kg/m^3)	Coarse aggregate(Kg/m^3)		Percent replacement by Rubber	Water cement ratio
				Gravel	Rubber		
1	PC	436	654	1309	00	00	0.45
2	UTR-5	436	654	1243	66	05	0.45
3	UTR-10	436	654	1178	131	10	0.45
4	UTR-15	436	654	1112	196	15	0.45
5	NTR-5	436	654	1243	66	05	0.45
6	NTR-10	436	654	1178	131	10	0.45
7	NTR-15	436	654	1112	196	15	0.45
8	CTR-5	436	654	1243	66	05	0.45
9	CTR-10	436	654	1178	131	10	0.45
10	CTR-15	436	654	1112	196	15	0.45

Where,

UTR-5 represents untreated 5% rubber.

NTR-5 represents sodium hydroxide treated rubber.

CTR-5 represents cement treated rubber.

PC represents plain concrete.

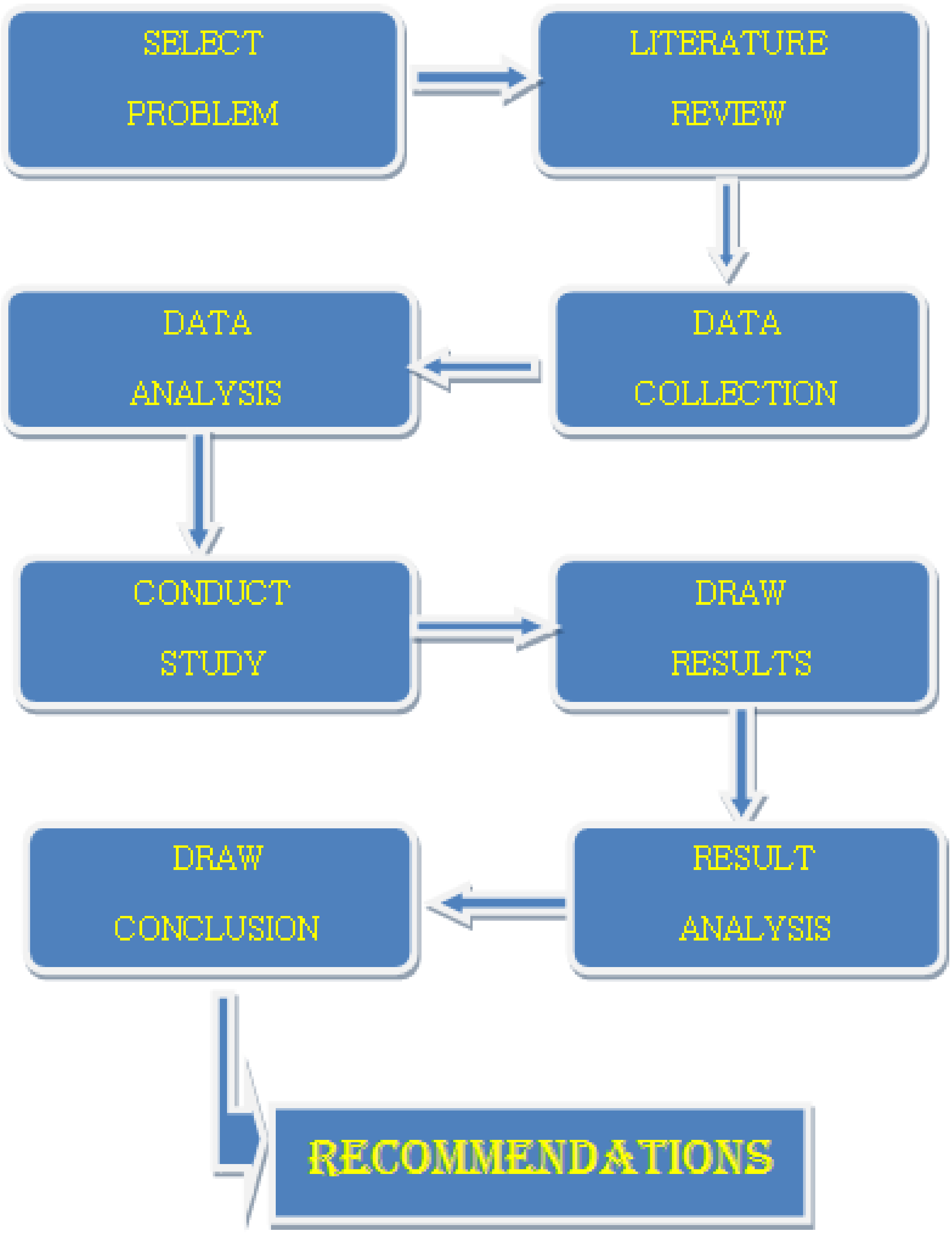
6.3 Treatments

The treatments to the rubber aggregate particles before being used into the casting of our samples are the surface treatment with one molar sodium hydroxide and cement paste. One molar of NaOH solution is prepared and the rubber particles are dipped in the solution for almost 20 minutes before being used in the concrete. Same procedure is adopted in case of the treatment with cement paste in which cement and water is mixed to form a thick paste and then rubber particles are kept soaked in it for almost 20 minutes before being used in the concrete. These treatments are done in order to improve the surface characteristics of the rubber particles so that its bonding with cement in the concrete gets enhanced to impart better strength to the hardened concrete.

Figure 6.1: NaOH-treated Rubber

Figure 6.2: Cement paste-treated rubber

6.4 Work Layout Plan



CHAPTER 7
RESULTS AND DISCUSSION

7.1 Workability

The workability of both the treated and untreated rubberized concrete is found to be less than the plain concrete and decreases with the increase in percentage replacement of aggregates. As seen in the graph in Figure 1, apart from NTR-5, which has a slight increase of 1mm in slump value than the UTR-5, all other replacement levels and treatments show a decrease in the workability as the percentage replacement is increased. Low workability of rubberized concrete (untreated) is due to hindrance of movement of concrete paste and natural aggregates by rubber aggregates and due to improper bonding. When bonding is improved by NaOH treatment, decrease in workability is due to increase in viscosity. When cement paste treatment is given to rubber, workability decreases due to adherence of cement particles on rubber particles which absorb water from concrete and make less water available to provide workability.

Table 7.1: Slump values of different samples

SAMPLE	SLUMP VALUE (mm)	PERCENT REDUCTION OF SLUMP
PC	50	0
UTR-5	47	6
UTR-10	45	10
UTR-15	43	14
NTR-5	48	4
NTR-10	44	12
NTR-15	40	20
CTR-5	45	10
CTR-10	42	16
CTR-15	35	30

Figure 7.1: Rubberized concrete sample for workability test

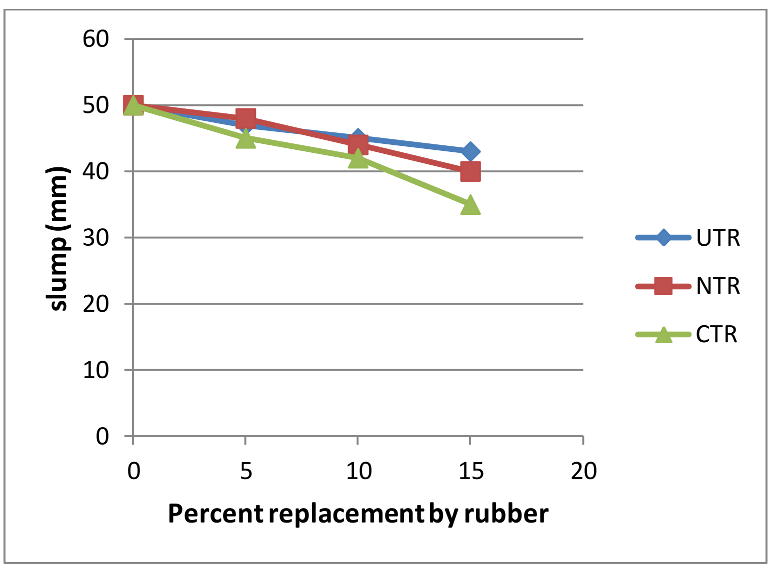


Figure 7.2: Slump vs percent replacement by rubber

7.2 Compressive strength

Table 7.2: Compressive strength of different samples

SAMPLE	7-DAY COMPRESSIVE STRENGTH-CUBE (N/mm^2)	28-DAY COMPRESSIVE STRENGTH CUBE (N/mm^2)
PC	19.11	27.33
UTR-5	13.87	19.80
UTR-10	16.44	23.50
UTR-15	15.60	20.40
NTR-5	16.40	23.30
NTR-10	17.70	25.30
NTR-15	11.11	15.60
CTR-5	15.60	22.2
CTR-10	12.11	15.50
CTR-15	17.33	21.70

The 7 days compressive strength of NTR-10 is found to be highest among all the replaced mixes but lower than plain concrete. However 92.62% compressive strength of plain concrete is regained in this case which is quite satisfactory considering the material used. Similarly, 28 days compressive strength is found to be highest for NTR-10 but again lower than plain concrete. It accounts for 92.57% compressive strength of the conventional normal concrete which is quite considered satisfactory. The compressive strengths of untreated and cement treated rubberized concrete as compared to NTR-10 and plain concrete is found to be very less. Huge difference of elastic modules, lack of decent bonding and low adhesion between concrete constituents and untreated rubber particles may be attributed for less compressive strength. It is also due to low strength of rubber particles than concrete matrix around them and thus when force is applied; cracks first of all appear in contact zone of rubber and concrete matrix.

Figure 7.3: Cube under compression

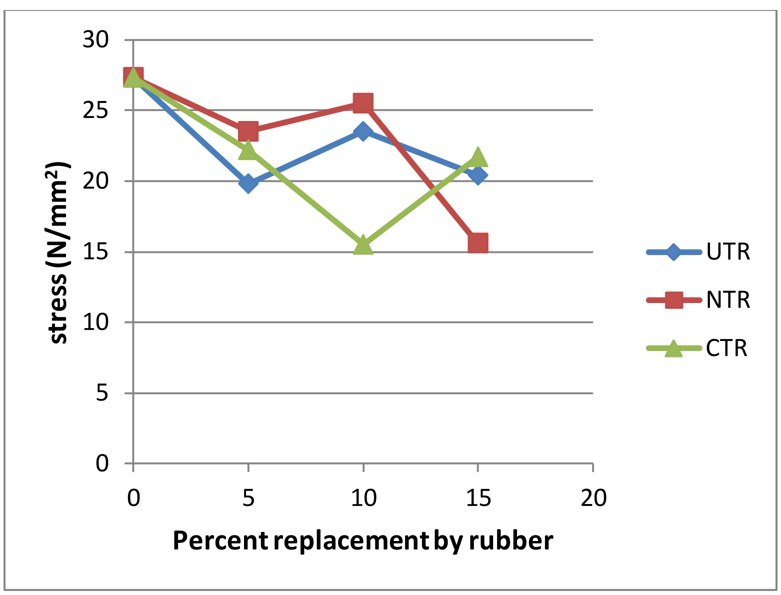


Figure 7.4: Variation of 28 day compressive strength vs percent replacement by rubber

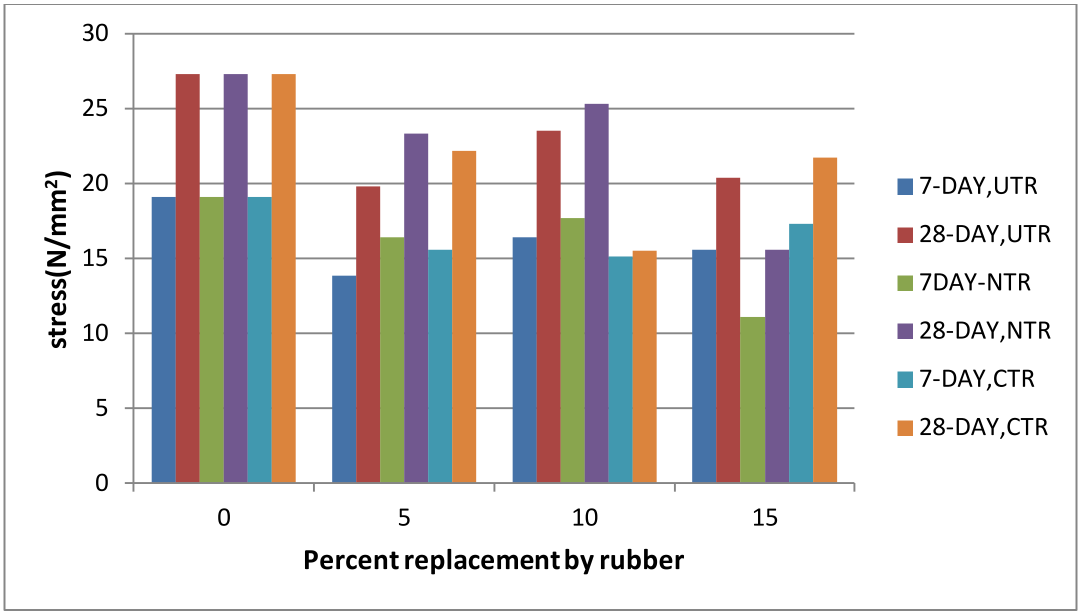


Figure 7.5: Comparison between 7 and 28 day compressive strength on varying percentages of rubber

7.3 Flexural strength

Table 7.3: Flexural strength test results

SAMPLE	28-DAY FLEXURAL STRENGTH BEAM (N/mm^2)	ULTIMATE LOAD (KN)	DISPLACEMENT (mm)
PC	8.10	16.20	0.96
UTR-5	7.95	15.90	1.12
UTR-10	6.90	13.80	1.10
UTR-15	6.40	14.80	0.80
NTR-5	9.30	18.60	1.30
NTR-10	8.75	17.50	1.50
NTR-15	7.51	15.02	1.38
CTR-5	9.25	18.50	1.60
CTR-10	8.51	17.02	1.45
CTR-15	8.00	16.00	1.30

Flexural strength shows a varying trend in our present study. 28 days flexural strength of NTR-5 is found to be highest among all replacement mixes as well as plain concrete. Untreated rubber concrete showed decrease in flexure strength while as treated rubber showed varying trend. In case of the treated rubberized concretes, the maximum flexural strength corresponds to 5% replacement level while as minimum flexural strength corresponds to 15% replacement. The increase in strength as compared to the normal conventional concrete at 5% replacement by treated rubber is found to be around 13%. The mixtures with less cement content are less stiff. As the rubber aggregates can bridge cracks caused by flexural loading, the less stiff specimens with rubber aggregates can withstand additional loading after cracking. Thus increase in treated rubber aggregate content increases the flexural strength but only up to a replacement range of 5%.

Figure 7.6: Two point flexural loading on beam

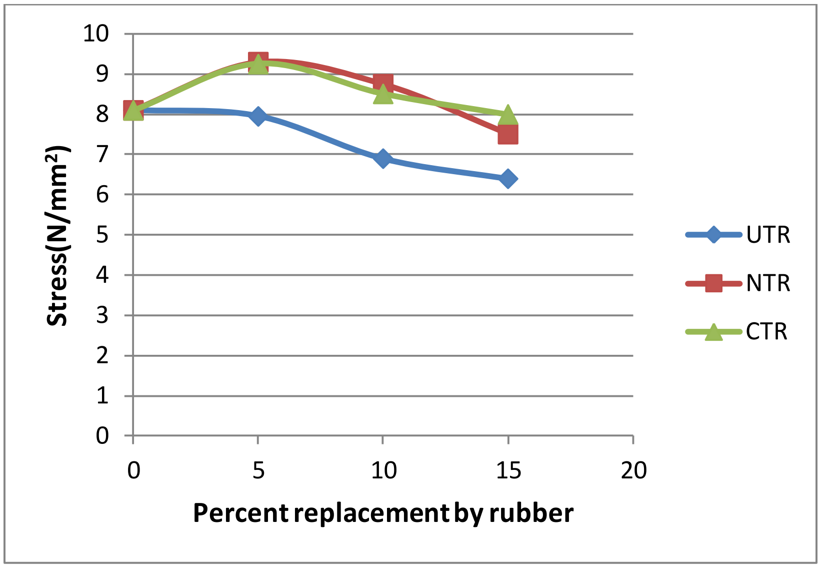


Figure 7.7: Variation of 28 day flexural strength vs percent replacement by rubber

7.4 Split tensile strength

Table 7.4: Split tensile strength of different samples

SAMPLE	28-DAY SPLIT TENSILE STRENGTH CYLINDER (N/mm^2)
PC	2.38
UTR-5	2.10
UTR-10	1.90
UTR-15	1.60
NTR-5	3.82
NTR-10	5.72
NTR-15	6.36
CTR-5	4.76
CTR-10	4.28
CTR-15	4.07

Split tensile strength after 28 days is found to be greater in each case where treated rubber is used, and it is found to be highest at NTR-15(Sodium hydroxide treated with 15% replacement). At this replacement level, the split tensile strength is 2.67 times strength of normal concrete which is very huge and encouraging. This Increase in split tensile strength after giving treatment to rubber is due to combined effect of improved bonding by treatment and flexible nature gained by concrete due to rubber particle.

Figure 7.8: cylinder under split tensile load

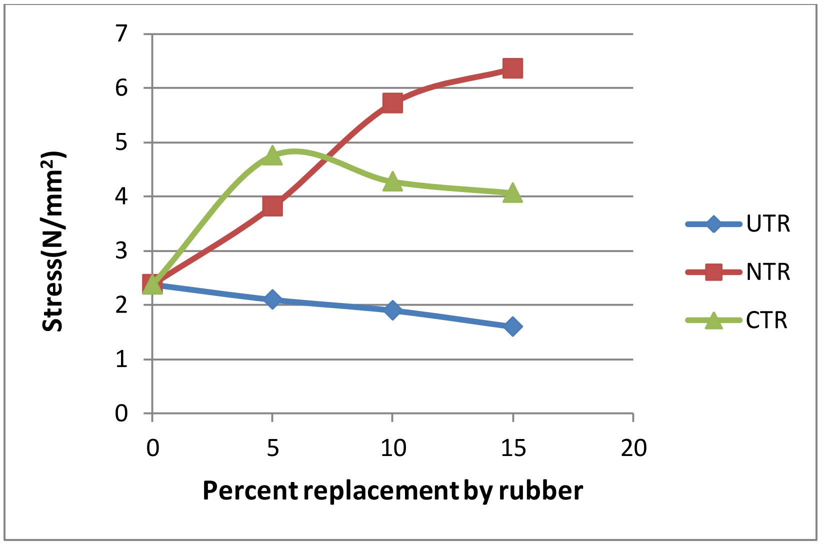


Figure 7.9: Variation of 28 day split tensile strength vs percent replacement by rubber

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

8.1 Conclusion

1 Rubber has great capability of becoming a permanent member of concrete family because of its wide variety of decent properties like better flexibility, light weight and easy availability. It can be very environmental friendly to use this waste material in construction industry.

2 Treated rubberized concrete possesses more compressive strength as compared to the untreated rubberized concrete. However, even after the surface treatment is given to the rubber, only 92.57% compressive strength of normal conventional concrete is regained.

3 Flexural and split tensile strength of almost all replacement levels of treated rubberized concrete is found to be more than in the normal conventional concretes. 28 day flexural and split tensile strength is found to be highest at NTR-5 and NTR-15 respectively.

4 The purpose of this study was to determine if a waste material like worn out tyres enhance the basic properties of concrete. The data presented in this research shows that there is great potential for the utilization of tyres as aggregates. It is considered that used tyres would provide much greater opportunities for value adding and cost recovery, as it could be used as a replacement for more expensive material such as rock aggregate.

5 Using rubber aggregates decreases the workability of the resultant mix, but this problem can be dealt with the use of the certain plasticizers.

8.2 Future Scope

Easy availability of waste tyre rubber and never ending output of waste tyres from the tyre industry means that this waste product will always need to be recycled. And based on the present research and other work done on this topic, there is great potential of tyre rubber to be used in the construction industry. The use of waste tyre rubber results in more economical and eco friendly concrete. Also if some treatments are provided to rubber, the strength properties surely increase. If some new and better techniques of its use are found to overcome the present flaws which previous researches have shown, there will be greater opportunity for waste tyre rubber to be used in the construction industry.

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