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EXPERIMENTAL AND ANALYTICAL STUDY ON SOIL STABILIZATION USING WASTE CRUMB RUBBER TYRE FOR ENHANCED SUBGRADE PERFORMANCE

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ABSTRACT

Pervious concrete, also known as permeable or porous concrete, is characterized by its high water permeability due to the presence of interconnected void structures that allow water to pass freely through it. This study presents a synergistic evaluation of key parameters such as porosity, compressive strength, and water permeability in recycled aggregate-based pervious concrete.

The experimental investigation focuses on determining void content, compressive strength at 7 and 28 days and permeability using the falling head method. It was observed that optimizing aggregate size combinations, particularly within the ranges of 10-5 mm and 3-5 mm, leads to an improvement in compressive strength.

The relationship between porosity and 28-day compressive strength was found to be adversely affected when recycled aggregates were used in place of natural aggregates. However, other influencing factors such as binder type, age of concrete, aggregate size and specimen configuration exhibited a moderate effect on the porosity-strength relationship.

The results further indicate that the permeability of pervious concrete is primarily governed by its porosity and is not significantly influenced by the replacement of natural aggregates with recycled aggregates. The interrelationship among compressive strength, porosity and permeability developed in this study can be effectively utilized for mix proportioning of pervious concrete using both natural and recycled coarse aggregates to meet the desired

strength and permeability requirements.

KEYWORDS: Permeability, Pervious Concrete, Recycled Concrete Aggregate, Porosity, Mix Design, Compressive Strength.

1. INTRODUCTION

1.1 General

Civil engineers encounter a wide range of soils weak, strong, soft, and hard yet construction must proceed under all such conditions. To achieve the required engineering properties, a technique known as soil stabilization is used. It involves improving soil strength, reducing permeability and compressibility, and enhancing durability through methods such as compaction, use of stabilizers, admixtures, and other treatments.

Soil stabilization is widely applied in pavement construction, where the primary goal is to increase stability while reducing overall project cost. Traditionally, materials like lime and cement are used, but their high cost and environmental impact have encouraged the use of locally available and waste materials. One such material is crumb rubber obtained from waste tires. Its utilization not only reduces environmental hazards but also improves certain engineering properties of soil, especially when used as a partial replacement with cement.

This study focuses on evaluating the optimum proportion of crumb rubber tire in soil stabilization and its effect on properties such as optimum moisture content, maximum dry density, unconfined compressive strength, and California Bearing Ratio (CBR). Results indicate that while crumb rubber enhances some properties, a small amount of cement is still necessary to achieve adequate strength and durability. Thus, the combined use of crumb rubber and cement provides a cost-effective and environmentally sustainable solution for pavement construction.

1.2 Need of Present Study

The rapid growth of the automobile industry has led to a significant increase in the generation of waste tyres worldwide, creating serious environmental and disposal challenges. Conventional disposal methods such as stockpiling, landfilling, and open burning pose severe threats to human health and the environment. Stockpiled tyres act as breeding grounds for mosquitoes and vermin, increasing the risk of diseases, while also creating fire hazards that are difficult to control and release toxic gases. Landfilling of tyres reduces landfill capacity due to their non-biodegradable nature and tendency to resurface, causing damage to landfill covers. Open burning of tyres leads to the emission of harmful pollutants such as dioxins, furans, and other toxic gases, contributing to air pollution and health hazards.

In developing countries like India, the increasing demand for infrastructure, particularly in highway construction, requires cost-effective and sustainable construction materials. At the same time, the availability of conventional stabilizing agents such as cement and lime is becoming expensive and environmentally unsustainable due to high energy consumption and carbon emissions. In this context, the utilization of waste crumb rubber tyre as a soil stabilizing material presents a promising solution. The use of crumb rubber not only addresses the problem of waste disposal but also enhances the engineering properties of weak sub-grade soils, such as improving strength and bearing capacity. This dual benefit makes it an attractive alternative for sustainable pavement construction. Furthermore, the need to identify the optimum proportion of crumb rubber for maximum improvement in soil properties necessitates detailed experimental investigation. Therefore, this study aims to evaluate the effect of varying percentages of crumb rubber tyre on the engineering behavior of clayey soil, with a focus on parameters such as compaction characteristics, strength and California Bearing Ratio (CBR). Hence, the present study is undertaken to develop an eco-friendly, economical and efficient method of soil stabilization using waste tyre rubber, contributing towards sustainable infrastructure development and effective waste management.

1.3 Objectives of the Study

The main objectives of the present study are to:

- Study the basic engineering properties of clayey soil.
- Investigate the effect of varying percentages of crumb rubber tyre (2%, 4%, 6%, 8%, and 10%) on soil properties.
- Determine the compaction characteristics such as Optimum Moisture Content (OMC) and Maximum Dry Density (MDD).
- Evaluate the strength characteristics of stabilized soil using Unconfined Compressive Strength (UCS) test.
- Determine the California Bearing Ratio (CBR) values for different proportions of crumb rubber.
- Identify the optimum percentage of crumb rubber for maximum improvement in soil performance.
- Assess the suitability of crumb rubber stabilized soil for pavement sub-grade applications.

1.4 Scope of the Study

- The study is limited to laboratory investigation on clayey soil.
- Crumb rubber tyre is used as a stabilizing material in varying proportions.
- Standard laboratory tests such as Atterberg limits, Proctor compaction test, UCS, and CBR tests are conducted.
- The study focuses on evaluating compaction, strength, and bearing capacity characteristics of soil.
- Field implementation and long-term performance analysis are beyond the scope of this study.
- Environmental and economic benefits are discussed qualitatively.

1.5 Problem Statement

Because they don't break down and can be harmful when thrown away in ways like burning or landfilling, getting rid of old tires has become a big environmental problem. Weak sub-grade soils with low bearing capacity make it much harder to build roads, which raise the costs of both building and maintaining them.

Using cement and lime to stabilise soil is effective, but it costs a lot and has a negative impact on the environment because it releases carbon. So, we need to look into other, cheaper, and more environmentally friendly ways to stabilise things.

In this case, used crumb rubber tires could make the soil better while also solving the problem of getting rid of trash. However, systematic experimental investigation is necessary to assess its efficacy and to identify the optimal proportion for maximising enhancements in soil strength and bearing capacity.

2. Literature Review

2.1 Introduction

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

A lot of research work has been carried out in the materials used for soil stabilization.

Brajesh Mishra had studied that the soil strength is effectively improved by the use of different percentage of lime contents. Addition of lime to expansive soil brings major changes in compaction and strength behavior of expansive soil.

Umar Jan and Vinod kumar Vinpulkerni investigated soil stabilization using shredded rubber tyre and their investigation. Helps in increasing the load carrying capacity of soil with reduced swelling potential due to the addition of rubber.

V.Mallikarjuna and T.Bindu Mani carried out soil stabilization by using proper proportions of plastic content which helps in increasing the CBR of the soil.

Dr.P.G. Rakaraddi had investigated using rubber crumbs and concluded that the increased CBR helps to reduce the total thickness of the pavement.

Phani Kumar, D. Ganga, P. Swathi, Priyadarsini, Ch. Naga Bharath carried out investigation on soil stabilization using rubber tyre chips and concluded that the stabilization along with rubber tyre chips increases the CBR value which leads to increased strength.

3. Material Used

3.1 Soil

Residual clayey soil, which is commonly found in the Raipur region of Chhattisgarh, is used in the present study. The soil sample was collected from a depth of approximately 0.5 m using the disturbed sampling method. The selected soil represents locally available sub-grade soil conditions typically encountered in pavement construction in and around Raipur.

A soil mass consists of solid particles forming a porous structure, where the voids may be filled with air, water, or a combination of both. In general, soil is a three-phase system comprising solid particles, water, and air. The engineering behavior of soil depends on the interaction between these phases.

To analyze the type and characteristics of soil, various properties need to be studied, including water content, void ratio, porosity, degree of saturation, bulk density, specific gravity, and Atterberg limits. These properties play a crucial role in determining the suitability of soil for construction purposes, particularly in sub-grade applications.

Water Content: - the water content is defined as the ratio of the mass of water to the mass of soil. It is expressed as a percentage but used as a decimal in computation. The water content of fine grained soils such as silts, clays is more than the coarse grained soils such as gravels and sands. The water content of some soils can be more than 100%, which indicate that more than 50% of total mass is that of water. Water content of soil is an important property the characteristics of soil, especially a fine grained soil, change to a marked degree with the variation of its water content.

$W = (W_w/W_s) \times 100$

Void ratio: - it is defined as the ratio of the volume of voids to the volume of solids. Thus

$e = (V_v/V_s)$

For coarse grained soils, the void ratio is generally smaller than that for fine grained soil; it may have a value even greater than unity.

Porosity: - it is defined as the ratio of volume of voids to the total volume. Thus

$n = (V_v/V)$

Porosity is generally expressed as percentage. Both porosity and void ratio are measures of the denseness. As the soil becomes more and more dense their void ratio and porosity decreases.

Degree of Saturation: - it can be defined as the ratio of volume of water to the volume of voids.

$S = V_w/V_v$

It is generally expressed as percentage. It is equal to 0% when soil is completely dry and 100% when soil is fully saturated.

Percentage Air Voids: - it is the ratio of the volume of air to the total volume.

$A = V_a/V$

Air Content: - it is the ratio of volume of air to the volume of voids. Thus

$a_c = V_a/V_v$

Bulk Unit Weight: - the bulk unit weight is defined as the total weight per unit total volume.

$\gamma = W/V$

Specific Gravity of Solids: - it is defined as the ratio of the mass of the given volume of solids to the mass of an equal volume of water at 4°C.

G = ρs/ρw

Various Clay Minerals: -the coarse grained soils generally contain the mineral quartz and feldspar. These minerals are strong and electrically inert. The behavior of such soils does not depend upon the nature of the nature of the minerals present. The behavior of fine grained soil, on the other hand depends on the nature and characteristic of the minerals. The most significant property of clay depends on the type of mineral. The various minerals that are present in soil are: The soil particles are also classified on the basis of their shape and size. Mechanical analysis is used to separate the soil into different fractions based on the particle size.

Table 3.1 Properties of the Residual Soil.

Physical Properties	**Value (%)**
Natural Water Content	13.7%
Liquid Limit	39.15%
Plastic Limit	28.85%
Plasticity Index	10.3%
Linear Shrinkage	6.71%
Specific Gravity	2.306

Table 3.2 Particles of soil.

Sand	40%
Silt	44%
Clay	18%

3.2 Waste Crumb Rubber Tire

Crumb rubber wastes can be used as a light weight material either in the form of powder, chips, shredded and as whole. They are used above and below ground water. Many works regarding the use of scrap tire in geotechnical application have been done especially as embankment material. The reuse application for tire is how the tire are processing basically includes shedding, removing of metal reinforcing and further shredding until the desired material are achieved. Scrap tire perhaps rank among the most extensively researched and implemented recycled material in recent year. Potentially usable forms include whole tire, sliced tires, tire chips, and smaller soil like particles referred to collectively as crumb rubber.

Table 3.3 Properties of Crumb Rubber Tire.

Constituent	**Composition (%)**
Ash Content %	09 - 11%
Acetone %	10 - 12%

Moisture %	0.010%
Carbon Black %	22 - 24%
Specific Gravity %	1.5 - 2.0%
RHC (By Difference) %	60 - 65%

Figure 3.1 Use Crumb Rubber Tire Particles for Soil Stabilisation in an Experimental Study.

4. METHODOLOGY

4.1 General

The laboratory tests were performed first on natural soil which includes optimum moisture content, atterberg's limits, unconfined compaction test, and California bearing ratio test. The unconfined compaction test, and California bearing ratio test were conducted on optimum moisture content and maximum dry density. Later on specimens were made by adding three different percentage of waste crumb rubber tire i.e. 2%, 4%; 6%; and 8% along crumb rubber tyre in each case to add adequate soil property to the mix. For all these three proportions effects were studied on the properties of soil like optimum moisture content, unconfined compression strength, maximum dry density and California bearing ratio values. The various tests conducted are discussed here:-

4.2 Water Content Test

The water content is the measure of wetness of a soil mass. The water content can be determined by one of the following methods:

- Oven drying method
- Torsion balance method
- Pycnometer method
- Sand bath method

- ❖ Alcohol method
- ❖ Calcium carbide method
- ❖ Radiation method

Procedure: - take the reprehensive soil sample of measured weight.
Obtain the weight of the dry container with lid.
Measure the weight of sample with container
Dry the sample for a period of 16 hrs or till constant mass.
Again measure the weight of sample with container.
Calculations: - Weight of water (Ww) = W1-W2
Weight of solid particles (Ws) = W2-Wc
Water content WC = Ww/Ws *100

Table 4.1 Water Content.

S. No.	Sample	Ww	Ws	% Wc
1	Natural Soil	37 gm	200 gm	18.5%
2	Soil +2% Crumb Rubber tire	48 gm	200 gm	24 %
3	Soil +4% Crumb Rubber Tire	52 gm	200 gm	26 %
4	Soil +6% Crumb Rubber Tire	54 gm	200 gm	27 %
5	Soil +8% Crumb Rubber Tire	55.8 gm	200 gm	27.9 %
6	Soil +10% Crumb Rubber Tire	58 gm	200 gm	29 %

4.3 Consistency/Atterberg's Limit

The consistency of fine grained soil is the physical state in which it exists. It is used to denote the degree of fineness of the soil. The consistency of soil is indicated by soft, firm or hard. The water content at which the soil changes from one state to the other are known as consistency limits or Atterberg's limits.

A soil containing high water content is in a liquid state. It offers no shearing resistance and can flow like liquid. It has no resistance to shear deformation and therefore shear strength is zero. As the water content is reduced the soil becomes stiffer and starts developing resistance to shear deformation. At some particular water content, soil becomes plastic. The water content at which the soil changes from liquid state to plastic state is known as liquid limit. In other words the liquid limit is the water content at which soil ceases to be liquid.

The soil in the plastic state can be molded into various shapes. As the water content is reduced the plasticity of the soil decreases. Ultimately the soil passes from the plastic state to the semi solid state and stops behaving like plastic. It clacks when molded. The water content at which the soil becomes semisolid is known as plastic limit. The numerical difference between liquid limit and plastic limit is known as plasticity index.

PI = LL-PL

Liquid Limit Test

The liquid limit is the water content at which the soil changes from the liquid state to plastic state. At the liquid limit, the clay is practically like a liquid, but possesses a small shearing strength. The shearing strength at that stage is the smallest value that can be measured in the laboratory.

Figure 4.1 Experimental Setup for Liquid Limit Determination Using Casagrande Apparatus

Table 4.2 Liquid Limit Determination.

Sample	**Natural Soil**	**2% Crumb Rubber Tire**	**4% Crumb Rubber Tire**	**6% Crumb Rubber Tire**	**8% Crumb Rubber Tire**	**10% Crumb Rubber Tire**
Determination no.	1	1	1	1	1	1
No. of Blows	25	24	23	22	21	20
Weight of Container + Weight of soil (W_1)	32	34	35	36	37	38
Weight of container (W_0)	12	12	12	12	12	12
Weight of Container + Oven dry soil (W_2)	26	27	28	29	30	31
Weight of Water (W_1-W_2)	6	7	7	7	7	7
Weight of Oven Dry Soil (W_2-W_0)	14	15	16	17	18	19
(W_1-W_2/W_2-W_0)×100	42.85%	46.66%	43.75%	41.17%	38.88%	36.84%

4.3.1 Proctor Test

Theory: soil compaction is the process of application of stress on soil to increase the density of soil; this is achieved by the removal of air from the pores of soil. It is an instantaneous process unlike consolidation which is a time dependent process. Compaction requires soil in three phases.

Apparatus required:

- Proctor mould having volume 944cc. internal dia.10.2 cm and height 11.6 cm with a collar assembly and detachable plate.
- Rammer having weight 2.5 kg.
- Sample extruder with mixing tools like mixing pan, spatula, towel and spoon.
- Weight balance of 15 kg capacity.

Procedure:

- Take oven dried sample mix it with desired water content and mix thoroughly.
- Place the sample in three layers in the mould by compacting in three layers with 25 blows of 2.5 kg rammer on each layer.
- Remove the collar and trim the sample weight it accurately.
- Calculate the density by dividing the weight of sample with volume i.e. 944cc.
- Remove the sample from upper and lower portion of sample to calculate OMC.

Figure 4.2 Standard Proctor Compaction Test in Laboratory.

Density: (Proctor Test)

Table 4.3 Density Proctor Test.

Determination no.	Soil	Soil+2% Crumb Rubber Tire	Soil+4% Crumb Rubber Tire	Soil+6% Crumb Rubber Tire	Soil+8% Crumb Rubber Tire	Soil+10% Crumb Rubber Tire
Weight of empty mould + Base Plate (W_1)kg	5090	4995	4985	4940	4870	4710
Weightof compacted soil + Base plate (W_2) kg	2110	2015	2005	1960	1890	1730
Bulk unit weight of compacted soil γ (gm/cc)	2.11	2.015	2.005	1.96	1.890	1.73
Water Content (w)	13.75%	14.59%	14.05%	13.01%	12.68%	11.96
Dry unit weight γd = γ/(1+w).(gm./cc)	1.85%	1.76	1.761	1.73	1.68	1.55

Figure 4.3 Measurement of Cylindrical Soil Sample.

Dia. of mould = 100 mm

Height of mould=127.3 mm

Volume of mould=1000 cm^3

4.3.2 California Bearing Ratio Test

California bearing ratio is the ratio of force per unit area required to penetrate into a soil mass with a circular plunger of 50mm diameter at the rate of 1.25 mm/min.

The tests used to evaluate the strength properties of soils may be broadly divided into three groups:

- ❖ Shear tests
- ❖ Bearing test
- ❖ Penetration tests

Apparatus

- ❖ Moulds 2250cc capacity with base plate, stay rod and wing nut
- ❖ Collar confirming
- ❖ Spacer Disc confirming
- ❖ Metal rammer confirming
- ❖ Expansion measuring apparatus with the adjustable stem, perforated plates, tripod
- ❖ Loading machine having a capacity of at least 5000kg and equipped with a Movable head or base that travels at a uniform rate of 1.25mm / min for use in Forcing the penetration plunger in to the specimen.
- ❖ Dial gauge two numbers reading to 0.01mm.
- ❖ IS sieves 37.50 or 22.50 or 19 mm and 4.75 mm.
- ❖ Miscellaneous apparatus such as mixing bowl, straight edge, scales, soaking tank, drying oven, filter paper, dishes and calibrated measuring jar.

Procedure

- ❖ There are two types of methods in compacting soil specimen in the CBR moulds

a) Static Compaction method.

b) Dynamic Compaction method.

- ❖ The material used in the above two methods shall pass 19mm sieve for fine grained soils and 37.50 mm sieve for coarse materials up to 37.50 mm.
- ❖ Replace the material retained on 19 mm sieve by an equal amount of material passing 19 mm sieve and retained on 4.75 mm sieve
- ❖ Replace the material retained on 37.50mm sieve by an equal amount of material passing 37.50 mm sieve and retained on 4.75mm sieve.

a) Static Compaction

❖ In this method calculate the mass of wet soil at required moisture content to give a desired density when compacted in a standard test mould as given below

Volume of mould = 2250cc.

Weight of dry soil (W) = 2250 x MDD

Weight of wet soil =1+ m/100 x W

Weight of water = Weight of wet soil - Weight of dry soil.

m = Optimum moisture content obtained from the laboratory compaction test.

❖ Take oven dried soil sample of calculated weight and thoroughly mix with water (OMC) as obtained from the above equation.

❖ Record the empty weight of the mould with base plate, with extension collar removed (m_1).

❖ Place the correct mass of the wet soil in to the mould in five layers.

❖ Gently compact each layer with the spacer disc.

❖ Place a filter paper on top of the soil followed by a 5cms displacer disc.

❖ Compact the mould by pressing it in between the platens of the compression testing machine until the top of the spacer disc comes flush with the top of the mould.

❖ Held the load for about 30 seconds and then release.

❖ In some soil types where a certain amount of rebound occurs, it may be necessary to reapply load to force the displacer disc slightly below the top of the mould so that on rebound the right volume is obtained.

❖ Remove the mould from the compression testing machine.

❖ Remove the spacer disc and weigh the mould with compacted soil (m_2).

❖ Replace the extension collar of the mould.

❖ Prepare two more specimens in the same procedure as described above.

b) Dynamic Compaction

❖ Take representative sample of soil weighing approximately 6 kg and mix thoroughly at OMC.

❖ Record the empty weight of the mould with base plate, with extension collar removed (m1).

❖ Replace the extension collar of the mould.

❖ Insert a spacer disc over the base plate and place a coarse filter paper on the top of the spacer disc.

❖ Place the mould on a solid base such as a concrete floor or plinth and compact the wet soil in to the mould in five layers of approximately equal mass each layer being given 56 blows with 4.90kg hammer equally distributed and dropped from a height of 450 mm above the soil.

❖ The amount of soil used shall be sufficient to fill the mould, leaving not more than about 6mm to be struck off when the extension collar is removed.

❖ Remove the extension collar and carefully level the compacted soil to the top of the mould by means of a straight edge.

❖ Remove the spacer disc by inverting the mould and weigh the mould with compacted soil (m_2).

❖ Place a filter paper between the base plate and the inverted mould.

❖ Replace the extension collar of the mould.

❖ Prepare two more specimens in the same procedure as described above.

❖ In both the cases of compaction, if the sample is to be soaked, take representative samples of the material at the beginning of compaction and another sample of remaining material after compaction for the determination of moisture content.

❖ Each sample shall weigh not less than 100g for fine-grained soils and not less than 500 for granular soils.

❖ Place the adjustable stem and perforated plate on the compacted soil specimen in the mould.

❖ Place the weights to produce a surcharge equal to the weight of base material and pavement to the nearest 2.5 kg on the perforated plate.

❖ Immerse the whole mould and weights in a tank of water allowing free access of water to the top and bottom of specimen for 96 hours.

Table 4.4 CBR Test Value.

Penetration Depth (mm)	Unit Standard Load (kgf/cm^2)	Total Standard Load (kgf)
2.50	70	1370
5.00	105	2055
7.50	134	2630
10.0	162	3180
12.5	183	3600

Table 4.5 Ordinary Soil

Value of one Division in Dial Ring = 1kg

Penetration	Proving Ring Reading	Axial Load Kg/cm^2	Unit Standard Load	CBR (%)
0.0				
0.5	30			
1.0	41			

1.5	46			
2	52			
2.5	56	3.472	70	4.96%
3	59			
4	67			
5	72	4.464	105	4.25%
7.5	85			
10				
12.5				

Table 4.6 Soil + 2% Crumb Rubber Tyre.

Penetration	Proving Ring Reading	Axial Load Kg/cm^2	Unit Standard Load	CBR (%)
0.0				
0.5	32			
1	39			
1.5	46			
2	52			
2.5	56	3.472	70	4.96%
3	58			
4	64			
5	72	4.464	105	4.25%
7.5	80			
10				
12.5				

Table 4.7 Soil + 4% Crumb Rubber Tyre

Penetration	Proving Ring Reading	Axial Load Kg/cm^2	Unit Standard Load	CBR (%)
0.0				
0.5	28			
1	40			
1.5	46			
2	52			
2.5	57	3.534	70	5.04%
3	60			
4	65			
5	68	4.216	105	4.00%
7.5	75			
10				
12.5				

Table 4.8 Soil + 6% Crumb Rubber Tyre.

Penetration	Proving Ring Reading	Axial Load kg/cm^2	Unit Standard Load	CBR (%)
0.0				
0.5	18			
1	32			
1.5	40			
2.0	54			

2.5	58	3.59	70	5.12%
3	64			
4	78			
5	96	5.95	105	5.66%
7.5	124			
10				
12.5				

Table 4.9 Soil + 8% Crumb Rubber Tyre.

Penetration	Proving Ring Reading	Axial Load kg/cm^2	Unit Standard Load	CBR (%)
0.0				
0.5	9			
1	21			
1.5	39			
2	56			
2.5	68	4.216	70	6.022%
3	78			
4	93			
5	106	6.572	105	6.25%
7.5	136			
10				
12.5				

Table 4.10 Soil + 10% Crumb Rubber Tyre.

Penetration	Proving Ring Reading	Axial Load kg/cm^2	Unit Standard Load	CBR (%)
0.0				
0.5	14			
1	24			
1.5	46			
2	58			
2.5	70	4.34	70	6.2%
3	82			
4	104			
5	124	7.68	105	7.31%
7.5	138			
10				
12.5				

Figure 4.4 Load Frame Setup for California Bearing Ratio (CBR) Test.

5 RESULT ANALYSIS

5.1 Water Content Variation

Figure 5.1 shows the variation of water content with respect to the percentage of crumb rubber tyre (CRP). It is observed that the water content of soil increases gradually with the increase in crumb rubber content. The natural soil exhibits a water content of about 18.5%, which increases to approximately 24%, 26%, 27%, 27.9%, and 29% for 2%, 4%, 6%, 8%, and 10% crumb rubber tyre respectively. This increasing trend can be attributed to the hydrophobic nature of crumb rubber particles, which do not absorb water. The inclusion of rubber particles in the soil increases the void spaces and reduces the cohesion between soil particles.

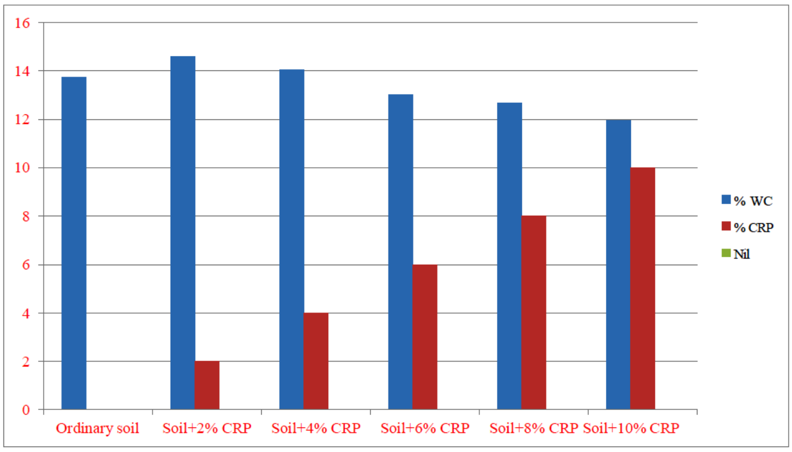

Figure 5.1 Graphs between Water Content Vs % Crumb Rubber Tyre.

5.2 Dry Density Variation

Figure 5.2 shows the variation of dry density with respect to the percentage of crumb rubber tyre (CRP). It is observed that the dry density of soil decreases with the increase in crumb rubber content. The maximum dry density of natural soil is about 1.85 gm/cc, which gradually decreases to approximately 1.76, 1.76, 1.73, 1.68 and 1.55 gm/cc for 2%, 4%, 6%, 8% and 10% crumb rubber tyre respectively. This decreasing trend is mainly due to the low specific gravity and lightweight nature of crumb rubber particles compared to soil. The addition of rubber particles creates more voids within the soil matrix and reduces the compactness of the mixture. As a result, the overall dry density of the soil rubber mix decreases with increasing rubber content.

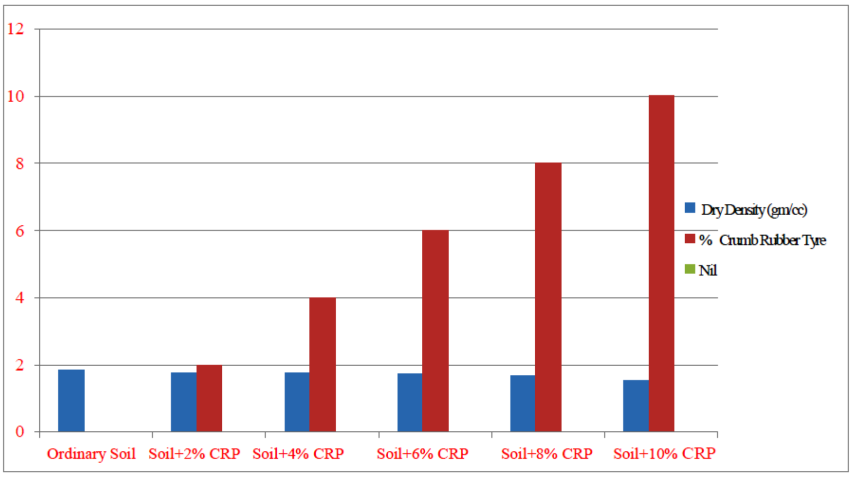

Figure 5.2 Graphs between MDD Vs % Crumb Rubber Tyre.

5.3 CBR Value Variation

Figure 5.3 shows the variation of California Bearing Ratio (CBR) with respect to the percentage of crumb rubber tyre (CRP). It is observed that the CBR value of soil increases with the increase in crumb rubber content. The natural soil shows a CBR value of about 4.96%, which gradually increases with the addition of crumb rubber tyre, reaching approximately 5.04%, 5.12%, 6.02%, and 6.20% for 4%, 6%, 8%, and 10% CRP respectively.

This increasing trend is attributed to the reinforcing effect of crumb rubber particles within the soil matrix. The rubber particles improve load distribution, increase resistance to penetration, and enhance the flexibility of the soil. As a result, the soil exhibits better strength and bearing capacity under loading conditions.

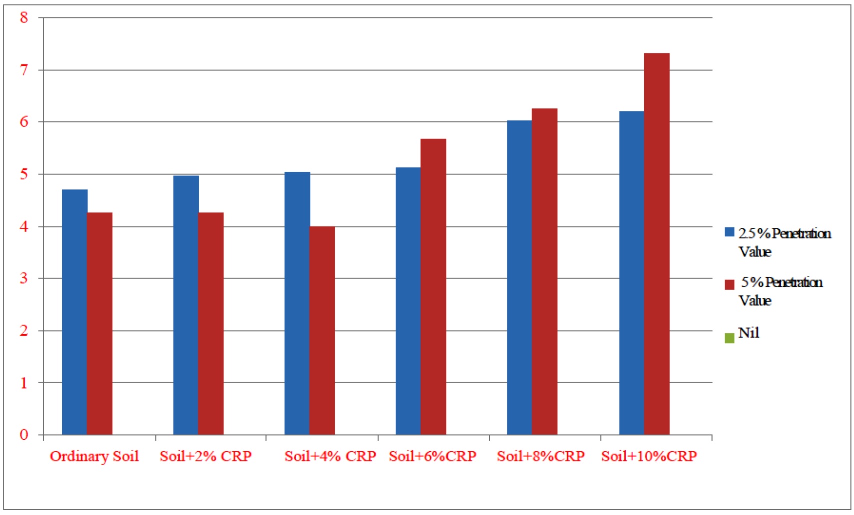

Figure 5.3-Graph between CBR Vs % Crumb Rubber Tyre.

6.1 CONCLUSION

- The inclusion of crumb rubber tyre in clayey soil resulted in a decrease in Maximum Dry Density (MDD) due to the lightweight nature of rubber particles, while the Optimum Moisture Content (OMC) showed an increasing trend with higher rubber content.
- The California Bearing Ratio (CBR) values (both soaked and unsoaked) significantly improved with the addition of crumb rubber tyre, indicating enhanced load-bearing capacity of the soil, making it suitable for sub-grade applications.
- The addition of crumb rubber tyre improved the strength characteristics of soil, including better resistance to deformation and improved ductility behavior.
- An optimum range of 6% to 10% crumb rubber tyre content was found effective in achieving maximum improvement in engineering properties of soil.
- The use of crumb rubber tyre helps in reducing environmental pollution caused by waste tyre disposal and promotes sustainable construction practices.
- Partial replacement of conventional stabilizers (like cement/lime) with crumb rubber tyre leads to a cost-effective and eco-friendly solution for sub-grade stabilization in pavement construction.

6.2 Future Aspect

- Field studies can be conducted to evaluate the long-term performance and durability of crumb rubber stabilized subgrade under actual traffic conditions.
- The effect of crumb rubber tyre can be further studied in combination with other stabilizers such as lime, fly ash, or cement for hybrid stabilization techniques.

- Investigation can be extended to different types of soils (sandy, silty, expansive soils) to generalize the applicability of the method.
- Dynamic loading and cyclic behavior of stabilized soil can be analyzed for better understanding of pavement performance.
- Environmental studies can be carried out to assess leachability and long-term environmental impact of crumb rubber in soil.
- Optimization techniques and numerical modeling can be used for analytical prediction of soil behavior with crumb rubber inclusion.
- Large-scale implementation can be explored in rural road construction projects to achieve sustainable and economical infrastructure developmen

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