

# Eco-Friendly Ground Improvement Through By-Product Incorporation

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## ABSTRACT

Red soil is the third largest soil group in India and it possess lower strength compared to other soil due to its porous and fragile structure and it has a higher swelling capacity, thereby it requires stabilization. Red soil stabilization is usually done using lime, fly ash, granulated blast slag etc., of which construction & demolition waste is the major factor. An analysis indicates that India produces about 530 million tons of mineral waste annually from excavation, building, and demolition activities. Therefore, we must make the greatest use of these minerals in order to preserve natural resources. The third largest type of soil in India is called red soil. Because of its porous and brittle structure, red soil is weaker than other soil types and has a greater capacity for swelling, so stabilization is necessary. Typically, fly ash, granulated blast slag, lime, and refuse from building and demolition are used to stabilize red soil. Studying red soil's engineering characteristics and improve their strength. The CBR value is computed after the debris is introduced to the soil at various percentages.

**Keywords:** Atterbergs limits, California Bearing Ratio test, Impact value, Natural coarse aggregate, Red soil, Recycled coarse aggregate, Specific gravity, Water absorption.

## CHAPTER 1

### 1.1 INTRODUCTION

#### 1.1.1 GENERAL

Reusing waste materials into fresh building materials has been viewed in certain nations as one of the primary goals of sustainable construction projects in recent years. The primary emphasis of this research is the partial replacement of soil in lean stabilization using recycled concrete aggregate as coarse aggregate.

Any land-based structure needs a strong foundation in order for the entire structure to be supported. The soil surrounding the foundation is extremely important for its strength. Therefore, in order to work with soils, we must be properly informed on their characteristics and the variables that influence their behavior. Soil stabilization is a method that aids in achieving the necessary qualities in soil for construction projects. Improving the qualities of the soil has been necessary since the start of building. Various techniques were employed by the Chinese, Roman, and Inca civilizations to enhance the strength of their soil, and some of these techniques were so successful that their buildings and roadways still stand today.

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. Soil stabilization was used but due to the use of obsolete methods and

also due to the absence of proper technique, soil stabilization lost favor. In recent times, with the increase in the demand for infrastructure, raw material, sand fuel, soil stabilization has started to take a new shape. It is becoming a more widely used and economical technique for improving soil due to improved research, materials, and equipment.

### 1.1.2 SOIL STABILIZATION

The process of stabilizing soil involves modifying its mechanical and/or chemical qualities to create a better soil material with all the required engineering properties.

Generally, soils are stabilized to make them stronger and more resilient, or to stop erosion and dust accumulation. The production of a soil material or system that will hold under the intended use conditions and for the engineering project's intended life is the primary goal.

Soil testing is essential to the success of soil stabilization since the qualities of soil can fluctuate significantly between locations and sometimes even within a single location. Soil stabilization can be achieved using a variety of techniques, all of which should be tested in a laboratory setting using actual soil samples prior to field application.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Ground Improvement by Construction and Demolition Waste (CDW) Soil

##### Mixture Replacement

Author: - 1.César Augusto Hidalgo 2.Fredy Muñoz 3.Gloria Isabel Carvajal

**Abstract:** In several countries, brick and ceramic tile are the most important construction materials; therefore, associated waste generation is common in construction and demolitions. An alternative use for waste is to incorporate it into road construction. However, the biggest limitation to use it as structural pavement layers is that strength and durability regulatory requirements are not met for highways when it is used. As an alternative, construction and demolition waste (CDW) soil mixtures are proposed as subgrade improvements which require less of a thickness increase of pavement structures to meet highway standards. The results of this article present the behavior of silty soil, brick residues, and ceramic tile mixtures in different added material ratios.

**Introduction:** CDW production has generated a negative impact on the environment and a social problem in communities. Most CDW materials come from the demolition and rehabilitation of existing buildings, representing a significant percentage of the solid wastes generated annually worldwide approximately 60%. **Materials and Methods:** Brick and ceramic tile residues were selected from construction sites and were modified by a primary crushing process, obtaining elongated rectangular or cone shape particles with sizes ranging from 19 to 25 mm. Masonry waste is an aggregate from Castilian brick produced in industrial plants in the region, and ceramic tile waste includes ceramic fragments from floors and porcelain tile..

**Results and Discussion:** Regarding the physical characteristics and the granulometric curves of the two materials used as additions to the soil mixture, different characteristics were observed, such as absorption and physical wear of the ceramic tile waste in the Los Angeles Abrasion Test having values half as high as those obtained for the brick residue, mainly due to the difference in the production process. The results showed that more CDW content increased the maximum dry unit weight and the optimum moisture content decreased. Significant for optimum humidity, tending to decrease its value as the dosage increased. Stabilizer type was also influential on the optimal humidity, presenting an average decrease of 20% when ceramic tile CDW was added, compared to the use of brick CDW optimal humidity decreases and

maximum density increases when the CDW percentage increases. The relationship between these two variables can be observed by the significant decreases in optimum humidity and increases in maximum dry density until 40% waste content. CBR value increase from 2.23% to 120% was observed when 70% of CDW was added. However, the addition of 40% CDW already contributed an important value of more than 1000% in soil CBR increase, one of the most important variables in pavement design.

Conclusions: The strength and stiffness of soil and CDW mixtures increase with CDW content. It is observed that the strength given by the CBR values increased gradually to contents of about 40%, and for higher values it grew exponentially. Considering the pavement configuration analyzed (granular sub base, granular base, and asphalt layer), CDW content from 0 to 30% decreased the granular sub base thickness until excluding it; from 30% to 50%, the thickness of the granular base decreased; and for CDW content greater than 50%, granular materials were not required, because the mechanical soil strength was greater. The CDW sub grade addition se decreased; and for CDW content greater than 50%, granular materials were not required, because the mechanical soil strength was greater. The CDW sub grade addition in soil implied a pavement cost reduction from 7% to 52% The CDW sub grade addition in soil implied a pavement cost reduction from 7% to 52%. However, the structural behavior of the asphalt layer in the improved soil does not guarantee the durability of the pavement.

### 3.2 Use of Construction and Demolition Waste Material for Soil Stabilization

Author: Md. Hamjala Alam\*, Tanmoy Mondal, Tarun Dev, Arijit Kumar Banerji, Chanchal Das

Abstract: Soil stabilization is the method of modifying and improving soil engineering properties. Construction and demolition (C&D) debris are solid wastes accessible at construction sites at nominal cost. This study mainly investigates the changes in the soil behavior, precisely the strength characteristics, on mixing the C&D wastes by replacing the original soil with 5%, 10%, 15% and 20% of the C&D debris respectively. The results demonstrated that up to certain extent the strength characteristics improved.

Introduction: Soil is a combination of minerals, dead and living organisms, air and water. Due to significant interaction of these four components, soil is rendered as an essential natural resource. . In this study an effort has been made to use the debris, available at local construction sites, as soil stabilizers to ameliorate the soil properties and stabilize the locally available soil for the construction of buildings and other concrete and RCC structures over it without the fear of structural failure due to settlement of the foundation soil.

Materials and Methods: They concluded that different wastes like wood ash, fly ash, rice husk ash etc. were being utilized as soil stabilizers but the C&D waste was not being utilized for soil stabilization. The C&D debris can improve the soil characteristics and enhance the vital soil engineering properties like bearing capacity, compressive strength and shear strength.

Results and Discussion: The Uniformity Coefficient was observed as 5.5 and the Coefficient of Curvature was observed as 1.01. The water content (w) of the original soil sample was 14.715%, WL was about 29%, WP was about 12.82%, the PI was about 16.18%, and G was about 2.36. The MDD value was 1.79 kg/cm<sup>3</sup> at an OMC of 19%. Replacing the virgin soil with 5%, 10%, 15% and 20% respectively. The value of shear stress of original soil at different values of the normal stress was found to be 0.045, 0.065, and 0.080 respectively. The CBR test was initially done with the original soil at both soaked and unsoaked conditions. Then the soil was replaced consecutively by 5%, 10%, 15% and 20% of C&D debris and the test was repeated under soaked and unsoaked conditions. It was realized that under soaked conditions the CBR at 2.5 mm penetration initially decreased for the 5% replacement of soil with the waste but the CBR

value then increased for 10% and 15% replacement of soil with the waste but the value then dropped finally at 20% replacement of soil with the C&D debris. It was also observed that in soaked condition the CBR value at 5 mm decreased for the 5% and 10% replacement but the value then increased at 15% of replacement of soil with the waste and ultimately declined again at 20% of replacement of soil with the C&D debris.

**Conclusions:** So overall from the present study it can be concluded that the soil stabilization using C&D debris, in terms of shear strength, compressive strength and subgrade strength, was satisfactory and some of the results obtained for a few tests were very encouraging. The C&D debris usage will be an effective tool for solid waste management, as it leads to proper use of the debris and also help in maintaining cleanliness and cater towards the goal of sustainable development for the betterment of the future generation.

### 3.3 Use of Recycled Construction and Demolition (C&D) Wastes in Soil Stabilization

Author: Sangeetha .S.P, ZhimoholiT.Chophi, Pooja Venkatesh and Muhammad

Fahad

**Abstract:** With the growing construction sector, there is a constant rise in wastes generated by both construction and demolition activities. According to an estimate by Building Material Promotion Council (BMPTC), 150 million tones of construction and demolition (C&D) wastes are generated in India annually. This paper examines the properties of Black cotton soil and investigates the use of recycled C&D wastes in soil stabilization of black cotton soil.

**Introduction:** Soil stabilization is broadly defined as the process of improving the engineering properties of weak soil with the use of stabilizing agents or admixtures. Soil stabilization is mainly carried out in three methods, namely: mechanical stabilization, chemical stabilization, and polymer stabilization. There is a substantial history of the use of soil stabilization admixtures to improve poor sub grade soil performance by controlling volume change and increasing strength

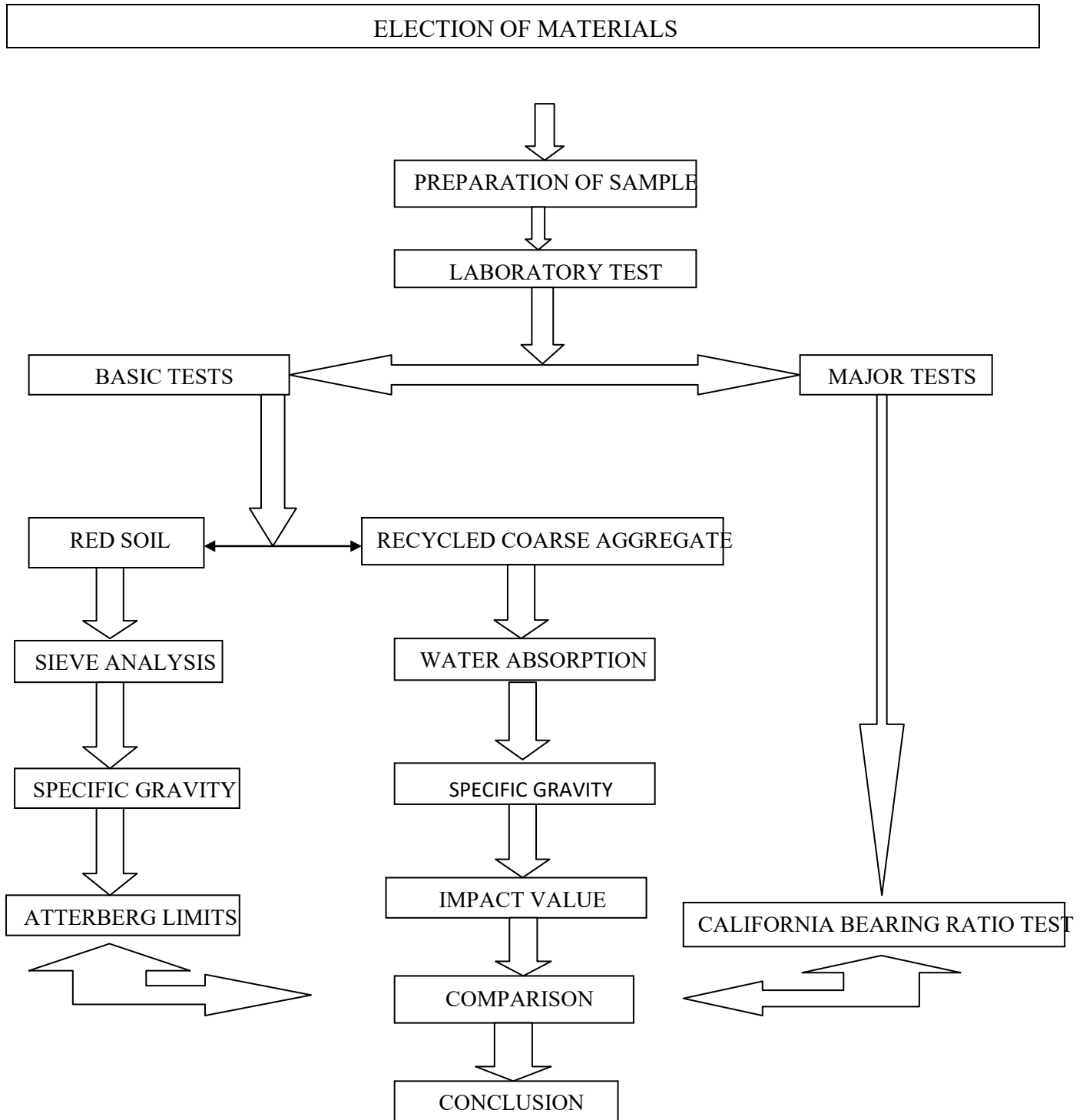
**Materials and Methods:** The C&D wastes were acquired from a dumping site in Shollinganallur, Chennai, Tamil Nadu. Black cotton soil, also known as expansive soil, is amongst the most problematic soils in construction. However, C&D wastes such as soil stabilizers have been newly introduced especially the use of recycled concrete aggregates.

**Results and Discussion:** It was observed that the values of Liquid limit was varying between 49% to 58% and plastic limit between 22% to 29% for an addition of 25% to 5% addition of C&D waste. Plasticity index and dry density were high for an addition of 10% C&D wastes. Moisture content was 21.5%, 19.3%, 18.23%, 19% and 18.1% for percentage increase of C&D wastes from 5% to 25% addition. The liquid limit of the soil changed from 51% to 49.21% with the addition of 25% recycled C&D wastes. The optimum moisture content of the Black Cotton sample was 15% and increased to 18.09% with the addition of 25% C&D wastes. With the addition of 5%, 10%, 15% and 20% C&D wastes, CBR values increased to 4.80%, 9.70%, 14.35% and 16.30% respectively. The values of maximum dry density gradually decrease with the addition of 5%, 10%, 15% and 20% C&D wastes, MDD values changed to 1.932, 2.083, 1.827, and 1.740 (g.cc-1) respectively.

**Conclusions:** The use of C&D wastes soil stabilizer has been studied before and the results obtained in this research are similar to the results of other research studies, which goes to prove that C&D wastes can be used as soil stabilizers. In addition, there is a problems caused by them assive C&D wastes generation such as pollution of water bodies, green areas, public spaces, and the biggest one among them being the depletion of finite landfill spaces can be curbed. The use of C&D wastes as a soil stabilizer will not only

improve the engineering properties of soil, it will also reduce the costs of the overall project and negate the impact on the environment, thus leading to a more sustainable way of construction.

### METHODOLOGY



## CHAPTER 4

### 4.1 MATERIAL AND ITS PROPERTIES

#### 4.1.1 General

Generally speaking, soil stabilization involves combining soil sample, water content, and recycled coarse aggregate to absorb waste building materials. To generate low-cost soil material stabilization, the stabilization's attributes must be improved. The following components were utilized in this study to create the soil mixture.

### 4.2 MATERIALS USED

#### 4.2.1 Red Soil

Sesquioxide concentrations are high in red soils, which are heavily leached soils found in humid tropical regions. Red soils are classified in the orders of Oxisols and Ultisols in the current U.S. Soil Taxonomy system; on occasion, they are also classified as Alfisols, Mollisols, and even Inceptisols. Red soils are predominantly found in South America, Central Africa, South and Southeast Asia, China, India, Japan and Australia. Red soil is a type of soil that typically develops in warm, temperate, and humid climates and comprises approximately 13% of Earth's soils. It contains thin organic and organic-mineral layers of highly leached soil resting on a red layer of alluvium. Red soils contain large amounts of clay and are generally derived from the weathering of ancient crystalline and metamorphic rock. They are named after their rich red color, which can vary from reddish brown to reddish yellow as a result of their high iron content. It is usually low in nutrients and humus and can be difficult to cultivate due to its low water holding capacity however, the fertility of these soils can be optimized with liming and other farming techniques. India is rich with red soils in their southern, eastern, and northern regions. Applications of lime and fertilizers are important strategies for replenishing soil fertility and improving crop yields on these soils.



**Fig: 01**

#### 4.2.2 Recycled Coarse Aggregate

Crushed concrete is available nowadays in large quantities, which results from the demolition of old structure sand waste concrete from new structures. A report presented in 1999 to the European Commission estimated the amount of no recycled construction waste to be 130 million ton/year. A decrease in the compressive strength was generally observed in all concretes in which the natural coarse

aggregate was replaced with recycled aggregate prepared by the crushing of old concrete. The mechanical properties of the concrete decreased with the increase in the proportion of aggregate replaced. In that only 20% of the natural aggregate can be replaced with recycled coarse aggregate in the preparation of new concrete of all strength classes, and limited the concrete classes when 100% recycled construction waste is used in the Pavement Construction. Crushed construction and demolition waste, including concrete, aggregate materials, and crushed stones, are used to make recycled coarse aggregate (RCA). Recycled Coarse Aggregate (RCA) is a material derived from the processing of inorganic material, typically concrete, previously used in construction. It consists of aggregate particles that have been crushed, processed, and graded to meet specifications for use in new construction.

**Fig: 02**

**RCA can be used in various applications, including:-**

1. Concrete production
2. Road construction (base course, subbase, and surface course)
3. Building foundations
4. Drainage systems
5. Pavement construction

**Using RCA offers several benefits, such as:-**

1. Conservation of natural resources
2. Reduction of landfill waste
3. Energy savings
4. Lower greenhouse gas emissions
5. Potential cost savings

**However, RCA also has some limitations and considerations, including:-**

1. Variability in quality and properties
2. Potential contamination
3. Limited availability in some areas
4. Specialized processing and handling requirements

Overall, Recycled Coarse Aggregate is a valuable resource that can contribute to sustainable construction practices and reduce the environmental impact of building activities.

## **CHAPTER 5**

### **5.1 BASIC TESTS OF RED SOIL AND RECYCLED COARSE AGGREGATE:-**

1. Specific Gravity

2. Liquid Limit
3. Plastic Limit
4. Plasticity Index
5. Sieve Analysis
6. Impact Value
7. Water Absorption

### 5.1.1 SPECIFIC GRAVITY

The specific gravity (G) of soil is the ratio of the unit weight of solid soil particles to the unit weight of water. It's a dimensionless unit that's an important parameter in soil mechanics. The specific gravity of soil particles is typically between 2.65 and 2.85, but can vary depending on the type of soil:

- Inorganic soils: Usually have a specific gravity of 2.60–2.80, but tropical iron-rich laterite and some other lateritic soils can have a specific gravity of 2.75–3.0 or higher
- Organic soils: Have a specific gravity of less than 2
- Sandy soils: Have a specific gravity of 2.63–2.67

Finer soils generally have a higher specific gravity than coarser soils. The specific gravity of soil can be used to calculate other soil parameters, such as porosity, dry and saturated density, and degree of saturation. To determine the specific gravity of soil, we need the following equipment:

Volumetric flask, Balance, Vacuum pump, Distilled water, Funnel, Spatula, and Drying oven.

Specific gravity of soil is the ratio of the density of soil to the density of water. It's a dimensionless quantity that represents the mass of a given volume of soil compared to the same volume of water. Specific gravity (Gs) is calculated using the following formula:

$G_s = \gamma_s / \gamma_w$  where:

$G_s$  = specific gravity of soil

$\gamma_s$  = density of soil

$\gamma_w$  = density of water (approximately 1 g/cm<sup>3</sup> or 1000 kg/m<sup>3</sup>)

Knowing the specific gravity of soil is important in various geotechnical and civil engineering applications, such as:

1. Soil classification and identification
2. Calculation of soil volume and weight
3. Design of foundations and earth structures
4. Soil compaction and stabilization
5. Hydrological and drainage studies.

### 5.1.2 LIQUID LIMIT

The liquid limit (LL) of soil is the water content at which the soil behaves like a liquid, and it's an important parameter in geotechnical engineering. It's defined as the moisture content at which a soil specimen, when subjected to a standardized disturbance, flows like a liquid.

Here are some key aspects of the liquid limit:-

1. Definition: The liquid limit is the water content (%) at which a soil specimen, when subjected to 25 blows in a standard liquid limit test, flows 13 mm (0.5 inches) in 10 seconds.
2. Determination: The liquid limit is typically determined using the Casagrande apparatus or the fall cone test.
3. Range: Liquid limit values range from around 20% to over 100%, depending on the soil type and composition.

4. Soil classification: LL is used in soil classification systems, such as the Unified Soil Classification System (USCS) and the AASHTO soil classification system.
5. Engineering significance: LL is used to predict soil behavior, such as:
  - Compressibility
  - Permeability
  - Shear strength
  - Compaction characteristics
6. Correlation with other soil properties: LL is related to other soil properties, such as plasticity index, shrinkage limit, and undrained shear strength.

### 5.1.3 PLASTIC LIMIT:-

The plastic limit (PL) of soil is the water content at which the soil begins to exhibit plastic behavior, meaning it can be molded and shaped without crumbling or cracking. It's an important parameter in geotechnical engineering, as it helps predict soil behavior and stability.

Here are some key aspects of the plastic limit:

1. Definition: The plastic limit is the water content (%) at which a soil specimen can be rolled into a thread of 3 mm (0.12 inches) diameter without breaking or crumbling.
2. Determination: The plastic limit is typically determined using the Casagrande apparatus or the hand rolling test.
3. Range: Plastic limit values range from around 10% to over 50%, depending on the soil type and composition.
4. Soil classification: PL is used in soil classification systems, such as the Unified Soil Classification System (USCS) and the AASHTO soil classification system.
5. Engineering significance: PL is used to predict soil behavior, such as:
  - Workability
  - Compaction characteristics
  - Shear strength
  - Stability
6. Correlation with other soil properties: PL is related to other soil properties, such as liquid limit, plasticity index, and shrinkage limit.

The plastic limit is also used to calculate the plasticity index (PI), which is the difference between the liquid limit and plastic limit. PI provides valuable information about soil's plasticity and behavior.

### 5.1.4 PLASTICITY INDEX

The plasticity index (PI) is a measure of a soil's plasticity, which is its ability to change shape without cracking or crumbling. It's calculated as the difference between the liquid limit (LL) and plastic limit (PL):  
$$PI = LL - PL$$

The plasticity index provides valuable information about soil behavior, such as:

1. Workability: Soils with high PI are more workable and can be easily molded.
2. Compressibility: Soils with high PI are more compressible.
3. Shear strength: Soils with high PI tend to have lower shear strength.
4. Stability: Soils with high PI may be more prone to settlement or instability.

Interpretation of plasticity index values:

- Low PI (0-10): Soils are relatively non-plastic and may be prone to cracking.

- Medium PI (10-20): Soils exhibit moderate plasticity and are generally workable.
- High PI (20-30): Soils are highly plastic and may be prone to settlement or instability.
- Very high PI (above 30): Soils are extremely plastic and may exhibit poor engineering properties.

### 5.1.5 SIEVE ANALYSIS

Sieve analysis of red soil is a laboratory test used to determine the particle size distribution of the soil. It involves passing a soil sample through a series of sieves with decreasing mesh sizes to separate the particles into different size fractions.

Here are some key aspects of sieve analysis of red soil:

- **Objective:** To determine the particle size distribution and gradation of red soil.
- **Test method:** ASTM D422 or AASHTO T88 standard method.
- **Sieve sizes:** Typically, 4.75 mm, 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, and 0.075 mm.
- **Procedure:**
  - Dry the soil sample to a constant weight.
  - Pass the sample through the sieves, starting from the largest mesh size.
  - Collect and weigh the retained particles on each sieve.
- **Results:**
  - Particle size distribution curve (PSD) - Gradation parameters:
  - Coarse fraction (>4.75 mm)
  - Sand fraction (0.075 mm to 4.75 mm)
  - Silt fraction (0.002 mm to 0.075 mm)
  - Clay fraction (<0.002 mm)
- **Interpretation:**
  - Red soil typically has a high sand content (60-80%) and low clay content (<10%).
  - The PSD curve can indicate the soil's drainage, compaction, and strength properties.
- **Engineering significance:**
  - Sieve analysis helps in:
  - Soil classification
  - Designing foundations and earth structures
  - Selecting appropriate construction material
  - Predicting soil behavior under different loads and conditions

### 5.1.6 IMPACT VALUE

The impact value of coarse aggregate is a measure of its resistance to impact or shock loads. It's an important parameter in civil engineering, as it affects the durability and stability of structures like roads, bridges, and buildings.

The impact value is determined by the Aggregate Impact Test (AIV), which involves subjecting a sample of aggregate to a specified number of impacts using a standardized hammer. The percentage of aggregate that breaks or crushes is then calculated.

Here are some key aspects of impact value:

1. **Definition:** Impact value is the percentage of aggregate that passes through a 2.36 mm sieve after being subjected to 15 blows in the AIV test.

2. Range: Impact values typically range from 5% to 40%.
3. Interpretation:
  - Low impact value (<10%): Aggregate is strong and resistant to impact.
  - Medium impact value (10-20%): Aggregate is moderately resistant to impact.
  - High impact value (20-30%): Aggregate is weak and prone to breakage.
  - Very high impact value (>30%): Aggregate is unsuitable for construction purposes.
4. Factors affecting impact value:
  - Aggregate type and quality
  - Size and shape of aggregate particles
  - Surface texture and roughness
  - Presence of weak or fragile particles
5. Engineering significance: Impact value is used to evaluate the suitability of aggregate for various construction applications, such as:
  - Road construction
  - Concrete production
  - Bridge construction
  - Building foundations

In general, a lower impact value indicates a more durable and stable aggregate, while a higher impact value suggests a weaker and more prone to breakage aggregate.

#### 5.1.7 WATER ABSORPTION

Water absorption of coarse aggregate is the percentage of water absorbed by the aggregate when it's fully saturated. It's an important property in civil engineering, as it affects the durability and stability of structures like roads, bridges, and buildings.

Here are some key aspects of water absorption:

1. **Definition:** Water absorption is the percentage of water absorbed by the aggregate compared to its dry weight.
2. **Test method:** The water absorption test is typically conducted using the ASTM C127 or AASHTO T84 standard method.
3. **Range:** Water absorption values typically range from 0.1% to 5%.
4. **Interpretation:**
  - Low water absorption (<1%): Aggregate is dense and less prone to damage from freeze-thaw cycles.
  - Medium water absorption (1-2%): Aggregate is moderately absorbent.
  - High water absorption (2-5%): Aggregate is highly absorbent and may be prone to damage from freeze-thaw cycles.
5. **Factors affecting water absorption:**
  - Aggregate type and quality
  - Porosity and permeability
  - Surface texture and roughness
  - Presence of micro-cracks or defects
6. **Engineering significance: Water absorption affects:**
  - Durability and stability of structures
  - Freeze-thaw resistance

- Resistance to chemical attack
- Workability and finishability of concrete

In general, a lower water absorption value indicates a more durable and stable aggregate, while a higher value suggests a more porous and potentially weaker aggregate.

## CHAPTER 6

### 6.1 MAJOR TESTS OF RED SOIL AND RECYCLED COARSE AGGREGATE:-

#### 6.1.1 STANDARD PROCTOR TEST

The Standard Proctor test is a laboratory test used to determine the optimal moisture content and maximum dry density of red soil, which is essential for geotechnical engineering applications.

Here are some key aspects of the Standard Proctor test for red soil:

- **Objective:** To determine the maximum dry density and optimal moisture content of red soil.
- **Test method:** ASTM D698 or AASHTO T99 standard method.
- **Procedure:**
  - Prepare a soil sample and mix it with varying amounts of water.
  - Compact the soil mixture in a mold using a standardized compaction effort (56 blows per layer).
  - Measure the dry density and moisture content of each compacted sample.
- **Results:**
  - Moisture-density curve
  - Maximum dry density (MDD)
  - Optimal moisture content (OMC)
- **Interpretation:**
  - MDD represents the highest achievable density.
  - OMC is the moisture content at which MDD is achieved.
  - Red soil typically has an OMC between 15-20% and MDD around 1.8-2.0 g/cm<sup>3</sup>.
- **Engineering significance:**
  - Standard Proctor test results help in:
  - Soil compaction and stabilization
  - Foundation design and construction
  - Pavement and embankment construction
  - Soil improvement and remediation
- **Factors affecting Standard Proctor test results:**
  - Soil type and gradation
  - Compaction effort and method
  - Moisture content and density
  - Soil structure and fabric



**Fig: 03**

### 6.1.2 CALIFORNIA BEARING RATIO (CBR) TEST:-

The California Bearing Ratio (CBR) test is a penetration test used to evaluate the load-bearing capacity of soils, including red soil. It measures the resistance of the soil to penetration and is commonly used to determine the soil's bearing capacity for road construction, foundation design, and other geotechnical applications.

Here are some key aspects of the CBR test for red soil:

- **Objective:** To determine the CBR value, which represents the ratio of the load required to penetrate the soil to a certain depth to the load required to penetrate a standard crushed stone material.
- **Test method:** ASTM D1883 or AASHTO T193 standard method.
- **Procedure:**
  - Prepare a compacted soil sample in a mold.
  - Apply a surcharge weight to simulate overburden pressure.
  - Penetrate the soil with a cylindrical plunger at a constant rate.
  - Record the load and corresponding penetration depth.
- **CBR value calculation:**
  - $CBR = (\text{Load at 2.5 mm penetration} / \text{Standard load}) \times 100$
- **Interpretation:**
  - CBR values range from 0 to 100%.
  - Higher CBR values indicate better load-bearing capacity.
  - Red soil typically has CBR values between 5-20%.
- **Engineering significance:**
  - CBR values help in:
  - Designing pavement thickness and foundation depths
  - Selecting appropriate construction materials
  - Evaluating soil stability and settlement potential
- **Factors affecting CBR values:**
  - Soil type and gradation

- Moisture content and density
- Compaction effort and method
- Overburden pressure and surcharge weight.

**CHAPTER 7**

**7.1 EXPERIMENTAL TEST RESULTS**

**7.1.2 TEST RESULTS ON RED SOIL:-**

**TABLE 1. GRAIN SIZE ANALYSIS**

Soil type: Red Soil	Retained	% pass
Gravel	0	100
Coarse Sand	5	95
Medium Sand	23	72
Fine Sand	30	42
Silt & Clay	42	<b>0</b>
<b>Check</b>	<b>100</b>	

**TABLE 2. ATTEBERG LIMIT**

LIQUID LIMIT					
Number of blows	45	34	24	10	5
Weight of container (W1)	15.56	20.78	11.02	12.56	21.21
Container + wet soil (W2)	54.01	50.00	32.50	34.96	59.51
Container + dry soil (W3)	48.62	45.00	26.98	28.50	47.53
Weight of water (W2-W3)	5.39	5.00	5.52	6.46	11.98
Weight of dry soil (W3-W1)	33.06	24.22	15.96	15.94	26.32
Moisture content	16.30	20.64	34.59	40.53	45.50

PLASTIC LIMIT	
WGT OF CONTAINER (W1)	13.51
CONTAINER + WET SOIL (W2)	21.04
CONTAINER + DRY SOIL (W3)	19.90
WGT OF WATER (W2-W3)	1.14
WGT OF DRY SOIL (W3-W1)	6.39
<b>MOISTURE CONTENT</b>	<b>18</b>

<b>Number of Blows</b>	45	34	24	10	5
<b>Moisture Content in %</b>	16.30	20.64	34.59	40.53	45.50
<b>Liquid Limit (LL) %</b>	34				
<b>Plastic Limit (PI) %</b>	18				

Plasticity Index( IP) %	16
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**TABLE 3 SPECIFIC GRAVITY**

Sl.No	Description	Trial 1	Trial 2	Trial 3	Trial 4
1	Mass of gas jar and ground glass plate in g (M1)	51.160	51.15	51.16	51.16
2	Mass of gas jar, plate and Soil in g(M2)	61.158	61.11	61.12	61.13
3	Mass of gas jar, plate, soil and water in g (M3)	117.658	116.87	116.83	116.85
4	Mass of gas jar, plate and water in g (M4)	111.380	110.63	110.63	110.63
5	Specific gravity $G = (M2-M1)/(M4-M1) - (M3-M2)$	2.69	2.68	2.65	2.66
<i>The specific gravity shall be calculated at 27°C. If the room temperature is different than 27°C, the following corrections shall be done</i>					
1	specific gravity G	2.69	2.68	2.65	2.66
2	Relative density of Water room temperature	1	1	1	1
3	Relative density of water at 27°C	0.9997	0.9994	0.9994	0.9991
4	$K = \text{Relative density of Water room temperature} / \text{Relative density of water at 27°C}$	1.0003	1.0006004	1.00060036	1.0009008 11
5	$G' = \text{Corrected specific gravity at 27°C}$	2.69	2.68	2.65	2.66
<b>Average Specific Gravity</b>		<b>2.67</b>			

**TABLE 4 CALIFORNIA BEARING RATIO**

Graphical Analysis of CBR		
Type of Compaction	Heavy	Dial Gauge Least Count 1
Conversion factor	7.56	Division = 0.02mm
Penetration in mm	Dial Reading	Load in Kg
0	0.0	0.00
0.50	7.0	52.92
1.00	13.0	98.28
1.50	17.0	128.52
2.00	20.0	151.20
<b>2.50</b>	<b>29.2</b>	<b>220.75</b>
3.00	32.0	241.92

4.00	34.6	261.58
<b>5.00</b>	<b>38.0</b>	<b>287.28</b>
7.50	40.5	306.18
10.00	43.0	325.08
12.50	51.0	385.56

**CBR CALCULATIONS**

Mould No	Test Unit Load (Kg)		CBR (%)		CBR Reported
	2.5 mm	5.0 mm	2.5 mm	5.0 mm	
1	220.75	287.28	16.11	13.98	<b>16.11</b>
Note : Graph for load vs penetration attached			Standard unit Load :@ 2.5mm :1370 Kg =		16.11
CBR : (Test unit load / Standard Unit load)*100			@ 5.00mm :2055 Kg =		13.98

**GRAPH:**

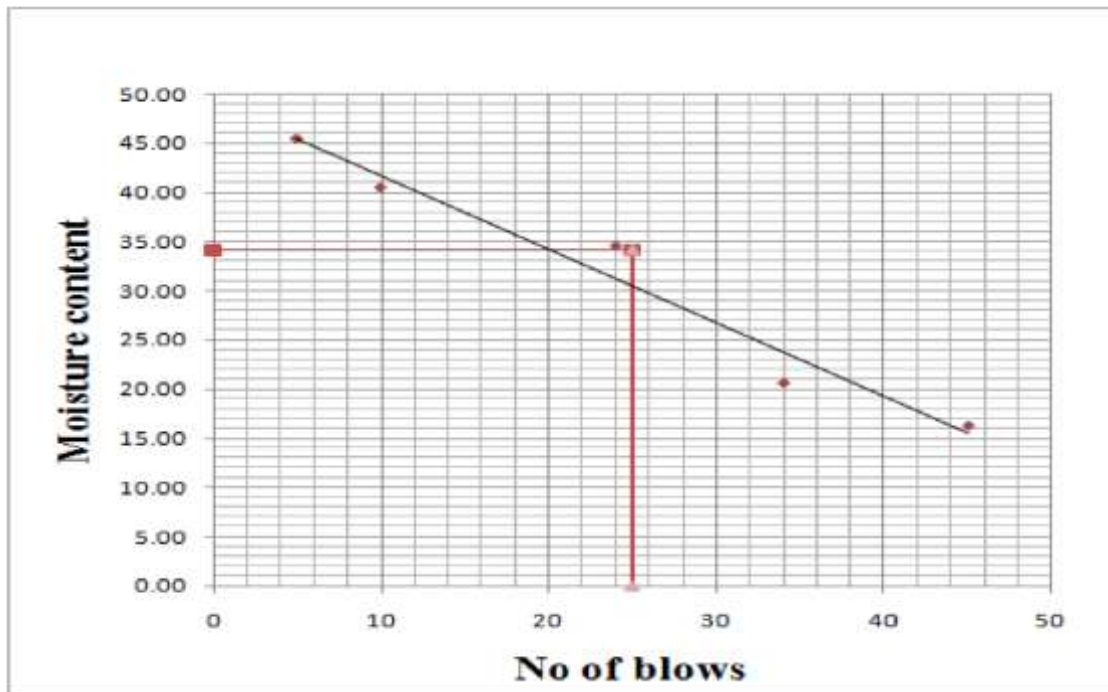


Fig: 04 Liquid Limit

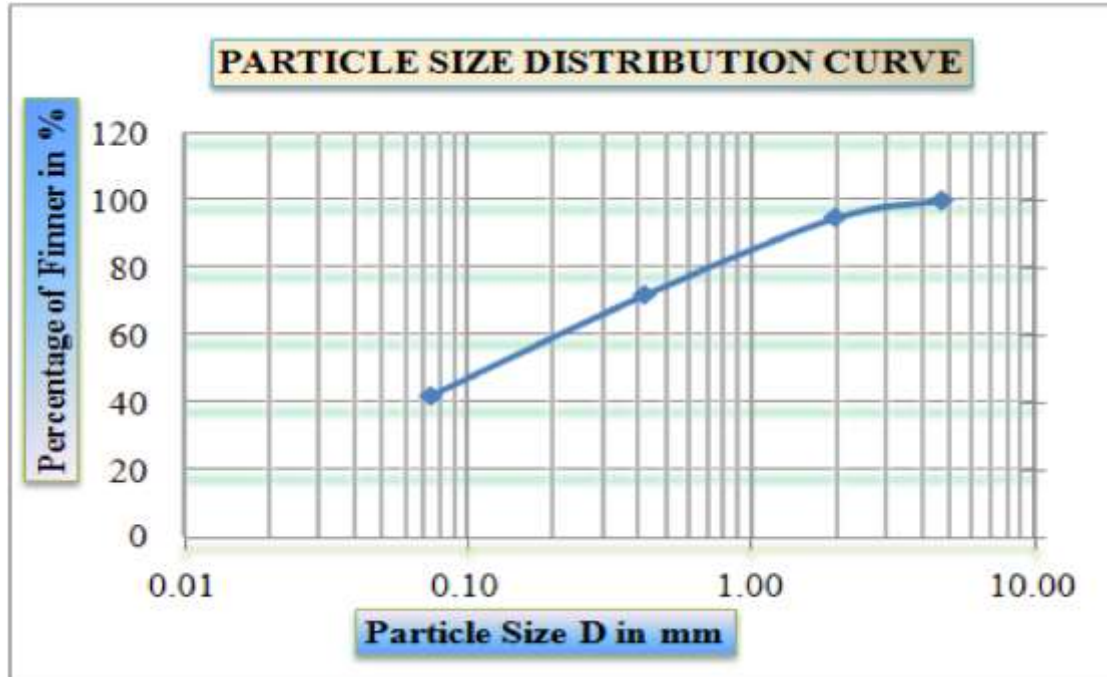


Fig: 05

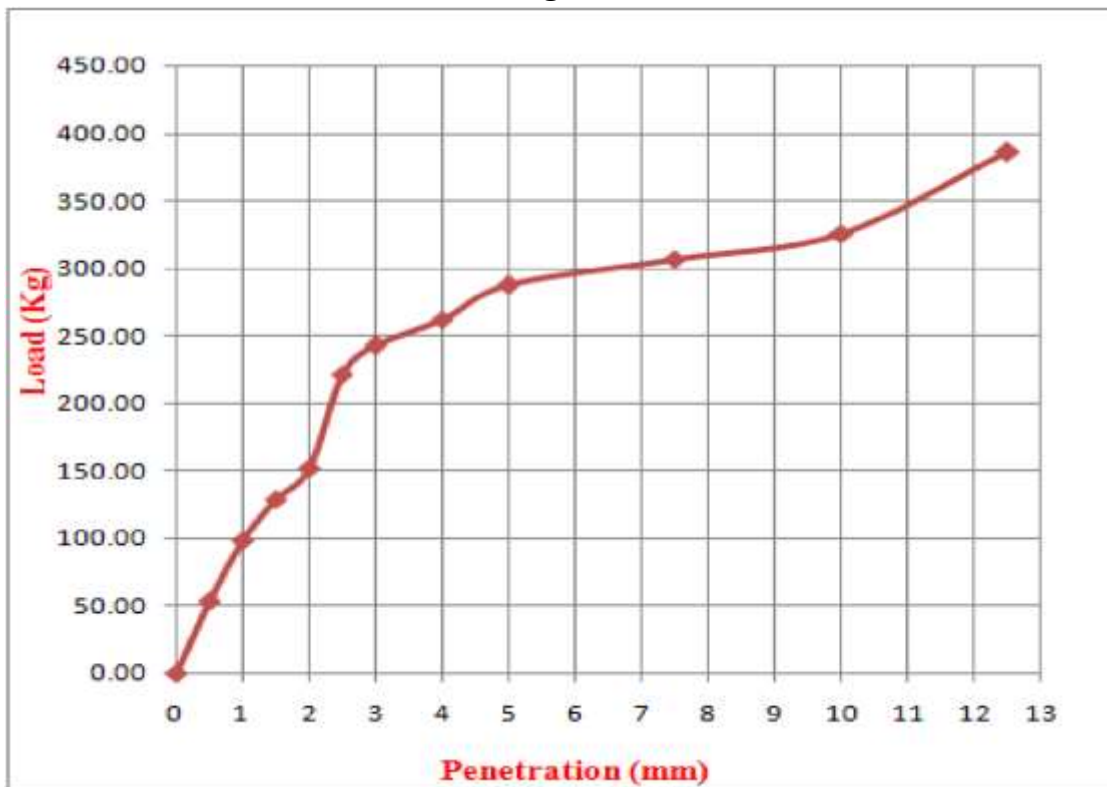


Fig: 6 California Bearing Ratio

TABLE 5 ENGINEERING PROPERTIES OF TEST RESULTS ON RED SOIL

Sl. No	Description of Items	Results
1.	Specific Gravity of Red Soil	2.67

2.	Liquid Limit (%)	<b>34</b>
3.	Plastic Limit (%)	<b>18</b>
4.	Plasticity Index (%)	<b>16</b>

**TABLE 6. PHYSICAL PROPERTIES OF RED SOIL**

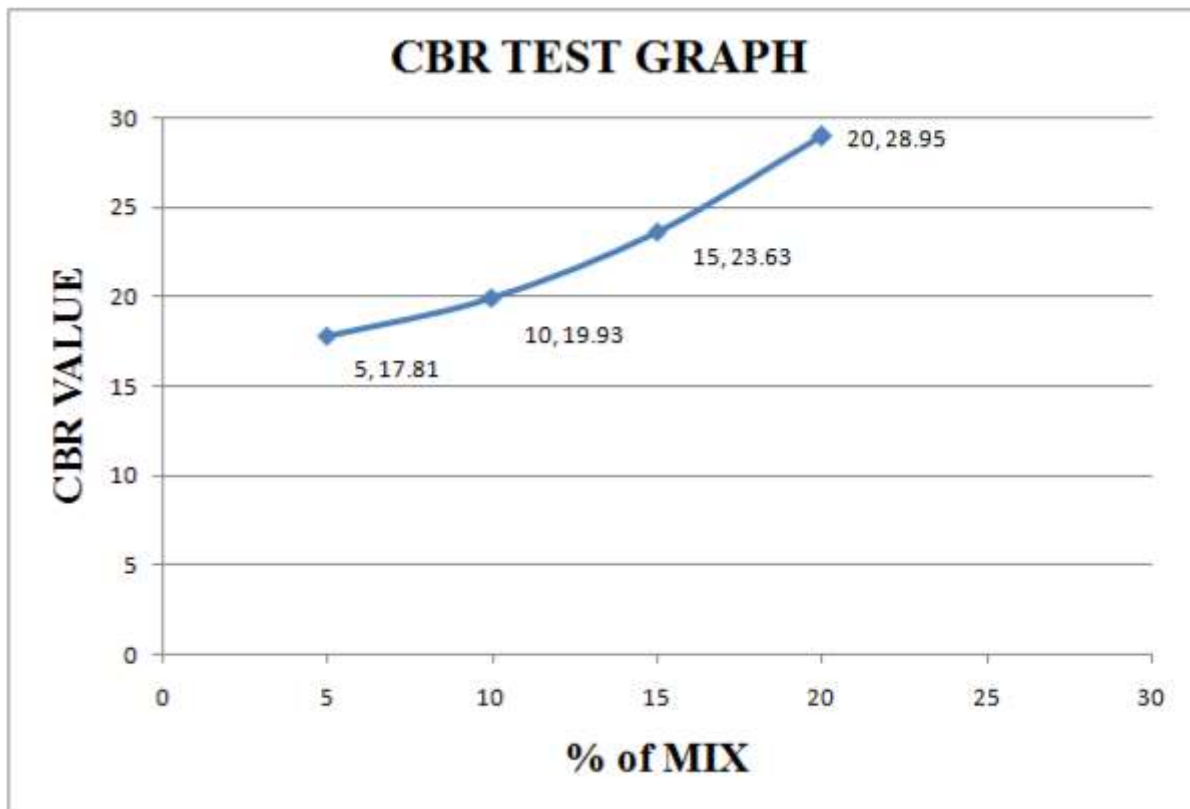
Sl. No	Properties	Results	IS Code Reference
1.	Specific Gravity	<b>2.67</b>	IS 2720 – (Part 3-Sec-1 & 2)
2.	Liquid Limit (%)	<b>34</b>	IS 2720 – (Part 4)
3.	Plastic Limit (%)	<b>18</b>	IS 2720 – (Part 4)
4.	Plasticity Index (%)	<b>16</b>	IS 2720 – (Part 4)
5.	CBR Value (%)	<b>16.11</b>	IS 2720 – (Part 16)

**TABLE 7. PHYSICAL PROPERTIES OF RECYCLED COARSE AGGREGATE**

Sl.No	Properties	Results	Acceptable Limit	IS Code Reference
1.	Specific Gravity	<b>2.68</b>	2.4 - 2.9	IS 2386_(Part 3)
2.	Impact Value (%)	<b>10.17</b>	-	IS 2386_(Part 4)
3.	Water Absorption (%)	<b>1.02</b>	0.1 -2% of Max	IS 2386_(Part 3)

**TABLE 8. REPLACEMENT OF RED SOIL WITH RCA IN VARIOUS PROPORTIONS**

Sl.No	Sample Name	Proportion of Sample Replaced	CBR Value
1.	Normal Red Soil	-	16.11%
2.	RS +P-1	5%of RCA	17.81
3.	RS +P-2	10%of RCA	19.93
4.	RS +P-3	15%of RCA	23.63
5.	RS +P-4	20%of RCA	28.95



**Fig 7.GRAPH BETWEEN % OF MIX AND CBR VALUE**

## CONCLUSION

Based on the Experimental Results and the Pavement Design as per IRC: 37-2001 the following conclusions were made,

- The RCA is mixed with Red Soil of different mix proportions i.e., (5%, 10%,15% and 20%); as a result there is an increase in CBR Value with increase in % of RCA replaced.
- The increase in CBR Value leads to decrease in Pavement Thickness which reduces the construction cost of the Pavement.

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#### CODE BOOKS AND STANDARDS

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