# IMPROVEMENT OF PAVEMENT SUBGRADE SOIL BY COMPACTION TECHNIQUES

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***Abstract:*** The primary function of pavement is to transmit loads to the sub-base and underlying soil. The heavy wheel loads and fast traffic on modern highways require adequate cover called the pavement on the natural soil to provide hard wearing surface and to distribute the loads within the bearing capacity of the soil without getting over stressed itself.

We can improve sub grade soil strength by applying compaction techniques. By doing this compaction process on sub grade soil the voids are going to reduce by cohesive attraction between sub grade soil particles. And we can add some admixtures like ordinary Portland cement, fly ash, quick lime, rice husk or by wood to get more strength for pavements.

Wood admixtures are mixed with cohesive soil to make soil samples. To understand the influences of admixtures on the soil properties, tests of the specific gravity, Atterberg limits, compaction, California bearing ratio (CBR), were performed on those samples. The study shows that the strength of specimens with the wood admixture to soil addition was improved to approximately 3–7 more times better than that of the untreated soil. In some samples, the wood admixture additive improved the CBR values by up to more times that of untreated soil.

**Keywords:** Consistency Limits – Atterberg limits, California Bearing Ratio (CBR) test, Proctor Compaction Test.

## I. INTRODUCTION

Soil stabilization may be defined as the alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil. Stabilization, in a broad sense, incorporates the various methods employed for modifying the properties of a soil to improve its engineering performance. Soil stabilization refers to the procedure in which a special soil, cementing material, or other chemical materials are added to a natural soil to improve one or more of its properties.

### 1.1 Objectives of Highway Pavements

The objective of laying pavement is to support the wheel loads and to transfer the load stresses through a wider area on the soil subgrade below. Thus, the magnitude of stresses transferred to the subgrade soil through the pavement layers are considerably lower than the contact pressure or compressive stresses directly under the wheel load applied on the pavement surface.

The reduction in the wheel load stress due to the pavement depends both on its thickness and the characteristics of the materials used in the different pavement layers placed over the soil subgrade. A pavement layer material is considered more effective or superior, if it can distribute the wheel load stress through a larger area per unit thickness of the layer.

### 1.2 Structural Requirements for Pavements

The 'pavement structure' of the road is designed, constructed and maintained by the highway engineer from structural point of view, the pavement structure is to be designed to sustain the heavy wheel loads and their repeated applications due to the moving traffic. The structural design of the pavement is to be carried out considering the various design factors related to the traffic, soil type, drainage, climate and environmental factors and desirable design life.

The pavement structural generally consists of few layers of selected superior pavement materials laid over a prepared soil subgrade, each pavement layer is laid evenly and is well- compacted over a compacted 'soil subgrade' to serve as the highway pavement or the carriageway for the movement of road vehicles.

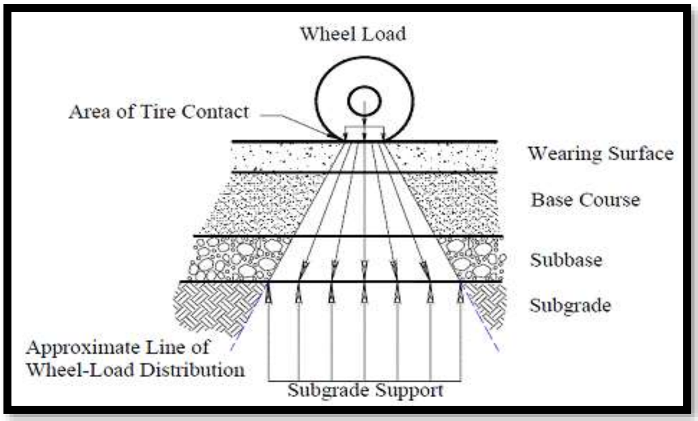



Fig 1.1 Pavement Structure

**1.3 Longitudinal Cracking**

These cracks run longitudinally along the pavement and are caused by thermal stress and/or traffic loadings. They occur frequently at joints between adjacent travel lanes or between a travel lane and the shoulder, where hot mix density is lower, and voids are higher. Longitudinal cracking may be associated with raveling and poor adhesion or stripping. These cracks can be effectively treated with crack sealants.

Fig1.2 Formation of Longitudinal Cracking

**1.4 Transverse Cracking**

Transverse Cracks are occurring perpendicular to the centerline of the pavement or laydown direction. Transverse cracks are generally caused by thermally induced shrinkage at low temperatures.

Fig 1.3 Formation of Transverse Cracking

## II. LITERATURE REVIEW

**Latvia, 2014 CSP 2015**

Renewable energy sources (RES) accounted for a 36.8% (approx. 69PJ) share of the gross inland energy consumption in Latvia, 2014 (CSP 2015). 82.1% of renewable energy was produced by different kind of wood fuel, but 24.3% of it was produced in cogeneration plants (CSP 2015). It was estimated that approximately 52 ktons of wood fly ash (WFA) was generated as a by-product by cogeneration of electricity and heat in 2014.

**Bohrn and Stampfer 2014**

showed enhanced durability and bearing capacity relative to the conventionally designed road sections in the same circumstances. Frost susceptibility, heave, deformation and cracking problems are reduced.

**Du et al. 1999, 2013, Nematollahi et al. 2014**

Cement has been used extensively for the stabilization of soft soils and pavement materials. Production of ordinary Portland cement involves considerable generation of $CO_2$. Approximately every 1 ton of ordinary Portland cement produced would emit approximately 1 ton of $CO_2$.

**Cosentino et al. 2012; Thakur and Han 2015 Wen et al. (2010)**

The effect of chemical stabilizers on creep and permanent deformations of fly ash–stabilized RAP has been investigated recently. Regarding the effectiveness of high-carbon fly ash to stabilize recycled pavement materials. Geo polymer has near-zero carbon foot print because it is produced from fly ash, an industrial waste from coal power stations.

**Arul rajah et al. 2013**

The research aim is to evaluate the performance of C&D materials that are stabilized with alkaline-activated fly ash–slag geopolymer in pavement base/sub base applications. The approach seeks a low-carbon solution to geo polymerization using room temperature curing. This would eliminate the need for temperature curing in the field, which is difficult to implement at the construction site. The permeability of unbound C&D materials has been reported previously.

**Disfani Rahmanet et al. 2014**

The reuse of recycled C&D materials in civil engineering infrastructure applications will result in a low carbon solution, considering that recycled materials have significant carbon savings compared with virgin quarried materials C&D materials have been used in recent years in various civil engineering applications such as roads, embankments, pipe bedding, and back filling

## III. EXPERIMENTATION AND METHODOLOGY

A series of laboratory model tests were conducted in this experimental program. The main aim of this study is to investigate the utilization of Wood Residue by mixing them with low-strength soil, stabilized by wood byproduct for improving the road sub-grade stability.

### 3.1 Soil

Soil used in this study was collected from a site in Moinabad, India at 2m depth from the ground level.

According to IS classification system, the disturbed soil samples collected from above location was air dried and pulverized thoroughly prior to laboratory testing. An initial screening is done, and soil is made free from grass and weeds. Thus, prepared soils are bagged and used in laboratory for determination of properties

### 3.2 Physical Properties of Wood Residue

Table 3.1 Different Types of Wood Residues

| | **P. Leiophylla** | | | **P. Montezumae** | | | **P. Pseudostrobus** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Wood** | **Bark** | **Wood-Bark** | **Wood** | **Bark** | **Wood-Bark** | **Wood** | **Bark** | **Wood-Bark** |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Initial Moisture Content (%)** | 49.6 (±1.0) | 42.5 (±1.5) | 44.3 (±0.8) | 48.9 (±0.5) | 33.6 (±1.2) | 41.9 (±1.0) | 56.0 (±0.7) | 36.1 (±1.3) | 40.8 (±0.7) |
| **Bulk Density (G.Cm-3)** | 0.19 (±0.01) | 0.30 (±0.00) | 0.31 (±0.01) | 0.20 (±0.00) | 0.19 (±0.01) | 0.22 (±0.01) | 0.19 (±0.00) | 0.25 (±0.01) | 0.24 (±0.01) |
| **Calorific Value (Mj.Kg-1)** | 18.57 (±1.1) | 18.74 (±6.5) | 18.70 (±0.9) | 18.01 (±4.2) | 18.60 (±5.3) | 18.87 (±2.1) | 18.23 (±2.0) | 17.95 (±4.7) | 18.93 (±6.6) |

## IV. CALCULATIONS AND RESULT

### 4.1 Specific Gravity Test Result for Untreated Soil

Table 4.1 Specific Gravity of Soil

| **S.No** | **Observations and Calculations** | **Sample 1** | **Sample 2** | **Sample 3** |
|---|---|---|---|---|
| 1 | Mass of empty pycnometer ($M_1$) gms | 512 | 513 | 513 |
| 2 | Mass of pycnometer and dry soil($M_2$) gms | 712 | 713 | 712 |
| 3 | Mass of pycnometer, soil and water($M_3$) gms | 1564 | 1569 | 1560 |
| 4 | Mass of pycnometer filled with water($M_4$)gms | 1444 | 1447 | 1435 |

**Calculations**

Mass of empty pycnometer ($M_1$) =512 gms

Mass of the pycnometer and dry soil ($M_2$) =712 gms

Mass of the pycnometer, soil and water ($M_3$) =1564 gms

Mass of the pycnometer filled with water only ($M_4$) =1442 gms

$$G_S = \frac{\text{Mass of soil}}{\text{Mass of water displaced by soil}}$$

$$= \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

**Results:** The specific gravity of the soil is = 2.56

### 4.2 Liquid limit for untreated soil sample

Table 4.2 Liquid Limit for Soil Sample

| **S.No** | **Observations and Calculations** | **Sample 1** | **Sample 2** | **Sample 3** |
|---|---|---|---|---|
| 1 | No of blows | 15 | 30 | 60 |
| 2 | Water added (ml) | 40 | 35 | 30 |

| | | | | |
|---|---|---|---|---|
| 3 | Can no | 1 | 2 | 3 |
| 4 | Mass of empty can ($M_1$) gms | 20 | 20 | 21 |
| 5 | Mass of can + wet soil ($M_2$) gms | 60 | 62 | 55 |
| 6 | Mass of can +dry soil($M_3$) gms | 52 | 53 | 49 |
| 7 | Mass of water ( $M_2$-$M_3$) gms | 8 | 9 | 6 |
| 8 | Mass of dry soil ($M_3$-$M_1$) gms | 32 | 33 | 28 |
| 9 | Water content % | 25 | 33.33 | 21.42 |

**Result**

Average Water content = (25+33.33+21.42)/3

The liquid limit = 26.58 %

### 4.3 Plastic Limit of Soil Sample

Table 4.3 Plastic Limit

| S.No | Observation and calculations | Sample |
|---|---|---|
| 1 | Mass of empty can, $M_1$ gms | 23 |
| 2 | Mass of can +wet soil ($M_2$) gms | 28 |
| 3 | Mass of can + dry soil ($M_3$) gms | 27 |
| 4 | Mass of water ($M_2$-$M_3$) gms | 1 |
| 5 | Mass of dry soil ($M_3$-$M_1$) gms | 4 |
| 6 | Water content % | 20 |

**Result:** The plastic limit of sample is 20 %

### 4.4 Plasticity Index

$I_P = W_L – W_P$ =26.58-20

$I_P$ = 6.58 %

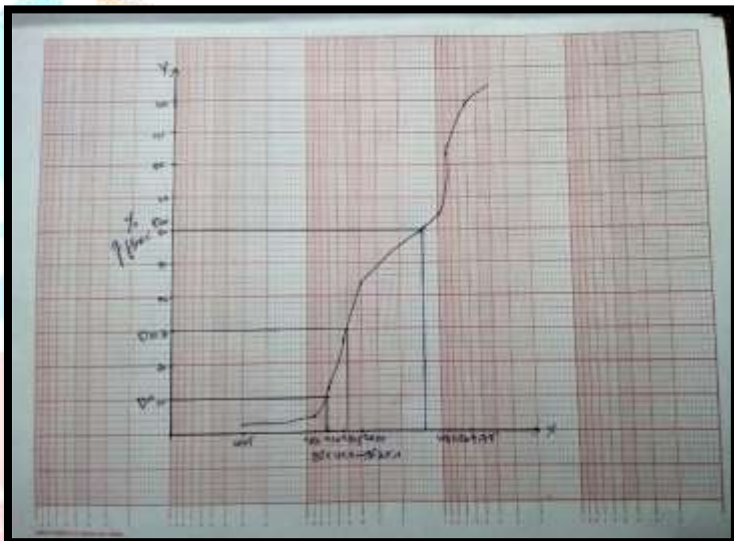
### 4.5 The $C_U$ and $C_C$ Value of The Untreated Soil

Table 4.4 Sieve Analysis

| S.No | Sieve Size (mm) | Amount of Soil Retained (gm.) | Percentage (%) of Soil Retained | Cumulative Percentage of Soil Retained | Percentage (%) of Finer |
|---|---|---|---|---|---|
| 1. | 4.75 | 12 | 1.2 | 1.2 | 98.8 |
| 2. | 2.36 | 154 | 15.4 | 16.6 | 83.4 |
| 3. | 1.18 | 186 | 18.6 | 35.2 | 64.8 |

| | | | | | |
|---|---|---|---|---|---|
| 4. | 600µ | 210 | 21.0 | 56.2 | 43.8 |
| 5. | 425µ | 176 | 17.6 | 73.8 | 26.2 |
| 6. | 300µ | 142 | 14.2 | 88 | 12 |
| 7. | 150µ | 68 | 6.8 | 94.8 | 5.2 |
| 8. | 75µ | 30 | 3.0 | 97.8 | 2.2 |
| 9. | Pan | 22 | 2.2 | 100 | 0 |

Graph 4.1 Sieve Analysis



**Calculations**

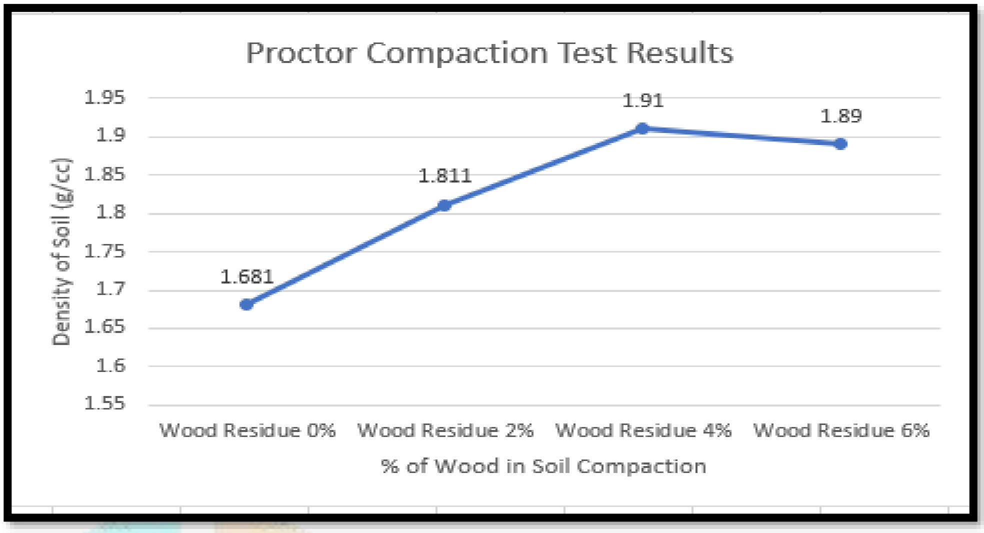
The graph, between % of finer and the sieve size on semi log graph, then we obtain the values of $D_{10}$, $D_{30}$, $D_{60}$.
Hence, D10 is the diameter of sieve size corresponding to 10% finer than that size and then
Co-efficient of uniformity $C_U = D_{60} / D_{10}$
Co- efficient of curvature $C_C = (D_{30})2 / (D_{10} \times D_{60})$

**Result**

Co-efficient of uniformity of given sample, $C_U = 3.21$
Co-efficient of curvature of given sample, $C_C = 0.573$

**4.6 Proctor Compaction Test**

Graph 4.2: Proctor Compaction Test Results




**Sample 1, Wood Residue 0%**

The maximum dry density and optimum moisture content of the untreated soil, it can be observed that the maximum dry density as 1.681 g/cc and optimum moisture content is 11.53%

**Sample 2, Wood Residue 2%**

The maximum dry density and optimum moisture content of the untreated soil and 2% wood, it can be observed that the maximum dry density as 1.840 g/cc and optimum moisture content is 12.5%

**Sample 3, Wood Residue 4%**

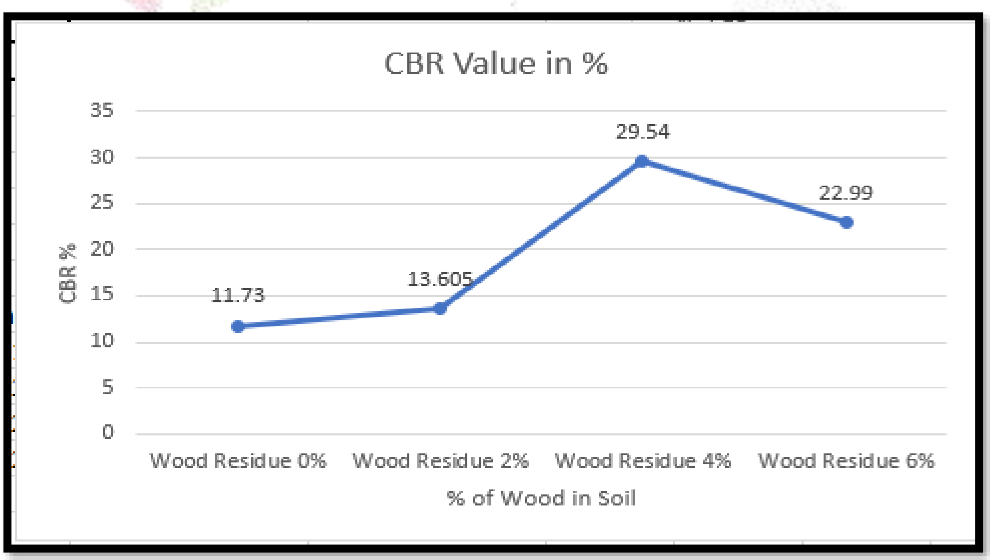
The maximum dry density and optimum moisture content of the untreated soil and 4% wood, it can be observed that the maximum dry density as 1.91 g/cc and optimum moisture content is 12.5%

**Sample 4, Wood Residue 6%**

The maximum dry density and optimum moisture content of the untreated soil and 6% wood material, it can be observed that the maximum dry density as 1.89 g/cc and optimum moisture content is 12.5%

**4.7. CBR Test of Soil Sample**

Graph 4.3: CBR Value of Soil Samples



**Sample 1, Wood Residue 0%**
The load vs. penetration for the untreated soil, it can be observed that the UN soaked CBR value is 11.73%.

**Sample 2, Wood Residue 2%**
The load vs. penetration for the untreated soil and 2% wood material, it can be observed that the UN soaked CBR value is 13.605%.

**Sample 3, Wood Residue 4%**
The load vs. penetration for the untreated soil and 4% wood material, it can be observed that the UN soaked CBR value is 29.54%.

**Sample 4, Wood Residue 6%**
The load vs. penetration for the untreated soil and 6% wood material, it can be observed that the UN soaked CBR value is 22.99%.

## CONCLUSION

The following conclusions are drawn based on the laboratory studies carried out in the work.

i. Wood residues material are added to soil up to the percentage of 2%, 4%, 6%.
ii. When the adding of 4% there is a considerable increase in MDD vales, where as a further increases of wood material decrease MDD values.
iii. For the untreated soil the MDD value is 1.68(g/cc) and water content 12%.
iv. Adding 2% of wood, the MDD value is increased, when compared to untreated soil.
v. Adding of 4% of wood, the MDD value further also increased
vi. Adding of 6% of wood, the MDD value is decreased
vii. When soil treated with wood there is increases in CBR value up to 4% where further increase in wood% there is a decrease in CBR value.

## FURTHER SCOPE OF WORK

i. Similar work can be done using other additives and admixtures to arrive the optimum combination used in construction of roads on soil sub grades.
ii. This study can extend for the use of various stabilized materials like slag, pond ash and fly ash as a sub base course and fill material in roads.
iii. The reinforcement technique can be adopted for higher load carrying capacity of the pavement road sub grades.

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