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RESEARCH ARTICLE

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# STABILIZATION WITH NANO MATERIALS AND CEMENT FOR IMPROVEMENT OF SOIL PROPERTIES FOR ROADS

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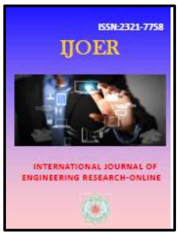


**ABSTRACT**

A considerably high increase in infrastructure development has been witnessed in India since last two decades due to which the construction of pavements is taking place at a fast rate. In this process, the pavements need to be laid on soft and unfavorable grounds for most of the times. California Bearing Ratio (CBR) value of such type of subgrade soils is very low due to which the thickness of pavement layers increases. This in turn requires large quantities of natural materials leading to depletion of valuable natural resources. Conversion of locally available difficult soil into suitable construction material would be an economical solution. So, the option is to modify the properties of the existing soil so that it meets the design requirements, which is also called soil stabilization. Cementing method of soil stabilization is an established procedure of improvement of ground used as sub-grade for pavements. In view of this, apart from the conventional cement, several commercial stabilizers have emerged in the last few years. It is therefore necessary to evaluate the effectiveness of such new commercial stabilizers vis-a-vis that of traditional stabilizer, the Cement. In line with this, an attempt has been made in the present study to evaluate the effectiveness of one of the new commercial stabilizers viz., Zycobond, Terrasil manufactured by Zydex industries vis-a-vis that of traditional stabilizer, the Cement. The scope of present study is limited to study the mechanism of stabilization process in terms of the macroscopic results of CBR values.The study is confined to one type of soil and two commercial stabilizers viz., Zycobond and Terrasil of M/s Zydex make.

## 1. INTRODUCTION

Due to depletion of the sources of stone, cost of the road construction material increases. Therefore, it is necessary to use alternative material for construction which would reduce the overall cost of pavement construction. Stabilization of the sub grade soil can lead to reduce the thickness of the pavement layers and it works out to be economical. Cement is a very popular stabilizer all over the world particularly for coarse grained soils. Soil stabilization is the permanent alteration of any property of the soil to improve its engineering performance. From the economical point of view, stabilized gravel road can be constructed in the areas where traffic volume is low. For the stabilization of soil, modification can be done by adding additives such as lime, cement, fly ash etc., to increase the strength, durability and performance of the soil so that it can be used for the construction of sub-base or base in rural road construction. Now-a-days a number of other proprietary additives are also being used for stabilization of various types of soils, which often accomplished by physical or chemical stabilization. In stabilization process, soil stabilization depends mainly on chemical reactions between stabilizer and soil minerals to achieve the desired effect. In this study, cement stabilization is used to modify soil properties along with small quantity of organo-silane based Nano materials. This additive eliminates capillary rise and water ingress from top, and reduces water permeability. Additive assists in improvement of durability. In this study stabilization has been done using cement and Organo-silane nano materials. In the present study, the behavior of sandy clay type soil with and without stabilization was investigated.

**2. NEEDS AND ADVANTAGES**

Pavement design is based on the premise that minimum specified structural strength will be achieved for each layer must resist shearing, avoid excessive deflections that cause fatigue cracking with in the layer or in overlying layers and prevent excessive permanent deformation through dencification. As the quality of layer is increased, the ability of that layer to distribute the load over greater area is generally increased, so that a reduction in the required thickness of the pavement layer may be permitted. Some of the attributes of soil modifications mentioned below.

**QUALITY IMPROVEMENT:** After adding additives the engineering properties of soil shall change. There is reliable improvement in soil properties such as soil grain size analysis, lowering the values of Plasticity index or swelling Potential and increase in bearing capacity of soil. In wet weather stabilization may also be used to provide a working Platform for construction operations. These type of soil qualities improvement are referred to as soil modification. Stabilization can enhance the properties of road materials and give pavement layers the following attributes.

A substantial property of their strength is retained ever after they become saturated with water. Minimize the deflections. Resistance to soil erosion is improves. Materials in the supports layer cannot contaminate the stabilized layer. The elastic module of granular layers constructed above stabilized layer is increased. The stabilized layer is suitable for use as capping layer or working Platform when the *in situ* material is excessively wet or weak and removal is not economical.

**THICKNESS REDUCTION:** The Strength of soil layer can be improved through the use of additives and that will help in minimizing the thickness of stabilized material compared with an un stabilized.

**GENERAL USES OF SOIL STABILIZATION:**

- Improve the mechanical qualities of local road construction soils
- Increase loading capacity (CBR)
- Improve structural integrity
- Reduce harmful moisture penetration
- Provide longer economic life of the road bed
- Reduce maintenance costs
- Lower road construction costs

**3. MATERIALS**

**THE FOLLOWING MATERIALS ARE USED IN STABILIZATION PROCESS**

A) Soil
B) Cement
C) Terracil
D) Zycobond
E) Water

**3.1. SOIL:** The term soil have various meanings, depending upon the general professional field in which it being considered. For engineering purposes, soil is defined as natural aggregate of mineral grains, loose or moderately cohesive, inorganic and organic in nature. According to the geologist, soil is defined as disintegrated rock and according to agriculturist, and soil is the loose mantle at the surface of the earth which favours the growth of plants. The soil is produced by the mechanical or chemical weathering of solid rocks which may be igneous rock, sedimentary rock or metamorphic rock.

**3.2. CEMENT:** The history of Cementing material is as old as the history of engineering construction. The investigations of L.J Vicat led him to prepare an artificial hydraulic lime by calcining an intimate mixture of lime stone and clay. This process may be regarded as leading knowledge to the manufacture of Portland cement. James Frost also patented a cement of his kind in 1811 and established a factory in London District. In the early period, cement was used for mortar making only. Later the use of cement was extended for making concrete. As the use of Portland cement was increased for making concrete, engineers called for consistently higher

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standard, material for use in major works. Association of Engineers, consumers and cement manufactures have been established to specify standards for cement.

**3.3. TERRASIL:** It is water soluble, easy to apply, nanotechnology compound. It is a UV & heat stable reactive soil modifier to stabilize and waterproof soil subgrade. It is a green technology enabling minimal use of aggregates. It reacts with water loving silanol groups of sand, silt, clay, and aggregates to convert it to highly stable water repellent alkyl siloxane bonds and forms a breathable in-situ membrane. It resolves the critical sub-surface issues.


Figure 1- Terrasil

**3.4. ZYCOBOND:** It is acrylic co-polymer dispersion for the soil particles and imparting resistance to soil erosion and dust control. It is blended with Terrasil and showered on compacted soils. It enhances the quality of soil layer, controls soil disintegration, quick drying of soil layers/earth road after downpours and thus it helps in reducing maintenance cost.


Figure 2- Zycobond

**3.5. WATER:** Water using for mixing and curing for stabilized mixes shall be clean and free from injurious amounts of oils, salt and acid etc. It shall meet the requirements as IS 456.Potable water is generally considered to be acceptable for stabilization works. The permissible limits for solids in water should be as follows.

**4. TESTS & RESULTS**

**4.1. GRAIN SIZE ANALYSIS**

Figure 3-Sieve analysis

**4.1.1. NON TRAFFIC ZONE NORMAL SAMPLE PROPERTIES**

Table No: 1 Observation of Grain Size analysis of Conventional soil sample

| GRAIN SIZE ANALYSIS OF SOIL | | | | | |
|---|---|---|---|---|---|
| ( As per IS 2720, Part - 4 ) | | | | | |
| Type of Material | | : Red gravel-60% & Insitu soil-40% | Proposed use | : Stabilization (Non-Traffic zone) | |
| Weight of Oven Dry sample in gms | | 15250 | | | |
| Sieve size(mm) | Weight retained (gm) | Cumulative weight retained (gm) | % Retained | % Passing | Remarks |
| 100 | 0 | 0 | 0 | 100 | |
| 75 | 0 | 0 | 0 | 100 | |
| 26.5 | 0 | 0 | 0 | 100 | |
| 19 | 481 | 481 | 3.15 | 96.85 | |
| 4.75 | 1215 | 1696 | 11.12 | 88.88 | |
| 2 | 1864 | 3560 | 23.34 | 76.66 | |
| 0.425 | 1389 | 4949 | 32.45 | 67.55 | |
| 0.075 | 4111 | 9060 | 59.41 | 40.59 | |
| Pan | | | | | |


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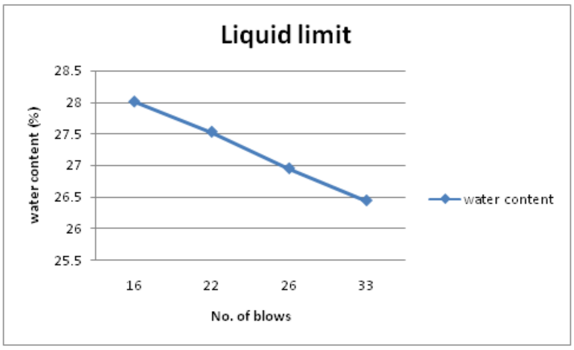
| DESCRIPTION OF PARTICLE | | SIEVE SIZE (mm) | ( % ) |
|---|---|---|---|
| Gravel | Coarse | 75 - 19 | 3.15 |
| | Fine | 19 - 4.75 | 7.97 |
| Sand | Coarse | 4.75 - 2.00 | 12.22 |
| | Medium | 2.00 - 0.425 | 9.11 |
| | Fine | 0.425 - 0.075 | 26.96 |
| Silt & Clay | | Passing through 0.075 | 40.59 |

### 4.1.2. LQUID LIMIT ANDPLASTIC LIMIT

Fig. No. 4 Liquid limit and plastic limit

Table No:2 Observation of Liquid & Plastic Limit of soil on SAMPLE A

| | LIQUID LIMIT | | | | PLASTIC LIMIT | | |
|---|---|---|---|---|---|---|---|
| Determination No | 1 | 2 | 3 | 4 | 1 | 2 | Avg |
| No. of Blows | 16 | 22 | 26 | 33 | - | - | |
| Weight of water | 4.53 | 4.2 | 4.58 | 4.24 | 1.17 | 1.34 | |
| Wt of Dry material | 16.18 | 15.27 | 18.14 | 16.03 | 6.78 | 7.2 | |
| Water Content | 28.01 | 27.53 | 26.95 | 26.44 | 17.26 | 18.61 | 17.94 |



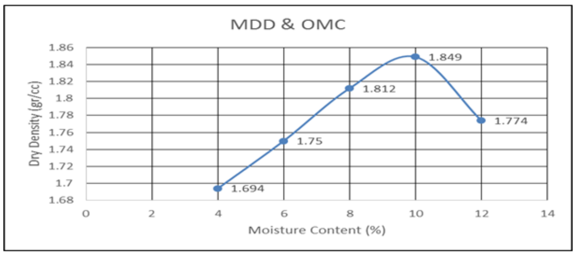

Graph No.1 – Liquid Limit For Conventional sample

### 4.1.3. COMPACTION TEST

Fig. No. 5 compaction test

Table No: 3 Observation of Proctor test of soil on SAMPLE A

| Determination No. | Wt. of compacted soil+ mould | Amount of water added (ml) | Wet density (ᵞ) | Moisture content (w) (%) | Dry density |
|---|---|---|---|---|---|
| | (kg) | | | | = ᵞ/1+w |
| 1 | 10050 | 187 | 1.791 | 5.07 | 1.693 |
| 2 | 10190 | 238 | 1.853 | 6.29 | 1.75 |
| 3 | 10420 | 270 | 1.978 | 8.69 | 1.812 |
| 4 | 10680 | 304 | 2.071 | 10.58 | 1.849 |
| 5 | 10580 | 327 | 2.027 | 12.19 | 1.774 |




Graph 2 showing the MDD & OMC of sample.

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### 4.1.4. FREE SWELL INDEX TEST

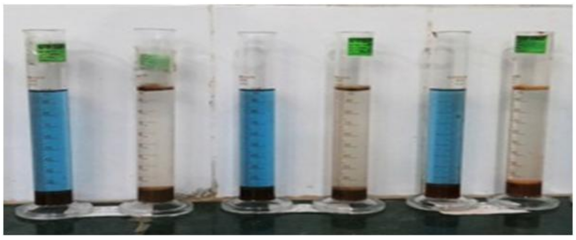


Fig. No. 6 Free swell index test

Table No: 4 Observation of Free Swelling Index of soil on SAMPLE A

| S. NO | Sample Level in Water (Vw) | Sample Level in Kerosene (Vk) | Free Swell in Water (Vw- | Free Swell index (Vw-Vk)/Vk x100) | Remarks |
|---|---|---|---|---|---|
| 1 | 11 | 9.5 | 1.5 | 15.79 | |
| 2 | 10.5 | 9 | 1.5 | 16.67 | |
| | | | Ave | 16.23 | |

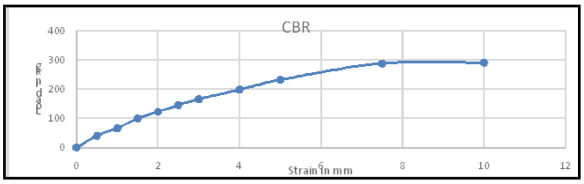
### 4.1.5. CBR TEST

Fig. No.7 C.B.R test

Table No:5 Observation of California Bearing Ratio of soil

| S NO. | Strain gauge reading | Strain (mm) | Proving ring reading | Load in kg |
|---|---|---|---|---|
| 1 | 50 | 0.5 | 6 | 39.78 |
| 2 | 100 | 1 | 10 | 66.3 |
| 3 | 150 | 1.5 | 15 | 99.45 |
| 4 | 200 | 2 | 18.5 | 122.66 |
| 5 | 250 | 2.5 | 22 | 145.86 |
| 6 | 300 | 3 | 25 | 165.75 |
| 7 | 400 | 4 | 30 | 198.9 |
| 8 | 500 | 5 | 35 | 232.05 |
| 9 | 750 | 7.5 | 43.5 | 288.01 |
| 10 | 1000 | 10 | 44 | 291.72 |

Graph:3 showing California Bearing Ratio of sample A




### 4.2. NON TRAFFIC ZONE STABILIZED SAMPLE PROPERTIES

#### 4.2.1.1. UCS OF SOIL WITH 3% CEMENT AND TERRACIL & ZYCOBOND AS 0.6 Kg/Cum

Table No:6 Observation of Unconfined Compressive Strength of Stabilized soil with 3.0% Cement, Terracil & Zycobond as 0.6 Kg/Cum

<table>
<tr><th colspan="7">COMPRESSIVE STRENTH OF SOIL STABILIZATION CUBES</th></tr>
<tr><th colspan="7">( As per IS : 516 )</th></tr>
<tr><td>Name of work :</td><td colspan="4">NON TRAFFIC ZONE MIX DESIGN</td><td colspan="2" rowspan="2">Size Of the Cube : 15x15x15 cm</td></tr>
<tr><td>Details of Design Mix :</td><td colspan="4">Cement 3%, Terracil & Zycobond 0.6 Kg/Cum</td></tr>
<tr><th rowspan="2">Specimen ID</th><th rowspan="2">Age</th><th rowspan="2">Weight of the Cube (Kgs)</th><th rowspan="2">Density (gr/cc)</th><th colspan="2">Crushing Details</th><th rowspan="2">Average Compressive Strength (N/mm2)</th></tr>
<tr><th>Load at Failure (KN)</th><th>Compressive Strength ($N/mm^2$)</th></tr>
<tr><td>1</td><td rowspan="5">7Days</td><td>7152</td><td>2.119</td><td>28</td><td>1.24</td><td rowspan="5">1.18</td></tr>
<tr><td>2</td><td>7120</td><td>2.11</td><td>24</td><td>1.07</td></tr>
<tr><td>3</td><td>7136</td><td>2.114</td><td>26</td><td>1.16</td></tr>
<tr><td>4</td><td>7135</td><td>2.114</td><td>27</td><td>1.2</td></tr>
<tr><td>5</td><td>7142</td><td>2.116</td><td>28</td><td>1.24</td></tr>
</table>

### 4.3. NON TRAFFIC ZONE STABILIZED SOIL SAMPLE PROPERTIES

#### 4.3.1. GRAIN SIZE ANALYSIS

Table No: 7 Observation of Grain Size analysis of stabilized soil sample

GRAIN SIZE ANALYSIS OF SOIL

( As per IS 2720, Part - 4 )

| Type of Material | : Red gravel-60% & Insitu soil-40% | Proposed use | :Stabilization (Non-Traffic zone) | |
|---|---|---|---|---|
| Weight of Oven Dry sample in gms | 15250 | | | |

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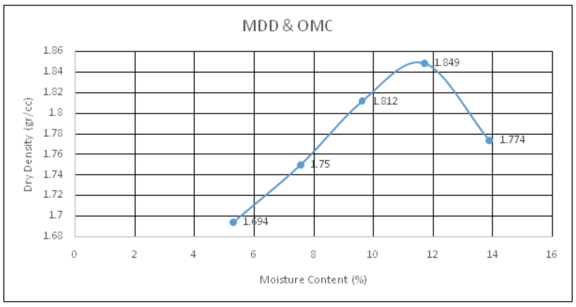
| Sieve size(mm) | Weight retained ( gm) | Cumulative weight retained (gm) | % Retained | % Passing | Remarks |
|---|---|---|---|---|---|
| 100 | 0 | 0 | 0 | 100 | |
| 75 | 0 | 0 | 0 | 100 | |
| 26.5 | 0 | 0 | 0 | 100 | |
| 19 | 481 | 481 | 3.15 | 96.85 | |
| 4.75 | 1215 | 1696 | 11.12 | 88.88 | |
| 2 | 1864 | 3560 | 23.34 | 76.66 | |
| 0.425 | 1389 | 4949 | 32.45 | 67.55 | |
| 0.075 | 4111 | 9060 | 59.41 | 40.59 | |
| Pan | | | | | |

| DESCRIPTION OF PARTICLE | | SIEVE SIZE (mm) | ( % ) |
|---|---|---|---|
| Gravel | Coarse | 75 - 19 | 3.15 |
| | Fine | 19 - 4.75 | 7.97 |
| Sand | Coarse | 4.75 - 2.00 | 12.22 |
| | Medium | 2.00 - 0.425 | 9.11 |
| | Fine | 0.425 - 0.075 | 26.96 |
| Silt & Clay | | Passing through 0.075 | 40.59 |

**4.3.2. COMPACTION TEST**

Table No: 8 Observation of Proctor test of soil Determination

| Determination No. | Wt. of Compacted soil+ mould (kg) | Amount of water added(ml) | Wet density(ϒ) | Moisture Content achieved (w)(%) | Dry density = ϒ/1+w |
|---|---|---|---|---|---|
| 1 | 10030 | 187 | 1.782 | 5.31 | 1.693 |
| 2 | 10318 | 238 | 1.91 | 7.57 | 1.75 |
| 3 | 10572 | 270 | 2.023 | 9.64 | 1.812 |
| 4 | 10693 | 304 | 2.077 | 11.72 | 1.849 |
| 5 | 10606 | 327 | 2.038 | 13.9 | 1.774 |




Graph 4 showing the MDD & OMC

**4.3.3. FREE SWELLINDEX FOR STABILIZED SOIL SAMPLE**

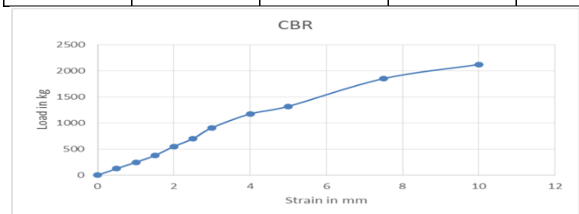
Table No: 9 Observation of Free Swelling Index of soil

| SL NO | Sample Level in Water (Vw) | Sample Level in Kerosene (Vk) | Free Swell in Water (Vw-Vk) | Free Swell index (Vw-Vk)/Vk x100) | Remarks |
|---|---|---|---|---|---|
| 1 | 11 | 10 | 1 | 10 | |
| 2 | 10.5 | 9.5 | 1 | 10.53 | |
| | | | Ave | 10.27 | |

**4.3.4. CBR TEST FOR STABILIZED SOIL**

Table No: 10 Observation of California Bearing Ratio of soil

| S NO. | Strain gauge reading | Strain (mm) | Proving ring reading | Load in kg |
|---|---|---|---|---|
| 1 | 50 | 0.5 | 20 | 132.6 |
| 2 | 100 | 1 | 39 | 258.57 |
| 3 | 150 | 1.5 | 57 | 377.91 |
| 4 | 200 | 2 | 83 | 550.29 |
| 5 | 250 | 2.5 | 105.5 | 699.47 |
| 6 | 300 | 3 | 137 | 908.31 |
| 7 | 400 | 4 | 177 | 1173.51 |
| 8 | 500 | 5 | 199 | 1319.37 |
| 9 | 750 | 7.5 | 279 | 1849.77 |
| 10 | 1000 | 10 | 320 | 2121.6 |




Graph 5 showing the California Bearing Ratio.

### 5. COMPARISON

Table No: 11 Showing the comparison of normal soil and stabilized soil in Non-Traffic Zone

| NON TRAFFIC ZONE | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **NORMAL SOIL SAMPLE** | | | | | | | **STABILIZED SOIL SAMPLE** | | | |
| | **O.M.C (%)** | **M.D.D g/cc** | **C.B.R (%)** | **F.S.I (%)** | **U.C.C $N/mm^2$** | | **O.M.C (%)** | **M.D.D g/mm** | **C.B.R (%)** | **F.S.I (%)** |
| **SAMPLE - A** | 10 | 1.849 | 11.29 | 16.23 | Cement 3%, Terracil & Zycobond 0.6 Kg/Cum | 1.18 | 11 | 1.865 | 64.2 | 10.27 |
| | | | | | Cement 4%, Terracil & Zycobond 0.6 Kg/Cum | 1.37 | | | | |
| | | | | | Cement 5%, Terracil & Zycobond 0.6 Kg/Cum | 1.99 | | | | |
| **SAMPLE - B** | 10.7 | 1.843 | 12.21 | 15.79 | ----- | | 11.6 | 1.862 | 62.91 | 7.65 |
| **SAMPLE - C** | 10.9 | 1.867 | 10.32 | 14.65 | ------ | | 11.3 | 1.866 | 70.97 | 9.3 |

### 6. CONCLUSION

**FOR NON TRAFFIC ZONE**

I have collected three soils samples at non-traffic zone which are named as SAMPLE A, SAMPLE B, SAMPLE C and I investigated the engineering properties of the soil samples. From the data, I have made the following conclusions,

The SAMPLE A, SAMPLE B and SAMPLE C are having the O.M.C of 10%, 10.7%, 10.9% respectively, M.D.D of 1.849 g/cc,1.843 g/cc,1.867 g/cc respectively, C.B.R values of 11.29%, 12.21%, 10.32% respectively and having free swell index values of 16.23%, 15.79%, 14.65% respectively.

Based on above values SAMPLE A got better results, but it has low U.C.S strength as per IRC recommendations. But as perIRC SP: 89 – 2010, The Required UCS value for NON TRAFFIC ZONE is 1.5 to 3.0 N/mm2. In order to make the soil sample as pavement subgrade material and shoulder material, I choose cement, terracil &Zycobond with different proportions. I treated the soil sample with admixtures with different mixing proportions and finally got the required UCS value is achieved at 5.0% of Cement and Terracil & Zycobond 0.6 Kg/m3.

The above proportion of admixtures (5.0 % of Cement and Terracil & Zycobond 0.6 Kg/m3) is adopted for all three soil samples A,B, and C. and I observed the following values,The SAMPLE A, SAMPLE B, SAMPLE C are having the O.M.C of 11%, 11.6%, 11.30% respectively, M.D.D of 1.865 g/cc, 1.862 g/cc, 1.866 g/cc respectively, C.B.Rvalues of 64.20%, 62.21%, 70.97% respectively and free swell index values of 10.2%, 7.6%, 9.3% respectively.

Based on above values I am suggesting that, all the three soil samples can be used as shoulder material for pavement in non-traffic zone area.

By using this stabilizing technique we can reduce the quantity of soil that can be used in non-traffic zone as a shoulder material and minimize the permeability at great extent.Hencethe durability of Pavement is also increased.

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