Mechanical Behavior of Soil Cement Blends with Osorio Sand

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Abstract
This paper present the analysis made from the axial compression of the mixture between sand, Portland cement and water. In their given proportions, this mixture results in the named "soil cement" in which the amount of sand is strengthened by the bonding of cement through the sand voids, allowing the optimization of sandy soils exposed to large mechanical stresses, such as subgrade and base materials used in pavements. For this purpose, axial and diametral compression tests were conducted, molded with Osorio Sand, a common aggregate found in the south of Brazil with well-known characteristics. The composition were prepared with 3% and 7% of cement and 10% moisture content. For each one of the compositions were molded specimens for three void ratios, testing three specimens of each configuration for five different cure times, totalizing 144 specimens tested. The conclusions shows that the higher the cement percentage and smaller the void ratio, the bigger is the resistance, stabilizing the resistance increase around the fourteenth day. Also, values for initial shear modulus and Young’s modulus are presented for the material.

Keywords: Soil Cement, Soil Reinforcement, Ground Improvement, Sand Improvement, Laboratory Testing.
1 Introduction

Treatment of soils with cement is an attractive technique when the project requires improvement of the local soil for the construction of subgrades for highways and rail tracks, among others. This paper aims to evaluate the mixture product between Portland cement and Osorio Sand, a well-known aggregate from southern Brazil, when subjected to axial and diametral compression.

Three specimens were molded for each composition and cure age. The mixture has value of moisture fixed on 10%, while the cement percentage, void ratio and cure age were varied. Two different percentage of cement were tested: 3% and 7%, for the void ratio there was three different values: 0.60, 0.66 and 0.72, and the cure age when the specimens were test were seven, fourteen, twenty-eight and fifty-six days.

For each one of the configurations, the axial and diametral compression tests were conducted according to the Brazilian standard NBR 12025. The body of this paper will present the materials, methods, results and conclusions obtained.

2 Materials

Basically, three materials were used in order to mold the specimens: Osorio Sand, High Early Strength Portland Cement (CPV-ARI), and water. These materials will be described in detail in sequence.

2.1 Osorio Sand

The Osorio Sand is a fine aggregate commonly found in the city of Osorio, in southern Brazil. This type of sand is being commonly used, presenting a fine granulometry, round-shaped, uniform and free of organic matter. It was classified under ASTM D2487-06 as nonplastic uniform fine sand (SP). Mineralogical analysis showed that the sand particles were predominantly quartz. The properties and granulometric distribution are shown in table 1 and figure 1.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Osorio Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.65</td>
</tr>
<tr>
<td>Coefficient of Uniformity, Cu</td>
<td>2.11</td>
</tr>
<tr>
<td>Coefficient of Curvature, Cc</td>
<td>1.15</td>
</tr>
<tr>
<td>Grain diameter, $D_{10}$</td>
<td>0.09 mm</td>
</tr>
<tr>
<td>Grain diameter, $D_{50}$</td>
<td>0.17 mm</td>
</tr>
<tr>
<td>Minimum Void Ration, $e_{min}$</td>
<td>0.60</td>
</tr>
<tr>
<td>Maximum Void Ration, $e_{max}$</td>
<td>0.85</td>
</tr>
</tbody>
</table>
2.2 High Early Strength Portland Cement

The High Early Strength Portland Cement, commercially known in Brazil as CPV-ARI, is essentially characterized by its binder potential in the presence of water, an intrinsic factor of the cementing materials. The distinctive of this cement is to present a high development of resistance after the first few days of cure, tending to stabilize this increase of resistance after seven days.

The CPV-ARI present the above characteristics due to the high degree of grind which this cement undergoes after calcination. In comparison with other Portland Cement, it also has pure mixture, being composed of 95 to 100% of clinker, still may receive the addition of 0 to 5% of limestone filler, absent of pozzolanic additions.

The use of this type of cement is justified by present the same development of compressive resistance observed in other cements in seven days, with only three days of cure, thus allowing the tests executions with a lower age of at least seven days.

2.3 Water

To the add the moisture necessary to the blend, was used water from the artesian wells of the University of Passo Fundo, both for molding as for the preparation for the rupture tests of the specimens. It may contain impurities, however, it is the type of water that most closely matches the use cases of soil cements on the field.

3 Procedures

To create the necessary blend, three different void ratios were stipulated: 0.60, 0.66 and 0.72. These values fit inside the range of minimum and maximum range of void ratios predicted to the Osorio Sand.
The percentage between soil and cement is defined by the ratio between the mass of cement and the mass of dry blend. This values were established at 3 and 7%.

In order to distinguish the specimens, the following denotation was used: x%_ey_zd_CPj, where the variable x represents the blend's percentage of cement, y detonates the void ratio (e), z detonates the cure age in days and j represents the specimen's number.

3.1 Molding of the Specimens

The preparation of the specimens in order to attend the laboratory tests of axial and diametral compression was conducted under laboratory conditions and followed the Brazilian standard ABNT NBR 12024/92, which deals with the molding and curing of cylindrical specimens of soil-cement.

The specimens were molded for contemplate the cement cure time of seven, fourteen, twenty-eight and fifty-six days, performing the cure in hermetic environment without moisture loss. The molds used have diameter equal to 50 mm by 100 mm long, being made of Polyvinyl Chloride (PVC) with reinforced walls and metal clamps in order to resist the efforts of compaction.

For the compaction of the specimen, a wooden socket was used with three visible layers in order to attend the 100 mm high, where the void ratio desired was obtained by changing the layer mass under a constant height.

The prepared samples were stored until 24 hours before the test in plastic bags to avoid moisture loss, from which they were immersed in water to realize the test close to a full saturated condition.

After the mold release of the specimen, several controls were realized to guarantee that the specimen was reliable. These controls included moisture tests, dimensions check and real density tests.

3.2 Axial and Diametral Compression Tests

For conduce the tests, a simple compression press was used. The press is automatic and has a constant speed of compression equal to 1.14 mm/min. In order to acquire the data about the load, a load cell with maximum capacity of 10,000 kgf was used.

Twenty-four hours before the rupture, the specimens were immersed in a container full of water to approximate the state of saturation - situation where all the porous voids are filled with water and consequently the resistance tends to be lower.

In the axial compression test (also known as simple compression test) the load is applied on the faces of the specimen, producing a rupture due to the pure compression and obtains the direct value of compression resistance of the specimen. As for the diametral compression tests, the load is applied in the bigger dimension of the specimen (the body), producing a rupture due to the tension of the material, being able this way to obtain an indirect value of tension resistance.

4 Results and Conclusions

The average of the results for axial and diametral compression tests is presented on figure 2, 3, 4 and 5. Based on these data is noticed that the void ratio is inversely proportional to the resistance since that the more dense is the mixture, the bigger is it resistance to mechanical efforts.

For the axial compression, the results for the 7% blend show a bigger influence due to the cure time than the results for the 3% cement percent. These mixtures also suffer from a bigger influence due to the void ratio than the other one. The relationship between the resistances with 7% of agglomerate over the 3% ranges from 3 to 4 times with an increase of 4% of cement percentage.

In the tension resistance due to diametral compression tests, the increase of resistance with cure time is visible again as expected. For these results is able to see that the gap between the results with
7% and 3% of cement percentage isn't that big as for the axial compression results, although the increase with the cement percentage and void ratio it's still remarkable.

The results for Initial shear modulus and Young modulus, calculated through the equation proposed by Caberlon (2008), are expressed in the table 2. It can be seen that the Young's modulus increases as the cement percentage increases and the void ratio decreases.

**Table 2 - Initial Shear Modulus and Young Modulus**

<table>
<thead>
<tr>
<th>Void Ratio</th>
<th>Cement %</th>
<th>Initial Shear Modulus (MPa)</th>
<th>Young's Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.60</td>
<td>7</td>
<td>5111.2</td>
<td>12778.1</td>
</tr>
<tr>
<td>0.66</td>
<td>7</td>
<td>4680.2</td>
<td>11700.5</td>
</tr>
<tr>
<td>0.72</td>
<td>7</td>
<td>4320.7</td>
<td>10801.8</td>
</tr>
<tr>
<td>0.60</td>
<td>3</td>
<td>2444.2</td>
<td>6110.6</td>
</tr>
<tr>
<td>0.66</td>
<td>3</td>
<td>2238.7</td>
<td>5596.8</td>
</tr>
<tr>
<td>0.72</td>
<td>3</td>
<td>2072.8</td>
<td>5182.0</td>
</tr>
</tbody>
</table>

**Figure 2 - Average Unconfined Axial compression Resistance for 7% blends results.**
Figure 3 - Average Unconfined Axial compression Resistance for 3% blends results.

Figure 4 - Average Diametral Compression Resistance for 7% blends results.
Figure 5 - Average Diametral Compression Resistance for 3% blends results.

References

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