STUDIES ON STRENGTH CHARACTERISTICS OF SOIL MIXED WITH JAROFIX

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ABSTRACT: Industrialization and infrastructural development, has created huge scarcity of construction materials and increased accumulation of industrial wastes all over the world. The production of large quantity of waste materials faces handling and disposal problems. Jarosite, a waste material produced during extraction of zinc ore is converted to Jarofix, more stabilized and inert form, by the addition of hydrated lime and Portland cement. In the present condition, about 15 million tons of Indian Jarofix is accumulated, with an annual production of 5 million tons. Presently, with a little utilization, Jarofix is dumping on productive land and has become crucial environmental hazard. The present study is an investigation into the effect of Jarofix on geotechnical properties of red earth. This investigation includes the study on the variation of properties of the soil such as Atterberg’s limits, compaction characteristics, compressive strength and CBR values when the Jarofix is mixed with the soil. The major findings of the present study is that, even though there is a reduction in strength characteristics of the soil with the addition of jarofix, the properties are improving with age.

KEYWORDS: Jarofix, Waste utilization, ground improvement, geotechnical properties

1 Introduction

In recent years due to the rapid development of infrastructures along with scarcity of useful land and building materials, engineers all over the world compelled to improve the properties of soil and to find alternate materials for construction. Generally ground improvement techniques are recommended when the soil is weak. Improvement of soil could be achieved by soil modification or stabilization, or both. Soil modification is the additions of a modifier like cement, lime, fly ash, cement kiln dust, bagasse ash, rice husk etc., to soil. [Beena et al.(2013)]

Also a great concern is there about various pollution because of the drastic industrialization and urbanization. All over world, huge quantities of hazardous wastes are generated during different industrial processes. Presently in India, about 960 million tonnes of solid waste is being generated annually as by-products during industrial, mining, municipal, agricultural and other processes. Of this 4.5 million tonnes are hazardous in nature and all over the world these faces serious problems of handling and disposal [Nitisha et al.(2014)]. Now dumping over the land has been the main option available for the disposal. This has created non utilization of large area of land and other environmental problems. So the utilization of these waste materials for ground modification is big option in finding solution to this problem. Also various studies are being carried out all over the world to discover new materials which would be more cost effective compared to usual materials using in the field especially using wastes. One among the wastes is from zinc industries which are releasing immense quantity of jarosite as solid residues. Approximately 0.25 million tonnes per annum is released in India. Jarosite is a by-product of hydro-metallurgical process, used for production of zinc and lead. Jarosite is a waste material produced during extraction of zinc ore concentrate by hydrometallurgy operation. It is acidic in nature. Due to the presence of toxic substances like zinc, lead, cadmium, copper and other metallic and non-metallic oxides and are susceptible to leaching and also which may cause adverse or chronic effects on environment or on human health, is universally considered as hazardous waste. Because of this jarosite falls under hazardous waste category as per the prevailing Hazardous Waste (Management, Handling and Trans-boundary Movement) Rules, 2008.[Nitisha Rathore et al.(2014)] Thus, its world-wide disposal has become a major environmental concern. So the best way to solve the disposal problem of Jarosite is to decrease the quantity for disposal by bulk utilization for infrastructure development. When Jarosite is mixed with lime and cement, the resulting stable material is called Jarofix. [Sinha et al. (2015)] At present, the accumulated Indian Jarofix is about 15 million tons while the annual production is about 5 million tons [Sinha et al.(2012)]
Presently, the utilization of dumped Jarofix is much more crucial and concern in India due to large amounts of Jarofix produced without having any application. The material is occupying costly agricultural land and has become environmental hazard. Only a few literatures are available regarding the utility of Jarofix material for different civil engineering applications.

2 Literature review.

Anu Raj et al. (2014) have studied the variation of Atterberg’s limits and swelling characteristics of bentonite Jarofix mixtures and it shows a decreasing trend when the percentage of Jarofix increases. Sinha et al. (2012) have studied the possibilities of utilization of Jarofix for embankment and sub grade layers and was concluded that Jarofix have the potential for the construction of road embankment while the Jarofix soil mixture may be used for construction of embankment and subgrade layer of road pavement. Sinha et al. (2013) have evaluated the geotechnical characteristics of Jarosite and its utilization for road construction.

3 Experimental work

3.1 Materials

3.1.1 Soil

Soil sample used in this study is laterite soil, which are most commonly observed soil type in Kerala. Laterite soil sample used in the study was taken from a site nearly 5 km from the Aluva, Ernakulam district, Kerala by machine excavation after clearing of 1m top soil.

3.1.2 Jarofix

Jarofix is collected from Binani Zinc Ltd, Binanipuram., Kochi, Kerala and is brought to laboratory in polythene bags. The Geotechnical properties of soil and Jarofix were determined as per IS standards and are as shown in the Table 1. The chemical characteristics of Jarofix are as in Table 2.

Table 1 Geotechnical properties of Soil and Jarofix

<table>
<thead>
<tr>
<th>Properties</th>
<th>Soil</th>
<th>Jarofix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity</td>
<td>2.52</td>
<td>2.31</td>
</tr>
<tr>
<td>Liquid Limit (%)</td>
<td>47</td>
<td>61</td>
</tr>
<tr>
<td>Plastic Limit (%)</td>
<td>27</td>
<td>44</td>
</tr>
<tr>
<td>Plasticity Index (%)</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Shrinkage Limit (%)</td>
<td>21</td>
<td>32</td>
</tr>
<tr>
<td>Optimum Moisture Content (%)</td>
<td>18.5</td>
<td>48.3</td>
</tr>
<tr>
<td>Maximum Dry Density (kN/m$^3$)</td>
<td>17</td>
<td>11.6</td>
</tr>
<tr>
<td>UCC (kN/m$^2$)</td>
<td>272.1</td>
<td>63.8</td>
</tr>
</tbody>
</table>

Table 2 Chemical characteristics of Jarofix

<table>
<thead>
<tr>
<th>Chemical components</th>
<th>Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_3$</td>
<td>19-31</td>
</tr>
<tr>
<td>CaO</td>
<td>4-18</td>
</tr>
<tr>
<td>SiO</td>
<td>3-12</td>
</tr>
<tr>
<td>Al$_2$O$_3$</td>
<td>&lt;12</td>
</tr>
<tr>
<td>Fe$_2$O$_3$</td>
<td>18-36</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>&lt;4</td>
</tr>
<tr>
<td>Cadmium</td>
<td>&lt;0.08</td>
</tr>
<tr>
<td>Lead</td>
<td>&lt;5.5</td>
</tr>
<tr>
<td>Zinc</td>
<td>&lt;3.5</td>
</tr>
</tbody>
</table>

(*As supplied by Binani Zinc Ltd, Binanipuram., Kochi, Kerala)

4 Experimental studies

For studying the changes in the properties of the soil when mixed with Jarofix various experiments such as Consistency limits, Proctor Compaction tests, Unconfined Compressive Strength tests and CBR tests were conducted on parent soil samples and the soil mixed with 10,20,30,40 and 50% of Jarofix. The soil and Jarofix were weighted and mixed fully on dry weight basis for all experiments. Then the samples for the strength tests were prepared at OMC and maximum dry density. All the experiments were conducted as per I.S. specifications.

4.1 Results and discussions

4.1.1 Effect of Jarofix on consistency Limits

Consistency limits are related to so many engineering properties of soil and are used to understand the stress history and properties of soil to be used in construction. The limits are depending on the amount and type of clay in a soil and give an assessment of cohesion of the soil. The variation of Atterberg’s limits with the addition of Jarofix is as shown in the Figure 1.

![Fig. 1 Variation of Atterberg’s limits with Jarofix](image)

From the experimental results liquid limit is found to increases from 47% to 53%, plastic limit increases from 27% to 41% while the plasticity index decrease from 20% to 12% as the percentage of Jarofix increases.
increases. Also the shrinkage limit increases from 21% to 35%. High water holding capacity of Jarofix and cation exchange happens in the soil Jarofix mixture may be the reason for this.

4.1.2 Effect of Jarofix on compaction characteristics

The different soil and Jarofix mixes were compacted in the metal moulds of 100 mm diameter in three layers (25 blows on each layer) using a compactor with a hammer of 2.6 kg dropping from 310 mm height. The compaction curves obtained for the samples are as shown in the Figure 2.

![Compaction curves for different soil Jarofix mixes](image)

Fig. 2 Compaction curves for different soil Jarofix mixes

Maximum dry density and OMC were found from the compaction curves and are varying with the addition of Jarofix. They are presented in the Figure 3 and Figure 4.

![Variation of maximum dry density](image)

Fig. 3 Variation of maximum dry density

![Variation of OMC](image)

Fig. 4 Variation of OMC

When the percentage of Jarofix increases to 50%, maximum dry density was found to decrease from 17.0 kN/m³ to 14.4 kN/m³ while OMC is found to increase from 18.5% to 34%. The change in maximum dry density may be due to the lower value of the same for Jarofix and the increase in OMC may be due to addition of more fine particle to the soil and higher water holding capacity of Jarofix.

4.1.3 Effect of Jarofix on UCC

The samples for the test were prepared by initial dry mixing of soil and corresponding quantity of Jarofix content and the specimen for the testing were prepared by adding water content at OMC. The sample size is 3.8 cm diameter and 7.6 cm height. The stress strain graphs were plotted for the different samples tested and the UCC values were obtained from the graph. Variation of UCC values with different percentage of increasing Jarofix is as shown in Figure 5. From the results it is clear that, as the percentage of Jarofix increases unconfined compressive strength decreases. Its value is 272.1 kN/m² for parent soil and is decreases to 154.7 kN/m² as the percentage of Jarofix increases to 50%. UCC value of Jarofix is less than the parent soil and this may be the reason for the reduction in the value when more percentage of Jarofix is added to the soil.

![Variation of UCC values](image)

Fig. 5 Variation of UCC values

In order to study the long term effect of Jarofix mixed soil, UCC samples were prepared with different proportions of Jarofix as mentioned earlier and they are sealed with in air tight plastic bags for preserving water content for different days.

![Variation of UCC values with age](image)

Fig. 6 Variation of UCC values with age

The samples prepared were tested after 7 days, 14 days, 28 days, 56 days and 90 days. From the results
(Figure 6) it is observed that for all Jarofix mixed samples the UCC value increase with age. The strength gain may be due to pozolonic reaction, cation exchange and strength gaining compounds formed with in the soil Jarofix mixture in presence of water due to the chemical components present in the Jarofix.

4.1.4 Effect of Jarofix on CBR values

The samples for unsoaked CBR were prepared at OMC obtained from compaction test. CBR value for the soil was 23.65% and the value decreases to 15.1% when 50% Jarofix mixed with the soil. This may be due to the addition of Jarofix with a lower CBR value than the parent soil. The variation is as shown in the Figure 7.

![Figure 7 Variation of CBR values](image)

Similar to study the variation of UCC values with age, soil is mixed with different proportions of Jarofix at OMC water content and preserved it in sealed air tight containers. Then the samples were compacted in the CBR mould after 7 days, 14 days, 28 days, 56 days and 90 days.

![Figure 8 Variation of CBR values with age](image)

A similar trend obtained for UCC has observed here also. For each percentage CBR values increases with number of days. The reason may be the same as mentioned in the increase in UCC value. The variations are as shown in the Figure 8.

5 Conclusions

1. The consistency limits, which are significant index property of soil, are found to be increasing, where as the Plasticity index, which is a measure of plastic nature and softness of soil is decreasing when different percentages of Jarofix are added.

2. While evaluating compaction characteristics, the maximum dry density decreases and the optimum moisture content increases when the percentage of Jarofix added to the parent soil increases.

3. UCC value which is one of the easiest method to find the strength of the soils, shows a decreasing trend when the percentage of Jarofix increases, where as for every soil Jarofix mixture the UCC values increases with age.

4. One of the major design factors of flexible pavement, CBR values also observed to be decreasing as the percentage of Jarofix to the virgin soil increases whereas the strength increases when the samples were sealed for different days.

More studies are needed to understand the complete behavior of the soil Jarofix mix and the studies are continuing to explore the application of these materials in road and sub grade improvement.

References


