Comparative Study on Soil Stabilization using Industrial by Products and Coconut Coir

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ABSTRACT: Waste disposal has become a serious concern in developing countries like India. The substitution of these waste materials in the form of stabilizing agents in soil stabilization is a modern approach by which waste materials can be advantageously used. In many instances, the soil has proven to be problematic for the construction of various infrastructures like embankments, pavements, foundations, hydraulic barriers, etc. In the present study, a particular type of soil is stabilized to improve the physical properties by using multiple admixtures. In general, additives such as lime, cement, saw dust, stone dust, and other compounds are used for the stabilization of soil over years. This study is conducted to evaluate the viability of using Coconut Coir Fibre (CC) along with stone dust (SD)/pond ash (PA) as a stabilization material. A comparative analysis on the effect of CC with SD as well CC with PA on engineering characteristics of silty soil is presented in the present study. A sequence of laboratory experiments was conducted on silty soil blended with Coconut Coir Fibre along with proportions of Stone Dust/Pond Ash from 0.5% to 1.5% and 30% as constant respectively by mass of dehydrated soil. The experimental outcomes shown a significant change in properties of soil, which conclude that the coconut coir along with stone dust as a very potential additive to improve the characteristics of silty soil compared to that of pond ash.

KEYWORDS: Soil Stabilization, coconut coir, stone dust, pond ash, OMC, MDD, CBR, industrial waste, sustainability

1. INTRODUCTION
Soil Stabilization becomes necessary as there is a restriction on availability of decent sites for construction. The key objective of Stabilization is to recover the characteristics of soil as it is necessary where the available soil is weak. Soil stabilization is a process where natural or manufactured additives or binders are used to improve the index and engineering properties of soils. Additives such as lime, cement, saw dust, stone dust and other compounds have been used over the years with greater improvement to soil properties. In India, abundance in availability of waste material like coal ash, plastics, stone quarry, recycled aggregate, polythene etc. have been helpful in improving the soil strength over the recent years.
However, ash was proven to be less significant in soil stabilization [5][18]. Stabilization is mainly used to reduce the permeability and compressibility of the soil, while increasing the shear parameters. Stabilization is mainly used to condense the perviousness and compressibility characteristics of the soil, and increase the shear parameters. The improvement of soil properties is done by blending or mixing the materials. It is not ideal that with increase in the quantity of any additive to soil, the strength or properties of the soil are improved. Hence, an optimal proportion of additive shall be added for improvement of any soil is to be evaluated [5].

India is a country with a very huge population, in recent decades construction of roads and buildings are done even on weak soils. The throwing away of waste material is also an immense problem due to scarcity of land. The requirement for proper disposal techniques or dumping waste creates an impact on environment [4]. Also, upsurge in populace has increased the mandate for terrestrial acquisition. Industrial wastes have been the major concern regarding this aspect of sustainable use of resources and waste materials. The use of these wastes in improving various characteristics of many other materials is efficient [17][18]. Use of industrial and agricultural waste to stabilize soil, improves the ground and also reduces the environmental pollution. As they are locally available, minimization of the construction cost and sustainable development are attained. Several studies were led around the world to know changes in various index and engineering properties of soil due to the addition of admixtures to the soil. The paper mainly focuses on the study of engineering properties i.e. O.M.C, M.D.D and C.B.R for a soil stabilised with coconut fibres and pond ash in comparison to the soil stabilised with coconut fibre and stone dust.

The crumpled stone or rock is a form of construction aggregate, formed by mining appropriate rock deposit and then breaking to the desired size using crushers. However, it is discrete from gravel, which is produced by natural processes of weathering and erosion. The use of crushed stone powder reduces the dry shrinkage and micro-cracks which help in high performance of stabilized materials [16]. Pond ash is a combination ash obtained due to the mixture of two by – products from the thermal power plants. Pond ash has been the greatest concern in environmental point of view [4]. Pond ash has been prevalent for its self-hardening characteristics [14].

Coir fibres are extracted from the fruit (coconut) of the coconut tree. The coconut fibre is extracted from the outer shell of a coconut [15]. The common name is coir, scientific name “cocos nucifera” and plant family of coconut fibre is Arecacea. Coconut fibres are categorized as tan fibre and white fibre. Tan fibre is extracted from the mature coconuts, where it is thick and strong with high abrasion resistance. And the white fibres are extracted from immature coconuts. These are smooth and fine in nature, However, these are considered weak. The main considerations regarding that, it would be a renewable resource and CO2 neutral material and biodegradable with low density and cheap availability. Coir fibre diameter is about 0.1 - 1.5mm and length is 3 - 15cm. The coconut coir is elastic in nature and an adequately used material as commercial product i.e., mattress [15].

2. METHODOLOGY:
The most common method of stabilization is to mix the soil with an admixture to form a product with improved properties. The stabilized soil material has relatively high strength, low permeability and compressibility to the actual virgin soil. Stabilization of soil does not alone indicate the improvement by additives but also indicates the advanced technology usage. Improved chemical and mechanical stabilization are necessary when considering waste materials like crushed asphalt pavement, copper – zinc slag and rubber tyre chips etc. Such materials need to be recycled and theses may contain potential hazardous materials [1]. Hence the use of industrial and agricultural waste can help in sustainable soil stabilization.

Coconut coir is collected from the locally available regions in the present study. The length of the fibre was considered 3 cm. Incremental percentages of coconut coir, say 0.5%, 1.0%, 1.5% and 2.0% when used in stabilization were identified to be optimal [13]. The coconut fibres, in proportions of 0.5%, 1.0% and 1.5% along with 30% stone dust is considered as Sample-I study and the same fibre proportions with 30% pond ash as the Sample-II study.

The chemical properties of the stone dust and pond ash are presented in table-1 below:
Table – 1: Chemical Composition of Stone Dust [6] & Chemical Composition of Pond Ash [2] [6] [11].

| S.no | Constituents | Stone Dust (% by weight) | Constituents | Pond Ash (% by weight) |
|------|--------------|--------------------------|--------------|------------------------|
| 1    | SiO₂         | 60.5                     | SiO₂         | 42.7 – 47.6            |
| 2    | Al₂O₃        | 16.2                     | Al₂O₃        | 23.0 – 21.2            |
| 3    | Fe₂O₃        | 3.27                     | Fe₂O₃        | 17.0 – 9.75            |
| 4    | CaO          | 3.52                     | CaO          | 9.80 – 2.94            |
| 5    | MgO          | 0.95                     | MgO          | 1.54 – 1.45            |
| 6    | Na₂O         | 3.73                     | Na₂O         | 0.29 – 1.07            |
| 7    | K₂O          | 4.84                     | K₂O          | 0.96 – 1.05            |
| 8    | Loss on Ignition | 1.7                  | Loss on Ignition | 29.3               |

3. FLOWCHART:

![Flowchart](Chart_1.png)

4. Experimental Study:

Typical soil samples were collected at 1.5 m depth from two deposits, one in Aganampudi, Visakhapatnam, India and the other in Sheelanagar, Visakhapatnam, India. The properties of the soil samples designated as soil I and soil II. The depth at which the soil was collected it restricted to 1.5 m to avoid the inclusion of organic matter. Soil samples are classified as MI according to the Indian Soil Classification System. Silt has specific area with a characteristically non-sticky, plastic feel. [3]. The industrial by-products, stone dust and pond ash which are locally available along with coconut coir fibre are considered for soil I and soil II respectively.

The virgin soil properties have been understood by the experimental approach considering the index and engineering properties. Silty soils are very moisture subtle and their stability is being influenced significantly by the degree of compression attained during compaction.[13] Silty soils are aquaphobic. Hence, there would be difficulty in controlling moisture during
active compaction. This could be problematic during pavements constructions as well as under regular vehicular traffic loads.[7].

| S.no | Properties of the soil               | Value   |
|------|--------------------------------------|---------|
| 1    | Specific gravity                     | 2.65    |
| 2    | Grain size distribution              |         |
|      | a) Gravel (%)                        | 0.72    |
|      | b) Sand (%)                          | 25.6    |
|      | c) Fines (%)                         | 73.68   |
| 3    | Atterberg limits                     |         |
|      | a) Liquid limit (%)                  | 39      |
|      | b) Plastic limit (%)                 | 32.6    |
|      | c) Plasticity index (%)              | 6.4     |
| 4    | Compaction characteristics (heavy compaction) |       |
|      | a) Optimum moisture content (%)      | 11.6    |
|      | b) Maximum dry density (g/cc)        | 1.88    |
| 5    | Strength parameters                  |         |
|      | Un soaked CBR (%)                    | 3.37    |
| 6    | Differential free swell (%)          | 55%     |

Table – 2: Properties of Virgin Soil -I

| S.no | Properties of the soil               | Value   |
|------|--------------------------------------|---------|
| 1    | Specific gravity                     | 2.65    |
| 2    | Grain size distribution              |         |
|      | d) Gravel (%)                        | 0.51    |
|      | e) Sand (%)                          | 25.17   |
|      | f) Fines (%)                         | 74.32   |
| 3    | Atterberg limits                     |         |
|      | d) Liquid limit (%)                  | 38.4    |
|      | e) Plastic limit (%)                 | 32.1    |
|      | f) Plasticity index (%)              | 6.3     |
| 4    | Compaction characteristics (heavy compaction) |       |
|      | c) Optimum moisture content (%)      | 11.3    |
|      | d) Maximum dry density (g/cc)        | 1.87    |
| 5    | Strength parameters                  |         |
|      | Un soaked CBR (%)                    | 3.37    |
| 6    | Differential free swell (%)          | 55%     |

Table – 3: Properties of Virgin Soil -II

Observing the similarity in index properties for both the soil samples as shown in table -2 and table -3, the soil sample from Aganampudi, Visakhapatnam, India i.e., soil sample – I is considered for the stabilization purpose. The present sample – I is experimentally studied for 0.5%, 1.0% and 1.5% proportions of coconut coir (CC) by weight of dry soil along with 30% stone dust (SD) initially and then studied for 0.5%, 1.0% and 1.5% proportions of coconut coir (CC) by weight of dry soil along with 30% pond ash (PA). These samples are mixed with utmost care to obtain a homogenous mix. Light weight compaction was performed for all proportions of mixed soil and the optimum moisture content (OMC) and maximum dry density (MDD) are found out. The samples are later tested for the California bearing ratio (CBR). These tests are performed based on the Indian Standard Code recommended for soil tests. A comparative study based on the results obtained considering OMC, MDD and the CBR – value is made.

5. Results with discussions

The investigational results for optimum moisture content (OMC) and the maximum dry density (MDD) are obtained from the heavy weight compaction test. The results are presented in the table – 4 below for virgin soil, soil with varying proportions of coconut coir, stone dust
and pond ash. Comparison of these results based on OMC and MDD are presented in Graph – 1.

| COMPACTION | S.no | Sample                          | OMC | MDD | S.no | Sample                          | OMC | MDD |
|------------|------|---------------------------------|-----|-----|------|---------------------------------|-----|-----|
| 1          | Virgin soil                     | 11.6| 1.88| 1    | Virgin Soil                      | 11.6| 1.88|
| 2          | Soil + 0.5% CC + 30% SD         | 12.31| 1.86| 2    | Soil + 0.5% CC + 30% PA          | 12.53| 1.83|
| 3          | Soil + 1.0% CC + 30% SD         | 13.22| 1.81| 3    | Soil + 1.0% CC + 30% PA          | 13.54| 1.73|
| 4          | Soil + 1.5% CC + 30% SD         | 14.47| 1.72| 4    | Soil + 1.5% CC + 30% PA          | 14.9 | 1.57|

Table – 4: OMC and MDD values obtained for different considerations

These test samples are further tested for CBR value under unsoaked condition. The representative values obtained for all the considered proportions of admixtures are presented in the table – 5 below. A bar graph showing the comparison of CBR values for all the considered proportions are presented in the Graph – 2.

| CBR         | S. No | Sample                          | CBR (unsoaked) | S. No | Sample                          | CBR (unsoaked) |
|-------------|-------|---------------------------------|----------------|-------|---------------------------------|----------------|
|             | 1     | Virgin soil                      | 3.27           | 1     | Virgin Soil                      | 3.27           |
|             | 2     | Soil + 0.5% CC + 30% SD         | 4.26           | 2     | Soil + 0.5% CC + 30% PA          | 3.37           |
|             | 3     | Soil + 1.0% CC + 30% SD         | 5.41           | 3     | Soil + 1.0% CC + 30% PA          | 3.86           |
|             | 4     | Soil + 1.5% CC + 30% SD         | 5.98           | 4     | Soil + 1.5% CC + 30% PA          | 4.59           |

Table – 5: CBR values obtained for different considerations

For the above results, it can be clearly observed that, when 1.5% CC considered, there is 30% increase in CBR value for SD compared to PA in the soil sample considered. When 1.0% CC considered, there is 40% increase in CBR value for SD compared to PA in the soil sample.
considered and when 0.5% CC is considered, there is 26.4% increase in CBR value for SD compared to PA in the soil sample considered.

For SD + CC Soil sample, with 1% increase in CC, there is an increase of 1.4 times the CBR value. For PA + CC Soil sample, with 1% increase in CC, there is an increase of 1.36 times the CBR value.

6. Conclusions

Based on the experimental test fallouts, conclusions are drawn:

- Slight increase in strength of stone dust considered soil sample with respect to coconut coir as compared to that of the pond ash considered soil.
- By addition of coconut coir and stone dust to the silty soil sample, is a great rise in CBR value.
- The effect of coconut coir in the improvement of this particular soil is predominant in both aspects as nearly equal proportion of improvement is observed i.e., 1.4 times in Soil + CC + SD and 1.36 times in Soil + CC + PA.
- At any considered proportions of coconut coir, the strength parameters of the CC + SD soil sample show better results than that of CC + PA soil sample.

Conflicts of Interest:
The authors state that they have no conflict of interest.

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