Experimental investigation of bottom ash as a capable Soil Stabilizer

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Abstract. The development of infrastructure in India is rapidly growing. These structures demand adequate soil as foundation/subgrade, but in India where expansive soil covers 51.8 hectares of land surface nearly. Stabilization of these expansive soils is the priority of engineers. Where on the other hand bottom ash from a thermal power plant is directly dumped which contaminates the environment. In soil stabilization, a stabilizer is added to soil in optimum quantity to achieve maximum dry density and have minimum penetration. In this study bottom ash’s potential is examined as a soil stabilizer and compared with non-conventional stabilizer. Soil is modified with bottom ash at dosages of 10\%, 20\%, 30\% and 40\% to inspect the various engineering properties. Atterberg limits (LL, PL, and PI), Compaction characteristics (OMC & MDD) and California bearing ratio test are performed and compared with nano-polymer modified soil samples. Results show that bottom ash can be utilized as a stabilizer for road construction.

Key Words: Bottom ash, Nano-polymer, Soil Stabilizer etc.

1. Introduction

As we all know soil plays a key role in the stability of each kind of structure whether it’s a pavement or a high rise skyscraper. The performance of the pavement and stability structure are majorly dependent on the soil beneath it. Different type of soil possess a different kind of engineering properties but apparently, the properties of soil differ place to place and sometimes soil may deficient of some important properties and this kind of situation cause a costly remedial process for improving the engineering properties of the soil and thus making it more stable. It is required when the soil available for construction is not suitable for the anticipated purpose. However, the term stabilization restricted to the process which alters the soil material itself for improvement of its properties. To enhance the engineering properties of soil, chemical additives are popularly used as soil stabilizers. The generally used stabilizers are cement, fly ash, lime, GGBS, bottom ash, and kiln dust. Nowadays, utilizing cement and lime is not favored due to increases in an environmental problem [1]. The researcher had developed many sustainable binders such as polymers, ionic and fibers in past decades which can be used as soil stabilizers [2] [3]. These non-traditional binders enhance the properties of soil but the same time increases the cost of the project [4]. In thermal power plants burning of coal generates fly ash (75-80\%) and bottom ash (20-25\%). Fly ash is more popular than bottom ash and it has much utilization as a cementitious material in different engineering products due to its pozzolanic nature [5]. Bottom ash has the potential to be used as a cementitious material in civil engineering project but there is limitation such as a slow pozzolanic reaction and sandy properties [6][7]. In the present study is to investigate the potentiality of bottom ash as a promising soil stabilizer. Verification of bottom ash as soil stabilizer is done by extensive tests on soil mixed bottom ash and outcomes are compared with non-traditional stabilizer. Soil Tech (nano-polymer) is chosen for the validation of this research. Outcomes of bottom ash and soil tech should fulfil specification of MoRTH[8]. Nano-
polymer works as a molecular level binder to soil and utilize water as lubrication it under mechanical compaction.

2. Materials

2.1 Soil

The soil for experimentation is taken from the nearby site of Jhotwara, Jaipur (Rajasthan). Soil is dried and broken into grains to pass through 4.75 mm. Specific Gravity and Sieve analysis was carried out respectively as per IS 2720- part 3 [9] and part 4[10] finding were that soil is expansive in nature. Physical properties of soil samples are examined as per IS 2720 and values are displayed in Table 1.

| Property                  | Value      |
|---------------------------|------------|
| Specific Gravity          | 2.65       |
| Maximum Dry Density       | 1.38 gm/cc |
| Optimum Moisture Content  | 27.9%      |
| Liquid Limit              | 66%        |
| Plastic Limit             | 37%        |
| Plastic Index             | 29%        |

2.2 Bottom Ash

As for this investigation, Bottom Ash is acquired from Kota Super Thermal Power Station (KTPS), Kota, Rajasthan shown in figure 1. Bottom ash is a greyish red color, granule spherical, irregular and porous, and has a rough surface. Particle size range from fine aggregate to fine sand (5mm-0.75mm). The specific gravity of the bottom ash used in this investigation is nearly 2.35 depending upon its chemical composition. The bulk density is nearly 700 kg/m3. Water absorption is nearly equal to 15%. The fineness modulus which is found by sieve analysis is found to 4.5.

2.3 Nano-Polymer

In this research, Soil Tech’s third-generation Nano-polymer binder is chosen it has industrial acclaimed material. Nano-polymer is elastomers that achieve strength from mechanical compaction and does not become brittle when watered. Soil Tech polymer gains binding strength from compaction to get better binding with polymers more compaction would require. Soil Tech polymer will start binding when exposed to air. They are dark in color with a specific gravity of 2.5 and fully soluble in water.
3. Experimental Investigation

3.1 Mixing Details

For this research, the soil is mixed with bottom ash and nano-polymer individually at a four-level treatment level. Each level of bottom ash substitution is compared with the nano-polymer results and these results are validating as MoRTH specification[8]. Bottom ash is mixed at an interval of 10% from 0 to 40% and Nano-Polymers (0-1.00%) at an interval of 0.25%. as shown in Table 2.

| Treatment Level | Material       | Bottom ash | Nano-Polymer |
|-----------------|----------------|------------|--------------|
| 0               | 0%             | 0.00%      |
| 1               | 10%            | 0.25%      |
| 2               | 20%            | 0.50%      |
| 3               | 30%            | 0.75%      |
| 4               | 40%            | 1.00%      |

3.2 Atterberg limits

Estimation of atterberg limits important to understand changes in various indexes of soil with different treatment level Atterberg Limit consist of following Liquid Limit, Plastic Limit and Plasticity Index calculated as IS 2720- part 5 [11] Samples are prepared with oven-dried soil mixed bottom ash and nano-polymer individually at different treatment levels. Atterberg limits outcomes are showed in Table 3. Bottom ash and Nano-polymer decrease the liquid limit of soil from 66% to 44% and 42% respectively. Bottom ash results are nearly equivalent to Nano-Polymer results. The plasticity index is also linearly decreasing with the level of treatment from Figure 2 and Figure 3 we can observe that liquid limit and plasticity index results satisfy the limit of 50%, according to the guidelines of MoRTH, third and second treatment level respectively.

| Treatment Level | Bottom ash | Nano-Polymer |
|-----------------|------------|--------------|
|                 | LL (%)     | PL (%)       | PI (%)       |
| 0               | 66         | 37           | 29           |
| 1               | 62         | 36           | 26           |
| 2               | 57         | 33           | 24           |
| 3               | 49         | 32           | 17           |
| 4               | 44         | 32           | 12           |

Figure 2: Liquid limit at different treatment level
3.3 Compaction Test

Maximum dry density (MDD) at Optimum moisture content (OMC) of soil samples with bottom ash and nano-polymers at different treatment levels are examined by the Modified proctor test as per IS:2720-part 8 [12]. The compaction characteristics of different soil samples are shown in Table 4. It has been observed from Figure 4 that OMC is reduced by the increment of bottom ash to 30% after it starts increasing. While in the case of the amount nano-polymers increases OMC is in decreasing continuously. Figure 5 shows a continuous increment of MDD addition of nano-polymers and bottom ash in a similar manner.

Table 4 Compaction characteristics at different treatment level

| Mix Level | Bottom ash | Nano-Polymer |
|-----------|------------|--------------|
|           | OMC (%)    | MDD (gm/cc) | OMC (%)    | MDD (gm/cc) |
| 0         | 27.9%      | 1.38         | 27.9%      | 1.38         |
| 1         | 23.7%      | 1.45         | 22.6%      | 1.49         |
| 2         | 20.5%      | 1.52         | 19.7%      | 1.58         |
| 3         | 17.2%      | 1.68         | 17.8%      | 1.69         |
| 4         | 19.8%      | 1.57         | 16.7%      | 1.71         |
3.4 CBR Test
Soaked CBR is performed to estimate the penetration capacity of soil samples at extreme conditions. The procedure was followed accordingly IS:2720-Part 16 [13]. Soil samples are prepared at the OMC of individual soil mixes to achieve MDD after that samples are soaked for 96 hrs duration before testing. Table 5 shows soaked CBR values bottom ash and nano-polymer mixed soil samples at different treatment levels. CBR values bottom ash mix soil samples show better results than nano-polymer mixes observed from Figure 6.

Table 5 CBR value at different treatment level

| Treatment Level | Bottom ash | Nano-Polymer |
|-----------------|------------|--------------|
| 0               | 2.5        | 2.5          |
| 1               | 7.9        | 5.6          |
| 2               | 12.5       | 10.8         |
| 3               | 20.6       | 16.9         |
| 4               | 17.4       | 20.1         |

Figure 5: MDD at different treatment level

Figure 6: MDD at different treatment level
4. Conclusion

In this study, bottom ash is used on expansive soil to inspect different parameters and compare the results with a nano-polymer stabilizer. Atterberg limits finding can be concluded that the addition of bottom ash below 30% shows quite good results but not are in satisfactory limits. Atterberg values of soil samples with nano-polymer dosage at 0.5% are similar to bottom ash dosage at 30%. Increasing the dosage of bottom ash reduces the water demand of soil to achieve maximum density. The particle size of bottom ash helps soil to become denser. The maximum dry density of the soil sample is increased from 1.38 to 1.68gm/cc by adding bottom ash 30 % to the soil. MDD of soil mixed nano-polymer is similar. CBR values of soil mixed with bottom ash are increased due to the pozzolanic nature of the material. Bottom ash has the potential to utilize as soil stabilizer where it is easily available. Using bottom ash reduces the cost of soil stabilizing material and solve the dumping problem. Future investigates would be focused on exploring the microstructural behavior of the modified soil.

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