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IMPACT OF THE ADDITION OF PALM KERNEL SHELL ASH CONTENT ON THE STRENGTH AND COMPACTION CHARACTERISTICS OF BLACK COTTON SOIL

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Abstract: Black cotton soil is a very problematic soil in nature, so it is necessary to stabilize it before the start of any construction work. Specifically, where the work is in village road construction and the availability of funds is less, in such a case we required a low-cost soil stabilization method. Palm kernel shell ash is basically waste material and is available at a low cost. The palm kernel shell is the outer shell fraction that is left after the extraction of palm oil in mills. This palm kernel shell has a good calorific value of around 4200 Kcal/Kg, so it is used in boilers instead of coal. After the burning of the palm kernel shell, the ash is formed which is called palm kernel shell ash (PKSA). The PKSA is waste material, and it is dumped into nearby municipal sites. It will create a problem of pollution in the environment. Instead of that, we can utilize it as a soil stabilizer. The PKSA is a pozzolanic material, it contains free lime which will react chemically with alumina and silica and form a gel that will create a bond between soil particles and increase the strength of the soil. It contains free lime which will react chemically with the alumina and silica present in the black cotton soil. The chemical reaction will take place between $Ca(OH)_2$ and SiO_2, Al_2O_3 which ultimately results in C-S-H (calcium silicate hydrate), C-A-H (calcium alumina hydrate) and C-A-S-H(calcium alumino silicate hydrates) gel which binds all soil grains and increases the soil strength. In this research work, the 0, 3, 6 and 9% PKSA is added to the soil for stabilization. The standard proctor test and UCS test were performed on black cotton soil. The MDD value of soil was 1686 Kg/m^3 which is reduced to 1541.85 Kg/m^3 with the addition of 9% PKSA, and the OMC value of soil was 18.5% which was increased to 21.99% with the addition of 9% PKSA. The UCS value of soil was initially 394.33 KPa which is increased to 1022.23 KPa with the addition of 9% PKSA and after a curing period of 21 days.

Index Terms **– Soil stabilization, Palm kernel shell ash (PKSA), UCS, Black cotton soil, pozzolanic reaction, pozzolanic waste.**

1. INTRODUCTION

In a rapidly growing country like India, the rate of industrialization and urbanization is very fast, and it is necessary to provide transportation more accessible and feasible throughout the country. But it is not always because of the presence of very problematic soil like black cotton soil. The black cotton soil is mostly present in many states. It is found maximum in Gujarat, Madhya Pradesh, Maharashtra, etc. It covers 12-16% of the total land area of India. The black cotton soil has montmorillonite mineral present in its structure, due to this black cotton soil will undergo excessive volumetric changes. When the moisture content of the soil is reduced soil will shrink and when the moisture content increases it will swell excessively. This behavior of soil will lead to cracks in the foundation and affect the stability of any structure. Therefore, it is necessary to stabilize the black cotton soil before the start of any construction work so that it can resist heavy loads and the durability of the structure or roads can be increased. For the treatment of black cotton soil engineers have incorporated various materials for soil stabilization like cement stabilization, lime stabilization, fly ash stabilization, bitumen stabilization, lime-fly ash stabilization, stabilization by pozzolanic materials, etc.

Ikeagwuani, Chijioke Christopher, Nwoji Ugochukwu Clifford, and Ekwuilo Kingsley Ikechukwu investigated the stabilization of black cotton soil using 0,4,8,12,16 and 20% PKSA + 4% lime mixture used for soil stabilization. [1] The study shows that PKSA was found to be an effective soil stabilizer. With the increase in PKSA content soaked CBR value is increased at 4% lime + 8% PKSA content soil attains a maximum soaked CBR value of 5.1% where the soaked CBR value is 1.5%, and the unsoaked CBR value of soil was 3.2% which is increased to 10.2% for 4% Lime + 8% PKSA content is added to the soil.

Yulian Firmana Arifin and Gazali Rahman investigated the use of palm kernel shell ash along with cement for stabilization. First cement is added to CH type of soil then evaluated that the optimum dose of cement is 10% required, then the 2,6 and 10% PKSA is added to the soil along with 10% cement. [2] It was observed that the with addition of PKSA in soil the strength of soil is increased. The same proportion of cement and PKSA are studied for different curing periods and results show that the strength of soil increases with the increase in the curing period of soil. The strength of soil does not only depend on the amount of stabilized added but also depends on the curing period of the soil.

Clement A. Amagu, Beatrice O. Enya, Jun-ichi Kodama and Mostafa Sharifzadeh investigated a study on the Impacts of the addition of palm kernel shells content on mechanical properties of compacted shale used as alternative landfill liners. [3] The mechanical properties of soil stabilized with varying % of Palm kernel shell ash (PKSA) and pulverized palm kernel shell (PPKS) are used up to 12% (at increments of 2%) by West African Standard (WAS) and Modified AASHTO Standard (MAS) for compactive efforts to ascertain their stability as landfill liners barrier in waste containment application. It was found that with the addition of Palm kernel shell ash (PKSA) or Pulverized palm kernel shell (PPKS) content in CH type of soil the maximum dry density is decreased, and optimum moisture content is increased. It was also found that with the increase in PKSA content in the soil the UCS value of the soil is increased, and the hydraulic conductivity of the soil is reduced with an increase in PKSA content. It is also observed that PKSA gives better results as compared to PPKS.

Dr. Festus A. Olutoge, Habeeb A. Quadri and Oladipupo S. Olafusi conducted a study on Investigation of strength properties of palm kernel shell ash concrete. [4] It was identified that PKSA has pozzolanic properties that enable it to replace cement in concrete as a partial replacement of cement. PKSA used in research contains Si$O2$ + $Al2O3$ + $Fe2O3$ = 66.572% which is more than 50%. It also contains a Free lime (Ca) in its chemical composition so it can be classified under type C fly ash. With the addition of PKSA as a partial replacement for cement exhibits a lower water absorption rate and slower setting time of concrete.

Oluwatudium O. E, Sadeeq J. and Osinubi K. J investigated a study on the Improvement of the index and compaction characteristics of black cotton soil with palm kernel shell ash. [5] The PKSA was added in soil by 2% intervals up to 12%. It was found that the Liquid limit is decreased and the plastic limit is increased with the addition of PKSA in the soil. Thus, the plasticity index of soil is reduced. The standard proctor test is performed by three standards British standard light compaction test, the West African standard and the British standard heavy compaction test. It is found that the MDD value of soil is decreased OMC value of soil is increased with the addition of PKSA.

Onyelowe K. C and Maduabuchi M. N investigated a study on Waste Management and application of waste micro-sized Palm kernel shell ash (MSPKSA) in the stabilization of engineering soil. [6] After the extraction of palm oil from palm fruit the shell is left which is called the palm kernel shell. After the burning of the palm kernel shell, the ash is formed under a controlled temperature of between 600° C and 800° C and in most cases uncontrolled open-air burning. The 0,3,6,9,12 and 15% PKSA is added to stabilize lateritic soil. The CBR value of soil was 14% which increased to 76% with the addition of 15% PKSA. The UCS value of the soil was 194.26 KPa which increased to 381.62 KPa, 397.08 KPa and 400.11 KPa with the addition of 15% of PKSA in the soil and after the curing period of 7,14 and 28 days.

2. MATERIALS

2.1. Palm kernel shell ash (PKSA)

The palm kernel shell was collected from one local company. Then the palm kernel shells were sundried for 3-4 days. After that, it was burned in the presence of air. After the burning of the palm kernel shell, the ash forms which is called PKSA. The PKSA was collected. Then PKSA was sieved through a 75-micron IS sieve. The PKSA which passed through the sieve was used for the experiment.

Figure 1 *Palm kernel shell ash*

2.2 Black cotton soil

The black cotton soil was collected from the south Gujrat side of India. The soil was collected from a 1.2 m depth from the ground surface. Then the index test on soil was carried out in the laboratory. The percentage of the fine was found to be more than 90% by wet sieve analysis. The MDD value of soil was 1686 Kg/m^3 and the OMC of soil was 18.5%. The Unconfined compressive strength of the soil was 394.33 KPa.

Figure 2 *Black cotton soil*

3. LABORATORY INVESTIGATION PROGRAM

3.1 Standard proctor test

The standard proctor test was performed as per the specifications given by [IS 2720(part 7)-1980]. The 0%, 3%, 6%, and 9% PKSA were added to the black cotton soil, and the test was performed. The MDD value of Black cotton soil was 1686 Kg/m^3, which is reduced to 1636.18 Kg/m^3, 1575.73 Kg/m^3 and 1541.85 Kg/m^3 with the addition of 3%, 6% and 9% PKSA to the soil. The reduction in MDD value of BCS with the addition of 3% PKSA is 2.95%, with the addition of 6% PKSA is 6.54% and with the addition of 9% PKSA is 8.56%.

The OMC value of black cotton soil is 18.5%, which is increasing with the addition of PKSA in the soil. The OMC value of BCS was increased to 20.46%, 21.08%, and 21.996% for the addition of 3%, 6% and 9% PKSA in soil. The increase in OMC value of BCS with the addition of 3% PKSA is 10.6%, with the addition of 6% PKSA is 13.95%, and with the addition of 9% PKSA is 18.9%.

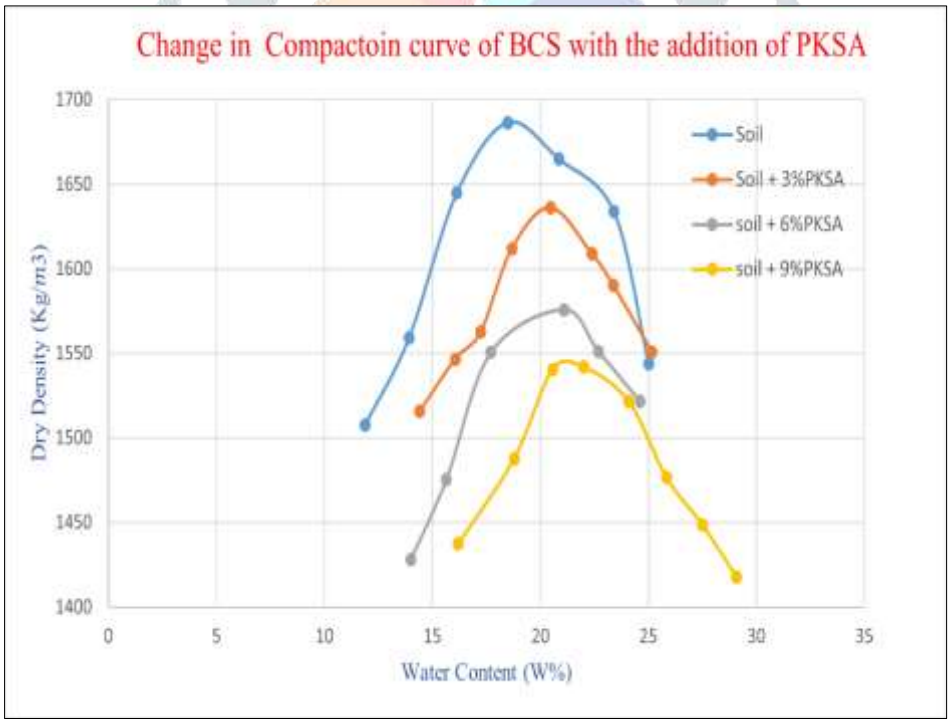

Figure 3 *Relationship between MDD and OMC of PKSA + BCS mixture*

The increase in MDD and decrease in the OMC value can be due to the following reasons. The addition of lighter material in the soil will replace the heavy soil particles and it will result in a decrease in the MDD value of soil because the density of PKSA is around 500-700 Kg/m^3 and the density of soil is 1686 Kg/m^3. The water absorption rate of PKSA is slow so it can cause an increase in the OMC value of soil. Another possible reason is due to the pozzolanic reaction of PKSA with soil leading to the combining of all the soil particles together and some enclosed voids can be left in between the soil structure that will result in the reduction of MDD value of soil.

3.2 Unconfined compressive strength test

The unconfined compressive strength test was performed by the procedure mentioned in [IS 2720 (Part 10)-1991] on the conventional Unconfined compressive strength test machine in the laboratory. The UCS test samples were prepared of standard size which is 38 mm diameter and 76 mm height. The samples are prepared for Black cotton soil + 3% PKSA, Black cotton soil +6% PKSA and Black cotton soil + 9% PKSA. These samples were cured in a desiccator for 3, 7 and 21 days. After the curing period, each sample was tested in the laboratory.

Figure 4 *UCS test on black cotton soil*

The result shows that there is a considerable increase in the Unconfined compressive strength of black cotton soil with the addition of PKSA content in the soil. The initial UCS value of black cotton soil was found to be 394.33 KPa, which is increased to 435.33 KPa, 479 KPa, and 534.52 KPa with the addition of 3%, 6% and 9% of PKSA in soil and at the end of 3 days of curing. After 7 days of curing the UCS value increased to 507.89 KPa,621.73 KPa and 749.21 KPa with the addition of 3%, 6% and 9% PKSA. After 21 days of curing the UCS value of the soil increased to 641.16 KPa, 729 KPa and 1022.23 KPa with the addition of 3%, 6%, and 9% PKSA.

The increase in the UCS value of BCS after 3 days of curing is 10.4%, 21.47% and 35.55% with the addition of 3%, 6% and 9% of PKSA. After 7 days of curing the increase in UCS value is 28.8%, 57.66% and 89.99% with the addition of 3%, 6% and 9% of PKSA. After 21 days of curing the increase in UCS value is 62.59%, 85.04% and 159.23% with the addition of 3%, 6% and 9% of PKSA.

The increase in UCS value is caused due to the Pozzolanic reaction caused by PKSA. PKSA contains a 7.38% calcium oxide which will react with the alumina and silica present in the black cotton soil and forms a calcium alumina hydrate gel, calcium silicate hydrate gel and calcium alumina silicate hydrate gel which will react chemically with black cotton soil and increase the strength of soil.

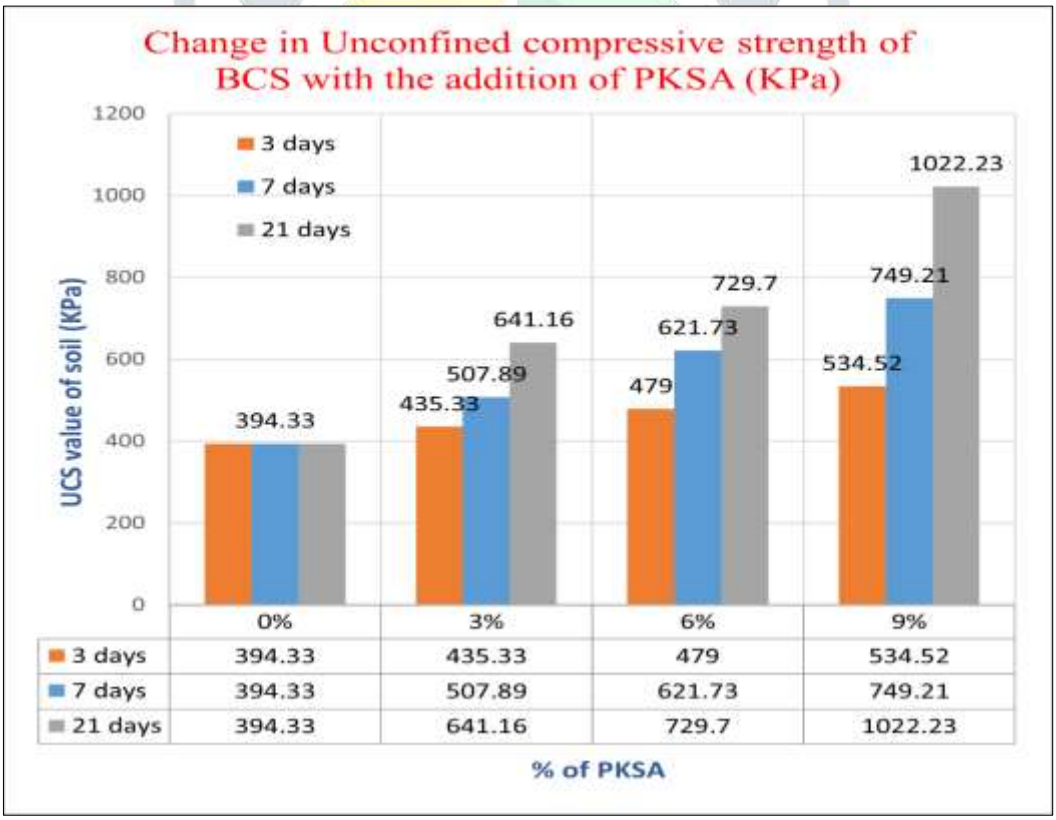

Figure 5 *UCS values of soil + PKSA after the curing period of 3,7 and 21 days*

4. POZZOLANIC REACTION OF PKSA

The PKSA contains free lime, and the sum of SiO_2, Al_2O_3 and Fe_2O_3 is near to 50% which indicated material may have pozzolanic properties. The free lime present in palm kernel shell ash contains a free lime that will react chemically with the alumina and silica present in black cotton soil. It forms a calcium alumina hydrate gel, calcium silicate hydrate gel and calcium alumina silicate hydrate gel which will react chemically with black cotton soil and create a bond between the soil particles. That will increase the strength of the black cotton soil.

$Ca^{+2} + 2OH^- + SiO_2$ = C-S-H (calcium silicate hydrate)

$Ca^{+2} + 2OH^- + Al_2O_3$ = C-A-H (calcium alumina hydrate)

$Ca^{+2} + 2OH^- + SiO_2 + Al_2O_3$ = C-A-S-H (calcium alumino silicate hydrates)

5. ENVIRONMENTAL IMPACT

The Palm kernel shell ash is a waste material that is disposed of to open municipal land sites, which creates environmental problems like air pollution, contamination of groundwater, etc. Instead of that PKSA can be used as a soil stabilizer and can give a solution for open land site disposal. Conventional soil stabilizers like cement also create some environmental problems during their manufacturing process. Replacement of PKSA as a soil stabilizer instead of cement will also help in reduction of environmental problems.

6. CONCLUSION

The MDD value of black cotton soil was 1686 Kg/m^3 which is reduced to 1636.18 Kg/m^3, 1575.73 Kg/m^3 and 1541.85 Kg/m^3 with the addition of 3% ,6% and 9% PKSA respectively. The occurrence of this may be due to the addition of low-density material (PKSA) into the soil. There may be the chances of the creation of enclosed air voids which leads to this.

The OMC Value of black cotton soil was 18.5% which increased to 20.46%, 21.08% and 21.996% with the addition of 3%, 6% and 9% PKSA respectively. The increase in the OMC can be due to the low water absorption rate of PKSA and due to the pozzolanic reaction in the soil.

The Unconfined compressive strength of BCS was 394.33 KPa which is increased to 435.33 KPa, 479 KPa and 534.52 KPa with the addition of 3% ,6% and 9% PKSA respectively and after the curing period of 3 days.

The UCS value of black cotton soil was increased to 507.89 KPa, 612.73 KPa and 749.21 KPa with the addition of 3% ,6% and 9% PKSA respectively and after the curing period of 7 days.

The UCS value of BCS was increased to 641.16KPa, 729.7KPa and 1022.23 KPa with the addition of 3%, 6% and 9% PKSA respectively and after the curing period of 21 days.

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