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IMPROVEMENT OF COMPACTION AND STRENGTH CHARACTERISTICS OF WEAK CLAYEY SOIL WITH DATE PALM LEAF MATS

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Abstract - *Till date various work of research have been reported based on testing and trial showing successful utilization of geosynthetics. But the widespread use of geosynthetic composite is leading to disadvantages of high initial cost and also sometimes may show adverse effect on environment. Therefore the natural geotextiles are emerging as realistic alternatives in various applications of geotechnical engineering. The increasing applications of natural fibers such as jute, coir, sisal etc. encourages the search for the utilization of other natural fibers whose potential is yet to be determined. The date palm leaves are easily and abundantly available in many countries worldwide, including India, and have a possible potential to be beneficial when incorporated with soil mass. The paper particularly investigates, the results about the influence of inclusion of date palm leaf mats on compaction and strength characteristics of locally available soil. Reinforcement was provided by placing layers of date palm leaf mats at different depths in compacted soil and California bearing ratio was evaluated for each case. The study of such results indicated improvement in strength of the compacted soil which can be beneficial for road construction where available in-situ soil is not significantly strong even after compaction.*

Key Words: **Natural geotextiles, Date palm leaf mats, Reinforcement, CBR, Subgrade improvement.**

1. INTRODUCTION

Almost all the human civilizations in the world started on alluvial soils and main components of the needed construction in such human activity were mainly soils. With accumulated experience, through continuous efforts they developed means of using soils for making bricks, roads, small dams, embankments, forts etc. and identified at the very initial stage, the variations in the properties of available soils and need for improving the properties of soils, to suit desired construction capability.

Since ancient ages, many natural materials were identified for use as reinforcement, for soft soil. There are evidences of the use of woven mats made of reeds in temples of Babylon, the use of tree twigs with leaves (as tensile elements) in construction of Great Wall of China, uses of straw and hay to reinforce mud blocks and bamboo thatch in mud walls in India. In Kerala, there is an age old practice of spreading coconut leaves over sub-grades. Also stolon of tress were laid on soft marshy soils to facilitate walking in some developing countries. But unfortunately no systematic continuous research in developing design methods quantifying the engineering properties of inclusive materials to be used in such constructions, were neither attempted nor recorded. However intensive research started in early 1950s to find means of utilizing the accumulating byproducts during fractional distillation of crude in oil refineries for gainful use and eliminating disposal problem for end wastes. In the process polymeric materials like polyamide, polyethylene, etc. were developed for making synthetic fibers. Worldwide research started to develop methods of using such material for improving soil properties to desired levels. Thus the concept of geosynthetics originated. The success of man-made geosynthetics was completely based on vigorous research, studies and trials and its growth has been remarkable over the last five decades. The concept of reinforcing soil with inclusion was given by French architect-engineer Henri Vidal in 1963 and was employed in construction of retaining walls which were reinforced by inclusion of linear strips placed horizontally. Later this concept was verified in 1969 by Vidal and Schlosser in LCPC cohesion theory, also Hausmann (1976) proposed Sigma model and Tau model, dealing with bond and tensile failure of soil with reinforcement. Since then the concept of reinforced earth has been well established and present conventional reinforcement methods consist the inclusion of fibers, strips, grids into the soil mass for improving the bearing capacity, filter and drainage control. Recently, methods of random mixing of various types of fibers, have attracted increasing attention in many geotechnical applications like airfield construction. In fact use of geosynthetics in civil engineering heralded a new revolution in civil engineering. However presently, the market is dominated by synthetic geotextiles, but it has certain disadvantages compared to natural geotextiles. They are:

- Synthetic geotextiles are not eco-friendly, particularly where they are laid open to sunshine/ atmosphere.
- The products are not renewable
- Increasing price of polymeric raw materials, due to the diminishing amount of available crude in earth, leads to increase in the overall cost of geotextiles.

Thus the need of an eco-friendly, renewable, abundantly available and economically viable alternative became important in environ conscious and economically backward countries. As a result, search for suitable natural geotextiles have been important. In the last two decades soil used with different natural geotextiles made from natural fibers are in evidence. Many natural fibers have been identified and tested for possible use in construction. The natural fibers are found to have superior properties to the man-made synthetic fibers for soil reinforcement, separation, filtration, drainage. Though biodegradability property of natural geotextiles may add to its disadvantage in some cases, but the fibers are extremely beneficial, if used in proper places, such as for erosion control, drainage and slope protection, where the strength required can be attained before their degradation due to consolidation. Also treating the fibers with various other materials such as bitumen, lime etc. can extend their life span. The natural fibers after degradation forms ligmose, which again enhance the fertility, texture, and organic content in soil. In India apart from jute, coir, sisal, hemp etc. the date palm plants are grown abundantly and such plant leaves can be gathered in huge quantities for any gainful use at very low cost. However extensive research have not been executed with Date palm leaf materials, indicating the need to identify their possible application for different desired functions if used in construction with soil. The paper presents the results of experimental work based on improving soft soil by adding reinforcement in form of date palm leaf mats.

2. REVIEW OF LITERATURE

The outcomes of several research work involving geotextile made from natural fibers like jute [1] [2] , coir [3] [4] , sisal [5], bamboo [6], banana leaf [7] etc. in geotechnical engineering have been reported in literature. The successful use of these natural geotextiles as reinforcement, separation, filtration and drainage purpose, encourages the possible utilization of other natural fibers which are abundantly available in nature. With this perspective the date palm leaves are selected for this particular work. Date palm plants are grown profusely in India, and presently people in rural areas depend largely on weaving and yarning mats, ropes, bags made out of date palm leaves. But such fibers can be source of geotextile at low cost particularly when used as reinforcement sheet because of having low cost for transferring them to geotextile form. A few case studies are available regarding the use of date palm leaf as geotextile. Marandi et el (2008) [8], performed UCS, California bearing ratio and compaction tests on soil samples reinforced with date palm fibers. The results showed that at 10mm fiber length, the maximum and residual strengths were increased with increase in fiber inclusion from 0% to 1%. Similar trend was observed with varying fiber length from 20mm to 40 mm. Jamellodin et al. (2010)[9] found a significant improvement in the failure deviator stress and shear strength parameters of the soft soil when reinforced with palm fibers. Ahmad et al. (2010) [10] mixed palm fibers with silty sand soil to investigated the increase of shear strength during triaxial compression. The specimens were tested with 0.25% and 0.5% content of palm fibers of different lengths i.e. 15mm, 30mm, and 45mm. Reinforced silty sand with 0.5% fibers of 30mm length showed 25% increase in friction angle and 35% in cohesion compared to those of unreinforced sand. The experimental investigation by Adili, Al-Sundany, and Azzam, (2013) [11] presented experimental results of the influence of date palm leaf fibers on strength and stiffness response of a typical soil. Local Iraqi date palm leaf was used for this purpose and were dried and crushed to finer grain size in order to obtain randomly reinforced soil sample. The size of the fibers were chosen after passing through sieves of suitable size mixture ranging from 1,2,8,12 &16 mm. Tests conducted were shear test and consolidation and displacement test. The results showed cohesion and internal friction of the reinforced soil was increased with increasing the percentage of added fibers and with increasing of fiber lengths, compared to the unreinforced soil. Also the settlement test of the soil showed that the date palm leaf improved the soil structure at the adding percentage of 1 mm as well as 16 mm length. However no such extensive work have been reported using date palm leaf mats for reinforcing weak subgrade soil.

3. SCOPE OF WORK

The studies in literature survey indicate that there is a possibility for improvement in the strength and compaction characteristics of soil by inclusion of date palm leaf mats. Therefore, with the aim of getting more comprehensive results, the experimental program was undertaken. For this experimental work, the date palm leaf mats were collected from Salboni village, Paschim Medinipur, West Bengal, for using them as reinforcement to improve the compaction and strength characteristics of cohesive soil collected from Aoasberia village, Diamond Harbour-II, South 24 Parganas, West Bengal The collected soil was subjected to different routine testing for finding its index properties, compaction characteristics, un-soaked California bearing ratio (CBR) value at optimum moisture content (OMC) and also un-soaked CBR values for same soil compacted at dry and wet of OMC. The effect of using date palm leaf mats, on placing them at different positions in compacted soil at OMC, dry of OMC and wet of OMC, was investigated. The mats were placed within different depths in the mould during compaction and CBR tests were conducted. Four cases of mat placement was adopted as given in table 1.

Table-1 Cases of date palm leaf mat placement

Case-1	The date palm leaf mat placed at middle of the CBR mould. (Fig.1.a)
Case-2	The date palm leaf placed at one-third and two-third of the CBR mould (Fig.1.b)
Case-3	The date palm leaf mesh placed at one-third and middle of CBR mould. (Fig 1.c)
Case-4	The date palm leaf mesh placed at middle and two third of CBR mould. (Fig.1.d)

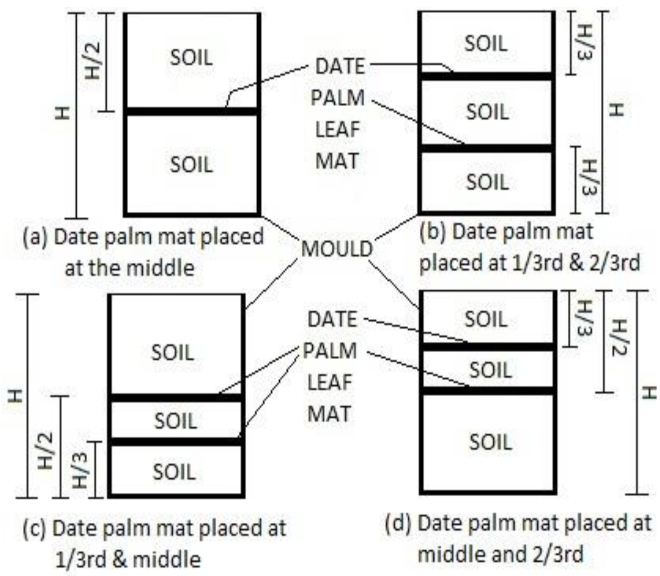

Fig.1. Different positions of date palm leaf mats in compacted soil

4. MATERIALS USED

Local Soil

The soil used for the experimental program was collected from Aoasberia village, Diamond Harbour-II, South 24 Parganas, West Bengal. The results of preliminary tests on the soil are given in table 2 and the soil is accordingly classified as CI (inorganic clay with medium plasticity).

Date Palm Leaf Mat

For this work, date palm leaf mats were collected from Salboni village, Paschim Medinipur, West Bengal. The physical properties of the mats used for the study are presented in table-3

Table -2 Properties of the used local soil

Soil properties	**Values**
Liquid limit	47%
Plastic limit	25%
Specific gravity	2.63
Sand	0%
Silt	69.25%
Clay	30.75%
Optimum moisture content	15%
Maximum dry density	1.72 g/cc
California bearing ratio value (un-soaked) at OMC (15%)	6.5
California bearing ratio value (un-soaked) at dry of OMC (12%)	7.4
California bearing ratio value (un-soaked) at wet of OMC (18%)	5.6

Table-3 Physical Properties of date palm leaf mat

Size	150 mm dia
Thickness	2.5 mm
Mass	10.2 gm

5. EXPERIMENTAL RESULTS AND DISCUSSION

As already discussed, the experimental work involves the placement of the Date palm leaf mats in four different layers (as stated in table 1) in the soil bed for improving the compaction and strength characteristics of the soil. The initial soil was mixed with predetermined amount of water, such that the water content equals that of optimum moisture content. For each case of reinforcement placement, the soil was compacted in three equal layers in the mould by conventional method. In the first case, the 1st layer of soil was compacted up to one-third of the mould with 55 number of blows. Then in the second layer one-sixth portion of soil was compacted with 27 number of blows, then the date palm leaf mat was then placed over that layer, and the rest one-sixth portion was compacted with 28 number of blows. The third layer was then compacted with 55 number of blows. It was checked that the date palm leaf mat was placed at the middle of the mould as given in fig 1.a. For the second case of reinforcement placement, initially one-third layer was compacted with 55 number of blows, and the first date palm leaf mat was placed over it, then the next one-third layer was compacted with 55 number of blows and the second Date palm leaf mat was placed over it. The final one-third portion of soil was then compacted and the placement of the mats were checked as given in fig.1.b. In the third case, the first Date palm leaf mat was positioned over the initially compacted one-third layer, then one-sixth portion of soil was compacted with 27 number of blows and the second Date palm leaf mat was placed over it. The rest one-sixth portion was then compacted with 28 number of blows, followed by the compaction of the final layer (fig.1.c). For the fourth case, initially one-third portion of soil was compacted. Then one-sixth portion was compacted as in previous cases and the first Date palm leaf mat was placed over it, followed by the compaction of the rest one-sixth portion. The second Date palm leaf mat was then positioned over the compacted layer and the final one-third layer was compacted (fig1.d).At the end of placement each of these samples were subjected to CBR test and the load vs penetration curve for each case is shown in fig 2. The CBR value was calculated from the graph for each case of Date palm leaf mat placement in conventional way. The corresponding values are given in table 4.Similar placement of Date palm leaf mat was conducted at dry of OMC as well as wet of OMC. Their corresponding curves are given in fig. 3, fig.4 and the CBR values are given in table 5 and table 6 respectively.

Table -4 Different CBR values at OMC (15%)

CASE NO.	CBR VALUES	% INCREASE IN CBR VALUE
CASE -1	7.9	21
CASE-2	8.6	32
CASE-3	7.2	11
CASE-4	9.2	41.5

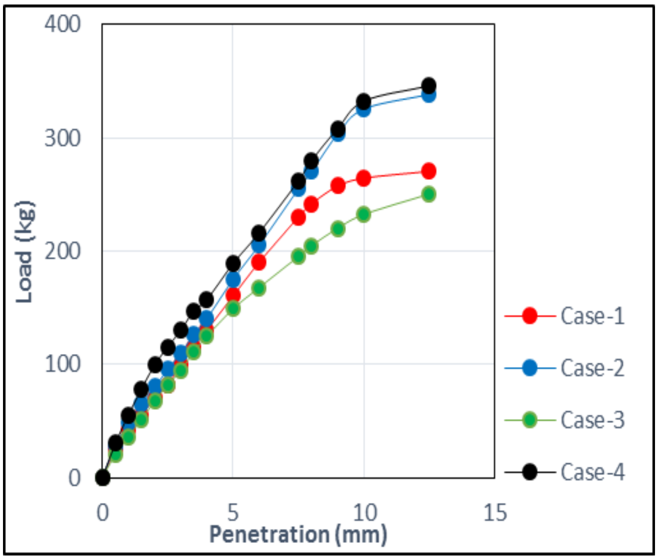

Fig.2. Load vs penetration graph showing the four cases of Date palm leaf mat placement at OMC of 15%

Table -5 Different CBR values at dry OMC (12%)

CASE NO.	CBR VALUES	% INCREASE IN CBR VALUE
CASE -1	9.0	22
CASE-2	9.7	31
CASE-3	8.6	16
CASE-4	9.8	32.4

Table -6 Different CBR values at wet OMC (18%)

CASE NO.	CBR VALUES	% INCREASE IN CBR VALUE
CASE -1	7.2	28
CASE-2	7.9	41
CASE-3	6.9	23
CASE-4	8.3	48

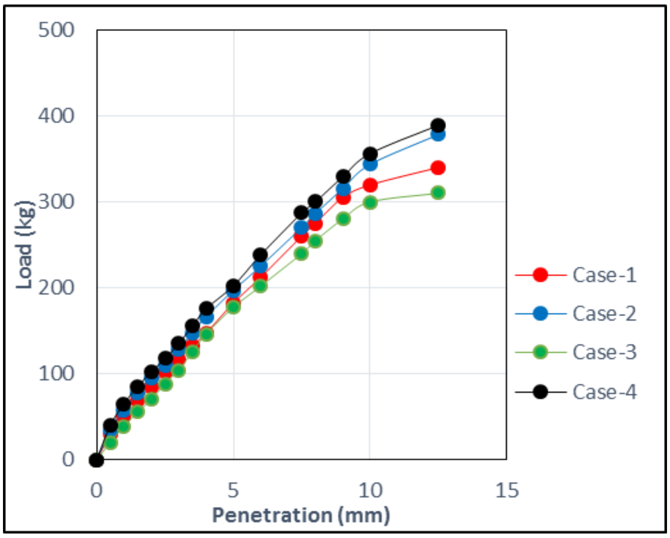

Fig.3. Load vs penetration graph showing the four cases of Date palm leaf mat placement at dry of OMC of 12%

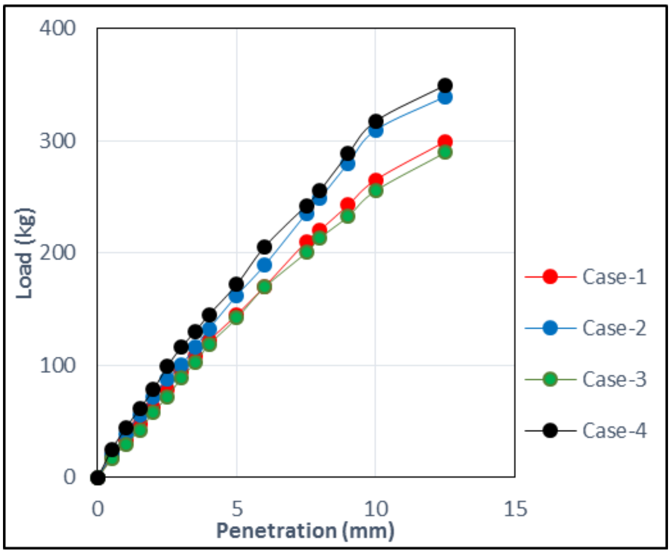

Fig.4. Load vs penetration graph showing the four cases of Date palm leaf mat placement at wet of OMC of 18%

From the fig. 2 it is seen that when CBR value is evaluated at OMC, then the CBR value is highest for case 4, where the increment is about 41.5% with respect to the CBR value of unreinforced soil. The lowest value is observed at case 3, showing an increment of 11% than that of unreinforced CBR value. Case 1 and case 2 shows intermediate values of CBR, where the increments in CBR values are 21% and 32% respectively. Similar trend is seen for the soil being compacted at dry of OMC and wet of OMC, as given in table 5 and table 6 respectively.

6. CONCLUSIONS

From this experimental program, conducted in the laboratory to examine the improvement of CBR value of compacted local soil with the inclusion of date palm leaf mats at different depths in the mould, while water content of soil was varied through dry of OMC, to optimum moisture content, to wet of OMC, the following conclusions can be drawn:

I. Inclusion of date palm leaf mat placed in whatever position as tested and soil compacted at different moisture contents, indicate definite improvement over that of compacted soil without the inclusion of mats.

II. Maximum improvement is noticed when two Date palm leaf mats are placed at middle position and two-third position of the mould, as in Case-4. This has been true for each case of moisture content that has been tested.

III. However least improvement in the CBR value of the compacted soil with inclusion of Date palm leaf mats is observed when the mat was placed at one-third position and middle position of the mould as in Case-3. This has been true for each case of moisture content that has been tested.

IV. The increment in the CBR value of the compacted soil are seen to be in between the maximum and minimum values, for all cases of moisture content, when placed at the middle of the mould as in Case-1 and at one-third position and two-third position of the mould as in Case-2.

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