Suitability of Marble Dust- Soil Composite as Landfill Liner Material

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***Abstract*— Suitability of a selected soil as landfill liner material is a major aspect that has to be considered while constructing a landfill. There are certain specifications that are to be satisfied by the selected soil to act as an effective liner material. Properties like Hydraulic conductivity, Strength characteristics, Index properties, Particle size and volumetric shrinkage has a general range of values to be satisfied. Marble dust is the waste product produced on chiseling and smoothening action of marble pieces.This study is conducted to analyse the suitability of reusing waste marble dust as landfill liner material by adding it with a locally available soil collected from Thiruvananthapuram. Marble dust is treated in varying percentages of 0, 5, 10, 12.5, 15 and 20 percentage with soil and tests are conducted which include hydraulic conductivity test, index properties, compaction test, unconfined compression test and check for volumetric shrinkage. From the results it was understood that an addition of 12.5 percentage of marble dust in soil provided optimum results.**

Keywords—Marble dust; Thonakkal clay;Landfill liner; Compactive effort; Unconfined compressive strength; Hydraulic conductivity; Volumetric shrinkage strain

I. INTRODUCTION

Increased industrialization around the globe has lead to a scenario where the ease of living has improved tremendously, but along with it the amount of waste generation has also become immense. The generated wastes may be of different types like domestic waste, agricultural waste, mining waste, industrial or commercial waste etc. All these wastes once disposed of without any proper protection or proper management leads to their accumulation and pose as hazardous for the living organisms and environment. Hence a well planned and executed waste disposal is necessary to act as a helping hand for the rapid industrialization and technological advancement around the world. One of the most suitable method by which this can be achieved is by installation of an engineered landfill. Modern landfills are well-engineered facilities that are located, designed, operated, and monitored to ensure compliance with federal regulations. Each of the components of a landfill system is important and its proper functioning is of major concern since any minor defect may lead to inefficient working of landfill system andtremendous environmental hazards. The major components of a landfill include a liner system, waste containment body and a cover system, out of which the lower most component is a liner system which confines the landfill system from the surrounding soil and prevents the soil and ground water from being subjected to contamination. Since the proper working of liner system directly indicates the satisfactory working of landfill, the material used as liner has to satisfy certain necessary criteria. The main priority of construction engineers is to make use of the soil already available in the site as liner. Usually this does not become possible due to unsatisfactory properties of the soil insitu, which necessitates use of additives like sodium bentonite, calcium bentonite etc. Researchers throughout the world have been experimenting with different additives in locally available soils to make it suitable as liner material.

Production of waste from any industry is a part of the industry’s functioning. It is of utmost importance to ensure that the waste produced does not affect the society or living organisms. The best suitable way to manage the wastethus produced, is to recycle it or make it useful as some additive in soil, concrete or as fill.Waste marble dust is the fine waste portion of marble formed through the chiseling and polishing of marble pieces. These processes are done by spraying water over it.So the waste marble is discarded as slurry, which on drying gets transported by wind and cause problems to humans and society. These wastes are also produced from buildings under construction where tiles are laid and polished. Thus the effective utilization of this waste is of high importance, and has been used as cement replacement additive in concrete blocks. Studies relating to utilization of marble dust to improve soil properties have been evolving in the recent past.

In the current study, the use of locally available soil treated with waste marble dust as landfill liner is evaluated. The soil used is collected from Thiruvananthapuram district and the waste marble dust is collected from marble producing industries in Bangalore.

From the previous studies conducted it has been concluded that the soil can be considered suitable as liner material mainly when the hydraulic conductivity provides value of less than or equal to 1 x 10^{-9} m/s, such that no percolation of leachate or water is allowed to the underlying soil. This is achieved when percentage fines is greater than or equal to 20–30%; plasticity index (PI) is greater than or equal to 7–10%; percentage gravel is less than 30% and maximum particle size is 25–50mm [1][2]. In addition to the value of hydraulic conductivity ≤ 1 x 10^{-9} m/s, a liner material need to have a minimum load carrying capacity 200kPa and the volumetric shrinkage should be less than or equal to 4% [3].

II. MATERIALS AND METHODOLOGY

A. Materials used

*1) Soil:*The soil used in this study is naturally occurring soil, collected from English India Clay Ltd., Thonakkal which is mineralogically kaolinite clay. The properties of soil are studied using standard procedures.The particle size distribution of soil is presented in Fig. 1 and the index properties of soil is summarised in Table 1. From the test results, it was identified that the soil can be classified as clay of intermediate plasticity (CI) according to Unified Soil Classification system.

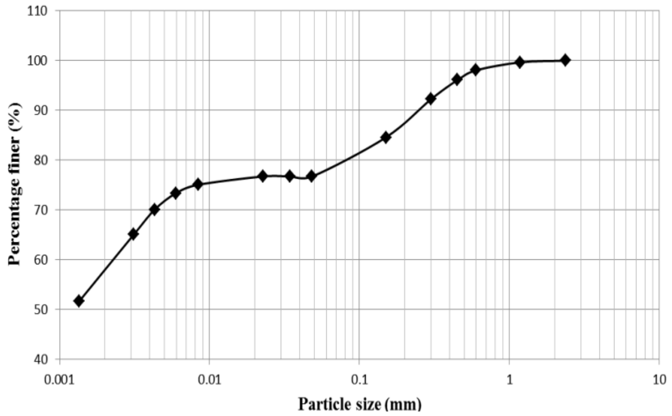

Fig. 1. Particle size distribution of natural soil.

TABLE I. PROPERTIES OF SOIL USED

Properties	Value obtained
Natural water content (%)	22.5
Liquid limit (%)	47
Plastic limit (%)	25.3
Shrinkage limit (%)	19.4
Plasticity index (%)	21.7
Specific gravity	2.48
Optimum moisture content (%)	31.1
Maximum dry density (g/cc)	1.384
Unconfined compressive strength (kPa)	103.7
Percentage sand (%)	21.5
Percentage silt (%)	20.5
Percentage clay (%)	58
Unified Soil Classification	CI

2) Marble dust: The marble dust used in the study is collected from marble producing industries, Bangalore. The sample was air dried before testing. They were added to soil in varying percentages of 5%, 10%, 15% and 20% of soil.The particle size distribution and specific gravity tests were done for marble dust and the results are obtained as in Table 2.

TABLE II. PROPERTIES OF MARBLE DUST COLLECTED

Properties	Value obtained
Percentage of silt sized particles (%)	60
Percentage of clay sized particles (%)	40
Specific gravity	2.63

B. Methodology

1) Index properties: The tests to determine index properties of soil were done using IS 2720.1985 (Part V). They were done in soil treated with 0%, 5%, 10%, 15% and 20% marble dust to understand the variation in properties of untreated as well as treated soil. change the default, adjust the template as follows.

2) Compaction tests: The tests to determine the optimum moisture content and maximum dry density were done using both standard proctor compactive effort and modified proctor compactive effort according to IS 2720.1980 (Part VII) and IS 2720.1983 (Part VIII) respectively. The same is repeated for soil treated with 5%, 10%, 15% and 20% marble dust.

3) Unconfined compressive strength test: The variation in unconfined compressive strength of soil at 0%, 5%, 10%, 15% and 20% marble dust treated soil compacted at OMC were obtained based on IS 2720.1991(Part X).

4) Hydraulic conductivity testing: Hydraulic conductivity testing was done using consolidometer apparatus and falling head method was used, according to IS 2720.1986 (Part XVII). The permeant used was water and value of coefficient of permeability was recorded once it reached a constant value after complete saturation.

5) Volumetric shrinkage strain testing: Volumetric shrinkage was calculated by extruding cylindrical specimen from compaction mould. The extruded compacted cylindrical specimens were air dried in a laboratory table with room temperature for 30 days. Three measurements of height, diameters were calculated with Vernier caliper to nearest 0.01mm. The average diameter and height was used to calculated volume and thereby volumetric shrinkage strain.

III. RESULTS AND DISCUSSIONS

1) Index properties

a) Effect of marble dust addition in liquid limit: Marble dust added to soil in 0%, 5%, 10%, 15% and 20% were subjected to liquid limit test using Casagrande apparatus and the variation is given in Fig. 2. The liquid limit decreased with increased addition of marble dust, which was obtained as a result of the non-plastic behavior of marble dust. The value reduced from 47% for 0% marble dust to 43.1% for 5% marble dust addition. After which the reduction was gradual with minimum value obtained at 40.7% for 20% marble dust addition [4].

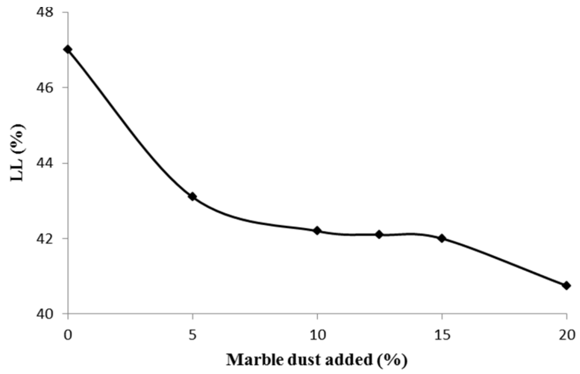

Fig. 2. Variation of liquid limit with marble dust addition.

b) Effect of marble dust addition in plastic limit: The addition of marble dust in soil increased the plastic limit of soil from its natural plastic limit. The increase was higher till 5% marble dust addition, with which the plastic limit increased from 25.3% (for untreated soil) to 34.1%. After which, the increase was gradual and a maximum value of 36.7% was obtained for 20% marble addition. The variation is shown in Fig. 3 [4].

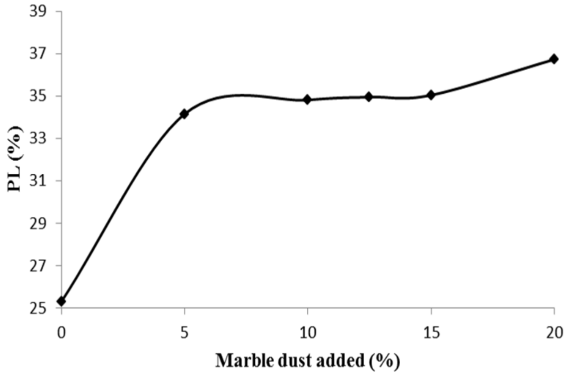

Fig. 3. Variation of plastic limit with marble dust addition.

c) Effect of marble dust addition in plasticity index: As the liquid limit decreases and plastic limit increases with marble dust addition, a decrease of plasticity index was observed in the treated soil. The variation is reported in Fig. 4. Also from the plasticity chart, the soil has become silt of low plasticity upon addition of marble dust [4].

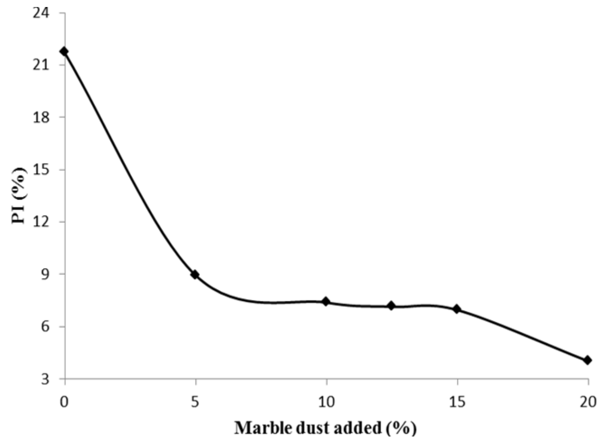

Fig. 4. Variation of plasticity index with marble dust addition.

2) Compaction characteristics: The maximum dry density and optimum moisture content of untreated and marble dust-treated soil is obtained through standard as well as modified proctor method. As the percentage of marble dust addition increases from 0% to 20%, it was observed that the maximum dry density increased from 1.384g/cc for 0% marble dust to 1.552g/cc for 20% marble dust and the optimum moisture content decreased from 31.1% for 0% marble dust to 24% for 20% marble dust addition with standard proctor effort. With modified proctor effort the trend was same, with optimum moisture content decrease from 22.4% at 0% marble dust addition and 18.9% at 20% addition. The variation in maximum dry density also indictaed increase from 1.634g/cc at 0% dust addition to 1.675g/cc at 20% marble dust addition.

The decrease of optimum moisture content is accounted to the fact that the replacement of soil with marble dust reduces the attraction to water particles. The increase in maximum dry density is related to the increased specific gravity of marble dust (2.63) replacing soil with lower specific gravity (2.5) [5].It can be observed that the optimum moisture content has reduced and maximum dry density has increased further at each marble dust percentage addition in compaction using modified proctor effort. This is due to the increased compactive effort for modified compactive effort as compared to standard compactive effort.

The variations of optimum moisture content and maximum dry density with different marble dust additions using both compactive efforts are presented in Fig. 5 and Fig. 6 respectively.

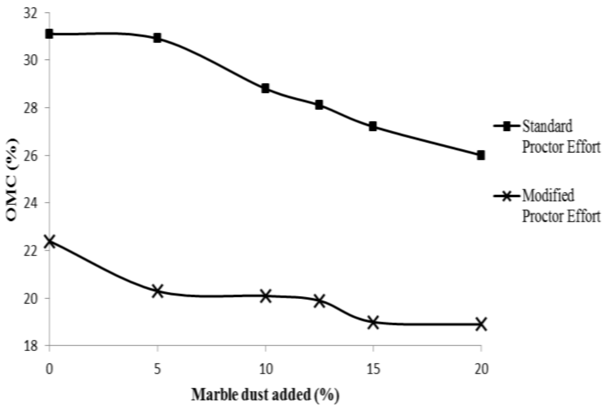

Fig. 5. Variation of OMC with marble dust addition.

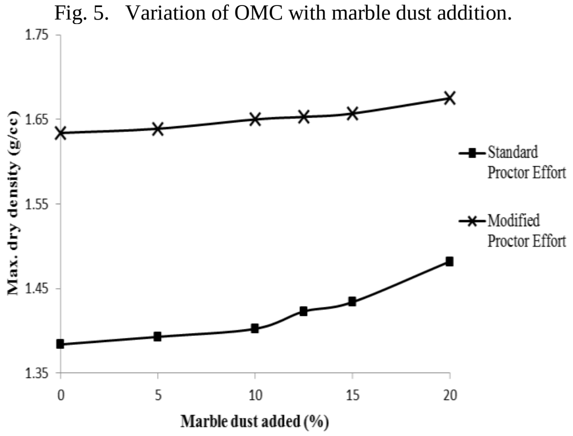

Fig. 6. Variation of maximum dry density with marble dust addition.

3) Unconfined compressive strength: The variation of UCC strength of soil compacted at optimum moisture content and corresponding dry densities,using standard and modified proctor effort with different percentage addition of marble dust is given in Fig.7. The value was observed to increase from 103.7kPafor 0% marble dust to 169kPafor 5% marble dust and 212.1kPa for 12.5% marble dust addition. After this, the value reduced to 160.7kPafor 15% marble dust and further decrease to 138.2kPafor 20% marble dust with standard proctor ecompactive effort. In the case of modified proctor effort, least value of 227.2kPafor 0% marble dust to 409.4kPafor 5% marble dust and 775.6kPafor 12.5% marble dust addition was obtained. After this, the value reduced to 661.1kPafor 15% marble dust and further decrease to 570.3kPafor 20% marble dust. This suggests that the optimum amount of marble dust addition lies between 12.5% and 15% addition.

The increase in UCC strength is attributed to the bonding of calcium ions of marble dust with silicates or aluminates present in the soil. After 12.5% marble dust addition, the reduction observed can be related to the availability of excess pozzolanic material which remains unbonded with soil [6].

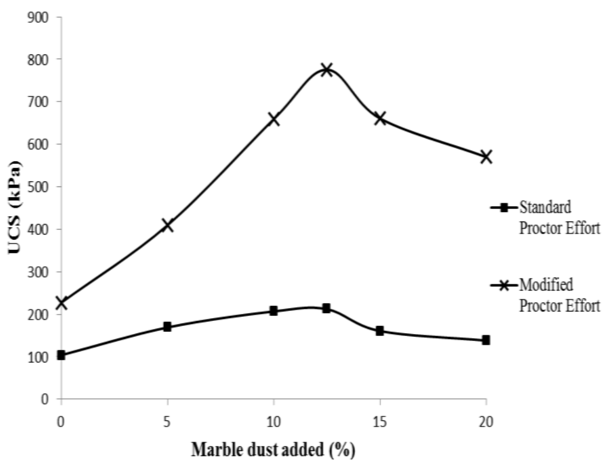

Fig. 7. Variation of unconfined compressive strength with marble dust addition.

A minimum value of 200kPa should be the load carrying capacity of a landfill liner. Here, unconfined tsrentgh greater than or equalto 200kPa was obtained at 10% and 12.5% marble dust addition with standard proctor effort and with all the five percentage additions with modified proctor effort.

4) Hydraulic conductivity testing: The hydraulic conductivity testing is done using consolidometer apparatus. Falling head method is used for measuring the hydraulic conductivity since it provides more accurate results in fine soil. Testing has been continued The test was done in soil compacted at required water content and dry density and is allowed for complete saturation by providing permeation for 24 to 48 hours. The value of k was then recorded without applying any additional stressuntil the last three measurements of hydraulic conductivity varied by no more than 8% [7].After recording this value, an additional stress of 200kPa was applied which is the minimum load carrying capacity of landfill liner and its subsequent coefficient of permeability was also reported. Fig. 8. indicates the variation in the coeficient of hydaulic conductivity (k) with varying percentage addition of marble dust in soil compacted using standard proctor compactive effort. The variation upon an additional stress of 200kPa application in soil is also shown. Fig. 9. indicates the same variations upon modified proctor effort.

From the figures, it can be seen that the trend was that of an initial decrease to minimum value and subsequent increase in hydraulic conductivity value on increasing percentages of marble dust addition. The value was generally found to decrease till about 12.5% and later on increase slightly. In the case of standard proctor effort, the value of k decreased upto 1.72 x 10^{-9} m/s at 12.5% dust addition from a value of 4.63 x 10^{-9}m/s at 0% dust. Later it slightly increased to 2.5 x 10^{-9} m/s at 20% dust addition. For the same cases, when an additional stress of 200kPa was applied, the least value of k obtained was 9.8 x 10^{-10}m/s at 12.5% marble dust addition. The initial value was 4.21 x 10^{-9} m/s at 0% addition and after least value at 12.5% addition it increased slightly to 1.6 x 10^{-9} m/s at 20% addition.

These trends were same with modified proctor effort with 3.84 x 10^{-9} m/s at 0% dust addition without additional stress and 2.8 x 10^{-9}m/s with additional stress. The value decreased to 5.6 x 10^{-10}m/s at 12.5% addition without additional stress application and 3.8 x 10^{-10}m/s with stress application. It lateron increases slightly to 1.57 x 10^{-9}m/s at 20% addition without additional stress and 7.4 x 10^{-10}m/s with additional stress.

The initial decrease in hydraulic conductivity is due to the reduction in pore spaces as the fines from the marble dust filled the voids thus reducing water flow. On the other hand, the increase in hydraulic conductivity is due to the presence of excess marble dust content which remained unbonded with soil that has changed the soil matrix leading to increased flocculation [8].The k value decreased significantly with higher compactive effort which is due to increased penetration by the compaction rammer on soil surface resulting in closer alignment of particles along the failure surface thus, yielding decreased frequency of large voids that could conduct flow. The additional of 200kPa alsocontributes to the formation of a closed soil matrix leading to reduced hydraulic conductivity.

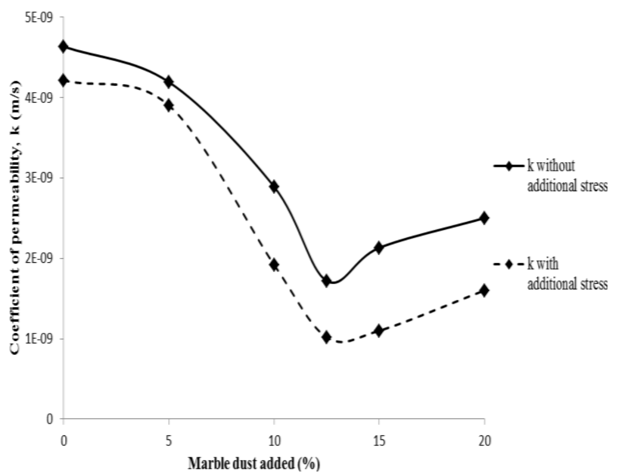

Fig. 8. Variation of coefficient of hydraulic conductivity with marble dust addition with standard proctor effort.

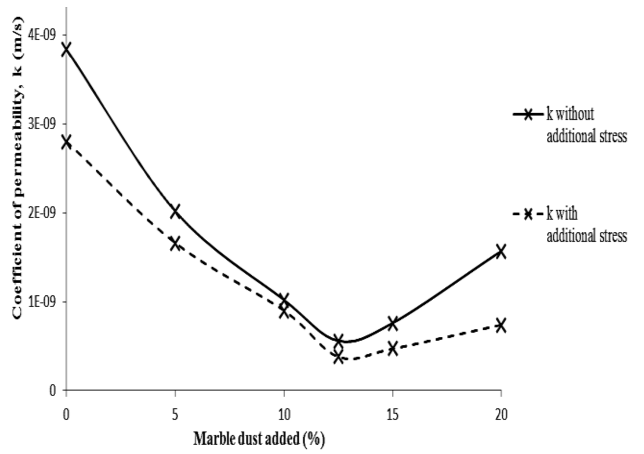

Fig. 9. Variation of coefficient of hydraulic conductivity with marble dust addition with modified proctor effort.

5) Volumetric shrinkage strain: The volumetric shrinkage strain (VSS) was calculated by measuring change in height, diameter and thereby volume of compacted specimen extruded from the compaction mould, till it was completely dry. Fig. 10. shows the variation in volumetric shrinkage strain of soil treated with marble dust at both standard as well as modified compactive effort. With standard compactive effort, the VSS is found to decrease from 15.3% at 0% marble dust addition to 3% at 10% marble dust addition. It lateron increased slightly to 4% at 12.5% dust addition and 7.8% at 20% dust addition. The trend is same with modified proctor effort i.e. 6.2% VSS at 0% marble dust addition to 2.7% at 10% addition. Afterwards a slight increase to 3.4% at 12.5% dust addition and 4.4% at 20% marble dust addition.

The increase after 10% marble dust addition is attributed to the increase in fines with larger surface area present in the soil mixture that required more water at the corresponding OMC for reaction. Consequently, this resulted in higher shrinkage during drying.

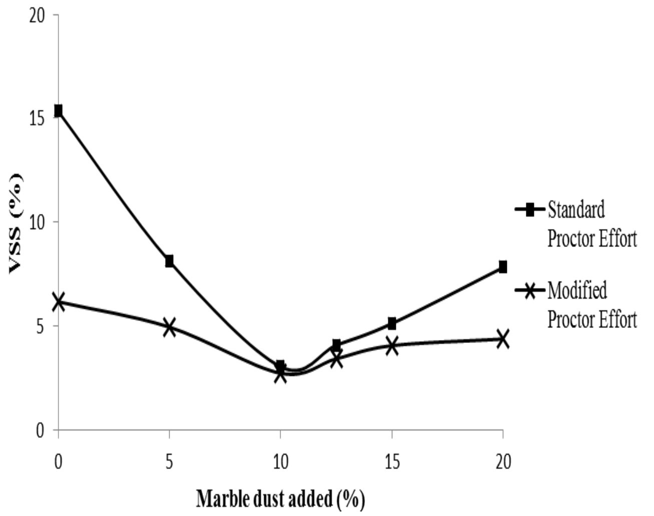

Fig. 10. Variation of volumetric shrinkage strain with marble dust addition.

IV. CONCLUSIONS

From the study conducted, it is understood that marble dust can be used as an effective liner additive material. It can also be seen that marble dust can be used as an effective stabilizing material also. The basic conclusions obtained are;

- The liquid limit was found to decrease upon marble dust addition while the plasticity limit increased and the plasticity index decreased.
- The unconfined compressive strength gave a maximum value of 212.1kPa using standard proctor compactive effort and 775.6kPa using modified compactive proctor effortupon 12.5% marble dust addition.
- Hydraulic conductivity was found to decrease till 12.5% marble dust addition and later on increased slightly. Compaction using modified proctor effort gave best results of 5.6 x 10^{-10} m/s without additional stress application and 3.8 x 10^{-10} m/s with additional stress application at 12.5% marble dust addition.
- Volumetric shrinkage reduced till 10% addition and slight increase was observed afterwards.
- Soil compacted with modified proctor effort gave better results compared to that with standard compactive effort.

Thus the optimum value of marble dust addition can be proposed as 12.5% marble dust additionbut hydraulic conductivity of soil compacted using standard proctor effort did not give desired value without adding any additional stress. Otherwise all the results gave satisfactory conditions as liner when 12.5% marble dust was added at both compactive efforts; even though soil compacted with modified proctor effort gave better results.

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