EVALUATION OF VOLUMETRIC SHRINKAGE OFMARBLE DUST-SOIL COMPOSITE

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Abstract

Locally available reddish soil was analysed for volumetric shrinkage strain by treating it with marble dust till 40%. Volumetric shrinkage strain in soils indicates the variation in volume of compacted soil, which will result in inducing cracking of soil sample. This property majorly affects soil used as liner material since shrinkage and subsequent cracking results in voids, which interrupt the proper functioning of liner. The soil sample were compacted using standard and modified Proctor compactive effort using moulding water contents -2, 0 and +2 percentage relative to optimum. The soil samples compacted at required water content and corresponding density were extruded from the compaction mould and kept fordrying, till it was completely dry. The variation in volume and weight of sample is recorded each consecutive 5 days. The results obtained indicated that the volumetric shrinkage strain were large within the first five days of drying. The weight also found to decrease largely within first five days of drying. The VSS value was found to decrease till 25 percentage marble dust addition and there after increase slightly. It was also found to increase with higher moulding water content. Using the results, compaction plane of acceptable zones were also plotted, from which marble dust addition percentages satisfying the regulatory value of VSS ≤ 4% is proposed as 25%.

Keywords:*Marble dust, Landfill liner, Compactive effort, Hydraulic conductivity, Volumetric shrinkage strain, Relative to optimum*

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1. INTRODUCTION

Landfill is a commonly used waste containment system which acts as a satisfactory disposal facility when all of its components are properly working. One of the major components of a landfill is the liner and cover system, which prevents the migration of leachate or waste particles to the surrounding environment or affecting the ground water. The liner system should have certain satisfactory properties to help the proper functioning of a landfill. One of such property is the volumetric shrinkage strain. A maximum volumetric shrinkage strain of less than or equal to 4% is suggested suitable for any material to be used as liner material.

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, marble dust is treated to a locally available soil collected from Thiruvananthapuram, Kerala to analyse the variation in volumetric shrinkage strain with different effects.

2. MATERIALS AND METHODOLOGY

2.1 Materials Used

2.1.1 Soil

The soil used in this study is naturally occurring soil collected Thiruvananthapuram district, Kerala which was red in colour. The properties of soil are studied using standard procedures.

2.1.2 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 10%, 20%, 25%, 30% and 40% of soil. The particle size distribution and specific gravity tests were done for marble dust and the results are obtained as in Table 1.

Table -1: Properties of Marble dust used

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

2.2 Methodology

2.2.1 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%, 10%, 20%, 25%, 30% and 40% marble dust to understand the variation in properties of untreated as well as treated soil.

2.2.2 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 10%, 20%, 25%, 30% and 40% marble dust.

2.2.3 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.

3. RESULTS AND DISCUSIONS

3.1 Index Properties

The particle size distribution of soil is presented in Fig. 1 and the index properties of soil is summarised in Table 2. From the test results, it was identified that the soil can be classified as silt of intermediate plasticity (MI) according to Unified Soil Classification system. The soil contains 57.8% sand, 9.1% silt and 33.1% clay particles. The variation in Liquid limit, Plastic limit, Plasticity Index, Shrinkage limit, and Specific gravity is also provided.

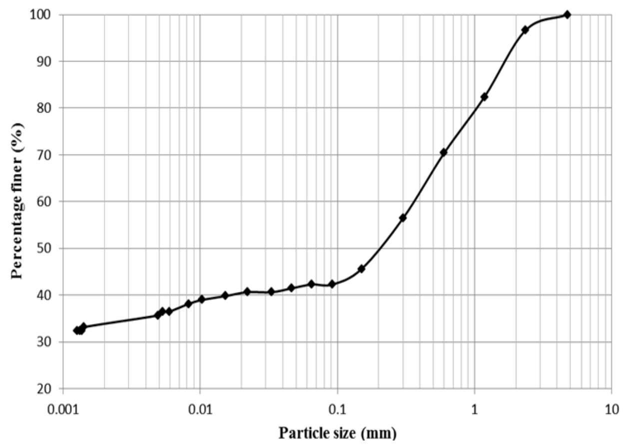


Fig -1: Particle size distribution of soil

3.2 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 40%, it was observed that the maximum dry density increased from 1.683g/cc at 0% marble dust addition to 1.693g/cc at 40% dust addition for Standard Proctor and optimum moisture content decreased from 17.5% to 16.2%. in the case of Modified Proctor, maximum dry density increased from1.778g/cc to 1.872g/cc with marble dust addition from 0 to 40%. The optimum moisture content decreased from 15.2% to 11.9%.

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 (2.54) [1]. The variations of optimum moisture content and maximum dry density with different marble dust additions using both compactive efforts are presented in Fig. 2a and 2b.

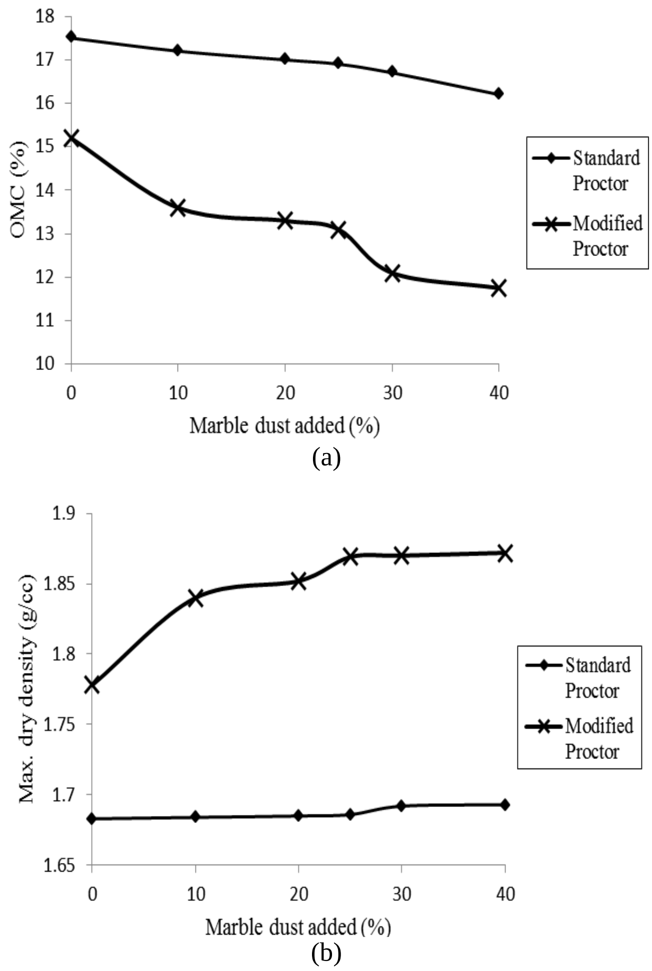


Fig-2: Variation with marble dust addition in (a) optimum moisture content, (b) maximum dry density

3.3 Volumetric Shrinkage Strain

The method of testing volumetric shrinkage of soil was done in laboratory by simulating field condition, which permitted free shrinkage. But contradicting to field conditions the drying of soil is done through sides also, which in a field case is not possible. 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. The variation in weight is also measured. Since the variation of VSS and weight remained relatively constant after 20 days, the variation till 30 days was only studied.

Table -1: Properties of Soil

Properties	**Value obtained**					
	0	10	20	25	30	40
Natural water content (%)	22.5					
Liquid limit (%)	49.5	46.7	44.4	44.1	43.8	37.7
Plastic limit (%)	28.7	26.05	25	24.85	24.72	19.28
Shrinkage limit (%)	15.70	15.76	15.82	15.92	15.95	16.00
Plasticity index (%)	20.8	20.65	19.4	19.25	19.08	18.42
Specific gravity	2.544	2.55	2.58	2.591	2.598	2.61
Optimum moisture content (%)						
Standard Proctor	17.5	17.2	17	16.9	16.7	16.2
Modified Proctor	15.2	13.6	13.3	13.1	12.1	11.9
Maximum dry density (g/cc)						
Standard Proctor	1.683	1.684	1.685	1.686	1.692	1.693
Modified Proctor	1.778	1.84	1.852	1.869	1.87	1.872
Colour	Red					

The effect of two types of compactive efforts, moulding water content, relative water content with optimum and different percentages of marble dust addition was studied.

3.3.1 Effect of Marble Dust Addition at OMC

The variation of VSS with varying percentages of marble dust addition is shown in Fig. 3. It can be seen that the volumetric shrinkage strain decreases to a minimum till 25% marble dust addition in soil and there after it increases lightly till 40% addition for both compactive efforts. The initial decrease till 25% is due to the filling up of marble dust in the soil which has reduced shrinkage properties. As the marble dust addition percentage increases beyond 25%, the fines content increases which absorb more water for reaction and result in increased shrinkage.

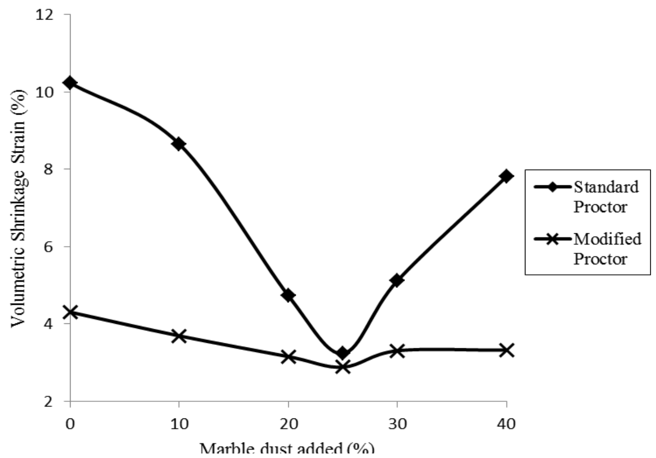


Fig-3: Variation in volumetric shrinkage strain with marble dust addition

3.2.2 Effect of Drying

The effect of drying in the soil samples was observed by the variation in weight as well as the volumetric shrinkage strain recorded. The variation in weight of soil compacted at OMC with varying percentages of marble dust using standard and modified proctor effort for the drying period is given in Fig. 4a to 4f. The variation in VSS is also shown in Fig. 5a to 5f.
From the results, it can be observed that the loss in weight is sharp in the initial five days of the drying period; thereafter remaining relatively constant till 30 days drying period. The variation in VSS indicated a gradual increase till 30 days with a relatively sharp increase within first five days. Also it can be seen that the rate of variation is affected by different compactive efforts. Soil compacted at higher compactive effort shrunk less since the moulding water content is less, resulting in lower shrinkage. The volumetric shrinkage strain and moulding water content is directly related. [2]

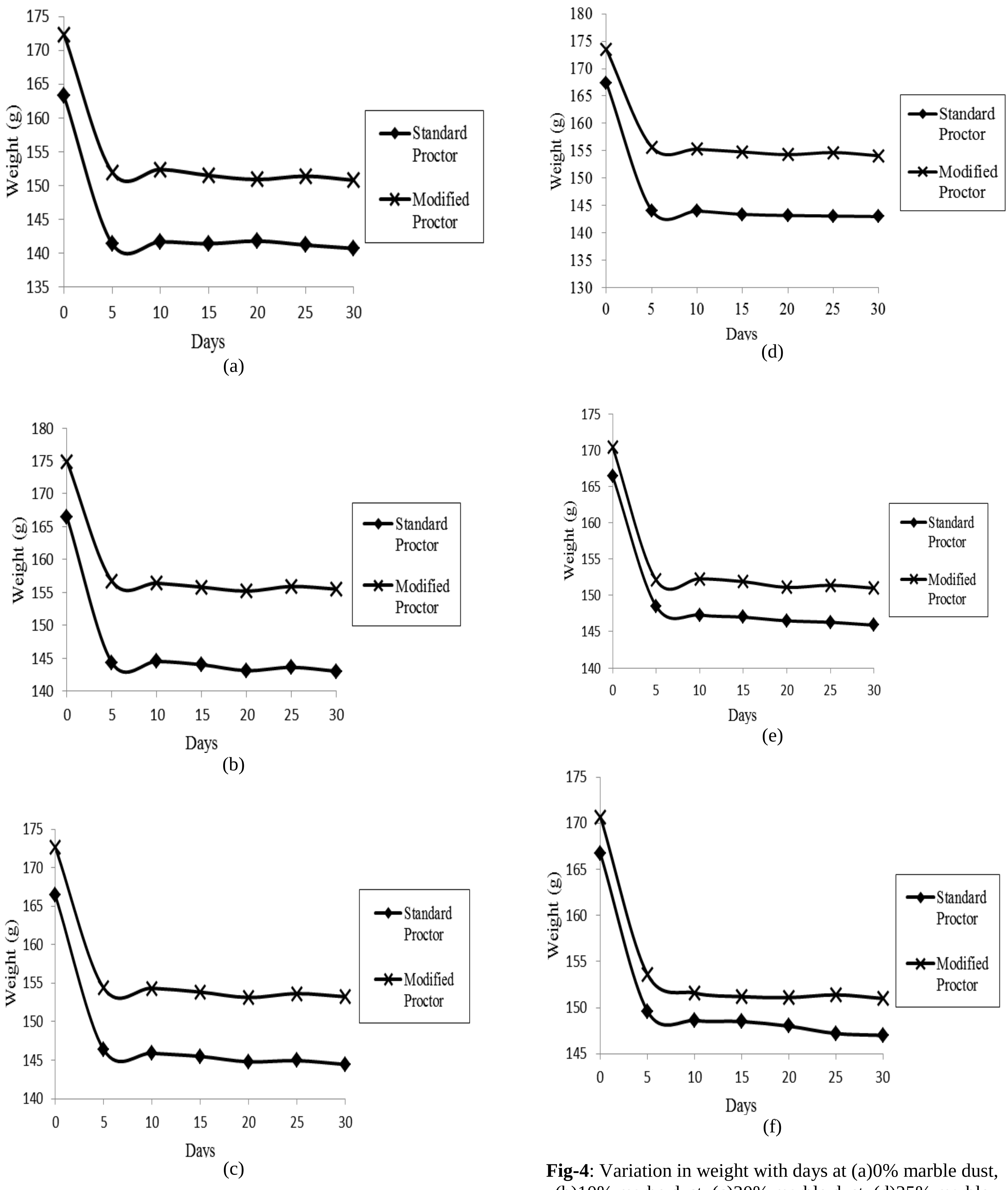
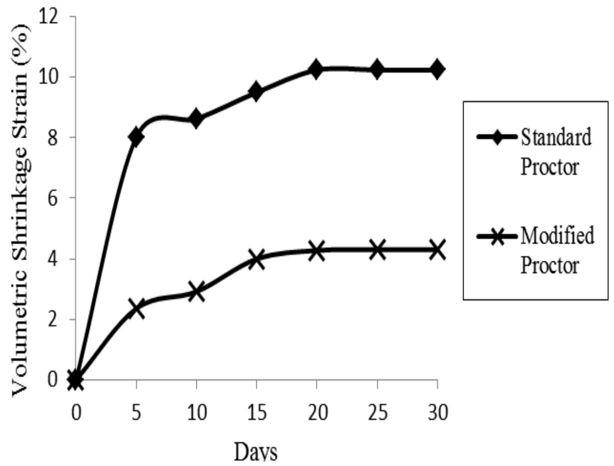
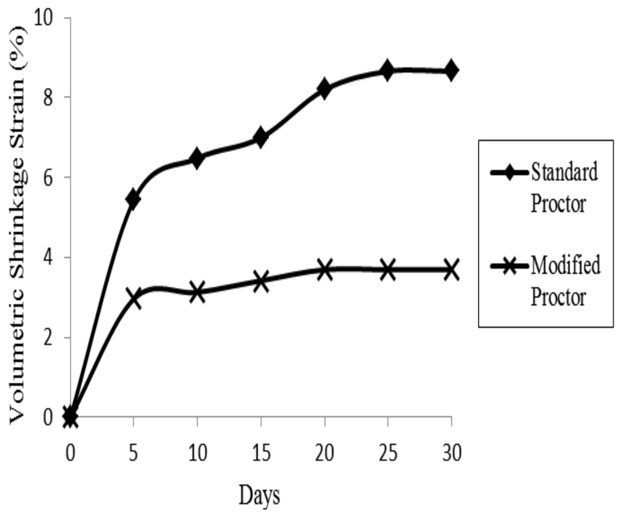


Fig-4: Variation in weight with days at (a)0% marble dust, (b)10% marbe dust, (c)20% marble dust, (d)25% marble dust, (e)30% marble dust and (f)40% marble dust



(a)



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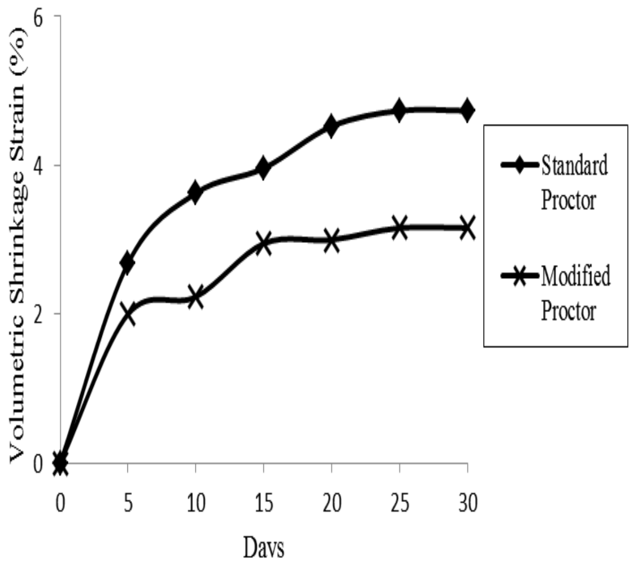

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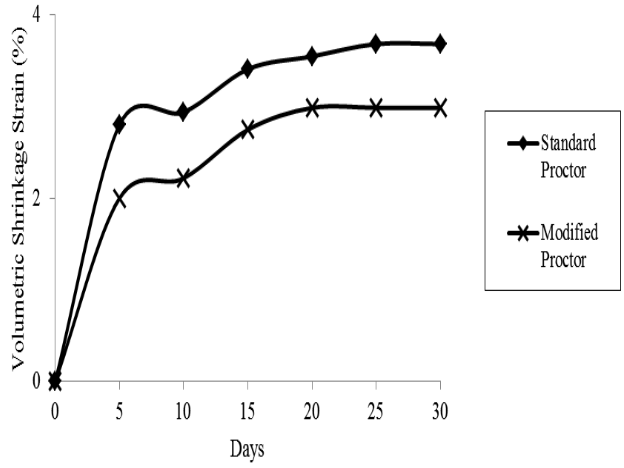

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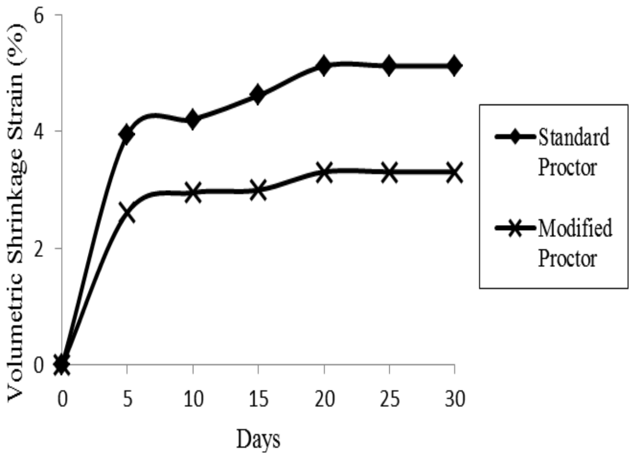

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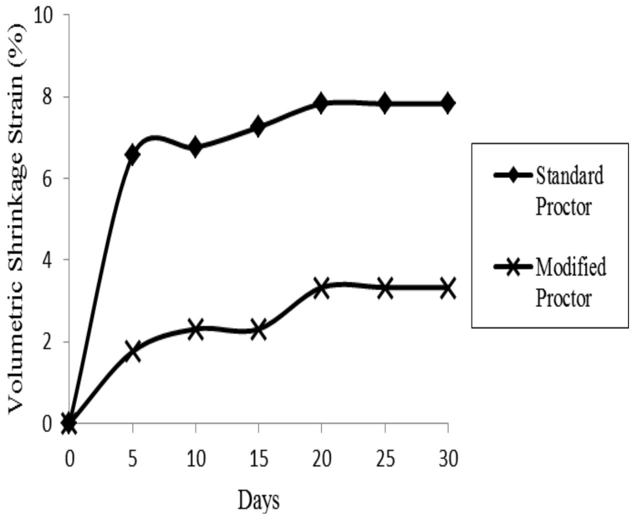


(f)

Fig-5: Variation in VSS with days at (a)0% marble dust, (b)10% marbe dust, (c)20% marble dust, (d)25% marble dust, (e)30% marble dust and (f)40% marble dust

3.2.3 Effect with Moulding Water Content

The effect of moulding water content in volumetric shrinkage strain is indicated in Fig. 6a to 6f. It can be seen that the VSS value increases as the moulding water content increases for both Standard Proctor compaction as well as Modified Proctor compaction.

From the results, it can be observed that with 0% marble dust addition, a maximum value of 4% volumetric shrinkage strain was obtained at 14.9% water content using Modified Proctor effort. Soil compacted using Standard Proctor did not give desired result. With 10% marble dust addition, maximum value of 4% volumetric shrinkage strain was obtained at 14.05% moulding water content using Modified Proctor effort. Similar to 0% dust addition, none of the samples compacted using Standard Proctor gave desired value. With 20% marble dust addition, maximum value of 4% volumetric shrinkage strain was obtained at 16.1% water content using Standard Proctor and using Modified Proctor, 15.3% moulding water content gave necessary value. Using 25% marble dust addition, with Standard Proctor 17.75% water content gave a maximum value of 4% VSS. With Modified Proctor, maximum VSS of 3.67% is obtained at 15.1% water content. Upon adding 30% marble dust, maximum value of 4% volumetric shrinkage strain is obtained at 15.025% water content using Standard Proctor. Using Modified Proctor, 12.9% moulding water content gave 4% VSS. With 40% marble dust addition, 14.5% moulding water content using Standard Proctor and 12.4% water content using Modified Proctor gave 4% VSS.

3.2.4 Effect of Water Content Relative to Optimum

The variation in VSS with water content relative to optimum upon addition of different percentages of marble dust is given in Fig. 7a to 7f. The variation in VSS for soil compacted at range of -2 to 2% of the optimum moisture content is shown From the trend obtained, it can be understood that the volumetric shrinkage increased with higher moulding water content. This is so since the soil compacted at higher moulding water content has higher amount of water, which leads to higher shrinkage [2] [3]. The soil compacted at higher moulding water content has more water particles present in the voids, resulting in more deflocculated and dispersed soil structure. On drying the water evaporates quickly. When a higher compactive effort is used for compaction, the water content present at each moulding water contents reduce; which result in reduced VSS.

From the results, it can be observed that with 0% marble dust addition, a maximum value of 4% volumetric shrinkage strain was obtained at 0.3% relative to optimum moisture content at dry side of optimum using Modified Proctor effort. None of the values using Standard Proctor effort gave the desired value. With 10% marble dust addition, maximum value of 4% volumetric shrinkage strain was obtained at 0.45% relative to optimum moisture content at wet side of optimum using Modified Proctor effort. Similar to 0% dust addition, none of the samples compacted using Standard Proctor gave desired value. With 20% marble dust addition, maximum value of 4% volumetric shrinkage strain was obtained at 0.9% relative to optimum moisture content at dry side of optimum using Standard Proctor and using Modified Proctor, 2% relative to optimum moisture content at wet side of optimum gave necessary value. Using 25% marble dust addition, with Standard Proctor 0.875% relative to optimum moisture content at wet side of optimum gave a maximum value of 4% VSS. With Modified Proctor, maximum VSS of 3.67% is obtained at 2% relative to optimum moisture content at wet side of optimum. Upon adding 30% marble dust, maximum value of 4% volumetric shrinkage strain is obtained at 1.675% relative to optimum moisture content at dry side of optimum using Standard Proctor. Using Modified Proctor, 0.8% relative to optimum moisture content at wet side of optimum gave 4% VSS. With 40% marble dust addition, -2% relative to optimum moisture content at dry side of optimum using Standard Proctor and 0.5% relative to optimum at wet side of optimum using Modified Proctor gave 4% VSS.

3.2.5 Acceptable Zones

A zone of acceptance was plotted for each of the marble dust addition percentages. This was done by relating dry density and moulding water content with the desired value of volumetric shrinkage strain i.e. ≤4%. The compaction planes were used for the purpose and the acceptable zones for each percentage of marble dust addition is given in Fig.8a to 8f.

The acceptable zone for VSS of the soil treated with 0% marble dust was obtainedat moulding water contents ranging from 13.2 to 14.9%for Modified Proctor and soil compacted using Standard Proctor did not fall within the acceptable zone (Fig. 8a). For 10% marble dust addition, it was achieved from 11.6 to 14.05% moulding watercontent for modified Proctor and none of the specimen compacted using Standard Proctor came in the acceptable zone (Fig. 8b). For 20% marble dust treatment, moulding water content from 15 to 16.1% and 11.3 to 15.3% for Standard Proctor and Modified Proctor respectively fell within acceptable zone (Fig. 8c). With 25% dust addition, moulding water content from 14.9 to 17.8% and11.1 to 15.8% using Standard and Modified Proctor gave desired value (Fig. 8d). Moulding water content from 14.7 to 15.1% and 10.1 to 12.9% using Standard and Modified Proctor effort came under the acceptable zone (Fig. 8e). For 40% marble dust addition, moulding water content from 14.2 to 14.5% and 9.9 to 12.4% using Standard and Modified Proctor effort gave necessary results (Fig. 8f).

The plots of acceptable zones show that 25% marble dust addition gave the best suitable compaction plane on which a volumetric shrinkage less than or equal to 4% is mostly satisfied. Out of the 6 specimens tested, 4 lie within the acceptable zone.

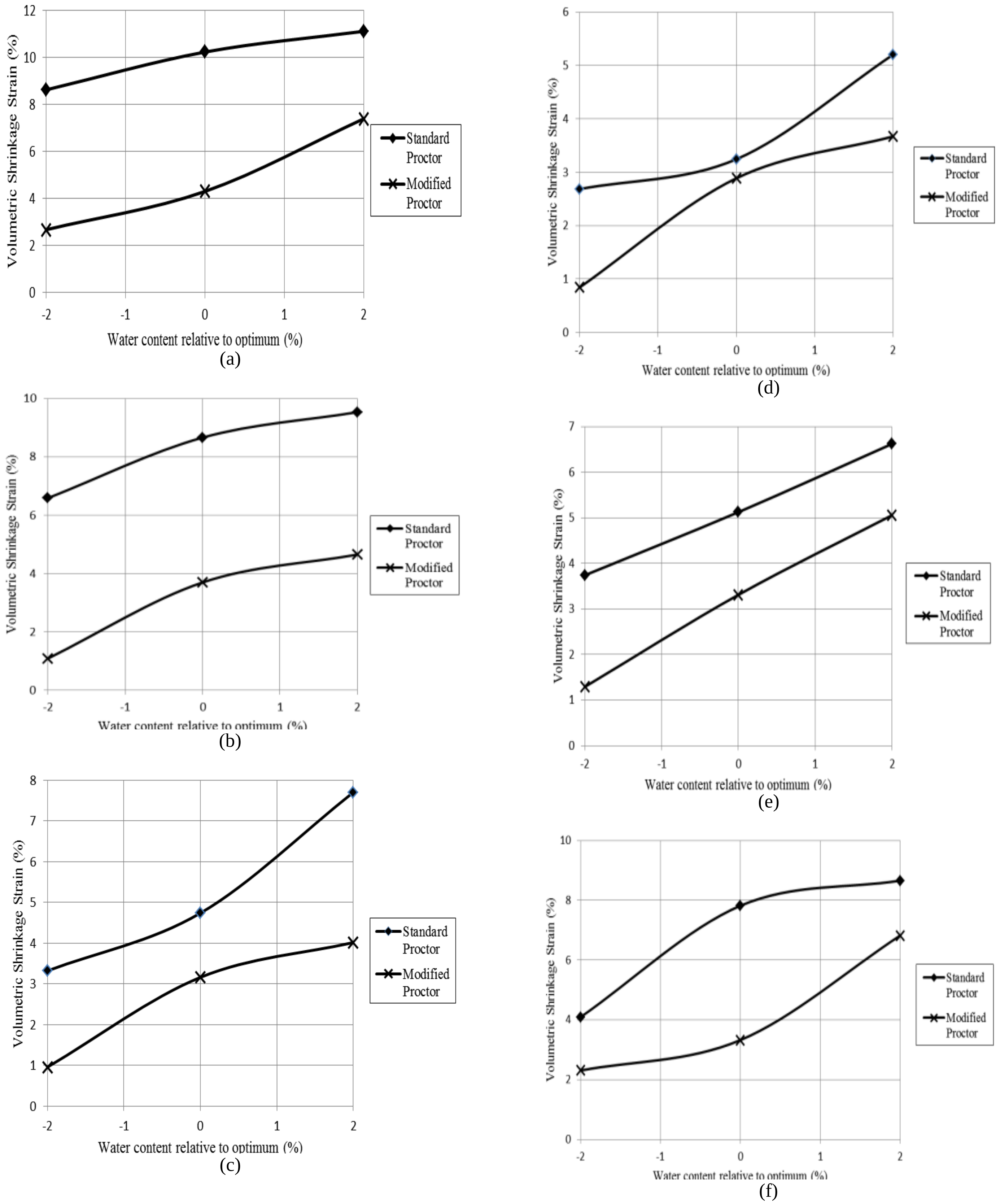


Fig-6: Variation in VSS with relative water content(a)0% marble dust, (b)10% marbe dust, (c)20% marble dust, (d)25% marble dust, (e)30% marble dust and (f)40% marble dust

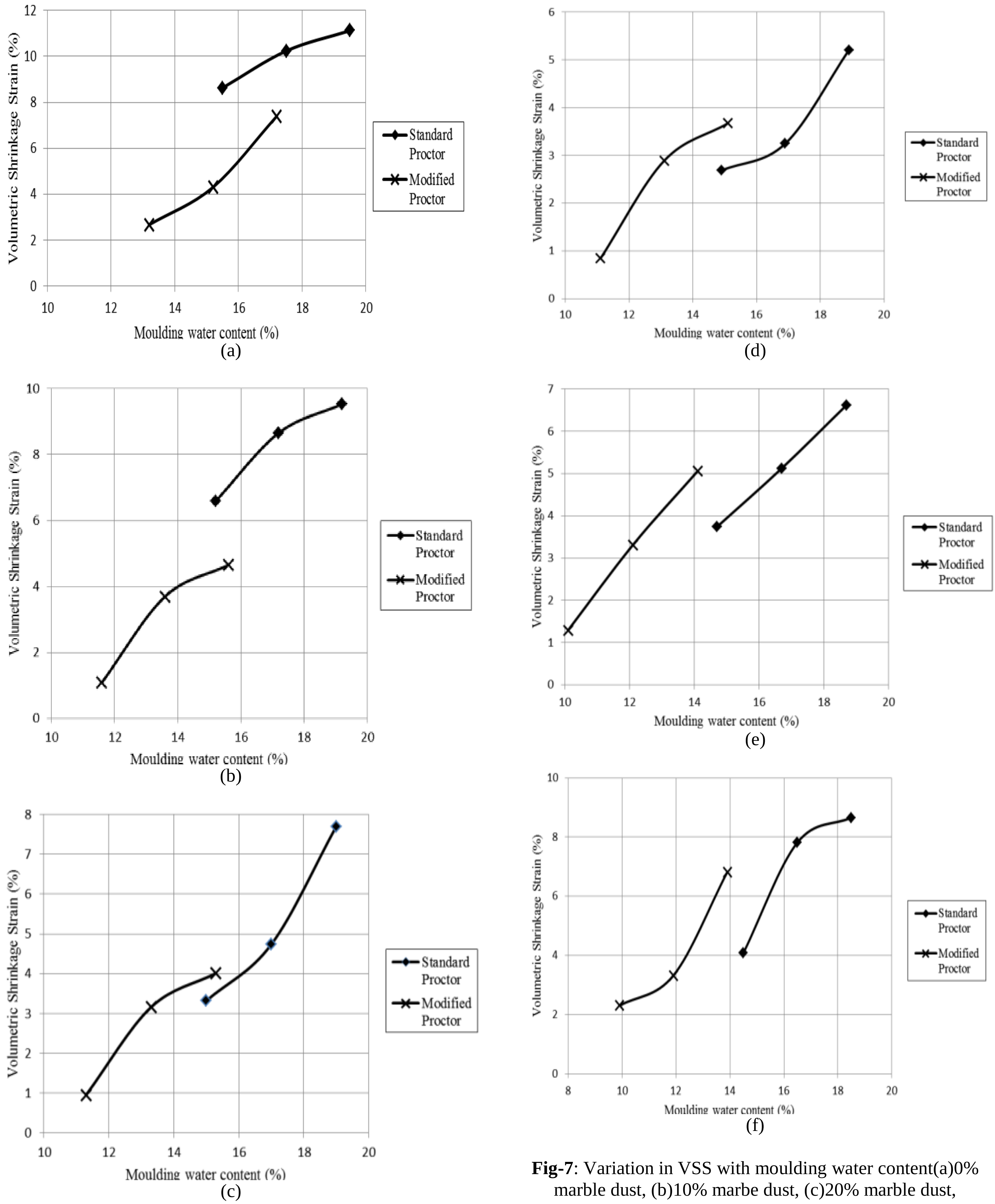
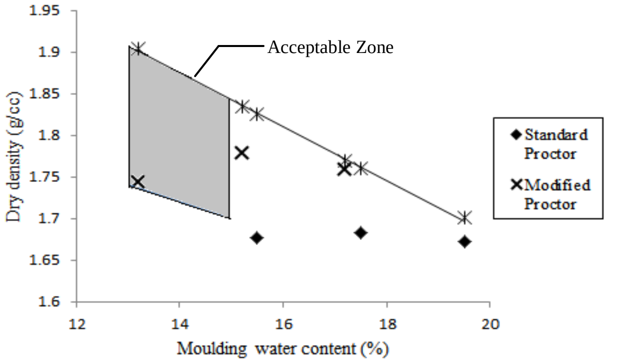


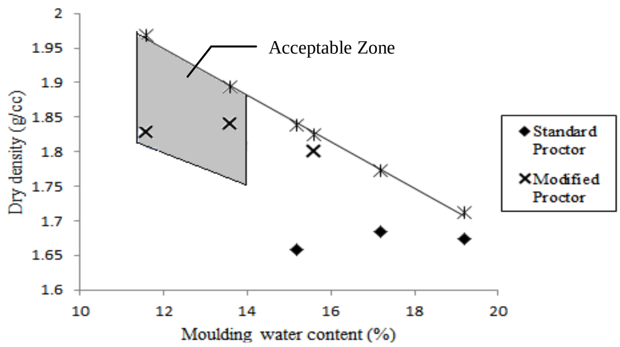
Fig-7: Variation in VSS with moulding water content(a)0% marble dust, (b)10% marbe dust, (c)20% marble dust, (d)25% marble dust, (e)30% marble dust and (f)40% marble dust

4. CONCLUSION

Locally available soil was treated with waste marble dust to evaluate the variations in volumetric shrinkage strain. The compacted soil samples using Standard and Modified Proctor effort were extruded from the mould and allowed for drying till 30 days. The variation in volume and weight was recorded every 5 consecutive days.



(a)



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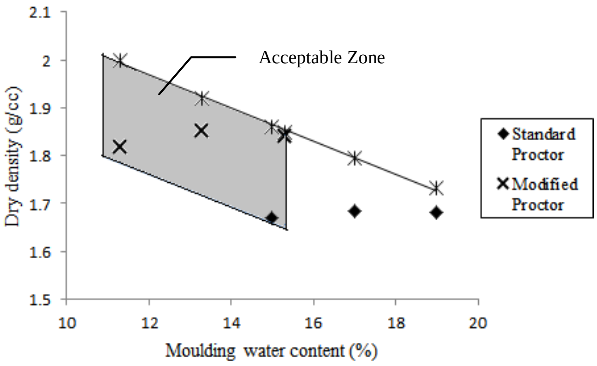

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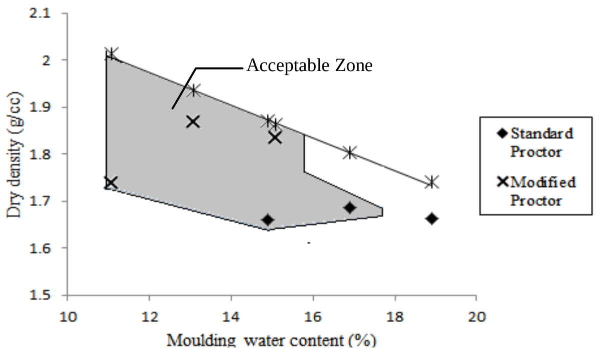

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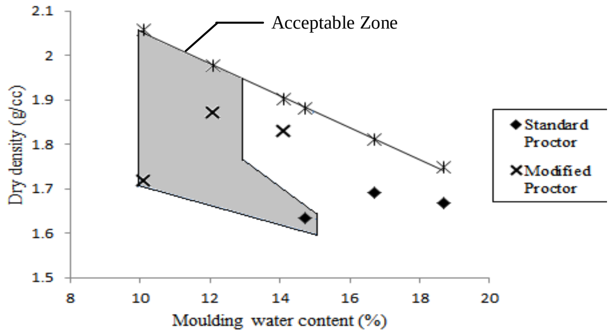

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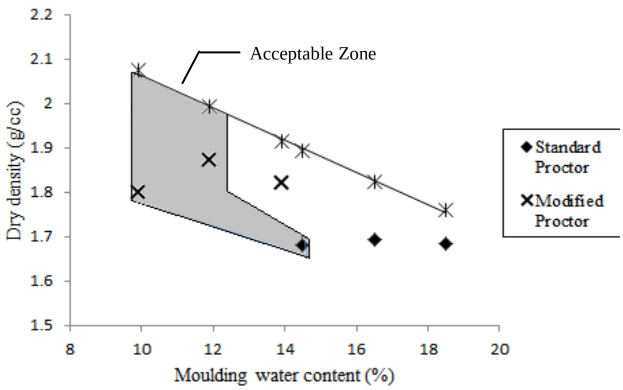

(f)

Fig-8: Acceptable zones for (a)0% marble dust, (b)10% marbe dust, (c)20% marble dust, (d)25% marble dust, (e)30% marble dust and (f)40% marble dust

From the results obtained, the following conclusions can be arrived upon.

- Compaction using marble dust resulted in higher maximum dry density and lower optimum moisture content.
- Higher variation in volumetric shrinkage strain and weight was recorded in the initial five days of drying.
- VSS decreased till a minimum up to 25% marble dust addition and later on increased slightly, in both cases
- VSS increased with higher moulding water content and moulding water relative to optimum, while it decreased on higher compactive effort.

Based on the plots of acceptable zone, addition of 25% marble dust in soil provided the most optimum results considering volumetric shrinkage strain values.

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