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Design of Slope for Road Embankment with the Help of Software for Fine Sand with Ceramic Tile Waste Material

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Abstract: *The main objective of the present investigation is to assess the usefulness of ceramic tile waste as admixture for fine sand, and focused to improve the engineering properties of fine sand to make it capable to reduced cross section of embankment for road construction. This research paper includes laboratory experimental work, software work and cost analysis work. Different laboratory experiments were performed on fine sand with direct mixing of fine sand of different dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc (M.D.D.) and different percentage 0%, 2%, 4%, 8% and 12% by dry weight of fine sand of ceramic tile waste material having particles size range between 2.36 mm to 4.75 mm. A geotechnical software was used for stability analysis of road embankments of various heights of 6.0 m, 7.5 m and 9.0 m. The rate analysis was done manually according to B.S.R. 2014, P.W.D., Rajasthan, India and cost reduction ratios were calculated. The reduction in cross-section of road embankment was tremendous and the cost of the construction was also reduced to a good extent.*

Keywords: *Direct shear test, road embankment, factor of safety, ceramic tile waste material, slope stability analysis*

I. Introduction

In western Rajasthan (India), fine sand available in abundance, being loose and cohesionless in natural form poses a problem for construction of embankment for highway and railway due to its low bearing capacity and low compressive strength. Rapidly constructed embankments with fine sand have a significant influence on the slope stability of these embankments so as not to cause any slope failures. Stabilization of fine sand from locally available material is very important to reduce the construction cost of road embankment. The aim of present work is the economical and beneficial utilization of such wastes for improving geotechnical properties of fine sand which is to be used as a base material for road embankment construction.

Utilization of ceramic tile waste material for improvement of properties of fine sand is a cost effective and sustainable technique. A huge quantity of ceramic tile waste is produced due to warping and breaking of ceramic tiles in different manufacturing units every year in India, so it can be used as admixture for fine sand. The best method to handle ceramic tile waste is to utilize it for engineering applications. Fine sand mixed with ceramic tile waste material as admixture has great scope for the construction of road embankment.

The main aim of this study is to find possibility of utilization of ceramic tile waste material in massive earth work for construction of road embankments. An attempt has been made for the slope stability analysis with the help of geotechnical software for road embankments of different heights for two lane road keeping allowance for shoulders built with the primary construction material fine sand which has been stabilized with the beneficial and economical utilization of ceramic tiles waste material for improving its properties resulting in the steepening of the side slope of the road embankment along with maintaining the required factor of safety and thus optimizing the slope for road embankment because of the reduction in its cross-sectional area. Geotechnical software is based on limit equilibrium method. Morgenstern-Price method is used in this analysis. The values of the dry densities and the angle of internal friction of fine sand mixed with various percentages by weight of fine sand of ceramic tile waste have been taken from the experiments conducted in the laboratory.

Arora et al (2016) carried out an economical study on safety of earthen embankments by use of marble slurry. The embankment made from such stabilized soil at different M.S. ratio have been tested for slope stability analysis keeping other variable constant and it is found safe up to 25% marble slurry. Factor of safety is calculated by software with two different methods i.e. Bishop and Morgenstern Price. It was found that Bishop Method leads lower value in compare to Morgenstern Price.

Many researchers like AK Mishra et al (2001), B.L. Swami (2002), Dhawan, P. K (1994), Kumar P. et al (2008), S. Chandra et al (2005), Akash Gupta et al (2016), Aditya Kumar Anupam et al (2013) also worked on utilization of different waste materials in construction of roads.

II. Materials And Their Properties

2.1 Fine Sand

Fine sand is spread in huge areas throughout the Western Rajasthan (India). The fine sand used in present investigation was brought from location near Jodhpur, Rajasthan. Table 1 and figure 1 show the particle size distribution curve and various geotechnical properties determined by the particle size distribution analysis.

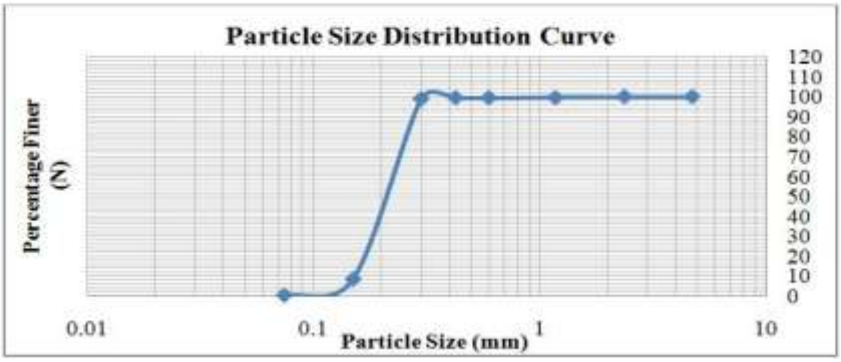

Figure 1: Particle Size Distribution Curve

Table 1: Various Geotechnical Properties of Fine Sand

S. No.	Property	Test Media (Fine Sand)
1.	Coefficient of Uniformity (C_u)	1.31
2.	Coefficient of Curvature (C_c)	1.08
3.	Mean Diameter (D_{50}) mm	0.20
4.	Effective Size (D_{10}) mm	0.16
5.	Fine Soil Fraction (75 µ)	0.10%

2.2 Ceramic Tile Waste Material

Ceramic tile is nonmetallic, inorganic solid prepared by the action of heat and subsequent cooling. Ceramic material may have crystalline or partly crystalline structure, or may be amorphous, because most common ceramics are crystalline materials. The earlier ceramics were pottery objects made from clay either by itself or mixed with other materials, hardened in fire. Later ceramics were glazed and fired to create a colored, smooth surface. The ceramic tile waste used in present work was of Kajaria Company. The ceramic tile waste was bought from a manufacturing unit from Bikaner, Rajasthan (India). Table 2 shows the physical and engineering properties of ceramic tile waste material.

Table 2: Physical and Engineering Properties of Ceramic Tile Waste Material

Physical and Engineering Properties of Ceramic Tile Waste Material	
Density	2.27 gm/cc
Water Absorption (For 24 hours)	4% by dry weight

III. Investigation Program

The investigation program included the preliminary tests, slope stability analysis and cost analysis of road embankment constructed by fine sand and mix compositions of fine sand and ceramic tile waste. Following investigations were carried out:

1. Standard Proctor Test for determining different dry densities for fine sand.
2. Direct Shear Test to determine angle of internal friction of fine sand having different dry densities and mix compositions with different percentage by weight of ceramic tile waste material.
3. Slope Stability analysis by software for different heights of embankment for mix compositions of different dry densities of fine sand and different percentage by weight of ceramic tile waste material.
4. Cost analysis for determining cost reduction ratio for different heights of embankment for different mix compositions of fine sand and ceramic tile waste material.

Table 3 shows the variable which are investigated in present research.

Table 3: Variables Investigated in Present Research

S. No.	Effect of	Variables	Range Investigated
1.	Moisture content in sand	Dry density	1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc
2.	Ceramic tile waste material on different properties of sand	Size passing sieve size	4.75 mm passing and 2.36 mm retaining
3.	Mix ceramic tile waste material by dry weight of fine sand	Proportion percentage	0%, 2%, 4%, 8% and 12%
4.	Different heights of embankments	Height of embankment	6.0 m, 7.5 m and 9.0 m

IV. Investigation Results

4.1 Standard Proctor Test

The geotechnical properties of soil are dependent on the dry density and moisture content at which the soil is compacted. The aim of standard proctor test is to determine the relationship between the moisture content and dry density of soils. In order to obtain these parameters, standard proctor test was performed in accordance with IS 2720 (Part VII). The figure 2 obtained by experiment shows that required dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc (M.D.D.) for present investigation occur at 4%, 12% and 18% water content respectively.

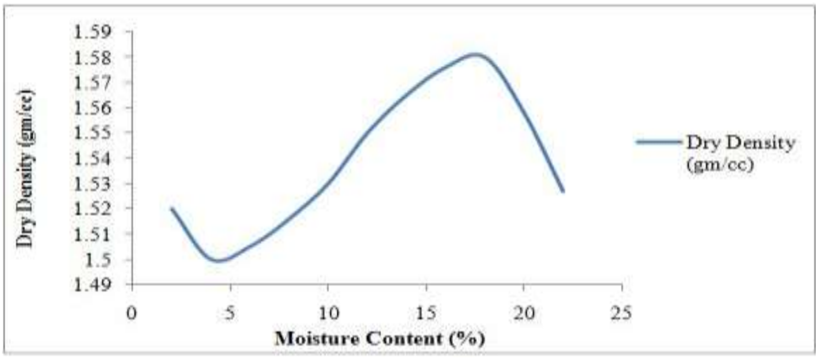

Figure 2: Dry Density v/s Moisture Content Curve

4.2 Direct Shear Test

The direct shear test is used to determine the shear strength properties of soils using the direct shear apparatus. Tests were carried out with a strain controlled shear apparatus at rate of 1.25 mm/min to determine angle of internal friction (ϕ) of different mix compositions of fine sand and ceramic tile waste material in accordance with ID 2720 (Part XIII). Direct shear tests were performed on mix composition of fine sand of 1.50 gm/cc, 1.55gm/cc and 1.58 gm/cc dry density with ceramic tile waste material of 0%, 2%, 4%, 8% and 12% by dry weight of fine sand. The results of direct shear tests are given in table 4.

Table 4: Variation of Angle of Internal Friction (ϕ) with Dry Density of Fine Sand and Percentage by Weight of Ceramic Tile Waste Material

Dry Density (gm/cc)	Angle of Internal Friction ϕ (Degree)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
1.50	29.28°	35.96°	37.18°	41.70°	43.73°
1.55	32.09°	38.37°	42.70°	44.70°	46.55°
1.58	34.72°	42.73°	45.65°	47.43°	48.28°

4.3 Slope Stability Analysis

The software used in this investigation is one of powerful tool for analysis, include the use of finite element computed pore-water pressure and stresses in a slope stability analysis. It is widely used in various civil engineering applications. Slope model was formed with the help of slope soil properties. This software is used to find out lowest value of factor of safety. Morgenstern-Price method was used to calculate factor of safety. According to IRC 75:1979, the acceptable factor of safety for the design of low embankments is 1.25. Investigation is done for two lane road embankment of height 6.0 m, 7.5 m, 9.0 m and width 8 m (taking allowance for shoulders) by steeping of side slope to the maximum extent till the factor of safety of the critical slip surface remains within the recommended limit of 1.25 as per IRC 75:1979. Figures 3 shows a typical critical slip surface and figure 4 shows the entry and exit of slip surfaces.

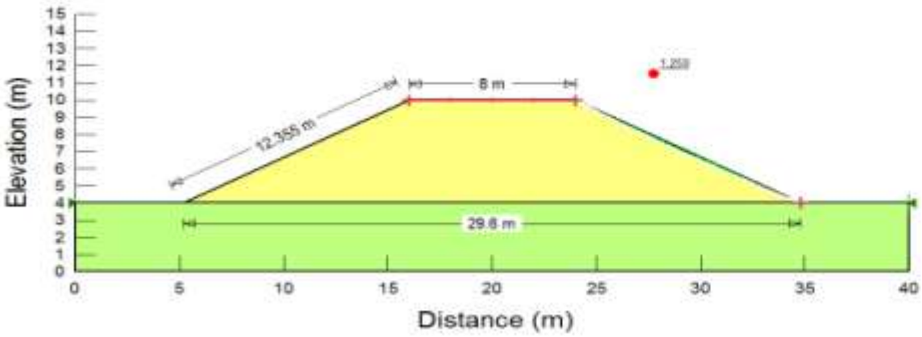

Figure 3: Critical Slip Surface when Height of Embankment = 6.0 m, slope = 1.8:1, Dry Density of Fine Sand = 1.58 gm/cc and Ceramic Tile Waste Material by Weight = 0%

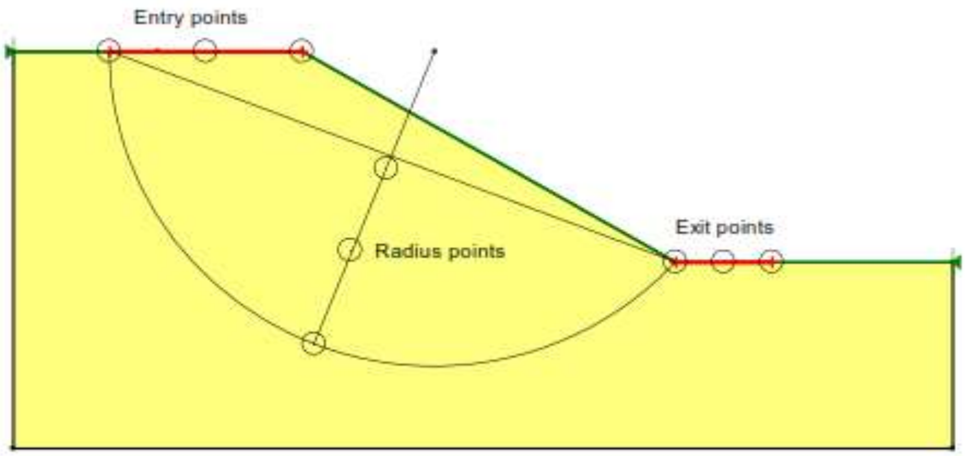

Figure 4: Schematic Diagram of the Entry and Exit of Slip Surface

Tables 5, 6 and 7 show the results of slope stability analysis for different height of embankment i.e. 6.0 m, 7.5 m and 9.0 m for different mix compositions of fine sand of different dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc and different percentage 0%, 2%, 4%, 8% and 12% by weight of ceramic tile waste material. The steepest slope of the embankment is found when fine sand of different dry densities mixed with 12% by weight ceramic tile waste material.

Table 5 : Results of Slope Stability Analysis for Mix Compositions of Fine Sand of 1.50 gm/cc Dry Density and Different Percentages by Weight of Ceramic Tile Waste Material

S. No.	Height of Embankment (m)	Ceramic Tile Waste Material (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	29.28°	2.24:1	1.259
2.	6.0	2	35.96°	1.72:1	1.250
3.	6.0	4	37.18°	1.65:1	1.254
4.	6.0	8	41.70°	1.4:1	1.250
5.	6.0	12	43.73°	1.31:1	1.256
6.	7.5	0	29.28°	2.24:1	1.259
7.	7.5	2	35.96°	1.72:1	1.250
8.	7.5	4	37.18°	1.65:1	1.254
9.	7.5	8	41.70°	1.4:1	1.250
10.	7.5	12	43.73°	1.31:1	1.256
11.	9.0	0	29.28°	2.24:1	1.259
12.	9.0	2	35.96°	1.72:1	1.250
13.	9.0	4	37.18°	1.65:1	1.254
14.	9.0	8	41.70°	1.4:1	1.250
15.	9.0	12	43.73°	1.31:1	1.256

Table 6 : Results of Slope Stability Analysis for Mix Compositions of Fine Sand of 1.55 gm/cc Dry Density and Different Percentages by Weight of Ceramic Tile Waste Material

S. No.	Height of Embankment (m)	Ceramic Tile Waste Material (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	32.09°	2:01	1.256
2.	6.0	2	38.37°	1.58:1	1.253
3.	6.0	4	42.70°	1.40:1	1.250
4.	6.0	8	44.70°	1.27:1	1.259
5.	6.0	12	46.55°	1.19:1	1.258
6.	7.5	0	32.09°	2:01	1.256
7.	7.5	2	38.37°	1.58:1	1.253
8.	7.5	4	42.70°	1.40:1	1.250
9.	7.5	8	44.70°	1.27:1	1.259
10.	7.5	12	46.55°	1.19:1	1.258
11.	9.0	0	32.09°	2:01	1.256
12.	9.0	2	38.37°	1.58:1	1.253
13.	9.0	4	42.70°	1.40:1	1.250
14.	9.0	8	44.70°	1.27:1	1.259
15.	9.0	12	46.55°	1.19:1	1.258

Table 7 : Results of Slope Stability Analysis for Mix Compositions of Fine Sand of 1.58 gm/cc Dry Density and Different Percentages by Weight of Ceramic Tile Waste Material

S. No.	Height of Embankment (m)	Ceramic Tile Waste Material (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	34.72°	1.8:1	1.250
2.	6.0	2	42.73°	1.36:1	1.259
3.	6.0	4	45.65°	1.22:1	1.250
4.	6.0	8	47.43°	1.15:1	1.254
5.	6.0	12	48.28°	1.12:1	1.259
6.	7.5	0	34.72°	1.8:1	1.250
7.	7.5	2	42.73°	1.36:1	1.259
8.	7.5	4	45.65°	1.22:1	1.250
9.	7.5	8	47.43°	1.15:1	1.254
10.	7.5	12	48.28°	1.12:1	1.259
11.	9.0	0	34.72°	1.8:1	1.250
12.	9.0	2	42.73°	1.36:1	1.259
13.	9.0	4	45.65°	1.22:1	1.250
14.	9.0	8	47.43°	1.15:1	1.254
15.	9.0	12	48.28°	1.12:1	1.259

4.4 Rate Analysis

Construction of Embankment with Material obtained from Roadway Cutting Item:

Contraction of Embankment with approved materials deposited at the site obtained from roadway cutting and excavation from drain and foundation or other structures graded and compacted to meet requirement = Rs. 34 per cum (as per unified B.S.R., P.W.D., Rajasthan, June 2014)

Add About (lump sum 7.5% Extra for ceramic tile waste material for its crushing, mixing and transportation)

Cost of Earthwork stabilized by ceramic tile wastage Material = 34 + 0.075x34 = 36.55 Rs per cum

Table 8, 9 and 10 represent the saving of quantity of earthwork, cost of earthwork and cost reduction ratio of fine sand of dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc mixed with 0%, 2%, 4%, 8% and 12% by weight of ceramic tile waste material for different heights of embankment 6.0 m, 7.5 m and 9.0 m for 1 km long two lane road.

Table 8 : Saving of Quantity of Earthwork and Cost Reduction Ratio for Road Embankment of Different Heights and 1 km Long Two Lane Road for Fine Sand of Dry Density 1.50 gm/cc using Different Percentage by Weight of Ceramic Tile Waste Material

S. No.	Height of Embankment (m)	Ceramic Tile Waste Material (%)	Width of Pavement (m)	Area (Sqm)	Quantity of Earthwork (Cum)	Saving of quantity of earthwork (Cum)	PWD BSR Rate per cum	Cost (Rs)	Saving of Cost (Rs)	Cost Reduction Ratio
1.	6.0	0	8	128.64	128640.00	--	34.00	4373760.00	--	1.00
2.	6.0	2	8	109.92	109920.00	18720.00	36.55	4017576.00	356184.00	0.92
3.	6.0	4	8	107.40	107400.00	21240.00	36.55	3925470.00	448290.00	0.90
4.	6.0	8	8	98.40	98400.00	30240.00	36.55	3596520.00	777240.00	0.82
5.	6.0	12	8	95.16	95160.00	33480.00	36.55	3478098.00	895662.00	0.80
6.	7.5	0	8	186.00	186000.00	--	34.00	6324000.00	--	1.00
7.	7.5	2	8	156.75	156750.00	29250.00	36.55	5729212.50	594787.50	0.91
8.	7.5	4	8	152.81	152812.50	33187.50	36.55	5585296.88	738703.13	0.88
9.	7.5	8	8	138.75	138750.00	47250.00	36.55	5071312.50	1252687.50	0.80
10.	7.5	12	8	133.69	133687.50	52312.50	36.55	4886278.13	1437721.88	0.77
11.	9.0	0	8	253.44	253440.00	--	34.00	8616960.00	--	1.00
12.	9.0	2	8	211.32	211320.00	42120.00	36.55	7723746.00	893214.00	0.90
13.	9.0	4	8	205.65	205650.00	47790.00	36.55	7516507.50	1100452.50	0.87
14.	9.0	8	8	185.40	185400.00	68040.00	36.55	6776370.00	1840590.00	0.79
15.	9.0	12	8	178.11	178110.00	75330.00	36.55	6509920.50	2107039.50	0.76

Table 9 : Saving of Quantity of Earthwork and Cost Reduction Ratio for Road Embankment of Different Heights and 1 km Long Two Lane Road for Fine Sand of Dry Density 1.55 gm/cc using Different Percentage by Weight of Ceramic Tile Waste Material

S. No.	Height of Embankment (m)	Ceramic Tile Waste Material (%)	Width of Pavement (m)	Area (Sqm)	Quantity of Earthwork (Cum)	Saving of Quantity (Cum)	PWD BSR Rate per cum	Cost (Rs)	Saving of Cost (Rs)	Cost Reduction Ratio
1.	6.0	0	8	120.00	120000.00	--	34.00	4080000.00	--	1.00
2.	6.0	2	8	104.88	104880.00	15120.00	36.55	3833364.00	246636.00	0.94
3.	6.0	4	8	98.40	98400.00	21600.00	36.55	3596520.00	483480.00	0.88
4.	6.0	8	8	93.72	93720.00	26280.00	36.55	3425466.00	654534.00	0.84
5.	6.0	12	8	90.84	90840.00	29160.00	36.55	3320202.00	759798.00	0.81
6.	7.5	0	8	172.50	172500.00	--	34.00	5865000.00	--	1.00
7.	7.5	2	8	148.88	148875.00	23625.00	36.55	5441381.25	423618.75	0.93
8.	7.5	4	8	138.75	138750.00	33750.00	36.55	5071312.50	793687.50	0.86
9.	7.5	8	8	131.44	131437.50	41062.50	36.55	4804040.63	1060959.38	0.82
10.	7.5	12	8	126.94	126937.50	45562.50	36.55	4639565.63	1225434.38	0.79
11.	9.0	0	8	234.00	234000.00	--	34.00	7956000.00	--	1.00
12.	9.0	2	8	199.98	199980.00	34020.00	36.55	7309269.00	646731.00	0.92
13.	9.0	4	8	185.40	185400.00	48600.00	36.55	6776370.00	1179630.00	0.85
14.	9.0	8	8	174.87	174870.00	59130.00	36.55	6391498.50	1564501.50	0.80
15.	9.0	12	8	168.39	168390.00	65610.00	36.55	6154654.50	1801345.50	0.77

Table 10 : Saving of Quantity of Earthwork and Cost Reduction Ratio for Road Embankment of Different Heights and 1 km Long Two Lane Road for Fine Sand of Dry Density 1.58 gm/cc using Different Percentage by Weight of Ceramic Tile Waste Material

S. No.	Height of Embankment (m)	Ceramic Tile Waste Material (%)	Width of Pavement (m)	Area (Sqm)	Quantity of Earthwork (Cum)	Saving of Quantity (Cum)	PWD BSR Rate per cum	Cost (Rs)	Saving of Cost (Rs)	Cost Reduction Ratio
1.	6.0	0	8	112.80	112800.00	--	34.00	3835200.00	--	1.00
2.	6.0	2	8	96.96	96960.00	15840.00	36.55	3543888.00	291312.00	0.92
3.	6.0	4	8	91.92	91920.00	20880.00	36.55	3359676.00	475524.00	0.88
4.	6.0	8	8	89.40	89400.00	23400.00	36.55	3267570.00	567630.00	0.85
5.	6.0	12	8	88.32	88320.00	24480.00	36.55	3228096.00	607104.00	0.84
6.	7.5	0	8	161.25	161250.00	--	34.00	5482500.00	--	1.00
7.	7.5	2	8	136.50	136500.00	24750.00	36.55	4989075.00	493425.00	0.91
8.	7.5	4	8	128.63	128625.00	32625.00	36.55	4701243.75	781256.25	0.86
9.	7.5	8	8	124.69	124687.50	36562.50	36.55	4557328.13	925171.88	0.83
10.	7.5	12	8	123.00	123000.00	38250.00	36.55	4495650.00	986850.00	0.82
11.	9.0	0	8	217.80	217800.00	--	34.00	7405200.00	--	1.00
12.	9.0	2	8	182.16	182160.00	35640.00	36.55	6657948.00	747252.00	0.90
13.	9.0	4	8	170.82	170820.00	46980.00	36.55	6243471.00	1161729.00	0.84
14.	9.0	8	8	165.15	165150.00	52650.00	36.55	6036232.50	1368967.50	0.82
15.	9.0	12	8	162.72	162720.00	55080.00	36.55	5947416.00	1457784.00	0.80

4.5 Comparative Study

Figures 5, 6 and 7 have been plotted between the height and the cross-sectional area of the embankment for different percentages by weight of ceramic tile waste material mixed with the fine sand of different dry densities. The graphs show that the cross-sectional area reduces when the percentage by weight of ceramic tile waste material mixed with the fine sand increases irrespective of the height of embankment and dry density of fine sand.

The graphs between the height and the cross-sectional area of the embankment are more or less linear for different percentages by weight of ceramic tile waste mixed with the fine sand. The graphs clearly indicate that when percentage by weight of ceramic tile waste material mixed with the fine sand increases from 0% to 12%, the cross sectional area reduces to the maximum extent implying that slope is the steepest when percentage by weight of ceramic tile waste material is 12% irrespective of the height of the embankment. It is also concluded that the slope is maximum when fine sand having maximum dry density i.e. 1.58gm/cc mixed with 12% by weight of ceramic tile waste material.

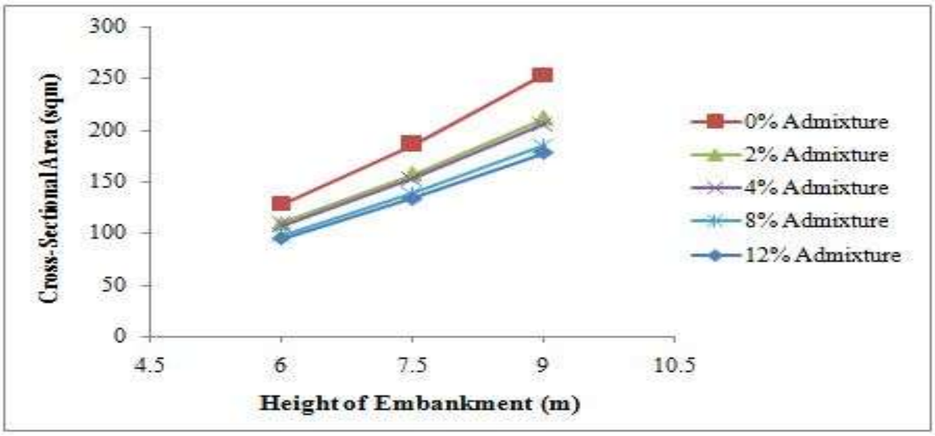

Figure 5: Variation in Cross-Sectional Area of Road Embankment with its Height for Mix Compositions of Fine Sand of 1.50 gm/cc Dry Density and Different Percentages by Weight of Ceramic Tile Waste Material

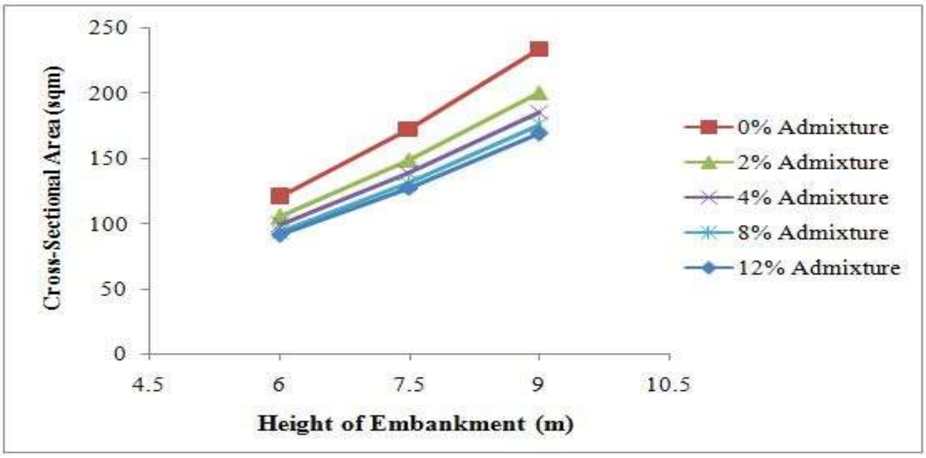

Figure 6: Variation in Cross-Sectional Area of Road Embankment with its Height for Mix Compositions of Fine Sand of 1.55 gm/cc Dry Density and Different Percentages by Weight of Ceramic Tile Waste Material

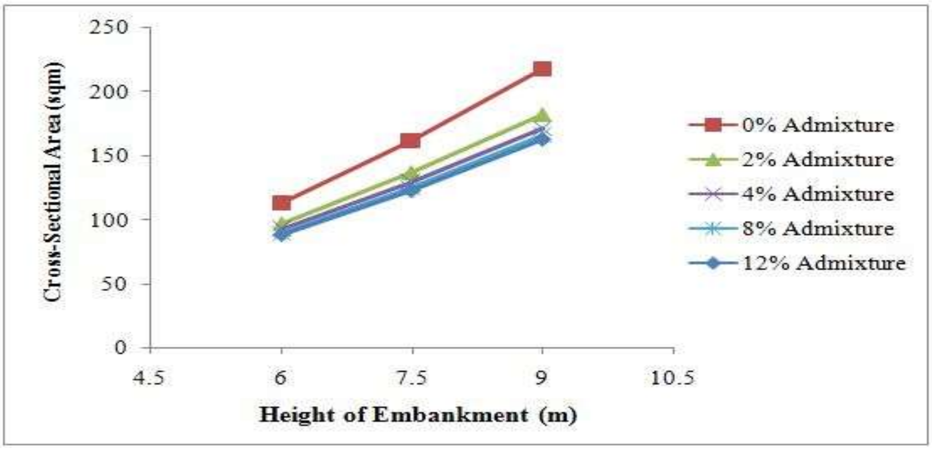

Figure 7: Variation in Cross-Sectional Area of Road Embankment with its Height for Mix Compositions of Fine Sand of 1.58 gm/cc Dry Density and Different Percentages by Weight of Ceramic Tile Waste Material

V. Conclusions

The following conclusions are drawn from present investigation:

1. The slope stability analysis conducted by the software provides results in a very short time and thus can be used easily for the design of slope of road embankments.
2. When the percentage of ceramic tile waste material by weight mixed with fine sand is increased from 0% to 12%, irrespective of the height of the road embankment, its slope is steepened from 2.24:1 to 1.31:1, 2:1 to 1.19:1 and 1.8:1 to 1.12:1for density 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc respectively.
3. For 1.50 gm/cc dry density of fine sand, cross-sectional area reduces from 128.64 sqm. to 95.16 sqm, 186.00 sqm to 133.69 sqm and 253.44 sqm to 178.11 sqm for road embankment of height 6.0 m, 7.5 m and 9.0 m respectively by using percentage by weight of ceramic tile waste material from 0% to 12%.
4. For 1.55 gm/cc dry density of fine sand, cross-sectional area reduces from 120.00 sqm. to 90.84 sqm, 172.50 sqm to 126.94 sqm and 234.00 sqm to 168.39 sqm for road embankment of height 6.0 m, 7.5 m and 9.0 m respectively by using percentage by weight of ceramic tile waste material from 0% to 12%.
5. For 1.58 gm/cc dry density of fine sand, cross-sectional area reduces from 112.80 sqm. to 88.32 sqm, 161.35 sqm to 123.00 sqm and 217.80 sqm to 162.72 sqm for road embankment of height 6.0 m, 7.5 m and 9.0 m respectively by using percentage by weight of ceramic tile waste material from 0% to 12%.
6. The maximum cost reduction ratio for the road embankment of height 6.0 m are 0.80, 0.81 and 0.84 when the dry density of the fine sand is 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc respectively mixed with 12% by weight of ceramic tile waste material. Thus the approximate saving in the cost of construction of road embankment of height 6.0 m varies between 16% to 20%.
7. The maximum cost reduction ratio for the road embankment of height 7.5 m are 0.77, 0.79 and 0.82 when the dry density of the fine sand is 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc respectively mixed with 12% by weight of ceramic tile waste material. Thus the approximate saving in the cost of construction of road embankment of height 7.5 m varies between 18% to 23%.
8. The maximum cost reduction ratio for the road embankment of height 9.0 m are 0.76, 0.77 and 0.80 when the dry density of the fine sand is 1.50 gm/cc, 1.50 gm/cc and 1.58 gm/cc respectively mixed with 12% by weight of ceramic tile waste material. Thus the approximate saving in the cost of construction of road embankment of height 9.0 m varies between 20% to 24%.
9. The reduction in cross-section of road embankment was excellent and the cost of the construction is also reduced to a great extent.

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