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RESEARCH ARTICLE

DESIGN OF SLOPE FOR ROAD EMBANKMENT WITH THE HELP OF SOFTWARE FOR FINE SAND WITH SANITARY WARE WASTE MATERIAL

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Abstract

Fine sand is not readily suitable for construction of embankments for roads. This research paper includes laboratory experimental work, software work, as well as 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 and different percentage 0%, 2%, 4%, 8% and 12% of sanitary ware 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., P.W.D., Rajasthan, India and cost reduction ratios were calculated. The cross-sectional area and construction cost of road embankment were reduced to a great-extent.

Introduction:-

Rajasthan is area wise the largest state of India. The most unique offering of Rajasthan is the majestic fine sand in the western part. As per Indian Standard Classification System of soils, the fine sand has nil cohesion and very low compressive strength. Many engineering constructions such as road and railway embankments are often constructed with this fine sand. 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. The dilemma that the engineers nowadays face is to determine the suitability of the analysis methods for slope stability of the embankments and the subsequent optimum construction cost.

A huge quantity of sanitary ware waste is produced due to warping and braking of sanitary wares in different manufacturing units every year in India, so it can be used as admixture for fine sand. The best method to handle sanitary ware waste is to utilize it for engineering applications in order to conserve the natural valuable resources like fine sand. There is a great scope of stabilization of fine sand with the admixture of sanitary ware waste material for the construction of road embankments.

The objective of present investigation is to determine the optimum slope of a two lane road embankment as a consequence of stabilization of fine sand with the help of beneficial and economical utilization of admixture of sanitary ware waste material thus resulting in reduced cross sectional area of the road embankment because of the

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steepening of slope of the embankment till the recommended factor of safety so that there is no slope failure caused to the slope stability. A geotechnical software which is based on limit equilibrium method has been used in simulating and stability analysis of embankments of various heights founded with fine sand of different dry densities mixed with different percentage of sanitary ware waste material. Bishop simplified 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 of sanitary ware 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 el at (2013) also worked on utilization of different waste material in construction of roads.

Materials and Their Properties:-

Fine Sand:-

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

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%

Sanitary Ware Waste Material:-

Materials used to manufacture sanitary ware are vitreous china clay. A lot of sanitary ware waste is produced during formation of sanitary wares. The sanitary wares used in present work were of *Sonalika* Company. The sanitary ware waste was brought from a manufacturing unit near Bhuj, Gujarat (India). Table 2 shows the physical and engineering properties of tested sanitary ware waste material.

Table 2:- Physical and Engineering Properties of Sanitary Ware Waste Material.

Physical and Engineering Properties of Sanitary Ware Waste Material	
Density	2.35 gm/cc
Water Absorption (For 24 hours)	3% by dry weight

Investigation Program:-

The investigation program included the preliminary tests, slope stability analysis and cost analysis of road embankment founded by fine sand and mix compositions of fine sand with sanitary ware 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 sanitary ware 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 sanitary ware waste material.
4. Cost analysis for determining cost reduction ratio for different heights of embankment for different mix compositions of fine sand and sanitary ware 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.	Sanitary ware waste material on different properties of sand	Size passing sieve size	4.75 mm passing and 2.36 mm retaining
3.	Mix sanitary ware waste material by dry weight of sand	Proportion percentage	0%, 2%, 4%, 8% and 12%
4.	Different heights and slopes of embankments	Height of embankment	6.0 m, 7.5 m and 9.0 m

Investigation Results:-

Standard Proctor Test:-

The geotechnical properties of soil are dependent on the moisture and density at which the soil is compacted. The aim of the Standard Proctor Test was to determine the various densities corresponding to various water contents. In order to obtain these parameters, the standard proctor test was performed in accordance with IS 2720 (Part VII). The figure 1 obtained by experiment shows that required dry densities 1.50 gm/cc, 1.55 gm/cc and 1.58 gm/cc (MDD) for investigation occur at 4%, 12% and 18% water content respectively.

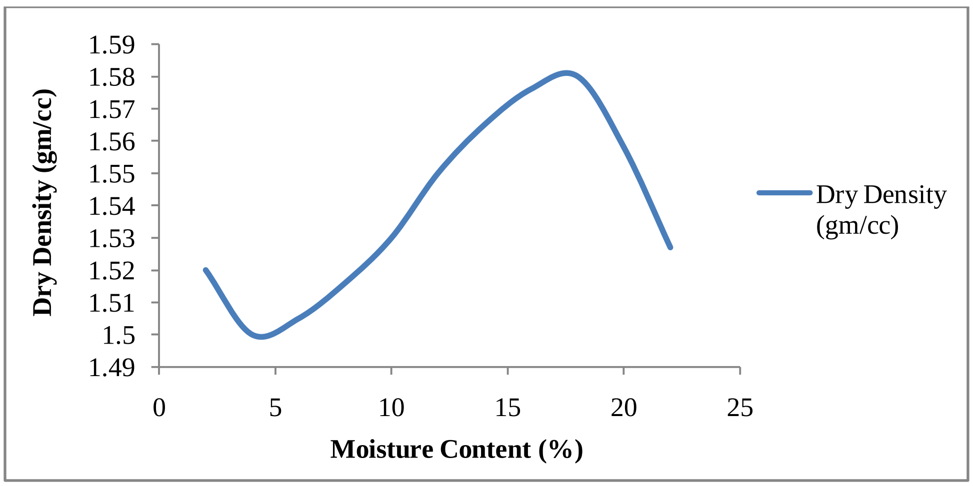

Figure 1:- Dry Density v/s Moisture Content Curve

Direct Shear Test:-

The Direct Shear Test is used to determine the shearing strength of the fine sand using the direct shear apparatus. Direct shear tests were performed on mix composition of fine sand of 1.50 gm/cc, 1.55gm/cc and 1.58 gm/cc density with sanitary ware waste material of 0%, 2%, 4%, 8% and 12% by dry weight of sand. 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 composition in accordance with ID 2720 (Part XIII). The results of direct shear tests are given in table 4.

Table 4:- Variation of Angle of Internal Friction (ϕ) with Dry Density of Sand and % Admixture

Dry Density (gm/cc)	Angle of Internal Friction ϕ (Degree)				
	Mix Composition				
	0% Admixture	2% Admixture	4% Admixture	8% Admixture	12% Admixture
1.50	29.29°	35.96°	38.36°	40.61°	43.73°
1.55	32.09°	39.52°	42.73°	45.65°	47.43°
1.58	34.72°	41.70°	44.70°	46.55°	49.10°

Slope Stability Analysis:-

The software which was used in this investigation is widely used in various civil engineering applications. It is one of powerful tools for analysis, include the use of finite element computed pore-water pressure and stresses in a stability analysis. Slope/w model formed with the help of slope geometry soil properties. This software is used to find out lowest value of factor of safety. Factor of safety is calculated by Bishop simplified method. 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 2 and 3 show the entry and exit of slip surface and all valid critical slip surfaces.

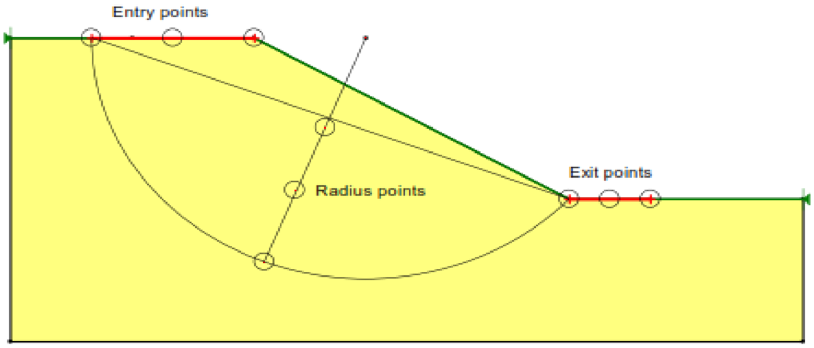

Figure 2:- Schematic Diagram of the Entry and Exit of Slip Surface

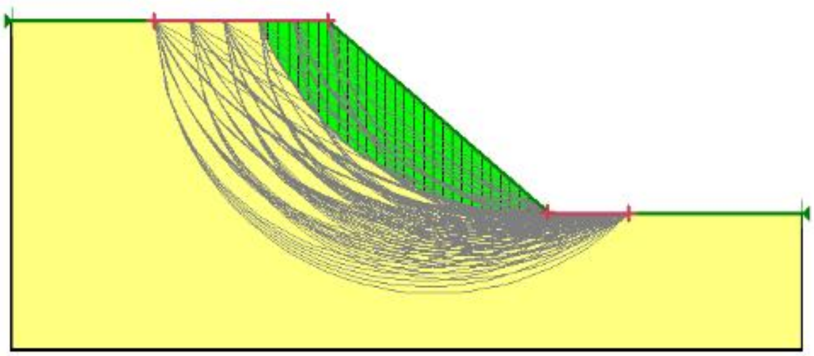

Figure 3:- Display of all Valid Critical Slip Surfaces

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% of sanitary ware waste material. The steepest slope of the embankment is found when fine sand of different dry densities mixed with 12% sanitary ware waste material.

Table 5:- Results of Slope Stability Analysis of Mix Compositions of Fine Sand of 1.50 gm/cc Dry Density and Different Percentages of Sanitary Ware Waste Material.

S.No.	Height of Embankment (m)	Admixture (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	29.29°	2.24:1	1.259
2.	6.0	2	35.96°	1.72:1	1.250
3.	6.0	4	38.36°	1.58:1	1.253
4.	6.0	8	40.61°	1.46:1	1.254
5.	6.0	12	43.73°	1.31:1	1.256
6.	7.5	0	29.29°	2.24:1	1.259
7.	7.5	2	35.96°	1.72:1	1.250
8.	7.5	4	38.36°	1.58:1	1.253
9.	7.5	8	40.61°	1.46:1	1.254

10.	7.5	12	43.73°	1.31:1	1.256
11.	9.0	0	29.29°	2.24:1	1.259
12.	9.0	2	35.96°	1.72:1	1.250
13.	9.0	4	38.36°	1.58:1	1.253
14.	9.0	8	40.61°	1.46:1	1.254
15.	9.0	12	43.73°	1.31:1	1.256

Table 6:- Results of Slope Stability Analysis of Mix Compositions of Fine Sand of 1.55 gm/cc Dry Density and Different Percentages of Sanitary Ware Waste Material

S.No.	Height of Embankment (m)	Admixture (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	32.09°	2:01	1.257
2.	6.0	2	39.52°	1.52:1	1.256
3.	6.0	4	42.73°	1.36:1	1.259
4.	6.0	8	45.65°	1.22:1	1.250
5.	6.0	12	47.43°	1.15:1	1.254
6.	7.5	0	32.09°	2:01	1.257
7.	7.5	2	39.52°	1.52:1	1.256
8.	7.5	4	42.73°	1.36:1	1.259
9.	7.5	8	45.65°	1.22:1	1.250
10.	7.5	12	47.43°	1.15:1	1.254
11.	9.0	0	32.09°	2:01	1.257
12.	9.0	2	39.52°	1.52:1	1.256
13.	9.0	4	42.73°	1.36:1	1.259
14.	9.0	8	45.65°	1.22:1	1.250
15.	9.0	12	47.43°	1.15:1	1.254

Table 7:- Results of Slope Stability Analysis of Mix Compositions of Fine Sand of 1.58 gm/cc Dry Density and Different Percentages of Sanitary Ware Waste Material

S.No.	Height of Embankment (m)	Admixture (%)	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	41.70°	1.40:1	1.250
3.	6.0	4	44.70°	1.27:1	1.259
4.	6.0	8	46.55°	1.19:1	1.258
5.	6.0	12	49.10°	1.09:1	1.257
6.	7.5	0	34.72°	1.8:1	1.250
7.	7.5	2	41.70°	1.40:1	1.250
8.	7.5	4	44.70°	1.27:1	1.259
9.	7.5	8	46.55°	1.19:1	1.258
10.	7.5	12	49.10°	1.09:1	1.257
11.	9.0	0	34.72°	1.8:1	1.250
12.	9.0	2	41.70°	1.40:1	1.250
13.	9.0	4	44.70°	1.27:1	1.259
14.	9.0	8	46.55°	1.19:1	1.258
15.	9.0	12	49.10°	1.09:1	1.257

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 sanitary ware waste material for its crushing, mixing and transportation)

Cost of Earthwork stabilized by sanitary ware 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% sanitary ware 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 Embankment of Different Heights and 1 km Long Two Lane Road for Fine Sand of Dry Density 1.50 gm/cc using Different % of Sanitary Ware Waste Material

S. No.	Height of Embankment (m)	Admixture (%)	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	-	1.00
2.	6.0	2	8	109.92	109920.00	18720.00	36.55	4017576	356184.00	0.92
3.	6.0	4	8	104.88	104880.00	23760.00	36.55	3833364	540396.00	0.88
4.	6.0	8	8	100.56	100560.00	28080.00	36.55	3675468	698292.00	0.84
5.	6.0	12	8	95.16	95160.00	33480.00	36.55	3478098	895662.00	0.80
6.	7.5	0	8	186.00	186000.00	-	34.00	6324000	-	1.00
7.	7.5	2	8	156.75	156750.00	29250.00	36.55	5729213	594787.50	0.91
8.	7.5	4	8	148.88	148875.00	37125.00	36.55	5441381	882618.80	0.86
9.	7.5	8	8	142.13	142125.00	43875.00	36.55	5194669	1129331.00	0.82
10.	7.5	12	8	133.69	133687.50	52312.50	36.55	4886278	1437722.00	0.77
11.	9.0	0	8	253.44	253440.00	-	34.00	8616960	-	1.00
12.	9.0	2	8	211.32	211320.00	42120.00	36.55	7723746	893214.00	0.90
13.	9.0	4	8	199.98	199980.00	53460.00	36.55	7309269	1307691.00	0.85
14.	9.0	8	8	190.26	190260.00	63180.00	36.55	6954003	1662957.00	0.81
15.	9.0	12	8	178.11	178110.00	75330.00	36.55	6509921	2107040.00	0.76

Table 9:- Saving of Quantity of Earthwork and Cost Reduction Ratio for Embankment of Different Heights and 1 km Long Two Lane Road for Fine Sand of Dry Density 1.55 gm/cc using Different % of Sanitary Ware Waste Material

S. No.	Height of Embankment (m)	Admixture (%)	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	120.00	120000.00	-	34.00	4080000.00	-	1.00
2.	6.0	2	8	102.72	102720.00	17280.00	36.55	3754416.00	325584.00	0.92
3.	6.0	4	8	96.96	96960.00	23040.00	36.55	3543888.00	536112.00	0.87
4.	6.0	8	8	91.92	91920.00	28080.00	36.55	3359676.00	720324.00	0.82
5.	6.0	12	8	89.40	89400.00	30600.00	36.55	3267570.00	812430.00	0.80
6.	7.5	0	8	172.50	172500.00	-	34.00	5865000.00	-	1.00
7.	7.5	2	8	145.50	145500.00	27000.00	36.55	5318025.00	546975.00	0.91
8.	7.5	4	8	136.50	136500.00	36000.00	36.55	4989075.00	875925.00	0.85
9.	7.5	8	8	128.63	128625.00	43875.00	36.55	4701243.75	1163756.25	0.80
10.	7.5	12	8	124.69	124687.50	47812.50	36.55	4557328.13	1307671.88	0.78
11.	9.0	0	8	234.00	234000.00	-	34.00	7956000.00	-	1.00
12.	9.0	2	8	195.12	195120.00	38880.00	36.55	7131636.00	824364.00	0.90
13.	9.0	4	8	182.16	182160.00	51840.00	36.55	6657948.00	1298052.00	0.84
14.	9.0	8	8	170.82	170820.00	63180.00	36.55	6243471.00	1712529.00	0.78
15.	9.0	12	8	165.15	165150.00	68850.00	36.55	6036232.50	1919767.50	0.76

Table 10:- Saving of Quantity of Earthwork and Cost Reduction Ratio for Embankment of Different Heights and 1 km Long Two Lane Road for Fine Sand of Dry Density 1.58 gm/cc using Different % of Sanitary Ware Waste Material

S. No.	Height of Embankment (m)	Admixture (%)	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	112.80	112800.00	-	34.00	3835200.00	-	1.00
2.	6.0	2	8	98.40	98400.00	14400.00	36.55	3596520.00	238680.00	0.94
3.	6.0	4	8	93.72	93720.00	19080.00	36.55	3425466.00	409734.00	0.89
4.	6.0	8	8	90.84	90840.00	21960.00	36.55	3320202.00	514998.00	0.87
5.	6.0	12	8	87.24	87240.00	25560.00	36.55	3188622.00	646578.00	0.83
6.	7.5	0	8	161.25	161250.00	-	34.00	5482500.00	-	1.00
7.	7.5	2	8	138.75	138750.00	22500.00	36.55	5071312.50	411187.50	0.93
8.	7.5	4	8	131.44	131437.50	29812.50	36.55	4804040.63	678459.38	0.88
9.	7.5	8	8	126.94	126937.50	34312.50	36.55	4639565.63	842934.38	0.85
10.	7.5	12	8	121.31	121312.50	39937.50	36.55	4433971.88	1048528.13	0.81
11.	9.0	0	8	217.80	217800.00	-	34.00	7405200.00	-	1.00
12.	9.0	2	8	185.40	185400.00	32400.00	36.55	6776370.00	628830.00	0.92
13.	9.0	4	8	174.87	174870.00	42930.00	36.55	6391498.50	1013701.50	0.86
14.	9.0	8	8	168.39	168390.00	49410.00	36.55	6154654.50	1250545.50	0.83
15.	9.0	12	8	160.29	160290.00	57510.00	36.55	5858599.50	1546600.50	0.79

Comparative Study:-

Figures 4, 5 and 6 have been plotted between the height and the cross-sectional area of the embankment for different percentages of sanitary ware waste material mixed with the fine sand of different dry densities. The graphs show that the cross-section area reduces .when the percentage by of sanitary ware waste material mixed with the fine sand increases irrespective of the height of embankment and 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 of sanitary ware waste mixed with the fine sand. The graphs clearly indicate that when percentage sanitary ware 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 of sanitary ware 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% of sanitary ware waste material.

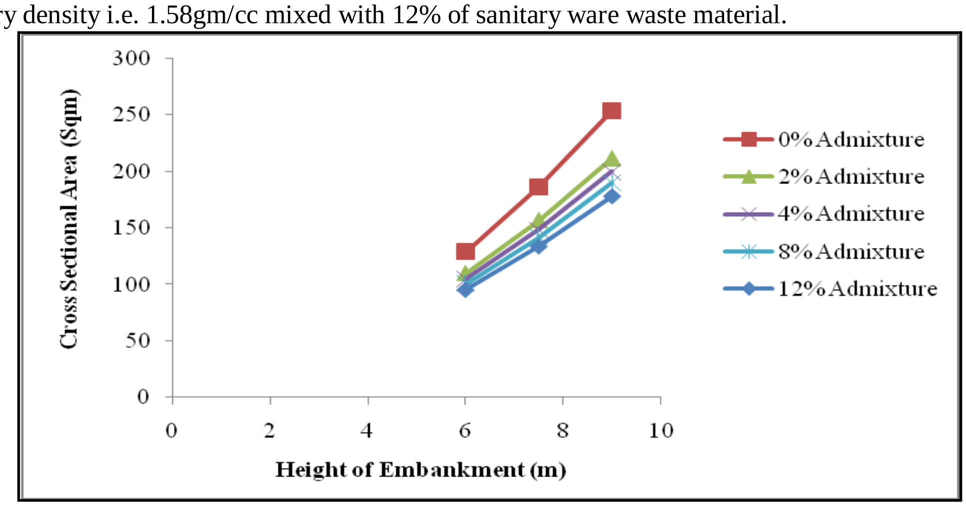

Figure 4:- Variation in Cross Sectional Area of Embankment with its Height for Mix Compositions of Fine Sand of 1.50 gm/cc Dry Density and Different Percentages of Sanitary Ware Waste Material

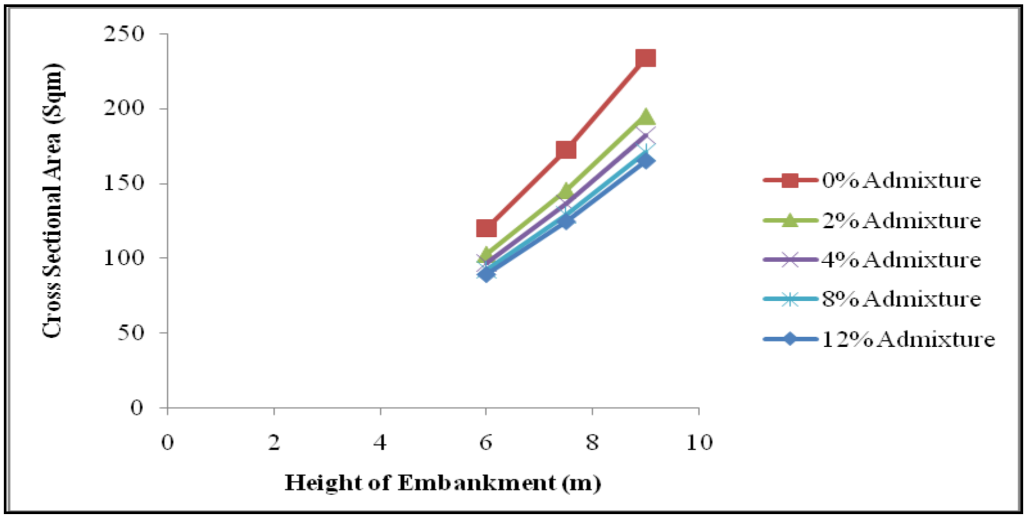

Figure 5:- Variation in Cross Sectional Area of Embankment with its Height for Mix Compositions of Fine Sand of 1.55 gm/cc Dry Density and Different Percentages of Sanitary Ware Waste Material.

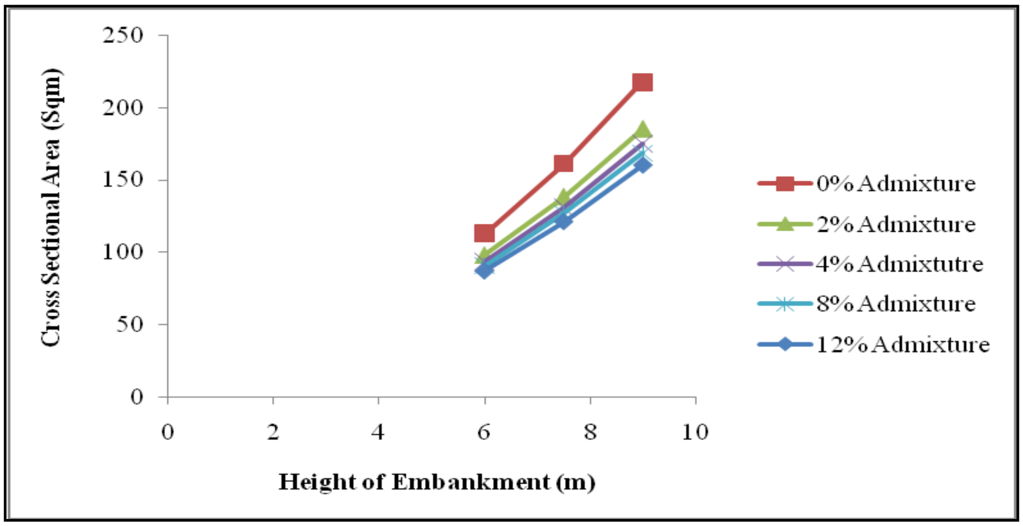

Figure 6:- Variation in Cross Sectional Area of Embankment with its Height for Mix Compositions of Fine Sand of 1.58 gm/cc Dry Density and Different Percentages of Sanitary Ware Waste Material

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 sanitary ware 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 to1.31:1, 2:1 to1.15:1 and 1.8:1 to 1.09:1for 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 178.11sqm for road embankment of height 6.0 m, 7.5 m and 9.0 m respectively by using percentage of admixture as sanitary ware waste material from 0% to 12%.
4. For 1.55 gm/cc dry density of fine sand, cross sectional area reduces from 120 sqm to 89.40 sqm, 172.50 sqm to 124.69 sqm and 234.00 sqm to 165.15 sqm for road embankment of height 6.0 m, 7.5 m and 9.0 m respectively by using percentage of admixture as sanitary ware 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 87.24 sqm, 161.25 sqm to 121.31 sqm and 217.80 sqm to 160.29 sqm for road embankment of height 6.0 m, 7.5 m and 9.0 m respectively by using percentage of admixture as sanitary ware waste material from 0% to 12%.

6. The maximum cost reduction ratio for the road embankment of height 6.0 m varies from 0.80 to 0.83 when the density of the fine sand varies from 1.50 gm/cc to 1.58 gm/cc mixed with 12% sanitary ware waste material. Thus the approximate saving in the cost of construction of road embankment of height 6.0 m varies between 17% to 20%
7. The maximum cost reduction ratio for the road embankment of height 7.5 m varies from 0.77 to 0.81 when the density of the fine sand varies from 1.50 gm/cc to 1.58 gm/cc mixed with 12% sanitary ware waste material. Thus the approximate saving in the cost of construction of road embankment of height 7.5 m varies between 19% to 23%.
8. The maximum cost reduction ratio for the road embankment of height 9.0 m varies from 0.76 to 0.79 when the density of the fine sand varies from 1.50 gm/cc to 1.58 gm/cc mixed with 12% sanitary ware waste material. Thus the approximate saving in the cost of construction of road embankment of height 9.0 m varies between 21% to 24%.
9. The reduction in cross-section of road embankment was tremendous and the cost of the construction is also reduced to a good extent.

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