

Design of Slope for Road Embankment with Software by Utilization with Plastic Waste Material (Polybags) for Dune Sand

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ABSTRACT: Huge quantities of plastic waste is being produced annually widespread in Rajasthan, India. Bulk utilization of this plastic waste produced is possible in geotechnical engineering applications like construction of road embankments. This research paper includes the design of slope for road embankment with the help of software by utilization for dune sand with plastic waste material (polybags). Different laboratory experiments were performed on dune sand with direct mixing of dune sand of different dry densities 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc (M.D.D.) with different percentage 0%, 0.06%, 0.7%, 0.9% and 1.0% by weight of polybags having strip size of 5.0 mm X 5.0 mm. A geo-technical software was used for calculating the factor of safety for road embankments of various heights 6.0 m, 7.5 m and 9.0 m. The rate analysis was done manually according to B.S.R. 2016, P.W.D., Rajasthan, India and the cost reduction ratios were also calculated. The reduction in cross-section area of the road embankment was tremendous and its cost of construction also reduced to an appreciable extent.

KEYWORDS : Direct shear test, road embankment, factor of safety, polybags wastage material, slope stability analysis, geo-technical software

I. INTRODUCTION

Soil is the basic construction material which is used for the construction of road embankments. Dune sand is abundantly found in the western parts of the Rajasthan and many engineering constructions such as road and railway embankments are often constructed on these dune sand. The properties of such soil can be improved greatly by soil stabilization. This soil stabilization results in the reduction of the cost incurred for the construction of the road embankment on the dune sand.

The substantial amount of waste material like polythene, plastic carry bags, food packaging polybags are produced by various industries in the country. These material cause hazardous effects to the lands and the surroundings and there is a severe problem for their disposal. This plastic waste material has been used by many researchers in different types of utilization of sand with other additives. Test experiments conducted in this study illustrate the suitability of this waste material in providing stabilization effect to strengthen the soils. Thus, the plastic waste (polybags) available all over Rajasthan can be mixed in soil masses for its stabilization. This will save environment and the natural soil mass on the earth.

The basic aim for engineers nowadays is the optimization of cost of construction of the road embankments by stabilizing the soil with proper admixtures along with ensuring the safety of the slope they use for the road embankments by maintaining the recommended factor of safety. This can be achieved by using the proper stability analysis of embankments constructed on dune sand. A geotechnical software which is based on the limit equilibrium method has been used in simulating and stability analysis and estimation of embankments of various heights constructed on dune sand of different properties having laboratory determined different dry densities. Morgenstern-Price method has been used in this analysis.

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Vol. 6, Issue 10, October 2017

II. RELATED WORK

Kalumba D. and Chebet F.C. (2013) investigated the possibility of utilizing polyethylene shopping bags as a waste material to reinforce two selected sandy soils to pave way for its use in civil engineering projects such as in road bases, embankments and slope stabilization. Laboratory results obtained favorably suggest that an inclusion of this material in sandy soils would be effective for ground improvement in geotechnical engineering. Results indicate an improvement in peak friction angle on addition of the solid strips and perforated strips of varied lengths and concentrations for both the type of sands. Many other researchers like AK Mishra et al (2001), S. Chandra et al (2005), Kumar P. et al (2008), Aditya Kumar Anupam el at (2013), RP Arora et al (2016), Akash Gupta et al (2016) etc. have also worked on utilization of different waste material in construction of road embankments.

III. MATERIALS USED FOR PRESENT STUDY

3.1 DUNE SAND

Dune sand is found in abundance in Western Rajasthan, India. The sand used in present study was obtained from Village Osian, Jodhpur, Rajasthan at about 65-70 km away from Jodhpur on Jodhpur-Bikaner Highway. Dune sand has nil cohesion and poor compressive strength. Dune sand is uniform clean sand as per Unified Soil Classification System with particlesize rangingbetween 75 μ to 1 mm that is fine coarse sand and round to angular particle shape as per Indian Standard Classification System. Dune sand has very little to nil plasticity that is it is cohesion less and it's drainage property being fairly good with coefficient of permeability ranging between 10^{-4} mm/sec to 10^{-2} mm/sec. Table 1 shows the different geotechnical properties of dune sand.

Table 1: Properties of Dune Sand

S. No.	Property	Test Media (Dune Sand)
1.	Coefficient of uniformity (C_u)	1.43
2.	Coefficient of curvature (C_c)	0.88
3.	Mean Diameter (D_{50})	0.21 mm
4.	Effective size (D_{10})	0.16 mm
5.	Fine soil fraction (75 μ)	0%

3.2 PLASTIC WASTE MATERIAL (POLYBAGS)

Polyethylene is of low strength, hardness and rigidity but has a high ductility and impact strength as well as low friction. It shows strong creep under persistent force, which can be reduced by addition of short fibres. It feels waxy when touched. The usefulness of polyethylene is limited by its softening point of 80°C (176°F) (HDPE, types of low crystalline softens earlier). The melting point, for common commercial grades of medium and high density polyethylene, is typically in the range 120 to 180°C (248 to 356°F). The melting point for average, commercial, low density polyethylene is typically 105 to 115°C (221 to 239°F). These temperatures vary strongly with the type of polyethylene. Polyethylene consists of nonpolar, saturated, high molecular weight hydrocarbons. Therefore, its chemical behaviour is similar to paraffin. The individual macromolecules are not covalently linked. They tend to crystallize because of their symmetric molecular structure. Overall polyethylene is partially crystalline. Higher crystallinity increases density and mechanical & chemical stability. The density of LDPE is about 0.910 - 0.940 gm/cc. Polybags waste material is shown in Figure 1.

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Vol. 6, Issue 10, October 2017



Figure 1: Polybags Waste Material

IV. INVESTIGATION PLAN

This research paper includes laboratory experimental work, software analysis, as well as cost estimation. In the laboratory experiments, standard proctor test was performed to determine the three dry densities of dune sand i.e. 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc for further investigations. Direct shear tests were then conducted for determination of shear stress and angle of internal friction for dune sand of 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc dry densities mixed with different percentage 0%, 0.06%, 0.7%, 0.9% and 1.0% by weight of polybags having strip size of 5.0 mm x 5.0 mm. Further, slope stability analysis and calculation of cost reduction ratio were carried out for different heights of road embankment i.e. 6.0 m, 7.5 m and 9.0 m for above stated mixed compositions of dune sand.

V. INVESTIGATION RESULTS

5.1 STANDARD PROCTOR TEST

Standard proctor test is used to determine the relationship between dry density and water content of a compacted soil sample. The standard proctor test was performed in accordance with IS 2720 (Part VII) to find different dry densities of dune sand i.e. 1.57 gm/cc, 1.62 gm/cc and 1.67 gm/cc for the present investigation. Figure 2 shows the relationship between the dry density of dune sand and the corresponding water content.

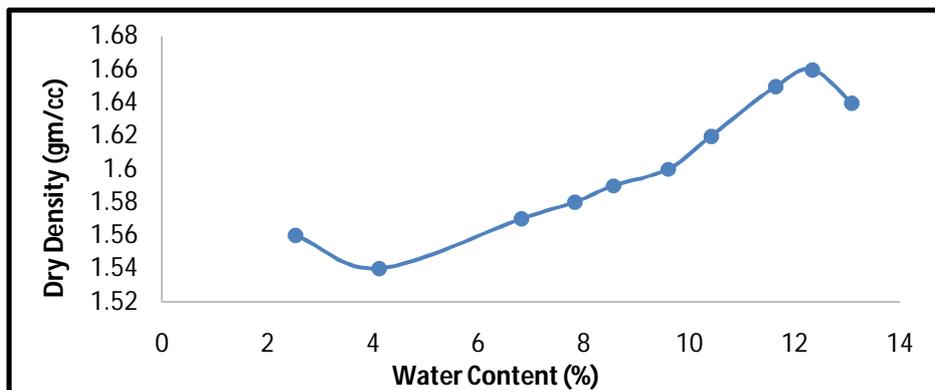


Figure 2: Variation of Dry Density with Moisture Content

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 10, October 2017

5.2 DIRECT SHEAR TEST

Direct shear test is used to determine the shear strength parameters of a sandy soil. Direct shear tests were carried out to determine the angle of internal friction (ϕ) of different mix compositions of dune sand of 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc dry density mixed with different percentage viz. 0%, 0.06%, 0.7%, 0.9% and 1.0% by weight of polybags waste material in accordance with ID 2720 (Part XIII). The results of direct shear tests are given in Table 2.

Table 2: Variation of Friction Angle (ϕ) for Different Mix Compositions of Dune Sand Mixed with Different Percentage by Weight of Polybags

Dry Density (gm/cc)	Angle of Internal Friction ϕ (Degree)				
	Mix Composition				
	0% Polybags Waste	0.06% Polybags Waste	0.7% Polybags Waste	0.9% Polybags Waste	1.0% Polybags Waste
1.57	30.00°	41.63°	40.47°	37.58°	36.93°
1.62	31.50°	42.51°	41.35°	37.92°	37.60°
1.66	33.00°	44.16°	43.35°	40.43°	38.59°

5.3 SLOPE STABILITY ANALYSIS

Slope stability analysis is performed to assess the safe design of man-made or natural slopes (e.g. embankments, open-pit mining, road cuts, landfills, excavations etc.) and the equilibrium conditions. In the present investigation, a modern geotechnical software program which is based on the limit equilibrium analysis is used to compute the factor of safety. Factor of safety is calculated by Morgenstern-Price method. According to IRC 75:1979, the recommended factor of safety for the design of low embankments is 1.25. Investigation is done for two lane road embankments of width 8 m (taking allowance for shoulders) and heights 6.0 m, 7.5 m, and 9.0 m by steeping of the side slope to the maximum extent such that the factor of safety of the critical slip surface remains within the recommended limit of 1.25 as stated by IRC. Figure 3 shows all the valid critical slip surfaces and Figure 4 shows a typical critical slip surface for a particular condition.

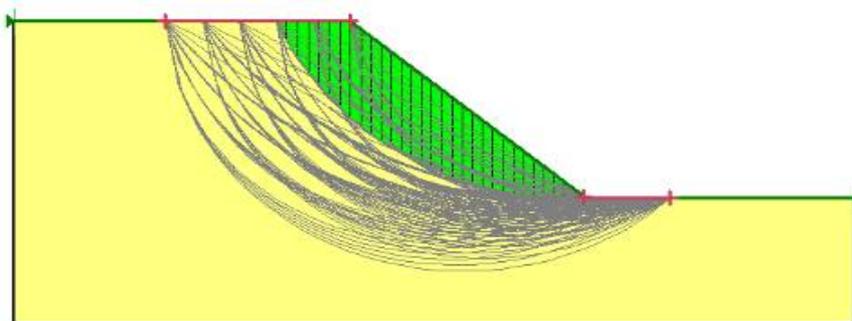


Figure 3: All Valid Critical Slip Surfaces

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 10, October 2017

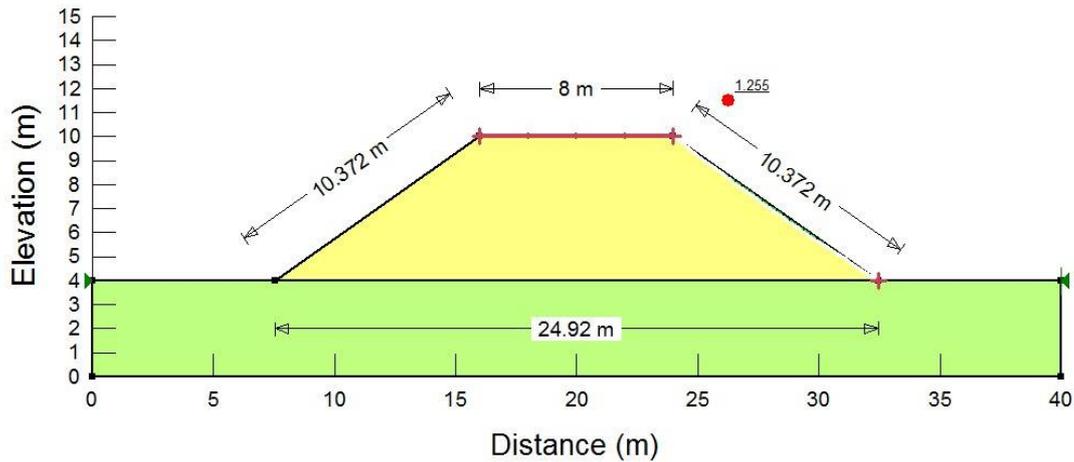


Figure4: Critical Slip Surface when Height of Embankment = 6 m, Dry Density of Dune Sand = 1.57 gm /cc and Percentage by Weight of Polybags Waste Material = 0.06%

Tables 3, 4 and 5 tabulates the results of slope stability analysis for different heights of embankment viz. 6.0 m, 7.5 m and 9.0 m for different mix compositions of dune sand of different dry densities 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc mixed with different percentage 0%, 0.06%, 0.7%, 0.9% and 1.0% by weight of polybags waste material. The steepest slope of the embankment is found when dune sand of different dry densities is mixed with 0.06% by weight of polybags.

Table 3: Slope Stability Analysis Results of Mix Compositions of 1.57 gm/cc Dry Density of Dune Sand Mixed with Different Percentages by Weight of Polybags Waste Material

S. No.	Height of Embankment (m)	Percentage of Plastic Wastage (Polybag) (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	30.00°	2.16:1	1.250
2.	6.0	0.06	41.63°	1.41:1	1.255
3.	6.0	0.7	40.47°	1.47:1	1.256
4.	6.0	0.9	37.58°	1.63:1	1.257
5.	6.0	1.0	36.93°	1.66:1	1.250
6.	7.5	0	30.00°	2.16:1	1.250
7.	7.5	0.06	41.63°	1.41:1	1.255
8.	7.5	0.7	40.47°	1.47:1	1.256
9.	7.5	0.9	37.58°	1.63:1	1.257
10.	7.5	1.0	36.93°	1.66:1	1.250
11.	9.0	0	30.00°	2.16:1	1.250
12.	9.0	0.06	41.63°	1.41:1	1.255
13.	9.0	0.7	40.47°	1.47:1	1.256
14.	9.0	0.9	37.58°	1.63:1	1.257
15.	9.0	1.0	36.93°	1.66:1	1.250

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 10, October 2017

Table 4: Slope Stability Analysis Results of Mix Compositions of 1.62 gm/cc Dry Density of Dune Sand Mixed with Different Percentages by Weight of Polybags Waste Material

S. No.	Height of Embankment (m)	Percentage of Plastic Wastage (Polybag) (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	31.50°	2.05:1	1.259
2.	6.0	0.06	42.51°	1.37:1	1.258
3.	6.0	0.7	41.35°	1.42:1	1.252
4.	6.0	0.9	37.92°	1.61:1	1.257
5.	6.0	1.0	37.60°	1.63:1	1.258
6.	7.5	0	31.50°	2.05:1	1.259
7.	7.5	0.06	42.51°	1.37:1	1.258
8.	7.5	0.7	41.35°	1.42:1	1.252
9.	7.5	0.9	37.92°	1.61:1	1.257
10.	7.5	1.0	37.60°	1.63:1	1.258
11.	9.0	0	31.50°	2.05:1	1.259
12.	9.0	0.06	42.51°	1.37:1	1.258
13.	9.0	0.7	41.35°	1.42:1	1.252
14.	9.0	0.9	37.92°	1.61:1	1.257
15.	9.0	1.0	37.60°	1.63:1	1.258

Table 5: Slope Stability Analysis Results of Mix Compositions of 1.66 gm/cc Dry Density of Dune Sand Mixed with Different Percentages by weight of Polybags Waste Material

S. No.	Height of Embankment (m)	Percentage of Plastic Wastage (Polybag) (%)	Angle of Internal Friction (ϕ)	Slope (H:V)	Factor of Safety
1.	6.0	0	33.00°	1.93:1	1.256
2.	6.0	0.06	44.16°	1.29:1	1.255
3.	6.0	0.7	43.35°	1.33:1	1.258
4.	6.0	0.9	40.43°	1.47:1	1.255
5.	6.0	1.0	38.59°	1.57:1	1.255
6.	7.5	0	33.00°	1.93:1	1.256
7.	7.5	0.06	44.16°	1.29:1	1.255
8.	7.5	0.7	43.35°	1.33:1	1.258
9.	7.5	0.9	40.43°	1.47:1	1.255
10.	7.5	1.0	38.59°	1.57:1	1.255
11.	9.0	0	33.00°	1.93:1	1.256
12.	9.0	0.06	44.16°	1.29:1	1.255
13.	9.0	0.7	43.35°	1.33:1	1.258
14.	9.0	0.9	40.43°	1.47:1	1.255
15.	9.0	1.0	38.59°	1.57:1	1.255

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 10, October 2017

5.4 RATE ANALYSIS

The rate analysis has been done as per the Basic Schedule of Rate – 2016 published by the Public Works Department, Jodhpur, Rajasthan. The cost of transportation has not been considered as the material is readily available at the construction site within the lead of 495 meters. The rate analysis is as follows:

Cost of earthwork in road embankment = Rs 36 per m³

The cost of mixing, rolling, compaction and grading of polybags waste material is assumed to be equal to 5% of the total cost of the earthwork in road embankment.

Thus, cost of mixing, rolling, compaction and grading of polybags waste material = 5% of Rs 36 = Rs 1.8 per m³.

Therefore, total cost of earthwork in road embankment of dune sand mixed with polybags waste material = 36 + 1.8 = Rs 37.8 per m³

The maximum reduction in cross-section area of the road embankment of dune sand of density 1.57 gm/cc is 125.76 km² to 98.76 km², 181.5 km² to 139.31 km² and 246.96 km² to 186.21 km² for height of the embankment 6 m, 7.5 m and 9 m respectively. The maximum reduction in cross section area of the road embankment of dune sand of density 1.62 gm/cc is 121.8 km² to 97.32 km², 175.31 km² to 137.06 km² and 238.05 km² to 182.97 km² for height of the embankment 6 m, 7.5 m and 9 m respectively. The maximum reduction in cross section area of the road embankment of dune sand of density 1.66 gm/cc is 117.48 km² to 94.8 km², 168.56 km² to 132.56 km² and 228.33 km² to 176.49 km² for height of the embankment 6 m, 7.5 m and 9 m respectively.

The maximum cost reduction ratio for the road embankment of height 6 m varies from 0.82 to 0.85 when the density of the dune sand varies from 1.57 gm/cc to 1.66 gm/cc. Thus, the approximate saving in the cost of road embankment construction of height 6 m varies between 15-18%. The maximum cost reduction ratio for the road embankment of height 7.5 m varies from 0.81 to 0.83 when the density of the dune sand varies from 1.57 gm/cc to 1.66 gm/cc. Thus, the approximate saving in the cost of road embankment construction of height 6 m varies between 17-19%. The maximum cost reduction ratio for the road embankment of height 9 m varies from 0.79 to 0.81 when the density of the dune sand varies from 1.57 gm/cc to 1.66 gm/cc. Thus, the approximate saving in the cost of road embankment construction of height 6 m varies between 19-21%.

Tables 6, 7 and 8 tabulates the saving in the quantity of earthwork, cost of earthwork and cost reduction ratio of dune sand of dry densities 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc mixed with 0%, 0.06%, 0.7%, 0.9% and 1.0% by weight of polybags for different heights of road embankment 6.0 m, 7.5 m and 9.0 m for 1 km long two lane road.

Table 6: Saving of Earthwork Quantity and Cost Reduction Ratio for Road Embankment of Different Heights for Dune Sand of Dry Density 1.57 gm/cc using Different % by Weight of Polybags Waste Material for 1 km Long Two Lane Road

S. No.	Height of Embankment (m)	Percentage of Plastic Wastage (Polybag) (%)	Width of Pavement (m)	Area (m ²)	Quantity of Earthwork (m ³)	Saving of Quantity of Earthwork (m ³)	PWD BSR Rate per m ³	Cost of Road Embankment (Rs)	Saving of Cost (Rs)	Cost Reduction Ratio
1.	6.0	0	8	125.76	125760.0	-	36.0	4527360.0	-	1
2.	6.0	0.06	8	98.76	98760.0	27000.0	37.8	3733128.0	794232.0	0.82
3.	6.0	0.7	8	100.92	100920.0	24840.0	37.8	3814776.0	712584.0	0.84
4.	6.0	0.9	8	106.68	106680.0	19080.0	37.8	4032504.0	494856.0	0.89
5.	6.0	1.0	8	107.76	107760.0	18000.0	37.8	4073328.0	454032.0	0.90
6.	7.5	0	8	181.50	181500.0	-	36.0	6534000.0	-	1
7.	7.5	0.06	8	139.31	139312.5	42187.5	37.8	5266012.5	1267987.5	0.81
8.	7.5	0.7	8	142.69	142687.5	38812.5	37.8	5393587.5	1140412.5	0.83
9.	7.5	0.9	8	151.69	151687.5	29812.5	37.8	5733787.5	800212.5	0.88
10.	7.5	1.0	8	153.38	153375.0	28125.0	37.8	5797575.0	736425.0	0.89
11.	9.0	0	8	246.96	246960.0	-	36.0	8890560.0	-	1

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Vol. 6, Issue 10, October 2017

12.	9.0	0.06	8	186.21	186210.0	60750.0	37.8	7038738.0	1851822.0	0.79
13.	9.0	0.7	8	191.07	191070.0	55890.0	37.8	7222446.0	1668114.0	0.81
14.	9.0	0.9	8	204.03	204030.0	42930.0	37.8	7712334.0	1178226.0	0.87
15.	9.0	1.0	8	206.46	206460.0	40500.0	37.8	7804188.0	1086372.0	0.88

Table 7: Saving of Earthwork Quantity and Cost Reduction Ratio for Road Embankment of Different Heights for Dune Sand of Dry Density 1.62 gm/cc using Different % by Weight of Polybags Waste Material for 1 km Long Two Lane Road

S. No.	Height of Embankment (m)	Percentage of Plastic Wastage (Polybag) (%)	Width of Pavement (m)	Area (m ²)	Quantity of Earthwork (m ³)	Saving of Quantity of Earthwork (m ³)	PWD BSR Rate per m ³	Cost of Road Embankment (Rs)	Saving of Cost (Rs)	Cost Reduction Ratio
1.	6.0	0	8	121.80	121800.0	-	36.0	4384800.0	-	1
2.	6.0	0.06	8	97.32	97320.0	24480	37.8	3678696.0	706104.0	0.84
3.	6.0	0.7	8	99.12	99120.0	22680	37.8	3746736.0	638064.0	0.85
4.	6.0	0.9	8	105.96	105960.0	15840	37.8	4005288.0	379512.0	0.91
5.	6.0	1.0	8	106.68	106680.0	15120	37.8	4032504.0	352296.0	0.92
6.	7.5	0	8	175.31	175312.5	-	36.0	6311250.0	-	1
7.	7.5	0.06	8	137.06	137062.5	38250	37.8	5180962.5	1130287.5	0.82
8.	7.5	0.7	8	139.88	139875.0	35437.5	37.8	5287275.0	1023975.0	0.84
9.	7.5	0.9	8	150.56	150562.5	24750	37.8	5691262.5	619987.5	0.9
10.	7.5	1.0	8	151.69	151687.5	23625	37.8	5733787.5	577462.5	0.91
11.	9.0	0	8	238.05	238050.0	-	36.0	8569800.0	-	1
12.	9.0	0.06	8	182.97	182970.0	55080	37.8	6916266.0	1653534.0	0.81
13.	9.0	0.7	8	191.52	191520.0	46530	37.8	7239456.0	1330344.0	0.84
14.	9.0	0.9	8	202.41	202410.0	35640	37.8	7651098.0	918702.0	0.89
15.	9.0	1.0	8	204.03	204030.0	34020	37.8	7712334.0	857466.0	0.9

Table 8: Saving of Earthwork Quantity and Cost Reduction Ratio for Road Embankment of Different Heights for Dune Sand of Dry Density 1.66 gm/cc using Different % by Weight of Polybags Waste Material for 1 km Long Two Lane Road

S. No.	Height of Embankment (m)	Percentage of Plastic Wastage (Polybag) (%)	Width of Pavement (m)	Area (m ²)	Quantity of Earthwork (m ³)	Saving of quantity of earthwork (m ³)	PWD BSR Rate per m ³	Cost of Road Embankment (Rs)	Saving of Cost (Rs)	Cost Reduction Ratio
1.	6.0	0	8	117.48	117480.0	-	36.0	4229280.0	-	1
2.	6.0	0.06	8	94.80	94800.0	22680	37.8	3583440.0	645840.0	0.85
3.	6.0	0.7	8	95.88	95880.0	21600	37.8	3624264.0	605016.0	0.86
4.	6.0	0.9	8	100.92	100920.0	16560	37.8	3814776.0	414504.0	0.90
5.	6.0	1.0	8	104.52	104520.0	12960	37.8	3950856.0	278424.0	0.93
6.	7.5	0	8	168.56	168562.5	-	36.0	6068250.0	-	1
7.	7.5	0.06	8	132.56	132562.5	36000	37.8	5010862.5	1057387.5	0.83
8.	7.5	0.7	8	134.81	134812.5	33750	37.8	5095912.5	972337.5	0.84
9.	7.5	0.9	8	142.69	142687.5	25875	37.8	5393587.5	674662.5	0.89
10.	7.5	1.0	8	148.31	148312.5	20250	37.8	5606212.5	462037.5	0.92

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Vol. 6, Issue 10, October 2017

11.	9.0	0	8	228.33	228330.0	-	36.0	8219880.0	-	1
12.	9.0	0.06	8	176.49	176490.0	51840	37.8	6671322.0	1548558.0	0.81
13.	9.0	0.7	8	179.73	179730.0	48600	37.8	6793794.0	1426086.0	0.83
14.	9.0	0.9	8	191.07	191070.0	37260	37.8	7222446.0	997434.0	0.88
15.	9.0	1.0	8	199.17	199170.0	29160	37.8	7528626.0	691254.0	0.92

5.5 COMPARATIVE STUDY

Figures 5, 6 and 7 show that the cross-section area is reduced most when the percentage of polybags waste material by weight mixed with the dune sand is 0.06% irrespective of the height of the embankment and the dry density of dune sand. The graphs between the height and the cross-section area of the embankment are more or less linear for different percentages of polybags waste material by weight mixed with the dune sand.

The graphs clearly indicate that when percentage of polybags waste material by weight mixed with the dune sand increases from 0% to 0.06%, the cross section area is reduced to the maximum extent i.e. the slope is the steepest irrespective of the height of the embankment and the density of the dune sand and when percentage of polybags waste material by weight mixed with the dune sand increases from 0.06% to 0.1%, the cross section area is increased though it is lesser than what it is at pure dune sand with no polybags waste material.

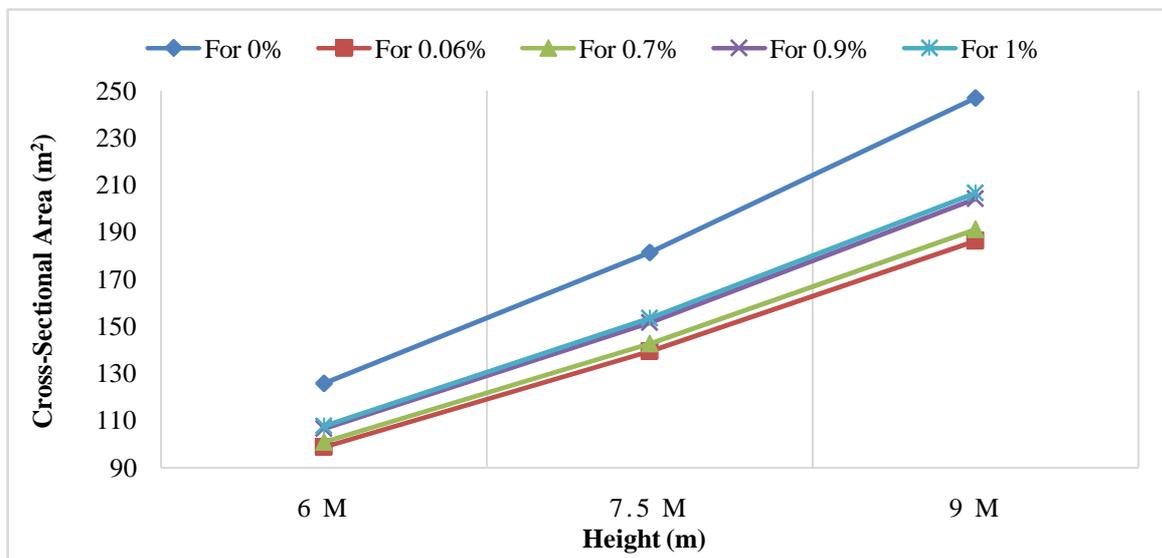


Figure 5: Variation in Cross-Sectional Area of Road Embankment with its Height for Mix Composition of Different Percentage by Weight of Polybags Waste Material mixed with Dune Sand of 1.57 gm/cc Dry Density

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Vol. 6, Issue 10, October 2017

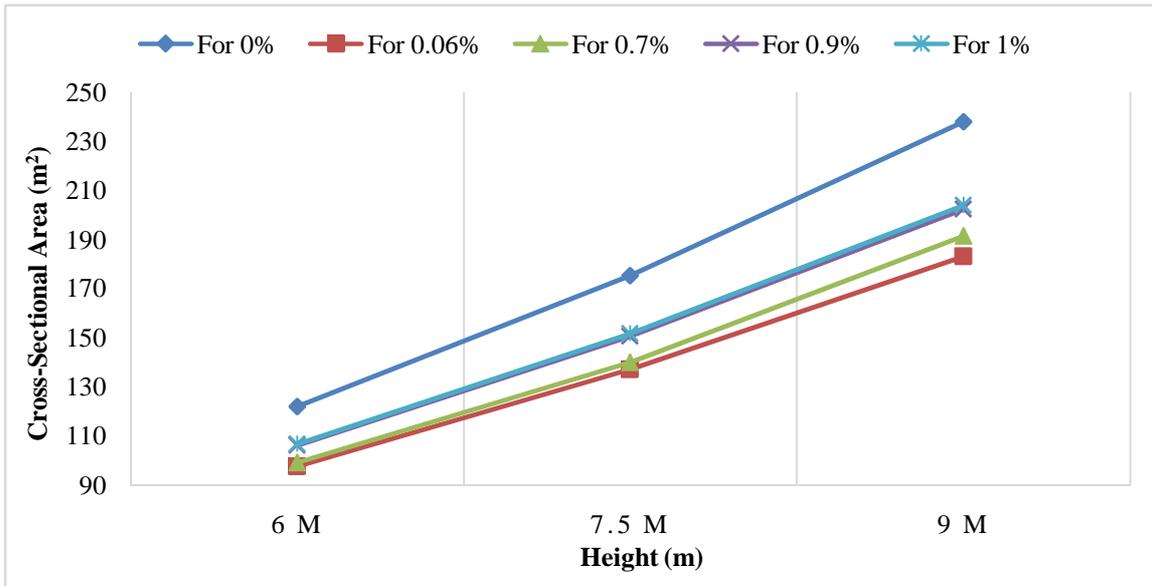


Figure 6: Variation in Cross-Sectional Area of Road Embankment with its Height for Mix Compositions of Different Percentages by Weight of Polybags Waste Material mixed with Dune Sand of 1.62 gm/cc Dry Density

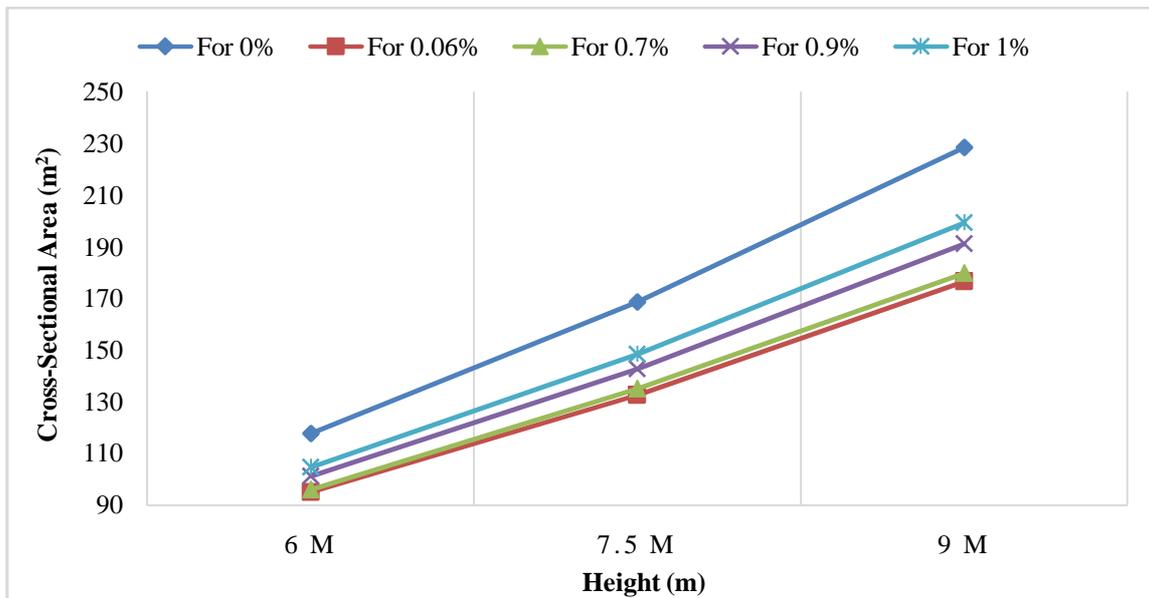


Figure 7: Variation in Cross-Sectional Area of Road Embankment with its Height for Mix Compositions of Different Percentages by Weight of Polybags Waste Material mixed with Dune Sand of 1.66 gm/cc Dry Density

VI. CONCLUSIONS

The results of the slope stability analysis have been described in detail in the present research work with suitable tables and graphs. The following conclusions are drawn from this present work:

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Vol. 6, Issue 10, October 2017

1. When the percentage by weight of polybags waste material mixed with dune sand is increased from 0% to 0.06%, irrespective of the height of the road embankment, its slope is steepened from 2.16:1 to 1.41:1, 2.05:1 to 1.37:1 and 1.93:1 to 1.29:1 for dune sand of dry density 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc respectively. The slope at 0.06% by weight of polybags mixed with dune sand is the steepest slope of the road embankment irrespective of its height.
2. As the percentage by weight of polybags waste material mixed with dune sand is increased from 0.06% to 1.0%, the slope turns gentler from 1.41:1 to 1.66:1, 1.37:1 to 1.63:1 and 1.29:1 to 1.57:1 for dune sand of dry density 1.57 gm/cc, 1.62 gm/cc and 1.66 gm/cc respectively, although the slope in all these cases is steeper than what it is at 0% by weight of polybags mixed with dune sand (i.e. pure dune sand).
3. Among the three dune sand samples taken in this investigation work, the steepest slope of the road embankment is found when the dry density and the friction angle of the soil is maximum irrespective of the height of the embankment. To put in figures the steepest slope of the road embankment evaluated is 1.29:1 which is found when the maximum dry density obtained is 1.66 gm/cc and the maximum friction angle of the soil evaluated is 44.16° which is obtained when the percentage by weight of polybags waste material mixed with dune sand is 0.06%.
4. The maximum reduction in the cross-section area of the road embankment irrespective of the density of the dune sand occurs when the percentage by weight of polybags waste material mixed with the dune sand is 0.06%. The maximum percentage reduction in the cross-section area of the road embankment of all the heights varies between 20-25% for all the dry densities of the dune sand.
5. In our scope of study, the maximum cost reduction ratio is 0.79 which is obtained when the density of the dune sand is 1.57 gm/cc and percentage by weight of polybags waste material mixed with dune sand is 0.06 % for the height of the road embankment equal to 9 m.
6. The slope stability analysis conducted by the software provides reliable results in short time and thus can be used for the design of slope for road embankments.

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