Assessment of Slope Stability in Pisurelem Goa using SLOPE/W Software

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Abstract - *Soil is the material which is capable of holding both substructure and superstructure loads and helps in transmission of load uniformly. Different places have variety of soil properties which reflects the stability of the respective area against slope and load. In order to find the serviceability of existing soil structure such as slope, embankment, foundation, etc., the preliminary step is to analyze and design the safety factor and parameter affecting the slope stability through suitable stability software. The aim of this paper is to analyze the stability of land used as landfill by using SLOPE/W. In these analysis three different sections was considered which uses both Morgenstem-Price Method and Bishop Method as slope stability methods. The results obtained are tabulated for 5 lowest slip surfaces (minimum factor of safety value) and details of minimum and maximum slide masses for each section using two methods are mentioned. From the obtained results the factor of safety for three sections was greater than 2 and reaches maximum value of approximately greater than 60, which indicates the greater stability value.*

Key Words: *Stability, factor of safety, lowest slip surface, slide mass, Morgenstem-Price Method, Morgenstem-Price Method.*

1. INTRODUCTION

The natural soil is one of the basic materials which play a vital role in construction works, mining engineering and so on. The structures like high rise buildings, dams, bridges, roads etc are constructed on the soil for reliable support and it helps in uniform distribution of load from structure to the soil. Different geographical area will exhibit different soil properties such as shear strength, water content, void ratio, bearing capacity, permeability, infiltration etc which resembles its way of loading carrying capacity and stability. Hence, the soil properties are not even in all the regions and provide a scope of investigation of soil properties before initiating the work.

In construction of load carrying structures like buildings, dams, landfill etc are to be constructed after undergoing stability analysis. Due to slope overstressing or depletion in shear strength of soil results in rapid or progressive displacement, which have major impact on failure of the structure, decrease in durability and other damages. Therefore the stability analysis should be carried out in the area where work to be carried out by obtaining all the details from the soil investigation. At the point when soil maintenances are developed on powerless subgrade soil, for example, delicate earth, broad soil and so on, there exist the issue as short term instability and inadequate drainage system.

Manual and software methods can be used for stability analysis. The software provides instant results and reduces time, which in turn provides graphical representation of inputs and results which helps in reducing ambiguity in documentation of reports. For Stability analysis, SLOPE/W software is utilized. SLOPE/W is the well known conventional software for soil and rock slopes or inclines. SLOPE/W software will be used to explore both simple and complex problematic situations with variety of slip surface shapes, pore-water pressure conditions, soil properties, and loading conditions. With this substantial features, SLOPE/W can be used to analyze the stability of various slopes, inclined mass, that will be experienced in our Geotechnical, Civil and Mining building ventures. SLOPE/W supports material model which includes un-drained, impenetrable, Mohr-Coulomb, high strength, bilinear, spatial Mohr-Coulomb and more. Piezometric line is used to define pore water pressure.

For the analysis, landfill located in north region Goa is considered. Ineffective solid waste management is a significant problem in India, especially in urban centers. As urbanization increases, the problems on solid waste management in the mega cities are also increases. Produces a huge quantity of chemicals that are hazardous. In Goa region, the hazardous waste produced is transported to Mumbai and Vadi in Karnataka for incinerating the hazardous waste generated. Transporting this toxic, reactive, explosive and corrosive is risk and expensive. Government of Goa decided to come up with Hazardous waste treatment facility within Goa. Landfill is being a major part of the treatment and requires safe leachate management system. On the basis of inventory and auditing works, the number of industries involved in generation of waste is 1250+. The total quantity of waste generated is 40,000 TPA. Designed life is 25 years. The area consists of 2 landfill of area, one is 134m x 100m and 171m x 100m. The test will be carried through borehole exploration, having various soil properties which is used as input data for the SLOPE/W software.

2. LITERATURE REVIEW

Kuo-Hsin Yang., et.al.[01] in this paper two dimensional embankment models was developed by using SEEP/W and SLOPE/W software in order to carry numerical modeling to investigate hydraulic response and stability of reinforced slope with different reinforcement drainage system subjected to rainfall and validation of the model by measuring PWP distribution within the embankment. The maximum sand cushion strength obtain was 163 kN/m^2 for both Geotextile and Geo-grid reinforcement for cushion thickness 35cm, the drainage and factor of safety increased more than 1.3 assumed. Study reveals that the loss of matric suction and development of a capillary barrier affect within the marginal backfill have negative effect on both global and local stability. To overcome this problem, design implication was done to improve the drainage through design, which enhanced the reinforcement tensile strength.

HAZWAMS-17 [02] In this code book the stability of landfill, methods of stability are discussed.

3. METHODOLOGY

The stability of side slopes of a landfill shall be checked for the Stability of excavated slopes.

The stability analysis shall be conducted using the following soil mechanics methods depending upon the shape of the failure surface. For the analysis, two methods are used in the software.

1. Morgenstem-Price Method
2. Bishop Method

The tests like dry density, moisture content, and unconfined compression strength are done in the field and respective results are used as software inputs

The software provides number of possible slip surfaces from minimum FOS to maximum FOS along with total volume of slide mass, total weight of side mass, total resisting moment, total activating moment, total resisting force, total activating force . It will give clear picture of FOS across the landfill.

4. TESTS CONDUCTED

Table 1: Field density & Moisture content

Properties	
Bulk Density	19.25 kg/m^3
Moisture Content	17.82 %

Table 2: Box shear (Consolidated quick)

Properties	
Cohesion constant	2400 kg/m^2
Φ - angle of repose	29^0

Table 3: Unconfined compression

Properties	
q_u	10060 kg/m^2

Table 4: Specific Gravity

Specific gravity	2.6

5. ANALYSIS

Location of the landfill – near IDC Honda, Pissurlem, Goa

Fig 1: Boreholes Location-Pissurlem IDC, Goa

(Fig 1 represents the location of the land where landfill is constructed in Pissurlem,)

Source: Google earth pro.

Note: The landfill is divided into three sections, named as 1-1, 2-2 and 3-3.

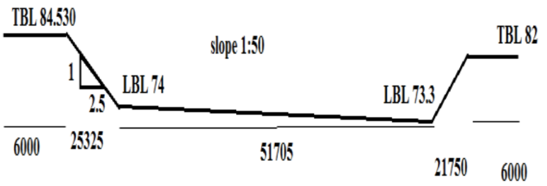

Fig 2: Section 1-1 of the considered landfill

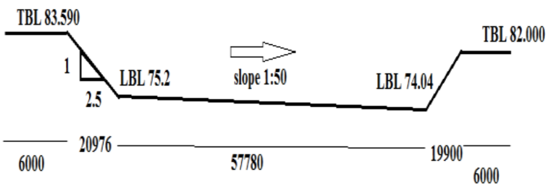

Fig 3: Section 2-2 of the considered landfill

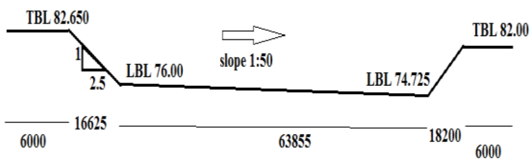

Fig 4: Section 3-3 of the considered landfill

INPUT VALUES

Bulk density – 19.25 kg/m^3

Cohesion constant – 2400 kg/m^2

Angle of repose(Φ) - 29^0

Unconfined compression (**q_u**)- 10060 kg/m^2

Piezometric line was aligned at 0m of 30m slope height

6. RESULT AND DISCUSSION

6. 1. Morgenstem-Price Method for section 1-1

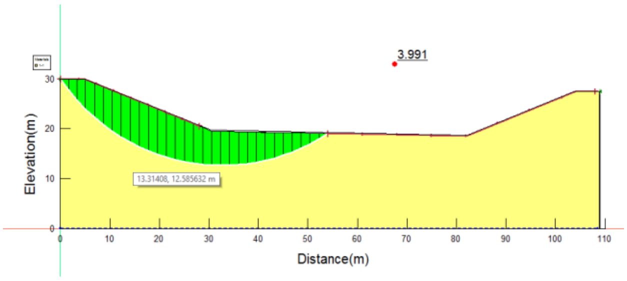

Fig 6.1: Minimum value of FOS for Section 1-1 with slip surface No-3

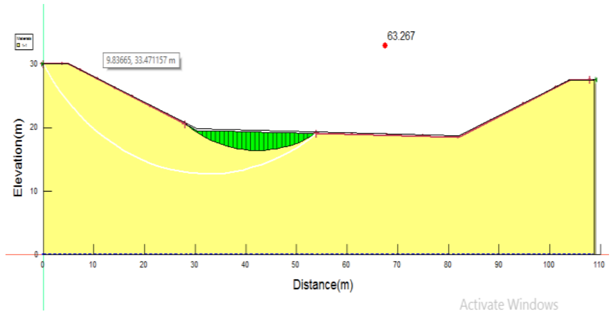

Fig 6.2: Maximum value of FOS for Section 1-1 with slip surface No-362

Table 6.1: Lowest Slip Surface details

Sl. No.	Slip No.	FOS	X center (m)	Y center(m)	Radius (m)
1	3	3.991	32.582	53.032	39.332
2	48	4.385	34.565	50.662	37.114
3	4	4.528	29.998	39.299	31.406
4	2	4.548	38.568	81.538	64.372
5	8	4.558	35.974	54.626	43.595

Table 6.2: Slide Mass details for Minimum FOS (slip surface No-3)

Sl. No.	Description	Value
1	FOS	3.991
2	Total volume	102.51 m^3
3	Total weight	1666.3 kN
4	Total Resisting Moment	55,277 kN m
5	Total Activating Moment	13,852 kN m
6	Total Resisting Force	1,275.6 kN
7	Total Activating Force	319.64 kN

Table 6.3: Slide Mass details for Maximum FOS (slip surface No-362)

Sl. No.	Description	Value
1	FOS	63.267
2	Total volume	14.602 m^3
3	Total weight	237.29 kN
4	Total Resisting Moment	8,819.7 kN m
5	Total Activating Moment	139.4 kN m
6	Total Resisting Force	317.99 kN
7	Total Activating Force	5.0262 kN

6.2. Morgenstem-Price Method for section 2-2

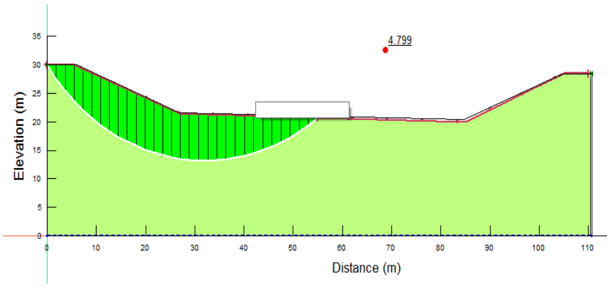

Fig 6.3: Minimum value of FOS for Section 2-2 with slip surface No-3

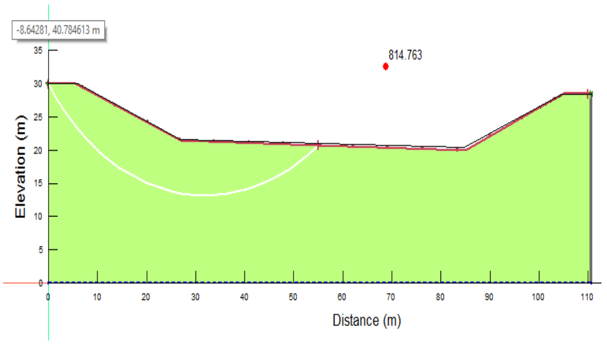

Fig 6.4: Maximum value of FOS for Section 2-2 with slip surface No-386

Table 6.4: Lowest Slip Surface details

Sl. No.	Slip No.	FOS	X center (m)	Y center(m)	Radius (m)
1	3	4.799	31.974	52.066	38.849
2	2	5.165	36.872	81.272	63.154
3	8	5.517	35.504	54.726	43.265
4	4	5.609	29.844	39.363	31.278
5	7	5.871	40.435	87.268	70.104

Table 6.5: Slide Mass details for Minimum FOS (slip surface No-3)

Sl. No.	Description	Value
1	FOS	4.799

2	Total volume	112.02 m^3
3	Total weight	2,128.4 kN
4	Total Resisting Moment	65.929 kN m
5	Total Activating Moment	13.739 kN m
6	Total Resisting Force	1,546.2 kN
7	Total Activating Force	322.21 kN

Table 6.6: Slide Mass details for Maximum FOS (slip surface No-386)

Sl. No.	**Description**	**Value**
1	FOS	814.763
2	Total volume	0.2121 m^3
3	Total weight	4.0299 kN
4	Total Resisting Moment	15.493 kN m
5	Total Activating Moment	19.016 kN m
6	Total Resisting Force	84.819 kN
7	Total Activating Force	0.1041 kN

6.3. Morgenstem-Price Method for section 3-3

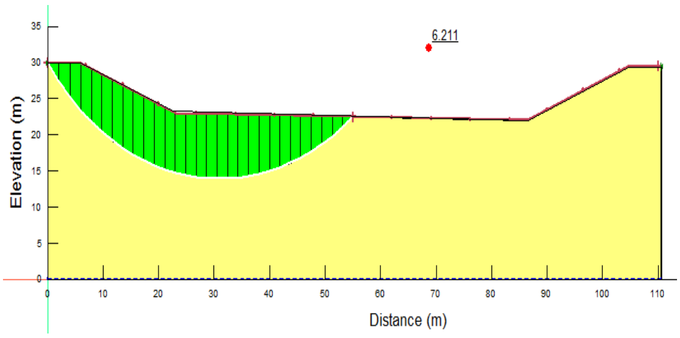

Fig 6.5: Minimum value of FOS for Section 3-3 with slip surface No-3

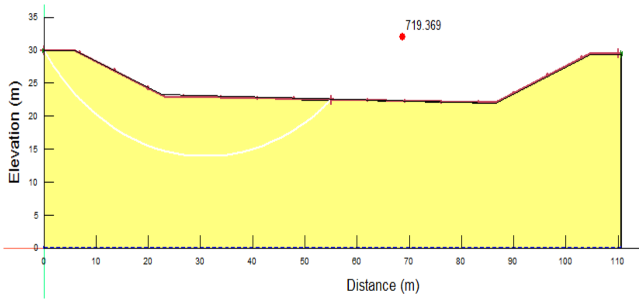

Fig 6.6: Maximum value of FOS for Section 3-3 with slip surface No-316

Table 6.7: Lowest Slip Surface details

Sl. No.	Slip No.	FOS	X center (m)	Y center(m)	Radius (m)
1	3	6.211	30.98	51.754	37.855
2	2	6.626	34.865	80.233	61.147
3	8	7.261	34.492	54.4	42.25
4	4	7.346	29.277	39.276	30.712
5	7	7.661	38.392	86.183	68.048

Table 6.8: Slide Mass details for Minimum FOS (slip surface No-3)

Sl. No.	Description	Value
1	FOS	6.211
2	Total volume	115.52m^3
3	Total weight	2,194.8 kN
4	Total Resisting Moment	66.187 kN m
5	Total Activating Moment	10.657 kN m
6	Total Resisting Force	1,593.8 kN
7	Total Activating Force	256.6 kN

Table 6.9: Slide Mass details for Maximum FOS (slip surface No-316)

Sl. No.	Description	Value
1	FOS	719.369
2	Total volume	0.24829 m^3
3	Total weight	4.7175 kN
4	Total Resisting Moment	1,912.2 kN m
5	Total Activating Moment	2.6582 kN m
6	Total Resisting Force	53.19 kN
7	Total Activating Force	0.07394 kN

6.4. Bishop Method for section 1-1

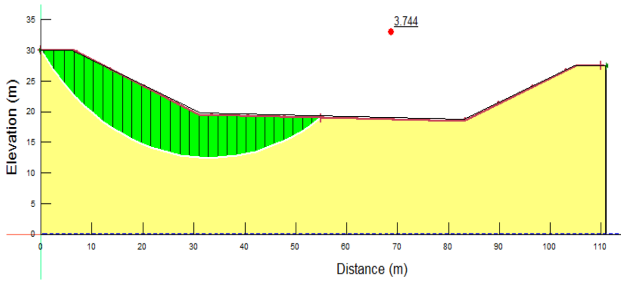

Fig 6.7: Minimum value of FOS for Section 1-1 with slip surface No-3

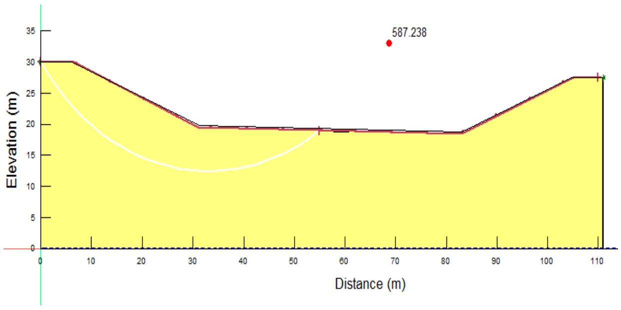

Fig 6.8: Maximum value of FOS for Section 1-1 with slip surface No-366

Table 6.10: Lowest Slip Surface details

Sl. No.	Slip No.	FOS	X center (m)	Y center(m)	Radius (m)
1	3	3.744	33.057	52.401	39.932
2	2	4.033	39.029	82.366	65.31
3	8	4.284	36.515	55.042	44.277
4	4	4.339	30.478	39.46	31.912
5	7	4.568	42.461	88.311	72.133

Table 6.11: Slide Mass details for Minimum FOS (slip surface No-3)

Sl. No.	Description	Value
1	FOS	3.744
2	Total volume	109.37 m^3
3	Total weight	2.078 kN
4	Total Resisting Moment	66.035 kN m
5	Total Activating Moment	17.639 kN m

Table 6.12: Slide Mass details for Maximum FOS (slip surface No-366)

Sl. No.	Description	Value
1	FOS	587.238
2	Total volume	0.25082 m^3
3	Total weight	4.7657 kN
4	Total Resisting Moment	1,945.5 kN m
5	Total Activating Moment	3.313 kN m

6.5. Bishop Method for section 2-2

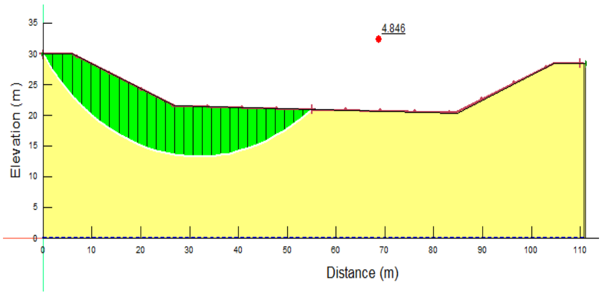

Fig 6.9: Minimum value of FOS for Section 2-2 with slip surface No-3

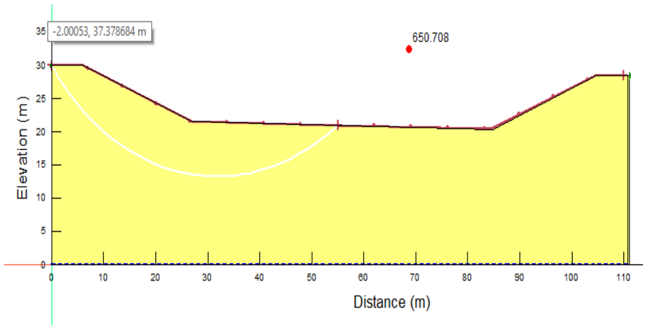

Fig 6.10: Maximum value of FOS for Section 2-2 with slip surface No-366

Table 6.13: Lowest Slip Surface details

Sl. No.	Slip No.	FOS	X center (m)	Y center(m)	Radius (m)
1	3	4.846	31.833	52.022	38.708
2	2	5.190	36.588	81.126	62.869
3	8	5.616	35.322	54.663	43.08
4	4	5.685	29.762	39.35	31.196
5	7	5.950	40.078	87.069	69.737

Table 6.14: Slide Mass details for Minimum FOS (slip surface No-3)

Sl. No.	Description	Value
1	FOS	4.846
2	Total volume	112.11 m^3
3	Total weight	2,130.1 kN

4	Total Resisting Moment	65.813 kN m
5	Total Activating Moment	13.581 kN m

Table 6.15: Slide Mass details for Maximum FOS (slip surface No-366)

Sl. No.	**Description**	**Value**
1	FOS	650.708
2	Total volume	0.24926 m^3
3	Total weight	4.7359 kN
4	Total Resisting Moment	1,926.1 kN m
5	Total Activating Moment	2.9599 kN m

6.6. Bishop Method for section 3-3

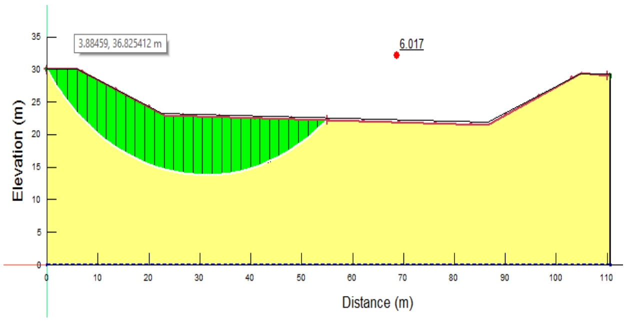

Fig 6.11: Minimum value of FOS for Section 3-3 with slip surface No-3

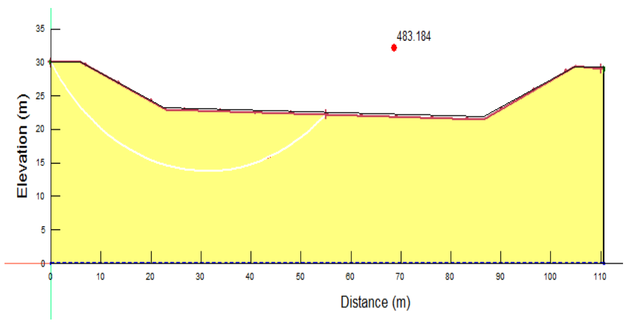

Fig 6.12: Maximum value of FOS for Section 3-3 with slip surface No-316

Table 6.16: Lowest Slip Surface details

Sl. No.	Slip No.	FOS	X center (m)	Y center(m)	Radius (m)
1	3	6.017	31.121	51.799	37.996
2	2	6.410	35.152	80.382	61.433
3	8	6.961	34.669	54.461	42.43
4	4	7.109	29.357	39.288	30.791
5	7	7.327	38.743	86.381	68.409

Table 6.17: Slide Mass details for Minimum FOS (slip surface No-3)

Sl. No.	Description	Value
1	FOS	6.017
2	Total volume	115.89 m^3
3	Total weight	2,201.9 kN
4	Total Resisting Moment	66.557 kN m
5	Total Activating Moment	11.062 kN m

Table 6.18 : Slide Mass details for Maximum FOS (slip surface No-316)

Sl. No.	Description	Value
1	FOS	483.184
2	Total volume	0.24638 m^3
3	Total weight	4.6813 kN
4	Total Resisting Moment	1,926.8 kN m
5	Total Activating Moment	3.9877 m

7. CONCLUSION

Table 7: Comparison of FOS between Morgenstem-Price Method and Bishop Method of three section

	Morgenstem-Price Method		Bishop Method	
	Mini. FOS	**Maxi. FOS**	**Mini. FOS**	**Maxi. FOS**
Section 1-1	3.991	63.267	3.744	587.238
Section 2-2	4.799	814.763	4.846	650.708
Section 3-3	6.211	719.369	6.017	483.184

From the obtained results the factor of safety for three sections was greater than 2 and reaches maximum value of approximately greater than 60, which indicates the greater stability value and shows that the considered slope is safe (where, FOS >2). The analysis can be carried by considering the weight of waste heaped on landfill.

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BIOGRAPHIES

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