Analysis of Embankment on Problematic soil

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ABSTRACT

In specific region of Dholera, where near to area ofhighway, water logging problem is very frequent and to preventing this problem to construction of embankment is very important. Slope stability assessment is essential for the safety and sustainable development of engineering.For present study, soil sample is collectedfor construction of embankment and to determine the soil properties and slope stability of embankment. It is assumed that the embankment is constructed at different height, different depth and different slope. And we consider condition that fulfils the requirements for selecting the embankment construction. The limit equilibrium method was considered for numerical analysis. The factor of safety (FOS) was determined by using the Bishop's method of slices and circular failure charts.The results showed that the embankment slope was unsuitable with factor of safety (FOS) less than 1.5, but stable when the FOS was greater than 1.5.Slope stability analysis revealed those slopes are mostly partially unsuitable.Mainly, excess rainfall triggered the slope stability, which directly affected on the geotechnical properties of the soil.

Keywords: Limit equilibriummethod, Bishop's Method, Microsoft excel, Geo 5, Embankment,slope stability.

INTRODUCTION

The analysing the Slope stability of an embankment involves assessing factors like soil type, slope angle, water content and external loads. Engineering typically use methods such as limit equilibrium analysis, finite element analysis or numerical modelling to evaluate the stability of embankments. The goal is to ensure that the embankment can withstand the forces acting upon it and remain stable over time. The state of Gujarat in India is a hub of development, especially in infrastructure. In Ahmedabad and the surrounding areas, development is happening rapidly. Dholera is one of the best examples of this. In the development of any city, road and highways play an important role. In development Dholera, one critical case we have explained to them. In the specific region of Ahmedabad - Dholera expressway has encountered several issues, one of which is waterlogging. To prevent this problem, embankments are being constructed. A brief overview of the slope stability assessment using the slope stability analysis methods by **S Ullah, M U Khan and G Rehman et al. (2020), Digvijay P. S., Guruprasd Chvan, Rupa N. Bartakke, Pooja R. Kothavale et al. (2017), and A review on numerical slope stability analysis by T N Singh, Rahul Thareja, Dhananjai Verma, Ashutosh kainthola et al. (2013).**

In many hilly regions, numerous issues arise, such as landslides and erratic rainfall. Researchers and developers analyse these affected areas to identify structural deformities and anticipate future problems. They then implement preventive measures to address these conditions. In India,in 2014, 140 people died due landslide. A hill slope failure analyse **by Chetan R Shah , Sandip S. Sathe , Prashant B Bhagawati & Santosh S. Mohite et al. (2019),**Analysis of slope stability of road cut slopes by**Mukta Sharma , Shivani Sharma , Mohit Kumar , S. K. Singh et al. (2019), Akhlesh Kumar , Ravi Kumar Sharma and Bikram Singh Mehta et al. (2020)**,Analytical and numerical stability analysis of road cut slope**by Hari Om Singh , Tariq Anwar Ansari , T N Singh et al. (2020),Sarada Prasad Pradhan , Tido T S , Amulya Ratna Roul et al.(2021)**.And A Comparative Study of Slope Stability Analysis Limit Equilibrium Method (LEM) And Finite Element Method (FEM) by **A. Burman, S. P. Acharya, R. R. Sahay and D. Maity et al.(2015)**&Comparative analysis of 2D and 3D slope stability problems using limit equilibrium technique-based Bishop's simplified method by **Brijbhan Rao, Avijit Burman, Lal Bahadur Roy, Sumit Kumar, Amit Kumar, Shiva Shankar Choudhary et al.(2023).**

In Slope stability analysis,various types of stabilized material used, such asfly ash, lime, cement, etc. In soft soil embankment, various percentages of fly ash are used to stabilize by**Tarun Kumar Rajak and Laxmikant Yadu et al.(2016)**, Improvement on expansive soil with jute fiber reinforcement by **Amit KumarSingh and R. K. Yadav et al.(2016)**, and chemical soil stabilization the bank of river Ghaghara by **Ashwani Kumar , Anupam Rawat and A.K.Sachan et al.(2017)**, Effect of Rice Husk Ash and Fly Ash on Black Cotton Soil by **Madhusudan Ramchandra Vaidya** and **Dr. Harirang Haribhau Shinde et al.(2018)** and Reinforced fly ash slope using different Geosynthetics by **S. Adhana and J. N. Mandal et al.(2011)**. And TheResearchers was studying the comparative study of LEM andFEM. InComparative Study Of Slope Stability Analysis Using Traditional Limit Equilibrium Method And Finite Element Method by **A. Burman, S. P. Acharya, R. R. Sahay and D. Maity et al.(2015)**,Comparative analysis of 2D and 3D slope stability problems using limit equilibrium technique-based Bishop's simplified method by **Brijbhan Rao , Avijit Burman , Lal Bahadur Roy, Sumit Kumar, Amit Kumar, Shiva Shankar Choudhary et al.(2023)** and Comparison of Fos Between LEM and FEM for Geotextile Reinforced Embankment on difficult foundation by **JigishaVashi , Atul Desai , C H Solanki and Babu V Sundararaman et al.(2020)**.

This study incorporates real soil data estimation in this dissertation work. It aims to evaluate the slope stability factor of safety on problematic soil and identify the safe factor of safety for different geometries (varying height, depth and slope) under all condition, including full fill. Additionally, it compares two software programs, Geo 5 and Microsoft Excel, to assess slope stability using the LEM method. Other conditions are also examined using Geo 5 software.

Problem Definition and Computation of slope stability

Near Dholera region, Gujarat waterlogging problems are more frequentand to reduce that problem, construction of suitable embankment is very important.In presentstudy, optimum design of embankment is considered and numerical analysis is done to determine effect of different geometrical parameters like height, depth and slope of embankment. Height of embankment is varied as6m, 9m, 12m with different depthof 3m, 6m, 9m. slope of1 in 1.5, 2.0, 2.5, 3.0 are carried out them. And we consider condition that fulfils the requirements for selecting the embankment construction. We also collected the soil samples from the embankment area for determining the soil properties and slope stability.

The embankment area in the foundation is constructed on problematic, high plasticity clay soil, while the embankments are constructed on SM (silty sand) soil.The embankment constructed based on all test results is denoted.The embankment area summary of soil parameter is below.

FOR FOUNDATION MATERIAL

Parameter	Symbol	Value
Liquid limit	wL	61.15
Plastic limit	wP	28.64
Index Plasticity	Ip	32.5
Specific Gravity	G	2.68
Density	ϒ	18.2
Free Swell Index	F.S.I(%)	86.6
Cohesion	C	40
Angle of Friction	Φ	12
Void Ratio	e	0.840
Coefficient of consolidation	Cc	0.185
Unconfined Compressive Strength	Qu	1.009

FOR EMBANKMENT MATERIAL

Parameter	Symbol	Value
Specific Gravity	G	2.67
Max. dry density	ϒd	18.6
Water content	W	14
Cohesion	C	0
Angle of Friction	Φ	30.5

About Geo5 Program

The program GEO5 allows geotechnical engineers to carry out limit equilibrium slope stability analysis of existing natural slopes, unreinforced man – made slopes or slopes with soil reinforcement.GEO5 is geotechnical software that is used to solve various geotechnical problems.LikeAnalysis of stability , Design of excavation , Design of retaining wall , Design of foundation , Analysis of soil settlement , Analysis of advanced finite element (F.E.) etc.

In this study, we have considered the soil parameter data for embankment and foundation materials used in the Geo 5 software. We have listed the values for embankment and foundation materials in a table.

- We have conducted many slope stability assessments. Details are provided below the table.The 36 model in GEO 5 software and Excel software have different geometries, as shown in the table below. And 252 analyses were completed in Geo 5 software using the bishop method.

No.		**Slope stability**		**Condition**		**Condition 1 m water logging**		**Sudden draw-down**	**Sudden draw-down**
		Bishop method		Dry static	Dry seismic	static condition	seismic condition	static condition	seismic condition
		FOS:1.5		FOS:1.4	FOS:1.1	FOS:1.4	FOS:1.1	FOS:1.4	FOS:1.1
		Geo-5	Excel	Geo-5		Geo-5		Geo-5	
(1) Height 6m and 3m clay layer depth At slope 1	1.5	0.88	2.49	1.24	1.04	1.27	1.02	1.17	1.02
	2.0	1.18	2.59	1.49	1.26	1.5	1.15	1.37	1.14
	2.5	1.47	2.70	1.78	1.42	1.75	1.3	1.59	1.27
	3.0	1.77	2.81	2.04	1.57	2.03	1.45	1.83	1.42
(2) Height 6m and 6m clay layer depth At slope 1	1.5	0.88	2.49	1.24	1.04	1.27	1.02	1.17	1.02
	2.0	1.18	2.59	1.5	1.25	1.5	1.15	1.38	1.15
	2.5	1.47	2.70	1.76	1.41	1.75	1.3	1.61	1.29
	3.0	1.77	2.81	2.04	1.57	2.03	1.45	1.83	1.42
(3) Height 6m and 9m clay layer depth At slope 1	1.5	0.88	2.49	1.24	1.04	1.27	1.02	1.17	1.02
	2.0	1.18	2.59	1.49	1.24	1.5	1.15	1.51	1.15
	2.5	1.47	2.70	1.75	1.42	1.75	1.3	1.73	1.27
	3.0	1.77	2.81	2.03	1.57	2.03	1.45	2	1.42
(4) Height 9m and 3m clay layer depth At slope 1	:1.5	0.88	1.80	1.13	0.94	1.09	0.94	1.1	0.96
	2.0	1.18	1.89	1.38	1.13	1.38	1.1	1.38	1.1
	2.5	1.47	1.97	1.65	1.33	1.65	1.27	1.66	1.27
	3.0	1.77	2.06	1.99	1.54	1.96	1.48	1.94	1.46
(5) Height 9m and 6m clay layer depth At slope 1	1.5	0.88	1.80	1.13	0.94	1.09	0.94	1.1	0.96
	2.0	1.18	1.89	1.38	1.15	1.38	1.1	1.38	1.1
	2.5	1.47	1.97	1.67	1.33	1.65	1.3	1.66	1.27
	3.0	1.77	2.06	1.93	1.52	1.92	1.48	1.94	1.45
(6) Height 9m and 9m clay layer depth At slope1	1.5	0.88	1.80	1.13	0.94	1.09	0.94	1.1	0.96
	2.0	1.18	1.89	1.38	1.15	1.38	1.1	1.38	1.1
	2.5	1.47	1.97	1.67	1.36	1.65	1.27	1.66	1.27
	3.0	1.77	2.06	1.99	1.54	1.96	1.48	1.94	1.46
(7) Height 12m and 3m clay layer depth At slope 1	1.5	0.88	1.58	1.06	0.9	1.05	0.89	1.06	0.9
	2.0	1.18	1.63	1.32	1.1	1.31	1.1	1.32	1.1
	2.5	1.47	1.72	1.61	1.28	1.57	1.3	1.59	1.28
	3.0	1.77	1.83	1.91	1.56	1.84	1.51	1.89	1.48
(8) Height 12m and	1.5	0.88	1.58	0.96	0.78	0.92	0.82	0.93	0.8
	2.0	1.18	1.63	1.33	1.1	1.3	1.11	1.32	1.11

6m clay layer depth At slope 1	2.5	1.47	1.72	1.63	1.28	1.57	1.3	1.59	1.3
	3.0	1.77	1.83	1.91	1.56	1.84	1.51	1.89	1.48
(9) Height 12m and 9m clay layer depth At slope 1	1.5	0.88	1.58	0.96	0.78	0.92	0.82	0.93	0.8
	2.0	1.18	1.63	1.34	1.1	1.3	1.09	1.34	1.13
	2.5	1.47	1.72	1.64	1.32	1.57	1.39	1.61	1.4
	3.0	1.77	1.83	1.99	1.5	1.95	1.48	1.91	1.46

Result and Discussion

- **The Geo 5 software result is denoted in graph as shown below.**
- We have discussed using the Geo 5 software to check different geometries and conditions for the factor of safety (FOS). And we consider condition that fulfils the requirements for selecting the embankment construction. We have discussed belowthe Geo 5 software slope stability condition graph.

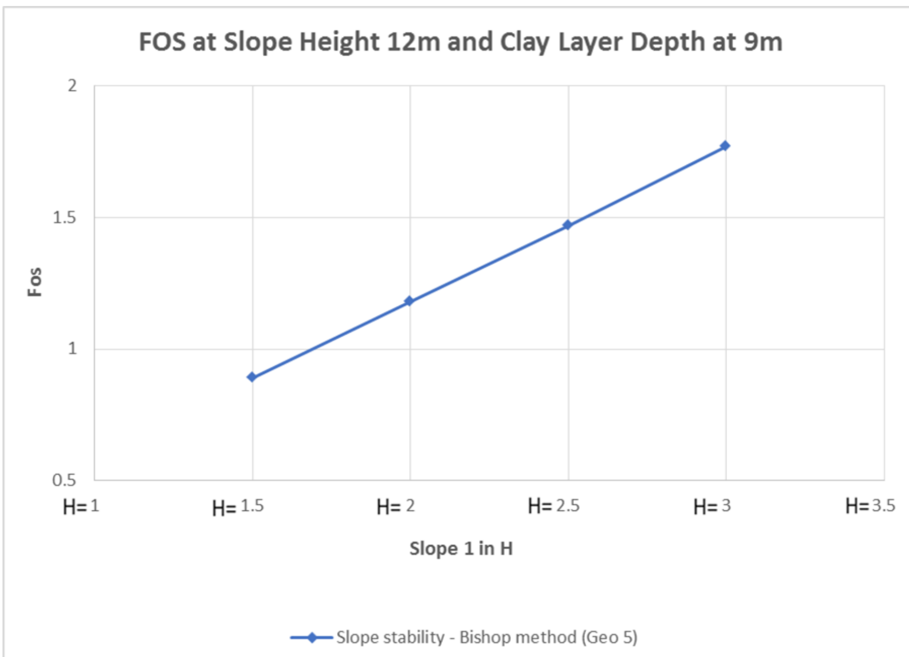

Figure 1 slope stability (Geo-5)

- In above figure-1, as the change in slope 1 in 1.5, 2.0, 2.5, and 3.0, the corresponding change in FOS(factor of safety) are 0.77, 1.23, 1.47, 1.77, respectively, while keeping the Height and depth constant. At constant height and depth, the change in slope 1 in 1.5, 2.0, 2.5 and 3.0 results in respective incrementsin the factor of safety(FOS).

- **To comparison of the study results is denoted using Microsoft excel and geo 5 software.**

- The comparison of slope stability analysis using the Bishop method in GEO5 and Microsoft Excel, based on the figures from 2 to 8.
- From the information provided in the 2 to 8 figures, it seems the comparison focuses on the Factors of Safety (FOS) obtained from the two software for the given slope stability analysis.
- Here, Comparison Geo 5 and Microsoft Excel for checking the slope stability and Bishop Method in the Limit Equilibrium Method (LEM) are used. And compare the factor of safety(FOS) results for slope stability between Geo 5 and Microsoft Excel, we should examine the differences in their results to determine which software provides more accurate results.
- In the GEO5 software, the FOS values appear to be constant across the different figures (2 to 8), indicating a stable and reliable result.In contrast, the FOS values obtained from the Microsoft Excel calculations show minor variations or changes across the different figures (2 to 8).

- This suggests that the GEO5 software provides more accurate and consistent FOS results when using the Bishop method for slope stability analysis, compared to the Microsoft Excel calculations.
- The constant FOS values in GEO5 are likely due to the robust algorithms and comprehensive geotechnical database integrated within the software, ensuring reliable and accurate slope stability analysis.
- The minor changes in FOS values observed in the Microsoft Excel calculations could be attributed to potential variations in the manual implementation of the Bishop Method or limitations in the spreadsheet-based approach.
- The figures show that the Factors of Safety (FOS) values obtained from the slope stability analysis using the Bishop method are generally more accurate and consistent in the GEO5 software compared to Microsoft Excel.
- In figures (2 to 8) show them the comparison of results in more accurate in geo 5 software. And to denote in them the FOS value for different geometry condition is constant and accurate in Geo 5 software, and minor have a changes FOS value for different geometry condition in Microsoft excel in them.

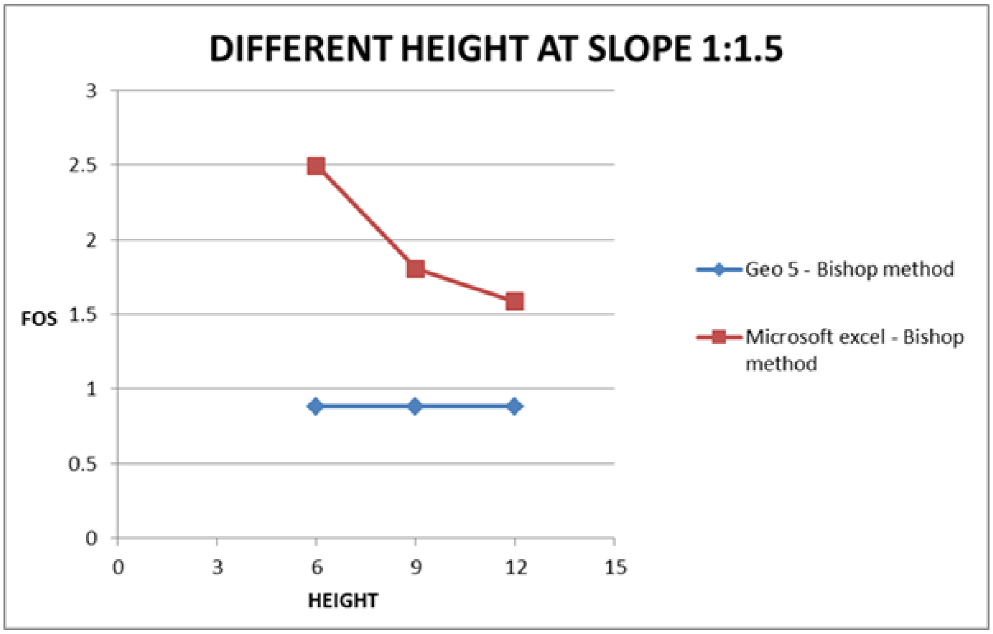

Figure 2 different height at Slope 1:1.5

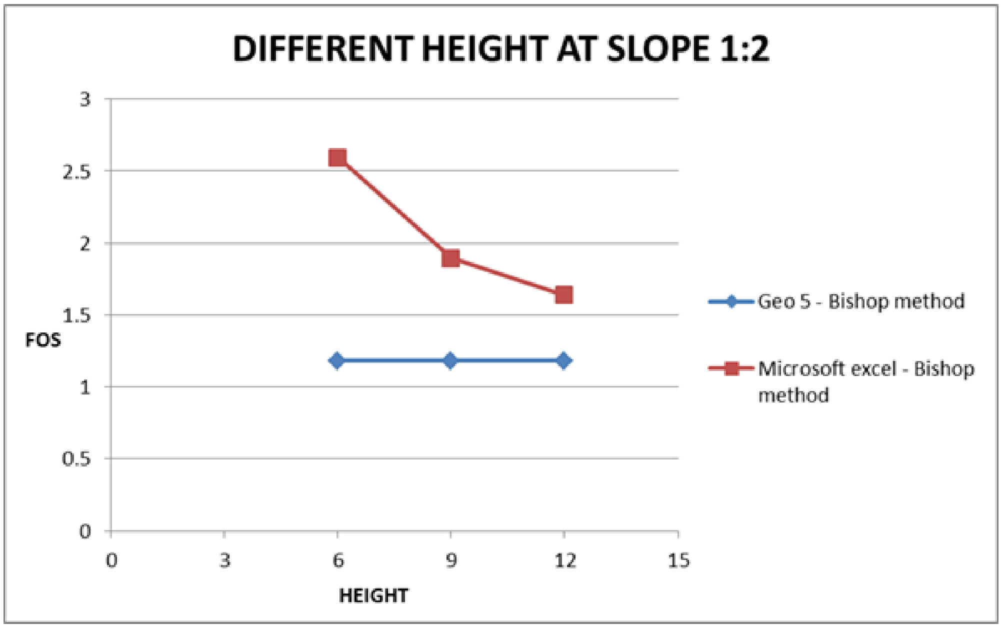

Figure 1 different height at Slope 1:2

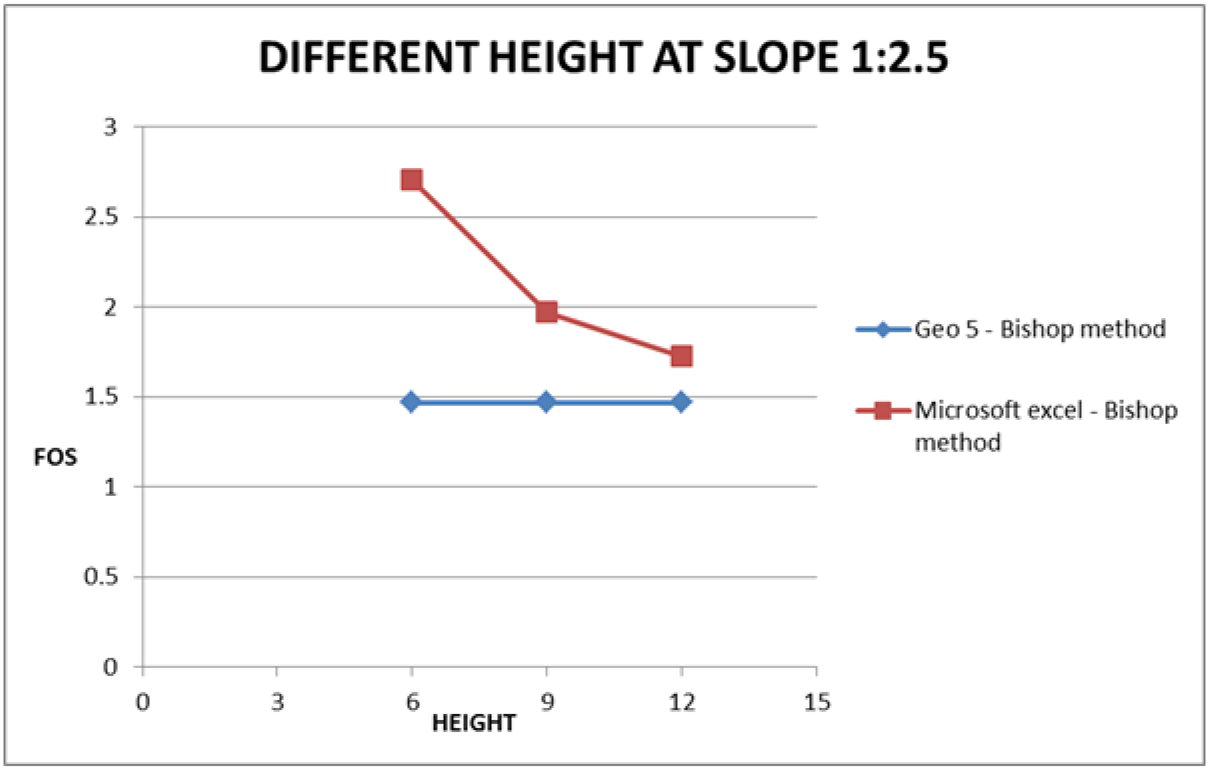

Figure 2 different height at Slope 1:2.5

Figure 3 different height at Slope 1:1.3

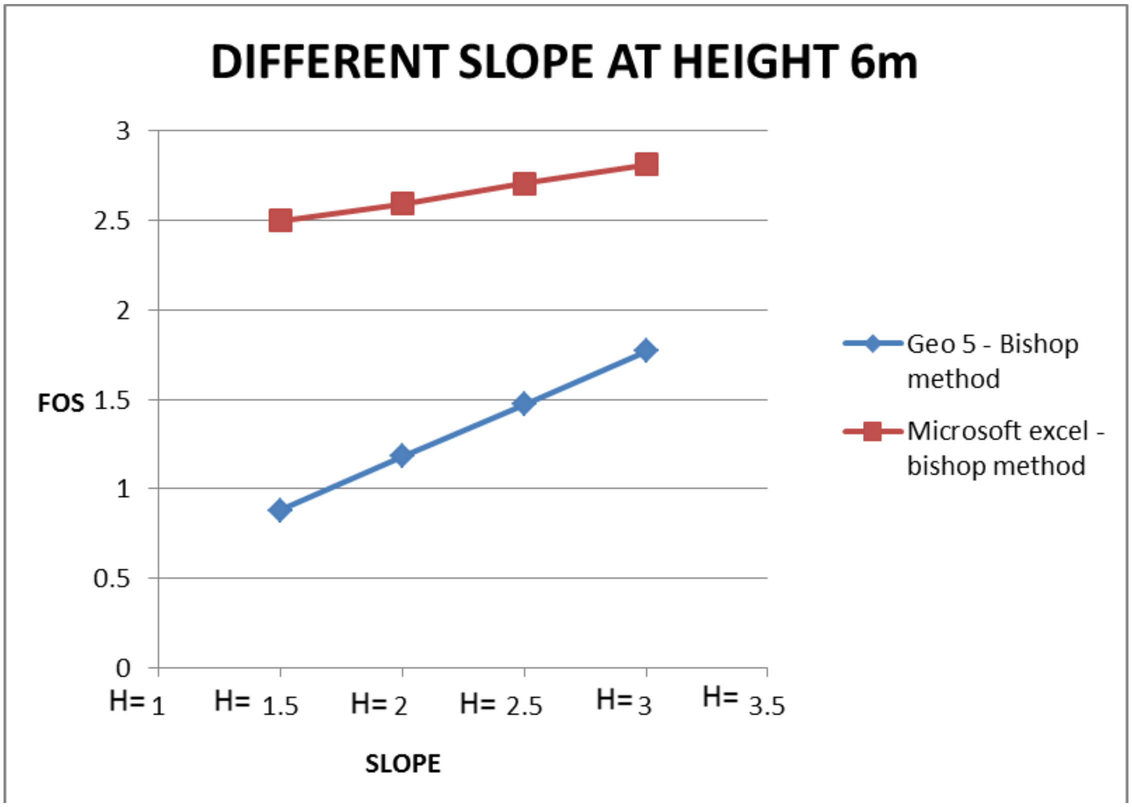

Figure 4 different Slope at Height 6m

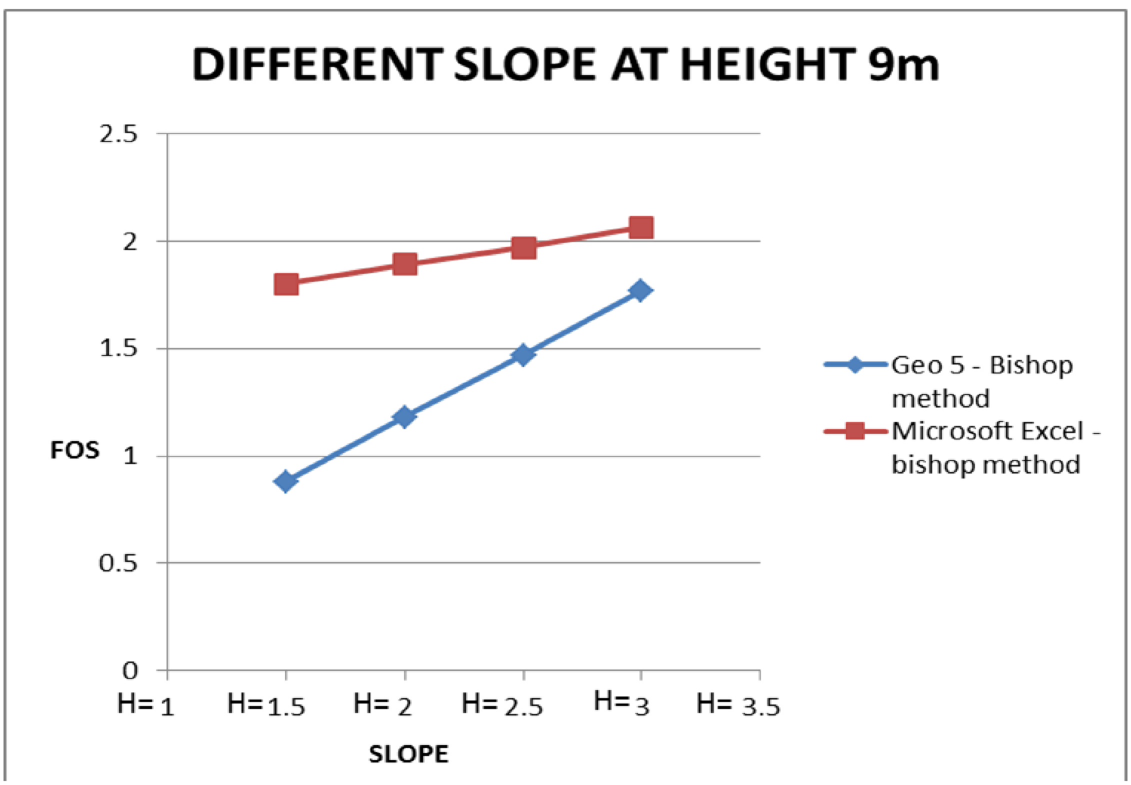

Figure 5 different Slope at Height 9m

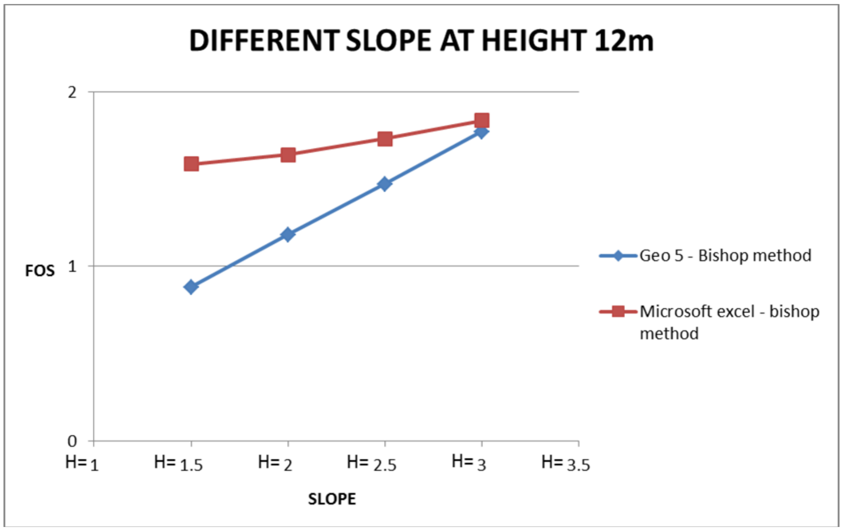

Figure 6 different Slope at Height 12m

- **The Geo 5 software checks slope stability analysis under different condition and present the results below.**
- In below figure 9 to 17, as the change in slope 1 in 1.5, 2.0, 2.5, and 3.0, the corresponding change in FOS (factor of safety) are Different for different condition, respectively, while keeping the Height and depth constant. At constant height and depth, the change in slope 1 in 1.5, 2.0, 2.5 and 3.0 results in respective increments in the factor of safety (FOS).
- In all the figures below, from 9 to 17, the graph shows minor changes in shape but constant changes in slope: 1, 1.5, 2.0, 2.5, and 3.0, respectively, in the Factor of Safety (FOS) value. However, the critical area of different conditions requires different safe FOS values. Thus, fulfilling the FOS value for different conditions ensures stability.
- In example above below 17, as the change in slope 1 in 1.5, 2.0, 2.5, and 3.0, the corresponding change in FOS (factor of safety) are Different for different condition, respectively,**(a)**Dry static condition in FOS corresponding to 0.96, 1.34, 1.64, 1.99. **(b)**Dry seismic condition in FOS corresponding to 0.78, 1.1, 1.32, 1.5. **(c)**1.0 m water logging static condition in FOS corresponding to 0.92, 1.3, 1.57, 1.95. **(d)**1.0 m water logging seismic condition in FOS corresponding to 0.82, 1.09, 1.39, 1.48. **(e)**Sudden draw down static condition in FOS corresponding to 0.93, 1.34, 1.61, 1.91. **(f)**Sudden draw down seismic condition in FOS corresponding to 0.80, 1.13, 1.4, 1.46. At constant height and depth, the change in slope 1 in 1.5, 2.0, 2.5 and 3.0 results in respective increments in the factor of safety (FOS).
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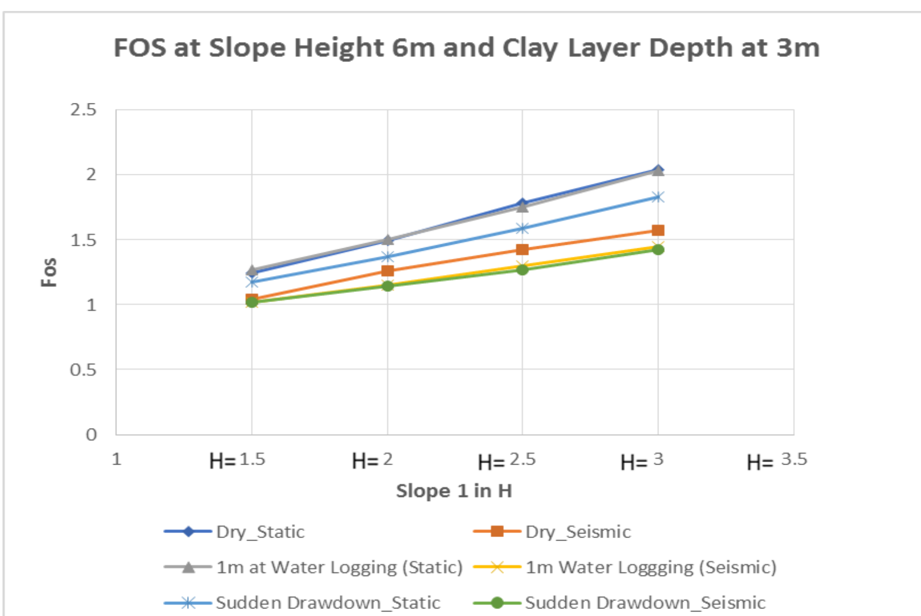

Figure 7 FOS at Slope height 6m and clay layer depth at 3m

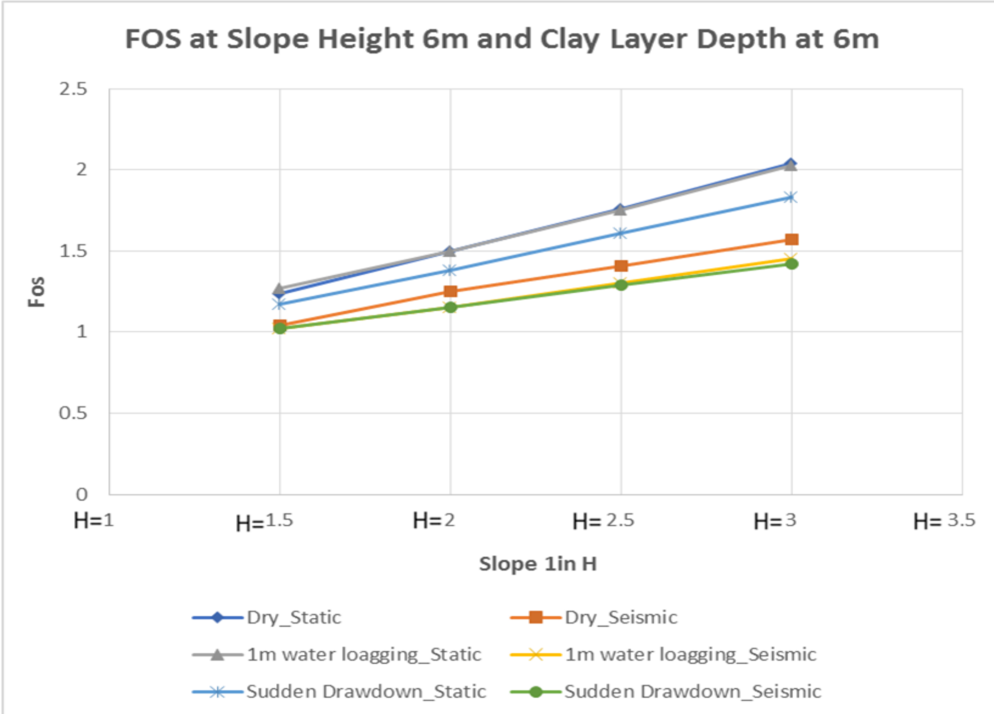

Figure 8 FOS at Slope height 6m and clay layer depth at 6m

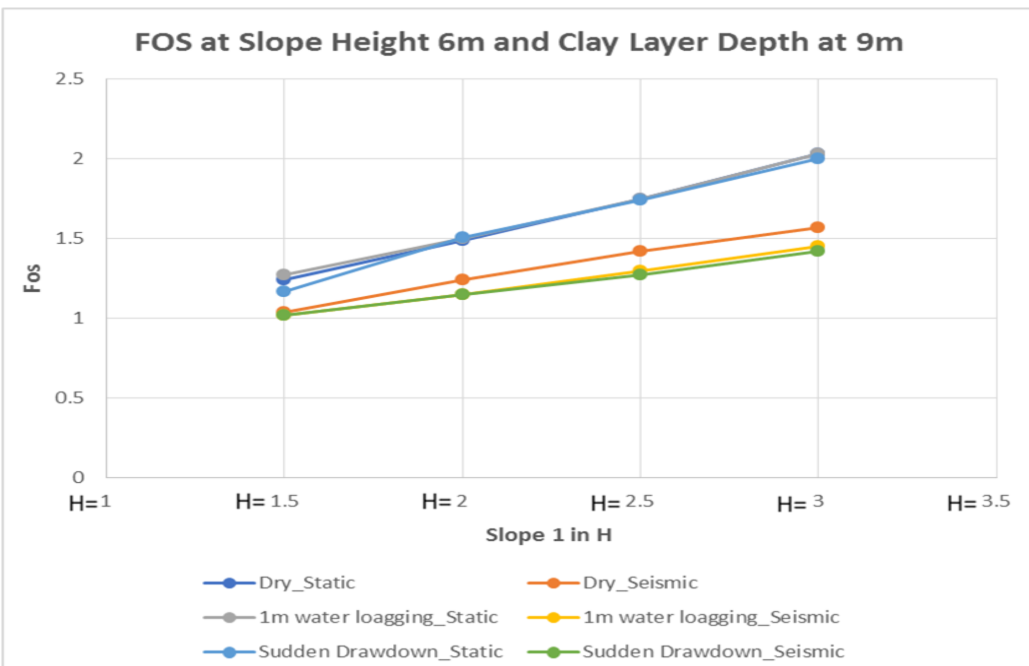

Figure 9 FOS at Slope height 6m and clay layer depth at 9m

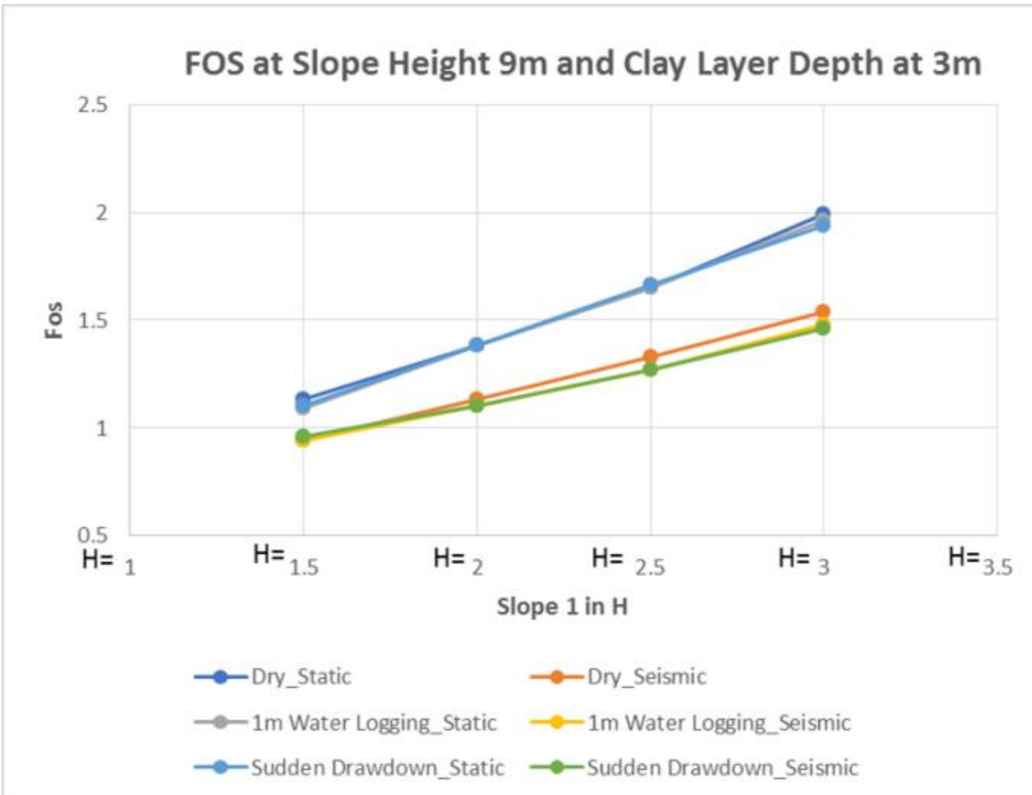

Figure 10 FOS at Slope height 9m and clay layer depth at 3m

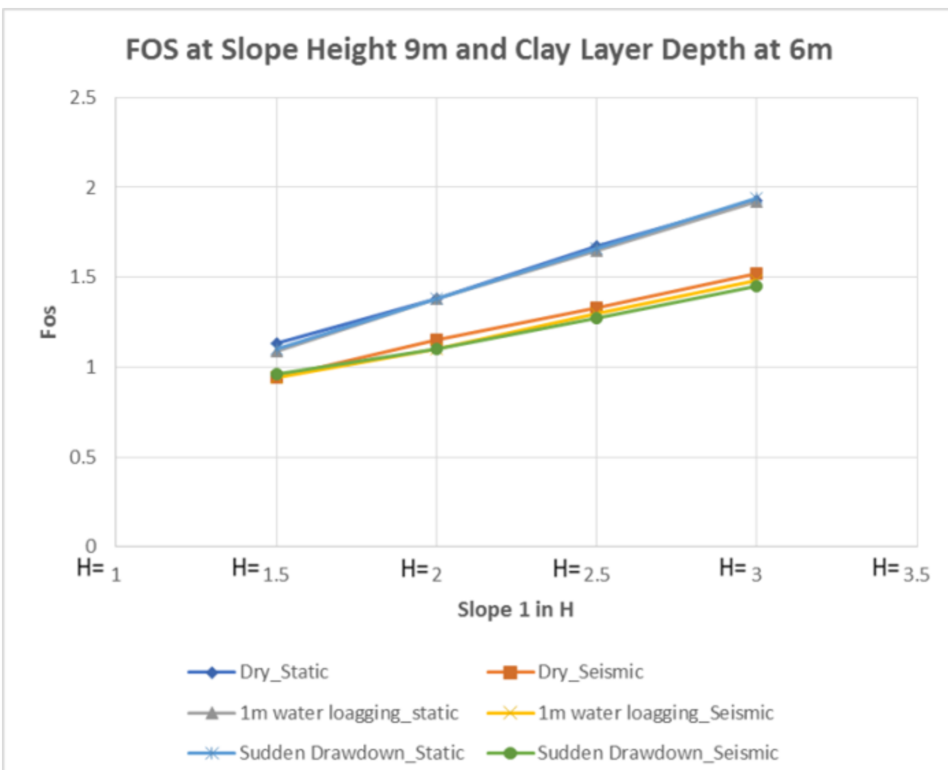

Figure 11 FOS at Slope height 9m and clay layer depth at 6m

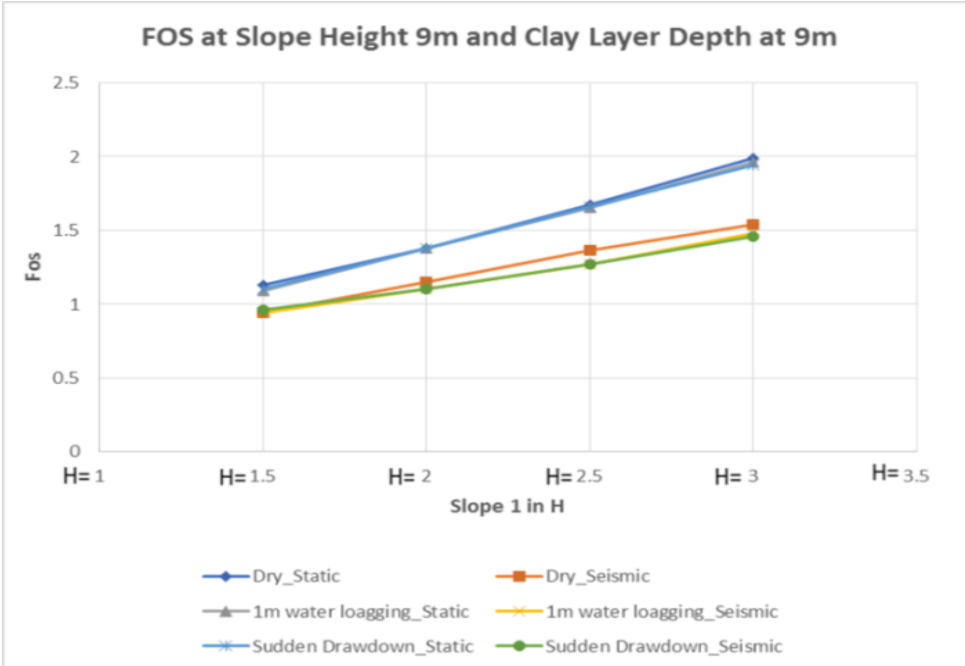

Figure 12 FOS at Slope height 9m and clay layer depth at 9m

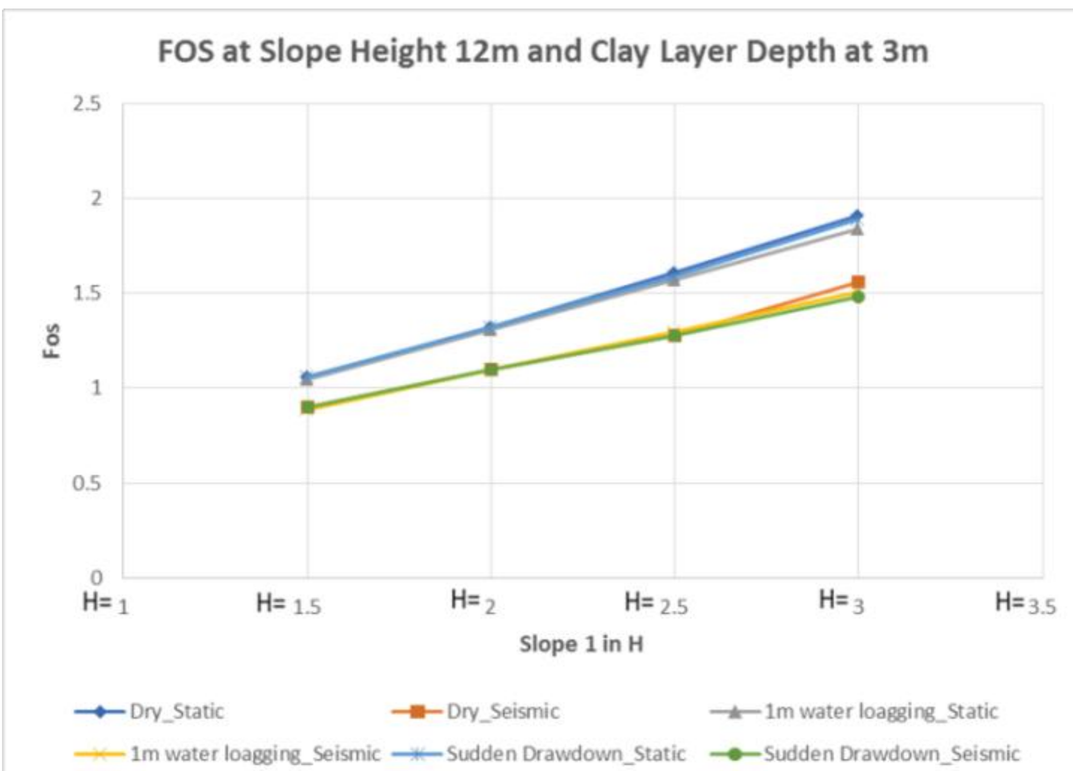

Figure 13 FOS at Slope height 12m and clay layer depth at 3m

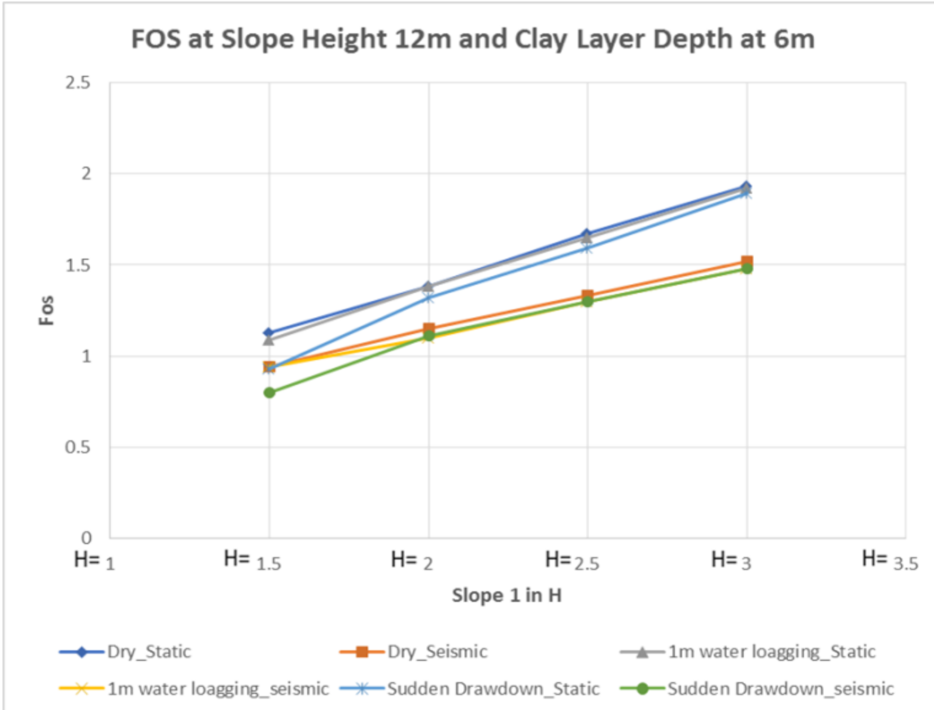

Figure 14 FOS at Slope height 12m and clay layer depth at 6m

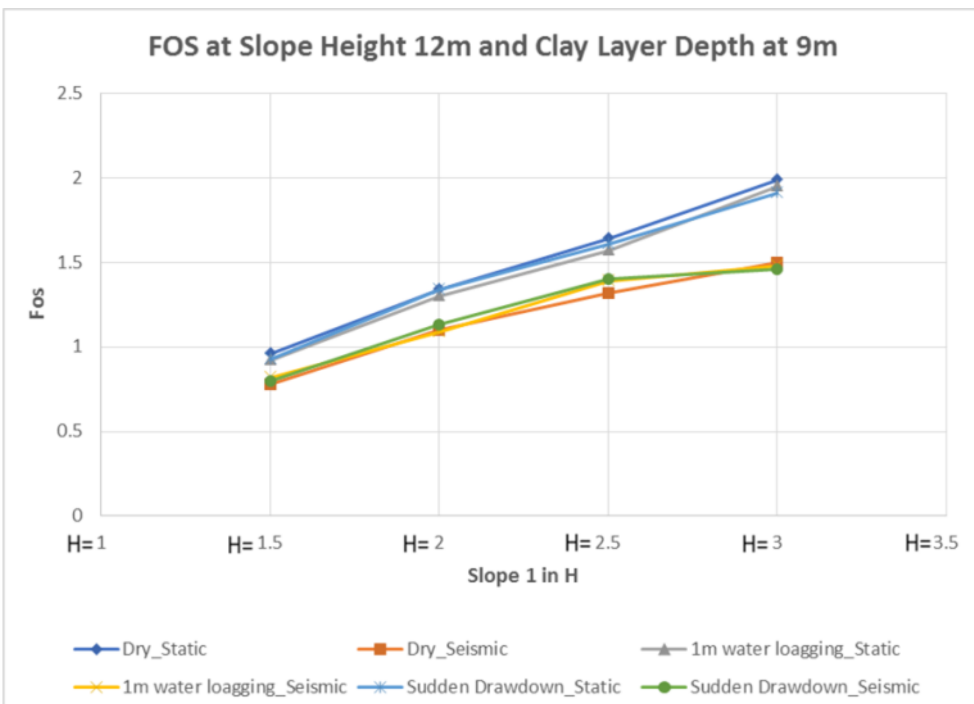

Figure 17 FOS at Slope height 12m and clay layer depth at 9m

CONCLUSIONS

- In this study, we aimed to assess the Factor of Safety (FOS) for slope stability on problematic soil embankments. We assumed that variations in the embankment's geometry, slope angle, height, and clay layer depth represent different conditions.

- For our research, we collected real field soil samples and conducted laboratory tests on them. Subsequently, we analyzed the data under different conditions to establish the real soil parameters.
- We calculated the FOS for slope stability on the problematic soil embankments and represented the safe FOS values for various conditions in this study.
- Additionally, we also compared the results using two software tools: Microsoft Excel and Geo 5. For some conditions, we exclusively used Geo 5 software for analysis. In our study, we applied the Bishop method within the Limit Equilibrium Method (LEM) to determine the FOS under different conditions.
- In our study using Geo 5 software, we analyzed various geometries and slope stability conditions to determine the safe Factor of Safety (FOS).
- Similarly, we examined different geometries and poor slope stability conditions in Geo 5 software, where we found the safe FOS.
- Additionally, we conducted a comparative study using Geo 5 software and Microsoft Excel for various geometries and slope stability conditions to determine the better software option for FOS.

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