A

MAJOR PROJECT REPORT

on

"Slope stability analysis of road embankment using Geostudio software"

Submitted in partial fulfilment of the requirements of the degree of

BACHELOR OF TECHNOLOGY

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DEPARTMENT OF CIVIL ENGINEERING

TECHNO INDIA NJR INSTITUTE OF TECHNOLOGY, UDAIPUR

SEPT- 2021

Department of Civil Engineering
Techno India NJR Institute of Technology, Udaipur

Certificate

This is to certify that this Major Project report entitled **"Slope stability analysis of road embankment using Geostudio software"** has completed the work under my supervision and guidance, henceapproved for submission in partial fulfillment for the award of Degree of Bachelor of Technology in Civil Engineering to the Department of Civil Engineering, Techno IndiaNJR Institute of Technology, Udaipur during academic session 2020-2021.

For Techno India NJR Institute of Technology
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Examiner certificate

This is to certify that the following students

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of final year B.Tech. (Civil Engineering), were examined for the project work entitled

“Slope stability analysis of road embankment using Geostudio software”

during the academic year 2020 – 2021 at Techno India NJR Institute of Technology,Udaipur

Remarks:Date:17.09.21

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Preface

Evaluation of the stability analysis for road embankment is not only a problem but also a challenge for Geotechnical Engineering. In manmade slope, the problem of choosing soil is an important role for stability condition. The main purpose of this study is to determine the stability of road fill embankment according to the factor of safety. In this study, the stability of slope was modeled in scenarios (different elevation, different inclination). Morgenstern price method and Bishop Method by Geo-studio was used in numerical analysis of slope.

The results of this study showed the suitability of slope in embankment construction according to the comparative study of factor of safety. In collected fill soil, slope (1:2) is most suitable for road fill embankment.

Different side slopes of embankment were analyzed with the SLOPE/W program. This program is intended for slope stability of embankment.

To fulfill one of the aims of the study, the LE based methods are compared based on the factor of safety (FOS) obtained for various elevation combinations. The comparison is mainly based on simplified slope geometry and assumed input parameters.

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ACKNOWLEDGMENT

We take this opportunity to record our sincere thanks to all who helped us to successfully complete this work. Firstly, we are grateful to our **supervisor Mr. Rakesh Yadav** for his invaluable guidance and constant encouragement, support and most importantly for giving us the opportunity to carry out this work.

We would like to express our deepest sense of gratitude and humble regards to our **Principal Mr. Pankaj Kumar Porwal** for giving invariable encouragement in our endeavours and providing necessary facility for the same. We are very thankful to our **Director Mr. Raj Shekhar Vyas** for encouraging us in this project work. Also a sincere thanks to all faculty members of CE, TINJRIT for their help in the project directly or indirectly.

Finally, we would like to thank my friends for their support and discussions that have proved very valuable for us. We are indebted to our parents for providing constant support, love and encouragement. We thank them for the sacrifices they made so that we could grow up in a learning environment. They have always stood by us in everything we have done, providing constant support, encouragement and love.

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Chapter 1

INTRODUCTION

GeoStudio enables you to combine analyses using different products into a single modeling project, using the results from one as the starting point for another. Multiple geometries, including 1D, 2D, and 3D geometries, may also be included in a single file.

GeoStudio provides many tools to define the model domain including coordinate import, geometric item copy-paste, length and angle feedback, region merge and split, and DWG/DXF file import. BUILD3D, GeoStudio's 3D geometry creation tool, offers a comprehensive suite of sketch features.

GeoStudio runs each analysis solver in parallel, allowing multiple analyses to be solved efficiently on computers with modern, multi-core processors. This saves substantial solve time especially for large 3D analyses.

GeoStudio provides powerful visualization tools, including graphing, contour plots, isolines or isosurfaces, animations, interactive data queries and data exports to spreadsheets for further analysis.

1.1 GEOSTUDIO SOFTWARE INCLUDES :-

BUILD 3D- Its powerful feature-based design allows for quick construction of 3D geotechnical models with complex topography or geology, sweeping tunnels or rivers, and 3D geometry from CAD files.

SLOPE/W – SLOPE/W is the leading slope stability software for soil and rock **slopes. SLOPE**/W can effectively analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, and loading conditions.

SEEP/W - SEEP/W is a powerful finite element software product for modeling groundwater flow in porous media. SEEP/W can model simple saturated steady-state problems or sophisticated saturated / unsaturated transient analyses with atmospheric coupling at the ground surface.

SIGMA/W - SIGMA/W is a powerful finite element software product for modelling stress and deformation in soil, rock, and structures. SIGMA/W analyses may range from simple linearelastic simulations to soil-structure interaction problems with nonlinear material models.

QUAKE/W - QUAKE/W is a powerful finite element software product for modeling earthquake liquefaction and dynamic loading. QUAKE/W determines the motion and excess pore-water pressures that arise due to earthquake shaking, blasts, or sudden impact loads.

TEMP/W - TEMP/W is a powerful finite element software product for modeling heat transfer and phase change in porous media. TEMP/W can analyze simple conduction problems to complex surface energy simulations with cyclical freeze-thaw.

CTRAN/W - CTRAN/W is a powerful finite element software product for modeling solute and gas transfer in porous media. CTRAN/W can be used to model simple diffusion-dominated systems through to complex advection-dispersion systems with first-order reactions.

AIR/W - AIR/W is a powerful finite element software product for modeling air transfer in mine waste and other porous media. AIR/W can be used to model a range of scenarios, from simple single phase air transfer problems to complex coupled air-water systems.

Chapter 2

SLOPE/W

SLOPE/W computes the factor of safety of earth and rock slopes. SLOPE/W can effectively analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, analysis methods and loading conditions. Using limit equilibrium, SLOPE/W can model heterogeneous soil types, complex stratigraphic and slip surface geometry, and variable pore-water pressure conditions using a large selection of soil models. Analyses can be performed using deterministic or probabilistic input parameters. Stresses computed by a finite element stress analysis may be used in addition to the limit equilibrium computations for the most complete slope stability analysis available. With this comprehensive range of features, SLOPE/W can be used to analyze almost any slope stability problem you will encounter in your geotechnical, civil, and mining engineering projects.

2.1 SLOPE/W can model almost any stability problem, including:

- Natural soil and rock slopes
- Construction excavations
- Earthen dams and levees
- Open-pit high walls
- Reinforced earth structures
- Slope stabilization design
- Slopes with surcharge or seismic loading
- Dam stability during rapid drawdown
- Partially and totally submerged slopes
- Unsaturated slopes subjected to infiltration
- Tailings dam stability

SLOPE/W is formulated in terms of moment and force equilibrium factor of safety equations, and supports a comprehensive list of limit equilibrium methods including Morgenstern-Price, Spencer, Bishop, Janbu, and the Ordinary method. The Morgenstern-Price method, for example, satisfies both force and moment equilibrium. This general formulation makes it easy to compute the factor of safety for a variety of methods and to readily understand the relationships and differences among all the methods.

SLOPE/W can also perform finite element stress-based stability and dynamic stability analyses. It uses finite element computed stresses from either SIGMA/W or QUAKE/W to calculate a stability factor by computing both total shear resistance and mobilized shear stress along the entire slip surface. SLOPE/W then computes a local stability factor for each slice.

2.2 Factor of safety methods for SLOPE/W :-

1. Bishop’s simplified method.
2. Janbu’s simplified method.
3. Spencer method.
4. Morgenstern-Price method.
5. Lowe-Karafiath method.

1. ***Bishop’s simplified method* -** In the 1950’s Professor Bishop at Imperial College in London devised a method which included interslice normal forces, but ignored the interslice shear forces. Bishop developed an equation for the normal at the slice base by summing slice forces in the vertical direction. The consequence of this is that the base normal becomes a function of the factor of safety. This in turn makes the factor of safety equation nonlinear (that is, FS appears on both sides of the equation) and an iterative procedure is consequently required to compute the factor of safety.
2. ***Janbu’s simplified method* -**The Janbu’s Simplified method is similar to the Bishop’s Simplified method except that the Janbu’s Simplified method satisfies only overall horizontal force equilibrium, but not overall moment equilibrium.
3. ***Spencer method* -**Spencer (1967) developed two factor of safety equations; one with respect to moment equilibrium and another with respect to horizontal force equilibrium. He adopted a constant relationship between the interslice shear and normal forces, and through an iterative procedure altered the interslice shear to normal ratio until the two factors of safety were the same. Finding the shearnormal ratio that makes the two factors of safety equal, means that both moment and force equilibrium are satisfied.
4. ***Morgenstern-Price method* -** Morgenstern and Price (1965) developed a method similar to the Spencer method, but they allowed for various user-specified interslice force functions.
5. ***Lowe-Karafiath method* -** The Lowe-Karafiath (L-K) method is essentially the same as the Corps of Engineers method, except that it uses another variation on the assumed interslice force function. The L-K method uses the average of the slice top (ground surface) and the base inclination.

The very large number of options in SLOPE/W can be somewhat confusing, especially when you are using the software for the first time. Some semblance of order can be made of these options by thinking of a problem in terms of five components. They are:

• Geometry – description of the stratigraphy and shapes of potential slip surfaces.

• Soil strength - parameters used to describe the soil (material) strength

• Pore-water pressure – means of defining the pore-water pressure conditions

• Reinforcement or soil-structure interaction – fabric, nails, anchors, piles, walls .

• Imposed loading – surcharges or dynamic earthquake loads

Chapter 3

HOW TO START

Steps to carry out slope stability through different methods :-

1. Open the Geostudio software.

2. Create a new file and select template.

3. Define the project name and other details.

4. Select the geometry and method of analysis.

5. Now make axes of graph by giving distance and elevation.
   {(Sketch – axes) from top toolbar.}

6. Make geometry by putting coordinates or by free hand.
   {(Sketch – lines) from top toolbar}

7. Now make regions of that particular geometry .
   {(Draw – region) from top toolbar}

8. Assign the material in particular region by putting the properties of that particular material.
   {(Draw – materials) from top toolbar}

9. Now make entry and exit points on surface.
   {(Draw – slip surface) from top toolbar}

10. Now click on start and after some seconds all the results are shown.

Chapter 4

METHOD OF ANALYSIS

IN THIS PROJECT WE WILL TAKING OUT THE RESULTS OF SLOPE STABILITY BY TWO METHODS :-

4.1Morgenstern-Price method.

4.2 Bishop's simplified method.

4.1 Morgenstern-Price Method : Morgenstern and Price (1965) developed a method similar to the Spencer method, but they allowed for various user-specified interslice force functions.

The interslice functions available in SLOPE/W for use with the Morgenstern-Price (M-P) method are:

- Constant
- Half-sine
- Clipped-sine
- Trapezoidal
- Data-point specified

Selecting the Constant function makes the M-P method identical to the Spencer method.

For illustrative purposes, let us look at a M-P analysis with a half-sine function for the same problem as was used to discuss the Spencer method. The result is presented in Figure 4.1.1.

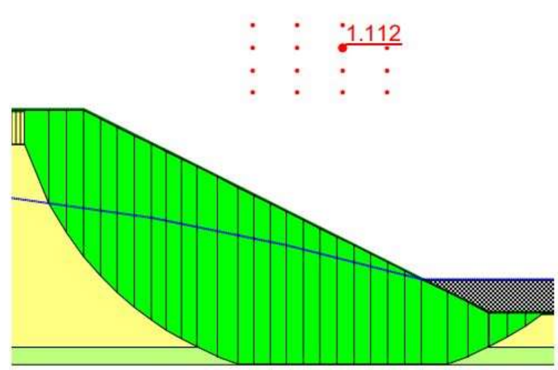


Figure 4.1.1 Result of Morgenstern and Price

Figure 4.1.2 shows how the moment and force factors of safety vary with lambda. The M-P Factor of safety occurs where the two curves across.

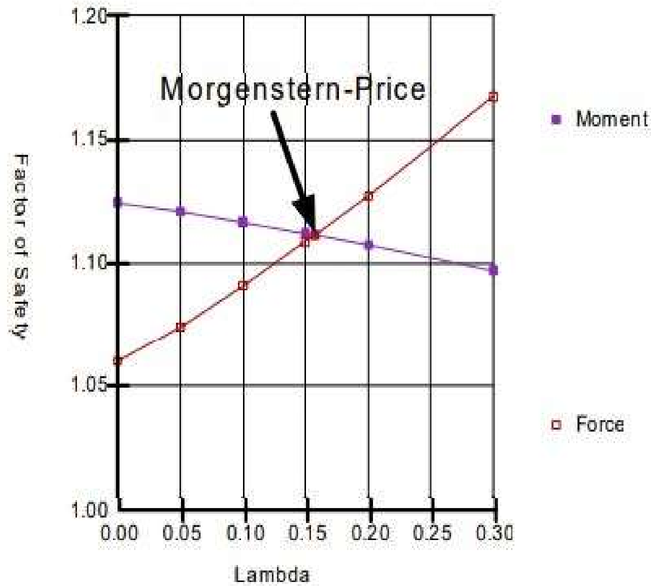


Figure 4.1.2 Morgenstern-price safety factor with half-sine function

The specified and applied interslice force functions are shown in Figure 4.1.3. The specified function has the shape of a half-sine curve. The applied function has the same shape, but is scaled down by a value equal to lambda which is 0.145.

Consider the forces on Slice 10 (Figure 4.1.4). The specified function at Slice 10 is 0.86 and lambda is 0.146. The normal force on the right side of Slice 10 is 316.62. The corresponding interslice shear then is,

$$X = E\lambda f(x)$$
$$X = 316.62 \times 0.146 \times 0.86$$
$$X = 39.7$$

This matches the interslice shear value on the free body diagram in Figure 4.1.4.

As with the Spencer method, the force polygon closure is very good with the M-P method, since both shear and normal interslice forces are included.

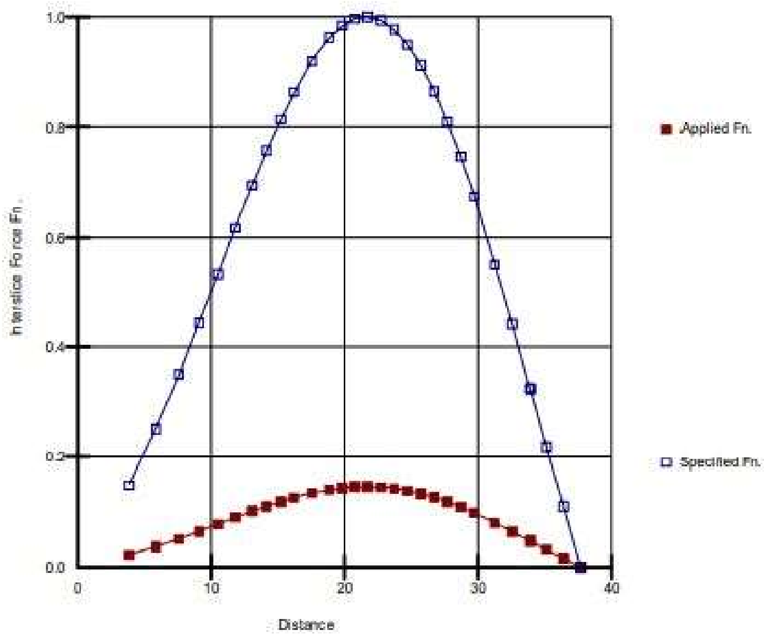


Figure 4.1.3 Interslice half-sine function

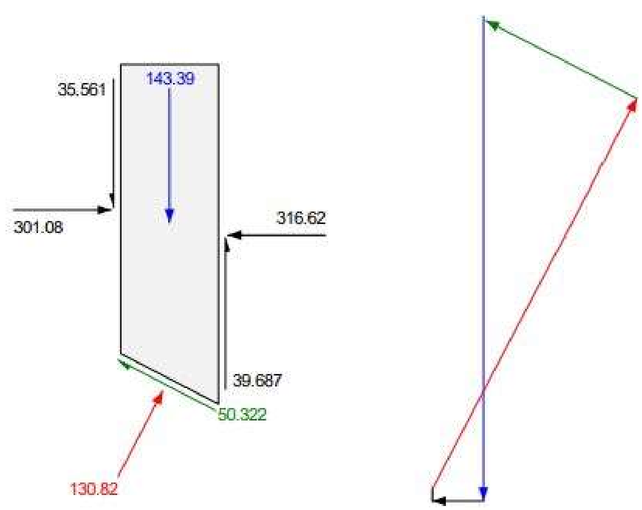


Figure 4.1.4 Free body and force polygon for morgenstern-price method

A significant observation in Figure 4.1.4 is that the M-P Factor of Safety (cross over point) is lower than the Bishop's Simplified Factor of Safety (moment equilibrium ay lambda zero). This is because the moment equilibrium curve has a negative slope. This example shows that a simpler method like Bishop's Simplified method that ignores interslice shear forces does not always err on the save side. A more rigorous method like the M-P method that considers both interslice shear and normal forces results in a lower factor of safety in this case.

In summary, the Morgenstern-Price method:

- Considers both shear and normal interslice forces,
- Satisfies both moment and force equilibrium, and
- Allows for a variety of user-selected interslice force function.

4.2 Bishop's Simplified Method : In the 1950's Professor Bishop at Imperial College in London devised a method which included interslice normal forces, but ignored the interslice shear forces. Bishop developed an equation for the normal at the slice base by summing slice forces in the vertical direction. The consequence of this is that the base normal becomes a function of the factor of safety. This in turn makes the factor of safety equation nonlinear (that is, FS appears on both sides of the equation) and an iterative procedure is consequently required to compute the factor of safety.

A simple form of the Bishop's Simplified factor of safety equation in the absence of any pore-water pressure is:

$$FS = \frac{1}{\sum W \sin\alpha} \Sigma \left[\frac{c\beta + W \tan\phi - \frac{c\beta}{FS} \sin\alpha \tan\phi}{m_\alpha} \right]$$

FS is on both sides of the equation as noted above. The equation is not unlike the Ordinary factor of safety equation except for the m_a term, which is defined as:

$$m_\alpha = \cos\alpha + \frac{\sin\alpha \tan\phi}{FS}$$

To solve for the Bishop's Simplified factor of safety, it is necessary to start with a guess for FS. In SLOPE/W, the initial guess is taken as the Ordinary factor of safety. The initial guess for FS is used to compute mα and then a new FS is computed. Next the new FS is used to compute mα and then another new FS is computed. The procedure is repeated until the last computed FS is within a specified tolerance of the previous FS. Fortunately, usually it only takes a few iterations to reach a converged solution.

Now if we examine the slice free body diagrams and forces polygons for the same slices as for the Ordinary method above, we see a marked difference (Figure 4.2.1). The force polygon closure is now fairly good with the addition of the interslice normal forces. There are no interslice shear forces, as assumed by Bishop, but the interslice normal forces are included.

In a factor of safety versus lambda plot, as in Figure 3-8, the Bishop's Simplified factor of safety falls on the moment equilibrium curve where lambda is zero (FS = 1.36). Recall that

$$X = E\lambda f(x)$$

The interslice shear is not included by making lambda zero.

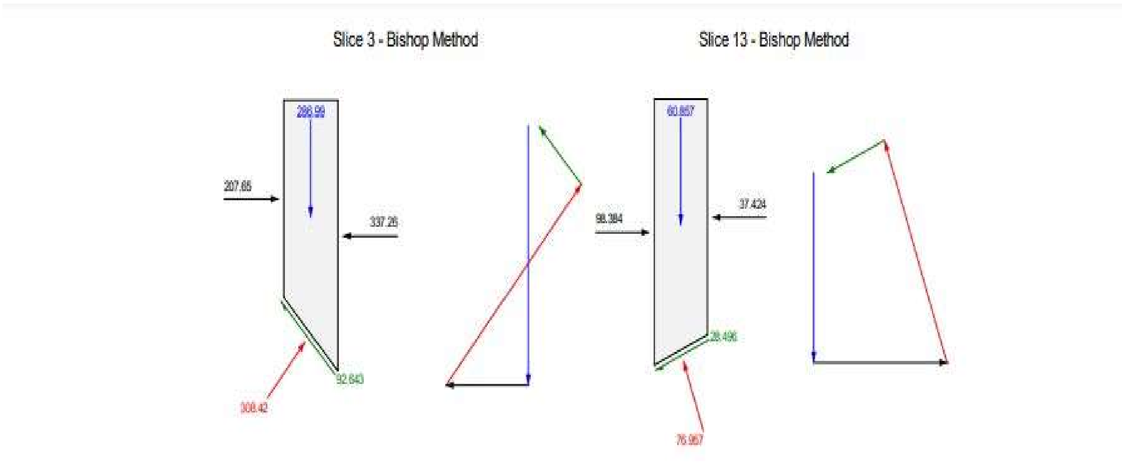


Figure 4.2.1 Free body diagram and force polygon for the Bishop's Simplified method

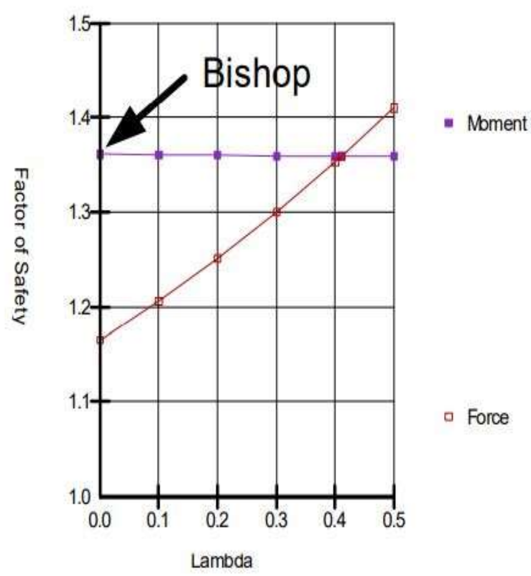


Figure 4.2.2 Bishop's Simplified Factor of safety

Note that in this case the moment factor of safety (Fm) is insensitive to the interslice forces. The reason for this, as discussed in the previous chapter, is that no slippage is required between the slices for the sliding mass to rotate. This is not true for force equilibrium and thus the force factor of safety (Ff) is sensitive to the interslice shear.

In summary, the Bishop's Simplified method,

(1) considers normal interslice forces, but ignores interslice shear forces, and

(2) Satisfies over all moment equilibrium, but not overall horizontal force equilibrium.

Chapter 5

ANALYSIS

In this analysis we will find the slope stability of road embankments by 2 methods (Morgenstern-Price method& Bishop's simplified method) of slope/w using Geostudio software.

In this analysis we will find the slope stability by taking different slopes and elevations :-

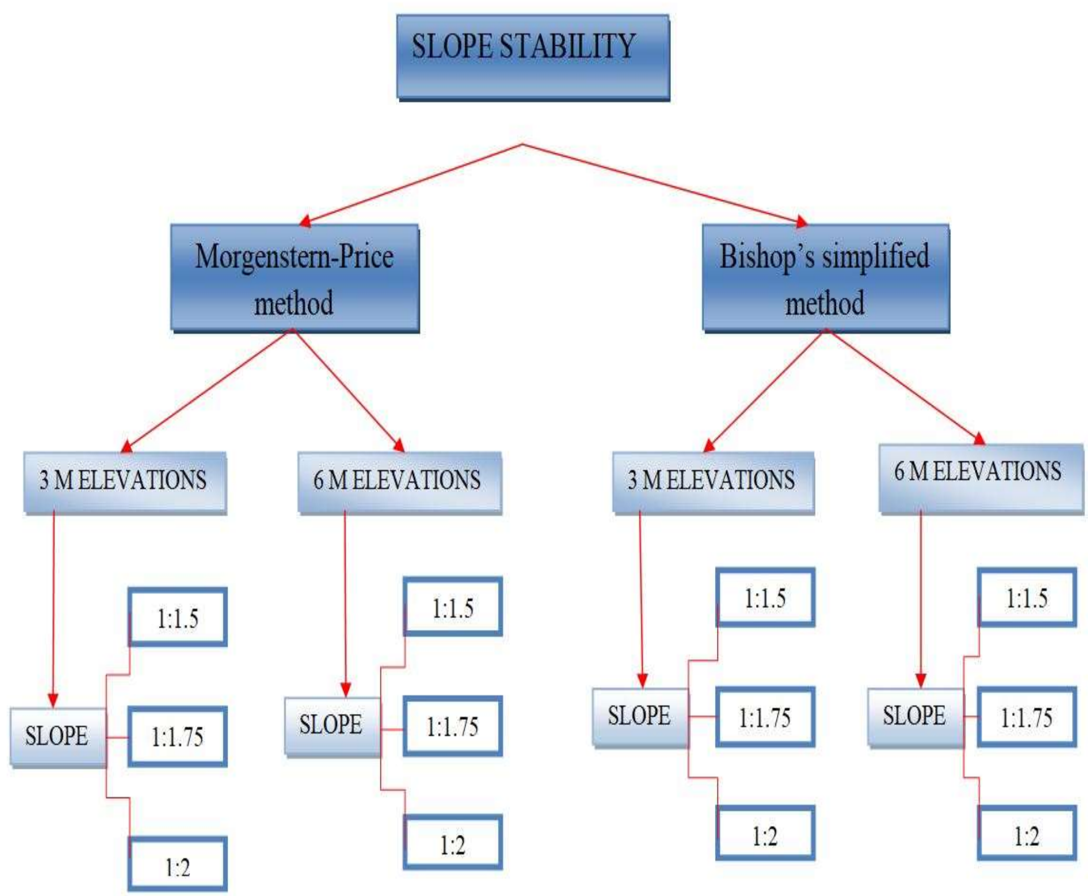


Figure 5 Table of analysis of different methods

RESULTS :

5.1 Morgenstern-Price method for Elevation 3M

5.1(1) SLOPE 1:1.5

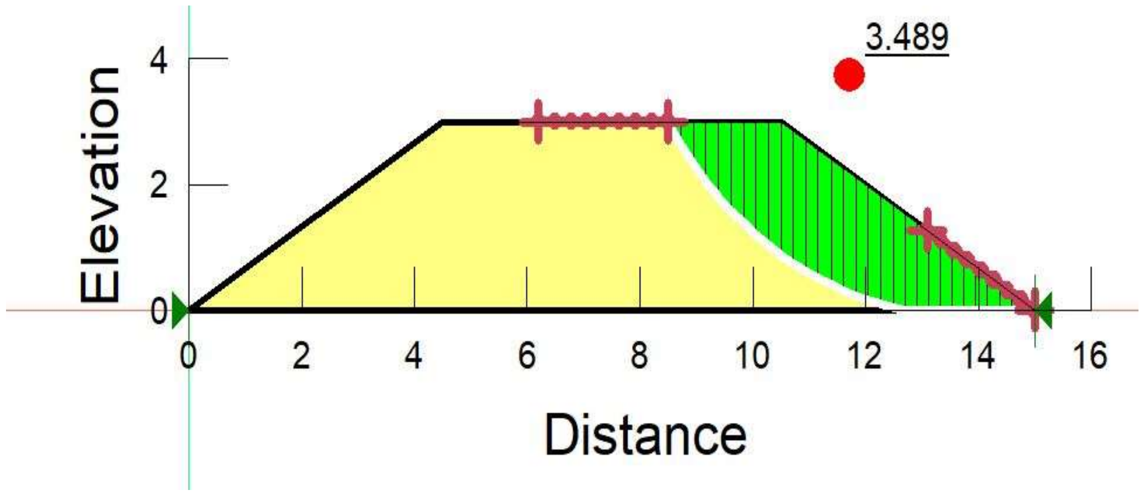


Figure 5.1 (1.1) Morgenstern-Price method factor of safety

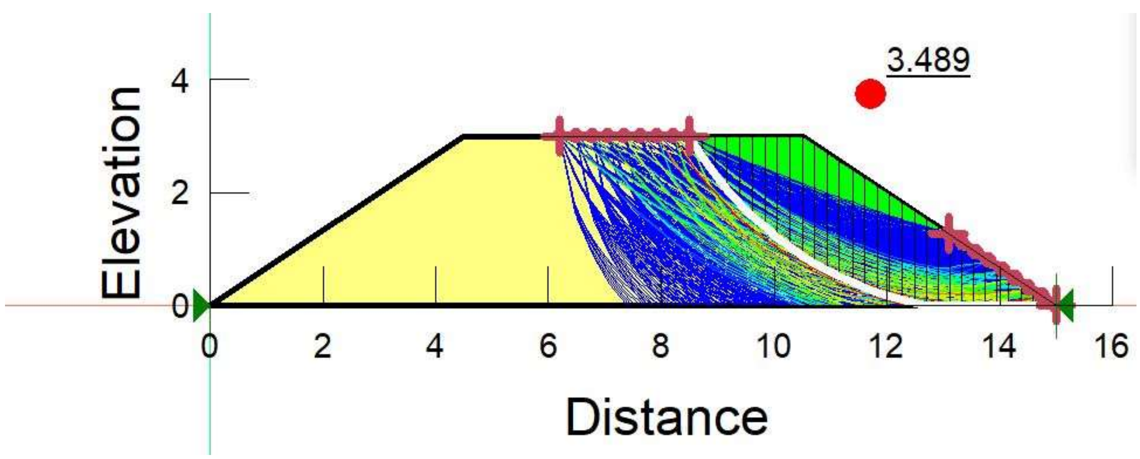


Figure 5.1(1.2) Morgenstern-Price method factor of safety with all slips

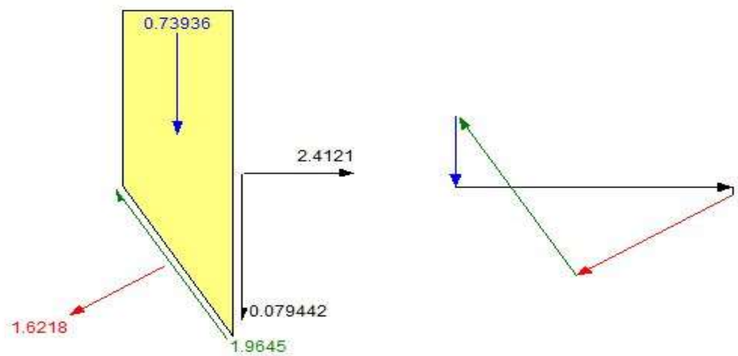


Figure 5.1(1.3) Free body and force polygon

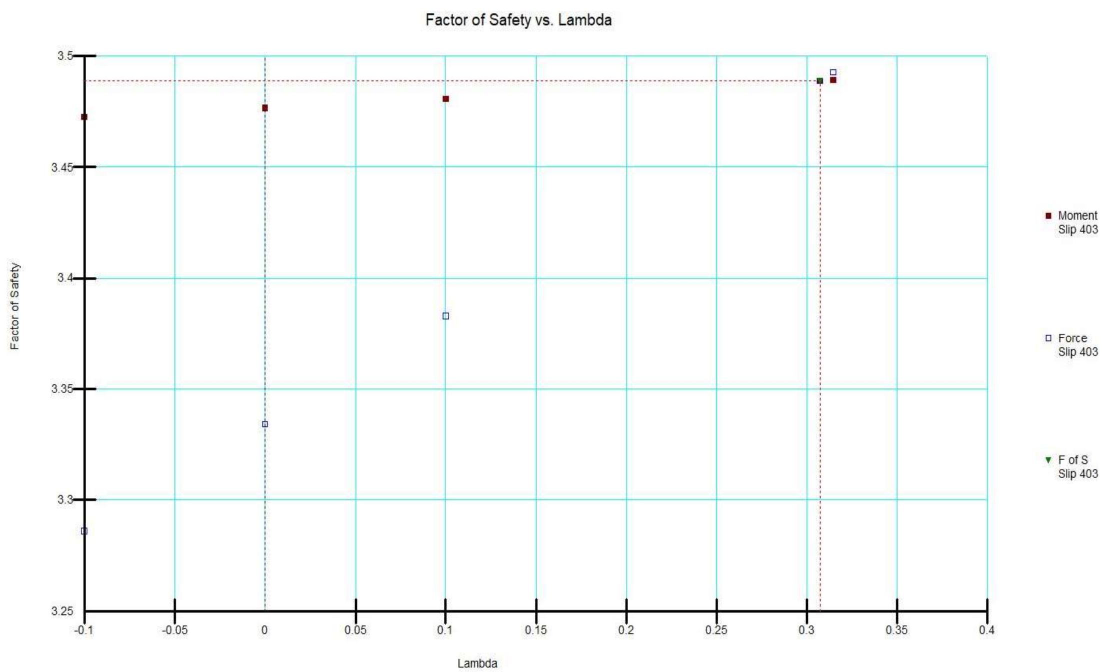


Figure 5.1(1.4) Factor of safety versus lambda (λ) plot

5.1(2) SLOPE 1:1.75

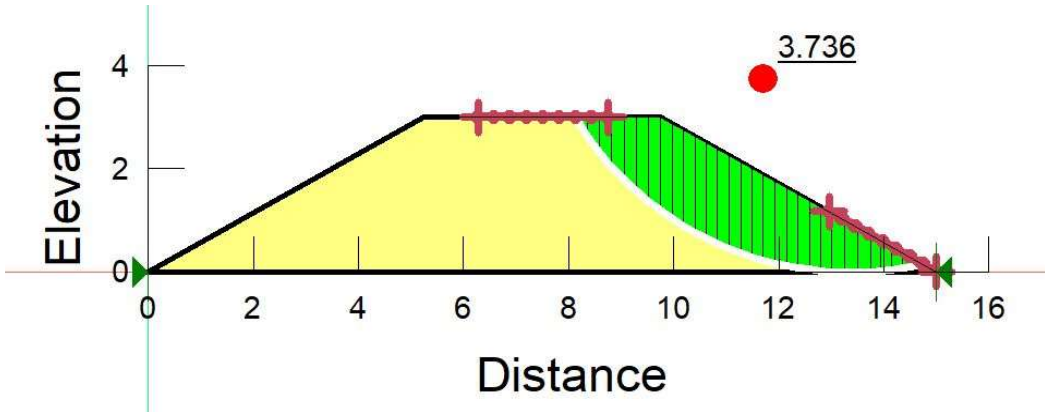


Figure 5.1(2.1) Morgenstern-Price method factor of safety

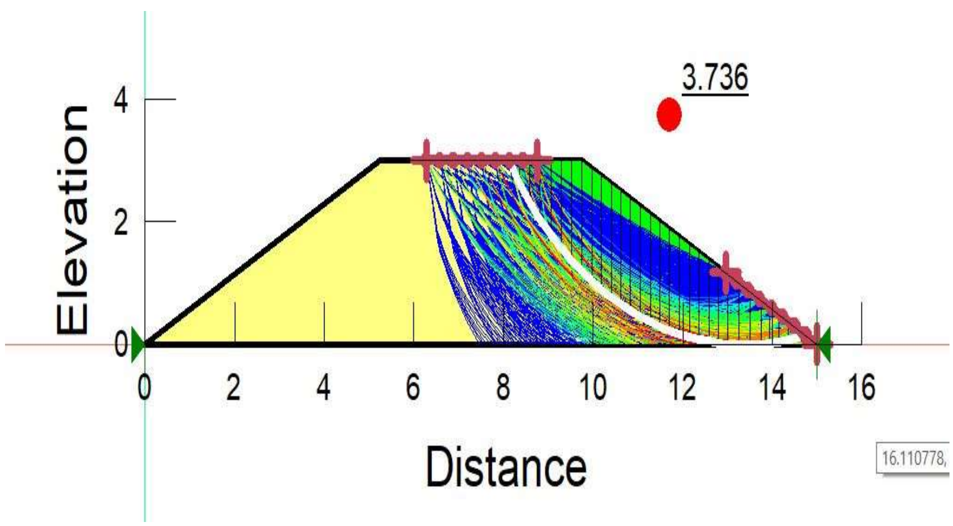


Figure 5.1(2.2) Morgenstern-Price method factor of safety with all slips

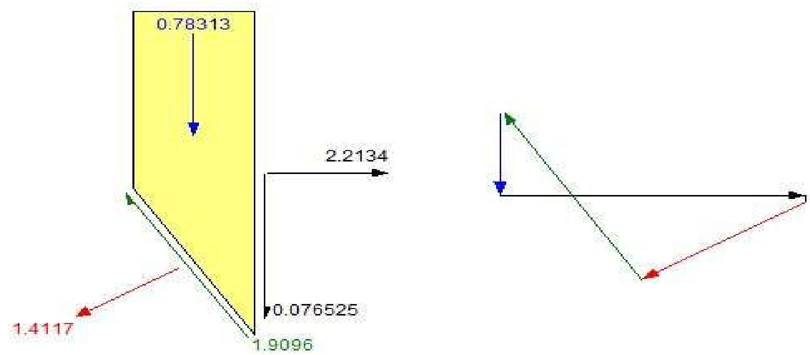


Figure 5.2(2.3) Free body and force polygon

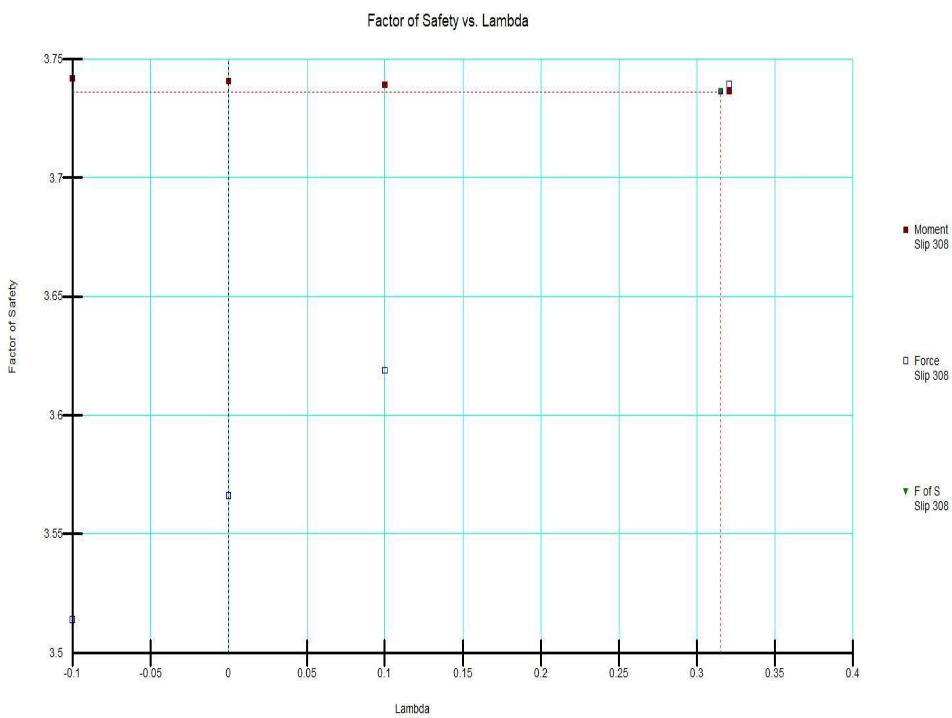


Figure 5.2(2.4) A factor of safety versus lambda (λ) plot

5.1(3) SLOPE 1:2

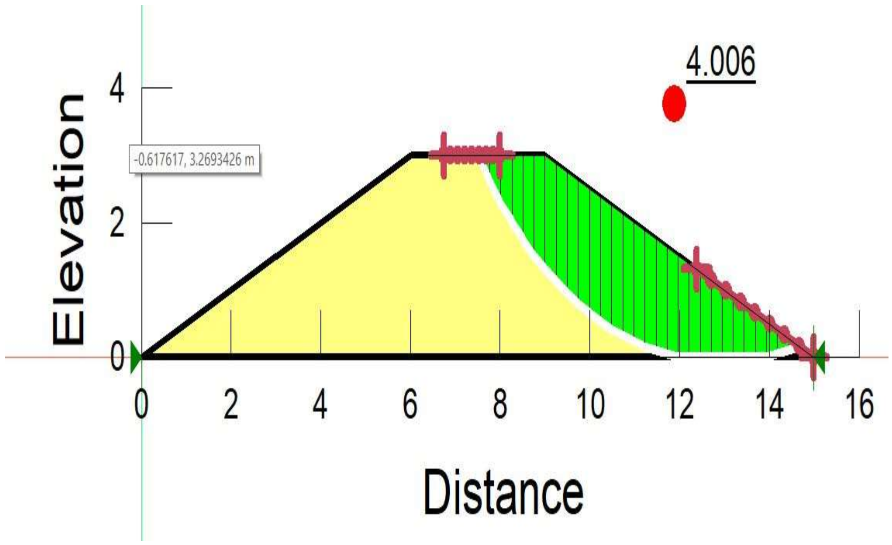


Figure 5.1(3.1) Morgenstern-Price method factor of safety

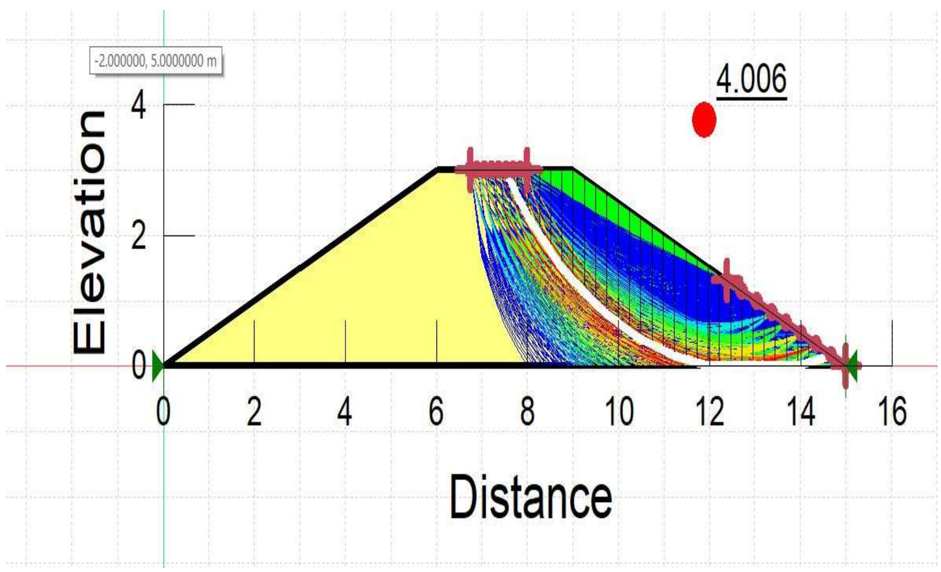


Figure 5.1(3.2) Morgenstern-Price method factor of safety with all slips

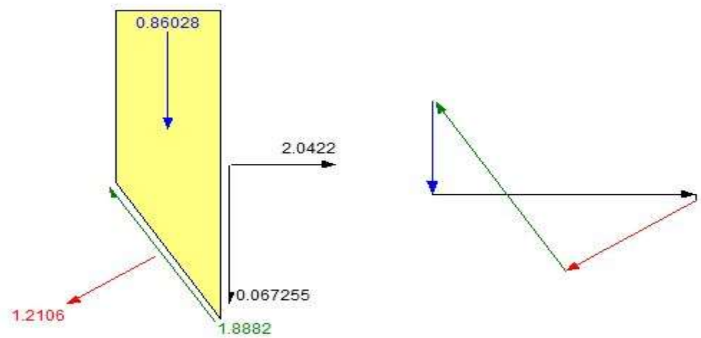


Figure 5.1(3.3) Free body and force polygon

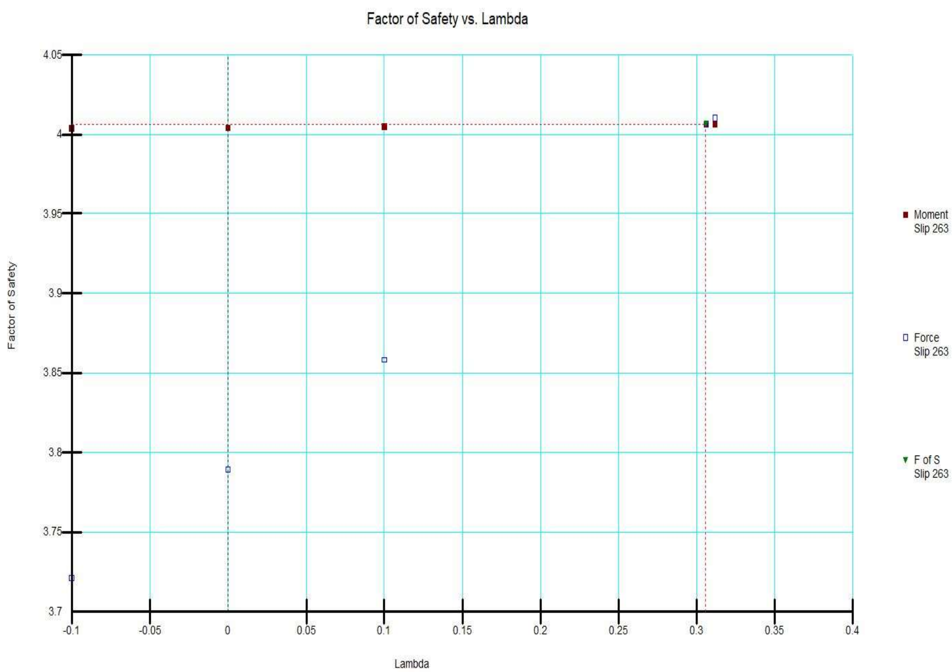


Figure 5.1(3.4) A factor of safety versus lambda (λ) plot

5.2 Morgenstern-Price method for Elevation 6M

5.2 (1) SLOPE 1:1.5

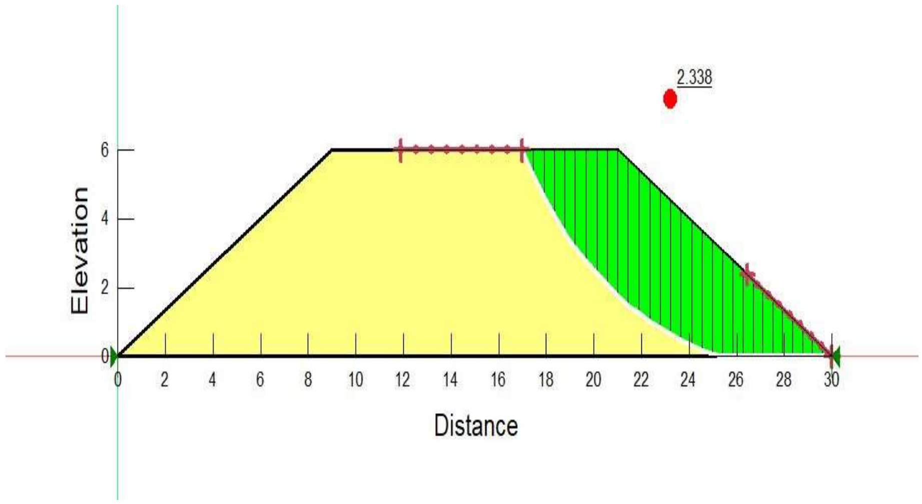


Figure 5.2(1.1) Morgenstern-Price method factor of safety

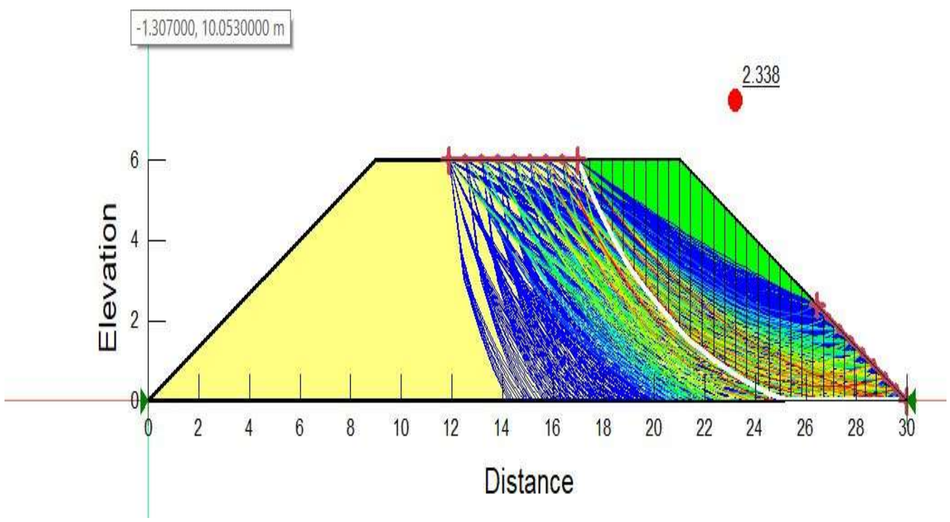


Figure 5.2(1.2) Morgenstern-Price method factor of safety with all slips

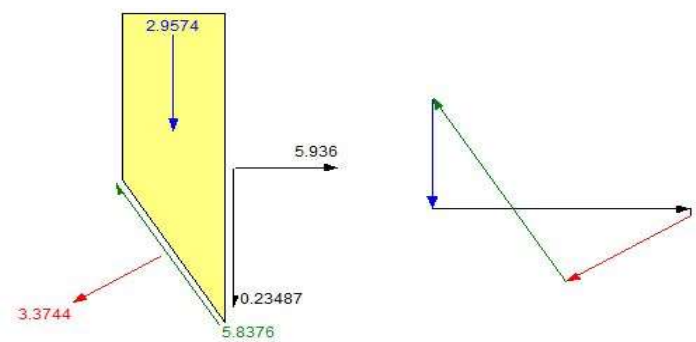


Figure 5.2(1.3) Free body and force polygon

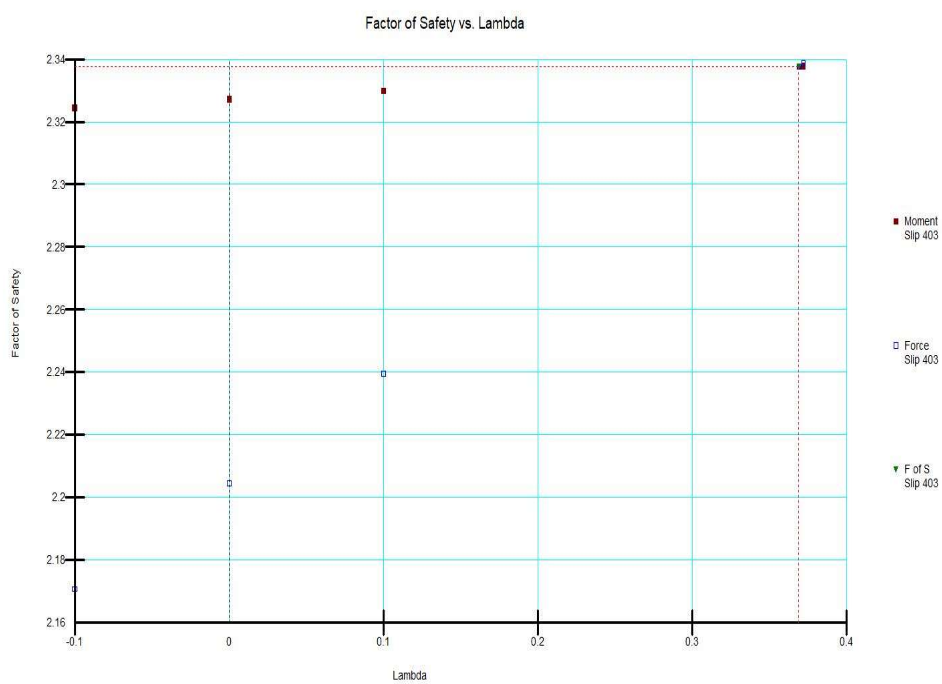


Figure 5.2(1.4) - A factor of safety versus lambda (λ) plot

5.2(2) SLOPE 1:1.75

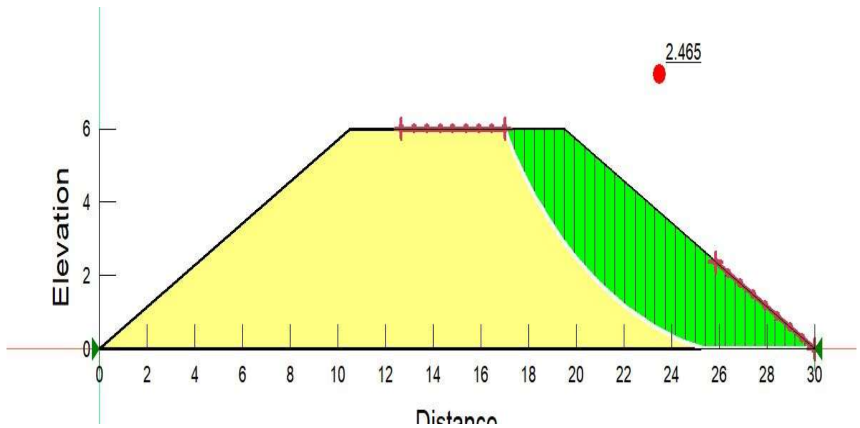


Figure 5.2(2.1) Morgenstern-Price method factor of safety

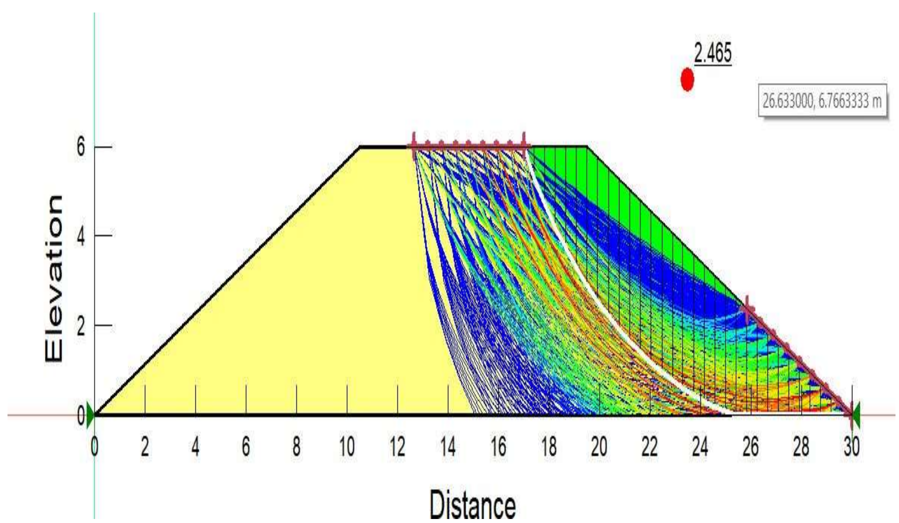


Figure 5.2(2.2) Morgenstern-Price method factor of safety with all slips

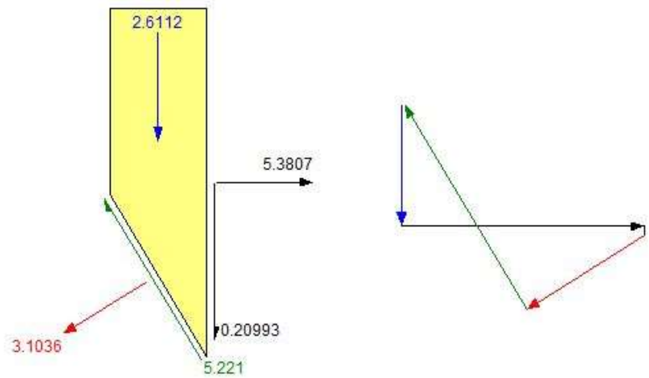


Figure 5.2(2.3) Free body and force polygon

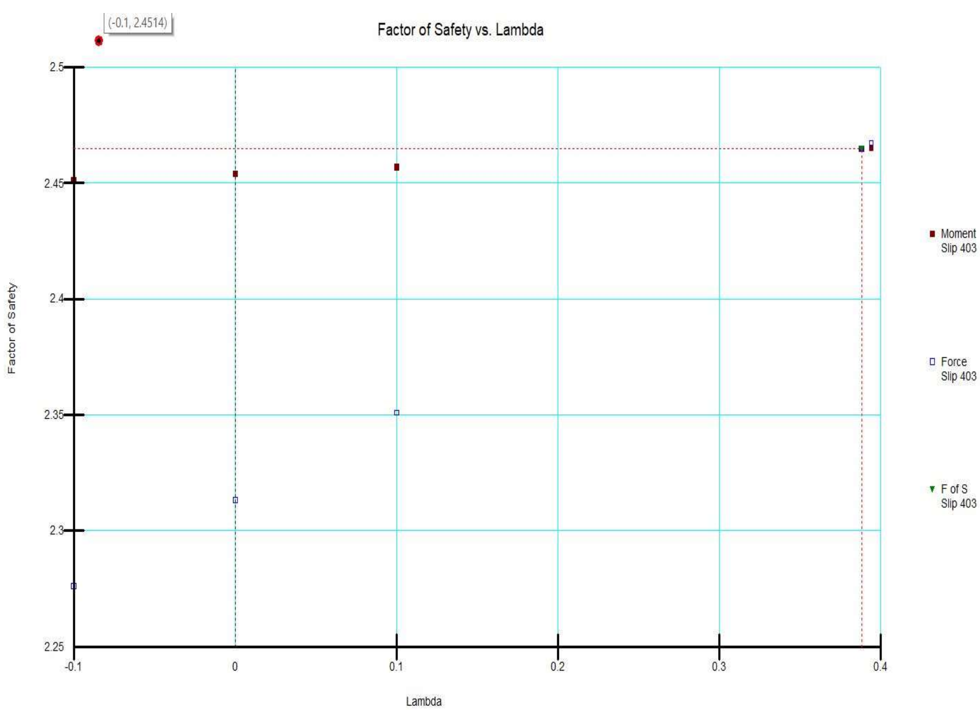


Figure 5.2(2.4) A factor of safety versus lambda (λ) plot

__5.2(3) SLOPE 1:2__

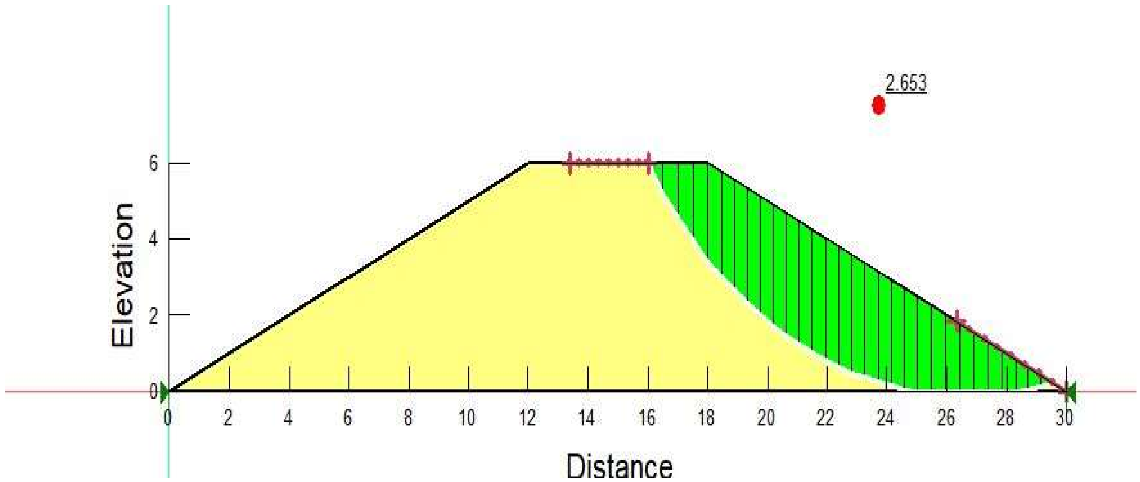


Figure 5.2(3.1) Morgenstern-Price method factor of safety

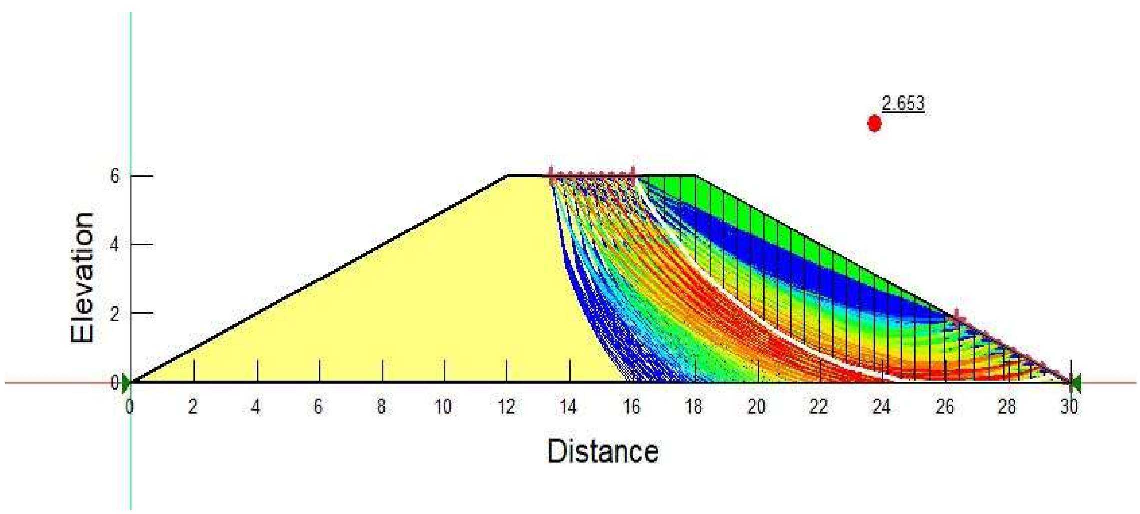


Figure 5.2(3.2) Morgenstern-Price method factor of safety with all slips

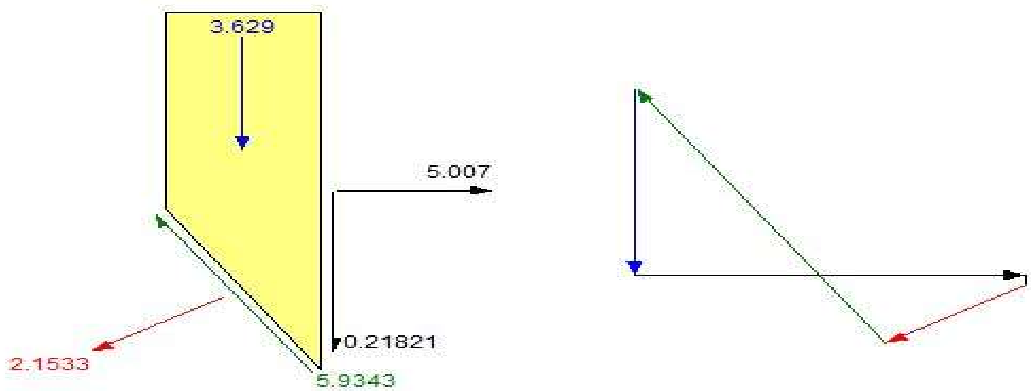


Figure 5.2(3.3) Free body and force polygon

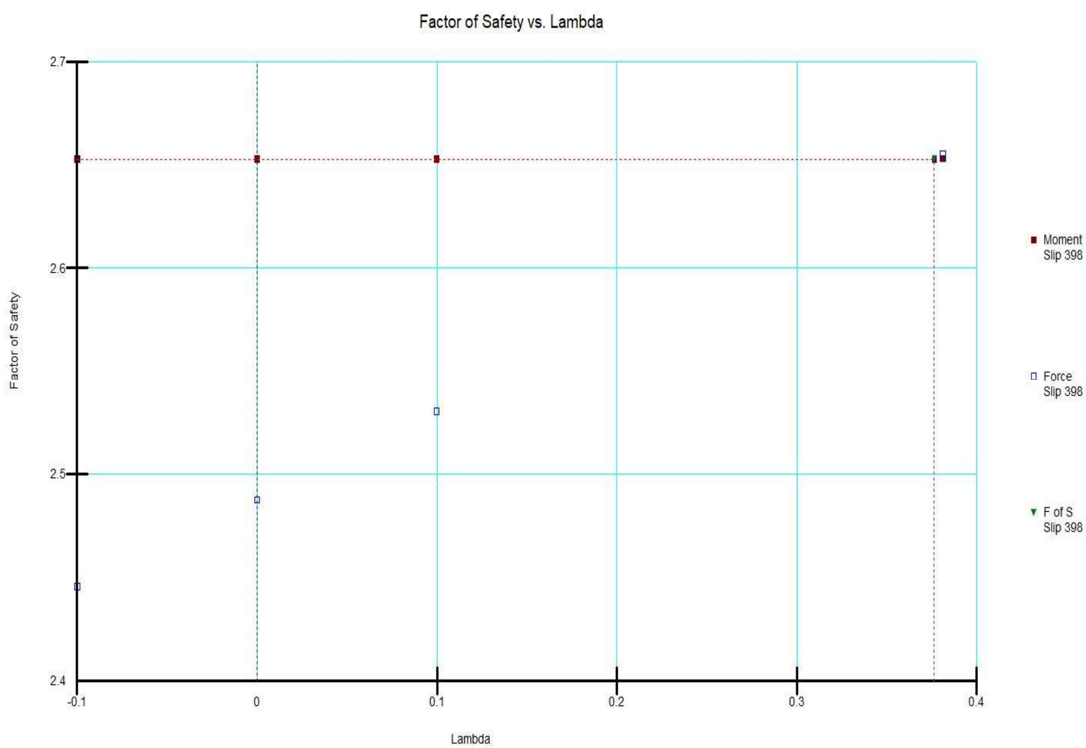


Figure 5.2(3.4) A factor of safety versus lambda (λ) plot

5.3 Bishop Method for Elevation 3m

5.3(1) SLOPE 1:1.5

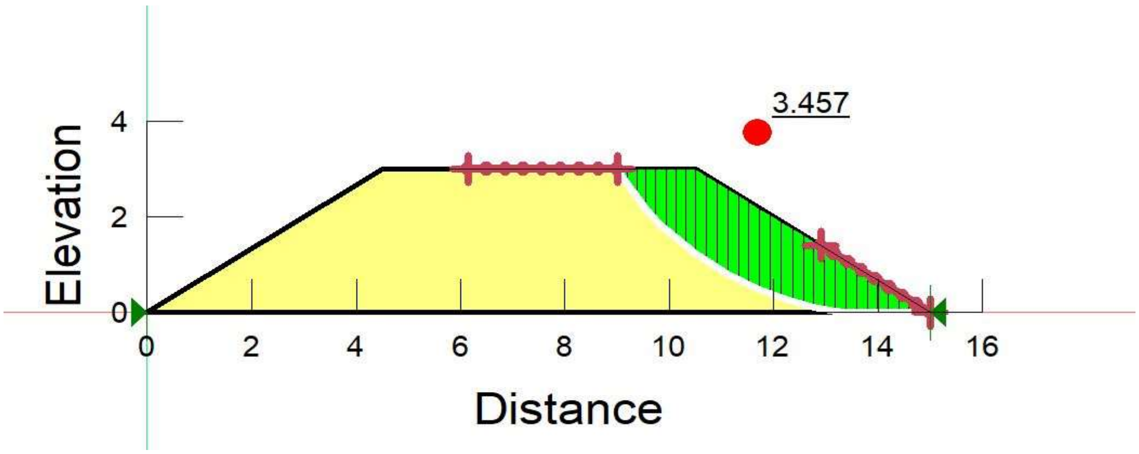


Figure 5.3(1.1) Bishop method factor of safety

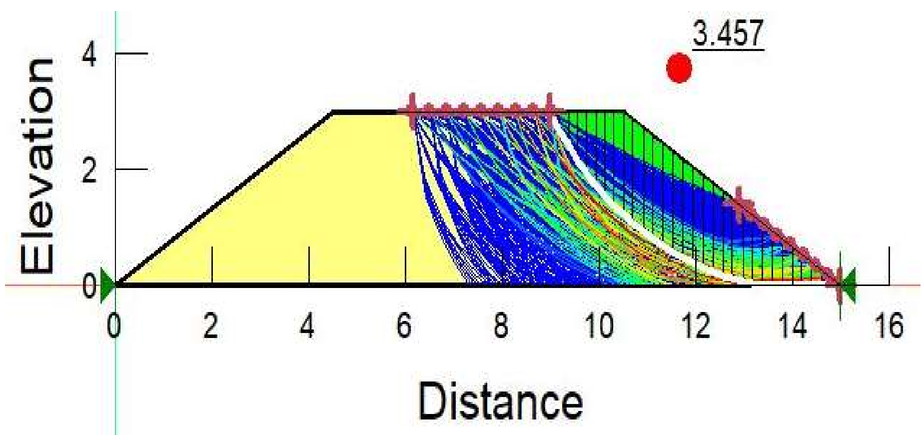


Figure 5.3(1.2) Bishop method factor of safety with all slips

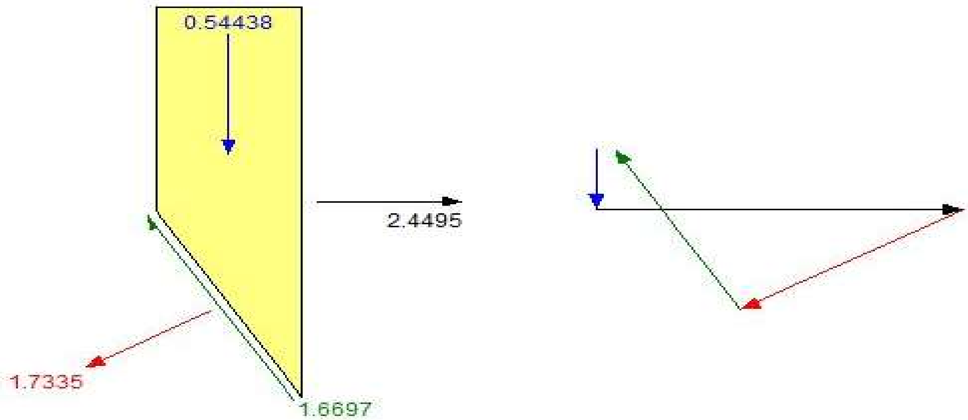


Figure 5.3(1.3) Free body and force polygon

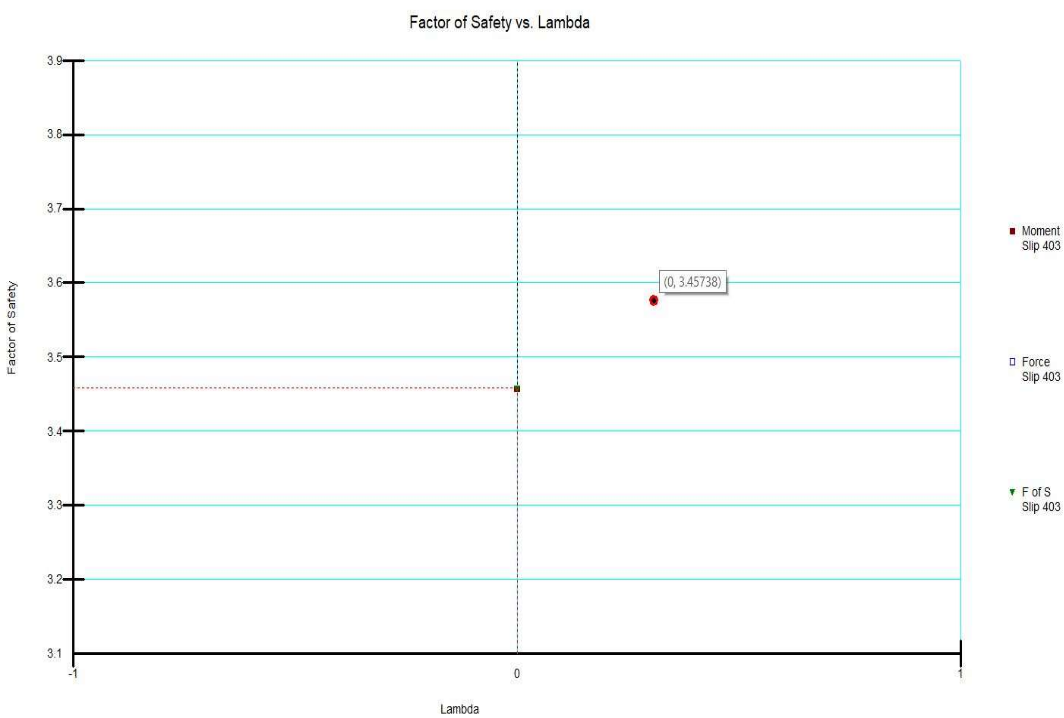


Figure 5.3(1.4) A factor of safety versus lambda (λ) plot

5.3(2) SLOPE 1.175

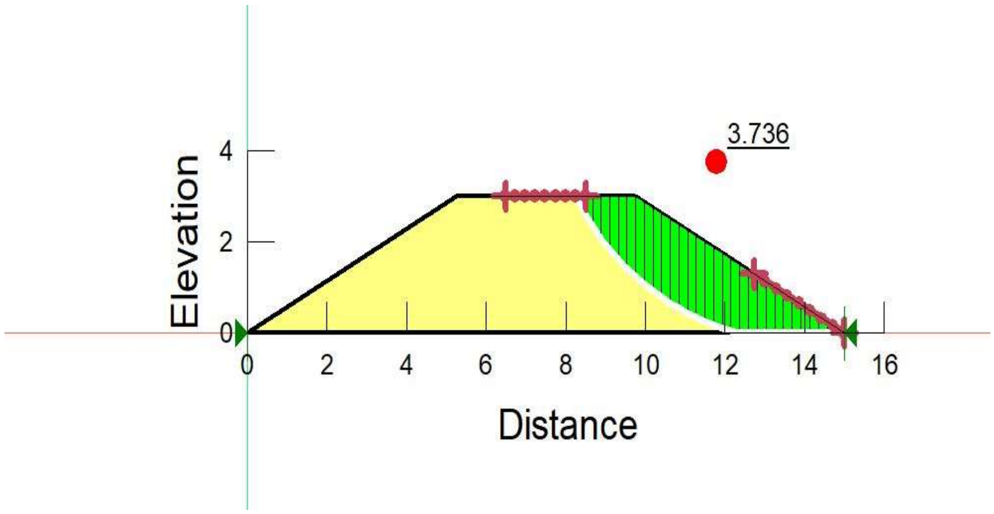


Figure 5.3(2.1) Bishop method factor of safety

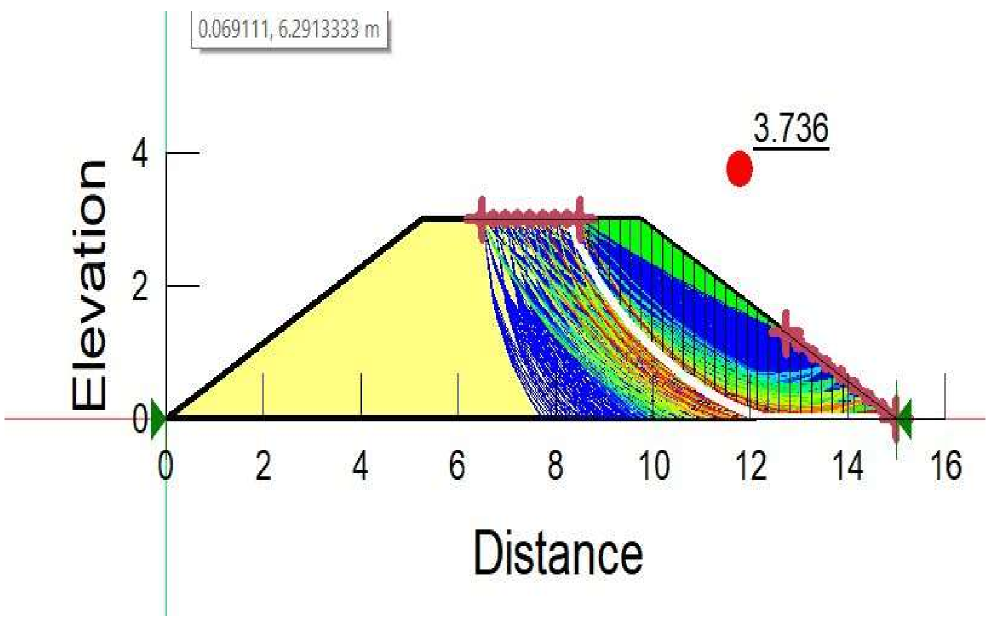


Figure 5.3(2.2) Bishop method factor of safety with all slips

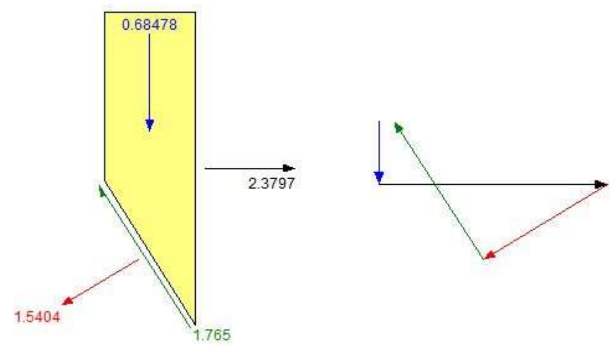


Figure 5.3(2.3) Free body and force polygon

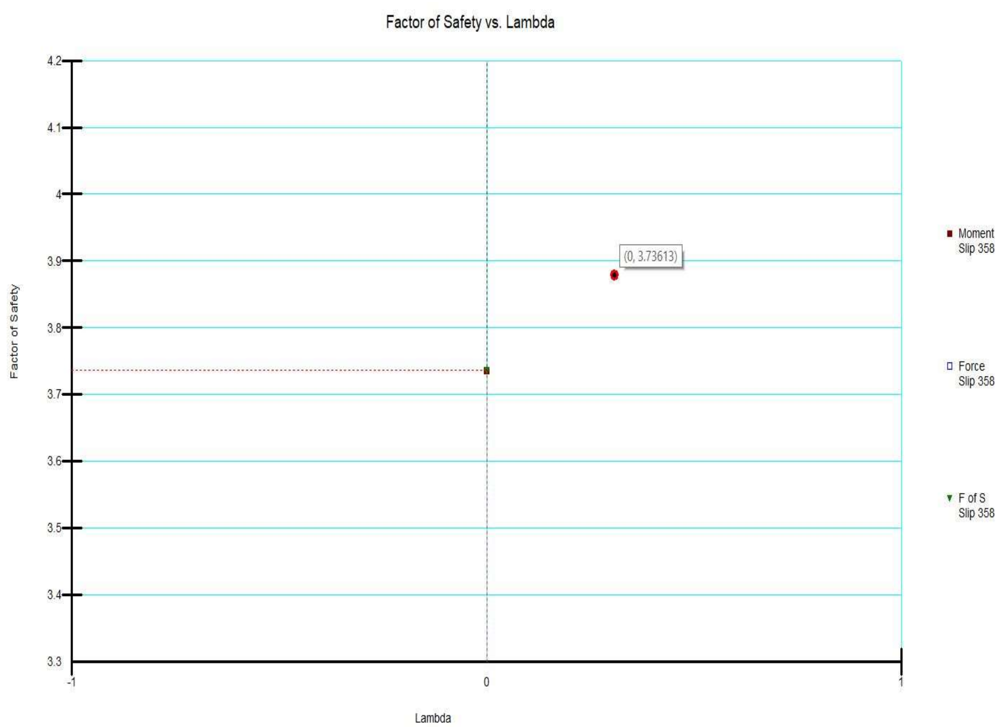


Figure 5.3(2.4) A factor of safety versus lambda (λ) plot

5.3(3) SLOPE 1:1.2

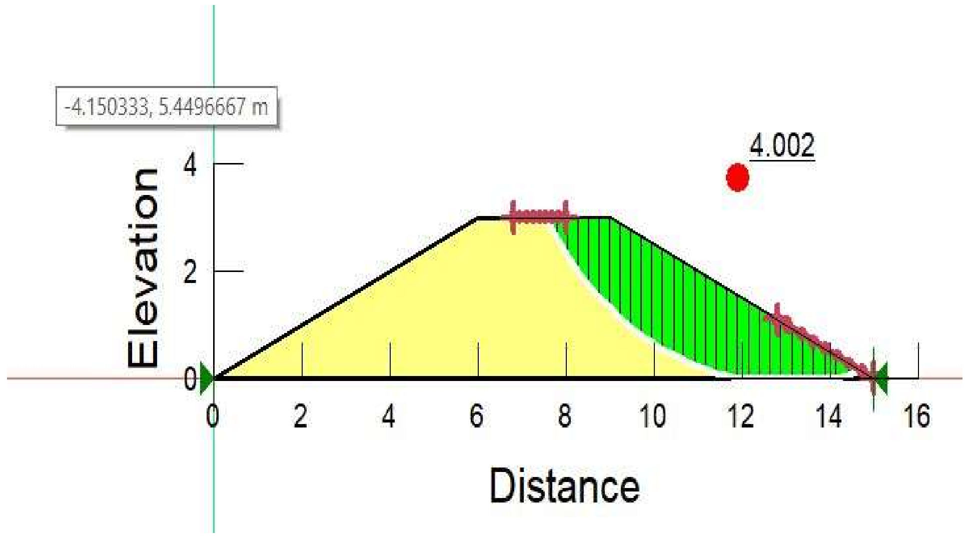


Figure 5.3(3.1) Bishop method factor of safety

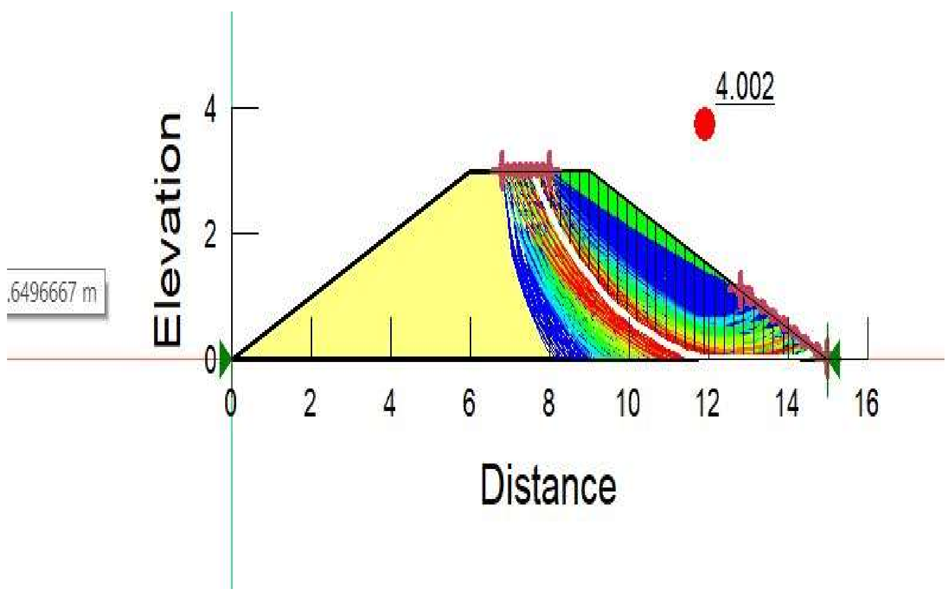


Figure 5.3(3.2) Bishop method factor of safety with all slips

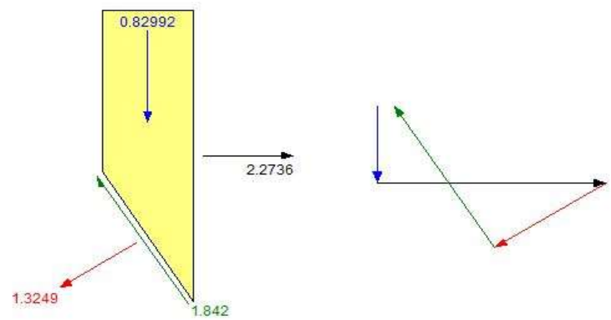


Figure 5.3(3.3) Free body and force polygon

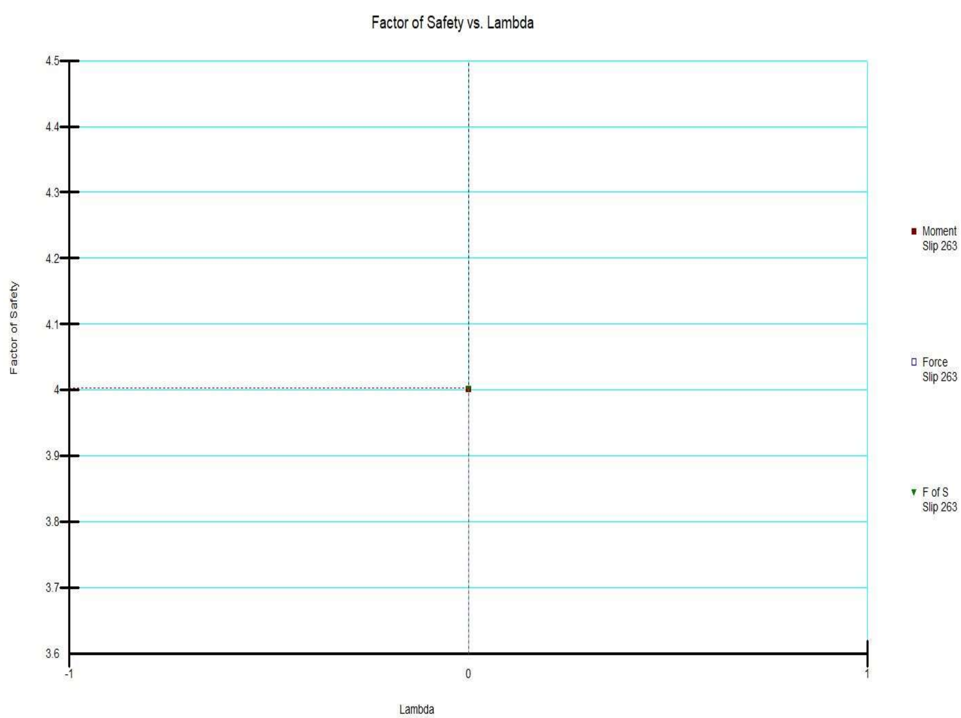


Figure 5.3(3.4) A factor of safety versus lambda (λ) plot

5.4 Bishop Method for Elevation 6m

5.4(1) SLOPE 1:1.5

Figure 5.4(1.1) Bishop Method factor of safety

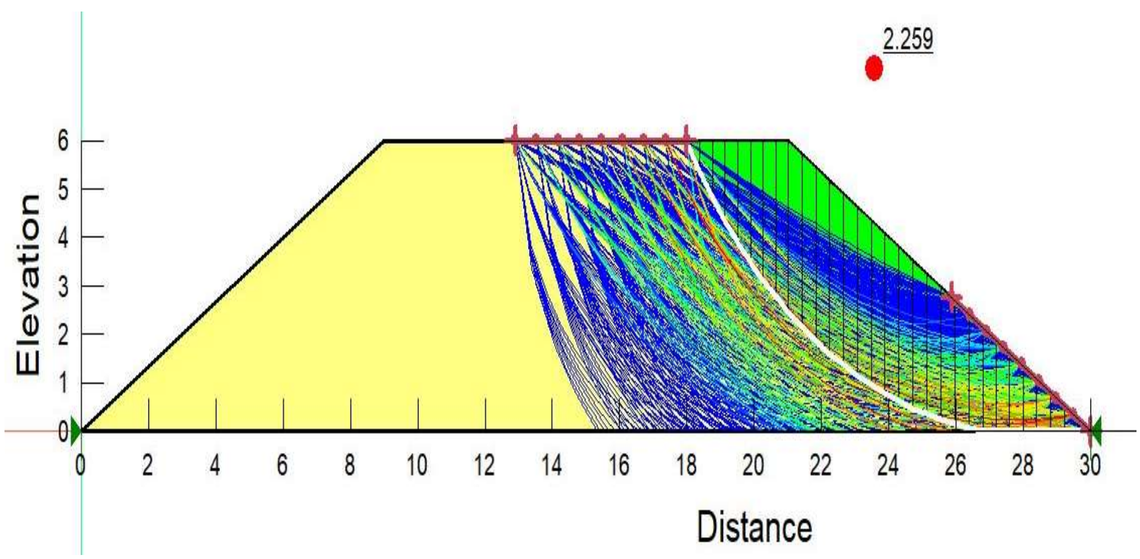


Figure 5.4(1.2) Bishop Method factor of safety with all slips

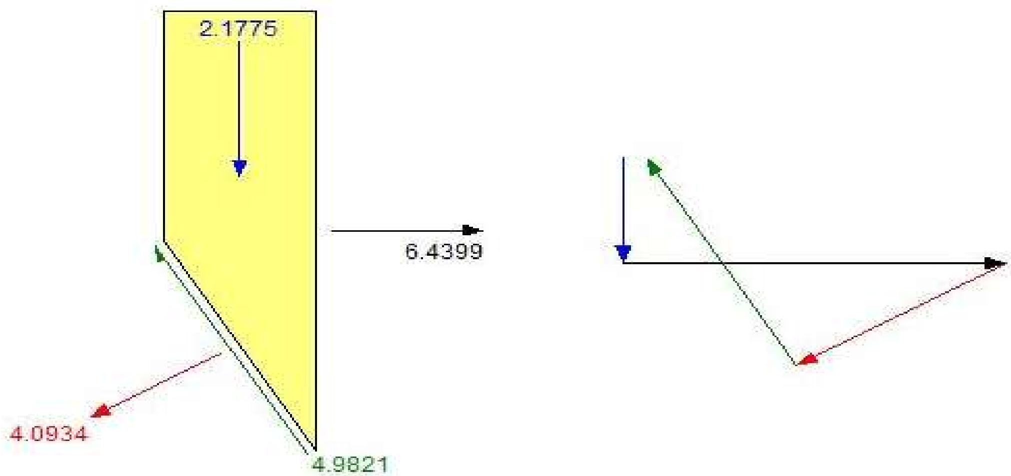


Figure 5.4(1.3) Free body and force polygon

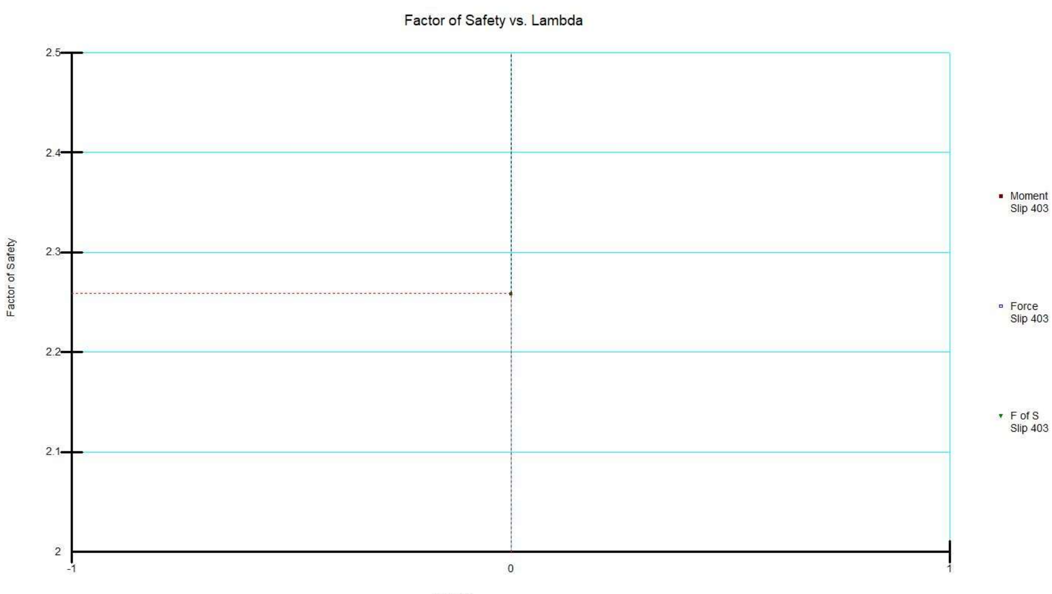


Figure 5.4(1.4) A factor of safety versus lambda (λ) plot

5.4(2) SLOPE 1:1.75

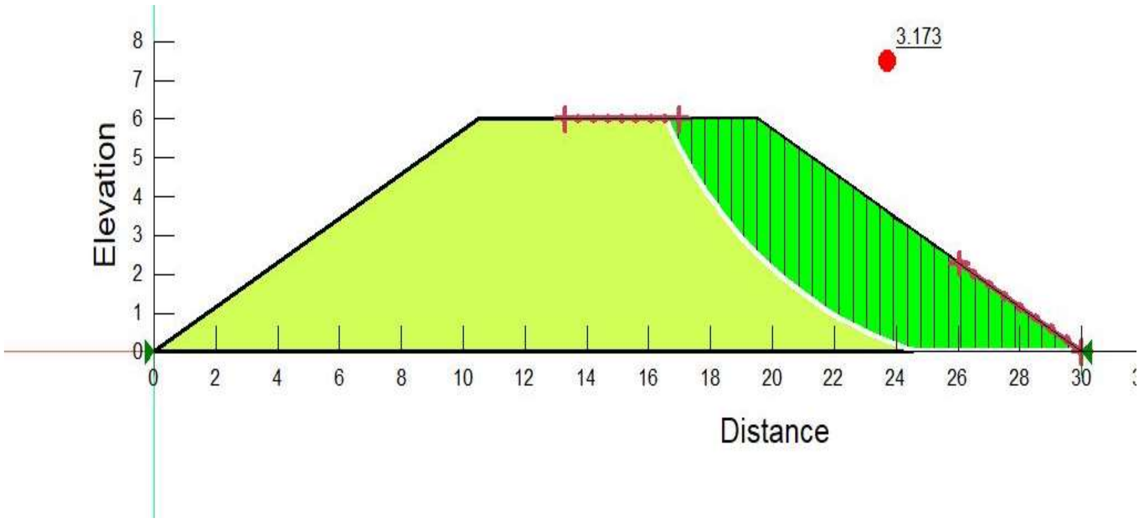


Figure 5.4(2.1) Bishop method factor of safety

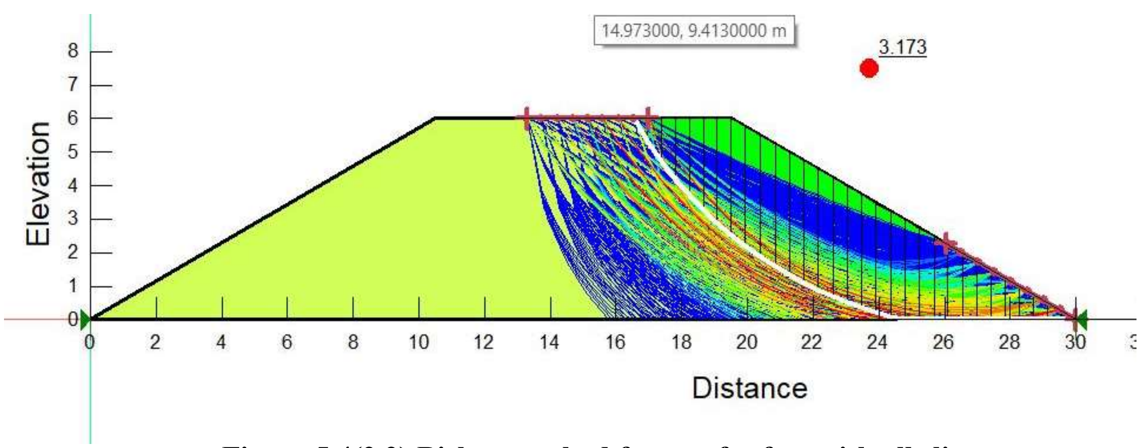


Figure 5.4(2.2) Bishop method factor of safety with all slips

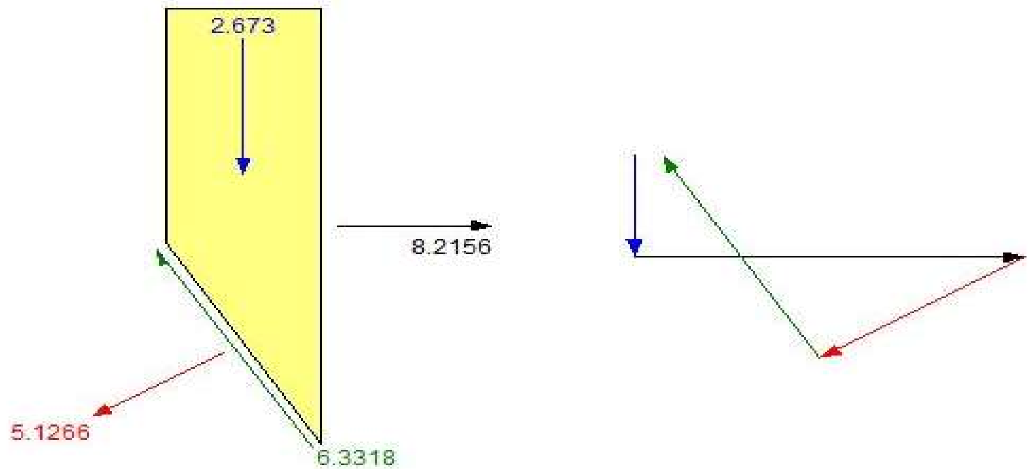


Figure 5.4(2.3) Free body and force polygon

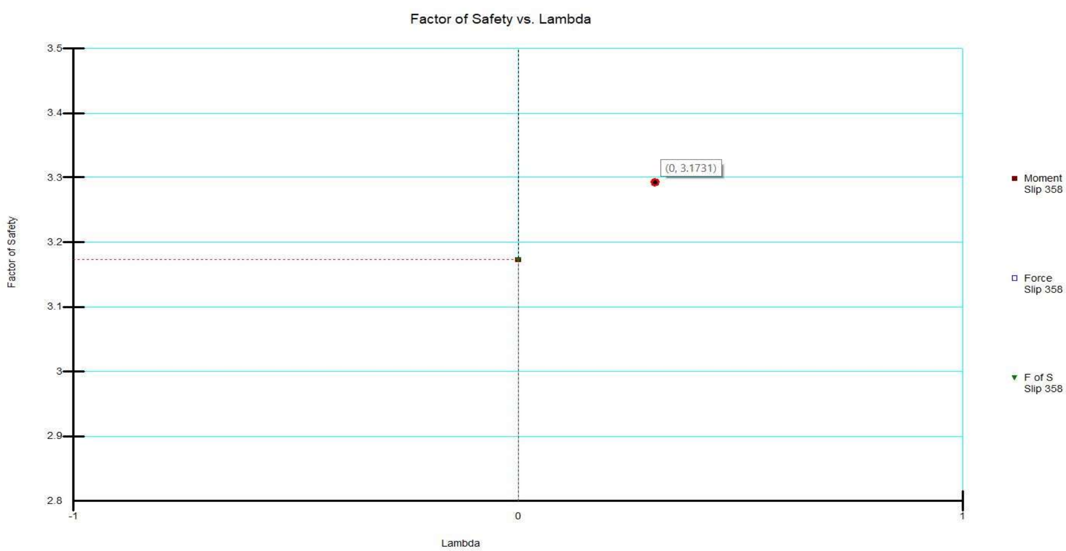


Figure 5.4(2.4) A factor of safety versus lambda (λ) plot

5.4(3)SLOPE 1:2

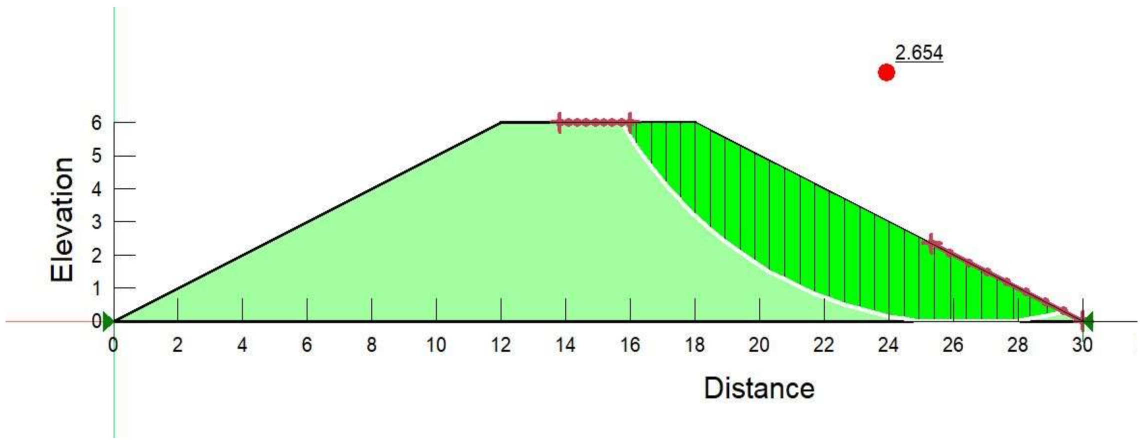


Figure 5.4(3.1) Bishop method factor of safety

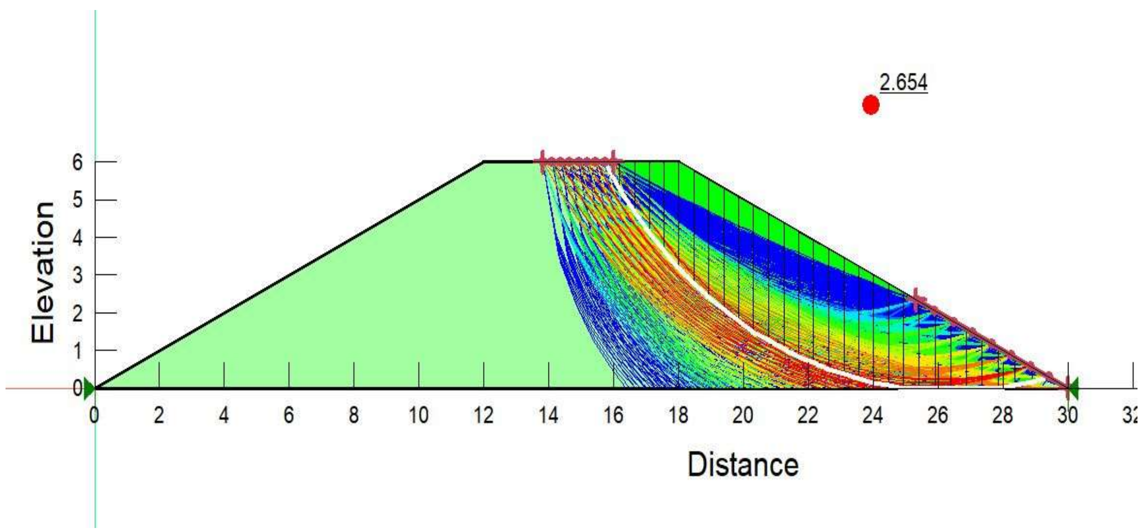


Figure 5.4(3.2) Bishop method factor of safety with all slips

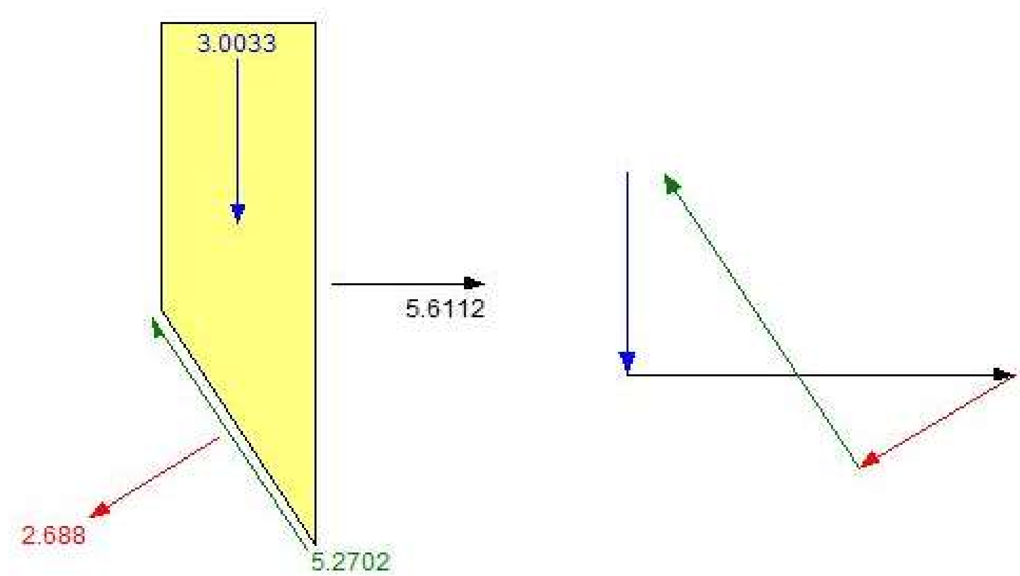


Figure 5.4(3.3) Free body and force polygon

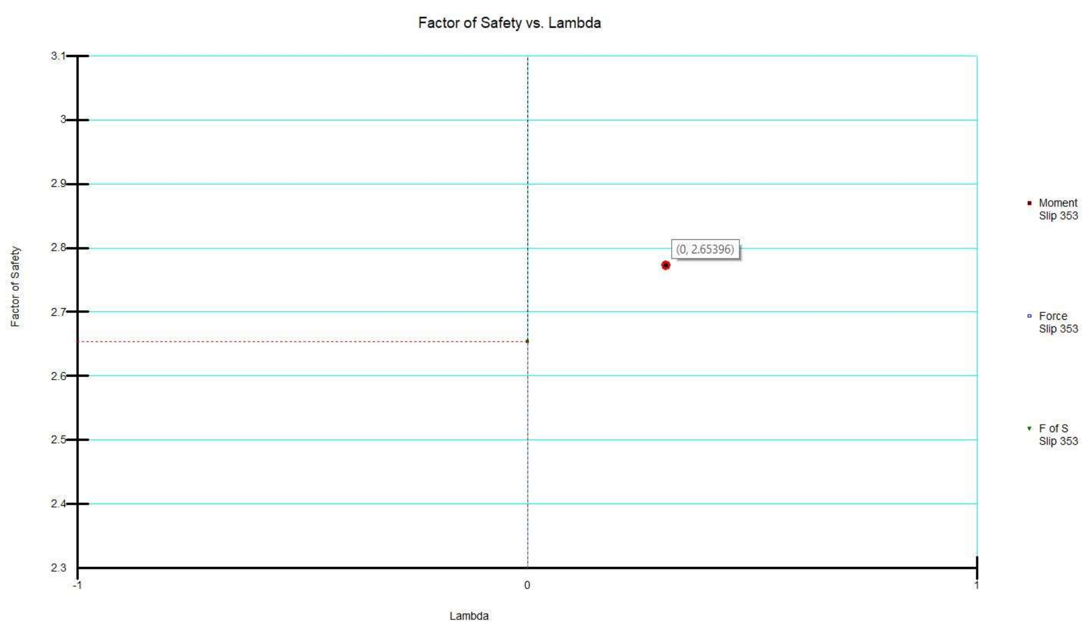


Figure 5.4(3.4) A factor of safety versus lambda (λ) plo

5.5 Comparison table and chart B/W Morgenstern-Price method & Bishop's simplified method

SLOPE	Morgenstern & Price method.		Bishop's method	
	3M ELEVATION	6M ELEVATION	3M ELEVATION	6M ELEVATION
1:1.5	3.489	2.338	3.457	2.259
1:1.75	3.736	2.465	3.736	3.173
1:2	4.006	2.653	4.002	2.654

Table 5.5.1 Results of both methods with different elevation and slope

SLOPE 1:1.5

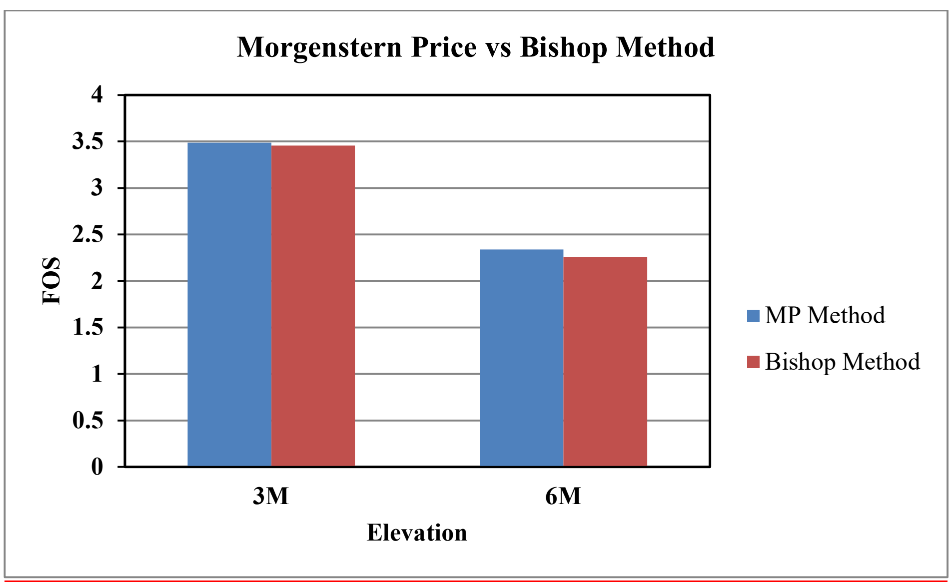


Figure 5.5.2 Morgenstern price Vs Bishop Method comparison chart for 1:1.5

SLOPE 1:1.75

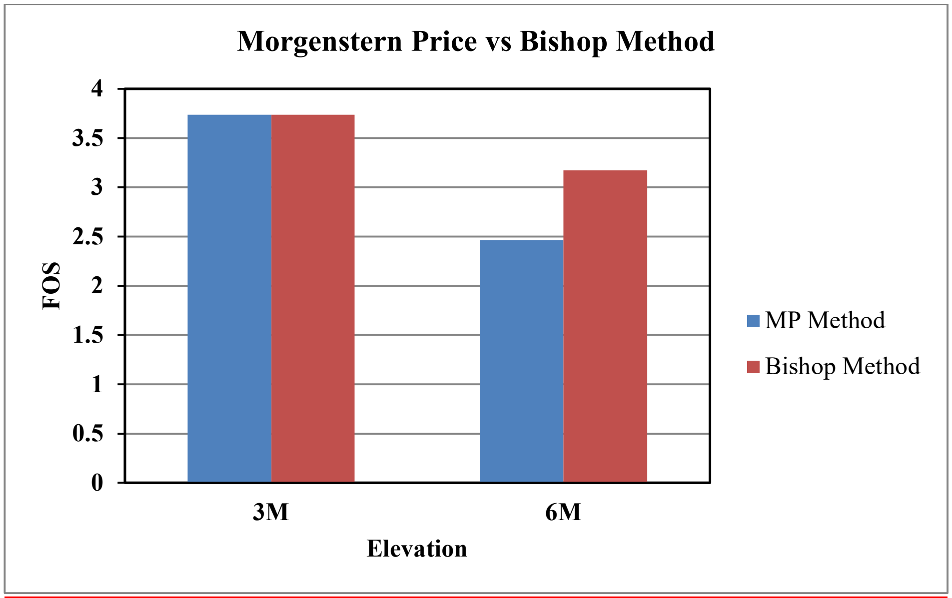


Figure 5.5.3 Morgenstern price Vs Bishop Method comparison chart for 1:1.75 slope

SLOPE 1:2

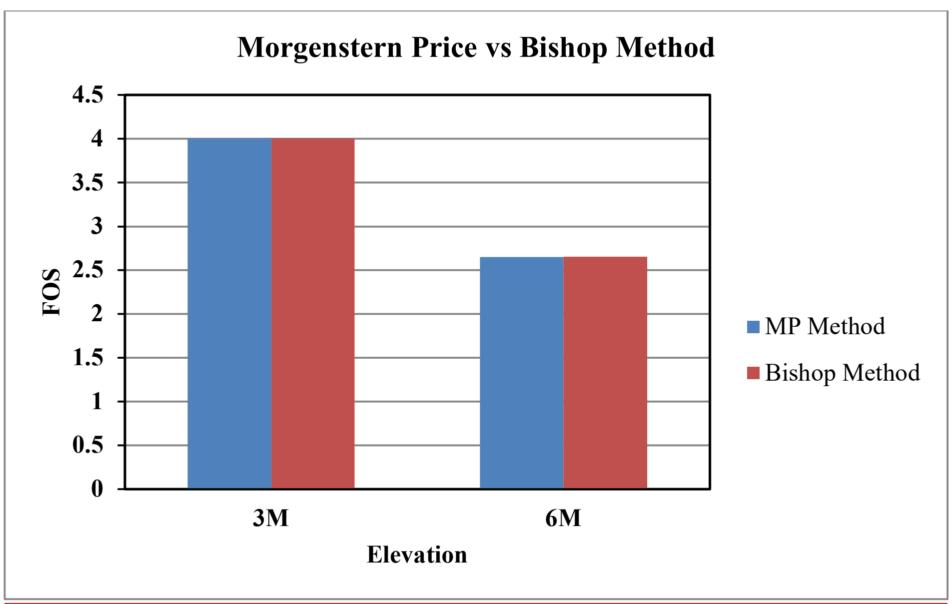
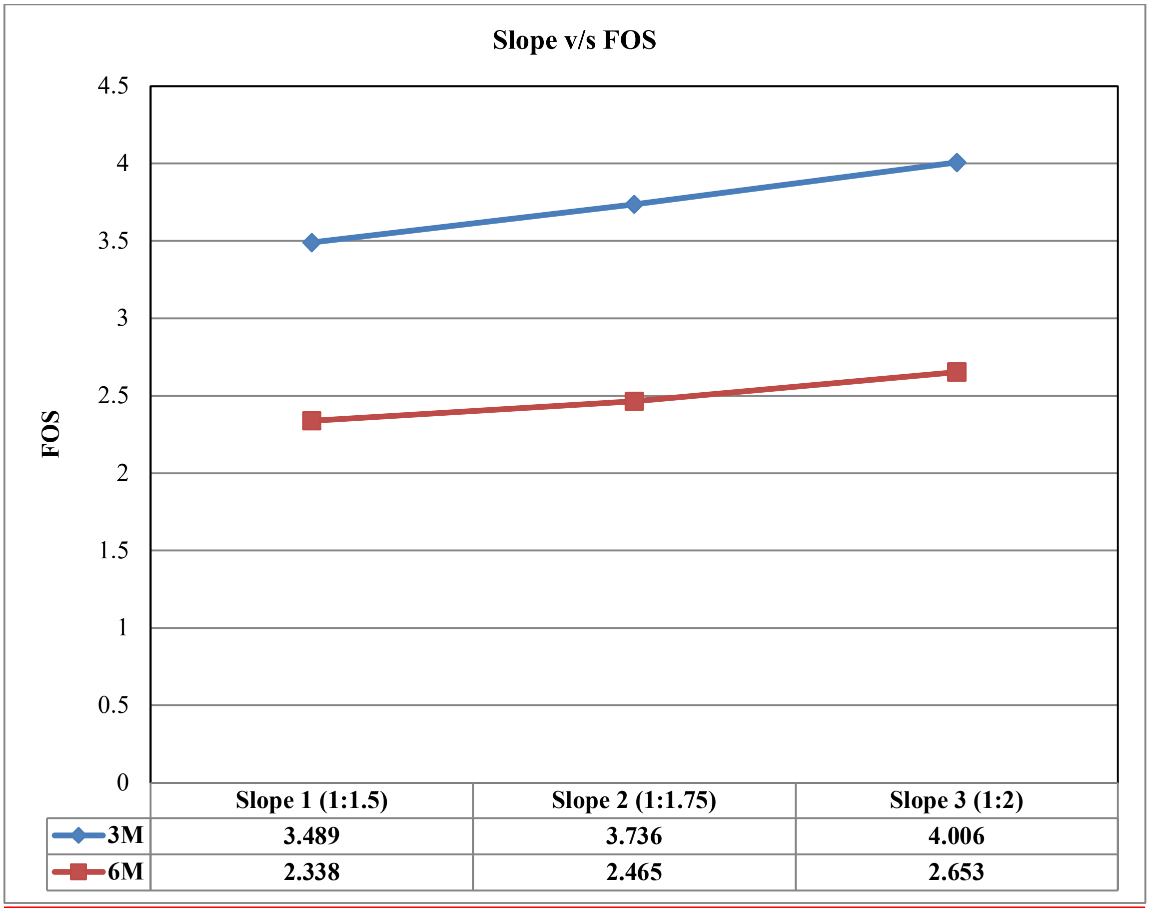


Figure 5.5.4 Morgenstern price Vs Bishop Method comparison chart for 1:2

SLOPE VS FACTOR OF SAFETY



	Slope 1 (1:1.5)	Slope 2 (1:1.75)	Slope 3 (1:2)
3M	3.489	3.736	4.006
6M	2.338	2.465	2.653

Figure 5.5.5 Slope Vs factor of safety graph

CONCLUSION

1. The value of factor of safety decreases with increase in the elevation of embankment.

2. The value of factor of safety Increases with increase in the side slope of embankment.

3. From slope stability analysis, it was obtained that slope 1:2 has the highest factor of safety (4.006) against failure.

4. Morgenstern price's method gives higher value of Factor of safety than Bishop's method. It means Morgenstern price's method is slightly better than Bishop's method.

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