Investigation of Advanced Non-Circular Slip Surface of Slopes

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Why is this investigation needed?

As technology has advanced over the past years, the slip surfaces analyzed during the design of slopes have become more advanced compared to the basic circular surfaces used in earlier years. While this has been happening, the slopes that were designed with the simpler circular methods and then re-evaluated with these new more complex non-circular methods are shown to have a lower factor of safety during re-evaluation. This then incites the question of what does this mean for engineering design? If we can prove that the more complex non-circular slip surface methods are more accurate, then a possible shift to a lower design factor of safety may be required. This would not mean that the slope is less stable, but that the methods to analyze these slopes have become more accurate; therefore, a higher factor of safety in design is not required.

In order to investigate this and be able to verify results, the use of case studies is being implemented. These case studies give us soil information and design information, which can be remodeled in software and then analyzed using the different non-circular slip surface method. These can then be compared to the equivalent results of common circular methods. This research is still ongoing, but during early stages, there have been "critical" inputs that must be acknowledged, as they will drastically affect the calculated factor of safety for the slope being analyzed.

How are we investigating this

- The use of slope stability software is being implemented with the plan to explore many of the software's that are used in geotechnical practice in order to explore as many slip surface search methods as practical (1)(2)(3)(5)
- There is also observation of "Critical Inputs" which will need to be observed
- The validation of some slopes will also be explored by Finite Element Analysis (FEM) software to verify that the surfaces found are valid (4)
- The checking of 3D models will also be done to make sure similar failure surfaces are being found as compared to the 2D model
- All current examples are models of case studies in order to verify results (6)

Illustration of the importance of this

- To show the importance of this topic, below Table 1 and Figure 1 show just how drastically the Factor of Safety (FS) can change based just on the slip surfaces search method used for the same 2D slope. (3)(5)(6)

James Bay Dike				
	Slip Method	Optimized	FS	% Diffrence
Circular	Circular Auto Refine - Optimized	Y	1.461	0.0%
	Circular Auto Refine - Convex - Optimized	Y	1.169	-20.0%
Simple Non-Circular	Non-Circular Auto Refine - Optimized	Y	1.163	-20.4%
	Non-Circular Auto Refine - Not Optimized	N	1.472	0.8%
	Path Search - Optimized	Y	1.732	18.5%
	Path Search - Not Optimized	N	1.759	20.4%
Non-Circular	Cuckoo - Optimized	Y	1.160	-20.6%
	Cuckoo - Not Optimized	N	1.183	-19.0%
	Particle Swarm Search - Optimized	Y	1.163	-20.4%
	Particle Swarm Search - Not Optimized	N	1.195	-18.2%
	Simulated Annealing - Optimized	Y	1.163	-20.4%
	Simulated Annealing - Not Optimized	N	1.173	-19.7%

Table 1: James Bay Dike Slip Surface Method Summary

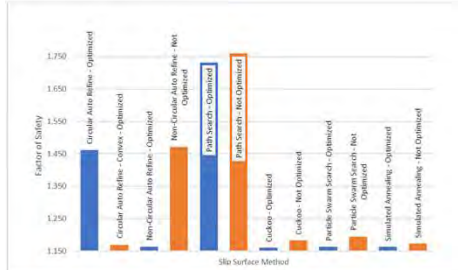

Figure 1: James Bay Dike Slip Surface Method Comparison

Critical Inputs

- Critical Inputs are inputs into the slip surface method that may cause the method to find an invalid slip surface, non-controlling slip surface, etc. Figure 2 below show (A) correct slip surface, (B) invalid slip surface, then (C) non-controlling slip surface. These were all found with the same method just varying inputs. (3)(5)(6)

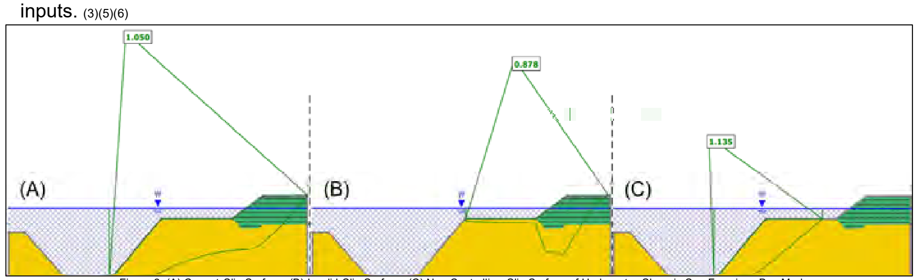

Figure 2: (A) Correct Slip Surface, (B) Invalid Slip Surface, (C) Non-Controlling Slip Surface of Underwater Slope in San Francisco Bay Mud

Finite Element Analysis Verification

- Finite Element Analysis can be implemented to check the slip surface for means of verification. For simplicity, the Figure 3 (A) below shows the correct slip surface using slope stability software, and this can be verified using finite element analysis, shown below in figure 3 (B) which very similarly matches the slope stabilities software a solution figure 3 (A). (3)(4)(6)

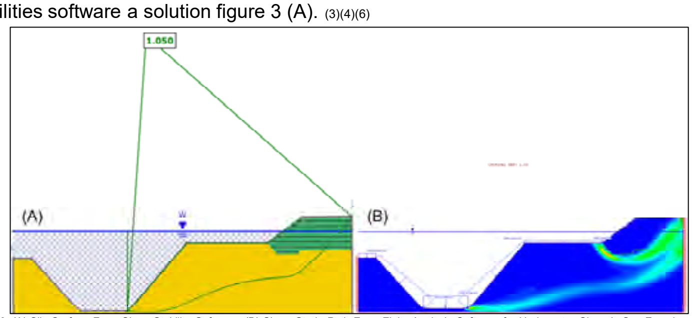

Figure 3: (A) Slip Surface From Slope Stability Software, (B) Shear Strain Path From Finite Analysis Software for Underwater Slope in San Francisco Bay Mud

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Preliminary 3D Model and Analysis

3D analysis has yet to be done for the investigation of advanced non-circular slip surface of slopes. There is much support that the factor of safety for 3D will be higher than 2D therefore it is assumed to not be a controlling model. This higher factor of safety is thought to come from the way that the soil forces are calculated and then used in order to find the slip surfaces of slopes. Analysis will be done in the future to either prove or disprove this topic, but these are the preliminary ideas.

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