

A Review on Slope Stability Analysis by Strength Reduction Method using MIDAS GTS

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ABSTRACT: For an earthquake prone region like the Himalaya, in the wake of ever increasing constructional activities, it is important to understand and analyse the causes and types of failures that occur on the soil slopes. More so, the regions prone to long rainy periods need even more detailed discussion around the importance of slope stability analysis. Depletion of vegetation and haphazard construction in hilly regions is another matter of concern which calls for controlling the slope failure hazards. MIDAS GTS NX is a Finite Element Modelling based tool that uses Strength Reduction Method to deduce the type and cause of slope failure. Based on the findings of the strength reduction analysis, slope strengthening measures can be performed to stabilize the slope and control its failure in the long run. This paper discusses the various aspects of modelling a slope on the software and analysing the behaviour of slope subjected to varying material properties and environmental conditions.

KEYWORDS: Slope stabilization, MIDAS GTS, Finite Element Modelling, Strength Reduction Method

I. INTRODUCTION

Strength Reduction Method (SRM) is a finite element based method of analysis. It is also known as SSRM [1] which is abbreviation of Shear Strength Reduction Method. Stability by strength reduction technique is achieved by weakening the soil in an elastic-plastic finite element analysis until the slope fails [2]. The Factor of Safety (FOS) is deemed to be the factor by which the soil strength is to be reduced to reach failure. Its main concept is the systematic reduction of the shear strength envelope of a material by a factor of safety and then performing the finite element analysis of the slope until the deformation are unacceptably large or the solutions do not converge.

SRM relies on arc length method which computes factor of safety that can accommodate a large number of nodes and elements spread over the entire soil mass. SRM gradually decreases the shear strength parameters until the convergence doesn't occur. At the point where calculations do not converge is considered as the failure point and maximum strength decrease rate at this point is considered as the least factor of safety of the soil slope under consideration.

The major drawback is that SRM consumes substantial amount of time (depending upon the parameters involved) and nonlinear analysis is performed over n number of times. However, because it involves exhaustive computation, accurate results are obtained. Moreover, the transition from initial slope condition to slope failure can be examined without having to assume the failure slope in advance.

SRM systematically searches for a critical factor of safety for a slope that was previously safe with a $FOS > 1$. Using appropriate material and strength properties FEM model is created either in 2D or 3D. Using incremental values of FOS, repeated iterations of FEM using SRM are carried out so as to reach a stage where material strength is reduced to such an extent that the slope fails. The critical value of FOS beyond which slope failure materializes would be termed as slope factor of safety. [3] [4] [5] [6].

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Shear Strength Reduction Method primarily involves the following three computational processes:

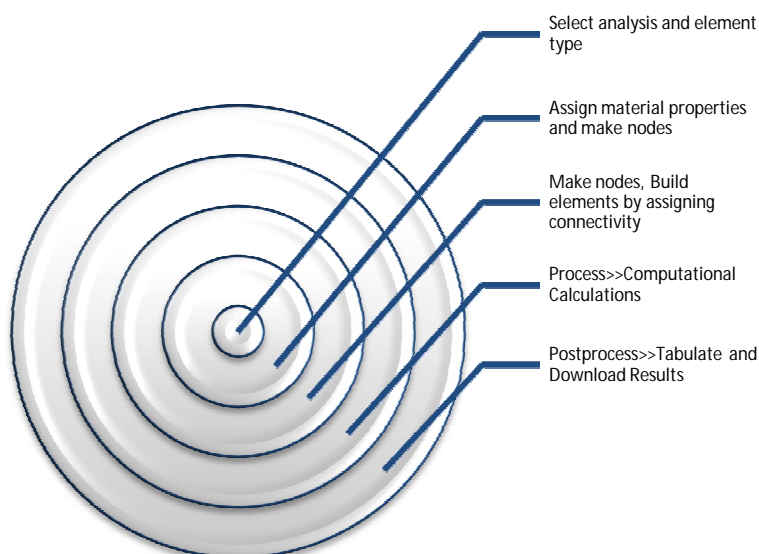
1. Depending upon the type of slope, a certain reduction factor known as Strength Reduction Factor is triggered while Finite Element Analysis is carried out by the software.
2. Multiple iterations are carried by varying the strength reduction factor until the soil slope model becomes unstable.
3. Thus a critical strength reduction factor is determined based on which the factor of safety of the soil slope is determined.

The SRM adopts Mohr-Coulomb [3] strength for slope stability analysis. This method is most commonly used criteria applicable to failure analysis of slopes in geotechnical engineering. A distinctive feature of this slope failure analysis model is the fact that it can explicitly predict the failure in principal stress space (maximum displacement) and shear-normal stress space (maximum shear) to which the given slope is subjected.

The procedural working of MIDAS GTS NX is explained in the following points.

1. Soil Sample Collection: Disturbed or Undisturbed Soil sample may be collected from a landslide area. Auto CAD drawings of slopes can also be imported directly in MIDAS for simulation.
2. Laboratory Testing of Soil Material for Classification of Soil and Determination of Engineering Properties
3. 3D FEM Modelling of Slope on MIDAS GTS NX software tool
4. Post Processing via Strength Reduction Method for determining Factor of Safety of the soil slope at different height and slope angles.
5. Strengthening of soil slope via Soil Nailing, Shotcreting, and Geogrid strengthening and re-determination of Factor of Safety of the soil slope.

The process overview can also be explained with the help of the following flowchart



The above flowchart clearly explains the systematic flow of operations that undergo while calculating factor of safety of a complex slope. Numerical calculations are automated and highly accurate which saves a substantial amount of time [3]. One disadvantage of working with this software is that one has to deal with inconsistent units. Coming close to

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choosing appropriate element size and defining suitable boundary conditions are the other two major drawbacks of this method but these two can be taken care of by taking inputs from historical data and topographical details.

Now that it has been amply made clear as to why SRM is far better a method [7] [8] as compared to other conventional methods to analyse a slope prone to failure, we shall discuss the related work done so far in the field of slope stability using FEM based on SRM.

II. RELATED WORK

Research work and investigations conducted in the field of slope stabilization by finite element method based upon SRM and other techniques are discussed below.

Griffiths and Lane [7] based their study on the assumption that FEM is way better approach while dealing with slope stability problems in terms of accuracy with respect to failure mechanism. The study observed that FEM required dealing with a lesser number of prior assumptions that provided for precise and output results. The paper illustrated various examples of slope stability problems and compared them with other solution models for soil slopes and dam stability. Graphical representation revealed that deformations and failure mechanisms were way better represented by FEM in comparison with traditional Limit Equilibrium Method. As a conclusion this study further emphasized on using FEM to obtain precise solutions for geotechnical problems.

Further, Dawson et al [8] investigated major differences between strength reduction method and traditional method of slices method. The study established that the critical failure surface and critical factor of safety were found automatically rather than assuming the failure plane automatically as was done in method of slices. SRM analyses were performed on a wide range of slope angles and slope heights and it was concluded that SRM provided fractionally marginal better values of Factor of Safety. The study mentioned that long run times required for performing SRM analysis was one of the major disadvantages of this method. It was further suggested that advancement in computer technology in coming years would easily overcome this drawback.

Tsai et al [9] studied ground deformation caused by construction of a cross passage during the construction stage of Delhi Metro via MIDAS GTS. 3D Finite Element Model was prepared and modified Mohr Coulomb method was used to perform the post construction deformation and displacement analysis caused by stresses induced. The study concluded by simulating the cross passage on the software that the soil properties had to be reconsidered to be able to minimize the deformations and displacements. Soil strength parameters used in the design stage were re-examined and it was recommended to change these properties based on the 3D analysis.

Saikia et al [10] conducted SRM analysis on soil slopes of Sonapur in Meghalaya and concluded that the factor of safety decreased with increase in the angle of inclination. Slopes going above 20m in height were concluded to be severely vulnerable to slope failures both in the dry as well as rainy conditions.

Chu [11] primarily aimed at identifying landslide failure and its mechanism along with sliding depth of the slope failure at the Su-Ao-Nan-Ao section of the Su-Hua Highway. The specific region was undertaken for this study because of the very high rainfall intensity in the region. The damage was aggravated during the 2010 Maggie Typhoon that caused havoc all across the country. The factor of safety of the slope was calculated as 0.9 whereas the shear strain distribution was also found to be near critical stage. The sliding depth was determined to be upwards of 15.6m all along the highway section. The study concluded that gully erosion was the primary cause of landslide induced slope failure on this section of the highway.

Tao [12] modelled mountain roads in the Yunnan province of western China using MIDAS and stabilized failing slopes using anti-slide piles. The insertion of piles improved the factor of safety from 0.95 to 1.10 and improved the overall safety of the slope. Yijie et al [13] not only designed geogrid for slopes but also observed the performance of these geogrids fixed on sensitive slopes by installing Fiber Bragg Grating sensors on them to observe the strain distribution on the slope during critical conditions.

Andreea [14] study observed stability of dam under two different water conditions by means of SRM via MIDAS GTS Nx. Maneciu Dam, a 75 meter high earth dam situated on the Teleajen River in Romania was chosen as the study site. 3D analysis using SRM was performed for steady state and transient state. Under steady state, the ground was assumed

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to be saturated with ground water level just 1m beneath the top surface of the dam. In transient stage, water was gradually receded and seepage analysis was performed. By means of 3D analysis, it was concluded that the dam would be stable under all the conditions provided the core and filter layers are designed using average value between Carsel and Rawl functions at the design stage.

Zhou [15] et al analysed Chengmenshan pit in China using MIDAS SRM. The said pit was one of the largest copper pits in the country that had stability issues. The analysis provided for dimensional changes in the supporting benches below the copper to lower down the major principal stresses at one of the corners of the pit that were bringing instability to the copper pit.

III. SUMMARY OF REVIEWED PAPER

The paper shows the effectiveness and accuracy of MIDAS GTS as slope stabilization software that is widely gaining popularity for performing slope stability analysis. The important aspect of using the tool is that it uses considerably a lesser number of assumptions while dealing with complex slopes. The accuracy and ability to predict critical failure surfaces in real-time by underlining the existing shear and displacement values could be of great help in controlling the menace of slope failures in Himalayan regions.

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