FEM-based modeling in soil-bioengineering

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1.0 INTRODUCTION

There are various methods to analyze the soil-bioengineering. Currently, available methods are limit equilibrium method (LEM) and stress deformation analysis. LEM is a conventional approach and has limited scope, where as stress deformation method is the naval and widely accepted analytical approach. However; limited analytical modeling techniques are still not clearly explained and verified the necessities of soil-bioengineering. In this circumstance, it has great challenges to work on numerical based modeling especially in soil-bioengineering. Bioengineering or vegetation role on slope stability is still not satisfactorily defined in technical literatures. That means there is no perfect analytical justification in increasing trend of bioengineering techniques for soil slope stability. There is no doubt that analytical approach covers all FEM based simulation that includes both stochastic and deterministic approach. It can easily address the wide range of material behaviors such as elastic, perfectly elastic, elastic and perfectly plastic, elasto-plastic and visco-plastic etc, however it has great challenges to cope soil-root matrix continuum as this study adopts homogenization approach instead of spectral approach. This paper simply ignored the soil root interface, though it has considerable scope on soil root interaction.

2.0 LEM VERSUS FEM BASED ANALYSIS

LEM approach considered equilibrium of forces acting on the trial failure surface. Assumed to be material properties are homogeneous, body above the trial failure surface is rigid and rate of mobilization of strength at every point on the failure surface is same. Actually, LEM based analysis is a simple and computationally economic technique and it is useful for the preliminary evaluation. But, in general material properties are spatially variable. There is no information about the deformation of the slope. Rate of mobilization of strength at every point is not necessarily the same. Analytical technique can predict the probable failure surface zone and, it can get the information on the deformation of the slope. Both homogeneity and heterogeneity in material properties can well be implemented (Kramer, 2003). However, in stress deformation analysis, failure path or surface can not be computed as FEM uses the continuous displacement but the failure path or surface is itself discontinuous. Thus to incorporate the failure path the new analytical approach is needed which can consider strengths and discontinuity nature of fracture. Virtually numerical computation solves any problems with any boundary conditions in any domains. With the advent of powerful computers, it is becoming the indispensable tool for the modern research. It is, without any doubt, most efficient non-destructive testing method. Physical simulation of the strengths and fracture phenomena is possible using analytical modeling techniques. Simulation of soil-root interaction, consideration of the progressive fracture in the soil-root networked continuum, and evaluation of the factor of safety based on the strengths and the fracture phenomena are the basis of this paper.

3.0 BASIS OF WORK FORMULATION

Here, we assess an average behavior of soil root matrix. In this model, three different responses are possible during shearing of a fiber reinforced soil composite, they are fibers break fibers stretch, and fibers slip, which gives the net increase in shear strength due to the effect of vegetative cover. Mathematical formulation of the governing equations incorporates two terms for bioengineering, i.e. average elasticity tensor for linearly elastic isotropic material including roots and average mass density of the material including roots are considered. Important point in the governing equation is the time evolution of the specified boundary conditions satisfying the evolution of the boundary. To solve these governing equations we discretize the continuum using the orthonormal functions over the delaunay tessellations. This governing equation further discretized in terms of the displacement field with the approximation of formulation with the consideration of the boundary of the continuum as the function of time. As usual we take the functional which has the time evolution characteristics of the traction term. Functional means any mathematical quantity which on minimization represents some physical behavior; generally we take total energy as functional (function of function). The functional can be minimized equating to zero and the final finite element equation can be obtained.

4.0 WORK FORMULATION PROCEDURE

Now, for the preliminary computation a simple arbitrary geometry of the slope with vegetative cover is considered for the modeling. The domain of slope can be discretised into networks of any reliable geometrical units. However, for the current case, the domain is discretized into the dealunay tessellations. Use of delaunay tessellations not only simplify the computational procedure but also minimizes the computational error and such type of tessellations are the only option that are possible in all the domain. For this we need to fix its boundaries. Fixed boundary at the bottom and vertically movable boundary at the left will be an appropriate choice relevant to the slope movement. The Finite Element Method is the most widely used numerical method in which continuous shape function are defined over

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the element to represent the displacement field, which makes it naturally difficult to treat the fracture which is inherently discontinuous in nature, however some procedure like joint element method can be incorporated for the fracture but computational cost is high in this approach. FEM is the most powerful tool to solve the boundary value problems. It can effectively simulate the ductile failure in the continuum. However, when it comes to brittle fracture, simply it does nothing with the discontinuous function! Thus progressive fracture and the fracture path cannot be simulated. Another method of fracture treatment is remeshing. It can simulate some behavior of fracture but, unable to simulate the progressive nature of fracture especially fracture path. Computational cost very high in this approach. The next newly evolving method is free mesh method in which influence function is defined over each node. The overlapping influence function makes somewhat difficult in fracture treatment (Yagawa and Furukawa, 2000). Another popular method is the discrete element method in which characteristic functions are defined over the element which introduces the discontinuity between the elements making the fracture treatment very easy however it lacks the precise mathematical formalism (Bathe, 1996). With this motivation and in view of the existing difficulties, alternative tool for the simulation of fracture is new approach that can effectively simulate the fracture in granular materials however, it is somehow empirical or trial and error in computation. Now, we have to choose appropriate failure criteria. In these circumstances, Mohr-Coulomb failure criterion has been chosen which is more appropriate for soil possessing both frictional and cohesive components of shear strength. After choosing an appropriate failure criterion another step will be to explain about fracture treatment. One possible way of fracture is on the edge which touches the boundary which is the most critical, geometrical configuration that introducing one new edge and one new node to make the domain compatible. Another possible way of fracture will be when the failure node lies in the domain of the continuum. In this case separation of only one edge is incompatible; hence, crack will be initiated from an edge which exceeds the yield criteria starting from a node of higher stress and accompanied with a next edge with highest stress among the remaining edges meeting at the failed node. Thus in this case one new node and two new edges are generated. When the failed node lies near the boundary, then all the conditions will be similar with the case when the failed node lies in the domain, except that the boundary node will also get failed. Therefore there will be generation of two failed edges and two failed nodes. The details of work

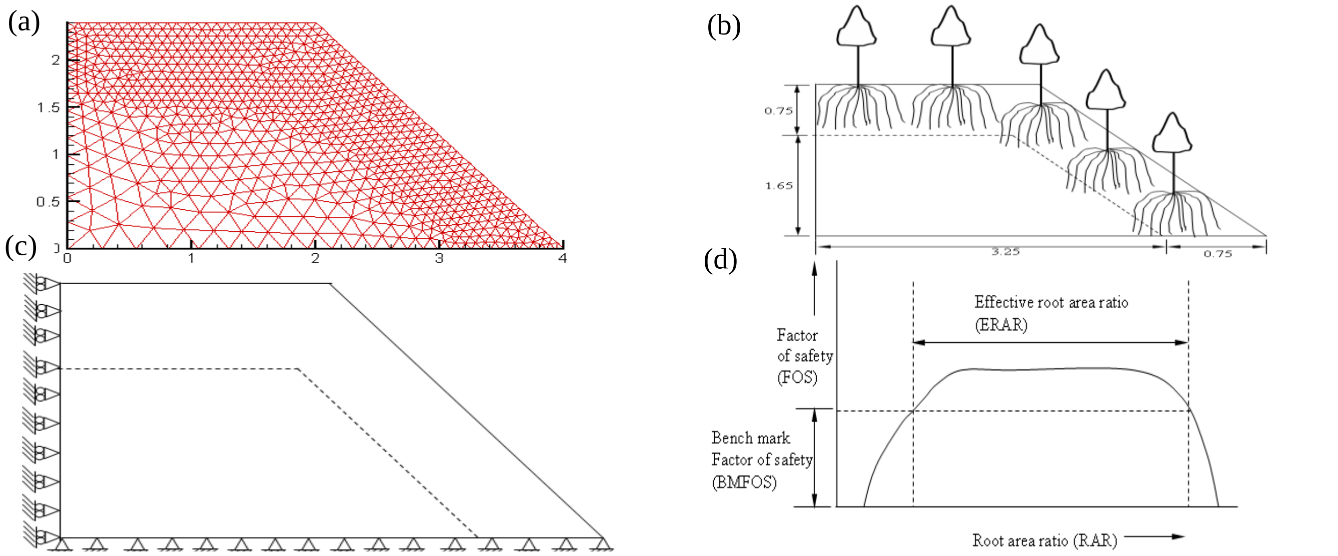

Fig.1 FEM based modeling in soil-bioengineering using Homogenization approach, (a) descretization effort; (b) appropriate boundary condition (c), and possible result (d).

formulation and tentative result summary are shown in Fig. (a) to Fig (d) of Fig.1. Result shows that vegetation has positive role in slope stability with certain root area ratio (RAR), beyond that value further increment in RAR will not be helped much and after certain RAR slope even lead to failure similar to the role of steel in Reinforced concrete structures (RCC).

5.0 CONCLUDING REMARKS

The main task of FEM based modeling is to compute the result in suitable and understandable form and to seek the proper verification means. There are some solved problems in the various technical literatures based on the classical method that will be the one way of comparing the results. The result obtained by this classical method should be necessarily comparable with the results obtained by numerical modeling. The scope, fundamentals or basis of work procedures are significantly differ in between classical or LEM based analysis and FEM based analysis. Some real simulation of similar work will be essentially needed for the good understanding of the real problems and verification as well.

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