Application of Spectral Element Method for Stability Evaluation of Nuta-Yone Landslide in Shikoku, Japan

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1 Introduction

Nuta-Yone Landslide (NYL) is situated in Otoyo town near the border of Kochi and Tokushima Prefecture, which lies on Shikoku Island of western Japan. NYL consists of two major clusters, known as Nuta and Yone, each of them further consists of several active blocks (SABO report, 2007). This paper focuses on ten major active blocks, five from Nuta cluster and five from the Yone cluster; all moving towards the northward flowing Minami-Daiogawa River (Fig. 1). According to the SABO report (2007), a large number of landslide slope enhancement measures (LSEM) have been implemented, which mainly consist of multi-layer deep underground perforated horizontal drains, ground water collecting wells, surface drains, and retaining walls on the basis of severity evaluation under the two main categories such as target conservation and past landslide activity.

This paper evaluates the stability analysis for LSEM of Nuta-Yone landslide by comparing the results of a 3D spectral element method (SEM). For this purpose, we use Specfem3D-Slope, one of the recently released parallel versions of open source program designed by Gharti et al. (2012). With this numerical tool, we can seek the fast and accurate numerical solution of a large-scale slope instability problem. Progressive failure phenomena and failure characteristics in response to the progressive nature can be evaluated in terms of safety factor in a more reliable manner. LEM can be used for preliminary evaluation of landslides, but it may not be appropriate for major steps of large-scale slope stability evaluation.

2 Numerical method

LEM is widely used to evaluate slope stability mainly because of its simplicity (i.e., working with minimal input data), but due to high accuracy quadrature rule and convenience of obtaining the interpolation polynomials, spectral element method is capable of solving a slope stability problem far more efficiently with promising accuracy using a diagonal mass matrix and implementing the hexahedral meshes (Fig. 2). However, a poor quality mesh creates numerical problems, such as an increase in the computational cost, lack of convergence, and the inaccuracy of the results, to address the real topography and complex subsurface structures. The biggest challenge for a successful application of the SEM includes the effective mesh operation. This method employs strength reduction technique to achieve progressive failure (Matsui & San, 1992), studies ground water fluctuation as per Berilgen (2007), and uses the concept of 3D elasto-plastic modeling as per Griffiths & Marquez. (1999).

3 Numerical results

To implement the LSEM in NYL site under consideration, the severity of the problem has been evaluated in two categories; ‘A’ and ‘B’. If movement of the block is rapid (active) and chances are high of significant losses of houses, roads, public places etc., such a situation is categorized under severity ‘A’. If the movement is not so rapid (less active block) and chances are comparatively less of losses of houses, roads, public places etc., such a situation is categorized under severity ‘B’. Based on the severity level, LSEM has been planned under two safety factor plan, ‘1.20’ and ‘1.05’. The severity under category ‘A’ and ‘B’ have been prioritized for the effective stability enhancement measures as high and low impact basis.

Simulation results of ten different slopes representing different landslide blocks at different stages of the failure gives the complete sense of progressive failure phenomena. Considering complex slope geometry, boundary condition and reliable material properties, the possible results in the form of progressive FOS and failure surface locations (Fig. 2) along with pore water pressure and displacement gives a complete sense of drawdown effect in LSEM projects (Fig. 3). It indicates how slope behaves with different stages of slope failure and how failure surface and displacement field go on changing with the evolution of slope boundary.

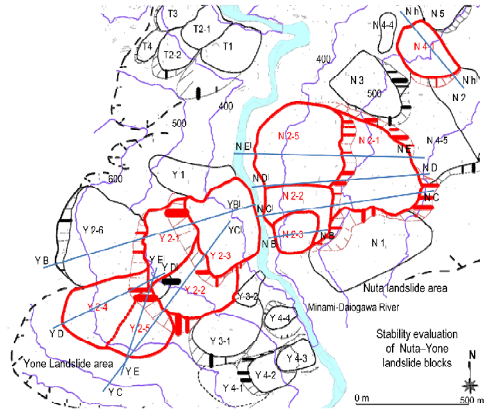

Fig 1. Identification of sliding blocks at Nuta-Yone landslides as per SABO report (2007).

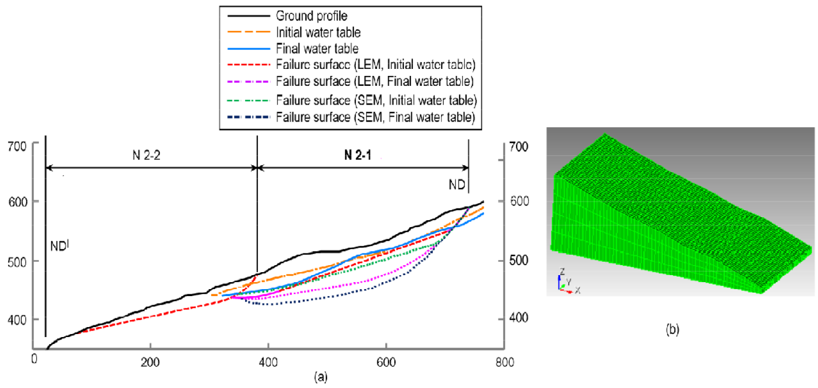

Fig 2. Slope model: (a) slope profile with water table positions and failure surfaces; (b) hexahedral discretization.

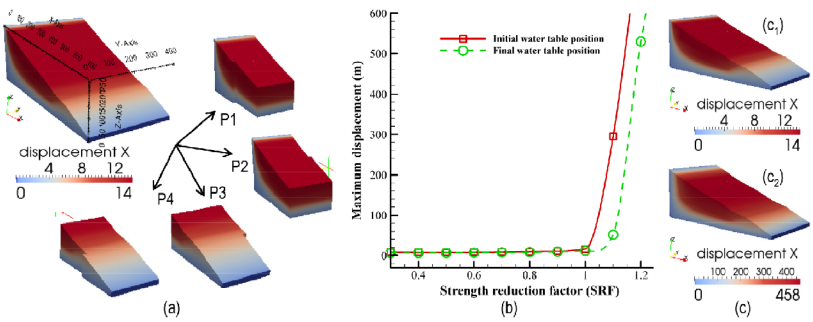

Fig 3. SEM Modeling: (a) domain decomposition; (b) displacement (m) vs. SRF; (c) displacement field at final water table positions (c1: at SRF 1.1; c2: at SRF 1.2) showing a fairly good results as compared with existing LEM.

4 Concluding remarks

The spectral element method can be considered as the most efficient method for large-scale slopes. It gives very accurate results with higher numerical stability.

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