Computers and Geotechnics 105 (2019) 168–182

Contents lists available at ScienceDirect

Computers and Geotechnics

journal homepage: www.elsevier.com/locate/compgeo

Research Paper

Continuous field based upper-bound analysis for the undrained bearing capacity of strip footings resting near clay slopes with linearly increased strength

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ARTICLE INFO

Keywords:
Undrained bearing capacity
Upper-bound limit analysis
Continuous field
Footing near slope
Linearly increased strength

ABSTRACT

The total-displacement loading EMSD (T-EMSD) method is applied in analyzing the undrained bearing capacity of strip footing near clay slope with linearly increased strength. According to the continuous field based upper-bound solutions obtained by the T-EMSD method, the consideration of strength gradient weakens the influence of strength ratio and slope height on the bearing capacity result. Investigation on corresponding velocity fields reveals that with the increase of the strength gradient the mobilized mechanism tends to contract around the foundation edge, thereby weakening the effect of the slope. Design equations are proposed based on the continuous field based upper-bound solutions. For subgrade with significant strength gradient, bearing capacity calculation with representative strength might lead to unacceptable overestimation and the present equation should be used in such case.

1. Introduction

In practice, the bearing capacity calculation is crucial to the design of shallow foundation. If a shallow footing is constructed near a slope, its bearing behavior will be influenced by the slope. Back in the year 1957, Meyerhof [18] analyzed the ultimate bearing capacity of a strip footing located near a slope by the method of characteristics. Kusakabe et al. [15] proposed an analytical upper-bound mechanism composed of both continuous shearing flow zone and several rigid blocks for the same problem. Limit equilibrium solutions for the footing near slope problem was derived by Azzouz and Baligh [1] from a circular arc collapse mechanism, and Narita and Yamaguchi [19] from a log shape sliding mechanism respectively. Analytical solutions for the ultimate bearing capacity of footings adjacent to slopes was also obtained by Saran et al. [21], using both the limit equilibrium and the lower-bound limit analysis approaches. Stress characteristics solution for the bearing capacity of strip footing embedded in slopes were provided by Kumar and Mohan Rao [14]. More recently, Castelli and Motta [2] developed a limit equilibrium method to evaluate the effect of slope on the bearing capacity of strip footings. Georgiadis [6] proposed an analytical upper-bound mechanism for the problem by modifying the layout of the continuous shearing zone from that of Kusakabe et al. [15]. Since all the methods reviewed above entail introducing some assumption concerning the collapse mechanism layout as a prior, they are categorized as analytical methods.

Although analytical methods are simple and convenient to use compared with numerical methods such as the Finite Element Method (FEM), the later generally render more accurate results, since less pre-assumption needs to be introduced. Elasto-plastic FE analyses were performed by Georgiadis [8] and Georgiadis [7] to investigate the influence factors over the undrained bearing capacity of a strip footing near an undrained clay slope, based on which practical design procedure was also proposed. Shiau et al. [22], Chakraborty and Kumar [3] and Farzaneh and Askari [5] applied the Finite Element Limit Analysis (FELA) method in analyzing the same problem respectively. Leshchinsky and Xie [16] and Zhou et al. [28] analyzed the bearing capacity as well as the failure mechanism of footing placed near slope through a numerical upper-bound method using the discontinuity layout optimization approach.

The evolution of the continuous field based upper-bound analysis method from analytical into numerical approach is briefly reviewed. Osman and Bolton [20] established the Mobilizable Strength Design (MSD) method, where the stress-strain relationship was introduced through a continuous field. The MSD method is further developed into the Extend Mobilizable Strength Design (EMSD) method [12], where the continuous mechanism could alter through the loading process. A

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https://doi.org/10.1016/j.compgeo.2018.10.002
Received 12 May 2018; Received in revised form 30 September 2018; Accepted 2 October 2018
0266-352X/

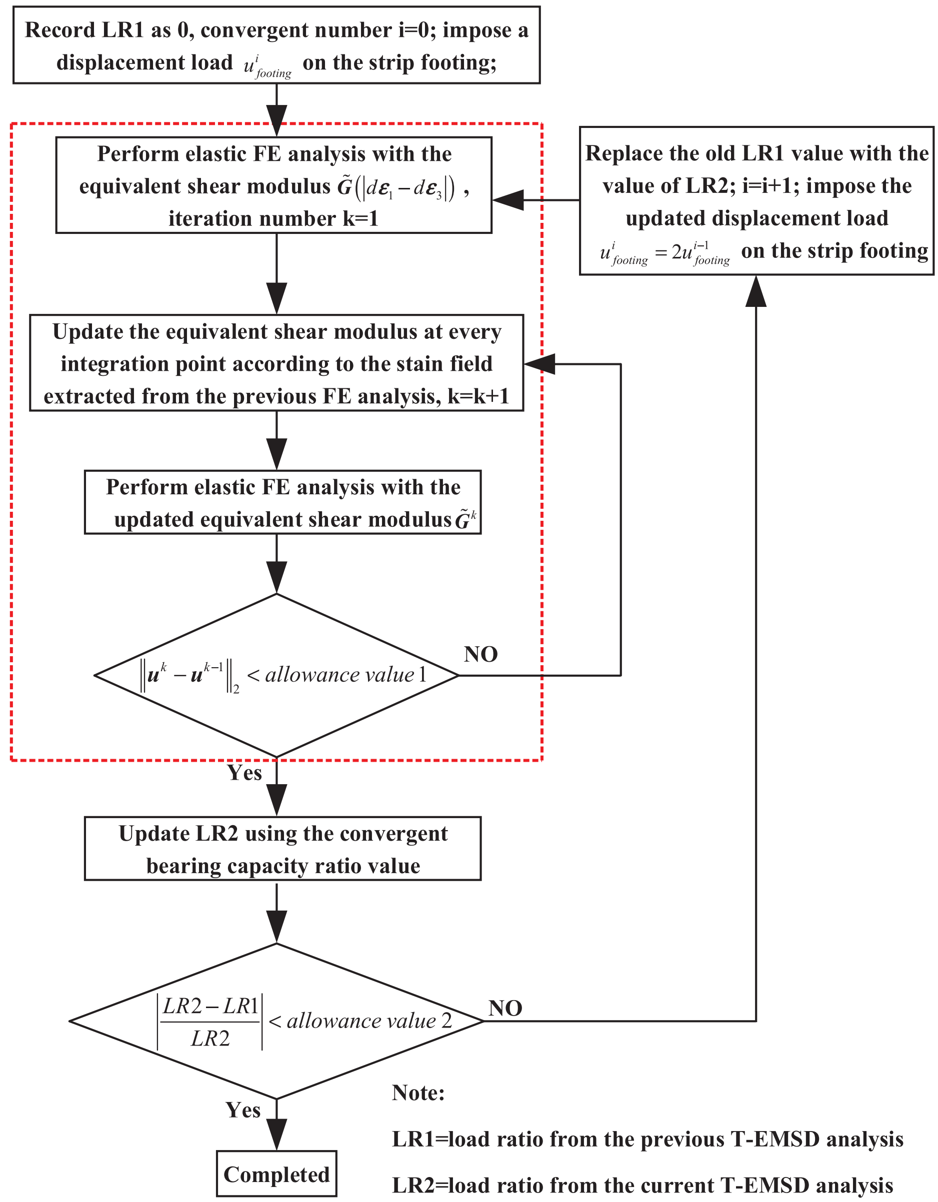
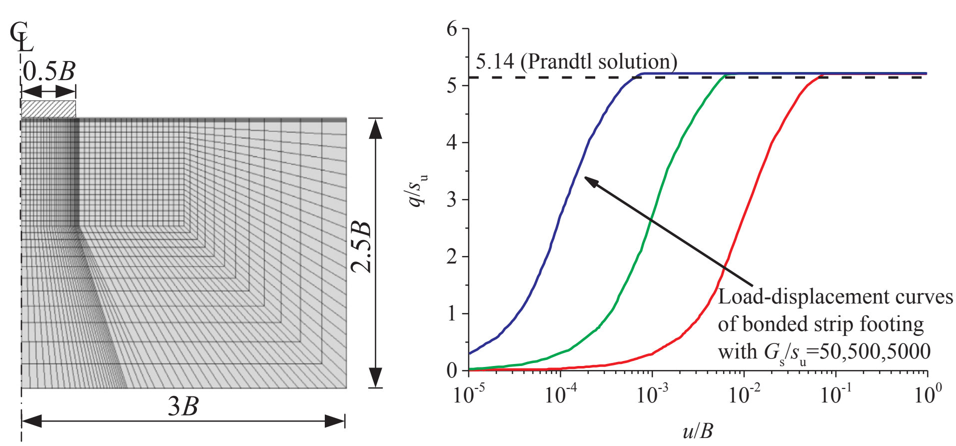


Fig. 1. Flow diagram of the T-EMSD method.



(a) FE mesh with 2052 elements
(b) T-EMSD results

Fig. 2. Effect of rigidity factor on the load-displacement curves.