氏　　　　　名	るーん　すふぁん　びん LUONG,Xuan Binh
学位の種類	博士（工学）
学位記番号	甲第１９２号
学位授与年月日	平成１８年　３月１７日
学位授与の要件	学位規則第４条第１項該当
学位論文題目	Studies on dynamic theory of rigid-plasticity
学位論文審査委員	（主査）　榎　明　潔 （副査）　木山英郎　　西田良平

学位論文の内容の要旨

In current analysis for earthquake–resistant design, there are two basic approaches. One is the stress–strain analysis and the other is the conventional pseudo–static analysis. A complete progressive failure analysis of stress and strain in a soil mechanics problem using the stress–strain approach is too complicated for practical application. On the other hand, the conventional pseudo–static approach is quite crude to predict the behavior of earth structures under seismic loading conditions. In this approach, the same acceleration is applied to every part of the structure and is treated as inertia forces acting permanently on the structure. The stability of the earth structure is evaluated in terms of safety factor. During the earthquake, the safety factor may drop below unity a number of times which will induce some relative displacements, but not cause the collapse of the structure. Thus, evaluating stability of the earth structure in terms of safety factor under dynamic loading is inadequate, and attention should be paid to earthquake–induced displacements. To avoid the complication of the stress–strain approach, and the inadequacy of the conventional pseudo–static analysis, it is desirable to develop herein an effective method for the earthquake–resistant design of earth structures.

The present thesis deals with an analysis method for the stability and motion of soil–like rigid–plastic structures such as slopes, shallow foundations, and retaining structures under dynamic loading conditions.

Although the classical theory of plasticity represented by Kötter's equation can be easily extended for dynamic plasticity problems with the introduction of accelerations as inertia forces, no researcher has done it because of the difficulty in determining acceleration distribution in the structure when failure occurs.

Here, a condition governing the acceleration distribution in the rigid–plastic body is introduced. Combining this condition with "Generalized Limit Equilibrium Method (GLEM)", the Dynamic GLEM is established and solutions for dynamic plasticity problems can be obtained, where the GLEM is one of limit equilibrium methods and proposed by Enoki et al. (1991a and 1991b) for static plasticity problems.

In Dynamic GLEM, the failed soil mass is considered as a rigid-plastic block system, in which the surrounding surfaces of the block are made up just of the slip planes. When sliding has not occurred, all blocks and sub-base take the same movement. Stability of the structure is analyzed by the Dynamic GLEM with condition that acceleration of every block is the same as the given acceleration.

When the given acceleration exceeds the critical value, the blocks move relative to each other and to the base beneath the failed soil mass along the slip planes. Across a slip plane the component of acceleration normal to the direction of relative displacement are continuous. With the introduction of this condition to the Dynamic GLEM, motion of every part of the structure can be analyzed.

The important conclusion here is that the analysis results of proposed method are in good agreement with the experimental ones in active problems. In passive problems, elastic deformation and volumetric change seem to suppress plastic deformation.

The present thesis is organized into 7 chapters.

Chapter 1 presents the general introduction, objectives and scopes, and layout of the thesis.

Chapter 2 presents the theoretical approach of proposed method including the introduction of the continuity condition of acceleration and the formulation of the Dynamic GLEM for both stability and motion analyses with two cases of study: limit equilibrium approach using force field in limit equilibrium states and upper bound approach using the kinematically admissible displacement rate field and the principle of virtual work.

Chapter 3 illustrates stability analyses of slopes, foundations, and retaining structures under seismic loadings. The relationship between limit equilibrium and upper bound approaches in stability analysis is discussed. Some comparisons of present solutions with existing solutions are demonstrated.

Chapter 4 presents motion analysis problems of slopes, foundations, and retaining structures under seismic loadings. The motion of foundations under external excitations and the investigation on deep failure of retaining structures are also described. The consideration of dilatancy angle and the use of peak and residual values of soil strength in calculation are discussed. The relationship between limit equilibrium and upper bound formulations in motion analysis is pointed out. Comparisons of proposed method with Newmark's method and Mononobe–Okabe method are figured out.

In Chapter 5, the experimental research to confirm the validity of proposed method is presented. The high-speed and large-displacement shear test is performed to investigate dynamic shear strengths of sandy soils. A number of experiments on models of slopes, foundations, and retaining walls are conducted and compared with theoretical analyses.

In chapter 6, the proposed method is applied to analyze motion of a supposed foundation subjected to the Western Tottori Earthquake–2000 and motion of a supposed retaining structure under Niigata Ken

Chuetsu Earthquake–2004 shaking. The application of proposed method to construct design charts for critical accelerations of infinite slopes and seismic bearing capacity is also demonstrated.

Finally, chapter 7 summarizes general conclusions of this research and makes suggestions regarding future subjects concerning with the proposed method.

審 査 結 果 の 要 旨

土木工学科においては兵庫県南部地震を契機に、供用期間中に発生する確率は低いが非常に激しい地震動に対しても、構造物の耐震性の評価を行い、終局変形量を修復可能な程度あるいは構造物全体系が崩壊しない程度にとどめることになった。このためには、地震時の土木構造物の塑性変形を解析する必要があるが、土木構造物に対する塑性変形解析方法の開発は遅れている。

本論文は、土を剛塑性体と仮定して地震時の運動を論じ、残留変位の解析方法を提案するものである。まず、鳥取県西部地震による斜面表層崩壊に関する現地調査結果の解釈の過程で榎らが気付いた「すべり面に垂直な加速度成分はすべり面の両側で等しい」という加速度の連続条件と、加速度を慣性力として、Kotter 式で代表される静的な古典的塑性論に導入し、破壊時と破壊後の地盤の運動を支配する方程式を導いた。次にそれを数値解析的に解くための動的一般化極限平衡法(Dynamic Generalized Limit Equilibrium Method)を提案し、斜面・擁壁・基礎などの土構造物の地震時における運動を解析した。最後に、解析結果と振動台を用いた模型実験結果を比較することによって、最大主応力方向が載荷前後で変化しない主動問題では良い一致が見られるが、方向が９０°変化する受動問題では土の体積変化の影響のためか両者に相違が見られることを示した。

本研究の成果の第一は、従来の静的な塑性理論に加速度の連続条件式を導入して、動的な塑性理論を定式化したことである。加速度の存在する一般的動的問題を対象にした定式化は、地震応答問題だけでなく振動や衝撃を利用した杭打ちや削岩などの施工問題の解決にも寄与できる。第二は、動的な塑性理論の解法として、動的一般化極限平衡法という数値解析法を提案し、多くの実際問題を解いたことである。この数値解析法はNewmark法と比べて塑性論的により合理的で、鉛直加速度も考慮できるという特徴がある。第三は、室内模型実験によって、剛塑性体仮定の適用しにくい問題を特定し、解析方法の適用範囲を明確に示したことである。

以上から、本論文は理論的価値が高いだけでなく、工学的実用性もあり、今後の地盤工学・耐震工学の発展に寄与するところが大きい。したがって、本論文は博士（工学）の学位に値するものと認められる。