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論　文　要　旨　(博士)

論文題目	A Study on Seismic Stability Evaluation of Retaining Structure (抗土圧構造物の地震時安定性評価に関する研究)

(要旨　1,200 字程度)

大きな被害地震においては，土構造物および抗土圧構造物の滑動や転倒などにより種々の構造物には甚大な被害が生じており，中でも，道路盛土・擁壁・斜面の崩壊，港湾施設における岸壁変形などの被害は，市民生活や経済活動に直接影響を及ぼすものであることから，地震時における被災メカニズムの解明や，耐震性能の高度化が求められている。同時に，土構造物および抗土圧構造物の耐震設計法は安全率に基づく従来型の手法である震度法から，性能規定型の設計法へと急速に移行しつつある。そのため，構造物の破壊条件のみならず変形や滑動量の合理的な評価法の開発が急がれている。

本研究の目的は抗土圧構造物の地震時滑動特性を明らかにし，その評価法を提案することである。本研究では，構造物の振動特性を直接取り入れることが可能な振動－滑動モデル(Vibration－Sliding Model)を提案するとともに，このモデルを活用した抗土圧構造物の耐震性評価に関して，最も重要な要求性能である地震時滑動量の評価法を検討している。さらに，振動－滑動モデルを用いた抗土圧構造物や盛土斜面の滑動量の算定方法を示すとともに，そのモデルの妥当性を検証している。

本論文では，まず，振動－滑動モデルを数式によって表現する数理モデルを構築し，数値解析法によって挙動を計算するためのプログラムコードを作成した。これを用いて基本的な条件のもとで実施した一連の数値実験によって，振動を伴いながら滑動する抗土圧構造物の基本的な振動－滑動応答特性を明らかにするとともに，地震時滑動量の評価における振動特性の卓越した重要性を示す。地震動のような不規則な振動に対する滑動応答特性はスペクトルの形式 (Earthquake Sliding Response Spectrum)で整理でき，抗土圧構造物の振動特性（固有振動数と減衰率）が与えられれば，抗土圧構造物の底面摩擦特性を考慮して地震時滑動量を簡易に推定することが可能になる。

次に，振動－滑動モデルの基本原理と数理モデルの妥当性を検証するために作製した，物理モデルについて一連の振動台実験を実施した。これにより，振動－滑動挙動を種々の条件で観察し，抗土圧構造物の滑動における振動特性の重要性を実体として明らかにするとともに，滑動－振動モデルの妥当性を検証した。

本研究により，抗土圧構造物の地震時における振動－滑動挙動のメカニズムが明らかとなり，その滑動量の評価法が振動特性を考慮できる合理的なものとなることで，抗土圧構造物の性能規定型の耐震設計を現実のものにする一助となれば，意義のあるものと考えられる。

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論文要旨（博士）

論文題目	A study on Seismic Stability Evaluation of Retaining Structure (抗土圧構造物の地震時安定性評価に関する研究)

(要旨　800 語程度)

In recent years, major earthquakes have occurred in various regions in Japan. And earth structures and retaining structures are significantly damaged in the earthquakes. Infrastructures and lifeline utilities which consist of highways, railways, bridges, buildings, river dikes, quay walls, retaining walls and soil slopes are directly influenced by the damage of earth structures and retaining structures. Therefore, to reveal the mechanism of the damage, and to improve the earthquake resistance of structures are demanded immediately.

In the earthquake resistant design of earth structures and retaining structures, a performance-based method is lately preferably employed instead of a conventional safety factor-based method. In the performance-based design, a certain degree of performance of the structure must be guaranteed even after the application of an earthquake of assumed intensity. In order to conduct the earthquake resistant design satisfactorily, the degree of the damage to the structure must be quantitatively estimated; the sliding displacement is a primary important factor as an index of the damage intensity for earth structures and retaining structures. The rigid mass-slider model originally proposed by Newmark is sometimes employed for the purpose, which makes it possible to calculate the sliding displacement of rigid mass on the frictional floor. In the framework of this method, the structure is modeled as a rigid mass and its natural frequency is disregarded. In the reality, however, the sliding displacement depends on the flexibility and natural frequency of structure. The evaluation method we introduce in this study employs a mathematical vibration-sliding model which consists of the mass, spring with dashpot, and slider to take account of the vibration properties of structure. In general, as earth structures and retaining structures possess the vibration properties, the vibration response characteristics of the structures during earthquakes are different by the relationship between the natural frequencies of the base and structures. Therefore, it is considered that the sliding response also strongly depends on its relationship. The effect of the vibration properties to the sliding displacement during earthquakes is not taken into account in the present earthquake resistance design method which is based on seismic coefficient method as a conservative side. If the effect of the structural vibration properties to the seismic stability of the structure is taken into account appropriately, rational and economical earthquake resistance design should be possible.

In this article, first a mathematical vibration-sliding model which consists of the mass, spring

with dashpot and frictional slider was built for a numerical analysis. From the analysis results, it was found that the sliding displacement strongly depended on the natural frequency of the structure, and became large in condition of the ratio of the structural natural frequency to the base frequency of around unity in particular. And, the relationship between the sliding displacement and the natural frequency were summarized in a form of response spectrum, where the calculated sliding displacement was plotted against the natural frequency of the structure with parameters such as damping and sliding margin. By using this response spectrum, simplified evaluation of the sliding displacement should be possible.

After that a series of shaking table tests on a physical vibration-sliding model was conducted to verify the evaluation method by means of the mathematical vibration-sliding model. The physical model was developed from the mathematical model, and could be taken into account the vibration properties. The observed results indicated the sliding displacement was depended on the natural frequency of the structure as wall as the calculated results for the mathematical model. And, a good agreement was found between the sliding behaviors observed with the physical model and those calculated with the mathematical model. Therefore, the validity of the evaluation method in the mathematical vibration-sliding model was clarified by shaking table tests on the physical vibration-sliding model.

Next, a series of shaking table tests on a retaining wall model with backfill ground in gravitational field was conducted to reveal the effect of earth pressures to the sliding displacement. In the tests, the retaining wall model with real form and the backfill ground employed drying fine sand were prepared. From the observed vibration-sliding behavior, it was found the sliding response characteristics of the retaining wall model acting earth pressures also depended on the natural frequency of the structure, and when the sliding occurred, the fluctuating earth pressures on the retaining wall model decreased. This means the effect of the fluctuating earth pressures to the sliding displacement is not very significant in this study. Therefore, it is considered this result is useful for the rational evaluation for earth pressure during earthquake.

Finally, the application of the evaluation method to practical problems; gravity type quay walls and soil slopes is presented.