博士論文

Development of Earthquake Risk Assessment System for Nepal

（ネパールを対象とした地震リスク評価システムの開発）

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Abstract

Earthquake is one of the most significant natural hazards in Nepal. There is a long history of destructive earthquakes that damaged large number of buildings and killed many people. Earthquake risk evaluation is the first step for realistic and effective planning and implementation of earthquake risk reduction as well as preparedness initiatives as it helps understanding the underlying problems and its magnitude. Different risk assessment methods are used in Nepal in some cities but the need is to do the risk assessment work at the national level and also at the large number of cities. Therefore, a need for a study on development of earthquake risk assessment system in Nepal which suggests appropriate tool/s for conducting earthquake risk assessment at different scale in Nepal, provides/recommend appropriate fragility functions for different types of Nepalese buildings and also suggest how much risk can be reduced if the risk reduction activities are implemented.

Eight different earthquake risk assessment methodologies and tools used in different cities and communities in Nepal were compared for their characteristics in terms of stakeholders' involvement, provisions of detail input and output, resources required for assessment works, simplicity for use, appropriateness for use at city level and national level and the tools and accessories are open source or not. HAZUS and Open Quake are found better options for national level risk assessment and RADIUS is found comparatively better for cities where there is no GIS information of buildings and infrastructures while as CAPRA GIS is found better for cities where GIS information of individual buildings and infrastructures are available.

Computation of fragility functions for non-engineered low strength brick masonry buildings in Nepal through time history analysis using Applied Element Method (AEM) was done. Extreme Loading for Structures (ELS) tool is used for AEM simulation. Key parameter required for non-linear analysis like shear strength of existing masonry buildings was obtained through direct shear test in actual field condition. The result obtained from AEM was compared with shaking table test results and a good agreement on experimental and numerical simulation result was found. Numerical models of several buildings with different configuration and number of stories for three different category of brick masonry buildings were prepared and analyzed with different mortar properties and different input motions. Damage state of all the buildings at the given input motions are recorded and cumulative probability of damage at each level of Peak Ground Acceleration (PGA) are recorded and a set of fragility functions for four damage state namely "Slight",

"Moderate", "Extensive" and "Complete" are computed for three different types of brick masonry buildings prevalent in Nepal.

For the development of fragility functions for stone masonry buildings, a new approach of clustering randomly generated triangular meshes to form random shaped stones is proposed in this study. Numerical models of two experimental cases, one for monotonic load case and the other for dynamic load case, were prepared applying the proposed new approach of modeling. The numerical simulation results obtained were compared with the experimental results. In monotonic loading case, the force-displacement relation and the crack patterns were compared with experimental results and a good agreement was found. While, in case of the shaking table test, the initiation and propagation of cracks, acceleration output at different stage of loading and overall damage of the building till collapse were compared. The experimental and numerical results showed a good agreement in all these compared parameters. The study found that the stone masonry structures can be simulated accurately in AEM using this technique of triangular meshing and clustering. Numerical models of representative stone masonry buildings with different configuration and mortar strength were prepared, analyzed and fragility functions were developed.

Retrofitting of masonry buildings in developing country like Nepal is a challenge because of the retrofitting cost. A combined system of using reinforced concrete bands and PP-bands together is proposed in this study and shaking table tests were conducted to compare the effectiveness. Two identical two-story stone masonry buildings of quarter scale were constructed and tested to compare the benefit of this proposed concept of retrofitting through shaking table test. One building model was retrofitted only with reinforced concrete bands and the other with the proposed combined system. Both the models were tested on shaking table with sinusoidal motions of different frequencies and amplitude. The result obtained were compared in terms of crack patterns and damage level, total mass loss at different stage of loading, hysteresis behavior and the cumulative energy dissipation. The comparison clearly shows that the model with combined system performed much better in terms of overall damage and loss of mass, better hysteresis behavior and also better energy dissipation capacity while the additional cost of PP-bands is negligible.

Numerical Simulation of masonry buildings with code recommended practices were conducted to discuss the change in fragility functions of earthquake resilient masonry buildings with the existing buildings. A remarkable change in safety as well as fragility functions were noticed from the comparison.

Finally, comparative study on earthquake damage assessment at the same scenario earthquake with existing buildings information was conducted using existing fragility functions and the newly developed fragility functions. The comparison clearly shows the use of the newly developed fragility functions gives more specific damage at the given location considering the varieties of buildings available in that location.