論 文 の 内 容 の 要 旨

論文題目 An Improved Methodology for Seismic Capacity Assessment of Reinforced Concrete Buildings using System Identification and Numerical Simulation
（システム同定と数値解析を用いた鉄筋コンクリート建物の耐震性評価法の改善）

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To assess the seismic vulnerability of buildings, many parameters must be addressed; however, there are limitations because of field restrictions and priorities. To carry out vulnerability analysis of Reinforced Concrete (RC) buildings, this research assesses the stiffness of a building by simplifications and reasonable assumptions of other parameters, such as strengths and reinforcement detailing, based on experience and the rapid visual screening (RVS) of buildings. The three major components of this study which combine to address the vulnerability of buildings are 1) a numerical tool for accurate modelling of buildings, 2) an identification methodology for estimating the material properties and 3) a reliable capacity quantification scheme for judging the vulnerability of buildings.

Firstly, the numerical tool for carrying out modelling of RC buildings used in this study is Applied Element Method (AEM). To verify the capability of AEM to carry out inelastic analysis and study the properties of plastic hinges corresponding to different damage states, a validation of rectangular RC columns was required. In the process of validation, certain compression failure issues were identified and solved with a proposal of new compression material models for the tool.

Secondly, to identify the material properties of the building, a method based on vibrational characteristics of the building was needed. In this stage, the natural frequencies and mode shapes are identified through Operational Modal Analysis (OMA). Further, a two-step identification methodology is developed which includes 2 steps of estimation of stiffness, where the first step consists of a conventional mode shape and natural frequency based stiffness estimation from an assumed based line. Using the output of this first step and an optimization problem based on minimizing the error between natural frequencies and mode shapes, can overcome the limitations of insufficient modal values to estimate the stiffness accurately.

Thirdly, in this study the capacity of the buildings is assessed based on estimating deformation based damage indices for each member of the structure. The global damage states are further estimated as a weighted sum of these local damage indices, where the weights are considered as inter storey drifts of the structure.

This thesis is divided into six chapters in the following manner:

Chapter 1: Introduction, Review and Proposed Methodology

This chapter presents the purpose of this research based on the motivation and background of damage assessment of buildings for potential earthquakes in future. A thorough literature review is substantiated for understanding the existing methods and its corresponding limitations. Furthermore, the problems in existing current methods and the need for an improved method to assess damage and seismic vulnerability are described, emphasising its corresponding applications.

Chapter 2: Numerical Simulation Tool used in the Study: Applied Element Method

This chapter introduces a numerical tool called Applied Element Method (AEM) used to assess the capacity of a building. However, certain limitations are identified in compression effects in the modelling of concrete in AEM, which are then addressed by changing the compression modelling of concrete. After implementing these changes, the tool is validated for different cases, and the importance of this tool model in various aspects to the behaviour of concrete is discussed.

Chapter 3: Identification Methodology, Derivation and Evaluation

This chapter develops a damage identification and the optimisation algorithm to estimate the material stiffness of a structure. Estimation of stiffness is done in two stages, first stage is the methodology, which is based on simple damage localization, and the second stage is optimisation problem to minimize the observed and estimated values obtained from the outcomes of the former step. Furthermore, the importance and various aspects of this methodology are discussed in this chapter and an iterative mass-update method to identify the mass of the system in the availability of scaled mode shapes is introduced. A theoretical implementation is also demonstrated based on the corresponding limitations and future scope of this method. Additionally, this chapter describes a simple experimental evaluation which was conducted by manufacturing steel frames with changing stiffness/damage states of its members. In these frames, since it is intended to study the possibility of modal analysis and material identification, the operational-modal analysis was performed to estimate natural frequencies and mode shapes, and then a modified identification procedure was applied to identify the stiffness of the members. The practical problems and issues of this method was discussed and corresponding alternatives and improvements are suggested

Chapter 4: Field Study and Identification of Buildings

This chapter describes a field study which was conducted in Nepal to verify the applicability of the developed method for obtaining the other parameters for numerical analysis, and also to understand the practical problems involved in obtaining the data and numerical modelling. This was achieved by measuring the dynamic properties of the buildings in addition to the qualitative assessment results obtained based on RVS. An Operational Modal Analysis (OMA) was also performed to estimate the natural frequencies and mode shapes of the system. Implementation of the two-step methodology developed in Chapter 3 is explained while emphasising certain modifications in application of the method as the field collected data had certain limitations for direct application of the method.

Chapter 5: Seismic Capacity Estimation of Buildings

Continuing from the previous chapter, this chapter implements a damage index formulation from the estimates of AEM based simulations consisting of AEM-based numerical simulations based on the identification of storey stiffness of the real buildings in Nepal. Since, this is the first time to use such a formulation of AEM, it is validated with an experimental frame from literature. The seismic capacity of the structure is then discussed with an emphasis on using damage indices estimated from the numerical simulations by estimating the global damage indices.

Chapter 6: Discussions and Conclusions

This chapter presents the conclusions of the study and how the proposed method could be useful in discussing the vulnerability of buildings for potential earthquakes. Furthermore, issues addressed in the study are examined, and the corresponding future scope of the work and its applicability are discussed.