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Assessment of the seismic performance of old riveted steel frame–RC wall buildings

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ABSTRACT

Seismic performance assessment of old dual riveted steel frame–RC wall buildings using the nonlinear dynamic procedure is presented. The study is based on an existing nine-storey building located in Wellington, New Zealand. The building is representative of medium rise steel framed buildings from the first half of the 20th century.

A three dimensional numerical model of the building was developed in an inelastic structural analysis program. Nonlinear characterisations necessary for the prediction of the inelastic cyclic behaviours of the structural components were incorporated into the numerical model. Details of the structural configuration and member properties for the analyses were determined from the original engineering drawings, the construction specifications, as-built concrete strength test results and literature on properties of steel sections used around the period the building was constructed. The inelastic time history analyses were conducted using a suite of seven earthquake records relevant to the seismicity of the building's location.

Modal properties of the numerical model compare well with results of a physical test conducted on the building. The implemented modelling procedure appeared to have predicted the most probable seismic performance of this type of building, which would not have been captured by other simplified procedures. The assessment also highlighted the adverse effects the characteristics and location of the walls have on the seismic performance of this type of building by introducing significant torsional and vertical irregularities.

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1. Introduction

The New Zealand standard model building by-law [1] introduced earthquake design requirements in 1935, for the first time after the disastrous 1931 Hawke's Bay earthquake claimed 285 lives. Many buildings built prior to 1935 pose significant risk to their occupants and the public in general. Seismic assessment and, if deemed necessary, retrofitting of old buildings, preferably without loss of heritage attributes, are crucial steps towards ensuring better performance in future earthquakes. The task of accurately assessing seismic performance has been made difficult, since until recently sufficient data on the inelastic cyclic behaviour of the structural components of these buildings and numerical tools which could model these properties have been unavailable.

The current New Zealand Building Act [2] requires the ultimate seismic capacity of all existing buildings not to be exceeded in moderate level earthquakes, which are defined as one-third as strong as the design level earthquakes (1/3rd DLEs). Buildings which do not satisfy this criterion are considered likely to collapse at the DLE level, are classified as "earthquake-prone" and are required to be upgraded to two thirds of the standard of an equivalent new building (2/3rd NBS) or demolished. If the building has historical significance, then the upgrading scheme is expected to maintain its heritage attributes. Under the Act, buildings which will have their ultimate capacity exceeded in earthquakes which are two-thirds as strong as the design level earthquakes (2/3rd DLEs) are classified as "earthquake-risk" for the DLE, but are not required to undergo any upgrading.

One of the goals of this study was to determine to which class the case study building located in Wellington, New Zealand (the subject of this paper) belongs, using the Non-linear Dynamic Procedure (NDP) [3] and taking into account of its torsional and vertical irregularity. Unlike other assessment procedures, the NDP allows efficient incorporation of experimentally verified analytical models of the structural components into the numerical model. P-Δ effects can be directly accounted for, no specific lateral loading pattern needs to be assumed, and the earthquake records, chosen based on the seismicity and soil condition of the building site, can be directly used in the analyses. However, the suitability of this method could be hindered by the scarcity of sufficient data on the cyclic behaviour of the structural components and lack of simulation tools, which could incorporate the analytical models satisfactorily. Moreover, the method is complex to implement, computationally expensive and time-consuming to apply. It also requires experience in both modelling and understanding the outputs to obtain appropriate results.

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