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P-DELTA EFFECTS IN MEDIUM HEIGHT MOMENT RESISTING STEEL FRAMES UNDER SEISMIC LOADING

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ABSTRACT

An analytical investigation of the P-Δ effects in medium height steel moment resisting frames excited by selected earthquake motions is reported.

The frames with various design drifts and fundamental natural periods of free vibration were designed according to the loadings provisions for New Zealand's highest seismic risk zone (Wellington) of the Draft Code of Practice for General Structural Design and Design Loading for Buildings, DZ4203 [10] as issued as a "Draft for Comment" in May 1986[2].

The effect of strength degradation was investigated. Dynamic magnification factors for the member forces and displacement were also observed. Limits for the maximum plastic hinge rotation, inelastic drift, displacement magnification and prediction of maximum plastic hinge rotation based on the inter storey drift are suggested.

INTRODUCTION

Many previous investigations of P-Δ effects have indicated that the combination of large gravity loads and lateral displacement, especially in medium to high rise buildings, could cause this second order effect to become significant. In these investigations, the level of significance of the P-Δ effect has been expressed in terms such as stability indices, drift indices and the ratio of base shear to total mass. When the P-Δ effect becomes significant, consideration must be given to the large increases in displacement, curvature ductility, plastic hinge rotation and drift in order to maintain the stability and serviceability of the structures.

There are many different approaches to solving for P-Δ effects. In static analyses the increase of secondary moment can be taken into account as the product of relative inter-storey displacement and the vertical force. In dynamic time-history analyses the effect of changing coordinates must be taken into account in every step of the time-history analysis.

For static analyses, the use of a drift limit and stability index at a certain level of loading as was done in a previous study [3,10] can enable the effect of P-Δ to be dealt with in a practical and simple way. The complexity of P-Δ effects in dynamic time-history analyses arise because of the characteristics and the intensities of different earthquakes and structural properties of the materials.

In this study, thirteen two-bay steel moment resisting frames were designed for various "design drifts" (see the later section on the Seismic Design and Analysis of the Frames) and fundamental natural periods of free vibration, based on the DZ4203's equivalent static approach with a basic seismic acceleration coefficient for Wellington [10]. The behaviour of the frames has been investigated by inelastic time-history analyses using five different earthquake records.

Relationships between the results of the equivalent static analysis and dynamic time-history analysis were derived in order to convert the inelastic time-history analysis to the static analysis based on DZ4203 since dynamic time-history analyses are expensive to carry out. Satisfactory design drift limits are recommended and the influence of drift limitations on plastic hinge rotation and on designing the frame lateral stiffness are also described. The influence of the P-Delta effect on ductilities and plastic hinge rotations are discussed elsewhere [13,14].

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[2] Subsequent to the submission of comment on this draft code, there has been a second draft for comment together with several revisions. This paper does not address the variations that have been put forward in these later documents.