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Effect of the Distribution of Mass and Structural Member Discretization on the Seismic Response of Steel Buildings

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Abstract: The response of steel moment frames is estimated by first considering that the mass matrix is the concentrated type (M_L) and then consistent type (M_C). The effect of considering more than one element per beam is also evaluated. Low-, mid- and high-rise frames, modeled as complex-2D-MDOF systems, are used in the numerical study. Results indicate that if M_L is used, depending upon the response parameter under consideration, the structural model, the seismic intensity and the structural location, the response can be significantly overestimated, precisely calculated, or significantly underestimated. Axial loads at columns, on an average basis, are significantly overestimated (up to 60%), while lateral drifts and flexural moments at beams are precisely calculated. Inter-story shears and flexural moments at columns, on average, are underestimated by up to 15% and 35%, respectively; however, underestimations of up to 60% can be seen for some individual strong motions. Similarly, if just one element per beam is used in the structural modeling, inter-story shears and axial loads on columns are overestimated, on average, by up to 21% and 95%, respectively, while the lateral drifts are precisely calculated. Flexural moments at columns and beams can be considerably underestimated (on average up to 14% and 35%, respectively), but underestimations larger than 50% can be seen for some individual cases. Hence, there is no error in terms of lateral drifts if M_L or one element per beam is used, but significant errors can be introduced in the design due to the overestimation and underestimation of the design forces. It is strongly suggested to use M_C and at least two elements per beam in the structural modeling.

Keywords: steel moment frames; concentrated mass matrix; consistent mass matrix; inelastic seismic behavior; multi-degree of freedom systems

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1. Introduction

A considerable number of problems related to building analysis and design procedures have been studied for many years. For steel building structures subjected to strong earthquakes, modeling the stiffness (K), damping (C), and stiffness (K) matrices has not been the exception. The appropriate modeling of such matrices is a crucial step toward an accurate estimation of the seismic response. One of the most widely used structural systems in steel buildings is that based on moment-resisting frames (MRFs), where the prismatic framed-type members are represented by beam and beam-column members. It is essential to properly represent the aforementioned matrices, at both local and global levels, for this structural system.

The most common and simplest procedure to define the inertial properties of a building is to consider the mass as a concentrated type at the translational degrees of freedoms (DOFs) defined in the structure; it will result in a matrix (M_L) with non-zero numbers in the diagonal corresponding to such DOFs. It is possible, however, to derive a kinematically