AV-05

Effect of vertical vibration on story drift, column axial force and beam acceleration of steel moment frames subjected to near-fault motions

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1. Objectives

Effects of vertical motions on structural response are addressed particularly immediately after damaging earthquakes but have not been paid much attention in seismic design practices. This is partly due to the inherent safety margin attached to design in vertical directions. Near-fault ground motions observed in recent earthquakes are significantly larger than those considered in current seismic design, and there is a possibility of different characteristics associated with the vertical components of these motions. To examine in detail the characteristics of vertical vibration effects on the structural responses, the writers carried out extensive numeric analysis of steel moment frames subjected to near-fault motions.

2. Methods

Low- to medium-rise steel moment frames of 2 to 12 stories were chosen as representative structures. Two sets of records (conventional set and near-fault set) were adopted. The near-fault set consists of 11 fault-normal components of strong motions recorded in the 1995 Kobe Earthquake. For each steel moment frame and each ground motion, six cases were analyzed. They were:

H-1: Each beam of the frame consisted of one beam element; the frame was subjected to horizontal motions only.

H-6: Each beam of the frame was discretized into six elements to allow for beam vertical vibration; the frame was subjected to horizontal motions only.

V-1: Same as H-1; the frame was subjected to vertical motions only.

V-6: Same as H-6; the frame was subjected to vertical motions only.

VH-1: Same as H-1; the frame was subjected to horizontal and vertical motions simultaneously.

VH-6: Same as H-6; the frame was subjected to horizontal and vertical motions simultaneously.

Case VH-6 (horizontal and vertical simultaneously) and Case H-6 (horizontal only) were compared to investigate the effects of vertical motion on the maximum story drift. VH-6 and SRSS of H-6 and V-6 were compared to evaluate the effects of vertical motions on the axial forces of columns. V-6 and VH-6 were compared to evaluate the effects of vertical motions on beam vertical accelerations. The results obtained from the two record sets were also compared to investigate the characteristics of near-fault vertical motions. In the course of comparison, the results were estimated statistically as median values and standard deviation.

3. Results

Major conclusions obtained from this study are as follows:

(1) Effects of vertical motions on the maximum story drift are minimal.
(2) The SRSS approximation using the results of horizontal motion only and those of vertical motion only is applicable to estimate the axial forces of columns generated by horizontal and vertical vibration simultaneously.
(3) Vertical motion has a significant contribution to the column axial forces. The axial forces induced by vertical motion range from 20 percent to 60 percent of the total axial forces in which those induced by horizontal motion (due to overturning) are included. The vertical contribution is larger for short frames than for tall frames.
(4) Beam maximum vertical accelerations can be estimated from the analysis with vertical motions only.
(5) The vertical ground motions are amplified significantly in beams located in upper floors of tall frames. The amplification relative to the maximum ground acceleration reaches more than five in some cases.
(6) Relative effects of vertical motion on structural response do not differ much between the near-fault and conventional ground motions.