Influence of Orientation of Seismic Records on Structural Response

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Summary

The present paper aims to investigate the influence of the orientation of recorded horizontal ground motion components on structural response within the context of Linear Response History Analysis. Two symmetric and an asymmetric building are studied for bi-directional ground motions along the horizontal structural axes. The ground motions are represented by: (a) the recorded accelerograms; (b) the recorded accelerograms transformed to other sets of orthogonal axes forming with respect to the initial ones an angle of $\theta=30^o$, 60^o,…,360^o and (c) the recorded accelerograms transformed to the principal directions of the ground motion. Furthermore, the analytically accurate maximum structural response for any direction of earthquake ground motion is computed. The evaluation of the results shows that the structural response is significantly affected by the orientation of the recorded ground motion components.

Keywords: Seismic analysis, time history analysis, bi-directional ground motions, recorded components orientation.

1. Introduction

One of the methods that modern seismic codes (FEMA356, NEHRP2003, EC8, UBC) suggest for seismic analysis of structures is the (linear or nonlinear) time history analysis. According to this method a spatial model of the structure is analyzed using simultaneously imposed consistent pairs of earthquake ground motion records along the horizontal axes of the structure. The application of this method induces many questions regarding, among others, the influence of the orientation of recorded horizontal ground motion components, which is determined by the recording angle of the accelerograph, on the structural response.

2. Analyses procedures

Two symmetric (SSBE and SSBD) and an asymmetric (SABE) single storey buildings were considered in the present study. Each one of the three models was subjected to 19 bi-directional ground motions along the two horizontal structural axes, for which linear time history analyses were conducted. The ground motions were represented by: (a) the recorded accelerograms; (b) the recorded accelerograms transformed to other sets of orthogonal axes forming with the initial ones an angle of $\theta=30^o$, 60^o,…,360^o and (c) the recorded accelerograms transformed to the principal directions of ground motion. For each time history load case the maximum absolute values of the bending moments at every critical cross section of the beams, as well as the axial stresses at every critical cross section of the columns were determined. Moreover, for each ground motion the accurate maximum values of the aforementioned response quantities were computed using appropriate, analytically derived formulae.

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3. Analyses results

For each building and ground motion considered the ratios $r_0(\theta)$ (ratio of the maximum absolute value of a response quantity R for recording angle θ to the maximum absolute value of the same response quantity for recording angle $\theta=0^o$) and $r(\theta)$ (ratio of the maximum absolute value of a response quantity R for recording angle θ to the analytically accurate maximum value of the same response quantity) are computed. The plots of these ratios corresponding to the bending moment M in a beam of the model SSBE are shown in Figures 1 and 2, where each of the 5 different lines corresponds to an individual ground motion record. Furthermore, Figures 3 and 4 illustrate the variation of ratio r_0 with regard to the recording angle for several response parameters of model SABE under the Loma Prieta earthquake. The black vertical line corresponds to the principal directions of the ground motion.

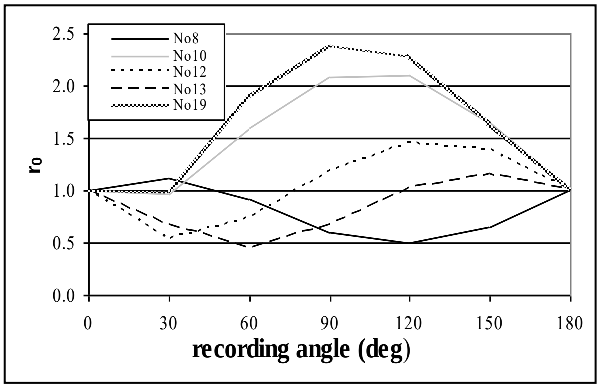

Fig. 1: Ratio r_0 for bending moment M in beam BX5 of model SSBE

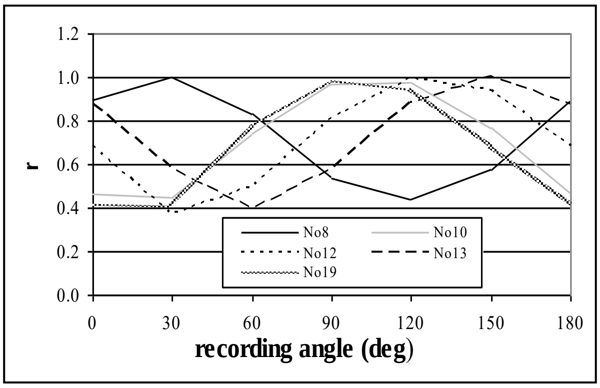

Fig. 2: Ratio r for bending moment M in beam BX5 of model SSBE

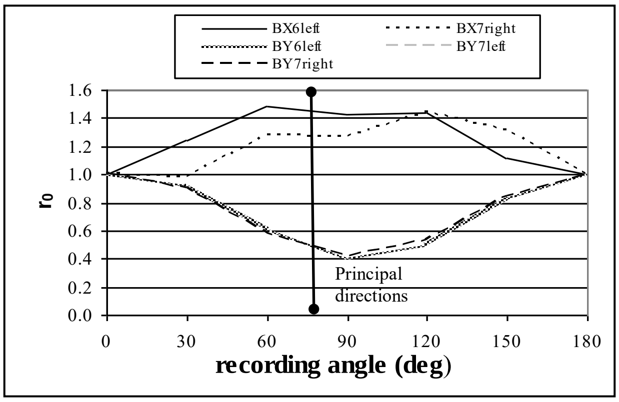

Fig. 3: Ratio r_0 for beam's bending moments of model SABE under ground motion No 11

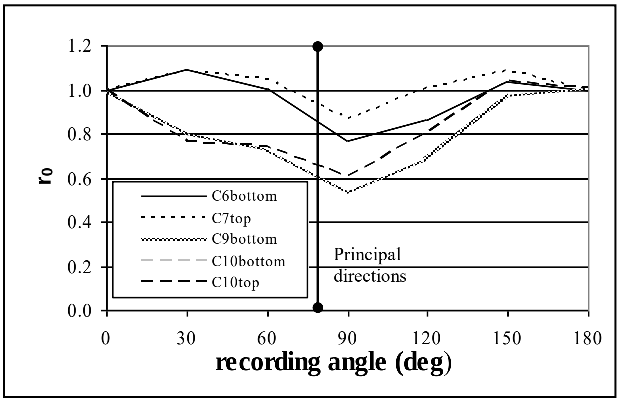

Fig. 4: Ratio r_0 for columns' axial stresses of model SABE under ground motion No 11

4. Conclusions

The investigation of the influence of the orientation of recorded seismic components on structural response has shown that the structural response is strongly affected by the recording angle of ground motion if the accelerograms are applied along the structural axes. The accelerograms along the principal directions of ground motion applied along the structural axes do not produce the maximum response. This is true even for structures with two axes of symmetry. Also it has been shown that the accurate maximum value of a response quantity can be up to 2.7 (Fig. 2) (for the buildings and ground motions considered) times larger than the response produced if the recorded accelerograms are applied along the structural axes. This influence can be removed by using the analytically derived formula for the accurate computation of the maximum response. This formula is convenient to use and requires very little additional computation effort. Minor modification of the existing software tools by their developers would automate the process of computing the accurate maximum response within the context of linear time history analysis.