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VERTICAL EARTHQUAKE COMPONENT – DISTANCE EFFECTS ON THE STRUCTURAL BEHAVIOR OF THE FRAME

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1. INTRODUCTION

In structural design, for the most part of the 20th century, vertical components of the earthquake ground motions have been mostly treated as secondary when compared to the horizontal components. Advances in measurement and data acquisition methods, increase in number of recording stations, developments in analysis and interpretation of recorded ground motions and, finally, unfortunate occurrences of strong earthquakes such as Northridge in 1994, and Kobe in 1995, showed that the existing approach to analysis of the vertical earthquake component on structures needs to be reevaluated (Broderick, Elnashai 1995; Papazoglu, Elnashai 1996; and others) [1]. This approach relied on the 2/3 rule for the peak vertical to peak horizontal acceleration, which was used to scale down the horizontal component in order obtain vertical ground acceleration. In addition, vertical component was analyzed only for cantilevers and larger beam spans. This resulted in some of the specific properties of strong vertical ground motion to be neglected, most notably its intensity and frequency content. Since Northridge 1994 and Kobe 1995 earthquakes occurred within modern urban areas, large number of ground motion records were obtained, therefore enabling the engineers to clearly distinguish specific effects of vertical earthquake component. In recent years, this lead to some/small code improvements, such as EN 1998 which now requires vertical component to be analyzed for locations within 10 km from the known faults (Varevac et all, 2010) [2]. Still, frequency content and possibility of long period pulses occurrence (forward directivity) are not analyzed. In recent times, engineers and researches, made significant number of studies showing that vertical earthquake component can be significant for structural response, and that it should be included in analysis especially considering ever increasing capabilities for numerical simulations in everyday structural engineering.

2. NUMERICAL ANALYSIS

In an effort to further demystify the effects of the vertical earthquake component, this study deals with the response of the RC frame subjected to strong ground motions recorded from the 1994 Northridge earthquake [3]. Two records were chosen: 17645 Saticoy street (2.31 km epicentral distance) and 16628 Lost Canyon Drive (25.12 km epicentral distance), Figure 1, and 2. Table 1, shows general information on chosen ground motions.

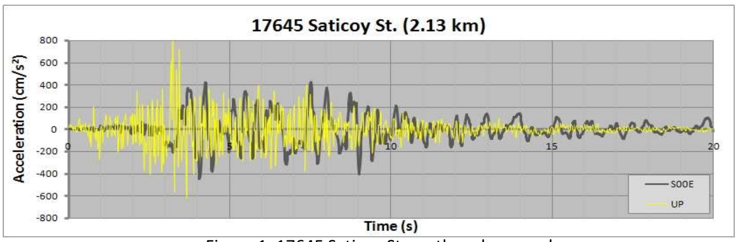


Figure 1. 17645 Saticoy St. earthquake record

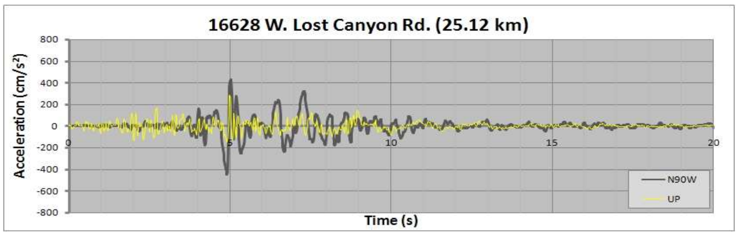
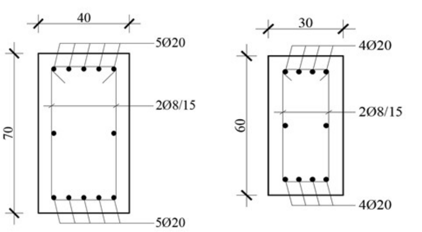


Figure 2. 16628 W. Lost Canyon Rd. earthquake record

Table 1. General information on chosen ground motions

Station	Comp.	Peak accel. [m/s²]	Epicent. distance [km]
17645 Saticoy street	S00E	4,44	2,31
	UP	7,85	
16628 Lost Canyon Drive	N90W	4,46	25,12
	UP	2,80	



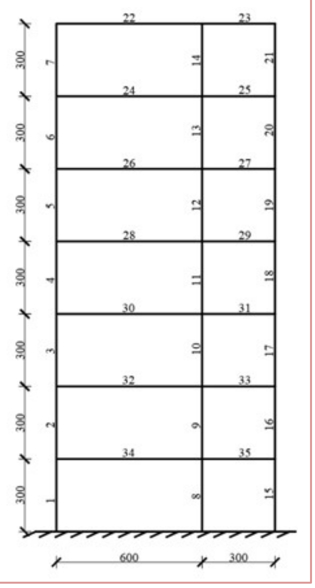


Figure 3. RC frame structure
a) Upper, left figure: column cross-section
b) Figure in the middle: beam cross-section
c) Figure on the right: analyzed frame

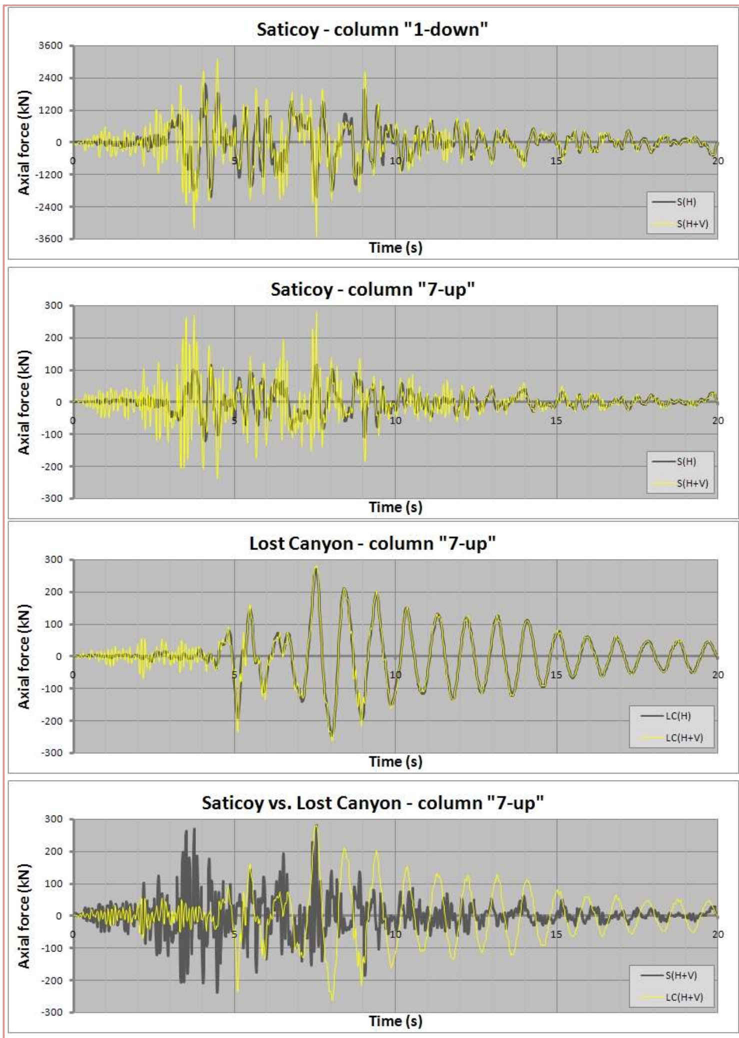


Figure 3. Calculation results – axial forces

Table 2. Comparative results for axial forces and bending moments in the left, top, column

Station	Comp.	N_{max} (kN)	N_{min} (kN)	M_{max} (kNm)	M_{min} (kNm)
17645 Saticoy street	H	114.83	-120.90	340.35	-358.35
	H+V	280.13	-238.53	455.42	-393.46
16628 Lost Canyon Drive	H	269.66	-246.34	807.85	-743.87
	H+V	279.79	-261.49	799.43	-732.14

4. CONCLUSIONS

Within this study, when compared to the horizontal excitation only, the response of the RC frame is significantly different when it is subjected to combined effect of horizontal and vertical earthquake component. Upper columns of the analyzed frame show larger differences in axial forces. Earthquake ground motion, recorded closer to the epicenter, resulted in axial forces that are 2.4 times higher, while at the distance of 25 km calculated differences of internal forces are negligible.

Considering the current advances in structural analysis, seismology, and possible damaging effects of the vertical ground motions, especially in regions with known seismically active faults, the design of seismically resistant structures should also take into account the effects of the vertical ground motion effects.

References:

[1] S. J. Kim, C. J. Holub, A. S. Elnashai, Analytical assessment of the effect of vertical earthquake motion on RC bridge piers, Journal of Structural Engineering, February 2011

[2] D. Varevac, H. Draganic, G. Gazic, Influence of the vertical component of earthquake on large span RC beams, Technical Gazzete 17, 3, 2010

[3] “Cosmos Virtual Data Center”, California, http:// db.cosmos-eq.org/

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