Progetto DPC-ReLUIS 2022-2024 WP 18

Task3: Azione sismica verticale

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

Towards the Integration of Vertical and Horizontal Earthquake Ground Motion Synchronism in Design Guidelines

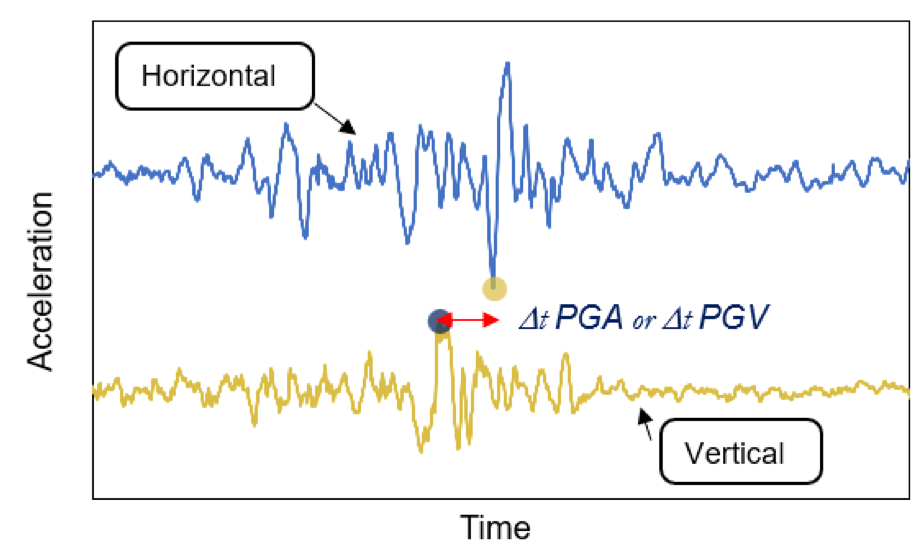
C. G. Lai[1], A. G. Özcebe[2], R. Rodriguez-Plata[3,1], A. Balia[1,3], Y. F. Waktola[1,3]

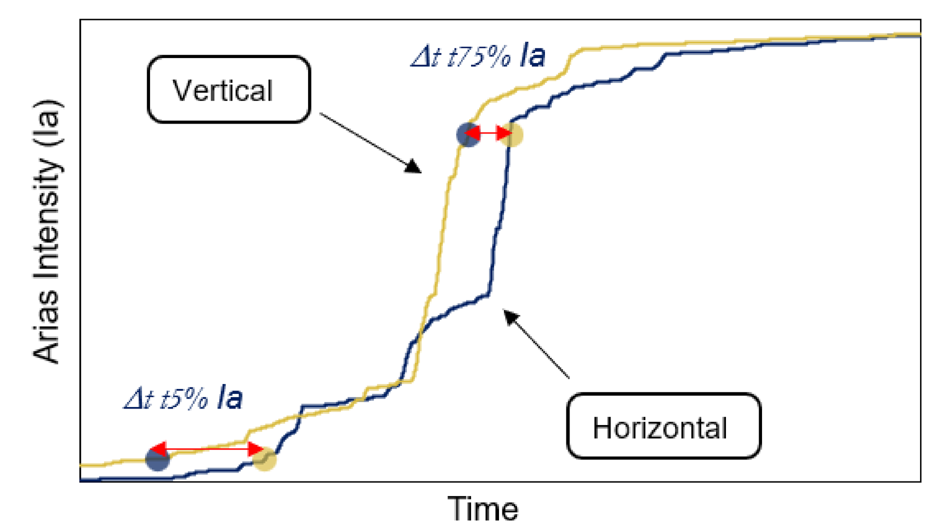
[1]*Università di Pavia, Italy.* [2]*Fondazione Eucentre.* [3]*IUSS-Pavia*

1. INTRODUCTION

The vertical (V) component of earthquake ground motion alone becomes less influential to the seismic response with respect to the horizontal component (H). However, simultaneous occurrence of strong motion in both components of motion would have greater consequences. In this respect, simultaneous arrivals of H and V components become important, a condition referred as to ***synchronism***, which is defined as a phase difference or time delay between H and V:

$$\phi_{IM} = (\Delta t\ IM)_{H-V}$$

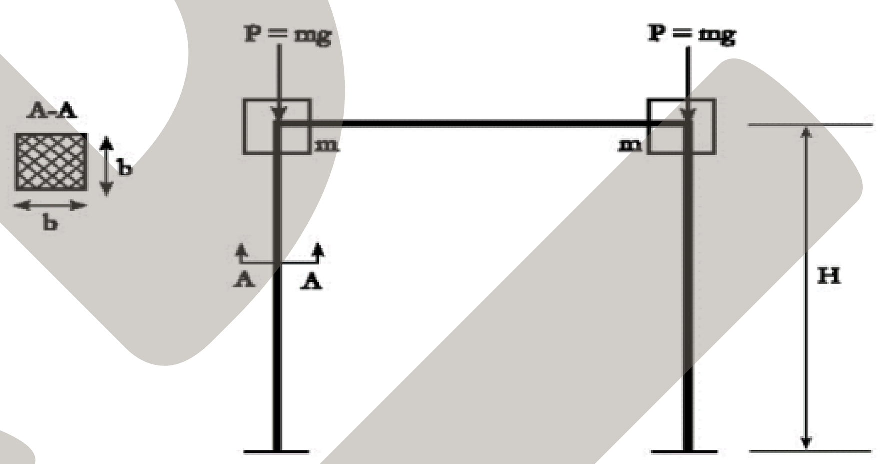


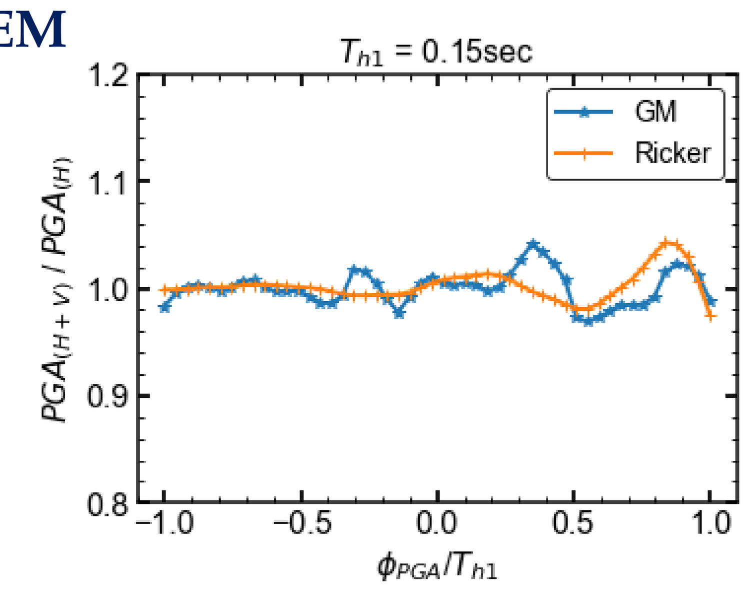


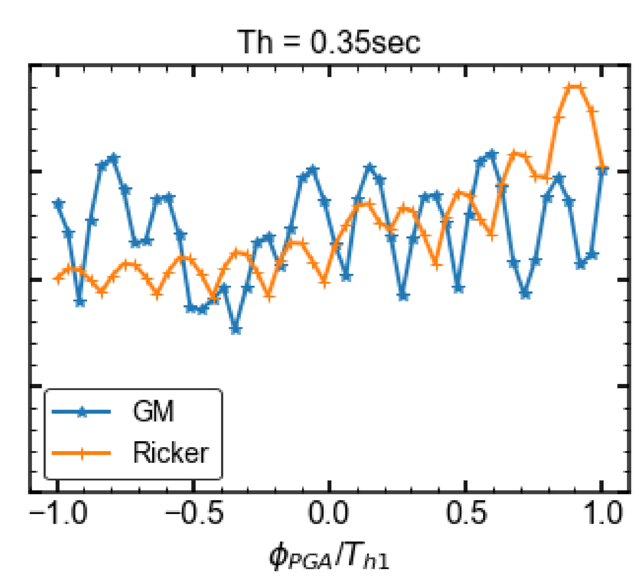
2. SYNCRHONISM AND STRUCTURAL RESPONSE: SIMPLIFIED 2DoF SYSTEM

The numerical models carried with OpenSees platform (McKenna, 2011):

- Linear material properties
- Geometric nonlinearity (e.g., co-rotational formulation, Hardyniec and Charney, 2015).







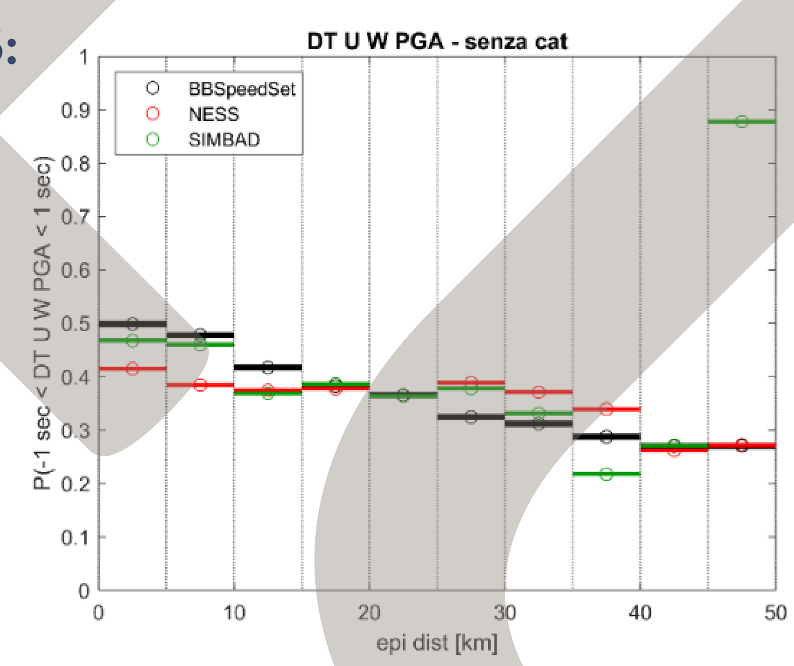
3. SYNCRHONISM IN NEAR-FIELD CONDITIONS: SEISMOLOGICAL CHARACTERISTICS

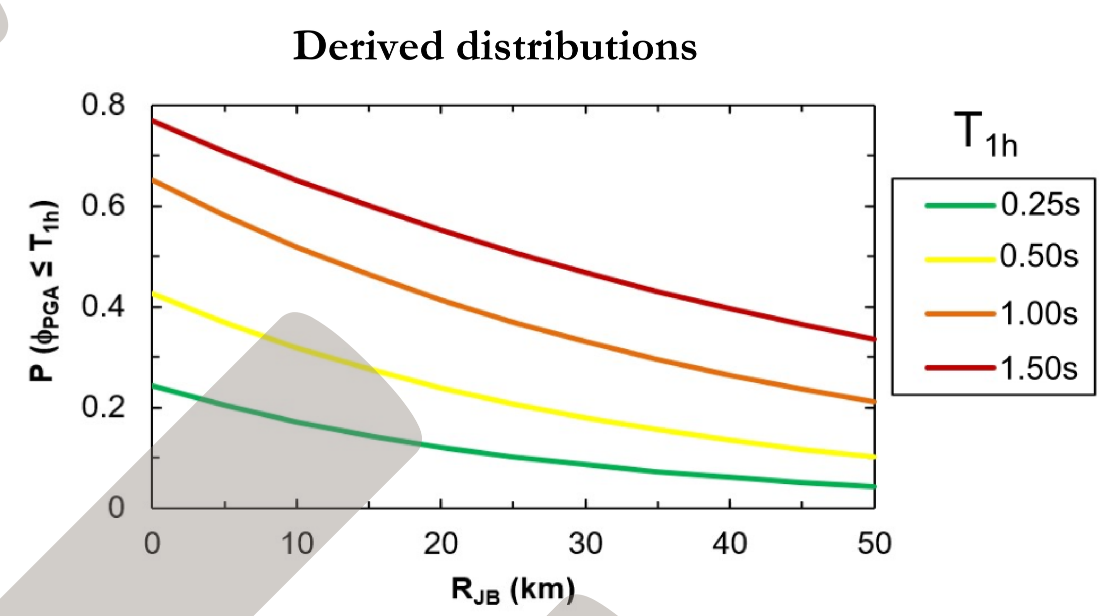
Catalogue based study:

- *NESS* (Near-Source Strong motion) *v2* (Sgobba *et al.*, 2021)
- *SIMBAD v6* (Smerzini *et al.*, 2014) - used for verification purposes
- *BB-SPEEDset v1* (Paolucci *et al.*, 2021)

Probability of synchronism: probability of smaller than a preselected threshold value X_t:

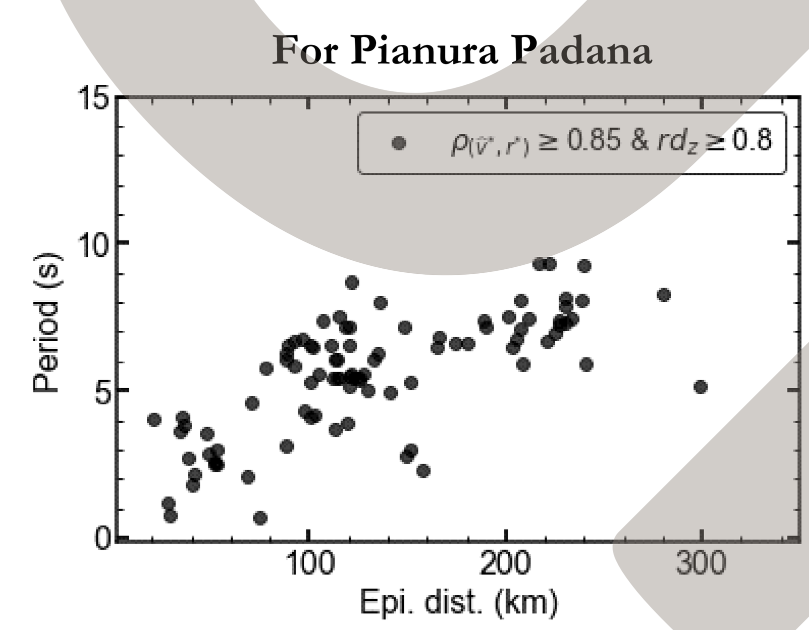
$$P(|\phi_{IM}| < X_t) = P(|(\Delta t\ IM)_{H-V}| < X_t)$$

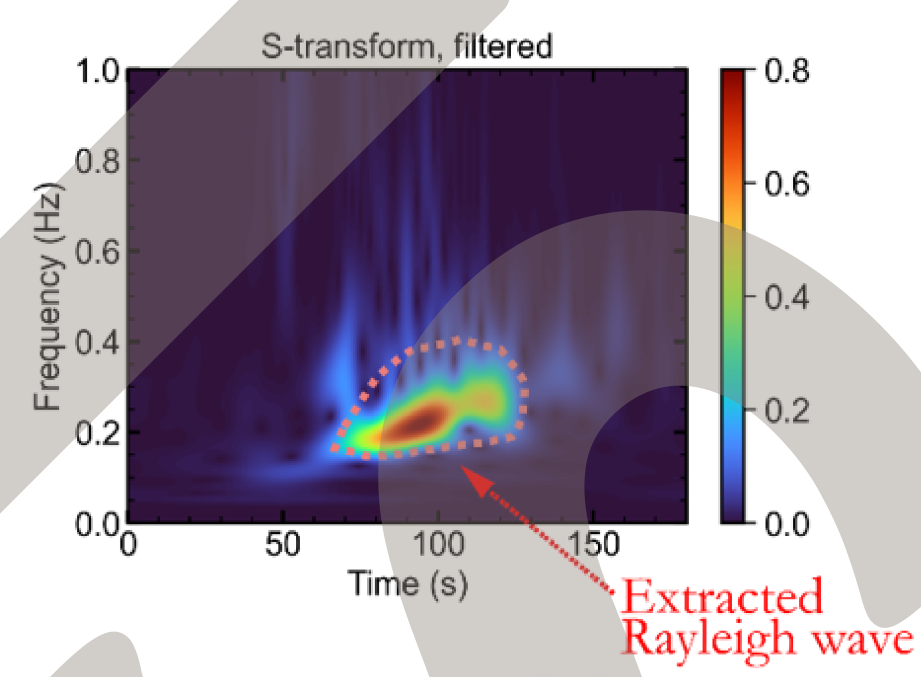




4. SYNCRHONISM IN FAR-FIELD CONDITIONS: BASIN-INDUCED SURFACE WAVES.

1. Basin-induced Rayleigh waves are extracted from ground motion records by means of a time-frequency polarization processing technique. The method is based on the analytical framework initially proposed by Pinnegar (2006), and later extended by Meza-Fajardo et al. (2015).
2. Synchronism of basin-induced surface waves (SW) for the Po-Plain. Synchronism of SWs dominated records linked to the fundamental period of SWs.





CONCLUSIONS AND FUTURE WORK

- Maximum excitation on the structure when $X_t \sim 90\% T_{h1}$ .On the other hand, the maximum constructive interference between the horizontal and vertical response of the structure may amplify the horizontal displacement demand up to 10%. **Analysis with more realistic frame structures foreseen considering non-linear response and the insights from §3 and §4 are**
- Predictive models generated for $P(|\phi_{IM}| \leq X_t)$ by using NESS and NESS + BB_SPEED.
- Proposed criteria for selecting records dominated by Rayleigh wave motion based on the correlation coefficient $\rho(\hat{v}, r)$ and coefficient rd_z of the extracted SW waves. **Similar studies on sedimentary basins around the globe are in progress**.

SELECTED REFERENCES:

Kim, S. J., Holub, C. J., & Elnashai, A. S. (2011). Analytical assessment of the effect of vertical earthquake motion on RC bridge piers. Journal of Structural Engineering, 137(2), 252-260.

Mazzieri, I., Stupazzini, M., Guidotti, R., & Smerzini, C. (2013). SPEED: SPectral Elements in Elastodynamics with Discontinuous Galerkin: A non-conforming approach for 3D multi-scale problems. International Journal for Numerical Methods in Engineering, 95(12), 991-1010.

Meza-Fajardo KC, Papageorgiou AS and Semblat J (2015) Identification and Extraction of Surface Waves from Three-Component Seismograms Based on the Normalized Inner Product. Bulletin of the Seismological Society of America 105(1): 210–229.

Paolucci, R., Smerzini, C., & Vanini, M. (2021). BB-SPEEDset: A validated dataset of broadband near-source earthquake ground motions from 3D physics-based numerical simulations. Bulletin of the Seismological Society of America, 111(5), 2527-2545.

Sgobba S., Felicetta C., Lanzano G., Ramadan F., D'Amico M., Pacor F. (2021) NESS2.0: an updated version of the worldwide dataset for calibrating and adjusting 2 ground-motion models in near-source. Bull Seismol Soc Am., 111 (5): 2358–2378.