Progetto DPC-ReLUIS 2024-2026 WP 18
task 3

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

ReLUIS WP.18 Task 3:
Terremoto di progetto e selezione di accelerogrammi:

Impact of Seismic Input Selection Criteria (UHS vs CMS) on the Nonlinear Response of Reinforced Concrete Structures with Emphasis on Vertical Motion

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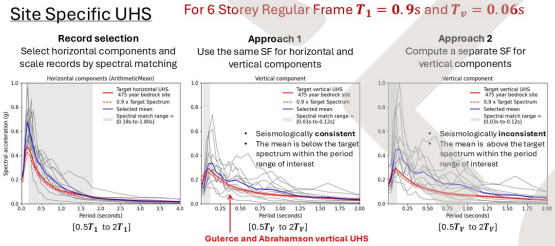
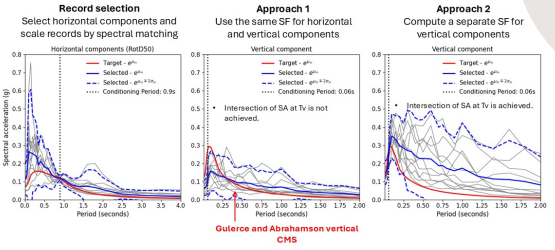
SUMMARY We compare the effect of target spectra (UHS vs CMS) in the code-compatible, multi-component time-history-based seismic assessment of reinforced concrete (RC) frames, both with and without friction isolators. Non-structural components are included by evaluating peak floor accelerations in the models. We consider PMM interaction in the column members through a state-of-the-art fiber section in OpenSees. The convergence issues due to failure in the section are prevented by using a highly stable implicit-explicit solver. The response of the frames examined with particular attention to their sensitivity to vertical ground-motion components. Two record sets are selected at the 475-year return period for the Guardiagrele site. First, the vertical component is scaled with the horizontal scaling factors keeping the characteristics of the ground motion record. Then, independent scaling factors are computed for the vertical component to match the vertical target spectra. The vertical CMS is obtained through the empirical H/V ratio relationships proposed by Gülerce and Abrahamson (2011). While the same-factor approach imposes no special requirements, the separate-factor approach can produce unrealistically high vertical accelerations. As an alternative, a unified scaling-factor strategy may be adopted to simultaneously satisfy both horizontal and vertical target spectra.
Keywords: Multi-component record selection, Vertical component, Conditional spectrum, Uniform hazard spectrum, Reinforced concrete frames, Time history-based assessment

Traditional 3-Component Record Selection

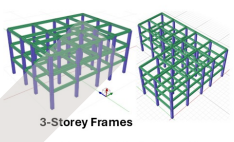
Site Specific UHS — For 6 Storey Regular Frame $T_1 = 0.9$s and $T_v = 0.06$s

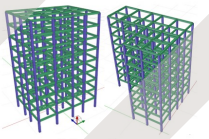


Conditional Mean Spectrum



RC Frame Structures (NTC 2018)

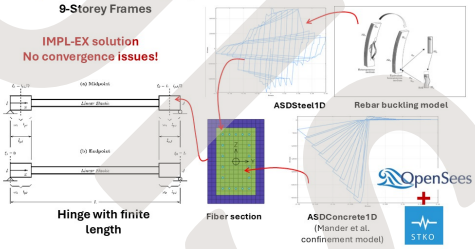


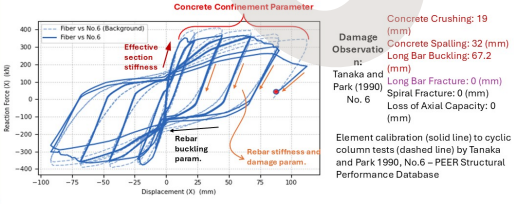


Structure Typology	T0 (s)
3-storey regular frame	0.45
3-storey L-plan frame	0.46
6-storey regular frame	0.91
6-storey L-plan frame	0.92
9-storey regular frame	1.38
9-storey L-plan frame	1.40

0.5 cracked

IMPL-EX solution
No convergence issues!





Proposed Multi-Component Approach

$\boldsymbol{E(SF)}$ is the 3-component error function for a single record:

$$E(SF) = \frac{1}{W}\sum_{i=0}^{T_N} \omega_H(T_i)\cdot[\boldsymbol{SF}\times Sa_H(T_i) - \mu_H(T_i)]^2 + \omega_V(T_i)\cdot[\boldsymbol{SF}\times Sa_V(T_i) - \mu_V(T_i)]^2 + \lambda\cdot P(SF,T_i)$$

- $\boldsymbol{\lambda}$ and $\boldsymbol{P(SF,T_i)}$ penalizes events that are 10% lower than the target spectra.
- $\omega_H(T_i) = \begin{cases} 1, Ti \in [0.5T_1, 2T_1] \\ 0, \quad otherwise \end{cases}$ and $\omega_V(T_i) = \begin{cases} 1, Ti \in [0.5T_V, 2T_V] \\ 0, \quad otherwise \end{cases}$

Conclusions

- Same scaling factor approach fails to conserve CMS in vertical component and UHS requirement in $[0.5\boldsymbol{TV}$ to $2\boldsymbol{TV}]$.
- Separate scaling factor approach results in large vertical accelerations which can be considered safe however, nonstructural components may experience larger vertical accelerations

Future Work Implement the proposed database search algorithm in Python and select a set using a unified scaling factor (2H+V).

References

Gülerce, Z., & Abrahamson, N. A. (2011). Site-Specific Design Spectra for Vertical Ground Motion. Earthquake Spectra, 27(4), 1023–1047.
Volkan Ozsarac, Ricardo Monteiro & Gian Michele Calvi (2023) Probabilistic seismic assessment of reinforced concrete bridges using simulated records, Structure and Infrastructure Engineering
Deierlein, G. G., Reinhorn, A. M., & Willford, M. R. (2010). Nonlinear structural analysis for seismic design: A guide for practicing engineers (NIST GCR 10-917-5). National Institute of Standards and Technology.