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► **To cite this version:**

Bastien Bodnar, Fabrice Gatuingt, Frédéric Ragueneau, Jean-François Deü, Walid Larbi, et al.. POD-DEIM Model Order Reduction in the Case of Damaging RC Structures Subjected to Earthquakes. JJCAB2022. 12ème Journées Jeunes Chercheurs en Acoustique Vibrations et Bruit, Nov 2022, Lyon, France. hal-04050207v2

HAL Id: hal-04050207

<https://cnam.hal.science/hal-04050207v2>

Submitted on 31 Mar 2023

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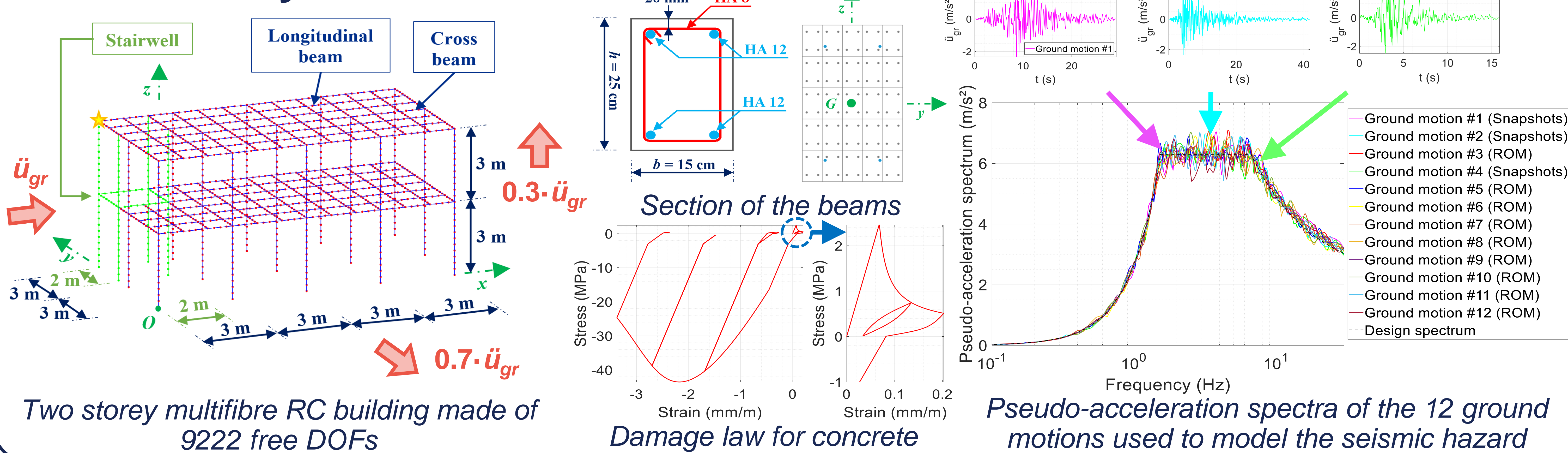
POD-UDEIM MODEL ORDER REDUCTION IN THE CASE OF DAMAGING RC STRUCTURES SUBJECTED TO EARTHQUAKES

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Earthquake Engineering, Reinforced Concrete, Multifibre Beam Elements, Reduced Order Model (ROM), Proper Orthogonal Decomposition (POD), Unassembled Discrete Empirical Interpolation Method (UDEIM)

Earthquake engineering hybrid testing requires the use of efficient nonlinear ROMs that can be run in real time. To tackle this problem, a POD-UDEIM hyper reduced order model is here associated to a non-iterative α -OS time-integration scheme to speed up FEM analyses on a two-storey RC structure made of damaging multifibre beam elements. In this work, the seismic hazard is modelled by a set of 12 earthquakes fitting the same design spectrum.

Case study



Full order FEM analyses with ground motions #1, #2 and #4

Snapshots

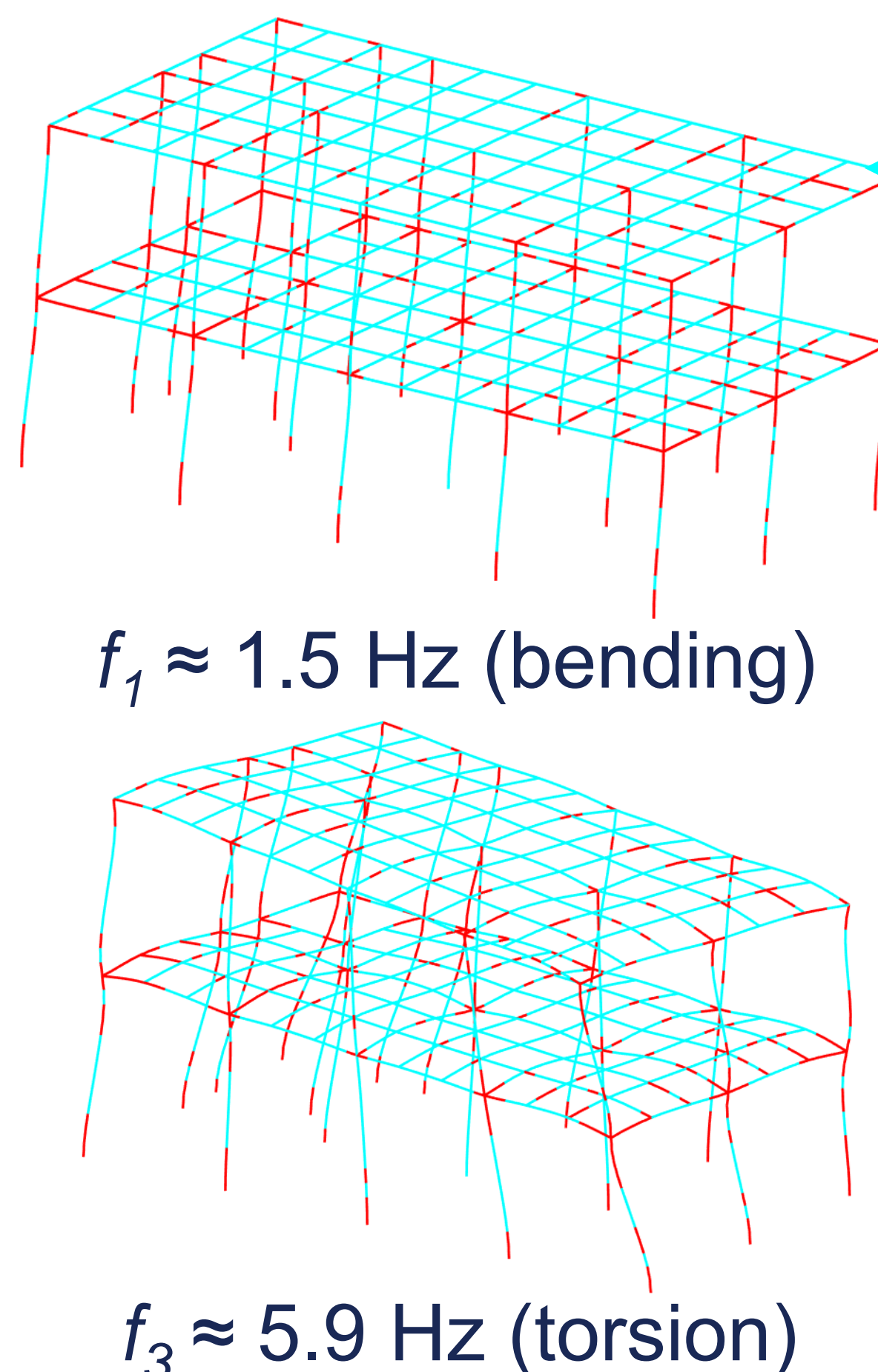
Non iterative α -OS time scheme

$$M \cdot \ddot{u} + C \cdot \dot{u} + K_E \cdot u + \tilde{r}_{NL}(\tilde{u}) = -M \cdot \Gamma \cdot \ddot{u}_{gr}(t)$$

Explicit prediction of the nonlinear part of the restoring force vector

SVD on a set of N snapshots of u

POD-modes



$$u \approx B \cdot q$$

Projection of the displacements on a basis B made of n POD-modes

SVD on a set of N snapshots of \tilde{r}_{NL}

UDEIM-modes

Domain where the restoring forces are interpolated - 1295 elements

Reduced integration domain (RID) - 417 elements

Basis made of m UDEIM-modes

$$A = \Psi \cdot (P^T \cdot \Psi) +$$

Partition matrix related to all the components of the RID

Interpolation operator

$$\tilde{r}_{NL,u} \approx A \cdot \tilde{r}_{NL,u}^{RID}$$

Interpolation of the nonlinear part of the unassembled restoring force vector on the full domain

Online phases

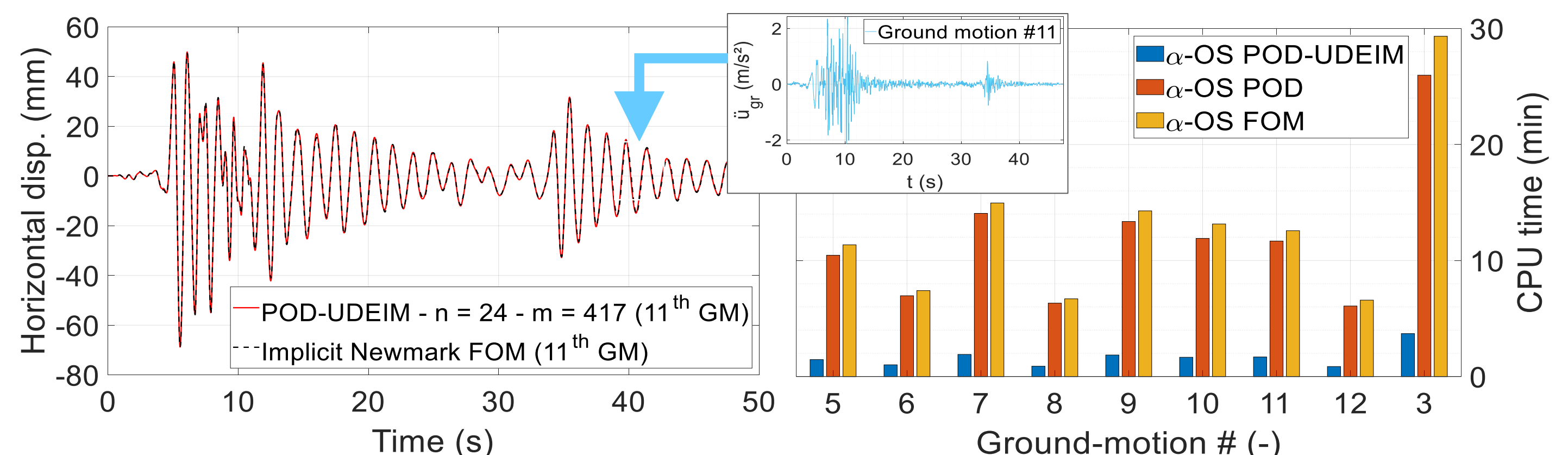
$$1 - \frac{\sum_{i=1}^n \lambda_i}{\sum_{i=1}^N \lambda_i} \leq \varepsilon$$

Singular value related to the i th mode

POD : $\varepsilon = 1 \cdot 10^{-2} \rightarrow n = 24$

UDEIM : $\varepsilon = 1 \cdot 10^{-2} \rightarrow m = 417$

Criterion used to set the number of POD and UDEIM modes



Ground motion	#3	#5	#6	#7	#8	#9	#10	#11	#12
Error/Implicit NM (%)	0.2	0.1	0.2	0.3	0.2	0.3	0.3	0.2	0.6
Time saving POD (%)	11	8	6	6	6	6	10	7	8
Time saving POD-UDEIM (%)	87	87	86	87	87	87	87	87	87

The error is less than 0.6 % with a 87 % time saving during each online phase.

Reduced order FEM analyses with ground motions #3 and #5 to #12

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