Earthquake Engineering Applications Enhanced with HPC

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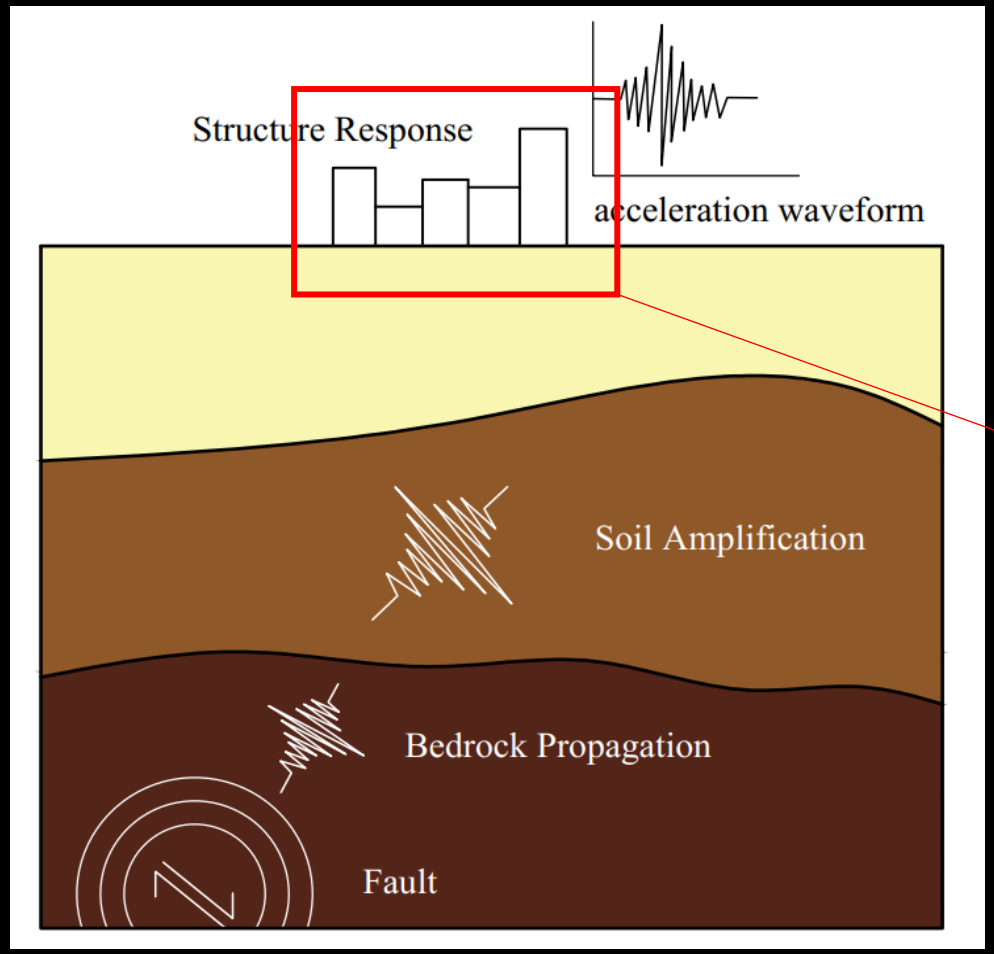
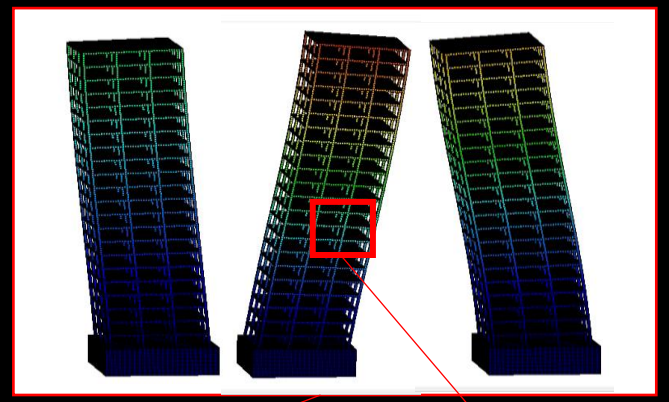
UP ERDFI Webinar on High Impact R&D through HPC

Objective: Develop Tools for Seismic Response Simulation

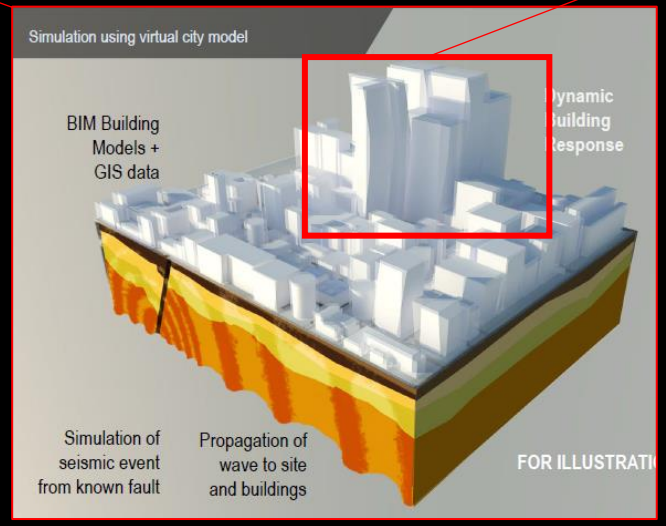
(Fault → Site → City → Structure → Component)



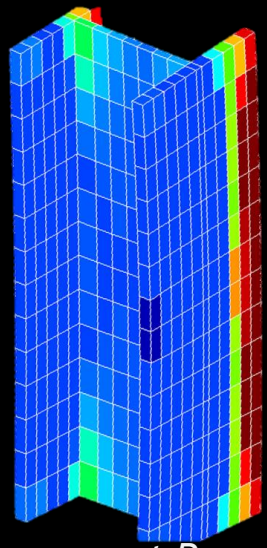
Fault to site earthquake motion propagation



Structure Response

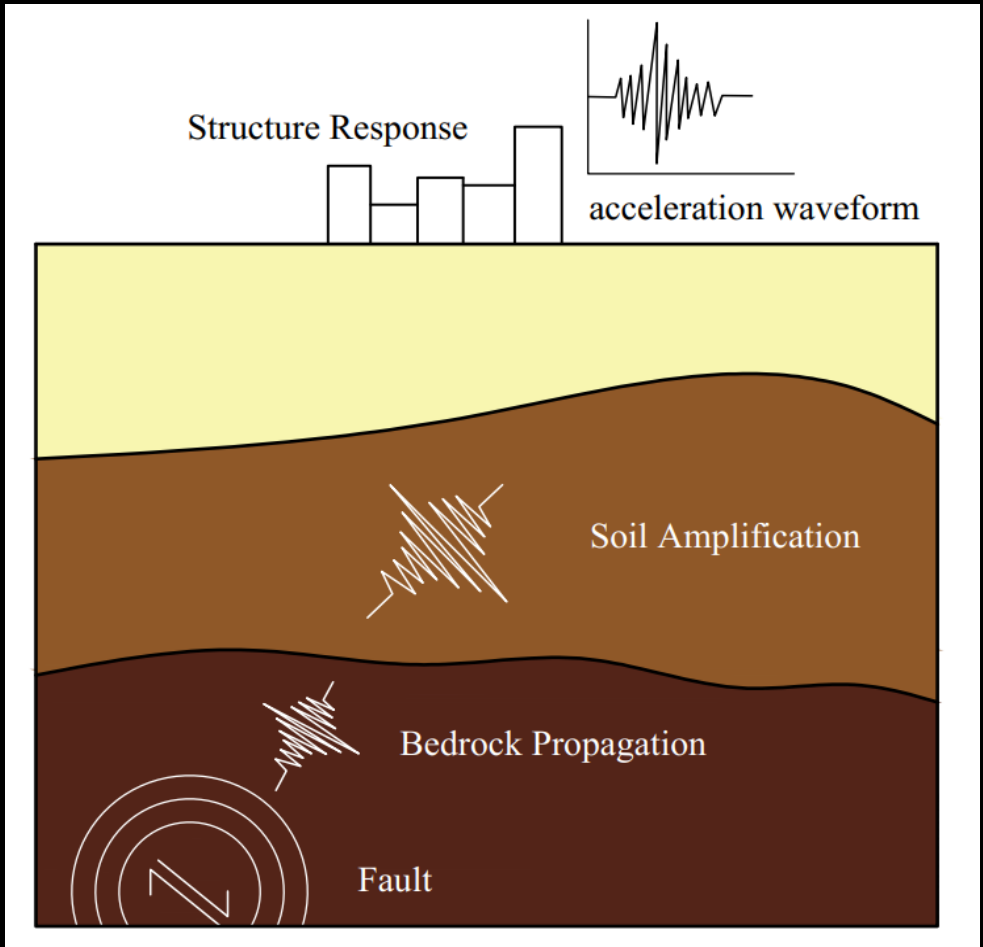


City Response



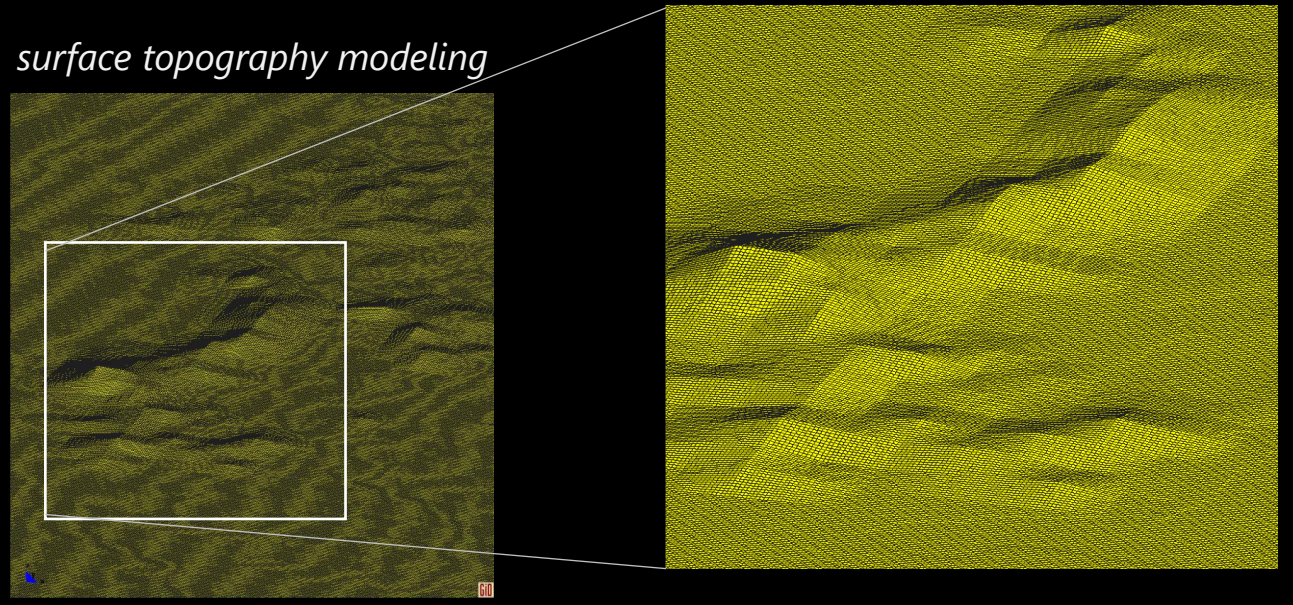
Component Response

ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT

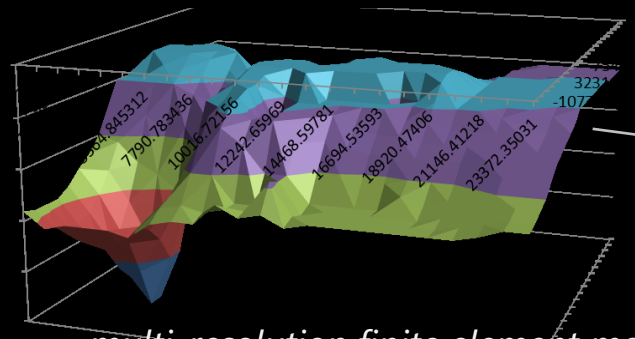


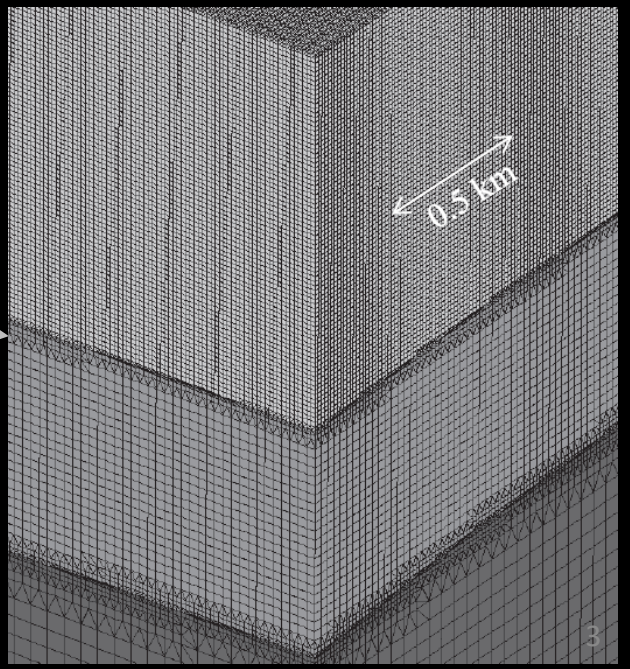
Fault to site earthquake motion propagation

surface topography modeling



crust layer interface modeling

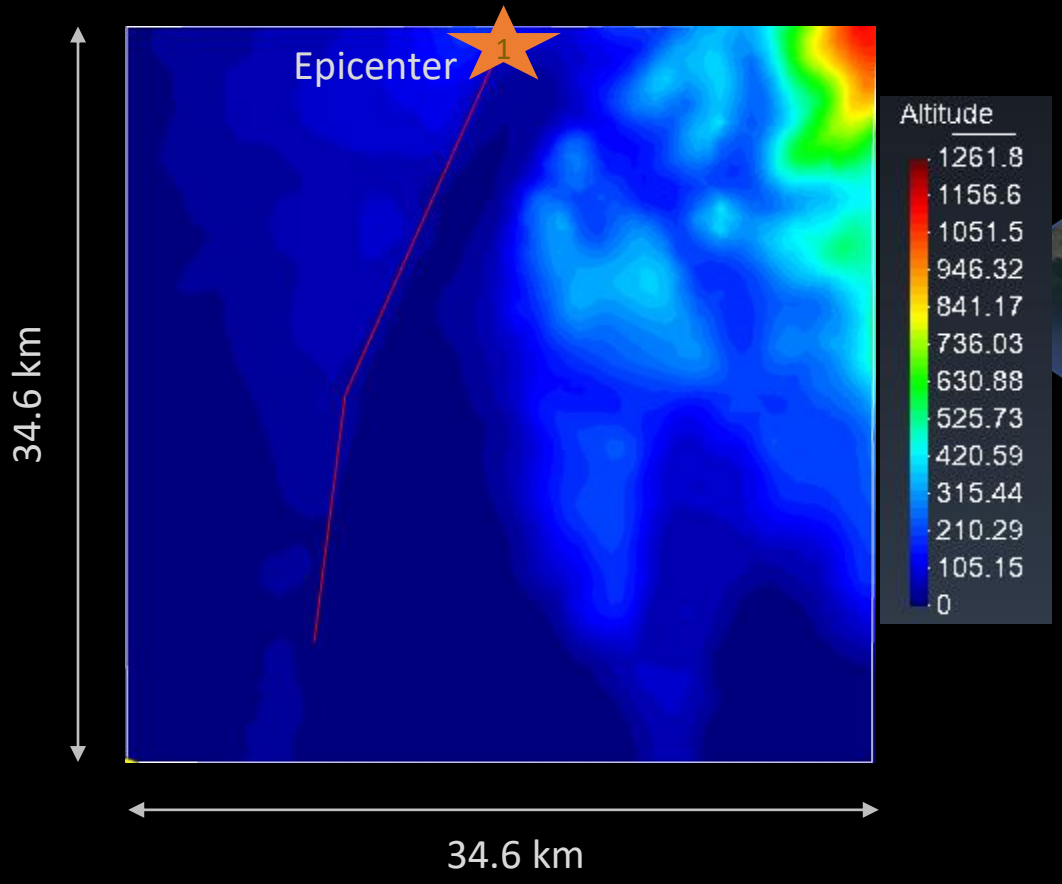




multi-resolution finite element model

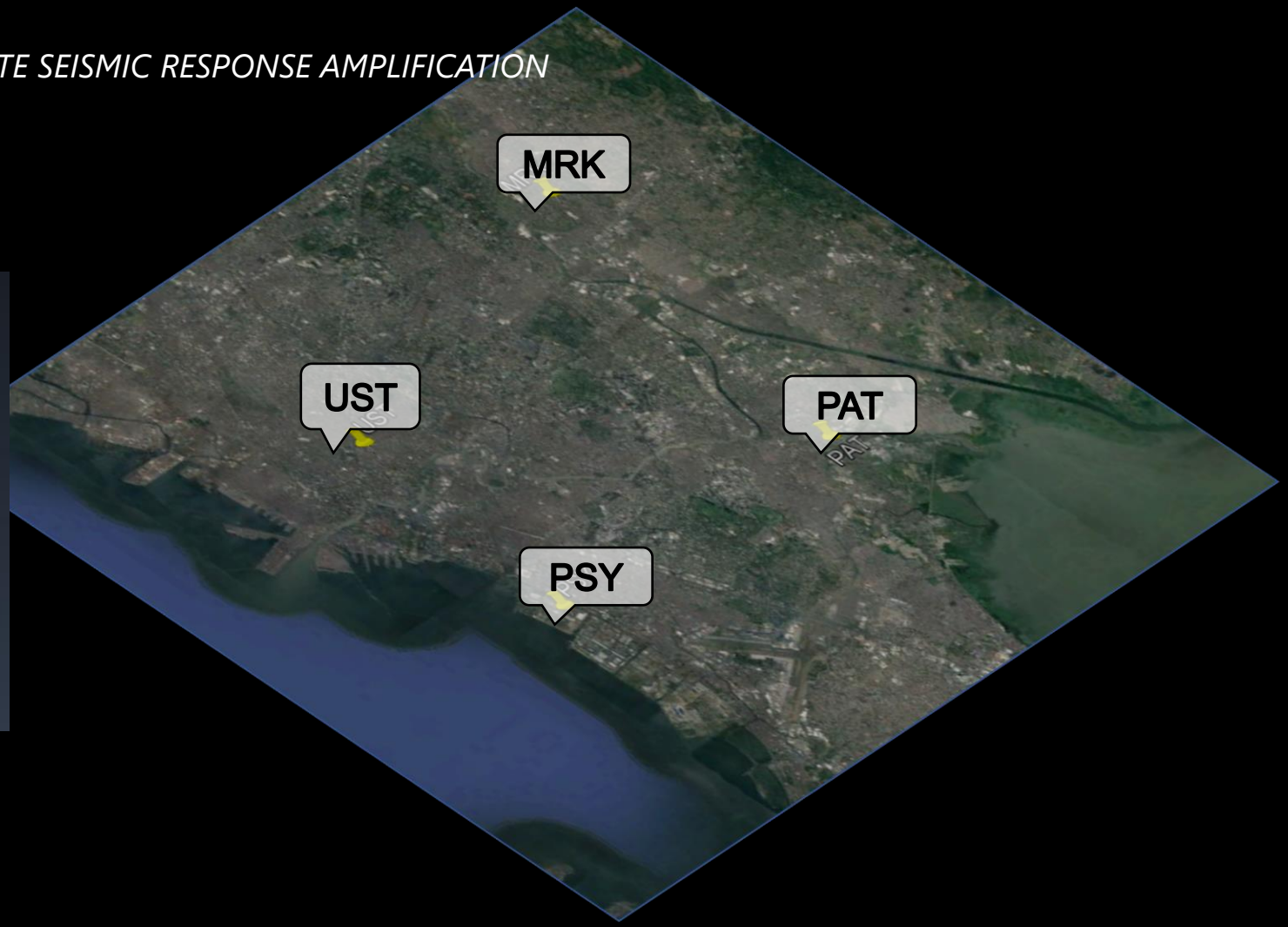
ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT

APPLICATION: METRO MANILA AND NEARBY REGIONS



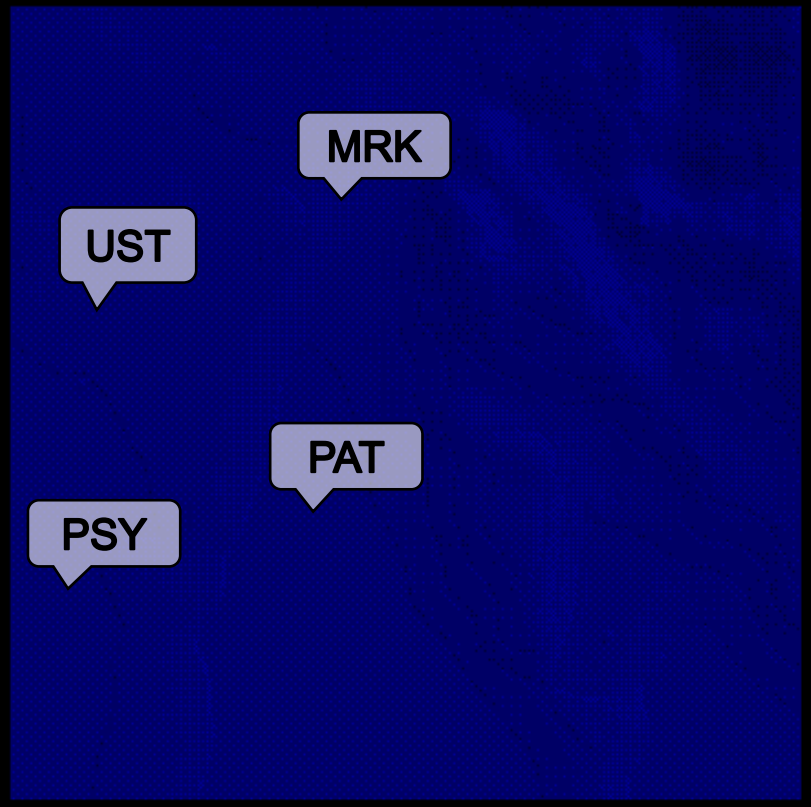
Finest resolution: 60 m

SITE SEISMIC RESPONSE AMPLIFICATION



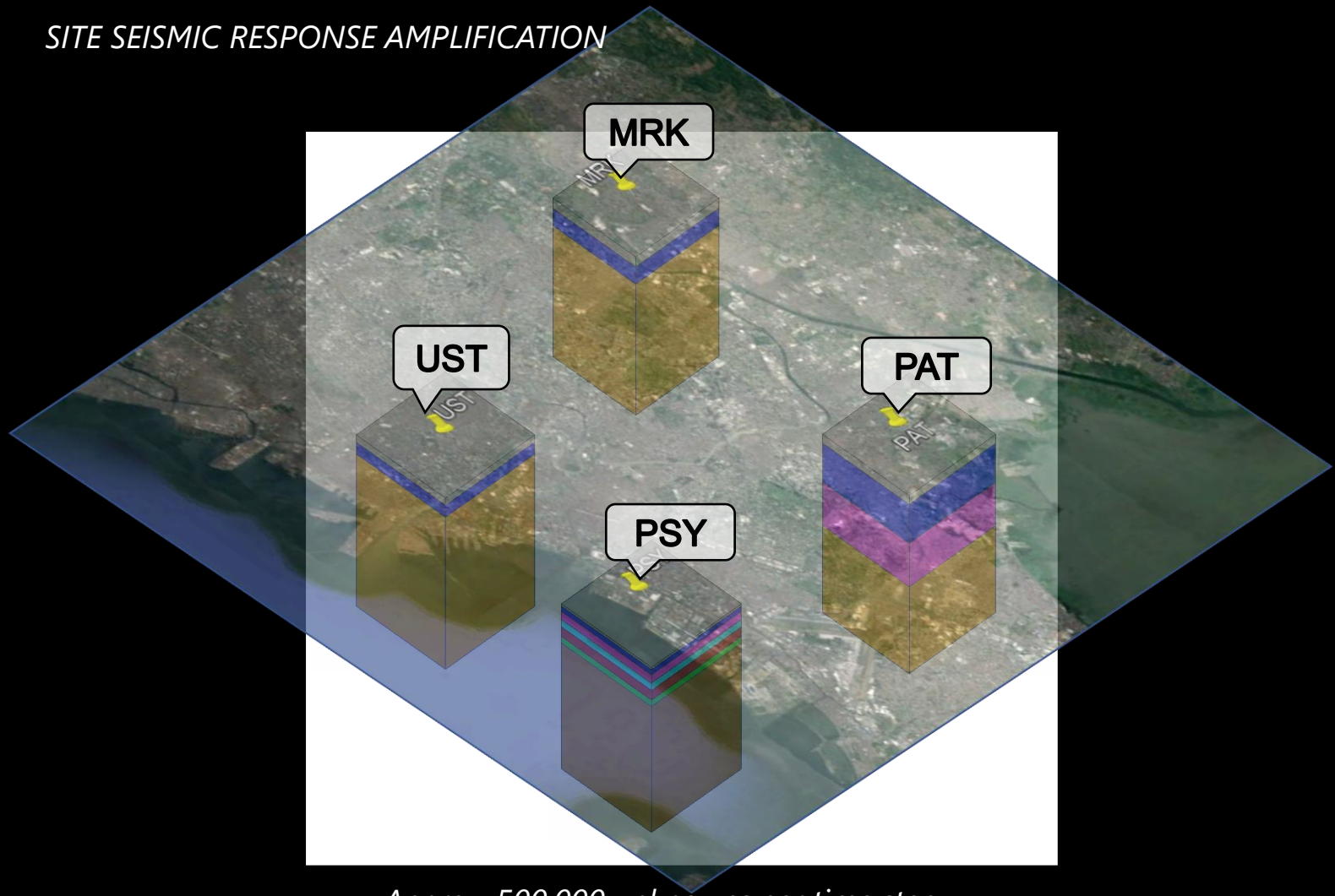
ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT

SCENARIO M7.2 WEST VALLEY FAULT EQ



Approx. 23 Million unknowns per time step computed using 120 cores of DOST ASTI CoARE HPC

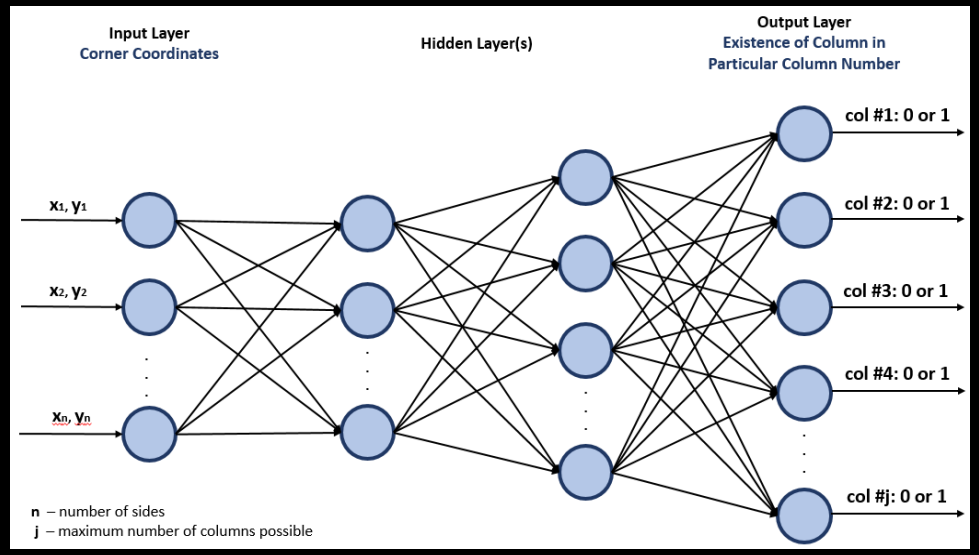
SITE SEISMIC RESPONSE AMPLIFICATION



Approx. 500,000 unknowns per time step computed using 2×2496 CUDA Cores *of DOST ASTI CoARE HPC*

ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT

Frame model generation from feature data (assisted by ANN)



Generated frame models

Loading case

Building mesh

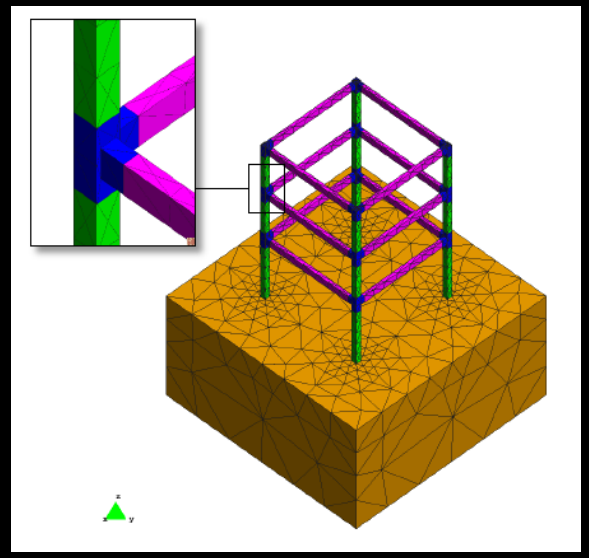
GIS (features)

Story drift results

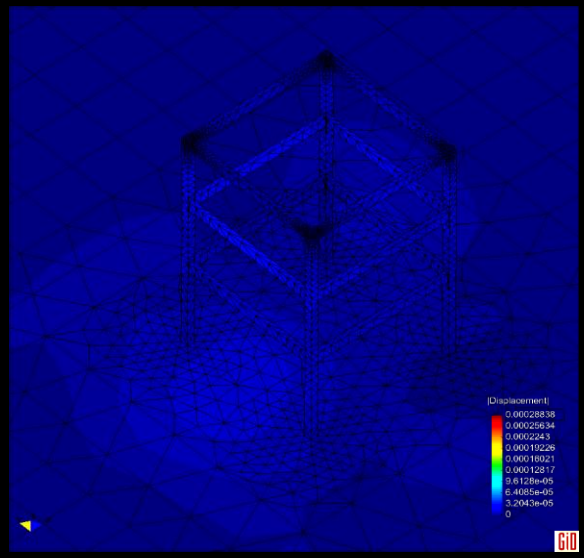
ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT

BIM representation

Finite Element Model

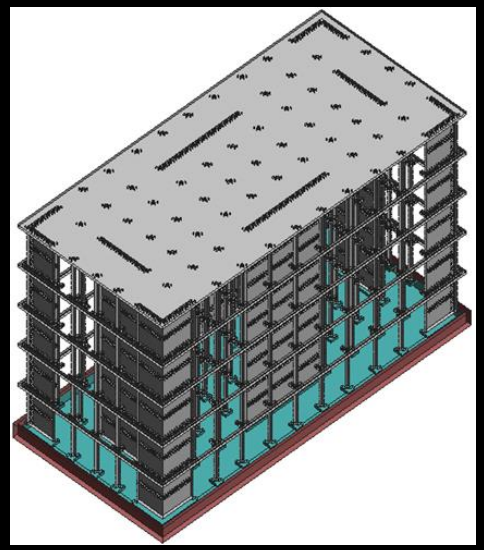


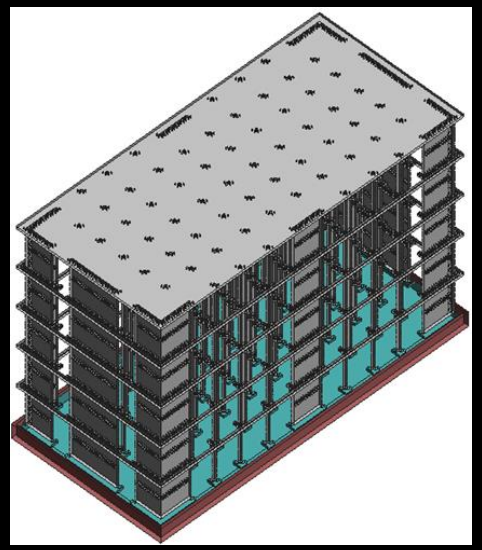
Building Response

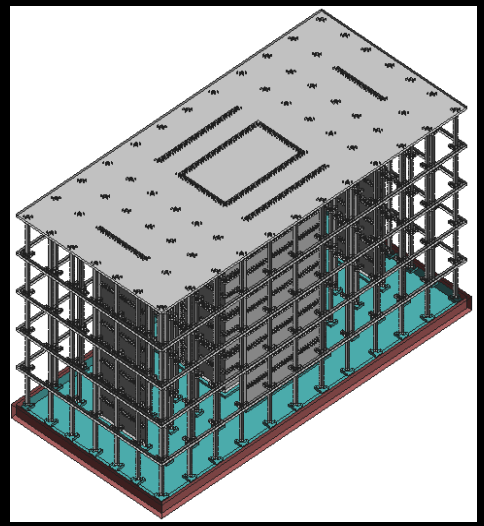


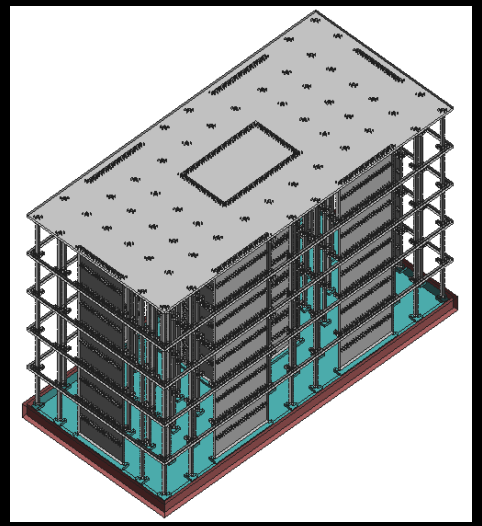
ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT

Automated Finite Element Model Generation of Multiple Dual System Configurations

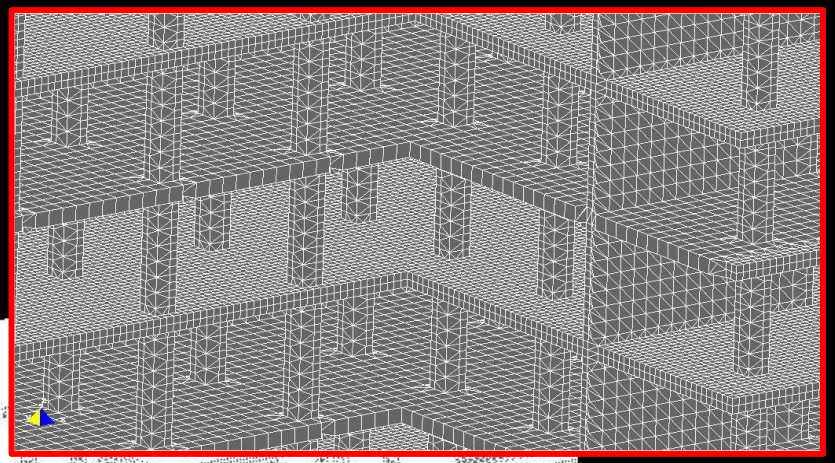




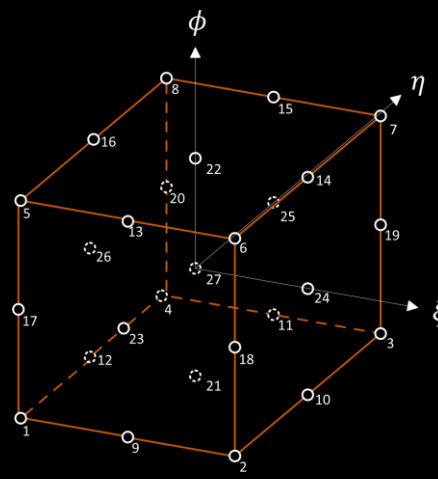




An multiresolution FEM model with 800, 000 elements generated using quadtree + octree partitioning
Runtime: 10 minutes using a single core of DOST ASTI CoARE HPC

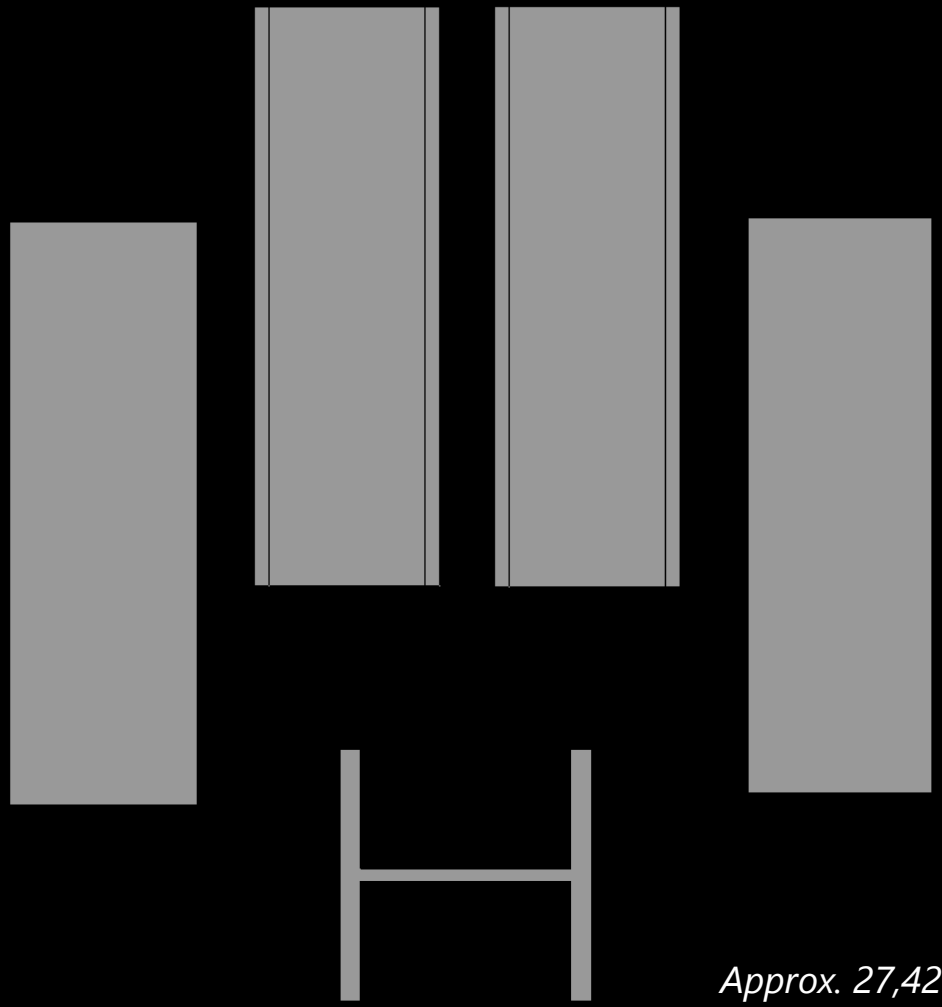


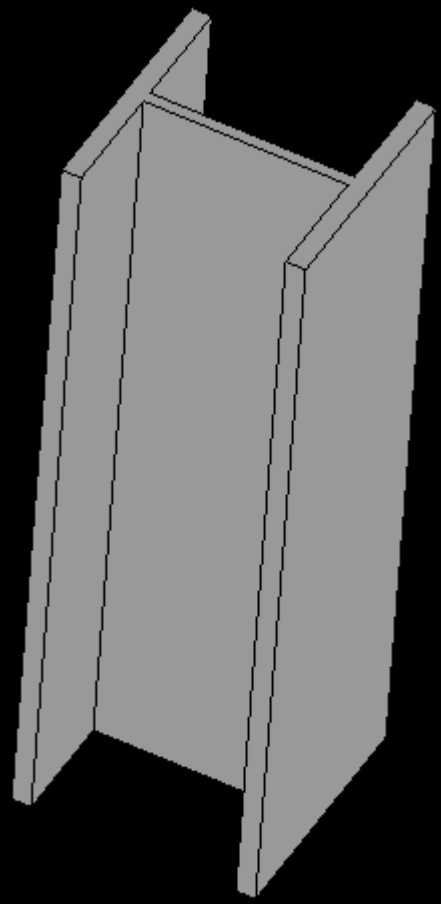
ANALYSIS: FAULT → SITE → CITY → STRUCTURE → COMPONENT



27-NODED HEXAHEDRAL ELEMENT

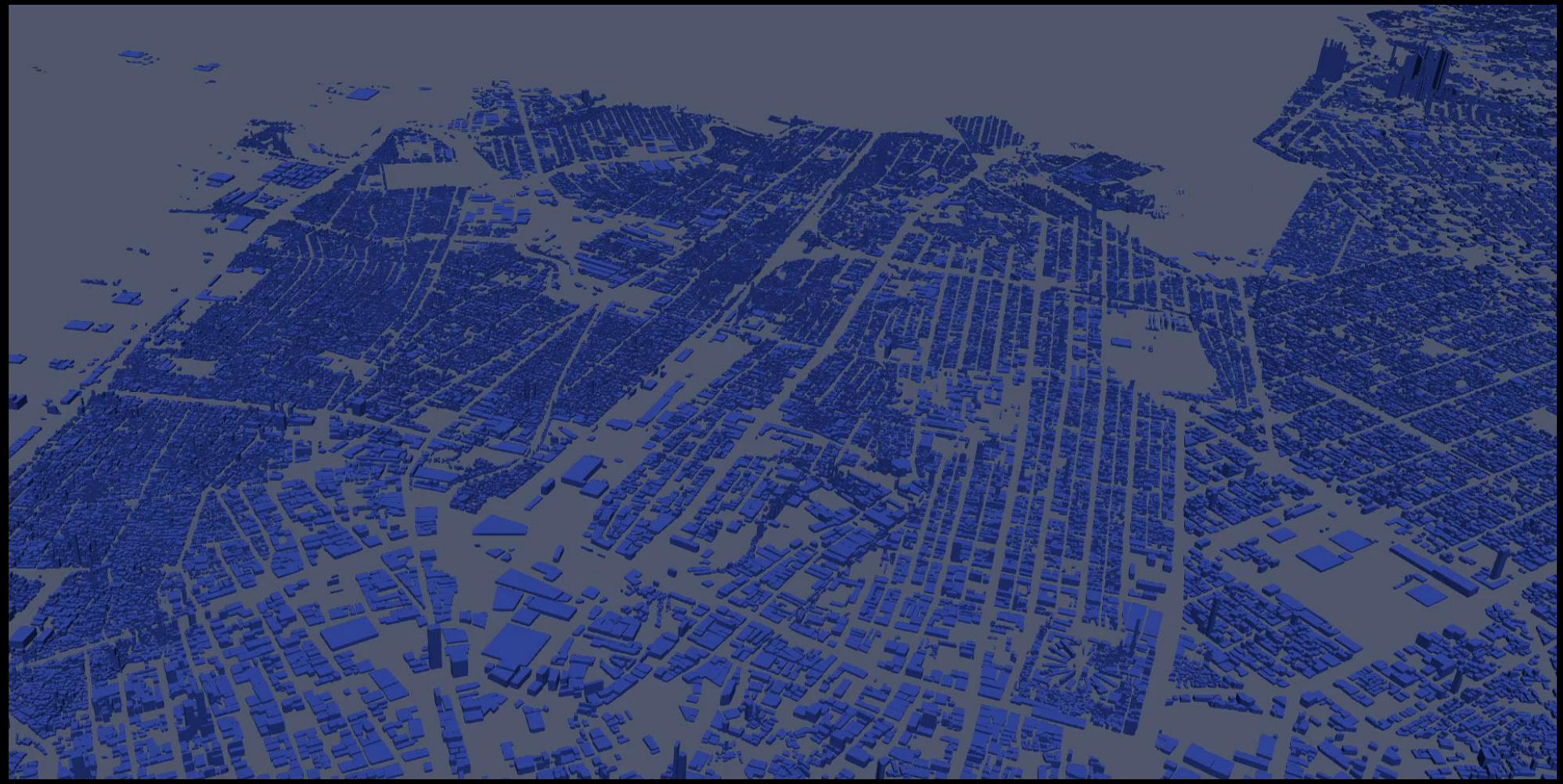
Deformation due to axial loading





Approx. 27,423 unknowns to solve per loading step
Computation: 33 min DOST ASTI CoARE HPC with OpenMP mutithreading

Ongoing Work: Dynamic Analysis of Whole Metro Manila

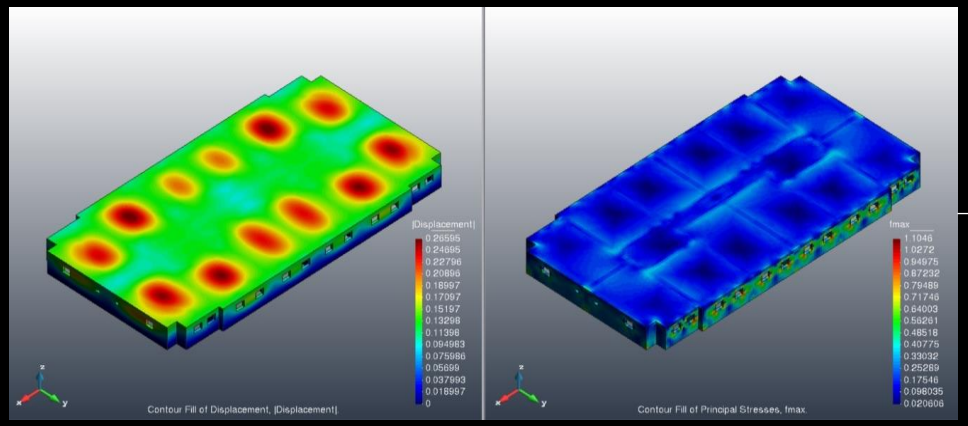


(Approx. 1.4Million target structures, or 350 Million unknowns per time step)

Estimated computation cost (one 40-sec EQ scenario simulation): 400 hours, 900 GB Memory

Ongoing Work: Integrated Visualization

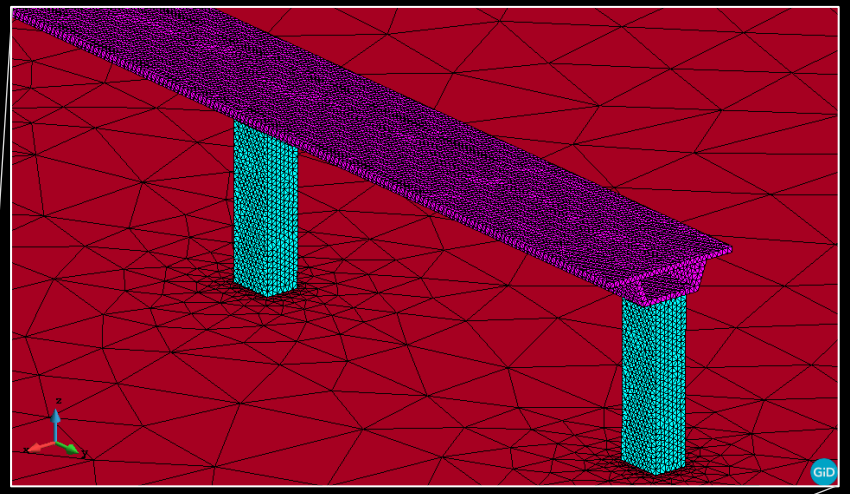
Integration of BIM model, Finite Element Analysis results, Utilization model

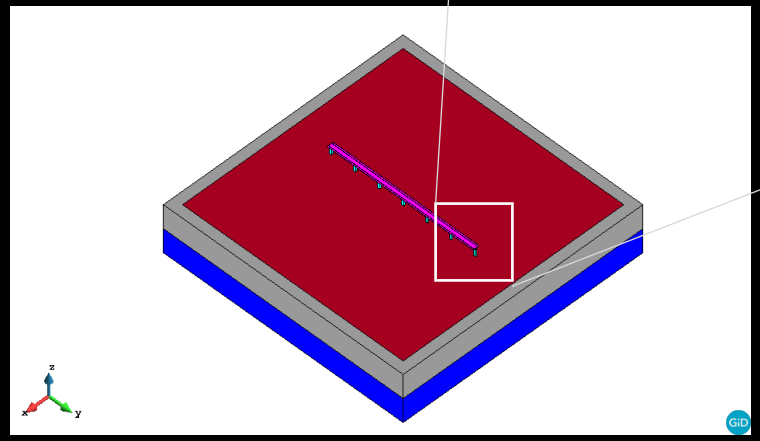


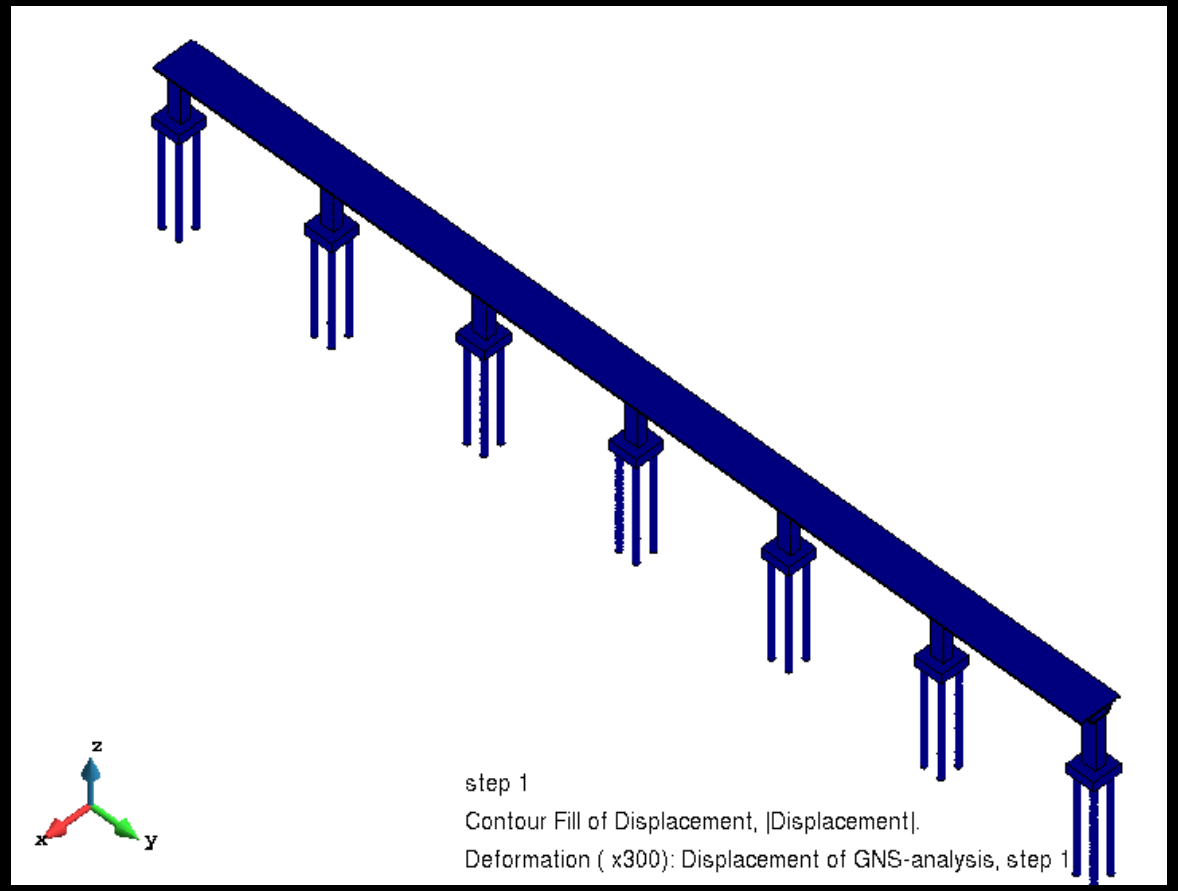
(FE Analysis of approx. 800,000 unknowns per time step solved in 2.7 hours)

Building Response-Augmented Virtual Environment (BRAVE) Postprocessing Tool

Ongoing Work: Dynamic Analysis of Infrastructure







(Approx. 760,000 unknowns per time step)

Estimated Computation cost (one 328-sec EQ scenario simulation): 35.5 hours

Concluding Remarks

- The availability of HPC resources has supported our team's research objective that focus on developing tools for simulating the various processes from fault-site-city-building-components.

- With the availability of HPC resources, we can implement and test new numerical and computing techniques to advance our research on hazard modeling, city and structural response analysis.

- HPC is not only computing with numbers. From it we can learn how to set the comprehensiveness of the models for the target application. It can harness creativity on how to address computationally costly operations. Being rooted in programming, it teaches patience, humility, and attention to detail.

Acknowledgement

- DOST-ASTI CoARE HPC
- DMCI Homes Computational Laboratory
- DOST-PHIVOLCS
- Computational Science and High Performance Computing Laboratory, Earthquake Research Institute, The University of Tokyo
- UP ERDFI

End of Presentation
Thank you for listening.

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Papers

Journal Publications:

Quinay, P. E., Soliman, J. M., Fader, A. R. (accepted, March 1, 2020) Development of city seismic response analysis approach for Metro Manila's low- to mid-rise RC structures using frame models generated from GIS feature and BIM data, *Journal of Earthquake and Tsunami*. https://doi.org/10.1142/S1793431120500219

Quinay, P. E., Grutas, R. (2019) Development of building-specific approach to city seismic response analysis for Metro Manila, *Philippine Engineering Journal*, Vol. 40, No.1, pp.41-50. https://journals.upd.edu.ph/index.php/pej/article/view/6798

Conference proceedings:

Quinay, P. E., Fader, A. R., Carangan, F. M., (2019) Development of static and dynamic modeling approaches using frame models for city seismic response analysis, *International Conference on Civil and Building Engineering Informatics (ICCBEI2019*, Sendai, Japan, November 7-8.

Quinay, P. E. (2019), Development of an integrated [source process-to-city response] earthquake simulation for Metro Manila (invited paper presentation), 2^{nd} *Technical Conference of ISSEP on In-depth Solutions to Structural Engineering Problems*, Manila City, September 27-28.

Papers

Conference proceedings:

Quinay, P. E., Grutas, R., Ichimura, T., Bautista, B., Hori, M. (2018) A two-step procedure for estimation of seismic response of urban areas in the Philippines, *Eleventh U.S. National Conference on Earthquake Engineering*, Los Angeles, California, June 25-29.

Quinay, P. E., Grutas, R., Bautista, B., Narag, I. (2018) Development of a feature-based approach for estimation of damaged structures in urban areas, *1st International Conference on Concrete and Steel Technology Engineering and Design (CASTED 2018)*, Pasay City, May 24-26.

Fader, A. R. and Quinay, P. E. (2018) Developing a structural analysis procedure utilizing BIM and HPC for application to large scale urban seismic response estimation, *1st International Conference on Concrete and Steel Technology Engineering and Design (CASTED 2018)*, Pasay City, May 24-26.