QuakeCoRE
NZ Centre for Earthquake Resilience

QuakeCoRE OpenSees Monthly Webconference 17 August 2016

UC University of Canterbury
The University of Auckland New Zealand
Resilient Organisations
GNS Science
Massey University
Victoria University of Wellington
The University of Waikato
BRANZ

Monthly Webconferences

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Objectives/Purpose:

- Provide a place where researchers can share the OpenSees-related work they are doing with the QuakeCoRE research community
- Provide a medium through which to hold presentations about OpenSees topics of interest, and to
- Generally facilitate collaboration and sharing between students and faculty working with OpenSees

Typical Agenda (will vary a bit week-to-week)**:**

- Updates on ongoing QuakeCoRE OpenSees development
- Student presentations on past/current/future OpenSees research (shorter)
- Seminars on OpenSees topics of general interest (longer)
- Community questions/discussion sessions

QuakeCoRE and OpenSees

QuakeCoRE is a national network of leading New Zealand earthquake resilience researchers intended to:

- Leverage strengths across the country and internationally
- Facilitate collaborative integrated multidisciplinary research that will support the development of an earthquake-resilient NZ

Flagship Programs:

- FP1: Ground Motion Simulation & Validation
- FP2: Liquefaction Impacts on Infrastructure
- FP3: Heritage, Safety & Economics: Addressing Earthquake-Prone Buildings
- FP4: Next-Generation Infrastructure
- FP5: Pathways To Resilience
- FP6: Spatially Distributed Infrastructure

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Technology Platforms:

- TP1: Experimental Laboratory Facilities
- TP2: Field Testing & Monitoring
- TP3: Open-source Community Datasets
- TP4: Computational Simulation and Data Visualization

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Technology Platform 4:

- Ground motion simulation
- Seismic response modelling of infrastructure
- Seismic performance and loss assessment

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Role of QuakeCoRE with OpenSees:

- Optimize implementation of OpenSees on NeSI HPC resources
- Development of pre/post-processing tools to streamline utilization of OpenSees by QuakeCoRE researchers
  - Mesh generation tools
  - 'Code blocks' for common or typical simulation types
  - Post-processing tools
  - Results visualization

Workshop Survey Results

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Summary – Who comprises the QuakeCoRE OpenSees research community?

- Largely composed (80%) of users with little or no experience with OpenSees
- Predominantly structural analysis
- The computational scope of most of the work is moderately demanding, with parametric studies comprising the main source of computational demand
- No consensus pre/post-processing tools or strategies in use throughout the community – more of a mix of different things
- Desire for improvement/assistance nearly equally in each of:
  - Pre-processing
  - Analysis tools
  - Post-processing
  - Visualization

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Community Input

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Community Input

We know a bit from the surveys and through discussions associated with the training workshops earlier this year, but where do we specifically stand as a research community?

- Name – Location/School – Topic

	Primary Analysis/Simulation Type		
	Structural	Soil-Structure Interaction	Geotechnical
Large single model (or limited param. study)		**Bilel Ragued**, UA PhD, 2D site-response/SSI study of Lyttelton port wharf structure (includes param study aspects)	**Seokho Jeong**, UC Postdoc, 2D/3D site response analysis at Heathcote Valley
Simpler model(s), with large parametric study	**Jarrod Cook**, UC PhD, Tension-only brace w/ ratcheting **Reagan Chandramohan**, Stanford PhD soon UC Postdoc, very large parameter study for structural systems (considers performance and loss assessment) **Masoud Moghaddasi**, UC/UA Postdoc, large parameter study for typical NZ structural systems to assess performance and loss region-specifically	**TBD**, UA PhD, 2D SSI models assessing effects of ground improvement on motions transferred to structure **TBD**, UA PhD, dynamic bridge analysis with SSI springs	**Kevin Foster**, UC PhD, site-response analysis using KiK-net downhole data **Hannah Dawson**, UA PhD, site-response analysis for range of profiles in Auckland area (fits btwn current and above cells)
Performance or loss assessment	**Karim Tarbali**, UC PhD, assessing demand and performance of SDOF/ MDOF subject to directivity motions		

Community Input

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What are your aspirations based on what is achievable in your analysis?

- Where are you currently and where do you want to be?
- What assistance may you need in order to achieve these goals?

	Goals for Analysis/Simulation		
	Now	6 months	18 months
Jarrod Cook	Have been modeling things in MATLAB, just starting to transition to OpenSees	Have parameter study up and running in OpenSees, working on increasing model complexity	Potential for larger, more complex, model to recreate shake table testing that may be done
Kevin Foster	Not started yet, in planning stages	Have parameter study up and running in OpenSees	Consideration of bi-directional shaking in context of soil column
Karim Tarbali	Finished with analysis for PhD	May apply concepts from research on SDOF/MDOF to other engineering systems (e.g. geotechnical, SSI)	
Seokho Jeong	1D/2D site response analysis of Heathcote Valley considering horizontal input motions	Examine soil response in Heathcote Valley to vertical input motions	Topographic amplification study for Port Hills, may consider 2D OpenSees studies
Hannah Dawson	Starting modeling soon, currently defining soil profiles from Vs data	Have site-response modeling effort well underway	Hopefully finished with modeling and wrapping up PhD
Bilel Ragued	Finishing very soon		
Reagan Chandramohan	Finishing PhD research (Stanford)	Extend framework from PhD to other systems (e.g. geotech, SSI), start becoming an OpenSees developer	
Masoud Moghaddasi	Running parameter study to assess effect of GM uncertainty on structural response	Start considering Monte Carlo simulations to account for uncertainties in the structure itself	

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Initial Workflow Tasks Identified for Support

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Initial Tasks

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Based on the community discussion from last month's meeting and the overall vision for OpenSees development through QuakeCoRE, the following areas have been identified as the initial tasks:

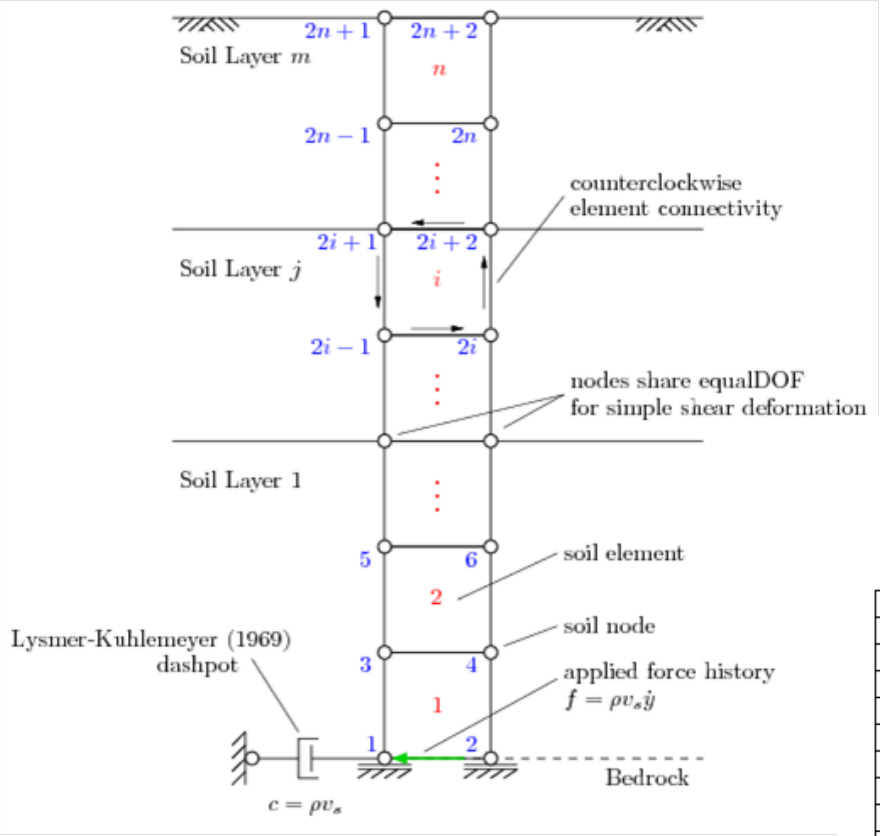
- Pre-process and post-processing tools for 1D site response analysis
- Workflow optimization for parallel analysis of very large models (OpenSeesSP)

Initial focus will emphasize post-processing and workflow tasks.

- A Python interpreter for OpenSees is set to be made available at some point.
- Python has been integrally incorporated into other aspects of Tech Platform 4 (particularly GM simulation workflow), therefore it is the preferred language for use with OpenSees once available
- No sense in spending significant time/effort on tcl scripts if strategic vision is to move to Python when ready

1D Site Response Analysis

- General modeling approach – column of plane strain quadrilateral elements

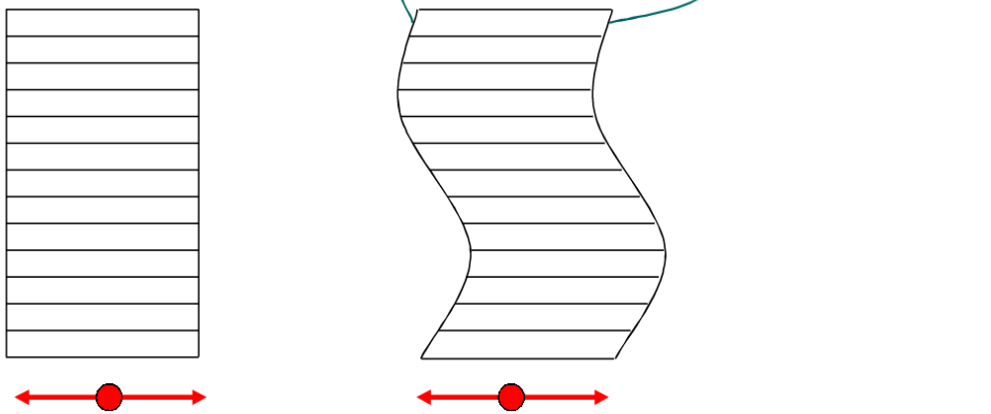


Total Stress:

quad, SSPquad, bbarQuad, …

Effective Stress:

quadUP, SSPquadUP, 9_4_QuadUP



1D Site Response Analysis

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freeFieldSingle.tcl (~/QuakeCoRE/OpenSeesWor...Files/module3_geotechnicalExamples/site) - VIM2

```
#--------------------------------------------------------------------------------------------------
#  1. DEFINE ANALYSIS PARAMETERS
#--------------------------------------------------------------------------------------------------

#---SOIL GEOMETRY
# thicknesses of soil profile (m)
set soilThick  40.0

#---MATERIAL PROPERTIES
# soil mass density (Mg/m^3)
set rho         1.7
# soil shear wave velocity (m/s)
set Vs          250.0
# soil shear modulus (kPa)
set G           [expr $rho*$Vs*$Vs]
# poisson's ratio of soil
set nu          0.0
# soil elastic modulus (kPa)
set E           [expr 2*$G*(1+$nu)]
# soil bulk modulus (kPa)
set bulk        [expr $E/(3*(1-2*$nu))]
# soil cohesion (kPa)
set cohesion    95.0
# peak shear strain
set gammaPeak   0.05
# soil friction angle
set phi         0.0
# reference pressure
set refPress    80.0
# pressure dependency coefficient
set pressCoeff  0.0
# bedrock shear wave velocity (m/s)
set rockVS      760
# bedrock mass density (Mg/m^3)
set rockDen     2.4

#---GROUND MOTION PARAMETERS
# time step in ground motion record
```

1D Site Response Analysis

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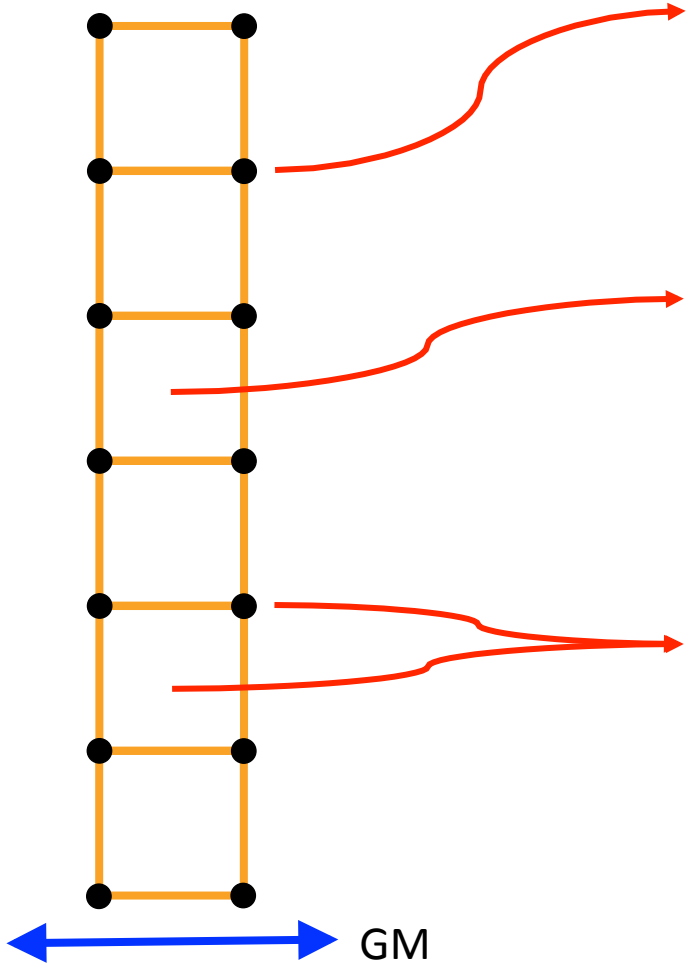
freeFieldSingle.tcl (~/QuakeCoRE/OpenSee.../module3_geotechnicalExamples/site) - VIM2

```
#--------------------------------------------------------------------------------------------------
#  3. DEFINE NODES FOR SOIL ELEMENTS
#--------------------------------------------------------------------------------------------------

# soil nodes are created in 2 dimensions, with 2 translational dof
model BasicBuilder -ndm 2 -ndf 2

set yCoord      0.0
set count       0
# loop over nodes
for {set j 1} {$j <= $numNodeY} {incr j 2} {
    node    $j              0.0         [expr $yCoord + $count*$sizeEleY]
    node    [expr $j+1]     $sizeEleX   [expr $yCoord + $count*$sizeEleY]

    set count [expr $count+1]
}
puts "Finished creating all soil nodes..."

#--------------------------------------------------------------------------------------------------
#  4. DEFINE DASHPOT NODES
#--------------------------------------------------------------------------------------------------

node 2000 0.0 0.0
node 2001 0.0 0.0

puts "Finished creating dashpot nodes..."

#--------------------------------------------------------------------------------------------------
#  5. DEFINE BOUNDARY CONDITIONS AND EQUAL DOF
#--------------------------------------------------------------------------------------------------

# define fixity of base nodes
fix 1 0 1
fix 2 0 1

# define fixity of dashpot nodes
fix  2000  1 1
fix  2001  0 1
```

1D Site Response Analysis

- Post-processing: what information do we want to get out of this model?



Nodal quantities:

- Acc/vel/disp time history at surface or depth
- Acc/vel/disp/pore pressure profiles in time
- Maximum acc/vel/disp/pore pressure profiles

Elemental quantities:

- Shear stress/strain profiles in time
- Maximum shear stress/strain profiles
- Shear stress/strain histories at depth
- Vertical/horizontal stress profiles/histories

Mixed quantities:

- Time histories, profiles in time, and maximum profiles of pore pressure ratio

1D Site Response Analysis

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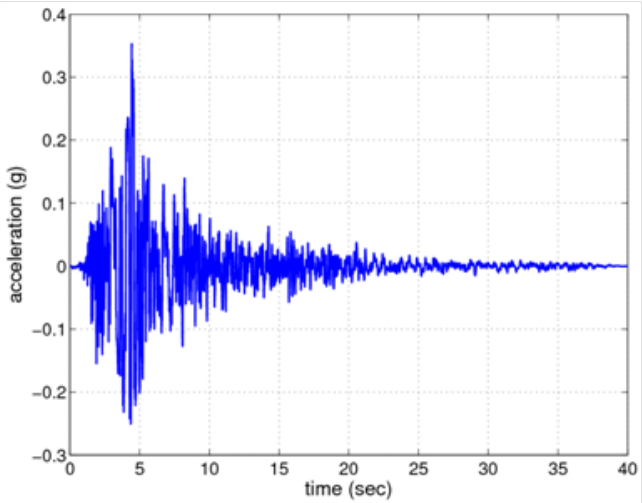
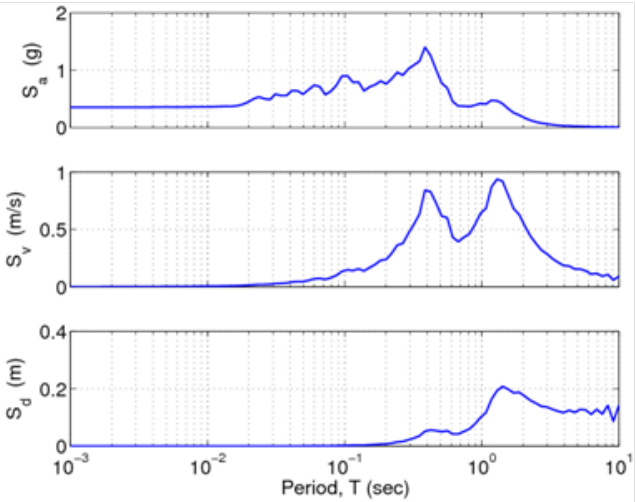
- Post-processing: how would we like to present this information?

Acceleration at surface



surface response spectra



1D Site Response Analysis

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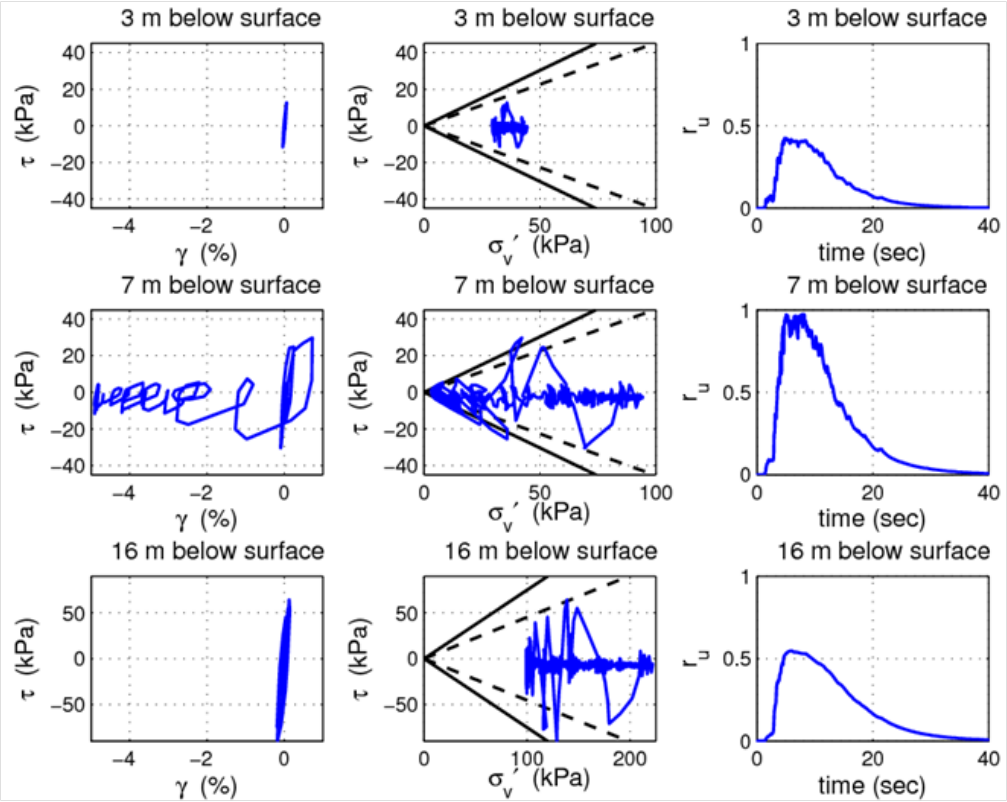
- Post-processing: how would we like to present this information?

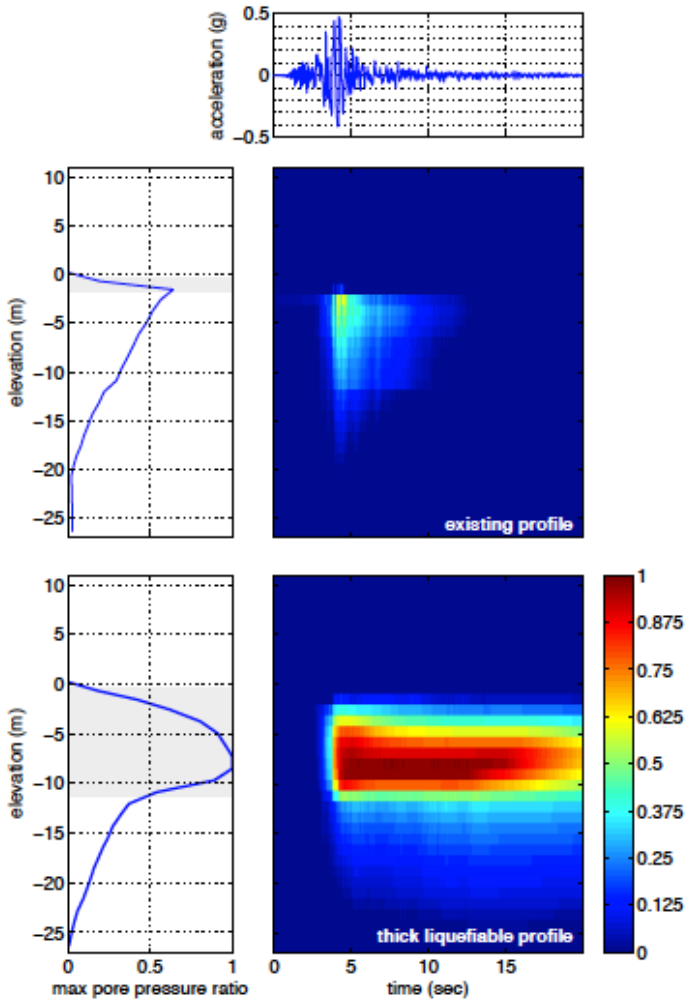
Constitutive (shear stress-strain) response at different depths within the soil profile



1D Site Response Analysis

- Post-processing: how would we like to present this information?

Maximum profiles and profile time histories



Parallel OpenSees Workflows

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Workflow optimization for parallel analysis of very large models (OpenSeesSP):

- Two options for parallel analysis using OpenSees
  - OpenSeesSP – single interpreter → very large models (many DOF)
  - OpenSeesMP – multiple interpreter → parameter studies (and very large models with manual domain decomposition)

- Currently, it appears that OpenSeesSP does not scale particularly well for the types of problems that have been analyzed with this parallel tool. Why?
  - Inefficient communication between processes
  - Master process (where single interpreter in running) is overloaded
  - Optimal size of decomposition has been reached
  - Too much communication due to choice of implicit integrator

- Work is underway to investigate these hypotheses using OpenSeesSP as implemented on the University of Auckland Pan cluster.

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Thank you!

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