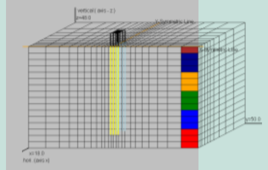
Wutec Geotechnical International (2024.10)

Wutec Geotechnical International

Software:

- **VERSAT-S2D**
- **VERSAT-D2D**
- **VERSAT-P3D**

Specialist consulting in geotechnical earthquake engineering

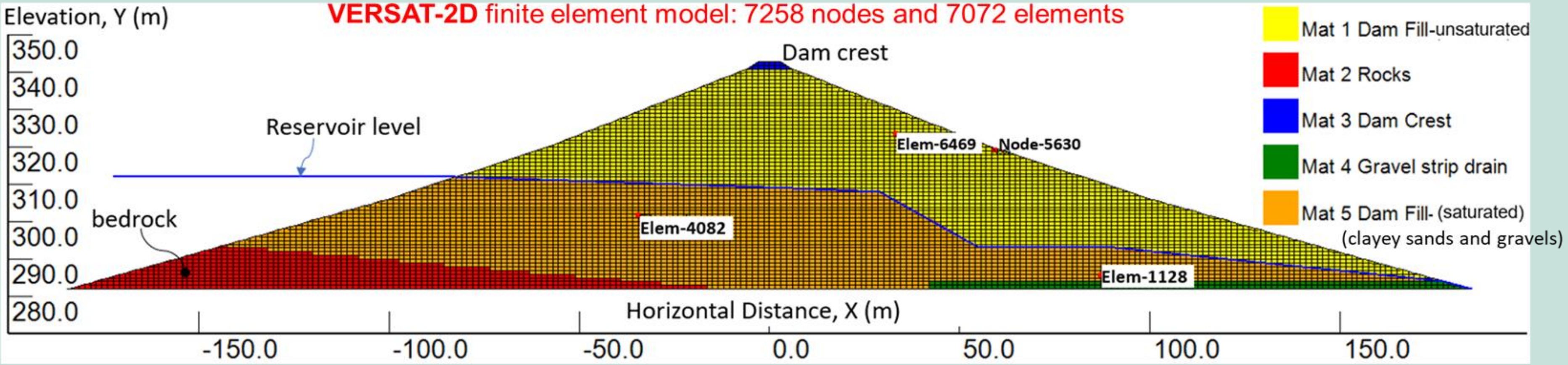


http://www.WutecGeo.com

SOFTWARE FEATURE

Wutec Geotechnical International

- Advanced technology with .NET Framework
- Easy to use
- Low cost
- World wide access without a hardware key

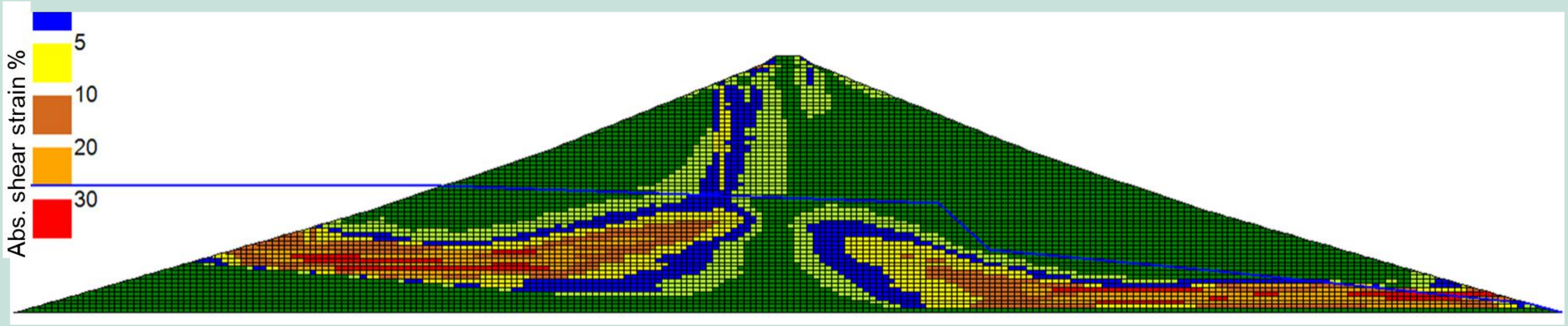


VERSAT-S2D

Wutec Geotechnical International

- A computer program for static 2D plane-strain finite element analyses of stress, deformation, and soil-structure interaction, e.g., soil/rockfill dams and slopes

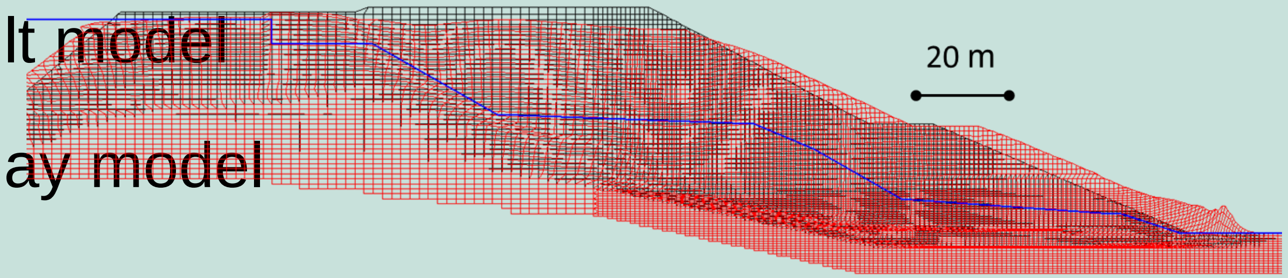
- Easy to use with its advanced mesh-generation, interactive windows and intuitive modelling technique.

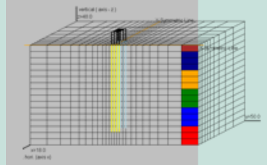


VERSAT-D2D

Wutec Geotechnical International

- A computer program for 2D time-history finite element analyses of earth structures subjected to dynamic loads from earthquakes, machine vibration, waves or ice actions.
- Nonlinear hysteretic soil model, and effective stress analysis with 3 models:
  - ➢VERSAT-sand model
  - ➢VERSAT-silt model
  - ➢VERSAT-clay model

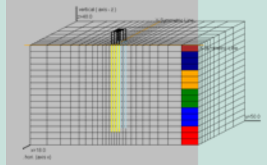




VERSAT-D2D

- Computing very efficiently with a typical PC-run-time of 4 hours for a model of 6000 elements and an input motion of 50 sec

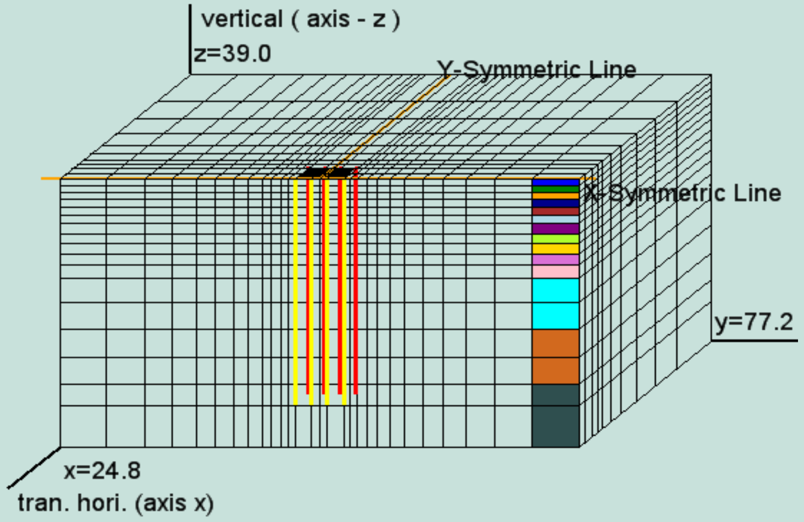
- Significantly increase the confidence limits of calculation by running more comparable analyses

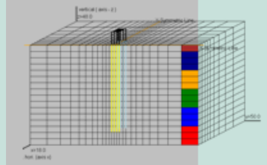


VERSAT-P3D.loading

Wutec Geotechnical International

- Computing pile response (shear, bending moment) subjected to lateral loads for a single pile or a pile group





VERSAT-P3D.stiffness

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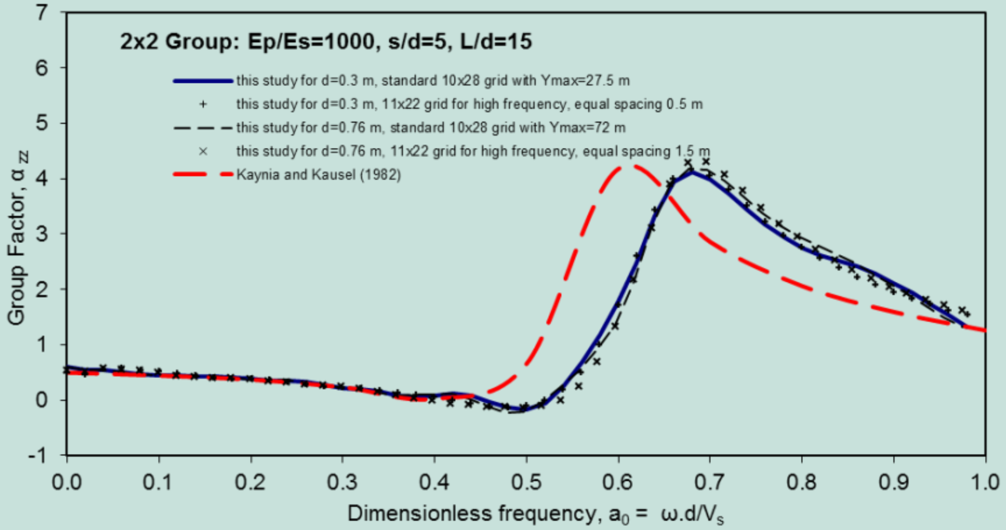
- Computing stiffness (static) and impedance (dynamic) for a single pile, a large-diameter caisson, or a pile group



VERSAT-P3D.shaking

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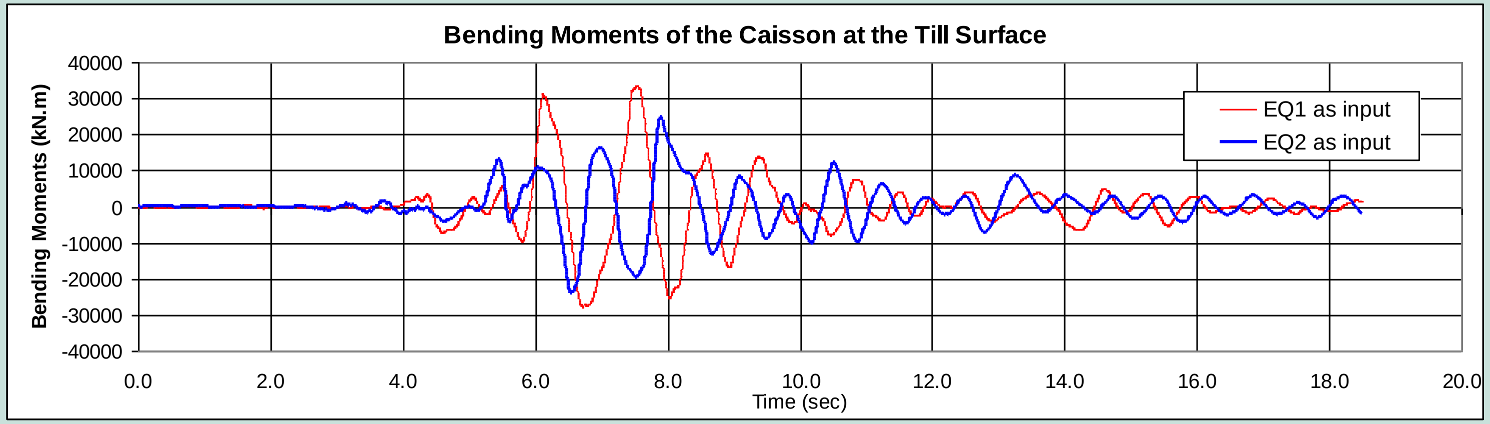
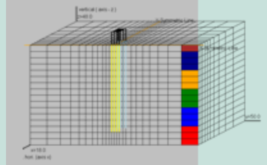
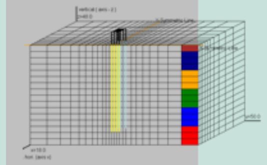
- Computing pile response subjected to ground shaking (earthquake) for a single pile or a pile group,
- Using the 3D finite element method and a self-generated mesh, for - P3D.all
- Using strain-compatible equivalent-linear method of analysis, for – P3D.all





Features of Our Software

- Uses advanced .NET technology for software development
- Does not require a hardware key
- Be run in any desktop or laptop computer being connected to the Internet.
- Cost significantly less to the user as a lump sum purchase is not required, and the license is granted on a yearly basis

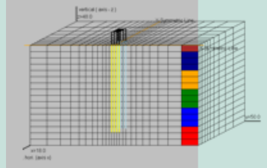


Geotechnical Calculation Library

http://www.wutecgeo.com/geo-computing.aspx

Wutec Geotechnical International

- The library is created to provide geotechnical engineers easily accessible and reliable solutions to some of the most common geotechnical problems including
  - Ground settlements due to soil consolidation,
  - Consolidation time corresponding to certain degree of consolidation,
  - Static and dynamic soil pressures on retaining walls,
  - Calculation for mechanically stabilized earth structures, lock blocks, retaining walls, etc.



Geotechnical Calculation Library http://www.wutecgeo.com/geo-computing.aspx

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- World-wide free access

Geotechnical Calculation Library (developing continues...)

Geotechnical calculation online library is created to provide geotechnical engineers easily accessible and reliable solutions to some of the most common geotechnical problems including ground settlements from one-dimensional soil consolidation (stresses calculated using the Boussinesq's equation), finite element solutions of the Terzaghi's consolidation equation, static Coulomb's and dynamic Mononobe-Okabe soil pressure coefficients, simple design calculation for mechanically stabilized earth structures, lock block retaining walls, and others. This library is developed under the supervision of Dr. Guoxi Wu, Ph.D., P.Eng. of BC, Canada

please go to HOME and accept limitation of liability before starting calculation...

Go back

The following applications are available as of August 20, 2012:

go to WickDrain	go to Consolidation settlement	go to Consolidation analysis
go to Soil pressure coefficients	go to Anchorage wall	go to MSE wall
go to Segmental Block wall		

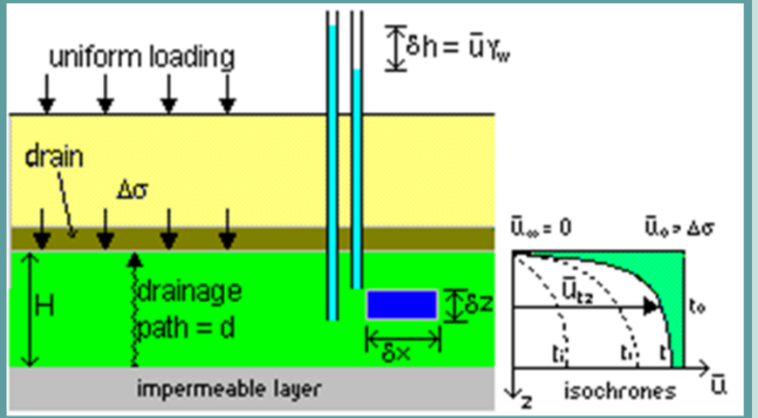
All calculations, including the finite element consolidation analysis, are carried out on the web server. A computer is not required to run the program; instead only an Internet browser is needed to setup input and display results.

WickDrain provides a simplified calculation of consolidation time for vertical drains. The calculation employs Barron's equation which only requires three input parameters, i.e., diameter of vertical drains, diameter of vertical drain influence zone, and coefficient of consolidation for drainage in horizontal direction.

Consolidation Settlement provides calculations of consolidation induced settlements of clayey soils in a multi-layer column. Each layer can have its own unique soil properties including total unit weight, initial void ratio, compression index C_c and recompression index C_r. The preconsolidation pressure (σ_p') can be assigned a constant value or as a ratio of the initial effective vertical stress for each layer. Settlement at any location, expressed by X and Y coordinate, under multi-zones of loading can be calculated. The incremental vertical stresses under the point of interest are computed using the

Geotechnical Calculation Models

Presentation [57 pages]on Wutec and Its Technology

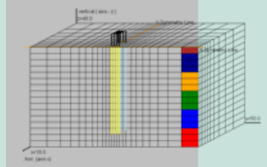


Terzaghi's diffusion equation for one-dimensional consolidation analysis:

$$c_v \frac{\partial^2 \bar{u}}{\partial z^2} = \frac{\partial \bar{u}}{\partial t}$$

$\bar{u}$ = excess pore water pressure
z = distance to the nearest drainage boundary
c_v = coefficient of consolidation, and

$$c_v = \frac{k}{m_v \gamma_w}$$



SITE RESPONSE ANALYSIS:

USING VERSAT-D2D

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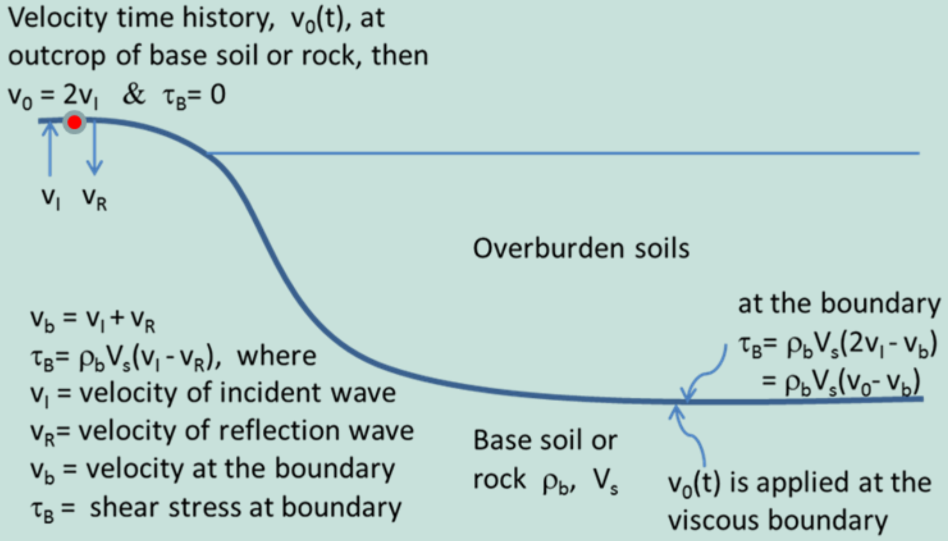
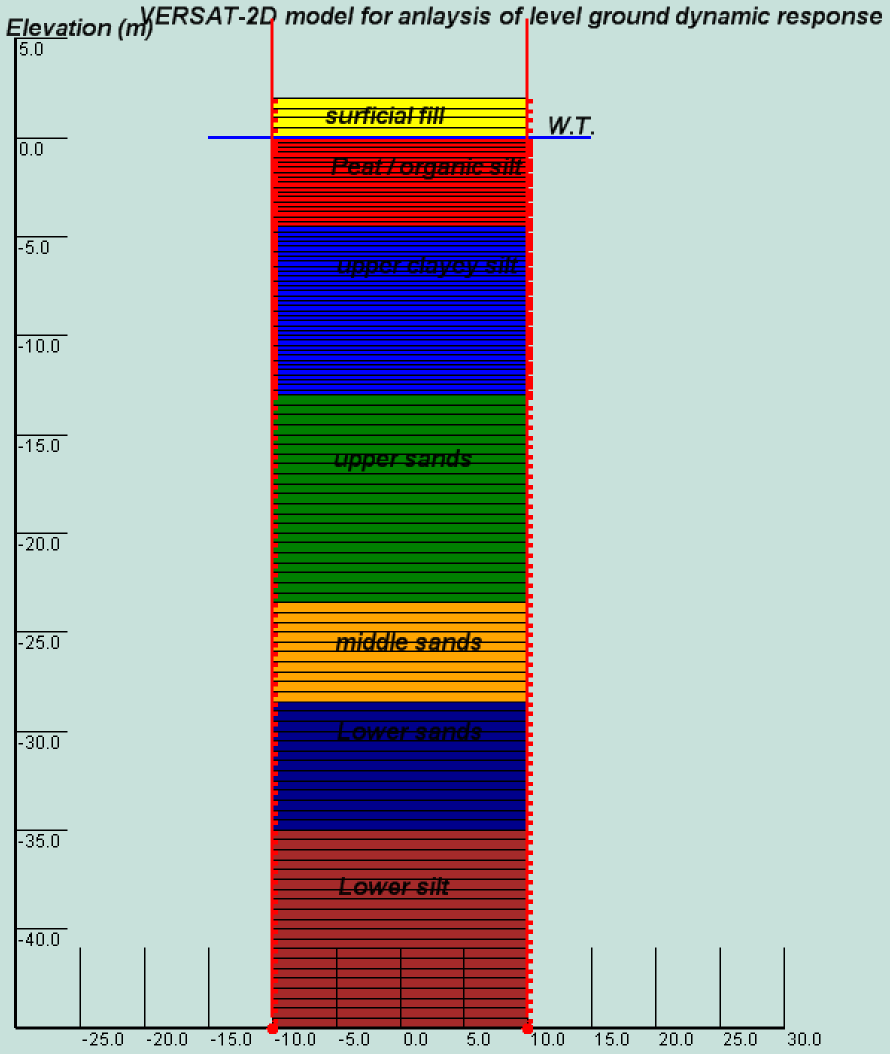
- Having problems with SHAKE or FLAC for the assignment?
- VERSAT-D2D (*1D module*) can help you deliver solutions in a simple but consistent & unified manner.



outcropping input motion using=> The elastic base model with a viscous boundary

SITE RESPONSE ANALYSIS:
USING VERSAT-D2D

Step 1:
Model Setup and static analysis (30 minutes required)



- Specify soil parameters including γ_{sat} (γ_{moist} above W.T.) for determining initial vertical stresses in preparation for a dynamic time-history analysis

SITE RESPONSE ANALYSIS:

USING VERSAT-D2D

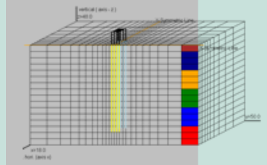
Step 2: Conduct a Dynamic Time-history Analysis
(60 minutes required)

- Specify parameters K_g and m for soil low-strain shear modulus, G_{max} (or simply, G)

$$G = K_g P_a \left(\frac{\sigma_m'}{P_a}\right)^m$$

  - For cohesionless soils, Kg=21.7K_{2max}, and m=0.5
  - For linearly increase G with depth, m=1.0
  - For constant G with depth, m=0

- Specify parameters (c, Φ) for soil shear strengths.



SITE RESPONSE ANALYSIS:

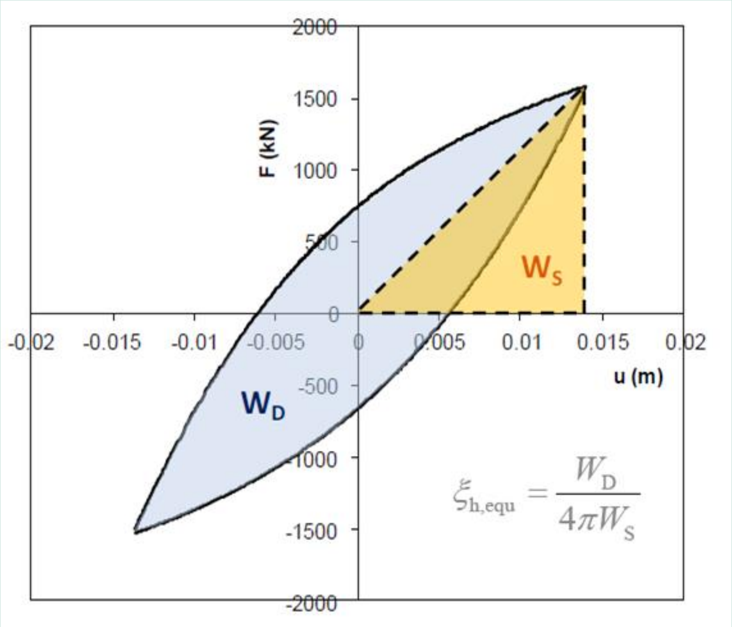
USING VERSAT-D2D

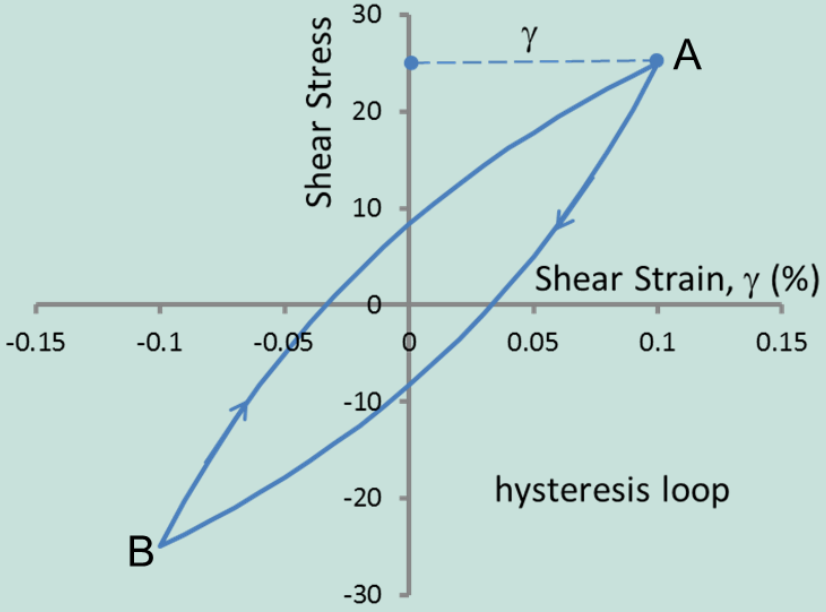
Step 2 … Material damping implied in a hysteresis loop

Hysteretic damping ratio from a hyperbolic $\gamma - \tau$ curve (point A);
and apply the Masing-rule on a full unloading (from A to B) – reloading (from B to A) loop:

$$\lambda = \frac{1}{4\pi}\frac{W_D}{W_S} = \frac{4}{\pi}\left(1+\frac{1}{R_f\gamma}\right)\left[1-\frac{1}{R_f\gamma}\ln(1+\gamma Rf)\right]-\frac{2}{\pi}$$

$$R_f = \frac{G_{max}}{\tau_{ult}}$$





SITE RESPONSE ANALYSIS:

USING VERSAT-D2D

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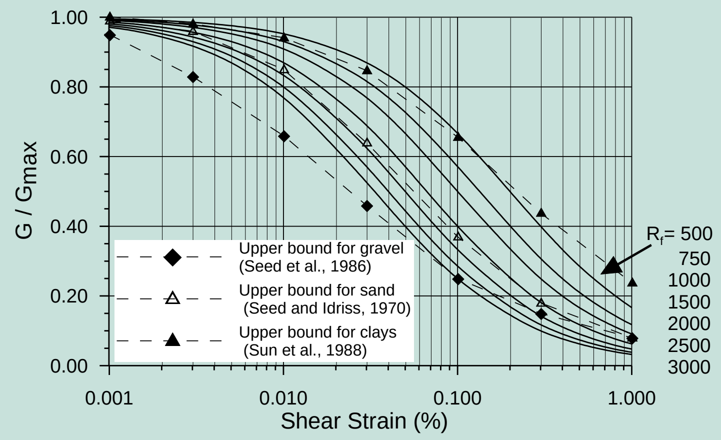
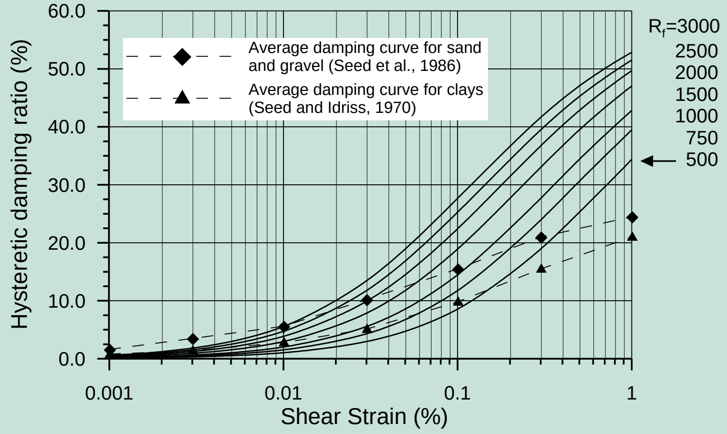
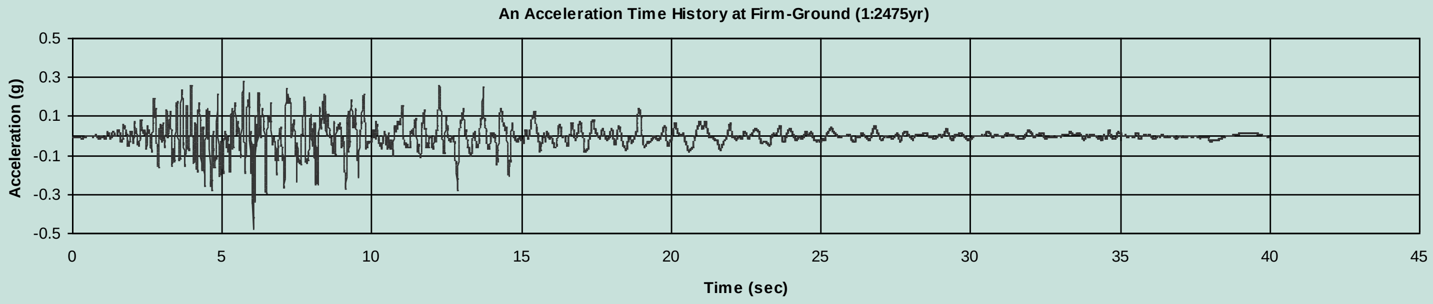
Step 2: continued…

- Specify modulus reduction factor R_f to match the desired G/G_{max} and λ curves, optional.
- Specify pore water pressure parameters such as $(N_1)_{60}$ if liquefaction is of concern.
- Specify an acceleration time-history as input at the base.
- Start the dynamic time-history analysis using the option of Gravity Off.







SITE RESPONSE ANALYSIS:
USING VERSAT-D2D

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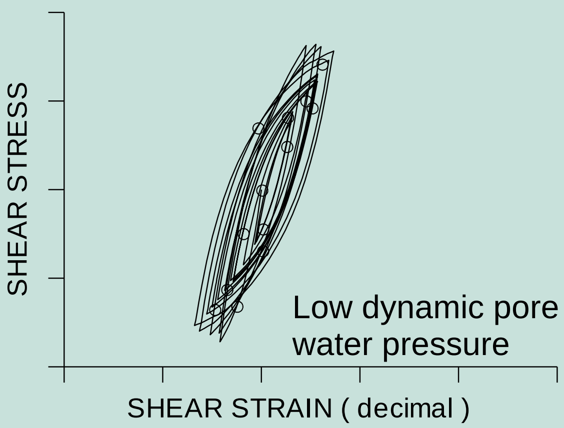
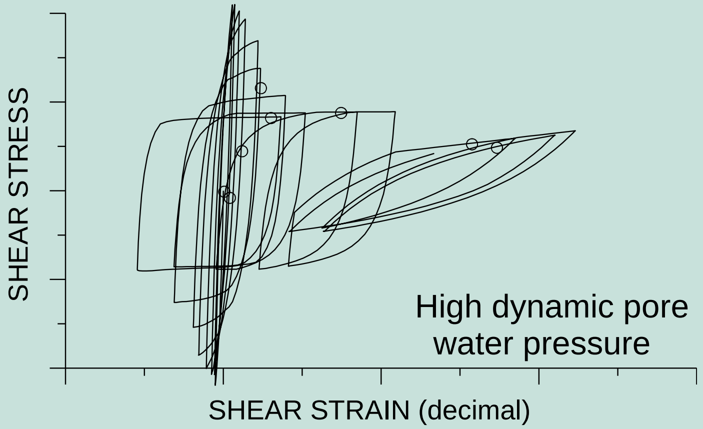
- VERSAT-2D nonlinear hysteretic soil model



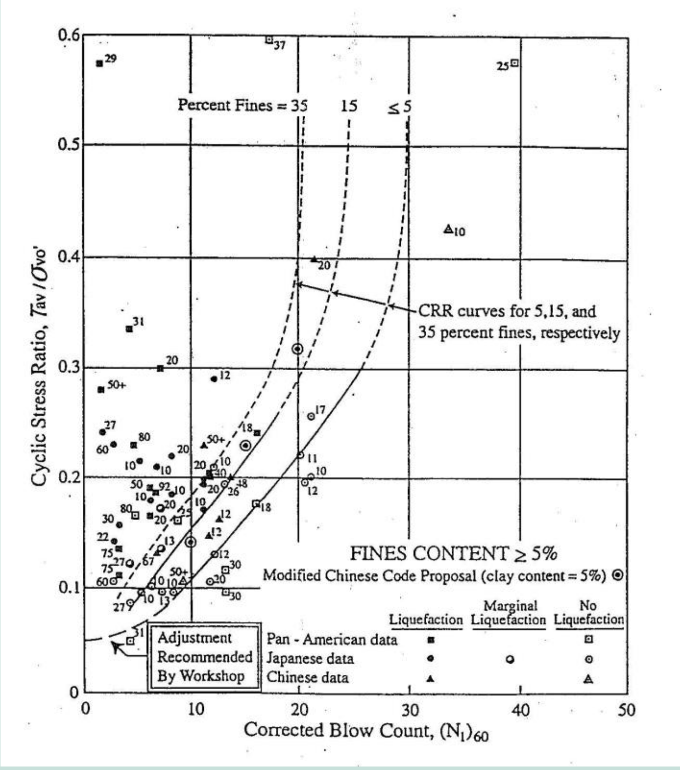


- Three pore water pressure models
  - Martin-Finn-Seed model (MFS)
  - Modified MFS Pore Water Pressure Model

$$E_r = M \bullet (\sigma_{v0}' - u)$$

  - Seed's Pore Water Pressure Model

$$u / \sigma_{v0}' = \frac{2}{\pi} \arcsin\left(\frac{N_{15}}{N_l}\right)^{\frac{1}{2\theta}}$$



SITE RESPONSE ANALYSIS:
USING VERSAT-D2D

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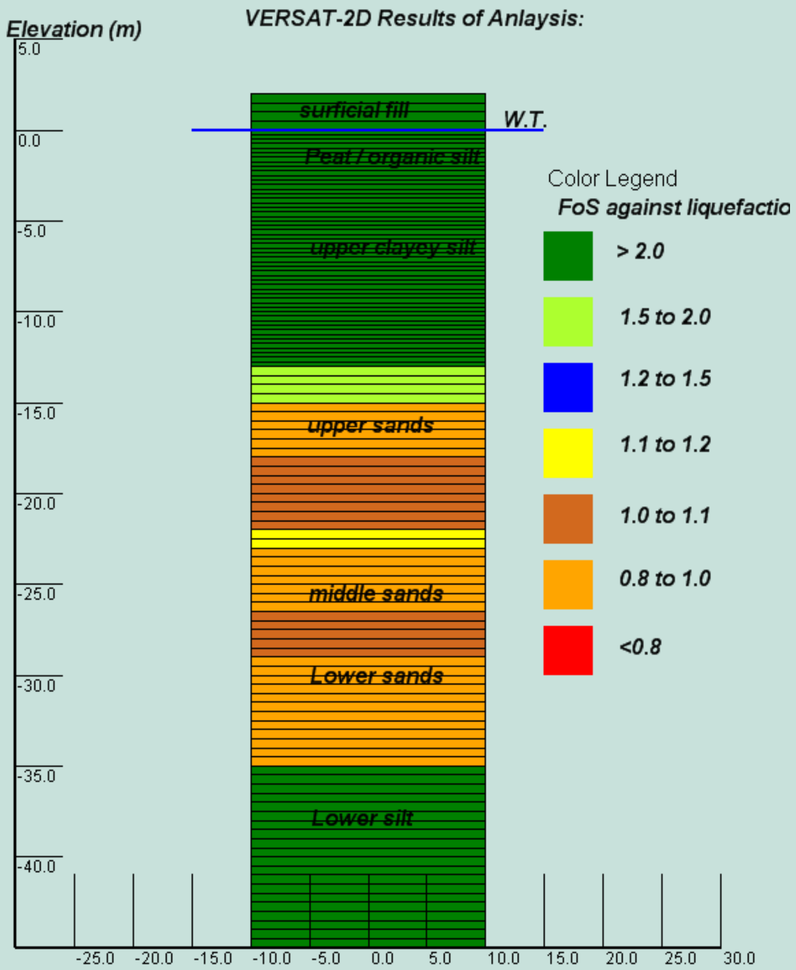
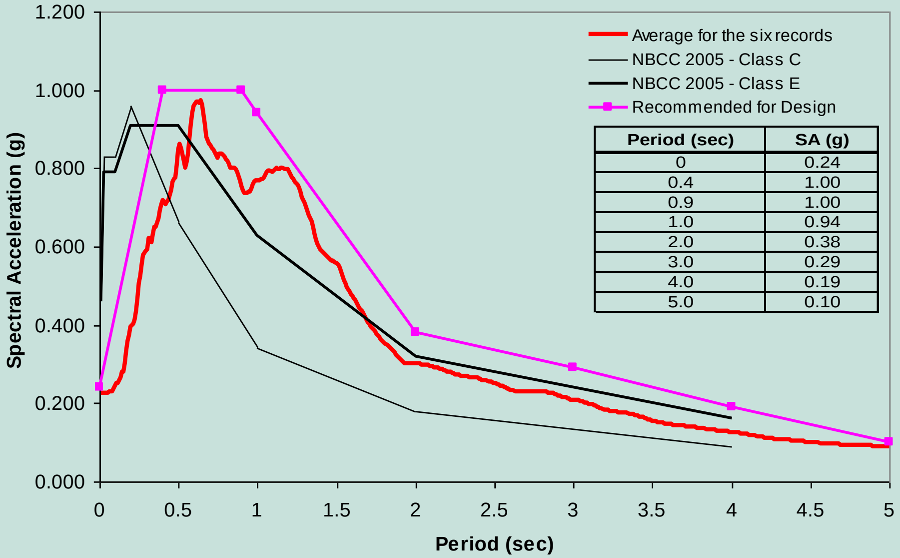
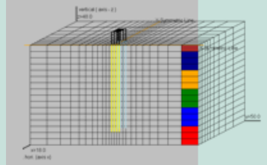
Step 3: Process Results



- The nonlinear hysteretic soil model and an effective stress analysis, that are built-ins of VERSAT-2D, can help you overcome problems related to shear strains exceeding the limit of application, shear stress exceeding the shear strength, & effect of dynamic pore water pressures. It can be done in an efficient but consistent fashion.

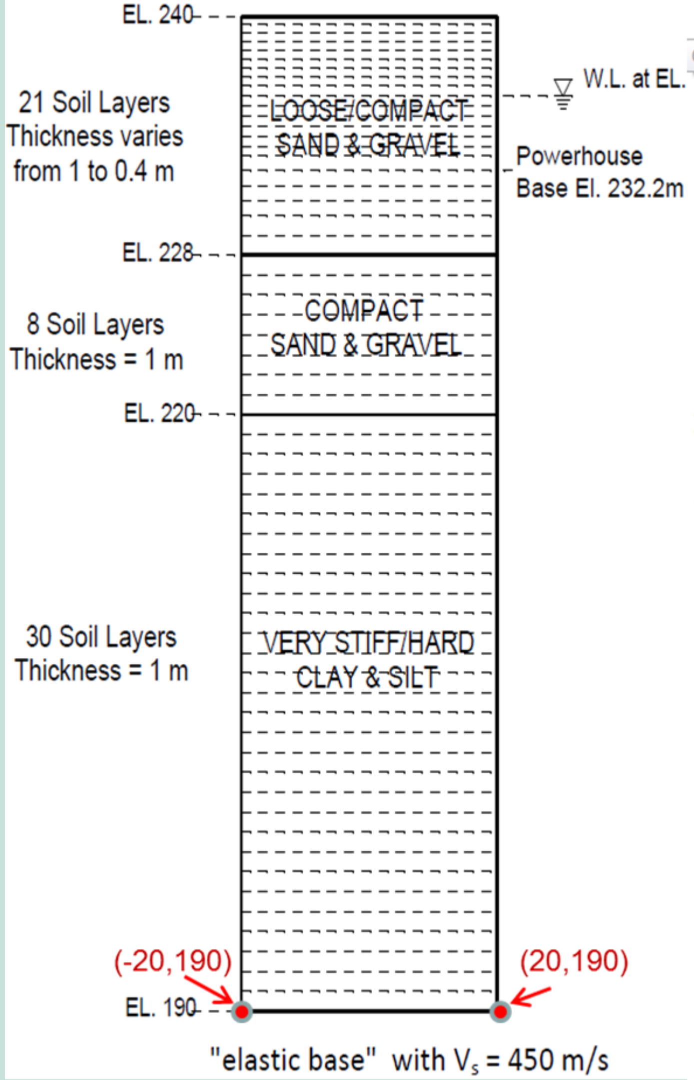


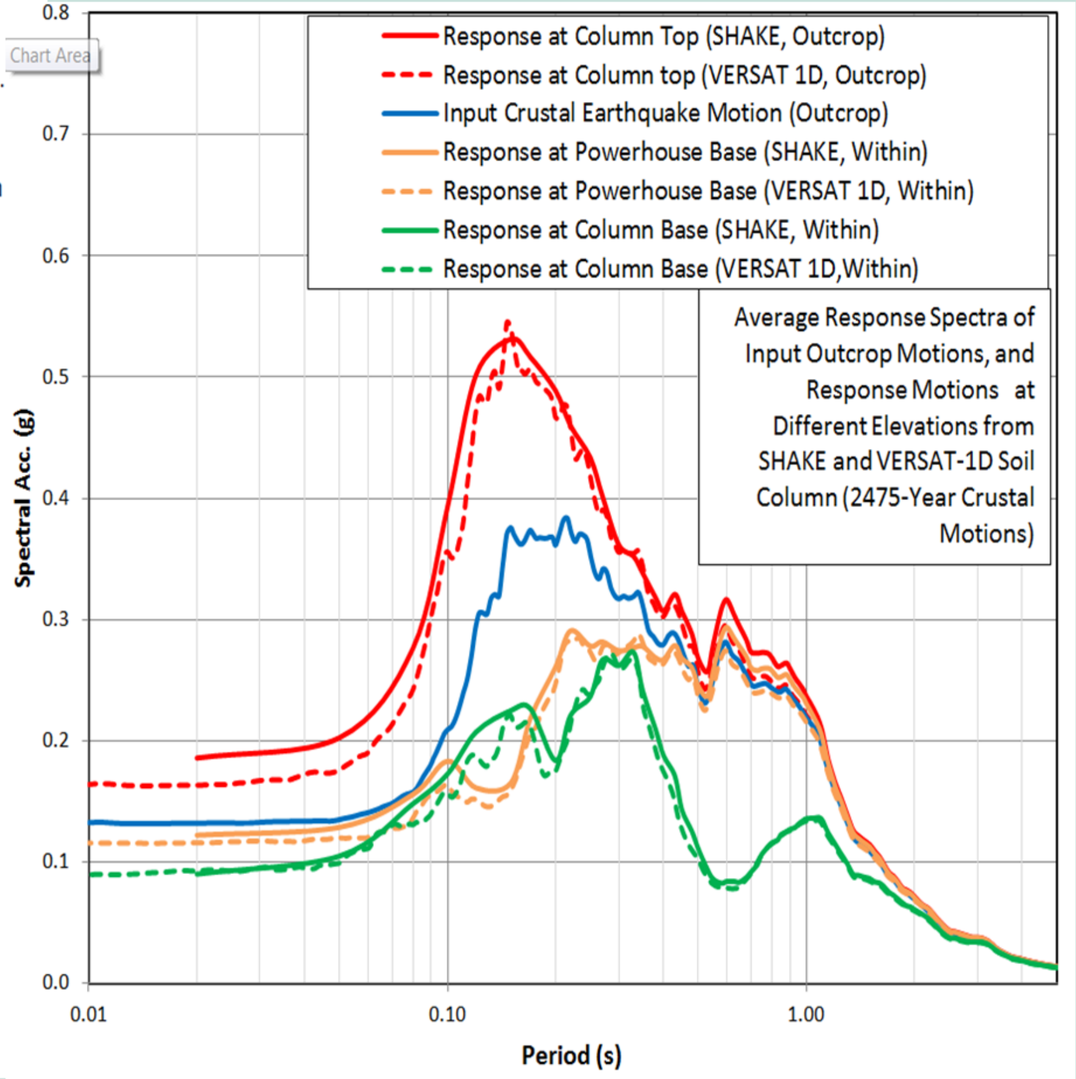
Period (sec)	SA (g)
0	0.24
0.4	1.00
0.9	1.00
1.0	0.94
2.0	0.38
3.0	0.29
4.0	0.19
5.0	0.10



SITE RESPONSE ANALYSIS:
USING VERSAT-D2D

Comparison between SHAKE and VERSAT-1D at low-moderate level of earthquake shaking: *SHAKE equivalent linear approximation is able to produce very good representation of true soil nonlinear hysteresis behavior*

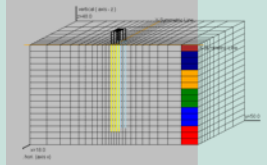




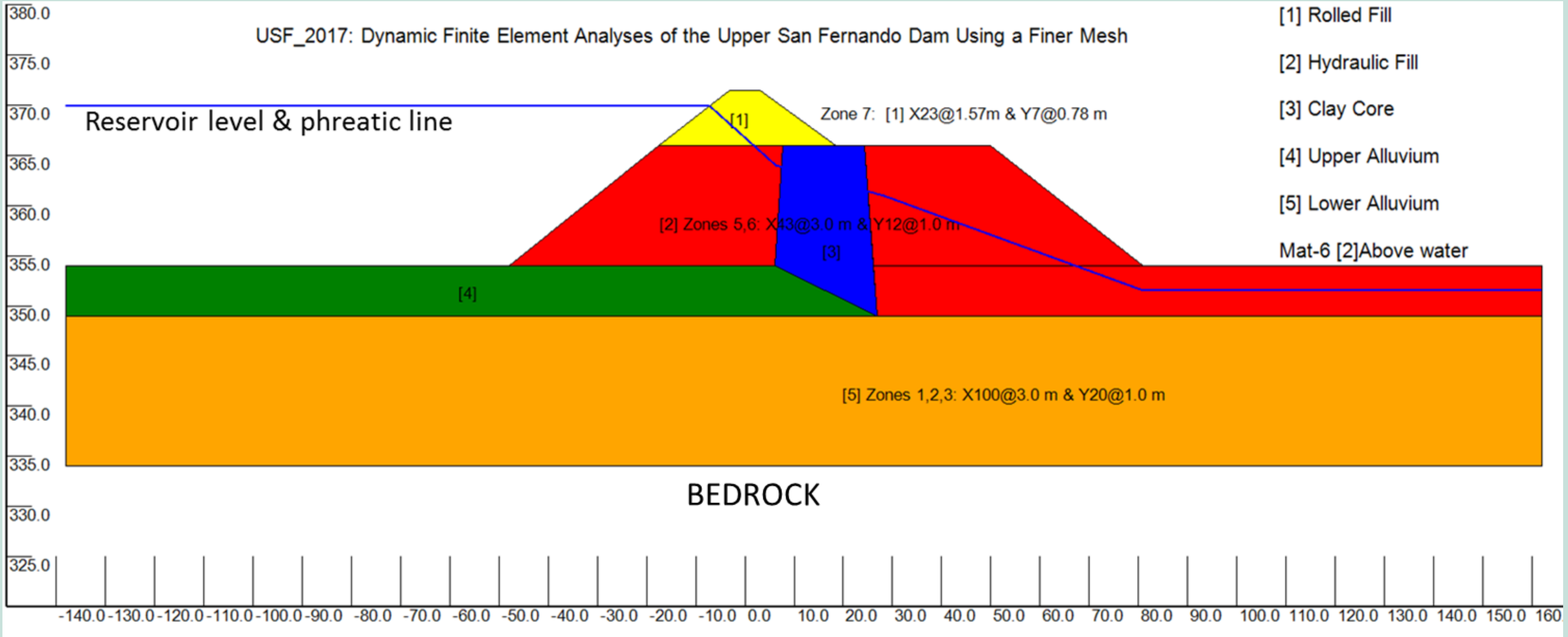
VERSAT-2D Application Selected

Wutec Geotechnical International

- 2023. Wu, G., Case History Studies of Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake, Geo-congress-2023, Los Angeles, US
- 2020. BC Hydro, VERSAT-2D seismic design verification dynamic analyses of John Hart Dam seismic upgrade – in construction 2023-2026
- 2016. BC Hydro, VERSAT-2D Seismic Stability And Deformation Analyses of WAC Bennett Dam
- 2014. BC Hydro, Dam Safety Upgrade of the Ruskin Dam Right Abutment
- 2013. BC Hydro, Dynamic Time-history Analyses of John Hart Middle Earthfill Dam on Over-consolidated Silts with Cyclic Strain Softening
- 2009. BC Hydro , Dynamic Time-history Analyses of John Hart Middle and North Earthfill Dam, Deficiency Investigation (DI) Report
- 2006. Golder Associates, Seismic upgrade design of the 3D box/pile foundations of the Pattullo Bridge in British Columbia
- 2006. Golder Associates, Seismic design of the Hwy. 15 North Serpentine River Bridge in Surrey, B.C. Proceedings of the 59th Canadian Geotechnical Conference, Vancouver, pp. 596-601.
- 2004. BGC Engineering, Dynamic analyses of Pueblo Viejo Mine Dam
- 2002. Metro Vancouver's First Narrows and Port Mann water supply crossings seismic vulnerability assessment
- 2002. EBA Engineering, Design of the Russ Baker Way Overpass on liquefiable sand - Vancouver Airport, Richmond, BC. Proceedings of the 6th International Conference on Short and Medium Span Bridges, Vancouver
- 2001. EBA Engineering, Earthquake-deformation analyses of east abutment soil slope, Cleveland Dam, Vancouver
- 2000. EBA Engineering, Geotechnical design of foundations for Skytrain Millennium Line, Vancouver, Canada
- 1998. Klohn-Crippen Consultants, Earthquake analysis of L-L tailings dam in Highland Valley, B.C., Canada



Upper San Fernando Dam: VERSAT-2D application under 1971 San Fernando earthquake



- 1971 San Fernando Earthquake 0.6g at the dam site
- Foundation: Alluvial sand, dense not liquefiable.
- Dam: Hydraulic sand fill with an average $(N_1)_{60} = 14$
- Clayey core, reservoir and phreatic surface within the dam as shown.

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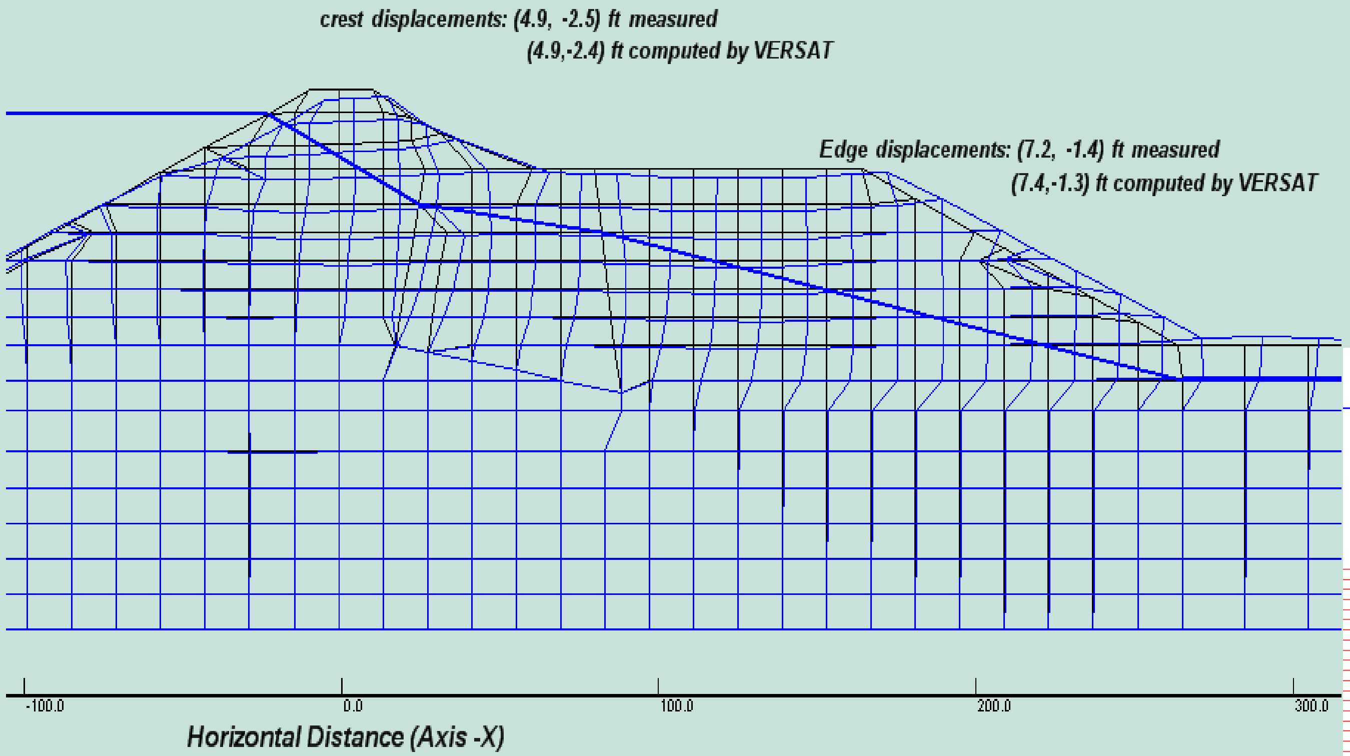
Upper San Fernando Dam: VERSAT-2D application under 1971 San Fernando earthquake

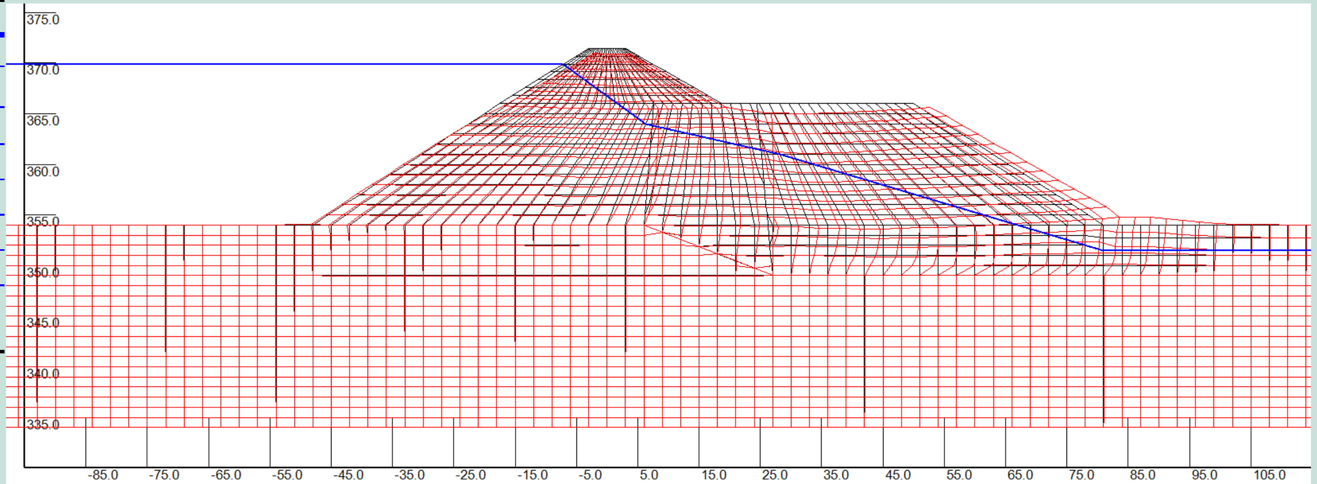
The dynamic analysis results are robust, consistent between

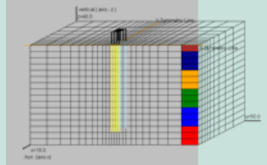
- 2001 small model, **and** 2017 large model.

2001 small model: 678 nodes and 625 elements



2017 Large model (2835 nodes and 2704 elements):
(2.72m, -0.4m) with Seed's PWP Model
(2.54m, -0.5m) with Wu (2001) PWP ,model





Wu, G. 2001. Earthquake induced deformation analyses of the Upper San Fernando dam under the 1971 San Fernando earthquake. Canadian Geotechnical Journal, 38: 1-15.
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Seismic Upgrade of BC Hydro Ruskin Dam:

VERSAT-2D application

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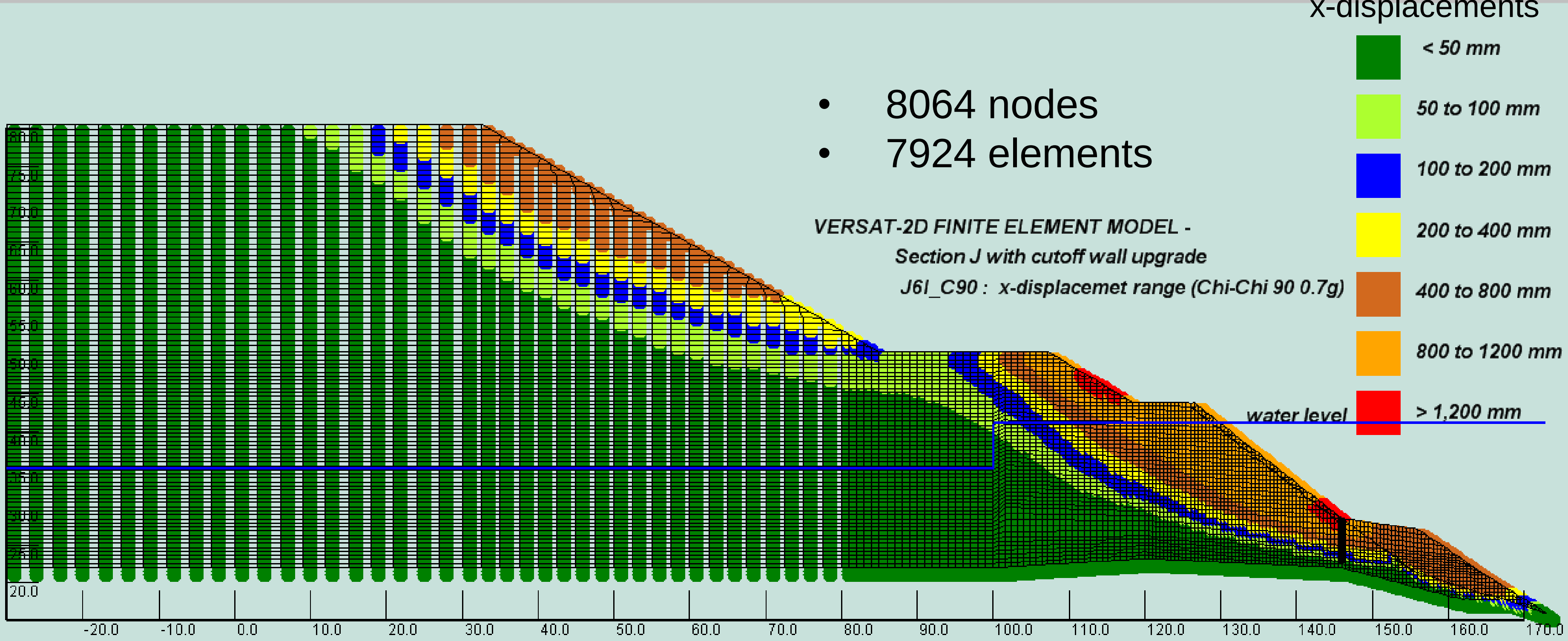
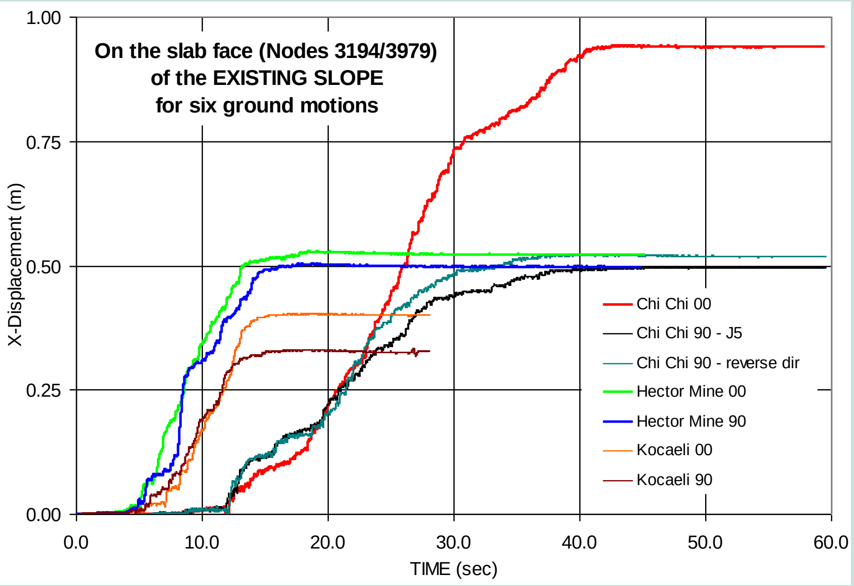
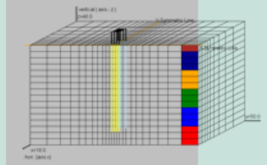
- 8064 nodes
- 7924 elements



VERSAT-2D Results:

End-of-earthquake horizontal displacements (above), and time histories of x-displacements (right) under various input ground motions.

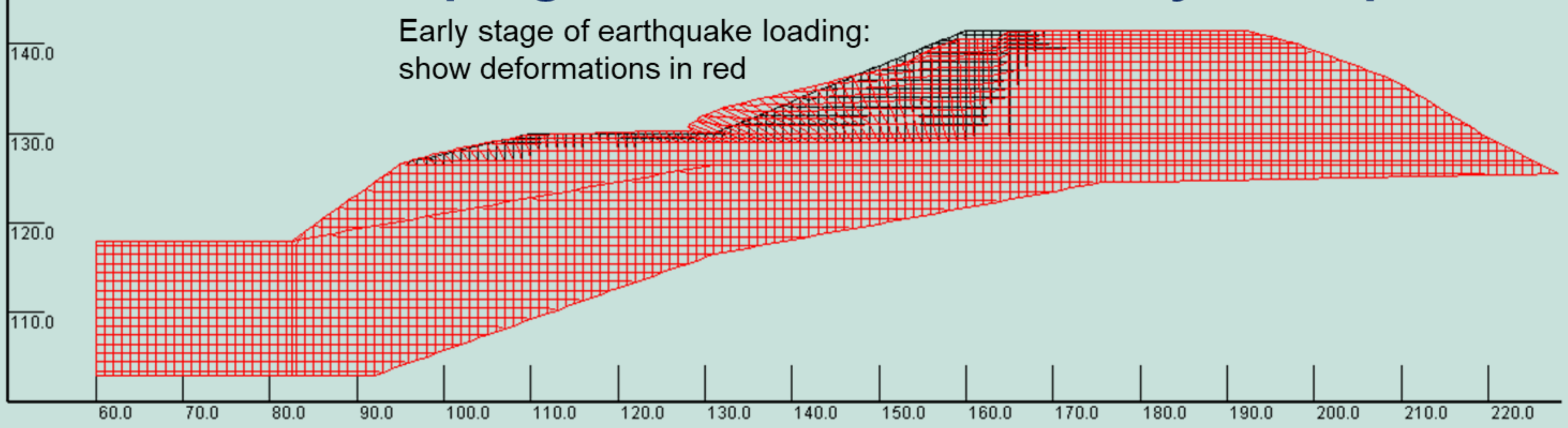


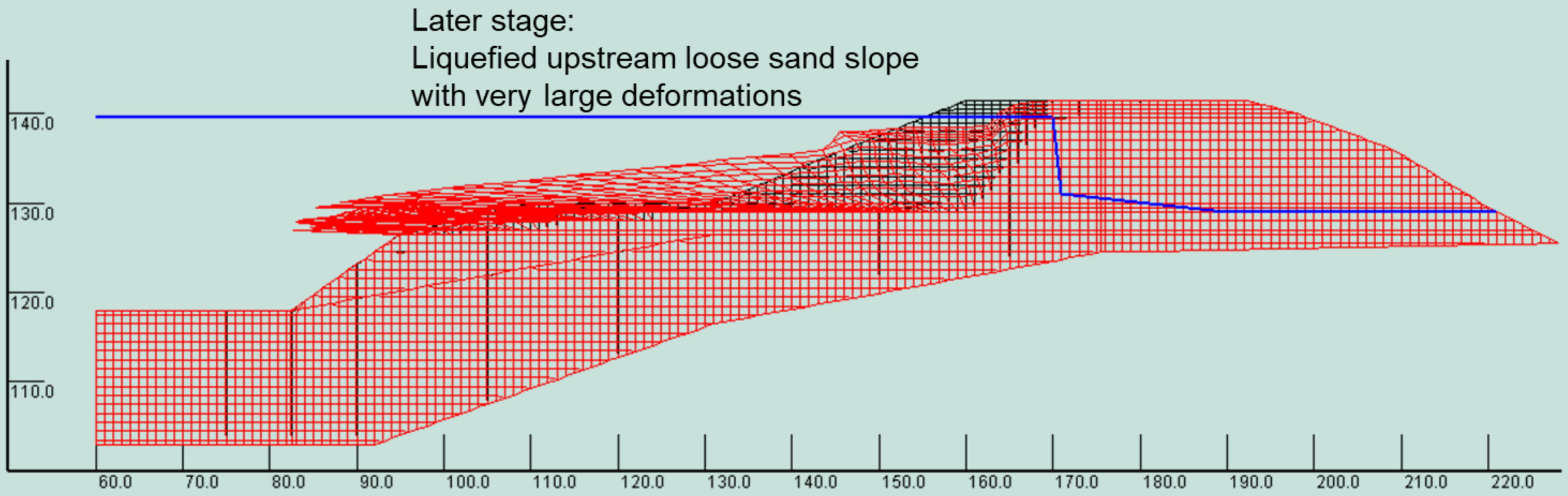


2010 John Hart Dam Deficiency Investigation:

VERSAT-2D Model

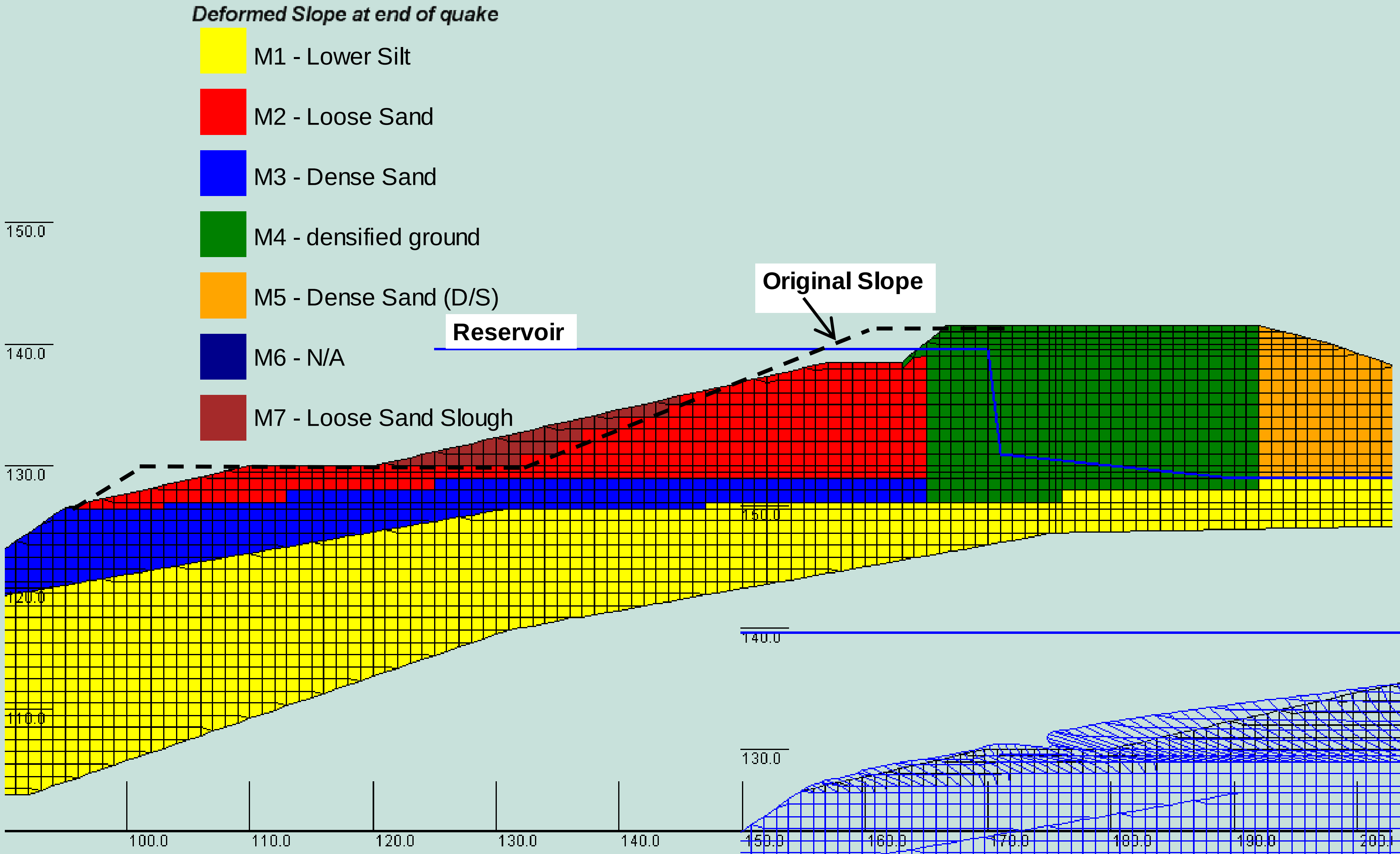
Simulation of progressive failure caused by earthquake:

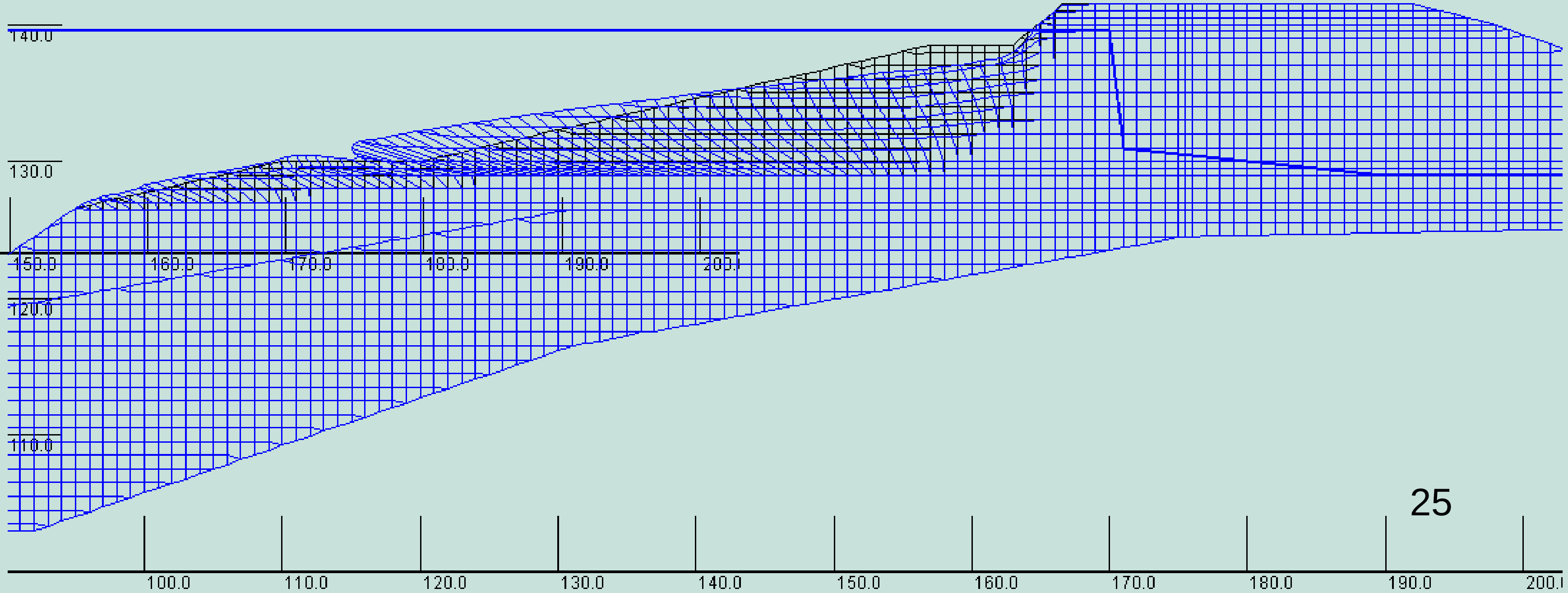




2010 John Hart Dam Deficiency Investigation:

STAGE 1 DEFORMED SLOPE





2010 John Hart Dam Deficiency Investigation:

Stage 2 and Stage 3 DEFORMED SLOPE, & final stable slope

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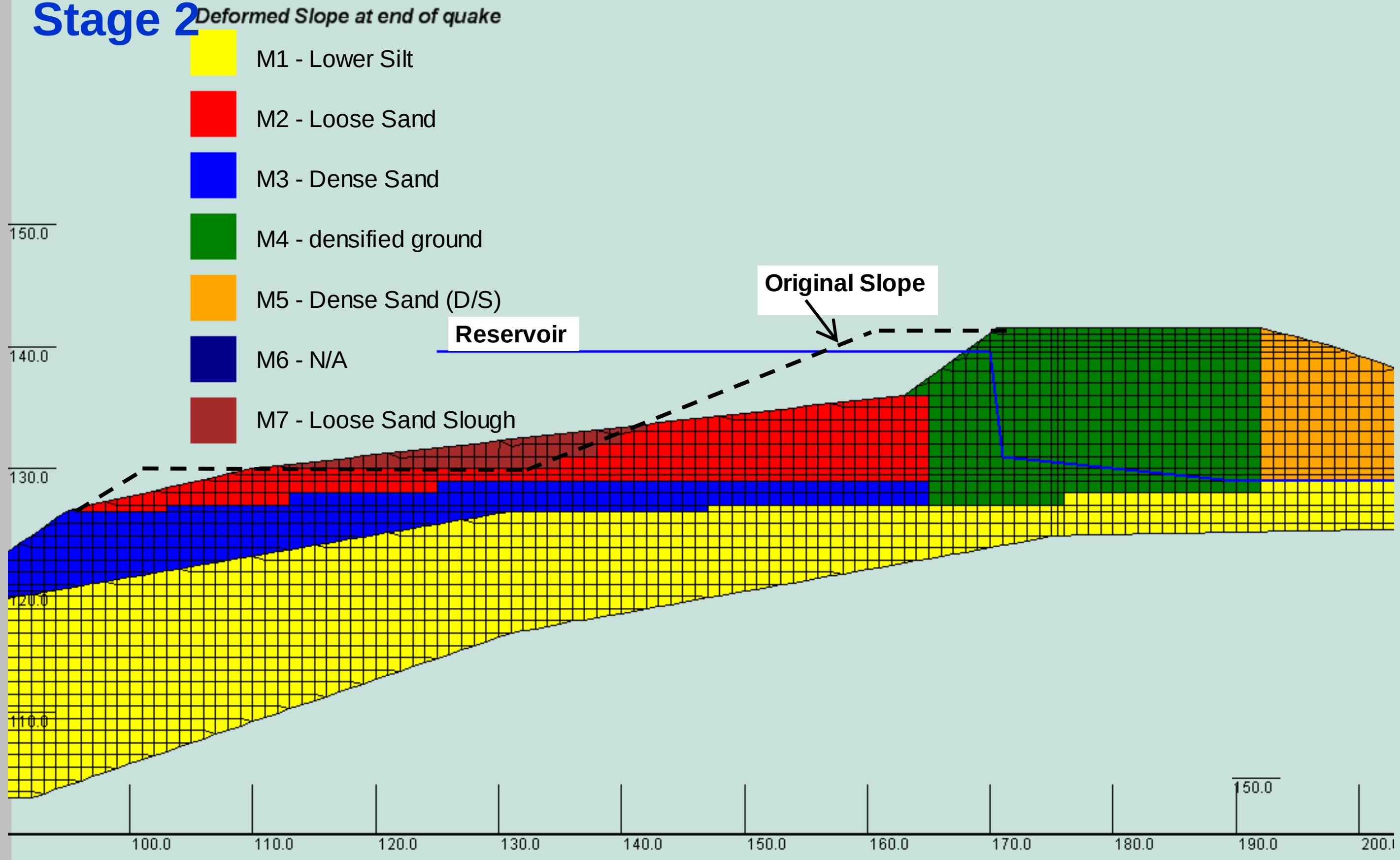
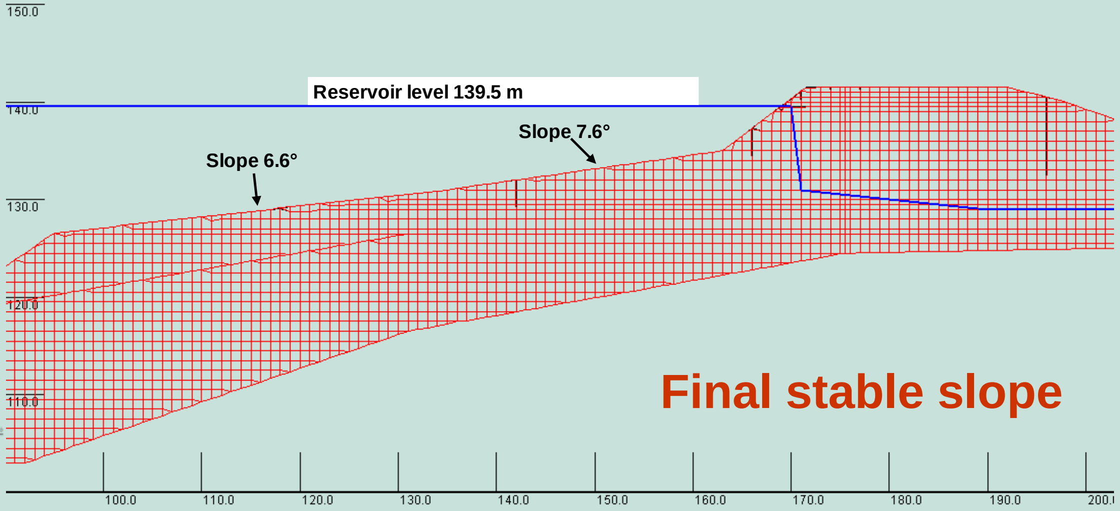
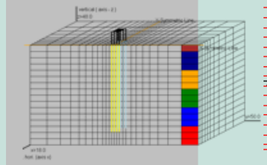
Stage 2

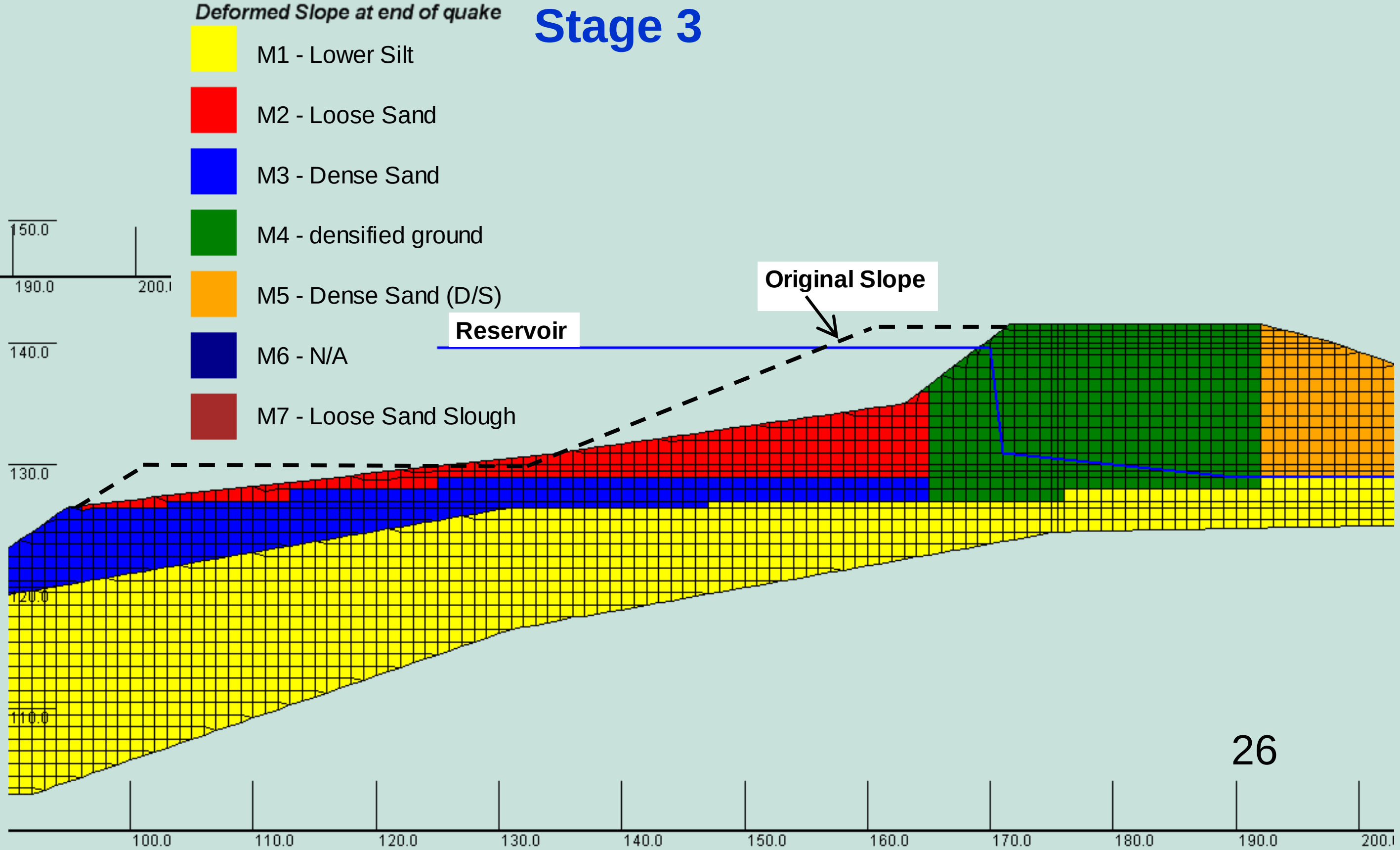




Final stable slope

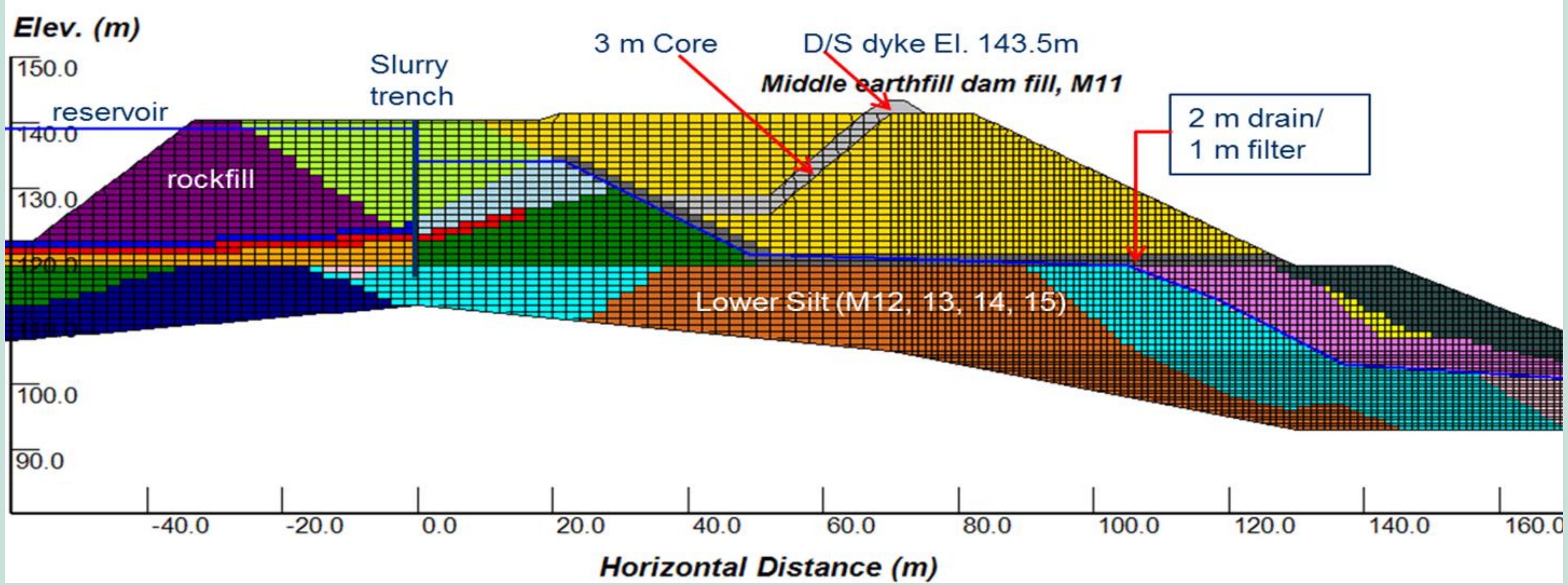


Stage 3



2013 John Hart Dam Seismic Performance Analyses

VERSAT-2D Dynamic Analyses



2013 John Hart Dam Seismic Performance Analyses

VERSAT-2D Dynamic Analyses

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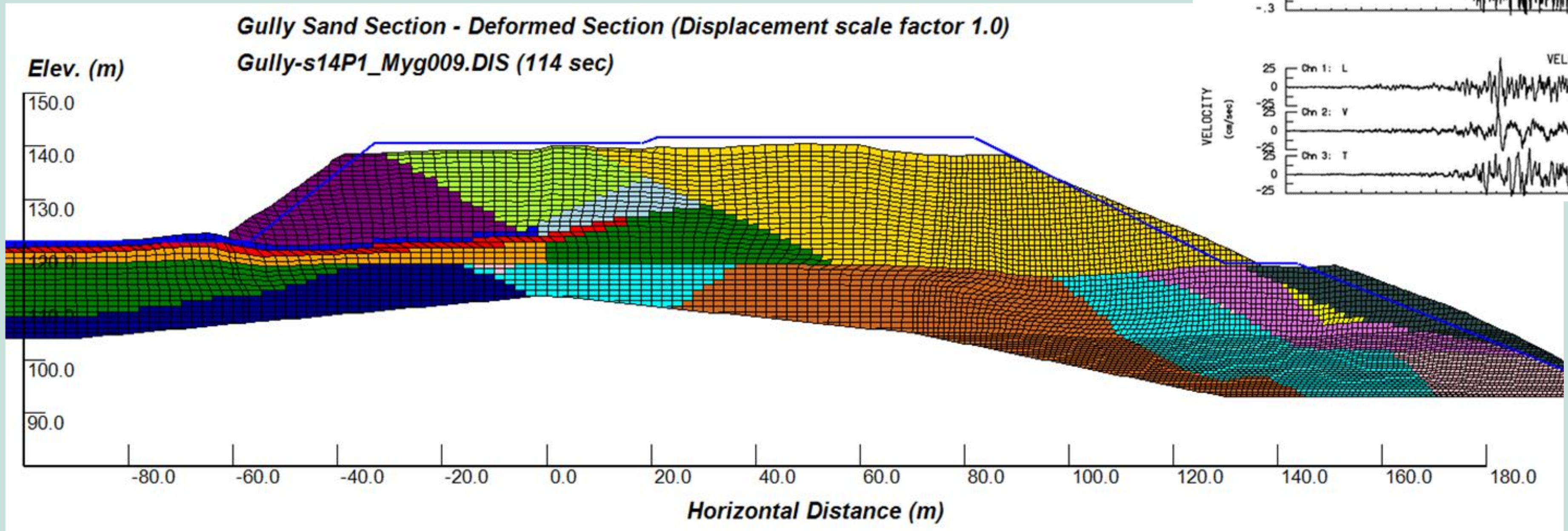
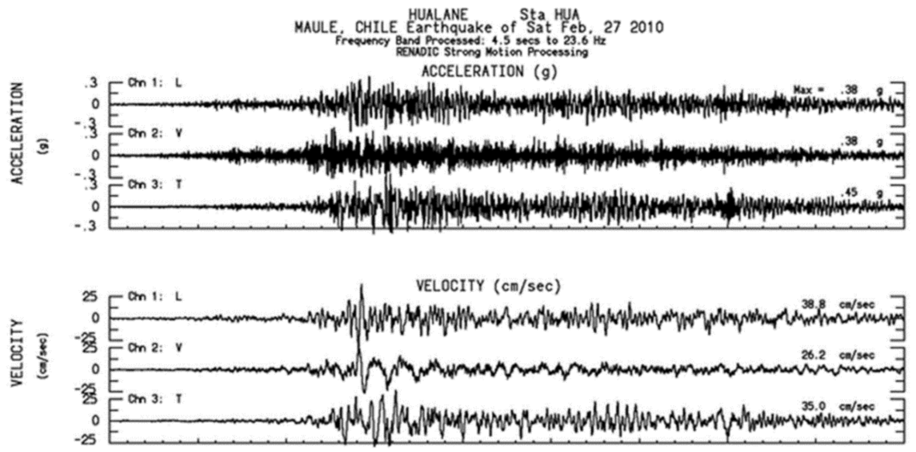
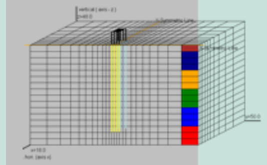
A deformed cross section (with colored soil zones) computed from the Tohoku MYG subduction motion



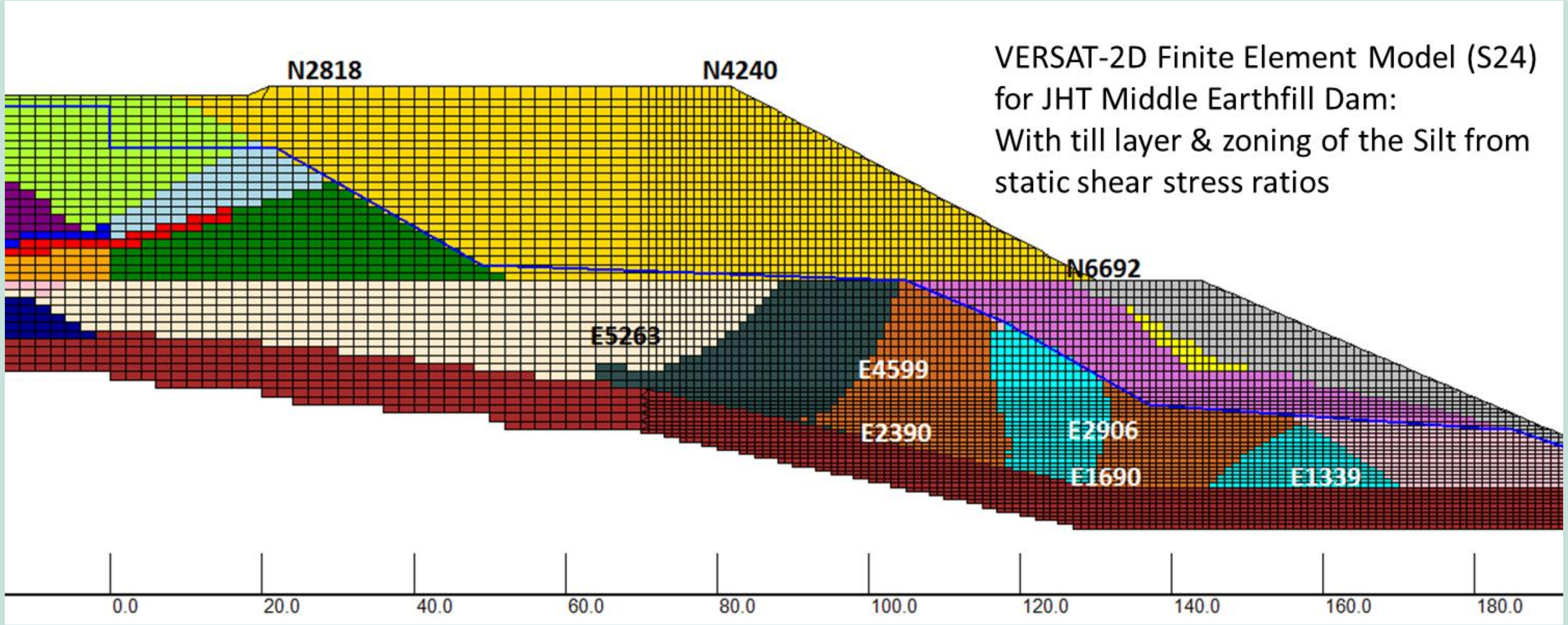


Finn W. D. Liam and Wu, Guoxi, 2013. Dynamic Analyses of an Earthfill Dam on Over-Consolidated Silt with Cyclic Strain Softening. Keynote Lecture, Seventh International Conference on Case Histories in Geotechnical Engineering, Chicago, US, April 29 - May 4. Download Now

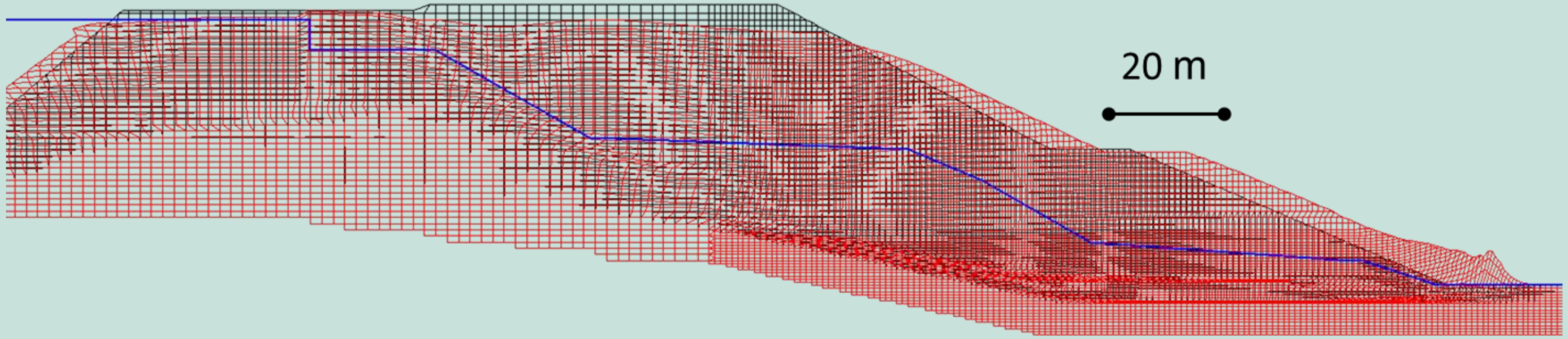


2016 John Hart Dam Seismic Upgrade

VERSAT-2D Sensitivity Analyses



Gully_s24RC_P1Hual
(assuming remolded shear
strengths in Silt)

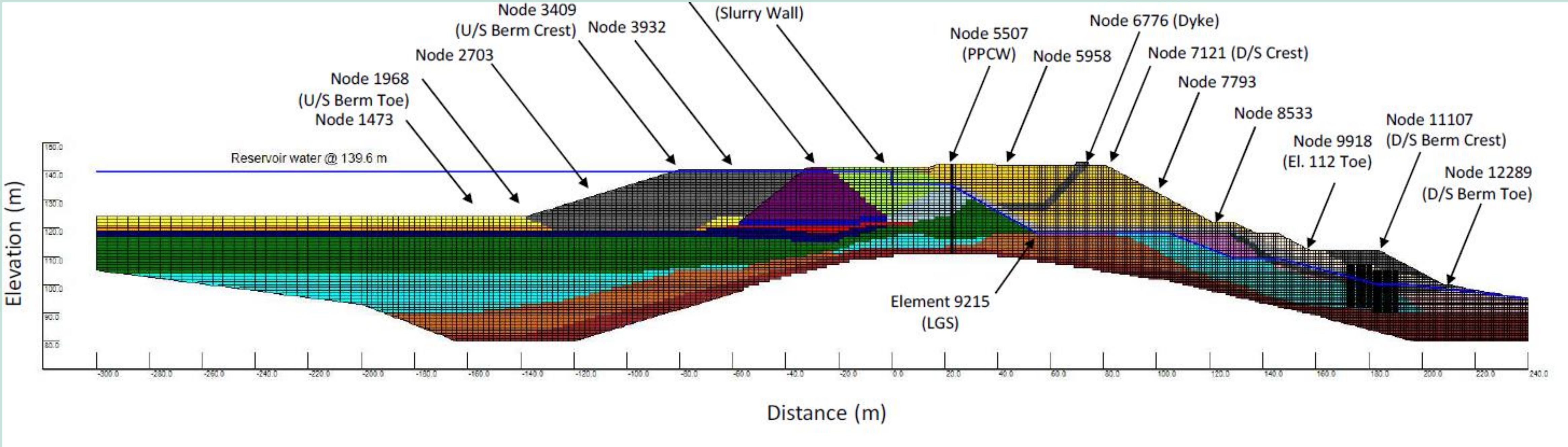


2020 John Hart Dam Seismic Upgrade Final Design

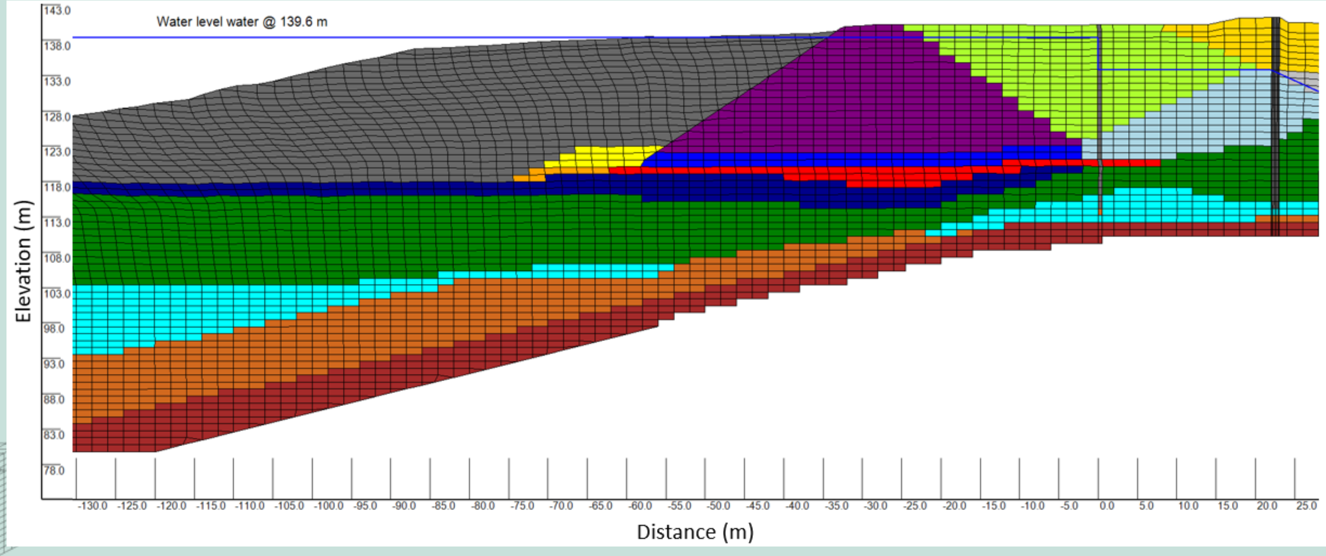
VERSAT-2D Dynamic Analyses (independent verifications to FLAC)

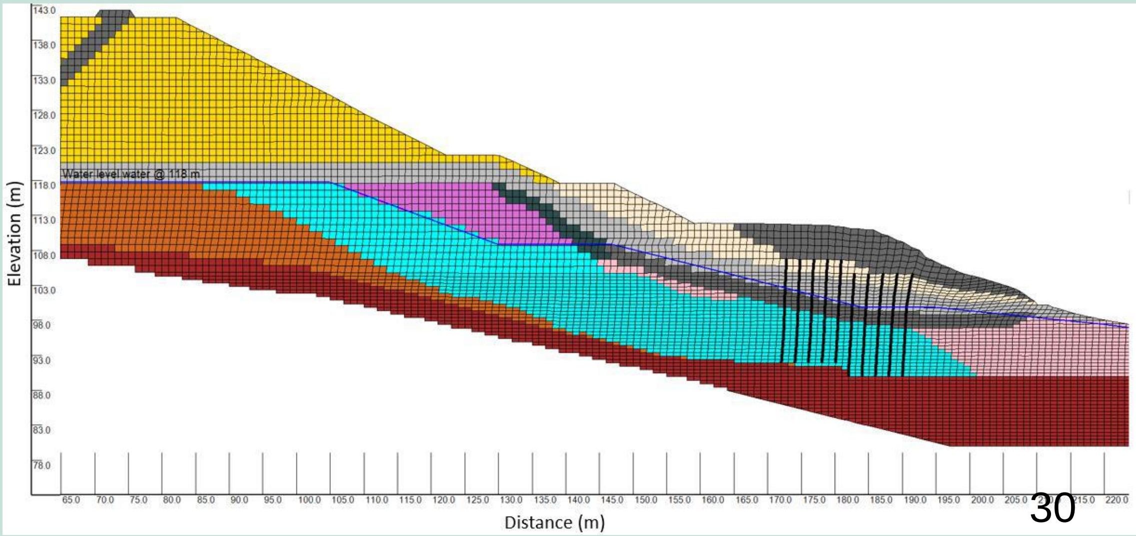
Wutec Geotechnical International

VERSAT-2D Design Model of Middle Earthfill Dam (MED) - Model with 13417 Elements



VERSAT-2D Computed end-of-earthquake deformed dam configurations:



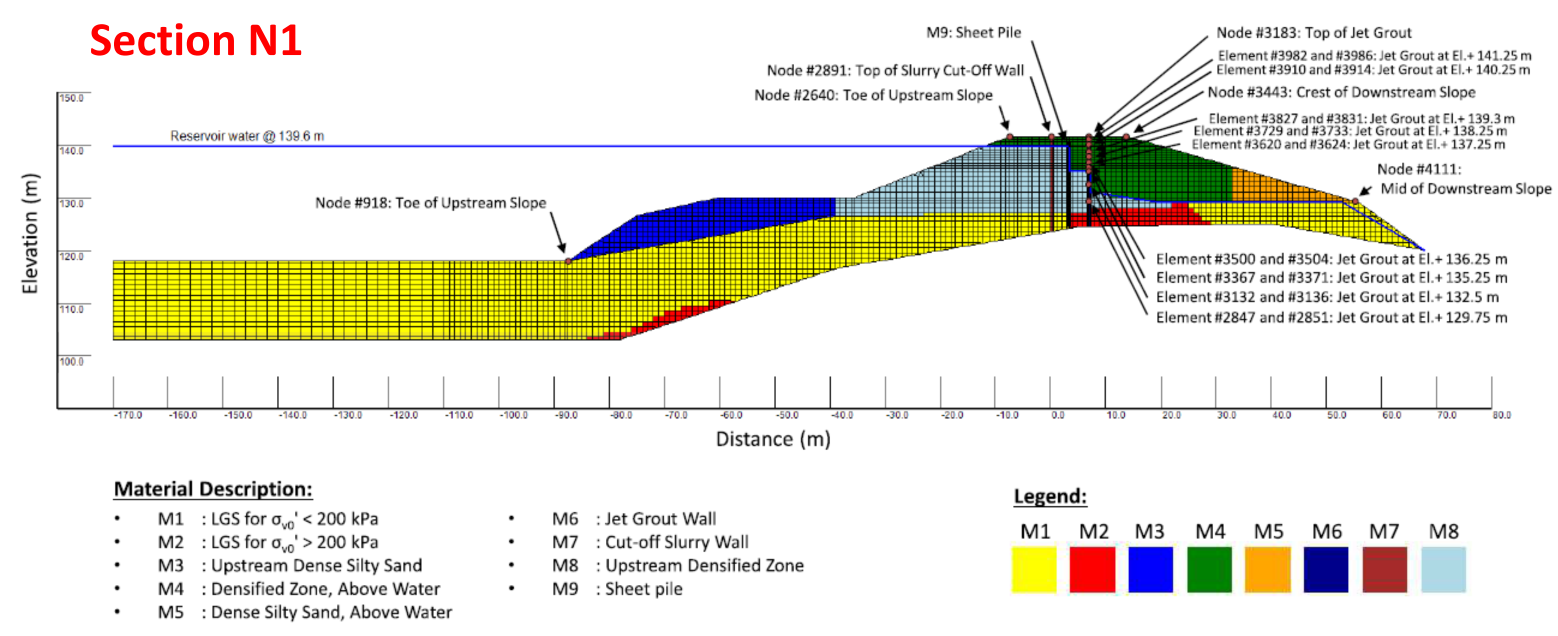


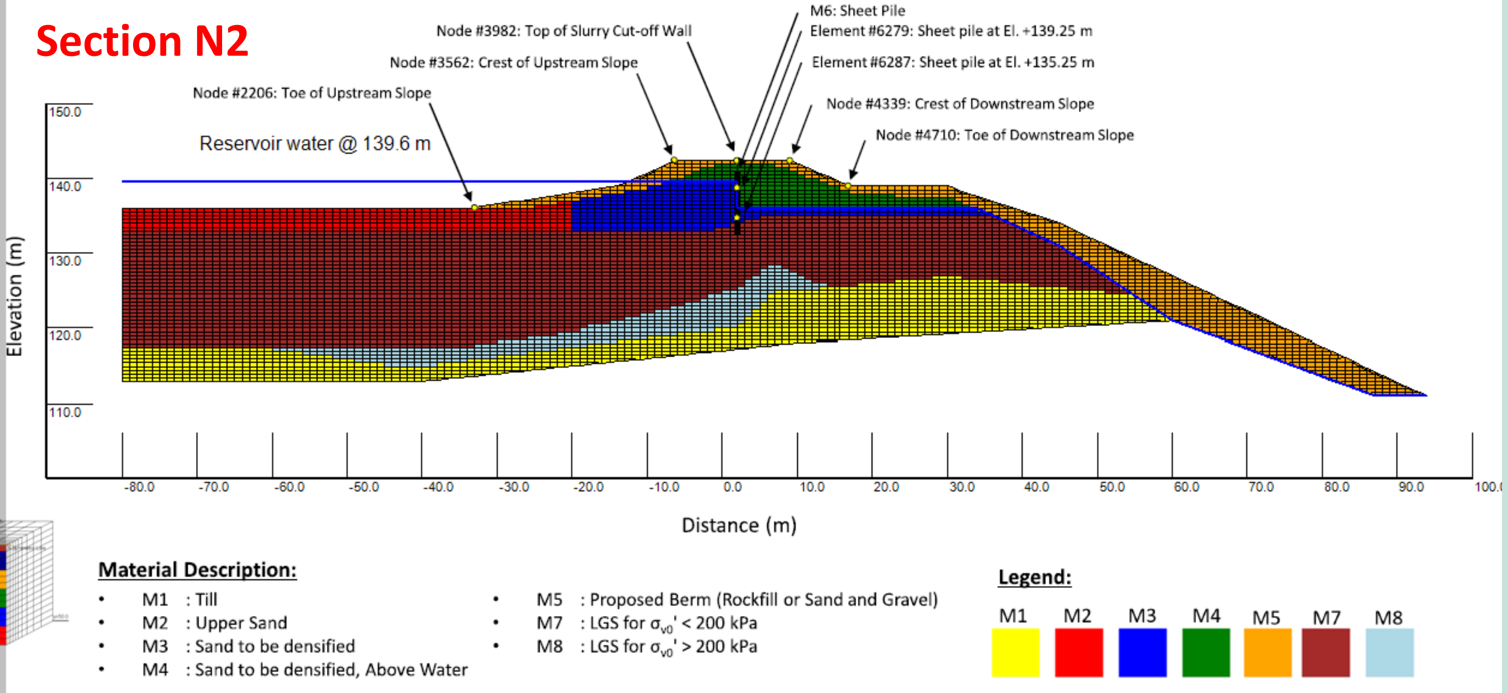
2020 John Hart Dam Seismic Upgrade Final Design

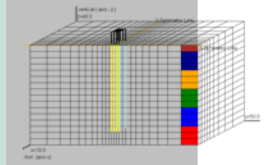
VERSAT-2D Dynamic Analyses (independent verifications to FLAC)

Wutec Geotechnical International

VERSAT-2D Design Models of North Earthfill Dam (NED) Section N1 and Section N2



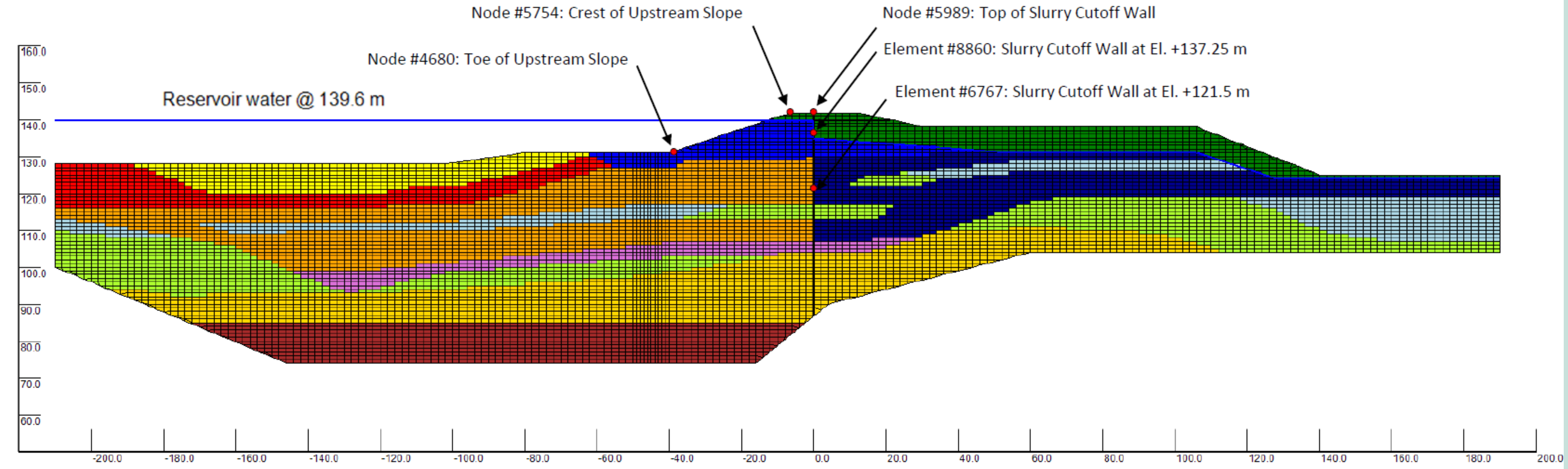




2020 John Hart Dam Seismic Upgrade Final Design

VERSAT-2D Dynamic Analyses (independent verifications to FLAC)

VERSAT-2D Design Model of Section M6 (transition from MED to Intake Dam)



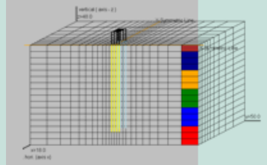
Material Description:

- M1 : Peat and Organics
- M2 : US Sand and Gravel
- M3 : DS Sand and Gravel
- M4 : DS Sand and Gravel, Above Water
- M5 : US Int. Sand and Silt
- M6 : DS Int. Sand and Silt
- M7 : Till
- M8 : Upper Silt and LGS for σ'_v<200 kPa
- M9 : Slurry Cutoff Wall
- M10 : Upper Silt and LGS for $\sigma'_v \geq$ 200 kPa
- M11 : LGS for σ'_v >= 350 kPa
- M12 : Lower Sand

Legend:

M1 M2 M3 M4 M5 M6

M7 M8 M9 M10 M11 M12



Reference:

- BC Hydro, 2024. John Hart Dam Seismic Upgrade Project – Design Basis for Final Design, v. 2024.10
- BC Hydro, 2021. John Hart Dam Seismic Upgrade Project – Preliminary Design Summary Report, Oct. 2021

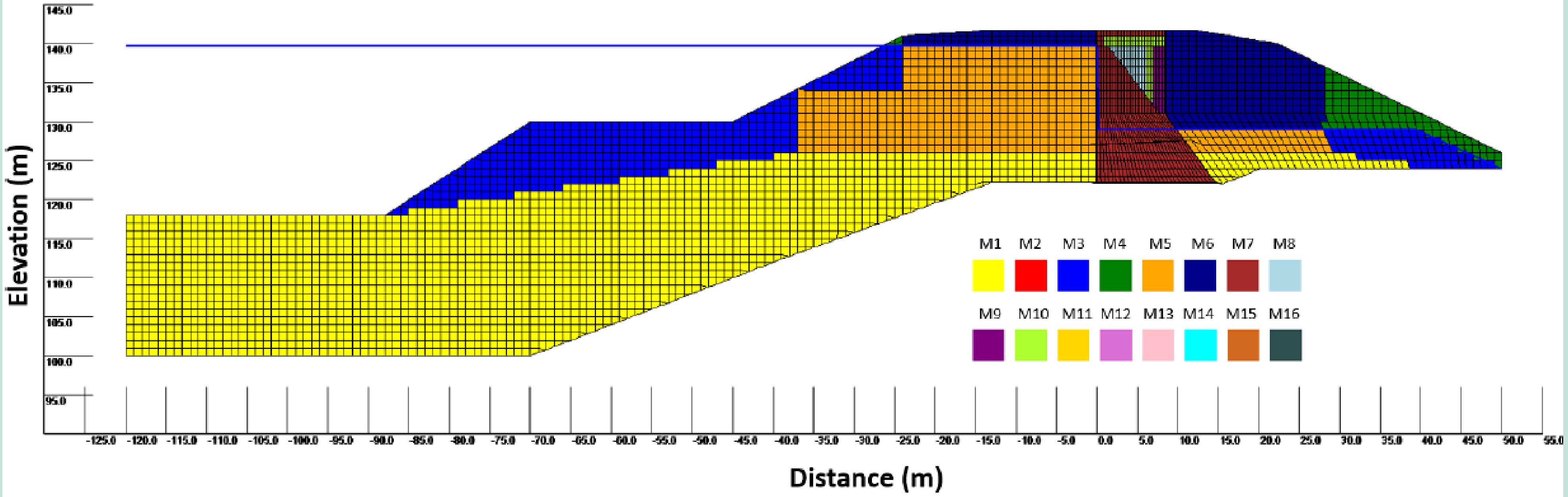
Note: Construction of the seismic upgrade project started in 2023 and will take a few years to complete.

2020 John Hart Dam Seismic Upgrade Final Design

VERSAT-2D Dynamic Analyses for Seismic Displacements

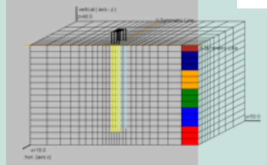
Wutec Geotechnical International

VERSAT-2D Design Analysis Model of section through block 16 of the concrete main dam



<u>Material Description</u>

- M1 : Lower Grey Silt
- M2 : *not used*
- M3 : Sand & Gravel
- M4 : Sand & Gravel, D/S
- M5 : Densified Soil
- M6 : Densified Soil, no WT
- M7 : Existing Concrete
- M8 : New Concrete
- M9 : 20% New Concrete
- M10 : 20% Existing + 80% New
- M11 : Contact with Silt, in water
- M12 : *not used*
- M13 : Contact with Densified Soil, in water
- M14 : Contact with Densified Soil, above water
- M15 : Frictional Joint in existing concrete (M7) at El. 127 m
- M16 : Frictional Joint in base of Block 16 at El. 122 m



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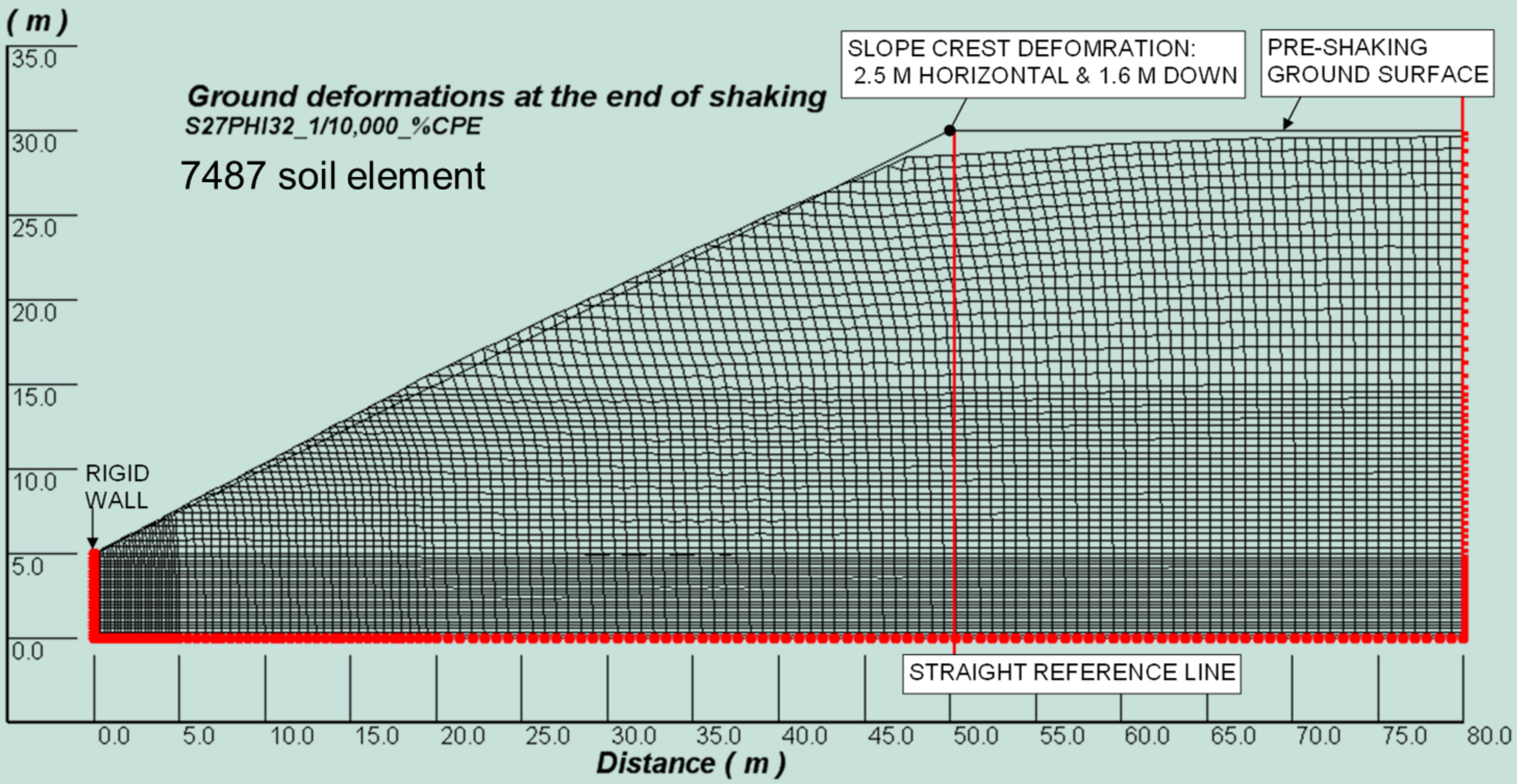
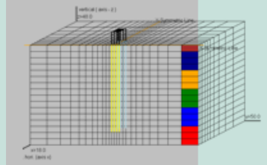
Seismic Soil Pressures: VERSAT-2D analysis

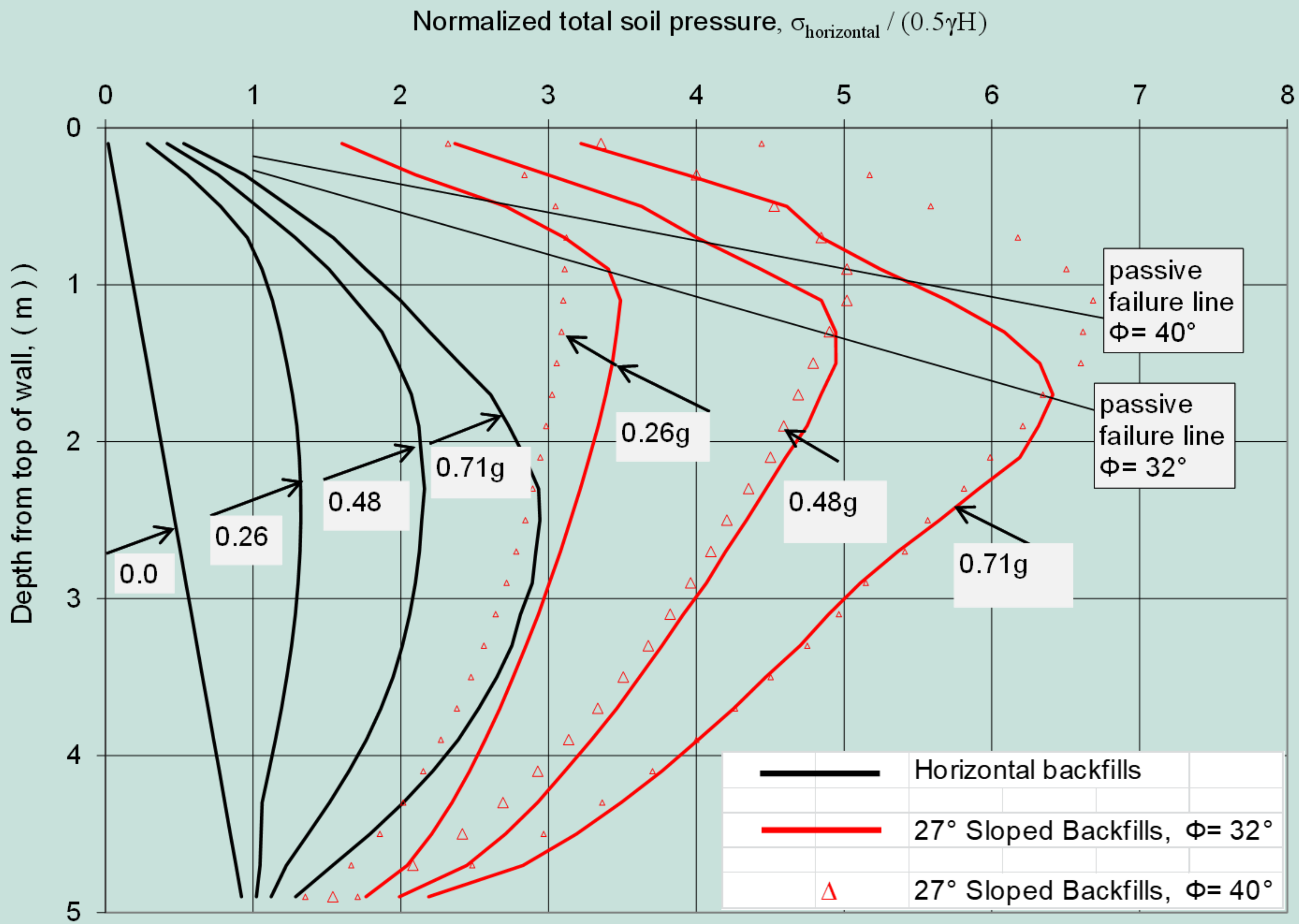




Wu, G. 2010. Seismic soil pressures on rigid walls with sloped backfills. Proceedings of the 5th International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, San Diego, California, US, May 24-29

Wutec Geotechnical International

Seismic Soil Pressures: VERSAT-2D analysis



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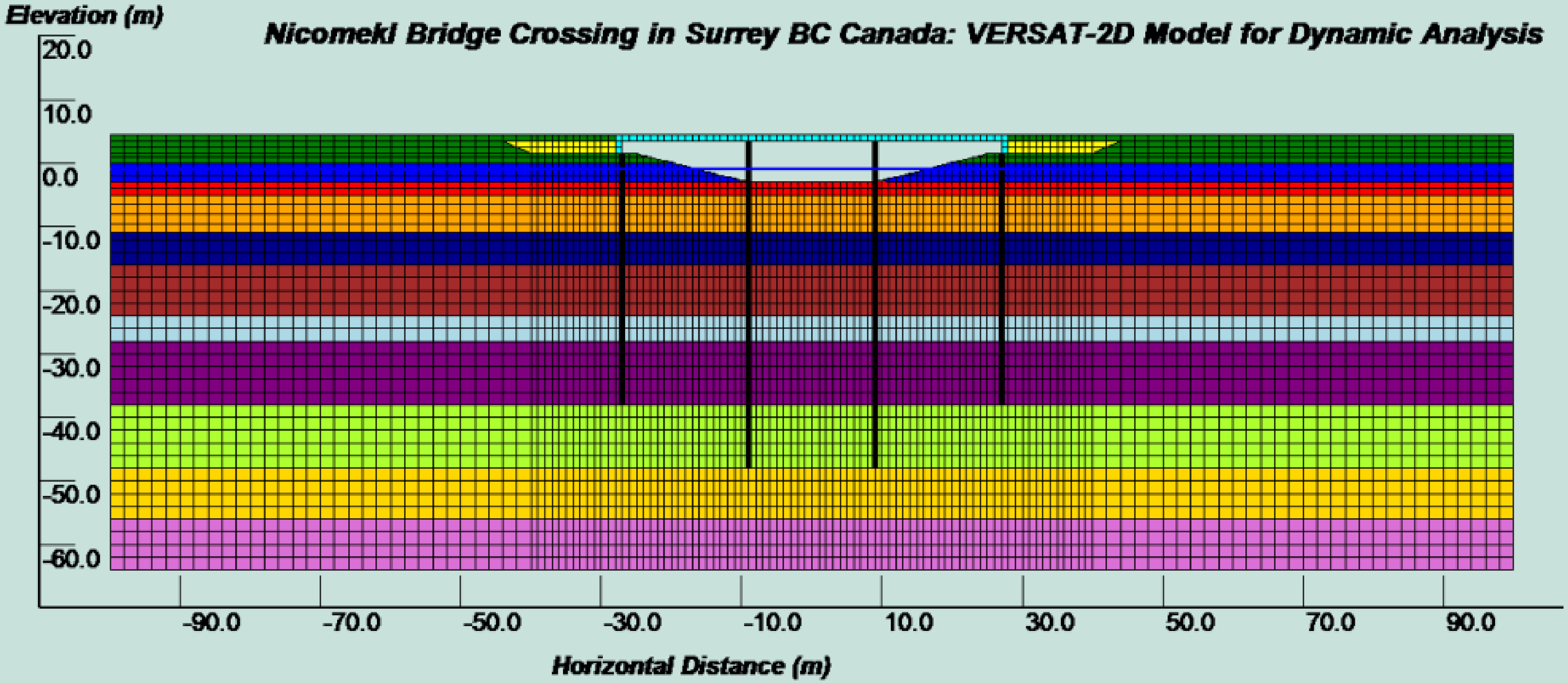
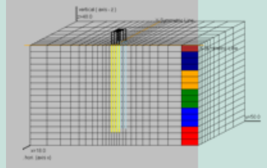
New **Serpentine River Bridge**: VERSAT-2D application



- Single Span Bridge on Soft Soils (24 m long, 14 m wide)
- 4716 nodes, 4572 elements, including bridge deck and abutment walls (Source: 2006 59th Canadian Geotechnical Conference)



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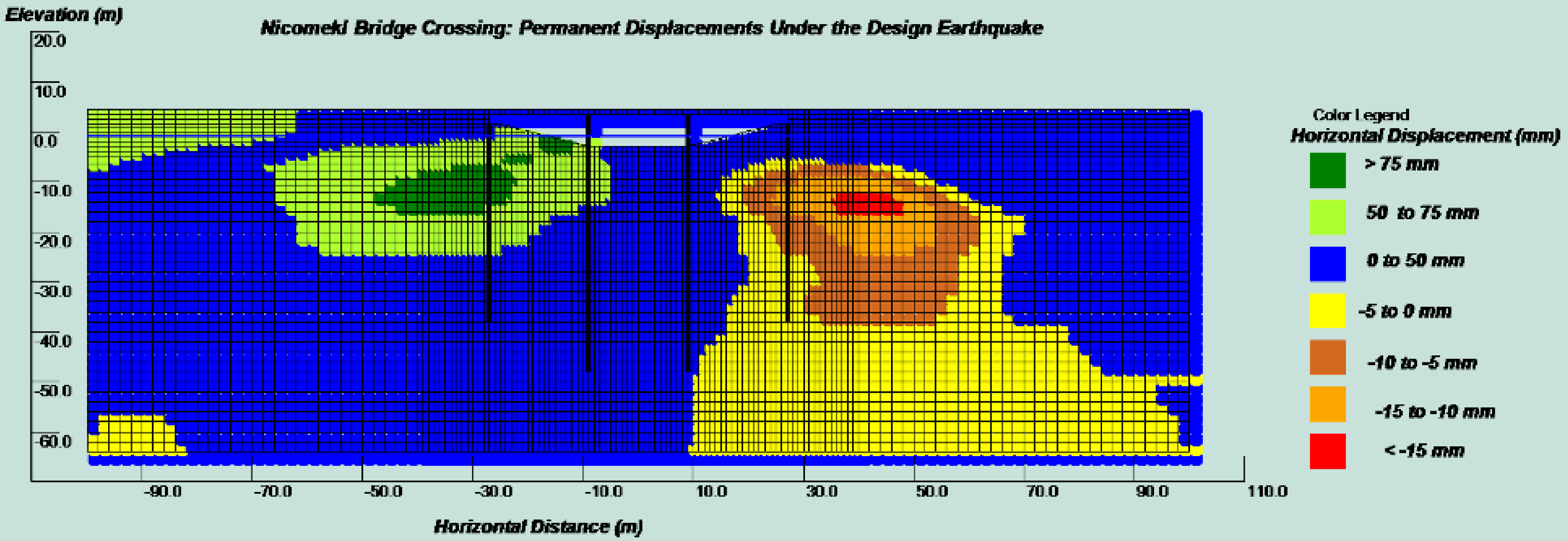
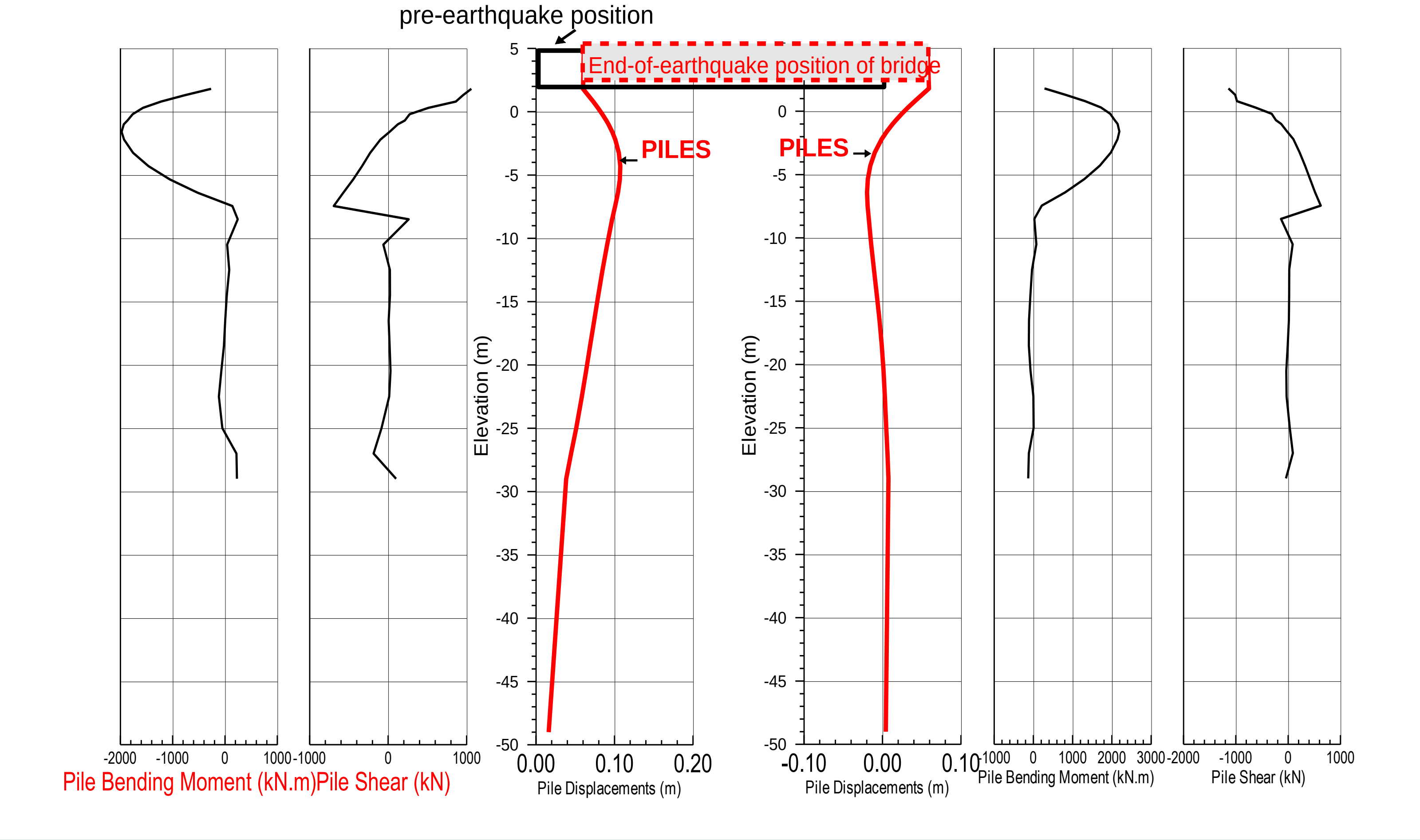
End-of-earthquake horizontal displacement contours

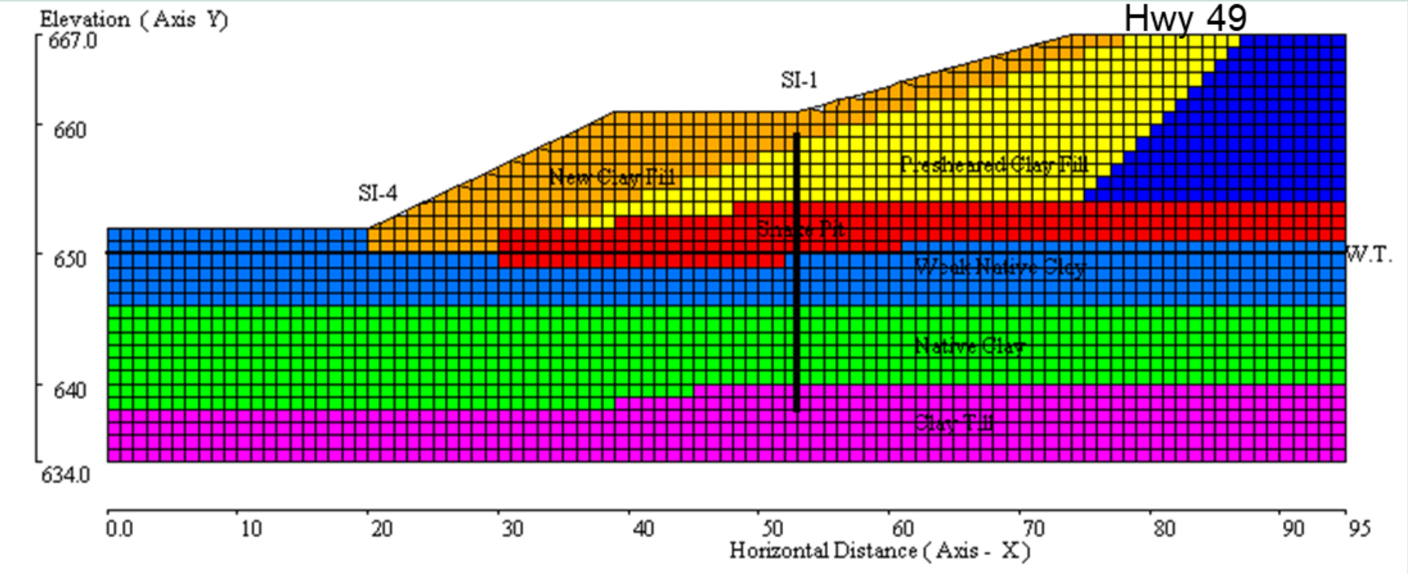


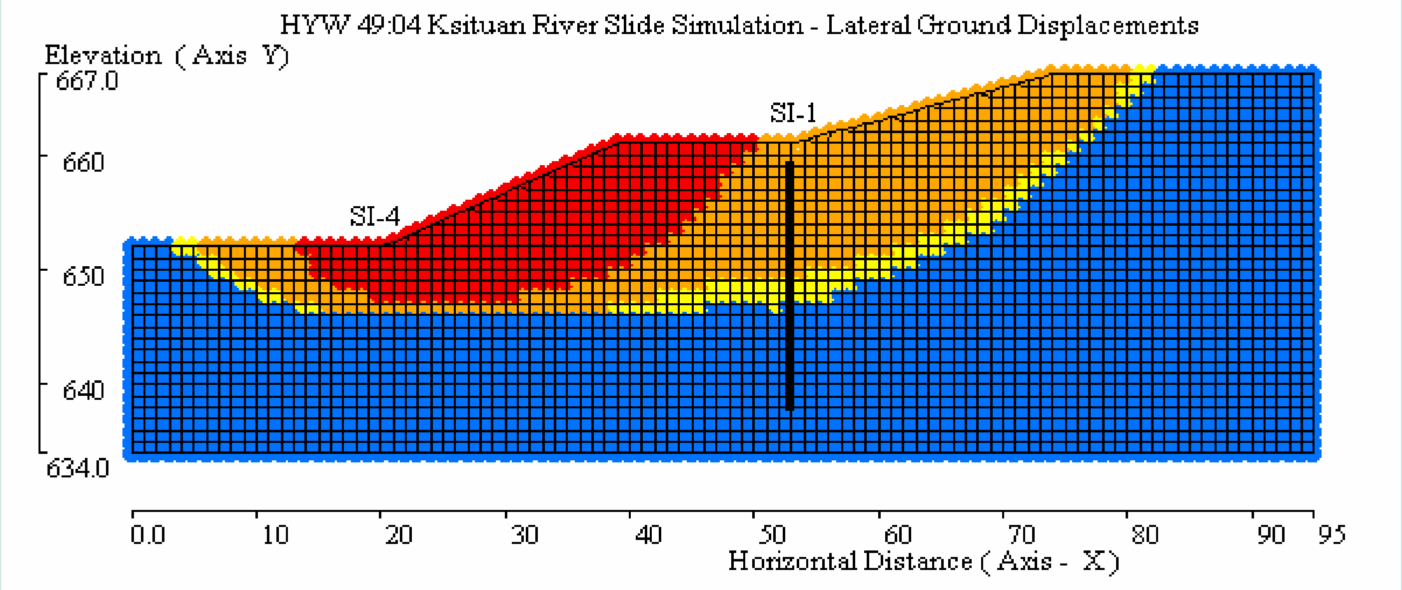
End-of-earthquake displacements of piles and bridge



Hwy 49 Remediation: VERSAT-2D application

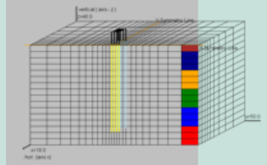
- Landslide deformations was observed on one side of Hwy 49.
- Driving piles was selected as remediation.
- VERSAT-2D analysis was carried out for pile design.





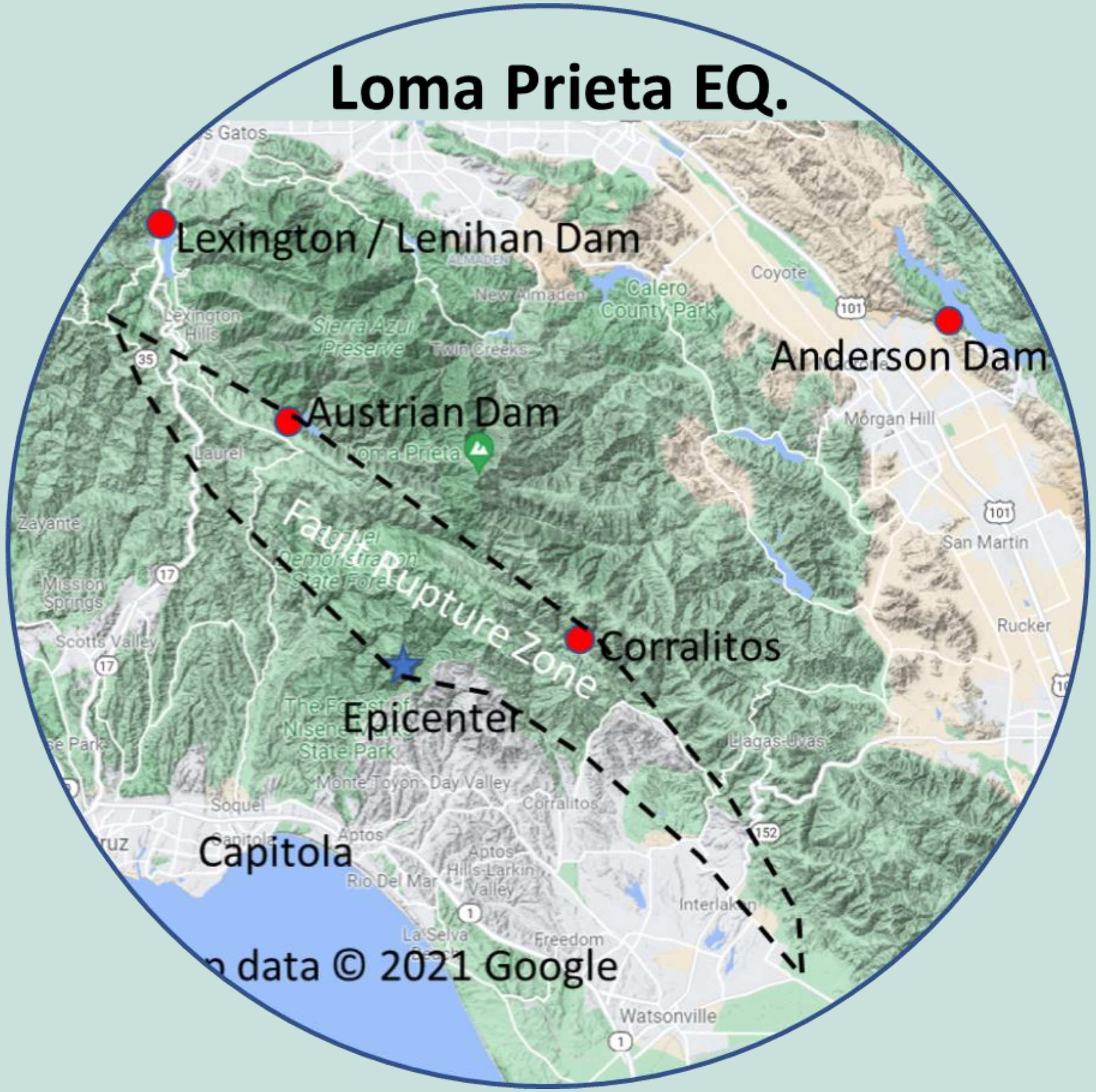
LEGEND
Lateral Ground Disp. (mm)
- < 100
- 100 to 200
- 200 to 1000
- > 1000

Maximum Shear in piles = (414, -508) kN
Maximum Moment in Piles = 3414 kN.m



Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake

VERSAT-2D Dynamic Analyses



1. The 1989 October 17 Loma Prieta earthquake fault rupture zone (Mw 6.93)
2. Ground motion recording stations (the Lexington station and the Corralitos station) and
3. Austrian Dam in California with a horizontal PGA 0.55-0.6 g (Harder et al. 1998)

Wu, Guoxi. 2023. Case History Studies of Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake. In Proceeding Geo-congress 2023 in Los Angeles, USA, March.

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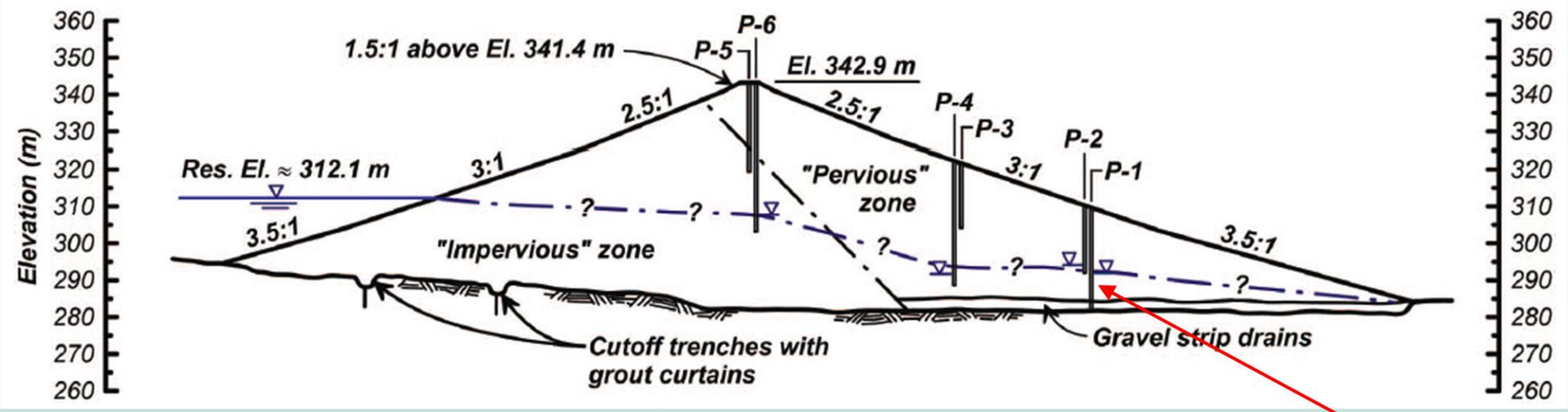
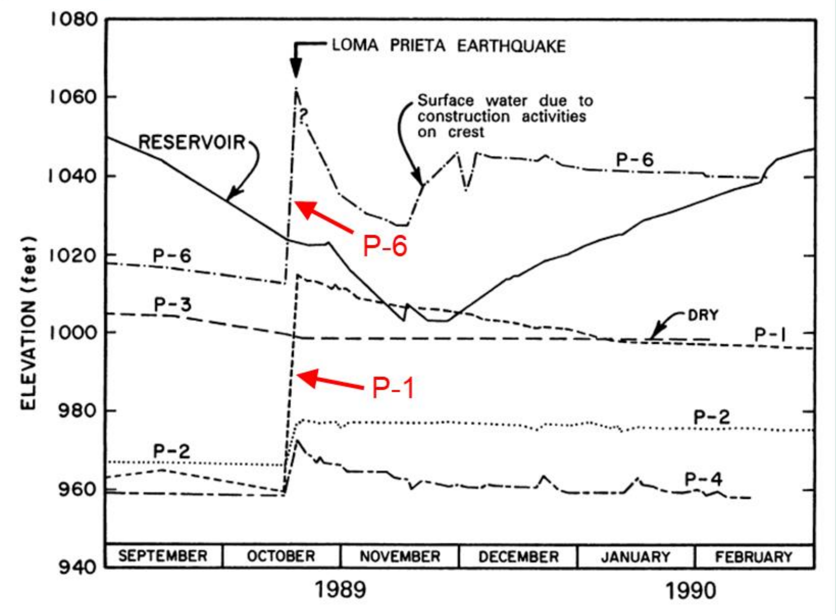
- **Austrian Dam** under the 1989 Loma Prieta Earthquake



Shear deformations



MAXIMUM CROSS SECTION

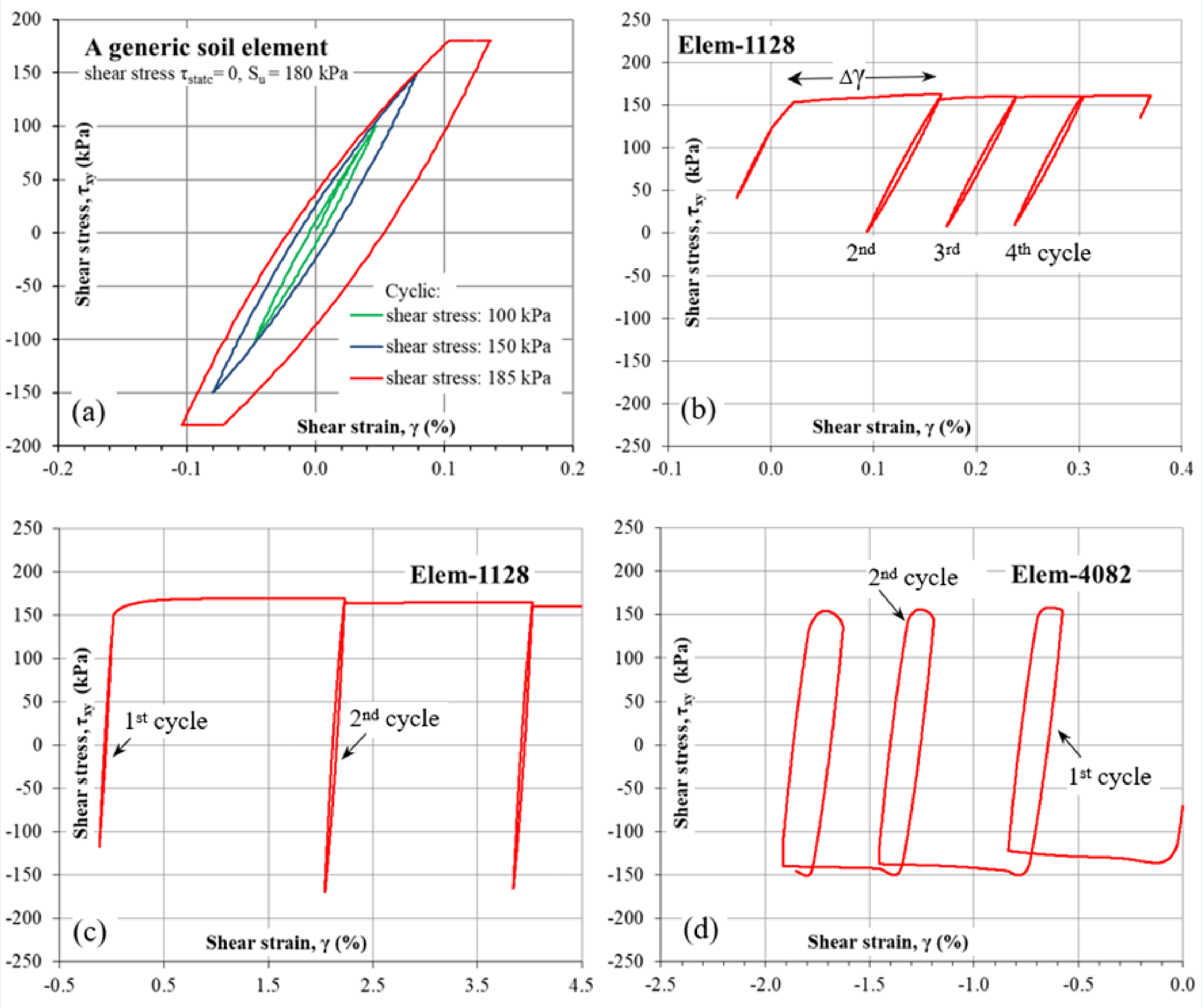
Damages by the earthquake:

- Rise of PWP in P-1, P-6, P-2, and P-3. PWP heads increased 15.2 m in P-6 and 16.8 m in P-1 two days after the EQ
- Standpipe in piezometer P-1 significantly deformed at El. 291-293 m), suggesting earthquake induced internal movements due to lateral spreading (Harder et al. 1998)

Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake

VERSAT-2D Dynamic Analyses

- **Dynamic total stress analysis of Austrian Dam** using **VERSAT–clay model**



Shear stress-strain response of saturated dam fills in constant shear stress amplitude cyclic (sine wave) loading:

(a) for a generic soil element at three stress levels;

(b) for soil element 1128 under the 0.1g input accelerations;

(c) for soil element 1128 under 0.3g

(d) for soil element 4082 under the 0.3g input accelerations.

Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake

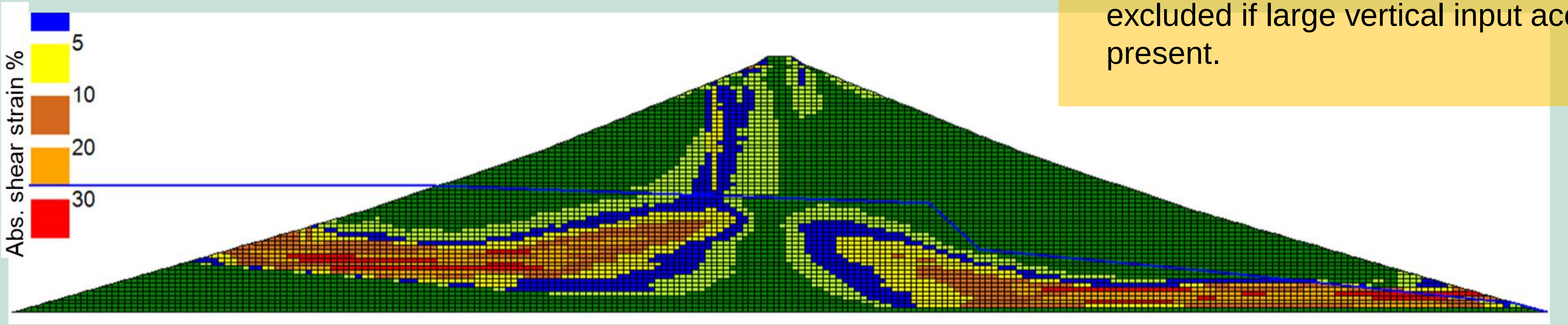
VERSAT-2D Dynamic Analyses

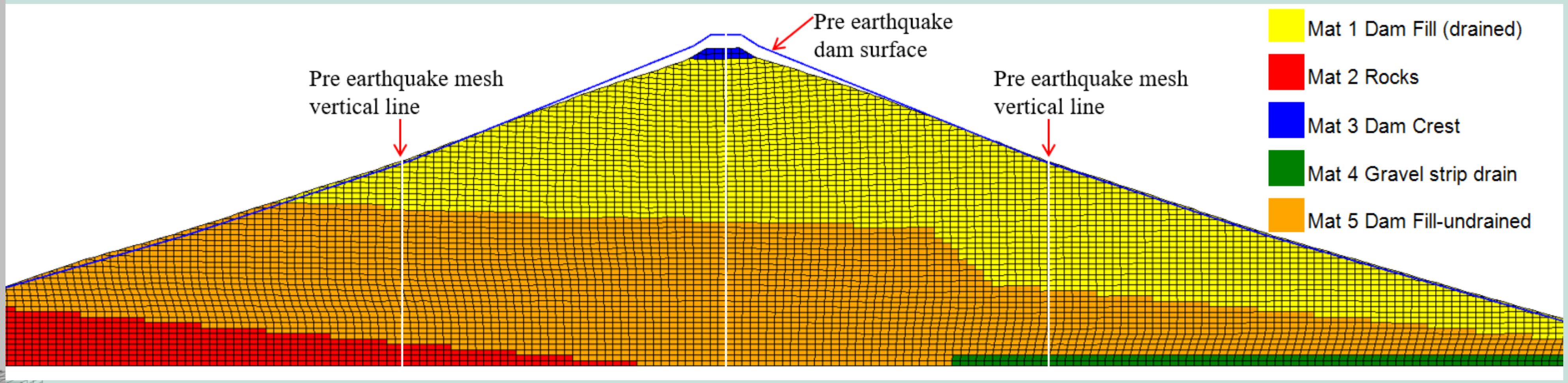
Austrian Dam under the 1989 Loma Prieta Earthquake

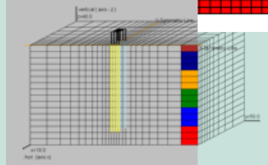
- Measured dam crest settlement ~0.76 m
- Computed crest settlement by VERSAT-2D: 0.70-0.77 m

For dynamic analyses of **Austrian Dam**:

- It is appropriate to linearly scale up recorded motions at Lexington station (on left abutment of Lenihan Dam) by a factor of 1.36. Study by Boulanger (2019) used recorded motions at Corralitos station.
- My study suggested that the total stress envelope (c-φ) approach be avoided whenever possible and be excluded if large vertical input accelerations are present.





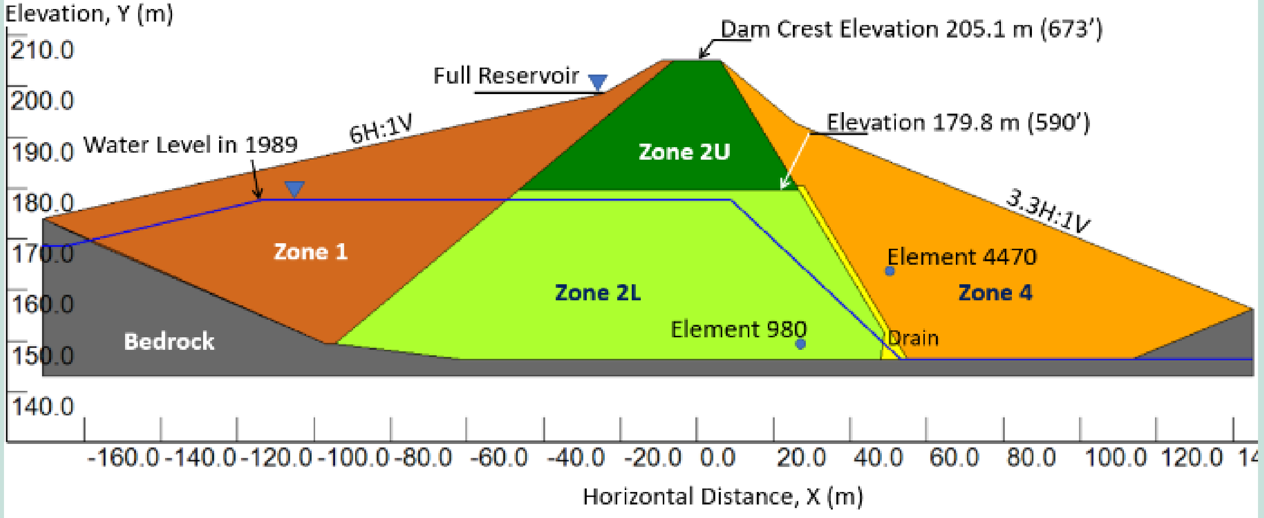


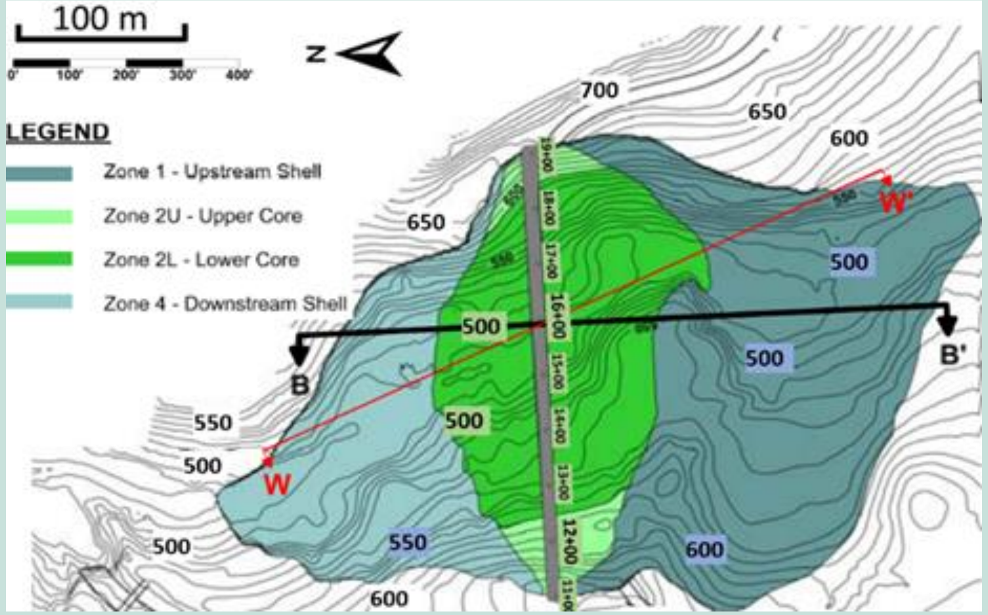
WGI (Wutec Geotechnical International). 2022. **Finite Element Dynamic Analyses of Austrian Dam.** Engineering Report No. WGI-220224 (100 pages) http://wutecgeo.com/publication.aspx

Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake

VERSAT-2D Dynamic Analyses

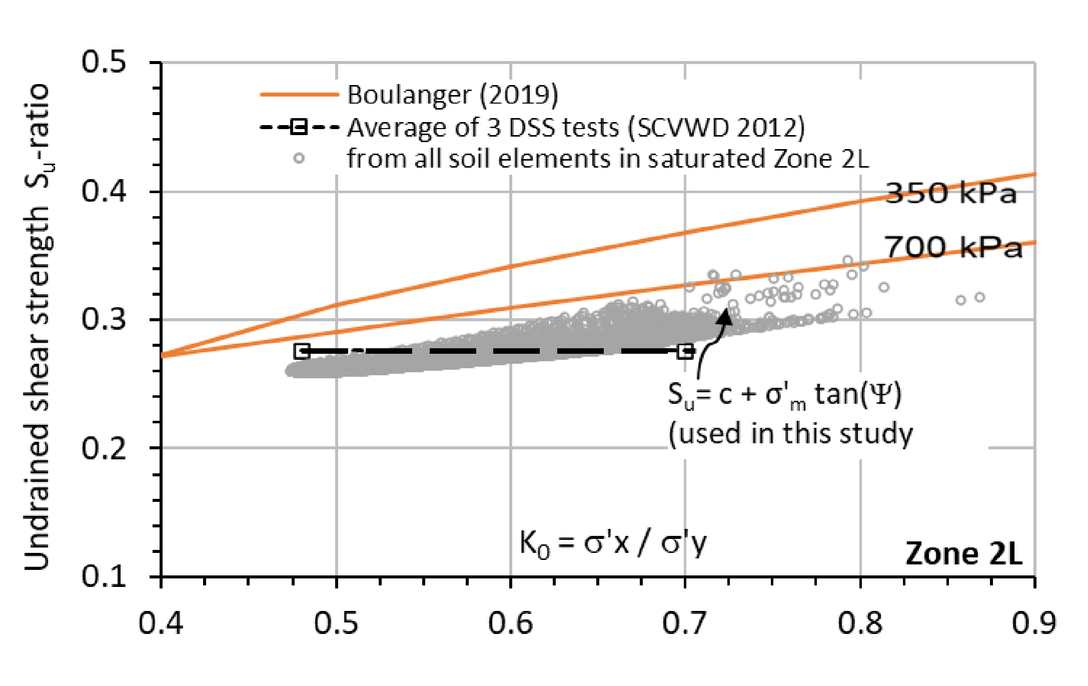
Lenihan Dam under the 1989 Loma Prieta Earthquake

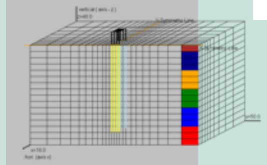




- Recorded accelerations on dam abutment bedrock had horizontal PGAs of 0.44g;
- Recorded accelerations on dam crest had a horizontal PGA of 0.45g
- Measured dam crest settlement ~ 0.25 m

Undrained shear strength in Zone 2L:





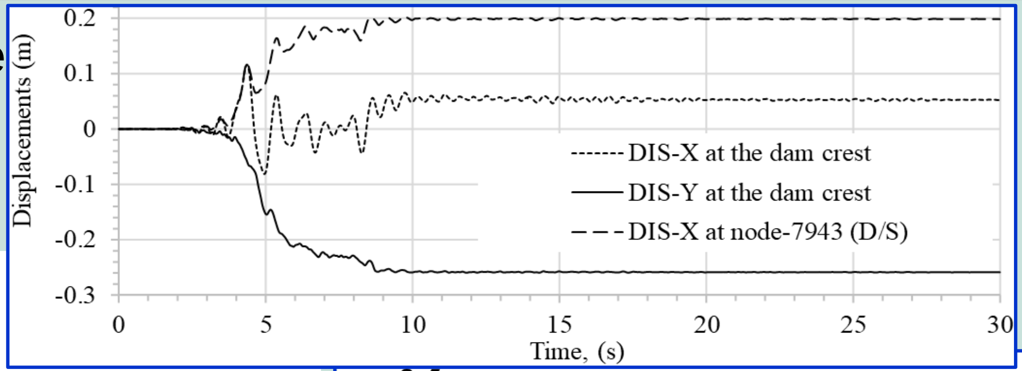
WGI (Wutec Geotechnical International). 2022. **Case Study of Lenihan Dam under the 1989 Loma Prieta Earthquake**. Engineering Report No. WGI-220301 (100 pages) http://wutecgeo.com/publication.aspx

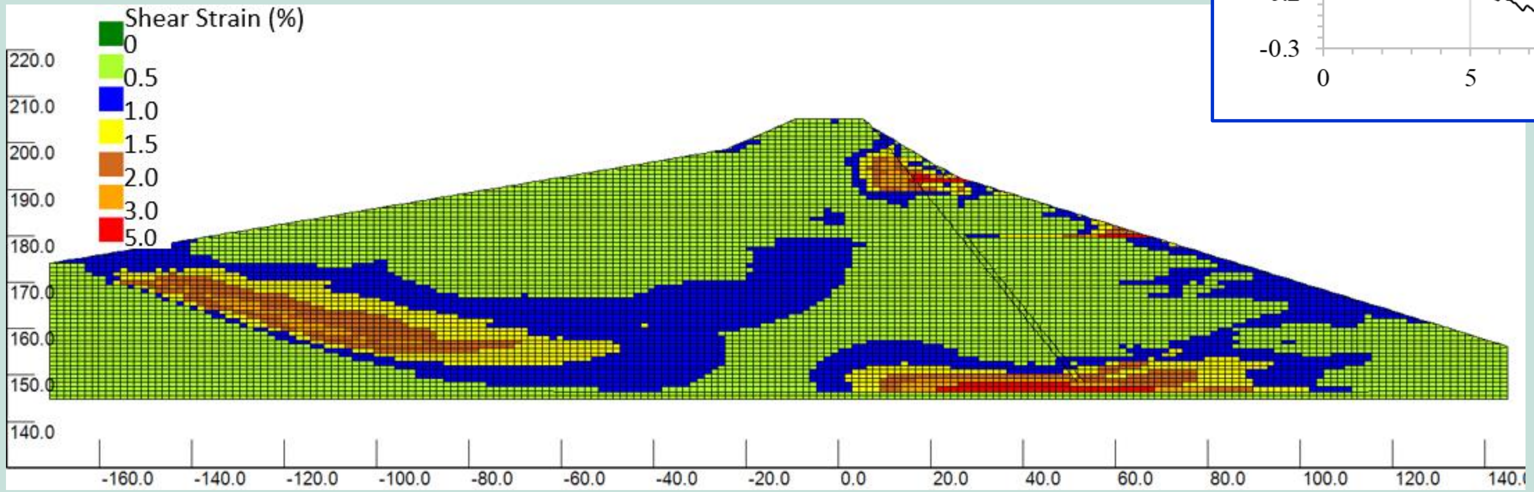
Lenihan and Austrian Dams under the 1989 Loma Prieta Earthquake
VERSAT-2D Dynamic Analyses

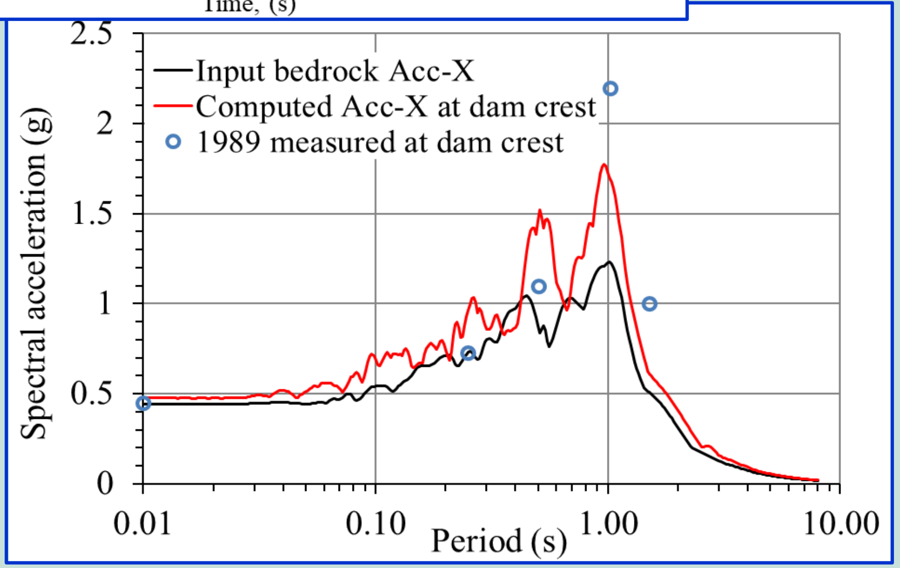
Wutec Geotechnical International

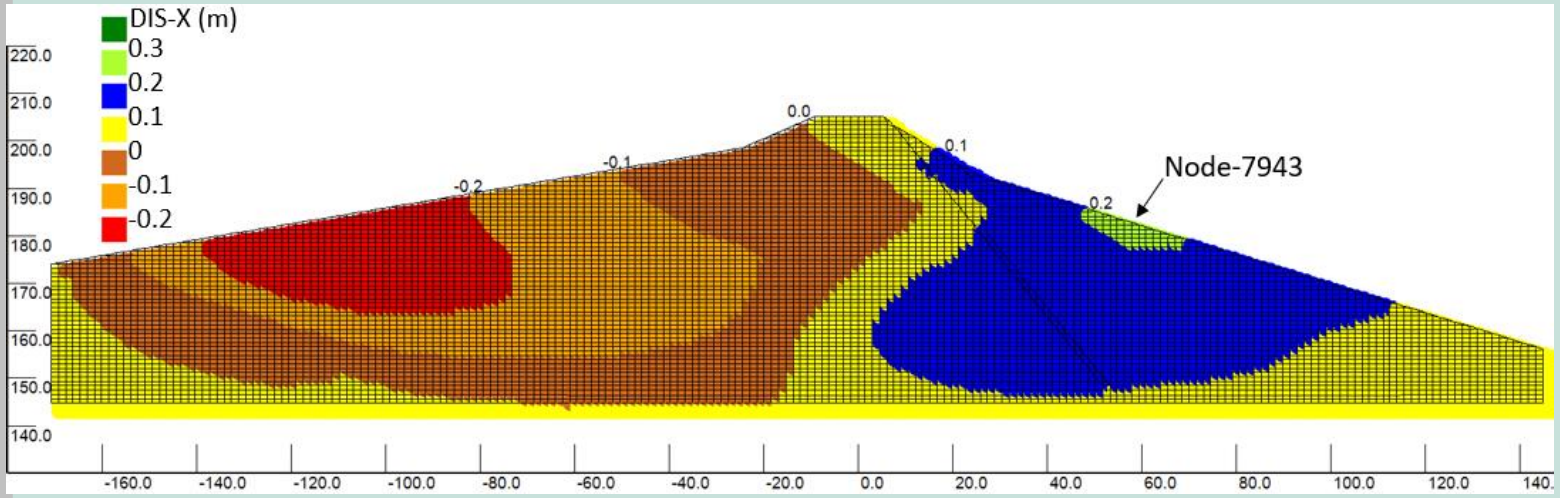
Lenihan Dam under the 1989 Loma Prieta Earthquake

- Measured dam crest settlement ~ 0.25 m
- Computed by VERSAT-2D: 0.47g, 0.25-0.35 m



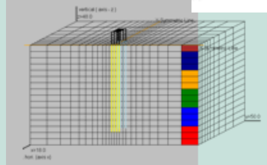






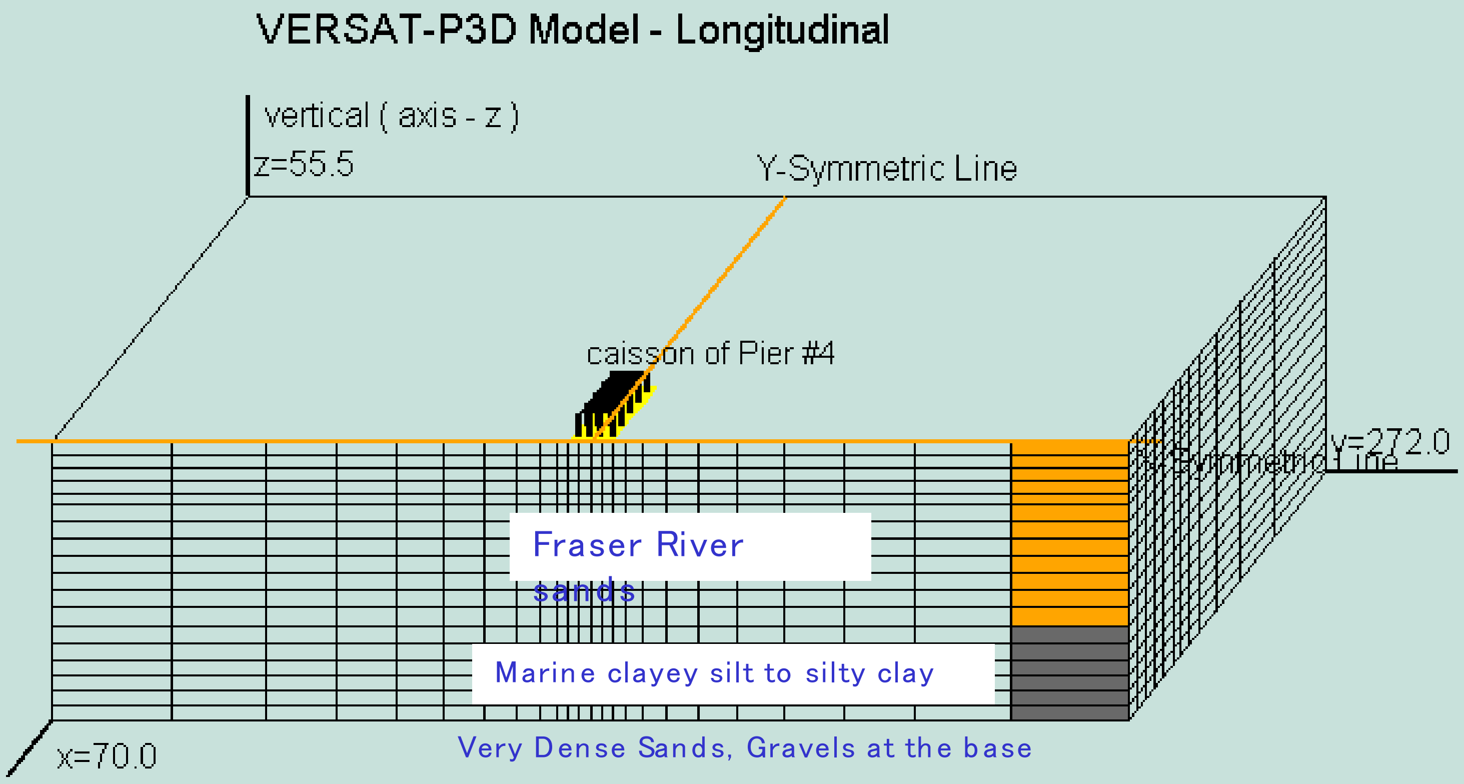
For dynamic analyses of **Lenihan dam:**

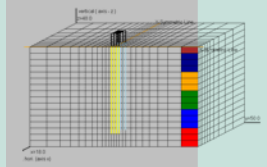
- It is appropriate for using cross-section W-W' to predict realistic dam displacements under the 1989 Loma Prieta earthquake.
- Studies by Hadidi et al. 2014 & Dawson and Mejia 2021 appear to have significantly underpredicted the dam crest settlement.



WGI (Wutec Geotechnical International). 2022. **Case Study of Lenihan Dam under the 1989 Loma Prieta Earthquake**. Engineering Report No. WGI-220301 (100 pages) http://wutecgeo.com/publication.aspx

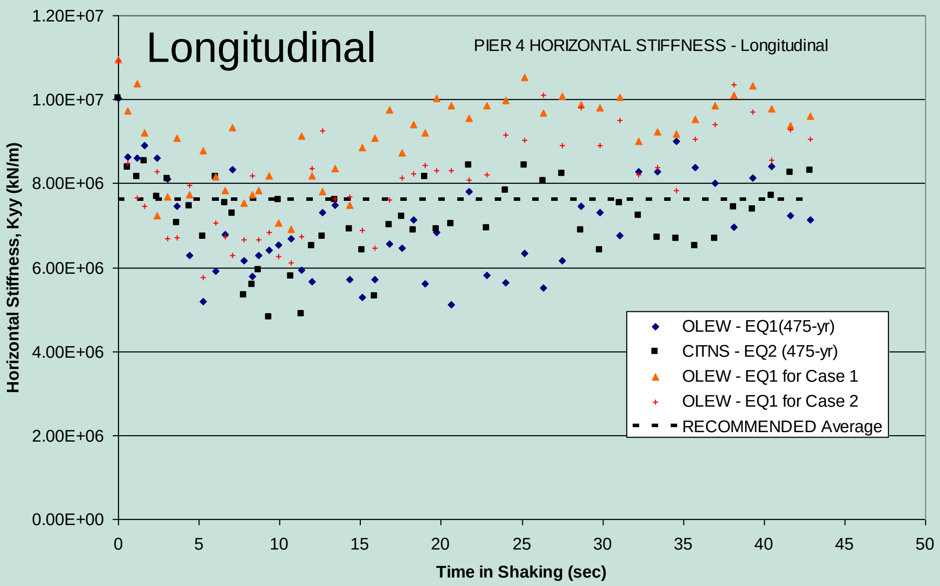
VERSAT-P3D MODEL OF PIER 4 CAISSON
- Longitudinal to Bridge Alignment

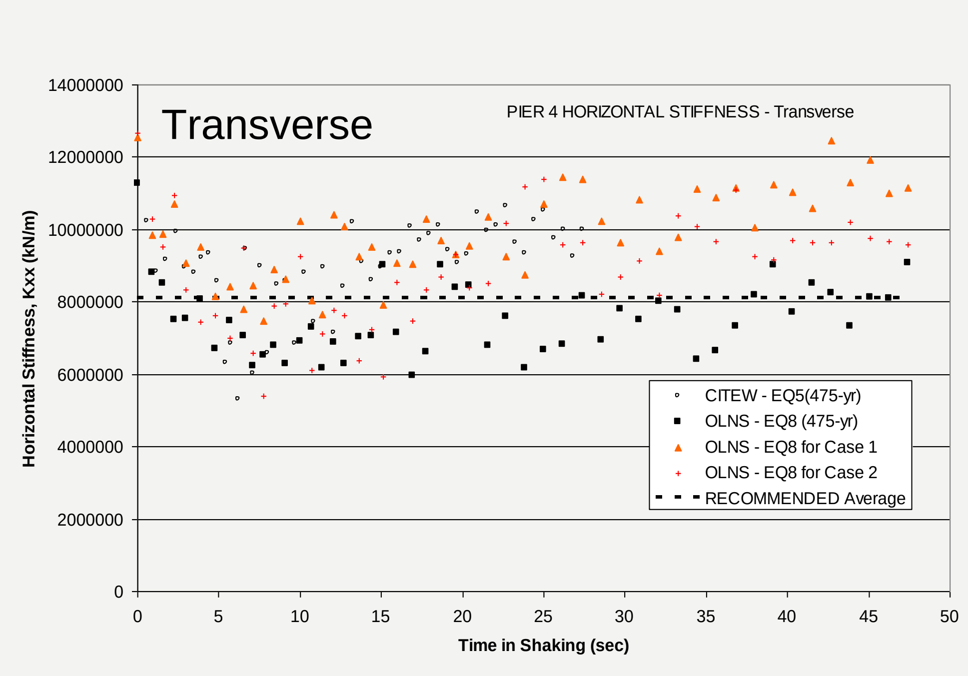




A Bridge Seismic Upgrade:

VERSAT-2D Application





VERSAT-P3D Results: Horizontal Stiffness Time-history of Pier 4 Caisson in two directions:

- **Longitudinal**
- **Transverse**

A CAISSON Study: VERSAT-P3D Application

point of interest

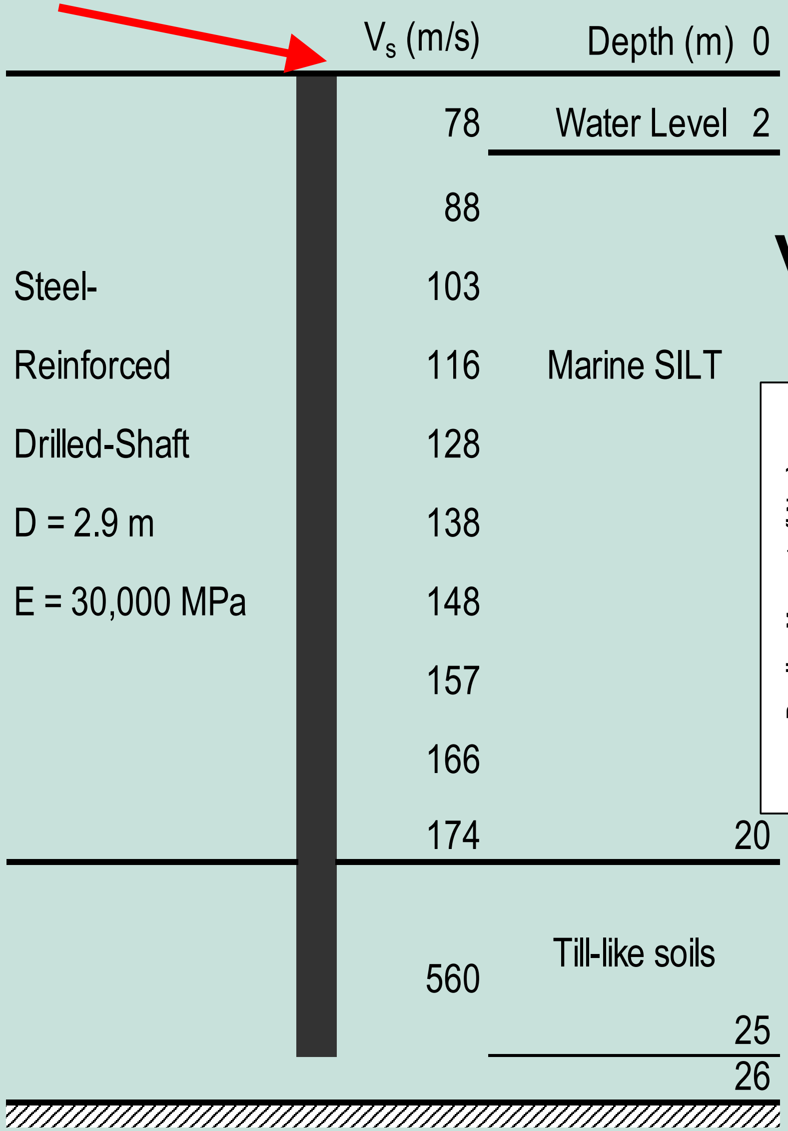
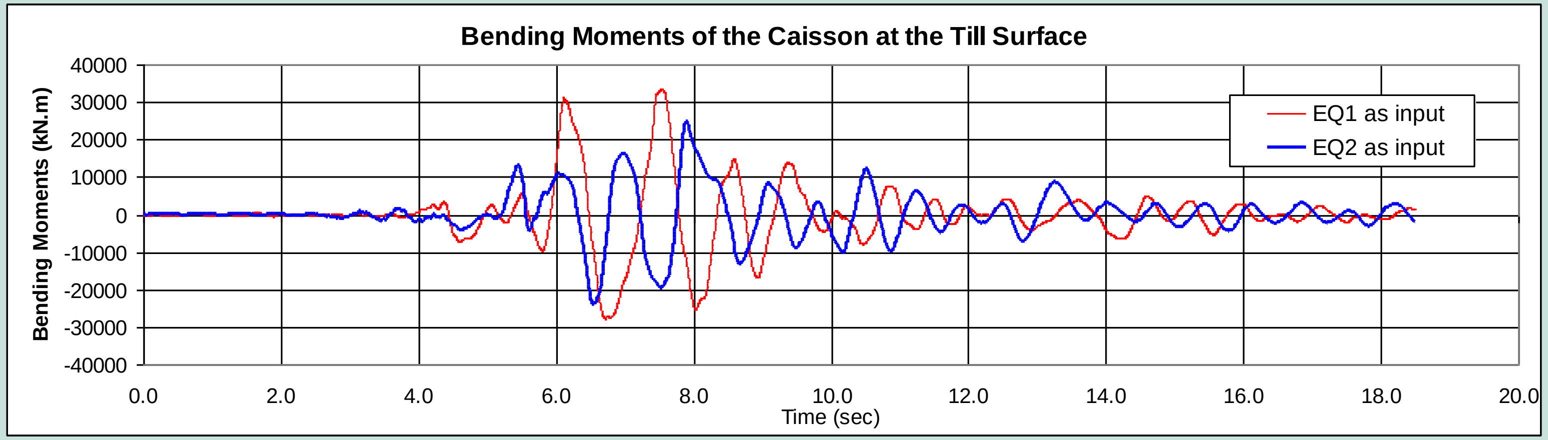
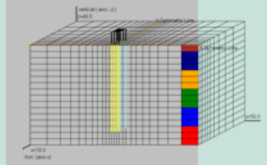


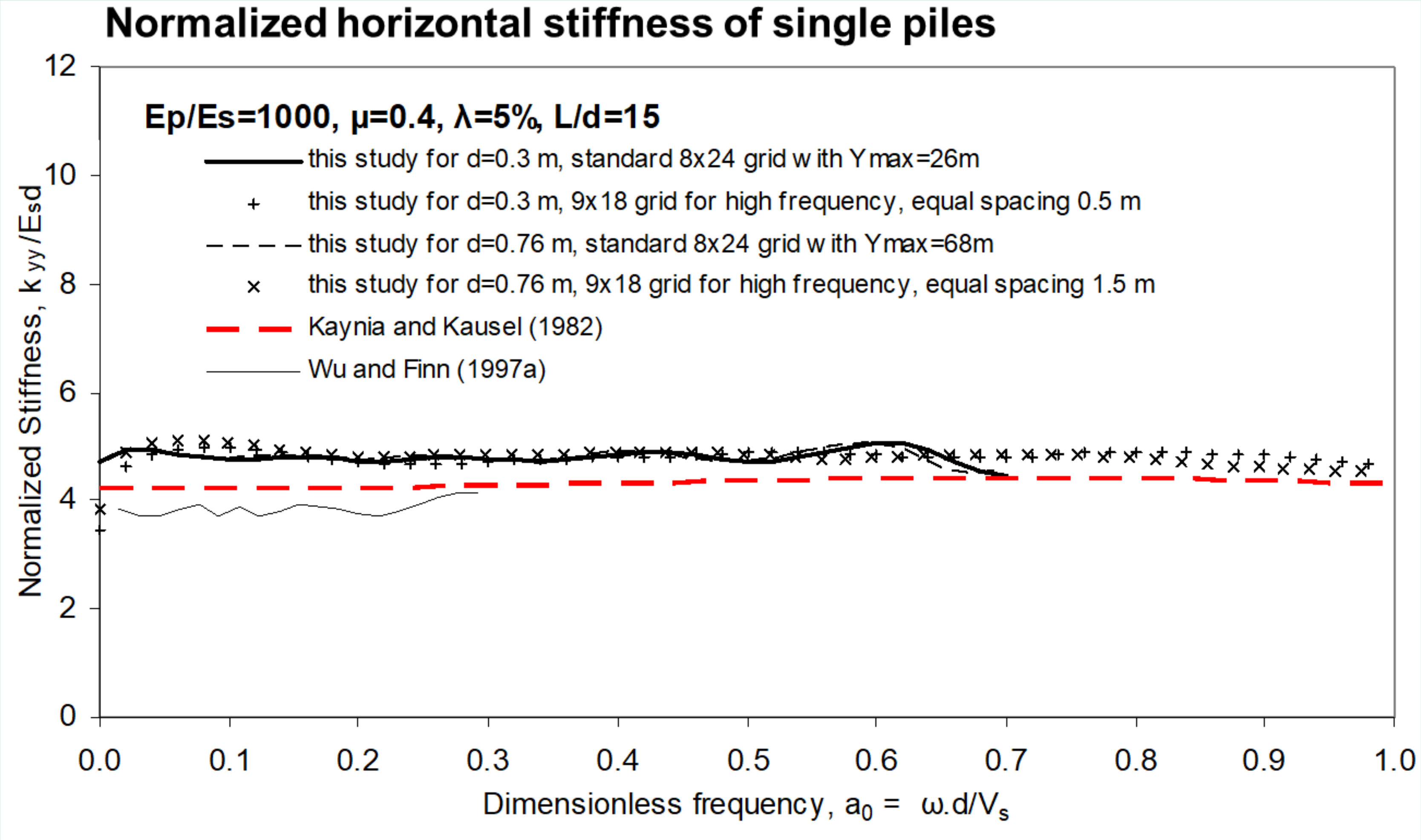
Figure 3 A Drilled-Shaft Embedded in Marine Silts and Till-Like Soils

VERSAT-P3D Results: Bending moments at the till surface (source: 7th GeoChina Conference in Beijing)

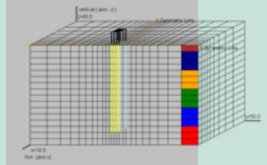




VERSAT-P3D Verification Study

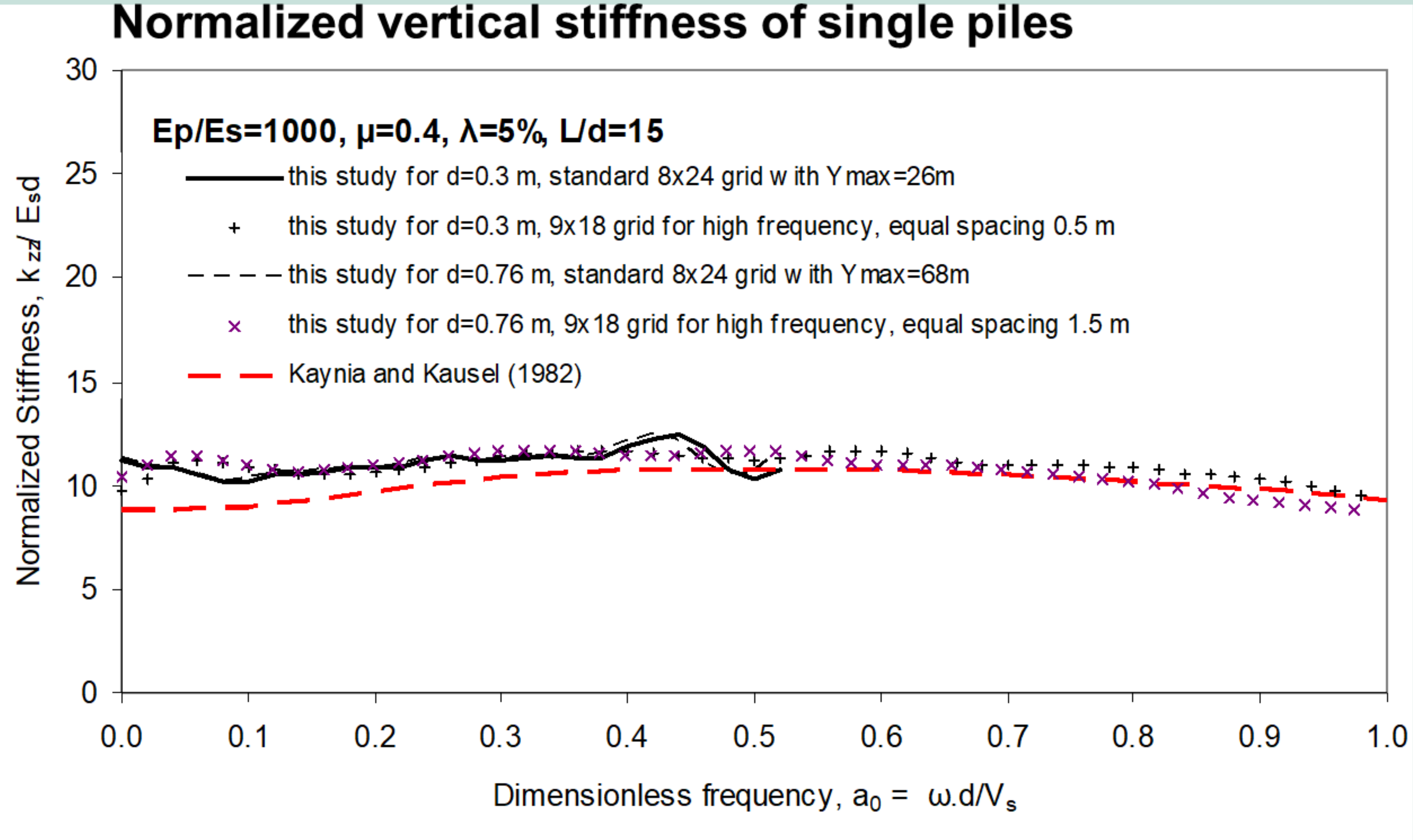


Note: The results are not affected by element size vs. pile size (Source: 2007 60th Canadian Geotechnical Conference)

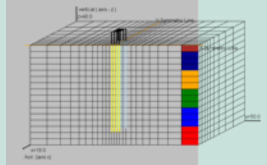


VERSAT-P3D Verification Study

Wutec Geotechnical International

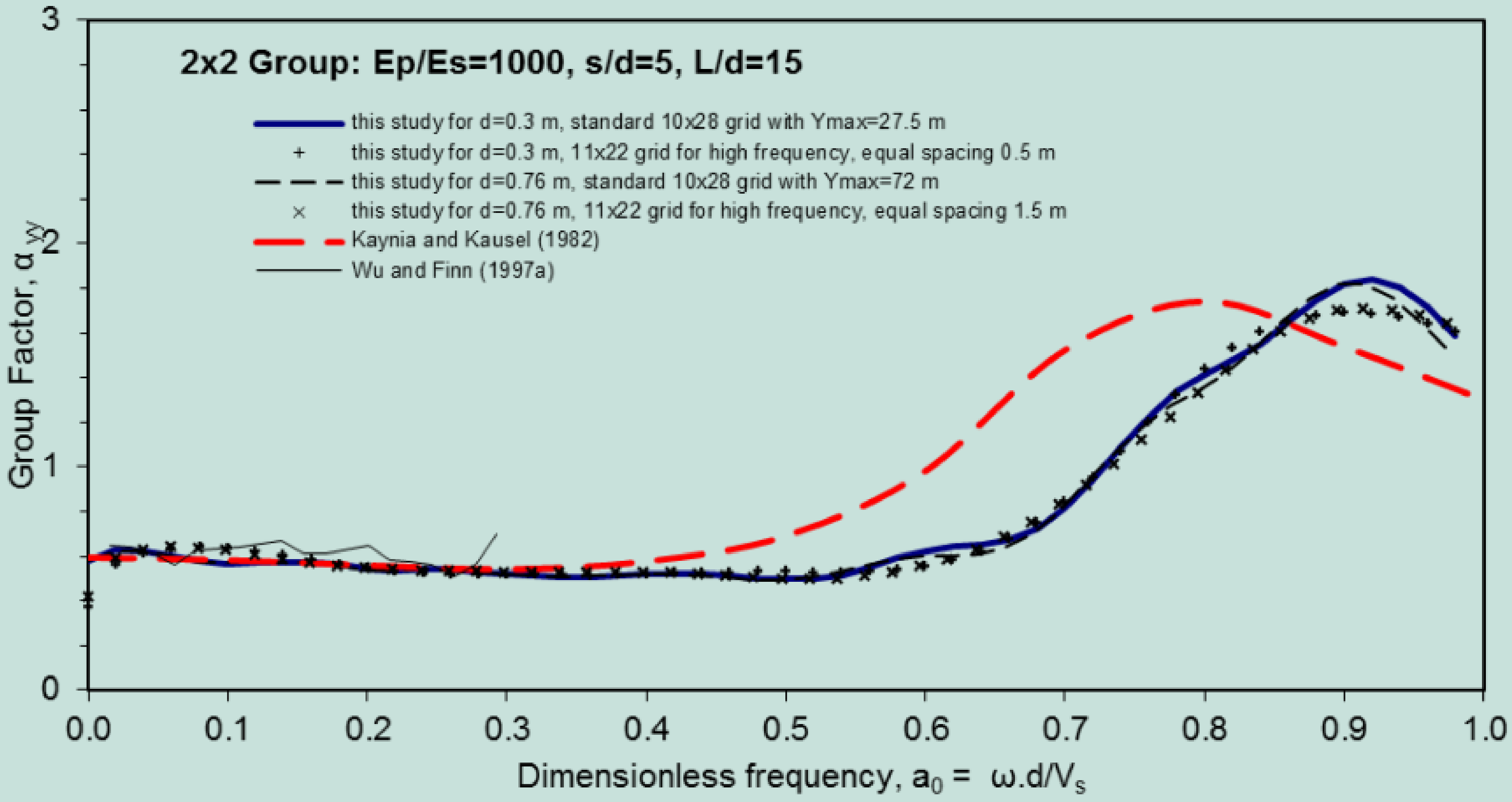


Note: The results are not affected by element size vs. pile size



VERSAT-P3D Verification Study

- **2x2 pile group: Horizontal stiffness**
- **The results are reliable over high-frequency range**



VERSAT-P3D Verification Study

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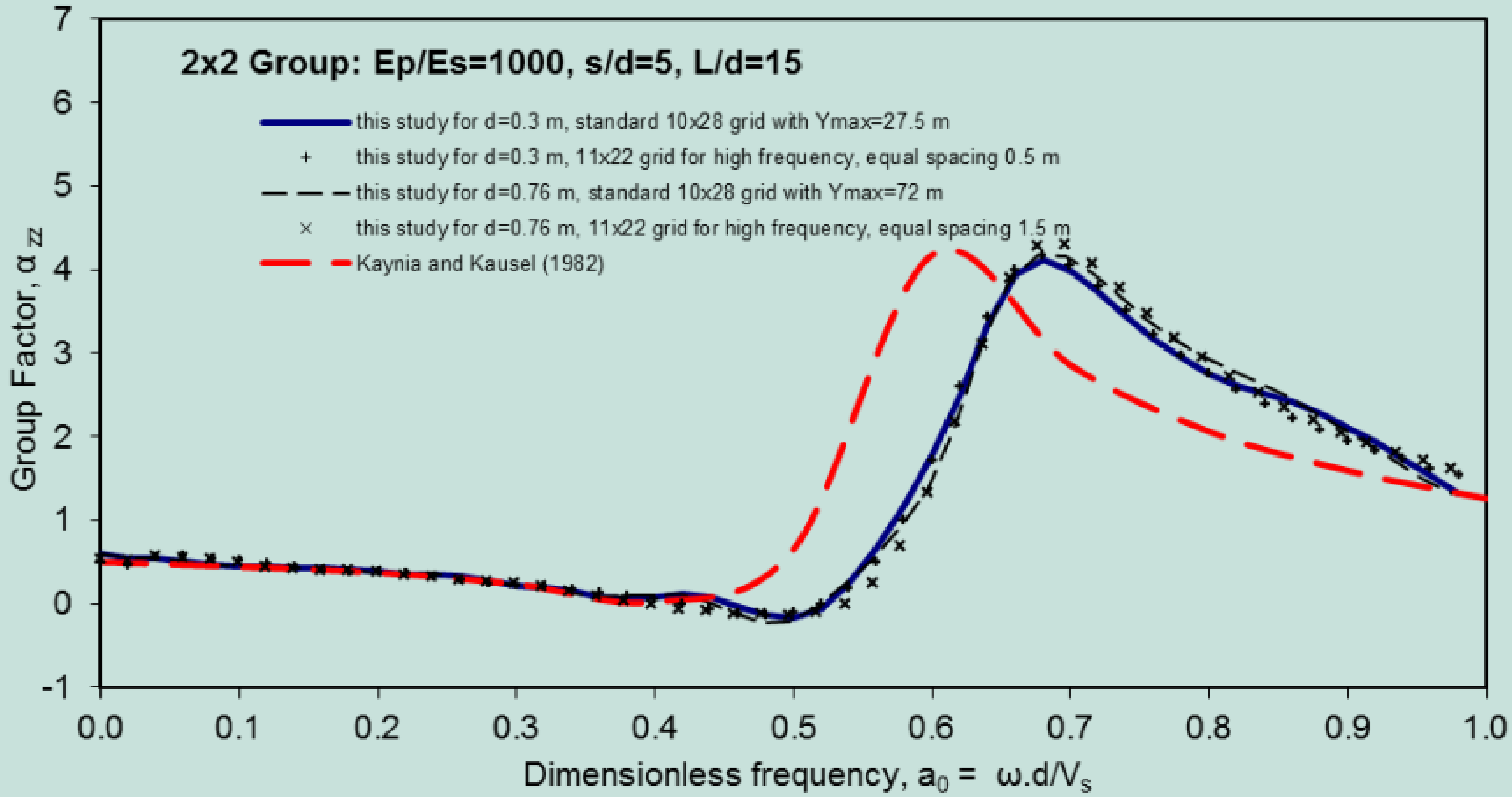
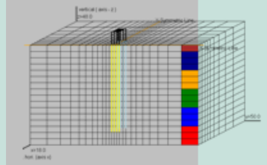
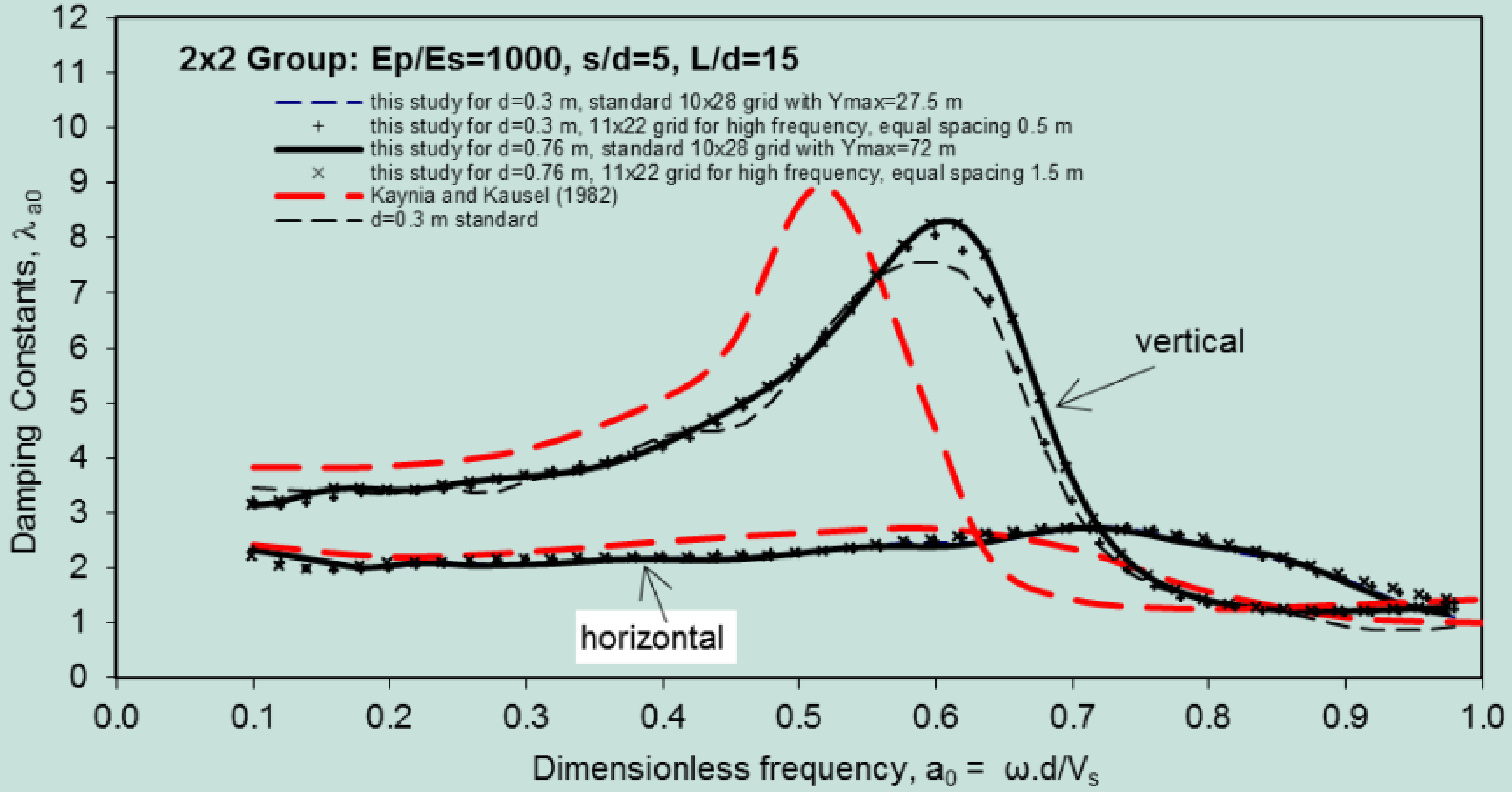
- **2x2 pile group: vertical stiffness**
- **The results are reliable over high-frequency range**





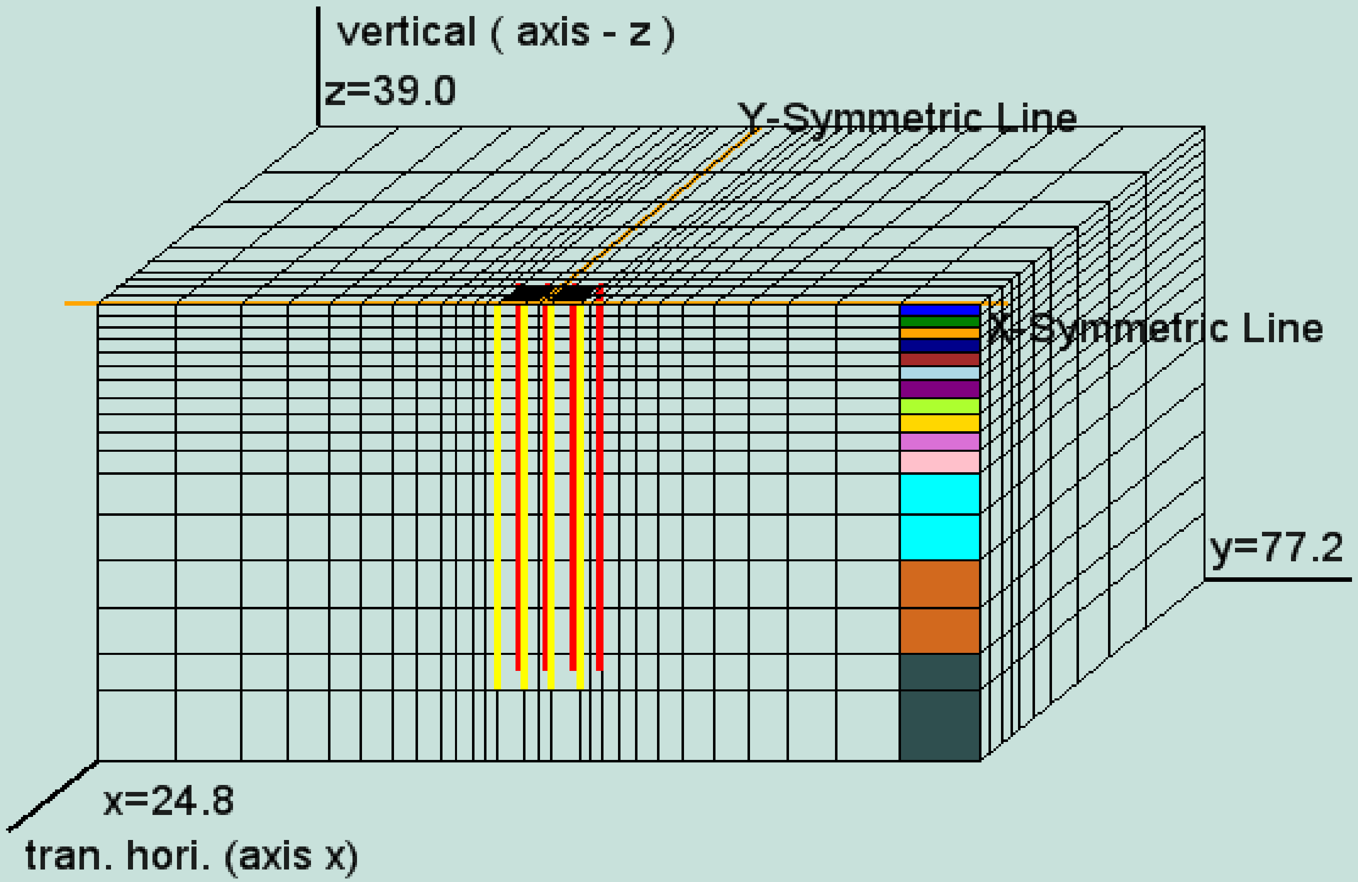
VERSAT-P3D Verification Study

- **2x2 pile group: Horizontal and vertical damping**
- **The results are reliable over high-frequency range**



VERSAT-P3D Verification Study

- **Analysis of Full-scale Tests (Huang et al., ASCE 2001)**
- **Quasi-3D finite element model used for the analysis of a 3x4 PC pile group**



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VERSAT-P3D Verification Study

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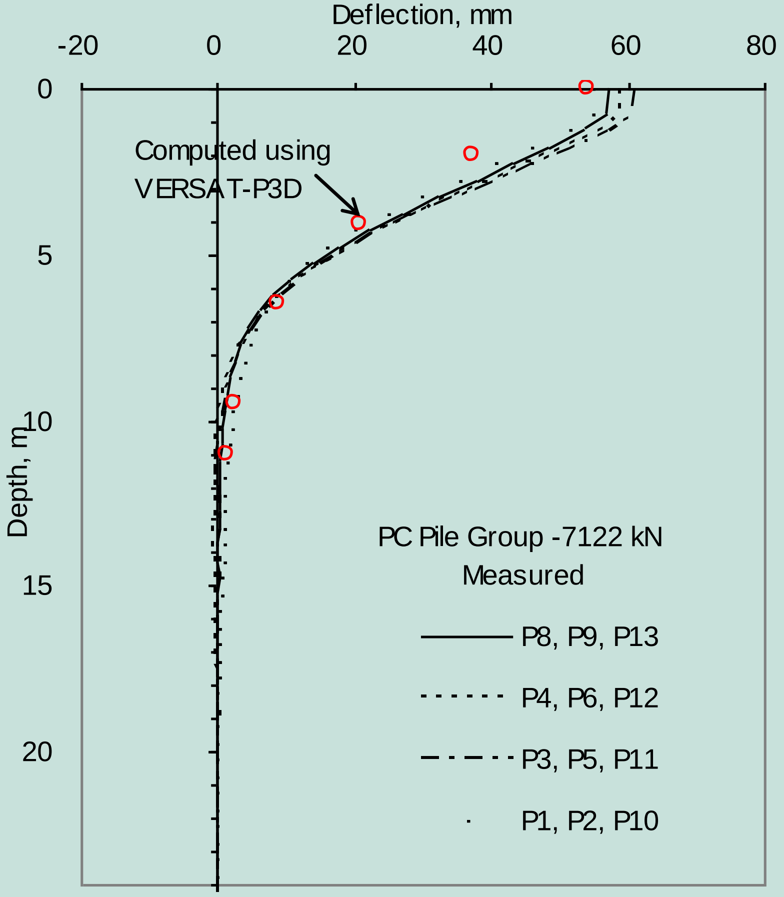
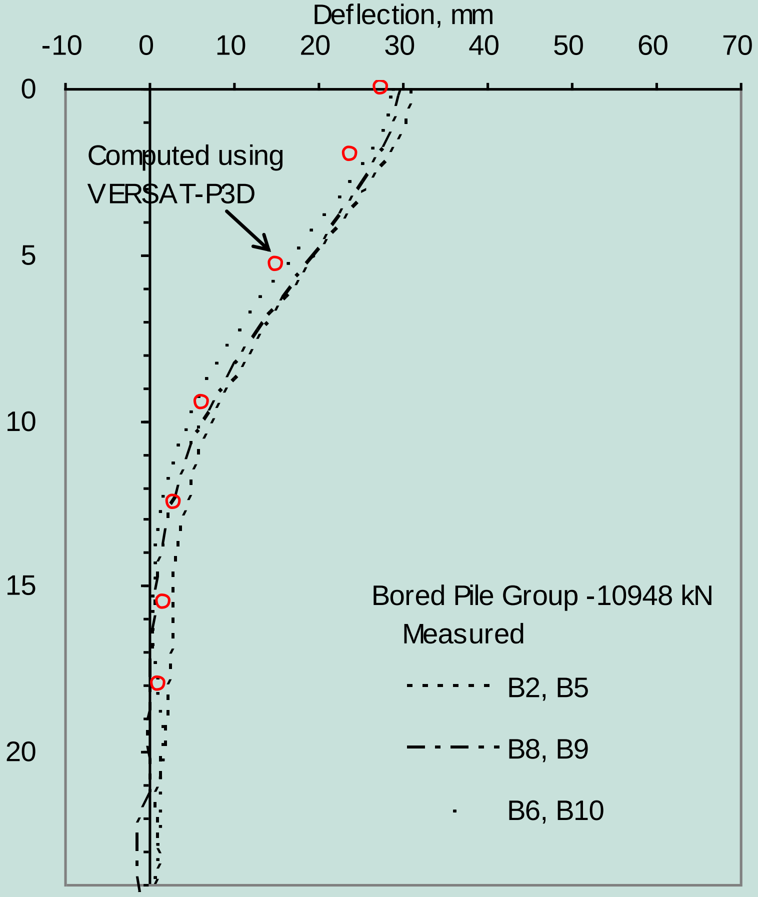
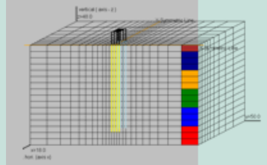
- **Analysis of Full-scale Tests:**
- **Comparison of pile deflection profile versus depth for pile groups**







Wutec Geotechnical International (WGI) (2024.10)

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THANK YOU!!

谢谢!!