

Validating numerical simulation of SSI and liquefaction using centrifuge data

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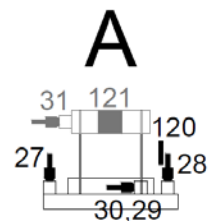
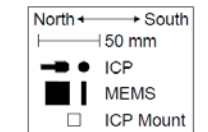
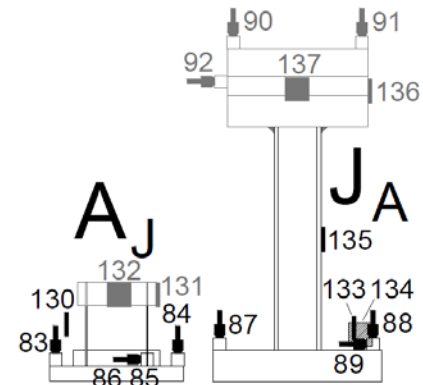
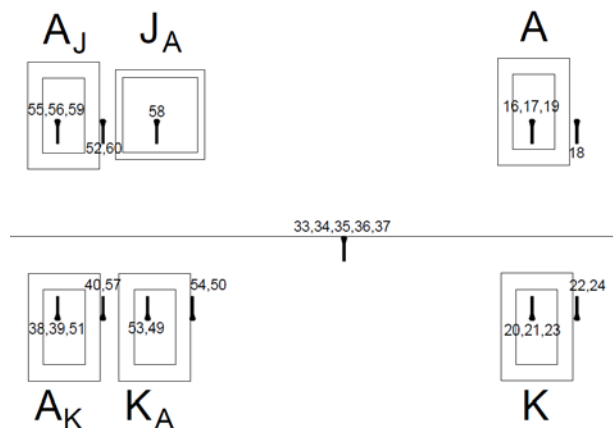
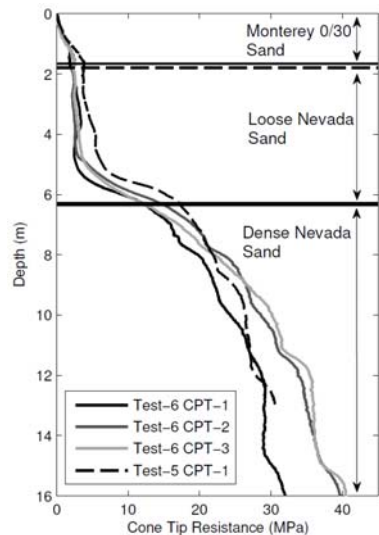
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Research Objective

The aim of the research project is to validate numerical simulation of liquefaction and its effect on soil-structure interaction using well constrained and well instrumented centrifuge testing results



Research Objectives

- ❖ Validate numerical models developed using:
 - Flac software package and PM4Sand version 3 constitutive soil model (Boulanger and Ziotopoulou, 2015)
 - OpenSEES software package and PDMY02 constitutive soil model (Yang et al., 2003, 2008)
 - ❖ Identify the relative strengths and weakness of the software packages and soil models in being able to simulate SSI and liquefaction
 - ❖ Choose software package and soil model for future research
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Centrifuge Tests

- ❖ The centrifuge models presented by Hayden et al. (2014) will be used to develop and validate the numerical models
- ❖ Centrifuge tests undertaken by Hayden et al. (2014) considered:
 - Behaviour of isolated and two adjacent structures
 - Response as a function of ground shaking, relative density of the sand and bearing pressure applied by the structures

Centrifuge Tests

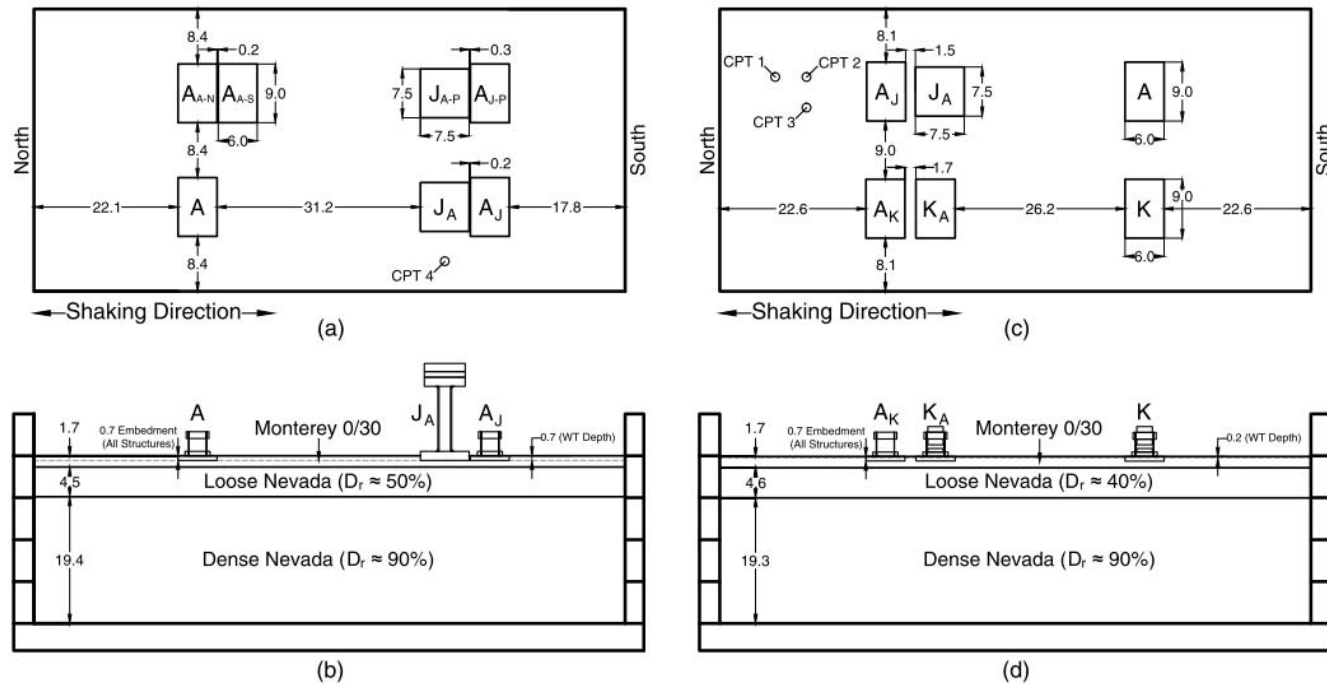



Fig. 2. Centrifuge test layout with prototype dimensions in meters: (a) T4.5-50 plan view; (b) T4.5-50 profile view; (c) T4.6-40 plan view; (d) T4.6-40 profile view

Obtained from Hayden et al. (2014)

Current Research Plan

- ❖ Single element testing – To simulate conventional laboratory testing
 - ❖ 1D free field response – Compare against the free field measurements from the Centrifuge test
 - ❖ 2D soil-structure interaction response
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Scope for Future Research

- ❖ Stepping stone for future research work:
 - Validate numerical simulation of Structure-Soil-Structure Interaction
 - Numerically simulation of real world, less well constrained case studies
 - Further parametric analysis – varying bearing pressure, ground conditions

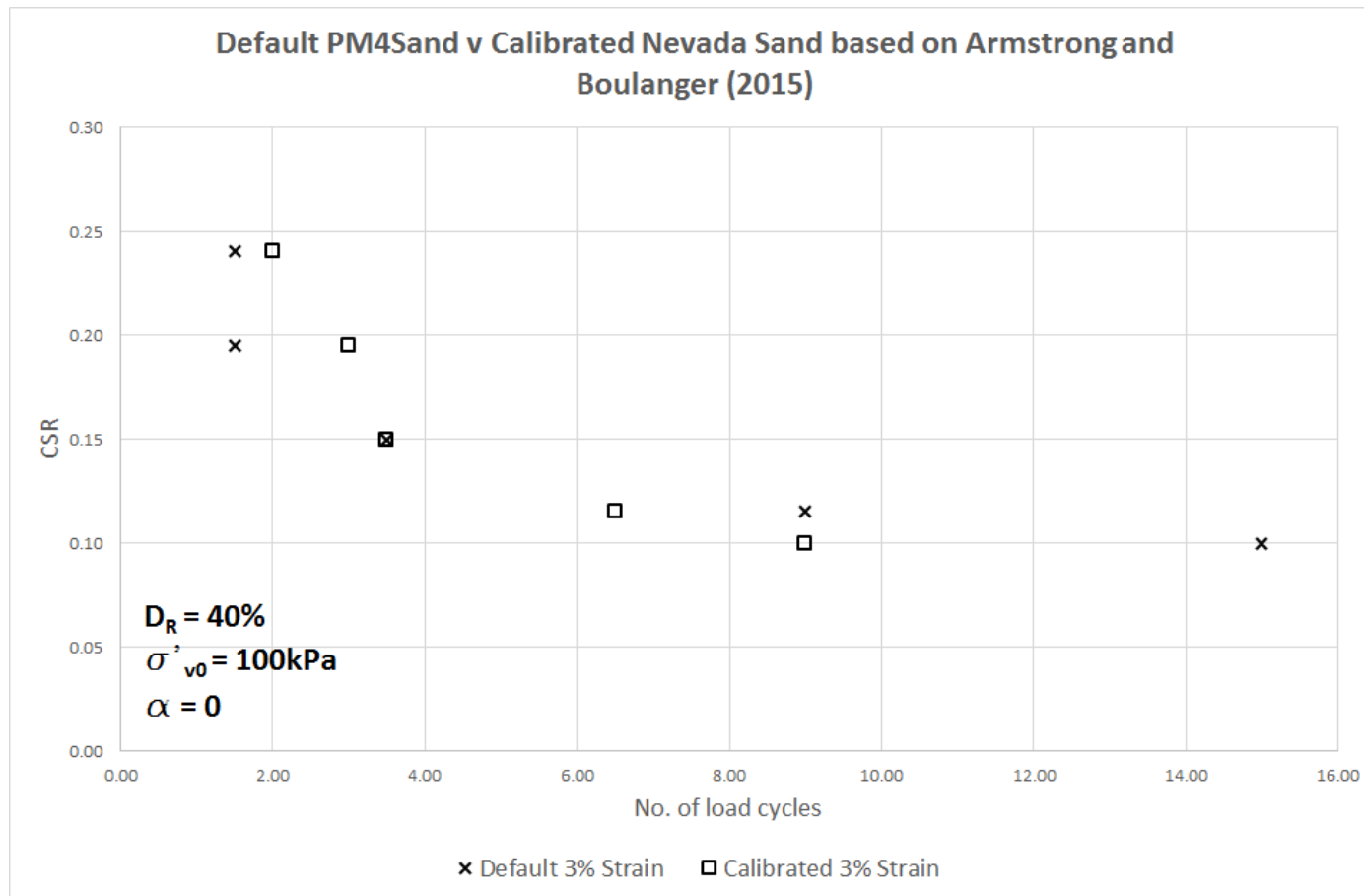
Single Element – PM4Sand

- ❖ Available as an user defined material on FLAC
- ❖ 24 input parameters – separated into 6 primary parameters and 18 secondary parameters
- ❖ Cyclic DSS calibration file available for PM4Sand used as starting point for the single element test

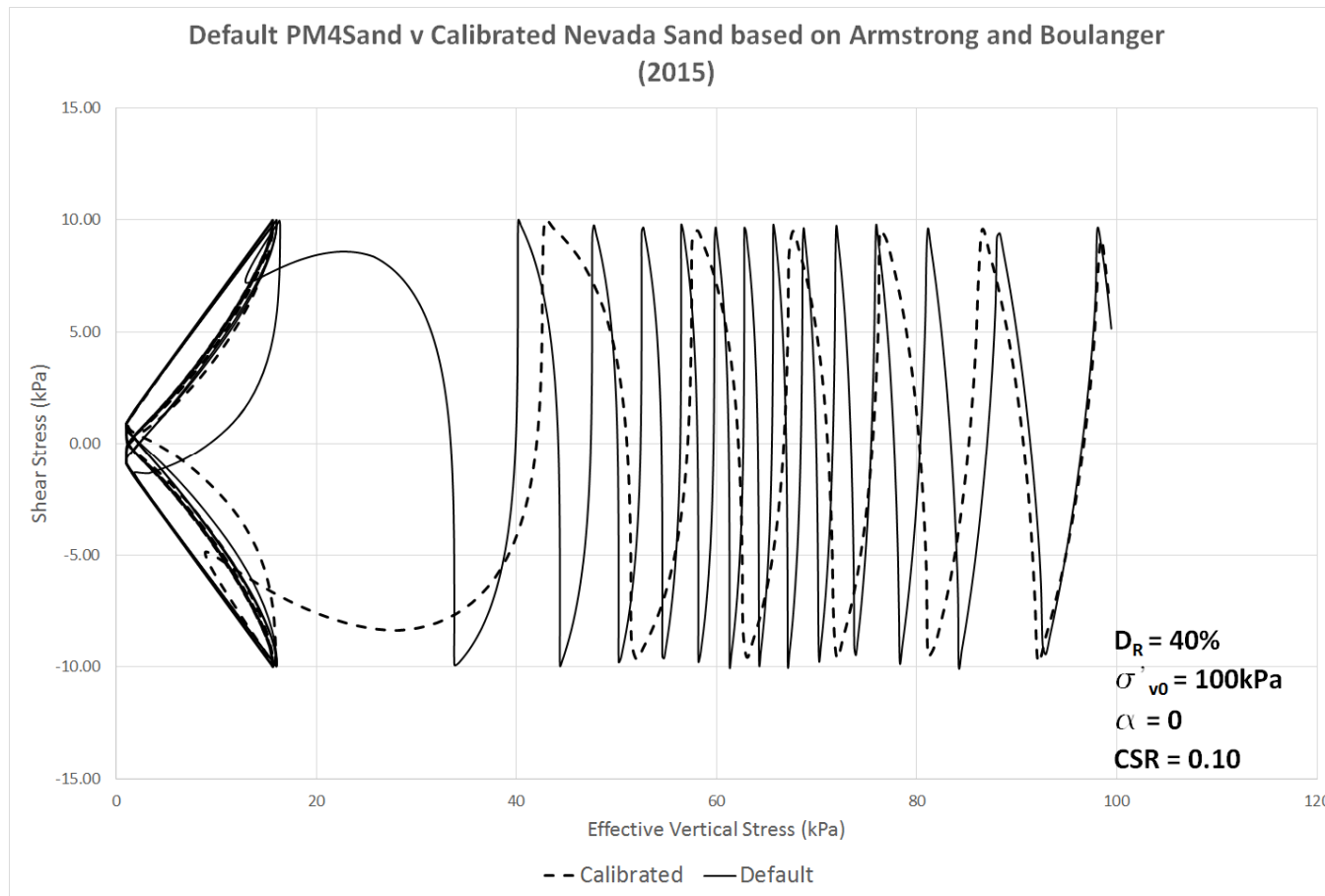
PM4Sand Comparing Default v Calibrated Parameters

Parameter	Default parameters approximated from Boulanger and Ziotopoulou (2015)	Calibrated Nevada Sand – Armstrong and Boulanger (2015)
Relative Density (Dr %)	40%	40%
e_{\max}	0.8	0.793
e_{\min}	0.5	0.485
e_0	0.68	0.67
V_{s1} (m/s)	151	179
Shear Modulus Constant	516	735
$\Phi_{CV'}$	33	32
Q (Bolton, 1986)	10	9.5
R (Bolton, 1986)	1.5	0.7
h_{p0}	0.48	0.056

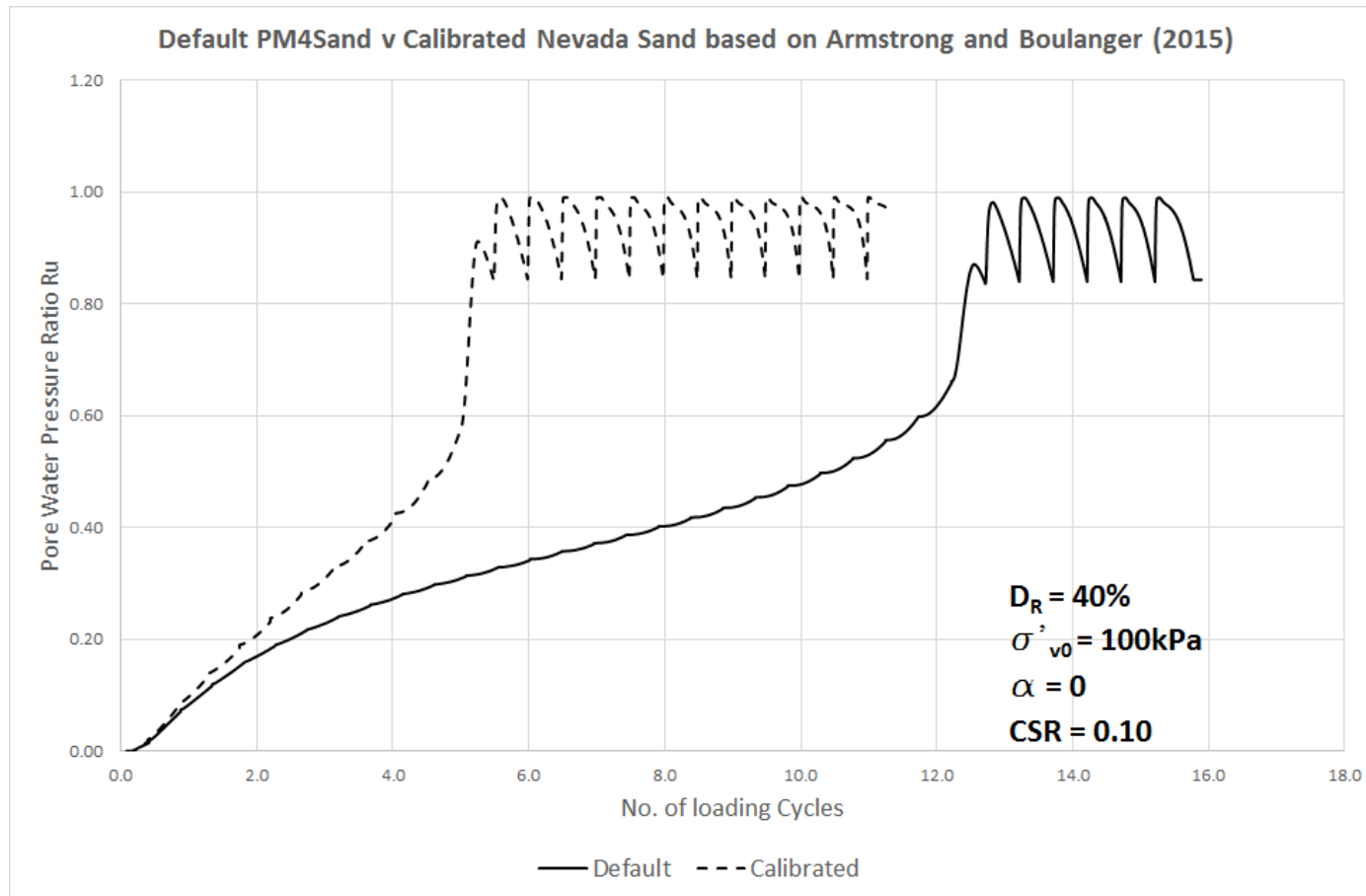
PM4Sand Comparing Default v Calibrated Parameters



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PM4Sand Comparing Default v Calibrated Parameters



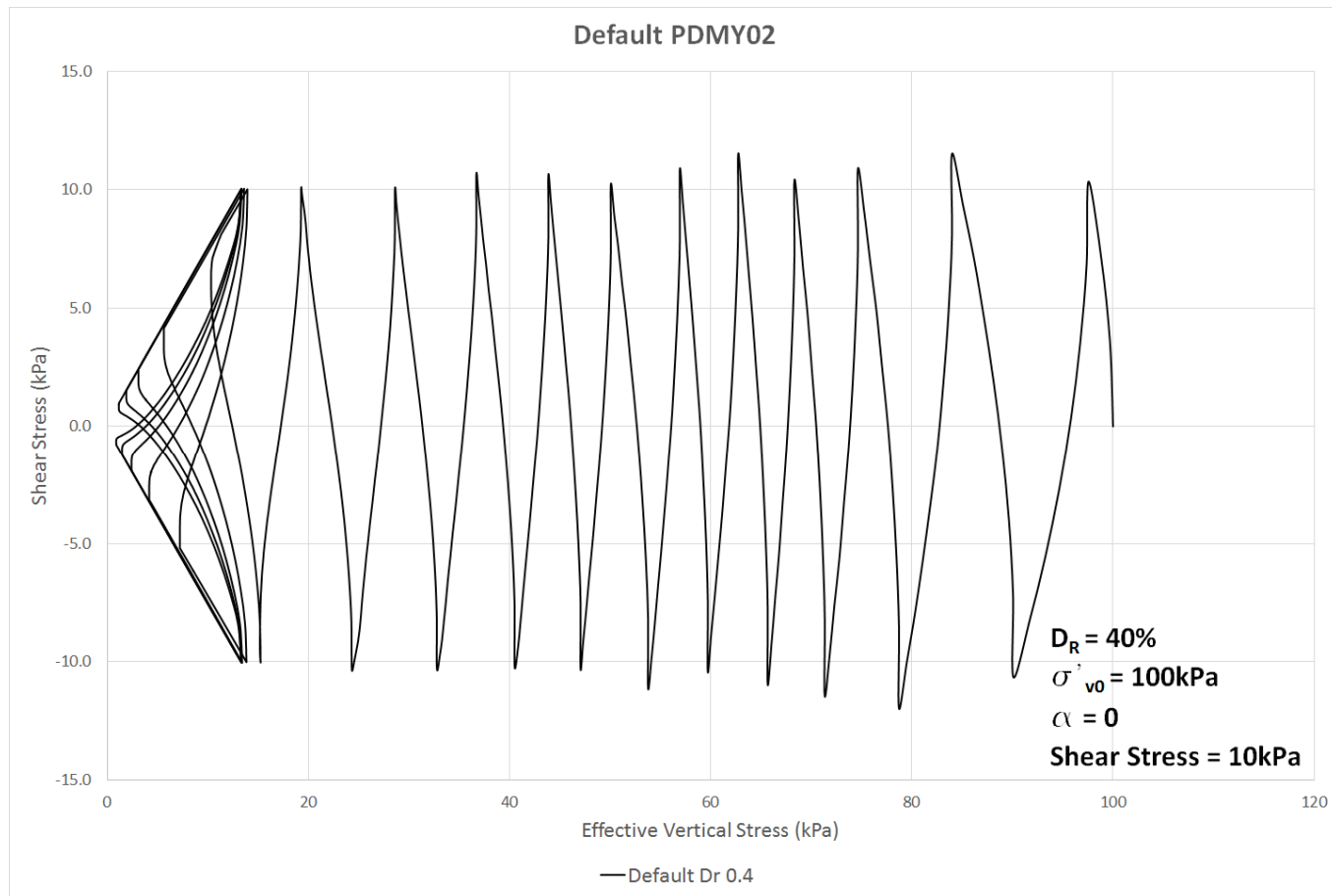
Single Element – PDMY02

- ❖ One of the models available that simulates the response characteristic of pressure sensitive soil material
- ❖ 22 input parameters

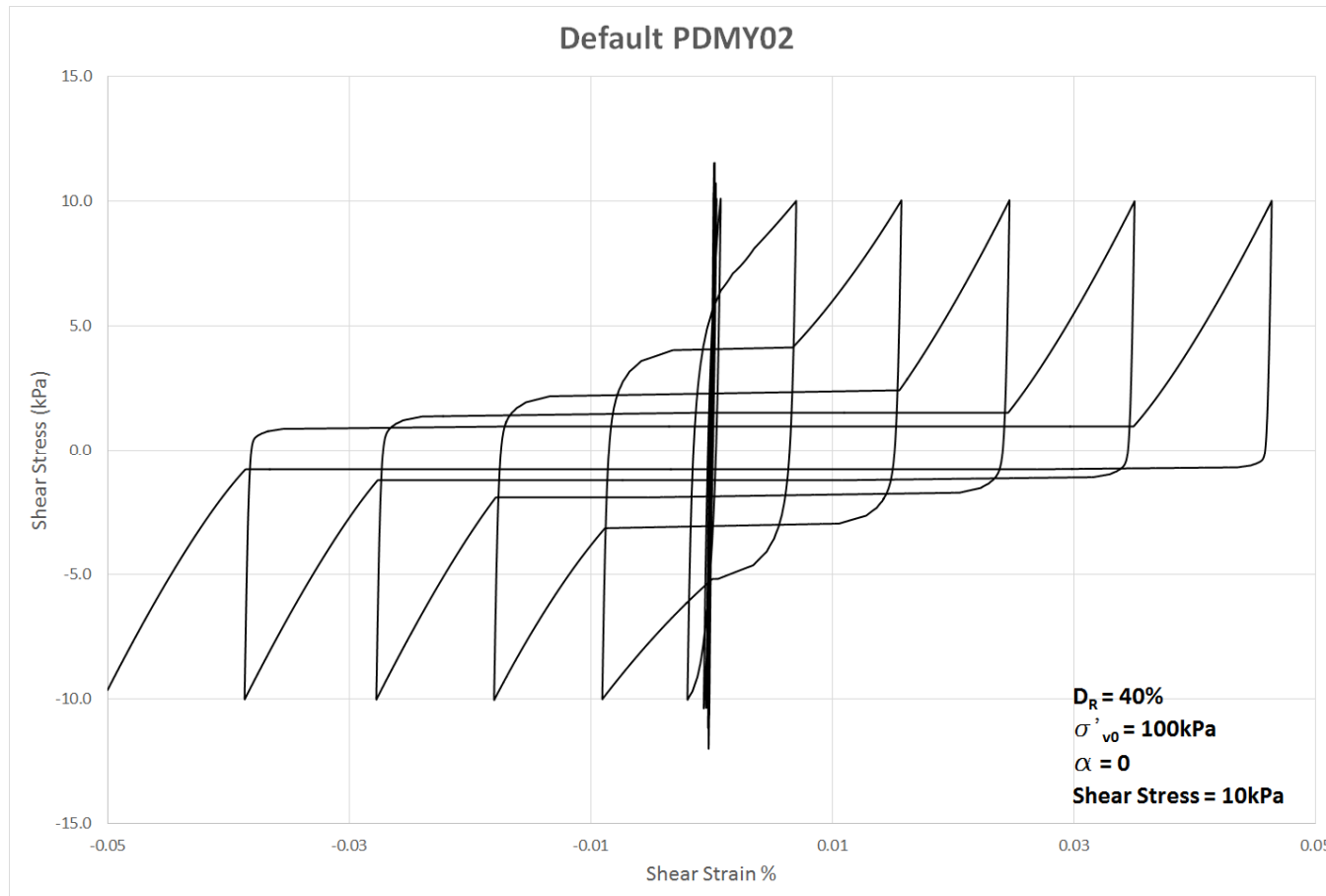
PDMY02 – Default v Calibrated

Parameter	Default parameters from OpenSees Wiki	Calibrated Nevada Sand – Karimi and Dashti(2016)
Dr	40%	40%
e	0.77	0.73
rho	1.8	1.96
refShearModul	9.00E+04	4.62E+04
refBulkModu	2.20E+05	1.23E+05
frictionAng	32	32
PTAng	26	30
peakShearStra	0.1	0.1
refPress (kPa)	100	100
pressDependCoe	0.5	0.5
Contra1	0.067	0.067
Contra2	5	4.5
Contra3	0.23	0.27
dilat1	0.06	0.02
dilat2	3	3
dilat3	0.27	0
NYS	20	20
liq1	1	1
liq2	0	0

PDMY02 – Default



PDMY02 – Default



1D Free Field Response

- ❖ Centrifuge tests contained number of instruments located away from the structure measuring free field response
- ❖ Aim to simulate a 1D column of single element representing the layered ground model used in the Centrifuge test
- ❖ Validate the ability of the soil models to capture volumetric mechanism contributing to liquefaction induced deformation

Mod. Port Island Free-Field Response

