A Study of Liquefaction Potential in Chiang Rai Province Northern Thailand

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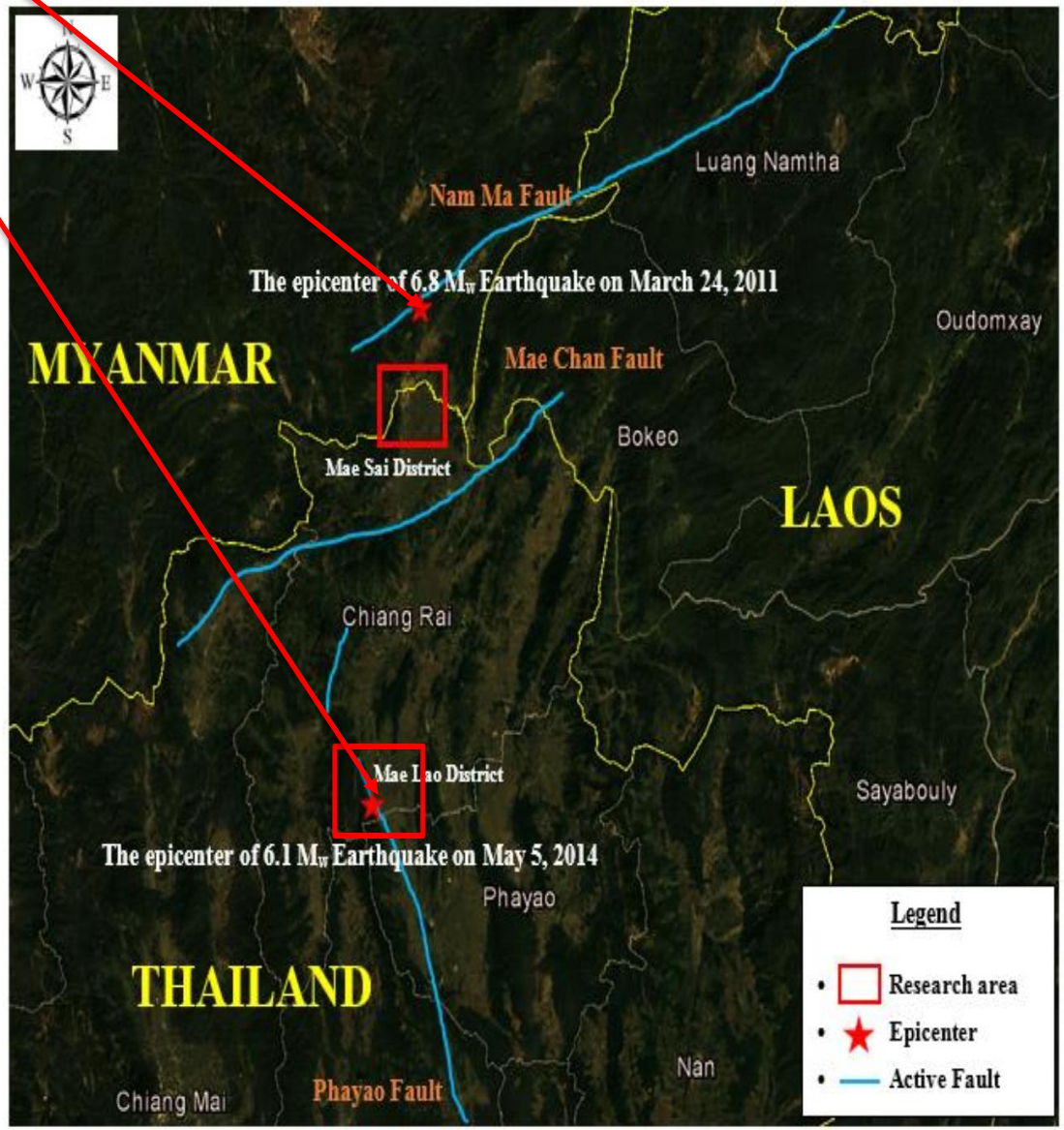
Outline

- Introduction
- Study Area
- Methodology
- Results and Discussion
- Concluding remarks

Introduction

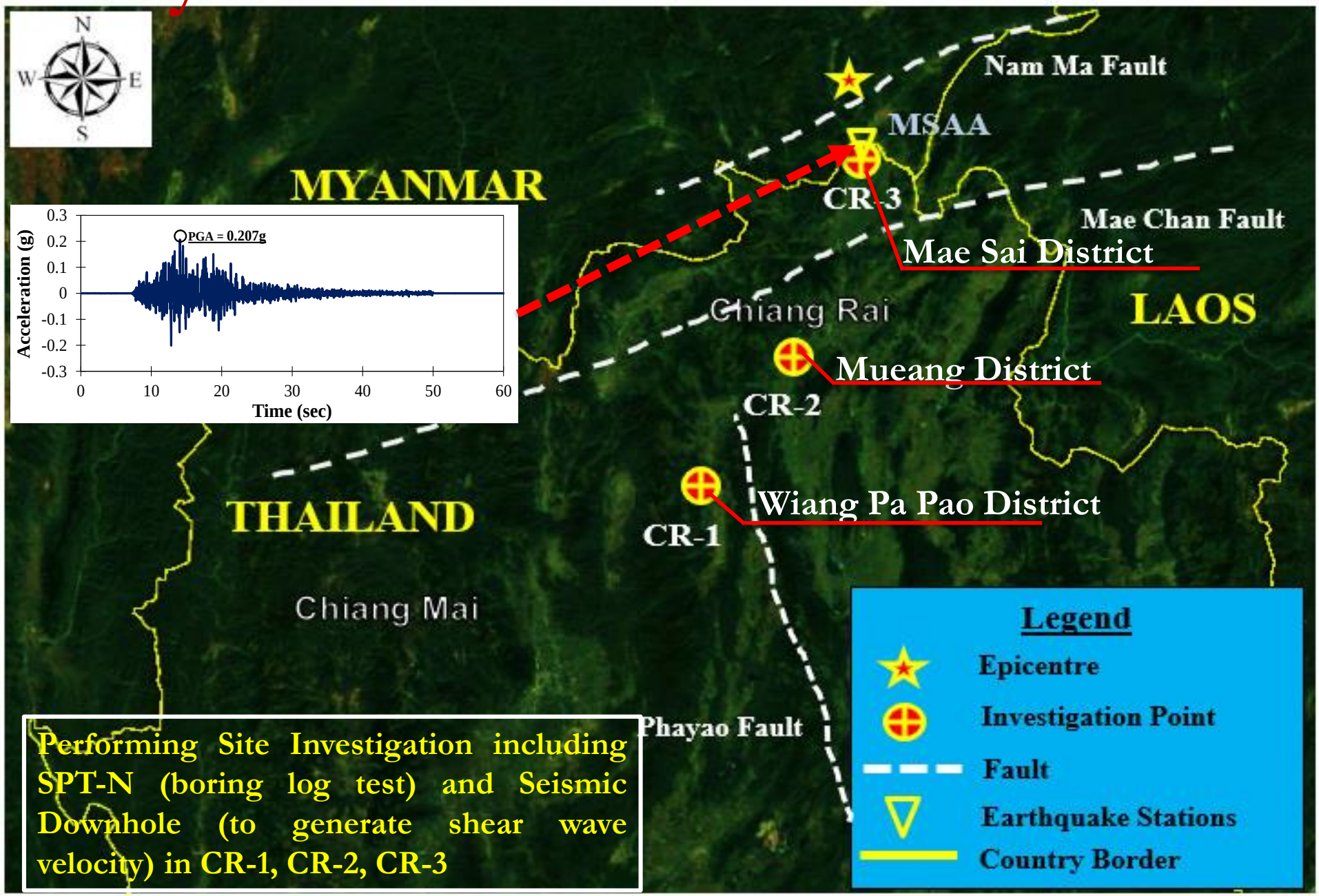
- Earthquake on 24 March 2011 (Magnitude of 6.8 M_w)
- Earthquake on 5 May 2014 (Magnitude of 6.1 M_w)
- Hit The Northern Thailand
- Liquefactions and other geotechnical hazards near the border were found as reported by **Ruangrassamee et al. (2012), Soralump and Feungaugsorn (2013), Soralump et al. (2014)**
- Intensive study of earthquake (liquefaction site response) was performed
- This study was focused on the first earthquake event (Tarlay Earthquake in 2011)



Impacts of the earthquakes in Northern Thailand

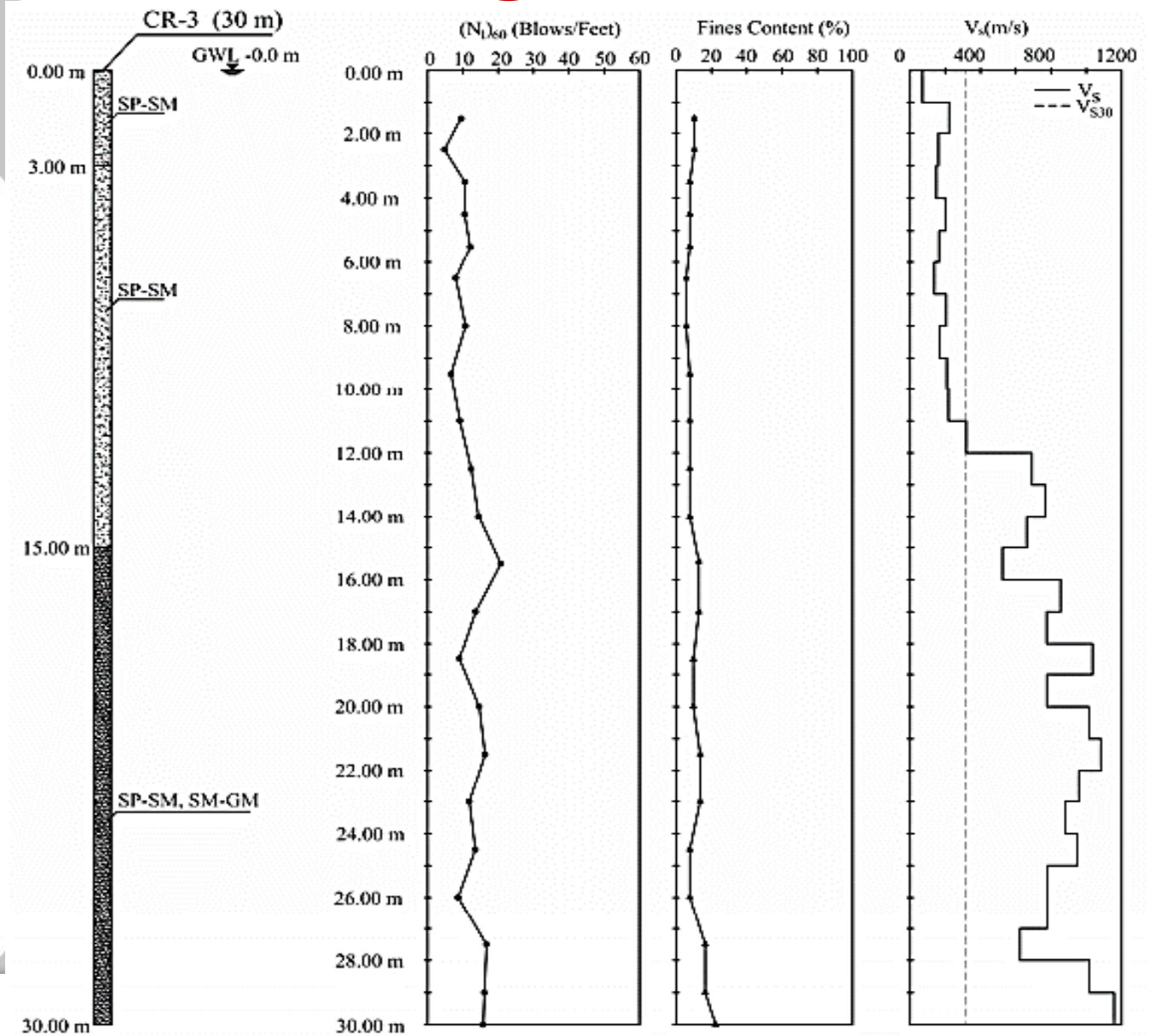
Liquefaction site response was performed to investigate soil behaviour during earthquake

Study Area



Performing Site Investigation including SPT-N (boring log test) and Seismic Downhole (to generate shear wave velocity) in CR-1, CR-2, CR-3

Site Investigation Results



Site Investigation Results

Briefly explanation of the site investigation results

Sandy soils were dominant in the Northern Thailand. Loose to Medium Sands were found on depth of 0 to 15 m. Shallow ground water level at 1 to 3 m depth. Low Soil Resistance at the shallow depth $(N_1)_{60}$ less than 15. Site Class of the sites are classified as Class D (Stiff Soil) based on **NEHRP (1998)**

Methodology

Start

↓

Literature Review

↓

Data Collection

- Site Investigation Data (SPT-N, Soil Profile, and Shear Wave Velocity Data)
- Earthquake event data from TMD (2015)

↓

One dimensional seismic ground response analysis using effective stress model (Cyclic 1D) proposed by **Elgamal et al. (2006)**

↓

Results

- Soil behaviour during earthquake
- Liquefaction time stages (initial time, pore pressure dissipation, liquefaction duration
- Prediction of impacted depth

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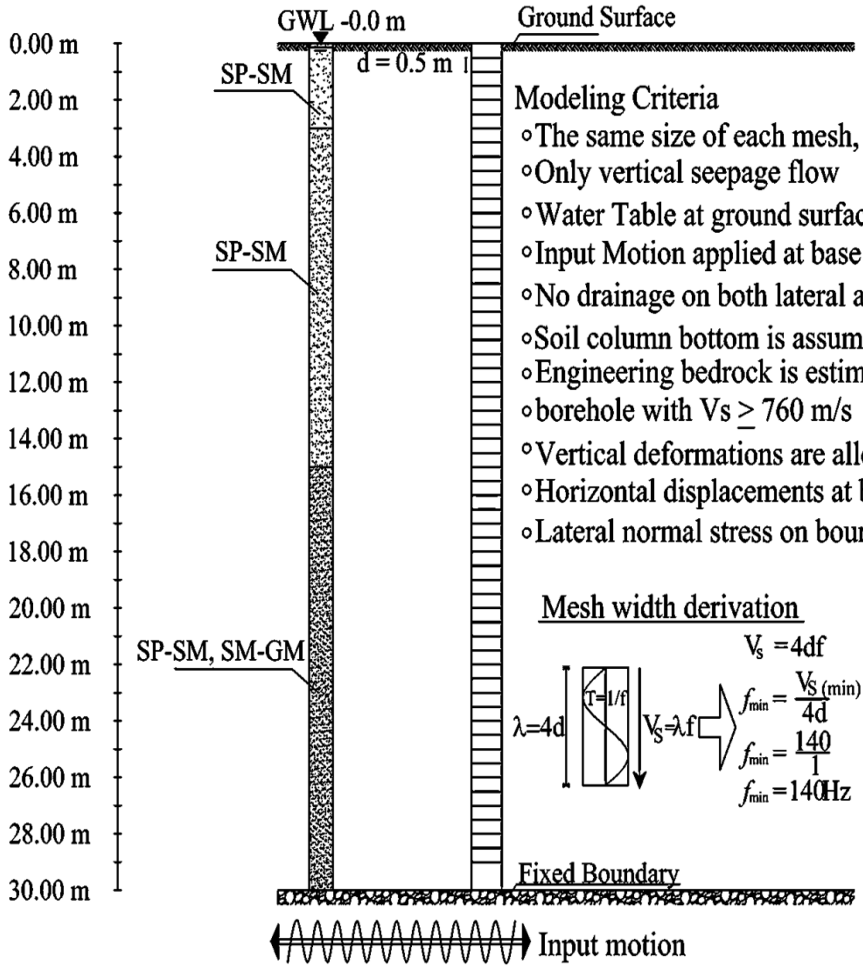
Conclusion

↓

Finish

One-dimensional modeling of site response analysis



Modeling Criteria

- The same size of each mesh, i.e. 0.5 m
- Only vertical seepage flow
- Water Table at ground surface
- Input Motion applied at base soil column
- No drainage on both lateral and base sides
- Soil column bottom is assumed as the fixed boundary
- Engineering bedrock is estimated at the bottom of
- borehole with Vs ≥ 760 m/s
- Vertical deformations are allowable
- Horizontal displacements at both sides are the same
- Lateral normal stress on boundaries are able to generate

Mesh width derivation

$d_{mesh} = \frac{V_{S30}}{4f_{min}}$

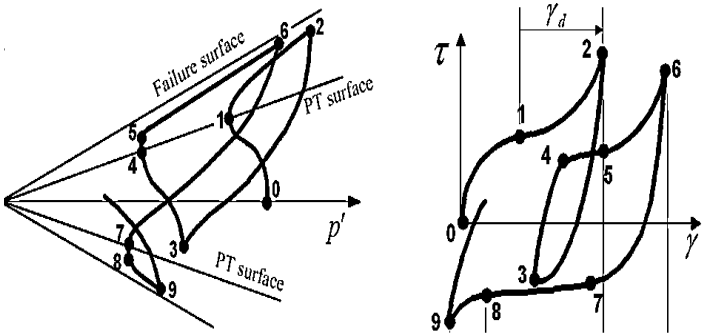
$d_{mesh} = \frac{329}{140}$

$d_{mesh} = 0.588$ m

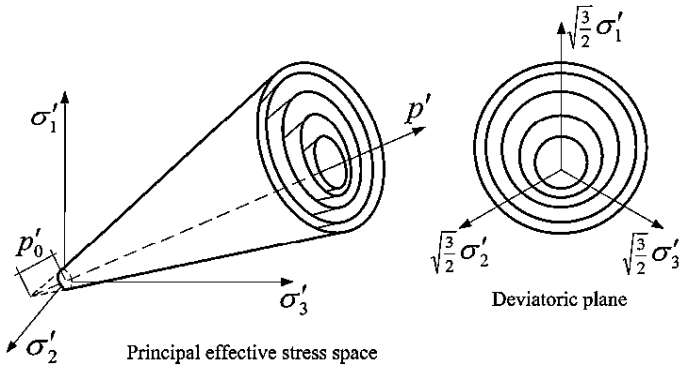
$d_{mesh} = 0.5$ to 0.6 m

$d_{mesh} = 0.5$ m

Modelling assumption for seismic response analysis through to liquefiable layer



Ilustration of effective stress paht on granular material (After Elgamal et al. (2006)



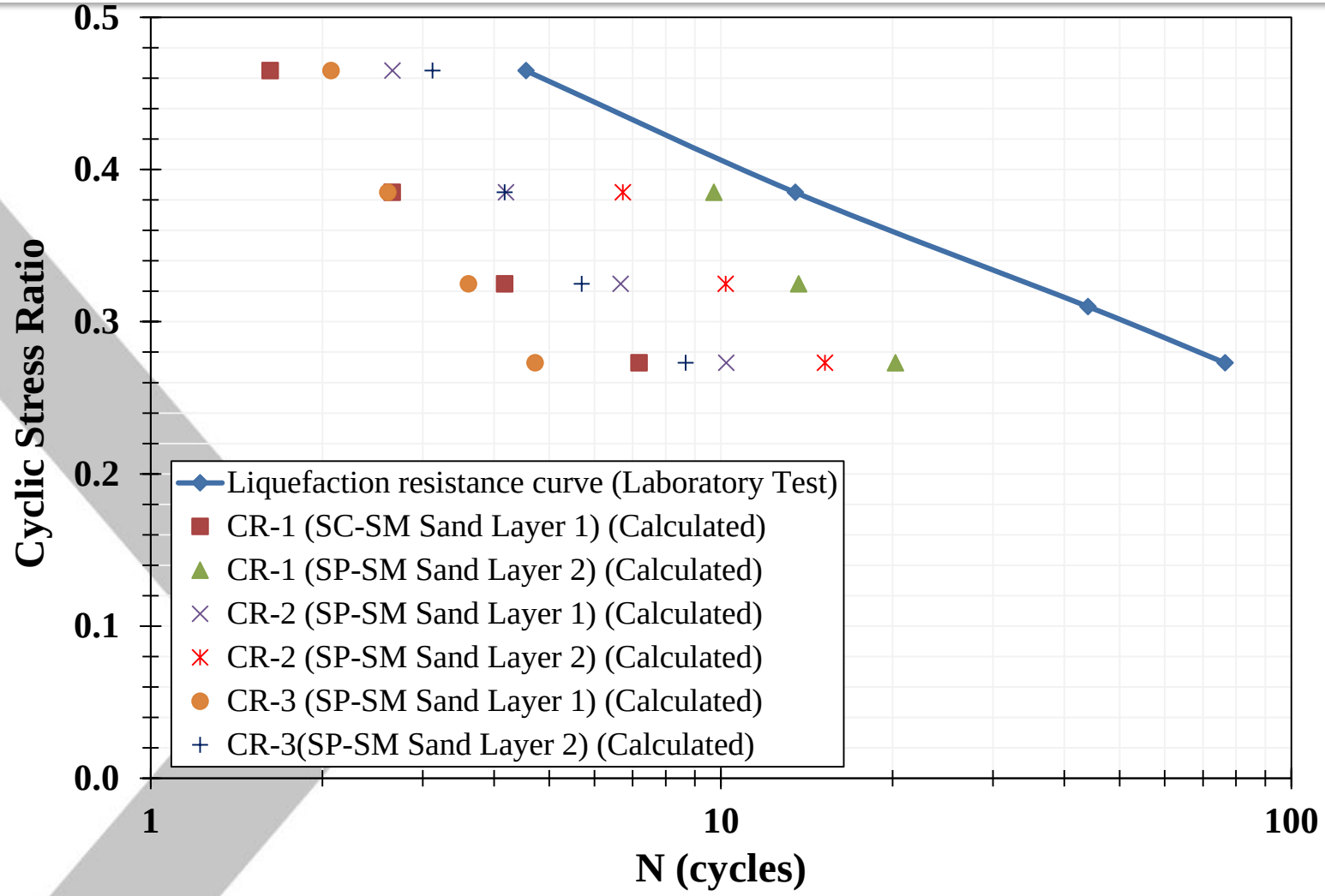
Multi-yield surface of kinematic hardening yield locus in principal stress plane and deviatoric plane (After Parra, 1996)

Table 1 Input material in this study.

BH	Material	Thickness (m)	γ (kN/m^3)	c (kPa)	ϕ (°)	FC (%)	k (m/s)	$V_{s(ave)}$ (m/s)	K_o (-)	p'_{ref} (kPa)	γ_{max} (%)	Liq (-)	c1 (-)	c2 (-)	d1 (-)	d2 (-)
CR-1	CL	2.0	1.3	18	-	80	1.1×10^{-9}	99	0.67	50	5	-	-	-	-	-
	SP-SM	3.0	1.7	0.3	28	8	6.6×10^{-5}	237	0.53	80	5	0.025	0.30	0.2	0.0	10
	SP-SM	5.5	2.0	0.3	29	8	6.6×10^{-5}	421	0.52	80	5	0.010	0.06	0.5	0.4	10
	SM, SP-SM, SM-GM	19.5	2.1	0.3	30	11	6.6×10^{-5}	472	0.50	80	5	0.003	0.01	0.6	0.6	10
CR-2	SP-SM	9.0	1.7	0.3	0	21	6.6×10^{-5}	195	1.00	80	5	0.025	0.30	0.2	0.0	10
	SP-SM	7.5	1.7	0.3	29	26	6.6×10^{-5}	259	0.52	80	5	0.025	0.30	0.2	0.0	10
	SM-GM,GP	2.5	2.0	0.3	9	19	6.6×10^{-5}	266	0.84	80	5	0.010	0.06	0.5	0.4	10
	SC	1.5	2.0	3	29	18	6.7×10^{-5}	273	0.52	80	5	0.010	0.06	0.5	0.4	10
	SM	3.0	2.0	0.5	19	16	6.9×10^{-5}	600	0.67	80	5	0.010	0.06	0.5	0.4	10
	SC	6.0	2.0	3	30	21	7.1×10^{-5}	634	0.50	80	5	0.010	0.06	0.5	0.4	10
	CL	0.5	1.4	20	-	94	1.1×10^{-9}	728	0.68	50	5	-	-	-	-	-
CR-3	SP-SM	3.0	1.7	0.3	28	7	6.6×10^{-5}	140	0.53	80	5	0.025	0.30	0.2	0.0	10
	SP-SM	12.0	2.0	0.32	29	9	6.9×10^{-5}	324	0.52	80	5	0.010	0.06	0.5	0.4	10
	SP-SM,SM-GM	15.0	2.1	0.25	30	9	7.0×10^{-5}	736	0.50	80	5	0.003	0.01	0.6	0.6	10

Note

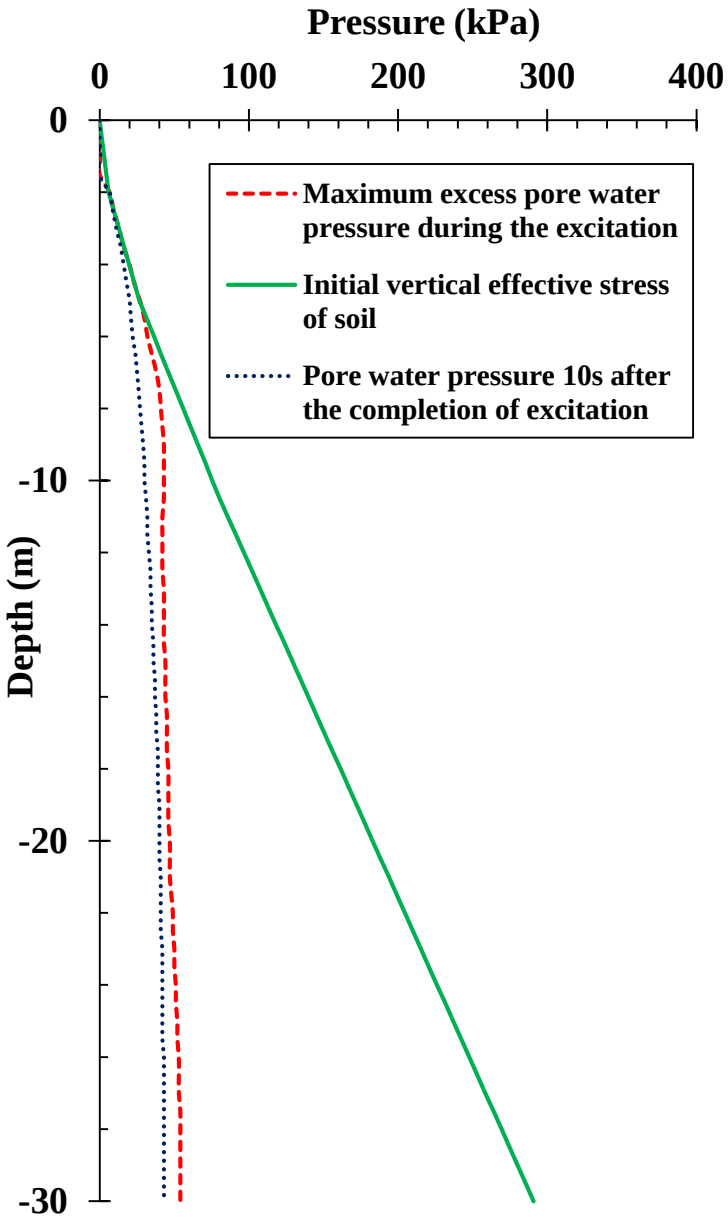
- γ and FC is saturated soil density and fines content , respectively
- c and ϕ are soil cohesion and internal friction angle, respectively
- k is permeability coefficient
- $V_{s(ave)}$ is the average shear wave velocity of soil layer
- K_o is lateral earth pressure at rest
- p'_{ref} is effective confinement pressure reference
- γ_{max} is peak shear strain
- Liq is liquefaction parameter
- c1 and c2 are contractive parameter
- d1 and d2 dilative parameter

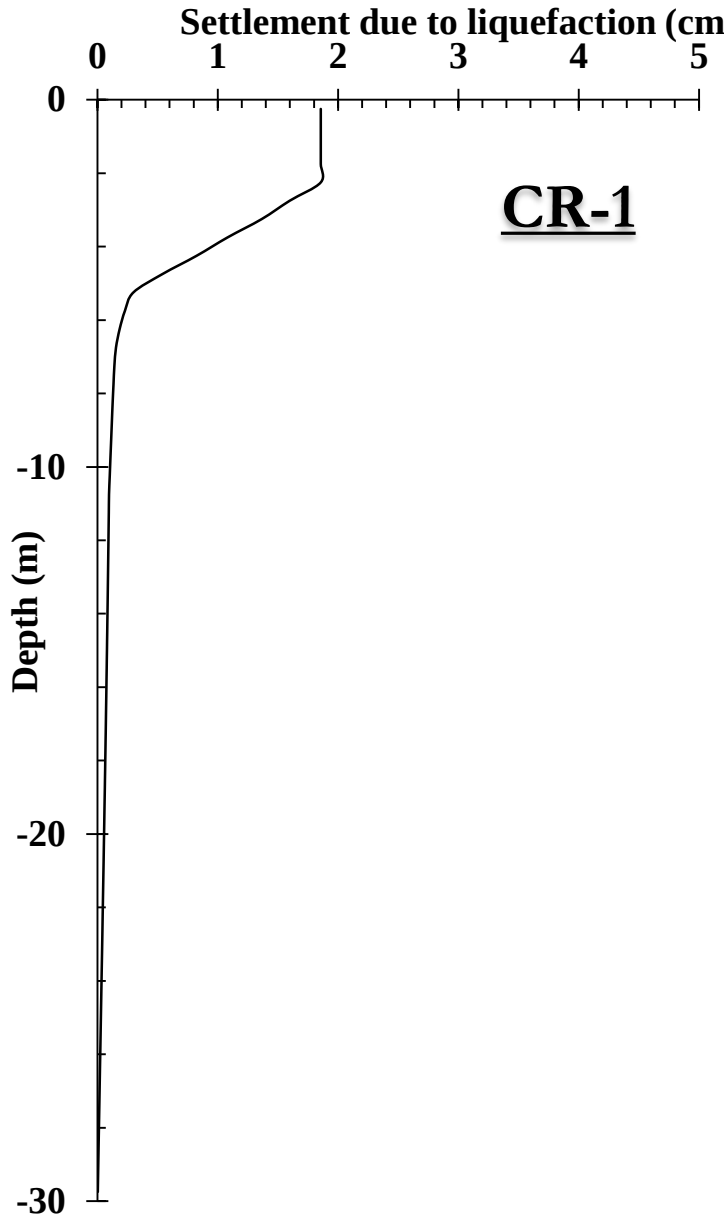


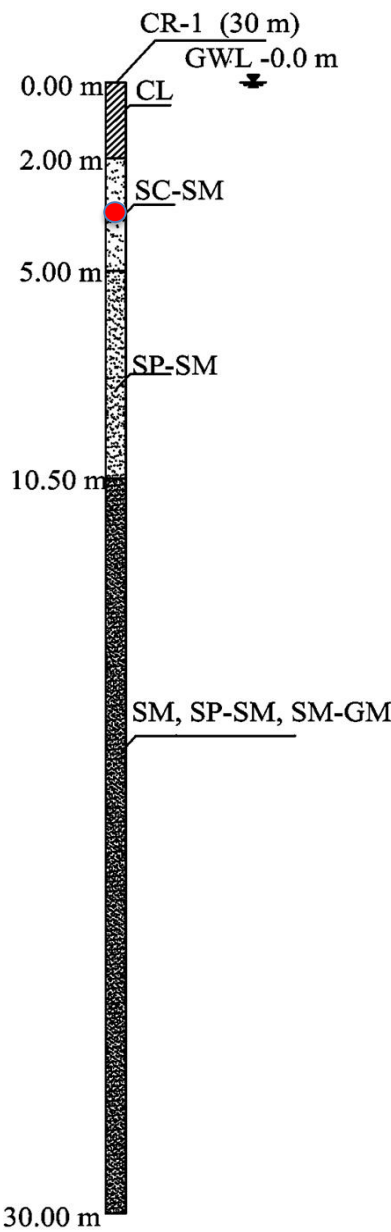
Liqufaction Resistance for SP-SM and SC-SM Layers in Chiang Rai

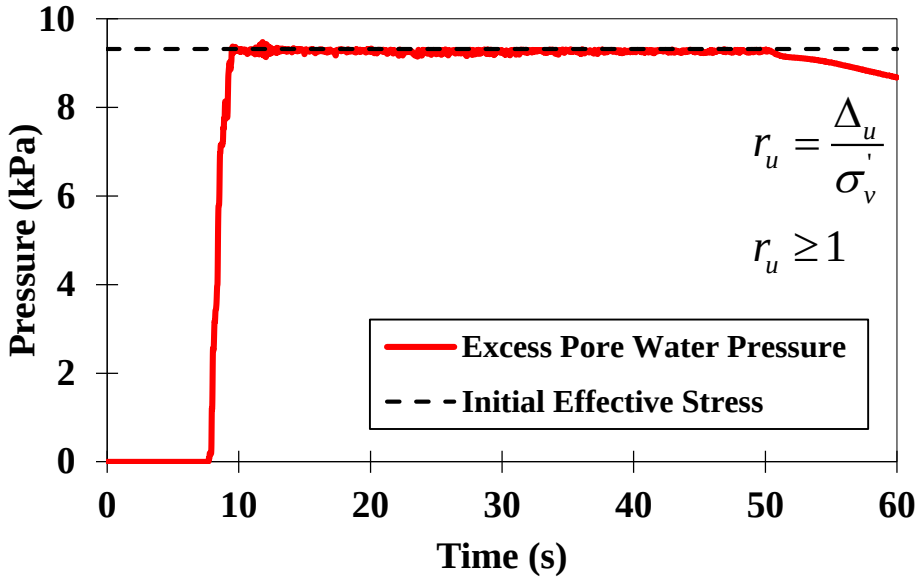
"First and second layers vulnerable to undergo liquefaction"

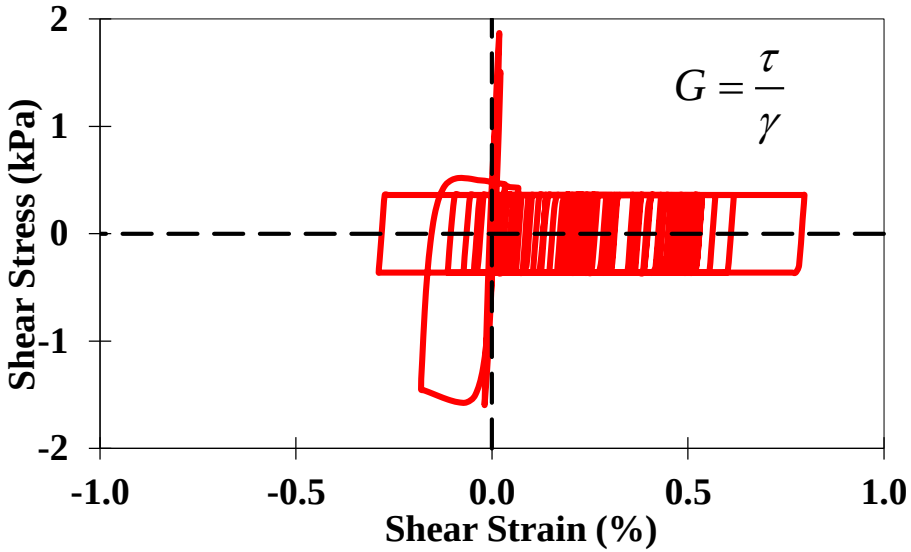
Result and Discussion

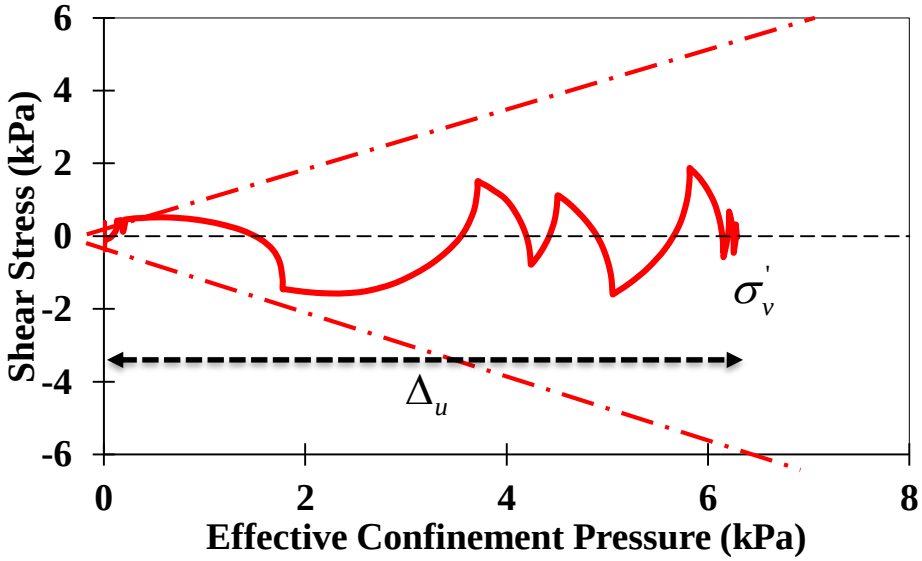




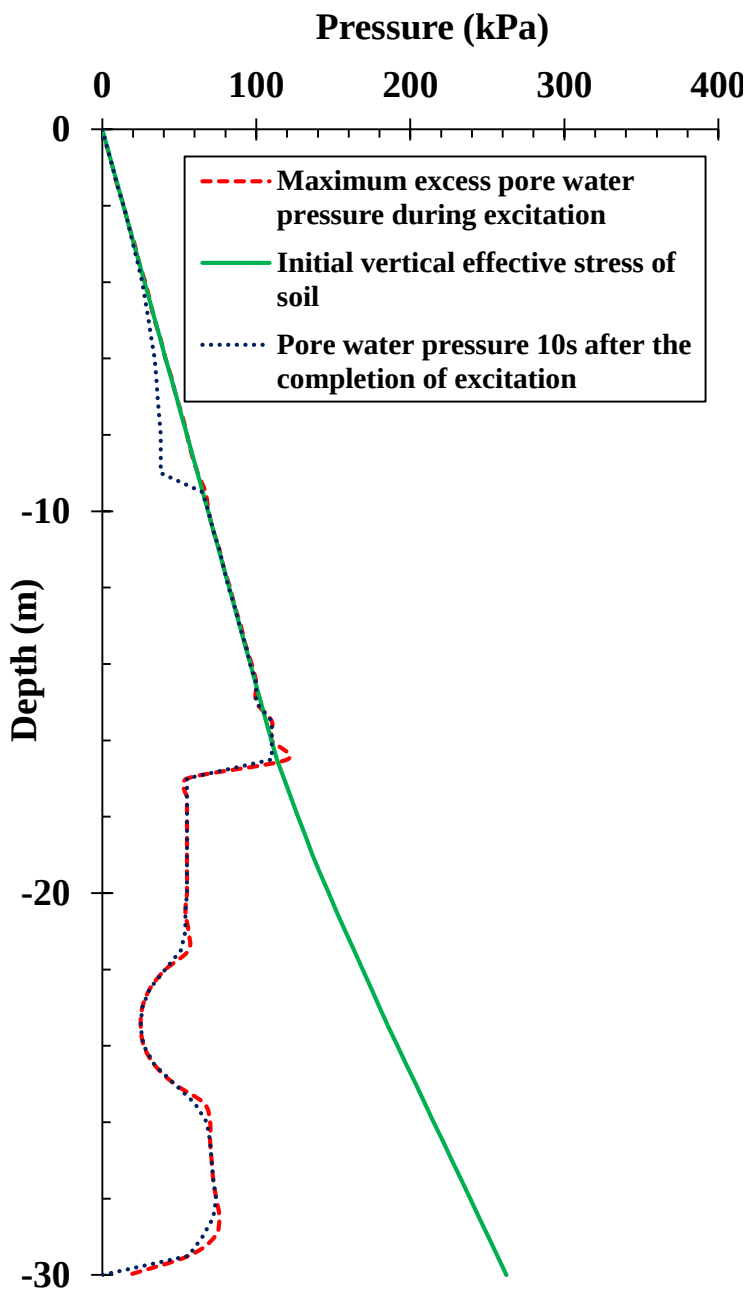


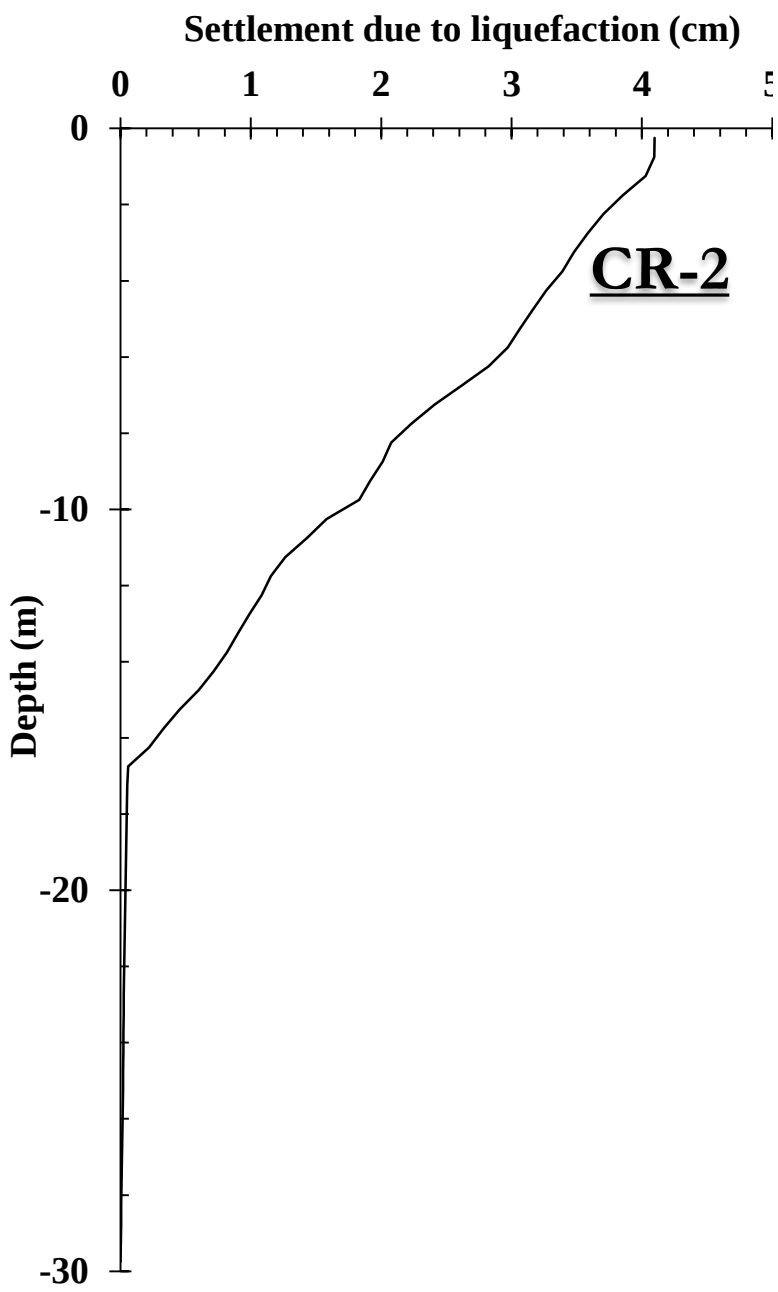


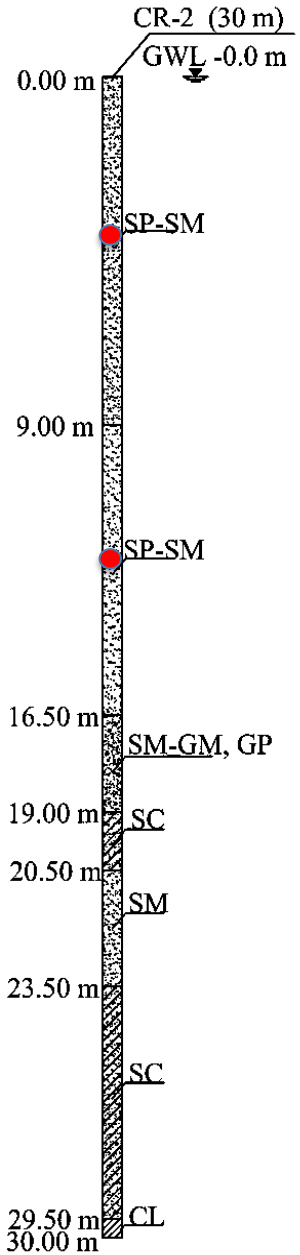


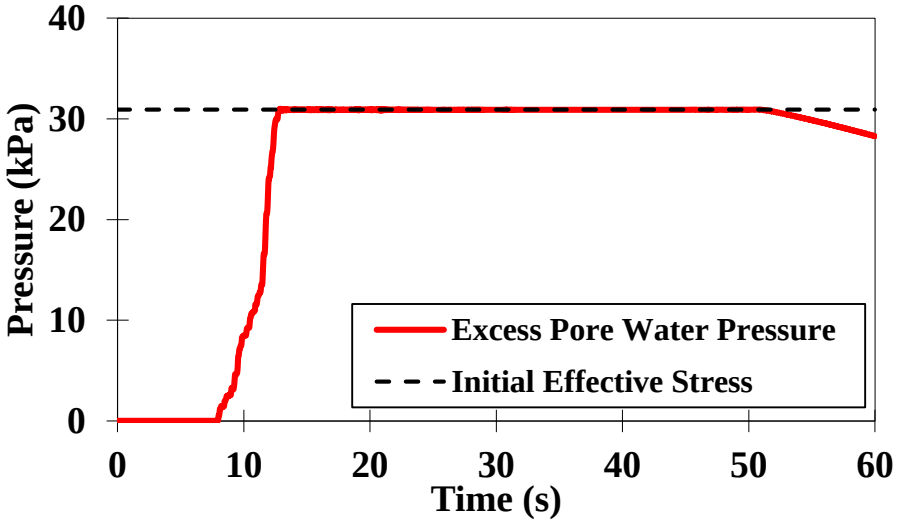


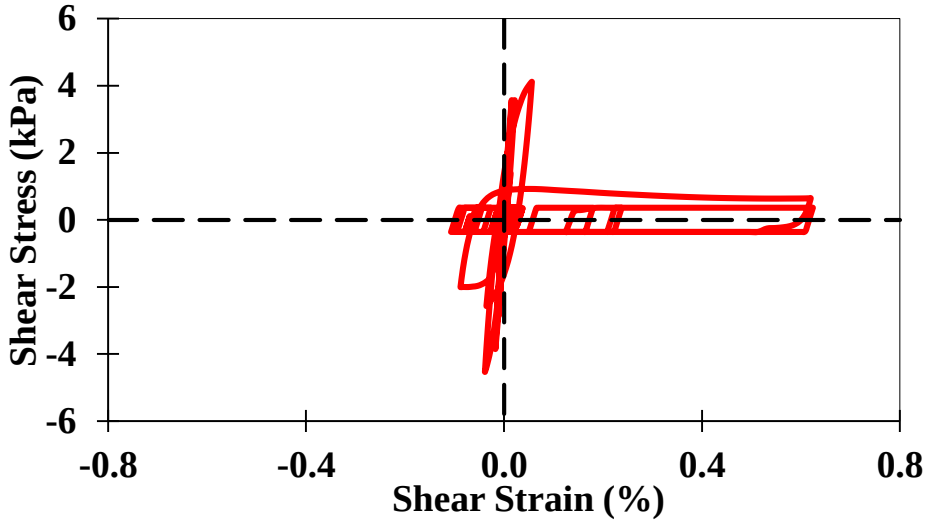
Soil behaviour at CR-1 (SC-SM Layer) (3.5 m)

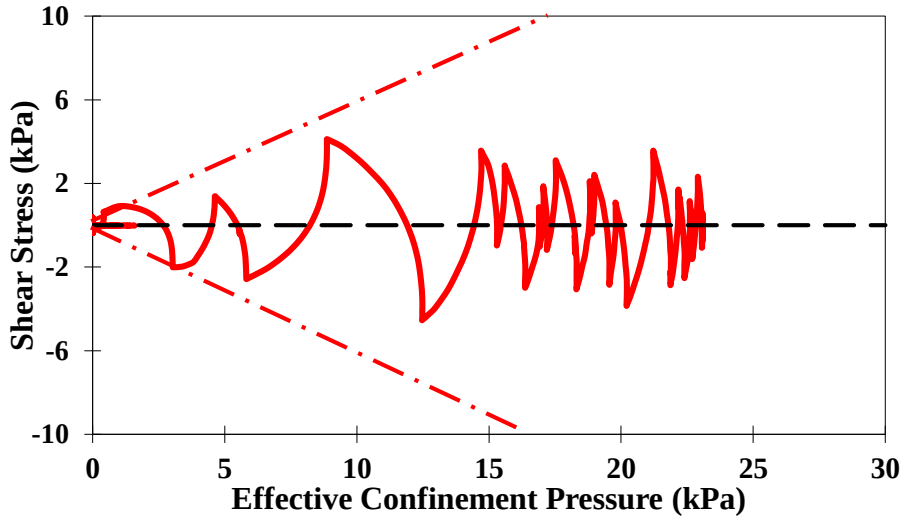

Pressure (kPa)
0
100
200
300
400
0
-10
-20
-30
Depth (m)
Maximum excess pore water pressure during excitation
Initial vertical effective stress of soil
Pore water pressure 10s after the completion of excitation


Settlement due to liquefaction (cm)
0
1
2
3
4
0
-10
-20
-30
Depth (m)
CR-2

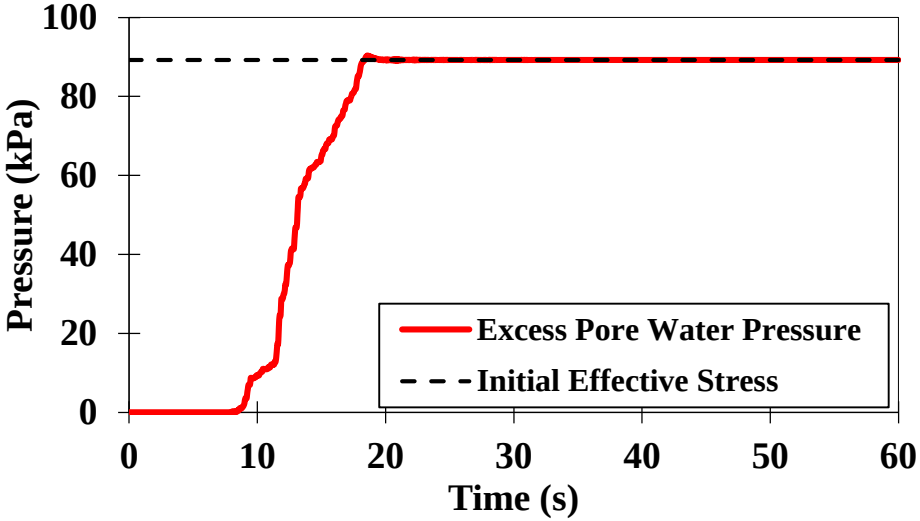

CR-2 (30 m)
GWL -0.0 m
0.00 m
SP-SM
9.00 m
SP-SM
16.50 m
SM-GM, GP
19.00 m
SC
20.50 m
SM
23.50 m
SC
29.50 m
CL
30.00 m

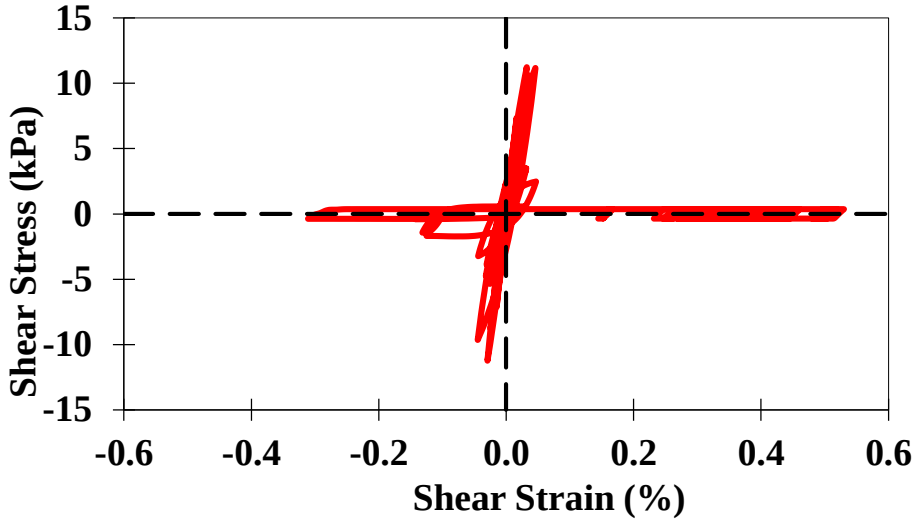


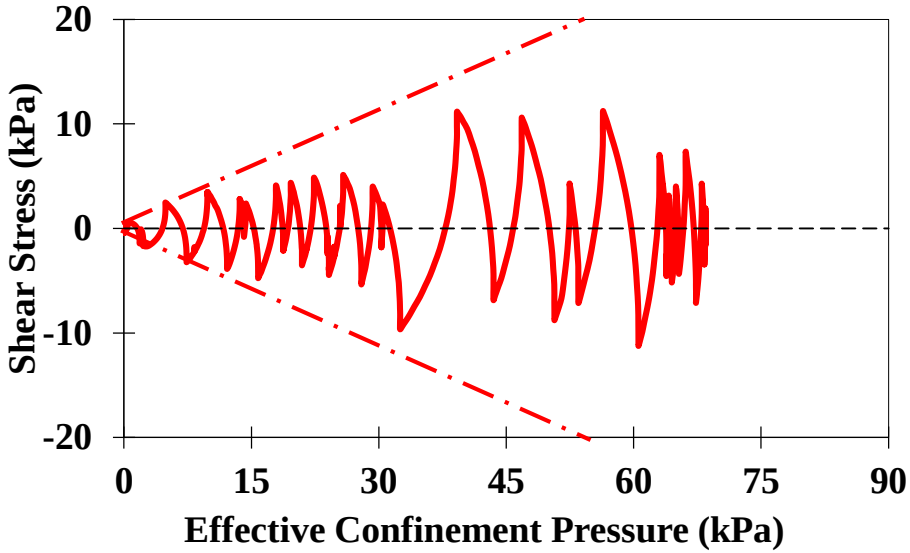




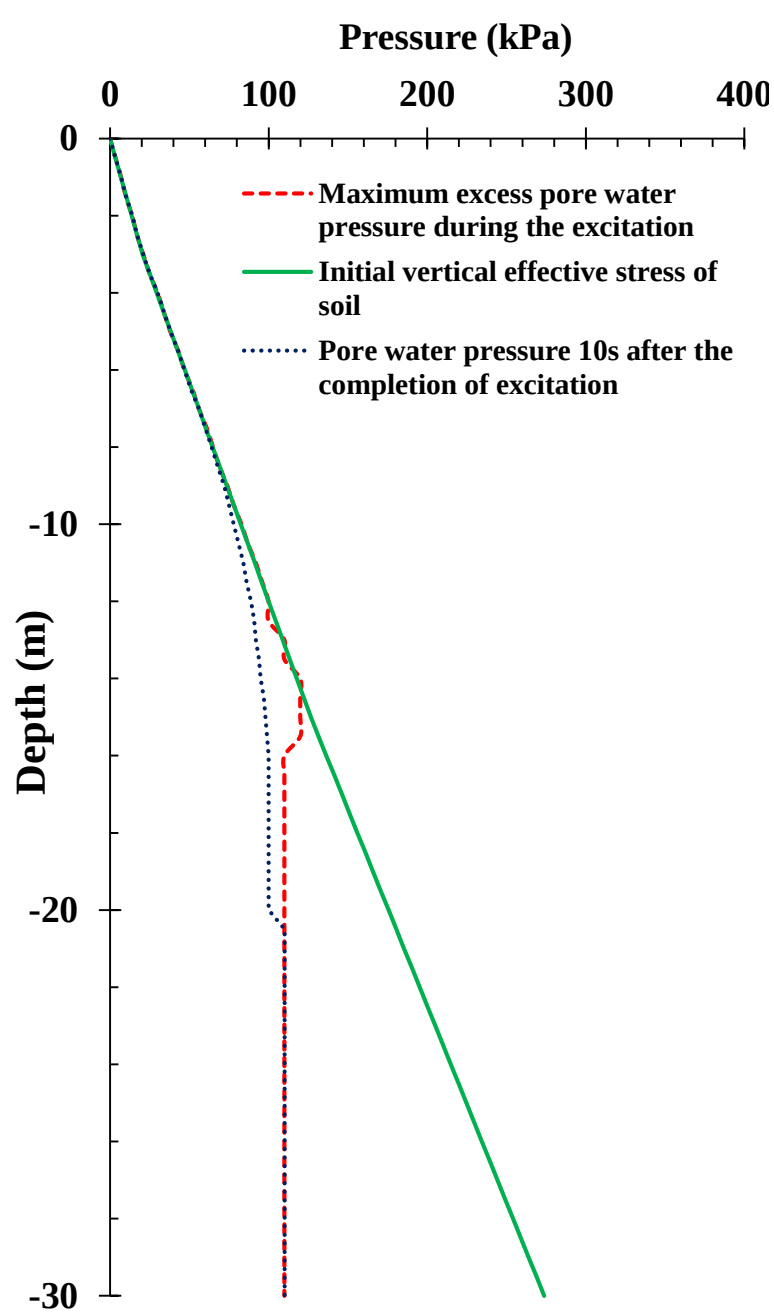
Soil behaviour at CR-2 (SP-SM Layer) (4.5 m)

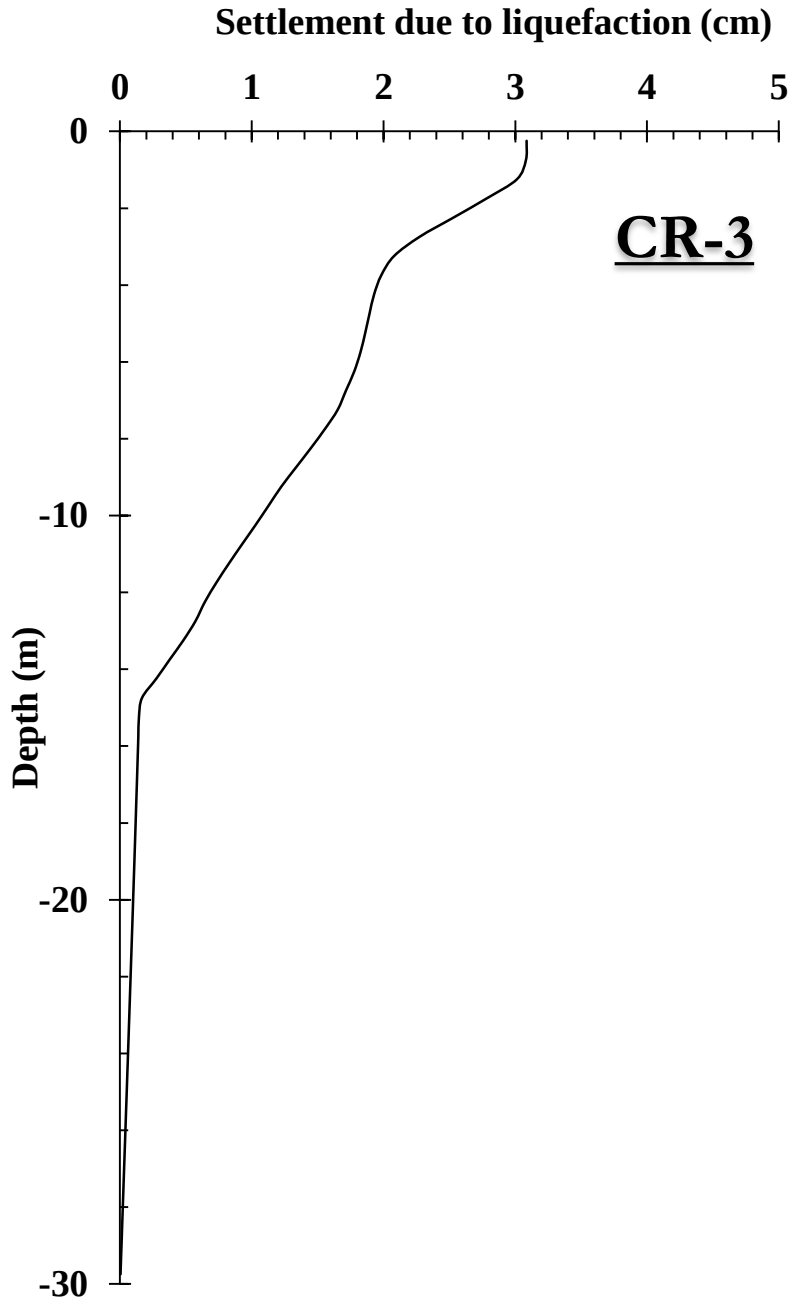


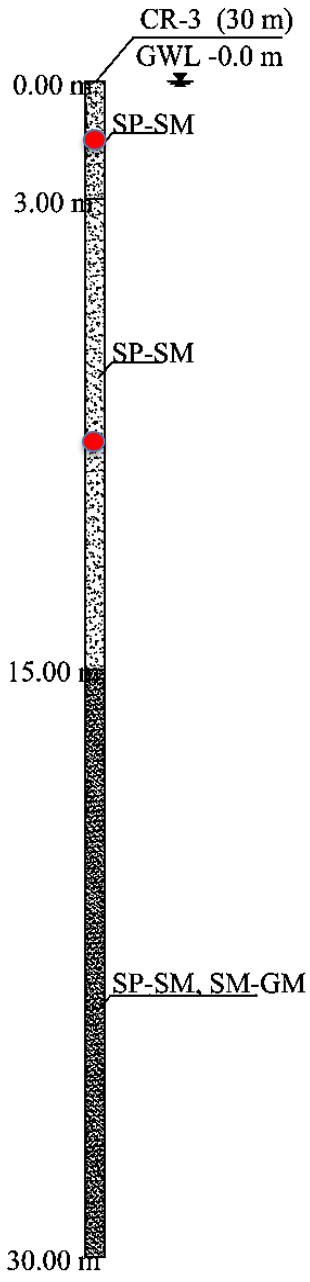


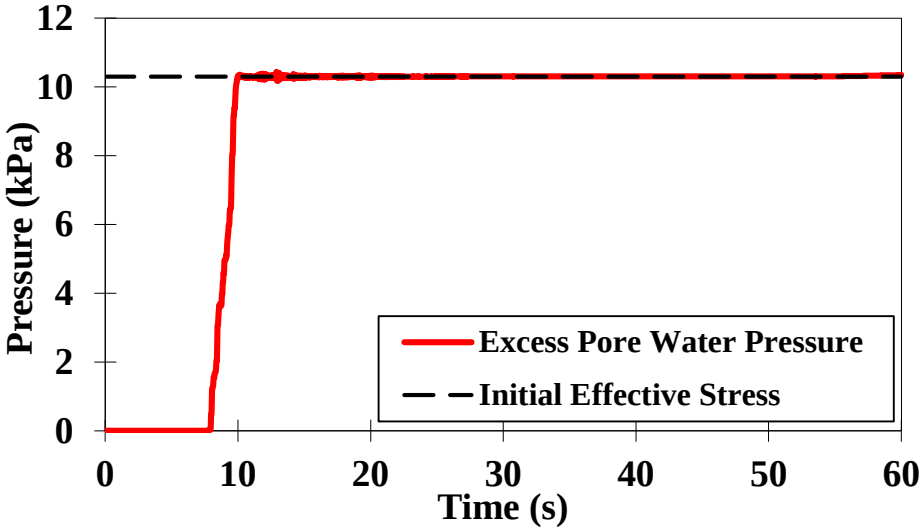


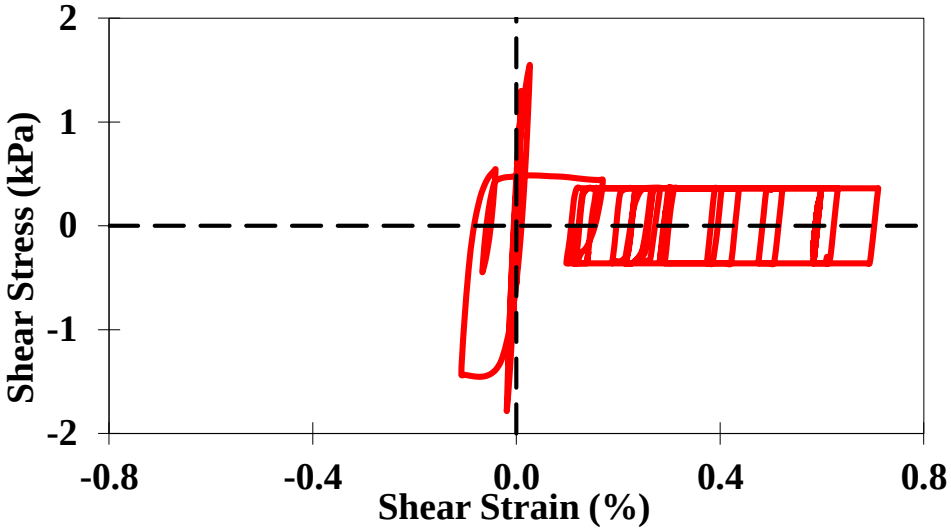
Soil behaviour at CR-2 (SP-SM Layer) (12.75 m)

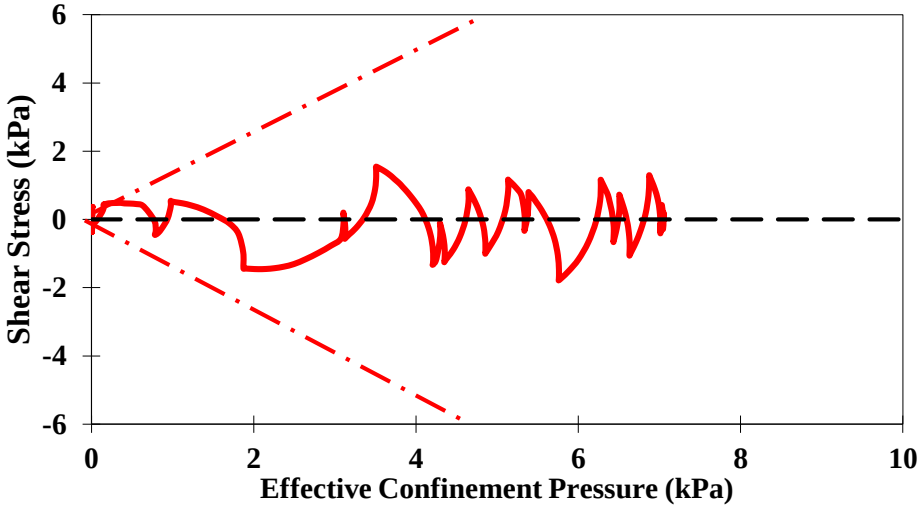

Pressure (kPa)
0
100
200
300
400
0
-10
-20
-30
Depth (m)
Maximum excess pore water pressure during the excitation
Initial vertical effective stress of soil
Pore water pressure 10s after the completion of excitation


Settlement due to liquefaction (cm)
0
1
2
3
4
5
0
-10
-20
-30
Depth (m)
CR-3

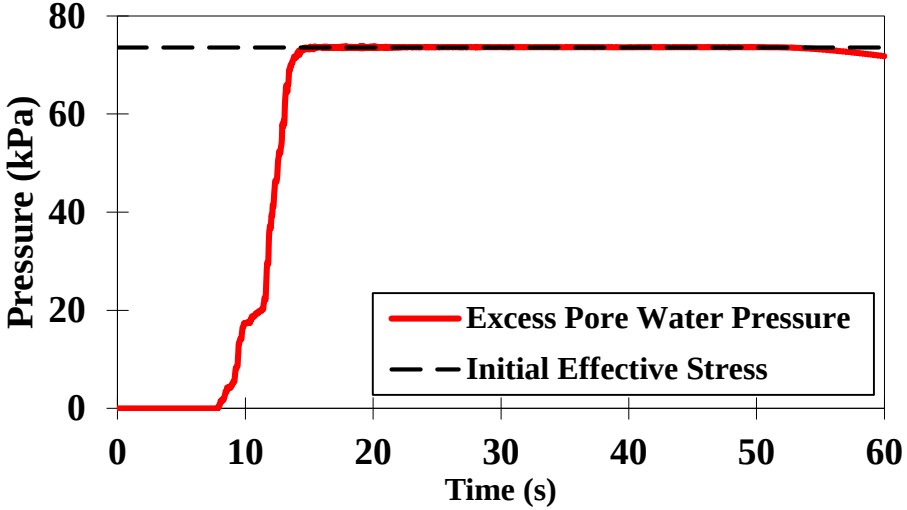

CR-3 (30 m)
GWL -0.0 m
0.00 m
SP-SM
3.00 m
SP-SM
15.00 m
SP-SM, SM-GM
30.00 m

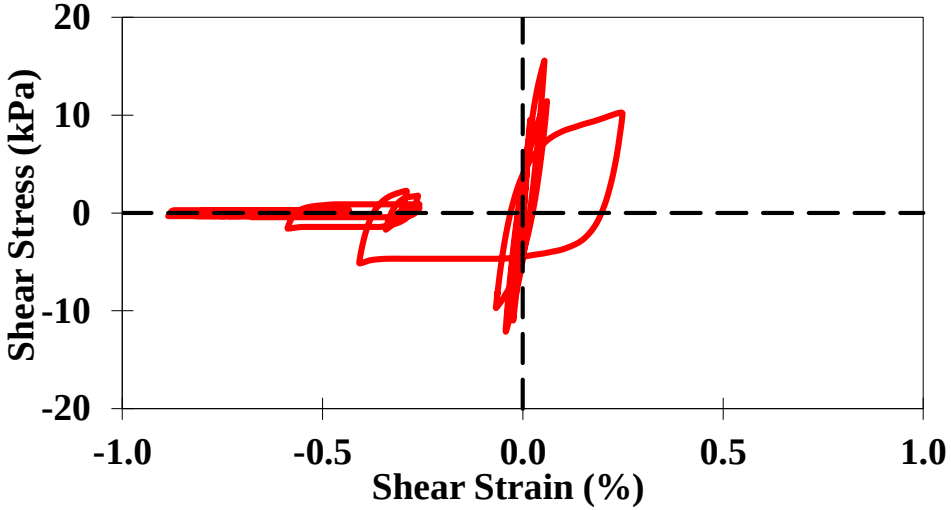


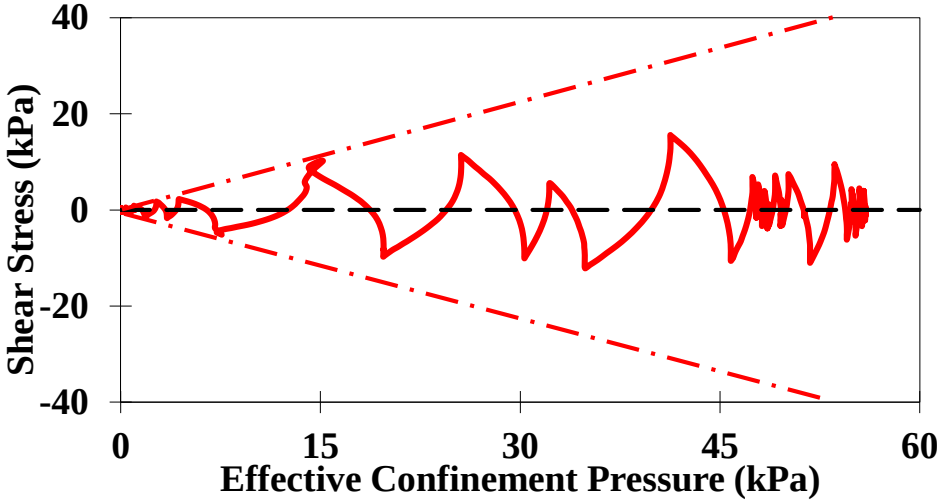




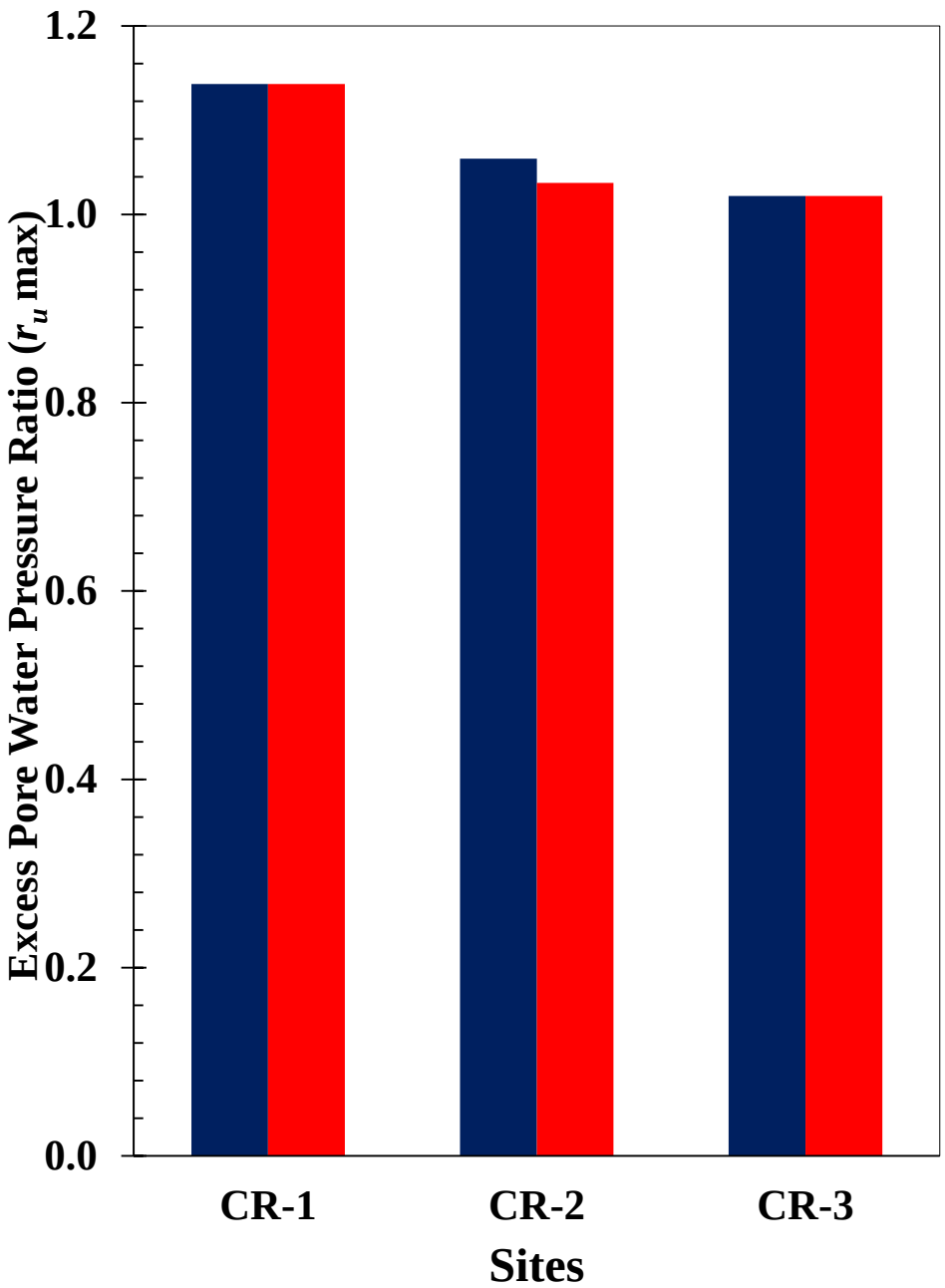
Soil behaviour at CR-3 (SP-SM Layer) (1.5 m)







Soil behaviour at CR-3 (SP-SM Layer) (12 m)


1.2
1.0
0.8
0.6
0.4
0.2
0.0
Excess Pore Water Pressure Ratio (r_u max)
CR-1
CR-2
CR-3
Sites

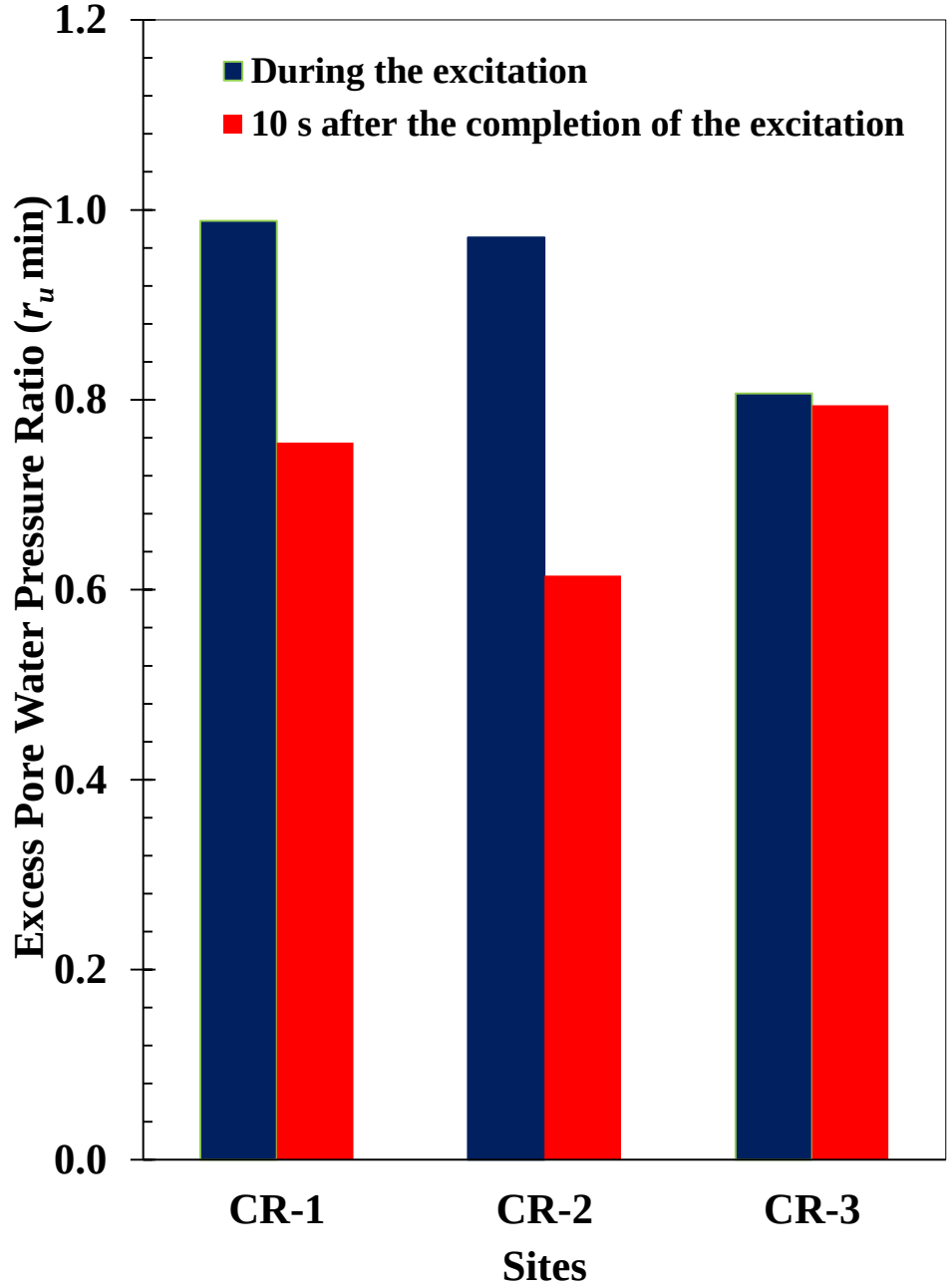

During the excitation
10 s after the completion of the excitation
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Excess Pore Water Pressure Ratio (r_u min)
CR-1
CR-2
CR-3
Sites

Table 2 Liquefaction duration on soil layers (red colors are the liquefiable layers).

Layers	Soil Type	Time taken in build-up liquefaction (sec)	Finished time of liquefaction (sec)	Duration of liquefaction (sec)
CR-1				
Layer 1	CL	0	0	0
Layer 2	**SC-SM**	**10**	**50**	**40**
Layer 3	SP-SM	0	0	0
Layer 4	SM, SP-SM, SM-GM	0	0	0
CR-2				
Layer 1	**SP-SM**	**13**	**52**	**39**
Layer 2	**SP-SM**	**17**	**60**	**43**
Layer 3	SM-GM,GP	0	0	0
Layer 4	SC	0	0	0
Layer 5	SM	0	0	0
Layer 6	SC	0	0	0
Layer 7	CL	0	0	0
CR-3				
Layer 1	**SP-SM**	**10**	**60**	**50**
Layer 2	**SP-SM**	**15**	**54**	**39**
Layer 3	SP-SM, SM-GM	0	0	0

$$r_u \text{ Percentage} = \frac{N \text{ of mesh for } r_u}{N \text{ of total mesh}} \bullet 100\%$$

Table 3 Percentage of r_u in sand layer.

r_u criteria	Percentage of r_u in overall sand layer (%)		
	CR-1	CR-2	CR-3
$r_u \geq 1$	8.77	38.33	32.79
$0.9 < r_u < 1$	5.26	18.33	19.67
$0.8 < r_u < 0.9$	5.26	0.00	1.64
$0.7 < r_u < 0.8$	3.51	0.00	6.56
$0.6 < r_u < 0.7$	5.26	0.00	8.20
$0.6 < r_u < 0.5$	3.51	0.00	13.11
$r_u < 0.5$	68.42	43.33	18.03

Table 4 Impacted depth based on r_u.

r_u criteria	Total Impacted depth (m)		
	CR-1	CR-2	CR-3
$r_u \geq 1$	2.54	11.31	9.84
$0.9 < r_u < 1$	1.53	5.41	5.90
$0.8 < r_u < 0.9$	1.53	0.00	0.49
$0.7 < r_u < 0.8$	1.02	0.00	1.97
$0.6 < r_u < 0.7$	1.53	0.00	2.46
$0.6 < r_u < 0.5$	1.02	0.00	3.93
$r_u < 0.5$	19.84	12.78	5.41

$$\mathrm{H}_{\text{impact}} = r_u \text{Percentage} \bullet H_{\text{total}} \text{ of sand layers}$$

Concluding remarks

- Loose sandy soils with low soil resistance and shallow ground water level were found
- Settlement due to liquefaction is about 1.8 to 4 cm at ground surface
- The first and second sand layers was possibly impacted significant effect of liquefaction
- The pore pressure after exitation was not easily drained (almost no significant different r_u before and after excitation)
- The attention to the possibility of stronger earthquake in the future (the impacted depth might be possibly deeper)
- The countermeasure effort to shallow foundation should be performed to minimise the impact of liquefaction

Acknowlegement

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Published Papers

- Mase L.Z., Likitlersuang, S., Tobita, T., 2016, Liqufaction Potential in Chiang Rai Province Northern Thailand due to the Tarlay Earthquake 2011. ***Proceeding of the 30th JSCE symp on Earthquake Engineering***, 17-19 October 2016, Kanazawa, Japan
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Thank you very much for the attention (^_^)