Progress report on
“Liquefaction study in Chiang Rai Northern Thailand”
(Geotechnical Earthquake Engineering)

Tetsuo Tobita, Kansai Univ. (former Kyoto Univ.)

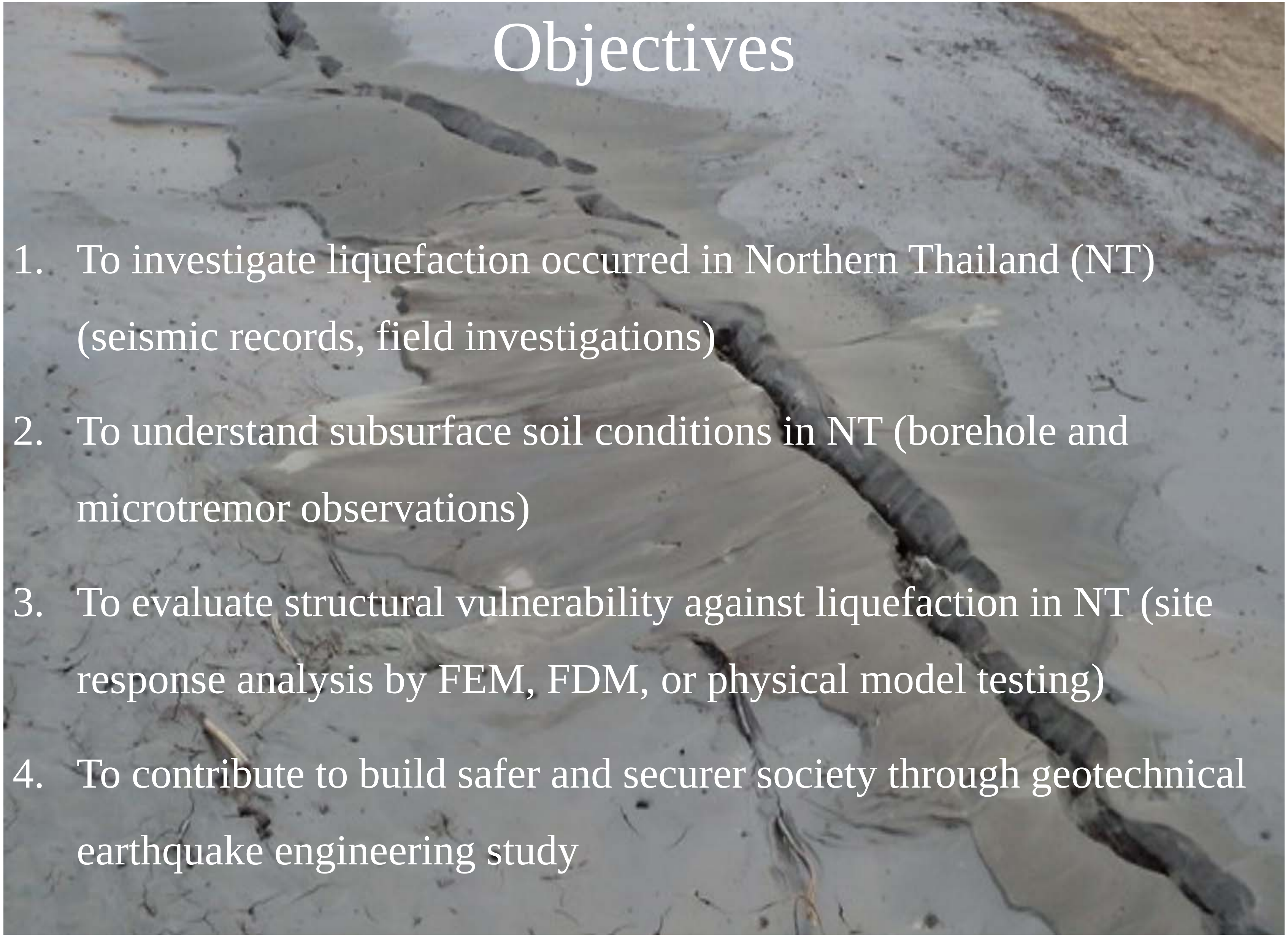
Suched Likitlersuang, Chulalongcorn Univ.

Suttisak Soralump, Kasetsart Univ.

Lindung Zalbuin Mase, Ph. D candidate, Chulalongcorn Univ. (supported by the AUN SEED-NET program)

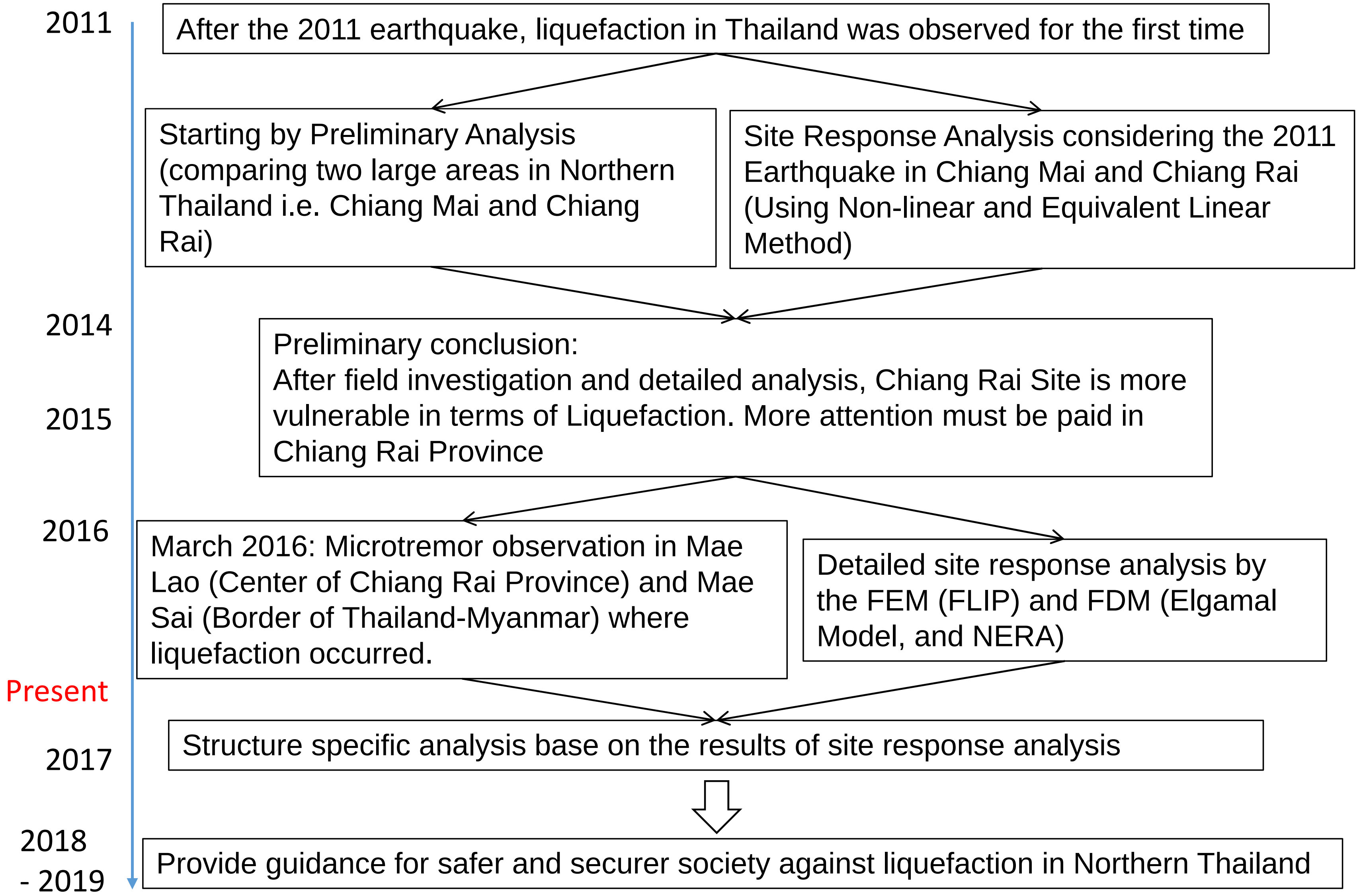
Objectives

1. To investigate liquefaction occurred in Northern Thailand (NT) (seismic records, field investigations)
2. To understand subsurface soil conditions in NT (borehole and microtremor observations)
3. To evaluate structural vulnerability against liquefaction in NT (site response analysis by FEM, FDM, or physical model testing)
4. To contribute to build safer and securer society through geotechnical earthquake engineering study



Sand boils observed in Mae Sai, Chiang Rai, Thailand after 2011 earthquake

Progress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After the 2011 earthquake, liquefaction in Thailand was observed for the first time
Starting by Preliminary Analysis (comparing two large areas in Northern Thailand i.e. Chiang Mai and Chiang Rai)
Site Response Analysis considering the 2011 Earthquake in Chiang Mai and Chiang Rai (Using Non-linear and Equivalent Linear Method)
2014
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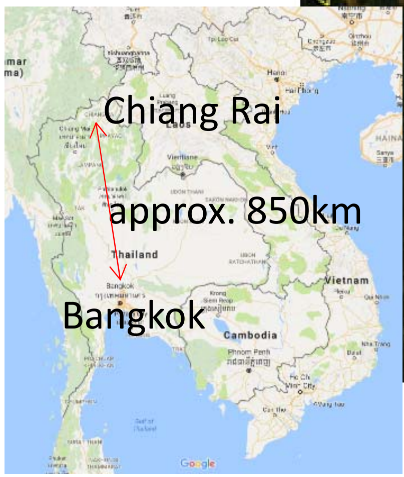
Preliminary conclusion:
After field investigation and detailed analysis, Chiang Rai Site is more vulnerable in terms of Liquefaction. More attention must be paid in Chiang Rai Province
2016
March 2016: Microtremor observation in Mae Lao (Center of Chiang Rai Province) and Mae Sai (Border of Thailand-Myanmar) where liquefaction occurred.
Detailed site response analysis by the FEM (FLIP) and FDM (Elgamal Model, and NERA)
Present
2017
Structure specific analysis base on the results of site response analysis
2018
- 2019
Provide guidance for safer and securer society against liquefaction in Northern Thailand

Introduction

- Earthquake on March 24, 2011
- Magnitude of 6.8 Mw
- Hit Border of Thailand-Myanmar
- Liquefactions near the border
- Liquefaction study should be one of the priority issues.

Approx. 30km:Epicenter – Mae Sai




MYANMAR
LAOS
THAILAND
Tachilek
Meung
HouayXay
Pak Tha
Khob
Phayao
Lampang
Chiang Mai
maphill
kilometers
0
10
20
30
© 2011 Maphill

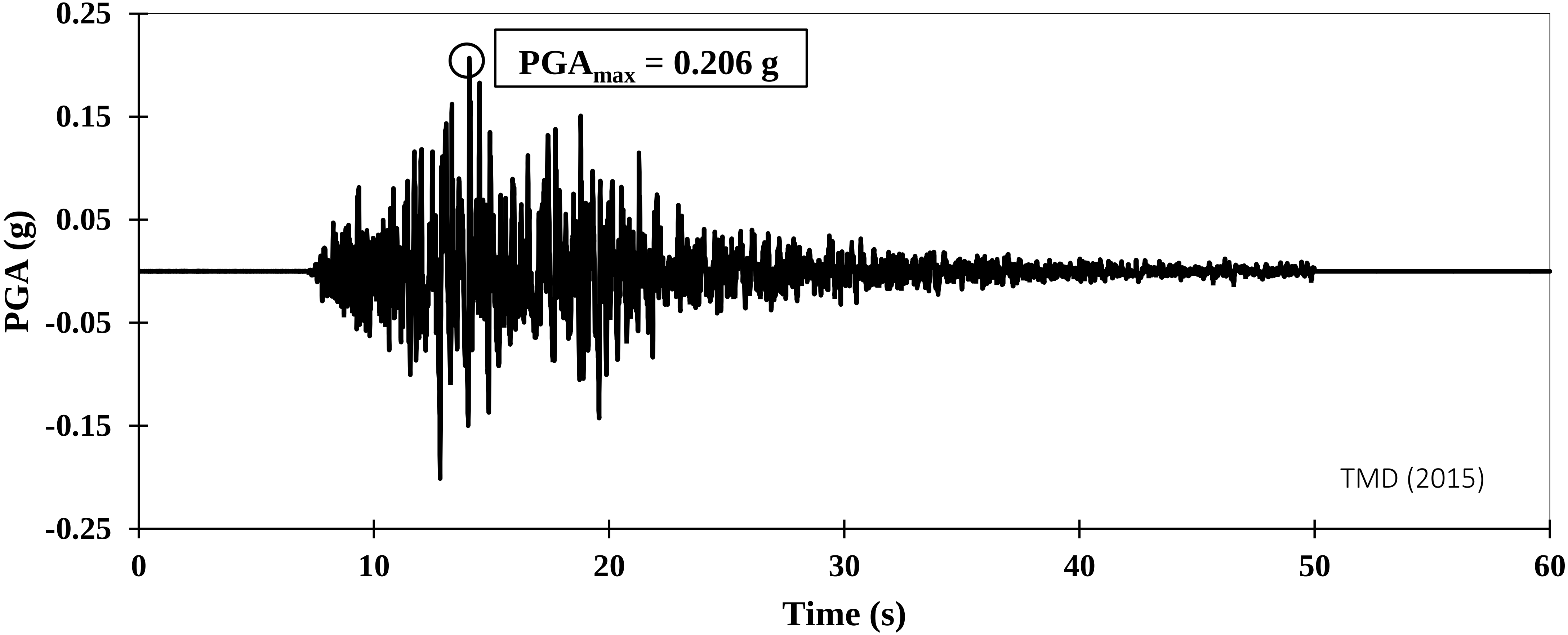


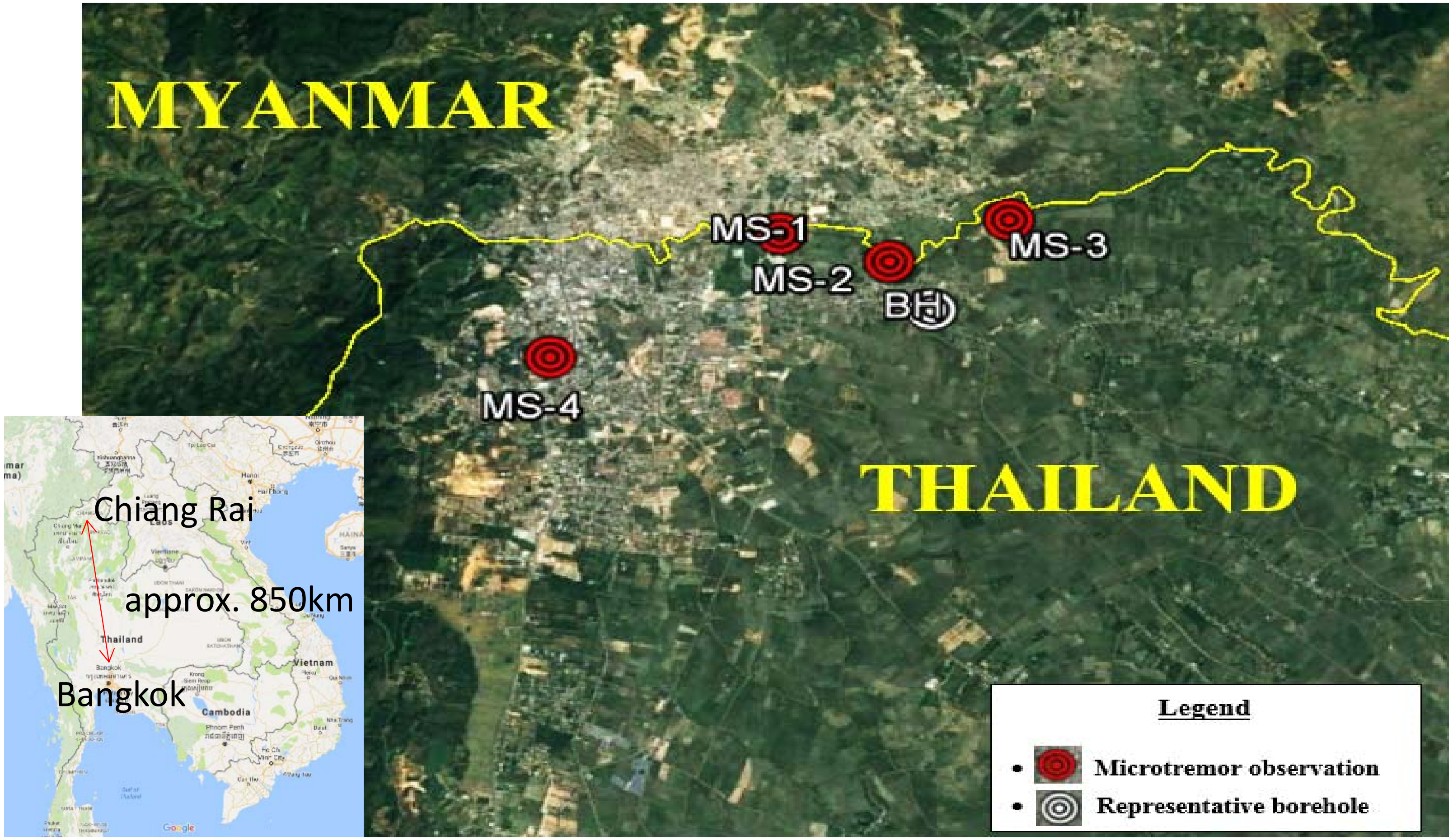
Fig.3 Acceleration record of Mae Sai Station during the 6.8 M_w earthquake on 24 March 2011[6).

Liquefaction Study in Northern Thailand is started

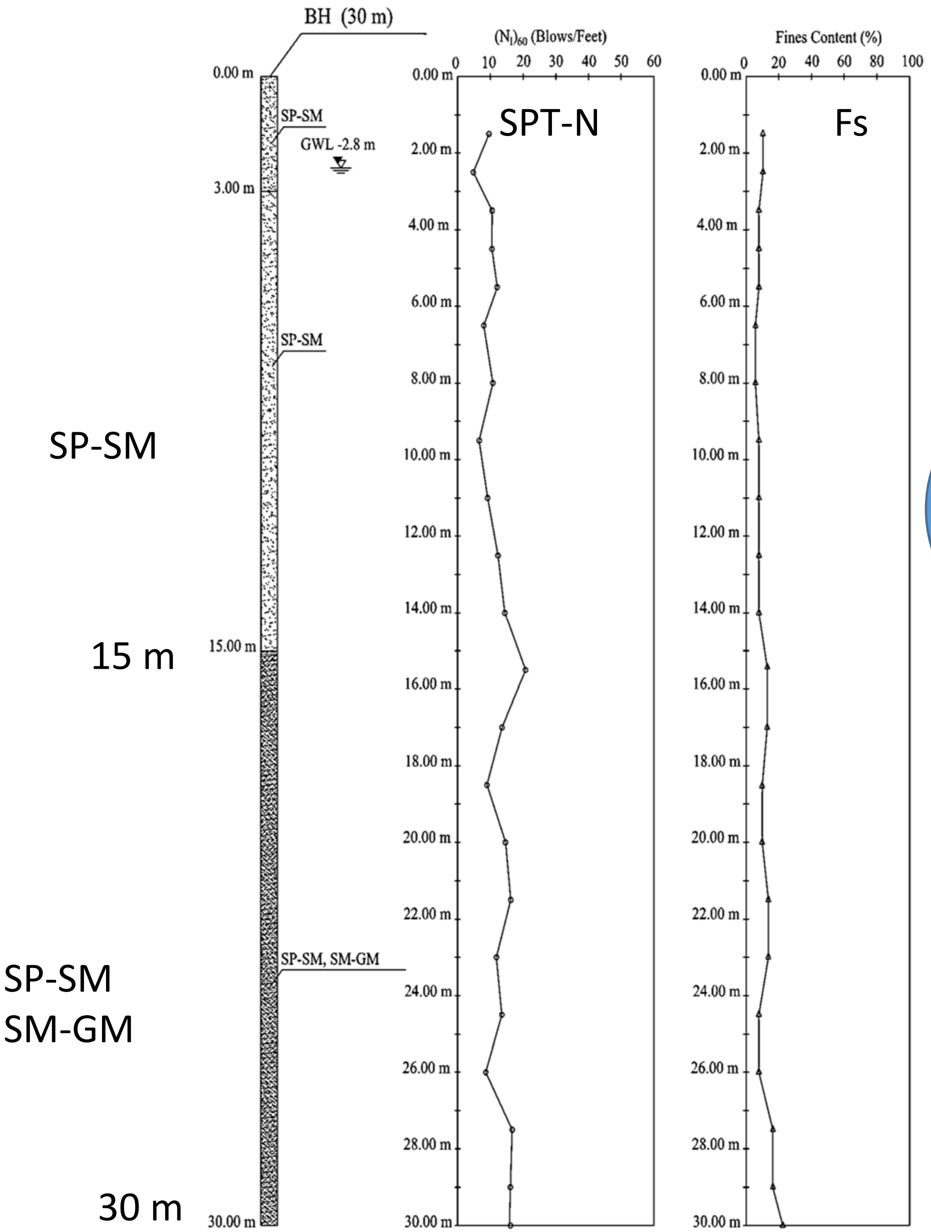
Soralump (2011)

Microtremor observation in Northern Thailand (Chiang Rai Province) (March, 2016)

Microtremor observation in Mae Sai (in March 2016)
(@ expected borehole locations)

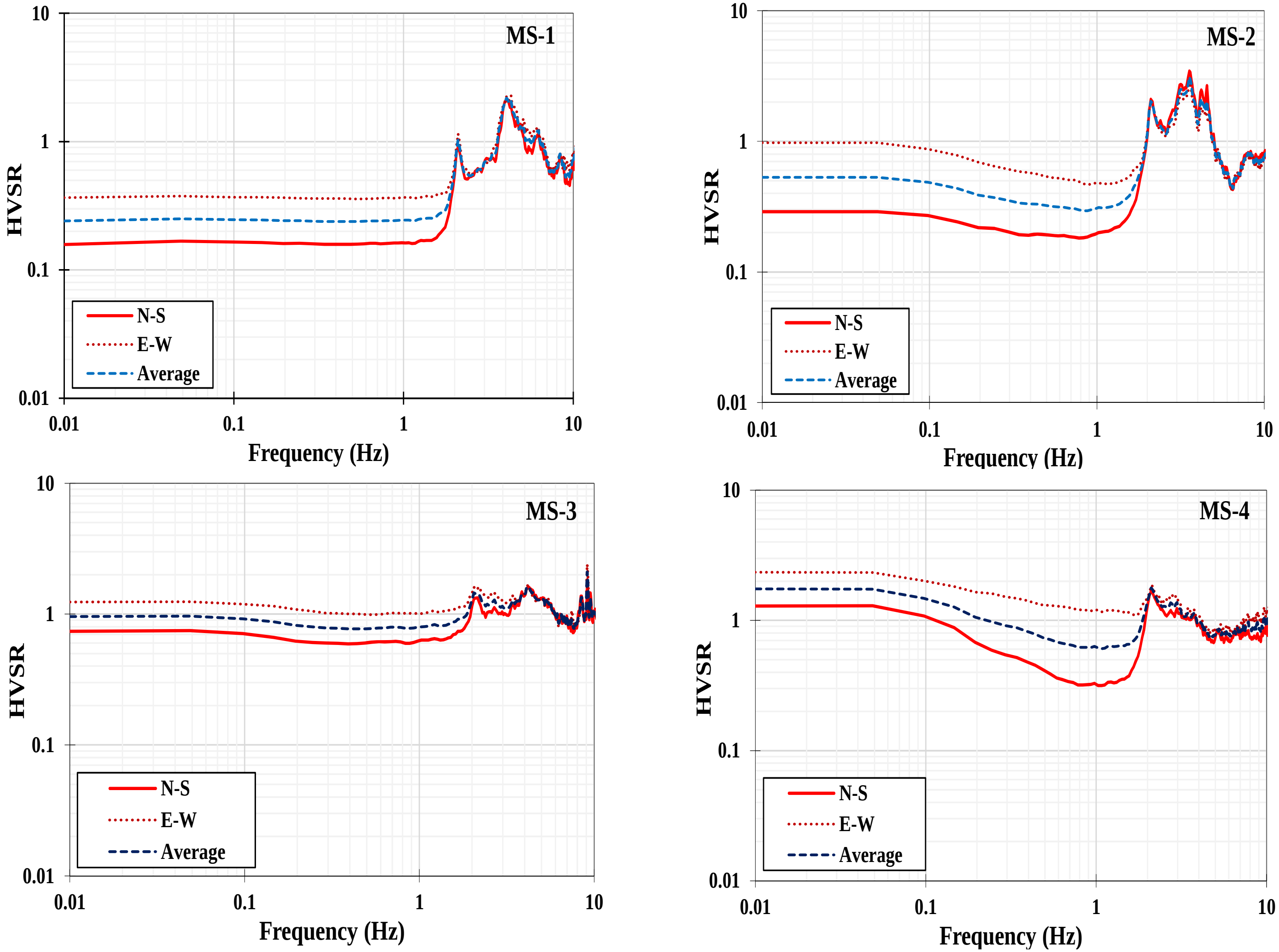


Field evidence of liquefaction in Mae Sai, Chiang Rai, Thailand

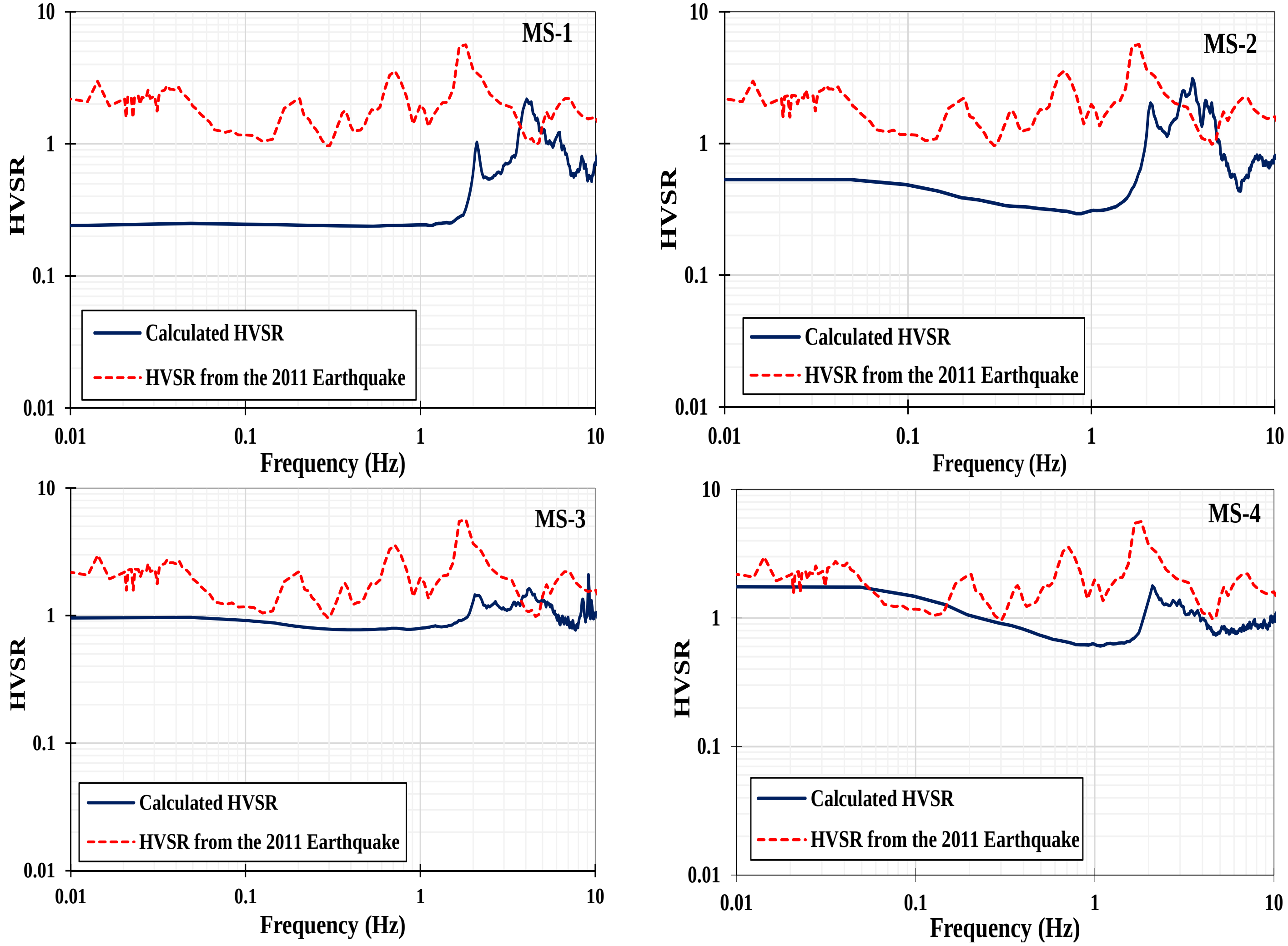


- Dominated by Sandy Soils
- Small value of (N1)60
- Fines Content less than 12%
- Higher Ground Water Level
- Liquefaction is probable

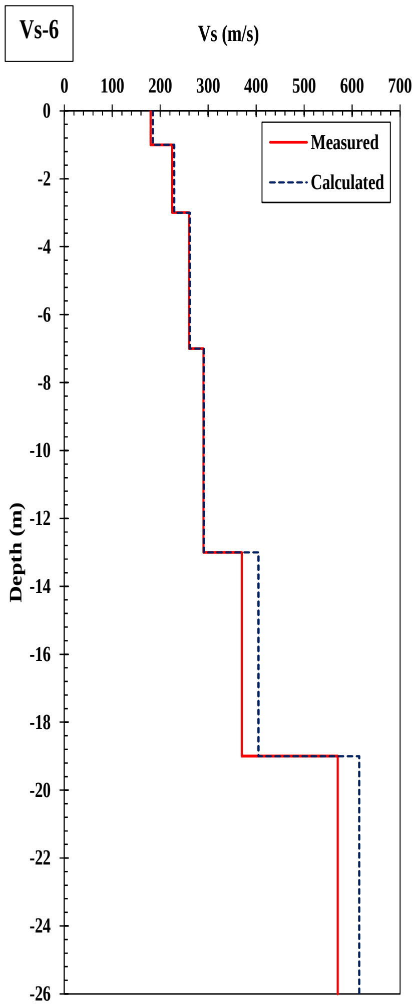
H/V spectrum by microtremor survey in Mae Sai

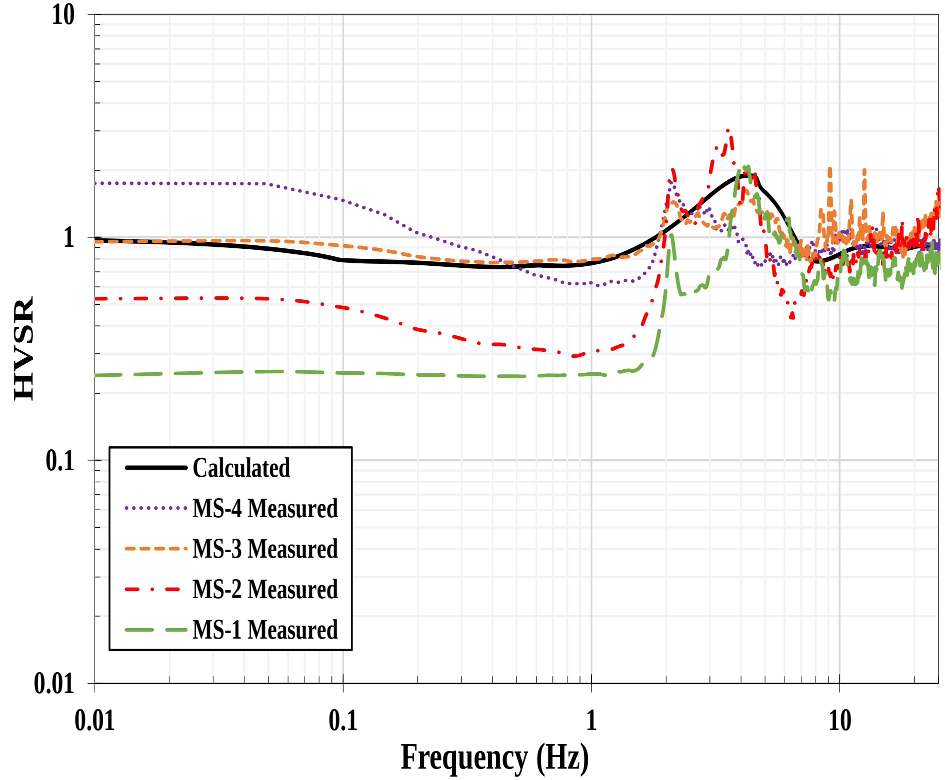


Comparison of the calculated HVSR and 2011 HVSR recorded at the closest station to epicenter



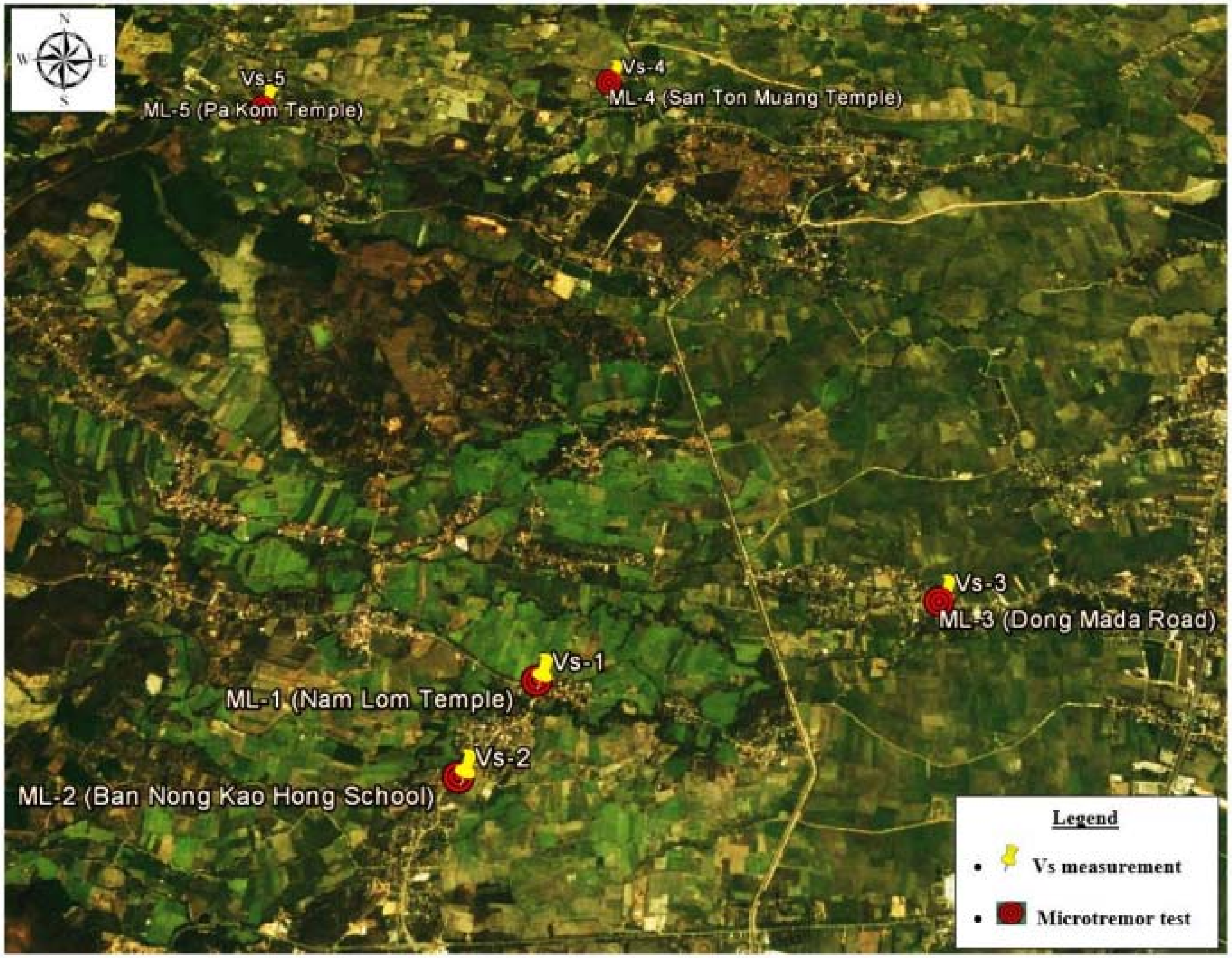
Inversion of HVSR (comparison of measured Vs and calculated Vs)



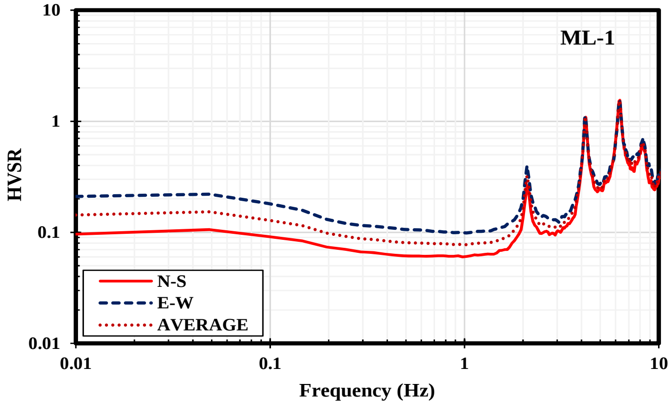


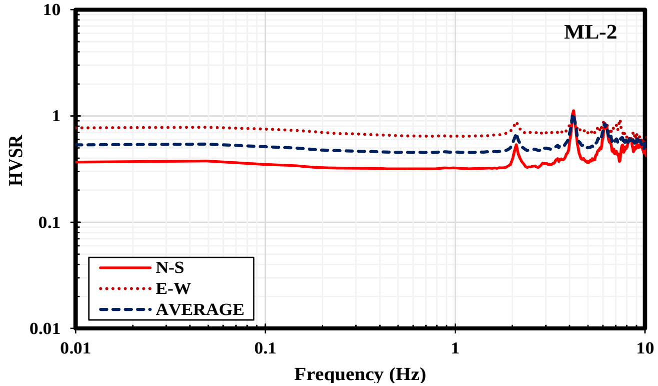
Comparison of Site HVSR and Inversed HVSR based on Vs data

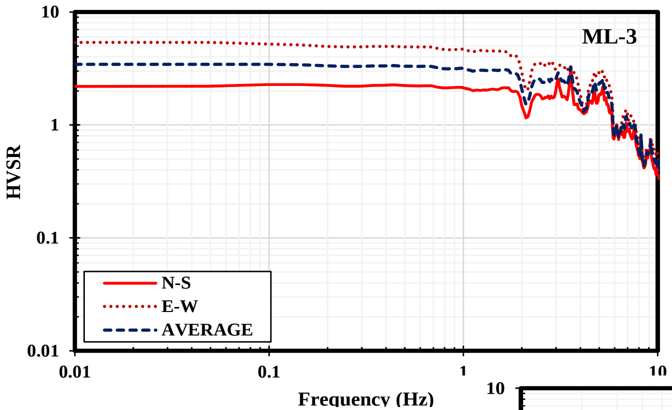
Local site observation in Mae Lao (in March 2016)

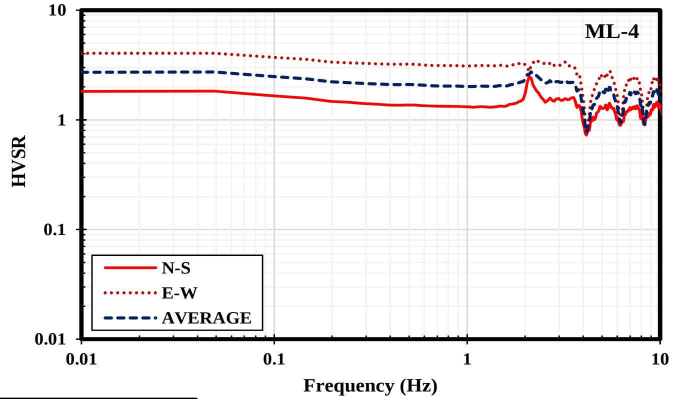


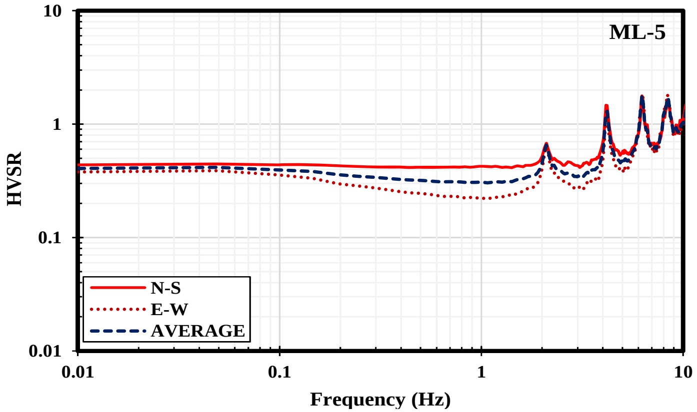
H/V spectrum by microtremor survey in Mae Lao



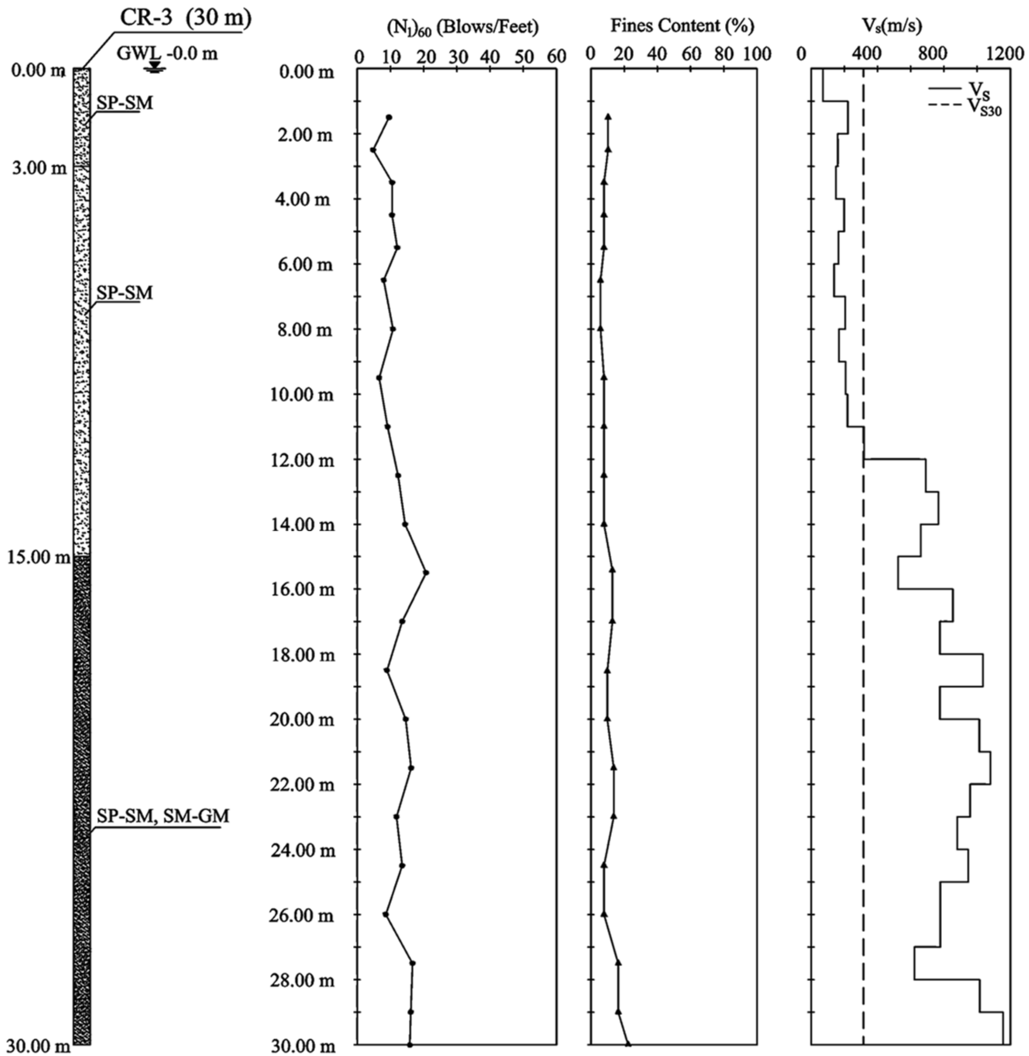


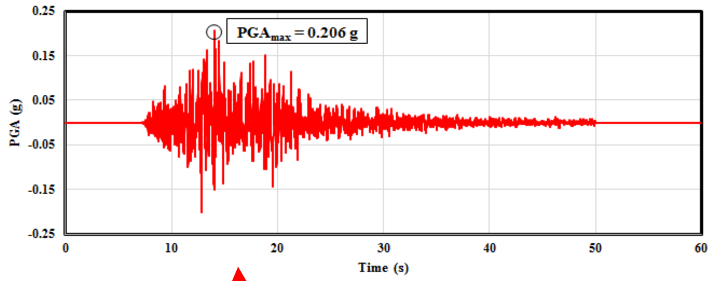


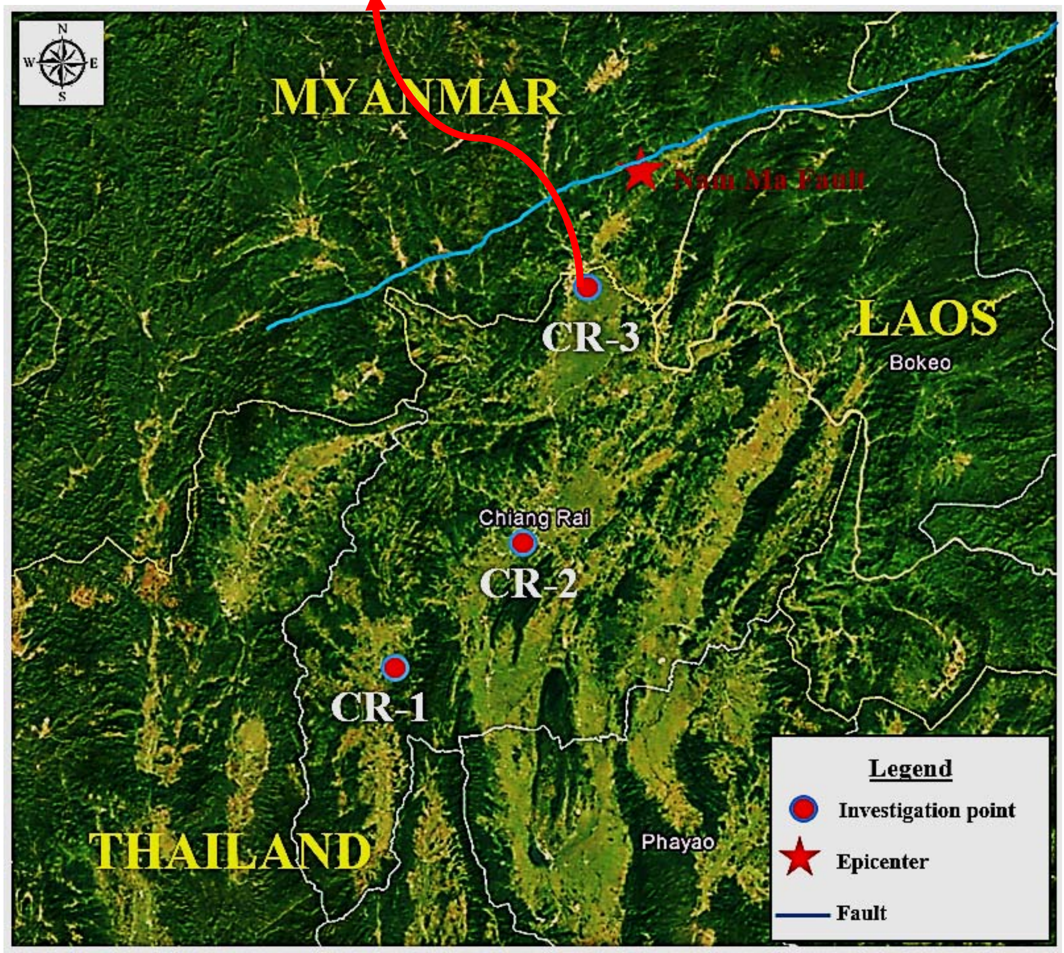




Numerical analysis







METHODOLOGY

- Preliminary Analysis (desk study) : soil type, interpretation of soil layer, SPT value, Vs, and empirical analysis
- Ground motion of 2011 earthquake recorded at the closest station i.e. Mae Sai, with PGA maximum of 0.2g
- 1D Finite Element Effective Stress Model proposed by Elgamal et al. (2006)
- Predict the behavior of soil liquefaction, time histories analysis

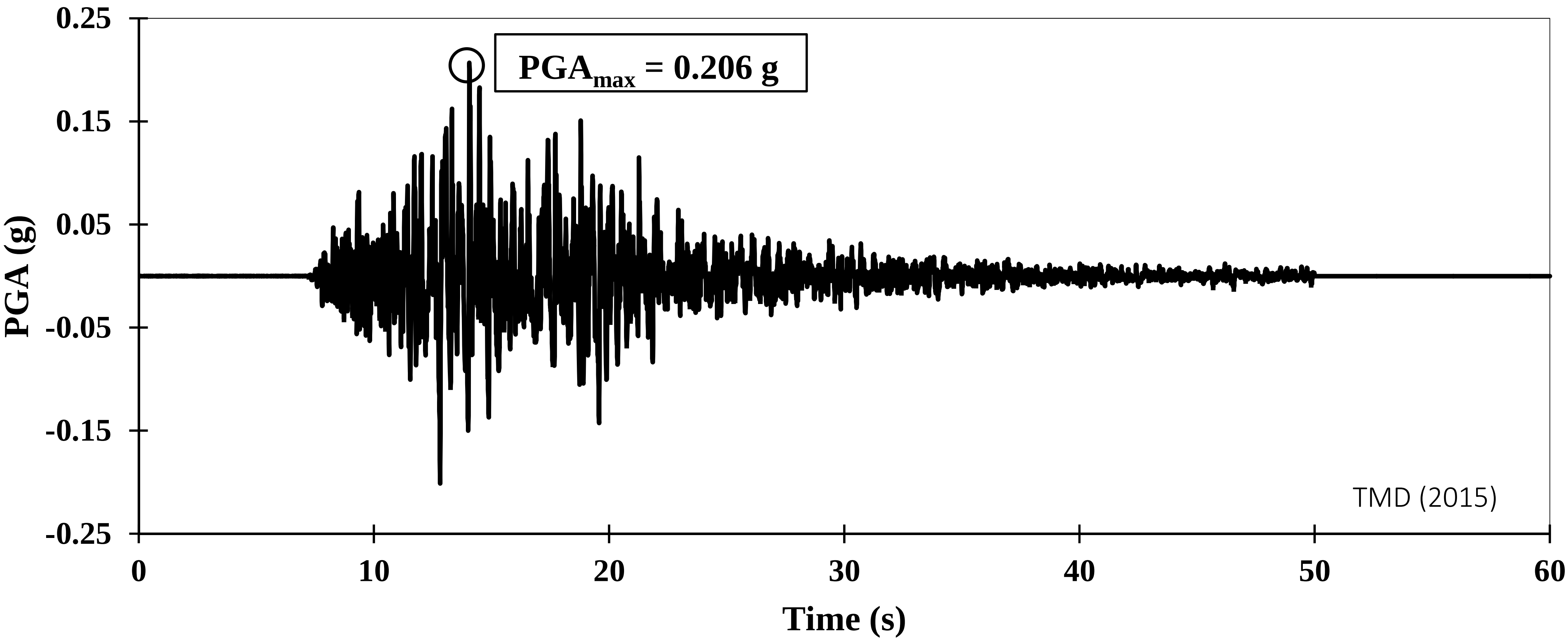
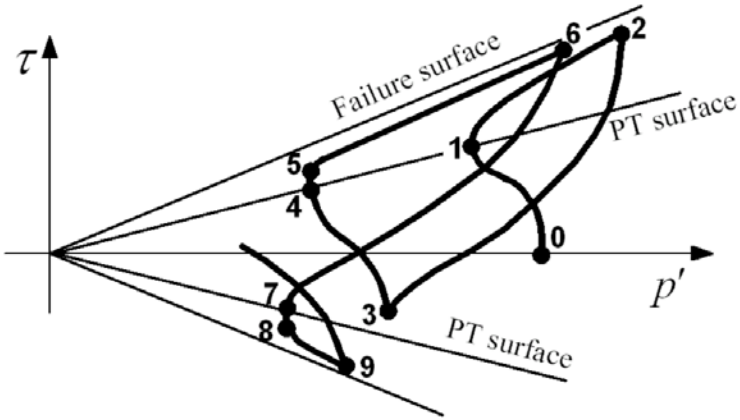


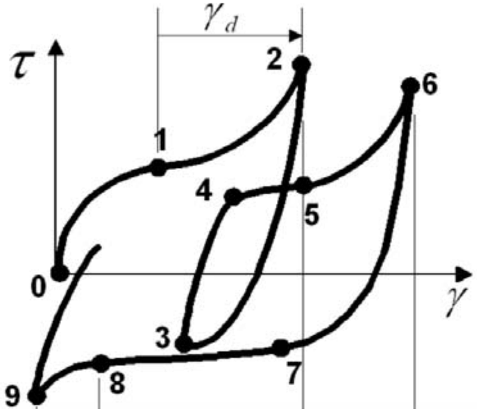
Fig.3 Acceleration record of Mae Sai Station during the 6.8 M_w earthquake on 24 March 2011[6).]

METHODOLOGY

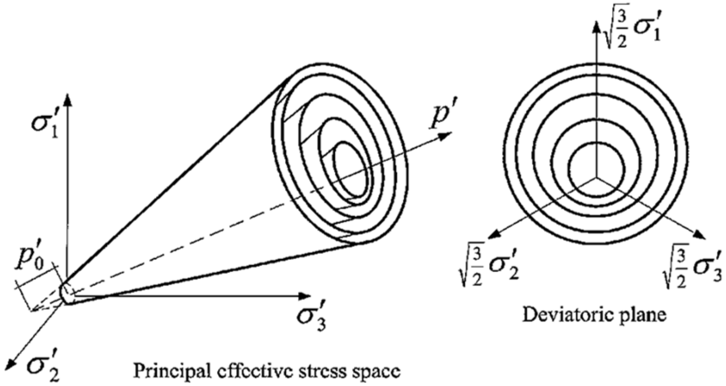
- Effective Stress Model (Elgamal et al., 2006)



Effective stress path of shear strain model for sand under cyclic mobility (Elgamal et al., 2006)

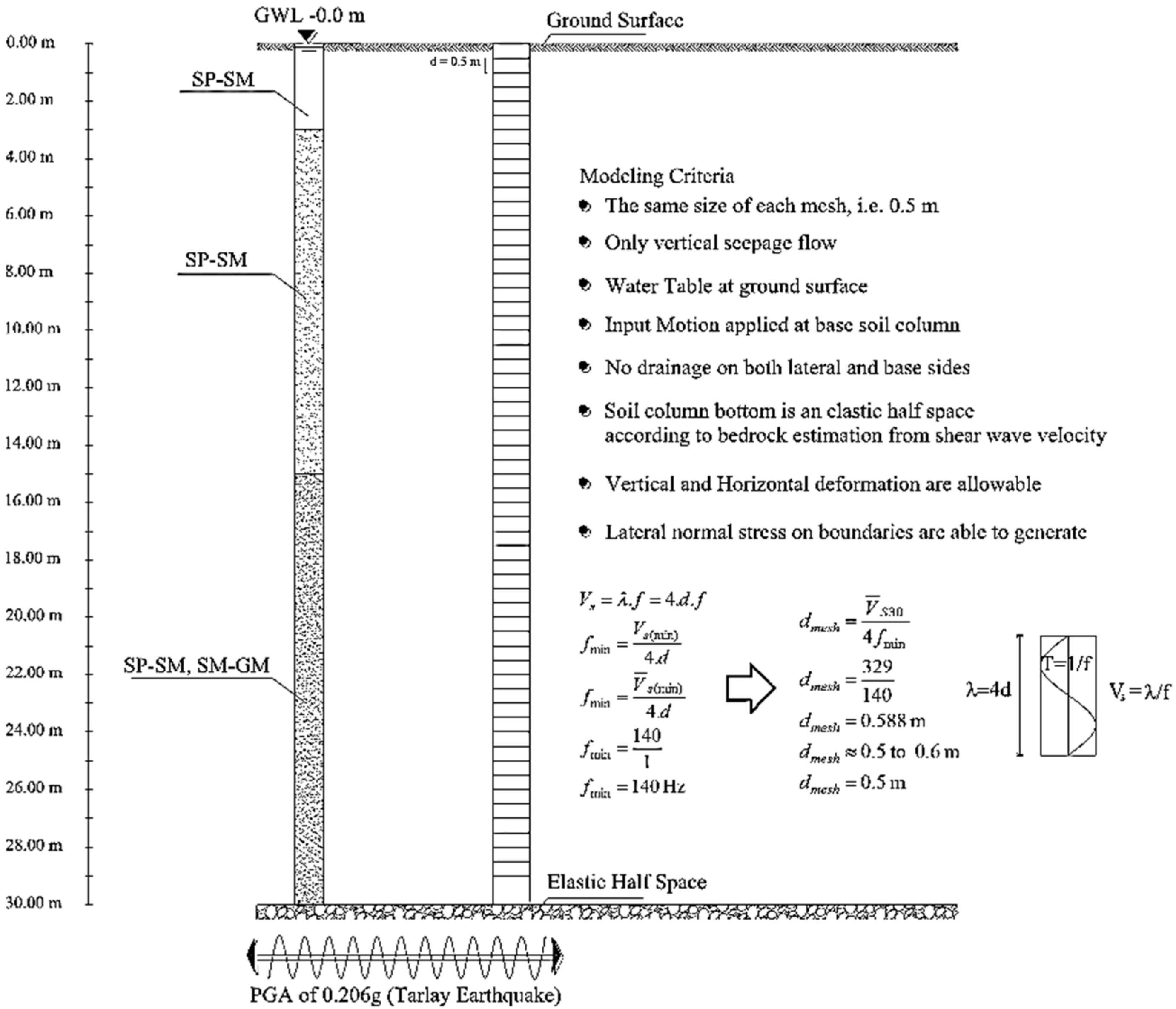


Stress-strain curve of shear strain model for sand under cyclic mobility (Elgamal et al., 2006)



Multi-yield surface of kinematic hardening yield locus in principal stress and deviatoric plane (after Prevost (1985) Parra (1996) and Yang (2000)

1D site response analysis



Input material parameters

BH	Material	Thickness	γ	*c*	ϕ	FC	permeability (*k*)	*Vs*	*Ko*	*p' ref*	γ_{max}	Liq parameter	Contraction Parameter		Dilation Parameter	
		(m)	(kN/m3)	(kPa)	(°)	(%)	(m/s)	(m/s)	(-)	(kPa)	(%)	*Liq 1*	*c1*	*c2*	*d1*	*d2*
CR-1	CL	2.00	1.30	18.00	-	80	1.10E-09	99	0.67	50	5	-	-	-	-	-
	SP-SM	3.00	1.70	0.30	28	8	6.60E-05	237	0.53	80	5	0.025	0.300	0.200	0.000	10
	SP-SM	5.50	2.00	0.30	29	8	6.60E-05	421	0.52	80	5	0.010	0.060	0.500	0.400	10
	SM, SP-SM, SM-GM	19.50	2.10	0.30	30	11.13	6.60E-05	472	0.50	80	5	0.003	0.010	0.600	0.600	10
CR-2	SP-SM	9.00	1.70	0.30	0	21	6.60E-05	195	1.00	80	5	0.025	0.300	0.200	0.000	10
	SP-SM	7.50	1.70	0.30	29	26	6.40E-05	259	0.52	80	5	0.025	0.300	0.200	0.000	10
	SM-GM,GP	2.50	2.00	0.30	9	19	6.60E-05	266	0.84	80	5	0.010	0.060	0.500	0.400	10
	SC	1.50	2.00	3.00	29	18	6.70E-05	273	0.52	80	5	0.010	0.060	0.500	0.400	10
	SM	3.00	2.00	0.50	19	16	6.90E-05	600	0.67	80	5	0.010	0.060	0.500	0.400	10
	SC	6.00	2.00	3.00	30	21	7.10E-05	634	0.50	80	5	0.010	0.060	0.500	0.400	10
	CL	0.50	1.40	20.00	-	94	1.10E-09	728	0.68	50	5	-	-	-	-	-
CR-3	SP-SM	3.00	1.70	0.30	28	7	6.60E-05	140	0.53	80	5	0.025	0.300	0.200	0.000	10
	SP-SM	12.00	2.00	0.32	29	9	6.90E-05	324	0.52	80	5	0.010	0.060	0.500	0.400	10
	SP-SM,SM-GM	15.00	2.10	0.25	30	9	7.20E-05	736	0.50	80	5	0.003	0.010	0.600	0.600	10

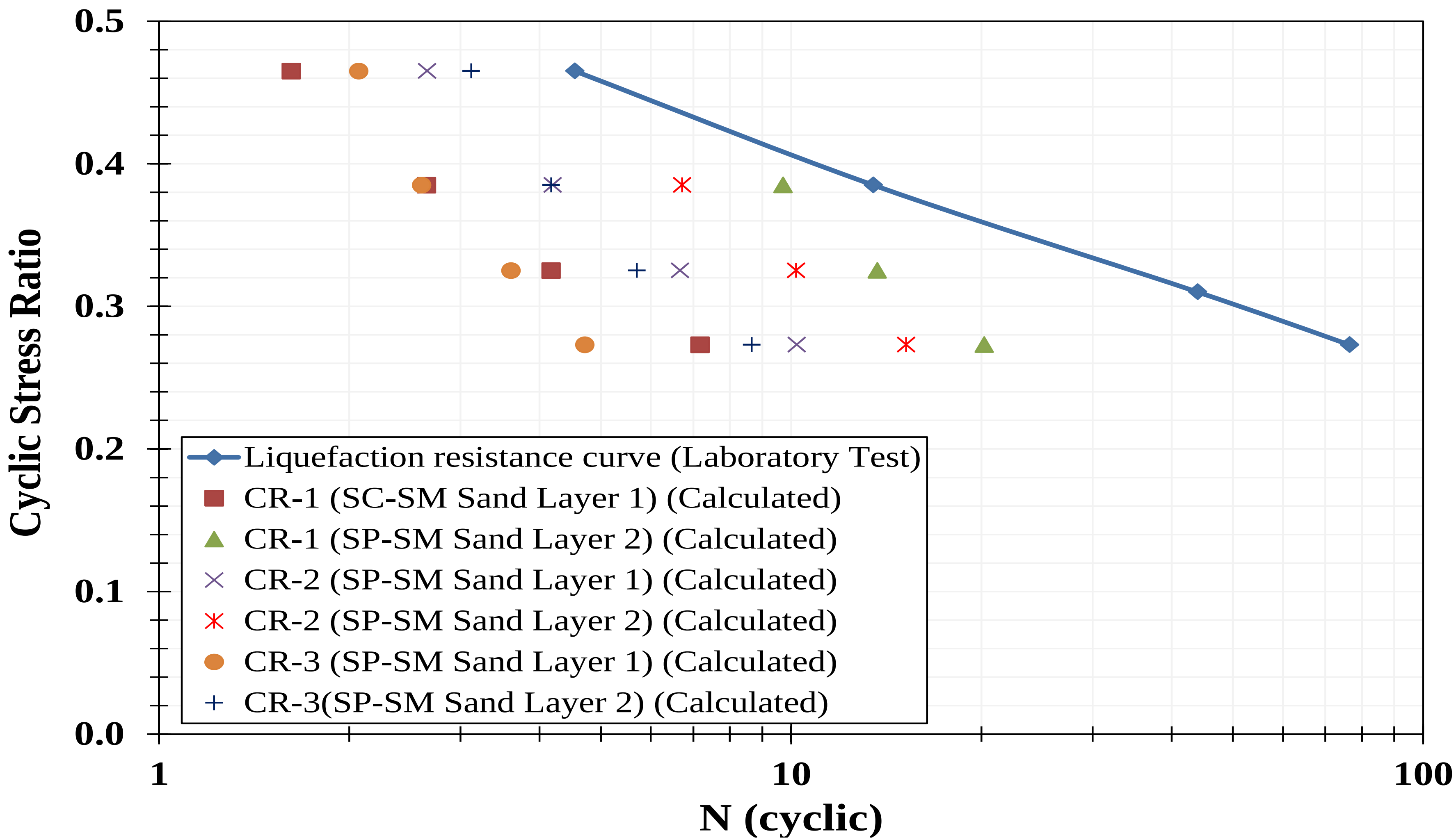
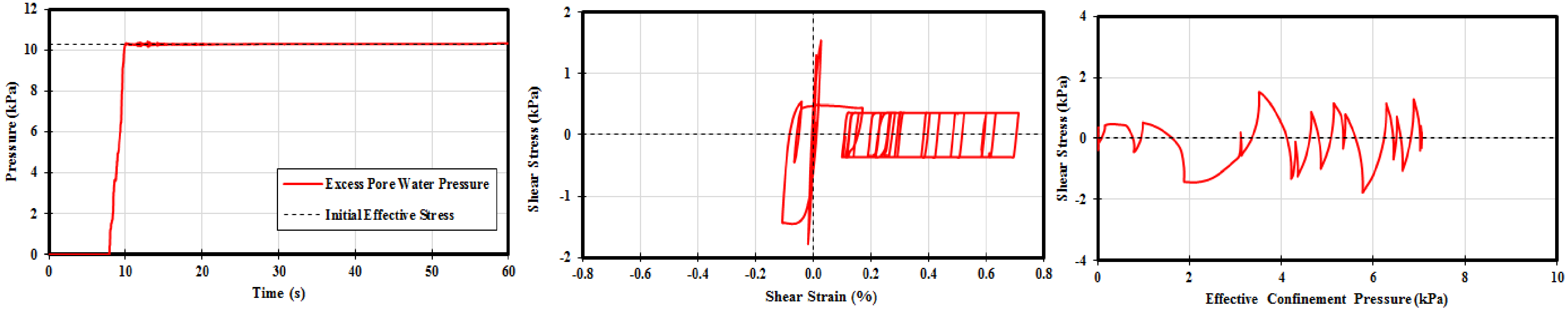
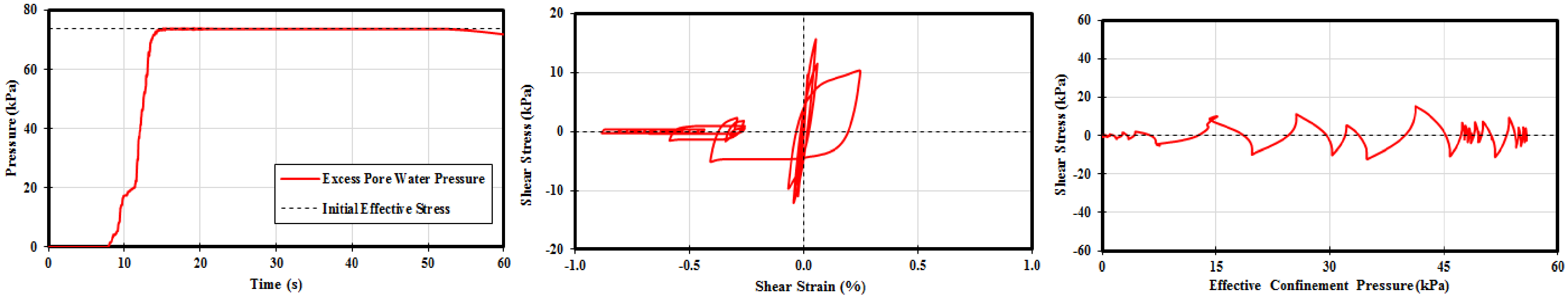


Fig.7 Liquefaction resistance curve comparison for all liquefiable layers from element simulations

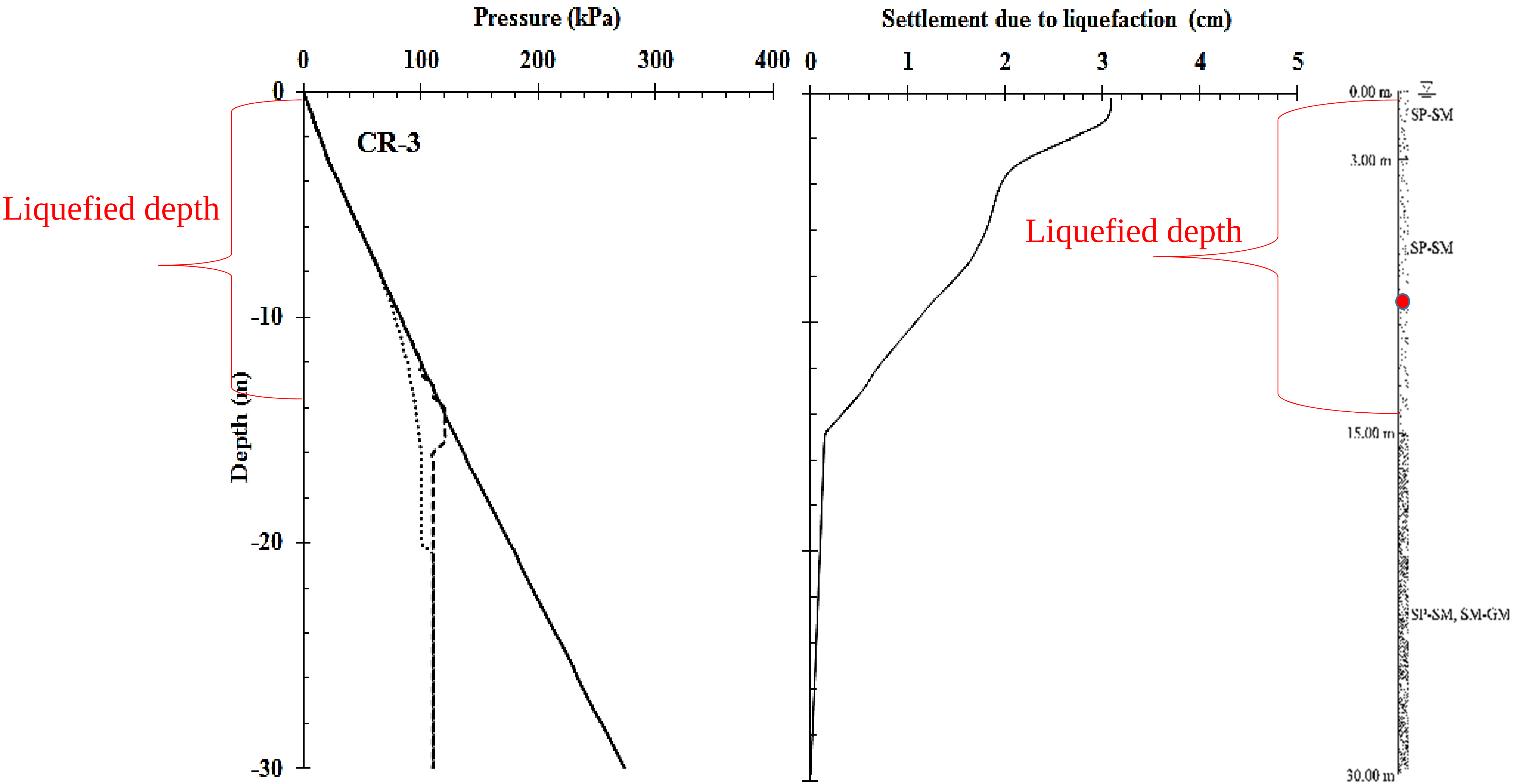


CR-3 (at 1.5 m)

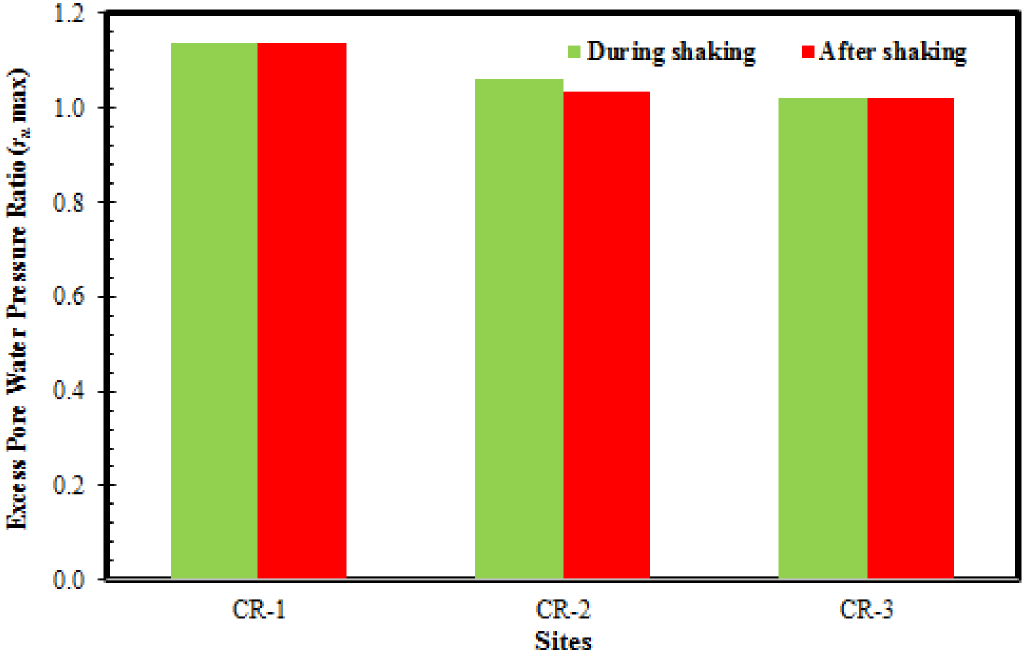


CR-3 (at 13 m)

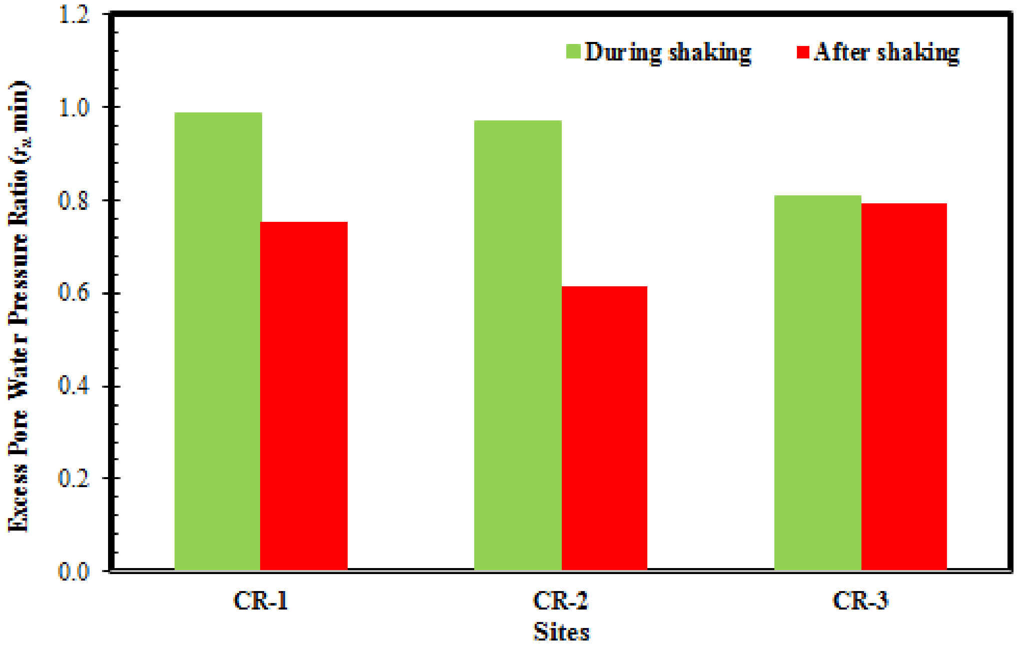
Pore water pressure and settlement due to liquefaction



Maximum-minimum excess pore water pressure ratio



Maximum excess pore water pressure ratio during and after shaking



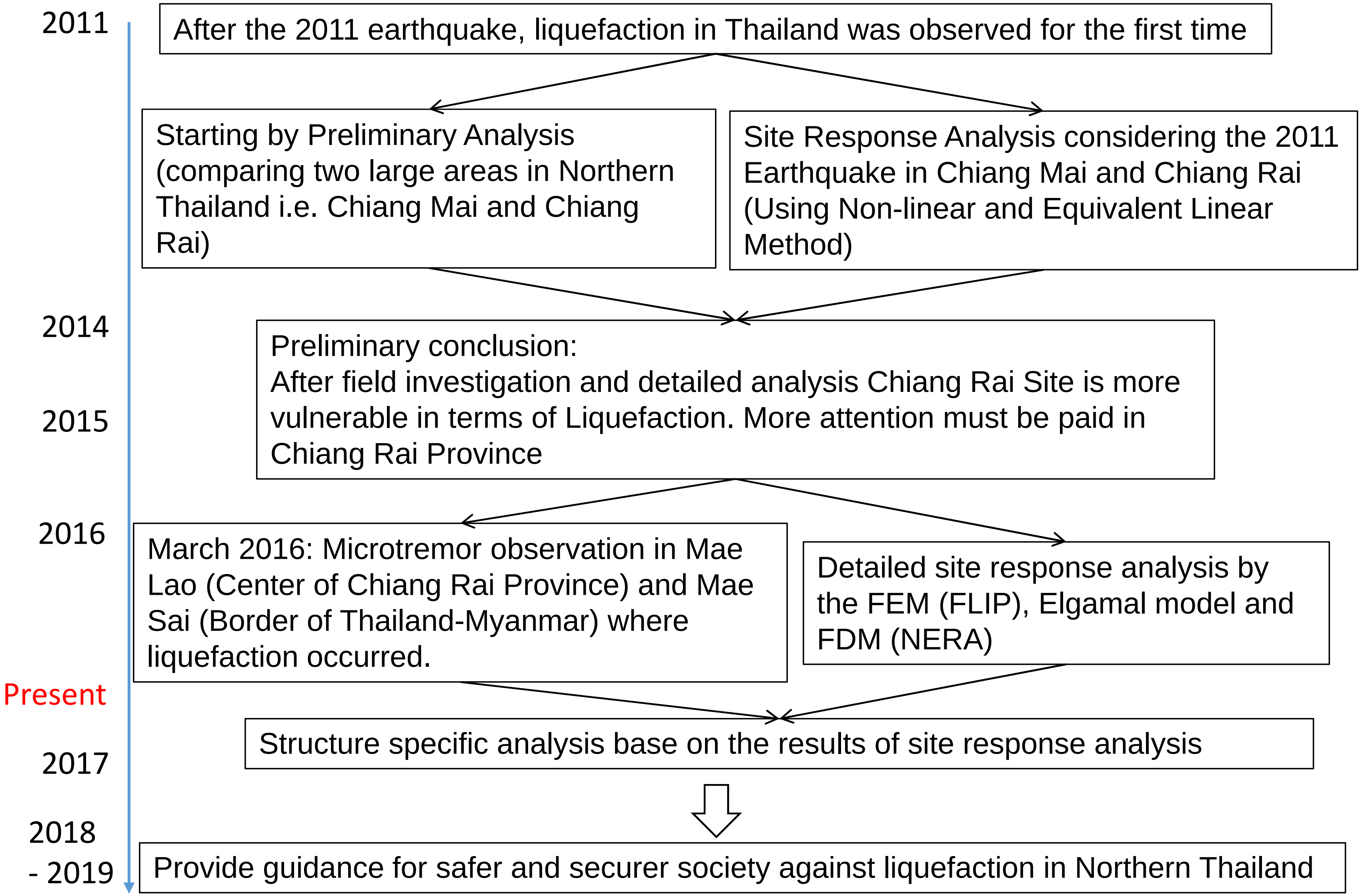
Minimum excess pore water pressure ratio during and after shaking

Conclusions (Numerical analysis)

Due to 24 March 2011 earthquake or Tarlay earthquake;

- Northern Thailand experienced heavy damage and catastrophic hazard. Liquefaction might be one of the major causes of disaster.
- Liquefaction was probable at upper 14 m layer of SP and SM with lower SPT-N value at CR-3 site.
- Based on the parametric studies, there are several factor influencing the excess pore water pressure ratio, such as fines content of soil type, and effective confining pressure.

Progress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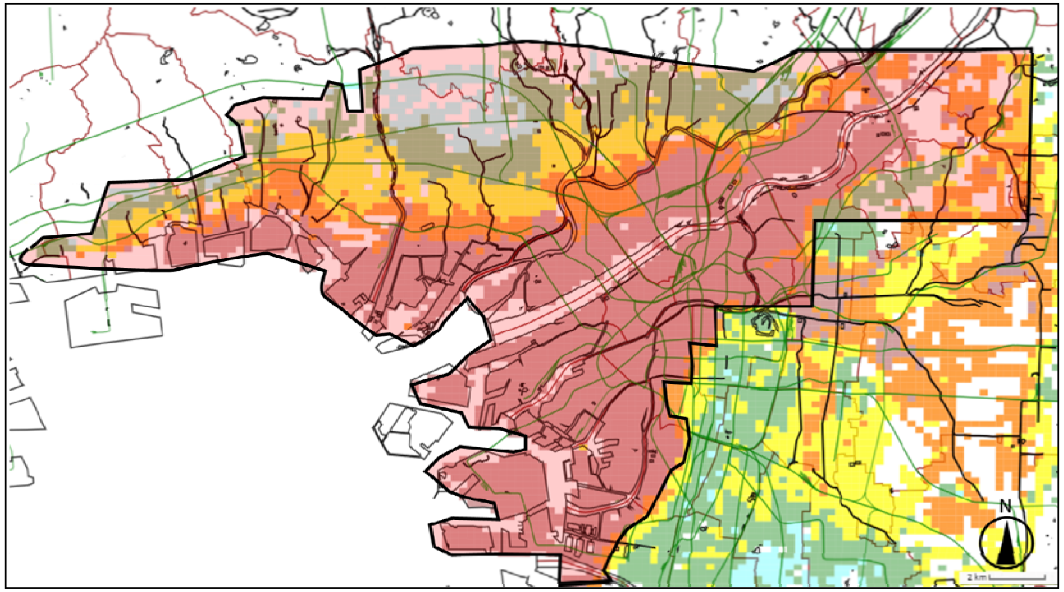
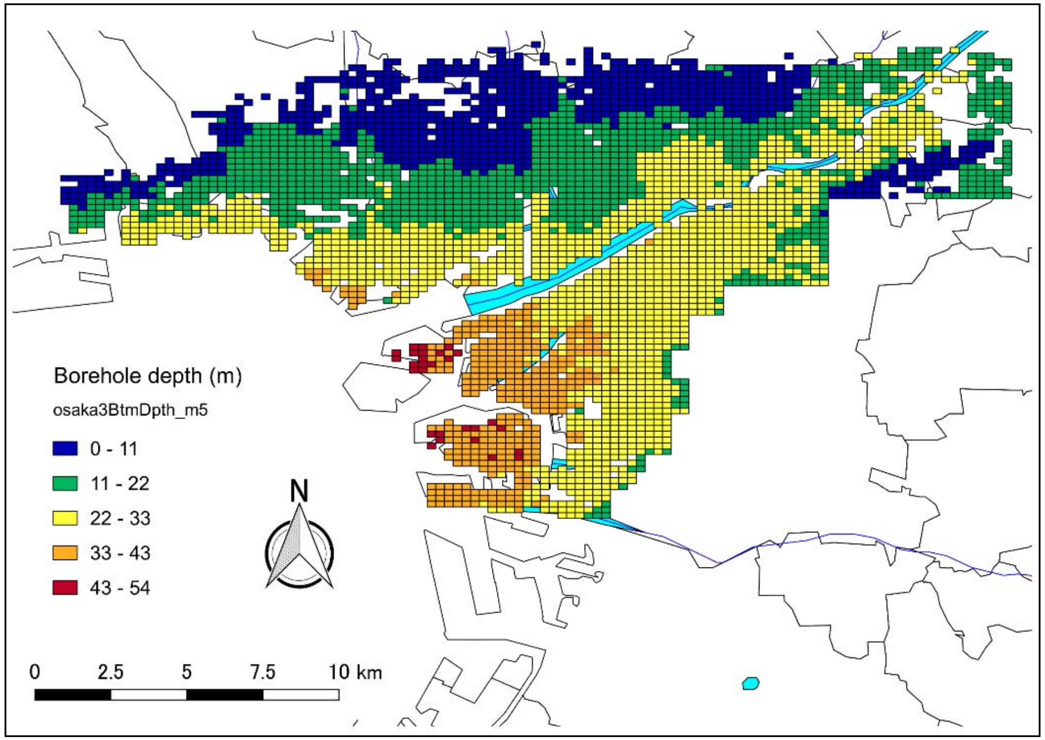
Possible future direction



KG-R Geotechnical Database for Osaka area
(SPT-N, soil classification, density, fines content with depth)

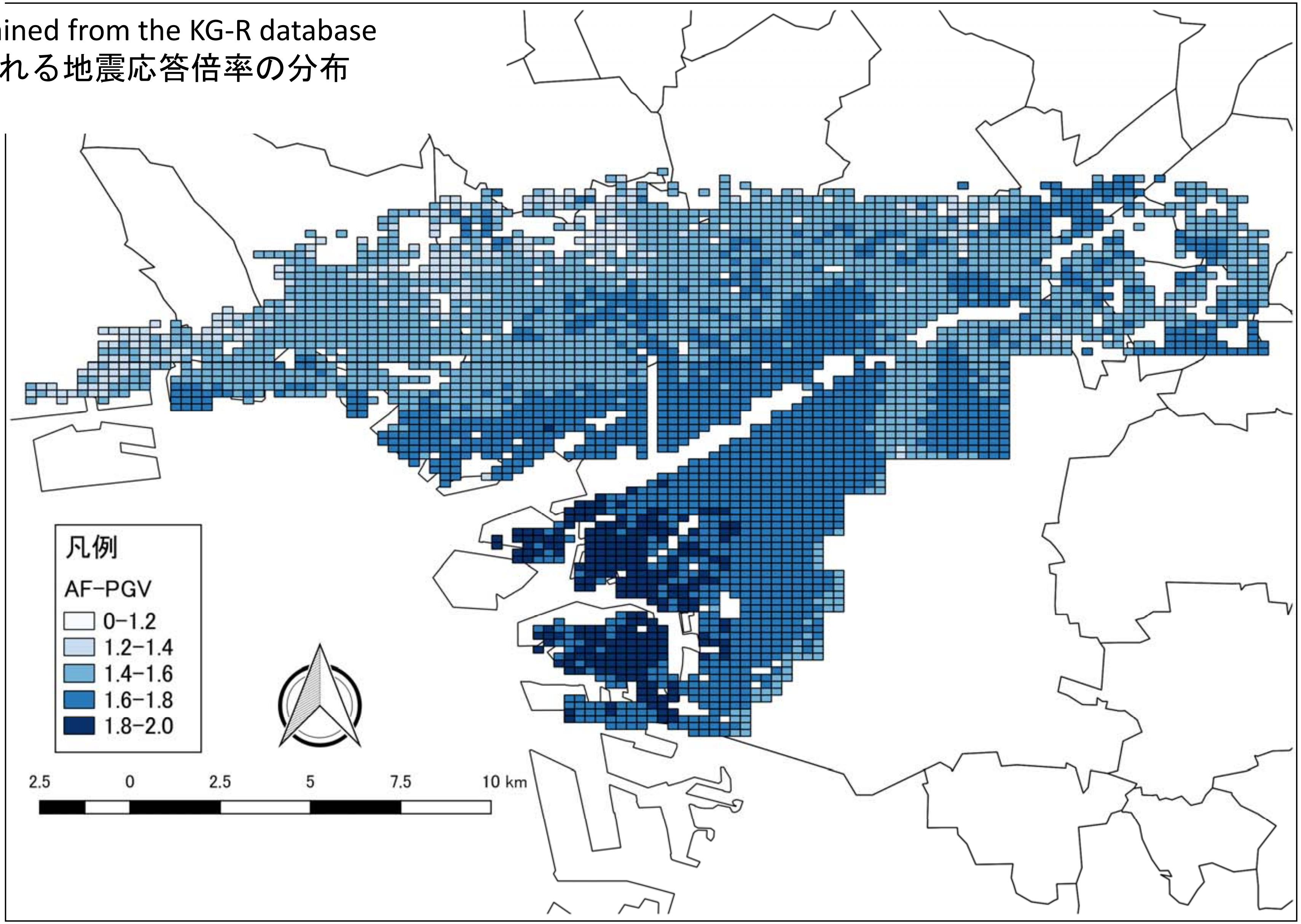
図9　関西地盤情報ライブラリー8)保存されている深度分布図と本研究で対象とする範囲(赤色網掛け)

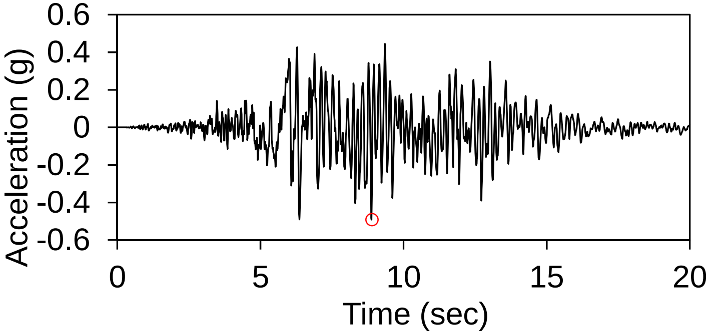


Distribution of borehole depths in KG-R database

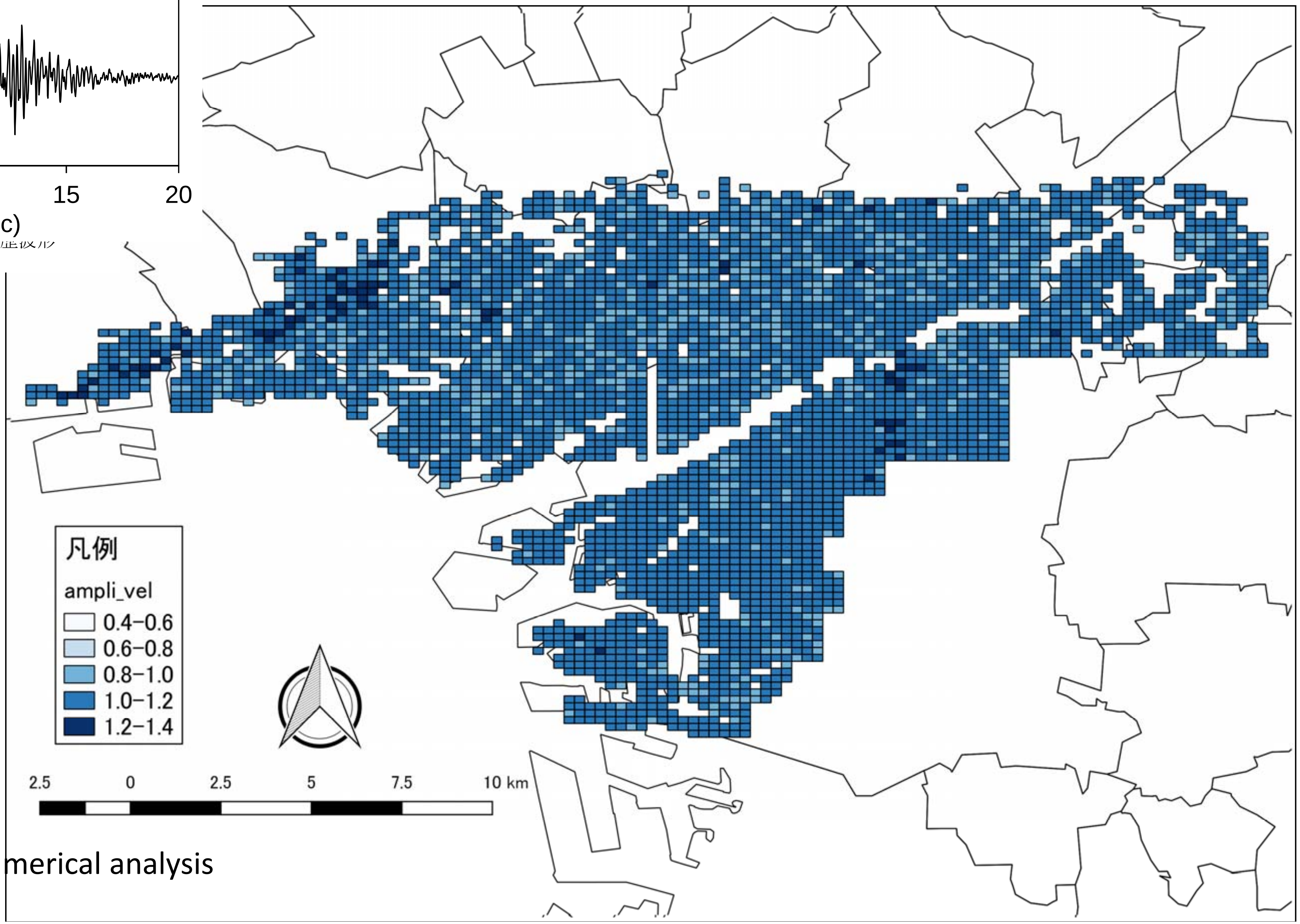
図15　最下端深度分布

Distribution of AVS30 obtained from the KG-R database
図19　AVS30から求められる地震応答倍率の分布





2016 Kumamoto Eq.
K-Net (KMM005)



Site amplification factor by numerical analysis

図18　地震応答倍率の分布

Thank you for your attention.

RESULTS and DISCUSSION

- Liquefaction duration

Liquefaction duration on liquefiable layer

Site	Liquefaction Duration (s)	
	Maximum	Minimum
CR-1	40	0
CR-2	43	39
CR-3	50	39

- Percentage of total r_u on overall sand layers and impacted depth

Percentage of r_u in sand layer.

Total r_u in overall sand layer (%)	Sites		
	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

Impacted depth based on r_u.

Impacted depth (m)	Sites		
	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