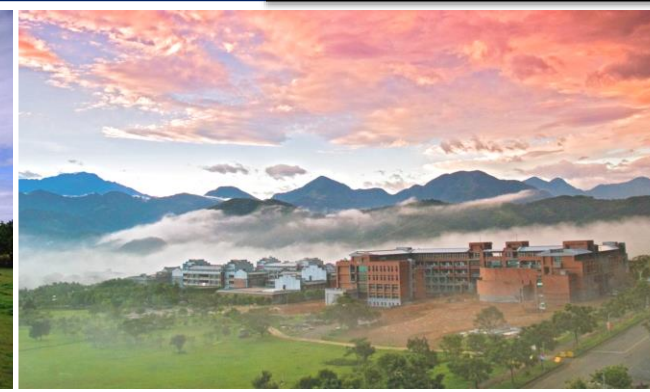
Seminar presentation

Mar 06, 2018
National Chi Nan University

加勁擋土牆面變形預測與可靠度分析



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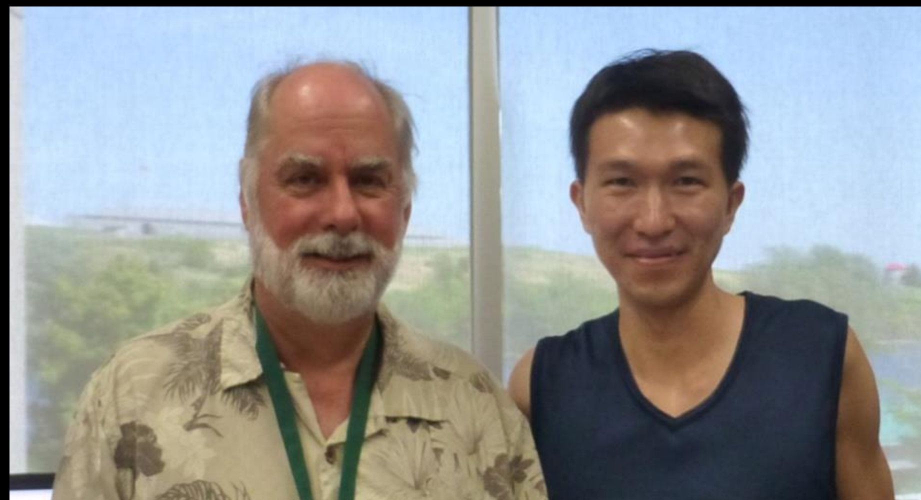
國立暨南國際大學
National Chi Nan University

Resume I



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Resume II

Publication List

•Lin Bo Hung, Yan Yu, Richard J. Bathurst and Chia-Nan Liu. 2016. Deterministic and Probabilistic Prediction of Facing Deformations of Geosynthetic-reinforced MSE Walls using a Response Surface Approach, Geotextiles and Geomembranes, Volume 44, Pages 813–823.

•Yan Yu.,Bo-Hung Lin.,Richard J. Bathurst.,(2015) Influence of choice of small- and large-strain mode in FLAC on soil-geosynthetic interaction problems,GEOQuebec 2015, conference paper.

•Liu**, C. N.**, Ching, J. Y., Lau, D. W., and Lin, B. H., (2012), Reliability analysis of geosynthetic-reinforced soil segmental wall under the constrain of maximum wall face displacement, Fifth Asian-Pacific Symposium on Structural Reliability and its Applications (5APSSRA), 23-25 May 2012, Singapore.

•Liu**, C. N.**, Wu, P. K., Ye, J. Y., and Lin, B. H., (2011), Observations of the soil particle movement during direct shear tests on soil-geosynthetic interfaces, International Symposium on Deformation Characteristics of Geomaterials, August 31~September 3, 2011, Seoul, Korea.

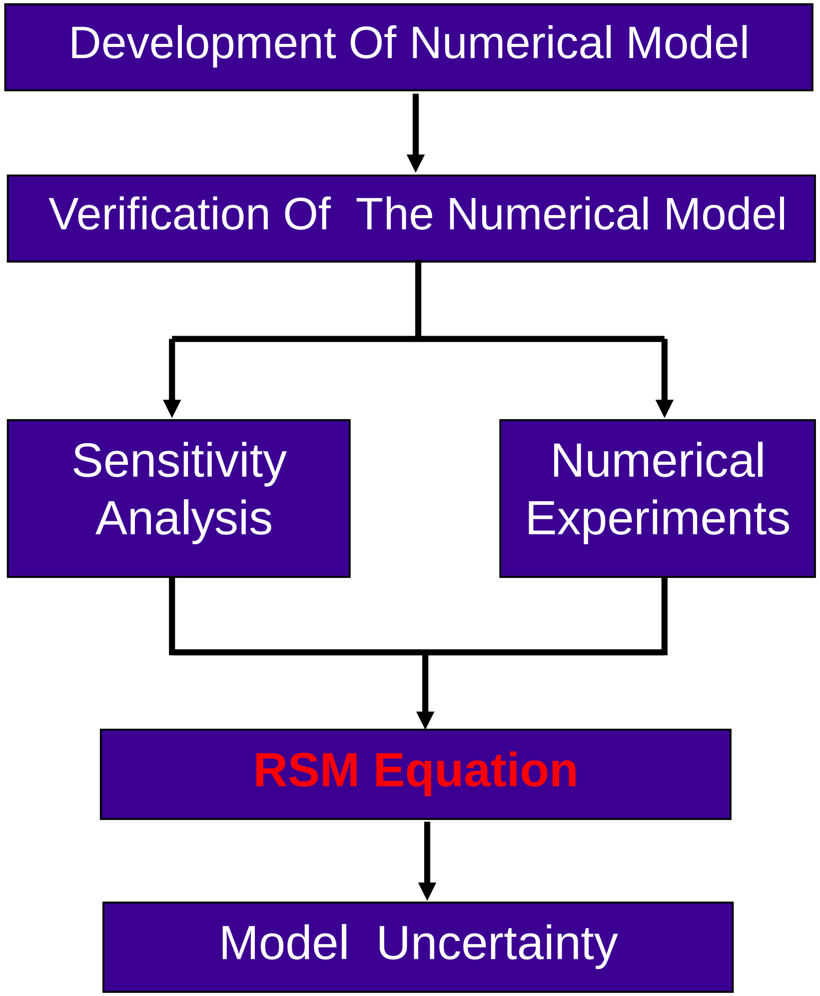
•Liu**, C. N.**, Zornberg J. G., Chen T. C., Ho, Y. H., and Lin B. H., (2009) Behavior of Geogrid-Sand Interfaces in Direct Shear Mode, ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 135, No. 12, 1863-1871.

Outline of Presentation

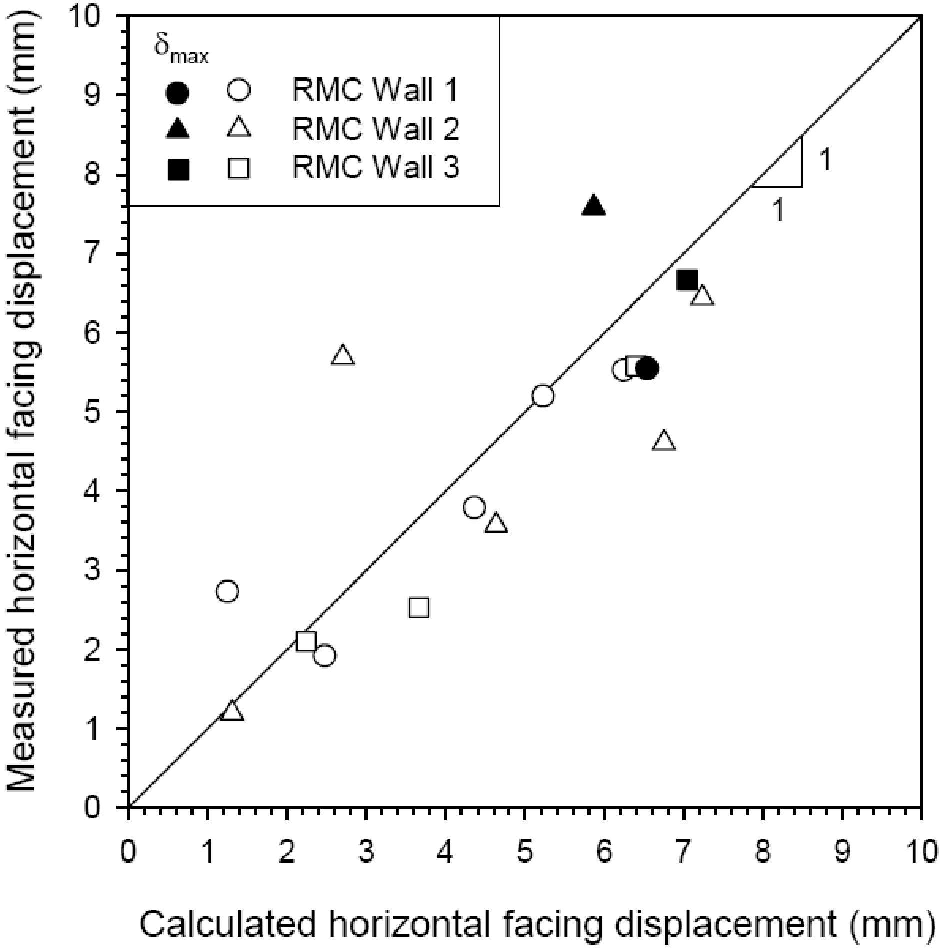
- I. Introduction.
- II. Section 2
- III. Section 3
- IV. Section 4
- V. Section 5
- VI. Section 6
- VII.Conclusions.

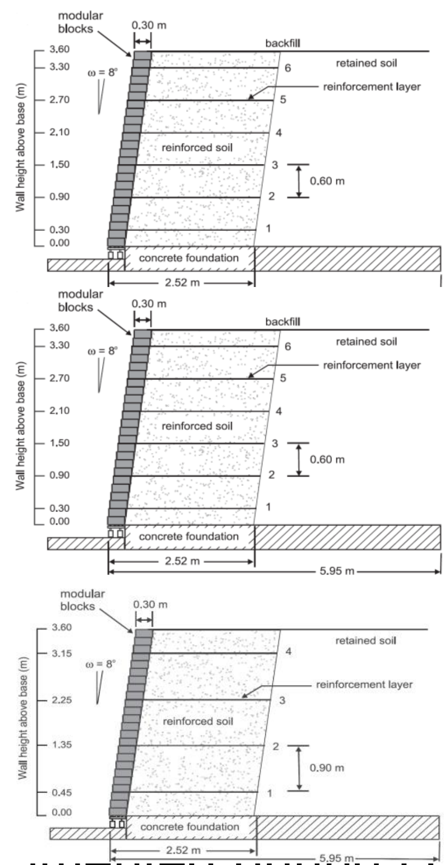
Introduction

Geosynthetic reinforced soil walls are a well-known and accepted mechanically stabilized earth (MSE) technology to perform the earth retaining wall function. Among a wide range of facing treatments in use today are walls with a modular concrete facing system most often constructed from molded dry-cast masonry (segmental) blocks. This study describes a methodology based on the response surface method (RSM) to express wall deformations of an example population of geogrid reinforced modular block soil walls in both deterministic and probabilistic terms.



Section 2
Segmental Block Walls





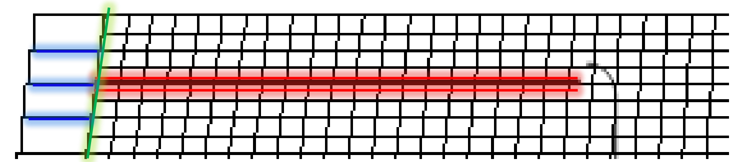
RMC Wall1

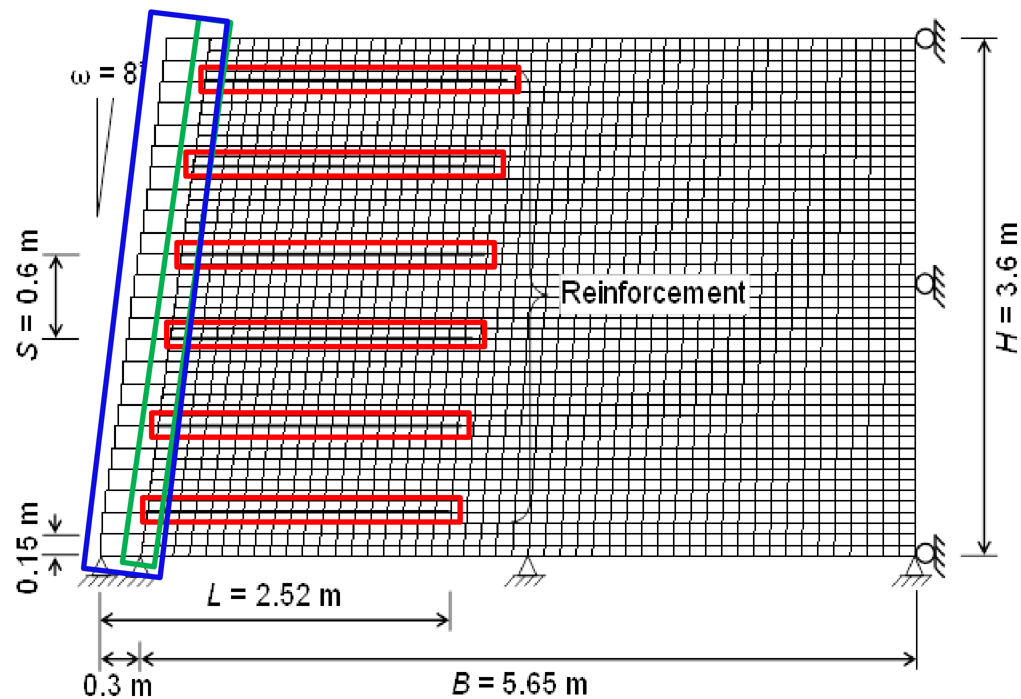
RMC Wall2

RMC Wall3

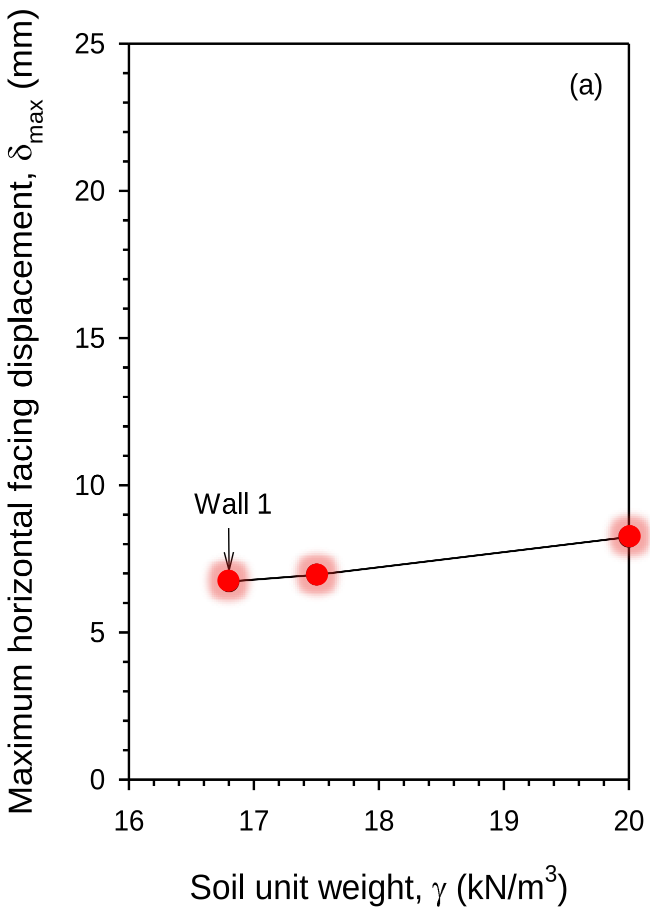
Numerical model

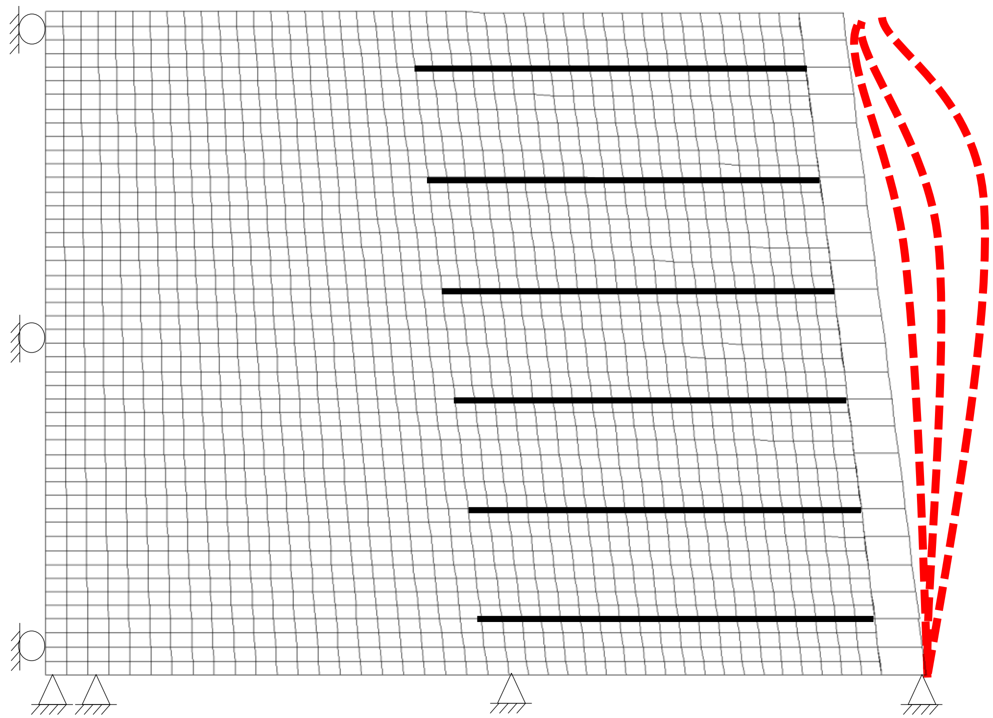
Parameter	Value
Reinforcement-soil interface	
Grout stiffness, $K_{s,g}$ (MN/m/m)	1
Grout frictional resistance, ϕ_g (degree)	44
Grout cohesive strength, C_g (kN/m)	2*
Soil-block interface	
Friction angle, ϕ_{sb} (degree)	44
Dilation angle, ψ_{sb} (degree)	11
Cohesion, c_{sb} (kPa)	1
Normal stiffness, $k_{n,sb}$ (MPa/m)	100
Shear stiffness, $k_{s,sb}$ (MPa/m)	1
Block-block interface	
Friction angle, ϕ_{bb} (degree)	57
Dilation angle, ψ_{bb} (degree)	0
Cohesion, c_{bb} (kPa)	46
Normal stiffness, $k_{n,bb}$ (MPa/m)	1000
Shear stiffness, $k_{s,bb}$ (MPa/m)	40



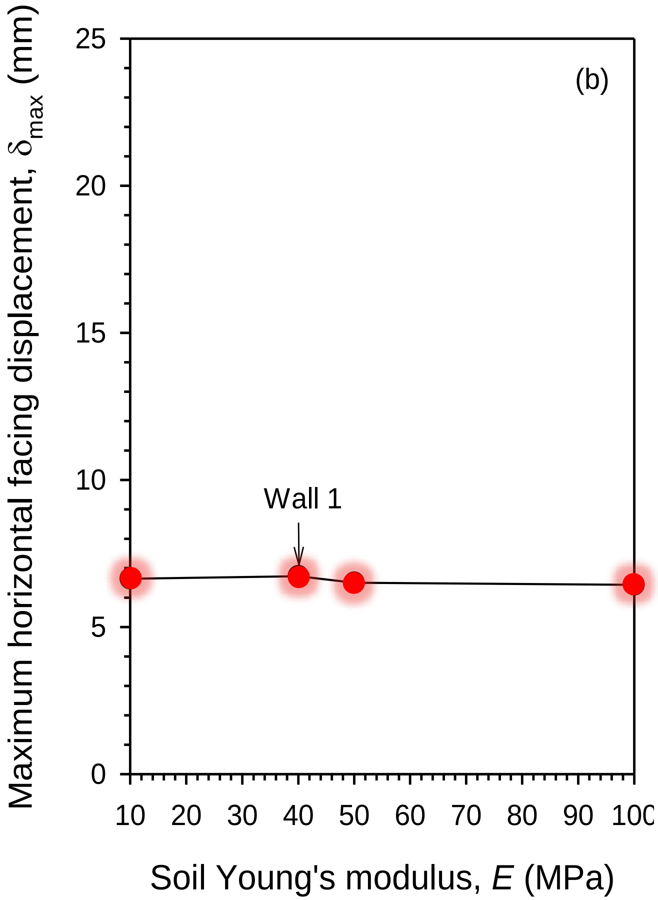


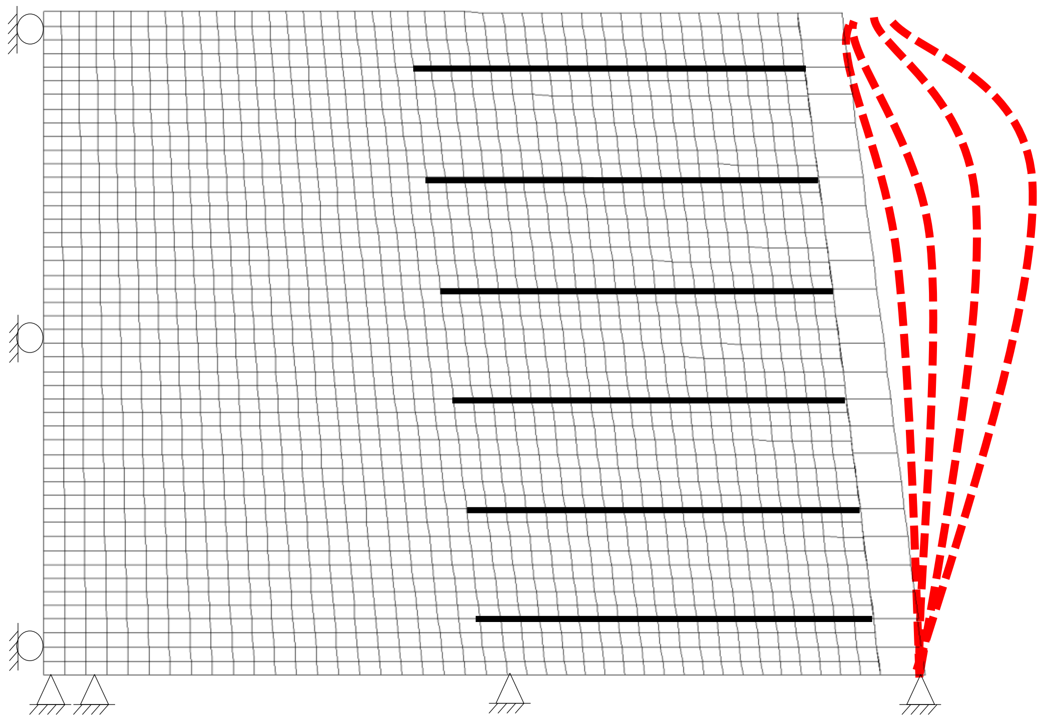
Sensitivity Influence Of Numerical Model I



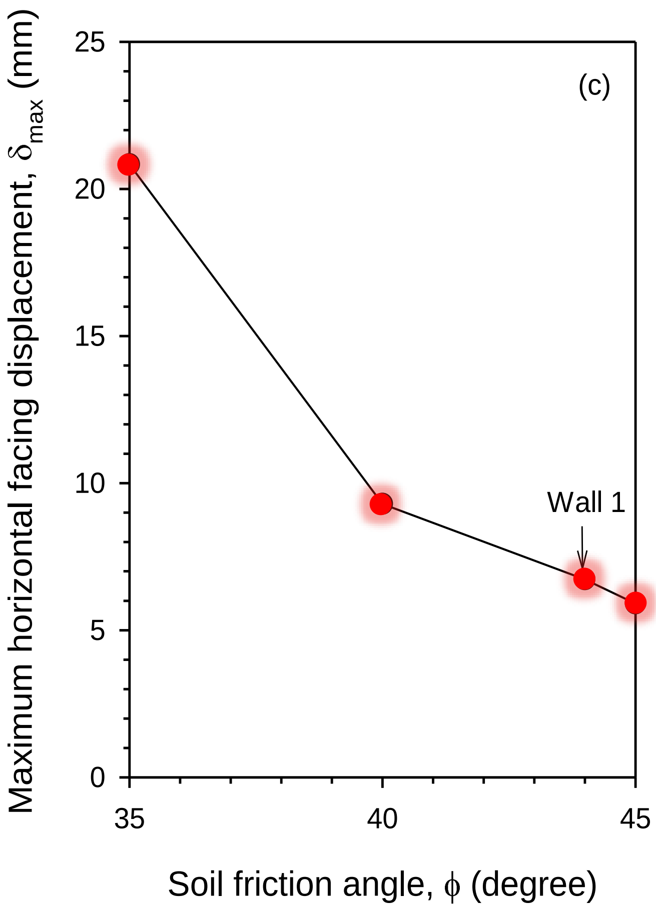


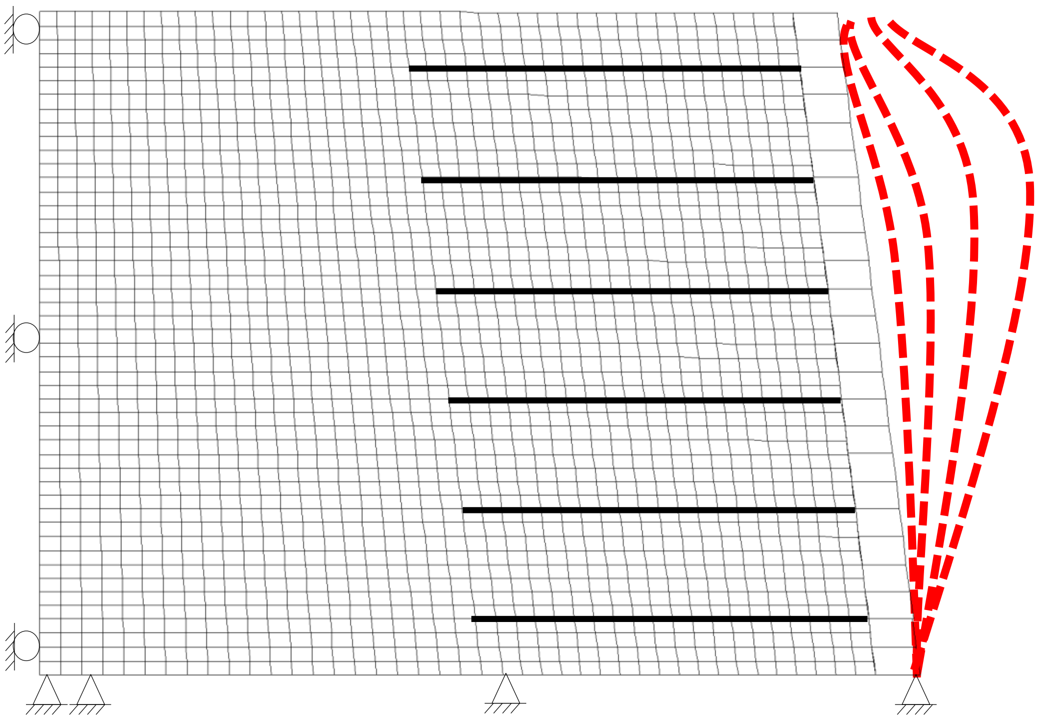
Sensitivity Influence Of Numerical Model II



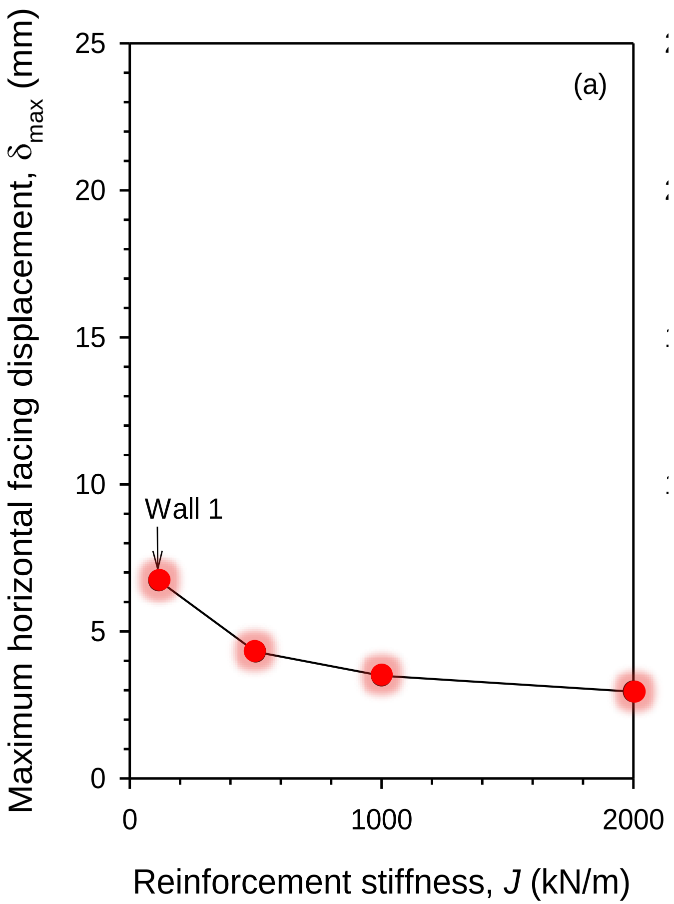


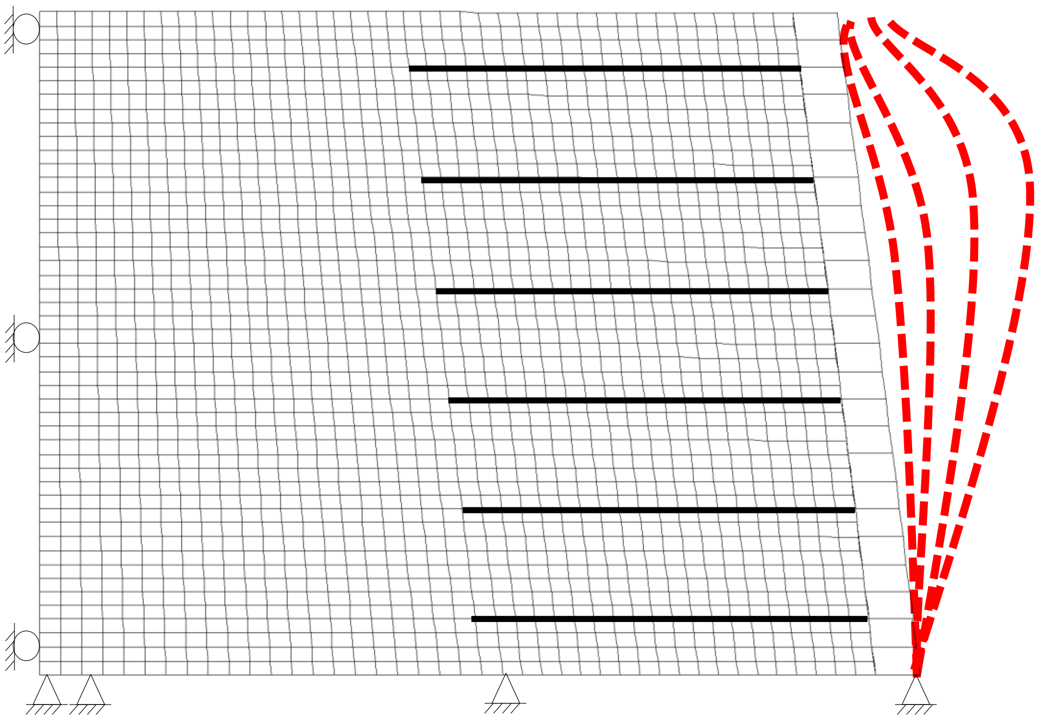
Sensitivity Influence Of Numerical Model III



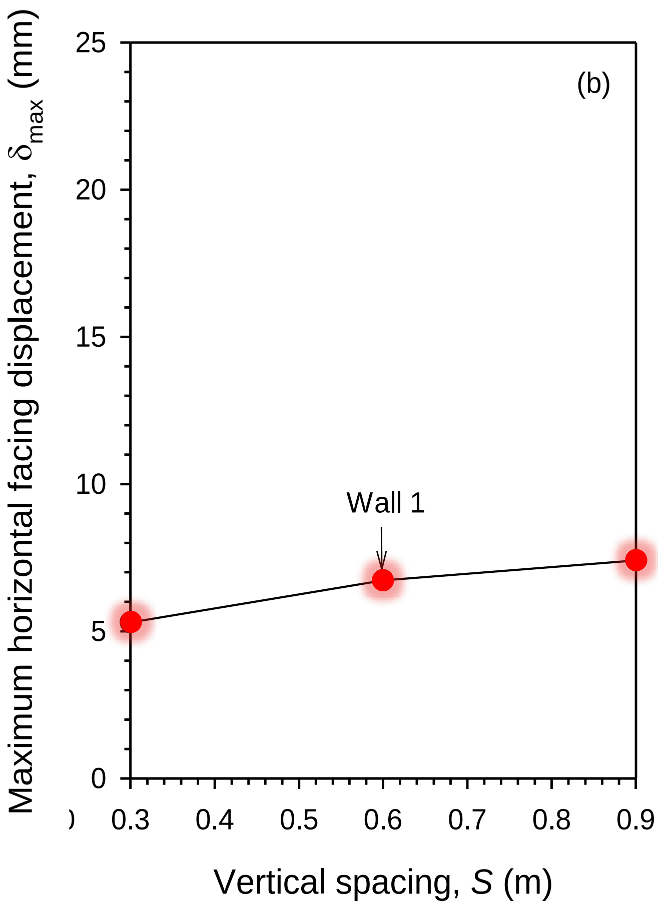


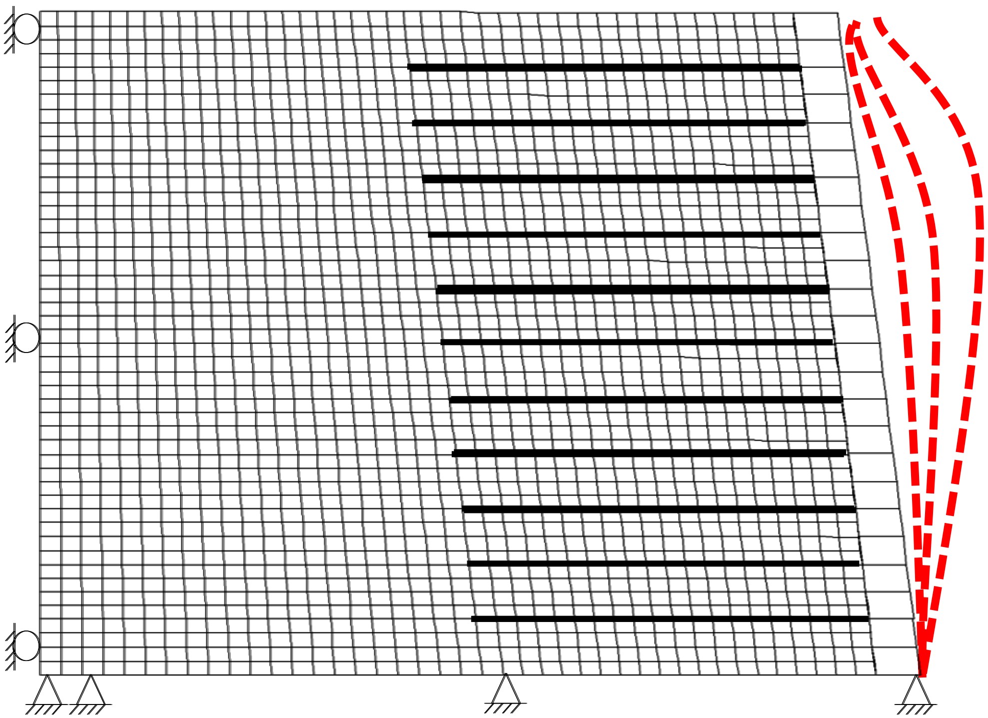
Sensitivity Influence Of Numerical Model IV



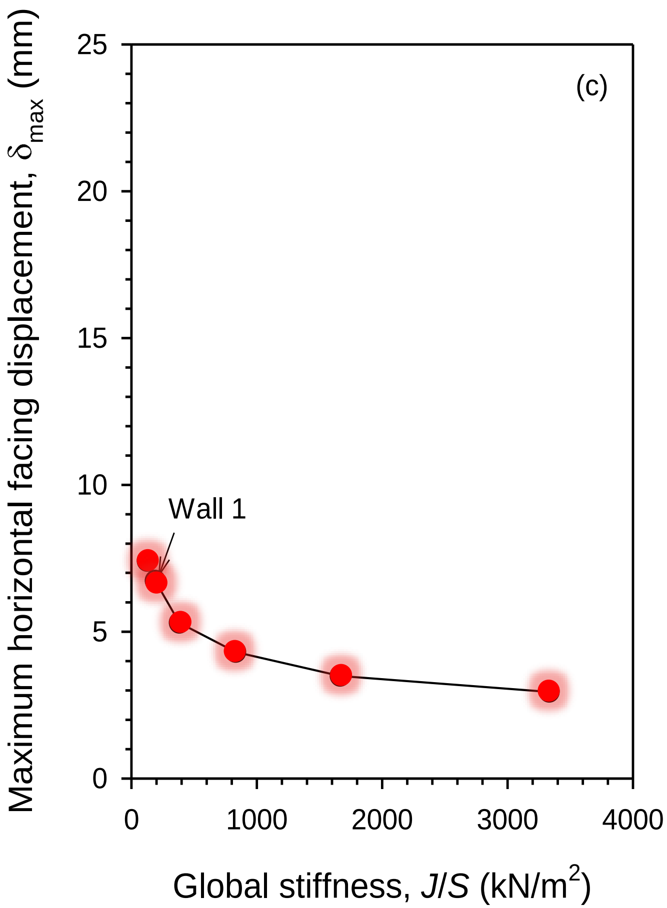


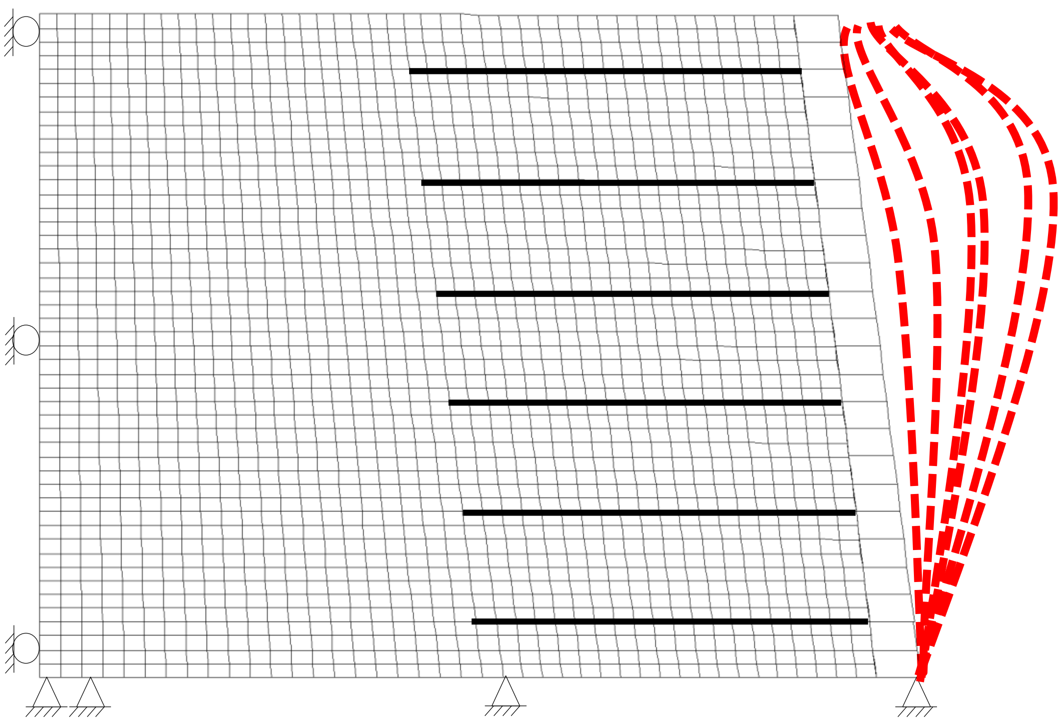
Sensitivity Influence Of Numerical Model V



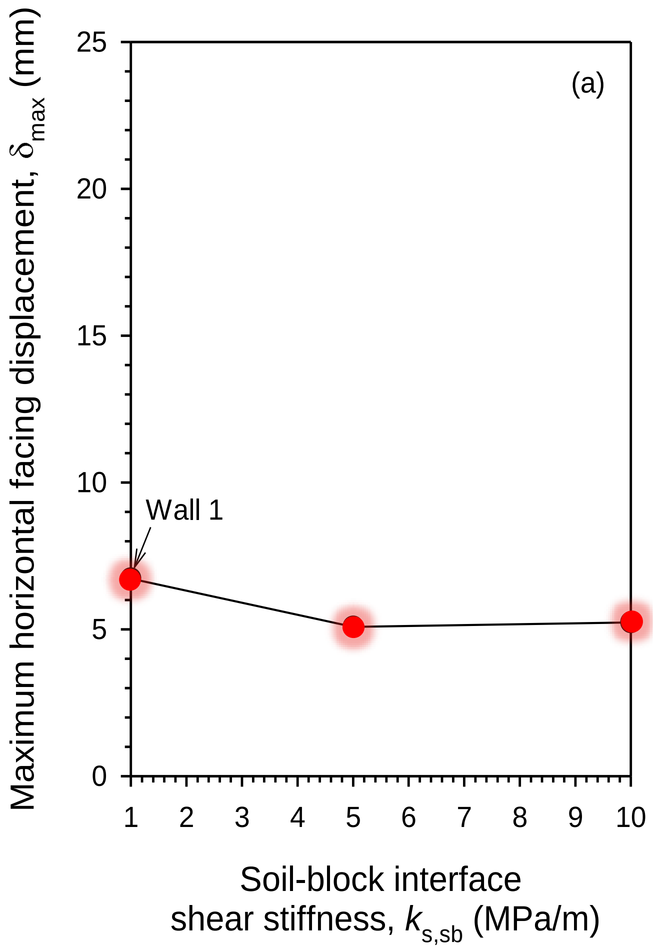


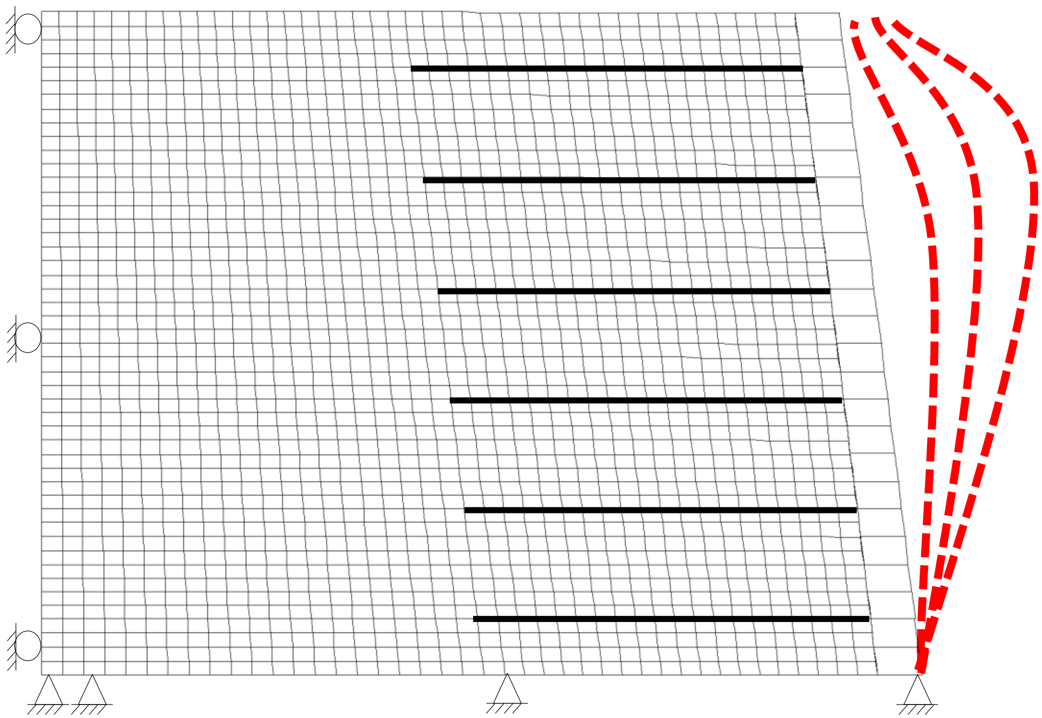
Sensitivity Influence Of Numerical Model VI



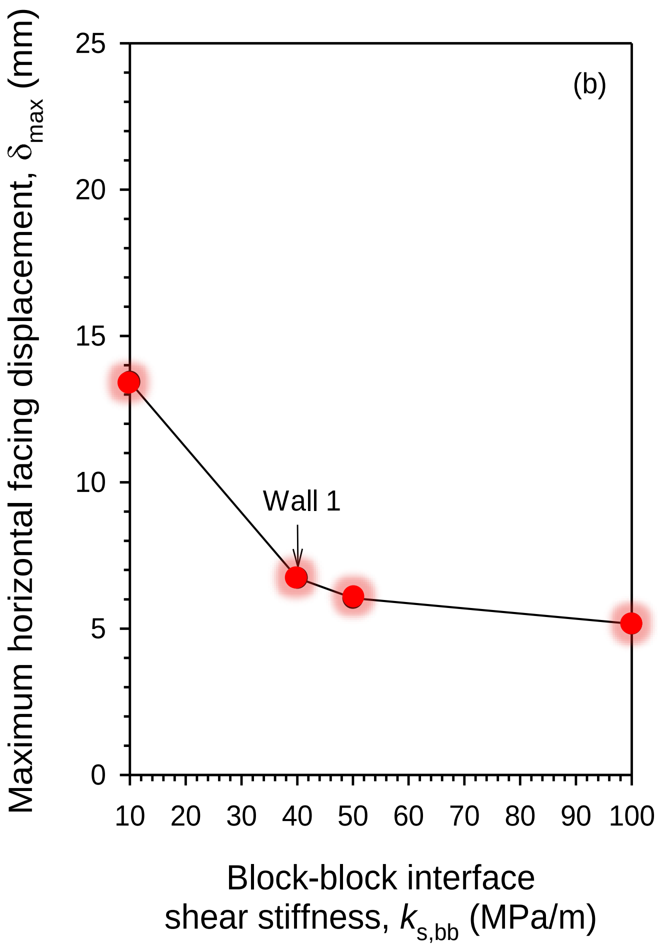


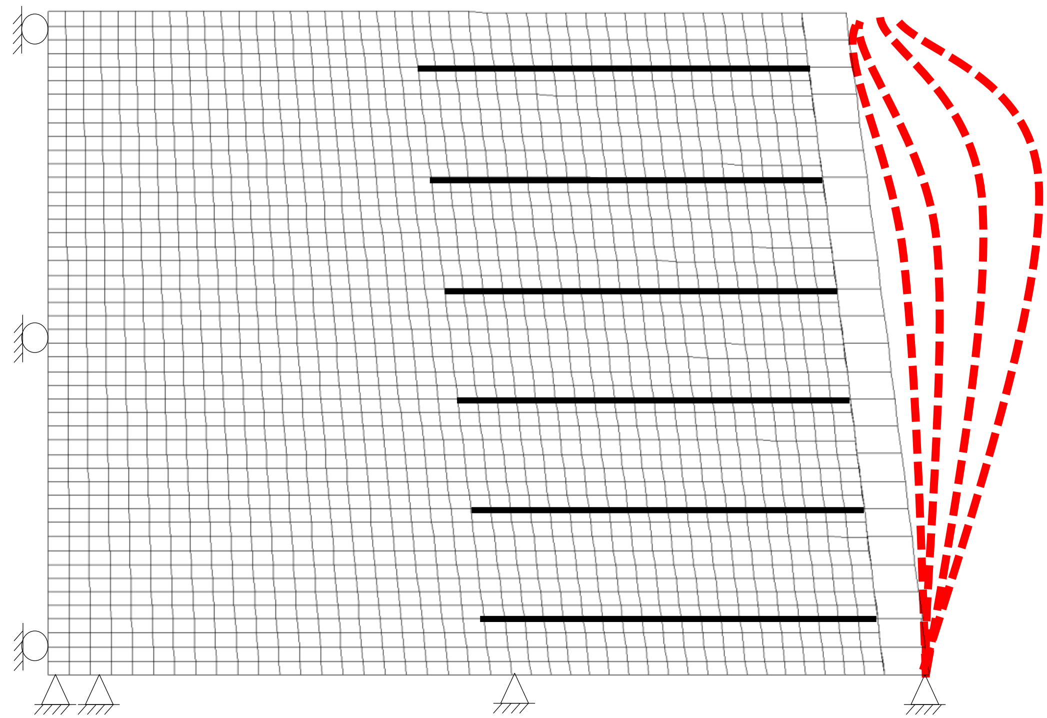
Sensitivity Influence Of Numerical Model VII



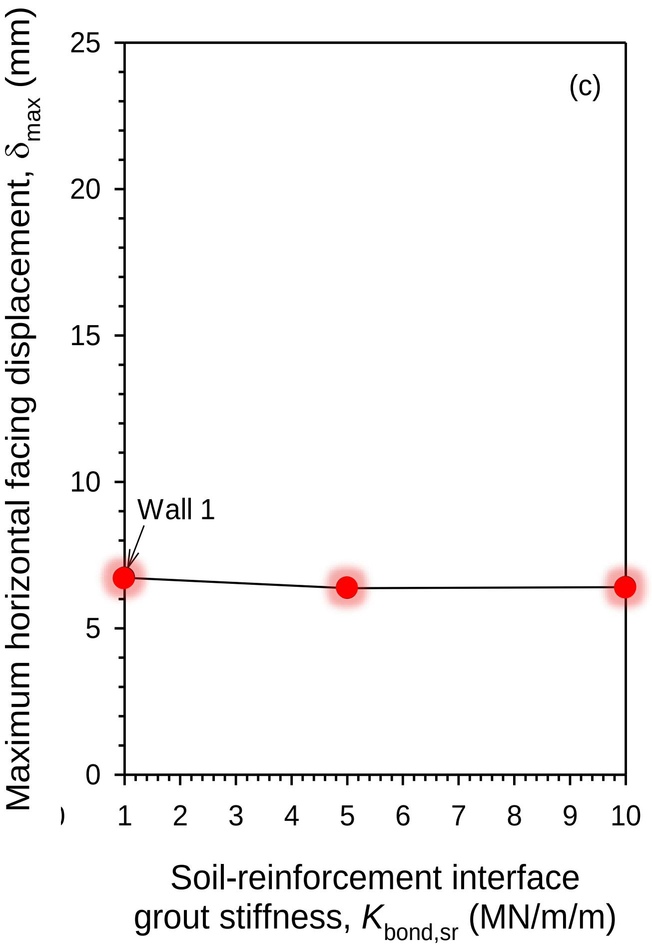


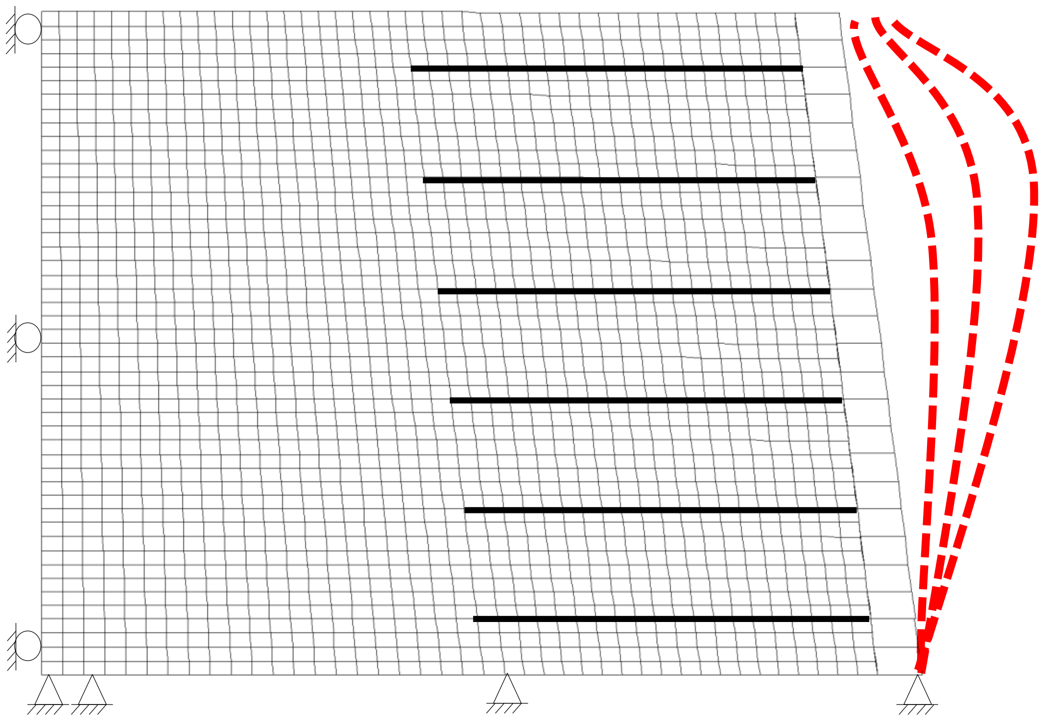
Sensitivity Influence Of Numerical Model VIII



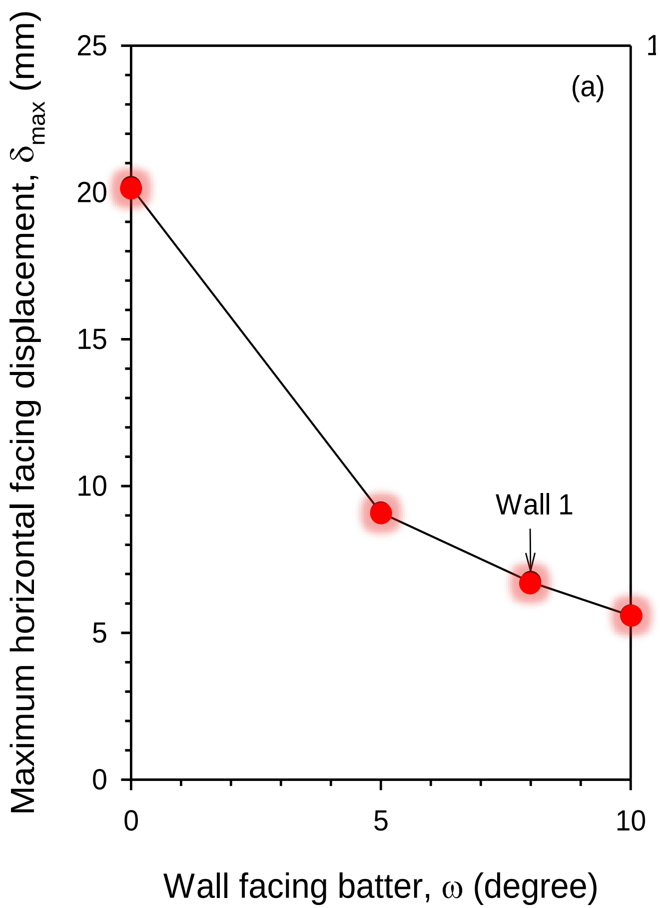


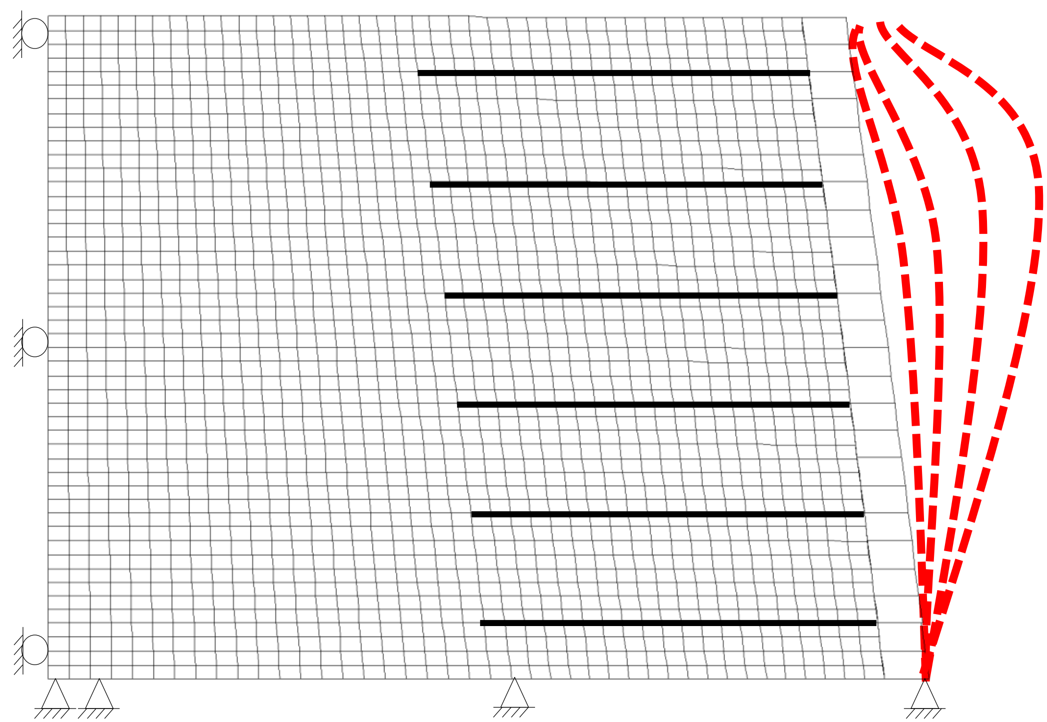
Sensitivity Influence of Numerical Model IX



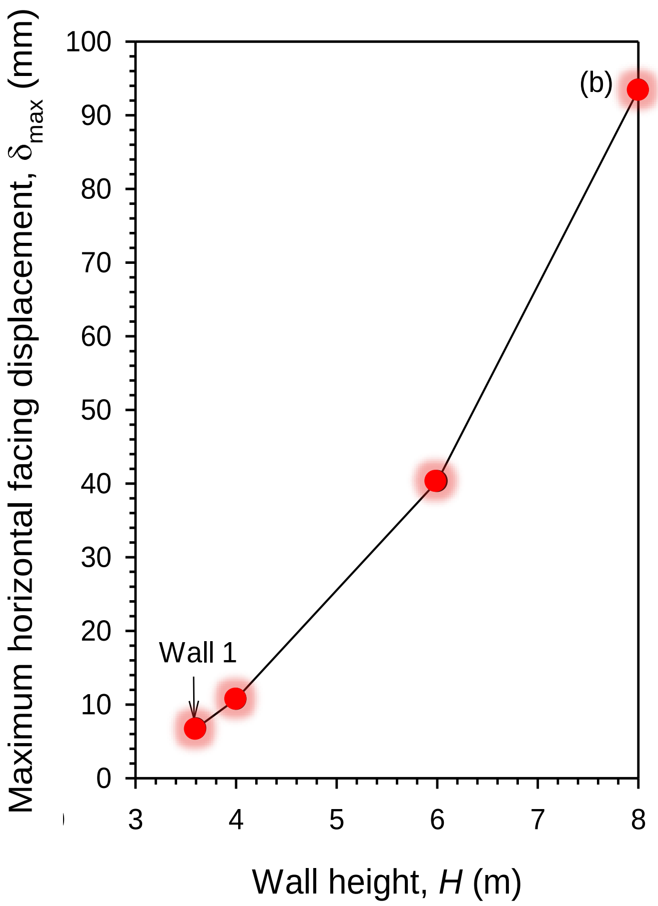


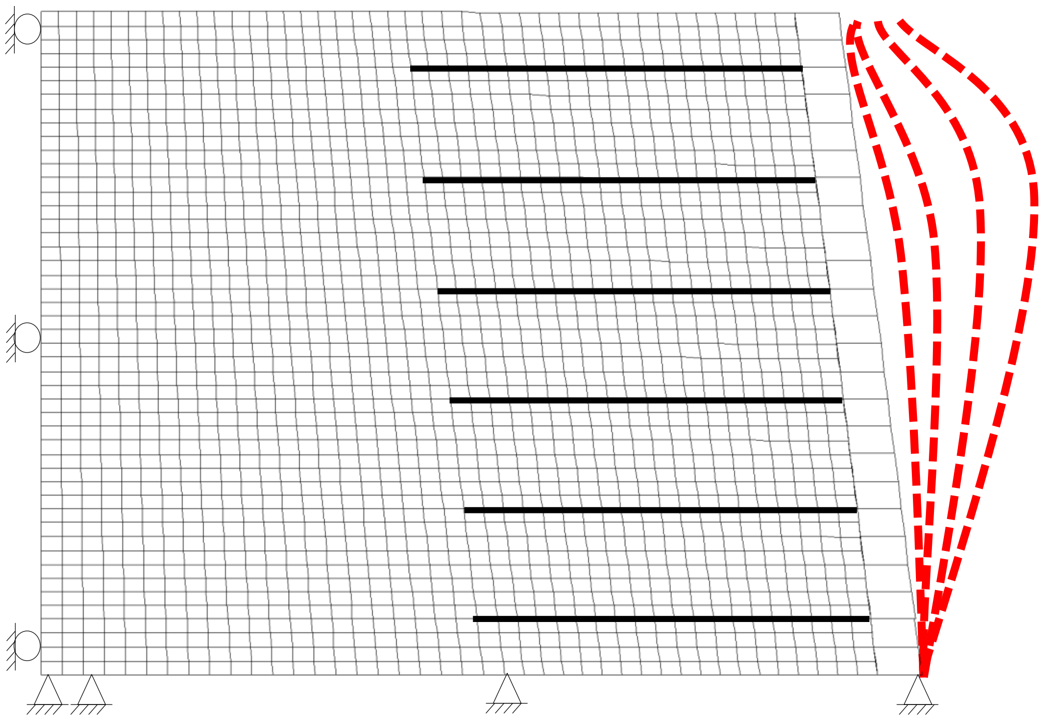
Sensitivity Influence of Numerical Model X



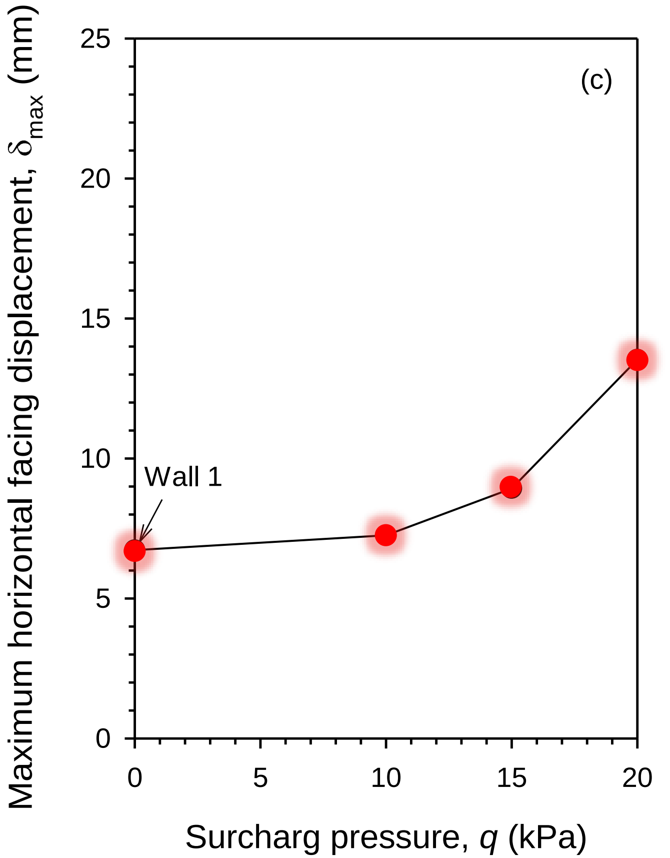


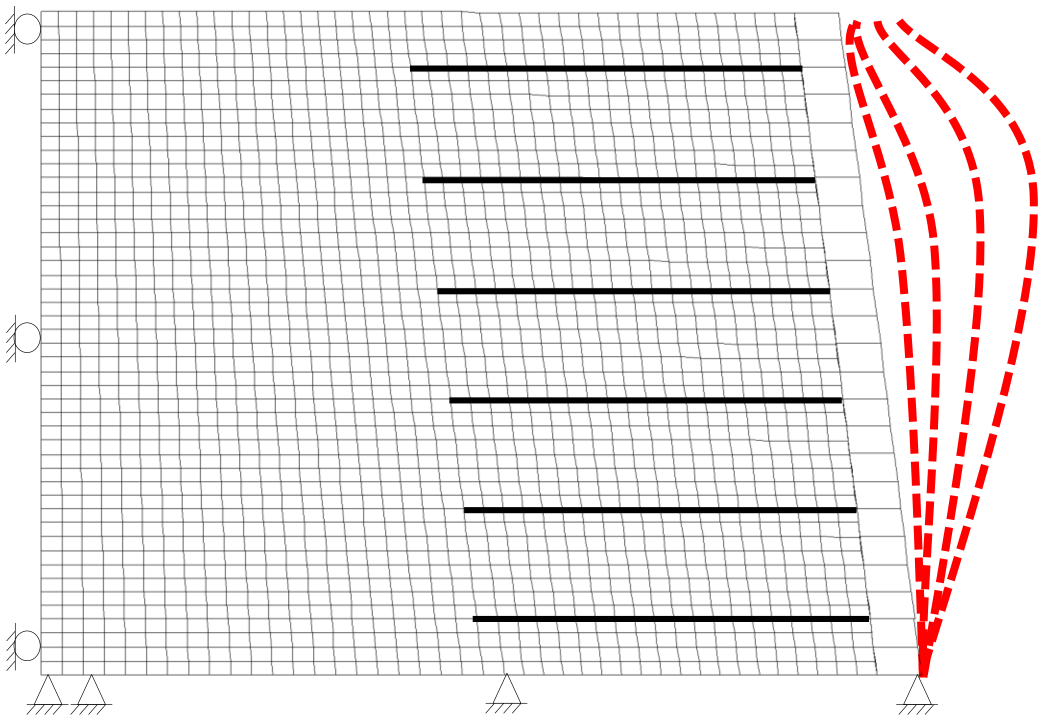
Sensitivity Influence of Numerical Model XI





Sensitivity Influence of Numerical Model XII

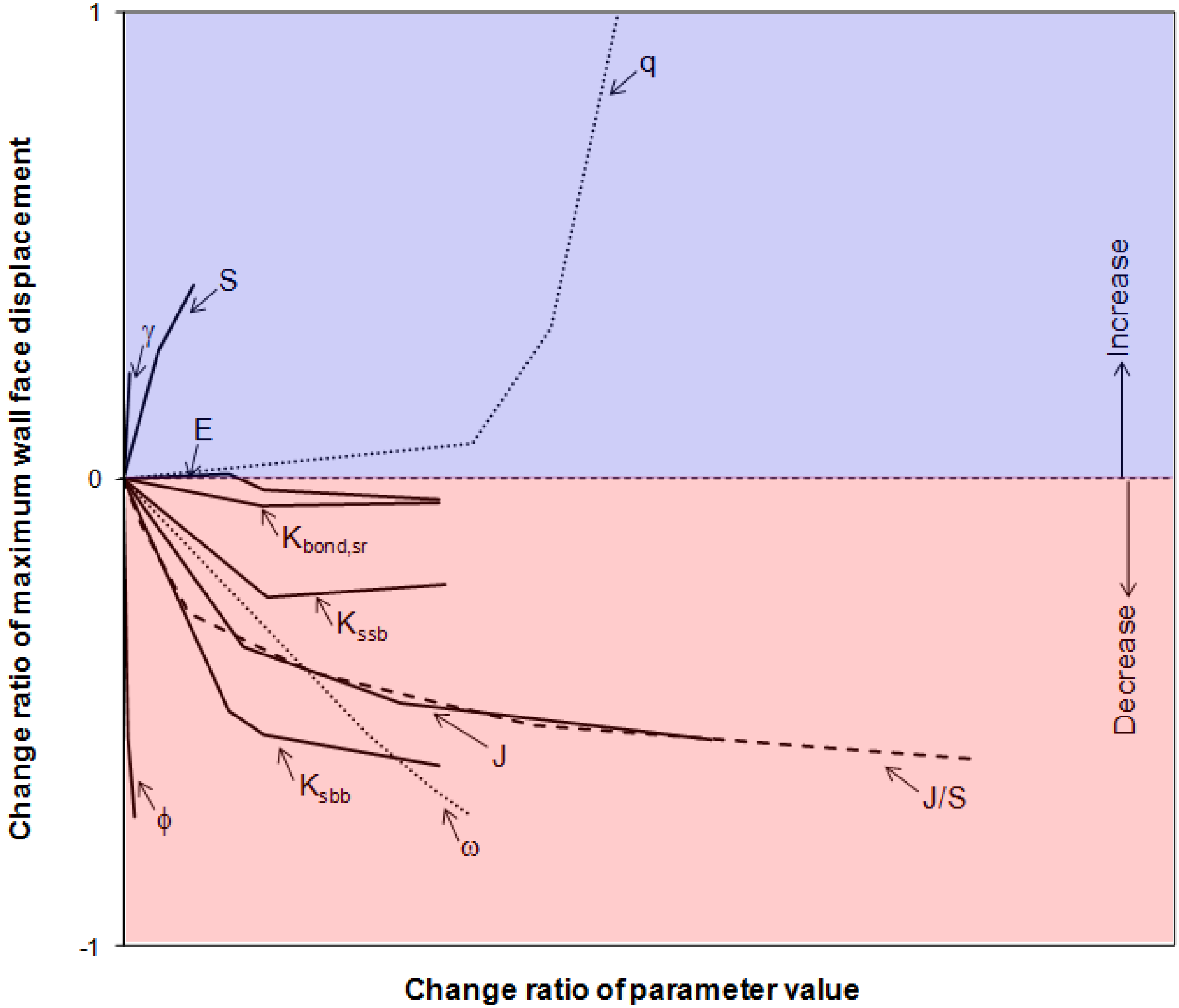




Sensitivity Influence of Numerical Model XIII

Unit weight of backfill soil
Vertical Spacing
Surcharge

Elastic modulus of backfill soil
Soil friction angle
Facing batter of wall
Reinforcement axial stiffness
Grout stiffness (Reinf.- soil)
Shear stiffness (block - soil)
Shear stiffness (block - block)

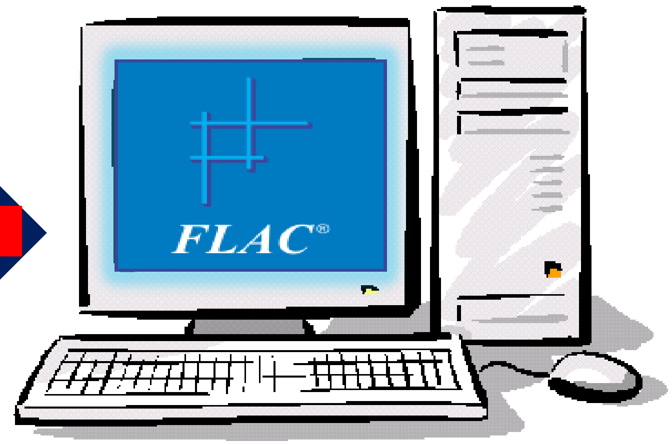


Numerical for Experiments MSE Wall I

Parameter	Value
Wall height, H (m)	4, **6**, 8
Facing batter, ω (degree)	0, **5**, 10
Soil friction angle, ϕ (degree)	35, **40**, 45
Soil dilation angle, ψ (degree)	ϕ-30
Cable grout frictional resistance, ϕ_g (degree)	ϕ
Soil-block interface friction angle, ϕ_{sb} (degree)	ϕ
Soil-block interface dilation angle, ψ_{sb} (degree)	ϕ-30
Reinforcement axial stiffness, J (kN/m)	500, **1000**, 2000
Reinforcement ultimate strength, T_{ult} (kN/m)	$0.1 \times J$
Block-block interface shear stiffness, $k_{s,bb}$ (MPa/m)	10, **50**, 100
Surcharge pressure, q (kPa)	0, **10**, 20

Numerical Experiments MSE Wall II

Test No	q (Pa)	S (m)	H (m)	J (N/m)	Ksbb (Pa/m)	φ (degree)	ω (degree)	δ max (m)
1	0	0.6	4	500000	10000000	35	0	0.023488
2	10000	0.6	4	500000	10000000	35	0	0.025512
3	20000	0.6	4	500000	10000000	35	0	0.035963
4	0	0.6	4	1000000	10000000	35	0	0.015731
5	10000	0.6	4	1000000	10000000	35	0	0.01703
6	20000	0.6	4	1000000	10000000	35	0	0.023765
7	0	0.6	4	10000000	10000000	35	0	0.012039
8	10000	0.6	4	10000000	10000000	35	0	0.012969
9	20000	0.6	4	10000000	10000000	35	0	0.017534
10	0	0.6	4	500000	10000000	40	0	0.015709
11	10000	0.6	4	500000	10000000	40	0	0.016904
12	20000	0.6	4	500000	10000000	40	0	0.023816
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
727	0	0.6	4	1000000	10000000	35	10	0.015731
728	10000	0.6	4	1000000	10000000	35	10	0.01703
729	20000	0.6	4	1000000	10000000	35	10	0.023765



PC Performance of 729

PC response result

RSM Equation I

Test No	q (Pa)	S (m)	H (m)	J (N/m)	Ksbb (Pa/m)	φ (degree)	ω (degree)	δ max (m)
1	0	0.6	4	500000	10000000	35	0	0.023488
2	10000	0.6	4	500000	10000000	35	0	0.025512
3	20000	0.6	4	500000	10000000	35	0	0.035963
4	0	0.6	4	1000000	10000000	35	0	0.015731
5	10000	0.6	4	1000000	10000000	35	0	0.01703
6	20000	0.6	4	1000000	10000000	35	0	0.023765
7	0	0.6	4	10000000	10000000	35	0	0.012039
8	10000	0.6	4	10000000	10000000	35	0	0.012969
9	20000	0.6	4	10000000	10000000	35	0	0.017534
10	0	0.6	4	500000	10000000	40	0	0.015709
11	10000	0.6	4	500000	10000000	40	0	0.016904
12	20000	0.6	4	500000	10000000	40	0	0.023816
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
727	0	0.6	4	1000000	10000000	35	10	0.015731
728	10000	0.6	4	1000000	10000000	35	10	0.01703
729	20000	0.6	4	1000000	10000000	35	10	0.023765

$$\underbrace{\{y\}}_{\text{Known number}} = \underbrace{[x_{i=1\sim6}]}_{\text{Known number}} \cdot \underbrace{\{\beta_{i=0\sim27}\}}_{\text{Un-Known number}}$$

$\{y\}$ = Simulation results, $\log(\delta_{max}/H)$
$[x_{i=1\sim6}]$ = Independent parameter matrix
$\{\beta_{i=0\sim27}\}$ = Regression coefficient

This study using Second-order model is:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_{11}^2 + \beta_{22} x_{22}^2 + \beta_{12} x_1 x_2$$

The second-order model is widely used in response surface methodology from Response Surface Method.

RSM Equation II

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6$$
$$+ \beta_7 x_1^2 + \beta_8 x_2^2 + \beta_9 x_3^2 + \beta_{10} x_4^2 + \beta_{11} x_5^2 + \beta_{12} x_6^2$$
$$+ \beta_{13} x_1 x_2 + \beta_{14} x_1 x_3 + \beta_{15} x_1 x_4 + \beta_{16} x_1 x_5 + \beta_{17} x_1 x_6$$
$$+ \beta_{18} x_2 x_3 + \beta_{19} x_2 x_4 + \beta_{20} x_2 x_5 + \beta_{21} x_2 x_6$$
$$+ \beta_{22} x_3 x_4 + \beta_{23} x_3 x_5 + \beta_{24} x_3 x_6$$
$$+ \beta_{25} x_4 x_5 + \beta_{26} x_4 x_6$$
$$+ \beta_{27} x_5 x_6 + \boxed{\varepsilon}$$

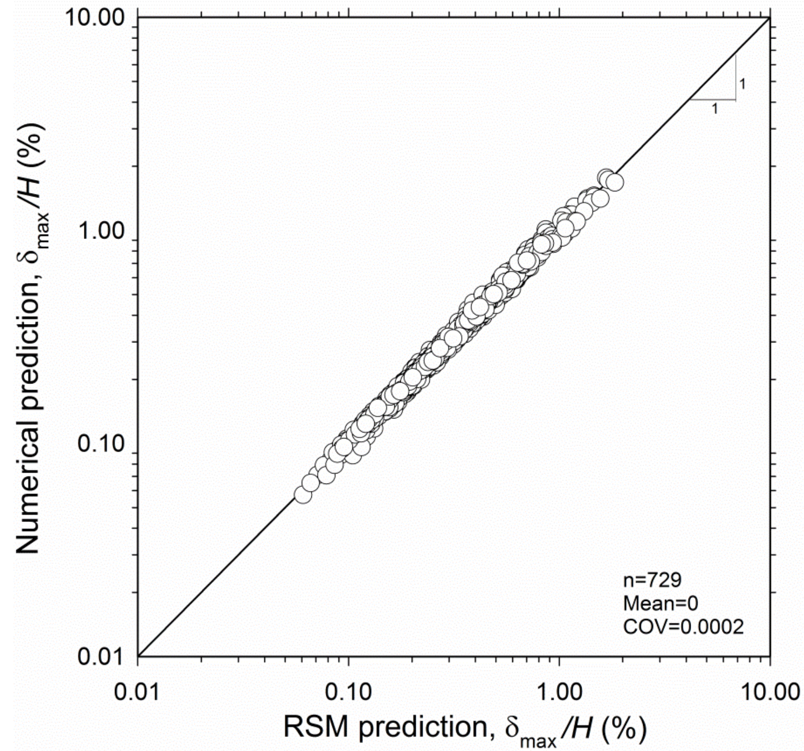
uncertainties

$$y = \ln\left(\frac{\delta_{\max}}{H}\right)$$

$$x_1 = \frac{q}{\gamma H} \qquad x_3 = \ln\left(\frac{\gamma}{K_{sbb}}\right) \qquad x_5 = \frac{S}{H\tan(\phi)}$$

$$x_2 = \ln\left(\frac{\gamma HS}{J}\right) \qquad x_4 = \frac{H}{S} \qquad x_6 = 1 - \tan(\omega)$$

No	Coefficient	Value
21	β20	1.997
22	β21	0.782
23	β22	-0.02
24	β23	-0.8
25	β24	-0.87
26	β25	1.644
27	β26	-0.11
28	β27	0.598



$$\mu_1 = mean\left[\log\left(\frac{\delta_{\max}}{H}\right)_{FLAC} - \log\left(\frac{\delta_{\max}}{H}\right)_{equation}\right]$$

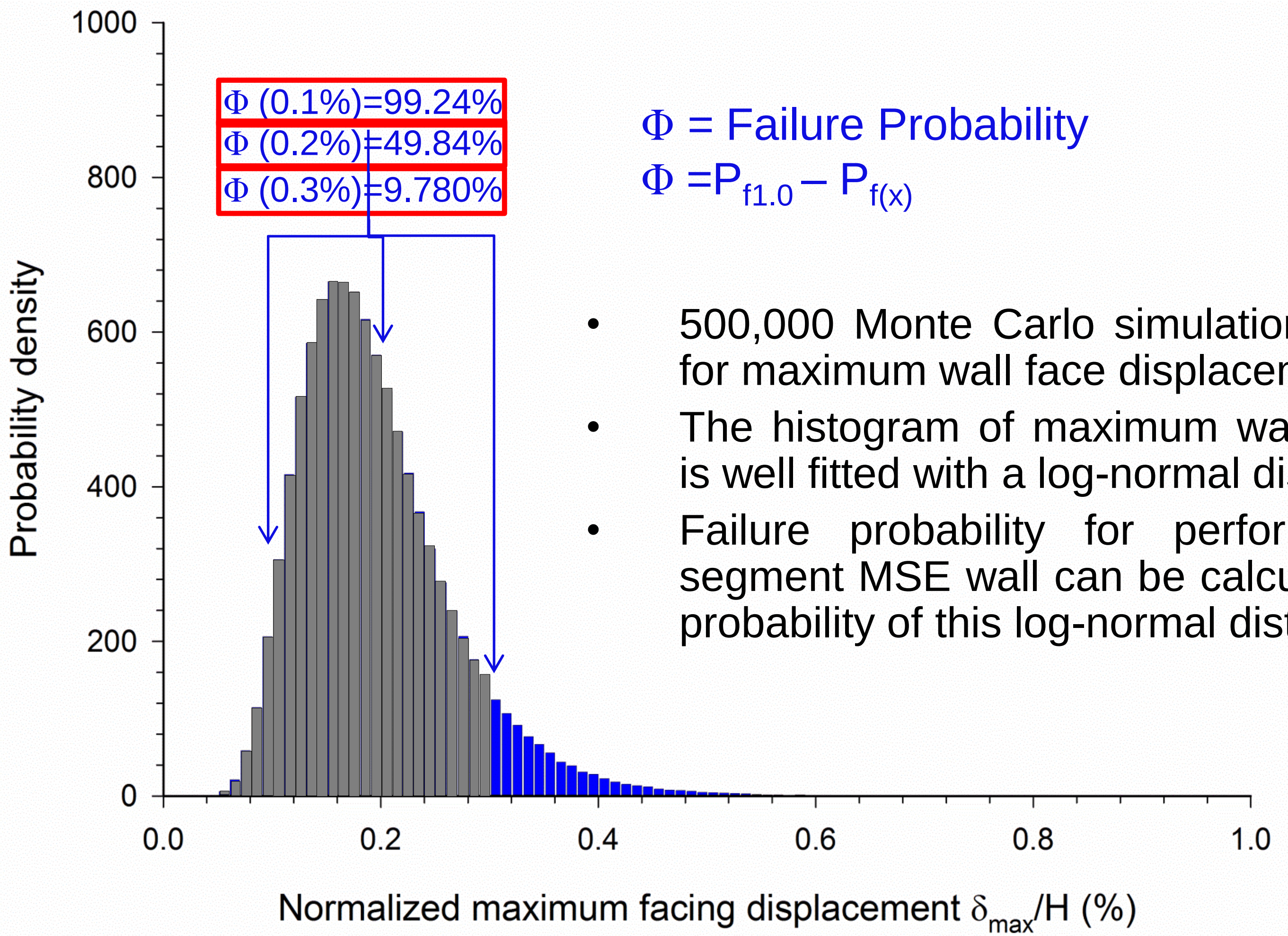
$$\sigma_1 = std\left[\log\left(\frac{\delta_{\max}}{H}\right)_{FLAC} - \log\left(\frac{\delta_{\max}}{H}\right)_{equation}\right]$$

The prediction of the RSM equation can be made deterministically using beast estimates of the input parameter values. The parameters are given by the bold face values in here.

Parameter	Mean	COV
Wall height, H (m)	4	10%
Facing batter, ω (degree)	5	10%
Soil friction angle, ϕ (degree)	40	10%
Reinforcement axial stiffness, J (kN/m)	1000	10%
Block-block interface shear stiffness, $k_{s,bb}$ (MPa/m)	50	10%
Surcharge pressure, q (kPa)	10	10%

Note: Model uncertainty (ε) has mean of zero and standard deviation of 0.05

Reliability Analysis II



Φ = Failure Probability

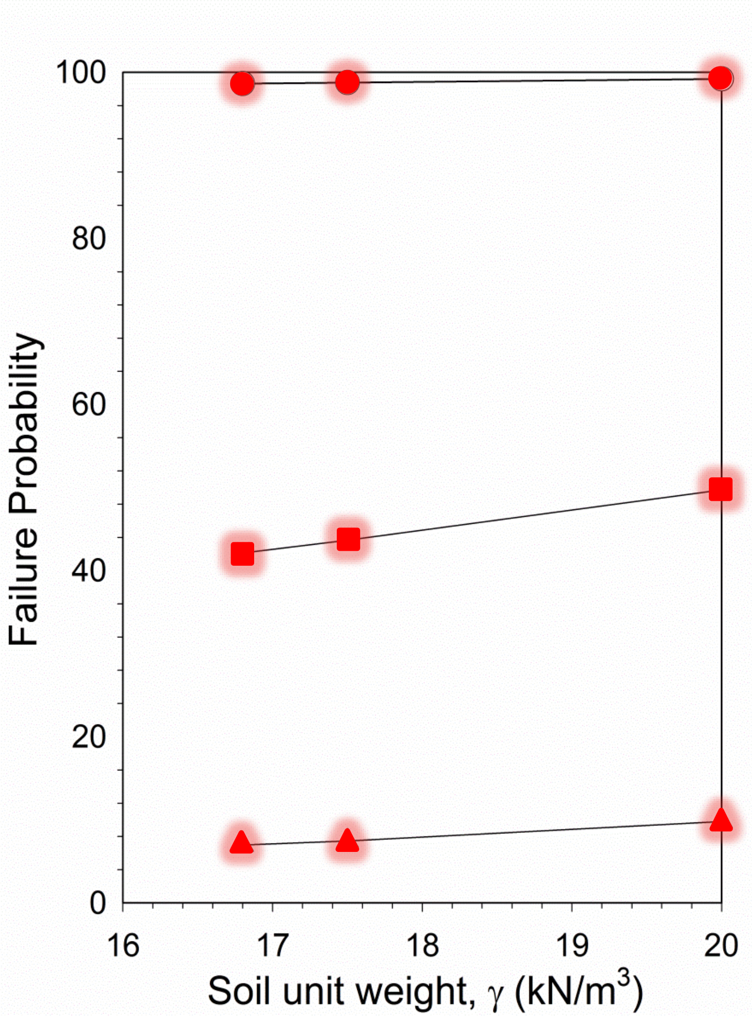
$\Phi = P_{f1.0} - P_{f(x)}$

- 500,000 Monte Carlo simulations of RSM equation for maximum wall face displacement.
- The histogram of maximum wall face displacement is well fitted with a log-normal distribution.
- Failure probability for performance criterion of segment MSE wall can be calculated as the exceed probability of this log-normal distribution.

Reliability Analysis III

case	Variable changed	λ	ζ	Probability of failure $\left(\frac{\delta_{max}}{H}\right) = 0.1\%$	Probability of failure $\left(\frac{\delta_{max}}{H}\right) = 0.2\%$	Probability of failure $\left(\frac{\delta_{max}}{H}\right) = 0.3\%$
Base-case	-	-6.19	0.31	99.21%	49.75%	9.797%
1	γ =16.8	-6.25	0.31	98.70%	44.70%	7.700%
2	γ =17.5	-6.26	0.31	98.60%	42.10%	7.800%
3	ϕ = 35	-5.79	0.32	100.00%	91.40%	51.20%
4	ϕ = 44	-6.48	0.31	92.80%	18.40%	2.200%
5	J = 500	-5.81	0.34	100.00%	88.90%	50.70%
6	J = 2000	-6.41	0.29	95.10%	26.10%	2.100%
7	K_{sbb} = 10000	-5.86	0.29	100.00%	90.40%	42.60%
8	K_{sbb} = 100000	-6.30	0.30	97.90%	36.90%	5.400%
9	ω = 0	-5.90	0.32	99.90%	84.40%	37.60%
10	ω = 10	-6.48	0.31	92.50%	19.60%	2.300%
11	H = 6	-5.83	0.32	100.00%	88.50%	46.60%
12	H = 8	-5.51	0.34	100.00%	98.70%	81.50%
13	q = 0	-6.26	0.31	98.50%	45.60%	6.900%
14	q = 20	-5.98	0.32	99.90%	76.60%	30.00%

Influence of RSM Equation I

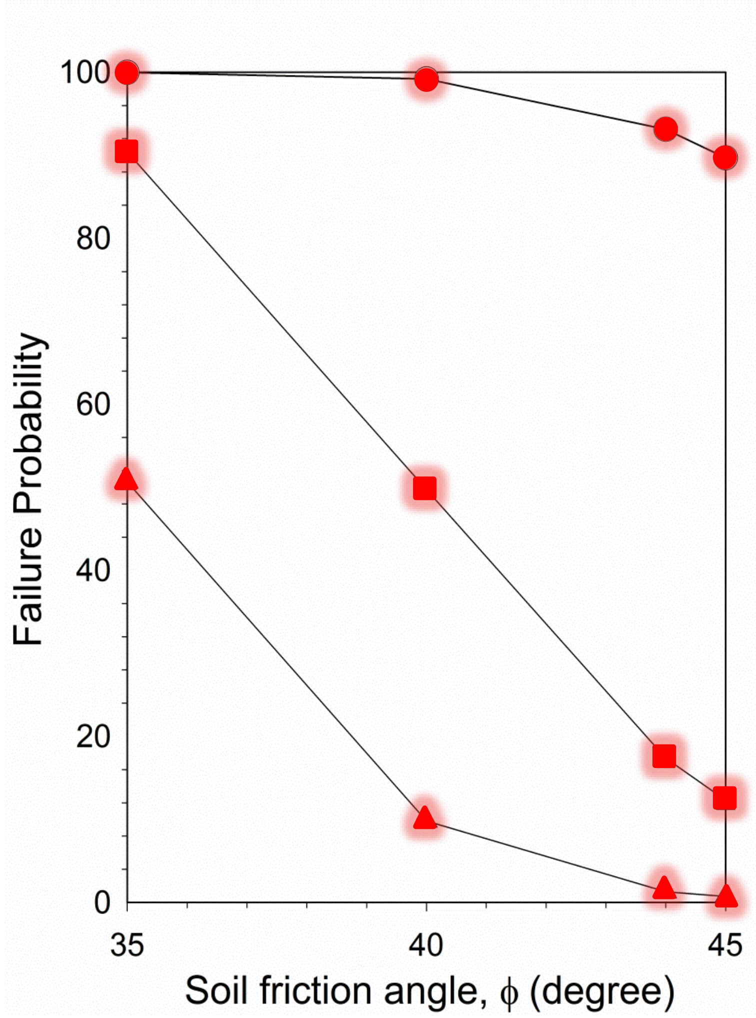


Φ (0.1%)=98.65%
Φ (0.1%)=98.77%
Φ (0.1%)=99.21%

Φ (0.2%)=42.13%
Φ (0.2%)=43.66%
Φ (0.2%)=49.72%

Φ (0.3%)=6.965%
Φ (0.3%)=7.448%
Φ (0.3%)=9.789%

Influence of RSM Equation II

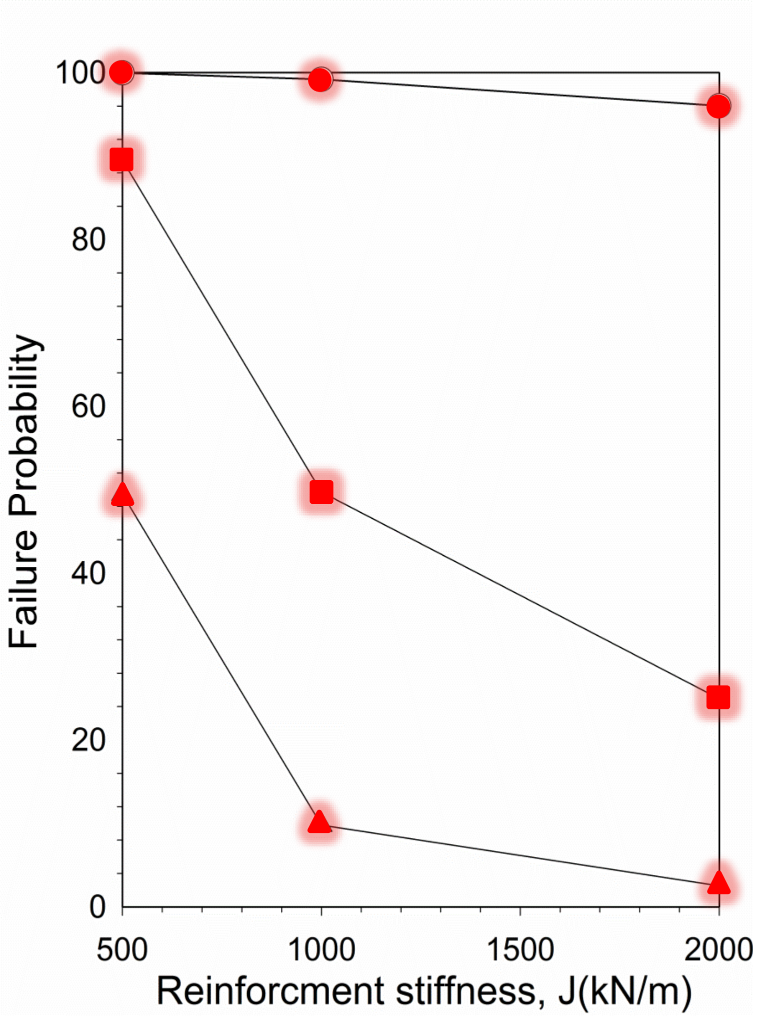


Φ (0.1%)=99.99%
Φ (0.1%)=99.21%
Φ (0.1%)=93.13%
Φ (0.1%)=89.69%

Φ (0.2%)=90.42%
Φ (0.2%)=49.72%
Φ (0.2%)=17.37%
Φ (0.2%)=12.32%

Φ (0.3%)=9.789%
Φ (0.3%)=50.66%
Φ (0.3%)=1.289%
Φ (0.3%)=0.711%

Influence of RSM Equation III

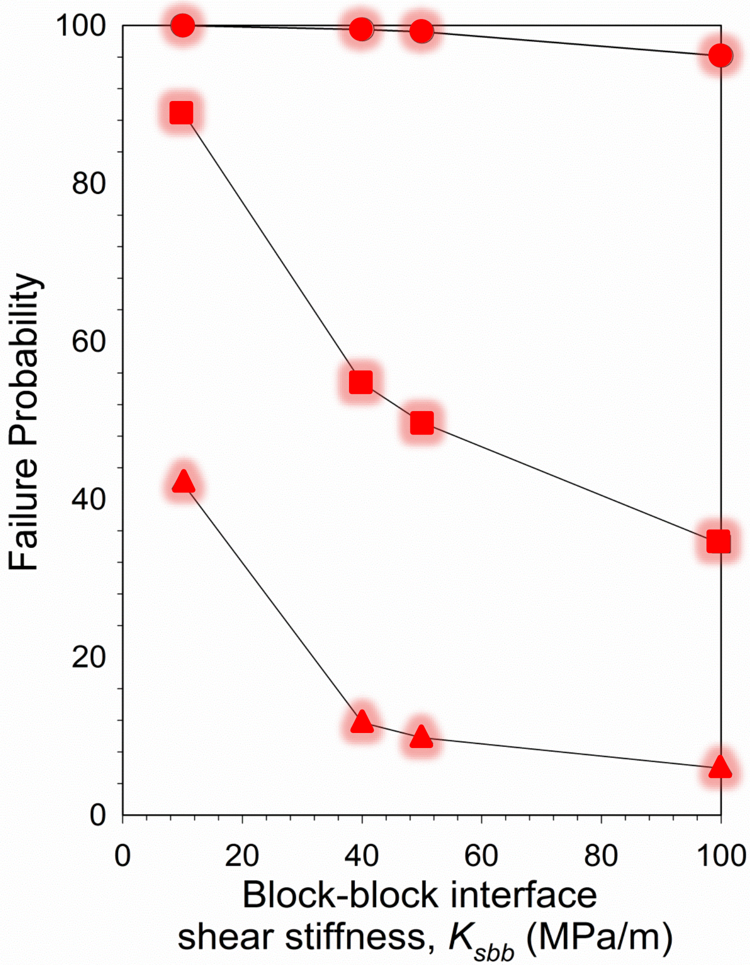


Φ (0.1%)=99.98%
Φ (0.1%)=99.21%
Φ (0.1%)=96.03%

Φ (0.2%)=89.53%
Φ (0.2%)=49.72%
Φ (0.2%)=24.94%

Φ (0.3%)=49.46%
Φ (0.3%)=9.789%
Φ (0.3%)=2.513%

Influence of RSM Equation IV

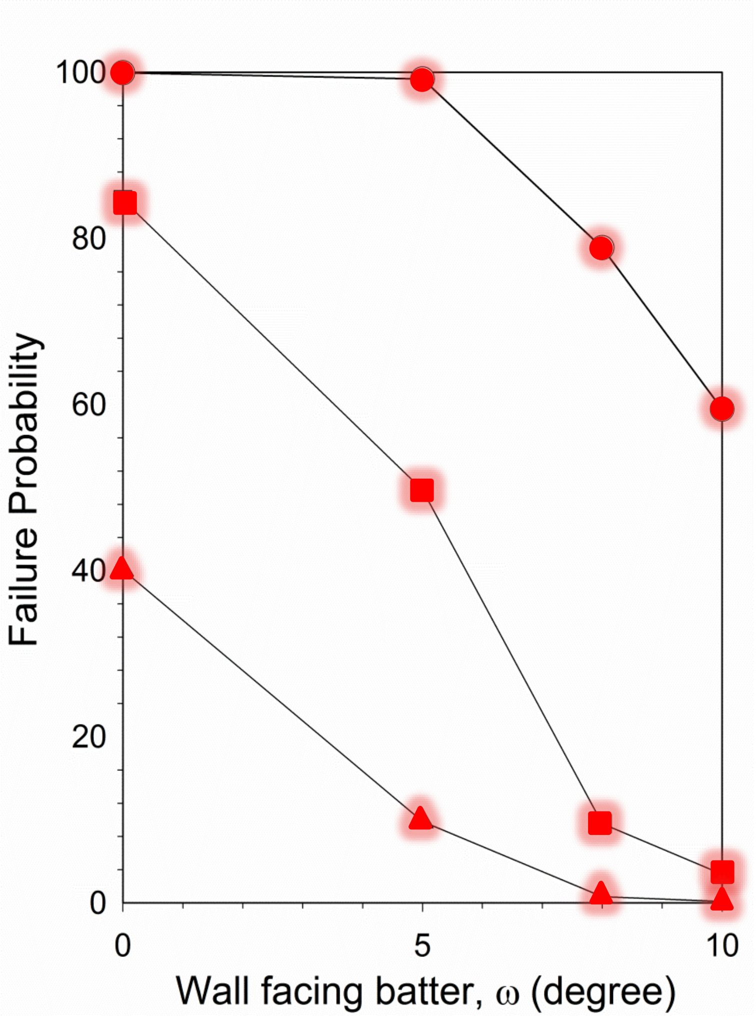


Φ (0.1%)=99.99%
Φ (0.1%)=99.50%
Φ (0.1%)=99.21%
Φ (0.1%)=96.15%

Φ (0.2%)=89.06%
Φ (0.2%)=54.70%
Φ (0.2%)=49.72%
Φ (0.2%)=34.34%

Φ (0.3%)=42.04%
Φ (0.3%)=11.71%
Φ (0.3%)=9.789%
Φ (0.3%)=5.934%

Influence of RSM Equation V

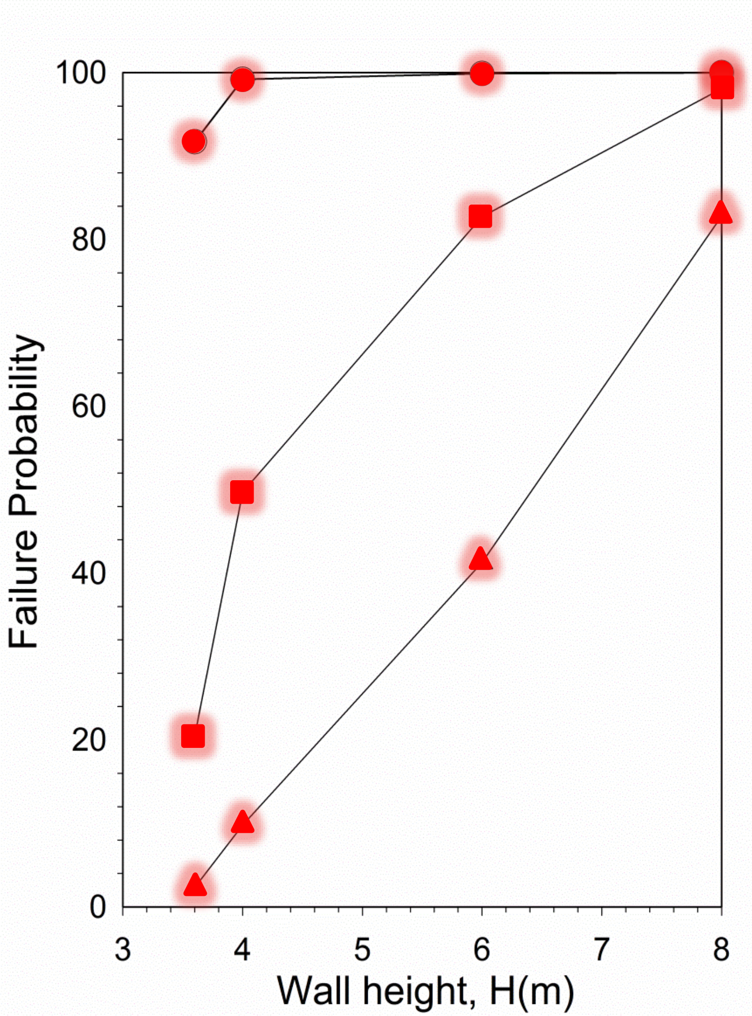


Φ (0.1%)=99.95%
Φ (0.1%)=99.21%
Φ (0.1%)=78.89%
Φ (0.1%)=59.44%

Φ (0.2%)=84.66%
Φ (0.2%)=49.72%
Φ (0.2%)=9.540%
Φ (0.2%)=3.444%

Φ (0.3%)=40.09%
Φ (0.3%)=9.789%
Φ (0.3%)=0.747%
Φ (0.3%)=0.172%

Influence of RSM Equation VI

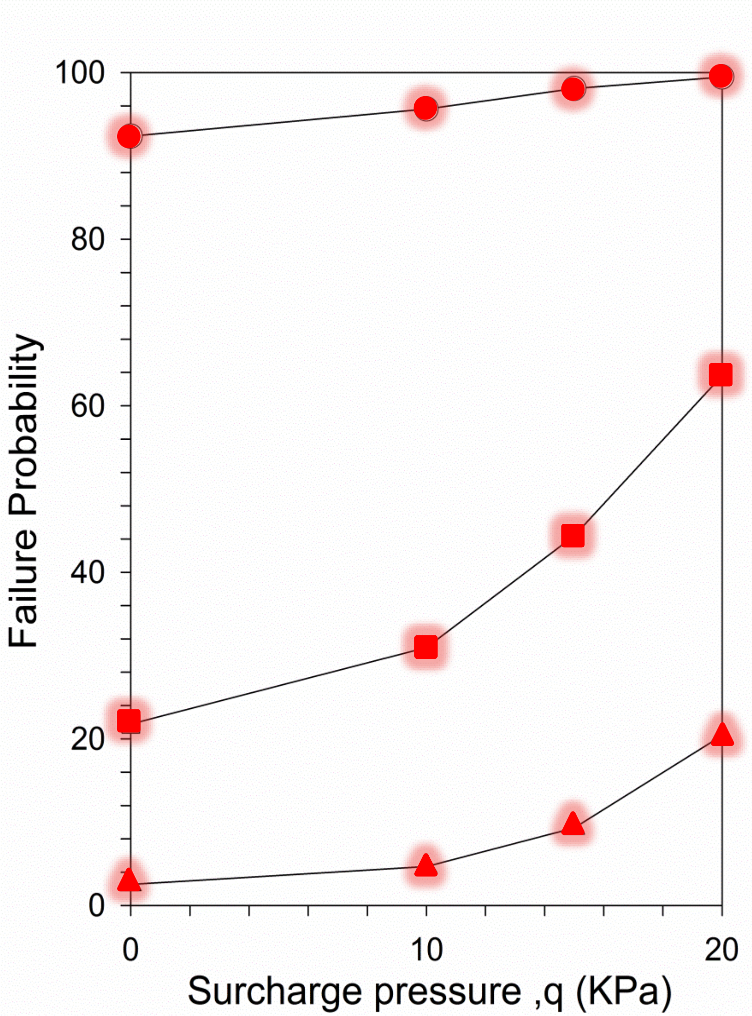


Φ (0.1%)=91.71%
Φ (0.1%)=99.21%
Φ (0.1%)=99.90%
Φ (0.1%)=99.99%

Φ (0.2%)=20.45%
Φ (0.2%)=49.72%
Φ (0.2%)=82.74%
Φ (0.2%)=98.09%

Φ (0.3%)=2.325%
Φ (0.3%)=9.789%
Φ (0.3%)=41.28%
Φ (0.3%)=82.82%

Influence of RSM Equation VII

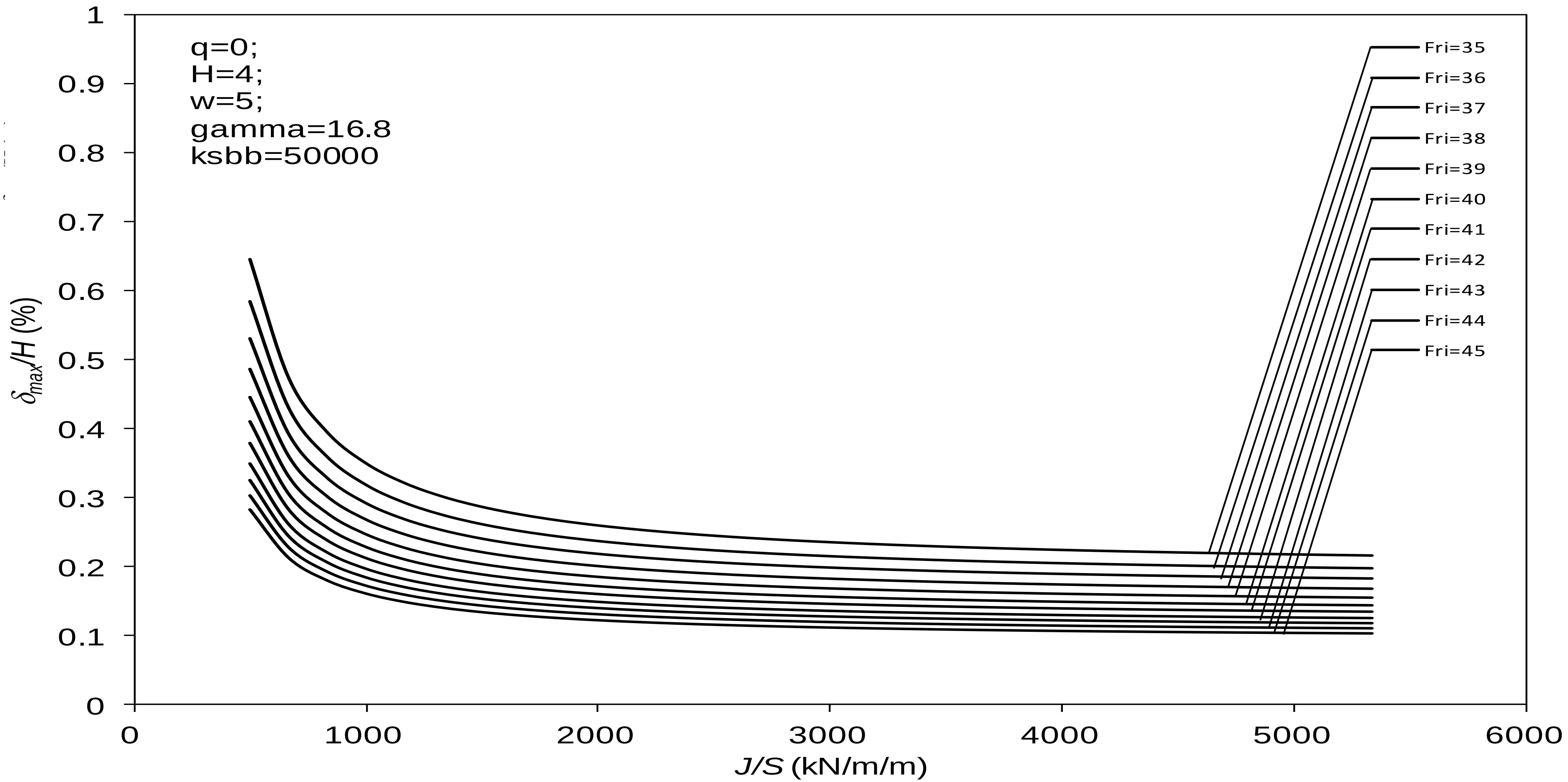


Φ (0.1%)=92.36%
Φ (0.1%)=95.63%
Φ (0.1%)=98.09%
Φ (0.1%)=99.46%

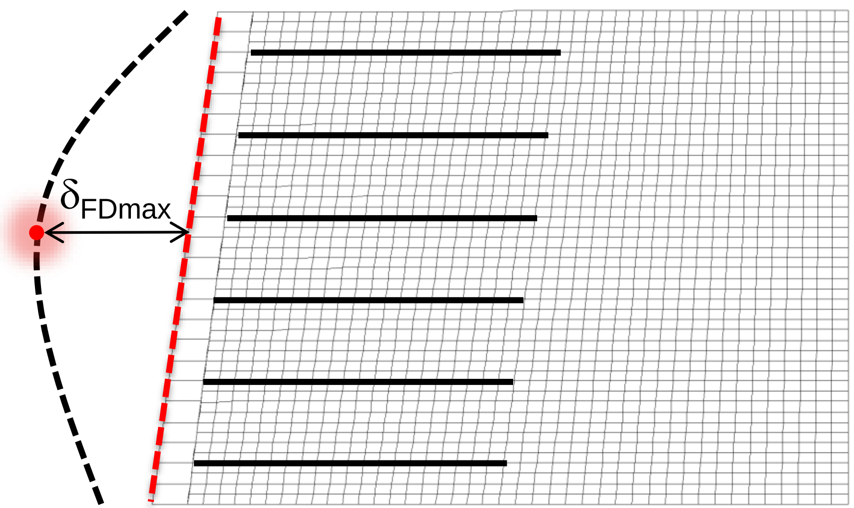
Φ (0.2%)=30.97%
Φ (0.2%)=21.78%
Φ (0.2%)=44.38%
Φ (0.2%)=63.63%

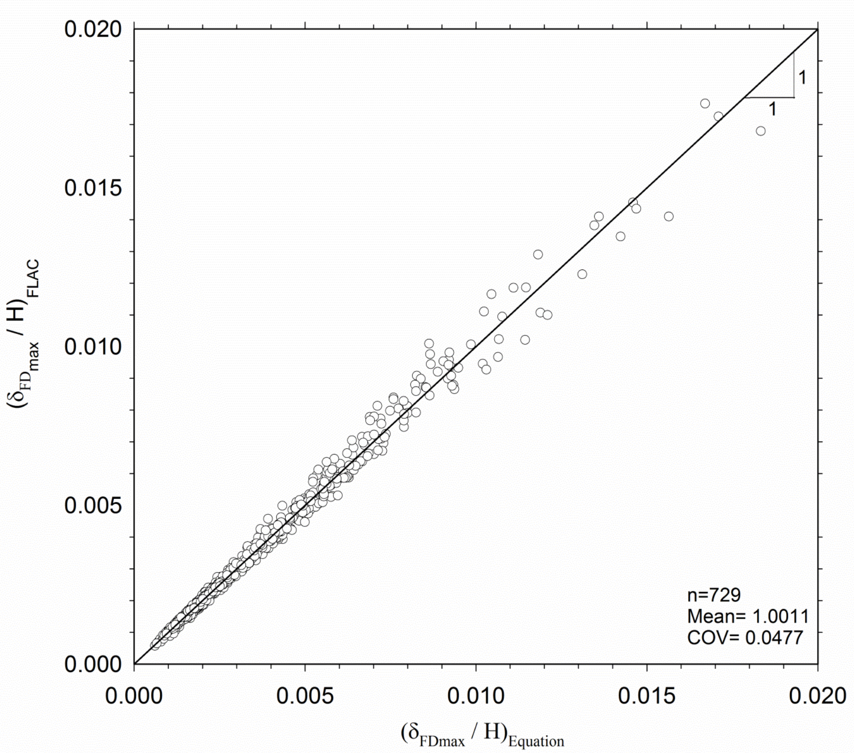
Φ (0.3%)=2.528%
Φ (0.3%)=4.680%
Φ (0.3%)=9.304%
Φ (0.3%)=20.41%

Reliability Based Design

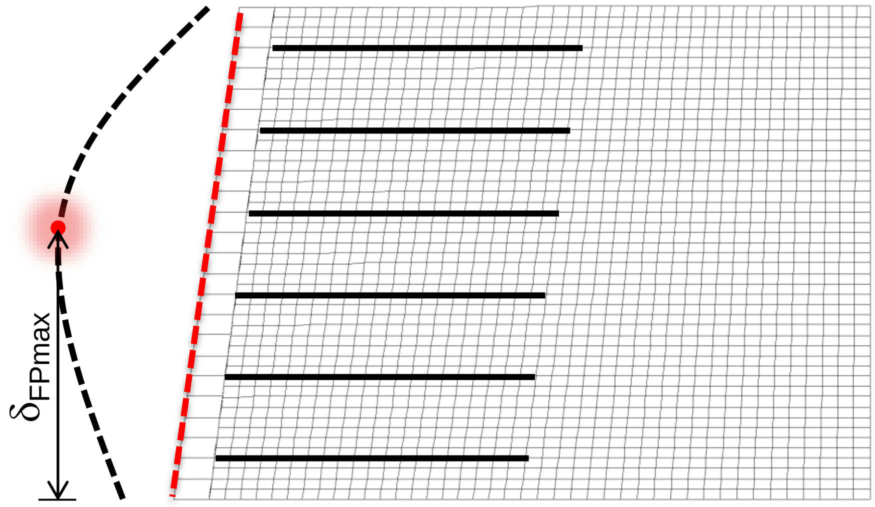


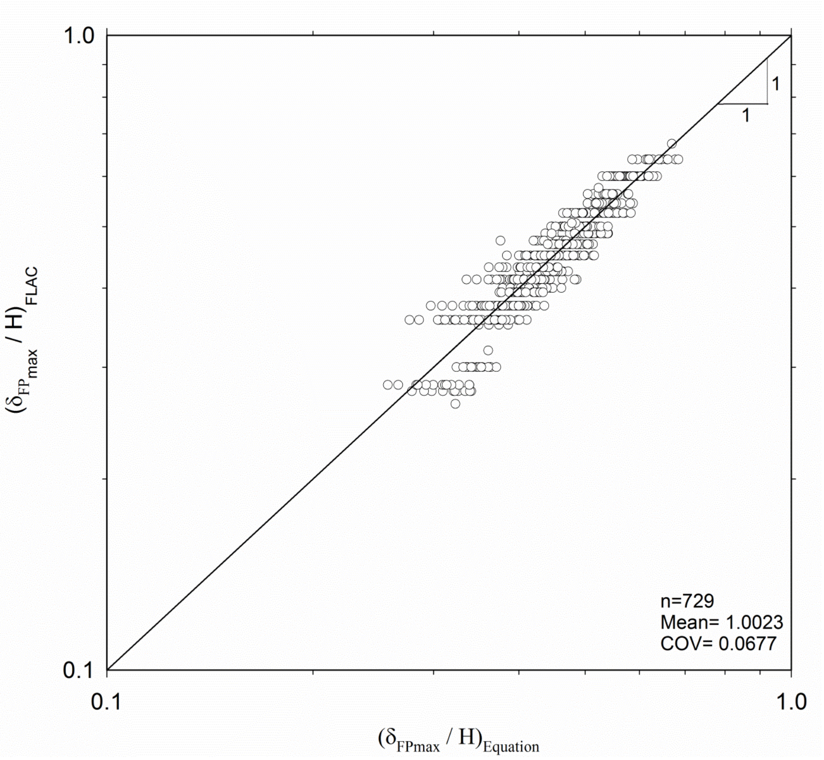
Section 4
Facing Deformation Pattern I



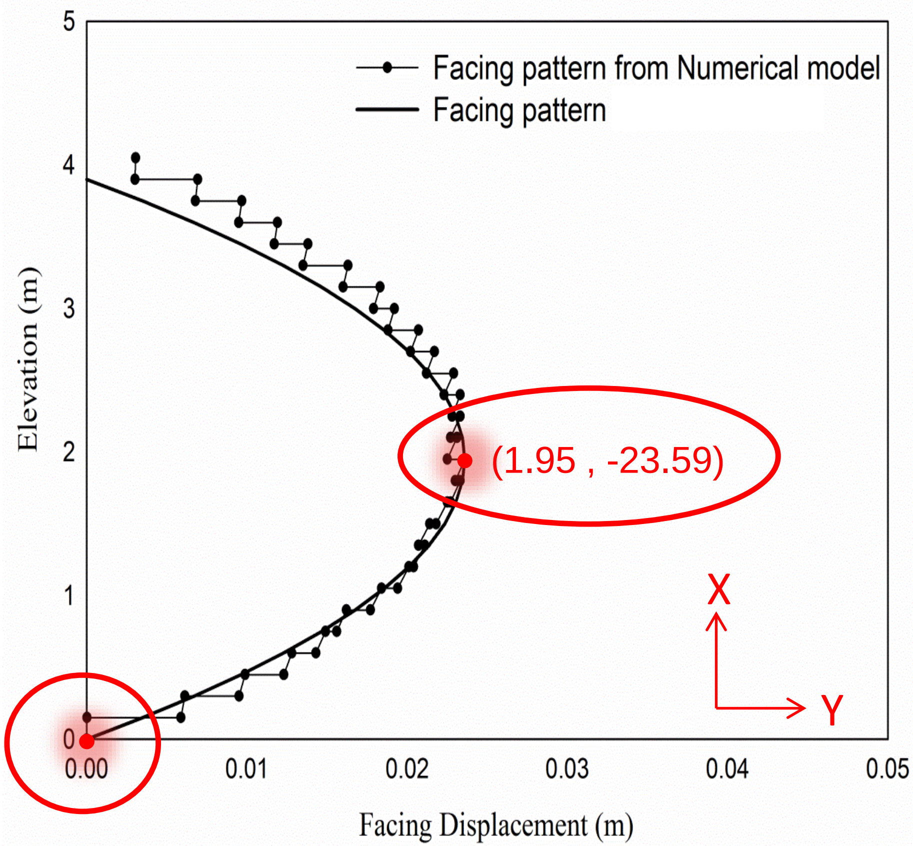


Facing Deformation Pattern II





Facing Deformation Pattern III



$Y=a(X-b)^2+C$

When X,Y= (1.95 , -23.59)

$-23.59=a(-1.95+1.95)^2+C$

$-23.59=C$

When X,Y = (0 , 0)

$Y=a(X-b)^2+C$

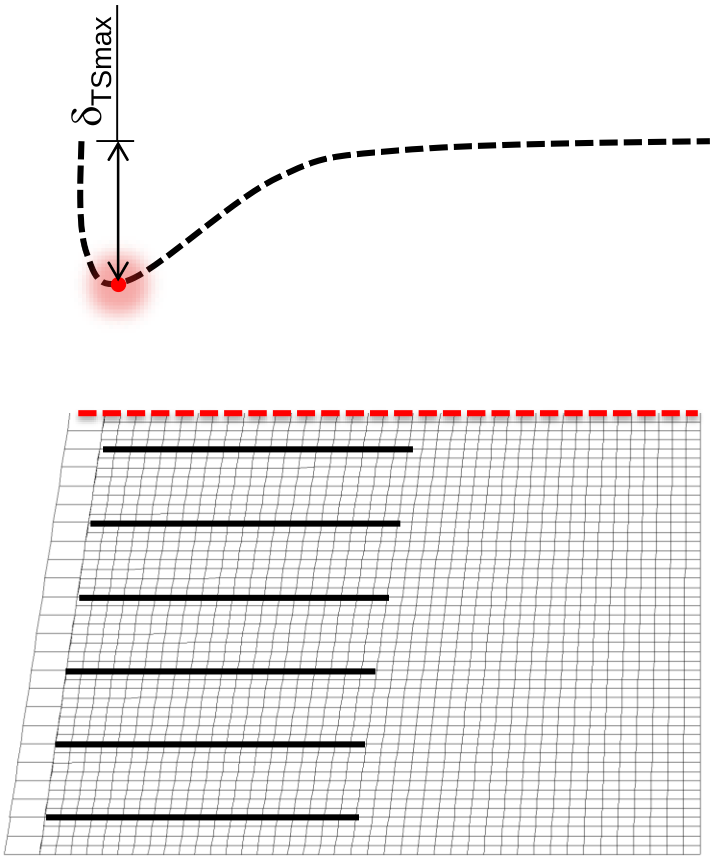
$0=a(0+1.95)^2+C$

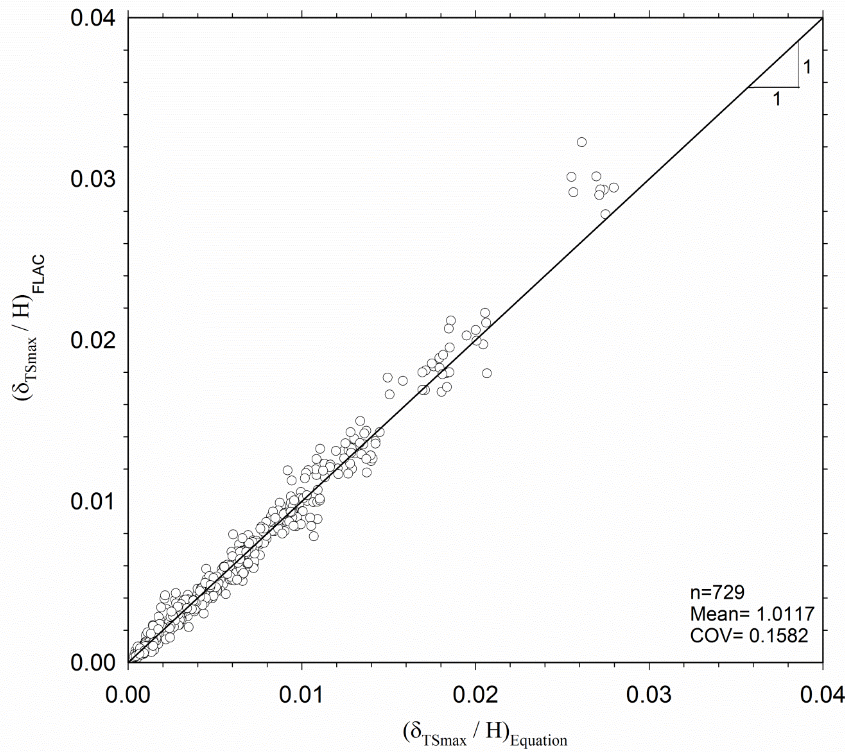
$0=a3.8025+(-23.59)$

$a=6.2$

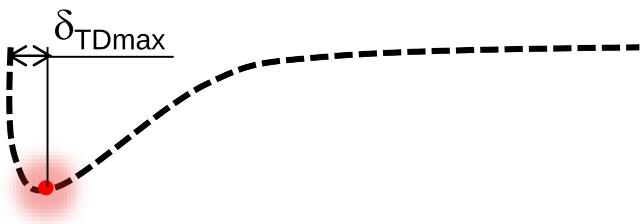
Parabola Function is **$Y=6.2(X+1.95)^2-23.59$**

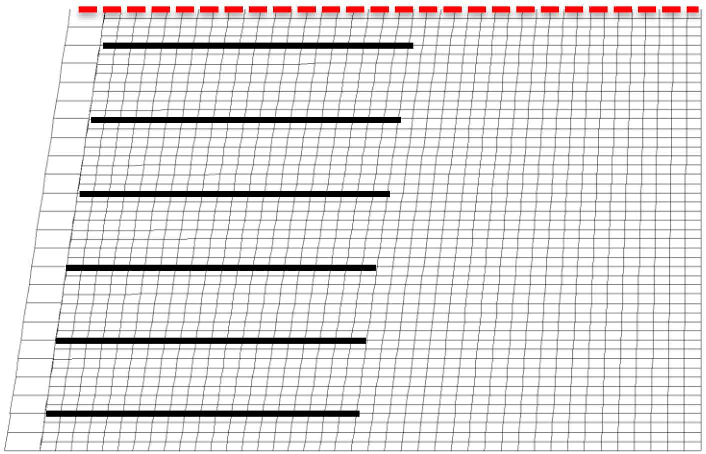
Top Settlement Curve I

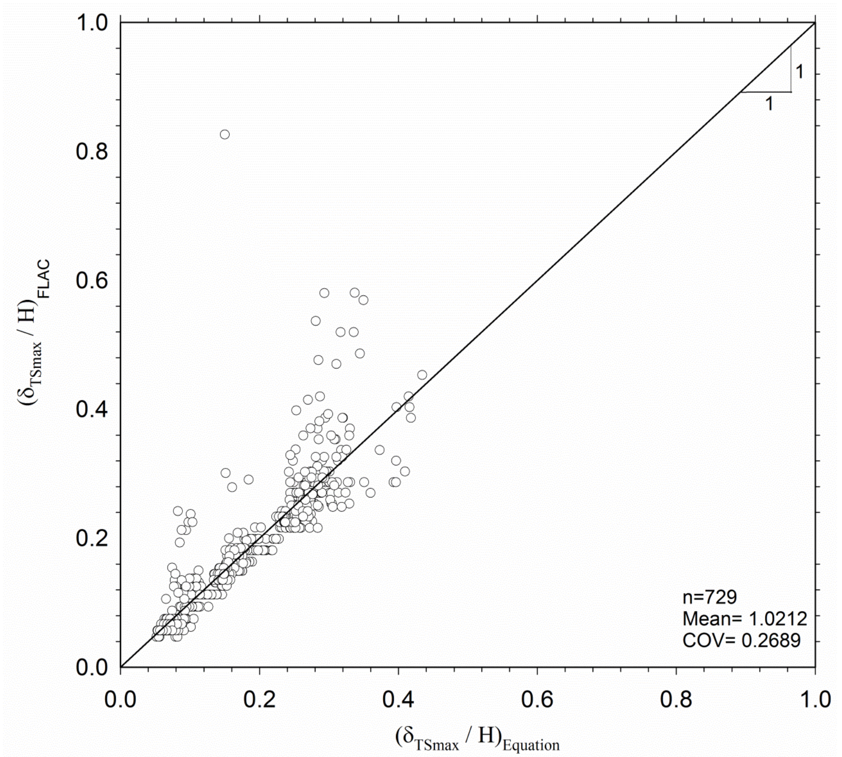




Top Settlement Curve II

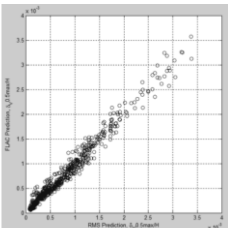




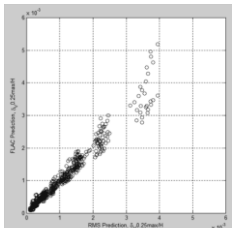


Top Settlement Curve III

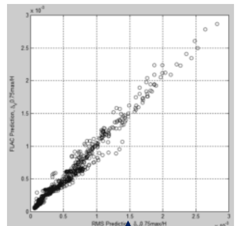
RSM_mean = 1.0190
RSM_COV = 0.2194



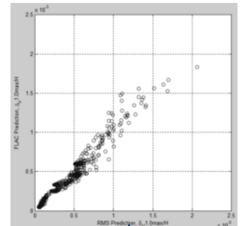
RSM_mean = 1.0138
RSM_COV = 0.1743



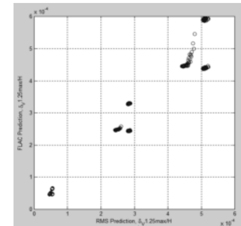
RSM_mean = 1.0143
RSM_COV = 0.1836



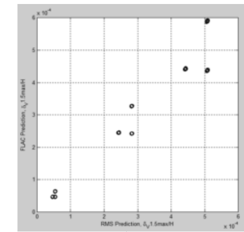
RSM_mean = 1.0118
RSM_COV = 0.1539

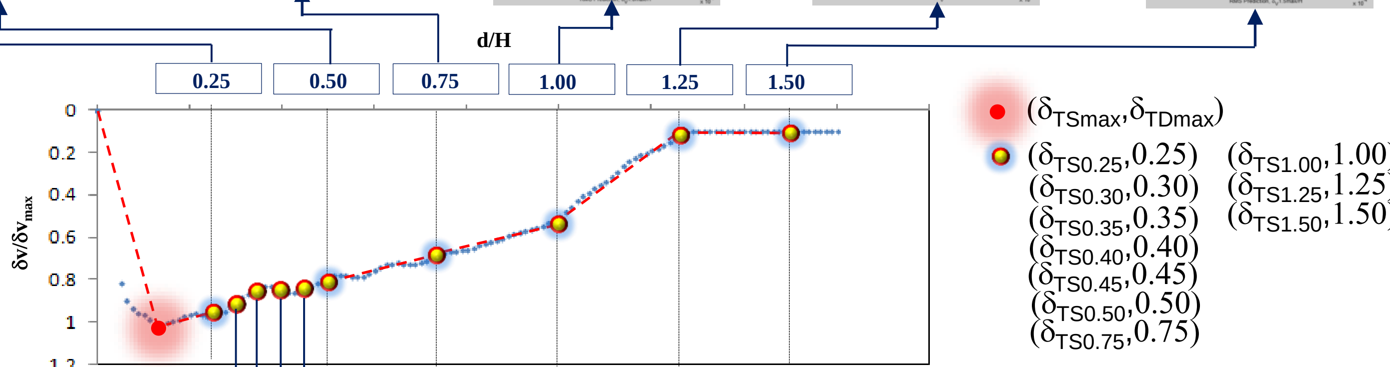


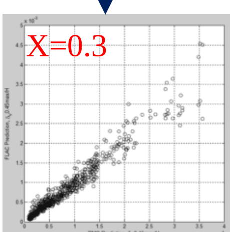
RSM_mean = 1.0075
RSM_COV = 0.1224



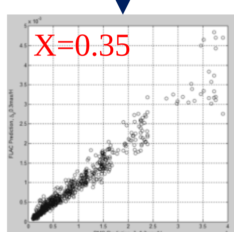
RSM_mean = 1.0077
RSM_COV = 0.1235



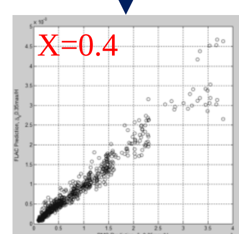




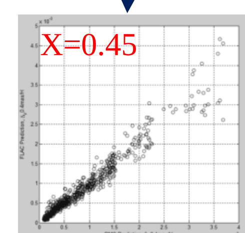
RSM_mean = 1.0244
RSM_COV = 0.2437



RSM_mean = 1.0198
RSM_COV = 0.2119

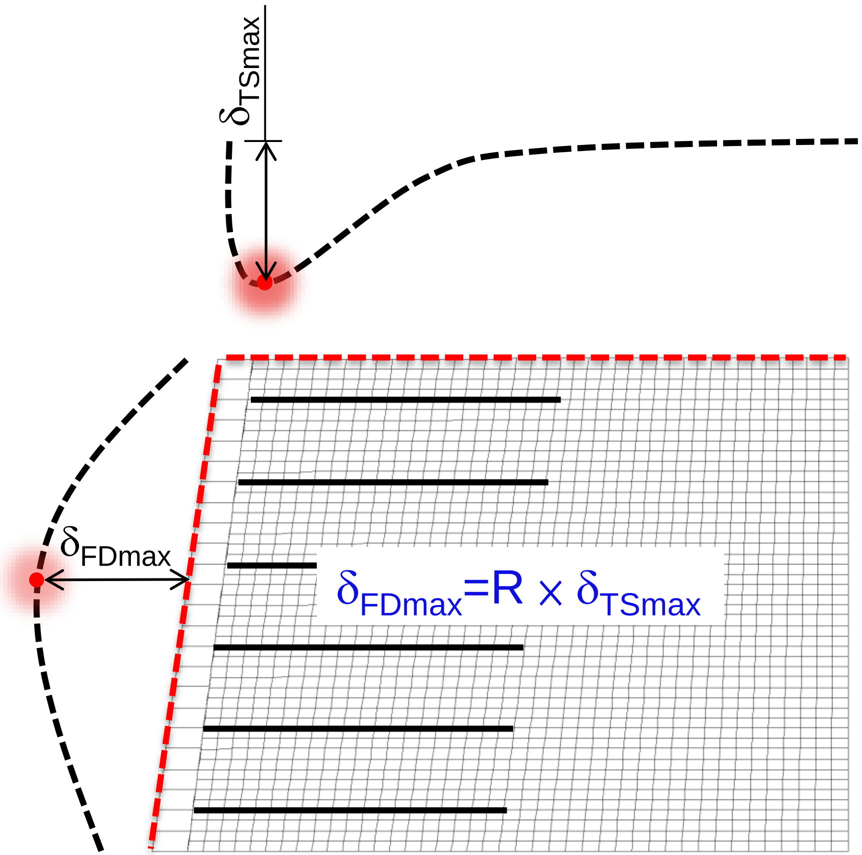


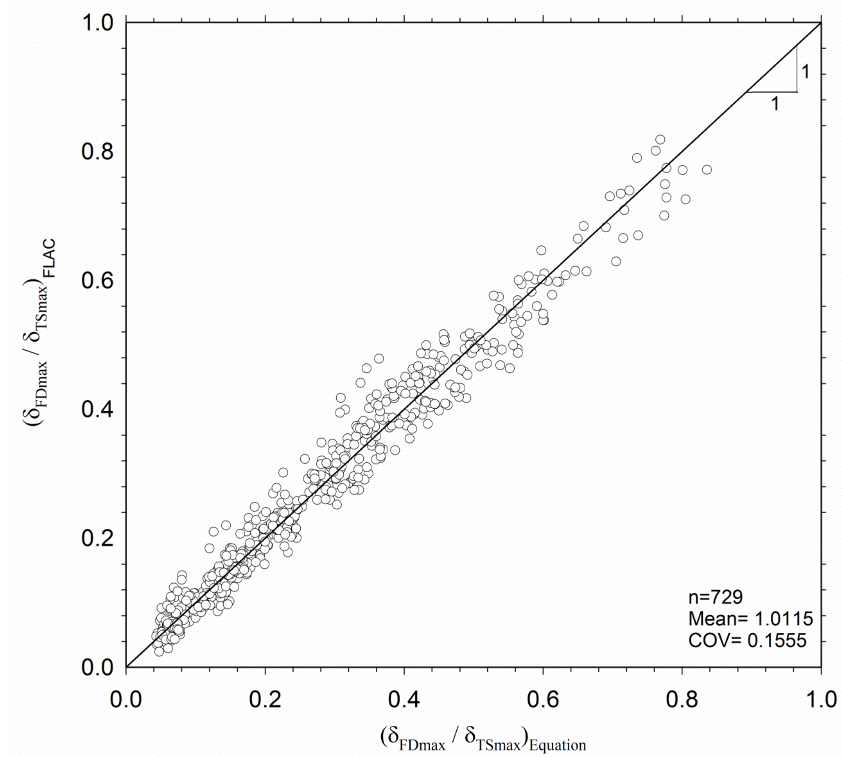
RSM_mean = 1.0207
RSM_COV = 0.2186



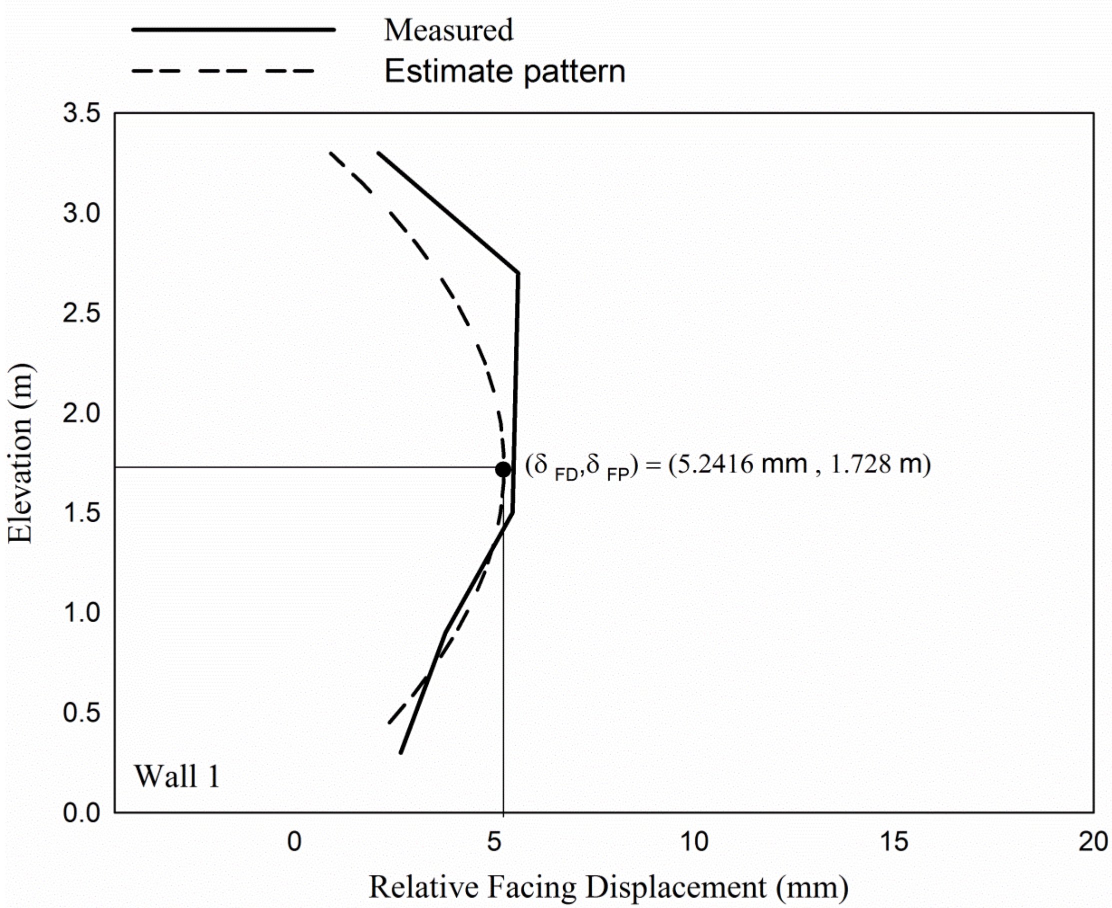
RSM_mean = 1.0214
RSM_COV = 0.2239

Facing displacement with top settlement relationship





Measured comparing estimated result I



$Y=a(X-b)^2+C$

$-5.2416=a(-1.728+1.728)^2+C$

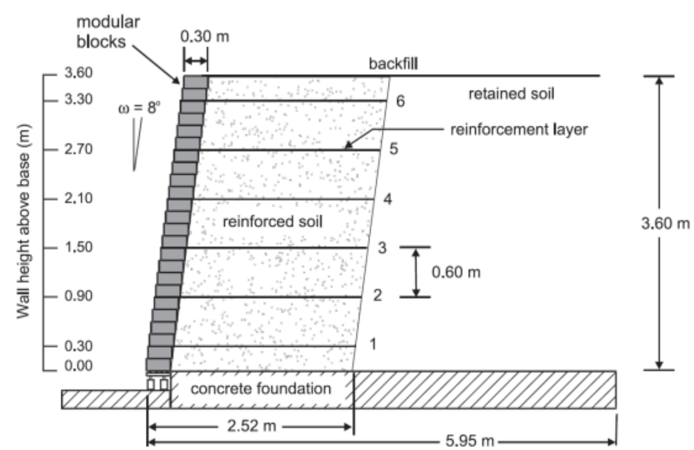
$-5.2416=C$

$0=a(0+1.728)^2+C$

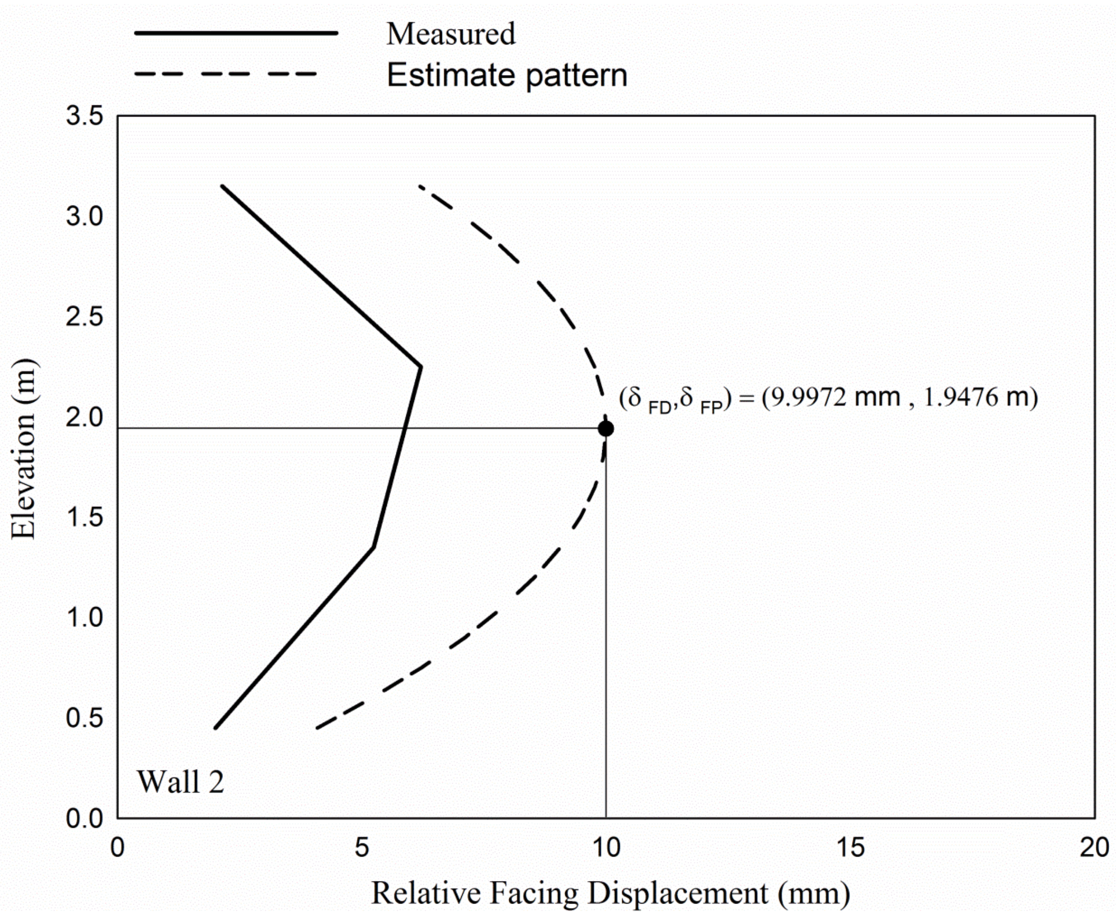
$0=a2.9859+(-5.2416)$

$a=1.7554$

$$\boxed{Y=1.7554(X+1.728)^2-5.2416}$$



Measured comparing estimated result II



$Y=a(X-b)^2+C$

$-9.9972=a(-1.9476+1.9476)^2+C$

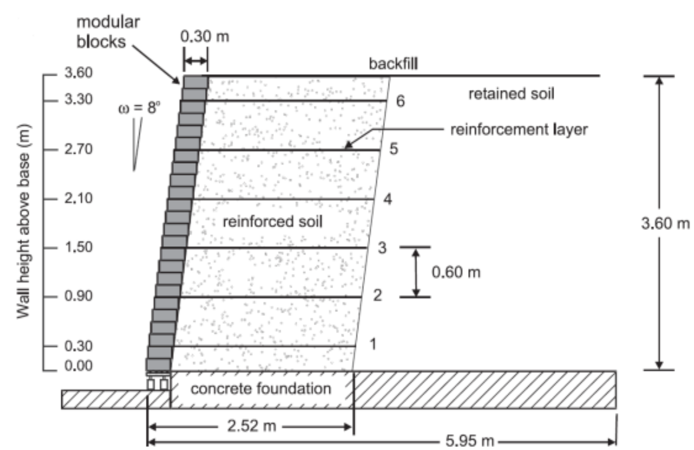
$-9.9972=C$

$0=a(0+1.9476)^2+C$

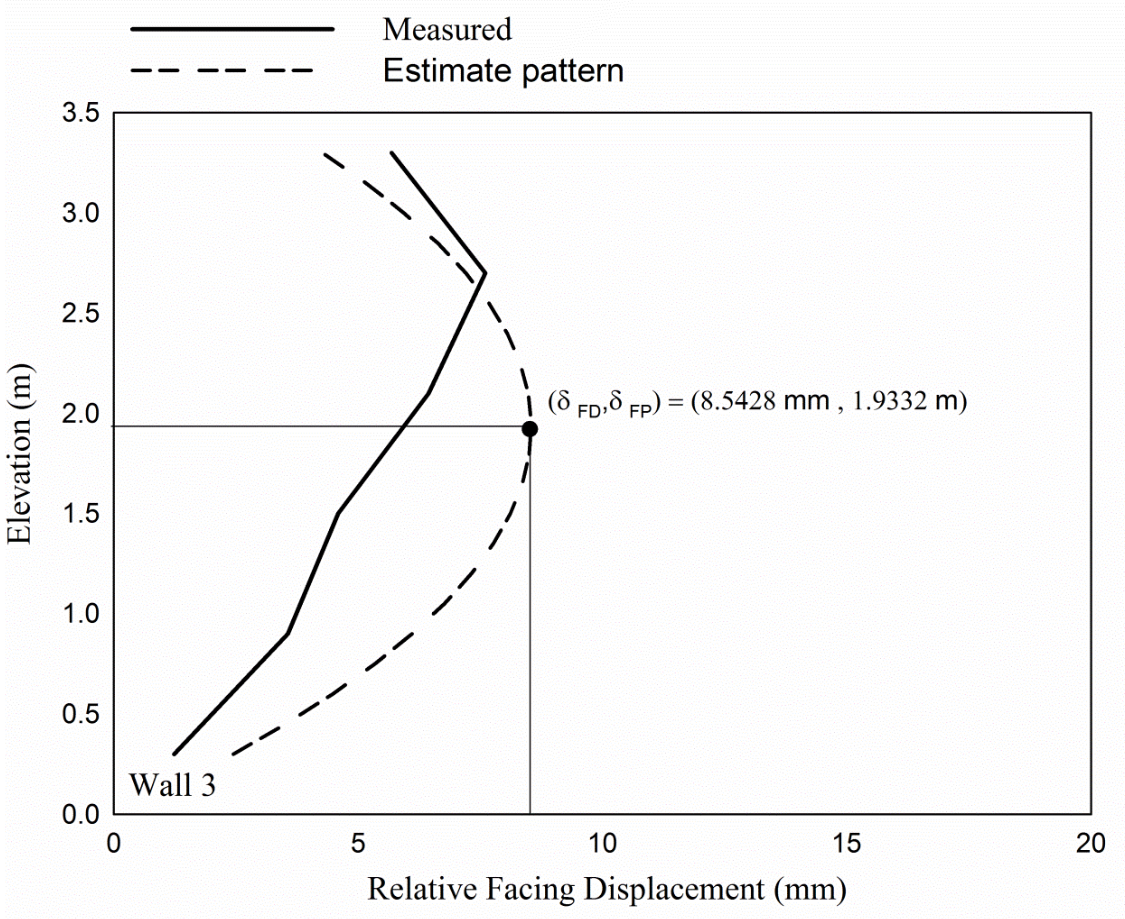
$0=a3.7931+(-9.9972)$

$a=2.6356$

$\boxed{Y=2.6356(X+1.9476)^2-9.9972}$



Measured comparing estimated result III



$Y=a(X-b)^2+C$

$-8.5428=a(-1.9322+1.9322)^2+C$

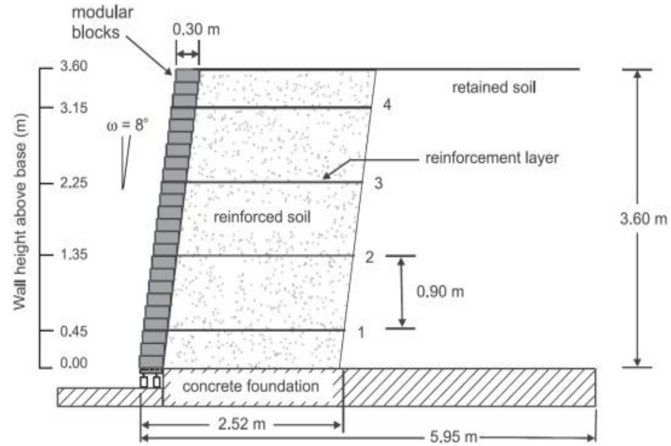
$-8.5428=C$

$0=a(0+1.9322)^2+C$

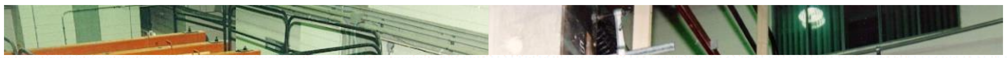
$0=a3.7334+(-8.5428)$

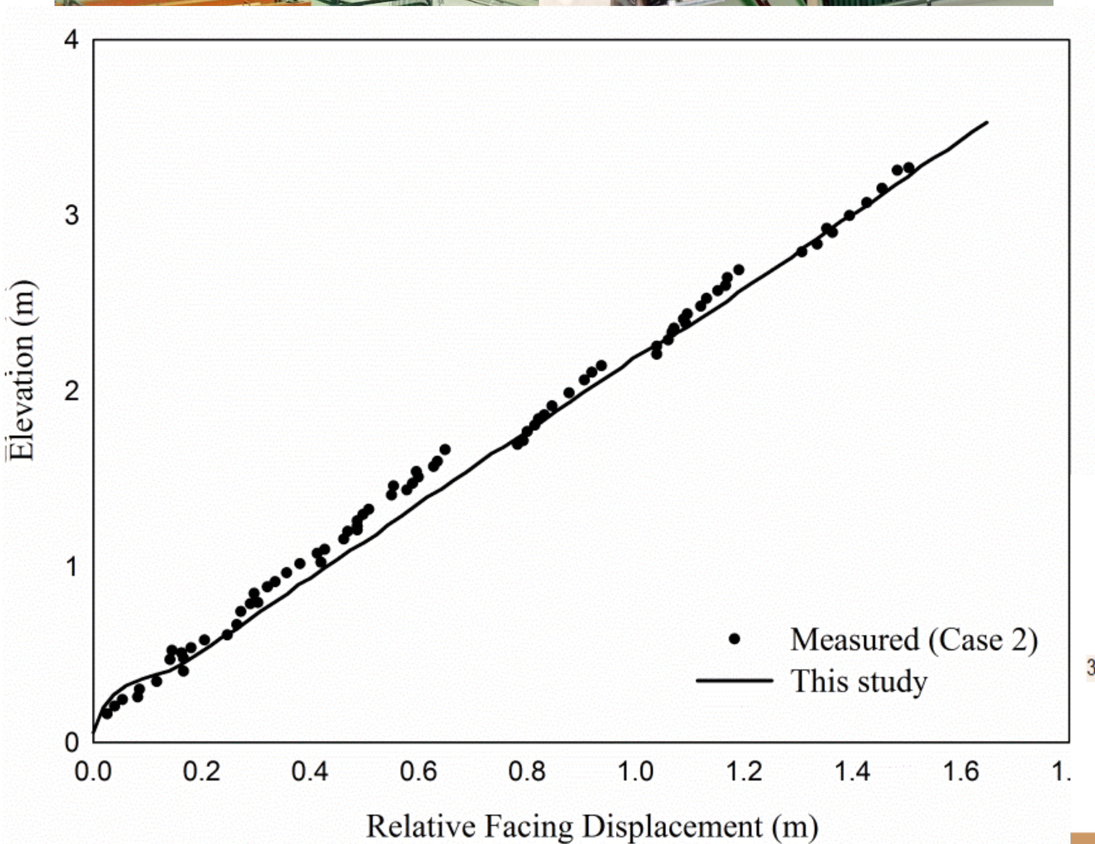
$a=2.288$

$$\boxed{Y=2.288(X+1.9322)^2-8.5428}$$

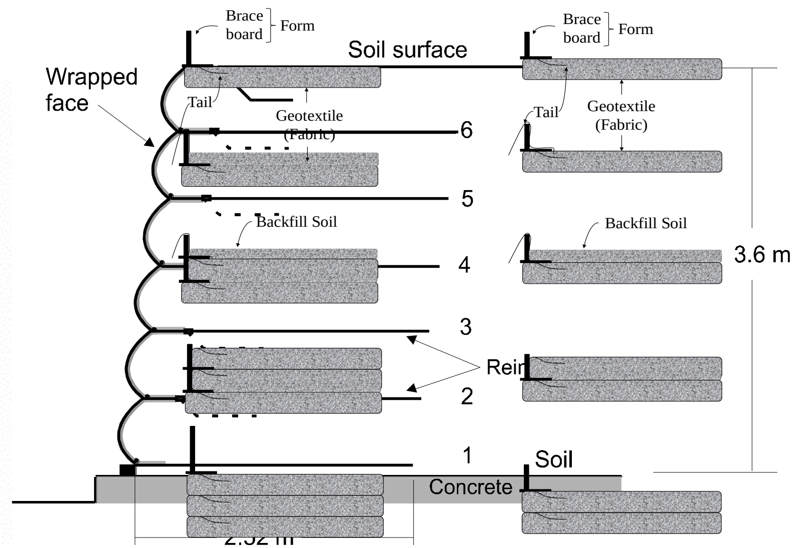


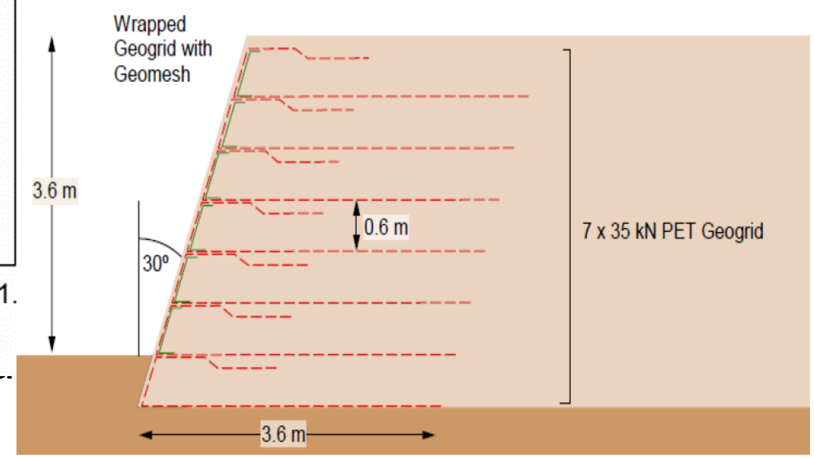
Section 5
Wrapped around wall





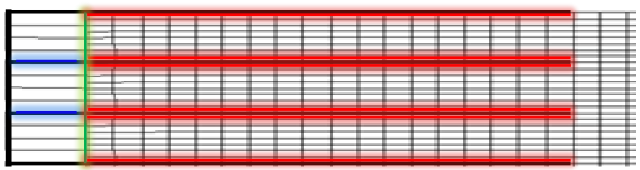
and surcharge application.

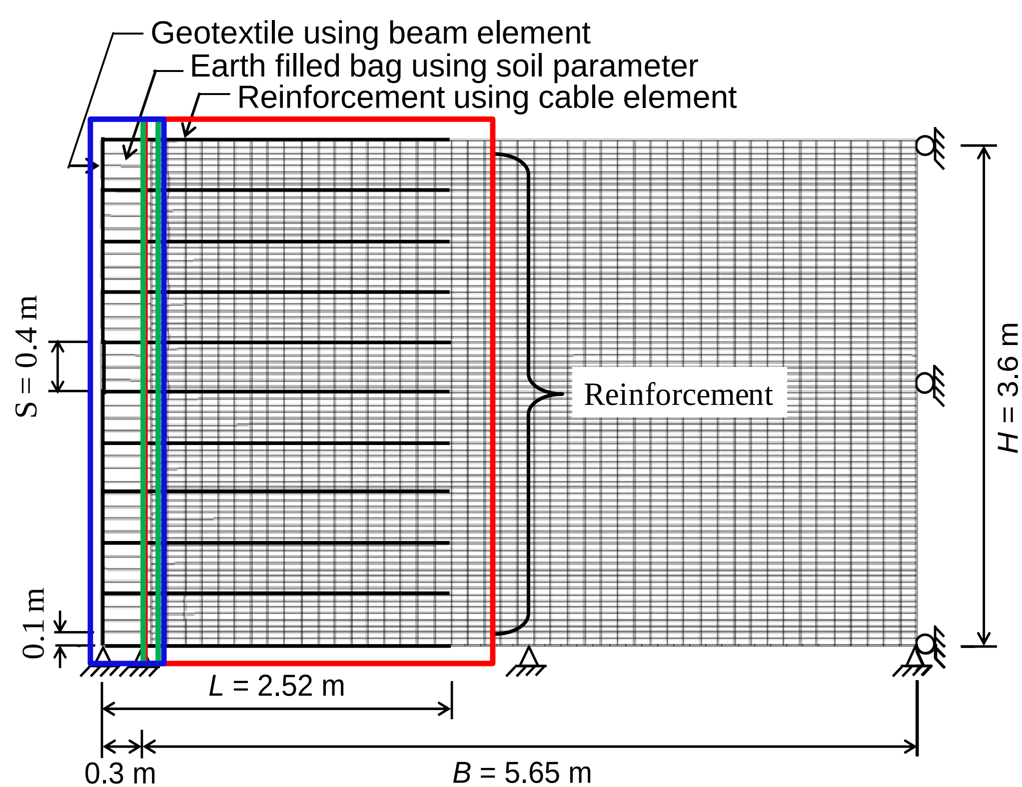




Numerical model

Parameter	Value
Reinforcement-soil interface	
Grout stiffness, $K_{s,g}$ (MN/m/m)	1
Grout frictional resistance, ϕ_g (degree)	44
Grout cohesive strength, C_g (kN/m)	2*
Soil-earth filled bag interface	
Friction angle, ϕ_{sb} (degree)	44
Dilation angle, ψ_{sb} (degree)	11
Cohesion, c_{sb} (kPa)	1
Normal stiffness, $k_{n,sb}$ (MPa/m)	100
Shear stiffness, $k_{s,sb}$ (MPa/m)	1
Geotextile-geotextile interface	
Friction angle, ϕ_{bb} (degree)	32
Dilation angle, ψ_{bb} (degree)	0
Cohesion, c_{bb} (kPa)	5
Normal stiffness, $k_{n,bb}$ (MPa/m)	1000
Shear stiffness, $k_{s,bb}$ (MPa/m)	4





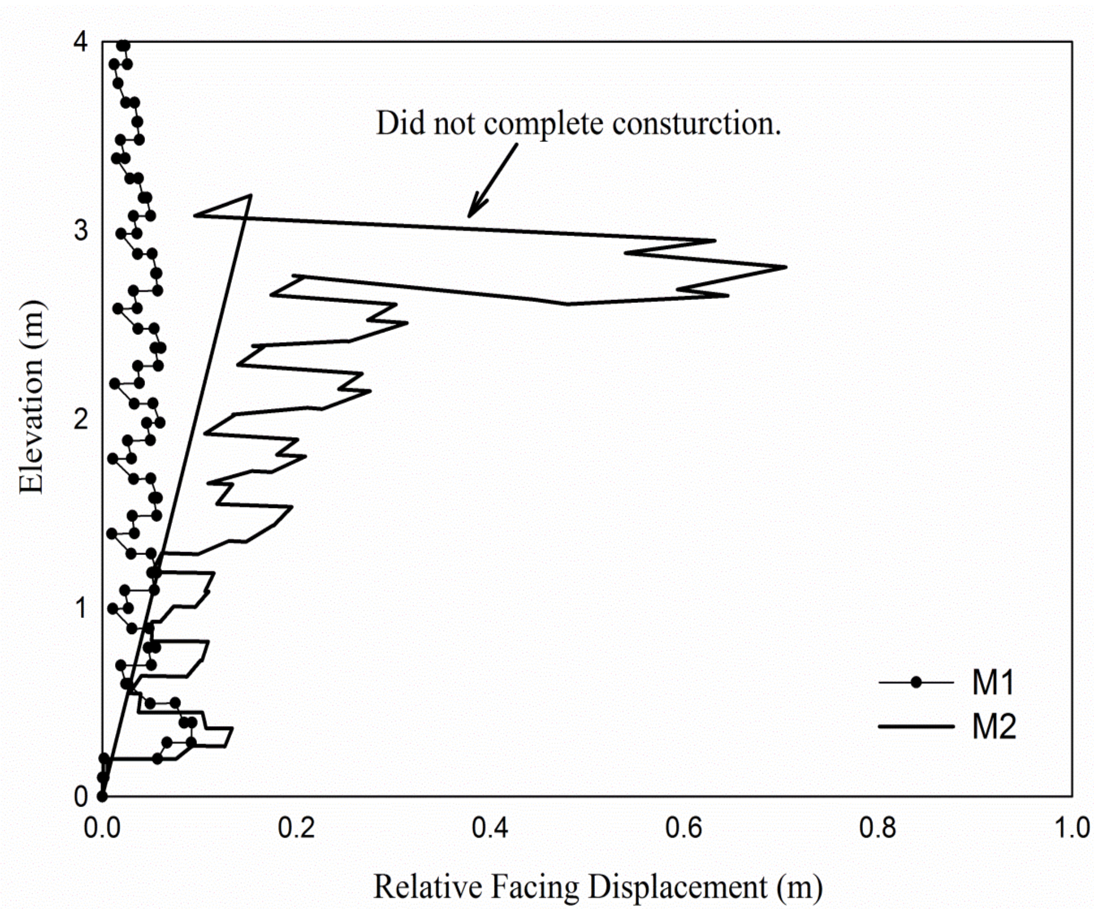
Sensitivity Influence Of Numerical Model I

No.	Reinforcement	Geotextile-Geotextile Interface	Bending moment
M1	Yes	ksbb=0.050MPa/m	EI=5e-4 kNm^2/m
M2	No	ksbb=0.050MPa/m	-
M3	No	ksbb=0.075MPa/m	-
M4	No	ksbb=0.500MPa/m	-
M5	Yes	ksbb=0.050MPa/m	*EI=5e-3 kNm^2/m
M6	Yes	ksbb=0.050MPa/m	*EI=5e-1 kNm^2/m
M7	Yes	ksbb=0.050MPa/m	**EA=EA×3
M8	Yes	ksbb=0.050MPa/m	**EA=EA×2

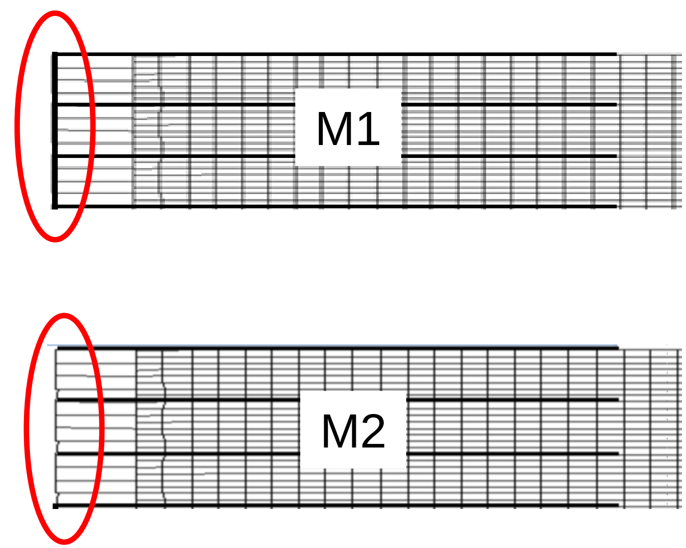
Note: *EI (bending stiffness) (kNm^2/m) for wrapped face beam element.
**EA (axial stiffness) (kN/m) for wrapped face beam element.

- The sensitivity analysis for wrapped face element using beam element.

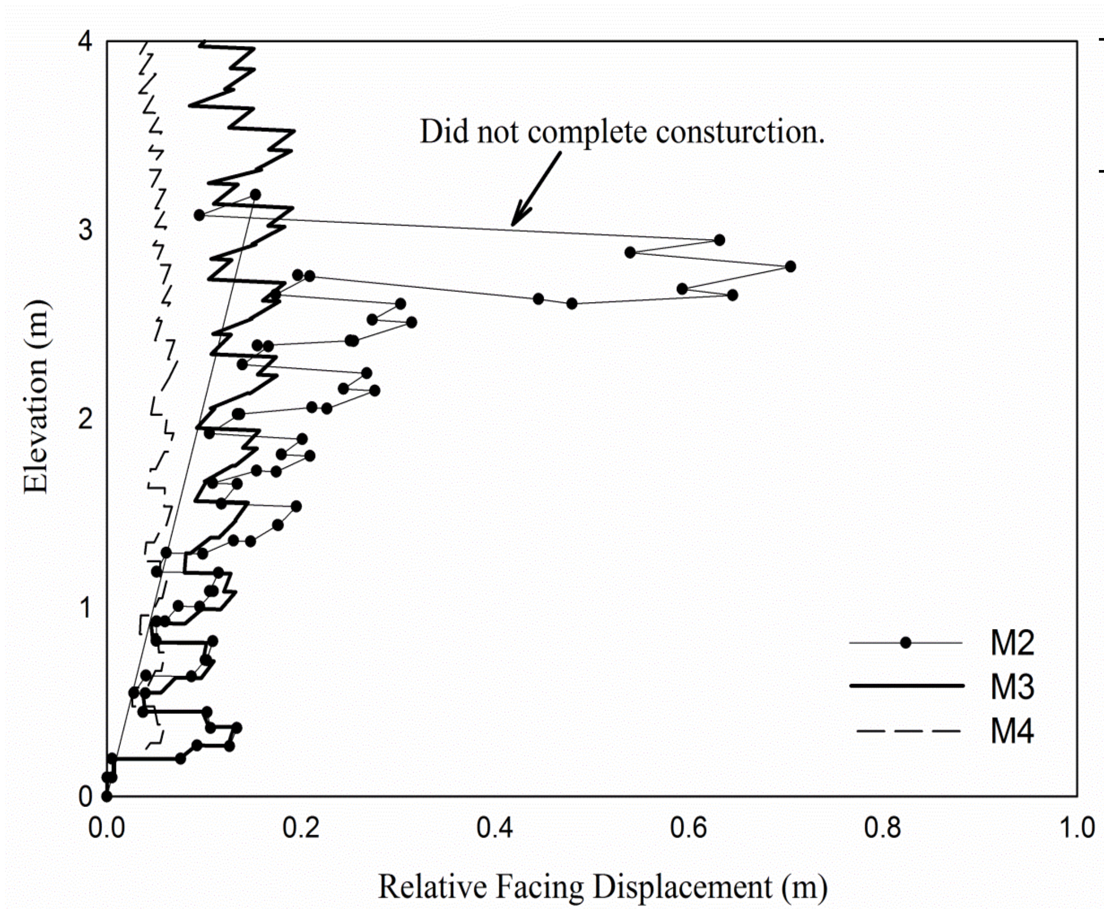
Sensitivity Influence Of Numerical Model II



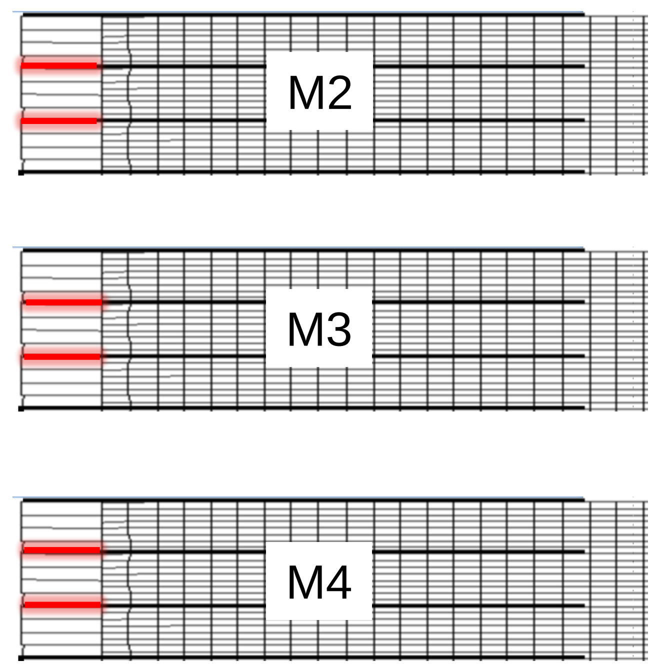
M1	Yes	ksbb=0.050MPa/m	EI=5e-4 kNm^2/m
M2	No	ksbb=0.050MPa/m	-

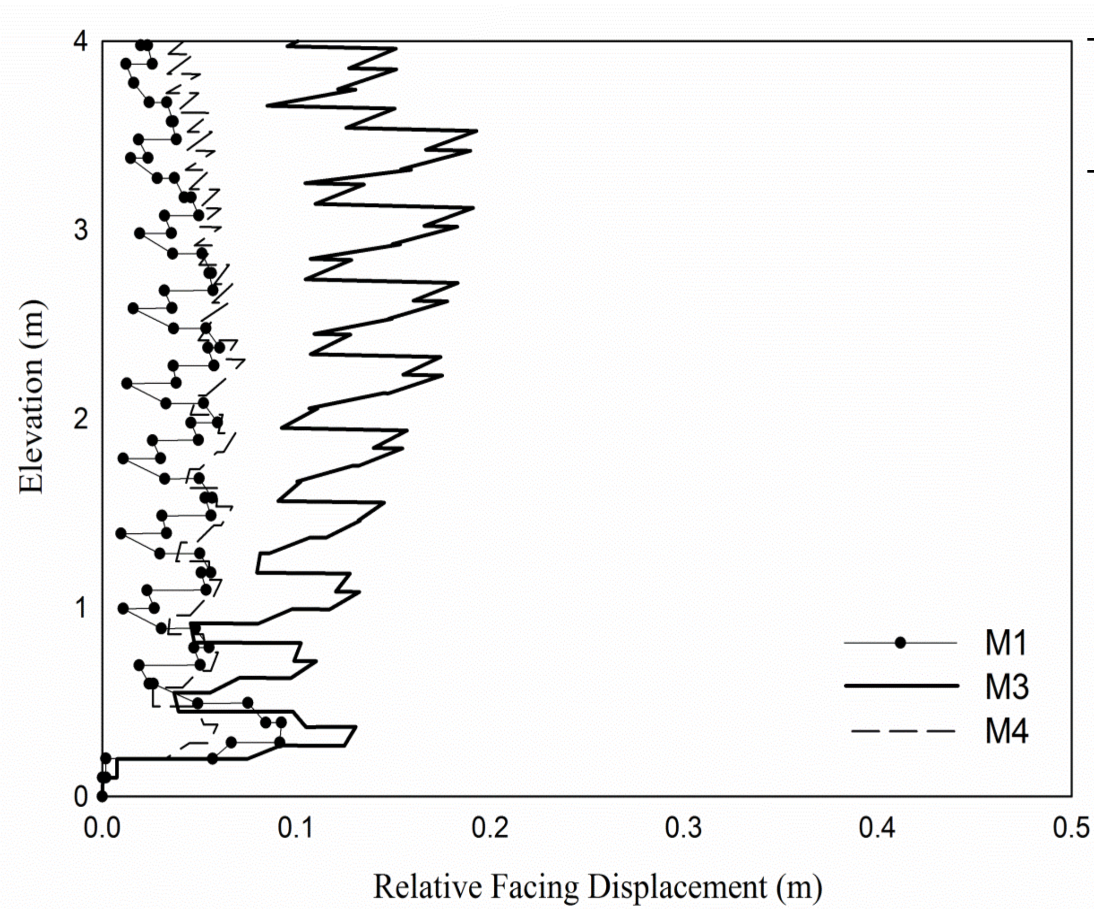


Sensitivity Influence Of Numerical Model III

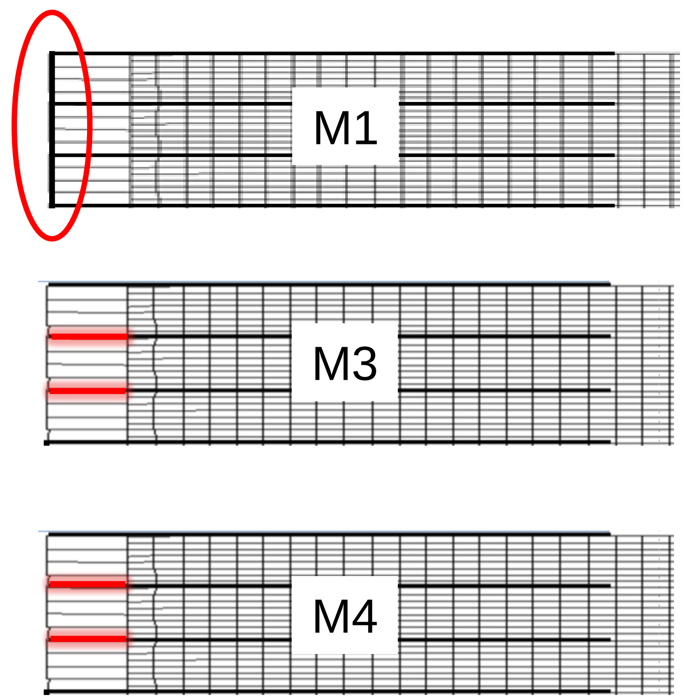


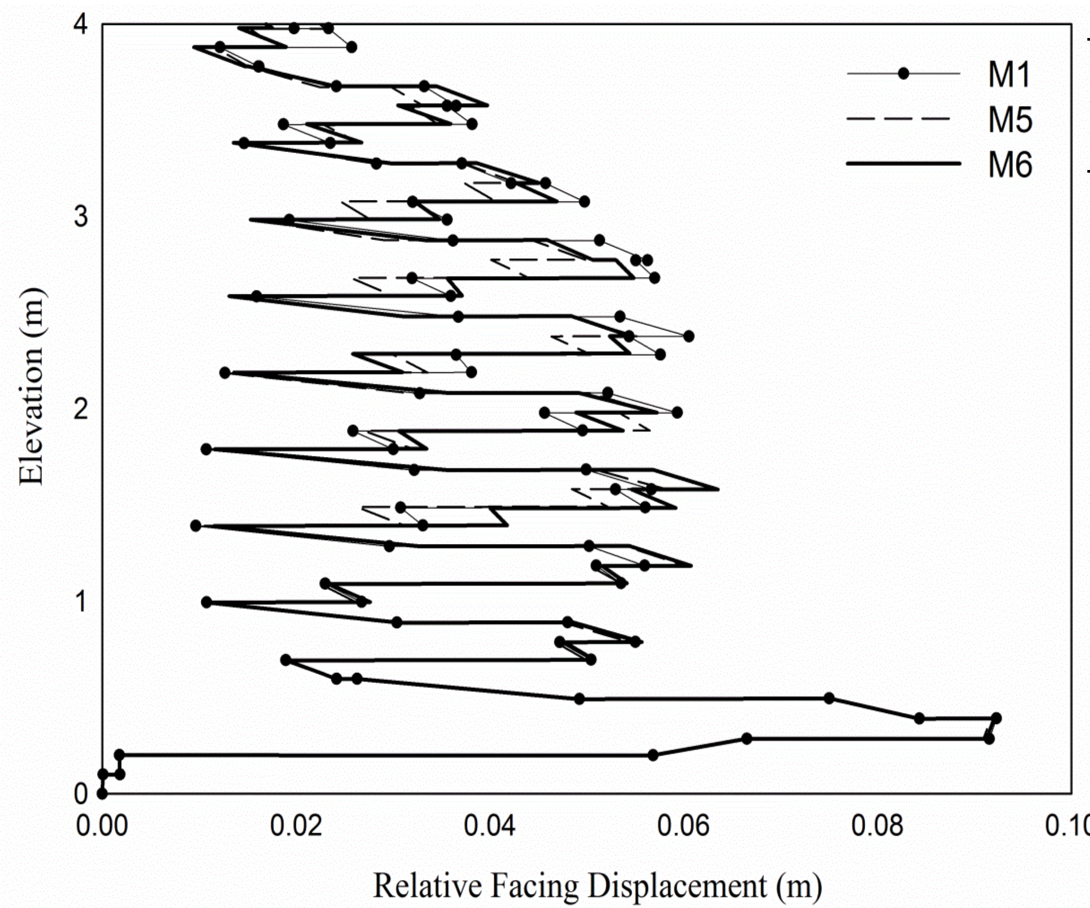
M2	No	ksbb=0.050MPa/m
M3	No	ksbb=0.075MPa/m
M4	No	ksbb=0.500MPa/m



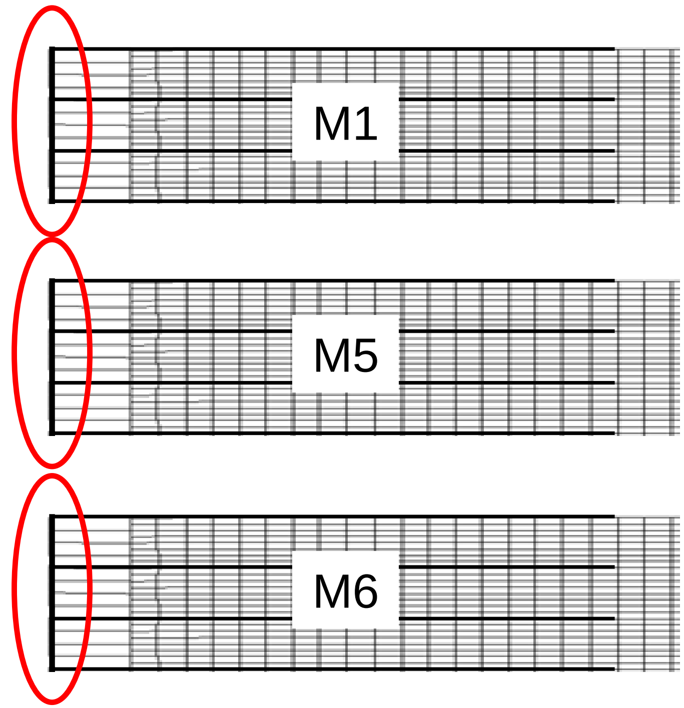


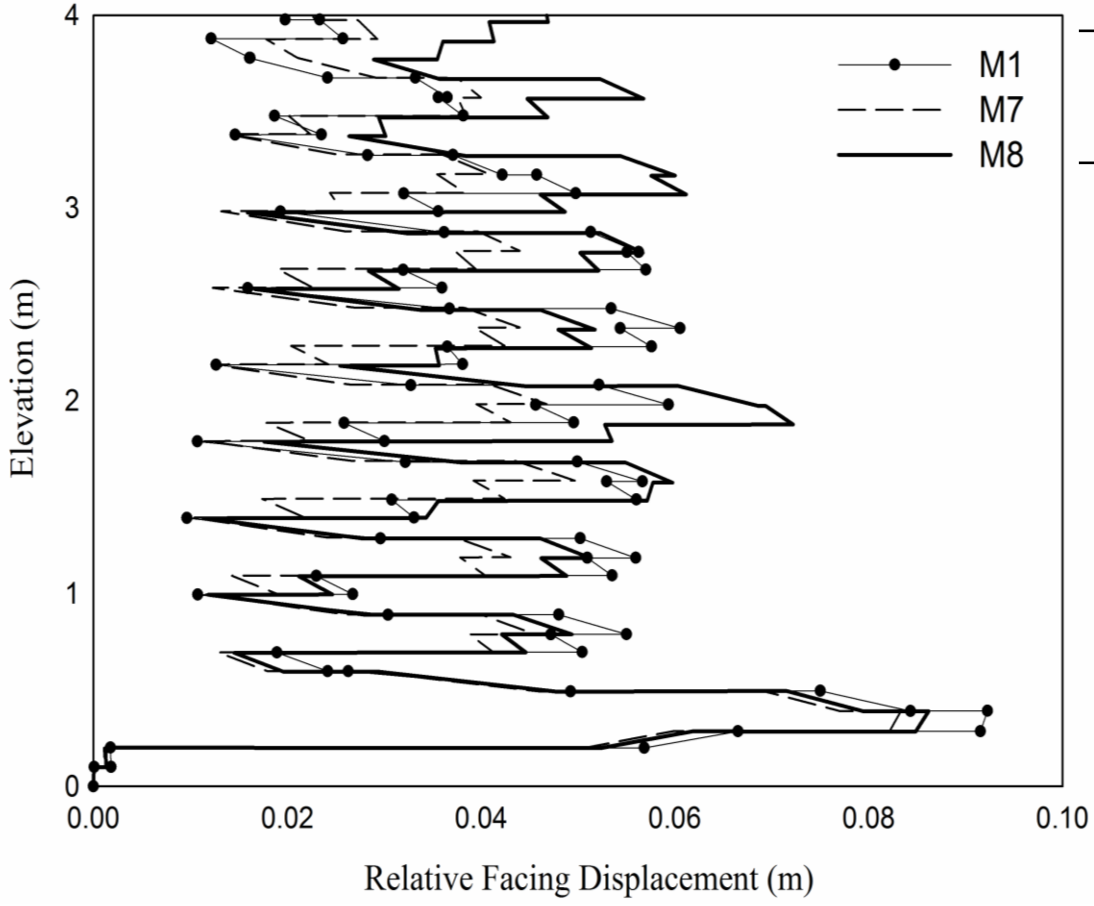
M1	Yes	ksbb=0.050MPa/m	EI=5e-4 kNm^2/m
M3	No	ksbb=0.075MPa/m	-
M4	No	ksbb=0.500MPa/m	-



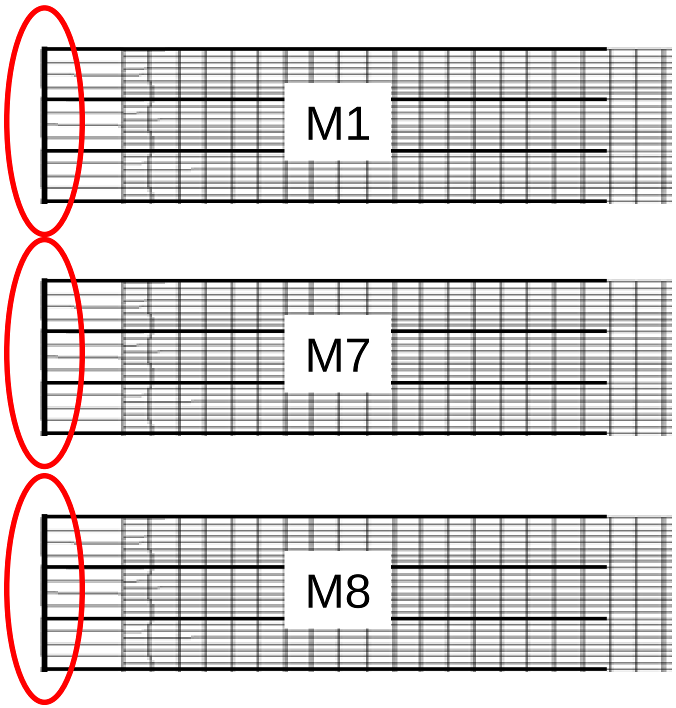


M1	Yes	ksbb=0.050MPa/m	EI=5e-4 kNm^2/m
M5	Yes	ksbb=0.050MPa/m	*EI=5e-3 kNm^2/m
M6	Yes	ksbb=0.050MPa/m	*EI=5e-1 kNm^2/m





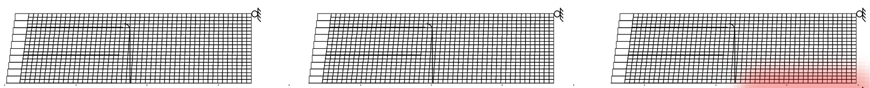
M1	Yes	ksbb=0.050MPa/m	EI=5e-4 kNm^2/m
M7	Yes	ksbb=0.050MPa/m	**EA=EA×3
M8	Yes	ksbb=0.050MPa/m	**EA=EA×2



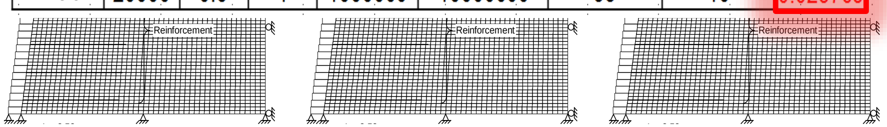
Numerical for Experiments MSE Wall I

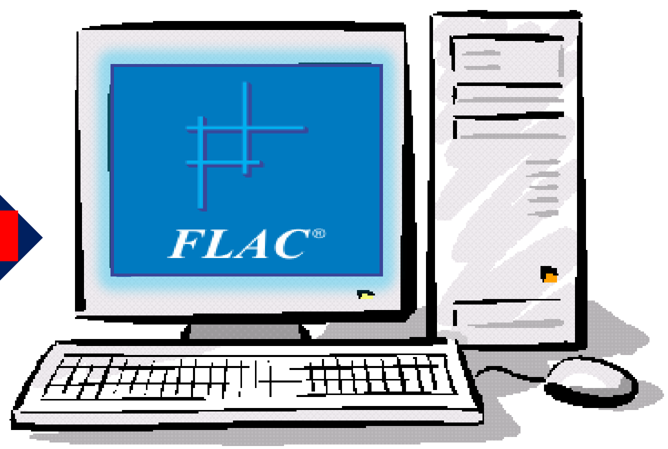
Parameter	Value
Wall height, H (m)	4, **6**, 8
Facing batter, ω (degree)	0, **5**, 10
Soil friction angle, ϕ (degree)	35, **40**, 45
Soil dilation angle, ψ (degree)	ϕ-30
Cable grout frictional resistance, ϕ_g (degree)	ϕ
Soil-earth-filled bag interface friction angle, ϕ_{sb} (degree)	ϕ
Soil-earth-filled bag interface dilation angle, ψ_{sb} (degree)	ϕ-30
Reinforcement axial stiffness, J (kN/m)	500, **1000**, 2000
Reinforcement ultimate strength, T_{ult} (kN/m)	$0.1 \times J$
Geotex.-Geotex. interface shear stiffness, $k_{s,bb}$ (MPa/m)	1, **5**, 10
Surcharge pressure, q (kPa)	0, **10**, 20
Compaction pressure, C_p (kPa)	8, **12.5**, 70

Numerical Experiments MSE Wall II



Test No	q (Pa)	S (m)	H (m)	J (N/m)	Ksbb (Pa/m)	φ (degree)	ω (degree)	δ max (m)
1	0	0.6	4	500000	10000000	35	0	0.023488
2	10000	0.6	4	500000	10000000	35	0	0.025512
3	20000	0.6	4	500000	10000000	35	0	0.035963
4	0	0.6	4	1000000	10000000	35	0	0.015731
5	10000	0.6	4	1000000	10000000	35	0	0.01703
6	20000	0.6	4	1000000	10000000	35	0	0.023765
7	0	0.6	4	10000000	10000000	35	0	0.012039
8	10000	0.6	4	10000000	10000000	35	0	0.012969
9	20000	0.6	4	10000000	10000000	35	0	0.017534
10	0	0.6	4	500000	10000000	40	0	0.015709
11	10000	0.6	4	500000	10000000	40	0	0.016904
12	20000	0.6	4	500000	10000000	40	0	0.023816
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
1456	0	0.6	4	1000000	10000000	35	10	0.015731
1457	10000	0.6	4	1000000	10000000	35	10	0.01703
1458	20000	0.6	4	1000000	10000000	35	10	0.023765





PC Performance of 1458

Response result

RSM Equation I

Test No	q (Pa)	S (m)	H (m)	J (N/m)	Ksbb (Pa/m)	φ (degree)	ω (degree)	δ max (m)
1	0	0.6	4	500000	10000000	35	0	0.023488
2	10000	0.6	4	500000	10000000	35	0	0.025512
3	20000	0.6	4	500000	10000000	35	0	0.035963
4	0	0.6	4	1000000	10000000	35	0	0.015731
5	10000	0.6	4	1000000	10000000	35	0	0.01703
6	20000	0.6	4	1000000	10000000	35	0	0.023765
7	0	0.6	4	10000000	10000000	35	0	0.012039
8	10000	0.6	4	10000000	10000000	35	0	0.012969
9	20000	0.6	4	10000000	10000000	35	0	0.017534
10	0	0.6	4	500000	10000000	40	0	0.015709
11	10000	0.6	4	500000	10000000	40	0	0.016904
12	20000	0.6	4	500000	10000000	40	0	0.023816
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
1456	0	0.6	4	1000000	10000000	35	10	0.015731
1457	10000	0.6	4	1000000	10000000	35	10	0.01703
1458	20000	0.6	4	1000000	10000000	35	10	0.023765

$$\{y\} = [x_{i=1\sim6}]\cdot\{\beta_{i=0\sim27}\}$$

Known number — Known number — Un-Known number

$\{y\}$ = Simulation results, $\log(\delta_{max}/H)$

$[x_{i=1\sim6}]$ = Independent parameter matrix

$\{\beta_{i=0\sim27}\}$ = Regression coefficient

The chapter 5 using three different model:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_{11}^2 + \beta_{22} x_{22}^2 + \varepsilon$$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \varepsilon$$

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_{11}^2 + \beta_{22} x_{22}^2 + \beta_{12} x_1 x_2 + \varepsilon$$

All model from Response Surface Method.

RSM Equation II

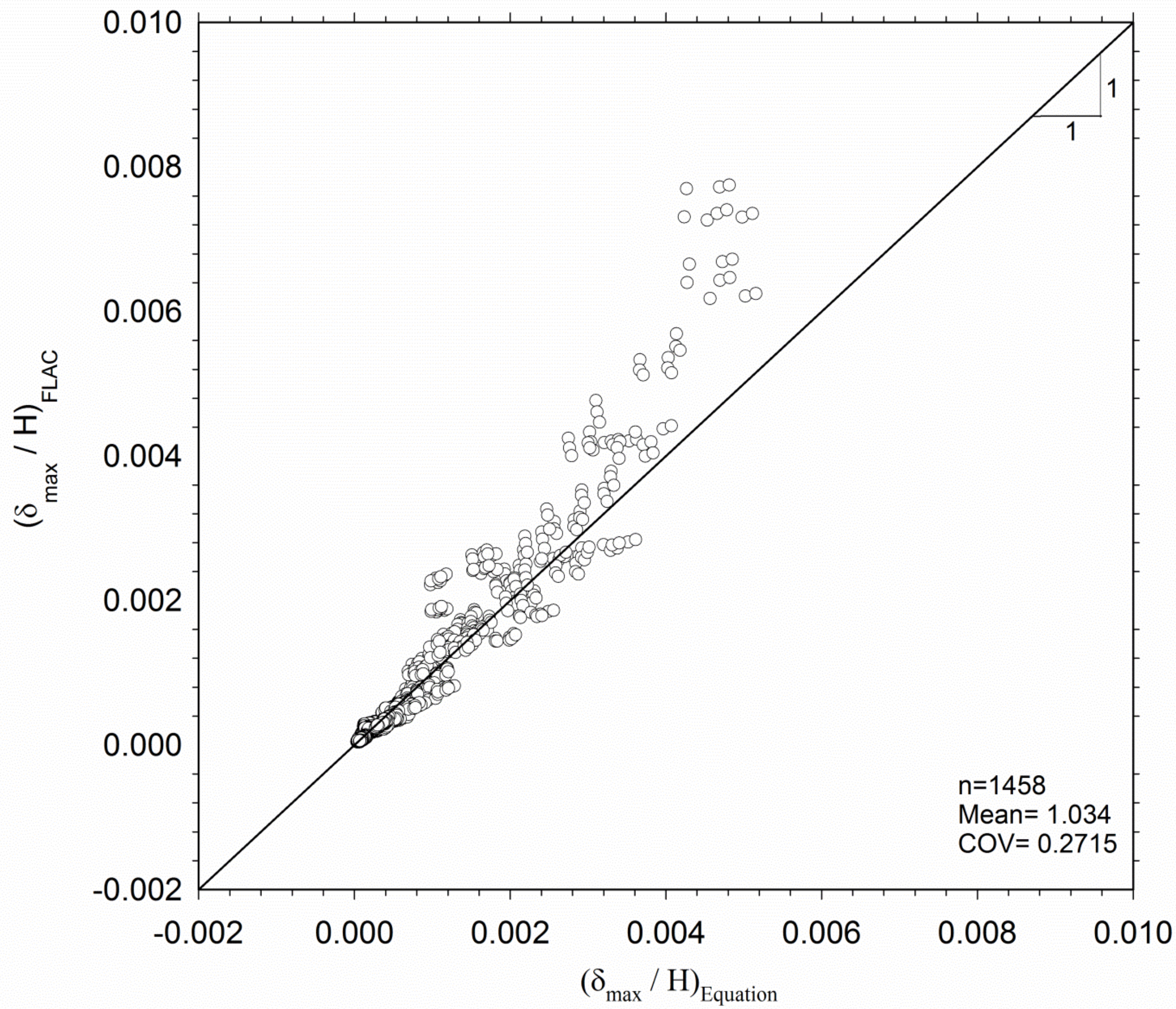
$y = \beta_0 + \beta_1 x_1 \cdots$

$+ \beta_7 x_1^2 + \beta_8 \cdots$

$$y = \ln\left(\frac{\delta_{max}}{H}\right.$$

$$x_1 = \frac{q}{\gamma H}$$

$$x_2 = \frac{C_p \times \cdots}{J}$$



t Value
-5.048
0.863
-0.749
0.771
63.683
0.329
-10.974
-1.536
8.590
0.007
0.000
-0.007
7.101
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

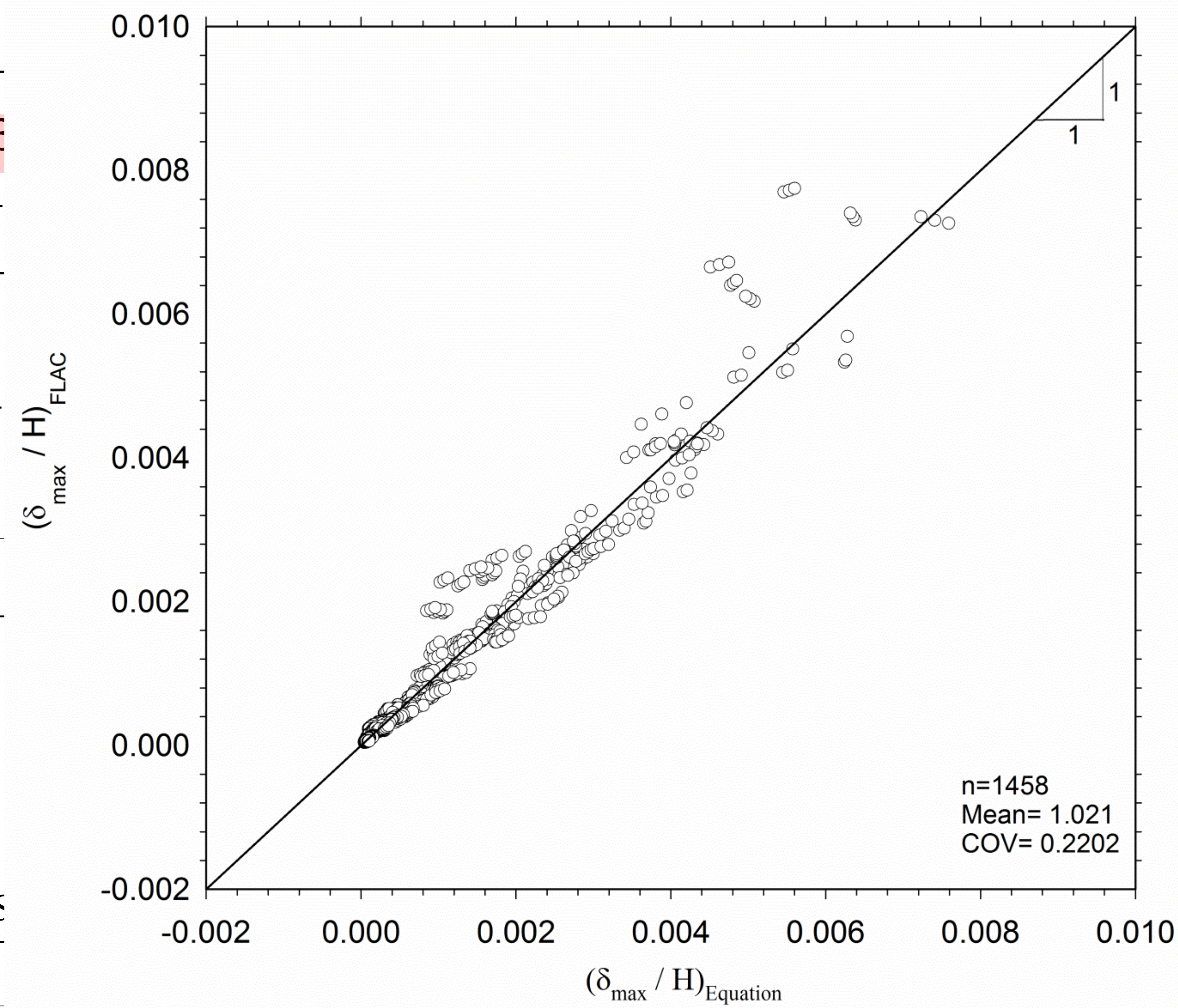
RSM Equation III

$$y = \beta_0 + \beta_1 x_1 -$$
$$+ \beta_7 x_1 x_2 + \beta$$
$$+ \beta_{12} x_2 x_3 +$$
$$+ \beta_{16} x_3 x_4 +$$
$$+ \beta_{19} x_4 x_5 +$$
$$+ \beta_{21} x_5 x_6 +$$

$$y = \ln\left(\frac{\delta_{\max}}{H}\right.$$

$$x_1 = \frac{q}{\gamma H}$$

$$x_2 = \frac{C_p \times S}{J}$$



t	Value
	-1.467
	2.066
	-44.239
	0.008
	-35.497
	-0.219
	-7.341
	-1.917
	-0.102
	-19.316
	-0.015
	-0.703
	-0.343
	181.206
	0.653
	18.076
	4.860
	0.009
	0.133
	3.398
	99.848
	0.144
	-
	-
	-
	-
	-
	-

RSM Equation IV

$y = \beta_0 + \beta_1 x_1 +$

$+ \beta_7 x_1^2 + \beta_8 x$

$+ \beta_{13} x_1 x_2 +$

$+ \beta_{18} x_2 x_3 +$

$+ \beta_{22} x_3 x_4 +$

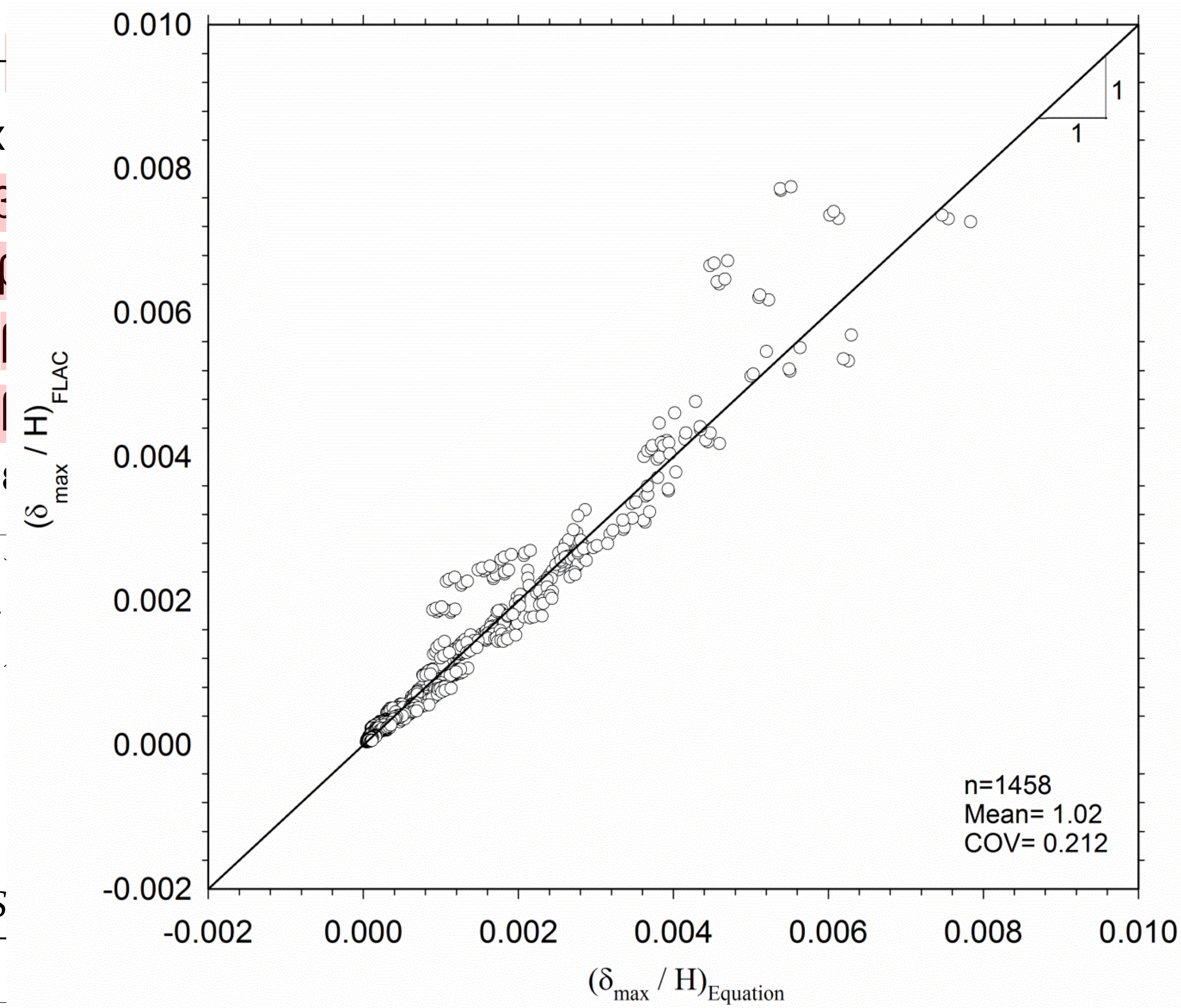
$+ \beta_{25} x_4 x_5 +$

$+ \beta_{27} x_5 x_6 +$

$$y = \ln\left(\frac{\delta_{max}}{H}\right.$$

$$x_1 = \frac{q}{\gamma H}$$

$$x_2 = \frac{C_p \times S}{J}$$



Value
3.891
2.097
-45.022
-0.362
-43.875
-0.328
-20.540
0.609
11.715
-0.017
0.000
0.002
7.140
-1.895
-0.103
-21.507
-0.015
-0.695
-0.250
178.600
0.661
18.496
5.189
0.008
0.129
4.063
100.847
0.147

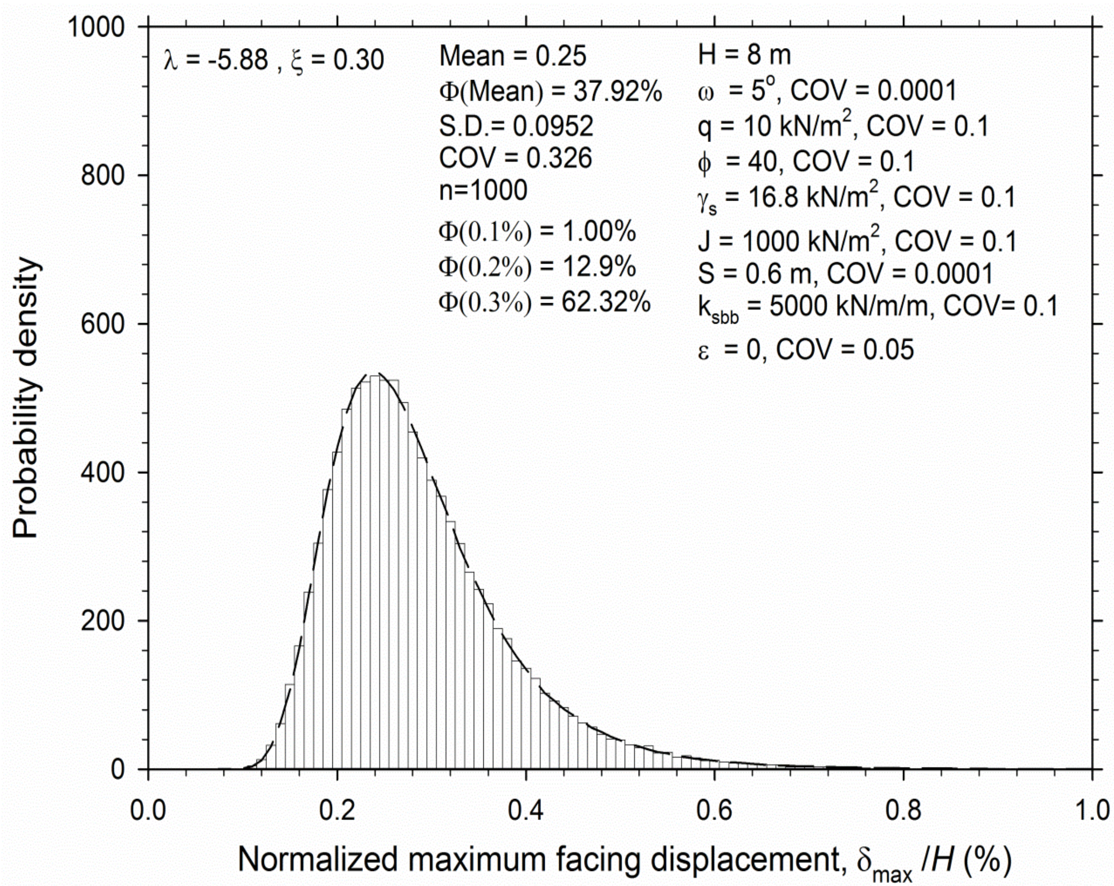
Reliability Analysis I

The prediction of the RSM equation can be made deterministically using beast estimates of the input parameter values. The parameters are given by the bold face values in here.

Parameter	Mean	COV
Wall height, H (m)	8	-
Facing batter, ω (degree)	5	-
Soil friction angle, ϕ (degree)	40	10%
Reinforcement axial stiffness, J (kN/m)	1000	10%
Geotextile-Geotex. interface shear stiffness, $k_{s,bb}$ (MPa/m)	5	10%
Surcharge pressure, q (kPa)	10	10%

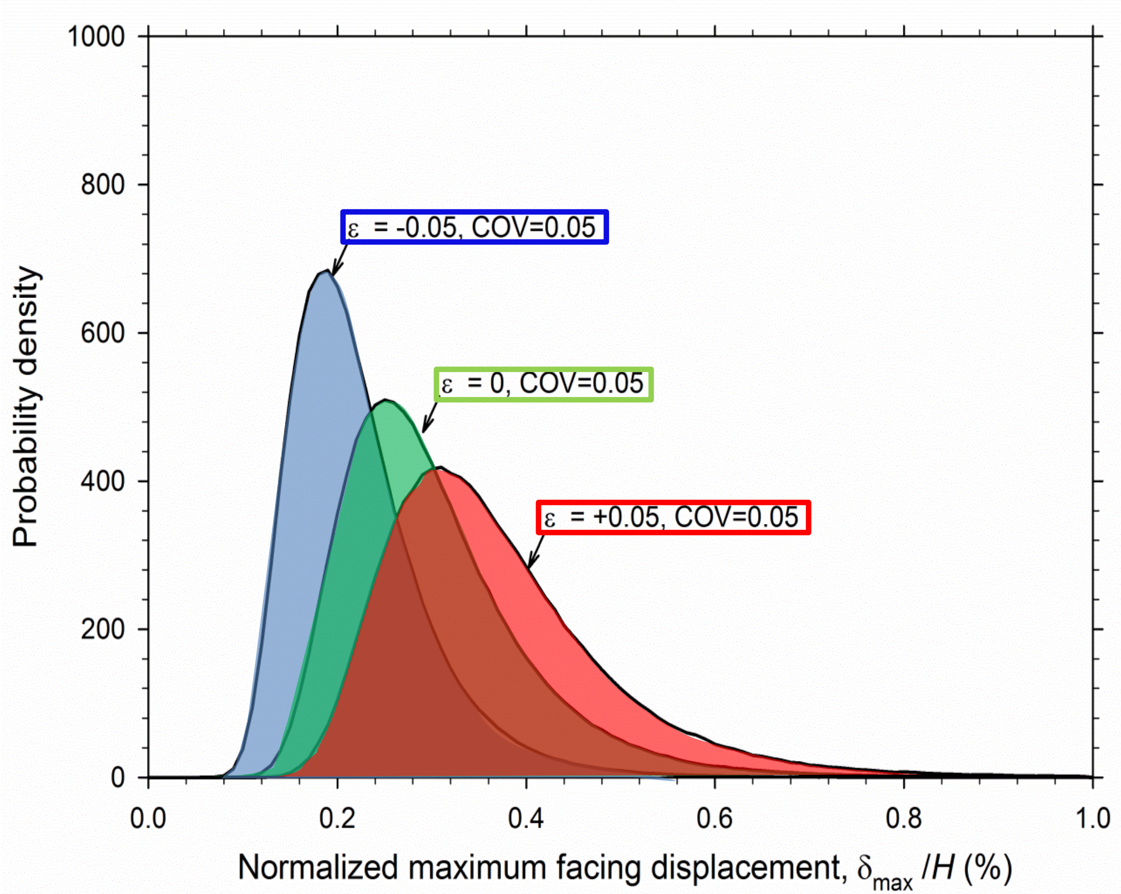
Note: Model uncertainty (ε) has mean of zero and standard deviation of 0.05

Reliability Analysis II



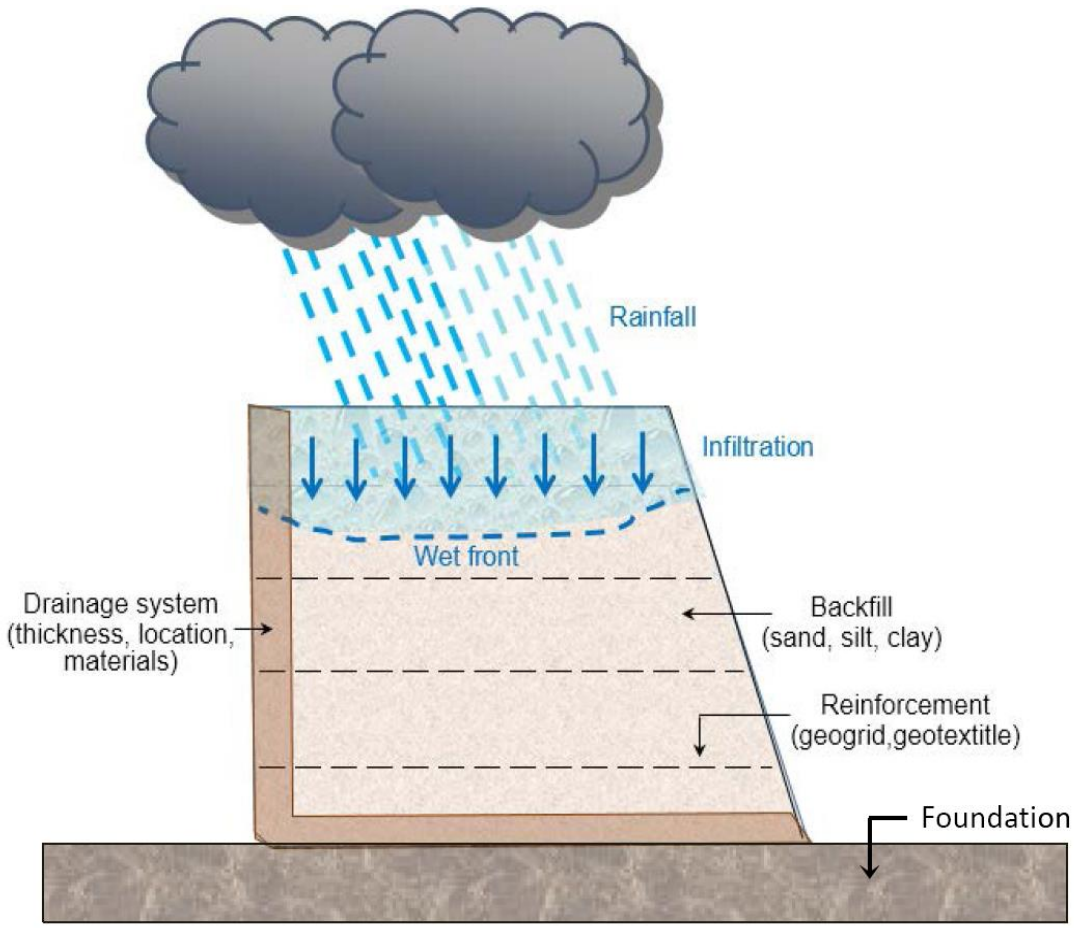
- 1,000,000 Monte Carlo simulations of RSM equation for maximum wall face displacement.
- The histogram of maximum wall face displacement is well fitted with a log-normal distribution.
- Failure probability for performance criterion of wrapped face MSE wall can be calculated as the failure probability of this log-normal distribution.

Model Uncertainty Reliability Analysis III



- We using same as parameters from previous page to did 1,000,000 Monte Carlo simulations .
- But input different model uncertainties values (we got different log-normal distribution.)
- Model uncertainty value has significant influence.

Section 6
Research In Future



Conclusions I

1. The RSM approach described in this study is demonstrated to be a practical technique to gather numerical predictions from a large number of numerical model results into a manageable and accurate empirical expression of the response feature of interest.

2. In this study the response of interest was wall deformations. However, the same approach is possible for any other response feature such as reinforcement strains, loads or backfill settlements.

3. The resulting response surface equations can then be used to carry out deterministic and probabilistic estimates of each response feature of interest.

Conclusions II

4. The successful implementation of this approach is on the premise of developing a sound and response surface method equation. The significance of model uncertainty in the response surface method equation to the reliability analysis is also highlighted by conducting parametric study analysis. The inclusion of more measurement data of model walls or field walls will calibrate the numerical model and thus after the response surface method equation to a better extent.

Seminar presentation

Jan 19, 2017
National Chi Nan University

Thank you
for your listening

國立暨南國際大學
National Chi Nan University