

MIDAS CONSTRUCTION TECHNICAL DOCUMENT COLLECTION

圧密・浸透(軟弱地盤)分野 3



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圧密・浸透(軟弱地盤)分野

3.

軟弱地盤材料の 構成パラメータ同定方法

中央大学 太田 秀樹 教授



MIDAS 地盤技術セミナー

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軟弱地盤材料の 構成パラメータ同定方法

中央大学 太田秀樹

発表内容概要

初期条件と境界条件

地盤の初期応力状態の具体的な計算方法を説明
施工手順などを簡略化せず 細かく入力すること

今日のメイン ⇒ カンニングのすすめ

沈下や変形などの実測値とよくあう妥当な解析結果
これまでにどのような工夫が凝らされてきたのか
土質試験から構成パラメータをどのようにして決めるか

理論的な模索もふくめて
実際の解析例を中心に紹介

発表内容概要

通り一遍に取り扱われることが多い地盤の初期応力状態の設定方法について 具体的な計算方法を説明する

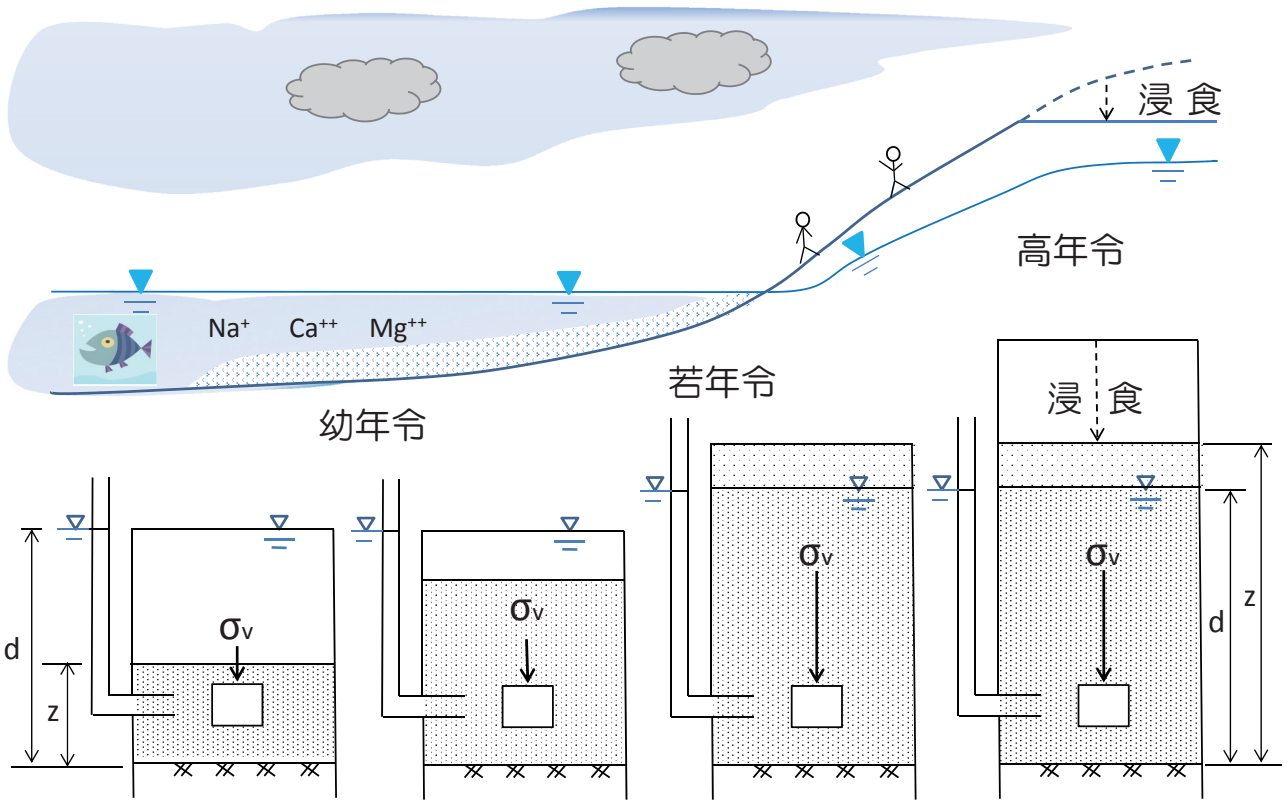
多種多様な軟弱地盤材料の土質試験結果から構成パラメータをどのようにして決めてゆくとよいか

結果的に 沈下や変形などの実測値とよくあう
妥当な解析結果を得るために
これまでにどのような工夫が凝らされてきたのか

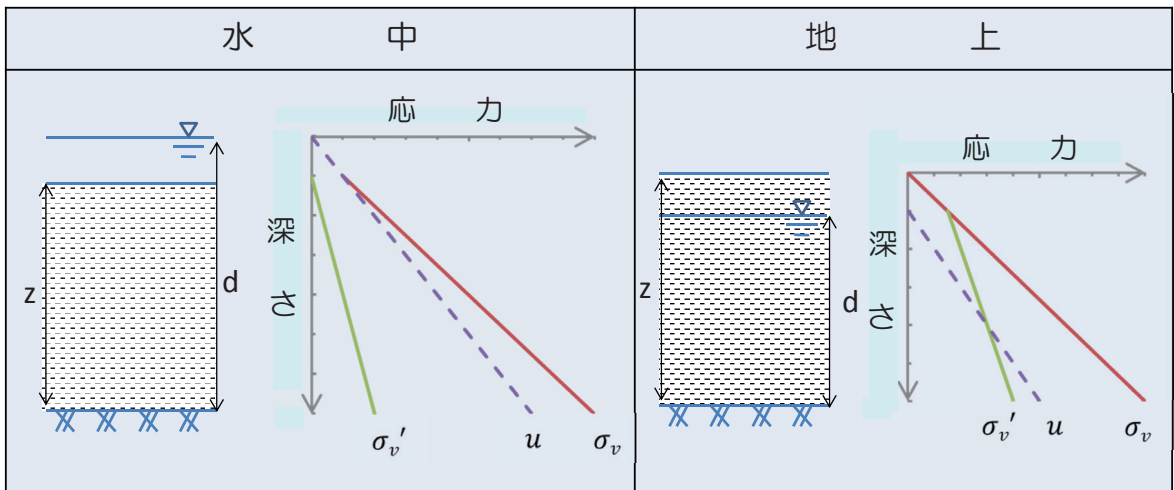
理論的な模索もふくめて
実際の解析例を中心に紹介する

初期条件

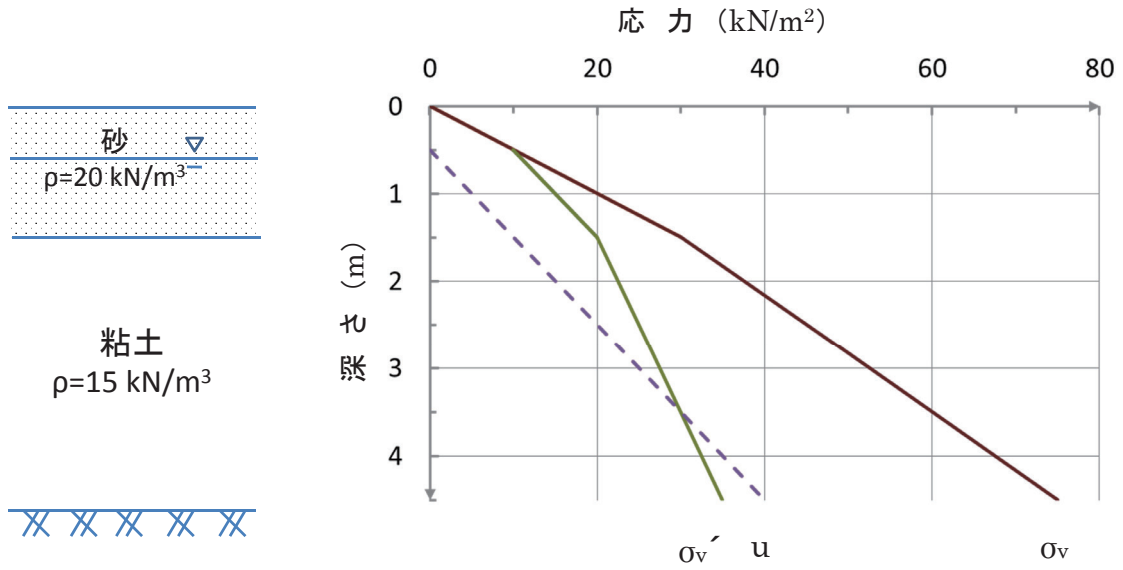
1. 間隙水圧 u
2. 上載圧 σ_v
3. 有効上載圧 $\sigma'_v = \sigma_v - u$
4. 有効水平応力 $\sigma'_h = K_0 \sigma'_v$
5. 水平応力 $\sigma_h = \sigma'_h + u$



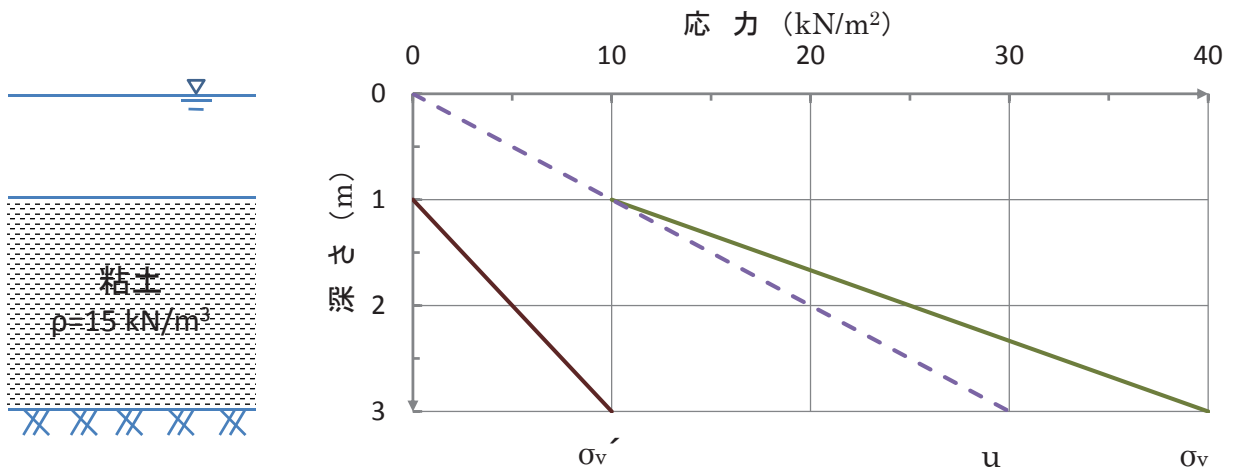
状態	正 規 圧 密		過 圧 密
構造	ゆるい構造		密な構造
全応力 間隙水圧 有効応力	$\sigma_v = \rho \cdot z + \rho_w(d - z)$ $-) u = \rho_w \cdot d$ $\sigma_v' = (\rho - \rho_w)z$ <p style="text-align: center; color: red;">水中重量</p>		$\sigma_v = \rho \cdot z$ $-) u = \rho_w \cdot d$ $\sigma_v' = (\rho - \rho_w)d + \rho(z - d)$ <p style="text-align: center; color: red;">水面下重量 水面上重量</p>



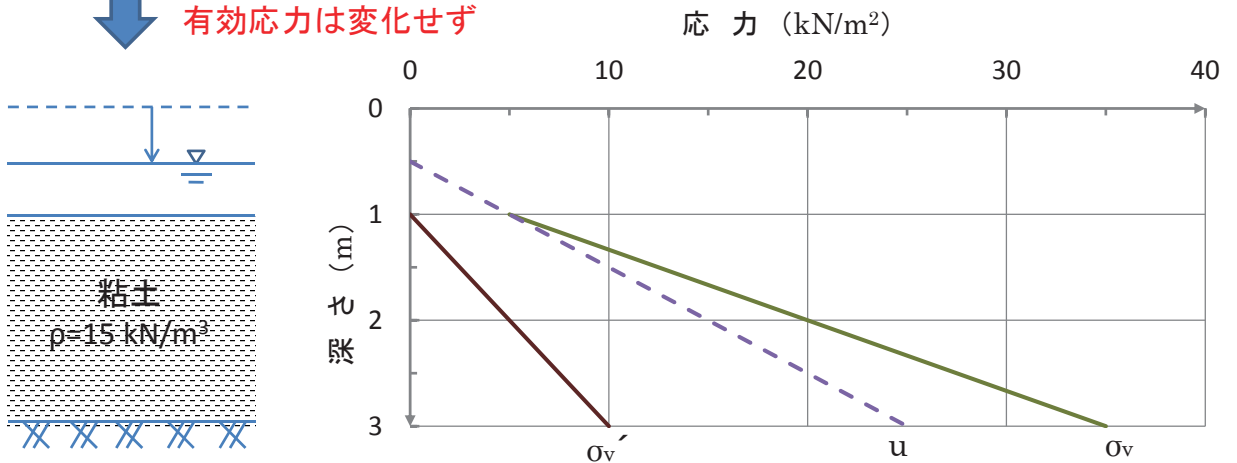
堆積土の年令変化と状態・構造・応力状況

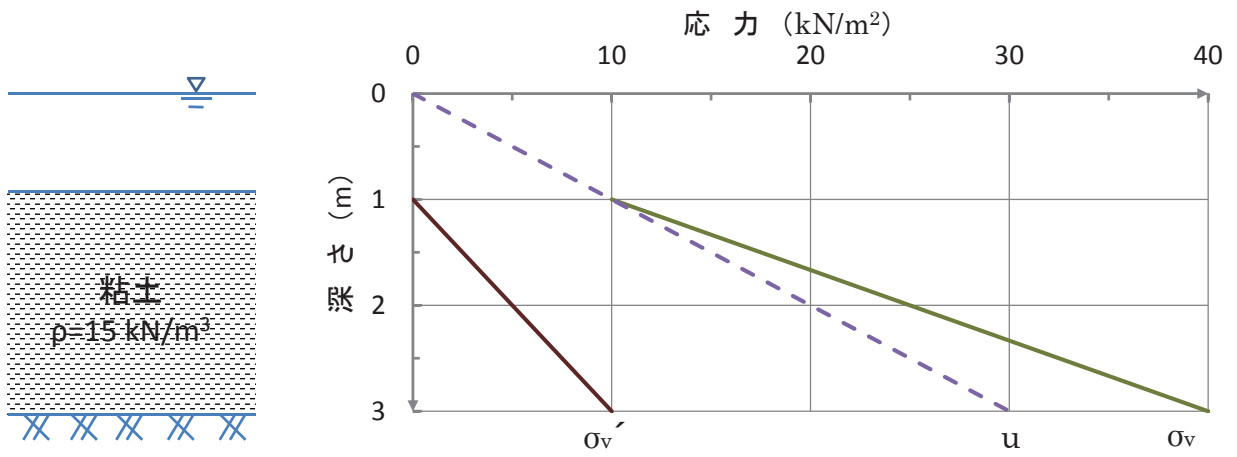


(100kPa=10tf/m²=1kgf/cm²)

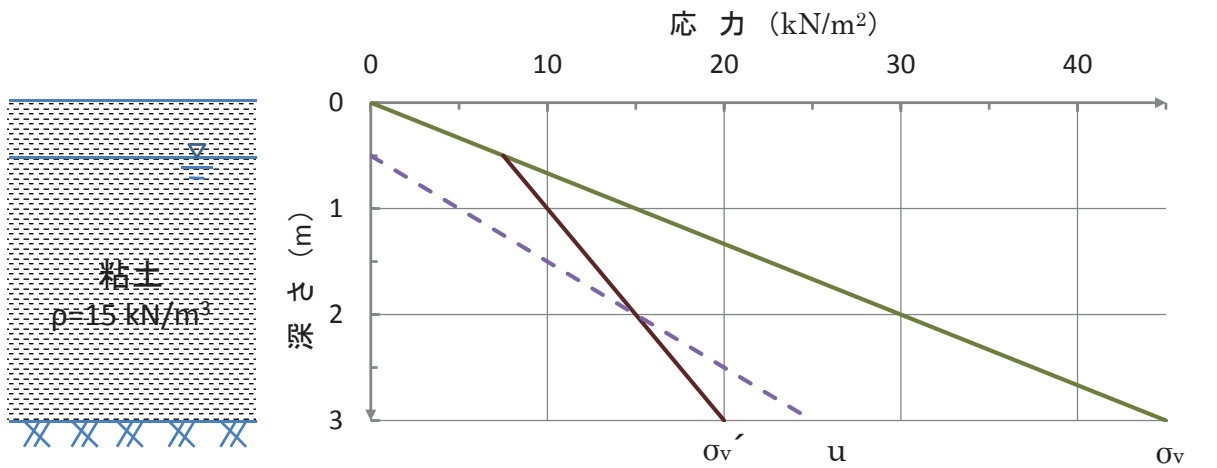
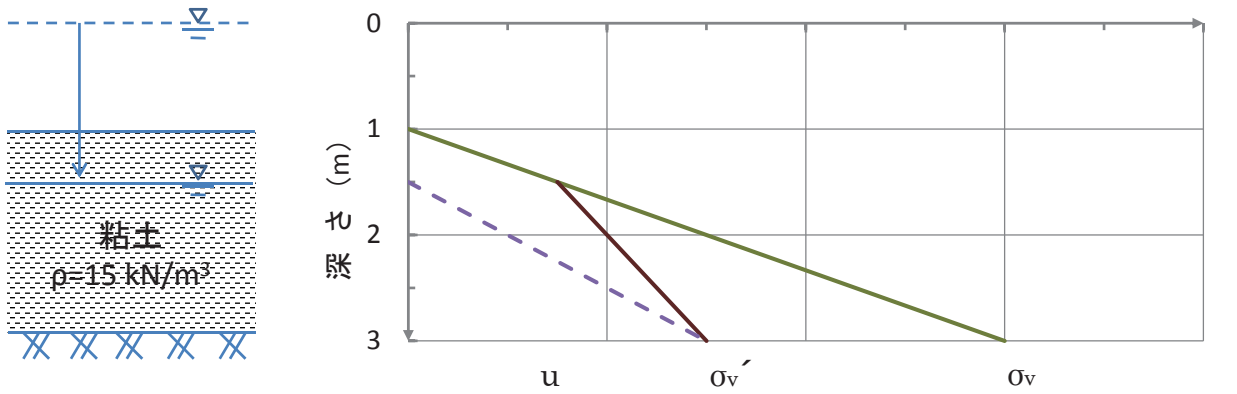


水深が変化
有効応力は変化せず

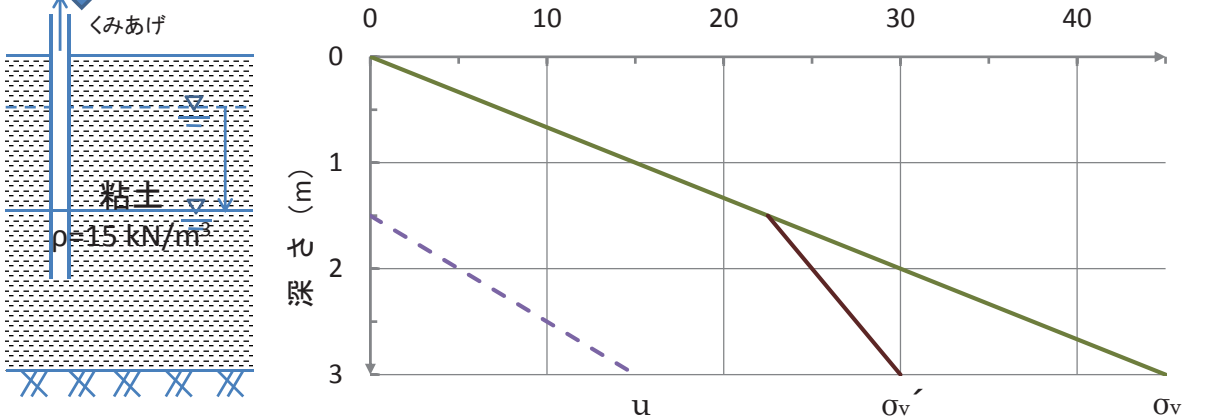


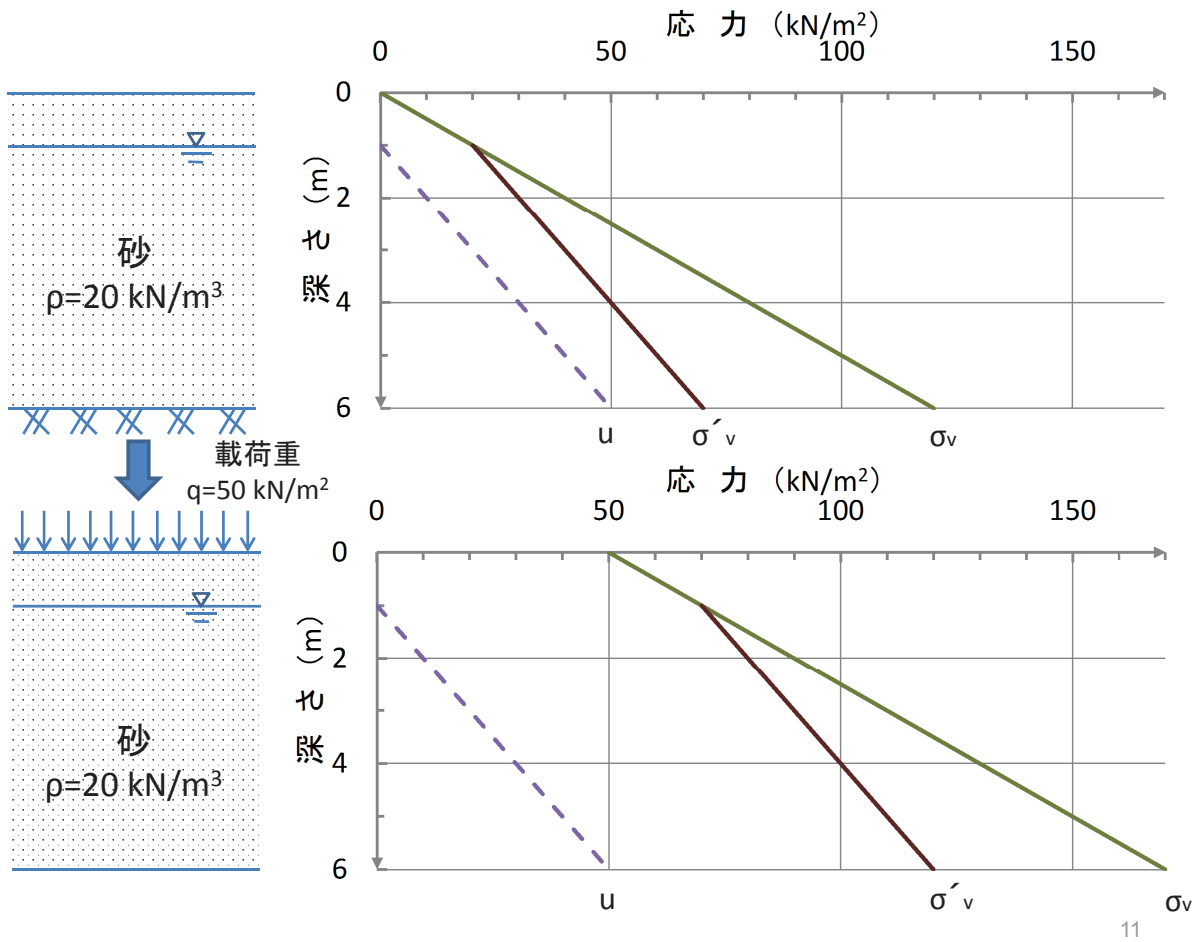


地下水水位が変化
有効応力も変化



地下水くみあげ
有効応力増加





解析事例

A. 1次元圧密と2次元圧密のちがい

九州横断道武雄北方インターチェンジ

道央自動車道 札幌ー岩見沢間の盛土沈下

秋田自動車道 傾斜基盤上の盛土

B. 超軟弱地盤でのいろいろな事例

大沢郷

スリランカ南部道路

すじみち

1. 問題の所在と研究のネライ
2. 1次元圧密と2次元圧密のちがい
3. Terzaghiの圧密理論と三笠の圧密理論
4. 九州横断道武雄北方インターチェンジにおけるプレロード盛土
道央自動車道 札幌－岩見沢間の盛土沈下
秋田自動車道 傾斜基盤上の盛土
5. 超軟弱地盤でのいろいろな事例
大沢郷
スリランカ南部道路

1. 問題の所在と研究のネライ

1次元圧密解析：

過去の経験からみて計算による予測の信頼性が十分でない、
感じている技術者が多い

でも

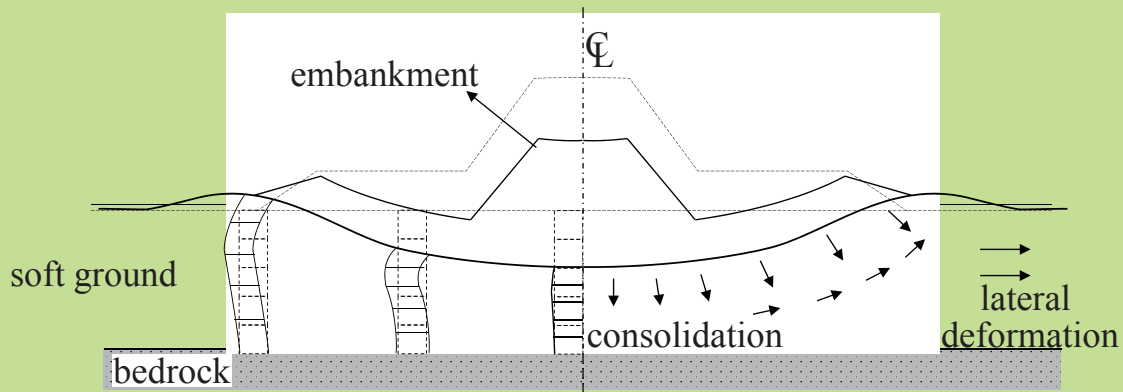
十分な安全率を確保しながら施工する場合：

破壊からほど遠い状態で施工しており、
粘土層のせん断にともなう側方流動が大きくないのであるから、
1次元圧密解析で沈下－時間関係を計算しても、
極端に実態と合わないわけではなかろう

2. 1次元圧密と2次元圧密のちがい

盛土のセンター直下であっても

粘土層が1次元圧密をしている訳ではないことに注意

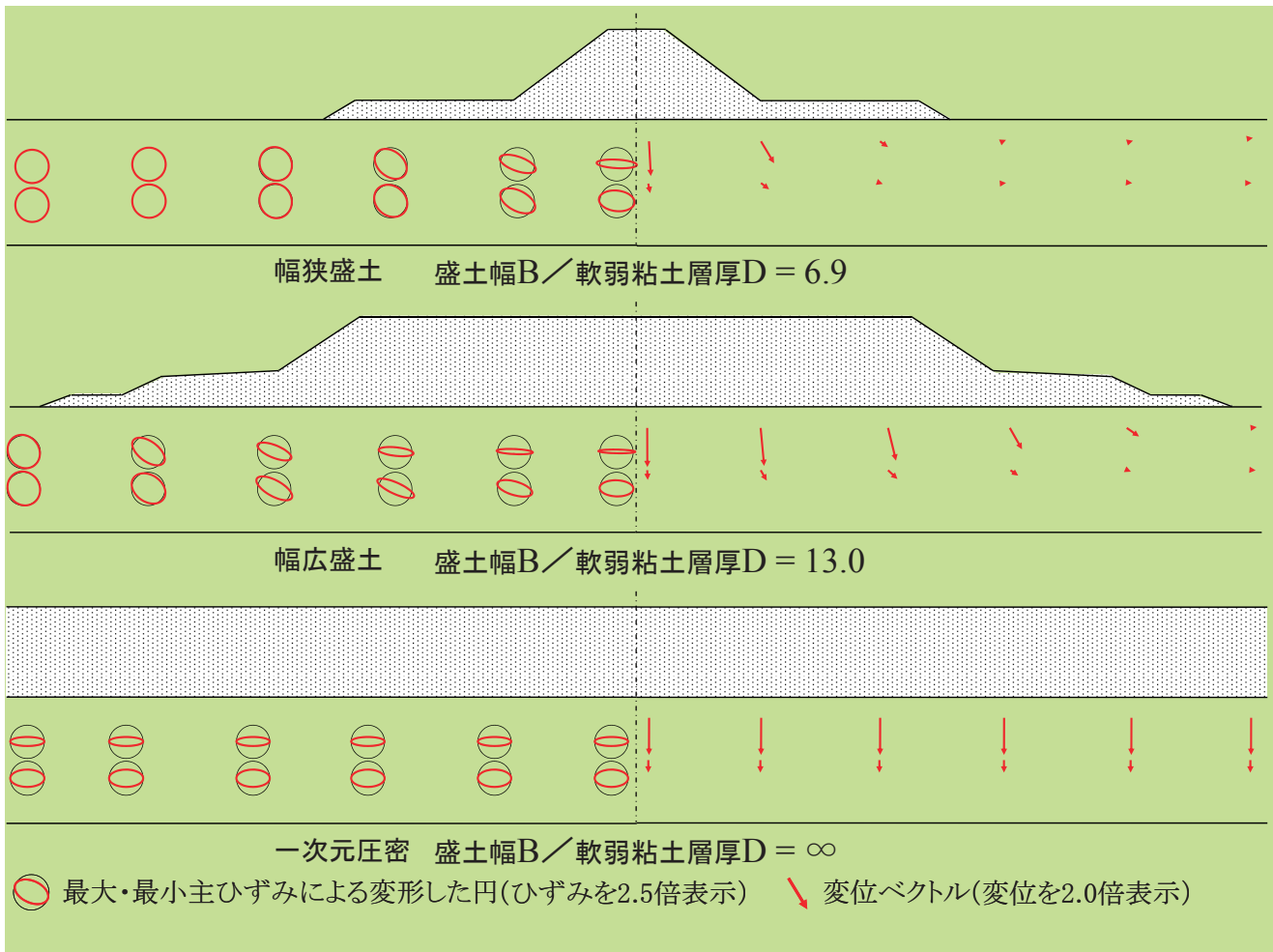


沈下予測 ...

2D (two-dimensional analysis) : 結構ややこしい

1D (one-dimensional analysis) : 簡単. でもよく合わない? .

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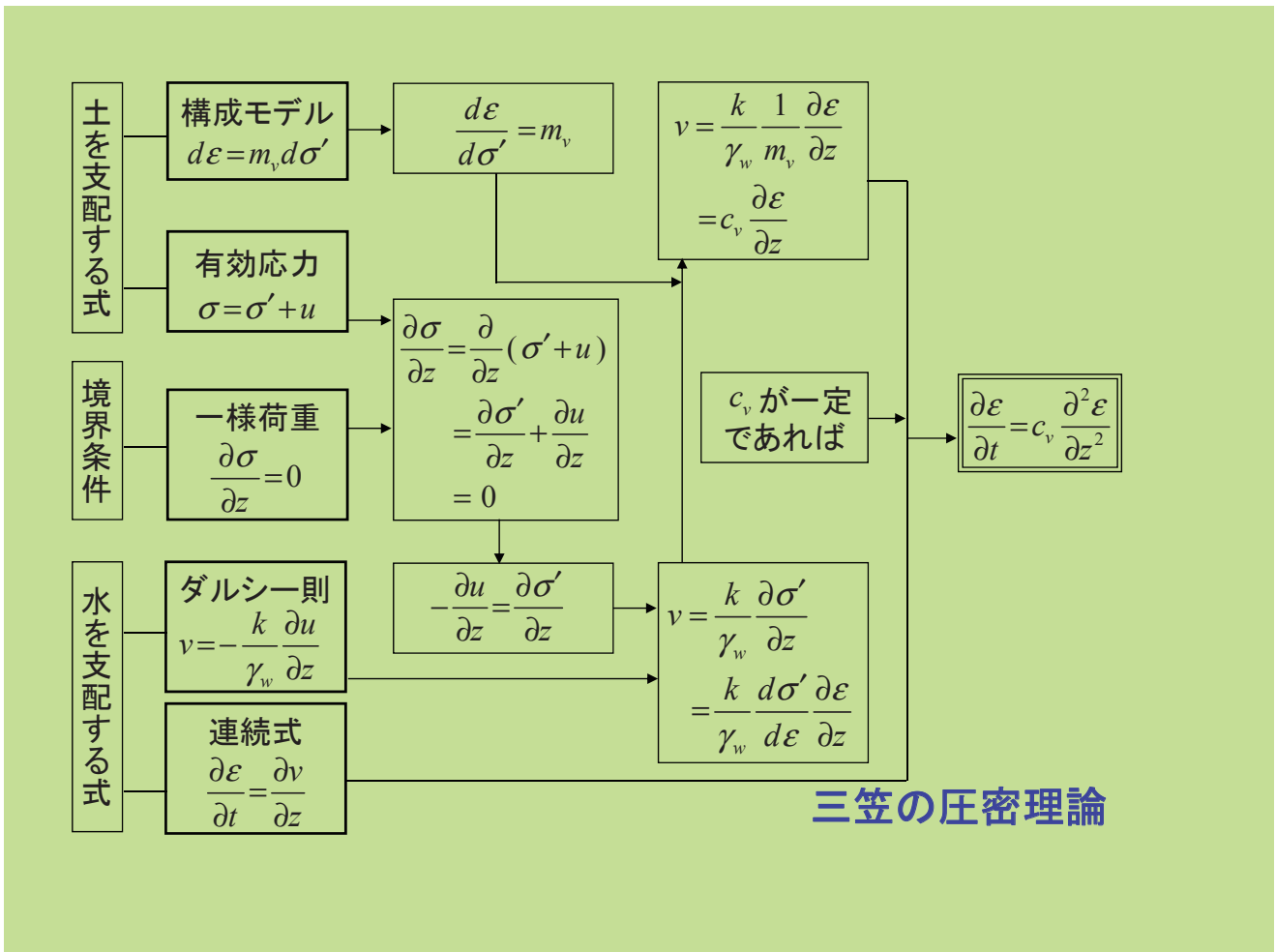
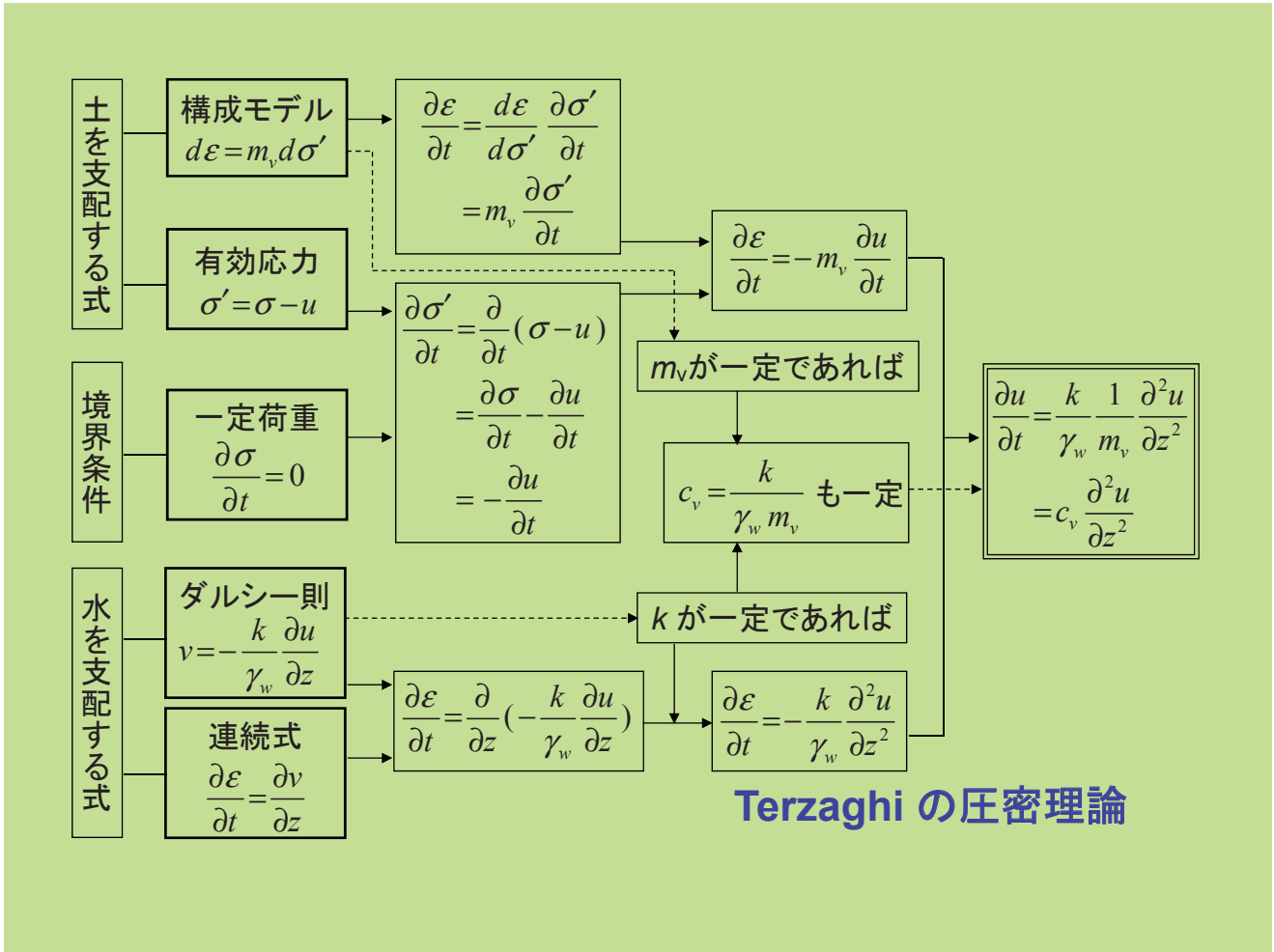
3. Terzaghiの圧密理論と三笠の圧密理論

Terzaghiの圧密理論:

透水係数 k と体積圧縮係数 m_v がともに一定値

三笠の圧密理論:

透水係数 k や体積圧縮係数 m_v がそれぞれ不変だとの仮定が不必要
その比である圧密係数 C_v が一定でありさえすればいい



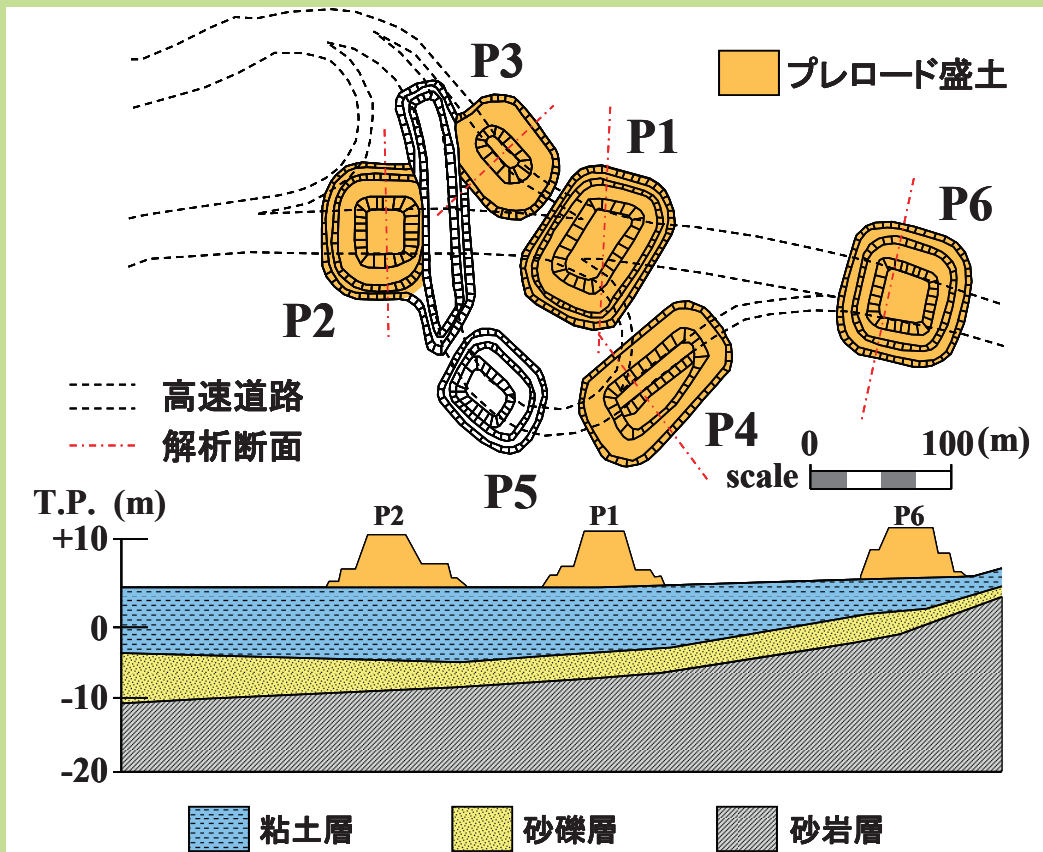
4.

九州横断道武雄北方インターチェンジ

道央自動車道 札幌ー岩見沢間の盛土沈下

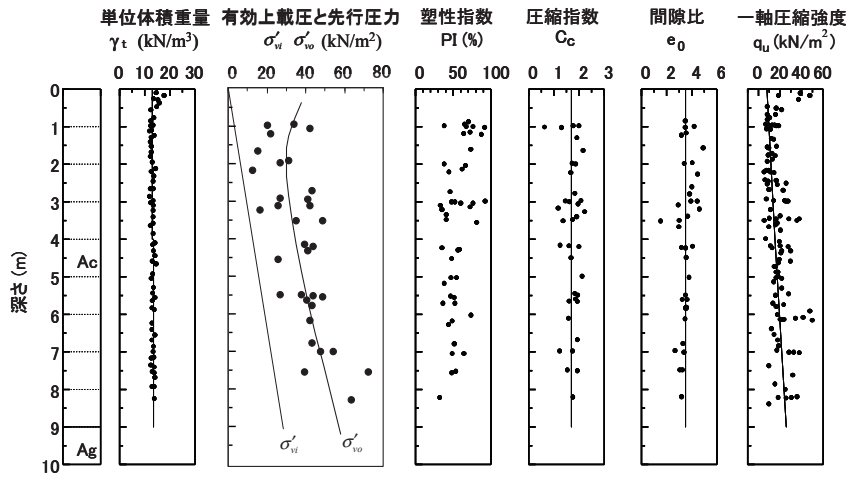
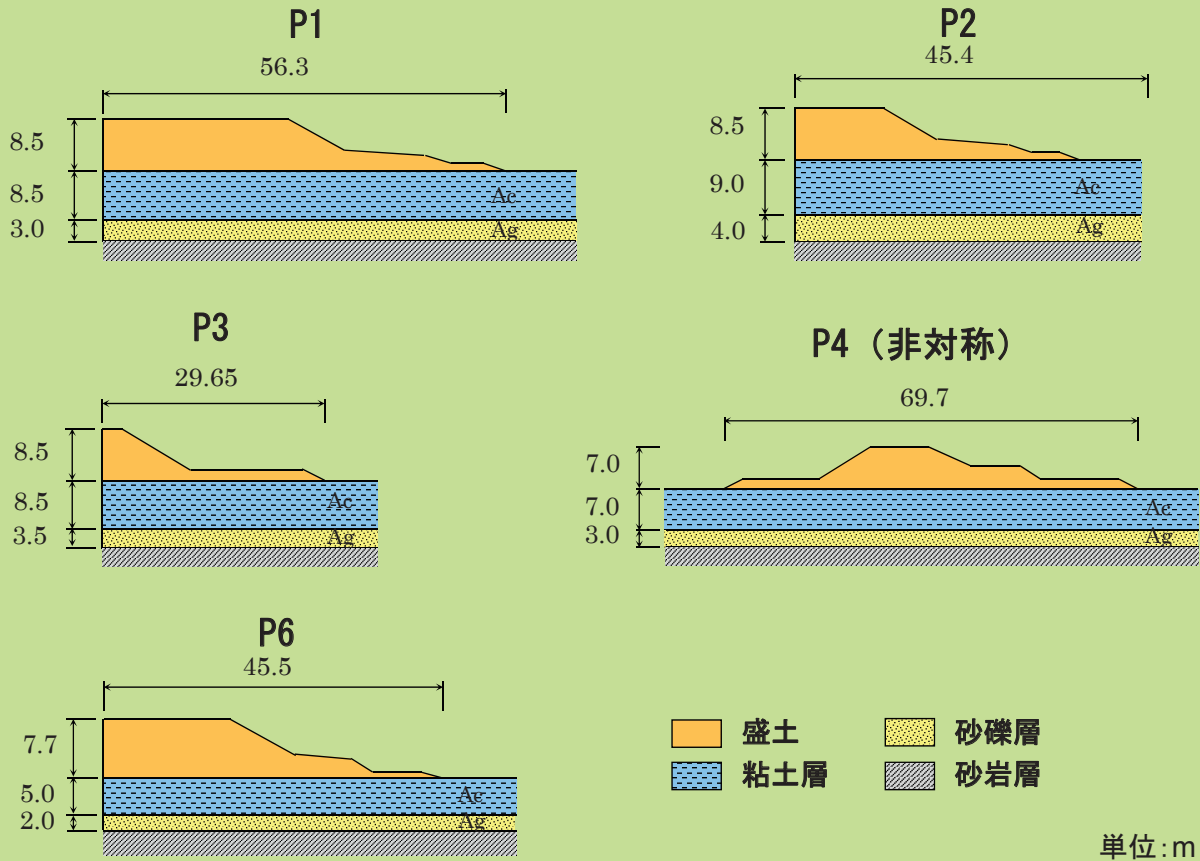
秋田自動車道 傾斜基盤上の盛土

九州横断道武雄北方インターチェンジ

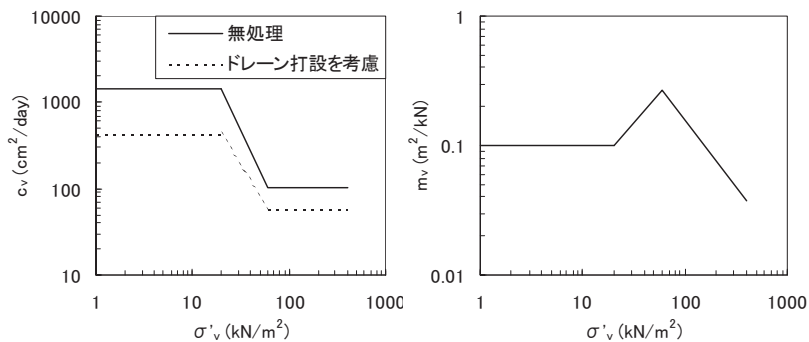


P1, P2, P3, P4, ~~P5~~, P6

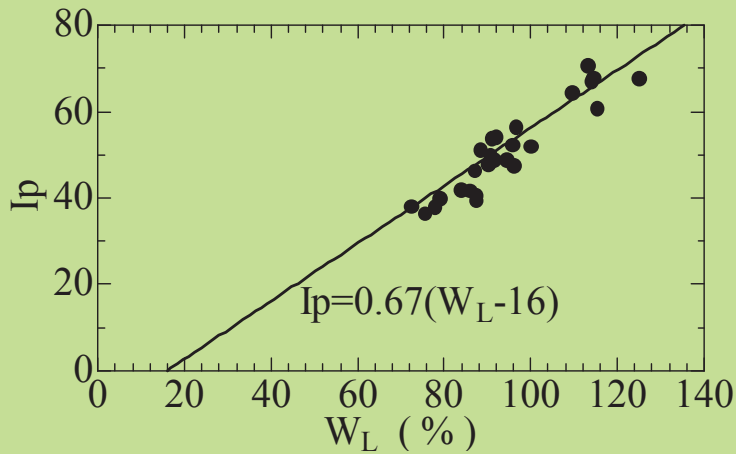
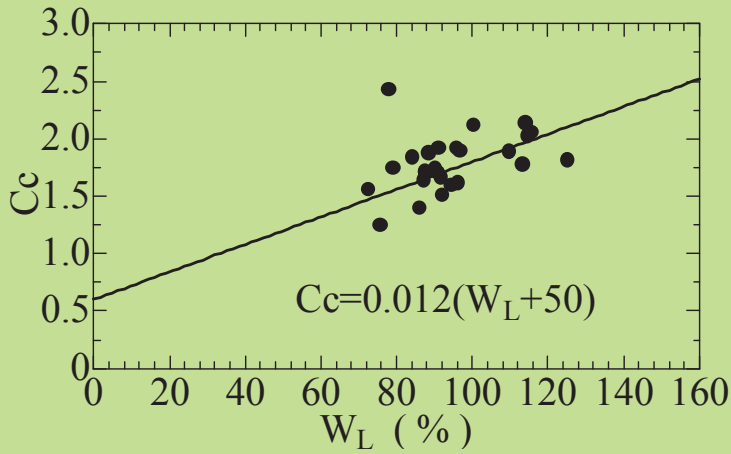
盛土形状(解析断面)



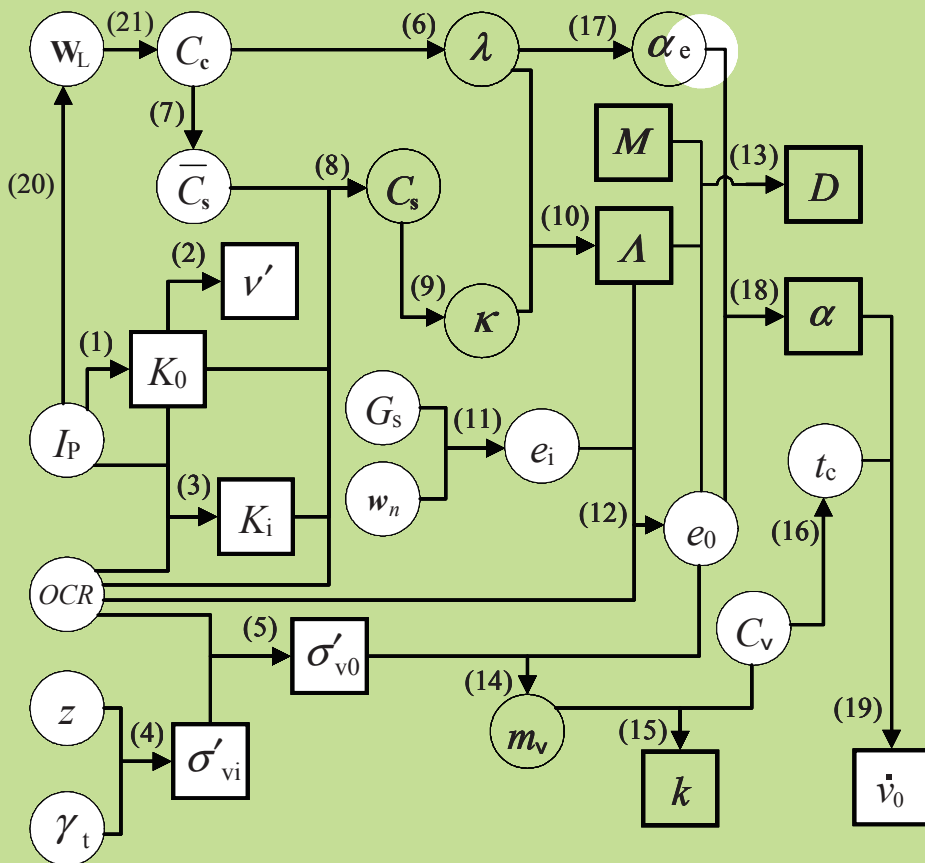
(a) 深度分布



(b) 圧密諸定数



有明粘土に
対して得られ
た経験式



- (1) $K_0 = 0.44 + 0.42 \times 10^{-2} I_p$ Massarsch (1979)
- (2) $v' = K_0 / (1 + K_0)$
- (3) $K_i = K_0 (OCR)^m$
 $m = 0.54 \exp(-I_p/122)$ (for Clay) Alpan (1967)
- (4) $\sigma'_{vi} = \gamma_i z - p_w$
- (5) $OCR = \sigma'_{v0} / \sigma'_{vi}$
- (6) $\lambda = 0.434 C_c$
- (7) $\bar{C}_s = C_c / 10$
- (8) $\bar{C}_s / C_s = 1 - \log \beta / \log(OCR)$
 $\beta = (1 + 2K_i) / (1 + 2K_0)$
- (9) $\kappa = 0.434 C_s$
- (10) $A = 1 - \kappa / \lambda$
- (11) $e_i = G_s w_n$
- (12) $e_0 = e_i - \lambda(1 - A) \ln(\overline{OCR})$
 $\overline{OCR} = OCR (1 + 2K_0) / (1 + 2K_i)$
- (13) $D = \lambda A / (M(1 + e_0))$ Ohta (1971)
- (14) $m_v = 3 \lambda / ((1 + e_0)(1 + 2K_0)\sigma'_{v0})$
- (15) $k = m_v c_v \gamma_w$
- (16) $t_c = H^2 T_v(90\%) / c_v$ Sekiguchi (1977)
- (17) $\alpha_e / \lambda = 0.05 \pm 0.02$ (for Peat)
 $\alpha_e / \lambda = 0.07 \pm 0.02$ (for Clay) Mesri & Godlewshi (1977)
- (18) $\alpha = \alpha_e / (1 + e_0)$ Sekiguchi (1977)
- (19) $\dot{v}_0 = \alpha / t_c$ Sekiguchi (1977)
- (20) $I_p = 0.67(W_L - 16)$
- (21) $C_c = 0.012(W_L + 50)$

3軸試験によって得られた内部摩擦角 ϕ'

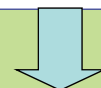
・有明粘土の特性(松村・三浦, 1990)

試料名	佐賀大学	兵庫粘土	諸富(1)	諸富(2)	蓮池粘土	白石(1)	白石(2)
M	1.355	1.242	1.587	1.356	1.065	1.587	1.500
	∧	∧	∧	∧	∧	∧	∧
	1.437	1.490	1.622	1.508	1.266	1.622	1.537



試料採取場所

塑性指数 I_p による推定値
 $M = 0.91$ ($\phi' = 23.3 \text{ deg.}$)
 $M = 0.96$ ($\phi' = 24.5 \text{ deg.}$)



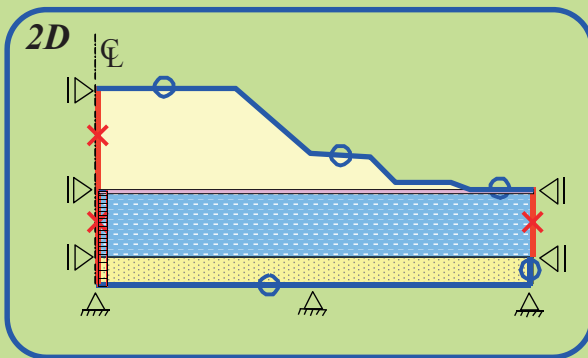
三軸試験結果に基づく値
 $M = 1.40$ ($\phi' = 34.6 \text{ deg.}$)

土質定数と境界条件

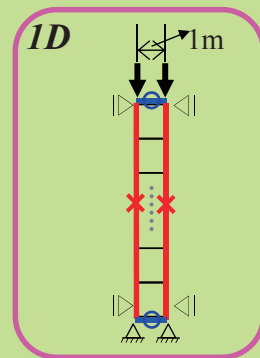
section	m depth	kN/m^3 γ_i	A	M	v'	K_0	K_i	α	\dot{v}_0	λ	e_0	OCR	k/γ_w
fill		20.00	$E = 25.00 \text{ Mpa}$										1.00E+01
Ac1	0.0~1.0	13.00	$E = 5.00 \text{ Mpa}$										1.44E-03
Ac2	1.0~2.5	13.00	0.80	1.40	0.41	0.69	1.31	8.18E-03	1.64E-05	0.74	3.51	4.00	1.44E-03
Ac3	2.5~4.0	13.00	0.80	1.40	0.39	0.65	1.02	8.18E-03	1.64E-05	0.74	3.51	3.50	1.44E-03
Ac4	4.0~5.0	13.50	0.80	1.40	0.39	0.65	0.91	8.18E-03	1.64E-05	0.74	3.51	3.00	1.44E-03
Ac5	5.0~7.0	13.50	0.80	1.40	0.39	0.65	0.88	8.18E-03	1.64E-05	0.74	3.51	2.50	1.44E-03
Ac6	7.0~9.0	13.50	0.80	1.40	0.39	0.65	0.85	8.18E-03	1.64E-05	0.74	3.51	2.50	1.00E-03
Ag		16.00	$E = 60.00 \text{ Mpa}$										1.00E-03

Fill, Crust and Gravel : \ggg Linear-elastic Material

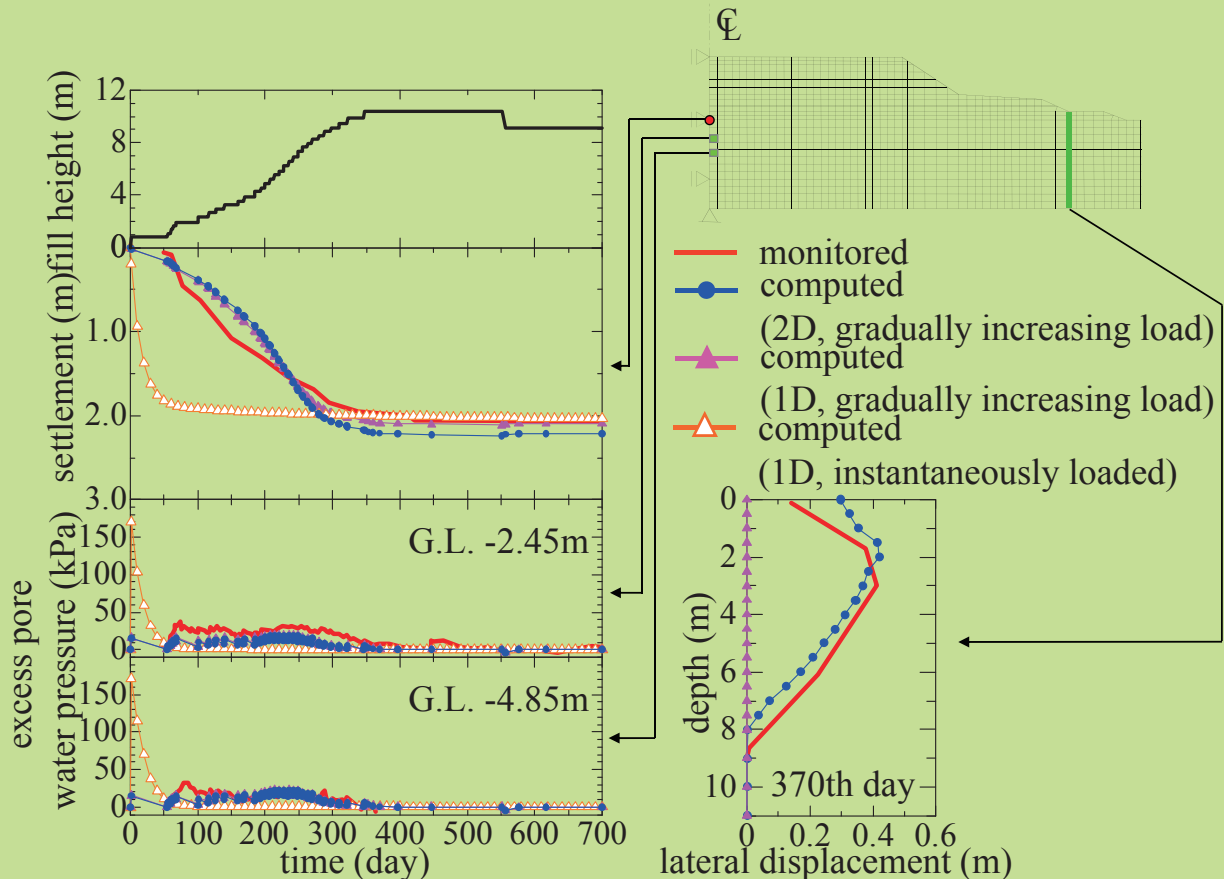
Clay : \ggg Elasto-viscoplastic Material



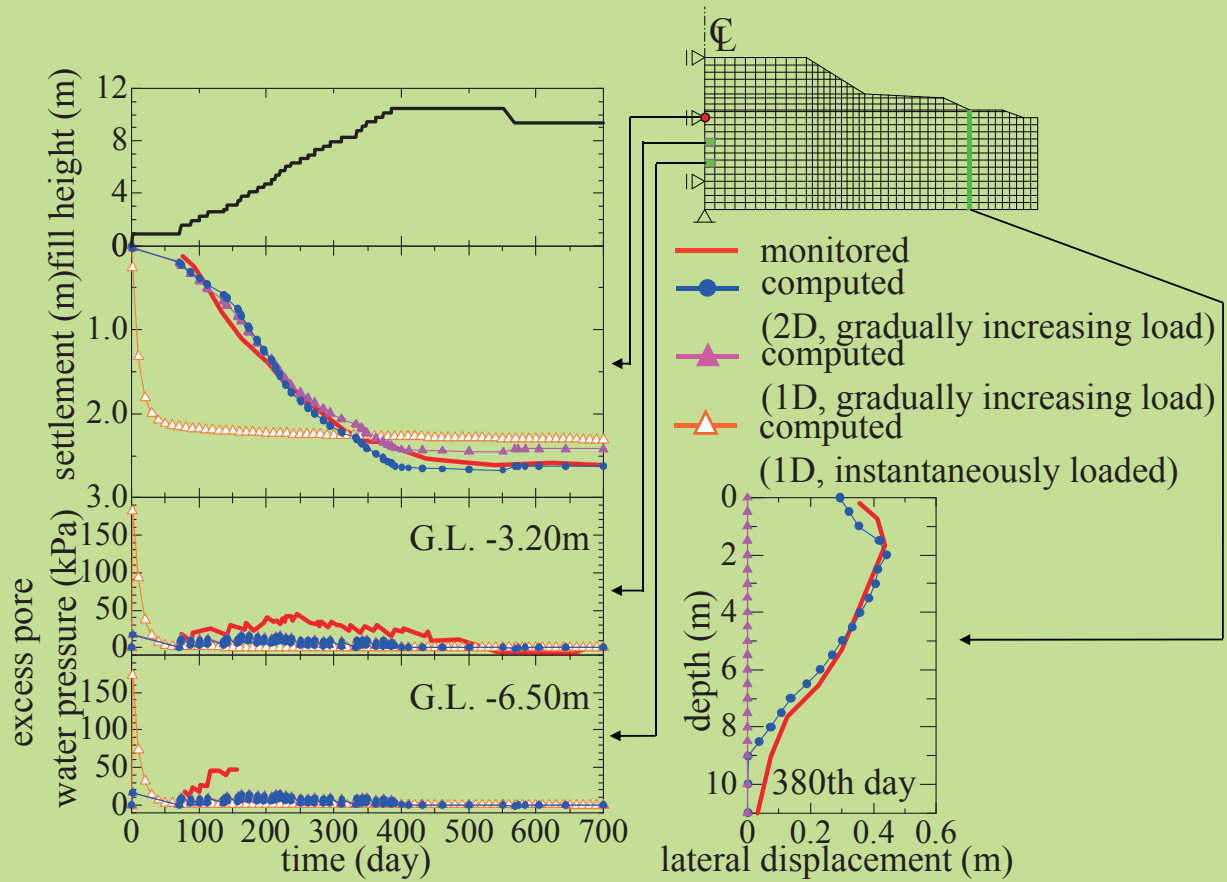
○ drainage
 × undrainage
 ↓ load



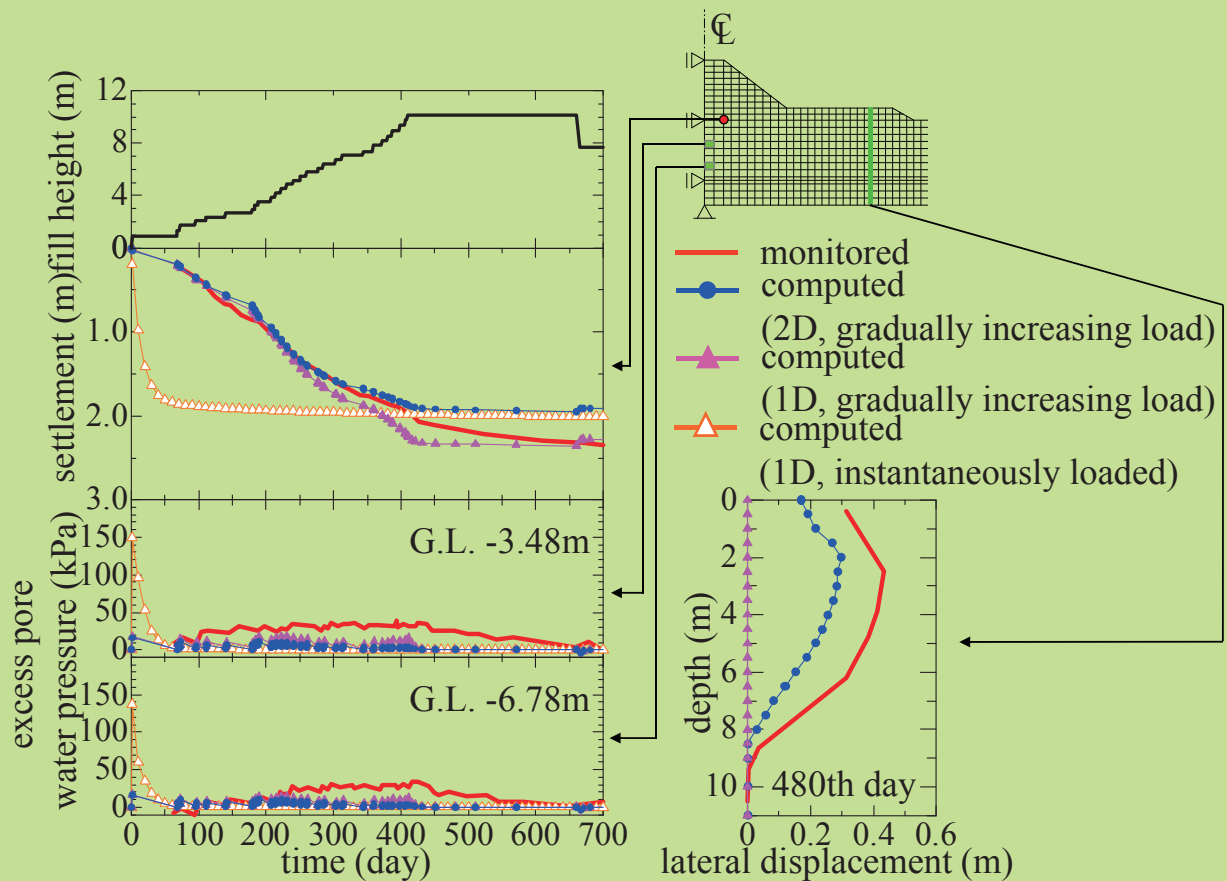
P1



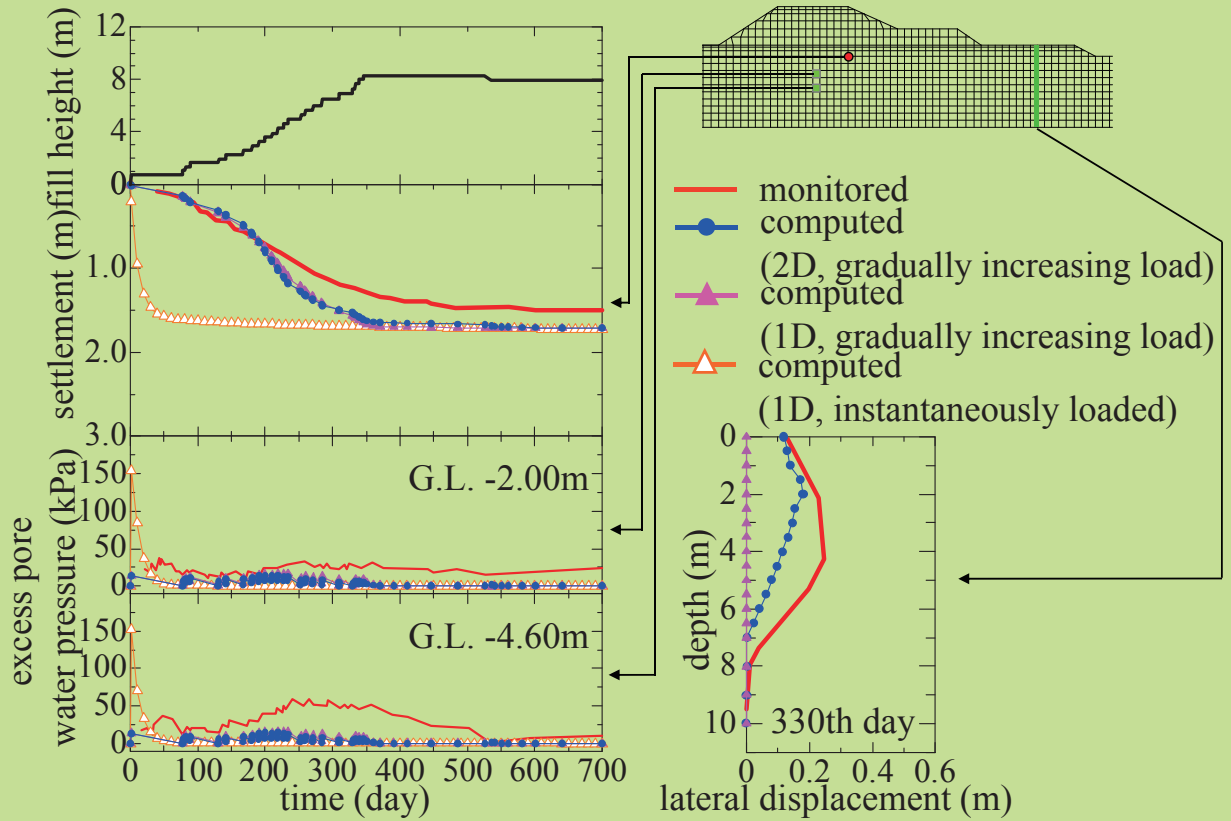
P2



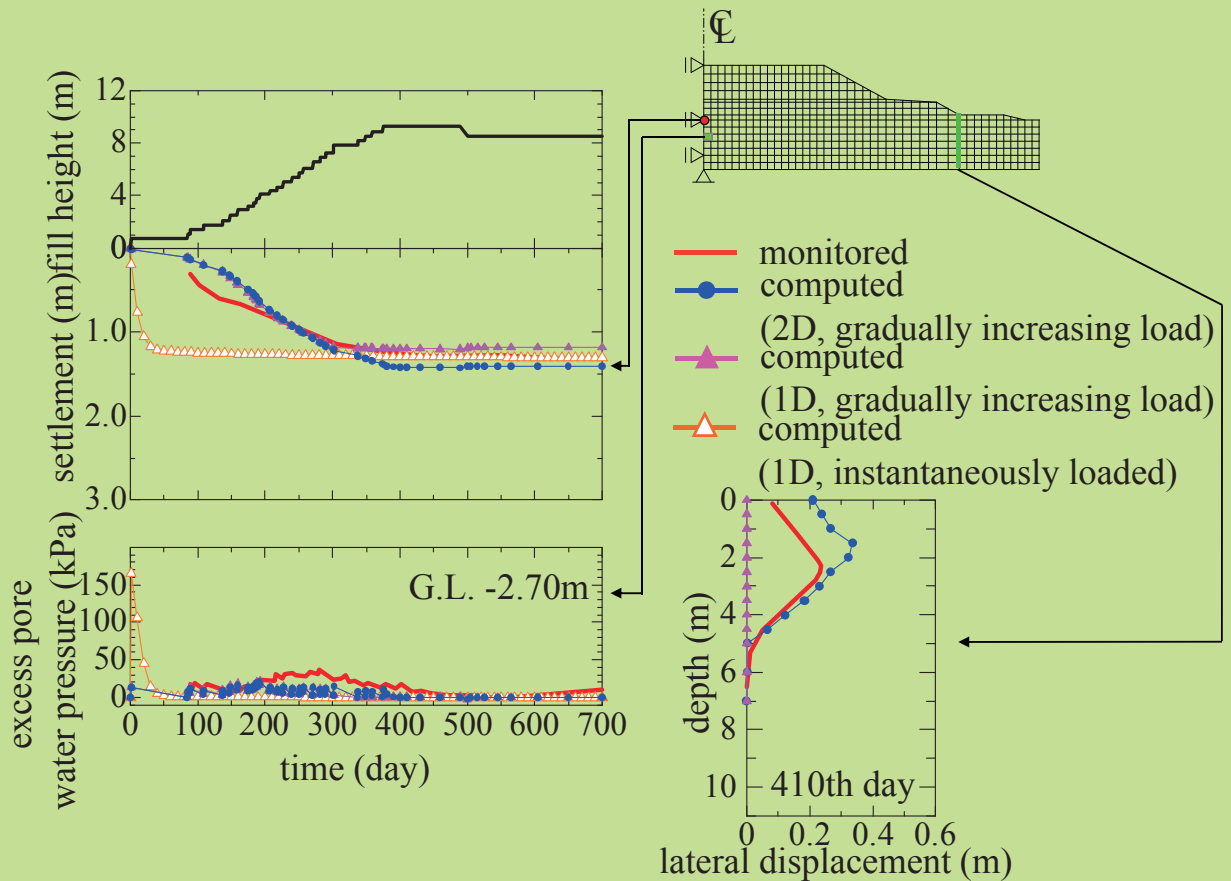
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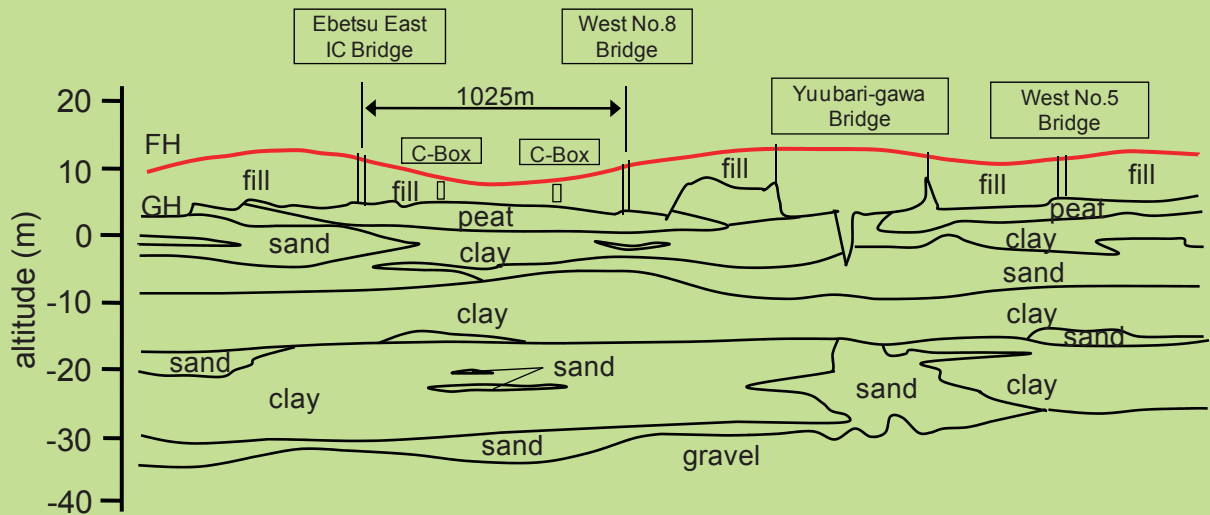
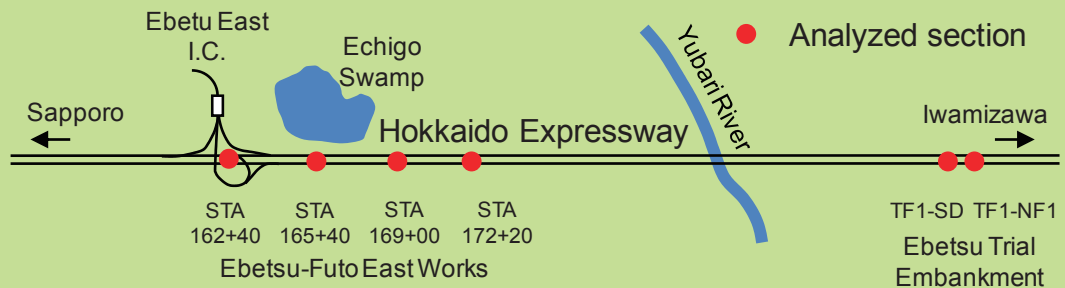
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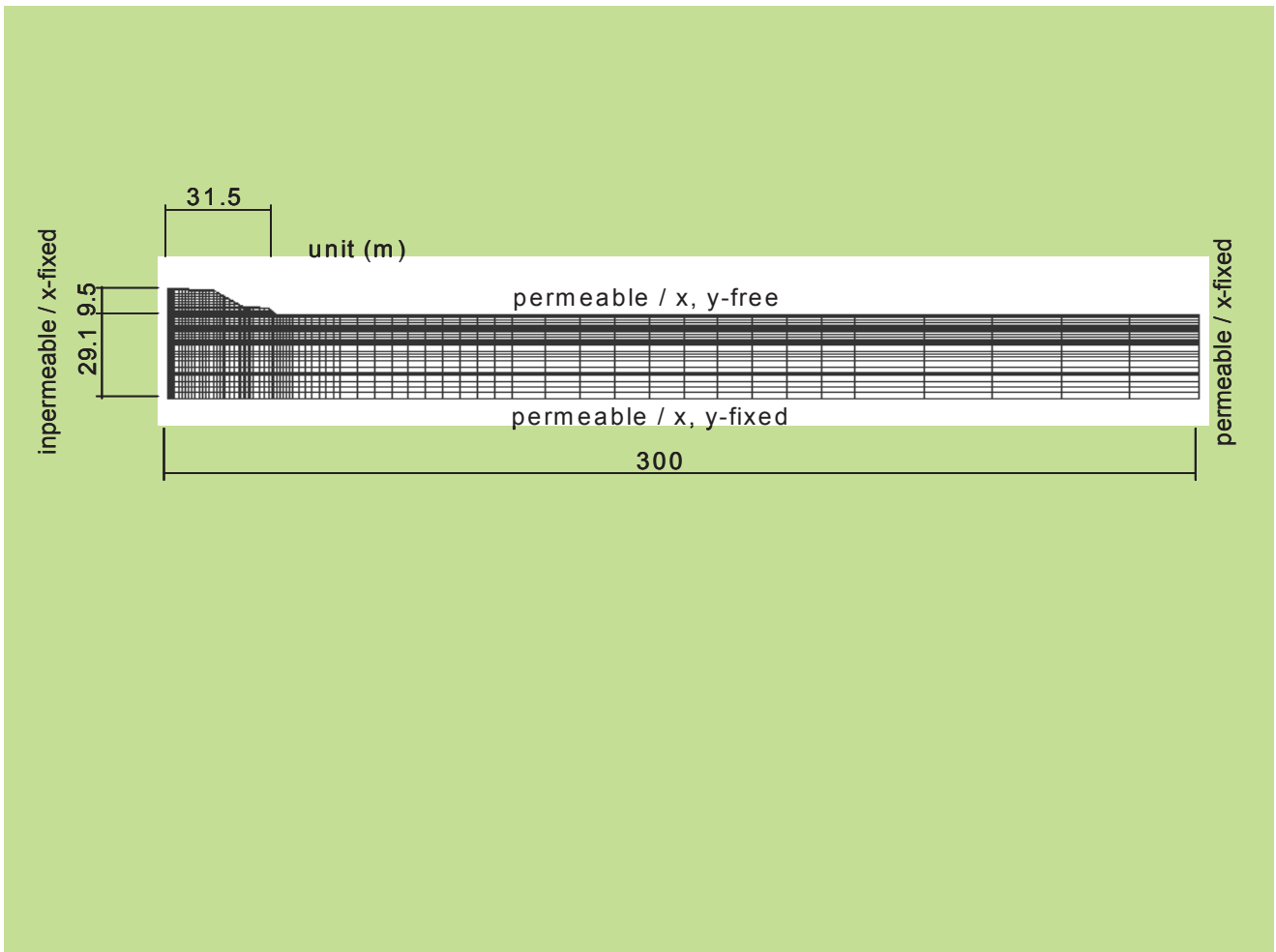
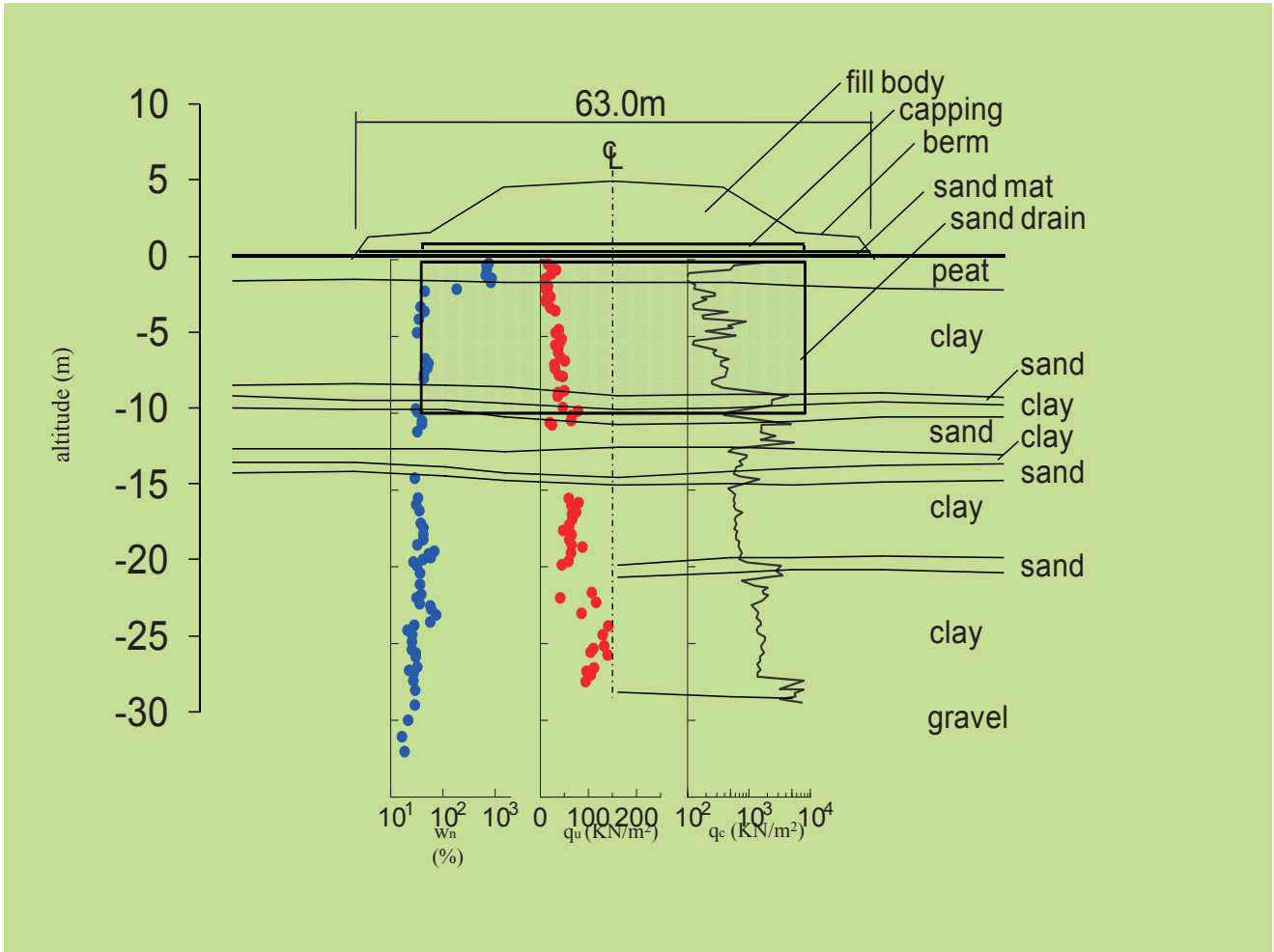


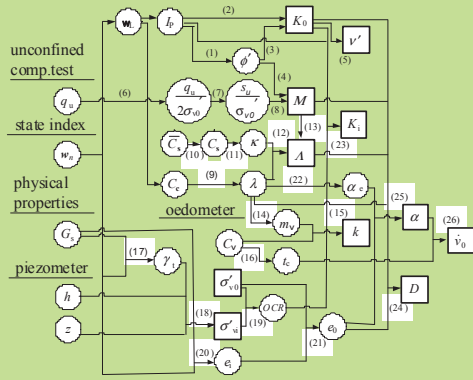
P6



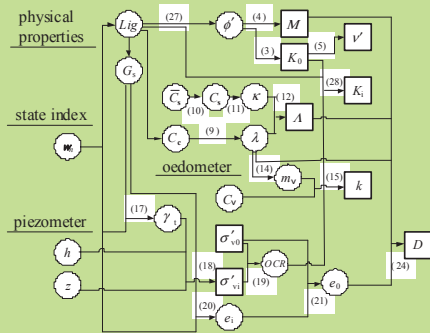
道央自動車道 札幌-岩見沢間の盛土沈下





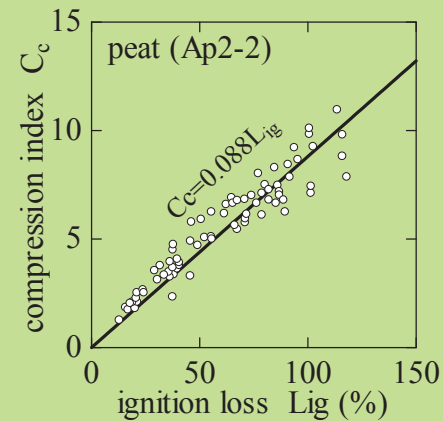
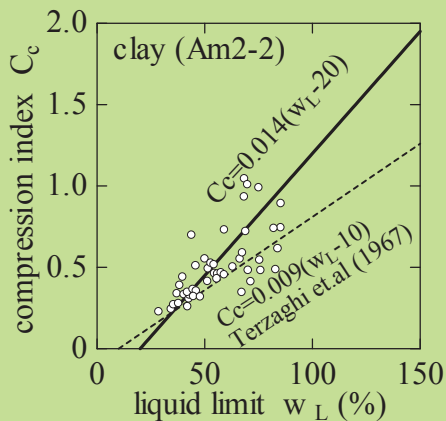
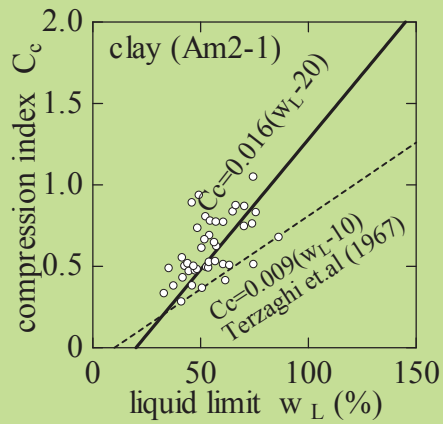
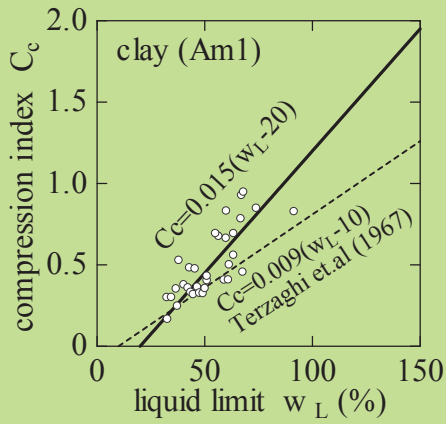


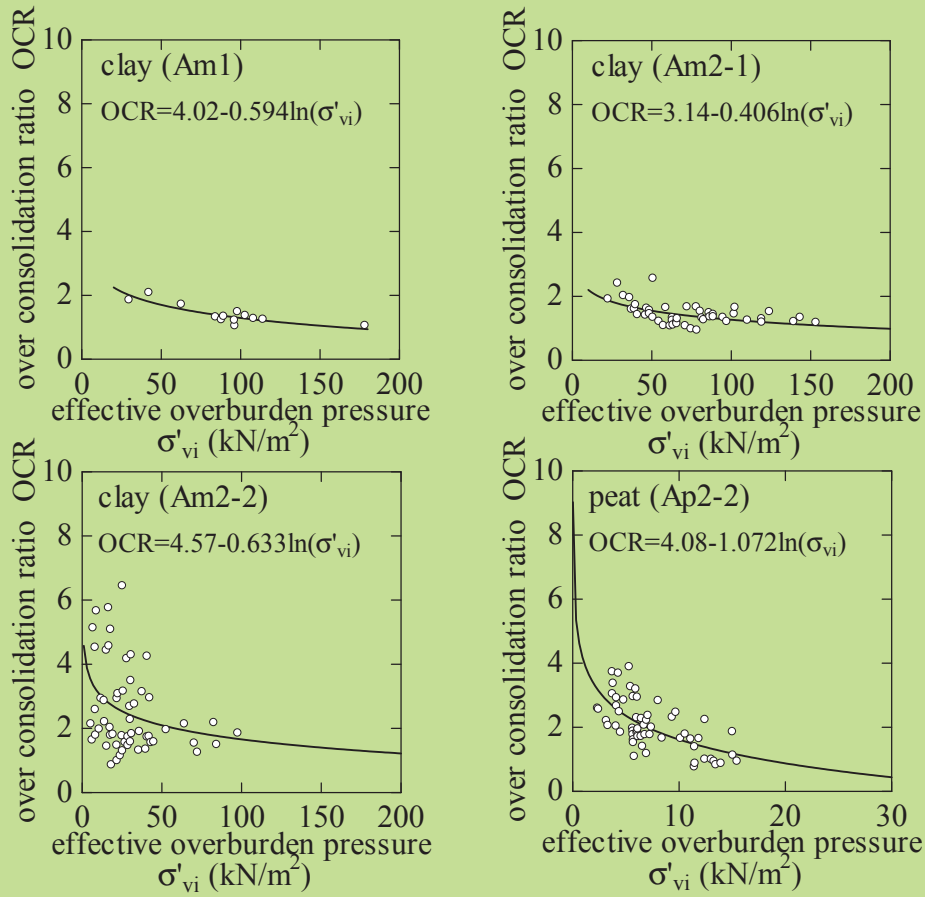
(a) clay



(b) peat

- (1) $\sin \phi' = 0.81 - 0.233 \log I_p$ Kenny (1959)
- (2) $K_0 = 0.44 + 0.42 \times 10^{-2} I_p$ Massarsch (1979)
- (3) $K_0 = 1 - \sin \phi'$ Jaky (1944)
- (4) $M = 6 \sin \phi' / (3 - \sin \phi')$
- (5) $V' = K_0 / (1 + K_0)$
- (6) $(q_u / 2 \sigma'_{v0})_{NC} = 1 / (OCR)^A (q_u / 2 \sigma'_{v0})_{OC}$ Ohta (1988)
- (7) $(S_u / \sigma'_{v0})_{CKOUC} = \mu (q_u / 2 \sigma'_{v0})_{NC}$ Ohta (1988)
- (8) M determined using $(S_u / 2 \sigma'_{v0})_{CKOUC}$ Ohta (1988)
- (9) $\lambda = 0.434 C_c$
- (10) $\bar{C}_s / C_s = 1 - \log \beta \log(OCR)$ Ohta (1988)
- $\beta = (1 + 2K_0) / (1 + 2K_0)$
- (11) $\kappa = 0.434 C_s$
- (12) $A = 1 - \kappa / \lambda$
- (13) $A = M / 1.75$ Karube (1975)
- (14) $m_v = 3 \lambda / ((1 + a_0)(1 + 2K_0) \sigma'_{v0})$
- (15) $k = m_v C_v \gamma_w$
- (16) $t_c = H^2 T(90\%) / C_v$ Sekiguchi (1977)
- (17) $\gamma_1 = G_s \gamma_w (1 + w_u) / (1 + G_s w_u)$
- (18) $\sigma'_{v0} = \gamma_1 z p_w$
- (19) $OCR = \sigma'_{v0} / \sigma'_{u0}$
- (20) $e_i = G_s w_u$
- (21) $e_0 = e_r \lambda (1 - A) \ln(OCR)$ Mesri &
- $OCR = OCR (1 + 2K_0) / (1 + 2K_0)$ Godlewshi (1977)
- (22) $\alpha_c / \lambda = 0.05 \pm 0.02$ (for clay) Mesri &
- $\alpha_c / \lambda = 0.07 \pm 0.02$ (for peat) Godlewshi (1977)
- (23) $K_1 = K_0 (OCR)^m$ Alpan (1967)
- $m = 0.54 \exp(-I_p / 122) + 0.45$ (for clay)
- (24) $D = \lambda A (M + 1 + a_0)$ Ohta (1971)
- (25) $\alpha = \alpha_c / (1 + a_0)$ Sekiguchi (1977)
- (26) $v_0 = \alpha / t_c$ Sekiguchi (1977)
- (27) $\phi' = 0.19 Lig + 32$ (for peat) Hayashi (2005)
- (28) $K_1 = K_0 (OCR)^m$ Hayashi (2006)
- $m = 0.005 Lig + 0.45$ (for peat)

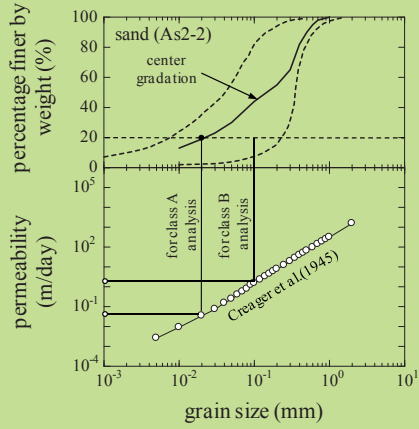




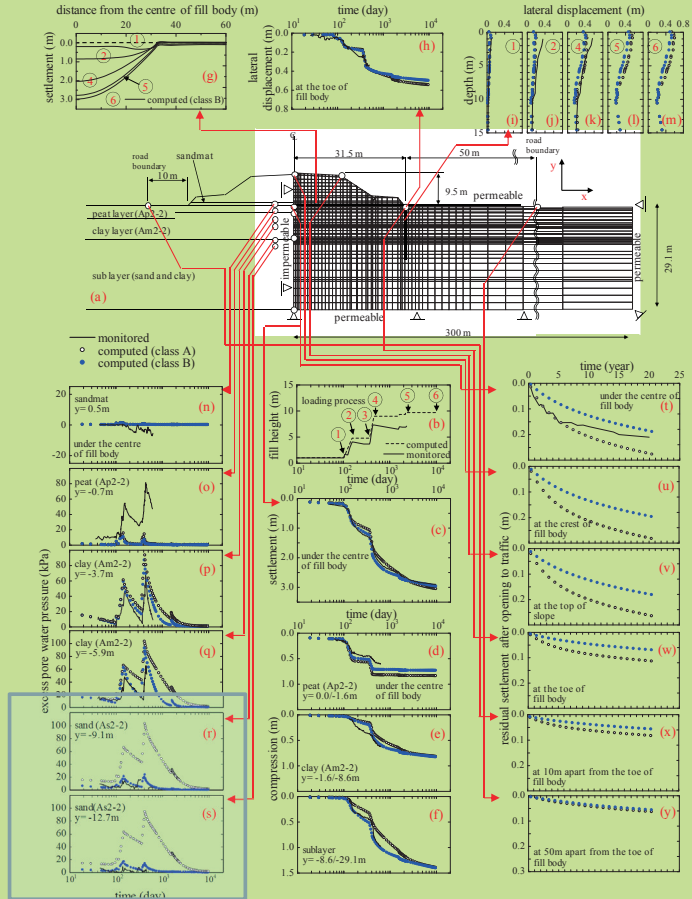
	clay (Am1)	clay(Am2-1)
$w_n(\%)-Lig(\%)$	-	-
$w_n(\%)-w_L(\%)$	$w_L=0.978 w_n+6.85$	$w_L=0.826 w_n+8.22$
$w_n(\%)-e_i$	$e_i=2.75 w_n/100$	$e_i=2.74 w_n/100$
$w_L(\%)-I_p(\%)$	$I_p=0.77(w_L-17)$	$I_p=0.80(w_L-17)$
$w_L(\%)-C_C$	$C_C=0.015(w_L-20)$	$C_C=0.016(w_L-20)$
C_C-C_S	$C_S=C_C/10$	$C_S=C_C/10$
$OCR-\sigma'_{vi}(\text{kN/m}^2)$	$OCR=4.02-0.594\ln(\sigma'_{vi})$	$OCR=3.14-0.406\ln(\sigma'_{vi})$

	clay(Am2-2)	peat(Ap2-2)
$w_n(\%)-Lig(\%)$	-	$w_n=10 Lig$
$w_n(\%)-w_L(\%)$	$w_L=0.711 w_n+15.45$	-
$w_n(\%)-e_i$	$e_i=2.65 w_n/100$	$e_i = w_n/100 \times 1/(0.00237 Lig+0.3)$
$w_L(\%)-I_p(\%)$	$I_p=0.75(w_L-15)$	-
$w_L(\%)-C_C$	$C_C=0.014(w_L-20)$	$C_C=0.088Lig$
C_C-C_S	$C_S=C_C/10$	$C_S=C_C/10$
$OCR-\sigma'_{vi}(\text{kN/m}^2)$	$OCR=4.57-0.633\ln(\sigma'_{vi})$	$OCR=4.08-1.072\ln(\sigma'_{vi})$

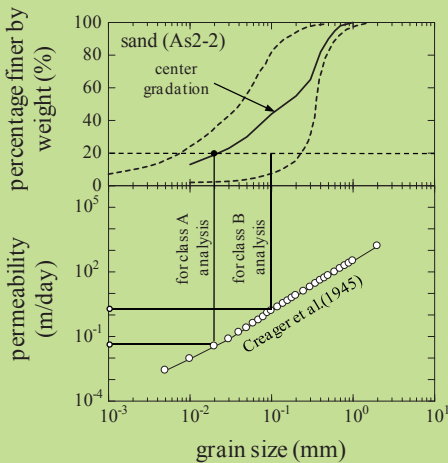
◆ Prediction of long-term performance of NF-1



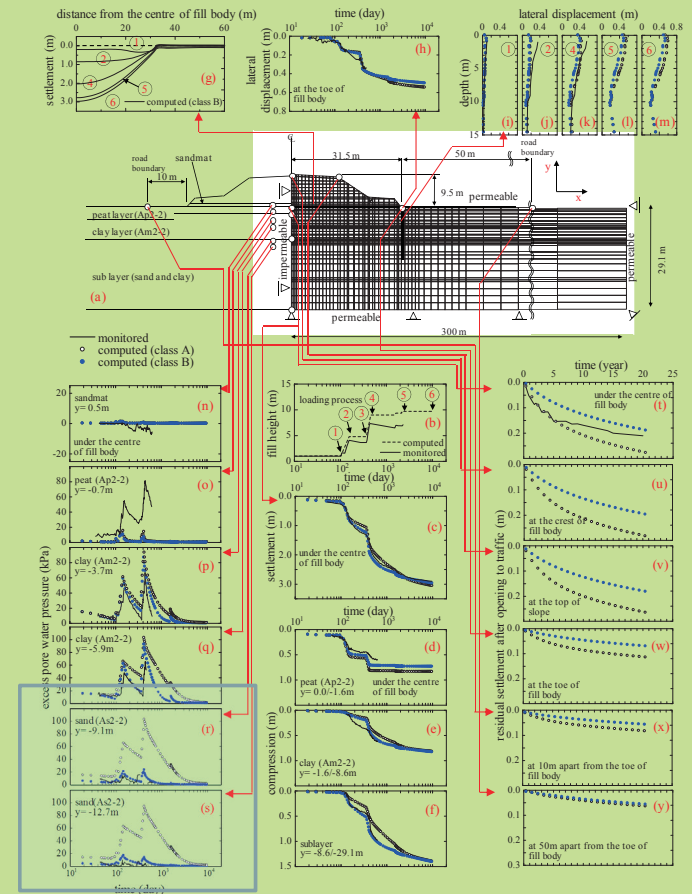
➤ The predicted pore water pressure drastically changes before and after modification of permeability of sandy layer.

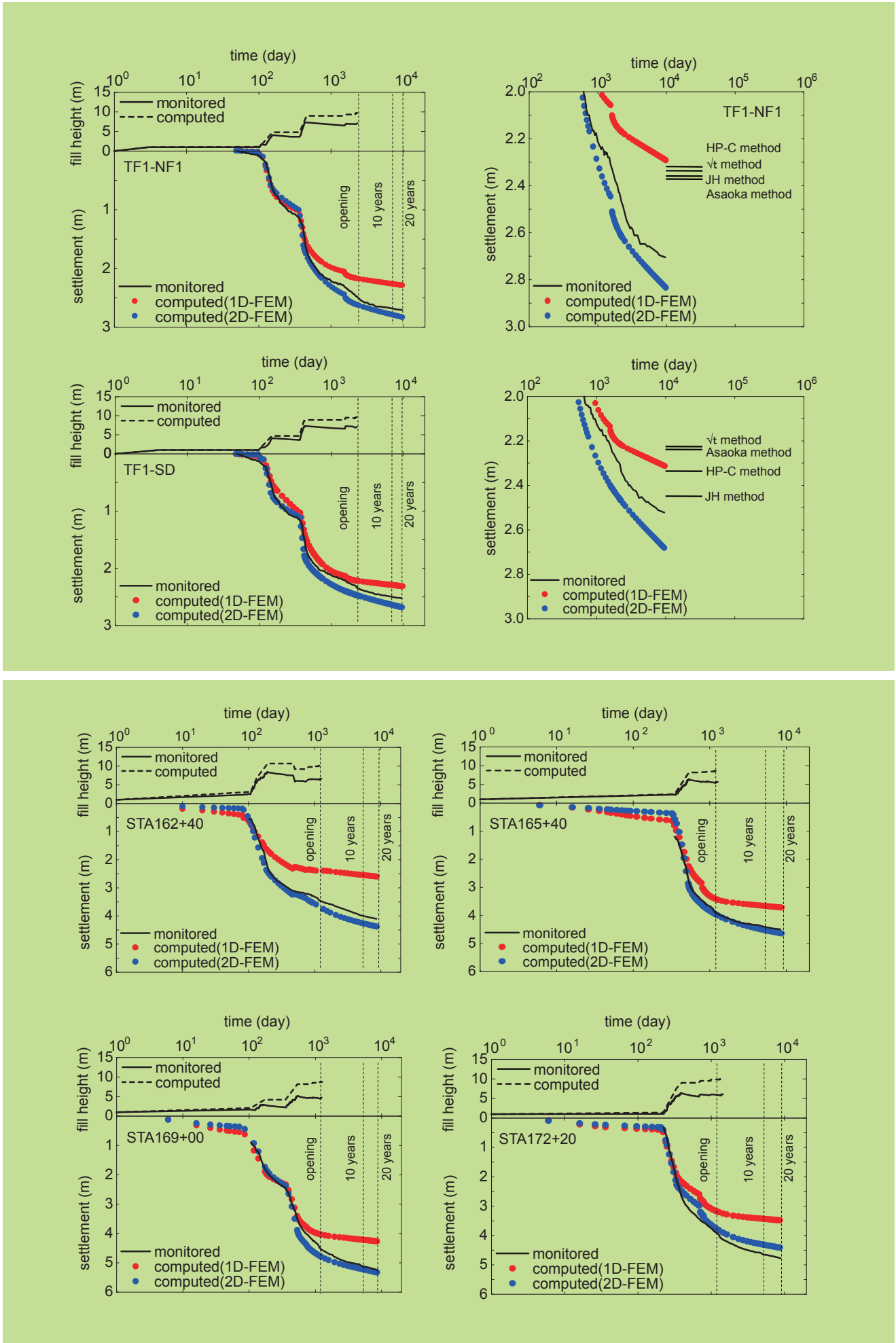


◆ Prediction of long-term performance of SD



Class B prediction gives much better agreement with the monitored values



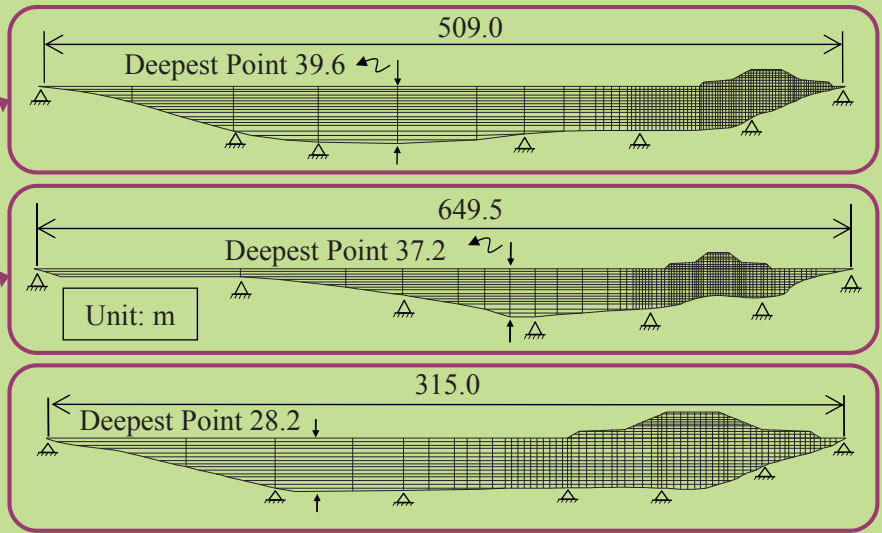


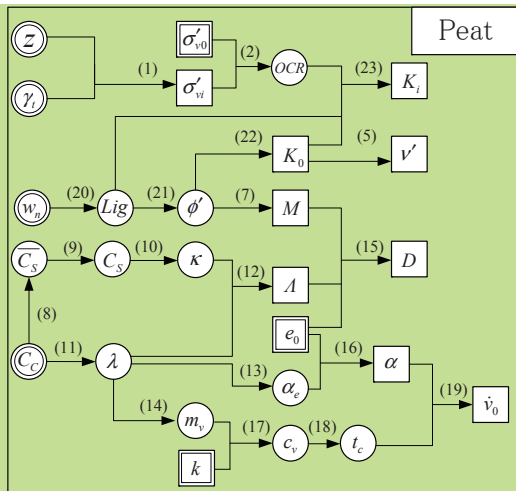
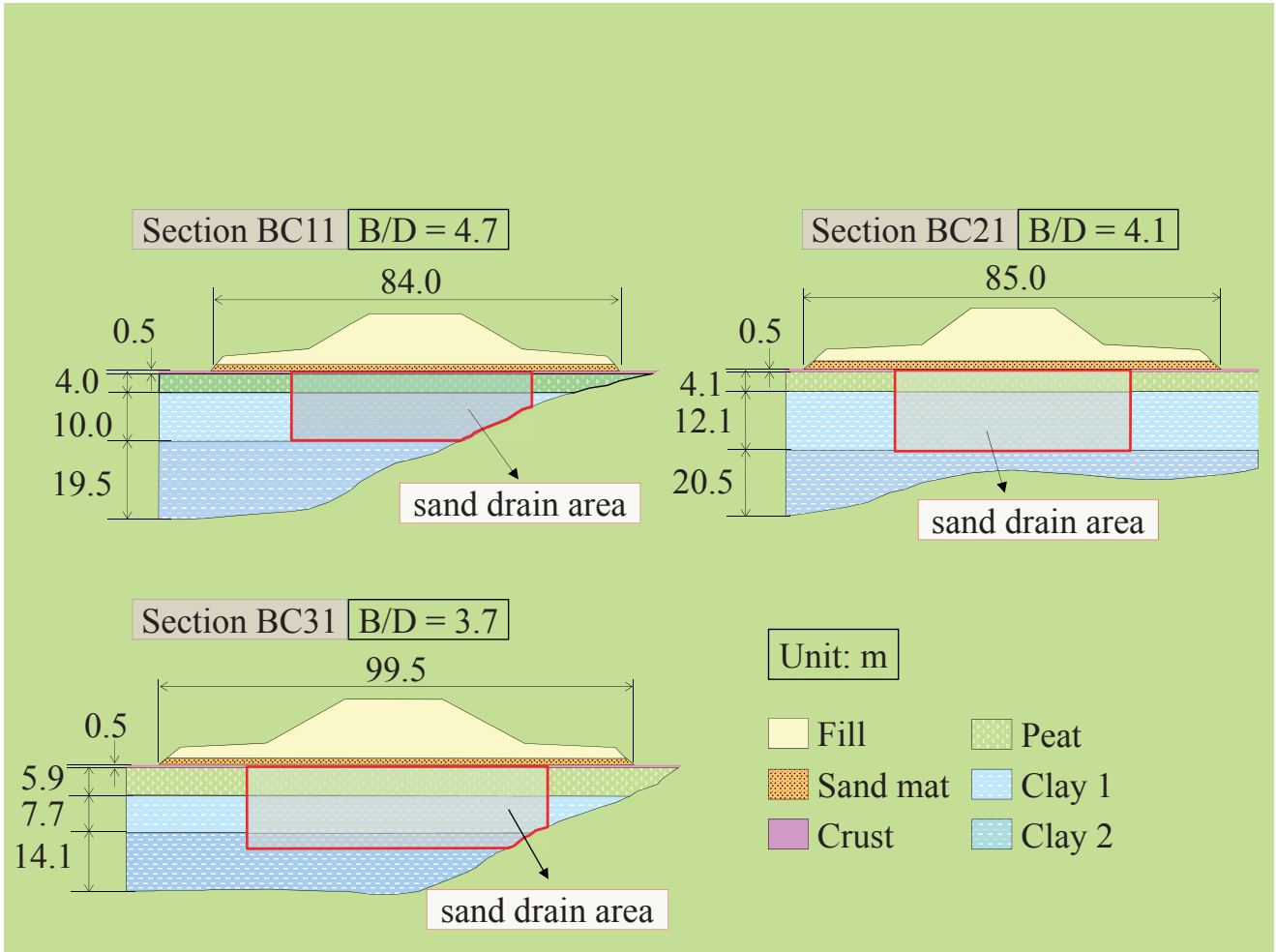
秋田自動車道 傾斜基盤上の盛土

秋田自動車道

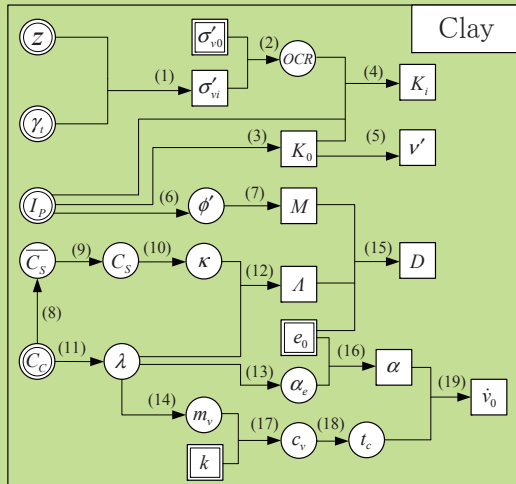


Construction period : 1993~1997
 Location : Soto-Asahikawa in Akita Prefecture
 Soft ground : peat and clay layer with various thickness
 Bedrock : sloping base
 Embankment sections : BC11, BC21, BC31





- (1) $\sigma'_{vi} = \gamma_i z - p_w$
- (2) $OCR = \sigma'_{v0} / \sigma'_{vi}$
- (3) $K_0 = 0.44 + 0.42 \times 10^{-2} Ip$ Massarsch (1979)
- (4) $K_i = K_0 (OCR)^m$ (for Clay)
 $m = 0.54 \exp(-Ip/122)$ Alpan (1967)
- (5) $v' = K_0 / (1 + K_0)$
- (6) $\sin \phi' = 0.81 - 0.233 \log Ip$ Kenny (1959)
- (7) $M = 6 \sin \phi' / (3 - \sin \phi')$
- (8) $\bar{C}_s = C_c / 10$
- (9) $\bar{C}_s / C_s = 1 - \log \beta / \log(OCR)$
 $\beta = (1 + 2K_0) / (1 + 2K_i)$
- (10) $\kappa = 0.434 C_s$
- (11) $\lambda = 0.434 C_c$
- (12) $A = 1 - \kappa / \lambda$
- (13) $\alpha_c / \lambda = 0.07 \pm 0.02$ (for Peat) Mesri &
 $\alpha_c / \lambda = 0.05 \pm 0.02$ (for Clay) Godlewshi (1977)
- (14) $m_v = 3 \lambda / ((1 + e_0)(1 + 2K_0)\sigma'_{v0})$
- (15) $D = \lambda A / (M(1 + e_0))$ Ohta (1971)
- (16) $\alpha = \alpha_c / (1 + e_0)$ Sekiguchi (1977)
- (17) $k = m_v c_v \gamma_w$
- (18) $t_c = H^2 T_v(90\%) / c_v$ Sekiguchi (1977)
- (19) $\dot{v}_0 = \alpha / t_c$ Sekiguchi (1977)
- (20) $w_n = Lig / 10$
- (21) $\phi' = 0.19 Lig + 32$ Hayashi (2005)
- (22) $K_0 = 1 - \sin \phi'$ Jaky (1944)
- (23) $K_i = K_0 (OCR)^m$ (for Peat)
 $m = 0.005 Lig + 0.45$ Hayashi (2006)

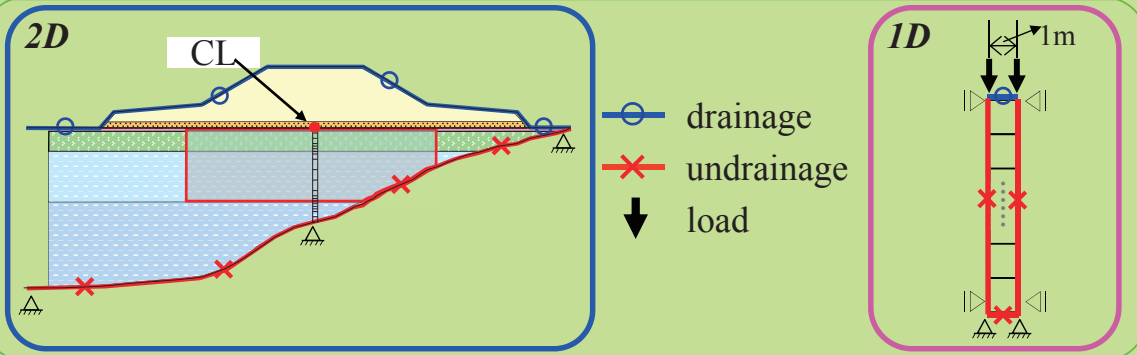


土質定数と境界条件

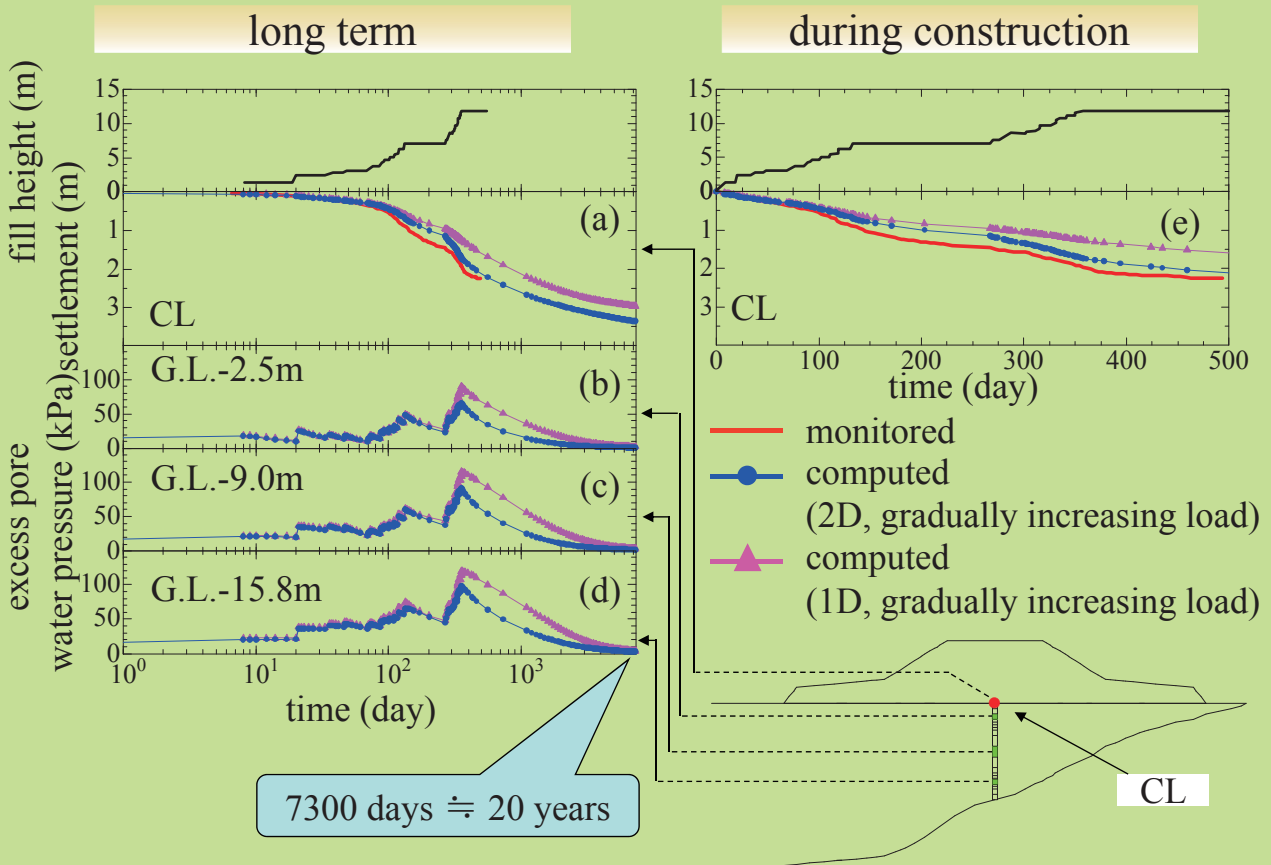
Layer	Depth (m)	D	A	M	ν'	K_0	K_i	α	$\dot{\nu}_0$	λ	e_0	λ_k	k/γ_w	$\gamma_i (kN/m^3)$
Fill		$E = 20.70 \text{ MPa}$											3.46E-04	16.30
Sand mat		$E = 9.81 \text{ MPa}$											5.60E+00	17.40
B Crust	0.0~0.5	$E = 10.00 \text{ MPa}$											5.50E-04	15.20
B Peat	0.5~4.5	0.075	0.85	2.90	0.28	0.38	0.84	1.78E-02	1.36E-07	1.97	6.74	0.95	5.50E-04	12.30
C Clay-1	4.5~14.5	0.103	0.88	0.91	0.41	0.70	0.87	5.34E-03	2.09E-07	0.33	2.09	0.31	4.00E-04	14.70
11 Clay-2	14.5~34.0	0.070	0.87	1.00	0.38	0.62	0.78	4.00E-03	7.84E-08	0.19	1.32	0.14	1.00E-04	16.30
B Crust	0.0~0.5	$E = 7.50 \text{ MPa}$											1.70E-03	14.88
B Peat	0.5~4.6	0.059	0.86	2.90	0.27	0.38	0.52	1.40E-02	3.80E-07	1.84	8.20	0.71	1.70E-03	10.99
C Clay-1	4.6~16.7	0.148	0.88	0.85	0.43	0.76	0.89	7.14E-03	4.43E-07	0.54	2.80	0.34	3.50E-04	14.32
21 Clay-2	16.7~34.2	0.073	0.87	1.04	0.37	0.60	0.76	4.34E-03	5.25E-07	0.22	1.50	1.25	3.00E-04	16.68
B Crust	0.0~0.5	$E = 8.00 \text{ MPa}$											6.50E-04	14.52
B Peat	0.5~6.4	0.049	0.86	2.90	0.30	0.43	0.62	1.15E-02	2.02E-07	0.82	4.00	0.47	6.50E-04	13.15
C Clay-1	6.4~14.1	0.120	0.88	0.84	0.43	0.77	0.91	5.74E-03	1.17E-07	0.48	3.20	0.38	1.80E-04	14.52
31 Clay-2	14.1~28.2	0.095	0.88	0.87	0.42	0.73	0.89	4.73E-03	3.74E-07	0.26	1.80	0.13	2.80E-04	16.68

Fill, Sand mat and Crust : \ggg Linear-elastic Material

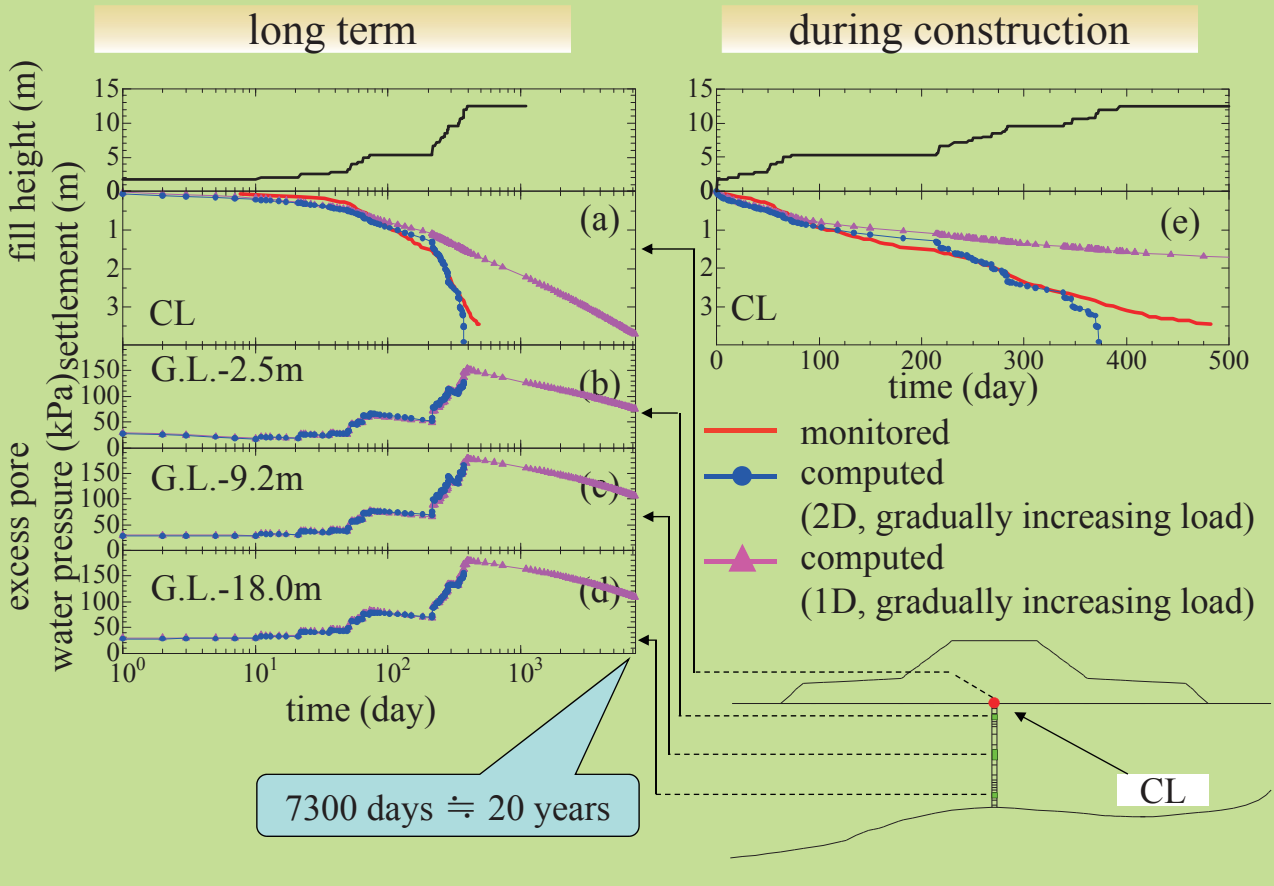
Peat and Clay : \ggg Elasto-viscoplastic Material



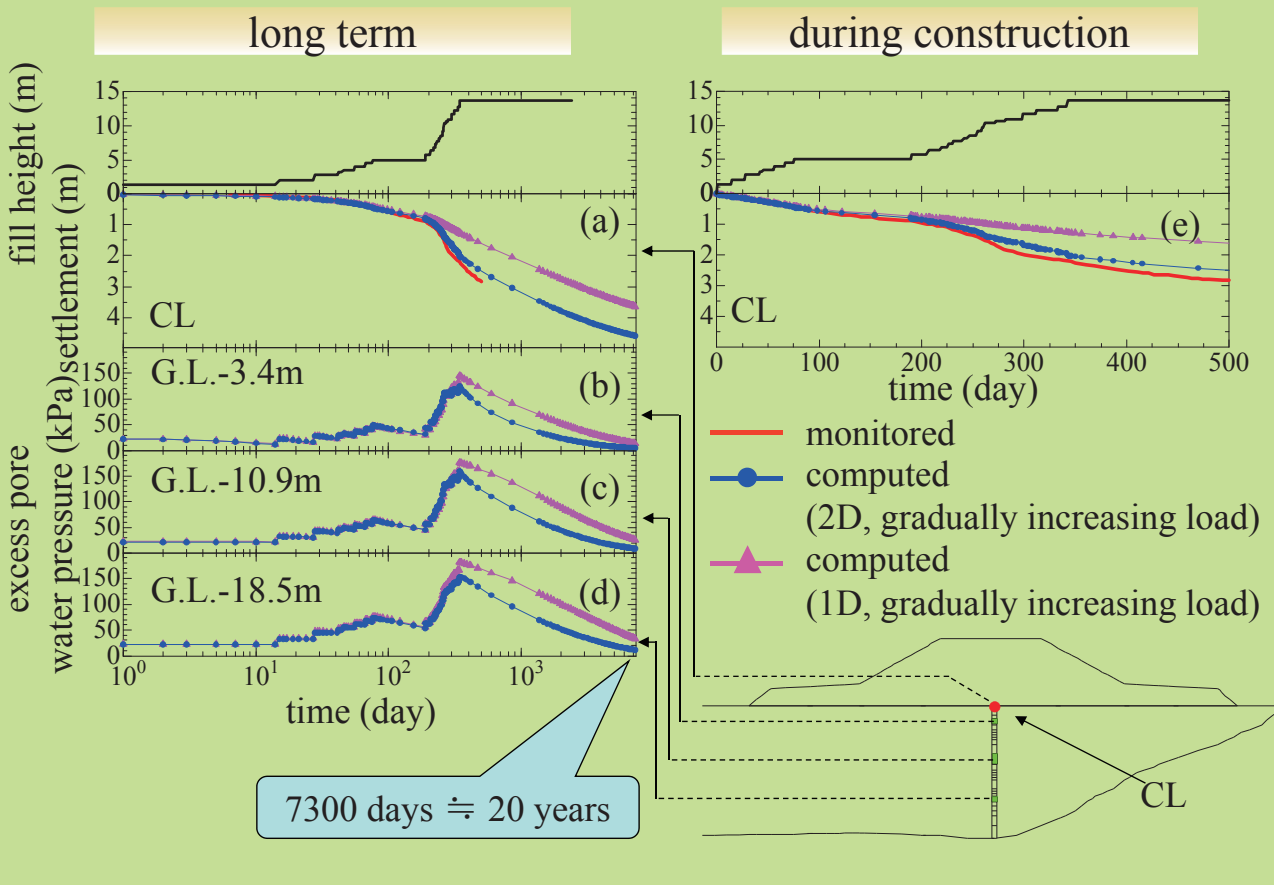
BC11

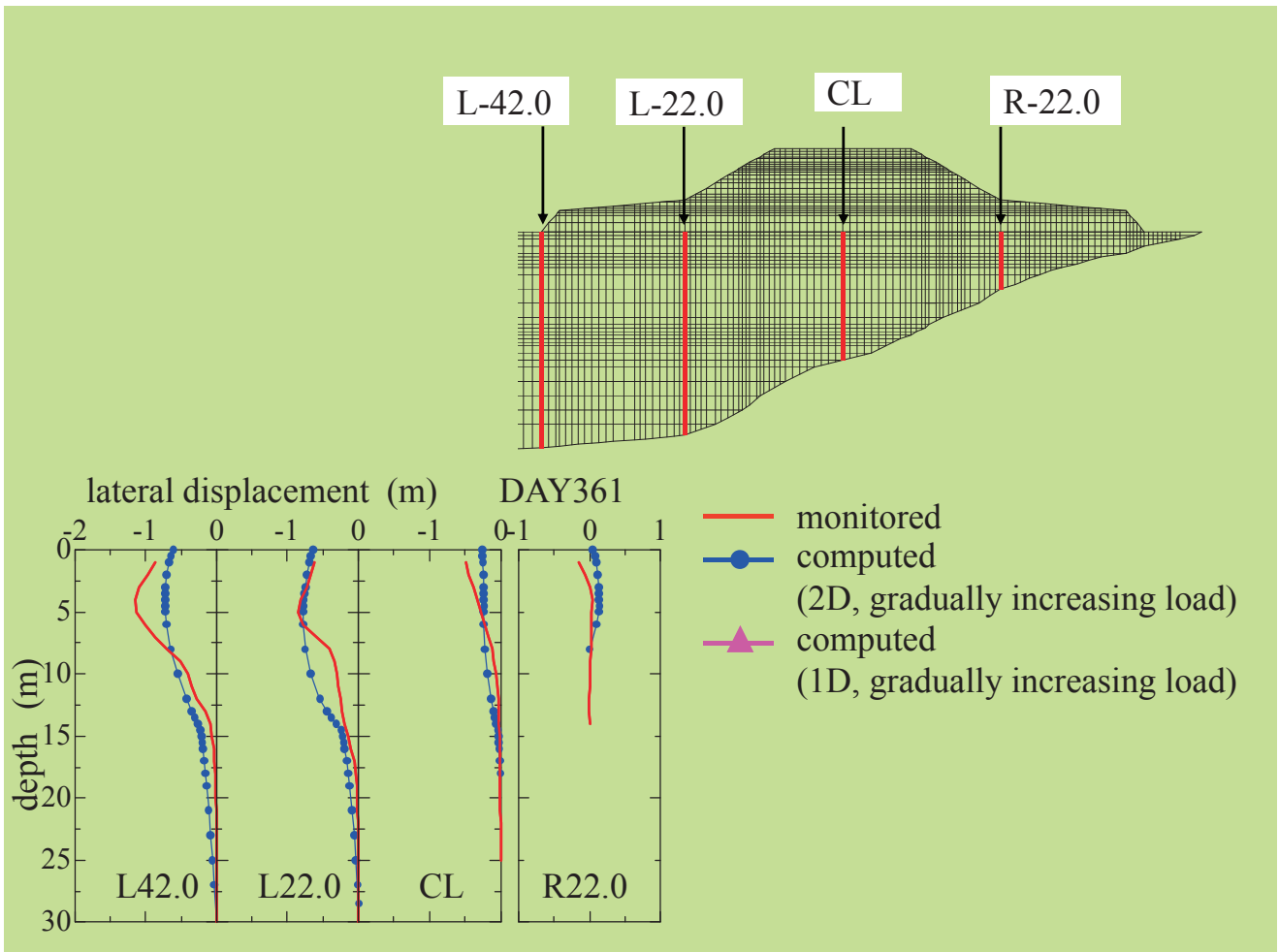
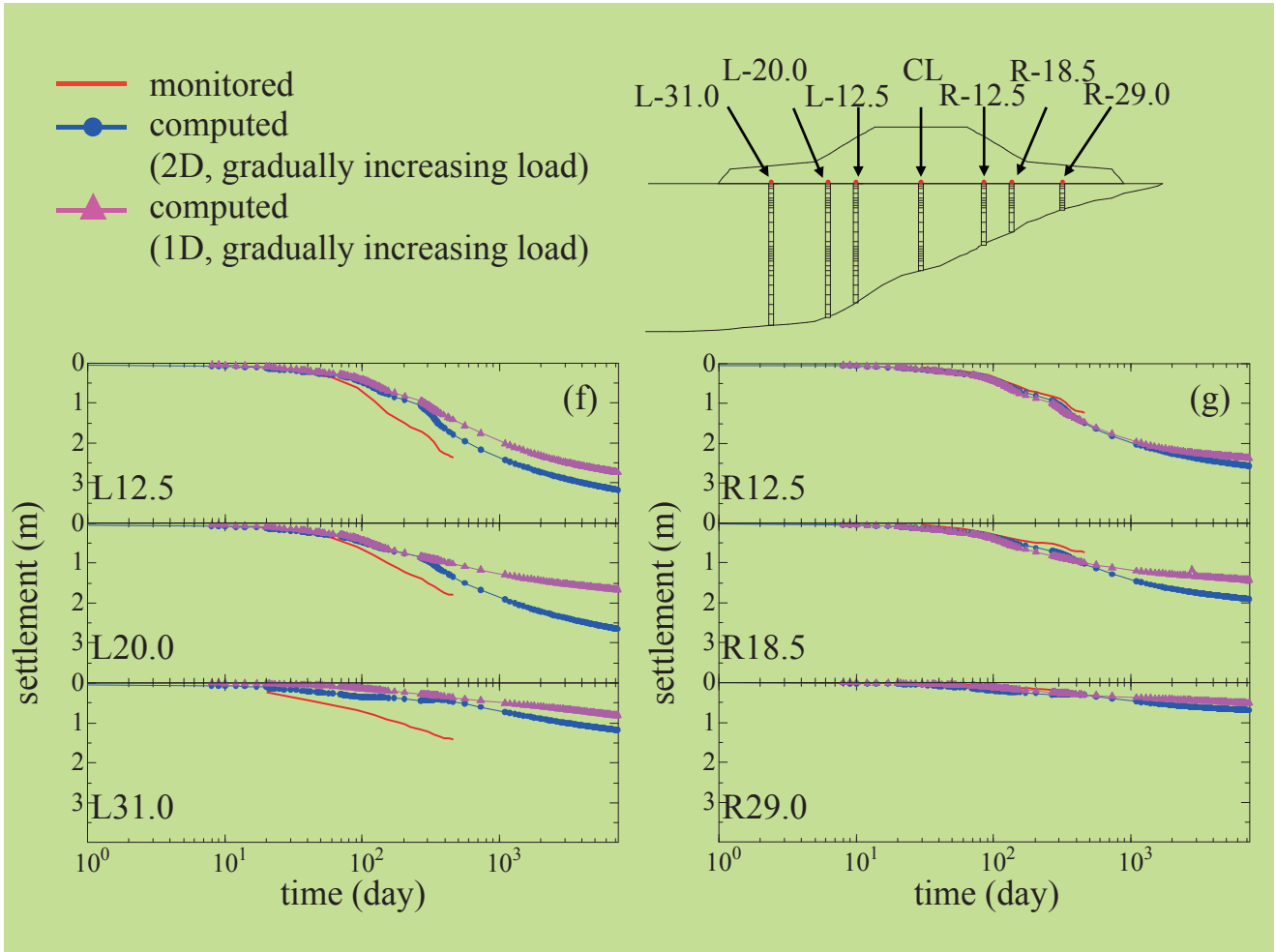


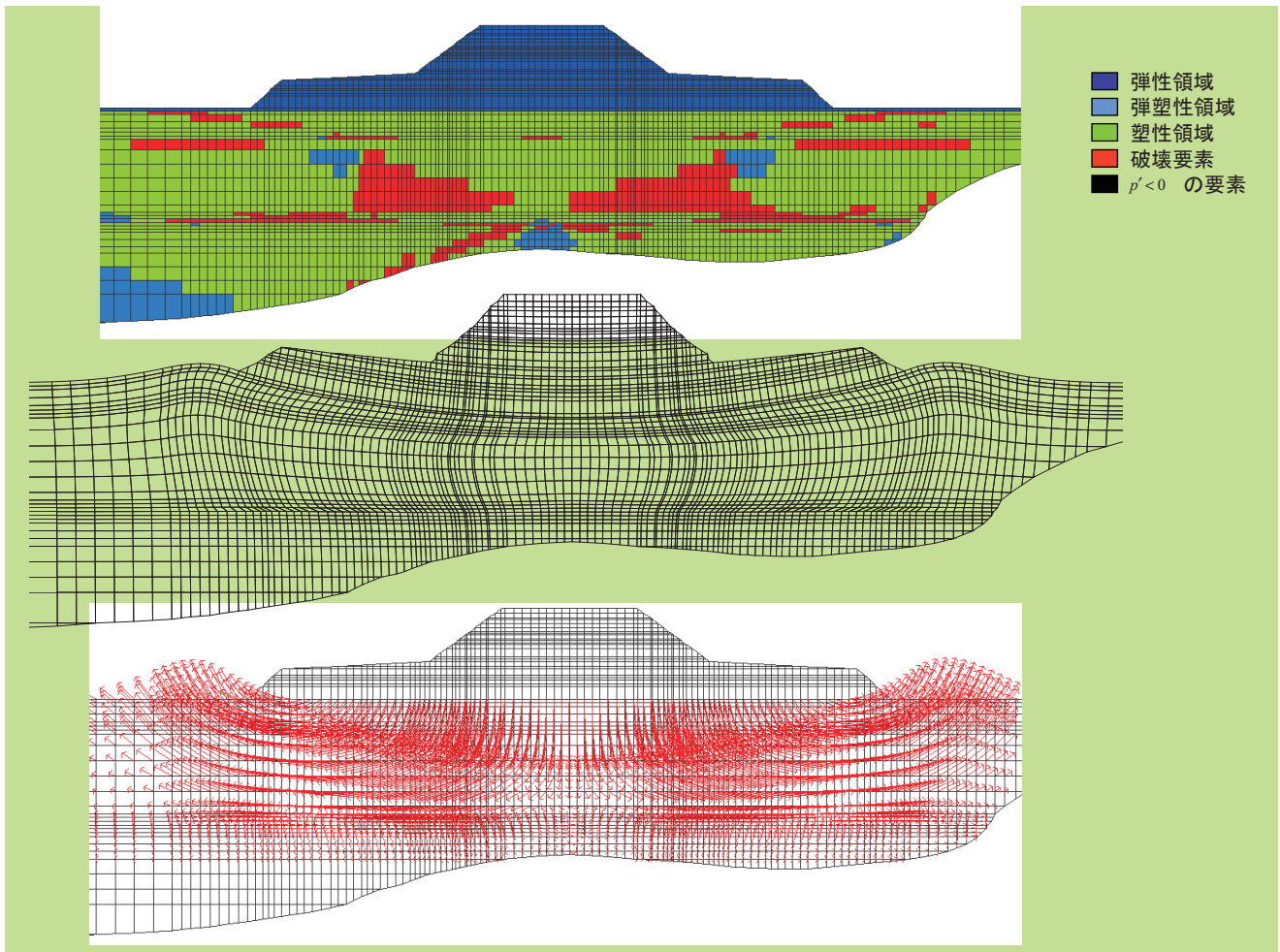
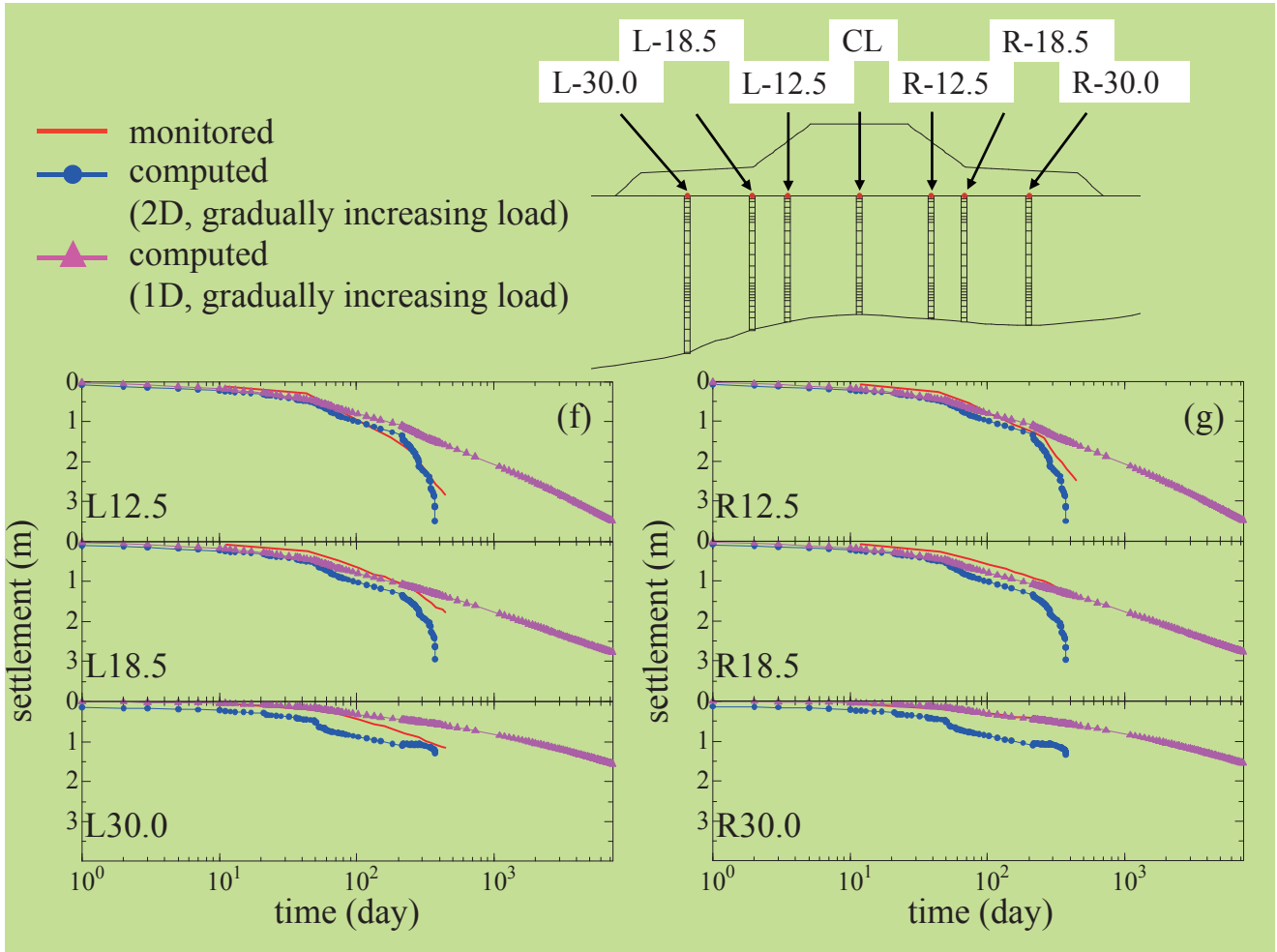
BC21

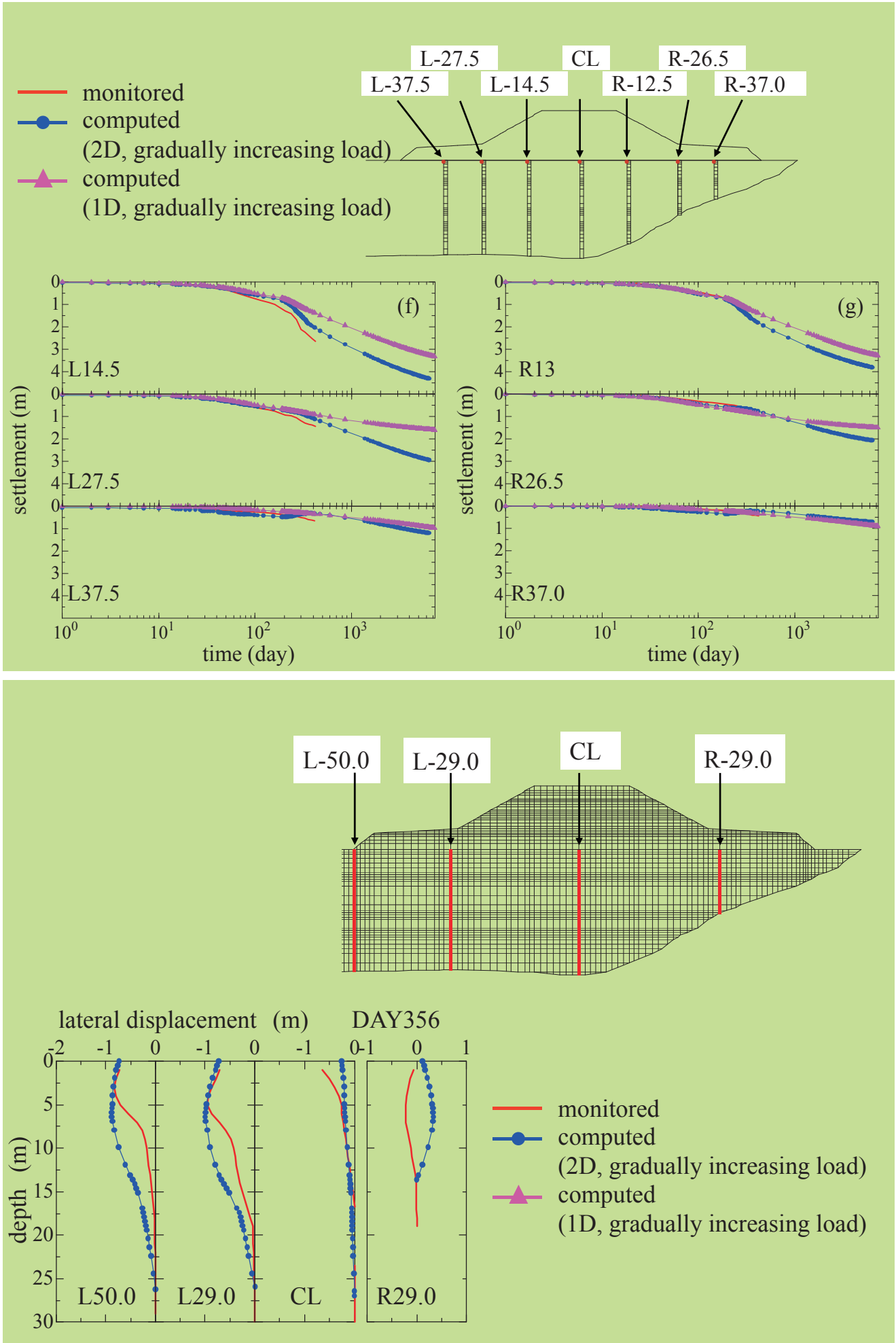


BC31









ここまでの結論

1次元圧密解析は、悪くない。

でも、Terzaghiの理論に固執するのは、やめましょう。

数値解析をつかって、簡便かつ正確に計算しましょう。

ここでは、DACSAR (Iizuka & Ohta, 1987) を使いましたが、
e-log p' 関係と e-log k 関係を使っているだけですから、EXCEL
でも計算できると思いますよ。

そうすれば、結構うまく行きそうですよ。

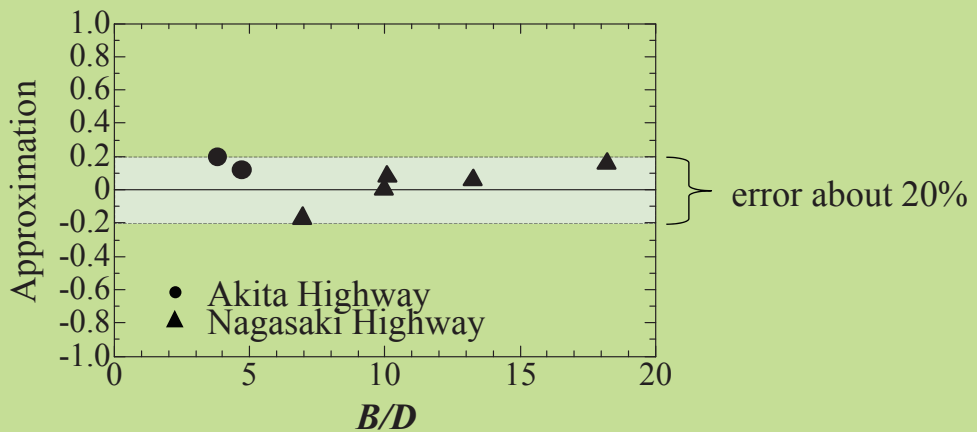
どれぐらいの差があるか

section	Akita Highway		Nagasaki Highway				
	BC11	BC31	P1	P2	P3	P4	P6
<i>H</i> (m)	11.7	13.7	8.5	8.5	8.5	7.0	7.7
<i>B</i> (m)	84.0	99.5	112.6	90.8	59.0	69.7	91.0
<i>D</i> (m)	17.5	26.0	8.5	9.0	8.5	7.0	5.0
<i>B/D</i>	4.7	3.7	13.2	10.1	6.9	10.0	18.2
S_{2D} (m)	3.38	4.70	2.22	2.62	1.95	1.72	1.41
S_{1D} (m)	3.02	3.82	2.21	2.42	2.28	1.71	1.18

B/D :

Approximation :

$$A = \frac{S_{2D} - S_{1D}}{S_{2D}}$$



5. 超軟弱地盤での いろいろな事例

大沢郷
スリランカ南部道路

どういう構成モデルを使うか？

なぜ？

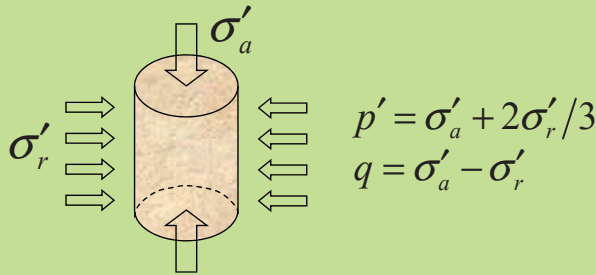
有名なモデル

- Original Cam-Clay model
- Modified Cam-Clay model

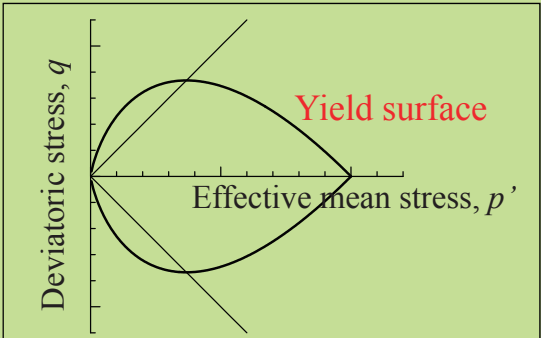
どちらが いいのだろうか？



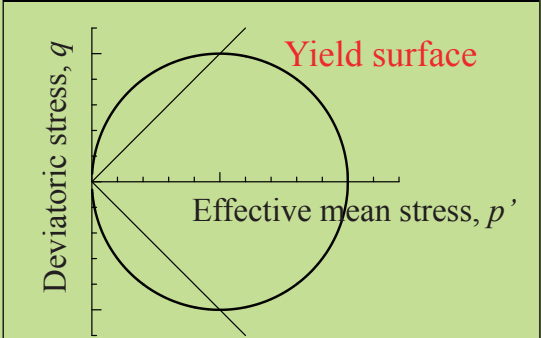
The undrained triaxial compression tests



- Shall we use ?
- ① Standard strain rate ← **fast**
 - ② Slow strain rate ← **real site**



Original Cam-Clay model



Modified Cam-Clay model

バーチカル・ドレーン

複雑な3次元現象→水は水平方向に流れる

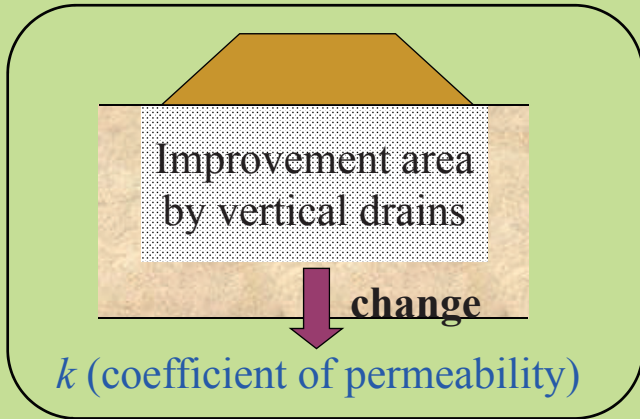
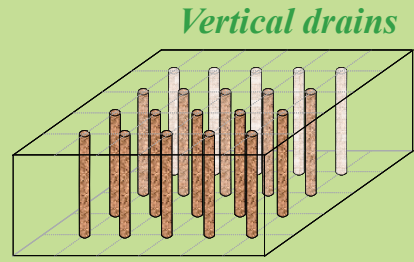
どうモデル化するか

バーチカル・ドレーンによる地盤改良

3-dimensional treatment is necessary

In many cases

< 2-dimension >



Mass permeability method

Problems...

- Difficult to evaluate how much we should change
- Arbitrariness characteristics
- Difficult to say that reproduction of the ground is precise

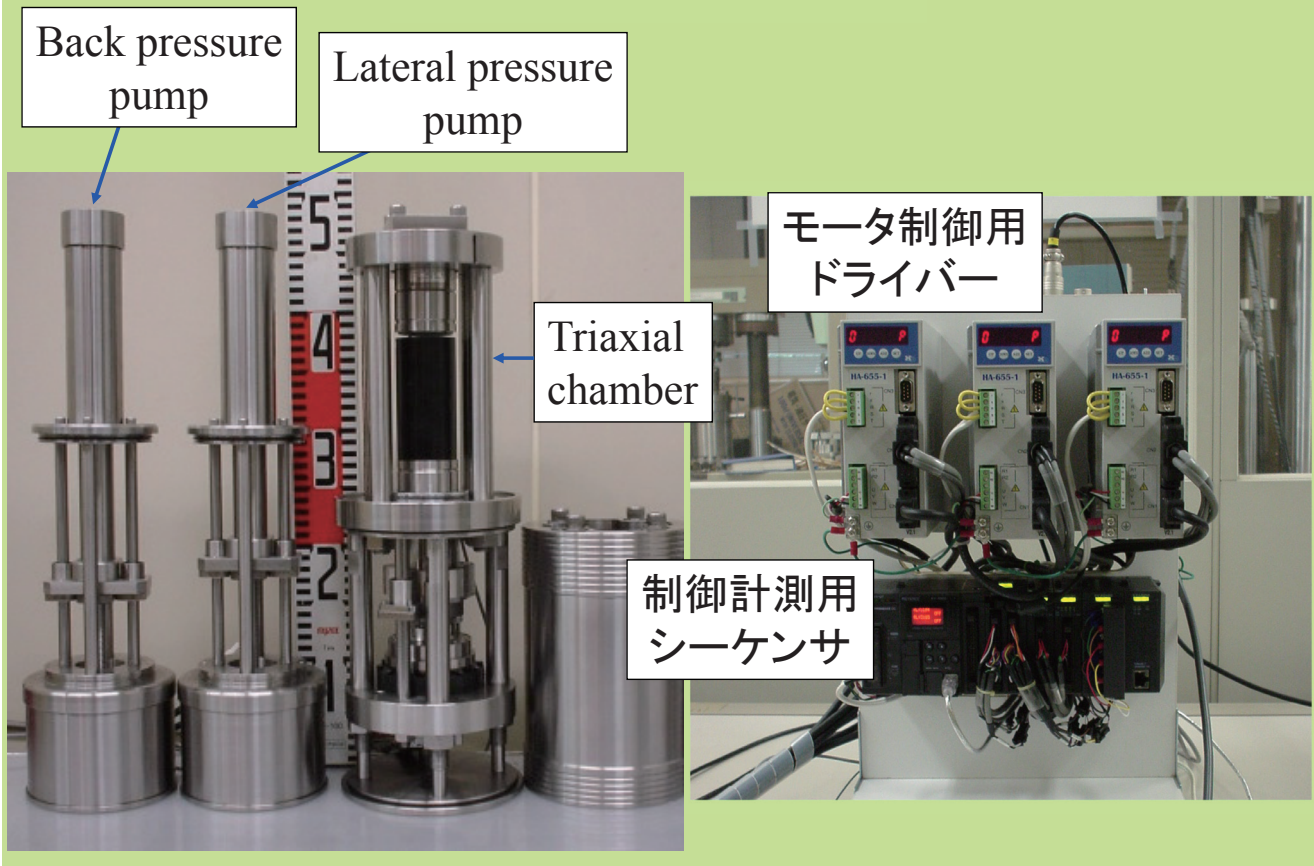
- ① **Macro-element method** : 合理的
- ② **Mass permeability method** : 伝統的

どちらがいい？

どういう構成モデルを使うか？

なぜ？

パスポート3軸試験機



Test samples

The undisturbed samples of clay

Test conditions

Size of the specimen $\phi 50\text{mm} @ 100\text{mm}$

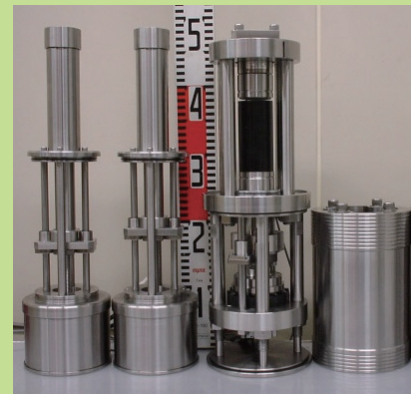
Test procedure:

Saturation the specimen

→ Isotropic consolidation

→ Undrained compression shear tests

Apparatus



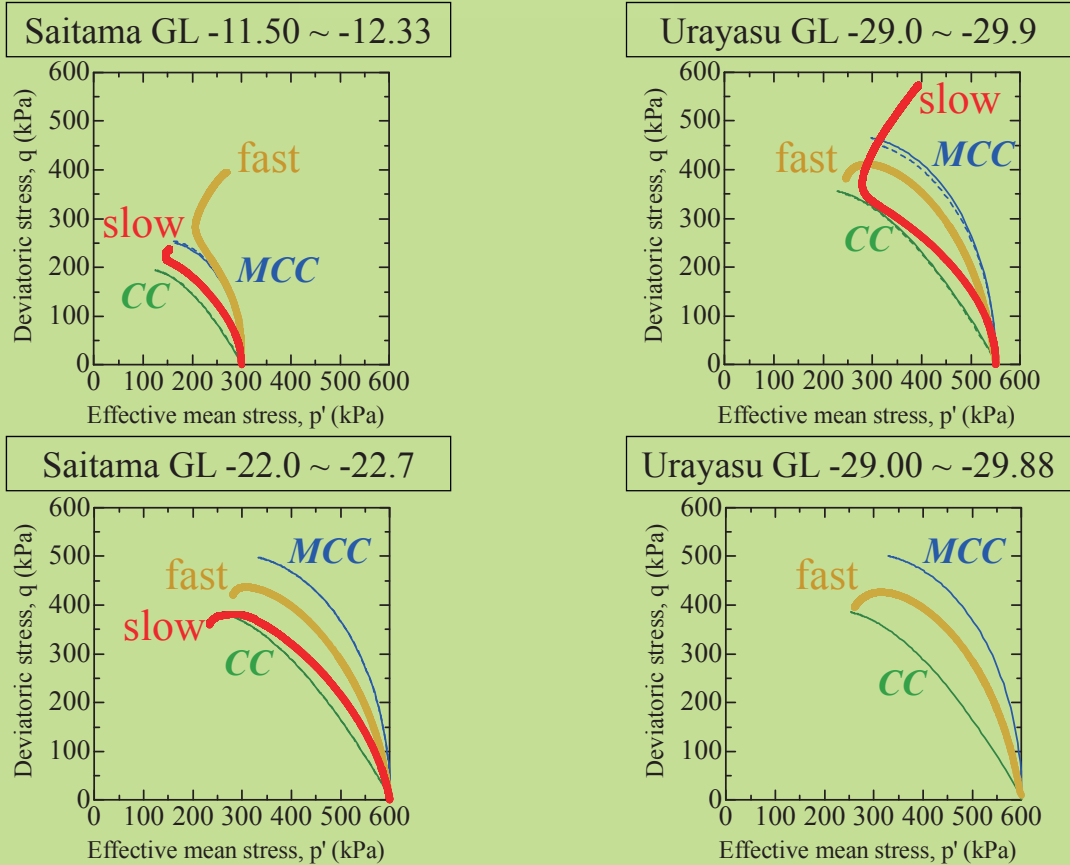
Test cases

No.	Sampling Position	Depth (m)	Consolidation stress (kN/m ²)	Axial strain rate (%/min)
①	Saitama	GL -11.50 ~ -12.33	300	0.05
②	Urayasu	GL -29.0 ~ -29.9	550	0.05
③	Urayasu	GL -22.0 ~ -22.7	600	0.05
④	Urayasu	GL -29.00 ~ -29.88	600	0.05
⑤	Saitama	GL -11.50 ~ -12.33	300	0.005
⑥	Urayasu	GL -29.0 ~ -29.9	550	0.005
⑦	Urayasu	GL -22.0 ~ -22.7	600	0.005

Fast
(Standard)

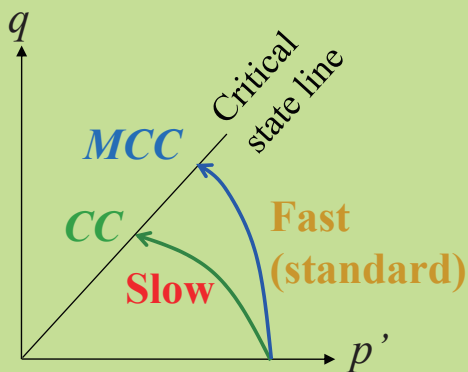
10 times slower
than standard

有効応力経路



結論

From triaxial test results

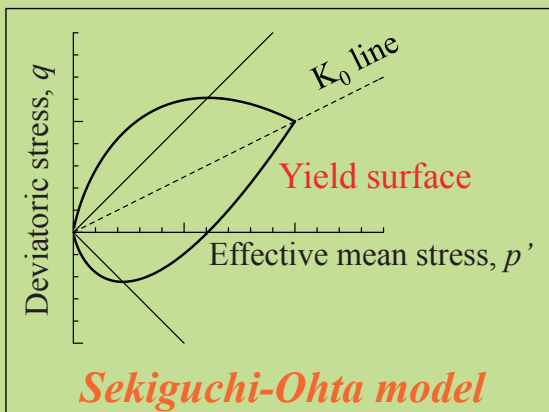


- ◆ Lab tests : **Fast**
→ *Modified Cam-Clay model*
- ◆ Site performance : **Slow**
→ *Original Cam-Clay model*

Shall we use **CC** in the analysis of site performance ?



The analysis in this study uses *Sekiguchi-Ohta model* which was extended from the *Original Cam-Clay model*.



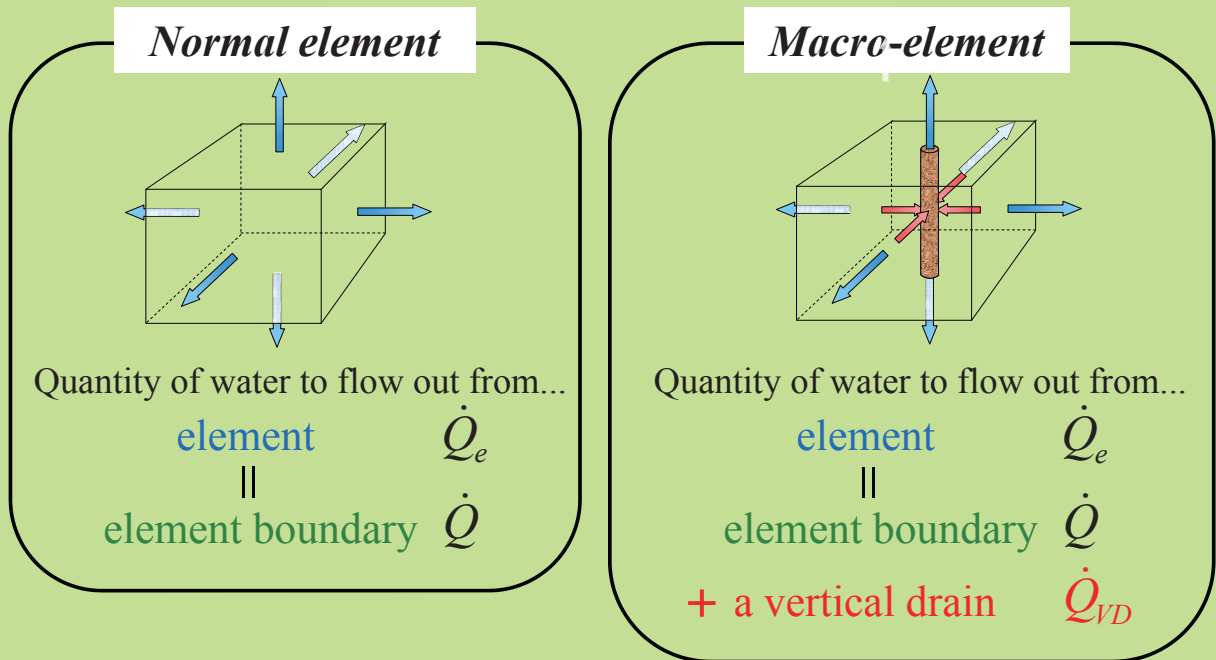
Sekiguchi-Ohta model

バーチカル・ドレーン

複雑な3次元現象→水は水平方向に流れる

どうモデル化するか

マクロエレメント法とは?



The macro-element method ← Sekiguchi(1986)

... very old proposal : **rational**

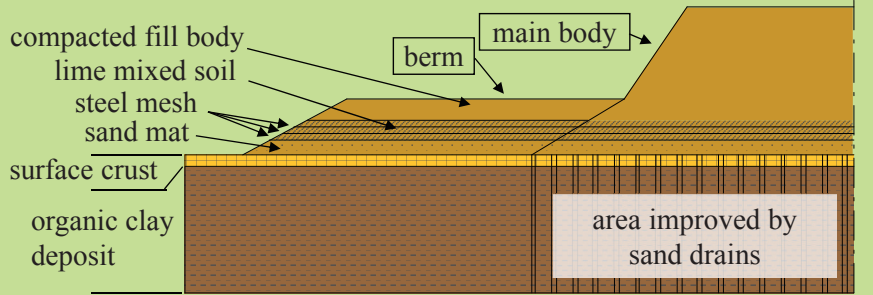
大沢郷

Field site

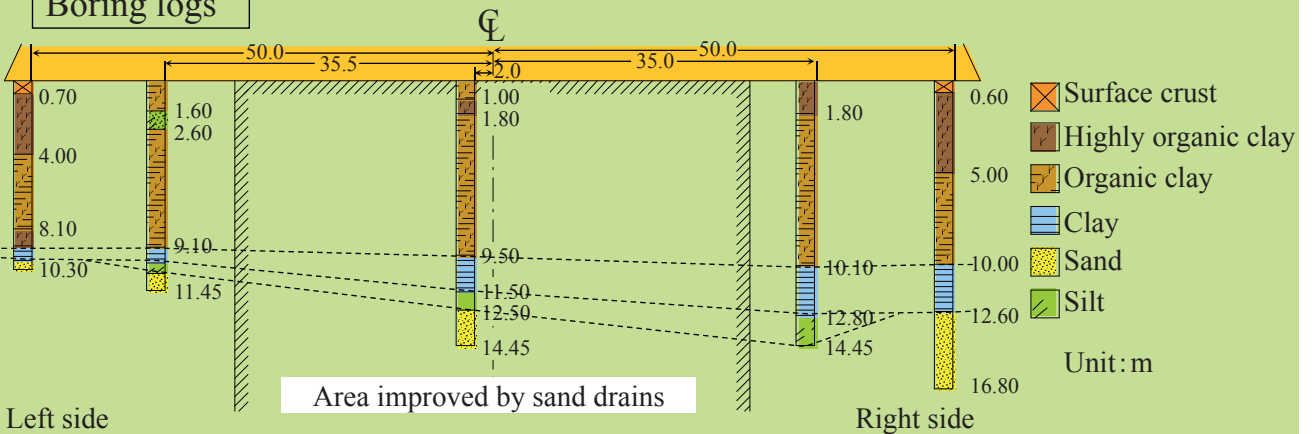


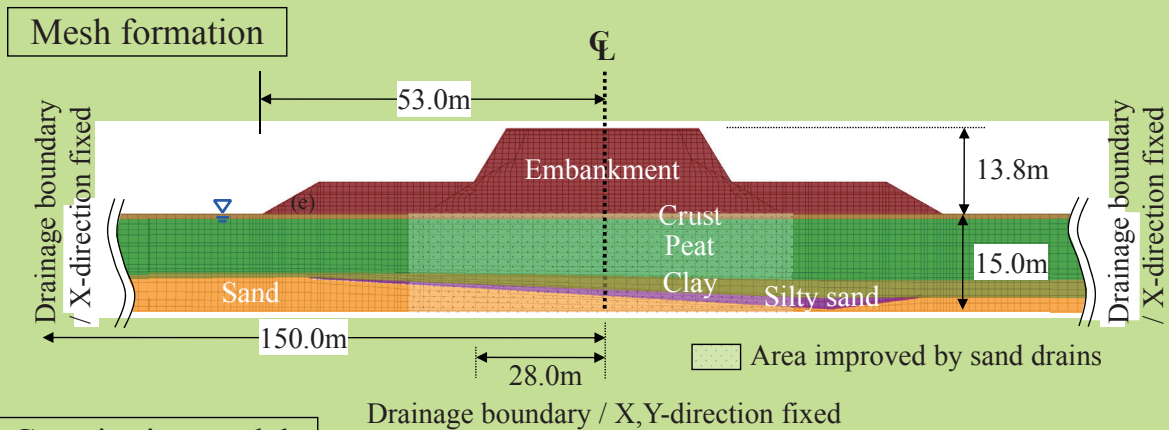
大沢郷の盛土

Configuration at analyzed section



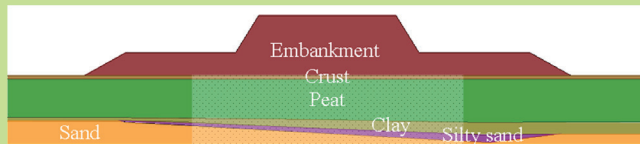
Boring logs





Constitutive models

Geological formation	Constitutive model
Embankment	Elasto-plastic model (<i>Sekiguchi-Ohta model</i>)
Crust	Linear elastic model
Peat	Elasto-plastic model (<i>Sekiguchi-Ohta model</i>)
Clay	Elasto-plastic model (<i>Sekiguchi-Ohta model</i>)
Silty sand	Linear elastic model
Sand	Linear elastic model



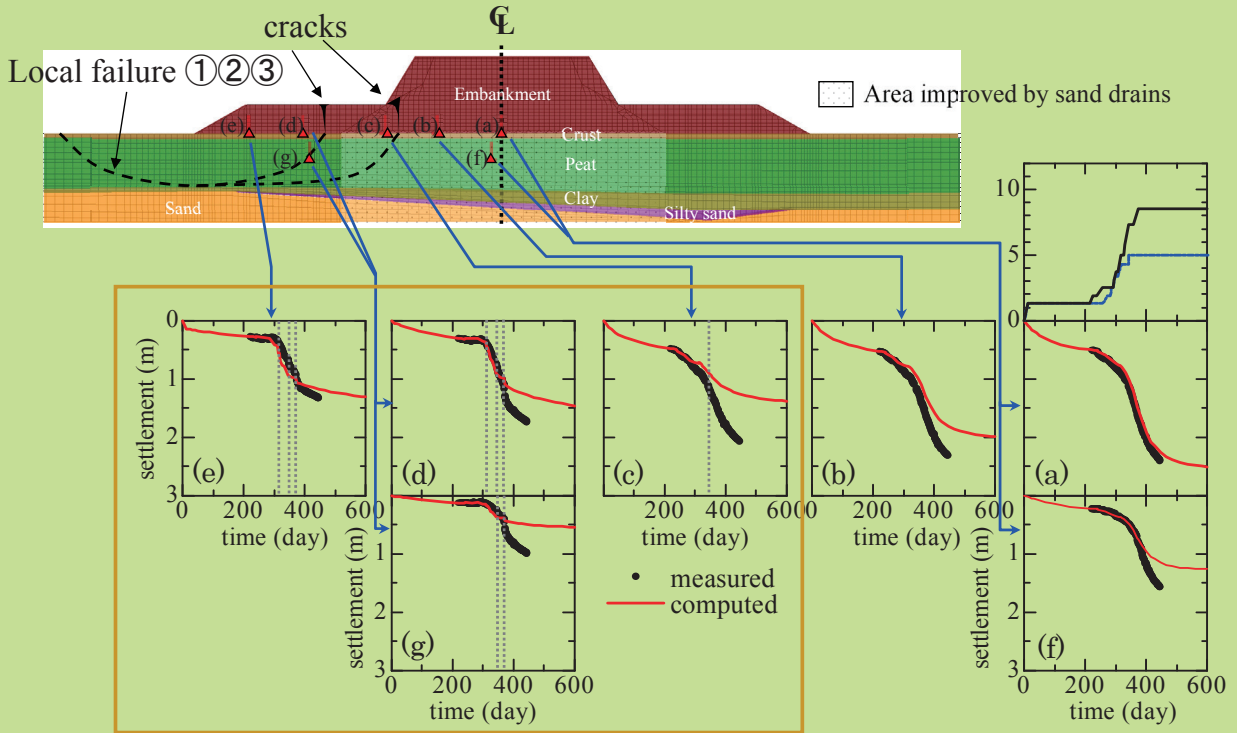
- : Obtained directly by laboratory tests
- : Determined by using some empirical equations or theoretical equations
- : Assumed as general value

Type of soil	Depth	Thickness	σ'_{vi}	σ'_{v0}	K_0	M	K_r	ν'	λ	λ_k	Λ	e_0	D	k
	[m]	[m]	[kN/m ²]	[kN/m ²]										[m/day]
Embankment			6.9	92.1	0.70	1.850	1.00	0.330	0.210	0.210	0.900	1.36	0.04300	8.60E-03
Sand mat			11.5	E = 51.2E+03 [kN/m ²]			1.00	0.330				1.36		6.00E-01
Surface crust	0.0 ~ 0.7	0.7	2.0	E = 7.5E+03 [kN/m ²]			1.00	0.330				8.70		3.32E-04
Peat	0.7 ~ 1.0	0.3	4.1	21.0	0.34	1.693	0.12	0.254	2.127	2.127	0.854	9.22	0.10494	3.32E-04
	1.0 ~ 2.0	1.0	4.6	10.4	0.34	1.693	0.19	0.254	2.127	2.127	0.867	9.52	0.10355	3.32E-04
	2.0 ~ 3.0	1.0	5.4	5.4	0.34	1.693	0.34	0.254	2.127	2.127	0.890	9.79	0.10362	3.32E-04
	3.0 ~ 4.0	1.0	6.2	6.2	0.34	1.693	0.34	0.254	2.127	2.127	0.941	9.80	0.10941	3.32E-04
	4.0 ~ 5.0	1.0	7.8	7.8	0.40	1.501	0.40	0.286	1.116	1.116	0.918	5.14	0.11109	1.20E-04
	5.0 ~ 6.0	1.0	10.4	10.4	0.42	1.429	0.42	0.297	0.743	0.743	0.914	3.55	0.10444	1.20E-04
	6.0 ~ 7.0	1.0	12.9	12.9	0.42	1.448	0.42	0.294	0.841	0.841	0.948	4.29	0.10401	1.20E-04
	7.0 ~ 8.0	1.0	15.3	15.3	0.41	1.467	0.41	0.291	0.939	0.939	0.969	5.11	0.10149	1.20E-04
	8.0 ~ 9.0	1.0	17.4	17.4	0.40	1.485	0.40	0.288	1.036	1.036	0.978	5.98	0.09772	1.20E-04
Clay	9.5 ~ 10.0	0.5	19.0	19.0	0.44	1.382	0.44	0.305	0.496	0.496	0.955	3.00	0.08582	1.20E-04
	10.0 ~ 11.0	1.0	25.3	40.7	0.55	1.155	0.70	0.355	0.260	0.260	1.149	1.64	0.08156	8.00E-05
	11.0 ~ 12.0	1.0	31.2	50.2	0.55	1.155	0.70	0.355	0.260	0.260	1.149	1.64	0.08156	8.00E-05
Silty sand	10.0 ~ 11.0	1.0	25.3	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	11.0 ~ 12.0	1.0	31.2	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	12.0 ~ 13.0	1.0	37.1	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	13.0 ~ 14.0	1.0	43.0	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
Sand	10.0 ~ 11.0	1.0	25.3	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	11.0 ~ 12.0	1.0	31.2	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	12.0 ~ 13.0	1.0	37.1	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	13.0 ~ 14.0	1.0	43.0	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00
	14.0 ~ 15.0	1.0	48.8	E = 5.9E+04 [kN/m ²]			0.50	0.330				1.59		1.0E+00

Macro-element method

Settlement

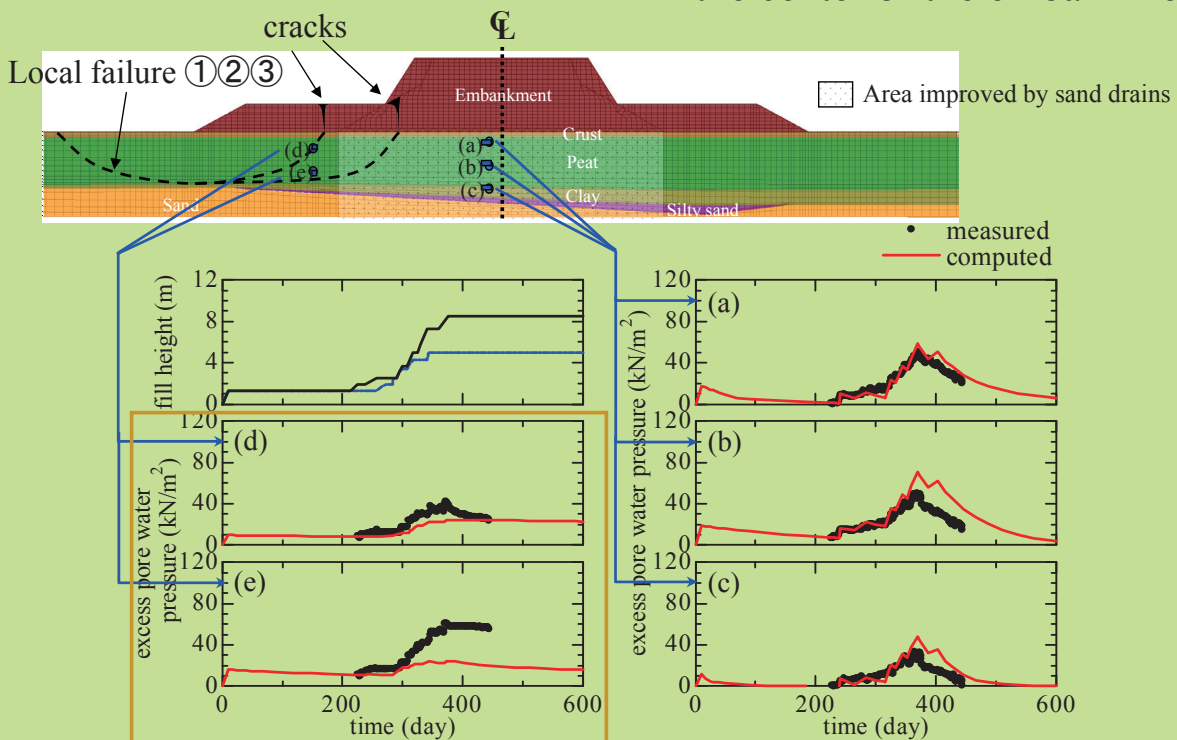
... agree well to the actual behavior near the center of the embankment



Macro-element method

Excess pore water pressure

... agree well to the actual behavior near the center of the embankment



Mass permeability method for modeling sand drains

- ◆ Horizontal direction } Coefficient of permeability is converted so that time for 50% consolidation of horizontal and vertical direction are the same
- ◆ Vertical direction

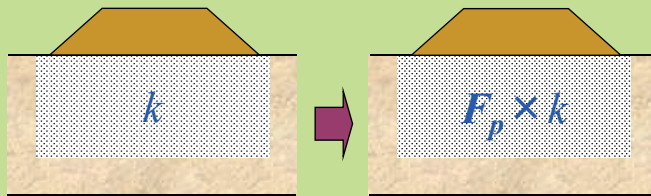
Vertical direction

$$t_v = \frac{T_v \cdot (H/2)^2}{c_v}$$

=

Horizontal direction

$$t_h = \frac{T_h \cdot (d_e/2)^2}{c_h}$$

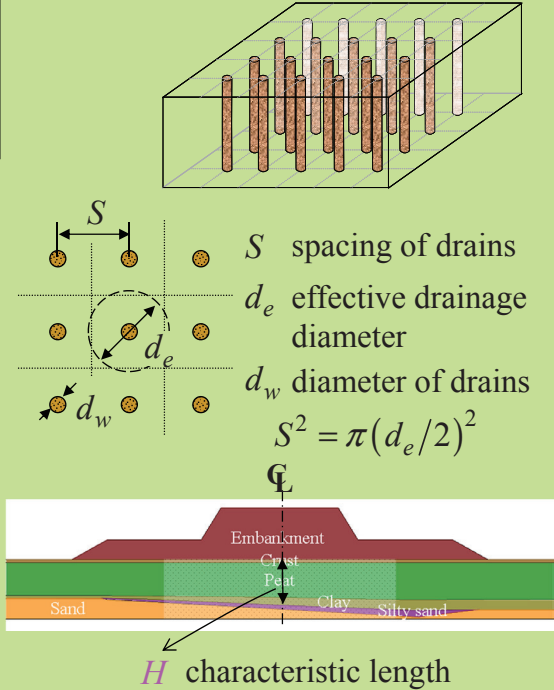


The factor for permeability F_p

$$F_p = c_v / c_h$$

F_p is obtained as **75.3**

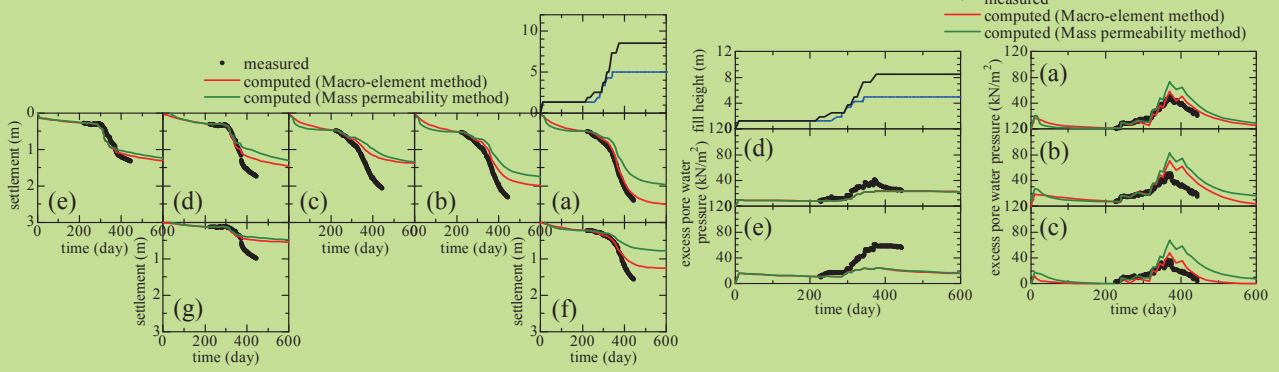
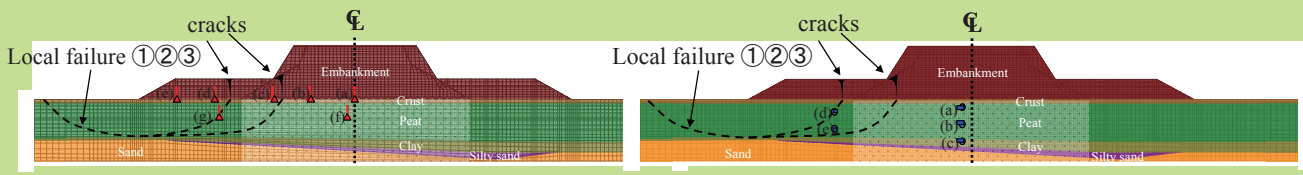
Vertical drains



Comparison macro-element method and the mass permeability method

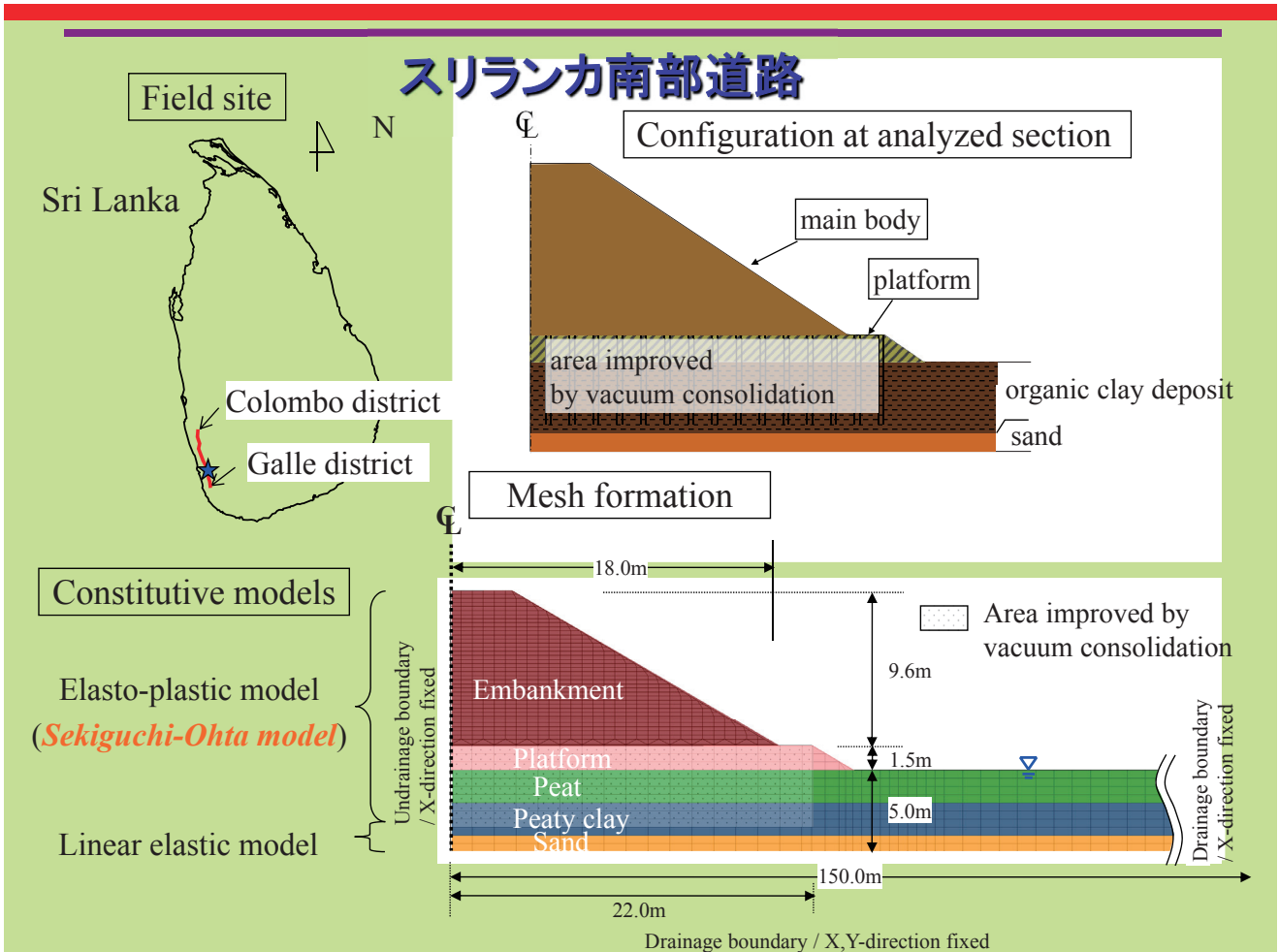
Settlement

Pore water pressure



Macro-element method : Good **Mass permeability method : No good**

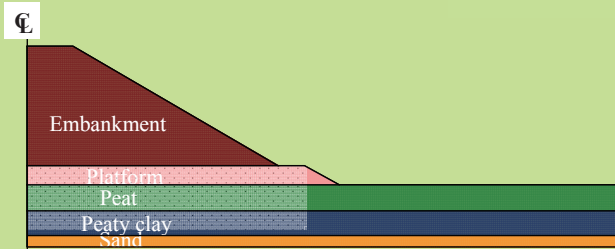
スリランカ南部道路







土質定数



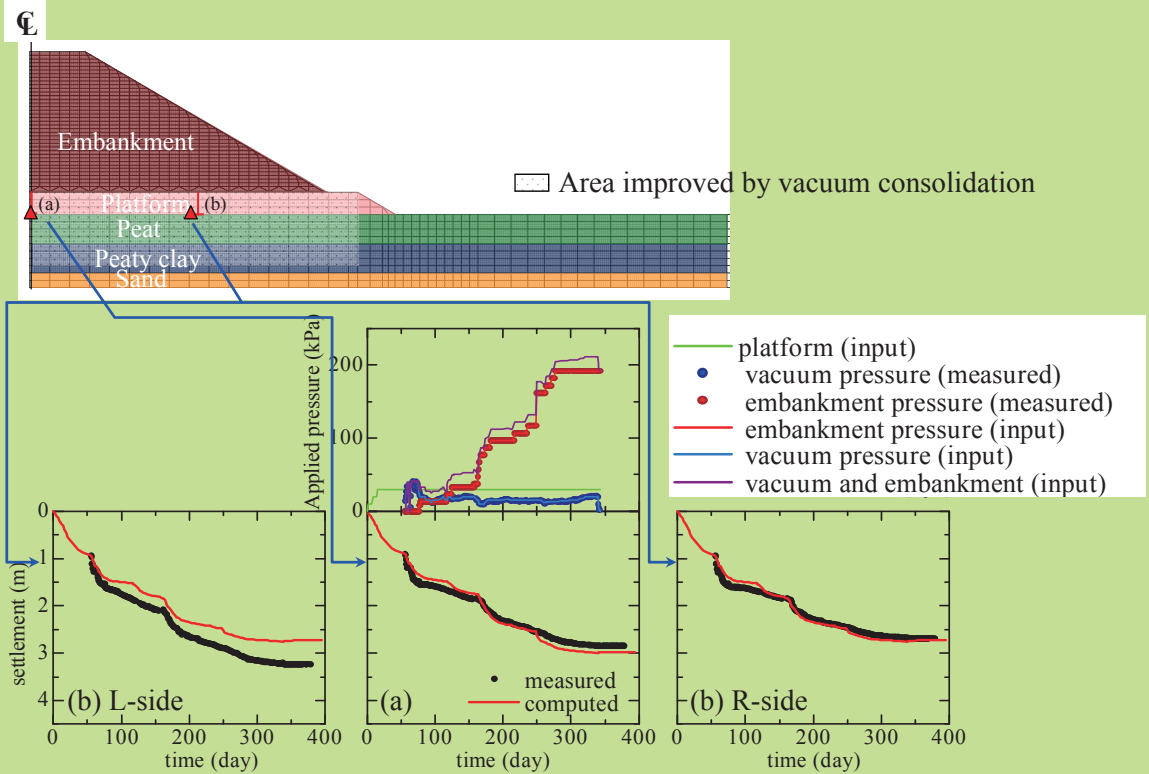
- : Obtained directly by laboratory tests
- : Determined by using some empirical equations or theoretical equations
- : Assumed as general value
- : quoted from parameters of embankment at Ohsawago

Type of soil	Depth [m]	Thickness [m]	σ_{vi} [kN/m ²]	σ_{v0} [kN/m ²]	K_0	M	K_t	ν'	λ	λ_k	Λ	e_0	D	k [m/day]
Embankment			6.900	92.1	0.700	1.850	1.00	0.330	0.210	0.210	0.900	1.360	0.043	8.60E-03
Platform			6.900	92.1	0.700	1.850	1.00	0.330	0.210	0.210	0.900	1.360	0.043	8.60E-03
Peat	0.0 ~ 0.5	0.5	0.549	14.0	0.595	1.619	4.88	0.373	1.736	1.736	0.803	4.018	0.172	4.00E-03
	0.5 ~ 1.0	0.5	1.648	14.0	0.595	1.619	2.39	0.373	1.736	1.736	0.817	4.209	0.168	4.00E-03
	1.0 ~ 1.5	0.5	2.757	14.0	0.595	1.619	1.72	0.373	1.736	1.736	0.824	4.297	0.167	4.00E-03
	1.5 ~ 2.0	0.5	3.855	14.0	0.595	1.619	1.38	0.373	1.736	1.736	0.828	4.356	0.166	4.00E-03
Peaty clay	2.0 ~ 2.5	0.5	5.082	14.0	0.595	1.412	1.01	0.373	0.651	0.651	0.853	2.514	0.112	4.00E-03
	2.5 ~ 3.0	0.5	6.435	14.0	0.595	1.412	0.90	0.373	0.651	0.651	0.855	2.529	0.112	4.00E-03
	3.0 ~ 3.5	0.5	7.779	14.0	0.595	1.412	0.81	0.373	0.651	0.651	0.856	2.542	0.111	4.00E-03
	3.5 ~ 4.0	0.5	9.133	14.0	0.595	1.412	0.75	0.373	0.651	0.651	0.857	2.552	0.111	4.00E-03
Sand	4.0 ~ 4.5	0.5	11.18	E = 5.9E+04 [kN/m ²]		0.50	0.330							1.00E-03
	4.5 ~ 5.0	0.5	15.29	E = 5.9E+04 [kN/m ²]		0.50	0.330							1.00E-03

Macro-element method

Settlement

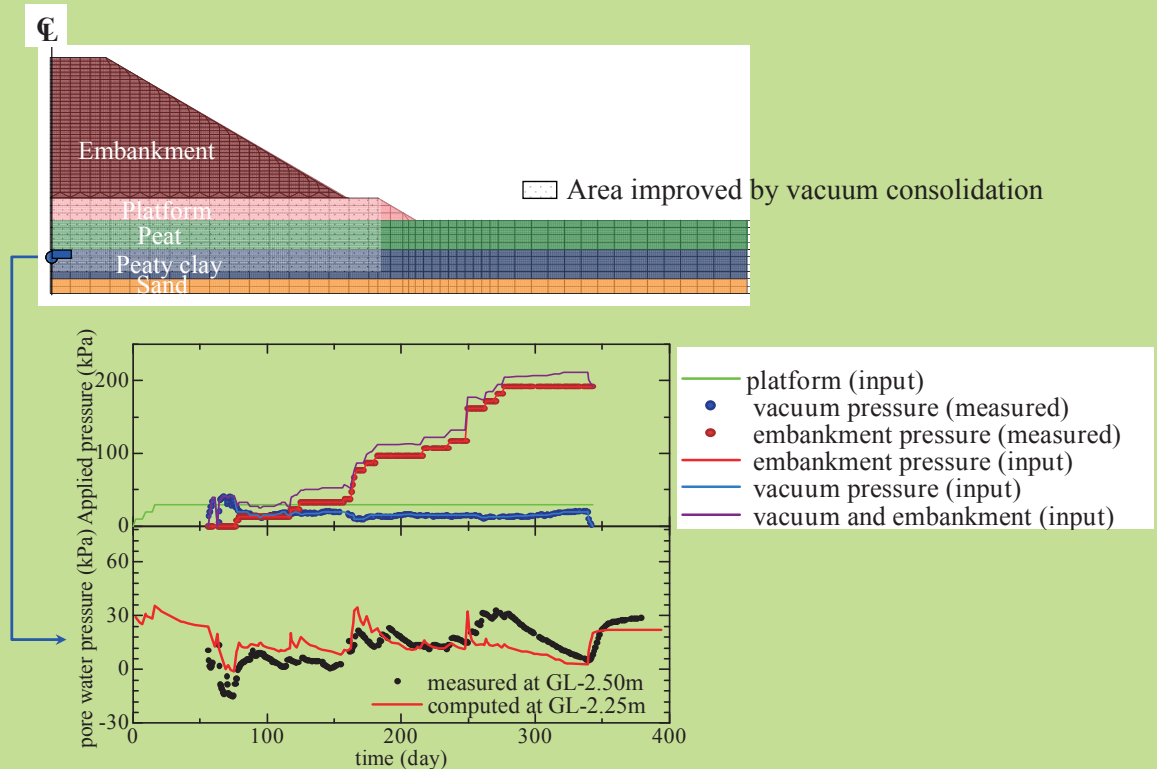
... agree well to the actual behavior



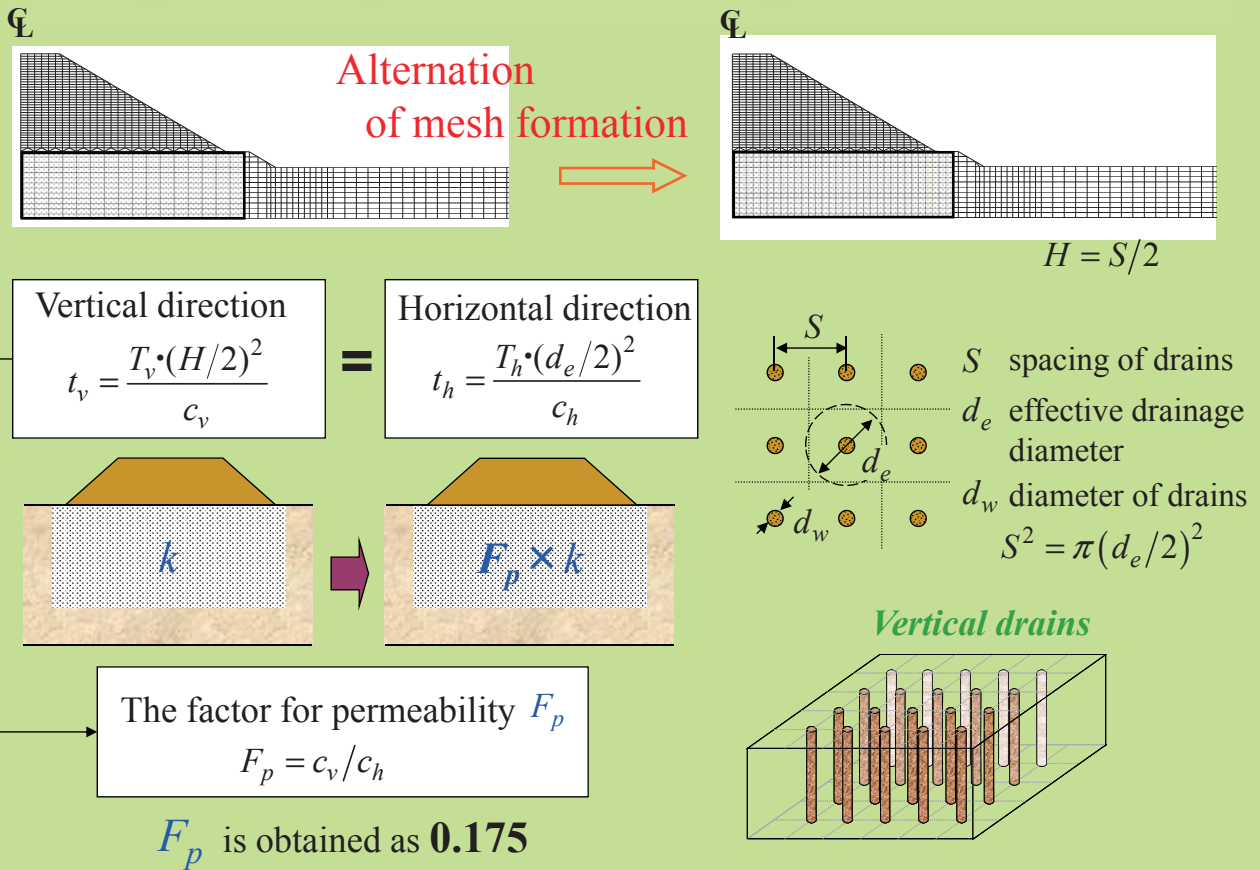
Macro-element method

Pore water pressure

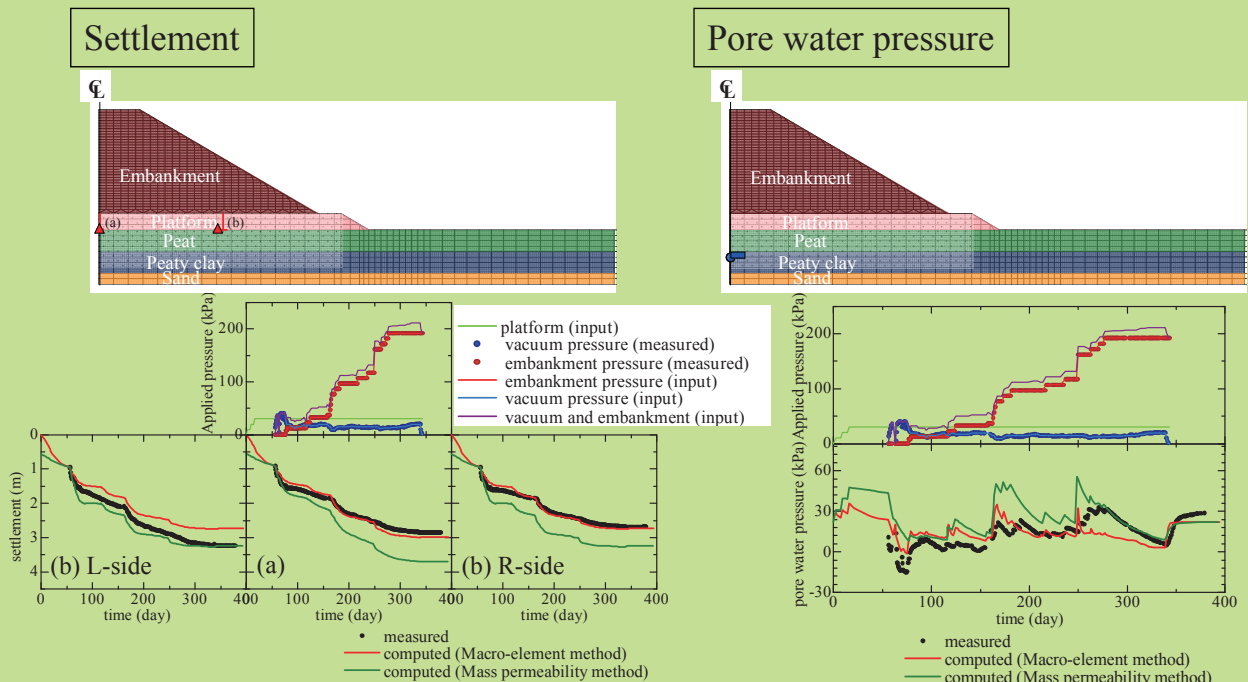
... agree well to the actual behavior



Mass permeability method for modeling vacuum consolidation



Comparison macro-element method and the mass permeability method



Macro-element method : Good **Mass permeability method : No good**

結論

3軸試験

現場のシミュレーション → *Original Cam-Clay model*
室内試験のシミュレーション → *Modified Cam-Clay model*

解析

バーチカル・ドレーン → *Macro-element method*

ご清聴、ありがとうございました

圧密・浸透(軟弱地盤)分野

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