超高型多階加勁檔土牆的設計理論與工程實踐

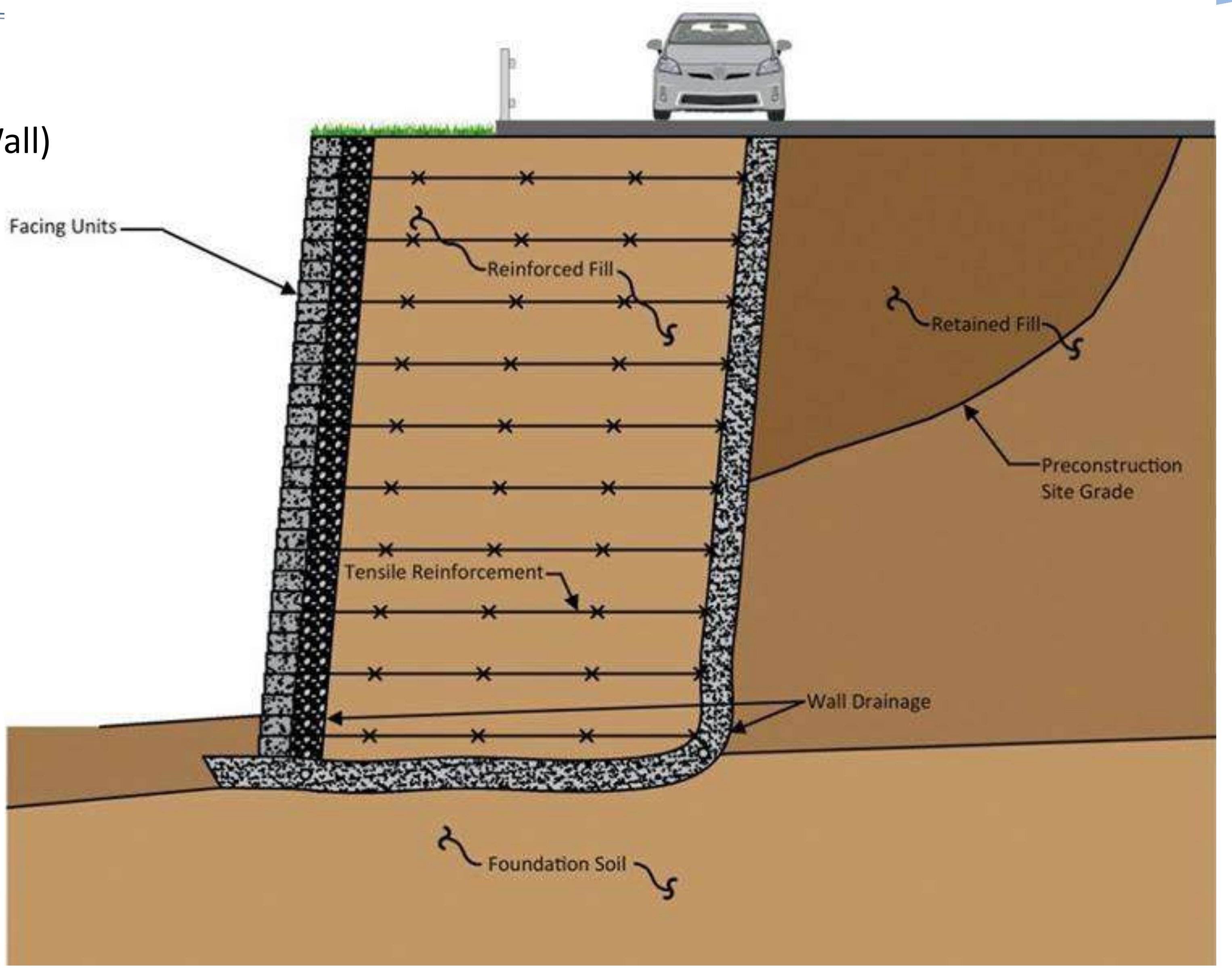
周知行，Ph.D., P.E.
Visual Slope, LLC，技術總監

提要：

- 什麼是加勁擋土牆
- 加勁擋土牆的歷史和應用
- 回顧單階加勁擋土牆和加勁邊坡的設計理論
- 加勁材料的受力分析
- 加勁邊坡的設計理論
- 單階加勁擋土牆的設計理論
    - 外部穩定分析
    - 承載力破壞
    - 沉陷量分析
    - 內部穩定分析
- 多階加勁擋土牆的設計理論和設計模型
- 多階加勁擋土牆實例

什麼是加勁擋土牆

MSE Wall (Mechanically Stabilized Earth Wall)



什麼是加勁擋土牆

塑製合成加勁材料

什麼是加勁擋土牆

鋼條加勁材料

什麼是加勁擋土牆

鋼網加勁材料

什麼是加勁擋土牆

多纖維加勁材料

什麼是加勁擋土牆

乾砌混凝土牆面

什麼是加勁擋土牆

鋼筋混凝土牆面

什麼是加勁擋土牆

Gabion(石籠)牆面

加勁擋土牆的歷史和應用

加勁擋土牆有近四十年的歷史，二十年前一般為單階牆低於二十米。

加勁擋土牆的歷史和應用

近二十年來，越來越多的多階加勁檔土牆高於40米。

加勁擋土牆的歷史和應用

園林工程

加勁擋土牆的歷史和應用

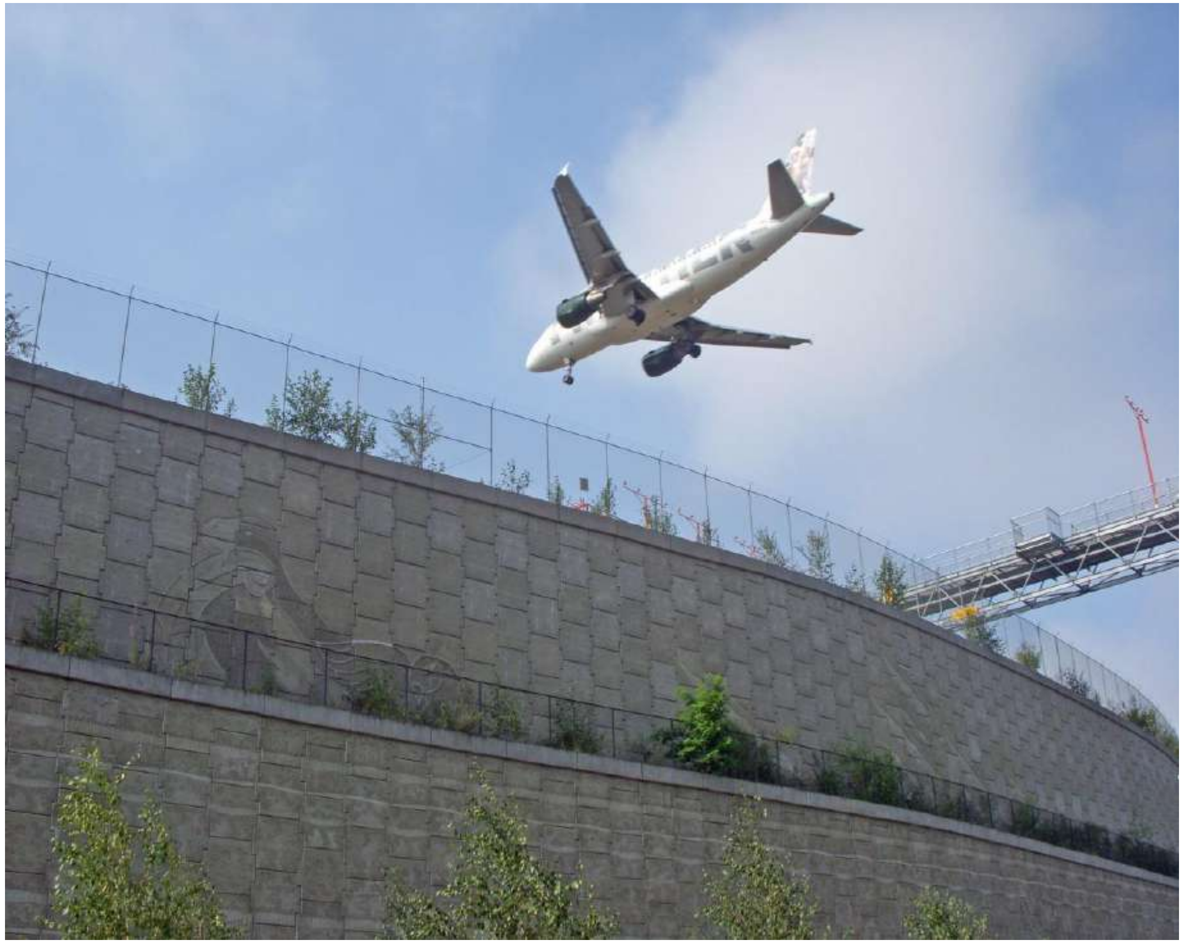
住宅工程

加勁擋土牆的歷史和應用

公路工程

加勁擋土牆的歷史和應用

機場工程

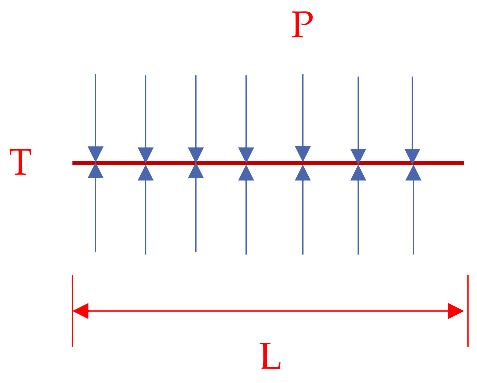


加勁擋土牆的歷史和應用

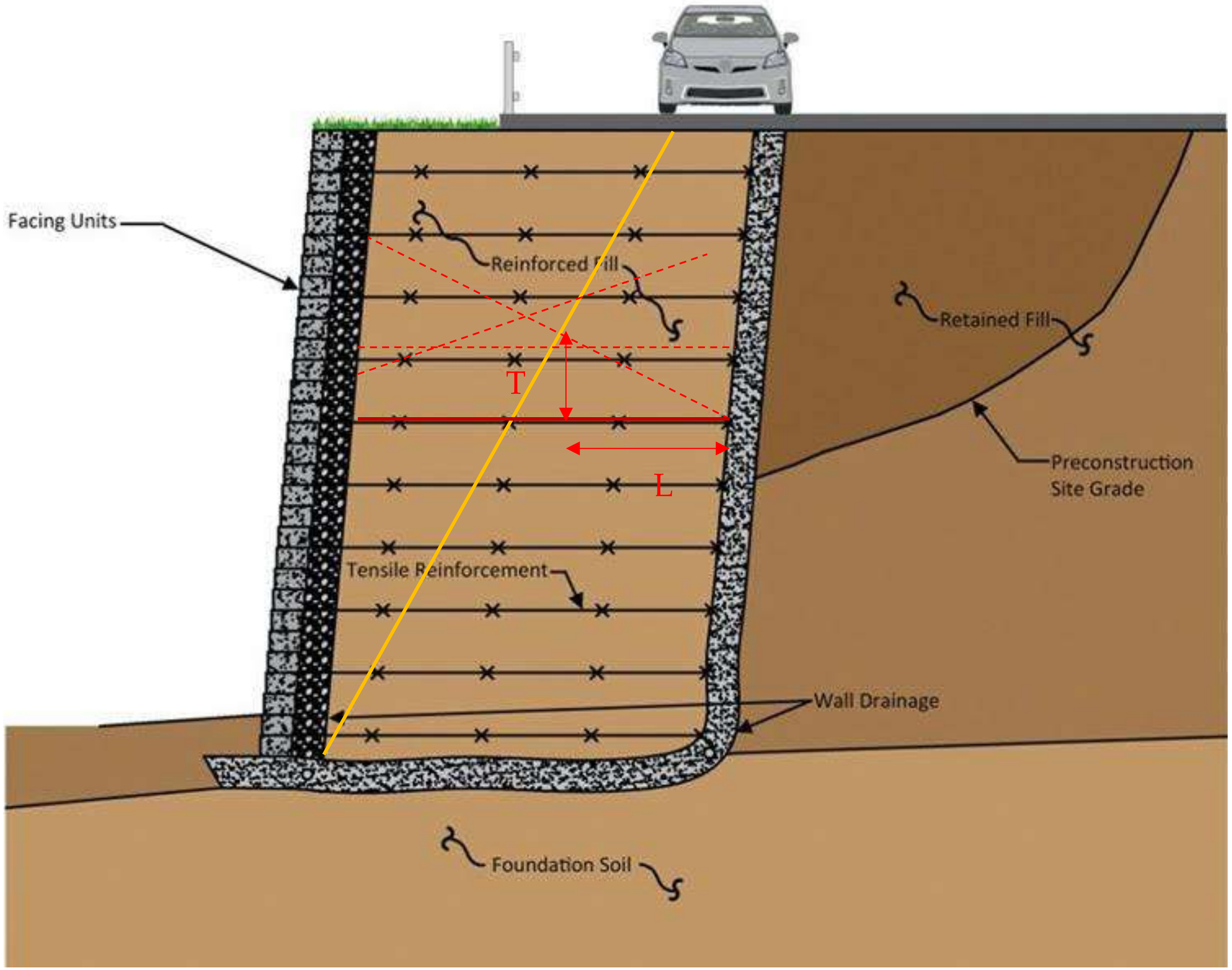
鐵路工程

回顧單階加勁擋土牆和加勁邊坡的設計理論

加勁材料的受力分析

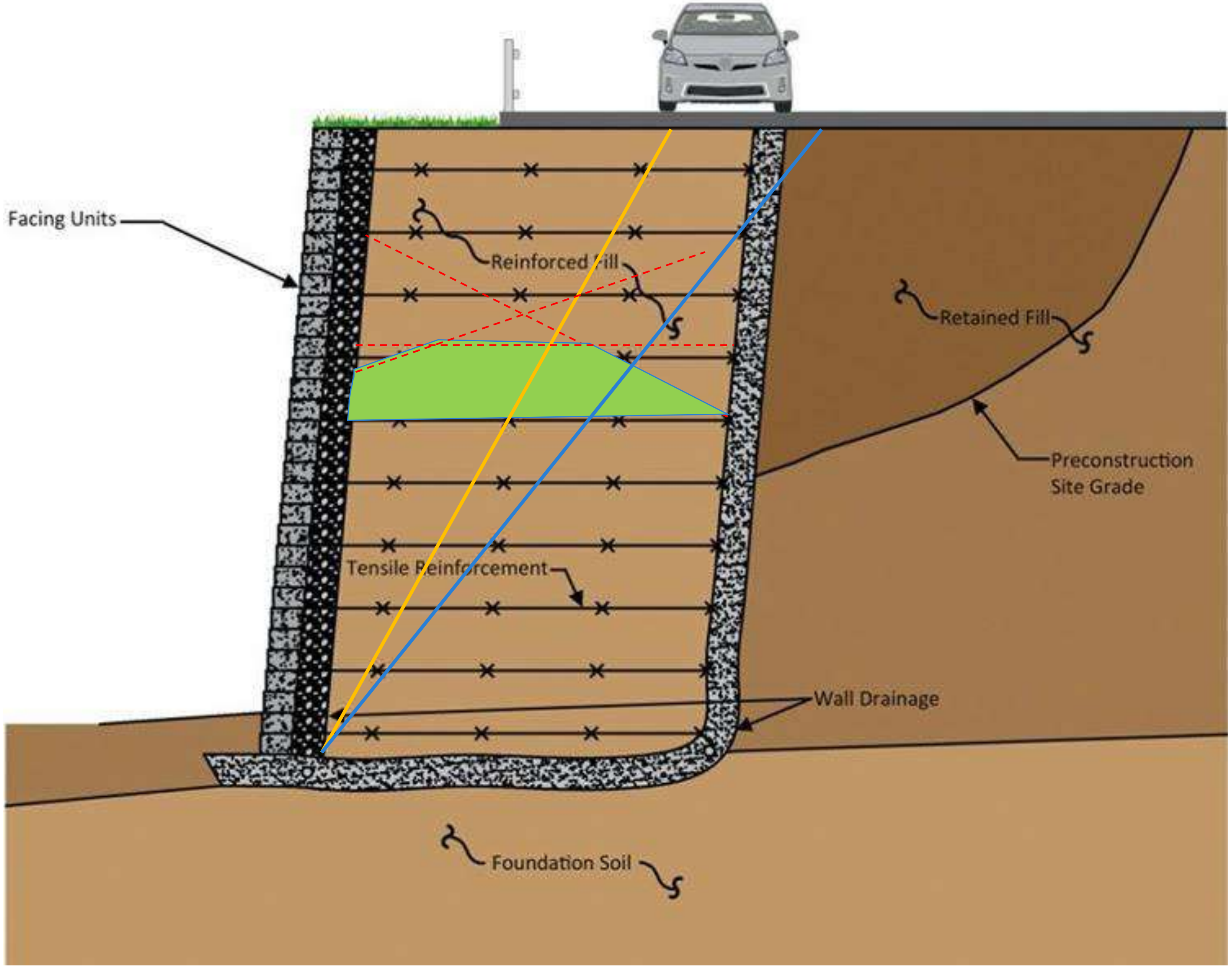


$$T = 2 \times P \times L \times 1$$



回顧單階加勁擋土牆和加勁邊坡的設計理論

加勁材料的受力分析



回顧單階加勁擋土牆和加勁邊坡的設計理論

加勁邊坡的設計理論 -破壞形式

總體穩定

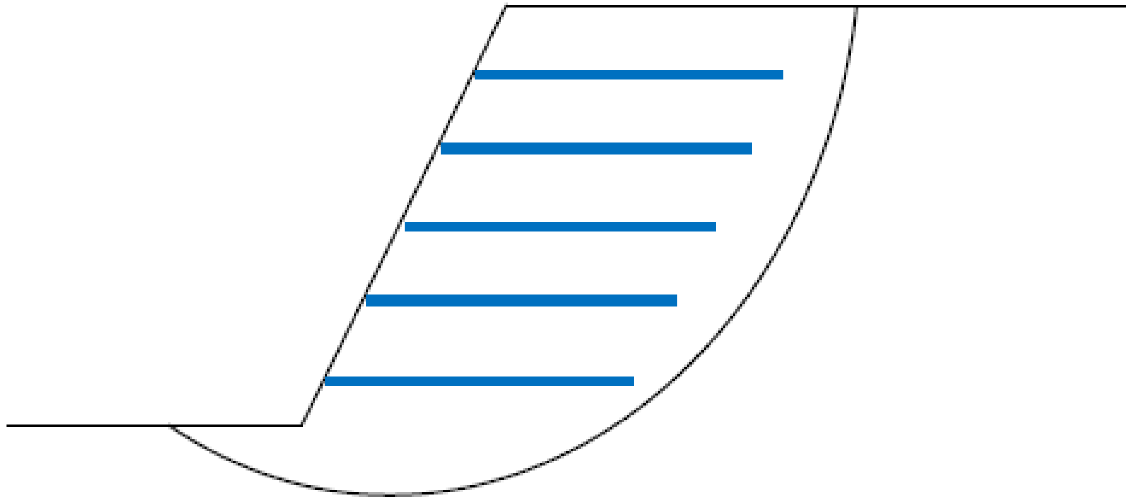


Figure 5 - Global Failure

回顧單階加勁擋土牆和加勁邊坡的設計理論

加勁邊坡的設計理論 -破壞形式

內部穩定

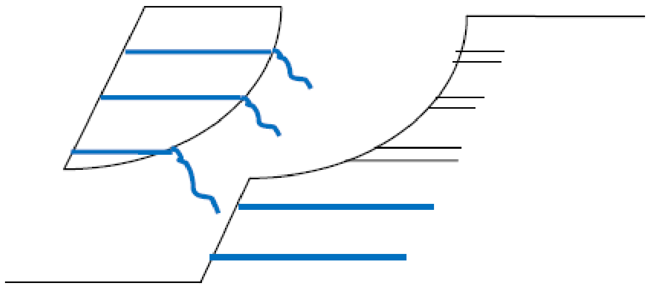


Figure 6 - Pullout from Back

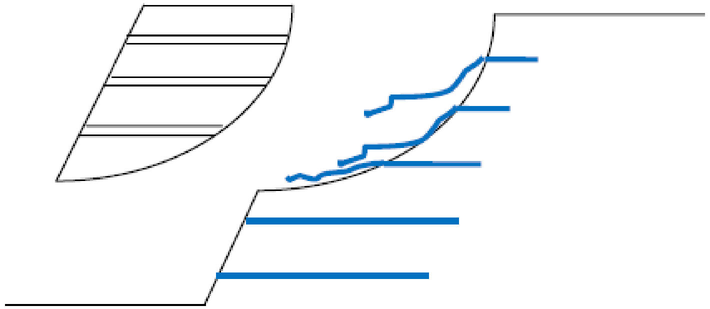


Figure 7 - Pullout from Front

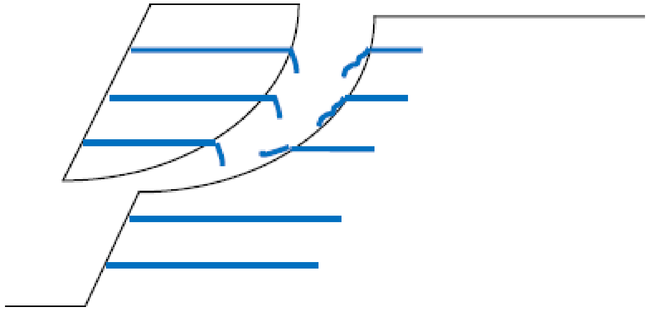


Figure 8 - Overstress Failure

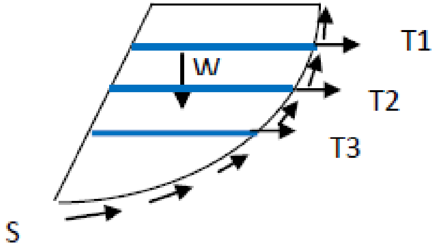


Figure 4 - Forces Acting on Failure Body

回顧單階加勁擋土牆和加勁邊坡的設計理論

加勁邊坡的設計理論 -破壞形式

土體沿加勁面滑移

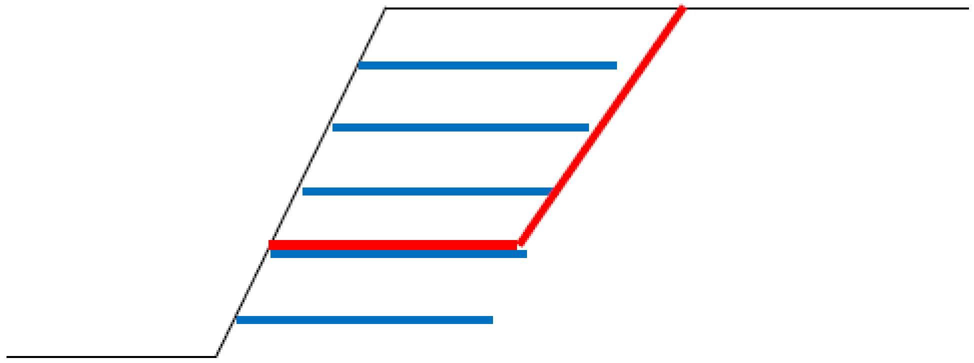


Figure 9 - Direct Sliding

回顧單階加勁擋土牆和加勁邊坡的設計理論

單階加勁擋土牆的設計理論

外部穩定分析

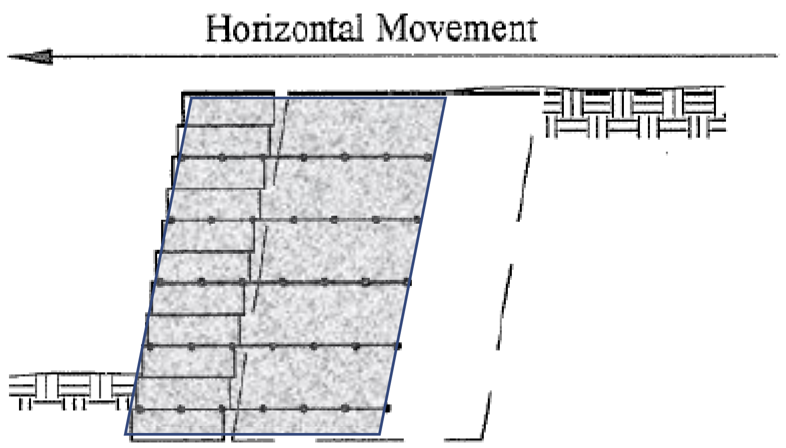


Figure 17 - Base Sliding (after NCMA Design Manual)

整體平滑破壞

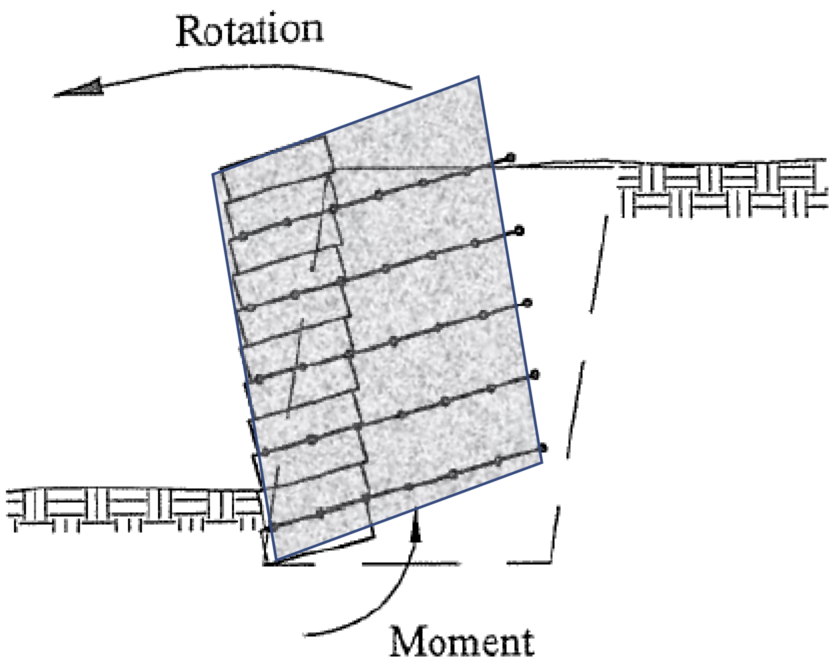


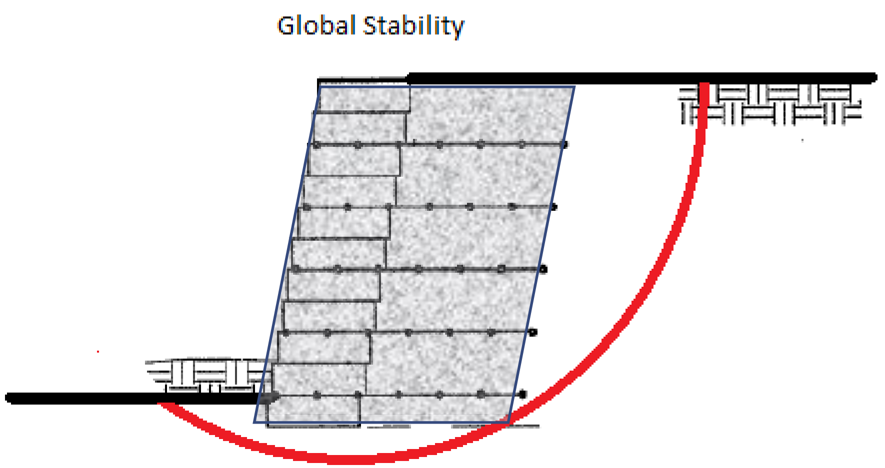
Figure 18 - Overturning (after NCMA Design Manual)

整體轉動破壞

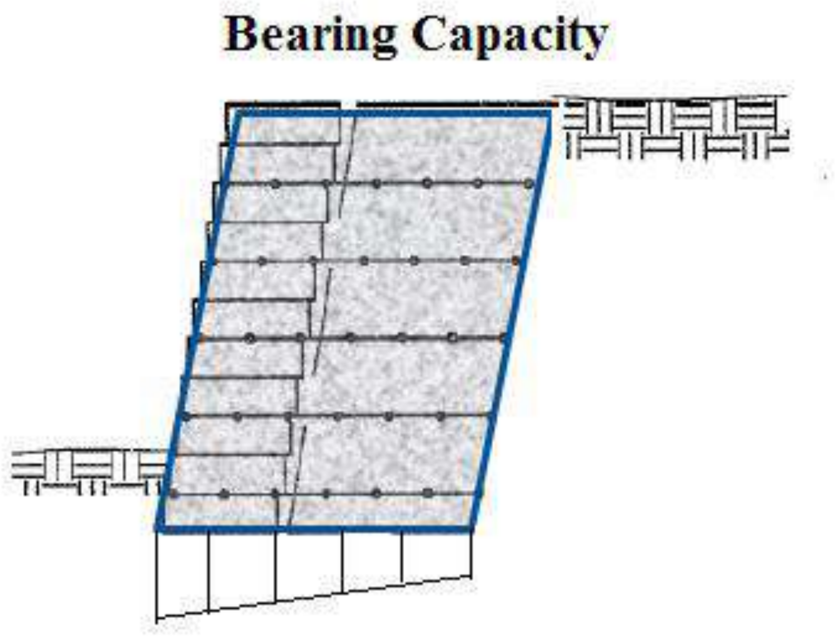
回顧單階加勁擋土牆和加勁邊坡的設計理論

單階加勁擋土牆的設計理論

外部穩定分析



整體滑坡破壞

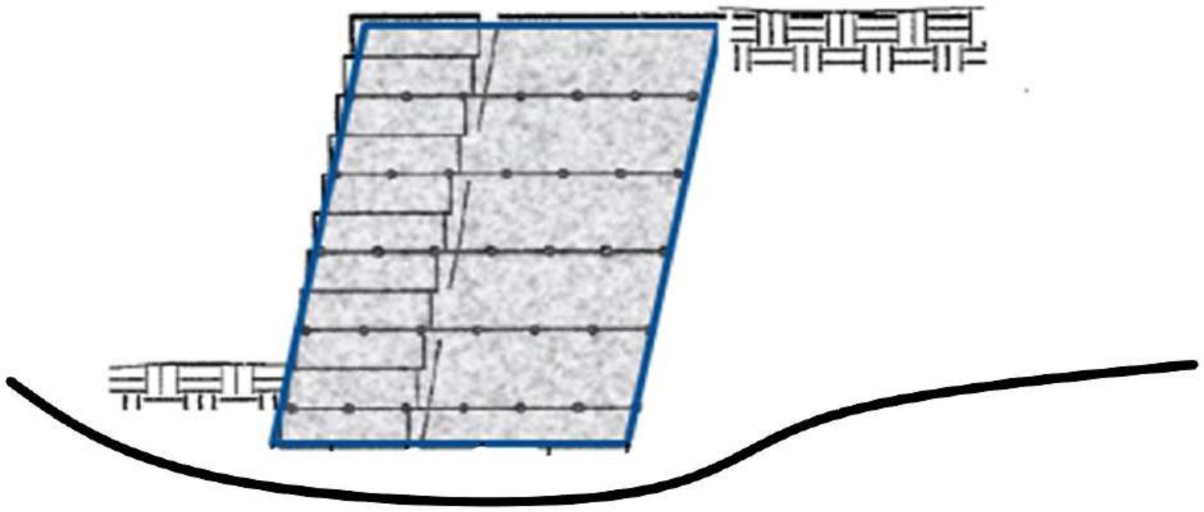


承載力破壞

回顧單階加勁擋土牆和加勁邊坡的設計理論

單階加勁擋土牆的設計理論

外部穩定分析



沉陷量分析

回顧單階加勁擋土牆和加勁邊坡的設計理論

單階加勁擋土牆的設計理論

內部穩定分析

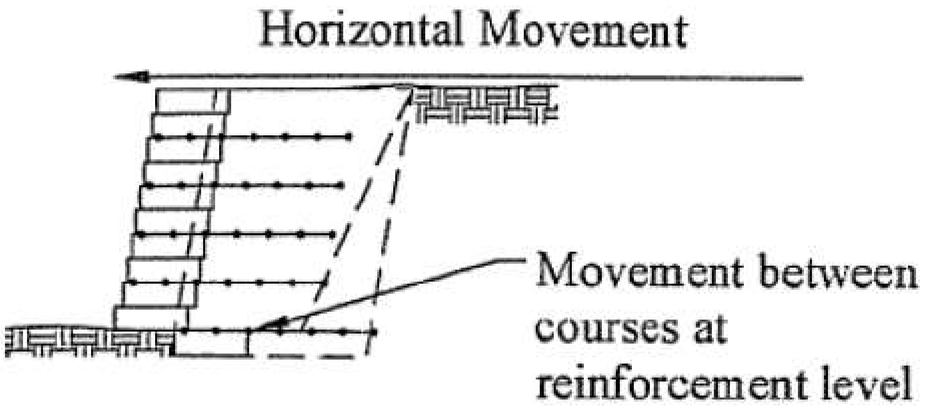


Figure 21 - Internal Sliding (after NCMA Design Manual)

層面滑動破壞

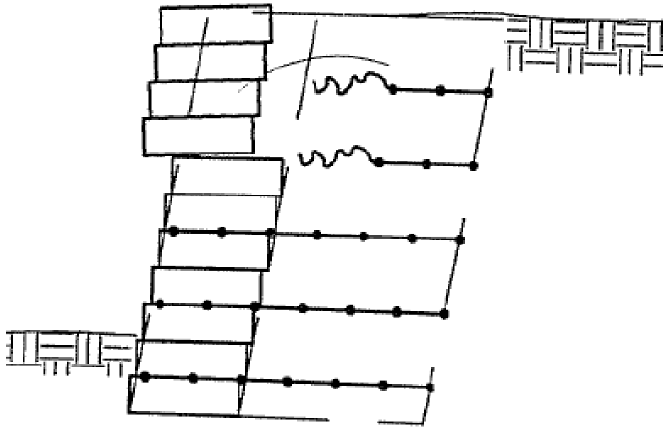


Figure 22 - Facing Connection (after NCMA Design Manual)

牆面連接破壞

回顧單階加勁擋土牆和加勁邊坡的設計理論

單階加勁擋土牆的設計理論

內部穩定分析

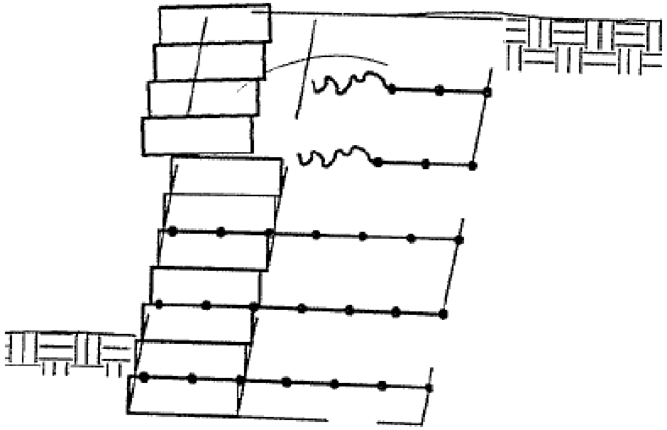


Figure 22 - Facing Connection (after NCMA Design Manual)

牆面連接破壞

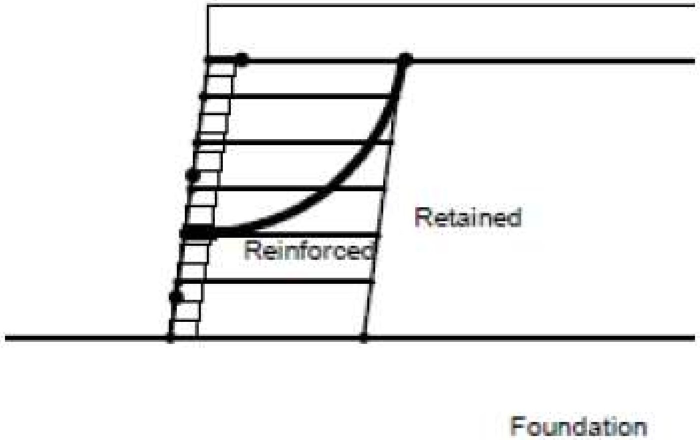
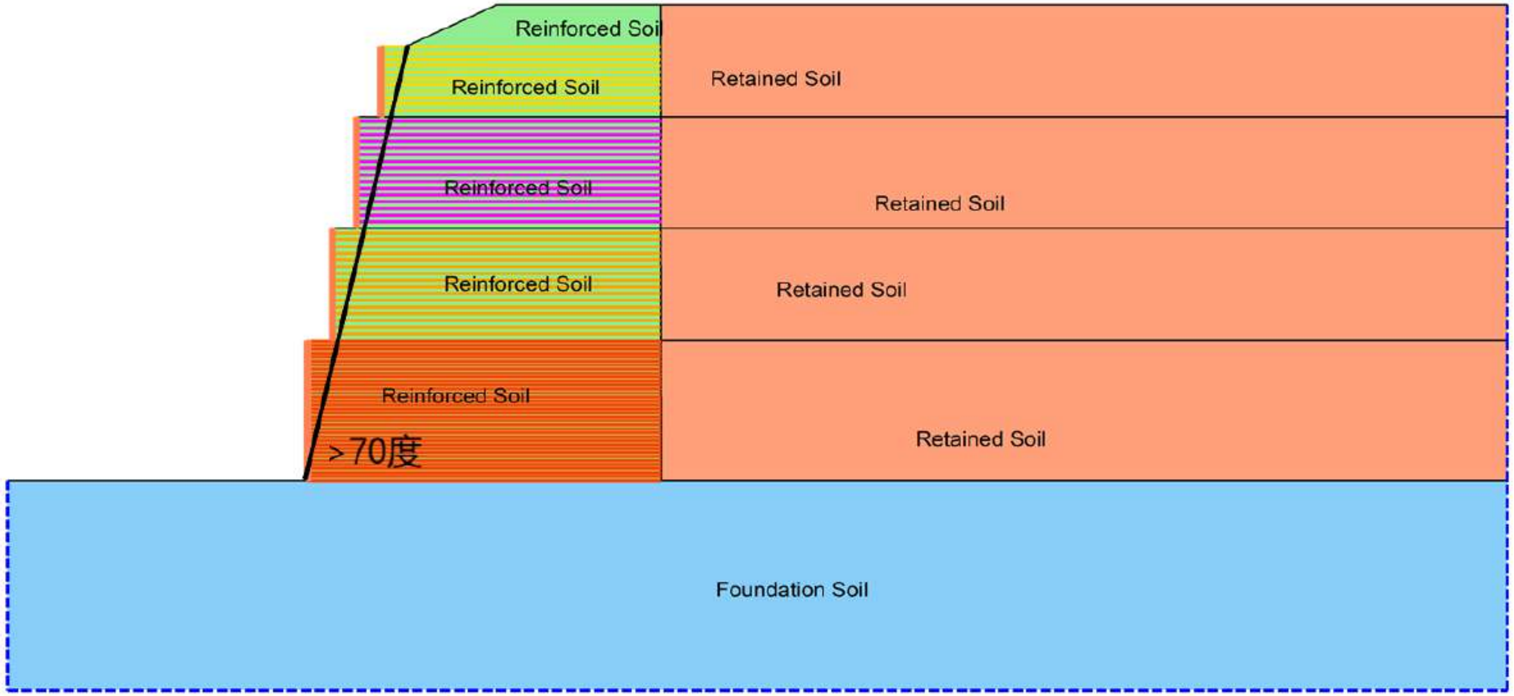


Figure 24 - Internal Compound Stability

內部綜合穩定分析

多階加勁擋土牆的設計理論和設計模型

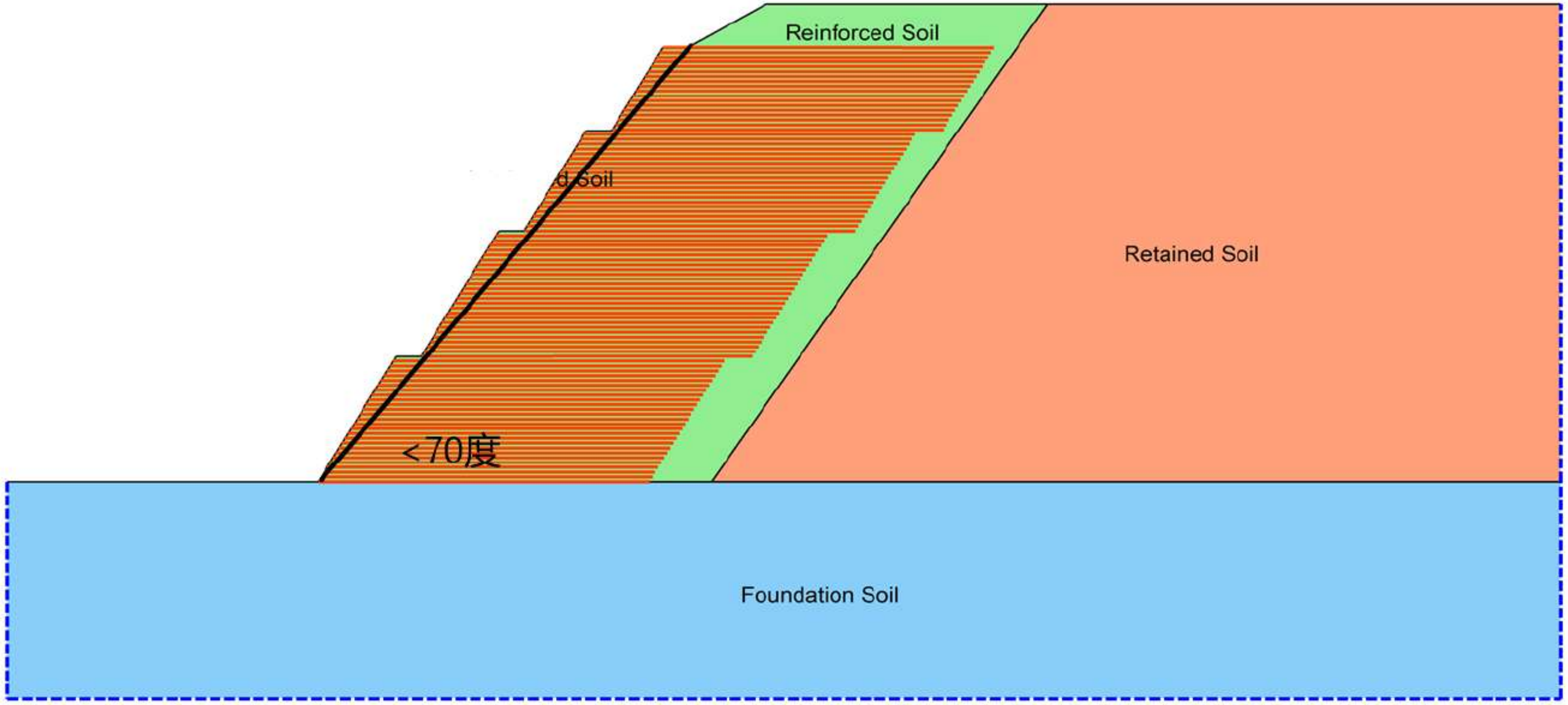
加勁擋土牆和加勁邊坡的區別



加勁擋土牆

多階加勁擋土牆的設計理論和設計模型

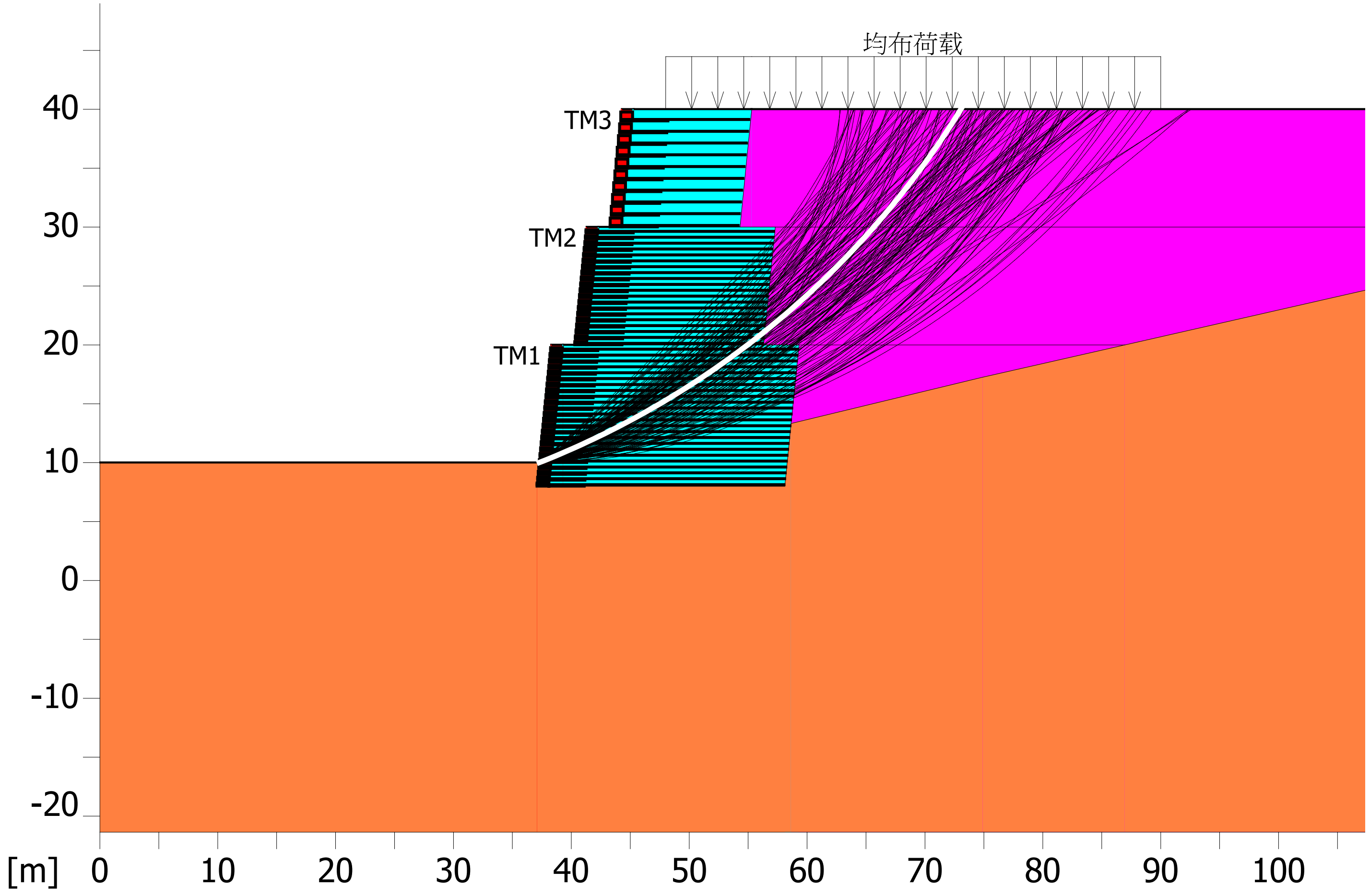
加勁擋土牆和加勁邊坡的區別



加勁邊坡

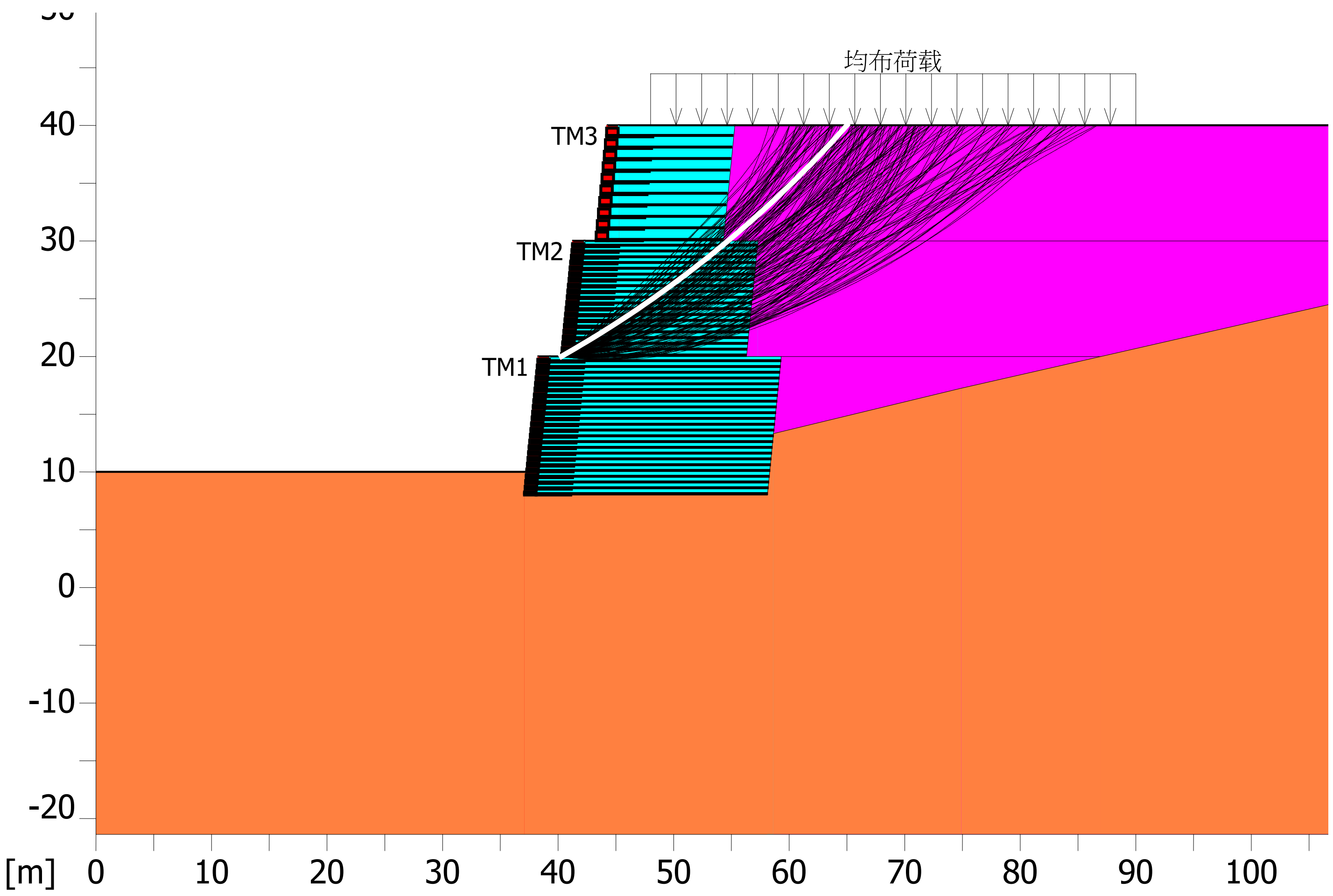
多階加勁擋土牆的設計理論和設計模型

用加勁邊坡的設計法設計多階加勁擋土牆



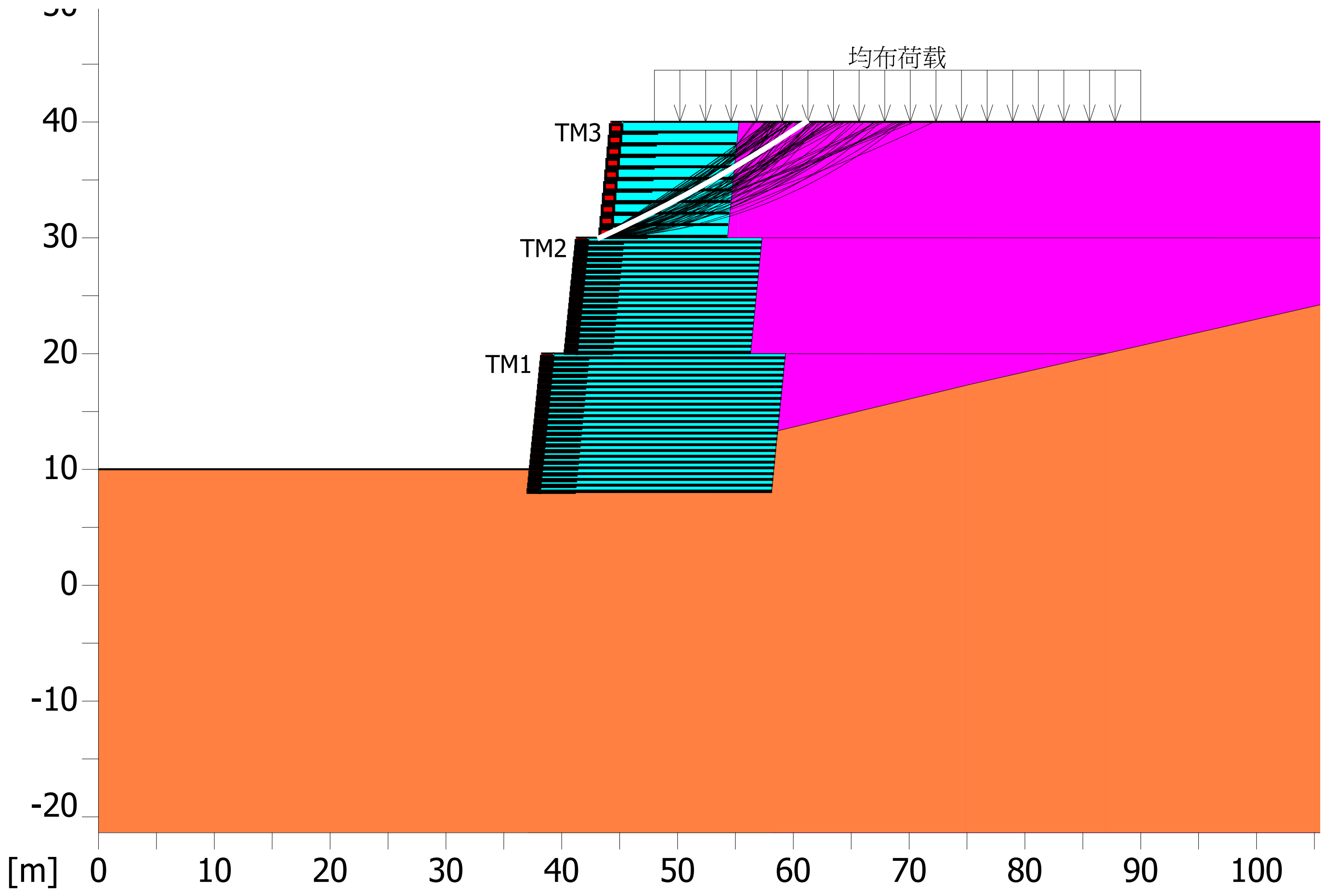
多階加勁擋土牆的設計理論和設計模型

用加勁邊坡的設計法設計多階加勁擋土牆



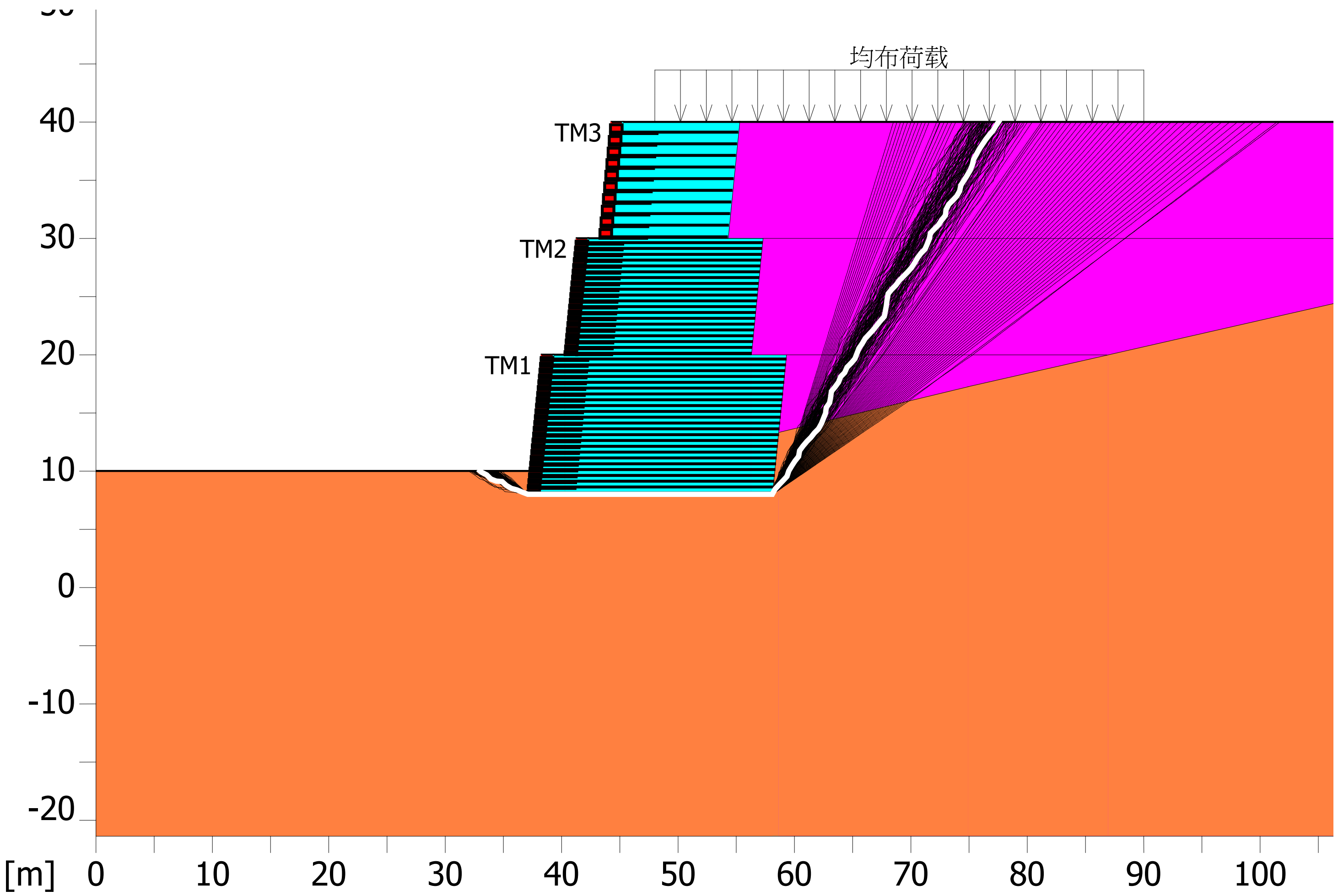
多階加勁擋土牆的設計理論和設計模型

用加勁邊坡的設計法設計多階加勁擋土牆



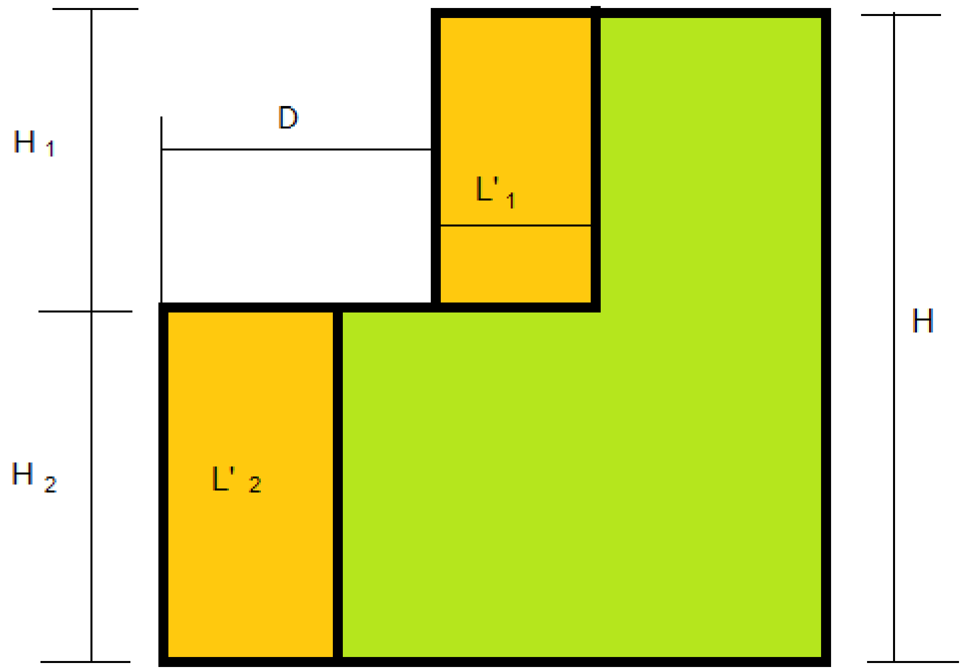
多階加勁擋土牆的設計理論和設計模型

用加勁邊坡的設計法設計多階加勁擋土牆



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

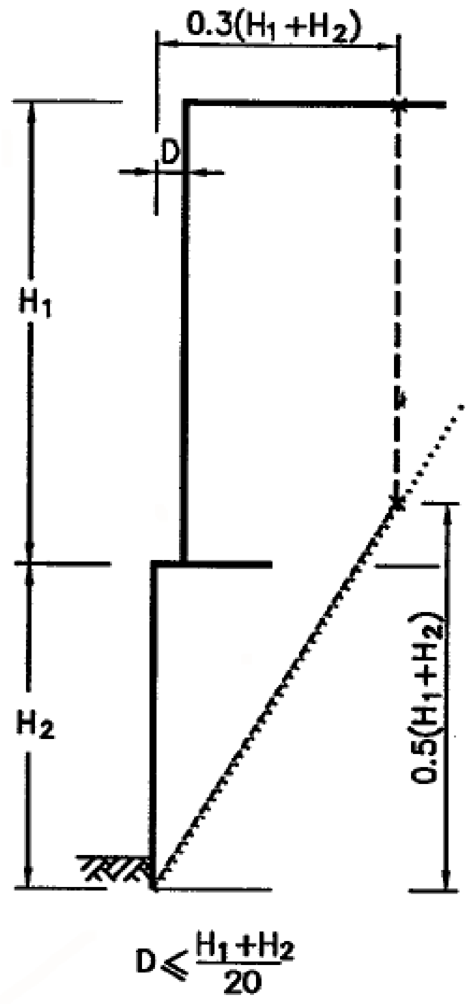
多台階加勁擋土牆的設計原則

1. $D < \dfrac{H_1 + H_2}{20}$

按單階牆體設計

牆高 $H = H_1 + H_2$

初步設計時加勁長度可按 $L' = 0.7H$



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

多台階加勁擋土牆的設計原則

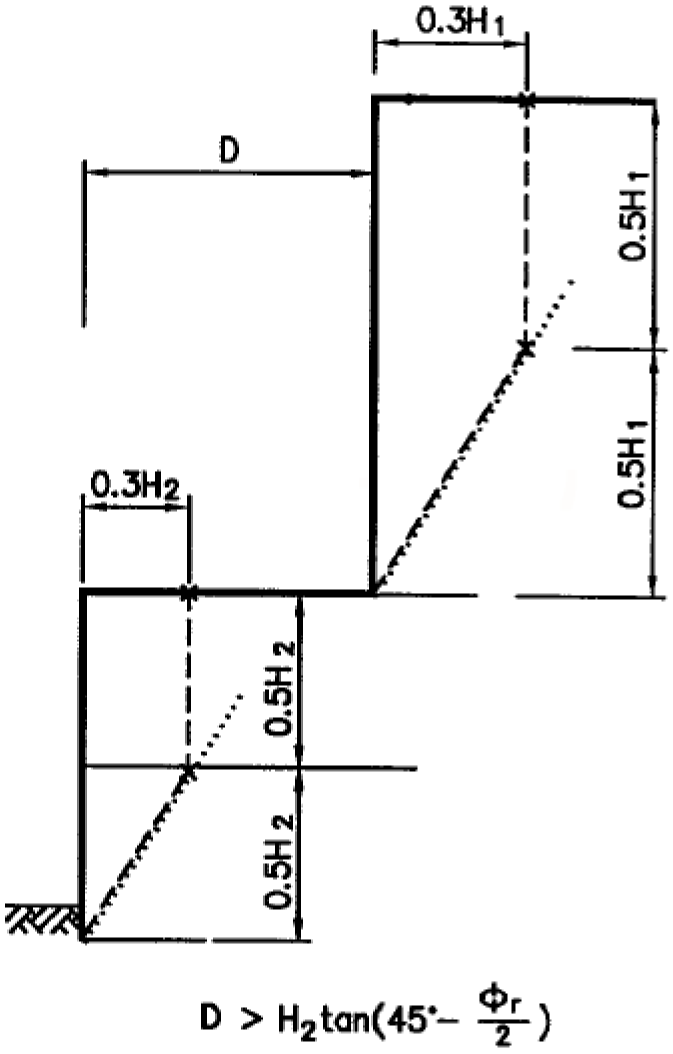
$$2.\ D > H_2 \tan(45^o + \frac{\varphi_r}{2})$$

按獨立加勁擋牆設計

初步設計時加勁長度可按

上牆加勁長度 $L'_1 = 0.7H_1$

下牆加勁長度 $L'_2 = 0.7H_2$



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

多台階加勁擋土牆的設計原則

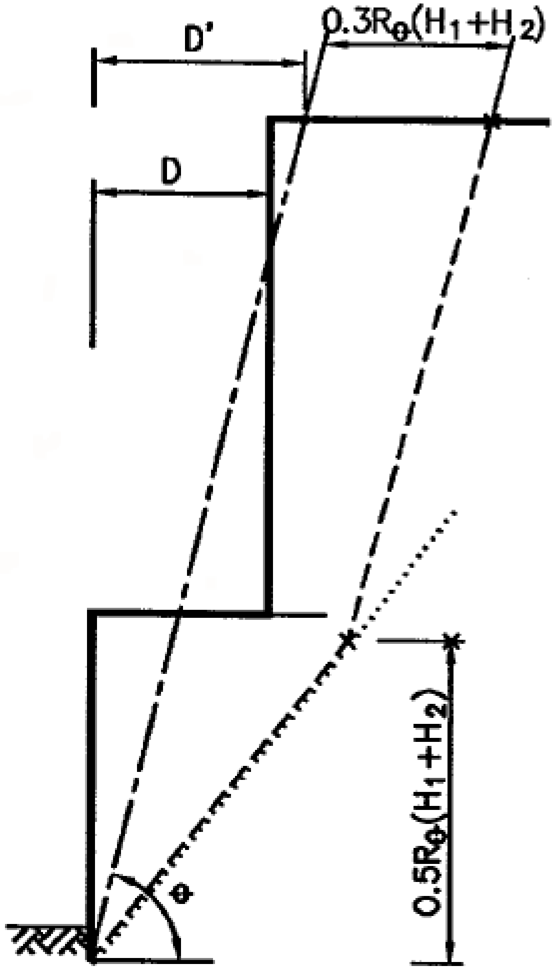
3. $\frac{H_1+H_2}{20} < \mathrm{D} \leq H_2 \tan(45^o - \frac{\varphi_r}{2})$

按多台階加勁擋牆設計

初步設計時加勁長度可按：

上牆加勁長度 $L'_1 = 0.7H_1$

下牆加勁長度 $L'_2 = 0.6(H_1 + H_2)$=0.6H

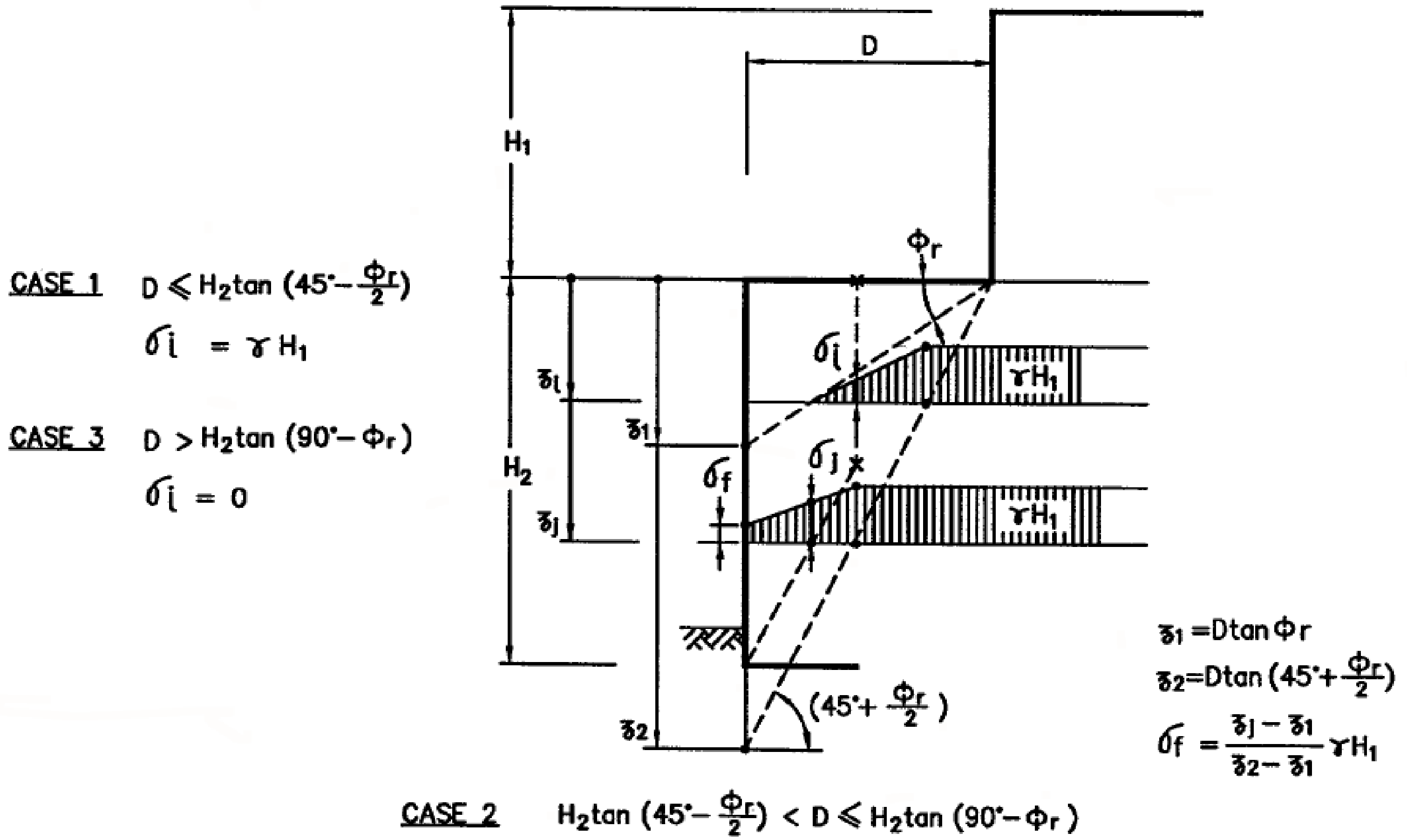


$\frac{H_1+H_2}{20} < D \leqslant H_2 \tan(45^\circ - \frac{\phi_r}{2})$

多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

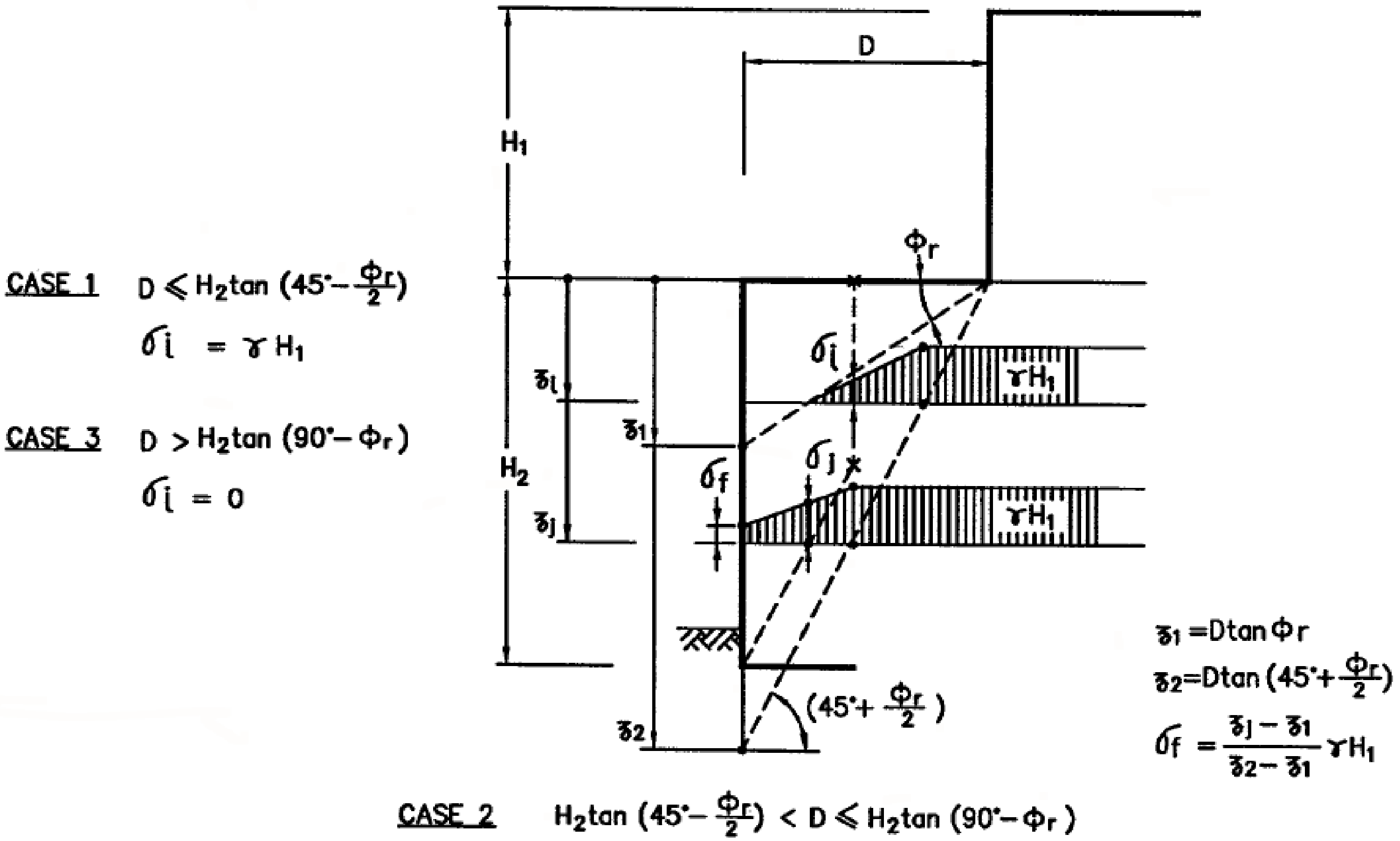
上牆對下牆的附加垂直壓力



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

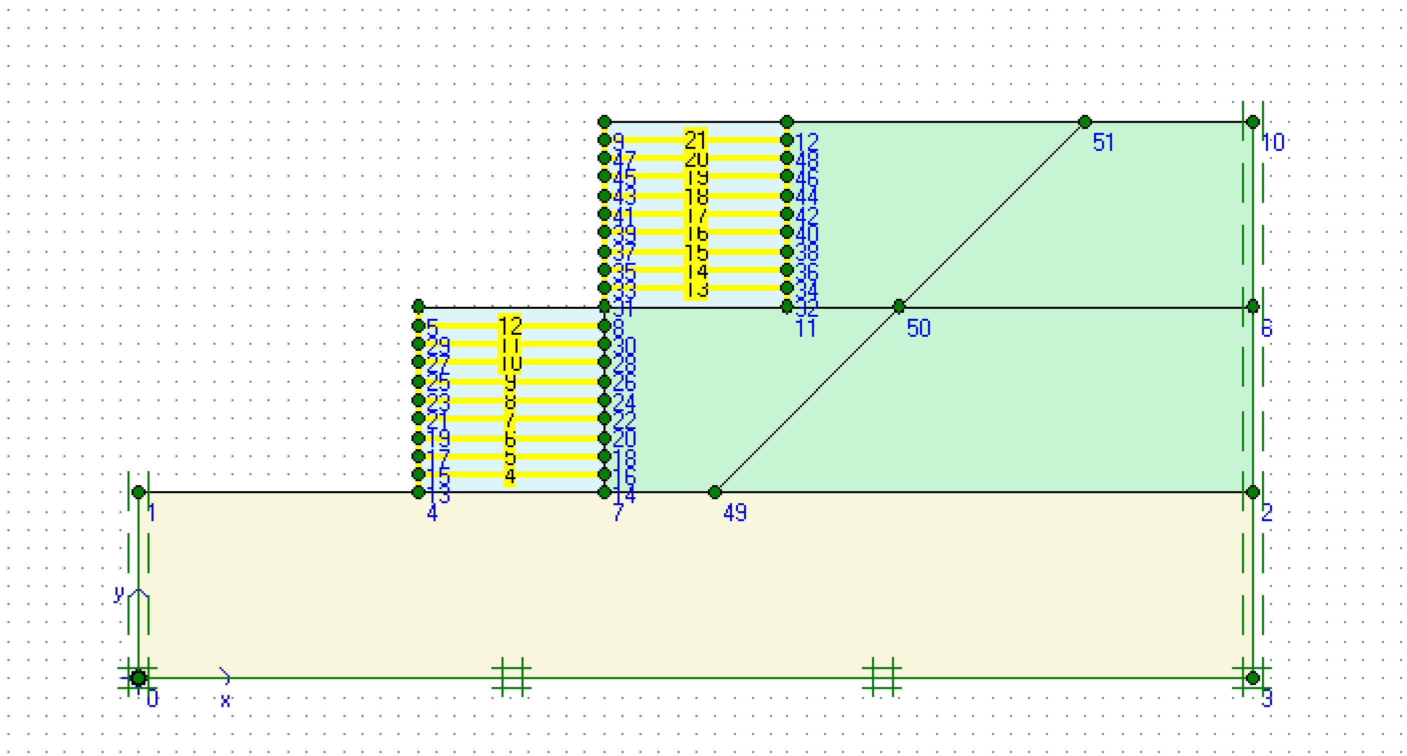
上牆對下牆的附加垂直壓力



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

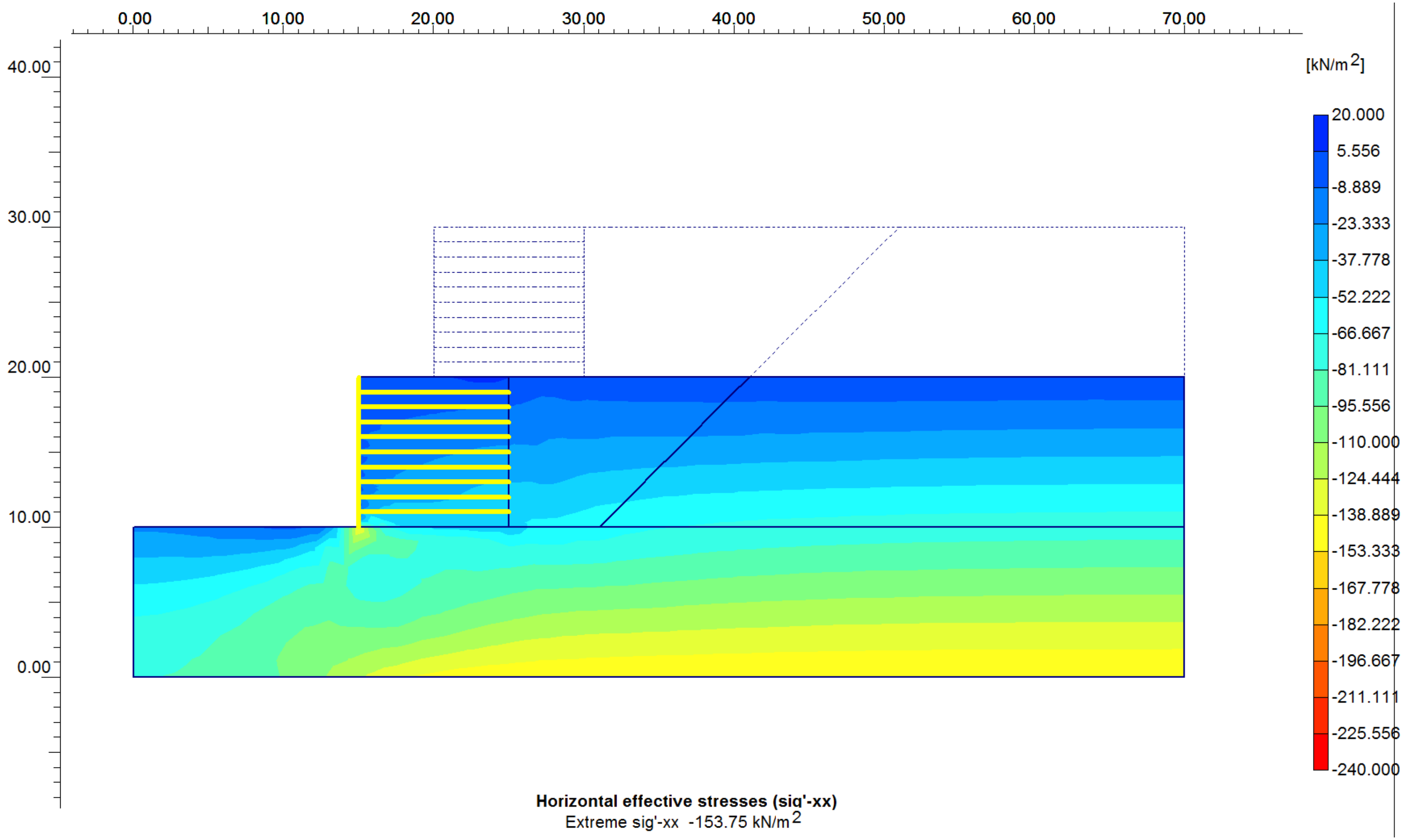
上牆對下牆影響的有限元素分析



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

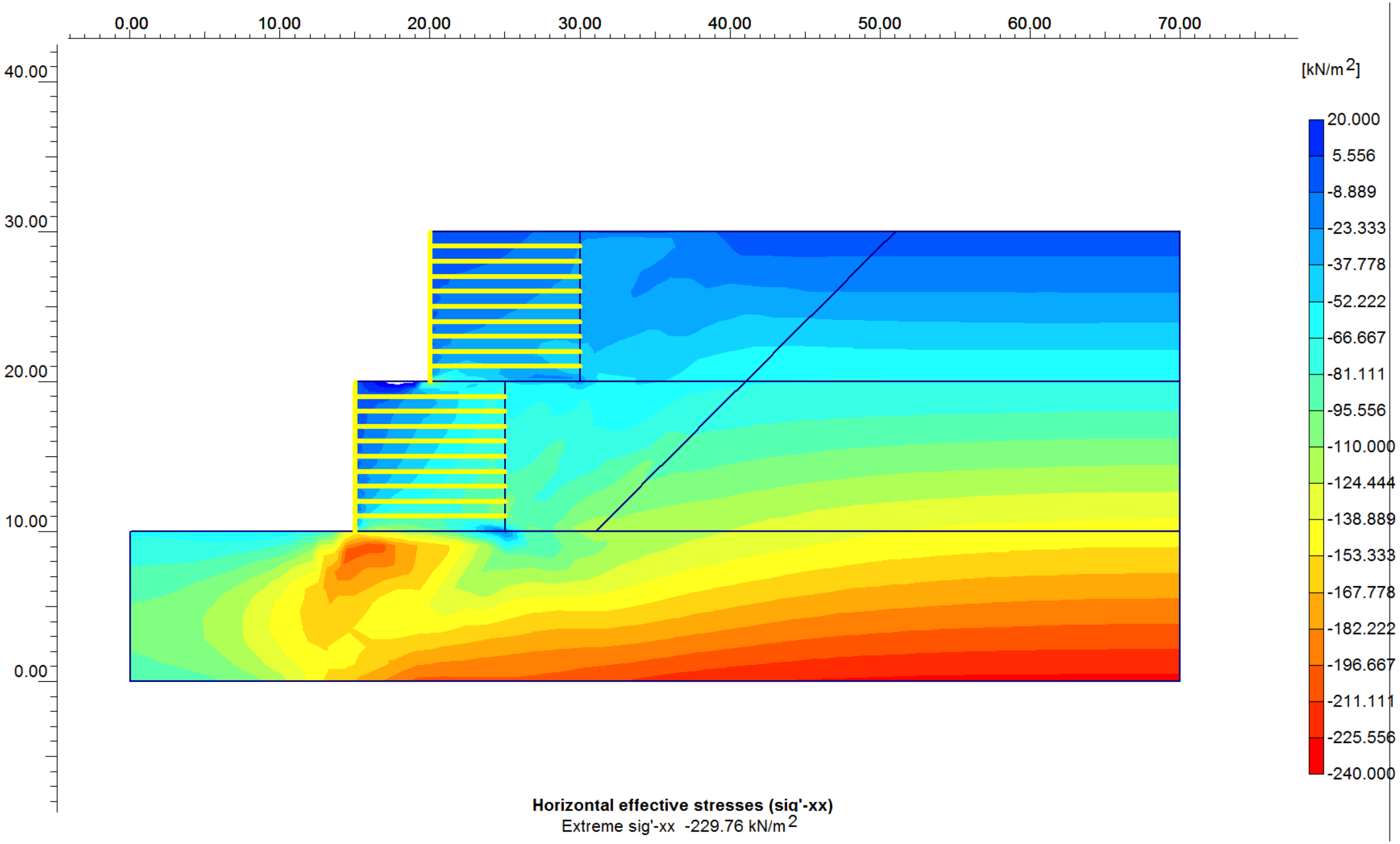
單階擋土牆土體水平壓力的分布



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

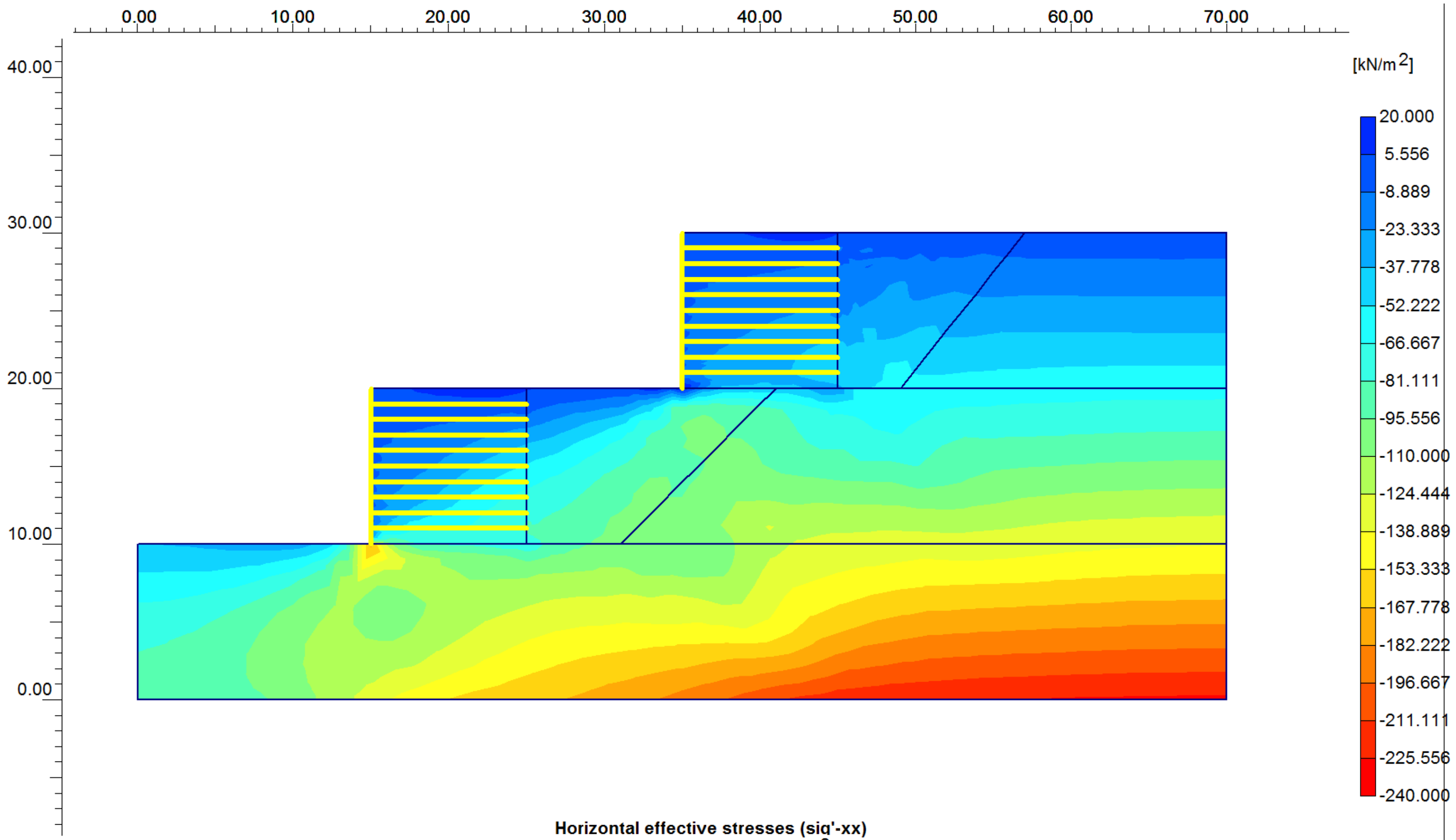
多台階擋牆土體水平
壓力的分布$D=0.5H_2$



多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

多台階擋牆土體水平
壓力的分布$D=2H_2$

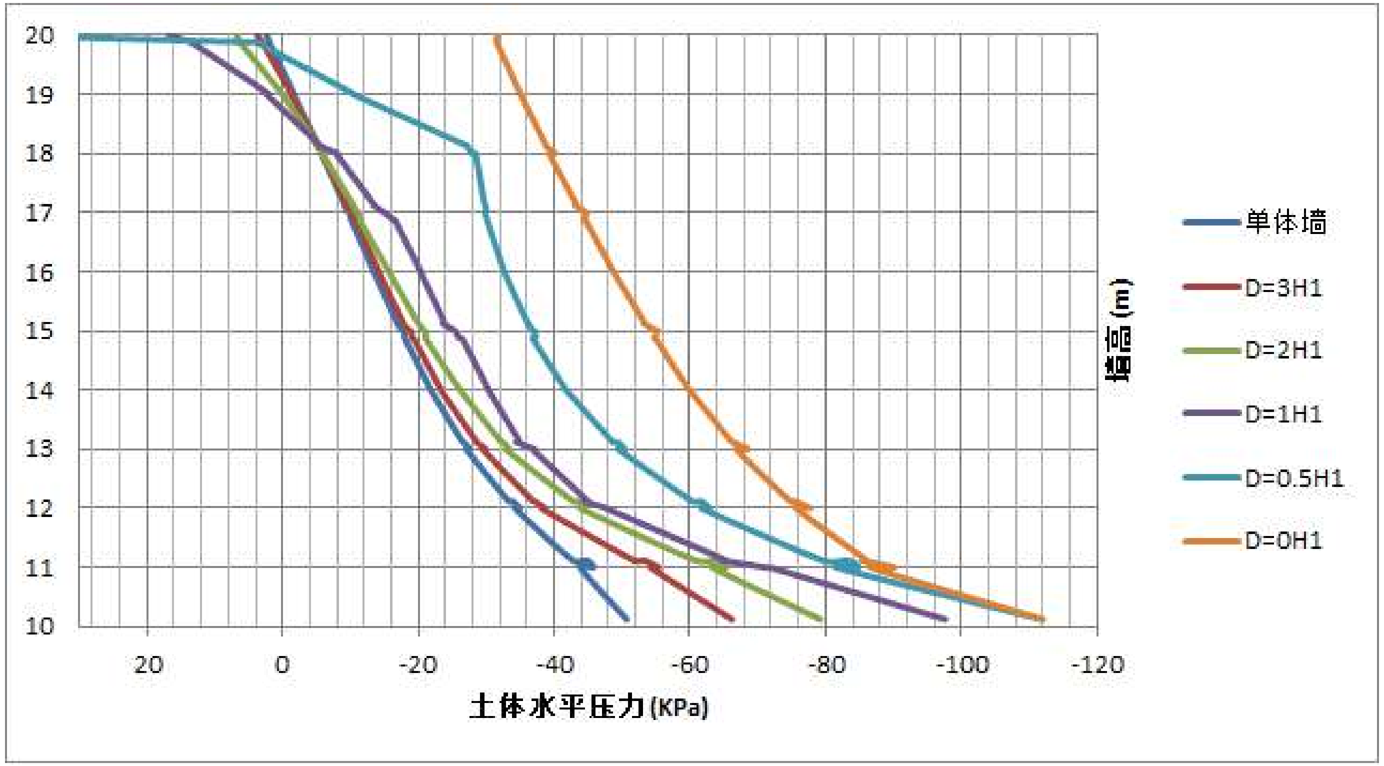


Horizontal effective stresses (sig'-xx)
Extreme sig'-xx -228.14 kN/m^2

多階加勁擋土牆的設計理論和設計模型

FHWA法設計多階加勁擋土牆

牆距D與水平壓力的關係



多階加勁擋土牆實例

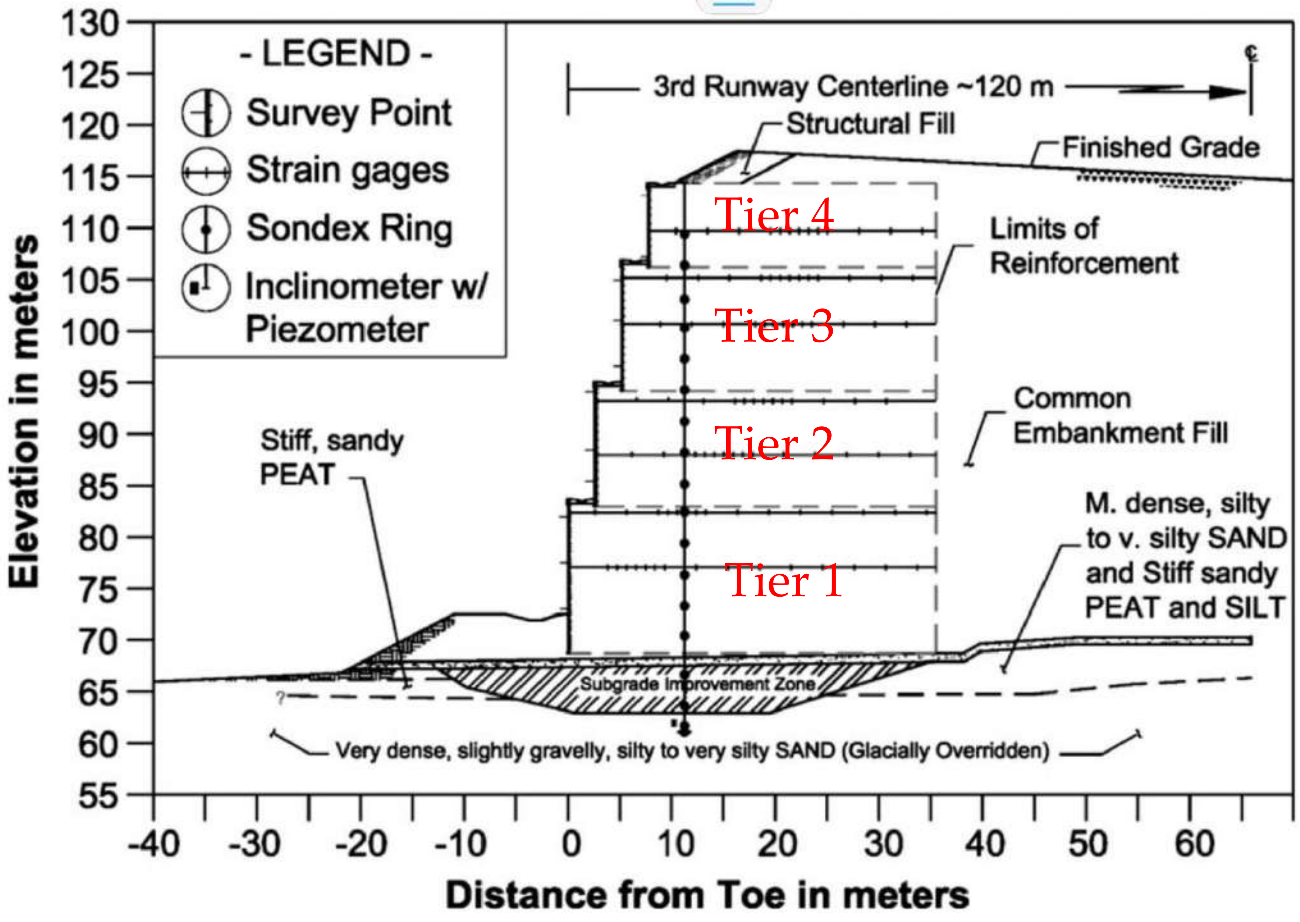
Seattle-Tacoma International Airport
New Third Runway

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway



多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

加勁擋土牆概況：

加勁擋土牆總高為45.7m,分為4階，台階寬為2.44m。牆頂坡高為4.5m,坡比為H2:V1。

Tier #	牆高 (m)	加勁長度 (m)	加勁層數	加勁水平間距 (m)
Tier 1	14.5	35.4	34	0.14
Tier 2	11.5	32.9	16	0.34
Tier 3	11.5	30.5	16	0.54
Tier 4	8.2	28	11	0.74

地震參數：

地震加速度0.3g.

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

土體參數：

土體名稱	土體單位重 (Kn/m^3)	摩擦角（度）	彈性模量 （MPa)	泊鬆比
加勁土體	22	37	200	0.25
牆背土體	20	28	180	0.3
牆底土體	20	34	250	0.25

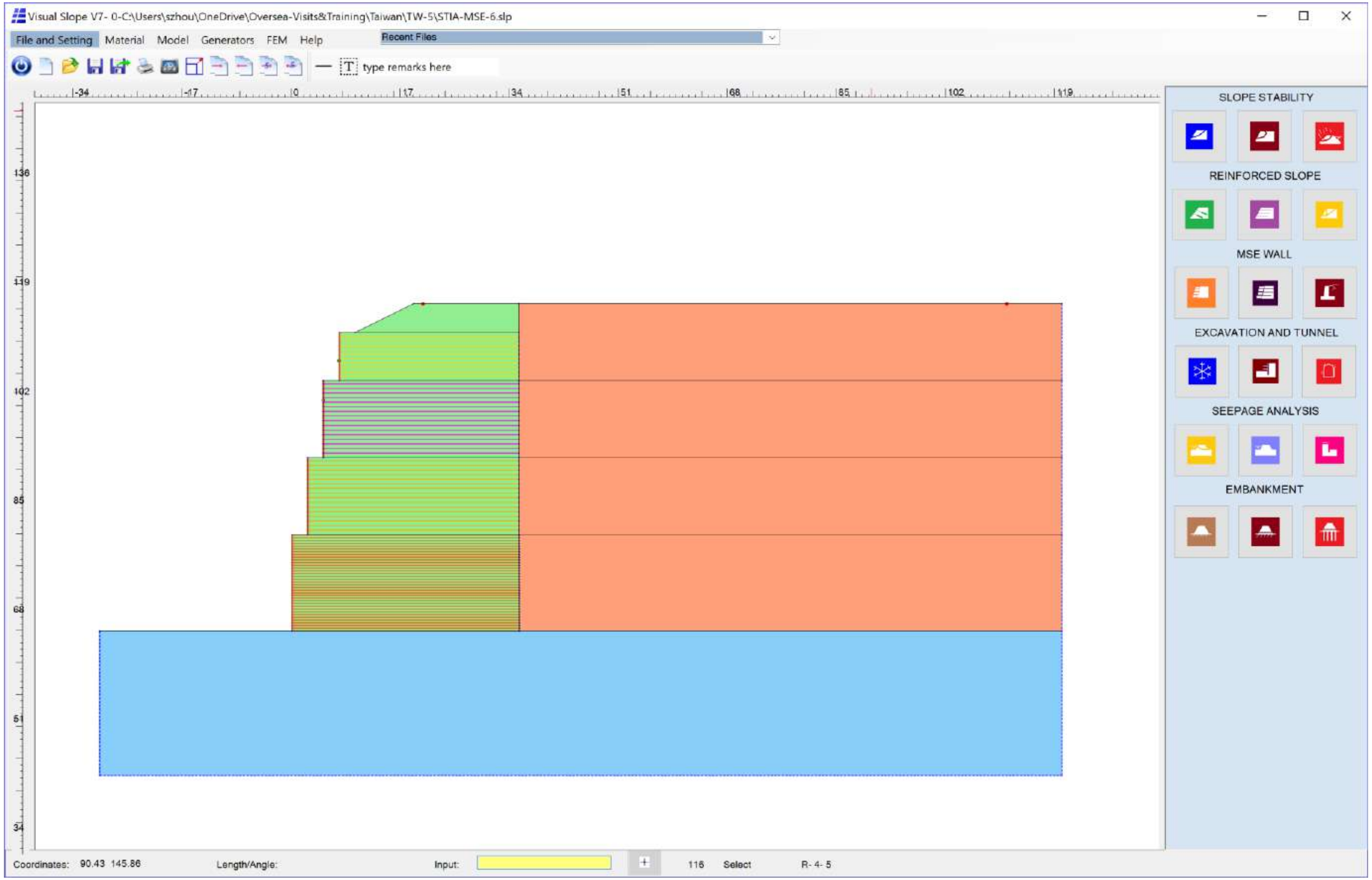
鋼條參數：

鋼條寬度 50mm, 鋼條厚度 6mm, 鋼條強度 448MPa。

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計模型



多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

加勁材料所需的參數

Geogrid

Grid Name		Tier 1 Strip
Long Term Allow. Strength	kn/m	959
Friction/Sliding Reduction 0~1		0.9
Cohesion/Pull out Reduction 0~1		0
Front Reduction 0~1		1
Area Reduction 0~1		0.375

Back End Fixity

- Free
- Fixed

Material

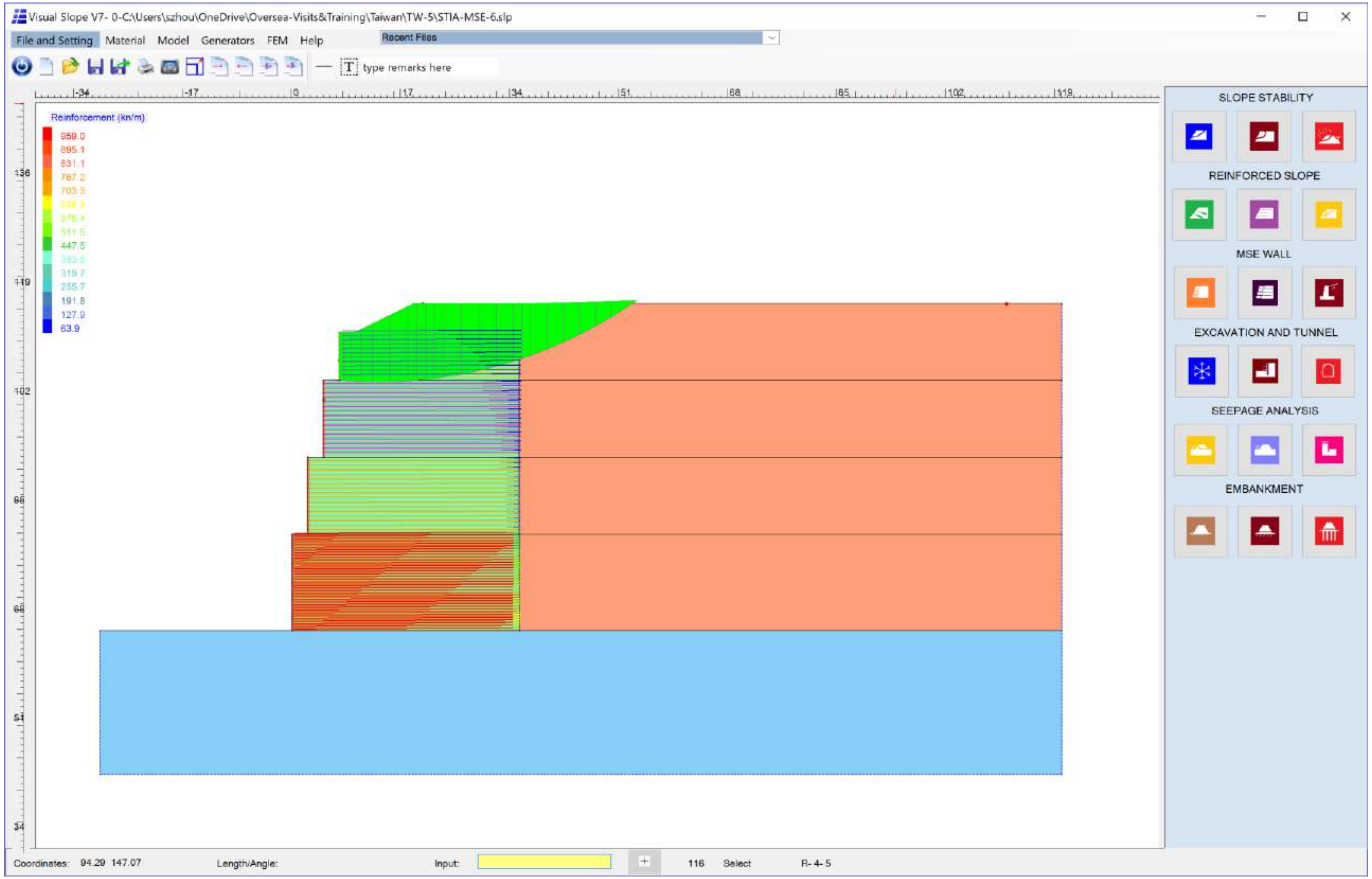
- Plastic
- Metal

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

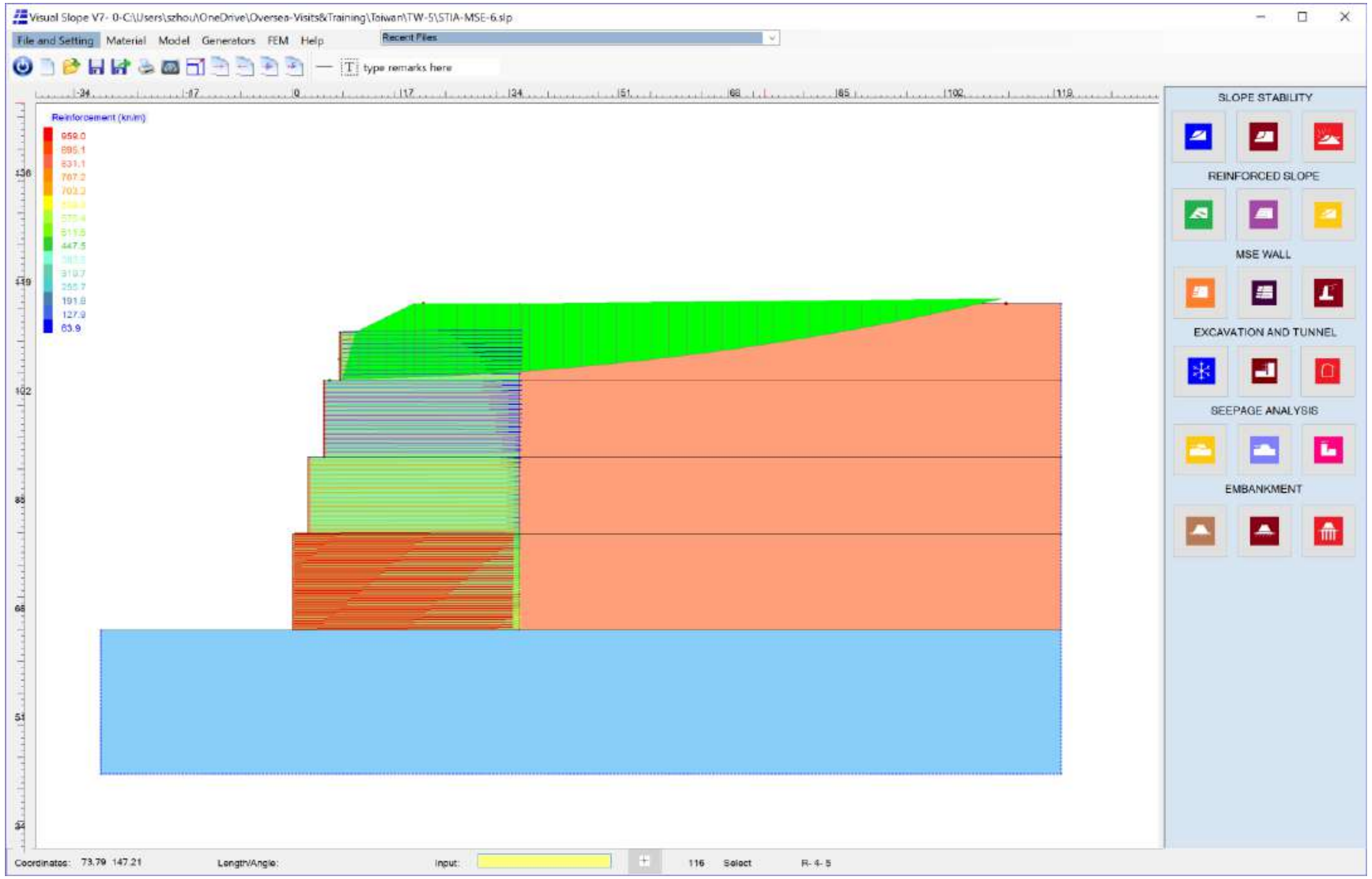
Tier 4 靜態安全系數：5.04



多階加勁擋土牆實例

設計方法1

Tier 4 地震狀態安全系數：1.52

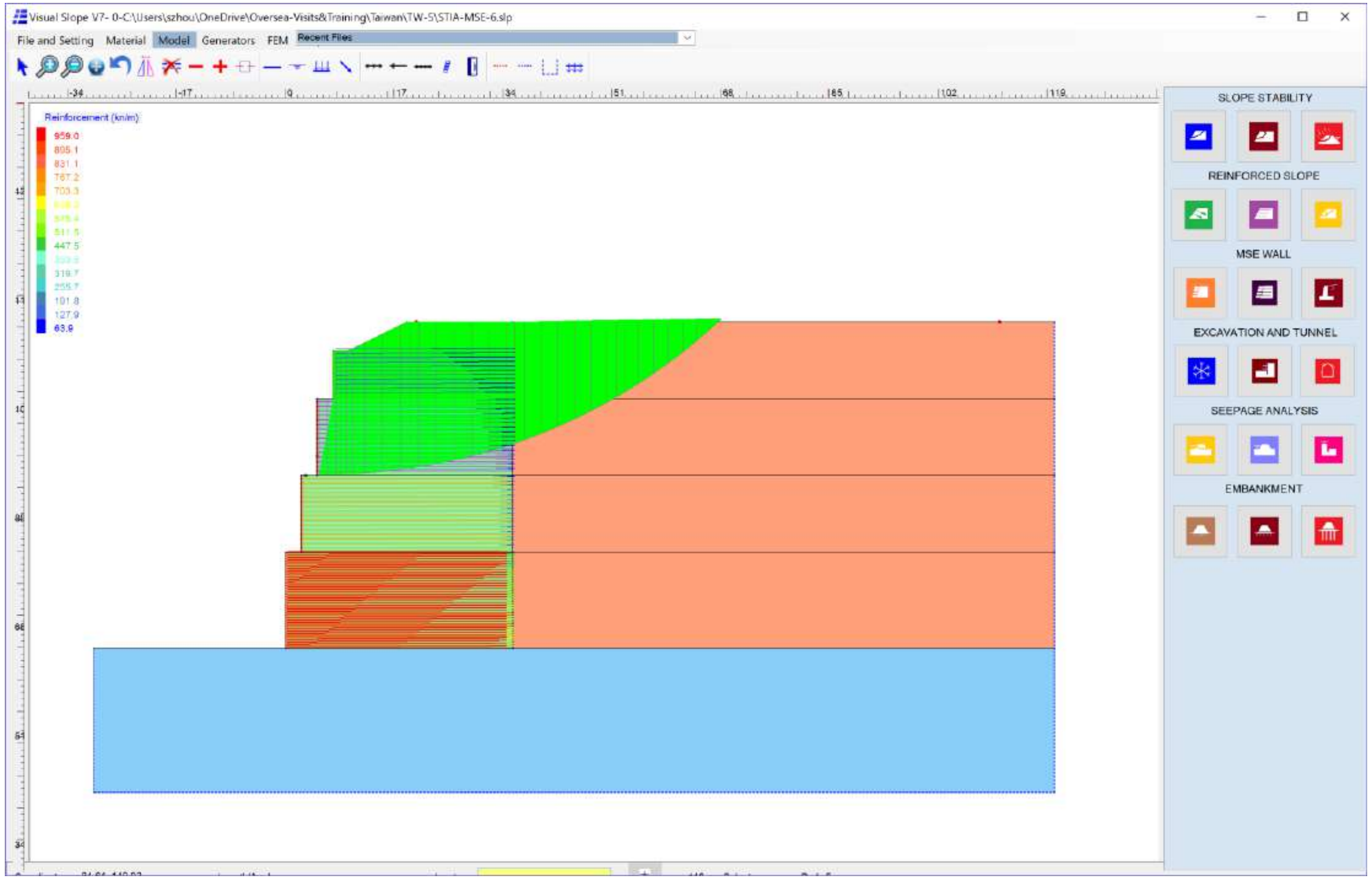


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

Tier 3 靜態安全系數：3.34

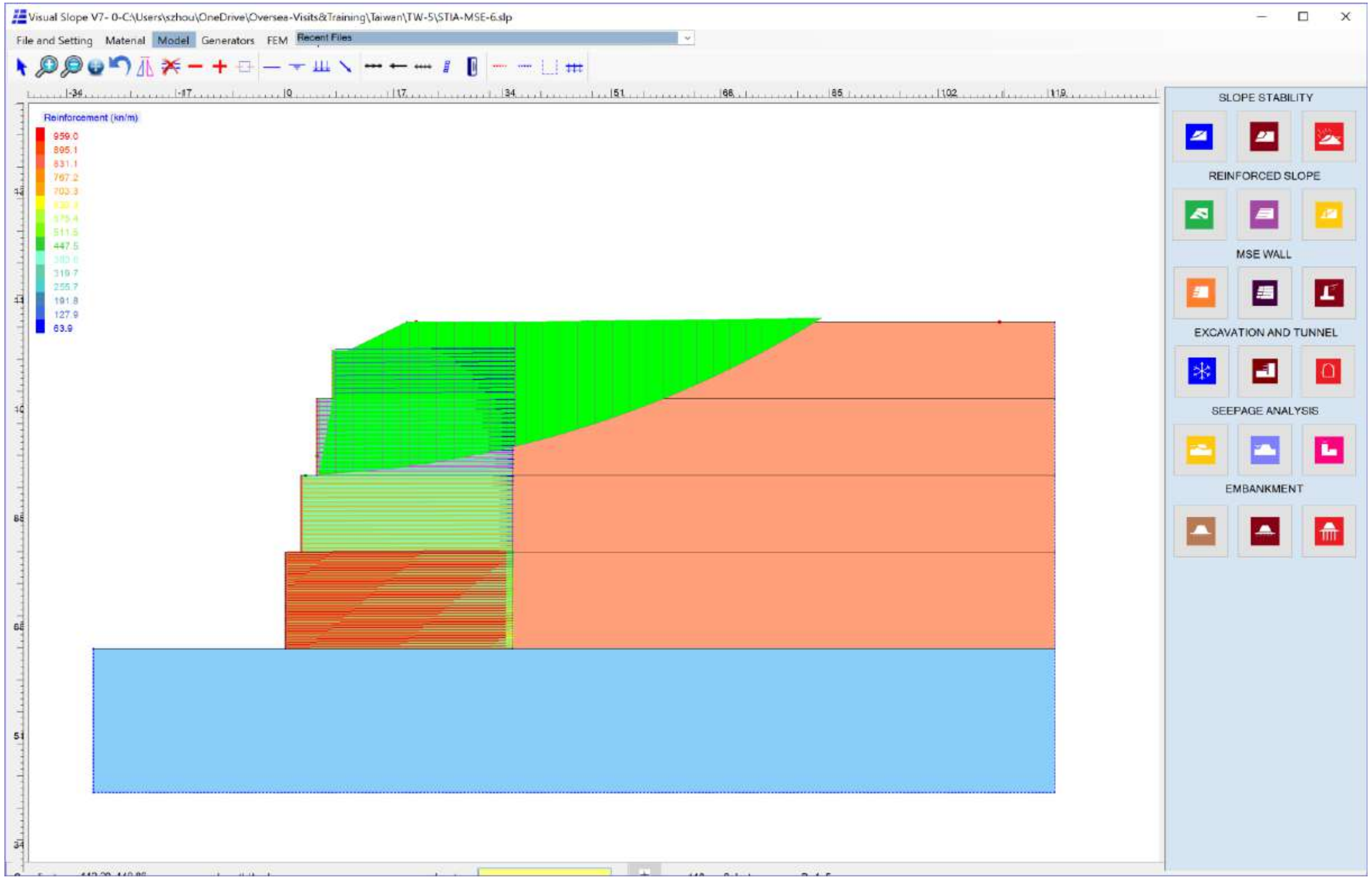


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

Tier 3 地震狀態安全系數：1.39

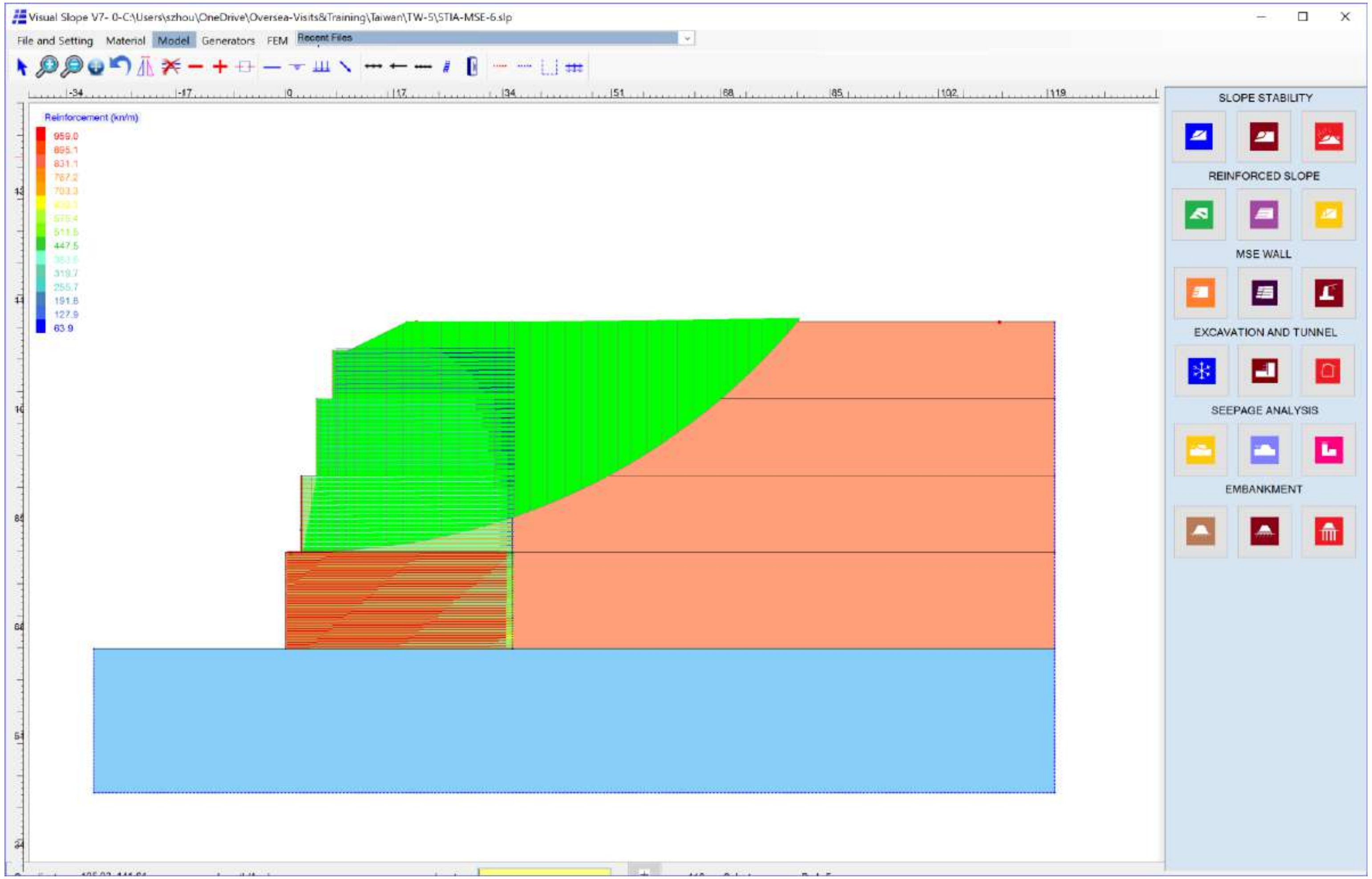


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

Tier 2 靜態安全系數：2.64

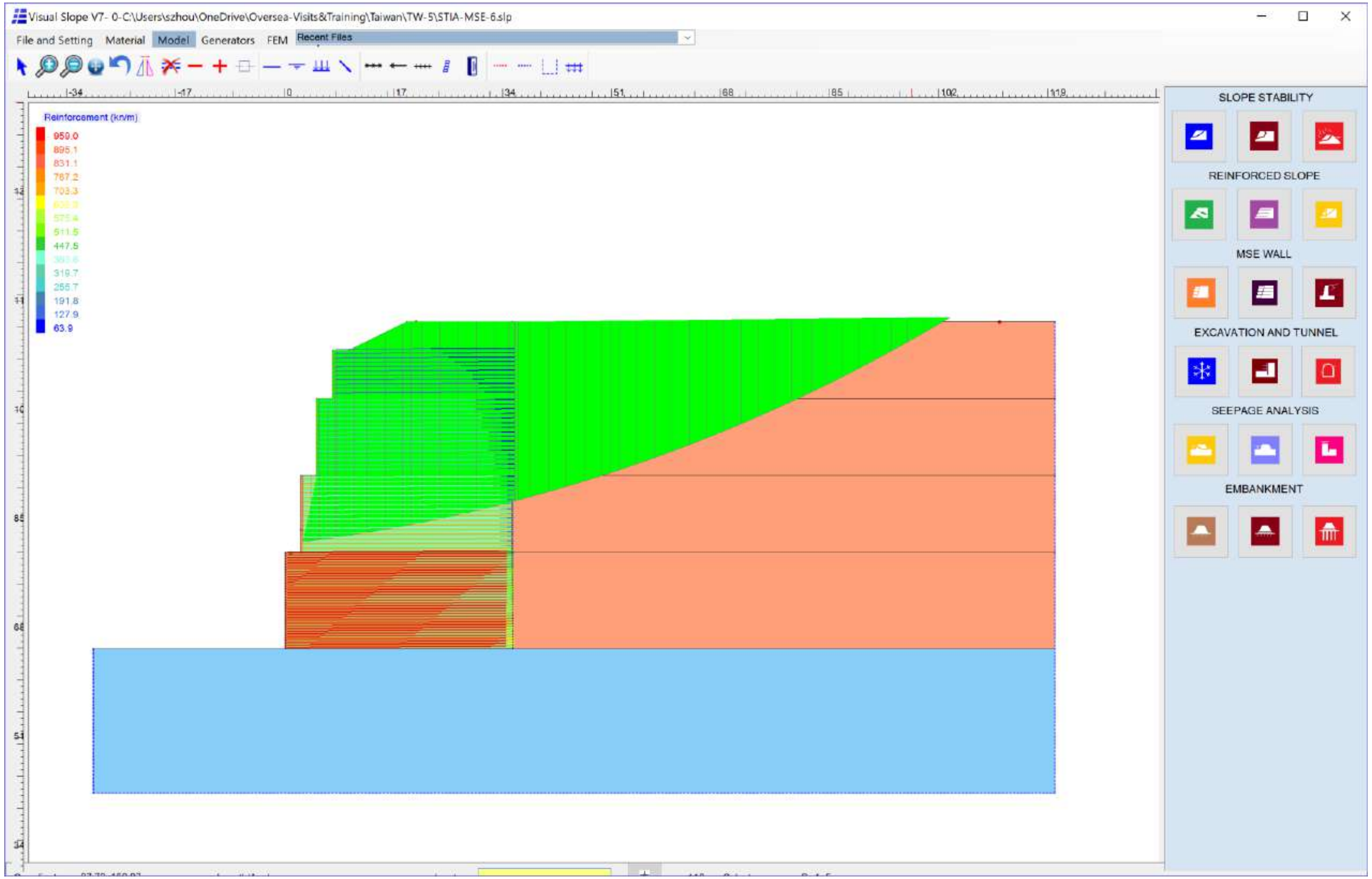


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

Tier 2 地震狀態安全系數：1.27

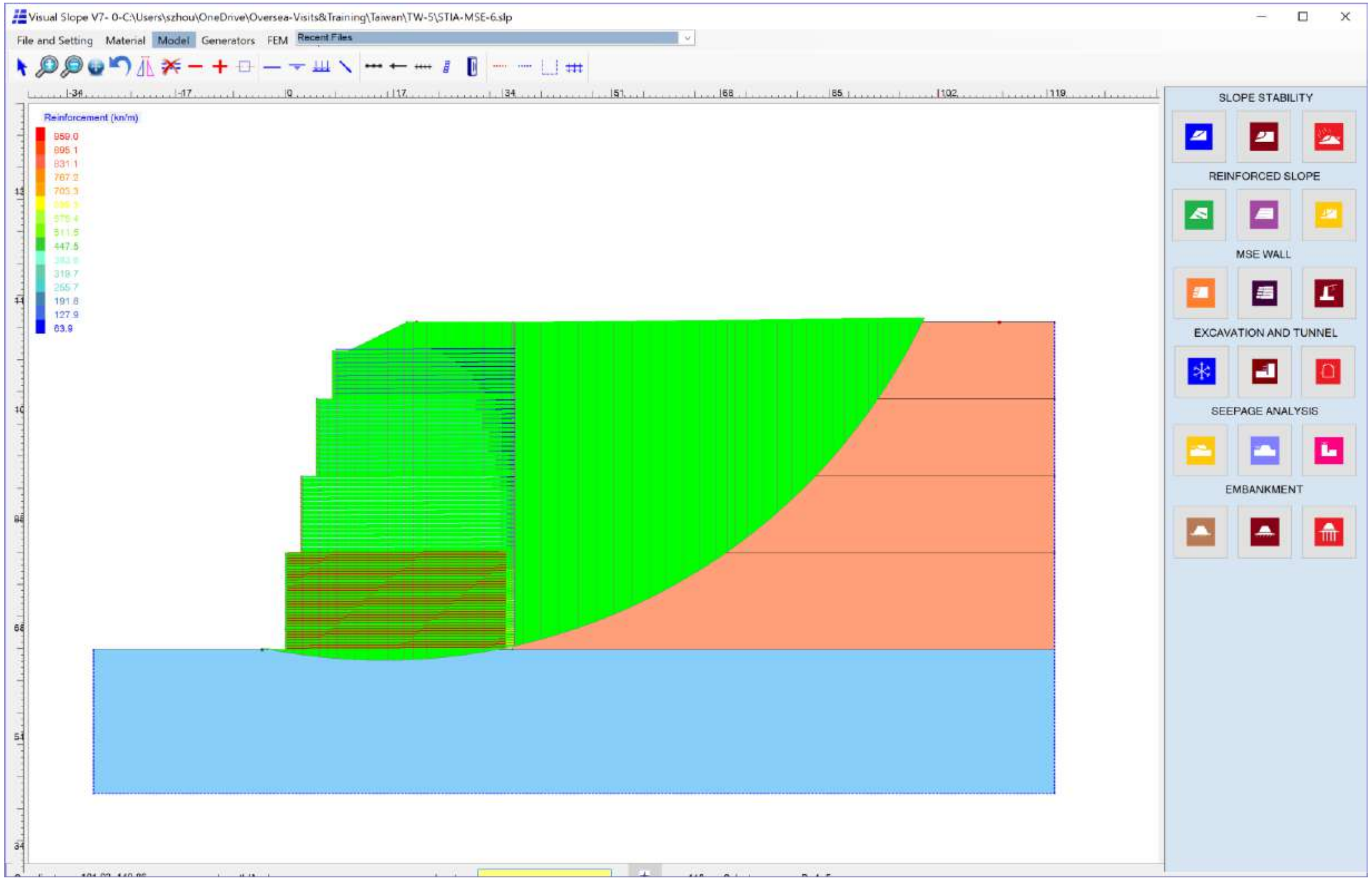


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

Tier 1 靜態安全系數：2.11

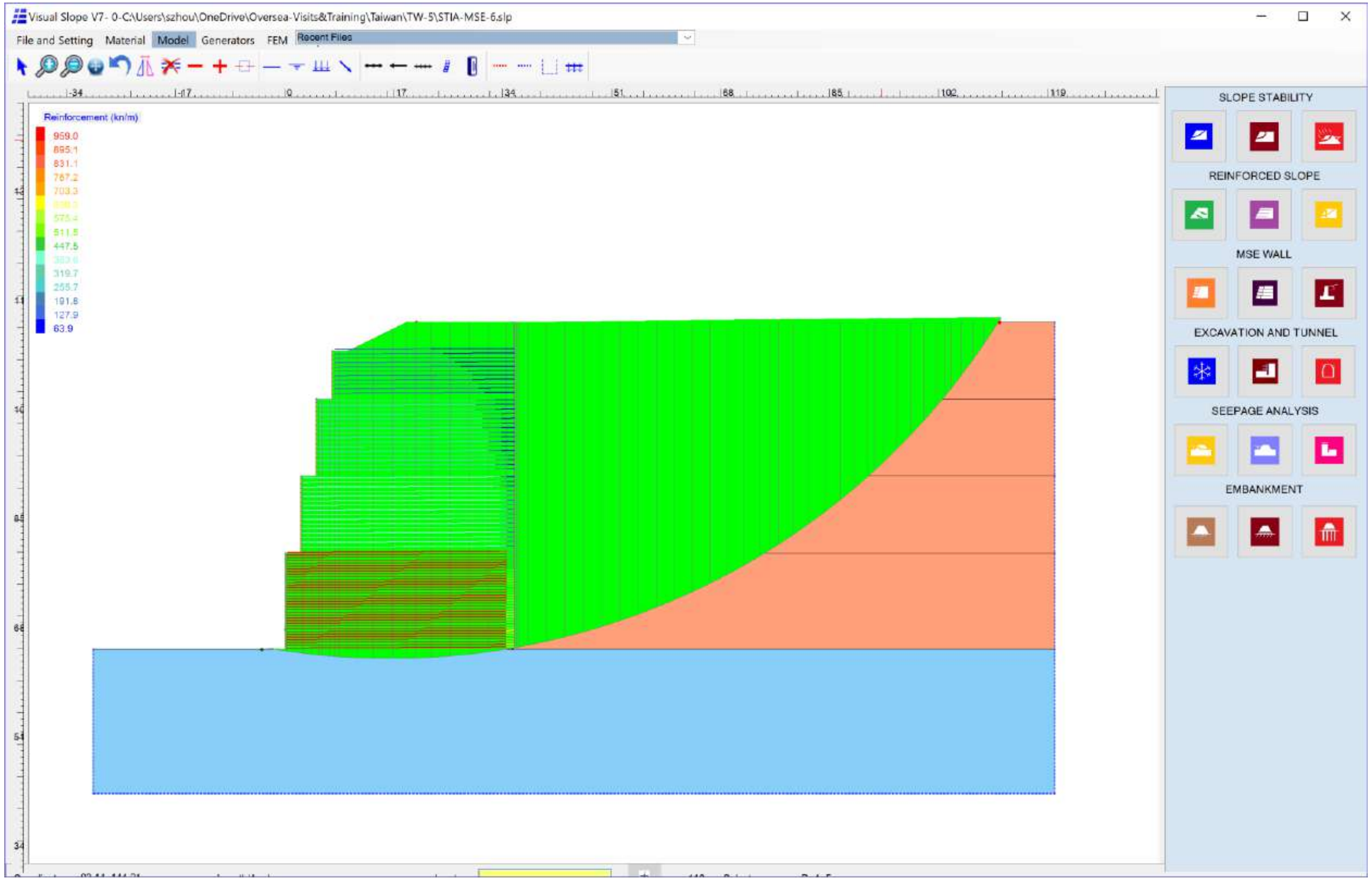


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

Tier 1 地震狀態安全系數：1.22

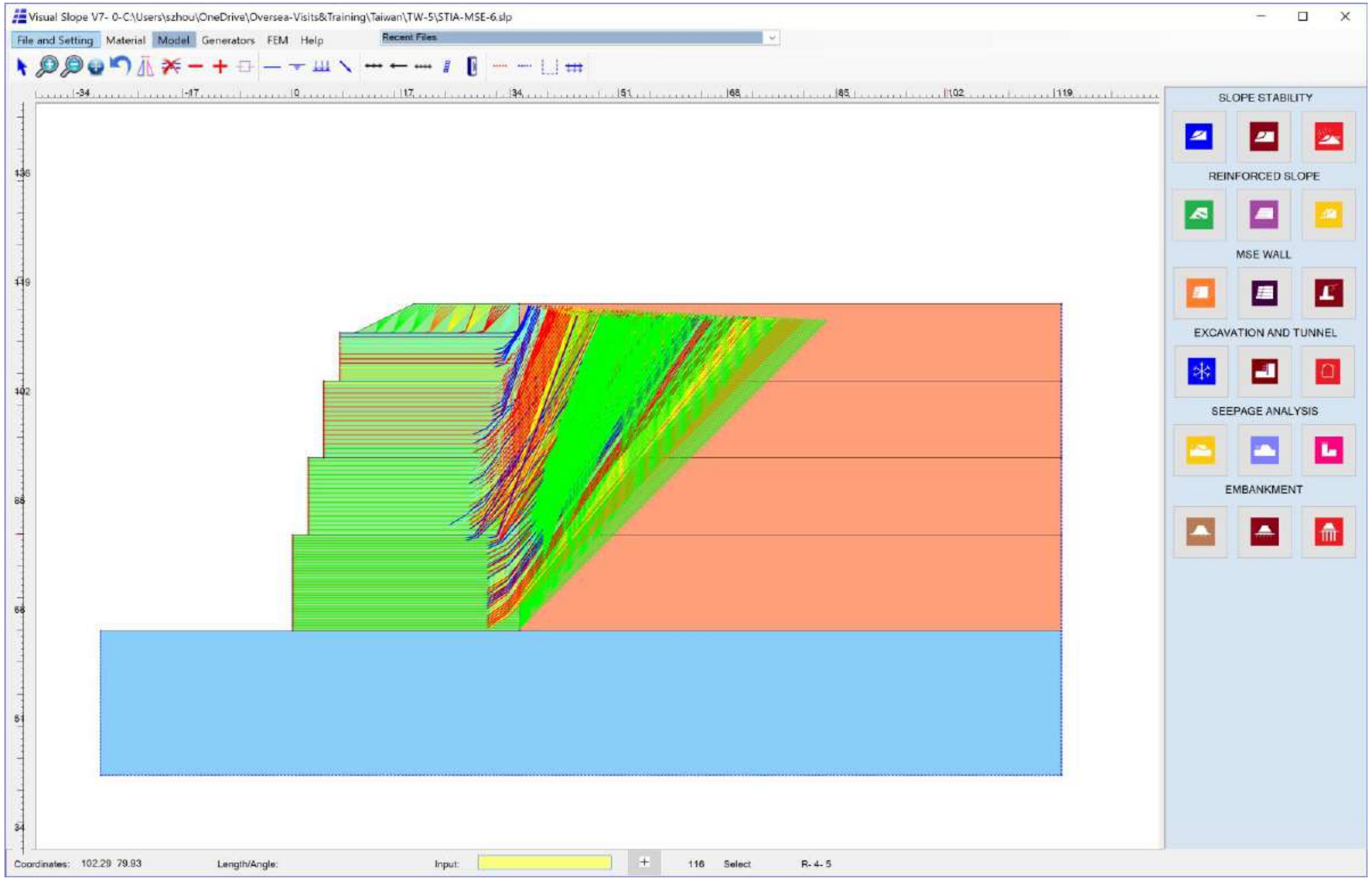


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

水平滑動最小安全系數：1.77

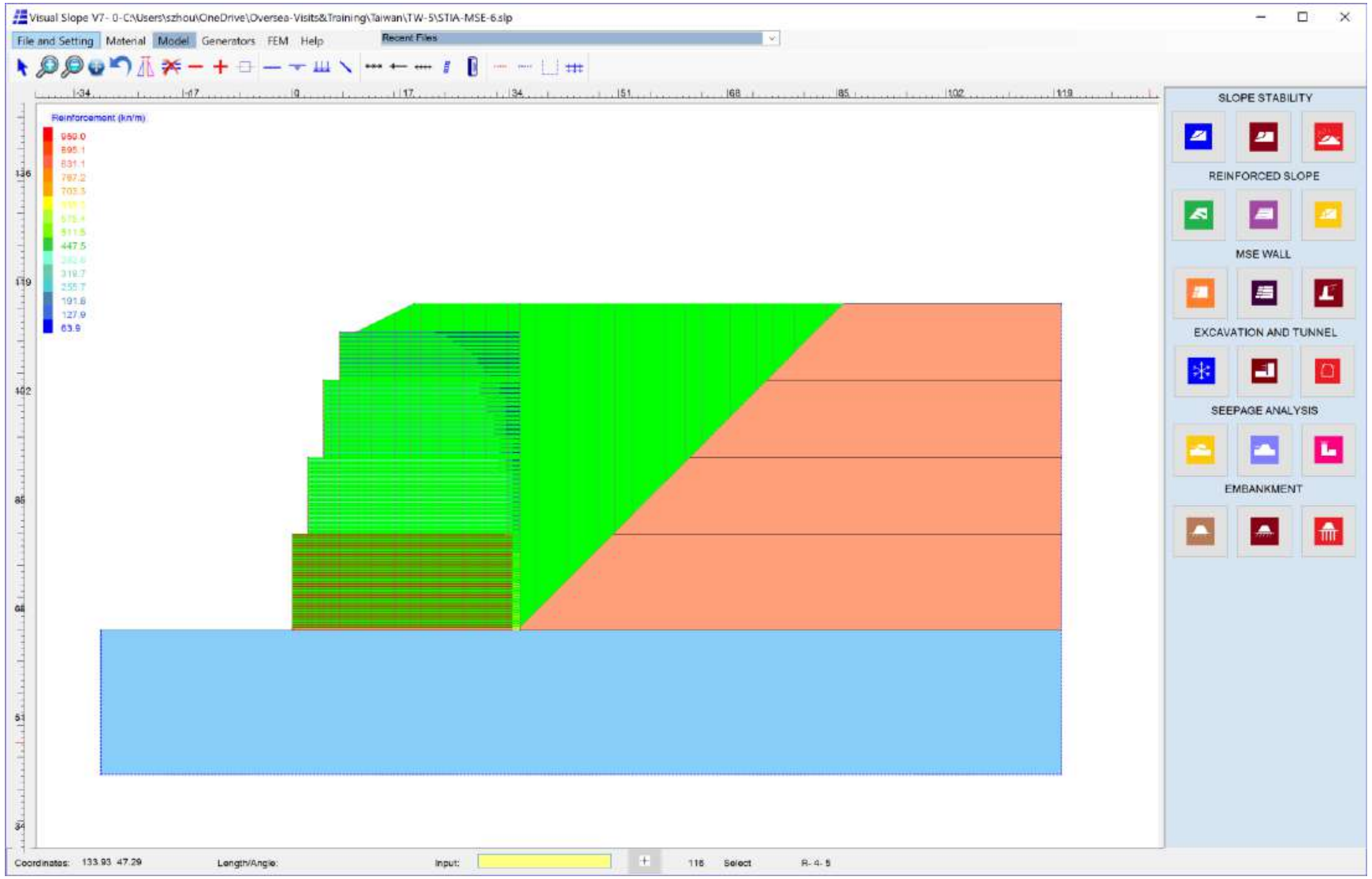


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

設計方法1

地震狀態水平滑動最小安全系數：1.06

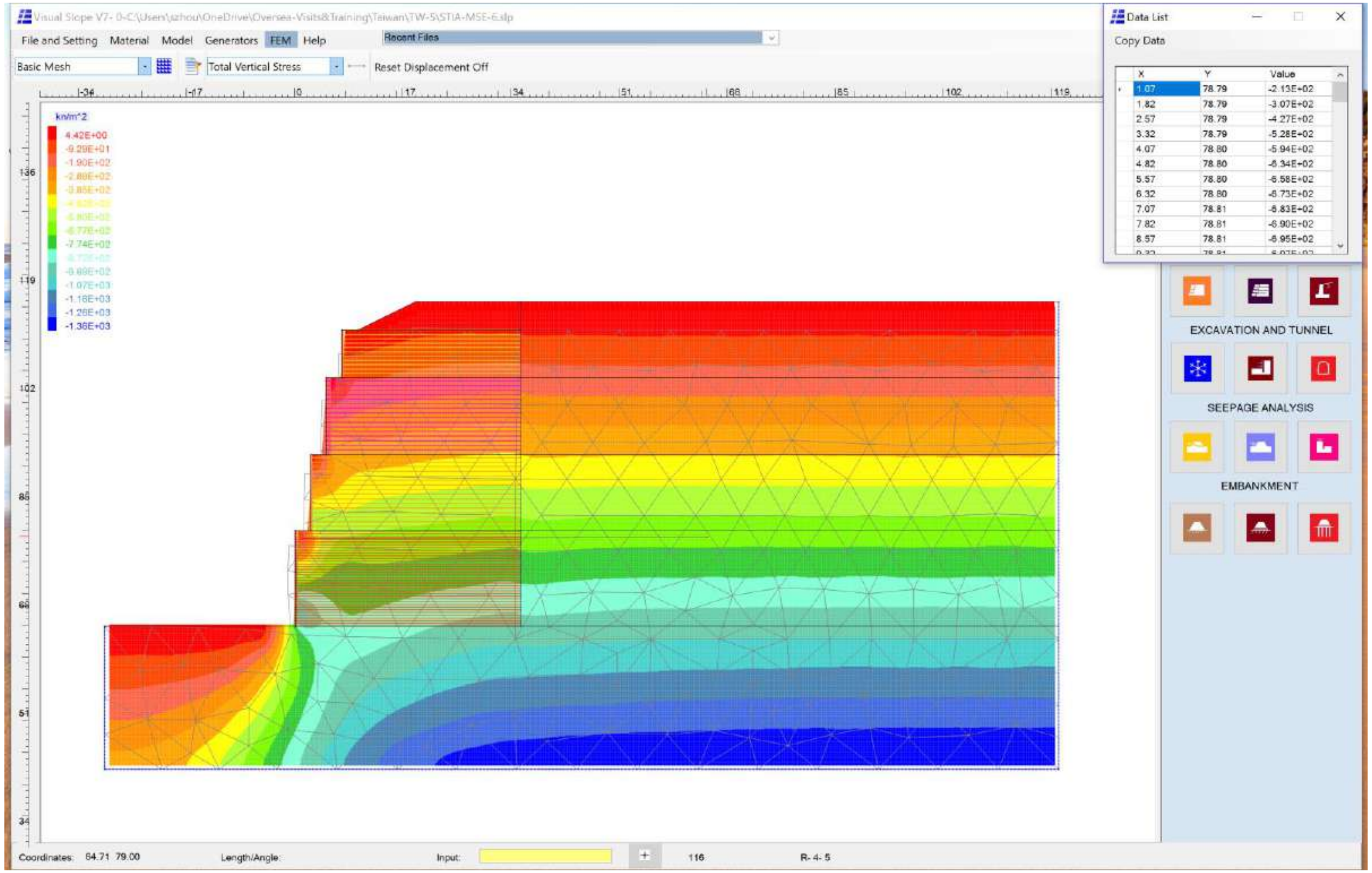


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA方法

有限元素法確認上牆對下牆的影響

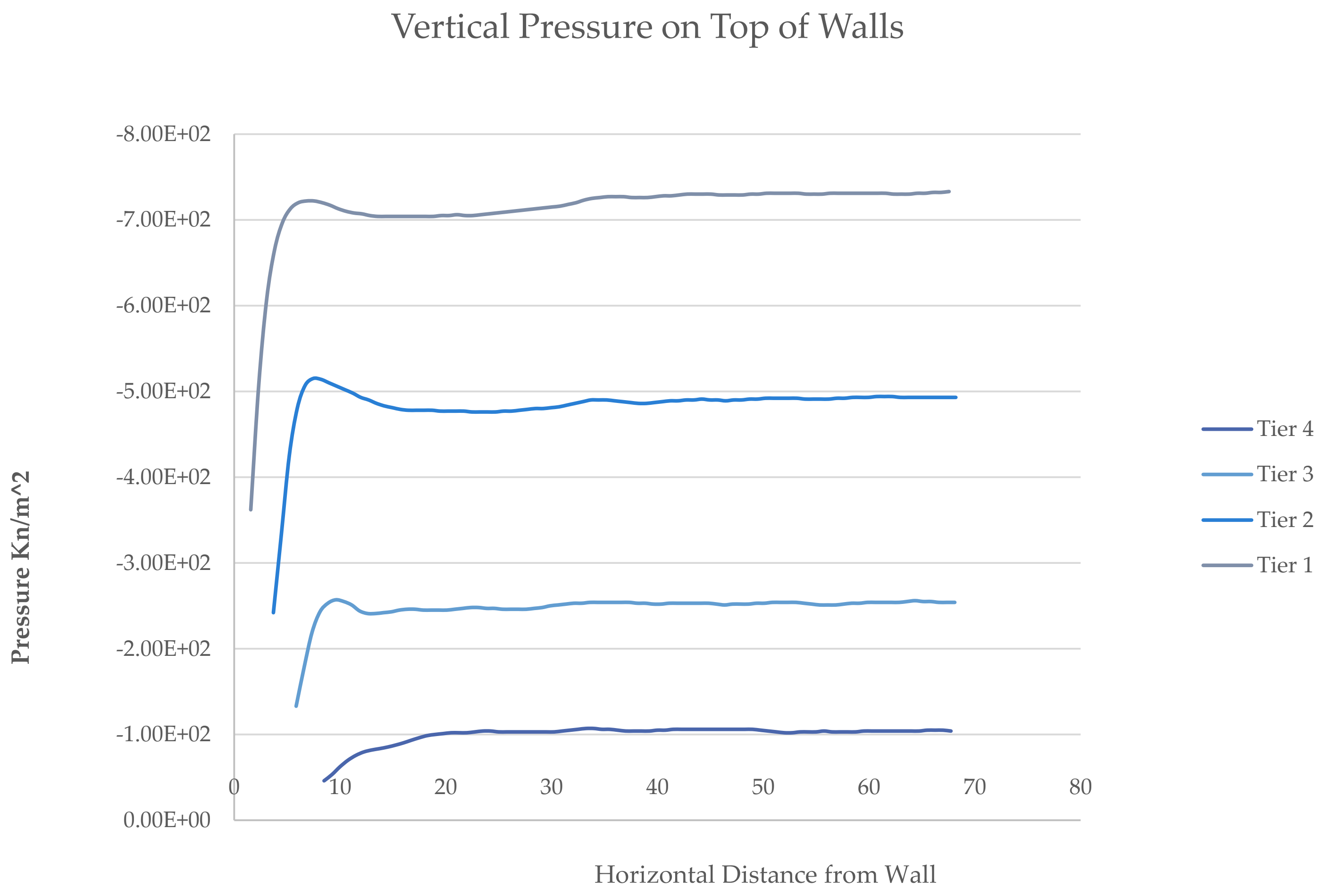


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA方法

有限元素法確認上牆對下牆的影響

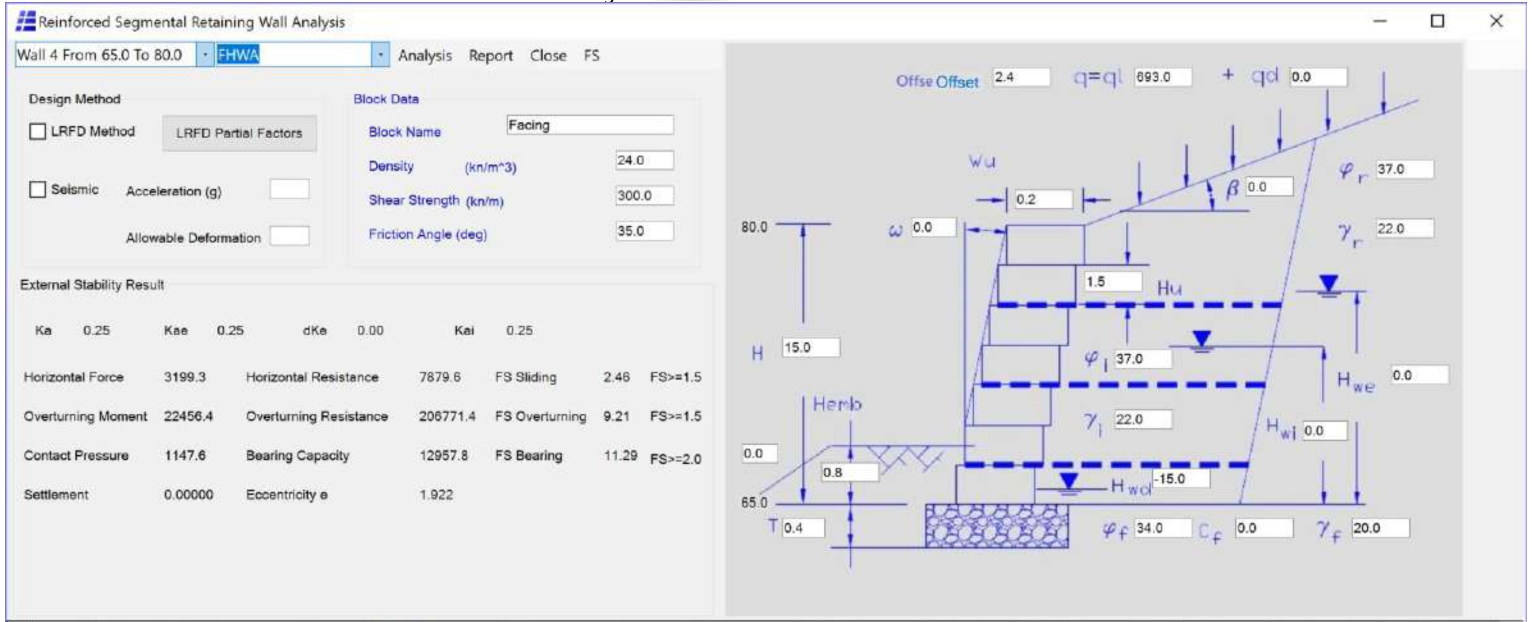


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA方法

Tier 1 外部穩定分析和內部穩定分析



Layer #	Reinforcement Type	Elevation	Length	Allowable Strength	Initial Connection	Friction	Max. Connection	Anchorage Length	Tensile Force	Eccentricity <=B/6	FS Overstress >=1.5	FS Pullout >=1.5	FS Sliding >=1.5
1	Tier 1 Strip	79.91	35.40	959.0	319.7	15.0	639.3	30.90	89.18	0.0000	10.75	122.41	1074.69
2	Tier 1 Strip	79.48	35.40	959.0	319.7	15.0	639.3	30.90	123.30	0.0009	7.78	89.51	187.25
3	Tier 1 Strip	79.06	35.40	959.0	319.7	15.0	639.3	30.90	122.29	0.0030	7.84	91.19	104.26
4	Tier 1 Strip	78.63	35.40	959.0	319.7	15.0	639.3	30.90	121.20	0.0064	7.91	93.00	72.00
5	Tier 1 Strip	78.21	35.40	959.0	319.7	15.0	639.3	30.90	120.07	0.0108	7.99	94.84	55.45
6	Tier 1 Strip	77.78	35.40	959.0	319.7	15.0	639.3	30.90	120.25	0.0165	7.98	95.68	44.99
7	Tier 1 Strip	77.35	35.40	959.0	319.7	15.0	639.3	30.90	117.56	0.0234	8.16	98.86	37.92
8	Tier 1 Strip	76.93	35.40	959.0	319.7	15.0	639.3	30.90	116.24	0.0311	8.25	100.97	32.92
9	Tier 1 Strip	76.50	35.40	959.0	319.7	15.0	639.3	30.90	114.83	0.0401	8.35	103.24	29.05
10	Tier 1 Strip	76.08	35.40	959.0	319.7	15.0	639.3	30.90	113.38	0.0500	8.46	105.56	26.08
11	Tier 1 Strip	75.65	35.40	959.0	319.7	15.0	639.3	30.90	113.15	0.0611	8.48	106.81	23.64
12	Tier 1 Strip	75.22	35.40	959.0	319.7	15.0	639.3	30.90	110.22	0.0732	8.70	110.70	21.63
13	Tier 1 Strip	74.80	35.40	959.0	319.7	15.0	639.3	30.90	108.58	0.0860	8.83	113.42	19.99
14	Tier 1 Strip	74.37	35.40	959.0	319.7	15.0	639.3	30.90	106.83	0.1000	8.98	116.36	18.56
15	Tier 1 Strip	73.95	35.40	959.0	319.7	15.0	639.3	30.90	105.42	0.1147	9.10	118.99	17.36
16	Tier 1 Strip	73.52	35.40	959.0	319.7	15.0	639.3	30.90	107.97	0.1307	8.88	117.23	16.29
17	Tier 1 Strip	73.09	35.40	959.0	319.7	15.0	639.3	30.90	108.03	0.1475	8.88	118.23	15.36
18	Tier 1 Strip	72.67	35.40	959.0	319.7	15.0	639.3	30.90	109.32	0.1649	8.77	117.86	14.55
19	Tier 1 Strip	72.24	35.40	959.0	319.7	15.0	639.3	31.05	110.65	0.1836	8.67	118.06	13.81
20	Tier 1 Strip	71.82	35.40	959.0	319.7	15.0	639.3	31.31	111.95	0.2026	8.57	118.64	13.16
21	Tier 1 Strip	71.39	35.40	959.0	319.7	15.0	639.3	31.57	114.63	0.2230	8.37	117.83	12.57
22	Tier 1 Strip	70.96	35.40	959.0	319.7	15.0	639.3	31.82	114.65	0.2443	8.36	119.77	12.02
23	Tier 1 Strip	70.54	35.40	959.0	319.7	15.0	639.3	32.08	115.98	0.2658	8.27	120.33	11.54
24	Tier 1 Strip	70.11	35.40	959.0	319.7	15.0	639.3	32.33	117.36	0.2887	8.17	120.87	11.09
25	Tier 1 Strip	69.69	35.40	959.0	319.7	15.0	639.3	32.59	118.71	0.3119	8.08	121.40	10.69
26	Tier 1 Strip	69.26	35.40	959.0	319.7	15.0	639.3	32.84	121.51	0.3363	7.89	120.51	10.30

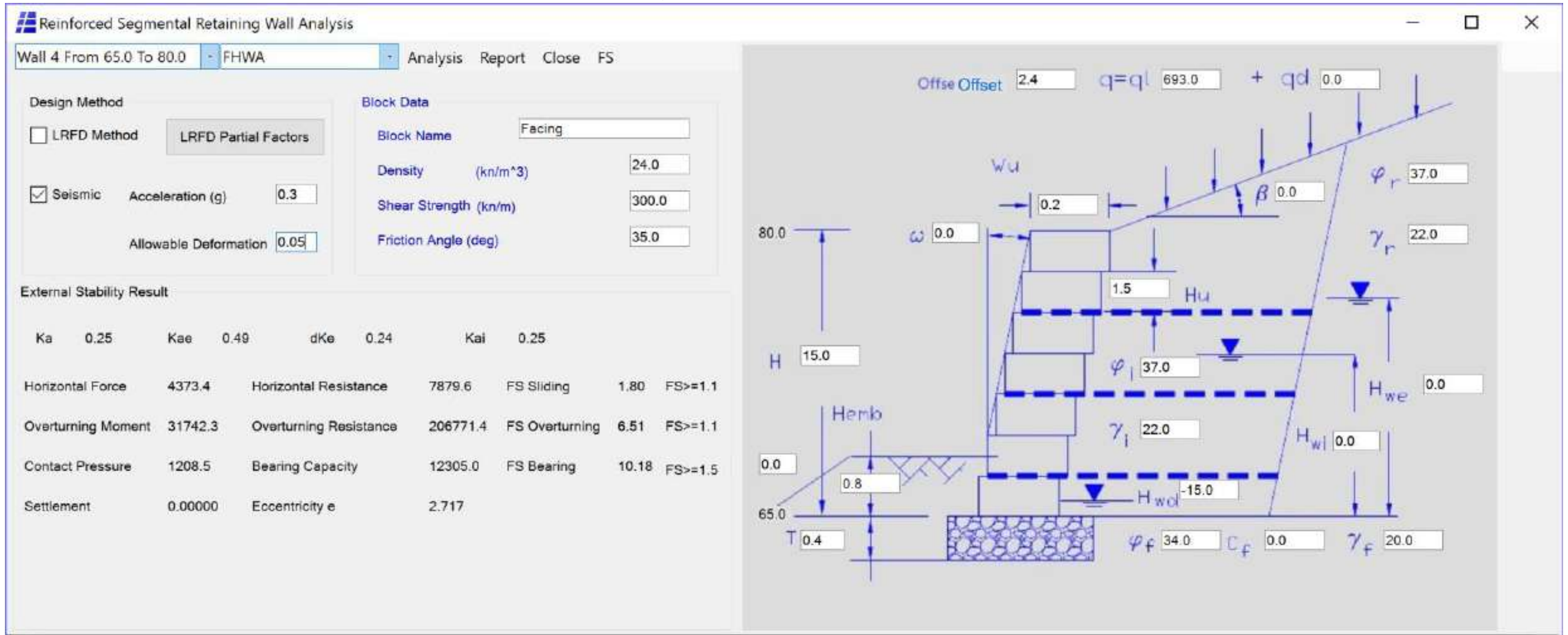
多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA方法

Tier 1地震狀態

外部穩定分析和內部穩定分析



Layer #	Reinforcement Type	Elevation	Length	Allowable Strength	Initial Connection	Friction	Max. Connection	Anchorage Length	Tensile Force	Eccentricity <=B/6	FS Overstress >=1.1	FS Pullout >=1.1	FS Sliding >=1.1
1	Tier 1 Strip	79.91	35.40	959.0	319.7	15.0	639.3	30.90	96.99	0.0000	9.89	3.86	739.27
2	Tier 1 Strip	79.48	35.40	959.0	319.7	15.0	639.3	30.90	134.19	0.0009	7.15	13.94	129.08
3	Tier 1 Strip	79.06	35.40	959.0	319.7	15.0	639.3	30.90	133.18	0.0030	7.20	22.49	72.02
4	Tier 1 Strip	78.63	35.40	959.0	319.7	15.0	639.3	30.90	132.09	0.0064	7.26	29.64	49.84
5	Tier 1 Strip	78.21	35.40	959.0	319.7	15.0	639.3	30.90	130.96	0.0108	7.32	35.54	38.46
6	Tier 1 Strip	77.78	35.40	959.0	319.7	15.0	639.3	30.90	131.26	0.0165	7.31	40.32	31.26
7	Tier 1 Strip	77.35	35.40	959.0	319.7	15.0	639.3	30.90	128.45	0.0234	7.47	45.46	26.40
8	Tier 1 Strip	76.93	35.40	959.0	319.7	15.0	639.3	30.90	127.13	0.0311	7.54	49.60	22.97
9	Tier 1 Strip	76.50	35.40	959.0	319.7	15.0	639.3	30.90	125.71	0.0401	7.63	53.53	20.31
10	Tier 1 Strip	76.08	35.40	959.0	319.7	15.0	639.3	30.90	124.27	0.0500	7.72	57.13	18.27
11	Tier 1 Strip	75.65	35.40	959.0	319.7	15.0	639.3	30.90	124.16	0.0611	7.72	59.93	16.59
12	Tier 1 Strip	75.22	35.40	959.0	319.7	15.0	639.3	30.90	121.11	0.0732	7.92	64.02	15.21
13	Tier 1 Strip	74.80	35.40	959.0	319.7	15.0	639.3	30.90	119.46	0.0860	8.03	67.24	14.08
14	Tier 1 Strip	74.37	35.40	959.0	319.7	15.0	639.3	30.90	117.71	0.1000	8.15	70.49	13.10
15	Tier 1 Strip	73.95	35.40	959.0	319.7	15.0	639.3	30.90	116.30	0.1147	8.25	73.48	12.27
16	Tier 1 Strip	73.52	35.40	959.0	319.7	15.0	639.3	30.90	118.99	0.1307	8.06	74.37	11.54
17	Tier 1 Strip	73.09	35.40	959.0	319.7	15.0	639.3	30.90	118.92	0.1475	8.06	76.84	10.90
18	Tier 1 Strip	72.67	35.40	959.0	319.7	15.0	639.3	30.90	120.21	0.1649	7.98	78.25	10.34
19	Tier 1 Strip	72.24	35.40	959.0	319.7	15.0	639.3	31.05	121.54	0.1836	7.89	79.95	9.83
20	Tier 1 Strip	71.82	35.40	959.0	319.7	15.0	639.3	31.31	122.84	0.2026	7.81	81.78	9.39
21	Tier 1 Strip	71.39	35.40	959.0	319.7	15.0	639.3	31.57	125.65	0.2230	7.63	82.58	8.98
22	Tier 1 Strip	70.96	35.40	959.0	319.7	15.0	639.3	31.82	125.54	0.2443	7.64	85.24	8.61
23	Tier 1 Strip	70.54	35.40	959.0	319.7	15.0	639.3	32.08	126.87	0.2658	7.56	86.83	8.27

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA LRFD方法

LRFD 系數

LRFD MSE

Limit State/LRFD

Load Factor	Static	Static-Seismic
Dead Surcharge, ES	1.5	1.5
Live Surcharge, LS	1.75	1.75
Seismic Load, ES	0	1
Vertical Earth Pressure, EV	1.35	1.35
Vertical Earth Pressure, EV (Sliding-Eccentricity)	1	1
Active Horizontal Earth Pressure, EH	1.5	1.5

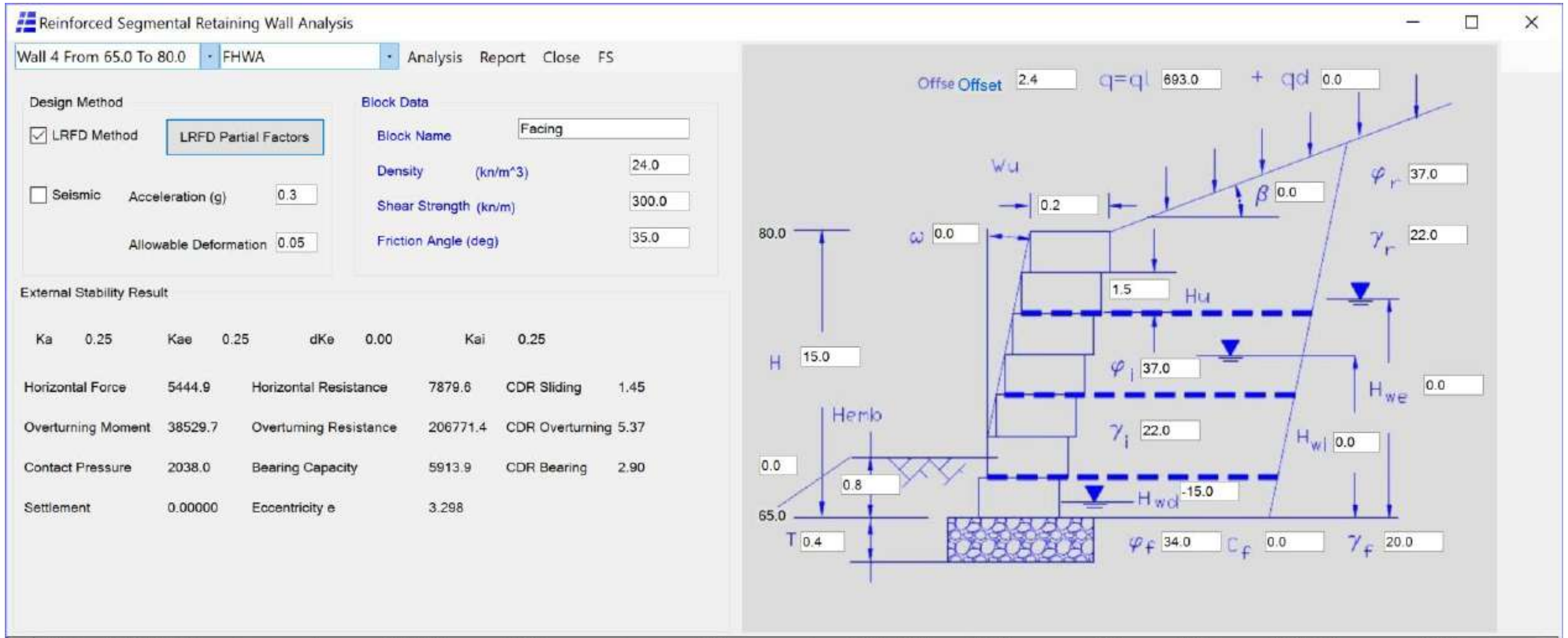
Resistance Reduction	Static	Static-Seismic
Geosynthetic Tensile Strength - Connector	0.9	1.2
Metal Strip Tensile Strength - Connector	0.75	1
Metal Grid Tensile Strength - Connector	0.65	0.85
Pullout Resistance	0.9	1.2
Bearing Capacity	0.5	0.5
Shear Resistance (Reinfoced Soil and	1	1
Shear Resistance (Reinfoced Soil and	1	1

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA方法

Tier 1
外部穩定分析和內部穩定分析



Layer #	Reinforcement Type	Elevation	Length	Allowable Strength	Initial Connection	Friction	Max. Connection		Eccentricity <=B/6	CDR Overstress	CDR Pullout	CDR Sliding	CDR Local Overturning	CDR Connection
1	Tier 1 Strip	79.91	35.40	959.0	319.7	15.0	639.3	7	0.0000	4.61	81.60	1074.21	623278.50	2.05
2	Tier 1 Strip	79.48	35.40	959.0	319.7	15.0	639.3	8	0.0009	3.35	59.61	186.78	18792.35	1.49
3	Tier 1 Strip	79.06	35.40	959.0	319.7	15.0	639.3	0	0.0031	3.38	60.69	103.78	5787.21	1.51
4	Tier 1 Strip	78.63	35.40	959.0	319.7	15.0	639.3	8	0.0065	3.42	61.84	71.53	2741.93	1.53
5	Tier 1 Strip	78.21	35.40	959.0	319.7	15.0	639.3	4	0.0110	3.47	63.01	54.98	1616.08	1.55
6	Tier 1 Strip	77.78	35.40	959.0	319.7	15.0	639.3	7	0.0167	3.47	63.52	44.52	1057.20	1.56
7	Tier 1 Strip	77.35	35.40	959.0	319.7	15.0	639.3	9	0.0237	3.56	65.58	37.46	746.50	1.60
8	Tier 1 Strip	76.93	35.40	959.0	319.7	15.0	639.3	0	0.0316	3.61	66.92	32.47	559.51	1.62
9	Tier 1 Strip	76.50	35.40	959.0	319.7	15.0	639.3	6	0.0409	3.66	68.36	28.60	433.05	1.65
10	Tier 1 Strip	76.08	35.40	959.0	319.7	15.0	639.3	1	0.0510	3.72	69.84	25.64	347.21	1.68
11	Tier 1 Strip	75.65	35.40	959.0	319.7	15.0	639.3	3	0.0624	3.74	70.61	23.19	283.60	1.69
12	Tier 1 Strip	75.22	35.40	959.0	319.7	15.0	639.3	9	0.0749	3.84	73.12	21.19	236.22	1.74
13	Tier 1 Strip	74.80	35.40	959.0	319.7	15.0	639.3	8	0.0882	3.91	74.85	19.55	200.71	1.78
14	Tier 1 Strip	74.37	35.40	959.0	319.7	15.0	639.3	9	0.1028	3.98	76.72	18.13	172.18	1.81
15	Tier 1 Strip	73.95	35.40	959.0	319.7	15.0	639.3	2	0.1181	4.05	78.38	16.93	149.91	1.84
16	Tier 1 Strip	73.52	35.40	959.0	319.7	15.0	639.3	3	0.1347	3.96	77.15	15.87	131.38	1.81
17	Tier 1 Strip	73.09	35.40	959.0	319.7	15.0	639.3	3	0.1524	3.97	77.73	14.94	116.16	1.81
18	Tier 1 Strip	72.67	35.40	959.0	319.7	15.0	639.3	2	0.1706	3.93	77.42	14.13	103.77	1.80
19	Tier 1 Strip	72.24	35.40	959.0	319.7	15.0	639.3	6	0.1902	3.89	77.47	13.40	93.07	1.78
20	Tier 1 Strip	71.82	35.40	959.0	319.7	15.0	639.3	7	0.2102	3.85	77.78	12.75	84.19	1.77
21	Tier 1 Strip	71.39	35.40	959.0	319.7	15.0	639.3	6	0.2317	3.77	77.17	12.16	76.38	1.73
22	Tier 1 Strip	70.96	35.40	959.0	319.7	15.0	639.3	3	0.2542	3.78	78.37	11.62	69.63	1.74

多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

FHWA方法

Tier 1地震狀態

外部穩定分析和內部穩定分析

Reinforced Segmental Retaining Wall Analysis

Wall 4 From 65.0 To 80.0 · FHWA · Analysis Report Close FS

Design Method

- [x] LRFD Method — LRFD Partial Factors
- [x] Seismic — Acceleration (g) 0.3
- Allowable Deformation 0.05

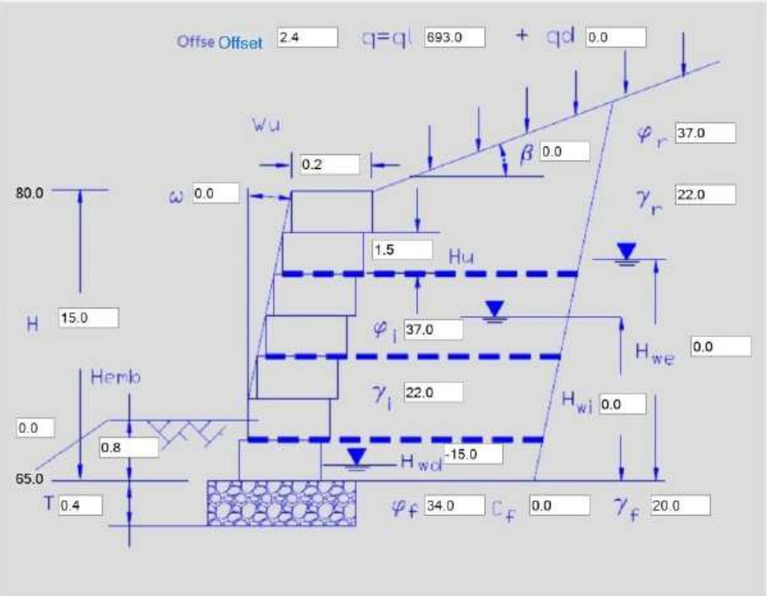
Block Data

Block Name	Facing
Density (kn/m^3)	24.0
Shear Strength (kn/m)	300.0
Friction Angle (deg)	35.0

External Stability Result

Ka	0.25	Kae	0.49	dKe	0.24	Kai	0.25

Horizontal Force	6619.0	Horizontal Resistance	7879.6	CDR Sliding	1.19
Overturning Moment	47815.6	Overturning Resistance	206771.4	CDR Overturning	4.32
Contact Pressure	2157.1	Bearing Capacity	5587.5	CDR Bearing	2.59
Settlement	0.00000	Eccentricity e	4.093		



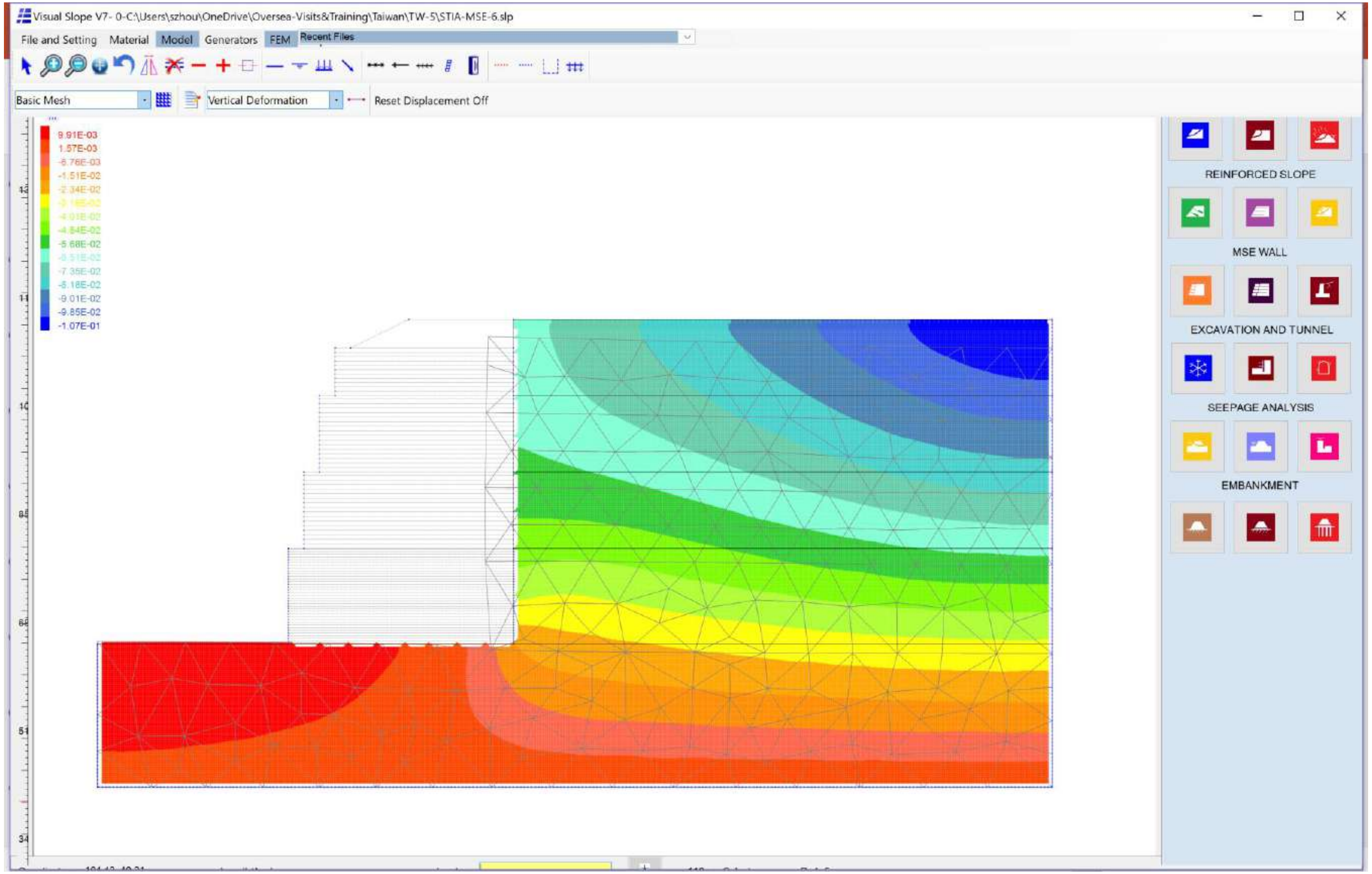
Layer #	Reinforcement Type	Elevation	Length	Allowable Strength	Initial Connection	Friction	Max. Connection		Eccentricity <=B/6	CDR Overstress	CDR Pullout	CDR Sliding	CDR Local Overturning	CDR Connection
1	Tier 1 Strip	79.91	35.40	959.0	319.7	15.0	639.3	8	0.0000	5.86	4.58	853.01	623278.50	1.95
2	Tier 1 Strip	79.48	35.40	959.0	319.7	15.0	639.3	6	0.0009	4.25	15.86	148.49	18792.35	1.42
3	Tier 1 Strip	79.06	35.40	959.0	319.7	15.0	639.3	9	0.0031	4.29	24.83	82.61	5787.21	1.44
4	Tier 1 Strip	78.63	35.40	959.0	319.7	15.0	639.3	7	0.0065	4.34	31.97	57.00	2741.93	1.45
5	Tier 1 Strip	78.21	35.40	959.0	319.7	15.0	639.3	3	0.0110	4.39	37.65	43.86	1616.08	1.47
6	Tier 1 Strip	77.78	35.40	959.0	319.7	15.0	639.3	8	0.0167	4.39	42.08	35.56	1057.20	1.48
7	Tier 1 Strip	77.35	35.40	959.0	319.7	15.0	639.3	8	0.0237	4.50	46.86	29.95	746.50	1.52
8	Tier 1 Strip	76.93	35.40	959.0	319.7	15.0	639.3	9	0.0316	4.56	50.62	25.99	559.51	1.54
9	Tier 1 Strip	76.50	35.40	959.0	319.7	15.0	639.3	5	0.0409	4.63	54.15	22.92	433.05	1.56
10	Tier 1 Strip	76.08	35.40	959.0	319.7	15.0	639.3	0	0.0510	4.69	57.37	20.57	347.21	1.59
11	Tier 1 Strip	75.65	35.40	959.0	319.7	15.0	639.3	5	0.0624	4.71	59.79	18.63	283.60	1.60
12	Tier 1 Strip	75.22	35.40	959.0	319.7	15.0	639.3	8	0.0749	4.84	63.51	17.04	236.22	1.65
13	Tier 1 Strip	74.80	35.40	959.0	319.7	15.0	639.3	6	0.0882	4.92	66.37	15.74	200.71	1.68
14	Tier 1 Strip	74.37	35.40	959.0	319.7	15.0	639.3	8	0.1028	5.01	69.27	14.61	172.18	1.71
15	Tier 1 Strip	73.95	35.40	959.0	319.7	15.0	639.3	1	0.1181	5.08	71.91	13.66	149.91	1.74
16	Tier 1 Strip	73.52	35.40	959.0	319.7	15.0	639.3	4	0.1347	4.98	72.37	12.81	131.38	1.70
17	Tier 1 Strip	73.09	35.40	959.0	319.7	15.0	639.3	2	0.1524	4.99	74.37	12.07	116.16	1.71
18	Tier 1 Strip	72.67	35.40	959.0	319.7	15.0	639.3	0	0.1706	4.94	75.37	11.43	103.77	1.70
19	Tier 1 Strip	72.24	35.40	959.0	319.7	15.0	639.3	4	0.1902	4.90	76.66	10.85	93.07	1.68
20	Tier 1 Strip	71.82	35.40	959.0	319.7	15.0	639.3	6	0.2102	4.85	78.08	10.34	84.19	1.67
21	Tier 1 Strip	71.39	35.40	959.0	319.7	15.0	639.3	7	0.2317	4.75	78.52	9.87	76.38	1.64
22	Tier 1 Strip	70.96	35.40	959.0	319.7	15.0	639.3	1	0.2542	4.76	80.72	9.44	69.63	1.65

多階加勁擋土牆實例

Seattle-Tacoma International Airport New Third Runway

沉陷分析

初始沉陷計算

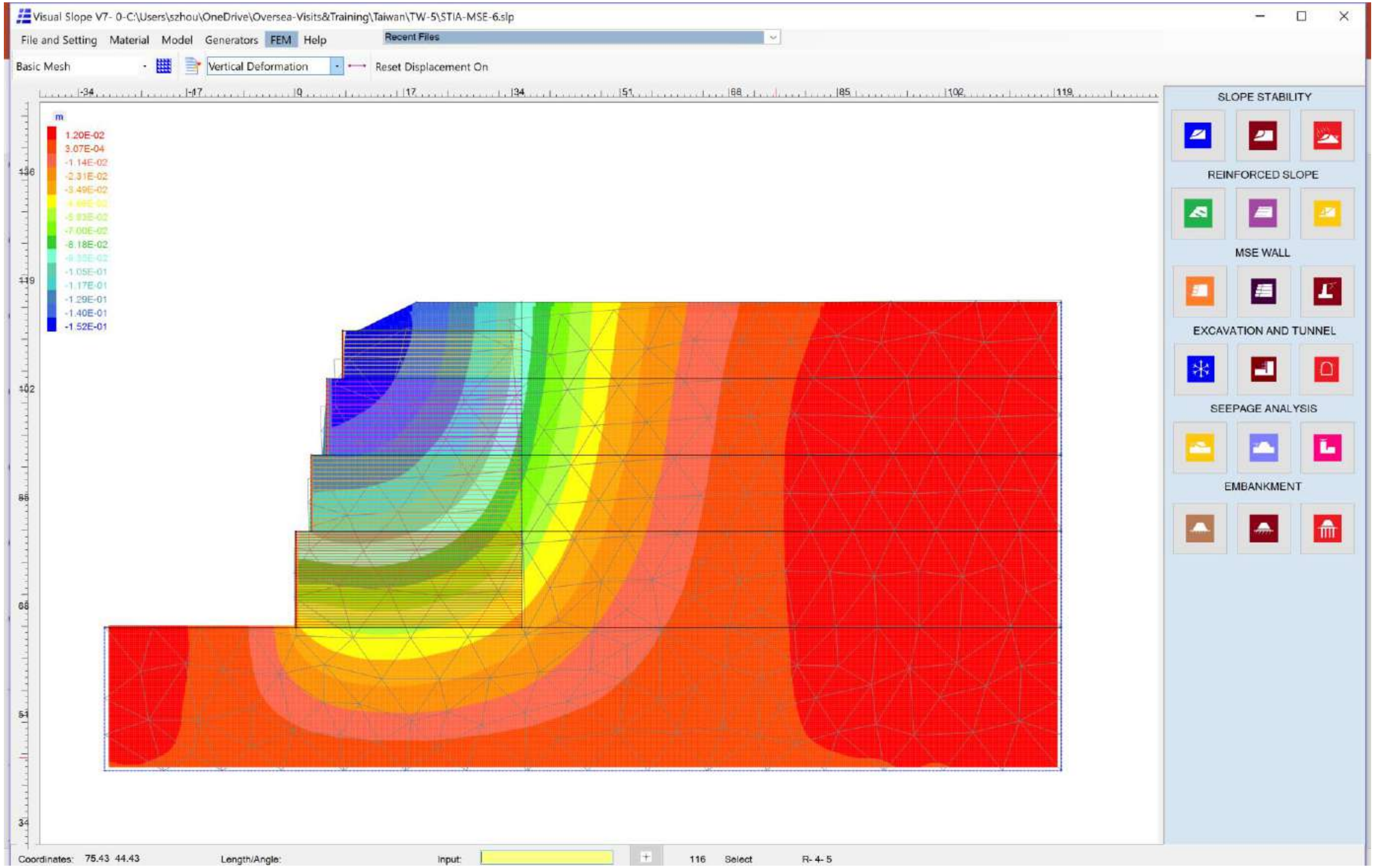


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

沉陷分析

最終沉陷量=4.2cm

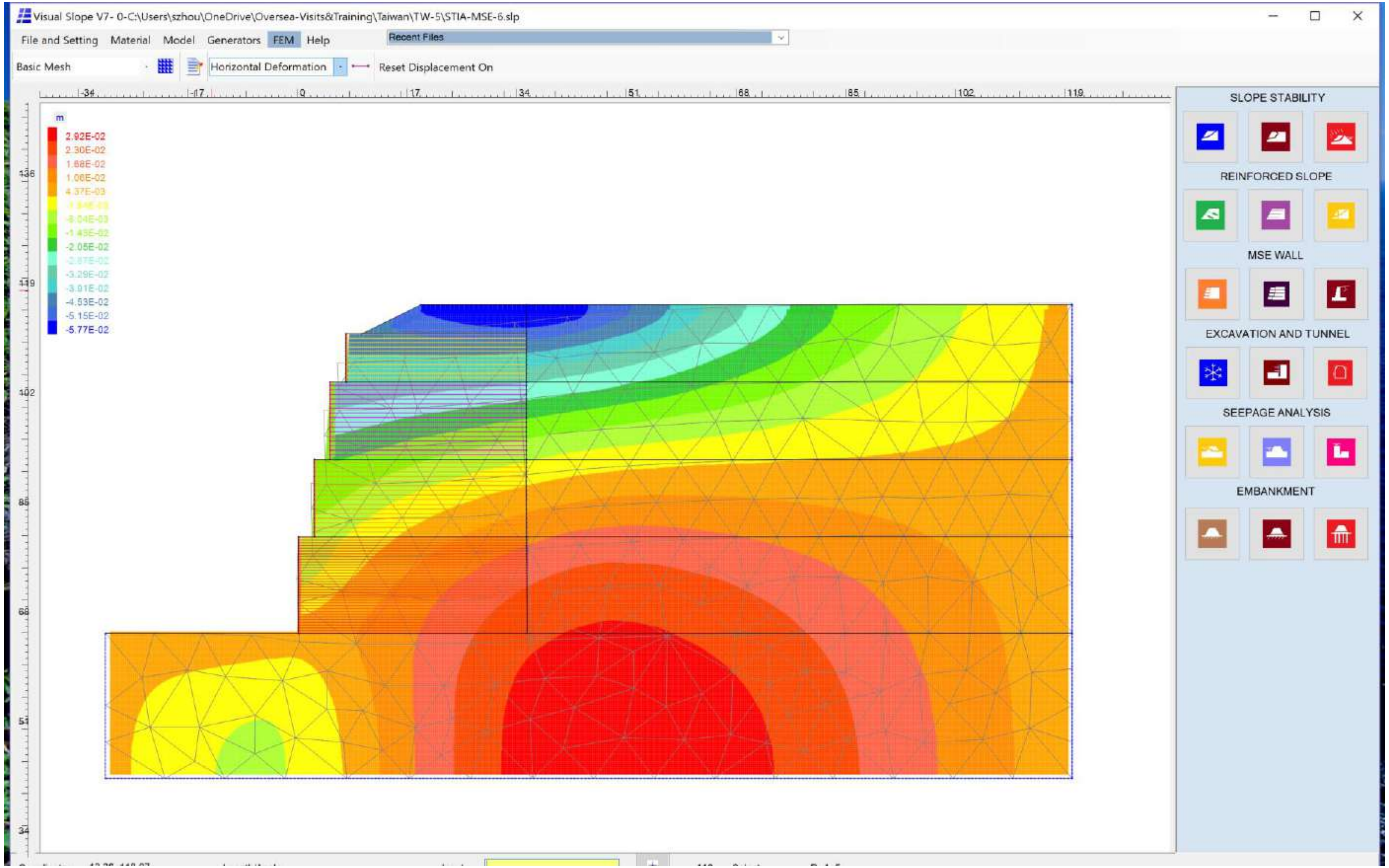


多階加勁擋土牆實例

Seattle-Tacoma International Airport
New Third Runway

變形分析

牆面水平變形=3.2cm



結論

- 在超高型多階加勁擋土牆的設計中，加勁邊坡設計法和FHWA法都可以使用。建議同時使用以便校核。
- FHWA法提供較詳細的結果，LRFD是發展趨勢。
- 有限元素法在超高型多階加勁擋土牆的設計中具有一定的作用。


昵图网 nipic.com/

謝謝