GTS NX開挖與邊坡2D/3D分析比較暨實務QA研討會

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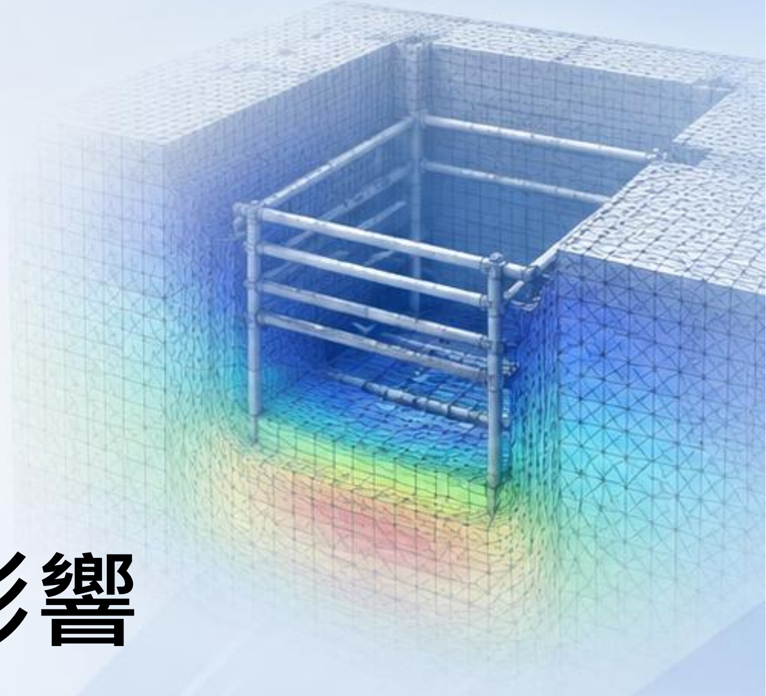
Agenda

- **Subject 1**
  - 開挖與邊坡工程之 2D/3D 數值分析效益比較與應用
    - 深開挖
    - 邊坡
- **Subject 2**
  - 全方位工程模擬解決方案
- **Subject 3**
  - 專案分析常見議題與經驗交流

Part1.深開挖

2D和3D模型對於分析之影響



2D和3D模型對於分析之影響

- **Part1.深開挖**
  - Part1.1 空間效應之影響
  - Part1.2 特殊空間效應之影響
  - Part1.3 側向支撐與空間構架配置之複雜性
  - Part1.4 鄰近結構與地下設施 3D 互制

Part1.1 空間效應之影響-1

2D或 3D深開挖(Deep Excavation)分析的主要差異

1.角隅效應(Corner Effect)與空間約束
2.長寬比(Aspect Ratio)的影響
3.支撐系統與結構分布的複雜性
4.鄰近基礎與地下設施的互制作用

比較項目	2D 深開挖分析	3D 深開挖分析
基本假設	平面應變條件，縱向無限延伸	三維空間完整幾何與邊界
計算效率	高(網格劃分快，求解數秒至數分鐘)	低(網格數量龐大，求解時間長)
連續壁變位	高估(尤其在角隅附近)	貼近實際監測分佈(中央大、角隅小)
地表沉陷槽	呈現沿斷面延伸的均勻沉陷槽	呈現具三維立體特徵的「碗狀」沉陷分佈
支撐模擬	僅能模擬斷面內的水平支撐/地錨	可模擬角隅撐、斜撐及複雜平面佈局

Part1.1 空間效應之影響-2

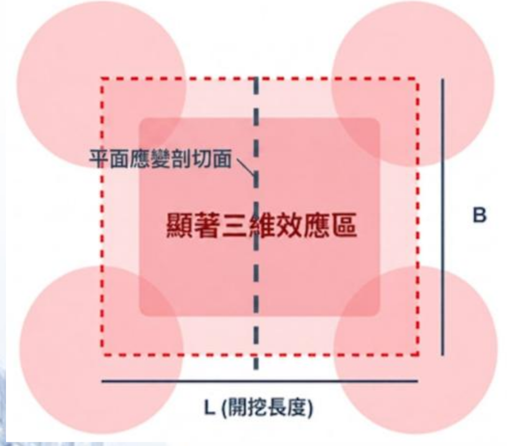
空間效應	比例/尺寸	開挖幾何型態	三維效應區的比率與分佈
顯著三維效應區 ***(3D Effect Dominated Zone)***	**L/B<1~ 1.5**	近正方形 / 方形	全區（100%）皆受顯著三維效應控制。 牆體與開挖區中央完全無法達到傳統的「平面應變狀態」，整體位移均受到四個角隅的強烈束制。
三維過渡區 ***(3D Transition Zone)***	**L/B =2 ~4**	一般矩形	**<u>短邊(B)</u>** 全段均處於顯著三維效應區 **<u>長邊(L)</u>** 兩側角落各約延伸出 (0.2~0.25)L有顯著三維效應區，僅長邊中央局部區域趨近平面應變。
平面應變區 ***(Plane Strain Zone)***	**L/B > 6**	狹長型	角落影響比例極低。 顯著三維效應僅侷限於角落兩端極小範圍，長邊有70%~80% 以上的區域可直接視為平面應變區。

L(開挖長度, Excavation Length)
B(開挖寬度, Excavation Width)
H(最終開挖深度, Final Excavation Depth)

Part1.1.1 顯著三維效應區-1

空間效應	比例	工程含意
顯著三維效應區 *(3D Effect Dominated Zone)*	L/B<1~ 1.5	顯著三維效應區是指開挖區的角落及其鄰近區域，擋土結構與地層的變形無法再簡化為傳統的「平面應變（Plane Strain）」狀態，而是呈現高度受空間幾何與角隅剛度影響的三維受力與變形行為。

L=70(m) / B=70(m) / H=10(m)



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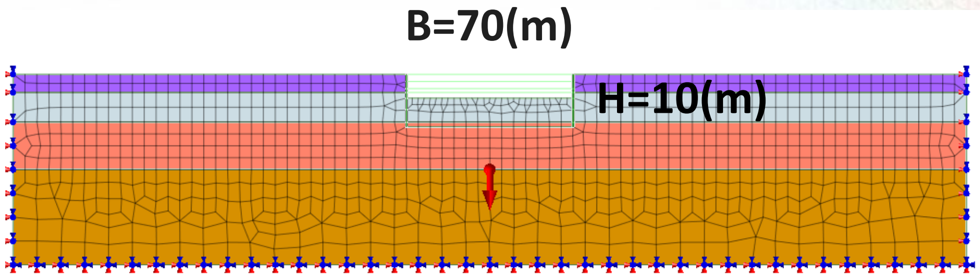
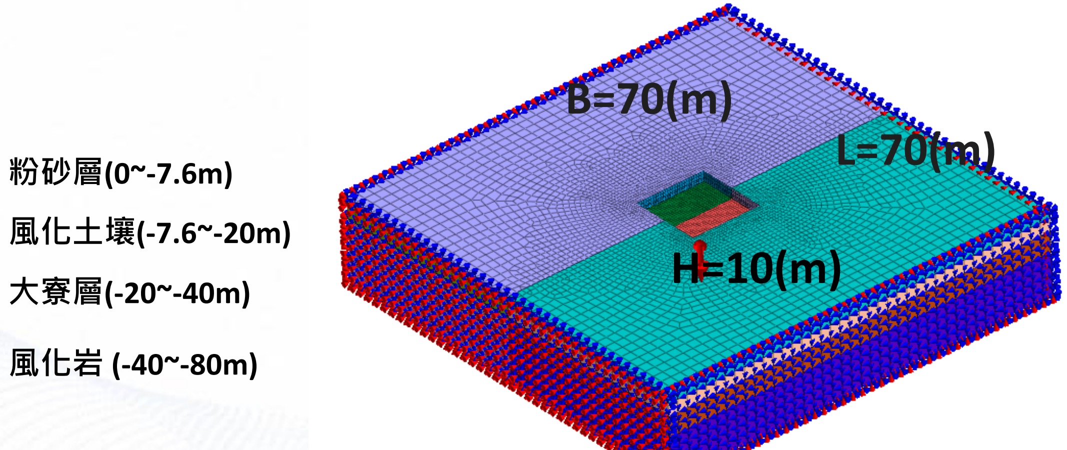
外側Element Size=10



GTS NX 2D模型



GTS NX 3D模型

Part1.1.1 顯著三維效應區-2

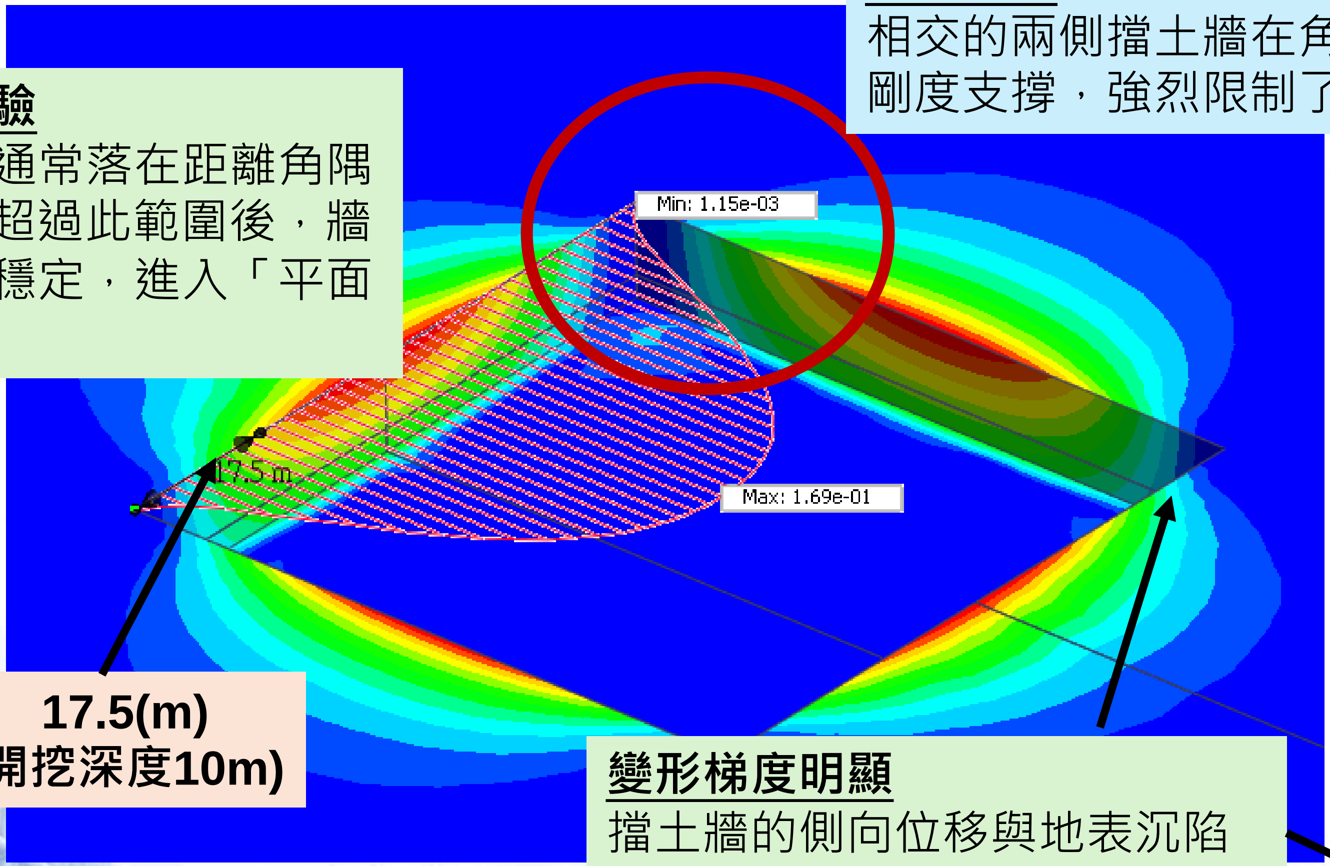
GTS NX 3D-Txz水平位移(m)

角隅效應

相交的兩側擋土牆在角隅處形成天然的幾何互鎖與高剛度支撐，強烈限制了壁體向開挖區內部的側向位移。

影響範圍經驗

三維效應區通常落在距離角隅約 1H~2H，超過此範圍後，牆體變形趨於穩定，進入「平面應變區」。

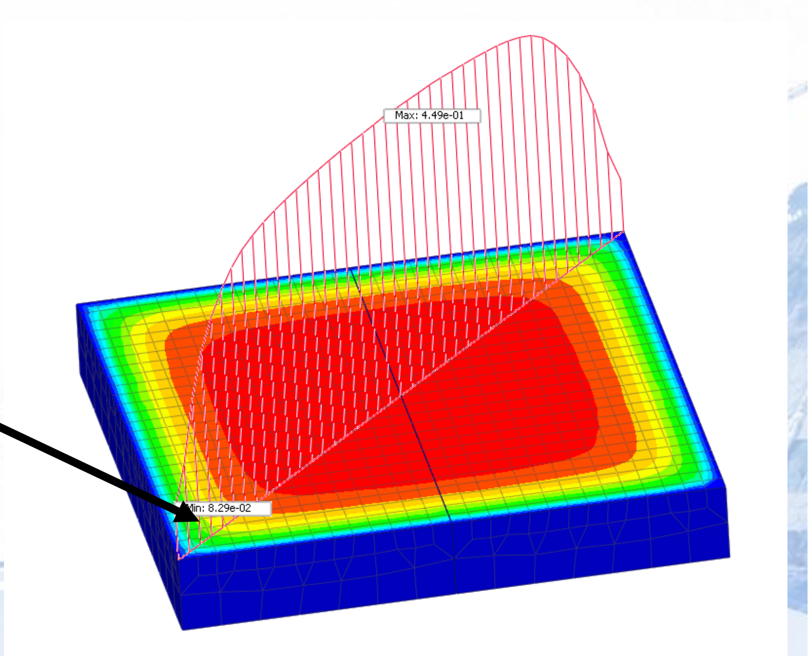


17.5(m)
(開挖深度10m)

變形梯度明顯

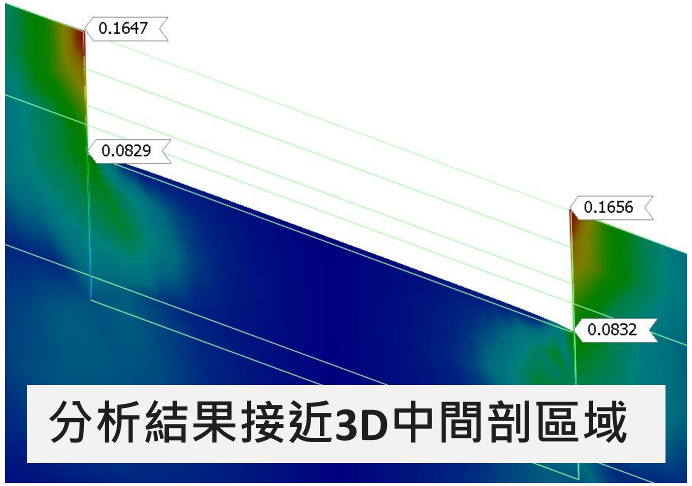
擋土牆的側向位移與地表沉陷會快速遞減。

GTS NX 3D-Ty地表沉陷(m)

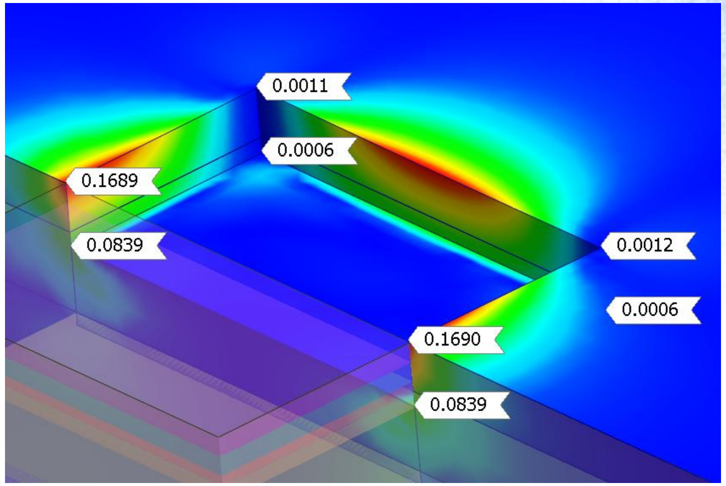


Part1.1.1 顯著三維效應區-3

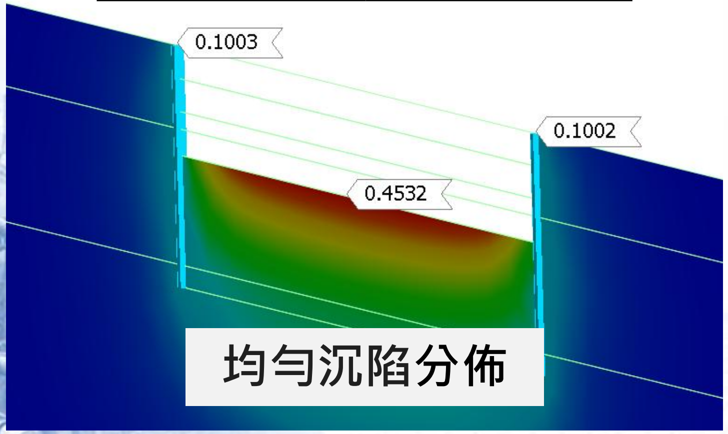
GTS NX 2D-Txz水平位移(m)



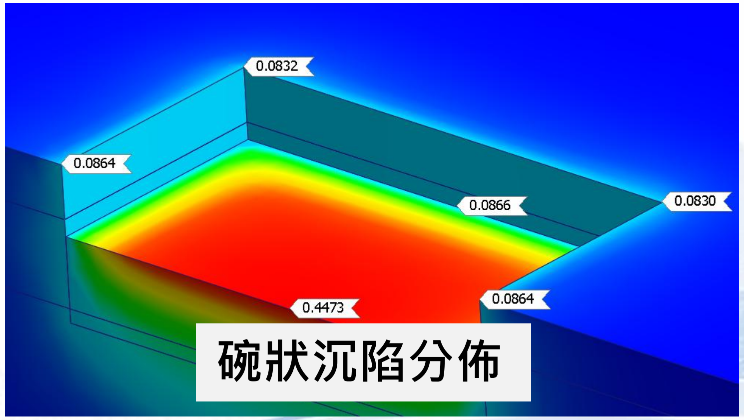
GTS NX 3D-Txz水平位移(m)



GTS NX 2D-地表沉陷(m)



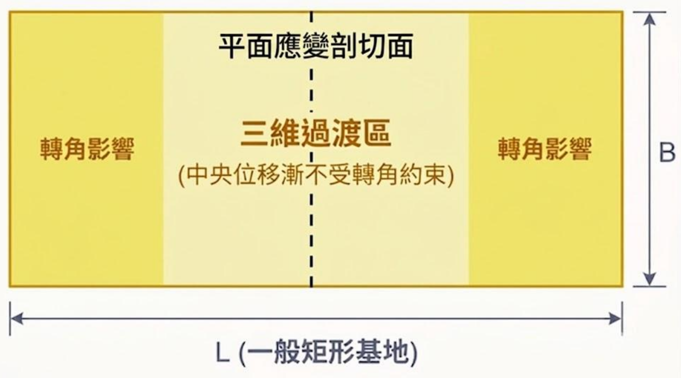
GTS NX 3D-地表沉陷(m)

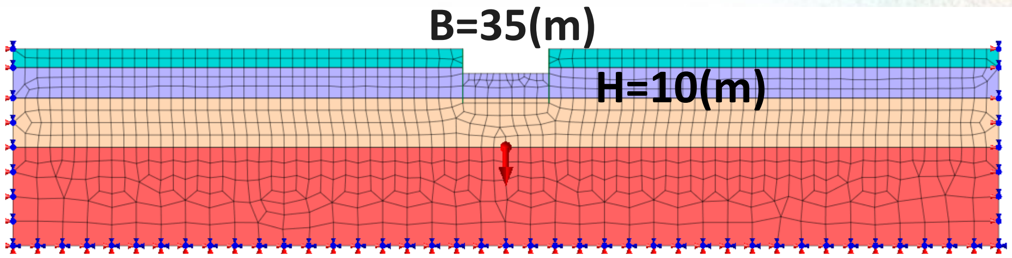


Part1.1.2 三維過渡區-1

空間效應	比例	工程含意
三維過渡區 *(3D Transition Zone)*	L/B =2 ~4	擋土結構與鄰近地層的變形行為，從角落的「顯著角隅束制（三維效應）」逐漸轉變、演進至中央「平面應變狀態(2D 行為)」之間的中間過渡區塊。

L=70(m) / B=35 (m) / H=10(m)





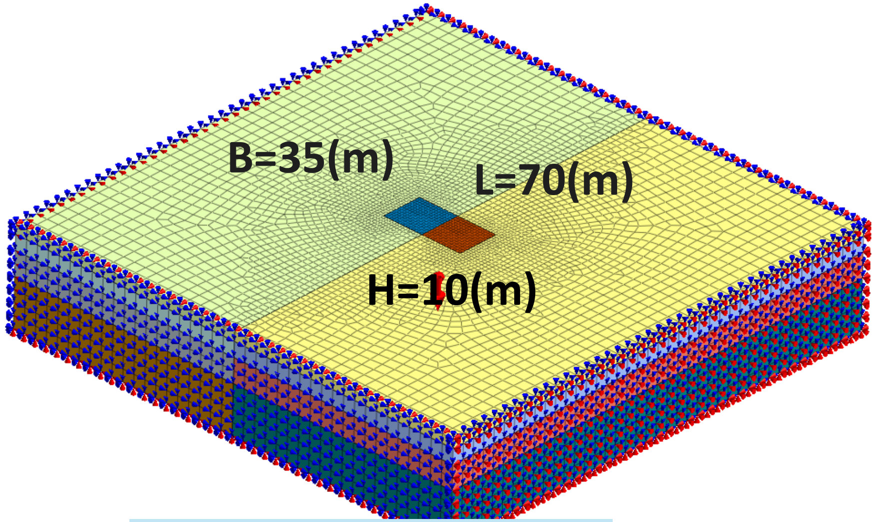
GTS NX 2D模型

粉砂層(0~-7.6m)

風化土壤(-7.6~-20m)

大寮層(-20~-40m)

風化岩 (-40~-80m)

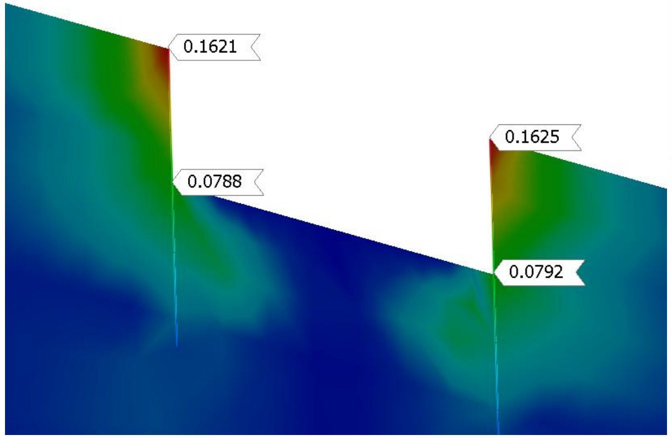


GTS NX 3D模型

開挖區域Element Size=2.5
非開挖區域Element Size=5
外側Element Size=10

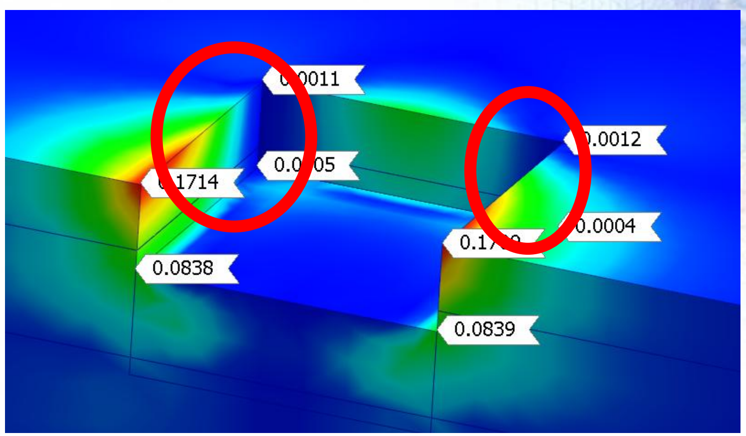
Part1.1.2 三維過渡區-2

GTS NX 2D-Txz水平位移(m)



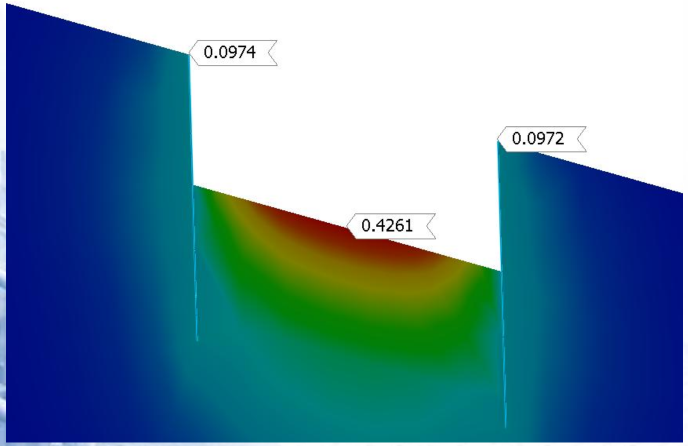
GTS NX 3D-Txz水平位移(m)

長邊(L)
顯著三維效
應區
(0.2~0.25)L

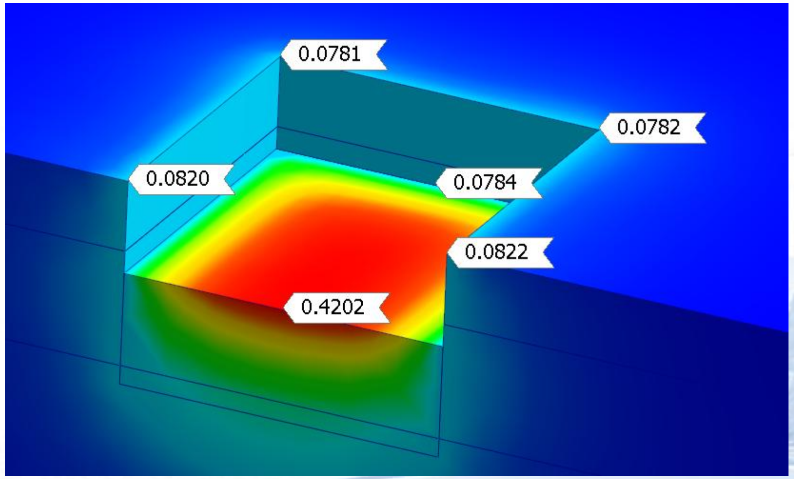


短邊(B)
全段均處
於顯著三
維效應區

GTS NX 2D-地表沉陷(m)



GTS NX 3D-地表沉陷(m)

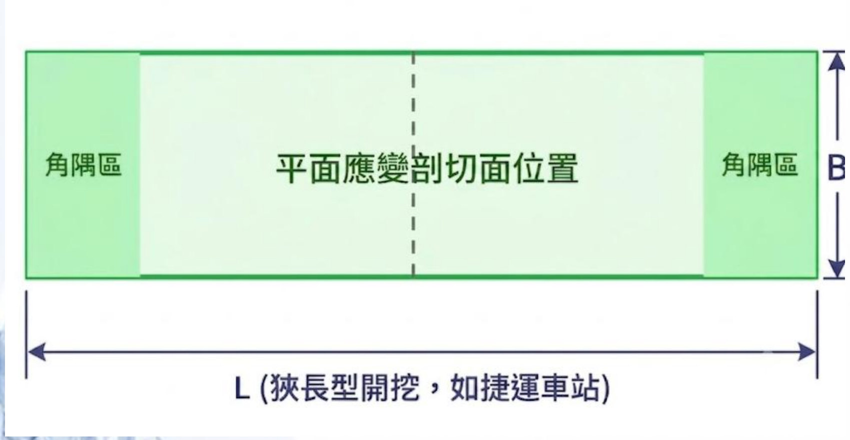


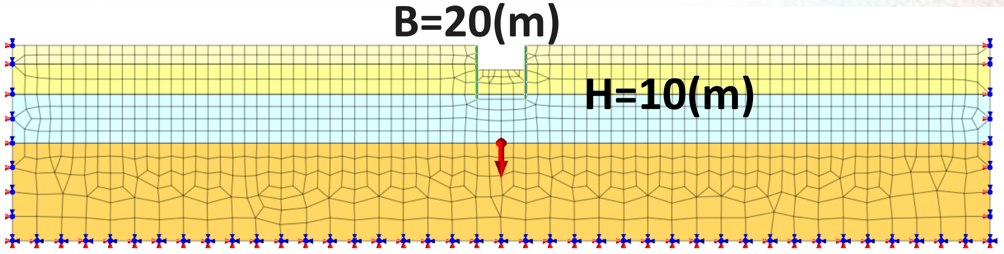
L=70(m) / B=35 (m) / H=10(m)

Part1.1.3 平面應變區-1

空間效應	比例	工程含意
平面應變區 *(Plane Strain Zone)*	L/B > 6	大尺寸基坑或地下工程開挖中，平面應變區(Plane Strain Zone)是指遠離轉角、開挖開口或端牆的中央區域。在此區域內，沿著開挖縱軸方向的開挖長度遠大於開挖深度與寬度，使得縱向應變趨近於零。

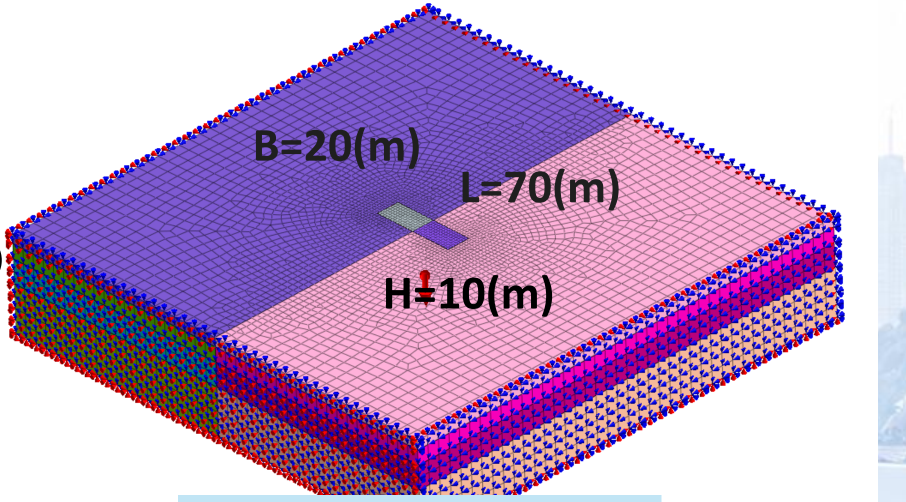
L=70(m) / B=20 (m) / H=10(m)





GTS NX 2D模型

粉砂層(0~-7.6m)
風化土壤(-7.6~-20m)
大寮層(-20~-40m)
風化岩 (-40~-80m)

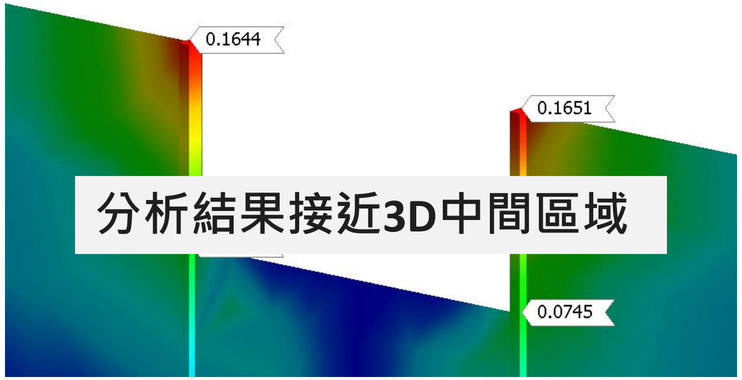


GTS NX 3D模型

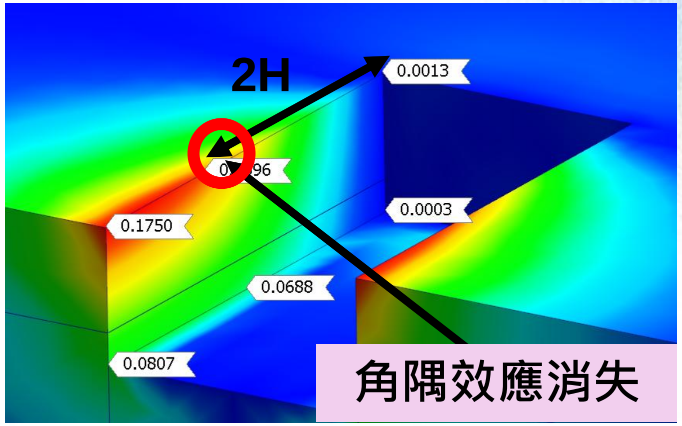
開挖區域Element Size=2.5
非開挖區域Element Size=5
外側Element Size=10

Part1.1.3 平面應變區-2

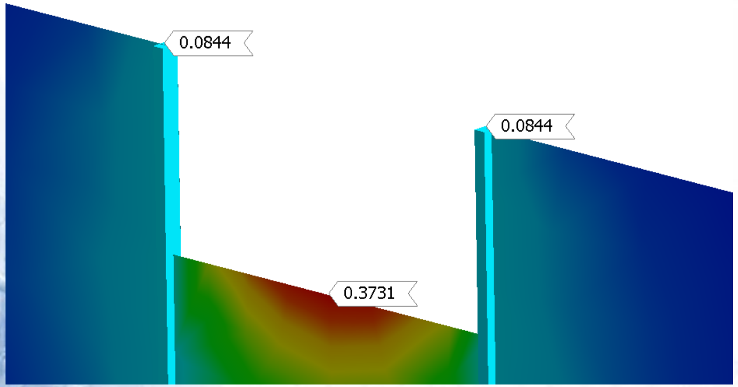
GTS NX 2D-Txz水平位移(m)



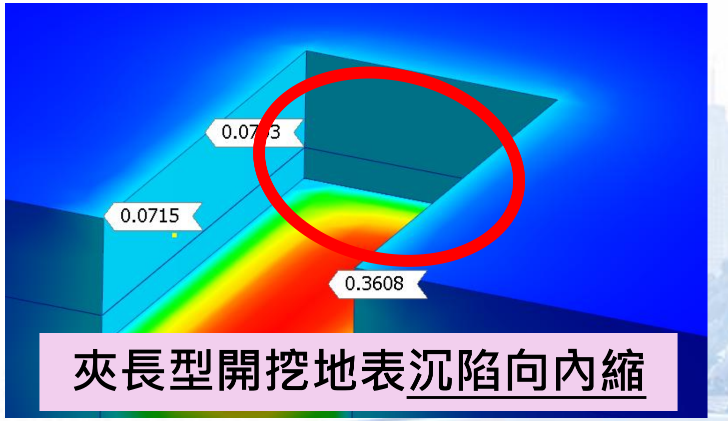
GTS NX 3D-Txz水平位移(m)



GTS NX 2D-地表沉陷(m)



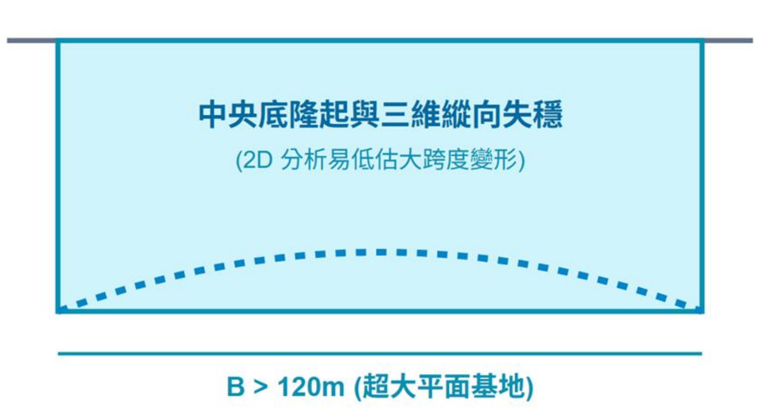
GTS NX 3D-地表沉陷(m)



Part1.2特殊空間效應之影響-1

判斷標準	尺寸
超寬開挖區 *(Ultra-wide Excavation Zone)*	B/H > 4~6

L=150(m) / B=120 (m) / H=10(m)



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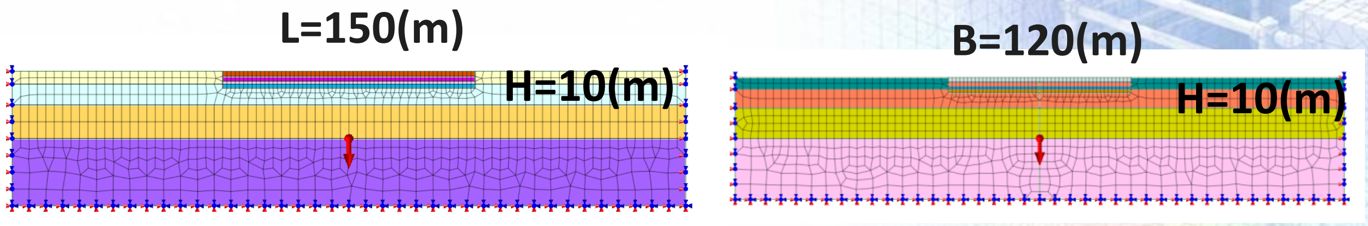
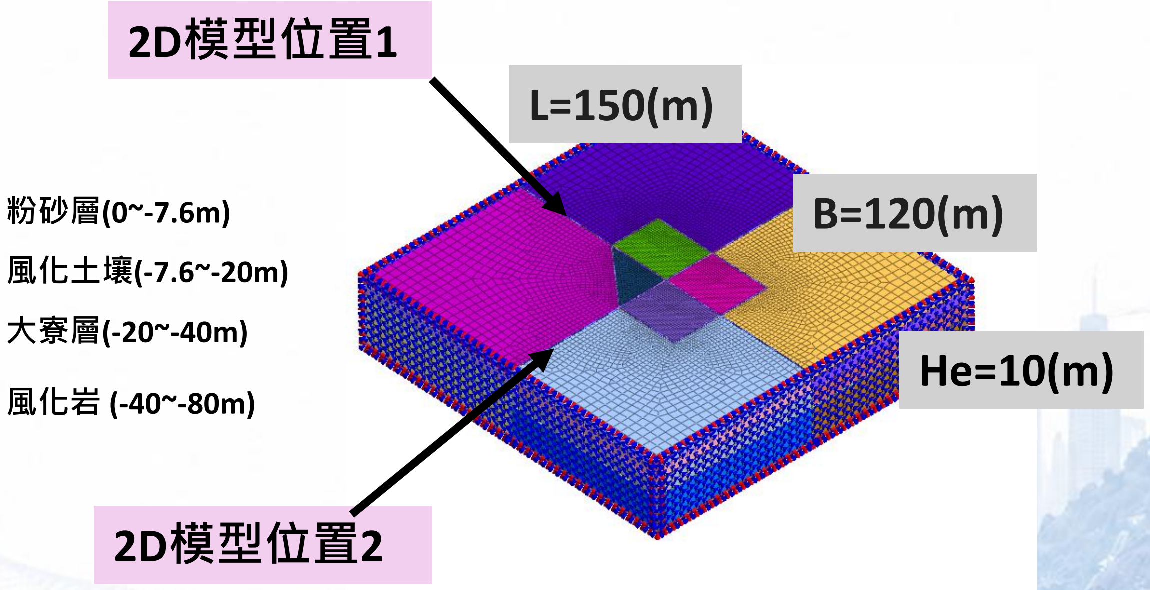
非開挖區域Element Size=5
外側Element Size=10



GTS NX 2D模型

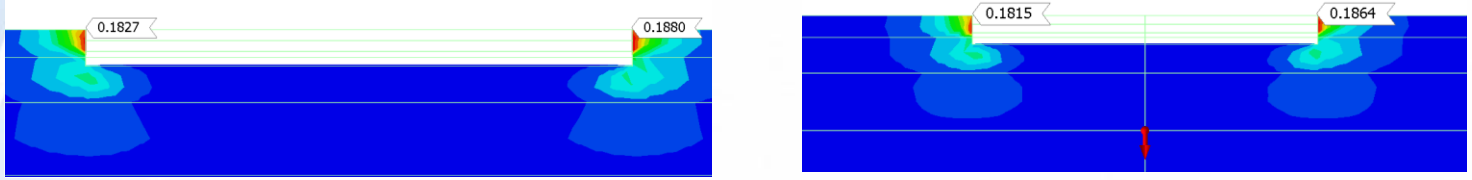


GTS NX 3D模型

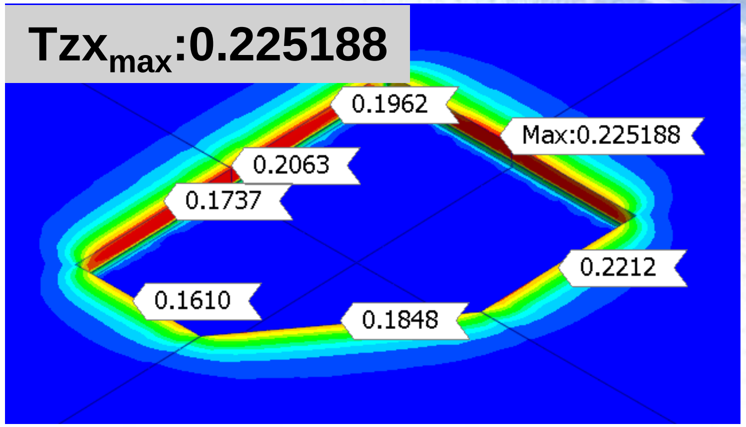
Part1.2特殊空間效應之影響-2

GTS NX 2D-Txz水平位移(m)

Tzx_{max}:0.1880

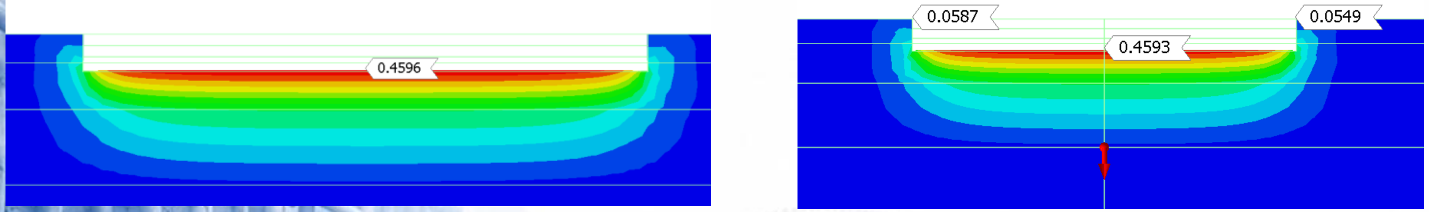


GTS NX 3D-Txz水平位移(m)

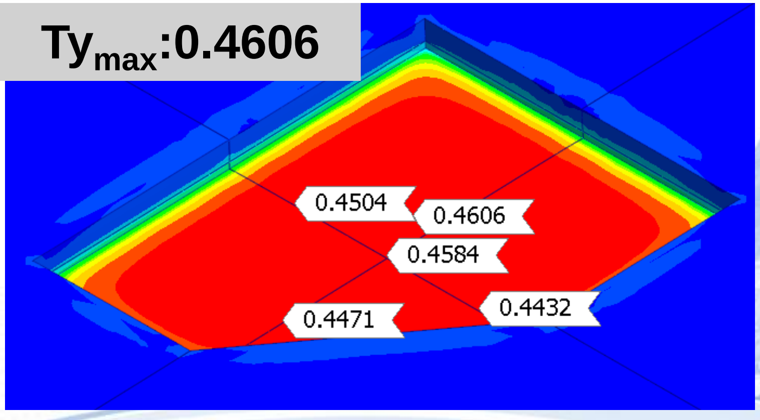


GTS NX 2D-地表沉陷(m)

Ty_{max}:0.4596



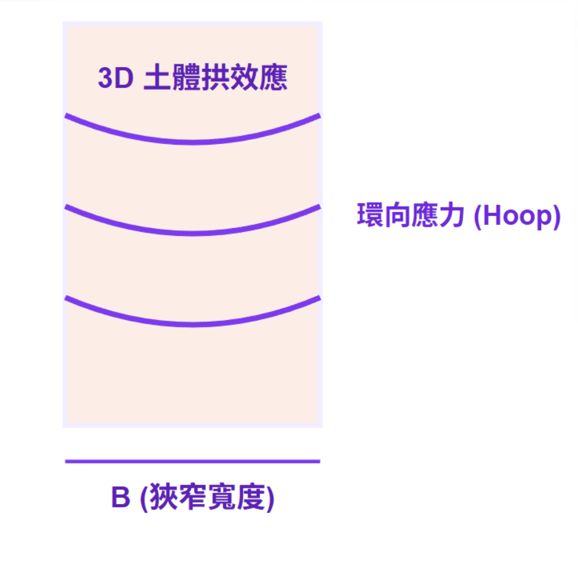
GTS NX 3D-地表沉陷(m)



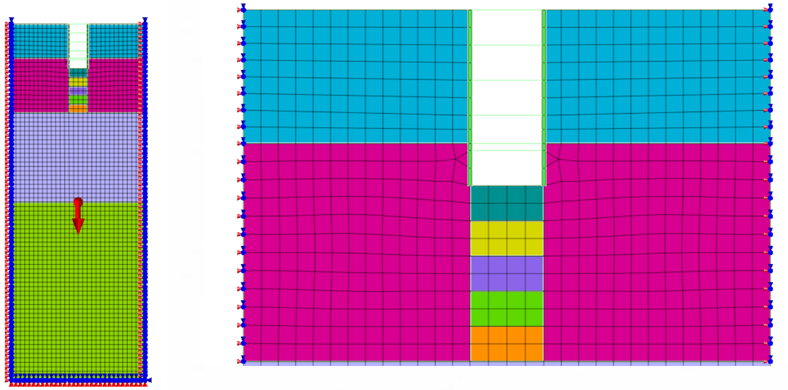
Part1.2特殊空間效應之影響-3

判斷標準	比例
狹窄豎井與溝渠區 *(Narrow Shaft / Trench Zone)*	B/He < 1.0

D=4.2(m) / H=2(m)/預鑄環片t=0.2m

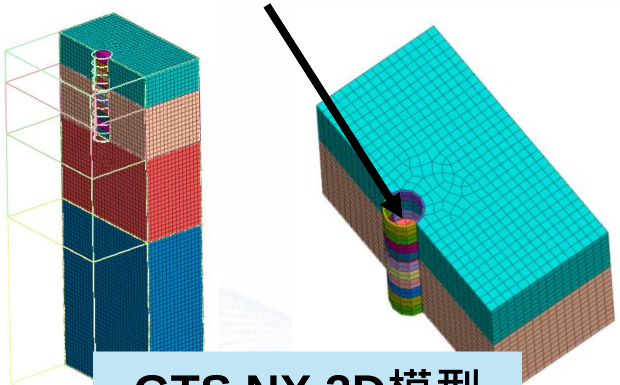


預鑄環片使用1D Beam元素代替



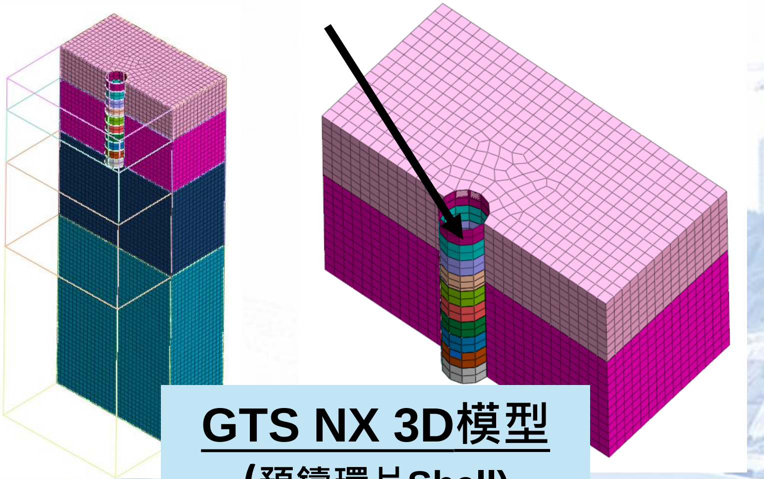
GTS NX 2D模型

預鑄環片使用Solid元素



GTS NX 3D模型
(預鑄環片Solid)

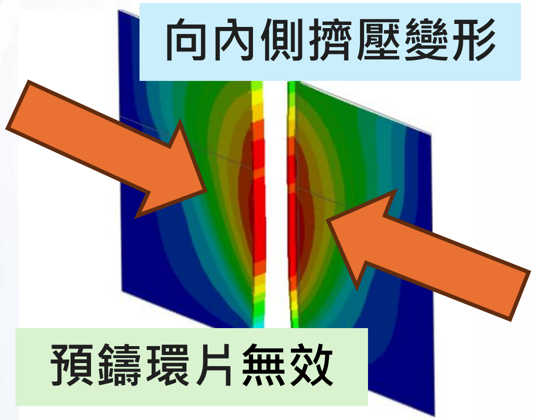
預鑄環片使用Shell元素



GTS NX 3D模型
(預鑄環片Shell)

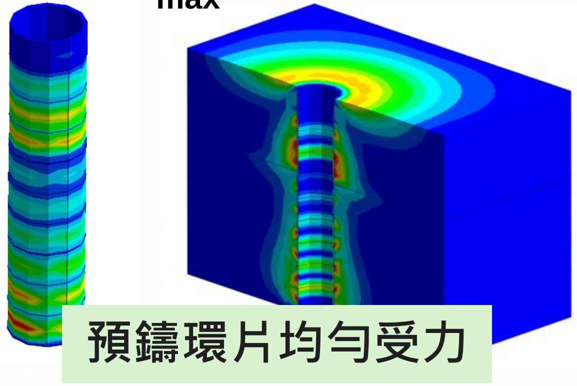
Part1.2特殊空間效應之影響-4

GTS NX 2D-Txz水平位移(m)



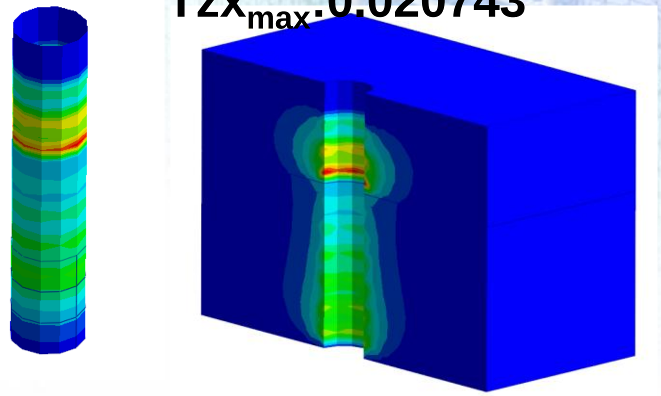
GTS NX 3D-Txz水平位移(m)
(預鑄環片Solid)

Tzx_{max}:0.06458

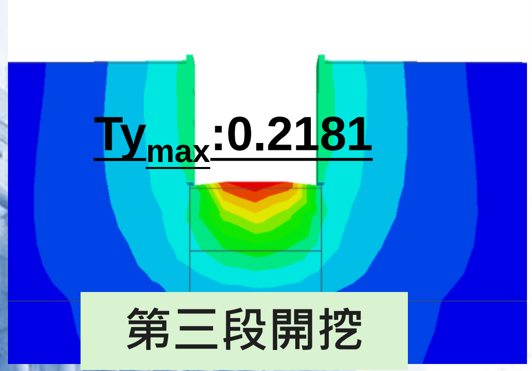


GTS NX 3D-Txz水平位移(m)
(預鑄環片Shell)

Tzx_{max}:0.020743

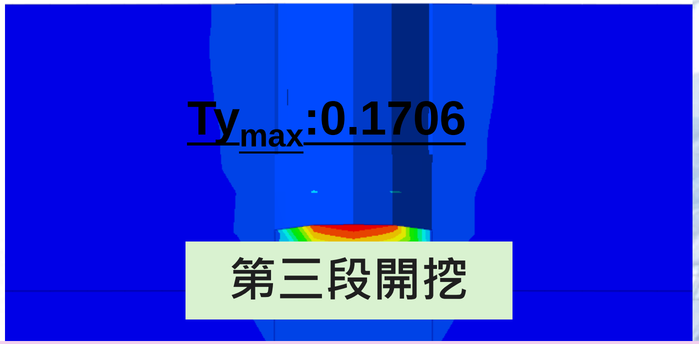


GTS NX 2D-地表沉陷(m)



GTS NX 3D-地表沉陷(m)
(預鑄環片Solid)

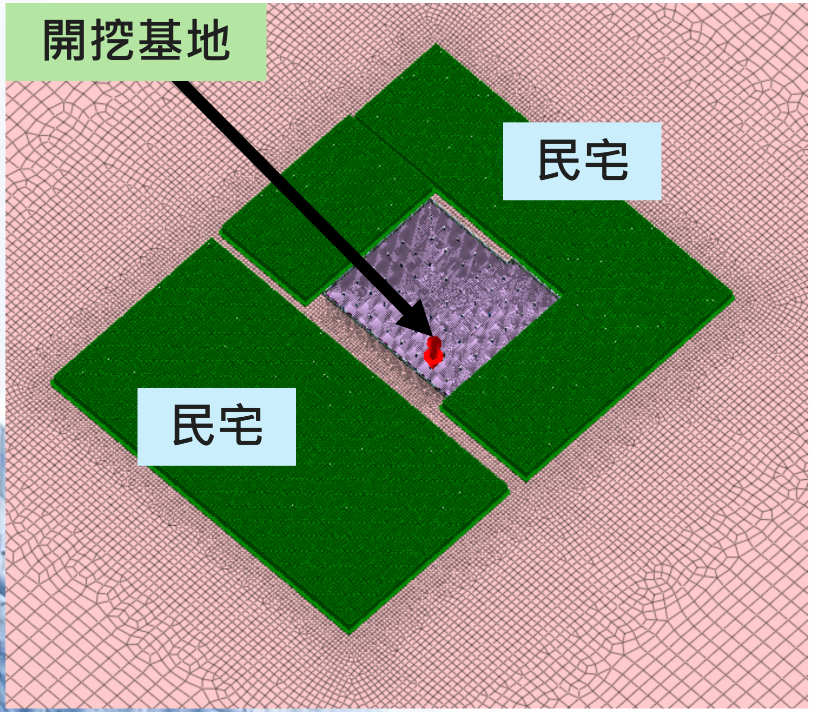
GTS NX 3D-地表沉陷(m)
(預鑄環片Shell)

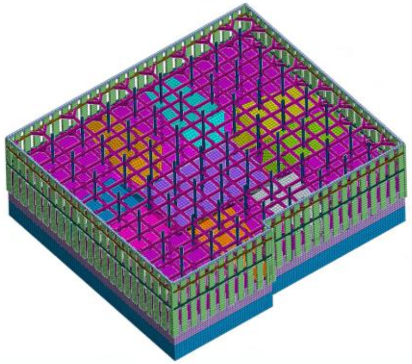


Shell Element： 基於薄/厚板殼理論，厚度僅為一個數值參數 t。法線變形受平面假定限制，無法計算混凝土壁厚內部的真實徑向擠壓與三維泊松效應。

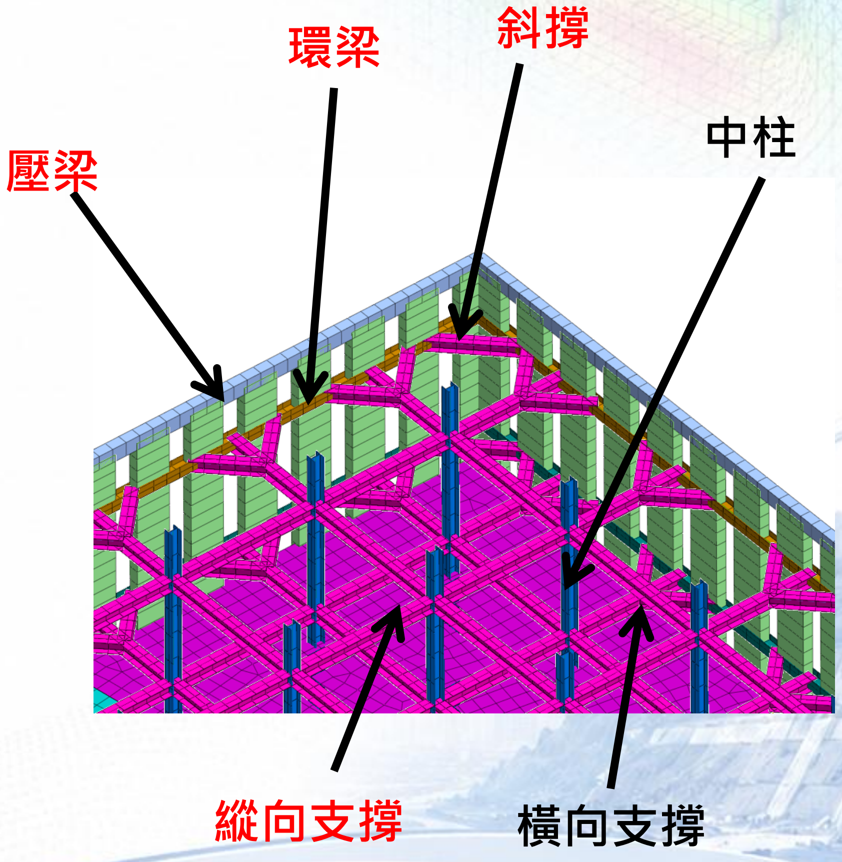
Part1.3 側向支撐與空間構架配置之複雜性-1

2D分析無法精確模擬斜撐與角隅段之空間集中應力，和複雜的擋土支撐結構，與特殊開挖方式。





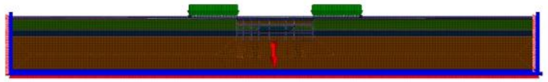
2D分析無法有效定義
縱向支撐/壓梁/環梁/斜撐



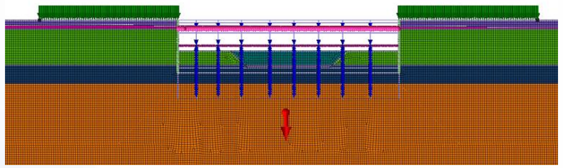
Part1.3 側向支撐與空間構架配置之複雜性-2

2D分析

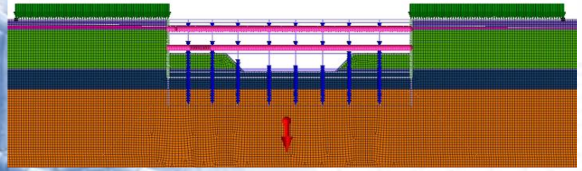
開挖第1階段



開挖第2階段

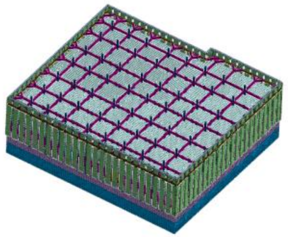


開挖第3_0階段

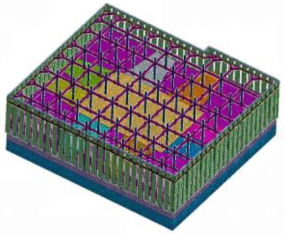


3D分析

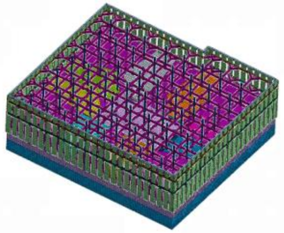
開挖第1階段



開挖第2階段



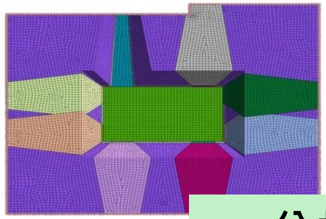
開挖第3_0階段



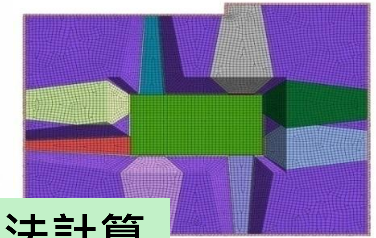
島式開挖

高度依賴空間幾何與三維應力重分配的開挖工法，若採用 2D模型分析，會因為簡化假設與實際力學行為嚴重衝突而無法得到合理的分析結果。

開挖第3_1階段

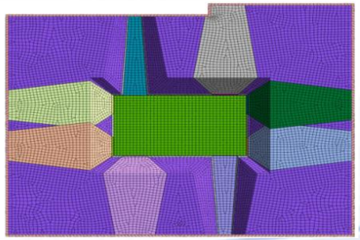


開挖第3_3階段

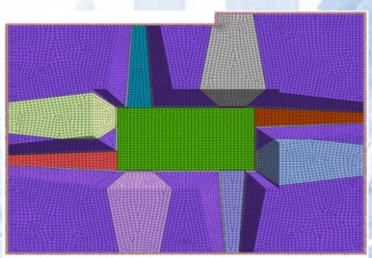


2D分析無法計算

開挖第3_2階段

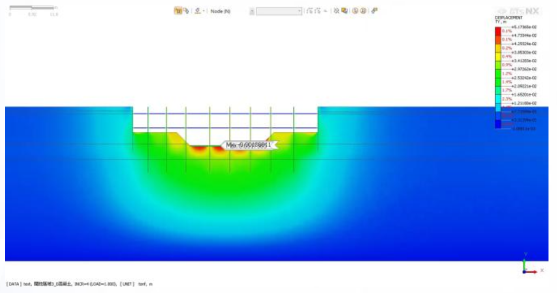


開挖第3_4階段

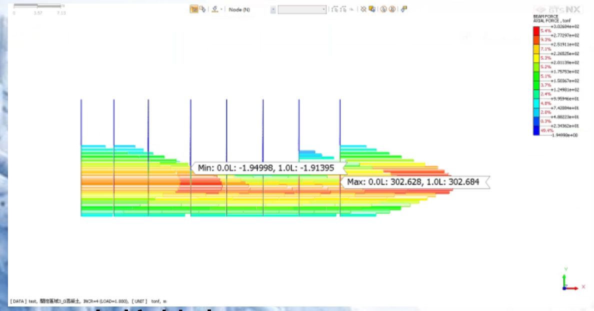


Part1.3 側向支撐與空間構架配置之複雜性-3

GTS NX 2D



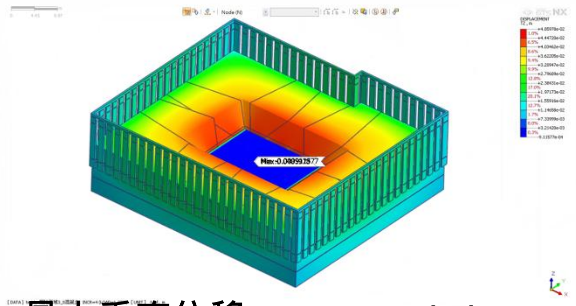
最大垂直位移:0.0517365 (m)



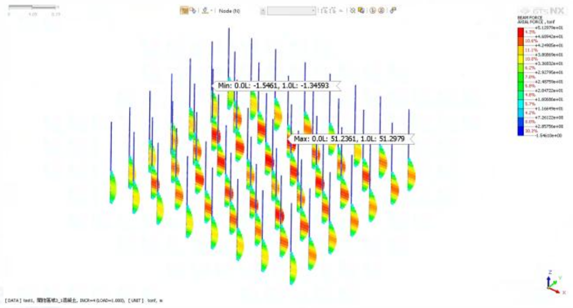
中柱軸力
Max:302.628(tonf)
Min:-1.94998(tonf)

GTS NX 3D

擋土柱Solid元素
(virtual Beam 得到相關設計參數)



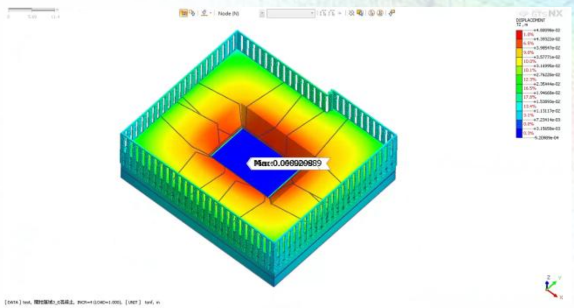
最大垂直位移: 0.0485978(m)



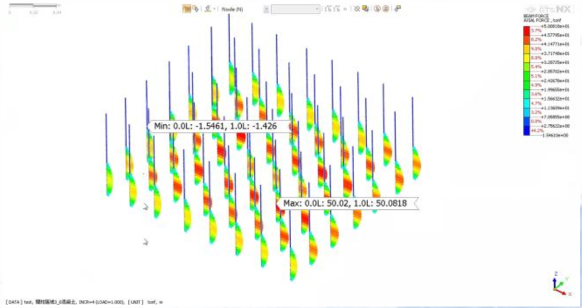
中柱軸力
Max:51.2979(tonf)
Min:-1.5461(tonf)

GTS NX 3D

擋土柱1D Beam元素



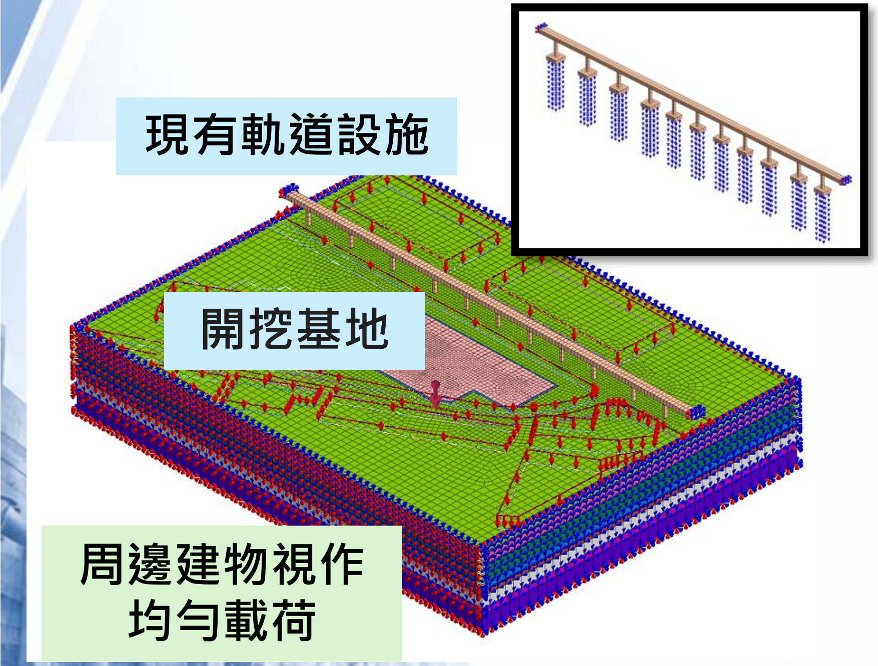
最大垂直位移:0.0480098 (m)

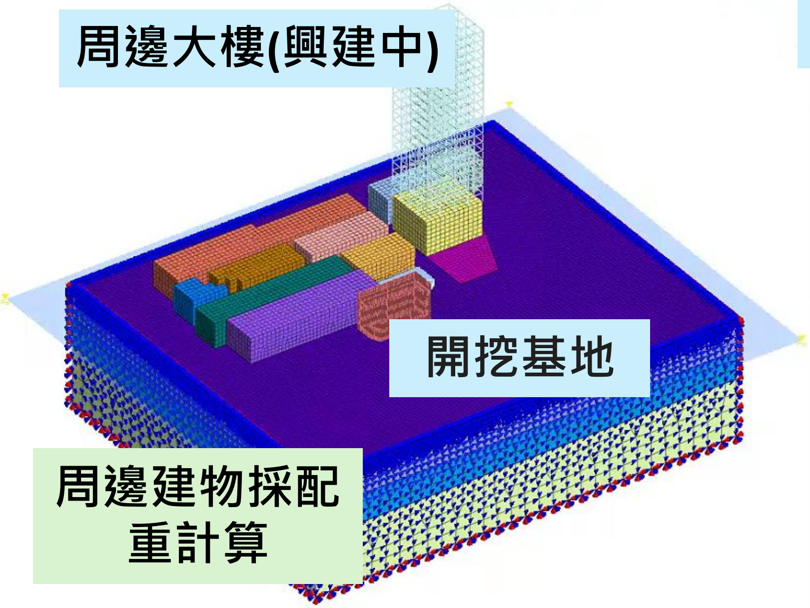


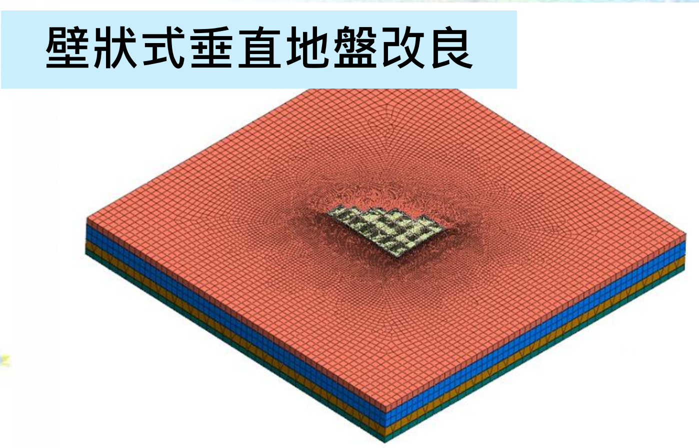
中柱軸力
Max:50.0818(tonf)
Min:-1.5461(tonf)

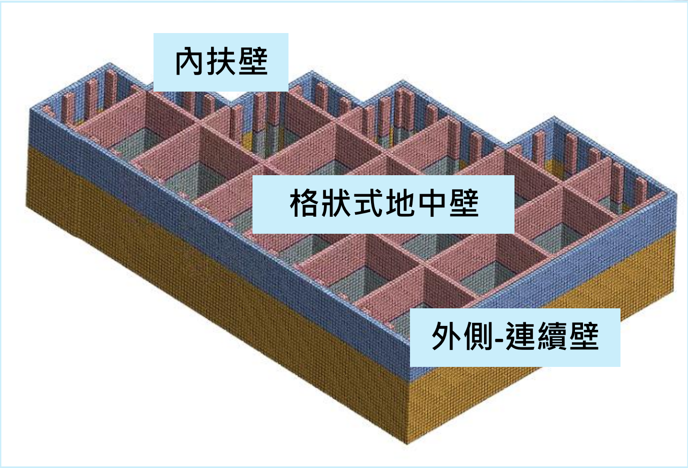
Part1.4 鄰近結構與地下設施 3D 互制

深開挖分析中，當鄰近有高敏感結構(如捷運隧道、古蹟、樁基新建物或大型管線)時，2D 分析或經驗公式無法真實反映空間邊界效應。此時，採用 3D 分析是評估複雜「土壤-結構-地下設施互制(SSI)」最精確的方法。









Part2.邊坡

2D和3D模型對於分析之影響

2D和3D模型對於分析之影響

- **Part2.邊坡**
  - Part2.1 空間效應之影響
  - Part2.2 平直斜坡
  - Part2.3 凸脊坡/山脊
  - Part2.4 凹谷坡/谷地
  - Part2.5 節理岩體模型強度折減法
  - Part2.6 人工邊坡

Part2.1 空間效應之影響

邊坡分析

1.強度折減法 (Strength Reduction Method ,SRM)

2D SRM:觀察單一剖面內土體破壞。

3D SRM:立體空間中變形與破壞。

2.極限平衡法 (Limit Equilibrium Method ,LEM)

2D LEM:將二维切片劃分為垂直的切條。

3D LEM:平面上將滑體投影區域網格化，將整個三維滑動體分割成許多底面為多邊形的垂直柱體。

極限平衡法 LEM未考量應力-變形關係，不考慮土體的剛度，無法提供開挖或加固過程中的地表位移與變形預測。

比較項目	2D SRM 邊坡分析	3D SRM 邊坡分析
基本假設	平面應變假設	真實的三維空間幾何模型
破壞面形狀	曲線(圓弧或折線)	三維曲面(碗狀/勺狀/非規則幾何)
側向邊界阻力	未考慮 (忽略側壁摩擦)	完整考慮 (包含兩側端部效應)
安全係數 (FS)	**保守(依照經驗判斷切面)**	**較符合真實大範圍空間**
複雜幾何與載重	僅適用斷面一致、長條型結構	適用集中載重、轉角開挖、不規則地形
計算與建模成本	低，建模迅速，適合敏感度與機率分析	高，網格劃分較複雜，計算耗時較長

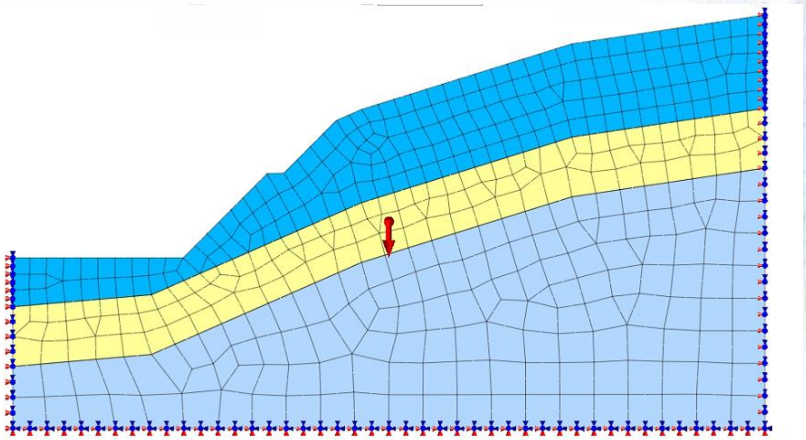
Part2.1 空間效應之影響

2D 分析為「平面應變(Plane Strain)」假設，即假定邊坡在垂直剖面方向無窮延伸，忽視了側向邊界約束與邊界剪應力；而 3D 分析 則能完整考慮滑體的三維空間幾何、側向抗剪力、空間應力重分佈以及地下水的三維匯集或發散效應。

分析項目	平直斜坡	凸脊坡/山脊	凹谷坡/谷地
2D 計算結果	略偏保守 (符合實際)	評估失真 (無法反映臨空與發散)	過度保守 (忽略側向拱效應抗力)
FS_{3D}/ FS_{2D} 比值	1.05 ~1.15	(1)純力學計算 < 1.0 (0.85~0.98) (2)考慮水文滲流，接近 1.0 或略高。	大於 1.0 (可達 1.15 ~1.40+)
側向剪切阻力	一般	側向抗力增益有限	3D拱效應極強
滲流	地下水流向與坡面法線平行，2D 與 3D 滲流場差異極小。	降雨或地下水在山脊處會向兩側發散，地下水位不易蓄積，孔隙水壓力通常較低，有利於穩定。	地表水與地下水會向谷地中心匯集，導致谷底孔隙水壓力高漲、飽和度提升，顯著降低土體有效應力。
2D 分析之影響	2D 分析略偏保守，但具備足夠代表性且計算效率高。	2D 分析無法捕捉山脊的多向臨空應力釋放與三維發散破壞路徑，容易誤判最危險滑動面的位置與方向。	2D 分析在力學上大幅低估安全係數(忽略側向拱效應)，無法精準模擬3D地下水匯集對谷底的沖刷與孔壓提升。

Part2.2 平直斜坡

分析項目	平直斜坡
2D 計算結果	略偏保守 (符合實際)
FS_{3D}/ FS_{2D} 比值	1.05 ~1.15
側向剪切阻力	一般
滲流	地下水流向與坡面法線平行，2D 與 3D 滲流場差異極小。
2D 分析之影響	2D 分析略偏保守，但具備足夠代表性且計算效率高。

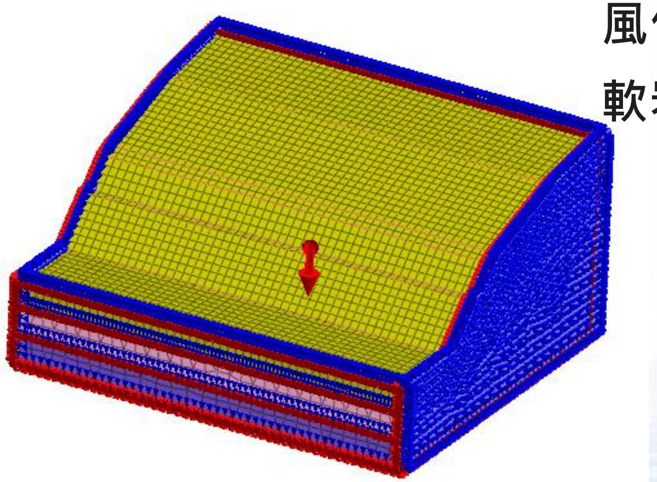


GTS NX 2D模型

風化土Element Size:1

風化岩Element Size:1.5

軟岩 Element Size:2



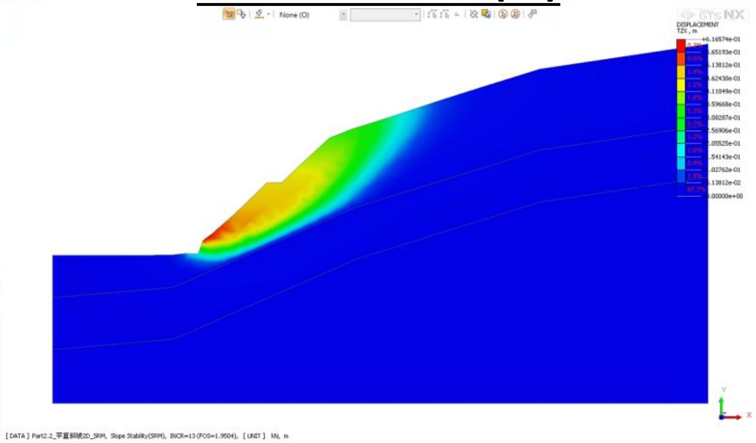
GTS NX 3D模型

Part2.2 平直斜坡

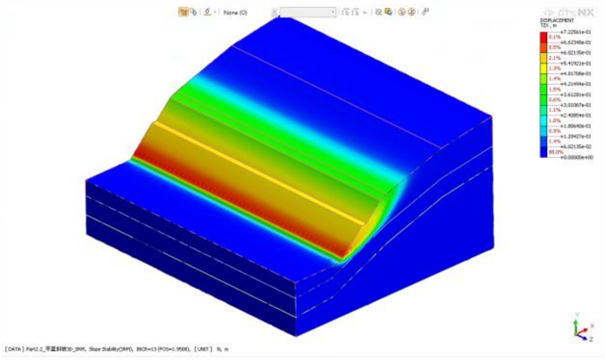
GTS NX 2D FOS:1.95039

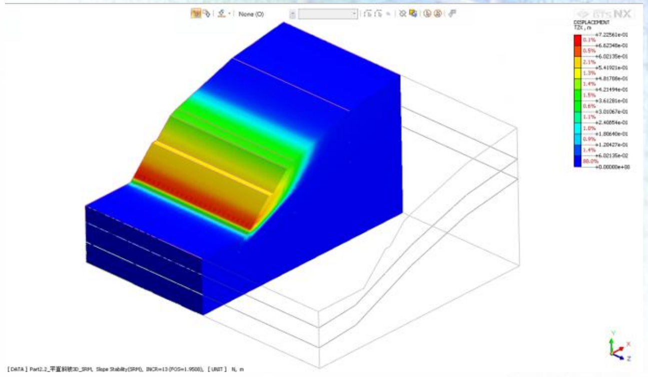
GTS NX 3D FOS:1.95078

Tzx Translation(m)

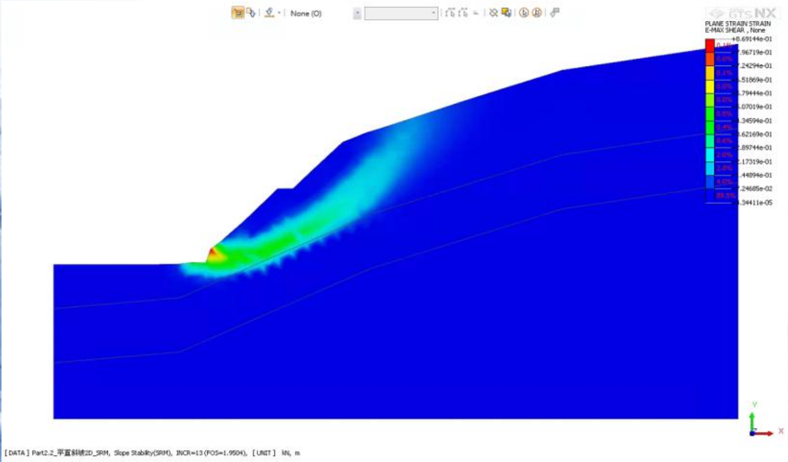


Tzx Translation(m)

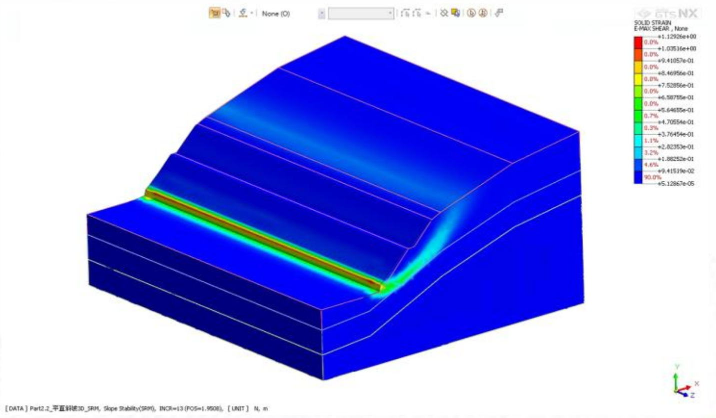


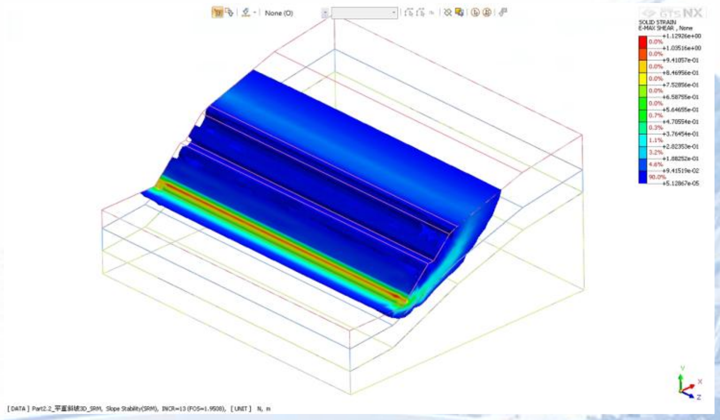


Maximum Shear Strain



Maximum Shear Strain

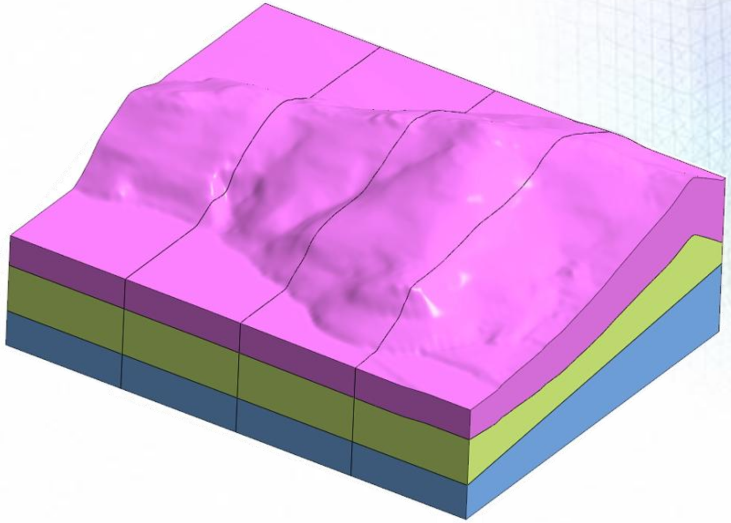


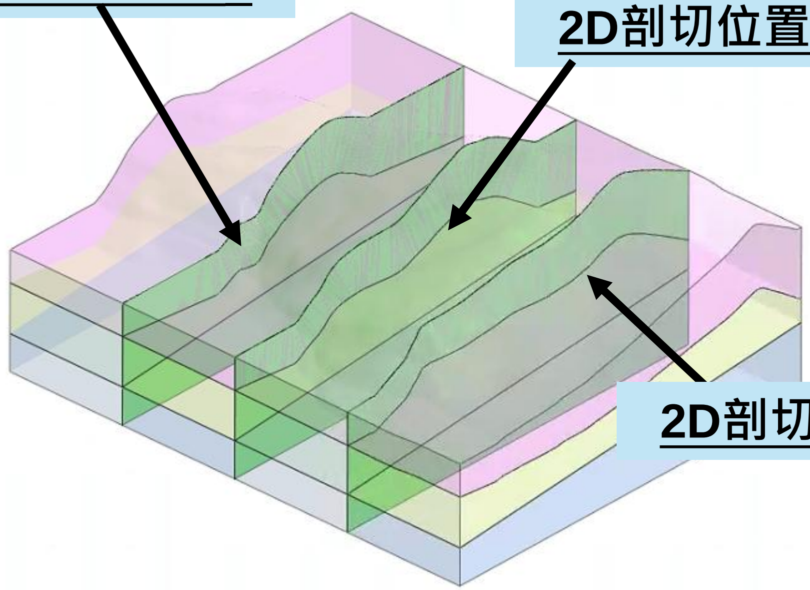


Part2.3 凸脊坡 / 山脊

分析項目	凸脊坡/山脊
2D 計算結果	評估失真 (無法反映臨空與發散)
FS_{3D}/ FS_{2D} 比值	(1)純力學計算 < 1.0 (0.85~0.98) (2)考慮水文滲流，接近 1.0 或略高。
側向剪切阻力	側向抗力增益有限
滲流	降雨或地下水在山脊處會向兩側發散，地下水位不易蓄積，孔隙水壓力通常較低，有利於穩定。
2D 分析之影響	2D 分析無法捕捉山脊的多向臨空應力釋放與三維發散破壞路徑，容易誤判最危險滑動面的位置與方向。

GTS NX 3D模型



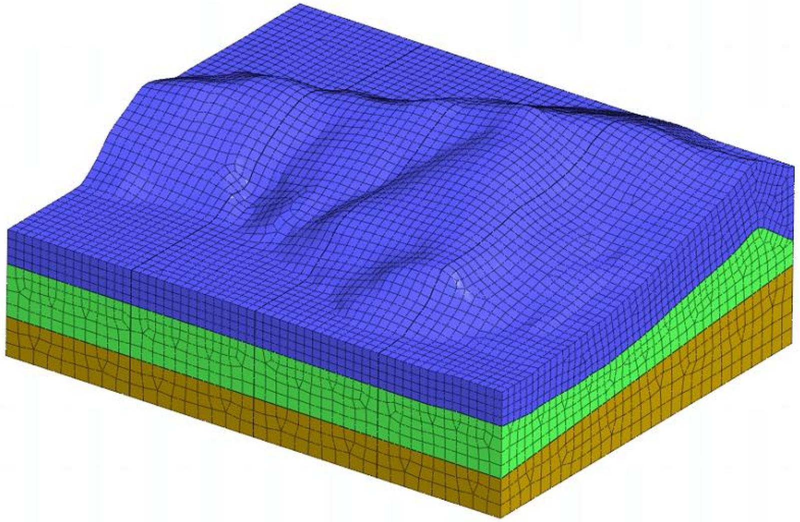


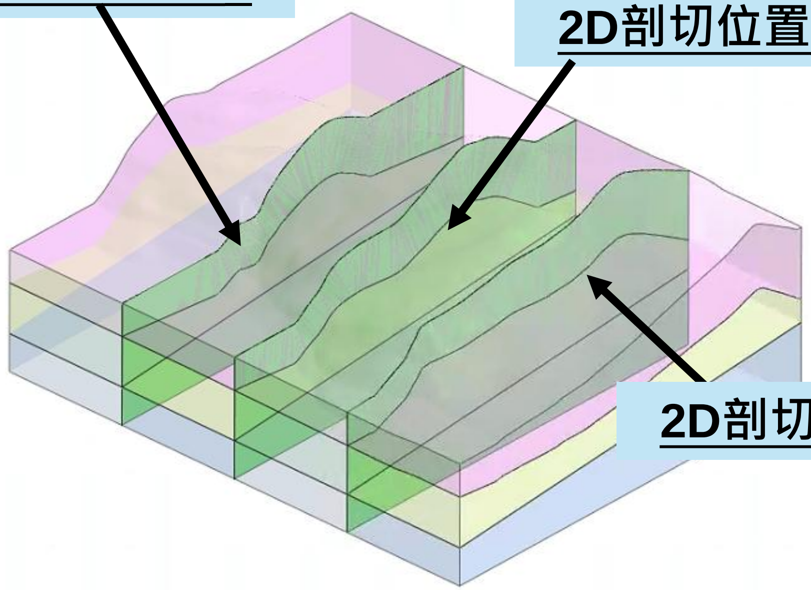
Part2.3 凸脊坡 / 山脊

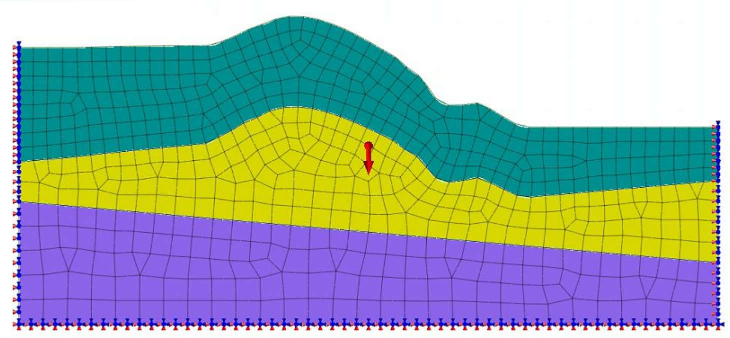
風化土Element Size:7.5

風化岩Element Size:10

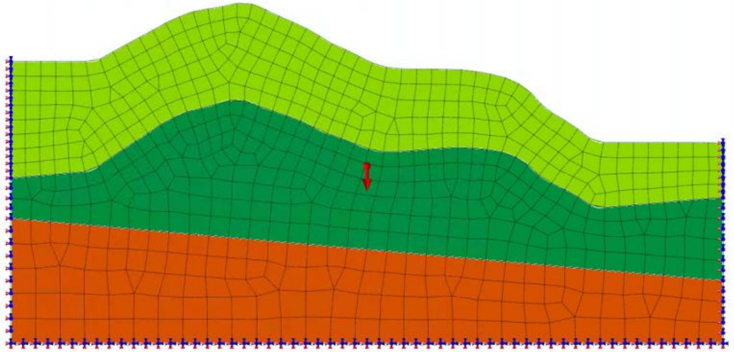
軟岩 Element Size:12.5



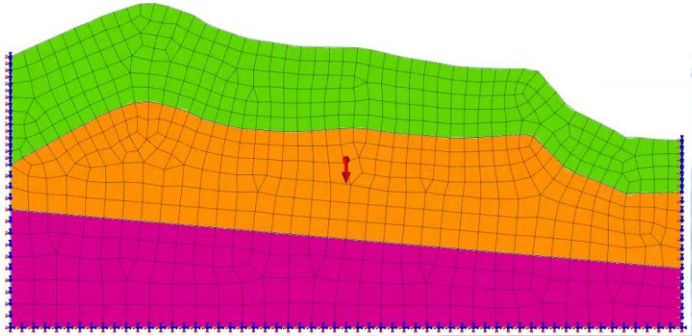




2D剖切位置1



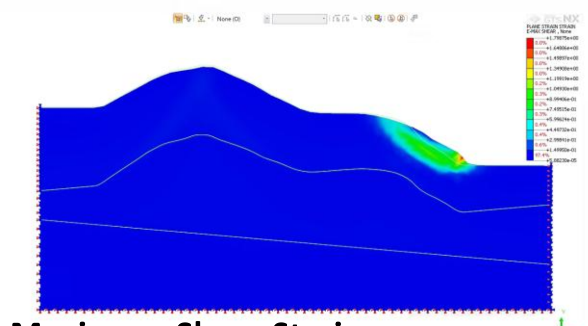
2D剖切位置2



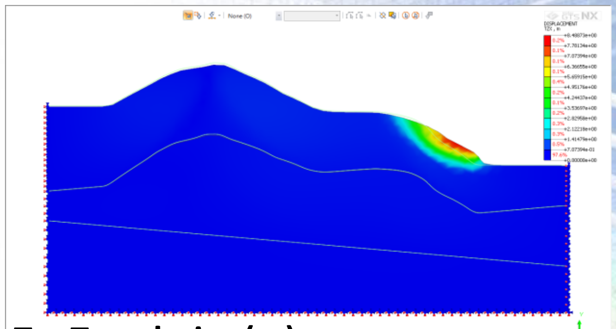
2D剖切位置3

Part2.3 凸脊坡 / 山脊

2D剖切位置2 FOS:1.5004

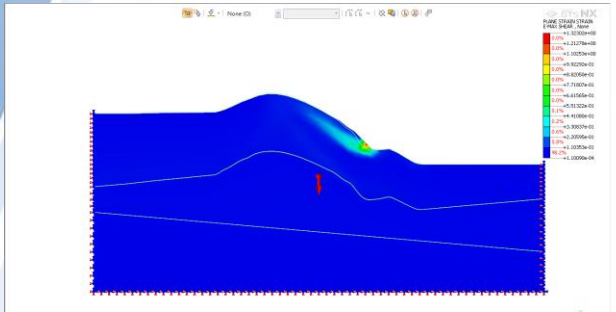


Maximum Shear Strain

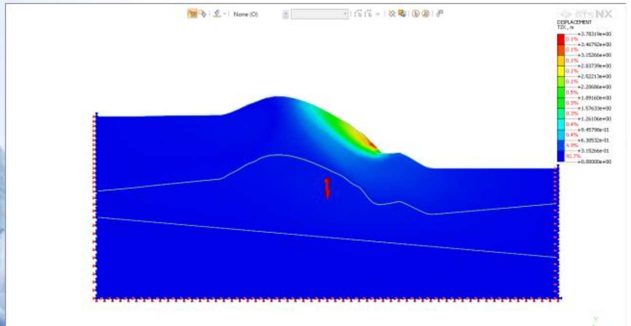


Tzx Translation(m)

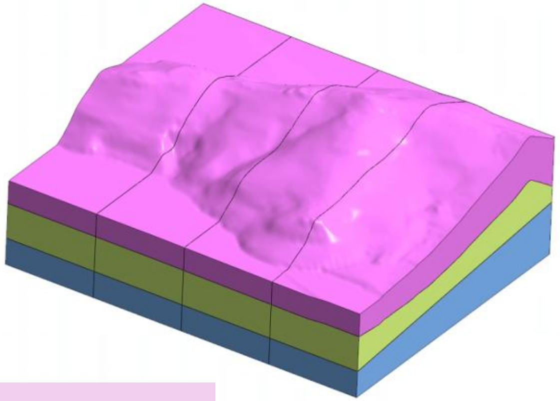
2D剖切位置1 FOS:1.27539



Maximum Shear Strain

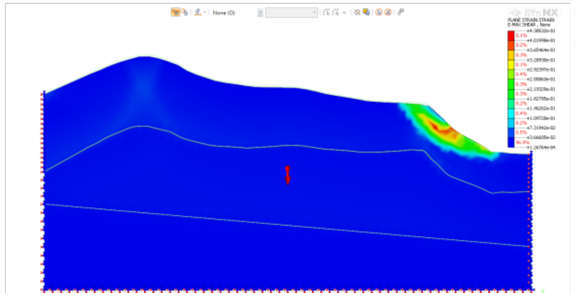


Tzx Translation(m)

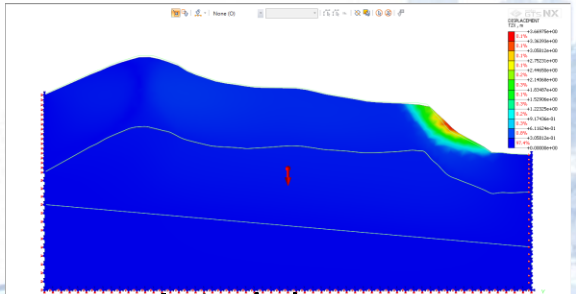


3D FOS:1.40312

2D剖切位置3 FOS:1.3750

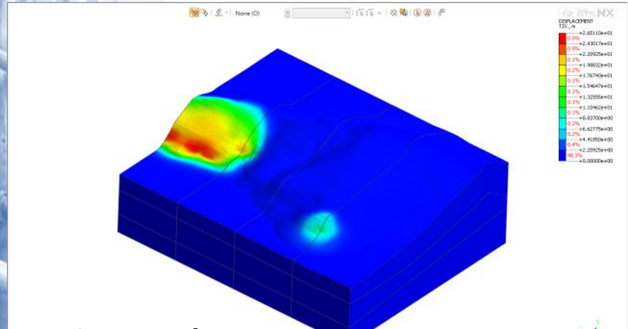


Maximum Shear Strain

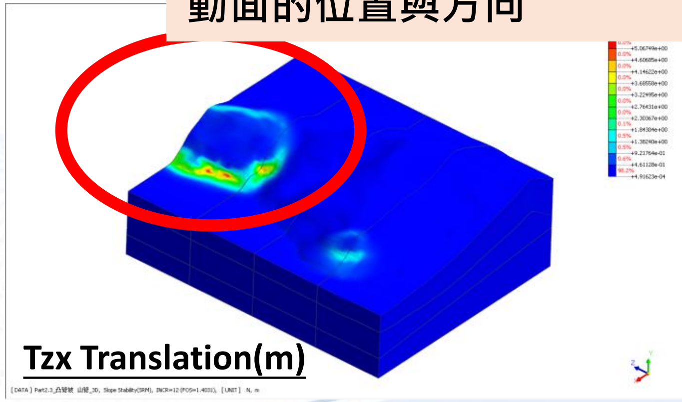


Tzx Translation(m)

2D分析可能誤判最危險滑動面的位置與方向



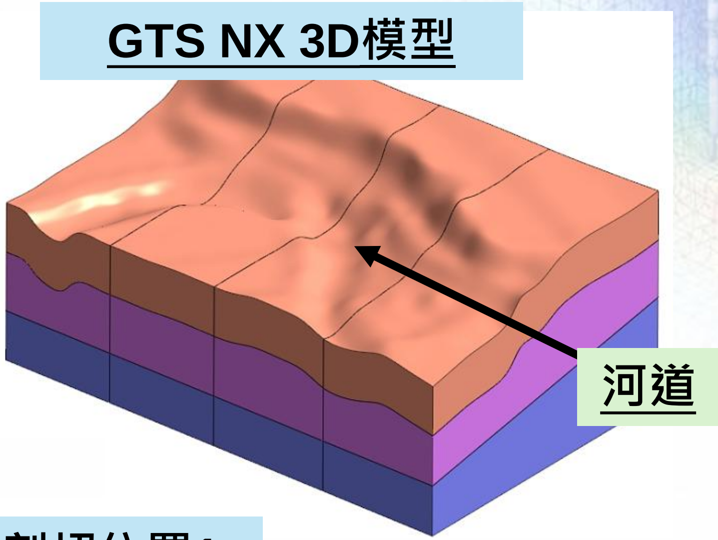
Maximum Shear Strain

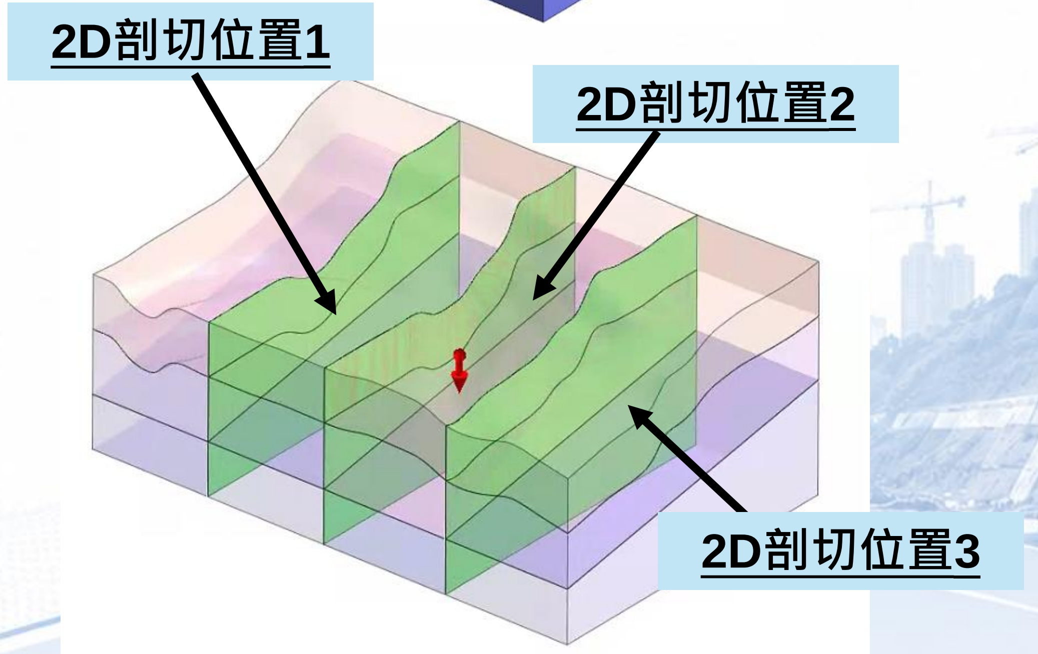


Tzx Translation(m)

Part2.4 凹谷坡 / 谷地

分析項目	凹谷坡/谷地
2D 計算結果	過度保守 (忽略側向拱效應抗力)
FS_{3D}/ FS_{2D} 比值	大於 1.0 (可達 1.15 ~1.40+)
側向剪切阻力	3D拱效應極強
滲流	地表水與地下水會向谷地中心**匯集**，導致谷底孔隙水壓力高漲、飽和度提升，顯著降低土體有效應力。
2D 分析之影響	2D 分析在力學上大幅低估安全係數(忽略側向拱效應)，無法精準模擬3D地下水匯集對谷底的沖刷與孔壓提升。



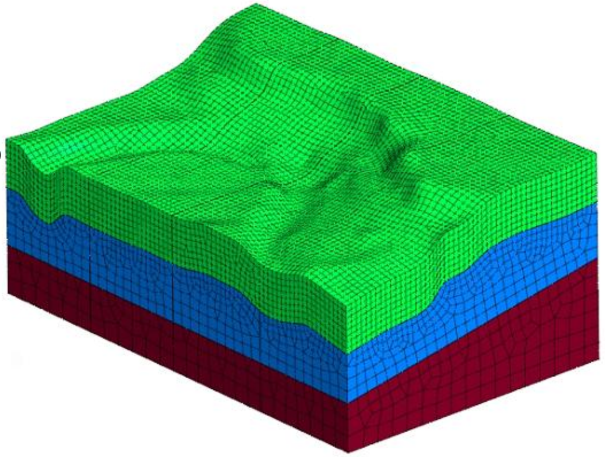


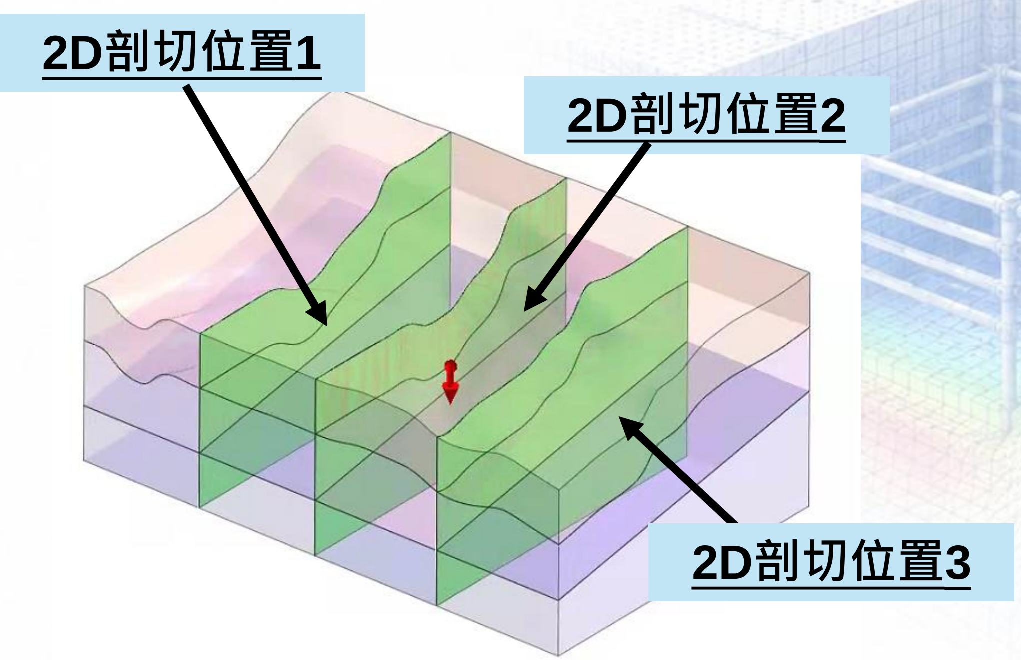
Part2.4 凹谷坡 / 谷地

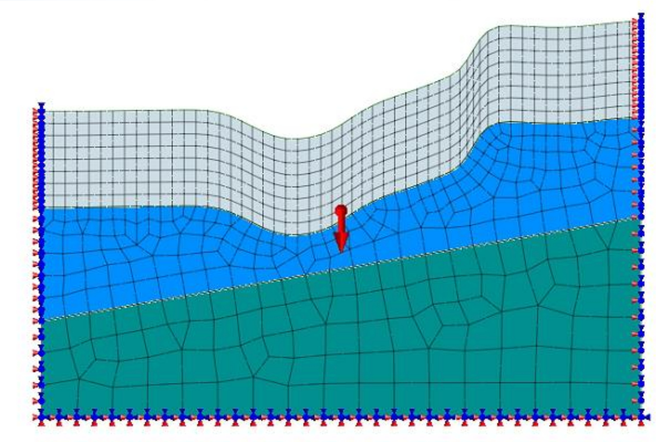
風化土Element Size:2.5

風化岩Element Size:5

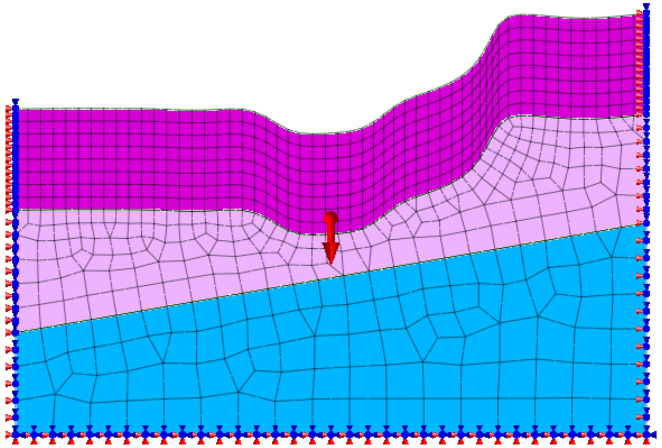
軟岩 Element Size:7.5



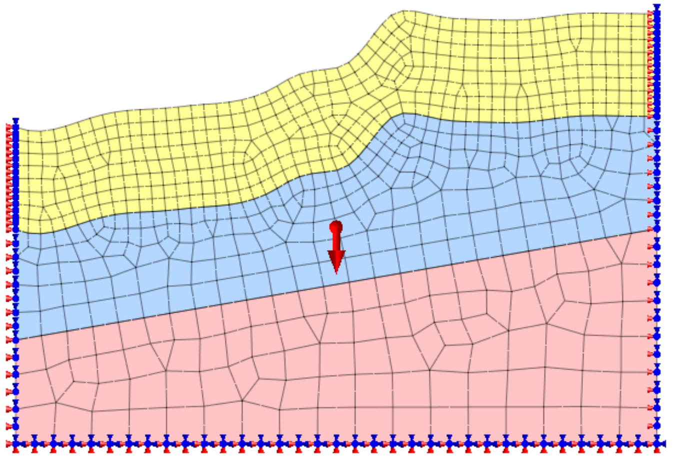




2D剖切位置1



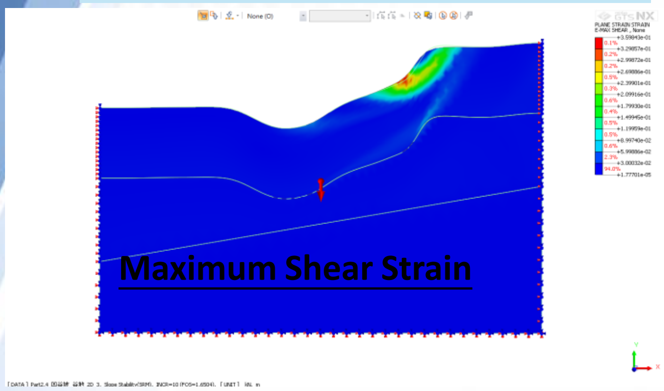
2D剖切位置2



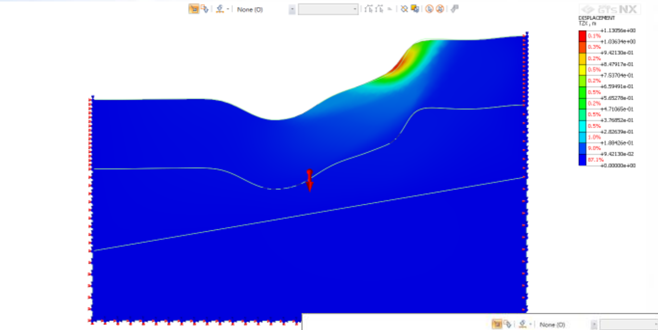
2D剖切位置3

Part2.4 凹谷坡 / 谷地

2D剖切位置1 FOS:1.65039

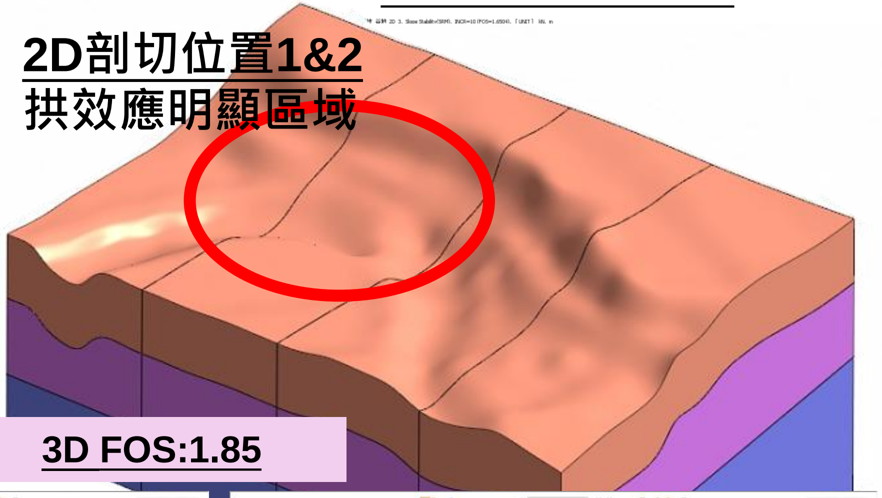


Maximum Shear Strain

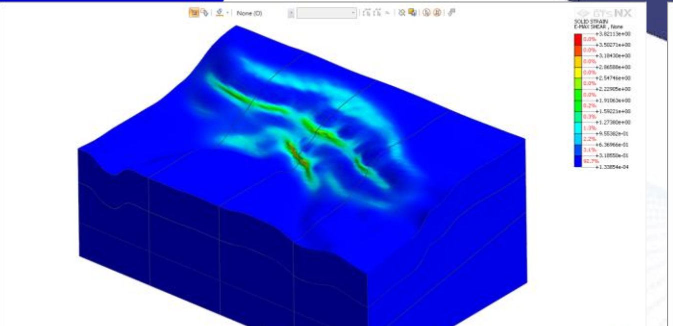


Tzx Translation(m)

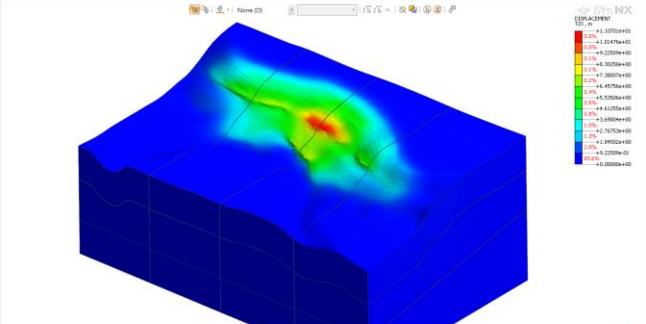
2D剖切位置1&2
拱效應明顯區域



3D FOS:1.85

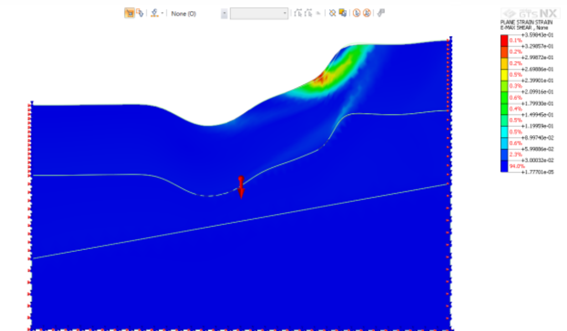


Maximum Shear Strain

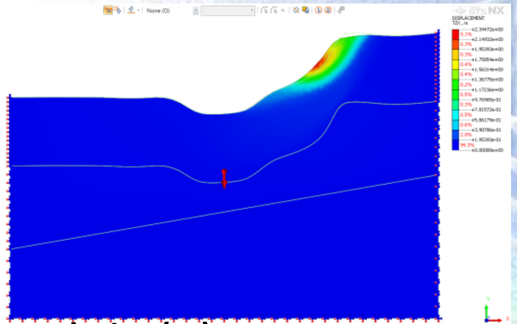


Tzx Translation(m)

2D剖切位置2 FOS:1.44687

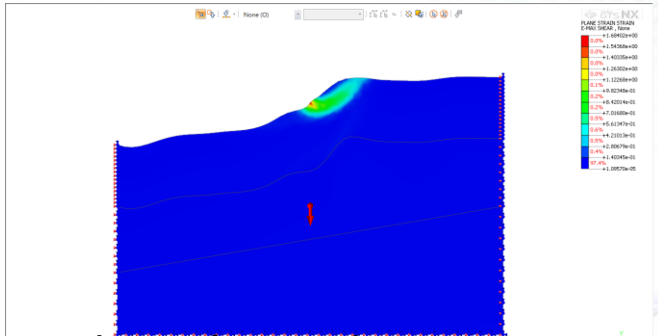


Maximum Shear Strain

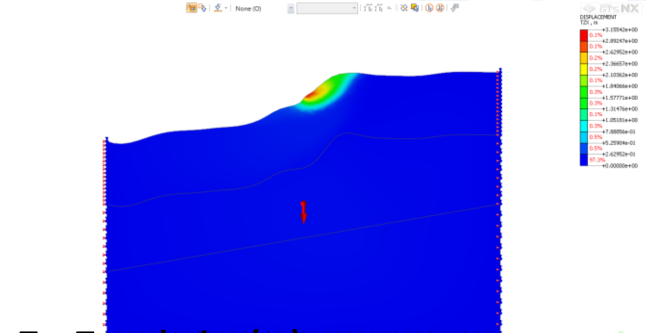


Tzx Translation(m)

2D剖切位置3 FOS:1.80078



Maximum Shear Strain



Tzx Translation(m)

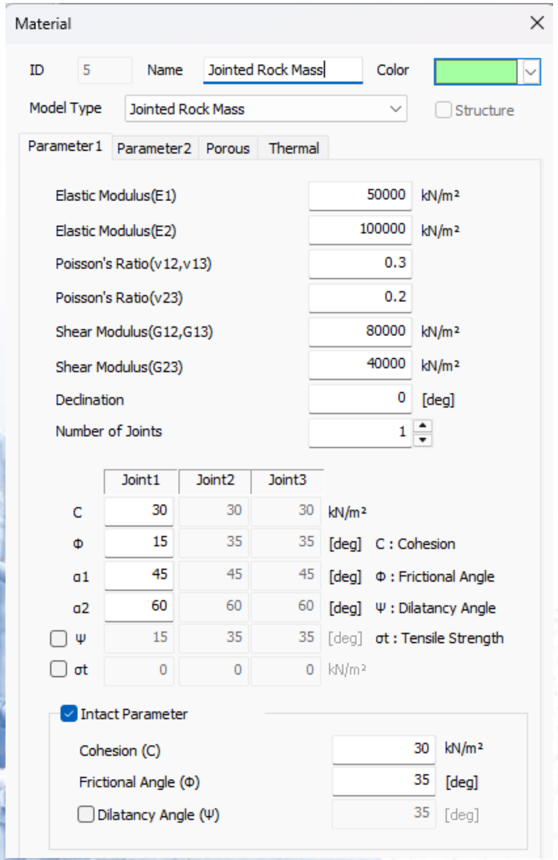
Part2.5 節理岩體模型強度折減法

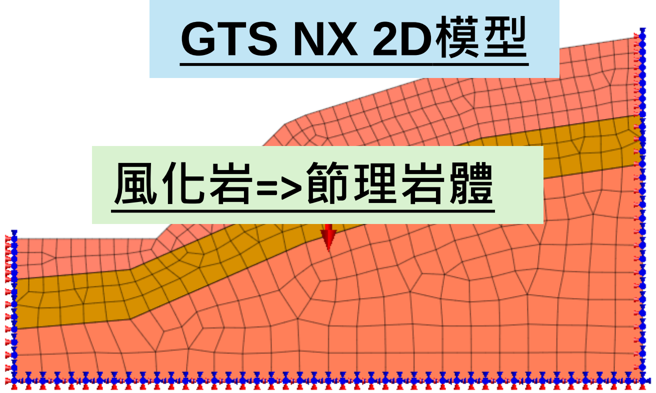
節理岩體模型(Jointed Rock Mass)

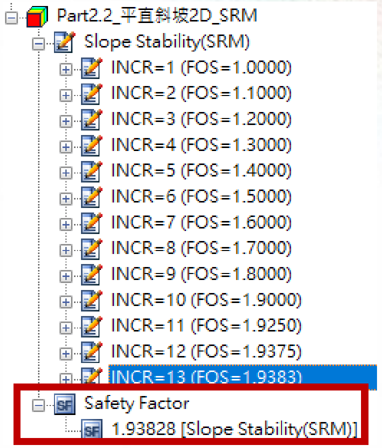
節理岩體是指被天然破裂面切割，分割成無數個完整岩塊的天然地質體。

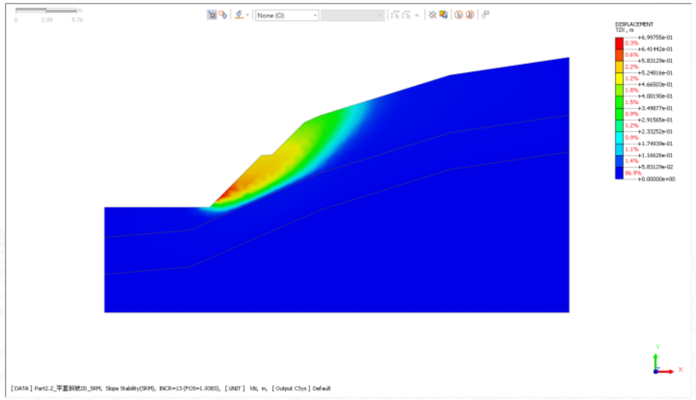
GTS NX節理岩體模型可模擬具有正交異向性(Orthotropic)材料特性的岩體，並可在分析過程中納入強度折減效應。它主要用於模擬含有明確弱面（如沉積層理、解理或天然節理組）的岩體行為。

Material > Orthotropic > Jointed Rock Mass

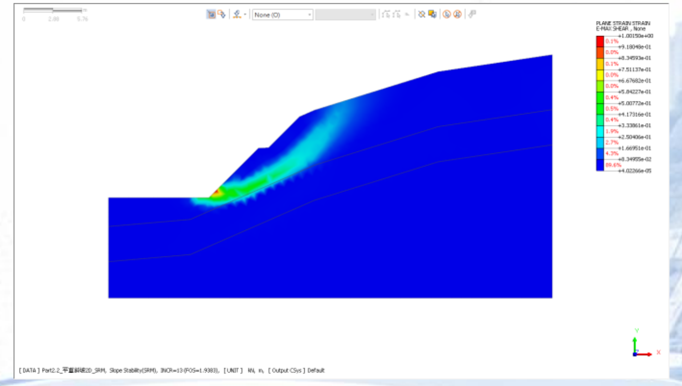








Txz Translation(m)

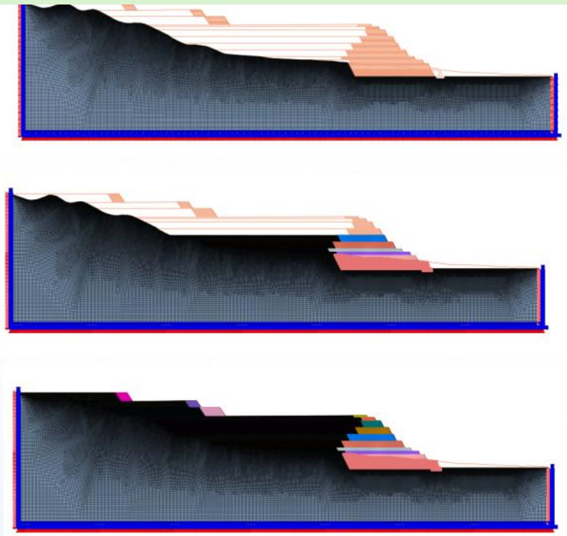


Maximum Shear Strain

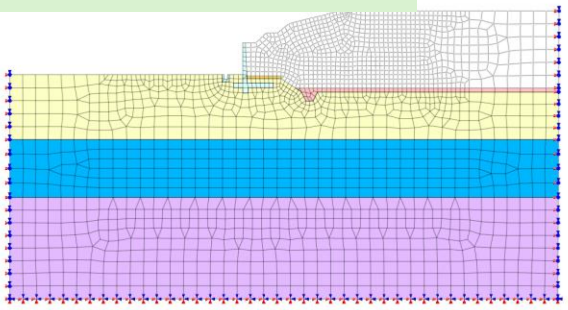
Part2.6 人工邊坡

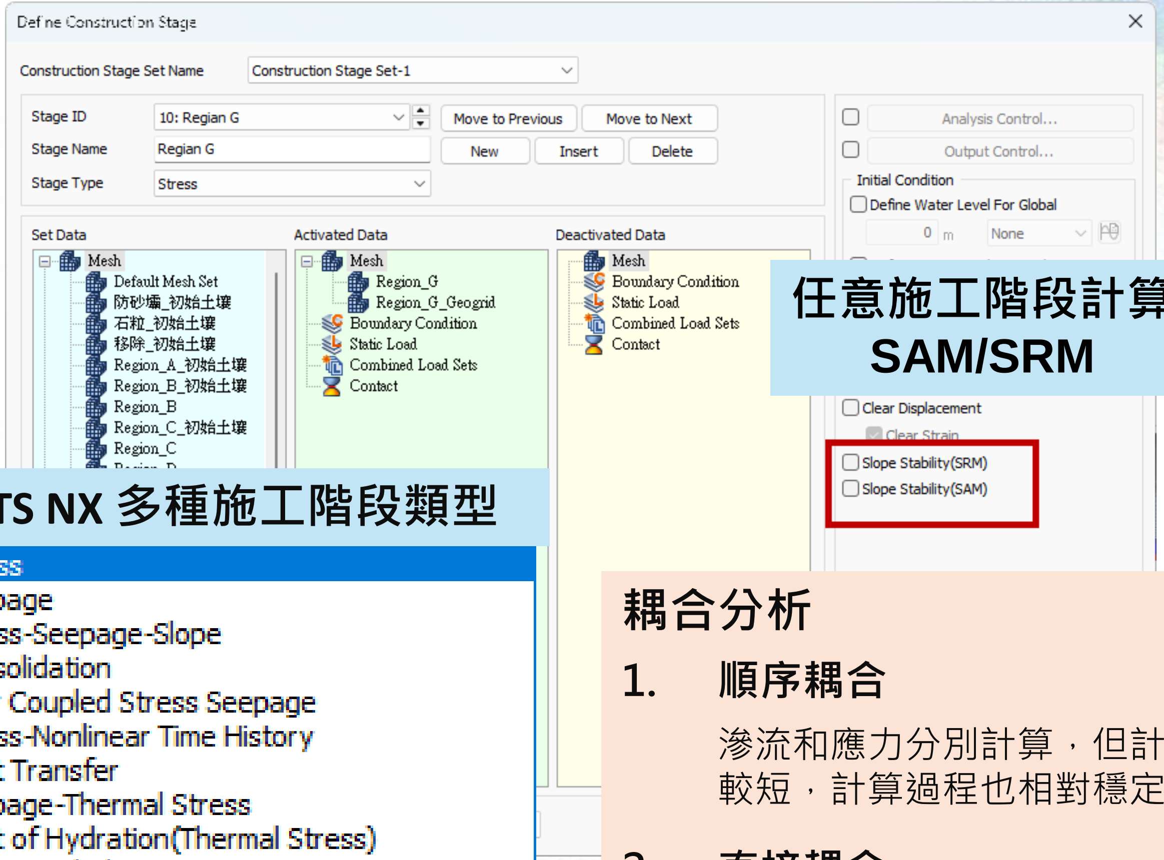
人工邊坡是因人類工程活動（如開發、開挖、填築土石等）而改變原有自然地形，或全新堆疊塑造而成的傾斜地面。與自然界經由數千萬年地質演變形成的「自然邊坡」不同，人工邊坡是在相對極短的時間內，透過人力或機械擾動土岩體所形成的。

回收掩埋場邊坡穩定計算



掩埋場擋土牆設計





任意施工階段計算 SAM/SRM

GTS NX 多種施工階段類型

- Stress
- Seepage
- Stress-Seepage-Slope
- Consolidation
- Fully Coupled Stress Seepage
- Stress-Nonlinear Time History
- Heat Transfer
- Seepage-Thermal Stress
- Heat of Hydration(Thermal Stress)
- Fully Coupled Stress Seepage Heat
- Stress-Seepage-Slope-Nonlinear Time History

耦合分析

1. **順序耦合**

   滲流和應力分別計算，但計算所需要時間較短，計算過程也相對穩定。

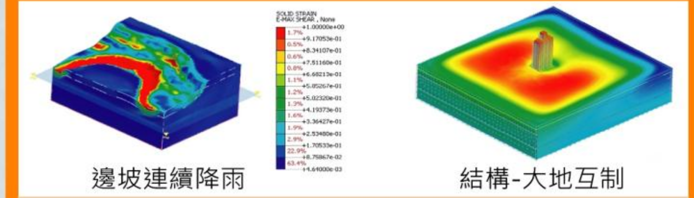
2. **直接耦合**

   滲流和應力同步計算，分析結果更符合現況，但計算所需要時間較長，計算過程也相對不穩定。

全方位工程模擬解決方案

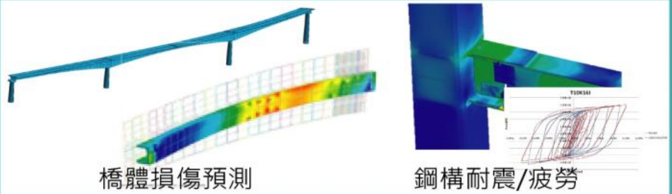
全方位工程模擬解決方案
One Platform, Every Solution

GTS NX 大地計算



2D/3D | 開挖 | 隧道 | 邊坡 | 滲流 | 壓密 | 動力

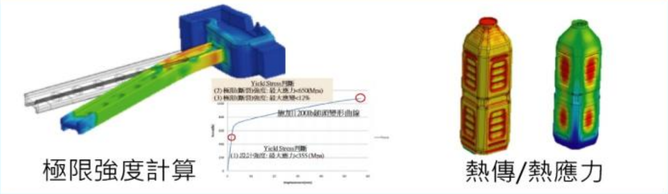
FEA NX 建築與橋梁



高階非線性 | 混凝土開裂/水化熱 | 鋼構耐震/疲勞 | 互制計算

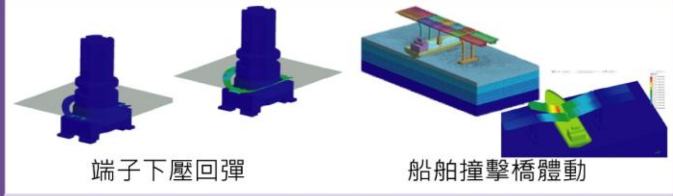
Solid Simulation

MeshFree 快速設計



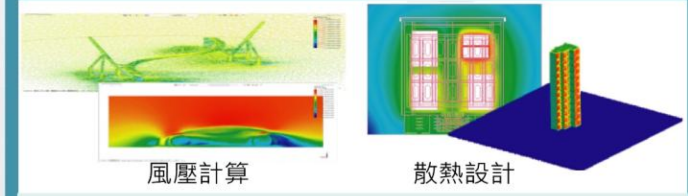
全中文 | 免網格 | 結構 | 動態 | 疲勞 | 熱傳/熱應力

NFX 多物理場



結構 | 特殊材料 | 熱 | 電 | 流 | 耦合計算

CFD 散熱與流場



不可壓縮流 | 可壓縮流 | 阻力計算 | 熱/輻射熱/焦耳熱 | 多相流

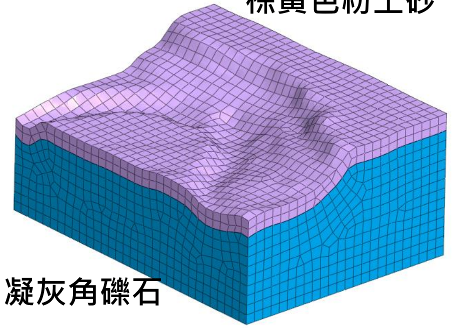
GTS NX 邊坡強降雨-滲流應力耦合分析

滲流-應力耦合分析結果
(每次滲流同時計算應力分布)

使用最後一時間步結果計算
SRM

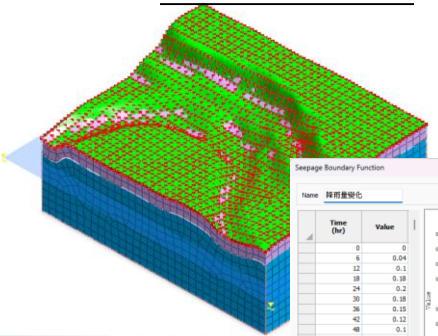
SRM分析結果

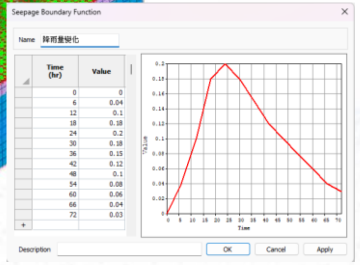
棕黃色粉土砂



凝灰角礫石

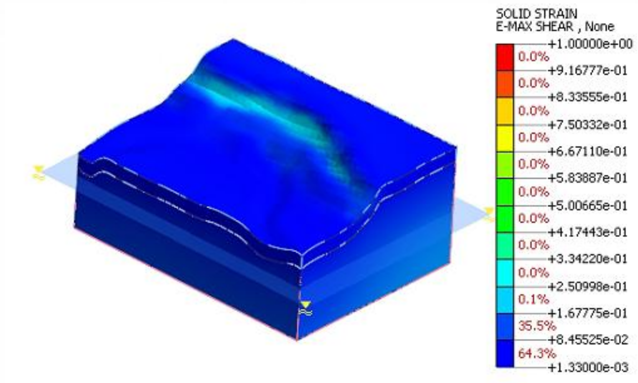
地表72hr降雨定義





平時(未降雨)

SRM安全係數1
Shear Strain

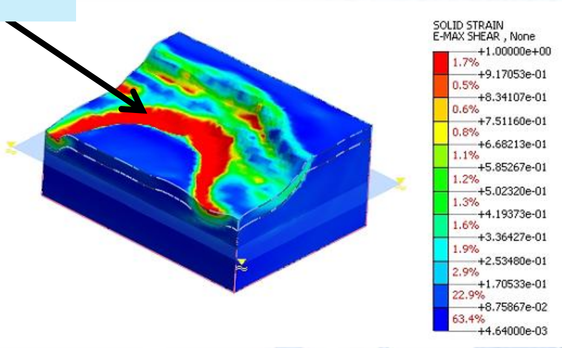


Shear Strain Maximum :0.2462

連續降雨72hr(直接法)

SRM安全係數1
Shear Strain

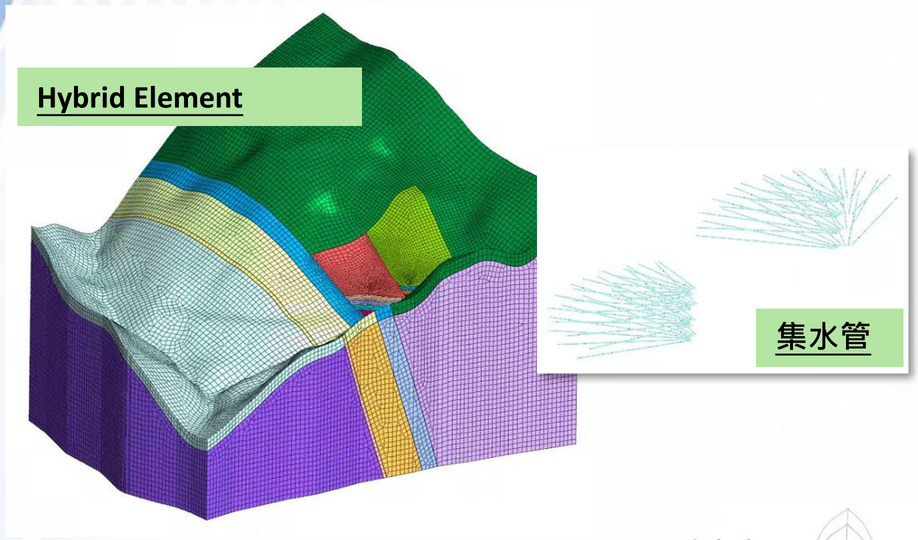
河道



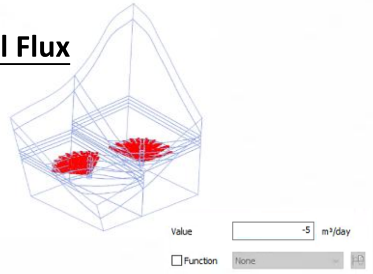
Shear Strain Maximum :4.39918

連續強降雨過程直接造成破壞

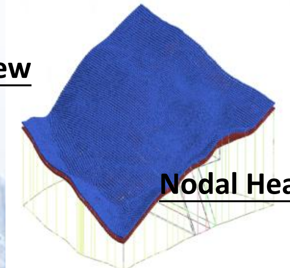
GTS NX 連續降雨後邊坡地下水位變化



Nodal Flux

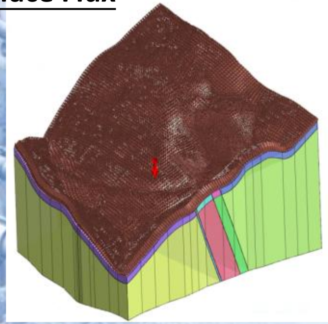


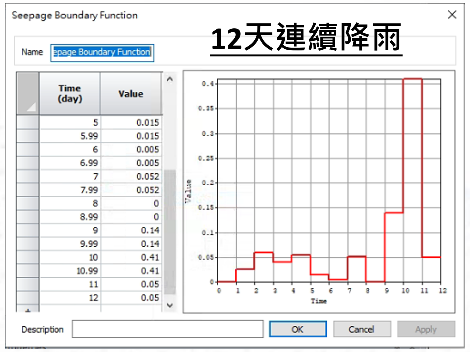
Review



Nodal Head Pressure=0

Surface Flux

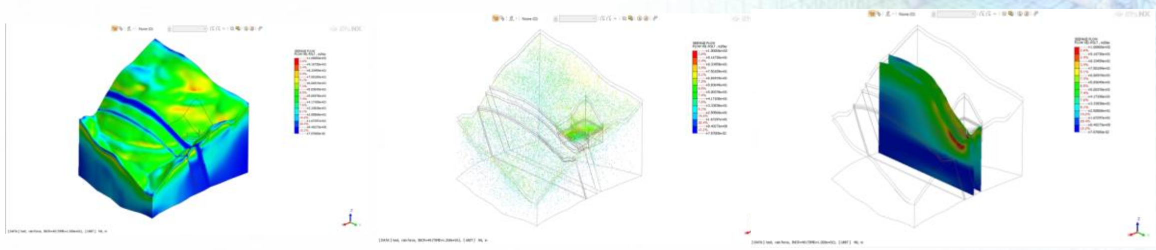




Time (day)	Value
5	0.015
5.99	0.015
6	0.005
6.99	0.005
7	0.052
7.99	0.052
8	0
8.99	0
9	0.14
9.99	0.14
10	0.41
10.99	0.41
11	0.05
12	0.05

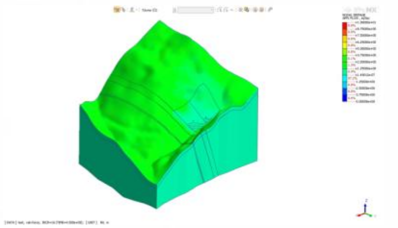
Flow Velocity Resultant(m/day)

12 days

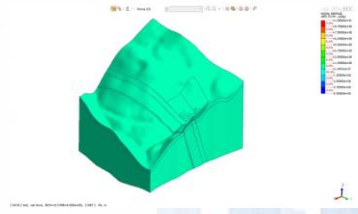


Applied Seepage Flow(m/day)

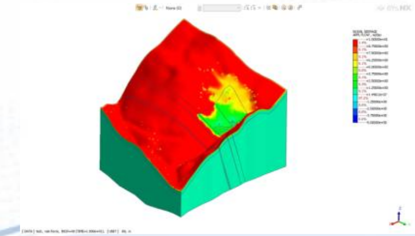
4 days



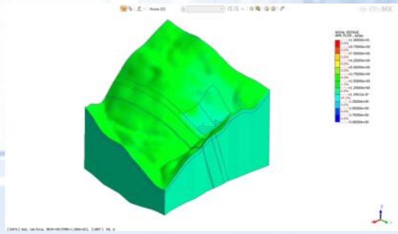
8 days



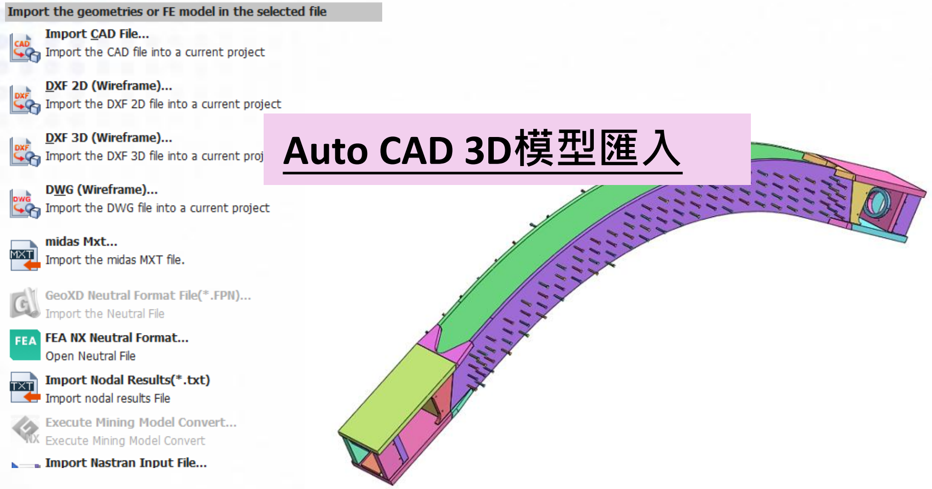
10 days



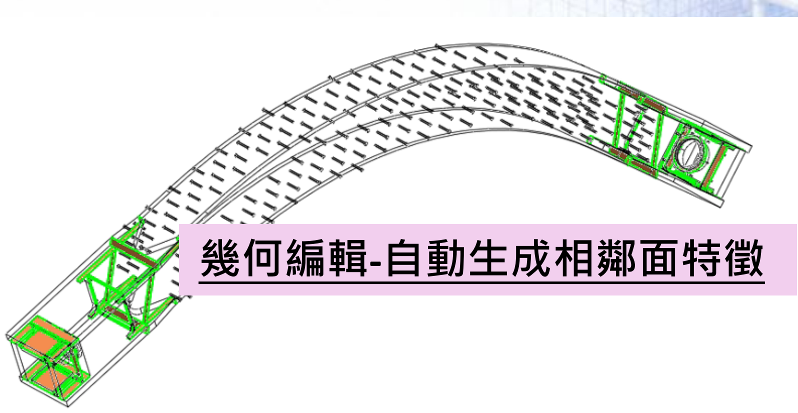
12 days



FEA NX 馬鞍形狀錨箱系統

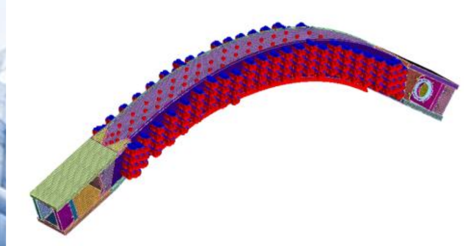


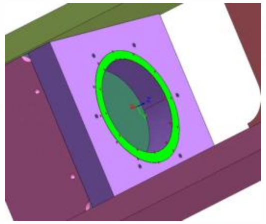
Auto CAD 3D模型匯入



幾何編輯-自動生成相鄰面特徵

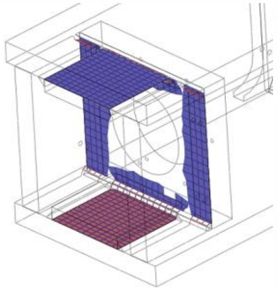
有限元素模型建立&計算

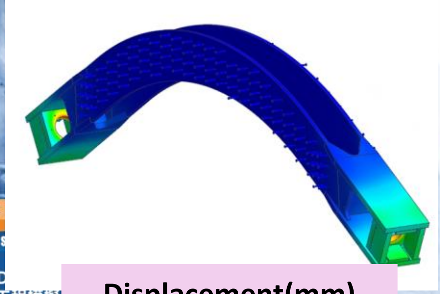




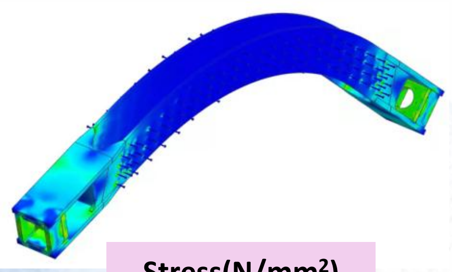
自訂局部座標

非線性-接觸計算

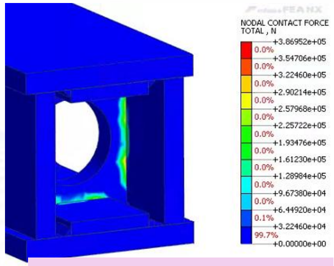




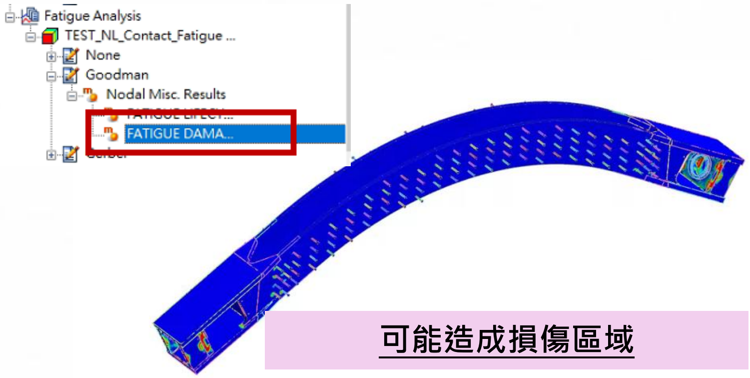
Displacement(mm)



Stress(N/mm²)

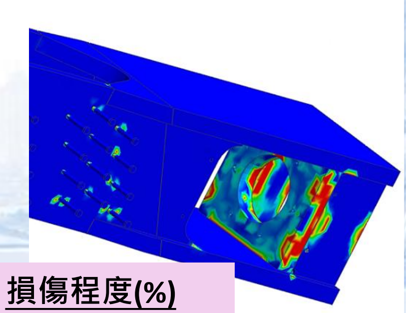


Contact Force(N)



可能造成損傷區域

ontact_Fatigue Results, Goodman, [UNIT] N, mm, [Output CSys] Default

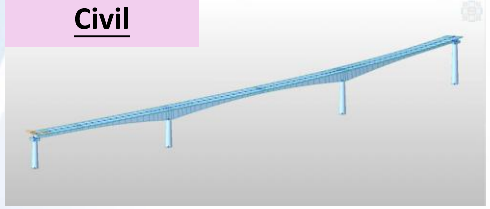


損傷程度(%)

FEA NX 混凝土橋體損傷預測

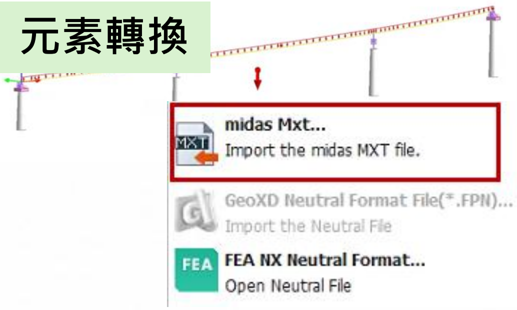
CIVIL Coupled with FEA NX

Civil



FEA NX

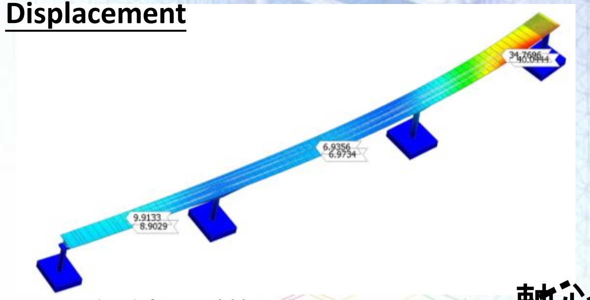
元素轉換



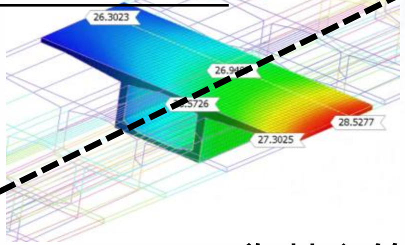
FEA NX

自動轉換成實體特徵

Displacement



3D元素各節點變形

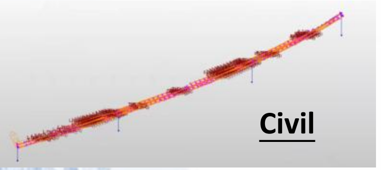


軸心

軸心

Civil 1D Beam為軸心節點變形量

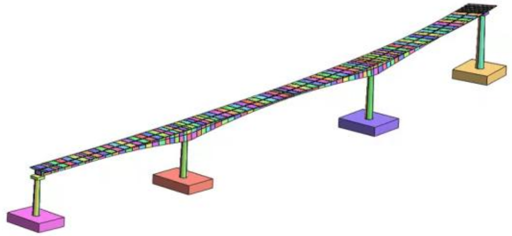
預力鋼腱(Tendon)



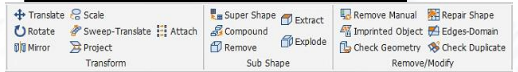
Civil

自動換Tendon空間座標

FEA NX



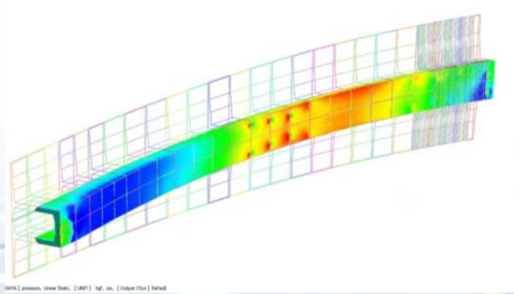
FEA NX標準幾何功能



FEA NX進階幾何功能

FEA NX自動&手動網格功能

Solid Stress-SXX

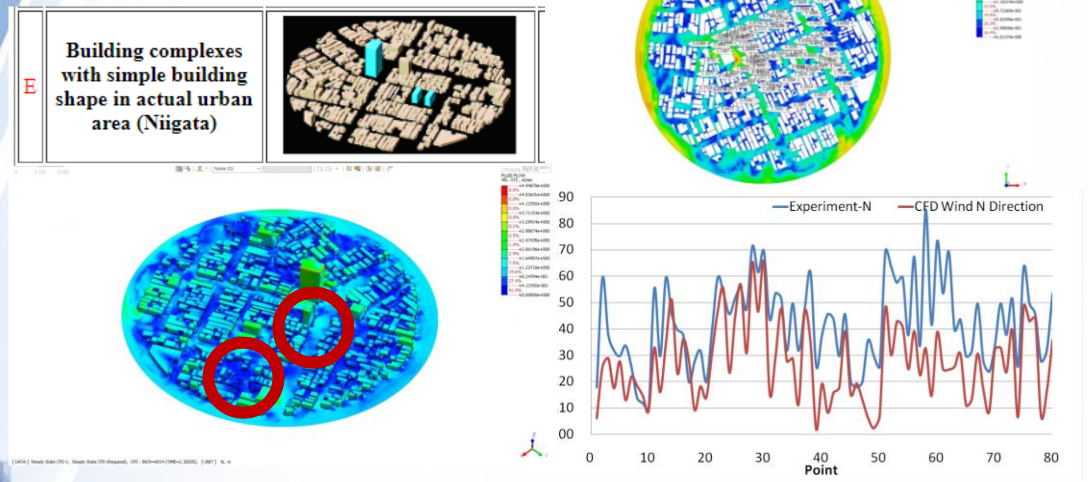


CFD 流場分析在土木領域應用

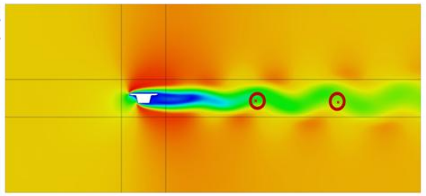
N Direction

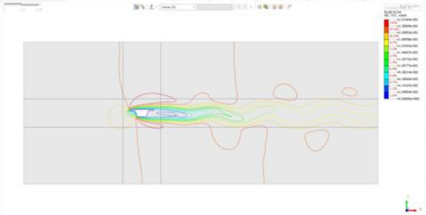
Standard Deviation : 8.46%

Correlation Coefficient:72.58%



Extract vortex node T2 flow velocity/time curve





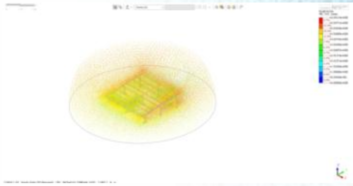
Bridge Section

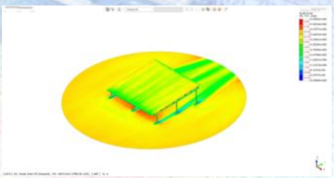
Vortex Shedding Frequency

Freq=1/(566-492)=0.0135Hz

Wind Tunnel Experiment

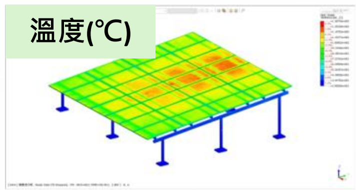
Computational fluid dynamics

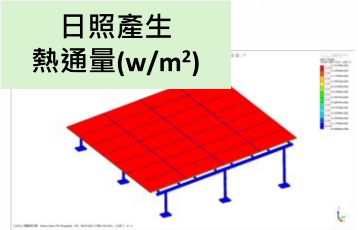


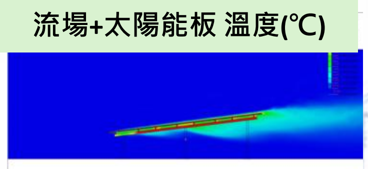


Solar panels

日照熱輻射&熱對流分析



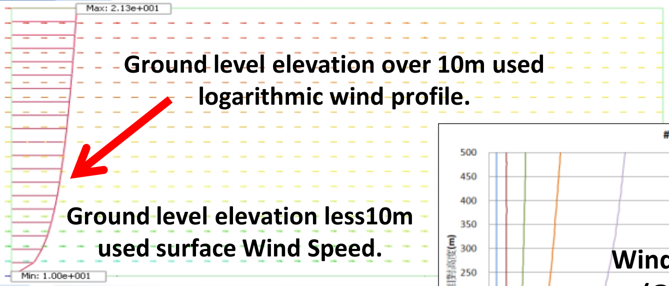


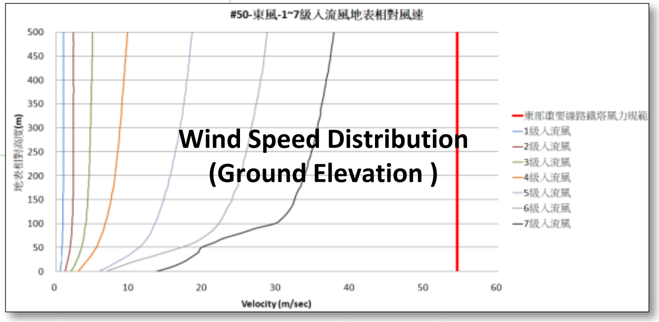


調整刻度最高溫度50(°C)

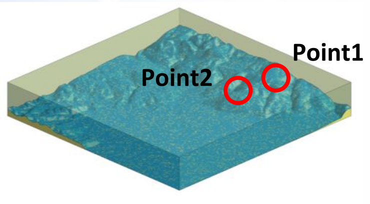
	Model Size	Model Modification	Required Time	Operator	Graphical results	Test Data	Price
CFD	Same scale	Easy	Shorter time	Professionals	Visualization	Exhaustive (all nodes)	Reasonable price
W/T	Scale down	Difficult	Longer time	Professionals	Basic	measurement point	High price

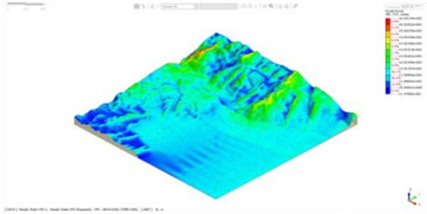
CFD 流場分析在土木領域應用

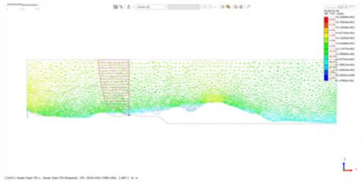




FEA Model

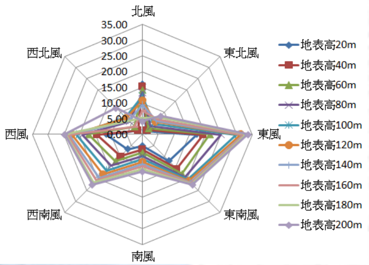


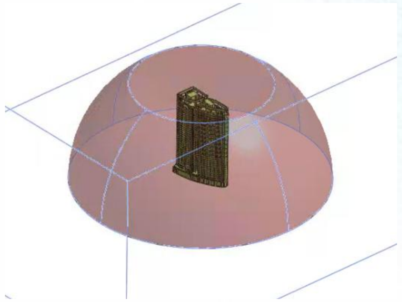


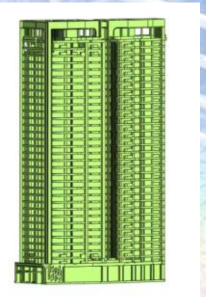


Ground Surface Features

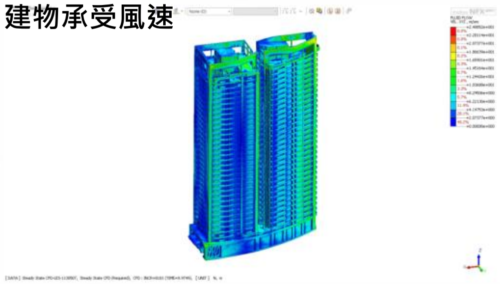
Wind Rose Diagram
(Force 7 wind)



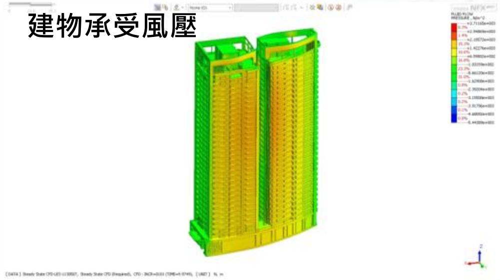


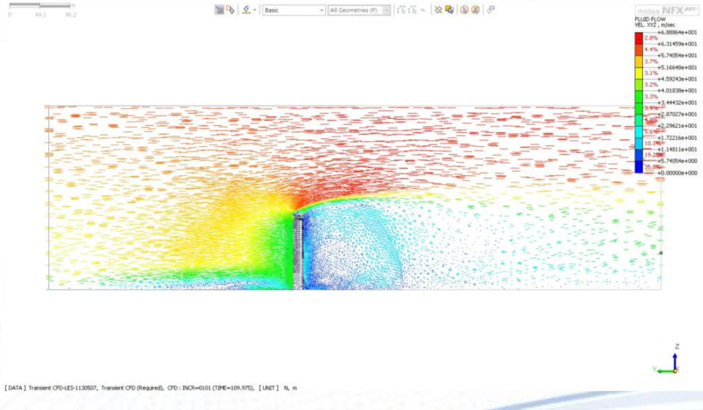


建物承受風速



建物承受風壓

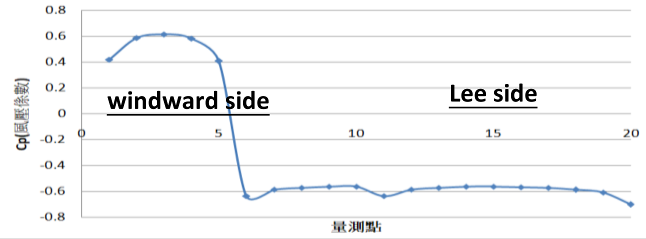




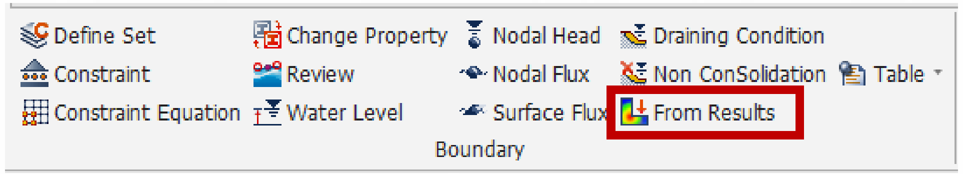
Pressure coefficient(C_p)

$$C_p = \frac{p - p_\infty}{\frac{1}{2}\rho_\infty V_\infty^2} = \frac{p - p_\infty}{p_0 - p_\infty}$$

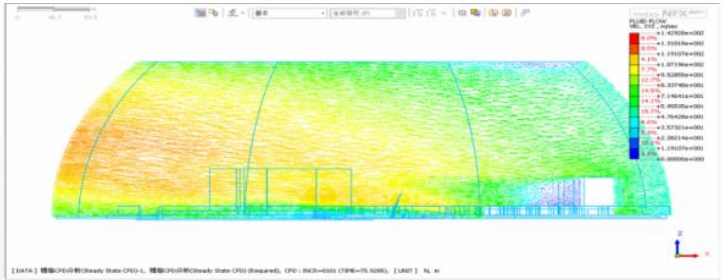
Building Wind pressure coefficient(Cp)

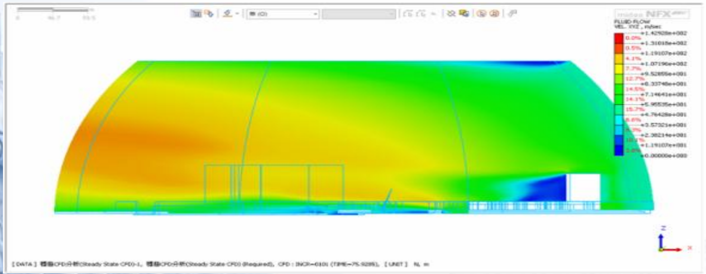


單向-流固耦合計算(CFD + GTS NX / FEA NX / NFX)



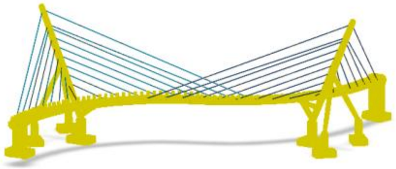
Step1. CFD Wind Field Analysis



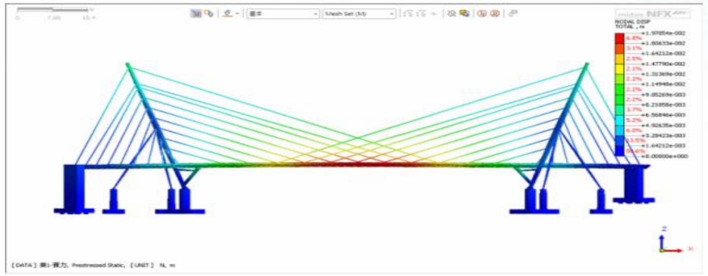


Hurricane-Level 14 Wind

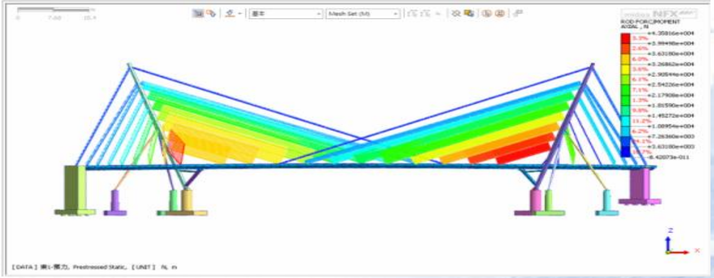
CFD Wind Pressure



Step2. Strength Analysis of Bridge Structure in Strong Wind



Bridge Deformation(m)

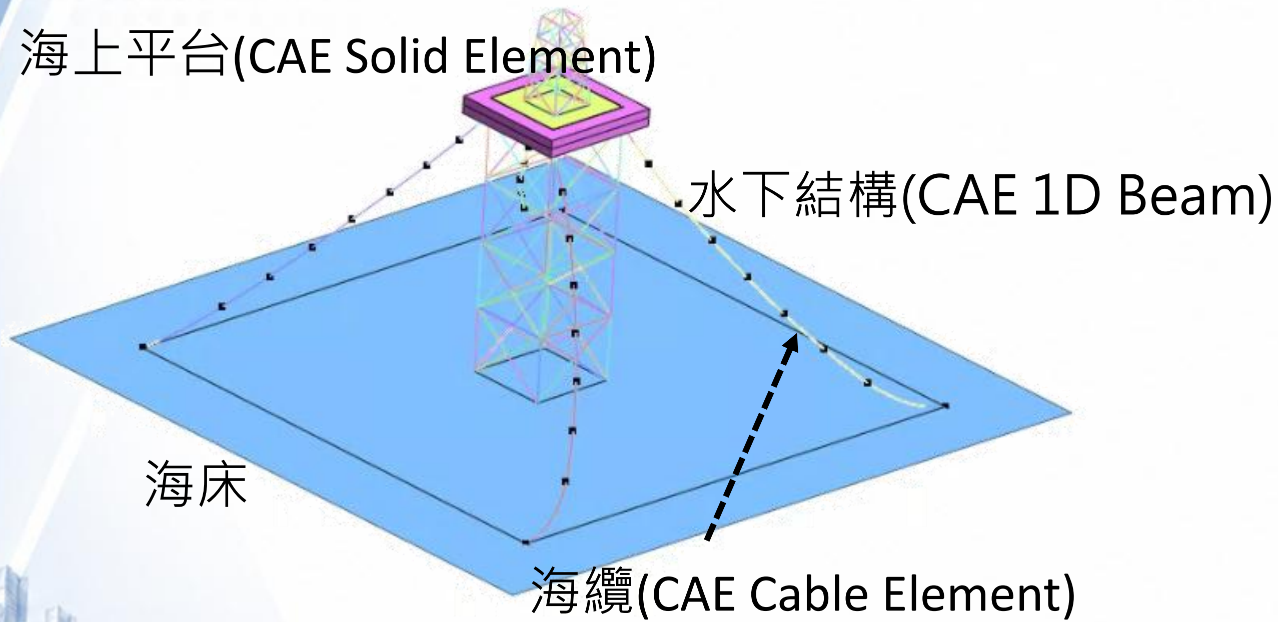


Axial force(N)

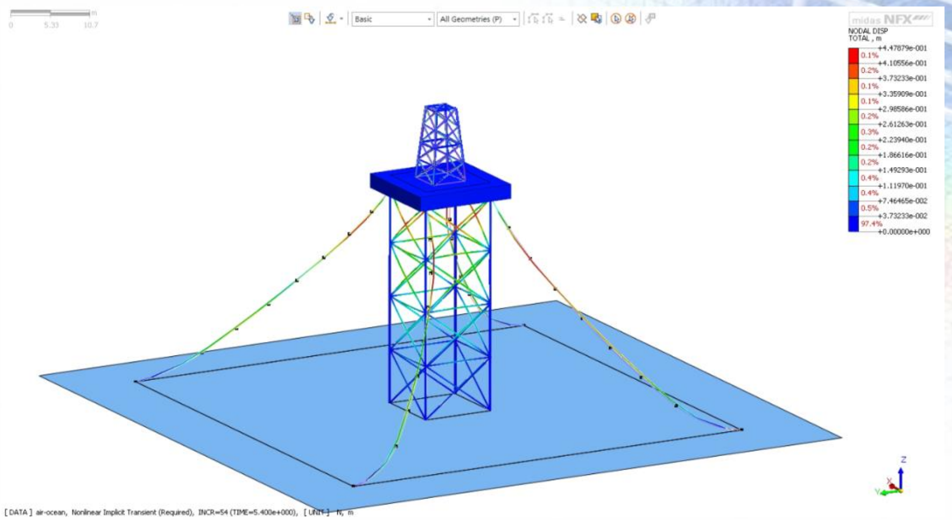
1 Way FSI Simulation(Fluid-Structure Interaction)

水上浮力耦合分析計算(流固耦合)

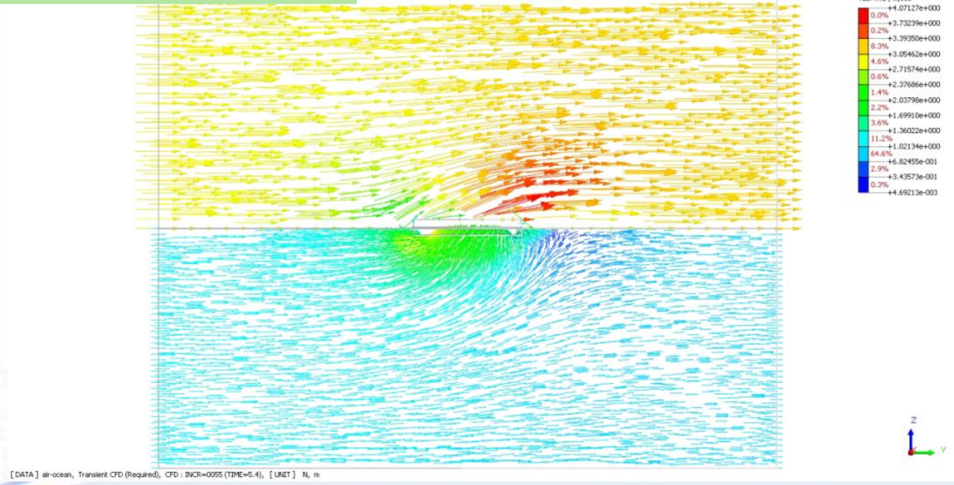
水上結構(CAE 1D Beam)



CAE-變形量

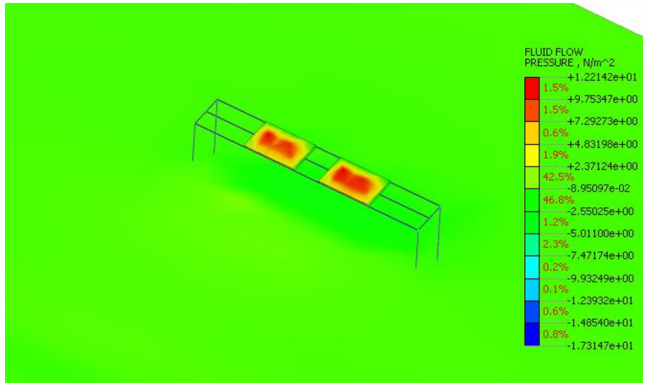


CFD-流速

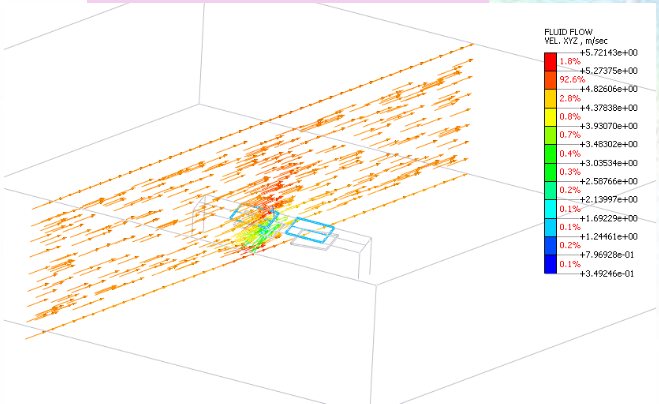


柔性太陽能板支架受強風下結構強度計算(流固耦合)

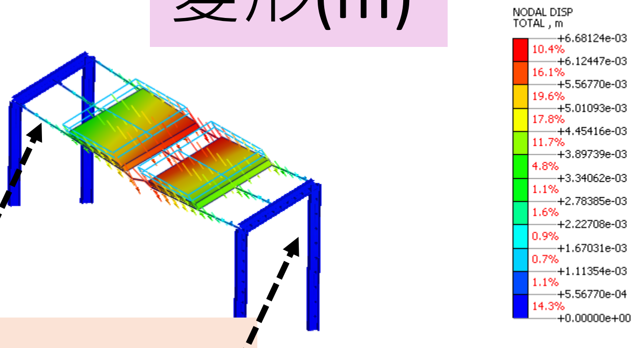
地表和太陽能板表面風壓



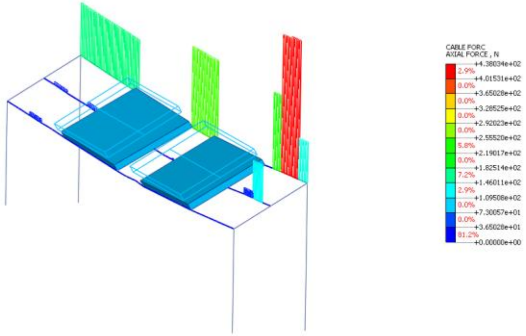
風速向量圖



變形(m)



Cable AXIAL Force(N)

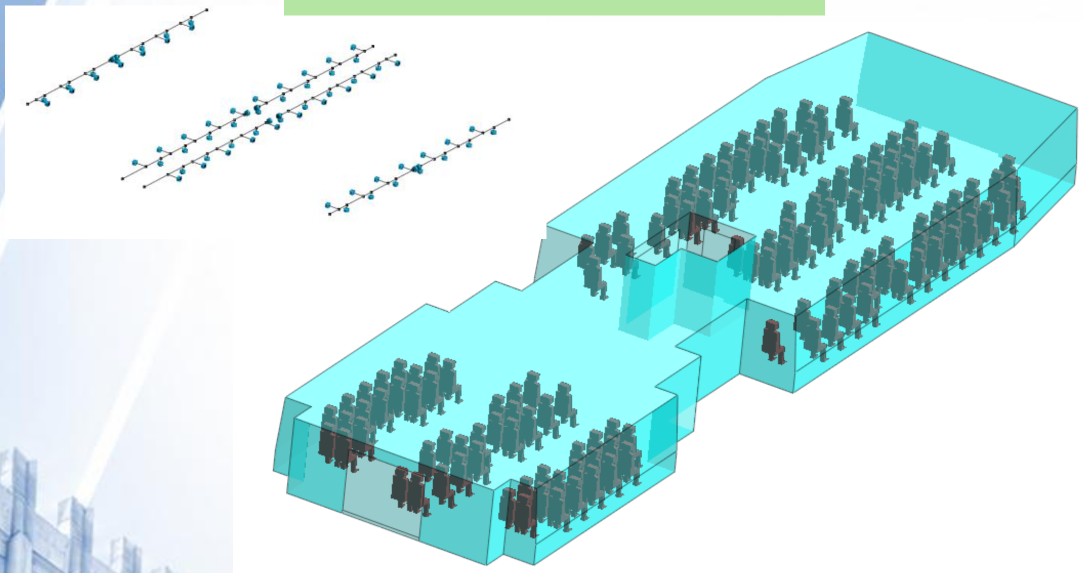


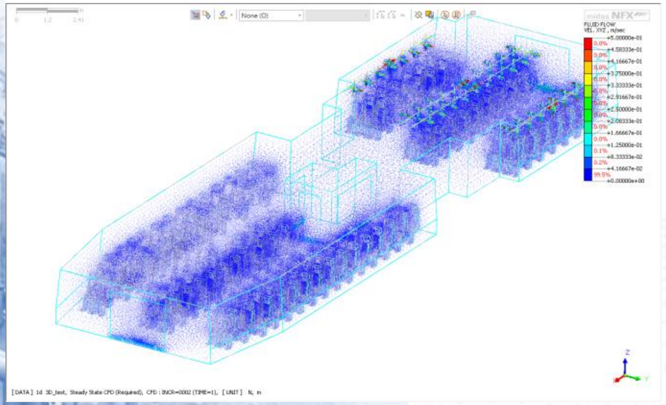
Cable Element

Beam Element

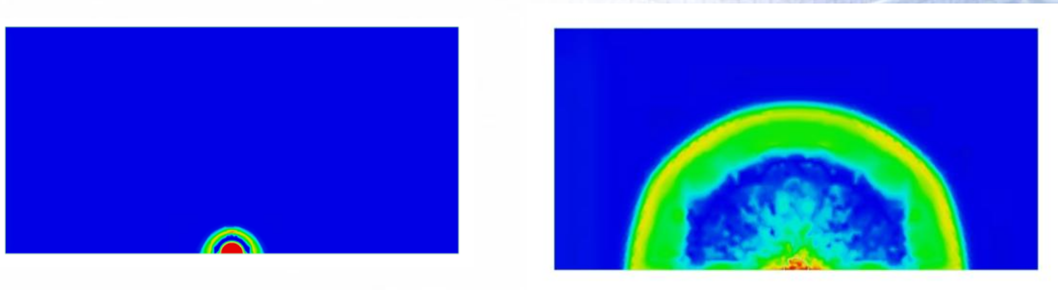
CFD高階應用

1D+3D CFD計算

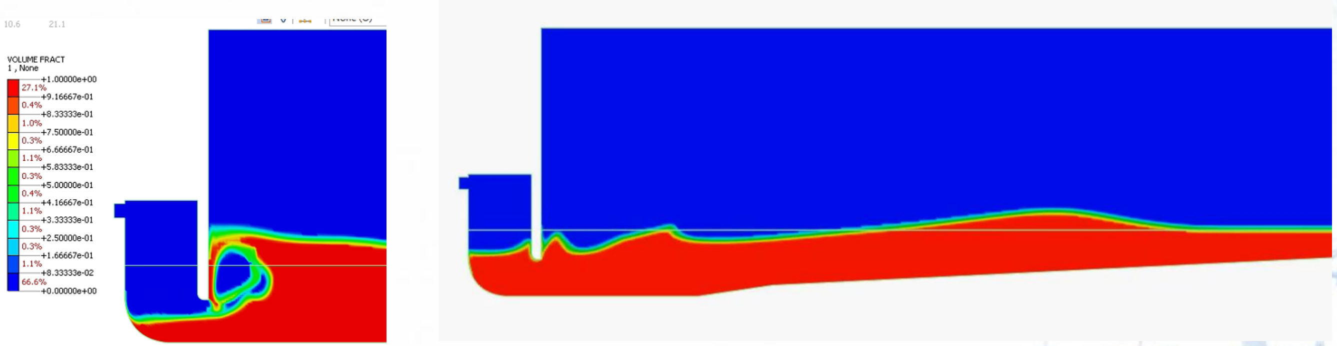




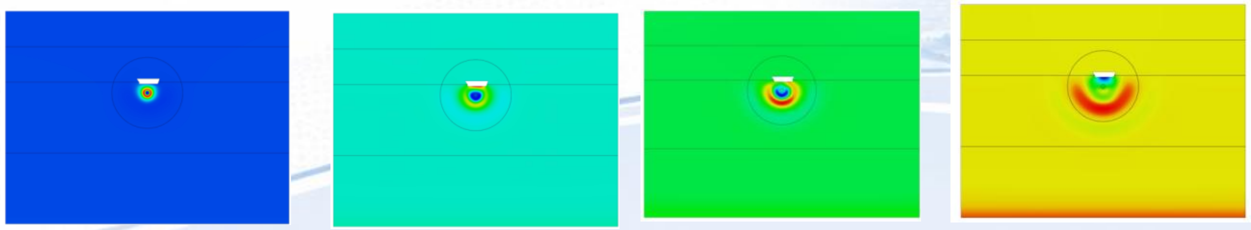
空氣爆破計算



造浪設施計算

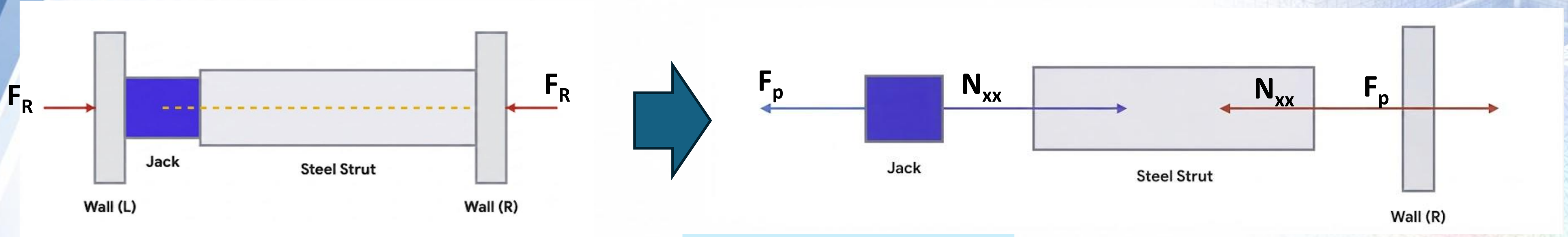


水下爆破計算



專案分析常見議題與經驗交流

連續壁(鋼板樁)+支撐預力間距換算驗証

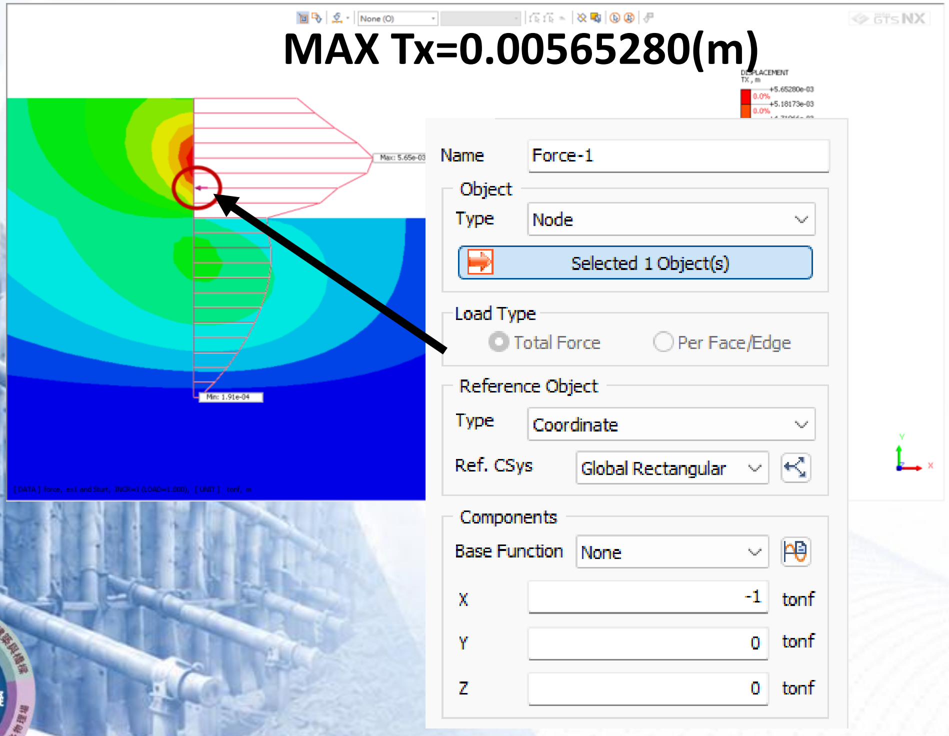


忽略支撐+集中力(F_p)

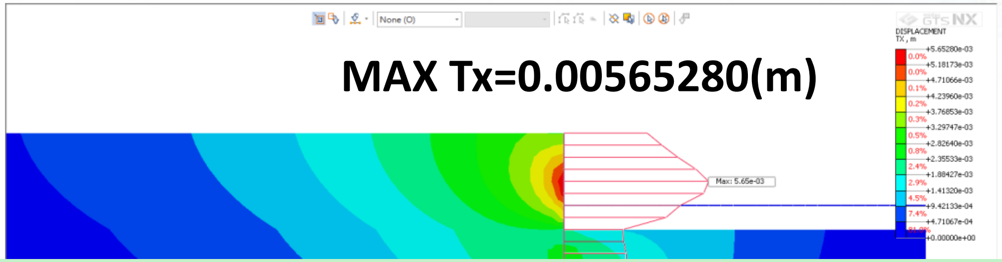
考慮支撐+預力(N_{xx})

鋼板樁10m/1支+支撐2m/1支

MAX Tx=0.00565280(m)

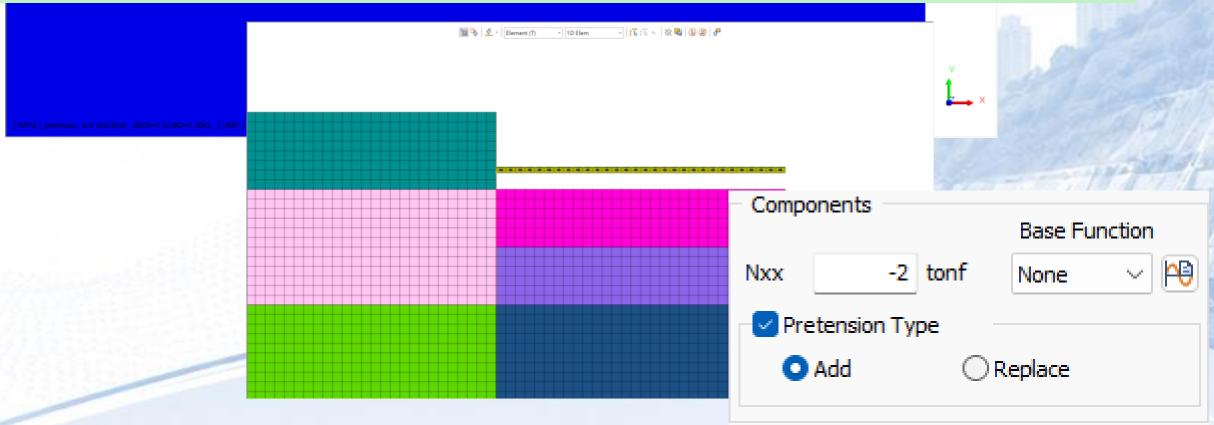


MAX Tx=0.00565280(m)



N_{xx}= 1tonf×10(鋼板樁10m 1支)/5(支撐2m1支共5支) = 2 (tonf)

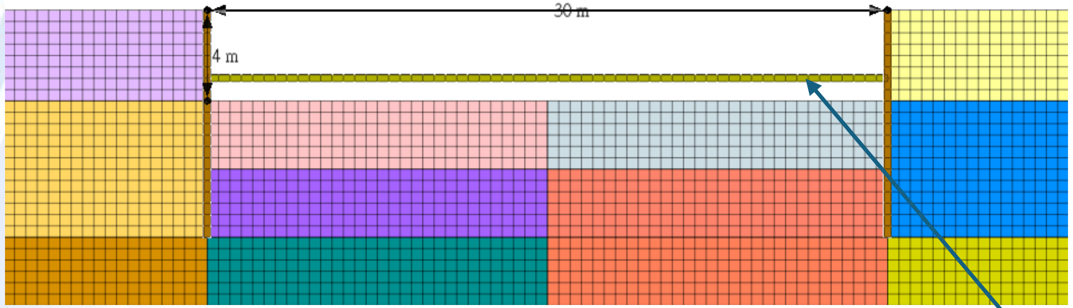
預力(N_{xx}) =-2 (tonf)



註:比對過程使用非常規數據進行測試。

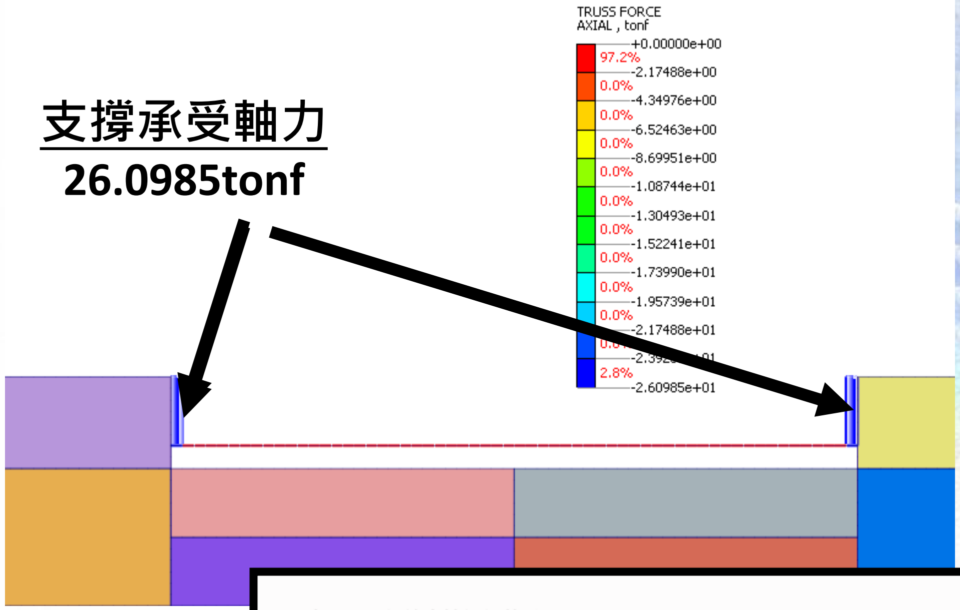
支撐預力估算

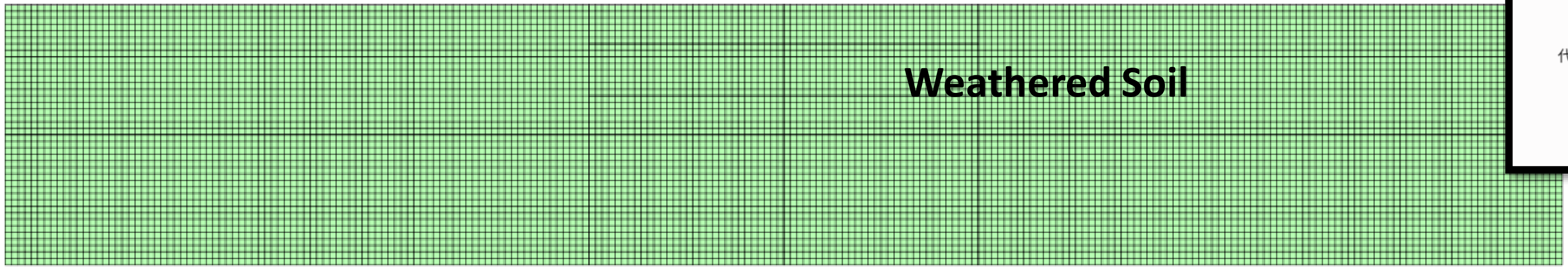
開挖範圍30
開挖深度4m



支撐1 3m深位置/每5m一支

支撐承受軸力
26.0985tonf





步驟二：計算支撐設計荷重 (P_d)

採用影響面積法。由於只有單層支撐位於 3m 深處，開挖底面為 4m。支撐需負擔的垂直影響範圍 (S_v) 通常取地表至支撐與開挖底面之間的一半：

- $S_v = 3\text{ m} + \frac{4\text{ m}-3\text{ m}}{2} = 3.5\text{ m}$

$$P_d = p \times S_h \times S_v$$

代入數值：

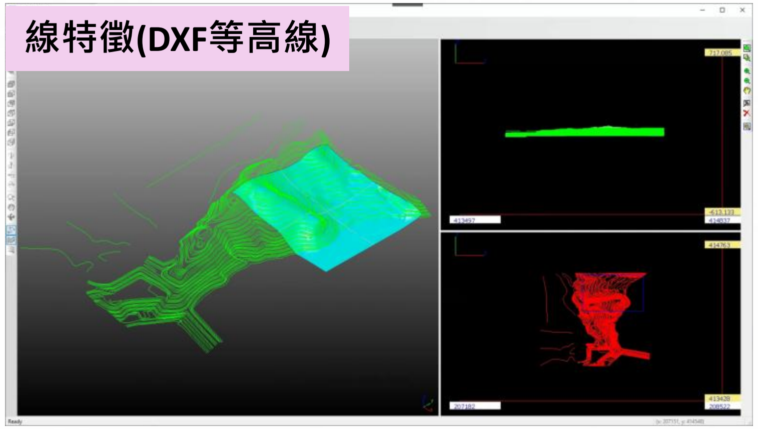
$$\boxed{P_d = 1.44\text{ tonf/m}^2 \times 5\text{ m} \times 3.5\text{ m} = 25.2\text{ tonf}}$$

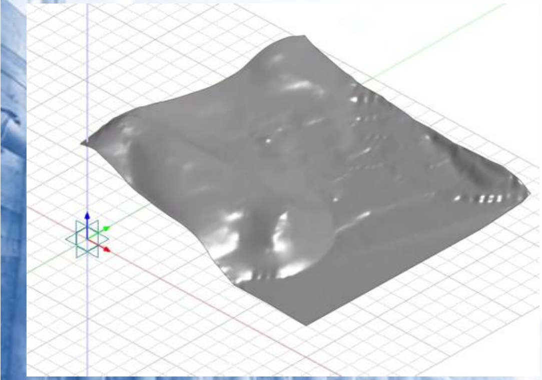
	Modulus of Elasticity(E) (tonf/m²)	Poisson's Ratio(ν)	Unit Weight(γ) (tonf/m³)	Unit Weight(Saturated) (tonf/m³)	Cohesion(C) (tonfm²)	Friction Angle(ϕ)
Weathered Soil	5000	0.35	1.8	1.9	1.5	32

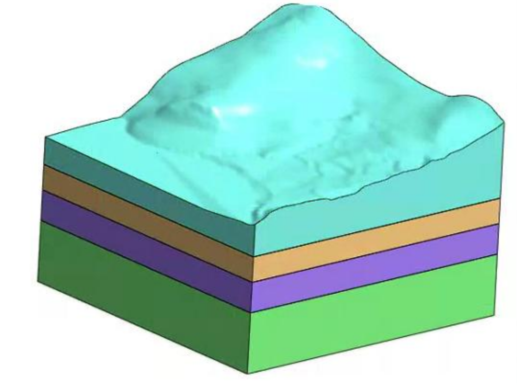
GTS NX 3D地形特徵

方式1.TGM建模

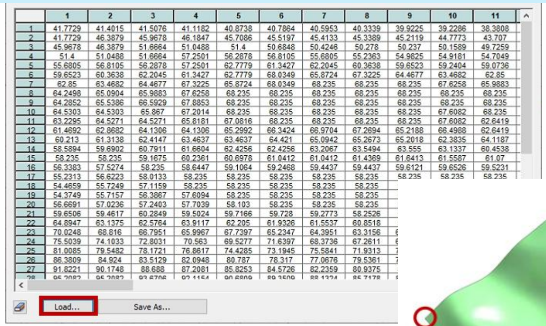
線特徵(DXF等高線)

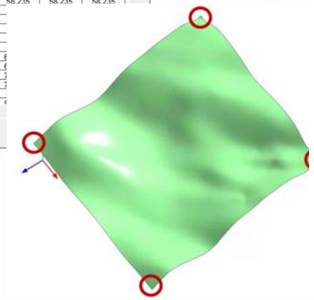


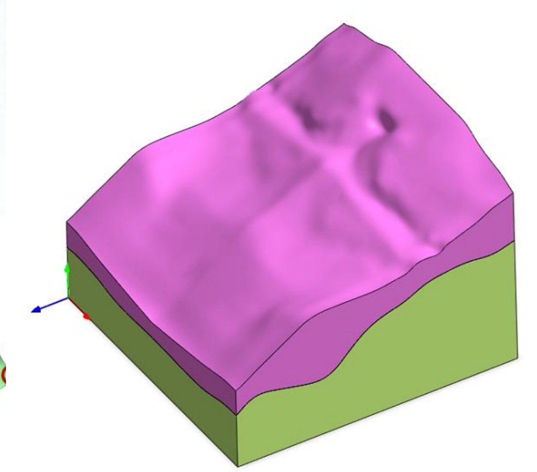




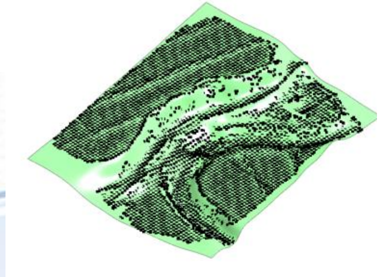
方式2.空間座標高度建模

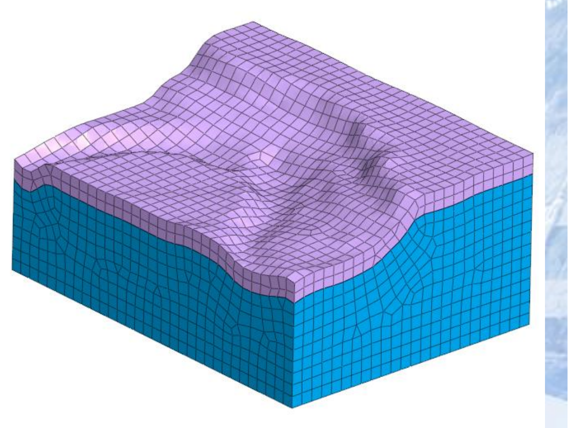






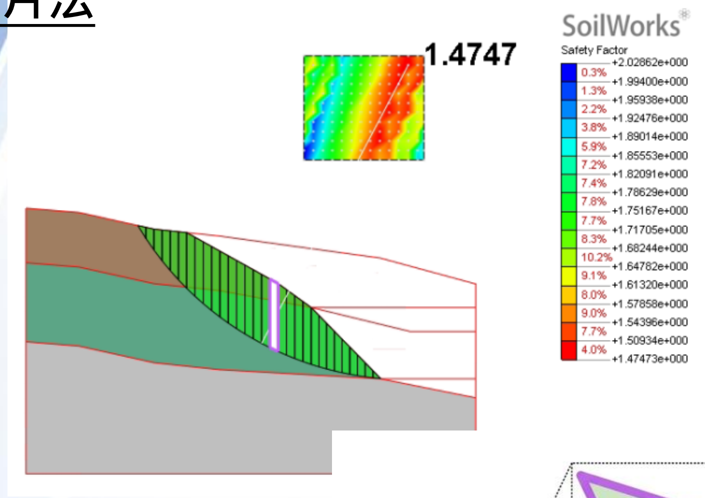
方式3.空間座標點建模

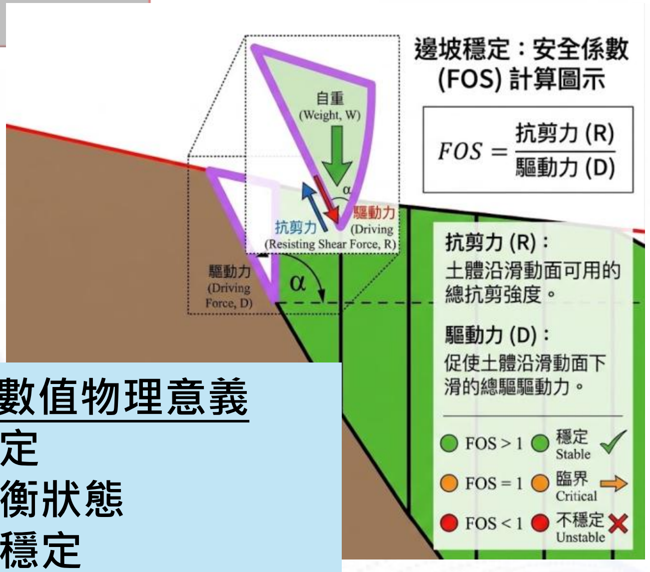




LEM/SRM分析比對

切片法





切片法安全係數數值物理意義

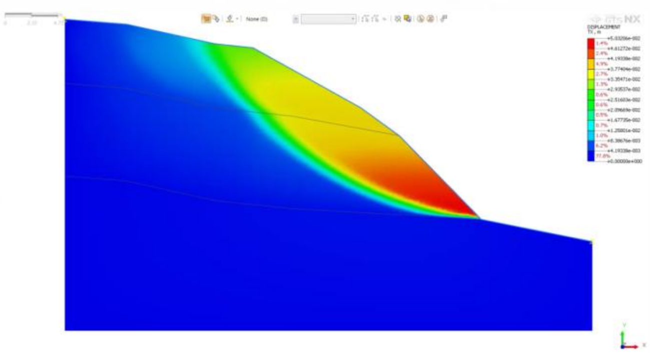
FOS > 1 ：邊坡穩定

FOS = 1 ：極限平衡狀態

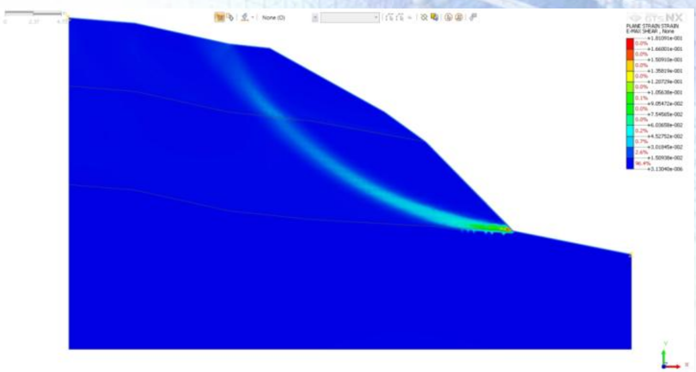
FOS < 1 ：邊坡不穩定

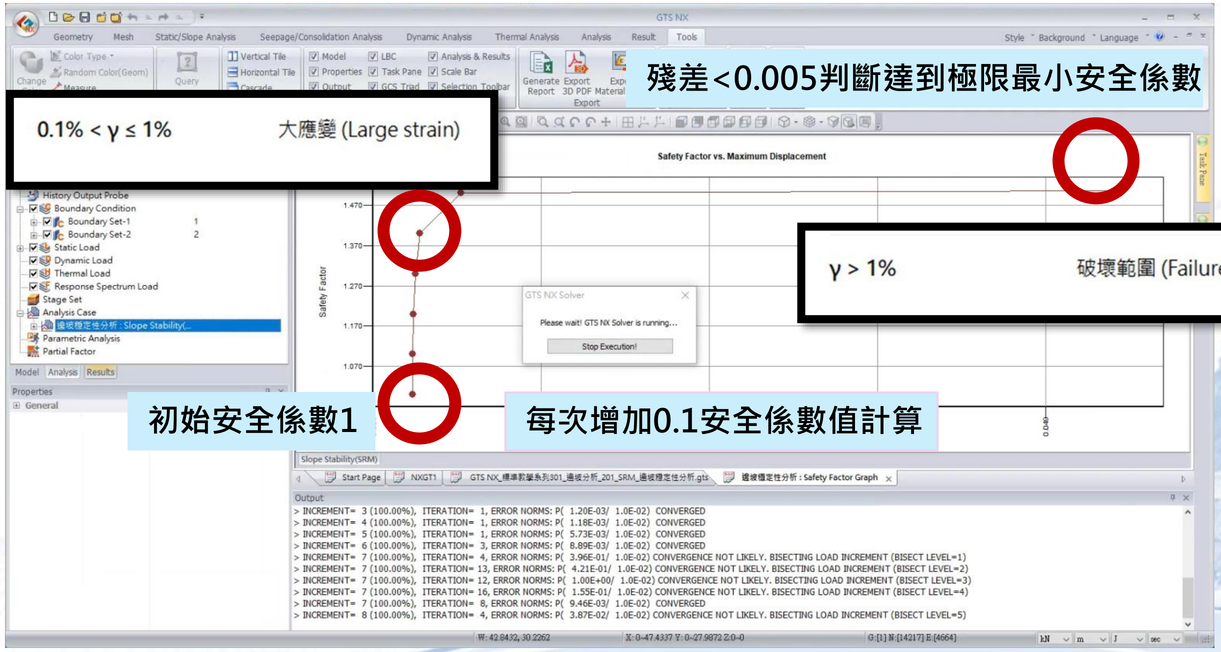
SRM透過水平變形和最大剪切應變判斷破壞面

Tx Translation(m)



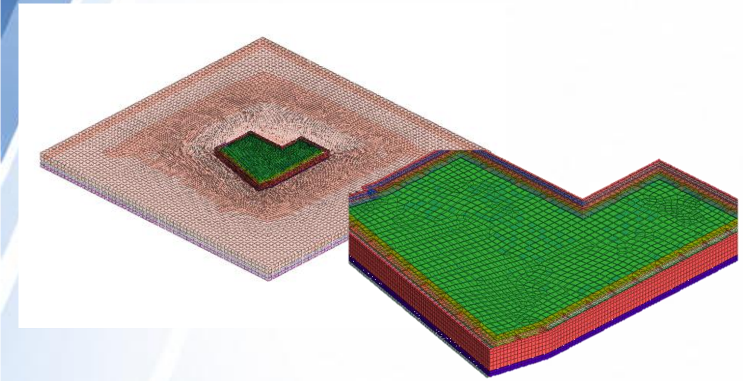
Maximum Shear Strain





1階元素VS.2階元素 SRM分析比對

SRM透過水平變形和最大剪切應變判斷破壞面
1階元素SRM計算過程會失真



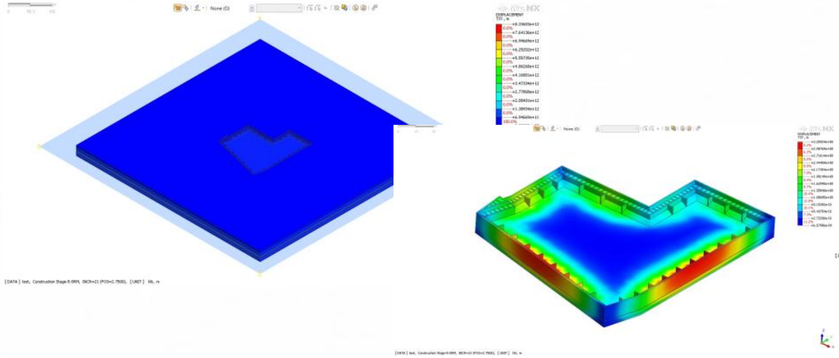
1階元素節點數

G:[1991] N:[117953] E:[170991]

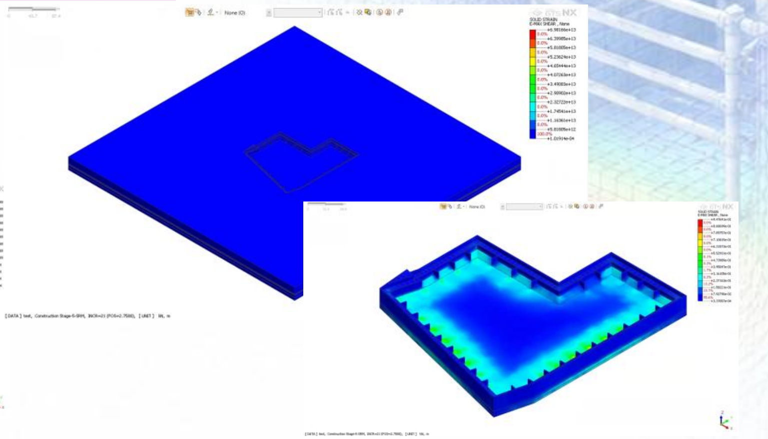
2階元素節點數

G:[1991] N:[525942] E:[170991]

1-order FOS=2.75

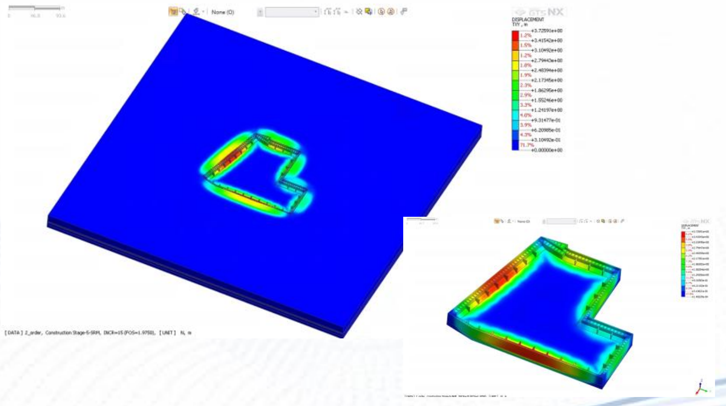


TXY Translation(m)

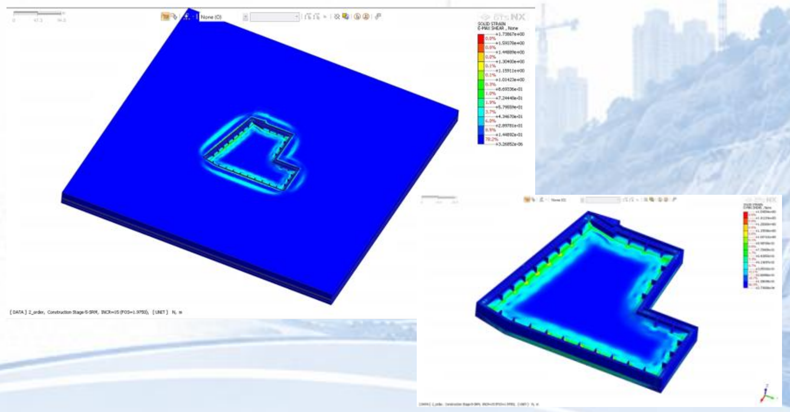


Maximum Shear Strain

2-order FOS=1.975



TXY Translation(m)



Maximum Shear Strain

GTS NX耦合分析

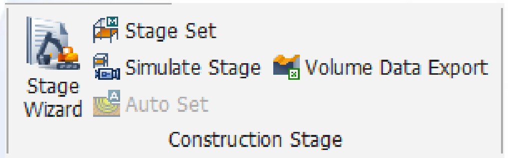
耦合分析

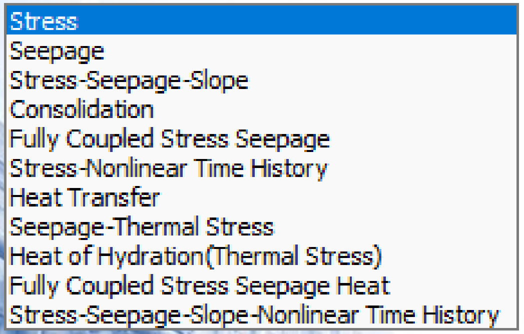
(1)順序耦合

滲流和應力分別計算，但計算所需要時間較短，計算過程也相對穩定。

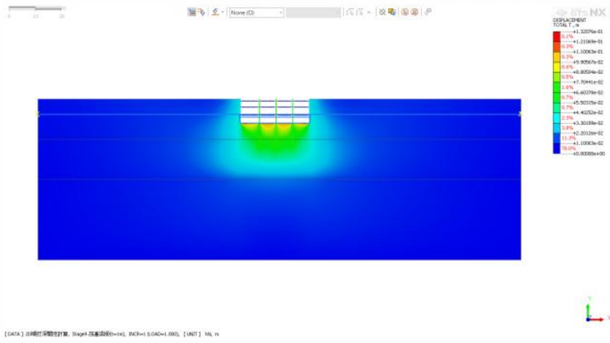
(2)直接耦合

滲流和應力同步計算，分析結果更符合現況，但計算所需要時間較長，計算過程也相對不穩定。

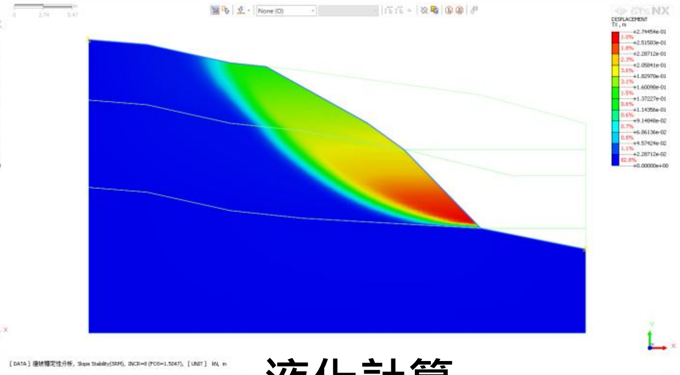




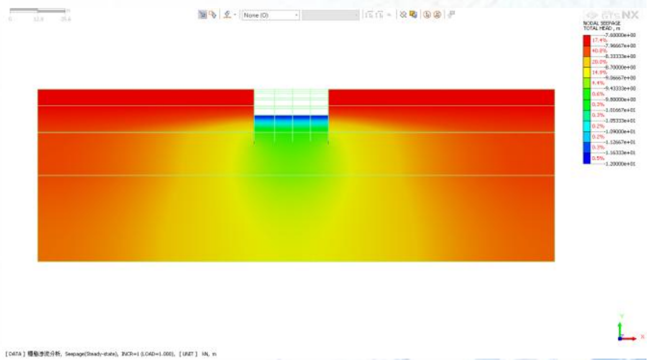
開挖計算



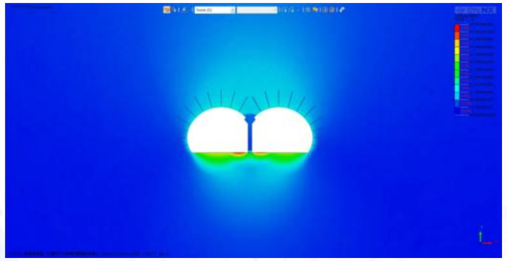
邊坡計算



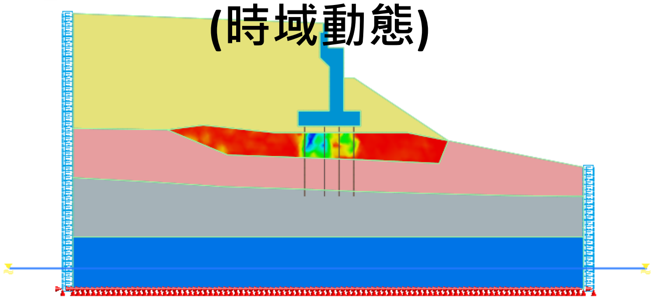
滲流計算



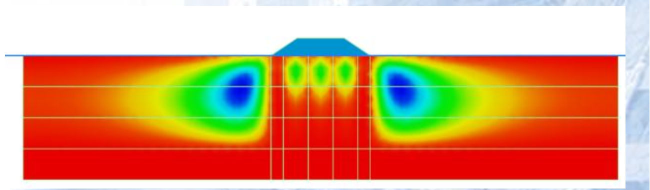
隧道計算



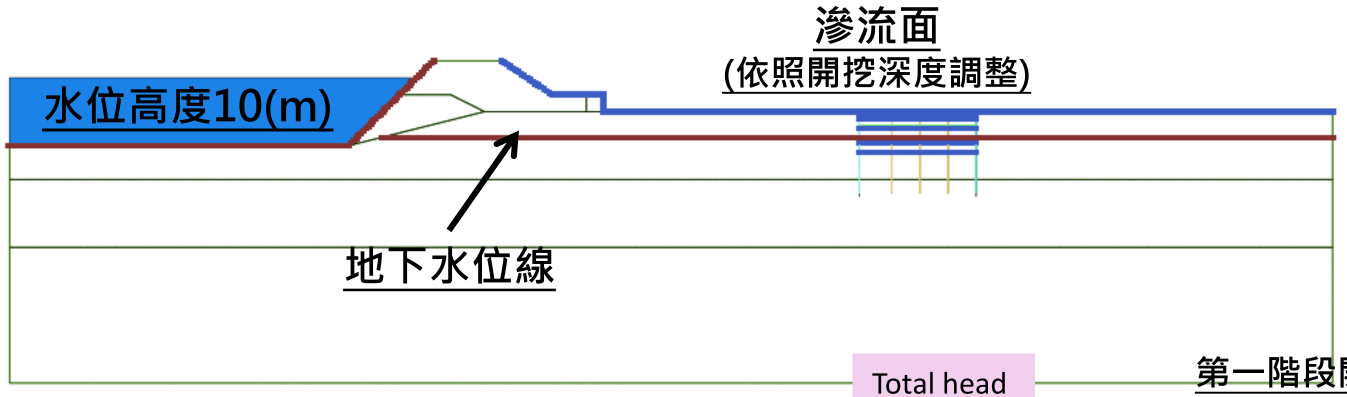
液化計算 (時域動態)



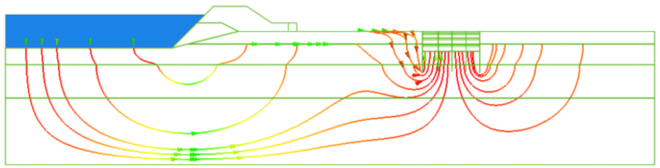
壓密計算

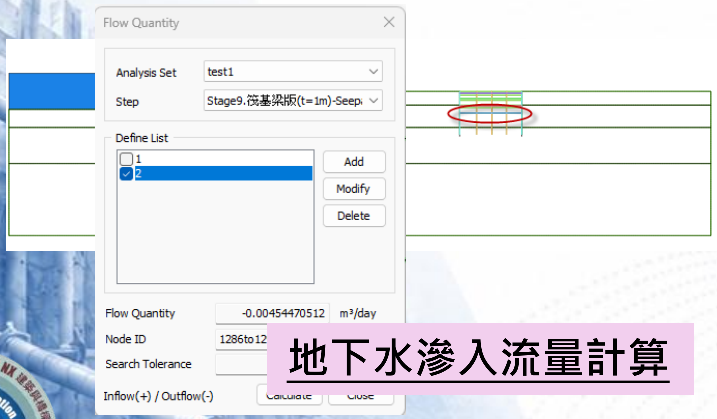


GTS NX耦合分析 -河道周邊深開挖



Flow path

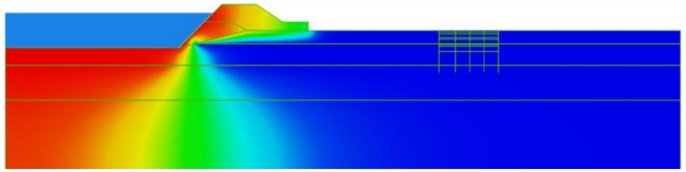




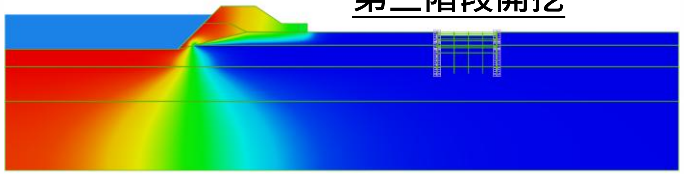
地下水滲入流量計算

Total head

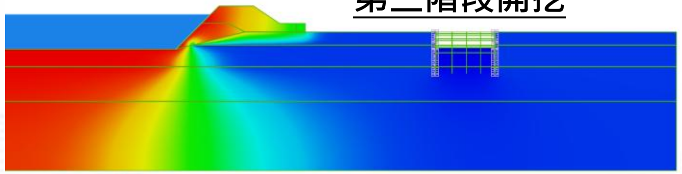
第一階段開挖



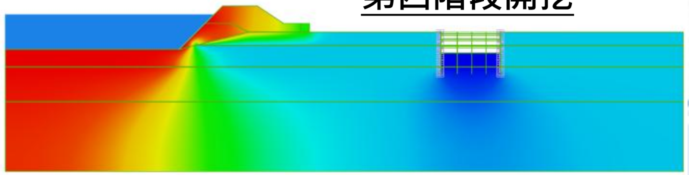
第二階段開挖



第三階段開挖

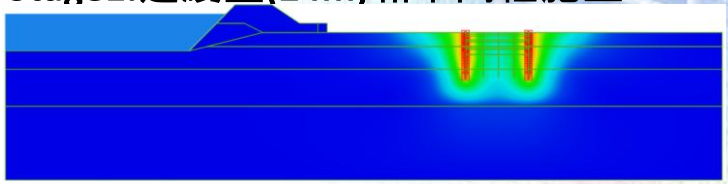


第四階段開挖

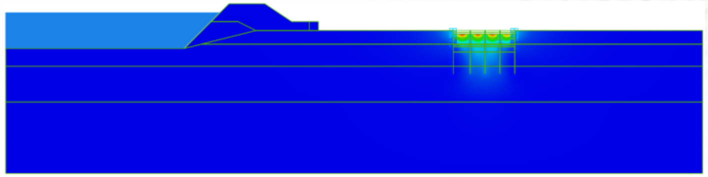


Total Displacement

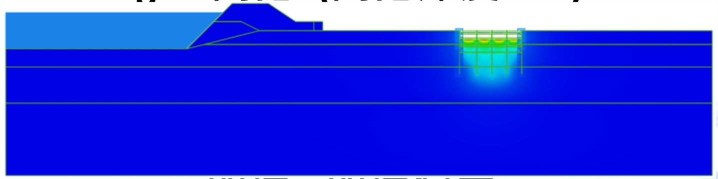
Stage1.連續壁(24m)和中間柱施工



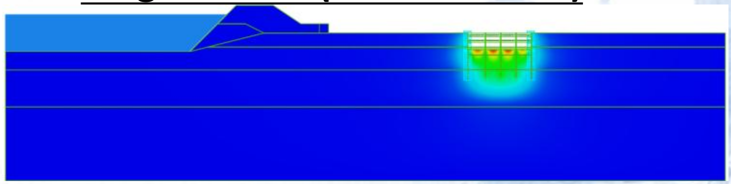
Stage2.開挖1(開挖深度-2m)



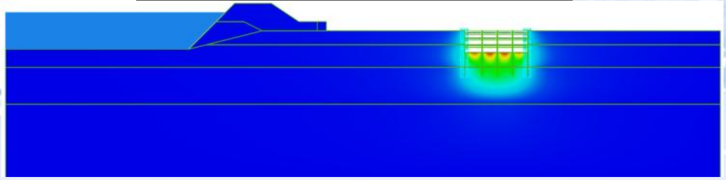
Stage4.開挖2(開挖深度-5m)



Stage6.開挖3(開挖深度-9m)

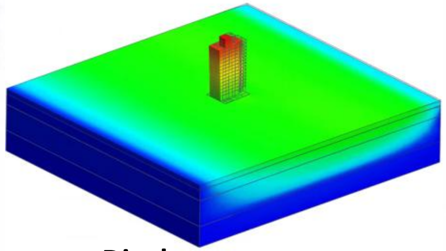


Stage8.最終開挖 (-12m)



GTS NX耦合分析 -土壤-結構互制(地震分析)

靜態地震力分析

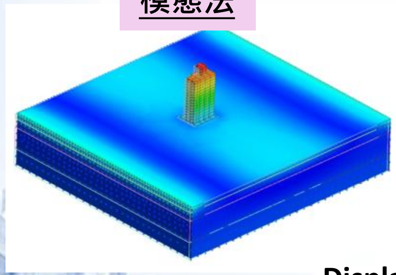


Displacement

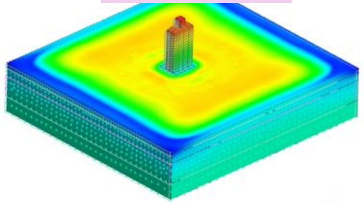
地震分析-線性歷時分析

(Absolute Max)

模態法



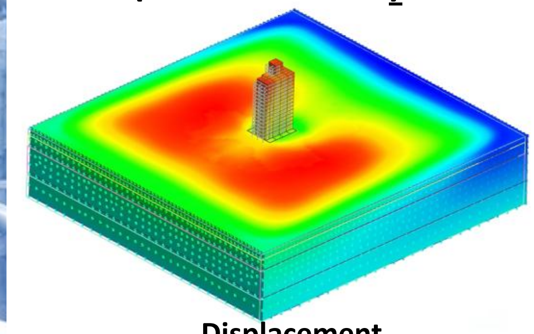
直接法



Displacement

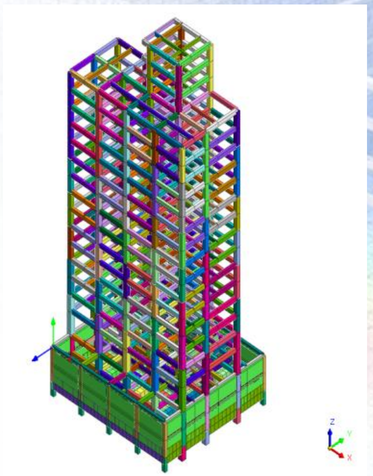
地震分析-非線性歷時分析

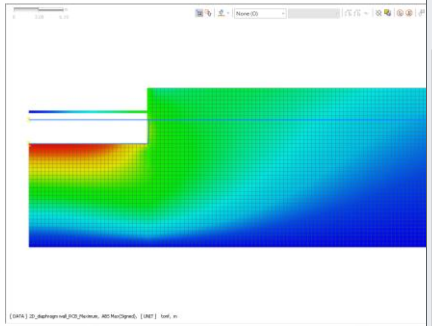
(Absolute Max)

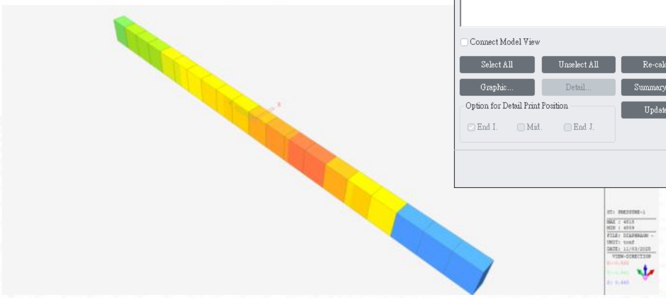


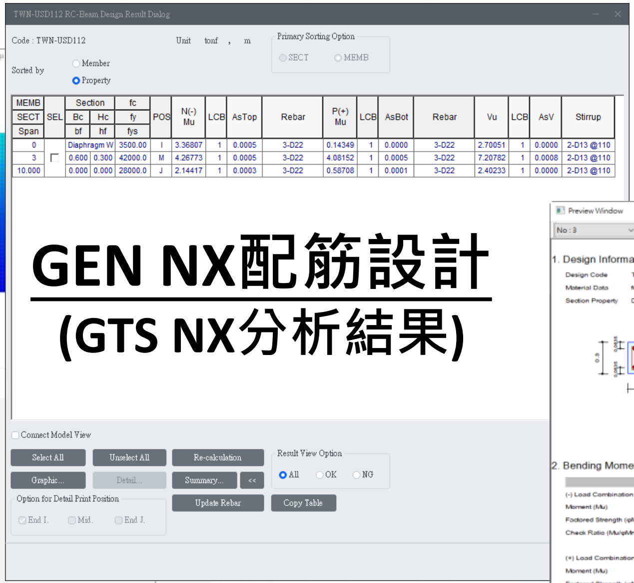
Displacement

Mxt File Type





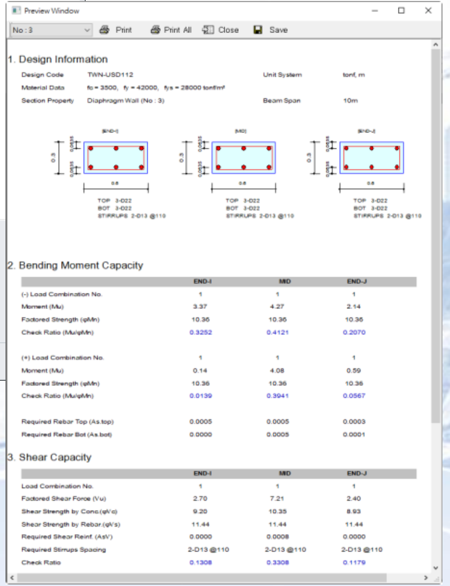




MEMB / SECT / Span	SEL	Section: Bc / bf	Section: Hc / hf	fc / fy / fys	POS	N(-) Mu	LCB	AsTop	Rebar	P(+) Mu	LCB	AsBot	Rebar	Vu	LCB	AsV	Stirrup
0		Diaphragm W		3500.00	I	3.36807	1	0.0005	3-D22	0.14349	1	0.0000	3-D22	2.70051	1	0.0000	2-D13 @110
3		0.600	0.300	42000.0	M	4.26773	1	0.0005	3-D22	4.08152	1	0.0005	3-D22	7.20782	1	0.0008	2-D13 @110
10.000		0.000	0.000	28000.0	J	2.14417	1	0.0003	3-D22	0.58708	1	0.0001	3-D22	2.40233	1	0.0000	2-D13 @110

GEN NX配筋設計

(GTS NX分析結果)



全方位工程模擬網站

https://www.midasuser.com.tw/SolidSimulation/

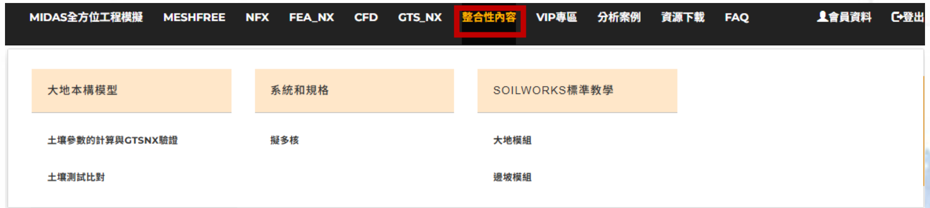
分析案例

GTS NX

教學範例/操作影片

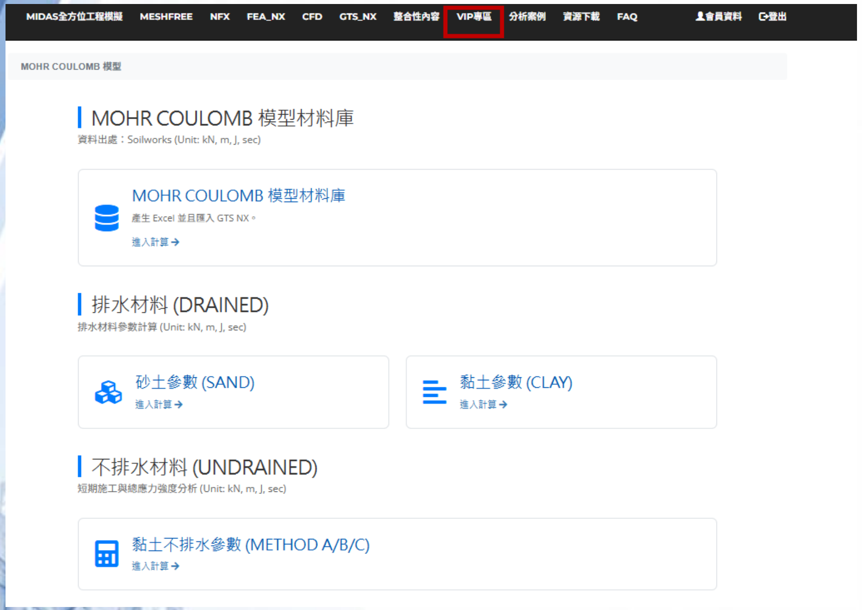
整合性內容

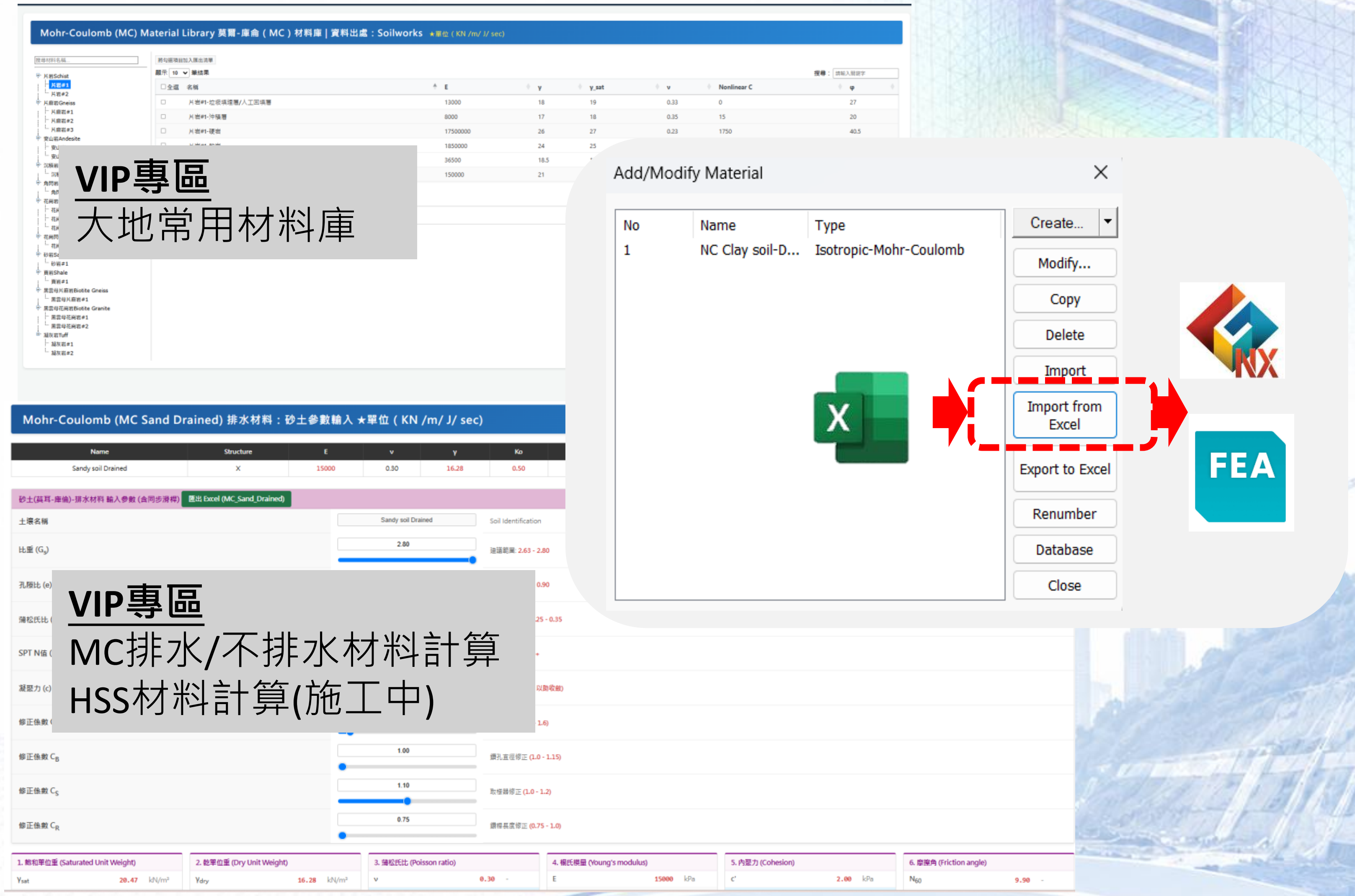
土壤參數計算和分析驗証



VIP專區

https://www.midasuser.com.tw/SolidSimulation/QuickLinks





VIP專區
大地常用材料庫

VIP專區
MC排水/不排水材料計算
HSS材料計算(施工中)

全方位工程模擬-VIP服務

全方位工程軟體系列-維護期內用戶限定

1.大地材料庫&地工試驗參數計算

2.專屬Line群組

(1)定期課程通知

(2)技術問題48hr內回覆

3.課程

(1)實體課程

(2)客制化課程

4.軟體

(1)軟體版本更新

(2)全方位工程軟體系列試用

GTS NX/FEA NX/NFX CAE/NFX CFD/ MeshFree

Taiwan MIDAS會員使用

1.網站教學資料

2.線上課程

3.成功案例

4.軟體下載

MIDAS全方位工程模擬 - 以卓越技術/定義完美服務

Defining Service through Engineering Excellence.

Q & A 時間

感謝您的聆聽，歡迎提問與交流

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官方網站 https://www.midasuser.com.tw/SolidSimulation/