GTS NX_標準教學系列

2D隧道施工階段

台灣邁達斯

註:範例相關參數使用假設條件。

側向土壓力
(Lateral Earth Pressure)

Lateral earth pressure is the pressure that soil exerts in the horizontal direction. The lateral earth pressure is important because it affects the consolidation behavior and strength of the soil and because it is considered in the design of geotechnical engineering structures such as retaining walls, basements, tunnels, deep foundations and braced excavations.

$$\sigma'_h = K \times \sigma'_v$$

K, is the coefficient of lateral earth pressure

σ'_h , is the horizontal effective stress

σ'_v, is the vertical effective stress

The effective stress is the inter granular stress calculated by subtracting the pore pressure from the total stress as described in soil mechanics.

The minimum stable value of K is called the active earth pressure coefficient, K_a; The maximum stable value of K is called the passive earth pressure coefficient, K_p
For a level ground deposit with zero lateral strain in the soil, the "at-rest" coefficient of lateral earth pressure, K_0 is obtained.

Reference

https://en.wikipedia.org/wiki/Lateral_earth_pressure

Initial Stress- K0 method

In general construction stage, the stress resulted from self weight is initial stress.
In GTS NX, the initial stress can be calculated by both **K0 method** and **self-weight analysis method**.

K0 method

The K0 method uses the constant K0 to calculate the horizontal stress from the vertical stress and sets it as the in-situ stress.

To use this method, the vertical stress σ_v needs to be calculated first using self-weight and this value is further used to calculate the horizontal stress through $\sigma_h = K0\ \sigma_v$.

In this case, the shear stress is assumed to be zero.
If the ground surface is not flat, the calculated stress state and self-weight is not in equilibrium.

So when the ground surface is not flat and K0 method is used to calculate initial stress, the analysis must be performed by using unbalanced force between resisting force according to the self weight and initial stress condition in order to make equilibrium condition.

Reference

GTS NX/FEA NX/Soilworks Manual

Initial Stress- Self Weight method

Self-weight analysis method

If the ground surface is flat, this method is the same as the K0=υ/(1- υ) of K0 method.

But if it's not, the results come out differently with the K0 method because the horizontal displacement and the shear stress occur.

Therefore, generally it is recommended to use self-weight analysis method if the ground surface is not flat.

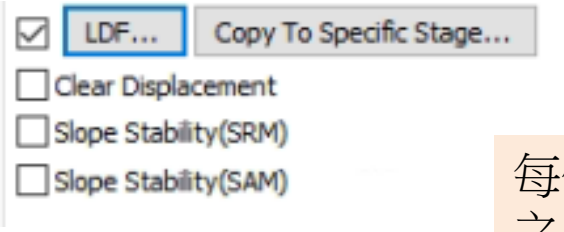
In this case the K0 value can't be set over 1, you must use K0 method to use K0 value over 1.

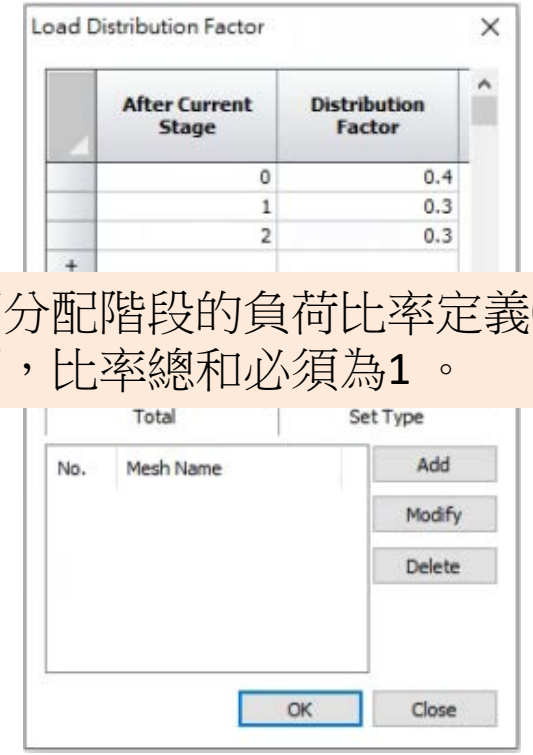
Reference

GTS NX/FEA NX/Soilworks Manual

載重分佈係數
(Load Distribution Factor)

在隧道開挖過程中，會發生朝向縱向和橫向的載重傳遞現象(拱形效應) ，拱形效應發生在兩個或多個平面上，將地面荷載以三維的方式散布，使隧道和整個盾構周圍也會發生位移。
在數值分析中考慮這種效應，必須直接進行 3 維有限元素分析，從最近的文獻和研究結果來看，已經證明3維隧道過程的效果可以在2維上反映出來。
透過LDF(載重分佈係數) ，將荷載劃分並將部分荷載施加到開挖階段之後的階段來推遲隧道開挖效果。



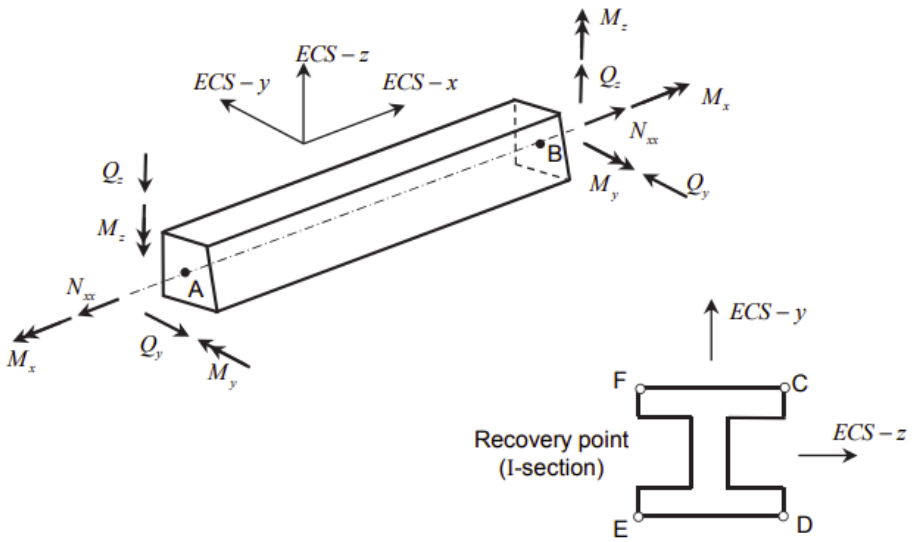


每個分配階段的負荷比率定義0 到 1 之間，比率總和必須為1 。

Reference

GTS NX/FEA NX/Soilworks Manual

梁元素應力結果
(Beam Element Stress Results)



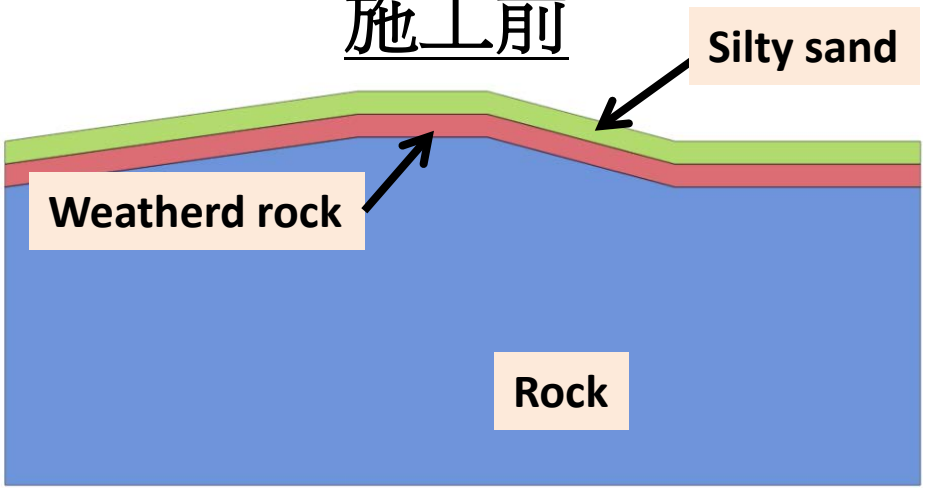
	Results	Explanation
Stress	Axial stress	Position : Section A-B of each segment σ_{xx}
	Torsional stress	Position : Section A-B of each segment Calculate from Torsion stress coefficient c ($\tau = Tc / J$)
	Shear stress	Position : Section A-B of each segment Calculate from shear modulus of cross-section area $\tau_{xy} = Q_y / (S_{ky} A)$, $\tau_{xz} = Q_z / (S_{kz} A)$
	Point stress	Position : Section A-B of each segment Bending Stress induced by user defined location σ_{xx}
	Max/Min stress	Position : Section A-B of each segment Max/Min of the sum of Axial stress and Point stress among location C~F
	Von-mises stress	Position : Section A-B of each segment $\sigma_v = \sqrt{\sigma_{xx}^2 + 3\left(\tau_{xy}^2 + \tau_{xz}^2\right)}$

Reference

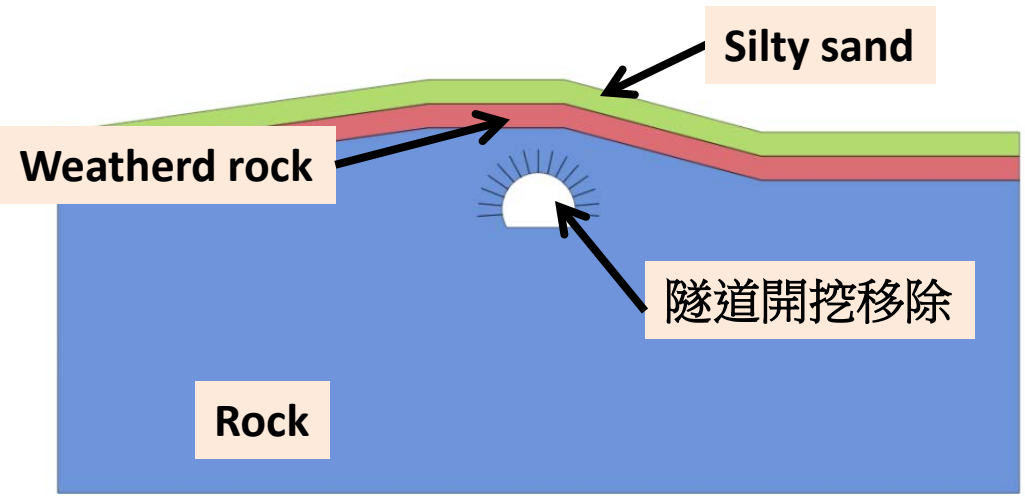
GTS NX/FEA NX/Soilworks Manual

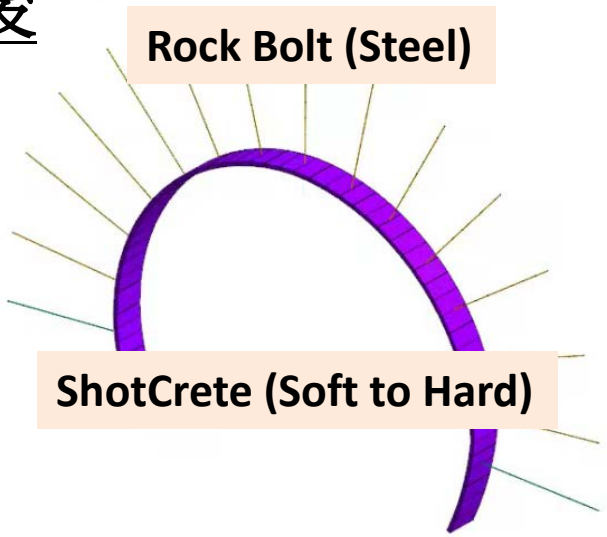
分析說明-材料

施工前



施工後

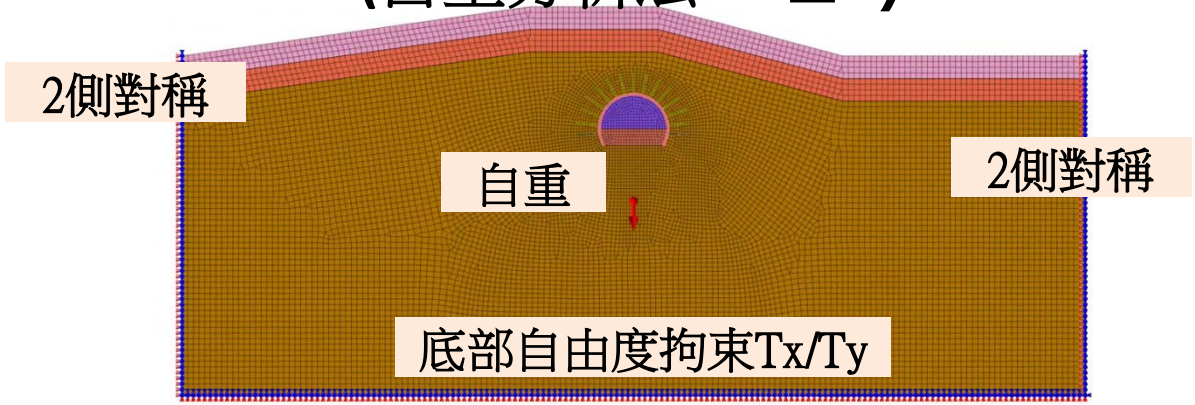




註:範例相關參數使用假設條件。

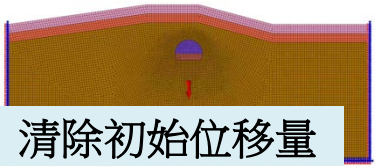
分析說明-施工流程

(自重分析法K0≦1)



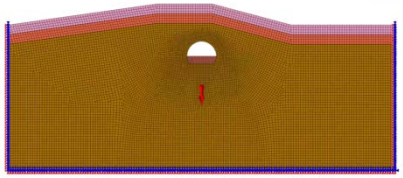
Stage1

計算地表現地情況。



Stage2

上半部開挖

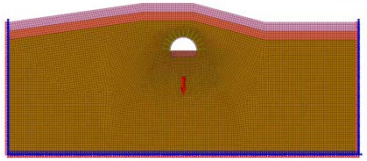


Stage3

上半部岩石螺栓
第1層噴射混凝土

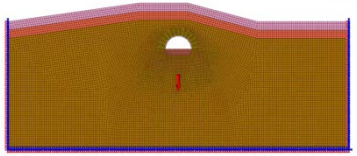
Stage4

上半部第2層噴射混凝土



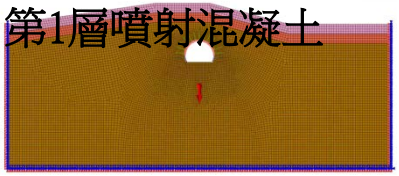
Stage5

下半部開挖



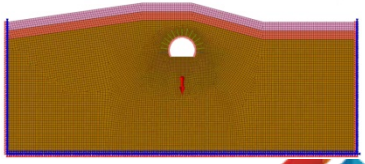
Stage6

下半部岩石螺栓
第1層噴射混凝土



Stage7

下半部第2層噴射混凝土



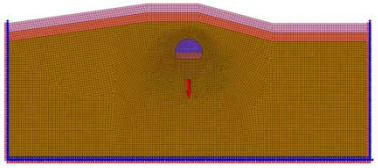
註:範例相關參數使用假設條件。

分析說明-施工流程

(K0 method [K0>1])

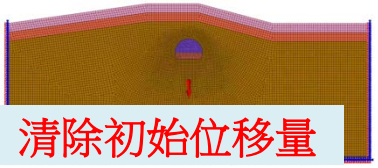
Stage1

計算地表自重情況。



Stage2

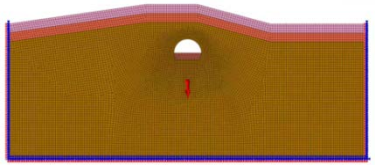
邊界條件不變動



清除初始位移量

Stage3

上半部開挖

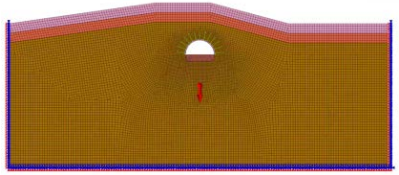


Stage4

上半部岩石螺栓
第1層噴射混凝土

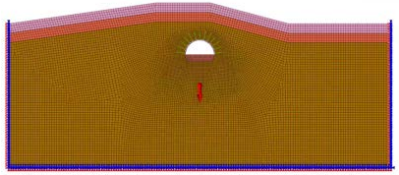
Stage5

上半部第2層噴射混凝土



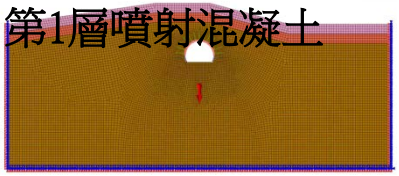
Stage6

下半部開挖



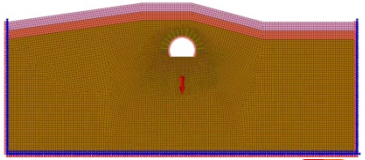
Stage7

下半部岩石螺栓
第1層噴射混凝土



Stage8

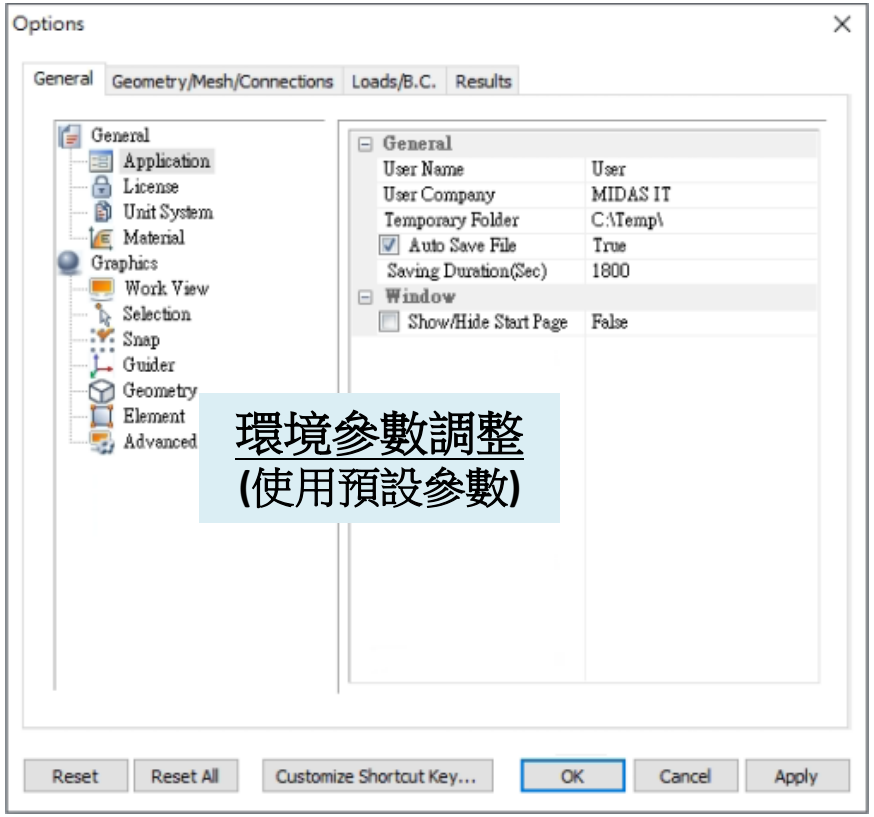
下半部第2層噴射混凝土



註:範例相關參數使用假設條件。

環境

新文件



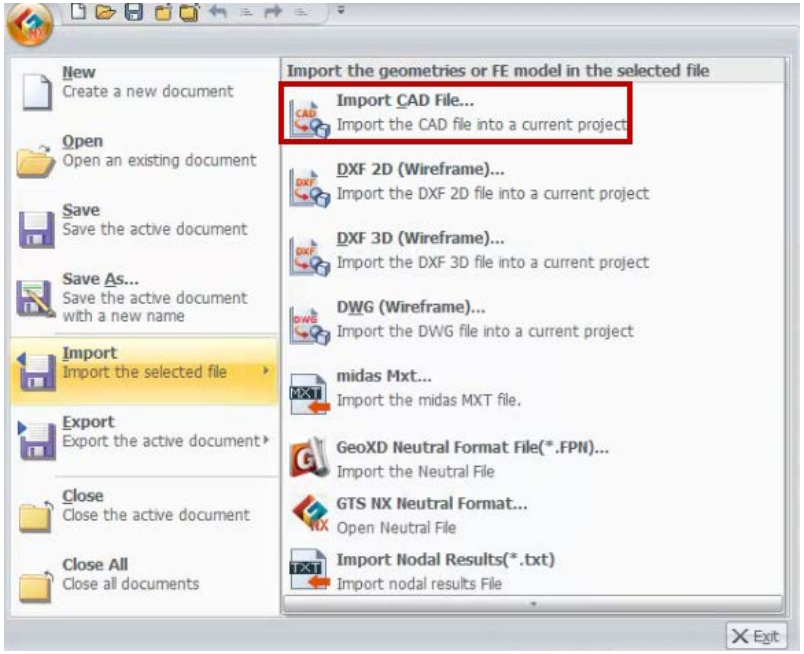
環境參數調整
(使用預設參數)

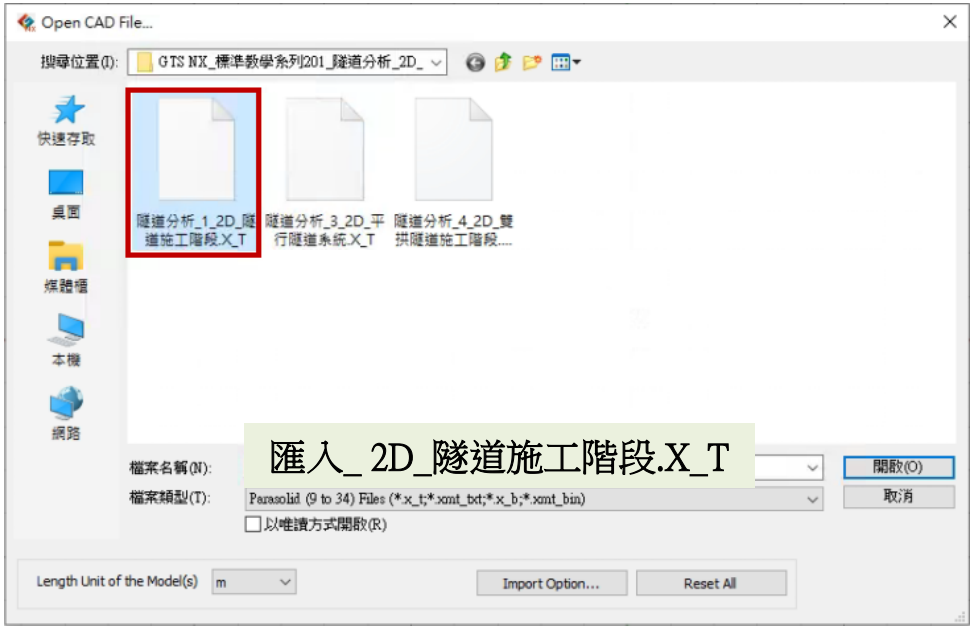
2D操作

切換單位

單位使用KN/m/J/sec

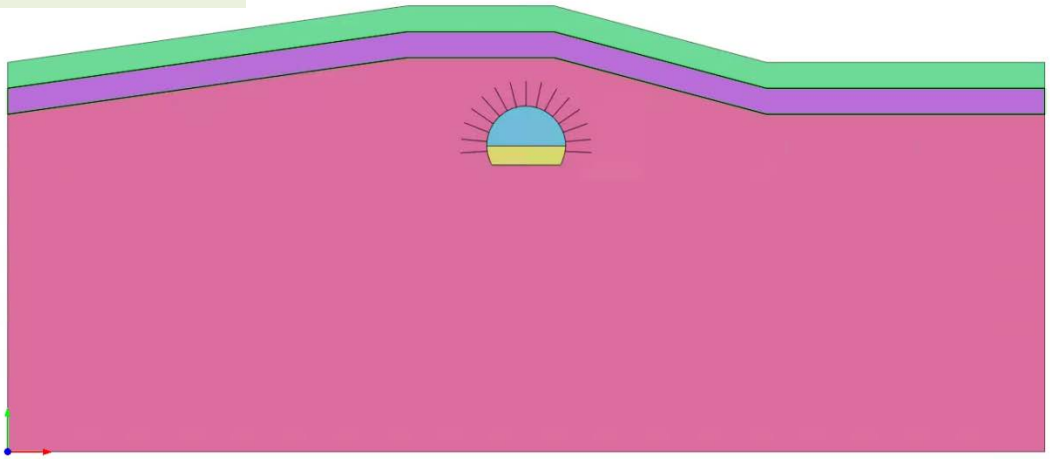
2D模型匯入



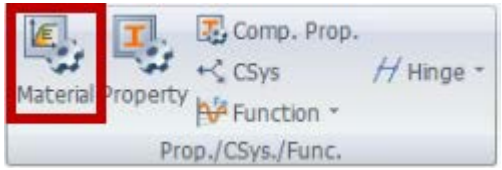


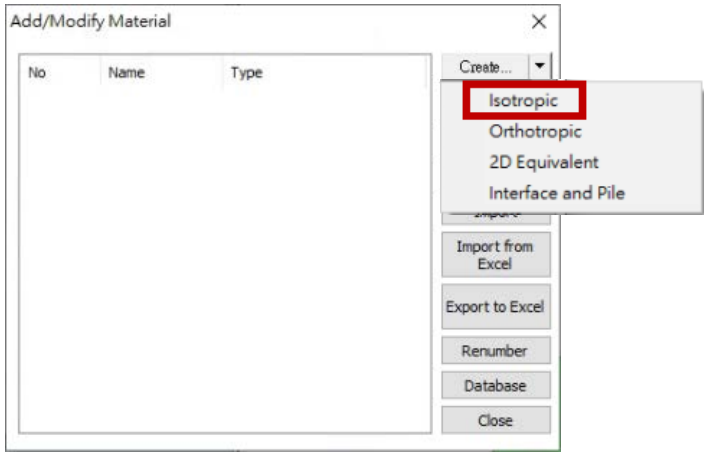
匯入_ 2D_隧道施工階段.X_T

面特徵模型

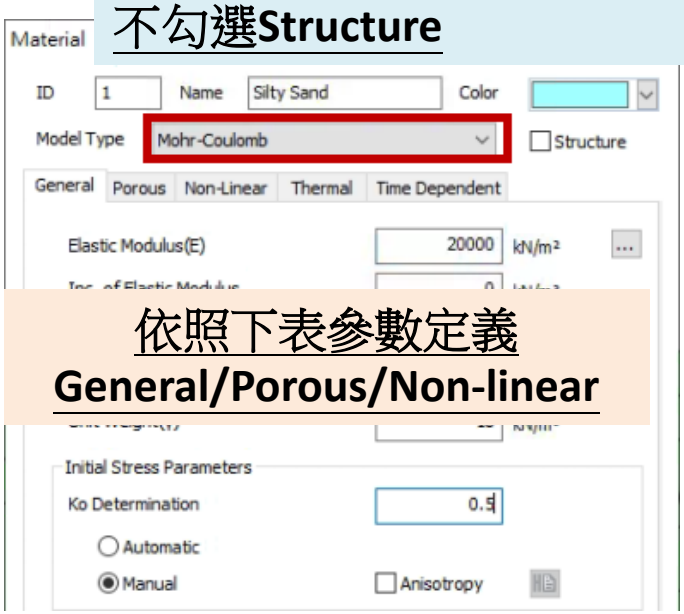


大地-材料





Model Type : Mohr-Coulomb
不勾選Structure

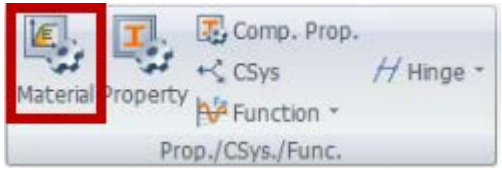


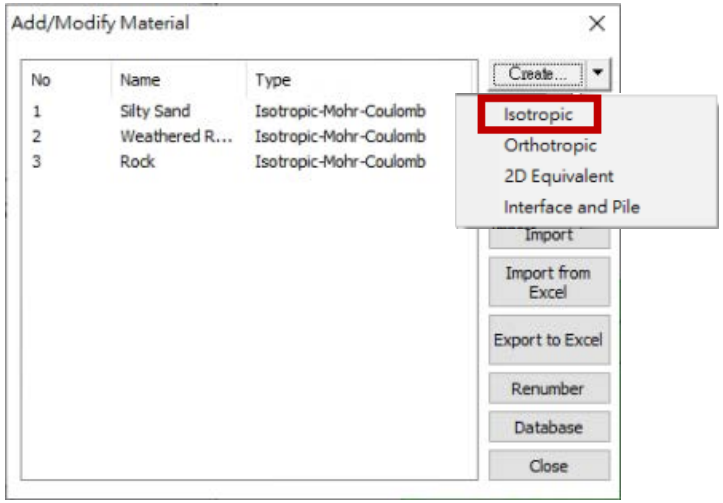
依照下表參數定義
General/Porous/Non-linear

Name	Modulus of Elasticity(E) (KN/m^2)	Poisson's Ratio(v)	Unit Weight(γ) (KN/m^3)	K0	Unit Weight (Saturated) (KN/m^3)	Cohesion(C) (KN/m^2)	Friction Angle(ϕ)
Silty Sand	2×10^4	0.35	18	0.5	19	0	30
Weathered Rock	2×10^5	0.33	21	0.5	22	30	33
Rock	1×10^7	0.22	26	0.5	27	3000	43

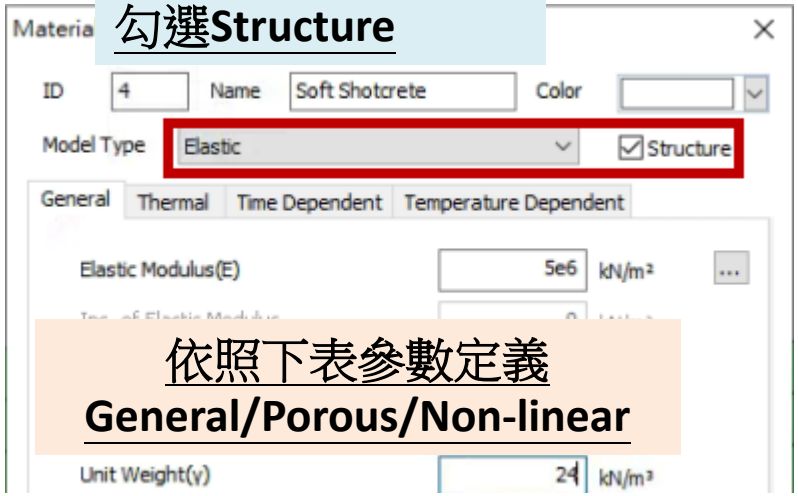
註:範例相關參數使用假設條件。

結構-材料





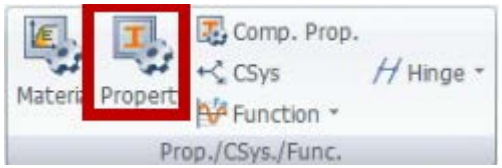
Model Type : Elastic
勾選Structure



依照下表參數定義
General/Porous/Non-linear

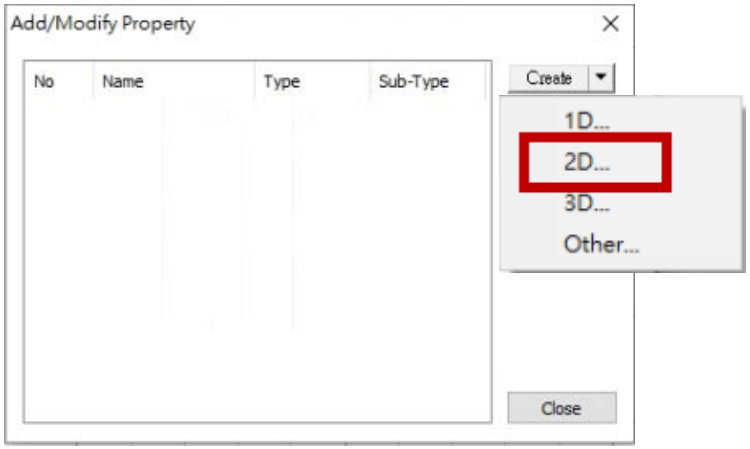
Name	Modulus of Elasticity(E) (KN/m²)	Poisson's Ratio(ν)	Unit Weight(γ) (KN/m³)
Soft ShotCrete	5×10^6	0.3	24
Hard ShotCrete	1.5×10^7	0.3	24
Rock Bolt	2.1×10^8	0.3	78

屬性-2D Plane Strain

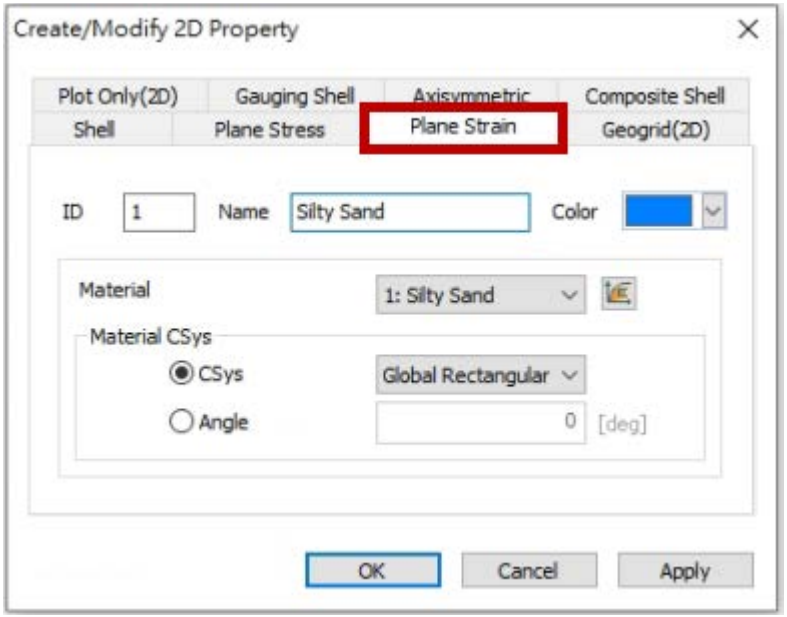


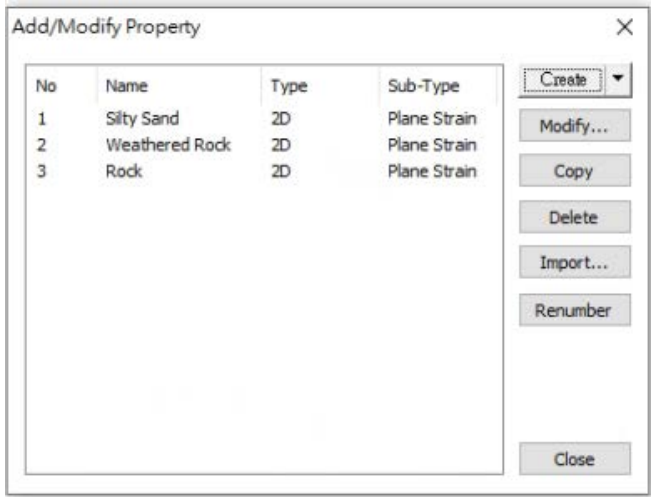
依序新增

Name: Silty Sand/Material: Silty Sand
Name: Weathered Rock/Material: Name:
Name: Rock/Material: Rock

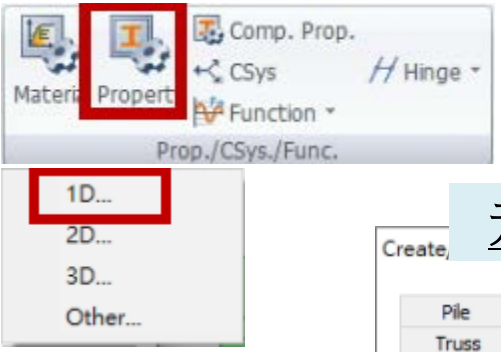


元素類型使用**Plane Strain**





屬性-1D Beam
(Soft ShotCrete)

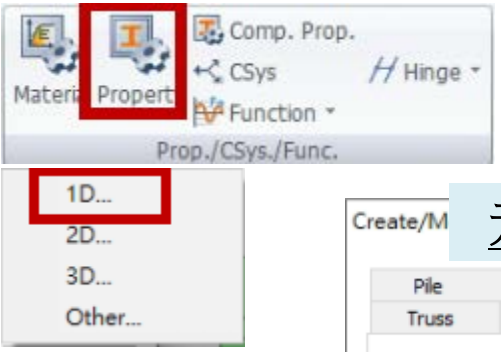


元素類型使用Beam

Name : Soft ShotCrete / Material: Soft ShotCrete

截面定義(Solid Rectangle)
H:0.12(m) /B:1 (m)

屬性-1D Beam
(Hard ShotCrete)



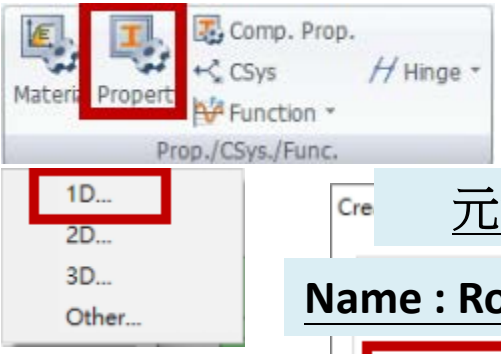
元素類型使用Beam

Name : Hard ShotCrete / Material: Hard ShotCrete

截面定義(Solid Rectangle)
H:0.12(m) /B:1 (m)

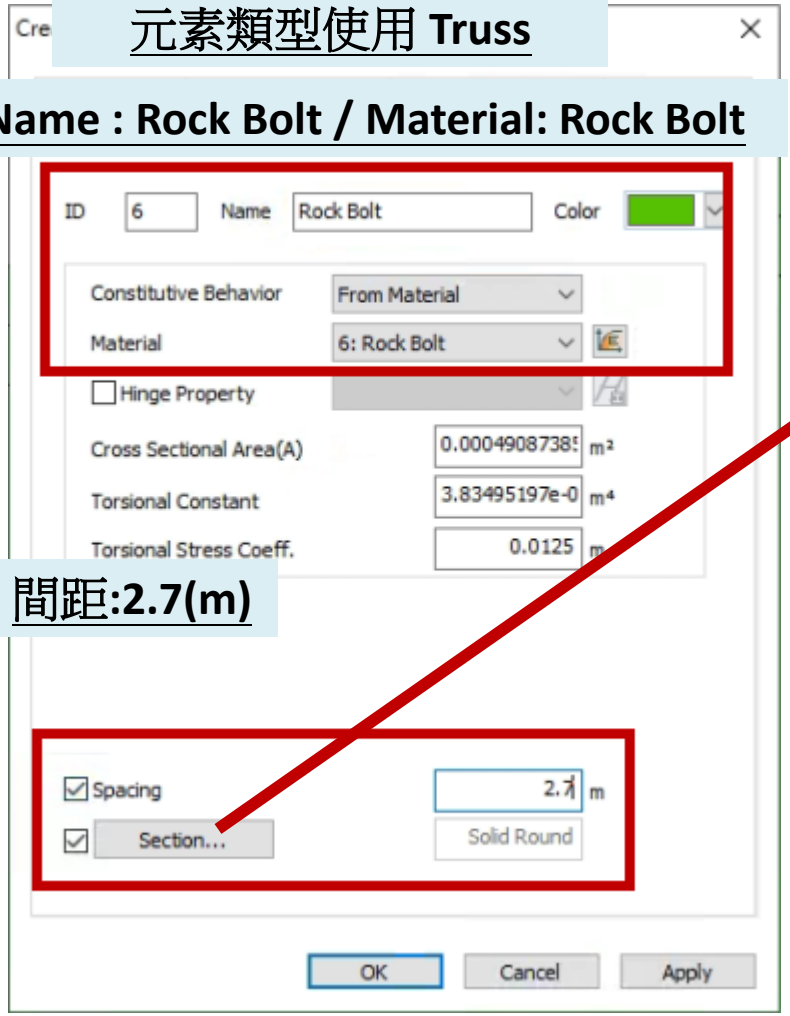
屬性-1D Truss

(Rock Bolt)

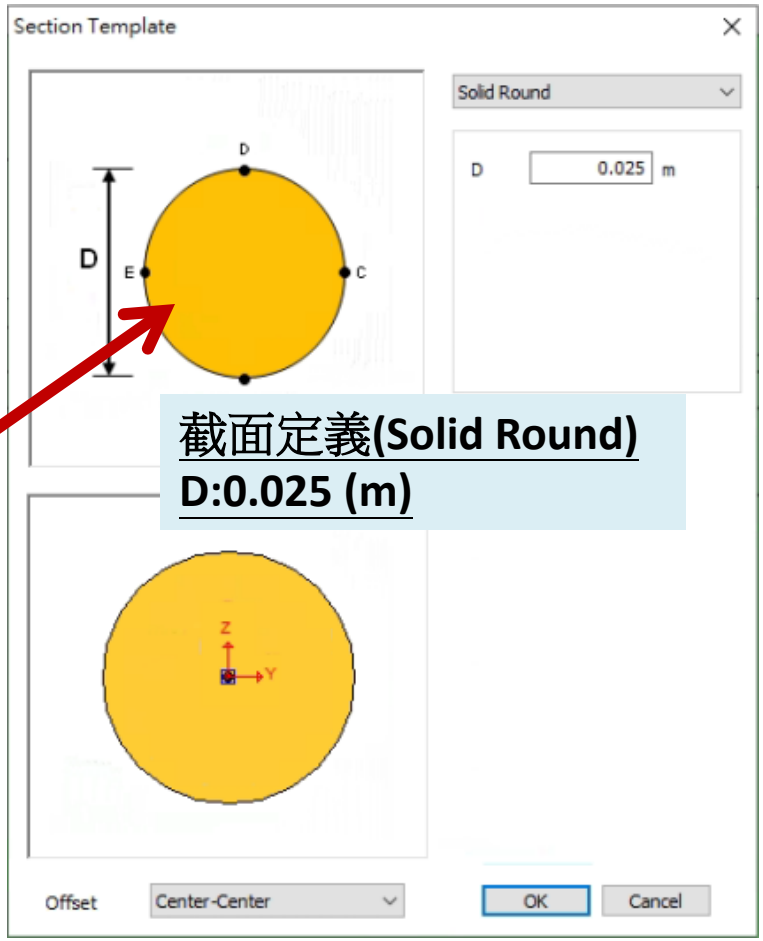


元素類型使用 **Truss**

Name : Rock Bolt / Material: Rock Bolt



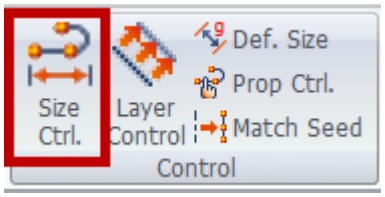
間距:2.7(m)

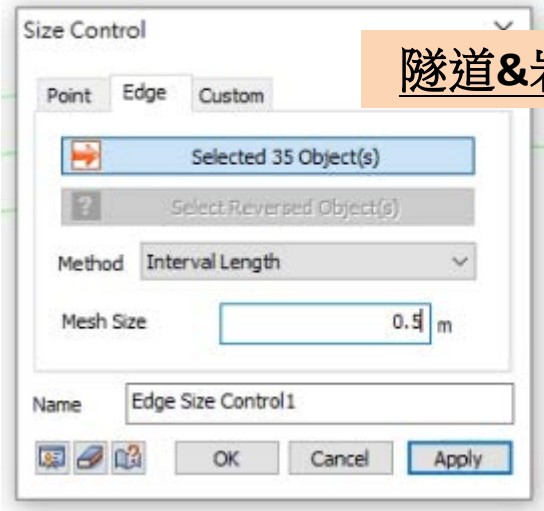


截面定義(Solid Round)
D:0.025 (m)

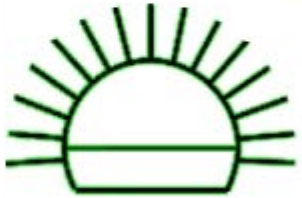
補充: CTC (spacing) which refers to distance between 1D elements.

手動網格尺寸指定

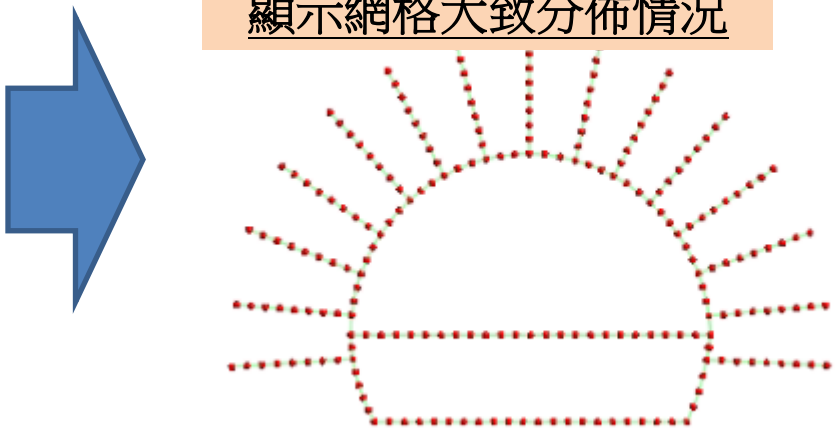




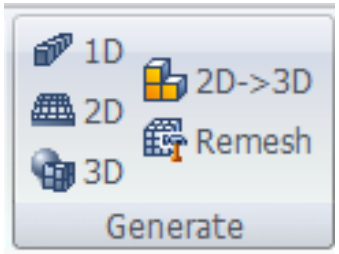
隧道&岩石螺栓周邊尺寸:0.5m



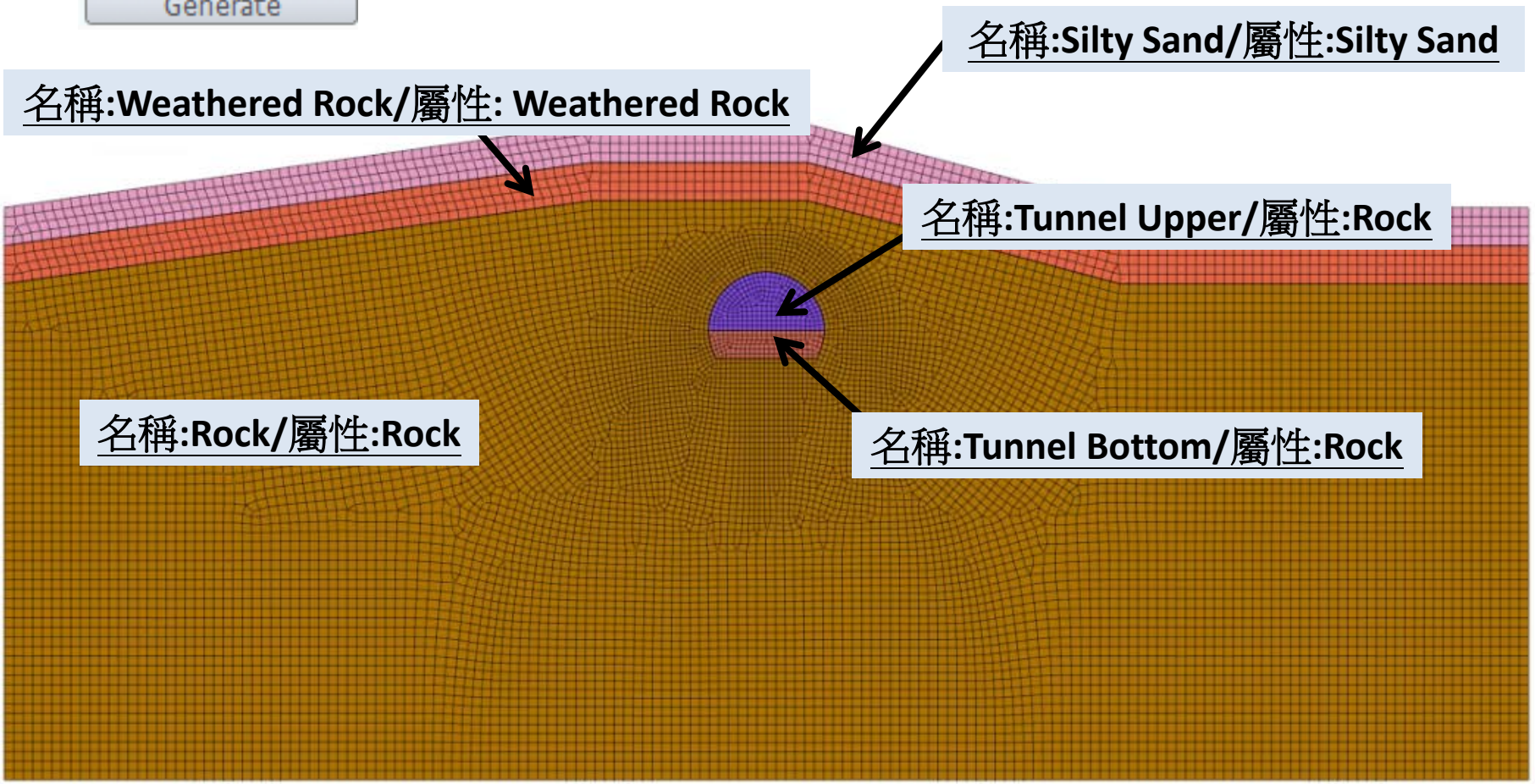
顯示網格大致分佈情況



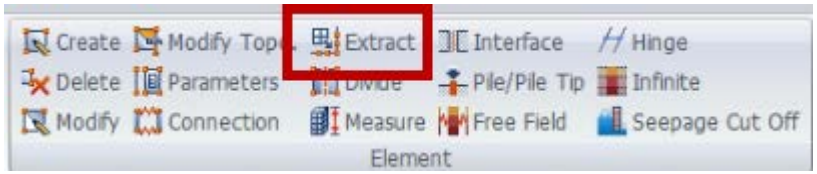
2D網格生成



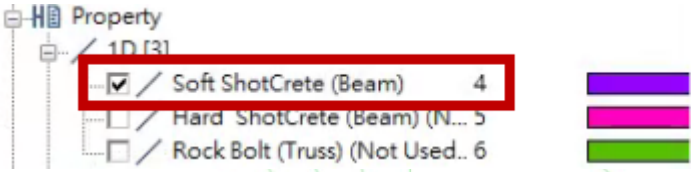
網格尺寸: 1



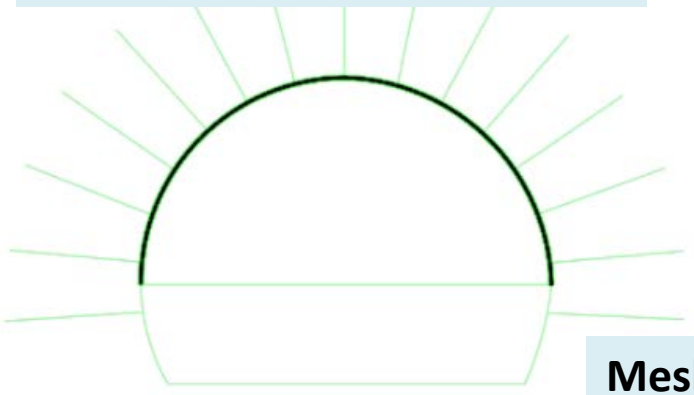
1D網格生成-噴射混凝土

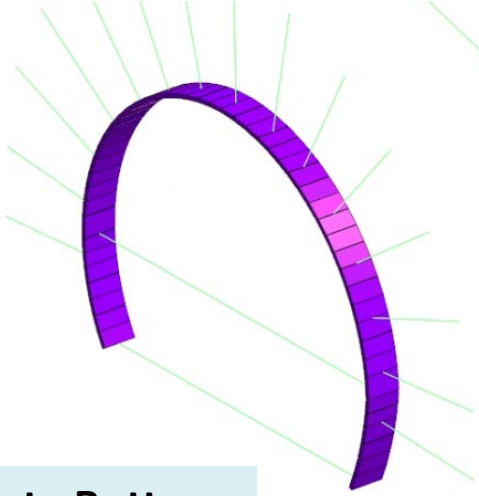


勾選Soft ShotCrete檢視截面

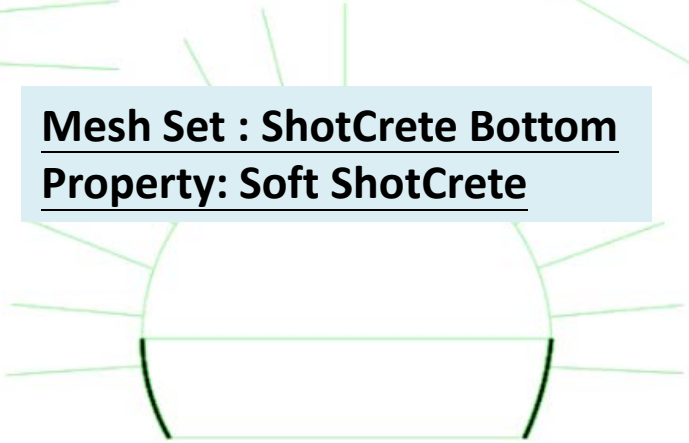


Mesh Set : ShotCrete Upper
Property: Soft ShotCrete



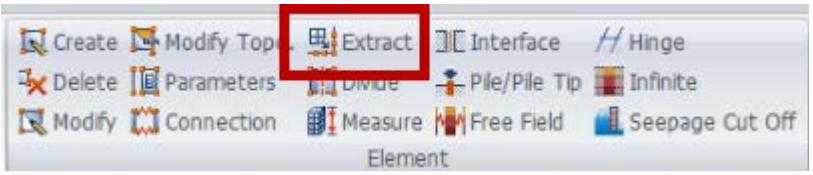


Mesh Set : ShotCrete Bottom
Property: Soft ShotCrete

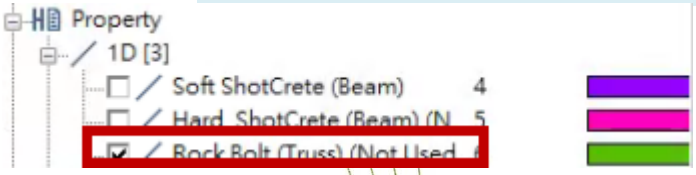


註:截面顯示不正確可以調整元素方向

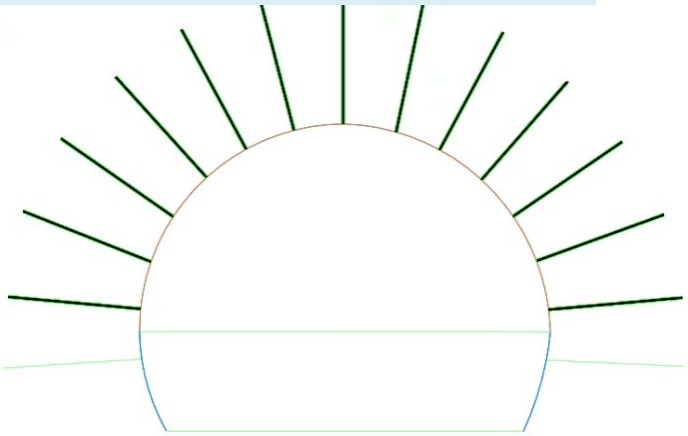
1D網格生成-岩石螺栓



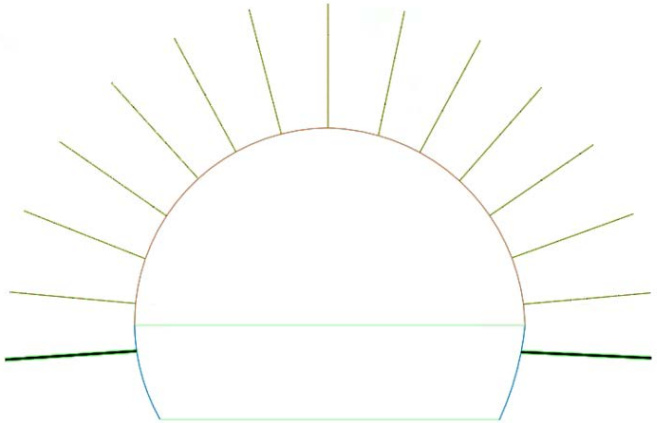
勾選Rock Bolt檢視截面



Mesh Set : Rock Bolt Upper
Property: Rock Bolt

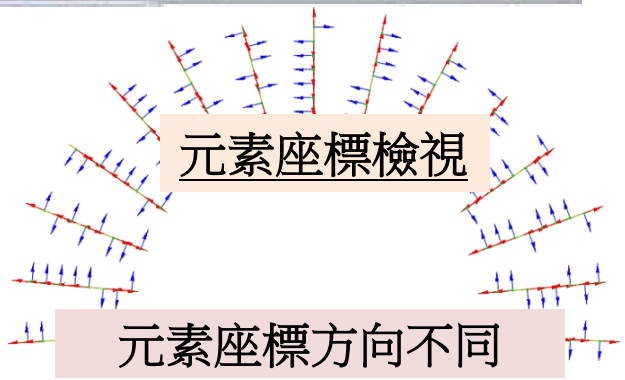


Mesh Set : Rock Bolt Bottom
Property: Rock Bolt

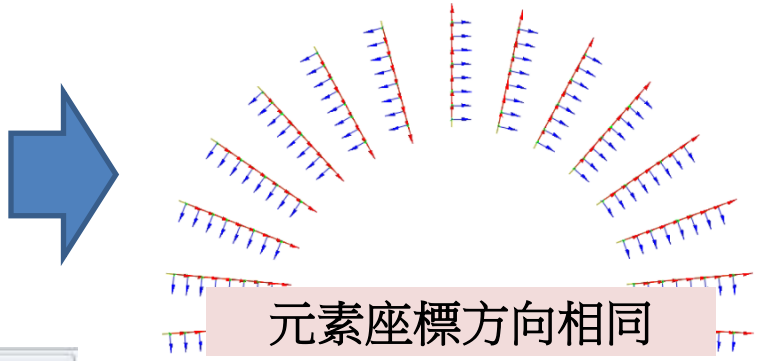


Rock Bolt Truss元素座標檢視/調整

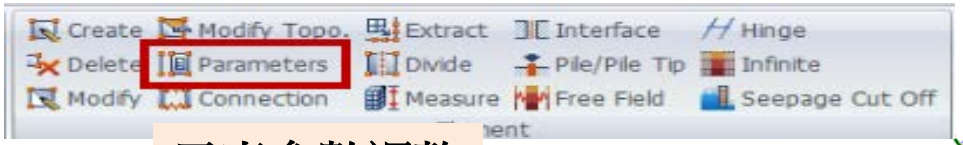
元素座標檢視



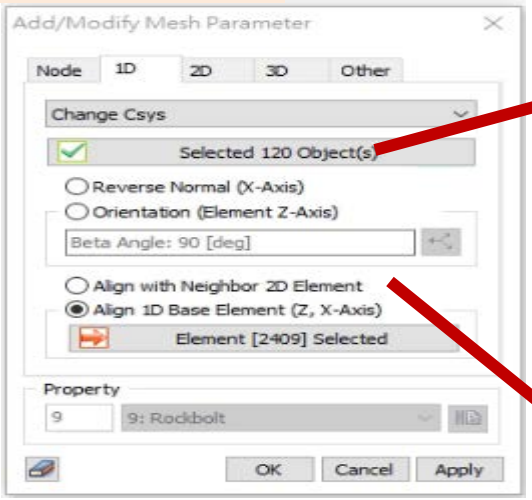
元素座標方向不同

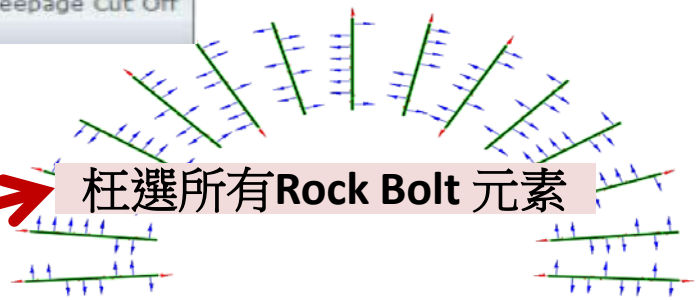


元素座標方向相同



元素參數調整





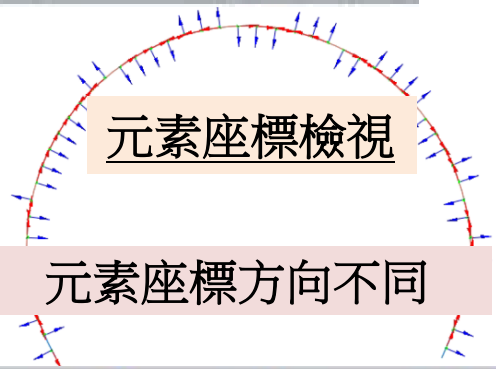
框選所有Rock Bolt 元素

選取1元素作為元素座標指定標準

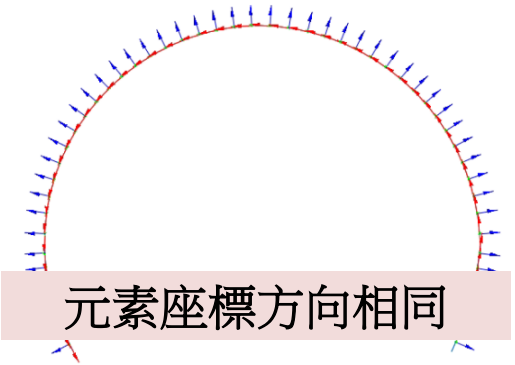
註:元素座標顯示時，建議不要開啓截面檢視。

ShotCrete Beam元素座標檢視/調整

元素座標檢視

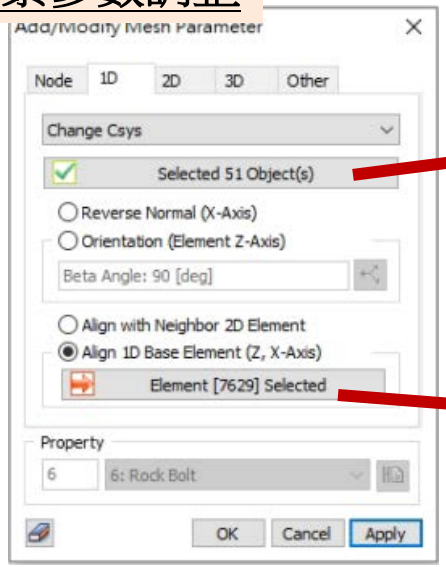


元素座標方向不同

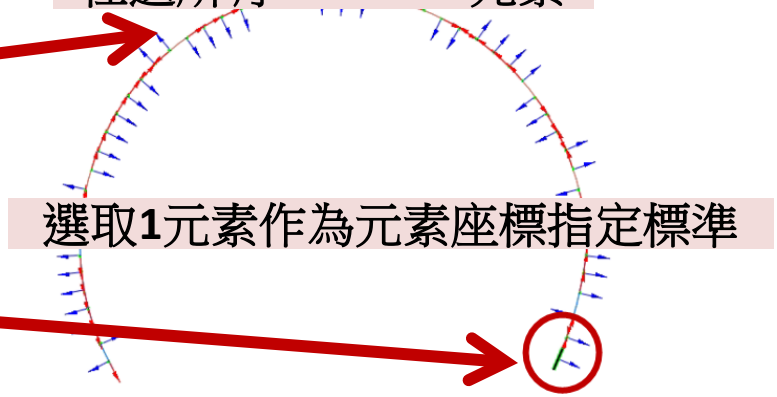


元素座標方向相同

元素參數調整



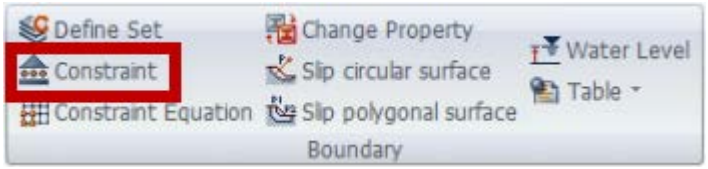
框選所有**Rock Bolt** 元素

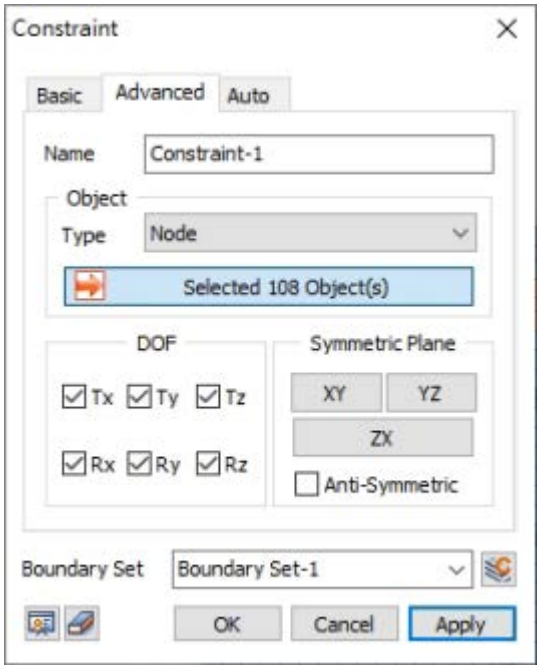


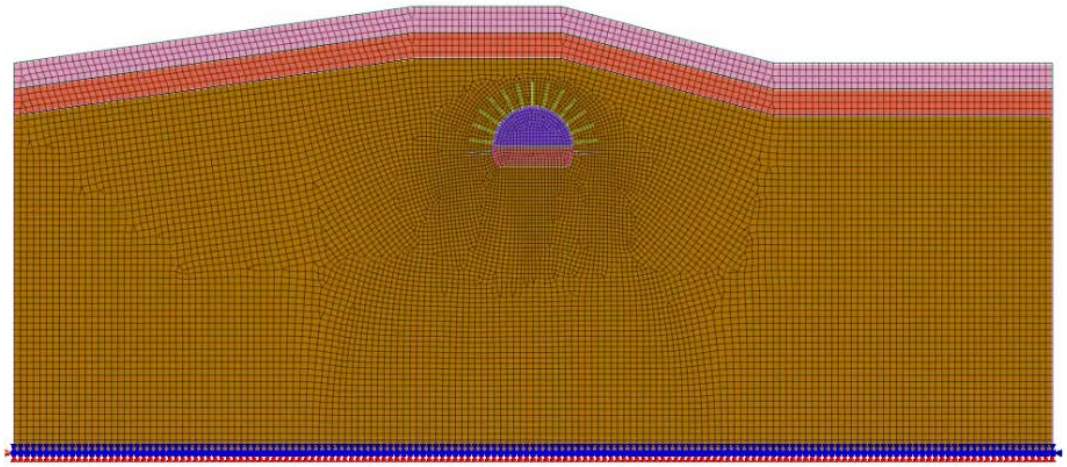
選取1元素作為元素座標指定標準

註:元素座標顯示時，建議不要開啓截面檢視。

底部邊界



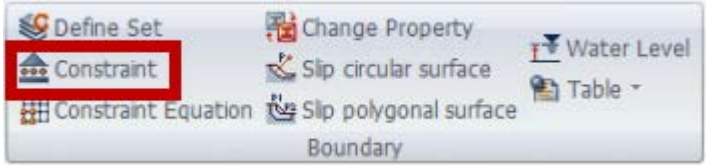


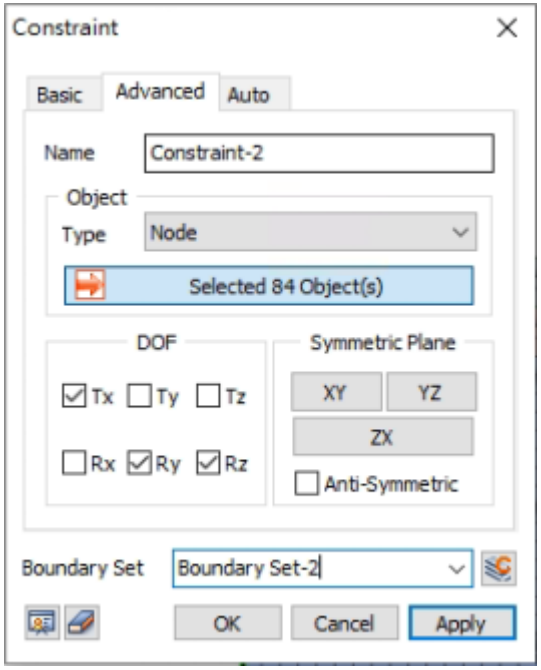


底部自由度拘束
Tx/Ty/Tz/Rx/Ry/Rz

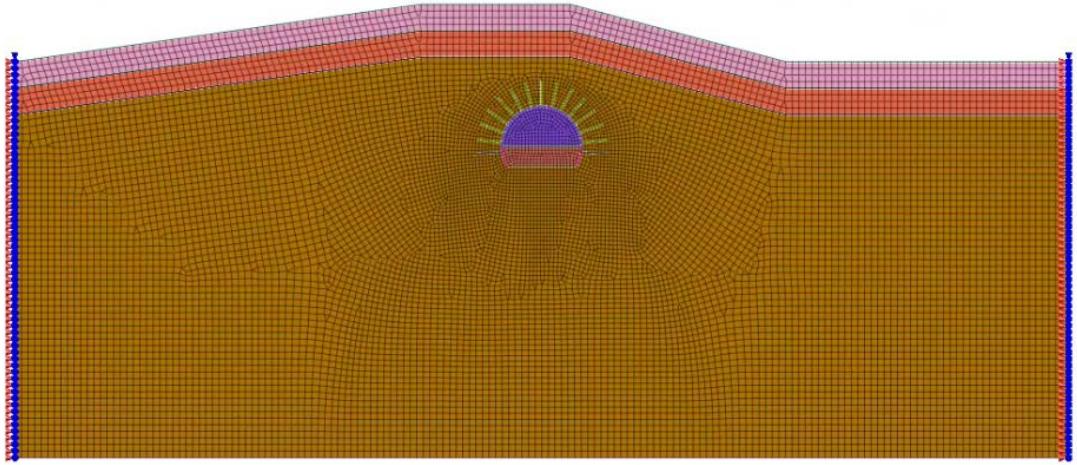
補充:元素和幾何特徵關聯性存在，邊界可以施加幾何特徵或節點。

對稱邊界



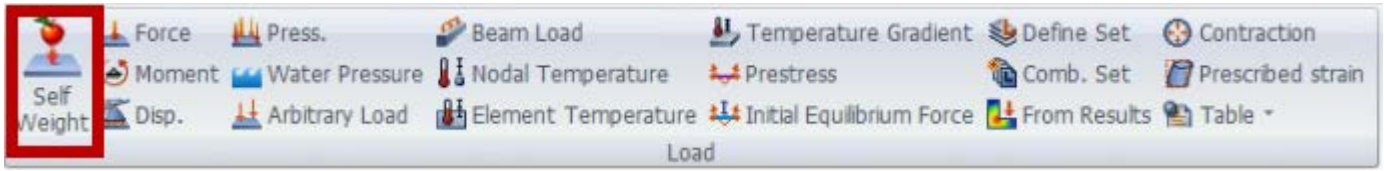


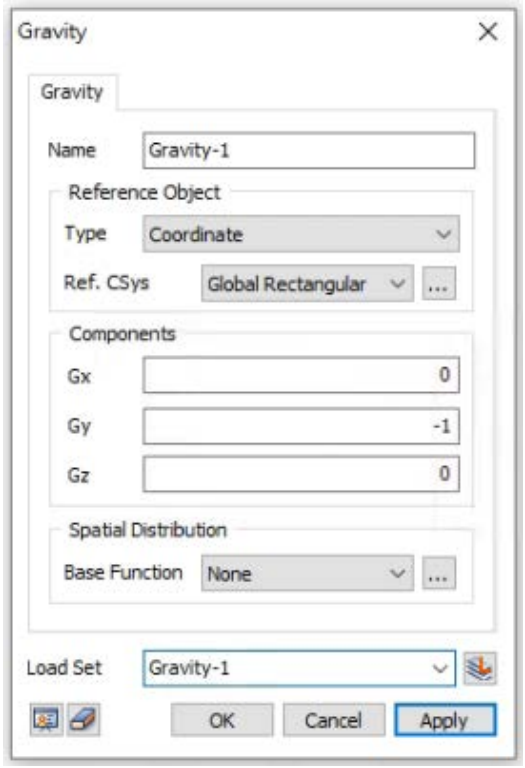
2側自由度拘束Tx/Ry/Rz

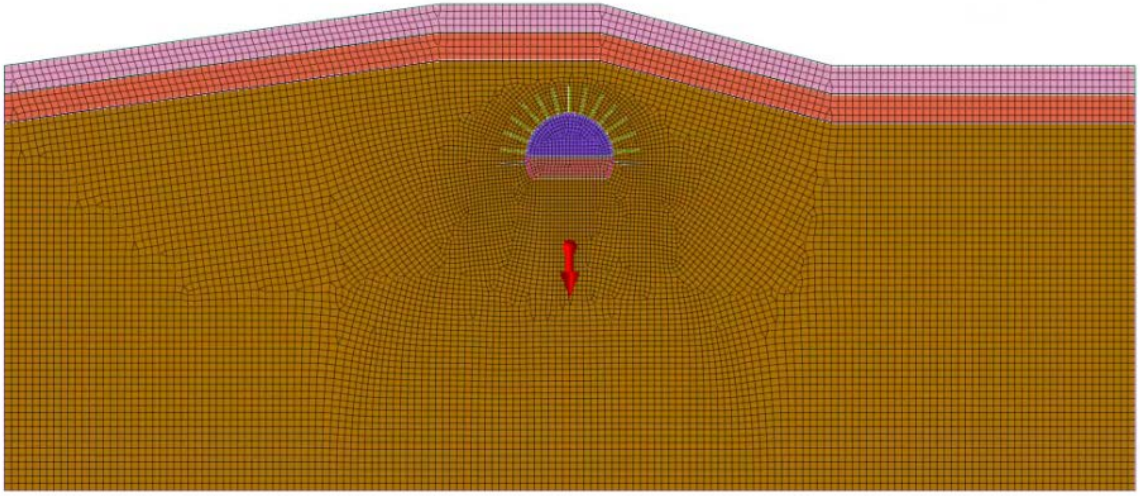


補充:建議不同邊界集使用不同邊界集名稱

初始應力-自重

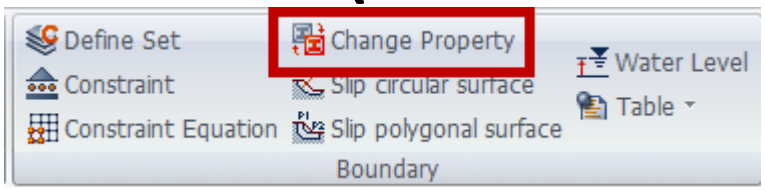

Self Weight
Force
Moment
Disp.
Press.
Water Pressure
Arbitrary Load
Beam Load
Nodal Temperature
Element Temperature
Temperature Gradient
Prestress
Initial Equilibrium Force
Define Set
Comb. Set
From Results
Contraction
Prescribed strain
Table
Load


Gravity
Gravity
Name
Gravity-1
Reference Object
Type
Coordinate
Ref. CSys
Global Rectangular
Components
Gx
0
Gy
-1
Gz
0
Spatial Distribution
Base Function
None
Load Set
Gravity-1
OK
Cancel
Apply

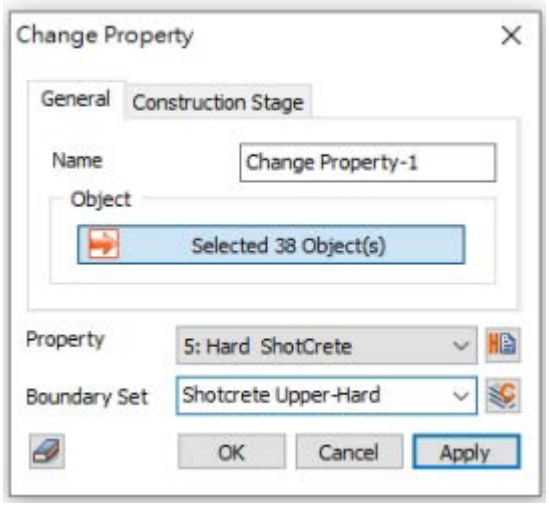


隧道上半部噴射混凝土

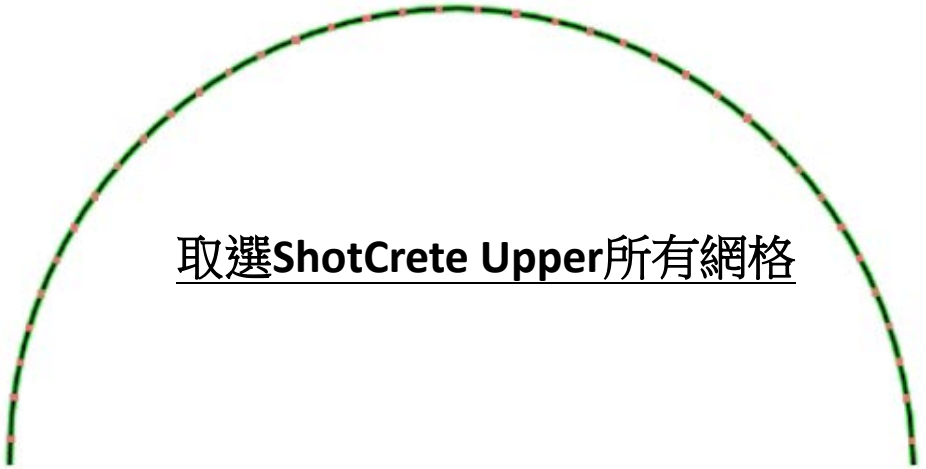
(Soft ShotCrete => Hard ShotCrete)



施工階段分次施加噴射混凝土
利用**Change Property**變更噴射混凝土強度

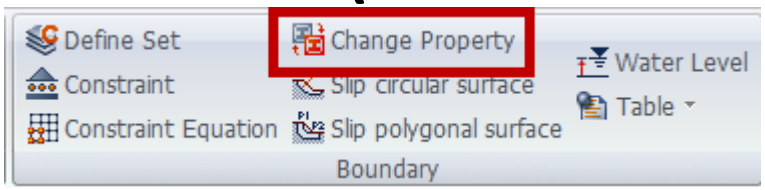


名稱:Shotcrete Upper-Hard/屬性:Hard ShotCrete

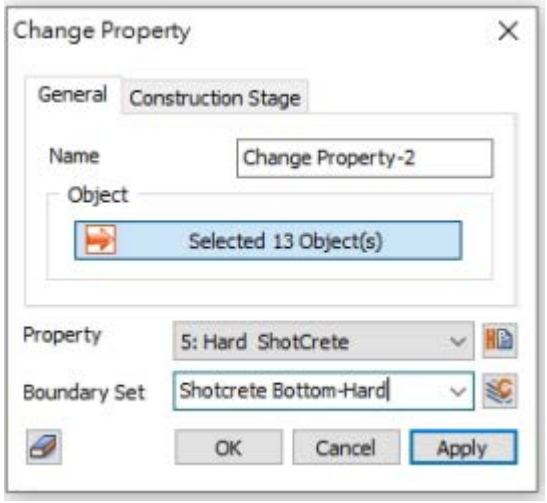


隧道下半部噴射混凝土

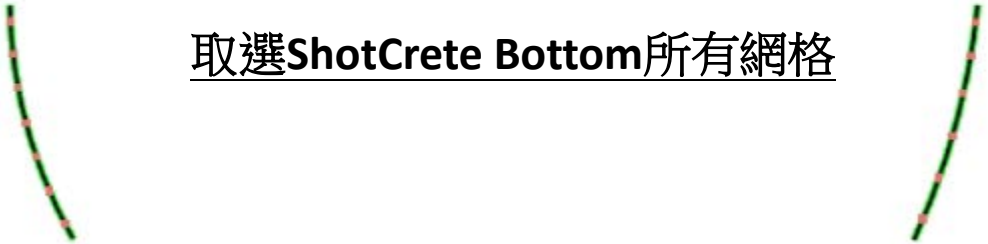
(Soft ShotCrete => Hard ShotCrete)



施工階段分次施加噴射混凝土
利用**Change Property**變更噴射混凝土強度



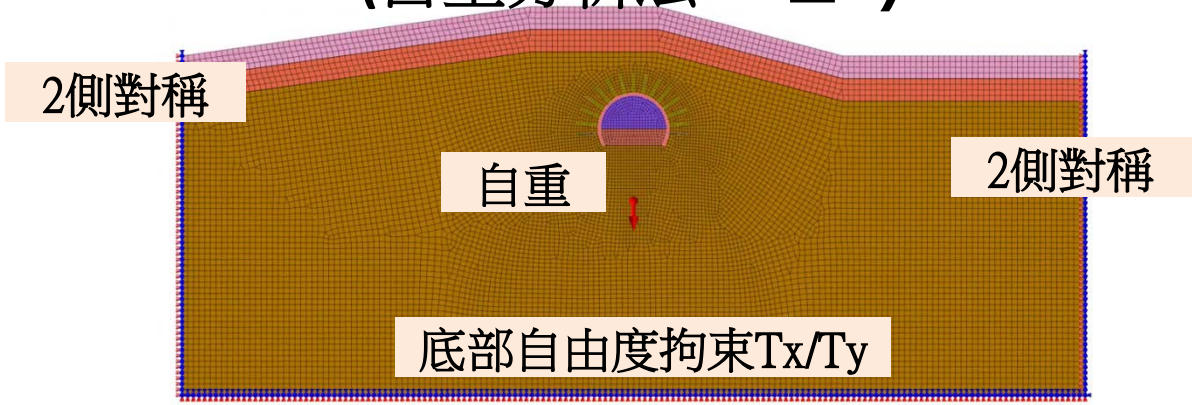
名稱:**Shotcrete Bottom-Hard**/屬性:**Hard ShotCrete**



取選**ShotCrete Bottom**所有網格

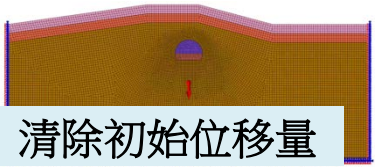
分析說明-施工流程

(自重分析法K0≦1)



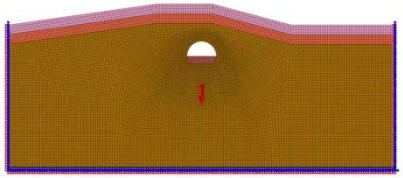
Stage1

計算地表現地情況。



Stage2

上半部開挖

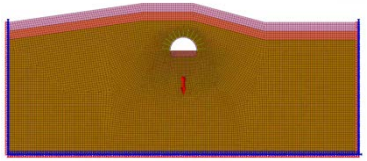


Stage3

上半部岩石螺栓
第1層噴射混凝土

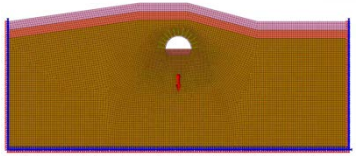
Stage4

上半部第2層噴射混凝土



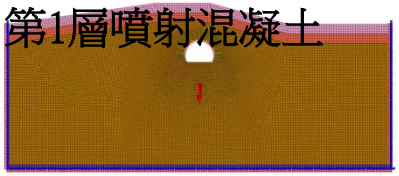
Stage5

下半部開挖



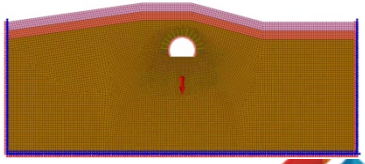
Stage6

下半部岩石螺栓
第1層噴射混凝土



Stage7

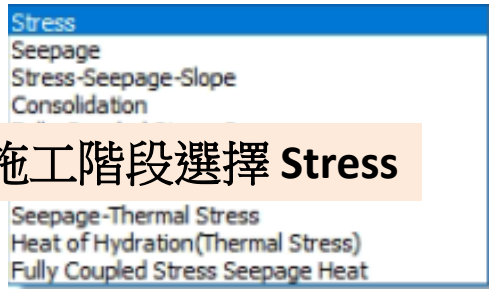
下半部第2層噴射混凝土



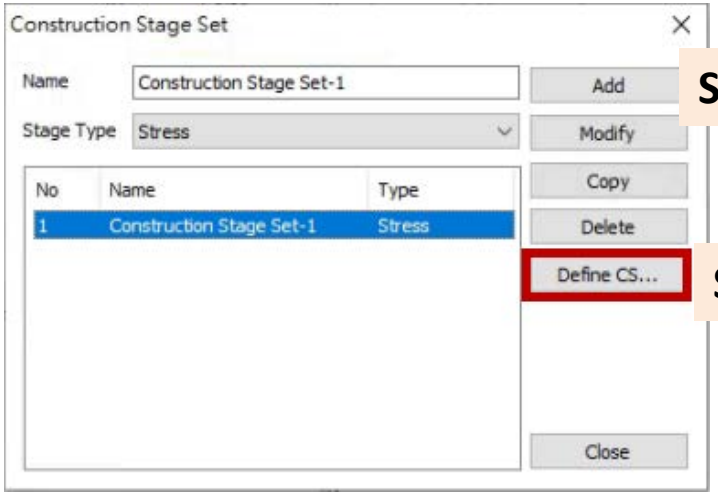
註:範例相關參數使用假設條件。

施工階段定義-1
(新增施工階段計算類型)

GTS NX提供多種施工階段類型

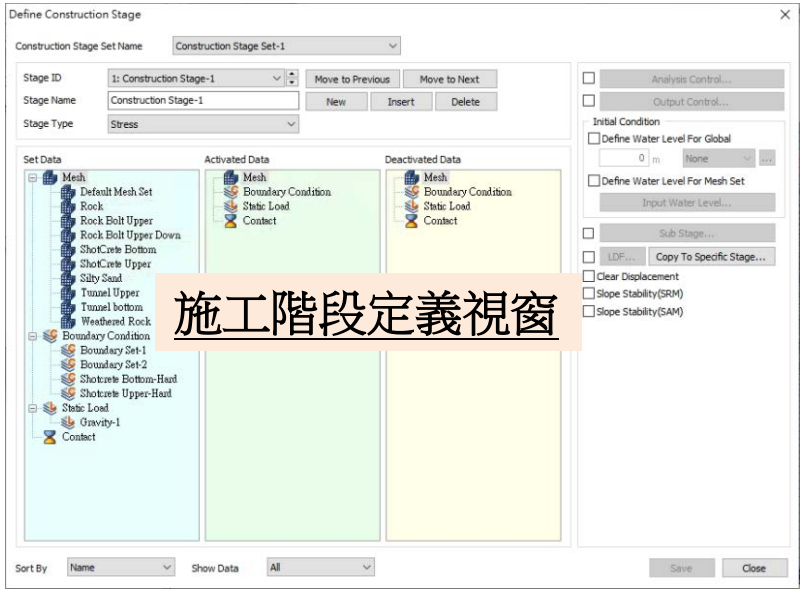


施工階段選擇 Stress



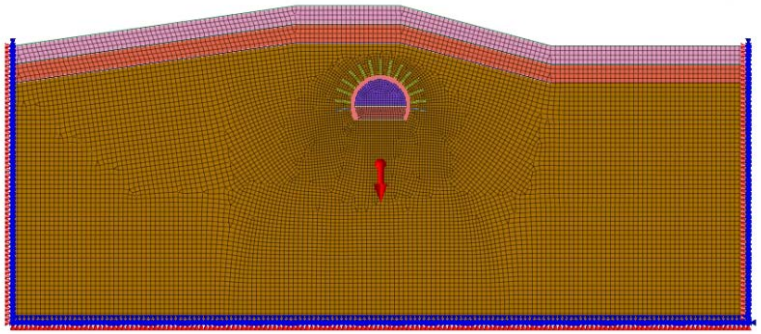
Step1.新增

Step2.編輯定義



施工階段定義視窗

施工階段提供同步檢視
(顯示所有網格集/邊界集/載荷集)



施工階段定義-2
(施工階段1:Initial Stage)

訂義工況名稱:Initial Stage/分析類型:Stress

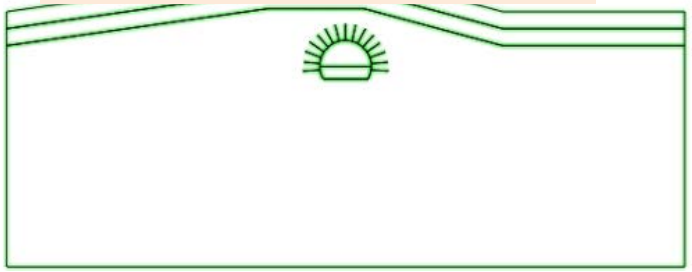
清除初始位移量

拖曳初始大地網格集/邊界集/Gravity載荷集 to Activated Data

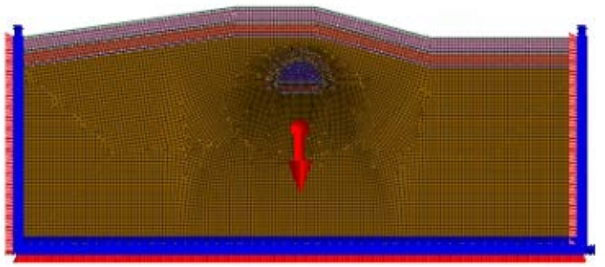
開啓施工階段檢視

儲存
(定義後務必儲存)

操作畫面-未施加條件前

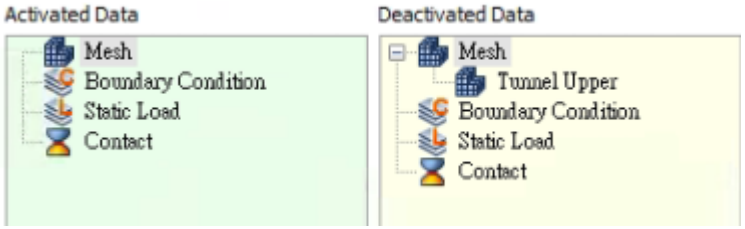


操作畫面-Initial Stage施工階段

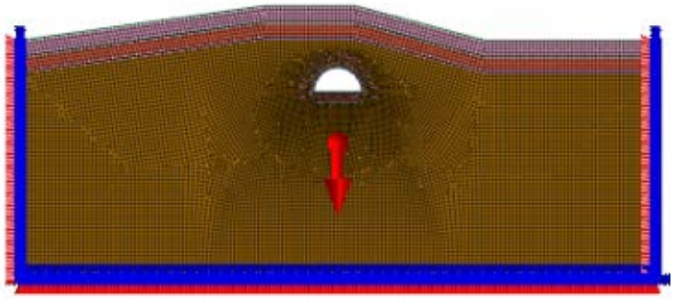


施工階段定義-3
(施工階段2~3)

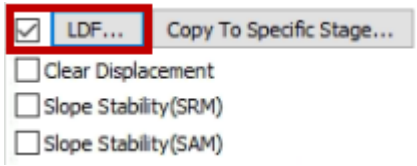
Stage2:上半部開挖



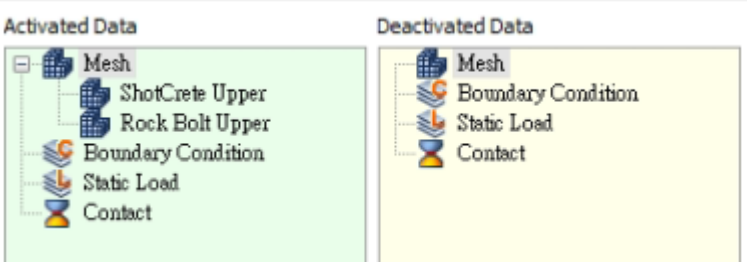
Deactivated Data
網格集:Tunnel Upper



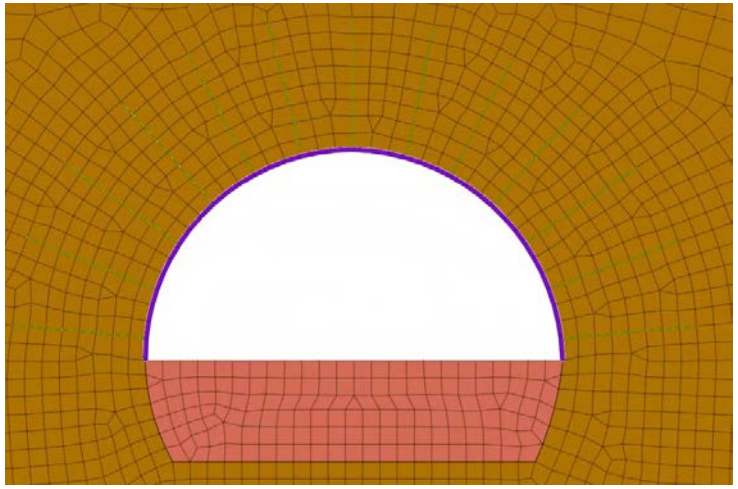
Load Distribution Factor分配係數



Stage3:上半部岩石螺栓&第1層噴射混凝土

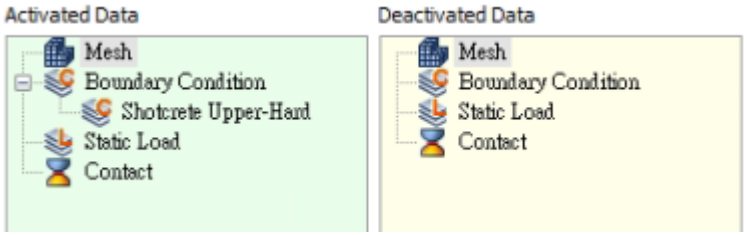


Activated Data
網格集:ShotCrete Upper
Rock Bolt Upper

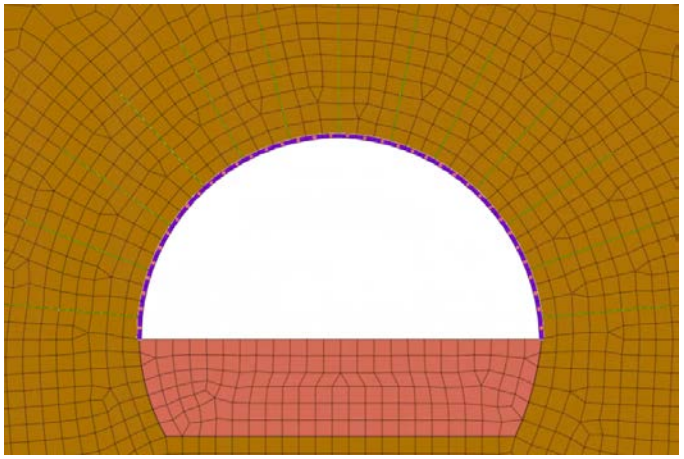


施工階段定義-4
(施工階段4~5)

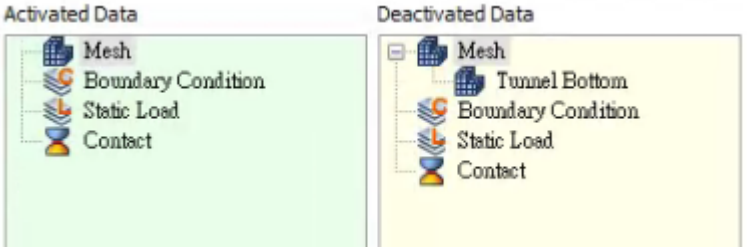
Stage4:上半部第2層噴射混凝土



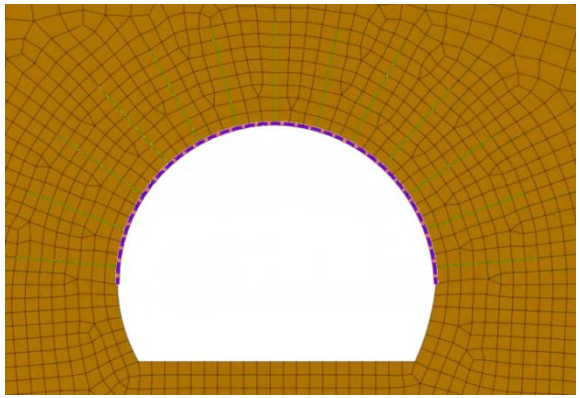
Activated Data
邊界集:ShotCrete Upper Hard



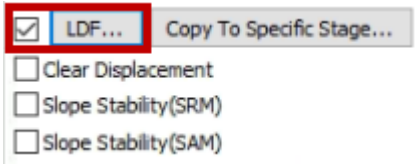
Stage5:下半部開挖



Deactivated Data
網格集:Tunnel Bottom

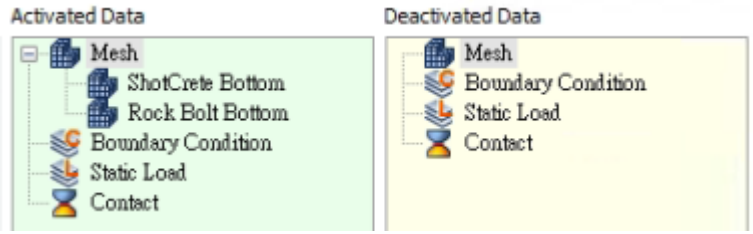


Load Distribution Factor分配係數

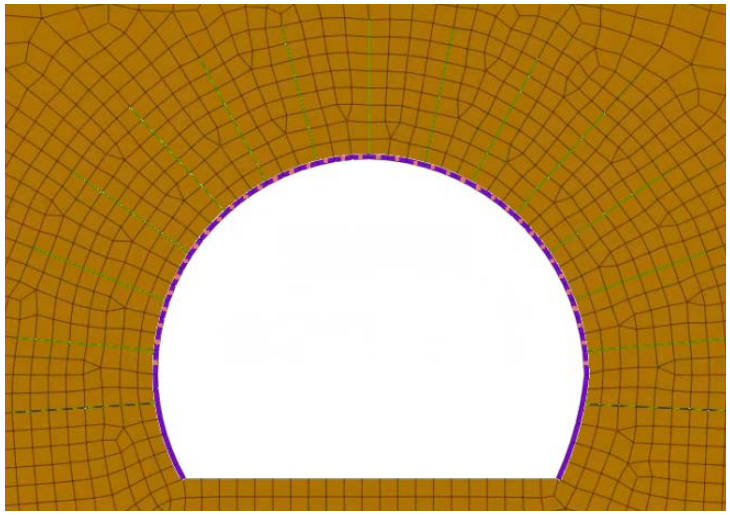


施工階段定義-5
(施工階段6~7)

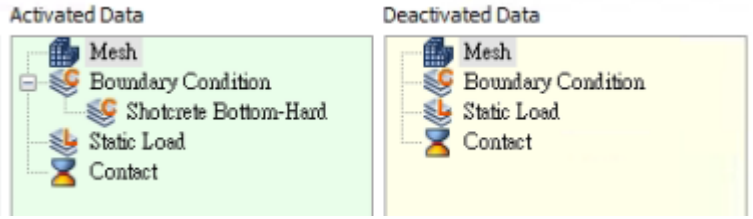
Stage6:下半部岩石螺栓&第1層噴射混凝土



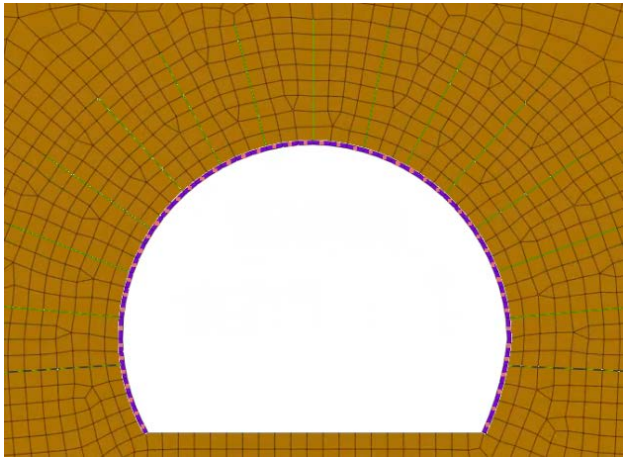
Activated Data
網格集:ShotCrete Bottom
Rock Bolt Bottom



Stage7:下半部第2層噴射混凝土



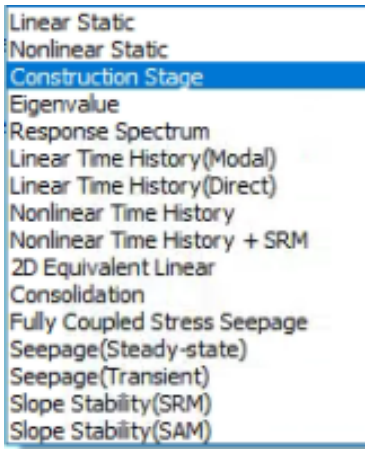
Activated Data
邊界集:ShotCrete Bottom Hard

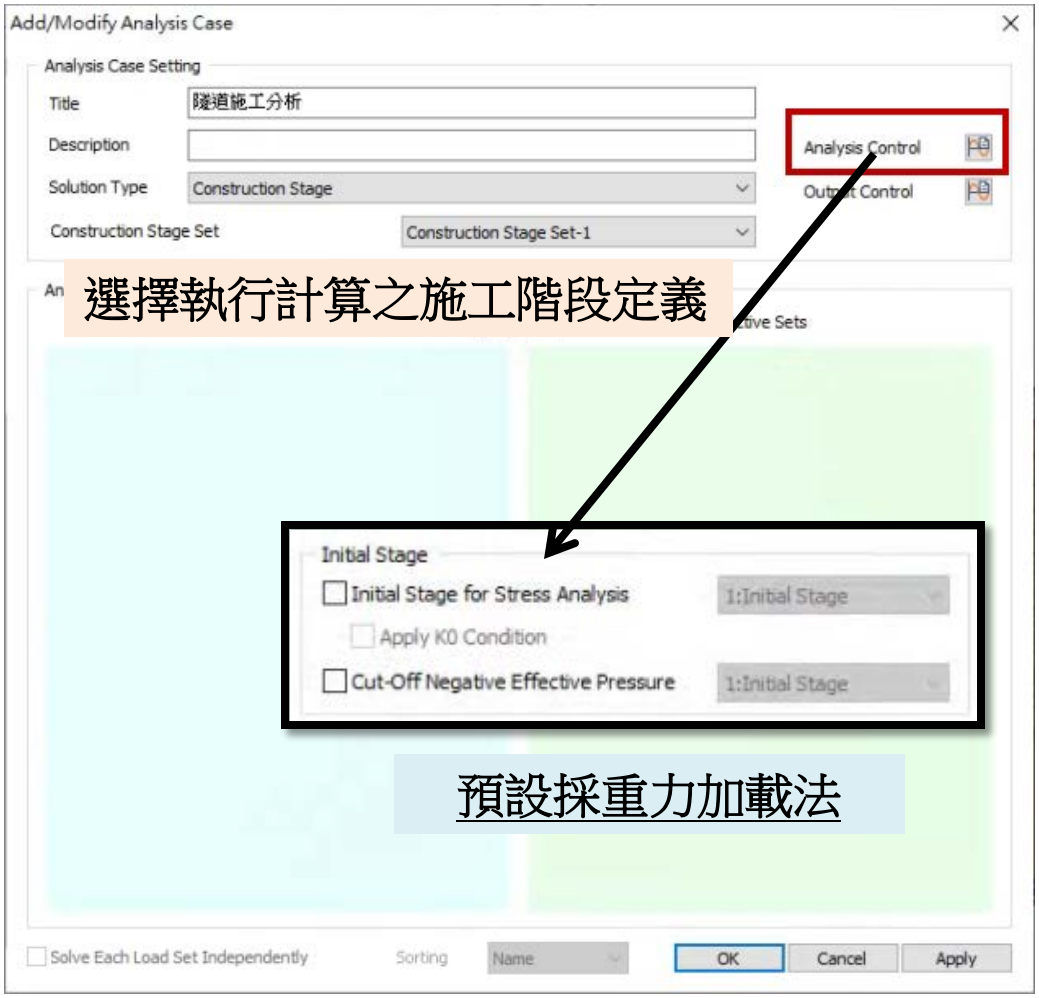


分析定義
(隧道開挖施工分析)

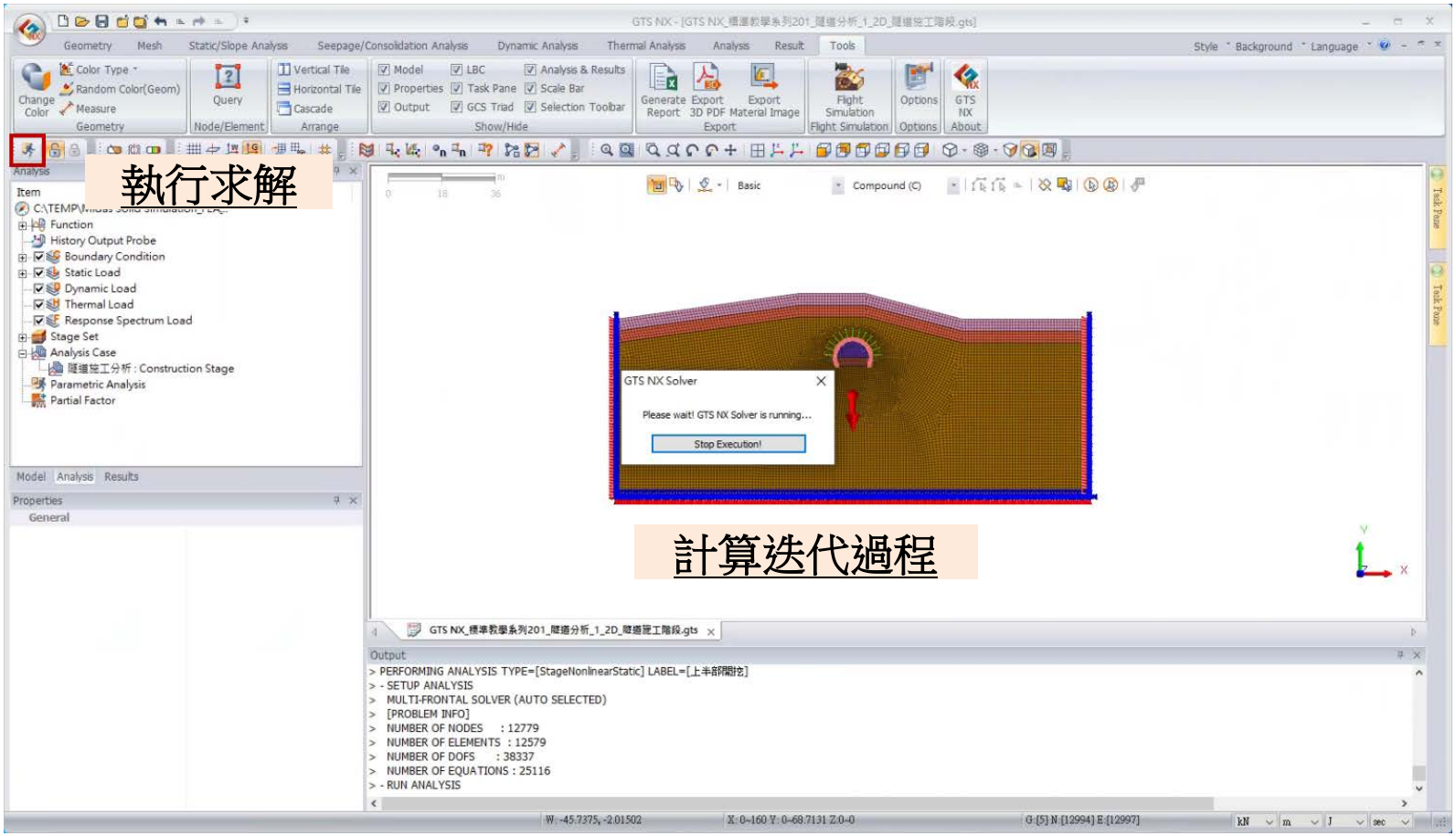
分析名稱:隧道施工分析/分析類型:**Construction Stage**

Construction Stage



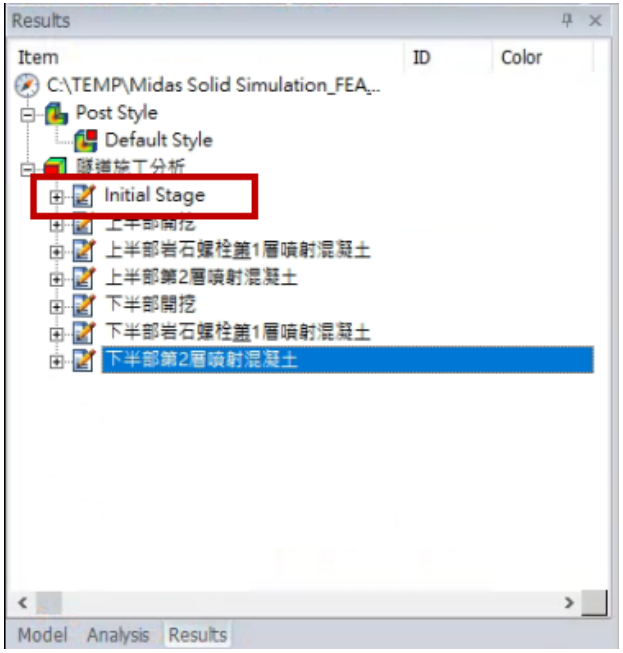


計算


執行求解
GTS NX Solver
Please wait! GTS NX Solver is running...
Stop Execution!
計算迭代過程
> PERFORMING ANALYSIS TYPE=[StageNonlinearStatic] LABEL=[上半部開挖]
> - SETUP ANALYSIS
> MULTI-FRONTAL SOLVER (AUTO SELECTED)
> [PROBLEM INFO]
> NUMBER OF NODES : 12779
> NUMBER OF ELEMENTS : 12579
> NUMBER OF DOFS : 38337
> NUMBER OF EQUATIONS : 25116
> - RUN ANALYSIS

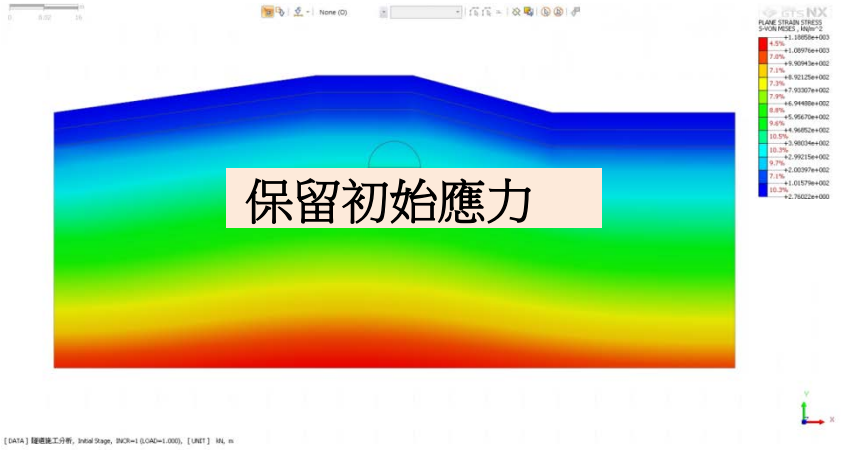
分析結果-1

依照施工階段定義順序
輸出7組結果

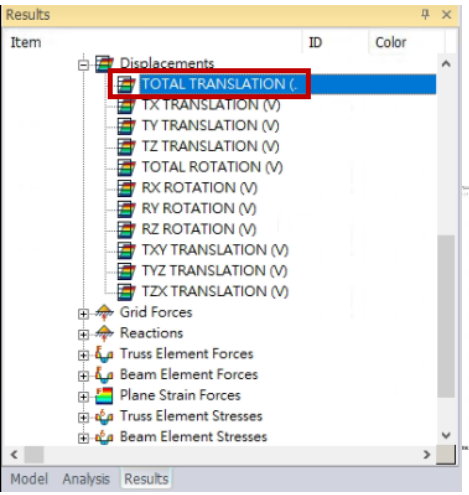


Initial Stage-Displacement

Initial Stage-Equivalent Stress (KN/m²)

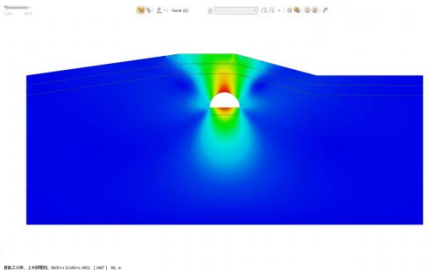


分析結果-2
(Displacement)

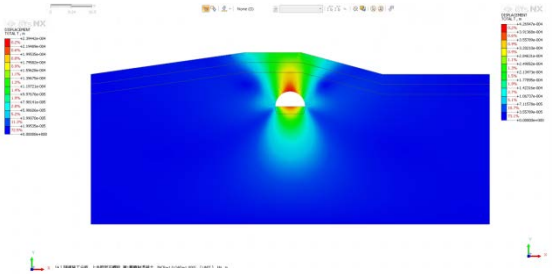


Stage1

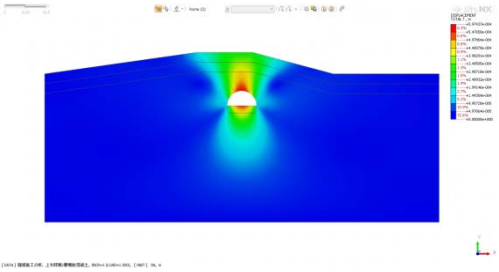
Stage2



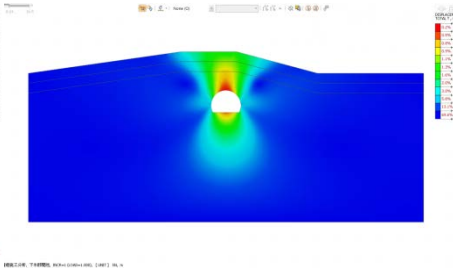
Stage3



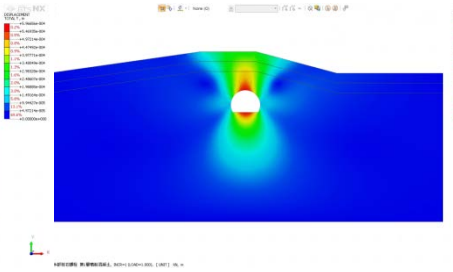
Stage4



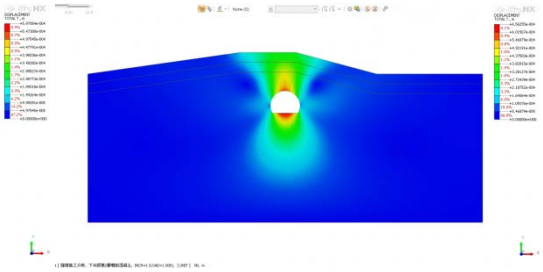
Stage5



Stage6



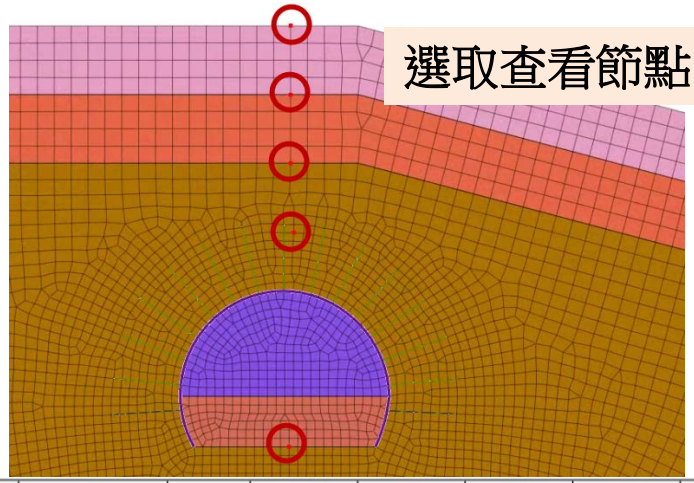
Stage7



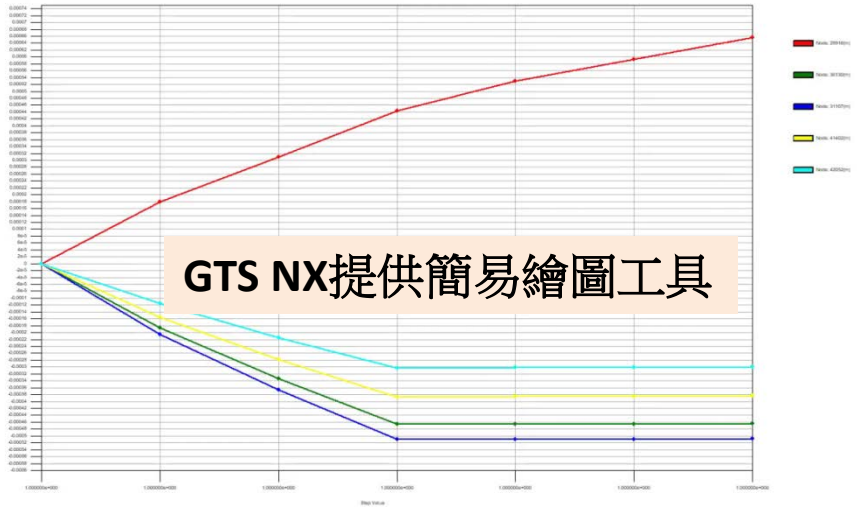
播放動畫 (施工階段)

分析結果-3

查看施工階段下沉量變化(Ty)

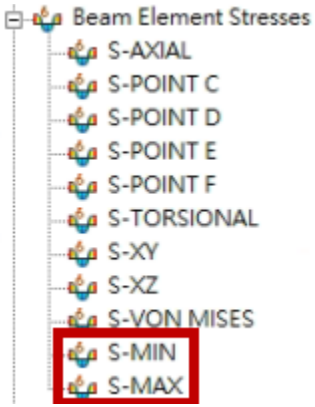


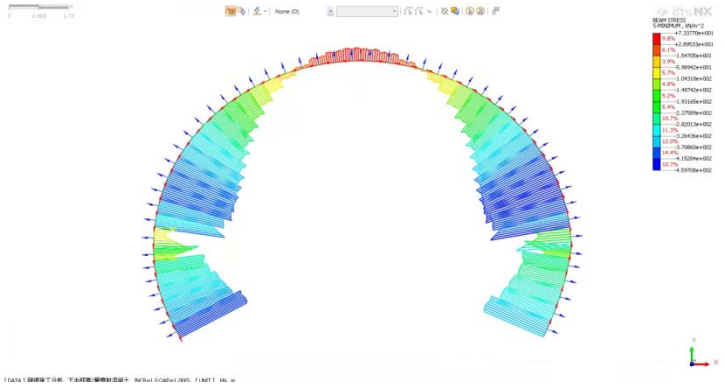
	No	Step	Step Value	Node: 29916 TY TRANSLATION (V) (m)	Node: 30130 TY TRANSLATION (V) (m)	Node: 31107 TY TRANSLATION (V) (m)	Node: 41402 TY TRANSLATION (V) (m)	Node: 42052 TY TRANSLATION (V) (m)
▶	1	Initial Stage:INCR=1 (LOAD=1.000)	1.000000e+000	0.000000e+000	0.000000e+000	0.000000e+000	0.000000e+000	0.000000e+000
	2	上半部開挖:INCR=1 (LOAD=1.000)	1.000000e+000	1.796390e-004	-1.872266e-004	-2.049077e-004	-1.555133e-004	-1.162193e-004
	3	上半部岩石螺栓&第1層噴射混凝	1.000000e+000	3.104981e-004	-3.345999e-004	-3.658732e-004	-2.780489e-004	-2.158401e-004
	4	上半部第2層噴射混凝土:INCR=1 (	1.000000e+000	4.439488e-004	-4.668378e-004	-5.107987e-004	-3.872668e-004	-3.039251e-004
	5	下半部開挖:INCR=1 (LOAD=1.000)	1.000000e+000	5.298318e-004	-4.657930e-004	-5.098069e-004	-3.857530e-004	-3.017927e-004
	6	下半部岩石螺栓&第1層噴射混凝	1.000000e+000	5.926664e-004	-4.659669e-004	-5.100375e-004	-3.855457e-004	-3.010809e-004
	7	下半部第2層噴射混凝土:INCR=1 (	1.000000e+000	6.561228e-004	-4.639175e-004	-5.079944e-004	-3.832282e-004	-2.984045e-004

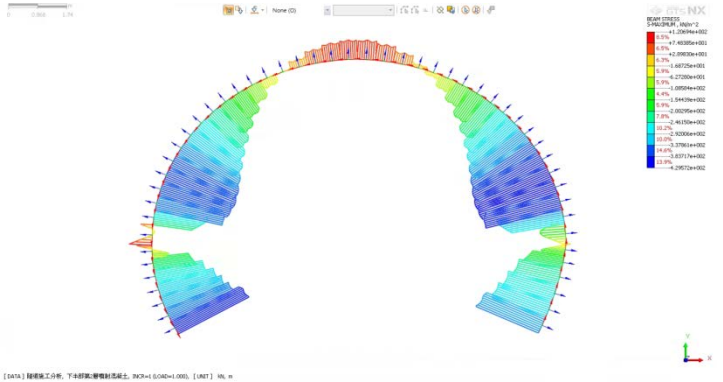


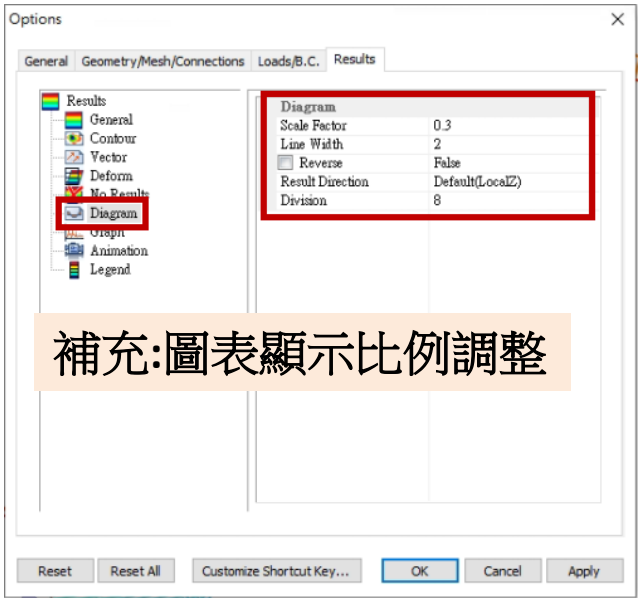
分析結果-4

GTS NX 的符號定義是(+)代表拉伸，(-)代表壓縮。
隧道分析，必須檢查噴射混凝土的彎曲壓縮應力是否在可接受的限度內。
彎曲壓縮應力，檢視梁元素應力 > S-MIN、S-MAX 的最大值 (-)。

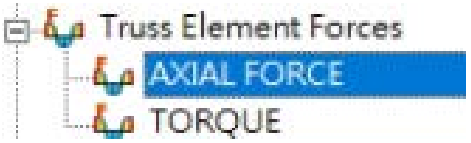


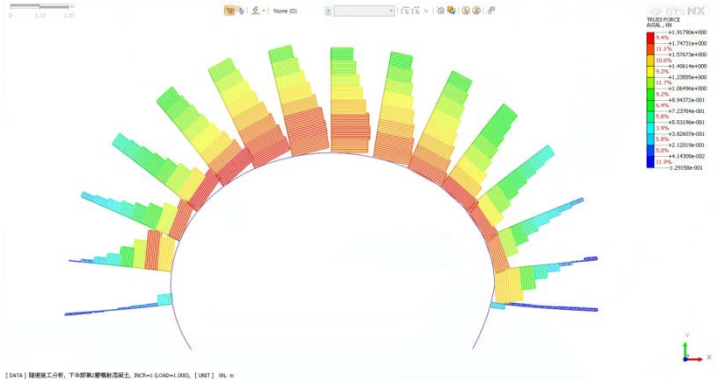


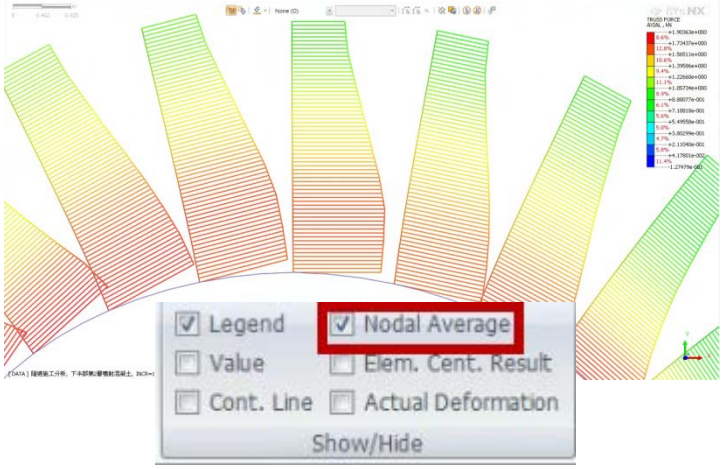




分析結果-5



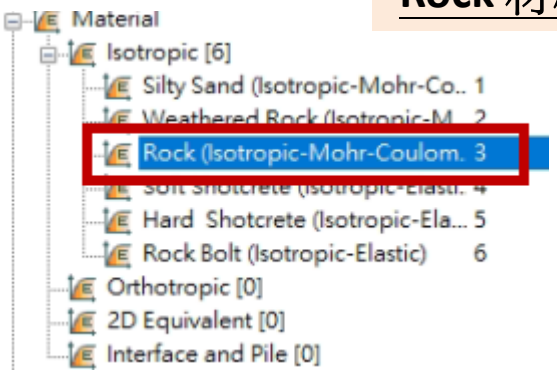


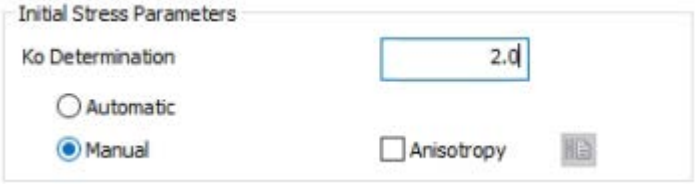


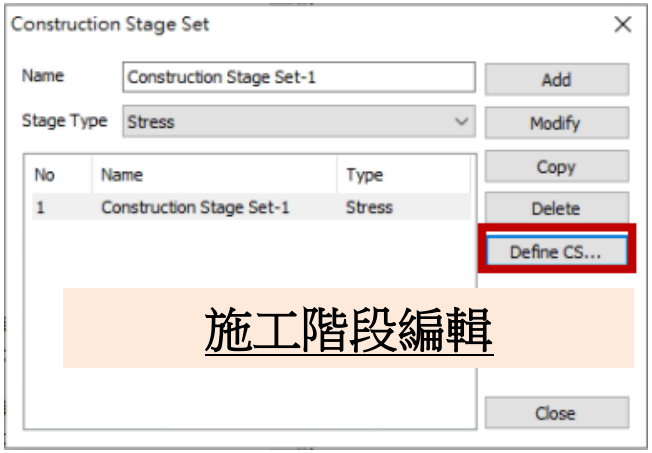
The [Nodal Average] is an option which shows the average results of adjacent nodes to make the contour or diagram look smoother.

K0 method分析設定-1

Rock 材料 K0值調整成2.0



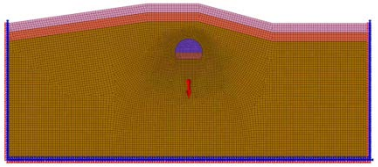


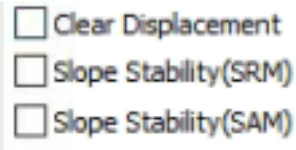


施工階段編輯

Stage1

計算地表自重情況。

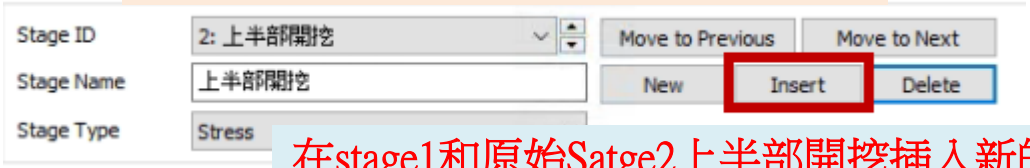




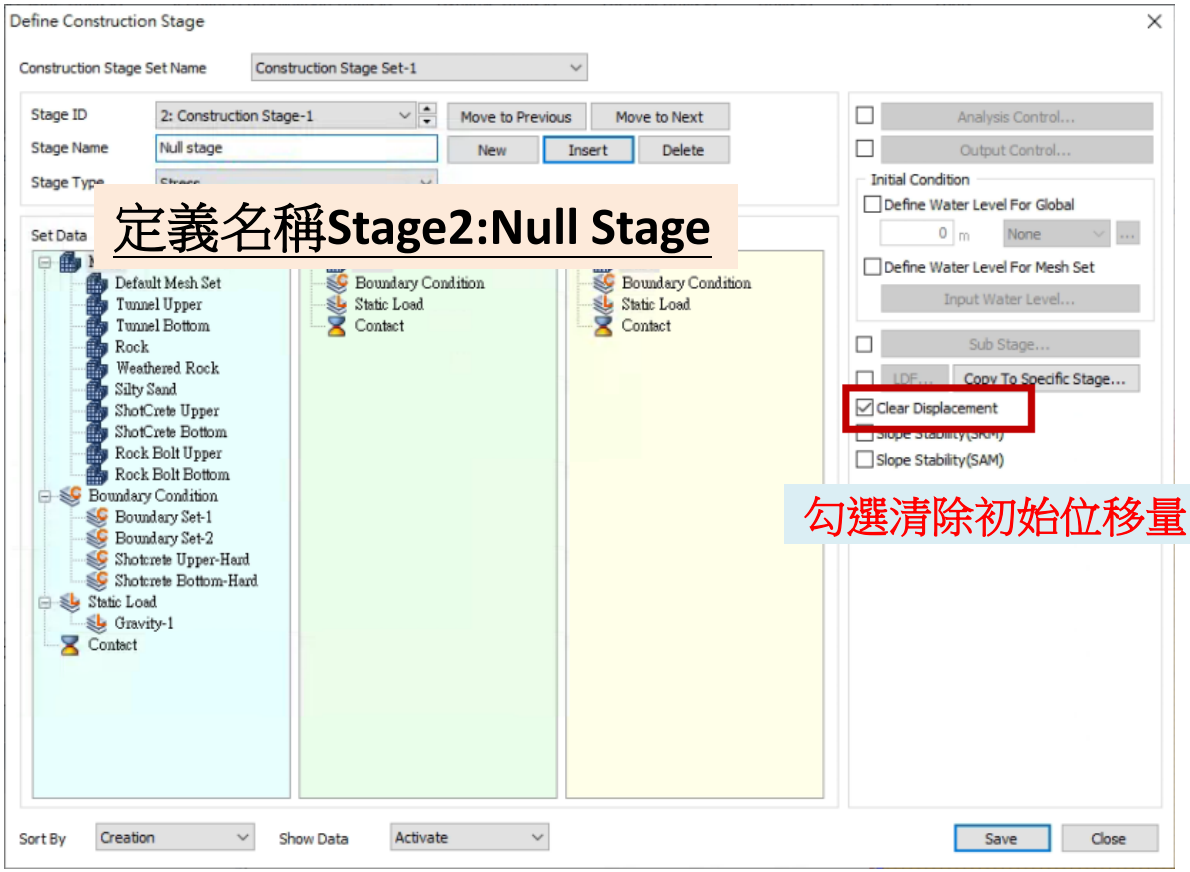
取消清除初始位移量

K0 method分析設定-2

切換工況到上半部開,點擊Insert



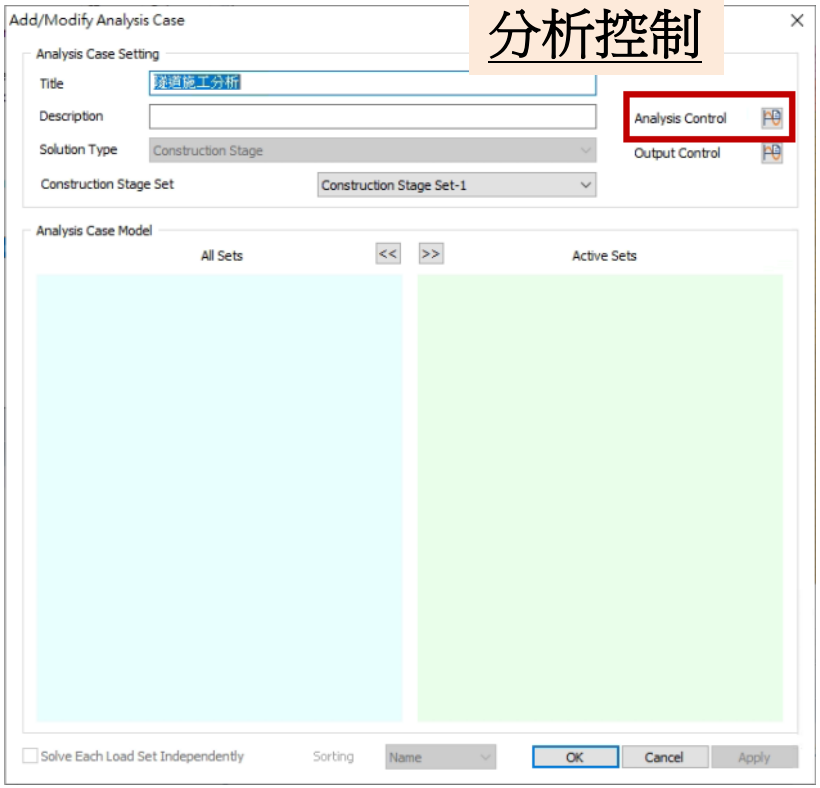
在stage1和原始Satge2上半部開挖插入新的工況



定義名稱Stage2:Null Stage

勾選清除初始位移量

K0 method分析設定-3



分析控制

指定始初施工定義&採K0邊界

GTS NX_標準教學系列

2D隧道施工對相鄰建築物的影響

台灣邁達斯

註:範例相關參數使用假設條件。

相鄰結構-角畸變&沉降

Damages in structures in the vicinity of ground excavation has been generally evaluated on the basis of final settlements upon completion of the excavation. The assessment of damages may also take place due to staged excavation.
The factors affecting the damage assessment include the settlements of various points of a structure, its **maximum settlement, horizontal settlement** ,etc. obtained through numerical analysis.

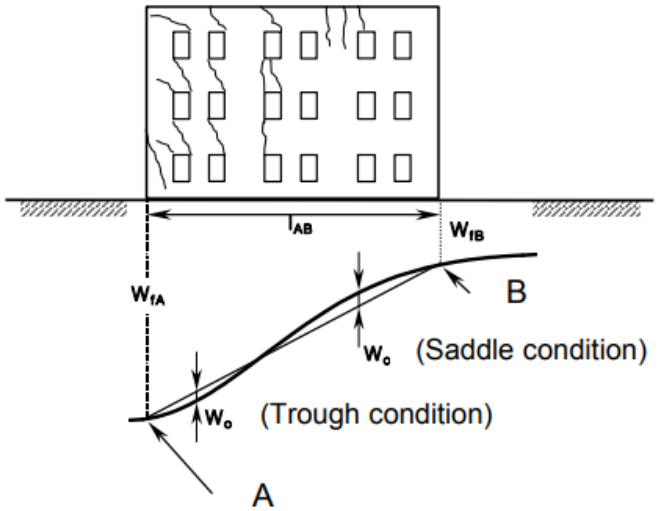
角度畸變

它是由兩點之間的差異沉降與兩點之間的距離所表示的旋轉角度。

$$\text{Angular displacement} = \frac{(w_{f_A} - w_{f_B})}{l_{AB}}$$

不均勻沉降

不均勻沉降是結構中兩點之間的相對沉降。



最大沉降

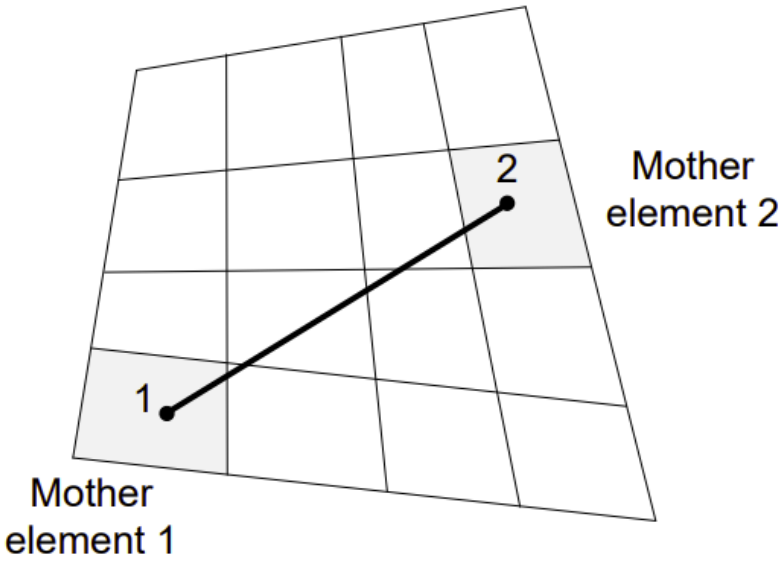
最大沉降是結構中最大沉降量。

Reference
GTS NX and FEA NX Analysis Reference

崁(嵌)入元素
(Embedded Element)

Embedded Truss/Beam Element

嵌入式元素不需要共享節點，因此更便於建模和分析。
嵌入式元素以嵌入形式使用在母單元內部，母單元可以是平面應變元素(2D 空間分析)，也可以是實體元素。
其中母單元包含每個崁(嵌)入元素節點，自動約束崁(嵌)入元素的節點位移與母單元的內部位移相同。

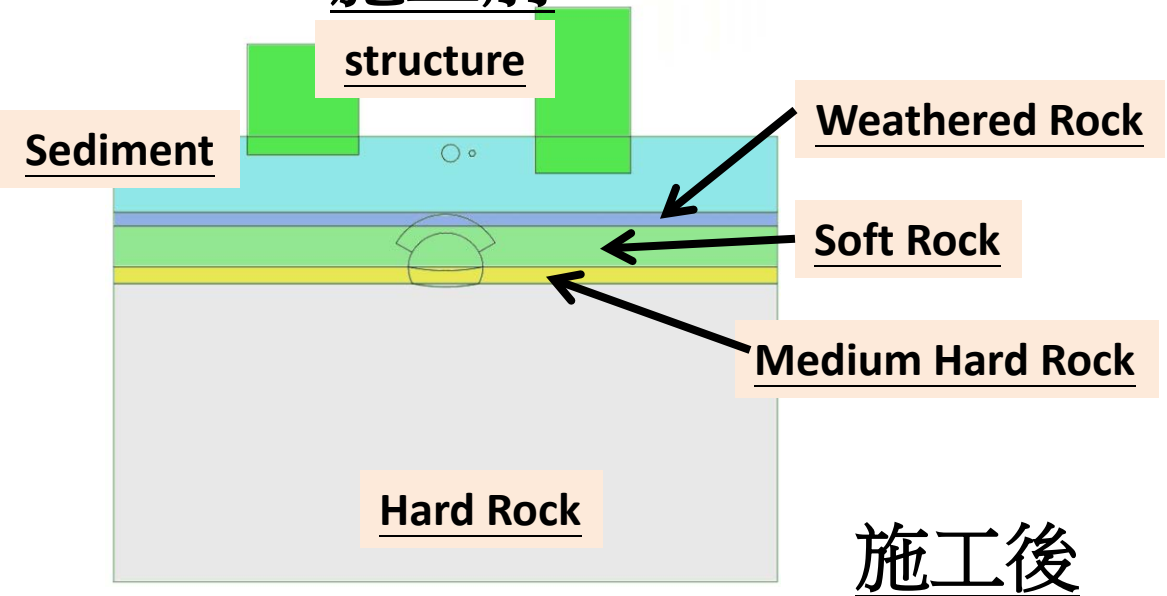


Reference

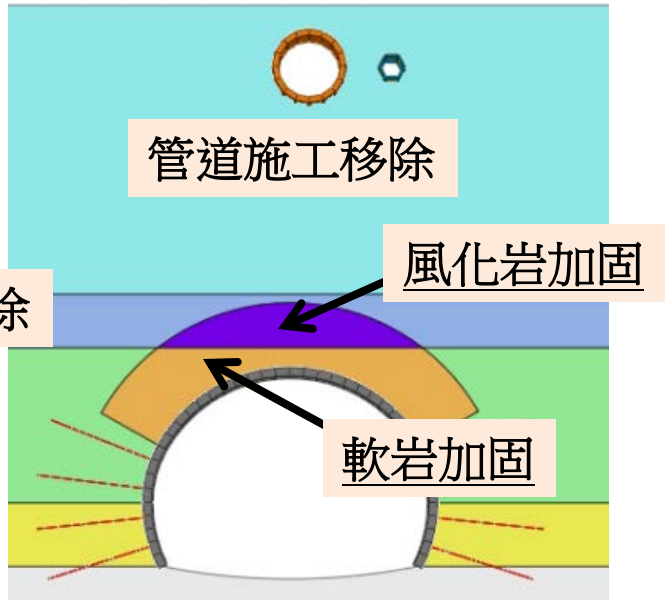
GTS NX and FEA NX Analysis Reference

分析說明-材料

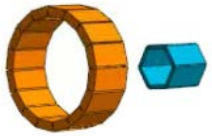
施工前



施工後

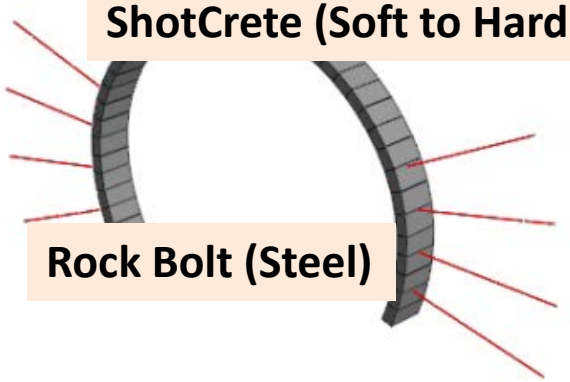


Pipe (Steel)

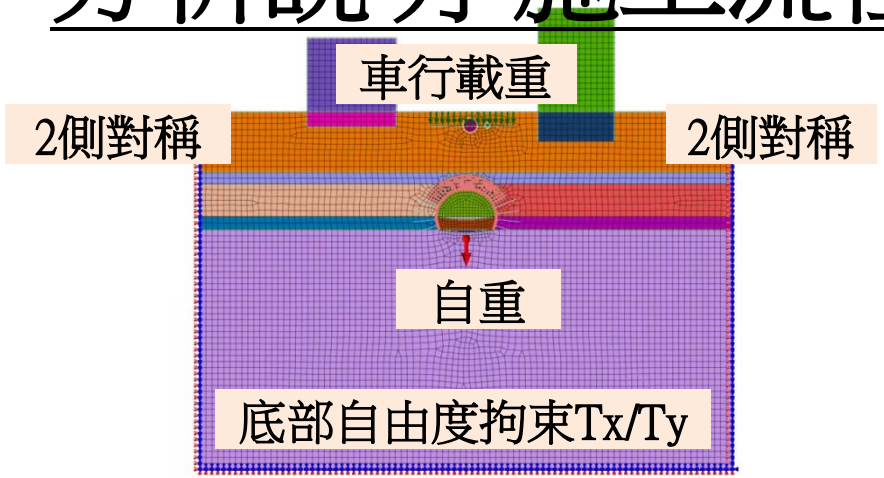


ShotCrete (Soft to Hard)

Rock Bolt (Steel)

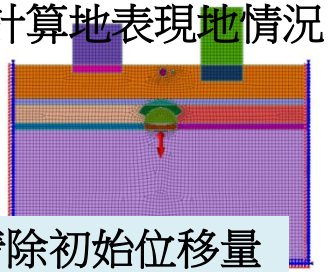


分析說明-施工流程



Stage1

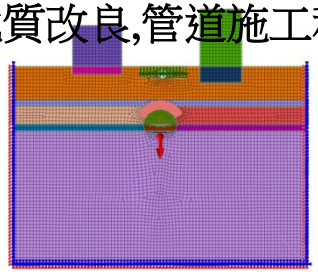
計算地表現地情況



清除初始位移量

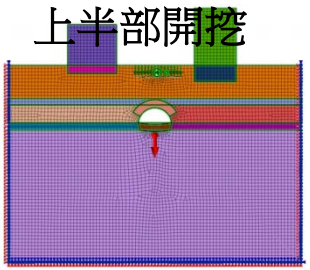
Stage2

地質改良,管道施工和車載



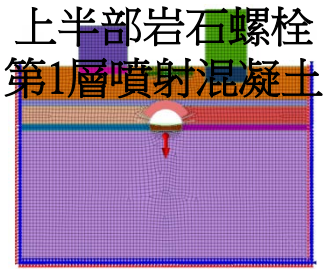
Stage3

上半部開挖



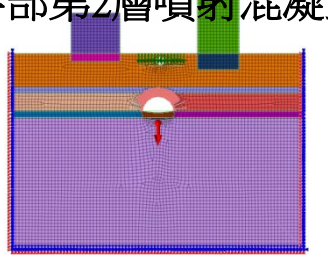
Stage4

上半部岩石螺栓
第1層噴射混凝土



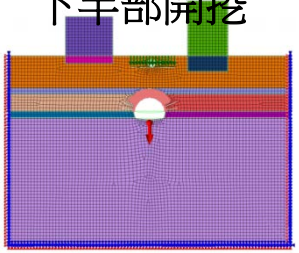
Stage5

上半部第2層噴射混凝土



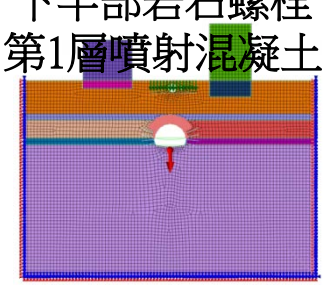
Stage6

下半部開挖



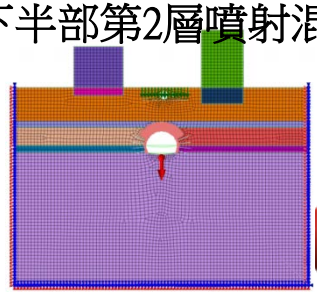
Stage7

下半部岩石螺栓
第1層噴射混凝土



Stage8

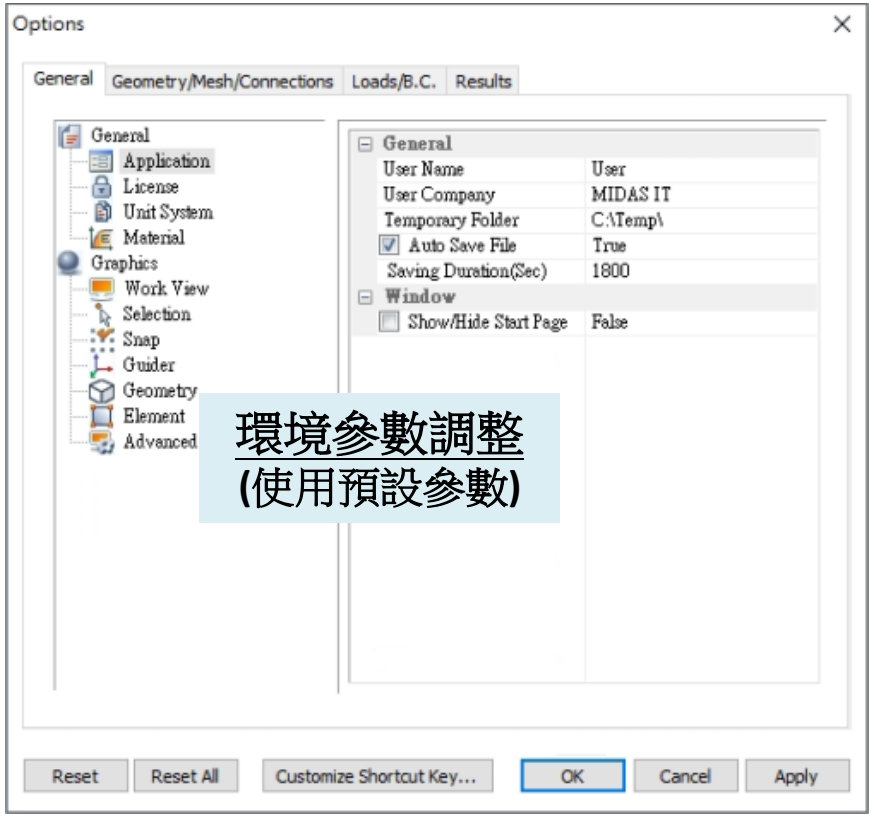
下半部第2層噴射混凝土



註:範例相關參數使用假設條件。

環境

新文件



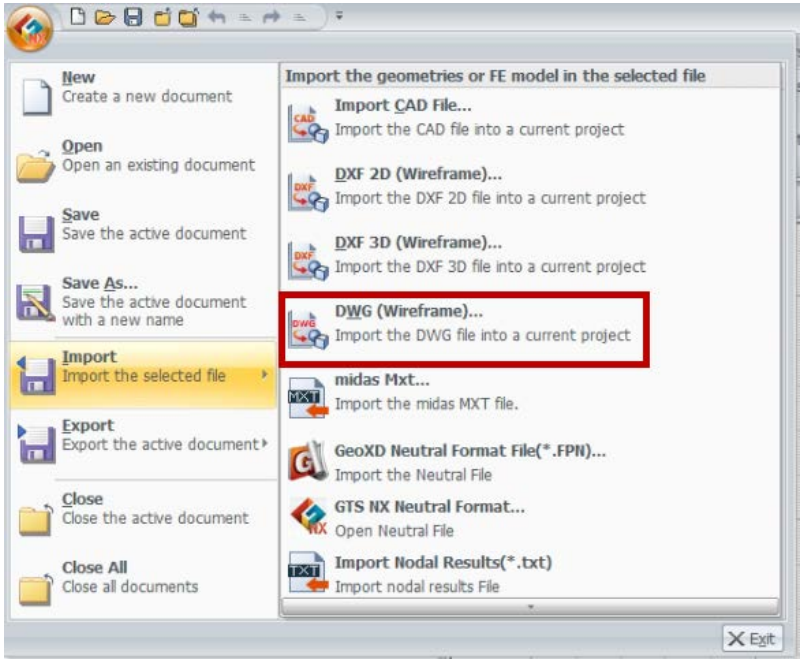
環境參數調整
(使用預設參數)

2D操作

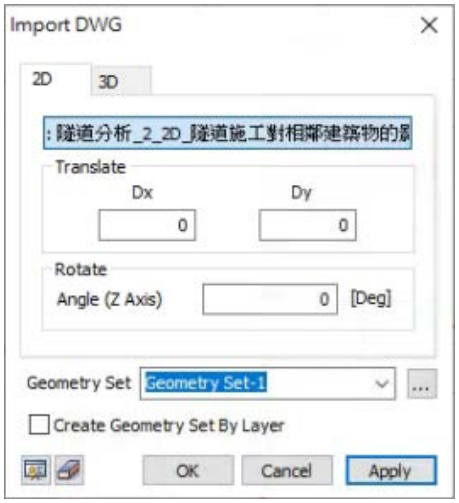
切換單位

單位使用KN/m/J/sec

2D模型匯入



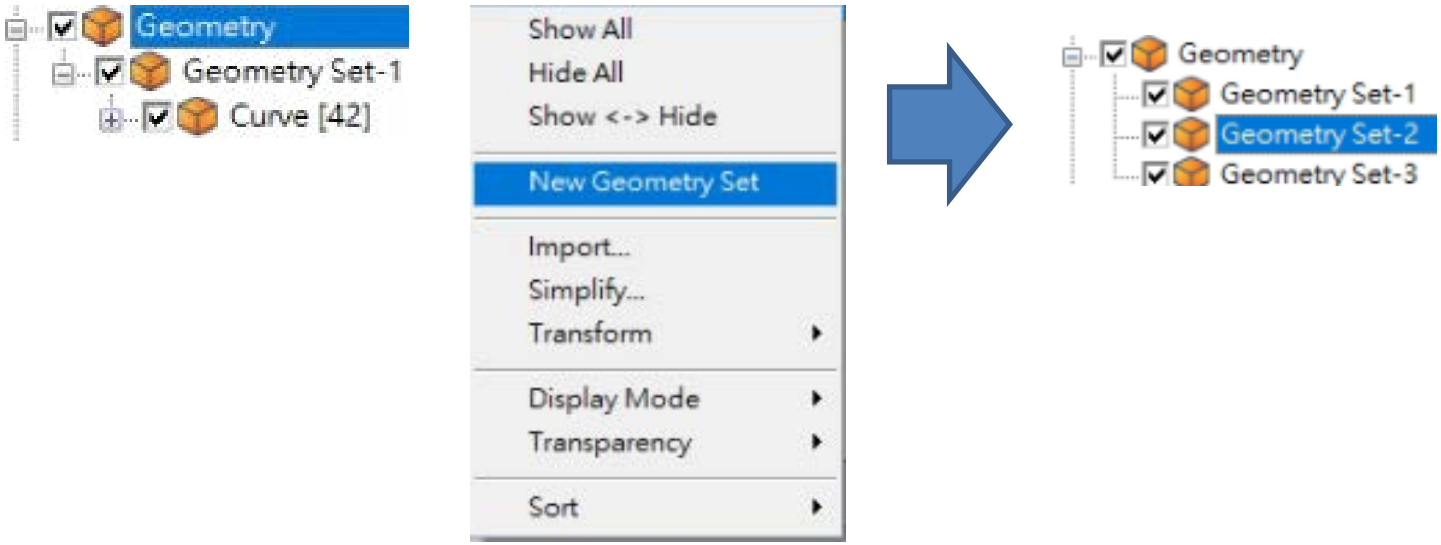
匯入_ 2D_隧道施工對相鄰建築物的影響.dwg



線特徵模型

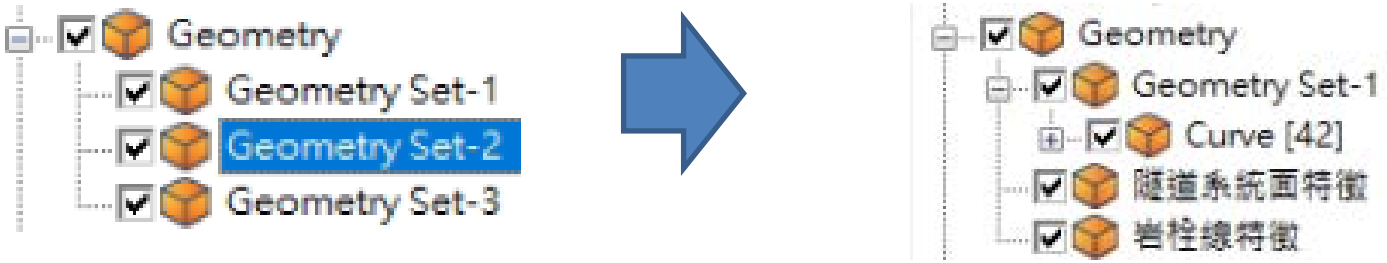
新增&編輯幾何集

滑鼠右鍵(新增2組幾何特徵)

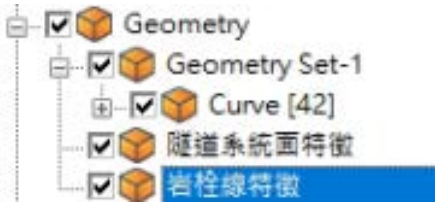


點選新增集合集,鍵盤F2(編輯名稱)

隧道系統面特徵&岩栓線特徵



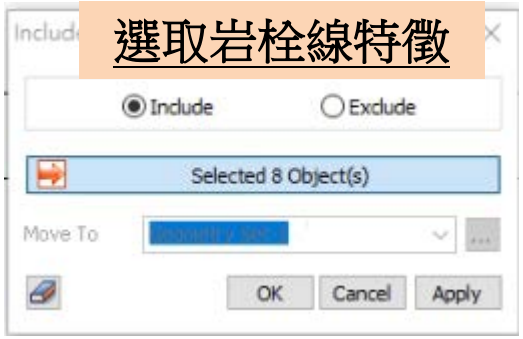
編輯岩栓線特徵幾何集

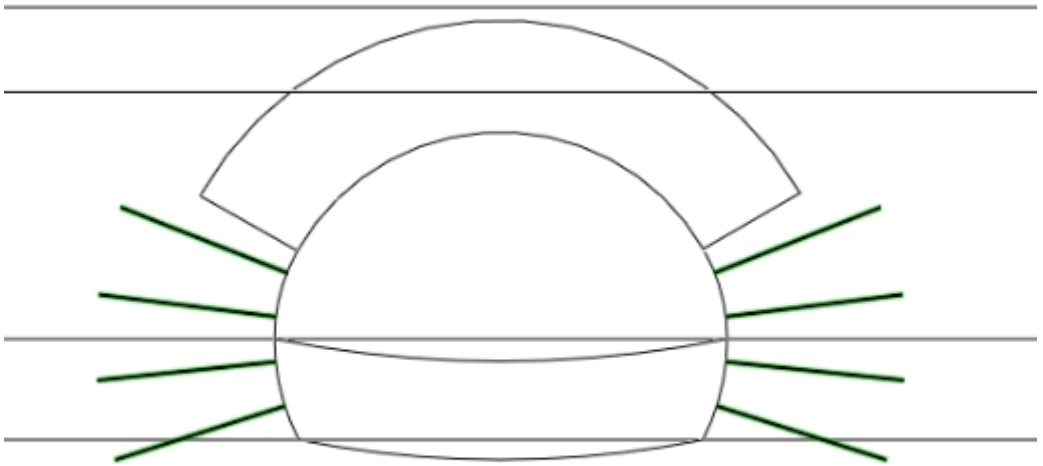


點選岩栓線特徵幾何集

滑鼠右鍵

選取岩栓線特徵

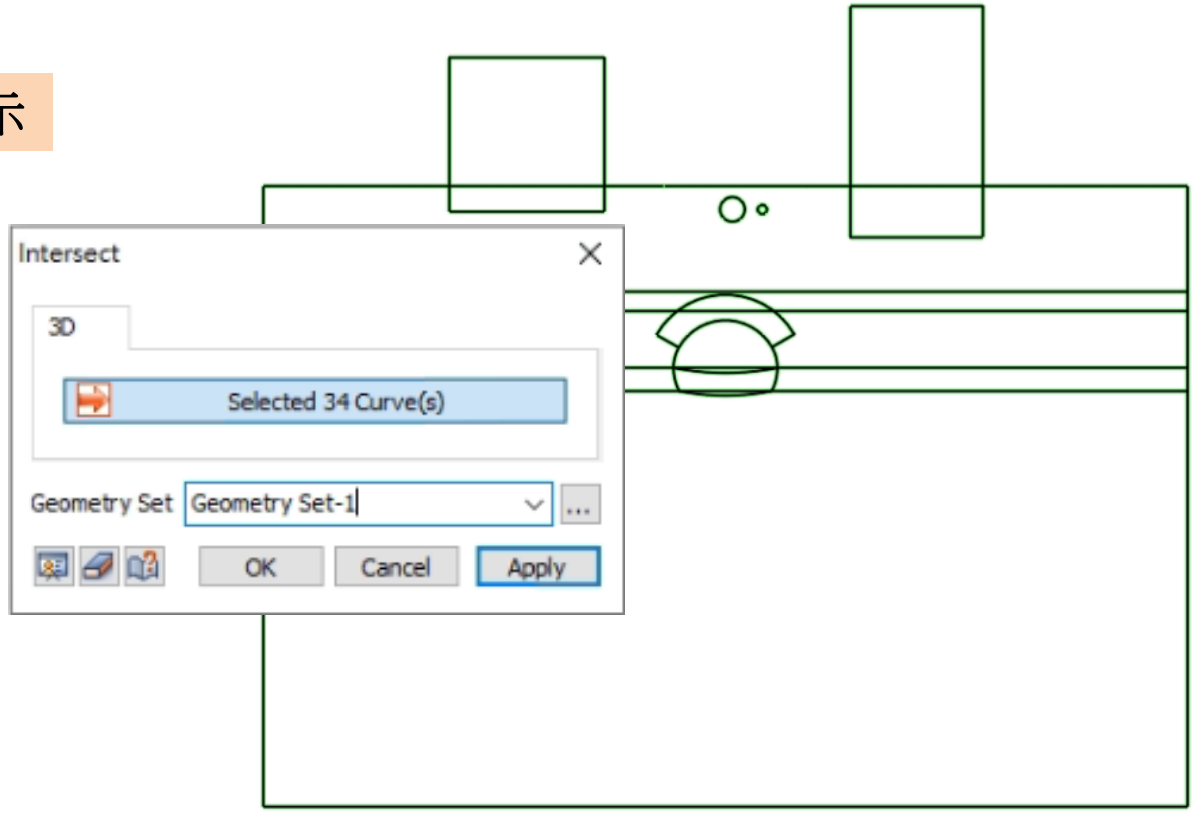




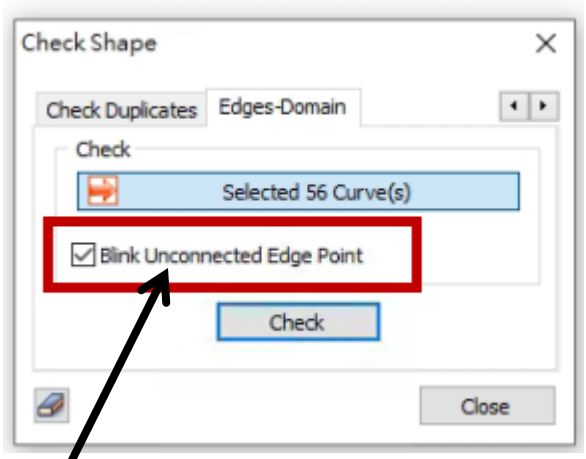
線特徵-交叉分割

框選其餘線特徵

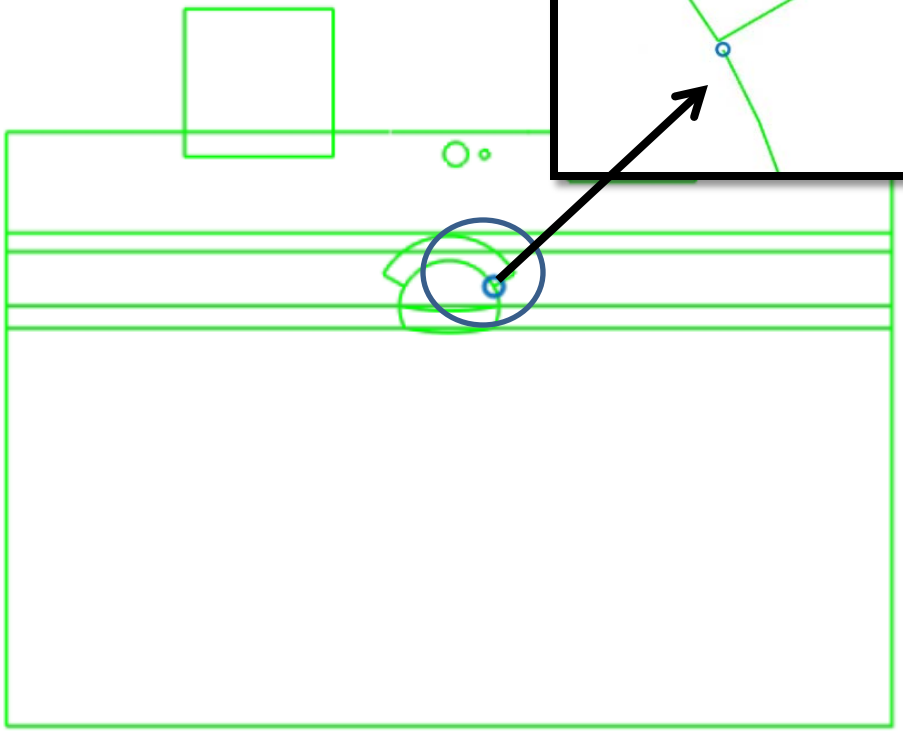
隱藏岩栓線特徵幾何集顯示

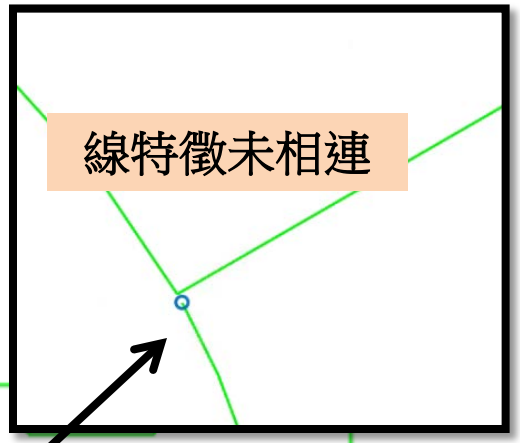


線特徵幾何檢查

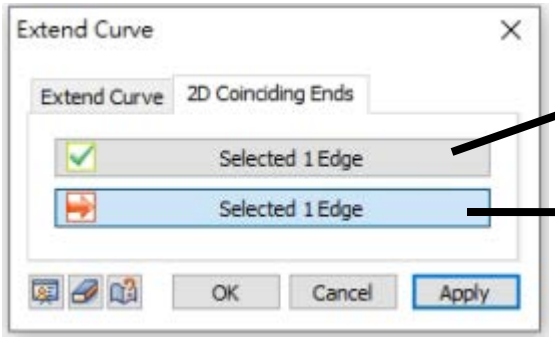


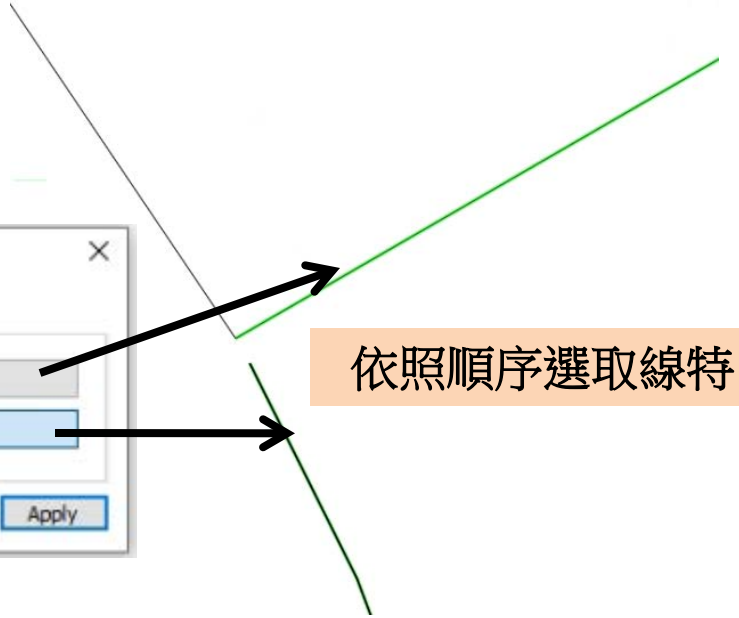
未相連線特徵顯示



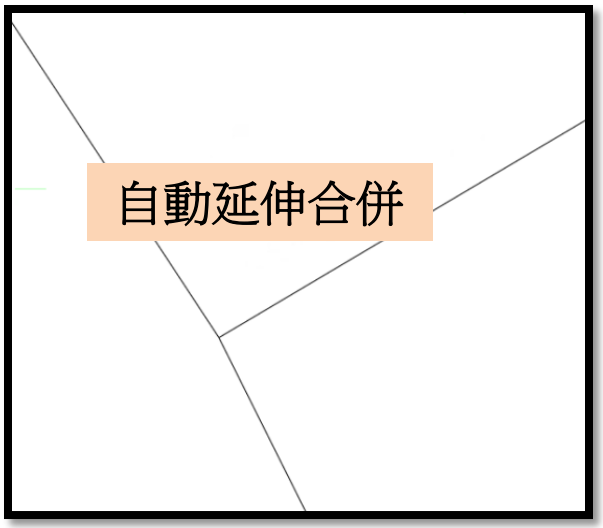


線特徵-自動延伸合併





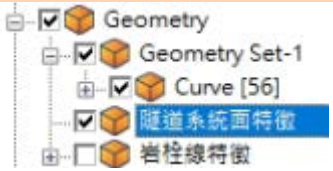
依照順序選取線特

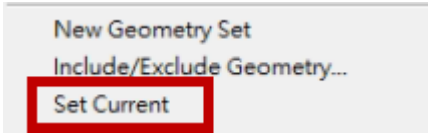


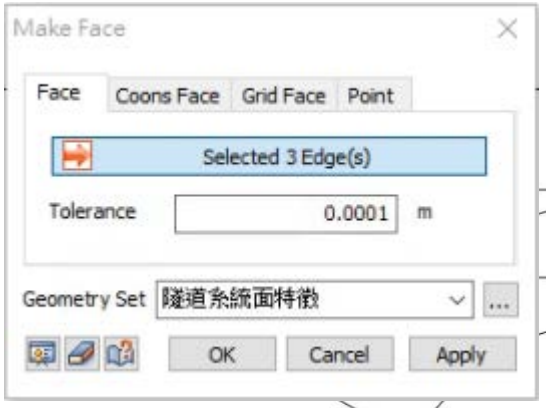
自動延伸合併

面特徵模型建立-1

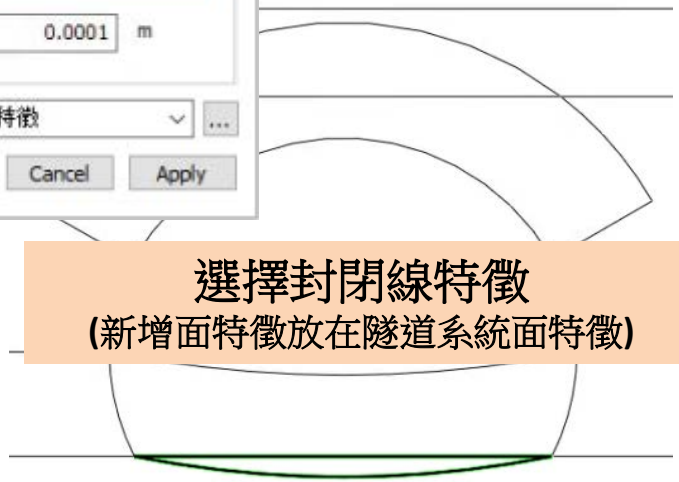
指定為**Current Geometry Set**
(接下來特徵產生在此幾何集)

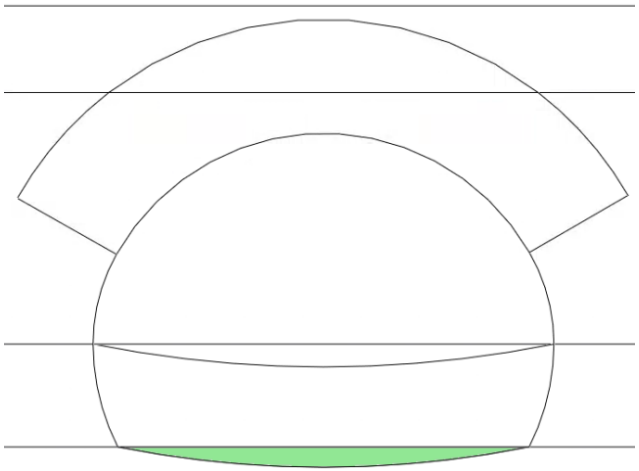






選擇封閉線特徵
(新增面特徵放在隧道系統面特徵)

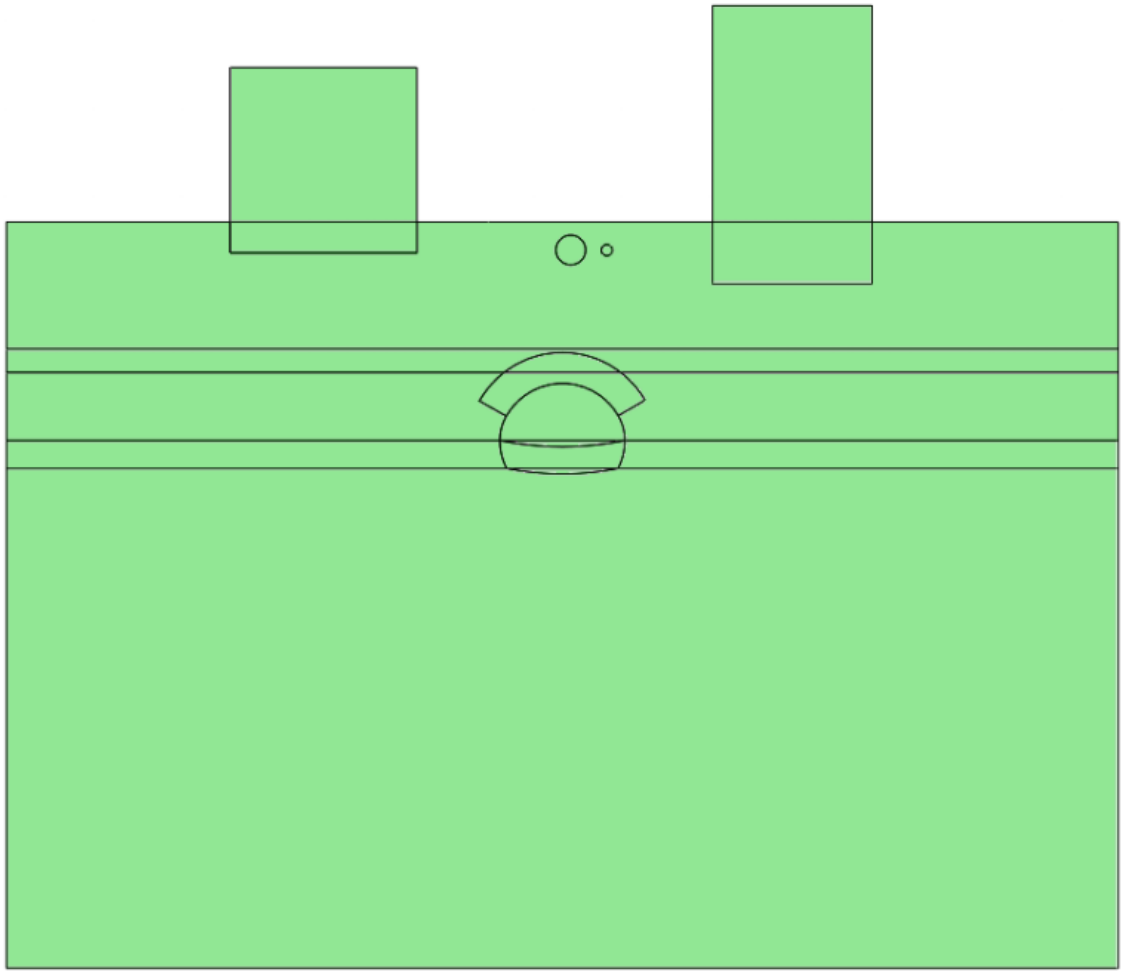




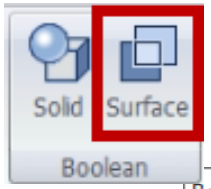
註:非封閉特徵無法產生面特徵

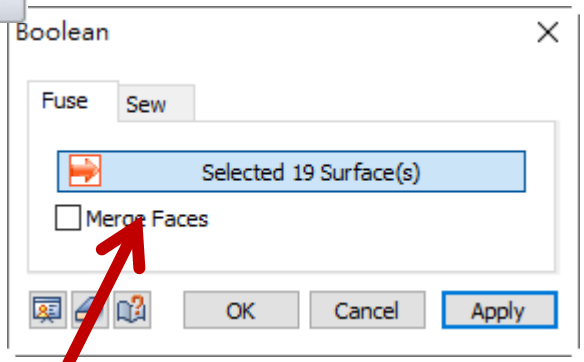
面特徵模型建立-2

依序完成其它特徵面建立

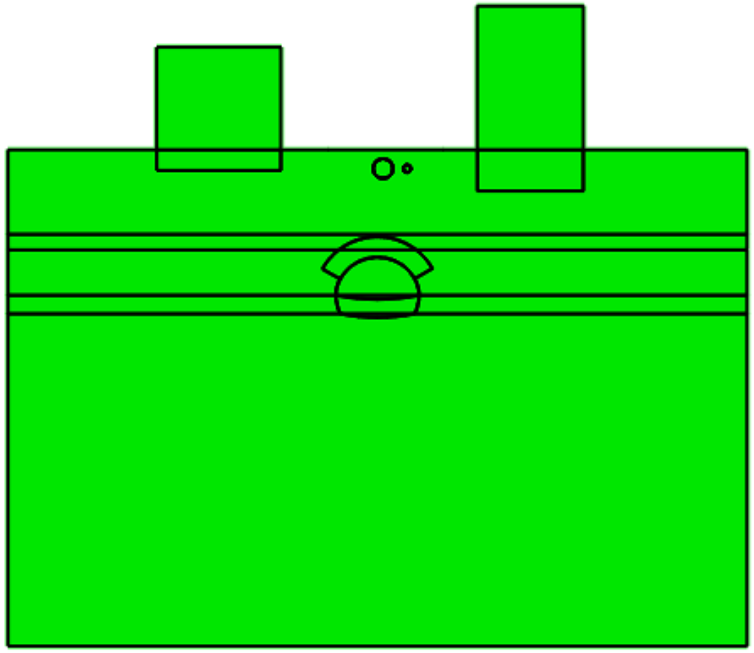


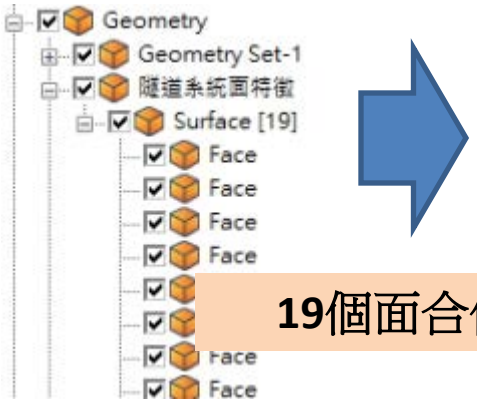
合併面特徵





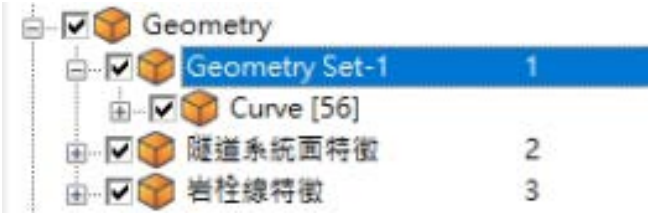
不勾選Merge Faces,保留線特徵





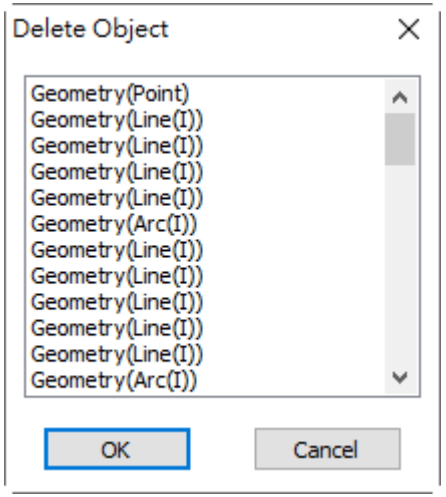
19個面合併成1個面

刪除多餘幾何特徵

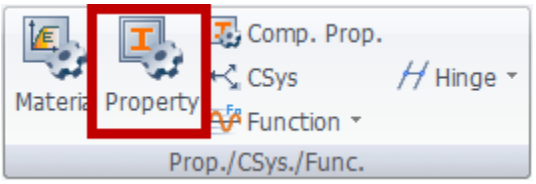


選取Geometry Set-1

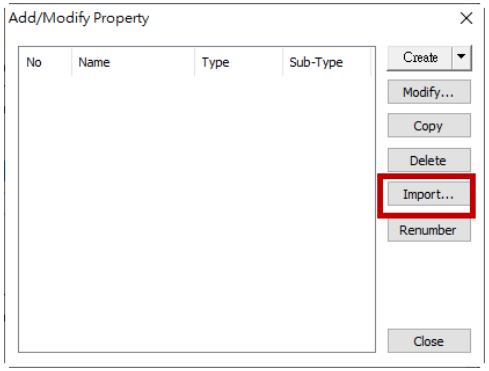
鍵盤DELETE

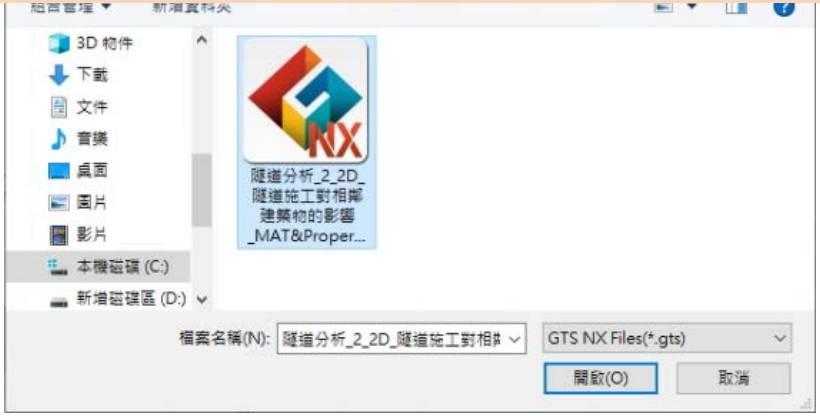


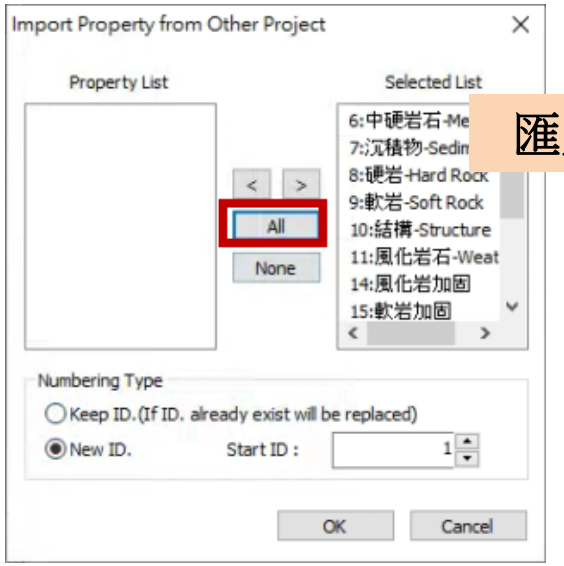
匯入材料&屬性



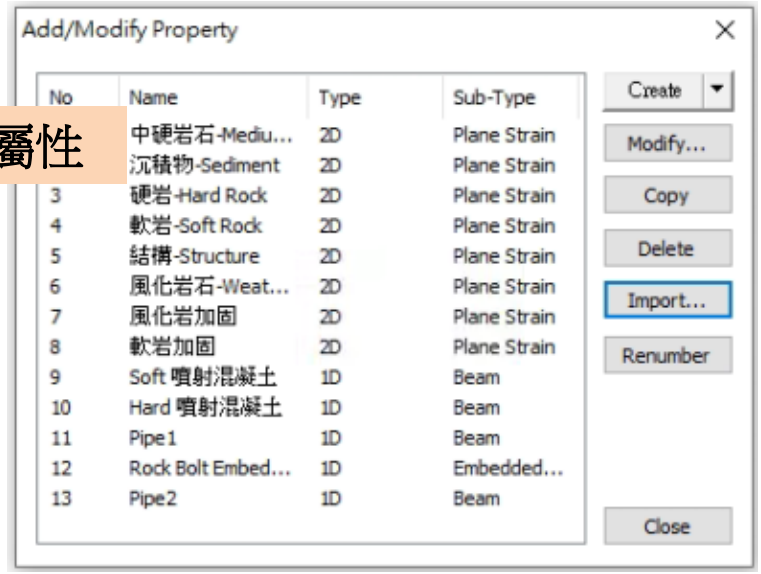
選擇檔案
(隧道施工對相鄰建築物的影響_MAT&Property.gts)





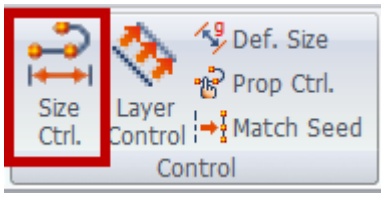


匯入所有屬性

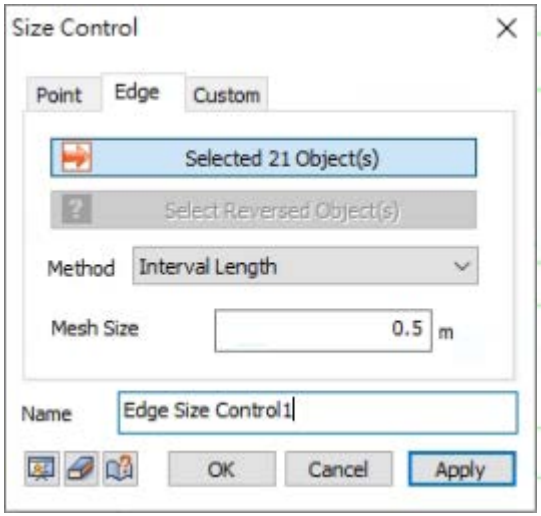


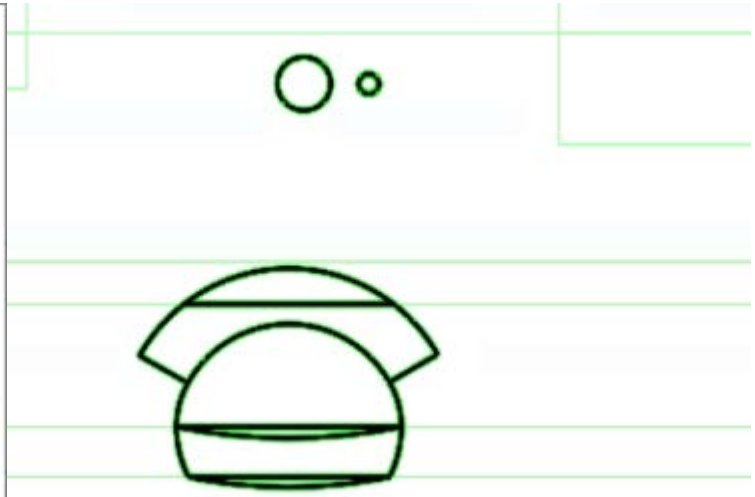
註:匯入屬性同時自動匯入材料性質

手動網格尺寸指定

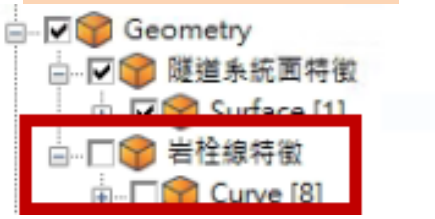


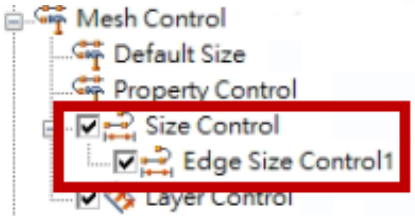
隧道&岩石螺栓&管道周邊網格尺寸:0.5m



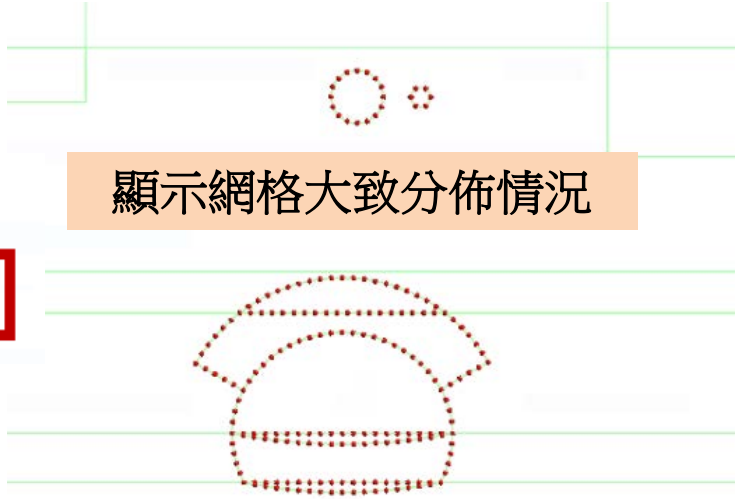


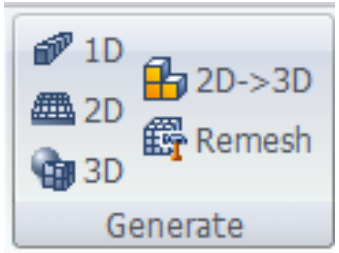
隱藏線特徵





顯示網格大致分佈情況





2D網格生成-1

(未開挖前材料分佈)

網格尺寸: 1

開啓各別特徵各自網格集

名稱:相鄰結構/屬性:structure

名稱:沉積物/屬性:Sediment

名稱:風化岩/屬性: Weathered Rock

名稱:軟岩/屬性:Soft Rock

名稱:中硬岩/屬性:Medium Hard Rock

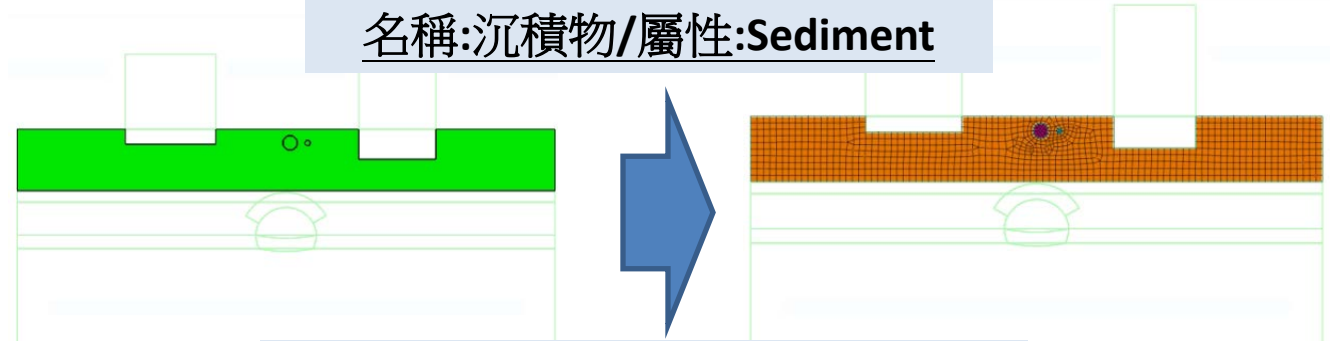
名稱:硬岩/屬性:Hard Rock

2D網格生成-2

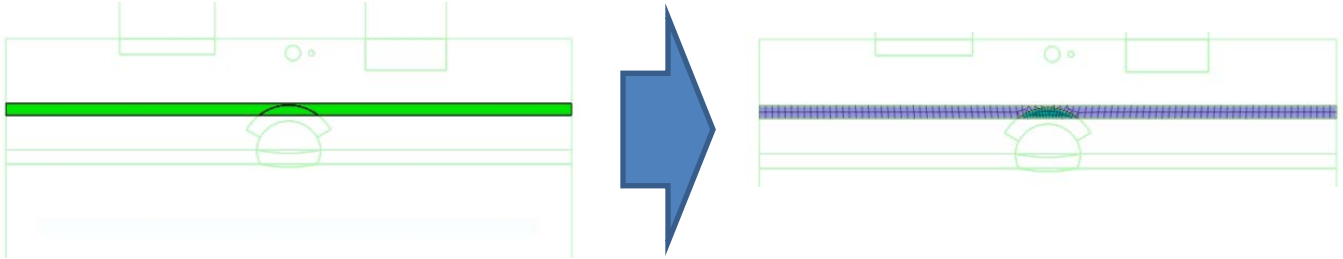
(未開挖前材料分佈)

名稱:相鄰結構/屬性:structure

名稱:沉積物/屬性:Sediment



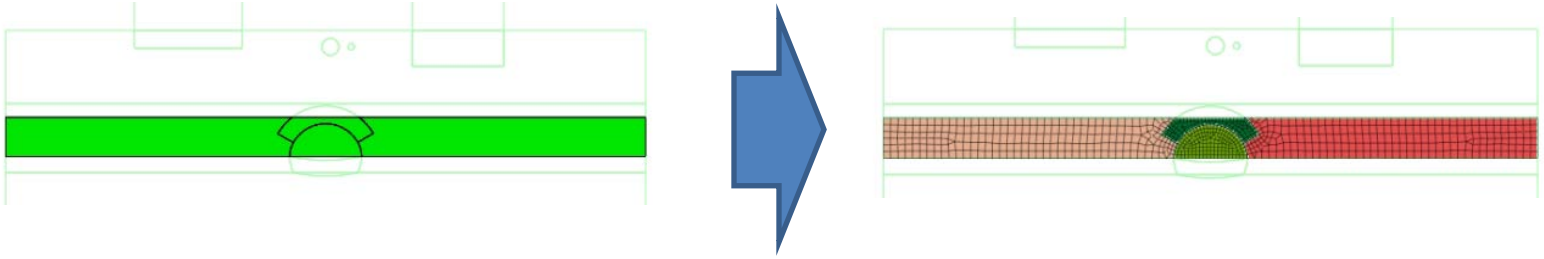
名稱:風化岩/屬性: Weathered Rock



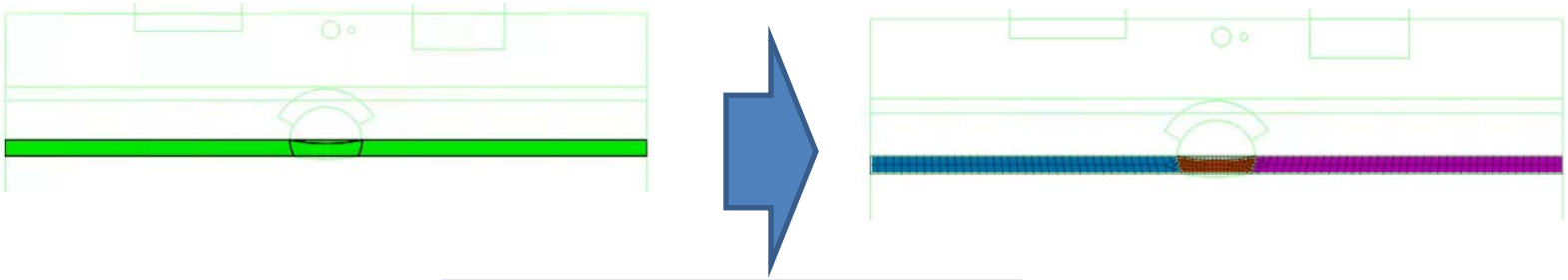
2D網格生成-3

(未開挖前材料分佈)

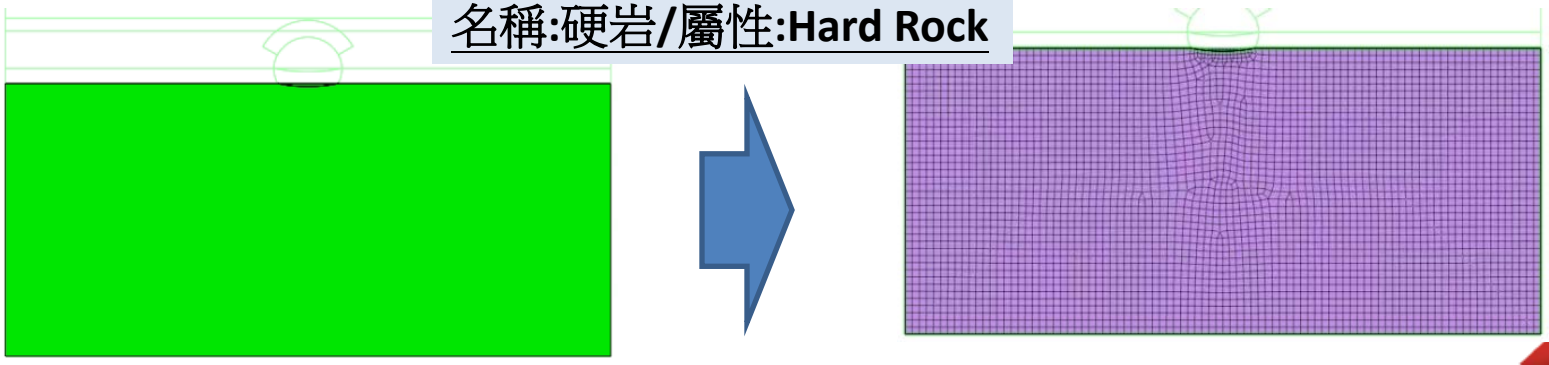
名稱:軟岩/屬性:Soft Rock



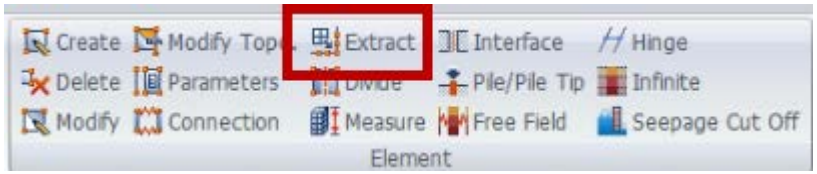
名稱:中硬岩/屬性:Medium Hard Rock



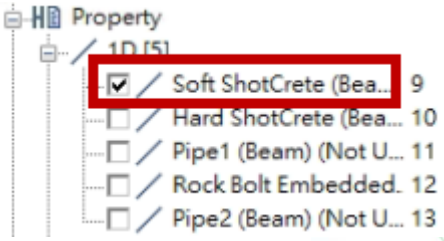
名稱:硬岩/屬性:Hard Rock



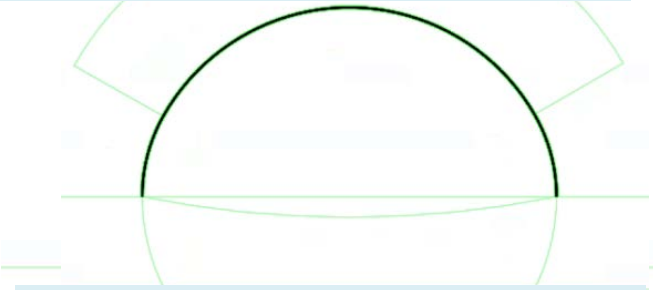
1D網格生成-噴射混凝土



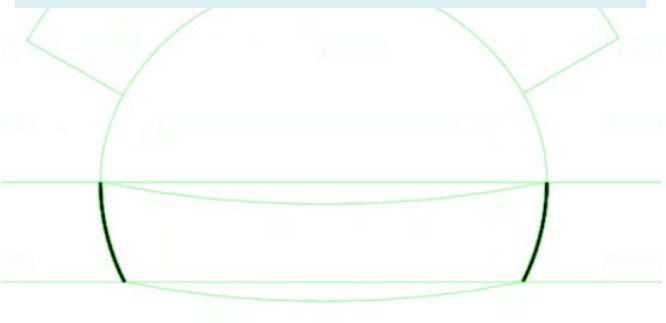
勾選Soft ShotCrete檢視截面



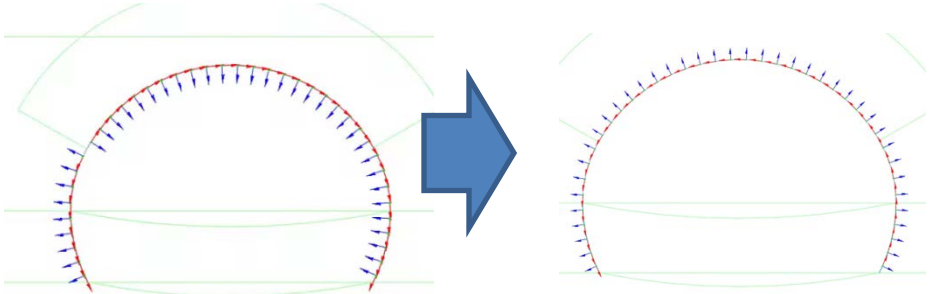
Mesh Set : ShotCrete Upper
Property: Soft ShotCrete



Mesh Set : ShotCrete Bottom
Property: Soft Shotcrete

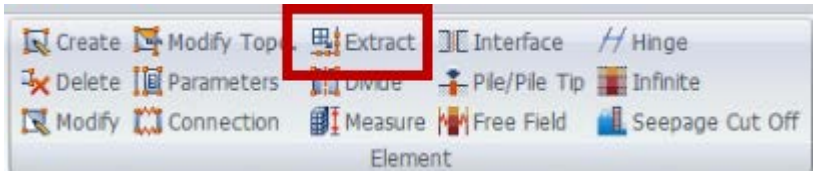


元素座標判斷調整

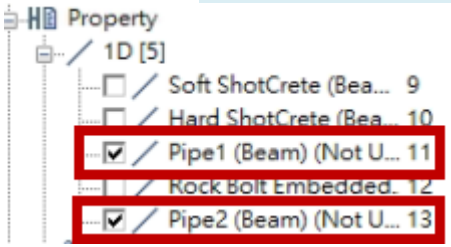


註:截面顯示不正確可以調整元素方向

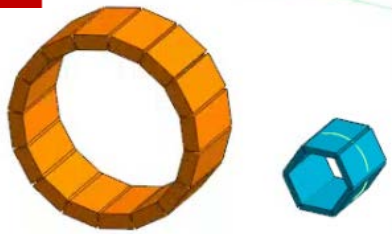
1D網格生成-管壁



勾選Pipe1/Pipe2檢視截面

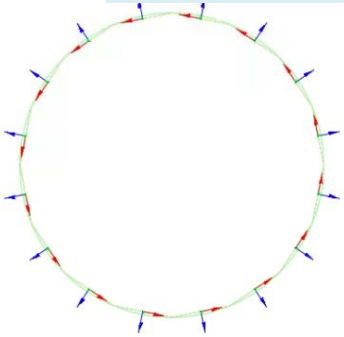


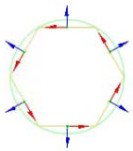
Mesh Set : Pipe1
Property: Pipe1



Mesh Set : Pipe2
Property: Pipe2

元素座標判斷調整

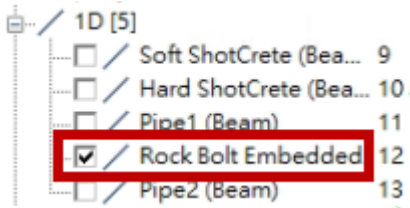


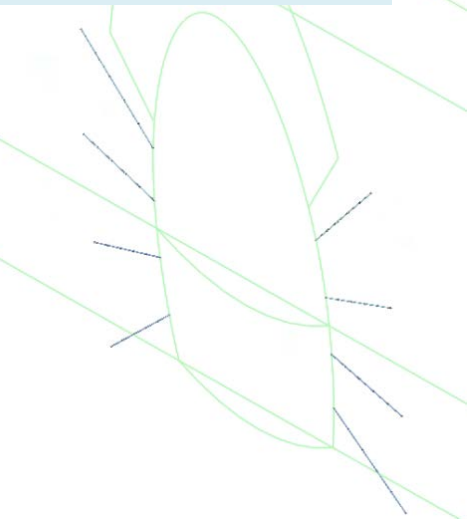


註:截面顯示不正確可以調整元素方向

1D網格生成-岩石螺栓

勾選Rock Bolt檢視截面

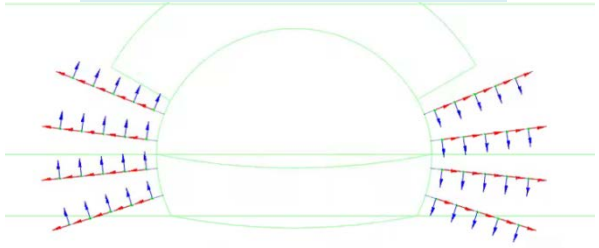




Mesh Set : Rock Bolt Upper
Property: Rock Bolt Embedded
Element Number:5

Mesh Set : Rock Bolt Bottom
Property: Rock Bolt Embedded
Element Number:5

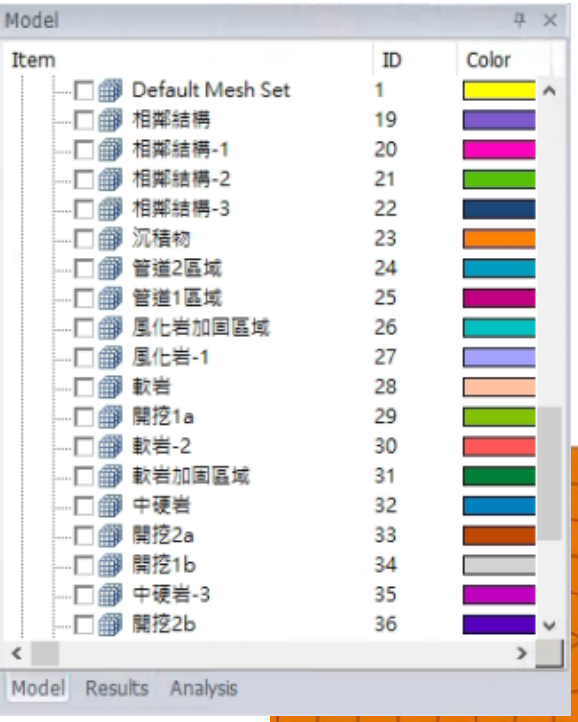
元素座標判斷調整

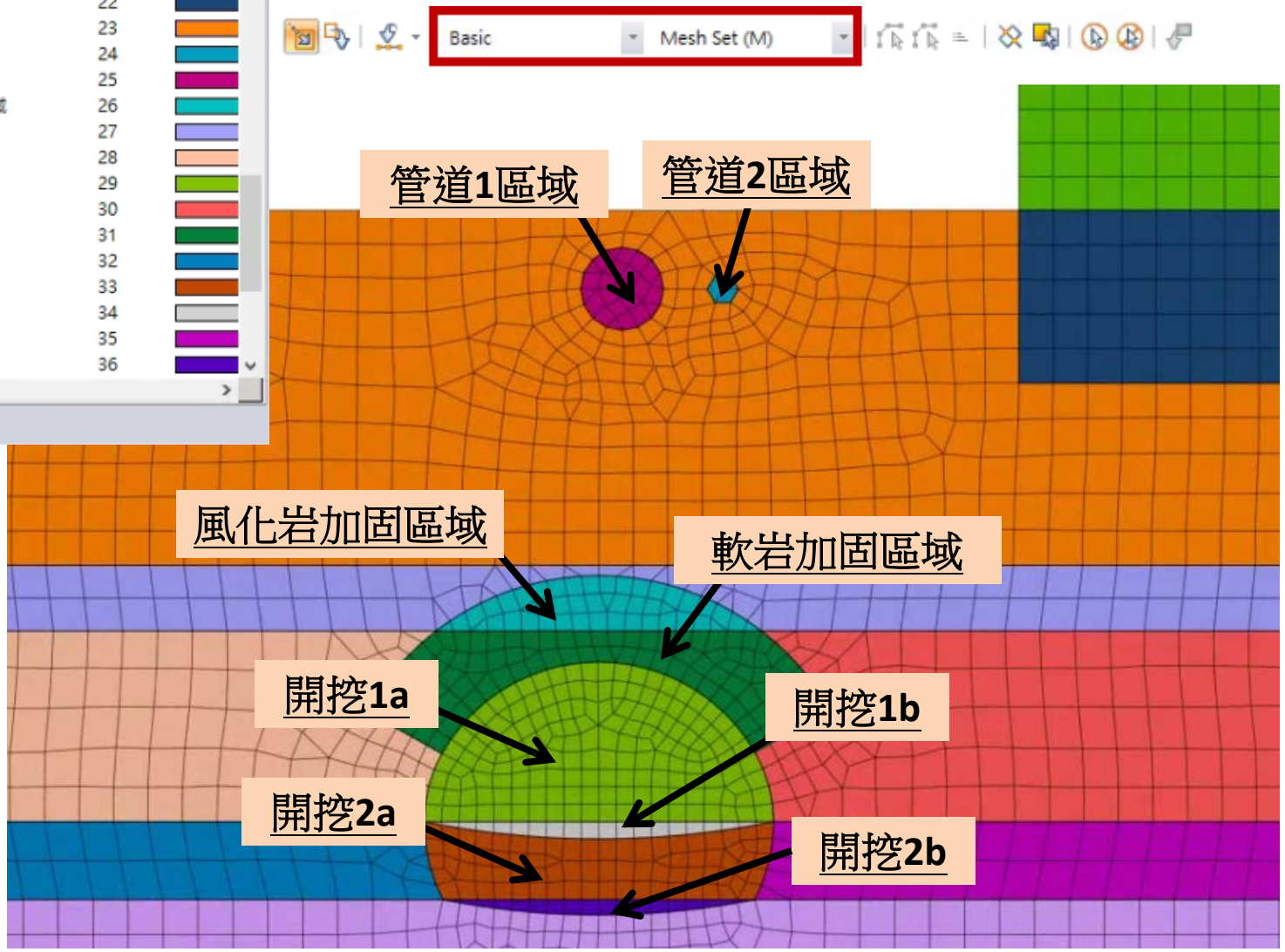


註:截面顯示不正確可以調整元素方向

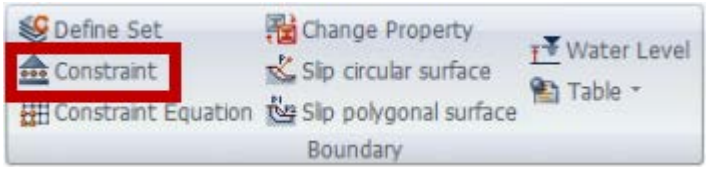
網格集編輯名稱

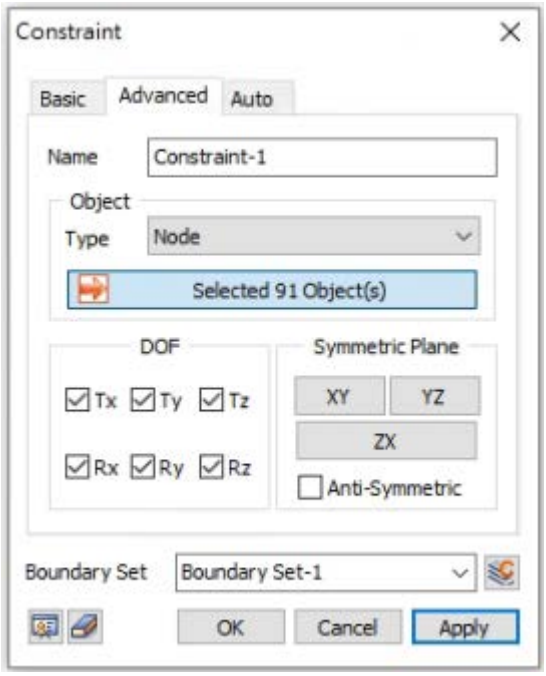
補充:直接使用網格集選取編輯名稱

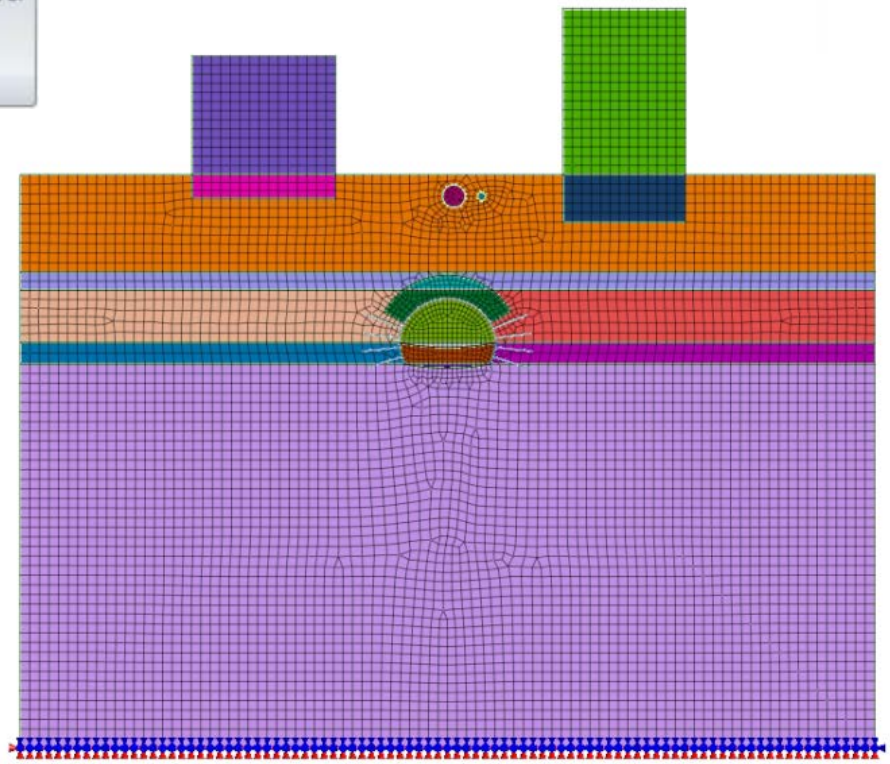




底部邊界



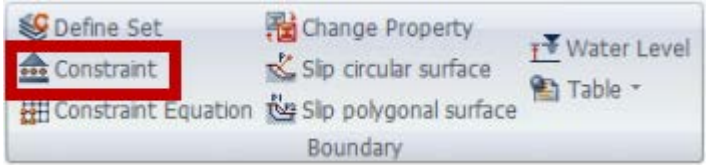




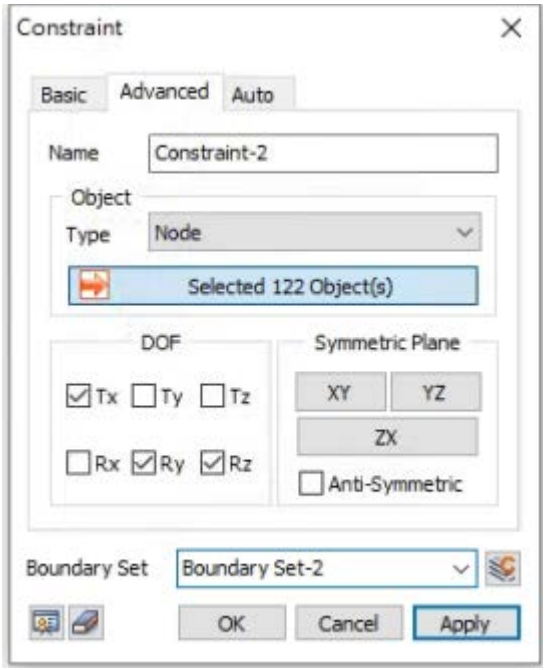
底部自由度拘束
Tx/Ty/Tz/Rx/Ry/Rz

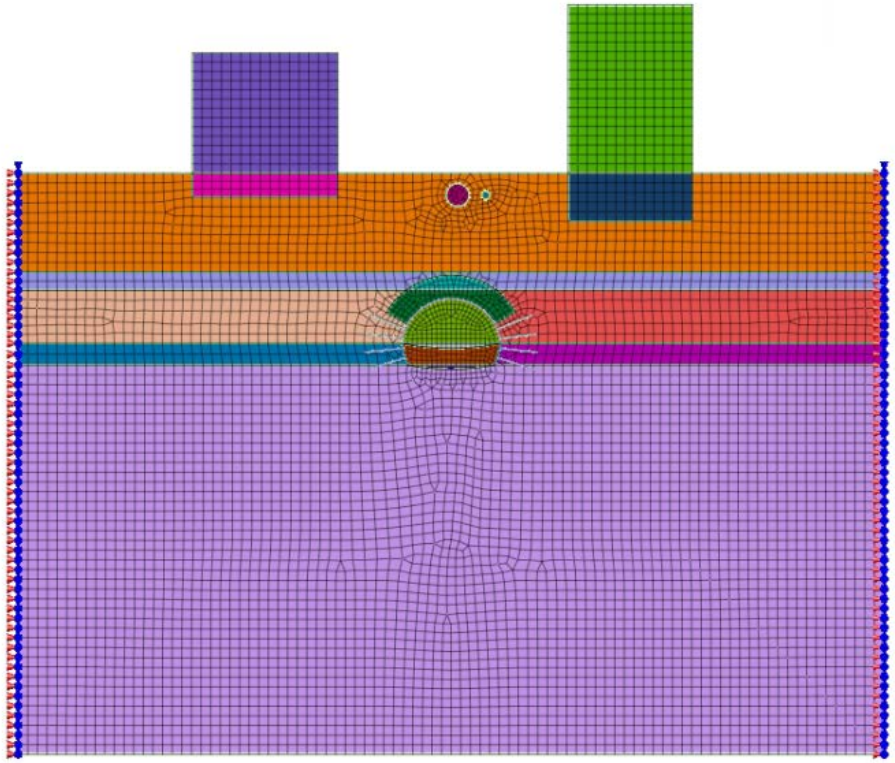
補充:元素和幾何特徵關聯性存在，邊界可以施加幾何特徵或節點。

對稱邊界



2側自由度拘束Tx/Ry/Rz

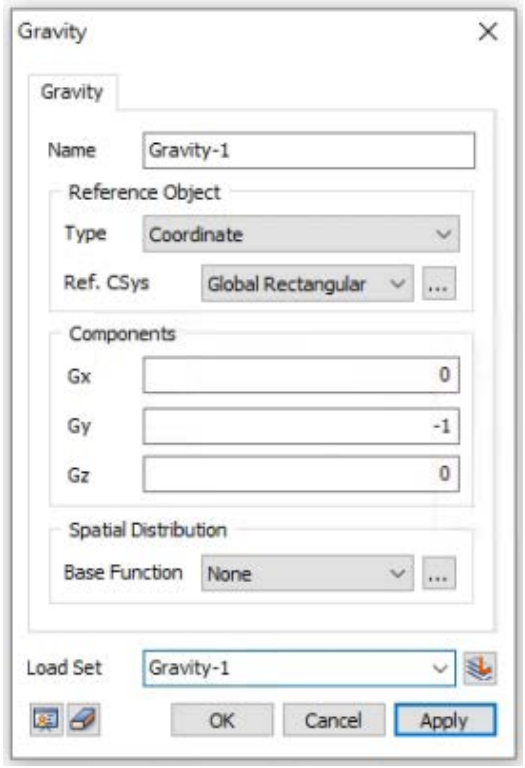


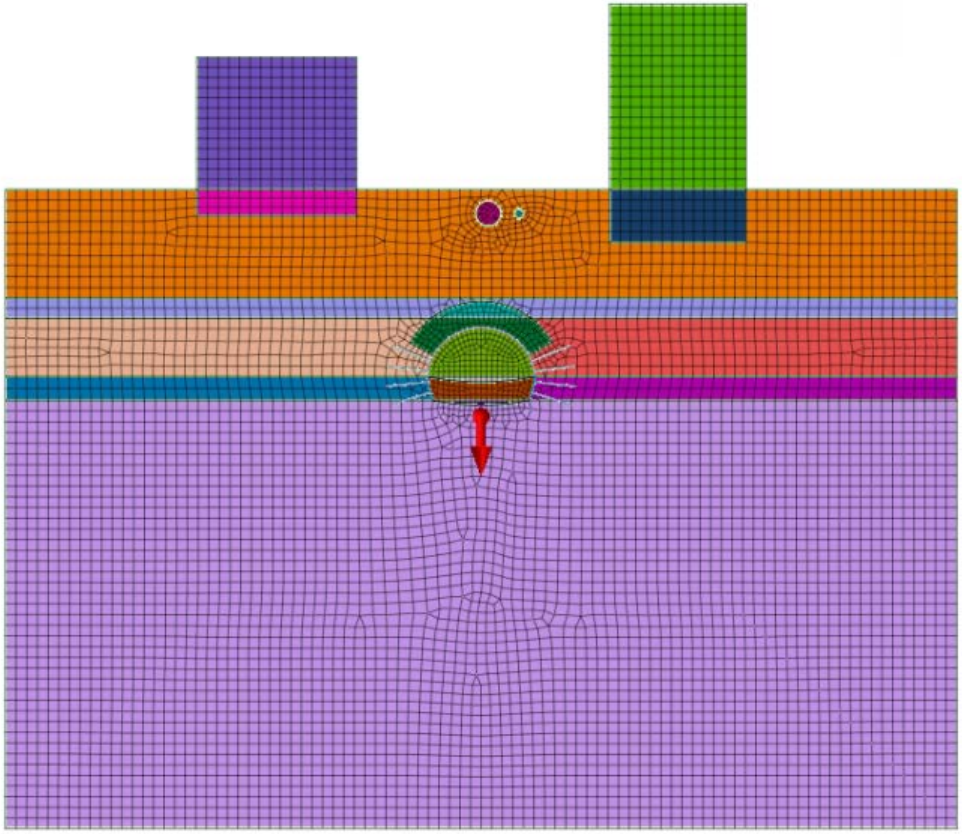


補充:建議不同邊界集使用不同邊界集名稱

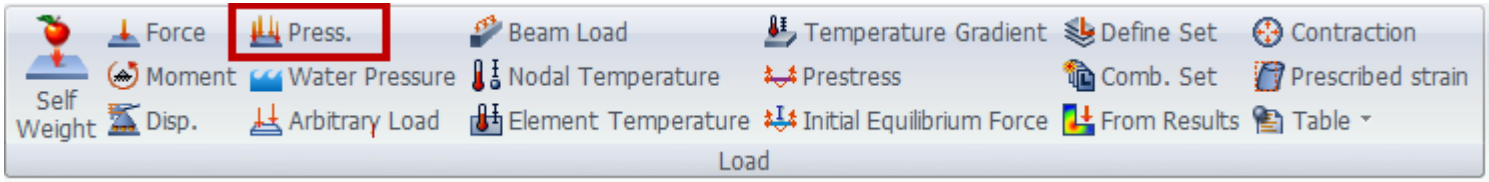
初始應力-自重

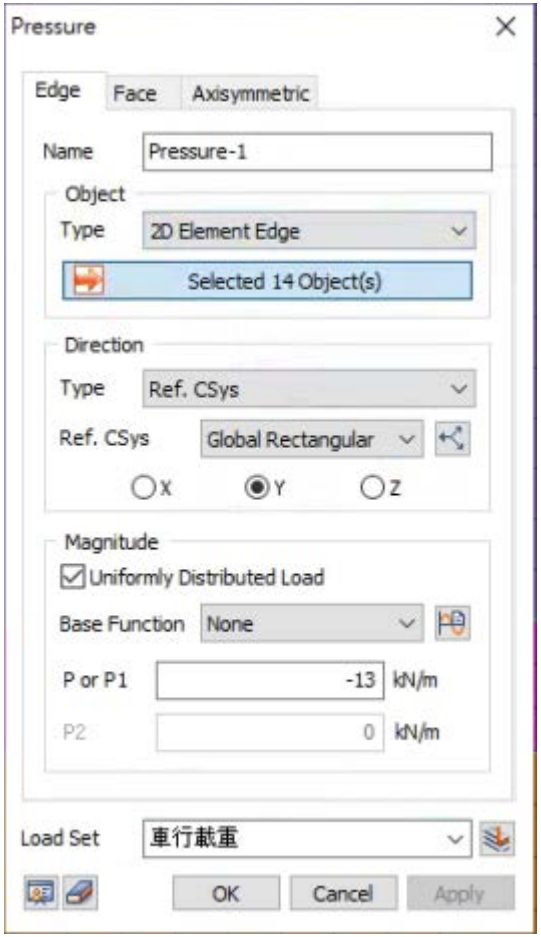

Self Weight
Force
Moment
Disp.
Press.
Water Pressure
Arbitrary Load
Beam Load
Nodal Temperature
Element Temperature
Temperature Gradient
Prestress
Initial Equilibrium Force
Define Set
Comb. Set
From Results
Contraction
Prescribed strain
Table
Load

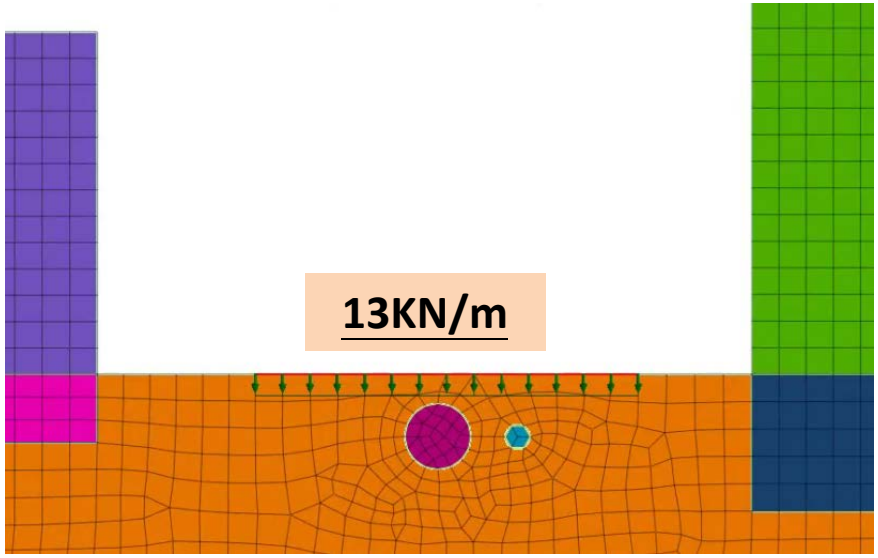

Gravity
Gravity
Name
Gravity-1
Reference Object
Type
Coordinate
Ref. CSys
Global Rectangular
Components
Gx
0
Gy
-1
Gz
0
Spatial Distribution
Base Function
None
Load Set
Gravity-1
OK
Cancel
Apply



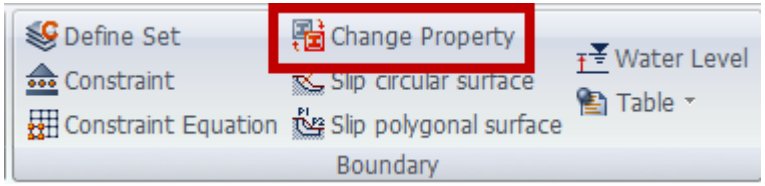
車行載重-Pressure



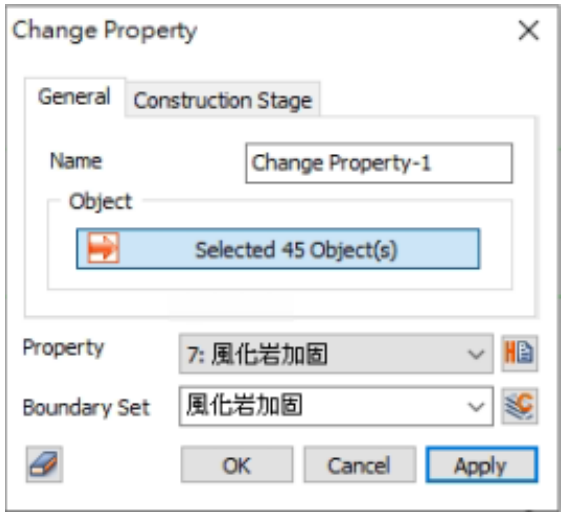




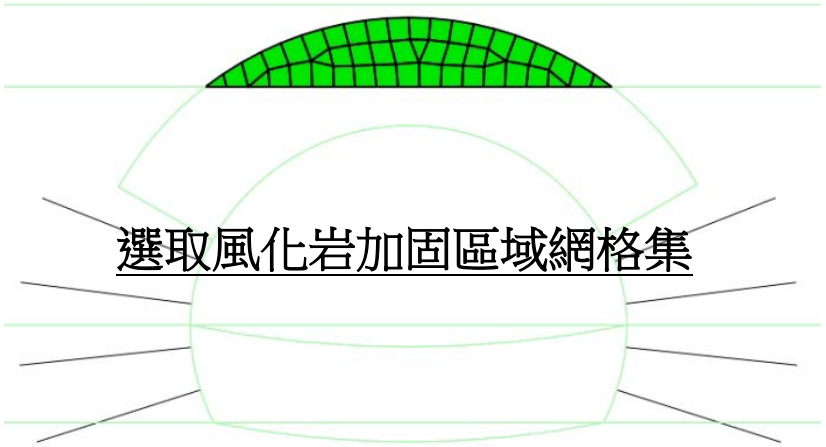
地質改良-1
(風化岩=> 風化岩加固)



地質改良
利用**Change Property**變更地質改良區域材質

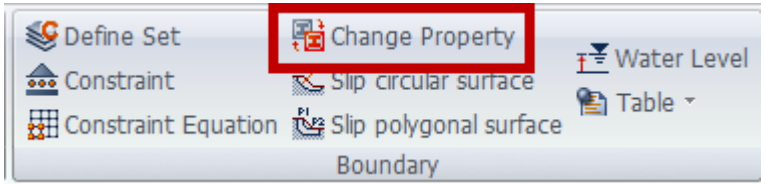


名稱:風化岩加固/屬性:風化加固

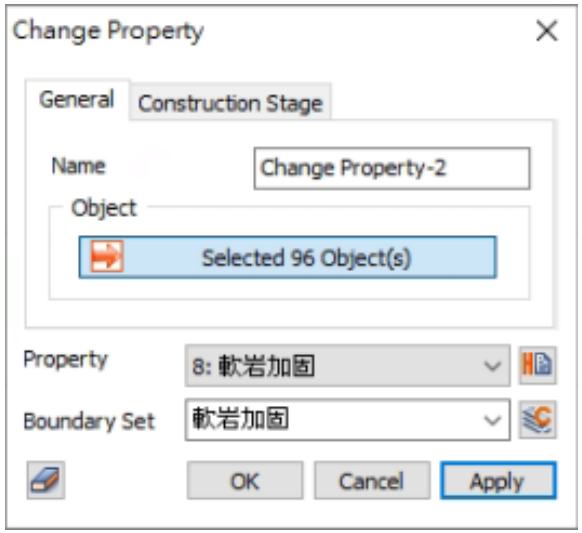


選取風化岩加固區域網格集

地質改良-2
(軟岩=> 軟岩加固)

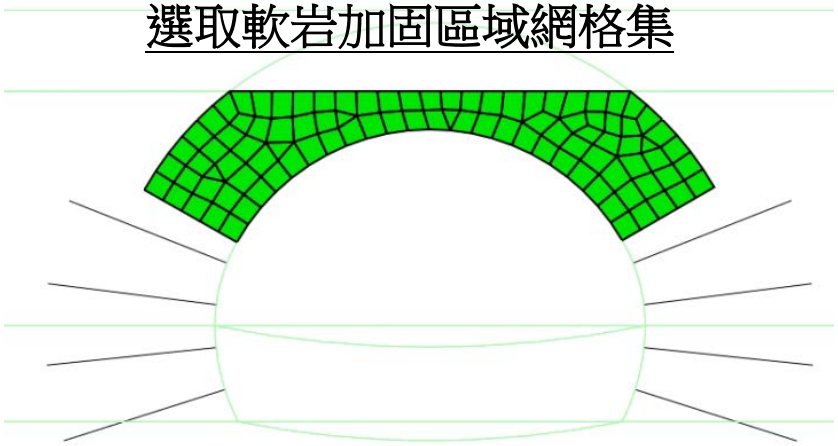


地質改良
利用**Change Property**變更地質改良區域材質



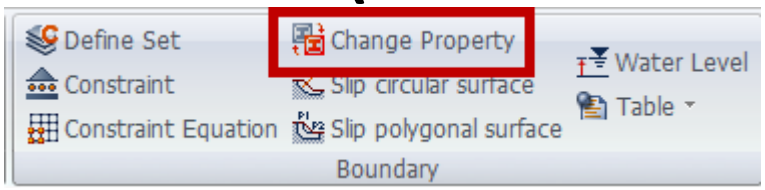
名稱:軟岩加固/屬性:軟岩加固

選取軟岩加固區域網格集



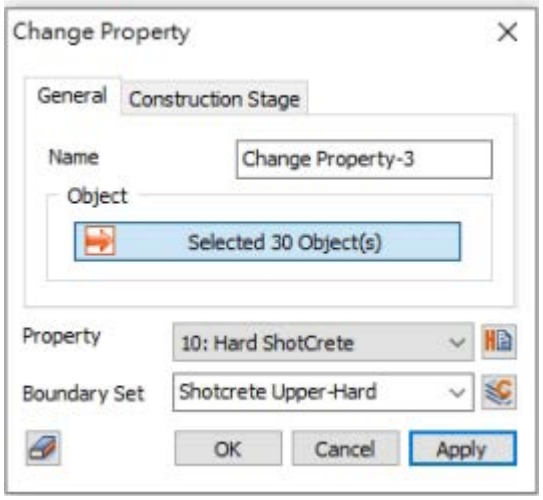
隧道上半部噴射混凝土

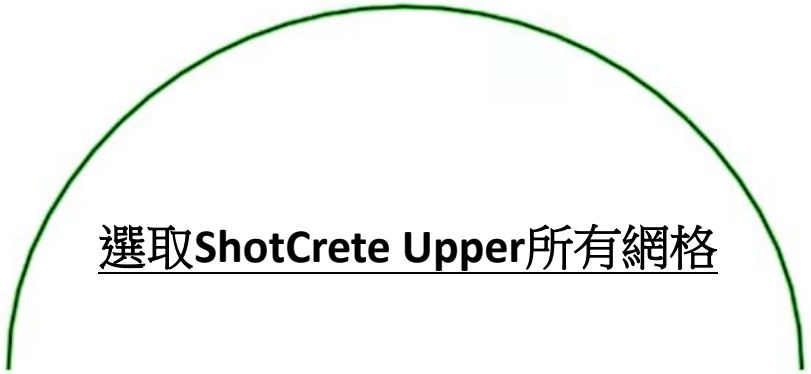
(Soft ShotCrete => Hard ShotCrete)



施工階段分次施加噴射混凝土
利用**Change Property**變更噴射混凝土強度

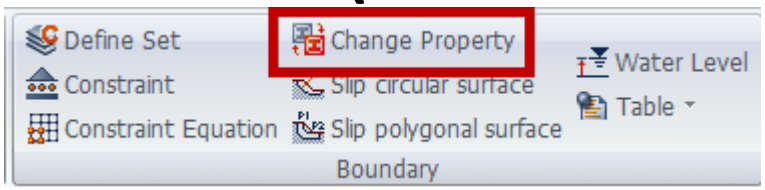
名稱:**Shotcrete Upper-Hard**/屬性:**Hard ShotCrete**





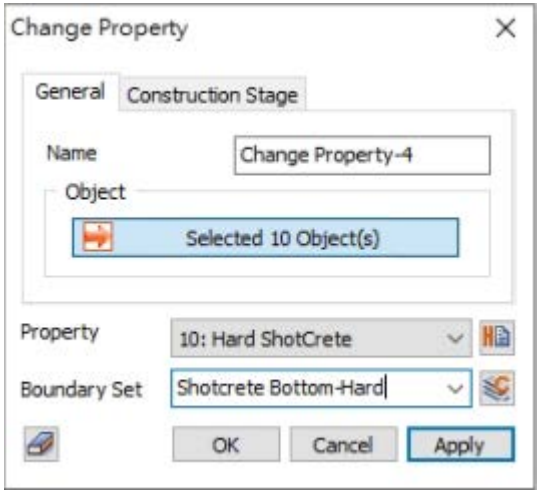
選取**ShotCrete Upper**所有網格

隧道下半部噴射混凝土
(Soft ShotCrete => Hard ShotCrete)



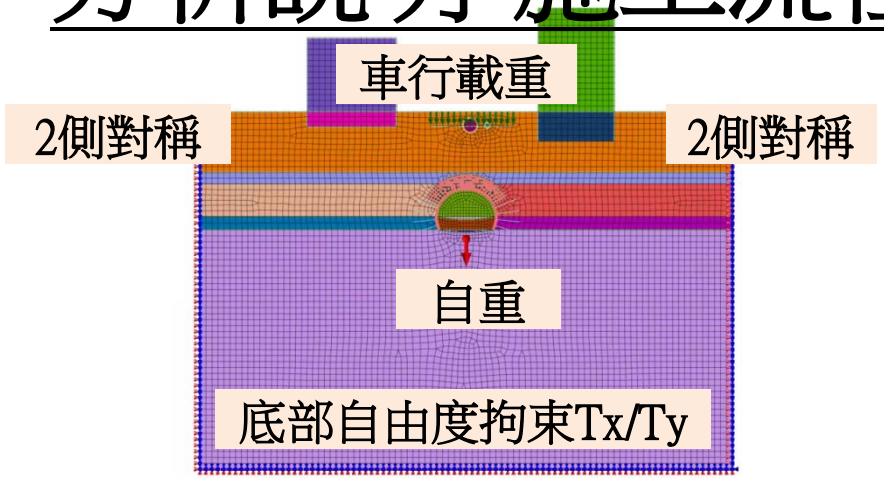
施工階段分次施加噴射混凝土
利用**Change Property**變更噴射混凝土強度

名稱:**Shotcrete Bottom-Hard**/屬性:**Hard ShotCrete**



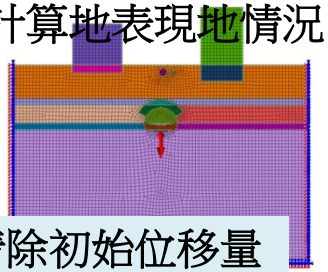
選取**ShotCrete Bottom**所有網格

分析說明-施工流程



Stage1

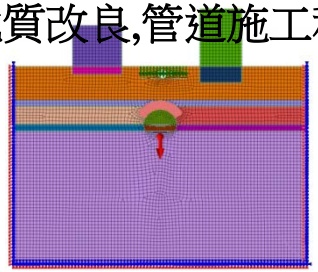
計算地表現地情況



清除初始位移量

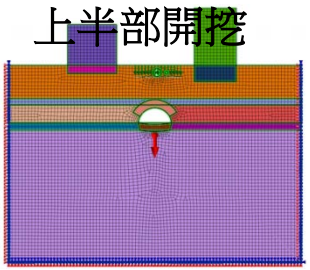
Stage2

地質改良,管道施工和車載



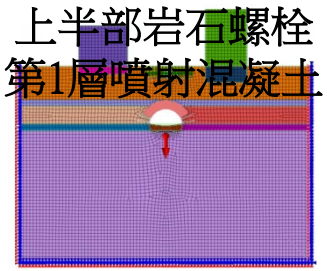
Stage3

上半部開挖



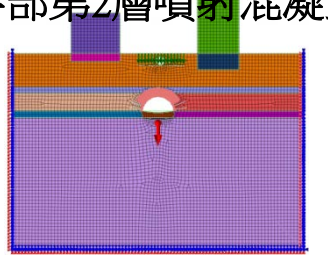
Stage4

上半部岩石螺栓
第1層噴射混凝土



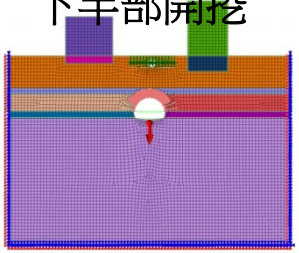
Stage5

上半部第2層噴射混凝土



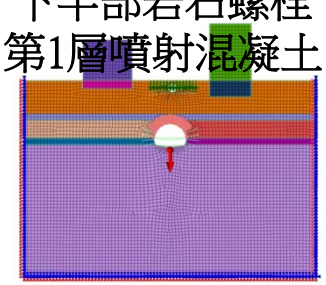
Stage6

下半部開挖



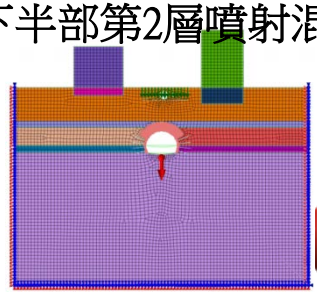
Stage7

下半部岩石螺栓
第1層噴射混凝土



Stage8

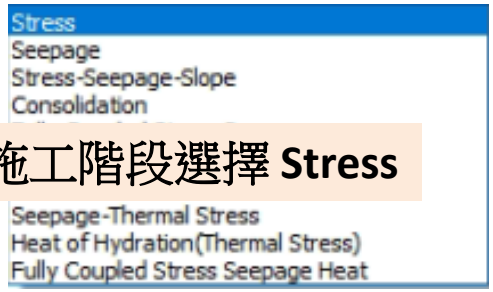
下半部第2層噴射混凝土



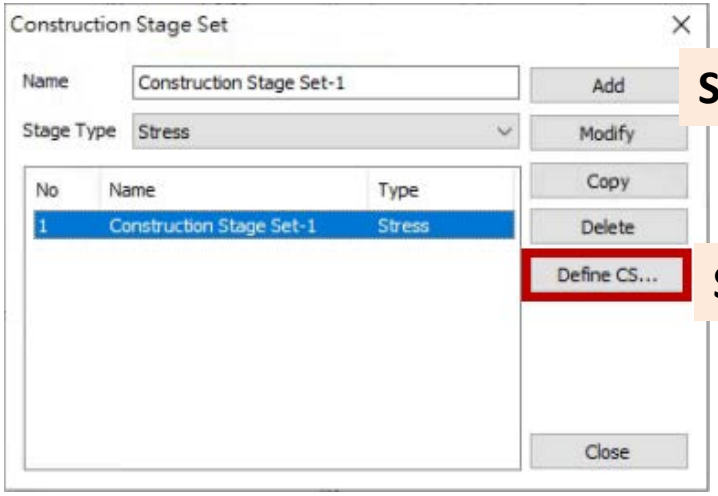
註:範例相關參數使用假設條件。

施工階段定義-1
(新增施工階段計算類型)

GTS NX提供多種施工階段類型

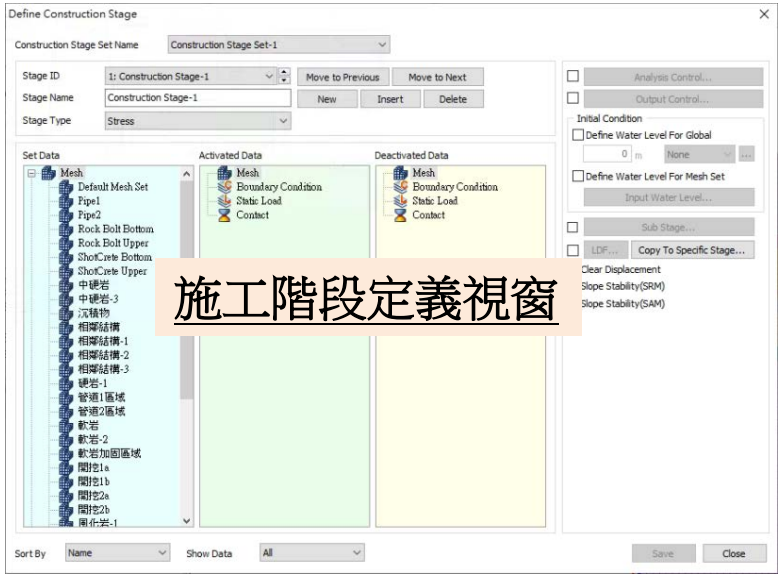


施工階段選擇 **Stress**



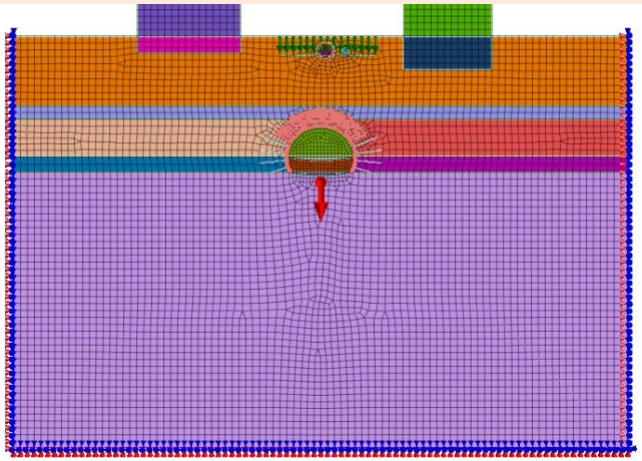
Step1.新增

Step2.編輯定義



施工階段定義視窗

施工階段提供同步檢視
(顯示所有網格集/邊界集/載荷集)



施工階段定義-2
(施工階段1:Initial Stage)

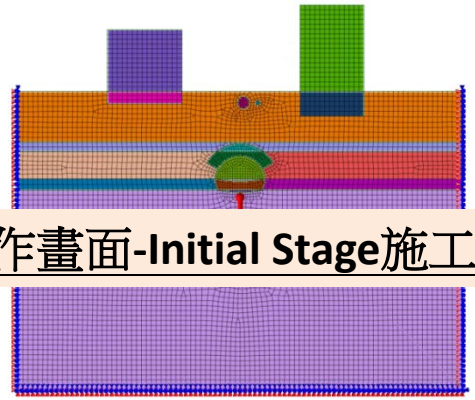
訂義工況名稱:Initial Stage/分析類型:Stress

清除初始位移量

拖曳初始大地&相鄰結構網格集/邊界集/Gravity載荷集 to Activated Data

開啓施工階段檢視

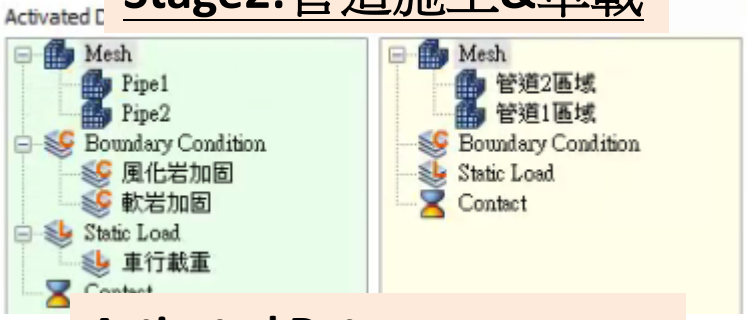
操作畫面-未施加條件前



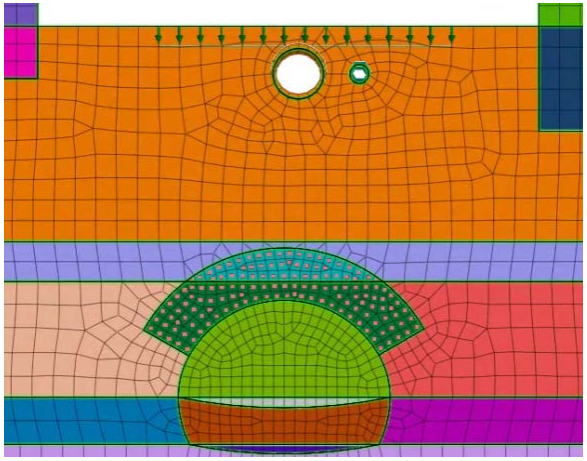
操作畫面-Initial Stage施工階段

施工階段定義-3
(施工階段2~3)

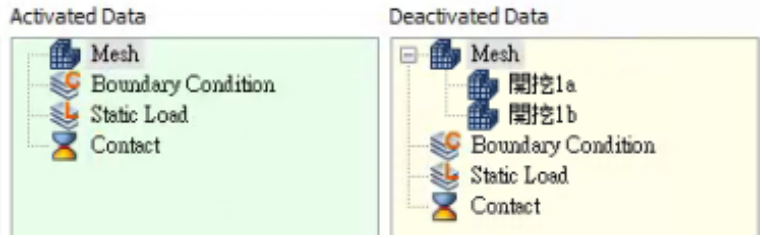
Stage2:管道施工&車載



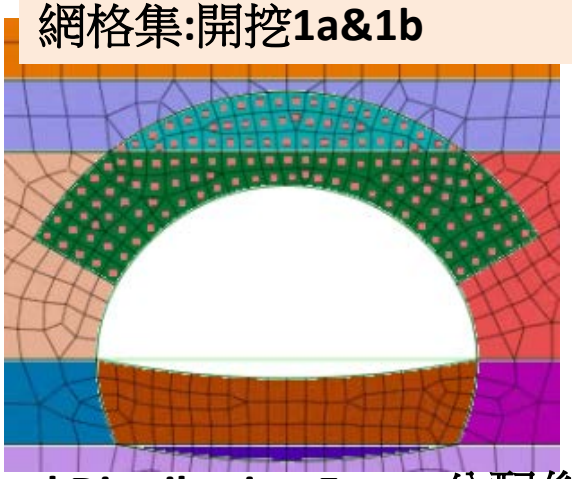
Activated Data
網格集:Pipe1&2
邊界集:風化岩&軟岩加固
載荷集:車行載重
Deactivated Data
網格集:管道1&2區域



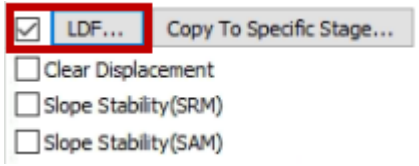
Stage3:隧道上半部開挖



Deactivated Data
網格集:開挖1a&1b

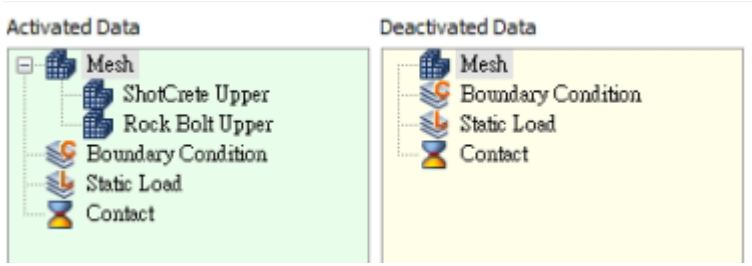


Load Distribution Factor分配係數

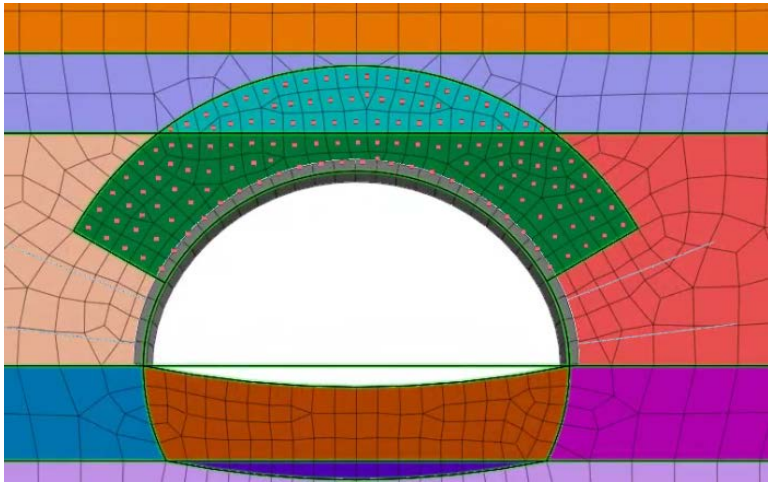


施工階段定義-4
(施工階段4~5)

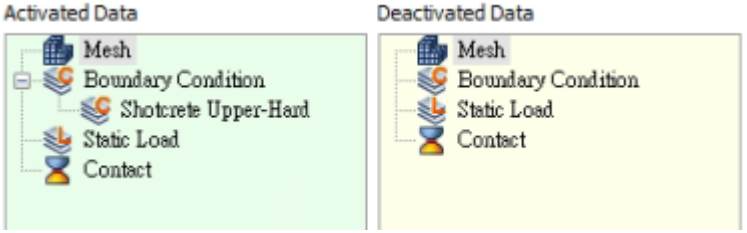
Stage4:上半部岩石螺栓&第1層噴射混凝土



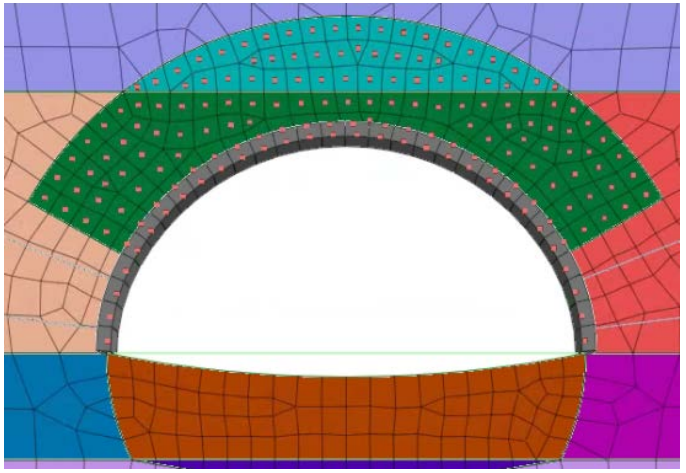
Activated Data
網格集:ShotCrete Upper
Rock Bolt Upper



Stage5:上半部第2層噴射混凝土

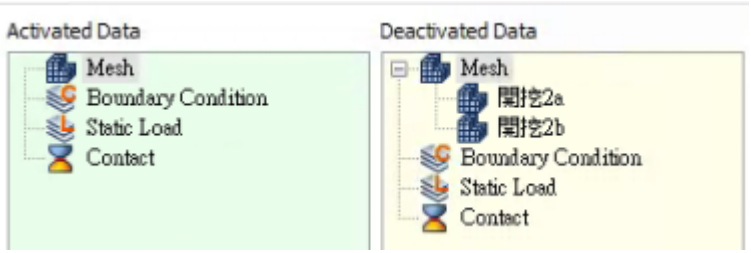


Activated Data
邊界集:ShotCrete Upper Hard

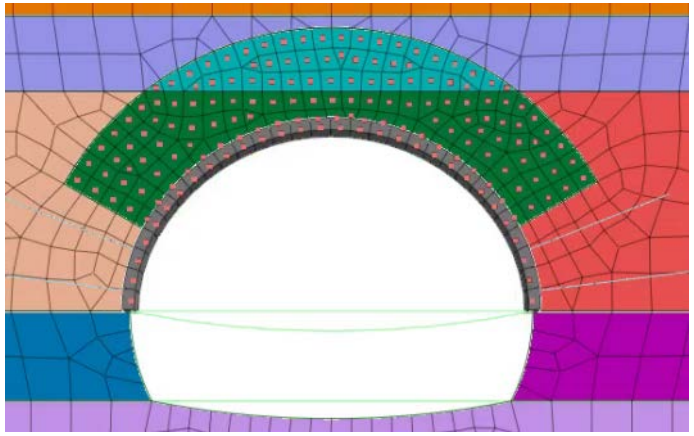


施工階段定義-5
(施工階段6~7)

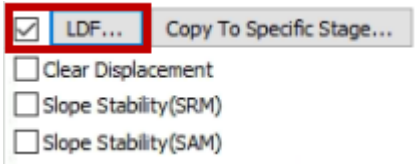
Stage6:下半部開挖



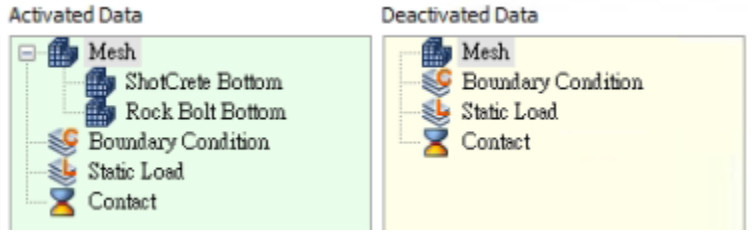
Deactivated Data
網格集:開挖2a&2b



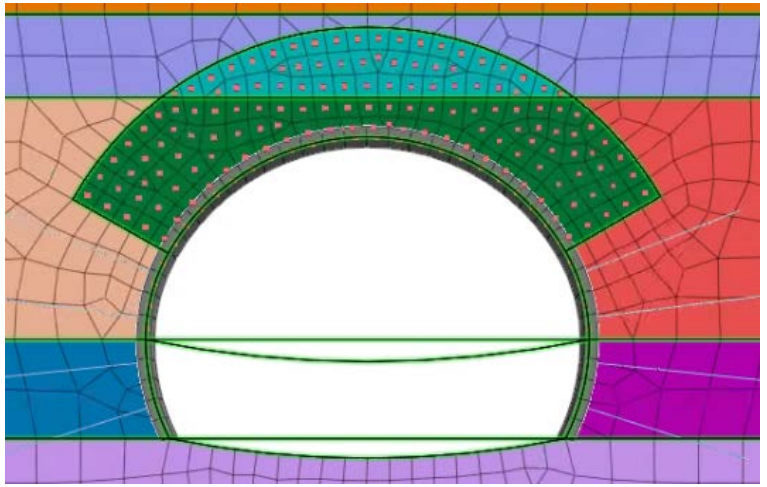
Load Distribution Factor分配係數



Stage7:下半部岩石螺栓&第1層噴射混凝土

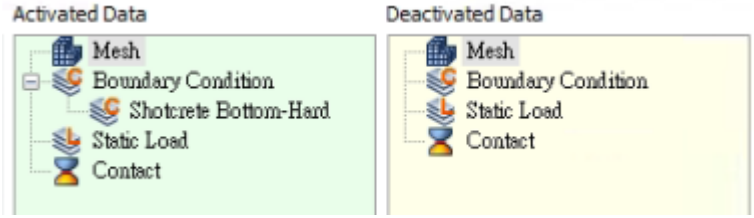


Activated Data
網格集:ShotCrete Bottom
Rock Bolt Bottom

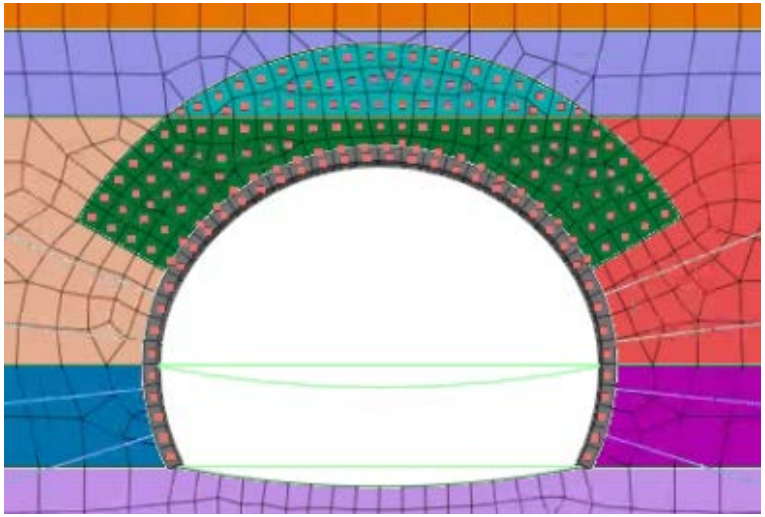


施工階段定義-6
(施工階段8)

Stage8:下半部第2層噴射混凝土



Activated Data
邊界集:ShotCrete Bottom Hard

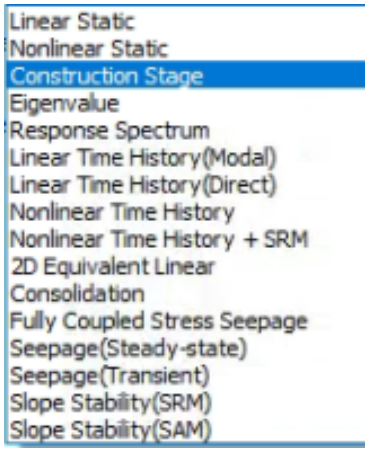


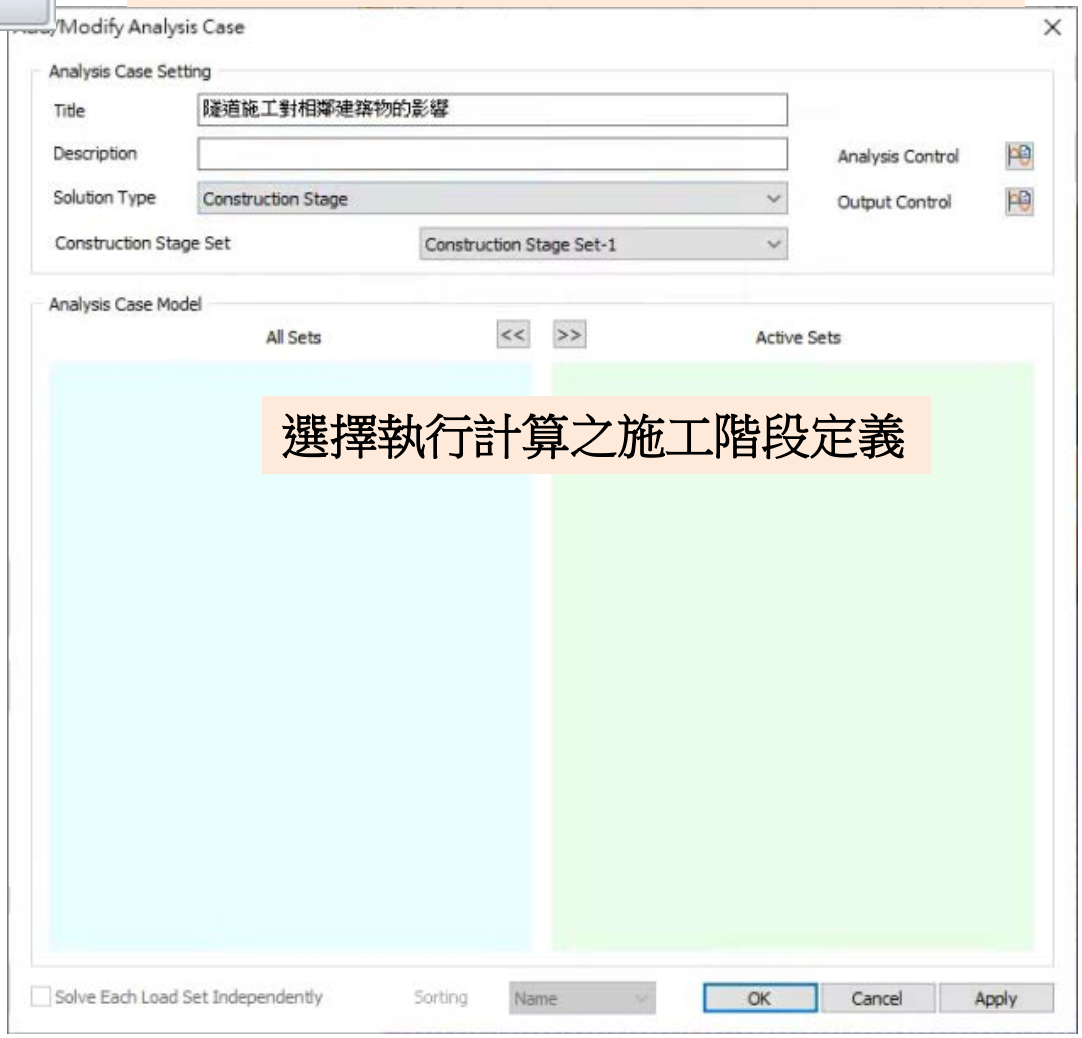
分析定義

(隧道施工對相鄰建築物的影響)

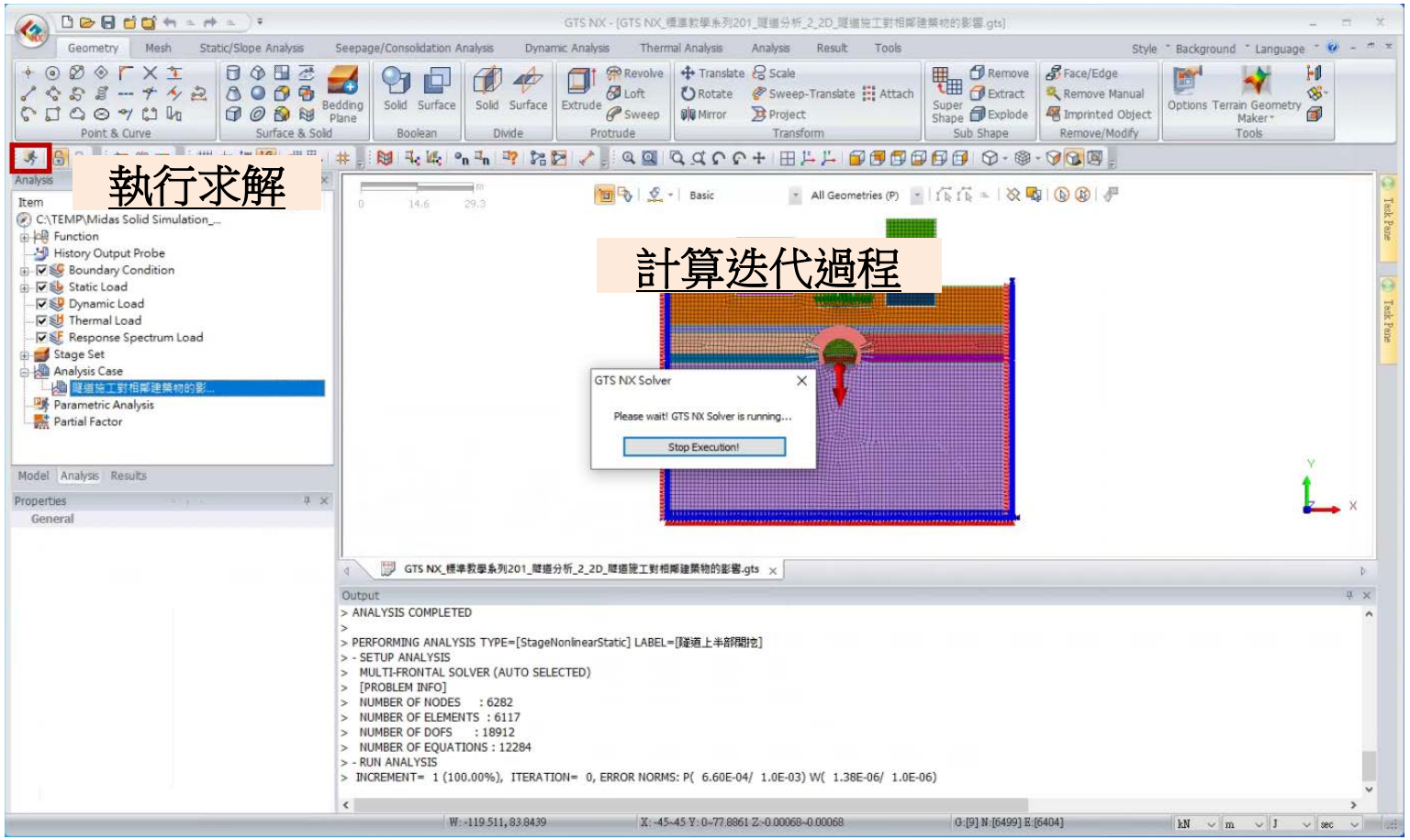
分析名稱:隧道施工對相鄰建築物的影響
分析類型:**Construction Stage**

Construction Stage



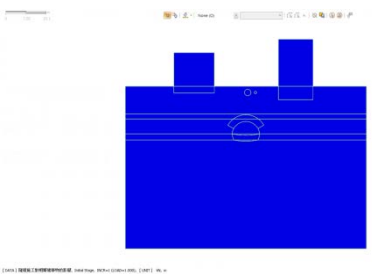


計算

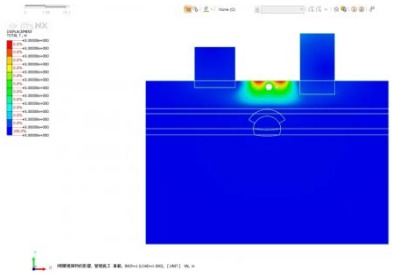

執行求解
計算迭代過程
GTS NX Solver
Please wait! GTS NX Solver is running...
Stop Execution!
> ANALYSIS COMPLETED
> PERFORMING ANALYSIS TYPE=[StageNonlinearStatic] LABEL=[隧道上半部開挖]
> - SETUP ANALYSIS
> MULTI-FRONTAL SOLVER (AUTO SELECTED)
> [PROBLEM INFO]
> NUMBER OF NODES : 6282
> NUMBER OF ELEMENTS : 6117
> NUMBER OF DOFS : 18912
> NUMBER OF EQUATIONS : 12284
> - RUN ANALYSIS
> INCREMENT= 1 (100.00%), ITERATION= 0, ERROR NORMS: P(6.60E-04/ 1.0E-03) W(1.38E-06/ 1.0E-06)

分析結果-1
(Displacement)

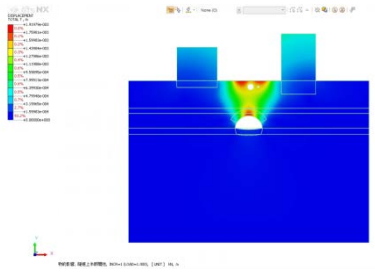
Stage1



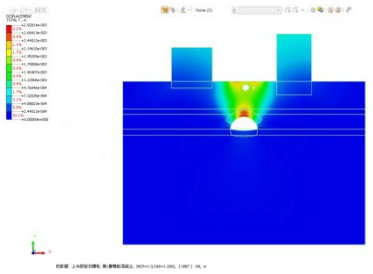
Stage2



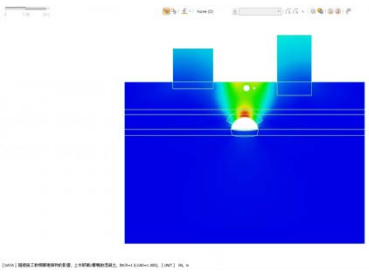
Stage3



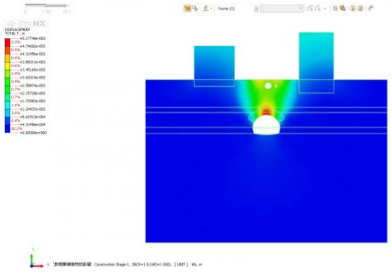
Stage4



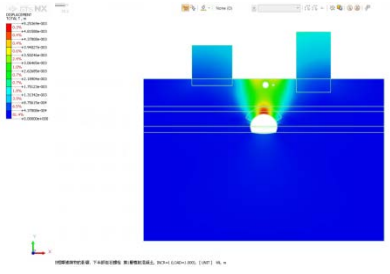
Stage5



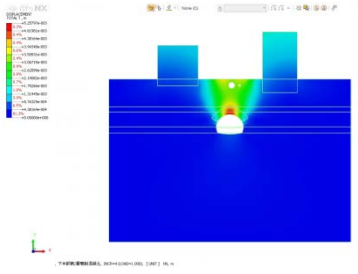
Stage6



Stage7



Stage8

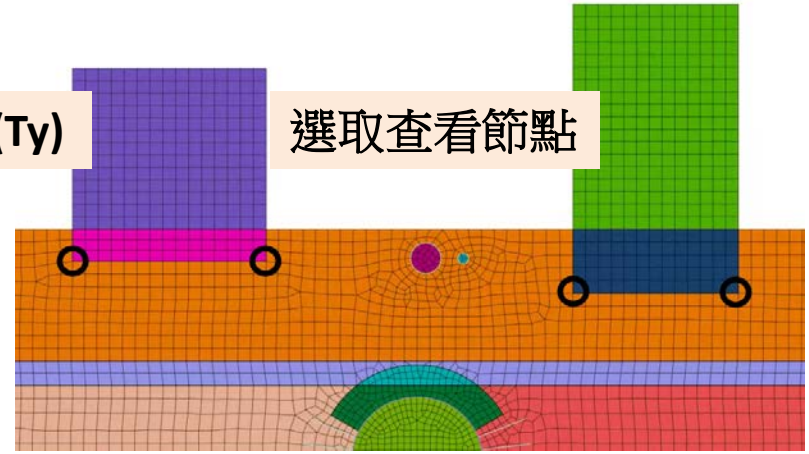


播放動畫 (施工階段)

分析結果-2

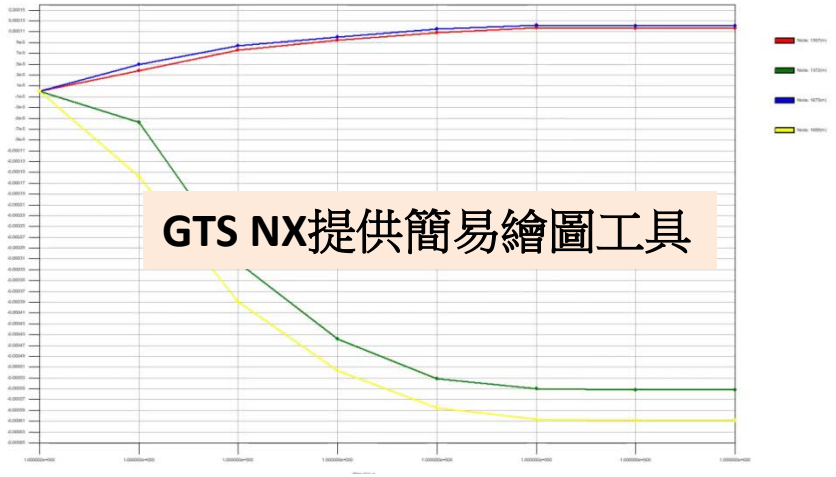
查看施工階段相鄰建物下沉量變化(Ty)

選取查看節點



輸出表格

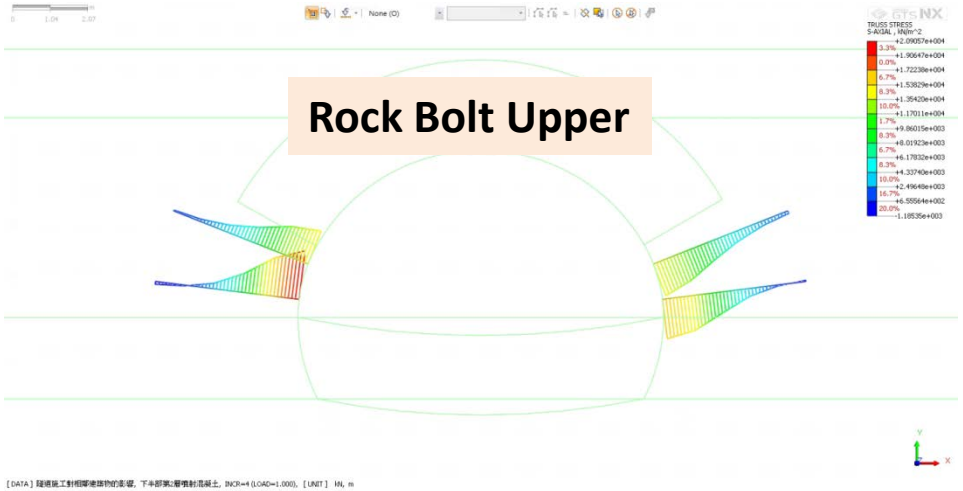
	No	Step	Step Value	Node: 1357 TY TRANSLATION (V) (m)	Node: 1372 TY TRANSLATION (V) (m)	Node: 1675 TY TRANSLATION (V) (m)	Node: 1688 TY TRANSLATION (V) (m)
▶	1	Initial Stage:INCR=1 (LOAD=1.000)	1.000000e+000	0.000000e+000	0.000000e+000	0.000000e+000	0.000000e+000
	2	管道施工&車載:INCR=1 (LOAD=1.	1.000000e+000	3.797610e-005	-5.743093e-005	4.999833e-005	-1.570297e-004
	3	隧道上半部開挖:INCR=1 (LOAD=1	1.000000e+000	7.647026e-005	-3.164942e-004	8.367044e-005	-3.888084e-004
	4	上半部岩石螺栓&第1層噴射混凝	1.000000e+000	9.452091e-005	-4.574776e-004	9.964647e-005	-5.163545e-004
	5	上半部第2層噴射混凝土:INCR=1 (	1.000000e+000	1.086303e-004	-5.312528e-004	1.146028e-004	-5.851694e-004
	6	下半部開挖:INCR=1 (LOAD=1.000)	1.000000e+000	1.169062e-004	-5.495434e-004	1.216792e-004	-6.063434e-004
	7	下半部岩石螺栓&第1層噴射混凝	1.000000e+000	1.159138e-004	-5.522660e-004	1.205319e-004	-6.089803e-004
	8	下半部第2層噴射混凝土:INCR=4 (	1.000000e+000	1.159035e-004	-5.522636e-004	1.205319e-004	-6.089802e-004

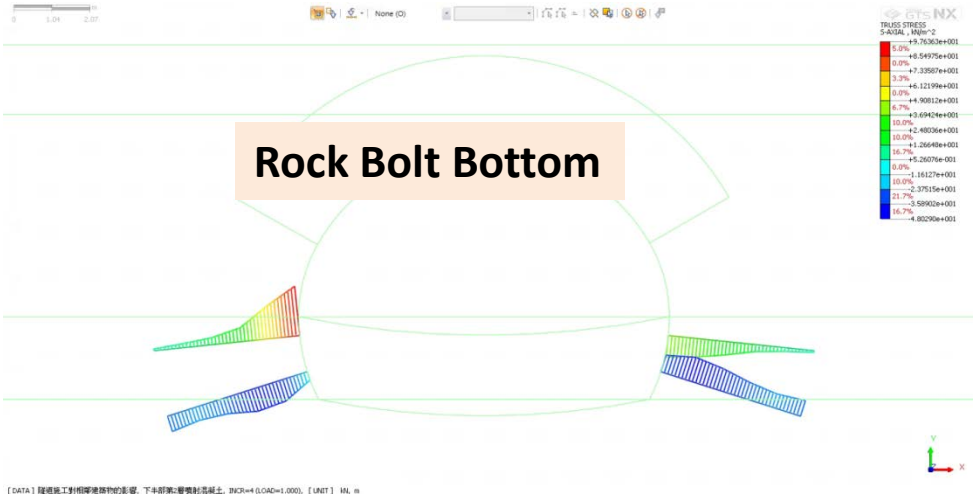


GTS NX提供簡易繪圖工具

分析結果-3

使用Truss Element 讀取Embedded Element結果





GTS NX_標準教學系列

3D隧道推進開挖

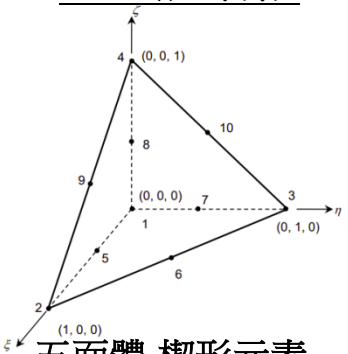
台灣邁達斯

註1:範例相關參數使用假設條件。
註2:建議操作3D隧道教學前，先熟悉2D隧道分析範例。

實體元素
(Solid Element)

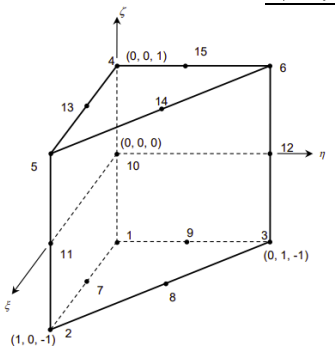
Solid elements are often used for modeling structures with volume, such as soils, thick walls, etc. The usable solid elements in GTS NX/FEA NX are tetrahedral, pentahedral and hexahedral shapes with 4/5/6/8/10/13/15/20 nodes. Pentahedral elements include wedge shapes and pyramid shapes.

四面體網格

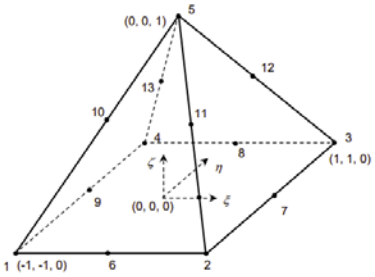


五面體-楔形元素
(Tetrahedral Element)

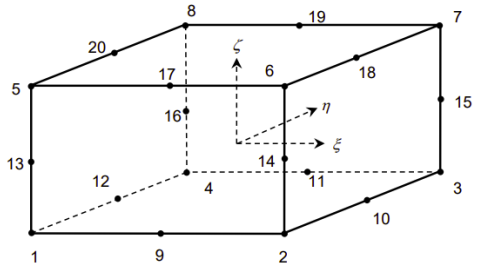
混合網格



五面體-楔形元素
(Wedge Element)



五面體-金字塔元素
(Pyramid Element)



六面體元素
(Hexahedral Element)

Reference

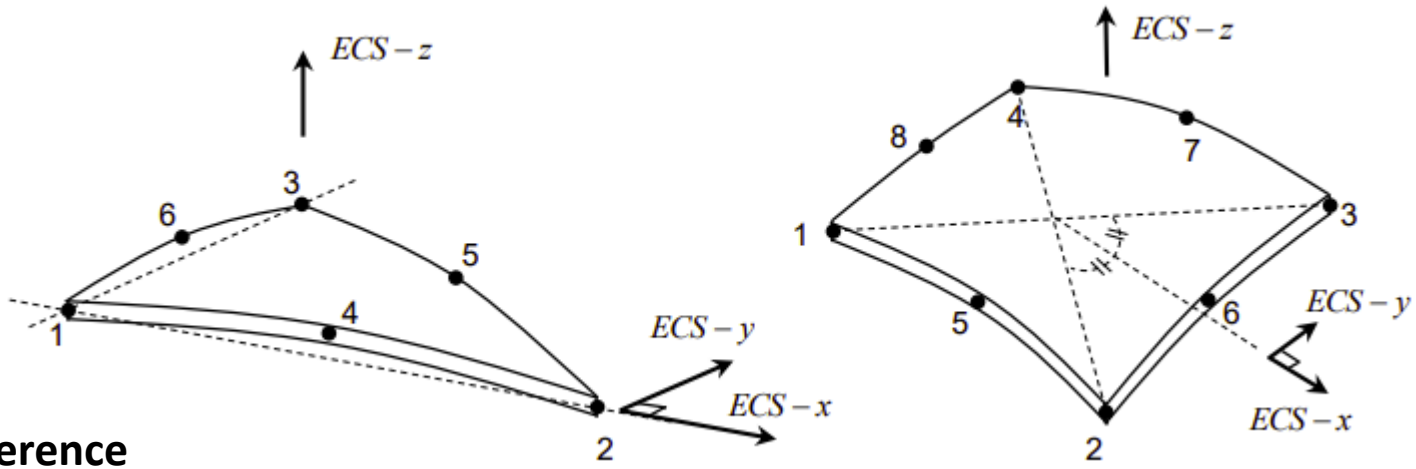
GTS NX and FEA NX Analysis Reference

殼元素
(Shell Element)

Shell elements are triangular or rectangular elements consisting of 3/4/6/8 nodes on a curve surface.
It is mainly used on thin structures that experience bending deformation and 2D stress states.
Bending and shear deformation can be considered.

Element thickness

The thickness of a shell element can be defined at the vertices in the same way as plane stress elements.
The material and effective thickness for bending and shear deformation can also be assigned individually.



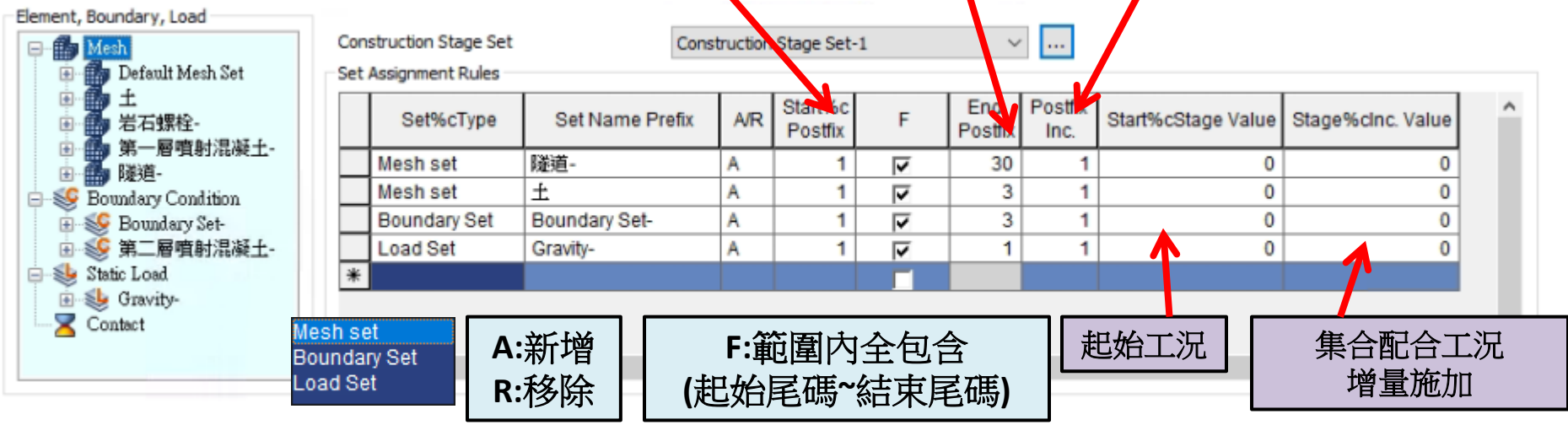
Reference
GTS NX & FEA NX Manual

施工階段嚮導模組

大集合-起始尾碼

大集合-結束尾碼

大集合-間隔選取



註1: (Name)-1 to (Name)-999 視為同一大集合,未加(-)不視作同一大集合

註2: I.S.=>Initial Stage=0 ,S1=>Stage1=1

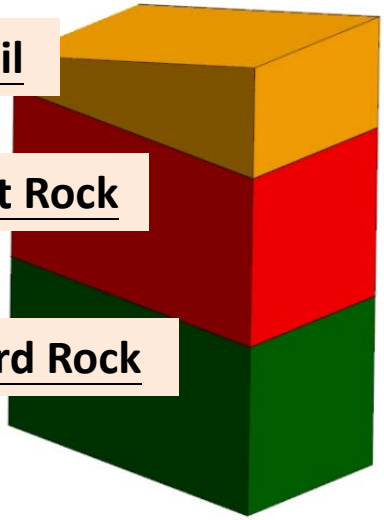
分析說明-材料

施工前

MAT: Soil

MAT: Soft Rock

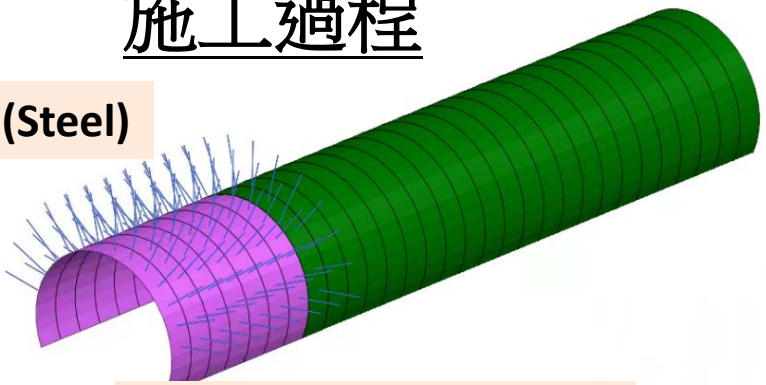
MAT: Hard Rock



隧道開挖移除

施工過程

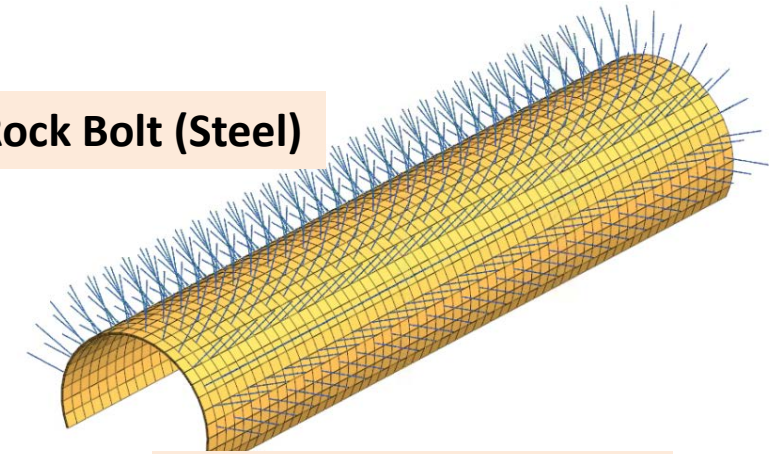
Rock Bolt (Steel)



ShotCrete (Soft to Hard)

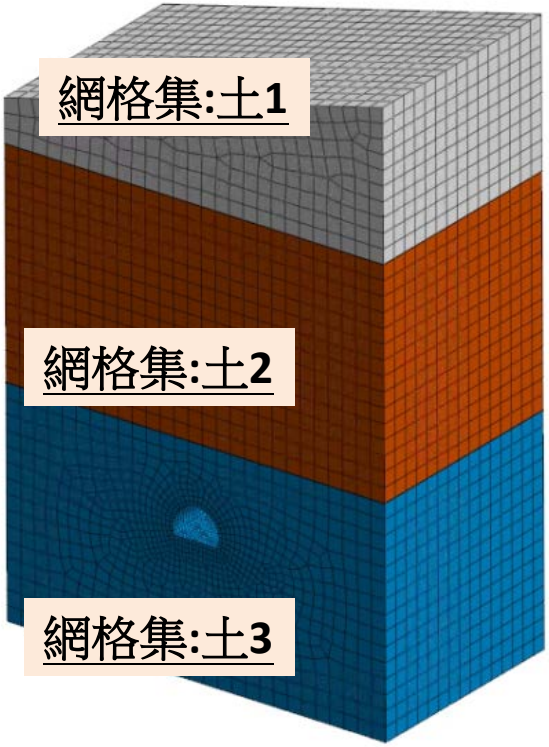
施工後

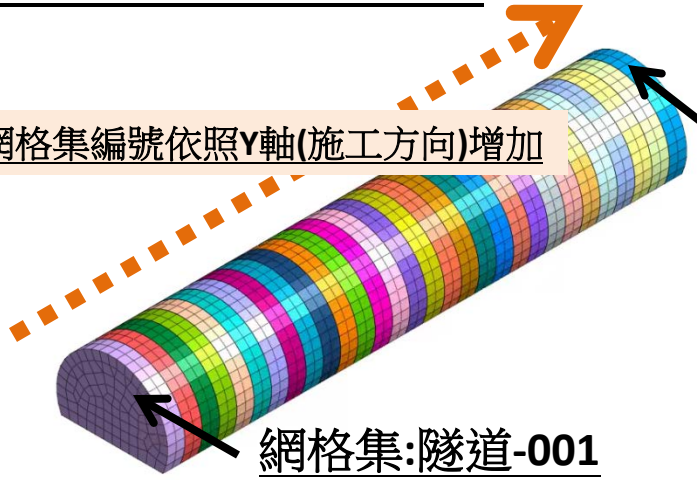
Rock Bolt (Steel)

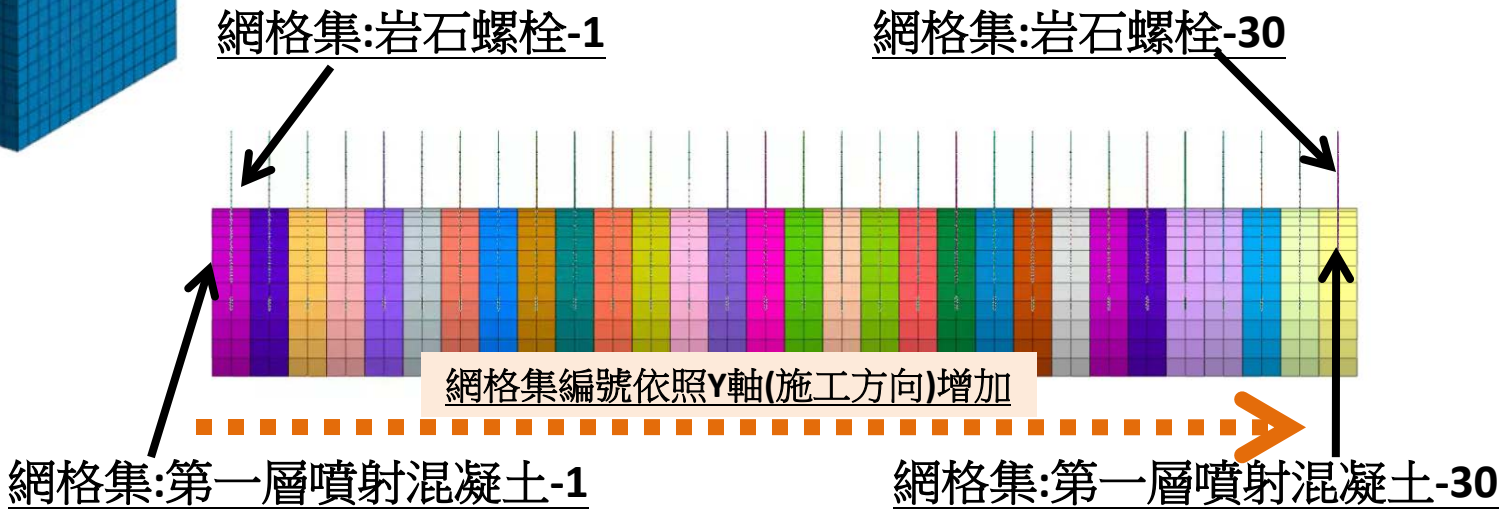


ShotCrete (Soft to Hard)

網格集說明

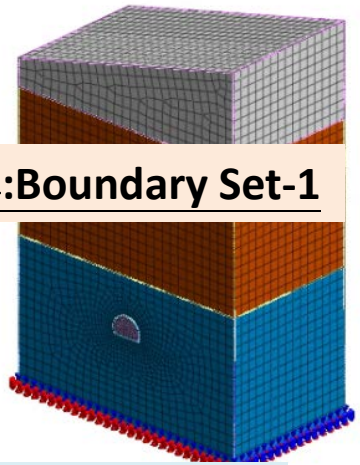






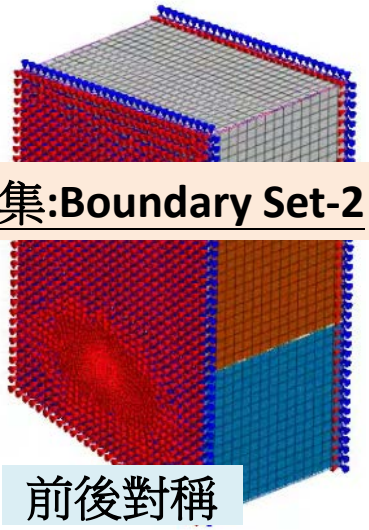
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

邊界集說明



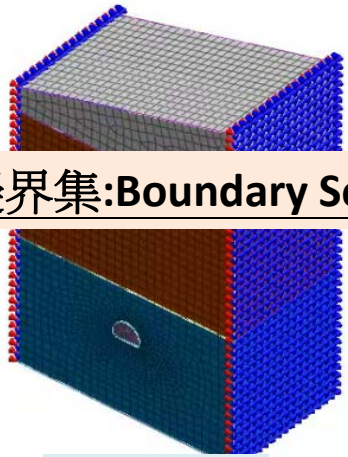
邊界集:Boundary Set-1

底部自由度拘束
Tx/Ty/Tz/Rx/Ry/Rz



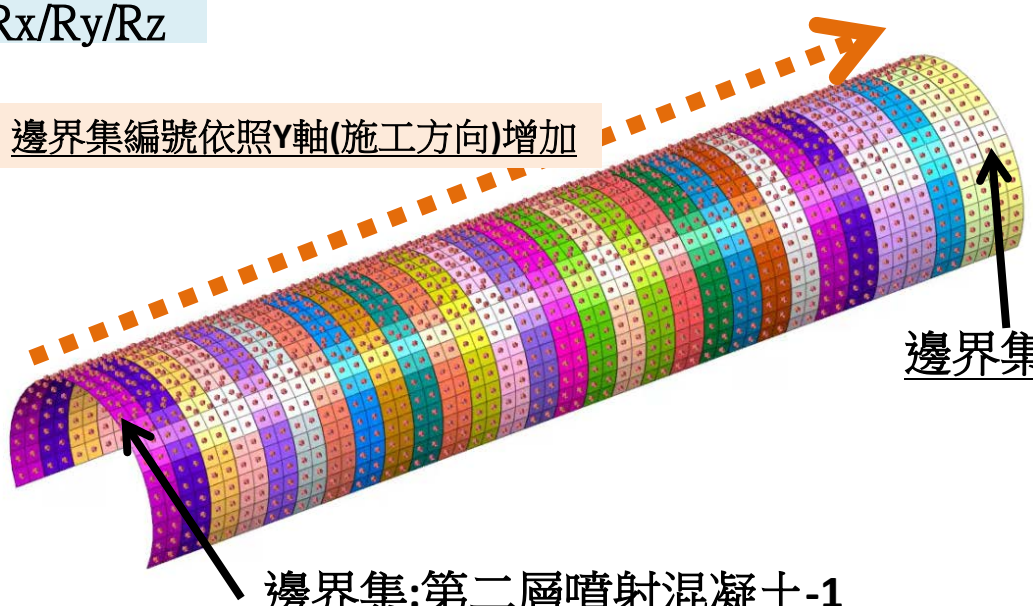
邊界集:Boundary Set-2

前後對稱



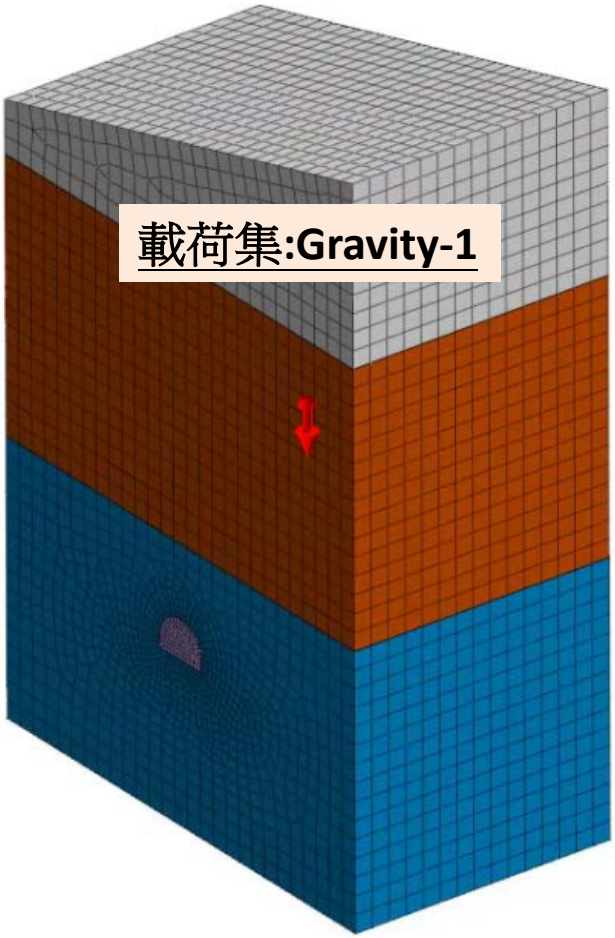
邊界集:Boundary Set-3

2側對稱



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

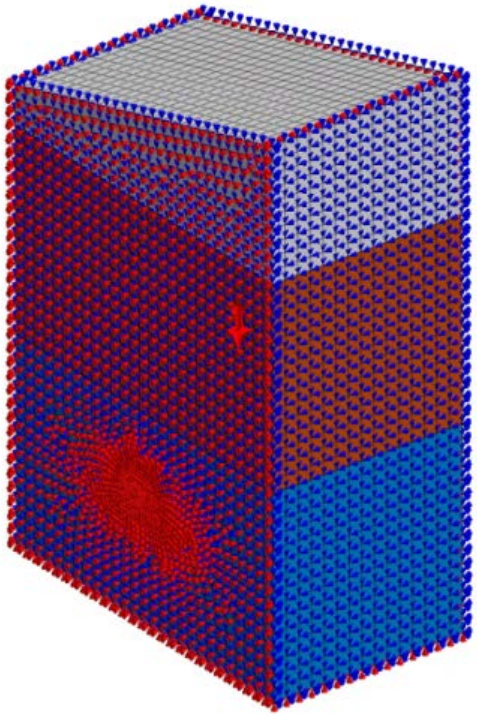
載荷集說明



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

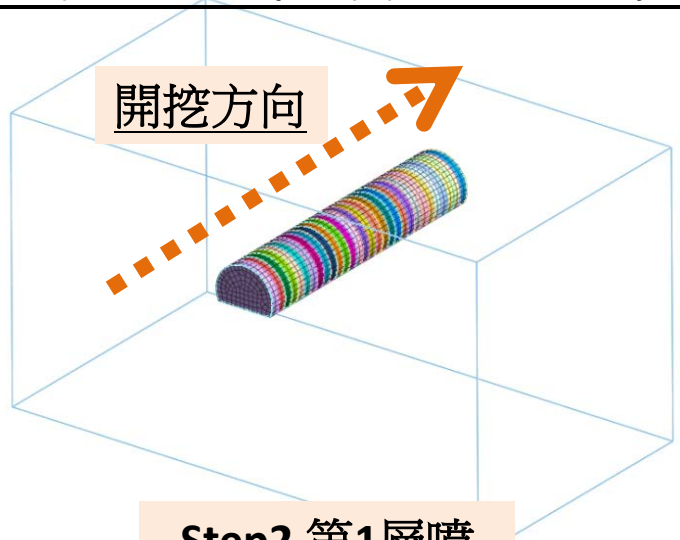
分析說明-隧道開挖前-初始條件

網格集	邊界集	載荷集
隧道-001~30	Boundary Set-1~3	Gravity-1
土1 ~土3		



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

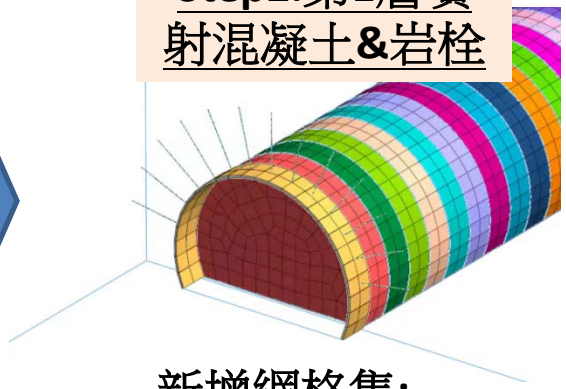
分析說明-隧道開挖-重覆施工過程



Step1.隧道開挖

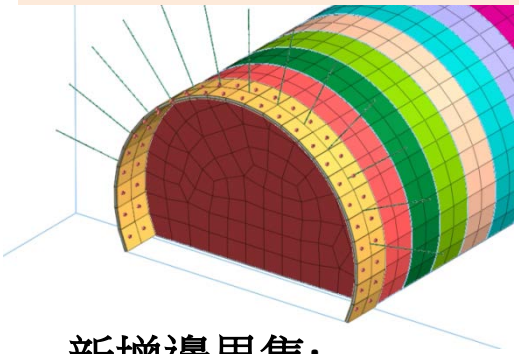
移除網格集:
隧道-001

Step2.第1層噴射混凝土&岩栓



新增網格集:
第一層噴射混凝土-1
岩石螺栓-1

Step3.第2層噴射混凝土



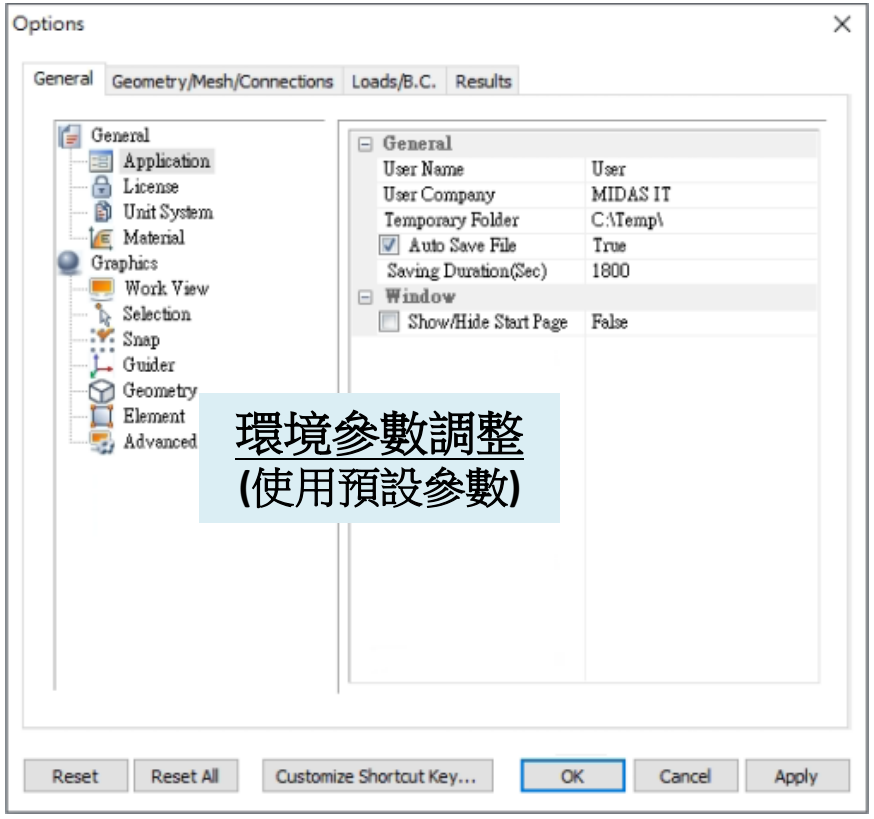
新增邊界集:
第二層噴射混凝土-1

註1:重覆相同施工過程至隧道貫穿。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段。

Part1.網格/邊界/載荷

環境

新文件



環境參數調整
(使用預設參數)

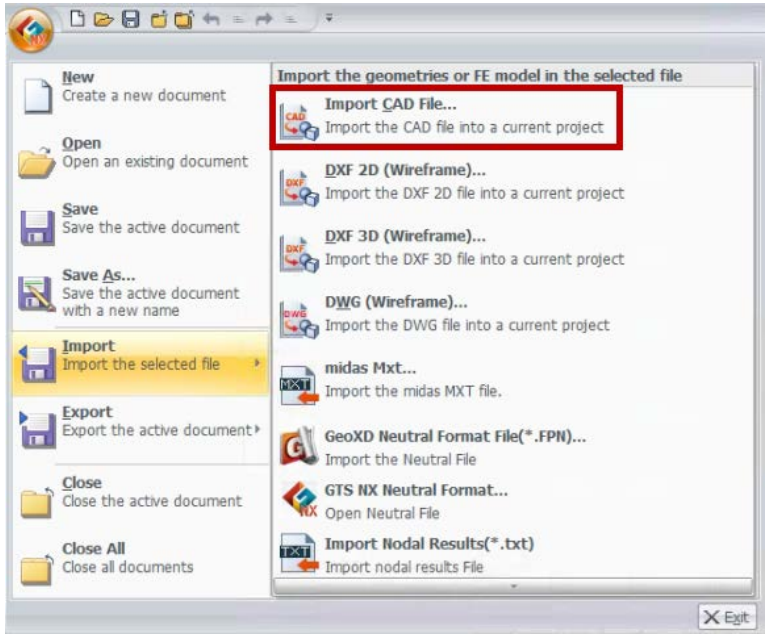
3D操作

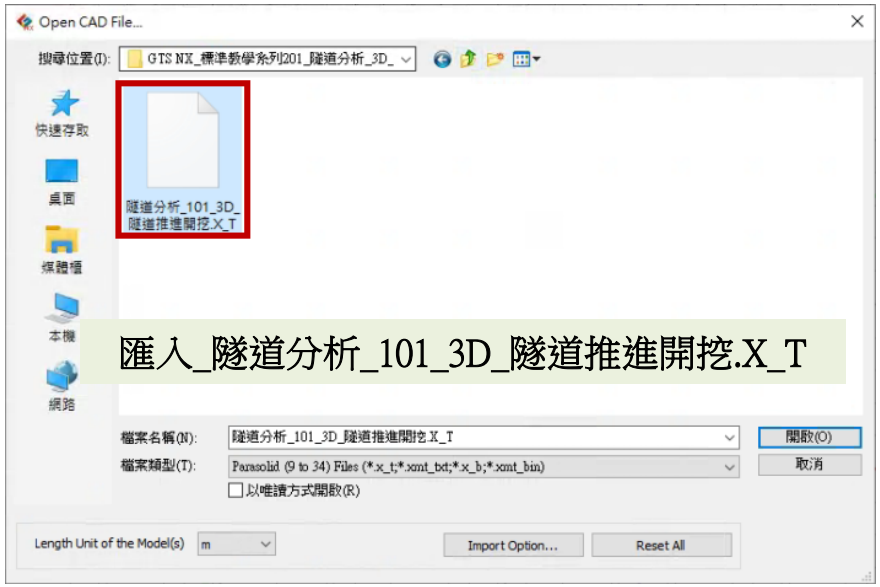
重力方向(Z)

切換單位

單位使用KN/m/J/sec

3D模型匯入

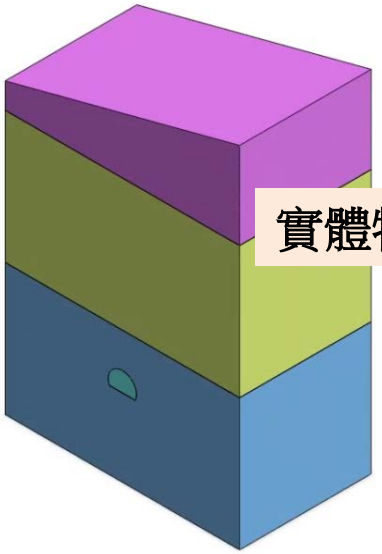




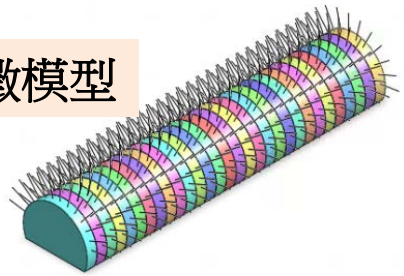
匯入_隧道分析_101_3D_隧道推進開挖.X_T

GTS NX支援常用3D格式

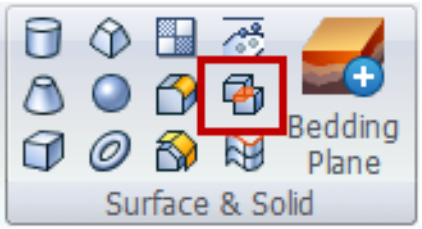
Parasolid (9 to 31) Files (*.x_t;*.xmt_txt;*.x_b;*.xmt_bin)
ACIS (R1 - 2020 1.0) Files (*.sat;*.sab;*.asat;*.asab)
STEP (AP203, AP214, AP242) Files (*.stp;*.step)
IGES (Up to 5.3) Files (*.igs;*.iges)
Pro-E (16 - Creo 6.0) Files (*.prt;*.prt.*;*.asm;*.asm.*)
CATIA V4 (CATIA 4.1.9 - 4.2.4) Files (*.model;*.exp;*.session)
CATIA V5 (V5 R8 - V5-6R2020) Files (*.CATPart;*.CATProduct)
Solid Works (98 - 2020) Files (*.sldprt;*.sldasm)
Unigraphics (11 - NX1899) Files (*.prt)
Inventor Part (V6 - V2020) Files (*.ipt)
Inventor Assembly (V11 - V2020) Files (*.iam)



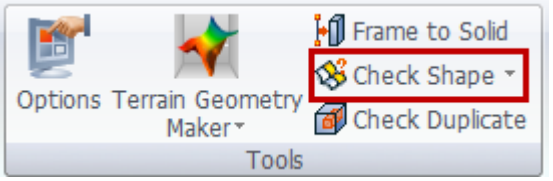
實體特徵模型

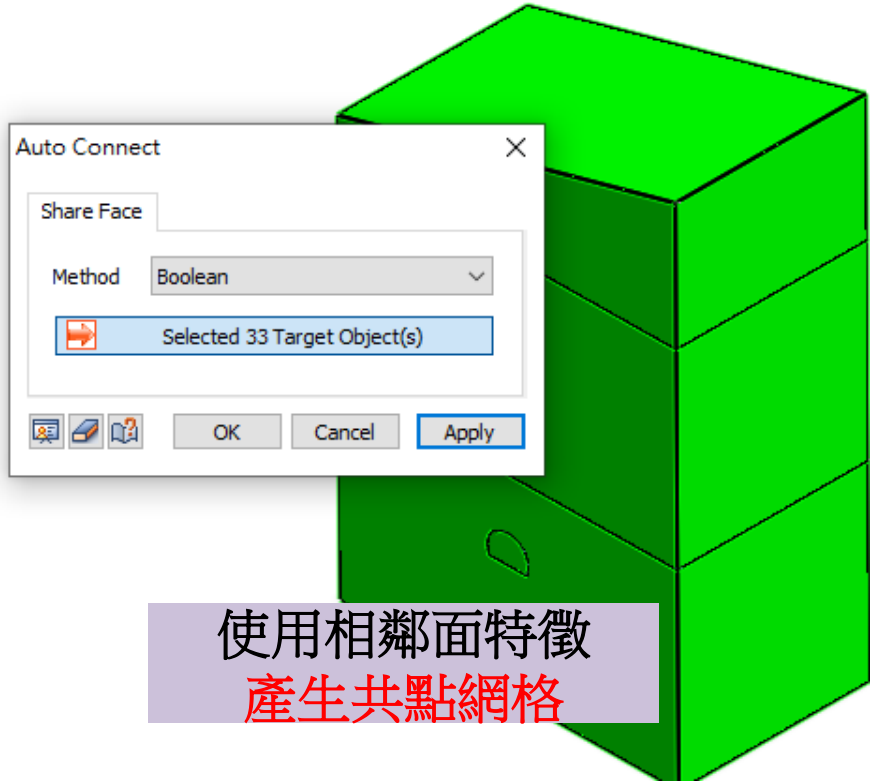


相鄰面特徵建立

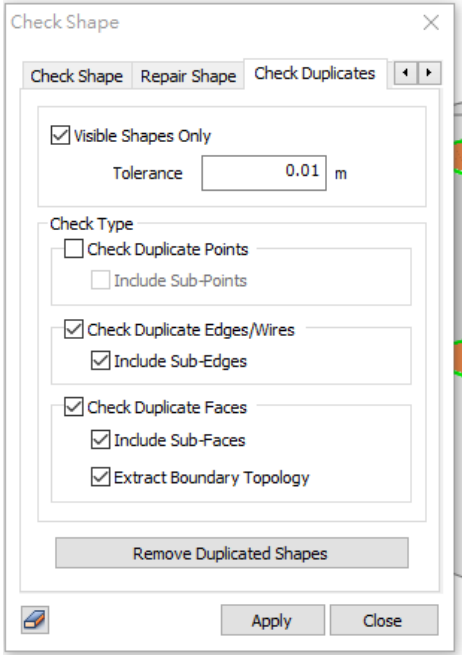


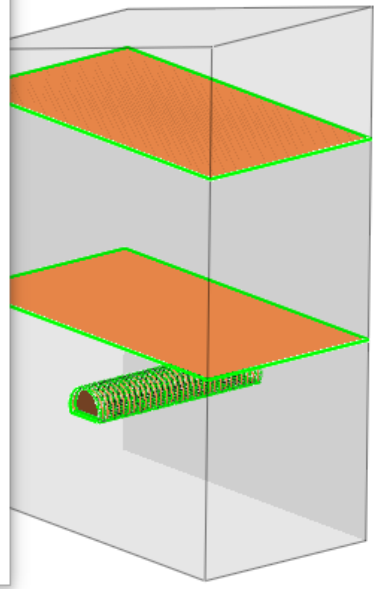
檢查幾何共面特徵





使用相鄰面特徵
產生共點網格



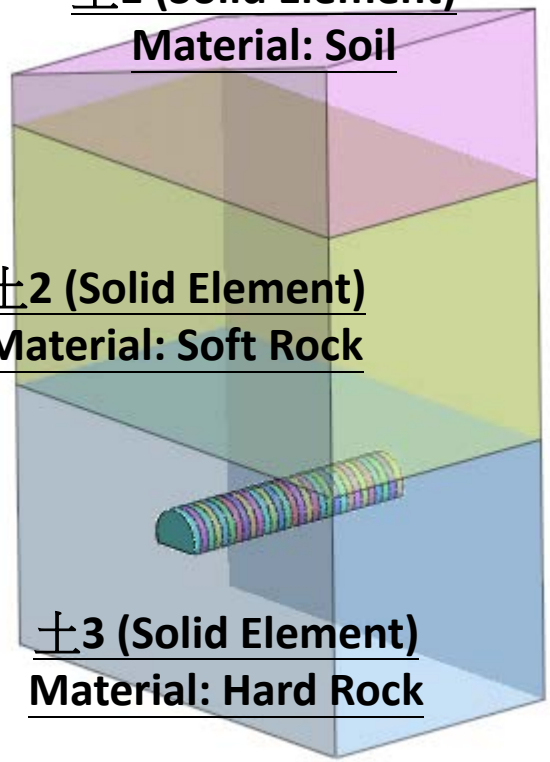


分析說明-材料&屬性

土1 (Solid Element)
Material: Soil

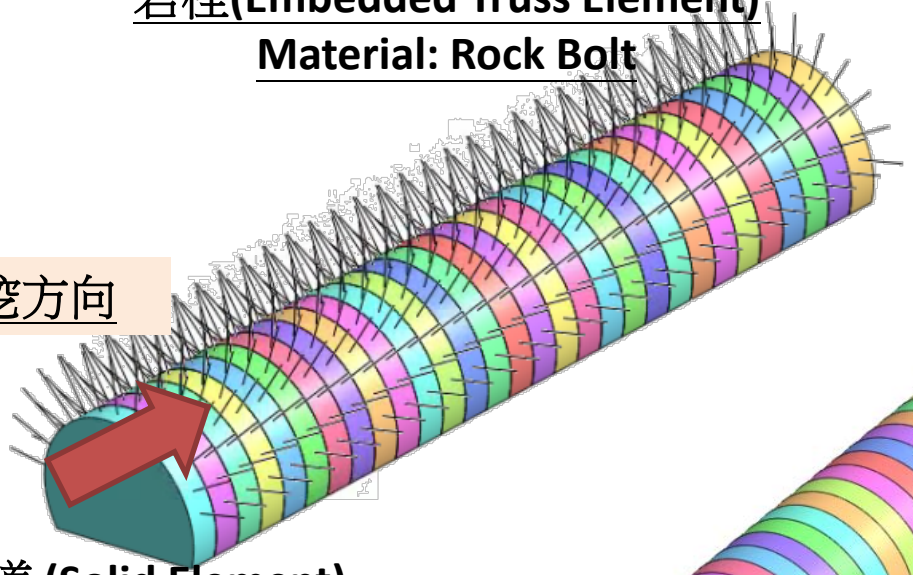
土2 (Solid Element)
Material: Soft Rock

土3 (Solid Element)
Material: Hard Rock

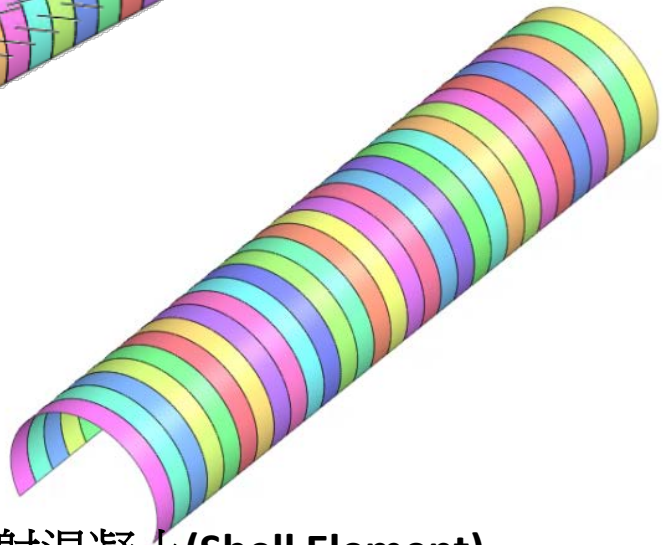


岩栓(Embedded Truss Element)
Material: Rock Bolt

開挖方向

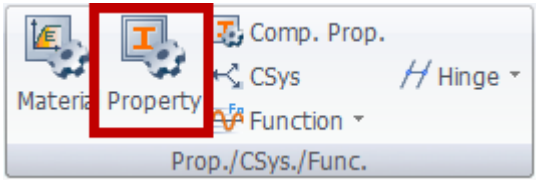


隧道 (Solid Element)
Material: Hard Rock

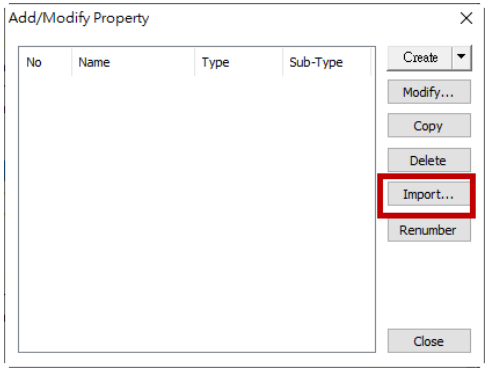


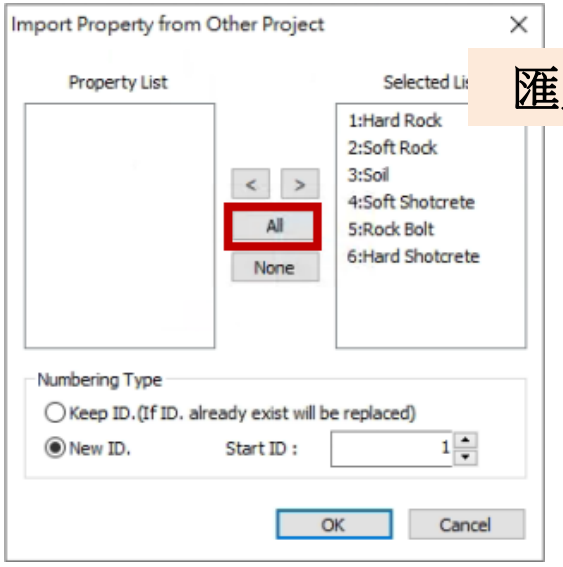
噴射混凝土(Shell Element)
Material: Soft Shotcrete=>Hard Shotcrete

匯入材料&屬性

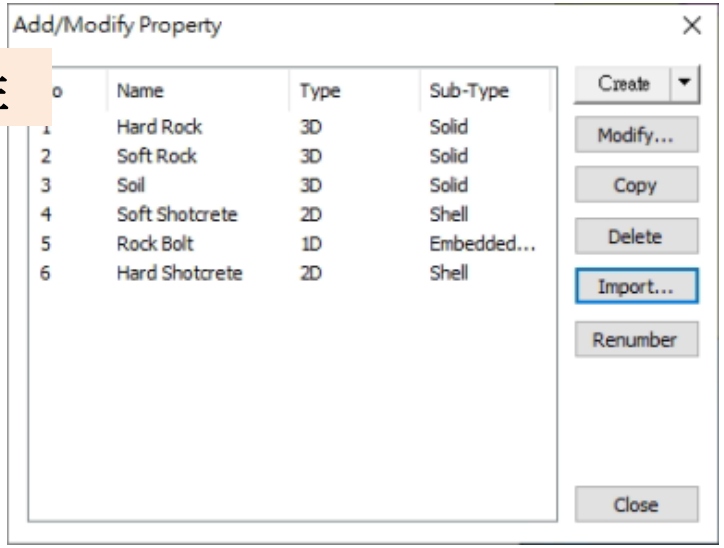


選擇檔案
(3D_隧道推進開挖_Mat&Property.gts)





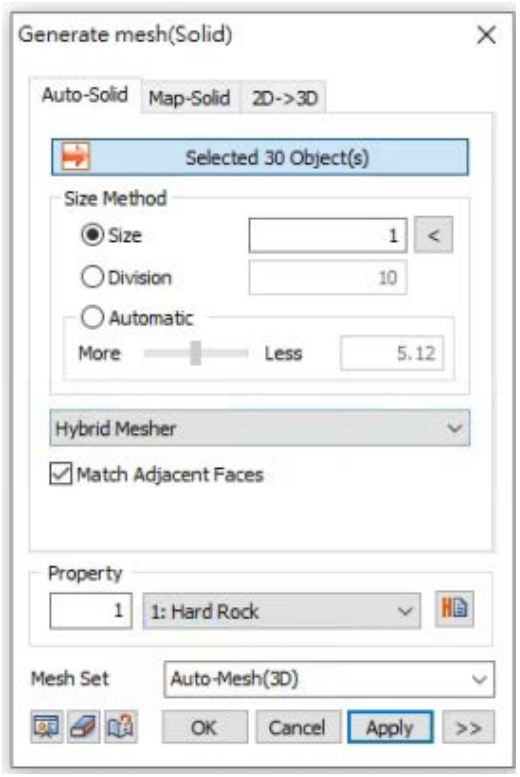
匯入所有屬性



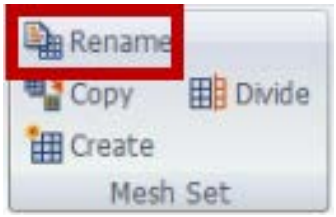
註:匯入屬性同時自動匯入材料性質

3D網格生成-開挖區域

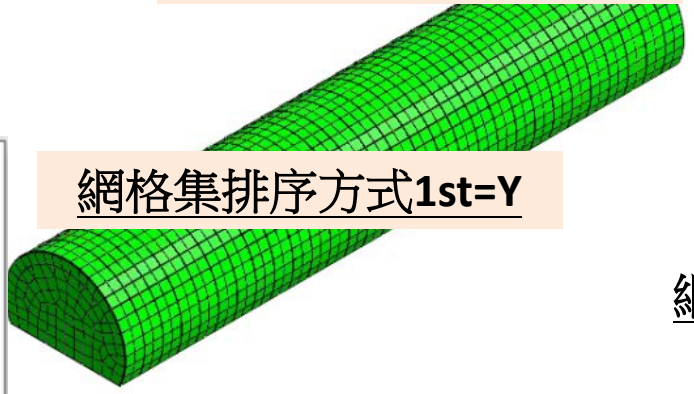
框選所有隧道幾何特徵
混合網格/網格尺寸: 1/屬性:**Hard Rock**



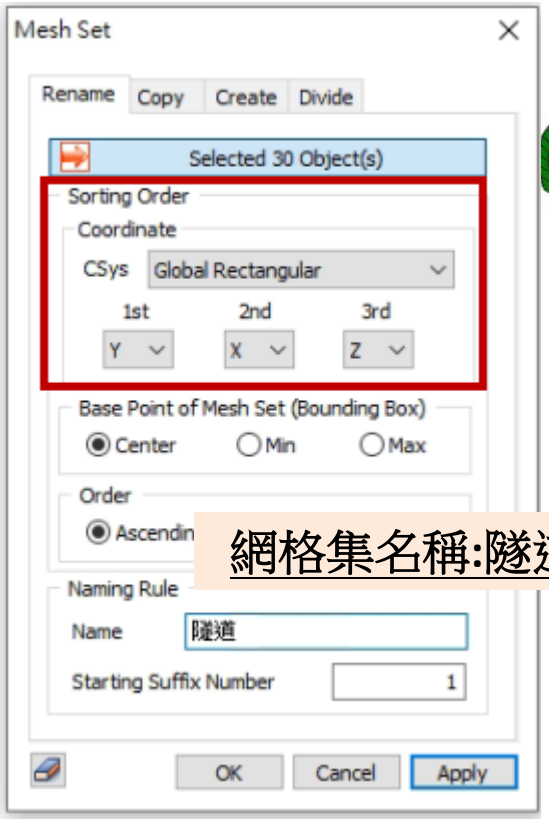
網格集名稱編輯-開挖區域



框選所有隧道網格集

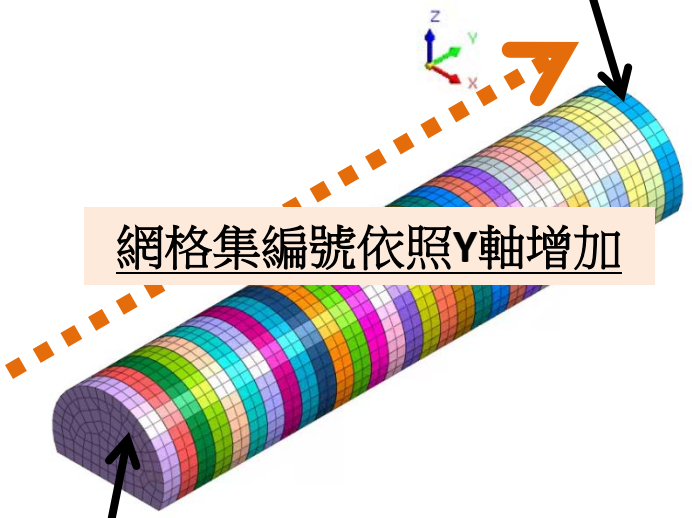


網格集排序方式1st=Y



網格集名稱:隧道

網格集:隧道-030



網格集編號依照Y軸增加

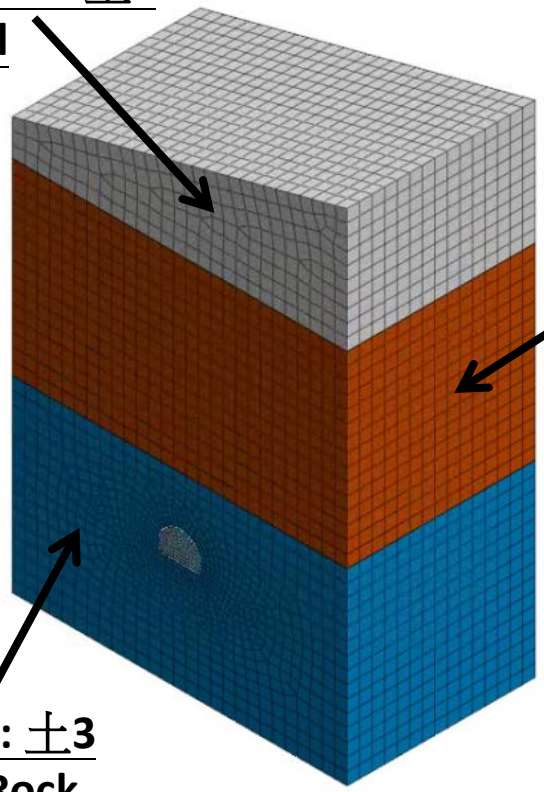
網格集:隧道-001

註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

3D網格生成-地層區域

混合網格/網格尺寸: 4

Step3.Mesh Set : 土1
Property: Soil

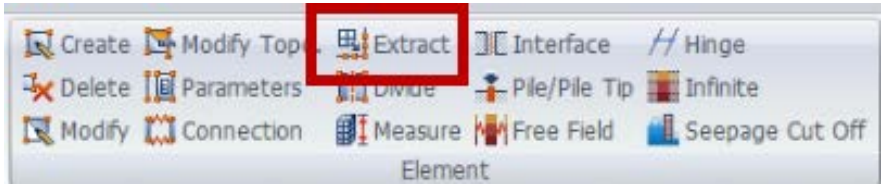


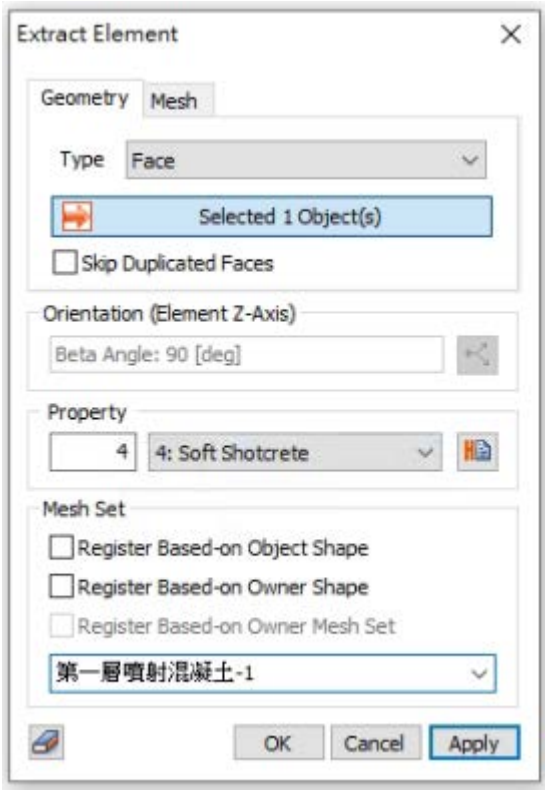
Step2.Mesh Set : 土2
Property: Soft Rock

Step1.Mesh Set : 土3
Property: Hard Rock

2D網格生成-第一層噴射混凝土-1

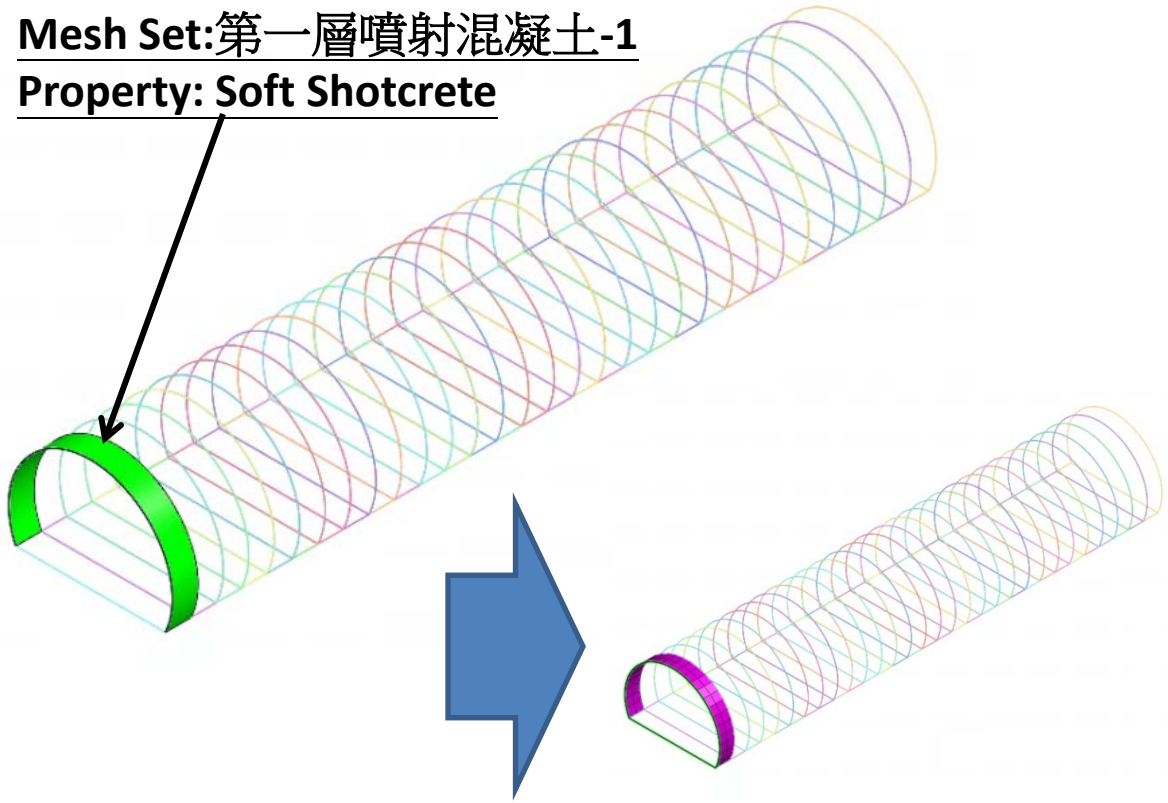
(Soft ShotCrete)





Mesh Set:第一層噴射混凝土-1

Property: Soft Shotcrete

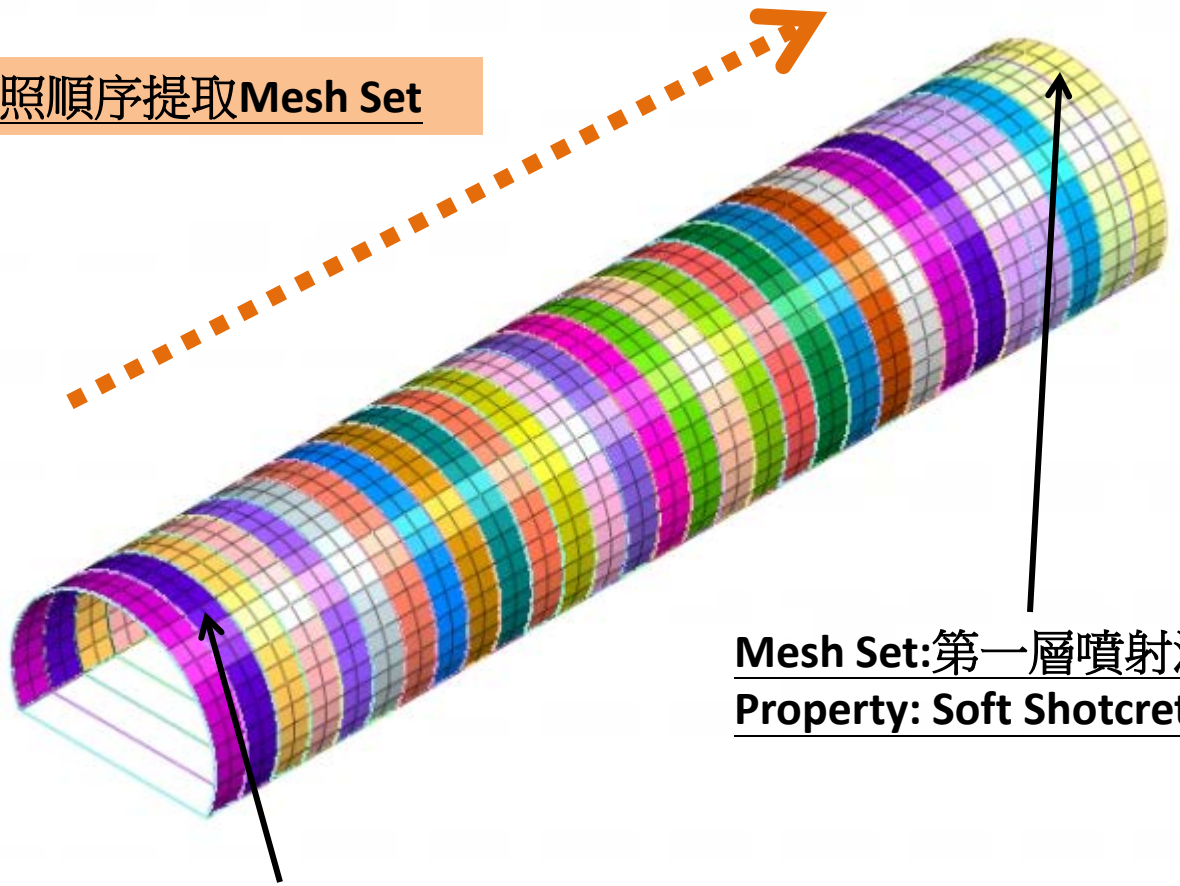


註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

2D網格生成-第一層噴射混凝土-2

(Soft ShotCrete)

依照順序提取Mesh Set

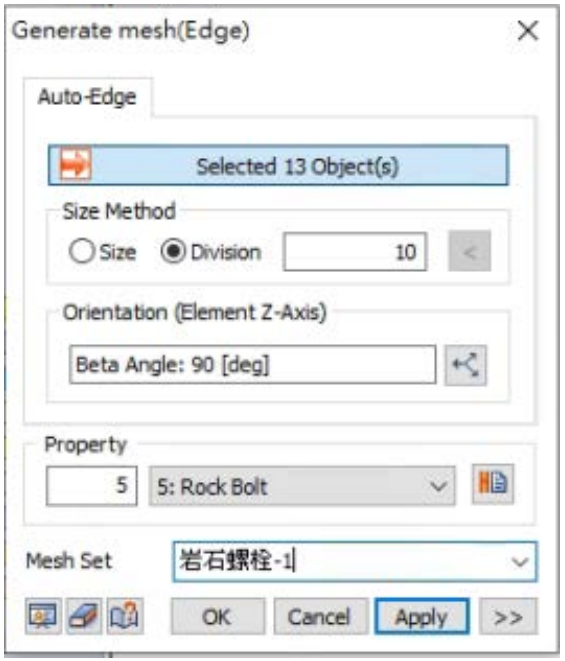


Mesh Set:第一層噴射混凝土-30
Property: Soft Shotcrete

Mesh Set:第一層噴射混凝土-2
Property: Soft Shotcrete

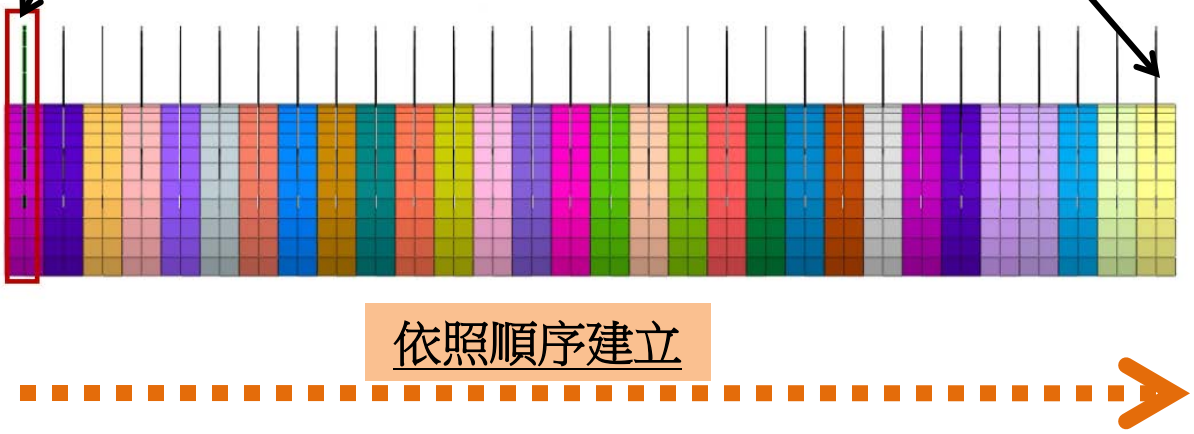
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

1D網格生成-岩石螺栓



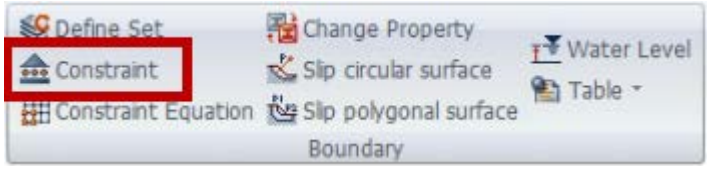
Mesh Set :岩石螺栓-1
Property: Rock Bolt
Division:10

Mesh Set :岩石螺栓-30
Property: Rock Bolt
Division:10



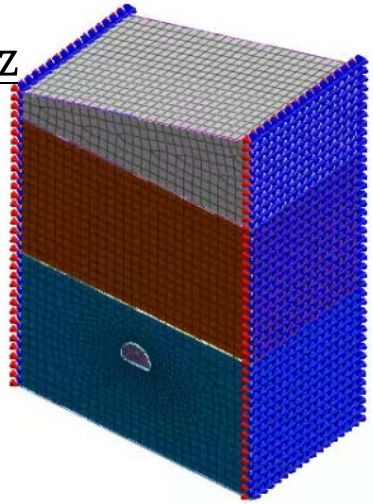
註1:Truss Element要共點, Embedded Truss Element不需要共點。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

邊界-拘束



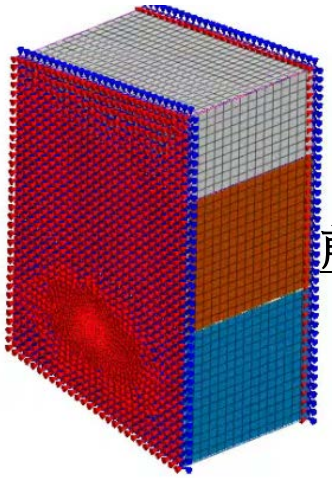
使用Face特徵選取節點

兩側Tx/Ry/Rz

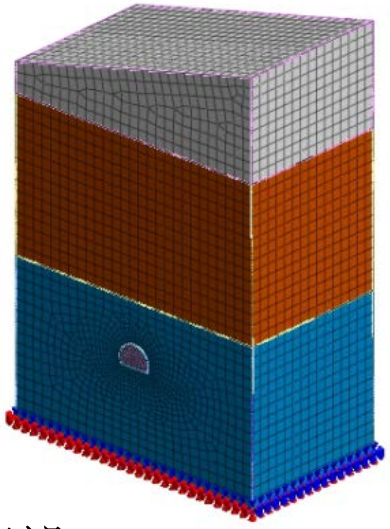


兩側Tx/Ry/Rz

前後Ty/Rx/Rz



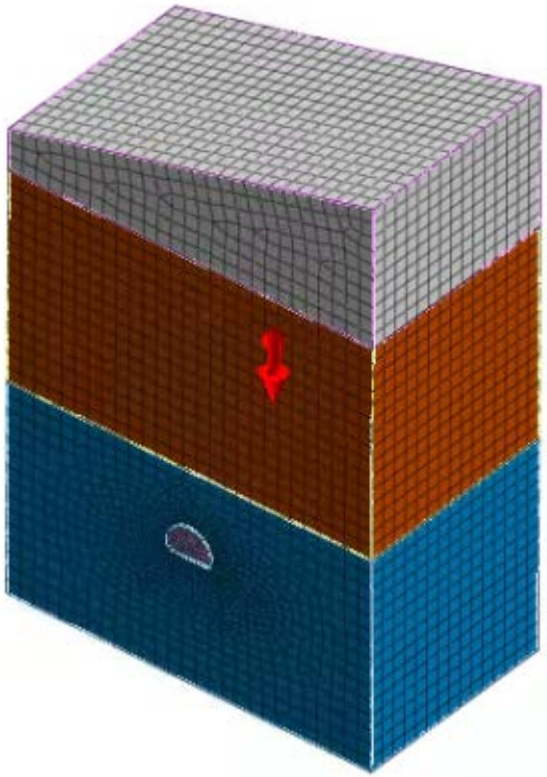
前後Ty/Rx/Rz



底部Tx/Ty/Tz/Rx/Ry/Rz

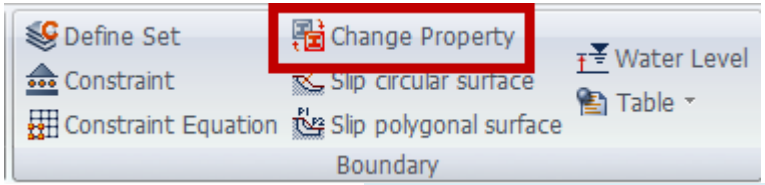
自重


Self Weight
Force
Moment
Disp.
Press.
Water Pressure
Arbitrary Load
Beam Load
Nodal Temperature
Element Temperature
Temperature Gradient
Prestress
Initial Equilibrium Force
Define Set
Comb. Set
From Results
Contraction
Prescribed strain
Table
Load



第二層噴射混凝土-1

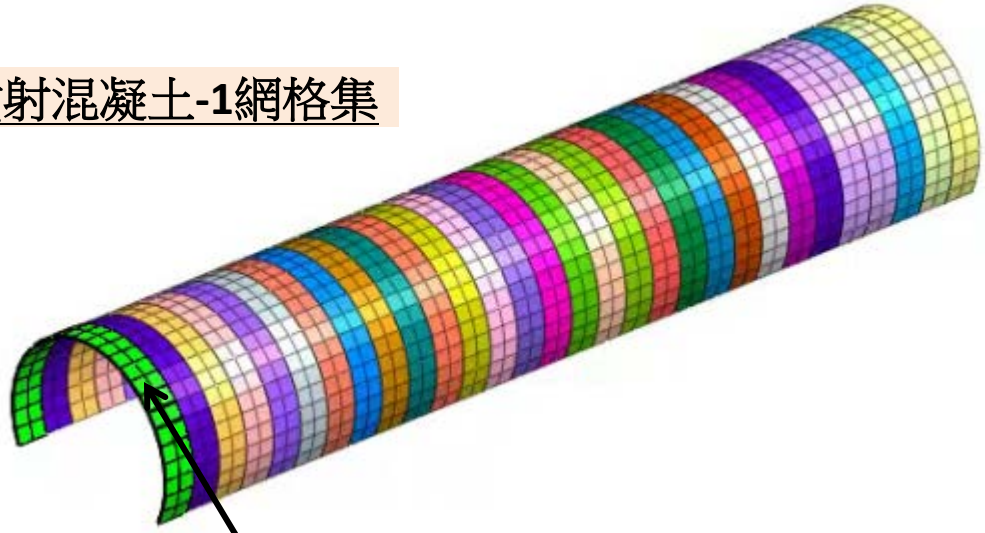
(Soft ShotCrete => Hard ShotCrete)



使用Mesh Set選取網格集

施工階段分次施加噴射混凝土
利用**Change Property**變更噴射混凝土強度/厚度

選取第一層噴射混凝土-1網格集



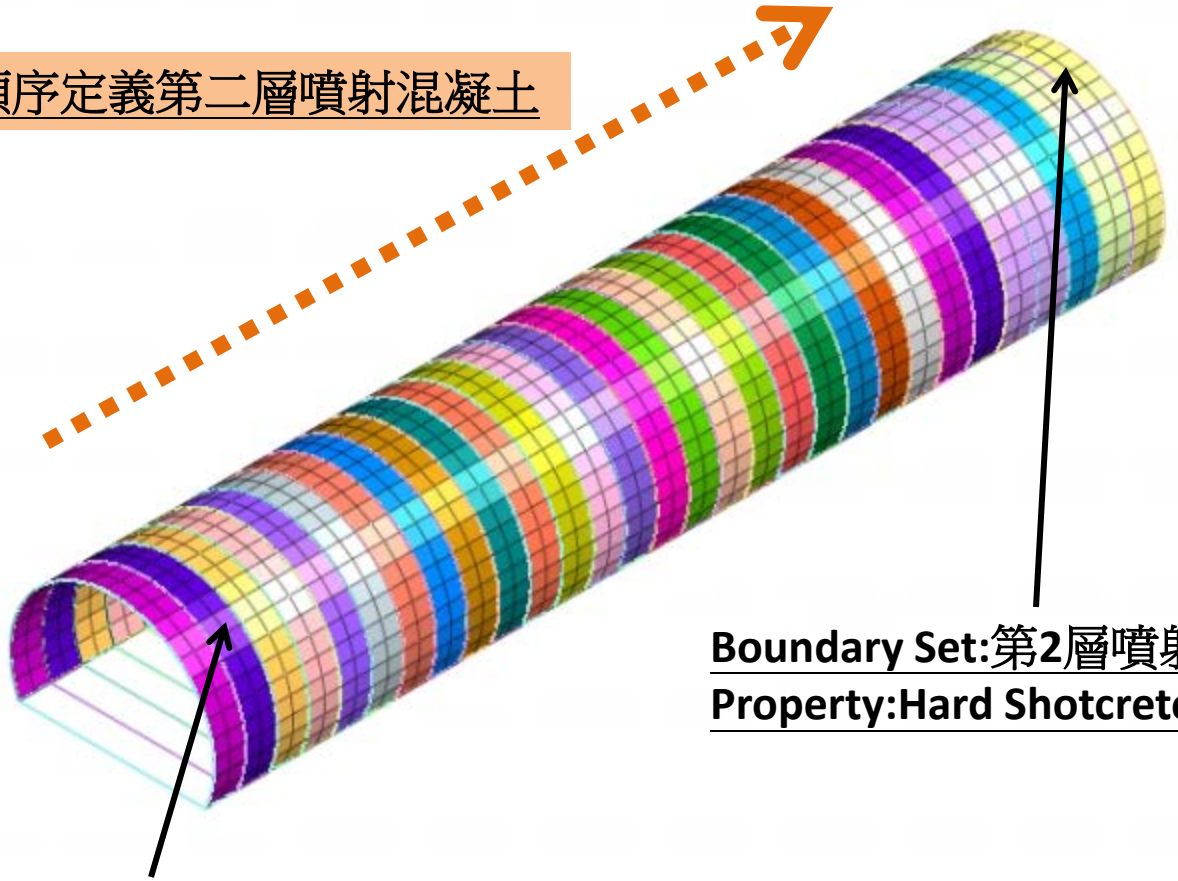
Boundary Set:第2層噴射混凝土-1
Property:Hard Shotcrete

註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

第二層噴射混凝土-2

(Soft ShotCrete => Hard ShotCrete)

依照順序定義第二層噴射混凝土



Boundary Set:第2層噴射混凝土-30
Property:Hard Shotcrete

Boundary Set:第2層噴射混凝土-2
Property:Hard Shotcrete

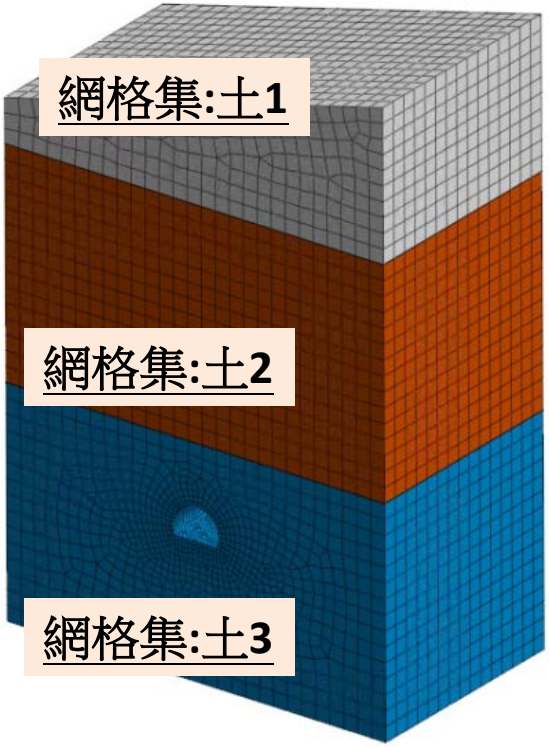
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

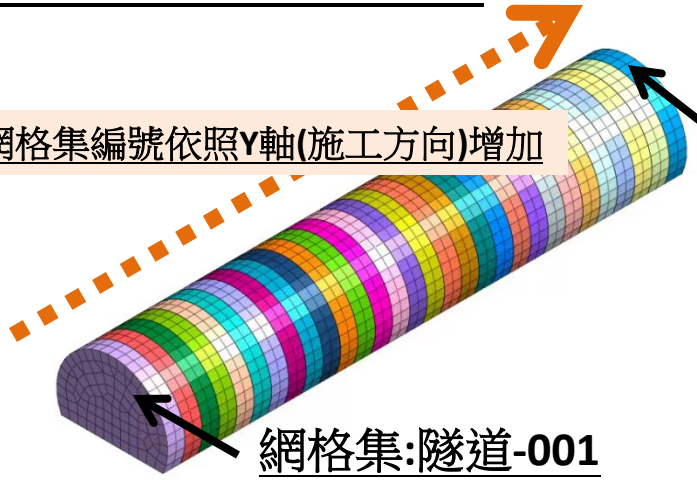
Part2.施工階段定義

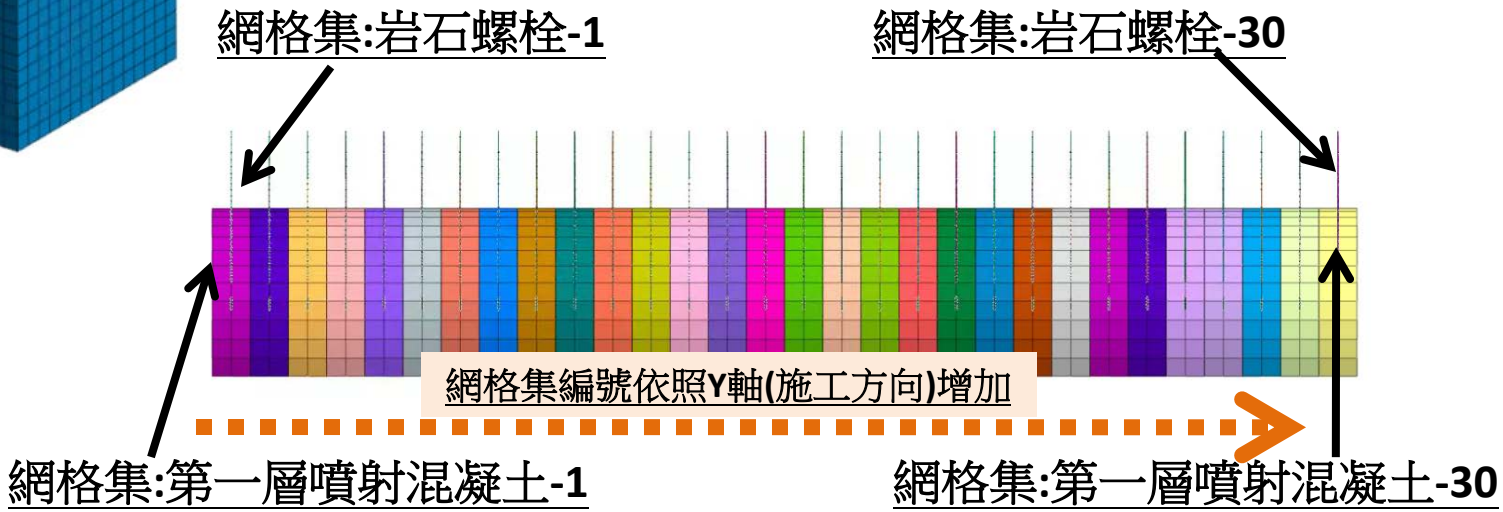
(施工階段嚮導)

註:施工階段嚮導適合規律施工過程定義

網格集說明

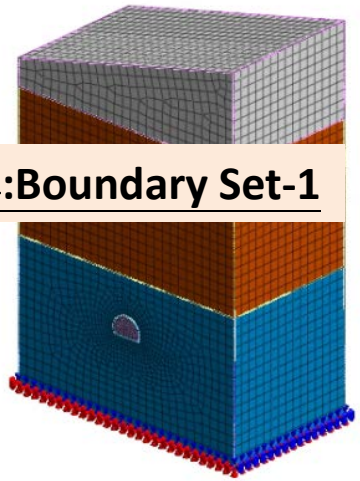




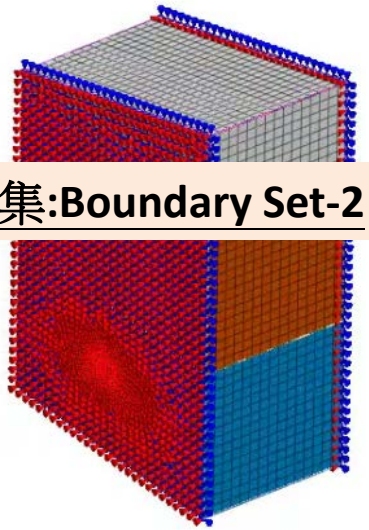


註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

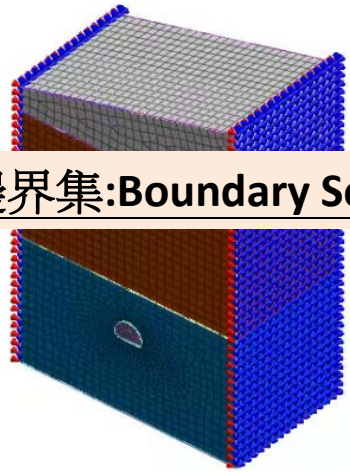
邊界集說明



邊界集:Boundary Set-1

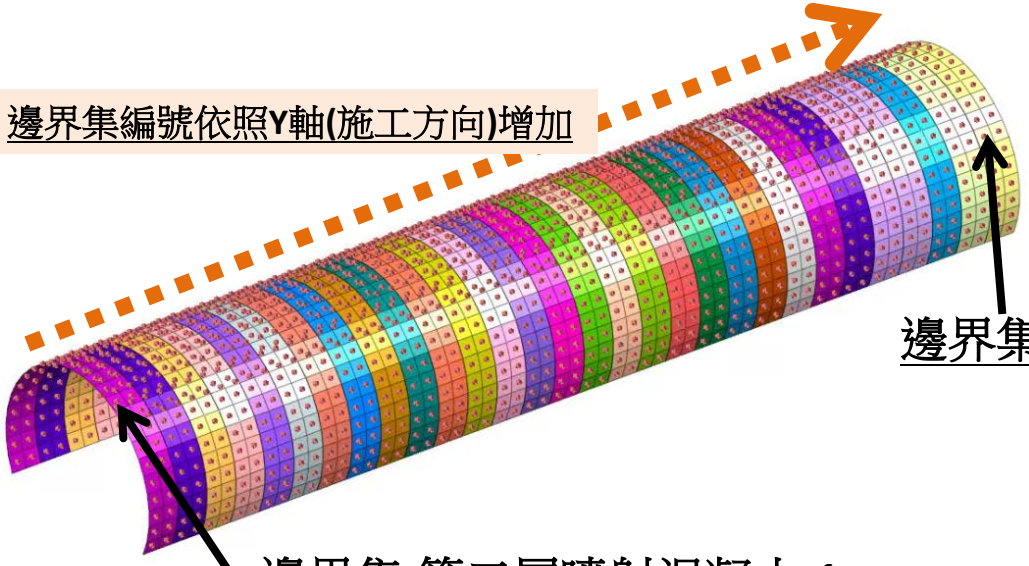


邊界集:Boundary Set-2



邊界集:Boundary Set-3

邊界集編號依照Y軸(施工方向)增加

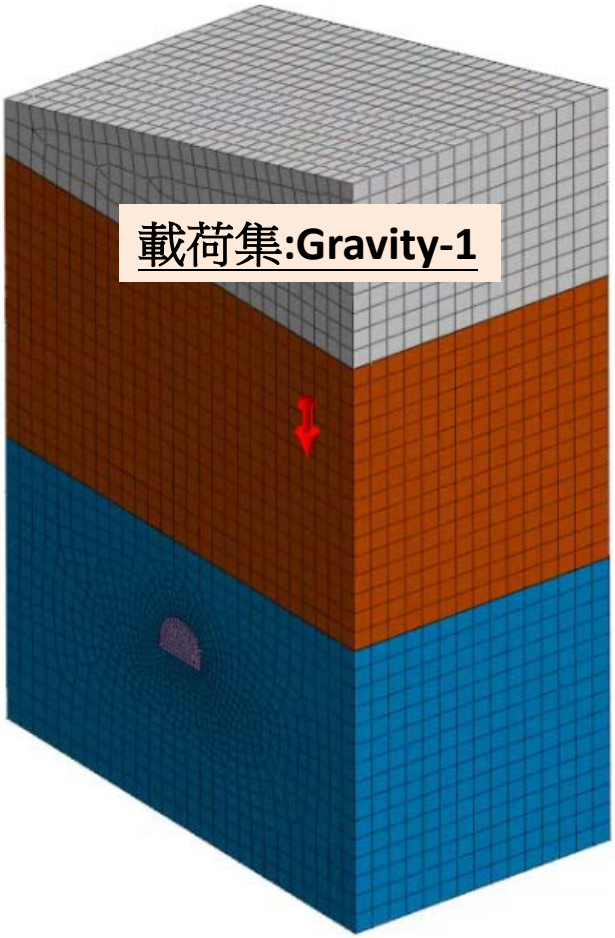


邊界集:第二層噴射混凝土-30

邊界集:第二層噴射混凝土-1

註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

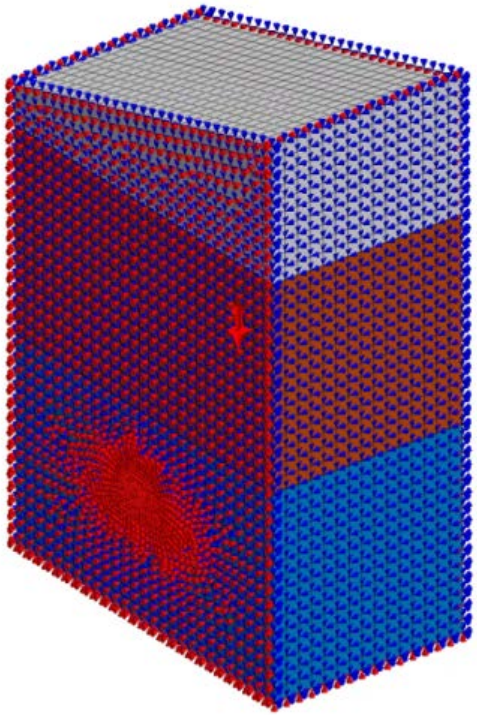
載荷集說明



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

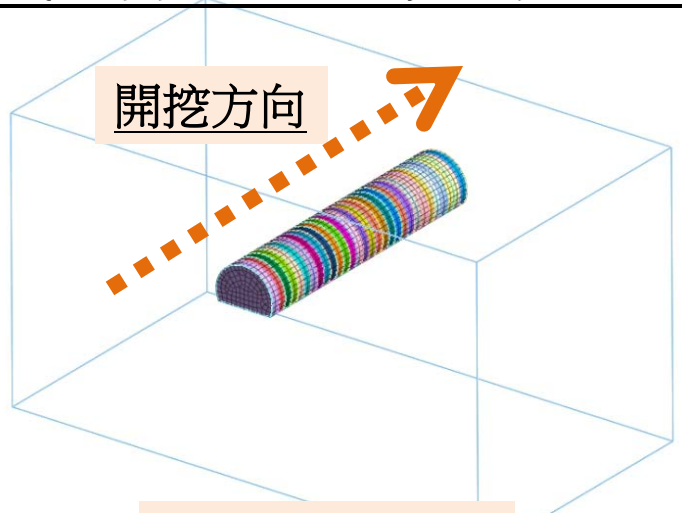
隧道開挖前-初始條件

網格集	邊界集	載荷集
隧道-001~30	Boundary Set-1~3	Gravity-1
土1 ~土3		



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

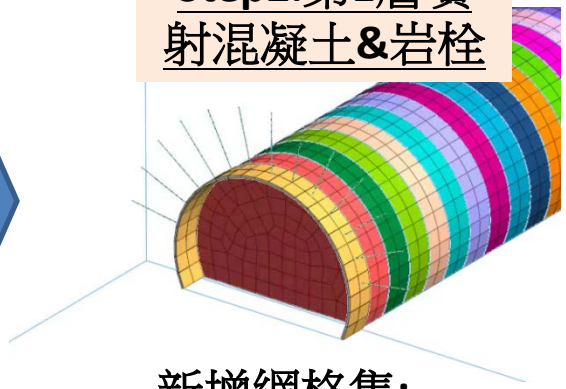
隧道開挖-重覆施工過程



Step1.隧道開挖

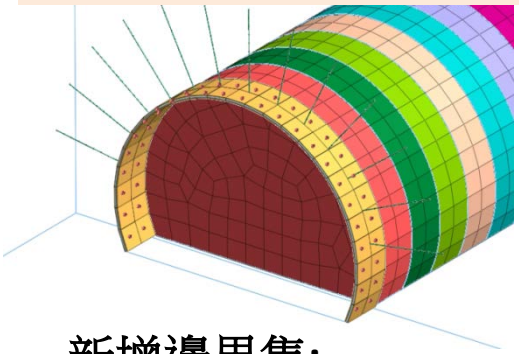
移除網格集:
隧道-001

Step2.第1層噴射混凝土&岩栓



新增網格集:
第一層噴射混凝土-1
岩石螺栓-1

Step3.第2層噴射混凝土



新增邊界集:
第二層噴射混凝土-1

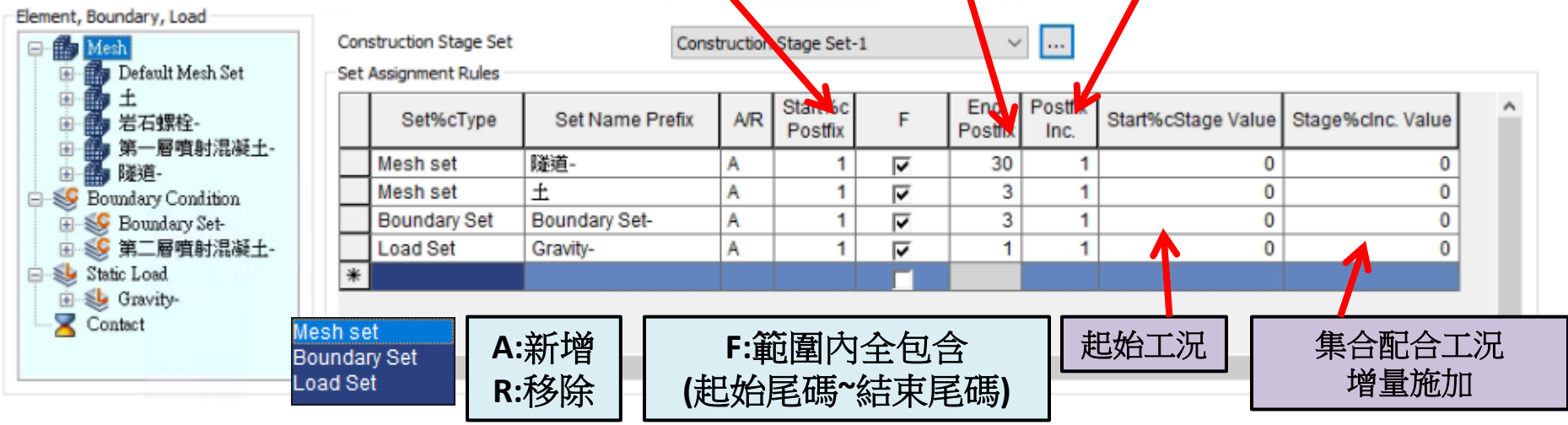
註1:重覆相同施工過程至隧道貫穿。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段嚮導模組

大集合-起始尾碼

大集合-結束尾碼

大集合-間隔選取

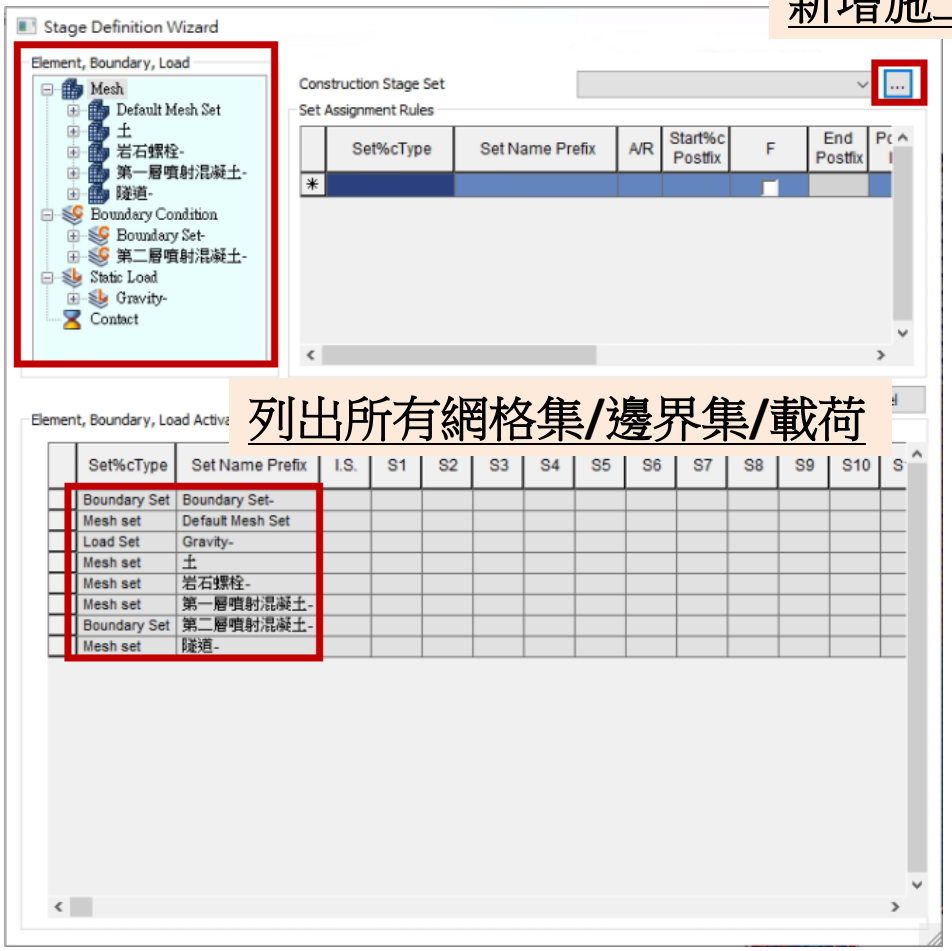


註1: (Name)-1 to (Name)-999 視為同一大集合,未加(-)不視作同一大集合

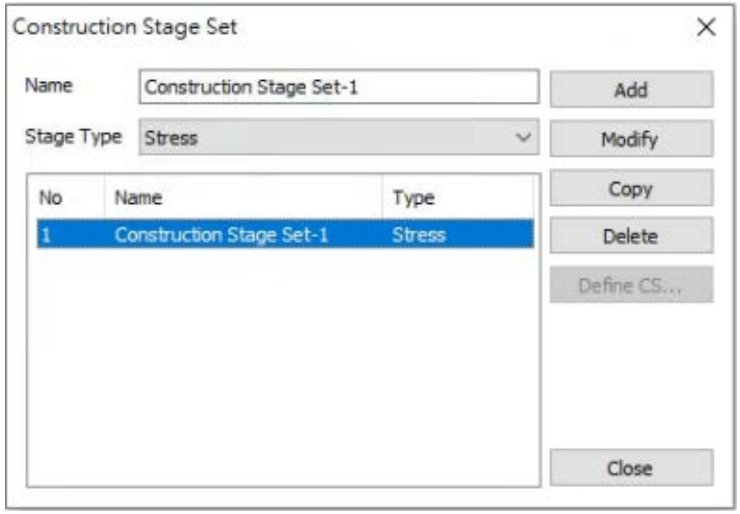
註2: I.S.=>Initial Stage=0 ,S1=>Stage1=1

施工階段-1

新增施工階段



列出所有網格集/邊界集/載荷



施工階段-2
(初始條件)

依序指定

Construction Stage Set: Construction Stage Set-1

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	隧道-	A	1	☑	30	1	0	0
	Mesh set	土	A	1	☑	3	1	0	0
	Boundary Set	Boundary Set-	A	1	☑	3	1	0	0
	Load Set	Gravity-	A	1	☑	1	1	0	0
*					☐				

Apply Assignment Rules　　OK

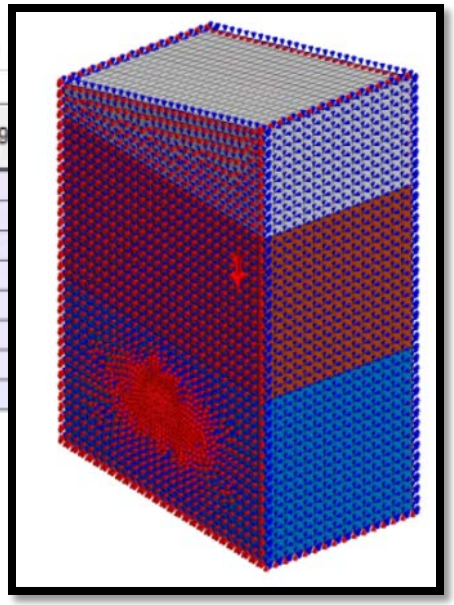
Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2	S3	S8	S9
	Boundary Set	Boundary Set-	A: 1to3					
	Mesh set	Default Mesh Set						
	Load Set	Gravity-	A: 1					
	Mesh set	土	A: 1to3					
	Mesh set	岩石螺栓-						
	Mesh set	第一層噴射混凝土-						
	Boundary Set	第二層噴射混凝土-						
	Mesh set	隧道-	A: 1to30					

邊界集
Boundary Set-1~3

載荷集
Gravity-1

網格集
土1 ~土3
隧道-001~30



註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-3
(隧道開挖)

依序指定

間隔3個工況施作1次

Construction Stage Set: Construction Stage Set-1

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	隧道-	R	1	☑	30	1	1	3
✳					☐				

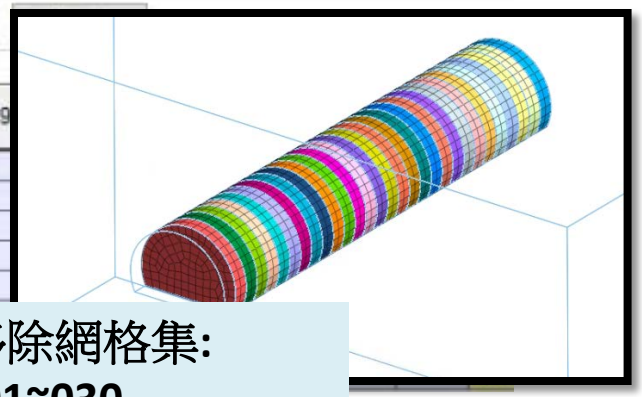
R:移除

第1個工況開始進行隧道開挖

Apply Assignment Rules | OK

Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2	S3	S4	S5	S6	S7	S8	S9
	Boundary Set	Boundary Set-	A: 1to3									
	Mesh set	Default Mesh Set										
	Load Set	Gravity-	A: 1									
	Mesh set	土	A: 1to3									
	Mesh set	岩石螺栓-										
	Mesh set	第一層噴射混凝土-										
	Boundary Set	第二層噴射混凝土-										
	Mesh set	隧道-	A: 1to30	R: 1			R: 2					



移除網格集:
隧道-001~030
(間隔3個工況施作1次)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-4
(第1層噴射混凝土&岩栓)

依序指定

間隔3個工況施作1次

Construction Stage Set: Construction Stage Set-1

Set Assignment Rules

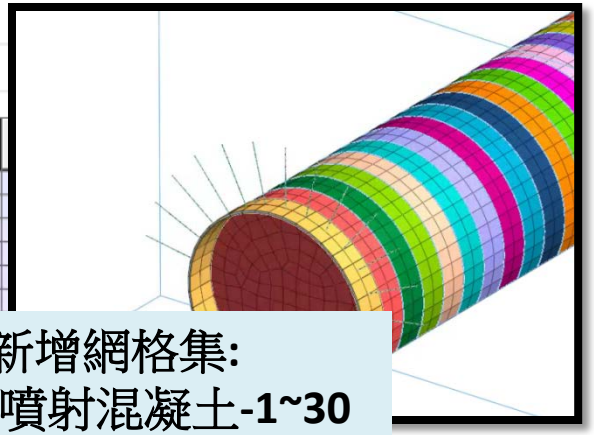
	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	岩石螺栓-	A	1	☑	30	1	2	3
	Mesh set	第一層噴射混凝土-	A	1	☑	30	1	2	3
✳					☐				

第2個工況開始進行

Apply Assignment Rules | OK | Cancel

Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
	Boundary Set	Boundary Set-	A: 1to3												
	Mesh set	Default Mesh Set													
	Load Set	Gravity-	A: 1												
	Mesh set	土	A: 1to3												
	Mesh set	岩石螺栓-			A: 1			A: 2			A: 3			A: 4	
	Mesh set	第一層噴射混凝土-			A: 1			A: 2			A: 3			A: 4	
	Boundary Set	第二層噴射混凝土-													
	Mesh set	隧道-	A: 1to30	R: 1			R: 2			R: 3					



新增網格集:
第一層噴射混凝土-1~30
岩石螺栓-1~30
(間隔3個工況施作1次)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-5
(第2層噴射混凝土)

依序指定

間隔3個工況施作1次

Construction Stage Set: Construction Stage Set-1

Set Assignment Rules

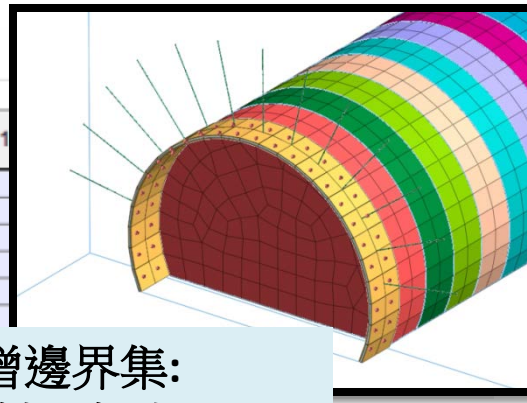
	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Boundary Set	第二層噴射混凝土-	A	1	☑	30	1	3	3
*					☐				

第3個工況開始進行

Apply Assignment Rules | OK | Cancel

Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S1
	Boundary Set	Boundary Set-	A: 1to3												
	Mesh set	Default Mesh Set													
	Load Set	Gravity-	A: 1												
	Mesh set	土	A: 1to3												
	Mesh set	岩石螺栓-			A: 1			A: 2			A: 3			A: 4	
	Mesh set	第一層噴射混凝土-			A: 1			A: 2			A: 3			A: 4	
	Boundary Set	第二層噴射混凝土-				A: 1			A: 2						
	Mesh set	隧道-	A: 1to30	R: 1			R: 2			R: 3					

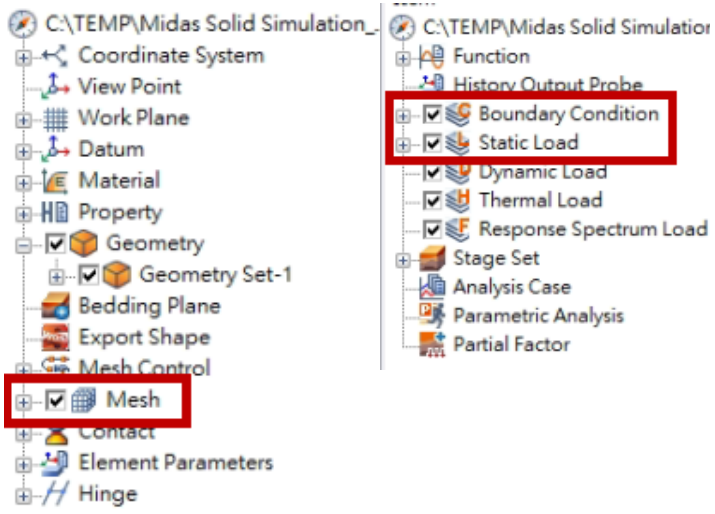


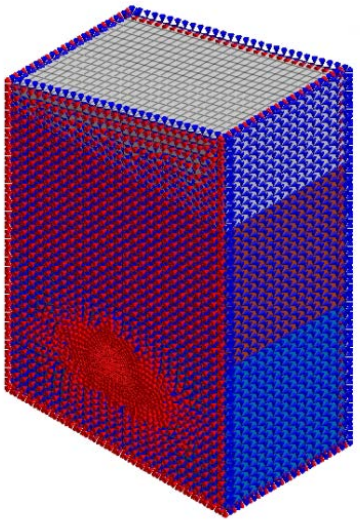
新增邊界集:
第二層噴射混凝土-1~30
(間隔3個工況施作1次)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

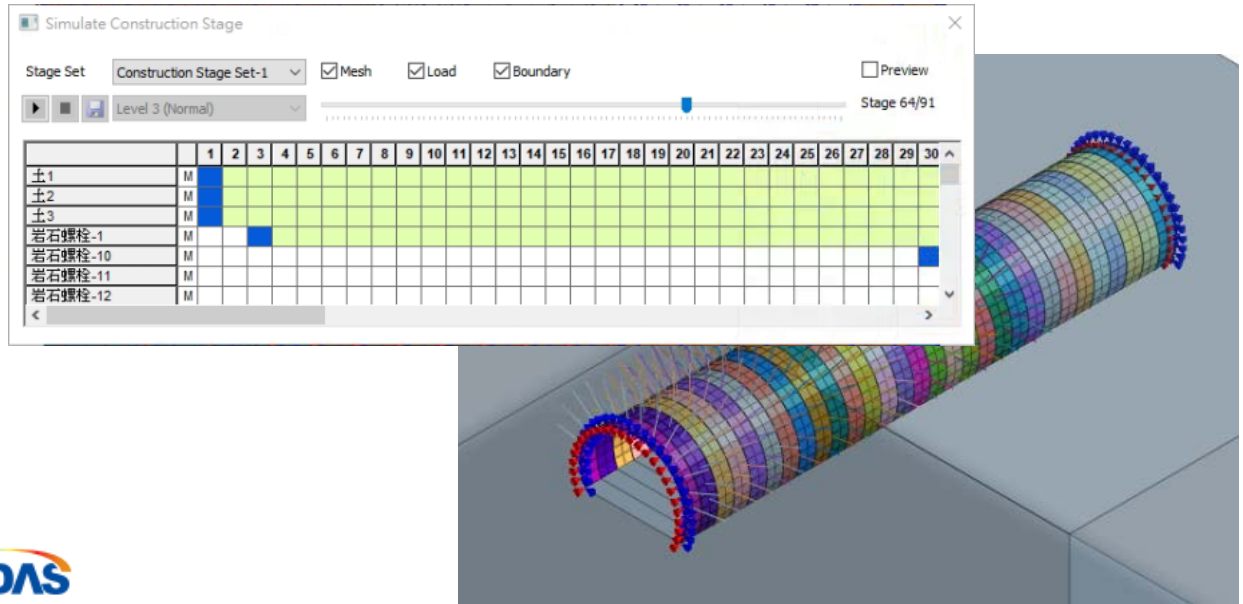
施工階段-6
(施工過程動畫檢視)

Step1.顯示所有網格集/邊界集/載荷集





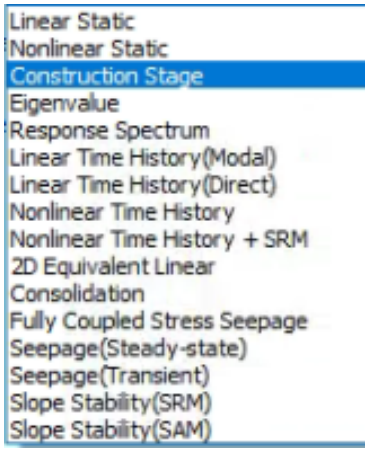
Step2.拖曳/播放檢視



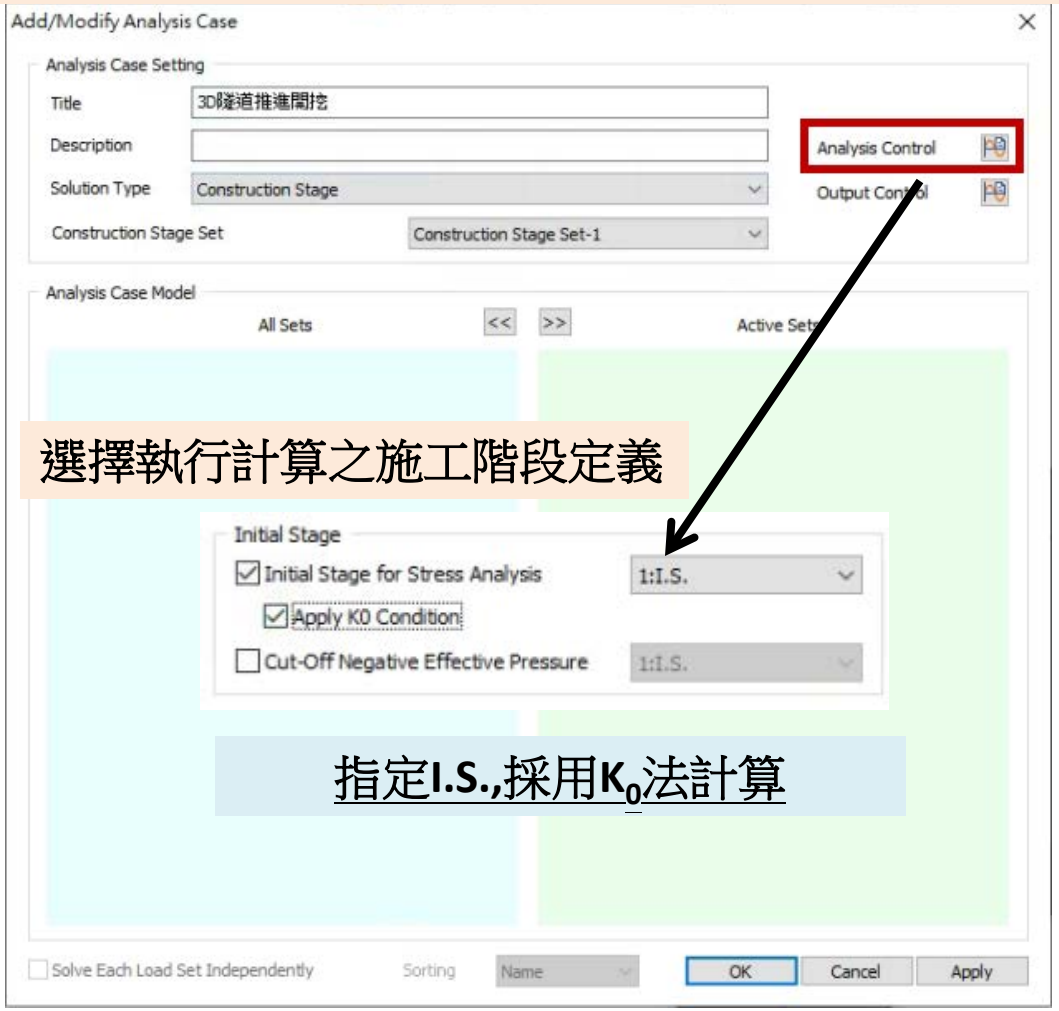
分析定義

(3D隧道推進開挖-K_0法)

Construction Stage



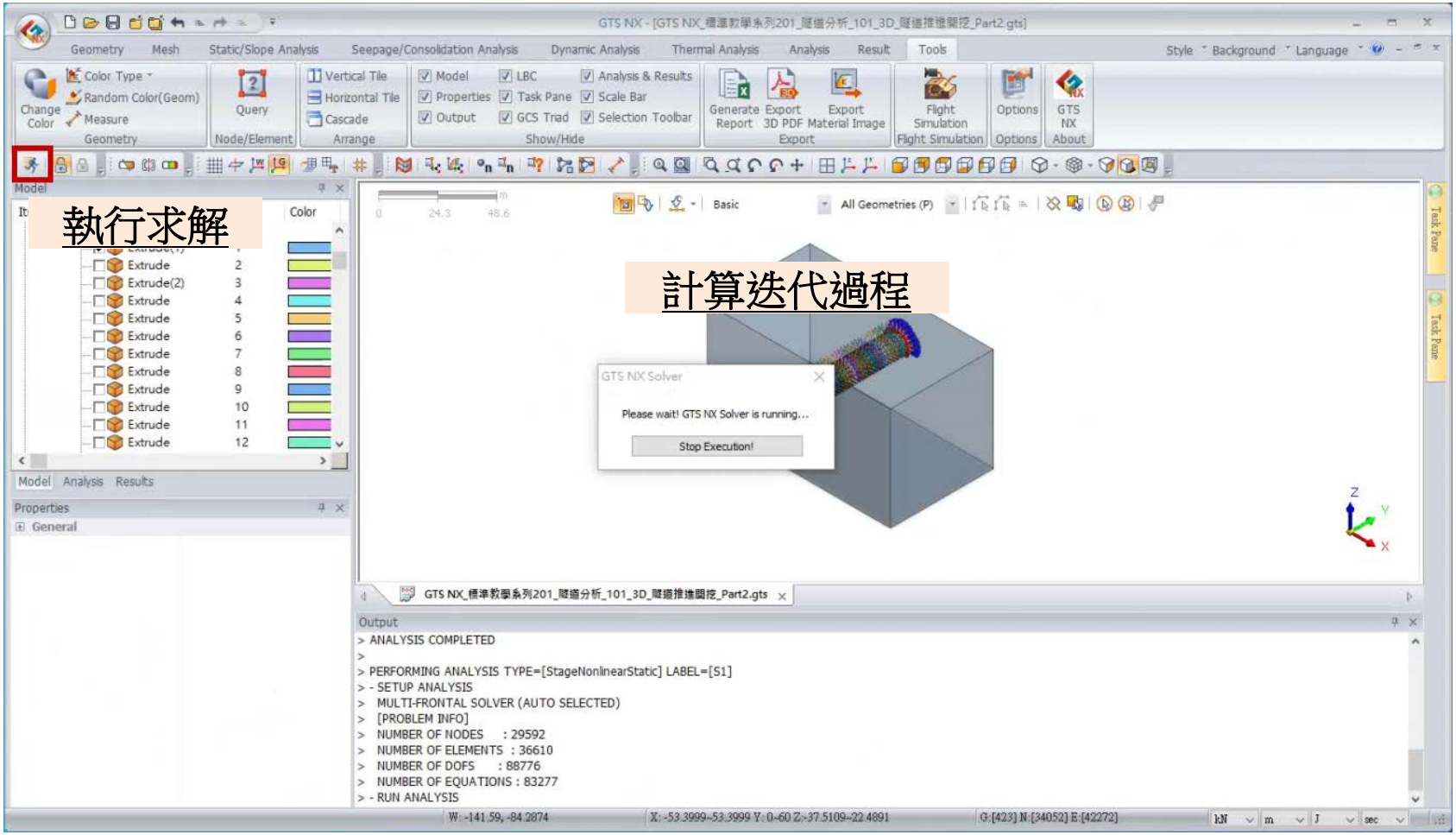
分析名稱:雙連拱隧道/分析類型:Construction Stage



選擇執行計算之施工階段定義

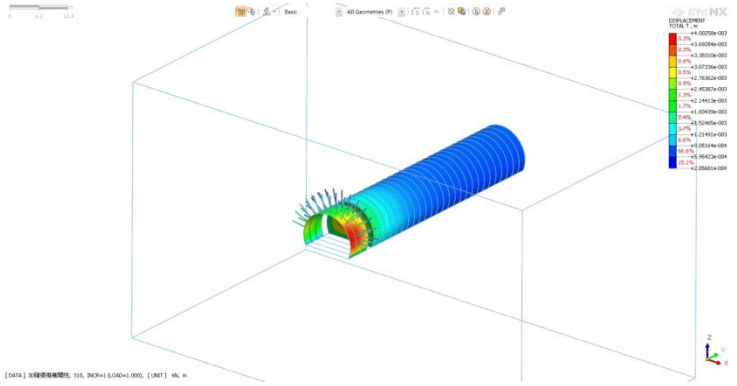
指定I.S.,採用K_0法計算

計算

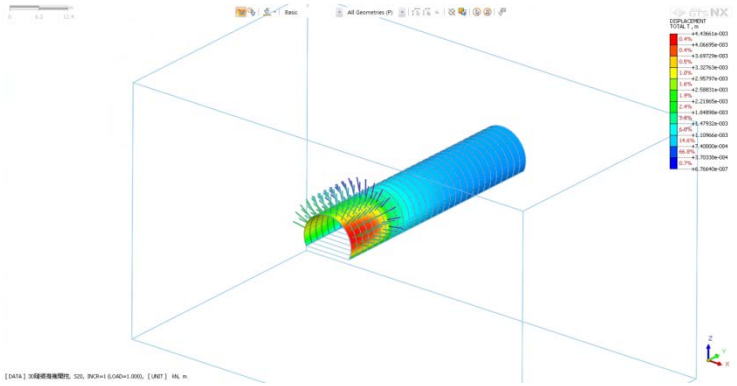

執行求解
計算迭代過程
GTS NX Solver
Please wait! GTS NX Solver is running...
Stop Execution!
Output
> ANALYSIS COMPLETED
> PERFORMING ANALYSIS TYPE=[StageNonlinearStatic] LABEL=[S1]
> - SETUP ANALYSIS
> MULTI-FRONTAL SOLVER (AUTO SELECTED)
> [PROBLEM INFO]
> NUMBER OF NODES : 29592
> NUMBER OF ELEMENTS : 36610
> NUMBER OF DOFS : 88776
> NUMBER OF EQUATIONS : 83277
> - RUN ANALYSIS

分析結果-1
(Displacement)

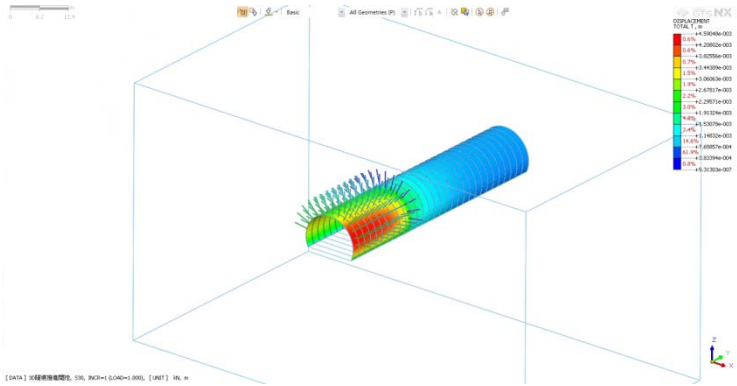
Stage10



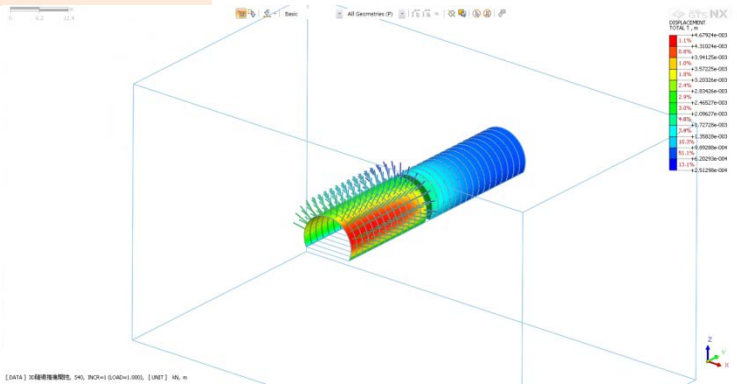
Stage20



Stage30 右導洞下半部開挖



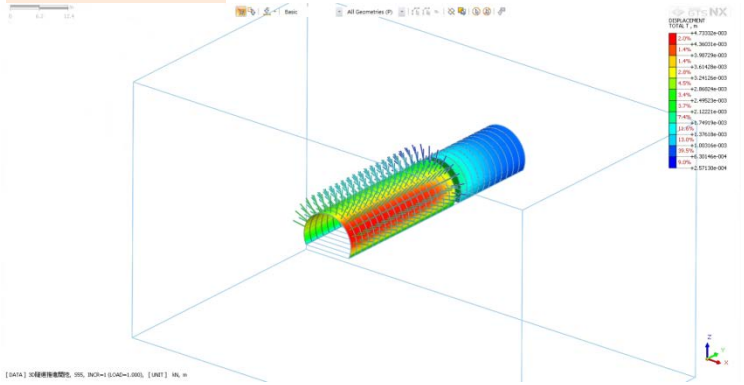
Stage40



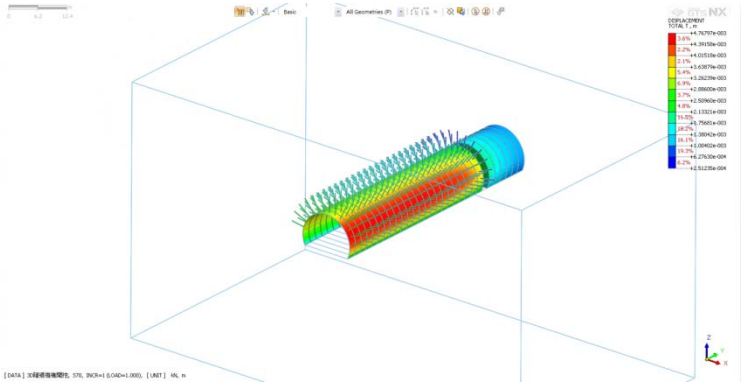
播放動畫 (施工階段)

分析結果-2
(Displacement)

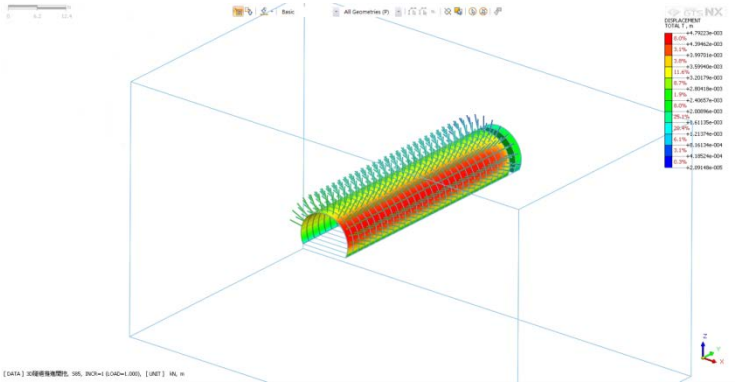
Stage55



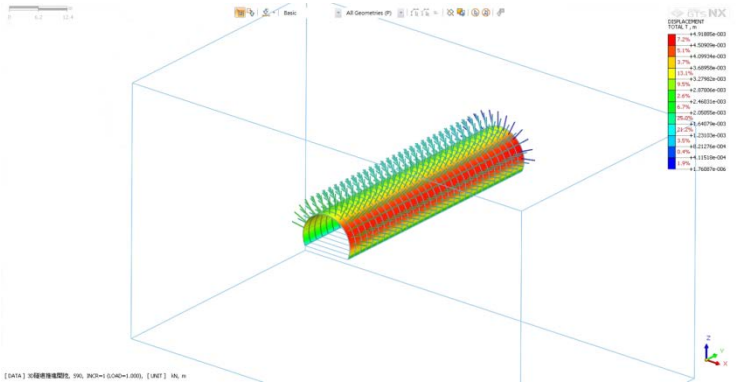
Stage70



Stage85



Stage90

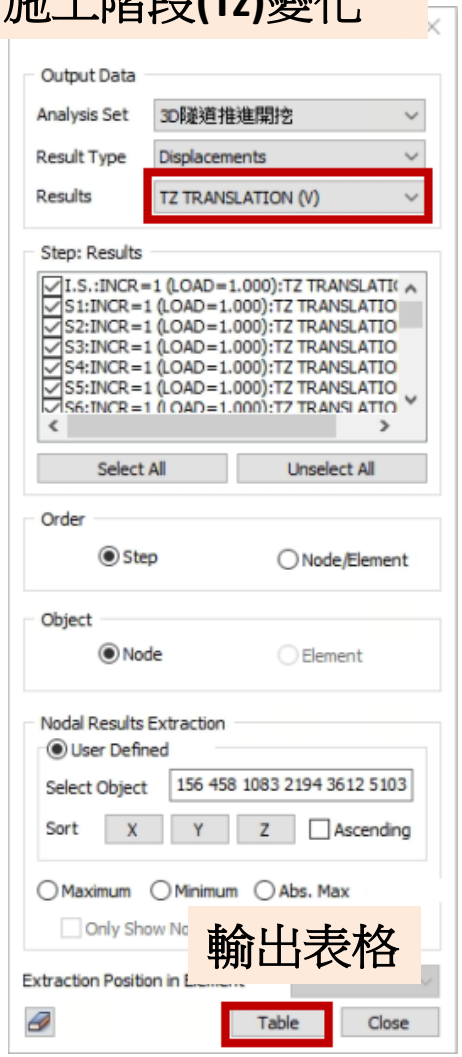


播放動畫 (施工階段)

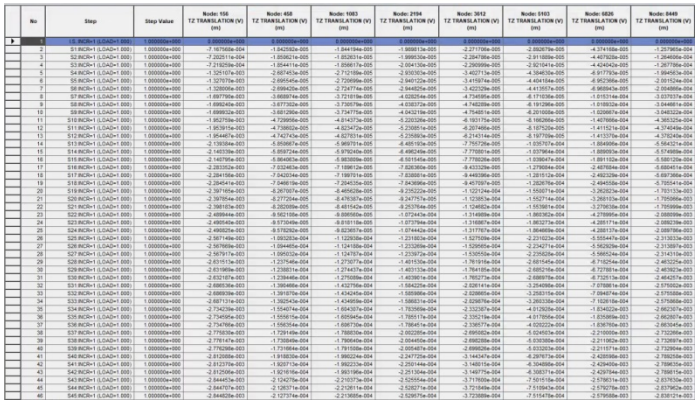
分析結果-3

選取查看節點

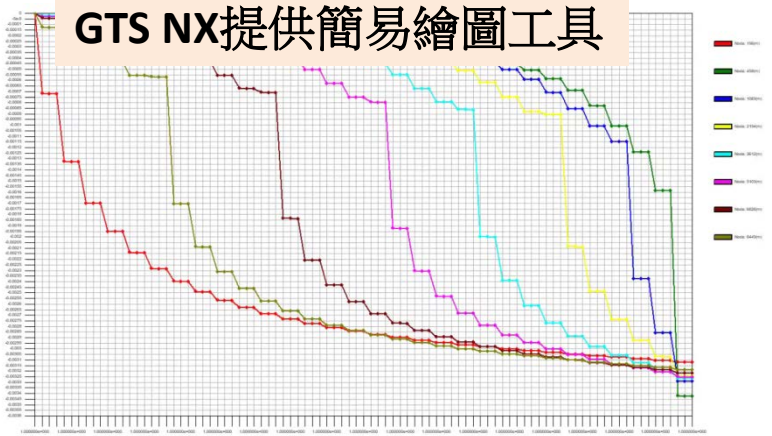
查看施工階段(Tz)變化



輸出表格



GTS NX提供簡易繪圖工具



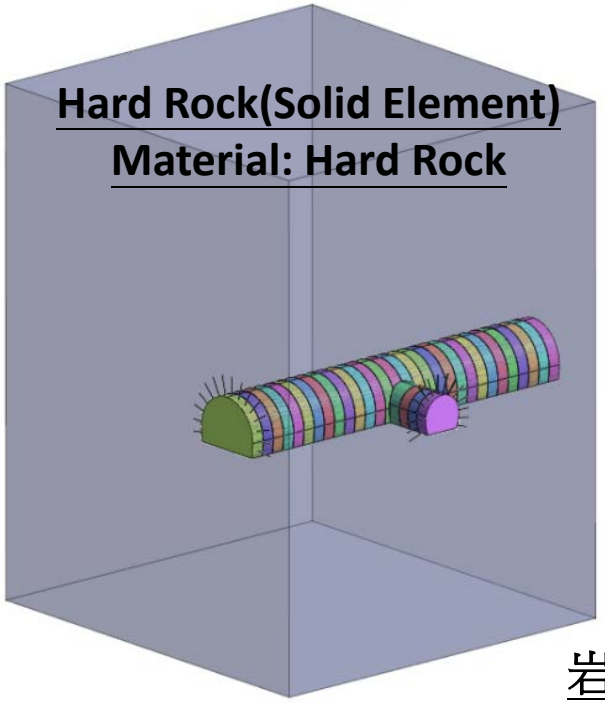
GTS NX_標準教學系列

3D隧道與連廊分析

台灣邁達斯

註1:範例相關參數使用假設條件。
註2:建議操作3D隧道教學前，先熟悉2D隧道分析範例。

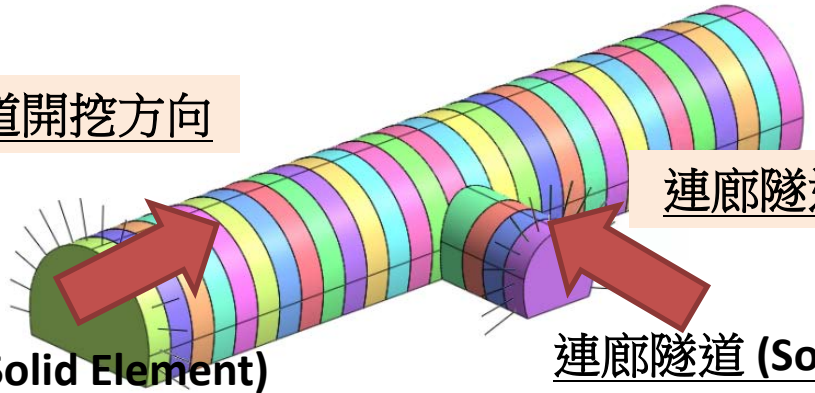
分析說明-材料&屬性



Hard Rock(Solid Element)
Material: Hard Rock

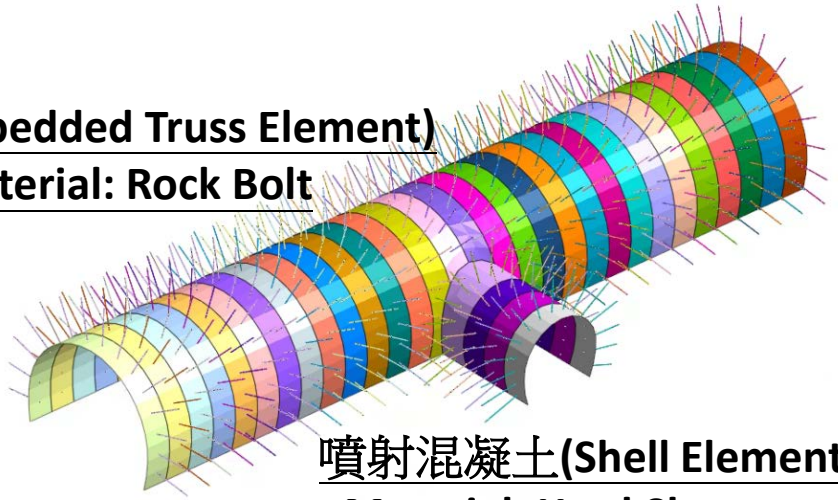
主隧道開挖方向

連廊隧道開挖方向



主隧道 (Solid Element)
Material: Hard Rock

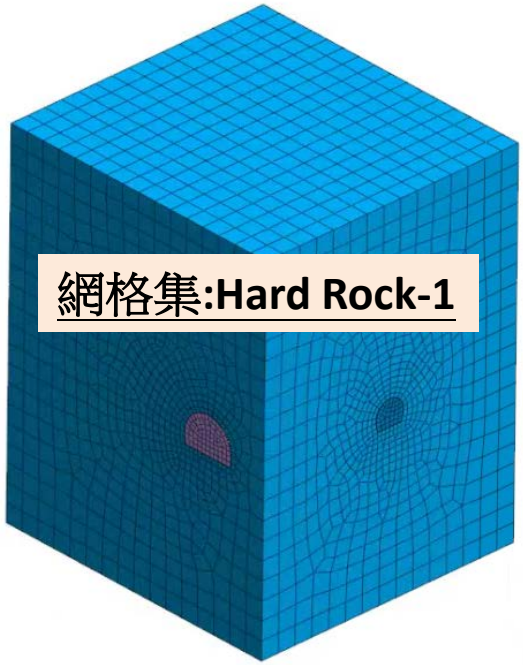
連廊隧道 (Solid Element)
Material: Hard Rock



岩栓(Embedded Truss Element)
Material: Rock Bolt

噴射混凝土(Shell Element)
Material: Hard Shotcrete

網格集說明-1

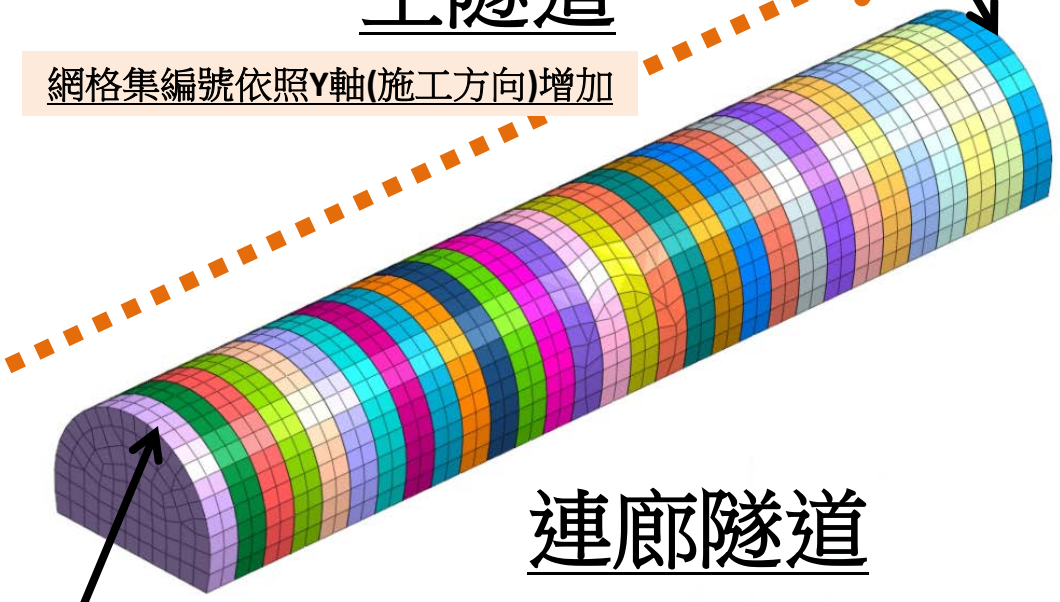


網格集:Hard Rock-1

網格集: Main Tunnel-030

主隧道

網格集編號依照Y軸(施工方向)增加

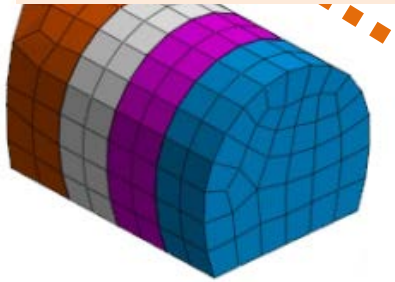


網格集: Main Tunnel-001

連廊隧道

網格集編號依照Y軸(施工方向)增加

網格集: Gallery Tunnel-004

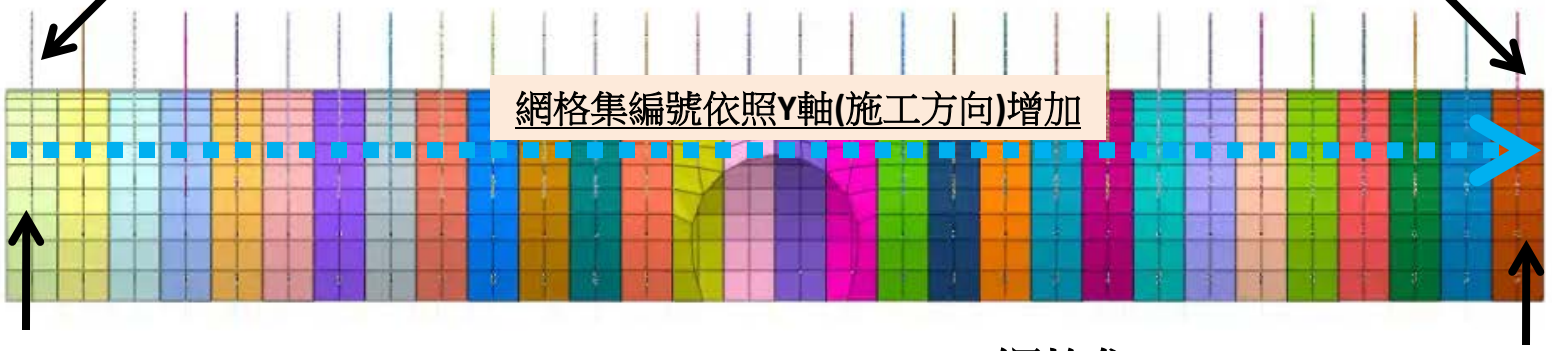


網格集: Gallery Tunnel-001

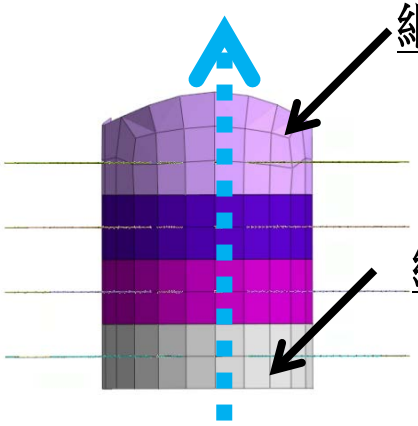
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

網格集說明-2

主隧道



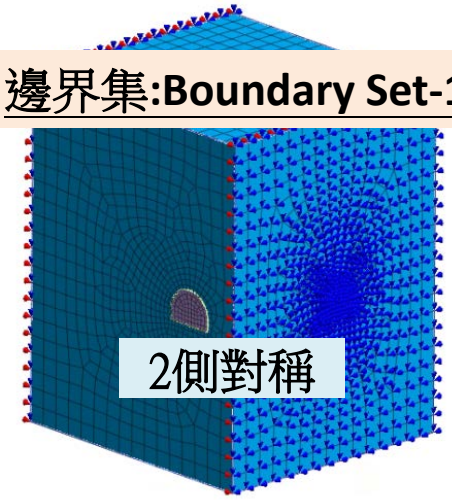
連廊隧道



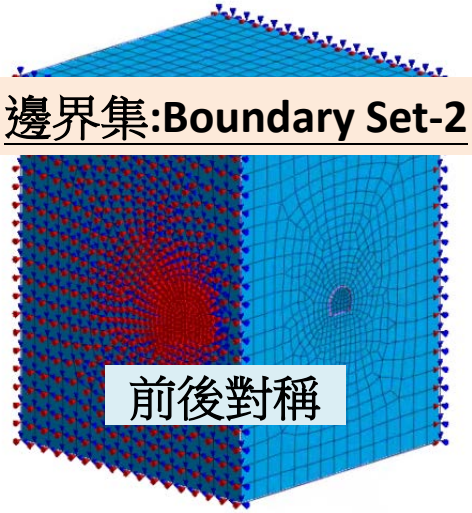
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

邊界集&載荷集說明

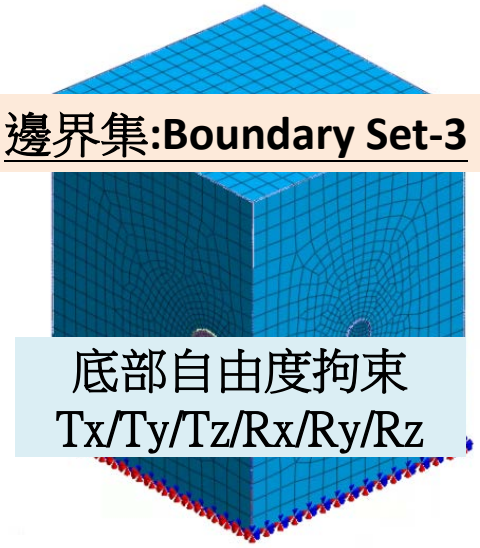
邊界集:Boundary Set-1



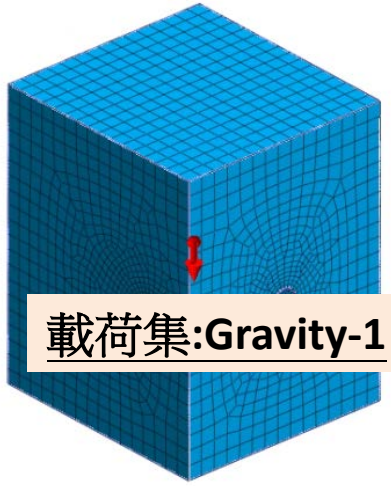
邊界集:Boundary Set-2



邊界集:Boundary Set-3



載荷集:Gravity-1

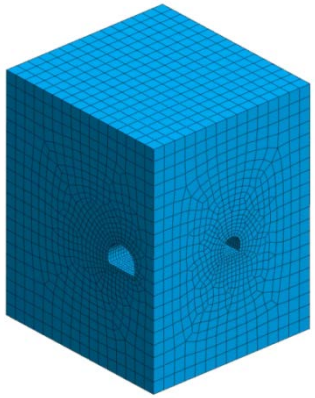


註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

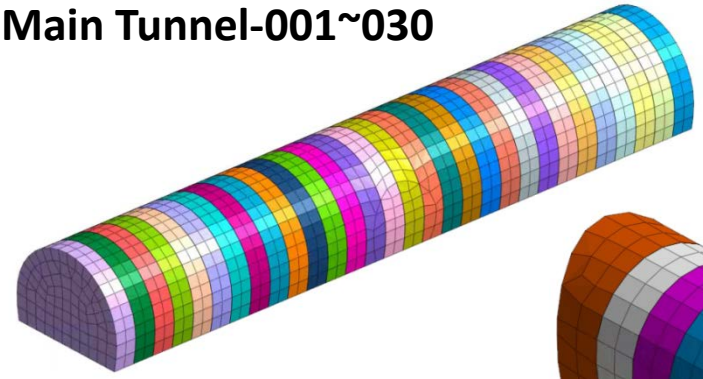
隧道開挖前-初始條件

網格集

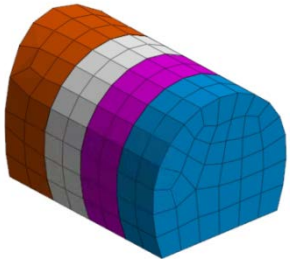
Hard Rock-1



Main Tunnel-001~030



Gallery Tunnel-001~004

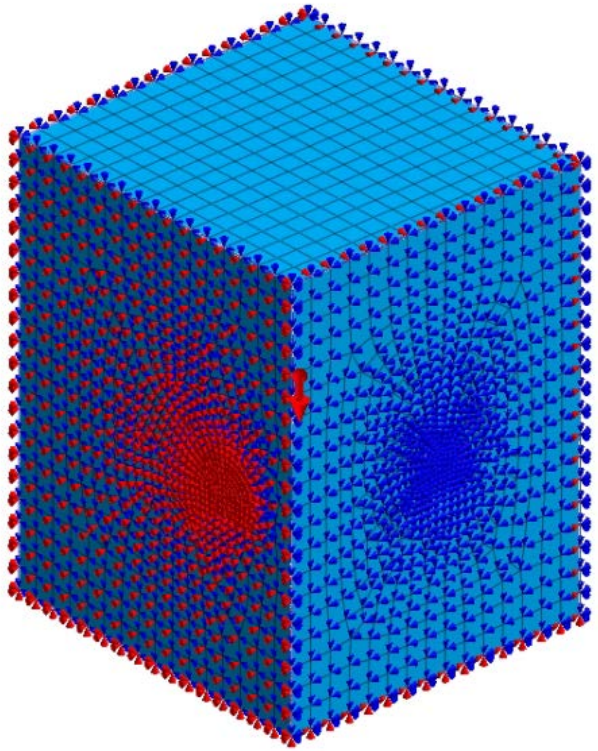


邊界集

Boundary Set-1~3

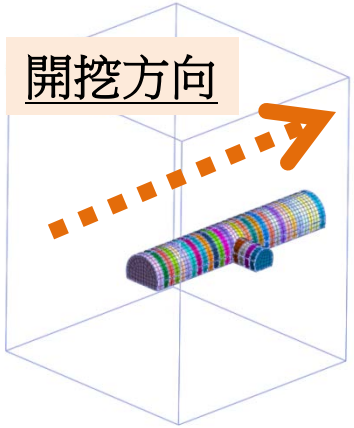
載荷集

Gravity-1



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

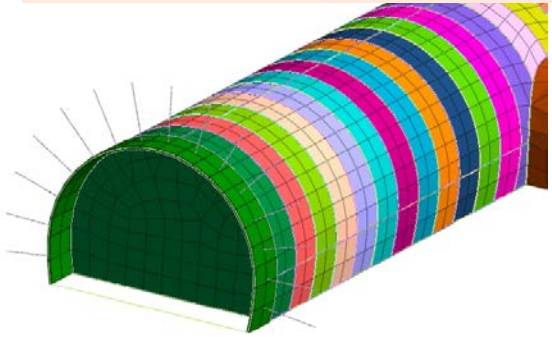
主隧道開挖-重覆施工過程



Step1. 隧道開挖

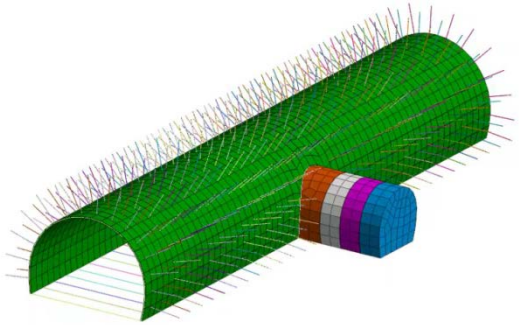
移除網格集:
Main Tunnel-001

Step2.噴射混凝土&岩栓



新增網格集:
Main Tunnel ShotCrete-1
Main Tunnel Rock Bolt-1

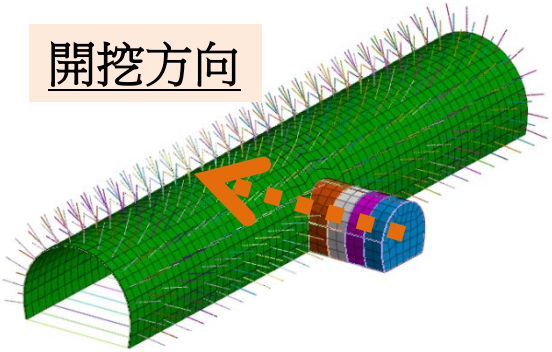
重覆施工~主隧道貫穿



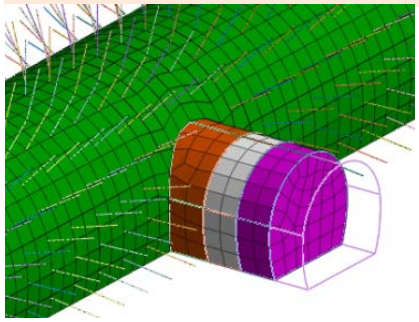
註1:重覆相同施工過程至隧道貫穿。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段。

連廊隧道開挖-重覆施工過程

開挖方向

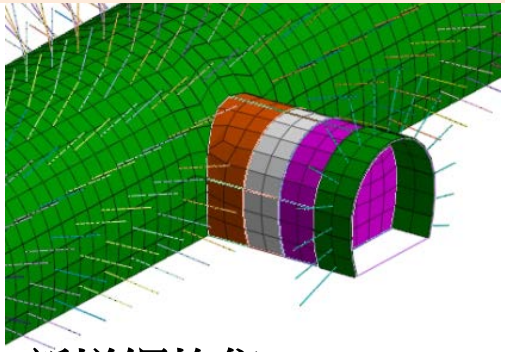


Step1. 隧道開挖



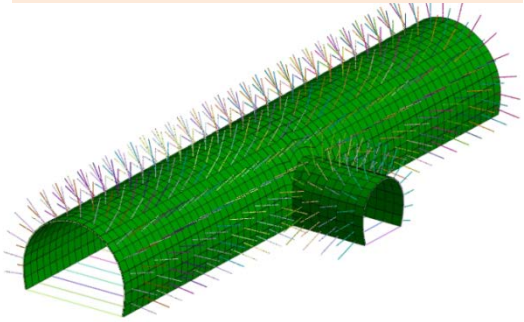
移除網格集:
Gallery Tunnel-001

Step2.噴射混凝土&岩栓



新增網格集:
Gallery Tunnel ShotCrete-1
Gallery Tunnel Rock Bolt-1

重覆施工~連廊隧道連接主隧道

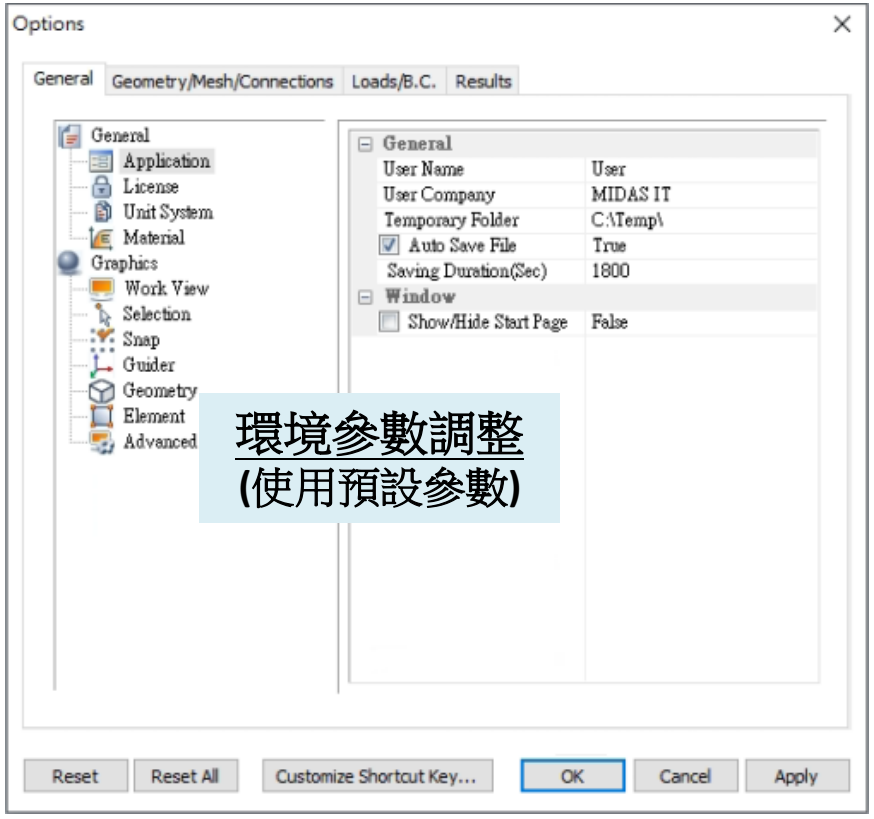


註1:重覆相同施工過程至連廊隧道連接主隧道。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段。

Part1.幾何特徵

環境

新文件



環境參數調整
(使用預設參數)

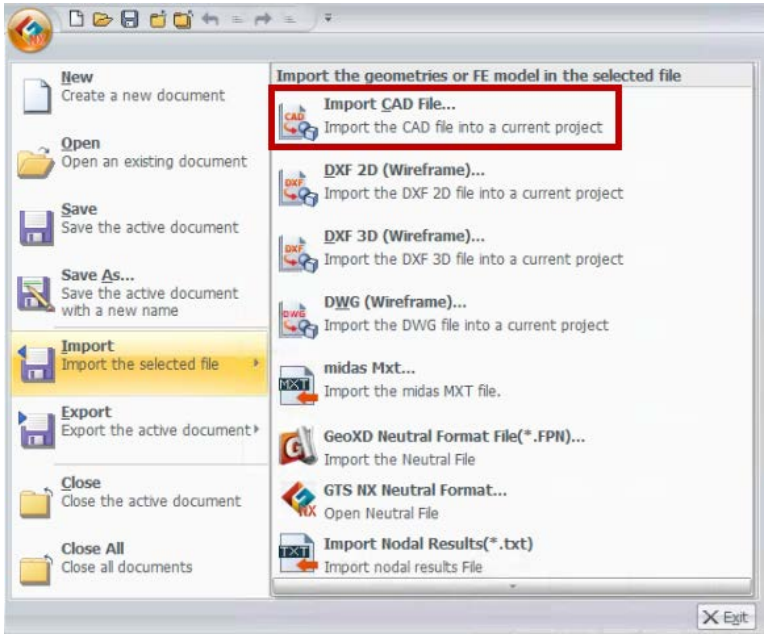
3D操作

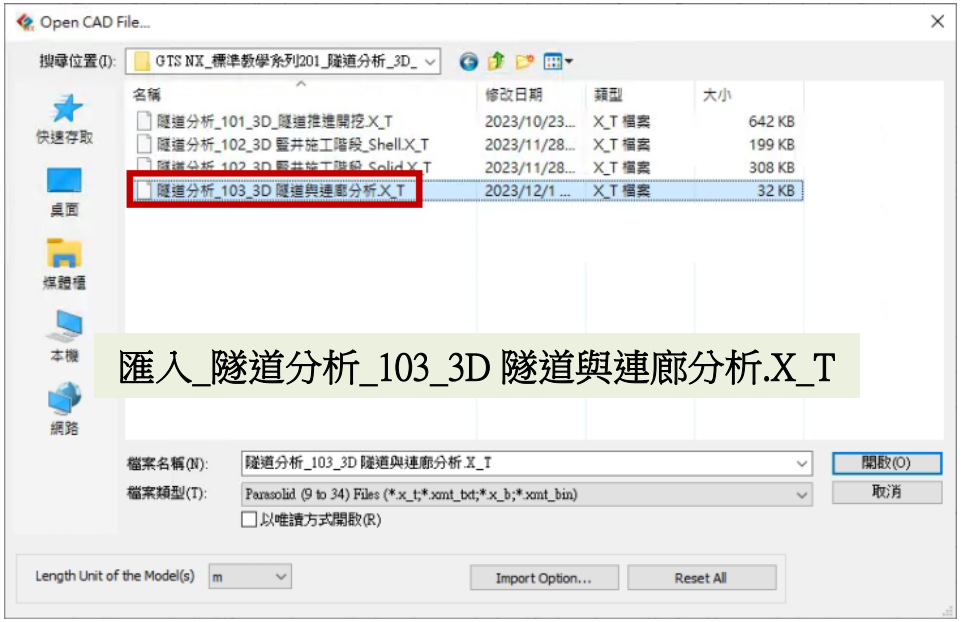
重力方向(Z)

切換單位

單位使用KN/m/J/sec

3D模型匯入



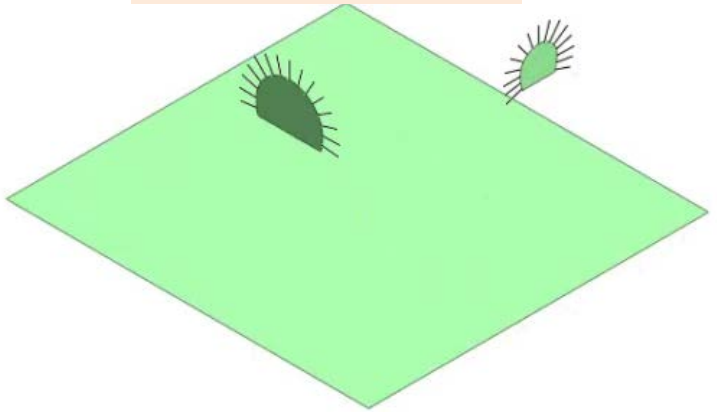


匯入_隧道分析_103_3D 隧道與連廊分析.X_T

GTS NX支援常用3D格式

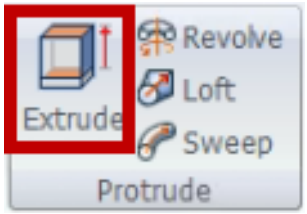
Parasolid (9 to 31) Files (*.x_t;*.xmt_txt;*.x_b;*.xmt_bin)
ACIS (R1 - 2020 1.0) Files (*.sat;*.sab;*.asat;*.asab)
STEP (AP203, AP214, AP242) Files (*.stp;*.step)
IGES (Up to 5.3) Files (*.igs;*.iges)
Pro-E (16 - Creo 6.0) Files (*.prt;*.prt.*;*.asm;*.asm.*)
CATIA V4 (CATIA 4.1.9 - 4.2.4) Files (*.model;*.exp;*.session)
CATIA V5 (V5 R8 - V5-6R2020) Files (*.CATPart;*.CATProduct)
Solid Works (98 - 2020) Files (*.sldprt;*.sldasm)
Unigraphics (11 - NX1899) Files (*.prt)
Inventor Part (V6 - V2020) Files (*.ipt)
Inventor Assembly (V11 - V2020) Files (*.iam)

面&線特徵模型

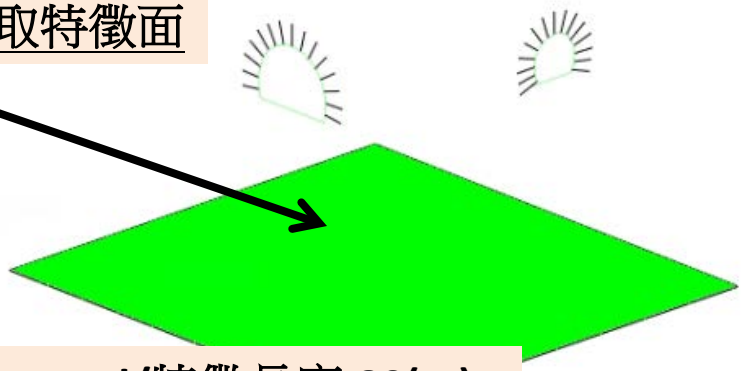


拉伸長出-1

(實體特徵)

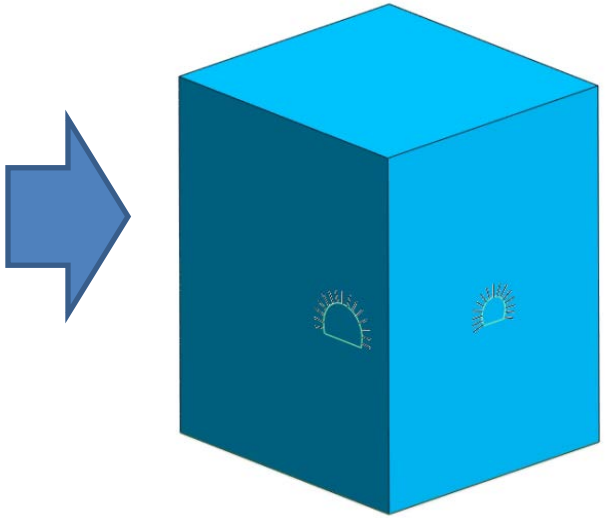


選取特徵面



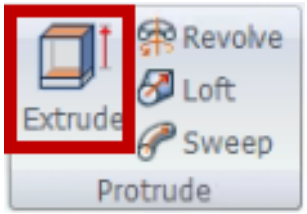
長出方向:Normal/特徵長度:80(m)

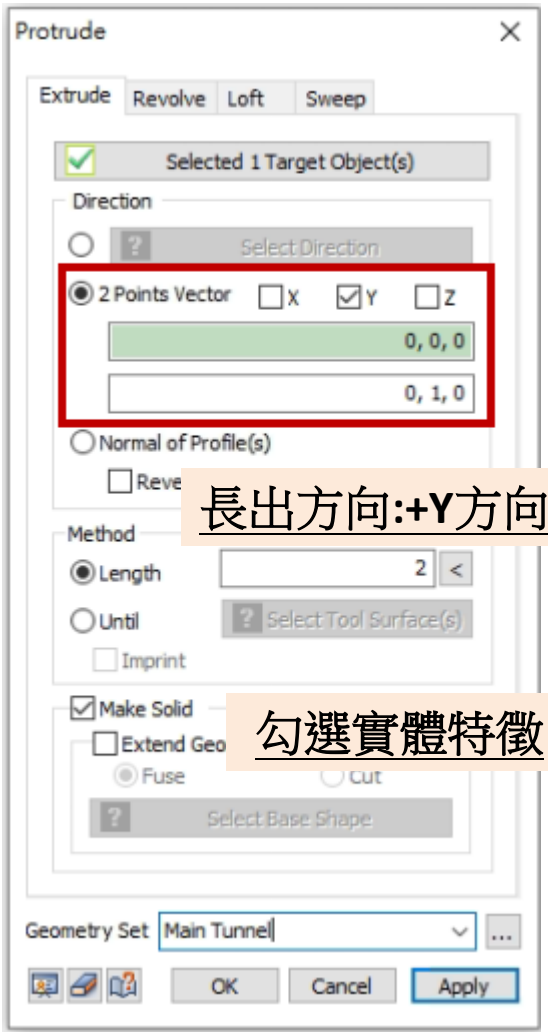
勾選實體特徵

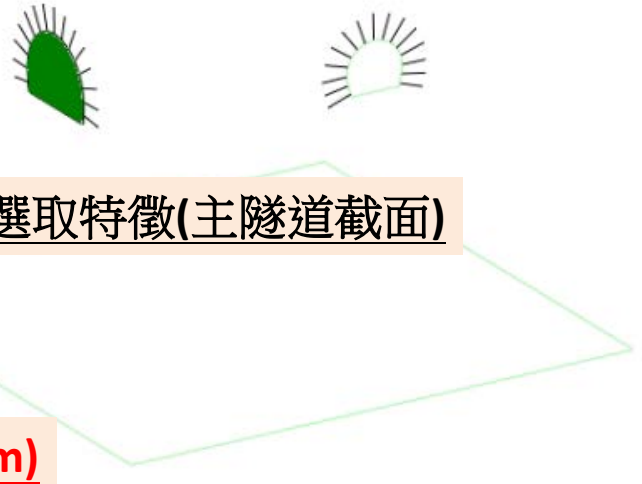


自訂幾何集名稱:Hard Rock

拉伸長出-2
(實體特徵)



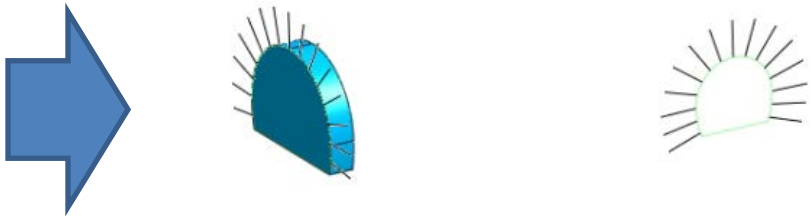




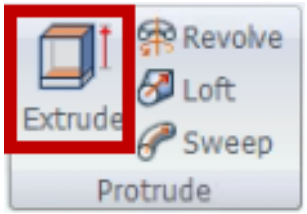
選取特徵(主隧道截面)

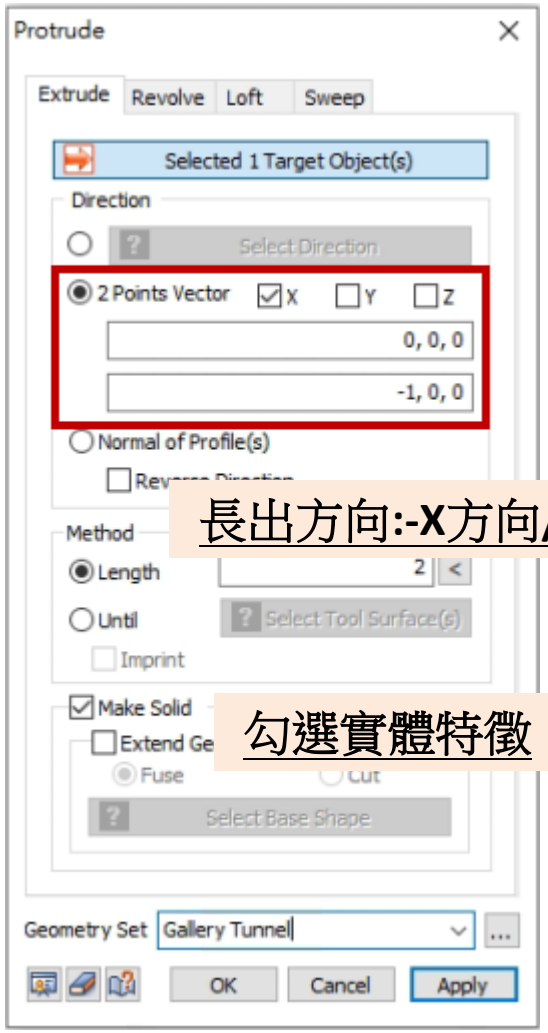
長出方向:+Y方向/特徵長度:2(m)

勾選實體特徵

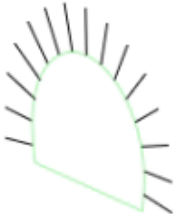


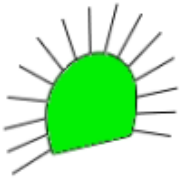
拉伸長出-3
(實體特徵)





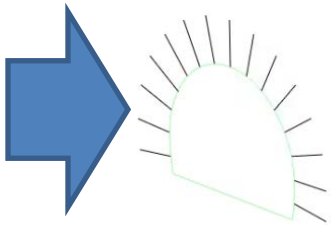
選取特徵(連廊截面)

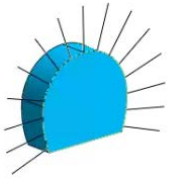




長出方向:-X方向/特徵長度:2(m)

勾選實體特徵



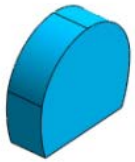


自訂幾何集名稱:Gallery Tunnel

複製實體特徵-1

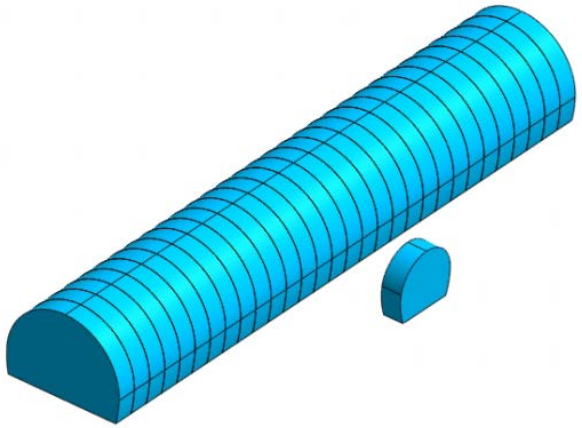
(主隧道)

選取特徵(主隧道)



方向:+Y方向

勾選Copy(uniform)/距離:2(m)/29次

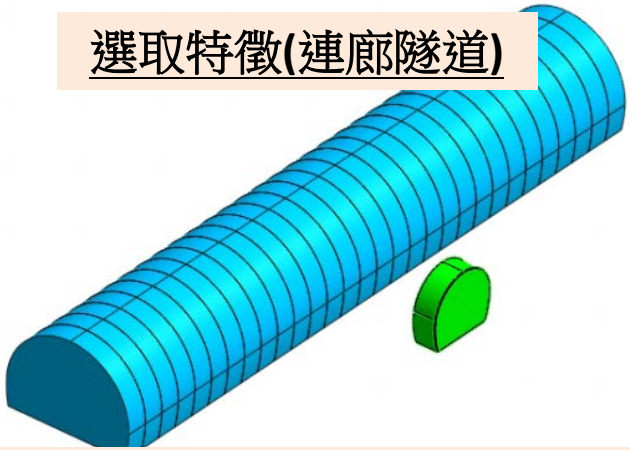


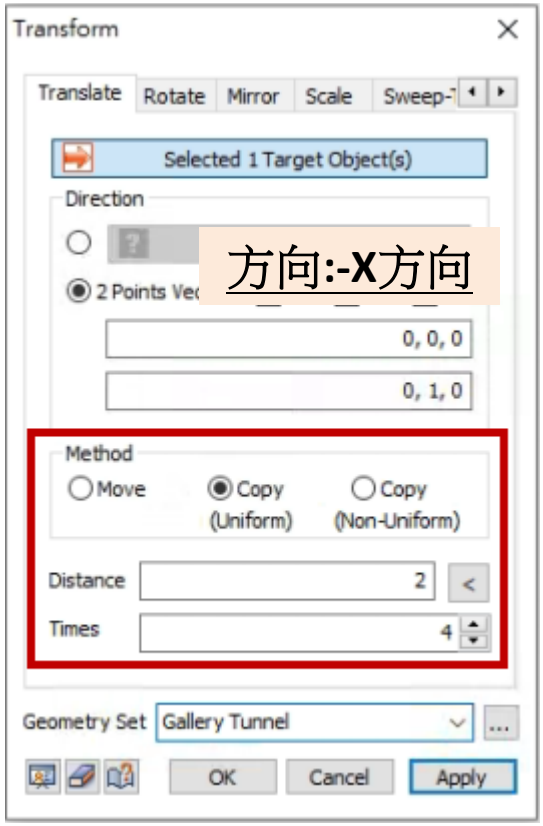
幾何集:Main Tunnel

複製實體特徵-2

(連廊隧道)

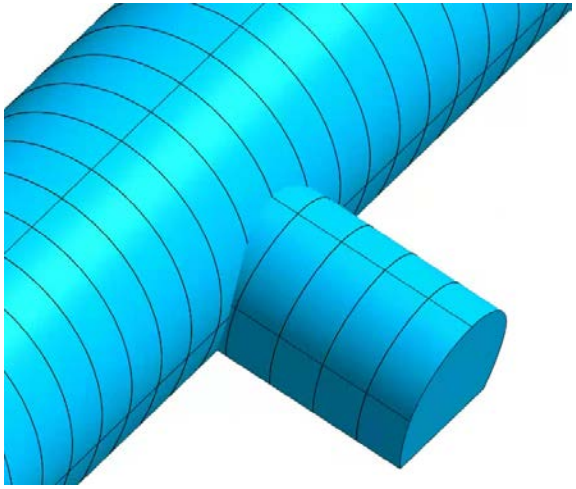
選取特徵(連廊隧道)





方向:-X方向

勾選Copy(uniform)/距離:2(m)/4次

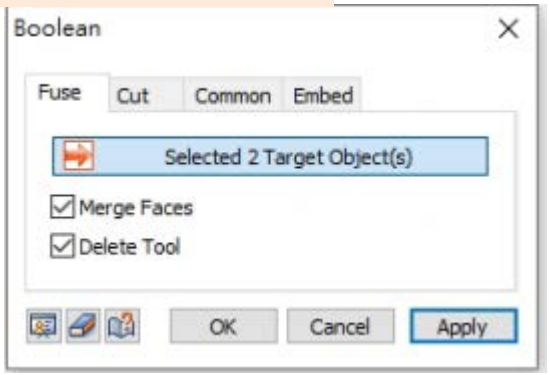


幾何集:Gallery Tunnel

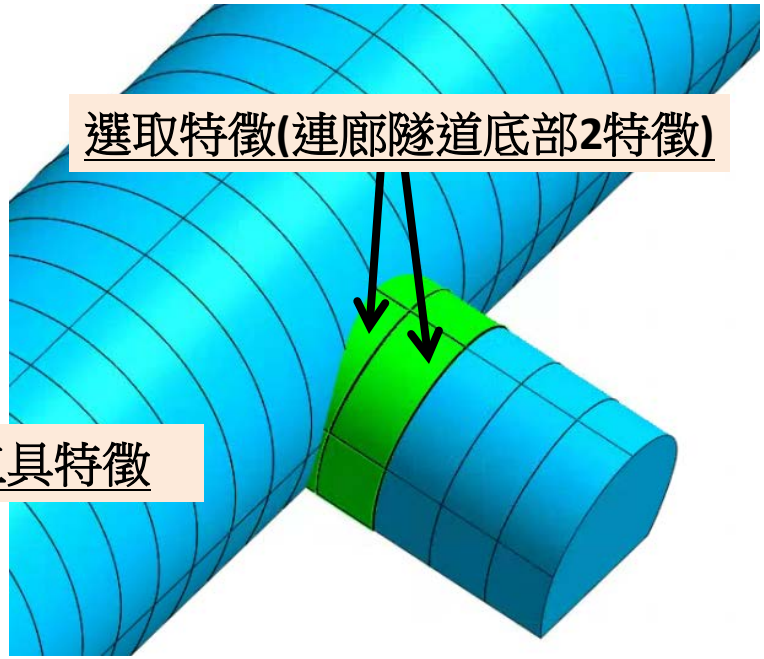
布林運算-1

(連廊隧道)

Fuse(合併特徵)

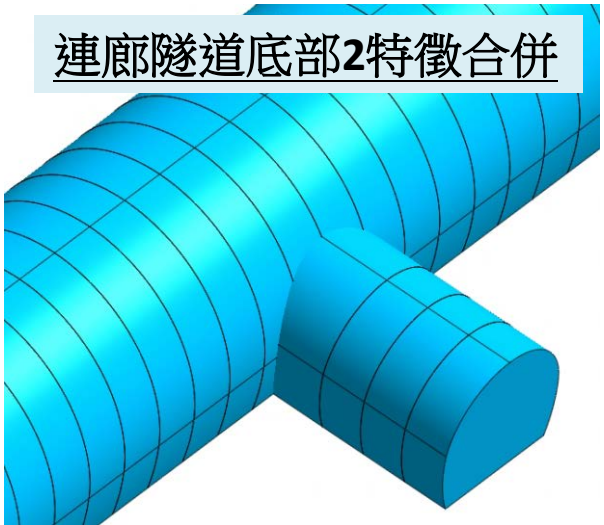


勾選合併特徵面&刪除工具特徵



選取特徵(連廊隧道底部2特徵)

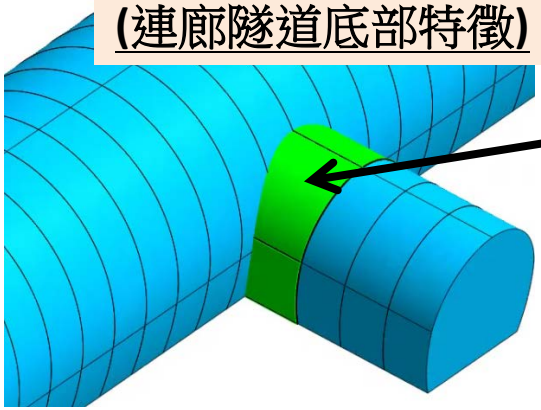
連廊隧道底部2特徵合併

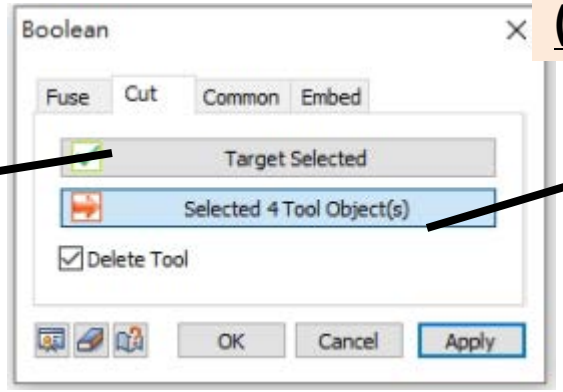


布林運算-2
(主隧道&連廊隧道)

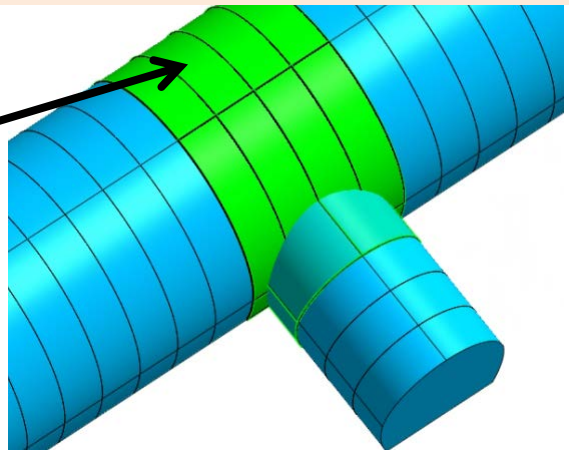
Cut(切割特徵)

目標特徵選取
(連廊隧道底部特徵)



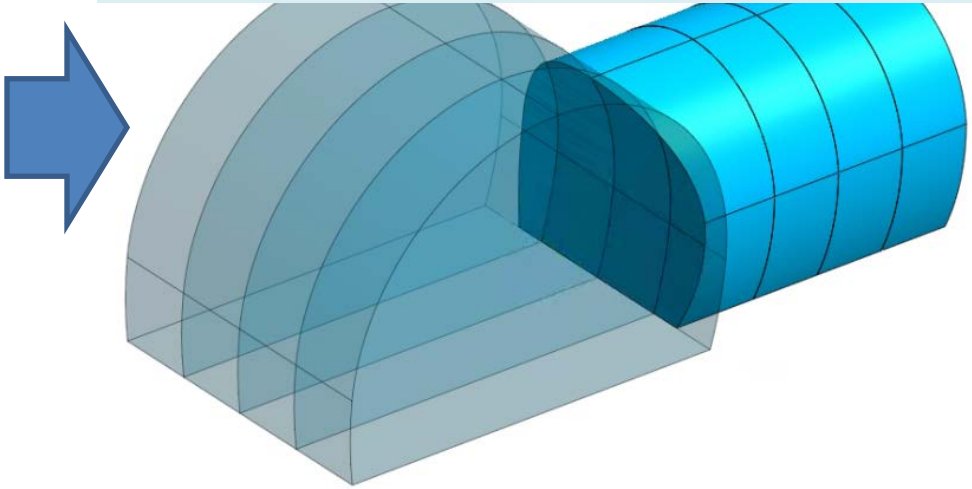


工具特徵選取
(主隧道與連廊隧道連接區域)



不要刪除工具特徵

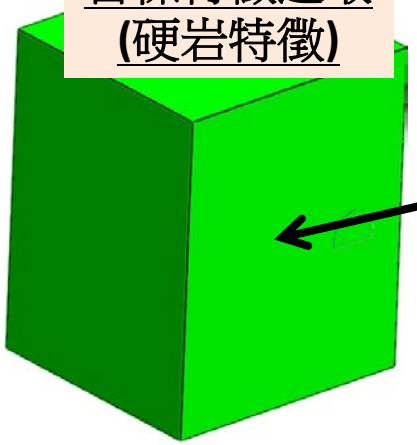
連廊隧道底部特徵與主隧道相交區域刪除



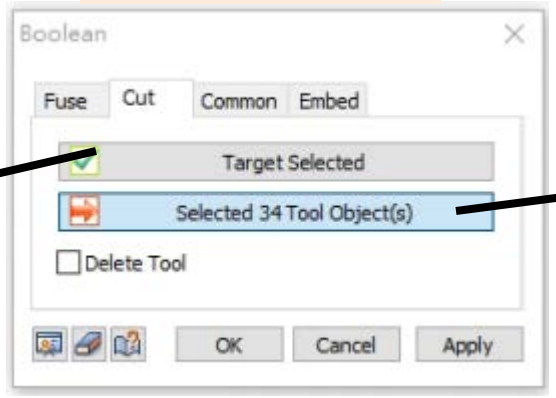
布林運算-3

(硬岩 &隧道)

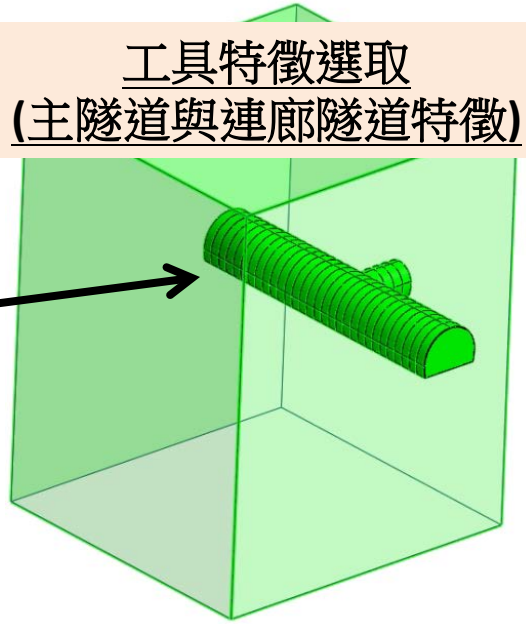
目標特徵選取
(硬岩特徵)



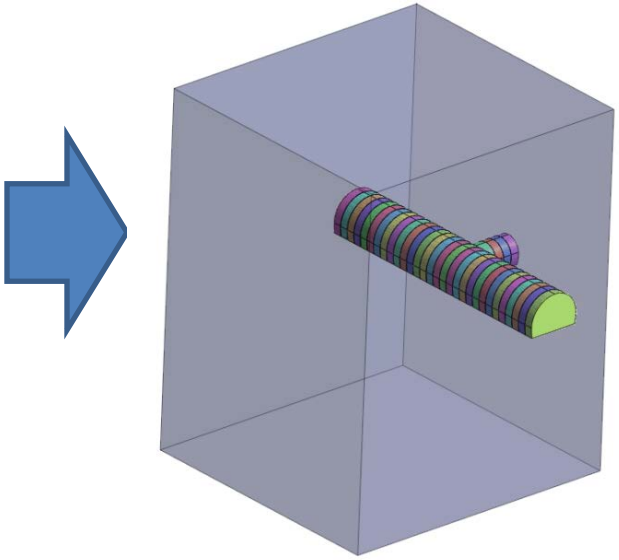
Cut(切割特徵)



工具特徵選取
(主隧道與連廊隧道特徵)



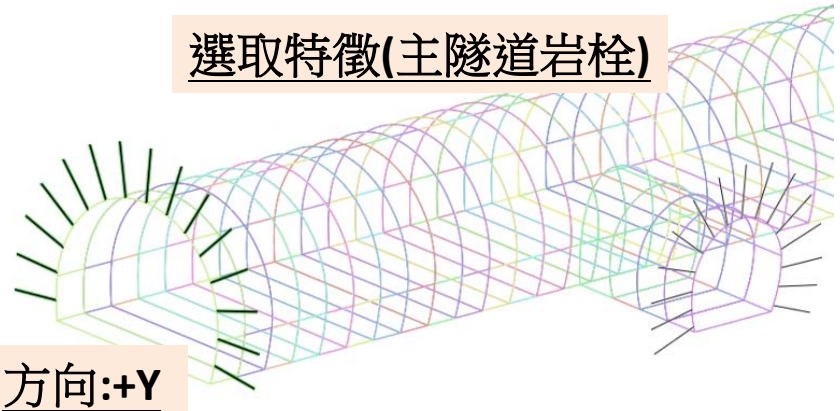
不要刪除工具特徵



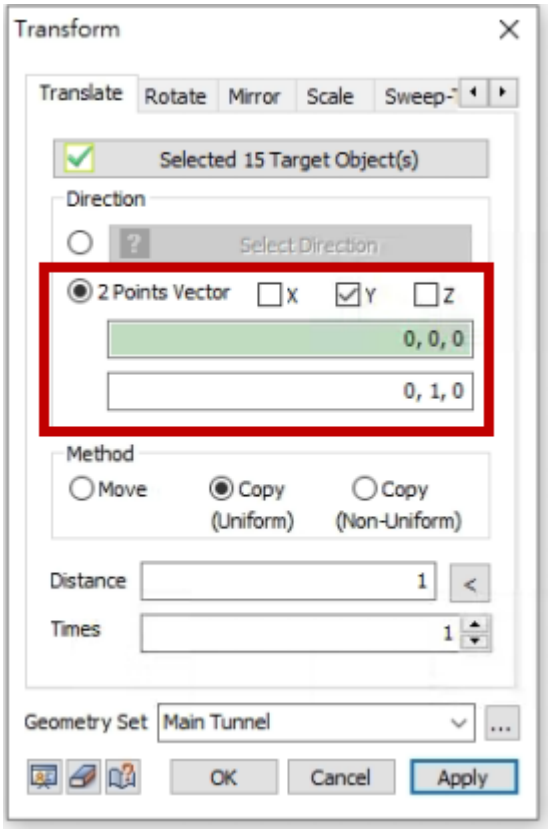
複製線特徵-1

(主隧道岩栓)

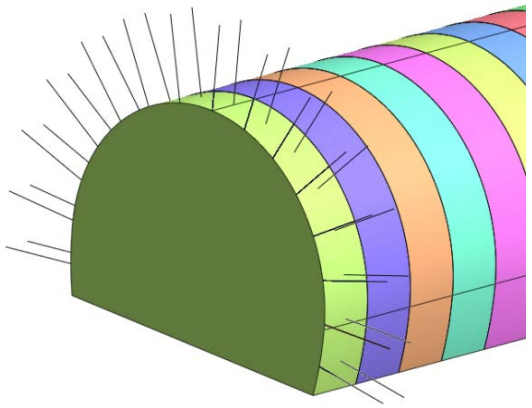
選取特徵(主隧道岩栓)



方向:+Y



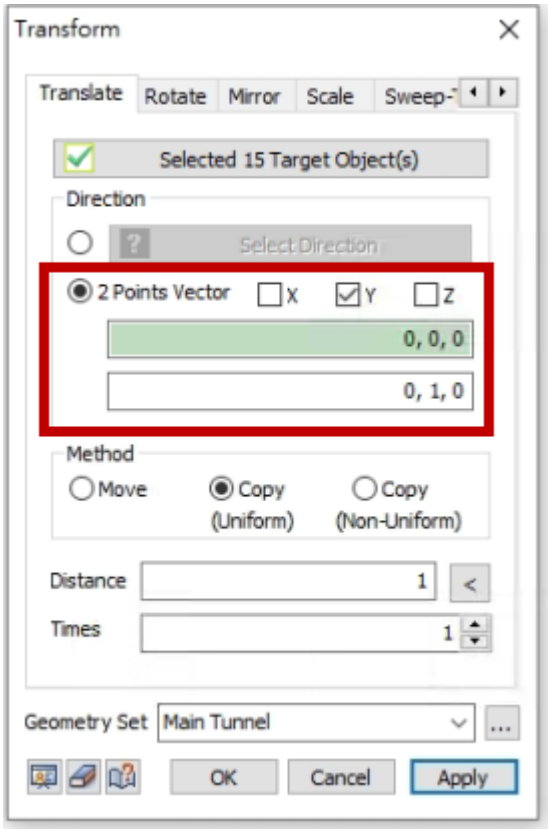
勾選Copy(uniform)/距離:1(m)/1次



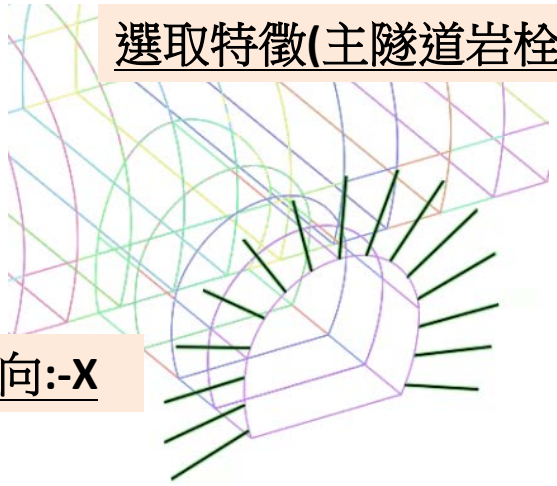
幾何集:Main Tunnel

複製線特徵-2

(連廊隧道岩栓)

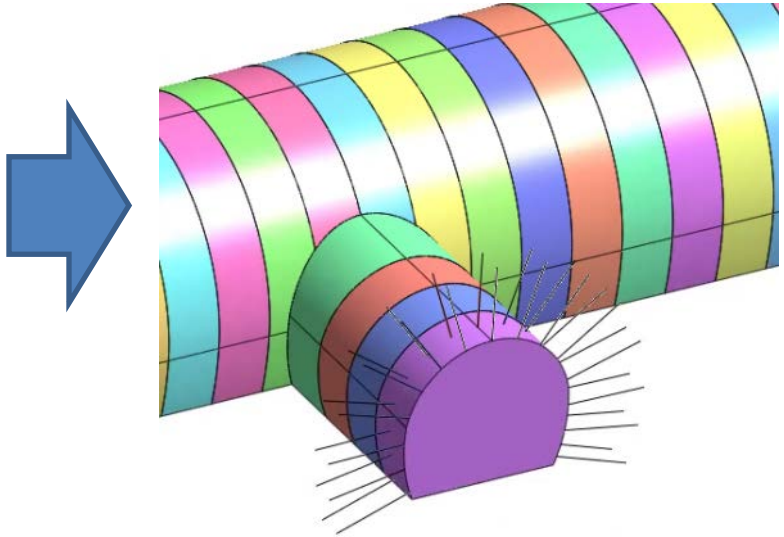


選取特徵(主隧道岩栓)



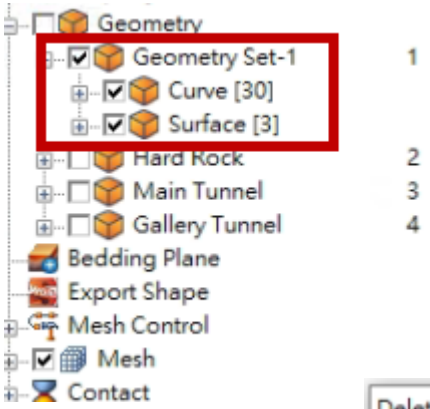
方向:-X

勾選Copy(uniform)/距離:1(m)/1次

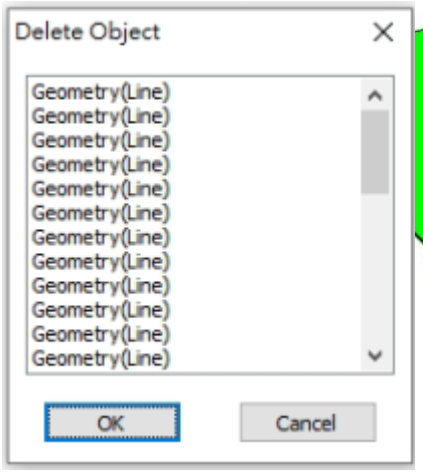


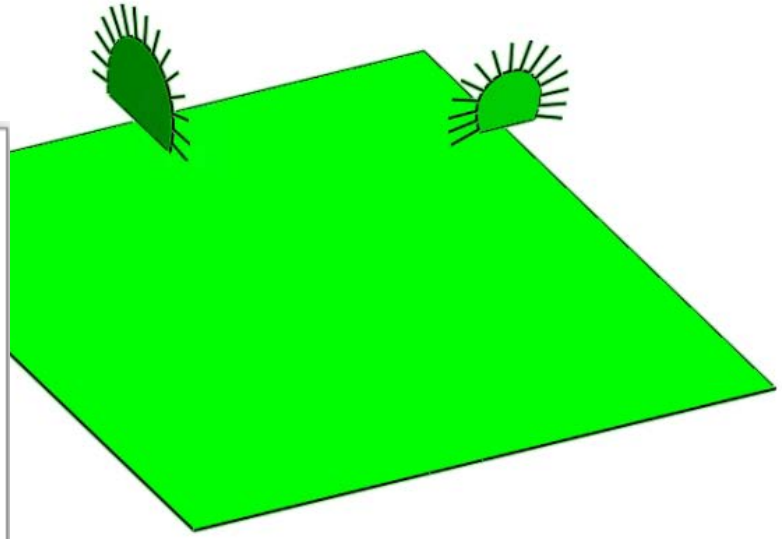
幾何集:Gallery Tunnel

刪除特徵



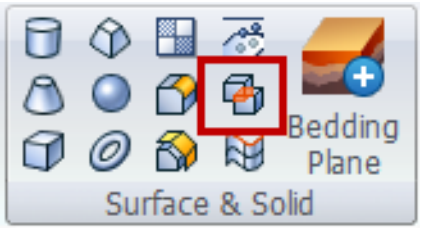
刪除幾何集**Geometry Set-1**所有特徵



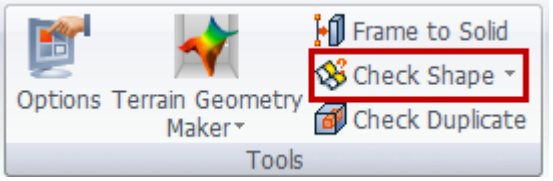


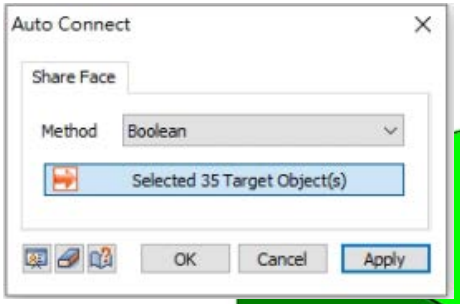
相鄰面特徵建立

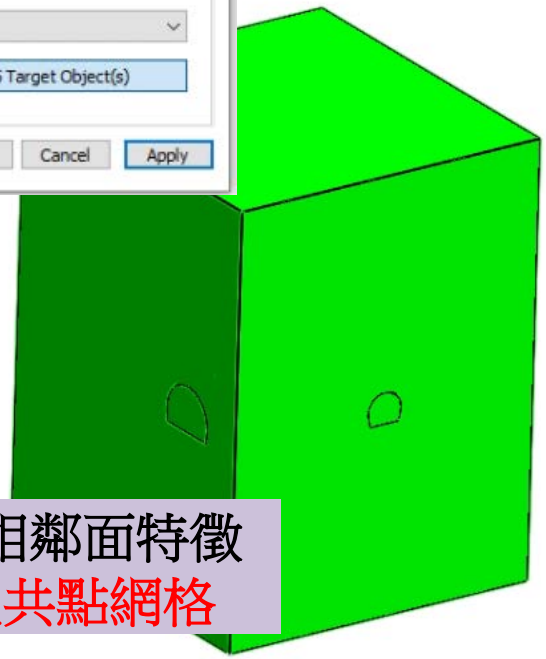
(實體特徵)



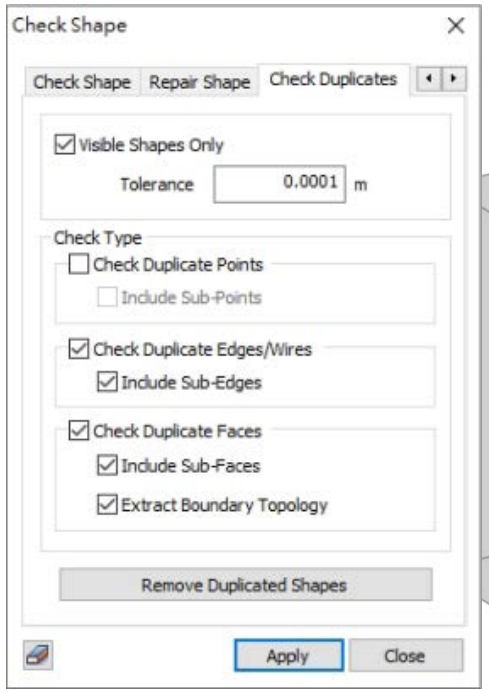
檢查幾何共面特徵

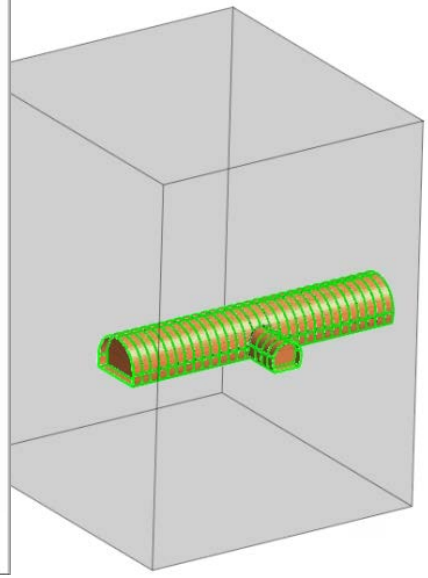






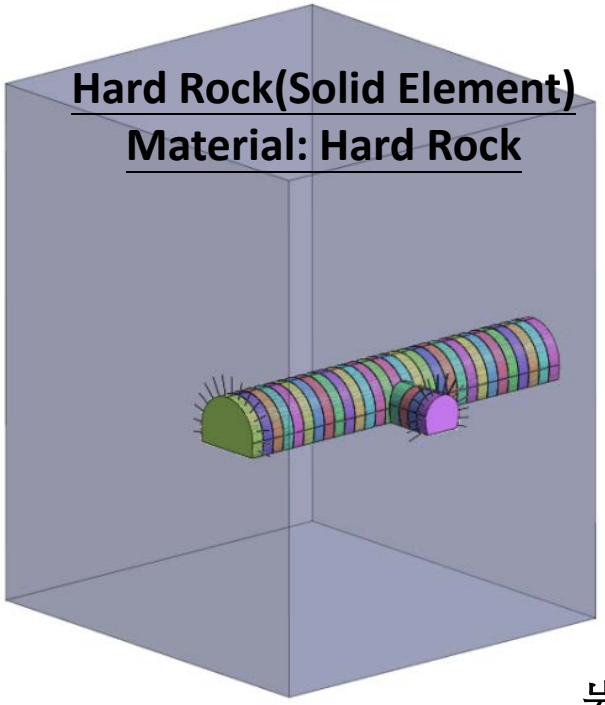
使用相鄰面特徵
產生共點網格





Part2.網格/邊界/載荷

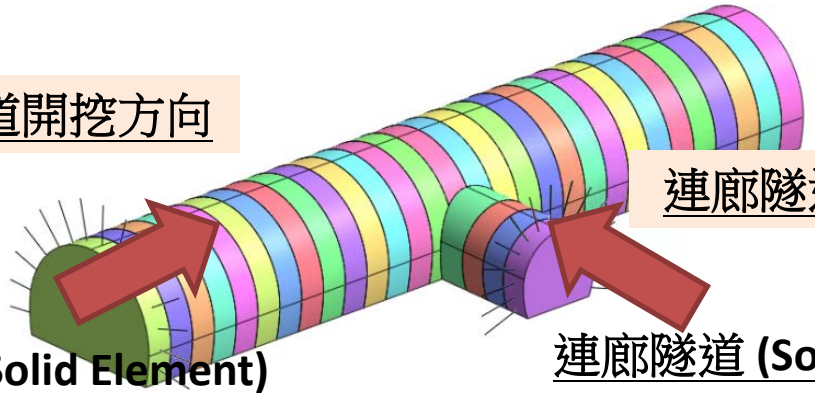
分析說明-材料&屬性



Hard Rock(Solid Element)
Material: Hard Rock

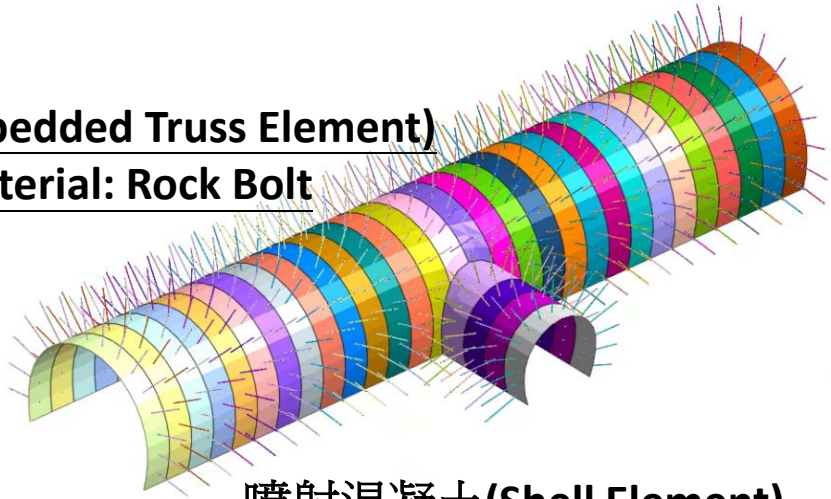
主隧道開挖方向

連廊隧道開挖方向



主隧道 (Solid Element)
Material: Hard Rock

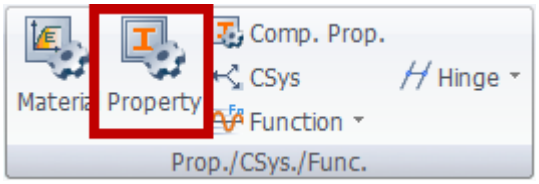
連廊隧道 (Solid Element)
Material: Hard Rock

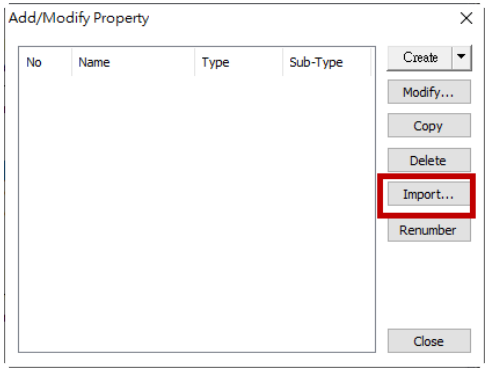


岩栓(Embedded Truss Element)
Material: Rock Bolt

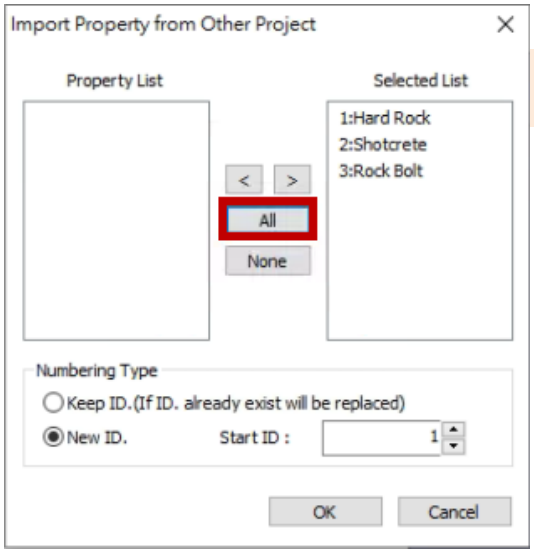
噴射混凝土(Shell Element)
Material: Hard Shotcrete

匯入材料&屬性

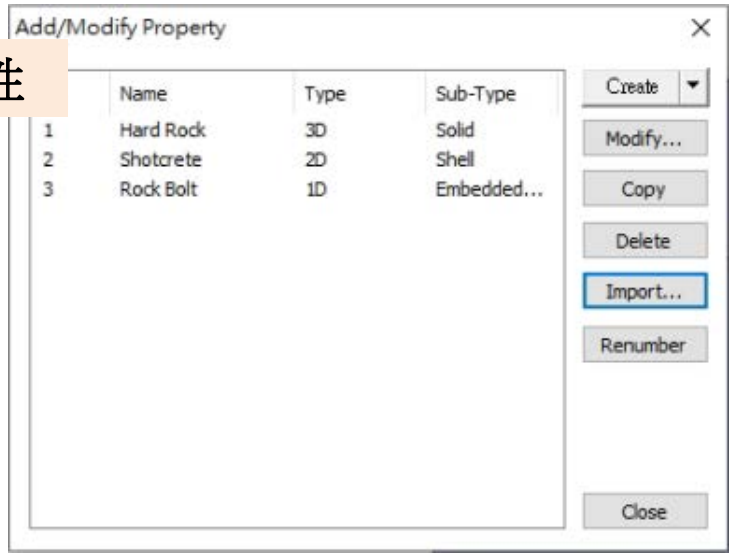




選擇檔案
(3D 隧道與連廊分析_Solid_Mat&Prop.gts)



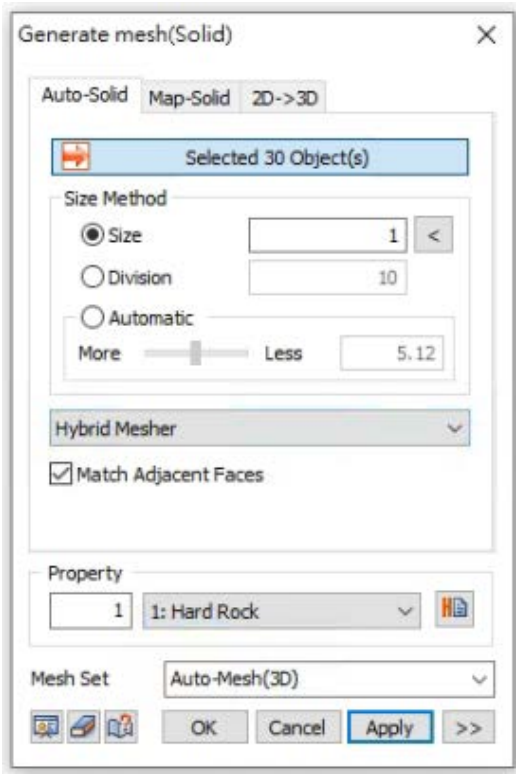
匯入所有屬性

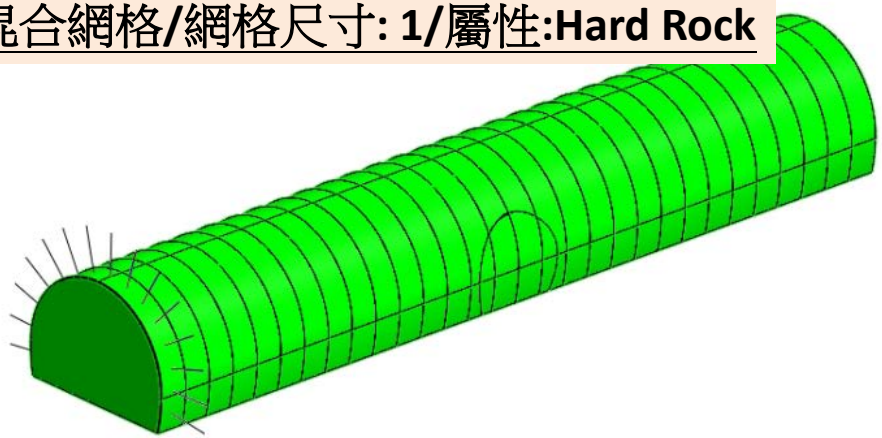


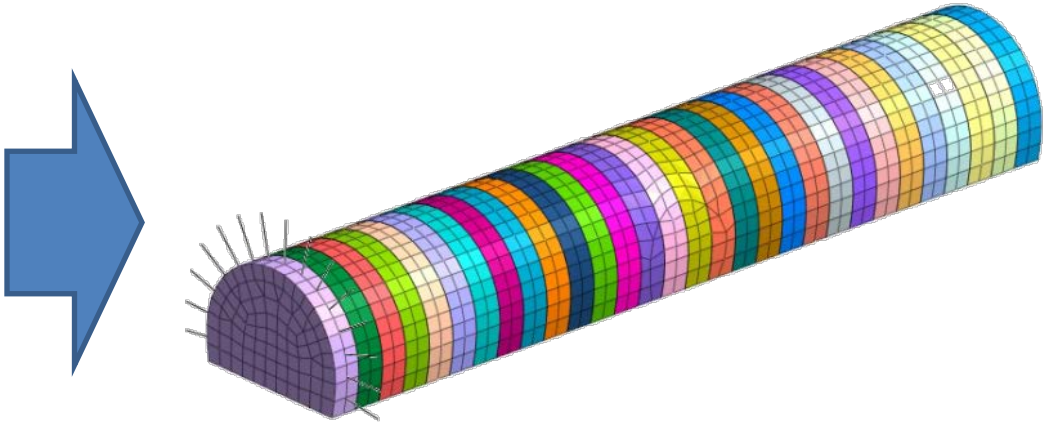
註:匯入屬性同時自動匯入材料性質

3D網格生成-主隧道區域

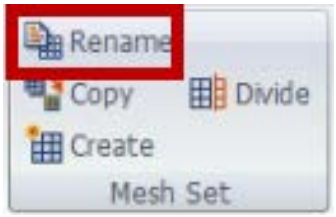
框選主隧道所有幾何特徵
混合網格/網格尺寸: 1/屬性:Hard Rock

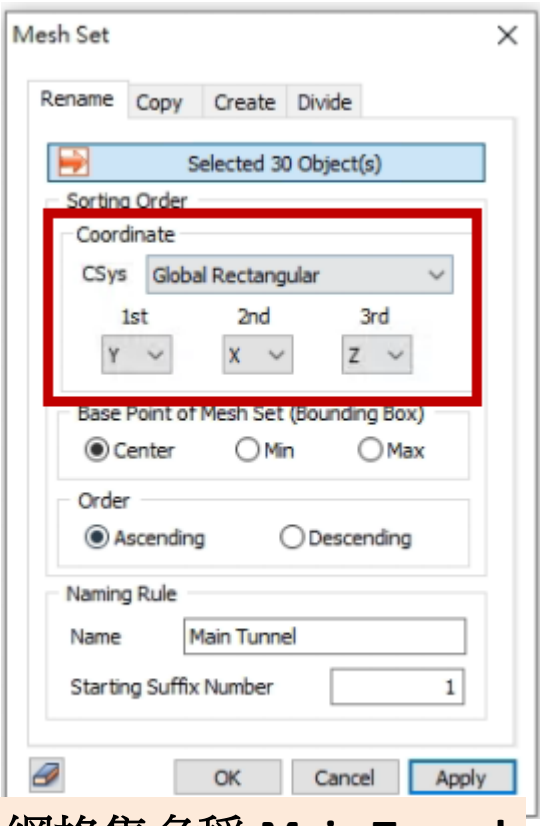






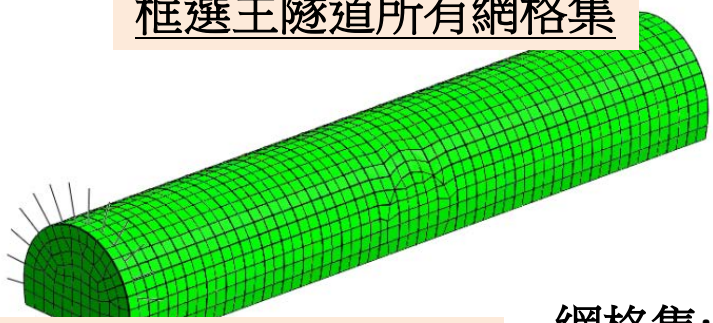
網格集名稱編輯-主隧道區域





網格集名稱:**Main Tunnel**

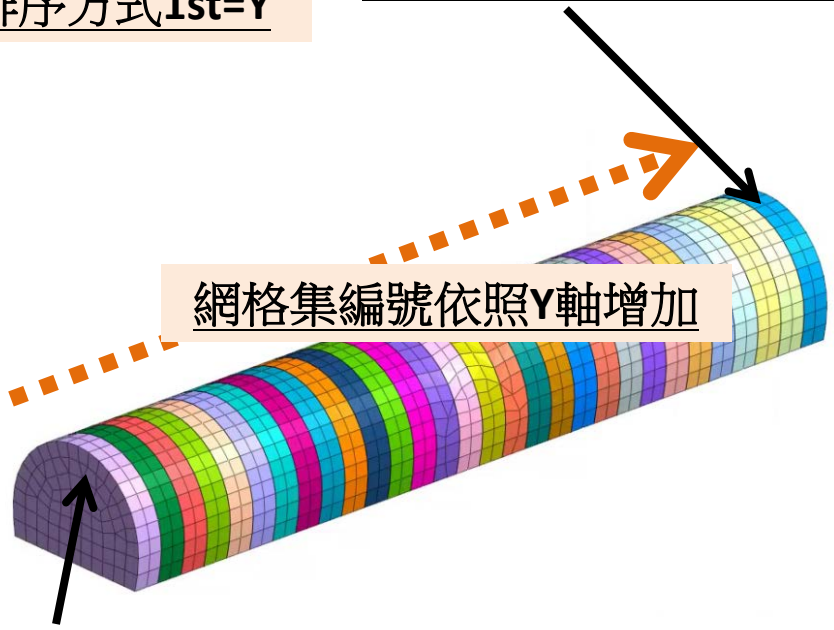
框選主隧道所有網格集



網格集排序方式**1st=Y**

網格集:**Main Tunnel-030**

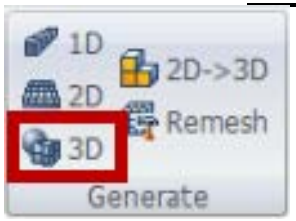
網格集編號依照**Y**軸增加



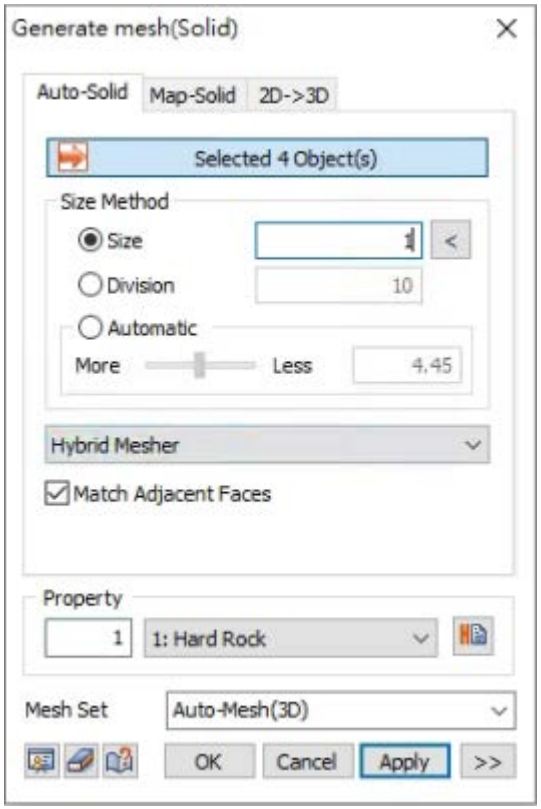
網格集:**Main Tunnel-001**

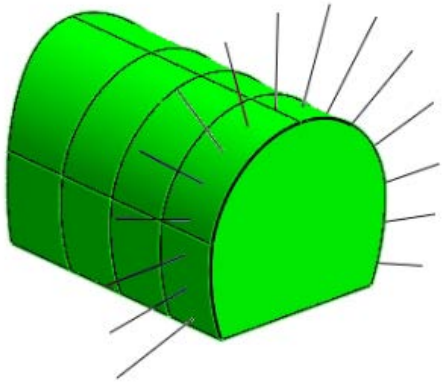
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

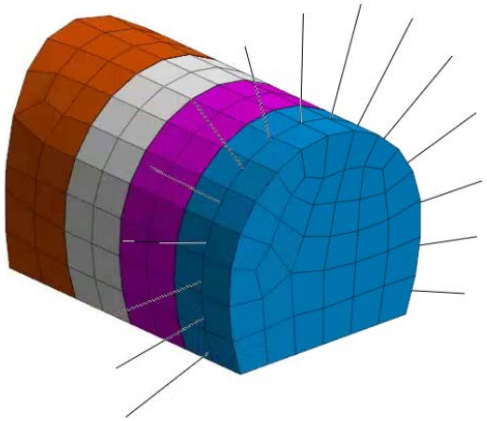
3D網格生成-連廊隧道區域



框選連廊隧道所有幾何特徵
混合網格/網格尺寸: 1/屬性:**Hard Rock**



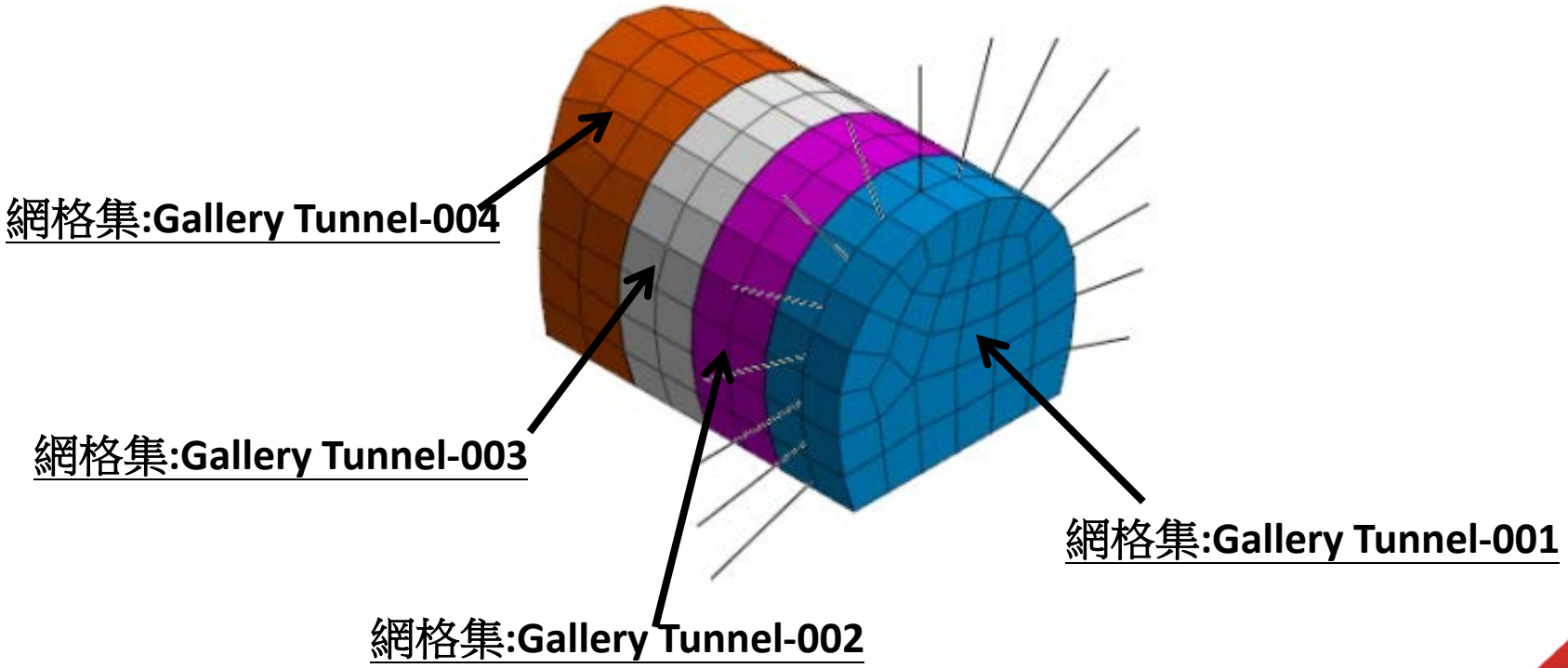




網格集名稱編輯-連廊隧道區域

網格集選取

手動編輯連廊隧道網格集名稱

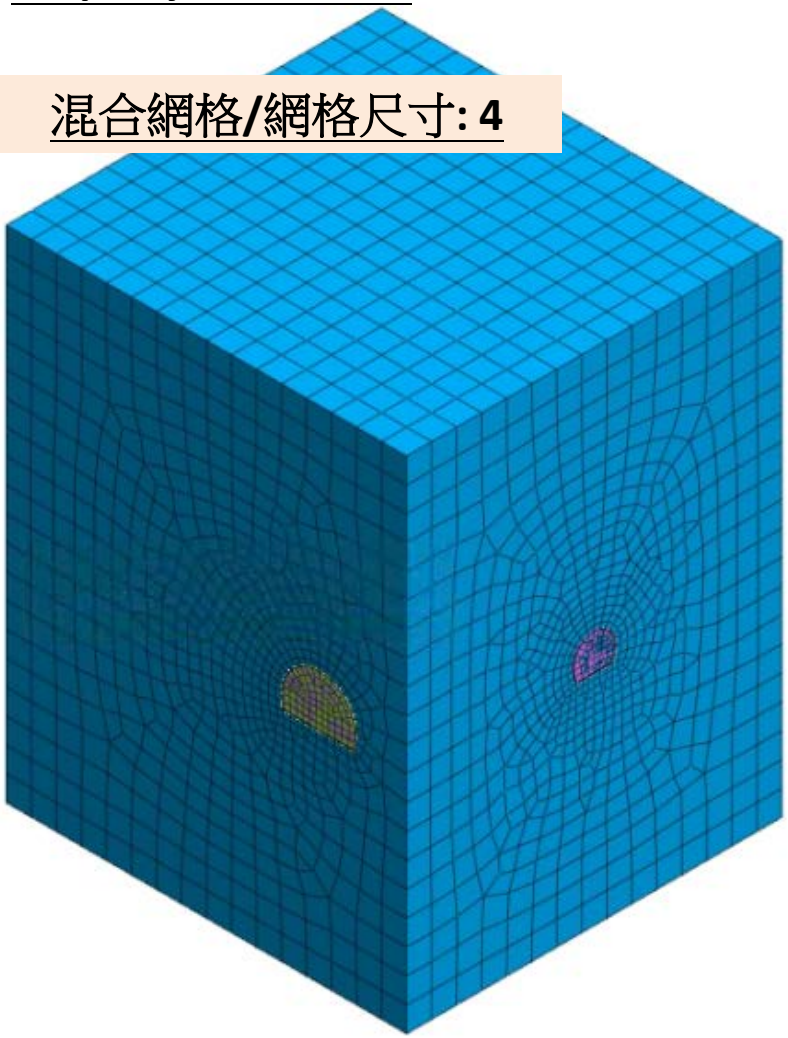


註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

3D網格生成-地層區域

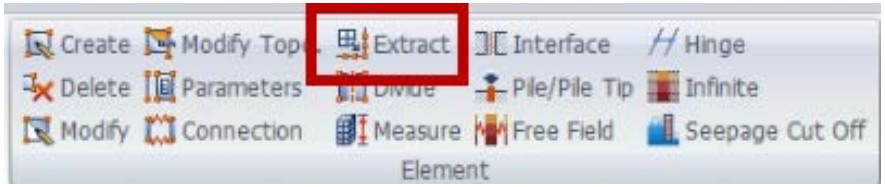
Mesh Set : Hard Rock-1
Property: Hard Rock

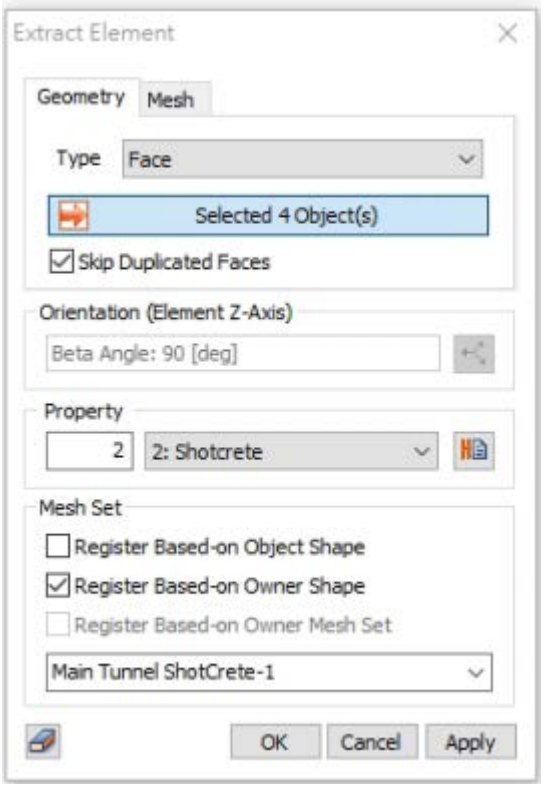
混合網格/網格尺寸: **4**



2D網格生成-噴射混凝土-1

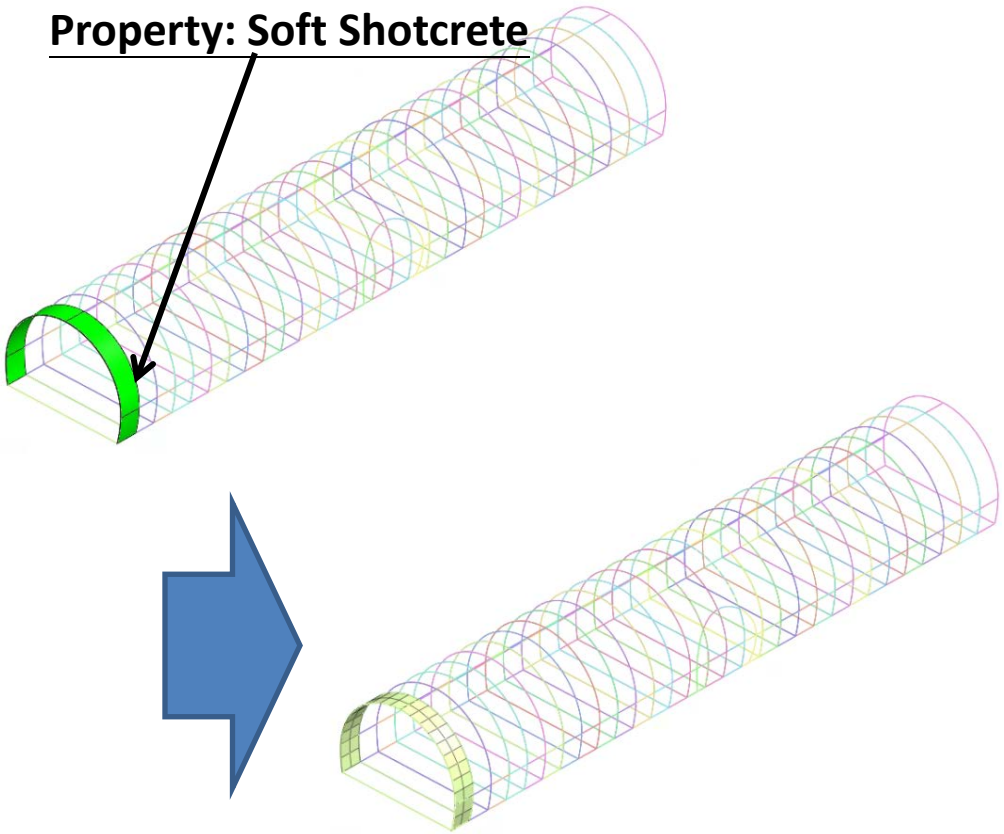
(Main Tunnel ShotCrete)





Mesh Set: Main Tunnel ShotCrete-1

Property: Soft Shotcrete



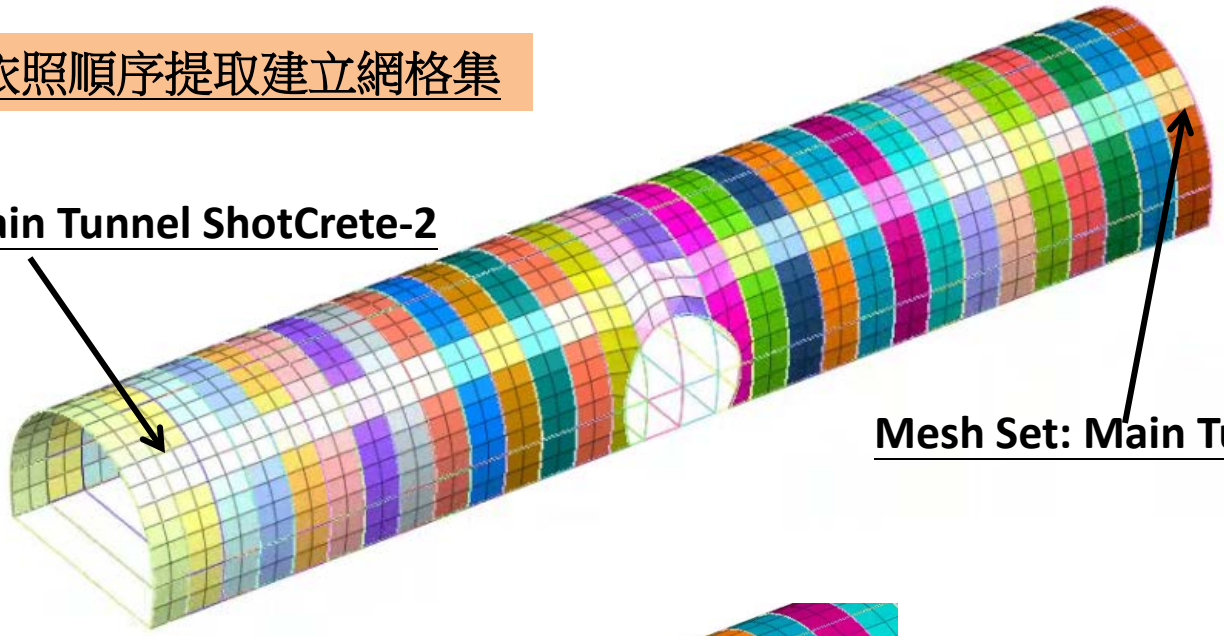
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

2D網格生成-噴射混凝土-2

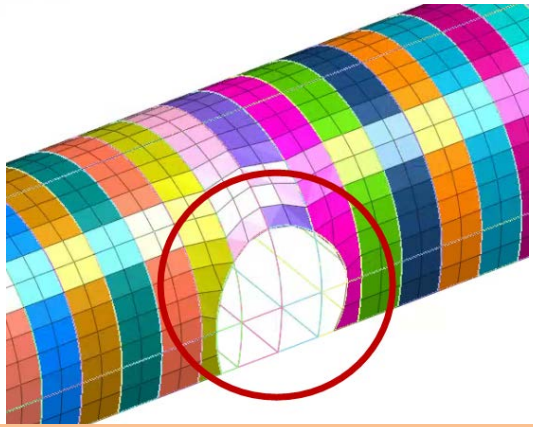
(Main Tunnel ShotCrete)

依照順序提取建立網格集

Mesh Set: Main Tunnel ShotCrete-2



Mesh Set: Main Tunnel ShotCrete-30

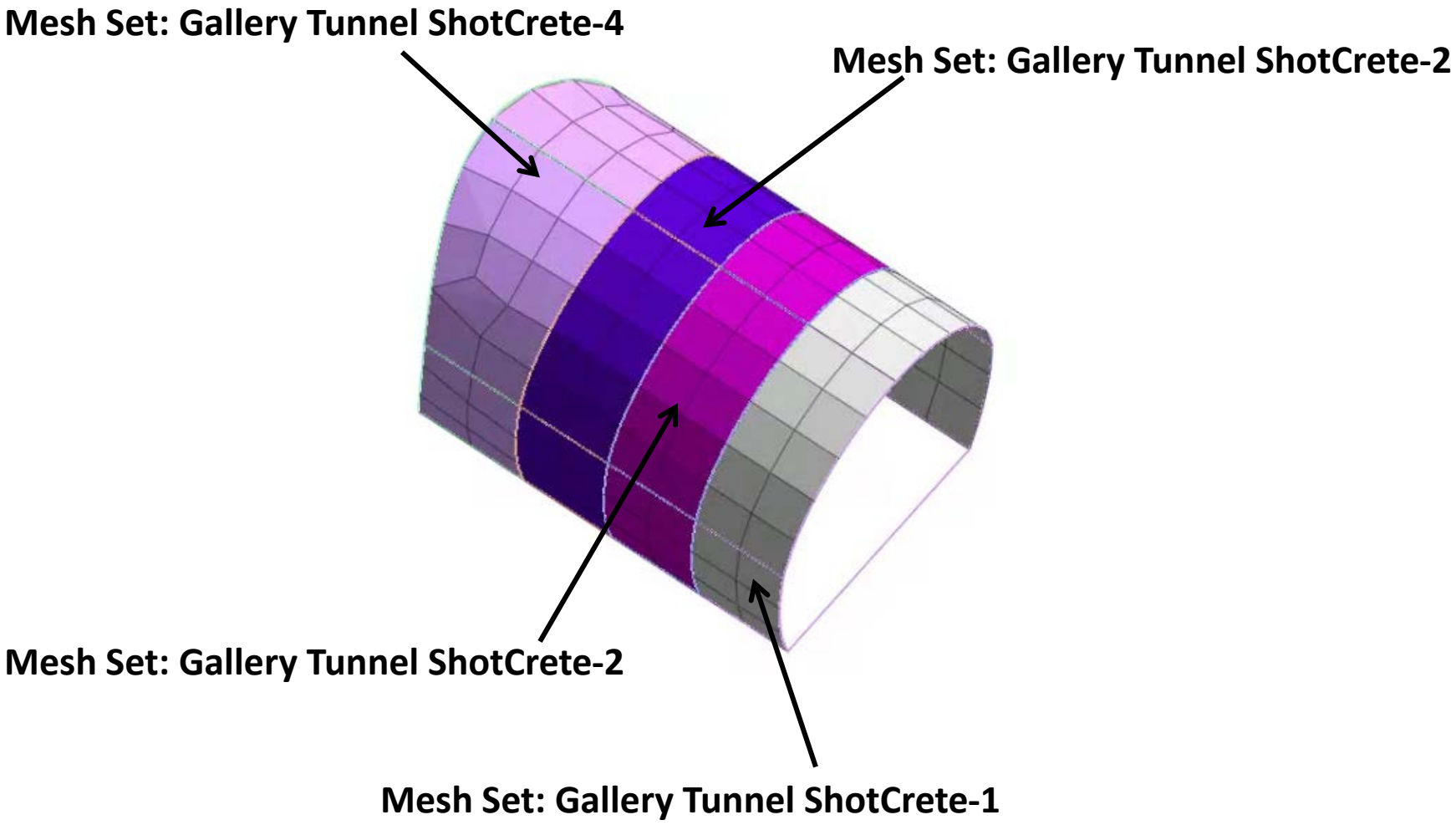


不提取主隧道和連廊隧道連接區域

註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

2D網格生成-噴射混凝土-3

(Gallery Tunnel ShotCrete)

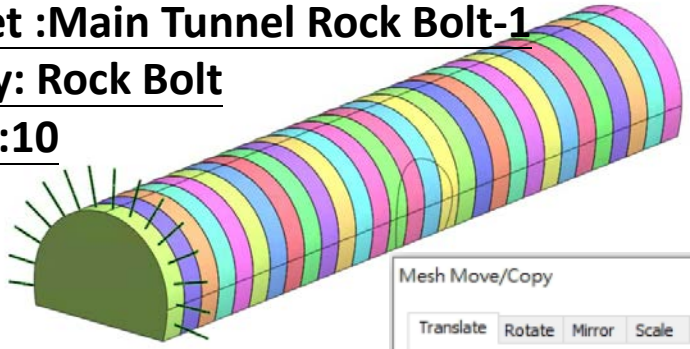


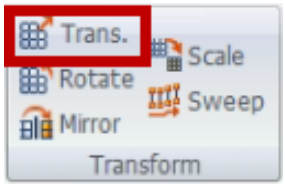
註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

1D網格生成-岩石螺栓-1

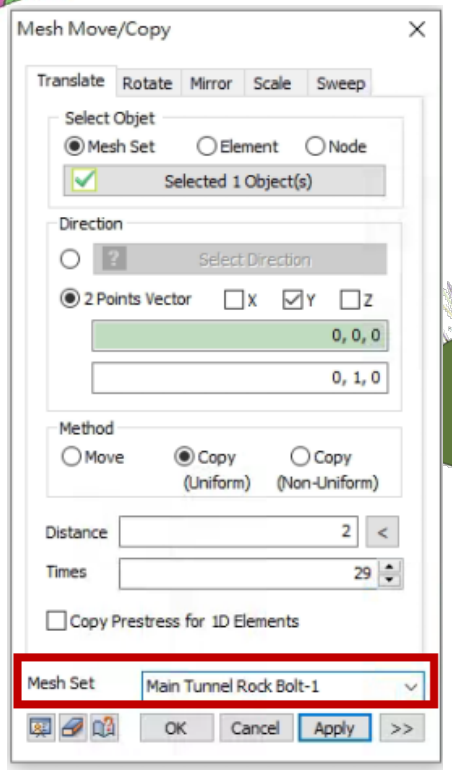
(主隧道岩石螺栓)

Mesh Set :Main Tunnel Rock Bolt-1
Property: Rock Bolt
Division:10

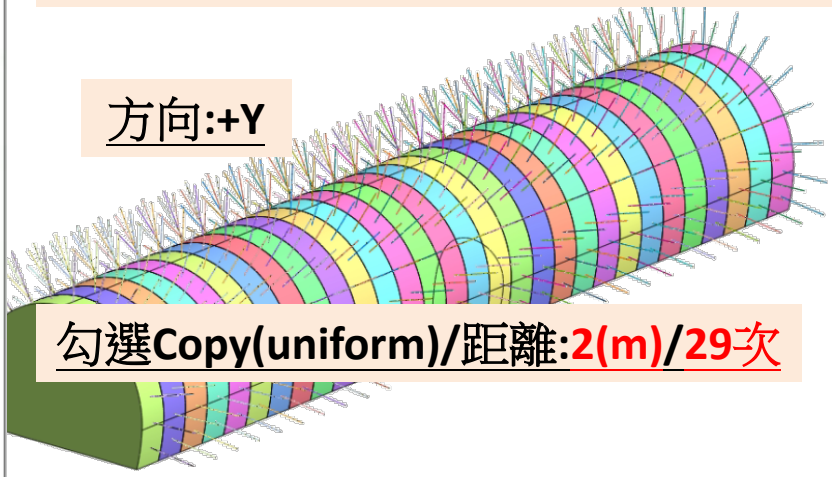




選取網格集(Main Tunnel Rock Bolt-1)



方向:+Y



勾選Copy(uniform)/距離:2(m)/29次

網格集選Main Tunnel Rock Bolt-1
(複製網格集會自動增量排序)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

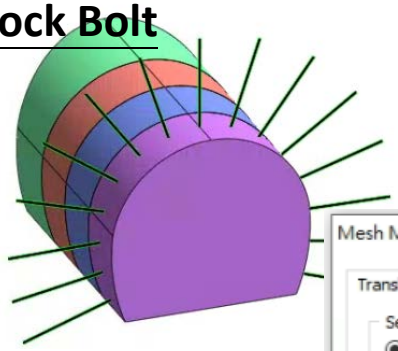
1D網格生成-岩石螺栓-2

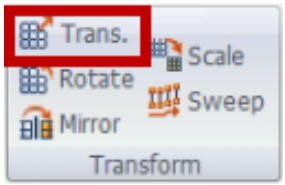
(連廊隧道岩石螺栓)

Mesh Set :Gallery Tunnel Rock Bolt-1

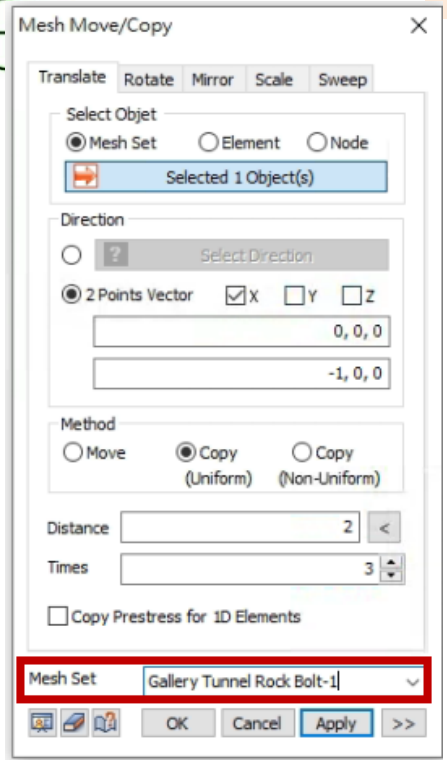
Property: Rock Bolt

Division:10

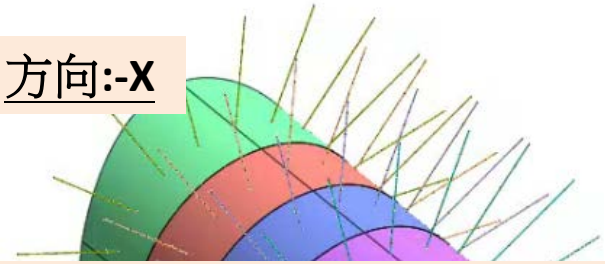




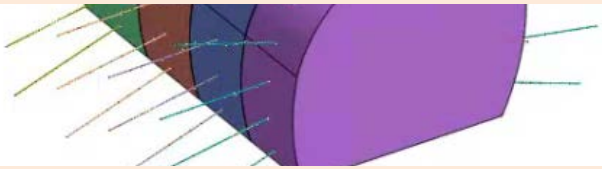
選取網格集(Gallery Tunnel Rock Bolt-1)



方向:-X



勾選Copy(uniform)/距離:2(m)/3次

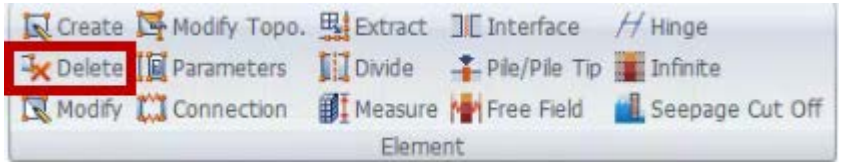


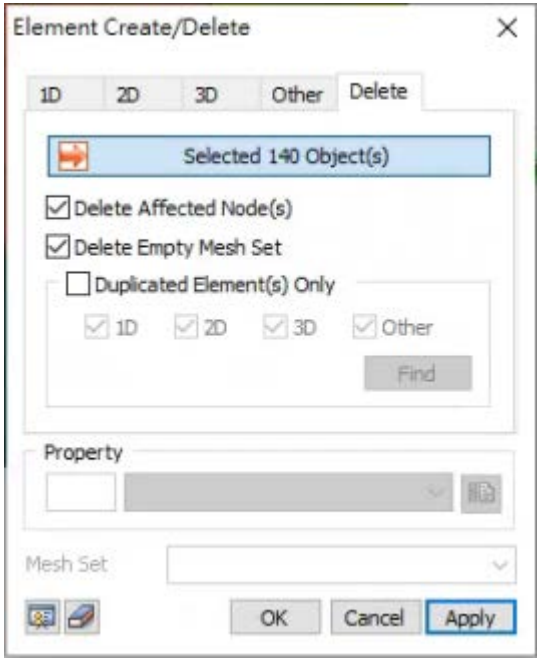
網格集選Gallery Tunnel Rock Bolt-1

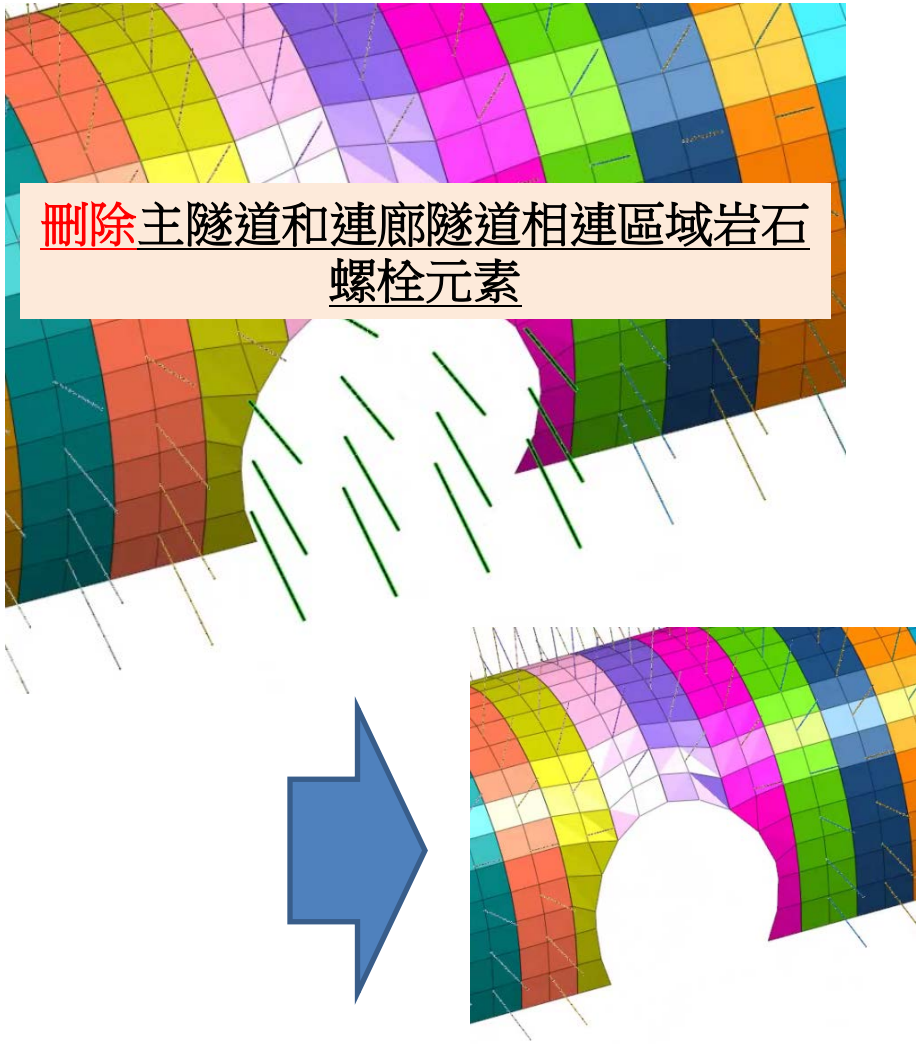
(複製網格集會自動增量排序)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

1D網格刪除-岩石螺栓

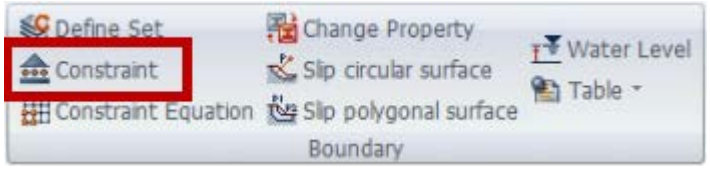

Create
Modify Topo.
Extract
Interface
Hinge
Delete
Parameters
Divide
Pile/Pile Tip
Infinite
Modify
Connection
Measure
Free Field
Seepage Cut Off
Element


Element Create/Delete
1D
2D
3D
Other
Delete
Selected 140 Object(s)
Delete Affected Node(s)
Delete Empty Mesh Set
Duplicated Element(s) Only
1D
2D
3D
Other
Find
Property
Mesh Set
OK
Cancel
Apply


刪除主隧道和連廊隧道相連區域岩石螺栓元素

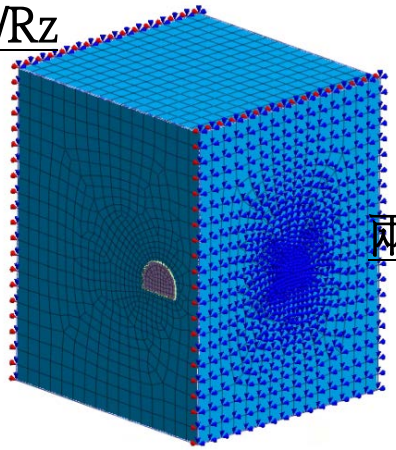
Part3. 邊界/載荷

邊界-拘束



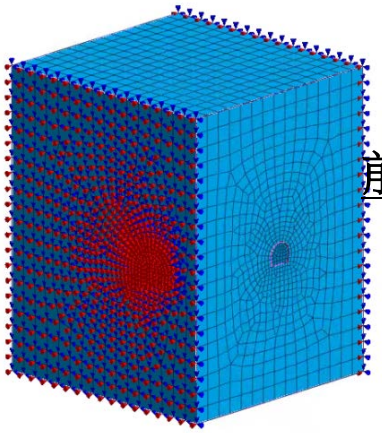
使用Face特徵選取節點

兩側Tx/Ry/Rz

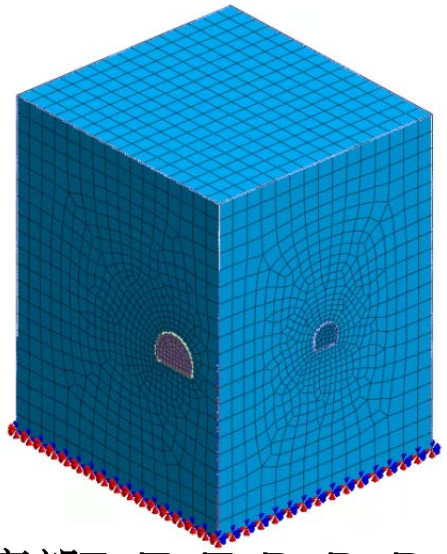


兩側Tx/Ry/Rz

前後Ty/Rx/Rz



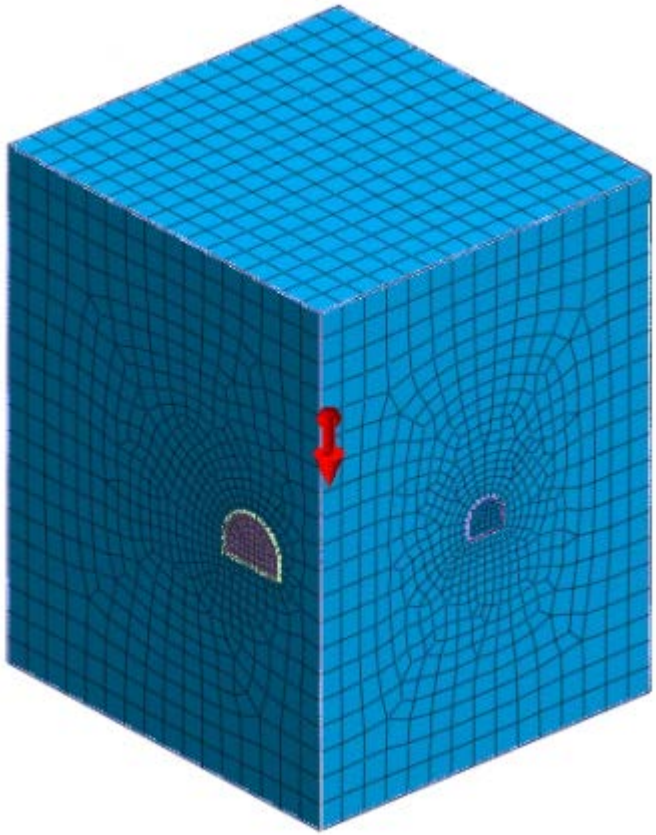
前後Ty/Rx/Rz



底部Tx/Ty/Tz/Rx/Ry/Rz

自重


Self Weight
Force
Moment
Disp.
Press.
Water Pressure
Arbitrary Load
Beam Load
Nodal Temperature
Element Temperature
Temperature Gradient
Prestress
Initial Equilibrium Force
Define Set
Comb. Set
From Results
Contraction
Prescribed strain
Table
Load



Part4.施工階段定義

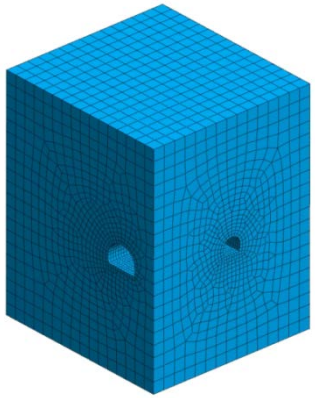
(施工階段嚮導)

註:施工階段嚮導適合規律施工過程定義

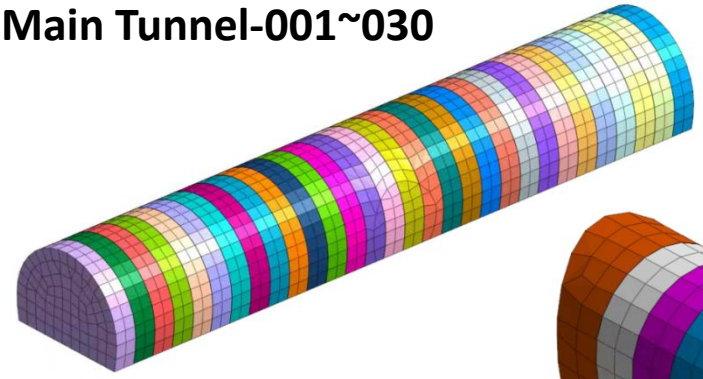
隧道開挖前-初始條件

網格集

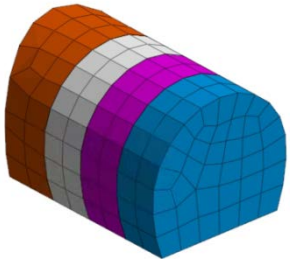
Hard Rock-1



Main Tunnel-001~030



Gallery Tunnel-001~004

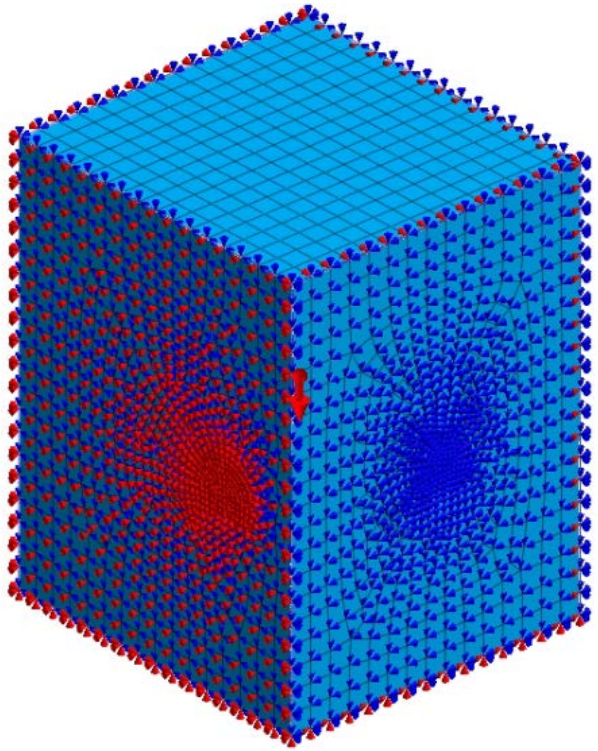


邊界集

Boundary Set-1~3

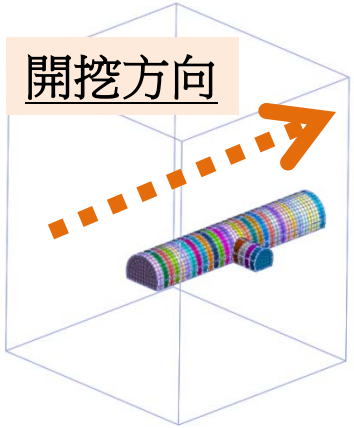
載荷集

Gravity-1



註:施工階段嚮導，依照網格集名稱順序編輯施工階段 。

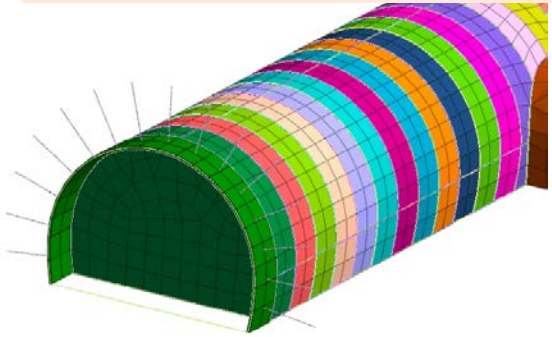
主隧道開挖-重覆施工過程



Step1. 隧道開挖

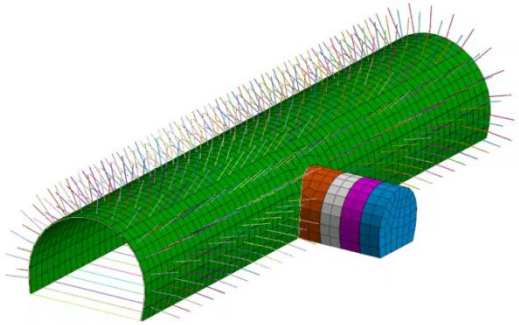
移除網格集:
Main Tunnel-001

Step2.噴射混凝土&岩栓



新增網格集:
Main Tunnel ShotCrete-1
Main Tunnel Rock Bolt-1

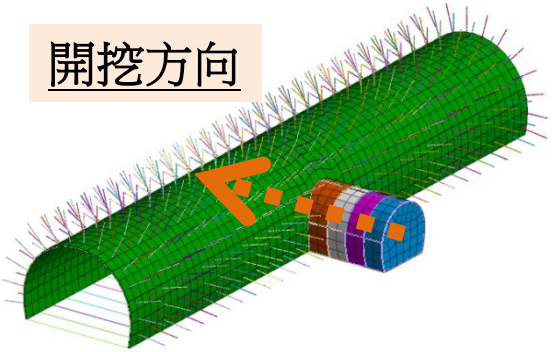
重覆施工~主隧道貫穿



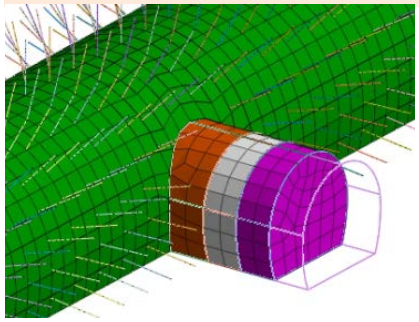
註1:重覆相同施工過程至隧道貫穿。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段。

連廊隧道開挖-重覆施工過程

開挖方向

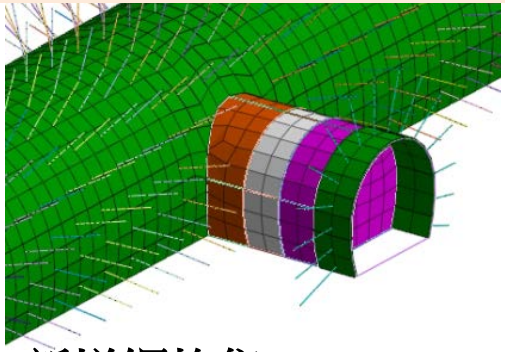


Step1. 隧道開挖



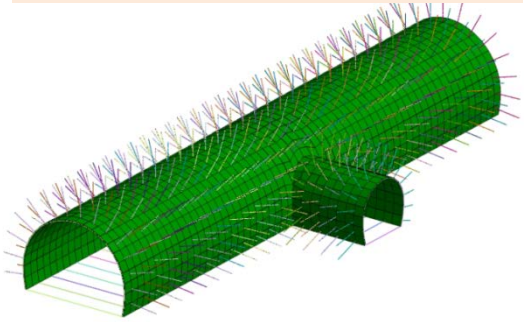
移除網格集:
Gallery Tunnel-001

Step2.噴射混凝土&岩栓



新增網格集:
Gallery Tunnel ShotCrete-1
Gallery Tunnel Rock Bolt-1

重覆施工~連廊隧道連接主隧道



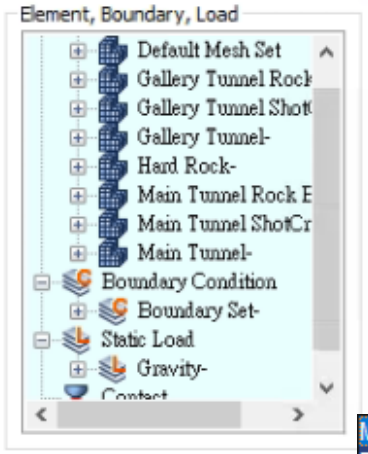
註1:重覆相同施工過程至連廊隧道連接主隧道。
註2:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段嚮導模組

大集合-起始尾碼

大集合-結束尾碼

大集合-間隔選取



Construction Stage Set: Construction Stage Set-1

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix I	Start%cStage Value	Stage%cInc. Value
	Mesh set	Gallery Tunnel-	A	1	☑	4	1	0	0
	Mesh set	Hard Rock-	A	1	☑	1	1	0	0
	Mesh set	Main Tunnel-	A	1	☑	30	1	0	0
	Boundary Set	Boundary Set-	A	1	☑	3	1	0	0
	Load Set	Gravity-	A	1	☑	1	1	0	0
*					☐				

Mesh set
Boundary Set
Load Set

A:新增
R:移除

F:範圍內全包含
(起始尾碼~結束尾碼)

起始工況

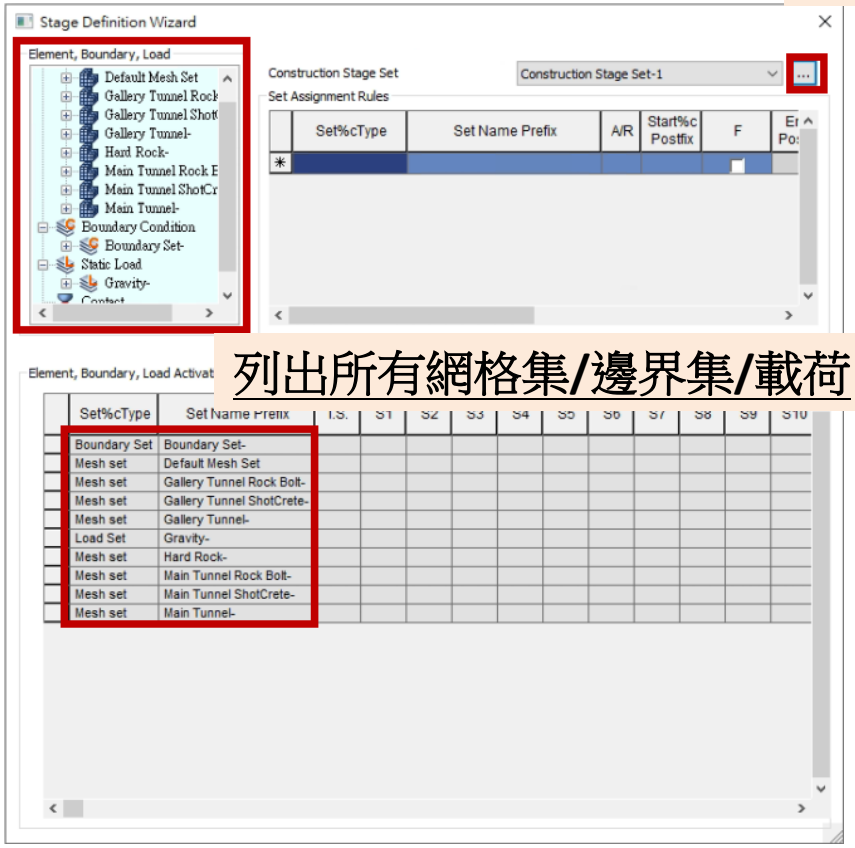
集合配合工況
增量施加

註1: (Name)-1 to (Name)-999 視為同一大集合,未加(-)不視作同一大集合

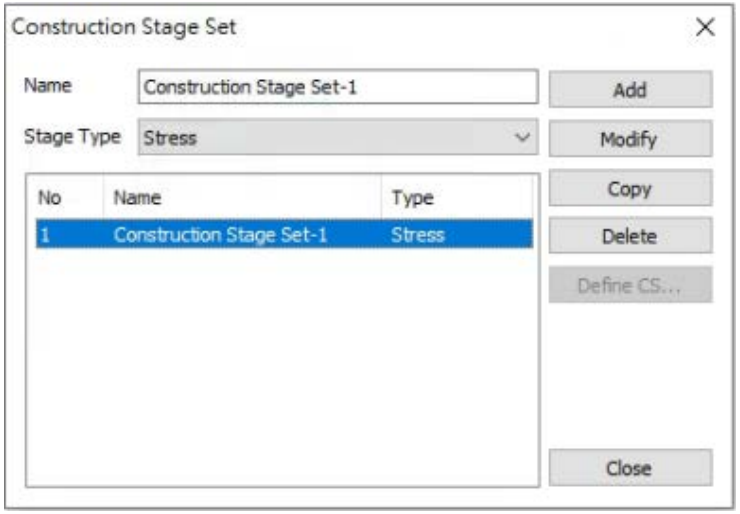
註2: I.S.=>Initial Stage=0 ,S1=>Stage1=1

施工階段-1

新增施工階段



列出所有網格集/邊界集/載荷



施工階段-2
(初始條件)

Construction Stage Set　Construction Stage Set-1　...　依序指定

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	Gallery Tunnel-	A	1	☑	4	1	0	0
	Mesh set	Hard Rock-	A	1	☑	1	1	0	0
	Mesh set	Main Tunnel-	A	1	☑	30	1	0	0
	Boundary Set	Boundary Set-	A	1	☑	3	1	0	0
	Load Set	Gravity-	A	1	☑	1	1	0	0
*					☐				

Apply Assignment Rules　OK

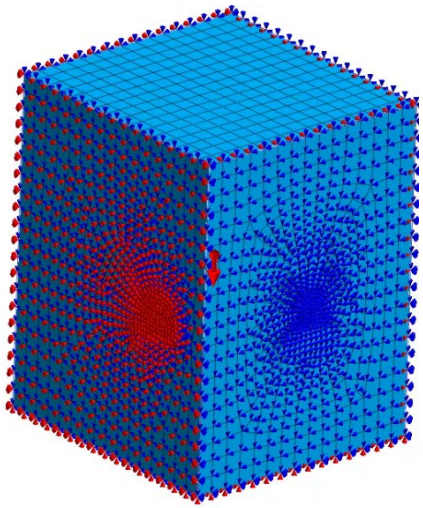
Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2
	Boundary Set	Boundary Set-	A: 1to3		
	Mesh set	Default Mesh Set			
	Mesh set	Gallery Tunnel Rock Bolt-			
	Mesh set	Gallery Tunnel ShotCrete-			
	Mesh set	Gallery Tunnel-	A: 1to4		
	Load Set	Gravity-	A: 1		
	Mesh set	Hard Rock-	A: 1		
	Mesh set	Main Tunnel Rock Bolt-			
	Mesh set	Main Tunnel ShotCrete-			
	Mesh set	Main Tunnel-	A: 1to30		

<u>邊界集</u>
Boundary Set-1~3

<u>載荷集</u>
Gravity-1

<u>網格集</u>
Hard Rock-1
Main Tunnel-001~030
Gallery Tunnel-001~004



註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-3
(主隧道開挖定義)

依序指定

Construction Stage Set: Construction Stage Set-1

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc Value
	Mesh set	Main Tunnel-	R	1	☑	30	1	1	2
*					☐				

間隔2個工況施作1次

R:移除

第1個工況開始進行隧道開挖

Apply Assignment Rules | OK | Cancel

Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17
	Boundary Set	Boundary Set-	A: 1to3																	
	Mesh set	Default Mesh Set																		
	Mesh set	Gallery Tunnel Rock Bolt-																		
	Mesh set	Gallery Tunnel ShotCrete-																		
	Mesh set	Gallery Tunnel-	A: 1to4																	
	Load Set	Gravity-	A: 1																	
	Mesh set	Hard Rock-	A: 1																	
	Mesh set	Main Tunnel Rock Bolt-																		
	Mesh set	Main Tunnel ShotCrete-																		
	Mesh set	Main Tunnel-	A: 1to30	R: 1		R: 2		R: 3		R: 4		R: 5								

移除網格集:
Main Tunnel-001~030
(間隔2個工況施作1次)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-4

(主隧道噴射混凝土&岩栓定義)

依序指定

Construction Stage Set-1 ...

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	Main Tunnel Rock Bolt-	A	1	☑	30	1	2	2
	Mesh set	Main Tunnel ShotCrete-	A	1	☑	30	1	2	2
✳					☐				

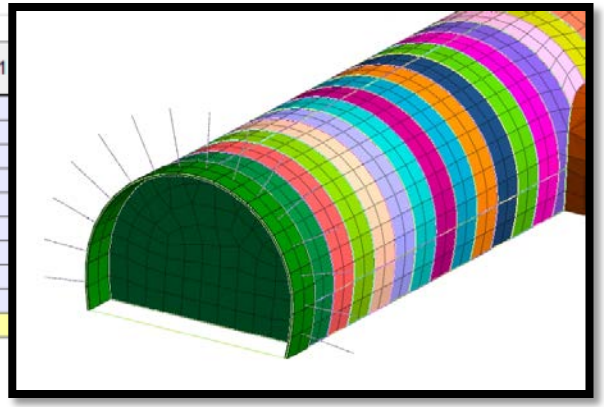
間隔2個工況施作1次

第2個工況開始進行

Apply Assignment Rules OK Cancel

Element, Boundary, Load Activation Status

	Set%cType	Set Name Prefix	I.S.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11
	Boundary Set	Boundary Set-	A: 1to3											
	Mesh set	Default Mesh Set												
	Mesh set	Gallery Tunnel Rock Bolt-												
	Mesh set	Gallery Tunnel ShotCrete-												
	Mesh set	Gallery Tunnel-	A: 1to4											
	Load Set	Gravity-	A: 1											
	Mesh set	Hard Rock-	A: 1											
	Mesh set	Main Tunnel Rock Bolt-			A: 1		A: 2		A: 3		A: 4		A: 5	
	Mesh set	Main Tunnel ShotCrete-			A: 1		A: 2		A: 3		A: 4		A: 5	
	Mesh set	Main Tunnel-	A: 1to30	R: 1		R: 2		R: 3		R: 4		R: 5		R: 6



新增網格集:

Main Tunnel Rock Bolt-1~30

Main Tunnel ShotCrete-1~30

(間隔2個工況施作1次)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-5
(連廊隧道開挖定義)

Construction Stage Set: Construction Stage Set-1

依序指定

間隔2個工況施作1次

Set Assignment Rules

	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	Gallery Tunnel-	R	1	☑	4	1	61	2
*					☐				

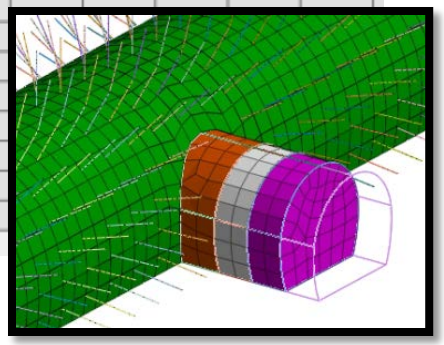
R:移除

第61個工況開始進行隧道開挖

Apply Assignment Rules | OK | Cancel

Element, Boundary, Load Activation Status

S55	S56	S57	S58	S59	S60	S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72	S73	S74
						R: 1		R: 2		R: 3		R: 4							
	A: 28		A: 29		A: 30														
	A: 28		A: 29		A: 30														
R: 28		R: 29		R: 30															



移除網格集:
Gallery Tunnel-001~004
(間隔2個工況施作1次)

註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-6

(連廊隧道噴射混凝土&岩栓定義)

Construction Stage Set: Construction Stage Set-1 ...

依序指定 間隔2個工況施作1次

Set Assignment Rules

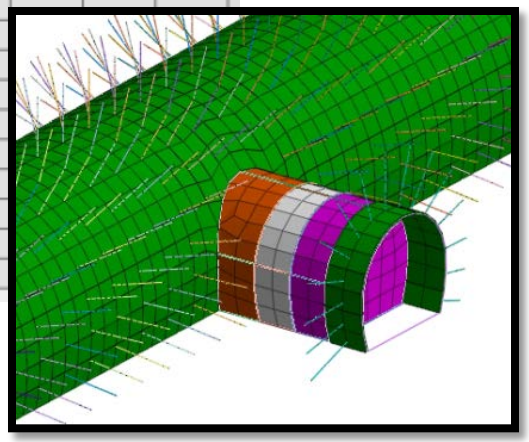
	Set%cType	Set Name Prefix	A/R	Start%c Postfix	F	End Postfix	Postfix Inc.	Start%cStage Value	Stage%cInc. Value
	Mesh set	Gallery Tunnel Rock Bolt-	A	1	☑	4	1	62	2
	Mesh set	Gallery Tunnel ShotCrete-	A	1	☑	4	1	62	2
✳					☐				

第62個工況開始進行

Apply Assignment Rules | OK | Cancel

Element, Boundary, Load Activation Status

	S55	S56	S57	S58	S59	S60	S61	S62	S63	S64	S65	S66	S67	S68	S69	S70	S71	S72
								A: 1		A: 2		A: 3		A: 4				
								A: 1		A: 2		A: 3		A: 4				
							R: 1		R: 2		R: 3		R: 4					
		A: 28		A: 29		A: 30												
		A: 28		A: 29		A: 30												
	R: 28		R: 29															



新增網格集:

Gallery Tunnel Rock Bolt-1~4

Gallery Tunnel ShotCrete-1~4

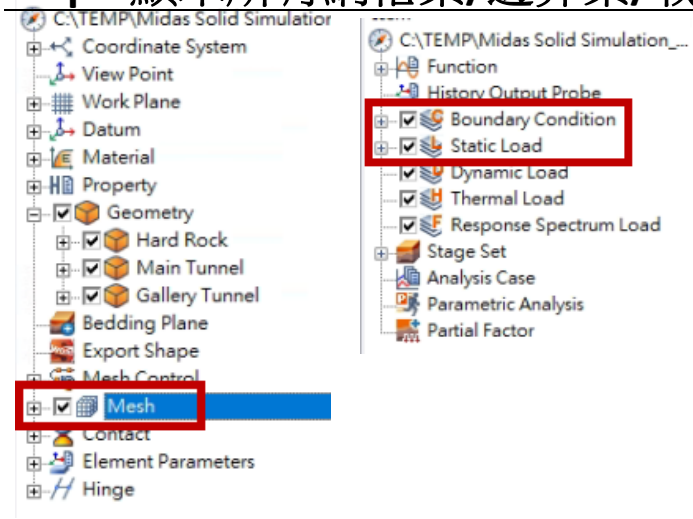
(間隔2個工況施作1次)

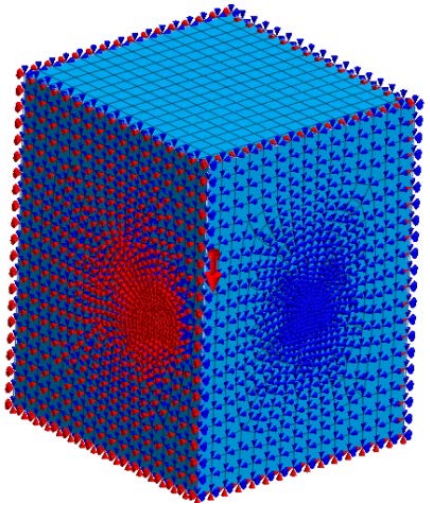
註:施工階段嚮導，依照網格集名稱順序編輯施工階段。

施工階段-7

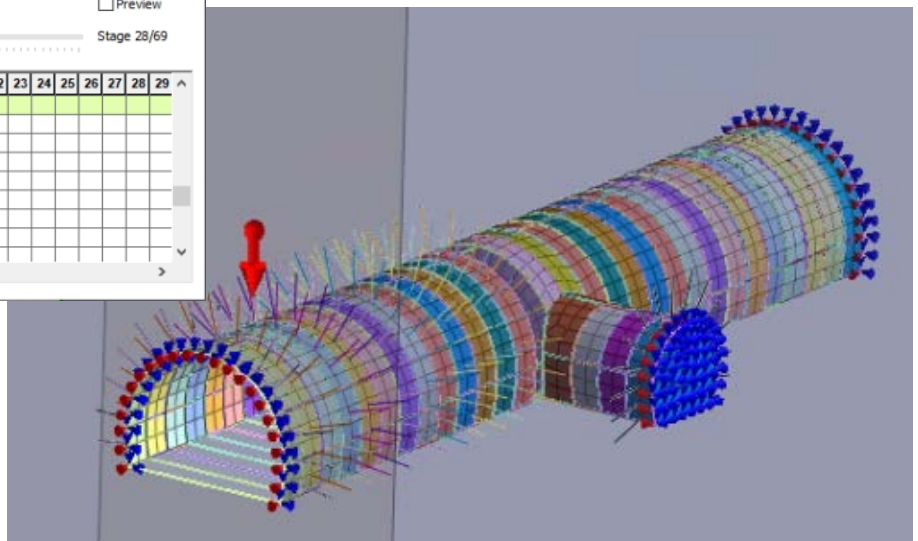
(施工過程動畫檢視)

Step1.顯示所有網格集/邊界集/載荷集





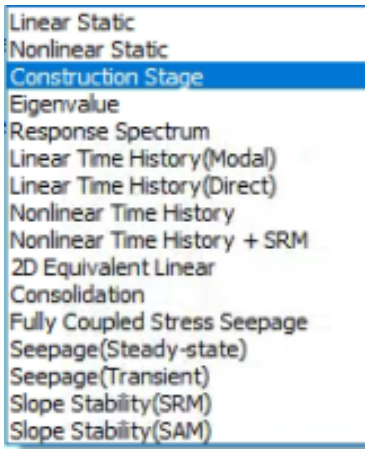
Step2.拖曳/播放檢視

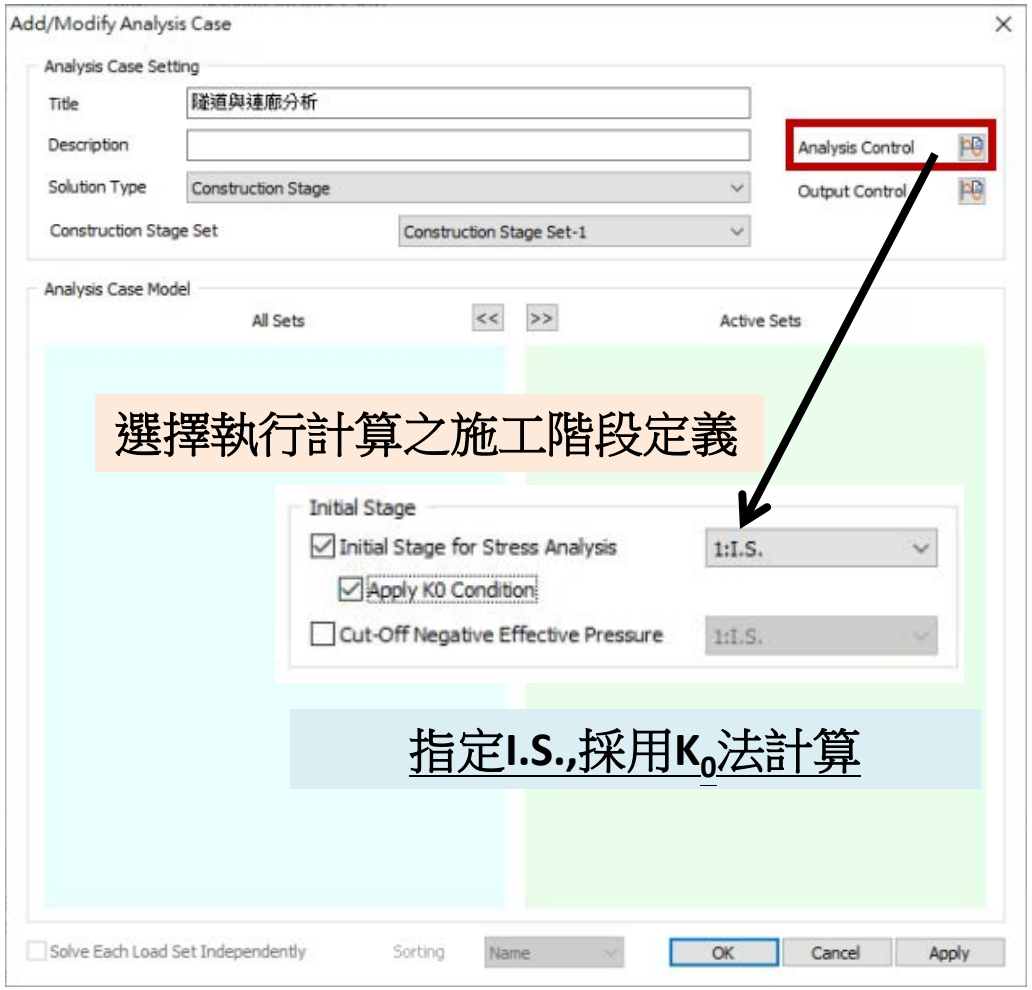


分析定義
(3D隧道與連廊分析)

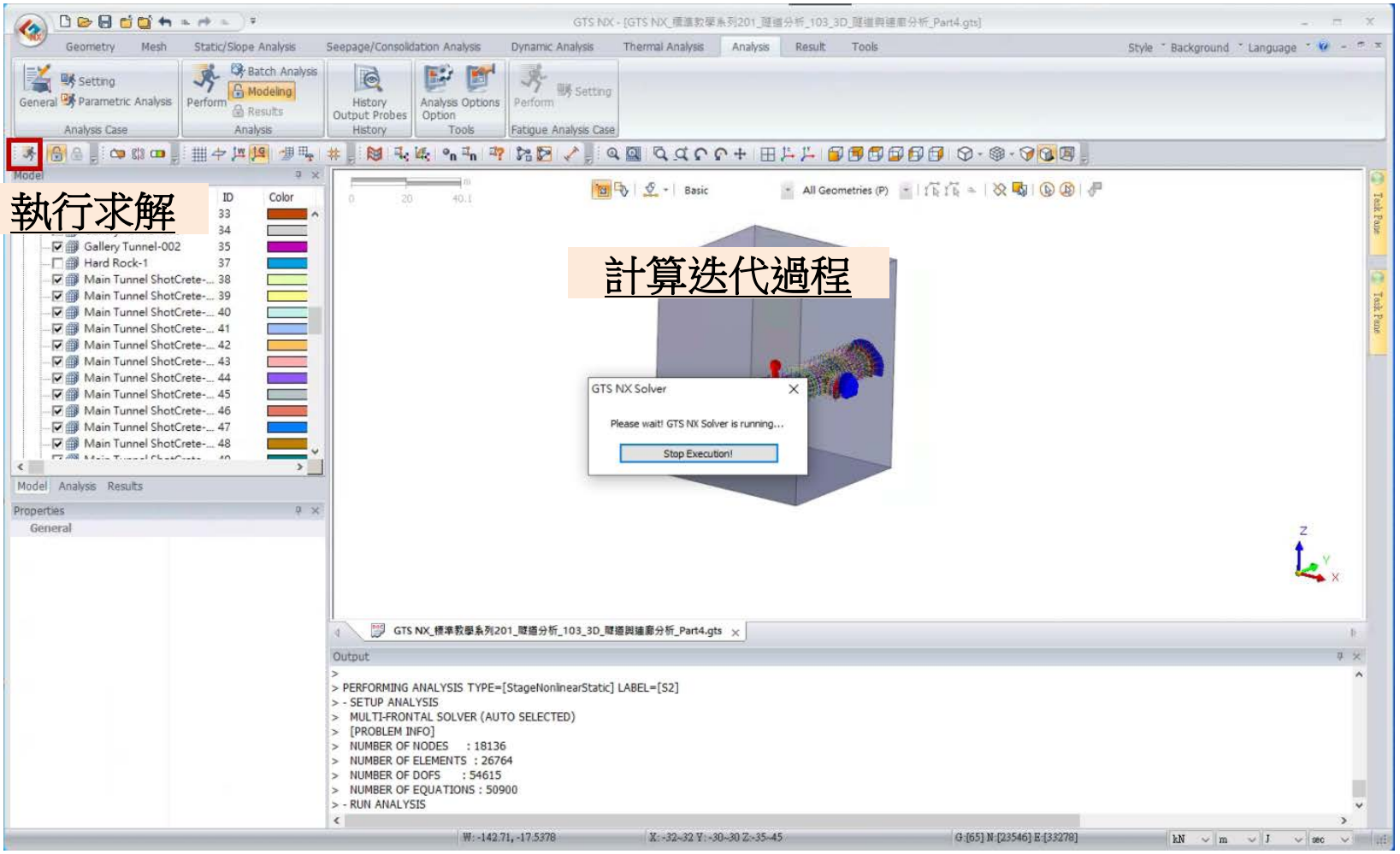
分析名稱:隧道與連廊分析/分析類型:**Construction Stage**

Construction Stage





計算

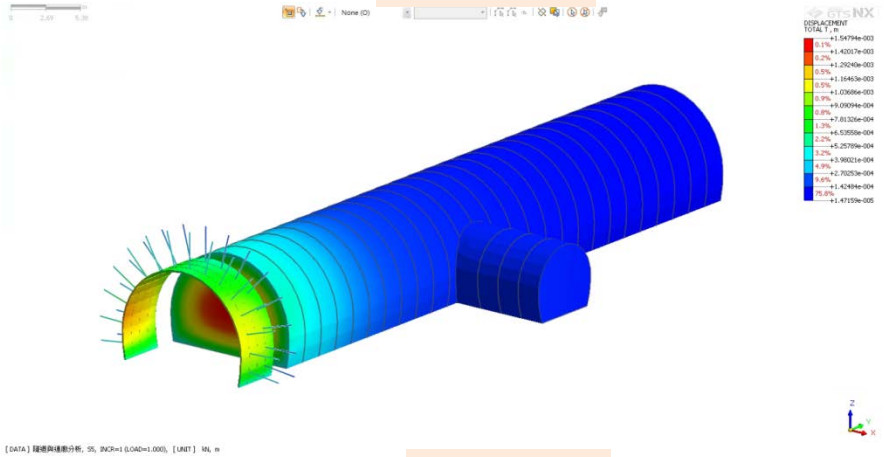

執行求解
計算迭代過程
GTS NX Solver
Please wait! GTS NX Solver is running...
Stop Execution!
> PERFORMING ANALYSIS TYPE=[StageNonlinearStatic] LABEL=[S2]
> - SETUP ANALYSIS
> MULTI-FRONTAL SOLVER (AUTO SELECTED)
> [PROBLEM INFO]
> NUMBER OF NODES : 18136
> NUMBER OF ELEMENTS : 26764
> NUMBER OF DOFS : 54615
> NUMBER OF EQUATIONS : 50900
> - RUN ANALYSIS

Part5.分析結果

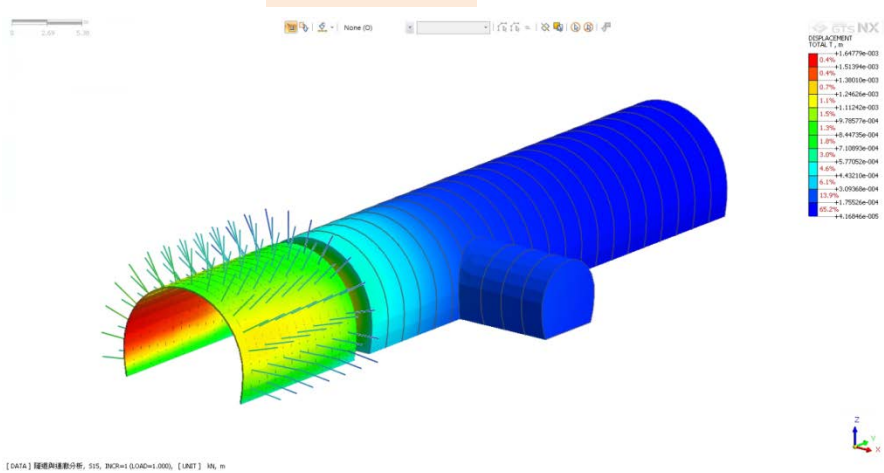
註:施工階段響導適合規律施工過程定義

分析結果-1
(Displacement)

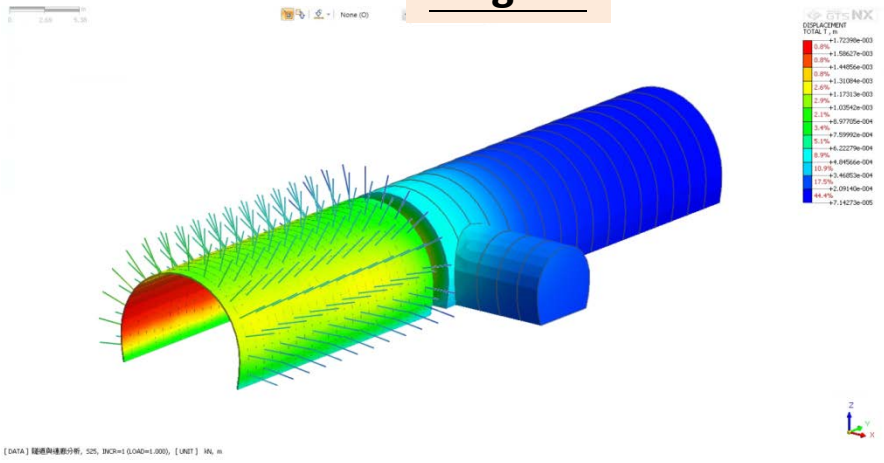
Stage5



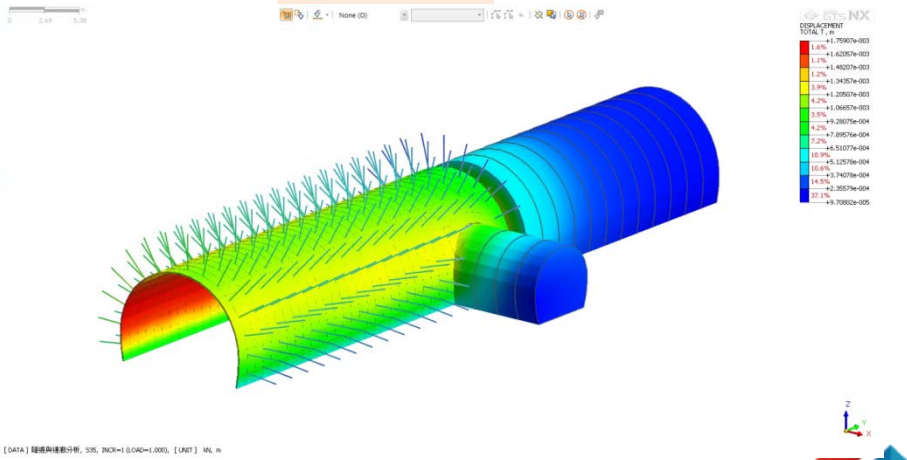
Stage15



Stage25

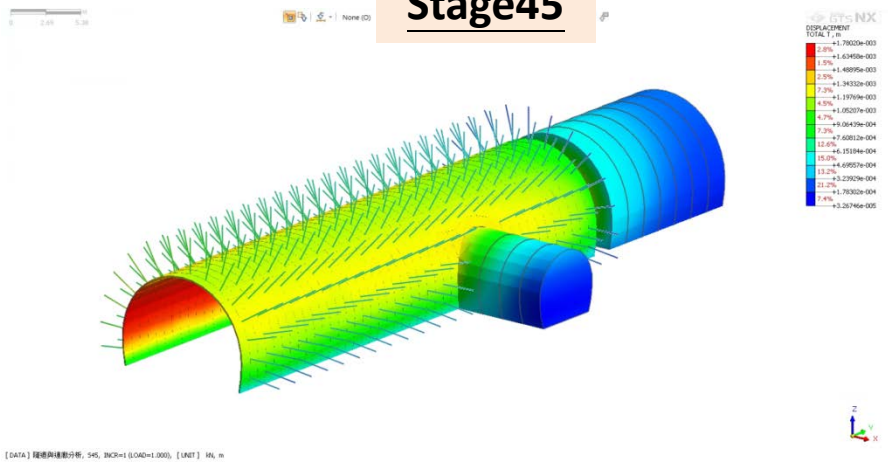


Stage35

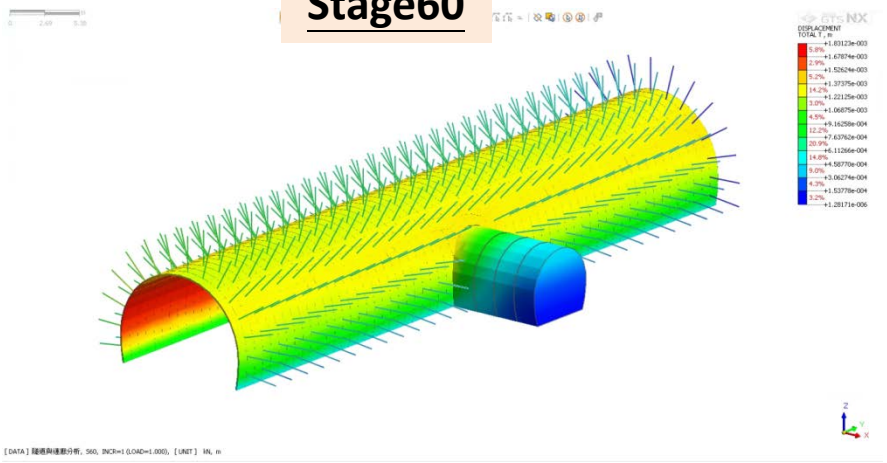


分析結果-2
(Displacement)

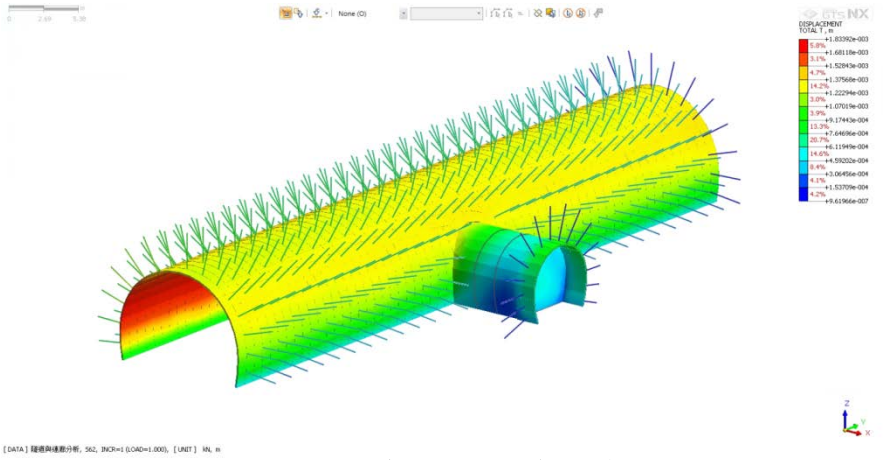
Stage45



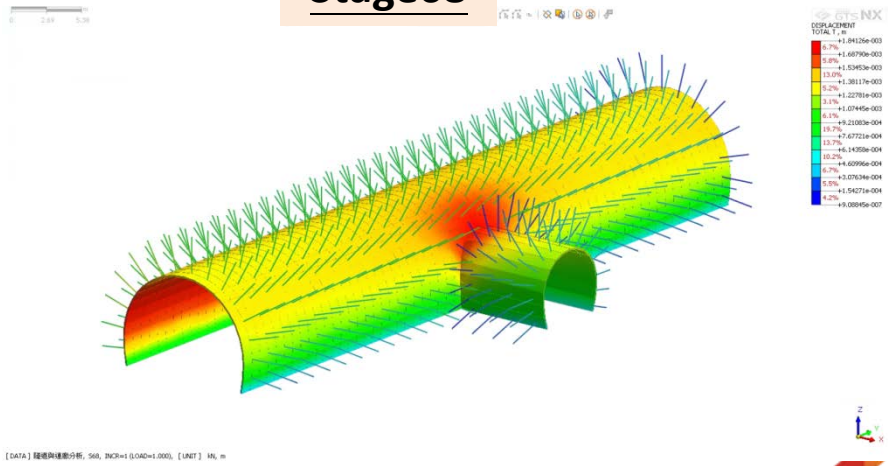
Stage60



Stage62



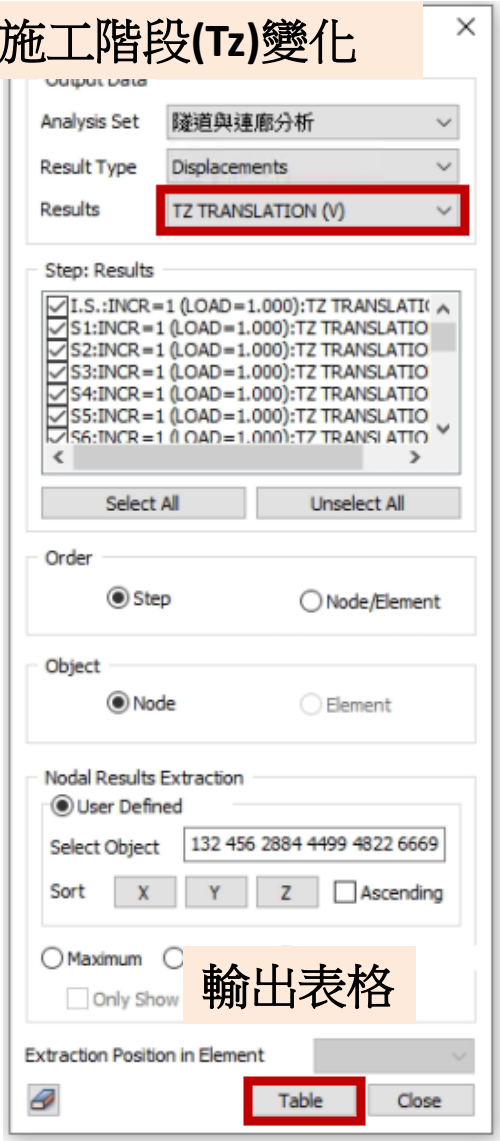
Stage68



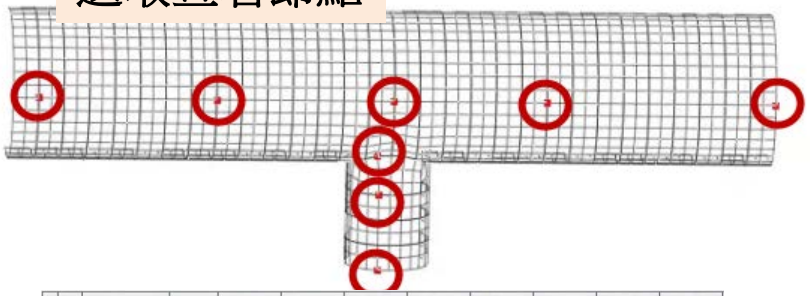
播放動畫 (施工階段)

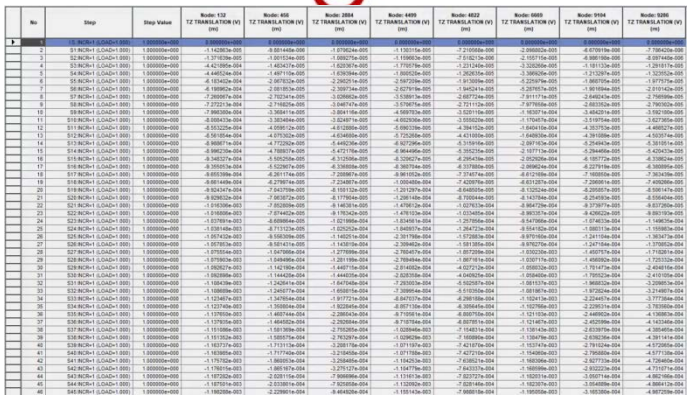
分析結果-3

查看施工階段(Tz)變化



選取查看節點





輸出表格

GTS NX提供簡易繪圖工具