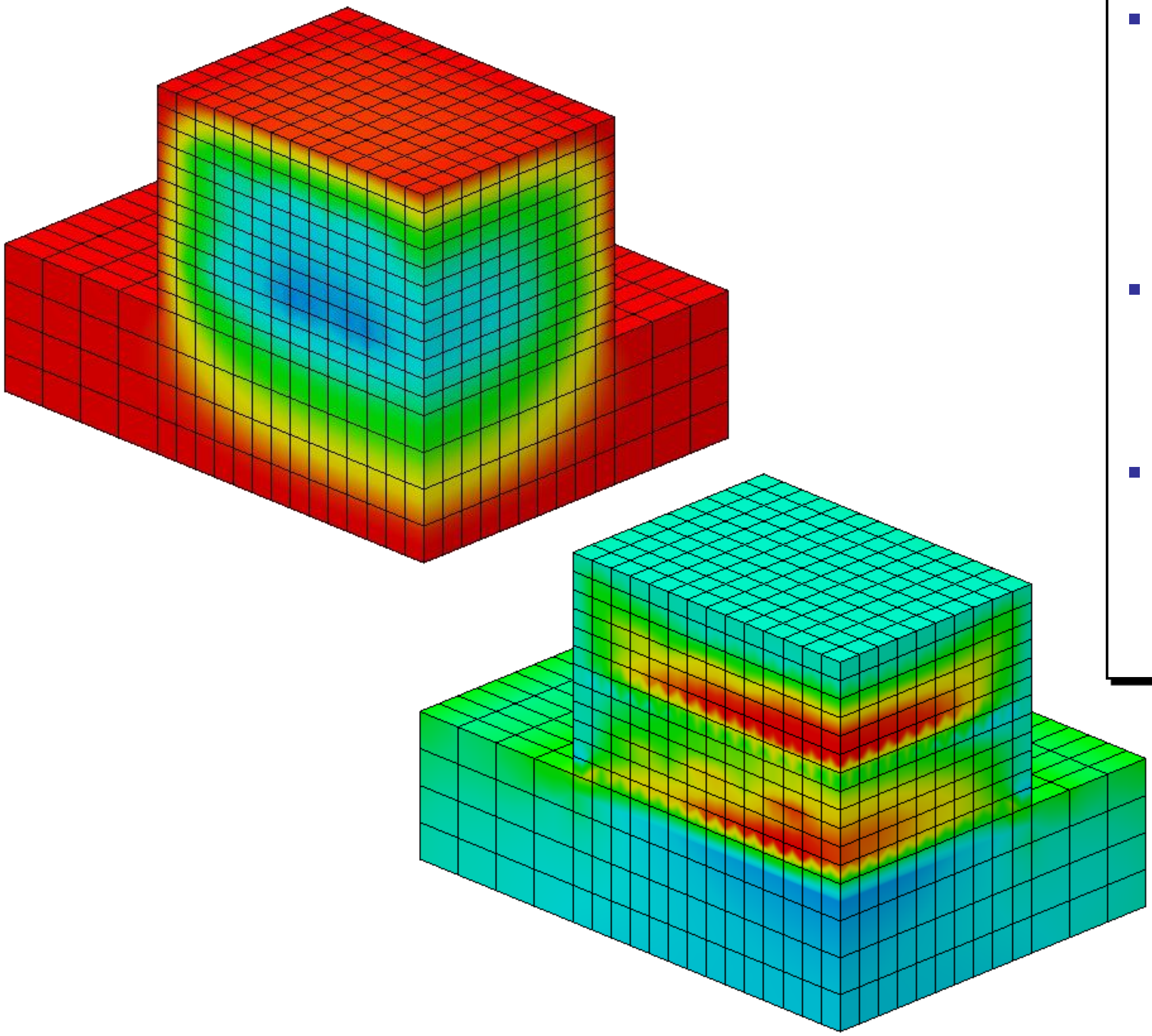
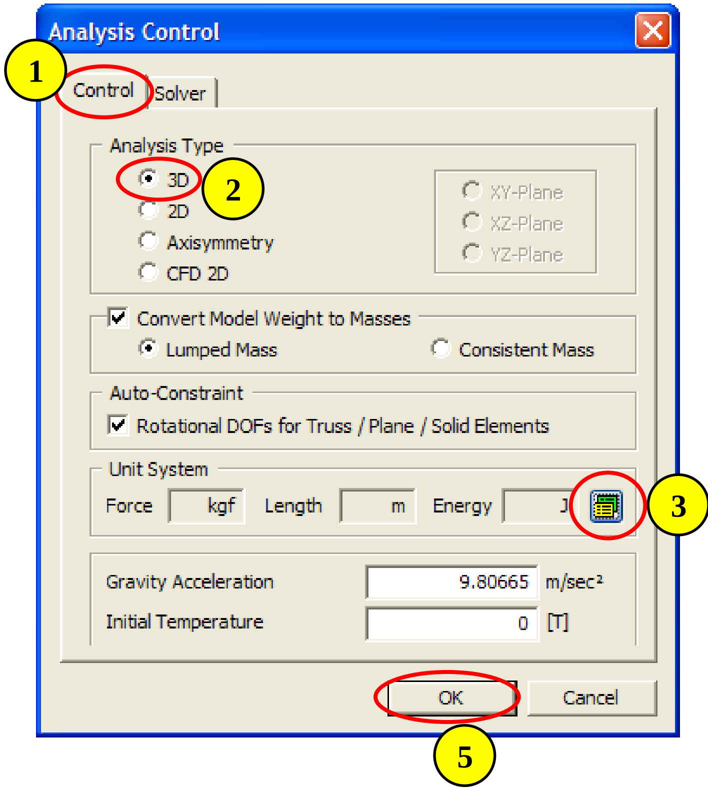
HA-1. Hydration - Pipe Cooling

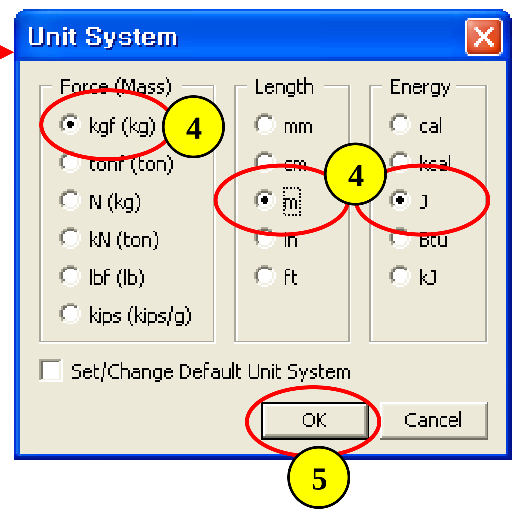


Overview

- **3-D Heat of Hydration Analysis**
- **Model**
  - *¼ Symmetric Model*
  - *Unit : kgf, m*
  - *Isotropic Elastic Material*
  - *Time Dependent Material*
  - *High-order Solid Element*
- **Load & Boundary Conditions**
  - *Constraint*
  - *Heat of Hydration Analysis*
  - *Heat of Hydration Stage*
- **Result Evaluation**
  - *Temperature*
  - *Principal Stress (P1)*
  - *Heat of Hydration Result Graphs*
  - *Animation Recording*

Step 1.





1. Analysis > Analysis Control – “Control” tab

2. Analysis Type : 3D

3. Click Button

4. Unit : kgf , m , J

5. Click [OK] Button

Analysis Control Dialog is automatically activated at startup.

Step 2.

1. Toggle off "Toggle Grid"

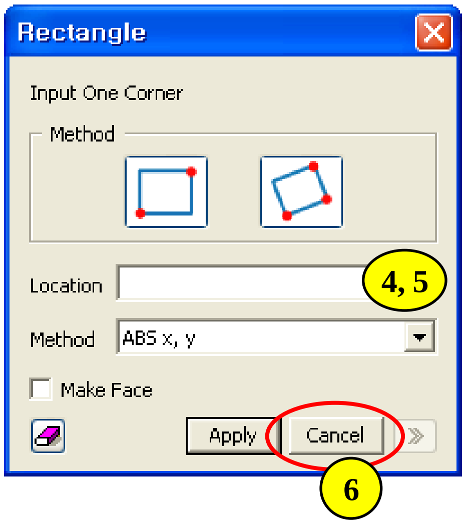
2. Click "Normal View"

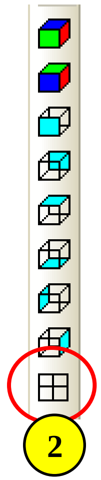
3. Geometry > Curve > Create on WP > Rectangle (Wire)...

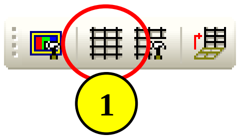
4. Location : (0), <-8.8, 6.4>

5. Location : (0), <-5.6, 4>

6. Click [Cancel] *Button*

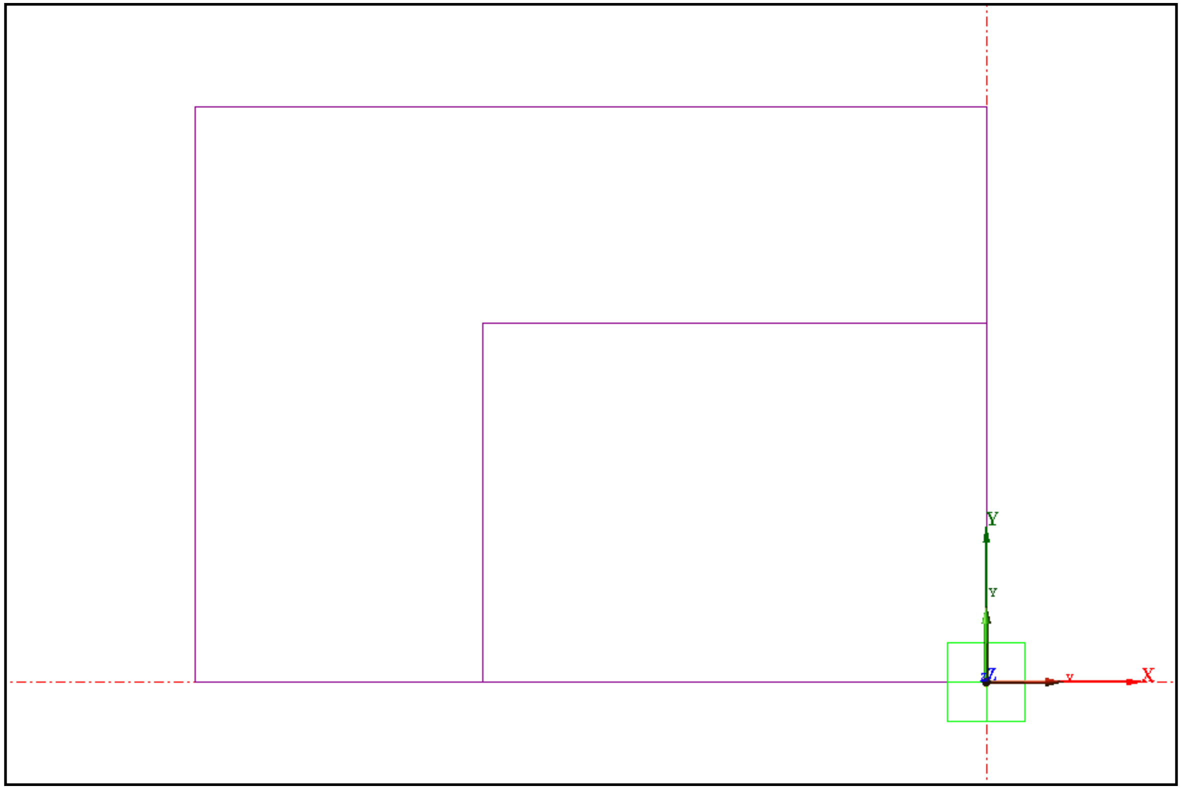






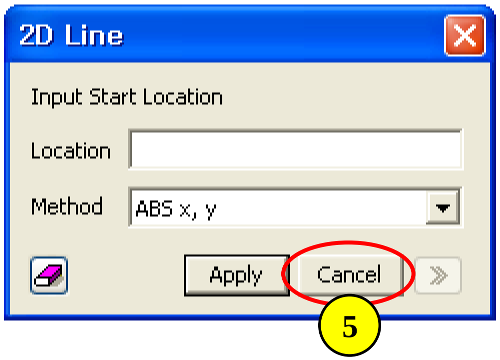
() : "ABS x, y" , <> : "REL dx, dy"
(0) same as (0, 0)

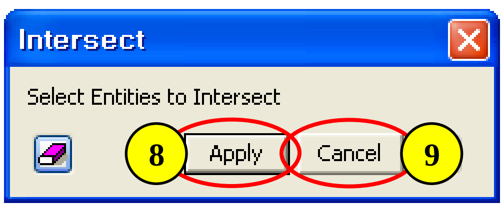
[Esc] *as shortcut for* [Cancel]

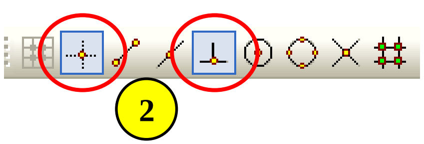


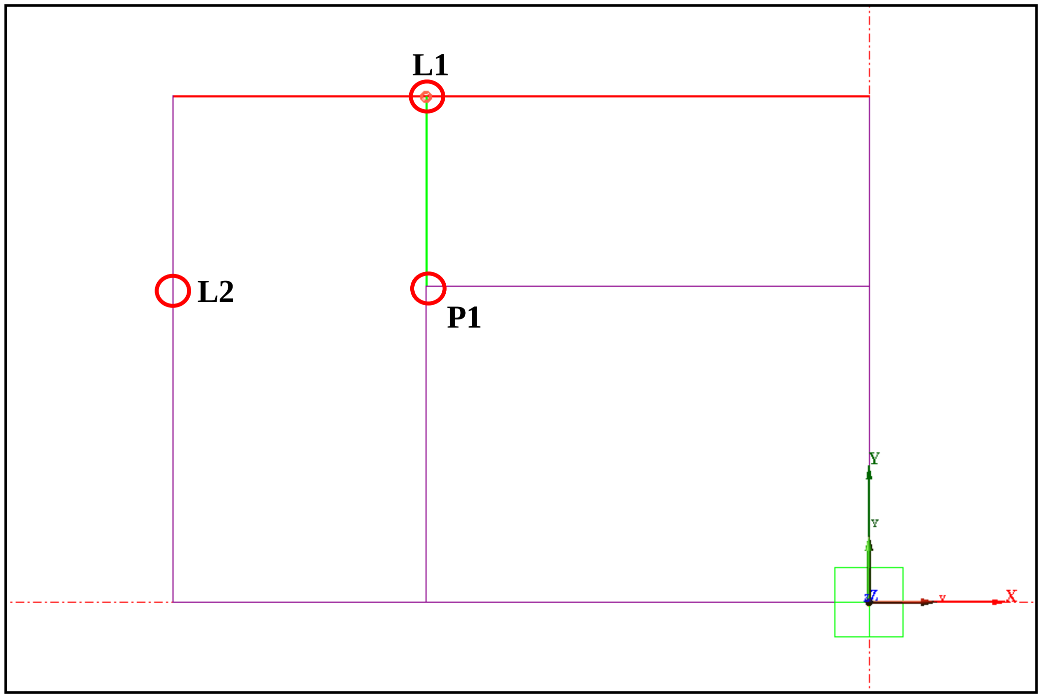
Step 3.

1. *Geometry > Curve > Create on WP > Line…*
2. *Toggle on "Vertex Snap" & "Perpendicular Snap"*
3. *Select P1 & L1 (See Figure)*
4. *Select P1 & L2 (See Figure)*
5. *Click* [Cancel] *Button*
6. *Geometry > Curve > Intersect...*
7. *Click "Displayed"*
8. *Click* [Apply] *Button*
9. *Click* [Cancel] *Button*





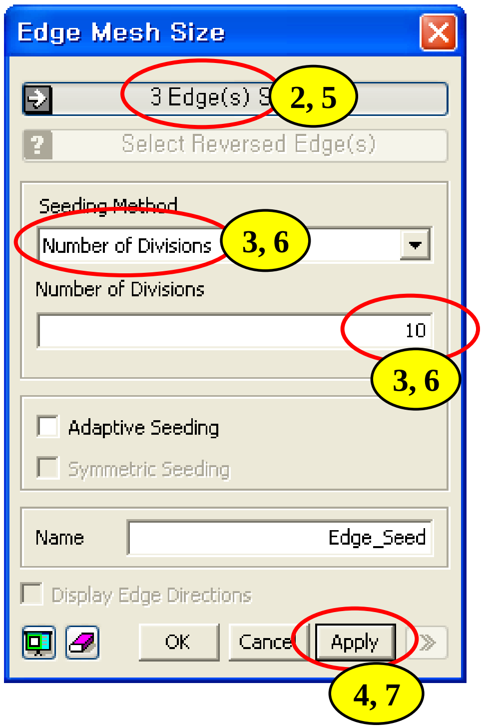




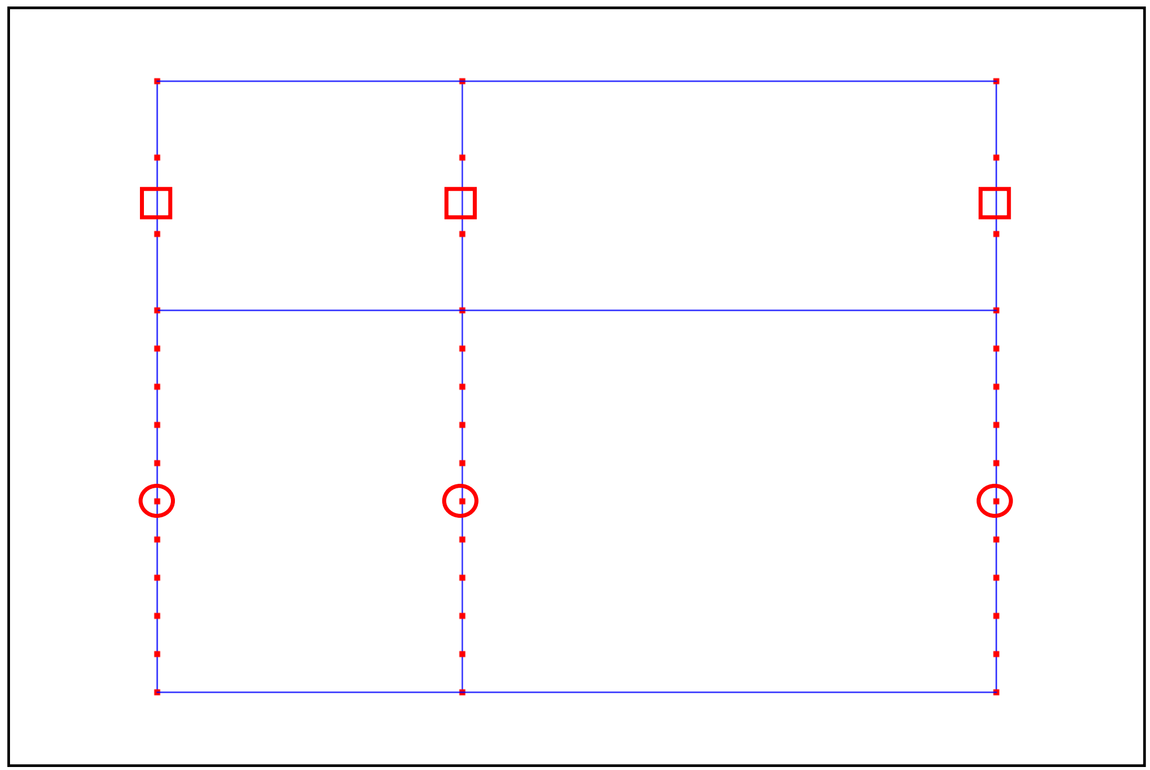
"Ctrl+A" as shortcut for "Select Displayed"

[Enter] *as shortcut for* [Apply]

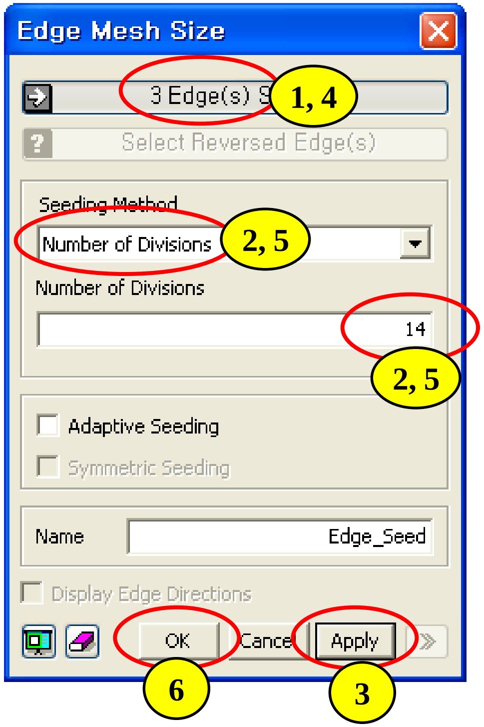
Step 4.



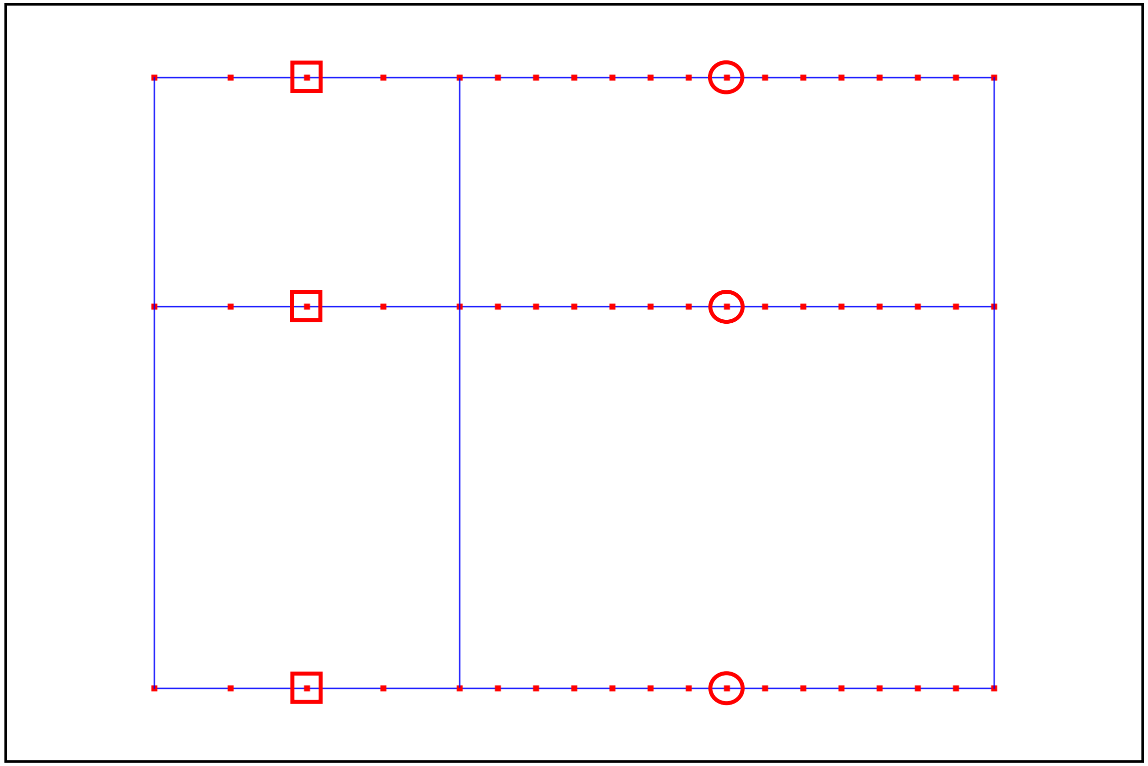
1. *Mesh > Size Control > Along Edge...*
2. *Select 3 Edges marked by "O" (See Figure)*
3. *Seeding Method : Number of Divisions (10)*
4. *Click* [Apply] *Button*
5. *Select 3 Edges marked by "□" (See Figure)*
6. *Seeding Method : Number of Divisions (3)*
7. *Click* [Apply] *Button*



Step 5.

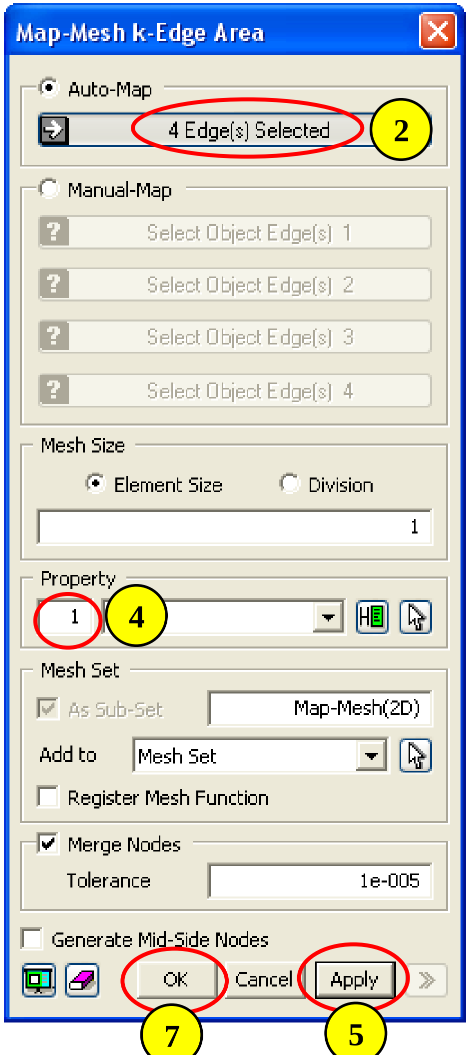


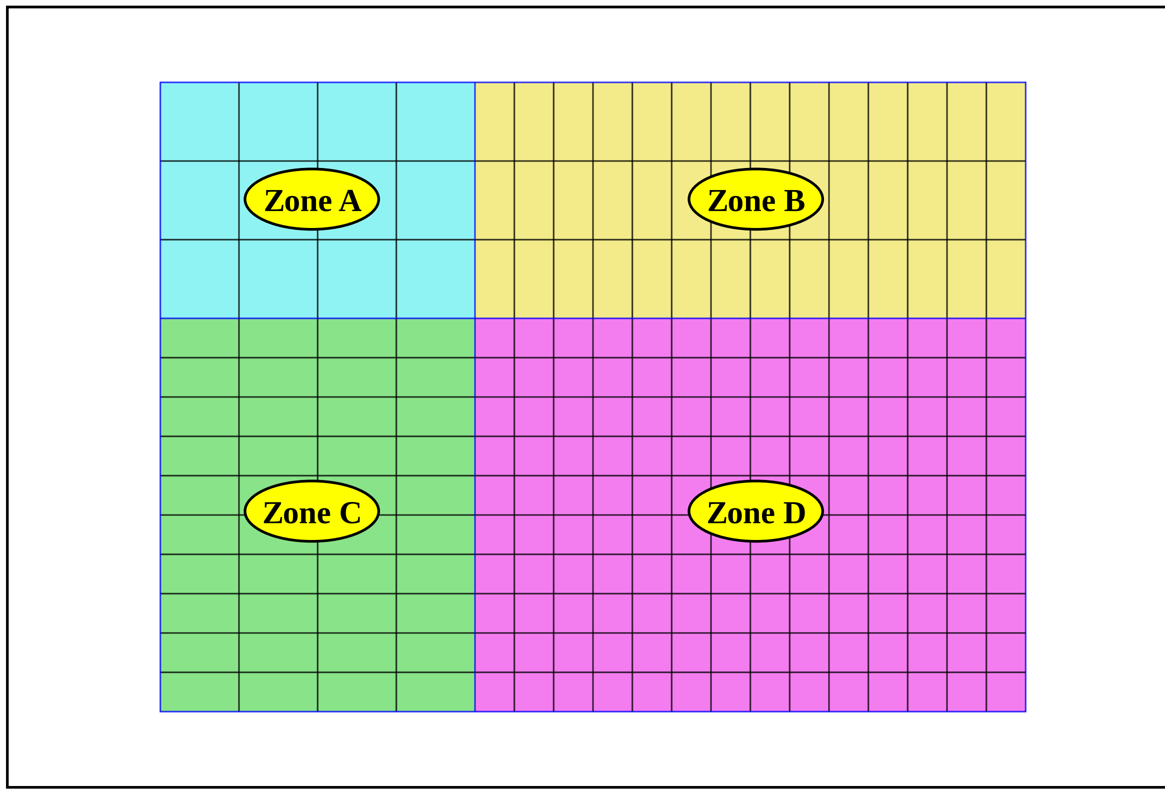
1. *Select 3 Edges marked by "O" (See Figure)*
2. *Seeding Method : Number of Divisions (14)*
3. *Click [Apply] Button*
4. *Select 3 Edges marked by "□" (See Figure)*
5. *Seeding Method : Number of Divisions (4)*
6. *Click [OK] Button*



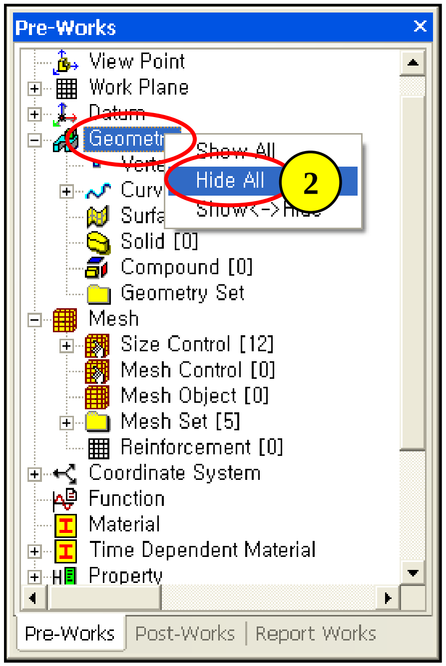
Step 6.

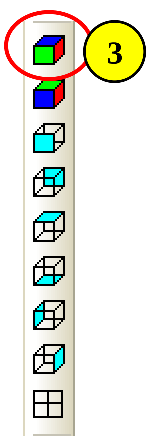
1. *Mesh > Map Mesh > k-Edge Area...*
2. *Select 4 Edges of Zone A*
3. *Use Default Mesh Size*
4. *Property : 1*
5. *Click* [Apply] *Button*
6. *Repeat step 2~5 for Zone B, C, D*
7. *Click* [OK] *Button*

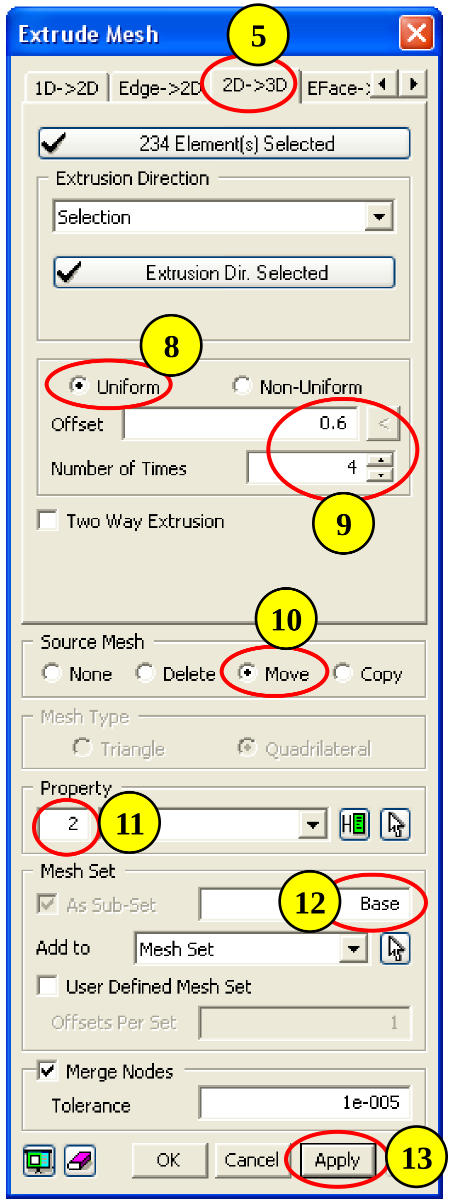




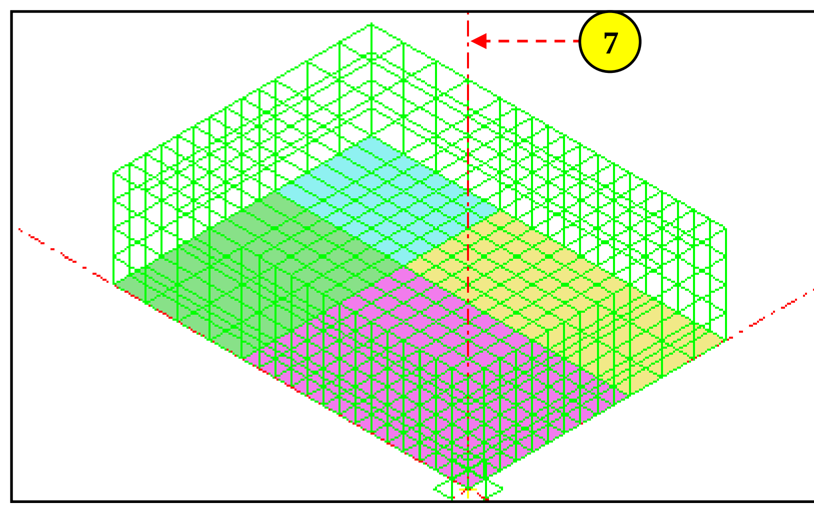
Step 7.



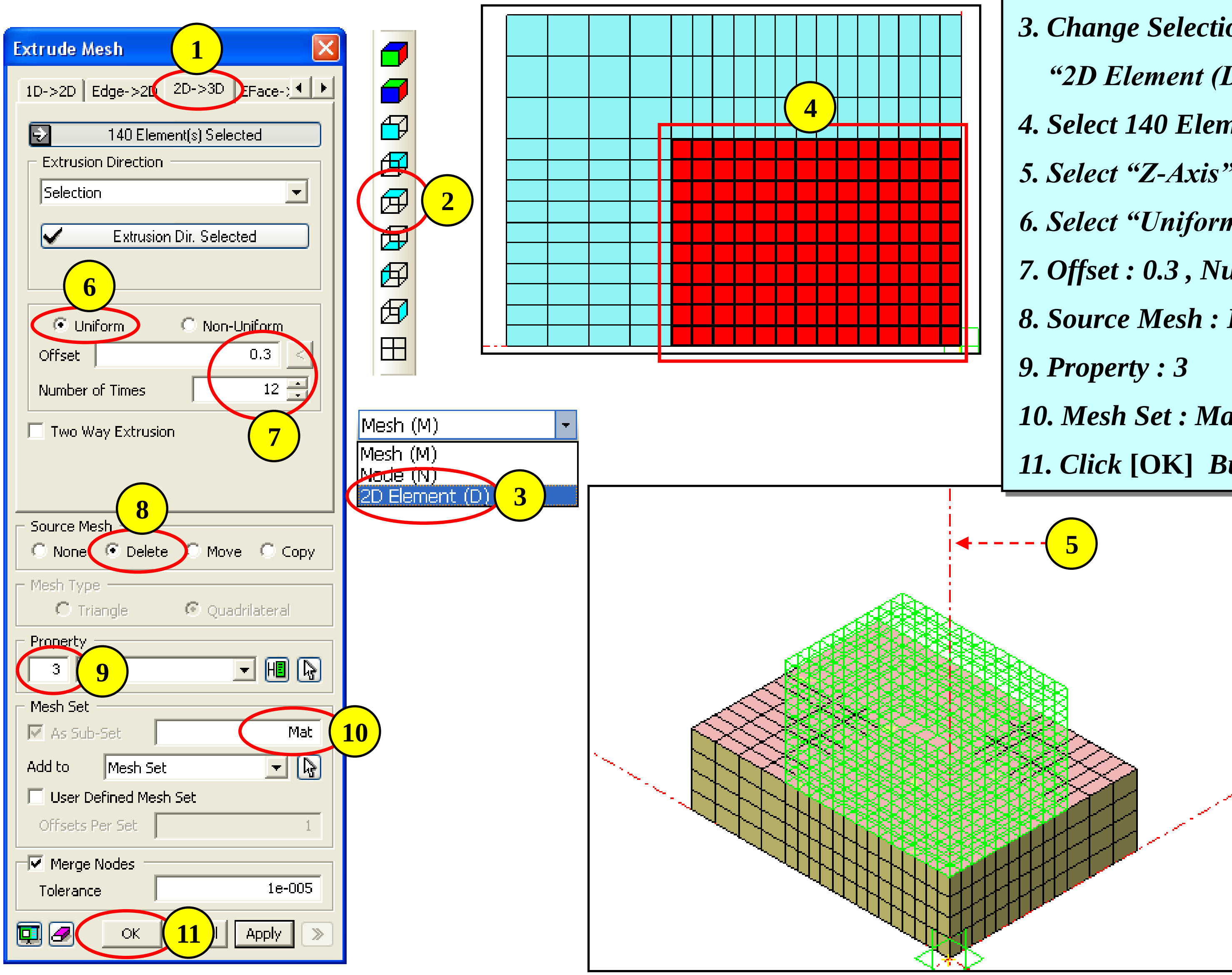




1. *Pre-Works Tree : Geometry...*
2. *Click Right Mouse Button and Select "Hide All"*
3. *Click "Isometric 1 View"*
4. *Mesh > Protrude Mesh > Extrude...*
5. *Select "2D->3D" tab*
6. *Click "Displayed"*
7. *Select "Z-Axis" for Extrusion Dir.*
8. *Select "Uniform"*
9. *Offset : 0.6 , Number of Times : 4*
10. *Source Mesh : Move*
11. *Property : 2*
12. *Mesh Set : Base*
13. *Click [Apply] Button*

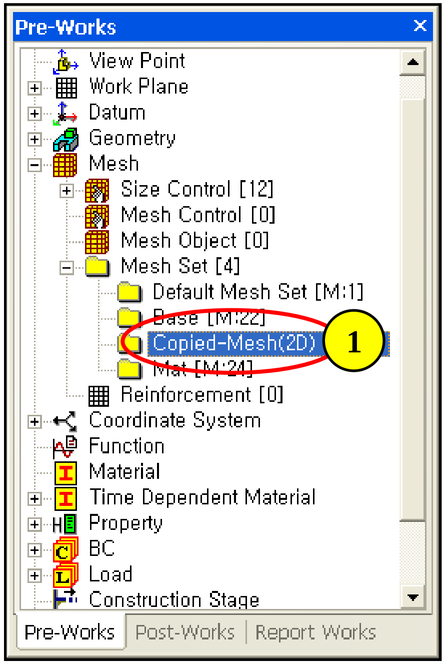


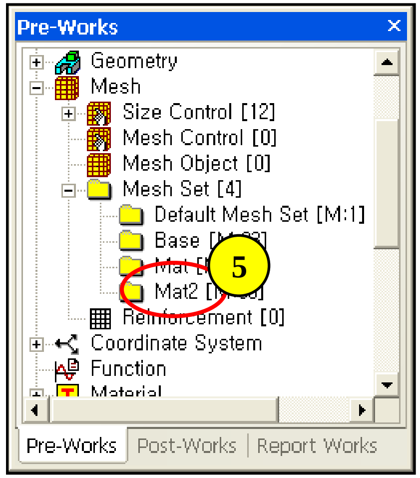
Step 8.



1. *Select "2D ->3D" tab*
2. *Click "Top View"*
3. *Change Selection Filter to "2D Element (D)"*
4. *Select 140 Elements (See Figure)*
5. *Select "Z-Axis" for Extrusion Dir.*
6. *Select "Uniform"*
7. *Offset : 0.3 , Number of Times : 12*
8. *Source Mesh : Delete*
9. *Property : 3*
10. *Mesh Set : Mat*
11. *Click [OK] Button*

Step 9.





1. Pre-Works Tree : Mesh > Mesh Set > Copied-Mesh(2D)...

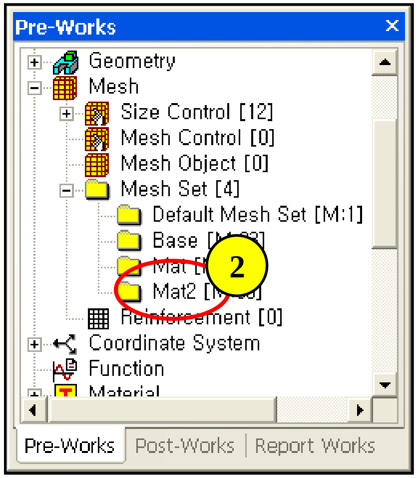
2. Press **[Delete]** *Key*

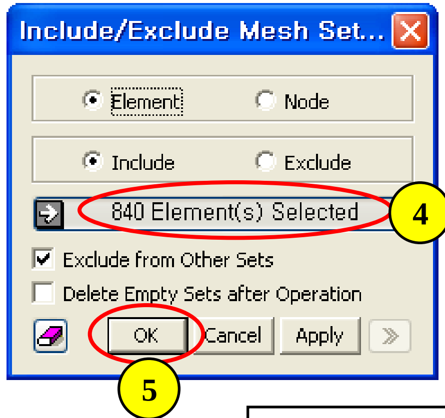
3. Pre-Works Tree : Mesh > Mesh Set...

4. Click Right Mouse Button and Select "New Mesh Set"

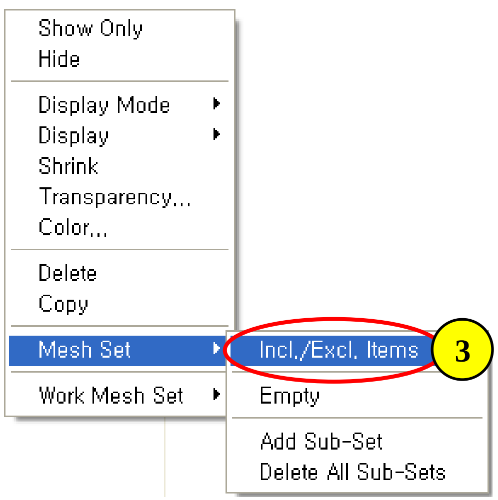
5. Enter the name "Mat2" for New Mesh Set

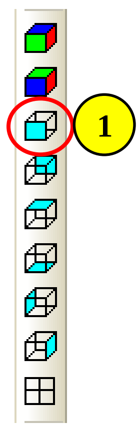
Step 10.

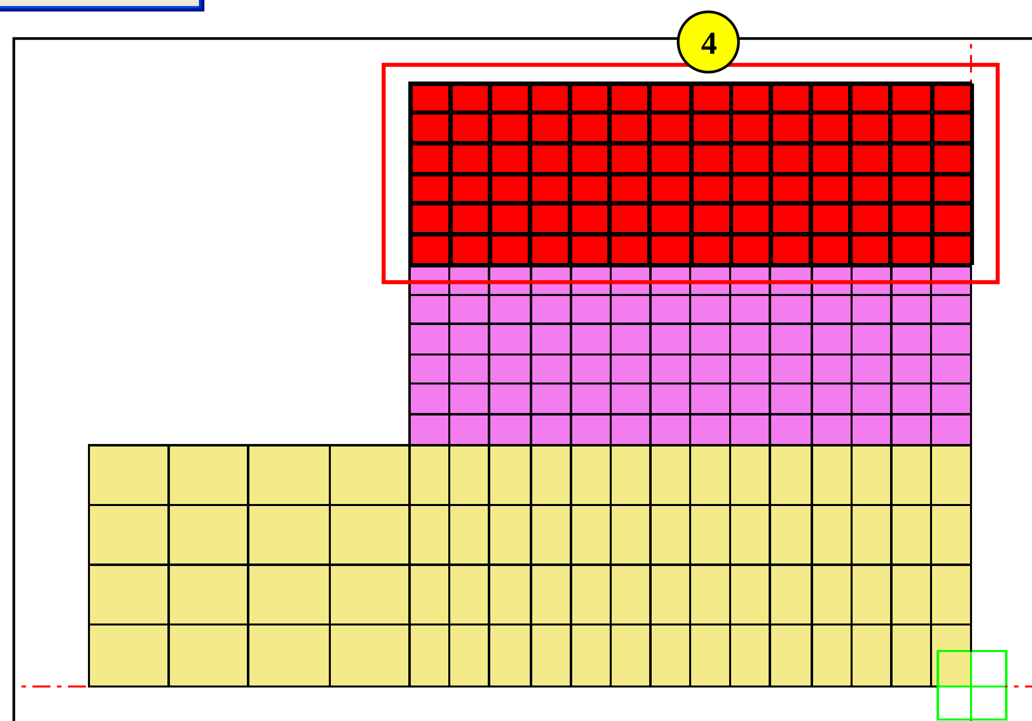




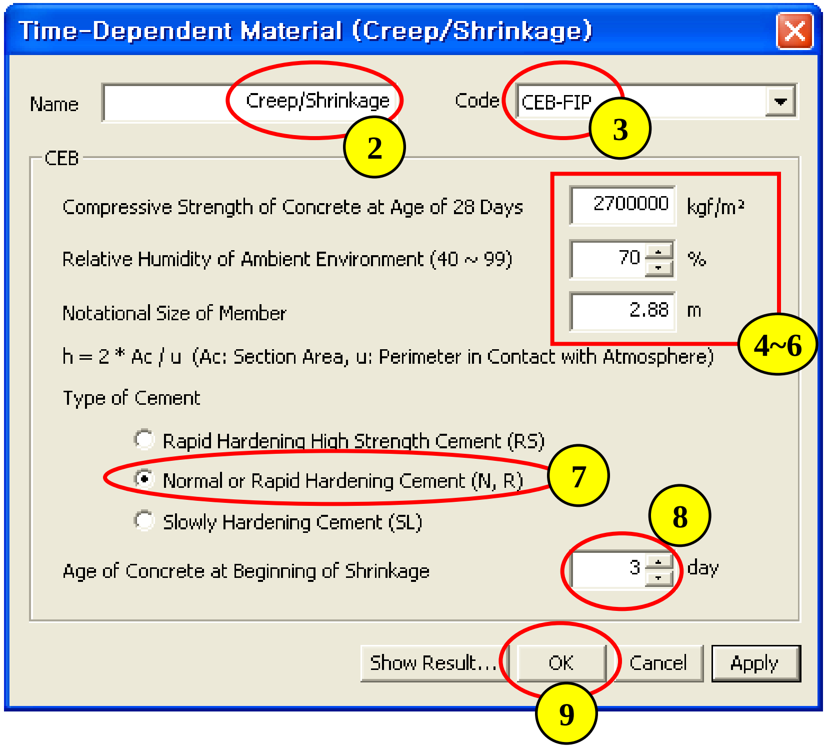
1. *Click "Front View"*
2. *Pre-Works Tree : Mesh > Mesh Set > Mat2...*
3. *Click Right Mouse Button and Select "Mesh Set > Incl./Excl. Items"*
4. *Select 840 Elements (See Figure)*
5. *Click [OK] Button*







Step 11.



1. Analysis > Time-Dependent Material > Creep/Shrinkage…

2. Name : Creep/Shrinkage

3. Code : CEB-FIP

4. Compressive Strength of Concrete at Age of 28 Days : 2700000 kgf/m²

5. Relative Humidity of Ambient Environment (40~99) : 70 %

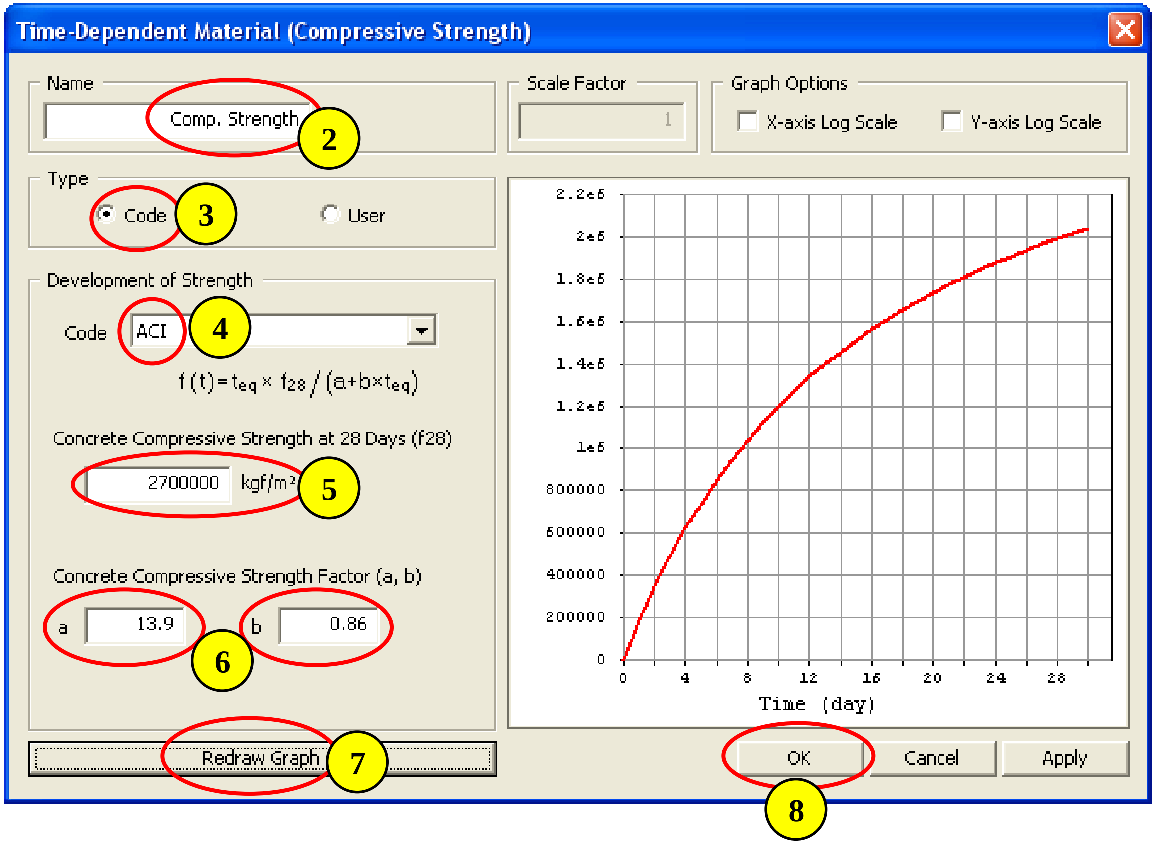
6. Notational Size of Member : 2.88 m

7. Type of Cement : Normal or Rapid Hardening Cement (N, R)

8. Age of Concrete at Beginning of Shrinkage : 3 Day

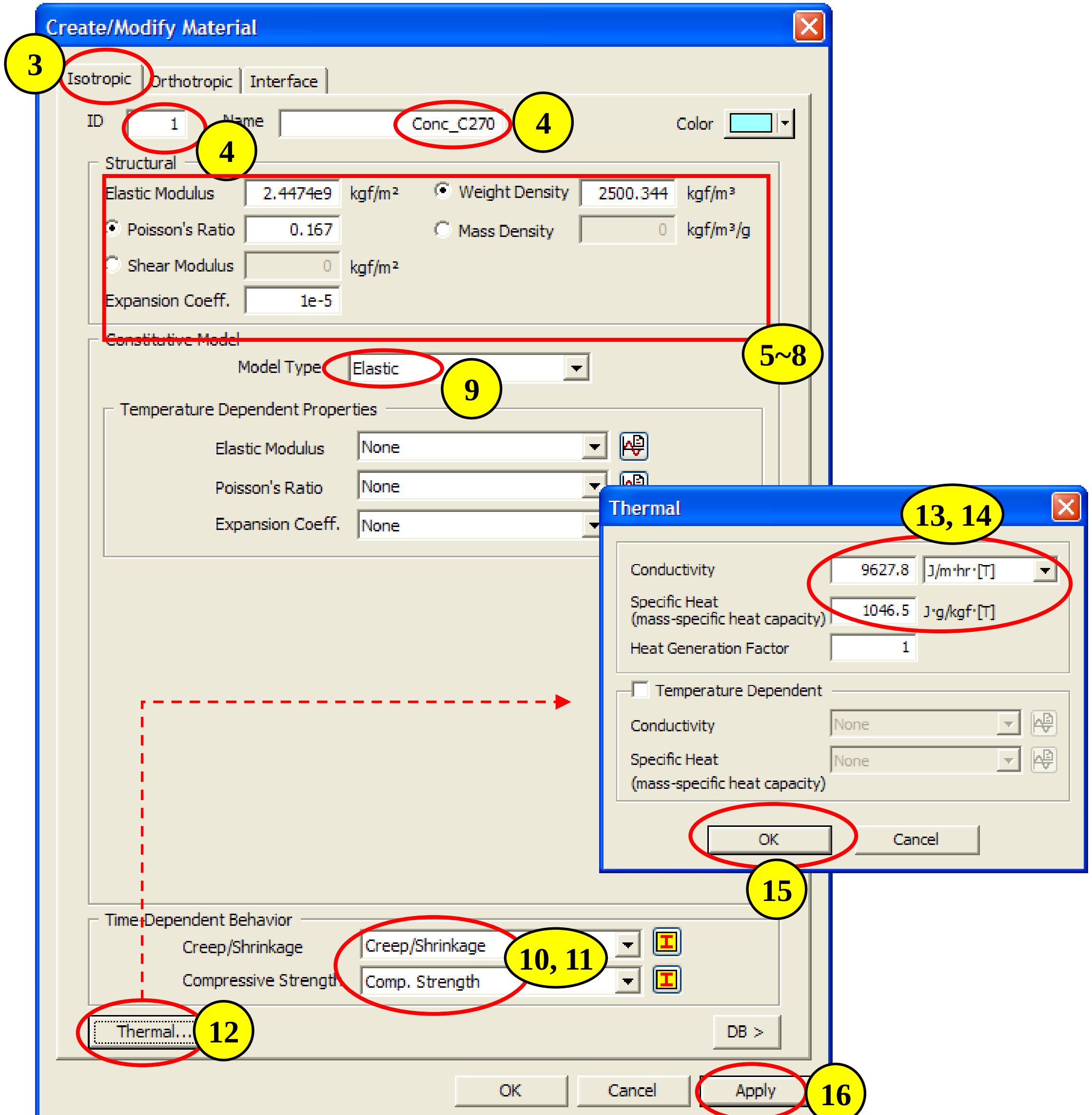
9. Click [OK] *Button*

Step 12.



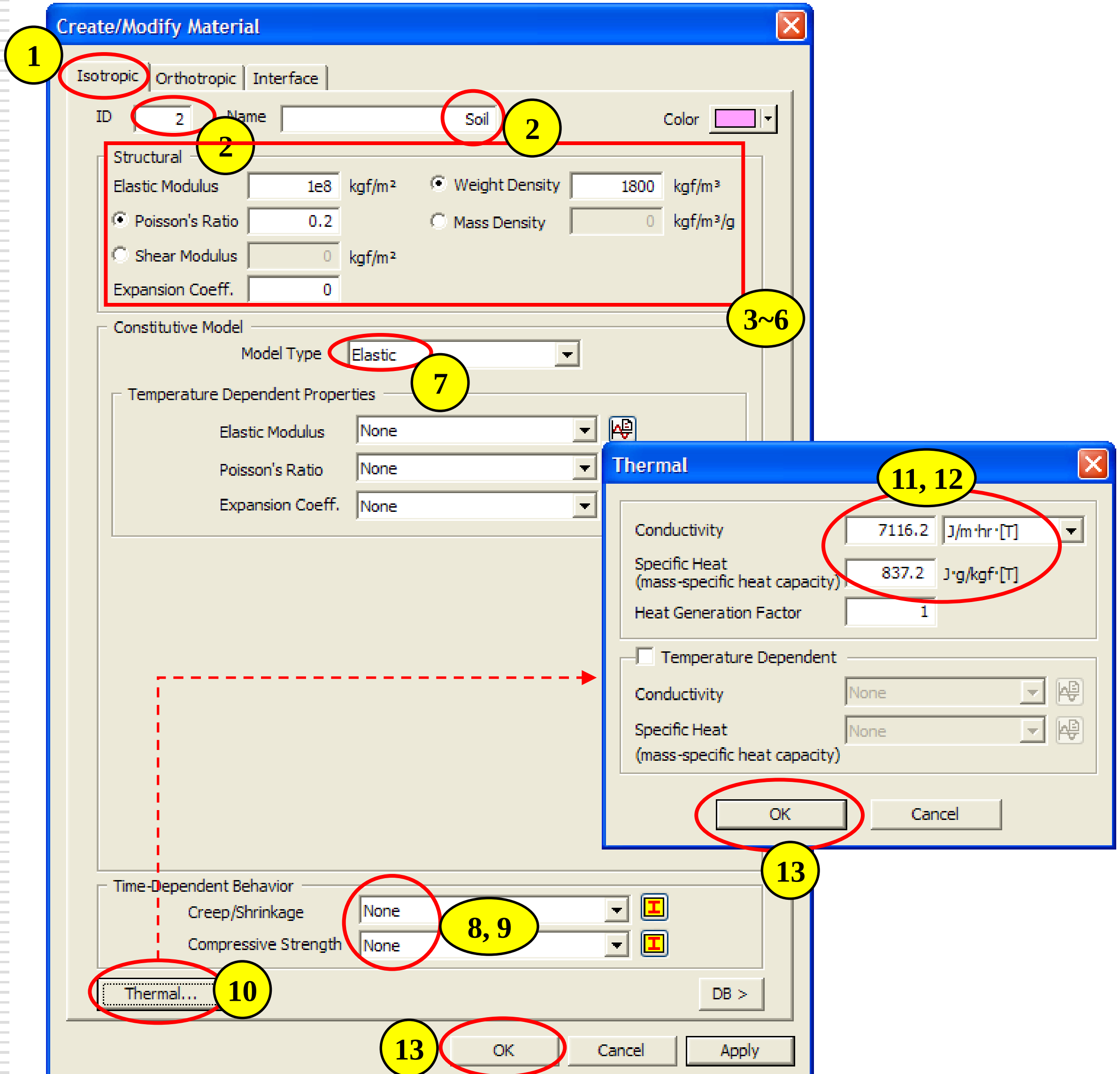
1. *Analysis > Time-Dependent Material > Compressive Strength…*
2. *Name : Comp. Strength*
3. *Type : Code*
4. *Code : ACI*
5. *Concrete Compressive Strength at 28 Days (f28) : 2700000 kgf/m²*
6. *Concrete Compressive Strength Factor (a, b) : a(13.9) , b(0.86)*
7. *Click* **[Redraw Graph]** *Button*
8. *Click* **[OK]** *Button*

Step 13.



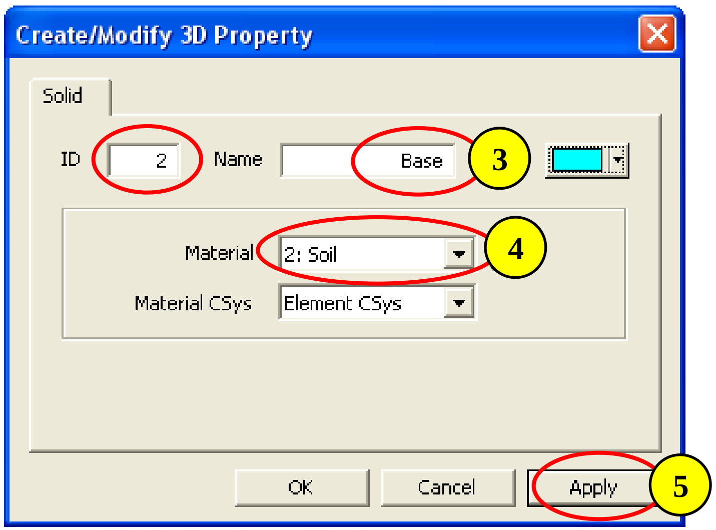
1. *Analysis > Material …*
2. *Click [Create] Button*
3. *Select "Isotropic" tab*
4. *ID : 1 , Name : Conc_C270*
5. *Elastic Modulus : 2.4474e9 kgf/m²*
6. *Poisson's Ratio : 0.167*
7. *Expansion Coeff. : 1e-5*
8. *Weight Density : 2500.344 kgf/m³*
9. *Model Type : Elastic*
10. *Creep/Shrinkage : Creep/Shrinkage*
11. *Compressive Strength : Comp. Strength*
12. *Click [Thermal...] Button*
13. *Conductivity : 9627.8 J/m·hr·[T]*
14. *Specific Heat : 1046.5 J·g/kgf · [T]*
15. *Click [OK] Button*
16. *Click [Apply] Button*

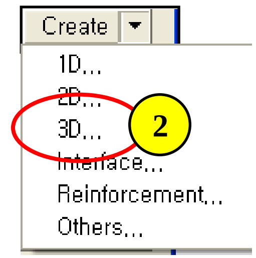
Step 14.



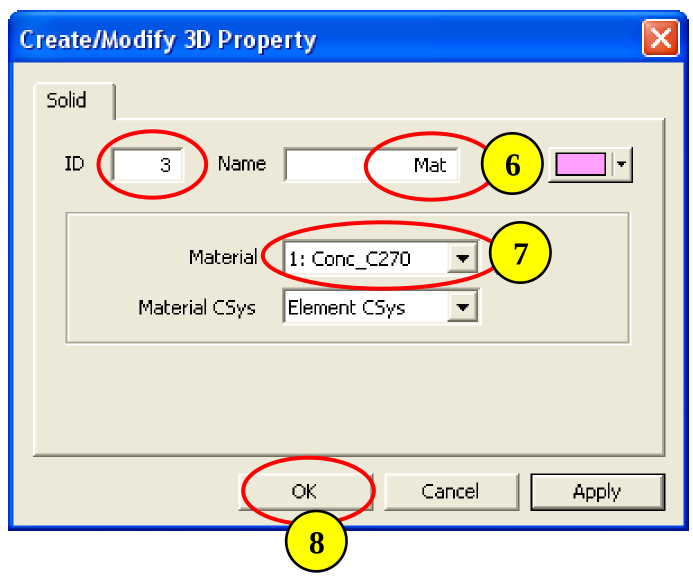
1. *Select "Isotropic" tab*
2. *ID : 2 , Name : Soil*
3. *Elastic Modulus : 1e8 kgf/m²*
4. *Poisson's Ratio : 0.2*
5. *Expansion Coeff. : 0*
6. *Weight Density : 1800 kgf/m³*
7. *Model Type : Elastic*
8. *Creep/Shrinkage : None*
9. *Compressive Strength : None*
10. *Click* [Thermal...] *Button*
11. *Conductivity : 7116.2 J/m·hr·*[T]
12. *Specific Heat : 837.2 J·g/kgf ·* [T]
13. *Click* [OK] *Button*
14. *Click* [Close] *Button*

Step 15.



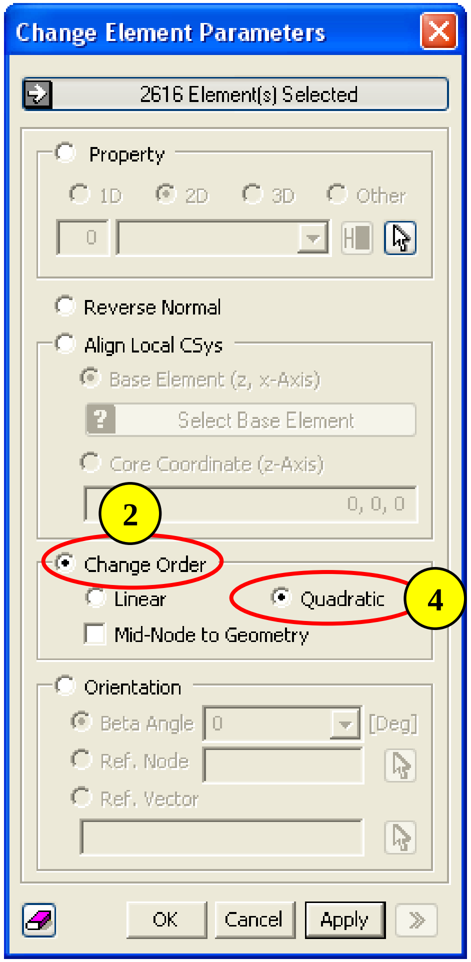


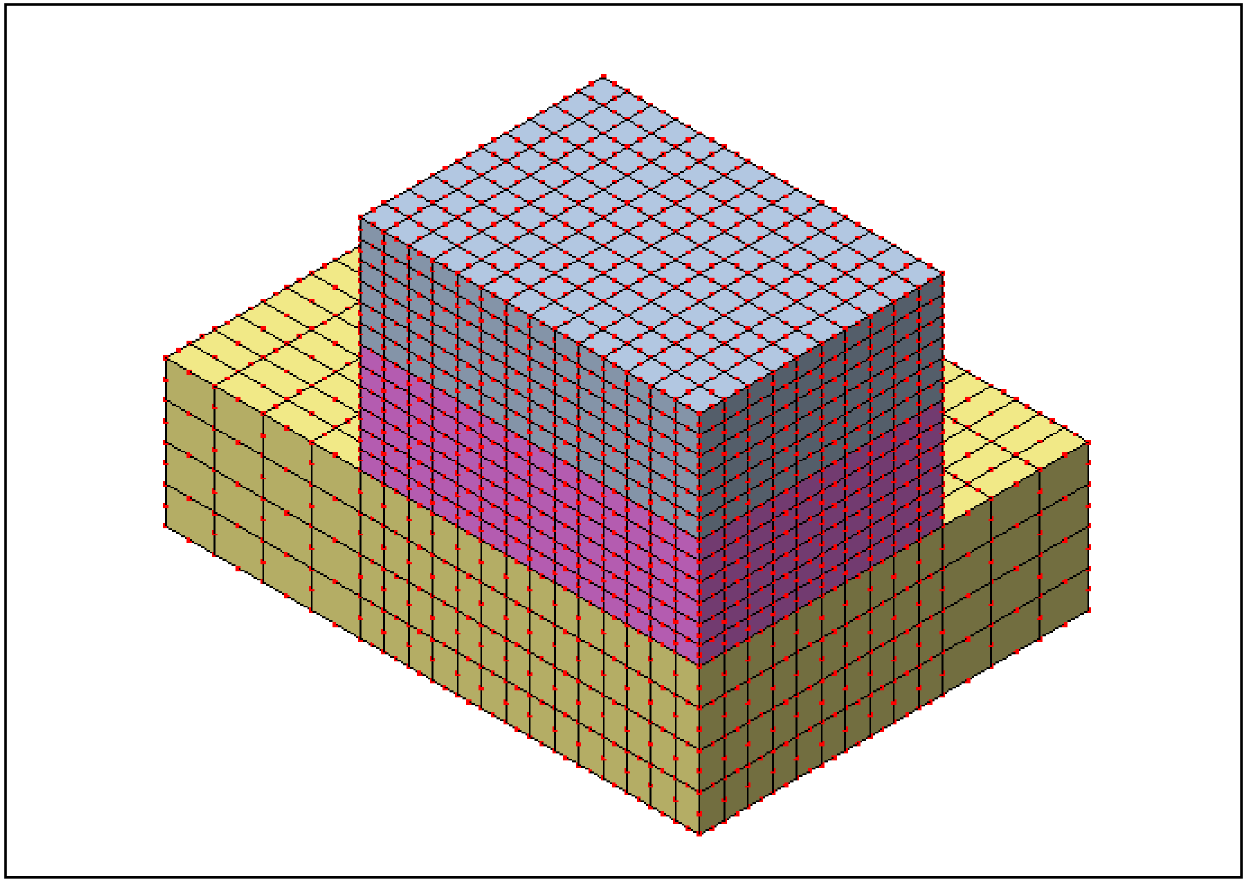
1. *Analysis > Property...*
2. *Create 3D…*
3. *ID : 2 , Name : Base*
4. *Material : (2: Soil)*
5. *Click* [Apply] *Button*
6. *ID : 3, Name : Mat*
7. *Material : (1: Conc_C270)*
8. *Click* [OK] *Button*
9. *Click* [Close] *Button*



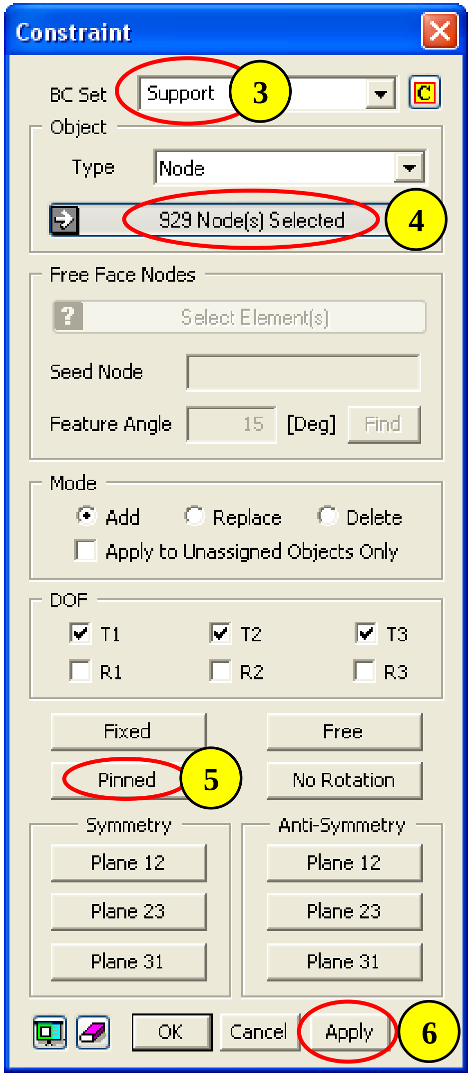
Step 16.

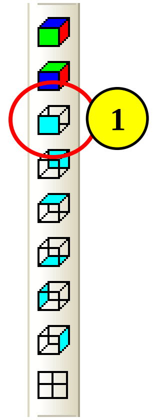
1. *Mesh > Element > Change Parameter...*
2. *Select "Change Order"*
3. *Click "Displayed"*
4. *Select "Quadratic"*
5. *Click [OK] Button*





Step 17.





1. Click "Front View"

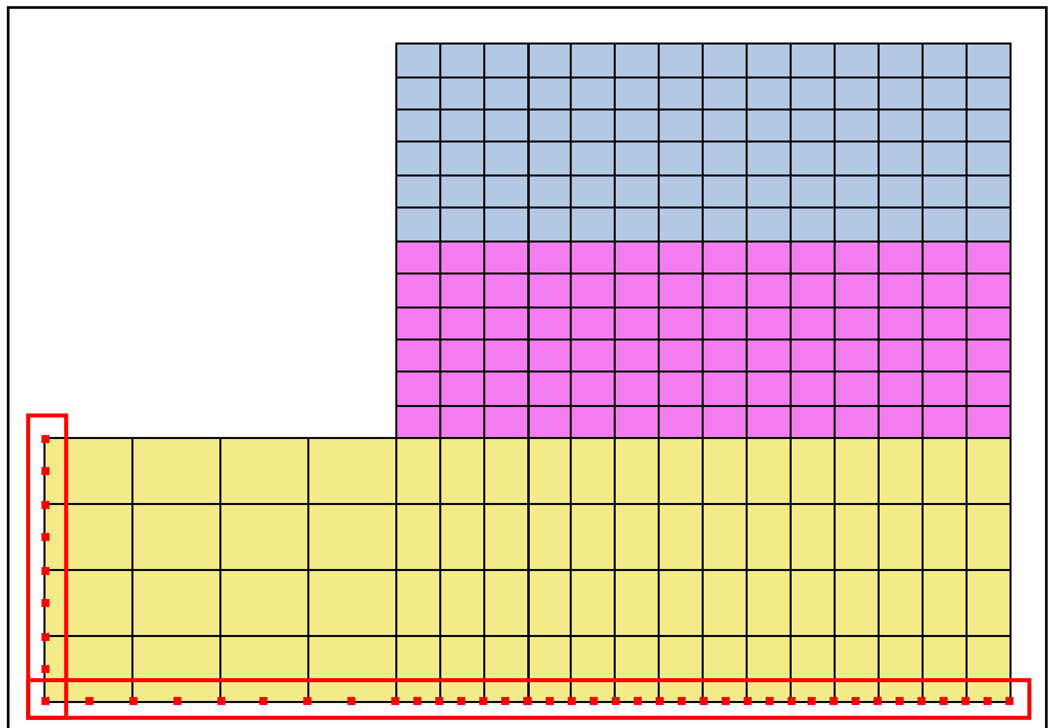
2. Analysis > BC > Constraint …

3. BC Set : Support

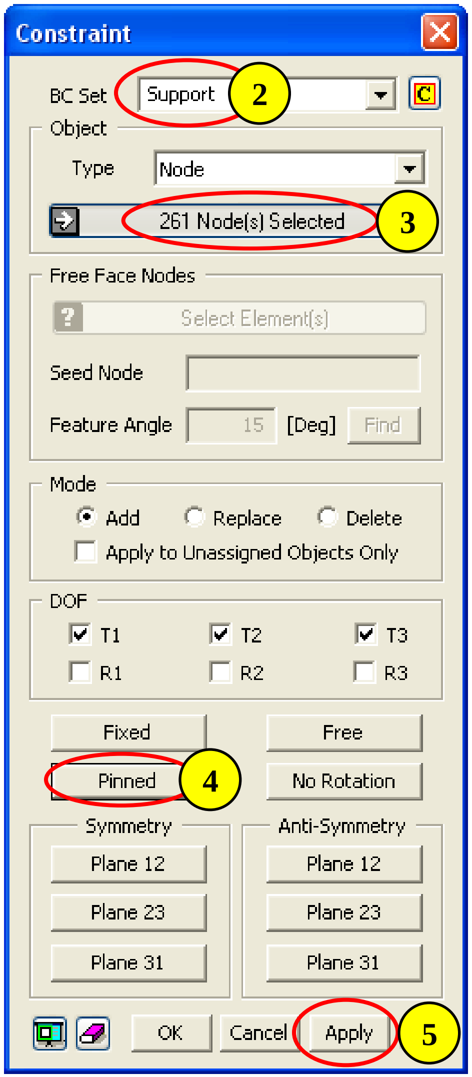
4. Select 929 Nodes (See Figure)

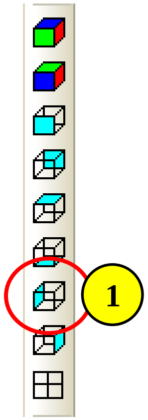
5. Click "Pinned"

6. Click [Apply] Button



Step 18.





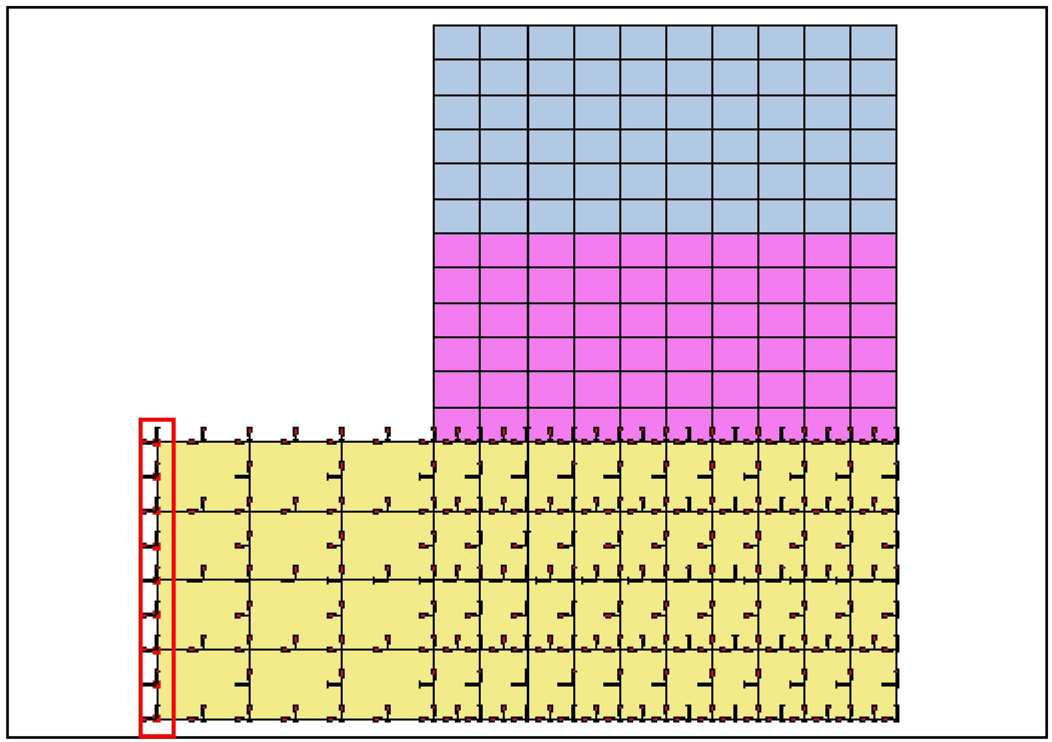
1. Click "Left View"

2. BC Set : Support

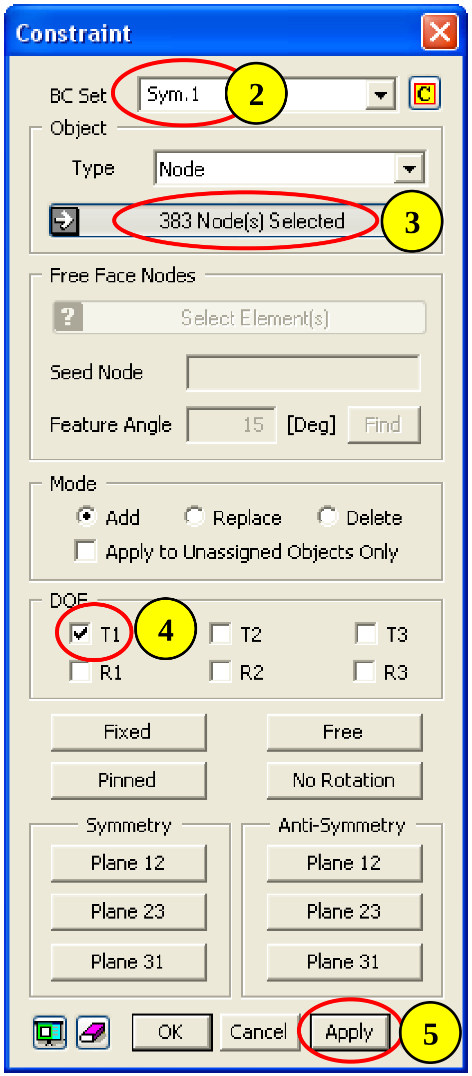
3. Select 261 Nodes (See Figure)

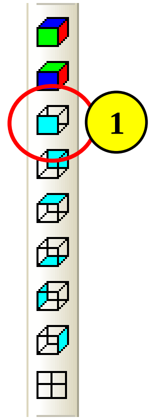
4. Click "Pinned"

5. Click [Apply] Button



Step 19.





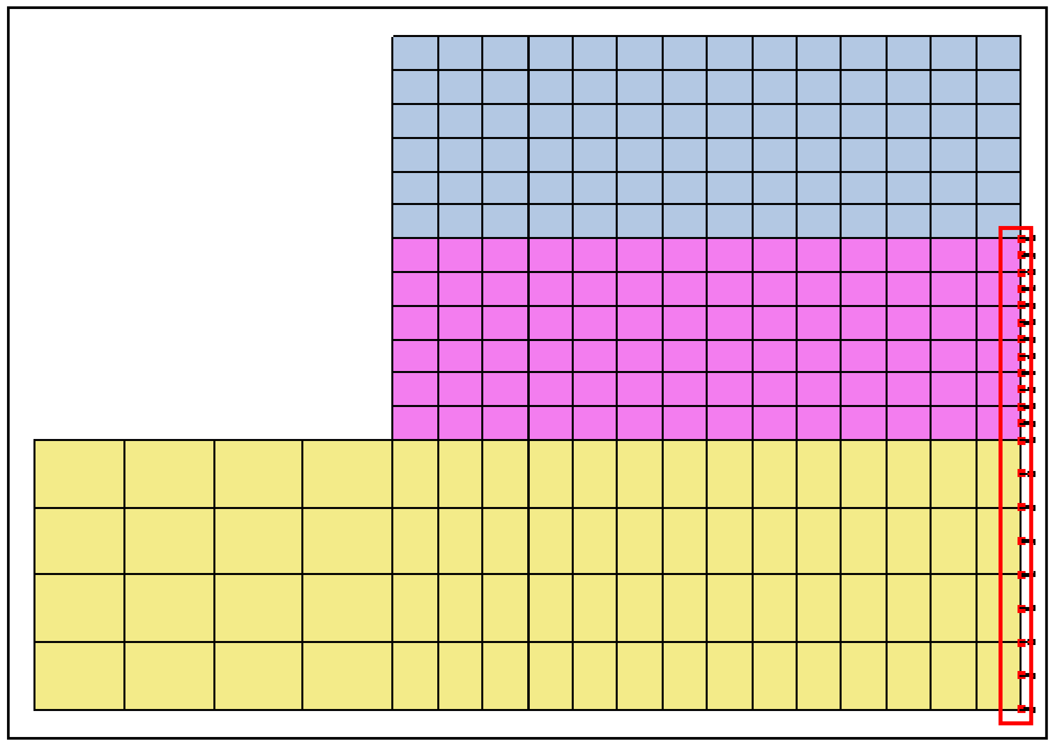
1. Click "Front View"

2. BC Set : Sym.1

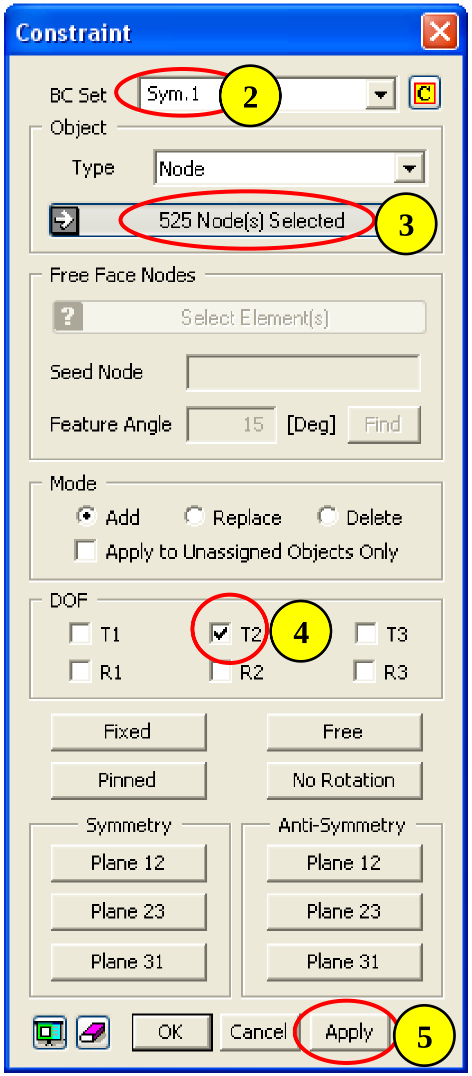
3. Select 383 Nodes (See Figure)

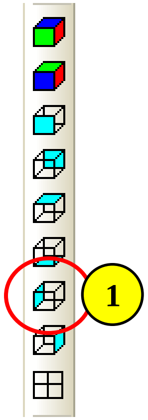
4. Check on "T1"

5. Click [Apply] *Button*



Step 20.





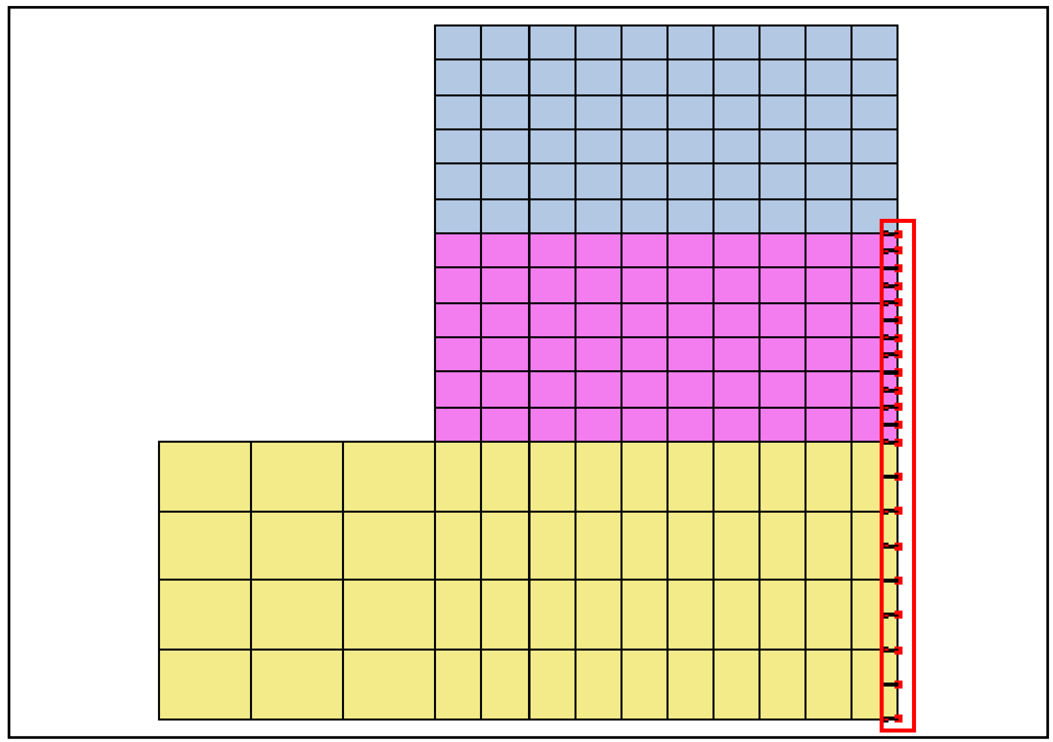
1. Click “Left View”

2. BC Set : Sym.1

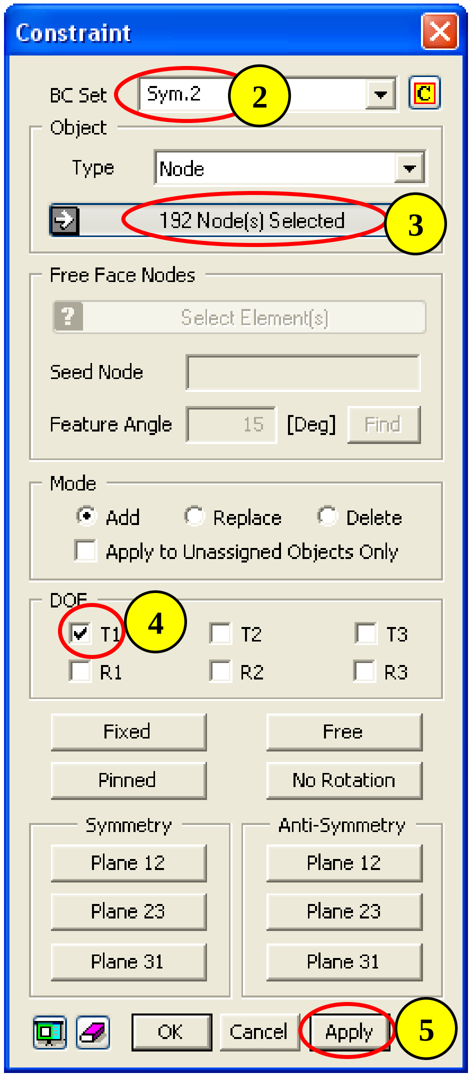
3. Select 525 Nodes (See Figure)

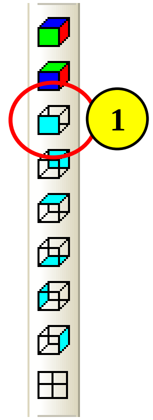
4. Check on “T2”

5. Click [Apply] *Button*



Step 21.





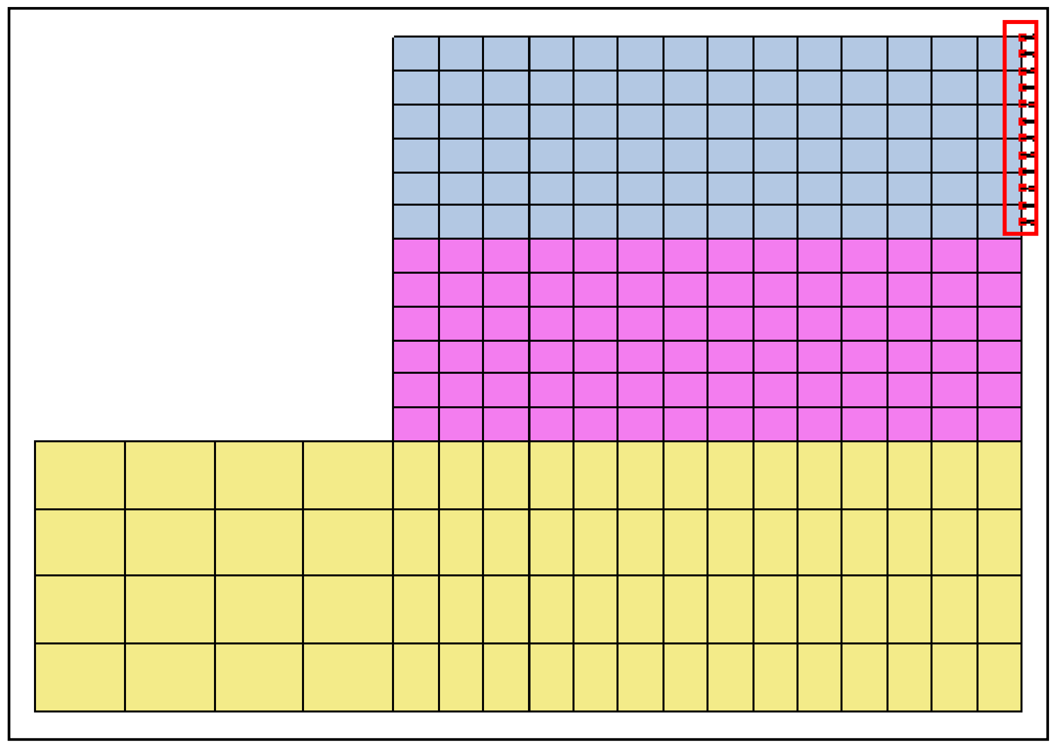
1. Click "Front View"

2. BC Set : Sym.2

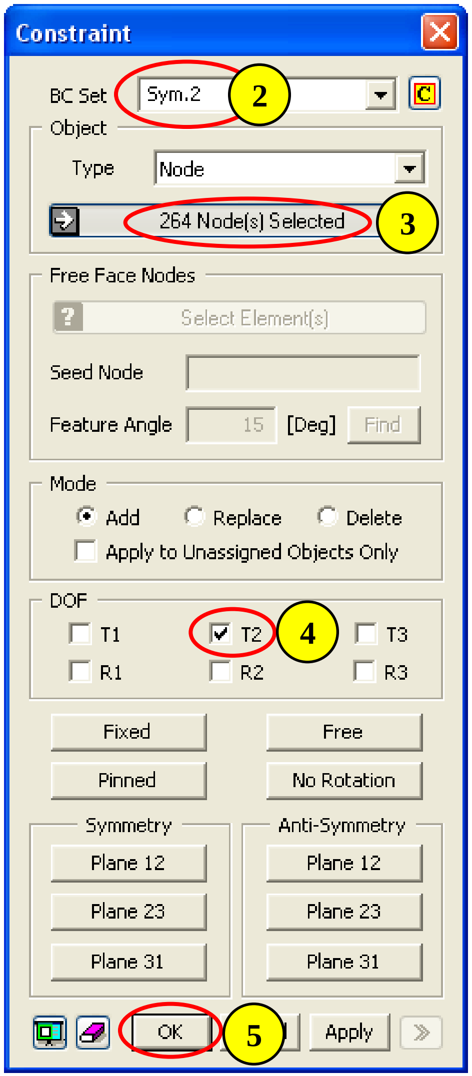
3. Select 192 Nodes (See Figure)

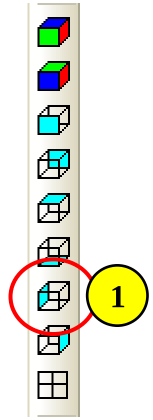
4. Check on "T1"

5. Click [Apply] *Button*

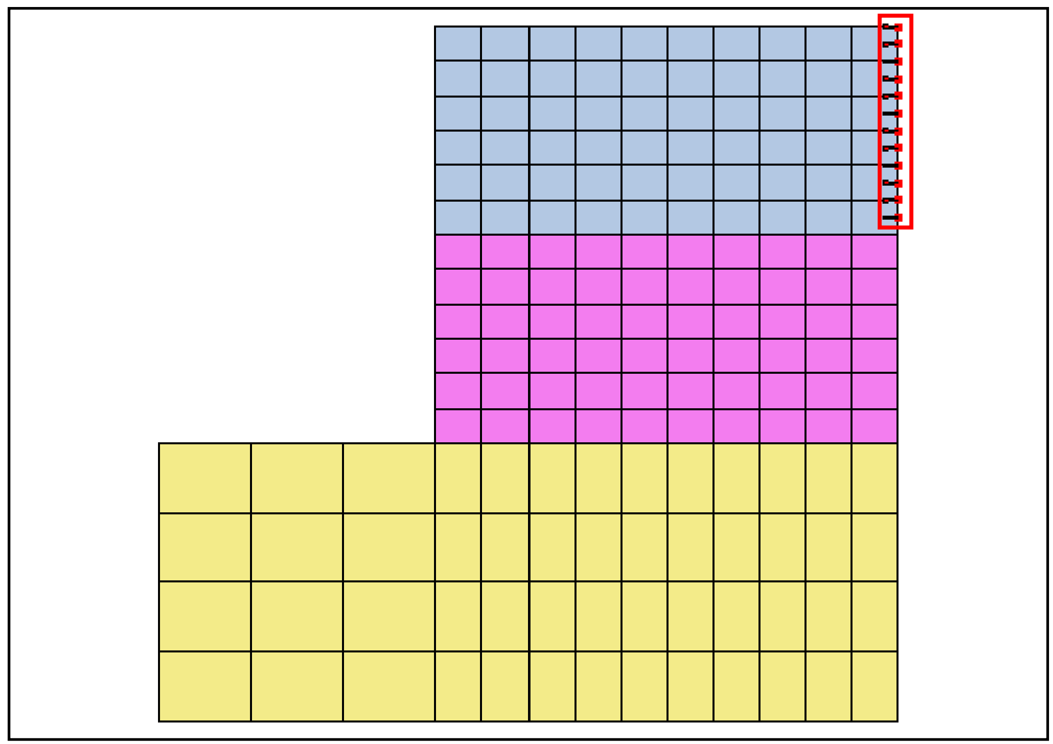


Step 22.

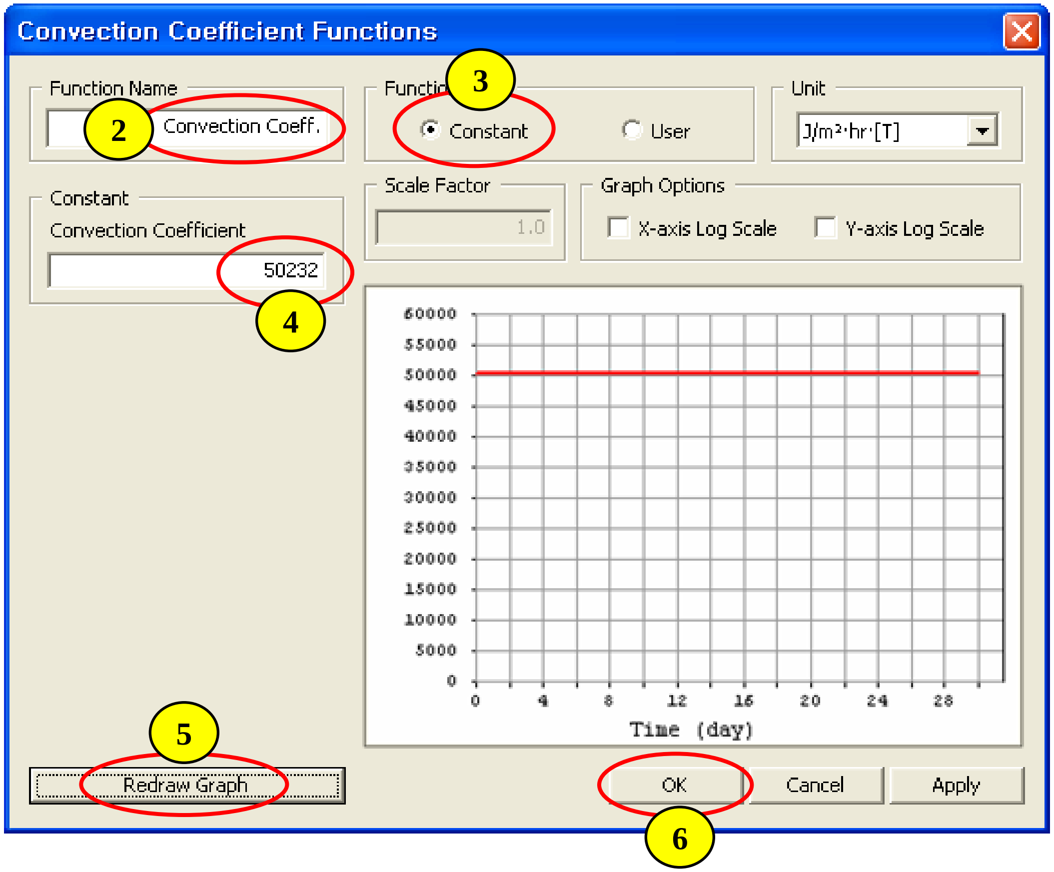




1. *Click "Left View"*
2. *BC Set : Sym.2*
3. *Select 264 Nodes (See Figure)*
4. *Check on "T2"*
5. *Click [OK] Button*



Step 23.



1. Analysis > Heat Transfer Analysis > Convection Coefficient Functions...

2. Function Name : Convection Coeff.

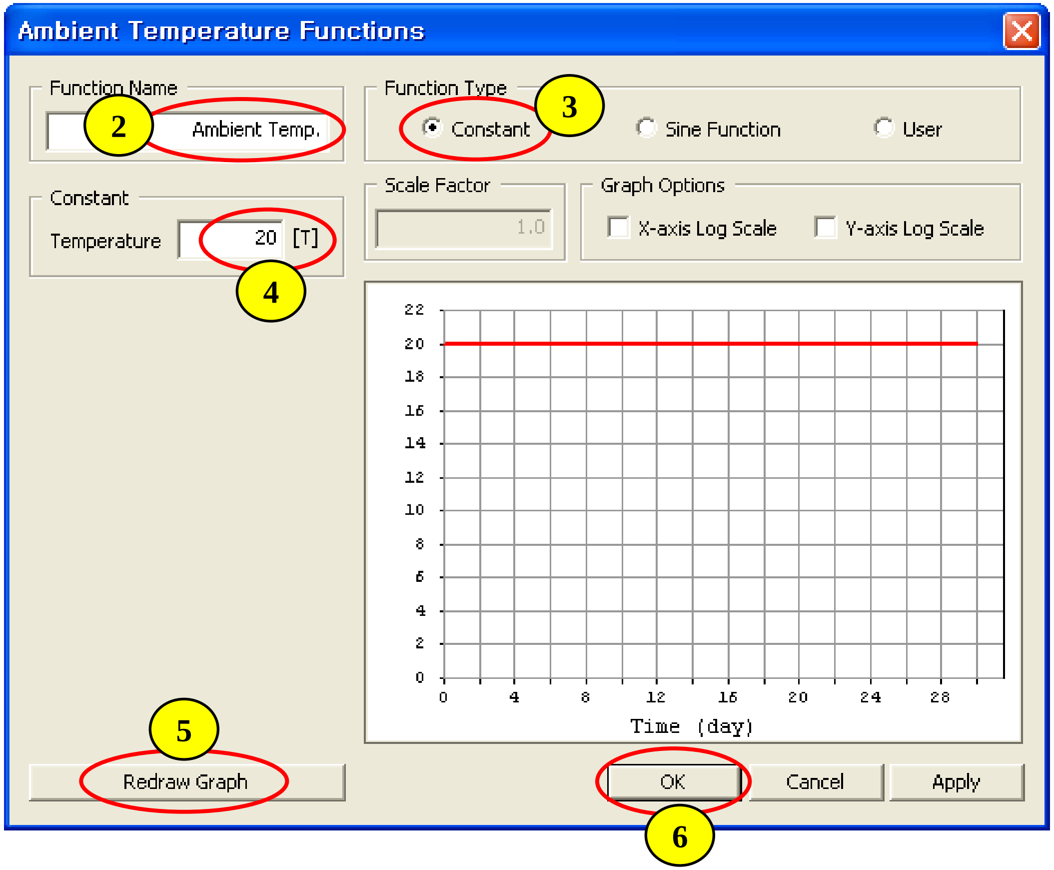
3. Function Type : Constant

4. Convection Coefficient : 50232 J/m²·hr·[T]

5. Click [Redraw Graph] *Button*

6. Click [OK] *Button*

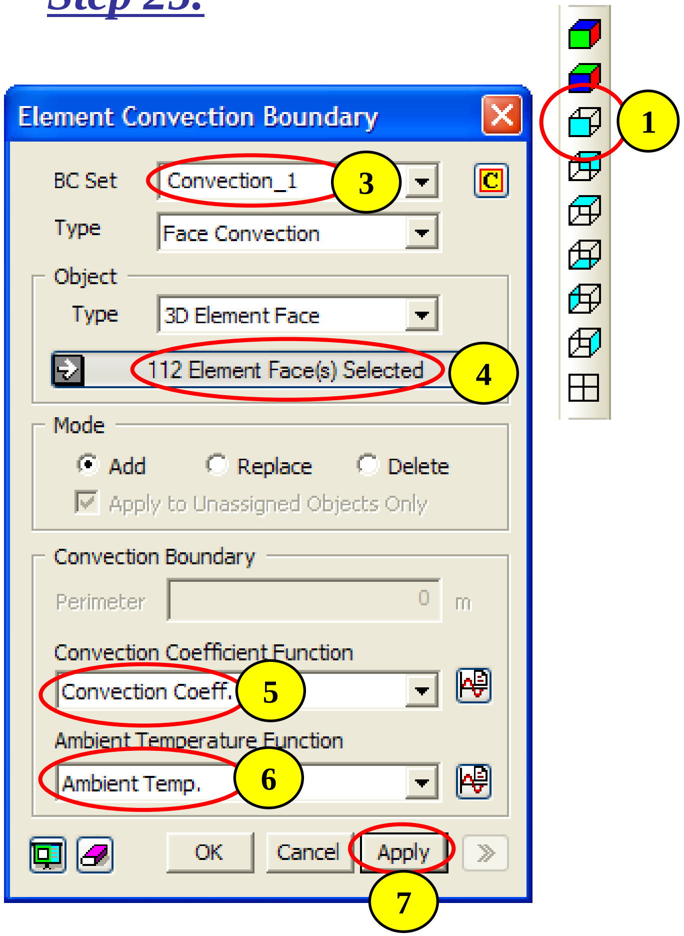
Step 24.

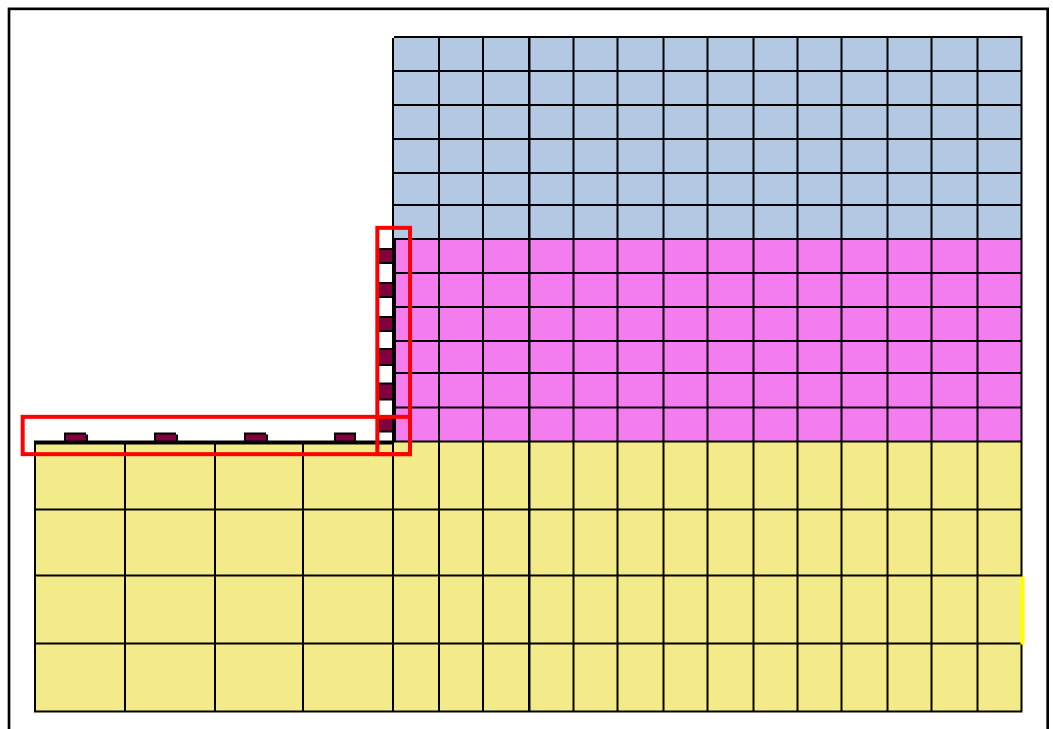


1. *Analysis > Heat Transfer Analysis > Ambient Temperature Functions...*
2. *Function Name : Ambient Temp.*
3. *Function Type : Constant*
4. *Temperature : 20* [T]
5. *Click* [Redraw Graph] *Button*
6. *Click* [OK] *Button*

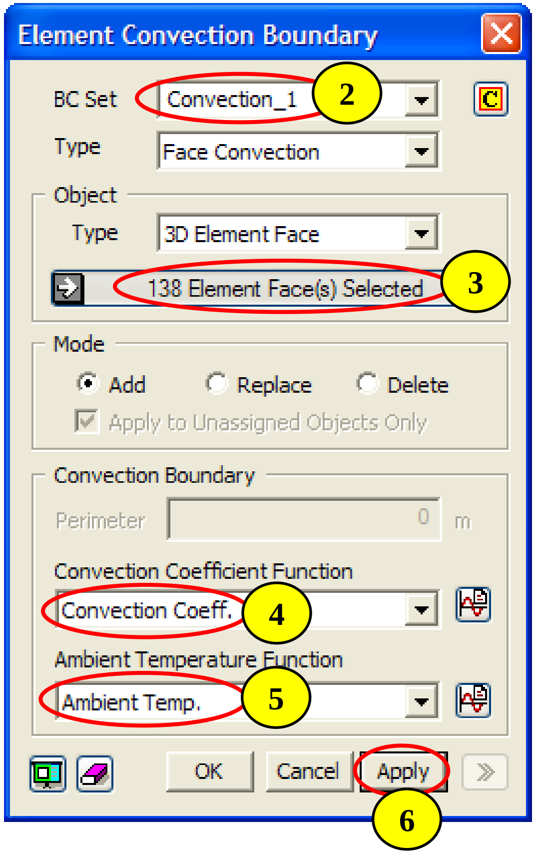
Step 25.

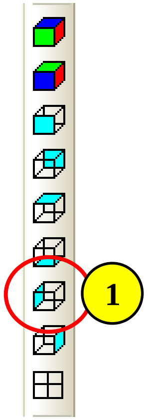
1. *Click "Front View"*
2. *Analysis > Heat Transfer Analysis > Convection Boundary...*
3. *BC Set : Convection_1*
4. *Select 112 Element Faces (See Figure)*
5. *Convection Coefficient Function : Convection Coeff.*
6. *Ambient Temperature Function : Ambient Temp.*
7. *Click* [Apply] *Button*



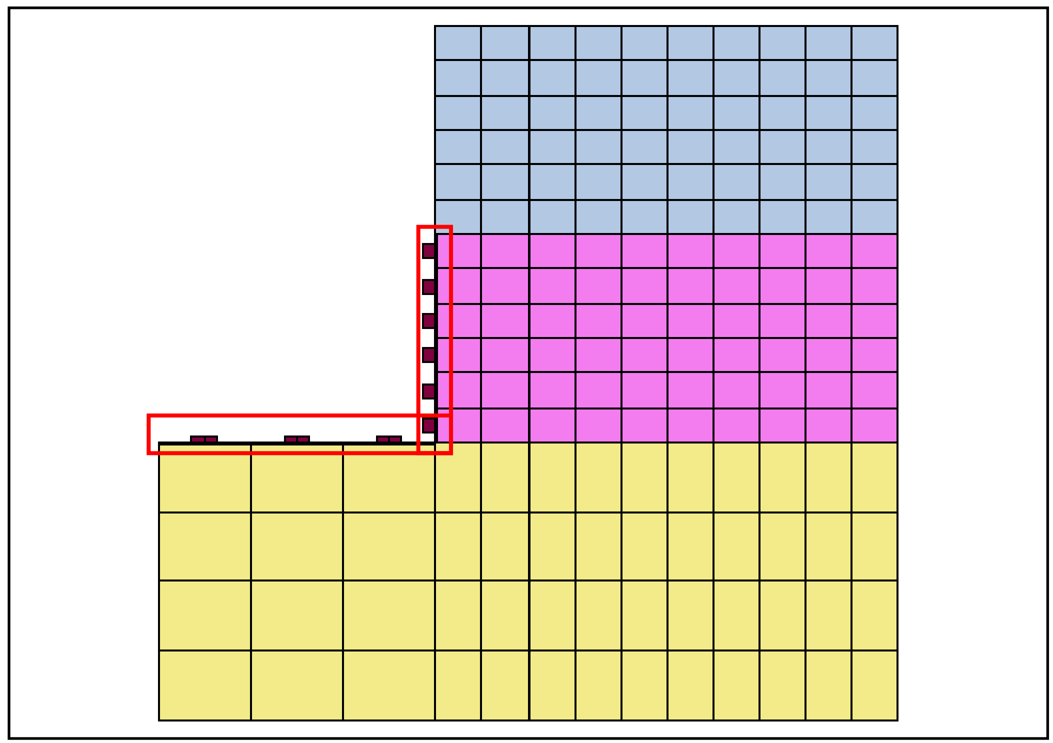


Step 26.

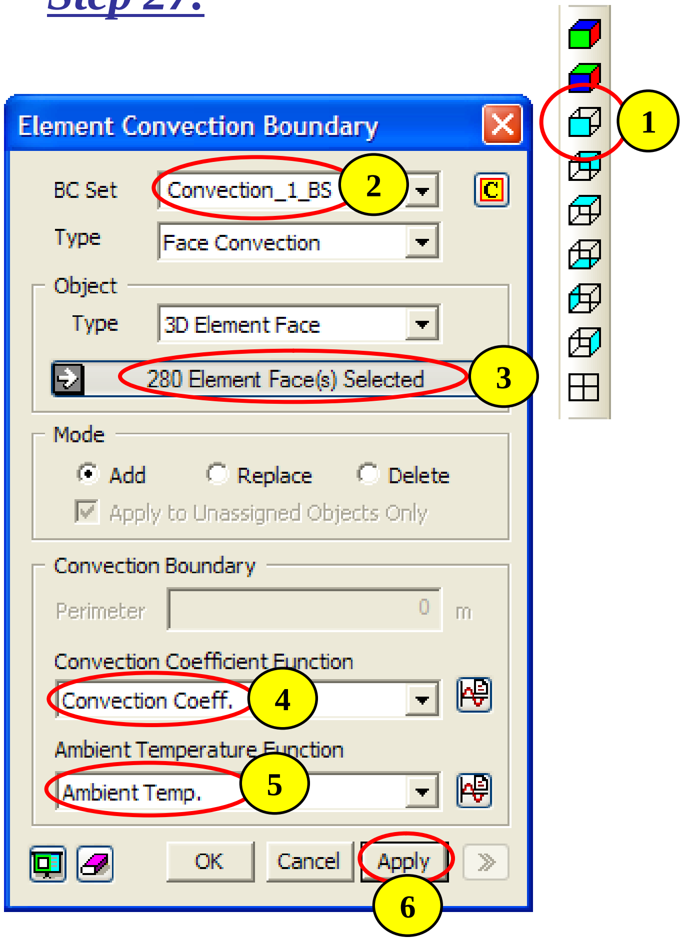




1. *Click "Left View"*
2. *BC Set : Convection_1*
3. *Select 138 Element Faces (See Figure)*
4. *Convection Coefficient Function : Convection Coeff.*
5. *Ambient Temperature Function : Ambient Temp.*
6. *Click* [Apply] *Button*



Step 27.



1. Click "Front View"

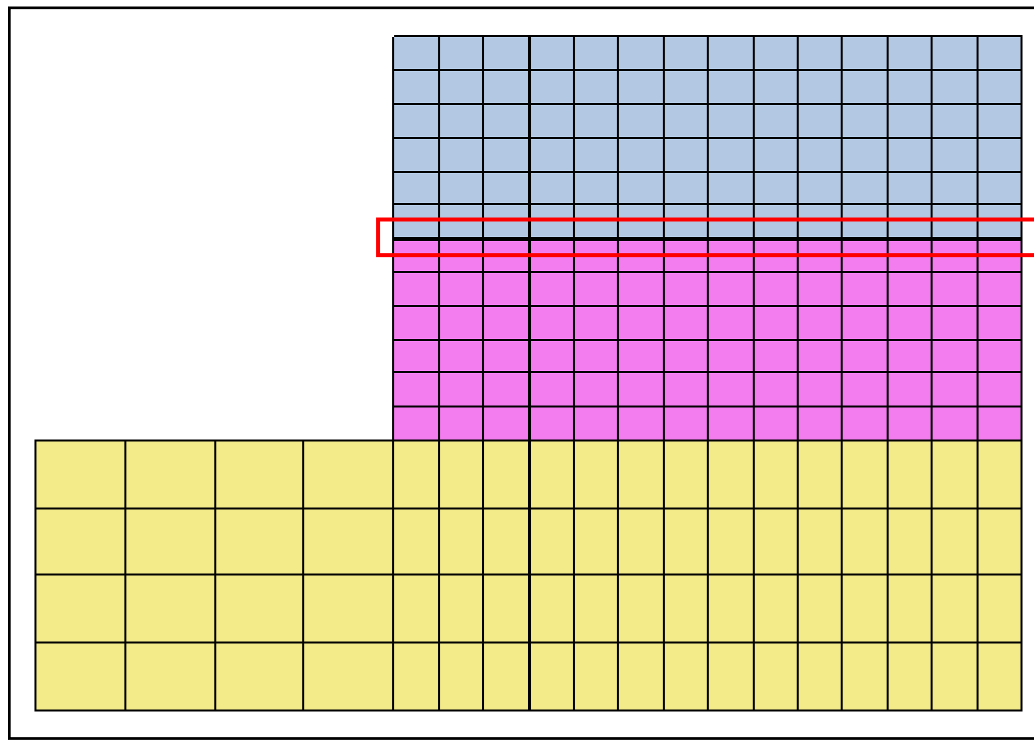
2. BC Set : Convection_1_BS

3. Select 280 Element Faces (See Figure)

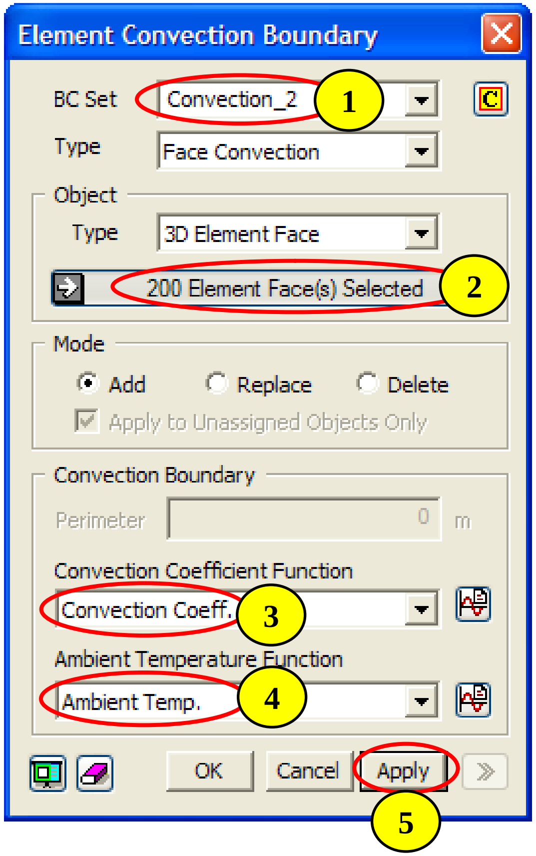
4. Convection Coefficient Function : Convection Coeff.

5. Ambient Temperature Function : Ambient Temp.

6. Click [Apply] *Button*



Step 28.



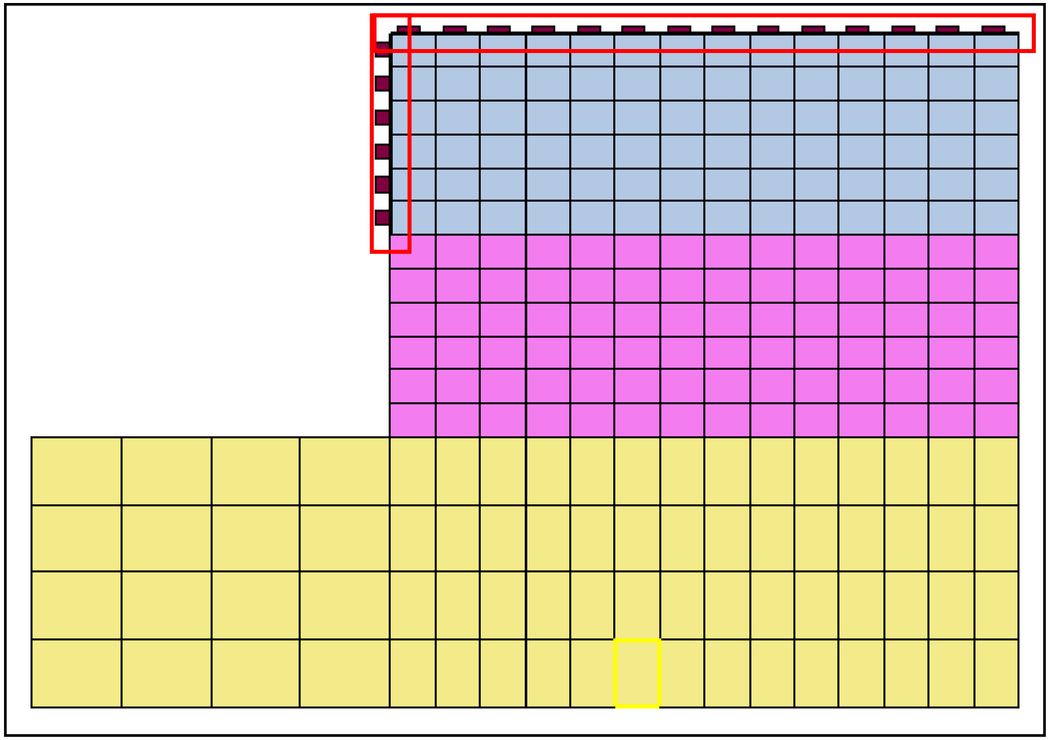
1. BC Set : Convection_2

2. Select 200 Element Faces (See Figure)

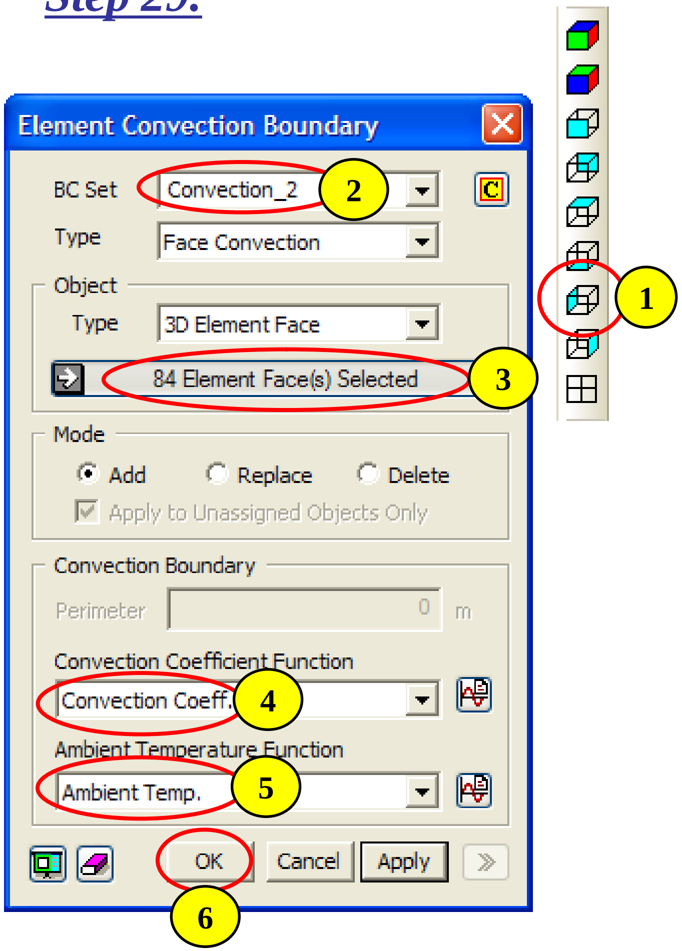
3. Convection Coefficient Function : Convection Coeff.

4. Ambient Temperature Function : Ambient Temp.

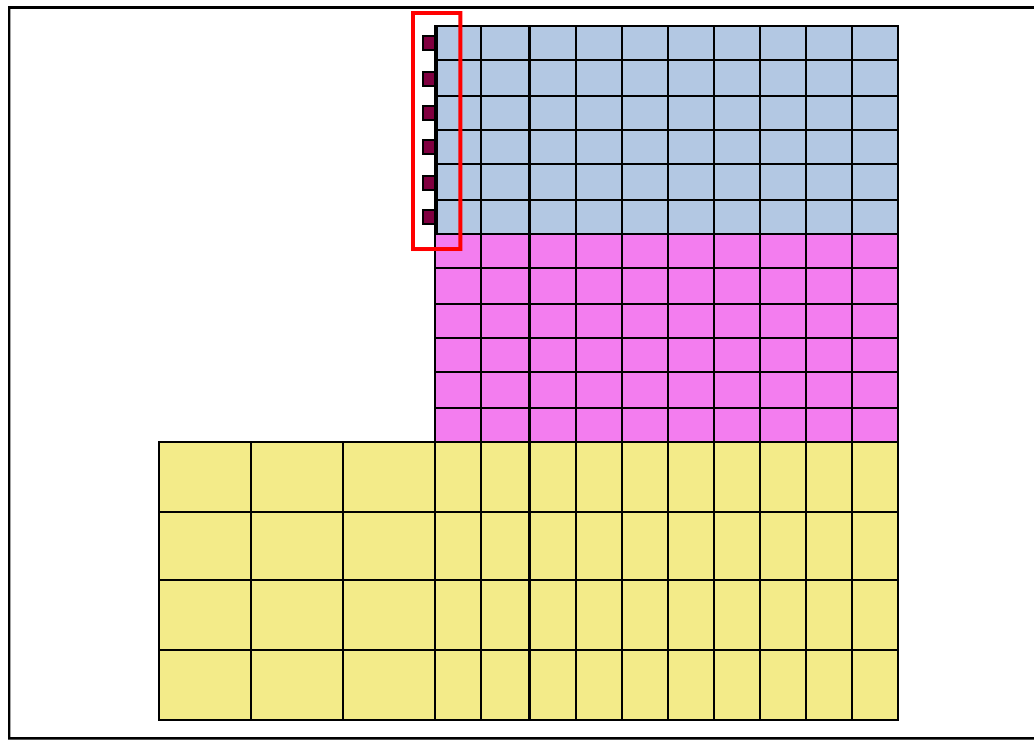
5. Click [Apply] *Button*



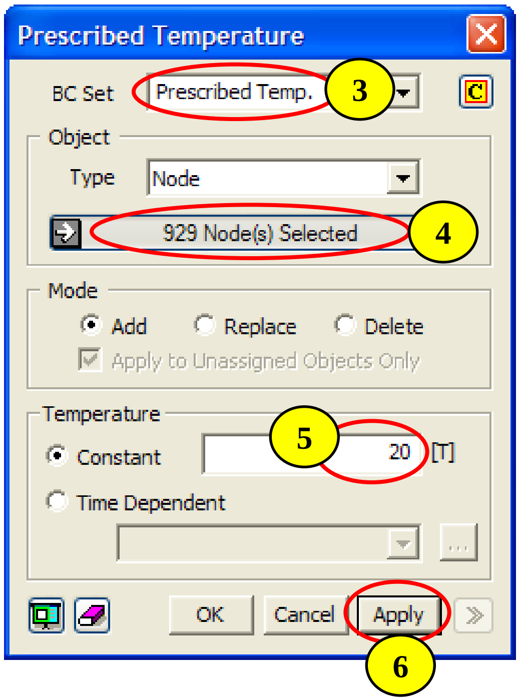
Step 29.

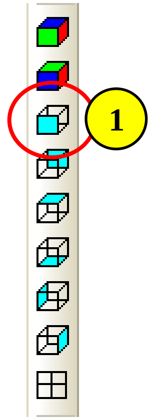


1. *Click "Left View"*
2. *BC Set : Convection_2*
3. *Select 84 Element Faces (See Figure)*
4. *Convection Coefficient Function : Convection Coeff.*
5. *Ambient Temperature Function : Ambient Temp.*
6. *Click* [OK] *Button*



Step 30.





1. Click "Front View"

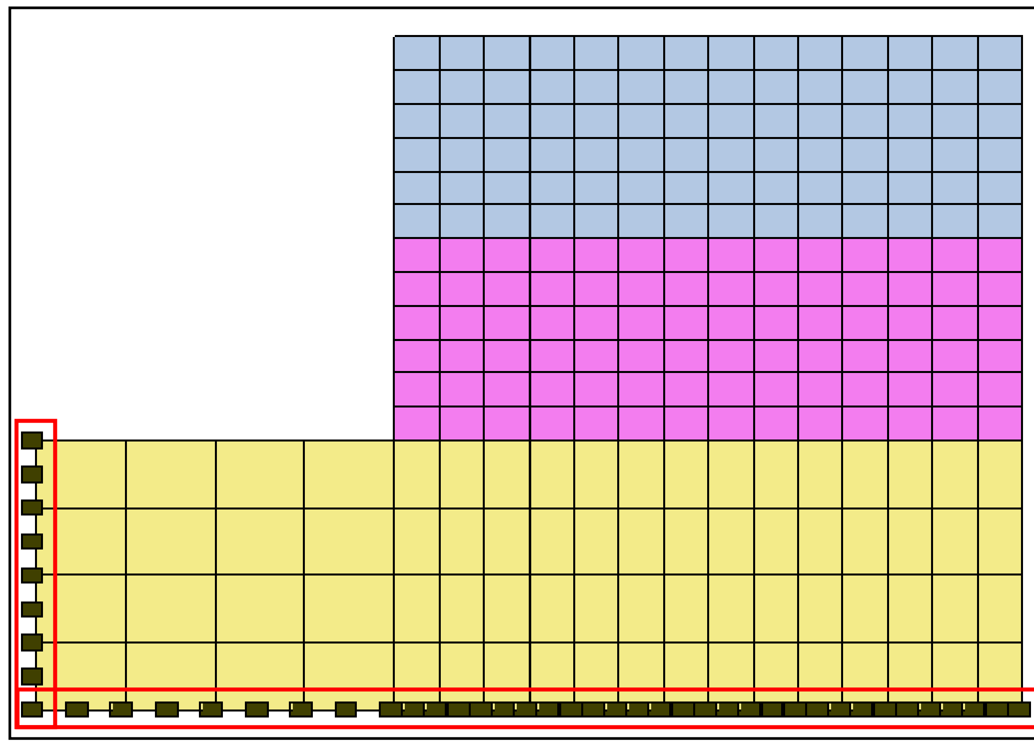
2. Analysis > Heat Transfer Analysis > Prescribed Temperature...

3. BC Set : Prescribed Temp.

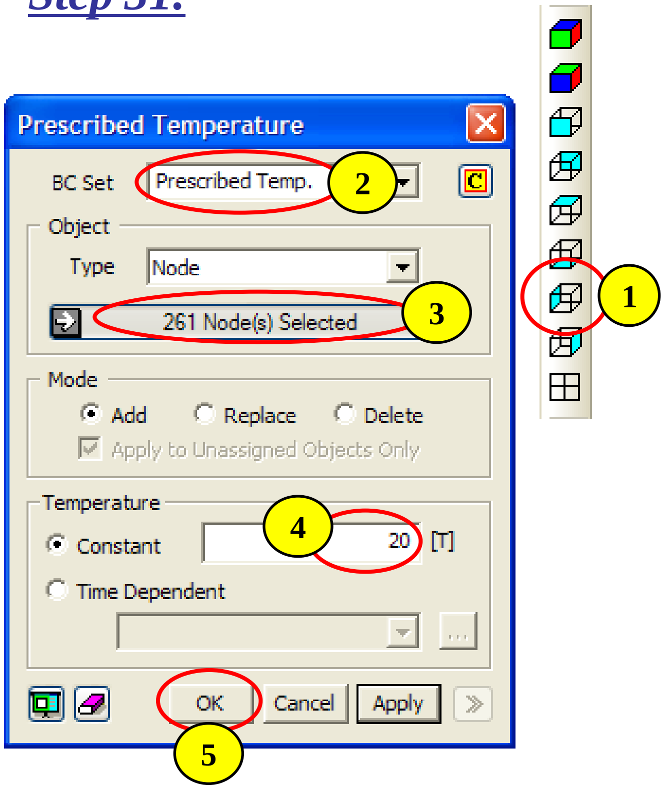
4. Select 929 Nodes (See Figure)

5. Temperature : 20 [T]

6. Click [Apply] *Button*



Step 31.



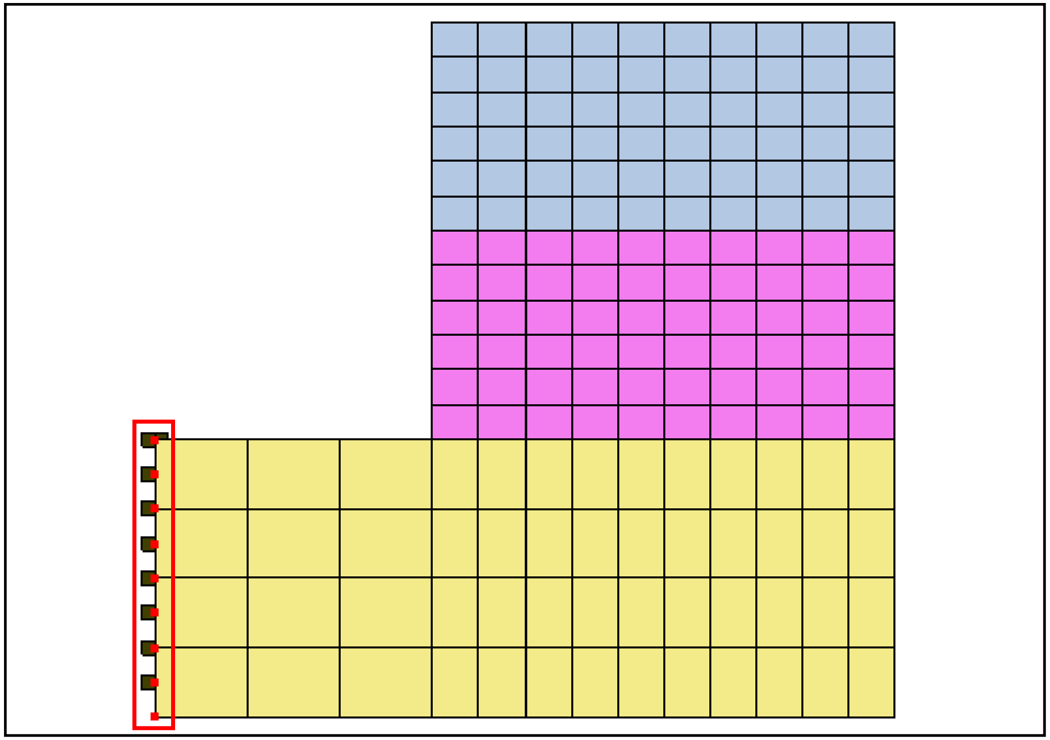
1. Click "Left View"

2. BC Set : Prescribed Temp.

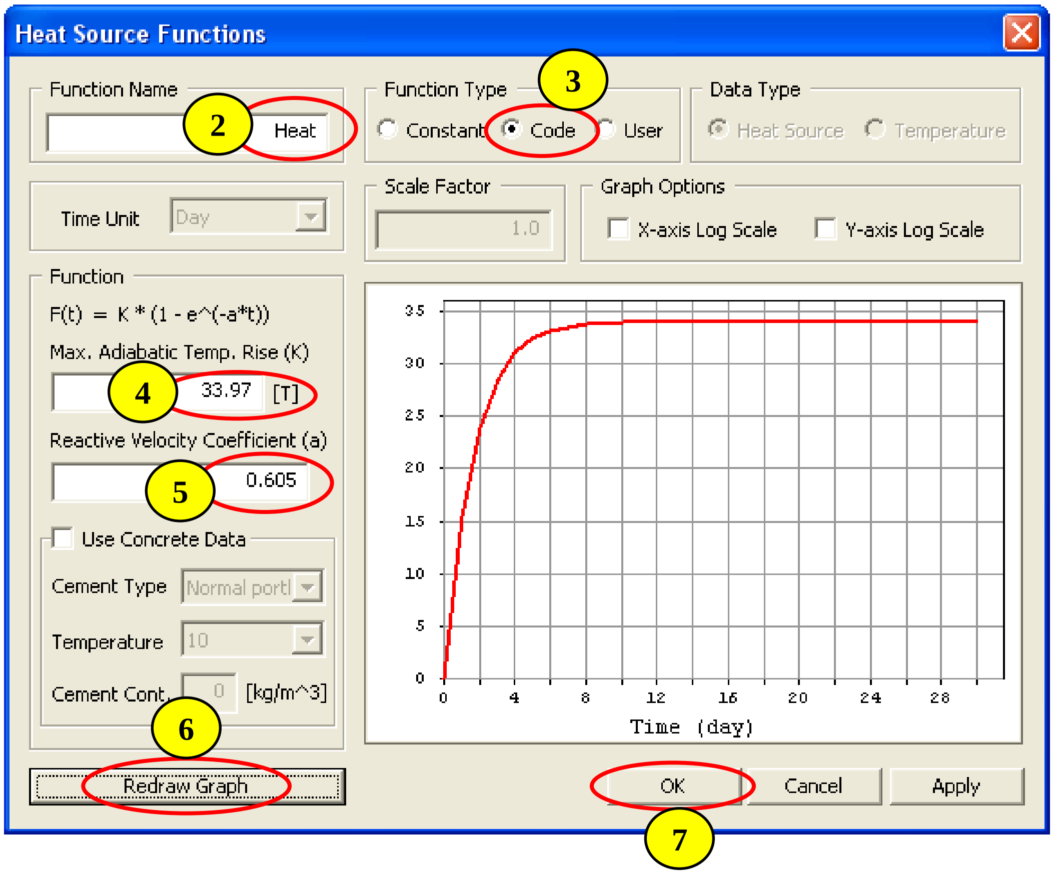
3. Select 261 Nodes (See Figure)

4. Temperature : 20 [T]

5. Click [OK] *Button*

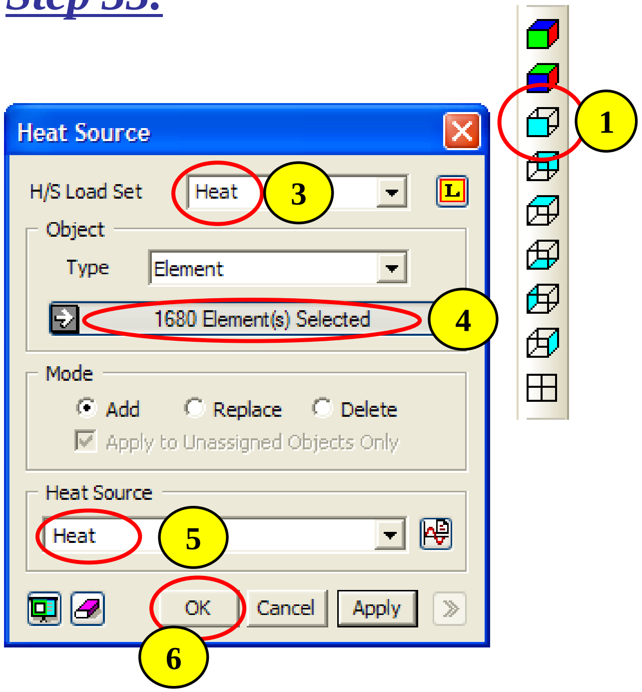


Step 32.



1. *Analysis > Heat Transfer Analysis > Heat Source Functions...*
2. *Function Name : Heat*
3. *Function Type : Code*
4. *Max. Adiabatic Temp. Rise (K) : 33.97* [T]
5. *Reactive Velocity Coefficient (a) : 0.605*
6. *Click* [Redraw Graph] *Button*
7. *Click* [OK] *Button*

Step 33.



1. Click "Front View"

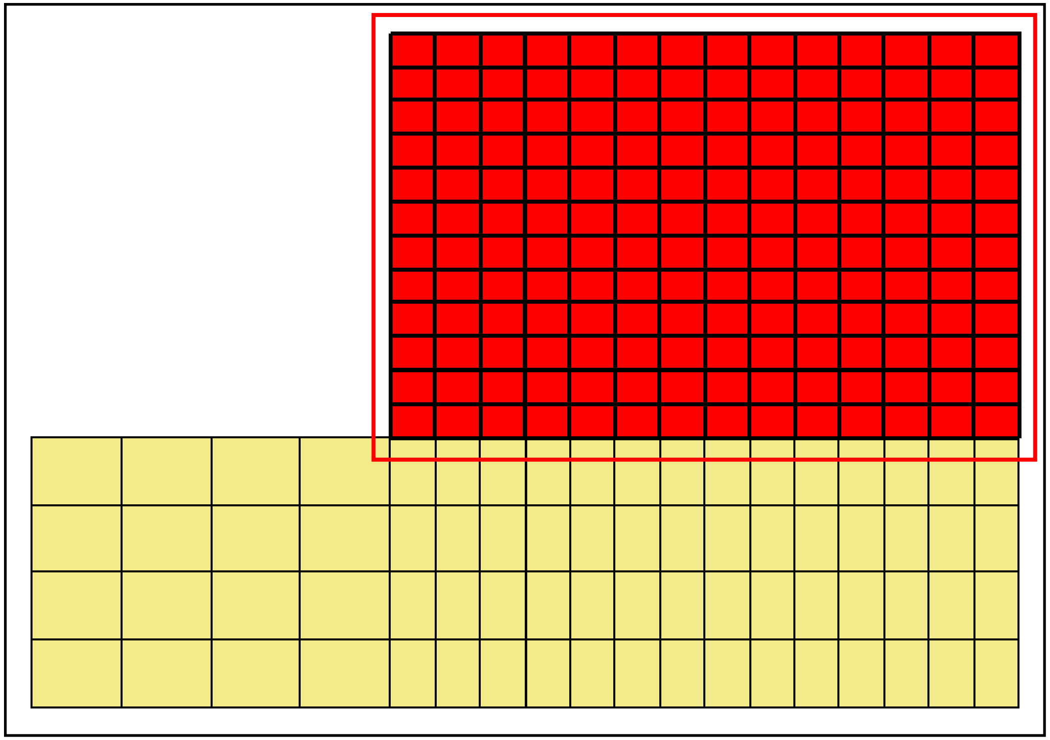
2. Analysis > Heat Transfer Analysis > Heat Source...

3. BC Set : Heat

4. Select 1680 Solid Elements (See Figure)

5. Heat Source : Heat

6. Click [OK] Button



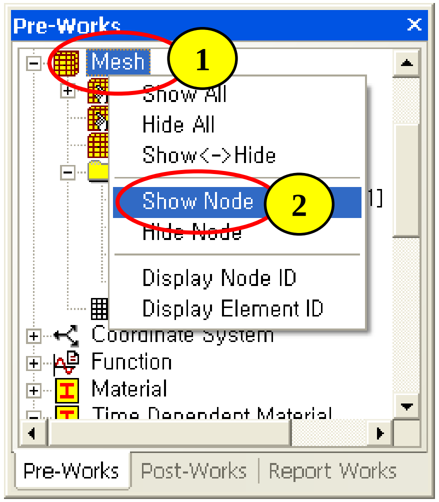
Step 34.

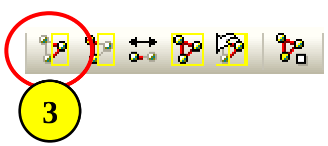
1. Pre-Works Tree : Mesh...

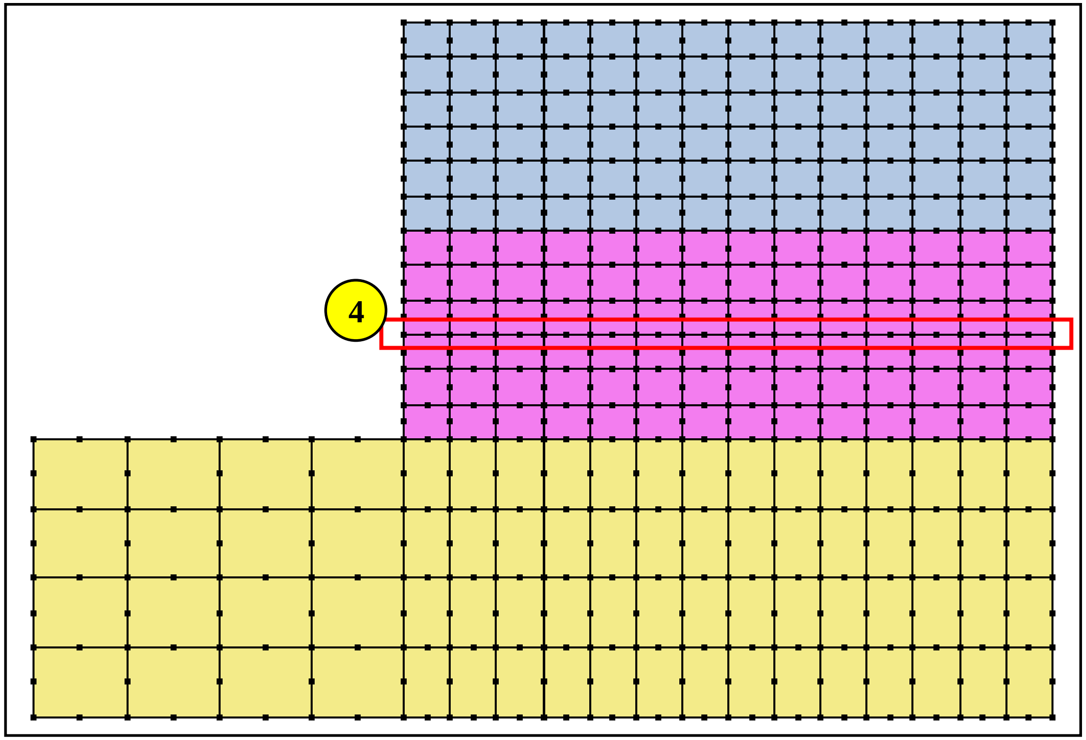
2. Click Right Mouse Button and Select Show Node

3. Click "Show Elem/Node" in "Mesh" Tabbed Toolbar

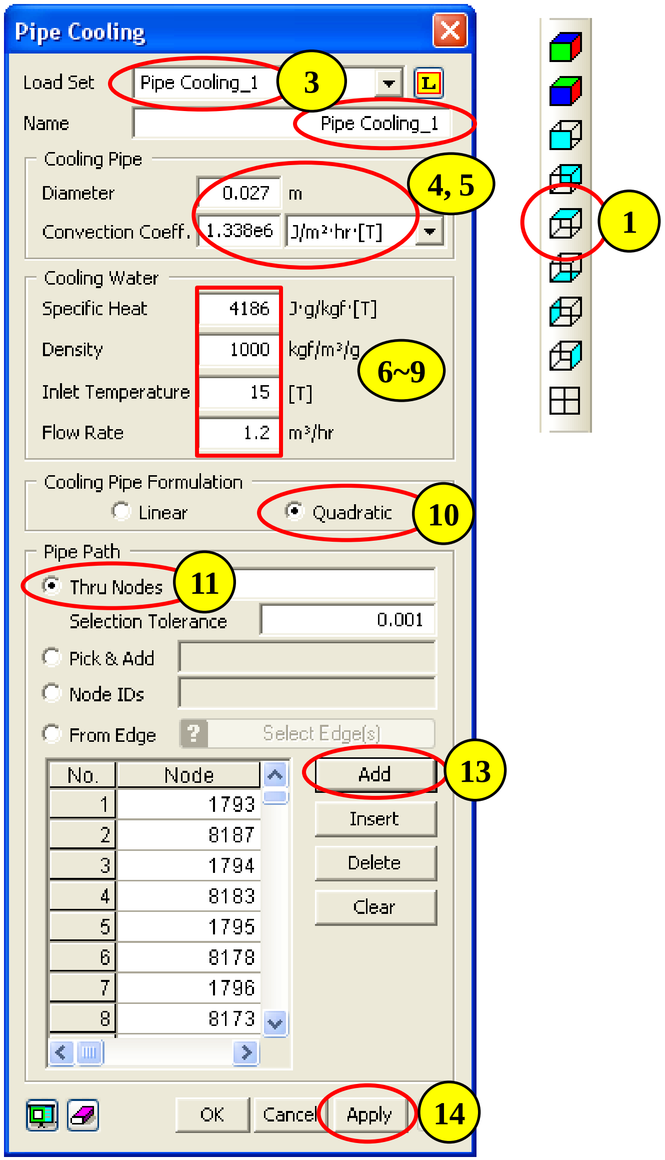
4. Select Nodes (See Figure)





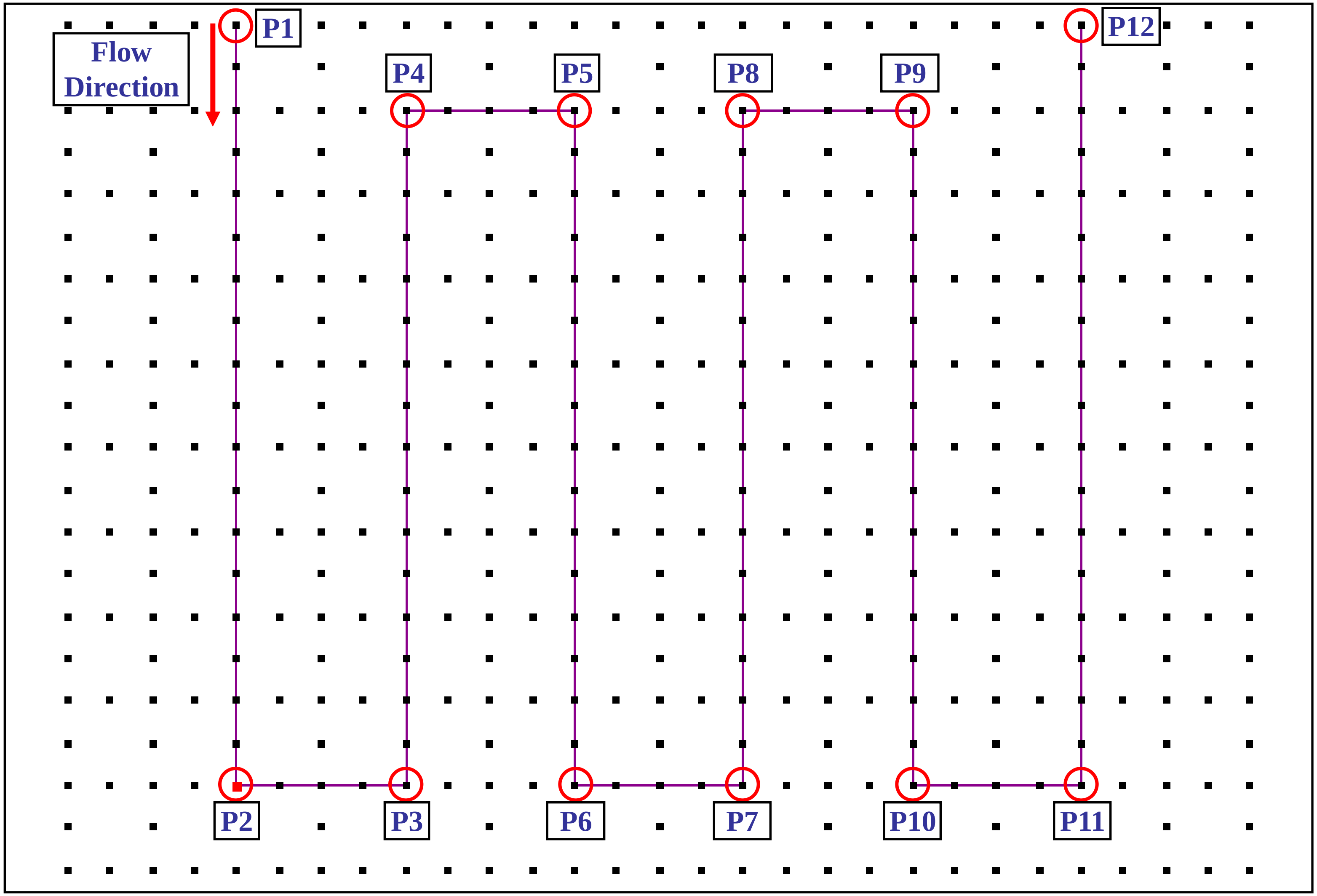


Step 35-1.

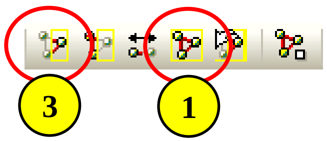


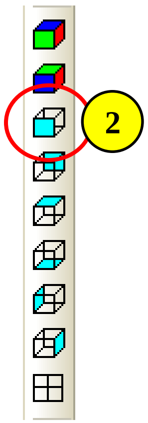
1. *Click "Top View"*
2. *Analysis > Heat Transfer Analysis > Pipe Cooling...*
3. *Load Set & Name: Pipe Cooling_1*
4. *Diameter : 0.027 m*
5. *Convection Coeff. : 1.338e6 J/m²·hr·*[T]
6. *Specific Heat : 4186 J·g/kgf·*[T]
7. *Density : 1000 kgf/m³/g*
8. *Inlet Temperature : 15* [T]
9. *Flow Rate : 1.2 m³/hr*
10. *Cooling Pipe Formulation : Quadratic*
11. *Pipe Path : Thru Nodes*
12. *Select P1 ~ P12 in sequential order (See Figure in 35-2)*
13. *Click* [Add] *Button*
14. *Click* [Apply] *Button*

Step 35-2.



Step 36.



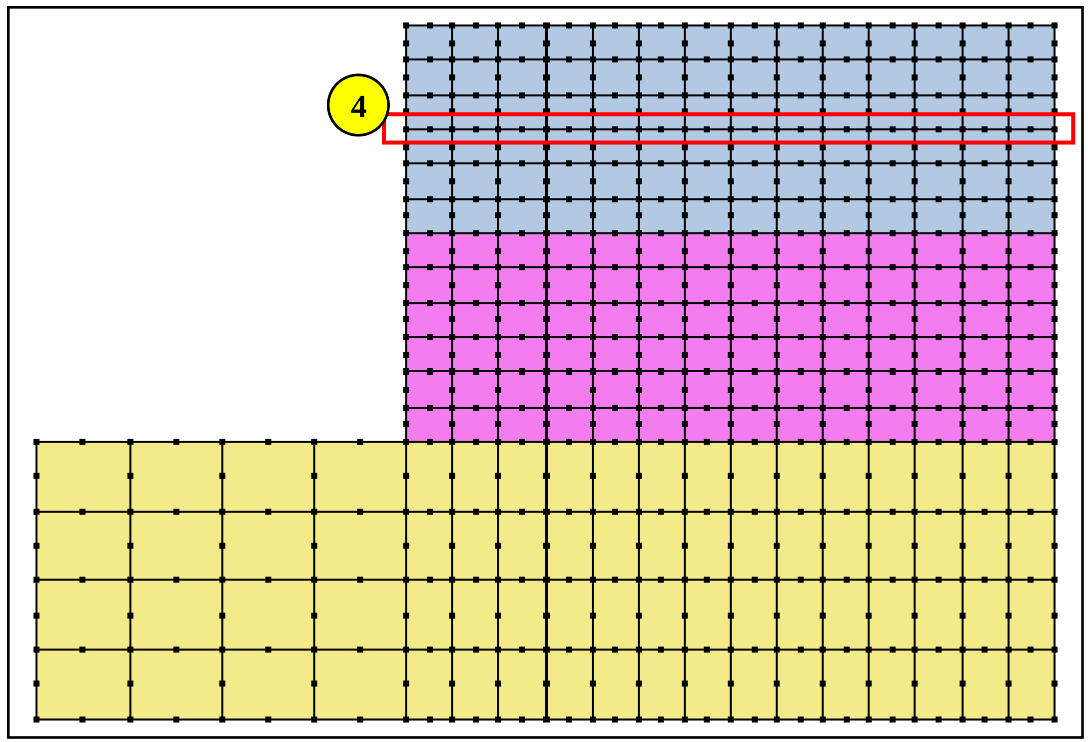


1. Click "Show All"

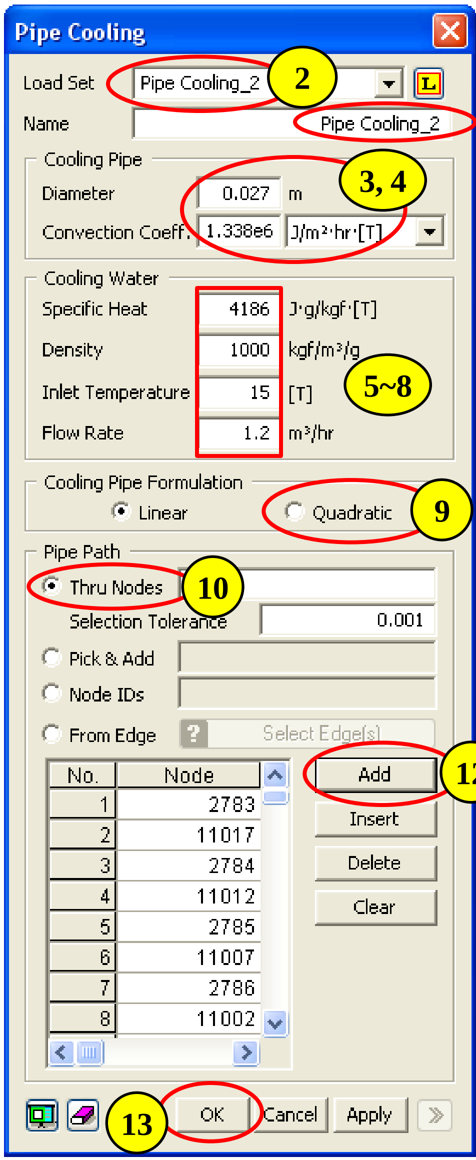
2. Click "Front View"

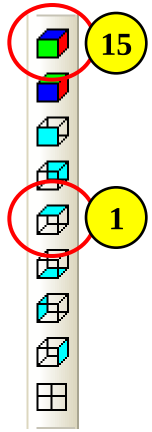
3. Click "Show Elem/Node"

4. Select Nodes (See Figure)

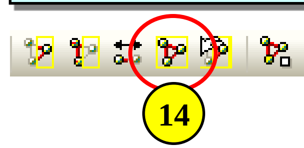


Step 37-1.

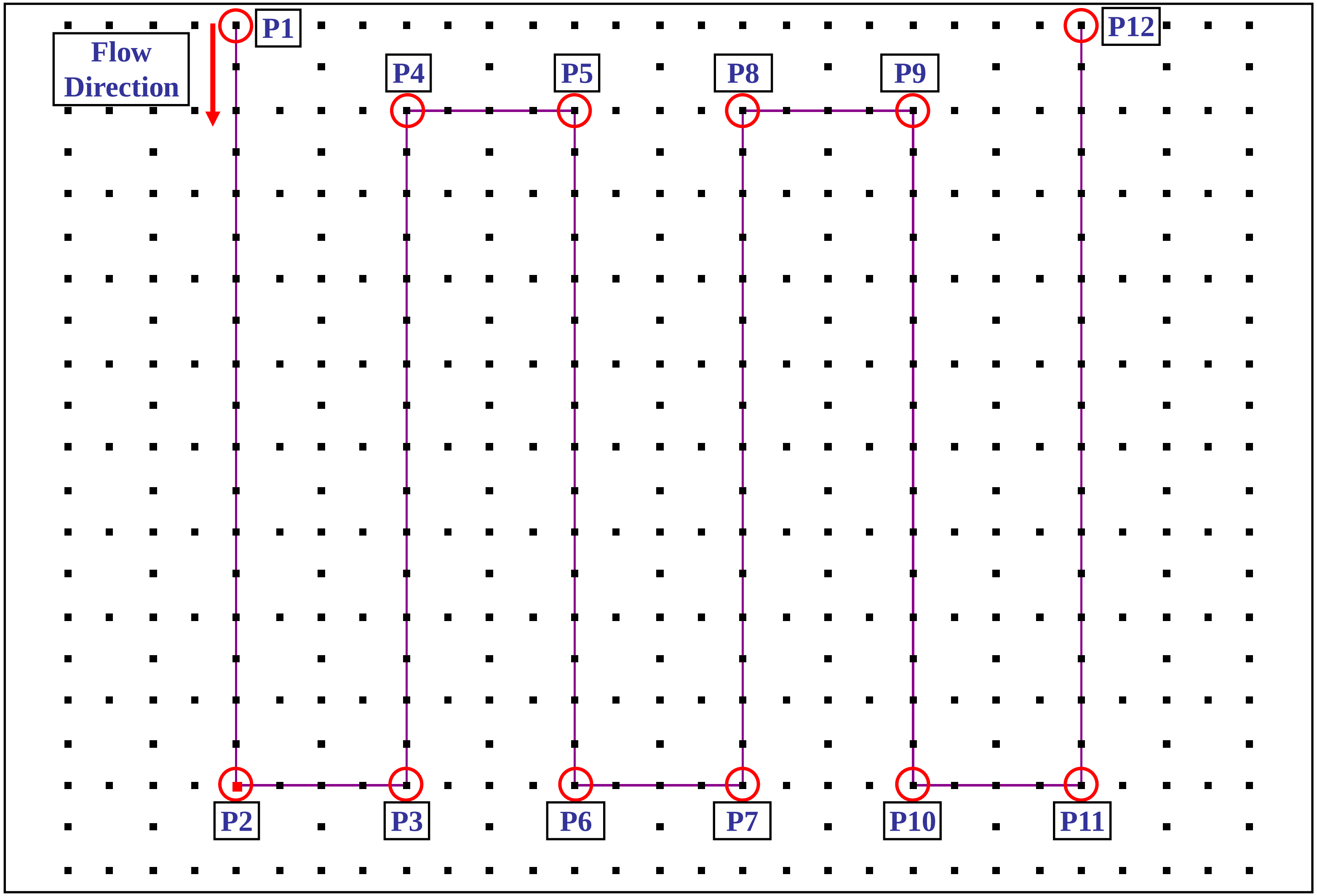




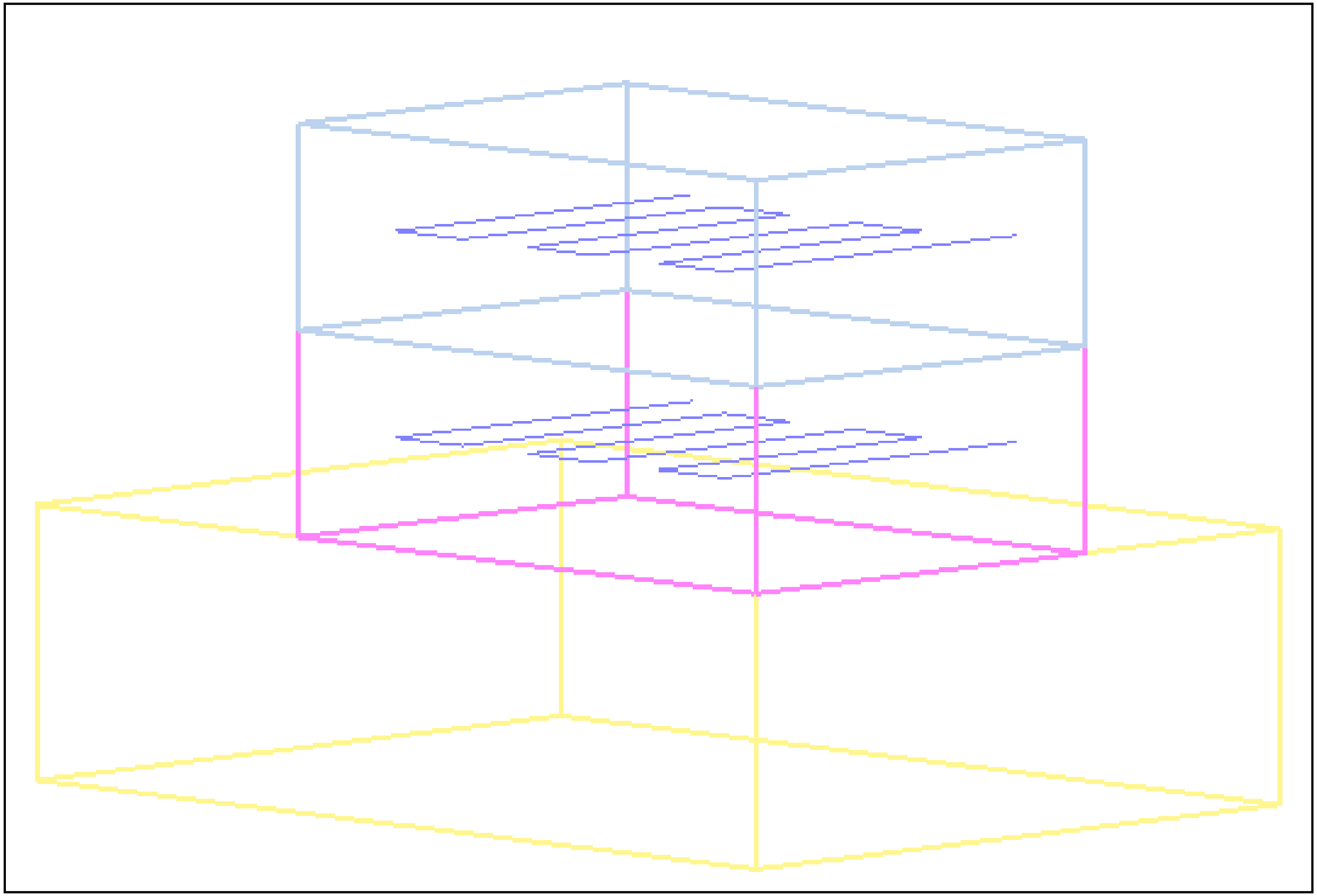
1. *Click "Top View"*
2. *Name & Load Set : Pipe Cooling_2*
3. *Diameter : 0.027 m*
4. *Convection Coeff. : 1.338e6 J/m²·hr·[T]*
5. *Specific Heat : 4186 J·g/kgf·[T]*
6. *Density : 1000 kgf/m³/g*
7. *Inlet Temperature : 15 [T]*
8. *Flow Rate : 1.2 m³/hr*
9. *Cooling Pipe Formulation : Quadratic*
10. *Pipe Path : Thru Nodes*
11. *Select P1 & P12 in sequential order (See Figure in 37-2)*
12. *Click [Add] Button*
13. *Click [OK] Button*
14. *Click "Show All"*
15. *Click "Isometric 1 View"*



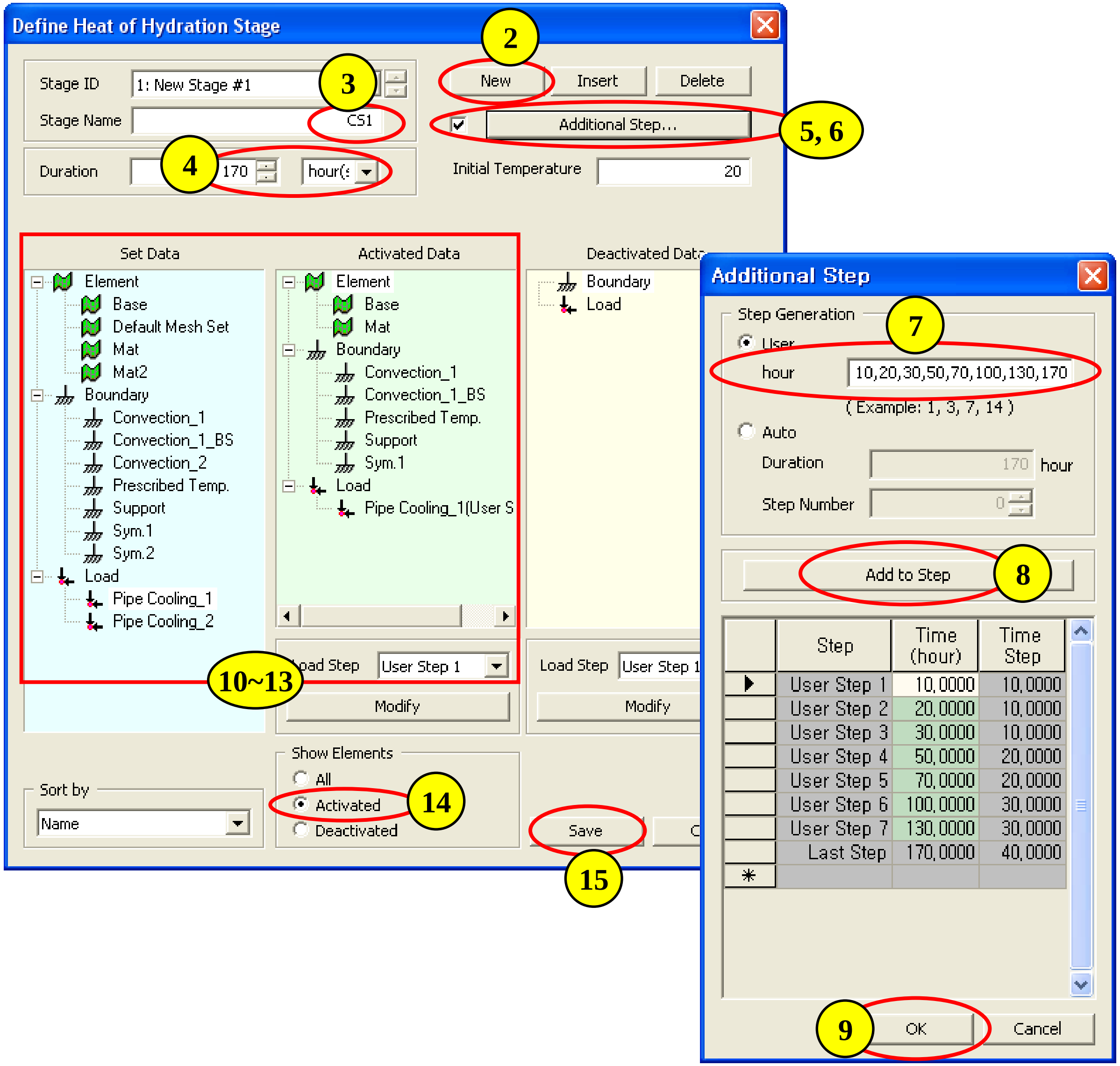
Step 37-2.



Step 37-3.

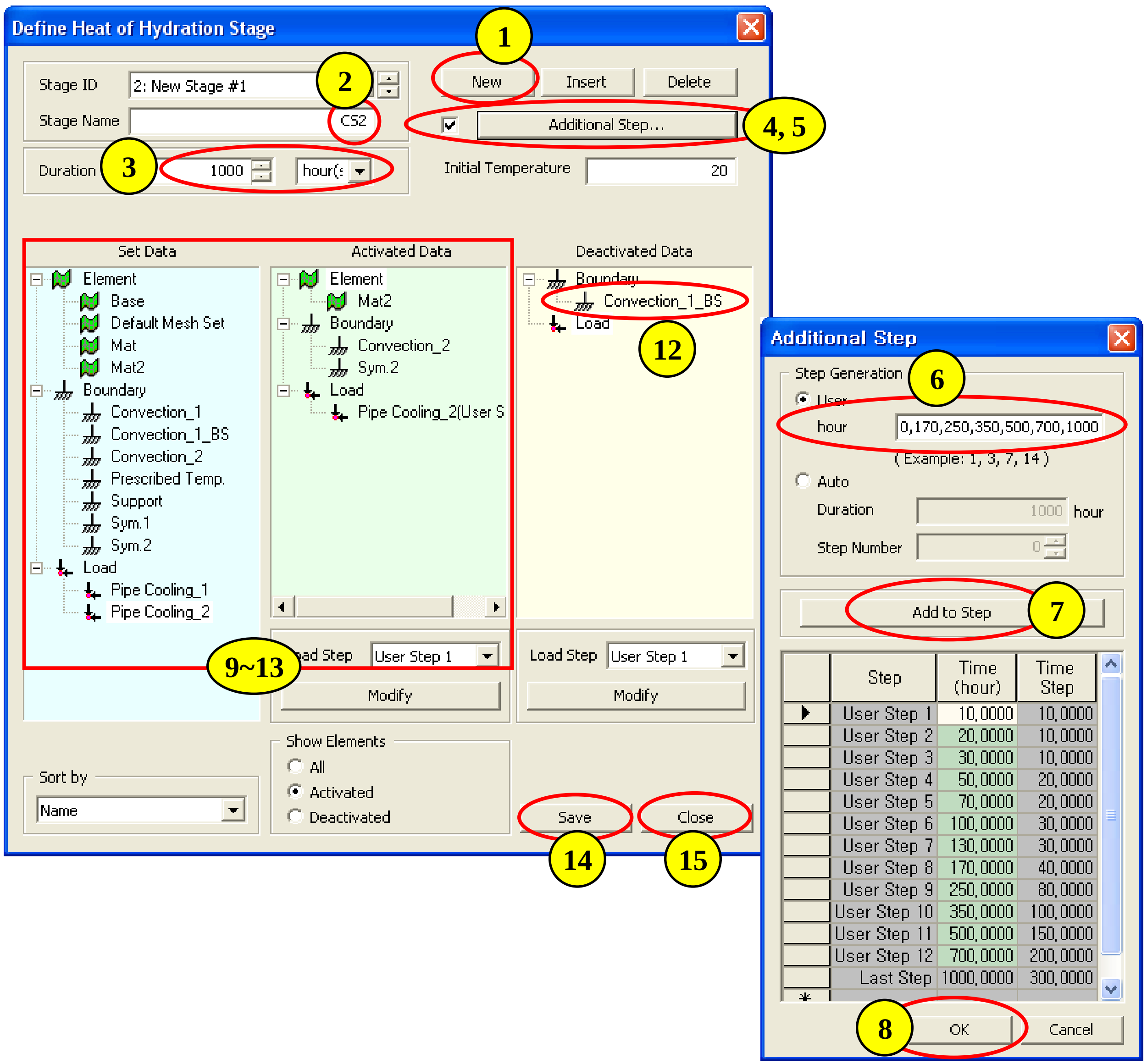


Step 38.



1. *Analysis > Heat of Hydration Stage > Define Heat of Hydration Stage…*
2. *Click* [New] *Button*
3. *Stage Name : CS 1*
4. *Duration : 170 hour(s)*
5. *Check on "Additional Step"*
6. *Click* [Additional Step...] *Button*
7. *hour : (10, 20, 30, 50, 70, 100, 130, 170)*
8. *Click* [Add to Step] *Button*
9. *Click* [OK] *Button*
10. *Load Step : User Step 1*
11. *Drag & Drop "Base" & "Mat" to "Activated Data" Window*
12. *Drag & Drop "Convection_1" , "Convection_1_BS" , "Prescribed Temp." , "Support" , "Sym. 1" to "Activated Data" Window*
13. *Drag & Drop "Pipe Cooling_1" to "Activated Data" Window*
14. *Check on "Activated"*
15. *Click* [Save] *Button*

Step 39.



1. Click **[New]** *Button*

2. Stage Name : CS 2

3. Duration : 1000 hour(s)

4. Check on "Additional Step"

5. Click **[Additional Step...]** *Button*

6. hour : (10, 20, 30, 50, 70, 100, 130, 170, 250, 350, 500, 700, 1000)

7. Click **[Add to Step]** *Button*

8. Click **[OK]** *Button*

9. Load Step : User Step 1

10. Drag & Drop "Mat2" to "Activated Data" Window

11. Drag & Drop "Convection_2" & "Sym. 2" to "Activated Data" Window

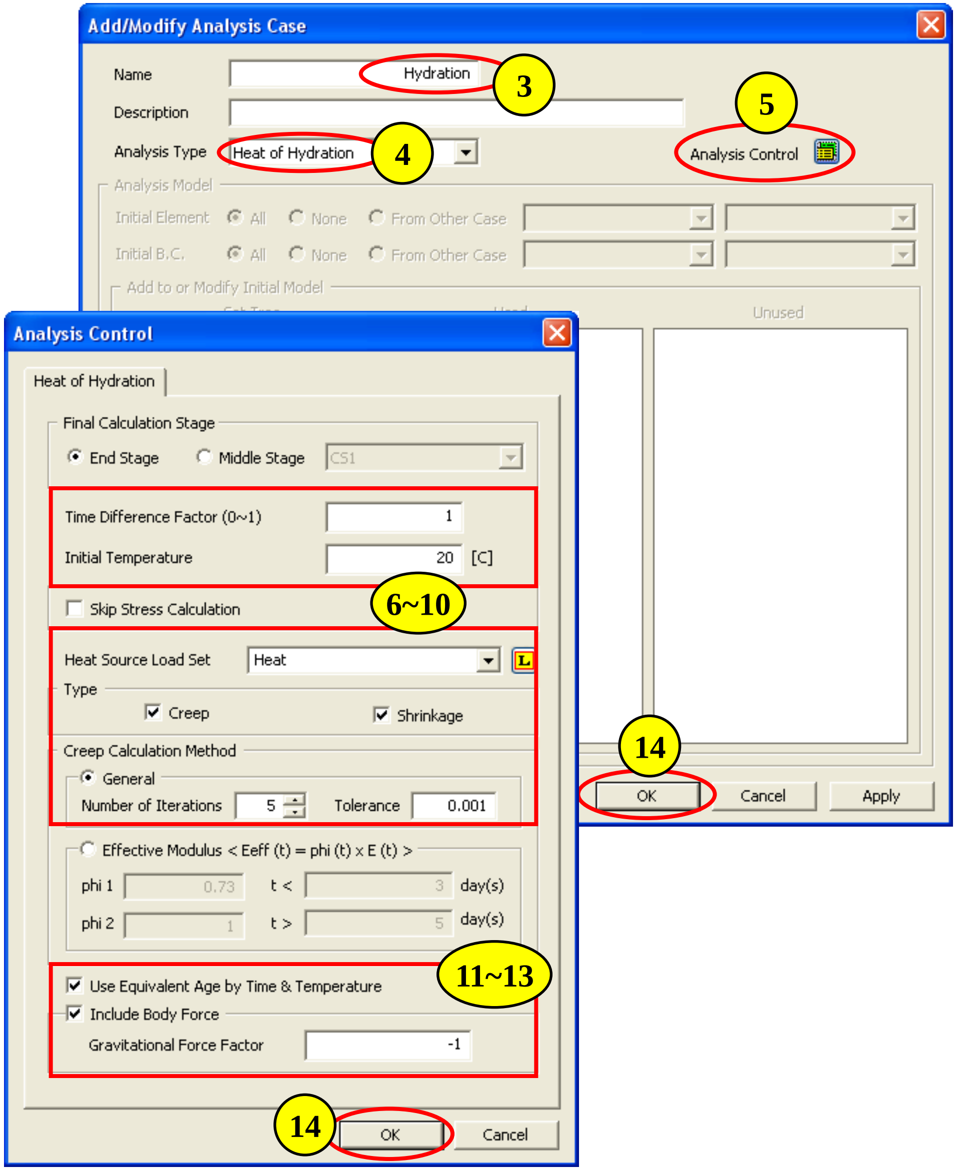
12. Drag & Drop "Convection_1_BS" to "Deactivated Data" Window

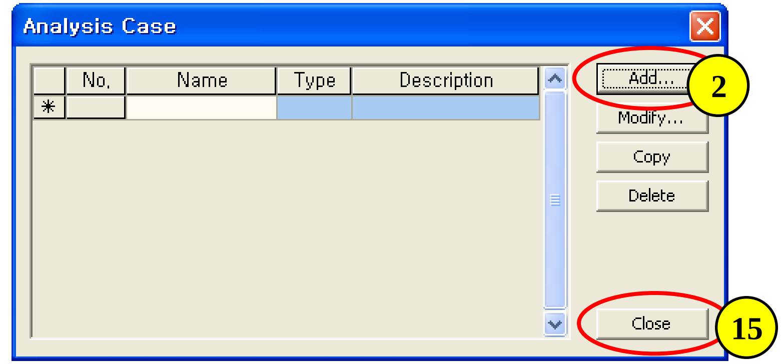
13. Drag & Drop "Pipe Cooling_2" to "Activated Data" Window

14. Click **[Save]** *Button*

15. Click **[Close]** *Button*

Step 40.





1. *Analysis > Analysis Case …*
2. *Click* [Add] *Button*
3. *Name : Hydration*
4. *Analysis Type : Heat of Hydration*
5. *Click* *Button of Analysis Control*
6. *Time Integration Factor (0~1) : 1*
7. *Initial Temperature : 20*
8. *Heat Source Load Set : Heat*
9. *Check on "Creep" & "Shrinkage"*
10. *Creep Calculation Method : General*
11. *Check on " Use Equivalent Age by Time & Temperature"*
12. *Check on "Include Body Force"*
13. *Gravitational Force Factor : -1*
14. *Click* [OK] *Button*
15. *Click* [Close] *Button*

Step 41.

1. Analysis > Solve...

2. Click [OK] Button

3. Post-Works Tree : Hydration (Structural Nonlinear) > Stage 1, STEP 1(10) > Nodal Misc. ...

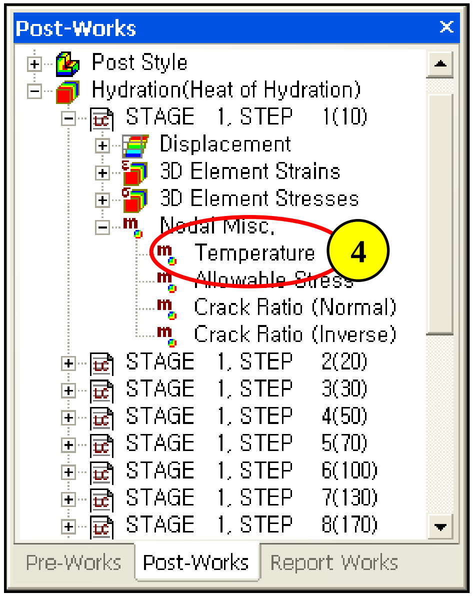
4. Double Click "Temperature"

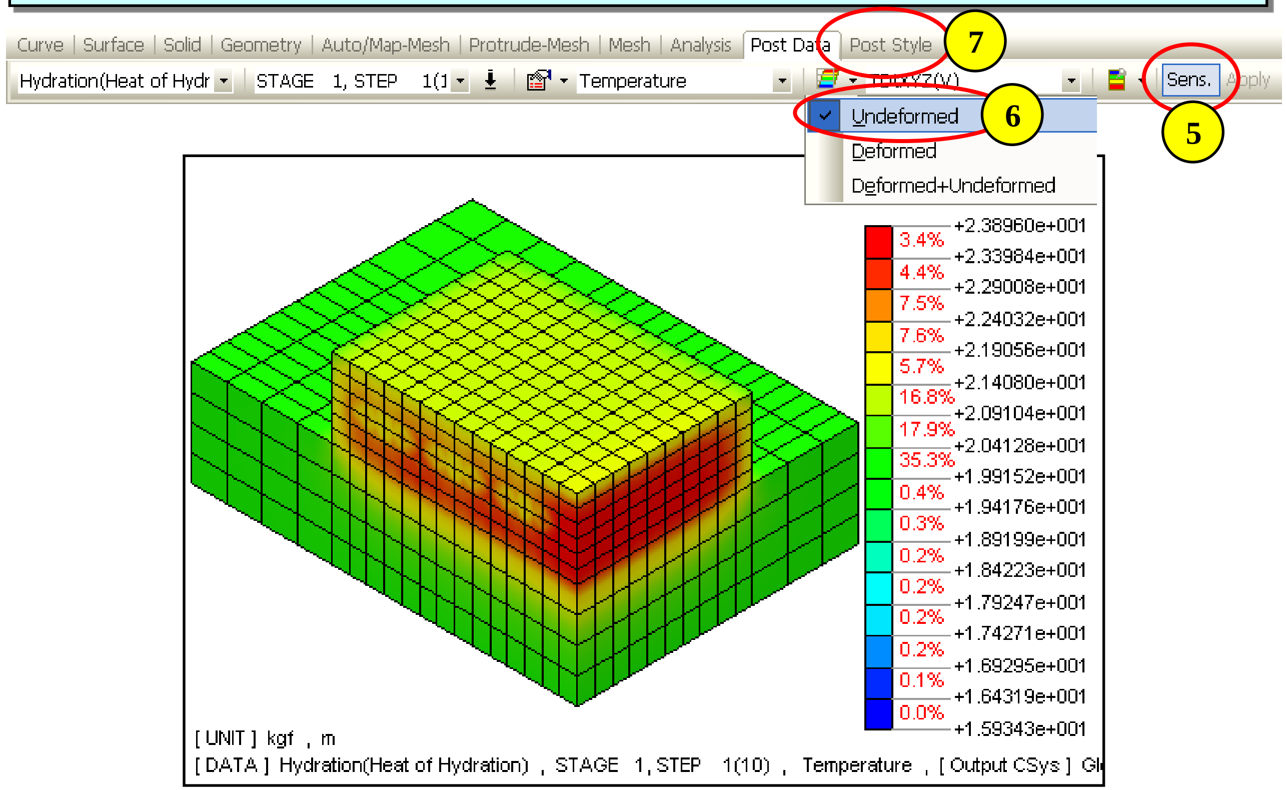
5. Click "Sens." Button

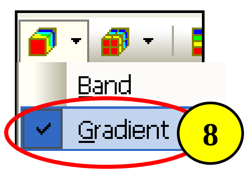
6. Select "Undeformed" for Mesh Shape (See Figure)

7. Click "Post Style" Toolbar

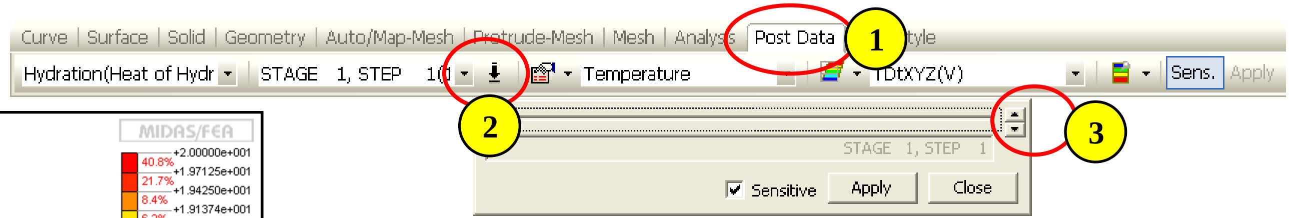
8. Select "Gradient" for Contour Type



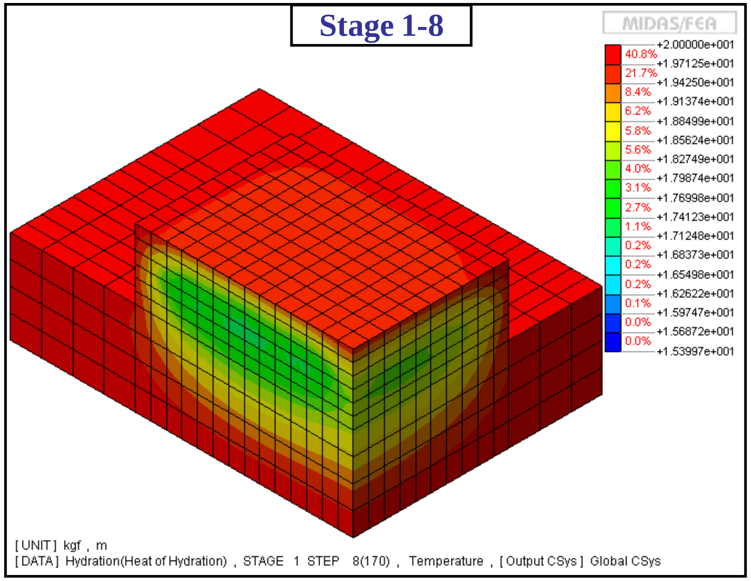


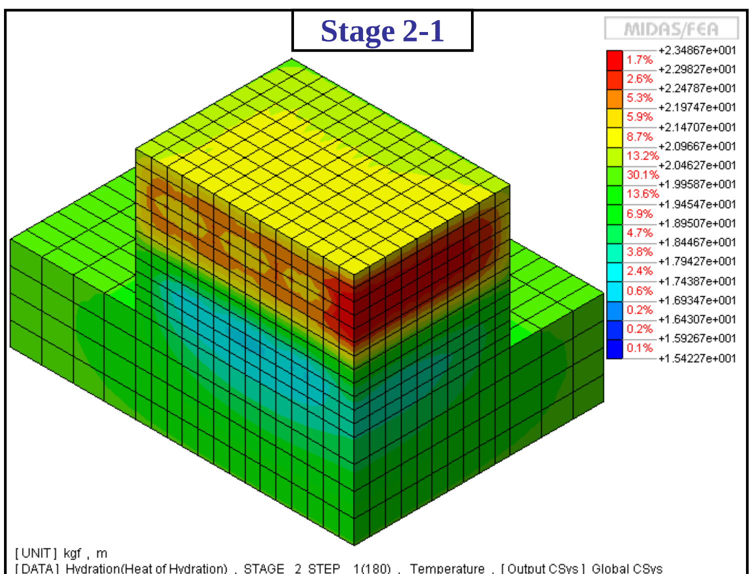


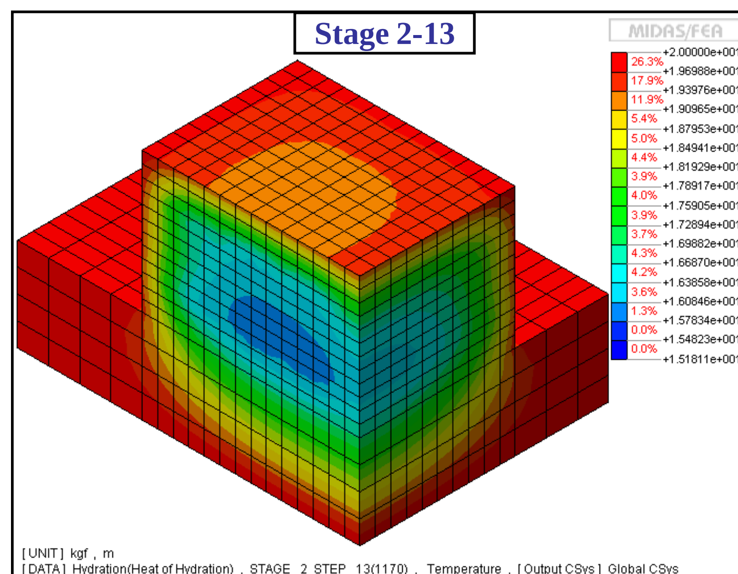
Step 42.



1. *Click "Post Data" Toolbar*
2. *Click "Output Set Slider" Button*
3. *Click* **[▲] or [▼] Button to Change Stage**

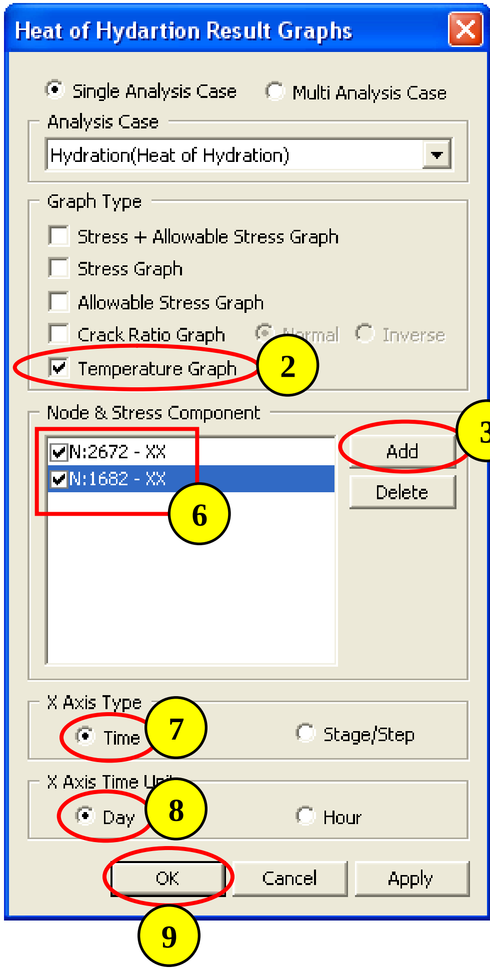


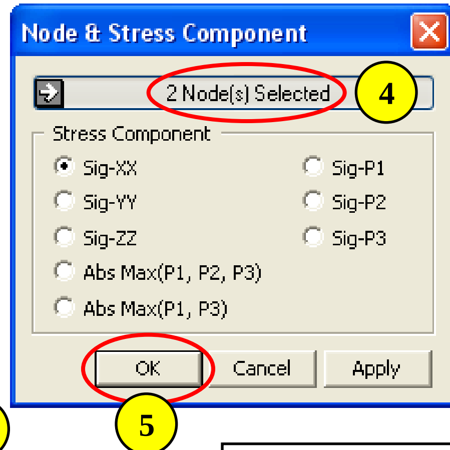


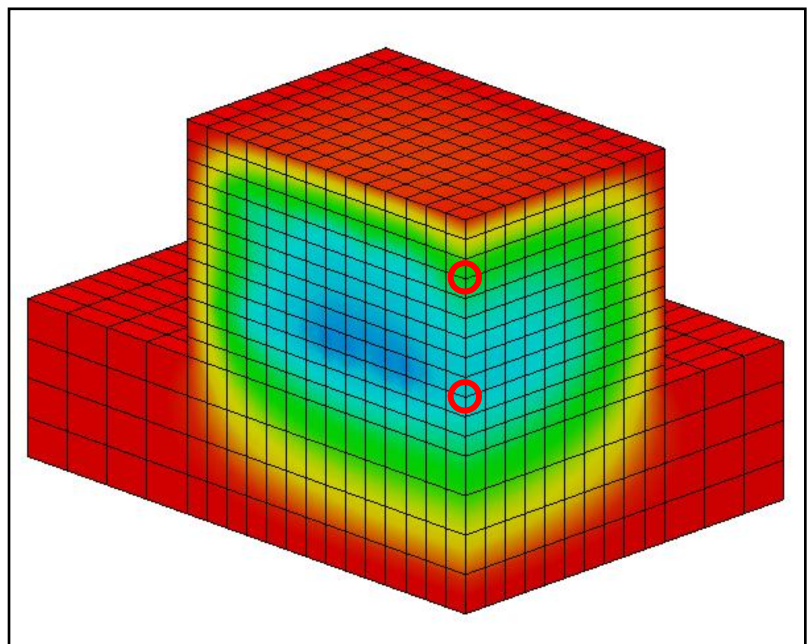


Step 43-1.

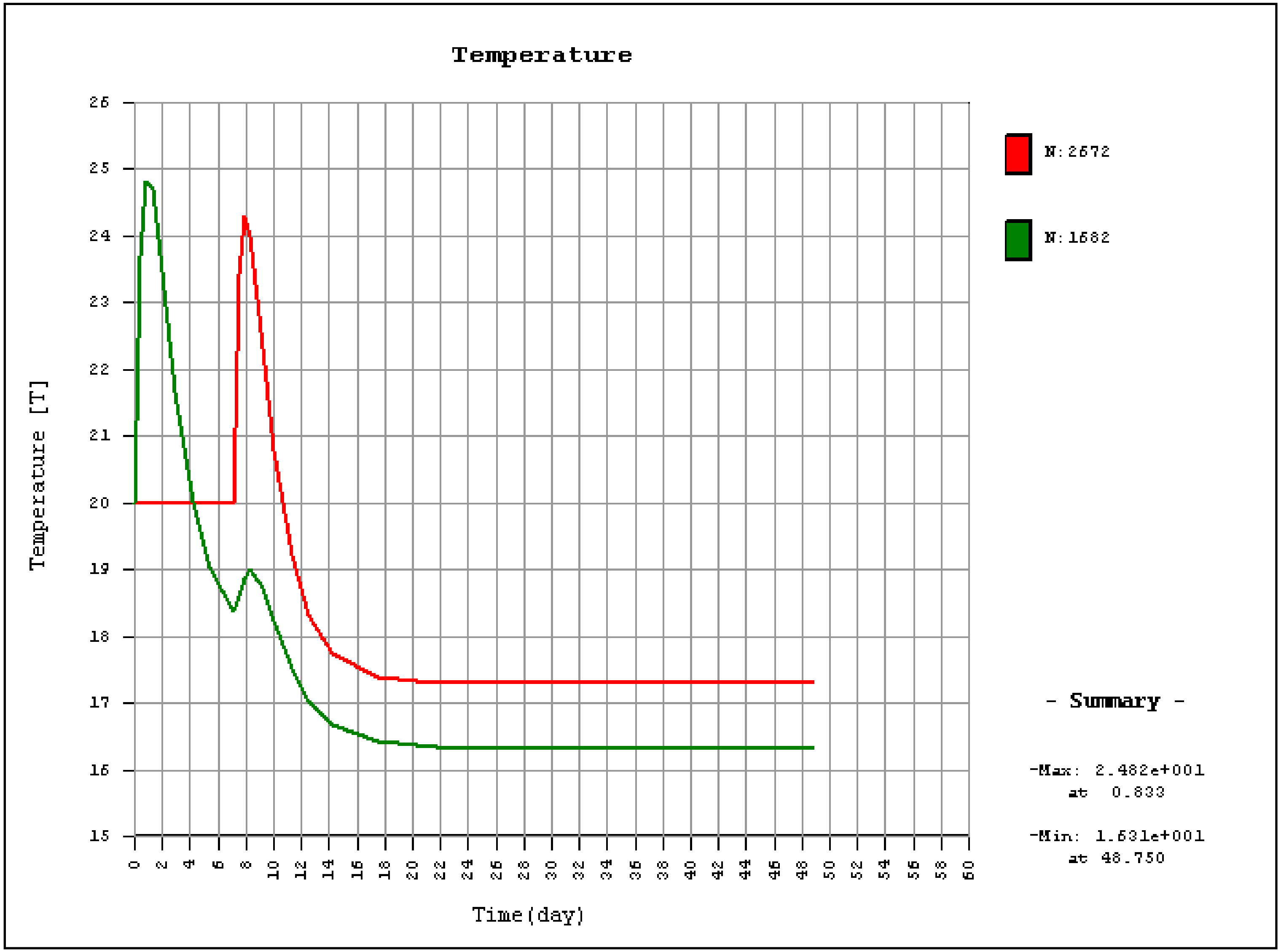
1. *Post > Heat of Hydration Result Graphs...*
2. *Check on "Stress Graph"*
3. *Click* [Add] *Button*
4. *Select 2 Nodes (See Figure)*
5. *Click* [OK] *Button*
6. *Check on all Components*
7. *X Axis Type : Time*
8. *X Axis Time Unit : Day*
9. *Click* [OK] *Button*



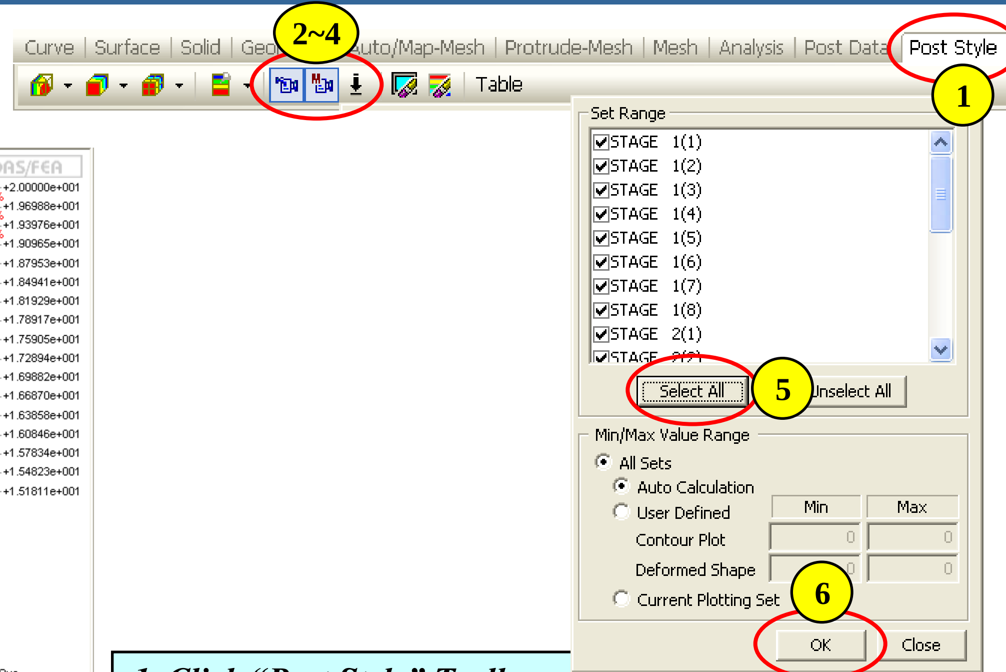


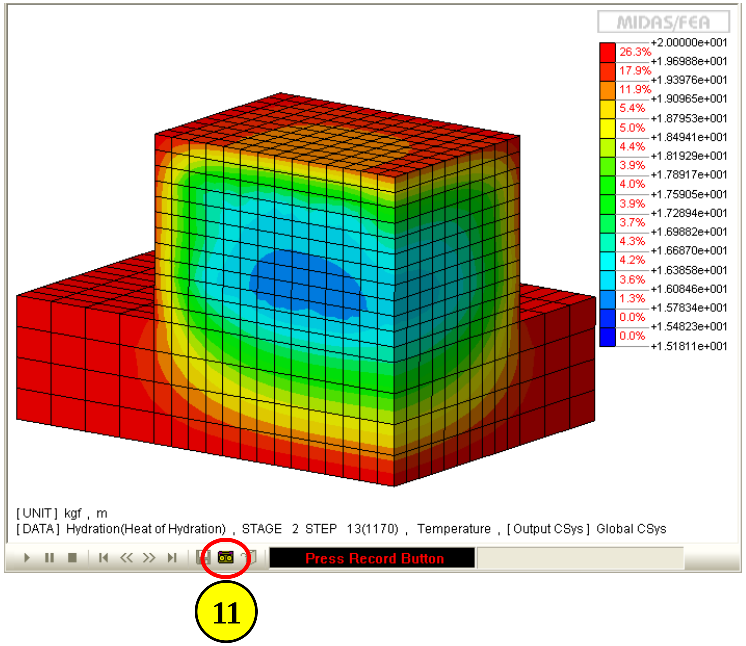


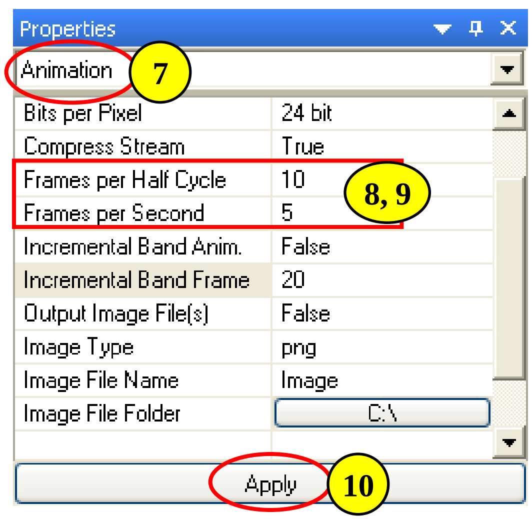
Step 43-2.


Temperature
Temperature [T]
Time(day)
26
25
24
23
22
21
20
19
18
17
16
15
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
N:2672
N:1682
- Summary -
-Max: 2.482e+001
at 0.833
-Min: 1.631e+001
at 48.750

Step 44.







1. Click "Post Style" Toolbar

2. Click "Animation Recording" Button

3. Click "Multi-Step Animation Recording" Button

4. Click "Animation Step"

5. Click [Select All] Button

6. Click [OK] Button

7. Property Window : Animation...

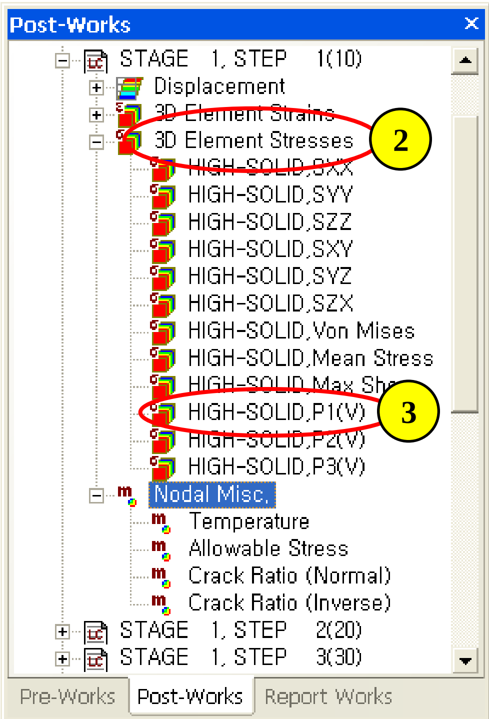
8. Frames per Half Cycle : 10

9. Frames per Second : 5

10. Click [Apply] Button

11. Click "Record" Button

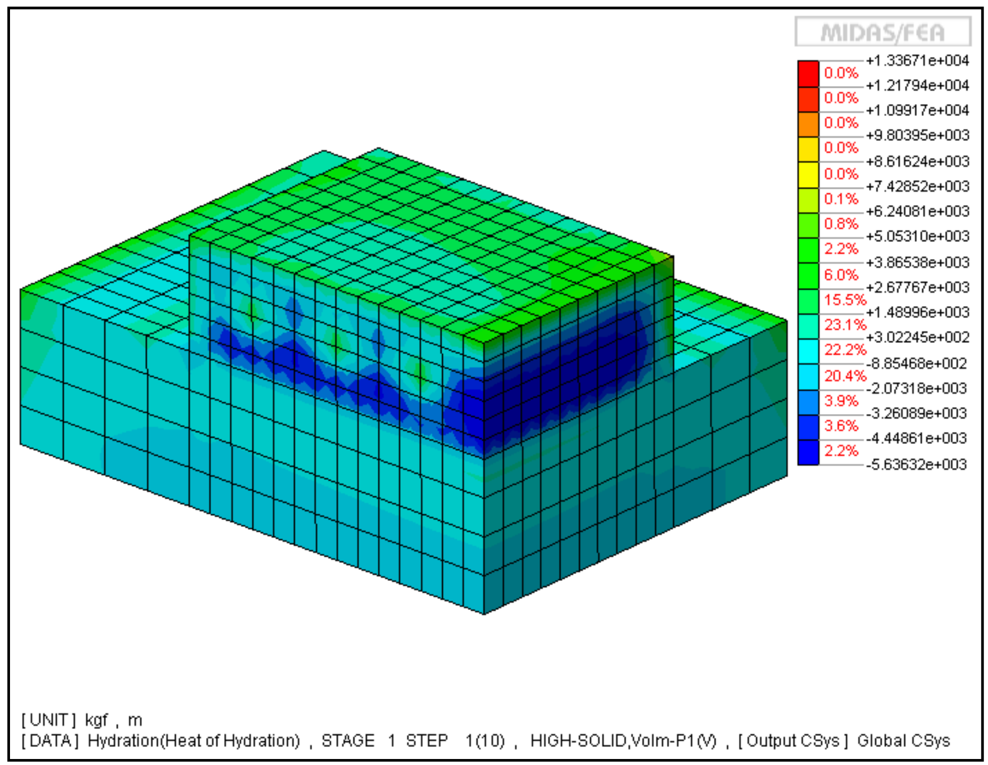
Step 45.



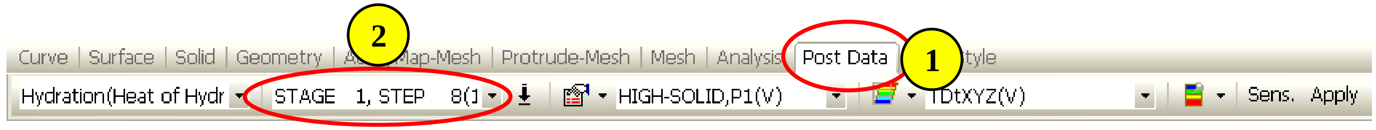
1. Turn off "Animation Recording"

2. Post-Works Tree : Hydration (Structural Nonlinear) > Stage 1, STEP 1(10) > 3D Element Stresses...

3. Double Click "HIGH-SOLID, P1(V)"



Step 46.



1. Click "Post Data" Toolbar

2. Select "STAGE 1, STEP 8(170)" for Output Set

3. Change Stage of Output Set