MIDAS Academy UK

Soil-structure interaction

Part 2 : Modelling Tutorial in MIDAS Civil and GTS NX

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midas Civil

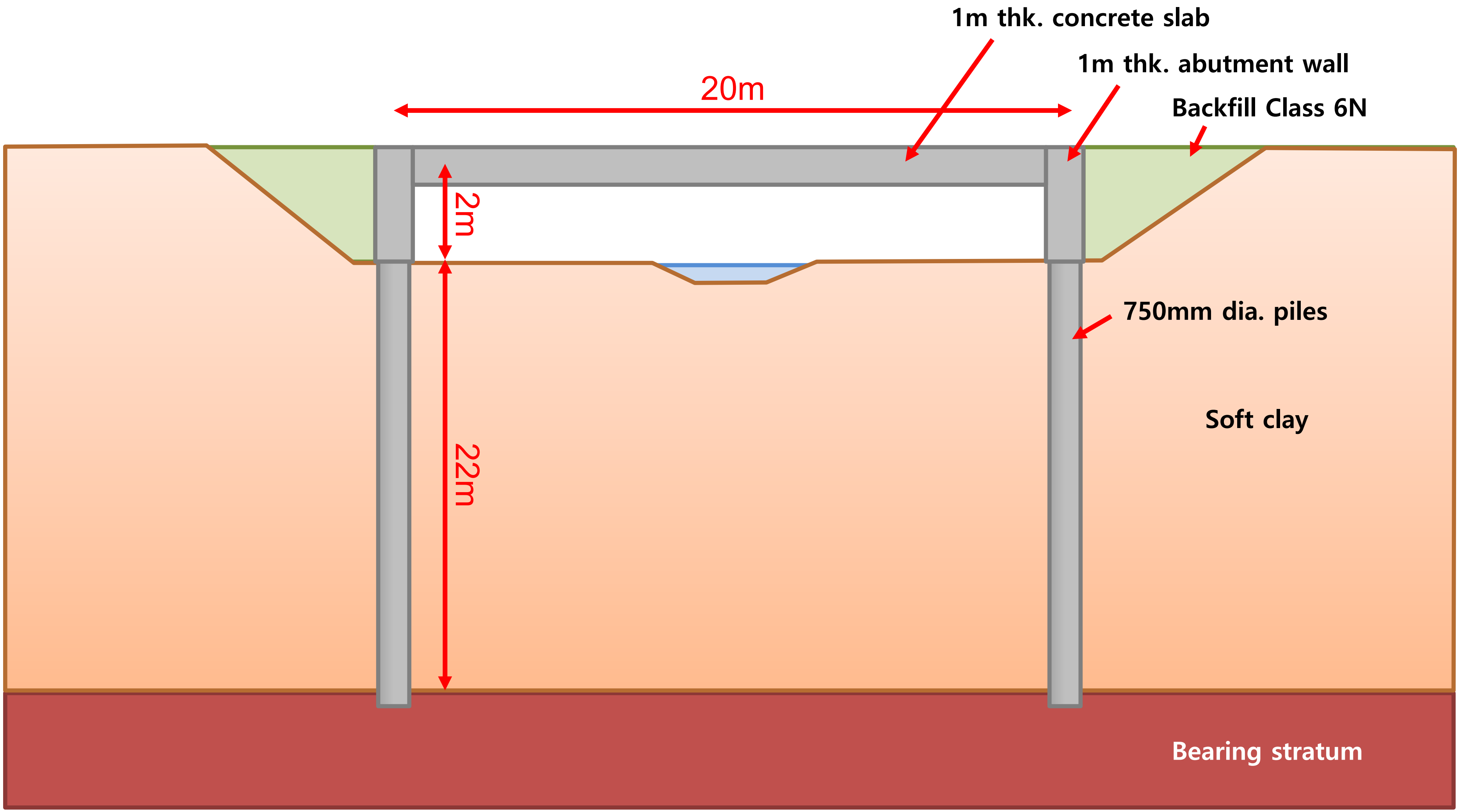
Contents

Main outcomes

1. Limit equilibrium method
2. Spring analogy: method of subgrade reaction, p-y curves
3. Continuum media approach
4. Requirements of the PD 6694-1

Example #1

General Arrangement



Example #2

Methods of analysis (according to PD 6694-1)

Limit equilibrium methods

- Depth of soil affected by abutment movement **can be identified without soil-structure interaction analysis**
- thermal movement ≤ 40 mm;
- skew ≤ 30°

PD 6694-1:2011 9.4.4

- Horizontal soil pressures on end screen and abutments that accommodate thermal movements by translation without rotation

Soil–structure interaction

- Depth of soil affected by abutment movement **cannot be easily identified** unless a soil-structure interaction analysis is performed
- thermal movement > 40 mm;
- skew > 30°
- over-consolidated backfill material
- layered soils

Example #1

Earth pressure

Backfill → Class 6N (MCHW specs)

Material properties → γ = 20kN/m³

→ φ = 35°

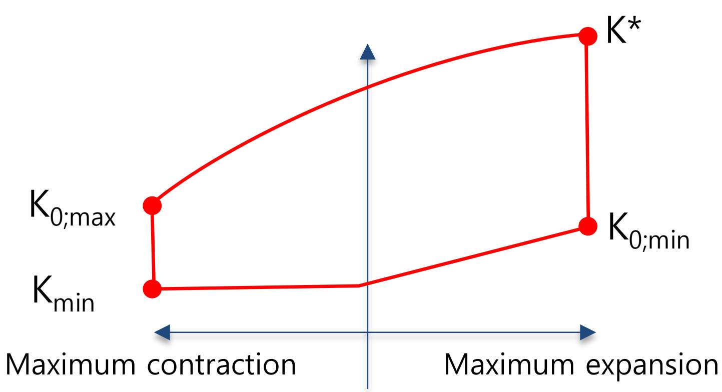
Lateral earth coefficients

→ K^* = ?

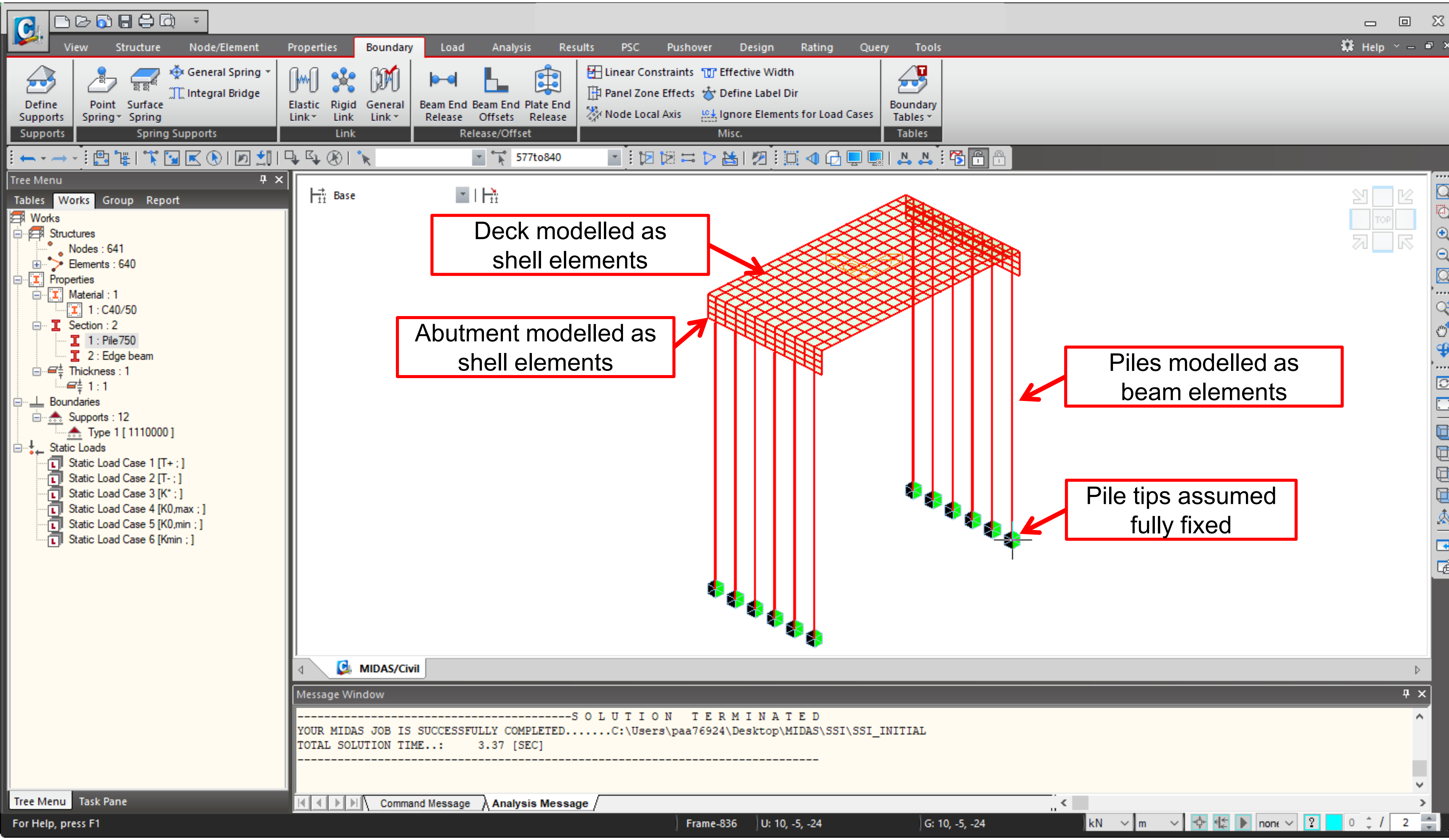
→ $K_{0;max}$ = 0.43

→ K_{min} = 0.15

→ $K_{0;min}$ = 0.29



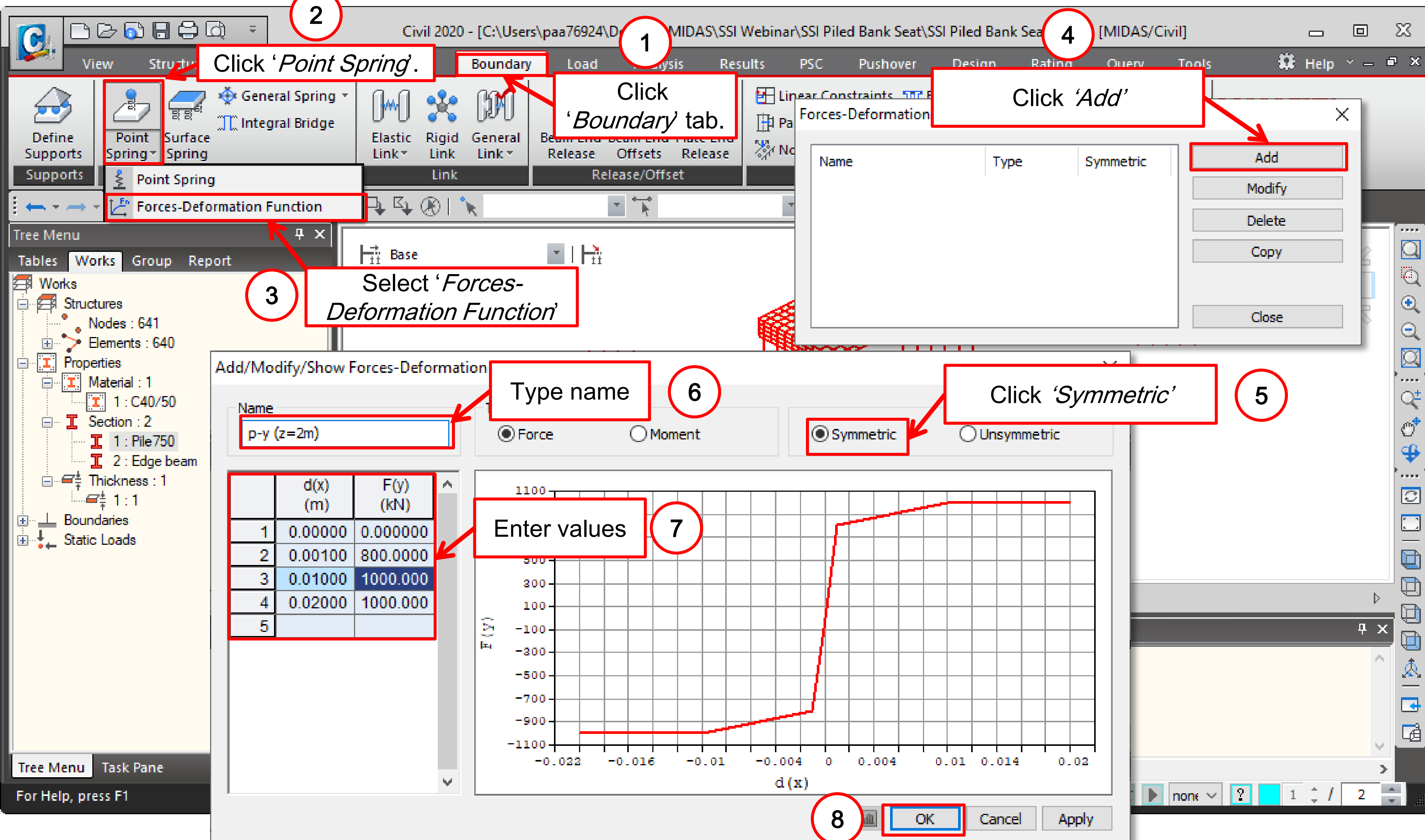
Model



Deck modelled as shell elements
Abutment modelled as shell elements
Piles modelled as beam elements
Pile tips assumed fully fixed
Works
Structures
Nodes : 641
Elements : 640
Properties
Material : 1
1 : C40/50
Section : 2
1 : Pile750
2 : Edge beam
Thickness : 1
1 : 1
Boundaries
Supports : 12
Type 1 [1110000]
Static Loads
Static Load Case 1 [T+ ;]
Static Load Case 2 [T- ;]
Static Load Case 3 [K* ;]
Static Load Case 4 [K0,max ;]
Static Load Case 5 [K0,min ;]
Static Load Case 6 [Kmin ;]
--S O L U T I O N   T E R M I N A T E D
YOUR MIDAS JOB IS SUCCESSFULLY COMPLETED.......C:\Users\paa76924\Desktop\MIDAS\SSI\SSI_INITIAL
TOTAL SOLUTION TIME..:   3.37 [SEC]

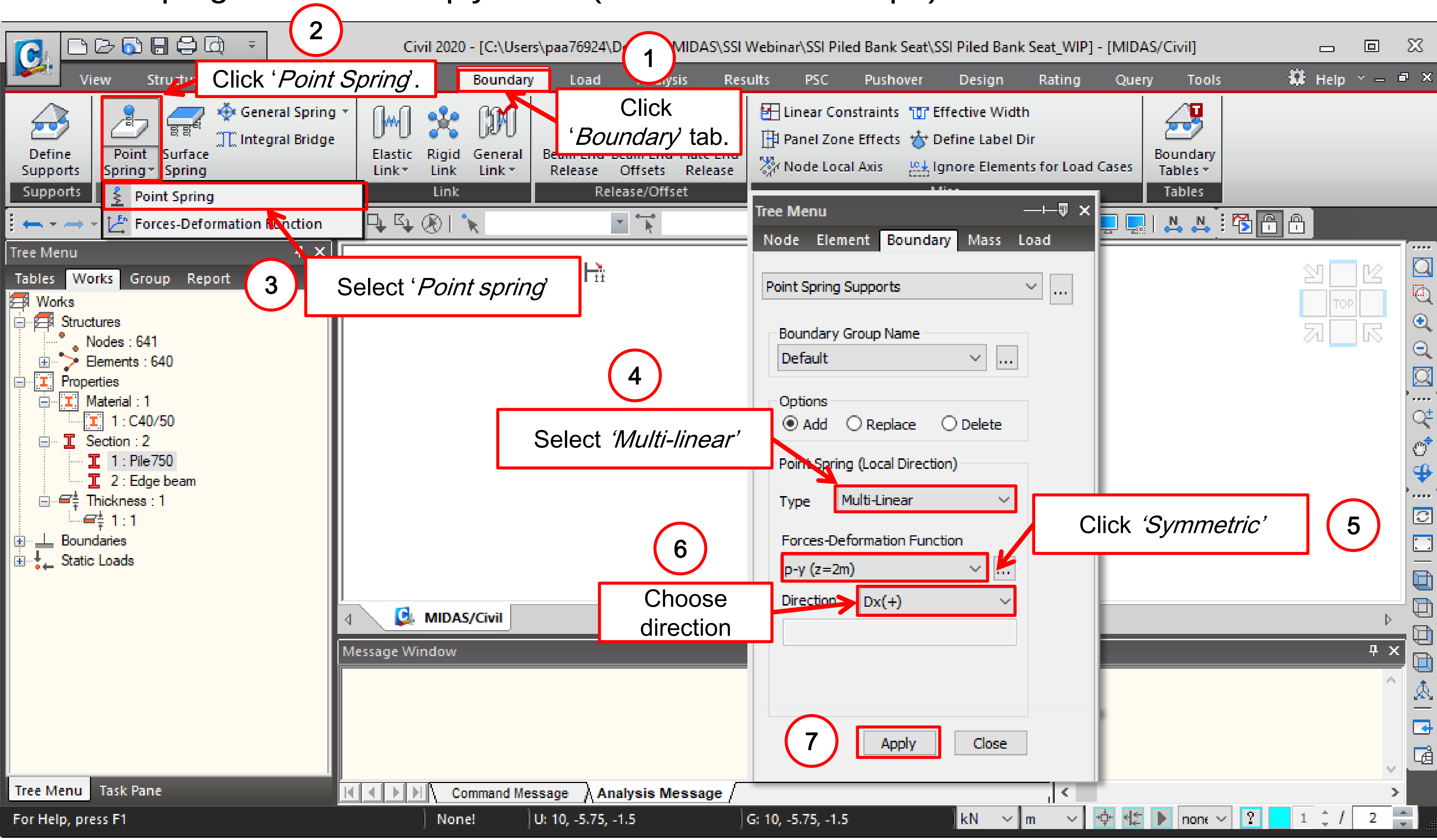
Example #1

- Pile springs – user-defined p-y curves (not used on this example)



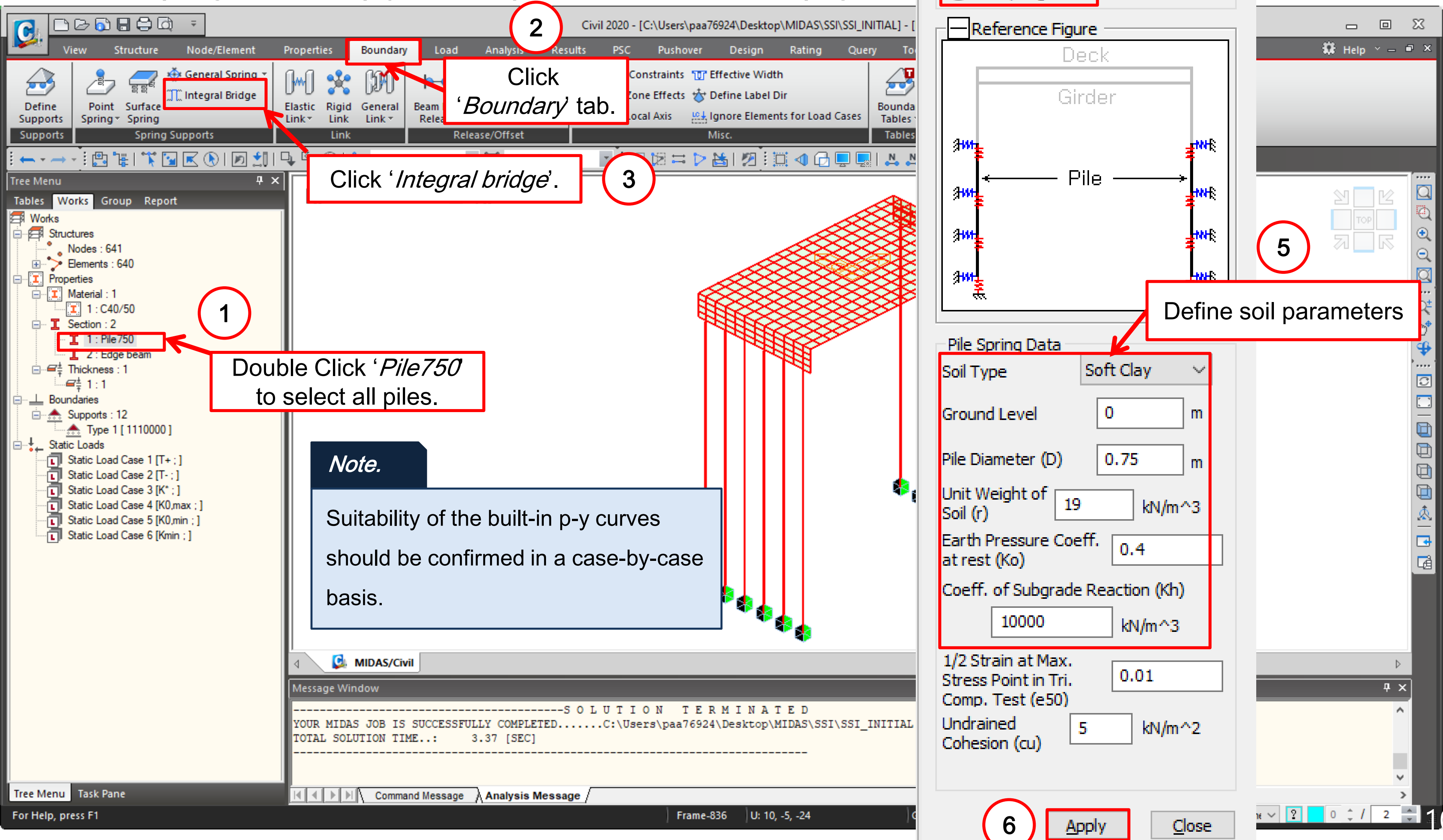
Example #1

- Pile springs – user-defined p-y curves (not used on this example)



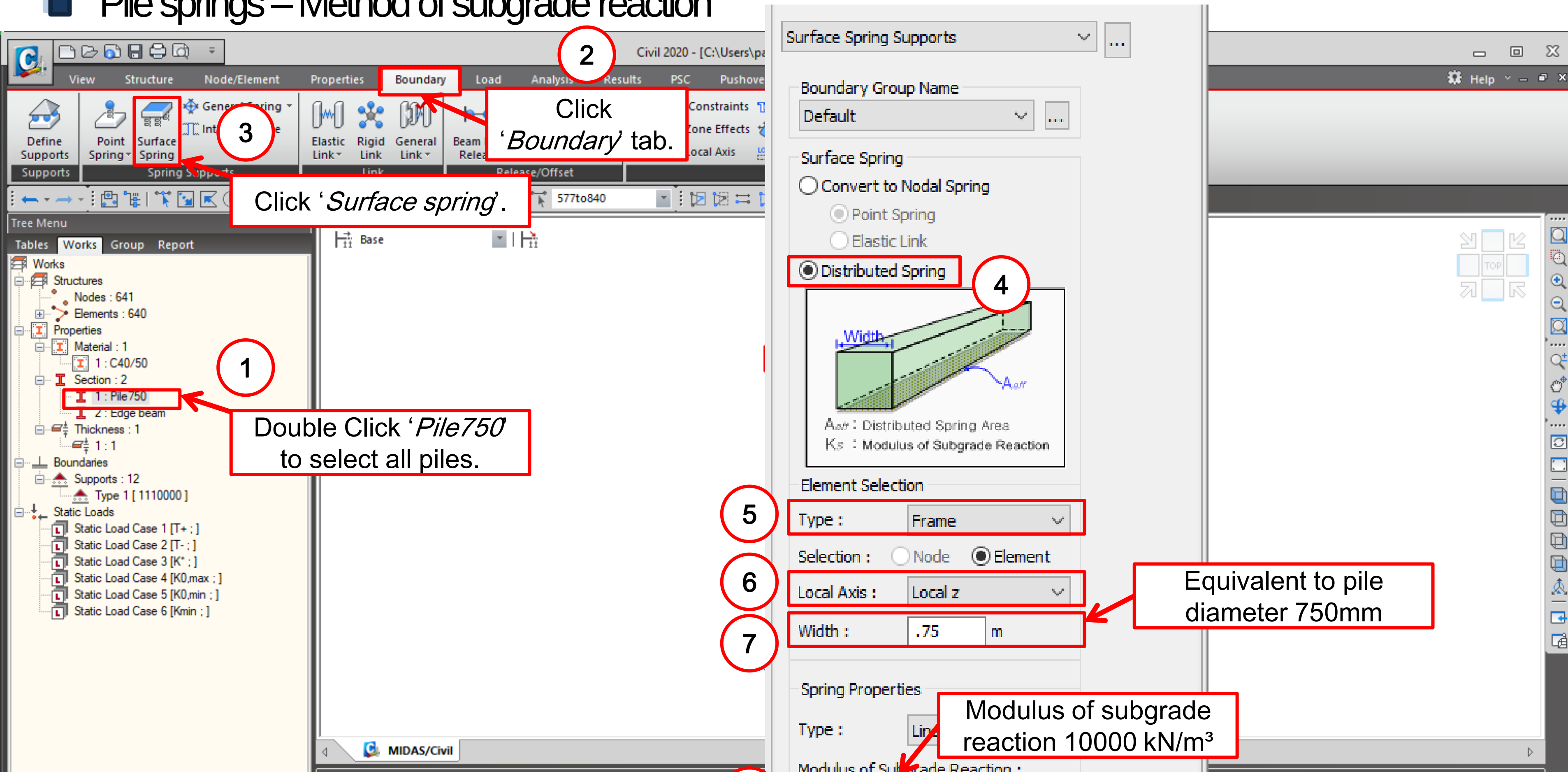
Example #1

- Pile springs – built-in p-y curves (not used on this example)



Example #1

Pile springs – Method of subgrade reaction

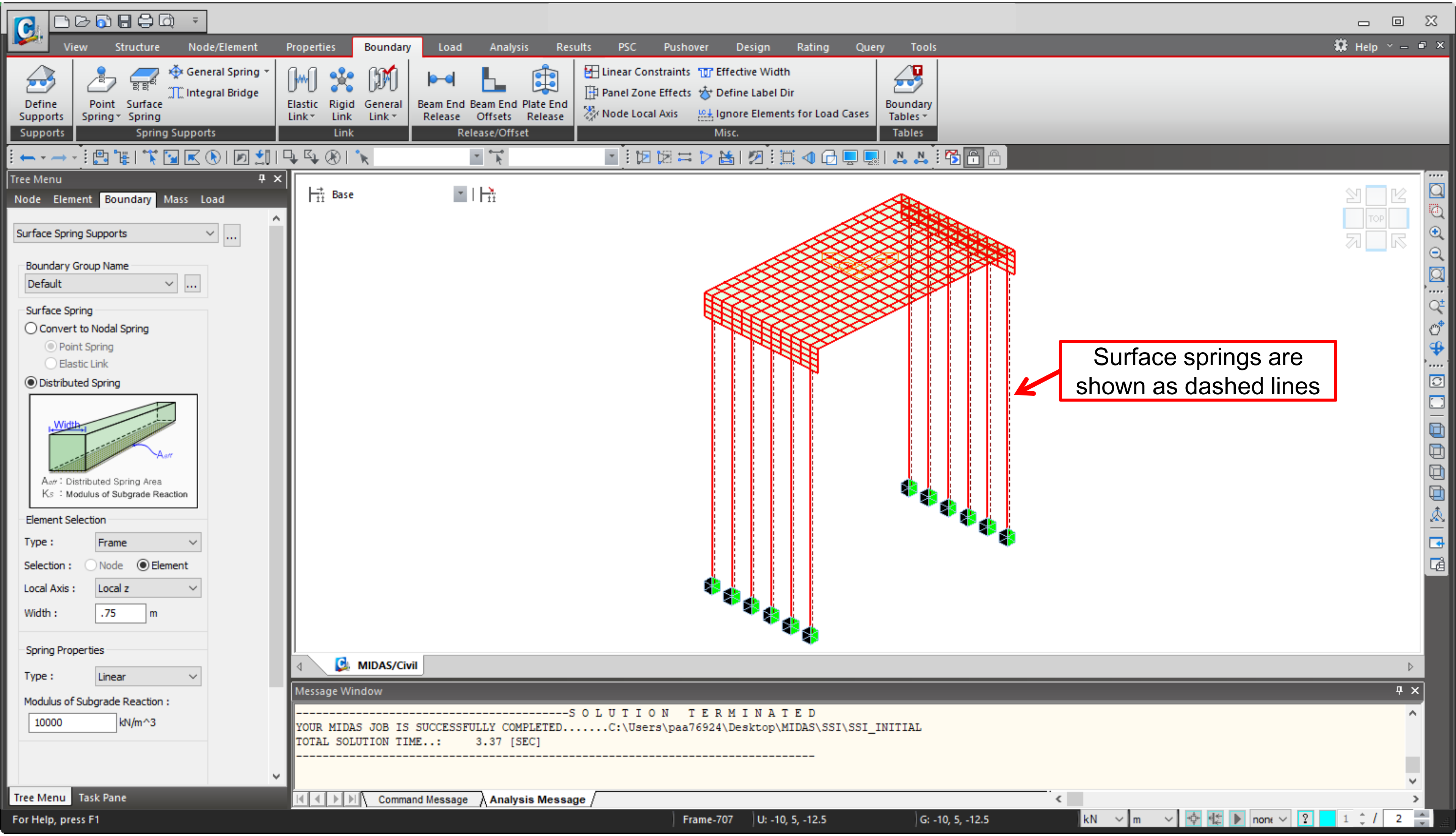


Note.

We will be using the method of subgrade reaction (linear springs)

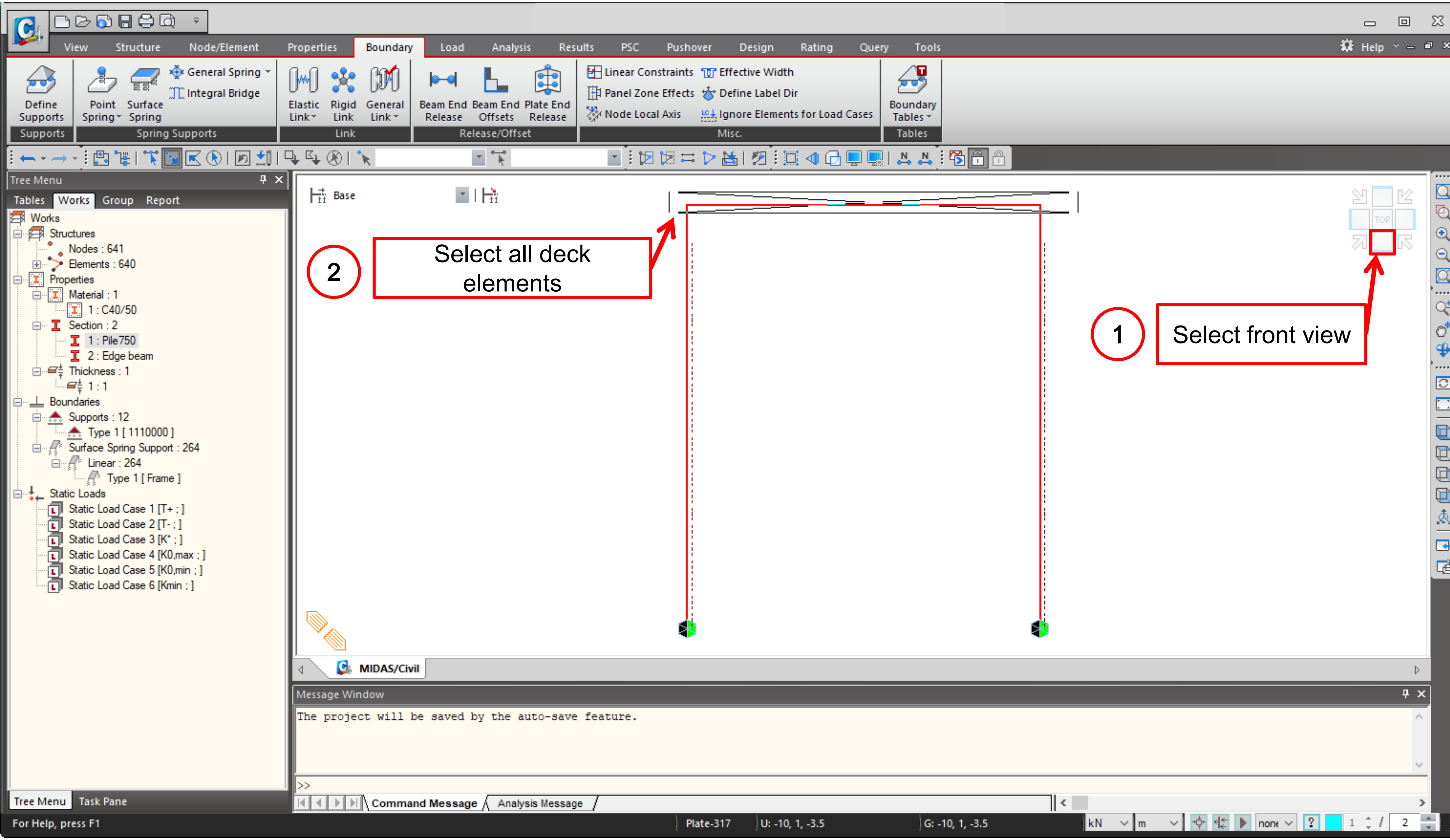
Example #1

- Pile springs – Method of subgrade reaction

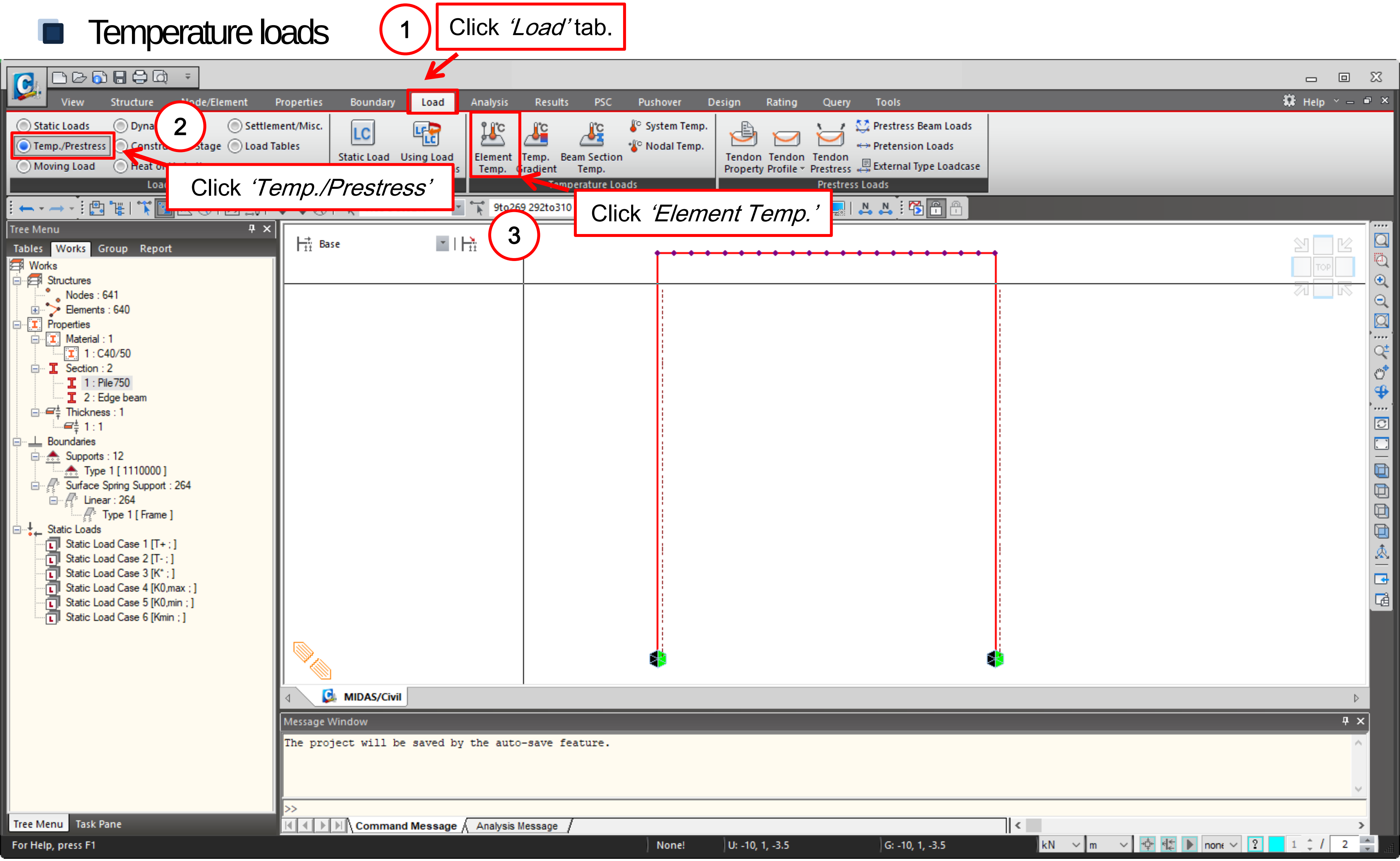


Example #1

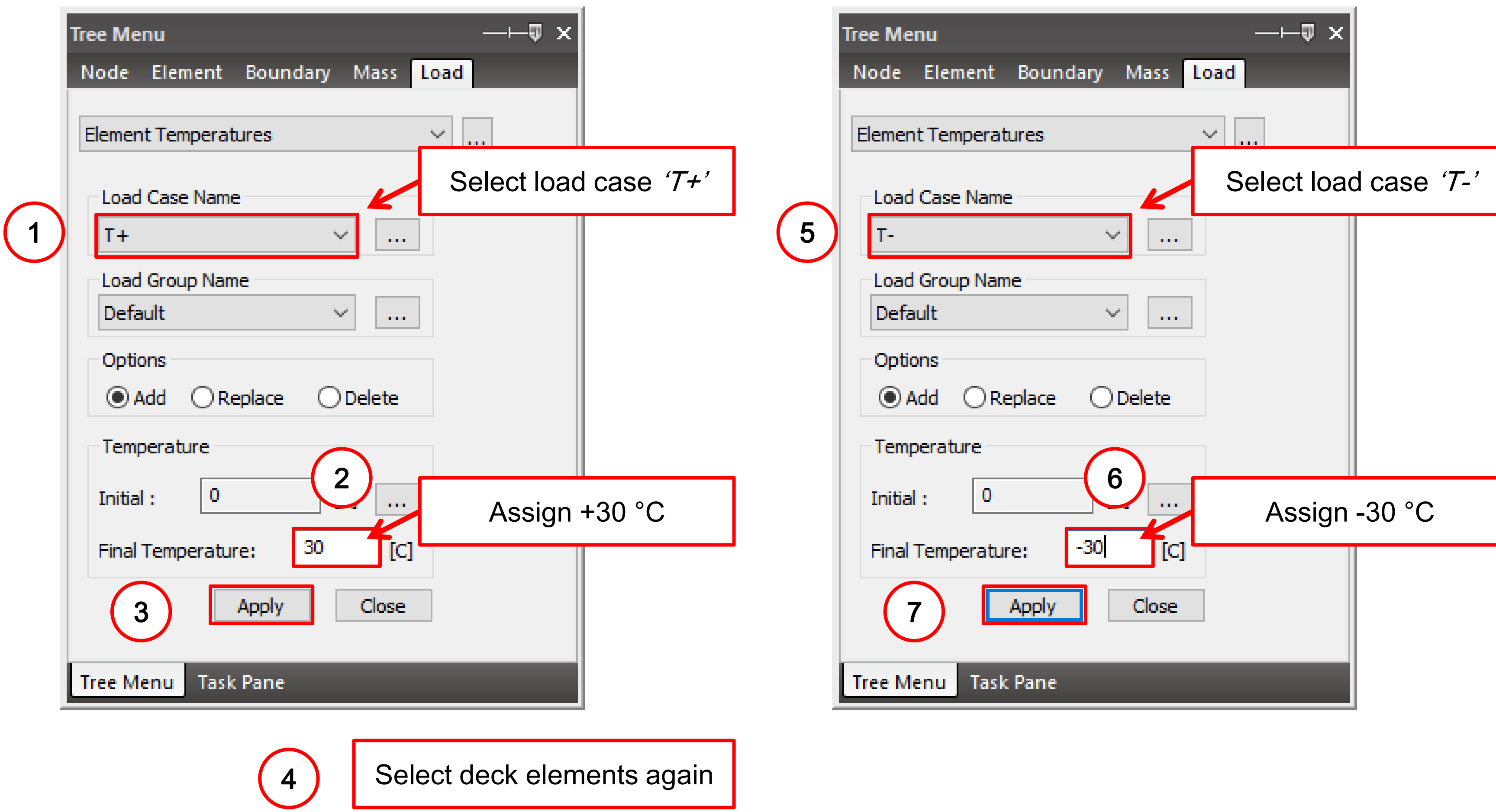
- Temperature loads



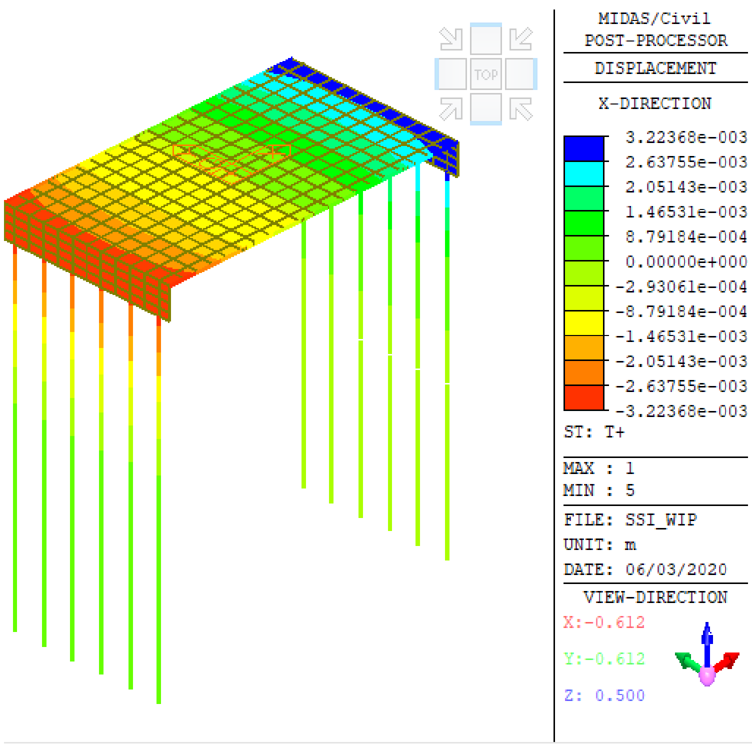
Temperature loads

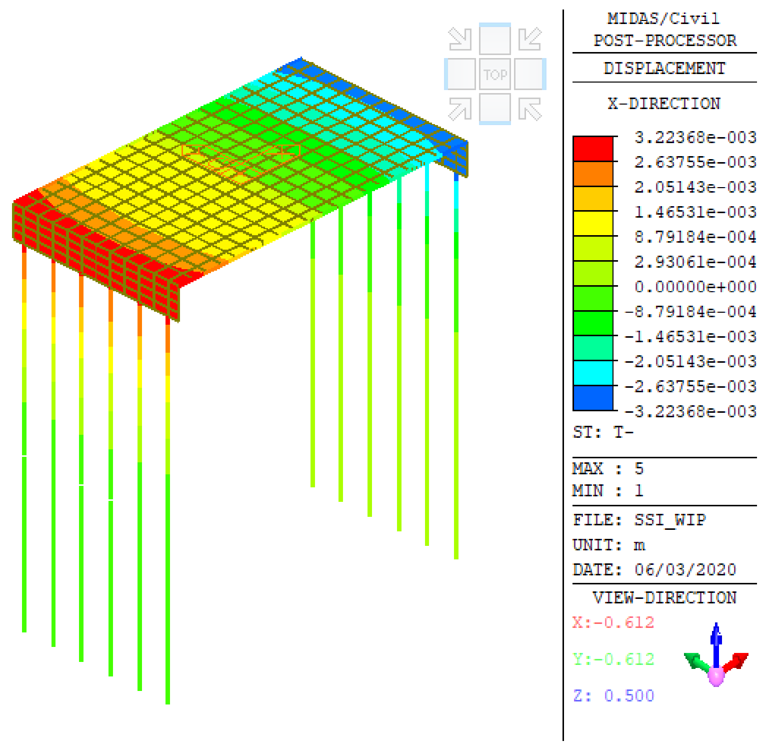


Temperature loads



Earth pressure





Thermal movement range – characteristic value: $d_k = 6\ mm$

Earth pressure

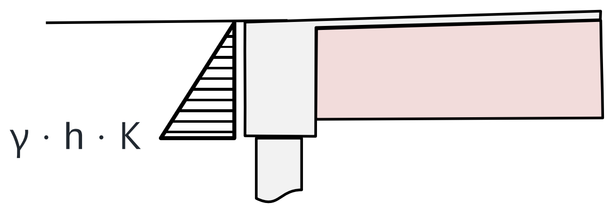
PD 6694-1:2011 9.4.3

$$K^* = K_0 + \left(\frac{40d'_d}{H}\right)^{0.4} K_{p;t}$$

$$d_d = \frac{1}{2} d_k (1 + \Psi \gamma_Q)$$

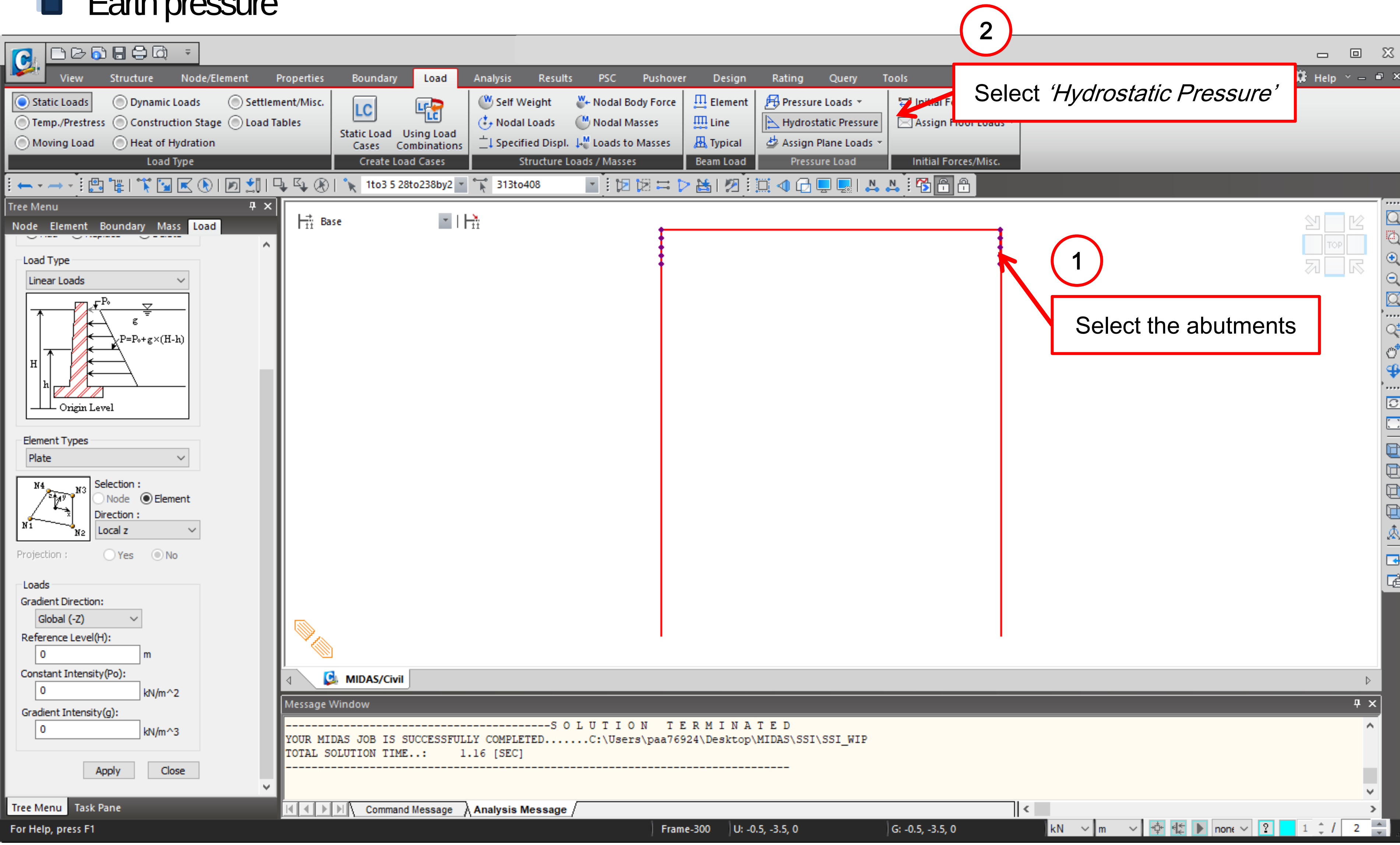
φ	K_0	d_k mm	Ψ	γ_Q	d_d mm	H mm	K_{pt}	K^*
35.0	0.43	6.0	1	1.55	7.7	2500	5.88	3.0

		γ [kN/m³]	h [m]	q [kN/m²]
K*	3.00	20	2	120
KO_{max}	0.43	20	2	17.2
KO_{min}	0.29	20	2	11.6
K_{min}	0.15	20	2	6



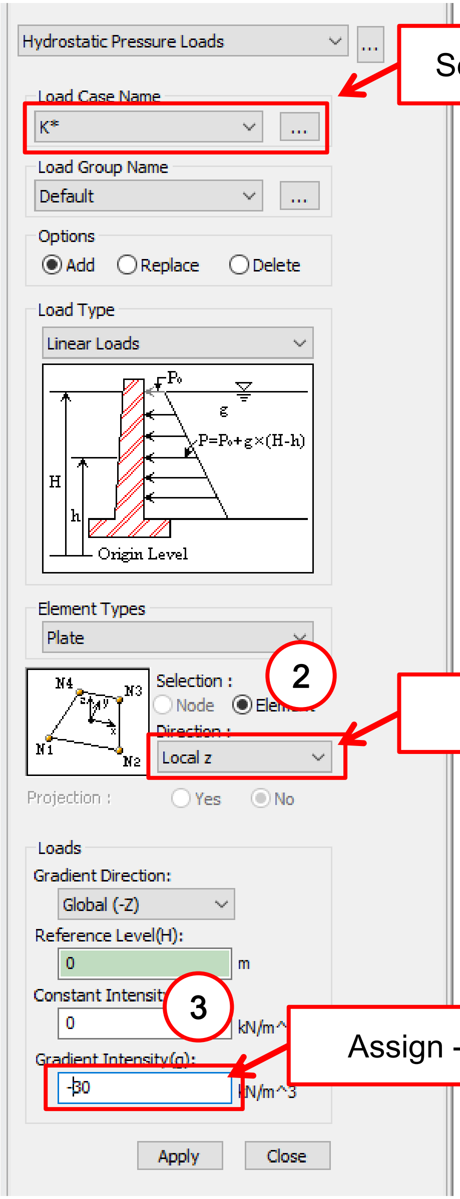
Example #1

- Earth pressure



Example #1

- Earth pressure



1

Select load case *'K*'*

2

Select *'Local z'*

3

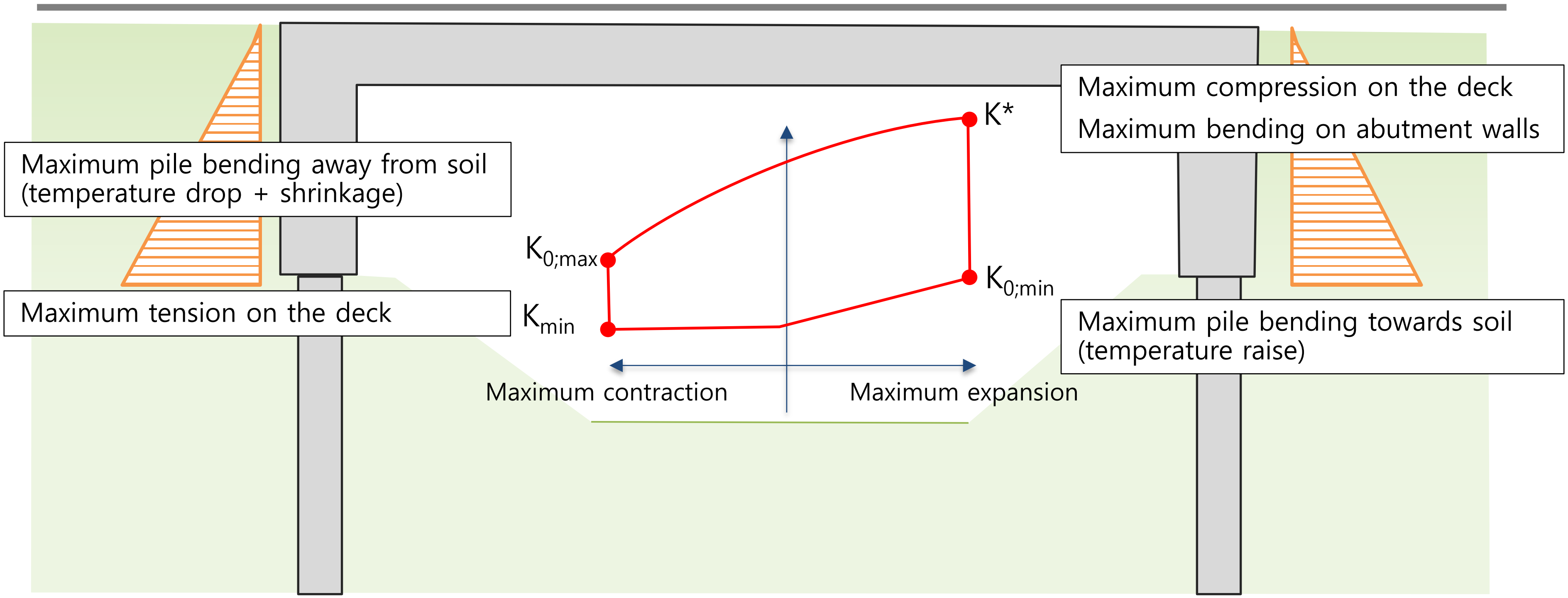
Assign -60 kN/m³

4

Repeat for load cases:
K0max: -8.6 kN/m³
K0,min: -5.8 kN/m³
Kmin: -3.0 kN/m³

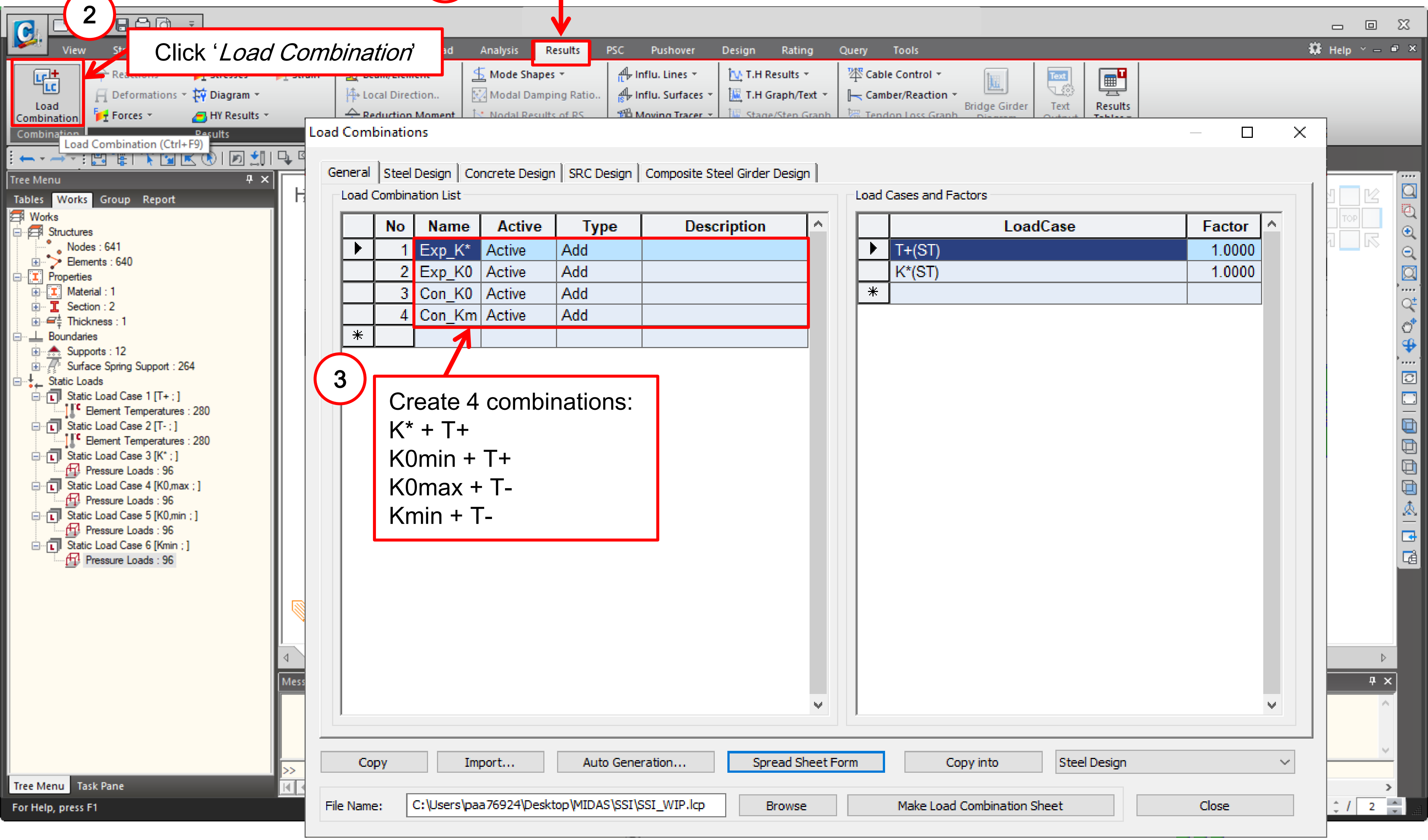
Example #1

Envelopes



Example #1

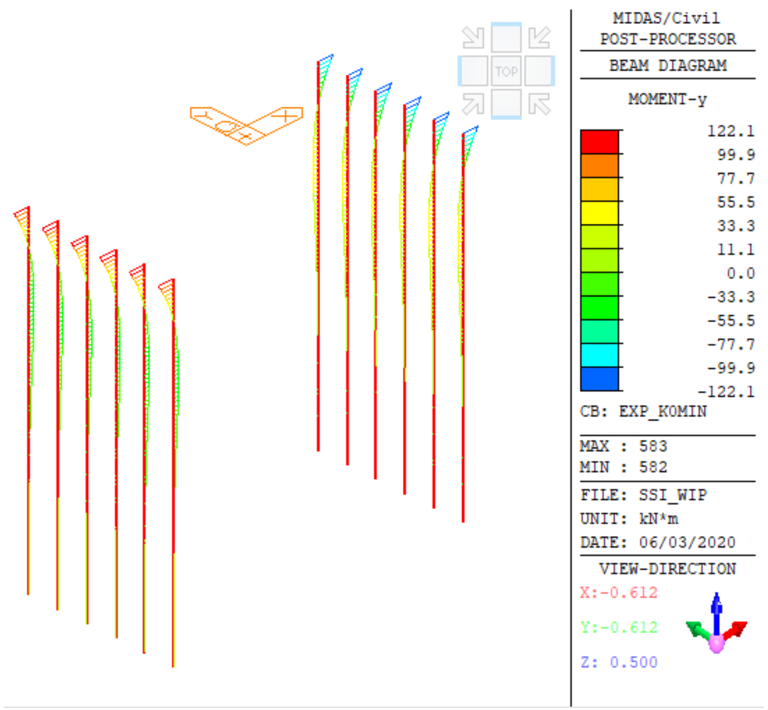
Envelopes



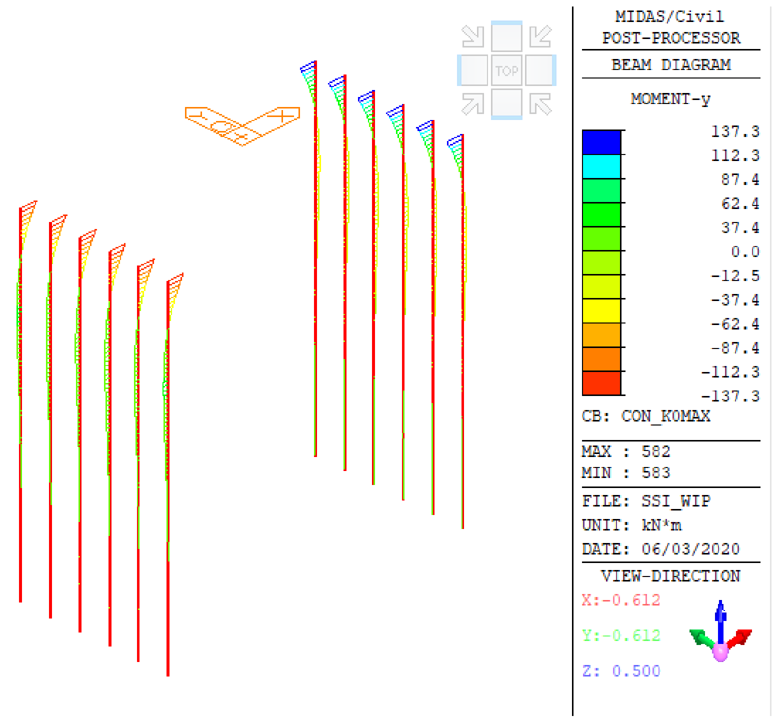
Example #1

- Envelopes

$K_{0,min}$ + Expansion
maximum moment in piles in expansion

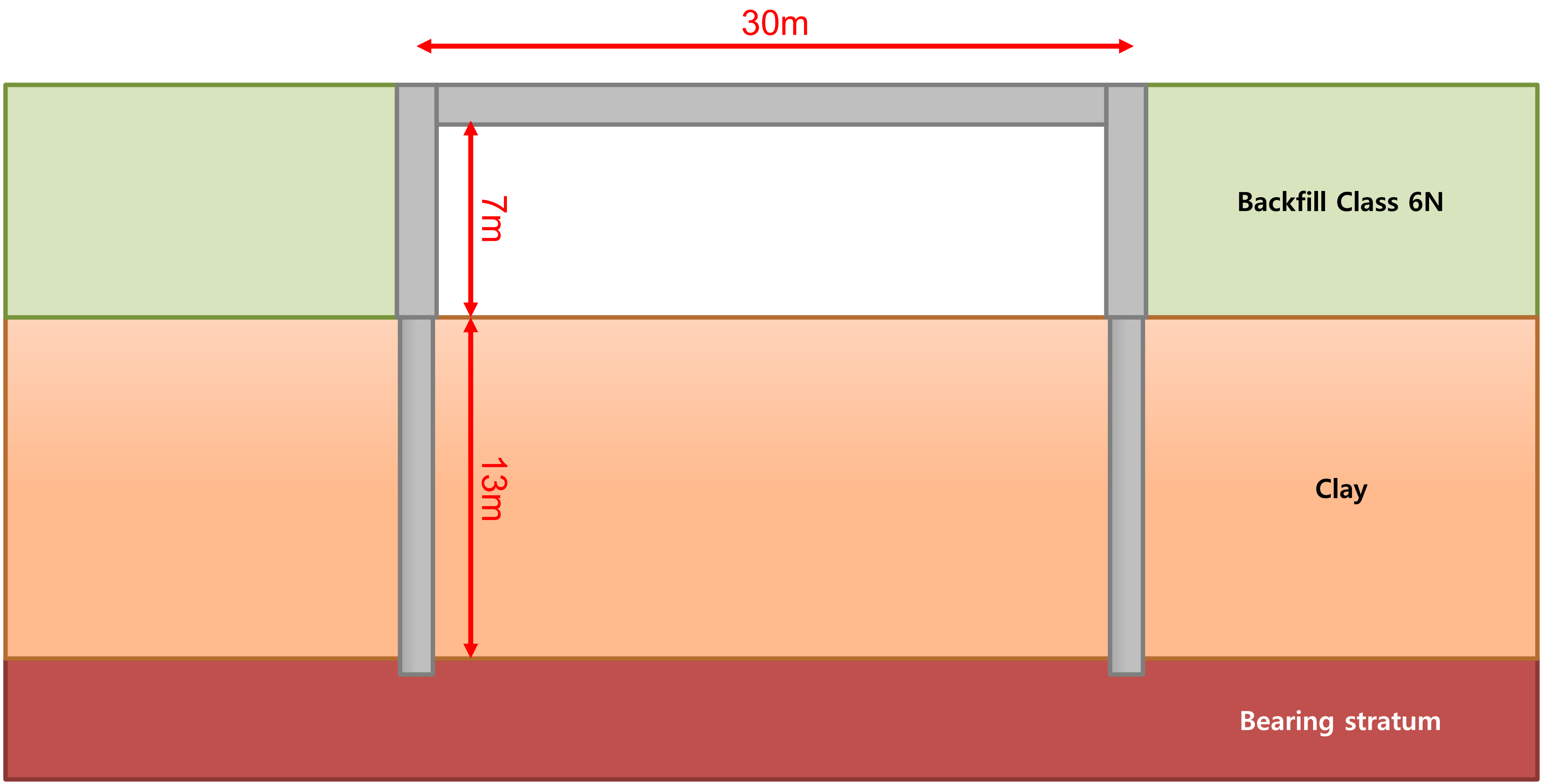


$K_{0,max}$ + Contraction
maximum moment in piles in contraction



Example #2

- General arrangement



Example #2

Methods of analysis (according to PD 6694-1)

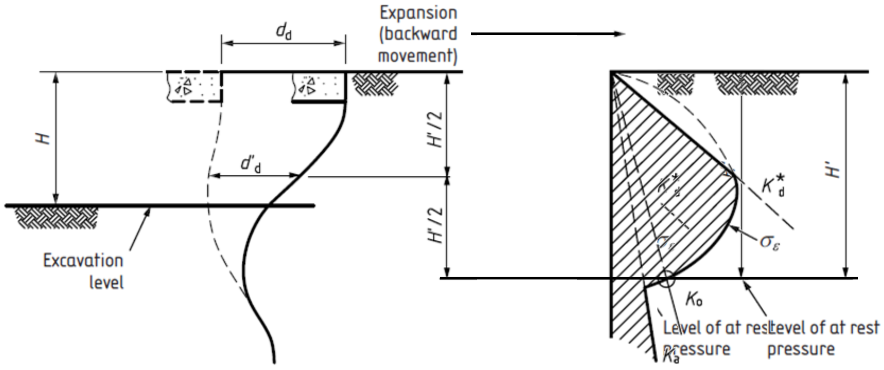
<u>Limit equilibrium methods</u>

- Depth of soil affected by abutment movement **can be identified** without soil-structure interaction analysis
- thermal movement ≤ 40 mm;
- skew ≤ 30°

<u>Soil–structure interaction</u>

- Depth of soil affected by abutment movement **cannot be easily identified** unless a soil-structure interaction analysis is performed
- thermal movement > 40 mm;
- skew > 30°
- over-consolidated backfill material
- layered soils

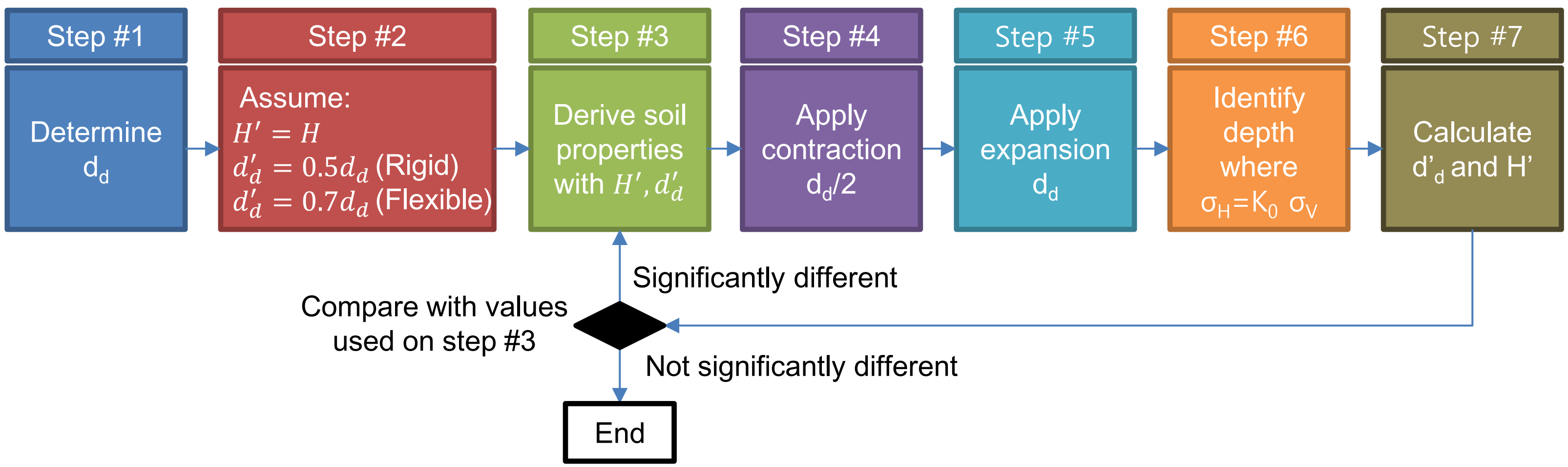
PD 6694-1:2011 9.4.5 Horizontal earth pressures on full height frame abutments on piles and embedded wall abutments (soil– structure interaction analysis)



Example #2

- Material properties (PD 6694-1:2011 Annex A)

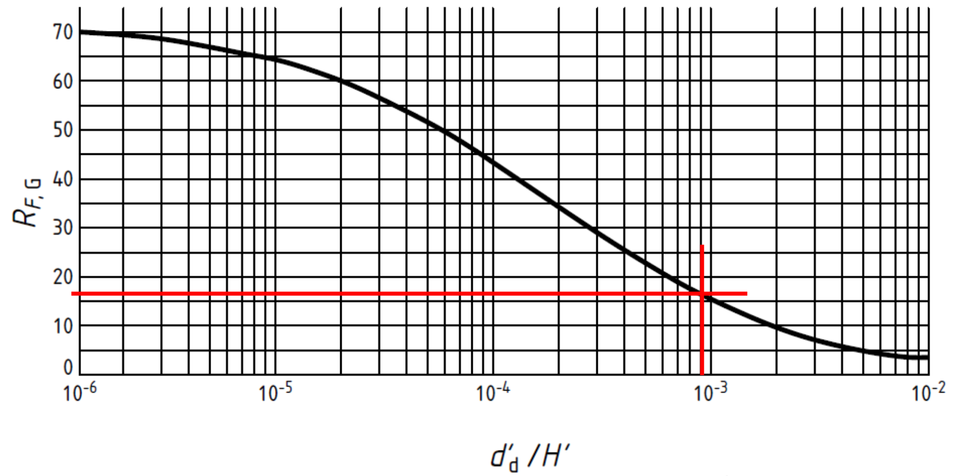
PD 6694-1:2011 Annex A



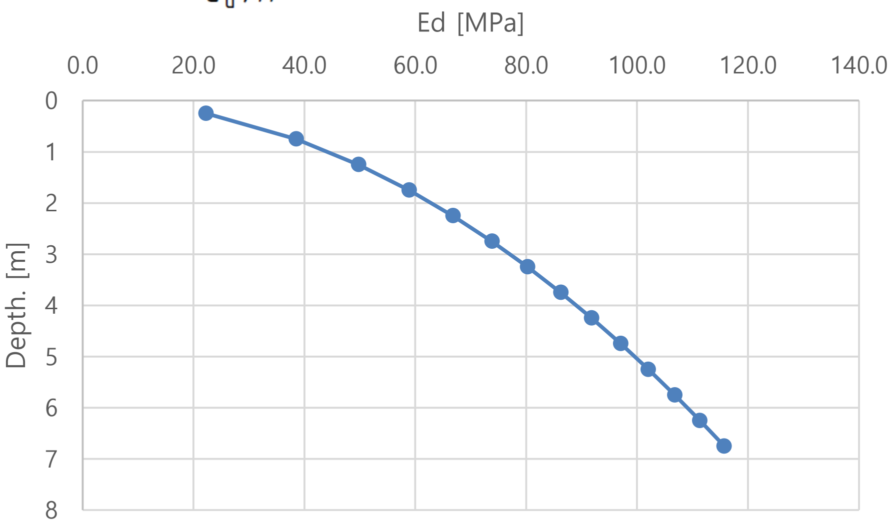
Example #2

Material properties (PD 6694-1:2011 Annex A)

φ	35	
K_0	0.43	
γ	20	kN/m³
ν	0.2	
d'	6.3	mm
H'	7	m
d'/H'	9.00E-04	
$R_{F,G}$	16	

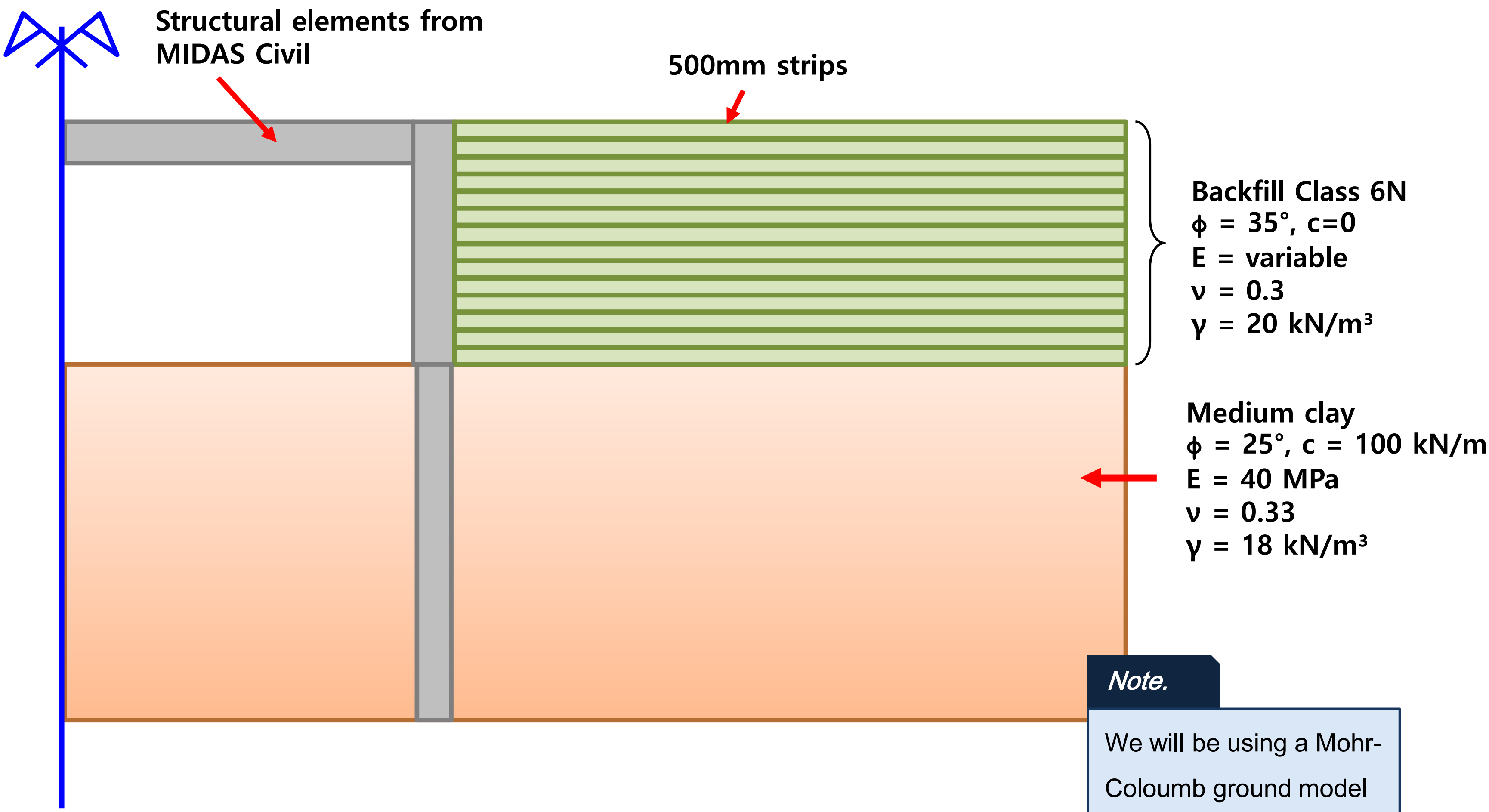


	z	σ_v	σ_m	G	E	Ed	Ed
	m	kN/m²	kN/m²	kN/m²	kN/m²	kN/m²	MPa
1	0.25	5	3.088079	6185.671	14845.6	22268.42	22.3
2	0.75	15	9.264236	10713.9	25713.4	38570.03	38.6
3	1.25	25	15.44039	13831.58	33195.8	49793.69	49.8
4	1.75	35	21.61655	16365.75	39277.8	58916.69	58.9
5	2.25	45	27.79271	18557.01	44536.8	66805.25	66.8
6	2.75	55	33.96886	20515.55	49237.3	73855.98	73.9
7	3.25	65	40.14502	22302.75	53526.6	80289.92	80.3
8	3.75	75	46.32118	23957	57496.8	86245.21	86.2
9	4.25	85	52.49734	25504.18	61210.0	91815.03	91.8
10	4.75	95	58.67349	26962.72	64710.5	97065.78	97.1
11	5.25	105	64.84965	28346.31	68031.1	102046.7	102.0
12	5.75	115	71.02581	29665.44	71197.0	106795.6	106.8
13	6.25	125	77.20196	30928.36	74228.1	111342.1	111.3
14	6.75	135	83.37812	32141.69	77140.1	115710.1	115.7



Example #2

General arrangement

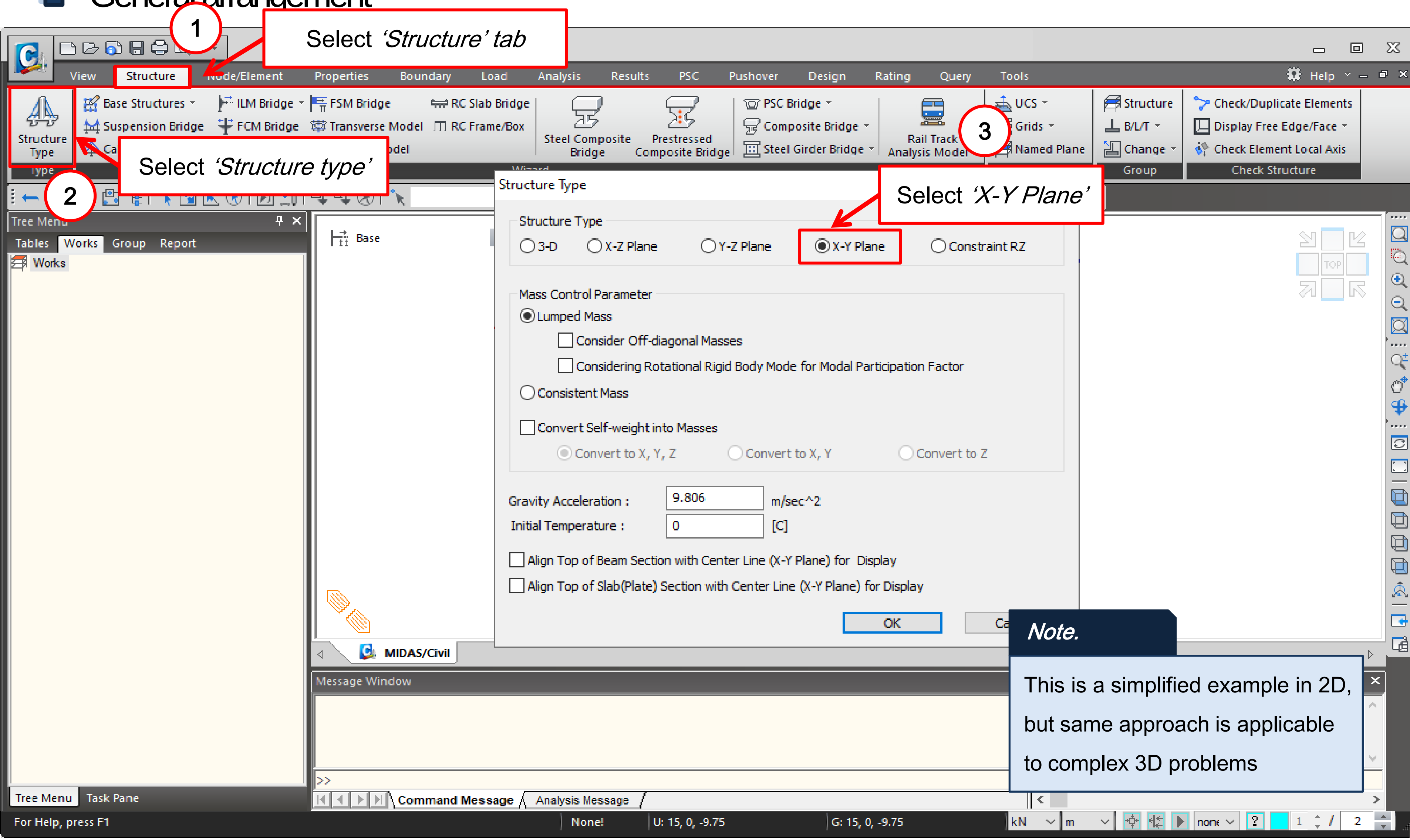


Note.

We will be using a Mohr-Coloumb ground model

Example #2

General arrangement

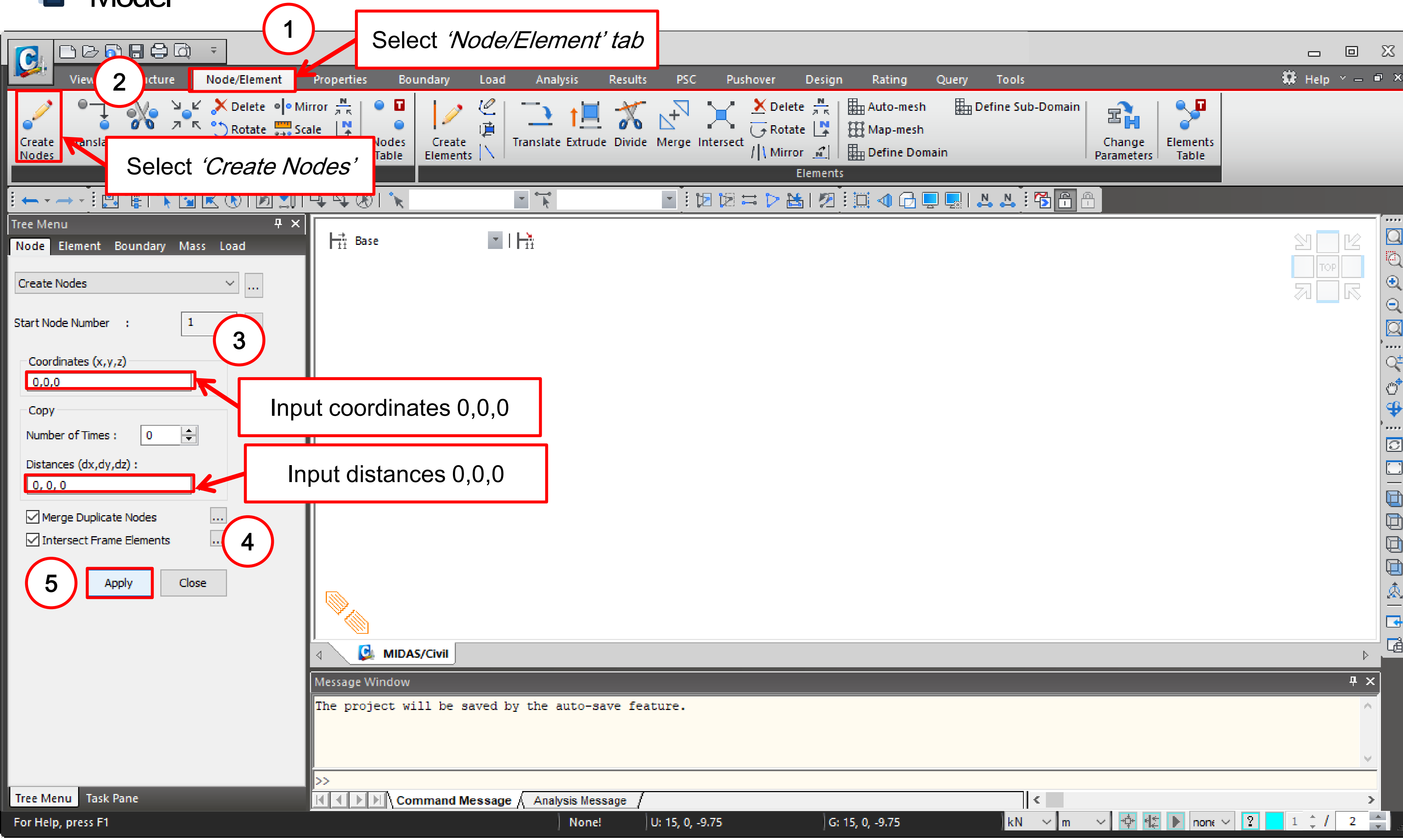


Note.

This is a simplified example in 2D, but same approach is applicable to complex 3D problems

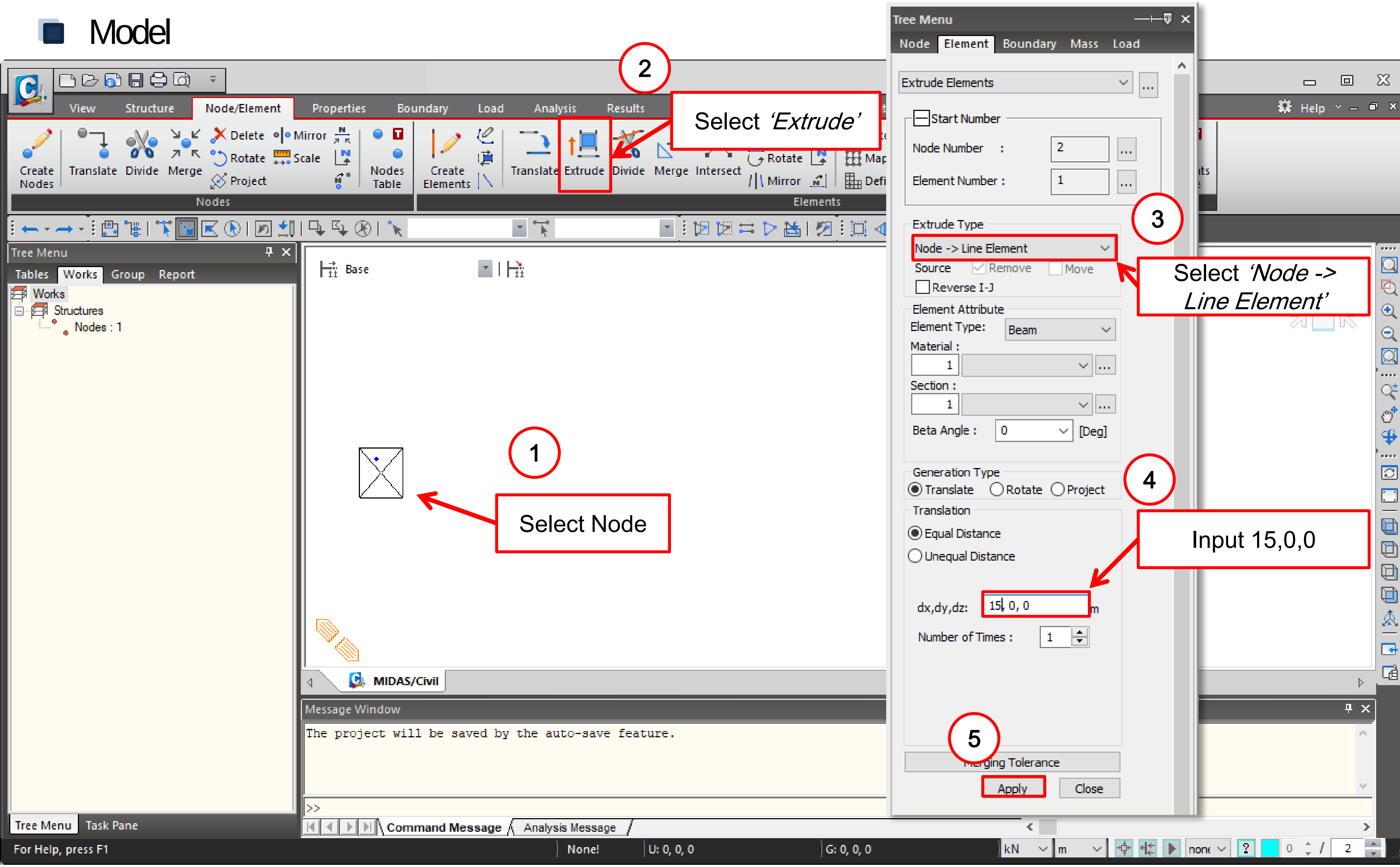
Example #2

Model



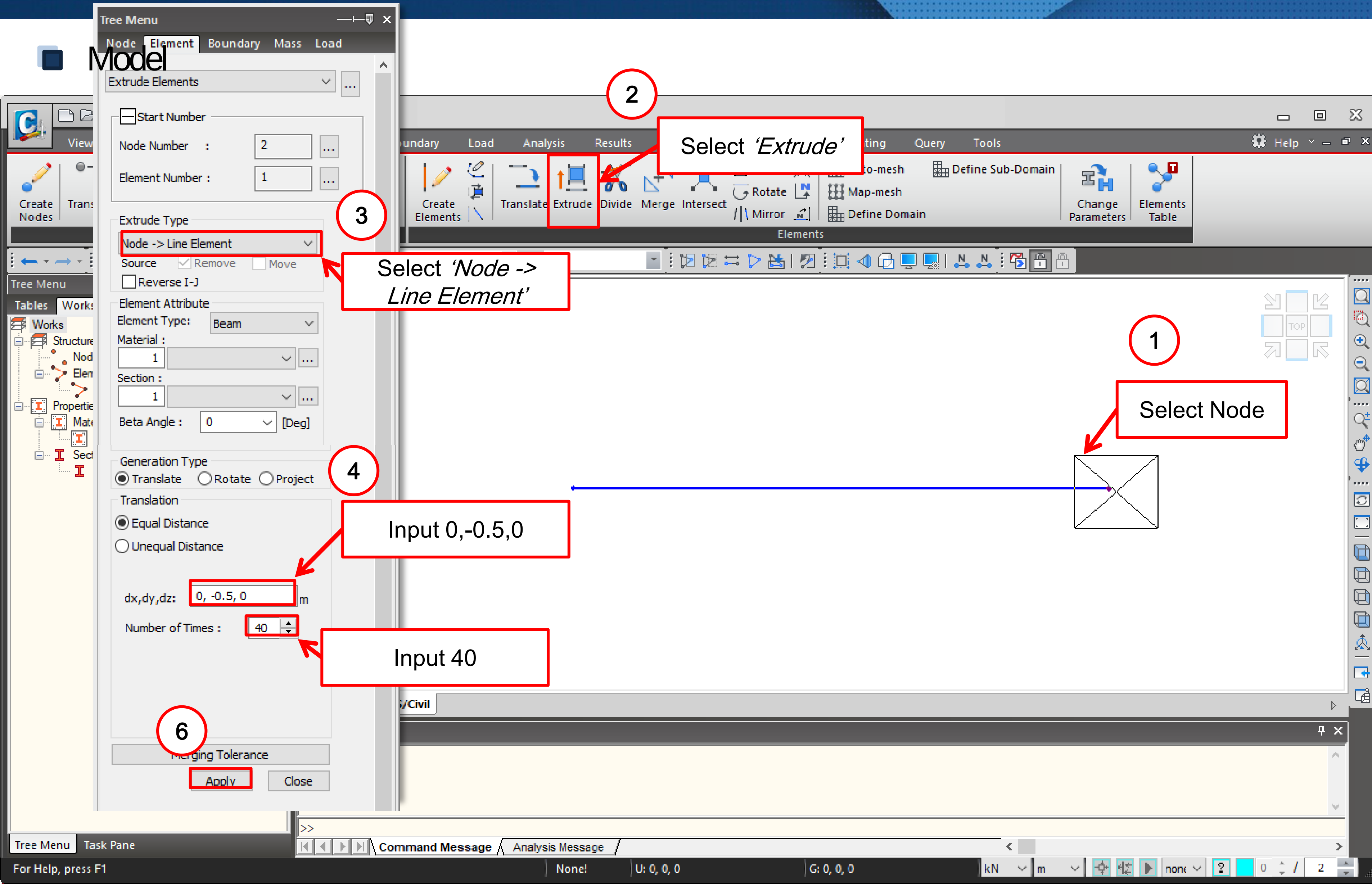
Example #2

Model



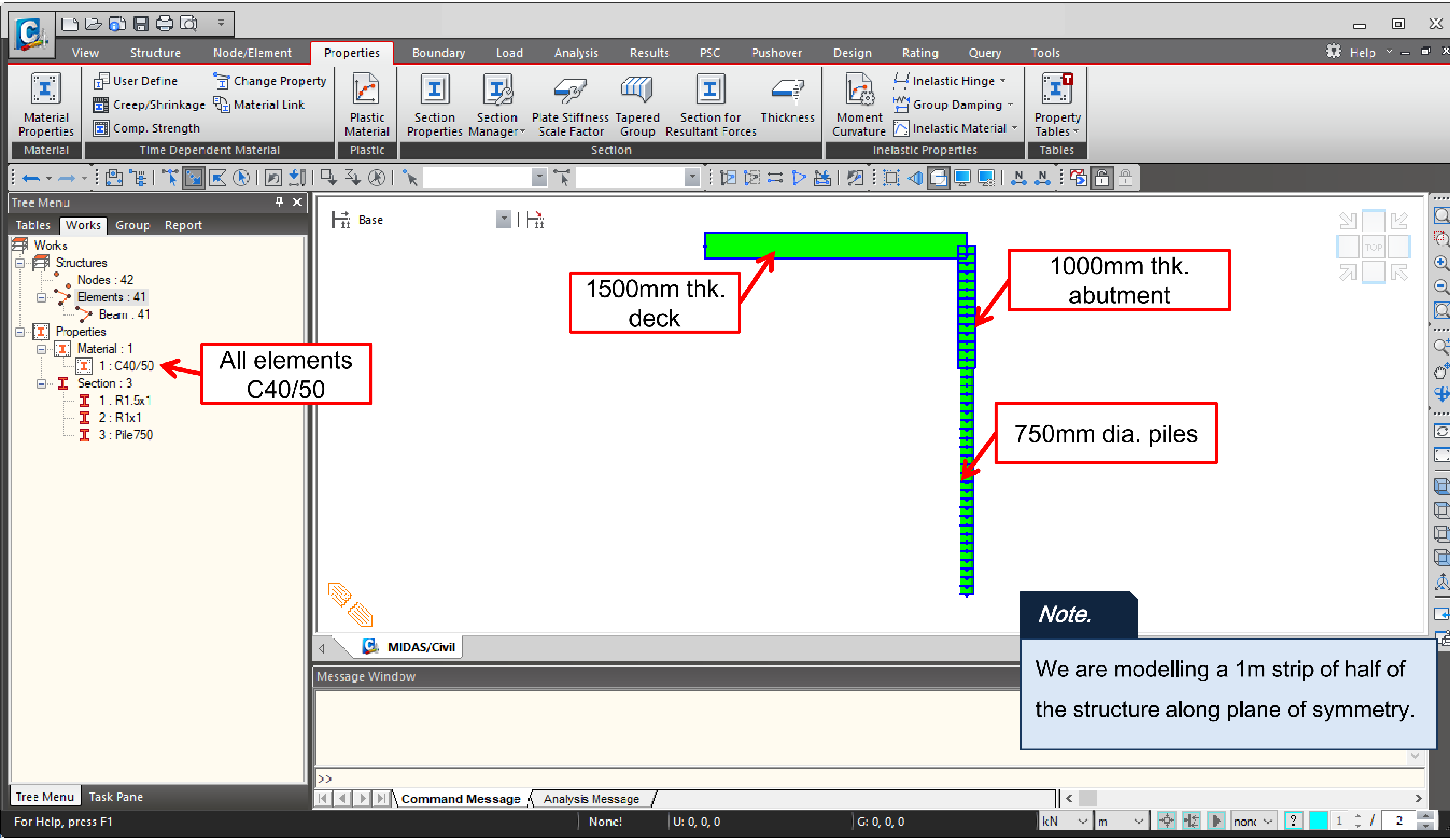
Example #2

- Model



Example #2

Midas Civil model

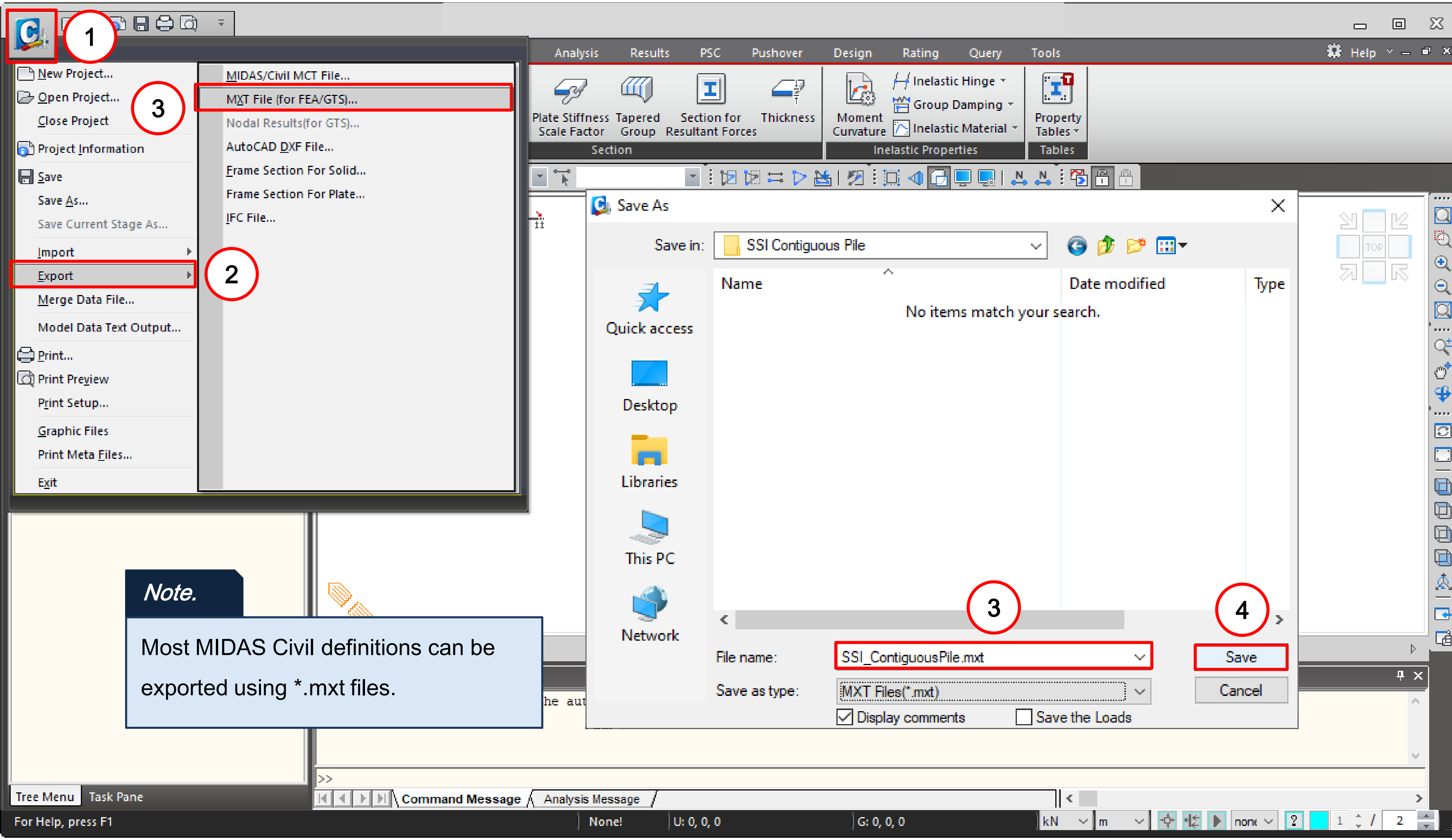


Note.

We are modelling a 1m strip of half of the structure along plane of symmetry.

Example #2

Midas Civil model

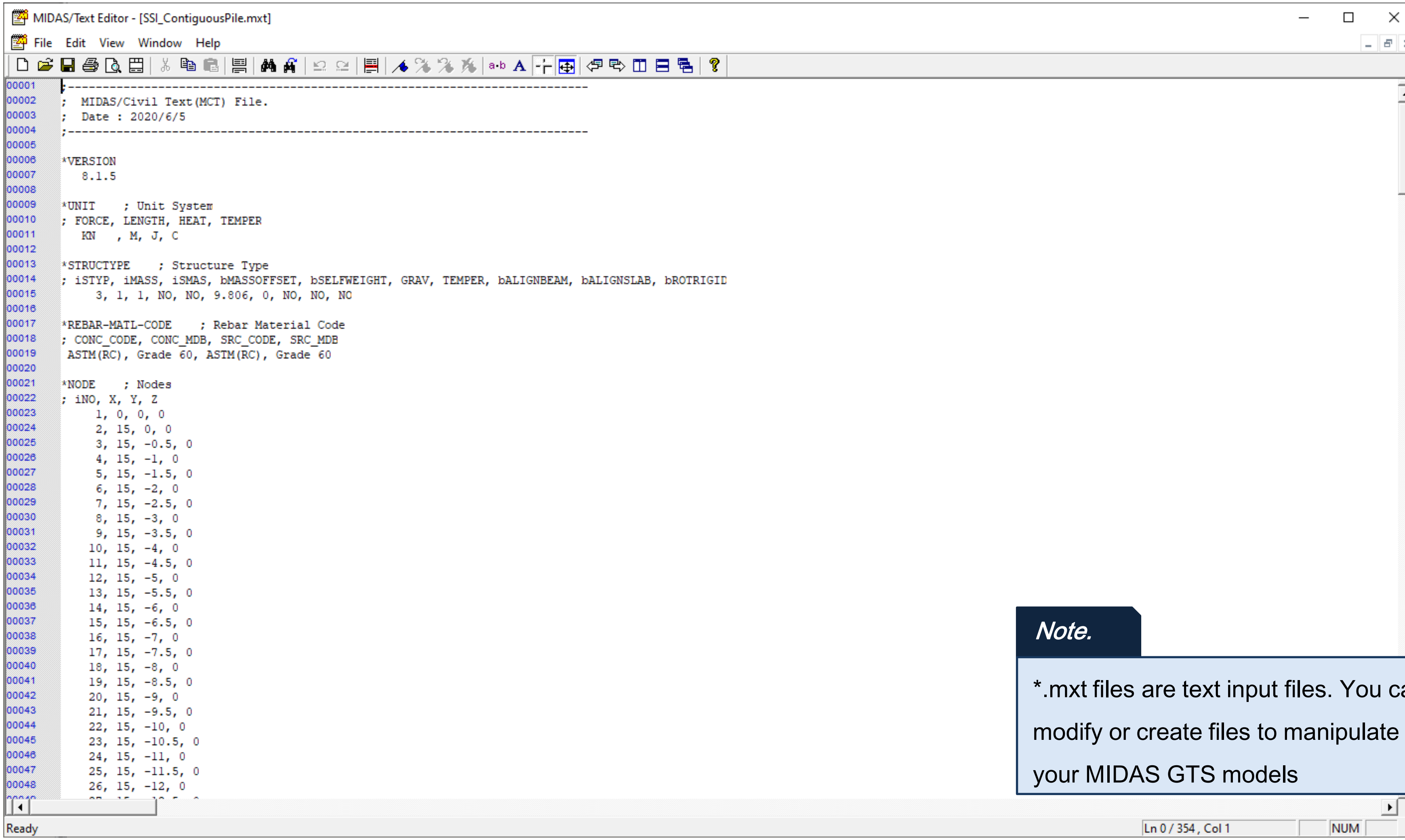


Note.

Most MIDAS Civil definitions can be exported using *.mxt files.

Example #2

Exchange file *.mxt




```
;---------------------------------------------------------------------------
;  MIDAS/Civil Text(MCT) File.
;  Date : 2020/6/5
;---------------------------------------------------------------------------

*VERSION
   8.1.5

*UNIT    ; Unit System
; FORCE, LENGTH, HEAT, TEMPER
   KN   , M, J, C

*STRUCTYPE    ; Structure Type
; iSTYP, iMASS, iSMAS, bMASSOFFSET, bSELFWEIGHT, GRAV, TEMPER, bALIGNBEAM, bALIGNSLAB, bROTRIGID
     3, 1, 1, NO, NO, 9.806, 0, NO, NO, NO

*REBAR-MATL-CODE    ; Rebar Material Code
; CONC_CODE, CONC_MDB, SRC_CODE, SRC_MDB
 ASTM(RC), Grade 60, ASTM(RC), Grade 60

*NODE    ; Nodes
; iNO, X, Y, Z
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     2, 15, 0, 0
     3, 15, -0.5, 0
     4, 15, -1, 0
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     6, 15, -2, 0
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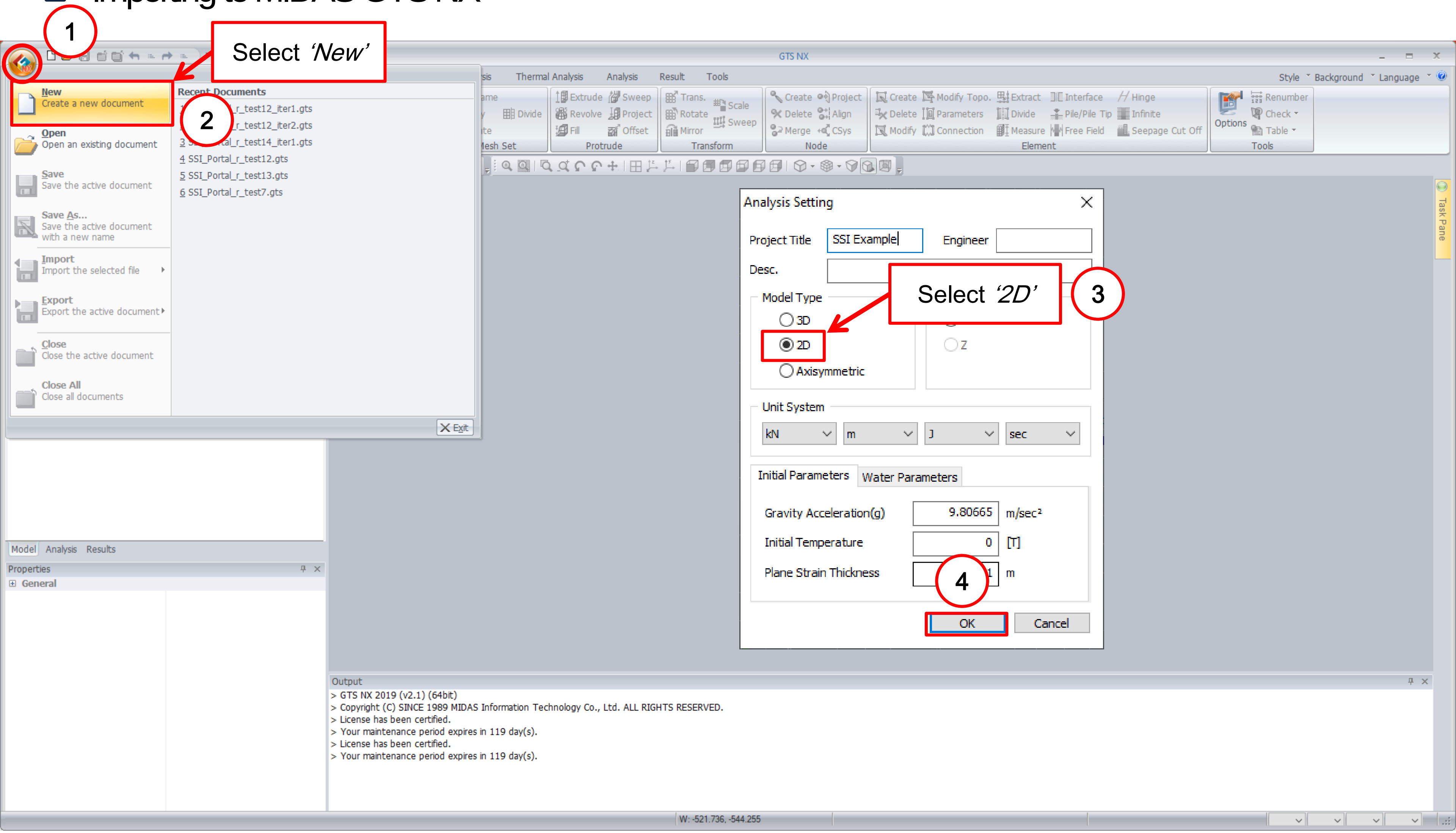
Note.

*.mxt files are text input files. You can modify or create files to manipulate your MIDAS GTS models

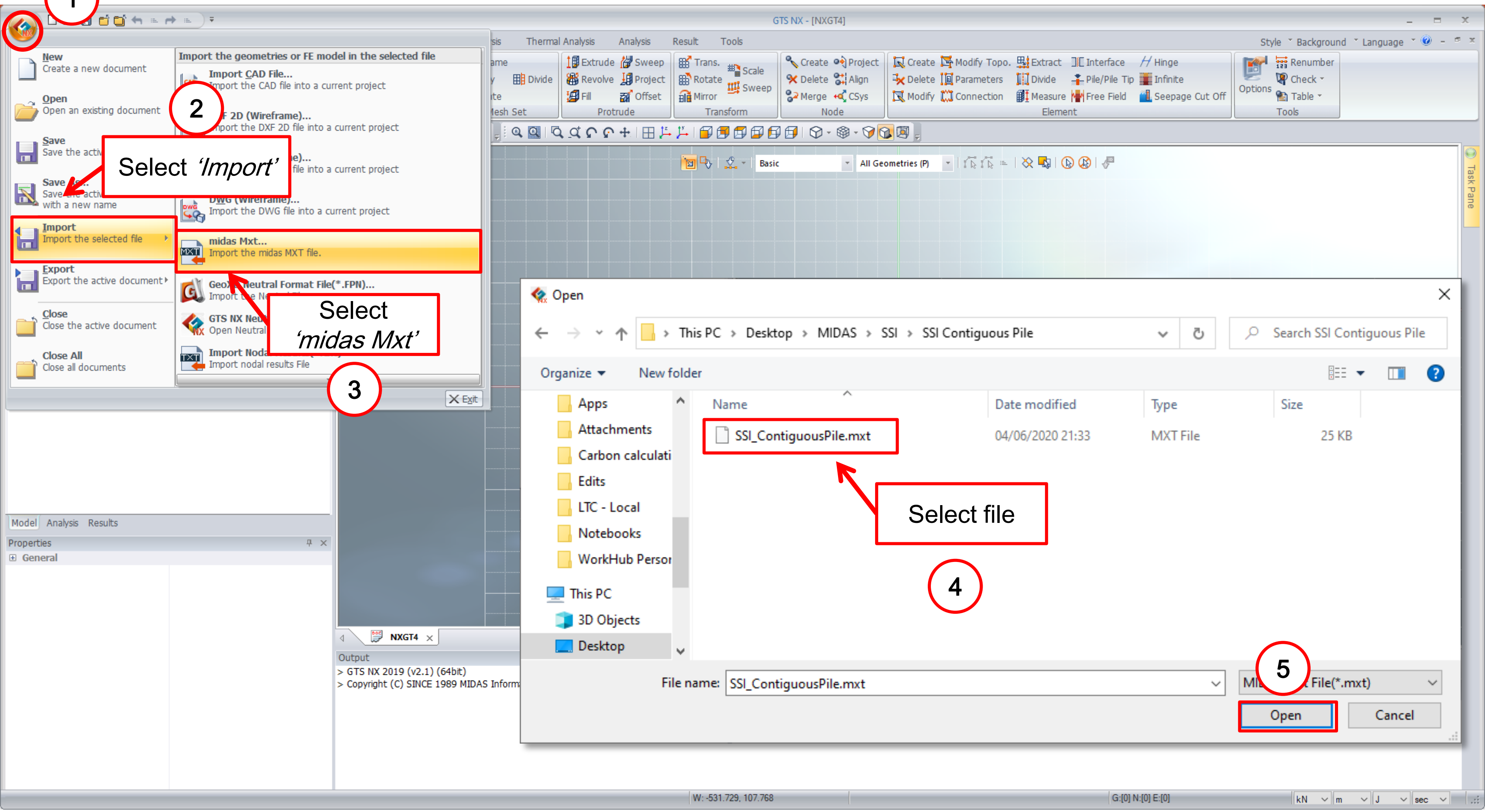
Example #2

Importing to MIDAS GTS NX



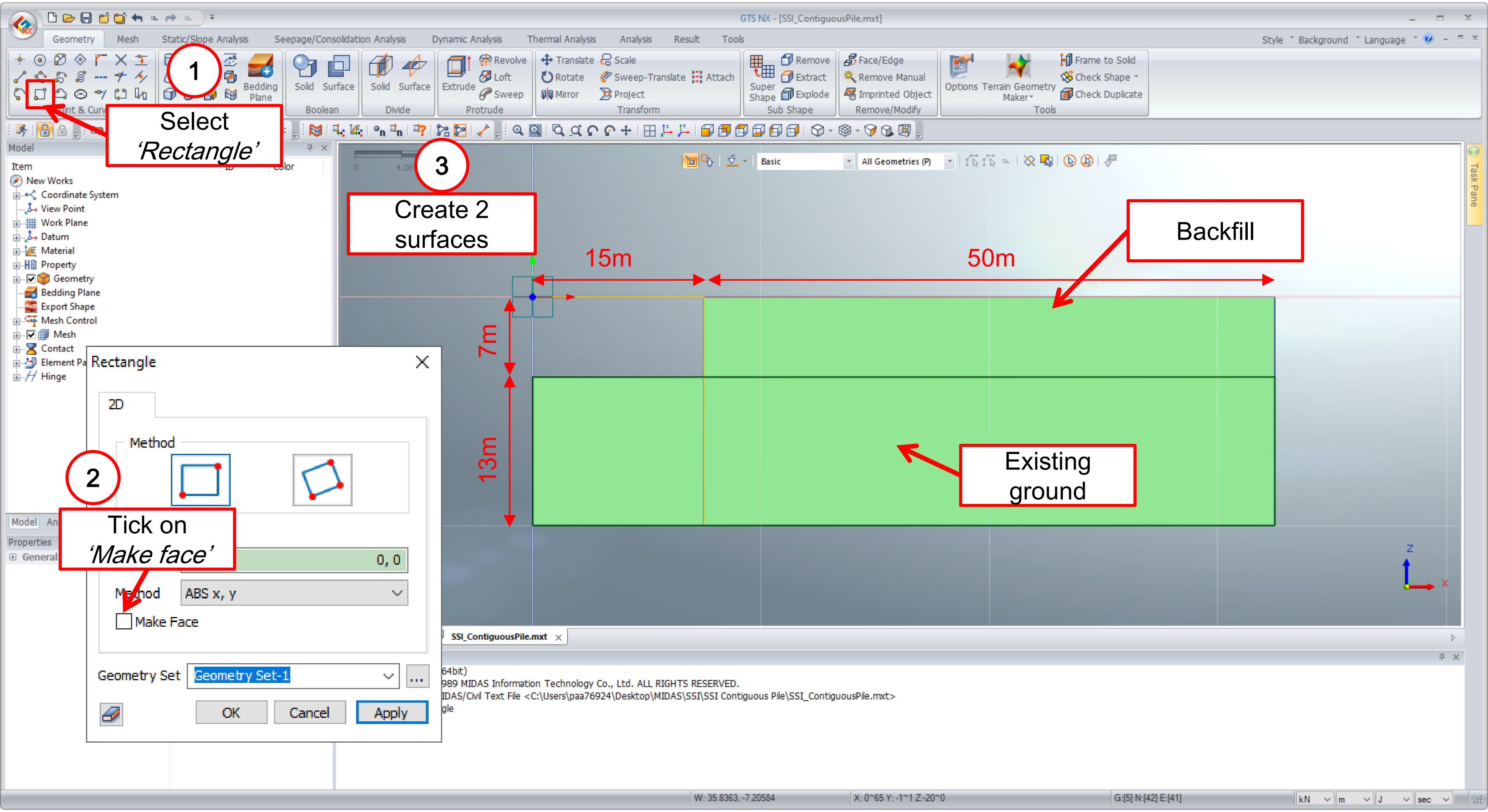
Example #2

- Importing to MIDAS GTS NX



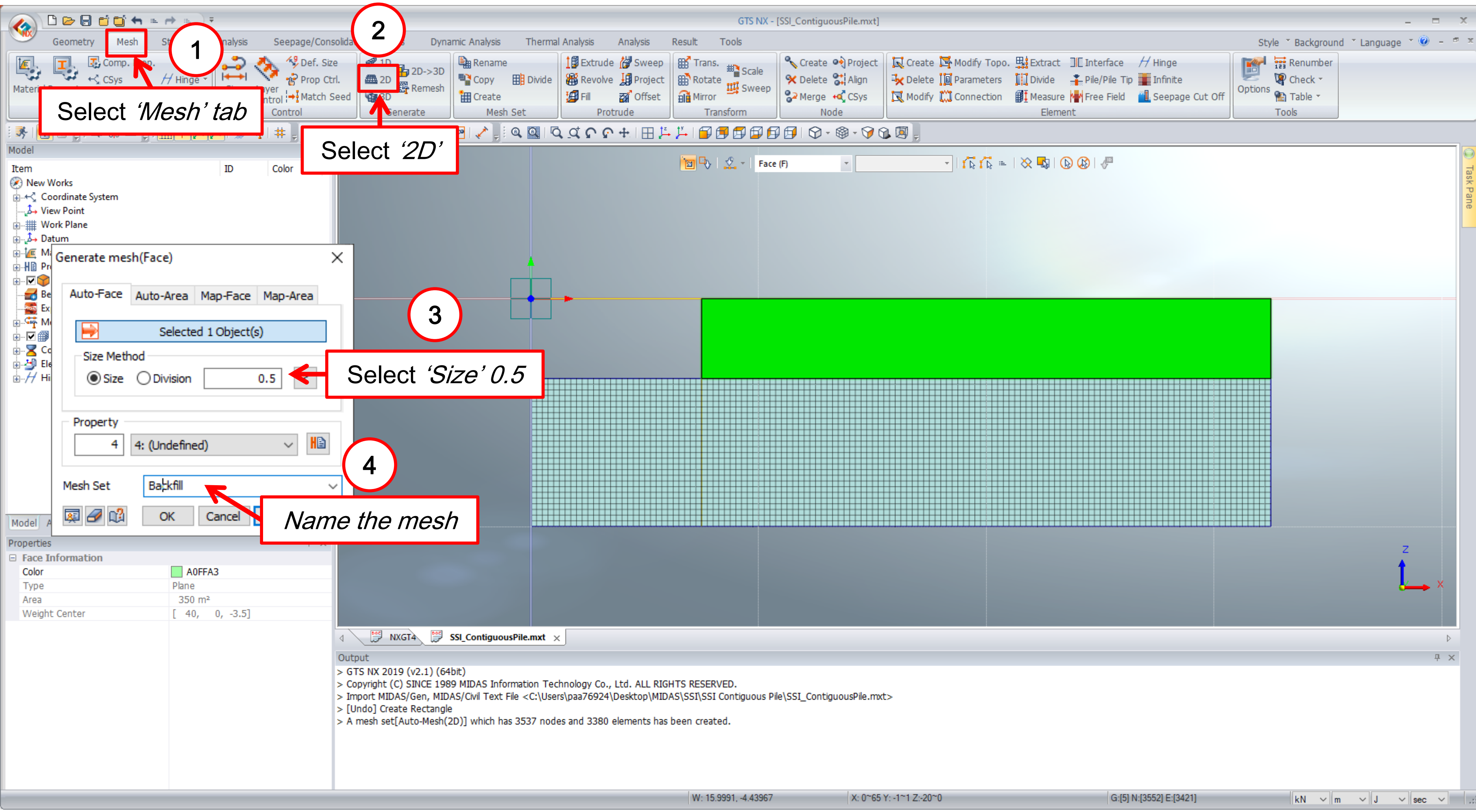
Example #2

- Create FE mesh for surrounding soil



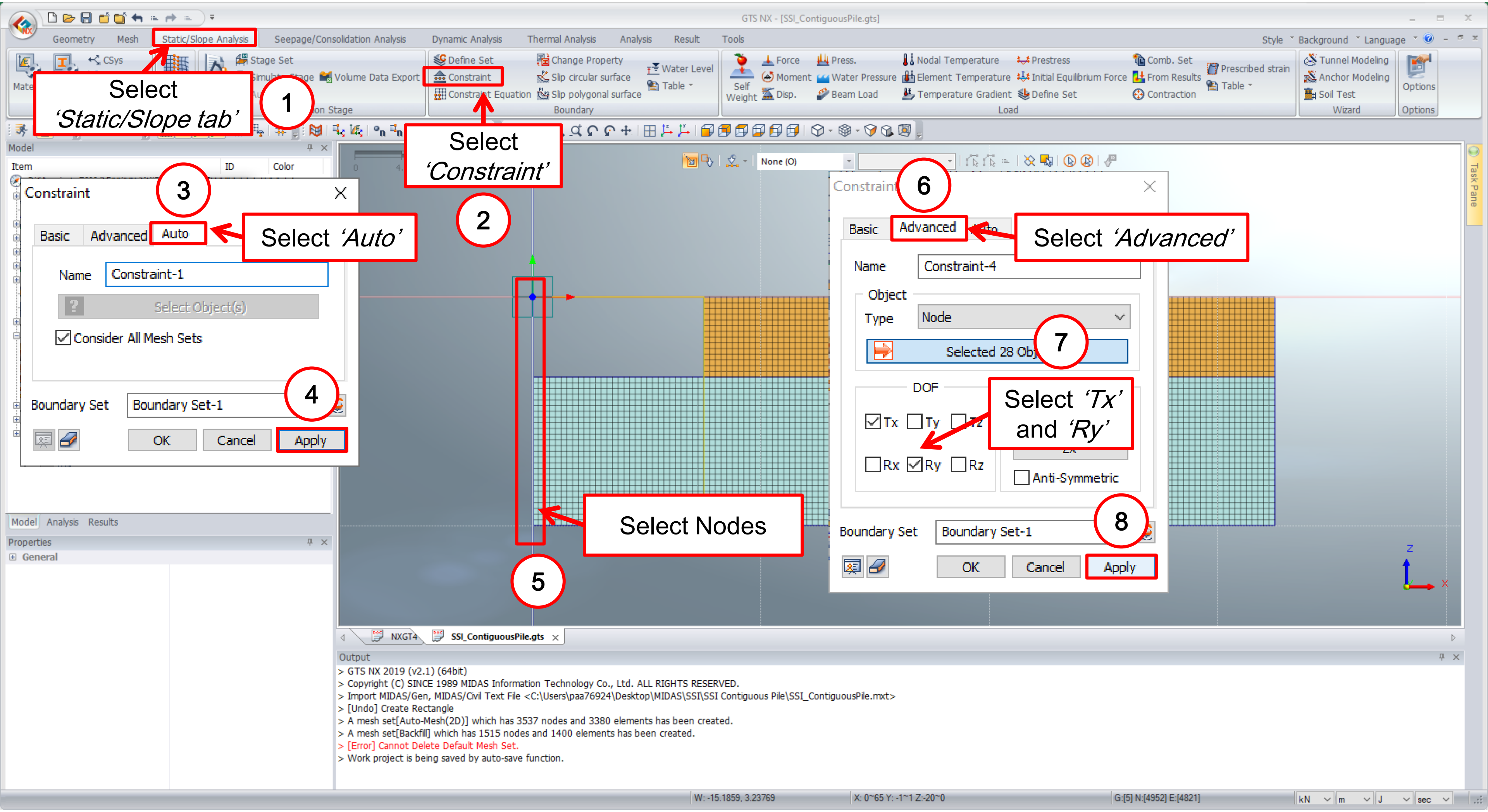
Example #2

- Create FE mesh for surrounding soil



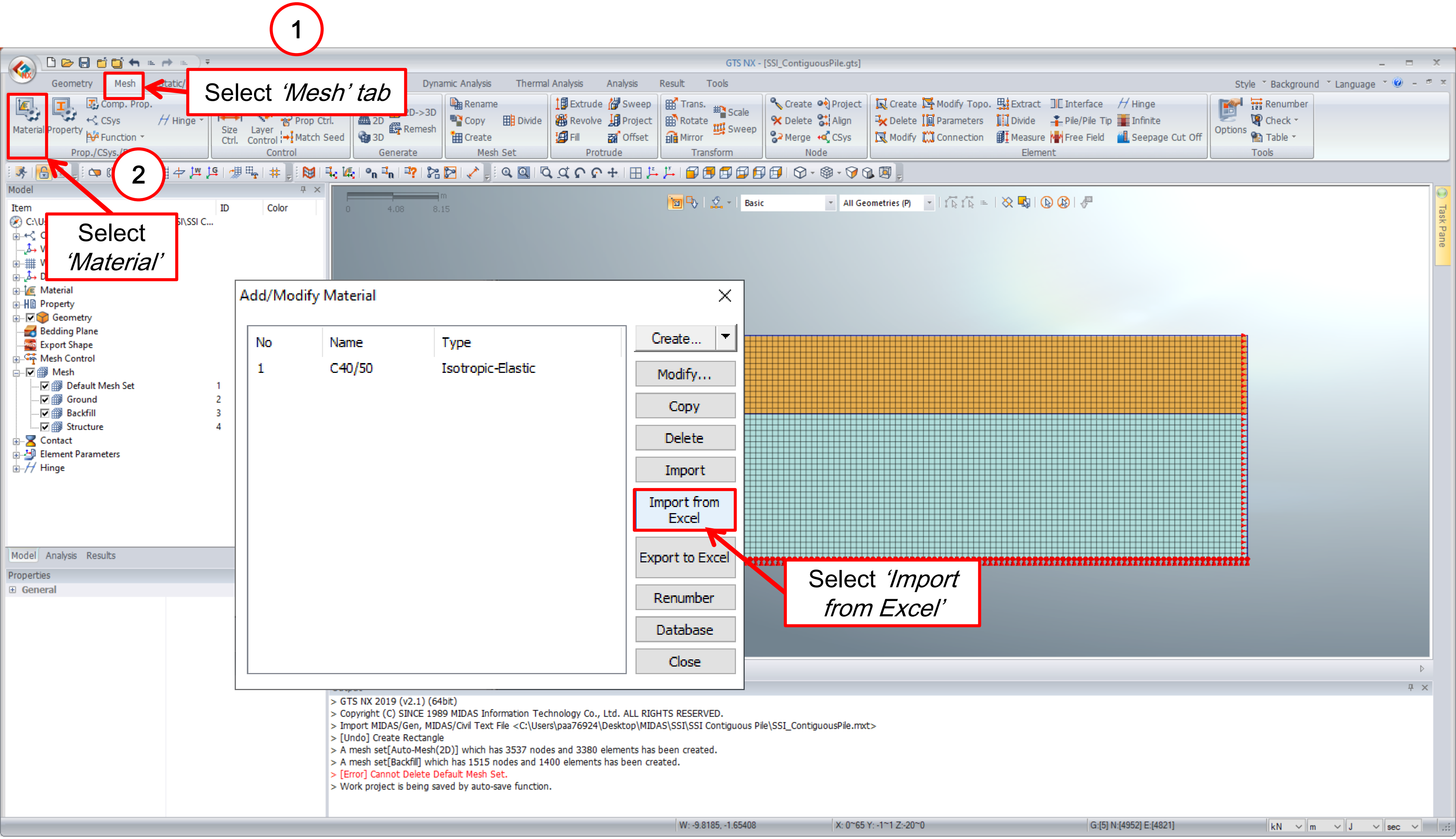
Example #2

- **Boundary conditions**



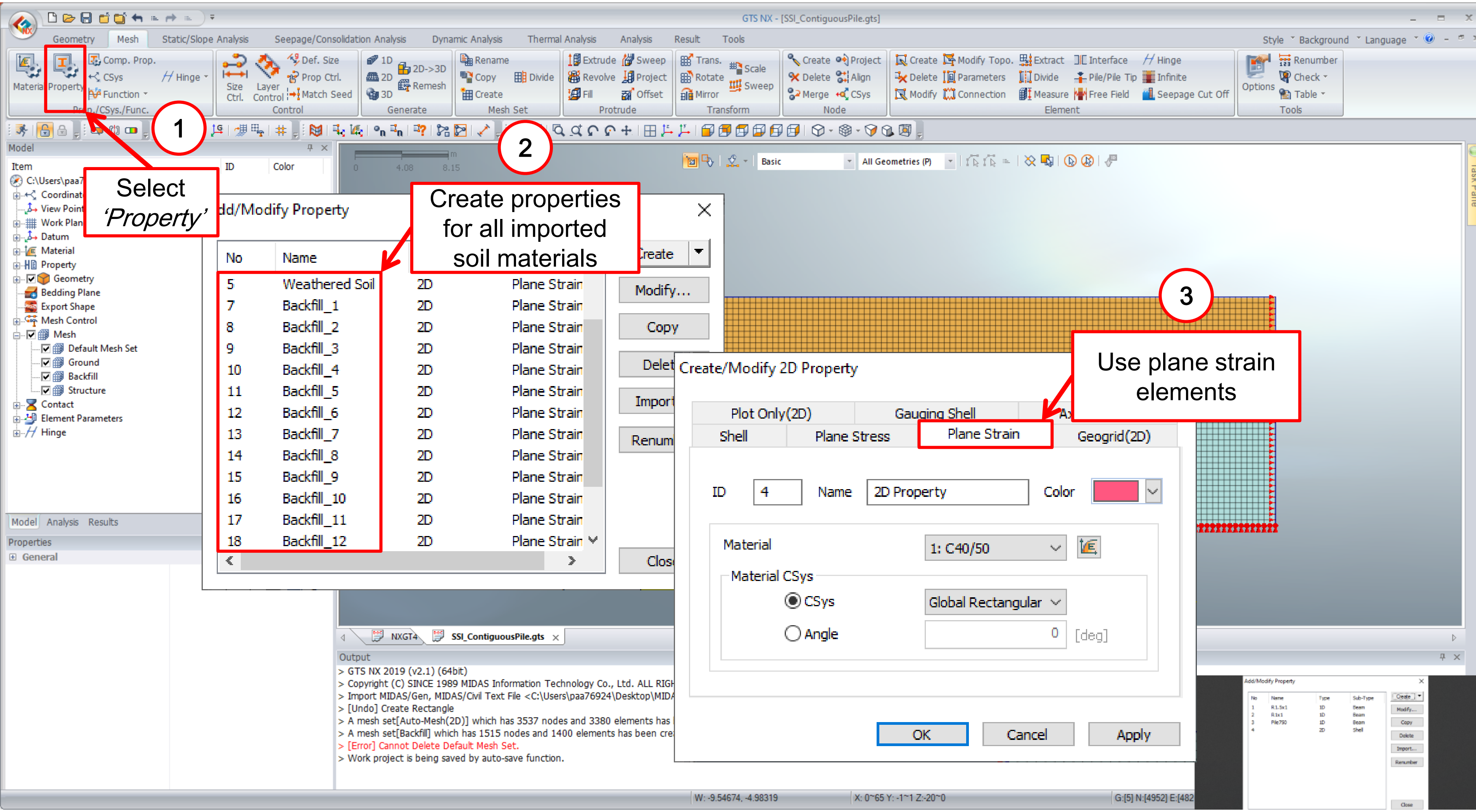
Example #2

Materials



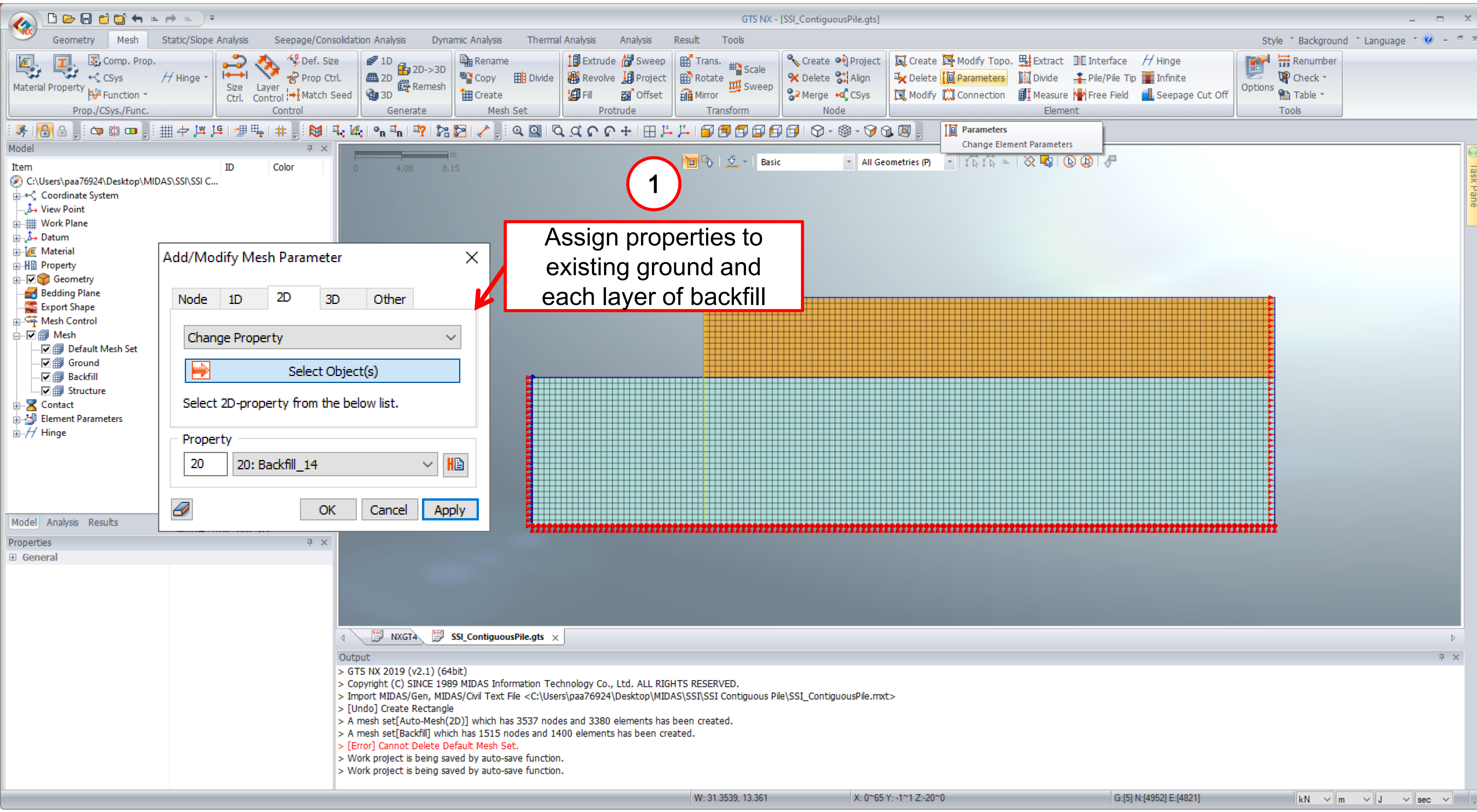
Example #2

■ Property assignment



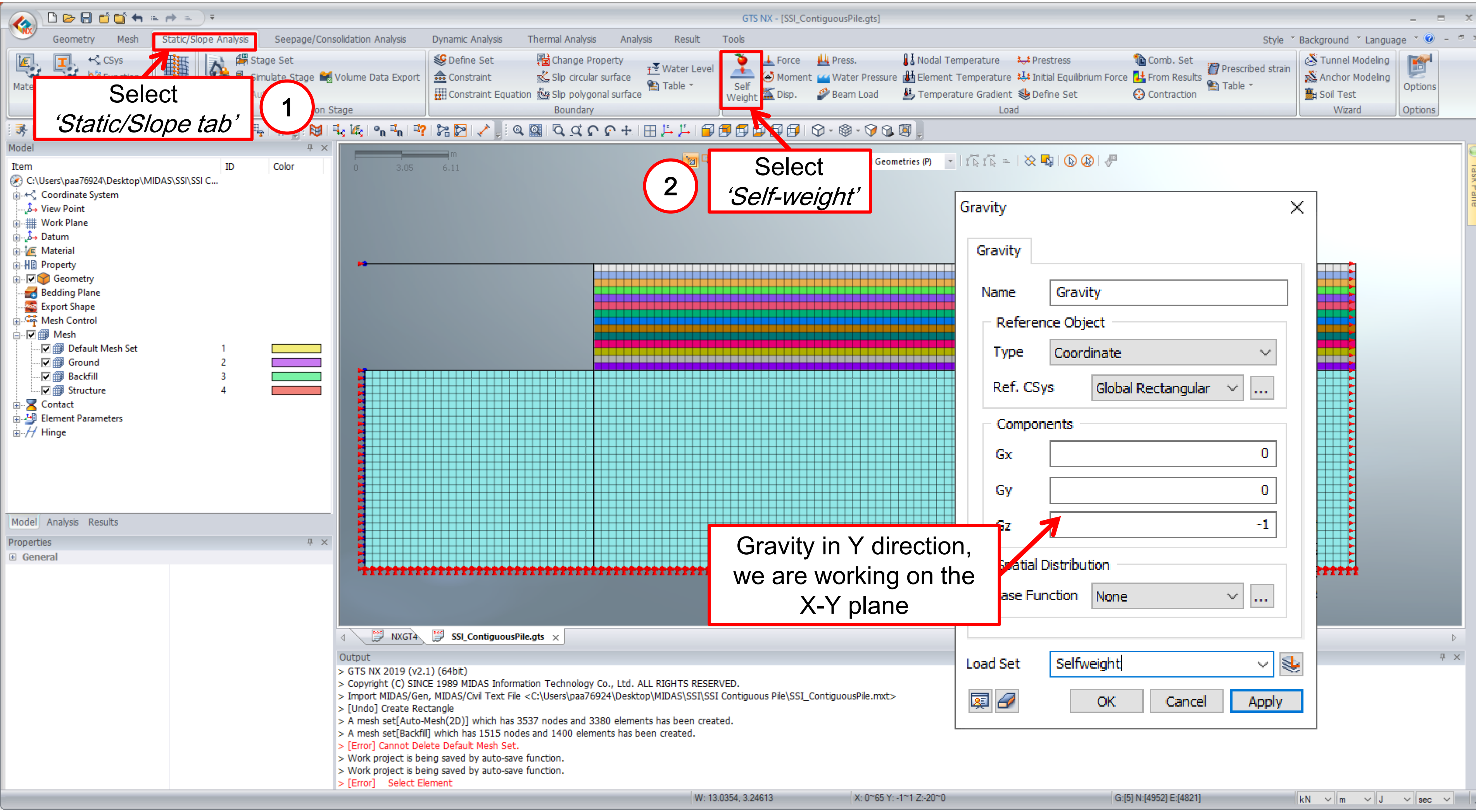
Example #2

- Property assignment



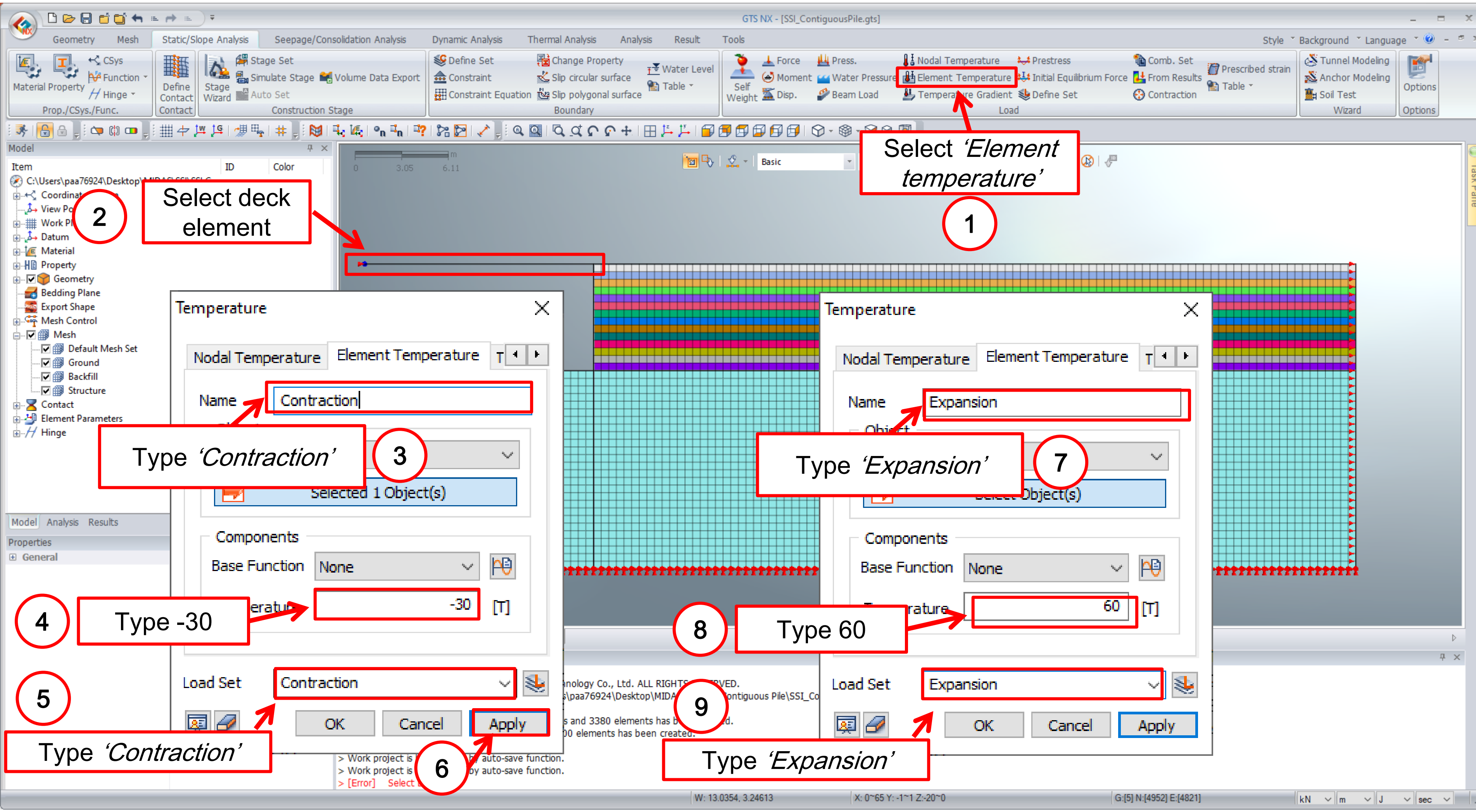
Example #2

Self-weight



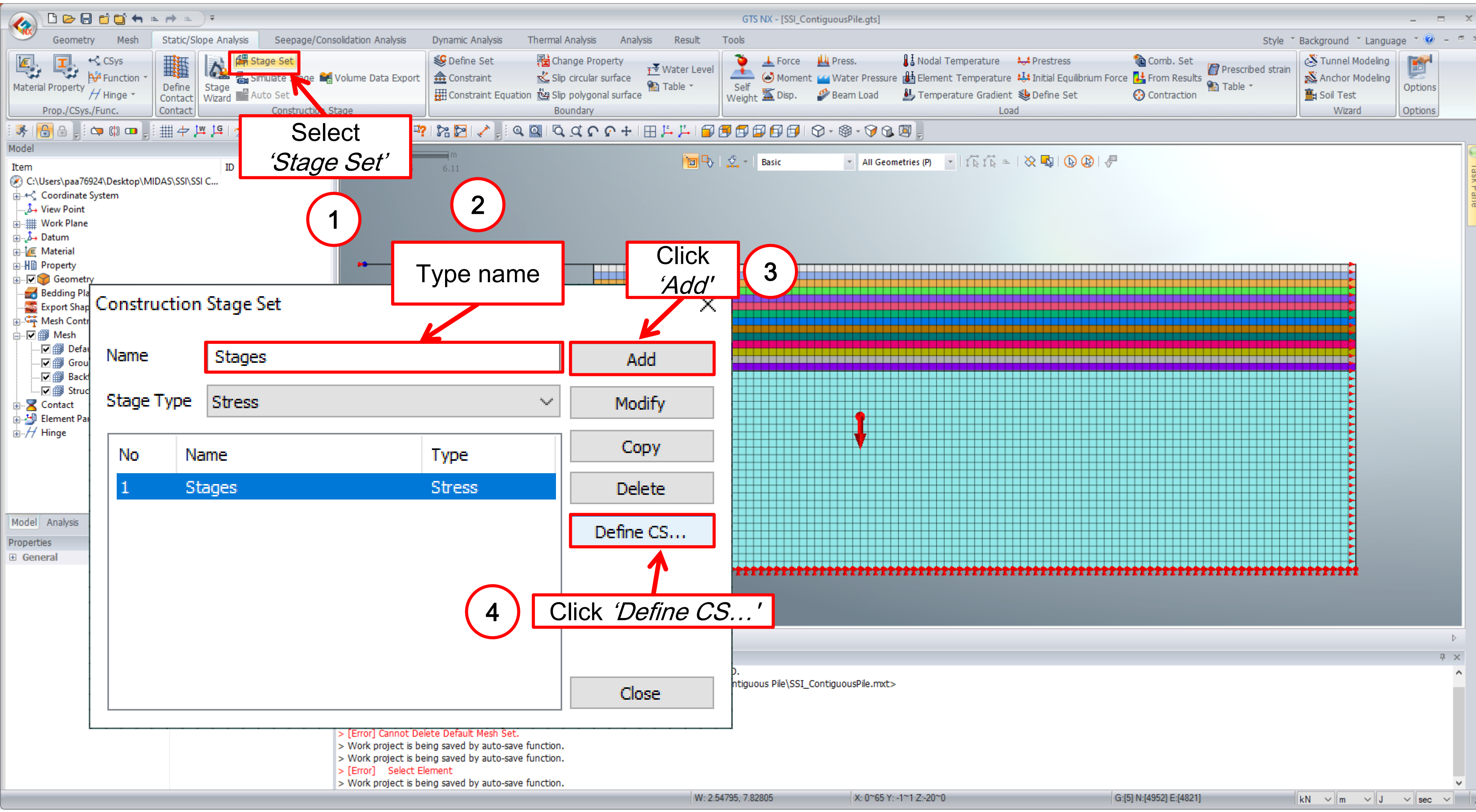
Example #2

Thermal loads



Example #2

- Construction stages



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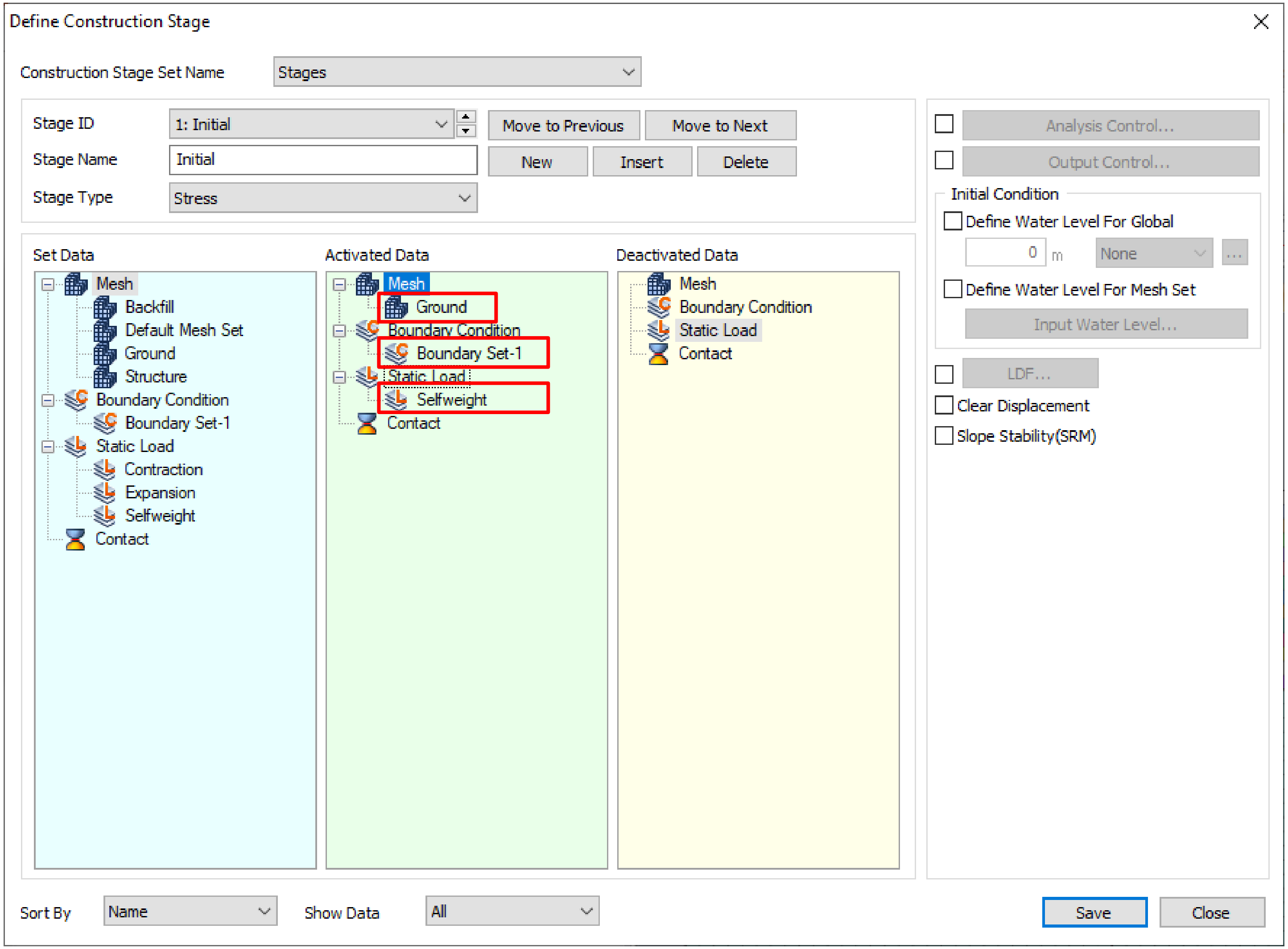
Construction stages



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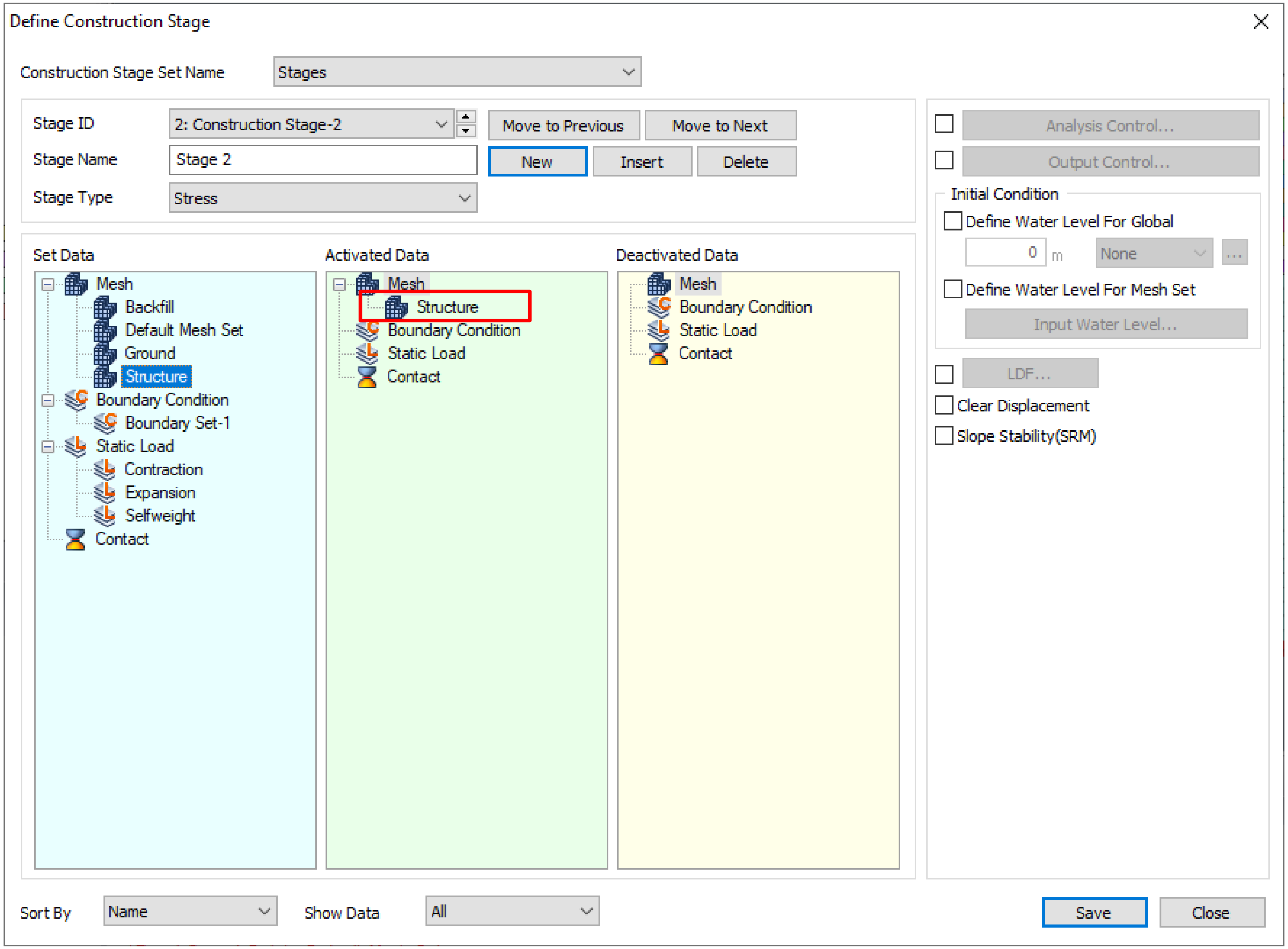
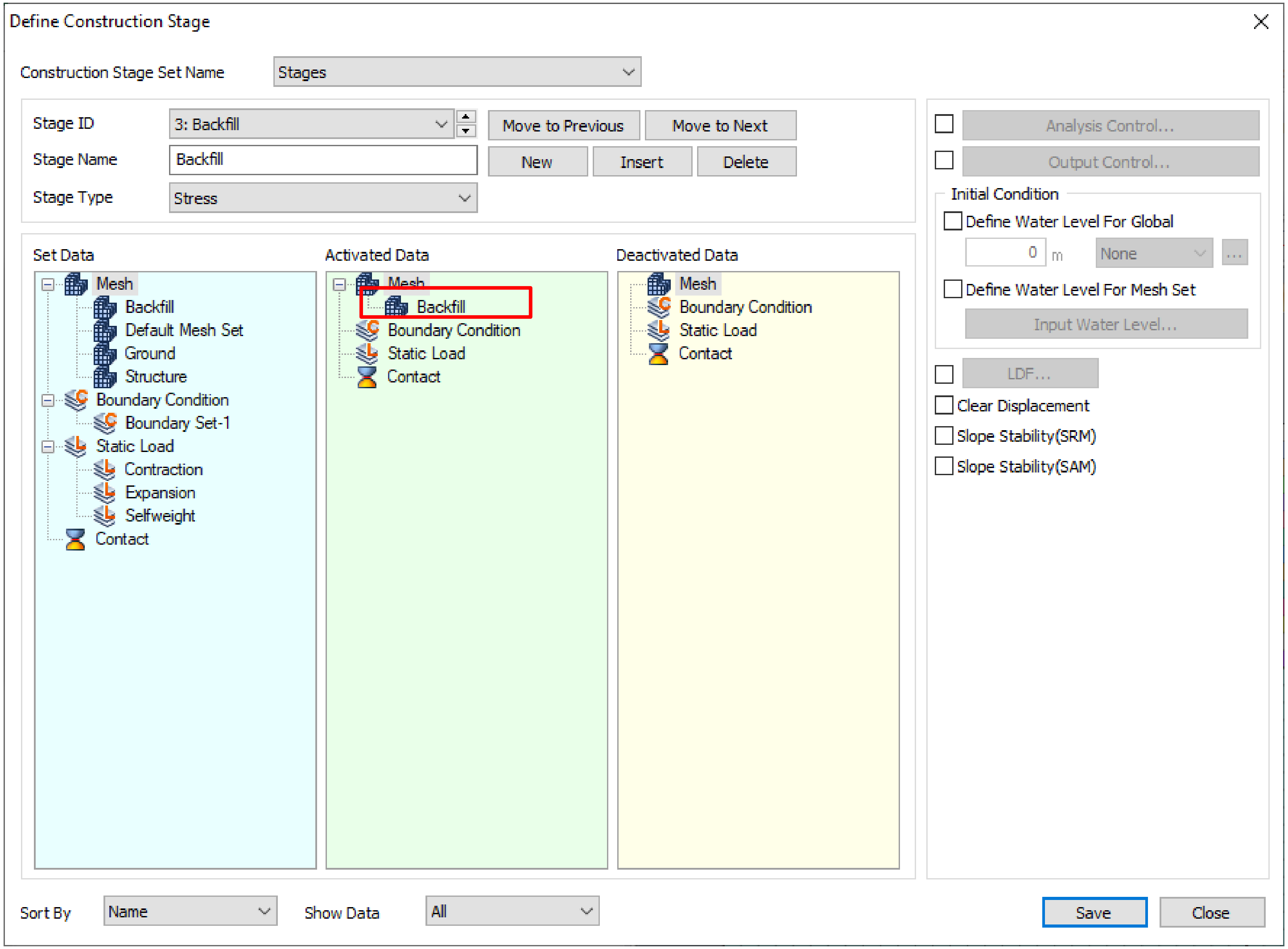
Construction stages

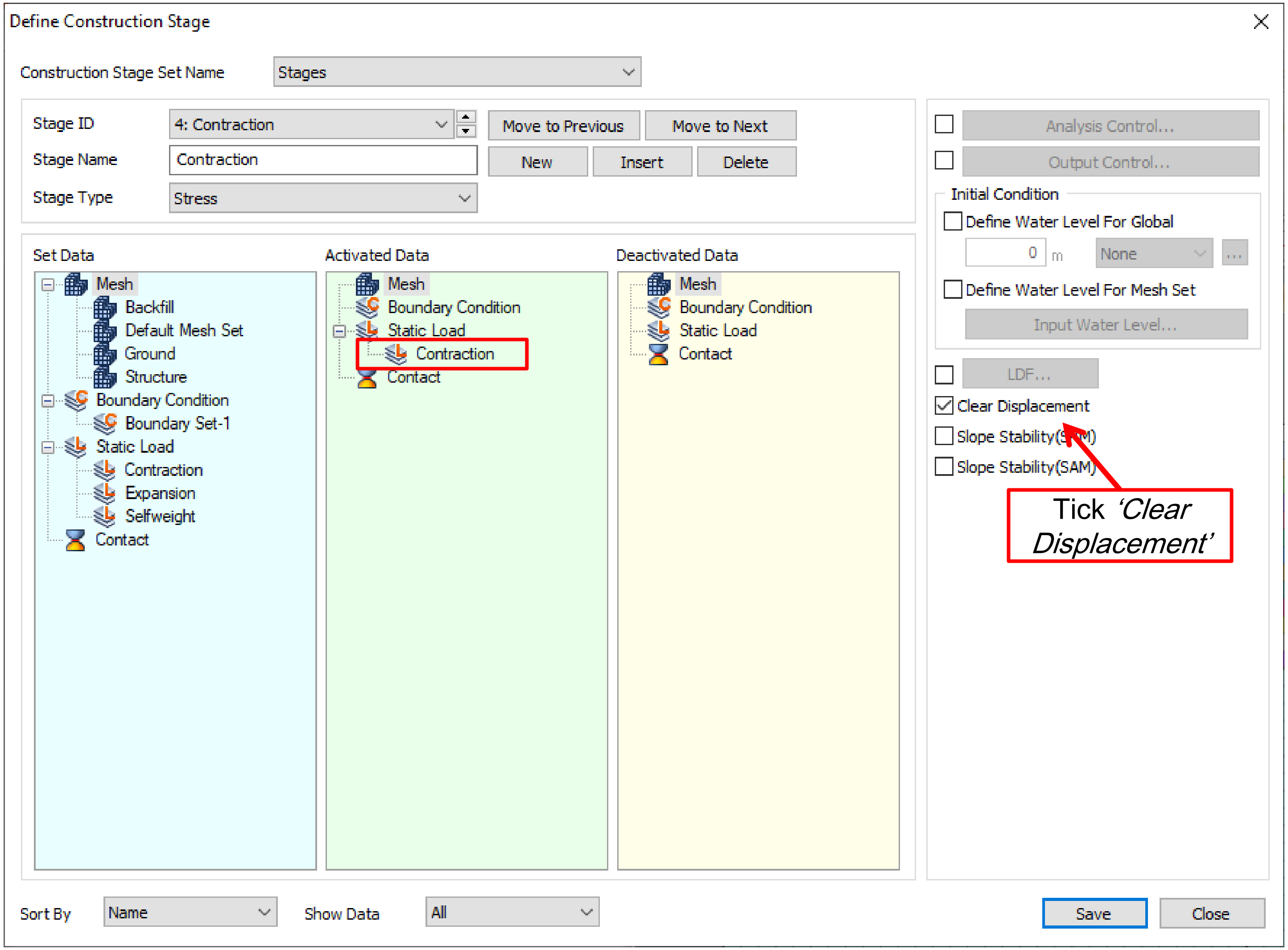


Example #2

Construction stages

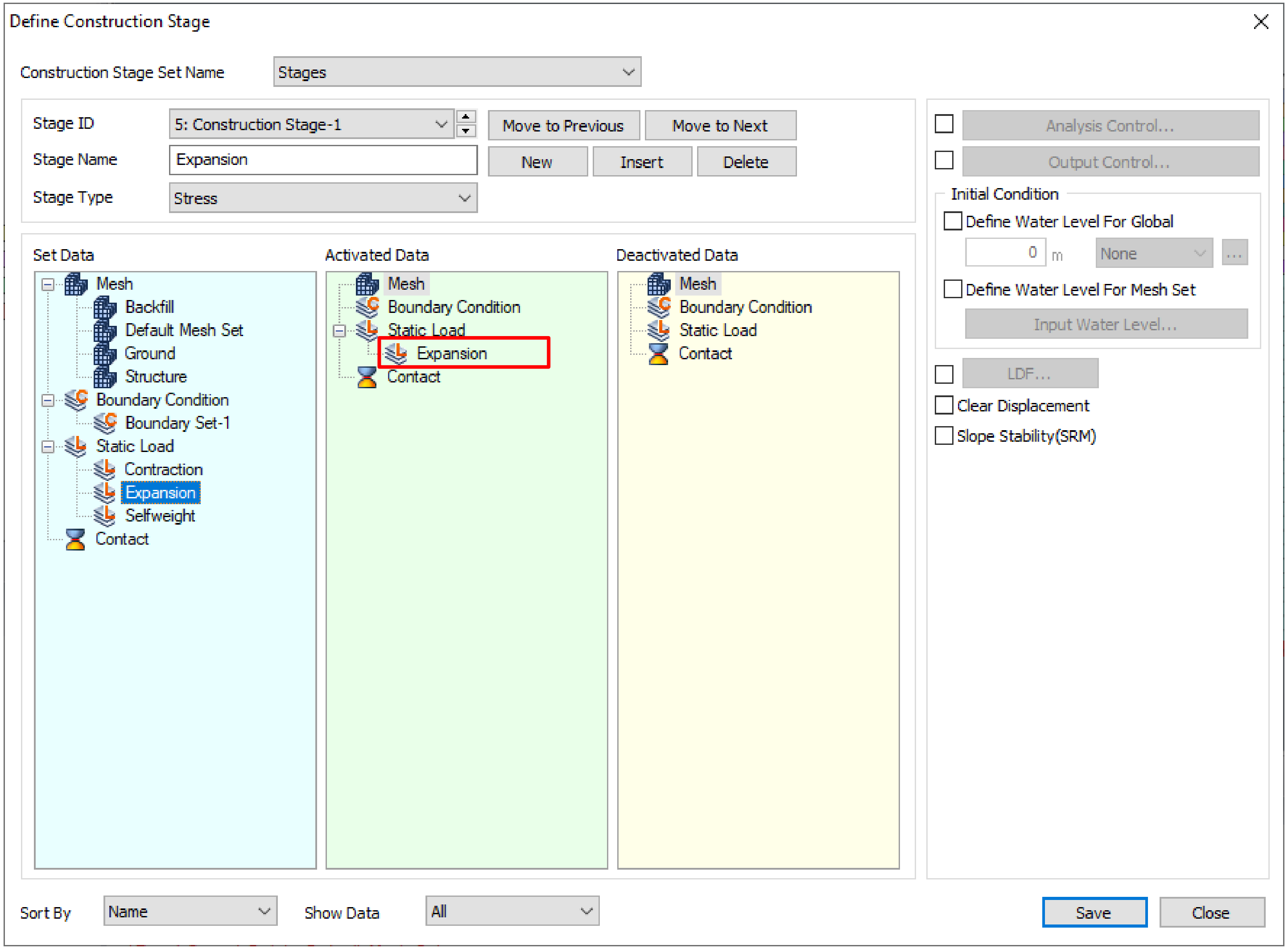


Construction stages



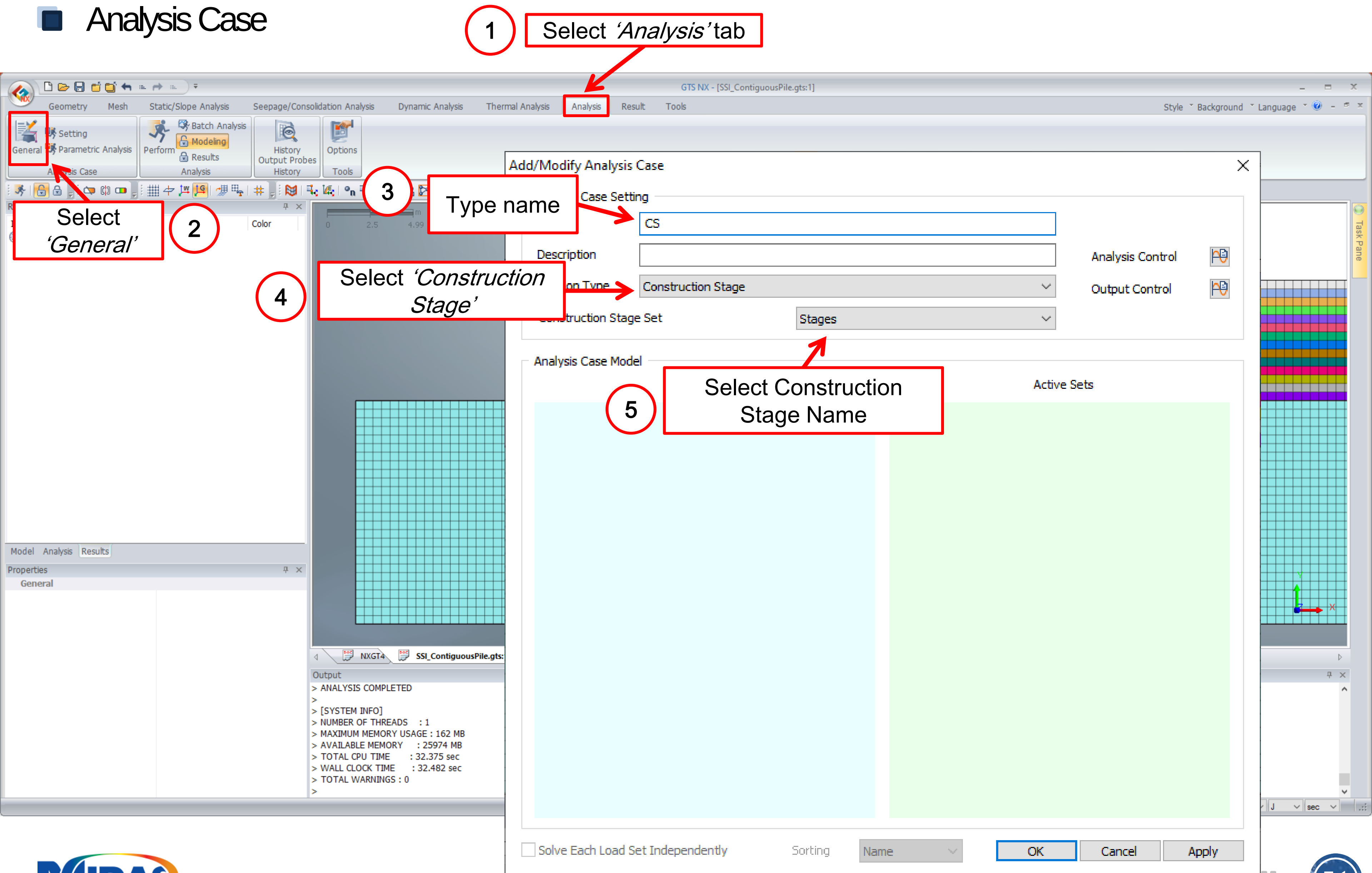
Example #2

Construction stages



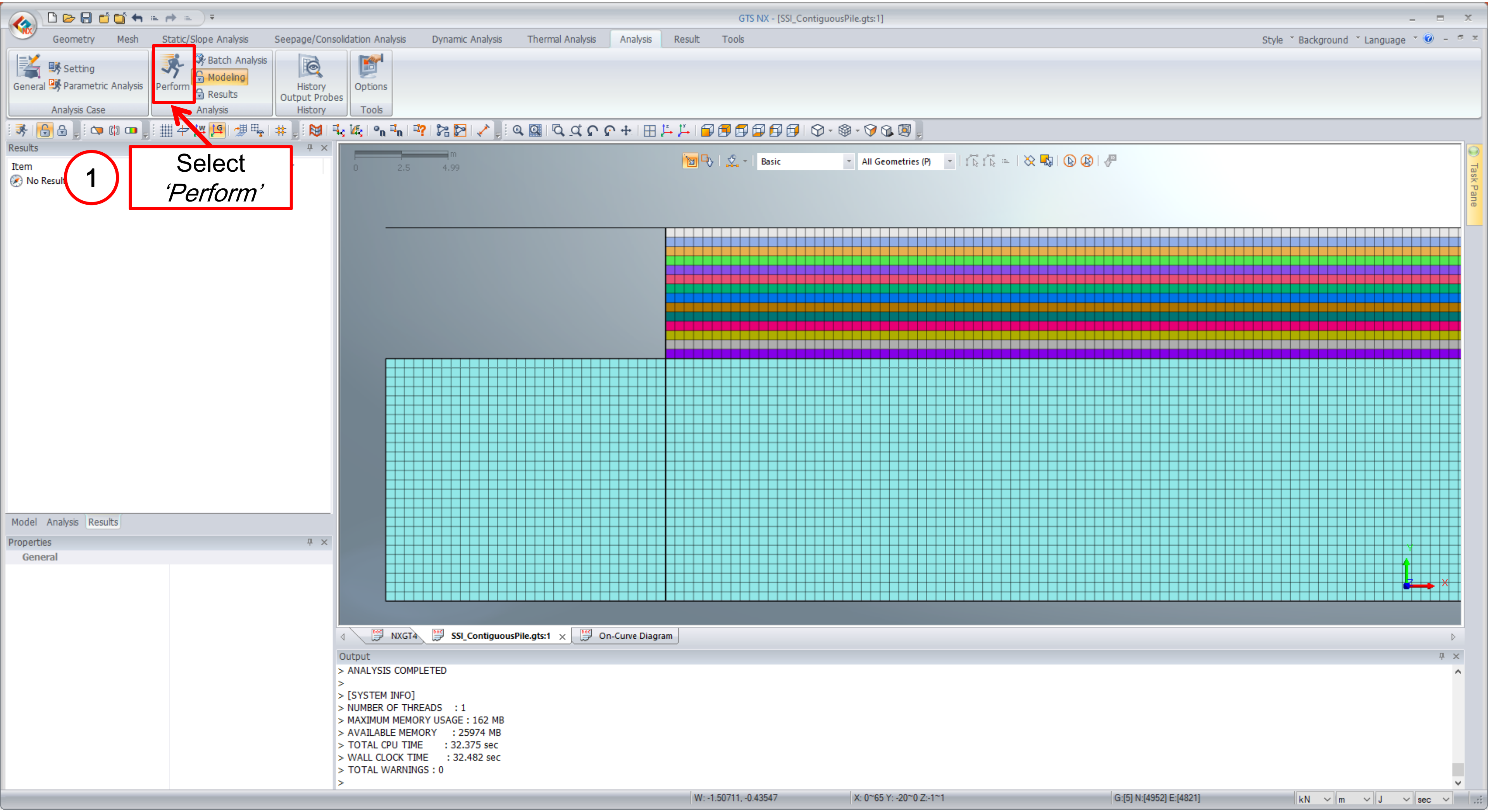
Example #2

Analysis Case



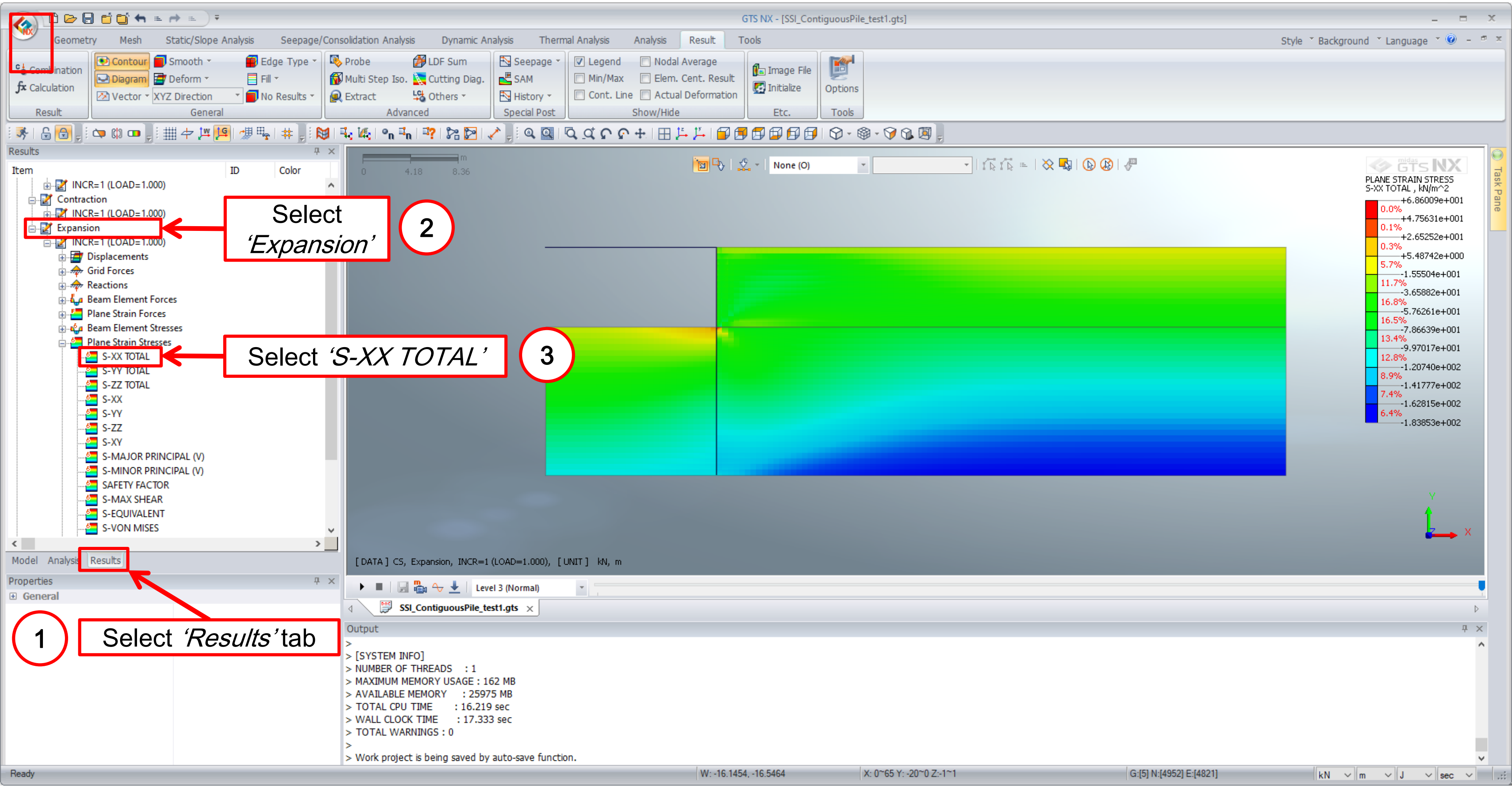
Example #2

- Set up analysis

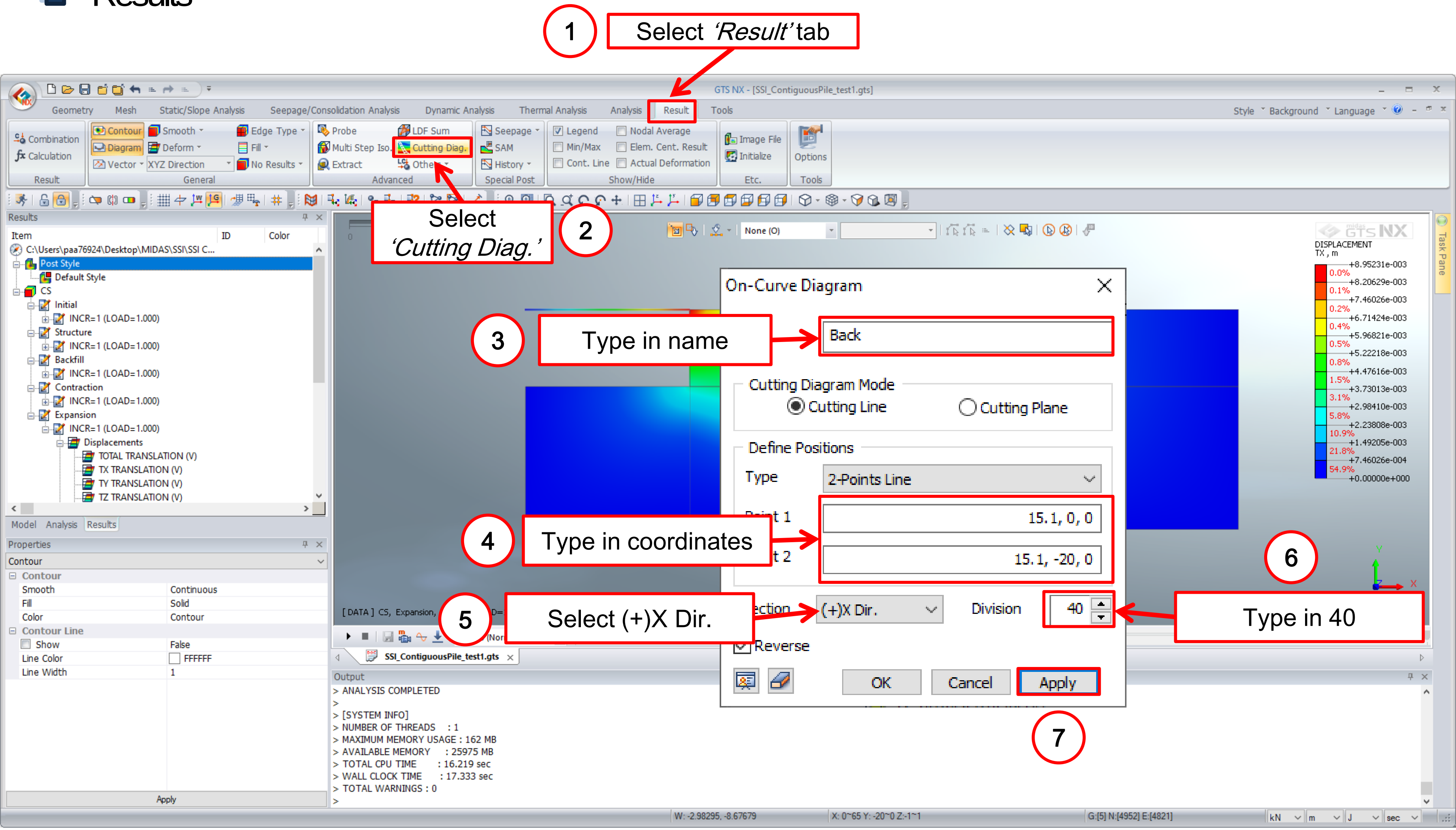


Example #2

- Results

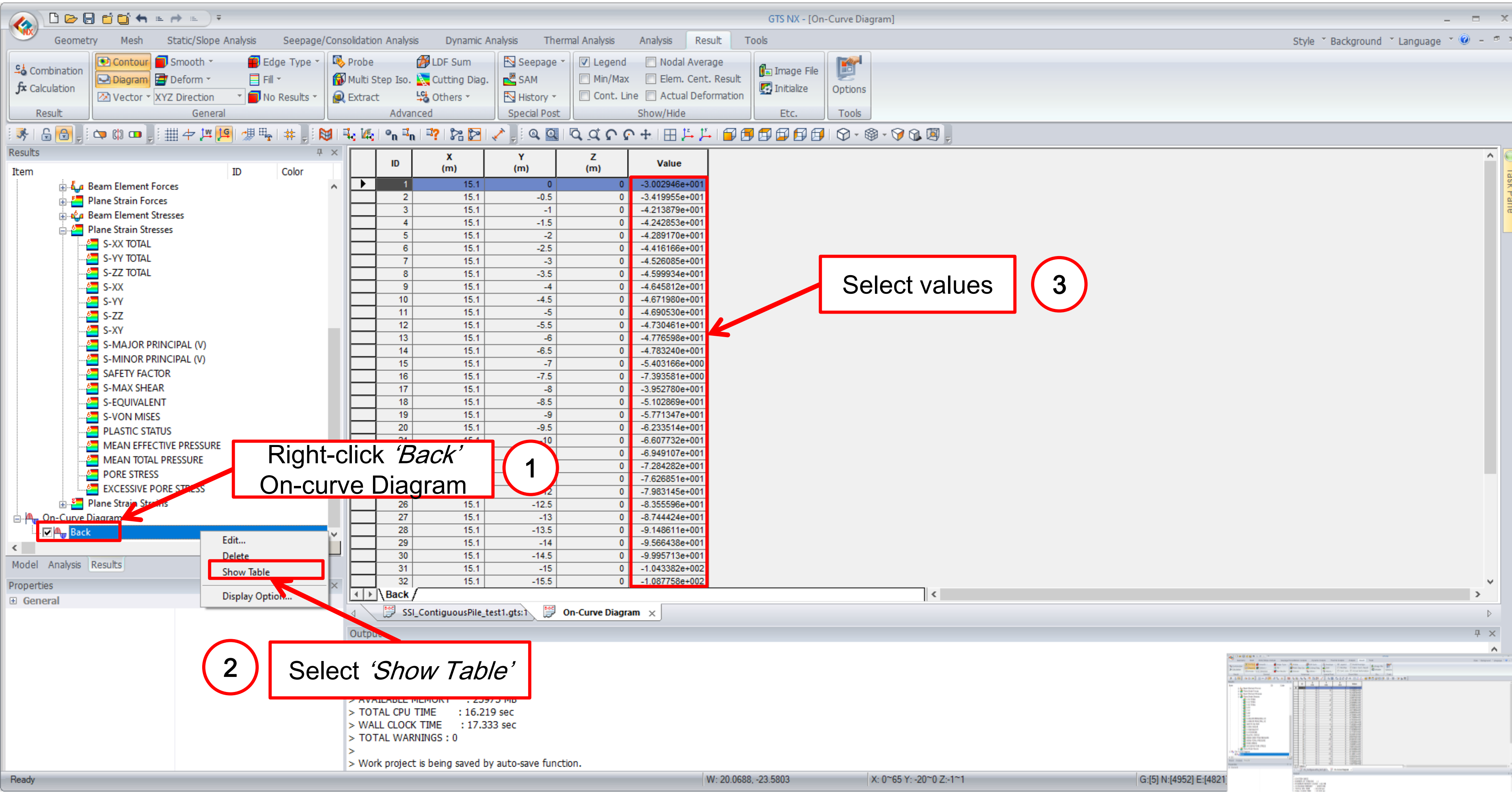


Results


1
Select 'Result' tab
2
Select 'Cutting Diag.'
3
Type in name
4
Type in coordinates
5
Select (+)X Dir.
6
Type in 40
7
On-Curve Diagram
Back
Cutting Diagram Mode
Cutting Line
Cutting Plane
Define Positions
Type
2-Points Line
15.1, 0, 0
15.1, -20, 0
(+)X Dir.
Division
40
Reverse
OK
Cancel
Apply
GTS NX - [SSI_ContiguousPile_test1.gts]
Geometry
Mesh
Static/Slope Analysis
Seepage/Consolidation Analysis
Dynamic Analysis
Thermal Analysis
Analysis
Result
Tools
Cutting Diag.
DISPLACEMENT
TX , m
> ANALYSIS COMPLETED
> [SYSTEM INFO]
> NUMBER OF THREADS : 1
> MAXIMUM MEMORY USAGE : 162 MB
> AVAILABLE MEMORY : 25975 MB
> TOTAL CPU TIME : 16.219 sec
> WALL CLOCK TIME : 17.333 sec
> TOTAL WARNINGS : 0

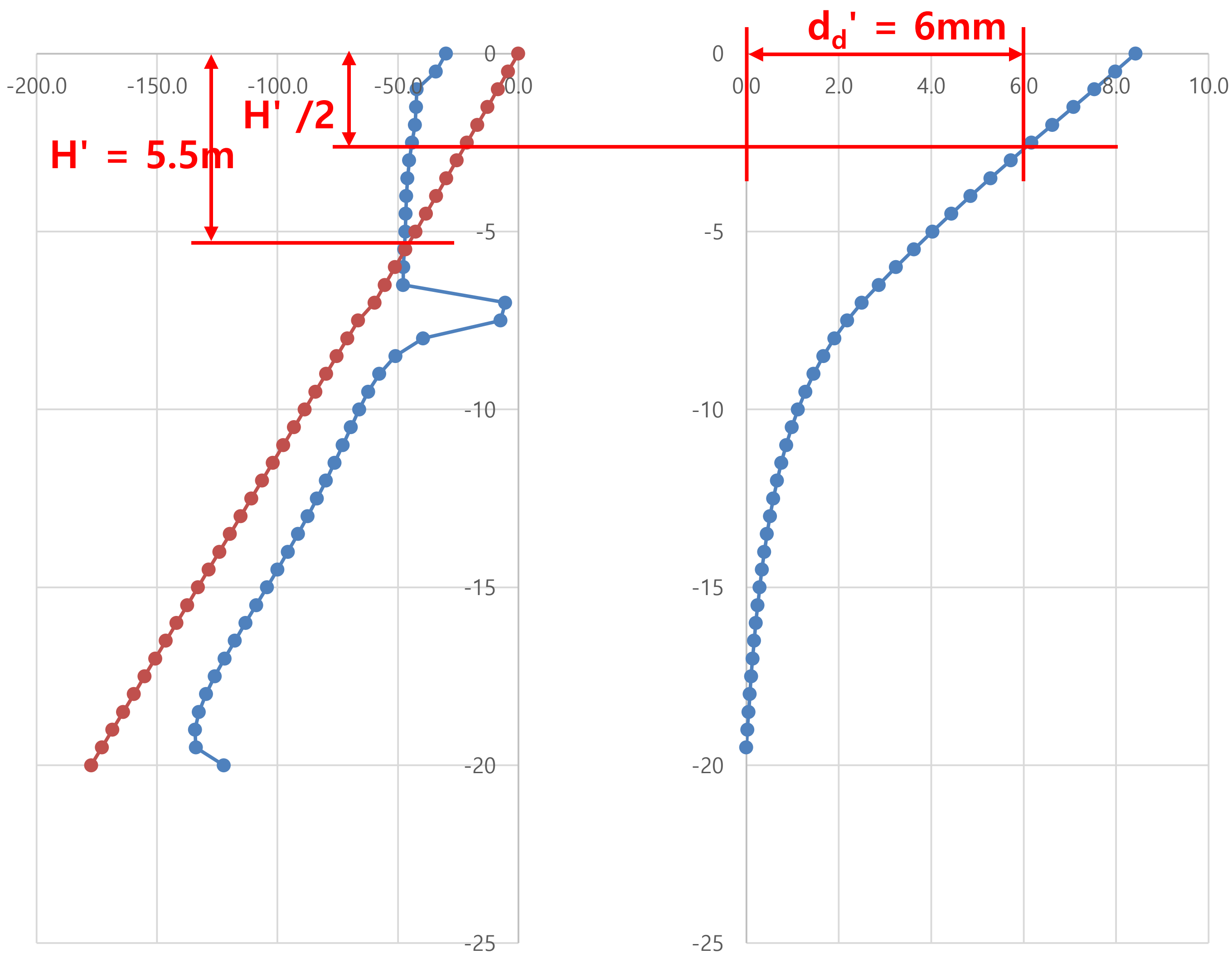
Example #2

Results



Example #2

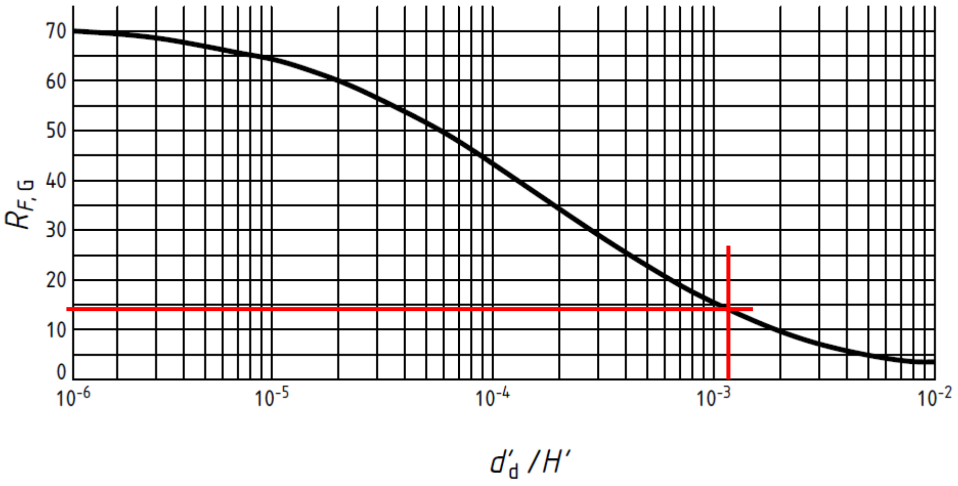
- Extract results



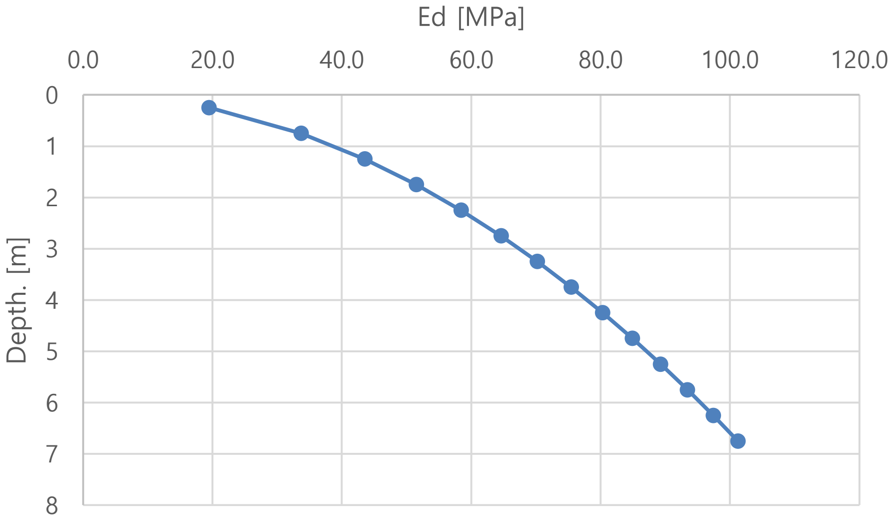
Example #2

- Recalculate material properties

d'	6.4	mm
H'	5.5	m
d'/H'	1.16E-03	
$R_{F,G}$	14	



	z	σ_v	σ_m	G	E	Ed	Ed
	m	kN/m²	kN/m²	kN/m²	kN/m²	kN/m²	MPa
1	0.25	5	3.088079	5412.462	12989.9	19484.86	19.5
2	0.75	15	9.264236	9374.66	22499.2	33748.78	33.7
3	1.25	25	15.44039	12102.63	29046.3	43569.48	43.6
4	1.75	35	21.61655	14320.03	34368.1	51552.11	51.6
5	2.25	45	27.79271	16237.39	38969.7	58454.59	58.5
6	2.75	55	33.96886	17951.11	43082.7	64623.98	64.6
7	3.25	65	40.14502	19514.91	46835.8	70253.68	70.3
8	3.75	75	46.32118	20962.38	50309.7	75464.56	75.5
9	4.25	85	52.49734	22316.15	53558.8	80338.15	80.3
10	4.75	95	58.67349	23592.38	56621.7	84932.55	84.9
11	5.25	105	64.84965	24803.02	59527.2	89290.87	89.3
12	5.75	115	71.02581	25957.26	62297.4	93446.13	93.4
13	6.25	125	77.20196	27062.31	64949.5	97424.32	97.4
14	6.75	135	83.37812	28123.98	67497.6	101246.3	101.2



Example #2

- Update model, recalculate and extract results