Construction Stage Analysis of a Bridge Using a Composite Section

This tutorial was structured in MIDAS/Civil Version 6.3.3.

CONTENTS

Introduction

When a section is composed of more than two materials, consideration should be given to the composite effect in the structural analysis. In addition, when the composite section includes concrete, be sure to consider creep and drying shrinkage.

The composite bridge, as treated in this tutorial, consists of concrete slab and steel I-shaped girder, which is modeled using the ***Composite Section*** wizard and the ***Construction Stage*** method. The result verification process will be identified later.

Bridge type and span constitution to be used in this tutorial are as follows:

Bridge type: Three-span continuous I-girder composite bridge (PSC floor)

Bridge length: L = 45.0 + 55.0 + 45.0 = 145.0 m

Bridge width: B = 12.14 m

Bevel: 90˚(perpendicular)

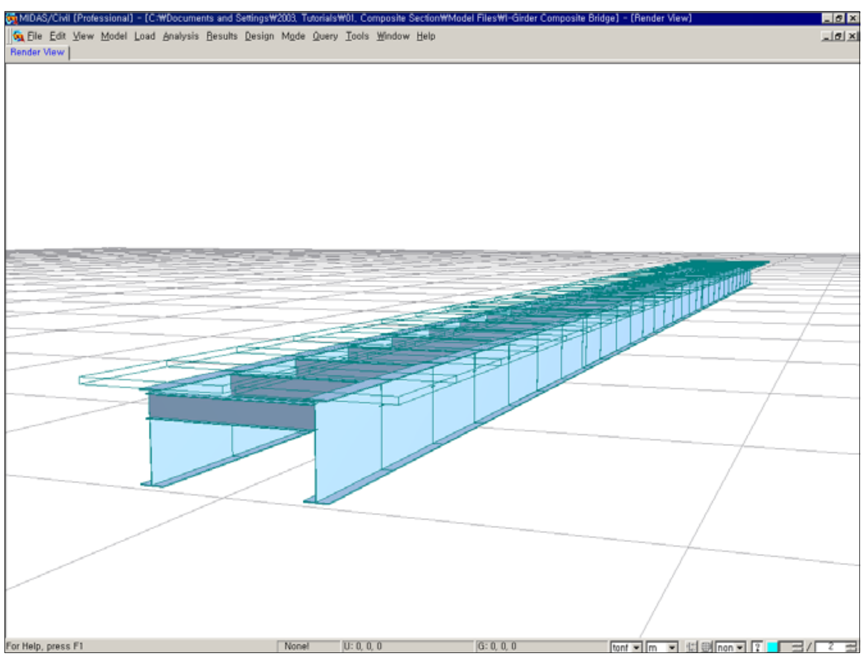


Figure 1. Analytical Model

MIDAS/Civil provides the ***Composite Section for Construction Stage*** command for performing the construction stage analysis of a composite section. In this tutorial, the structural analysis method covering both construction stage and composite section will be discussed.

The procedure to perform construction stage analysis of a composite bridge is as follows:

1. Define material and section properties
2. Define Structure Groups, Boundary Groups and Load Groups
3. Define construction stages
4. Activate the Boundary Groups and Load Groups corresponding to each construction stage
5. Activate the floor sections corresponding to each construction stage as per the construction sequence for floor slab
6. Review the analysis results for each construction stage

Cross Section

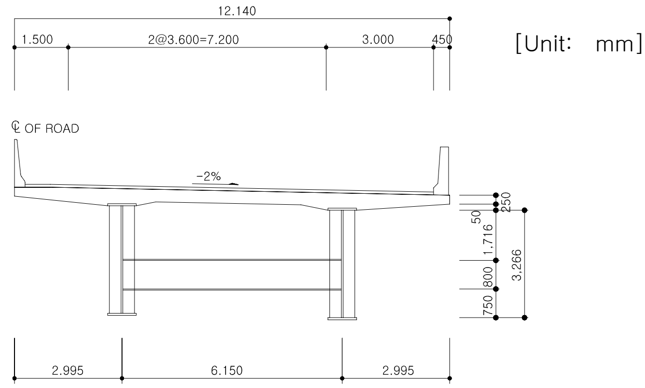


Figure 2. Section View

The bridge model used in this tutorial is simplified so that every girder has identical section and every cross beam also has identical section.

Materials

Member	Section	Remark
Girder	A53	Steel
Cross beam	A36	Steel
Slab	Grade C6000	Concrete (Use a function of compressive strength of concrete)

Loadings

- Dead Load before composite action

  - Self-weight of the steel girder: automatically converted to the Self Weight within the program

  - Self-weight of the concrete slab: entered into Beam Loads

- Dead Load after composite action

  - Entered into Beam Loads

Compose Construction Stages

➢ Define Load Cases and Load Groups

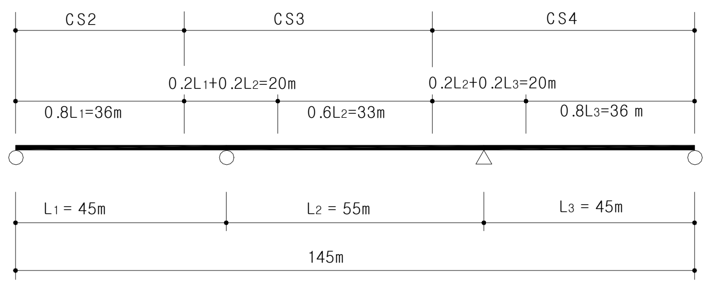


Figure 3. Construction sequence for deck and each part of the deck section

Now that slab has an inflection point at 0.2L from the interior support, when casting new concrete upon old concrete, make it happen at the inflection point where no stress occurs.

Load Case	Load Group	Load Type	Remark
DL (BC) 1	DL (BC) 1	Self Weight	Self-weight of the girder
DL (BC) 2	DL (BC) 2	Beam Loads	Self-weight of the slab corresponding to $0.8 \times$ L1 range
DL (BC) 3	DL (BC) 3	Beam Loads	Self-weight of the slab corresponding to $0.2 \times$ L1 + $0.8 \times$ L2 range
DL (BC) 4	DL (BC) 4	Beam Loads	Self-weight of the slab corresponding to $0.2 \times$ L2 + L3 range
DL (AC)	DL (AC)	Beam Loads	Additional dead loads (pavement, handrail, barrier)

➢ Define Boundary Groups

Boundary Condition Group	**Type of Boundary Conditions**	**Remark**
BGroup	Supports	Support condition
E_Width1	Effective Width Scale Factor	The ratio of the moment of inertia w. r. t. the effective width to the moment of inertia w. r. t. the total width, CS2 section (at the middle of the 1st span)
E_Width2	Effective Width Scale Factor	The ratio of the moment of inertia w. r. t. the effective width to the moment of inertia w. r. t. the total width, CS3 section (at the 1st interior support, at the middle of the 2nd span)
E_Width3	Effective Width Scale Factor	The ratio of the moment of inertia w. r. t. the effective width to the moment of inertia w. r. t. the total width, CS4 section (at the 2nd interior support, at the middle of the 3rd span)

➢ Define Construction Stages

Const. Stage	**Structure Group**	**Boundary Group**	**Load Group (Activation)**		**Duration**	**Remark**
			Group	**Step**		
CS1	SGroup	BGroup	DL (BC) 1 DL (BC) 2	First step First step	5	Non-composite section
CS2	-	E_Width1	DL (BC) 3	25 days (User step)	30	Composite action in CS2 section
CS3	-	E_Width2	DL (BC) 4	25 days (User step)	30	Composite action in CS3 section
CS4	-	E_Width3	DL (AC)	First step	10,000	Composite action in CS4 section

※ SGroup represents a Structure Group including all members (girders, cross beams).
※ One element group is enough since the geometry of the structure does not vary with construction stages.
※ Using the ***Composite Section for Construction Stage*** command, define a composite/noncomposite section in accordance with the construction sequence for deck.
※ Assume that it takes 25 days to manufacture formwork and concrete slab obtains the initial strength at 5 days. Accordingly, it would take 30 days to finish the construction.
※ The self-weight of the slab to be entered into ***Element Beam Loads*** will be activated at 25 days when formwork will have been completed.

- CS1
  - Generate steel girders and cross beams along the length of the bridge.
  - Use the ***Self Weight*** command to enter the self-weight of the girder and use the ***Element Beam Loads*** command to enter the self-weight of the slab of CS2 section (See Figure 4).
- CS2
  - CS2 section acts compositely.
  - Enter the effective width of CS2 section.
  - Use the ***Element Beam Loads*** command to enter the self-weight of the slab of CS3 section (See Figure 4).

- CS3
  - CS3 section acts compositely.
  - Enter the effective width of CS3 section.
  - Use the ***Element Beam Loads*** command to enter the self-weight of the slab of CS4 section (See Figure 4).
- CS4
  - CS4 section acts compositely.
  - Enter the effective width of CS4 section.
  - Use the ***Element Beam Loads*** command to enter additional dead loads.

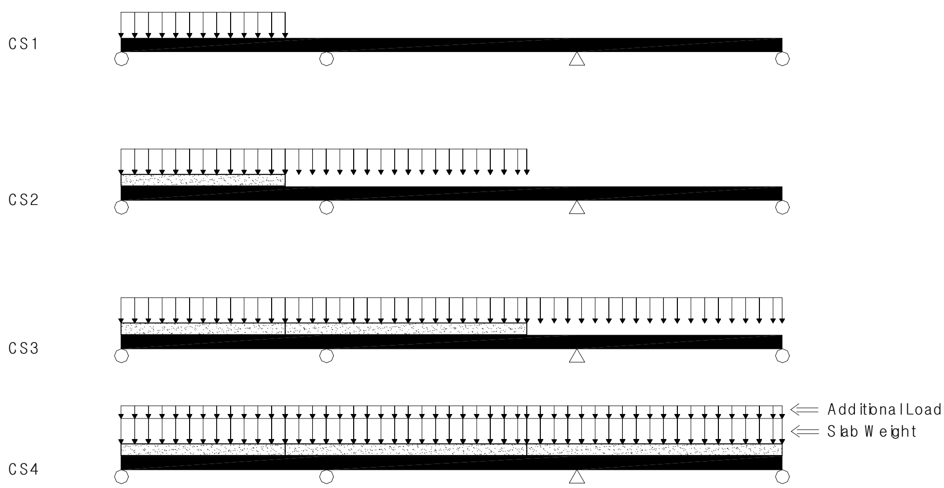


Figure 4. Slab weight and additional dead loads loaded at each construction stage

Set Working Condition and Enter Section/Material Properties

Open a new file (***New Project***) to begin a plate girder bridge model and save the file (***Save***) as 'I-Girder Composite Bridge'.

File / ***New Project***
File / ***Save*** **(I-Girder Composite Bridge)**

Set Working Condition

Set the unit system to 'kN' and 'm' for this tutorial model.

Tools / ***Unit System***
Length>**m** ; Force>**kN** ↵

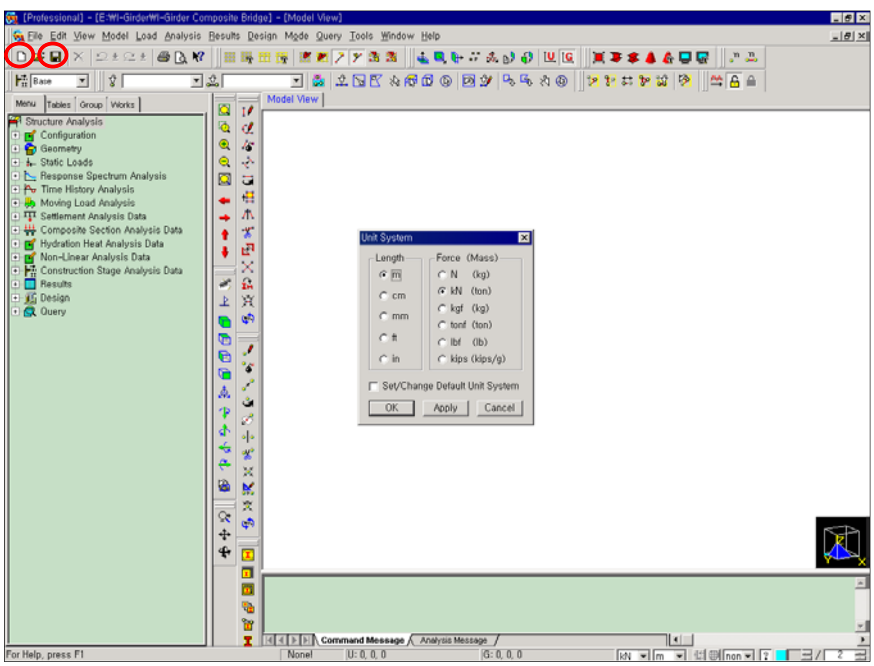


Figure 5. Initial View and ***Unit System*** dialog box

Enter Material Properties

Material properties for the girders, cross beams and slabs can be defined using built-in DB in MIDAS/Civil.

Model / Property / *Material*
Type>**Steel** ; Standard>**ASTM(S)**
DB>**A53** ↵ ; DB>**A36** ↵

Type>**Concrete** ; Standard>**ASTM(RC)**
DB>**Grade C6000** ↵

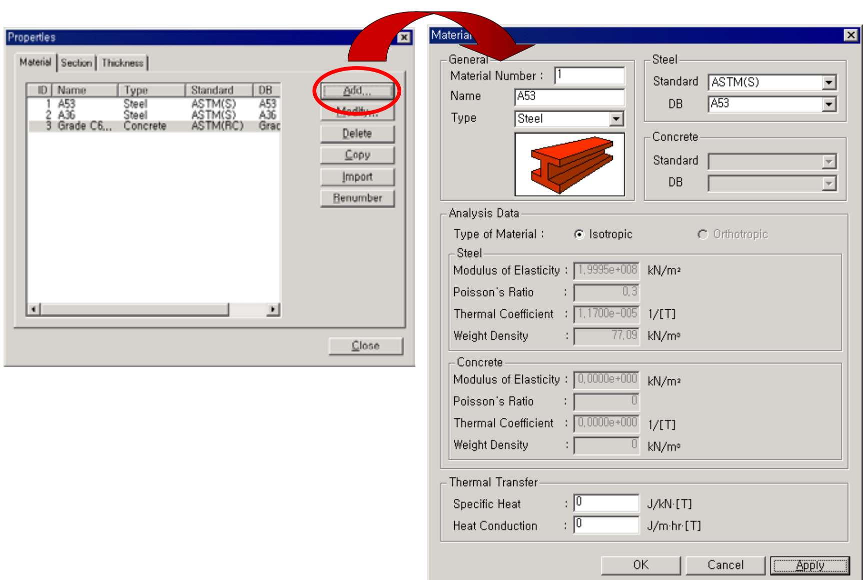


Figure 6. Enter material properties

Enter Section Properties

With the construction sequence considered, girders will have different section names from construction stage to stage. For this particular tutorial, assume that all girder sections are the same; in such case, girders will have identical section properties but different section names (i.e., Sect 1, Sect 2, Sect 3 and Sect 4). To create the cross beams, use User type section.

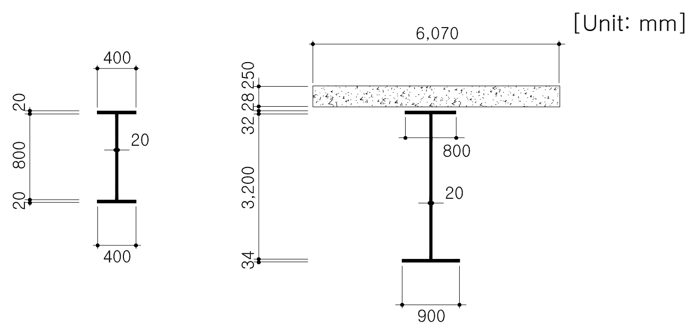


Figure 7. Section layout

➢ Section Table

Classification	**Section**	**Remark**
Girder	H 3200×800×900×20×32/34	Composite Section
Cross Beam	H 800×400×20×20/20	User type Section

Model / Property / ***Section***

Composite tab

Section ID **(1)** ; Name **(Sect 1)** ; Offset>**Center-Center**

Section Type>**Steel-I** ; Slab Width **(12.14)** ;

Girder>Num **(2)** ; CTC **(6.15)**

Slab>Bc **(6.07)** ; tc **(0.25)** ; Hh **(0.028)**

Girder>Hw **(3.2)** ; tw **(0.02)** ; B1 **(0.8)** ; tf1 **(0.032)** ; B2 **(0.9)** ; tf2 **(0.034)** ↵

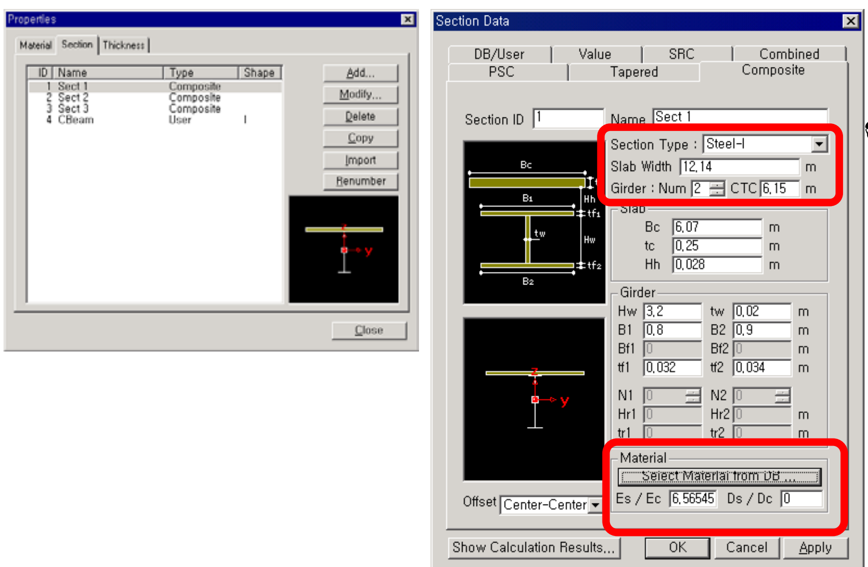
Material> Select Material from DB ...

Concrete Material>DB>**ASTM(RC)** ; Name>**Grade C6000**

Steel Material>DB>**ASTM(S)** ; Name>**A53** ↵

Section ID **(2)** ; Name **(Sect 2)** ↵

Section ID **(3)** ; Name **(Sect 3)** ↵



You may skip these fields if you are using the Composite Section for Construction Stage.

Figure 8. ***Section Data*** dialog box

DB/User tab

Section ID **(4)** ; Name **(CBeam)** ; Offset>**Center-Center**

Section Shape>**I-Section** ; **User**

H **(0.84)** ; B1 **(0.4)** ; tw **(0.02)** ; tf1 **(0.02)** ↵

Enter Time Dependent Material Properties

Time dependent material properties will be defined so as to consider variations in concrete strength led by variations in the modulus of elasticity of concrete, creep and drying shrinkage developing with time.

Time dependent material properties are determined from the CEB-FIP Code. A slab thickness of 25 cm will be used for computing Notational size of member.

- 28-day strength: 20000 kN/m^2
- Relative humidity: 70%
- Notational size: $2 \times Ac/u = (2 \times 12.14 \times 0.25) / (12.14+0.25)\ 2 = 0.245$
- Type of concrete: Normal-weight concrete
- Time of the removal of forms: 3 days after concrete placing (the time of the beginning of drying shrinkage)

Model / Property / *Time Dependent Material (Creep & Shrinkage)*

Name **(Mat-1)** ; Code>**CEB-FIP**

Compressive strength of concrete at the age of 28 days **(20000)**

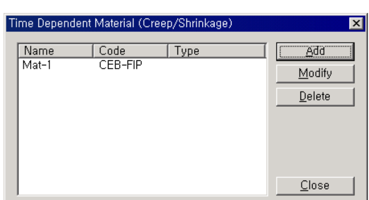
Relative humidity of ambient environment (40 ~ 99) **(70)**

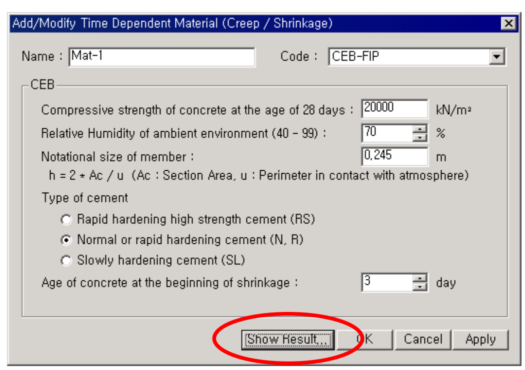
Notational size of member **(0.245)**

Type of cement>**Normal or rapid hardening cement (N, R)**

Age of concrete at the beginning of shrinkage **(3)** ↵

Input the Notational size of member calculated for a slab section.





Clicking on the Show Result... button will display creep and shrinkage function in a graph.

Figure 9. Define Time Dependent Material properties (Creep & Shrinkage) of concrete

Placed concrete is hardened and gains strength with age. To consider this, a function of compressive strength of concrete is given here by the CEB-FIP Code. The data entered in the ***Time Dependent Material (Creep / Shrinkage)*** dialog box is adopted in the ***Time Dependent Material (Comp. Strength)*** dialog box.

Model / Property / ***Time Dependent Material (Comp. Strength)***
Name **(Mat-1)** ; Type>**Code**
Development of Strength>Code>**CEB-FIP**
Concrete Compressive Strength at 28 Days (S28) **(20000)**
Cement Type(a)>**N, R : 0.25** ; Redraw Graph ↵

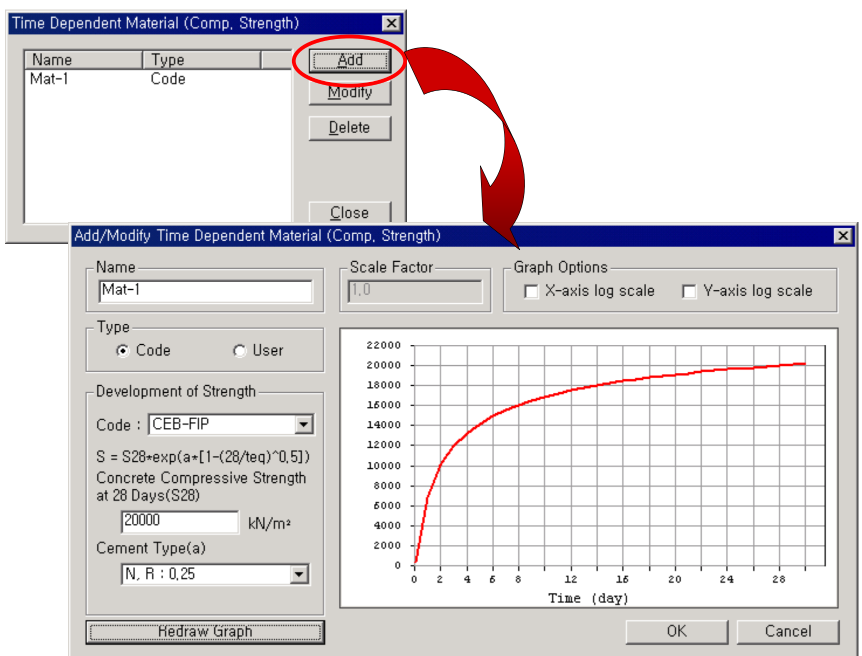


Figure 10. Define a function of time variant Compressive Strength of concrete

In MIDAS/Civil, time dependent material is defined separately from the conventional material, and time dependent material properties can be assigned to a conventional material selected.

In this tutorial, time dependent material properties will be assigned to the concrete slab (Grade C6000).

Model / Property / ***Time Dependent Material Link***
Time Dependent Material Type>Creep/Shrinkage>**Mat-1**
Comp. Strength>**Mat-1**
Select Material for Assign>Materials>
3:Grade C6000 [>] Selected Materials ; Operation>[Add / Modify]

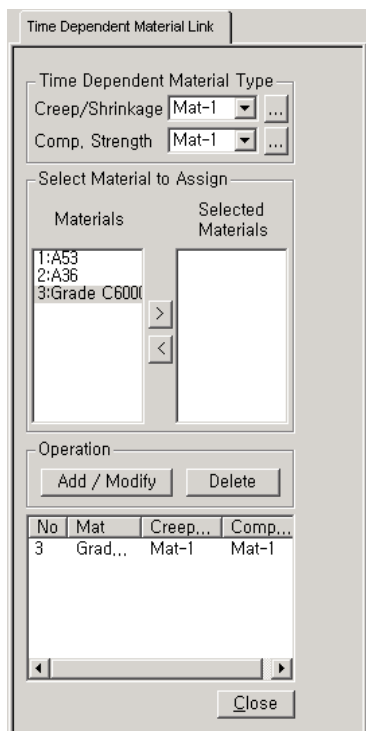


Figure 11. Assign Time Dependent Material properties to a conventional material

Construct a Bridge Model

After defining the groups required for composing construction stages, construct a bridge model for each construction stage. This tutorial explains a technique for assigning construction stages when using Composite Section.

Define Groups

See the table below to define the groups (Structure Groups, Boundary Groups and Load Groups) required for composing construction stages.

Const. Stage	**Structure Group**	**Boundary Group**	**Load Group (Activation)**		**Duration**	**Remark**
			Group	**Step**		
CS1	SGroup	BGroup	DL (BC) 1 DL (BC) 2	First step First step	5	Non-composite section
CS2	-	E_Width1	DL (BC) 3	25 days (User step)	30	Composite action in CS2 section
CS3	-	E_Width2	DL (BC) 4	25 days (User step)	30	Composite action in CS3 section
CS4	-	E_Width3	DL (AC)	First step	10,000	Composite action in CS4 section

Group tab

C Group>**Structure Group** **New…**

Name **(SGroup)** Add

C Group>**Boundary Group** **New…**

Name **(BGroup)** Add

Name **(E_Width)** ; Suffix **(1to3)** Add

C Group>**Load Group** **New…**

Name **(DL(BC))** ; Suffix **(1to4)** Add

Name **(DL(AC))** ; Suffix **( )** Add

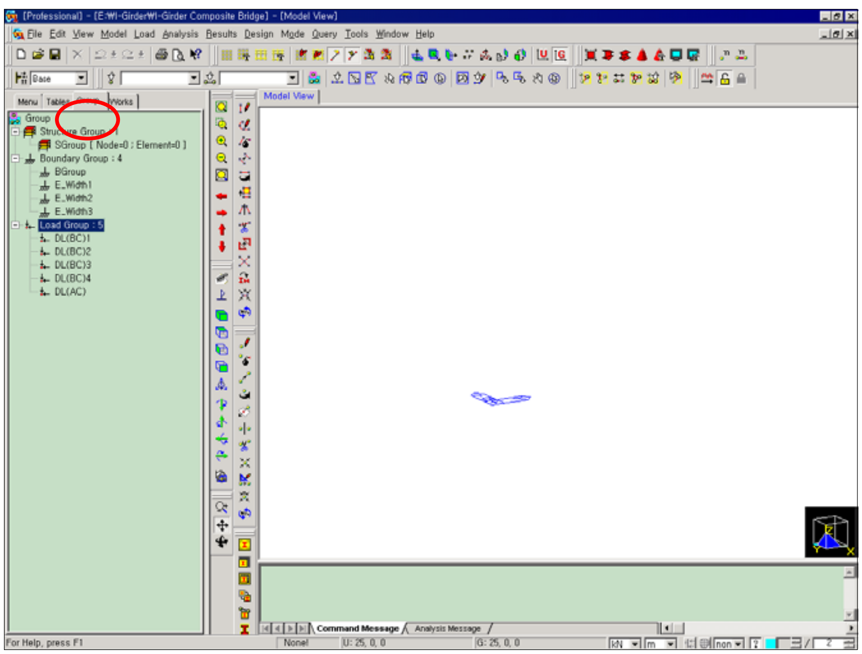


Figure 12. Define groups

Construct a Bridge Model

Generate Girders

Refer to Figure 13 to generate girders.

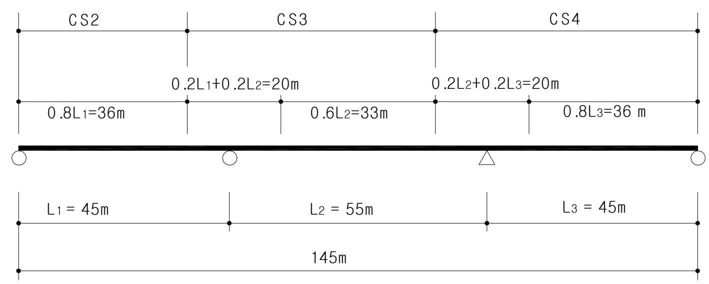


Figure 13. Construction sequence for deck and each part of the deck section

In this tutorial, cross beams are to be placed at a spacing of 5m and slab concrete is to be poured in accordance with the sequence as depicted in Figure 13. To consider the effective width of girders, girder elements will be generated to have the following lengths.

CS2 Section:	7@5 + 1	=	36m	(Use Sect 1)
CS3 Section:	4 + 3@5 +1 + 3 + 6@5	=	53m	(Use Sect 2)
CS4 Section:	1 + 3@5 + 4 + 1 + 7@5	=	56m	(Use Sect 3)

Top View , ***Node Snap*** (on), ***Element Snap*** (on), ***Auto Fitting*** (on)
Model / Nodes / ***Create Nodes***

Coordinates **(0, 0, 0)**

Copy>Number of Times **(1)** ; Distance **(0, 6.15, 0)** ↵

Model / Elements / ***Extrude Elements***

Select All

Extrude Type>**Node→Line Element**

Element Attribute>Element Type>**Beam**

Material>**1:A53** ; Section>**1 : Sect 1**

Generation Type>**Translate**

Translation>**Unequal Distance**

Axis>**x** ; Distance **(7@5,1,4,3@5,1,4,5@5,4,1,3@5,4,1,7@5)** ↵

Close

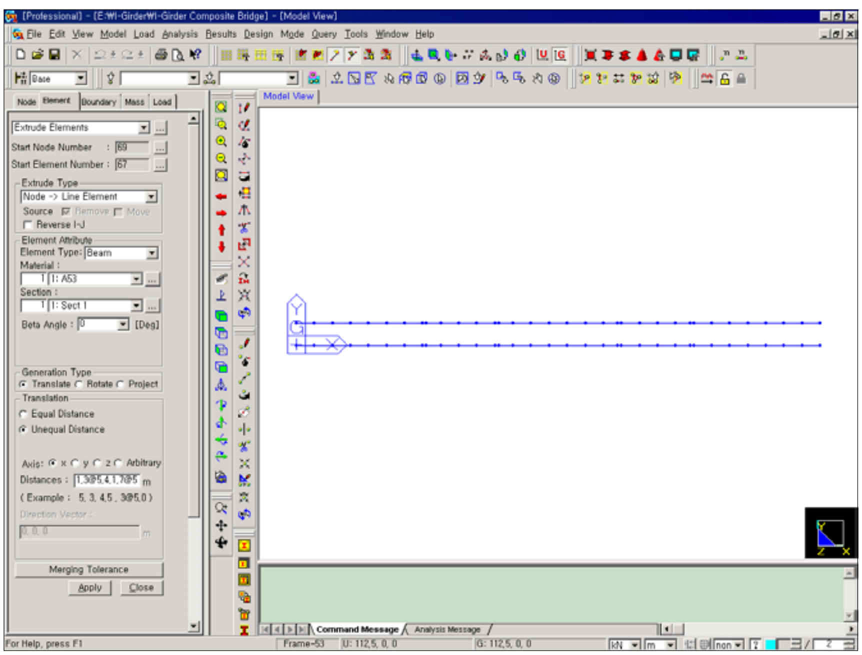


Figure 14. Generate girders

To assign the girder elements of CS3 to Sect 2, and the girder elements of CS4 to Sect 3, use the ***Drag & Drop*** feature.

Works tab

Select Window (Elements: **all girders in CS3 section;** that is, **17to40**)
Properties>Section>**Sect 2** (***Drag & Drop***)

Select Window (Elements: **all girders in CS4 section**; that is, **41to66**)
Properties>Section>**Sect 3** (***Drag & Drop***)

The distance between the nodes consecutively queried can be easily checked with Query Nodes (Figure 15 ①).

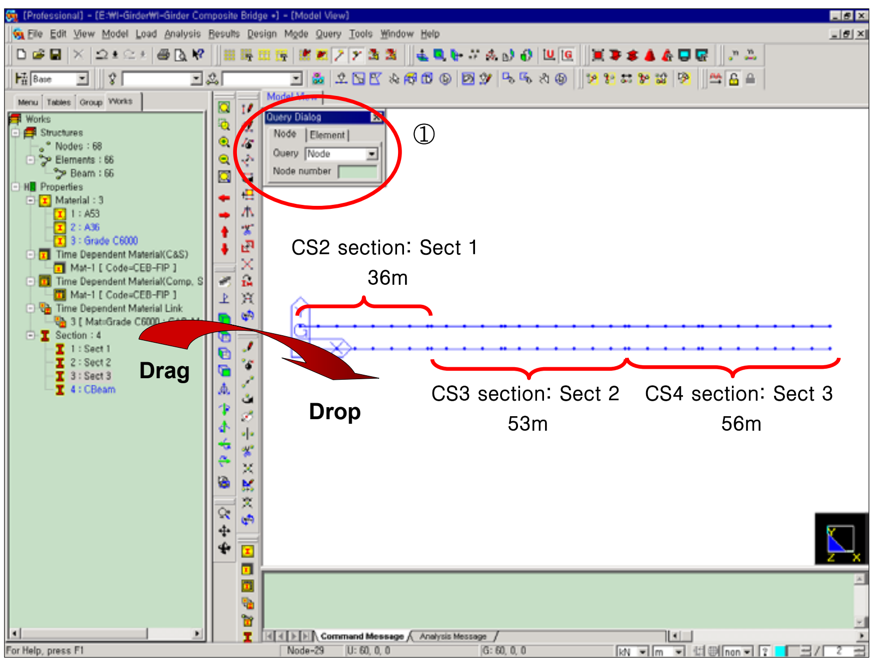


Figure 15. Different Section Names assigned to each part of the section

Generate Cross Beams

Generate cross beams as below.

Node Number (on)

Model / Elements / ***Create Elements***

Element Type>**General beam/Tapered beam**

Material>**2:A36** ; Section>**4:CBeam ;** Beta Angle **(0)**

Nodal Connectivity **(1, 2)**

Model / Elements / ***Translate Elements***

Select Recent Entities

Mode>**Copy** ; Translation>**Equal Distance**

dx, dy, dz **(5, 0, 0)** ; Number of Times **(145/5)** ↵

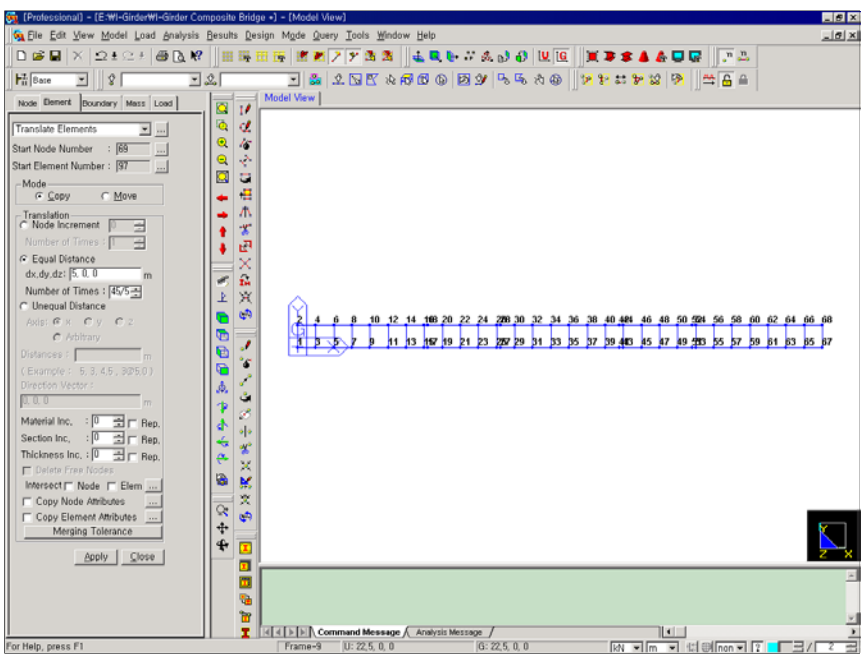


Figure 16. Generate cross beams

Input Boundary Conditions

Input Support Conditions

Since all boundary conditions of the structure are simultaneously activated at CS1, designate BGroup as a boundary group in which all boundary conditions of the bridge will be included.

Model / Boundary / ***Supports***

Boundary Group Name>**BGroup**

Select Single (Node: **21**)

Options>**Add** ; Support Types>**D-ALL** (on)

Select Single (Nodes: **1, 47, 67**)

Options>**Add** ; Support Types>**Dy, Dz** (on)

Select Single (Nodes: **2, 48, 68**)

Options>**Add** ; Support Types>**Dz** (on)

Select Single (Nodes: **22**)

Options>**Add** ; Support Types>**Dx, Dz** (on) ↵

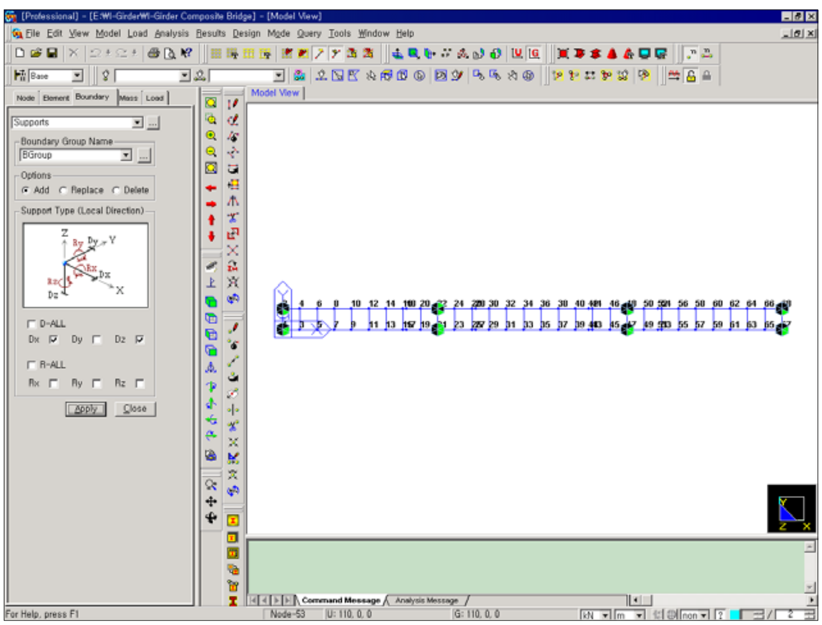


Figure 17. Enter boundary conditions

Input Effective Width

Enter the Scale Factors to be applied to the moment of inertia of girder sections to account for effective width. In MIDAS/Civil, the specified ***Effective Width Scale Factor*** will be used for calculating member stresses.

If you want to calculate stresses in a section to account for effective flange width, use the ***Effective Width Scale Factor*** command with the ratio of **Iyy of the effective section** to **Iyy of the gross section,** entered in the **Scale Factor for Iy** field.

Classification	**Effective width**	**Moment of inertia Iyy**		**Scale Factor for Iy, Iyy_2/Iyy_1**
		Iyy_1 (Full width)	**Iyy_2 (Effective width)**	
At the middle of the side span	5.653	0.4696905	0.4628585	0.985
At support	5.117	0.4696905	0.4530761	0.965
At the middle of the center span	5.839	0.4696905	0.4659784	0.992

Display
Boundary>**All** ; **Support** (on) ↵

Node Number (off), ***Element Number*** (on)

Model / Boundary / ***Effective Width Scale Factor***
Boundary Group Name>**E_Width1**
Select Single (Elements: **1~16**)
Scale Factor Iy **(0.985)** ↵

Boundary Group Name>**E_Width2**
Select Single (Elements: **17~26**)
Scale Factor Iy **(0.965)** ↵

Select Single (Elements: **27~40**)
Scale Factor Iy **(0.992)** ↵

Boundary Group Name>**E_Width3**

Select Single (Elements: **41~50**)

Scale Factor Iy **(0.965)** ↵

Select Single (Elements: **51~66**)

Scale Factor Iy **(0.985)** ↵

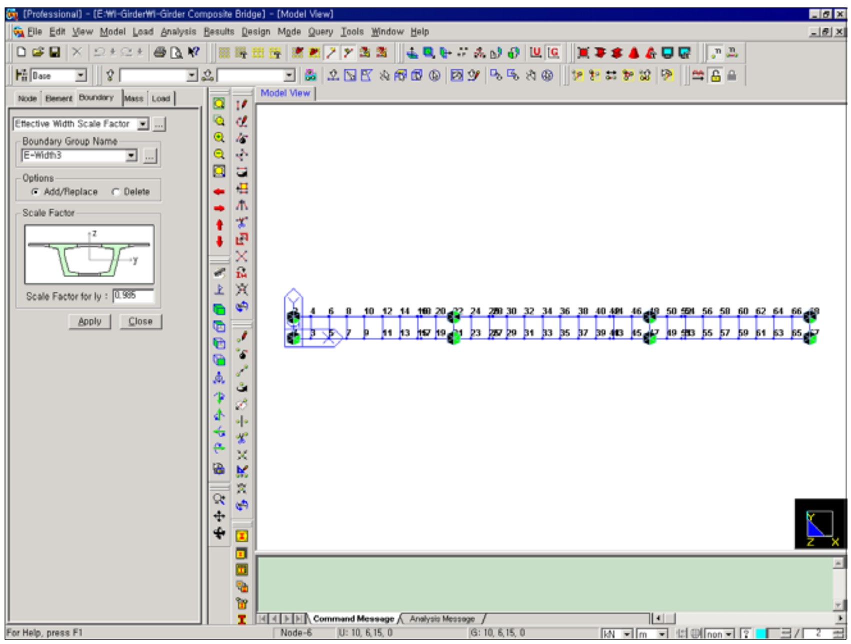


Figure 18. Enter a Scale Factor to be applied to the moment of inertia of a section to account for effective width

Input Loading Data

For this tutorial apply the pre- and post-composite loads by ***Element Beam Loads***. Refer to the table below to apply the loads to each construction stage.

Classification	Right girder		Left girder	
	Vertical load (FZ)	Torsional moment	Vertical load (FZ)	Torsional moment
Pre-composite load, DL (BC)	-38.96	-1.49	-38.96	1.49
Post-composite load, DL (AC)	-18.69	19.69	-18.69	-19.69

To define the loads to be applied to each construction stage, select Construction Stage Load for the Load Type.

First you must define Static Load Cases.

Load / ***Static Load Cases***

Name **(DL(BC)1)** ; Type>**Construction Stage Load (CS)** Add
Name **(DL(BC)2)** ; Type>**Construction Stage Load (CS)** Add
Name **(DL(BC)3)** ; Type>**Construction Stage Load (CS)** Add
Name **(DL(BC)4)** ; Type>**Construction Stage Load (CS)** Add
Name **(DL(AC))** ; Type>**Construction Stage Load (CS)** Add

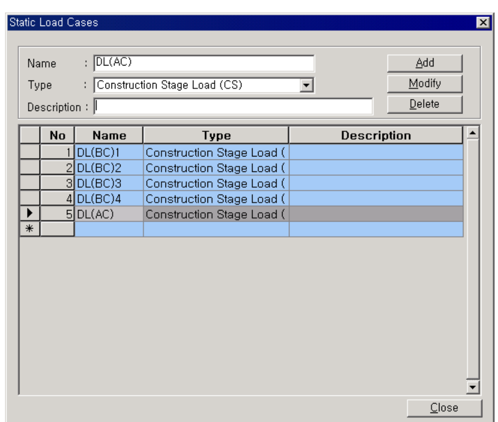


Figure 19. Define Static Load Cases

Assign Dead Loads for the Pre-Composite Section

Use the ***Element Beam Loads*** command to apply a uniform load to the beam elements.

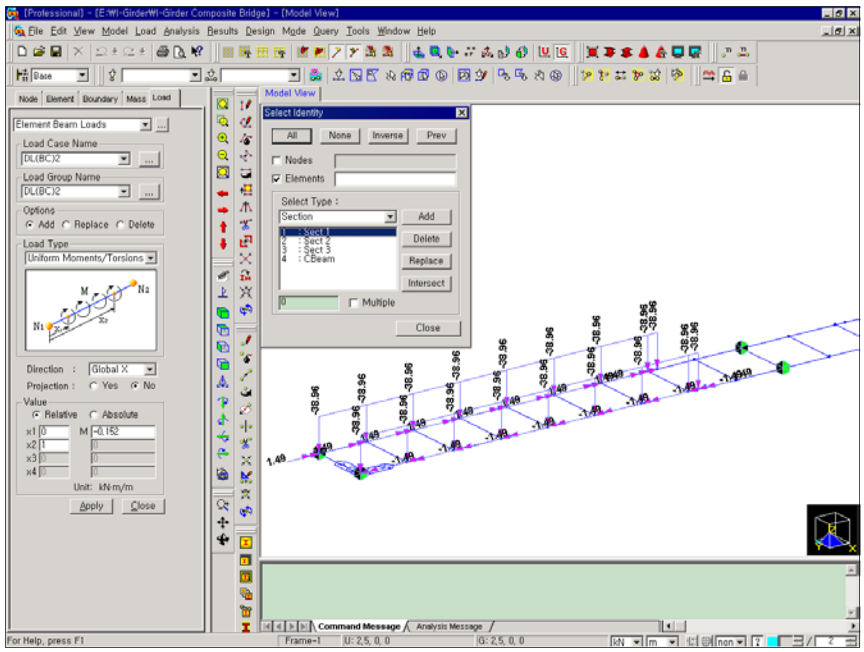


Figure 20. Apply pre-composite loads to the slab of the CS2 section

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Iso View, ***Element Number*** (off)

Load / ***Self Weight***

Load Case Name> **DL(BC)1** ; Load Group Name>**DL(BC)1**

Self Weight Factor>Z **(-1)** ; Operation>**Add**

Load / ***Element Beam Loads***

Select Identity-Elements

Select Type>**Section** ; **1:Sect 1** Add

Load Case Name> **DL(BC)2** ; Load Group Name>**DL(BC)2**

Load Type>**Uniform Loads**

Direction>**Global Z** ;   Projection>**No**   ;   Value>**Relative**
x1 **(0)**   ;   x2 **(1)**   ;   w **(-38.96)**   ↵

Select Polygon

(Elements: **2to16by2, 1st part of the composite section on the left girder**)
Load Type>**Uniform Moments/Torsions**
Direction>**Global X** ;   Projection>**No**   ;   Value>**Relative**
x1 **(0)**   ;   x2 **(1)**   ;   w **(1.49)**   ↵

Select Polygon

(Elements: **1to15by2, 1st part of the composite section on the right girder**)
x1 **(0)**   ;   x2 **(1)**   ;   w **(-1.49)**   ↵

Similarly, apply pre-composite load DL (BC) 3 to CS3 section and pre-composite load DL (BC) 4 to CS4 section.

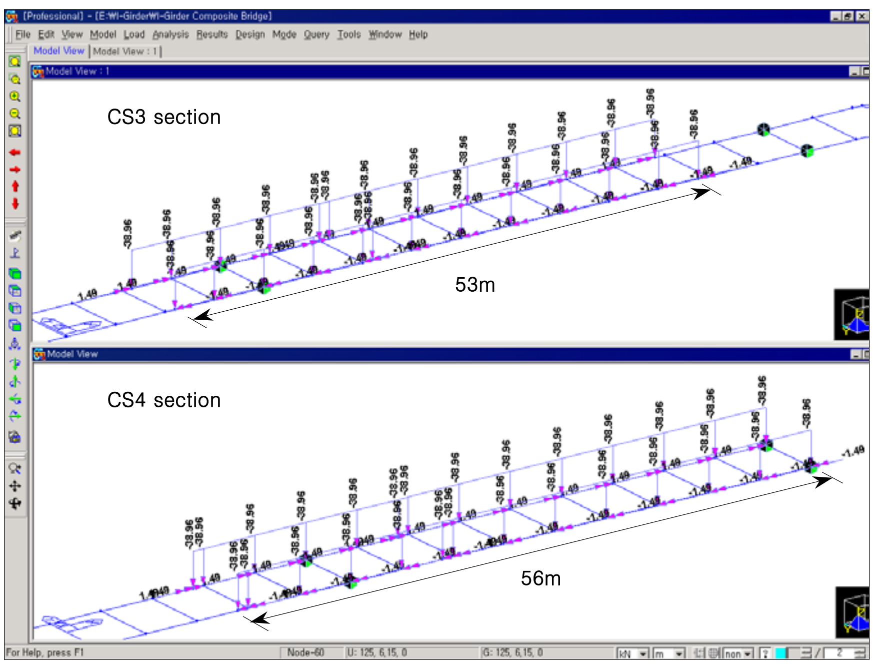


Figure 21. Slab loads of CS3 and CS4 sections

Assign Dead Loads for the Post-Composite Section

Use the ***Element Beam Loads*** command to apply a uniform load to the beam elements.

Load / ***Element Beam Loads***

Select Identity-Elements

Select Type>**Section** ; **1:Sect 1, 1:Sect 2, 1:Sect 3** Add

Load Case Name> **DL(AC)** ; Load Group Name>**DL(AC)**

Load Type>**Uniform Loads**

Direction>**Global Z** ; Projection>**No** ; Value>**Relative**

x1 **(0)** ; x2 **(1)** ; w **(-18.69)** ↵

Select Polygon (Elements: **2to62by2, left girders**)

Load Type>**Uniform Moments/Torsions**

Direction>**Global X** ; Projection>**No** ; Value>**Relative**

x1 **(0)** ; x2 **(1)** ; w **(-19.69)** ↵

Select Polygon (Elements: **1to61by2, right girders**)

x1 **(0)** ; x2 **(1)** ; w **(19.69)** ↵

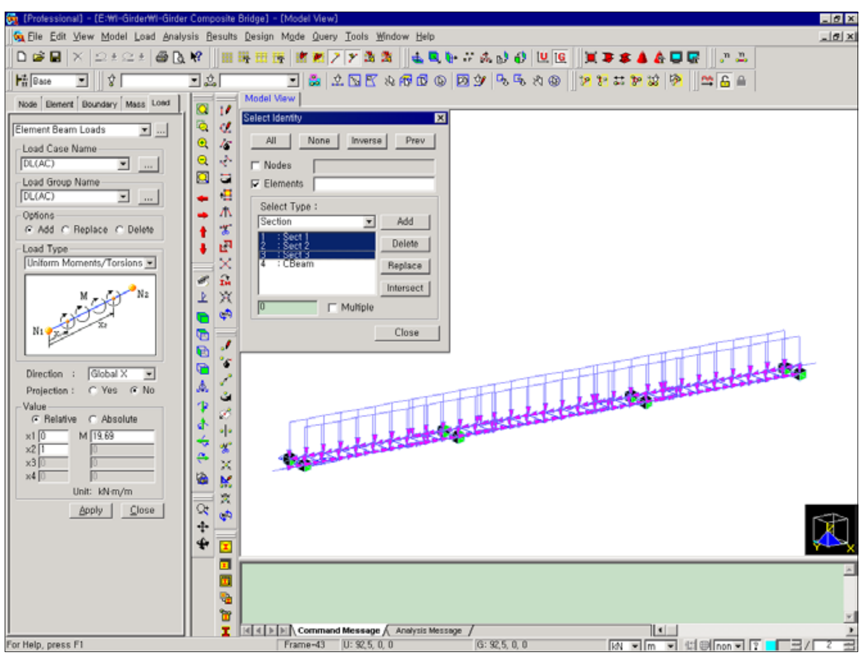


Figure 22. Enter additional dead loads

Define Construction Stages

Define an Element Group

Assign the desired nodes and elements to the Element Group, which will be dedicated to Construction Stages analysis later.

Group tab

Select All

Group>Structure Group>**SGroup** (***Drag & Drop***)

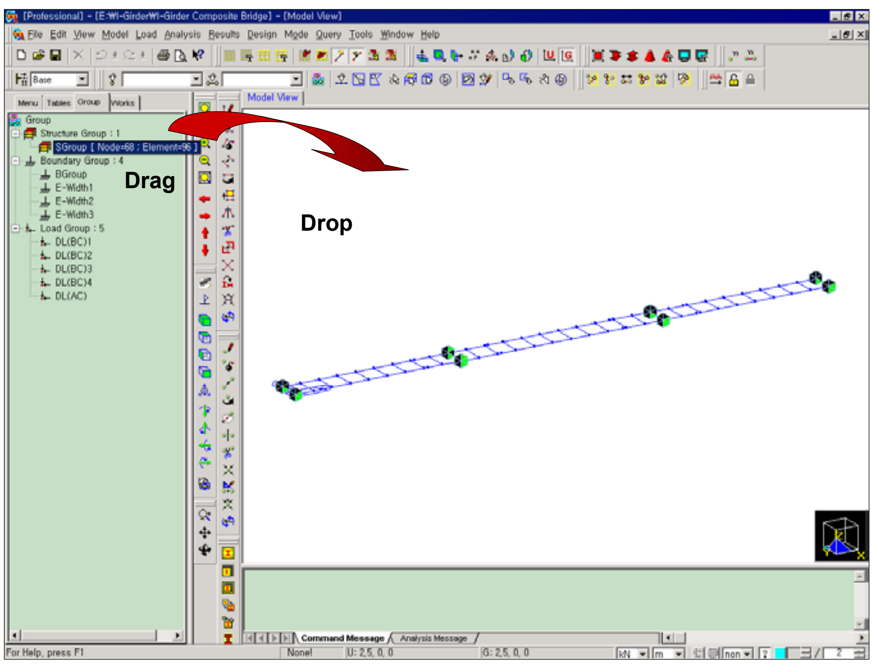


Figure 23. Assign the desired elements to the Structure Group

Compose Construction Stages

Refer to the following table to define each construction stage.

Const. Stage	**Element Group**	**Boundary Group**	**Load Group (Activation)**		**Duration**	**Remark**
			Group	**Step**		
CS1	SGroup	BGroup	DL (BC) 1 DL (BC) 2	First step First step	5	Non-composite section
CS2	-	E_Width1	DL (BC) 3	25 days (User step)	30	Composite action in CS2 section
CS3	-	E_Width2	DL (BC) 4	25 days (User step)	30	Composite action in CS3 section
CS4	-	E_Width3	DL (AC)	First step	10,000	Composite action in CS4 section

Click the **Generate** button to generate every construction stage at once, and then modify the data for the stage selected.

Load>Construction Stage Analysis Data> ***Define Construction Stage***
Generate
Stage>Name **(CS)** ; Suffix **(1to4)** ; Duration **(30)**
Addition Steps>Day **(25)** Add
Save Result>**Stage** (on), **Additional Steps** (on) ↵

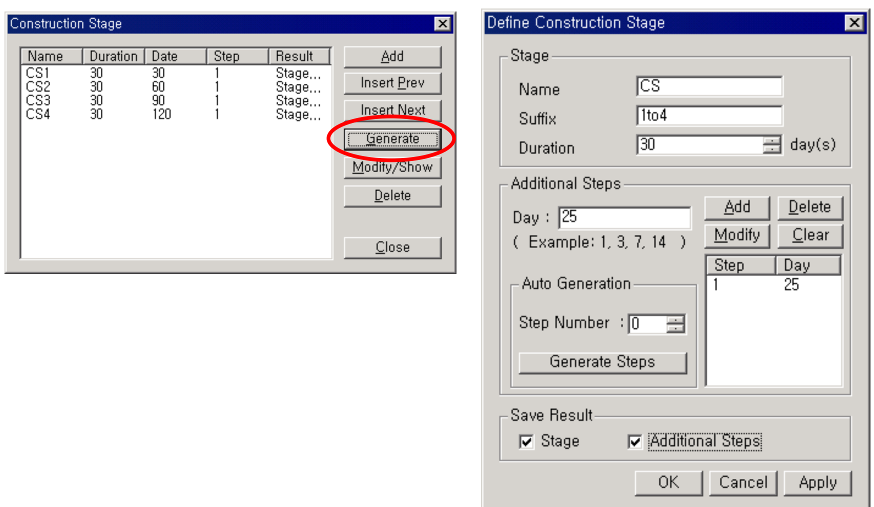


Figure 24. Generate construction stages by the Generate command

Click the **Generate** button to generate every construction stage at once, and then modify the data for the stage selected. Select CS1 and modify the data for the stage.

Name>**CS1** Modify/Show

Addition Steps>Day **(25)** Delete ; Duration **(5)**

Element tab

Group List>**SGroup**

Activation>Age **(0)** ; **Group List** Add

Boundary tab

Group List>**BGroup**

Activation>Support/Spring Position>**Deformed**

Group List Add

Load tab

Group List>**DL(BC)1, DL(BC)2**

Activation>Active Day>**First** ; **Group List** Add ↵

When "First" day is selected in the Active Day selection list, the selected load groups will be activated from the first day of the time span for each construction stage (Duration).

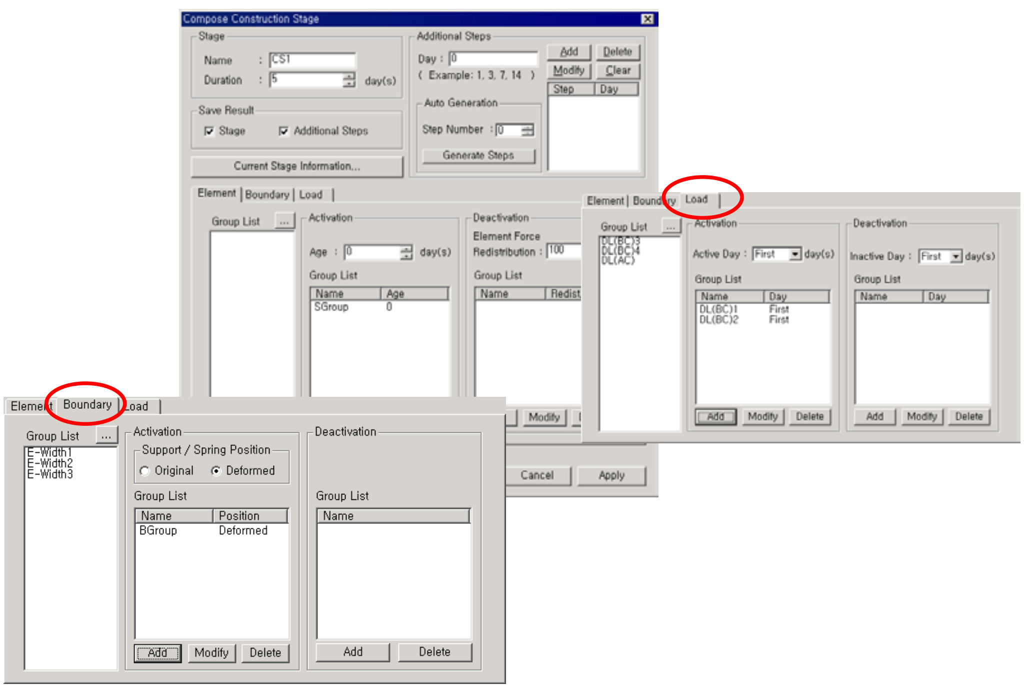


Figure 25. Modify the data for the stage

Select CS2 and modify the data for the stage.

Name>**CS2** Modify/Show

Boundary tab

Group List>**E_Width1**

Activation>Support/Spring Position>**Deformed**

Group List Add

Load tab

Group List>**DL(BC)3**

Activation>Active Day>**25** ; **Group List** Add ↵

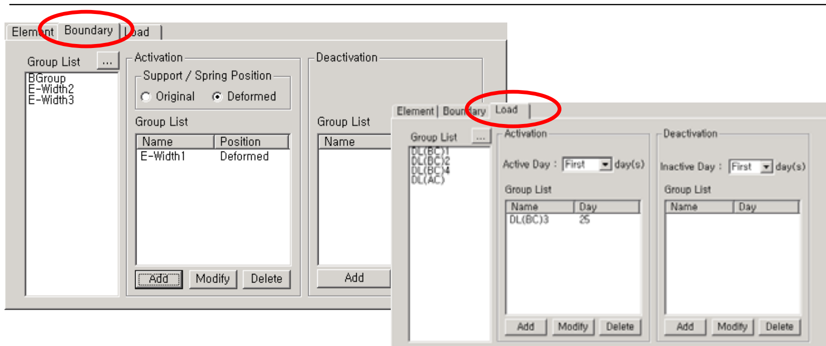


Figure 26. Modify the data for the stage CS2

Refer to the Figure 27 to modify the data for the stage CS3.

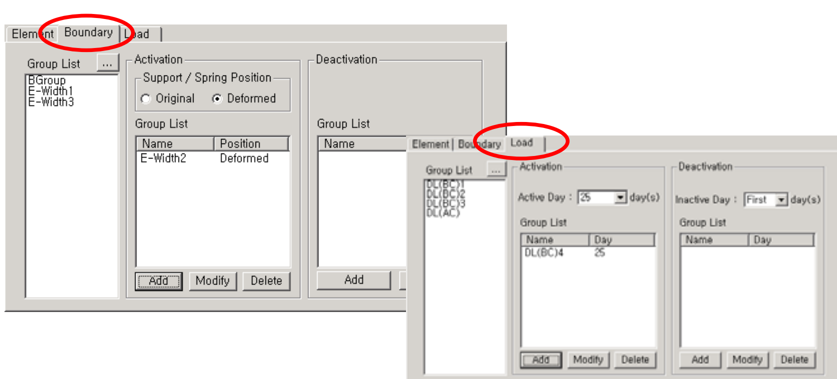


Figure 27. Modify the data for the stage CS3

In the CS4 stage, enter “10,000” days into the **Duration** field so that the long-term behavior of the structure can be observed, and change the data of load groups to activate the additional dead load.

Name > **CS4** [Modify/Show]

Addition Steps > Day **(25)** [Delete] ; Duration **(10000)**

Boundary tab

Group List > **E_Width3**

Activation > Support/Spring Position > **Deformed**

Group List [Add]

Load tab

Group List > **DL(AC)**

Activation > Active Day > **First** ; **Group List** [Add] ↵

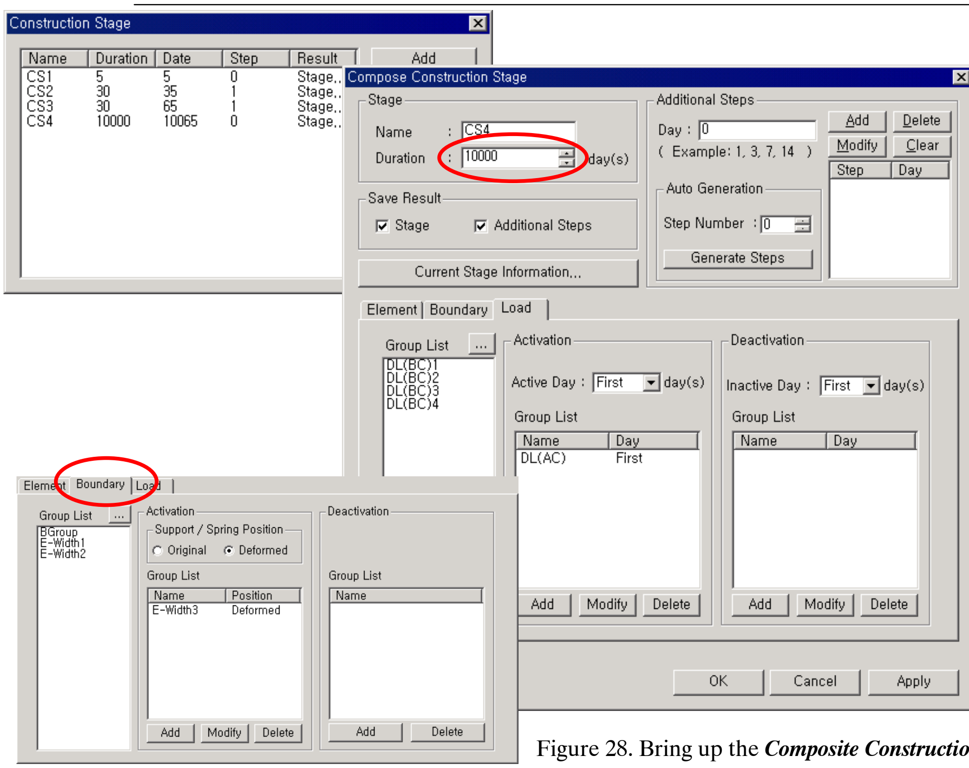


Figure 28. Bring up the ***Composite Construction Stage*** dialog box and modify the data for the construction stage CS4

Define the Composite Sections Corresponding to Each Construction Stage

Specify the construction stage at which the girder or slab sections become activated. When the **Section Type** is set to “Composite”, the previously defined section properties can be used. Refer to Figure 29 to specify the **Active Stage** at which the girder or slab sections become activated. For this example model assume that every girder is activated at CS1.

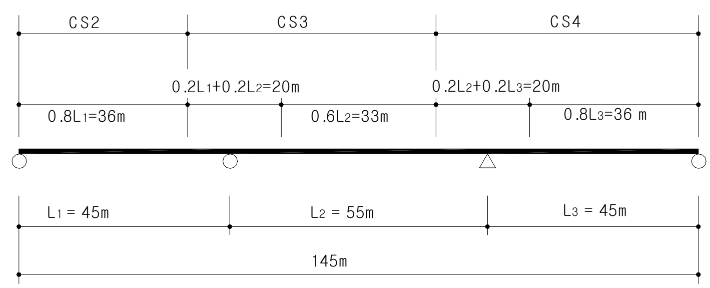


Figure 29. Construction sequence for deck and each part of the deck section

Firstly assign the first part of the slab section (i.e., CS2).

By default, **Composite Type** is set to “Normal”. Note that Part 1 and Part 2 only are available for entering construction stage. When “User” is selected from the **Composite Type** drop-down list, you can assign as many Parts as you desire, where you must use the outer dimensions or centroid pertaining to the post-composite section.

Load>Construction Stage Analysis Data>

Composite Section for Construction Stage Add

Active Stage>**CS1** ; Section>**1: Sect 1**

Composite Type>**Normal**

Construction Sequence

Part>1

Mat.Type>**Element** ; Compo. Stage>**Active Stage** ; Age **(0)**

Part>2

Mat.Type>**Material** ; Material>**3:Grade C6000** ; Compo. Stage>**CS2** ;

Age **(5)** ; Scale> Weight> **0** ↵

The girders (Part 1) will be activated in the Active Stage, that is, CS1 and slab (Part 2) activated in CS2.

An initial age input in the Composite Section for Construction Stage dialog box will have priority to the age input in the Define Construction Stage dialog box.

Input "0" in the Weight field so as not to include the self-weight of concrete in the automatic calculation of self-weight by the Self Weight command. Element Beam Loads will be used to input the self-weight of the composite concrete section.

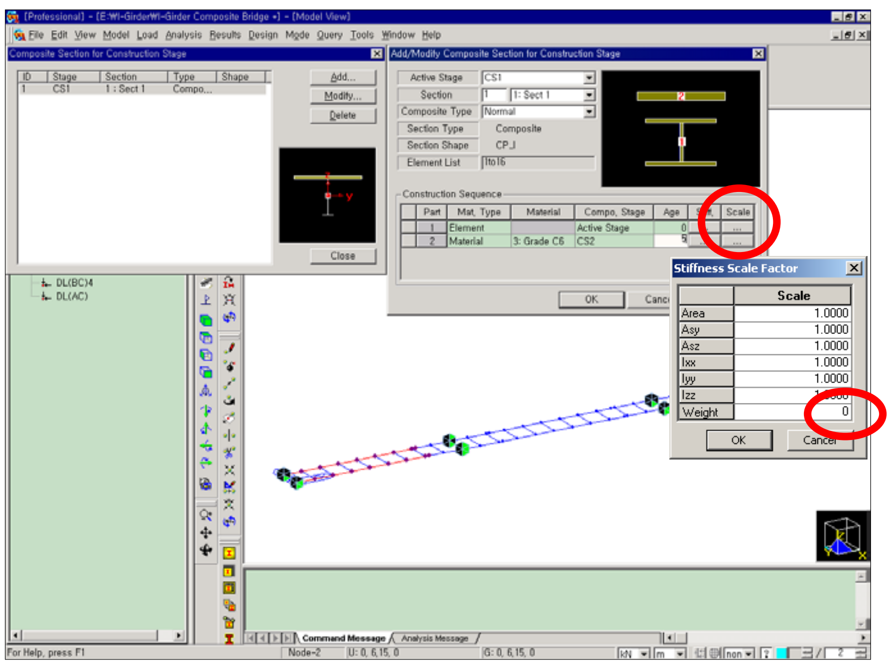


Figure 30. Define a composite section for construction stage CS1

Now assign the second and third part of the slab section.

Active Stage>**CS1** ; Section>**2: Sect 2**
Composite Type>**Normal**
Construction Sequence
Part>1
Mat.Type>**Element** ; Compo. Stage>**Active Stage** ; Age **(0)**
Part>2
Mat.Type>**Material** ; Material>**3:Grade C6000** ; Compo. Stage>**CS3** ;
Age **(5)** ; Scale> Weight> **0** ↵

Active Stage>**CS1** ; Section>**3: Sect 3**
Composite Type>**Normal**
Construction Sequence
Part>1
Mat.Type>**Element** ; Compo. Stage>**Active Stage** ; Age **(0)**
Part>2
Mat.Type>**Material** ; Material>**3:Grade C6000** ; Compo. Stage>**CS4** ;
Age **(5)** ; Scale> Weight> **0** ↵

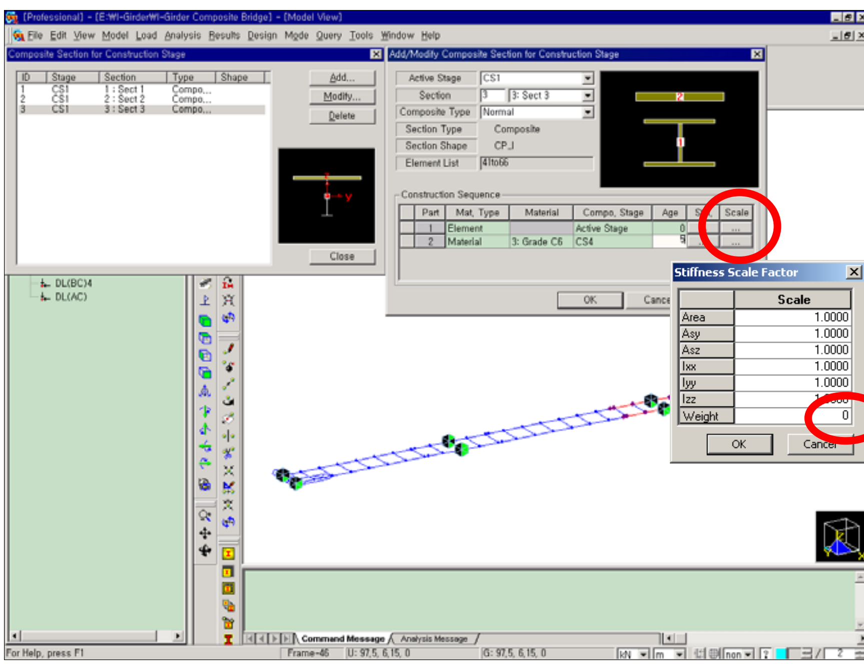


Figure 31. Define a composite section for construction stage CS3

Enter the conditions for a construction stage analysis.

Analysis>***Construction Stage Analysis Control***

Final Stage>**Last Stage**

Analysis Option>**Include Time Dependent Effect** (on)

Time Dependent Effect

Creep & Shrinkage (on) ; Type>**Creep & Shrinkage**

Convergence for Creep Iteration

Number of Iteration **(5)** ; Tolerance **(0.01)**

Internal Time Step for Creep **(1)**

Auto Time Step Generation for Large Time Gap (on)

Variation of Comp. Strength (on) ↵

Checking **Auto Time Step Generation for Large Time Gap** will create internal steps when the duration of the construction stage is too long, to consider the sustained loads.

Checking **Calculate Output of Each Part** will calculate the forces for each part of the composite section.

In a construction stage analysis, all the load cases except for tendon relaxation and time dependent loads are lumped into Dead (CS) and the results are produced under Dead (CS). With the **Load Cases to be distinguished from Dead Load for CS Output** checked, we can select Beam Loads or Nodal Loads as desired to be distinguished from the Dead (CS) and produce the results under Erection Load (CS).

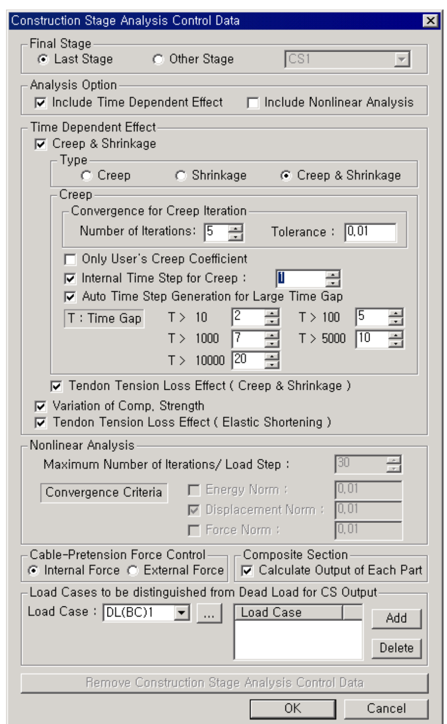


Figure 32. ***Construction Stage Analysis Control Data*** dialog box

Perform Structural Analysis

When the composite section model and construction stages are complete, the analysis will be performed.

Analysis>  ***Perform Analysis***

Review Analysis Results

There are two methods of reviewing analysis results from construction stage analysis. One is to review accumulated member forces and displacements of all the members at each specific construction stage, and the other is to review the changes of stresses in each part of the composite section due to preceding construction stages in a table format.

Review Member Forces

Review the member forces at the construction stage CS4, which represents the completion of long-term loss.

Where, Summation = Dead + Erection Load + Creep Secondary + Shrinkage Secondary.

Stage>**CS4**

Results / Forces / ***Beam Diagrams***

Load Cases/Combination>**CS:Summation** ; Step>**Last Step**

Components>**My**

Output Options>**5 Points** ; **Line Fill**

Type of Display>**Contour** (on) ↵

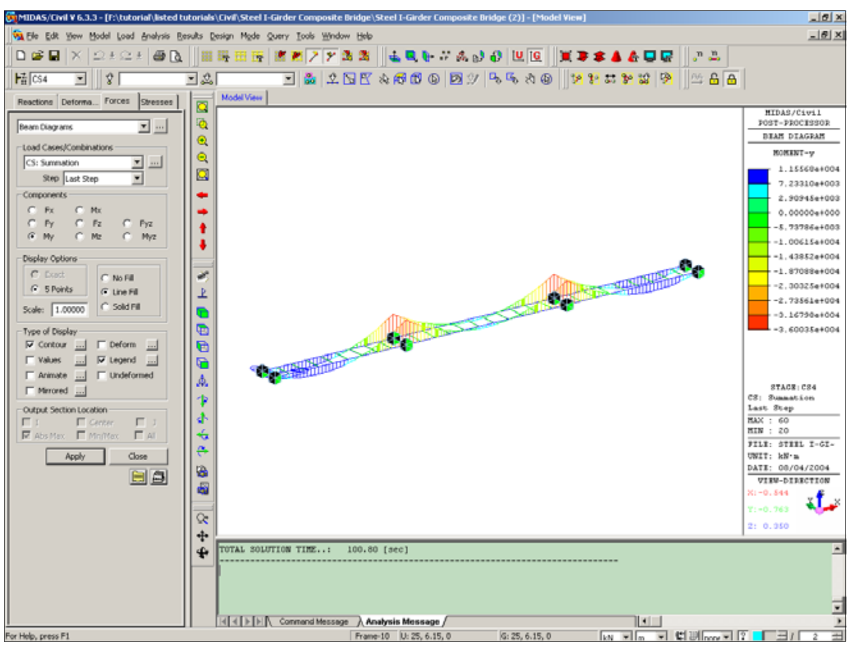


Figure 34. Moment diagram at CS4

As can be seen below, review the changes of moments stage by stage.

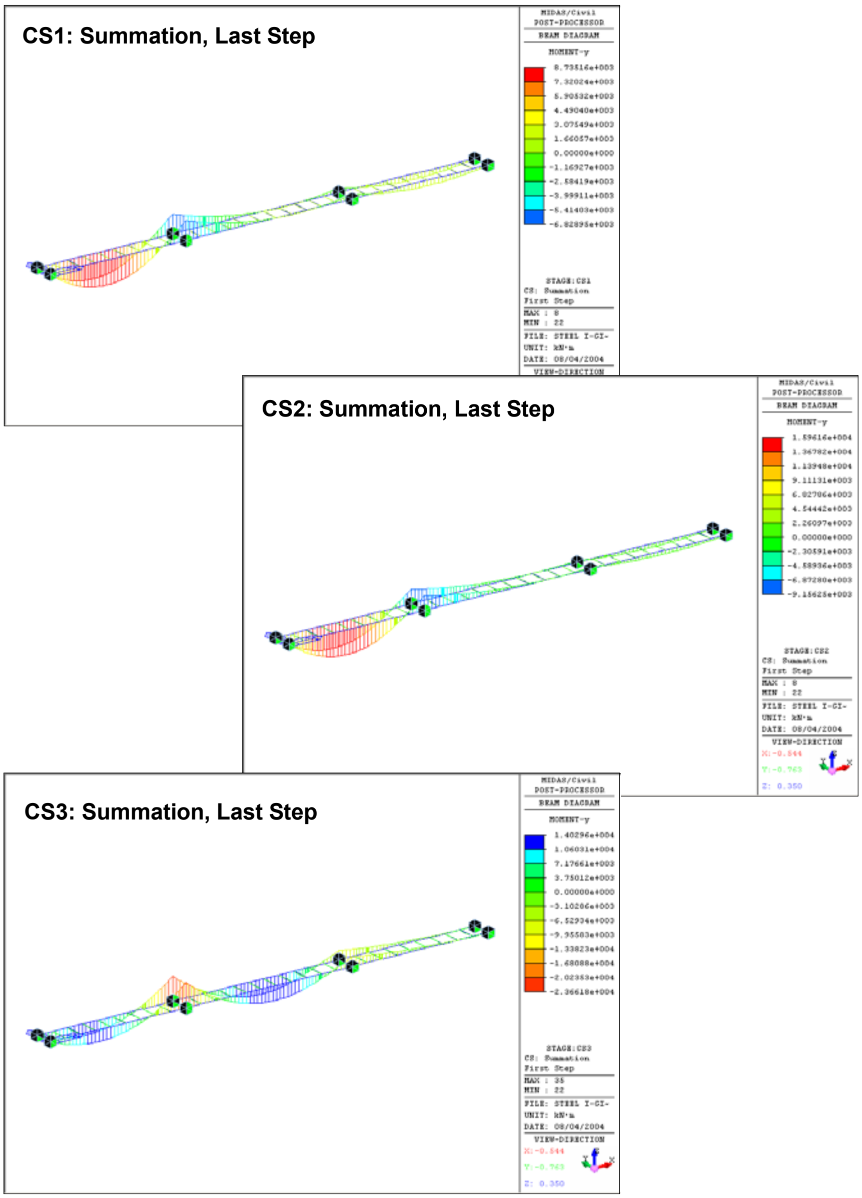


Figure 34. Moment diagram at CS4

Review Stresses

Review the stresses for each part of the composite section at the construction stage CS4, which represents the completion of long-term loss.

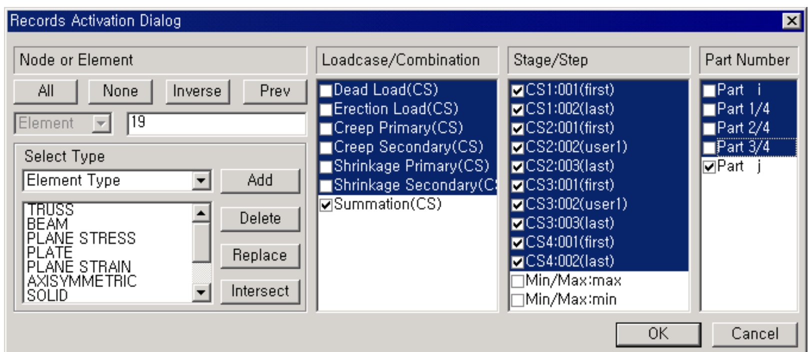
Results / Result Tables / Composite Section for C.S. / ***Beam Stress***

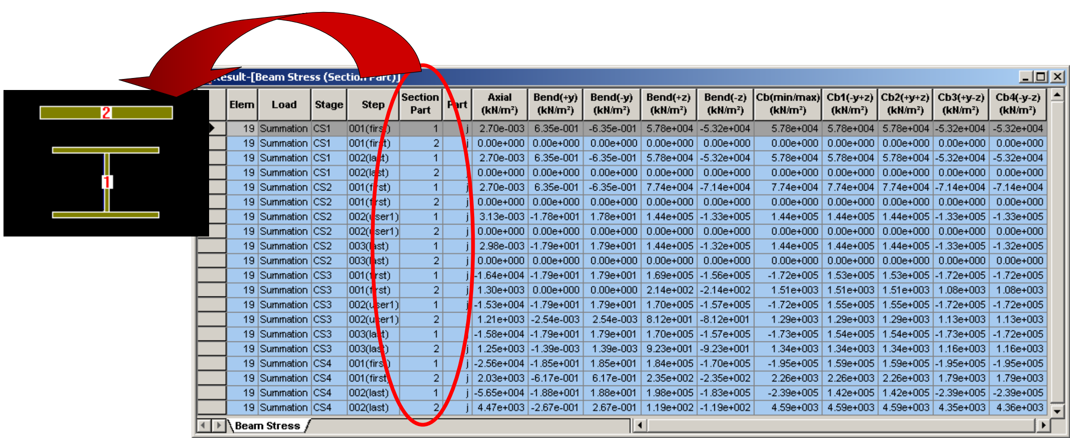
Node or Element> None ; **(19)**

Loadcase/Combination>**Summation(CS)** (on)

Stage/Step>**CS1:001(first) ~ CS4:002(last)** (on)

Part Number>**Part j** (on) ↵





Elem	Load	Stage	Step	Section Part	Part	Axial (kN/m²)	Bend(+y) (kN/m²)	Bend(-y) (kN/m²)	Bend(+z) (kN/m²)	Bend(-z) (kN/m²)	Cb(min/max) (kN/m²)	Cb1(-y+z) (kN/m²)	Cb2(+y+z) (kN/m²)	Cb3(+y-z) (kN/m²)	Cb4(-y-z) (kN/m²)
19	Summation	CS1	001(first)	1	j	2.70e-003	6.35e-001	-6.35e-001	5.78e+004	-5.32e+004	5.78e+004	5.78e+004	5.78e+004	-5.32e+004	-5.32e+004
19	Summation	CS1	001(first)	2	j	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000
19	Summation	CS1	002(last)	1	j	2.70e-003	6.35e-001	-6.35e-001	5.78e+004	-5.32e+004	5.78e+004	5.78e+004	5.78e+004	-5.32e+004	-5.32e+004
19	Summation	CS1	002(last)	2	j	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000
19	Summation	CS2	001(first)	1	j	2.70e-003	6.35e-001	-6.35e-001	7.74e+004	-7.14e+004	7.74e+004	7.74e+004	7.74e+004	-7.14e+004	-7.14e+004
19	Summation	CS2	001(first)	2	j	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000
19	Summation	CS2	002(user1)	1	j	3.13e-003	-1.78e+001	1.78e+001	1.44e+005	-1.33e+005	1.44e+005	1.44e+005	1.44e+005	-1.33e+005	-1.33e+005
19	Summation	CS2	002(user1)	2	j	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000
19	Summation	CS2	003(last)	1	j	2.98e-003	-1.79e+001	1.79e+001	1.44e+005	-1.32e+005	1.44e+005	1.44e+005	1.44e+005	-1.33e+005	-1.32e+005
19	Summation	CS2	003(last)	2	j	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000
19	Summation	CS3	001(first)	1	j	-1.64e+004	-1.79e+001	1.79e+001	1.69e+005	-1.56e+005	-1.72e+005	1.53e+005	1.53e+005	-1.72e+005	-1.72e+005
19	Summation	CS3	001(first)	2	j	1.30e+003	0.00e+000	0.00e+000	2.14e+002	-2.14e+002	1.51e+003	1.51e+003	1.51e+003	1.08e+003	1.08e+003
19	Summation	CS3	002(user1)	1	j	-1.53e+004	-1.79e+001	1.79e+001	1.70e+005	-1.57e+005	-1.72e+005	1.55e+005	1.55e+005	-1.72e+005	-1.72e+005
19	Summation	CS3	002(user1)	2	j	1.21e+003	-2.54e-003	2.54e-003	8.12e+001	-8.12e+001	1.29e+003	1.29e+003	1.29e+003	1.13e+003	1.13e+003
19	Summation	CS3	003(last)	1	j	-1.58e+004	-1.79e+001	1.79e+001	1.70e+005	-1.57e+005	-1.73e+005	1.54e+005	1.54e+005	-1.73e+005	-1.72e+005
19	Summation	CS3	003(last)	2	j	1.25e+003	-1.39e-003	1.39e-003	9.23e+001	-9.23e+001	1.34e+003	1.34e+003	1.34e+003	1.16e+003	1.16e+003
19	Summation	CS4	001(first)	1	j	-2.56e+004	-1.85e+001	1.85e+001	1.84e+005	-1.70e+005	-1.95e+005	1.59e+005	1.59e+005	-1.95e+005	-1.95e+005
19	Summation	CS4	001(first)	2	j	2.03e+003	-6.17e-001	6.17e-001	2.35e+002	-2.35e+002	2.26e+003	2.26e+003	2.26e+003	1.79e+003	1.79e+003
19	Summation	CS4	002(last)	1	j	-5.65e+004	-1.88e+001	1.88e+001	1.98e+005	-1.83e+005	-2.39e+005	1.42e+005	1.42e+005	-2.39e+005	-2.39e+005
19	Summation	CS4	002(last)	2	j	4.47e+003	-2.67e-001	2.67e-001	1.19e+002	-1.19e+002	4.59e+003	4.59e+003	4.59e+003	4.35e+003	4.36e+003

Figure 35. Check forces and stresses of the composite section at each construction stage in a table

When live loads and general loads are applied after construction stages are completed, the program creates a new load combination to combine those loads and construction stage loads and determines stresses for PostCS design (i.e., Post Construction Stage design).