Advanced Application 7

Construction Stage Analysis of a Bridge Using a Composite Section
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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](image)
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
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

<table>
<thead>
<tr>
<th>Member</th>
<th>Section</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girder</td>
<td>A53</td>
<td>Steel</td>
</tr>
<tr>
<td>Cross beam</td>
<td>A36</td>
<td>Steel</td>
</tr>
<tr>
<td>Slab</td>
<td>Grade C6000</td>
<td>Concrete (Use a function of compressive strength of concrete)</td>
</tr>
</tbody>
</table>

### 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

![Diagram](image)

*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.

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Load Group</th>
<th>Load Type</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL (BC) 1</td>
<td>DL (BC) 1</td>
<td>Self Weight</td>
<td>Self-weight of the girder</td>
</tr>
<tr>
<td>DL (BC) 2</td>
<td>DL (BC) 2</td>
<td>Beam Loads</td>
<td>Self-weight of the slab corresponding to 0.8 × L1 range</td>
</tr>
<tr>
<td>DL (BC) 3</td>
<td>DL (BC) 3</td>
<td>Beam Loads</td>
<td>Self-weight of the slab corresponding to 0.2 × L1 + 0.8 × L2 range</td>
</tr>
<tr>
<td>DL (BC) 4</td>
<td>DL (BC) 4</td>
<td>Beam Loads</td>
<td>Self-weight of the slab corresponding to 0.2 × L2 + L3 range</td>
</tr>
<tr>
<td>DL (AC)</td>
<td>DL (AC)</td>
<td>Beam Loads</td>
<td>Additional dead loads (pavement, handrail, barrier)</td>
</tr>
</tbody>
</table>
Define Boundary Groups

<table>
<thead>
<tr>
<th>Boundary Condition Group</th>
<th>Type of Boundary Conditions</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>BGroup</td>
<td>Supports</td>
<td>Support condition</td>
</tr>
<tr>
<td>E_Width1</td>
<td>Effective Width Scale Factor</td>
<td>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)</td>
</tr>
<tr>
<td>E_Width2</td>
<td>Effective Width Scale Factor</td>
<td>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)</td>
</tr>
<tr>
<td>E_Width3</td>
<td>Effective Width Scale Factor</td>
<td>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)</td>
</tr>
</tbody>
</table>

Define Construction Stages

<table>
<thead>
<tr>
<th>Const. Stage</th>
<th>Structure Group</th>
<th>Boundary Group</th>
<th>Load Group (Activation)</th>
<th>Duration</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS1</td>
<td>SGroup</td>
<td>BGroup</td>
<td>DL (BC) 1, DL (BC) 2</td>
<td>First step, First step</td>
<td>5</td>
</tr>
<tr>
<td>CS2</td>
<td>-</td>
<td>E_Width 1</td>
<td>DL (BC) 3</td>
<td>25 days (User step)</td>
<td>30</td>
</tr>
<tr>
<td>CS3</td>
<td>-</td>
<td>E_Width 2</td>
<td>DL (BC) 4</td>
<td>25 days (User step)</td>
<td>30</td>
</tr>
<tr>
<td>CS4</td>
<td>-</td>
<td>E_Width 3</td>
<td>DL (AC)</td>
<td>First step</td>
<td>10,000</td>
</tr>
</tbody>
</table>
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 (File / New Project) to begin a plate girder bridge model and save the file (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 > OK

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 / Properties / Add
Type>Steel ; Standard>ASTM(S)
   DB>A53>Apply ; DB>A36 > Apply
Type>Concrete ; Standard>ASTM(RC)
   DB>Grade C6000>OK

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**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Section</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girder</td>
<td>H 3200×800×900×20×32/34</td>
<td>Composite Section</td>
</tr>
<tr>
<td>Cross Beam</td>
<td>H 800×400×20×20/20</td>
<td>User type Section</td>
</tr>
</tbody>
</table>
Model / Properties / Section> Add
Composite tab
Section ID (1); Name (Sect 1); 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>
Concrete Material>DB>ASTM(RC); Name>Grade C6000, Ds/Dc=0
Steel Material>DB>ASTM(S); Name>A53; Offset>Center-Center > Apply
Section ID (2) ; Name (Sect 2)> Apply
Section ID (3) ; Name (Sect 3)> Apply

Figure 8. Section Data dialog box

Ds/Dc is the ratio of the unit wt. Steel and concrete. Its value is assigned zero because we treat slab wt. as beam load as opposed to self wt. calculated automatically by the program.

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) > OK
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/m²
- Relative humidity: 70%
- Notational size: \[ 2 \times \frac{Ac}{u} = \frac{(2 \times 12.14 \times 0.25)}{(12.14 + 0.25)} = 0.245 \]
- 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 / Properties / Time Dependent Material (Creep & Shrinkage)
Add> 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)
Show Results>Close>OK>Close

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.

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 / Properties / Time Dependent Material Link**
Time Dependent Material Type>Creep/Shrinkage>Mat-1
Comp. Strength>Mat-1
Select Material to Assign>Materials>
3:Grade C6000  X  Selected Materials; Operation> Add / Modify  >Close

---

*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.

<table>
<thead>
<tr>
<th>Const. Stage</th>
<th>Structure Group</th>
<th>Boundary Group</th>
<th>Load Group (Activation)</th>
<th>Duration</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS1</td>
<td>SGroup</td>
<td>BGroup</td>
<td>DL (BC) 1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DL (BC) 2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>First step</td>
<td>First step</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DL (BC) 3</td>
<td>25 days (User step)</td>
<td>Non-composite section</td>
</tr>
<tr>
<td>CS2</td>
<td>-</td>
<td>E_Width 1</td>
<td>DL (BC) 4</td>
<td>30</td>
<td>Composite action in CS3 section</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E_Width 2</td>
<td>DL (BC) 4</td>
<td>25 days (User step)</td>
<td>Composite action in CS3 section</td>
</tr>
<tr>
<td>CS4</td>
<td>-</td>
<td>E_Width 3</td>
<td>DL (AC)</td>
<td>10,000</td>
<td>Composite action in CS4 section</td>
</tr>
</tbody>
</table>
**Group tab (of left side Tree Menu)**

- **Group** > **Structure Group**
  - New…
  - Name (SGroup) **Add** > Close

- **Group** > **Boundary Group**
  - New…
  - Name (BGroup) **Add**
  - Name (E_Width); Suffix (1to3) **Add** > Close

- **Group** > **Load Group**
  - New…
  - Name (DL(BC)); Suffix (1to4) **Add**
  - Name (DL(AC)); **Add** > Close

---

**Figure 12. Define groups**
Construct a Bridge Model

Generate Girders

Refer to Figure 13 to generate girders.

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.

<table>
<thead>
<tr>
<th>Section</th>
<th>Length Calculation</th>
<th>Length</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS2</td>
<td>7@5 + 1</td>
<td>36m</td>
<td>(Use Sect 1)</td>
</tr>
<tr>
<td>CS3</td>
<td>4 + 3@5 + 1 + 3 + 6@5</td>
<td>53m</td>
<td>(Use Sect 2)</td>
</tr>
<tr>
<td>CS4</td>
<td>1 + 3@5 + 4 + 1 + 7@5</td>
<td>56m</td>
<td>(Use Sect 3)</td>
</tr>
</tbody>
</table>

*Figure 13. Construction sequence for deck and each part of the deck section*
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
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)>Apply

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
1. Select Window (Elements: all girders in CS3 section; that is, 17 to 40)
   Properties > Section > Sect 2 (Drag & Drop)
2. Select Window (Elements: all girders in CS4 section; that is, 41 to 66)
   Properties > Section > Sect 3 (Drag & Drop)

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) > Apply

- Model / Elements / Translate
- Select Recent Entities
- Mode > Copy; Translation > Equal Distance
dx, dy, dz ( 5, 0, 0 ) > Number of Times ( 145/5 ) > Apply

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.

```markdown
Model / Boundaries / Supports
Boundary Group Name > BGroup
Select Single (Node: 21)
Options> Add; Support Types> D-ALL (on) > Apply

Select Single (Nodes: 1, 47, 67)
Options > Add; Support Types > Dy, Dz (on) > Apply

Select Single (Nodes: 2, 48, 68)
Options> Add; Support Types > Dz (on) > Apply

Select Single (Nodes: 22)
Options > Add; Support Types> Dx, Dz (on) > Apply
```

*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.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Effective width</th>
<th>Moment of inertia Iyy</th>
<th>Scale Factor for Iy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Iyy_1 (Full width)</td>
<td>Iyy_2 (Effective width)</td>
</tr>
<tr>
<td>At the middle of the side span</td>
<td>5.653</td>
<td>0.4696905</td>
<td>0.4628585</td>
</tr>
<tr>
<td>At support</td>
<td>5.117</td>
<td>0.4696905</td>
<td>0.4530761</td>
</tr>
<tr>
<td>At the middle of the center span</td>
<td>5.839</td>
<td>0.4696905</td>
<td>0.4659784</td>
</tr>
</tbody>
</table>

Display Boundary> All; Support (on) ➔

Node Number (off), Element Number (on)

Model / Boundaries / Effective Width Scale Factor
Boundary Group Name>E_Width1
	Select Single (Elements: 1to16)
	Iy Scale Factor for Sbz ( 0.985 ) ➔ Apply

Boundary Group Name>E_Width2
	Select Single (Elements: 17to26)
	Iy Scale Factor for Sbz ( 0.965 ) ➔ Apply

	Select Single (Elements: 27to40)
	Iy Scale Factor for Sbz ( 0.992 ) ➔ Apply

Boundary Group Name>E_Width3
	Select Single (Elements: 41to50)
	Iy Scale Factor for Sbz ( 0.965 ) ➔ Apply

	Select Single (Elements: 51to66)
	Iy Scale Factor for Sbz ( 0.985 ) ➔ Apply
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.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Right girder</th>
<th>Left girder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vertical load (FZ)</td>
<td>Torsional moment</td>
</tr>
<tr>
<td>Pre-composite load, DL (BC)</td>
<td>-38.96</td>
<td>-1.49</td>
</tr>
<tr>
<td>Post-composite load, DL (AC)</td>
<td>-18.69</td>
<td>19.69</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Load / Static Load Cases</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name ( DL(BC)1 ); Type&gt;Construction Stage Load (CS)</td>
<td>Add</td>
</tr>
<tr>
<td>Name ( DL(BC)2 ); Type&gt;Construction Stage Load (CS)</td>
<td>Add</td>
</tr>
<tr>
<td>Name ( DL(BC)3 ); Type&gt;Construction Stage Load (CS)</td>
<td>Add</td>
</tr>
<tr>
<td>Name ( DL(BC)4 ); Type&gt;Construction Stage Load (CS)</td>
<td>Add</td>
</tr>
<tr>
<td>Name ( DL(AC) ); Type&gt;Construction Stage Load (CS)</td>
<td>Add</td>
</tr>
</tbody>
</table>

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
Select by 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 ); M( 1.49 ) Apply

Select Polygon
(Elements: 1to15by2, 1st part of the composite section on the right girder)
x1( 0 ); x2( 1 ); M( -1.49 ) Apply

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+Shift key+2:Sect 2+ Shift key+3:Sect 3

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 ) > Apply

Select by Polygon (Elements: 2to62by2, left girders)
Load Type>Uniform Moments/Torsions
Direction>Global X ;  Projection>No ;  Value>Relative
x1 ( 0 ) ; x2 ( 1 ) ; M (-19.69 ) > Apply

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

x1 ( 0 ) ; x2 ( 1 ) ; M ( 19.69 ) > Apply

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.

<table>
<thead>
<tr>
<th>Const. Stage</th>
<th>Element Group</th>
<th>Boundary Group</th>
<th>Load Group (Activation)</th>
<th>Duration</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SGroup</td>
<td>BGroup</td>
<td>DL (BC) 1</td>
<td>First step</td>
<td></td>
</tr>
<tr>
<td>CS1</td>
<td></td>
<td></td>
<td>DL (BC) 2</td>
<td>First step</td>
<td>5</td>
</tr>
<tr>
<td>CS2</td>
<td>-</td>
<td>E_Width 1</td>
<td>DL (BC) 3</td>
<td>25 days (User step)</td>
<td>30</td>
</tr>
<tr>
<td>CS3</td>
<td>-</td>
<td>E_Width 2</td>
<td>DL (BC) 4</td>
<td>25 days (User step)</td>
<td>30</td>
</tr>
<tr>
<td>CS4</td>
<td>-</td>
<td>E_Width 3</td>
<td>DL (AC)</td>
<td>First step</td>
<td>10,000</td>
</tr>
</tbody>
</table>
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

Stage > Name( CS ); Suffix( 1to4 ); Duration ( 30 )
Addition Steps > Day ( 25 )
Save Result>Stage (on), Additional Steps (on) > Apply > Cancel

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
- Addition Steps: Day (25)
- Element tab:
  - Group List > SGroup
  - Activation: Age (0)
- Boundary tab:
  - Group List > BGroup
  - Activation: Support/Spring Position > Deformed
- Load tab:
  - Group List: DL(BC)1 + Shift Key + DL(BC)2
  - Activation: Active Day > First
  - Group List: Add > Apply > OK

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](image)

Select CS2 and modify the data for the stage.
Name>CS2  
Boundary tab
Group List>E_Width1
Activation>Support/Spring Position>Deformed
Add

Load tab
Group List > DL (BC) 3
Activation>Active Day>25; Group List Add OK

**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 OK >Close

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.

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.

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.

<table>
<thead>
<tr>
<th>Active Stage</th>
<th>Section</th>
<th>Composite Type</th>
<th>Construction Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS1</td>
<td>Sect 2</td>
<td>Normal</td>
<td>Part&gt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mat.Type&gt;Element; Composite Stage&gt;Active Stage; Age (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Part&gt;2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mat.Type&gt;Material; Material&gt;3; Grade C6000; Composite Stage&gt;CS3; Age (5); Stiff. Scale&gt; Weight&gt; 0 &gt; OK &gt; Apply</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Active Stage&gt;CS1; Section&gt;3: Sect 3, Composite Type&gt;Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Construction Sequence</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Part&gt;1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mat.Type&gt;Element; Composite Stage&gt;Active Stage; Age (0)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Part&gt;2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mat.Type&gt;Material; Material&gt;3; Grade C6000; Composite Stage&gt;CS4; Age (5); Stiff. Scale&gt; Weight&gt; 0 &gt; OK &gt; Apply</td>
</tr>
</tbody>
</table>

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)

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.

![Figure 3. Moment diagram at CS4](image-url)
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)
Load case / Combination > Summation(CS) (on)
Stage/Step: CS1:001(first) ~ CS4:002(last) (on)
Part Number: Part j (on)

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).