

Tutorial

**Construction Stage Analysis using
FCM Bridge Wizard**

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Overview

Some representative post-tensioned box girder bridges are constructed by ILM (Incremental Launching Method), FCM (Free Cantilever Method or Balanced Cantilever Method), MSS (Movable Scaffolding System), etc. FCM is generally used in a terrain where obstacles such as rivers, creeks and roads lie under the bridge, which present difficulties in installing conventional shoring. FCM is generally used for long span bridges, which are typically accompanied with high piers. Since it involves constructing balanced cantilevers from a pier, it is often referred to as a balanced cantilever bridge.

Similar to any other segmental construction methods, FCM presents structural system changes in each construction stage, and each structural system needs to be analyzed throughout the construction process. The analyses also must reflect time dependent material properties, tendon relaxation, tension losses in tendons, etc., whose effects are then accumulated through the various stages of construction.

In this tutorial, MIDAS/Civil **FCM Wizard** is used to model construction sequence; analysis is performed; and, results for stresses, prestress losses and deflections are reviewed in construction stages.

This is an example of cast-in-place bridge.

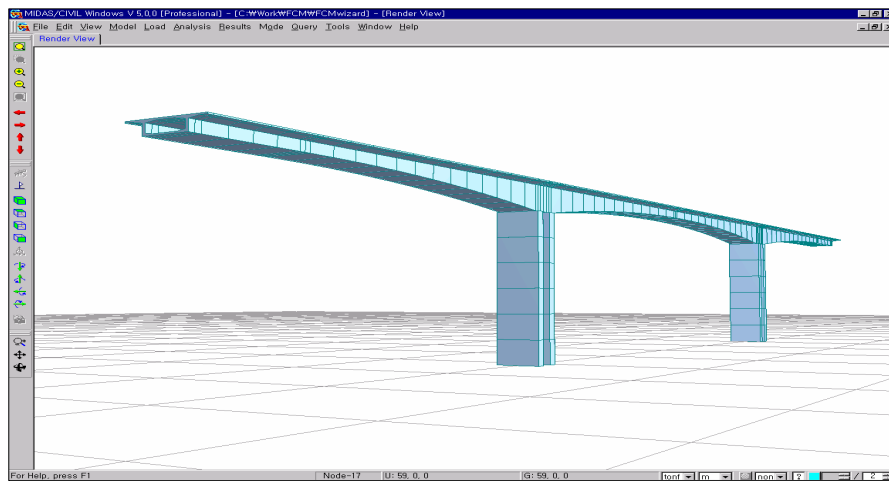


Figure 1. Analytical Model (Completed)

Bridge Dimensions and Section Views

Bridge Type:	3 span continuous PSC Box Bridge (FCM)
Bridge Span:	$L = 85.0 + 130.0 + 85.0 = 300.0$ m
Bridge Width:	$B = 12.7$ m (2 lanes)
Skew Angle:	90° (perpendicular)

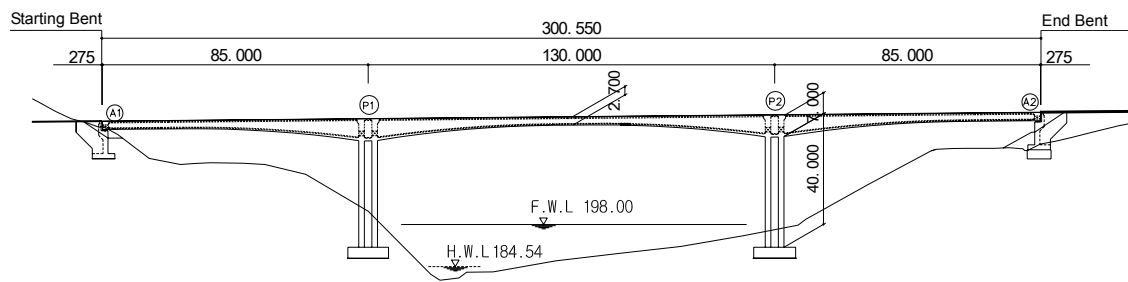


Figure 2. Sectional Elevation View

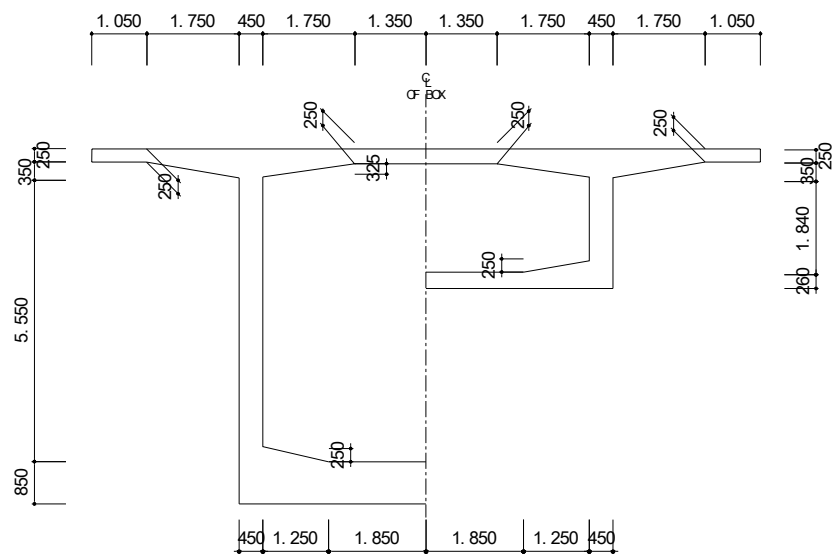


Figure 3. Section Views (Variable section)

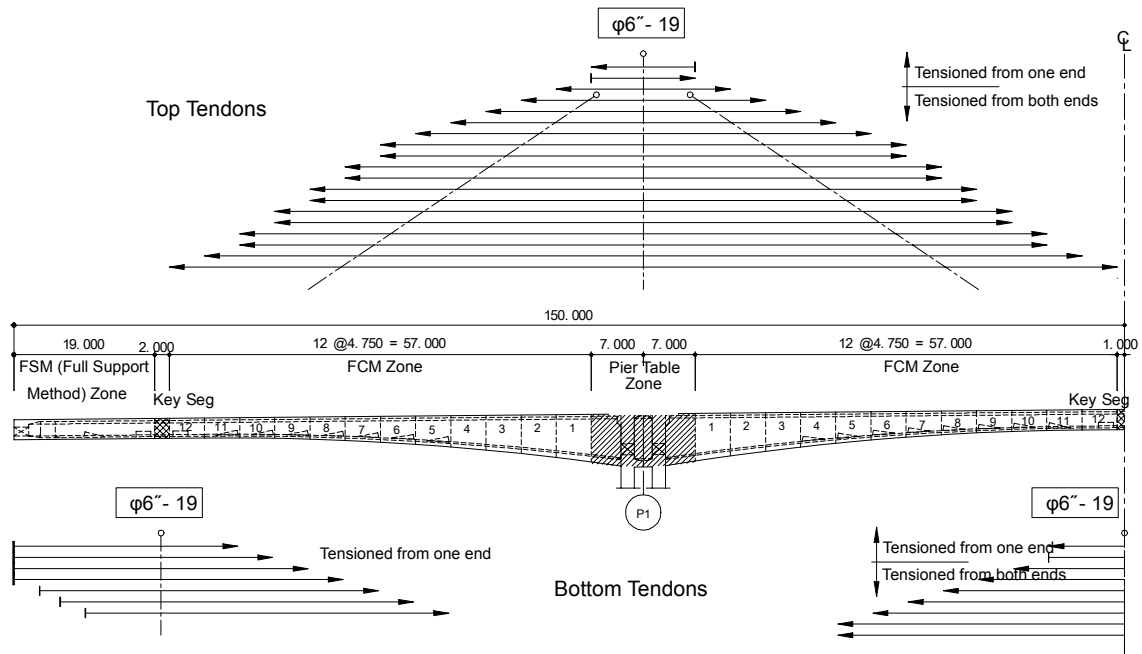
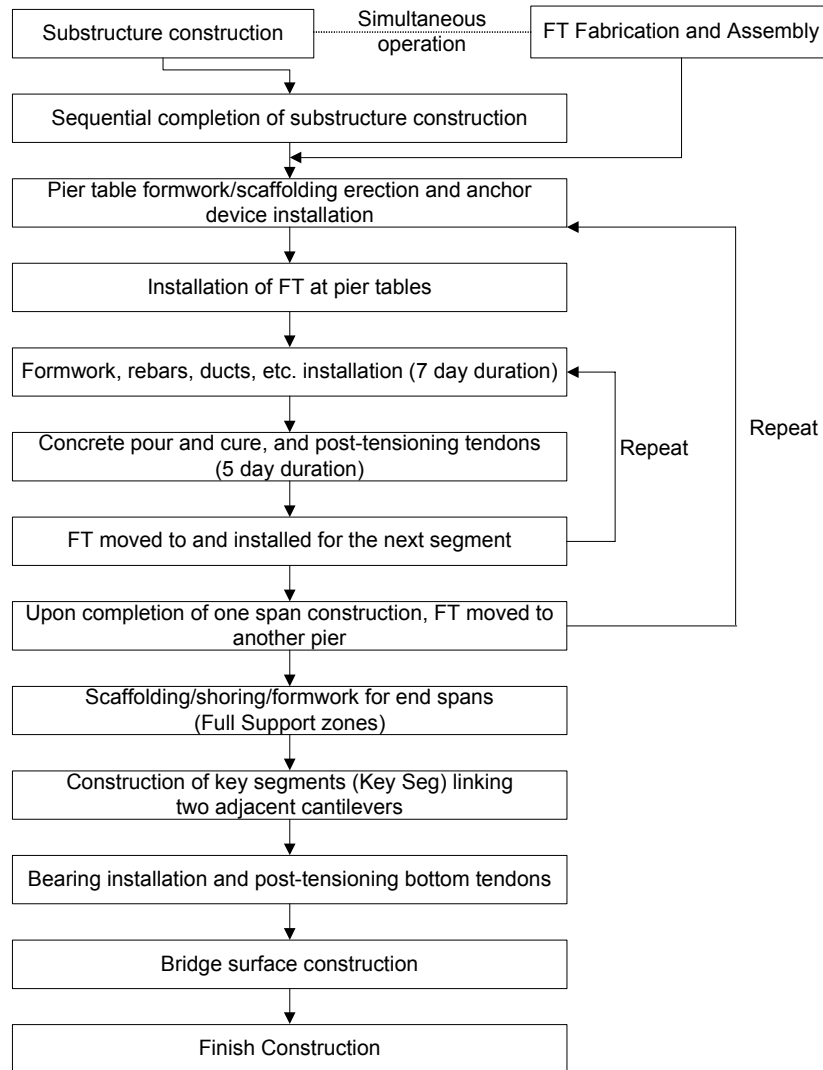


Figure 4. Tendon Layout

Construction Stages for FCM and Stage Analysis

The following outlines a general procedure for FCM construction.



Note: This example is a 3-span FCM bridge constructed with 4 Form Travelers (FT).
As such FT will not be relocated.

Procedure for performing construction stage analysis for FCM Bridge

The concept of construction stage analysis in MIDAS/Civil entails activation and deactivation of predefined Structure Groups, Boundary Groups and Load Groups at each stage of construction.

-
1. Define Material and Section Properties
 2. Structural Modeling
 3. Define Structure Groups
 4. Define Boundary Groups
 5. Define Load Groups
 6. Enter Loads
 7. Place Tendons
 8. Apply Prestress Loads
 9. Define & Link Time Dependent Material Properties
 10. Perform Structural Analysis
 11. Check Results
-

FCM Wizard automatically performs the steps 2 ~ 8.

Material Properties and Allowable Stresses

➤ Top Concrete

Design Strength: $f_{ck} = 400 \text{ kgf/cm}^2$

Initial Compressive Strength: $f_{ci} = 270 \text{ kgf/cm}^2$

Modulus of Elasticity: $E_c = 3,000W_c^{1.5} \sqrt{f_{ck}} + 70,000 = 3.07 \times 10^5 \text{ kgf/cm}^2$

Allowable Stresses

Allowable Stress	Immediately after stressing	After final losses
Compression	$f'_{ca} = 0.55f_{ci} = 148.5 \text{ kgf/cm}^2$	$f_{ca} = 0.4f_{ck} = 160.0 \text{ kgf/cm}^2$
Tension	$f'_{ta} = 0.8\sqrt{f_{ci}} = 13.1 \text{ kgf/cm}^2$	$f_{ta} = 1.6\sqrt{f_{ck}} = 32.0 \text{ kgf/cm}^2$

➤ Bottom Concrete

Design Strength: $f_{ck} = 270 \text{ kgf/cm}^2$

Modulus of Elasticity: $E_c = 2.35 \times 10^5 \text{ kgf/cm}^2$

➤ P.C Tendon (KSD 7002 SWPC 7B-Φ15.2mm (0.6" strand))

Yield Strength: $f_{py} = 160 \text{ kgf/mm}^2 \rightarrow P_y = 22.6 \text{ tonf/strand}$

Tensile Strength: $f_{pu} = 190 \text{ kgf/mm}^2 \rightarrow P_u = 26.6 \text{ tonf/strand}$

Cross Sectional Area: $A_p = 138.7 \text{ cm}^2$

Modulus of Elasticity: $E_p = 2.0 \times 10^6 \text{ kgf/cm}^2$

Inducted Post-tension: $f_{pi} = 0.72f_{pu} = 137 \text{ kgf/mm}^2$

Anchorage Slip: $\Delta s = 6 \text{ mm}$

Friction loss coefficients: $\mu = 0.30 / \text{rad}$

$k = 0.006 / \text{m}$

Allowable Stresses

Maximum stress at prestressing	Immediately after anchoring (f_{po})	Service loads after losses
$0.9f_{py} = 144 \text{ kgf/mm}^2$	$0.7f_{pu} = 133 \text{ kgf/mm}^2$	$0.8f_{py} = 128 \text{ kgf/mm}^2$

Loads

➤ Dead Loads

Self-weight

Use **Self Weight** command.

Superimposed (2nd) dead load

$$w = 3.432 \text{ tonf/m}$$

➤ Prestress

Tendon ($\varnothing 15.2 \text{ mm} \times 19 (\varnothing 0.6'' - 19)$)

$$\text{Cross sectional area: } A_p = 1.387 \times 19 = 26.353 \text{ cm}^2$$

Duct Size: 100 / 103 mm

Prestress load: 72% of tensile strength

$$f_{pj} = 0.72 f_{pu} = 13,680 \text{ kgf / cm}^2$$

$$P_j = A_p \cdot f_{pj} = 360.5 \text{ tonf}$$

Loss immediately after jacking/anchoring (Calculated by the program)

$$\text{Friction loss: } P_{(x)} = P_0 \cdot e^{-(\mu\alpha + kL)}$$

$$\text{Top Tendon: } \mu = 0.20, \quad k = 0.001$$

$$\text{Bottom Tendon: } \mu = 0.30, \quad k = 0.006$$

$$\text{Loss due to anchorage Slip} \quad \Delta I_c = 6 \text{ mm}$$

$$\text{Loss due to elastic shortening: } \Delta P_E = \Delta f_p \cdot A_{SP}$$

Final loss (Calculated by the program)

Relaxation

Loss due to creep and shrinkage

➤ Creep and Shrinkage

Conditions

Cement: Normal (Type 1) Cement

Concrete age when becoming subjected to the sustained loads: $t_o = 5$ days

Concrete age when becoming exposed to ambient condition: $t_s = 3$ days

Relative humidity: $RH = 70\%$

Ambient temperature or curing temperature: $T = 20^\circ\text{C}$

Code: CEB-FIP

Creep coefficient: Calculated by the program

Shrinkage strain of concrete: Calculated by the program

➤ **Form traveler load**

Assume as follows:

$$P = 80.0 \text{ tonf}$$

$$e = 2.50 \text{ m}$$

$$M = P \times e = 200.0 \text{ tonf}$$

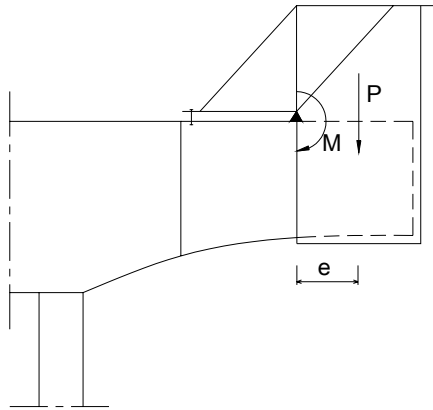





Figure 5. Form Traveler Load



Setting Modeling Environment

Open a new file ( **New Project**) and save it as '**FCM Wizard**' ( **Save**).

Set the units to '**tonf**' & '**m**'. The units can be changed at any time depending on the type of modeling input and results.

File /  **New Project**

File /  **Save (FCM Wizard)**

 The Unit System can be changed using the unit selection button () in the Status Bar at the bottom of the screen.

Tools / **Unit System** 

Length>**m** ; Force>**tonf** ↵

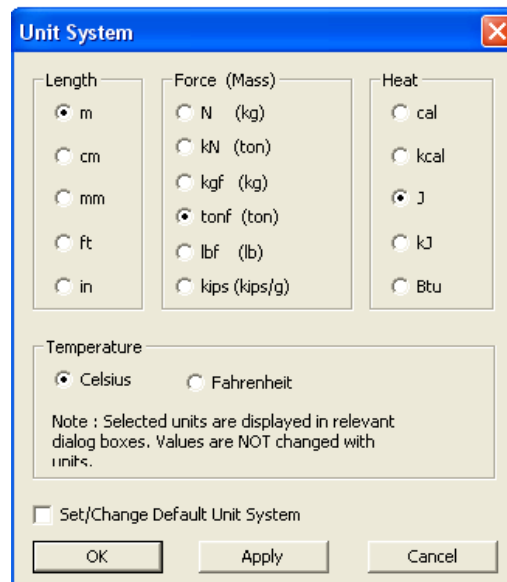


Figure 6. Setting Unit System

Section and Material Property Definition

Define material properties for the superstructure, substructure and tendons.

Use the **Apply** button when defining a number of properties.

Model / Properties /  **Material**

Type>**Concrete** ; Standard>**KS-Civil(RC)**

DB>**C400** ↵

Type>**Concrete** ; Standard>**KS-Civil(RC)**

DB>**C270** ↵

Name (**tendon**) ; Type>**User Defined** ; Standard>**None**

Analysis Data

Modulus of Elasticity (**2.0e7**)

Poisson's Ratio (**0.3**)

Thermal Coefficient (**1.0e-5**)

Weight Density (**7.85**) ↵

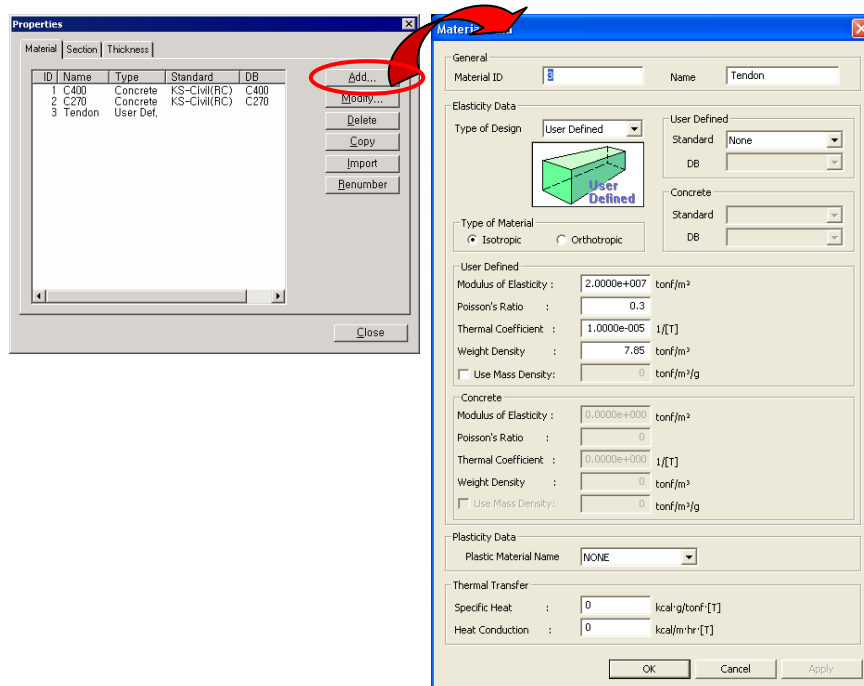


Figure 7. Material Properties Dialog

Section properties of PSC box sections can be specified in the FCM Wizard.

Define the section property of the piers as User Type.

Model / Properties /  **Section**

DB/User tab

Section ID (1) ; Name (Pier)

Section Shape>**Solid Rectangle** ; **User>H (1.8), B(8.1)** ↵

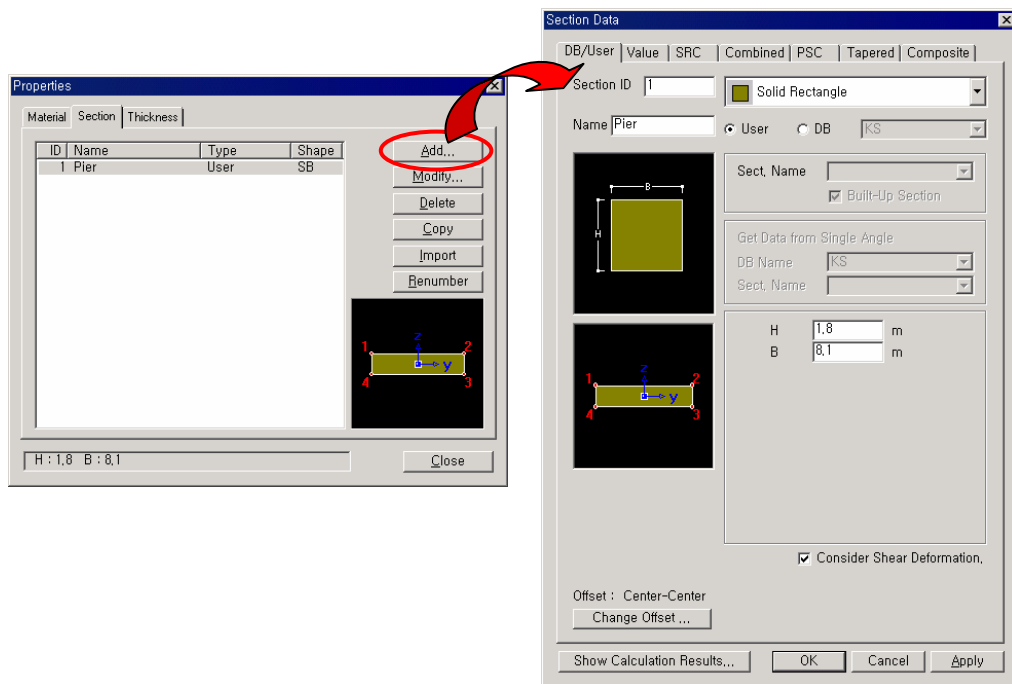


Figure 8. Section Properties Dialog

FCM Bridge Wizard Modeling

FCM Bridge Wizard in MIDAS/Civil consists of three tabs - Model, Section and Tendon.

In this example, 7 day duration is assumed for installation of formwork, rebars, sheath, etc. followed by 5 days for casting and curing of concrete.

Model Data Input

Specify material properties, geometry, construction segments (Figure 10), pier table dimensions, pier type and size, etc. in the Model Tab of FCM Bridge Wizard. Enter 12 days for constructing one segment (12 days[Ⓜ]).

Model / Structure Wizard / **FCM Bridge**

Bridge Model Data Type> **Type1**

Model tab

Material (Girder)>**1: C400** ; Material (Pier)>**2: C270**

Number of Piers (**2**) ; Pier Section>**1: Pier** ; Stage Duration (**12**)

Method>**Cast-in**

Pier Table>**P.T. (14)** ; **B (6)**

Key Segment>**K1 (2)** ; **K2 (2)**

Pier>**H (40)** ; **C (4.2)**

FSM>**FSM(L) (2, 4@4.25)** ; **FSM(R) (2, 4@4.25)**[Ⓜ]

Zone1 (**12@4.75**) ; Zone2 (**12@4.75**)

Elements within the FSM zones are segmented to account for tendon anchors. (Figure 10)

Click **Save As...** to save the Wizard data as a *.wzd file.

Recall an existing *.wzd file by clicking **Open...**

A Curved FCM bridge can be modeled by checking on "Radius" and entering the radius value.

A non-symmetrical FCM bridge or a FCM bridge constructed non-symmetrically, can be modeled by checking on "Advanced" and clicking the **Advanced...** button.

Figure 9. Model Tab in FCM Bridge Wizard

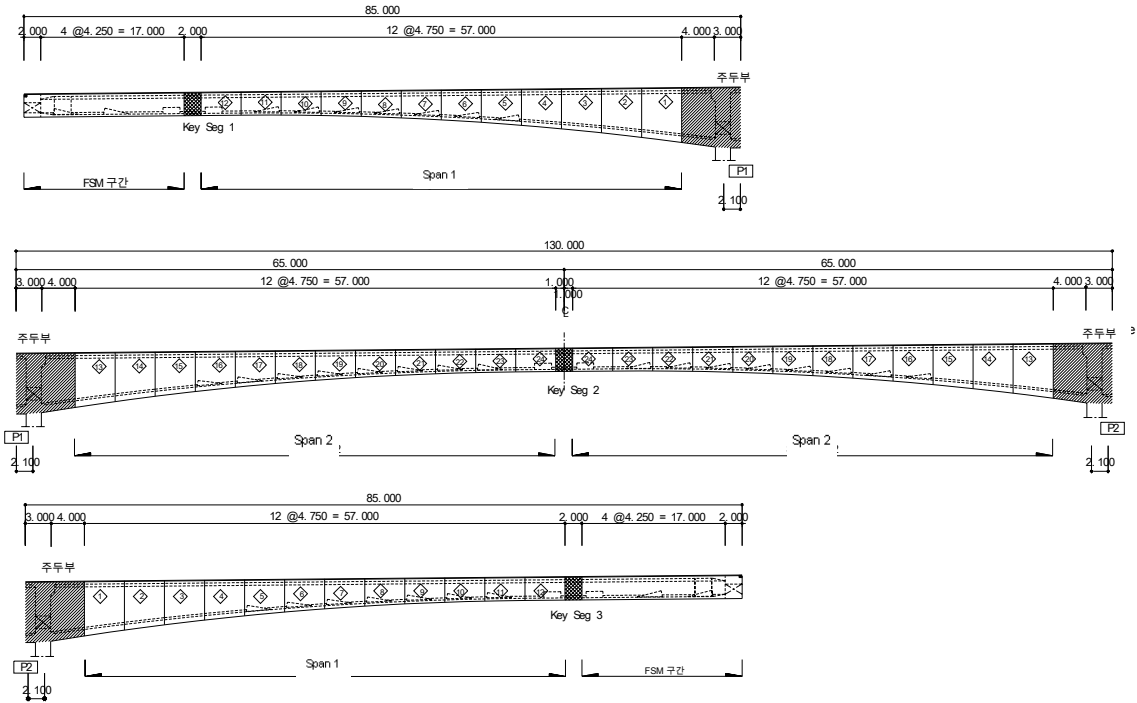


Figure 10. Layout of construction segments

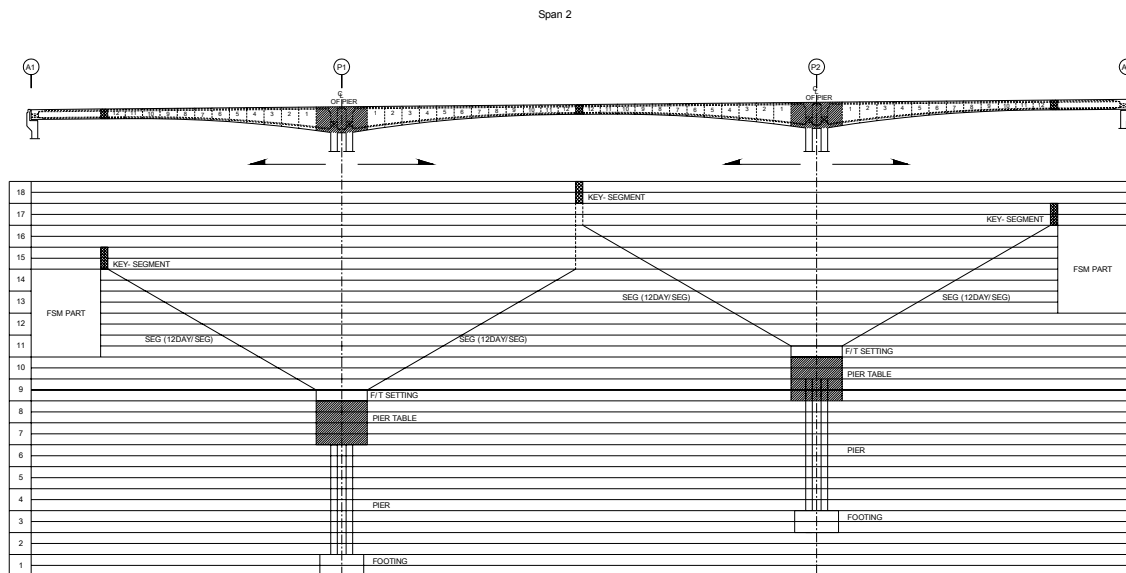


Figure 11. Construction Schedule (assumed)

In a typical FCM construction, not all the piers (substructures) are constructed simultaneously. As a result, the two cantilevers, which will be joined by a key segment, are not constructed at the same time, and the cantilevers have different ages at the time of erecting the Key Segment. Hence, the two cantilevers would undergo different creep, shrinkage and tendon losses, resulting in different stresses and deflections at the time of erecting the Key Segment. Such differences need to be reflected in preparing the construction stages for analysis.

🔊 Time Loads for Construction Stage are defined in Load > Construction Stage Loads > Load > Time Loads for Construction Stage.

MIDAS/Civil has a feature “**Time Loads for Construction Stage**”[🔊], which is used to impose elapsed times to specific elements. The difference in ages (concrete maturity) of the two cantilevers in this example is because of the time difference in erecting the first segments of the two adjacent pier tables. The two identical piers are erected by the same schedule, but pier P2 is constructed at a later time relative to pier P1. Such a time difference can be handled by **Time Loads for Construction Stage**.

Figure 11 illustrates the assumed construction schedule in which each horizontal line represents a 15-day duration. The construction of the first segment of pier P2 lags 60 days behind that of pier P1.

Click **Pier Table Placing...** to enter the time difference between the construction times of the two pier tables.

Pier Table Placing...

P.T.>P.T. 2

Day (60) ; Define ↵

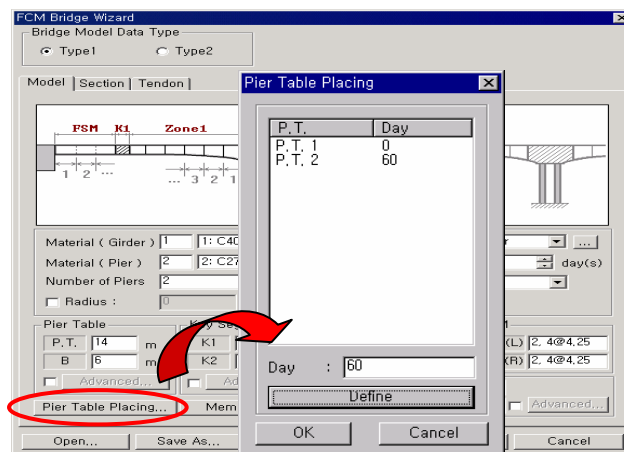


Figure 12. Input for time difference between 2 Pier Tables

Concrete properties change with time. Such time-dependent properties change relatively rapidly in early ages. Construction dead loads are generally applied in early ages. The initial member ages represent the time when formwork and temporary supports are removed after curing, and the members are subjected to permanent loads. Using the initial member ages, the program automatically calculates the modulus of elasticity, creep coefficient and shrinkage coefficient. The initial member ages are specified by deducting the time spent for erecting formwork and rebar placement from the stage duration, and are as follows:

- FSM zone: 60 days
- Key Seg.: 10 days
- Pier Table: 15 days
- Segment: 5 days
- Pier: 100 days

Click **Member Age...** to enter the initial Member Age of each main member.

🔊 The initial ages of the segments, whose self-weights of incompletely cured concrete are reflected in construction stages, and the initial ages of key segments, must be less than the duration for constructing one segment.

Member Age...

FSM (60) ; Segment (5) ; Key Seg (10)
Pier (100) ; Pier Table (15) ↴

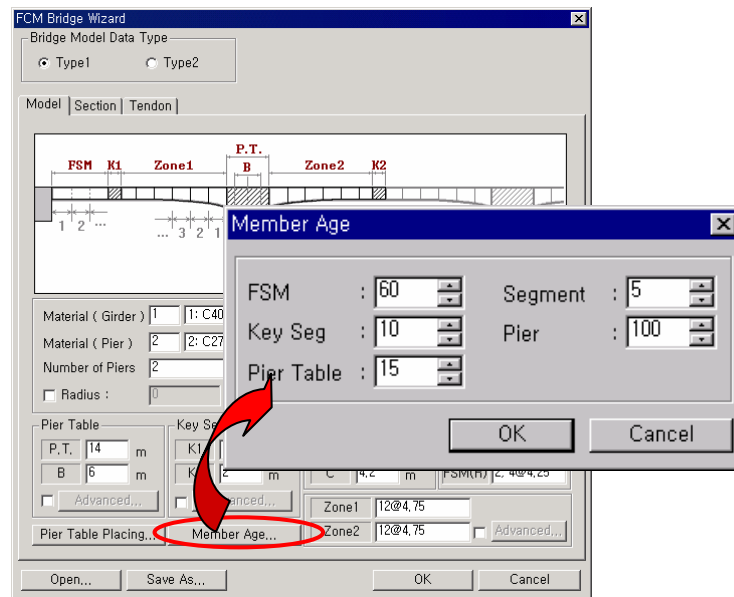


Figure 13. Input for initial Member Ages of main members

PSC Box Section Properties Input

In a FCM bridge construction, the sections at the piers are deeper than those at the mid spans to resist high moments and shear forces for cantilevers. By specifying the sections at the supports and mid-spans, the program automatically generates variable section profiles of a second order function. Enter the section dimensions referring to Figure 14 followed by selecting Drawing under View Option to verify the sections.

Refer to the On-line manual, "Using MIDAS/CIVIL > Model > Properties > Tapered Section Group"

The weight of the form traveler, which includes the formwork and its support devices, is entered with an eccentricity. This is internally converted into a vertical force and a moment, which are then applied at the end of the cantilever segment. If the "Include Wet Conc. Load" option is selected, the weight of the wet concrete is applied at the time of completing the formwork and rebar placement, which is the number of days equal to the stage duration less the member age. The member age in this case represents the curing period (in the immediately previous stage) of the member being activated in the current stage. After loading the form traveler, if the weight of the wet concrete is loaded with a time gap without changing the structural system, "Additional Steps" can be used rather than creating another construction stage.

Additional Steps are explained in the On-line manual, "Using MIDAS/CIVIL > Load > Construction Stage Analysis Data > Define Construction Stage"

It is recommended to include wet concrete load while defining construction stages in the FCM Wizard, as it results in more conservative stress calculations. However, if the camber control is referenced at the time of setting the form traveler, the deflection due to wet concrete should be ignored, or additional construction stages should be defined.

Section tab

1 Cell (on)

H1 (0.25) ; H2 (2.19) ; H3 (0.26) ; H4 (0.35)

H5 (0.325) ; H6 (0.25) ; H2-1 (5.9) ; H3-1 (0.85)

B1 (2.8) ; B2 (0.45) ; B3 (3.1) ; B4 (1.75) ; B5 (1.75)

B6 (1.25)

Form Traveler Load (include form load)>include Wet Conc. Load (on)

P (80) ; e (2.5)

View Option>Drawing

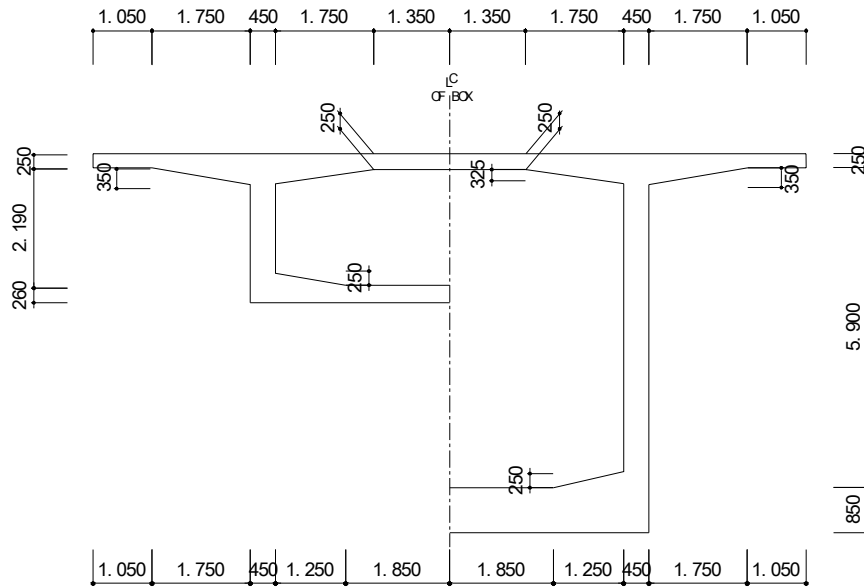




Figure 14. PSC box section

 **Selecting the 2 Cell option provides a section with a middle web.**

 The eccentricities (stiffness center location) of beam elements created in FCM Wizard are automatically referenced to the Center-Top. This is to reflect the variable PSC section. The stiffness is automatically calculated relative to the Center-Top.

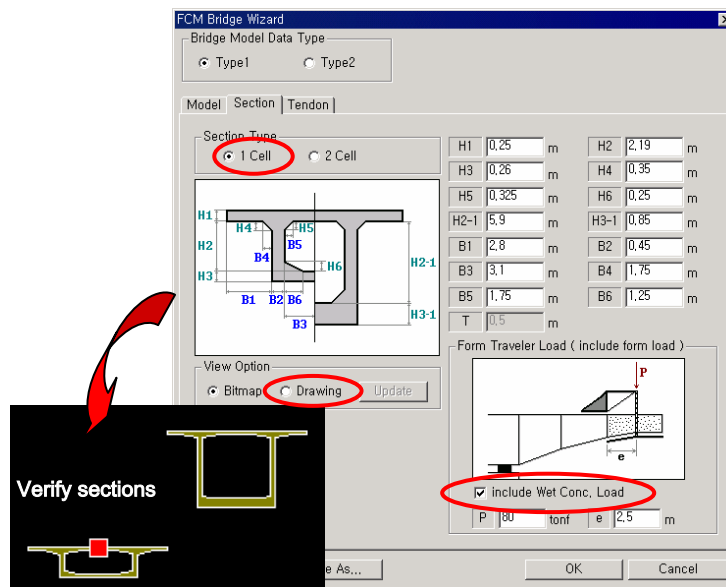



Figure 15. Section dimensions Input

Tendon Placement Input

The tendon placement and the number of tendons anchored in each stage are defined in the Tendon tab. Defining the tendon and anchorage locations in the section and the number of tendons anchored in each segment will automatically generate the tendon profile.

FCM Wizard permits only equally spaced tendons. For unequal spacings, an average spacing may be used, as it will not affect the overall construction stage analysis significantly.

 Tendon information can be entered using Tendon Profile even if Tendon Properties and Prestress have not been defined.

Tendon tab

Tendon and Prestress (on)

Section Type>1 Cell

H1 (0.17) ; H2 (0.32) ; H3 (0.29) ; H4 (0.14)


W1 (0.1) ; W2 (0.1) ; W3 (0.06) ; S (0.175)


DX1 (0.1) ; DY1 (0.3) ; DX2 (0.1)

DY2 (0.3) ; DX3 (0.3) ; DY3 (0.19)

Equal (on)

N1 (7) ; N2 (3) ; N3 (6) ; N4 (3) ; N5 (2)

N6 (7) ; N7 (2) ; N8 (5) 

 N7 and N8 represent the numbers of tendons in the FSM zones.

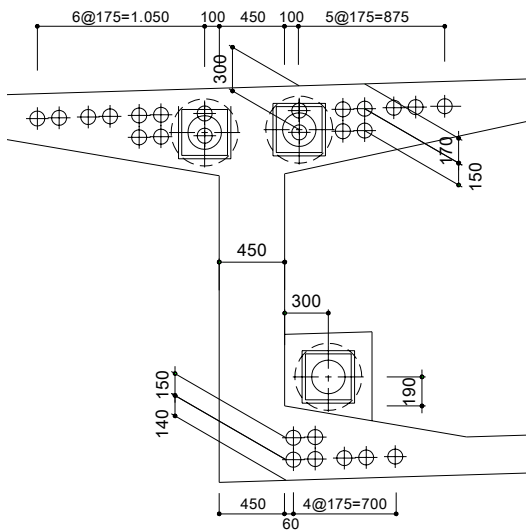


Figure 16. End span tendon placement.

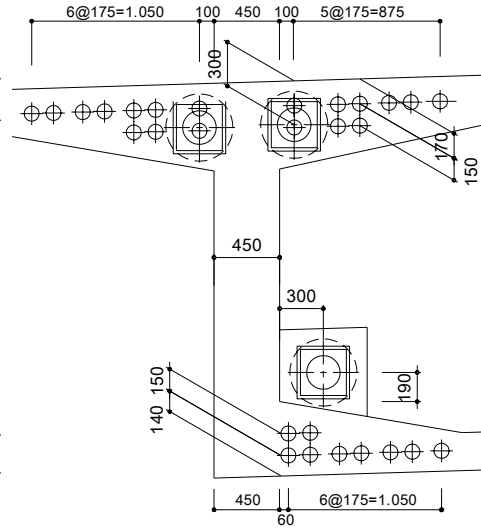


Figure 17. Center span tendon placement.

🔊 Selecting "Unequal" in Tendon Number allows us to input different numbers of tendons in Top/Bottom by spans and piers.

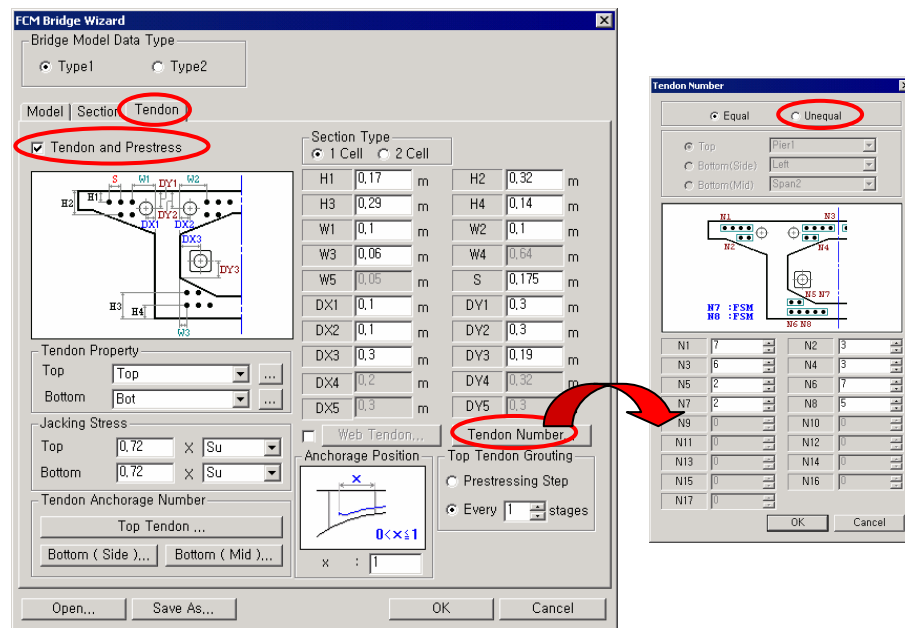


Figure 18. Tendon placement input

Enter the tendon properties and jacking stresses. The coefficients related to tendon losses are different for the top and bottom tendons, which are defined separately. 72% of the ultimate strength is specified for the jacking stress. Bottom tendons can be anchored away from the ends of the segments in which cases the anchor locations are specified in terms of segment length ratios.

Relaxation Coefficient is based on Magura's equation. For normal tendons, it is 10, and for low relaxation tendons, it is 45. Also, CEB-FIP and JTG-04 methods are available.

If Top tendon grouting is entered at Every 1 Stages, then the grouted section properties are calculated for the stage immediately after the grouted stage for stress calculations.

Tendon Property>...
Add

Tendon Name **(Top)** ; Tendon Type>**Internal (Post-tension)**

Material>**3: tendon**

Total Tendon Area **(0.0026353)**

or ...

Strand Diameter>**15.2mm (0.6 ")**

Number of Strands **(19)** ↓

Duct Diameter **(0.103)** ; Relaxation Coefficient **(CEB-FIP, 5)**

Ultimate Strength **(190000)** ; Yield Strength **(160000)**

Curvature Friction Factor **(0.2)**; Wobble Friction Factor **(0.001)**

Anchorage Slip>Begin **(0.006)** ; End **(0.006)**

Bond Type **(Bonded)** ↓

Tendon Name **(Bot)** ; Tendon Type>**Internal (Post-Tension)**

Material>**3: tendon**

Total Tendon Area **(0.0026353)**

or ...

Strand Diameter>**15.2mm (0.6 ")**

Number of Strands **(19)** ↓

Duct Diameter **(0.103)** ; Relaxation Coefficient **(CEB-FIP, 5)**

Ultimate Strength **(190000)** ; Yield Strength **(160000)**

Curvature Friction Factor **(0.3)**; Wobble Friction Factor **(0.001)**

Anchorage Slip>Begin **(0.006)** ; End **(0.006)**

Bond Type **(Bonded)** ↓

Close

Top>**Top** ; Bottom>**Bot**

Jacking Stress>Top (**0.72**) × (Su) ; Bottom **(0.72)** × (Su)

Anchorage Position **(1)**

Top Tendon Grouting>**Every (1) stages**

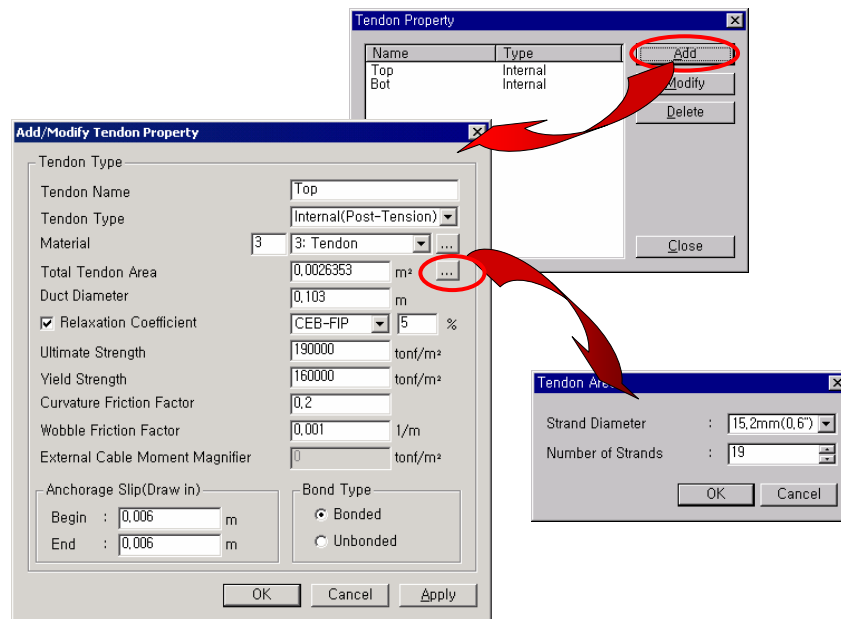


Figure 19. Tendon properties input

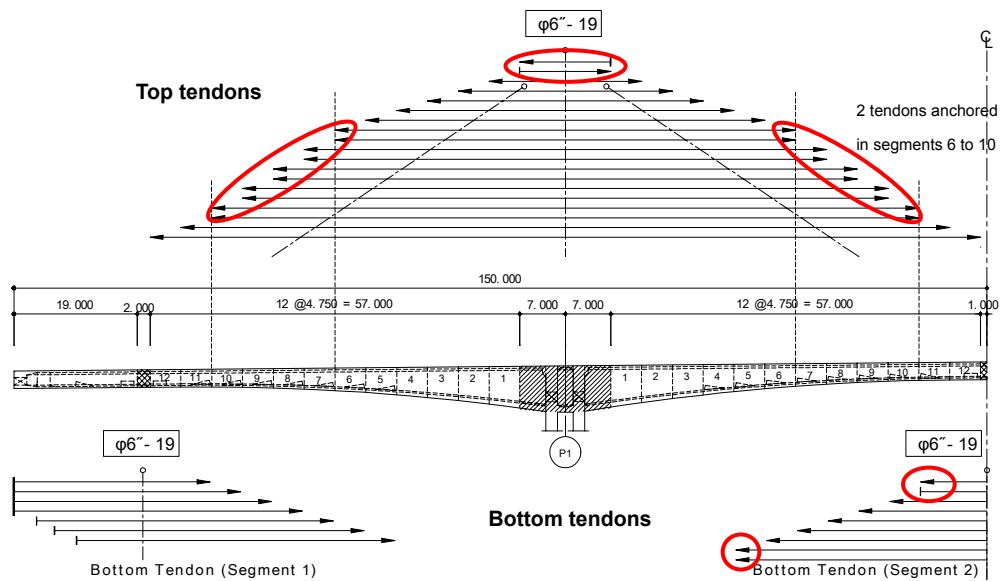


Figure 20. Longitudinal tendon layout

The tendon quantity increases with the increase in the cantilever length. In some segments 2 tendons are anchored. Specify the number of tendons anchored in each segment by referring to Figure 20.

Multiple segments can be selected while pressing the [Ctrl] key.

Tendon Anchorage Number

Top Tendon ...

Equal (on)

Segment>P.T, Seg6, Seg7, Seg8, Seg9, Seg10

Anch. Num (2) ; Define

Bottom (Side)...

Equal (on) ; Segment>Seg1, Seg2, Seg3, Seg4, Seg12

Anch. Num (0) ; Define

Bottom (Mid)...

Equal (on) ; Segment>Seg1, Seg2, Seg3, Seg4, Seg12

Anch. Num (0) ; Define

Segment>Seg5, Seg11

Anch. Num (2) ; Define

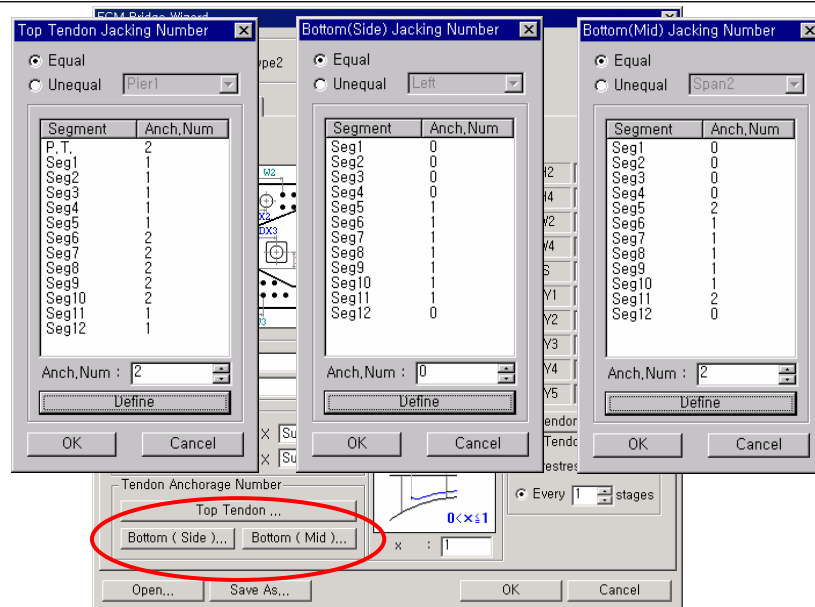
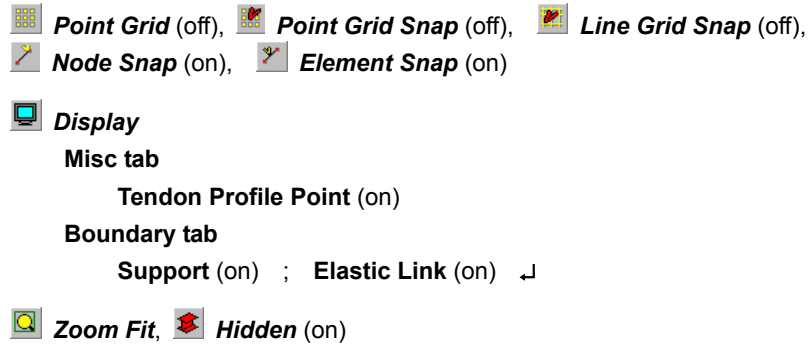


Figure 21. Input for the number of tendons anchored in each segment

After finishing the input, click **OK** to end FCM Bridge Wizard and verify the modeling. Check the modeling of the bridge and tendon layouts. Use **Zoom Window** and **Zoom Fit** to closely view local parts.



FCM Wizard automatically assigns roller conditions at each end of the bridge and fixed conditions for the pier supports. The Wizard also assigns infinitely stiff elastic links between the piers and the box girder sections.

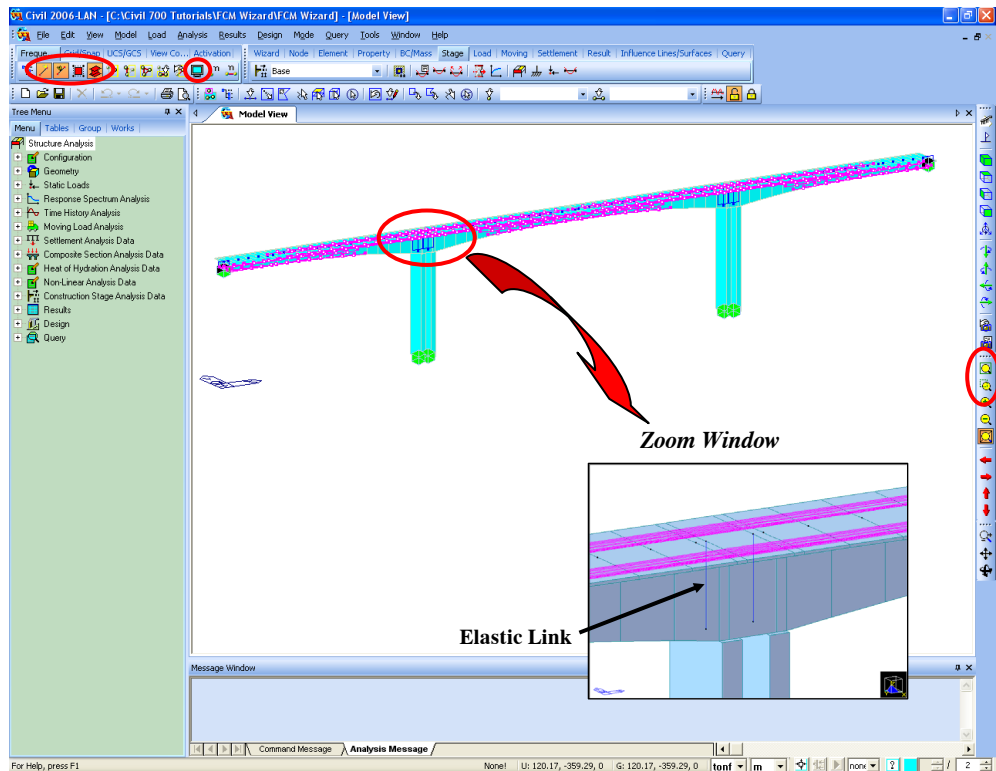


Figure 22. Bridge model generated by FCM Bridge Wizard

Corrections to input data and additional data input

Checking construction stages

When Construction Stage is defined, MIDAS/Civil has two operational modes (Base Stage mode and Construction Stage mode).

In the Base Stage mode, all input related to the structural model data, loading and boundary conditions is permitted. No analysis is performed for the Base Stage. Structural analysis is performed for Construction Stage. In the Construction Stage mode, no structural data is permitted to be changed or deleted other than the Boundary and Load Groups included in each stage.

🔊 In Construction Stage mode, nodes and elements cannot be changed or deleted. This can be done only in the Base Stage.

Construction Stage is defined by activating and deactivating Structure (element) Groups, Boundary Groups and Load Groups, not individual elements and boundary and load conditions. In the Construction Stage Mode, boundary and load conditions included in each activated Boundary Group and Load Group can be modified and deleted. 🔊

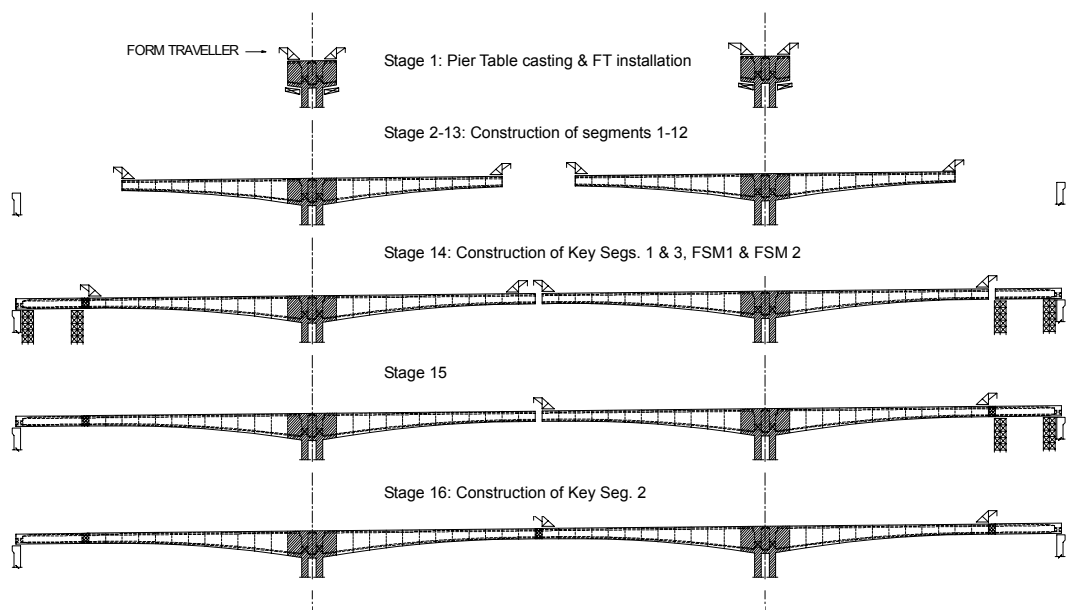


Figure 23. Construction sequence

The construction sequence shown in Figure 23 is summarized by relating it to activation and inactivation of Structure, Load and Boundary Groups in each construction stage.

-
1. Construction Stage 1
 - Activate Structure Groups for piers & pier tables
 - Activate Boundary Group (Support)
 - First day: activate prestress, form traveler (FT) & self-wt
 - 7th day: activate self-wt of wet concrete (segment 1)
 2. Construction Stage 2
 - Activate Segment 1
 - First day: inactivate FT and wet concrete of Construction Stage 1, and activate FT load and prestress
 - 7th day: activate self-wt of wet concrete (segment 2)
 3. Construction Stage 3~12: Repeat Construction Stage 2
 4. Construction Stage 13
 - Activate Segment 12
 - First day: inactivate FT and wet concrete of Construction Stage 12, and activate Key Seg. FT loads & prestress
 - 20th day: activate self-wt of wet concrete (Key Seg. 1 and Key Seg. 3)
 5. Construction Stage 14
 - Activate Key Seg. 1, 3 and FSM 1, 2
 - Activate Boundary Group (FSM_Left, FSM_Right)
 - First day: inactivate FT loads and self-wt of wet concrete of Key Seg. 1 and Key Seg. 3, and activate prestress
 - Last day: activate elements at the Pier 1 side and time load for FSM1
 6. Construction Stage 15
 - Activate self-wt of wet concrete of Key Seg. 2
 7. Construction Stage 16
 - Activate Key Seg. 2
 - First day: inactivate FT loads and self-wt of wet concrete, and activate prestress
 - First day: activate 2nd (superimposed) dead loads
-

Check the construction stages auto-generated by FCM Bridge Wizard. The Stage toolbar and **Works Tree** can be used to verify the construction stage information. From the Stage toolbar, each construction stage can be checked for activated and deactivated Structure Group, Boundary Group and Load Group in conjunction with **Works Tree**. The Stage toolbar also enables us to check the change of structures through the various construction stages in the Model View.



Display

Load tab

Load Case > **Load Value** (on) ; **Nodal Load** (on) ↵

Tree Menu>**Works tab**

Stage>**CS4** 🎧

🎧 After placing the cursor on the Stage Toolbar, arrows on the keyboard can be used to navigate between the stages. The wheel mouse can be used as well.

Construction stage information

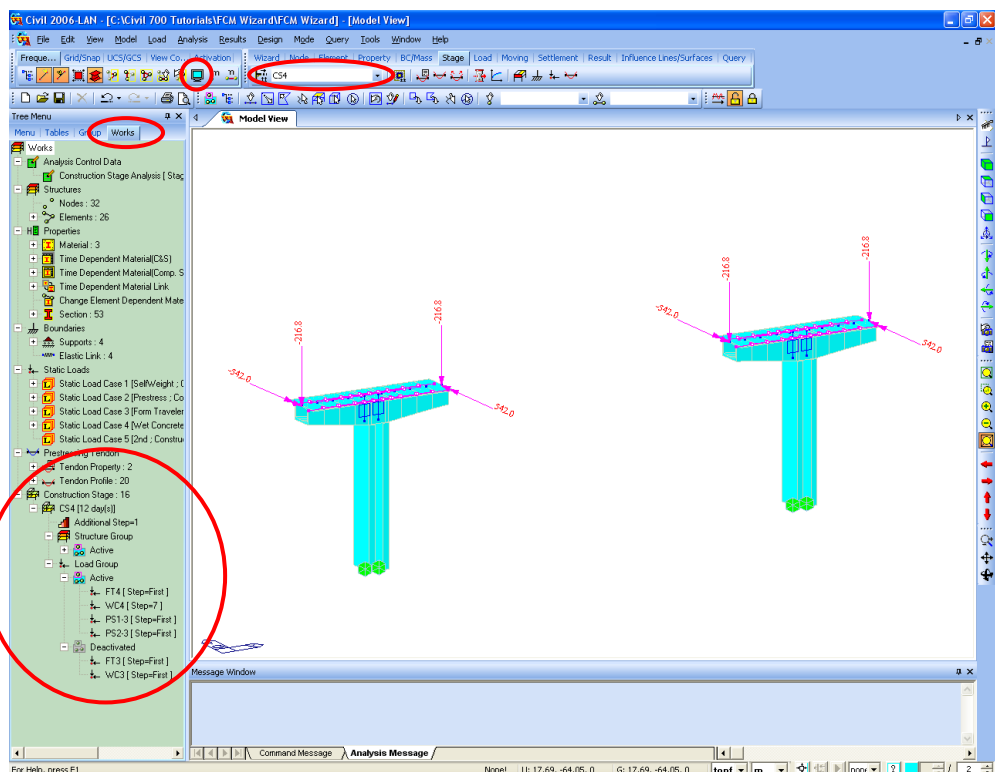


Figure 24. Structural system for the construction stage 4

Corrections to construction stages

In FCM Wizard, we have specified 12 days for constructing each segment. However, 30 days are required for constructing a Key Segment as per Figure 11. Accordingly, after activating segment 12, preparation for the construction of Key Segment is $30 - 10 = 20$ days (where 10 is the initial age of Key Segment). We then correct the construction stage duration for segment 12 to 30 days and assign an “Additional Step” of 20 days for applying the wet concrete weight of the Key Segments (KeyWC1 and KeyWC3).

Convert to Base Stage. Construction stage information can be changed in Base Stage only.

Hidden (off)

Stage>**Base**

Load / Construction Stage Analysis Data / **Define Construction Stage**

Name>**CS13** ;

Stage>Duration (**30**)

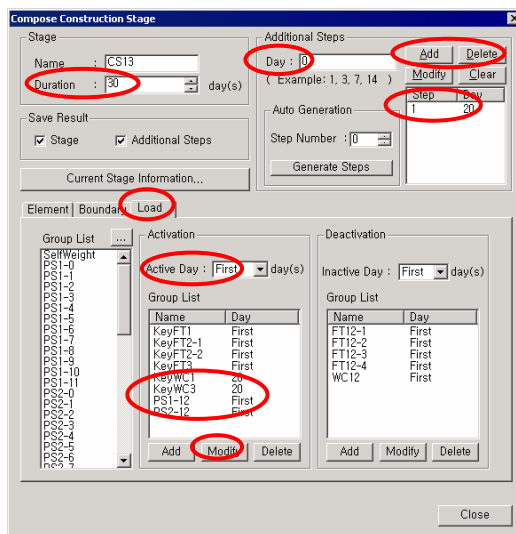
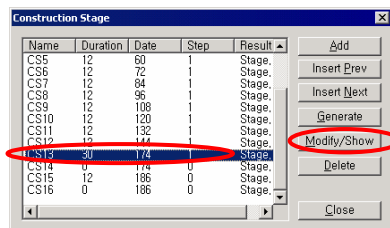
Additional Step>Step>**1** ; ; Day (**20**) ;

Load tab

Activation

Active Day>**20**


Group List>Name>**KeyWC1, KeyWC3**




Auto-generated Element, Boundary and Load Groups by Bridge Wizard is explained in “Define Structure (Boundary, Load) Group” in on-line manual.


Figure 25. Corrections to Construction Stage 13 information

Similar to Stage 13, Stage 15 is corrected. The construction schedule on Figure 11 indicates that the duration for constructing Key Segment 2 is 30 days. The stage duration for the Stage 15 is thus changed to 30 days.

Load / Construction Stage Analysis Data /  **Define Construction Stage**

Name>**CS15** ; 

Stage>Duration (**30**)

Additional Step>Day (**20**) 

Load tab

Activation

Active Day>**20**

Group List>Name>**KeyWC2-1, KeyWC2-2**  ↵

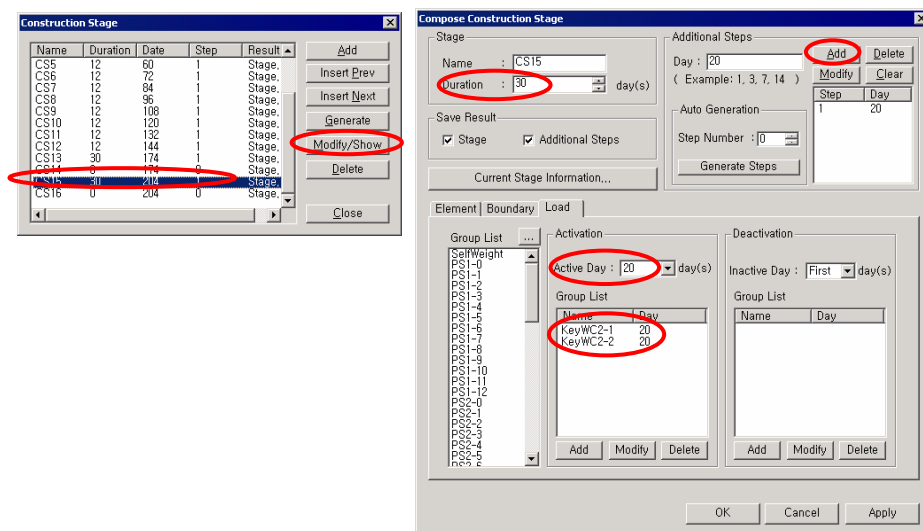



Figure 26. Corrections to Construction Stage 15 information

Once all the Key Segments are constructed, the 2nd dead load (superimposed dead load - pavement, barriers, railings, etc.) is applied. It is assumed that the camber control management due to creep is carried out until 10,000 days after applying the 2nd dead load. We will apply the 2nd dead load in CS16 and assign 10,000 days for its duration. For this, a load case is defined and a Load Group is created.

Load /  **Static Load Cases**

Name (2nd) ; Type>Construction Stage Load  ↵

Model / Group /  **Define Load Group**

Name (2nd)  ↵

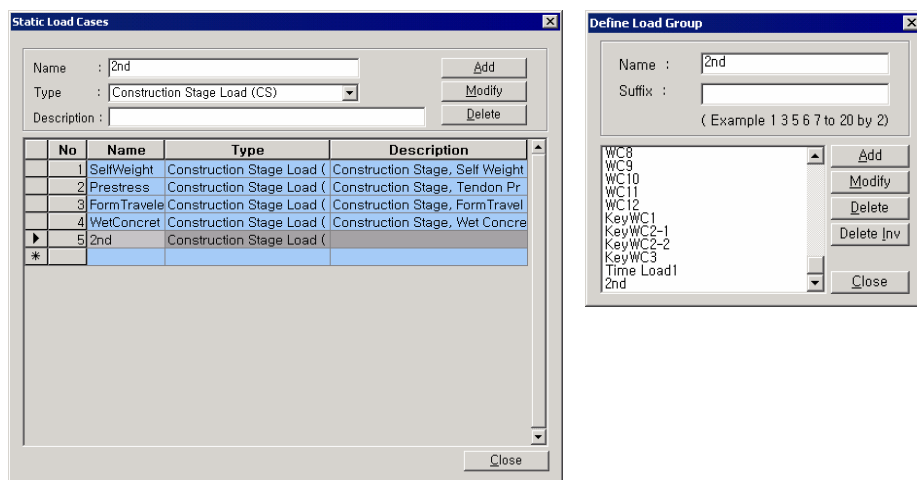


Figure 27. Definition of Load Case and creation of Load Group

We apply the 2nd dead load, 3.432 tonf/m, in the -Z direction.



Display

Load tab

Load Case>**Nodal Load** (off)

Misc tab

Tendon Profile (off)

Boundary tab

Support (off) ; Elastic Link (off) ↵

Load /  **Element Beam Loads**



Select Window (Ⓢ in Figure 28)

Load Case Name>**2nd** ; Load Group Name>**2nd**

Options>**Add** ; Load Type>**Uniform Load**

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

Value>**Relative** ; x1 (**0**), x2 (**1**), W (**-3.432**) ↵

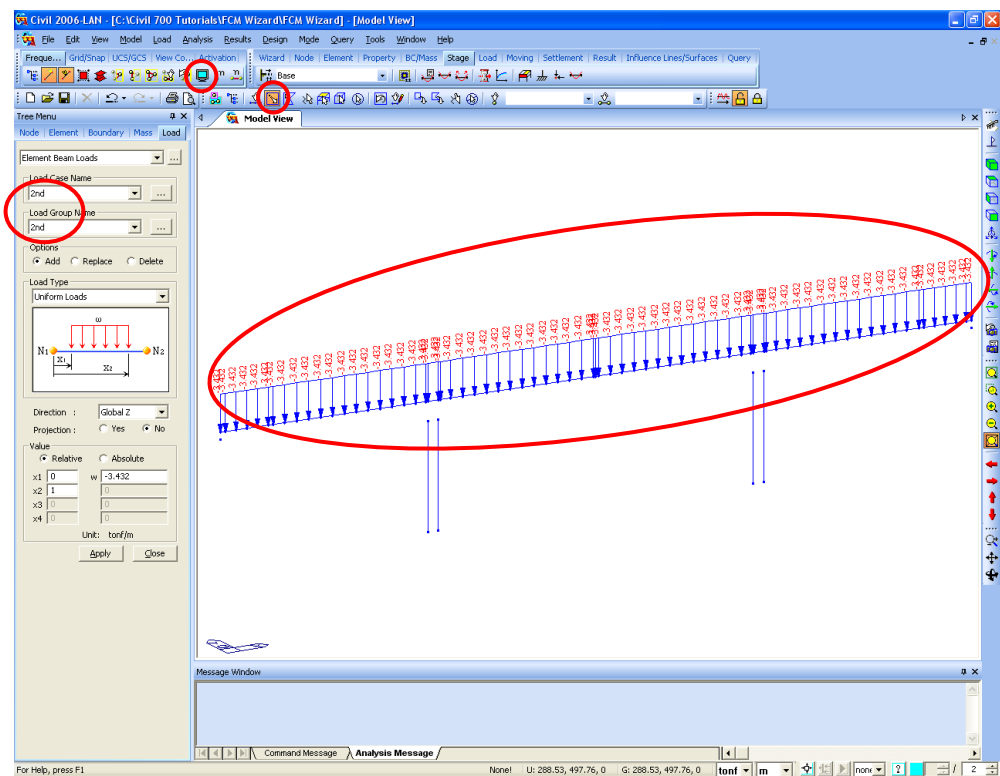


Figure 28. Applying the 2nd dead load

In Stage 16, Load Group "2nd" is activated, and its duration is changed to 10,000 days.

Load / Construction Stage Analysis Data /  **Define Construction Stage**

Name>**CS16** 

Stage>Duration (**10000**)

Load tab

Group List>Name>**2nd**

Activation

Active Day>**First**

 ↵

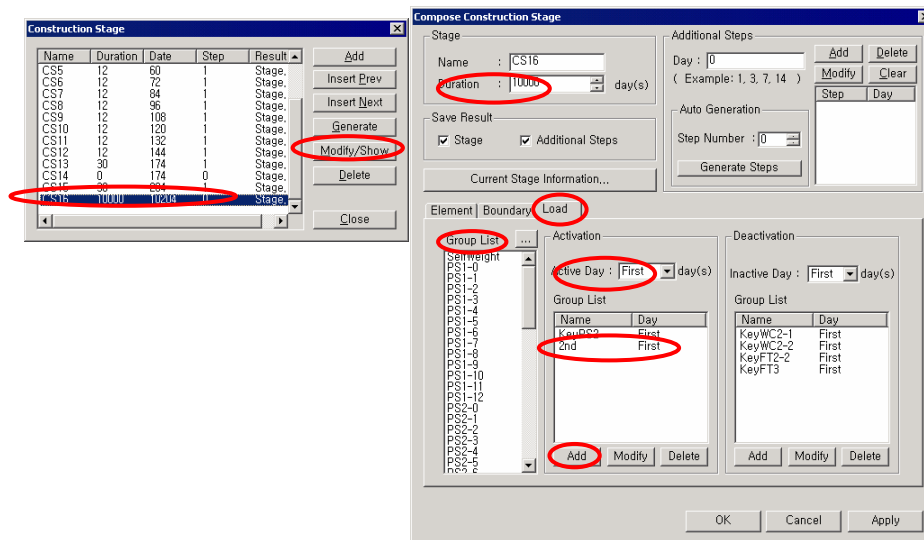


Figure 29. Corrections to Construction Stage 16 information


We will now check the construction stage data input. Activation (symbol “O”) and deactivation (symbol “X”) of Structure, Boundary and Load Groups are summarized.


Query /  Group Activation of Construction Stage


Result-[Group Activation Summary]																													
Group Name	CS1		CS2		CS3		CS4		CS5		CS6		CS7		CS8		CS9		CS1		CS1		CS1		CS1		CS1		
	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	A	T	
Group1-0	o	o			o				o		o		o		o		o		o		o		o		o		o		o
Pier1	o	o			o				o		o		o		o		o		o		o		o		o		o		o
Segment1-1			o	o			o		o		o		o		o		o		o		o		o		o		o		o
Segment1-2					o	o			o		o		o		o		o		o		o		o		o		o		o
Segment1-3							o	o		o		o		o		o		o		o		o		o		o		o	o
Segment1-4									o	o		o		o		o		o		o		o		o		o		o	o
Segment1-5											o	o		o		o		o		o		o		o		o		o	o
Segment1-6													o	o		o		o		o		o		o		o		o	o
Segment1-7															o	o		o		o		o		o		o		o	o
Segment1-8																	o	o		o		o		o		o		o	o
Segment1-9																			o	o		o		o		o		o	o
Segment1-10																					o	o		o		o		o	o
Segment1-11																							o	o		o		o	o
Segment1-12																									o	o		o	o
Group2-0	o	o			o				o		o		o		o		o		o		o		o		o		o		o
Pier2	o	o			o				o		o		o		o		o		o		o		o		o		o		o
Segment2-1			o	o			o		o		o		o		o		o		o		o		o		o		o		o
Segment2-2					o	o			o		o		o		o		o		o		o		o		o		o		o
Segment2-3							o	o		o		o		o		o		o		o		o		o		o		o	o
Segment2-4									o	o		o		o		o		o		o		o		o		o		o	o
Segment2-5											o	o		o		o		o		o		o		o		o		o	o
Segment2-6													o	o		o		o		o		o		o		o		o	o
Segment2-7															o	o		o		o		o		o		o		o	o
Segment2-8																	o	o		o		o		o		o		o	o
Segment2-9																			o	o		o		o		o		o	o
Segment2-10																					o	o		o		o		o	o
Segment2-11																							o	o		o		o	o
Segment2-12																									o	o		o	o
KeySeg1																										o	o		o
KeySeg2																												o	o
KeySeg3																													o
FSM1																													o
FSM2																													o
KeySegAll																													o
BridgeGirder																													o
SupportNode																													o


Figure 30. Structure Group Activation Summary

Definition and Link for time dependent material properties

Having completed the modeling of the structure, we now define the time dependent material properties (compressive strength gain curve, creep and shrinkage coefficients) and link them to each section. 

 Since the creep and shrinkage coefficients are a function of physical shapes (Notational Size of Member), we will define the time dependent material properties after determining the variable section dimensions.

Based on the CEB-FIP standards, different section dimensions result in different creep and shrinkage coefficients. That is, each section must be linked to the corresponding time dependent material properties. MIDAS/Civil automatically calculates time dependent material properties based on the concrete maturity (age) and apply them to the corresponding materials. Using ***Change Element Dependent Material Property***, the time dependent material properties are calculated as per CEB-FIP and automatically assigned to each corresponding element. 

 In order to automatically link (regular) material properties and time dependent material properties, section properties must be defined by DB/User Type or PSC Type.

The procedure for applying creep and shrinkage coefficients to the tapered elements by the ***Change Element Dependent Material Property*** function is as follows:

-
1. Define creep and shrinkage material properties as per CEB-FIP.
 2. Link time dependent material properties to (regular) material properties.
 3. Using the ***Change Element Dependent Material Property*** function, assign Notational Size of Member (dimensions of elements) to the elements.
-

When the above procedure is followed, the coefficients defined in the step 1 are not applied, and rather the creep and coefficients are calculated based on the member sizes defined in the step 3 and applied to the elements having the ***Change Element Dependent Material Property*** values.

Time dependent material properties are defined using the following values.

- 28 day strength: $f_{ck} = 400 \text{ kgf/cm}^2$ (PSC box girder), 270 kgf/cm^2 (pier)
- Relative humidity: RH = 70 %
- Notational Size: specify an arbitrary value (the above step 3 overrides this)
- Type of concrete: Normal concrete (N, R)
- Time at which formwork is removed: 3 days

28 day strength is converted into the current unit system.

Model / Properties / Time Dependent Material (Creep/Shrinkage)

Name **(C400)** ; Code>**CEB-FIP**

Compressive strength of concrete at the age of 28 days **(4000)**

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

Notational size of member **(1)**

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

Age of concrete at which shrinkage begins to take place **(3)**

Name **(C270)** ; Code>**CEB-FIP**

Compressive strength of concrete at the age of 28 days **(2700)**

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

Notational size of member **(1)**

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

Age of concrete at which shrinkage begins to take place **(3)**

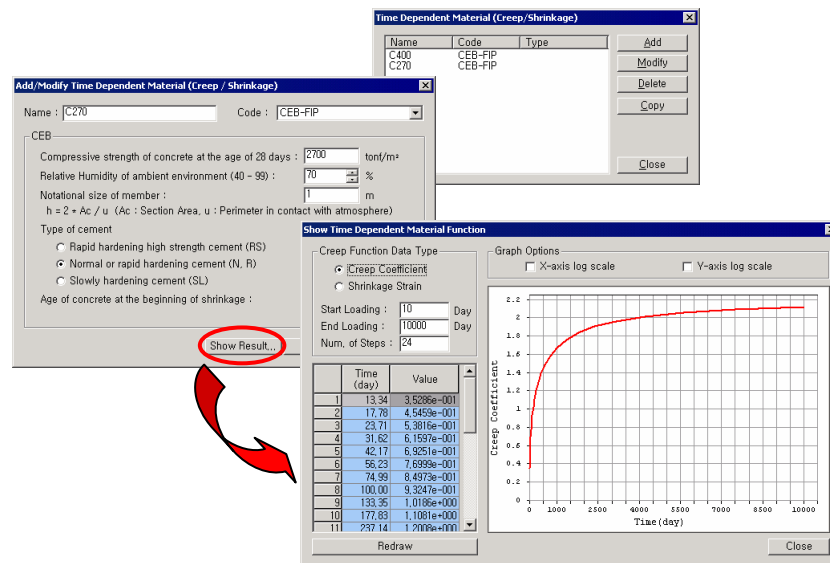


Figure 31. Definition of creep and shrinkage material properties

The curve for gain in concrete strength is defined for each grade of concrete. Such strength changes affect the modulus of elasticity. CEB-FIP code is used. Also the values used for defining creep and shrinkage are entered for defining concrete strength.

Model / Properties /  **Time Dependent Material (Comp. Strength)**

Name **(C400)** ; Type>**Code**

Development of Strength>Code>**CEB-FIP**

Concrete Compressive Strength at 28 Days **(4000)**

Cement Type(s) **(N, R : 0.25)**  ↵

Model / Properties /  **Time Dependent Material (Comp. Strength)**

Name **(C270)** ; Type>**Code**

Development of Strength>Code>**CEB-FIP**

Concrete Compressive Strength at 28 Days **(2700)**

Cement Type(s) **(N, R : 0.25)**  ↵

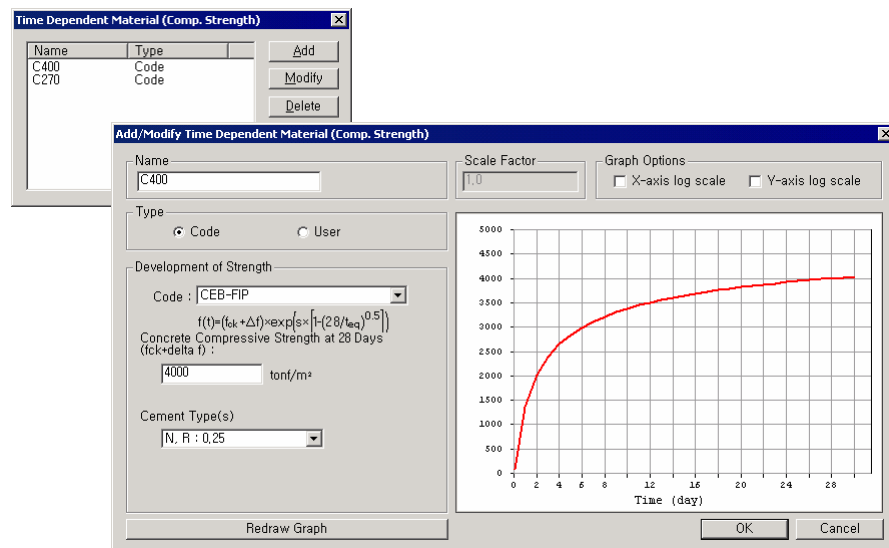


Figure 32. Definition of strength gain curve

The time dependent material properties (which are used in construction stages) are linked to the (regular) material properties (which are used in post construction stages).

Model / Properties / **Time Dependent Material Link**

Time Dependent Material Type

Creep/Shrinkage>**C400**

Comp. Strength>**C400**

Select Material for Assign>Materials>

1:C400 > Selected Materials Add / Modify

Time Dependent Material Type

Creep/Shrinkage>**C270**

Comp. Strength>**C270**

Select Material for Assign>Materials>

2:C270 > Selected Materials Add / Modify

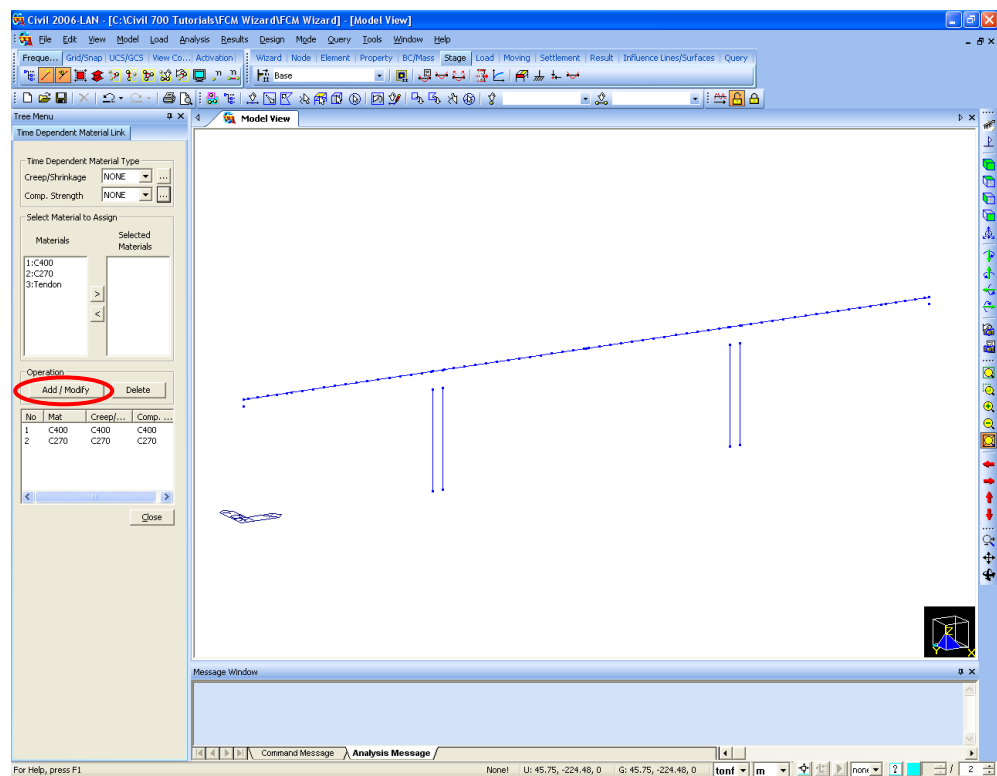


Figure 33. Time dependent and regular material properties link

When Notational Size of Member, h , is defined in **Change Element Dependent Material Property**, the “ h ” value that was defined in Time Dependent Material (Creep/Shrinkage) is ignored. New creep and shrinkage functions are calculated based on the “ h ” values defined in **Change Element Dependent Material Property** and are assigned to individual elements.

Selecting “Auto Calculate” automatically calculates the “ h ” values for all the selected elements, which are applied to the calculation of creep and shrinkage. Selecting “Input” allows us to specify user-defined “ h ” values for selected elements.

Model / Properties /  **Change Element Dependent Material Property**

 **Select all**

Option>**Add/Replace**

Element Dependent Material

Notational Size of Member>**Auto Calculate**  ↵

Code>**CEB-FIP** ↵

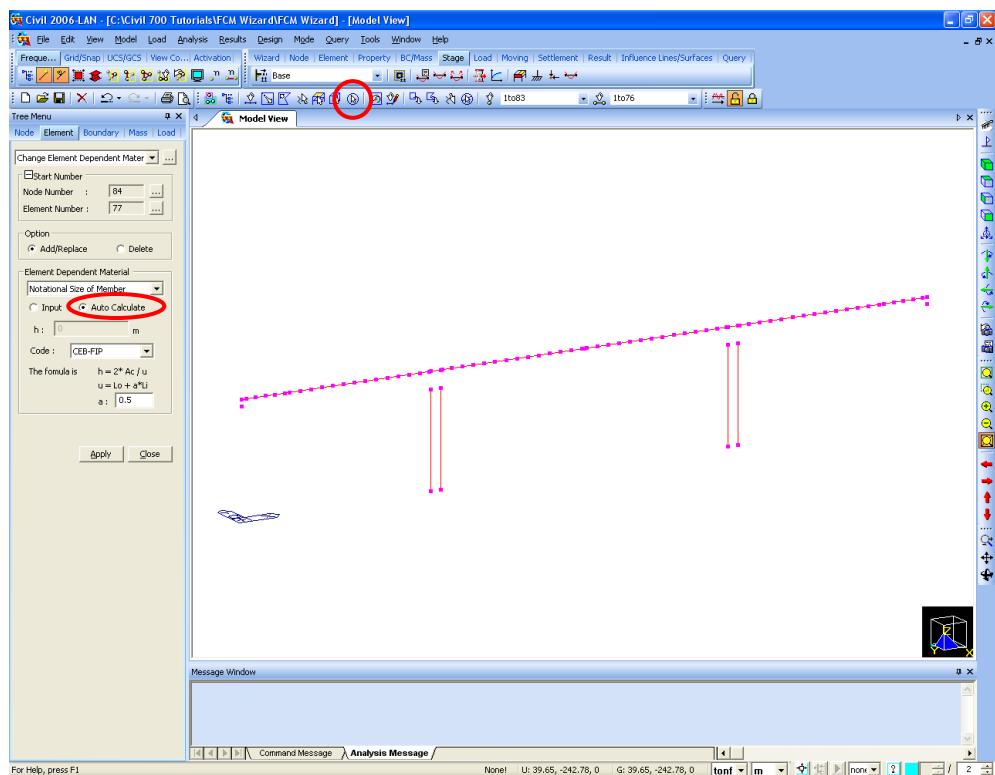





Figure 34. Input for Notational Size of Member, h

Removal of Tapered Section Groups

FCM Wizard creates **Tapered Section Group** for non-prismatic elements. The **Tapered Section Group** function automatically calculates the section properties of the varying element sections based on the section information at both ends of a member. MIDAS/Civil calculates all the section properties of the elements assigned in Tapered Section Group prior to performing analysis and retains the section data for analysis. Hence, it is recommended to remove Tapered Section Group prior to performing analysis, to save time.

🔊 Select TSGroup1~4 in the list box at the bottom.

🔊 Enter the starting number for newly created tapered section data as a result of removal of Tapered Section Groups.

Model / Properties /  **Tapered Section Group**
 Name>TSGroup1 ~ 4  Convert to Tapered Section...
 New Start Section Number (1) 

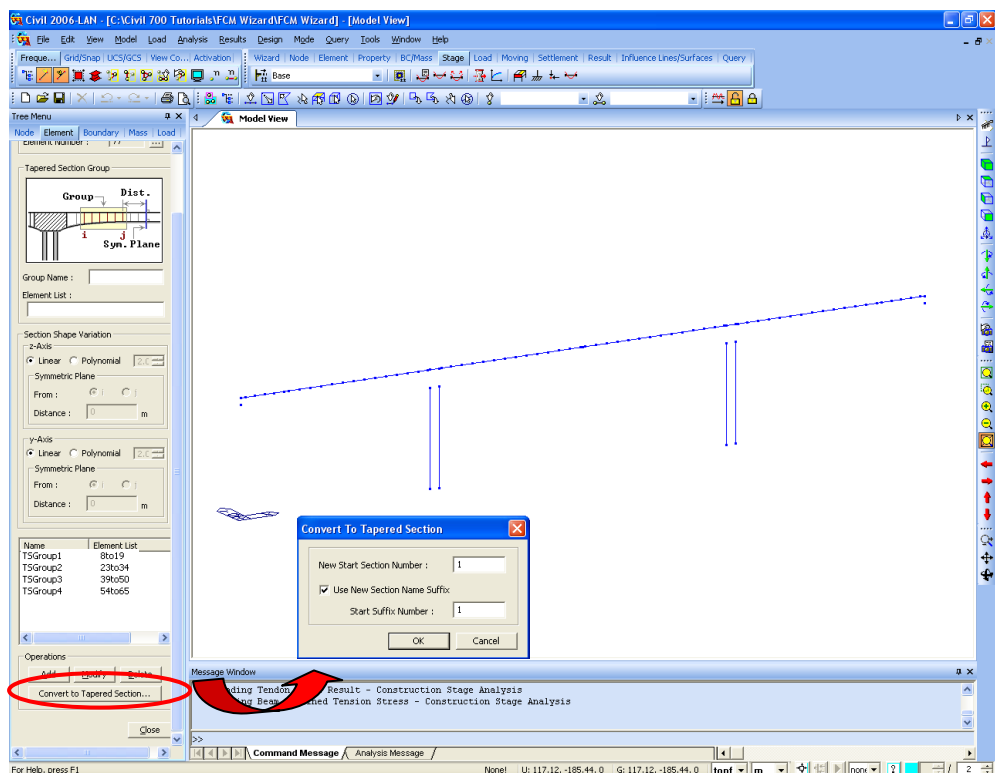


Figure 35. Removal of Tapered Section Group

Performing Structural Analysis

Having completed defining the structural model and construction stages, we now select the options to consider time dependent material properties and tension losses in tendons for construction stage analysis. We also define the convergence and iteration conditions for creep.

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**)

Auto Time Step Generation for Large Time Gap (on) 


Tendon Tension Loss Effect (Creep & Shrinkage) (on)


Variation of Comp. Strength (on)


Tendon Tension Loss Effect (Elastic Shortening) (on)

Beam Section Property Changes>**Change with Tendon** 

Save Output of Current Stage (Beam/Truss) (on)  

 If “Auto Time Step Generation” for Large Time Gap is checked on, additional time steps will be generated for those stages having duration beyond the specified periods to reflect long term effects.

 If “Change with Tendon” is checked on, the stiffness change in tendons is reflected in calculating construction stage stresses.

 If Save Output of Current Stage (Beam/Truss) is checked on, member forces at the current stage can be separately checked.

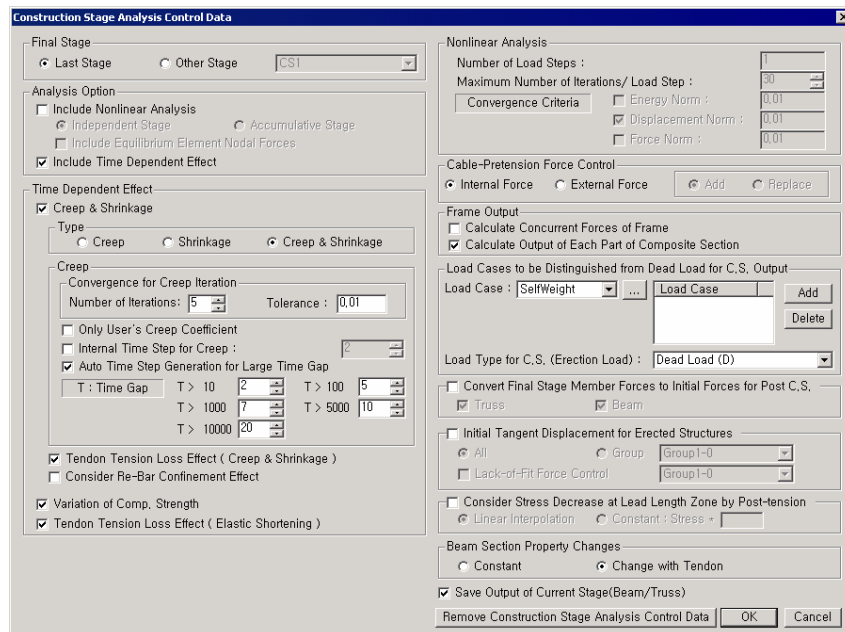


Figure 36. Definition of control parameters for construction stage analysis

When construction stage analysis is carried out, construction stage load cases are automatically generated. The loadings that are applied in construction stages are predominantly due to self-weight. Hence, the program generates all the loads lumped into "CS: Dead", except for creep, shrinkage and tendon loads. If there is a specific load case which needs to be separated from the "CS: Dead", such a load case is selected and assigned to "Load Cases to be Distinguished from Dead Load for CS Output", which is then classified as CS: Erection. For example, this function may be applied when we need to separately check the effects of form traveler loads from the total stage analysis results.

Up to this point we have completed all the input for the structural model and construction stages. We will now perform analysis.

Analysis /  **Perform Analysis**

Checking Analysis Results

Refer to Using MIDAS/Civil > Results > Bridge Girder Diagrams in the On-line manual.

Refer to Using MIDAS/Civil > Results > Stage/Step History Graph in the On-line manual.

Construction stage analysis results can be checked in two ways. Stresses and displacements accumulated up to a specific construction stage for all the members can be checked, or the change in stresses and displacements of a specific element can be checked with the progress of each construction stage. MIDAS/Civil generates graphs and tables to check both results.

Checking stresses and member forces by graphs

We will review the stresses at the section bottom at the stage 13 where the largest compressive stress occurs.

In MSS/FSM Wizards, Structure Groups for section stress checks are automatically generated. Bridge Girder is an element group to which the main girder is assigned.

Check on the Draw Allowable Stress Line and enter allowable compressive and tensile stresses whose values are displayed in dotted lines on the stress graph.

Stage>**CS13**

Results / **Bridge Girder Diagrams**

Load Cases/Combinations>Step List>**First Step, User Step** (on)

Load Cases/Combinations>**CS: Summation** ; Diagram Type>**Stress**

X-Axis Type>**Node** ; Bridge Girder Elem. Group>**Bridge Girder**

Components>**Combined**

Combined (Axial + Moment)>**Maximum**

Allowable Stress Line> **Draw Allowable Stress Line** (on)

>Comp. (1600) ; Tens. (320)

Generation Option>**Current Stage-Step**

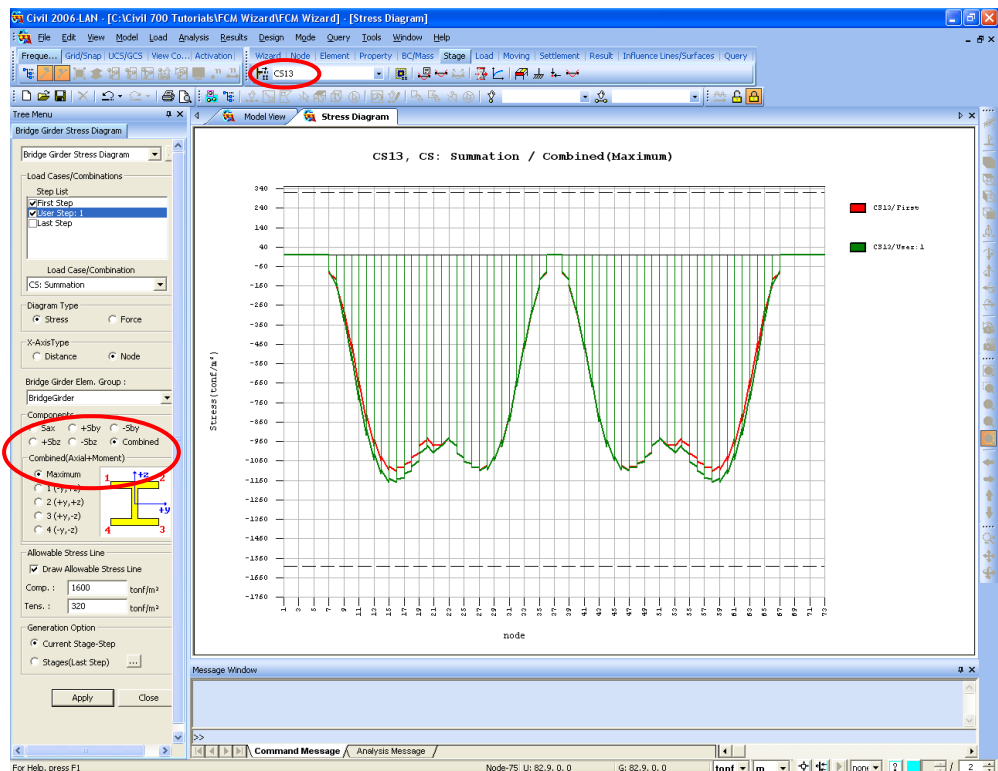


Figure 37. Bottom stress graph at the construction stage 13

If any specific area of the graph needs to be magnified, drag the mouse on that area, keeping the mouse button clicked. To revert back to the entire graph, right-click the mouse and select “Zoom-Out All”.

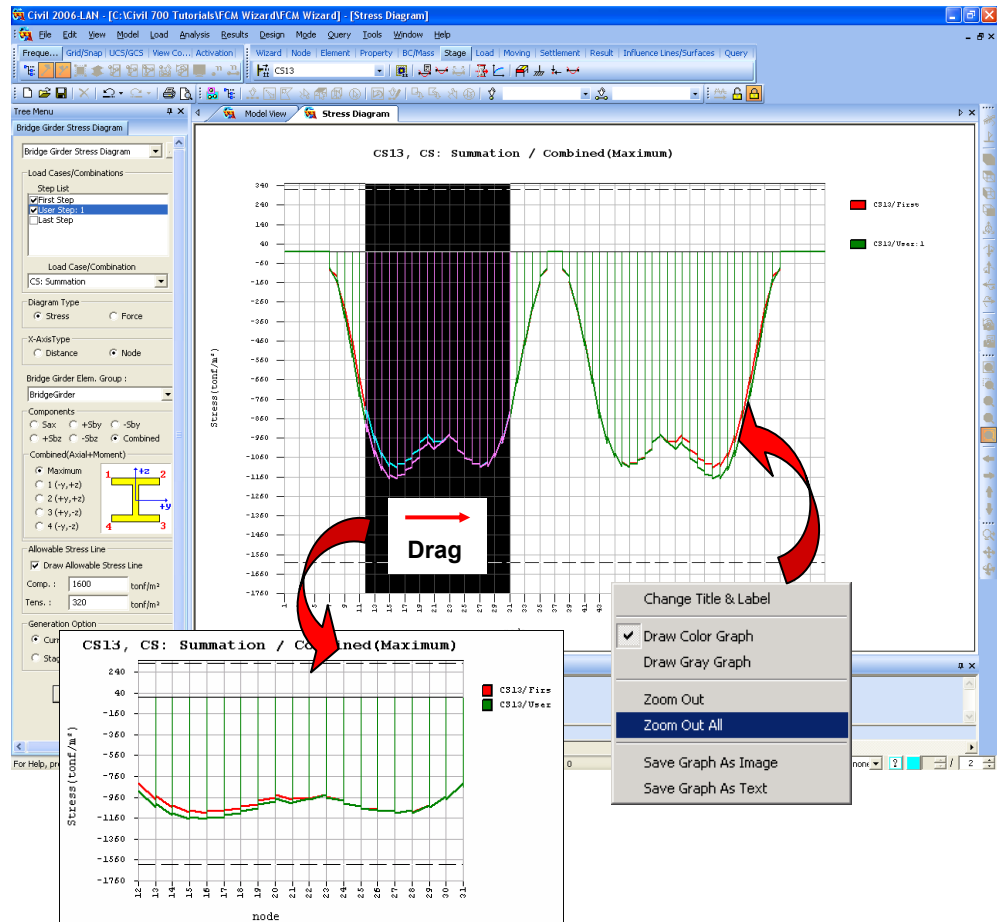


Figure 38. Magnifying the stress graph

Using the **Stage/Step History Graph**, we will check the change of stresses with construction stages for the pier table (element 19, i-end) on a graph.

Stage/Step History Graph can be viewed only when the Model View is active.

Model View

Results / **Stage/Step History Graph**

Define Function>**Beam Force/Stress**

Add New Function

Beam Force/Stress>Name (**Top**) ; Element No. (**19**) ; Stress (on)

Point>**I-Node** ; Components>**Bend(+z)**

Combine Axial (on) ↓

Beam Force/Stress>Name (**Bot**) ; Element No. (**19**) ; Stress (on)

Point>**I-Node** ; Components>**Bend(-z)**

Combine Axial (on) ↓

Mode>**Multi Func.** ; Step Option>**All Steps** ; X-Axis>**Stage/Step**

Check Function to Plot>**Top** (on) ; **Bot** (on)

Load Cases/Combinations>**Summation**

Graph Title (**Stress History**)

Graph

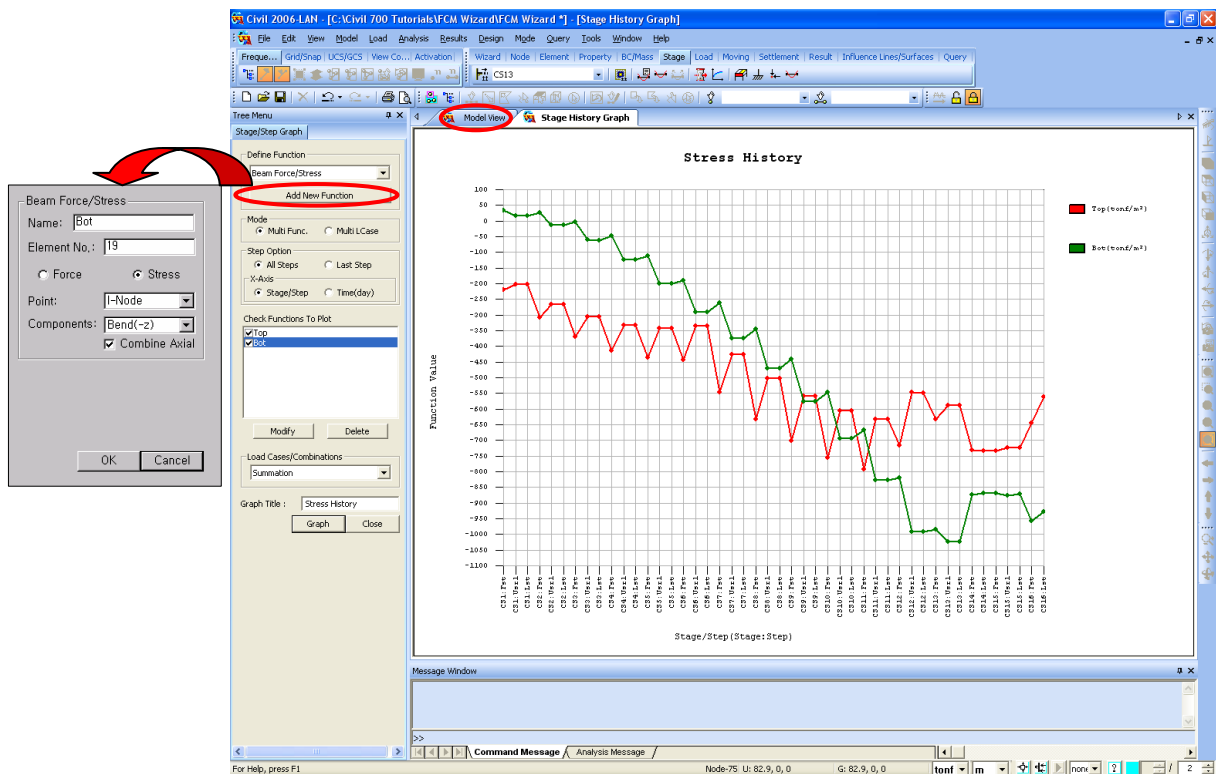


Figure 39. Graph showing the change of stresses by construction stages

Invoke the Context Menu in the **Stage/Step History Graph** by right-clicking the mouse. Select **Save Graph As Text** in the Context Menu and save the change in stresses in text form.

Save Graph As Text

File name (N) (Stress History)

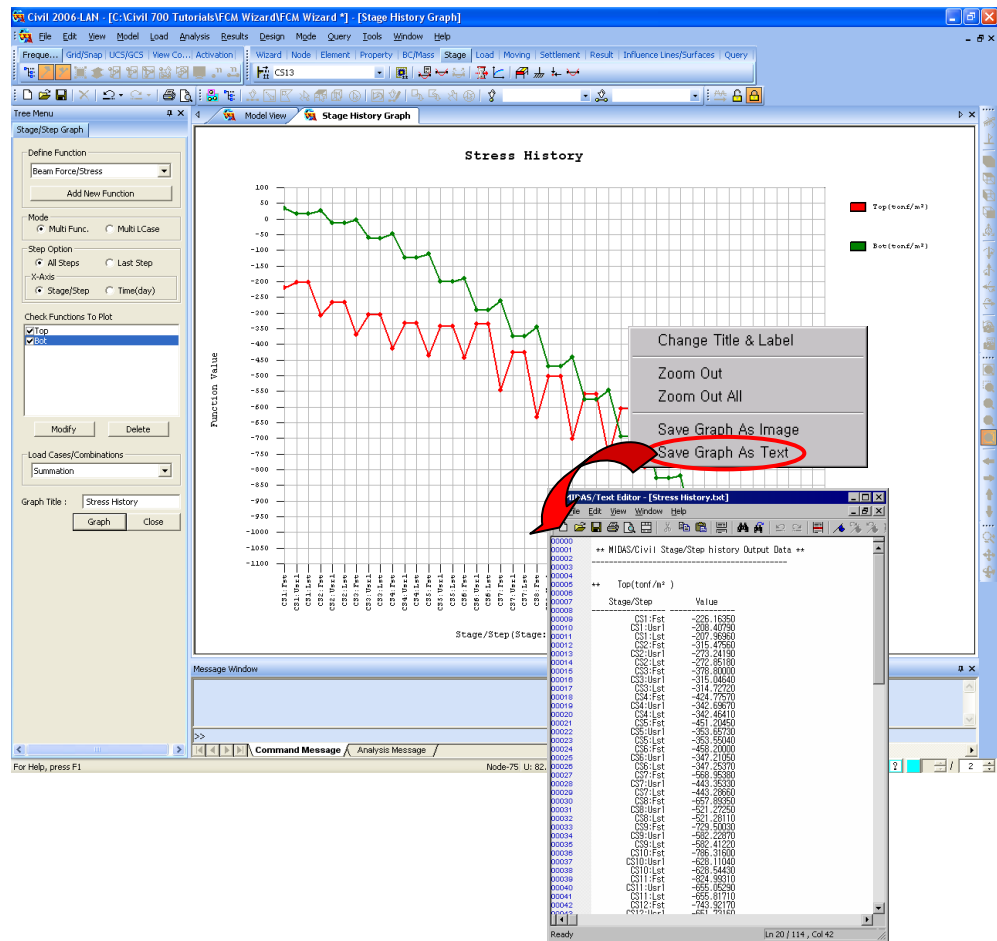


Figure 40. Saving stresses by construction stages as a text format

Using **Stage/Step History Graph**, we will now check the change in member forces by construction stages for the pier table (element 19, i-end) on a graph.

Model View

Results / **Stage/Step History Graph**

Define Function>**Beam Force/Stress**

Add New Function

Beam Force/Stress>Name (**Moment**) ; Element No. (**19**) ; Force (on)

Point>**I-Node** ; Components>**Moment-y** ↵

Mode>**Multi LCase**

Step Option>**Last Step** ; X-Axis>**Stage/Step**

Check Load Cases to Plot

Dead Load (on) ; **Erection Load** (on) ; **Tendon Primary** (on)

Tendon Secondary (on) ; **Creep Primary** (on)

Shrinkage Primary (on) ; **Creep Secondary** (on)

Shrinkage Secondary (on) ; **Summation** (on)

Defined Functions>**Moment**

Graph Title (**Moment**)

Graph ↵

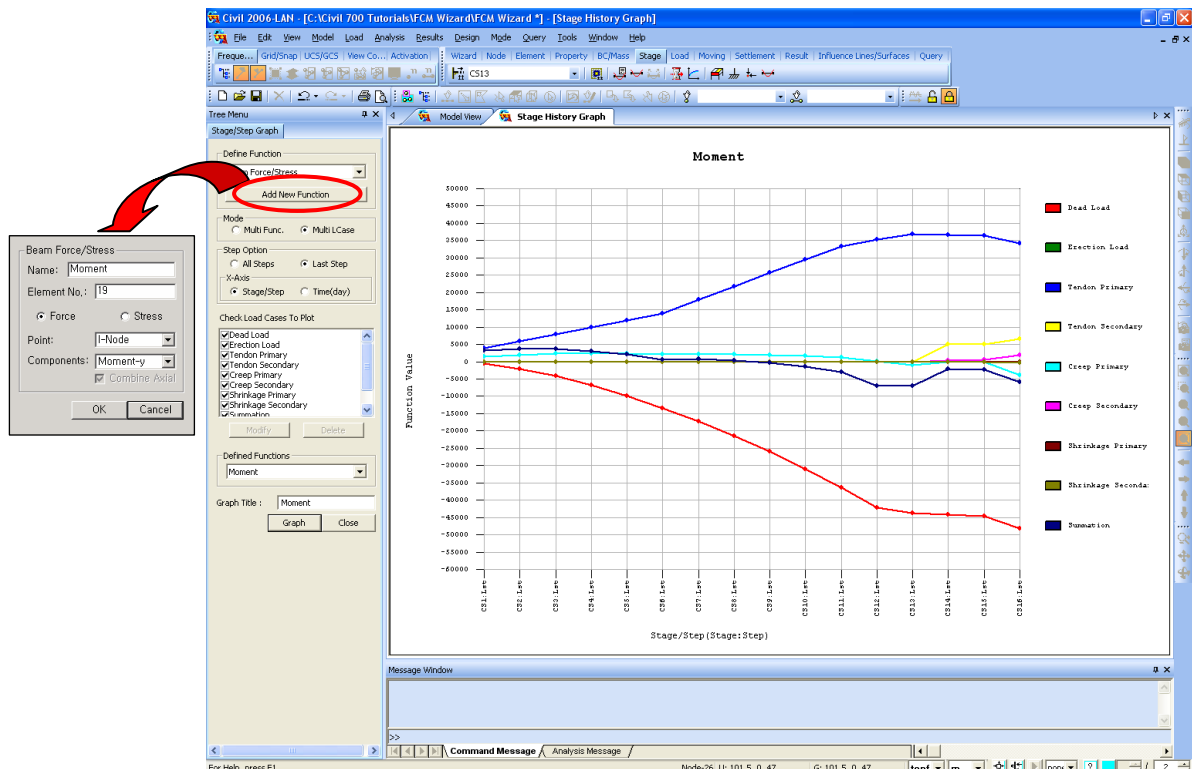



Figure 41. Graph showing the change in forces by construction stages

Checking stresses using tables.


When construction stage analysis results are checked in tables, **Records Activation Dialog** is used to sort the results by elements, load cases, stages, element parts of interest, etc. We will check the change in stresses with construction stages at the end of a pier table.


By selecting CS1 and CS16 while the Shift key is pressed, we can select all the construction stages from CS1 to CS16.

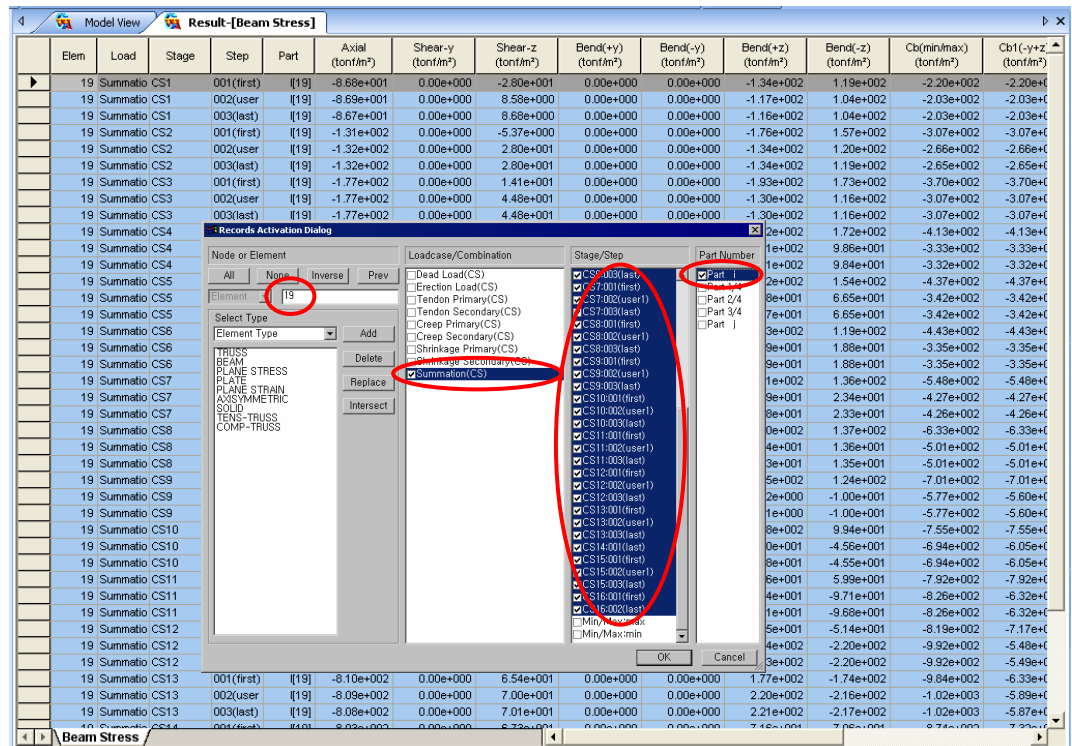
Results / Results Table / Beam /  **Stress**

Node or Element>Element (19)

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

Stage/Step>**CS1:001(first) ~ CS16:002(last)** (on) 

Part Number>**Part i** (on) 



The screenshot shows the 'Records Activation Dialog' window overlaid on a table of stress results. The dialog has several tabs: 'All', 'None', 'Inverse', and 'Prev'. The 'All' tab is selected. In the 'Loadcase/Combination' section, 'Summation(CS)' is checked. In the 'Stage/Step' section, 'CS1:001(first)' and 'CS16:002(last)' are selected. In the 'Part Number' section, 'Part i' is selected. The background table shows stress results for various elements (19) across different construction stages (CS1 to CS16). The table columns include: Elem, Load, Stage, Step, Part, Axial (tonf/m²), Shear-y (tonf/m²), Shear-z (tonf/m²), Bend(+y) (tonf/m²), Bend(-y) (tonf/m²), Bend(+z) (tonf/m²), Bend(-z) (tonf/m²), Cb(min/max) (tonf/m²), and Cb1(-y+z) (tonf/m²). The table data is as follows:

Elem	Load	Stage	Step	Part	Axial (tonf/m²)	Shear-y (tonf/m²)	Shear-z (tonf/m²)	Bend(+y) (tonf/m²)	Bend(-y) (tonf/m²)	Bend(+z) (tonf/m²)	Bend(-z) (tonf/m²)	Cb(min/max) (tonf/m²)	Cb1(-y+z) (tonf/m²)
19	Summatio	CS1	001(first)	[19]	-8.69e+001	0.00e+000	-2.80e+001	0.00e+000	0.00e+000	-1.34e+002	1.19e+002	-2.20e+002	-2.20e+002
19	Summatio	CS1	002(user)	[19]	-8.69e+001	0.00e+000	8.59e+000	0.00e+000	0.00e+000	-1.17e+002	1.04e+002	-2.03e+002	-2.03e+002
19	Summatio	CS1	003(last)	[19]	-8.67e+001	0.00e+000	8.69e+000	0.00e+000	0.00e+000	-1.16e+002	1.04e+002	-2.03e+002	-2.03e+002
19	Summatio	CS2	001(first)	[19]	-1.31e+002	0.00e+000	-5.37e+000	0.00e+000	0.00e+000	-1.76e+002	1.57e+002	-3.07e+002	-3.07e+002
19	Summatio	CS2	002(user)	[19]	-1.32e+002	0.00e+000	2.80e+001	0.00e+000	0.00e+000	-1.34e+002	1.20e+002	-2.66e+002	-2.66e+002
19	Summatio	CS2	003(last)	[19]	-1.32e+002	0.00e+000	2.80e+001	0.00e+000	0.00e+000	-1.34e+002	1.19e+002	-2.65e+002	-2.65e+002
19	Summatio	CS3	001(first)	[19]	-1.77e+002	0.00e+000	1.41e+001	0.00e+000	0.00e+000	-1.93e+002	1.73e+002	-3.70e+002	-3.70e+002
19	Summatio	CS3	002(user)	[19]	-1.77e+002	0.00e+000	4.48e+001	0.00e+000	0.00e+000	-1.30e+002	1.16e+002	-3.07e+002	-3.07e+002
19	Summatio	CS3	003(last)	[19]	-1.77e+002	0.00e+000	4.48e+001	0.00e+000	0.00e+000	-1.30e+002	1.16e+002	-3.07e+002	-3.07e+002
19	Summatio	CS4											
19	Summatio	CS4											
19	Summatio	CS4											
19	Summatio	CS5											
19	Summatio	CS5											
19	Summatio	CS5											
19	Summatio	CS6											
19	Summatio	CS6											
19	Summatio	CS6											
19	Summatio	CS7											
19	Summatio	CS7											
19	Summatio	CS7											
19	Summatio	CS8											
19	Summatio	CS8											
19	Summatio	CS8											
19	Summatio	CS9											
19	Summatio	CS9											
19	Summatio	CS9											
19	Summatio	CS10											
19	Summatio	CS10											
19	Summatio	CS10											
19	Summatio	CS11											
19	Summatio	CS11											
19	Summatio	CS11											
19	Summatio	CS12											
19	Summatio	CS12											
19	Summatio	CS12											
19	Summatio	CS13	001(first)	[19]	-8.10e+002	0.00e+000	6.54e+001	0.00e+000	0.00e+000	1.77e+002	-1.74e+002	-9.84e+002	-6.33e+002
19	Summatio	CS13	002(user)	[19]	-8.09e+002	0.00e+000	7.00e+001	0.00e+000	0.00e+000	2.20e+002	-2.16e+002	-1.02e+003	-5.89e+002
19	Summatio	CS13	003(last)	[19]	-8.08e+002	0.00e+000	7.01e+001	0.00e+000	0.00e+000	2.21e+002	-2.17e+002	-1.02e+003	-5.87e+002
19	Summatio	CS14											
19	Summatio	CS14											
19	Summatio	CS14											
19	Summatio	CS15											
19	Summatio	CS15											
19	Summatio	CS15											
19	Summatio	CS16											
19	Summatio	CS16											
19	Summatio	CS16											

Figure 42. Table showing stresses by construction stages

Checking prestress losses.

We will check the change in tension with construction stages due to prestress losses. In the **Tendon Time Dependent Loss Graph** dialog, only the tendons which exist in the current stage, can be checked. Hence, it is necessary to revert to the construction stage in which the tendon intended to be examined is included. For viewing the change of tension in a tendon with construction stages, click **Animate**.

Results / **Tendon Time-dependent Loss Graph**

Tendon>Top01-01

Animate

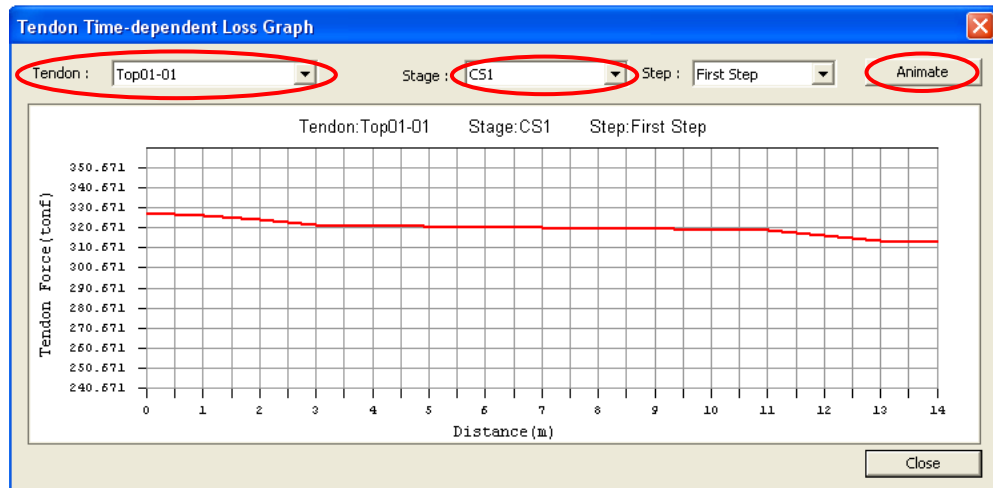
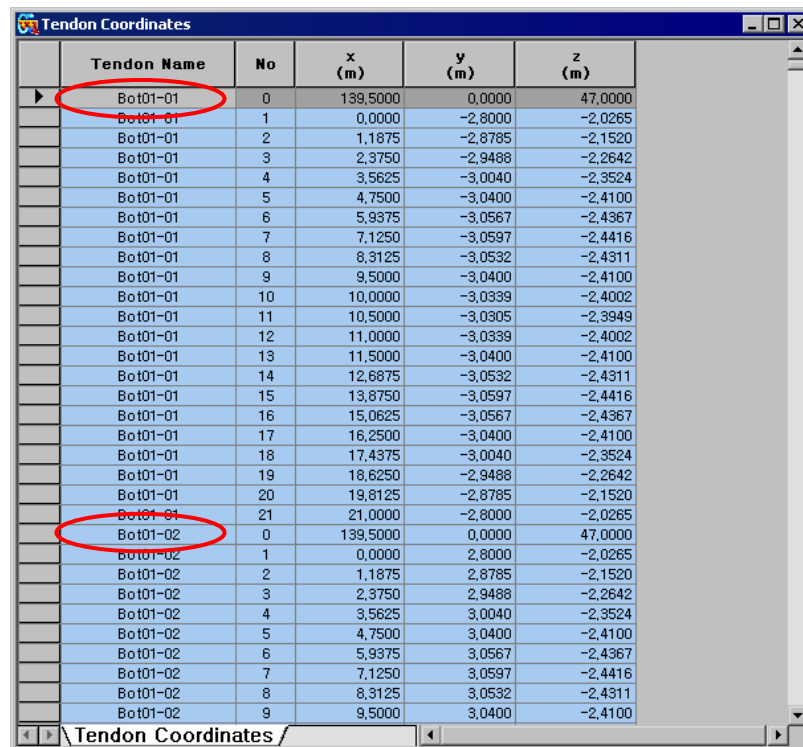


Figure 43. Prestress loss graph

Checking tendon coordinates.

MIDAS/Civil provides the coordinates of tendons at the quarter points of the elements to which tendons are assigned.

Results / Result Tables / Tendon / **Tendon Coordinates**



Tendon Name	No	x (m)	y (m)	z (m)
Bot01-01	0	139,5000	0,0000	47,0000
Bot01-01	1	0,0000	-2,8000	-2,0265
Bot01-01	2	1,1875	-2,8785	-2,1520
Bot01-01	3	2,3750	-2,9488	-2,2642
Bot01-01	4	3,5625	-3,0040	-2,3524
Bot01-01	5	4,7500	-3,0400	-2,4100
Bot01-01	6	5,9375	-3,0567	-2,4367
Bot01-01	7	7,1250	-3,0597	-2,4416
Bot01-01	8	8,3125	-3,0532	-2,4311
Bot01-01	9	9,5000	-3,0400	-2,4100
Bot01-01	10	10,0000	-3,0339	-2,4002
Bot01-01	11	10,5000	-3,0305	-2,3949
Bot01-01	12	11,0000	-3,0339	-2,4002
Bot01-01	13	11,5000	-3,0400	-2,4100
Bot01-01	14	12,6875	-3,0532	-2,4311
Bot01-01	15	13,8750	-3,0597	-2,4416
Bot01-01	16	15,0625	-3,0567	-2,4367
Bot01-01	17	16,2500	-3,0400	-2,4100
Bot01-01	18	17,4375	-3,0040	-2,3524
Bot01-01	19	18,6250	-2,9488	-2,2642
Bot01-01	20	19,8125	-2,8785	-2,1520
Bot01-01	21	21,0000	-2,8000	-2,0265
Bot01-02	0	139,5000	0,0000	47,0000
Bot01-02	1	0,0000	2,8000	-2,0265
Bot01-02	2	1,1875	2,8785	-2,1520
Bot01-02	3	2,3750	2,9488	-2,2642
Bot01-02	4	3,5625	3,0040	-2,3524
Bot01-02	5	4,7500	3,0400	-2,4100
Bot01-02	6	5,9375	3,0567	-2,4367
Bot01-02	7	7,1250	3,0597	-2,4416
Bot01-02	8	8,3125	3,0532	-2,4311
Bot01-02	9	9,5000	3,0400	-2,4100

Figure 44. Table of tendon coordinates

Checking tendon elongation.

Check the tendon elongations in a table.

Results / Result Tables / Tendon / **Tendon Elongation**

Tendon Elongation									
	Tendon Name	Stage	Step	Tendon Elongation		Element Elongation		Summation	
				Begin (m)	End (m)	Begin (m)	End (m)	Begin (m)	End (m)
▶	Bot01-01	CS16	001(first)	0.0000	0.1316	0.0000	0.0002	0.0000	0.1318
	Bot01-02	CS16	001(first)	0.1316	0.0000	0.0002	0.0000	0.1318	0.0000
	Bot01-03	CS16	001(first)	0.1324	0.0060	0.0002	0.0000	0.1327	0.0060
	Bot01-04	CS16	001(first)	0.1324	0.0060	0.0002	0.0000	0.1327	0.0060
	Bot01-05	CS16	001(first)	0.1880	0.0061	0.0003	0.0000	0.1884	0.0061
	Bot01-06	CS16	001(first)	0.1880	0.0061	0.0003	0.0000	0.1884	0.0061
	Bot01-07	CS16	001(first)	0.2455	0.0069	0.0004	0.0000	0.2459	0.0069
	Bot01-08	CS16	001(first)	0.2455	0.0069	0.0004	0.0000	0.2459	0.0069
	Bot01-09	CS16	001(first)	0.3005	0.0090	0.0005	0.0000	0.3010	0.0090
	Bot01-10	CS16	001(first)	0.3005	0.0090	0.0005	0.0000	0.3010	0.0090
	Bot01-11	CS16	001(first)	0.3519	0.0119	0.0006	0.0000	0.3525	0.0119
	Bot01-12	CS16	001(first)	0.3519	0.0119	0.0006	0.0000	0.3525	0.0119
	Bot01-13	CS16	001(first)	0.4000	0.0156	0.0006	0.0000	0.4006	0.0156
	Bot01-14	CS16	001(first)	0.4000	0.0156	0.0006	0.0000	0.4006	0.0156
	Bot01-15	CS16	001(first)	0.4449	0.0196	0.0007	0.0000	0.4456	0.0196
	Bot01-16	CS16	001(first)	0.4449	0.0196	0.0007	0.0000	0.4456	0.0196
	Bot01-17	CS16	001(first)	0.4397	0.0202	0.0007	0.0000	0.4404	0.0203
	Bot01-18	CS16	001(first)	0.4397	0.0202	0.0007	0.0000	0.4404	0.0203
	FSMBot1-01	CS14	001(first)	0.0000	0.1899	0.0000	0.0003	0.0000	0.1902
	FSMBot1-02	CS14	001(first)	0.0000	0.1899	0.0000	0.0003	0.0000	0.1902
	FSMBot1-03	CS14	001(first)	0.0000	0.2213	0.0000	0.0004	0.0000	0.2217
	FSMBot1-04	CS14	001(first)	0.0000	0.2213	0.0000	0.0004	0.0000	0.2217
	FSMBot1-05	CS14	001(first)	0.0000	0.2452	0.0000	0.0004	0.0000	0.2456
	FSMBot1-06	CS14	001(first)	0.0000	0.2452	0.0000	0.0004	0.0000	0.2456
	FSMBot1-07	CS14	001(first)	0.0000	0.2736	0.0000	0.0005	0.0000	0.2741
	FSMBot1-08	CS14	001(first)	0.0000	0.2736	0.0000	0.0005	0.0000	0.2741
	FSMBot1-09	CS14	001(first)	0.0000	0.2876	0.0000	0.0005	0.0000	0.2881
	FSMBot1-10	CS14	001(first)	0.0000	0.2876	0.0000	0.0005	0.0000	0.2881
	FSMBot1-11	CS14	001(first)	0.0000	0.2874	0.0000	0.0005	0.0000	0.2879
	FSMBot1-12	CS14	001(first)	0.0000	0.2874	0.0000	0.0005	0.0000	0.2879
	FSMBot1-13	CS14	001(first)	0.0000	0.2862	0.0000	0.0005	0.0000	0.2866
	FSMBot1-14	CS14	001(first)	0.0000	0.2862	0.0000	0.0005	0.0000	0.2866
	FSMBot2-01	CS14	001(first)	0.0000	0.1899	0.0000	0.0003	0.0000	0.1902
	FSMBot2-02	CS14	001(first)	0.0000	0.1899	0.0000	0.0003	0.0000	0.1902
	FSMBot2-03	CS14	001(first)	0.0000	0.2213	0.0000	0.0004	0.0000	0.2217
	FSMBot2-04	CS14	001(first)	0.0000	0.2213	0.0000	0.0004	0.0000	0.2217
	FSMBot2-05	CS14	001(first)	0.0000	0.2452	0.0000	0.0004	0.0000	0.2456
	FSMBot2-06	CS14	001(first)	0.0000	0.2452	0.0000	0.0004	0.0000	0.2456

Figure 45. Tendon elongation table

Checking tendon arrangement.

Effective prestress and prestress forces in tendons are tabulated as per tendon groups and construction stages.

The distance from the center of tendon group to the section centroid, directional cosine of tendon placement, vertical and horizontal components of tendon forces, etc. are tabulated.

Results / Result Tables / Tendon / **Tendon Arrangement**

4

Model View

Result-[Tendon Arrangement (Tendon Group)]

Elem	Part	Tendon Number	Yp (m)	Zp (m)	Average Sin Theta (deg)	Average Cos Theta (deg)	Average Stress (tonf/m ²)	Average Force (tonf)
The arrangement data for tendon group [Top-P 1-1] at the stage of [CS1]								
Tendon Group		Top-P 1-1	Stage		CS1	Apply		
7 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19 I		0	-3.3250	3.0213	0.1283	0.9917	119896.9066	315.9643
19 J		0	-3.3250	3.5389	0.1283	0.9917	120099.6952	316.4987
20 I		0	-3.3250	3.5389	0.0000	1.0000	120109.3012	316.5240
20 J		0	-3.3250	3.5389	0.0000	1.0000	120161.3746	316.6613
21 I		0	-3.3250	3.5389	0.0000	1.0000	120161.2052	316.6608
21 J		0	-3.3250	3.5389	0.0000	1.0000	120161.2052	316.6608
22 I		0	-3.3250	3.5389	0.0000	1.0000	120161.3746	316.6613
22 J		0	-3.3250	3.5389	0.0000	1.0000	120109.3012	316.5240
23 I		0	-3.3250	3.5389	-0.1283	-0.9917	120099.6952	316.4987
23 J		0	-3.3250	3.0213	-0.1283	-0.9917	119896.9066	315.9643
24 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24 J		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
25 I		0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Tendon Arrangement (Tendon Group)

Figure 46. Tendon arrangement table

Checking pretension losses in tendons.

Tension losses due to friction, anchorage draw-in, elastic shortening, creep, shrinkage and relaxation are generated.

Results / Result Tables / Tendon / **Tendon Loss**


Elem	Part	Stress (Immediate Loss) (tonf/m ²)	Elastic Deform. Loss (tonf/m ²)	Stress(Elastic Loss)/ Stress (Immediate Loss)	Creep/Shrinkage Loss (tonf/m ²)	Relaxation Loss (tonf/m ²)	Stress(All Loss)/ Stress(Immediate Loss)	Effective Num.
The Loss of tendon group [Top-P 1-1] at the stage of [CS1]								
Tendon Group		Top-P 1-1	Stage	CS1	Apply			
7 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19 I		121665.8325	93.5209	1.0008	-571.8353	-1290.6115	0.9855	2.0000
19 J		121693.7195	207.9387	1.0017	-511.0556	-1290.9074	0.9869	2.0000
20 I		121693.7195	216.3416	1.0018	-509.8525	-1290.9074	0.9870	2.0000
20 J		121694.0184	243.3548	1.0020	-485.0881	-1290.9105	0.9874	2.0000
21 I		121694.0184	241.7027	1.0020	-483.6055	-1290.9105	0.9874	2.0000
21 J		121694.0184	241.7027	1.0020	-483.6055	-1290.9105	0.9874	2.0000
22 I		121694.0184	243.3548	1.0020	-485.0881	-1290.9105	0.9874	2.0000
22 J		121693.7195	216.3416	1.0018	-509.8525	-1290.9074	0.9870	2.0000
23 I		121693.7195	207.9387	1.0017	-511.0556	-1290.9074	0.9869	2.0000
23 J		121665.8325	93.5209	1.0008	-571.8353	-1290.6115	0.9855	2.0000
24 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Elem	Part	Force (Immediate Loss) (tonf)	Elastic Deform. Loss (tonf)	Force(Elastic Loss)/ Force(Immediate Loss)	Creep/Shrinkage Loss (tonf)	Relaxation Loss (tonf)	Force(All Loss)/ Force(Immediate Loss)	Effective Num.
The Loss of tendon group [Top-P 1-1] at the stage of [CS1]								
Tendon Group		Top-P 1-1	Stage	CS1	Apply			
7 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
17 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
19 I		641.2519	0.4929	1.0008	-3.0139	-6.8023	0.9855	2.0000
19 J		641.3989	1.0960	1.0017	-2.6936	-6.8039	0.9869	2.0000
20 I		641.3989	1.1402	1.0018	-2.6872	-6.8039	0.9870	2.0000
20 J		641.4005	1.2626	1.0020	-2.5567	-6.8039	0.9874	2.0000
21 I		641.4005	1.2739	1.0020	-2.5489	-6.8039	0.9874	2.0000
21 J		641.4005	1.2739	1.0020	-2.5489	-6.8039	0.9874	2.0000
22 I		641.4005	1.2626	1.0020	-2.5567	-6.8039	0.9874	2.0000
22 J		641.3989	1.1402	1.0018	-2.6872	-6.8039	0.9870	2.0000
23 I		641.3989	1.0960	1.0017	-2.6936	-6.8039	0.9869	2.0000
23 J		641.2519	0.4929	1.0008	-3.0139	-6.8023	0.9855	2.0000
24 I		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24 J		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Figure 47. Tendon loss (stress and force) tables

Deformation at a specific construction stage.

MIDAS/Civil provides a function, which enables us to check the deformation of the structure at a specific stage. We will check the deformation at construction stage 13.

Results / Deformations /  **Deformed Shape**

Load Cases/Combinations>**CS: Summation**

Components>**DXYZ**

Type of Display>**Legend, Current Step Displ. (on)** ↵

For displaying the accumulated deformation up to the current stage:

Type of Display>**Current Step Displ. (off)** ↵

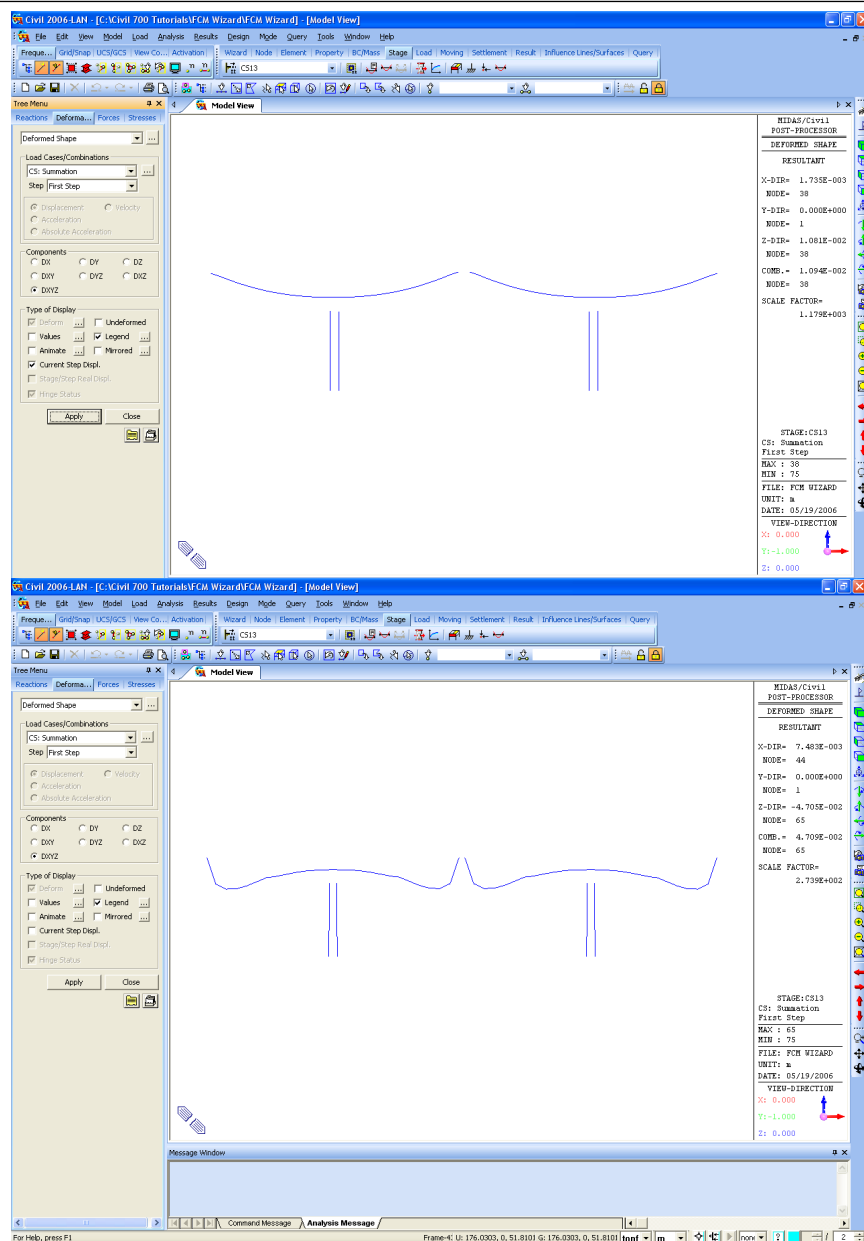



Figure 48. Deformation at a specific construction stage

Resulting member forces at a specific construction stage.

MIDAS/Civil provides a function, which enables us to check the member forces of the structure at a specific stage. For checking the forces, we will activate “Output of Current Stage (Beam/Truss)” in “Construction Stage Analysis Control”. We will check the member forces for construction stage 13.

Results / Forces /  **Beam Diagram**

Load Cases/Combinations>**CS: Summation**

Components>**My**

Display Options>**5 Points, Solid Fill, Scale (1.0)**

Type of Display> **Legend, Current Step Force (on)** ↵

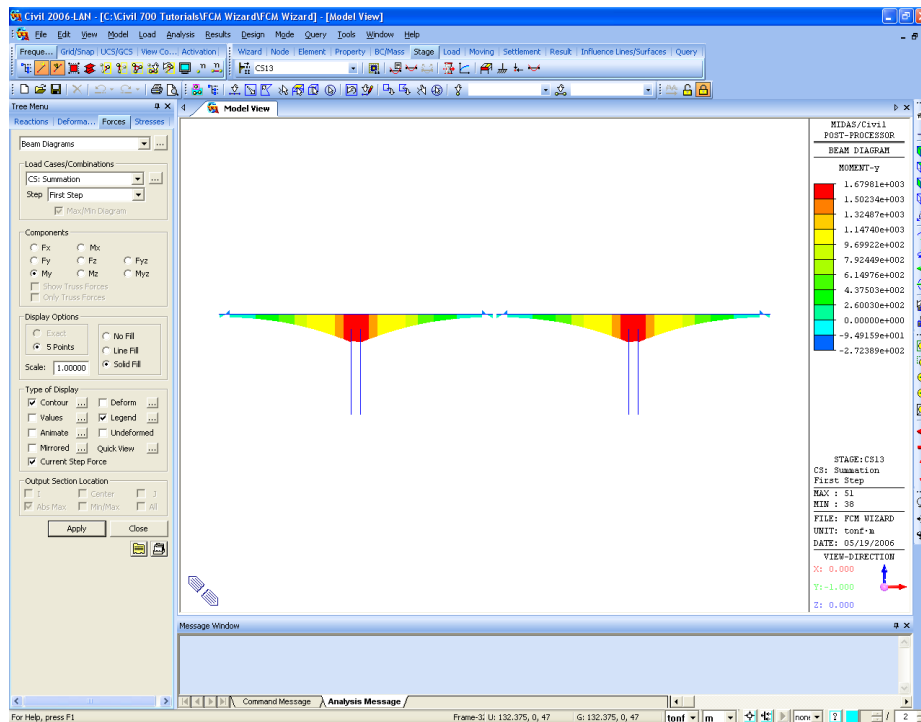


Figure 49. Member forces at a specific construction stage

Camber check.

In order to produce a camber graph, we need to select element and node groups corresponding to girders, supports and key segments. FCM Bridge Wizard automatically defines all the groups required for camber results. Select Camber Control groups to check cambers.

Results / FCM Camber / **FCM Camber Control**
 Bridge Girder Element Group>**Bridge Girder**
 Support Node Group>**SupportNode**
 Key-Segment Elem. Group>**KeySegAll** ↵

Results / FCM Camber / **FCM Camber Graph View**
 Camber Load Case>**Summation** (on) ↵

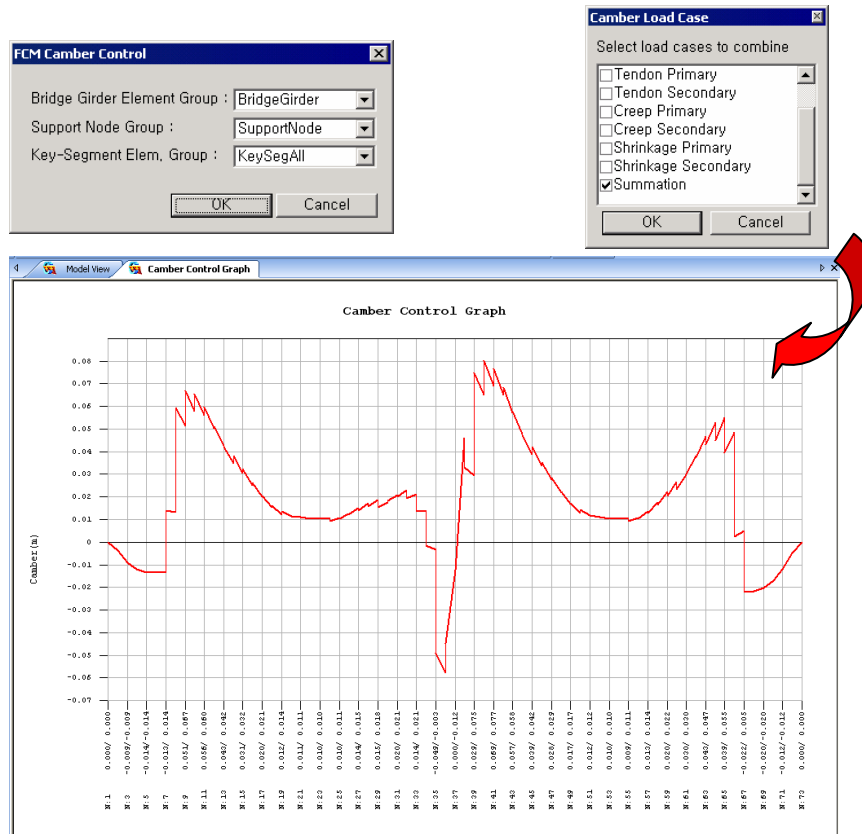


Figure 50. Camber graph

Camber control management.

Check the camber table, which will be used to manage cambers during construction. Camber tables are produced for each FSM zone and pier. In this example, FSM1 & FSM2 (pages 1 & 4, respectively) and Pier 1 & Pier 2 (pages 2 & 3, respectively) are generated.

Results / FCM Camber / **FCM Camber Table**

Camber Load Case>**Summation** (on) ↵

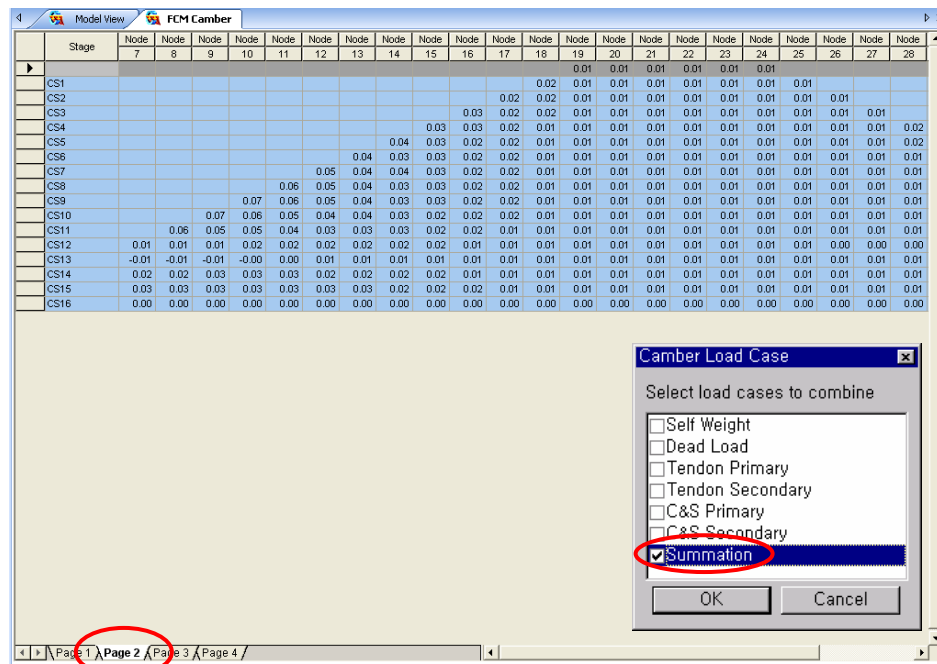


Figure 51. Camber control table

Checking element properties by construction stages.

For each construction stage, element properties (start maturity age, end maturity age, Modulus of Elasticity at start & end, accumulated shrinkage strain and accumulated Creep Coefficient) are tabulated.

Stage refers to the Construction Stage at which element properties are generated.

Stage>**CS14**

Results / Result Tables / Construction Stage / **Element Properties at Each Stage**

Elem	Start Age	End Age	Start Elasticity (tonf/in ²)	End Elasticity (tonf/in ²)	Cumulative Shrinkage	Creep Coeff
The Element properties at the stage of [CS14]						
Stage CS14						
1	60.00	72.00	3597324.9311	3624189.0598	-0.0000	0.3862
2	60.00	72.00	3597324.9311	3624189.0598	-0.0000	0.3862
3	60.00	72.00	3597324.9311	3624189.0598	-0.0000	0.3862
4	60.00	72.00	3597324.9311	3624189.0598	-0.0000	0.3862
5	60.00	72.00	3597324.9311	3624189.0598	-0.0000	0.3862
6	10.00	22.00	3178523.3940	3402677.8761	-0.0000	0.5427
7	35.00	47.00	3503555.6473	3557653.2491	-0.0000	0.8916
8	47.00	59.00	3557653.2491	3594733.5818	-0.0000	0.9574
9	59.00	71.00	3584733.5818	3622207.0513	-0.0000	1.0108
10	71.00	83.00	3622207.0513	3643626.6470	-0.0000	1.0541
11	83.00	95.00	3643626.6470	3660938.9626	-0.0000	1.0894
12	95.00	107.00	3660938.9626	3675312.4248	-0.0000	1.1179
13	107.00	119.00	3675312.4248	3687496.7681	-0.0000	1.1411
14	119.00	131.00	3687496.7681	3697986.2495	-0.0000	1.1597
15	131.00	143.00	3697986.2495	3707172.8129	-0.0000	1.1748
16	143.00	155.00	3707172.8129	3715279.0365	-0.0000	1.1871
17	155.00	167.00	3715279.0365	3722509.9374	-0.0000	1.1972
18	167.00	179.00	3722509.9374	3729012.9222	-0.0000	1.2056
19	179.00	201.00	3733959.6110	3734808.7988	-0.0000	0.9675
20	189.00	201.00	3733959.6110	3734808.7988	-0.0000	0.9629
21	189.00	201.00	3733959.6110	3734808.7988	-0.0000	0.9629
22	189.00	201.00	3733959.6110	3734808.7988	-0.0000	0.9675
23	189.00	201.00	3733959.6110	3734808.7988	-0.0000	1.2056
24	167.00	179.00	3722509.9374	3729012.9222	-0.0000	1.1972
25	155.00	167.00	3715279.0365	3722509.9374	-0.0000	1.1871
26	143.00	155.00	3707172.8129	3715279.0365	-0.0000	1.1748
27	131.00	143.00	3697986.2495	3707172.8129	-0.0000	1.1411
28	119.00	131.00	3687496.7681	3697986.2495	-0.0000	1.1597
29	107.00	119.00	3675312.4248	3687496.7681	-0.0000	1.1411
30	95.00	107.00	3660938.9626	3675312.4248	-0.0000	1.1179
31	83.00	95.00	3643626.6470	3660938.9626	-0.0000	1.0894
32	71.00	83.00	3622207.0513	3643626.6470	-0.0000	1.0541
33	59.00	71.00	3594733.5818	3622207.0513	-0.0000	1.0108
34	47.00	59.00	3557653.2491	3594733.5818	-0.0000	0.9574
35	35.00	47.00	3503555.6473	3557653.2491	-0.0000	0.8916
36	35.00	47.00	3503555.6473	3557653.2491	-0.0000	0.8916
39	47.00	59.00	3557653.2491	3594733.5818	-0.0000	0.9574

Figure 52. Element properties at construction stage 14

Section properties at the last construction stage.

*.out file, which is generated after analysis, contains the properties of transformed sections at each construction step.

When construction stage analysis is performed, transformed section properties at the last stage are tabulated.

The properties of transformed sections, which include tendons, vary with tendon properties, grouting timing and the change in modulus of elasticity of concrete.

Since the transformed section properties are generated at the last stage, it is easy to check the properties in "PostCS" (completed stage). These properties can be used to calculate stresses due to additional loads such as moving loads, temperature loads, etc.

Stage>PostCS

Results / Result Tables / Construction Stage / **Beam Section Prop. at Last Stage**


Beam Element (1to76) ; Part >I, J ↵


Elem	Part	Area (m²)	I _{xx} (m⁴)	I _{yy} (m⁴)	I _{zz} (m⁴)	C _{yp} (m)	C _{ym} (m)	C _{zp} (m)	C _{zm} (m)	W _A Area (m²)	Translational Distance	
											Local-y (m)	Local-z (m)
1	I	8.5730	20.2161	9.1449	89.4820	6.3500	6.3500	1.0651	1.5349	8.4857	0.0000	-0.00
1	J	8.5730	20.2161	9.2448	89.5592	6.3500	6.3500	1.0701	1.5299	8.4857	0.0000	-0.01
2	I	8.5948	20.2161	9.2636	89.7302	6.3500	6.3500	1.0724	1.5276	8.4857	0.0000	-0.01
2	J	8.5948	20.2161	9.2931	89.7170	6.3500	6.3500	1.0739	1.5261	8.4857	0.0000	-0.01
3	I	8.6166	20.2161	9.3118	89.8880	6.3500	6.3500	1.0762	1.5238	8.4857	0.0000	-0.02
3	J	8.6166	20.2161	9.3411	89.8550	6.3500	6.3500	1.0776	1.5224	8.4857	0.0000	-0.02
4	I	8.6384	20.2161	9.3597	90.0260	6.3500	6.3500	1.0799	1.5201	8.4857	0.0000	-0.02
4	J	8.6384	20.2161	9.3890	89.9744	6.3500	6.3500	1.0814	1.5186	8.4857	0.0000	-0.02
5	I	8.6384	20.2161	9.3890	89.9744	6.3500	6.3500	1.0814	1.5186	8.4857	0.0000	-0.02
5	J	8.6384	20.2161	9.3890	89.9744	6.3500	6.3500	1.0814	1.5186	8.4857	0.0000	-0.02
6	I	8.6384	20.2161	9.3890	89.9744	6.3500	6.3500	1.0814	1.5186	8.4857	0.0000	-0.02
6	J	8.6384	20.2161	9.3890	89.9744	6.3500	6.3500	1.0814	1.5186	8.4857	0.0000	-0.02
7	I	8.6602	20.2161	9.4022	90.2650	6.3500	6.3500	1.0794	1.5206	8.4857	0.0000	-0.02
7	J	8.6602	20.2161	9.4070	90.4562	6.3500	6.3500	1.0791	1.5209	8.4857	0.0000	-0.02
8	I	8.6821	20.2161	9.4202	90.6525	6.3500	6.3500	1.0771	1.5229	8.4857	0.0000	-0.02
8	J	8.7357	20.7721	9.7108	90.9133	6.3500	6.3500	1.0922	1.5394	8.5394	0.0000	-0.02
9	I	8.7575	20.7721	9.7188	91.2292	6.3500	6.3500	1.0859	1.5447	8.5394	0.0000	-0.01
9	J	8.9186	22.5081	10.6627	92.4636	6.3500	6.3500	1.1339	1.5888	8.7005	0.0000	-0.01
10	I	8.9404	22.5081	10.6721	92.7795	6.3500	6.3500	1.1274	1.5952	8.7005	0.0000	-0.01
10	J	9.2088	25.5871	12.3657	94.7540	6.3500	6.3500	1.2089	1.7670	8.9689	0.0000	-0.01
11	I	9.2306	25.5871	12.3782	95.0698	6.3500	6.3500	1.2022	1.7738	8.9689	0.0000	0.00
11	J	9.6064	29.9959	15.0163	97.8321	6.3500	6.3500	1.3194	1.8712	9.3446	0.0000	0.00
12	I	9.6282	29.9959	15.0346	98.1480	6.3500	6.3500	1.3123	1.8783	9.3446	0.0000	0.01
12	J	10.1113	36.1493	18.9077	101.6785	6.3500	6.3500	1.4667	1.9999	9.8278	0.0000	0.01
13	I	10.1331	36.1493	18.9354	101.9944	6.3500	6.3500	1.4591	2.0075	9.8278	0.0000	0.02
13	J	10.7236	44.1572	24.4365	106.3439	6.3500	6.3500	1.6524	2.1514	10.4183	0.0000	0.02
14	I	10.7236	44.1572	24.4382	106.4634	6.3500	6.3500	1.6470	2.1568	10.4183	0.0000	0.02
14	J	11.4215	54.2628	32.0632	111.8021	6.3500	6.3500	1.8817	2.3208	11.1161	0.0000	0.02
15	I	11.4215	54.2628	32.0737	111.6274	6.3500	6.3500	1.8759	2.3265	11.1161	0.0000	0.04
15	J	12.2267	66.7363	42.5647	117.4419	6.3500	6.3500	2.1544	2.5080	11.9213	0.0000	0.04
16	I	12.2485	66.7363	42.6396	117.7325	6.3500	6.3500	2.1511	2.5113	11.9213	0.0000	0.05
16	J	13.1611	82.2013	56.7729	124.3761	6.3500	6.3500	2.4734	2.7102	12.8339	0.0000	0.05
17	I	13.1829	82.2013	56.8757	124.5724	6.3500	6.3500	2.4699	2.7138	12.8339	0.0000	0.06
17	J	14.2028	99.7567	75.6568	131.9656	6.3500	6.3500	2.8373	2.9289	13.8539	0.0000	0.06
18	I	14.2246	99.7567	75.7970	132.2562	6.3500	6.3500	2.8335	2.9328	13.8539	0.0000	0.06
18	J	15.3519	120.2047	100.4813	140.4277	6.3500	6.3500	3.2464	3.1638	14.9812	0.0000	0.07
19	I	15.3956	120.2047	100.8589	140.9145	6.3500	6.3500	3.2381	3.1721	14.9812	0.0000	0.08
19	J	16.4281	139.6416	127.4131	148.3994	6.3500	6.3500	3.6208	3.3792	16.0138	0.0000	0.08

Figure 53. Element properties at construction stage 14

Checking member forces resulting from load combinations.

Once the PSC box bridge has been constructed, wearing surface, live load, temperature change, support settlement, etc. need to be combined with the effects of construction dead load. Structural analysis for loads other than the Construction Stage Load is carried out in the PostCS Stage (final stage). Such PostCS loads can be combined with the results of the construction stage analysis. Since we have not specified any load other than the construction stage load in this example, we will define load factors for the construction stage loads and check member forces. First, we will define the load combinations.

 We switch to the PostCS, as the load combinations can be defined or deleted in only Base Stage or PostCS Stage.

Stage>**PostCS** 

Results / **Combinations**

Active (on) ; Name (**Dead**) ; Type>**Add**

Load Case>**Dead Load (CS)** ; Factor (**1.3**)

Load Case>**Erection Load (CS)** ; Factor (**1.3**)

Load Case>**Tendon Secondary (CS)** ; Factor (**1.0**)

Load Case>**Creep Secondary (CS)** ; Factor (**1.3**)

Load Case>**Shrinkage Secondary (CS)** ; Factor (**1.3**)

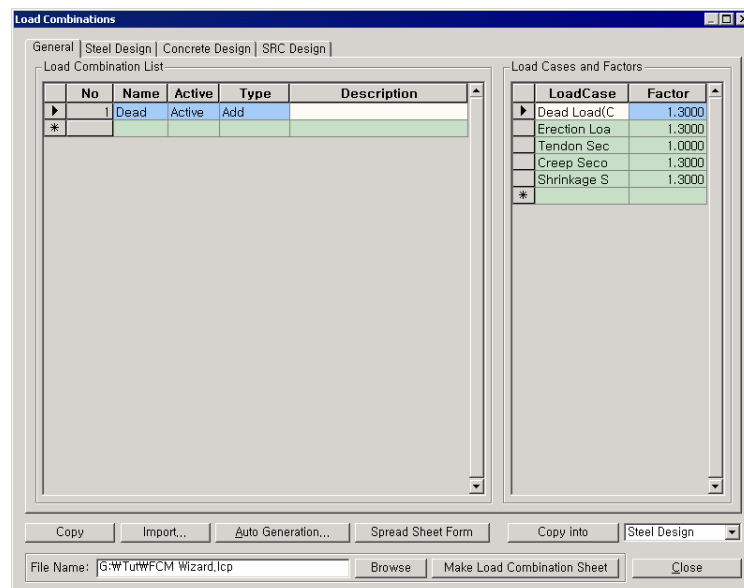


Figure 54. Definition of load combinations

Check bending moment diagram due to factored load combination.

Results / Forces /  **Beam Diagrams**

Load Cases/Combinations>**CB: Dead**

Components>**My**

Display Options>**5 Points, Solid Fill, Scale (1.0)**

Type of Display>**Contour (on) ; Legend (on)** ↵

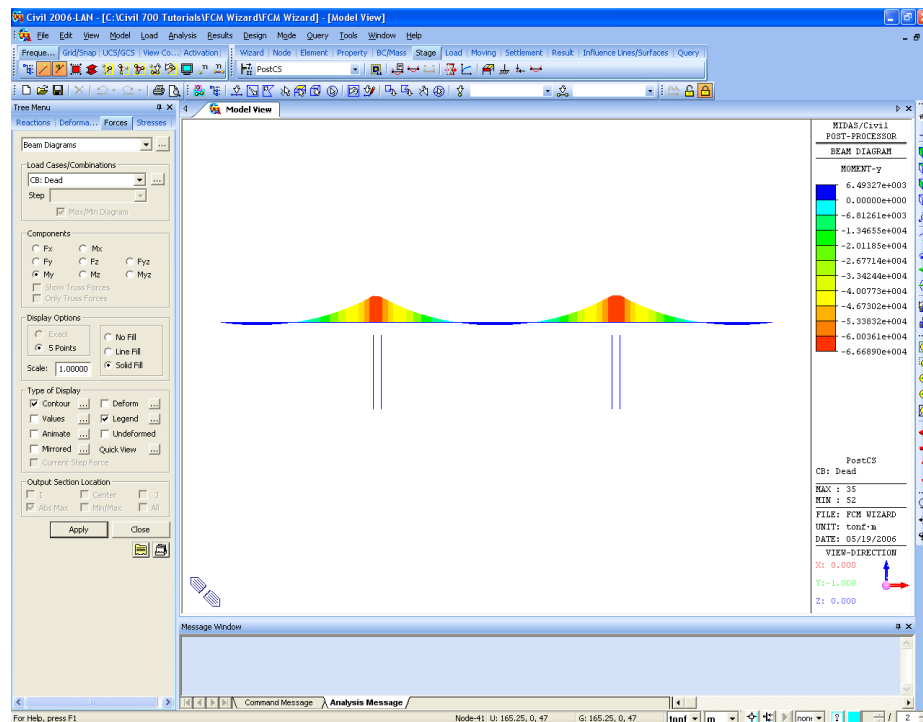


Figure 55. Bending moment diagram