Advanced Application 8

Example of Unknown Load Factors using Forward Construction Stage Analysis

(for illustrative purposes only)

8.1 Example Model Dimensions

For an asymmetrical cable-stayed bridge as shown in Figrue 1, we will find pretension loads for each construction stage by using the Unknown Load Factors feature, reflecting Forward Construction Stage Analysis.

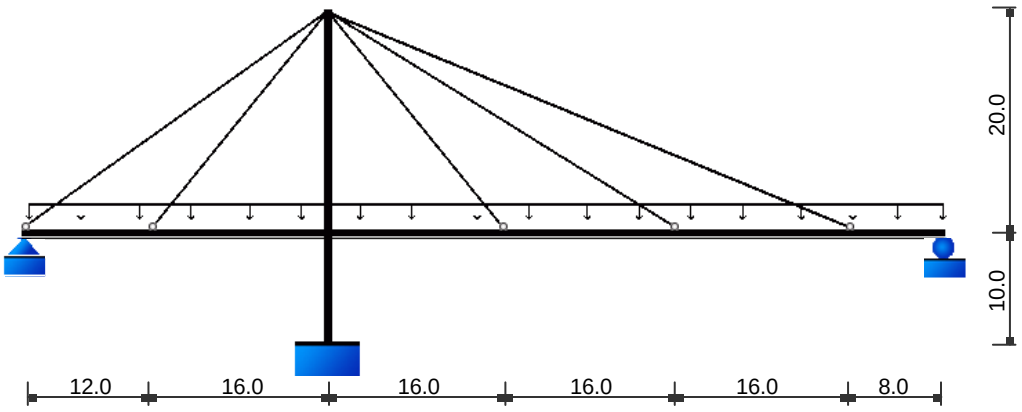


Figure 1. Configuration at the final stage of an asymmetrical cable-stayed bridge

Table 1. Material data of the example model

Classfication	Modulus of Elasiticity	Poisson's Ratio
Deck	3.0000e+006	0.3
Pylon	3.0000e+006	0.3
Cable	1.5750e+007	0.3

Table 2. Section data of the example model

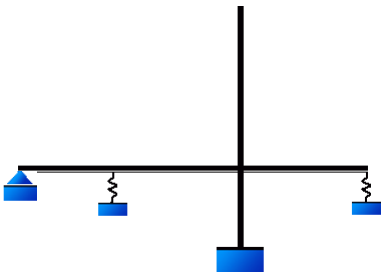
Classification	Cross-sectional Area	Moment of Inertia
Deck	4.3800	0.9200
Pylon	1.0000	2.7600
Cable	0.0062	-
Cable	0.0208	-

Table 3. Loading data of the example model

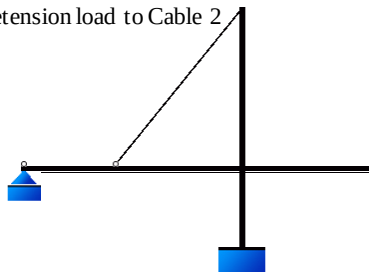
Classification	Load Type	Load Value
Dead load	Self weight	
Cable pretension load	Pretension Loads	1 tonf
Derick Crane	Nodal Loads	80 tonf
Segment	Nodal Loads	Gravity load: A x γ x L Eccentric Moment: A x γ x L x L/2
Superimposed (2nd) dead load	Element Beam Loads	1 tonf/m
Support movement	Specified displacement	1 mm

8.2 Construction Sequence

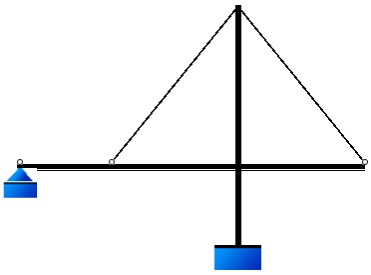
CS1: Erect Pylon and Deck



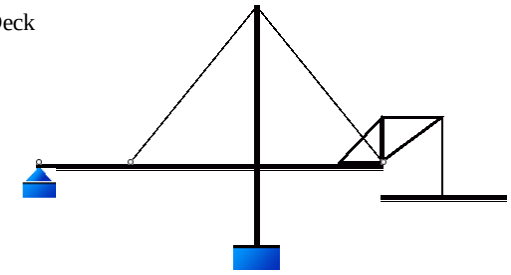
CS2: Remove temporary supports and apply pretension load to Cable 2



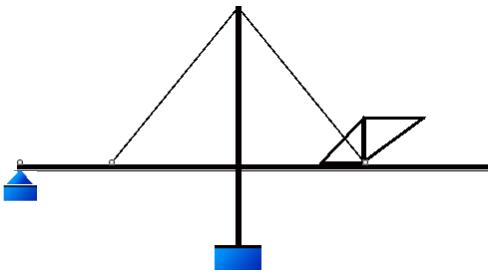
CS3: Apply pretension load to Cable 3



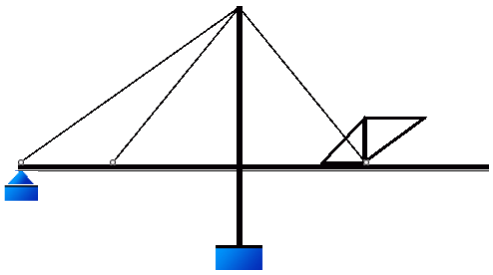
CS4: Install Derick Crane and place loads to Deck



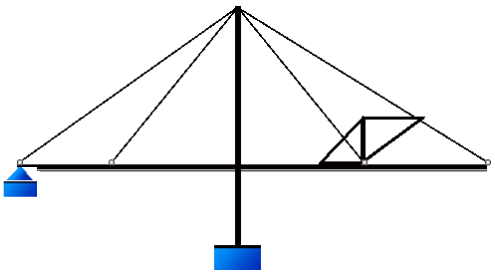
CS5: Construct additional Deck



CS6: Apply pretension load to Cable 1



CS7: Apply pretension load to Cable 4



CS8: Move Derick Crane and place loads to Deck

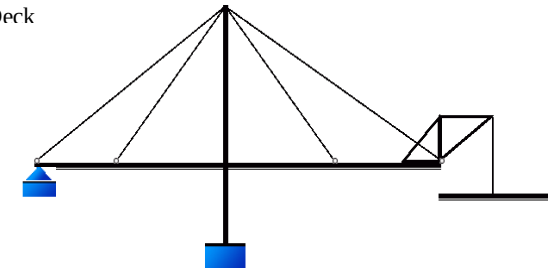
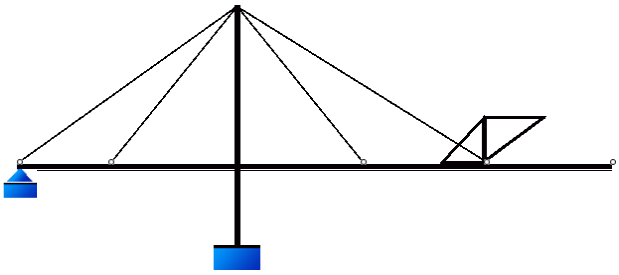
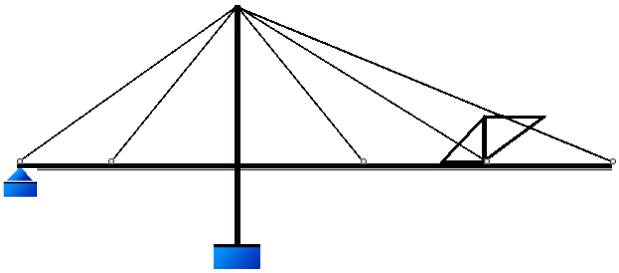


Figure 2. Construction Stages for the example model (CS1 ~ CS14)

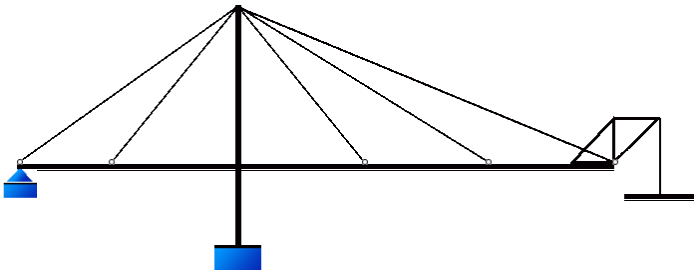
CS9: Construct additional Deck



CS10: Apply pretension load to Cable 5



CS11: Move Derick Crane and place loads to Deck



CS12: Construct additional Deck

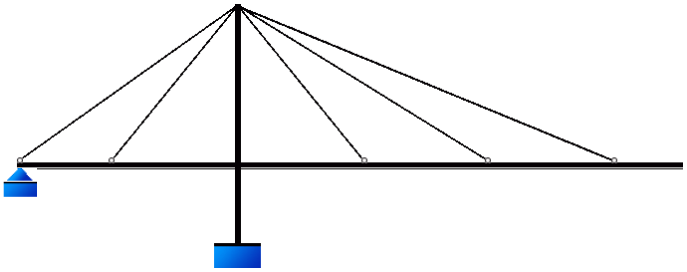
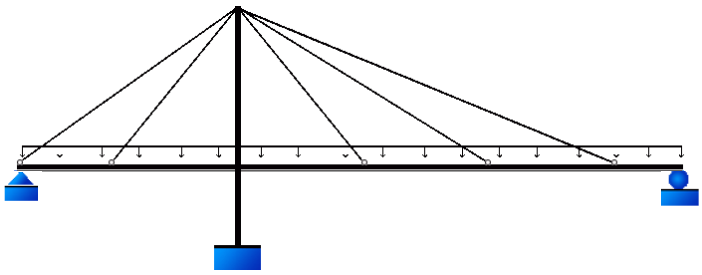


Figure 2 Construction Stages for the example model (CS1 ~ CS14) (Continued..)

CS13: Construct a support at the right span and place 2nd dead loads



CS14: Jack up the right support

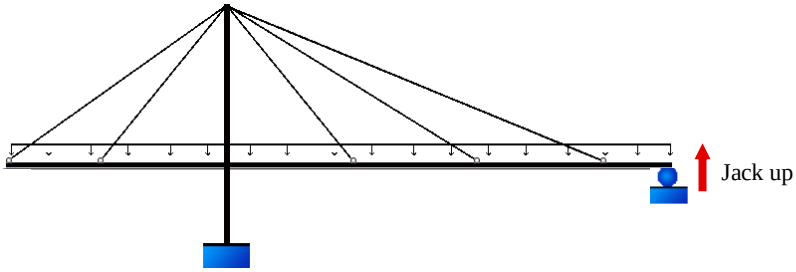


Figure 2 Construction Stages for the example model (CS1 ~ CS14) (Continued..)

8.3 Generating a Construction Stage Analysis Model

Construction consists of 14 stages, and the stages are defined in Table 4.

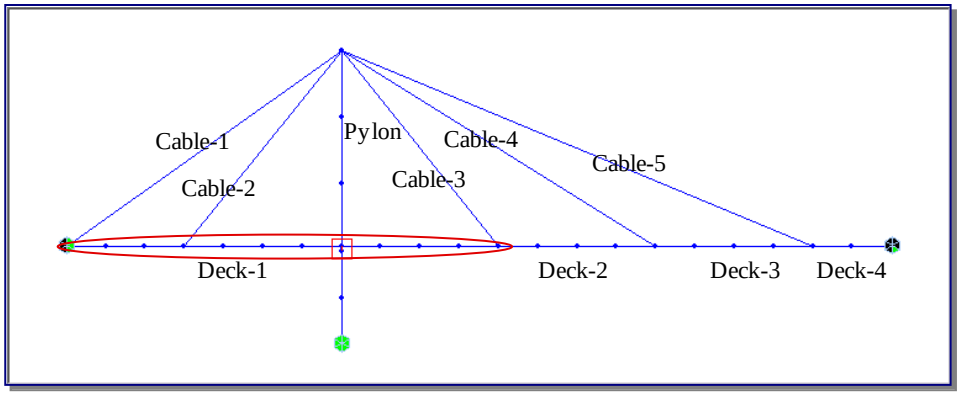


Figure 3. Structure Group names used for the example model

Table 4. Defining construction stages for the example model

Stage	Structure		Boundary		Load: Step	
	Activation	Deactivation	Activation	Deactivation	Activation	Deactivation
CS 1	Deck-1 Pylon	-	Deck-Left Pylon Elastic Sup Temporary	-	Selfw eight: First	-
CS 2	Cable-2	-	-	Temporary	Tension 02: Last	-
CS 3	Cable-3	-	-	-	Tension 03: First	-
CS 4	-	-	-	-	D/C-04: First Seg-04: First	-
CS 5	Deck-2	-	-	-	-	Seg-04: First
CS 6	Cable-1	-	-	-	Tension 06: First	-
CS 7	Cable-4	-	-	-	Tension 07: First	-
CS 8	-	-	-	-	D/C-08: First Seg-08: First	D/C-04: First
CS 9	Deck-3	-	-	-	-	Seg-08: First
CS 10	Cable-5	-	-	-	Tension 10: First	-
CS 11	-	-	-	-	D/C-11: First Seg-08: First	D/C-08: First
CS 12	Deck-4	-	-	-	-	D/C-11: First Seg-08: First
CS 13	-	-	Deck-Right	-	-	-
CS 14	-	-	-	-	Jack Up	-

(1) Construction Stage Analysis Model using MIDAS/Civil

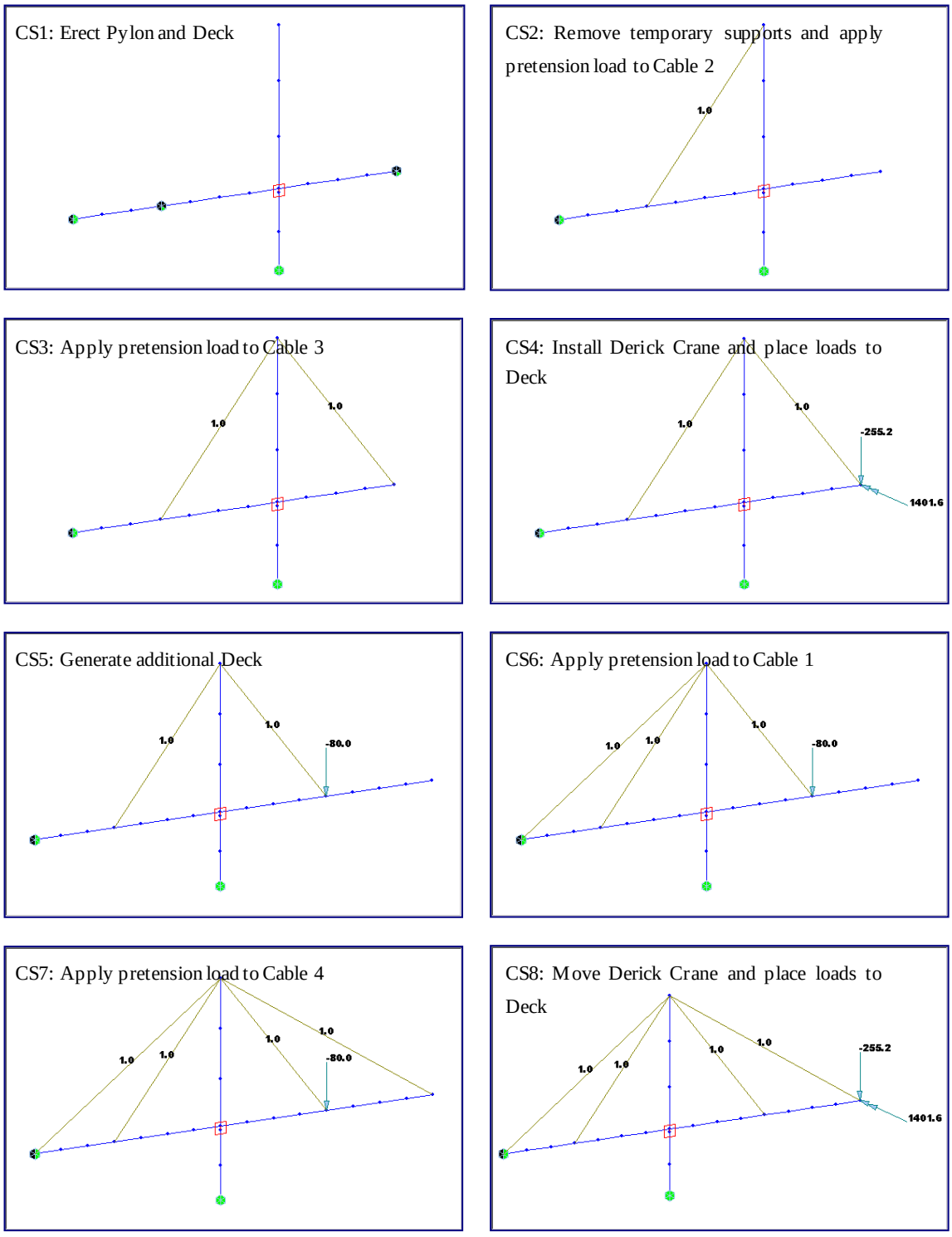


Figure 4. Construction Stage Analysis Model using MIDAS/Civil (CS1~CS14)

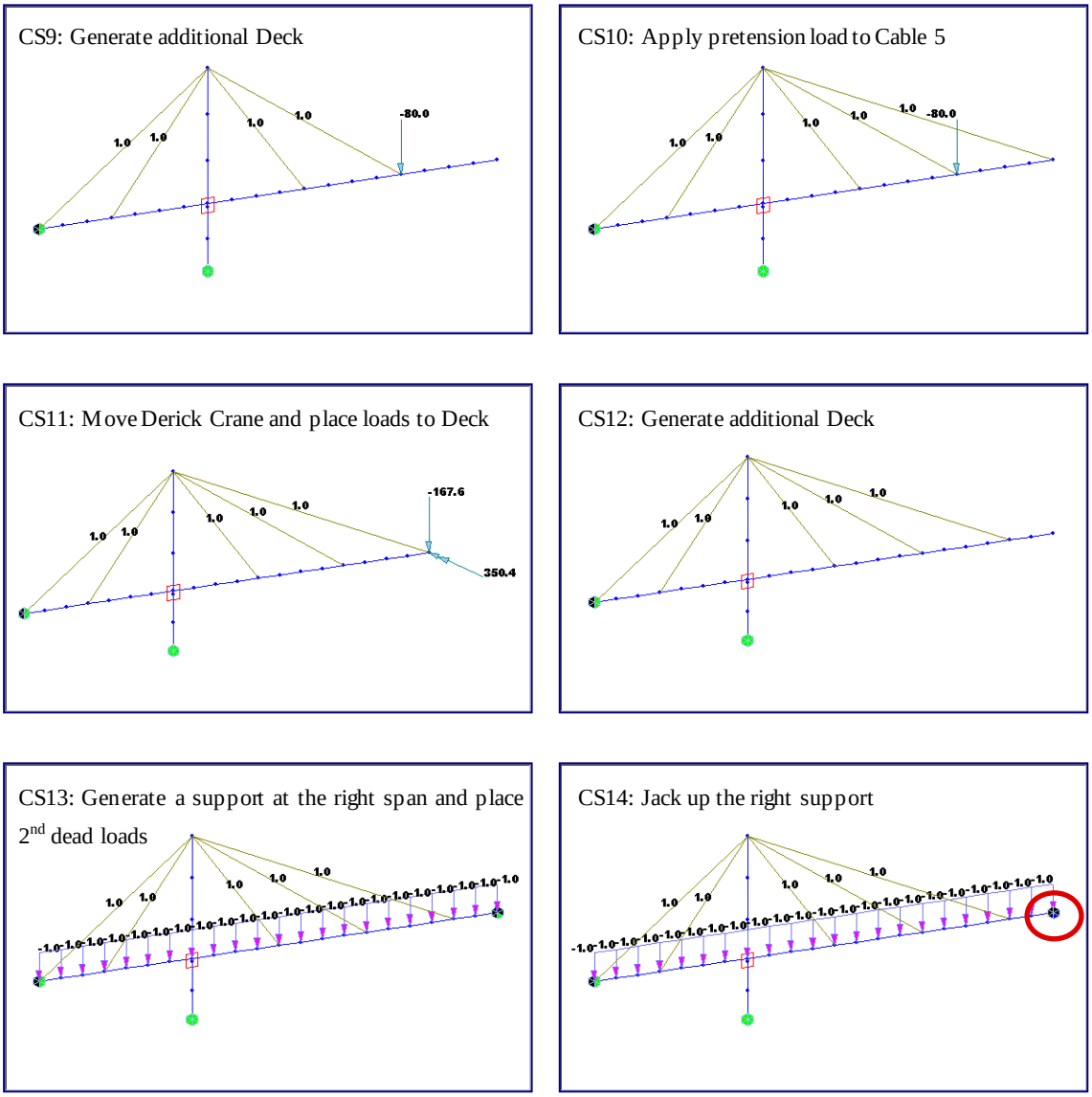


Figure 4. Construction Stage Analysis Model using MIDAS/Civil (CS1~CS14) (Continued..)

8.4 Input Data for Unknown Load Factors

- After construction stage analysis is complete, switch to Post CS.
- Select CS14, which is the final stage, for Stage Name.
- Select Stage/Steps at which cable pretension loads have been activated and a support has been jacked up (Figure 5).

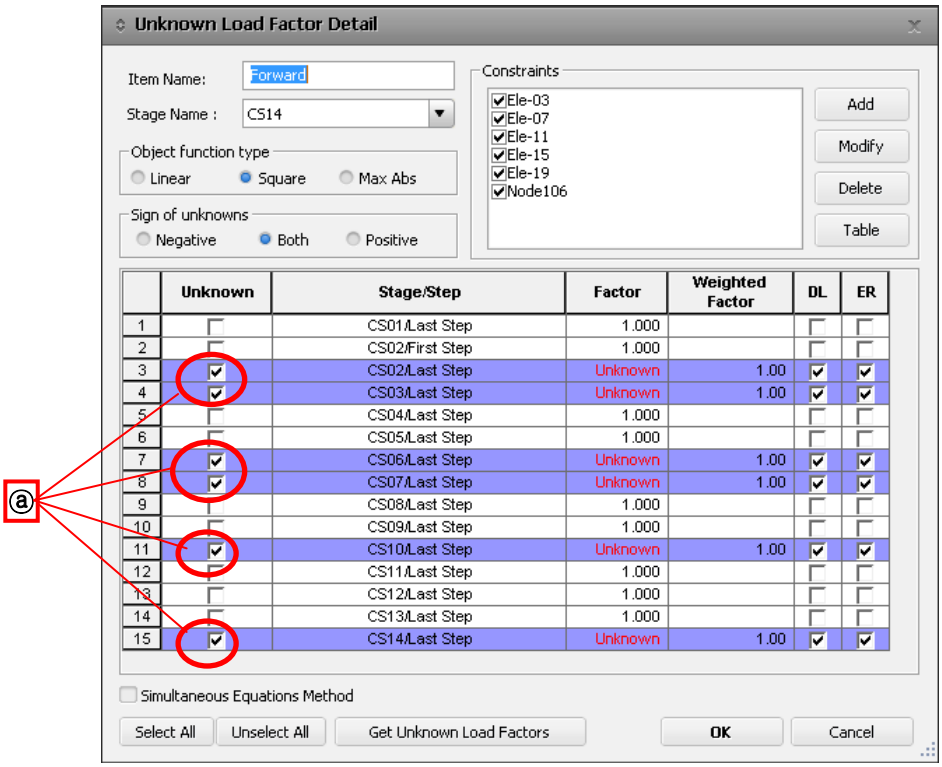


Figure 5. Input data for Unknown Load Factors

- Constrain bending moments of stringers, which are in contact with cables and the lateral displacement of the pylon at the final stage.

Table 5. Constrained conditions for the example model

	Constraint Name	Constraint Type	Element / Node	Point	Component	Inequality Condition	
						Upper Bound	Lower Bound
1	Ele-03	Beam Force	3	J	My	-220	-230
2	Ele-07	Beam Force	7	J	My	-210	-220
3	Ele-11	Beam Force	11	J	My	-240	-250
4	Ele-15	Beam Force	15	J	My	-240	-250
5	Ele-19	Beam Force	19	J	My	-170	-180
6	Node 106	Displacement	106	-	DX	0.0001	-0.0001

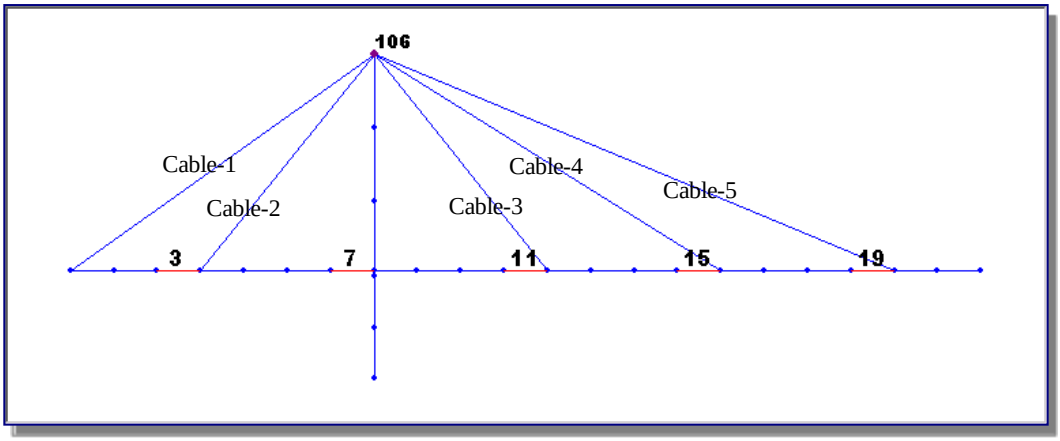


Figure 6. Elements and a node to be constrained

- Constraints can be readily modified using the MCT Command Shell feature. To display the entered constraints, input *UNKCONS for Command or Data of Tools>MCT Command Shell, followed by clicking the Insert Data button. Modify or add data within the text window and then click on the Run button. This will reflect the modification or addition of constraints in the program.

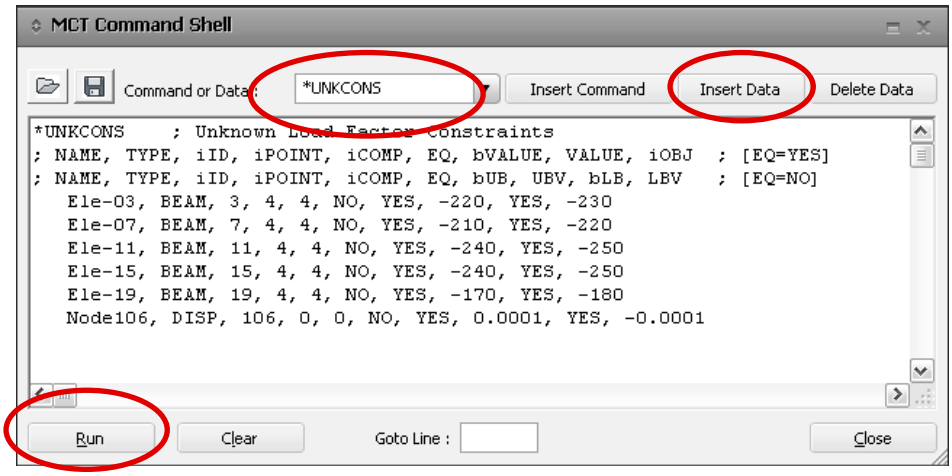


Figure 7. Modification or addition of constraints using MCT Command Shell

8.5 Unknown Load Factors Results

Unknown load factors, which satisfy constraint conditions (bending moments of stringers and lateral displacements of pylons) specified at the final stage, are displayed in a table form, as shown in Figure 8.

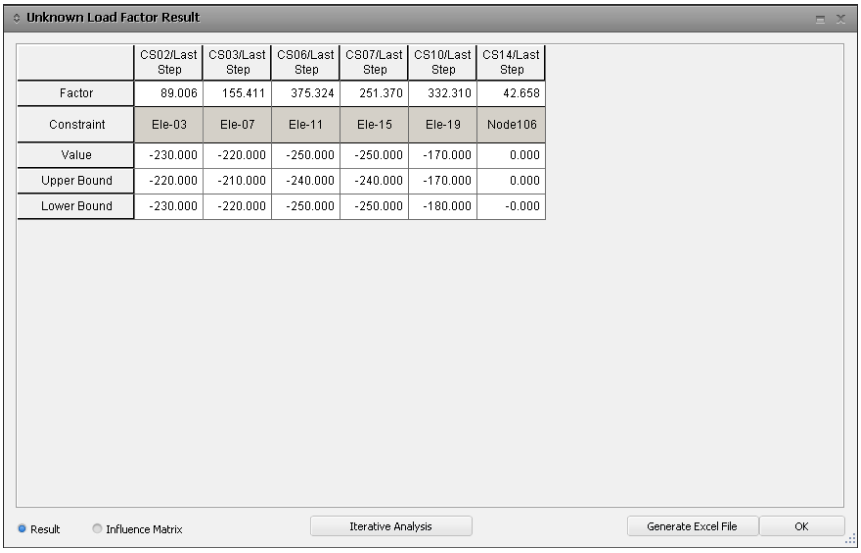


Figure 8. Unknown Load Factors results

Table 6. Calculated loads at each construction stage

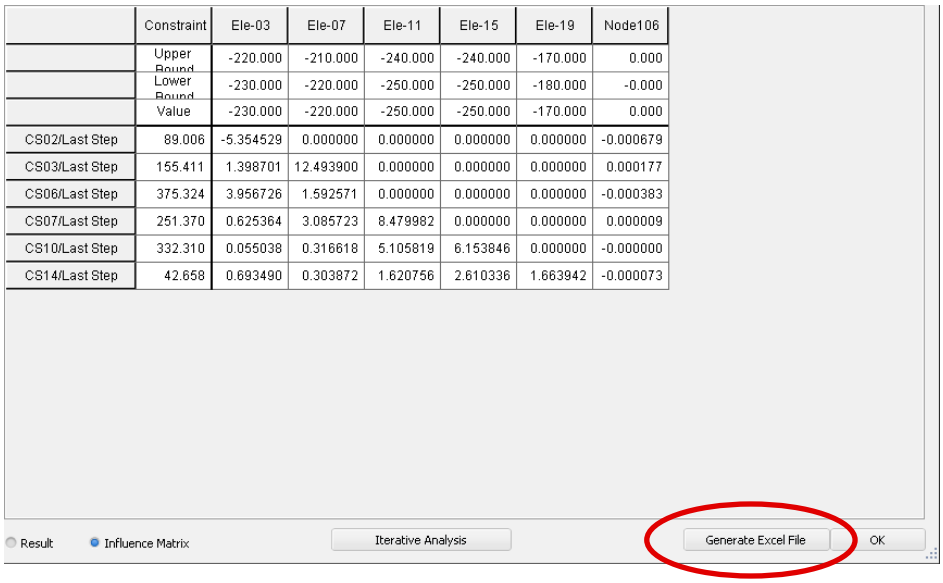
Classification	Stage/Step	Entered unit load	Unknown load factor	Actual load
Pretension of Cable 2	CS02/Last	1 tonf	89.006	89.006 tonf
Pretension of Cable 3	CS03/Last	1 tonf	155.411	155.411 tonf
Pretension of Cable 1	CS06/Last	1 tonf	375.324	375.324 tonf
Pretension of Cable 4	CS07/Last	1 tonf	251.370	251.370 tonf
Pretension of Cable 5	CS10/Last	1 tonf	332.310	332.310 tonf
Jack Up at right support	CS14/Last	1 mm	42.658	42.658 mm

Table 7. Results at the final stage (CS 14) after the calculated loads for each construction stage have been reflected

Unit: tonf·m, m

Classification	Bending moment of stringer					Lateral displacement of pylon
Location	Element 3(J)	Element 7(J)	Element 11(J)	Element 15(J)	Element 19(J)	Node 106
Final result	-230.0	-220.0	-250.0	-250.0	-170.0	0.0001

Influence Matrix obtained from Unknown Load Factors is shown in Figure 9.



	Constraint	Ele-03	Ele-07	Ele-11	Ele-15	Ele-19	Node106
	Upper Bound	-220.000	-210.000	-240.000	-240.000	-170.000	0.000
	Lower Bound	-230.000	-220.000	-250.000	-250.000	-180.000	-0.000
	Value	-230.000	-220.000	-250.000	-250.000	-170.000	0.000
CS02/Last Step	89.006	-5.354529	0.000000	0.000000	0.000000	0.000000	-0.000679
CS03/Last Step	155.411	1.398701	12.493900	0.000000	0.000000	0.000000	0.000177
CS06/Last Step	375.324	3.956726	1.592571	0.000000	0.000000	0.000000	-0.000383
CS07/Last Step	251.370	0.625364	3.085723	8.479982	0.000000	0.000000	0.000009
CS10/Last Step	332.310	0.055038	0.316618	5.105819	6.153846	0.000000	-0.000000
CS14/Last Step	42.658	0.693490	0.303872	1.620756	2.610336	1.663942	-0.000073

Figure 9. Displaying Influence Matrix

As shown in Figure 10, Influence Matrix obtained from Unknown Load Factors is convertible into an Excel sheet.

	A	B	C	D	E	F	G	H
1								
2	**UnknownLoad Factor Result (Influence Matrix)**							
3								
4	File Name :			Date : 2012/7/25				
5	Number of Constraints : 6			Number of Load Cases : 6				
6								
7								
8		Constraint	Ele-03	Ele-07	Ele-11	Ele-15	Ele-19	Node106
9	Factor	Upper Bound	-220	-210	-240	-240	-170	0.0001
10		Lower Bound	-230	-220	-250	-250	-180	-0.0001
11		Value	-229.9998998	-220.0000274	-249.9999778	-249.999989	-170.0000022	9.99319E-05
12	CS02/Last Step	89.00637817	-5.354528692	0	0	0	0	-0.000679016
13	CS03/Last Step	155.4107819	1.398700896	12.49389989	0	0	0	0.000177371
14	CS06/Last Step	375.3236389	3.956726365	1.592571261	0	0	0	-0.000382734
15	CS07/Last Step	251.3700409	0.625364259	3.085723262	8.479982435	0	0	9.28018E-06
16	CS10/Last Step	332.3103027	0.055038218	0.316618374	5.105818747	6.153845768	0	-3.15178E-07
17	CS14/Last Step	42.65824509	0.693490187	0.303871508	1.620756086	2.610335862	1.663942192	-7.34581E-05

Figure 10. Influence Matrix converted into an Excel sheet

8.6 Construction Stage Analysis

Load factors calculated from Unknown Load Factors are reflected in the staged construction model and the re-analyzed results are shown in Figure 11 and 12.

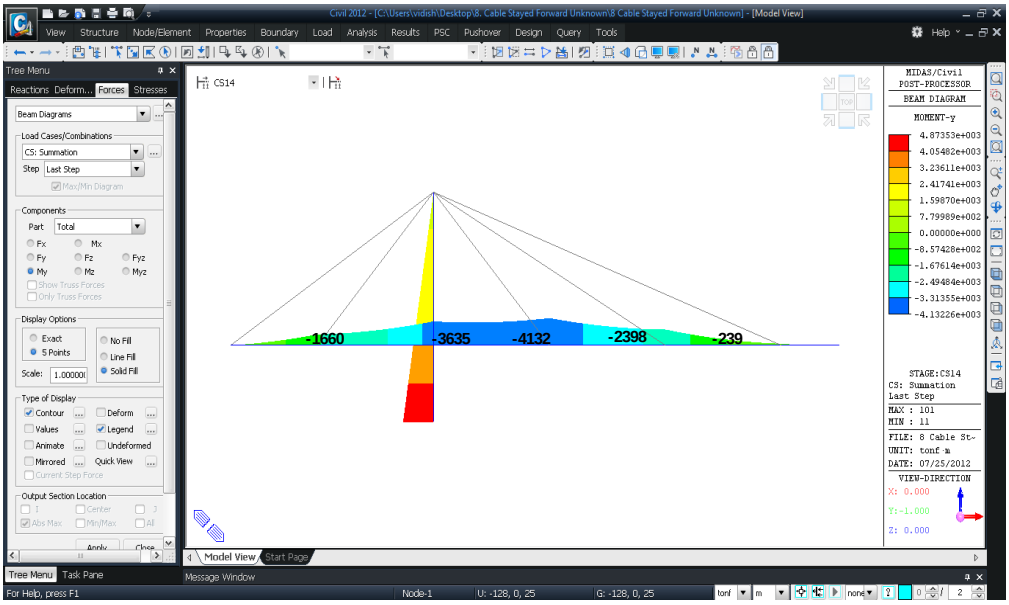


Figure 11. Bending moments at the final stage (CS14)

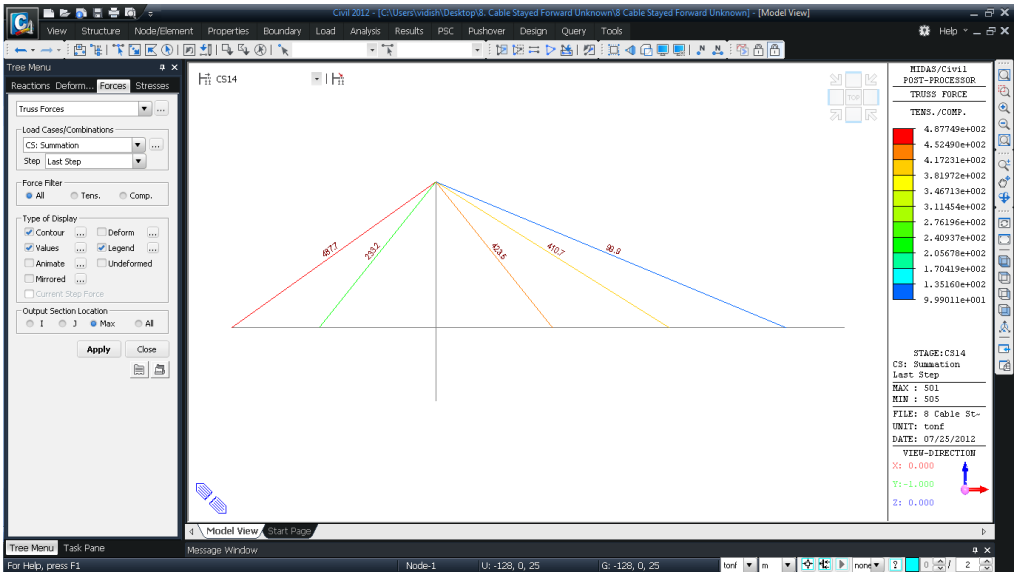


Figure 12. Cable axial forces at the final stage (CS14)

(1) Bending moments at each construction stage

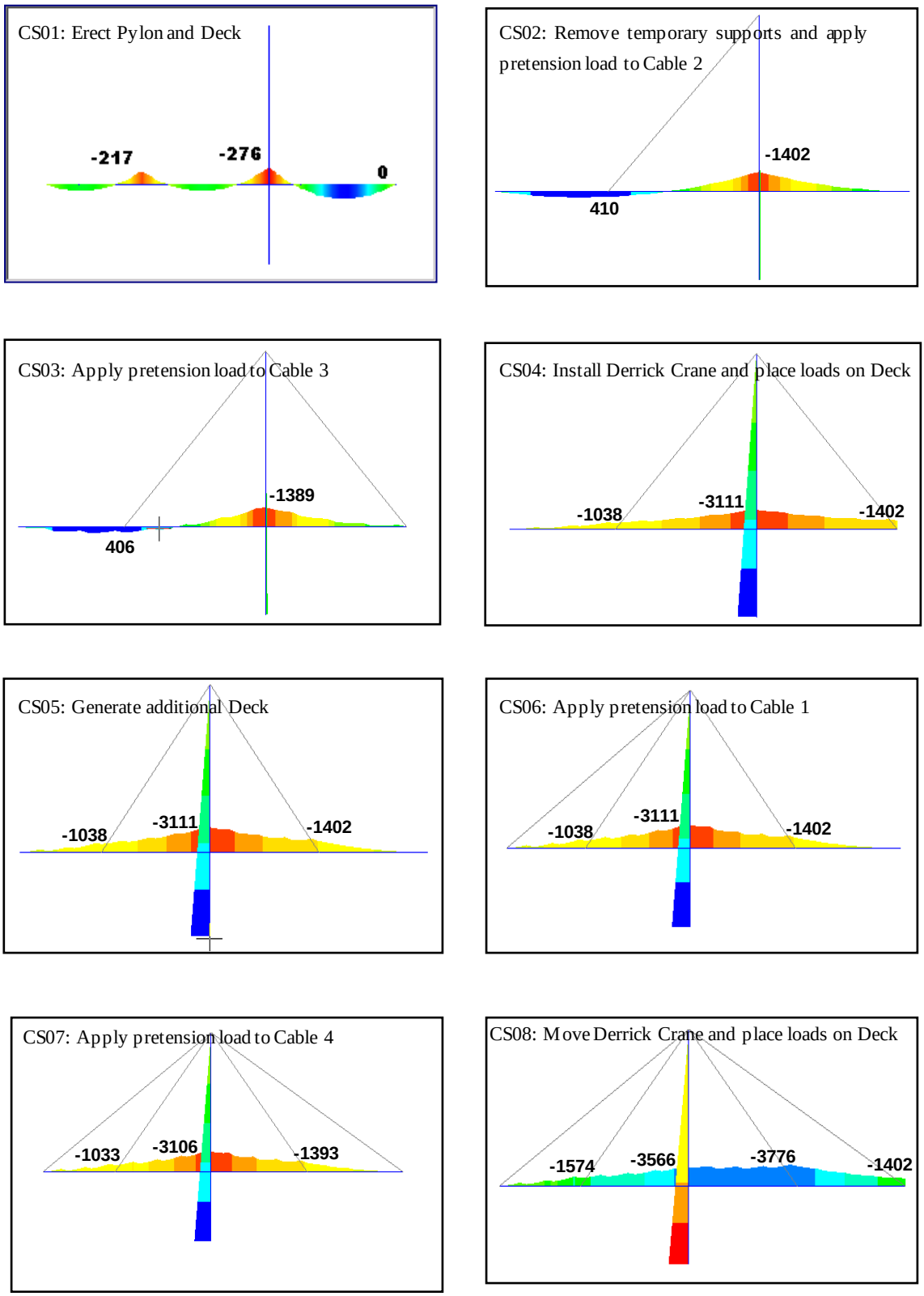


Figure 13-A. Bending moments at each construction stage (CS01~CS08)

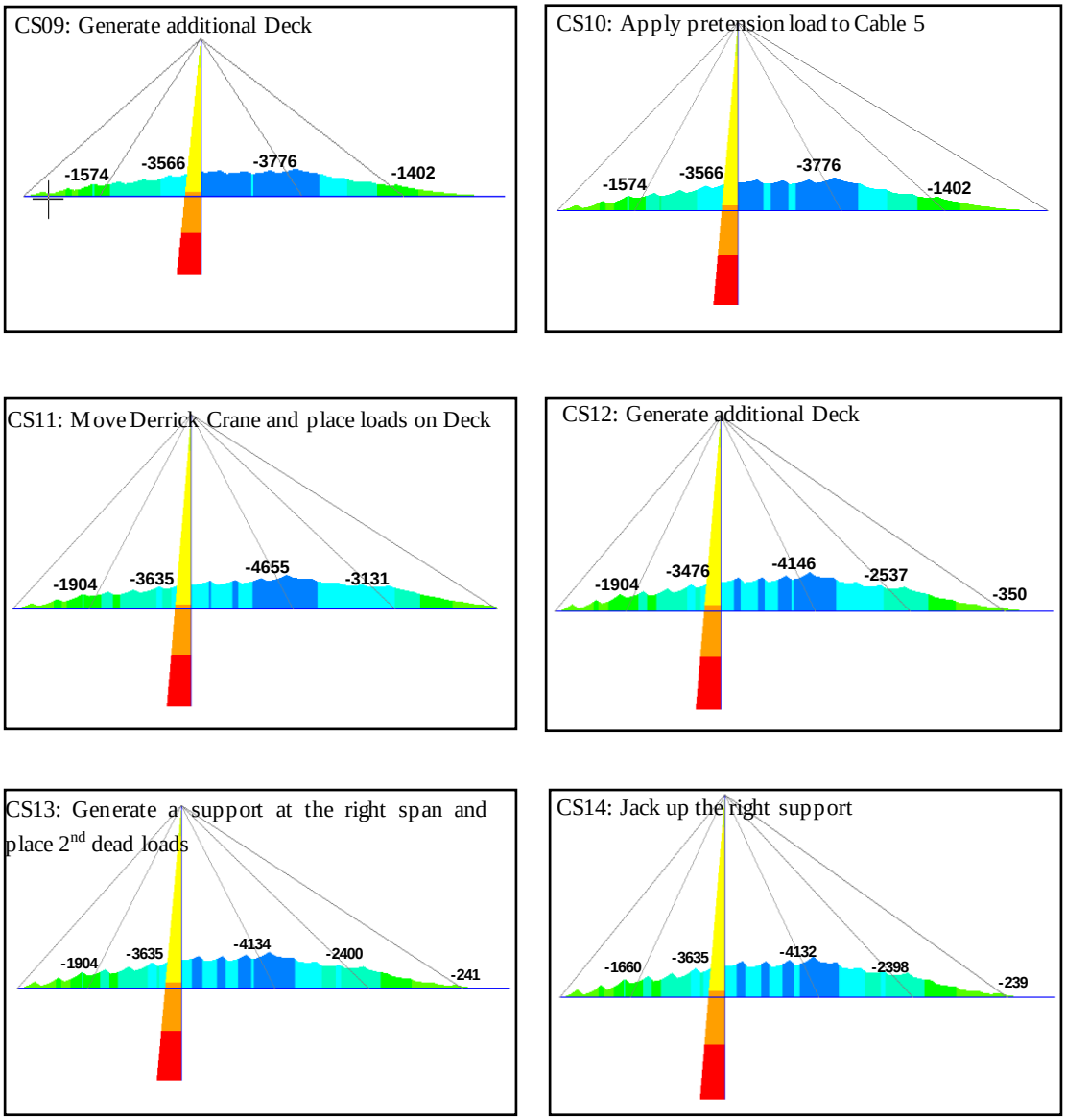


Figure 13-B. Bending moments at each construction stage (CS09~CS14)