Note: "This interim change revises the "Deflection of Short Cantilever" Equation in the "Hand Calculations" Section, found on Page 4 of this memo (See Highlighted Text). Be advised that MTD 11-34 is currently under additional, substantial revision, and will be issued in the coming months. If you need additional information, please contact the "Prestressed Concrete Committee."

11-34 HINGE CURL

This memo addresses the issue of upward deflection of the unloaded short cantilever of cast-in-place P/S concrete box girder bridges. This deflection is experienced prior to load transfer from the long cantilever side and is commonly termed, "hinge curl."

The intent of the following procedure is to give the design engineer a means whereby this "hinge curl" deflection may be predicted and to provide appropriate data on the contract plans dealing with this issue.

This memo simplifies a complicated time dependent process by using a Deflection Factor instead of separately considering the changes in concrete modulus, creep, shrinkage, and steel relaxation with time.

The designer is reminded that there is a variable period of time (usually between 30 and 180 days, sometimes much longer) in which the short cantilever remains unloaded after it has been stressed. The period of time and, therefore, the extent of curl is not predictable until the contractor's schedule is known. Experience indicates that the hinge does not always deflect downward at load transfer to the extent that it had previously deflected upward under the influence of the prestressing force. In the past, the camber diagrams shown on the plans have not solved the hinge deflection issue.

This memo assumes that falsework will remain in the adjacent spans until load transfer to the hinge takes place as per the specifications. Should it be desirable to remove falsework prior to load transfer, this memo should not be used and consideration be given to tieing down the short cantilever.

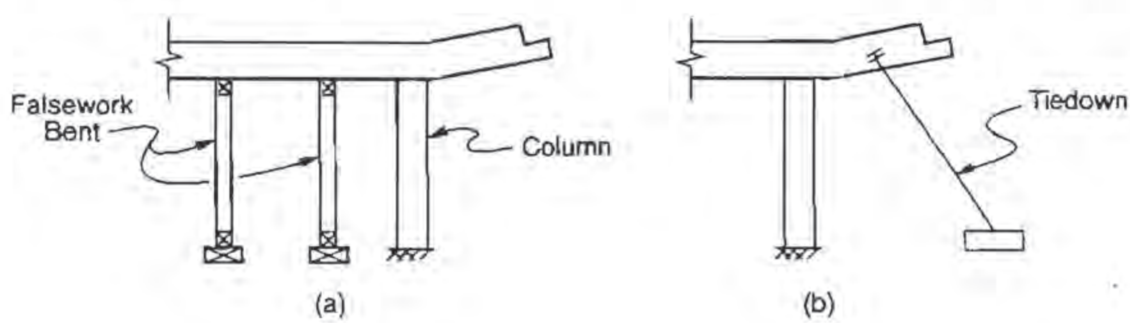


Figure 1
(a) Superstructure Supported by Falsework
(b) Hinge Tiedown

Memo converted to metric.

Notations and Nomenclature

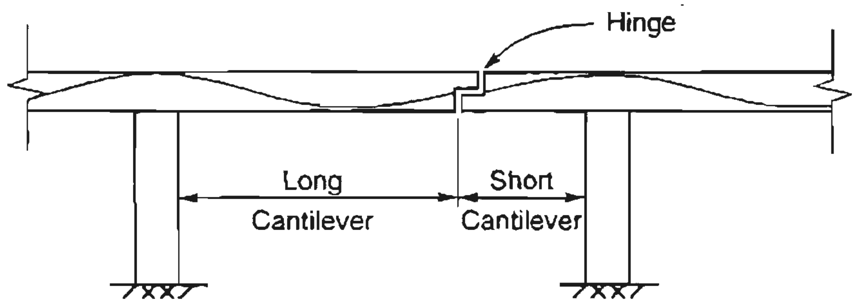


Figure 2: Hinged Section of Frame

e = eccentricity of prestress at hinge of short cantilever, m
E = $4\,800\ \sqrt{f'_c}$
I = moment of inertia of section, m^4
L = length of short cantilever, m
P_h = horizontal component of P_{jack} at anchorage of short cantilever, kN
P_v = vertical component of P_{jack} at anchorage of short cantilever, kN
T = transfer load at short cantilever
w = unit dead load of short cantilever, kN/m

Methods of Calculation

Three different methods of calculation will be addressed:

(1) BDS computer program (Bridge Design System)
(2) Hand calculations
(3) PCFRAME time dependent computer program

It should be noted that the PCFRAME program will give the most accurate results for it automatically accounts for the creep and strain characteristics of concrete. Since it is not our main production program, it should be used in special circumstances only. The BDS program currently calculates the hinge curl automatically. The hand calculations are for an approximate check and a 20% ± error can be expected. This is because the deflections due to prestress force are determined at the anchorage only, whereas BDS calculates upward forces due to prestress every 1/40 of the short cantilever length.

BDS Computer

Three different BDS runs will be required to produce the correct hinge curl in the program.

(1) Run BDS as you normally would and design for P_{jack}, etc.

(2) Use P_{jack} from (1), place a support at the end of the long cantilever. Do not include live loads, weight of closure pour, barriers, future overlay. This run will give you the transfer load from the long cantilever to the short.

(3) Model frame with short hinge separately. Use P_{jack} from (1), transfer load from (2). This run will produce hinge dead load and prestress deflections and calculate a camber diagram for long term effects.

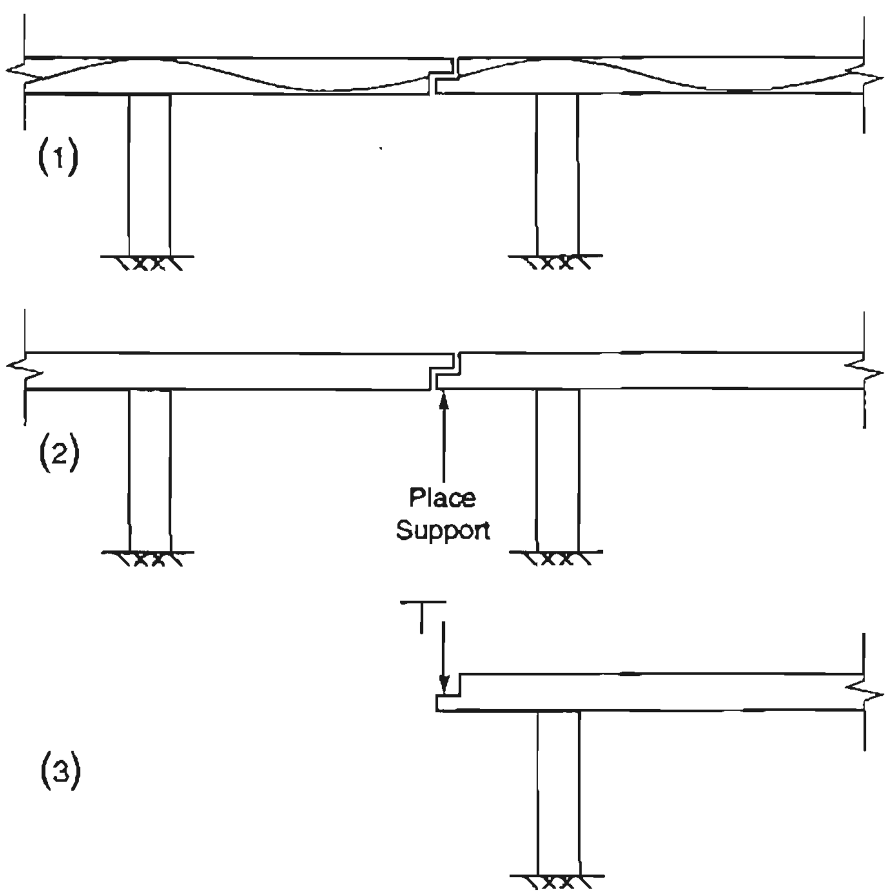


Figure 3: Bridge Design System Modeling Computer Runs

Deflection of Short Cantilever equation revised to raise Length (L) to the third power.

Hand Calculations

Deflection of Short Cantilever

$$\text{Curl} = \frac{-P_V L^3}{3EI} \pm \frac{P_H e L^2}{2EI} + \frac{wL^4}{8EI} + \frac{PL^3}{3EI} \qquad (1)$$

(A) (B) (C) (D)

Positive indicates a downward deflection

Deflection Components

(A) = Prestress vertical component
(B) = Prestress horizontal component
(C) = Distributed dead load of structure without barrier, future overlay, etc.
(D) = Concentrated load from hinge diaphragm or other miscellaneous.

Downward Deflection of Short Cantilever

$$\text{Deflection due to long span reaction} = \frac{TL^3}{3EI} \qquad (2)$$

Modify deflections for the long term effects. The Time vs. Deflection graph shown in Figure 4 is used to derive the long term camber equations.

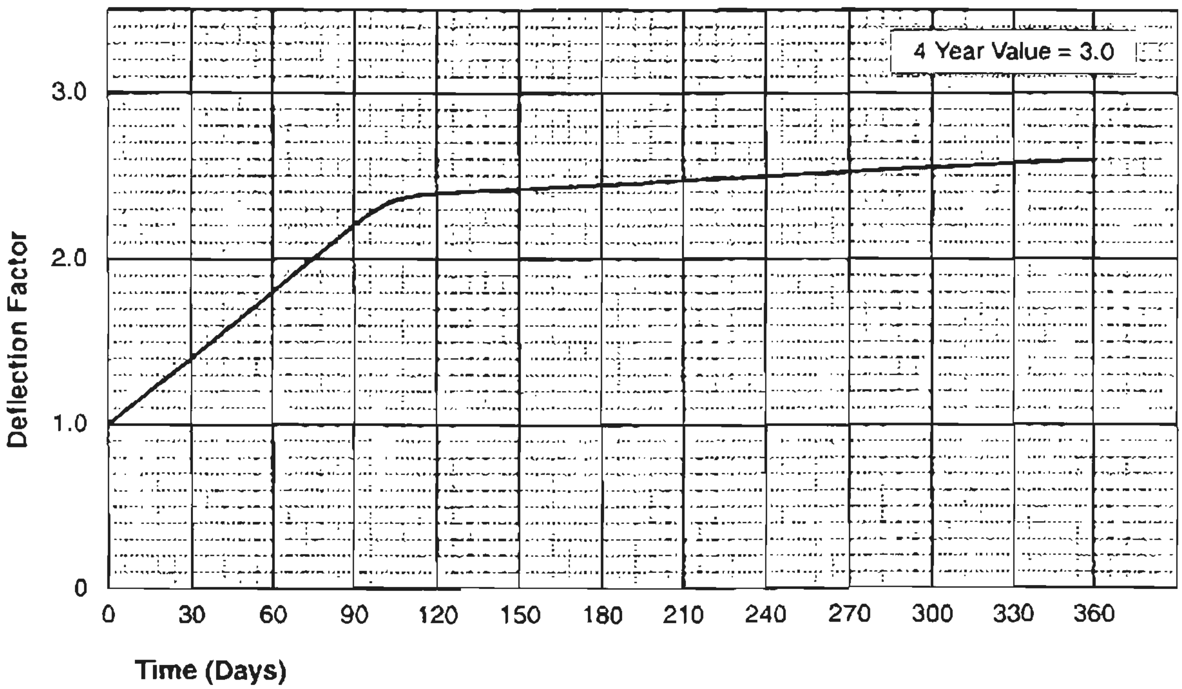


Figure 4: Long Term Deflection vs. Time

Previously calculated deflections are modified for long-term effects as follows:

Adjustment "A" – Profile Adjustment required at the long cantilever for transfer dead load less prestress uplift after load transfer (may be positive or negative value).

30 day value	=	$2.60 \times \Delta$ reaction – $1.60 \times \Delta$curl
60 day value	=	$2.20 \times \Delta$ reaction – $1.20 \times \Delta$curl
90 day value	=	$1.80 \times \Delta$ reaction – $0.80 \times \Delta$curl
120 day value	=	$1.60 \times \Delta$reaction – $0.60 \times \Delta$curl
180 day value	=	$1.55 \times \Delta$reaction – $0.55 \times \Delta$curl
240 day value	=	$1.50 \times \Delta$reaction – $0.50 \times \Delta$curl
360 day value	=	$1.40 \times \Delta$reaction – $0.40 \times \Delta$curl
720 day value	=	$1.25 \times \Delta$reaction – $0.25 \times \Delta$curl

Adjustment "B" – Profile Adjustment required for short cantilever (may be positive or negative value).

30 day value	=	$2.60 \times \Delta$reaction – $3.0 \times \Delta$curl
60 day value	=	$2.20 \times \Delta$reaction – $3.0 \times \Delta$curl
90 day value	=	$1.80 \times \Delta$reaction – $3.0 \times \Delta$curl
120 day value	=	$1.60 \times \Delta$reaction – $3.0 \times \Delta$curl
180 day value	=	$1.55 \times \Delta$reaction – $3.0 \times \Delta$curl
240 day value	=	$1.50 \times \Delta$reaction – $3.0 \times \Delta$curl
360 day value	=	$1.40 \times \Delta$reaction – $3.0 \times \Delta$curl
720 day value	=	$1.25 \times \Delta$reaction – $3.0 \times \Delta$curl

Development of Plan Camber Diagram

This step involves incorporating the predicted deflections into the camber diagram to be shown on the contract plans. The long term effect of creep and shrinkage is assumed to result in ultimate deflection three (3) times as great as immediate deflection, and this will occur over a four year period. Since the load transfer from the long hinge will usually occur sometime early in the period from 30 to 180 days after prestressing the short hinge span, a camber diagram with tabulated values is to be shown on the plans.

The suggested camber diagram to be drawn for the hinged span is shown in Figure 6. The normal diagram is shown along with an enlarged camber curve for the hinge span. Three values of camber are calculated and shown at the hinge. Camber "A" is calculated for the position of the long hinge side and Camber "B" is calculated for the position of the short hinge side.

PT. 1 – This is the theoretical camber if load transfer between hinges could be immediate.

PT. 2 – This is how much to adjust the theoretical camber up or down for the long cantilever which is dependent on the time of load transfer between hinges. (Adjustment "A")

PT. 3 – This is how much to adjust the theoretical camber up or down for the short cantilever. (Adjustment "B")

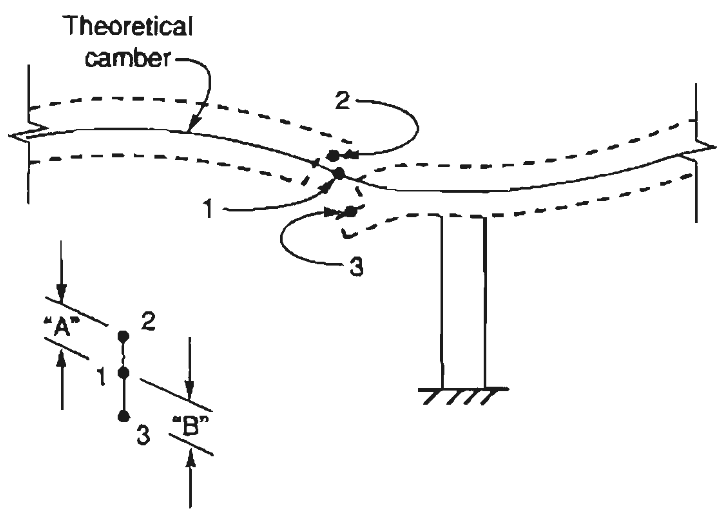
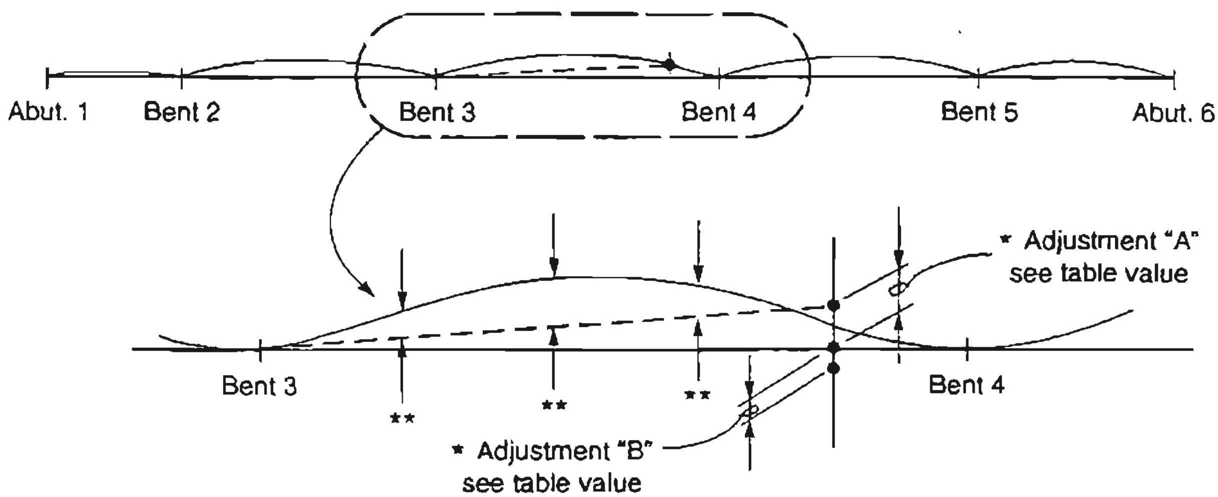


Figure 5: Adjustment to Theoretical Camber

Note: Instead of the field engineer having to adjust from theoretical camber as shown in Figure 5, Table 1 and Figure 6 will allow direct adjustments to the profile grade.



Note:

* See table for values to use — depends on period of time between prestressing of frame 2 and load transfer from frame 1.

** Adjusted values of camber taken from long cantilever values given in complete structure run of BDS. Decrease linearly back to bent for profile adjustment (add to profile grade).

Figure 6: Camber Diagram

Elapsed time in days measured from prestressing short hinge side till closure and load transfer.	Adjustment "A"	Adjustment "B"
30 days		
60 days		
90 days		
120 days		
180 days		
240 days		
360 days		
720 days		

This table is to be shown on contract plans.

Table 1: Time Dependent Camber Values

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