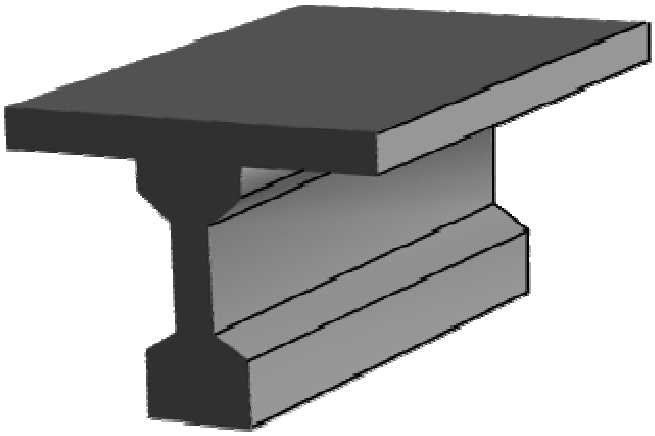
STRUCTWARE®

Program Documentation

for

PSBEAM

Prestressed Concrete Beam Program



CONTENTS

INTRODUCTION

PSBEAM may be used to design or review prestressed concrete beams with either pretensioning or post-tensioning reinforcement. Options are available to calculate stresses, deflections, ultimate moment capability and shear stirrup design. This program currently supports English units only. Prestressed concrete beam design may be performed using either AASHTO, AREMA or ACI-318 design criteria.

The online help file and graphical interface is shown in Section B. Verification problems are included in Section C. Additional information is contained in the following files installed in the program directory.

License.txt - The license agreement contains the terms and conditions for use of this program and documentation.

Readme.txt – The installation instructions, copyright notices and version history is contained in this file.

The following steps are recommended for users new to the program or specific features.

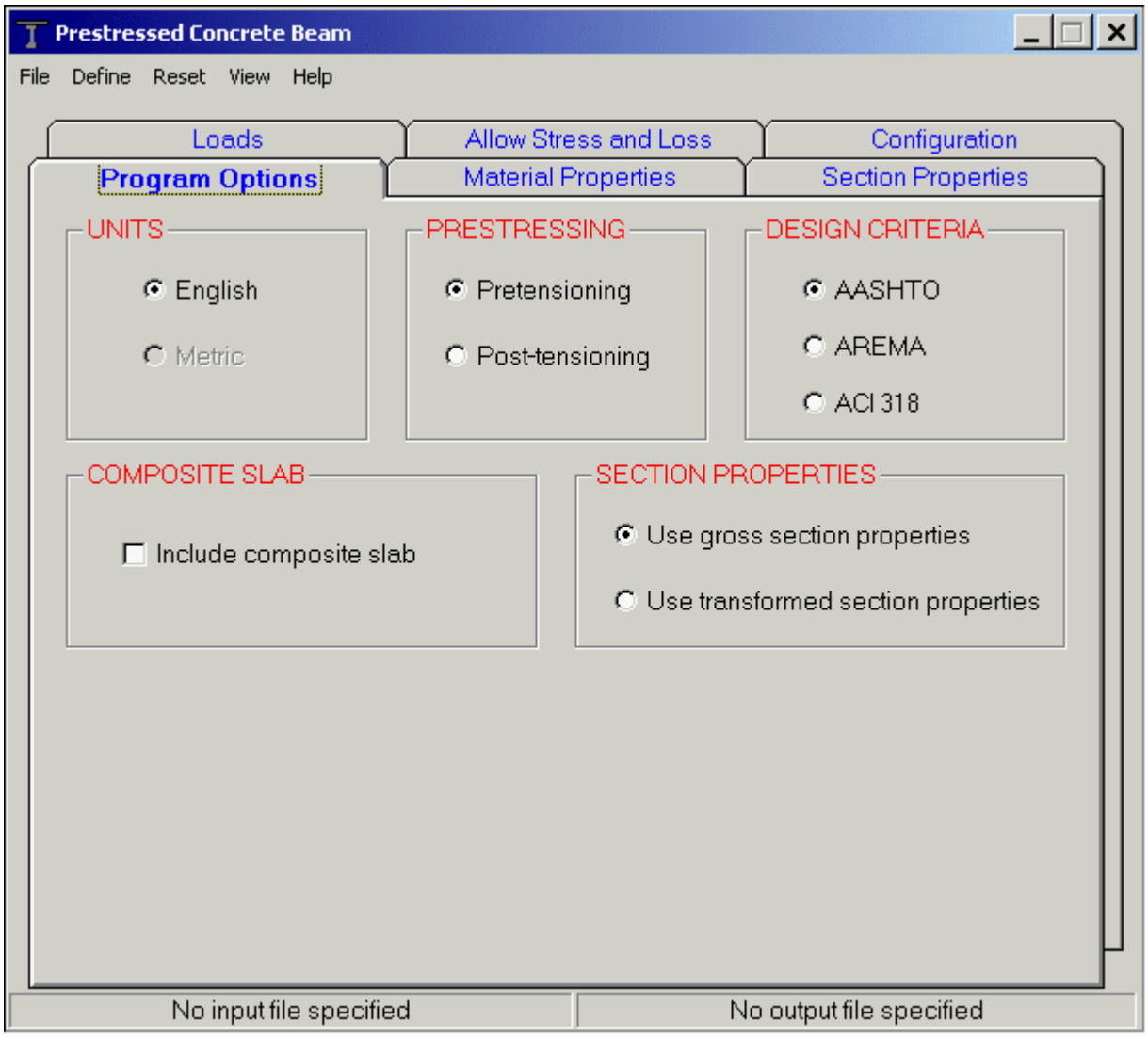
1. To learn how to use the program, view the Flash Demonstration Movie that is installed along with the program and read the "Instructions" section of the help file.

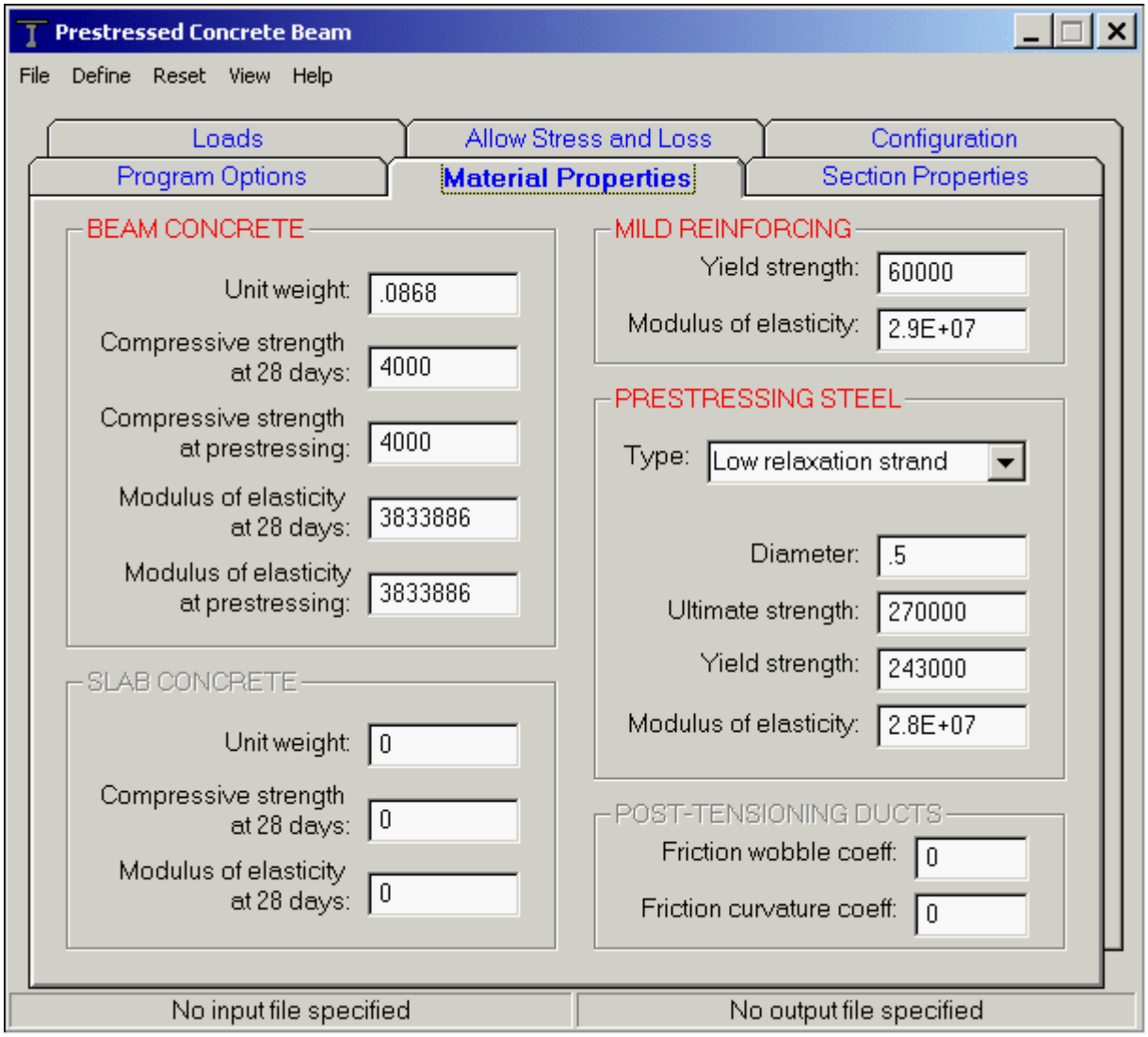
To apply this program to a specific problem, find a similar case in the Verification Problems section of this document. Run the program to see if you can reproduce the results. If your problem varies significantly from the Verification Problem, you should perform manual calculations for verification.

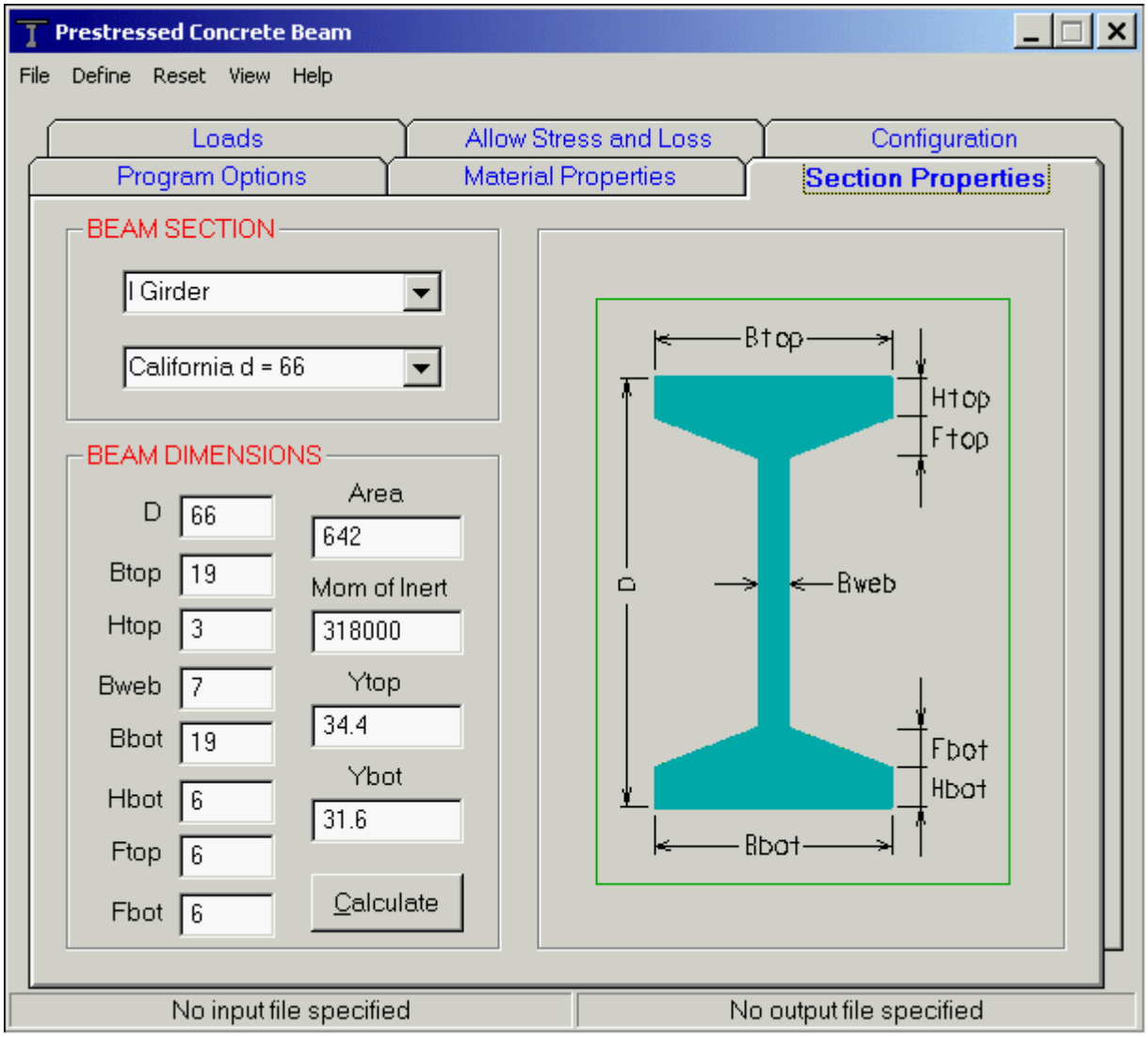
ONLINE HELP FILE

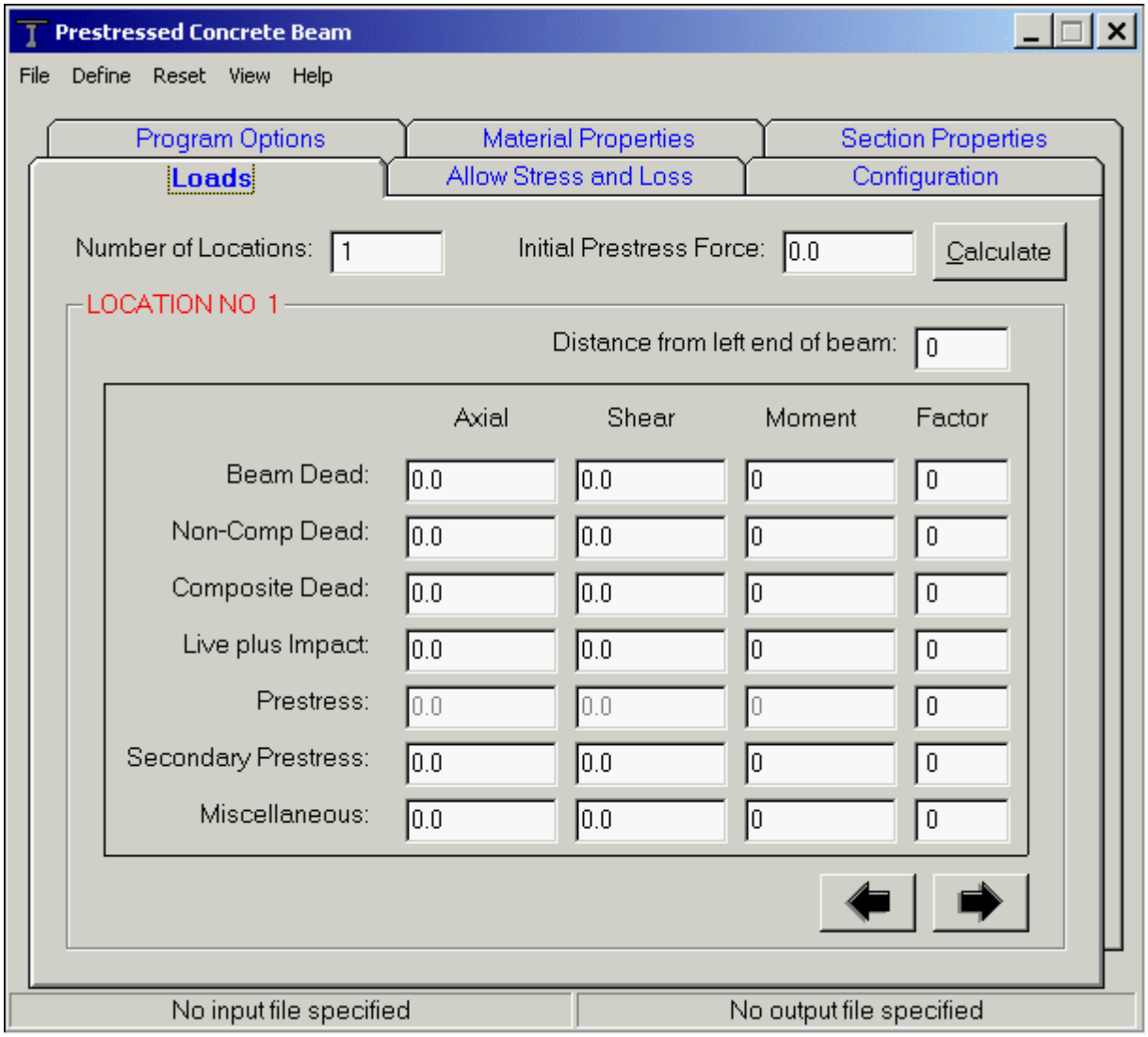
Psbeam help

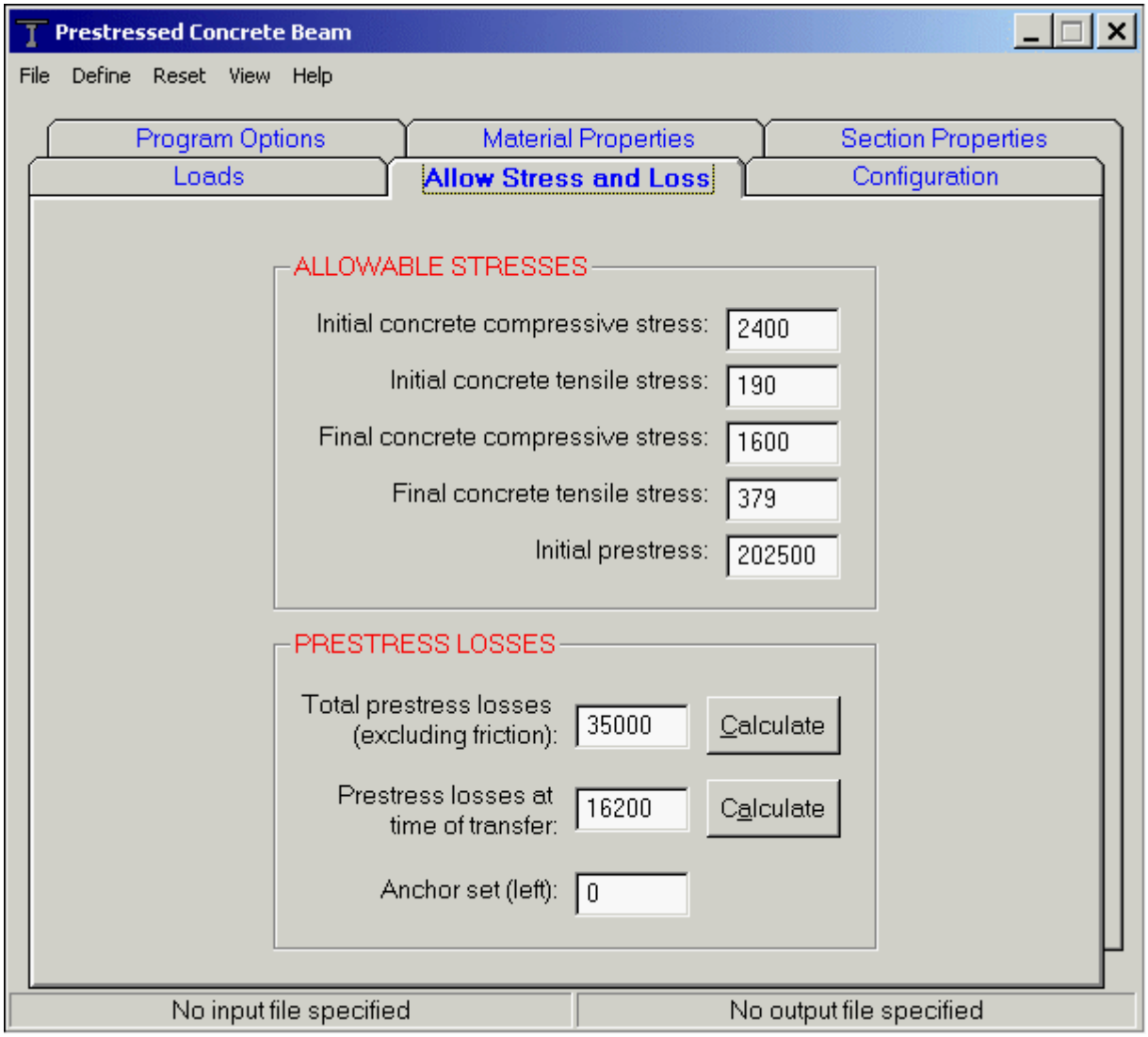
GRAPHICAL INTERFACE

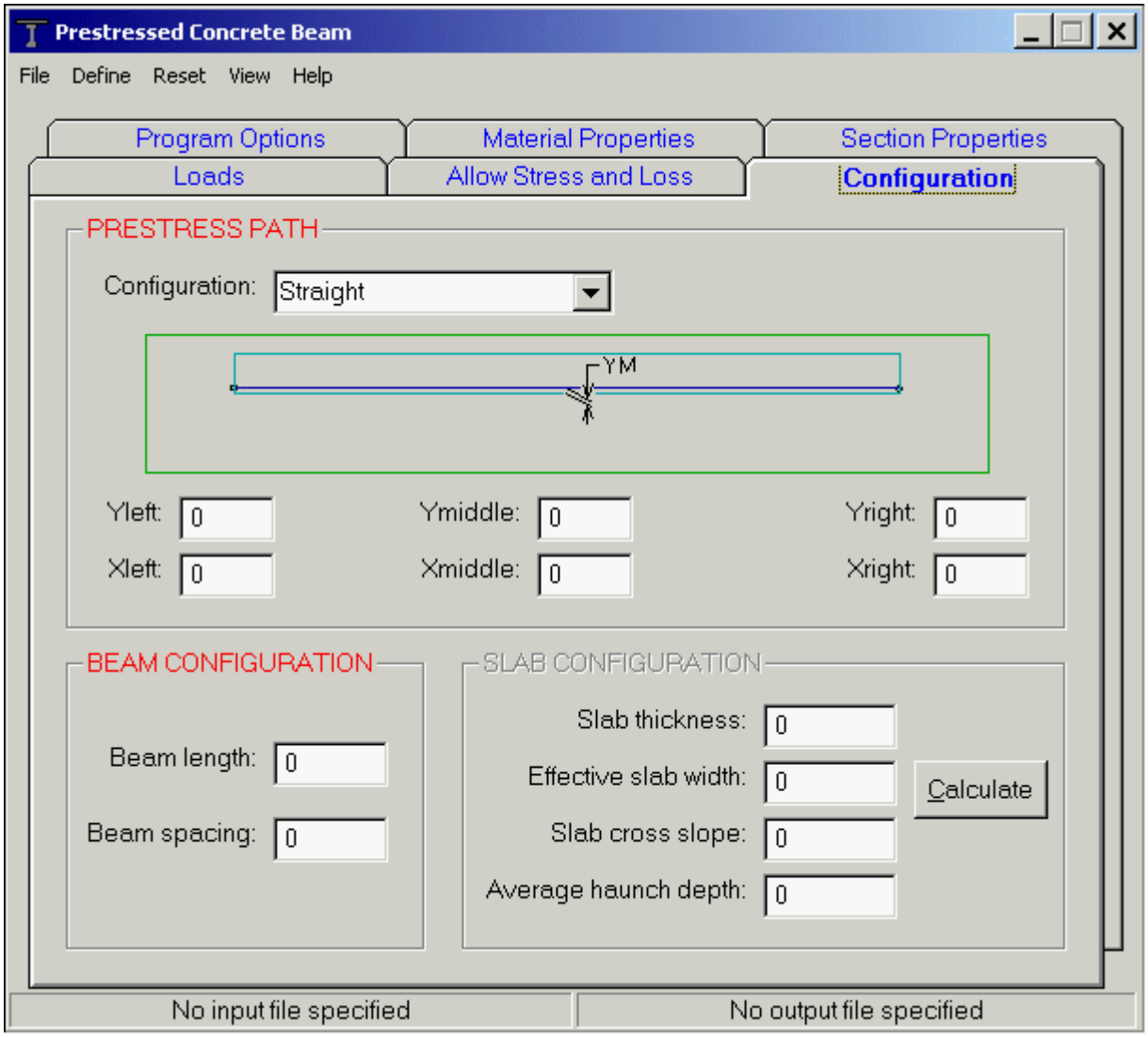



Prestressed Concrete Beam
File Define Reset View Help
Loads
Allow Stress and Loss
Configuration
Program Options
Material Properties
Section Properties
BEAM CONCRETE
Unit weight: .0868
Compressive strength at 28 days: 4000
Compressive strength at prestressing: 4000
Modulus of elasticity at 28 days: 3833886
Modulus of elasticity at prestressing: 3833886
SLAB CONCRETE
Unit weight: 0
Compressive strength at 28 days: 0
Modulus of elasticity at 28 days: 0
MILD REINFORCING
Yield strength: 60000
Modulus of elasticity: 2.9E+07
PRESTRESSING STEEL
Type: Low relaxation strand
Diameter: .5
Ultimate strength: 270000
Yield strength: 243000
Modulus of elasticity: 2.8E+07
POST-TENSIONING DUCTS
Friction wobble coeff: 0
Friction curvature coeff: 0
No input file specified
No output file specified


Prestressed Concrete Beam
File Define Reset View Help
Loads
Allow Stress and Loss
Configuration
Program Options
Material Properties
Section Properties
BEAM SECTION
I Girder
California d = 66
BEAM DIMENSIONS
D 66
Btop 19
Htop 3
Bweb 7
Bbot 19
Hbot 6
Ftop 6
Fbot 6
Area
642
Mom of Inert
318000
Ytop
34.4
Ybot
31.6
Calculate
Btop
Htop
Ftop
D
Bweb
Fbot
Hbot
Bbot
No input file specified
No output file specified


Prestressed Concrete Beam
File Define Reset View Help
Program Options
Material Properties
Section Properties
Loads
Allow Stress and Loss
Configuration
Number of Locations: 1
Initial Prestress Force: 0.0
Calculate
LOCATION NO 1
Distance from left end of beam: 0
Axial Shear Moment Factor
Beam Dead: 0.0 0.0 0 0
Non-Comp Dead: 0.0 0.0 0 0
Composite Dead: 0.0 0.0 0 0
Live plus Impact: 0.0 0.0 0 0
Prestress: 0.0 0.0 0 0
Secondary Prestress: 0.0 0.0 0 0
Miscellaneous: 0.0 0.0 0 0
No input file specified
No output file specified


Prestressed Concrete Beam
File Define Reset View Help
Program Options
Material Properties
Section Properties
Loads
Allow Stress and Loss
Configuration
ALLOWABLE STRESSES
Initial concrete compressive stress: 2400
Initial concrete tensile stress: 190
Final concrete compressive stress: 1600
Final concrete tensile stress: 379
Initial prestress: 202500
PRESTRESS LOSSES
Total prestress losses (excluding friction): 35000 Calculate
Prestress losses at time of transfer: 16200 Calculate
Anchor set (left): 0
No input file specified
No output file specified


Prestressed Concrete Beam
File Define Reset View Help
Program Options
Material Properties
Section Properties
Loads
Allow Stress and Loss
Configuration
PRESTRESS PATH
Configuration: Straight
YM
Yleft: 0
Ymiddle: 0
Yright: 0
Xleft: 0
Xmiddle: 0
Xright: 0
BEAM CONFIGURATION
Beam length: 0
Beam spacing: 0
SLAB CONFIGURATION
Slab thickness: 0
Effective slab width: 0
Slab cross slope: 0
Average haunch depth: 0
Calculate
No input file specified
No output file specified

VERIFICATION PROBLEMS

1. Verification Problem No. 1

    a. AREMA design criteria
    b. Post-tensioned
    c. Box section (non-composite)
    d. Simple-simple parabolic prestress path
    e. Gross section properties

2. Verification Problem No. 2

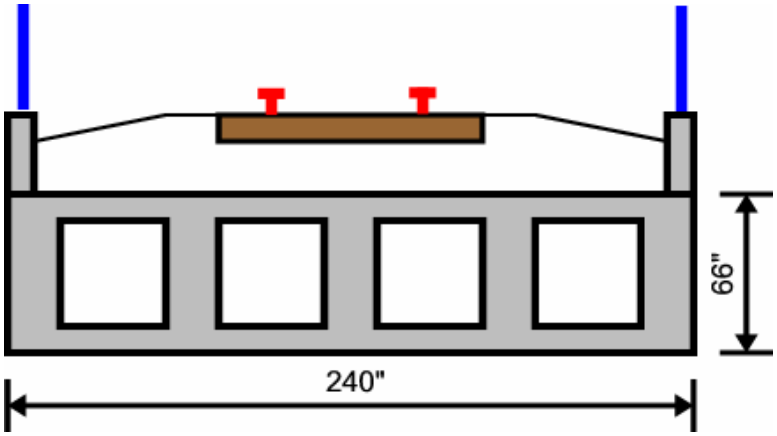
    a. ACI-318 design criteria
    b. Pretensioned
    c. I-section (non-composite)
    d. Two-point harped prestress path
    e. Gross section properties

3. Verification Problem No. 3

    a. AASHTO design criteria
    b. Pretensioned
    c. I-section (composite)
    d. Straight prestress path
    e. Transformed section properties

VERIFICATION PROBLEM NO. 1

- AREMA Design Criteria
- Post-tensioned girder



Web thickness = 12"
Top flange thickness = 10"
Bottom flange thickness = 6"

- Calculate loads

Span = 70 x 12 = 840"
M_L = 3415 x 2 = 6830 k-ft (AREMA Table 15-1-16)
Impact = 26%
M_{L+I} = 6830 x 1.26 = 8605.8 k-ft
V_{L+I} = 221.04 x 2 x 1.26 = 557.0 kips

Area = 240 x 16 + 12 x 5 x 50 = 6840 in^2
Weight = 6840 x 0.15 / 144 = 7.125 k/ft
$M_{girder} = 7.125\ (70)^2 / 8$ = 4364.1 k-ft
V_{girder} = 7.125 (70) / 2 = 249.4 k-ft

Added dead load = 5 k/ft (assumed for track, ballast and curbs)
$M_{adl} = 5\ (70)^2 / 8$ = 3062.5 k-ft
V_{adl} = 5 (70) / 2 = 175 k-ft

LOAD SUMMARY

DISTANCE	LOAD	SHEAR	MOMENT	FACTOR
0"	Girder	249.4	0	1.4
	Added DL	175.0	0	1.4
	L + I	557.0	0	2.333
420"	Girder	0	4364.1	1.4
	Added DL	0	3062.5	1.4
	L + I	0	8605.8	2.333

- Concrete properties

  f'c = 4000 psi
  f'ci = 4000 psi

- Prestressing steel

  f's = 270 ksi (low-lax)
  k = 0.0000167 k/in
  μ = 0.25

- Section properties

  A = 6840 in^2
  y_{bot} = (10 x 240 x 61 + 6 x 240 x 3 + 5 x 12 x 50 x 31) / 6840 = 35.63"
  y_{top} = 66 - 35.63 = 30.37"
  I = 2400 x $(61 - 35.63)^2$ + 1440 x $(35.63 - 3)^2$ + 3000 x $(35.63 - 31)^2$ + 20000 + 24320 + 625000
  I = 3.81 x 10^6 in^4

- Allowable stress and loss

  Initial compression = 0.6 x 4000 = 2400 psi
  Initial tension = 3 x $(4000)^{1/2}$ = 190 psi
  Final compression = 0.4 x 4000 = 1600 psi
  Final tension = 0 psi
  Initial prestress = 0.75 x 270 = 202.5 ksi

  Total prestress loss = 24 ksi
  Initial prestress loss = 202.5 - 0.69 x 270 = 16.2 ksi
  Anchor set = 3/8"

- Prestress path

  Simple-simple parabolic with Y = 12" at X = 420" and Y = 33" at X = 0" and 840"

- Verify calculations by comparison with BDS program

  File = BDS.OUT

ITEM	PSBEAM	BDS
section properties		
area =	6840	6903
inertia =	3791552	3815000
ytop =	30.368	30.2
ybot =	35.632	35.8
prestress forces @ x = 0		
initial force =	6290	6290
final force =	4759.9	4761.5
prestress forces @ x = 420		
initial force =	6290	6290
final force =	4958.1	4962.8
beam stresses @ x = 420		
prestress loss =	42879	42727
initial ps top =	-246	-249
initial ps bottom =	2101	2103
final ps top =	-214	-216
final ps bottom =	1826	1828
beam dead top =	419	418
beam dead bottom =	-492	-496
non-comp dead top =	294	291
non-comp dead bottom =	-345	-345
live top =	827	823
live bottom =	-970	-976
DL + LL + I top =	1327	1316
DL + LL + I bottom =	18	11
moment capacity @ x = 420		
Mu =	30475	30647
ϕMn =	30823	30521
Mild steel =	**0**	0.46
shear capacity @ x = 0		
Vu =	1893.6	1955
ϕVn =	1654.8	1638
Av/s =	**0.084**	0.111
deflection @ x = 420		
Final ps =	0.606	0.612

The prestress calculations for PSBEAM and BDS match well, however, the mild steel calculations need further investigation.

Moment capability @ x = 420

Mu = 1.4 x (4364.1 + 3062.5) + 2.333 x 8605.8 = 30474.6 k-ft

$\phi Mn = \phi[A_s * f_{su} * d\{1-0.6(\rho * f_{su} * / f'_c)\}]$

$\phi = 0.95$
$A_s * = 6290 / 202.5 = 31.06 \text{ in}^2$
$\rho * = 31.06 / (240 \times 54) = 0.002397$
$\gamma * = 0.28$ for low lax and 0.40 for stress-rel
$f_{su} * = f'_s [1-(\gamma * / \beta_1)(\rho * f'_s / f'_c)] = 270[1-(0.28/0.85)(0.002397 \times 270/4)] = 255.61$ ksi
a = 31.06 x 255.61 / (0.85 x 4 x 240) = 9.73" < 10" OK

$\phi Mn = 0.95[31.06 \times 255.61 \times 54 \{1 - 0.6 \times 0.002397 \times 255.61 / 4\}] / 12 = 30821$ k-ft
30821 k-ft > 30475 k-ft Therefore no mild reinforcement is required.

Shear capability @ x = 0

$V_u = 1.4 \times (249.4 + 175) + 2.333 \times 557 = 1893.6$ kips

$\phi V_{cw} = \phi[(3.5(f'_c)^{1/2} + 0.3 \times f_{pc}) \times b_w \times d + V_p]$
$\phi = 0.9$
d = 0.8 x 66 = 52.8"
Vp = 4759.9 x tan(5.71) = 475.9 kips
fpc = 475.9 / 6840 = 696 psi
$\phi V_{cw} = 0.9[(3.5(4000)^{1/2} + 0.3 \times 696) \times 60 \times 52.8 / 1000 + 475.9] = 1654.8$ kips
$A_v / s = (1893.6 - 1654.8)/(0.9 \times 60 \times 52.8) = 0.084$

PSBEAM Output file = ver1.out

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   P S B E A M                   *
*                                                         *
*                 INPUT DATA ECHO                         *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
12/27/02, 1:59 pm

P R O G R A M   O P T I O N S
=====================================================

Units              = English (inches, pounds)
Design Criteria    = AREMA
Prestressing       = Post-tensioning
Section Properties = Gross

M A T E R I A L   P R O P E R T I E S
=====================================================

BEAM CONCRETE

     Unit weight                           = 0.0868
     Compressive strength at 28 days       = 4000.00
     Compressive strength at prestressing  = 4000.00
     Modulus of elasticity at 28 days      = 3833886.
     Modulus of elasticity at prestressing = 3833886.

MILD REINFORCING

     Yield strength                        = 60000.00
     Modulus of elasticity                 = 29000000.

PRESTRESSING STEEL

     Type                                  = Low relaxation strand
     Diameter                              = 0.500
     Ultimate strength                     = 270000.00
     Yield strength                        = 243000.00
     Modulus of elasticity                 = 28000000.

POST-TENSIONING DUCTS

     Friction wobble coefficient           = 0.0000167
     Friction curvature coefficient        = 0.25
```

```
S E C T I O N   P R O P E R T I E S
=====================================================

BEAM SECTION AND DIMENSIONS

     Box Girder
     User defined
     D    = 66.000
     Btop = 240.000
     Htop = 10.000
     Bweb = 30.000
     Bbot = 240.000
     Hbot = 6.000
     Ftop = 0.000
     Fbot = 0.000

BEAM PROPERTIES

     Area = 6840.00
     MoI  = 3791552.
     Ytop = 30.368
     Ybot = 35.632

L O A D S
=====================================================
(Units = kip-ft)

Initial prestress force  = 6290.0
Number of load locations =  2

LOCATION NUMBER  1  AT X =  0

CASE                   AXIAL         SHEAR         MOMENT        FACTOR
-------------------------------------------------------------------------
BEAM DEAD              0.0           249.4         0.            1.400
NON-COMP DEAD          0.0           175.0         0.            1.400
COMPOSITE DEAD         0.0           0.0           0.            0.000
LIVE PLUS IMPACT       0.0           557.0         0.            2.333
PRESTRESS              0.0           0.0           0.            0.000
SECONDARY PRESTRESS    0.0           0.0           0.            0.000
MISCELLANEOUS          0.0           0.0           0.            0.000

LOCATION NUMBER  2  AT X =  420

CASE                   AXIAL         SHEAR         MOMENT        FACTOR
-------------------------------------------------------------------------
BEAM DEAD              0.0           0.0           4364.         1.400
NON-COMP DEAD          0.0           0.0           3063.         1.400
COMPOSITE DEAD         0.0           0.0           0.            0.000
LIVE PLUS IMPACT       0.0           0.0           8606.         2.333
PRESTRESS              0.0           0.0           0.            0.000
SECONDARY PRESTRESS    0.0           0.0           0.            0.000
MISCELLANEOUS          0.0           0.0           0.            0.000
```

```
A L L O W A B L E   S T R E S S   A N D   L O S S
=====================================================

ALLOWABLE STRESS

     Initial concrete compressive stress = 2200.
     Initial concrete tensile stress     = 190.
     Final concrete compressive stress   = 1600.
     Final concrete tensile stress       = 0.
     Initial prestress                   = 202500.

PRESTRESS LOSS

     Total prestress loss                = 24000.
     Prestress loss at time of transfer  = 16200.
     Anchor set                          = 0.375

C O N F I G U R A T I O N
=====================================================

PRESTRESS PATH

     Simple-Simple Parabolic
     Xleft        = 0.0               Yleft   = 33.000
     Xmiddle      = 420.0             Ymiddle = 12.000
     Xright       = 840.0             Yright  = 33.000

BEAM CONFIGURATION

     Beam length          = 840.000
     Beam spacing         = 0.000
```

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   P S B E A M                   *
*                                                         *
*                    OUTPUT DATA                          *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *

P R E S T R E S S   F O R C E S
=======================================================
(Units = kip-ft)

LOCATION NUMBER  1  AT X =  0

     CASE                              VALUE
     ------------------------------------------
     INITIAL FORCE                     6290.0
     CABLE ECCENTRICITY                -2.63
     FORCE AT TRANSFER                 5505.4
     MOMENT AT TRANSFER                -1207.
     FINAL FORCE                       4759.9
     FINAL MOMENT                      -1044.

LOCATION NUMBER  2  AT X =  420

     CASE                              VALUE
     ------------------------------------------
     INITIAL FORCE                     6290.0
     CABLE ECCENTRICITY                -23.63
     FORCE AT TRANSFER                 5703.6
     MOMENT AT TRANSFER                -11232.
     FINAL FORCE                       4958.1
     FINAL MOMENT                      -9764.

B E A M   S T R E S S E S
=======================================================

LOCATION NUMBER  1  AT X =  0
Prestress loss =  49259

     CASE                              TOP FIBER     BOTTOM FIBER
     ------------------------------------------------------------
     INITIAL PRESTRESS                 689.          941.
     FINAL PRESTRESS                   596.          814.
     SECONDARY PRESTRESS               0.            0.
     BEAM DEAD                         0.            0.
     NON-COMP DEAD                     0.            0.
     COMPOSITE DEAD                    0.            0.
     LIVE PLUS IMPACT                  0.            0.
     ------------------------------------------------------------
     INIT P/S + BEAM DL                689.          941.
     FINAL P/S + TOT DL                596.          814.
     P/S + ALL LOADS                   596.          814.
```

```
LOCATION NUMBER  2  AT X =  420
Prestress loss =  42879

     CASE                              TOP FIBER     BOTTOM FIBER
     ------------------------------------------------------------
     INITIAL PRESTRESS                 -246.         2101.
     FINAL PRESTRESS                   -214.         1826.
     SECONDARY PRESTRESS               0.            0.
     BEAM DEAD                         419.          -492.
     NON-COMP DEAD                     294.          -345.
     COMPOSITE DEAD                    0.            0.
     LIVE PLUS IMPACT                  827.          -970.
     ------------------------------------------------------------
     INIT P/S + BEAM DL                174.          1608.
     FINAL P/S + TOT DL                500.          988.
     P/S + ALL LOADS                   1327.         18.

CHECK CRITICAL CONCRETE STRESSES

     CASE                              ACTUAL        ALLOWABLE
     ------------------------------------------------------------
     TENSION (TOP FIBER)               174.          -190.         < OK >
     INITIAL COMPRESSION               1608.         2200.         < OK >
     FINAL TENSION (DL ONLY)           814.          0.            < OK >
     FINAL TENSION                     18.           0.            < OK >
     FINAL COMPRESSION                 1327.         1600.         < OK >

M O M E N T   C A P A C I T Y
=================================================
(Units = kip-ft)

X        Mult          1.2Mcr        phiMn
-------------------------------------------------
 0       0.            5047.         17100.        < OK >
 420     30475.        5047.         30823.        < OK >

B E A M   D E F L E C T I O N S
=================================================

Initial prestress deflection     =   0.697
Final prestress deflection       =   0.606
Simple beam dead load deflection =   0.265

S H E A R   C A P A C I T Y
=================================================
(Units = kip)

X        Vult          phiVn         Av/S
-------------------------------------------------
 0       1893.6        1654.8        0.084
 420     0.0           313.5         0.050
```

BDS Output file = BDS.OUT

```
**************************************************************************
*                            IAI-BDS                                     *
*                       Bridge Design System                             *
*                                                                        *
*                  By: Imbsen and Associates, Inc.                       *
*                    VERSION 4.2.4    23-AUG-99                          *
**************************************************************************


********** Licensed to: Holmes & Narver, Inc. - Orange, CA **********

                            LISTING OF THE SORTED INPUT FILE

 CARD             1         2         3         4         5         6         7         8
NUMBER    12345678901234567890123456789012345678901234567890123456789012345678901234567890
_______   ________________________________________________________________________________

   1      000     POST TENSIONING VERIFICATION PROBLEM NO 1                          000
   2      000     US                                                                 001
   3      000      1 1 2PRH 700           3834     150                               100
   4      000      1   0         200 5501000 600 312012   012                       200
   5      000      1 1   5000U                        TRACK AND BALLAST              300
   6      000      1 1000 1000 10 1026COOPER E80                                     500
   7      000     4                                              E80                1501
   8      000               1       140 217 217 217 233 130 130  90  95             550
   9      000     101A  1  50   275 450 275        25 20     L            4002470      600

          ________________________________________________________________________________
                   1         2         3         4         5         6         7         8
          12345678901234567890123456789012345678901234567890123456789012345678901234567890

IAI-BDS      Version 4.2.4       Licensed to: Holmes & Narver, Inc. - Orange, CA          Run time: 27-DEC-02 14:39:49  Page    1

                     POST TENSIONING VERIFICATION PROBLEM NO 1

FRAME DESCRIPTION
               END                          SUPPORT                                    CARRY 0VER
    MEM   JT.   COND                          OR              DEAD LOAD      K          FACTORS   RECALL
     NO  LT RT LT RT  DIR   SPAN      I      HINGE      E      UNI  SEC    LT    RT     LT    RT    MEM
                           (FT)    (FT**4)   (FT)    (KSI) (KIP/FT) (KCF)
   /---/ /---/ /---/ /---/ /-----/ /------/ /-----/  /------/ /--------/ /----------/ /----------/ /----/
     1   1  2   P R    H     70.0      0.00    0.0    3834.  0.000 0.150  0.00  0.00   0.00  0.00
```

POST TENSIONING VERIFICATION PROBLEM NO 1

SECTION PROPERTIES - INPUT

MEM NO	LOC. (FT)	RE CALL	Z (FT)	Y (FT)	W (FT)	D (FT)	TOP (IN)	BOT (IN)	NO	W (IN)	T (IN)	W (IN)	FACT T (FT)	W (IN)	FACT (FT)	L (FT)	EX (IN)	IN (IN)	L (FT)	EX (IN)	IN (IN)	E (KSI)	STORE
1	0.0		0.0	0.0	20.0	5.50	10.00	6.00	3	12.	0	12.	0.00	0	12.	0.00	0.0	0.	0.	0.0	0.	0.	3834.

+/-	CODE	V/D (FT)	H (FT)	Z (FT)	Y (FT)	AREA (FT**2)	IZZ (FT**4)	E (KSI)	E-STORE	STORE

SECTION PROPERTIES - OUTPUT

MEM NO	LOC. (FT)	DEPTH (FT)	Z-BAR (FT)	Y-BAR (FT)	AREA (FT**2)	IZZ (FT**4)	IYY (FT**4)	E (KSI)
1	0.0	5.50	10.00	2.98	47.94	183.96	1844.62	3834.00

MEMBER 1 PROPERTIES

LENGTH: 70.0 FT MIN E*I: 0.705E+06 KSI-FT**4 STIFF: 4.000 LT 4.000 RT C.O.: 0.500 LT 0.500 RT

POST TENSIONING VERIFICATION PROBLEM NO 1

FRAME PROPERTIES

MEM NO	JT	END COND LT	RT	LT RT	DIR	SPAN (FT)	MIN E*I (KSI-FT**4)	SUPPORT OR HINGE (FT)	E (KSI)	CARRY OVER FACTORS LT	RT	DISTRIBUTION FACTORS LT	RT
1	1	2	P	R	H	70.0	0.7053E+06	0.0	3834.	0.000	0.000	0.000	0.000

***** IF MEMBER IS HORIZONTAL SUPPORT OR HINGE FIELD EQUALS LOCATION OF HINGE FROM LEFT END OF MEMBER *****
***** IF MEMBER IS VERTICAL SUPPORT OR HINGE FIELD EQUALS SUPPORT WIDTH USED FOR MOMENT REDUCTION *****

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POST TENSIONING VERIFICATION PROBLEM NO 1

FIXED END MOMENTS TRIAL 0

MEM NO	FIXED END MOMENTS LT (KIP-FT)	RT (KIP-FT)	MEM NO	FIXED END MOMENTS LT (KIP-FT)	RT (KIP-FT)	MEM NO	FIXED END MOMENTS LT (KIP-FT)	RT (KIP-FT)
1	0.	0.						

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POST TENSIONING VERIFICATION PROBLEM NO 1

SIDESWAY DIAGNOSTICS

ERROR - FRAME MEMBER ARE ALL HORIZONT. OR ALL VERTICAL.

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POST TENSIONING VERIFICATION PROBLEM NO 1

*** SIDESWAY NOT CONSIDERED. SIDESWAY DIAGNOSTICS PRESENT. ***

HORIZONTAL MEMBER MOMENTS (KIP-FT) TRIAL 0

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	0.	1586.	2819.	3700.	4229.	4405.	4229.	3700.	2819.	1586.	0.

HORIZONTAL MEMBER STRESSES(PSI) TRIAL 0 BOTTOM FIBER

1	0.	-179.	-318.	-417.	-476.	-496.	-476.	-417.	-318.	-179.	0.

HORIZONTAL MEMBER STRESSES(PSI) TRIAL 0 TOP FIBER

1	0.	151.	268.	351.	402.	418.	402.	351.	268.	151.	0.

HORIZONTAL MEMBER SHEARS(KIPS) TRIAL 0

1	251.7	201.4	151.0	100.7	50.3	0.0	-50.3	-100.7	-151.0	-201.4	-251.7

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 0

TANGENTIAL ROTATIONS - RADIANS - CLOCKWISE POSITIVE

SPAN	LT. END	RT. END	SPAN	LT. END	RT. END	SPAN	LT. END	RT. END
1	0.001012	-0.001012						

HORIZONTAL MEMBER DEFLECTIONS IN FEET AT 1/ 4 POINTS FROM LEFT END - DOWNWARD POSITIVE

MEMBER 1 E= 3834. KSI 0.000 0.016 0.022 0.016 0.000

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POST TENSIONING VERIFICATION PROBLEM NO 1

LOAD DATA TRIAL 1

LINE	MEM	W OR P (KIP/FT)	LOAD CODE (KIP)	A (FT)	B (FT)	FIXED END MOMENTS LEFT (KIP-FT)	RIGHT (KIP-FT)	DEFLT	COMMENTS
	1	5.000	U	0.0	0.0	0.	0.		TRACK AND BALLAST
			ASSUMED DATA	70.0					

FIXED END MOMENTS TRIAL 1

MEM NO	FIXED END MOMENTS LT (KIP-FT)	RT (KIP-FT)	MEM NO	FIXED END MOMENTS LT (KIP-FT)	RT (KIP-FT)	MEM NO	FIXED END MOMENTS LT (KIP-FT)	RT (KIP-FT)
1	0.	0.						

```
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                     POST TENSIONING VERIFICATION PROBLEM NO 1

                          *** SIDESWAY NOT CONSIDERED. SIDESWAY DIAGNOSTICS PRESENT. ***
HORIZONTAL MEMBER MOMENTS (KIP-FT) TRIAL   1
MEM
 NO   LEFT     .1 PT    .2 PT    .3 PT    .4 PT    .5 PT    .6 PT    .7 PT    .8 PT    .9 PT    RIGHT

 1        0.    1102.    1960.    2572.    2940.    3062.    2940.    2572.    1960.    1102.       0.

HORIZONTAL MEMBER STRESSES(PSI) TRIAL  1    BOTTOM FIBER

 1        0.    -124.    -221.    -290.    -331.    -345.    -331.    -290.    -221.    -124.       0.

HORIZONTAL MEMBER STRESSES(PSI) TRIAL  1     TOP FIBER

 1        0.     105.     186.     244.     279.     291.     279.     244.     186.     105.       0.

HORIZONTAL MEMBER SHEARS(KIPS)  TRIAL  1

 1     175.0    140.0    105.0     70.0     35.0      0.0    -35.0    -70.0   -105.0   -140.0   -175.0

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                     POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL  1

TANGENTIAL ROTATIONS - RADIANS - CLOCKWISE POSITIVE
   SPAN    LT. END     RT. END     SPAN    LT. END     RT. END     SPAN    LT. END     RT. END

     1     0.000704   -0.000704

HORIZONTAL MEMBER DEFLECTIONS IN FEET AT 1/ 4 POINTS FROM LEFT END - DOWNWARD POSITIVE

     MEMBER  1    E= 3834. KSI     0.000     0.011     0.015     0.011     0.000
```

POST TENSIONING VERIFICATION PROBLEM NO 1

LIVE LOAD DIAGNOSTICS

LIVE LOAD GENERATOR COOPER E80

MEM NO.	NUMBER OF LIVE LOAD LANES SUPERSTRUCTURE LT.END	SUPERSTRUCTURE RT.END	SUBSTRUCTURE LT.END	SUBSTRUCTURE RT.END	RESISTING MOMENT OF UNIT STEEL POSITIVE (K-FT/SQ IN)	UNIT STEEL NEGATIVE	PLOT M ENV.	PLOT S SCALE	INFLUENCE LINES	GEN
1	1.000	1.000	1.0	1.0	0.	0.	0	0	NO	NO

LIVE LOAD NO	TRUCK OR TRAIN LOADING P1	D1	P2	D2	P3	D3	P4	D4	P5	D5	P6	D6	OVER LOAD	RRL	IMPACT	COMB CONTROL
4.	40.0	8.0	80.0	5.0	80.0	5.0	80.0	5.0	80.0	9.0	52.0	5.0	20. E80	YES		1

P7	D7	P8	D8	P9	D9	P10	D10	P11	D11	P12	D12
52.0	6.0	52.0	5.0	52.0	8.0	40.0	8.0	80.0	5.0	80.0	5.0

P13	D13	P14	D14	P15	D15	P16	D16	P17	D17	P18	D18
80.0	5.0	80.0	9.0	52.0	5.0	52.0	6.0	52.0	5.0	52.0	5.0

P19	D19	P20	D20	P21	D21	P22	D22	P23	D23	P24	D24
100.0	7.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

P25	D25	P26	D26	P27	D27	P28	D28	P29	D29	P30	D30
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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POST TENSIONING VERIFICATION PROBLEM NO 1

LL NO. 4. NEGATIVE LIVE LOAD MOMENT(KIP-FT) ENVELOPE AND ASSOCIATED SHEARS (KIPS)
*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SHEAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

HORIZONTAL MEMBER STRESSES(PSI) LL MAX NEG BOTTOM FIBER

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

HORIZONTAL MEMBER STRESSES(PSI) LL MAX NEG TOP FIBER

1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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POST TENSIONING VERIFICATION PROBLEM NO 1

LL NO. 4. DEAD LOAD PLUS NEGATIVE LIVE LOAD MOMENT(KIP-FT) ENVELOPE
*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	0.	1586.	2819.	3700.	4229.	4405.	4229.	3700.	2819.	1586.	0.

HORIZONTAL MEMBER STRESSES(PSI) FOR DL+LL MAX NEG BOTTOM FIBER

1	0.	-179.	-318.	-417.	-476.	-496.	-476.	-417.	-318.	-179.	0.

HORIZONTAL MEMBER STRESSES(PSI) FOR DL+LL MAX NEG TOP FIBER

1	0.	151.	268.	351.	402.	418.	402.	351.	268.	151.	0.

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POST TENSIONING VERIFICATION PROBLEM NO 1

LL NO. 4. POSITIVE LIVE LOAD MOMENT(KIP-FT) ENVELOPE AND ASSOCIATED SHEARS (KIPS)
*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	0.	3416.	6001.	7740.	8588.	8666.	8588.	7740.	6001.	3416.	0.
SHEAR	0.0	487.9	360.2	231.8	103.3	35.4	-103.3	-231.8	-360.2	-487.9	0.0

HORIZONTAL MEMBER STRESSES(PSI) LL MAX POS BOTTOM FIBER

1	0.	-385.	-676.	-872.	-967.	-976.	-967.	-872.	-676.	-385.	0.

HORIZONTAL MEMBER STRESSES(PSI) LL MAX POS TOP FIBER

1	0.	324.	570.	735.	816.	823.	816.	735.	570.	324.	0.

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POST TENSIONING VERIFICATION PROBLEM NO 1

LL NO. 4. DEAD LOAD PLUS POSITIVE LIVE LOAD MOMENT(KIP-FT) ENVELOPE
*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	0.	5001.	8820.	11440.	12817.	13071.	12817.	11440.	8820.	5001.	0.

HORIZONTAL MEMBER STRESSES(PSI) FOR DL+LL MAX POS BOTTOM FIBER

1	0.	-563.	-994.	-1289.	-1444.	-1472.	-1444.	-1289.	-994.	-563.	0.

HORIZONTAL MEMBER STRESSES(PSI) FOR DL+LL MAX POS TOP FIBER

1	0.	475.	838.	1087.	1217.	1242.	1217.	1087.	838.	475.	0.

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POST TENSIONING VERIFICATION PROBLEM NO 1

LL NO. 4. LIVE LOAD SHEAR(KIPS) ENVELOPES AND ASSOCIATED MOMENTS (KIP-FT)
*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

MEMBER	1 LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
POS. V	582.6	487.9	391.9	302.6	228.2	169.6	118.2	75.2	39.7	12.6	0.0
MOM.	0.	3416.	5789.	6355.	6389.	5935.	4962.	3683.	2222.	794.	0.
NEG. V	0.0	-12.6	-39.7	-75.2	-118.2	-169.6	-228.2	-302.6	-391.9	-487.9	-582.6
MOM.	0.	794.	2222.	3683.	4962.	5935.	6389.	6355.	5789.	3416.	0.
RANGE	582.6	500.5	431.6	377.8	346.3	339.1	346.3	377.8	431.6	500.5	582.6

POST TENSIONING VERIFICATION PROBLEM NO 1

LL NO. 4. DEAD LOAD PLUS LIVE LOAD SHEAR(KIPS) ENVELOPE
*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

MEMBER	1 LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
POS. V	834.3	689.3	542.9	403.3	278.5	169.6	67.8	-25.5	-111.4	-188.8	-251.7
NEG. V	251.7	188.8	111.4	25.5	-67.8	-169.6	-278.5	-403.3	-542.9	-689.3	-834.3

POST TENSIONING VERIFICATION PROBLEM NO 1

*** COOPERS LOADING WITH 20 AXLES WAS USED FOR THIS LIVE LOAD ***

LL NO. 4. LIVE LOAD SUPPORT RESULTS

	MAX. AXIAL LOAD	MAX. LONGITUDINAL MOMENT				
	AXIAL LOAD (KIPS)	MOMENT TOP (K-FT)	MOMENT BOT. (K-FT)	AXIAL LOAD (KIPS)	MOMENT TOP (K-FT)	MOMENT BOT. (K-FT)
SUPPORT JT. 1						
POSITIVE	582.6	0.	0.	0.0	0.	0.
NEGATIVE	0.0	0.	0.	0.0	0.	0.
SUPPORT JT. 2						
POSITIVE	582.6	0.	0.	0.0	0.	0.
NEGATIVE	0.0	0.	0.	0.0	0.	0.

THE RATIO OF SUBSTRUCTURE / SUPERSTRUCTURE LOADING IS 1.000

POST TENSIONING VERIFICATION PROBLEM NO 1

PRESTRESS COMBINATION DATA

INPUT:

	L.L. (1)	L.L. (2)	L.L. (3)	L.L. (4)	L.L. (5)	L.L. (6)
LIVE LOADS TO BE COMBINED:	0	0	0	1	0	0
LIVE LOAD LOAD FACTORS:	2.17	2.17	2.17	2.33	1.30	1.30

DEAD LOAD LOAD FACTOR: 1.40

PHI FACTOR FOR SHEAR : 0.90

PHI FACTOR FOR MOMENT: 0.95

ULTIMATE MOMENT APPLIED = 1.40 X (DL+ADL)
+ 2.33 X LL(4)
+ 1.00 X (P/S SEC. MOMENT)

ULTIMATE SHEAR APPLIED = 1.40 X (DL+ADL)
+ 2.33 X LL(4)
+ 1.00 X (P/S SEC. SHEAR)

PHI FACTOR FOR SHEAR = 0.90; PHI FACTOR FOR MOMENT = 0.95

POST TENSIONING VERIFICATION PROBLEM NO 1

INPUT PRESTRESSED DATA

TRIAL 10 FRAME 1 PATH A

MEM NO.	LLT/X (% / FT)	LLP/Y (% / FT)	LRT/Z (% / FT)	YLT/TYPE (FT /)	YLP/SLOPE (FT/)	YRT (FT)	U	K
1	0.00	0.50	0.00	2.75	4.50	2.75	0.25	0.0002

XLT(FT) = 0.0 XRT(FT) = 0.0 STEEL STRESS(KSI) = 270. JACKING % = 0.75 JACKING ENDS = L

ANCHOR SET(IN); LEFT = 0.375 RIGHT = 0.000 CONC. STRENGTH(PSI) = 4000. ALLOW. TENSION(PSI) = 0.

P-JACK(KIPS) = 0. SHORTENING PERCENT= 0 TOTAL LOSSES(KSI) = 24 RELATIVE HUMIDITY % = 70.

LOW-LAX = YES PLOT PATHS = NO PLOT STRESSES = NO

CABLE PATH OFFSETS (FT)

MEMBER	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	2.75	3.38	3.87	4.22	4.43	4.50	4.43	4.22	3.87	3.38	2.75

CABLE PATH ECCENTRICITIES (FT)

1	0.234	0.864	1.354	1.704	1.914	1.984	1.914	1.704	1.354	0.864	0.234

FORCE COEFFICIENTS

1	0.757	0.763	0.770	0.776	0.782	0.789	0.795	0.801	0.807	0.813	0.819

THE POINT OF NO MOVEMENT FOR PRESTRESSING IS IN SPAN 1, 70.00 FEET FROM THE LEFT END OF THE SPAN

THE LEFT ANCHOR SET LENGTH IS 70.00 FEET THE RIGHT ANCHOR SET LENGTH IS 0.00 FEET

THE FORCE COEF. AT THE LEFT END IS 0.757 THE FORCE COEF. AT THE RIGHT END IS 0.819

INITAL FORCE COEFF. AT POINT OF NO MOVEMENT = 0.938

***** LEFT ANCHOR SET LENGTH ACTUALLY EXTENDS BEYOND END OF TENDON PATH. *****

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POST TENSIONING VERIFICATION PROBLEM NO 1

SECONDARY MOMENT DUE TO PJACK = 1

TRIAL 10 FRAME 1 PATH A

FEM'S(K-FT) DUE TO SECONDARY EFFECTS BEFORE BALANCING

MEMBER	LEFT END	RIGHT END	MEMBER	LEFT END	RIGHT END	MEMBER	LEFT END	RIGHT END
1	0.000	0.000						

FEM'S DUE TO SECONDARY EFFECTS --- UNIT = K-FT

1	0.000	0.000

P/S MOMENT COEF.(FT)

*** SIDESWAY NOT CONSIDERED. SIDESWAY DIAGNOSTICS PRESENT. ***
ADJUSTED FOR LOSSES & SECONDARY MOMENTS BUT NO SHORTENING

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	-0.1771	-0.6596	-1.0423	-1.3224	-1.4974	-1.5645	-1.5211	-1.3647	-1.0926	-0.7025	-0.1916

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1 PATH A

HORIZONTAL MEMBER STRESSES (PSI) PRESTRESS ONLY BOTTOM FIBER AFTER ALL LOSSES

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	816.	1164.	1441.	1645.	1775.	1828.	1803.	1698.	1510.	1239.	883.

HORIZONTAL MEMBER STRESSES (PSI) PRESTRESS ONLY TOP FIBER AFTER ALL LOSSES

1	584.	302.	79.	-83.	-182.	-216.	-185.	-86.	83.	321.	632.

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1 PATH A

HORIZONTAL MEMBER MOMENTS DUE TO P/S (KIP-FT)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	-1115.	-4152.	-6560.	-8324.	-9425.	-9847.	-9574.	-8590.	-6877.	-4421.	-1206.

TANGENTIAL ROTATIONS - RADIANS - CLOCKWISE POSITIVE

SPAN	LT. END	RT. END	SPAN	LT. END	RT. END	SPAN	LT. END	RT. END
1	-0.002374	0.002416						

HORIZONTAL MEMBER DEFLECTIONS IN FEET AT 1/ 4 POINTS FROM LEFT END - DOWNWARD POSITIVE

MEMBER 1 E= 3834. KSI 0.000 -0.036 -0.051 -0.037 0.000

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1

HORIZONTAL MEMBER STRESSES FOR ALL P/S PATHS BEFORE LOSSES BOTTOM FIBER (PSI)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	944.	1344.	1663.	1896.	2044.	2103.	2072.	1949.	1732.	1420.	1010.

HORIZONTAL MEMBER STRESSES FOR ALL P/S PATHS BEFORE LOSSES TOP FIBER (PSI)

1	676.	349.	91.	-96.	-209.	-249.	-212.	-98.	95.	368.	724.

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1

HORIZONTAL MEMBER STRESSES FOR ALL P/S PATHS AFTER ALL LOSSES BOTTOM FIBER (PSI)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	816.	1164.	1441.	1645.	1775.	1828.	1803.	1698.	1510.	1239.	883.

HORIZONTAL MEMBER STRESSES FOR ALL P/S PATHS AFTER ALL LOSSES TOP FIBER (PSI)

1	584.	302.	79.	-83.	-182.	-216.	-185.	-86.	83.	321.	632.

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1

HORIZONTAL MEMBER STRESSES DL + P/S BEFORE ALL LOSSES BOTTOM FIBER (PSI)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	944.	1166.	1345.	1480.	1567.	1607.	1596.	1532.	1415.	1241.	1010.

HORIZONTAL MEMBER STRESSES DL + P/S BEFORE ALL LOSSES TOP FIBER (PSI)

1	676.	499.	359.	256.	192.	169.	189.	253.	362.	519.	724.

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1

HORIZONTAL MEMBER STRESSES DL + P/S AFTER ALL LOSSES BOTTOM FIBER (PSI)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	816.	985.	1123.	1228.	1299.	1332.	1327.	1281.	1193.	1061.	883.

HORIZONTAL MEMBER STRESSES DL + P/S AFTER ALL LOSSES TOP FIBER (PSI)

1	584.	452.	346.	268.	220.	202.	217.	266.	350.	472.	632.

HORIZONTAL MEMBER STRESSES DL + ADDED DL + P/S AFTER ALL LOSSES BOTTOM FIBER (PSI)

1	816.	861.	902.	939.	967.	987.	996.	991.	972.	936.	883.

HORIZONTAL MEMBER STRESSES DL + ADDED DL + P/S AFTER ALL LOSSES TOP FIBER (PSI)

1	584.	557.	533.	513.	499.	493.	496.	510.	536.	577.	632.

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POST TENSIONING VERIFICATION PROBLEM NO 1

TRIAL 10 FRAME 1

HORIZONTAL MEMBER STRESSES DL + ADDED DL + MAX POS LL + I + P/S BOTTOM FIBER (PSI)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	816.	476.	227.	67.	0.	11.	28.	119.	296.	552.	883.

HORIZONTAL MEMBER STRESSES DL + ADDED DL + MAX POS LL + I + P/S TOP FIBER (PSI)

1	584.	881.	1103.	1248.	1315.	1316.	1312.	1245.	1106.	901.	632.

HORIZONTAL MEMBER STRESSES DL + ADDED DL + MAX NEG LL + I + P/S BOTTOM FIBER (PSI)

1	816.	861.	902.	939.	967.	987.	996.	991.	972.	936.	883.

HORIZONTAL MEMBER STRESSES DL + ADDED DL + MAX NEG LL + I + P/S FOR TOP FIBER (PSI)

1	584.	557.	533.	513.	499.	493.	496.	510.	536.	577.	632.

**** MIN PJACK = 6290. KIPS CONC STRENGTH AT 28 DAYS = 3290. PSI AT STRESSING = 2921. PSI ****

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POST TENSIONING VERIFICATION PROBLEM NO 1

TOTAL PE MOMENTS FOR ALL MEMBERS. (KIP-FT)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	-1115.	-4152.	-6560.	-8324.	-9425.	-9847.	-9574.	-8590.	-6877.	-4421.	-1206.

TOTAL P/S DEFLECTION FOR TRIAL

TANGENTIAL ROTATIONS - RADIANS - CLOCKWISE POSITIVE

SPAN	LT. END	RT. END	SPAN	LT. END	RT. END	SPAN	LT. END	RT. END
1	-0.002374	0.002416						

HORIZONTAL MEMBER DEFLECTIONS IN FEET AT 1/ 4 POINTS FROM LEFT END - DOWNWARD POSITIVE

MEMBER 1 E= 3834. KSI 0.000 -0.036 -0.051 -0.037 0.000

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POST TENSIONING VERIFICATION PROBLEM NO 1

TOTAL TOP PF FOR TRIAL (KIPS)

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TOTAL BOTTOM PF FOR TRIAL (KIPS)

1	4765.	4805.	4845.	4885.	4924.	4963.	5002.	5041.	5079.	5117.	5155.

POST TENSIONING VERIFICATION PROBLEM NO 1

LONG TERM LOSSES
TOTAL LOSS (KSI) = SH + ES + CRC + CRS

MEM NO	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
1	20.9	22.2	23.9	25.5	26.8	27.4	27.3	26.5	25.2	23.7	22.7

SHEAR (KIPS) DESIGN - AASHTO 1980

,	LEFT	.1 PT	.2 PT	.3 PT	.4 PT	.5 PT	.6 PT	.7 PT	.8 PT	.9 PT	RIGHT
MEMBER: 1											
V-CABLE	462.	383.	290.	195.	98.	0.	100.	201.	304.	408.	500.
SECONDARY	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VU	1955.	1615.	1272.	944.	651.	395.	651.	944.	1272.	1615.	1955.
VC	1820.	1746.	1058.	642.	349.	341.	352.	656.	1094.	1814.	1911.
REQD WEB(IN)	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.	60.
AS(IN**2)/(FT)	1.33	0.60	* 1.34	1.54	1.42	0.60	* 1.41	1.49	1.21	0.60	* 0.99

NOTE: * AFTER REQD WEB INDICATES ADDITIONAL WEB WIDTH REQD. * AFTER AS(IN**2)/(FT) INDICATES MINIMUM REQD.

POST TENSIONING VERIFICATION PROBLEM NO 1
AASHTO ULTIMATE MOMENT

	SECOND MOMENT (K-FT)	ULT MOM APPLD (K-FT)	ULT MOM P/S CAP (K-FT)	AVERAGE FSU (KSI)	NEUTRAL AXIS (IN)	MILD STEEL REQD (SQ.IN)	COMBINED REINFORCEMENT INDEX	ULT MOM MILD CAP (K-FT)	ULT MOM TOTAL CAP (K-FT)
MEMBER: 1									
0.0 PT.	0.	0.	0.	0.00	0.00	0.00	0.000	0.	0.
0.1 PT.	0.	11722.	21991.	249.65	11.20	0.00	0.199	0.	21991.
0.2 PT.	0.	20672.	25724.	250.83	11.20	0.00	0.175	0.	25724.
0.3 PT.	0.	26816.	28412.	251.67	11.20	0.00	0.161	0.	28412.
0.4 PT.	0.	30046.	29991.	252.07	11.31	0.21	0.154	57.	30048.
0.5 PT.	0.	30647.	30521.	252.21	11.34	0.46	0.152	128.	30650.
0.6 PT.	0.	30046.	29991.	252.07	11.31	0.21	0.154	57.	30048.
0.7 PT.	0.	26816.	28412.	251.67	11.20	0.00	0.161	0.	28412.
0.8 PT.	0.	20672.	25724.	250.83	11.20	0.00	0.175	0.	25724.
0.9 PT.	0.	11722.	21991.	249.65	11.20	0.00	0.199	0.	21991.
1.0 PT.	0.	0.	0.	0.00	0.00	0.00	0.000	0.	0.

TENDON ELONGATION

PATH NO.	P-JACK (KIPS)	% JACK	FY (KSI)	AS (SQ IN)	AVE STRESS (KSI)	TENDON LENGTH (FT) *	ELONGATION (IN)
A	6290.	75.	270.	31.06	196.16	74.00	6.22

NOTE: TENDON LENGTH INCLUDES 4 FEET FOR JACKS.

MODULUS USED FOR P/S STEEL IS 28000. KSI

POST TENSIONING VERIFICATION PROBLEM NO 1

'APPROXIMATE QUANTITY'
==========

*****	CONCRETE SUPER	124 C.Y.	*****
*****	CONCRETE SUB	0 C.Y.	*****
*****	P/S TRIAL	7397 LBS.	*****

THE SUPERSTRUCTURE CONCRETE QUANTITY IS BASED ON THE UNIT WEIGHT OF CONCRETE SUPPLIED ON THE FRAME DESCRIPTION CARD. IT ASSUMES THAT ALL THE DEAD LOAD IS GIVEN IN TRIAL 0.

THE CONCRETE SUBSTRUCTURE QUANTITY IS BASED ON TRIAL 0 ONLY.

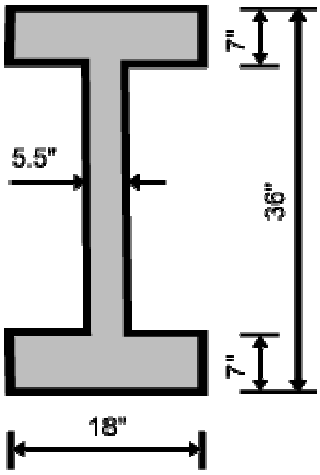
THE P/S QUANTITIES FOR STRAND ONLY ARE FOR EACH TRIAL, THAT WAS ENTERED AND IN THAT ORDER. STRAND USE IS BASED ON THE LENGTH FROM ANCHOR TO ANCHOR.

END OF JOB - 022086

INCREMENTED CLOCK TIME (SECONDS)= 0.

VERIFICATION PROBLEM NO. 2
(From TY Lin, "Design of Prestressed Concrete Structures", 3rd edition, Example 7-4)

- ACI 318 Design Criteria
- Pretensioned girder



LOAD SUMMARY

DISTANCE	LOAD	SHEAR	MOMENT	FACTOR
18"	Girder	9.142	14.15	1.4
*(30")	Live	56.071	86.79	1.7
240"	Girder	1.945	116.7	1.4
	Live	11.93	715.8	1.7

*Note: Use 30" rather than 18" from the original example problem to avoid complication from development of strands at end of girder (TY Lin example did not include any reduction for strand development but PSBEAM will calculate it automatically at ends of girder).

Beam length = 600"

- Concrete properties

  f'c = 7000 psi
  f'ci = 5500 psi

- Prestressing steel

  Area = 2.75 in^2
  f's = 270 ksi (stress-rel)

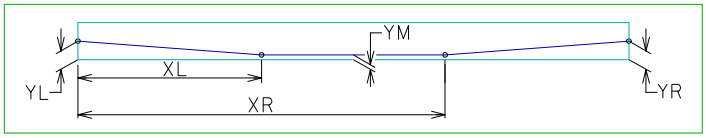
- Allowable stress and loss

  Initial compression = 0.6 x 5500 = 3300 psi
  Initial tension = 6 x $(5500)^{1/2}$ = 445 psi
  Final compression = 0.45 x 7000 = 3150 psi
  Final tension = 6 x $(7000)^{1/2}$ = 502 psi
  Initial prestress = 0.7 x 270 = 189 ksi

  Total prestress loss = 29 ksi
  Initial prestress loss = 13 ksi
  Pjack = 2.75 x 189 = 519.75 kips

- Prestress path

  Two-point harped path:



  XL = 240" YL = 6.12"
  XM = 300" YM = 4.5"
  XR = 360" YR = 6.12"

- Section properties

  A = 373 in^2
  y_{bot} = 18"
  y_{top} = 18"
  I = 2 x 18 x $(7)^3$ / 12 + 5.5 x $(22)^3$ / 12 + 2 x 126 x $(14.5)^2$ = 58892 in^4

- Verify shear capacity calculations by comparison with TY Lin example

ITEM	PSBEAM	TY Lin
shear capacity @ x = 30"		
Vu =	108.1	108.1
ϕVn =	93.5	93.2
shear capacity @ x = 240"		
Vu =	23.0	23.0
ϕVn =	20.9	20.9

- Verify stress values at x = 240" with hand calculations

Force at transfer = (189 - 13) x 2.75 = 484 kips
Moment at transfer = -484 x (18 - 4.5) / 12 = -544.5 k-ft

Final force = (189 - 29) x 2.75 = 440 kips
Final moment = -440 x (18 - 4.5) / 12 = -495 k-ft

Initial P/S + Beam DL (top) = 484/373 + (116.7 - 544.5) x 12 x 18 / 58892 = -0.271 ksi
Initial P/S + Beam DL (bot) = 484/373 + (-116.7 + 544.5) x 12 x 18 / 58892 = 2.867 ksi

Final P/S + Total DL (top) = 440/373 + (116.7 - 495) x 12 x 18 / 58892 = -0.208 ksi
Final P/S + Total DL (bot) = 440/373 + (-116.7 + 495) x 12 x 18 / 58892 = 2.567 ksi

P/S + All loads (top) = 440/373 + (116.7 + 715.8 - 495) x 12 x 18 / 58892 = 2.417 ksi
P/S + All loads (bot) = 440/373 + (-116.7 -715.8 + 495) x 12 x 18 / 58892 = -0.058 ksi

PSBEAM Output file = ver2.out

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   P S B E A M                   *
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12/27/02, 10:37 pm

P R O G R A M   O P T I O N S
=====================================================

Units              = English (inches, pounds)
Design Criteria    = ACI-318
Prestressing       = Pretensioning
Section Properties = Gross

M A T E R I A L   P R O P E R T I E S
=====================================================

BEAM CONCRETE

     Unit weight                           = 0.0868
     Compressive strength at 28 days       = 7000.00
     Compressive strength at prestressing  = 5500.00
     Modulus of elasticity at 28 days      = 5071754.
     Modulus of elasticity at prestressing = 4495630.

MILD REINFORCING

     Yield strength                        = 60000.00
     Modulus of elasticity                 = 29000000.

PRESTRESSING STEEL

     Type                                  = Stress relieved strand
     Diameter                              = 0.500
     Ultimate strength                     = 270000.00
     Yield strength                        = 243000.00
     Modulus of elasticity                 = 28000000.
```

```
S E C T I O N   P R O P E R T I E S
=====================================================

BEAM SECTION AND DIMENSIONS

     I Girder
     User defined
     D    = 36.000
     Btop = 18.000
     Htop = 7.000
     Bweb = 5.500
     Bbot = 18.000
     Hbot = 7.000
     Ftop = 0.000
     Fbot = 0.000

BEAM PROPERTIES

     Area = 373.00
     MoI  = 58892.
     Ytop = 18.000
     Ybot = 18.000

L O A D S
=====================================================
(Units = kip-ft)

Initial prestress force  = 519.8
Number of load locations =  2

LOCATION NUMBER  1  AT X =  30

CASE                   AXIAL         SHEAR         MOMENT        FACTOR
-------------------------------------------------------------------------
BEAM DEAD              0.0           9.1           14.           1.400
NON-COMP DEAD          0.0           0.0           0.            0.000
COMPOSITE DEAD         0.0           0.0           0.            0.000
LIVE PLUS IMPACT       0.0           56.1          87.           1.700
PRESTRESS              0.0           0.0           0.            0.000
SECONDARY PRESTRESS    0.0           0.0           0.            0.000
MISCELLANEOUS          0.0           0.0           0.            0.000

LOCATION NUMBER  2  AT X =  240

CASE                   AXIAL         SHEAR         MOMENT        FACTOR
-------------------------------------------------------------------------
BEAM DEAD              0.0           1.9           117.          1.400
NON-COMP DEAD          0.0           0.0           0.            0.000
COMPOSITE DEAD         0.0           0.0           0.            0.000
LIVE PLUS IMPACT       0.0           11.9          716.          1.700
PRESTRESS              0.0           0.0           0.            0.000
SECONDARY PRESTRESS    0.0           0.0           0.            0.000
MISCELLANEOUS          0.0           0.0           0.            0.000
```

A L L O W A B L E S T R E S S A N D L O S S
==========

ALLOWABLE STRESS

Initial concrete compressive stress	= 3300.
Initial concrete tensile stress	= 445.
Final concrete compressive stress	= 3150.
Final concrete tensile stress	= 502.
Initial prestress	= 189000.

PRESTRESS LOSS

Total prestress loss	= 29000.
Prestress loss at time of transfer	= 13000.
Anchor set	= 0.000

C O N F I G U R A T I O N
==========

PRESTRESS PATH

Harped

Xleft	= 240.0	Yleft	= 6.120
Xmiddle	= 300.0	Ymiddle	= 4.500
Xright	= 360.0	Yright	= 6.120

BEAM CONFIGURATION

Beam length	= 600.000
Beam spacing	= 60.000

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   P S B E A M                   *
*                                                         *
*                    OUTPUT DATA                          *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *

P R E S T R E S S   F O R C E S
=======================================================
(Units = kip-ft)

LOCATION NUMBER  1  AT X =  30

     CASE                              VALUE
     ------------------------------------------
     INITIAL FORCE                     519.8
     CABLE ECCENTRICITY                -12.08
     FORCE AT TRANSFER                 484.0
     MOMENT AT TRANSFER                -487.
     FINAL FORCE                       440.0
     FINAL MOMENT                      -443.

LOCATION NUMBER  2  AT X =  240

     CASE                              VALUE
     ------------------------------------------
     INITIAL FORCE                     519.8
     CABLE ECCENTRICITY                -13.50
     FORCE AT TRANSFER                 484.0
     MOMENT AT TRANSFER                -545.
     FINAL FORCE                       440.0
     FINAL MOMENT                      -495.

B E A M   S T R E S S E S
=======================================================

LOCATION NUMBER  1  AT X =  30
Prestress loss =  29000

     CASE                              TOP FIBER     BOTTOM FIBER
     ------------------------------------------------------------
     INITIAL PRESTRESS                 -490.         3085.
     FINAL PRESTRESS                   -445.         2805.
     SECONDARY PRESTRESS               0.            0.
     BEAM DEAD                         52.           -52.
     NON-COMP DEAD                     0.            0.
     COMPOSITE DEAD                    0.            0.
     LIVE PLUS IMPACT                  318.          -318.
     ------------------------------------------------------------
     INIT P/S + BEAM DL                -438.         3033.
     FINAL P/S + TOT DL                -393.         2753.
     P/S + ALL LOADS                   -75.          2434.
```

LOCATION NUMBER 2 AT X = 240
Prestress loss = 29000

CASE	TOP FIBER	BOTTOM FIBER
INITIAL PRESTRESS	-699.	3295.
FINAL PRESTRESS	-636.	2995.
SECONDARY PRESTRESS	0.	0.
BEAM DEAD	428.	-428.
NON-COMP DEAD	0.	0.
COMPOSITE DEAD	0.	0.
LIVE PLUS IMPACT	2625.	-2625.
INIT P/S + BEAM DL	-271.	2867.
FINAL P/S + TOT DL	-208.	2567.
P/S + ALL LOADS	2417.	-58.

CHECK CRITICAL CONCRETE STRESSES

CASE	ACTUAL	ALLOWABLE	
TENSION (TOP FIBER)	-438.	-445.	< OK >
INITIAL COMPRESSION	3033.	3300.	< OK >
FINAL TENSION (DL ONLY)	2567.	0.	< OK >
FINAL TENSION	-58.	-502.	< OK >
FINAL COMPRESSION	2434.	3150.	< OK >

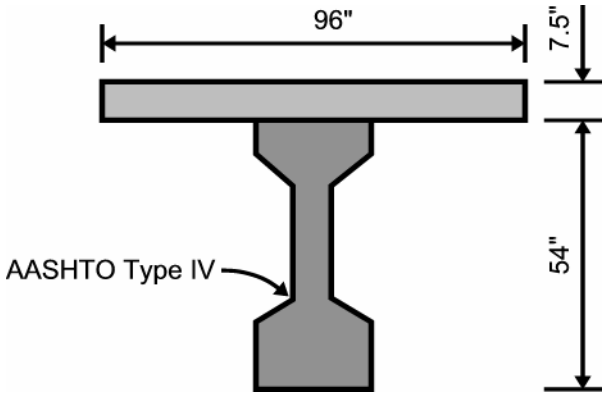
S H E A R C A P A C I T Y

(Units = kip)

X	Vult	phiVn	Av/S
30	108.1	93.5	0.010
240	23.0	20.9	0.005

VERIFICATION PROBLEM NO. 3
(From PCI, "Design Supplement to: Precast Prestressed Concrete Short Span Bridges", 1st edition, Example 3)

- AASHTO Design Criteria
- Pretensioned girder with composite slab
- Transformed section properties



LOAD SUMMARY

DISTANCE	LOAD	SHEAR	MOMENT
450"	Girder	0	578
	Non-comp DL	0	527
	Composite DL	0	241
	Live	0	977

Beam span = 900"

- Concrete properties

  Girder f'c = 5000 psi
  Girder f'ci = 4000 psi
  Slab f'c = 4000 psi

- Prestressing steel

  Area = 3.672 in^2
  f's = 270 ksi (stress-rel)

- Allowable stress and loss

  Initial compression = 0.6 x 5000 = 3000 psi
  Initial tension = 3 x $(4000)^{1/2}$ = 190 psi
  Final compression = 0.4 x 5000 = 2000 psi
  Final tension = 6 x $(5000)^{1/2}$ = 424 psi
  Initial prestress = 0.7 x 270 = 189 ksi

  Total prestress loss = 39.6 ksi
  Initial prestress loss = 18.9 ksi
  Pjack = 3.672 x 189 = 674 kips

- Prestress path

  Straight path: YM = 4" (distance from bottom fiber)

- Gross section properties (given)

  A = 789 in^2
  y_{bot} = 24.73"
  y_{top} = 29.27"
  I = 260730 in^4

- Calculate transformed beam section properties

  Eps = 28000 ksi
  Egirder = 4286 ksi
  n = 28000 / 4286 = 6.533

  A = 789 + (6.533 - 1) x 3.672 = 809.3 in^2
  y_{bot} = (789 x 24.73 + 20.32 x 4) / 809.3 = 24.21"
  y_{top} = 29.79"
  I = 260730 + 789$(0.52)^2$ + 20.32$(20.21)^2$ = 269243 in^4

- Calculate transformed composite section properties

  Eslab = 3834 ksi
  nslab = 3834 / 4286 = 0.894
  Io = 0.894 x 96 $(7.5)^3$ / 12 = 3017 in^4
  A = 809.3 + 0.894(720) = 1453 in^2
  y_{bot} = (809.3 x 24.21 + 644 x 57.75) / 1453 = 39.08 in
  y_{top} = 22.42 in
  I = 269243 + 809.3 $(14.87)^2$ + 3017 + 644 $(18.67)^2$ = 675688 in^4

- Verify stress values with hand calculations

  Force at transfer = (189 - 18.9) x 3.672 = 624.6 kips
  Moment at transfer = -624.6 x (24.21 - 4) / 12 = -1051.9 k-ft

  Final force = (189 - 39.6) x 3.672 = 548.6 kips
  Final moment = -548.6 x (24.21 - 4) / 12 = -923.9 k-ft

  Initial P/S + Beam DL (top) = 624.6/809.3 + (578 - 1051.9) x 12 x 29.79 / 269243 = 0.143 ksi
  Initial P/S + Beam DL (bot) = 624.6/809.3 + (-578 + 1051.9) x 12 x 24.21 / 269243 = 1.283 ksi

  Final P/S + Total DL (top) = 548.6/809.3 + (1105 - 923.9) x 12 x 29.79 / 269243 + 241 x 12 x 14.92 / 675688 = 0.982 ksi
  Final P/S + Total DL (bot) = 548.6/809.3 + (-1105 + 923.9) x 12 x 24.21 / 269243 - 241 x 12 x 39.08 / 675688 = 0.315 ksi

  Final P/S + All loads (top) = 548.6/809.3 + (1105 - 923.9) x 12 x 29.79 / 269243 + 1218 x 12 x 14.92 / 675688 = 1.241ksi
  Final P/S + All loads (bot) = 548.6/809.3 + (-1105 + 923.9) x 12 x 24.21 / 269243 - 1218 x 12 x 39.08 / 675688 = -0.363 ksi

  LL + (P/S + Total DL)/2 (top) = 0.982 / 2 + 977 x 12 x 14.92 / 675688 = 0.750 ksi

PSBEAM Output file = ver3.out

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   P S B E A M                   *
*                                                         *
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* * * * * * * * * * * * * * * * * * * * * * * * * * * * *
12/28/02, 11:48 am

P R O G R A M   O P T I O N S
=====================================================

Units              = English (inches, pounds)
Design Criteria    = AASHTO
Prestressing       = Pretensioning
Section Properties = Transformed

M A T E R I A L   P R O P E R T I E S
=====================================================

BEAM CONCRETE

     Unit weight                           = 0.0868
     Compressive strength at 28 days       = 5000.00
     Compressive strength at prestressing  = 4000.00
     Modulus of elasticity at 28 days      = 4286415.
     Modulus of elasticity at prestressing = 3833886.

SLAB CONCRETE

     Unit weight                           = 0.0868
     Compressive strength at 28 days       = 4000.00
     Modulus of elasticity at 28 days      = 3833886.

MILD REINFORCING

     Yield strength                        = 60000.00
     Modulus of elasticity                 = 29000000.

PRESTRESSING STEEL

     Type                                  = Stress relieved strand
     Diameter                              = 0.500
     Ultimate strength                     = 270000.00
     Yield strength                        = 243000.00
     Modulus of elasticity                 = 28000000.
```

```
S E C T I O N   P R O P E R T I E S
======================================================

BEAM SECTION AND DIMENSIONS

     I Girder
     AASHTO d = 54
     D    = 54.000
     Btop = 20.000
     Htop = 8.000
     Bweb = 8.000
     Bbot = 26.000
     Hbot = 8.000
     Ftop = 6.000
     Fbot = 9.000

BEAM PROPERTIES

     Area = 789.00
     MoI  = 260730.
     Ytop = 29.270
     Ybot = 24.730

L O A D S
======================================================
(Units = kip-ft)

Initial prestress force  = 694.0
Number of load locations =  1

LOCATION NUMBER  1  AT X =  450

CASE                   AXIAL         SHEAR         MOMENT        FACTOR
-------------------------------------------------------------------------
BEAM DEAD              0.0           0.0           578.          1.300
NON-COMP DEAD          0.0           0.0           527.          1.300
COMPOSITE DEAD         0.0           0.0           241.          1.300
LIVE PLUS IMPACT       0.0           0.0           977.          2.170
PRESTRESS              0.0           0.0           0.            0.000
SECONDARY PRESTRESS    0.0           0.0           0.            0.000
MISCELLANEOUS          0.0           0.0           0.            0.000

A L L O W A B L E   S T R E S S   A N D   L O S S
======================================================

ALLOWABLE STRESS

     Initial concrete compressive stress = 2400.
     Initial concrete tensile stress     = 190.
     Final concrete compressive stress   = 2000.
     Final concrete tensile stress       = 424.
     Initial prestress                   = 189000.
```

```
PRESTRESS LOSS

     Total prestress loss                = 39600.
     Prestress loss at time of transfer  = 18900.
     Anchor set                          = 0.000

C O N F I G U R A T I O N
=====================================================

PRESTRESS PATH

     Straight
     Xleft        = 0.0                Yleft   = 0.000
     Xmiddle      = 0.0                Ymiddle = 4.000
     Xright       = 0.0                Yright  = 0.000

BEAM CONFIGURATION

     Beam length          = 900.000
     Beam spacing         = 96.000

SLAB CONFIGURATION

     Slab thickness       = 7.500
     Effective width      = 96.000
     Cross slope          = 0.000
     Average haunch depth = 0.000

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
*                                                         *
*           P R O G R A M   P S B E A M                   *
*                                                         *
*                    OUTPUT DATA                          *
*                                                         *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

C O M P O S I T E   P R O P E R T I E S
=====================================================

Area =   1433.
MoI  =   650353.
Ytop =   21.93
Ybot =   39.57
```

```
T R A N S F O R M E D   P R O P E R T I E S
=====================================================

LOCATION NUMBER  1  AT X =  450
P/S STEEL LOCATED AT 4.00  FROM BOTTOM FIBER

     ITEM              BEAM          COMPOSITE
     ------------------------------------------------
     Area              809.          1453.
     MoI               269241.       675694.
     Ytop              29.79         22.43
     Ybot              24.21         39.07

P R E S T R E S S   F O R C E S
=====================================================
(Units = kip-ft)

LOCATION NUMBER  1  AT X =  450

     CASE                           VALUE
     ----------------------------------------
     INITIAL FORCE                  694.0
     CABLE ECCENTRICITY             -20.21
     FORCE AT TRANSFER              624.6
     MOMENT AT TRANSFER             -1052.
     FINAL FORCE                    548.6
     FINAL MOMENT                   -924.

B E A M   S T R E S S E S
=====================================================

LOCATION NUMBER  1  AT X =  450
Prestress loss =  39600

     CASE                           TOP FIBER     BOTTOM FIBER
     ------------------------------------------------------------
     INITIAL PRESTRESS              -625.         1907.
     FINAL PRESTRESS                -549.         1675.
     SECONDARY PRESTRESS            0.            0.
     BEAM DEAD                      767.          -624.
     NON-COMP DEAD                  700.          -569.
     COMPOSITE DEAD                 64.           -167.
     LIVE PLUS IMPACT               259.          -678.
     ------------------------------------------------------------
     INIT P/S + BEAM DL             143.          1283.
     FINAL P/S + TOT DL             982.          315.
     LL + (P/S + DL)/2              750.          -520.
     P/S + ALL LOADS                1241.         -363.
```

CHECK CRITICAL CONCRETE STRESSES

CASE	ACTUAL	ALLOWABLE	
TENSION (TOP FIBER)	143.	-190.	< OK >
INITIAL COMPRESSION	1283.	2400.	< OK >
FINAL TENSION (DL ONLY)	315.	0.	< OK >
COMP @ (LL + [PS+DL]/2)	750.	2000.	< OK >
FINAL TENSION	-363.	-424.	< OK >
FINAL COMPRESSION	1241.	2000.	< OK >