# WIN-SABRE

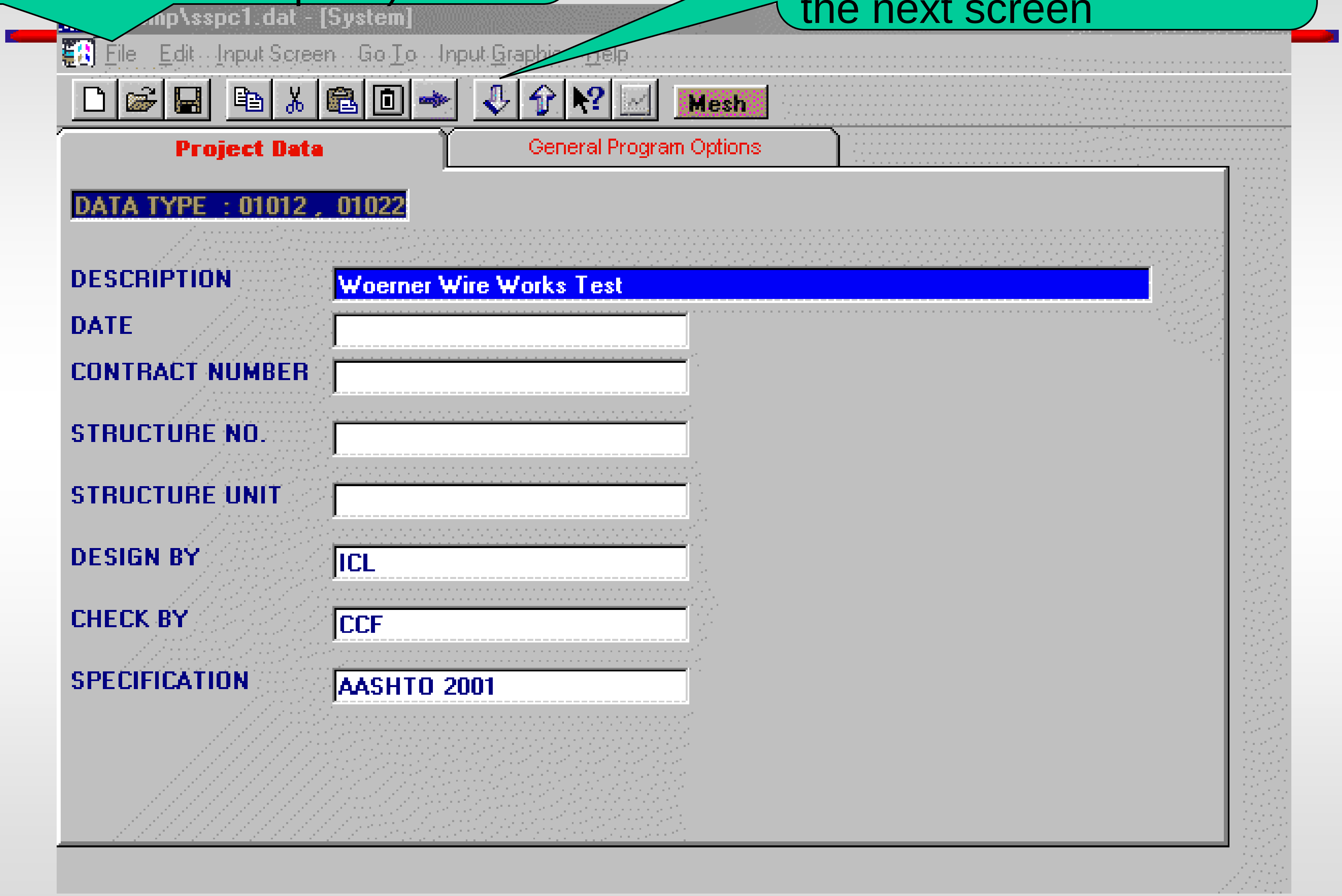
## Tutorial for ASD & LRFD
## (Cantilever)

Windows-Based Computer Analysis of 3-D Sign Bridge

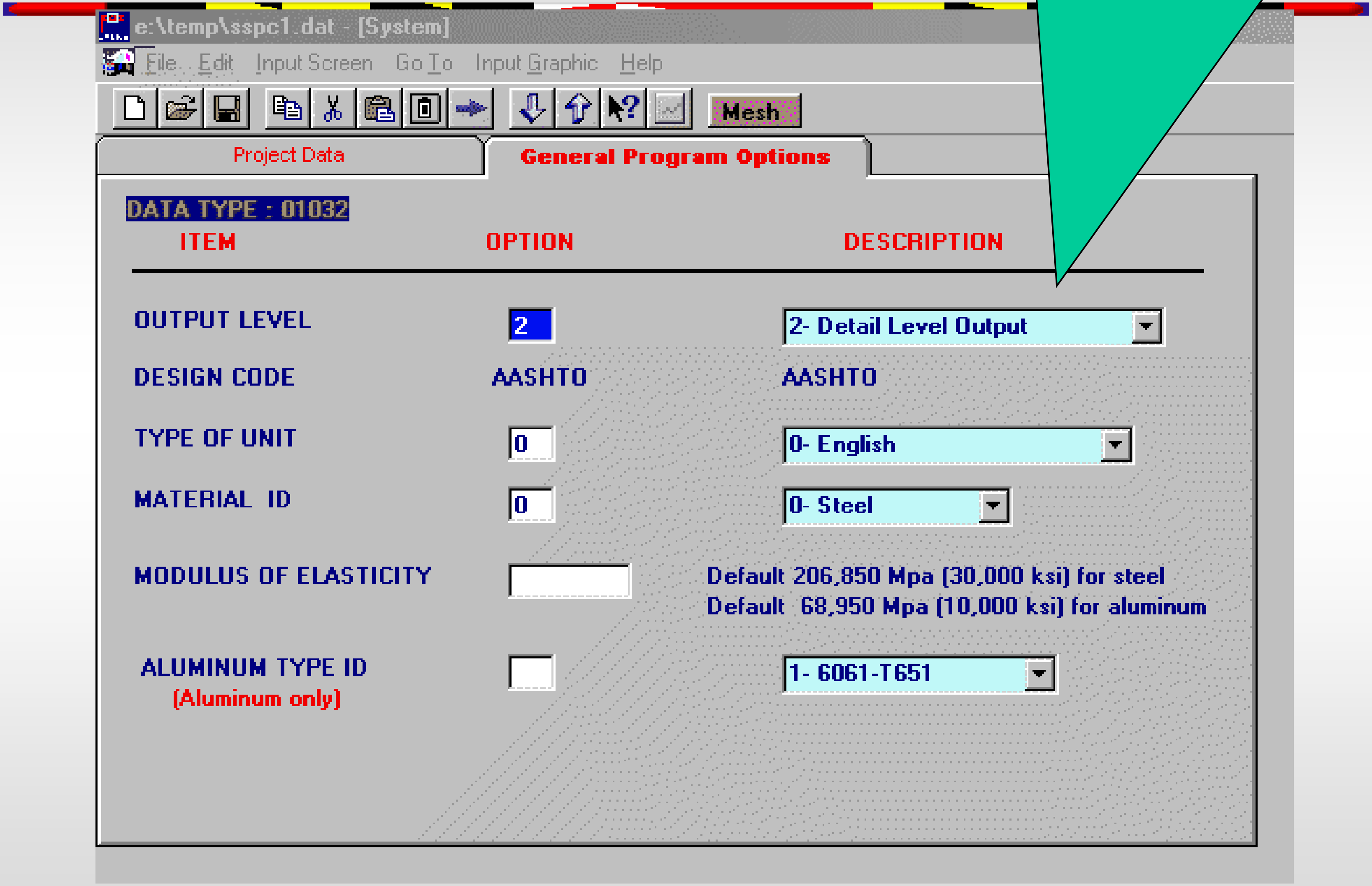
Chung C. Fu, Ph.D., P.E., Director
(http: www.best.umd.edu)

Step 1: Open an existing file or Create a new file. (File name will be shown on the Caption)

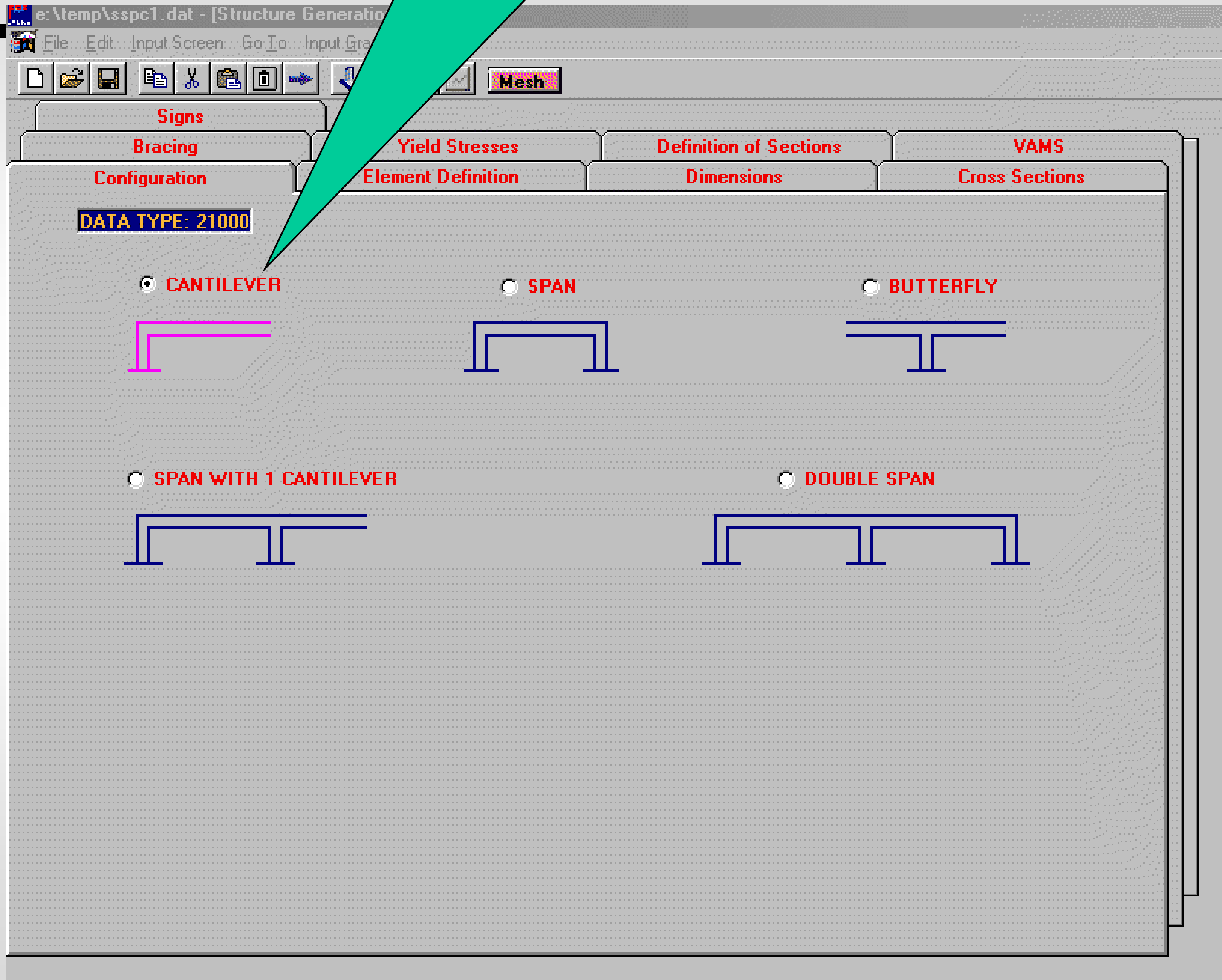
Step 1A: Once done, click Down Icon or next Tab to the next screen



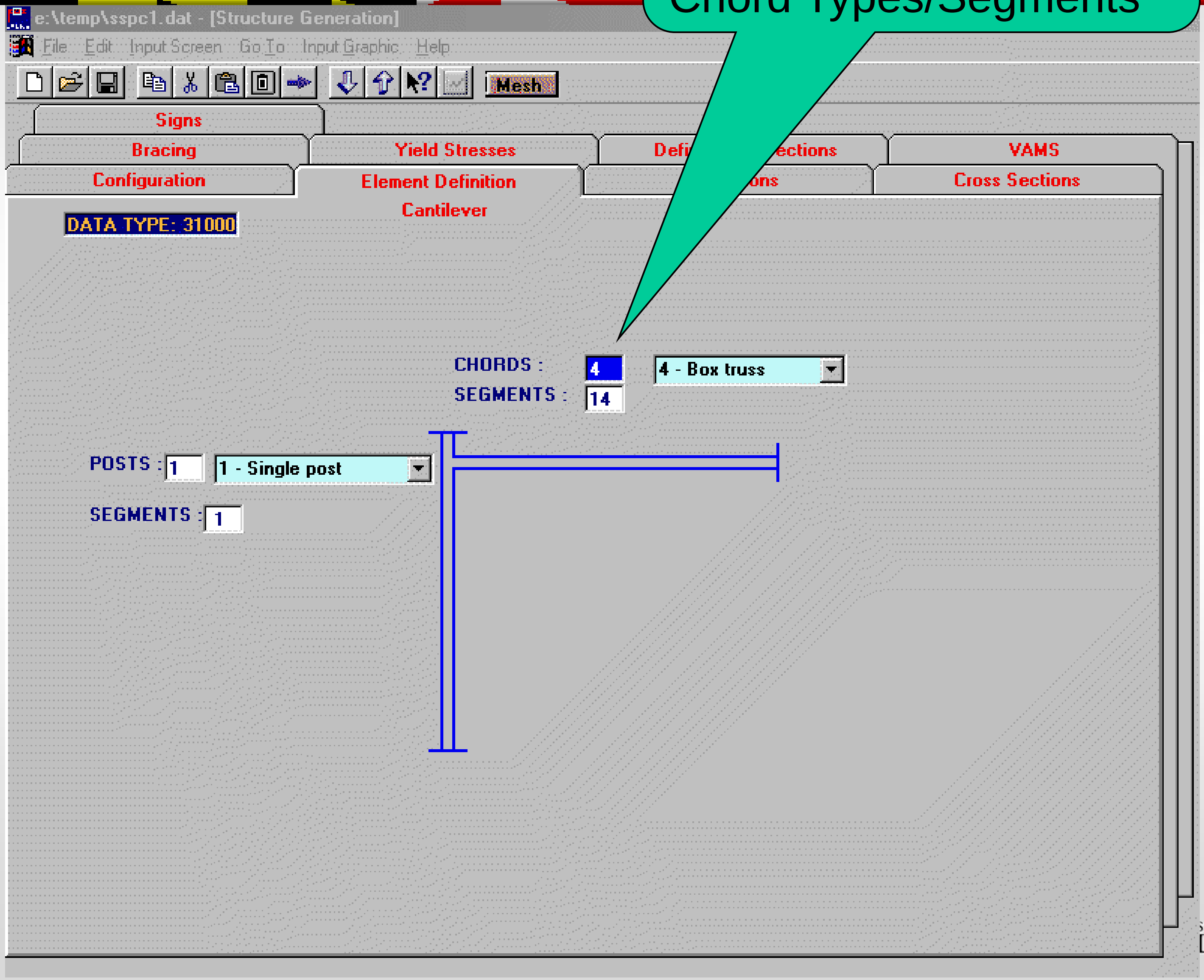
Step 2: Input General Program Options (Detailed level is needed for Postprocessor)



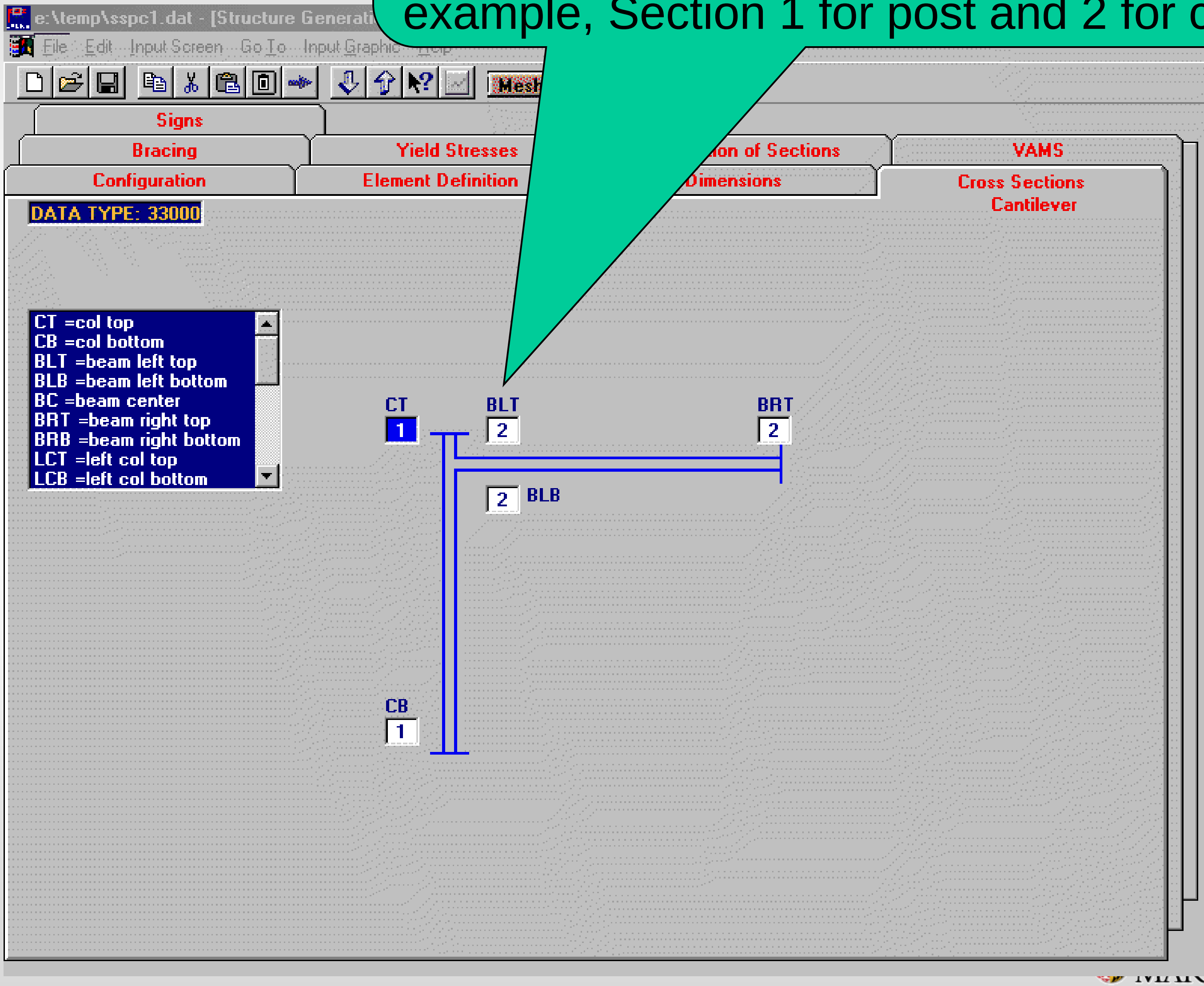
# Step 3: Select Configuration Type



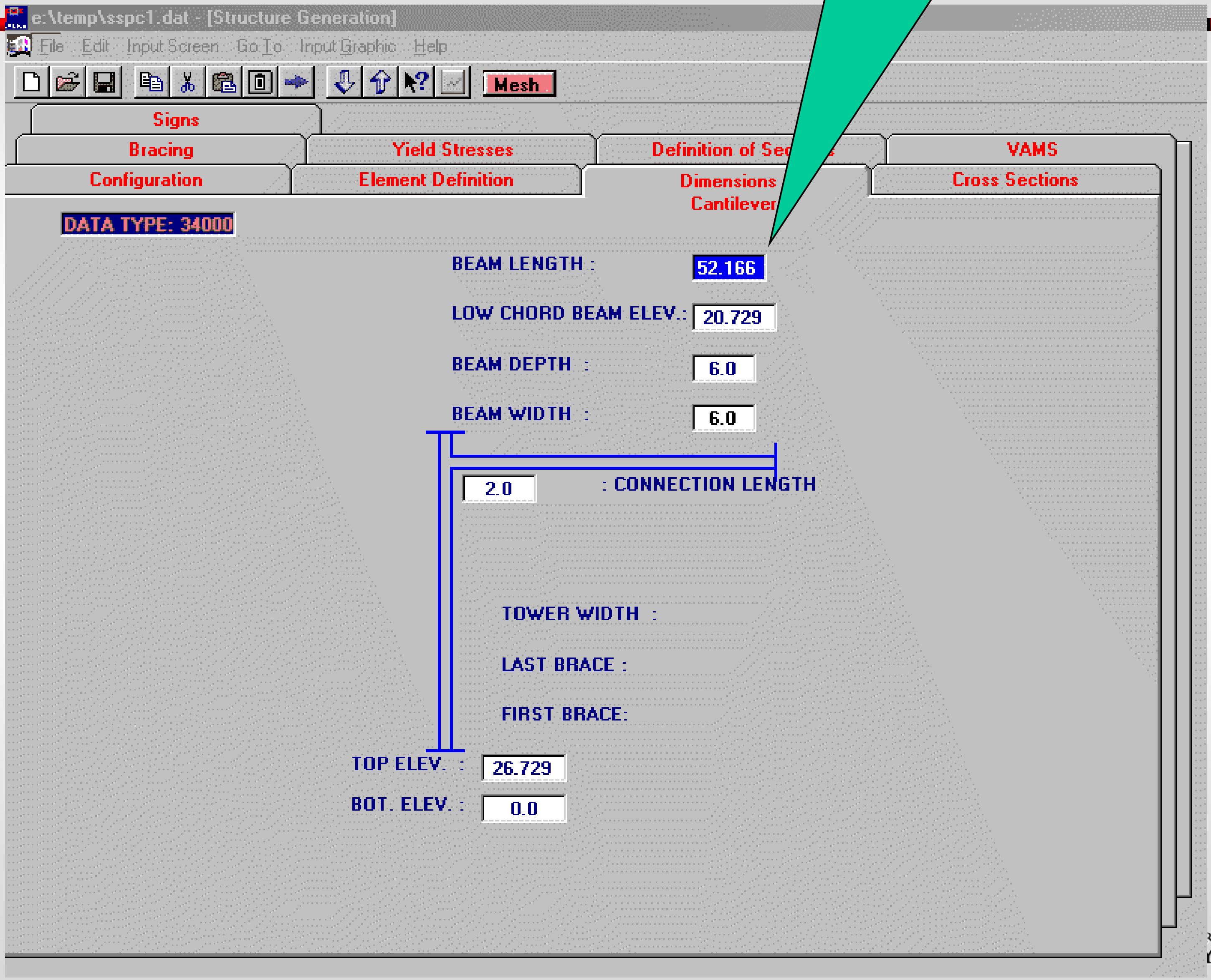
# Step 4: Select Post Type/Segments and Chord Types/Segments



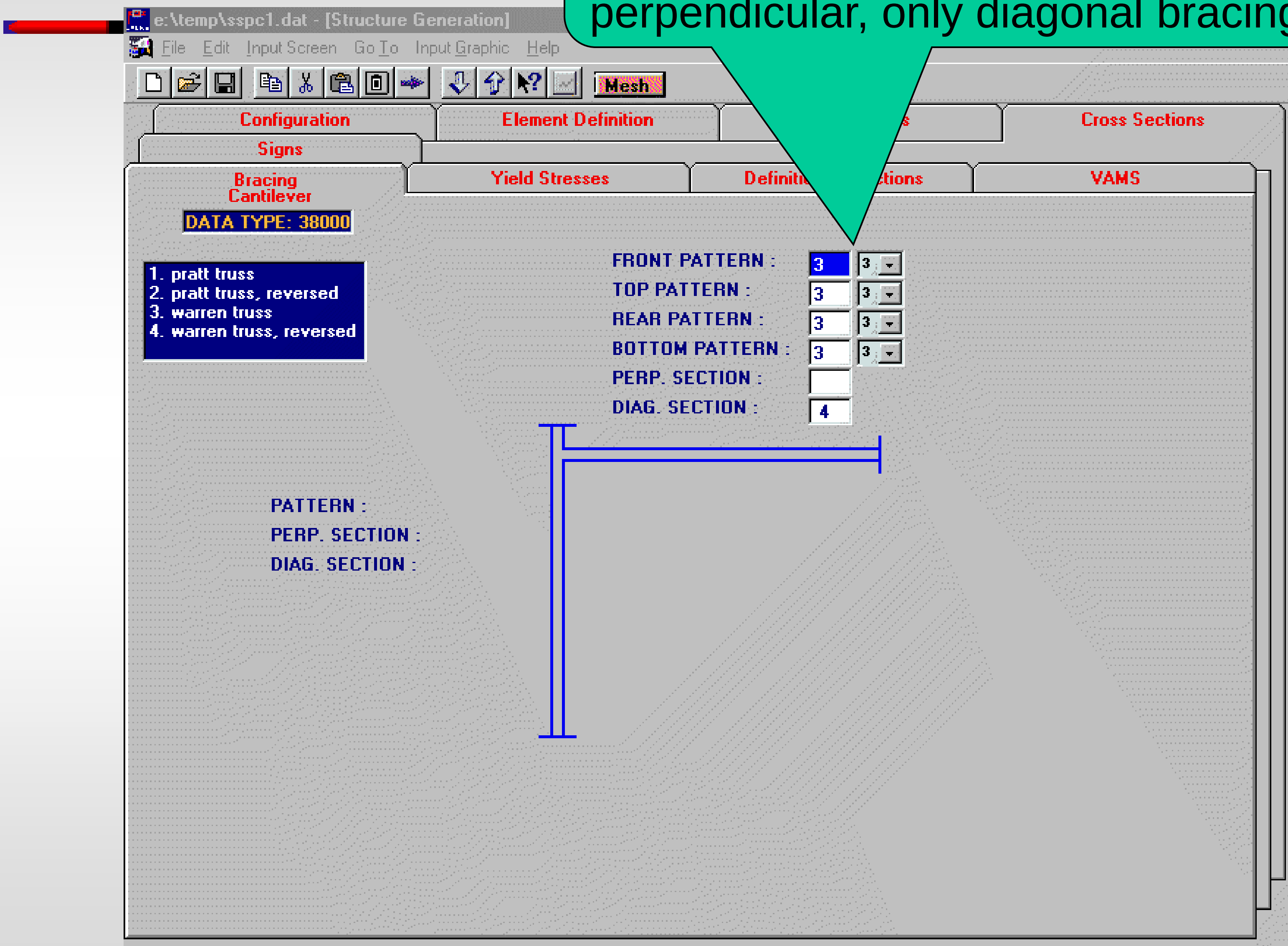
Step 5: Predefine Cross Section Numbers (see the screen for Definition of Sections) and assign them to Posts and Chords. (In this example, Section 1 for post and 2 for chords)



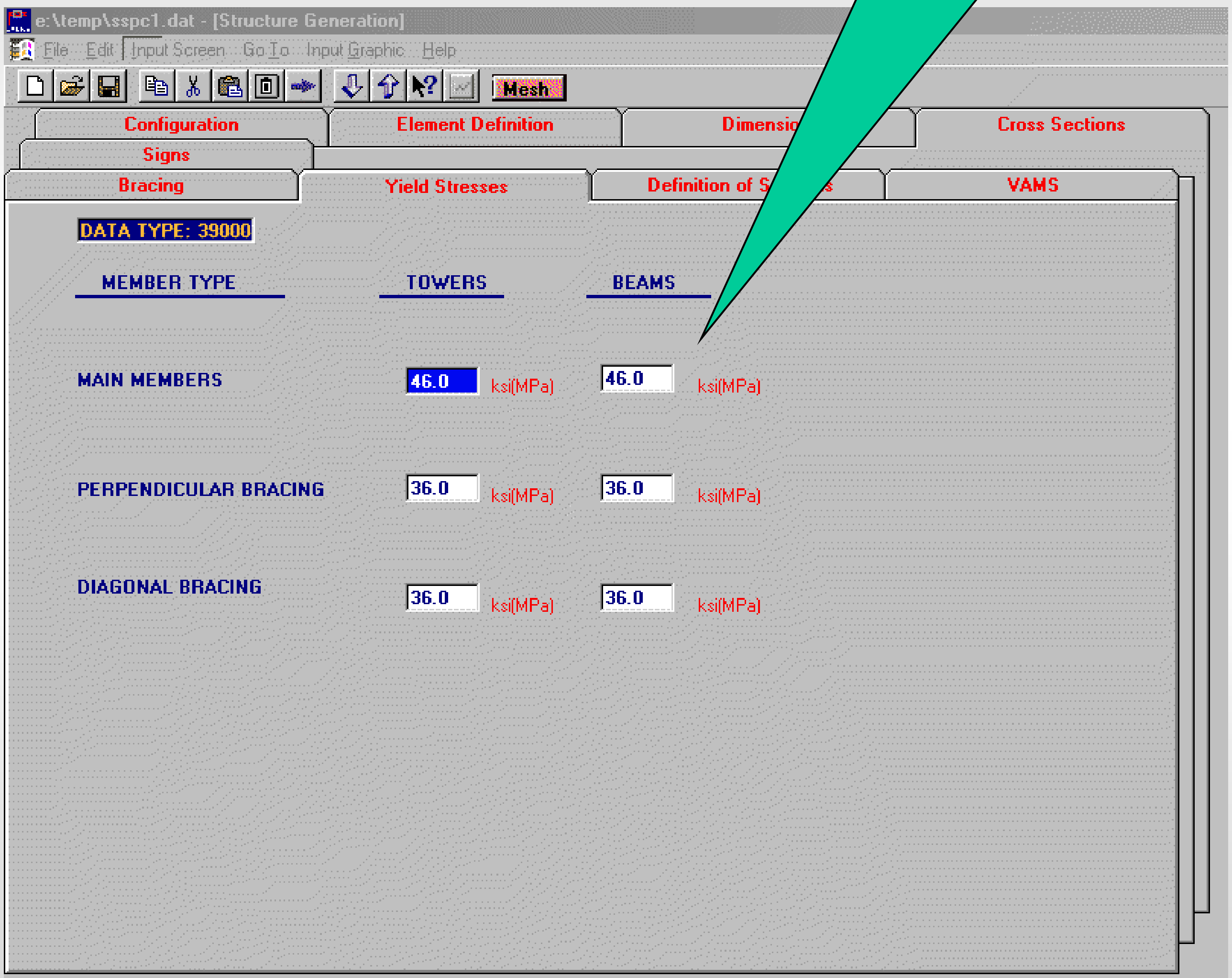
# Step 6: Input Dimensions



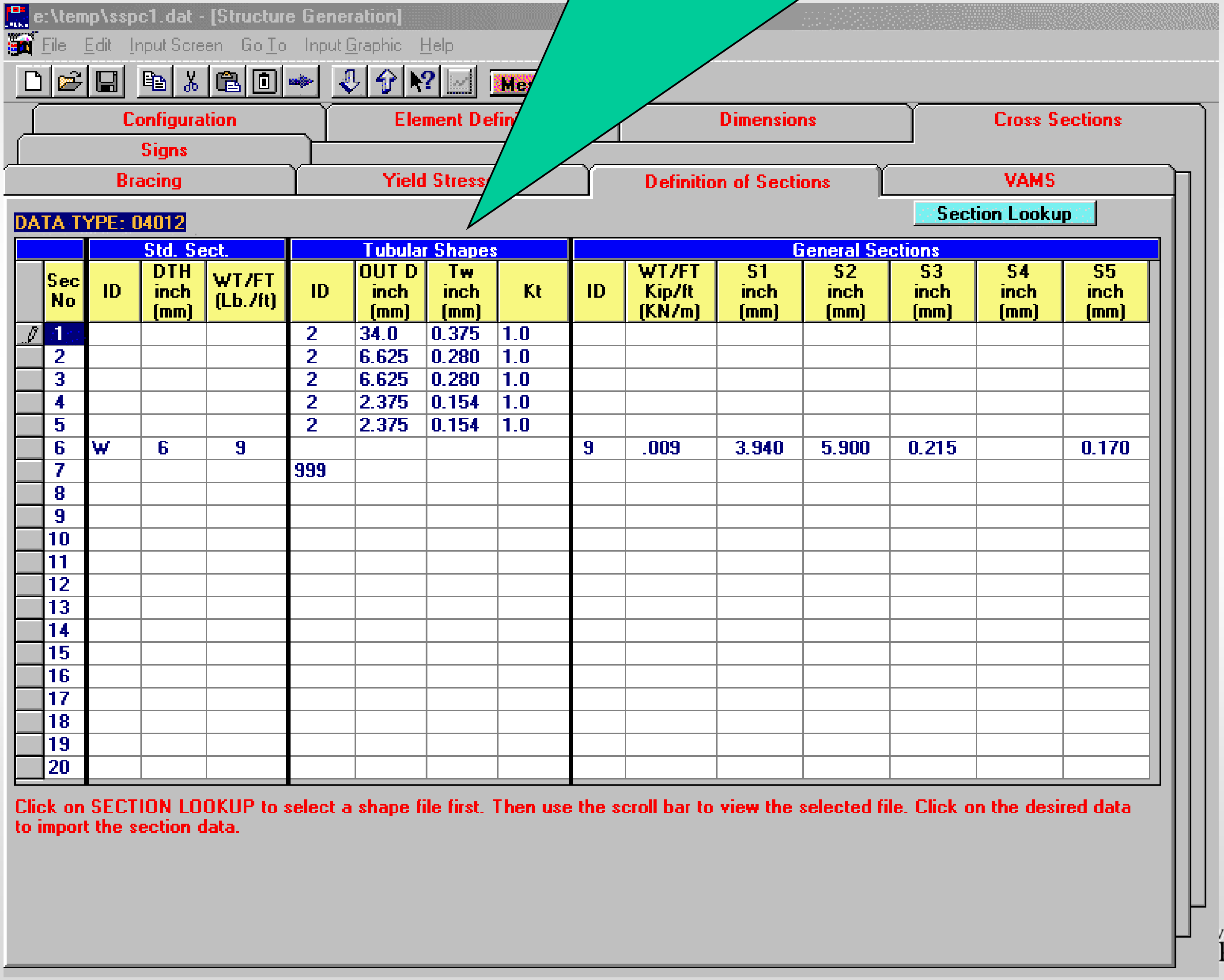
## Step 7: Input Bracing Patterns and Section Numbers (In this example, no perpendicular, only diagonal bracing.)



Step 8: Input Yield Stresses for all Members



Step 9: Define Sections used on the Cross Section screen (This example assigns 1 for the post, 2 for the chords, 4 for the bracing and 6 for the VAMs)




| | Std. Sect. | | | Tubular Shapes | | | | General Sections | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sec No | ID | DTH inch (mm) | WT/FT (Lb./ft) | ID | OUT D inch (mm) | Tw inch (mm) | Kt | ID | WT/FT Kip/ft (KN/m) | S1 inch (mm) | S2 inch (mm) | S3 inch (mm) | S4 inch (mm) | S5 inch (mm) |
| 1 | | | | 2 | 34.0 | 0.375 | 1.0 | | | | | | | |
| 2 | | | | 2 | 6.625 | 0.280 | 1.0 | | | | | | | |
| 3 | | | | 2 | 6.625 | 0.280 | 1.0 | | | | | | | |
| 4 | | | | 2 | 2.375 | 0.154 | 1.0 | | | | | | | |
| 5 | | | | 2 | 2.375 | 0.154 | 1.0 | | | | | | | |
| 6 | W | 6 | 9 | | | | | 9 | .009 | 3.940 | 5.900 | 0.215 | | 0.170 |
| 7 | | | | 999 | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | |

Click on SECTION LOOKUP to select a shape file first. Then use the scroll bar to view the selected file. Click on the desired data to import the section data.

Step 10: Define Vertical Attachment Members and their relationship to the Sign and Walkway (This example has 11 VAMs where 7-11 support Sign #1 and Walkway #1. Section 6 for all the VAMs)

e:\temp\sspc1.dat - [S

File Edit Input Screen

Configuration | Dimensions | Cross Sections

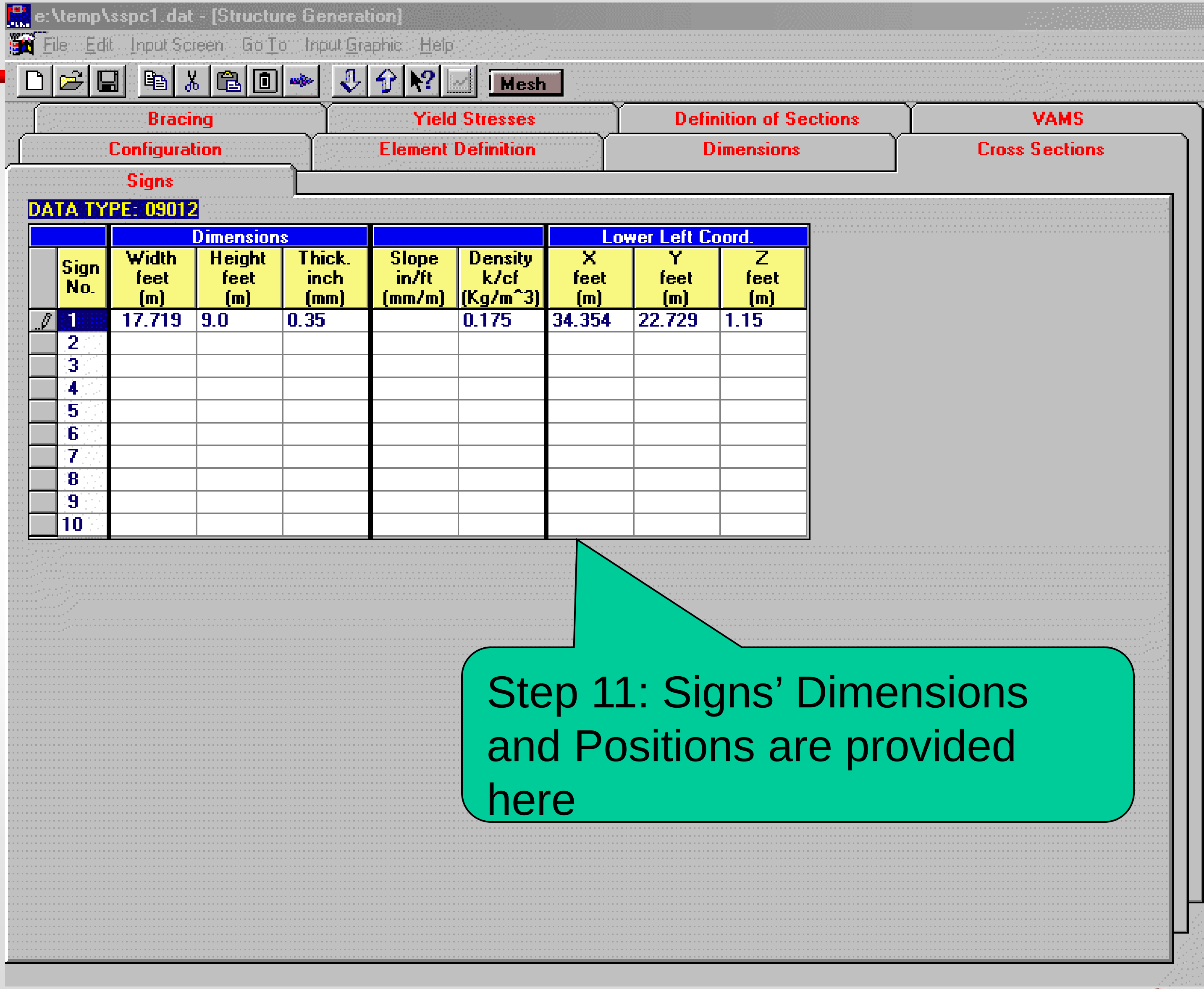
Signs

Bracing | Stresses | Definition of Sections | VAMS

DATA TYPE: 07012

| VAM ID | | Top VAM Coords. | | | | Supporting Members | | | Attached Sign Units | | | Walkway Units | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No | Sect. | X feet (m) | Y feet (m) | Z feet (m) | Length feet (m) | No. | No. | No. | No. | No. | No. | No. | No. | No. |
| 1 | 6 | 3.25 | 27.0 | 1.1 | 6.813 | 7 | 21 | | | | | | | |
| 2 | 6 | 7.417 | 27.0 | 1.1 | 6.813 | 8 | 22 | | | | | | | |
| 3 | 6 | 13.25 | 27.0 | 1.1 | 6.813 | 10 | 24 | | | | | | | |
| 4 | 6 | 17.417 | 27.0 | 1.1 | 6.813 | 11 | 25 | | | | | | | |
| 5 | 6 | 23.25 | 27.0 | 1.1 | 6.813 | 12 | 26 | | | | | | | |
| 6 | 6 | 29.25 | 27.0 | 1.1 | 6.813 | 14 | 28 | | | | | | | |
| 7 | 6 | 34.917 | 31.729 | 1.1 | 11.542 | 16 | 30 | | 1 | | | 1 | | |
| 8 | 6 | 38.917 | 31.729 | 1.1 | 11.542 | 17 | 31 | | 1 | | | 1 | | |
| 9 | 6 | 42.917 | 31.729 | 1.1 | 11.542 | 18 | 32 | | 1 | | | 1 | | |
| 10 | 6 | 46.917 | 31.729 | 1.1 | 11.542 | 19 | 33 | | 1 | | | 1 | | |
| 11 | 6 | 50.917 | 31.729 | 1.1 | 11.542 | 20 | 34 | | 1 | | | 1 | | |
| 12 | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | |

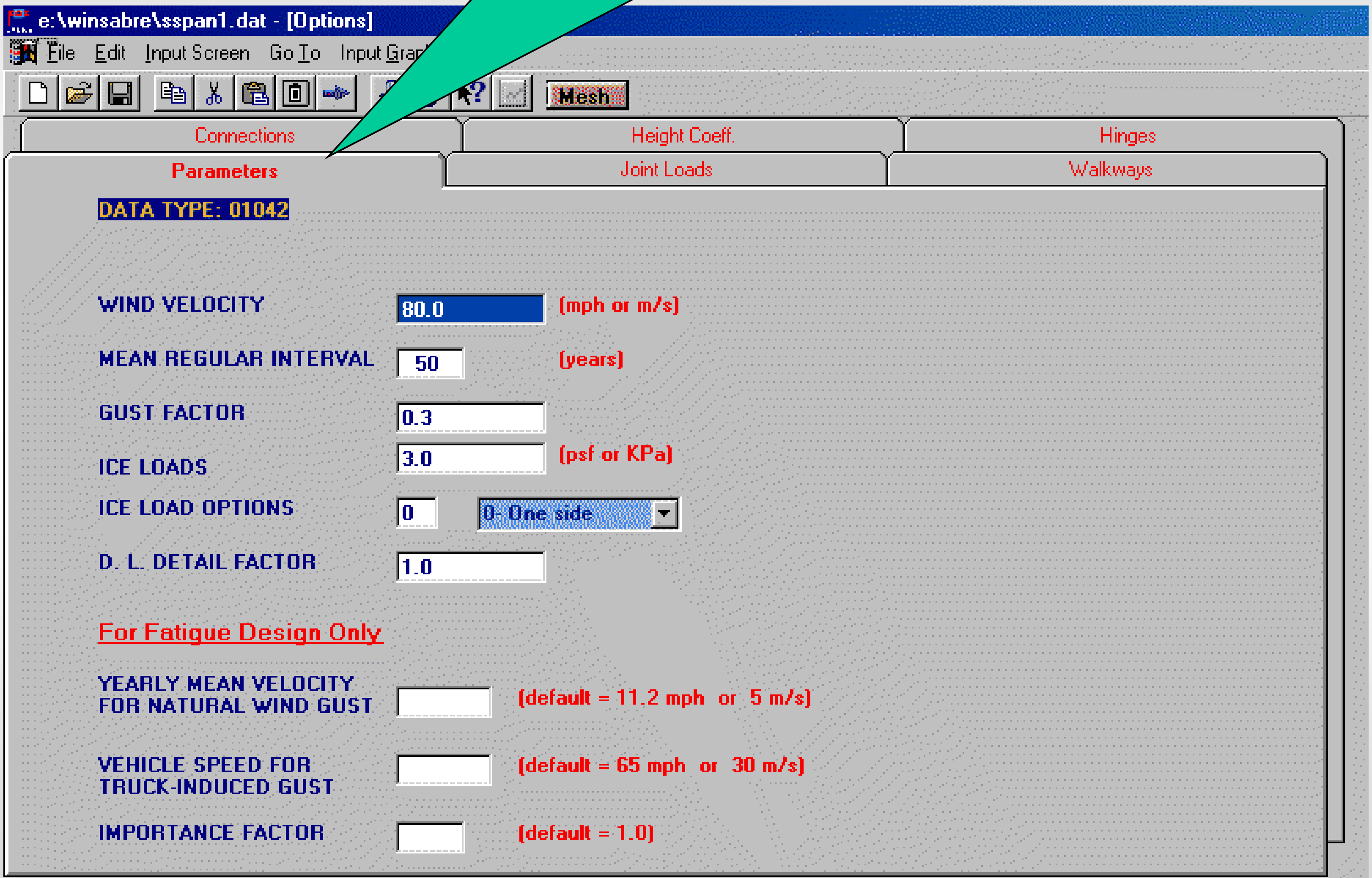
Step 10A: Supporting Members are figured out by the Mesh. No input is needed



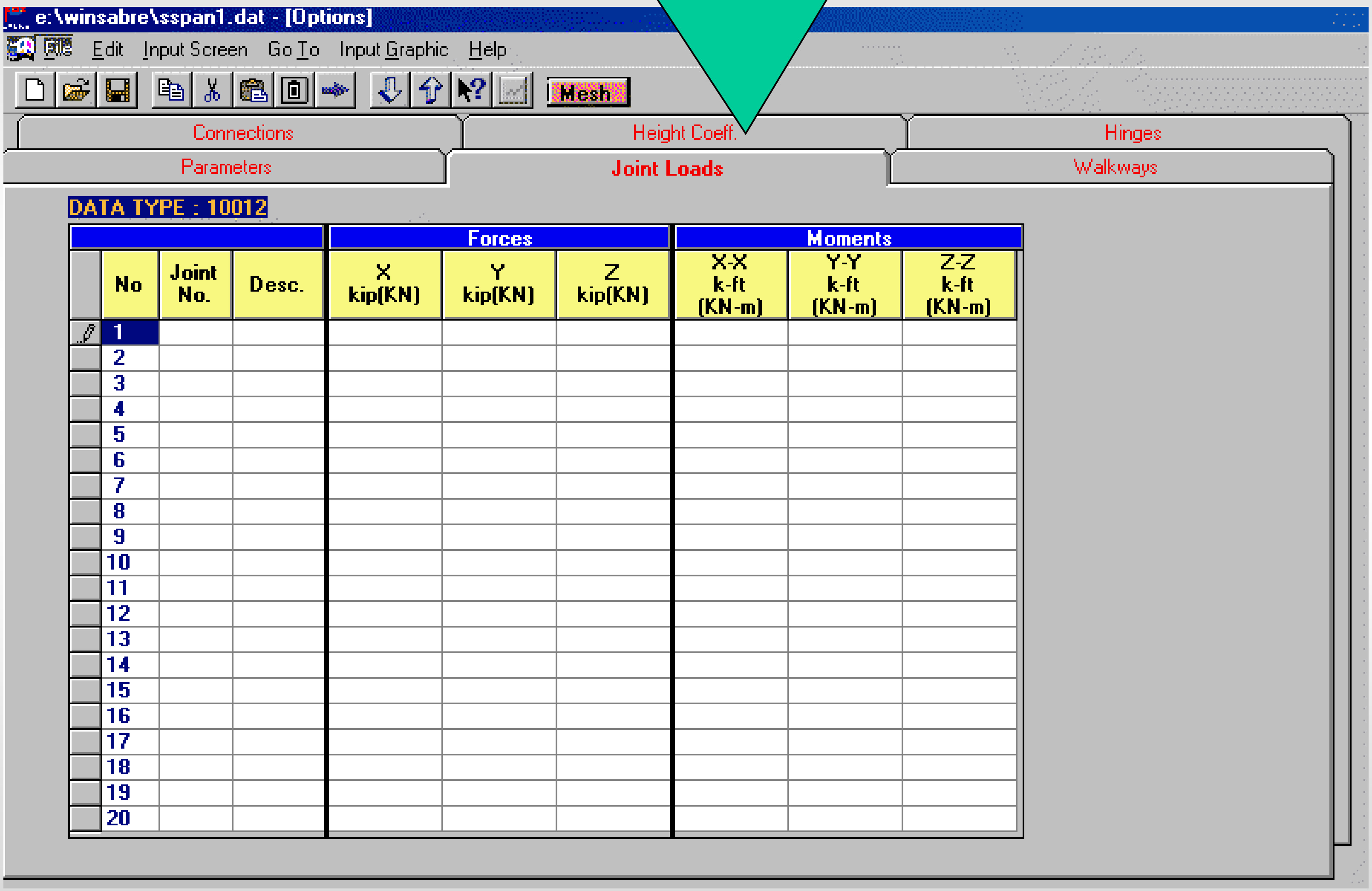

| | Dimensions | | | | | Lower Left Coord. | | |
|---|---|---|---|---|---|---|---|---|
| Sign No. | Width feet (m) | Height feet (m) | Thick. inch (mm) | Slope in/ft (mm/m) | Density k/cf (Kg/m^3) | X feet (m) | Y feet (m) | Z feet (m) |
| 1 | 17.719 | 9.0 | 0.35 | | 0.175 | 34.354 | 22.729 | 1.15 |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |

Step 11: Signs' Dimensions and Positions are provided here

No Step: Parameters are generated by Mesh, unless override is needed

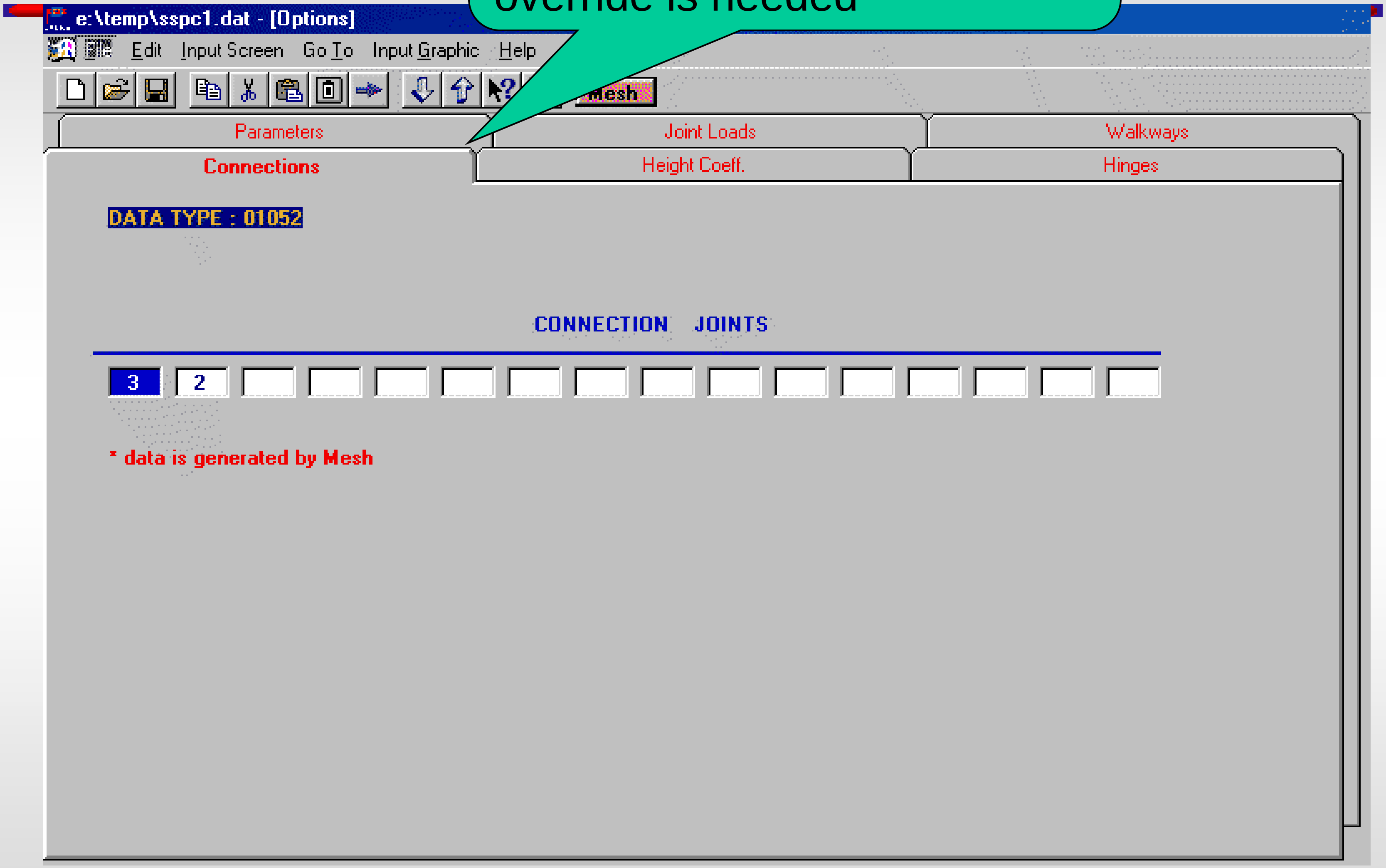


No Step: Joint Loads are generated by Mesh, unless additional Join Load is needed

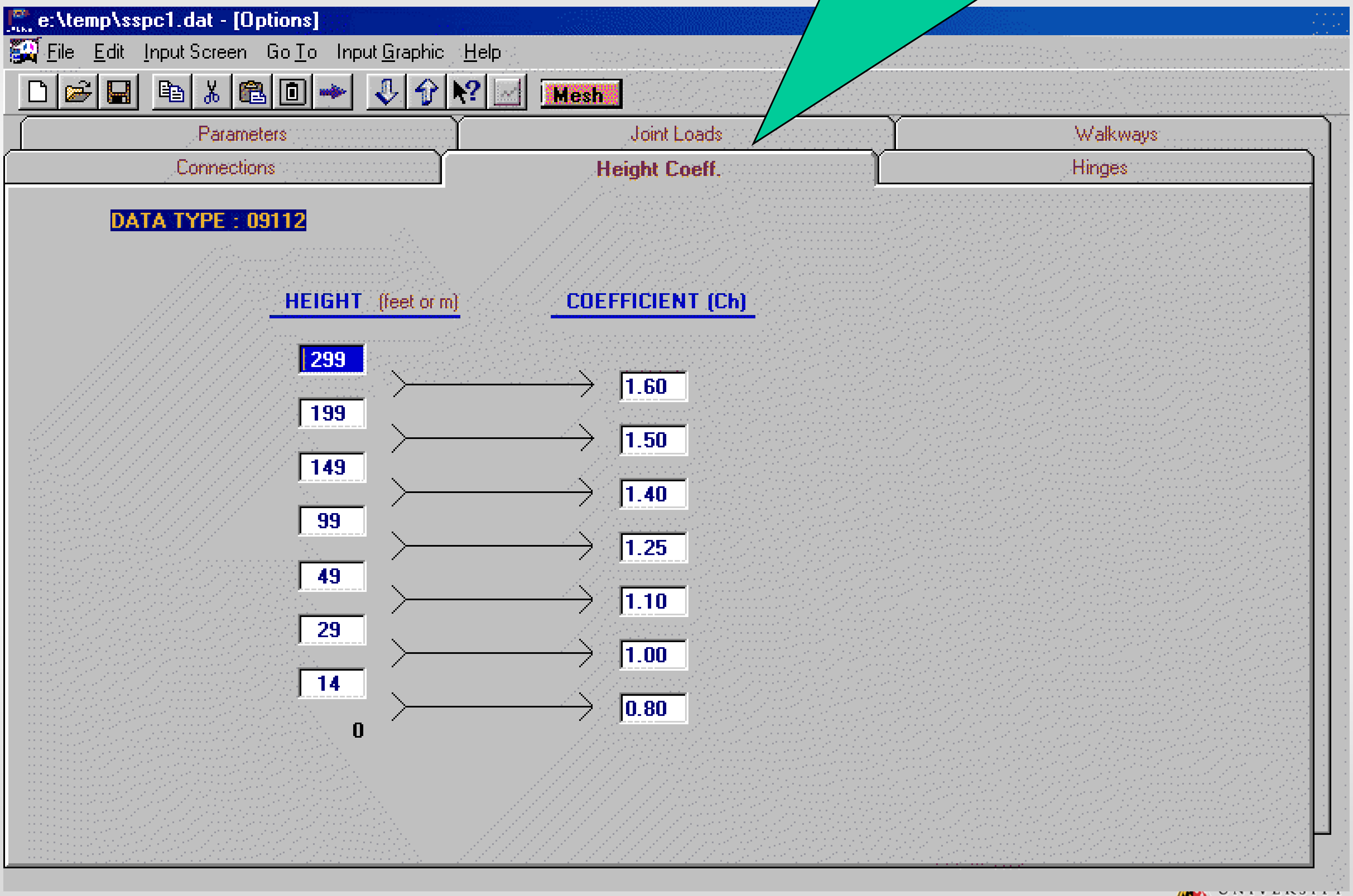



UNIVERSITY OF MARYLAND

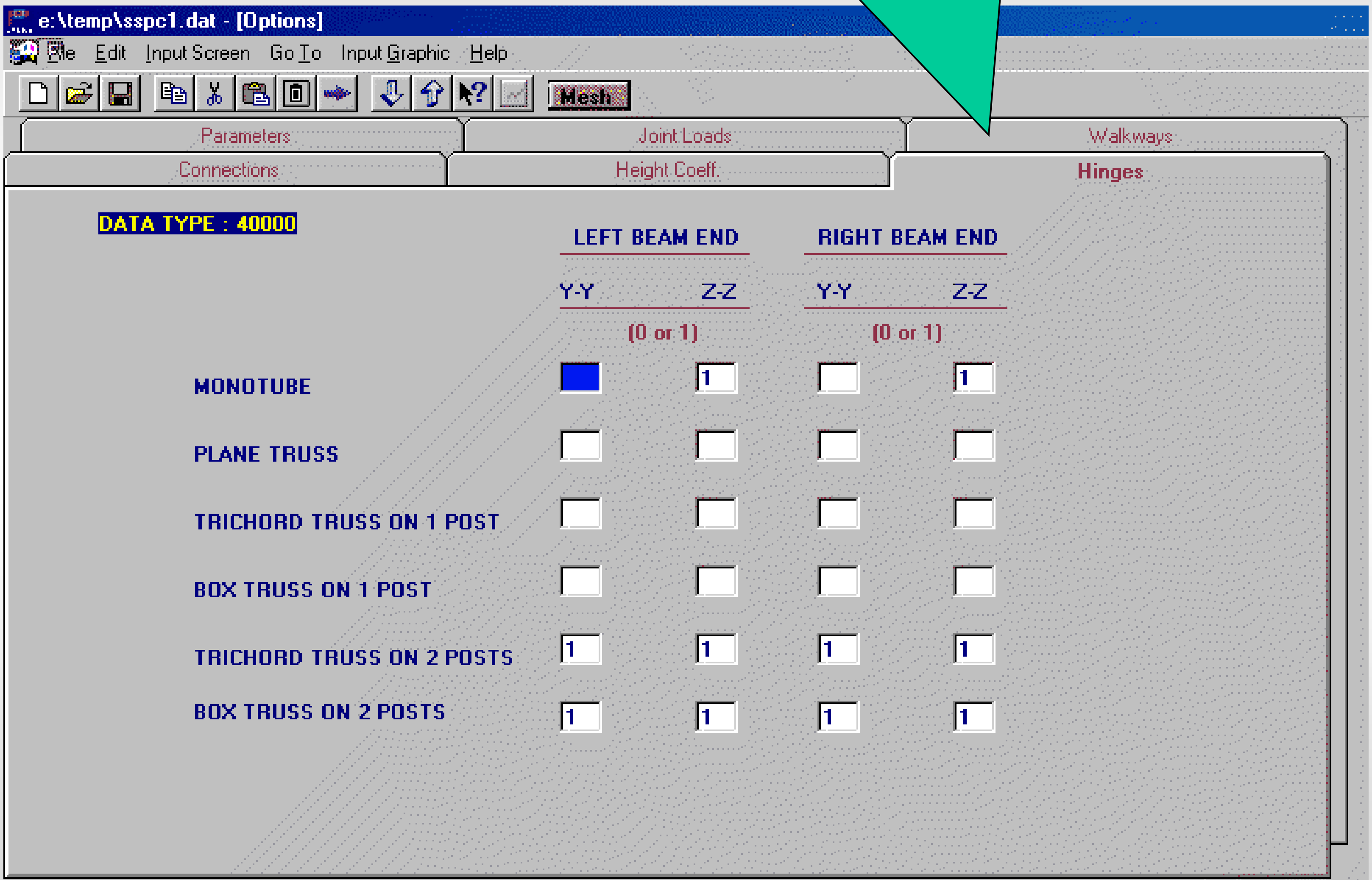
No Step: Connections are generated by Mesh, unless override is needed



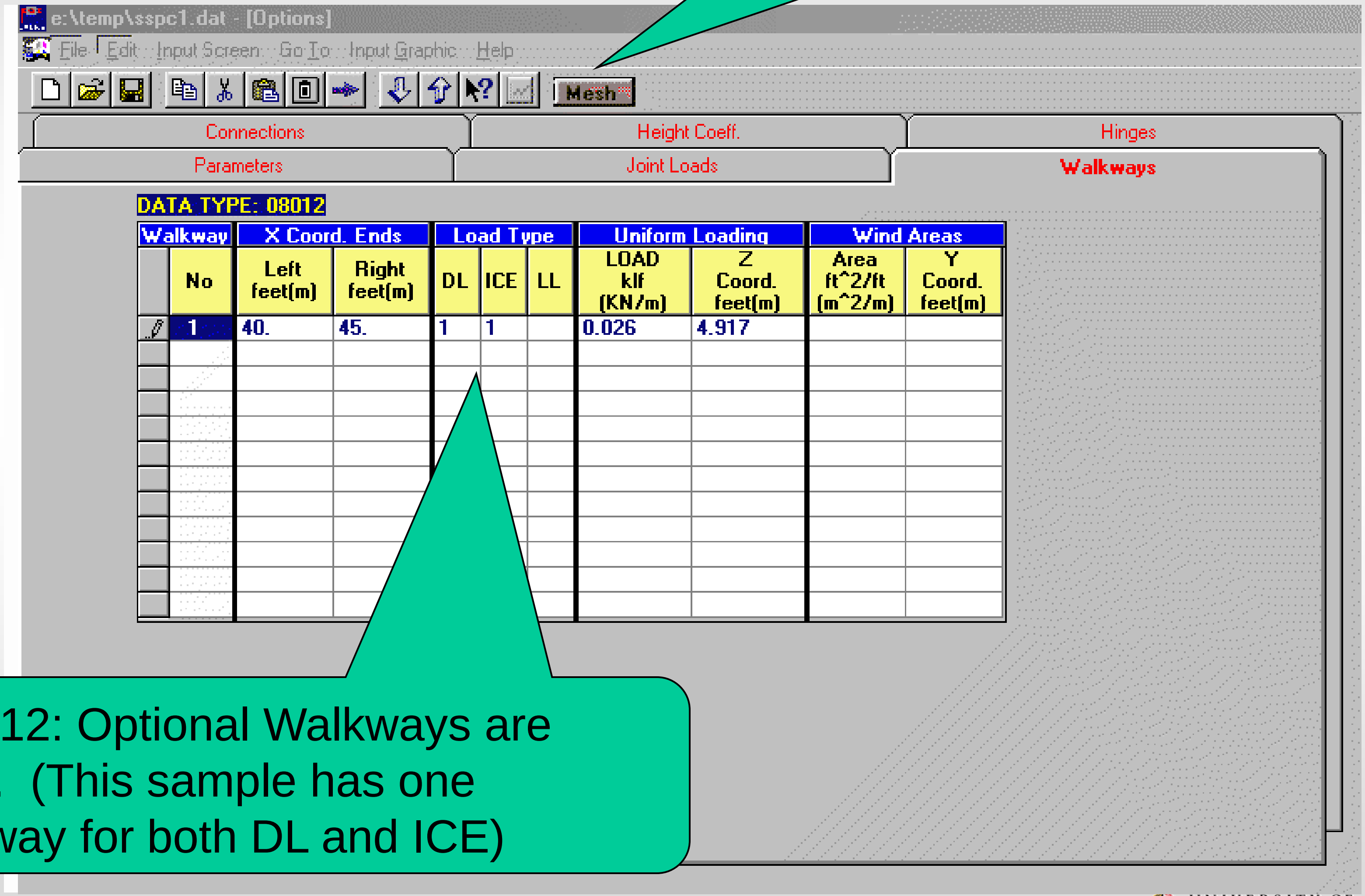
No Step: Height Coefficients are generated by Mesh, unless override is needed



No Step: Hinges, if exist, are generated by the program, unless overridden



Step 12A: Once done, click Mesh button and then Input Graphic on the Menu Bar




Step 12: Optional Walkways are input. (This sample has one walkway for both DL and ICE)

No Step: Joints are generated by Mesh, unless override is needed

e:\winsabre\sspan1.dat - [Structure Lookup]

File Edit Input Screen Go To Input Graphic Help

Mesh

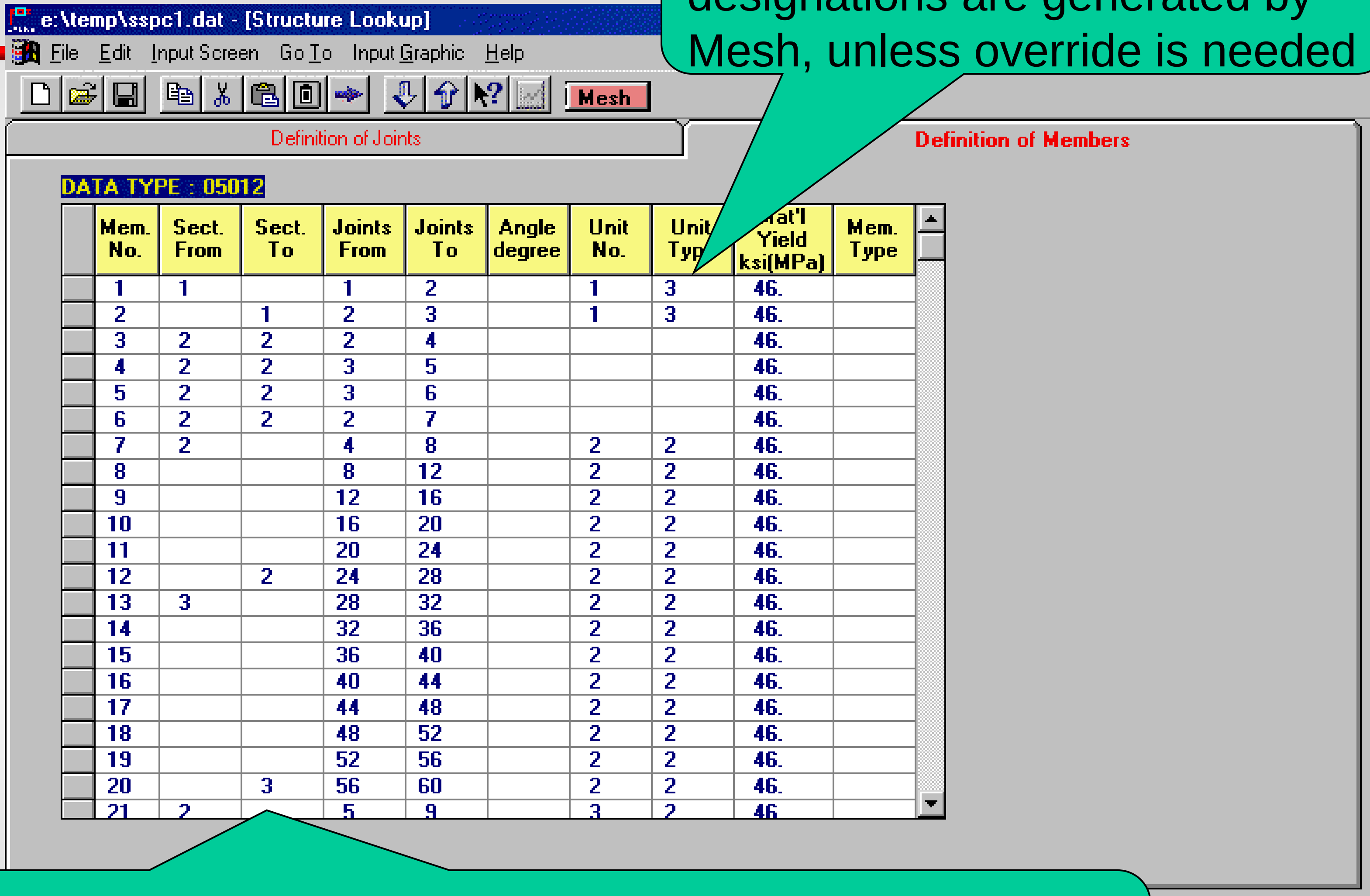
Definition of Joints

Definition of Members

DATA TYPE :03012

| | Coordinates | | | Supp. Translation | | | Supp. Rotation | | |
|---|---|---|---|---|---|---|---|---|---|
| JNT No | X ft(m) | Y ft(m) | Z ft(m) | X | Y | Z | XX | YY | ZZ |
| 1 | 0.00 | 0.00 | 2.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 0.00 | 0.00 | -2.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| 3 | 0.00 | 15. | 2.5 | | | | | | |
| 4 | 0.00 | 15. | -2.5 | | | | | | |
| 5 | 0.00 | 20. | 2.5 | | | | | | |
| 6 | 0.00 | 20. | -2.5 | | | | | | |
| 7 | 1. | 15. | 2.5 | | | | | | |
| 8 | 1. | 20. | 2.5 | | | | | | |
| 9 | 1. | 20. | -2.5 | | | | | | |
| 10 | 1. | 15. | -2.5 | | | | | | |
| 11 | 10. | 15. | 2.5 | | | | | | |
| 12 | 10. | 20. | 2.5 | | | | | | |
| 13 | 10. | 20. | -2.5 | | | | | | |
| 14 | 10. | 15. | -2.5 | | | | | | |
| 15 | 19. | 15. | -2.5 | | | | | | |
| 16 | 19. | 20. | -2.5 | | | | | | |
| 17 | 19. | 20. | 2.5 | | | | | | |
| 18 | 19. | 15. | 2.5 | | | | | | |
| 19 | 20. | 20. | -2.5 | | | | | | |
| 20 | 20. | 20. | 2.5 | | | | | | |

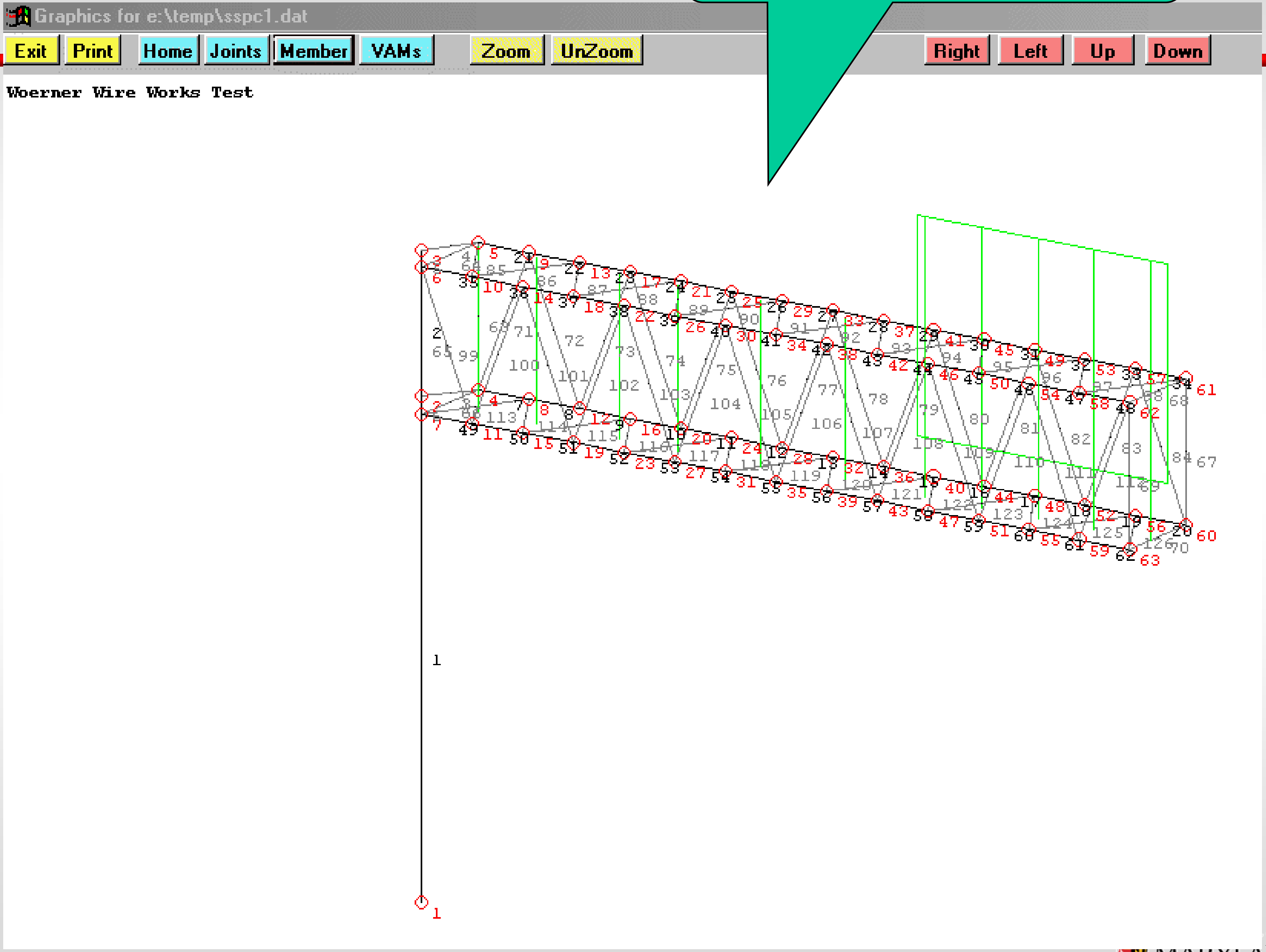
No Step: Members and section designations are generated by Mesh, unless override is needed



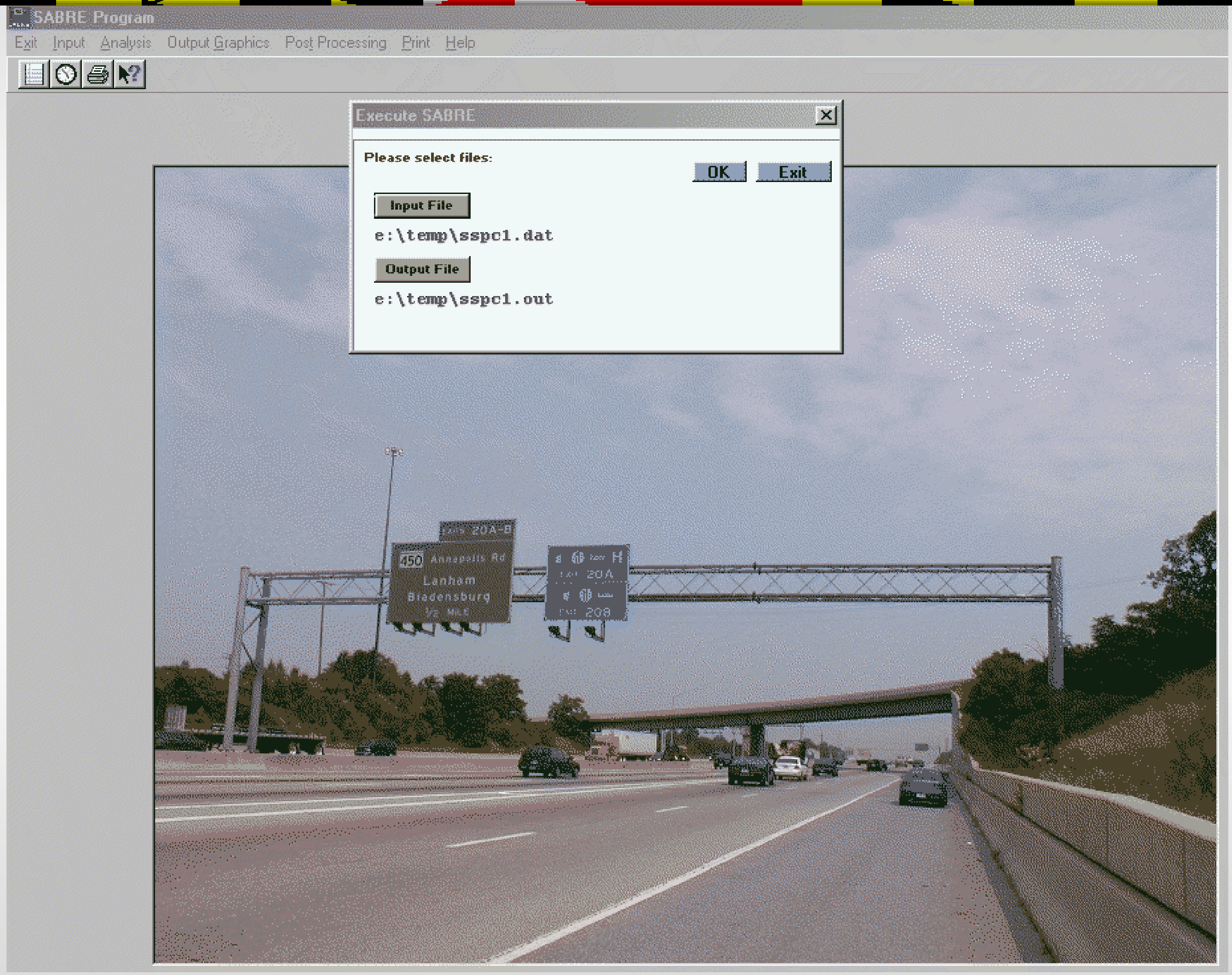

| Mem. No. | Sect. From | Sect. To | Joints From | Joints To | Angle degree | Unit No. | Unit Typ | at'l Yield ksi(MPa) | Mem. Type |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | 1 | 2 | | 1 | 3 | 46. | |
| 2 | | 1 | 2 | 3 | | 1 | 3 | 46. | |
| 3 | 2 | 2 | 2 | 4 | | | | 46. | |
| 4 | 2 | 2 | 3 | 5 | | | | 46. | |
| 5 | 2 | 2 | 3 | 6 | | | | 46. | |
| 6 | 2 | 2 | 2 | 7 | | | | 46. | |
| 7 | 2 | | 4 | 8 | | 2 | 2 | 46. | |
| 8 | | | 8 | 12 | | 2 | 2 | 46. | |
| 9 | | | 12 | 16 | | 2 | 2 | 46. | |
| 10 | | | 16 | 20 | | 2 | 2 | 46. | |
| 11 | | | 20 | 24 | | 2 | 2 | 46. | |
| 12 | | 2 | 24 | 28 | | 2 | 2 | 46. | |
| 13 | 3 | | 28 | 32 | | 2 | 2 | 46. | |
| 14 | | | 32 | 36 | | 2 | 2 | 46. | |
| 15 | | | 36 | 40 | | 2 | 2 | 46. | |
| 16 | | | 40 | 44 | | 2 | 2 | 46. | |
| 17 | | | 44 | 48 | | 2 | 2 | 46. | |
| 18 | | | 48 | 52 | | 2 | 2 | 46. | |
| 19 | | | 52 | 56 | | 2 | 2 | 46. | |
| 20 | | 3 | 56 | 60 | | 2 | 2 | 46. | |
| 21 | 2 | | 5 | 9 | | 3 | 2 | 46 | |

Step 12B: In this example, change of section occurs on the chords. After Mesh, modify Section 2 from joint 4 to 28 and Section 3 from joint 28 to 60

# Step 13: Input Graphic is shown on the screen

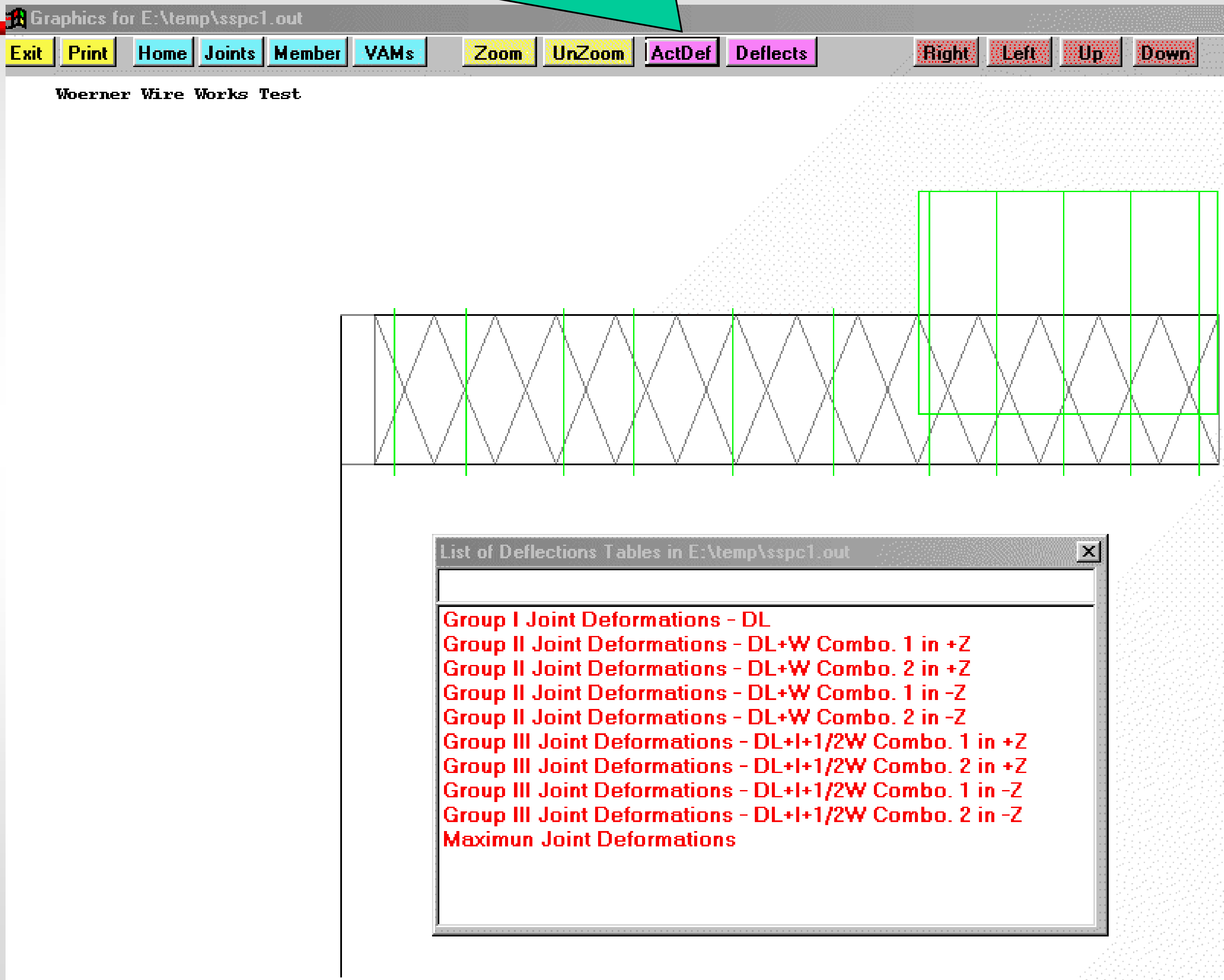


Step 14: Save the Input File, Exit from Input Utility and click Analysis

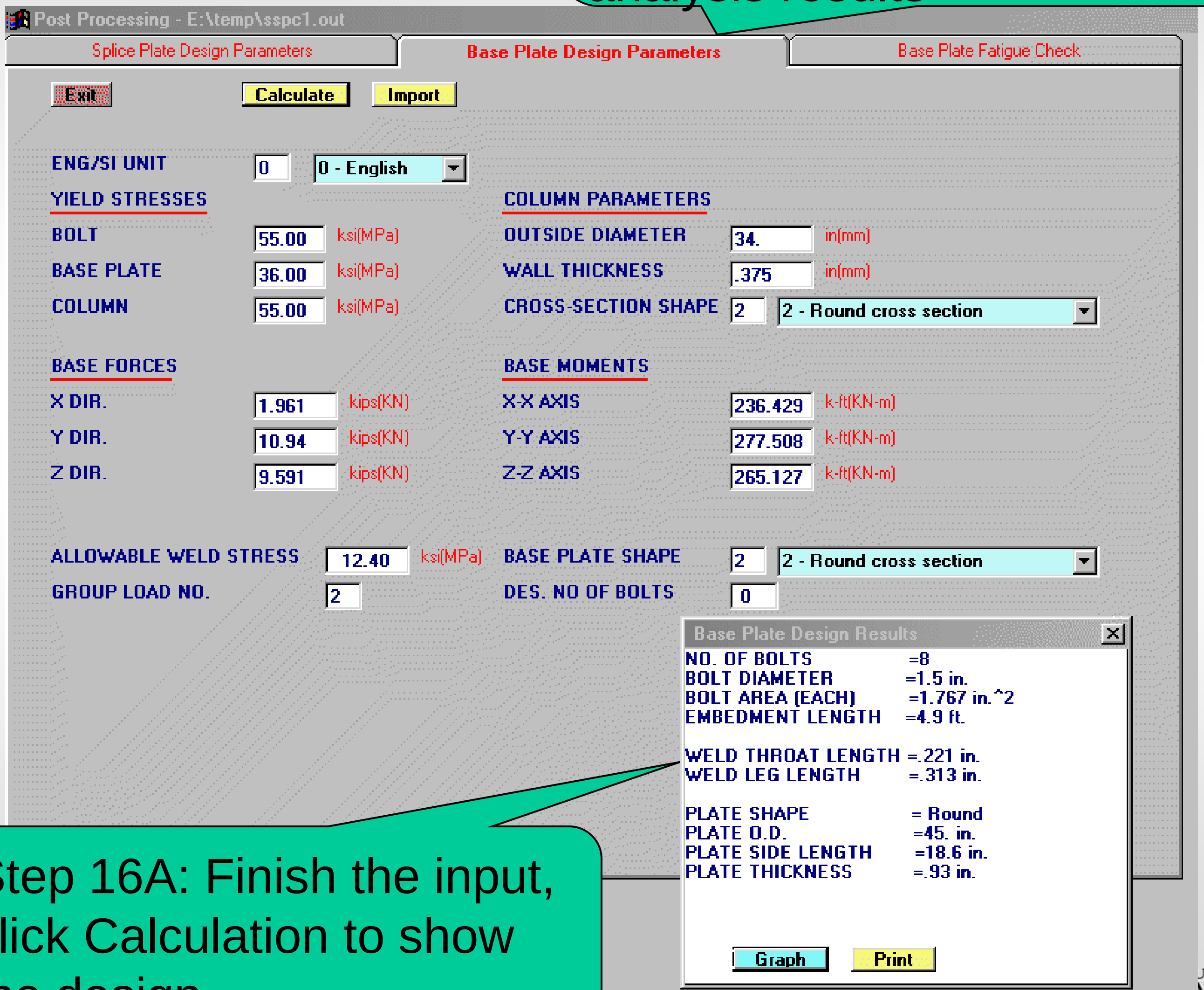



UNIVERSITY OF MARYLAND

Step 15: Exit from Analysis, click Output Graphics and select one item under ActDef for analysis status



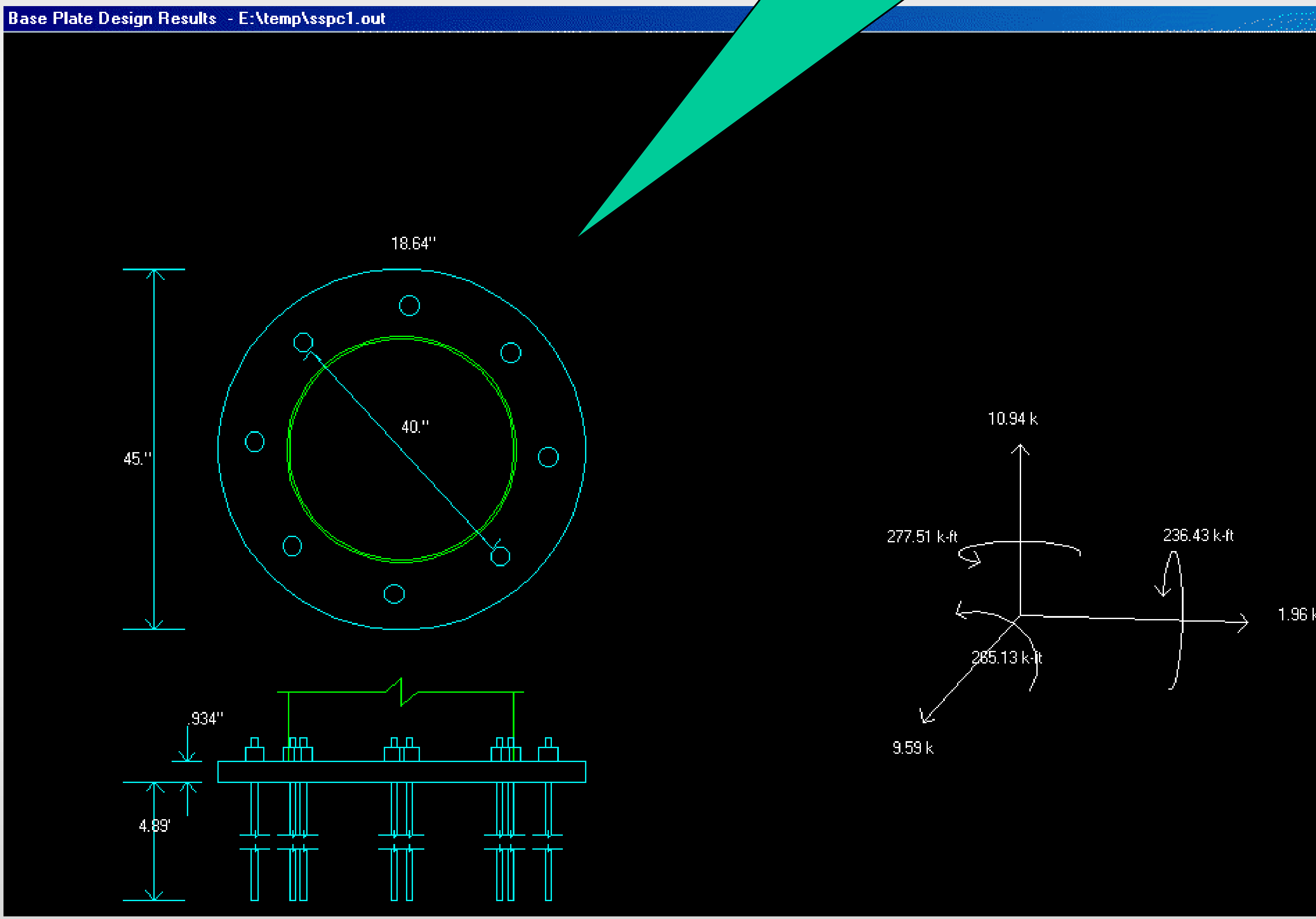
Step 16: Exit from Output Graphics, select Post Process, Base Plate Design and then click Import for the analysis results



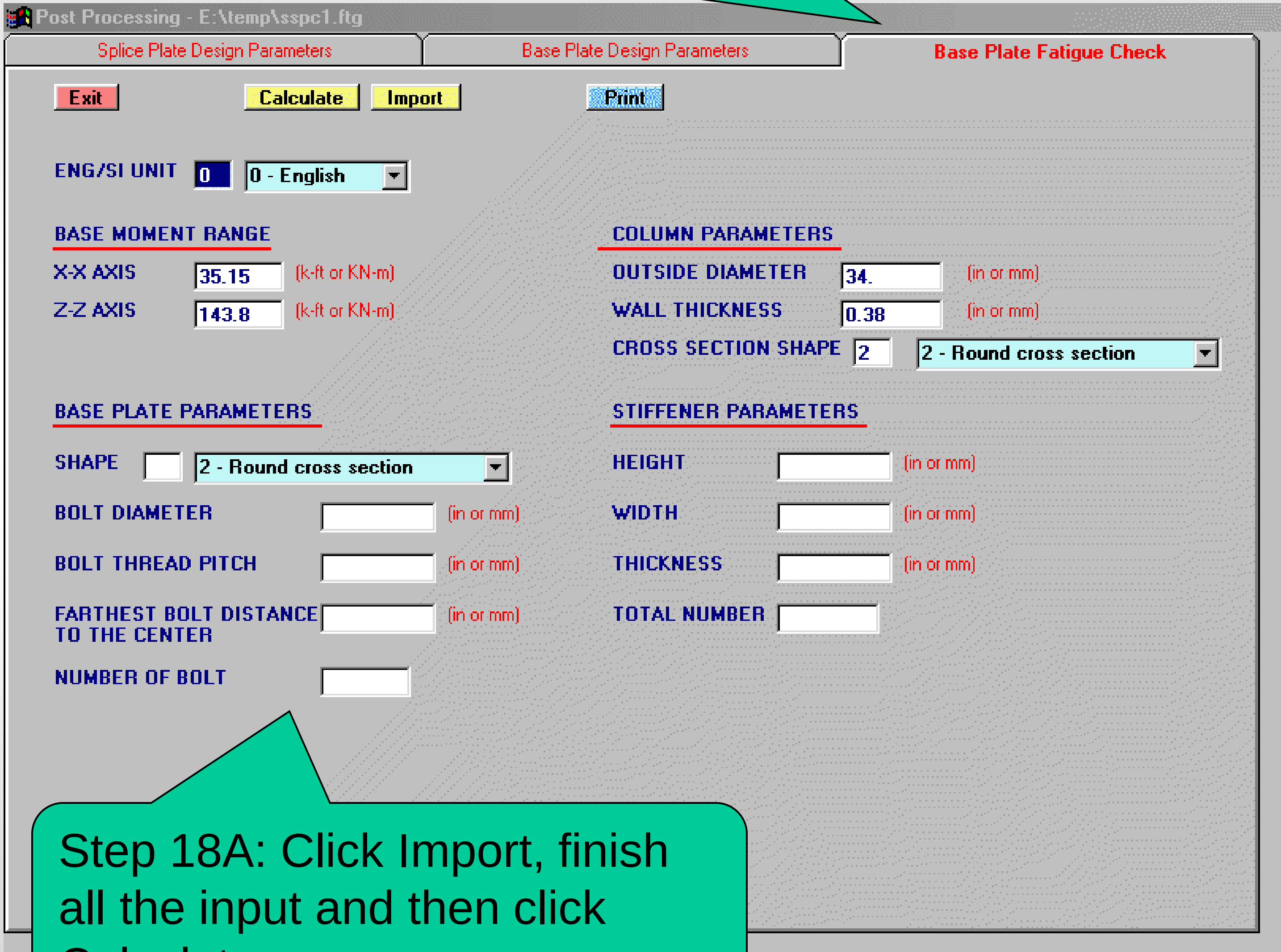

Step 16A: Finish the input, click Calculation to show the design

UNIVERSITY OF MARYLAND

Step 17: Click Graph on the Calculation popup screen to show the design

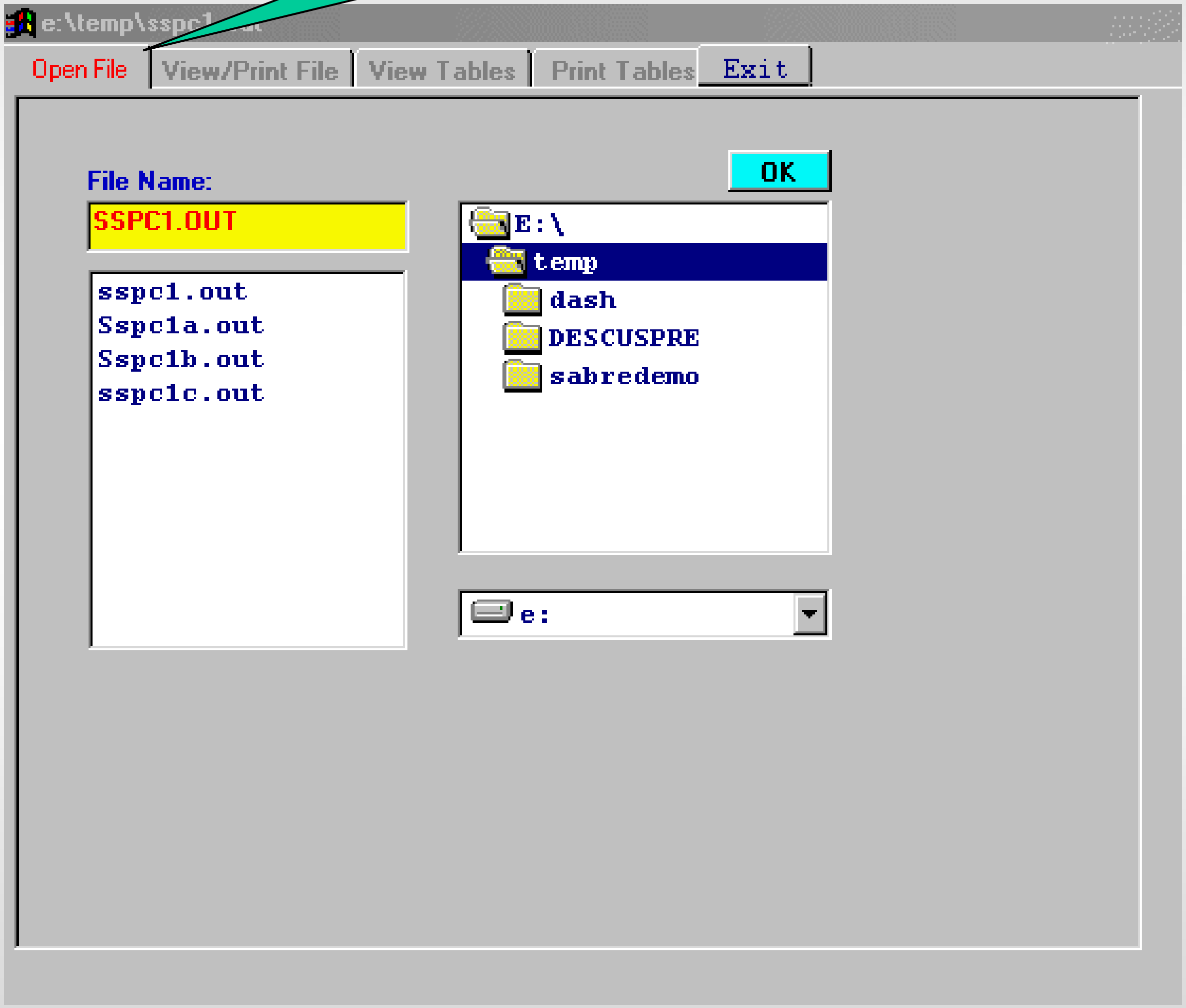


Step 18: Exit from Base Plate Design and Click the Tab for Base Plate Fatigue Check



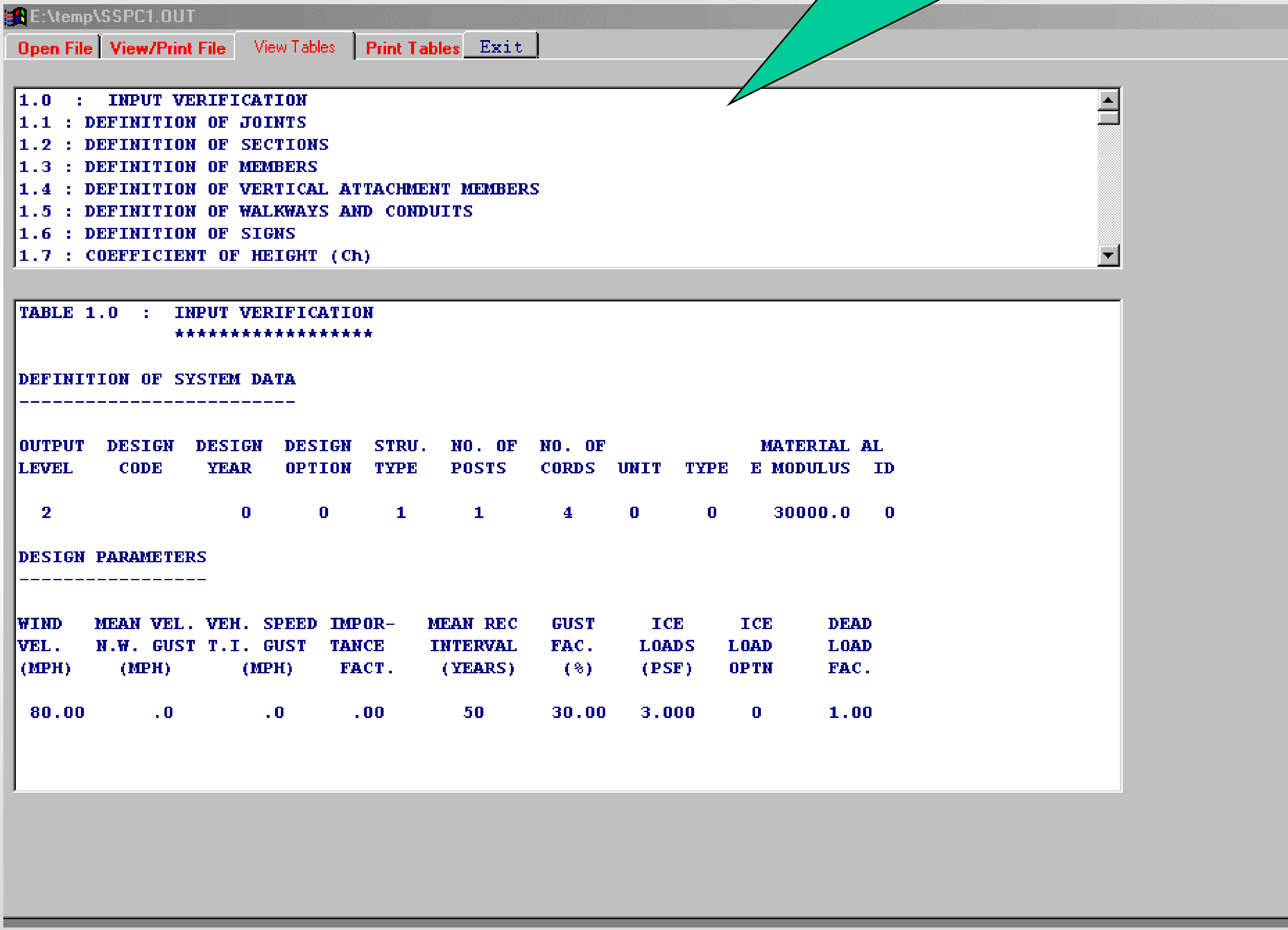

Step 18A: Click Import, finish all the input and then click Calculate

Step 19: Exit from Post Process. Click Print and then Open File




UNIVERSITY OF MARYLAND

Step 20: View or Print the whole File or Table by Table



E:\temp\SSPC1.OUT

Open File | View/Print File | View Tables | Print Tables | Exit

1.0 : INPUT VERIFICATION
1.1 : DEFINITION OF JOINTS
1.2 : DEFINITION OF SECTIONS
1.3 : DEFINITION OF MEMBERS
1.4 : DEFINITION OF VERTICAL ATTACHMENT MEMBERS
1.5 : DEFINITION OF WALKWAYS AND CONDUITS
1.6 : DEFINITION OF SIGNS
1.7 : COEFFICIENT OF HEIGHT (Ch)

TABLE 1.0 : INPUT VERIFICATION
******************

DEFINITION OF SYSTEM DATA
-------------------------

| OUTPUT LEVEL | DESIGN CODE | DESIGN YEAR | DESIGN OPTION | STRU. TYPE | NO. OF POSTS | NO. OF CORDS | UNIT | TYPE | MATERIAL E MODULUS | AL ID |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 0 | 0 | 1 | 1 | 4 | 0 | 0 | 30000.0 | 0 |

DESIGN PARAMETERS
-----------------

| WIND VEL. (MPH) | MEAN VEL. N.W. GUST (MPH) | VEH. SPEED T.I. GUST (MPH) | IMPOR-TANCE FACT. | MEAN REC INTERVAL (YEARS) | GUST FAC. (%) | ICE LOADS (PSF) | ICE LOAD OPTN | DEAD LOAD FAC. |
|---|---|---|---|---|---|---|---|---|
| 80.00 | .0 | .0 | .00 | 50 | 30.00 | 3.000 | 0 | 1.00 |

# AASHTO LTS-6 & AASHTO LTS-LRFD

Updated SABRE includes following improvements:

1. AASHTO LST-6 & AASHTO LTS-LRFD Fatigue Design
    a. Design parameters based on fatigue importance category
    b. Cantilever and non-cantilever structures

2. AASHTO LTS-LRFD Design
    a. Determination of wind speed and wind pressure
    b. Example of wind speed and wind pressure
    c. Wind strength design consideration



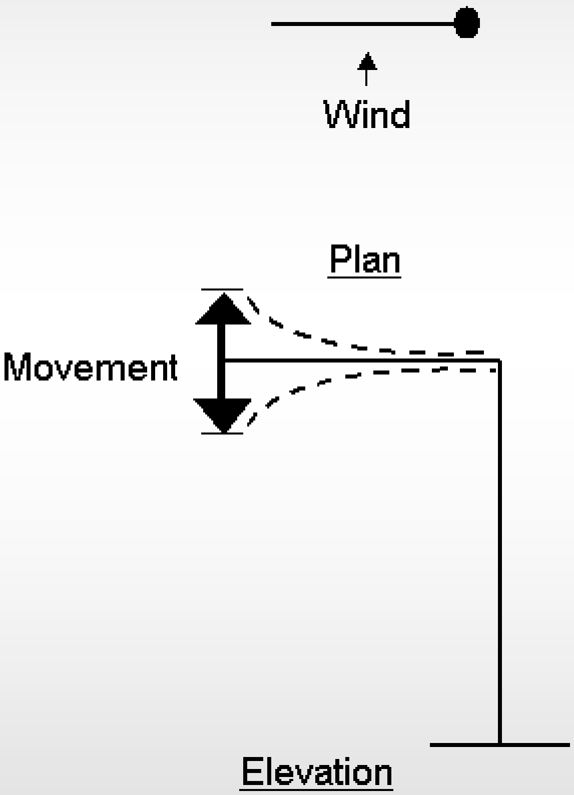
UNIVERSITY OF MARYLAND

# Fatigue Design Parameters

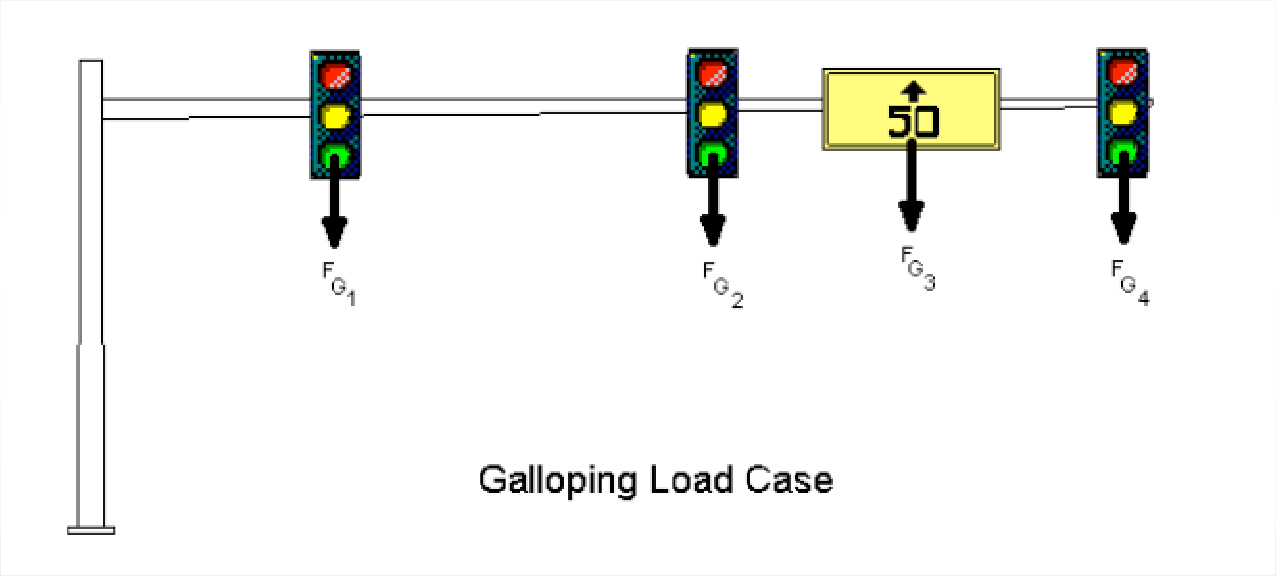
| Fatigue Importance Category | | | Galloping | Natural Wind Gusts | Truck-Induced Gusts |
|---|---|---|---|---|---|
| Cantilevered | I | **Sign**<br>Traffic Signal | **1.0**<br>1.0 | **1.0**<br>1.0 | **1.0**<br>1.0 |
| | II | **Sign**<br>**Traffic Signal** | **0.70**<br>**0.65** | **0.85**<br>**0.80** | **0.90**<br>**0.85** |
| | III | Sign<br>Traffic Signal | 0.40<br>0.30 | 0.70<br>0.55 | 0.80<br>0.70 |
| Non-Cantilevered | I | **Sign**<br>Traffic Signal | **x**<br>x | **1.0**<br>1.0 | **1.0**<br>1.0 |
| | II | **Sign**<br>Traffic Signal | **x**<br>x | **0.85**<br>0.80 | **0.90**<br>0.85 |
| | III | Sign<br>Traffic Signal | x<br>x | 0.70<br>0.55 | 0.80<br>0.70 |

- Cat. I – without "mitigation devices"; roadways with a speed limit in excess of 60 km/h (35 mph) and average daily traffic (ADT) exceeding 10,000 or average daily truck traffic (ADTT) exceeding 1000
- Cat. III - speed limits 60km/h (35 mph) or less
- Cat. II – not "explicitly" meeting I or III; (NCHRP 469 Act. 3.2.1.4: include any structures with mitigation devices that would otherwise meet the Category I criteria.)

# 1. Introduction : Fatigue Design Loads - Galloping

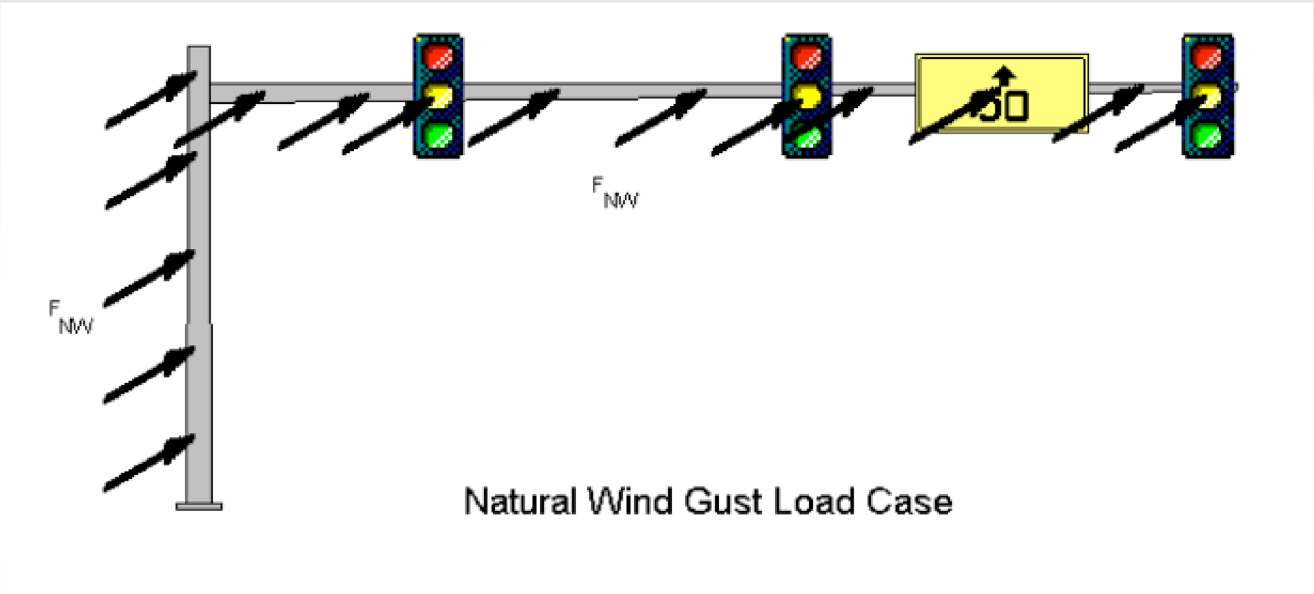



B. Galloping

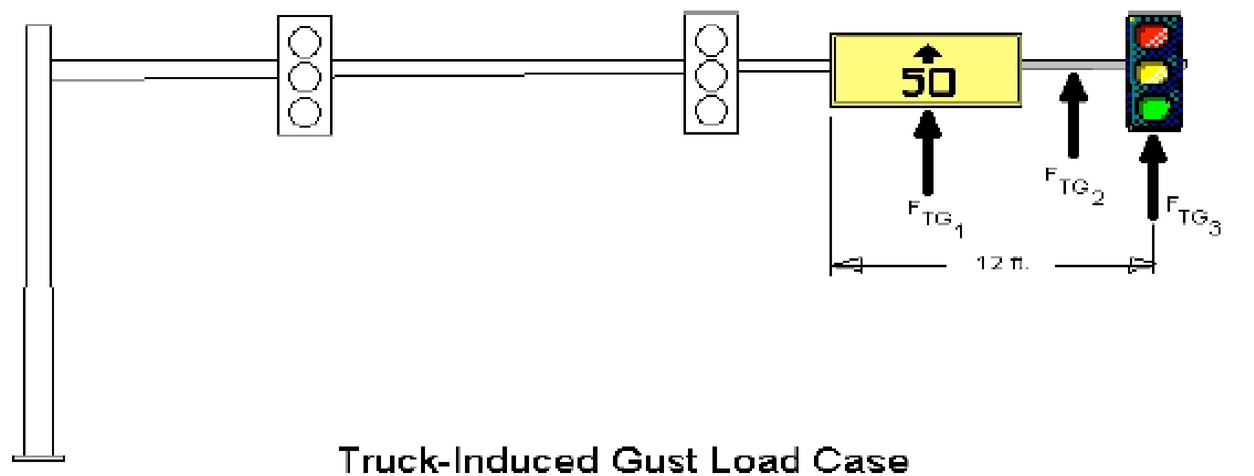



https://www.youtube.com/watch?v=fRIUOXpfiyI

# 1. Introduction : Fatigue Design Loads – Natural Wind & Truck-Induced Gust

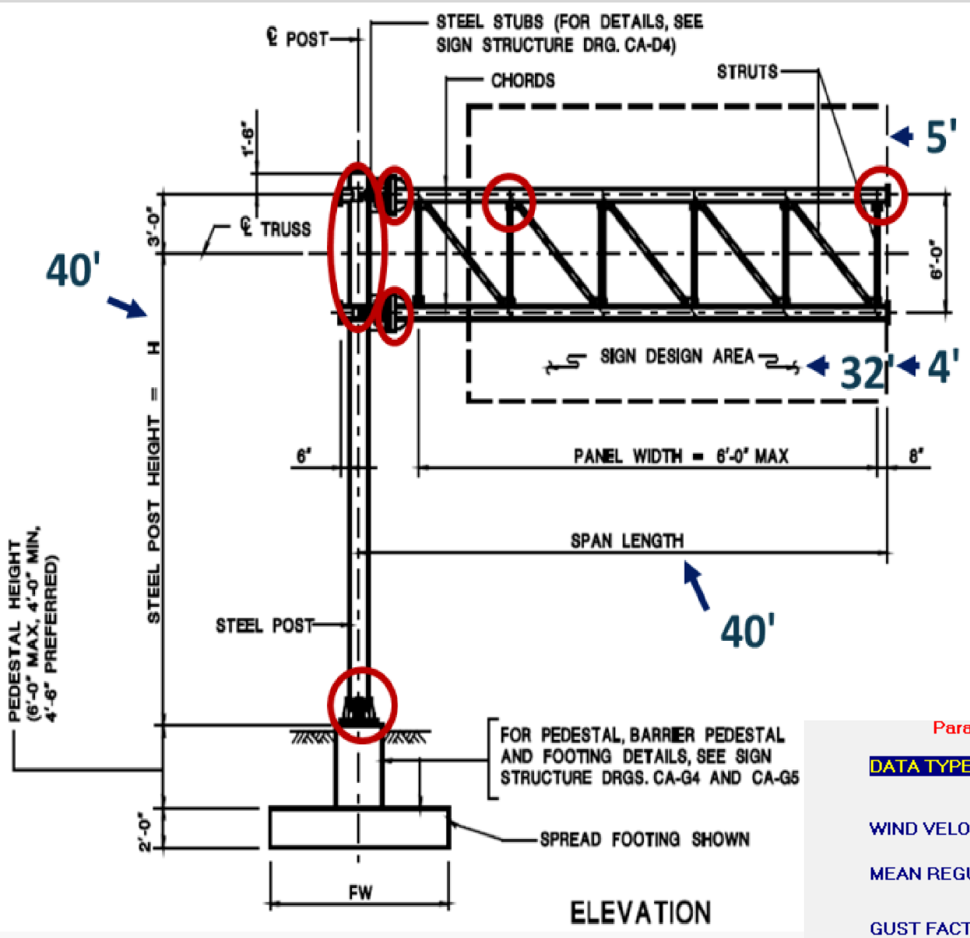



Natural Wind Gust Load Case



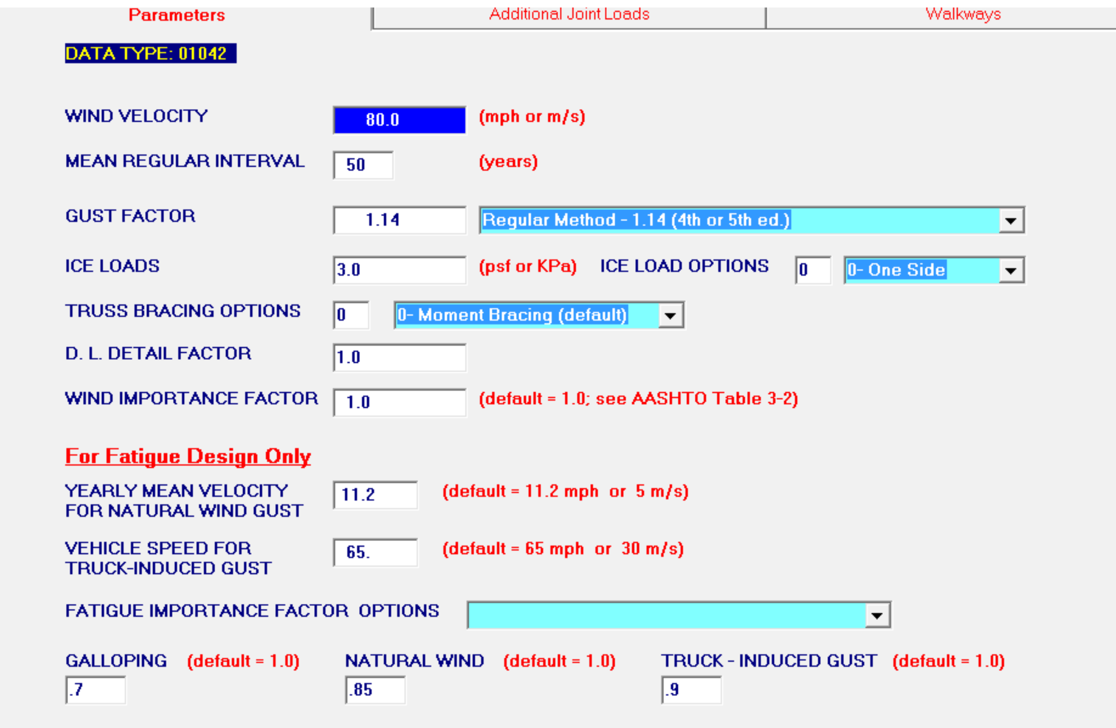

Truck-Induced Gust Load Case

# Fatigue Details




SABRE Fatigue Design Input

Source: NJDOT report "Fatigue Study on Structural Supports for Luminaries, Traffic Signals, Highway Signs", Chapter 8 example 1



# SABRE Fatigue Verification

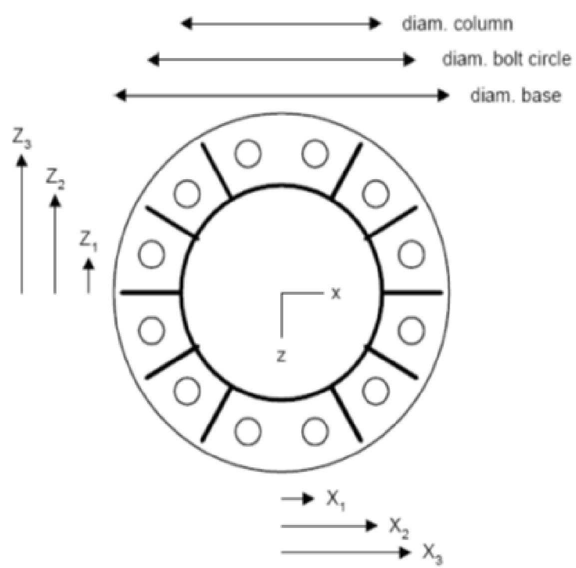
## Sabre calculation, NJDOT report and STAAD fatigue calculation comparison

| Example I | (Fatigue II) | Sabre | Report | STAAD |
|---|---|---|---|---|
| Joint load (kips) | Gallop | 7.056 | 7.056 | 7.056 |
| | Natural wind total | 3.761 | 3.2551* | 3.237* |
| | sign | 2.534 | 2.545 | 2.544 |
| | chord | 0.703 | 0.17 | 0.17 |
| | column | 0.525 | 0.5401 | 0.522 |
| | Truck.W | 0.408 | 0.271 | 0.271 |
| | TW sign | 0.134 | 0.134 | 0.134 |
| | TW chord | 0.274 | 0.137** | 0.137** |
| Moment (K-ft) | Gallop | 169.9 | 169 | 169.3 |
| | Natural.W | 63.6 | 57.65 | 61.1 |
| | Truck.W | 13.92 | 8.87 | 9.21 |

# Fatigue Check Example using Spreadsheet

Fatigue check using the spreadsheet example

- The sabre output file element #1 represent the base plate. The output list moments for both ends of element. Please select the higher moment from the table.
- The sabre file is in kip-ft unit, the spreadsheet is in kip-in. In this case, the moment should be, 6.2*12=74.4 kip-in.




Anchor rod stress calculation for N rods

| | | | |
|---|---|---|---|
| Dia $d_{ar}$ = | 2.5 | in | Red ink cells are for input |
| Thread series= | 4 | unc | |
| Crcle dia $d_{arc}$ = | 32 | in | |
| $M_{Z,TG,base}$ = | 74.4 | kip-in | moment from Sabre, k-in |
| Number of anchor rods = | 6 | | (min. 4 bolts) |
| Thread pitch = | 0.243575 | in | |

$A_T = \pi/4(d_{ar} - 0.9743/n)^2$

$A_T$ = 4.00 $in^2$

$I_{ar} = \Sigma A_T z^2$

$I_{ar}$ = 3112.33 $in^4$

Stress range

$(f_R)_{rod} = M_{Z,TG,base} \times c/I_{ar}$

$(f_R)_{rod}$ =

0.38 ksi — Category D, CAFL=7ksi — OK

0.38ksi

Cover | Title Page | Built-up Box | tube - tube | socket | Handlehole | Sheet1 | tube-gusset | stiffened base plate

# Wind Speed/Pressure

Wind loads based on 2013 ASD (STD-LTS) and 2015 LRFD are shown below:

a) 2013 wind pressure

$$Pz=0.00256K_z*G*V^2*I_r*C_d$$

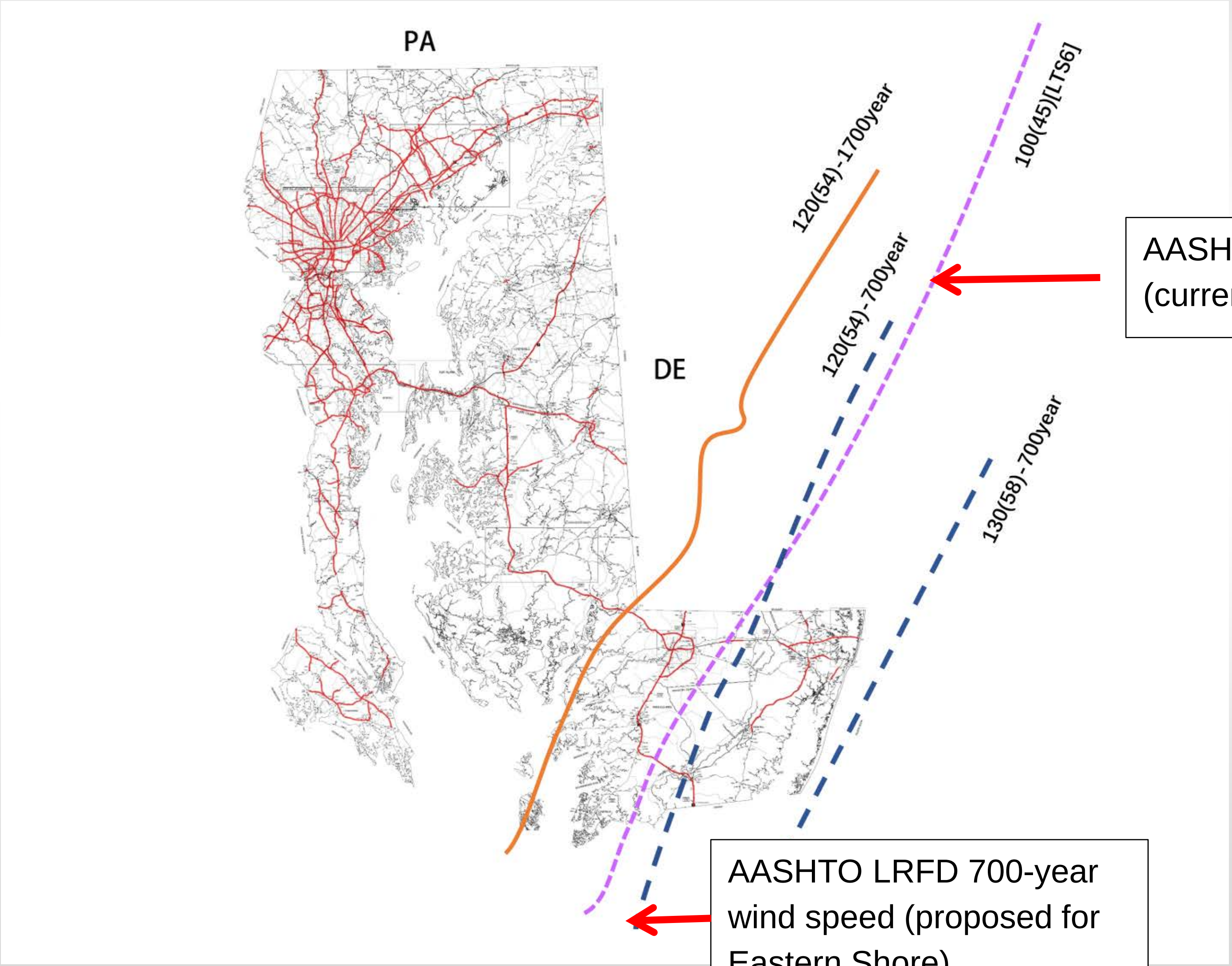
b) 2015 LRFD wind pressure

$$Pz=0.00256K_z*K_d*G*V^2*C_d$$

AASHTO LRFD-LTS Table 3.8-1 – Mean Recurrence Interval

| | Risk Category | | |
|---|---|---|---|
| Traffic Volume | Typical | High | Low |
| ADT ≤ 100 | 300 | 1700 | 300 |
| 100 < ADT ≤ 1000 | 700 | 1700 | 300 |
| 1000 < ADT ≤ 10000 | 700 | 1700 | 300 |
| ADT > 10000 | 1700 | 1700 | 300 |
| Typical: Failure could cross travelway | | | |
| High: Support failure could stop a lifeline travelway | | | |
| Low: Support failure could not cross travelway | | | |
| Roadside sign supports: use 10-yr MRI, see Figure 3.8-4 | | | |

# Example of Maryland Wind Speed/Pressure




AASHTO LTS-6 wind speed (current MD design 100 mph)

AASHTO LRFD 700-year wind speed (proposed for Eastern Shore)

# Example of Wind Speed/Pressure

Assumption:

$K_z$ = 0.87 for 2013 and 084 for the 2015 LRFD Specifications

$K_d$ = 0.85 (signal and sign support structures) for the 2015 LRFD Specifications only

G = 1.14 for both

$C_d$ = 1.20 for both

$I_r$ = 1.00 for the 2013 Specifications only

| Case 1 | 2013 | 2015 LRFD | 2015 LRFD | 2015 LRFD |
|---|---|---|---|---|
| Wind speed (V) | **100mph** | 100mph | 110mph | **120mph** |
| $P_z$ | **30.47** | 25.01 | 30.26 | **36.01** |

- For LTS-6 (2013) still use wind speed 100 mph statewide, which is equivalent for 110 mph for LTS-LRFD (2015)
- For LTS-LRFD (2015) may consider using wind speed 120 mph statewide (? To be determined)



UNIVERSITY OF MARYLAND

# Wind Strength Design Consideration

- LTS-6: Only basic load (BL) on one arm plane is considered

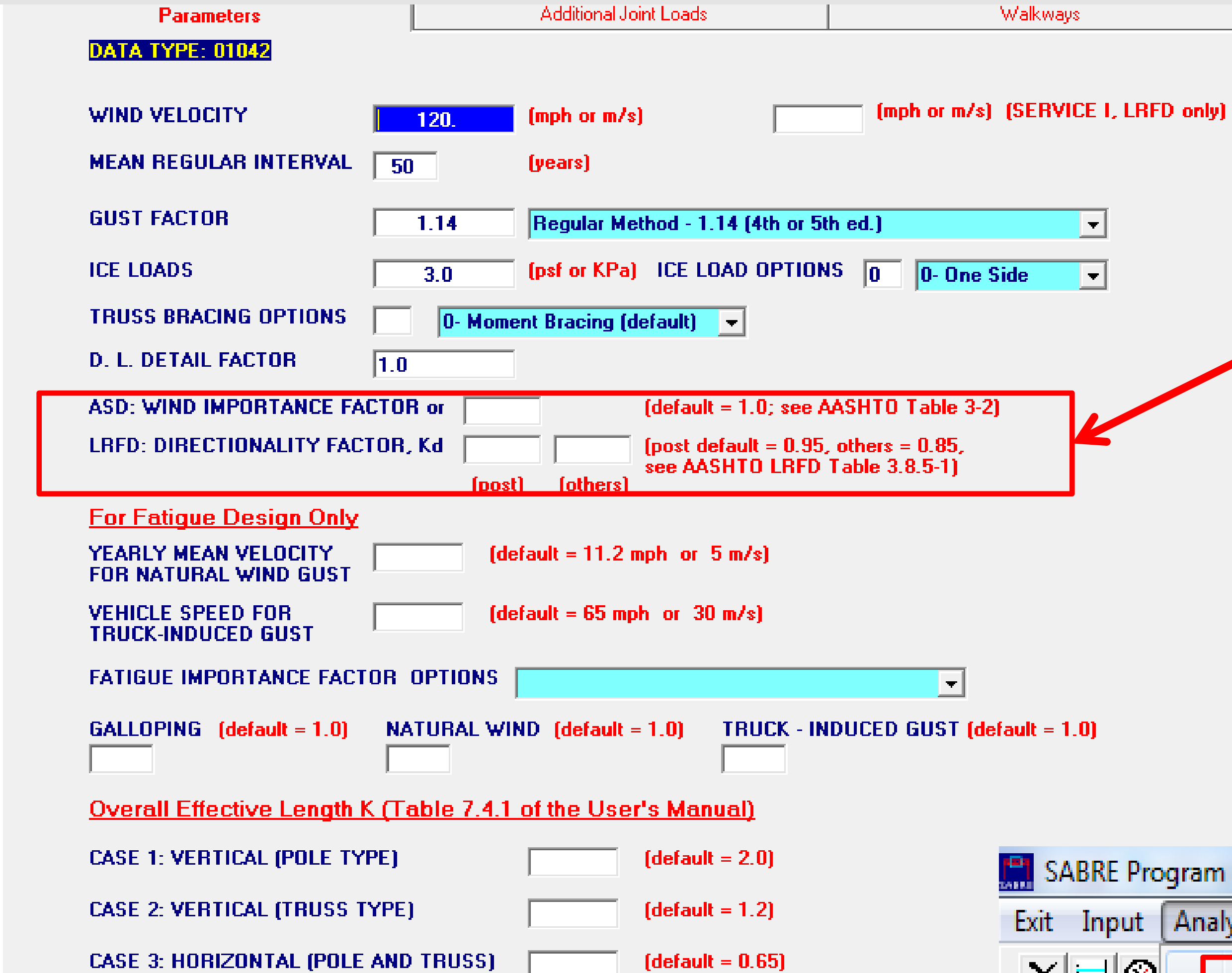
| Load Case | Normal component | Transverse component |
|---|---|---|
| 1 | 1.0 BL | 0.2 BL |
| 2 | 0.6 BL | 0.3 BL |

- LTS-LRFD: Two basic load are considered

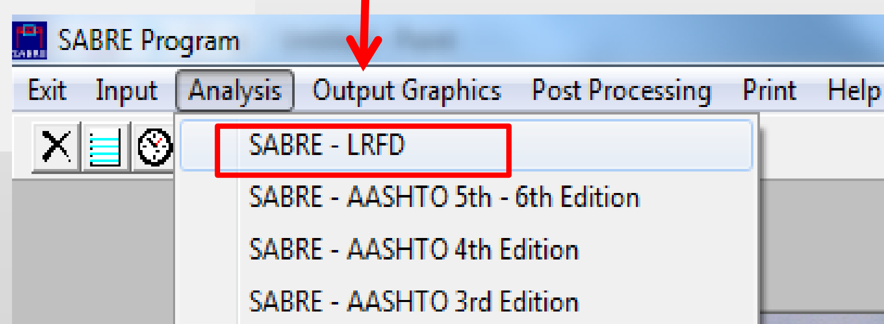
  (BLn) on one arm plane/(BLt) on the arm plane spaced at 90 degree

| Load Case | Normal component | Transverse component |
|---|---|---|
| 1 | 1.0 BLn | 0 |
| 2 | 0 | 1.0 BLt |
| 3 | 0.75 BLn | 0.75BLt |

# SABRE Input & Analysis Module for LRFD




See the red-ink block for the only input change of LRFD



# SABRE Load Combinations for LRFD

A. Strength Limit State

- Group 1 – 1.25DL + 1.6LL (T8.1, check for T10.1 & T13.1)

B. Extreme Limit State

- Group 2 – 1.1DC+W (Comb 1 +Z) (T8.2, check for T10.2, T13.2)
- Group 2 – 1.1DC+W (Comb 2 +Z) (T8.3, check for T10.3, T13.3)
- Group 2 – 1.1DC+W (Comb 3 +Z) (T8.4, check for T10.4, T13.4)
- Group 2 – 1.1DC+W (Comb 1 -Z) (T8.5, check for T10.5, T13.5)
- Group 2 – 1.1DC+W (Comb 2 -Z) (T8.6, check for T10.6, T13.6)
- Group 2 – 1.1DC+W (Comb 3 -Z) (T8.7, check for T10.7, T13.7)
- Group 3 – 0.9DC+W (Comb 1 +Z) (T8.8, check for T10.8, T13.8)
- Group 3 – 0.9DC+W (Comb 2 +Z) (T8.9, check for T10.9, T13.9)
- Group 3 – 0.9DC+W (Comb 3 +Z) (T8.10, check for T10.10, T13.10)
- Group 3 – 0.9DC+W (Comb 1 -Z) (T8.11, check for T10.11, T13.11)
- Group 3 – 0.9DC+W (Comb 2 -Z) (T8.12, check for T10.12, T13.12)
- Group 3 – 0.9DC+W (Comb 3 -Z) (T8.13, check for T10.13, T13.13)

C. LRFD Strength/Extreme Limit State Combination Checks

- Tower and Truss Member Capacities (T11.2 & T12.2)
- Tower and Truss Member Maximum Combined Force Ratios (CSR) (T11.4 & T12.4)

# SABRE Load Combinations for LRFD

D. Service I Limit State

- Group 4 – 1.0DC+ $W_{SE}$ (Comb 1 +Z) (T8.14, check for T9.14)
- Group 4 – 1.0DC+ $W_{SE}$ (Comb 2 +Z) (T8.15, check for T9.15)
- Group 4 – 1.0DC+ $W_{SE}$ (Comb 3 +Z) (T8.16, check for T9.16)
- Group 4 – 1.0DC+ $W_{SE}$ (Comb 1 -Z) (T8.17, check for T9.17)
- Group 4 – 1.0DC+ $W_{SE}$ (Comb 2 -Z) (T8.18, check for T9.18)
- Group 4 – 1.0DC+ $W_{SE}$ (Comb 3 -Z) (T8.19, check for T9.19)

E. LRFD Service Limit State Deflection Checks

- Maximum Joint Deflection tables (T9.10)

F. LRFD Fatigue Limit State Checks

- Group 5 – Galloping (T19.1, T9.11, T10.11, check for T20.1)
- Group 5 – Natural Wind Gust (T19.2, T9.12, T10.12, check for T20.2)
- Group 5 – Truck Gust (T19.3, T9.13, T10.13, check for T20.3)



UNIVERSITY OF MARYLAND