<u>Signal Span Calculation Program</u>

MDOT Traffic and Safety Support Area

Revised 1/18/11 **(REVISIONS IN YELLOW)**

Introduction: Due to the updated traffic signal design loads, the current MDOT span calculation program has been updated. The updated program offers the following advantages:

1) It is a Microsoft Excel spread sheet, so all the formulas are readily visible. This allows new users the ability to better understand the calculations.
2) It has a graphic component to provide a visual image of what the proposed span will look like.
3) It will model 3 and 4 way tie offs.
4) Weights may be hung on any of the spans.
5) The POCH is defined as the height from the top of the pole foundation rather than from the grade centerline.

The program is broken up into a number of Excel tabs. Depending on the complexity of the span not all of the tabs will be used.

This is an iterative process in which the designer will enter a best guess and then adjust the inputs depending on the results. Several checks are included to ensure that the proper POCHs and stem lengths are calculated to be transferred to the plan sheets.

General Assumptions:

1) Tension on spans is generally limited to 1500 pounds.
2) In the program Yellow cells are those that require data to be entered.
3) In the program Red cells are key calculated values that must be verified.
4) In the program Blue cells are calculated values.
5) The naming convention will follow that which is shown in Figure 1.

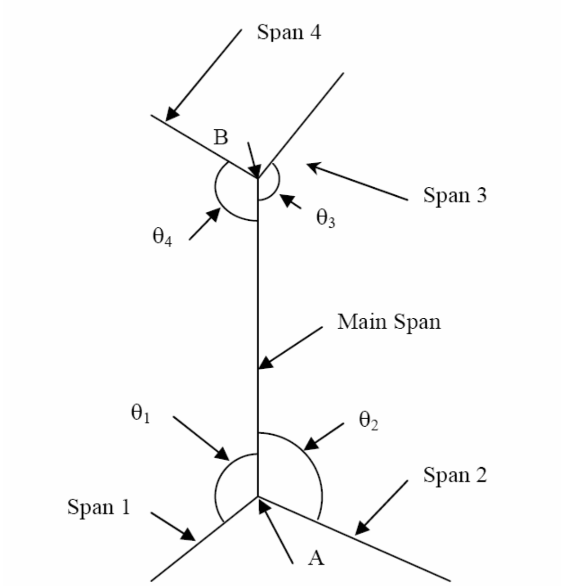

Figure 1: Naming Convention for Span Configurations

Simple Span: To determine the POCH heights and stem lengths for a simple span:

1) Go to the "Diag Main Spn" tab on the spread sheet.
2) Enter the span length in the upper portion of the sheet.
3) Enter the weight and equipment height on the lower portion of the sheet for each head to be mounted on the span. To determine the distance measure from Point A. If there is not a head at a particular distance, leave that cell blank.
4) Enter the horizontal force on the span. Typically start with something on the order of 1200 pounds. The horizontal force differs from the tension in that it does not include the vertical component of the force on the span wire, but typically they are very similar in magnitude. Actual tension on the span will vary as you travel across the span. The horizontal tension should be a constant assuming no wind or other dynamic loads.
5) Enter a first estimate for the connection heights at A and B above the plan grade centerline will be. Keep in mind any physical limitations (Pole heights, overhead obstructions, etc.).
6) Enter the elevations at the top of the pole foundations and at the plan grade centerline.
7) Review the 9 criteria in the upper portion of the sheet to verify they are within acceptable ranges:
    a. The tension at points A & B is the actual tension at the POCH and includes the vertical and horizontal components of force on the span wire. If it exceeds 1500 pounds, adjust the connection heights or horizontal force until the tension is at a reasonable level.
    b. The minimum vertical clearance should equal or exceed 17 feet. The "Diag Main Spn Chrt" tab shows a visual representation of the span. It shows the 17 foot minimum vertical clearance and the span height along the span, with downward spikes shown at each head.
    c. Ideally the stem lengths should be identical and of zero length. In practice this will not be possible for most designs. They should be kept as short and even as reasonably possible. Tilting the span one way or the other will often reduce the variation in stem lengths. Increasing the tension may help also.
    d. The minimum required pole length should be a pole length utilized by MDOT and shown in the Statewide Signal Details (i.e. 30 ft, 36 ft, or 40 ft).
    e. The POCH must be a minimum of 1.5 ft below the top of the pole.
8) Adjust the connection heights and horizontal force until a design is achieved in which the tension is acceptable, the POCHs are acceptable, the span and all heads are above the minimum under clearance and the stems are relatively small and even in length.
9) Record the POCHs, and stem lengths for each head. This information can then be transferred to the signal plan.
10) No other tabs need to be utilized for a simple span.

Box Span: To determine the POCH heights and stem lengths for a box span:

1) Go to the "Bx Spn 1" tab on the spread sheet.
2) Enter the span length in the upper portion of the sheet.
3) Enter the weight and equipment height on the lower portion of the sheet for each head to be mounted on the span. To determine the distance measure from Point A. If there is not a head at a particular distance, leave that cell blank.
4) Enter the horizontal force on the span. Typically start with something on the order of 1200 pounds. The horizontal force differs from the tension in that it does not include the vertical component of the force on the span wire, but typically they are very similar in magnitude. Actual tension on the span will vary as you travel across the span. The horizontal tension should be a constant assuming no wind or other dynamic loads.
5) Enter a first estimate for the connection heights at A and B above the plan grade centerline will be. Keep in mind any physical limitations (Pole heights, overhead obstructions, etc.).
6) Enter the elevations at the top of the pole foundations and at the plan grade centerline.
7) Review the 9 criteria in the upper portion of the sheet to verify they are within acceptable ranges:
    a. The tension at points A & B is the actual tension at the POCH and includes the vertical and horizontal components of force on the span wire. If it exceeds 1500 pounds, adjust the connection heights or horizontal force until the tension is at a reasonable level.
    b. The minimum vertical clearance should equal or exceed 17 feet. The "Bx Spn 1 Chrt" tab shows a visual representation of the span. It shows the 17 foot minimum vertical clearance and the span height along the span, with downward spikes shown at each head.
    c. Ideally the stem lengths should be identical and of zero length. In practice this will not be possible for most designs. They should be kept as short and even as reasonably possible. Tilting the span one way or the other will often reduce the variation in stem lengths. Increasing the tension may help also.
    d. The minimum required pole length should be a pole length utilized by MDOT and shown in the Statewide Signal Details (i.e. 30 ft, 36 ft, or 40 ft).
    e. The POCH must be a minimum of 1.5 ft below the top of the pole.
8) Adjust the connection heights and horizontal force until a design is achieved in which the tension is acceptable, the POCHs are acceptable, the span and all heads are above the minimum under clearance and the stems are relatively small and even in length.
9) Repeat steps 2 through 8 for the adjacent span, Span 2, on the "Bx Spn 2" tab. Continue with Span 3, 4, etc. on the respective tabs of the spreadsheet. Note that Pole B of Span 1 is the same pole as Pole A for Span 2 and so on for each adjacent span. Check that the same size pole is designated for each location and that the POCHs are at least 3 inches apart on a single pole. If different minimum pole lengths are designated for a single pole, use the longer pole length.
10) Record the POCHs, and stem lengths for each head. This information can then be transferred to the signal plan.

Three way tie off: In order to determine the POCHs and stem lengths for a three way tie off, the "Diag Main Spn", "3-Way Span 1" and "3-Way Span 2" tabs will be used.

1) Start the same as you would for a simple span. Assume point A is a fixed point in space and estimate the height for point A and enter that as the connection height at A. Point B is assumed to be connected to pole B. Keep in mind that the connection heights at the ends of spans 1 and 2 will likely need to be higher than the height at A.
2) Once you have a reasonable solution for the main span go to the "3-Way tie off" tab.
3) Enter the angles for θ_1 and θ_2, as shown in Figure 1. This will determine the tensions on Span 1 and Span 2.
4) Go to the "3-Way Span 1" tab.
5) Enter the length of Span 1.
6) Enter the weight and equipment height for the heads mounted on Span 1.
7) Enter an estimate for the connection height 1.
8) Enter the elevations at the top of the pole foundation and at the plan grade centerline.
9) Go to the "3-Way Span 2" tab.
10) Enter the length of Span 2.
11) Enter the weight and equipment height for the heads mounted on Span 2.
12) Enter the elevations at the top of the pole foundation and at the plan grade centerline.
13) On tabs "3-Way Span 1" and "3-Way Span 2", verify that the data in the upper right corner are within the acceptable ranges.
    a. If the tension exceeds 1500 pounds, adjust the connection heights until the tension is at a reasonable level. You may need to go back to the "Diag Main Spn" tab and adjust the height at point A. If you do, verify that the main span calculations are still acceptable.
    b. The minimum vertical clearance should equal or exceed 17 feet. The "3-Way Span 1 Chart" and the "3-Way Span 2 Chart" show a visual representation of these spans. It shows the 17 foot minimum vertical clearance and the span height along the span, with downward spikes shown at each head.
    c. Ideally the stem lengths should be identical and of zero length. In practice this will not be possible for most designs. They should be kept as short and even as reasonably possible. Tilting the span one way or the other will often reduce the variation in stem lengths.
    d. The minimum required pole length should be a pole length utilized by MDOT and shown in the Statewide Signal Details (i.e. 30 ft, 36 ft, or 40 ft).
    e. The POCH must be a minimum of 1.5 ft below the top of the pole. POCH 2 is a calculated value. Verify that it is in a reasonable range. Raising POCH 1 will reduce POCH 2 and vice versa.
14) Adjust the connection heights and horizontal force until a design is achieved in which the tension is acceptable, the POCHs are acceptable, the minimum vertical clearance is achieved and the stems are relatively small and even in length.
15) Record the POCHs, and stem lengths for each head. This information can then be transferred to the signal plan.

Four way tie off: A four way tie off is modeled in the same way as a three way tie off. The only difference is point B is also assumed to be a point fixed in space. Treat it similar to point A for the three way tie off.

1) Enter all the data for the "Diag Main Spn", "3-Way Span 1" and "3-Way Span 2" the same as done with a three way tie off. Point A still uses the "Threeway tie off" tab.
2) Use the "4-Way tie off" tab for the point B data.
3) The "4-Way Span 3" and "4-Way Span 4" tabs will be associated with the point B end of the span. They will be filled out similarly to the "3-Way Span 1" and "3-Way Span 2" tabs.
4) Keep in mind that if point A or B is moved, all spans will be impacted and the key data should be verified.

Appendix of calculations

Primary Span Forces: These calculations define the horizontal and vertical forces at the ends of the span, as shown in Figure 2.

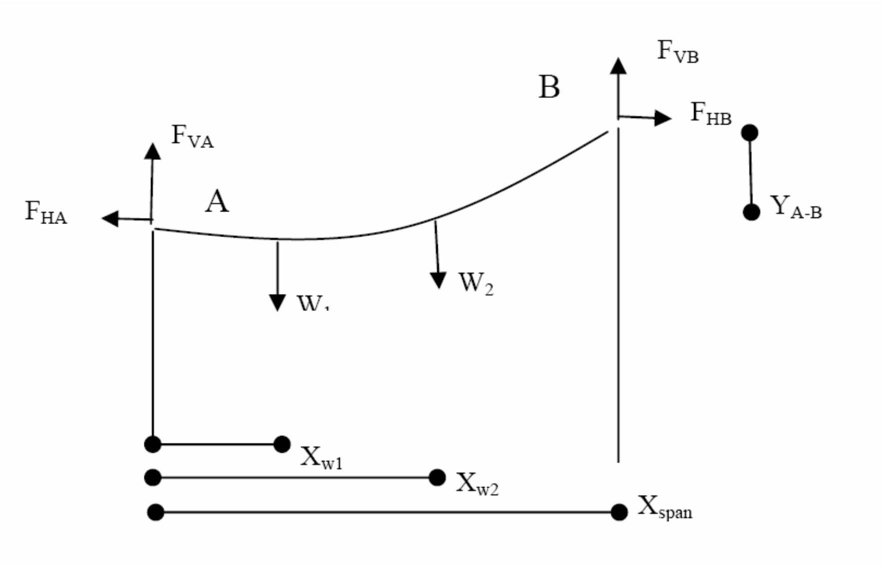

Figure 2: Forces at Ends of Span

F_{HA} = User defined

$F_{HB} = F_{HA}$ (assumes static loading, no wind or other dynamic loads)

W_X = User defined (loads placed across the span including the weight of the span wire.)

X_{WX} = User defined (based on the distance from point A to each load)

Y_{A-B} = User defined (difference in height between the ends of the span.)

$F_{VB} = (F_{HB} \text{ x } Y_{A-B} + W_1 \text{ x } X_{W1} + \ldots + W_X \text{ x } X_{WX}) / X_{span}$

$F_{VA} = W_1 + \ldots + W_X - F_{VB}$

$Tension_A = (F_{HA}^2 + F_{VA}^2)^{0.5}$

$Tension_B = (F_{HB}^2 + F_{VB}^2)^{0.5}$

Link calculations: Once the forces at the ends of the spans are determined, the span is divided into 1 foot links to determine how it sags, as shown in Figure 3. Starting at point A, F_{VX} is equal to F_{VA}. The horizontal forces are, by definition, always constant and defined by the horizontal tension selected. After the first link, use the vertical forces calculated from the previous link. The same methodology is used for the tie off spans.

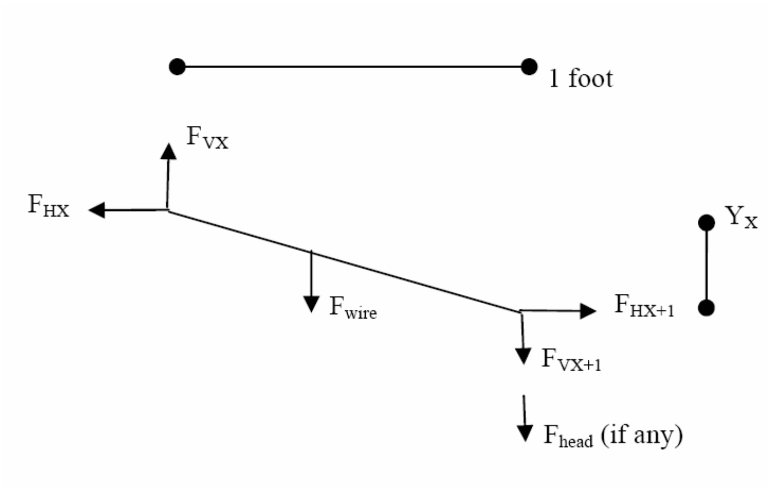

Figure 3: Forces at 1 ft Links

$F_{HX} = F_{HA} = F_{HX+1}$

$F_{VX} = F_{VX+1}$ (from previous link) or F_{VA} (if first link)

F_{wire} = user defined (typically 0.6 lb/ft)

F_{head} = user defined (only applies if there is a head on the link in question)

$F_{VX+1} = F_{VX} – F_{wire} – F_{head}$

$Y_X = (0.5 \text{ x } F_{wire} + 1.0 \text{ x } F_{head} + 1.0 \text{ x } F_{VX+1}) / F_{HX+1}$

Division of forces at a tie off: At a tie off point the horizontal forces in tie off spans which are perpendicular to the main span must be equal and opposite in order for the tie off point to remain stationary. Figure 4 is based on point A from a typical, plan view layout. Point B is determined by the same principal.

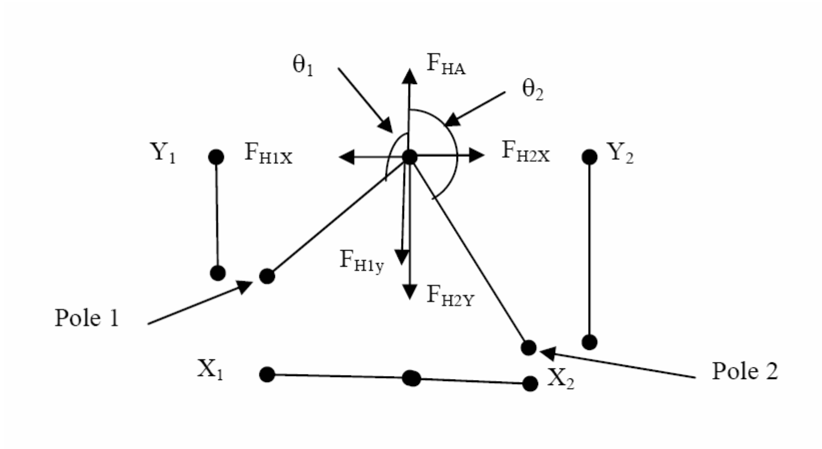

Figure 4: Forces at tie off

F_{HA} = known from primary span forces.

$F_{H1Y} = F_{HA} \times \tan(\theta_1 - 90) / [\tan(\theta_1 - 90) + \tan(\theta_2 - 90)]$

$F_{H1X} = (X_1 / Y_1) \times F_{H1Y}$

$F_{H1} = (F_{H1Y}^2 + F_{H1X}^2)^{0.5}$

$F_{H2Y} = F_{HA} - F_{H1Y}$

$F_{H2X} = F_{H1X}$

$F_{H2} = (F_{H2Y}^2 + F_{H2X}^2)^{0.5}$