

Loading Methods in TOWER and PLS-POLE

Introduction

Version 7 of PLS-POLE and TOWER introduces several new methods and modifies many of the existing ones for applying wind & ice loads to a structure. The new options include automatic loading as per ASCE 74-1991, ASCE 74-2009, NESC 2002, IEC 60826:2003, EN 50341-1 (CENELEC), EN 50341-3-9 (UK NNA), EN 50341-3-17 (Portugal NNA), REE (Spain), TPNZ (New Zealand) and ESAA C(b)1-2003. The existing options that have been simplified and integrated into the new loading methodology include: Wind on All, Wind on Face, SAPS Wind, RTE Hyp1 and RTE Hyp2. TIA/EIA 222-F and ANSI/TIA 222-G have been left unchanged. Selecting a wind loading method can result in the automation of a number of calculations:

- 1) Calculation of the structure gust response factor
- 2) Adjustment of wind speed with height
- 3) Automatic selection of a drag coefficient for poles (as a function of number of sides or Reynolds number) and for lattice towers (as a function of solidity ratio)

To support these new methods, a new column, *Wind/Ice Model*, is now available in the vector and wire load case tables. In addition to this column we have added *Structure Ice Thickness* and *Structure Ice Density* columns so that ice may be applied to a structure. Finally, you will find a *Wind Area Factor* column which can be used to adjust the wind load on the structure in the same manner that the *Dead Load Factor* adjusts the dead load.

Revisions

- Version 7.33: **ASCE 74-2006** (draft) made available
Automatic calculation of K_{com} for **UK NNA** users (see the technical note for more information)
- Version 8.10: Added **NESC 2007** which is effectively identical to NESC 2002.
- Version 10.36: **ASCE 74-2009** replaces ASCE 74-2006 (draft) now that the manual has been published.
- Version 11.11: **AS/NZS 7000:2010** added

Notes for Users of Previous Versions

Models made in previous versions open in version 7 without requiring any modifications. Any necessary translation will be performed automatically and an analysis of a structure model in version 7 will produce the same results as it did for that model in version 6. You do not need to make any changes in order to keep working the way you always have. However, you may want to modify your models and loading criteria to take advantage of the new options offered in version 7.

Getting Started with the New Methods

PLS-POLE models do not require any changes to use the new loading methods. Should you wish to take advantage of them, you need only select the method in the *Wind/Ice Model* column and input the appropriate *Terrain Category* in the *Loading Method Parameters* dialog reached from the *Vector Load Cases* or *Wire Load Cases* table. Please note that when using an automated method, you should input basic unadjusted wind pressures (normally at 10m or 33ft above the ground) in the *Transverse and Longitudinal Wind Pressure* columns. If you then run an analysis with the new method the following will occur: the appropriate drag coefficient will be selected based on pole shape and/or Reynolds Number (overriding whatever you input), the wind pressure will be adjusted with height, the basic input wind pressure will be adjusted by the *Wind Area Factor* and will also be adjusted by the calculated structure gust response factor and finally, ice will be applied to the pole. All of these effects are detailed in the ***Detailed Pole Loading Data for Load Case*** table in the *Analysis Results* report. You should carefully review this table for your preferred code as it supplies in one place all of the information necessary to understand what loads the program calculated and applied to your pole. Note that ice will only be applied to your structure if you input a non-zero ice thickness and that most codes (including NESC and ASCE) do not require ice to be applied to the structure even for load cases that specify ice on conductors. If you do input an ice thickness, the ice will only be applied to equipment, cables, guys, angles and the pole itself. Due to a lack of guidance on how ice accretes on arms, braces and insulators, ice is not applied to these elements.

In order to use the new loading methods with TOWER models you may need to make some modifications. If you elect to use a method that only applies wind on the face of the structure, such as ASCE74-1991, ASCE74-2009F (but not ASCE74-2009M), NESC 2002, IEC 60826, EN 50341, UK NNA, Portugal NNA, REE (Spain), TPNZ, ESAA C(b)1-2003 or AS/NZS 7000:2010 F you should do the following:

- 1) Open the *General/General Data* dialog and modify these settings:
 - A) Select the cross section shape (rectangular or triangular) of the structure body.
 - B) Check the *Allow separate faces for each section* checkbox. This will allow you to control the shielding effects of one portion of the structure on another and is required for delta configurations and chainette structures.
 - C) Input a *Ground Elevation Shift for Wind Height Adjust* if the structure is not resting directly on the ground.

- 2) If you have not already defined sections, do so using *Geometry/Sections/Table Edit*. In general, you should create sections at the border of a discontinuity in tower outline, to separate parts of the tower where the solidity ratio can be expected to substantially differ and for each mast of a chainette. Section heights should not exceed the maximum allowed by the code for zones over which wind pressure can be assumed constant. You should always have a clean boundary between two sections in the horizontal plane even when overriding section membership manually in the *Geometry/Angle Members* table. Note that loads (wind and dead) are divided evenly among all joints in a section, so placing your entire tower in a single section will result in a conservative distribution of dead load.

- 3) Input appropriate factors in *Geometry/Sections/Table Edit* for the *Transverse and Longitudinal Area Factor (CD From Code)* columns to account for any members that were not included in the TOWER model. The factors in these columns are used by any loading method that calculates a drag coefficient for a section as a function of the solidity ratio (ASCE74, IEC60826, EN 50341, UK NNA, Portugal NNA, REE, TPNZ, ESAA C(b)1 and AS/NZS 7000:2010 methods) and also by NESC 2002. You will note that columns corresponding to the other methods also exist, such as: *Transverse and Longitudinal Drag x Area Factor for Face (Wind on Face method)*, *Af and Ar Factor For Face EIA Only (TIA/EIA 222-F and G methods)*, *Transverse and Longitudinal Drag x Area Factor For All (Wind on All method)*, *SAPS Angle and Round Drag x Area Factor (SAPS, ASCE74-2009M, AS/NZS 7000:2010 M, RTE Hyp1 and RTE Hyp2 methods)*. Finally, you may notice a new column at the end of the sections table titled *Force Solid Face*. This can be used to override the calculated face area of a section with the gross area and can be useful for areas where the face computation is uncertain or one wishes to be conservative such as the transverse face of a crossarm. This setting only applies to section based loading methods and not to member based methods (such as Wind on All, SAPS, ASCE74-2009M, AS/NZS 7000:2010M, RTE Hyp1 and RTE Hyp2). A drag coefficient of 2 is always used with a solid face; however, you can modify this by inputting whatever *Transverse and Longitudinal Area Factor (CD From Code)* you find appropriate.

- 4) Inspect the transverse and longitudinal faces that TOWER automatically determined. TOWER was designed to automatically identify the faces for conventional lattice structures. If you have a chainette or otherwise unconventional structure, or simply don't like the face that TOWER identified, you can use the new *Geometry/Members/Override Face* and *Geometry/Members/Fence Override Face* commands to define your own face. Face overrides are stored in the *Geometry/Members/Capacities and Overrides* table should you want to edit them in a tabular format.

- 5) Run an analysis of your model and carefully inspect the detailed sections loading table **Section Load Case Information** printed in the *Analysis Results* report. This table includes within it all of the data you need to understand how TOWER calculated the load on this section and what that load was. For each type of tower you model, you should make sure that the gross area the program calculates using your section and face definition matches your expectations. Note that the ice load printed in this table is multiplied by the *Sections Dead Load Factor* for this section. Since the *Sections Dead Load Factor* is intended to account for the effects of members that were not included in the model, it is used to modify the ice load calculated for the section.

Note: we strongly encourage you to graphically review the member type (truss, beam or tension only), section membership and face settings of all members in your structure. To accelerate this process we have provided a keyboard shortcut that changes the color by mode. Press the *F9* key or use the *View/Cycle Color By* command to have the program cycle through the available color by modes. A new status bar indicator (in the lower right hand corner of your screen) indicates the current mode.

Notes for Telecommunications Users (TIA/EIA 222)

Since ANSI/TIA 222-G is still pending, TOWER and PLS-POLE version 7 do not have a new code to offer telecommunications users; however, they do offer a number of modeling improvements. In PLS-POLE, you can leave the drag coefficients blank and the program will calculate them for you as per TIA/EIA 222-F. You can inspect these drag coefficients as well as the loads that were placed on your pole by reviewing the **EIA Load Case Information** table which is printed for every load case. This table is the EIA analogue of the **Detailed Pole Loading Data** that is used for transmission codes. In TOWER, you can use the new *Force Solid Face* option to force the longitudinal face to be solid for any section. You will also note that the *Structure Type* input has migrated from the *General/EIA Options* dialog to *General/General Data* and been renamed *Structure Shape*. Another new TOWER option is the *Allow separate faces for each section* setting in *General/General Data* to automate wind loading for complex structures (such as multi-masted structures) that previously had to be done manually. When selected, no section is allowed to shield another section which allows for more than one face at any given elevation. Joints can now belong to more than one section which results in a more even distribution of load in the tower. Finally, you can now override the automatic calculation of face for every member in the structure using the new *Geometry/Graphical Member/Face Override* and *Geometry/Graphical Member/Fence Override Face* commands. This enables you to control the face and wind loading for previously tricky situations like outriggers.

Notes for PLS-CADD Users

PLS-CADD can be used to generate loads with the new methods. To do so, you will need to modify your *Criteria/Structure Loads* to select the Loading Method in the *Structure Wind Load Model* column, input the appropriate *Structure Wind Area Factor*, *Structure Ice Thickness* and *Structure Ice Density*. Users of the UK NNA will need to input K_{com} in the *Structure Wind Area Factor* column (or zero to trigger automatic calculation of K_{com}). PLS-CADD will read old projects and translate their criteria into the new format. Previous implementations of standards such as ASCE 1991, ASCE 2002 and NESC 2002 will be translated to a “Pre V7” Loading Method. For these legacy loading methods PLS-CADD will pass a wind pressure that has been adjusted by the structure gust response factor and adjusted for height as appropriate. The structure program will then apply this constant pressure to the structure. For any new loading method, PLS-CADD passes the structure program an unadjusted wind pressure and the structure program is responsible for calculating the final wind pressure according to whatever code was selected. Note that prior to version 7, you could not explicitly select *Standard*, *Wind on Face*, *Wind on All*, *SAPS*, *RTE Hyp1* or *RTE Hyp2* methods; however, one of these methods was in use depending on the settings made in the structure program and elsewhere. The centralization and simplification of the selection of Loading Method is a major benefit of version 7.

Additional information is available in the *Loading Changes in Version 7 of PLS-CADD* document available at http://www.powline.com/products/PLS-CADD_version7_loads.pdf

Detailed Notes for Each Method

We have done our best to faithfully implement the following aspects of some codes: selection of gust response factor, adjustment of wind with height and selection of drag coefficient. However, not all codes define all necessary concepts for all aspects of the loading method, some codes leave wide latitude for interpretation and some are just plain wrong. Below we will describe the major interpretations and deviations we may have taken from a given code as well as other items of interest.

For all codes, separate drag coefficients are not calculated for insulators and you should input a factored insulator area (real area * drag coefficient) in the insulator library. However, the insulator will see the same adjusted wind pressure as the rest of the structure (which includes poles, angle members, arms, guys, equipment etc.).

You can graphically review the drag coefficients, gust response factors and wind escalation that the program uses by clicking the *Create Graphs* button in the *Loading Method Parameters* dialog reached from *Loads/Vector Loads* by clicking on *Edit Loading Method Parameters*.

ASCE 74-1991

- A) No liberties were taken with this design guide.
- B) Note that all three ASCE variants (ASCE 74-1991, ASCE 74-2009F and ASCE 74-2009M) use the same terrain category.

ASCE 74-2009

- A) Two variations of this code have been implemented: ASCE 74-2009**F** and ASCE 74-2009**M**. ASCE 74-2009**F** applies wind to the **face** of a lattice tower with the drag coefficient calculated as a function of solidity ratio and the wind pressure calculated at the mid-height of each section. ASCE 74-2009**M** applies wind to all **members** based on fluid mechanics with the wind pressure calculated at the mid-height of each individual member. ASCE 74-2009M requires a constant drag coefficient of 1.6 for angles and 1.0 for rounds which should be input in the “SAPS Angle Drag X Area Factor” and “SAPS Round Drag X Area Factor” columns (last two columns) of *Geometry/Sections/Table Edit* in TOWER. You should also account for any members that have not been modeled (e.g. redundants); therefore, the factors you input may be slightly larger than 1.6 and 1.0.
The F (Face) version may work for conventional closed body lattice towers. The M (Member) version will work for any type of structure.
- B) The wind incidence factor (yaw wind factor) has been eliminated in the 2009 edition.

NESC 2002 and NESC 2007

- A) NESC 2002 does not define a Wind Incidence Angle Factor; therefore, for applying wind on lattice towers from other than the transverse direction we use the Wind Incidence Angle factor defined in ASCE 74-1991 (which is identical to that in IEC and CENELEC).
- B) Drag coefficients applied to angle members in the face of a lattice tower are 3.2 and 2.0 for rounds independent of the solidity ratio of the section as per Rule 252B2c.
- C) No provision was made for lattice towers with a triangular body shape. Therefore, TOWER will always use the drag coefficients for a rectangular cross section.
- D) Drag coefficients for poles are calculated as per Rule 252B2 with 1.0 being used for all but rectangular poles (which use 1.6).
- E) A constant wind pressure adjusted for 2/3 the structure height and gust response factor as per Rule 250C will be applied. We do not automate the 60ft exemption which is based on politics and not physics (structures less than 60ft will have wind applied on them).

IEC 60826:2003

- A) No provision was made for lattice towers with a triangular body shape. Therefore, TOWER will always use the drag coefficients for a rectangular cross section.
- B) G_t is not defined below 10m and above 60m and no guidance on the appropriate values to use for these situations was provided. Therefore, for $G_t < 10m$, the value of G_t at 10m will be used and for $G_t > 60m$, the value of G_t at 60m will be used.

A request for clarification of these points has been made to the IEC committee.

EN 50341-1:2001 (CENELEC)

- A) This is the generic version of the common European code and has been provided primarily for research and testing purposes.
- B) CENELEC did not provide for drag coefficients for poles. Therefore, drag coefficients for poles are selected from ENV 1991-2-4:1997 for less than 16 sided poles. IEC 60826:2003 drag coefficients are used for round, 16 and 18 sided poles.
- C) CENELEC did not provide exact equations for calculating drag coefficients for angle members as a function of solidity ratio, but its graph (Figure 4.2.3) matches the IEC 60826:2003 one (Figure 7), so the IEC equations are used. CENELEC did not provide anything for round members, so drag coefficients for round members are calculated using the IEC60826:2003 equations (Figure 8).
- D) No provision was made for lattice towers with a triangular body shape. Therefore, TOWER will always use the drag coefficients for a rectangular cross section.
- E) G_t is always assumed to be 1.05 in TOWER even for structures more than 60m tall.
- F) G_{pol} is always assumed to be 1.15 in PLS-POLE for all pole types (wood, steel, concrete and mast).

EN 50341-3-9:2001 (UK NNA)

- A) This is the National Normative Aspects of generic CENELEC for The United Kingdom and Northern Ireland as interpreted by the National Grid.
- B) ASCE74 drag coefficients are used for poles instead of those from ENV 1991-2-4.
- C) The calculated structure gust response factor will includes effects from K_{com} as $GRF = (1+G_b * K_{com})$. K_{com} should be input in the *Wind Area Factor* column in the *Vector Loads and Wire Loads* tables. The default value is one.
- D) The input structure ice thickness must already include any necessary adjustment.
- E) V_z is approximated as $V_z = V_r$ when $z < 10+he$ for poles, but calculated exactly for lattice towers.
- F) Lattice tower drag coefficients are taken from BS8100:1988 Appendix G Figure 4.3. Sub-critical flow is always assumed for round members.
- G) Wind incidence factor (yaw wind factor) is taken from BS8100:1988 Appendix G.4.1 Figure 4.2.

EN 50341-3-17:2001 (Portugal NNA)

- A) This is the National Normative Aspects of generic CENELEC for Portugal.
- B) Drag coefficients for round ($C_d = 0.6$) and four sided poles ($C_d = 1.85$) come from the NNA. For other polygonal shapes with less than 16 sides C_d is determined from ENV 1991-2-4. For 16 and 18 sided shapes IEC60826:2003 drag coefficients are used.
- C) No provision was made for lattice towers with a triangular body shape. Therefore, TOWER will always use the drag coefficients for a rectangular cross section.
- D) You should input V_{mean} and the program will apply K_g to obtain V_R automatically.

REE (Spain)

- A) This is the methodology used in Spain as provided by Red Eléctrica de España.
- B) REE did not provide for pole drag coefficients. Therefore, drag coefficients for poles are selected from ENV 1991-2-4:1997 for less than 16 sided poles. IEC 60826:2003 drag coefficients are used for round, 16 and 18 sided poles.
- C) Round members in the tower face use the IEC60826:2003 drag coefficients, angle members use $3 \cdot (1 - \text{solidity ratio})$. The input wind pressure should take this into account.
- D) No provision was made for lattice towers with a triangular body shape. Therefore, TOWER will always use the drag coefficients for a rectangular cross section.

RTE Hyp1 and RTE Hyp2

- A) These methods implement loading as per the specifications of RTE (the national grid operator in France). They are not based on CENELEC.
- B) These methods use SAPS wind loading and the SAPS wind power should always be input as zero when using them since wind should not escalate with height. The selection of SAPS wind was previously made in the *Wind Model* column which has been replaced by the *Wind/Ice Model* column.
- C) The *EDF Load Type* column has been removed now that these methods have been made available in the *Wind/Ice Model* column.

TPNZ (New Zealand)

- A) This is the methodology used in New Zealand as provided by Transpower & Maunsell.
- B) Pole drag coefficients are taken from table G2 of TP.DL 12.01.
- C) Lattice tower drag coefficients are taken from table 2.2.8.2[1-3] of AS3995. The “onto face” values are always used with yawed wind handled via ASCE 74 equation 2.6-5. Sub-critical flow is always assumed for round members.
- D) $M_{z,cat}$ is calculated as per the commentary of AS/NZS 1170 C4.2[7,8].

ESAA C(b)1-2003 (Australia)

- A) This is the methodology used in Australia as interpreted by Powerlink Queensland.
- B) Pole drag coefficients are taken from ASCE 74.
- C) Lattice tower drag coefficients are taken from BS8100:1988 Appendix G Figure 4.3. Sub-critical flow is always assumed for round members. This is identical to UKNNA.
- D) Wind incidence factor (yaw wind factor) is taken from BS8100:1988 Appendix G.4.1 Figure 4.2. This is identical to UKNNA.
- E) $M_{z,cat}$ is calculated as per AS/NZS 1170.2:2002 table 4.1(A) and 4.1(B).

AS/NZS 7000:2010

- A) Four variations of this code have been implemented: AS/NZS 7000:2010 **SF**, AS/NZS 7000:2010 **SM**, AS/NZS 7000:2010 **DF**, and AS/NZS 7000:2010 **DM** where **S** denotes synoptic wind and **D** Downdraft wind. For each of these the **F** (face) option applies wind to the **face** of a lattice tower with the drag coefficient calculated as a function of solidity ratio and the wind pressure calculated at the mid-height of each section. The **M** option applies wind to all **members** based on fluid mechanics with the wind pressure calculated at the mid-height of each individual member. The **M** options require a constant drag coefficient of 1.6 for angles and 1.0 for rounds which should be input in the “SAPS Angle Drag X Area Factor” and “SAPS Round Drag X Area Factor” columns (last two columns) of *Geometry/Sections/Table Edit* in TOWER. You should also account for any members that have not been modeled (e.g. redundants); therefore, the factors you input may be slightly larger than 1.6 and 1.0.
The **F** (Face) version may work for conventional closed body lattice towers. The **M** (Member) version will work for any type of structure. The methods are identical for PLS-POLE structures.
- B) Pole drag coefficients are taken from ASCE 74.
- C) For **F** options, lattice tower drag coefficients are taken from AS/NZS 7000:2010 section B5.1 which is a simplified version of BS8100:1988 Appendix G Figure 4.3 that removes support for round members and structures with a triangular cross section. Unfortunately, no guidance was provided for structures with those features so TOWER will default to BS8100:1988 whenever round members or a structure with a triangular cross section is encountered. This is effectively identical to BS8100:1988 which itself is identical to the UKNNA (EN50341-3-9).
- D) Wind incidence factor (yaw wind factor) is taken from B5.1 which is essentially identical to BS8100:1988 Appendix G.4.1 Figure 4.2, but with support for round members removed. So once again TOWER will default to BS8100:1988 whenever round members are encountered.
- E) For **S** options (synoptic wind): $M_{z,cat}$ is calculated as per AS/NZS 1170.2:2002 table 4.1(A).
For **D** options (downdraft wind): $M_{z,cat}$ is calculated as per B4.2.

SAPS Wind

- A) This method applies wind on the structure according to the principles of fluid mechanics with an assumption that no member shields another. This is one of the possible wind loading methods introduced in ASCE74-2009 (identified as ASCE74-2009M). France is the only nation to require this wind method; however, you may wish to use it in special situations since being based on physics it always works.

Wind on All

- A) This is a legacy method that applies an unadjusted constant pressure to the projection perpendicular to the wind of all members of a structure.
- B) Selecting Pre V7 Standard loading in your PLS-CADD criteria will always result in this method for poles and for towers that previously had the “Wind On Face” option in *General/General Data* unchecked.

Wind on Face

- A) This is a legacy method that applies an unadjusted constant pressure to a pole or to members in a face in a lattice tower.
- B) For poles this is the same as Wind on All.
- C) Selecting Pre V7 Standard loading in your PLS-CADD criteria can result in this method provided the tower model was created prior to version 7 and had the “Wind On Face” option in *General/General Data* checked.