

## **Cable Tensions in PLS-CADD**

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It is important to understand the rationale behind PLS-CADD when it comes to cable tensions. This is because cable tensions have a profound impact upon the cost, reliability and safety of a line. It has also been observed that this aspect of line design needs to be expounded to many users.

### **What is Sagging Data?**

Sagging data consists of

1. The cable condition (initial, final after creep or final after load)
2. the cable temperature under no wind and no ice
3. the horizontal tension (or the catenary constant)

The sagging data does NOT represent the anticipated conditions that will occur when the cable is run out and sagged. However you may choose to use these conditions if you wish. If the vibration condition is the most restrictive tension limit for most ruling span sections, then it is recommended that these conditions become the sagging data. However the selection of sagging data is rather arbitrary.

The sagging data specifies the status of the cable under a weather condition of no ice and no wind. This data defines the unstressed length a cable in the section from which the tensions under any weather case and cable condition can be derived.

All reporting of stringing information includes the sagging data. It is recommended that the sagging data be identical in each section of the line. This allows easy visual comparison of tensions between sections.

(More correctly, the sagging data should contain the weather case. This allows the most restrictive limiting horizontal tension to be manually entered. Internally PLS-CADD should record the tension at some arbitrary condition, say 0°C, no wind, no ice and the initial condition.)

### **Manual Sagging Preference**

PLS-CADD allows the user to set a preference for specifying the tension when manually sagging each section of cable. The two options are –

- a) Sag with catenary constant
- b) Sag with horizontal tension

The catenary constant determines the shape of the catenary. For a cable with no wind and no ice, the catenary constant is the ratio of horizontal tension to unit mass of the cable. The sag is inversely proportional to the catenary constant ie a large catenary constant represents a taut cable.

$$S = \frac{L^2}{8C} \text{ for a parabola}$$

where

S = mid-span sag

L = horizontal span length

C = catenary constant

Some utilities prefer to specify the catenary constant because of its influence upon the vibration characteristics of a cable.

### **Manual Sagging**

Manual sagging of a single section is performed in Sections/ Modify. The sagging data that can be manipulated are –

1. Condition
2. Temperature
3. Horiz. Tension (or Catenary)

Manual sagging of multiple sections is performed in Sections/ Table. The sagging data that can be manipulated are

1. Sag Condition
2. Sag Temperature
3. Sag Tension (or catenary)

Another method of “manual” sagging is graphical sagging. The sagging data that can be manipulated here are –

1. Condition
2. Temperature (or weather case)
3. Mouse coordinate (or survey point) to fit curve through

However when you manually sag you can only specify a no wind and no ice cable tension (or catenary constant). Therefore if a heavy loading condition is limiting the tensions and you wish to manually sag, then you will need to calculate the sagging data for each ruling span. It is recommended that manual sagging only be used when the tension is well below that permitted by the code.

### **Automatic Sagging**

Automatic sagging of a single section is performed in Sections/ Modify/ Automatic Sagging. Manipulation of any of the manual sagging data will have no affect on the tension. The sagging tension is wholly derived from the automatic sagging criteria. However the values that are entered for the manual sagging data (except for the tension or catenary which will be overwritten) will be reported in –

- “Section Modify” dialogue box
- String Chart Report
- Sag – Tension Report
- Line Summary Report

When a section is automatically sagged, PLS-CADD calculates the tension at the sag cable condition and the sag temperature, thus piecing back together all of the sagging data.

If the automatic sagging criteria are subsequently changed, the tensions in the sections that were automatically sagged DO NOT automatically update. The user must automatically sag each section again. This can be done quickly with Sections/ Table.

### **Section Checking**

The cable tension is limited by safety codes or guidelines in many countries. This is done to ensure the integrity of the line under extreme weather events. However aeolian vibration often limits the cable tension depending upon the degree to which bending stresses can be limited at the cable support points. Thus PLS-CADD has a table of cable tension criteria that places a ceiling on the cable tension under various weather conditions (cases).

Whenever a Section Check is performed, PLS checks that the cable tension criteria are not violated. It does not matter which method was used to sag the cable. Section Check does NOT check whether the automatic sagging criteria are violated.

The cable tension criteria can be viewed as a code check.

### **Criteria Tables**

The structure of the cable tension criteria table and the automatic sagging criteria table are the same. Each table consists of the following fields –

- a. Weather case
- b. Cable condition (initial, final after creep or final after load)
- c. Cable tension limit
  - a. Tangential or maximum tension expressed as % ultimate breaking tension
  - b. Tangential or maximum tension
  - c. Catenary constant

It is possible to enter all three cable tension limits. It is also possible to enter conflicting values ie values that do not represent the same tension for a given cable type. In this situation the most restrictive tension limit will determine the sagging tension.

The NESC (National Electrical Safety Code) approved by the American National Standards Institute requires that the tangential (or maximum) tension at the cable support be the limiting tension.

PLS-CADD has the option to make the limiting tension either

- b) The tangential tension at the supports of a level span of length equal to the ruling span. A level span is one whose supports are at the same elevation, or
- c) The maximum tangential tension in the section. The magnitude of the tangential tension varies with span length and support elevation. The maximum tangential tension occurs in the span with the longest equivalent level span.

Some countries use the horizontal component of tension as the limiting tension for stringing the cable. Typically the tangential tension is less than 3% greater than the horizontal component of tension.

If these countries are trying to achieve the maximum permissible tension allowed by their code, then they must convert their tension limits into catenary constants.

## Summary of Methods to Change the Tension

There are three primary ways of changing the cable tension in a section of line between termination structures –

1. Section Modify (Menu item Sections/ Modify)
  - a. Automatic Sagging  
The tension is determined by the automatic sagging criteria.
  - b. Manual Sagging  
The tension (or catenary constant) for this section can be changed.
2. Table Edit (Menu item Sections/ Table)  
The tension (or catenary constant) for each section can be edited in tabular form.
3. Graphical Sag (Menu item Sections/ Graphical Sag)  
The tension for this section is determined graphically by “rubber-banding” the cable.

The table below list the methods of changing cable tension and the parameters that can be changed using each method. A tick indicates that this parameter can be changed using this method. A cross indicates that it can not be changed.

Section Parameter	Automatic Sagging	Manual Sagging	Table Edit	Graphical Sag (without finite element)
Cable type	✓	✓	✓	✗
Weather case	✓ <sup>a</sup>	✗	✗	✓
Sag cable condition	✗ <sup>b</sup> ✓ <sup>a</sup>	✓	✓	✓
Sag temperature	✗ <sup>b</sup>	✓	✓	✓ <sup>c</sup>
Sag horiz. tension (or catenary)	✗ <sup>b</sup> (derived automatically)	✓	✓	✗ (derived graphically)
Max. tangential tension (or catenary)	✓ <sup>a</sup>	✗	✗	✗
Override calc. RS	✓	✓	✗	✗
Use actual RS	✓	✓	✗	✗

yellow - sagging data

a – can be changed via the table of automatic sagging criteria

b – these parameters in “Section Modify” have no affect on the sagging tension, however they do affect the reporting of sagging data

c – if a weather case is selected, the temperature of the weather case is adopted as the sag temperature

A definition of each parameter in the table is given below –

**Cable type** – the file name that contains the physical properties of the cable

**Weather case** – the wind load, the ice load and cable temperature combination specified in the table of weather cases

**Sag cable condition** – the cable condition (initial, final after creep or final after load) defines the amount of plastic elongation that exists in the cable.

**Sag temperature** – the cable temperature (with no wind nor ice) at which the sag tension (or catenary) is specified

**Sag catenary** – the catenary constant corresponding to the sag tension

**Sag tension** – the cable tension (with no wind nor ice) at the cable condition and temperature

**Override calc. RS** – the calculated ruling span can be overridden. Tension-change calculations utilise this ruling span instead of the actual ruling span. This would only be used when a subset of spans in a section is modelled in PLS-CADD and the ruling span of the subset does not correspond to the actual ruling span for the section.

**Use actual RS** – the actual ruling span is automatically calculated and used for all tension-change calculations. This is the preferred option.

### **Indirect Ways of Changing Tensions**

- 1) If the physical parameters in the cable data file are changed then the tensions will change for most weather cases. The sagging data will not change.
- 2) If structures are moved or deleted so that the section ruling span is significantly changed then the tensions may not be as anticipated. If you utilised the automatic sagging feature then you should automatically sag again.
- 3) The sagging characteristics of a section can be copied and then applied whenever a new section is added.