Incab

Sag and Tension Theory 101

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President

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ENGINEERING RCEP REGISTERED CONTINUING EDUCATION PROGRAM

PURPOSE AND LEARNING OBJECTIVES

This course will teach you the basics of sag and tension theory.

After this class, you will be able to:

1. Explain what sag is and its relationship to the low point in a span.
2. Explain what tension is.
3. Explain the “everyday” relationship between sag and tension and the three exceptions to this relationship.
4. State what creep is and how it changes sag and tension over time.
5. Explain what a catenary is and how it relates to sag and tension.
6. Explain what a parabola is, why it is used in lieu of a catenary, and how it relates to sag and tension.
7. State the approximate error in sag using the parabolic approximation.
8. State three (3) sources of sag error.
9. State the difference between elastic and plastic changes in conductor length and their effect on sag and tension calculations.

Incab University “School of Excellence in Fiber Optics”
Agenda

- Introduction
- Learning Objectives
- Presentation
- Q&A (Technical questions only)
- Let’s start!

An Acknowledgement

You have likely heard it said that “We stand on the shoulders of giants”

This is especially true for today’s presentation

I want to thank **Joe Renowden** for much, perhaps most, of today’s material

Joe is still active, and he consults, most notably on what could be called “CSI: Failed Stuff”

So, if you are dealing with a problem with any cable, fitting, or just about anything else that has broken/failed when it should not have, reach out to him at:

Joe Renowden, P.E.
561-371-2744
joe_renowden@ieee.org

Now let’s get to business…

Sag and Tension

Foundational Concepts

- Let's start with an easy question:
- "In an aerial system such as a transmission line, what is it exactly that sags and has tension?"
- If you answered:
    - The conductors,
    - The OPGW,
    - The ADSS,
    - The cables,
    - The wires, or
    - Similar
- Then go to the head of the class! Any of the above are correct!
- (But, don't get cocky, the questions do get harder as we continue)

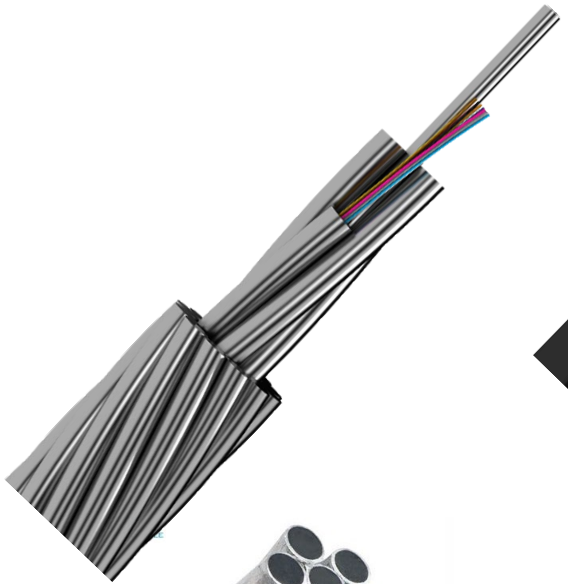
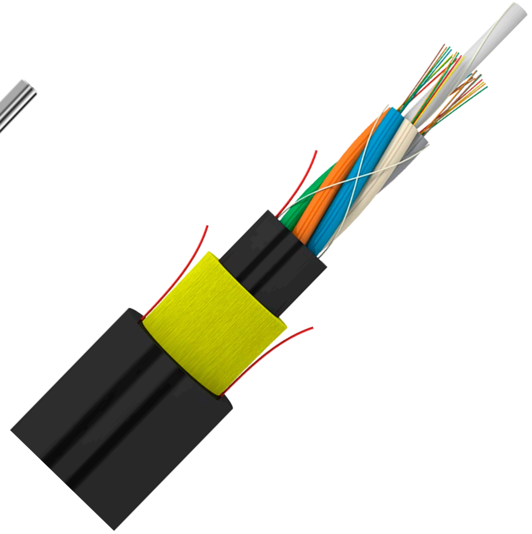
Sag and Tension

Foundational Concepts

- There are lots of different types of conductors, OPGW, ADSS, cables, wires, and etc.





Sag and Tension

Foundational Concepts

- You likely noticed on the last slide that aerial cables are made from many different materials

- In no specific order…

  - Copper
  - Aluminum – different alloys
  - Galvanized steel – with differing strengths and degree of galvanizing
  - Aluminum-clad steel - with differing conductivities available
  - Carbon fiber/Composite
  - Plastic – different kinds
  - Aramid (“Kevlar®”)
  - And more!

Sag and Tension

Foundational Concepts

- And there are various constructions
- Also, in no specific order…
  - Round wires versus trapezoidal wires
  - Different sizes of wires or other elements
  - A single strand of wire (was not shown) versus multiple strands
  - Differing numbers of layers
  - The ADSS cable (plastic and aramid) versus all the cables with metals

Foundational Concepts

Classifying Cables

- From an engineering standpoint, we could classify cables as:

1. Homogeneous construction:
    - All-aluminum conductor (AAC)
    - All-aluminum alloy conductor (AAAC)

2. Bimetallic homogeneous construction
    - Aluminum-clad steel (ACS, a.k.a. "alumoweld" ("AW"))
    - Copper-clad steel (commonly known as "copperweld" (CW))
    - Galvanized steel (cables such as 3/8-inch "HS", "EHS", and "UHS")

3. Bimetallic mixed construction
    - Aluminum Conductor Steel Reinforced (ACSR)
    - Aluminum Conductor Alloy Reinforced (ACAR)
    - Aluminum Conductor Steel Supported (ACSS) (originally "SSAC")(aluminum annealed)
    - OPGW

Within these, there are variations such as ACSR/AW (ACS core) or ACSR/TW (trapezoidal wires)

Foundational Concepts

Classifying Cables

- You could term the classifications on the previous slide "traditional"

- Many of today's transmission lines use conductors with a combination of metallic and non-metallic components designed for "High Temperature Low Sag" operation
  - Enables operation at higher temperatures (> 100°C), thereby permitting increased power transfer

Let's add these to our (growing) list:

4. Metallic and non-metallic combinations ("composites")
   - Aluminum Conductor Composite Reinforced (ACCR) – core wires are a metal-ceramic matrix
   - Aluminum Conductor Composite Core (ACCC) – a single core strand that is a carbon and fiberglass composite
   - Aluminum Conductor Composite Stranded Core (ACCS/C^7) – seven (7) core strands are carbon composite

Foundational Concepts

Classifying Cables

Let's not forget…

5. Non-metallic cables
    - All-Dielectric Self-Supporting (ADSS) with a very wide range of constructions, including different materials for strength

Plus, there are combinations of the preceding cables such as:

- Lashed cable systems – Typically a steel messenger cable supporting another cable:
    - "Old days" – messenger supporting a copper communications cable
    - "Today" – steel supporting a fiber optic communications cable
- Spacer cable systems – Typically a steel messenger cable with a series of "hangers" supporting three conductors (typically ACSR or AAC)

And, I know that I have left out at least two:

- Metallic Aerial Self-Supporting (MASS – think "ADSS but with metal"), and
- Figure-8 (think "Lashed" but integrated into a single cable)

Classifying Cables
Takeaways

When I started, I did not think it would take me so long to get through all the classifications of cables!

Here are the take-aways from the classification exercise:

1. There is a huge range of different types of cables in use on aerial systems today

2. They use a range of materials that have:
    - Different strengths
    - Different moduli of elasticity
    - Different densities
    - Different coefficients of thermal expansion

3. They have a wide range of construction and manufacturing processes, too

In turn, these lead to…

Classifying Cables

Conclusions

Therefore and no surprise:

- Different cable types will have different mechanical behaviors

- The behavior of cables in an aerial environment where temperature and weather (notably wind and “ice”) are constantly changing is quite complex

So, by now, if you are not at least a little worried, you will be…

Let’s move on to define sag

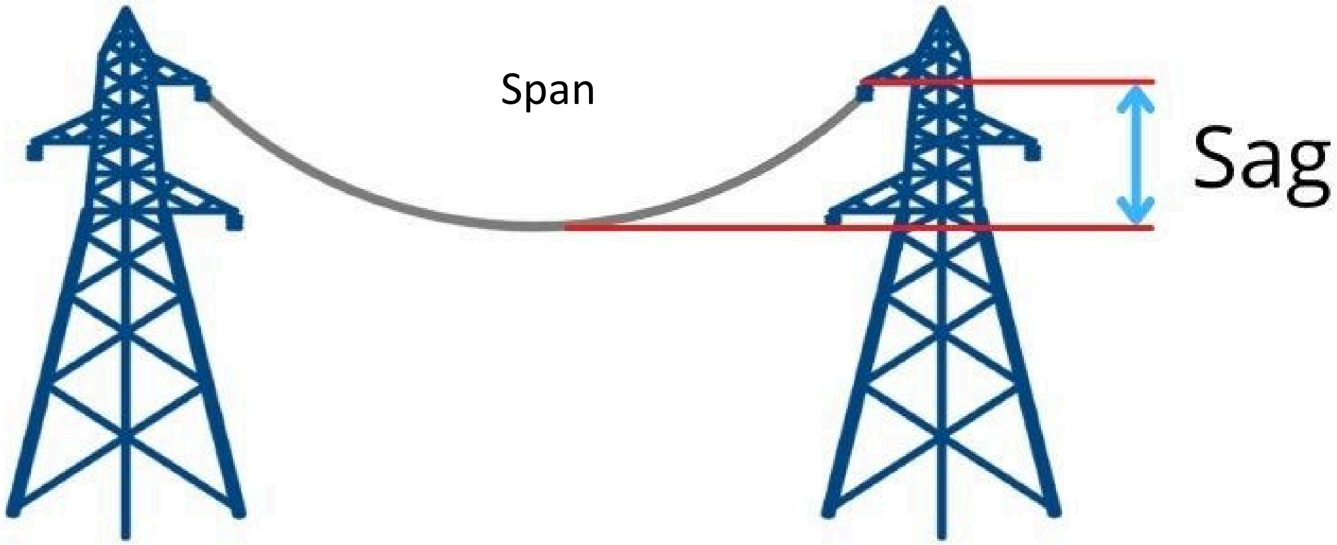
Note: Why “ice” (note the scare quotes)?

- Because there are different kinds of ice which means that they have different densities
- Consequently, they will affect a given cable differently
- Today, we will assume “typical” ice density of 57 lbs/ft^3 (913 kg/m^3)

Foundational Concepts

Sag Preface

We are going to consider a single span from one attachment point on one structure to a second attachment point on a second structure like this:



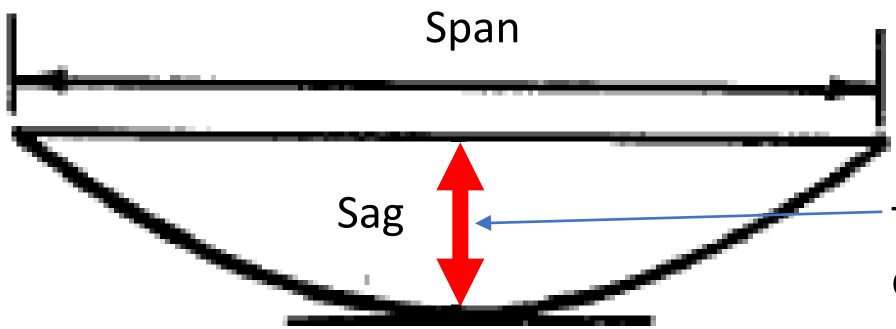
The sag concepts that follow will apply regardless of the cable type!

Foundational Concepts

Sag Defined

Geometrically, Sag is:

- The vertical distance from a straight line between the attachment points to a parallel line that is tangent to the cable

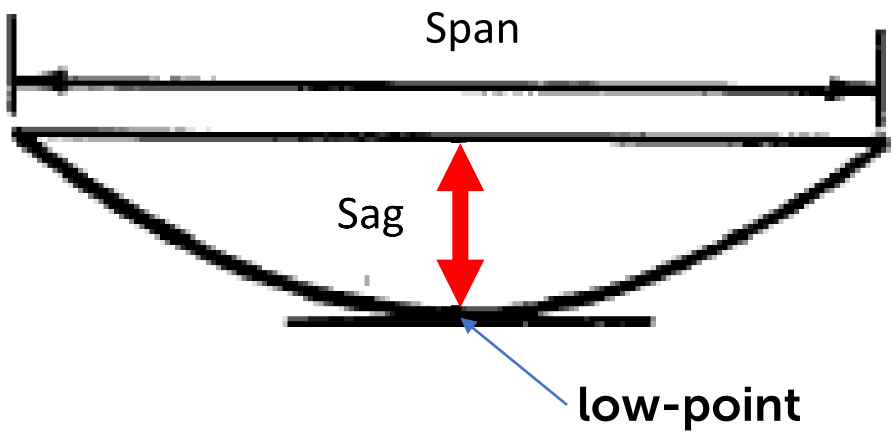


This vertical distance is the maximum vertical distance in the span of the cable

Foundational Concepts

Sag in a Level Span

In a **level span**, **sag** always at the exact mid-point of the span = "**midspan**"



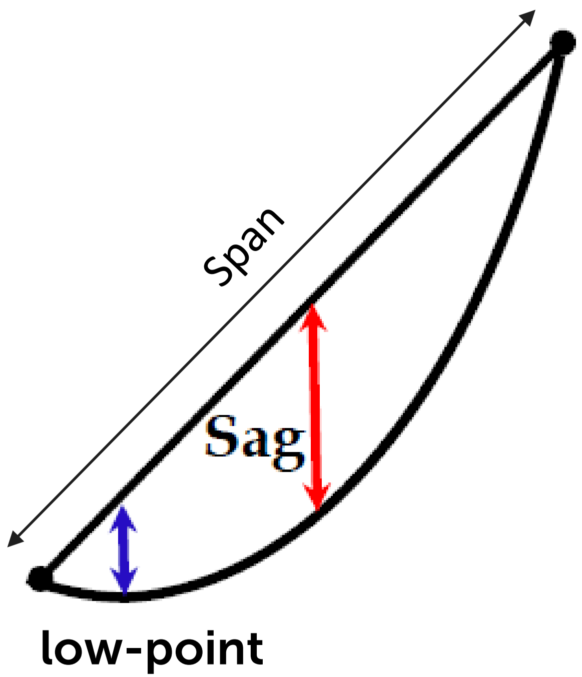
And, the **low-point** is also at **midspan**

A level span results when the attachment points are at the same height as in the preface illustration

Foundational Concepts

Sag in an Unlevel Span

In an **unlevel span**, **sag** once again is always at **midspan**



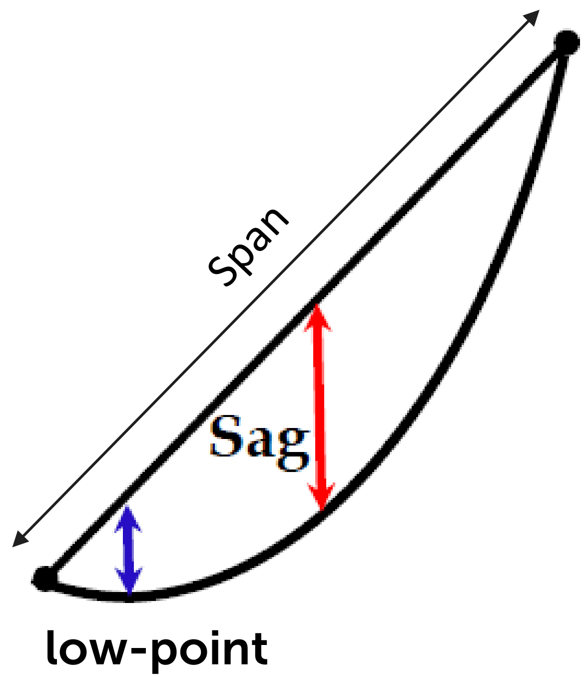
But, the **low-point** is **not** at **midspan** and the sag at the low-point is always less than the sag at midspan

An unlevel span results when the attachment points are at different heights such as structures at different elevations

Foundational Concepts

Sag in an Unlevel Span

So, if the **low-point** in an **unlevel span** is **not** at **midspan**, then where is it?



Answer: It must be calculated(!)

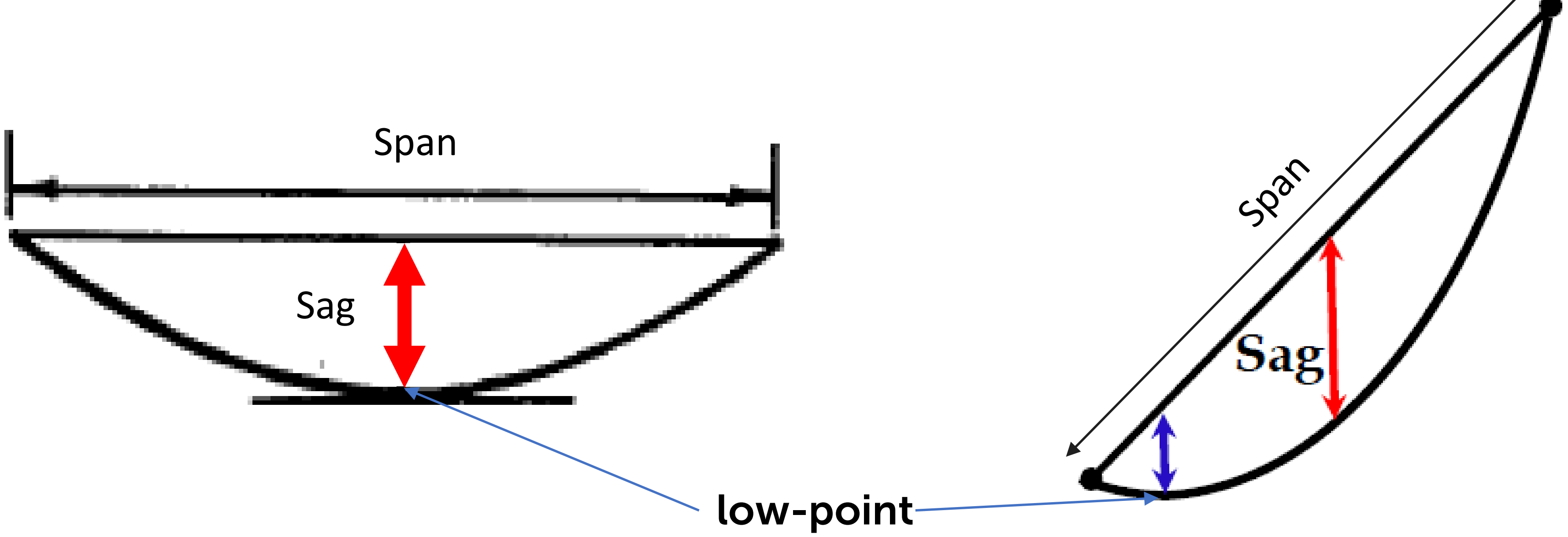
- It will not show up on a sag chart
- Nor can it be found using Google Maps

We will circle back to this in a moment

Foundational Concepts

Sag in a Level versus an Unlevel Span

Let's compare side-by-side, and observe



<u>**Level Span**</u>

- **Sag** at **midspan**
- **Low-point** at **midspan**
- **Low-point sag = midspan sag**

<u>**Unlevel Span**</u>

- **Sag** at **midspan**
- **Low-point <u>not</u>** at **midspan**
- **Low-point sag < midspan sag**

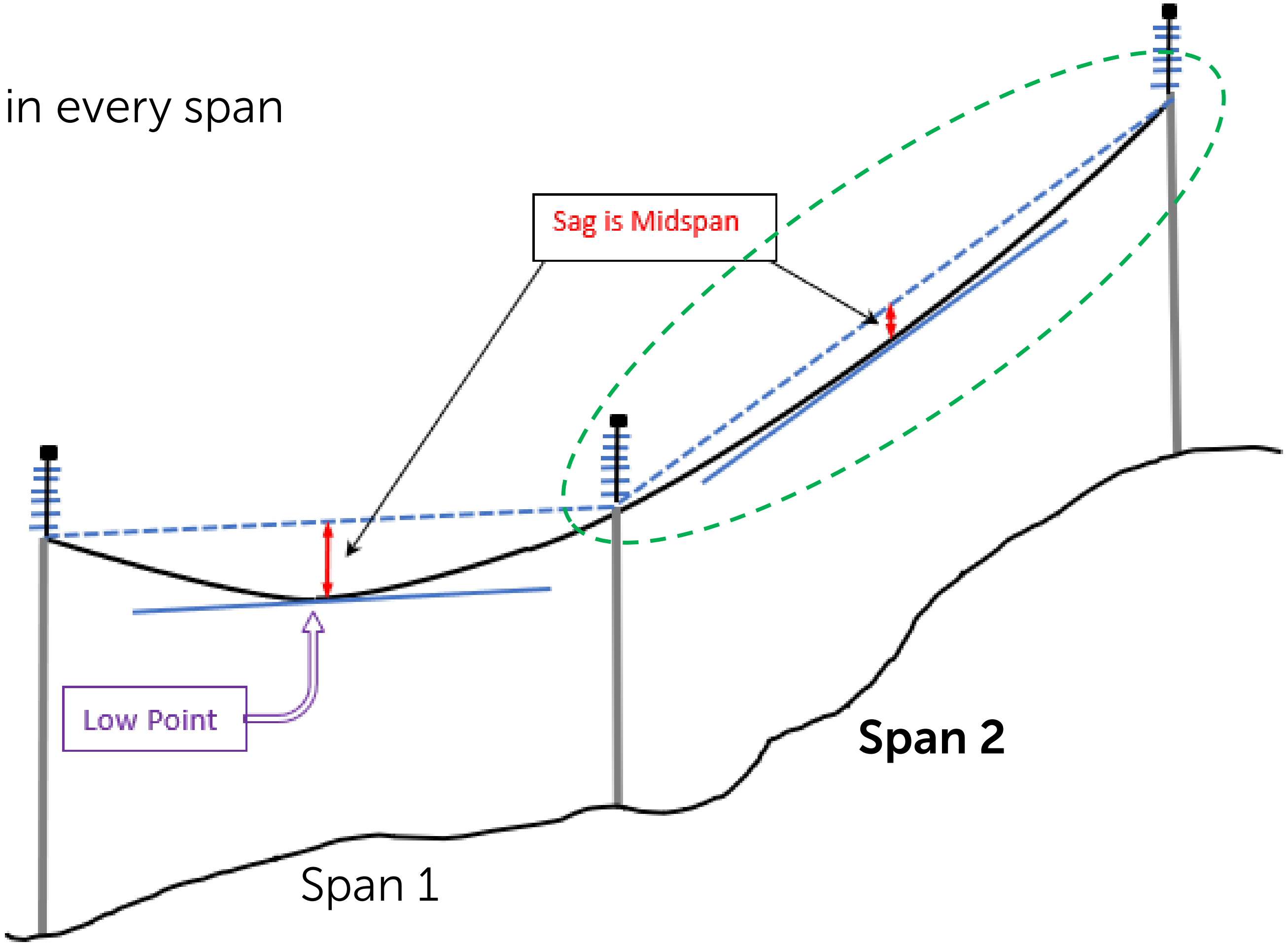
Foundational Concepts

Sag in a Level versus an Unlevel Span

There is <u>not always</u> a <u>low-point</u> in every span

Consider span 2 at right…

Notice that the sag is <u>still</u> at midspan in both spans



Foundational Concepts

Finding the Low-Point in an Unlevel Span

Recall that I said we can calculate the low-point in an unlevel span

Here's the math to do that!

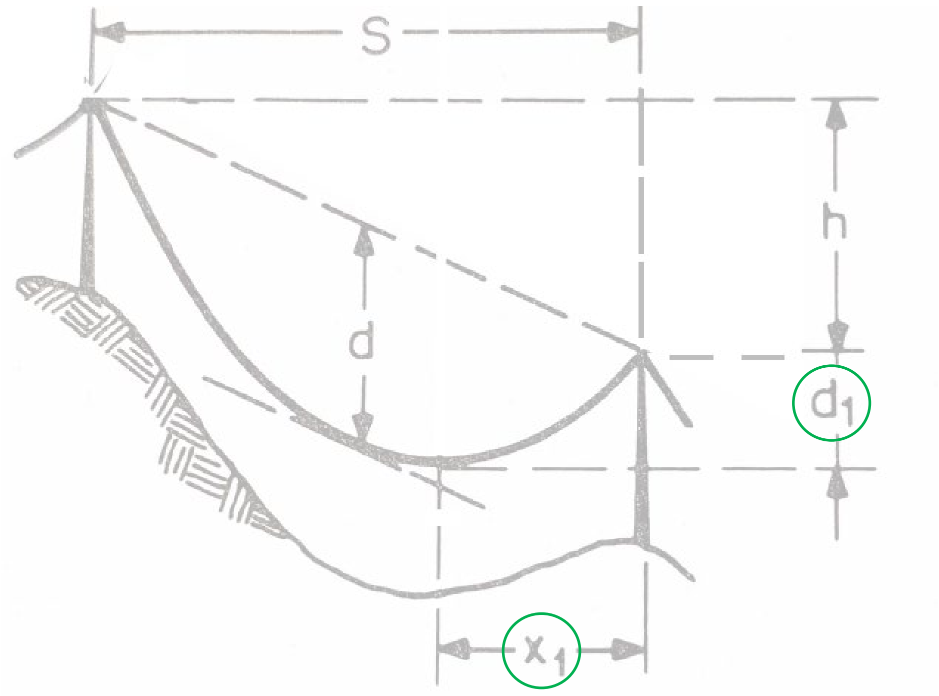


Fig. 14-28 Standard Handbook for Electrical Engineers, McGraw Hill, 12th Edition, 1987,

$$d_1 = d * (1 - h/4\,d)^2$$

$$X_1 = \left(\frac{S}{2}\right) * (1 - h/4\,d)$$

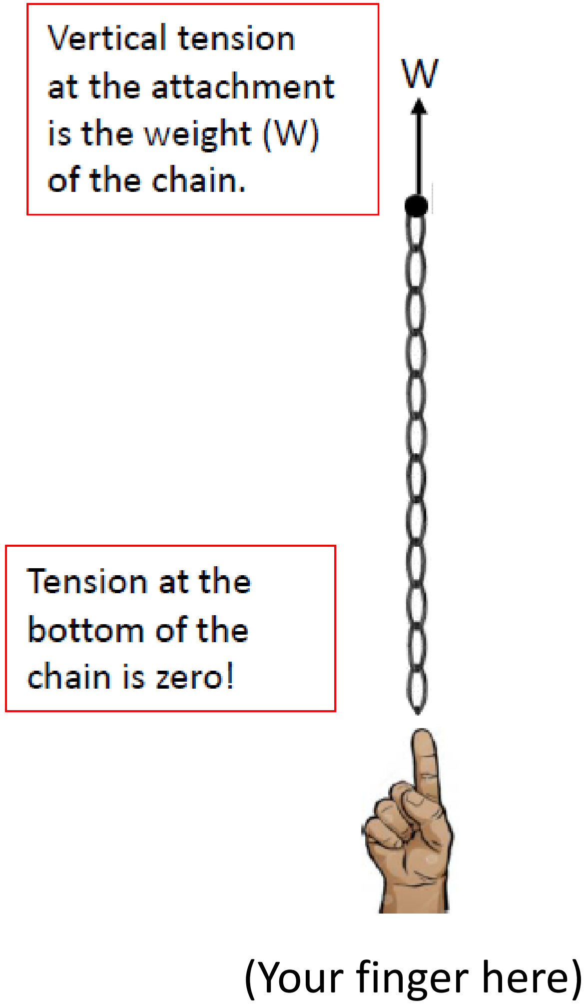
At first glance, these may seem intimidating, but they are not so bad when you look more closely

Let's move on to talk about tension

Foundational Concepts

Cable Tension

Consider if we hang a chain from a single attachment point



The tension concepts that follow will again apply regardless of the cable type!

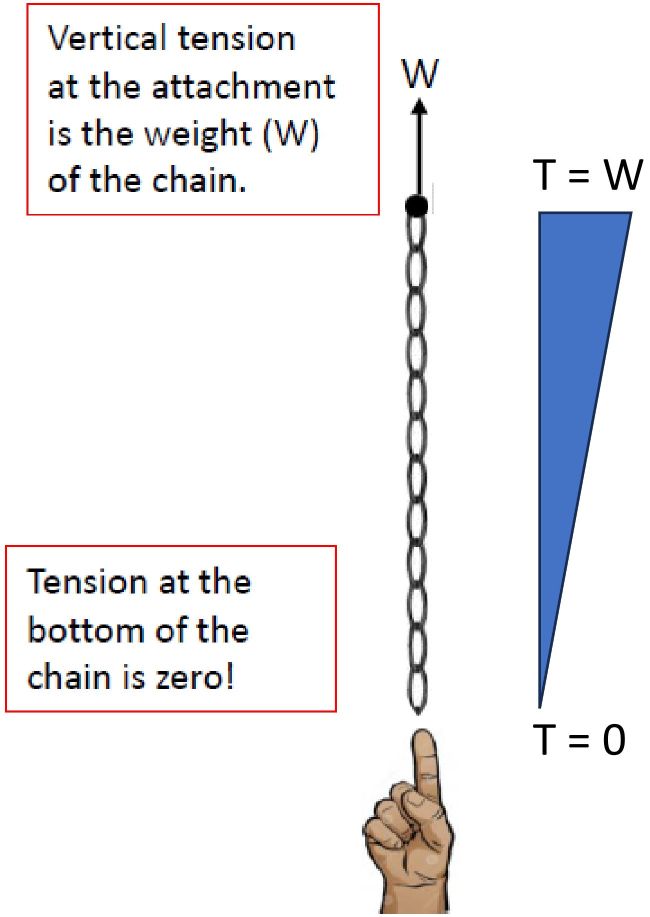
Foundational Concepts

Cable Tension

Observations

1. For the attachment point to be stationary, it must exactly resist the weight of the chain…
   ➔ No more, no less

2. If the tension at the attachment point is equal to the weight of the chain and there is no tension at the bottom of the chain, then…
   ➔ tension is varying from top to bottom



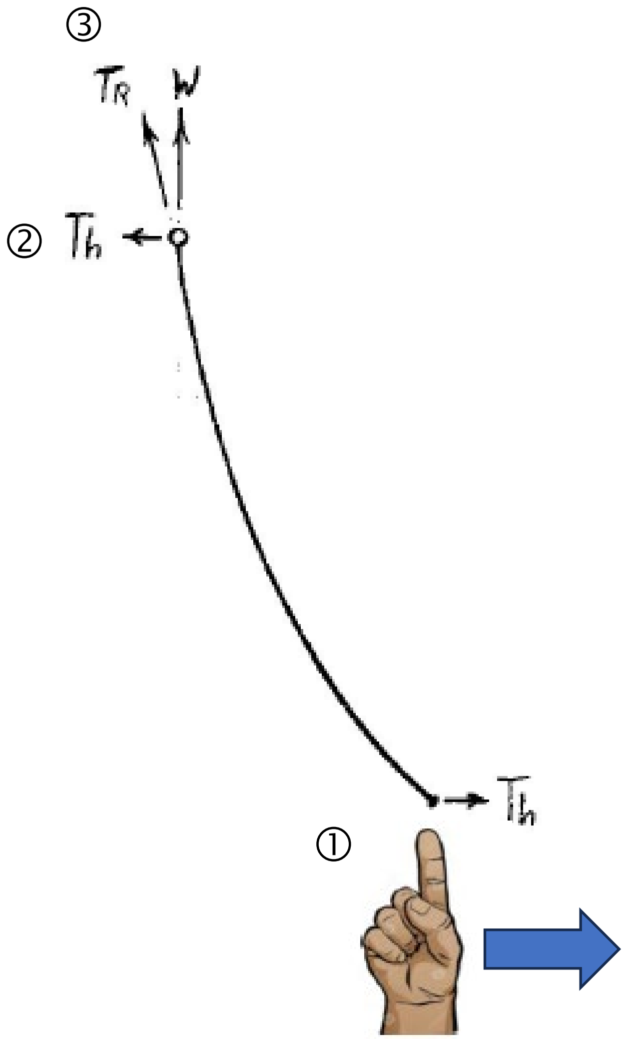
(Your finger here)

Foundational Concepts

Cable Tension

① If we pull the chain horizontally from the bottom, we impart a horizontal tension (T_h)

② That horizontal tension must be exactly balanced at the attachment point



③ We still have the weight of the chain itself, so now we have a resultant tension (T_R) caused by the interaction ("vector sum") of the cable weight W and the horizontal tension (T_h)

Mathematically:

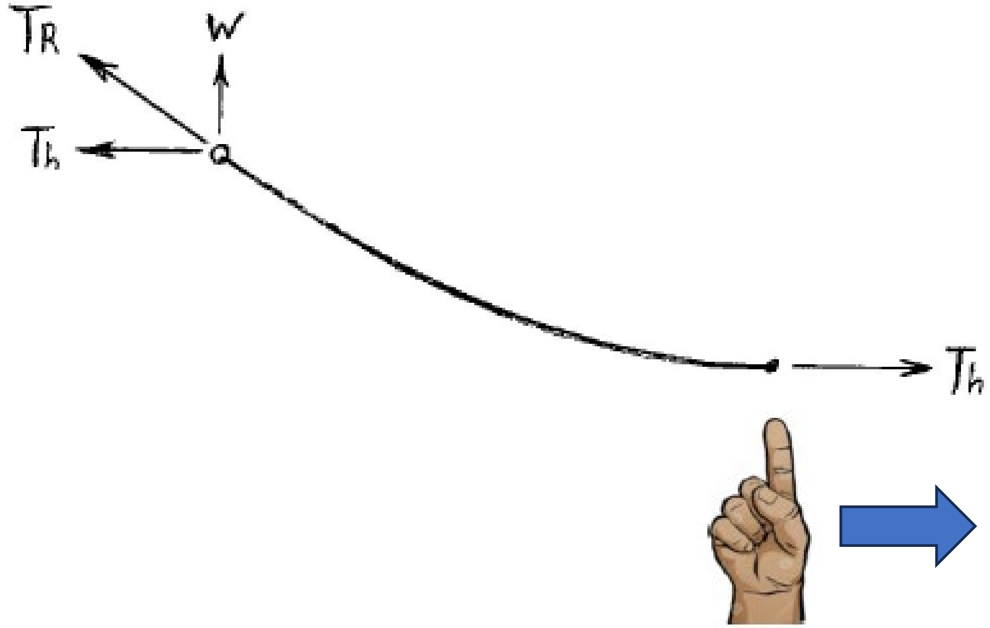
$$T_R = W + T_R$$

Here too, for the attachment point to remain stationary, it must exactly resist the resultant tension (T_R)

Foundational Concepts

Cable Tension

If we continue to pull, we will raise the endpoint higher…



This will increase the horizontal tension (T_h) at the attachment point

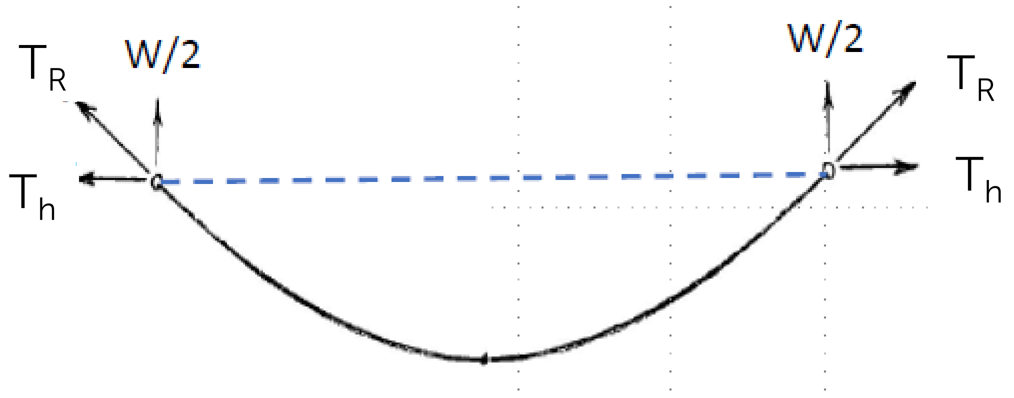
In turn, it will also increase the resultant tension (T_R)

Foundational Concepts

Cable Tension

By now, our fingers are tired, so let's fix both ends of the chain and observe what happens....

If we fix both ends at the same height, we have our level span back!



One half the chain's total weight is supported at each attachment point

Foundational Concepts

Cable Tension

What if we do not fix both ends at the same height?

Consider the case of a fully inclined span (no low point*)

All the chain's weight is supported at the higher attachment point

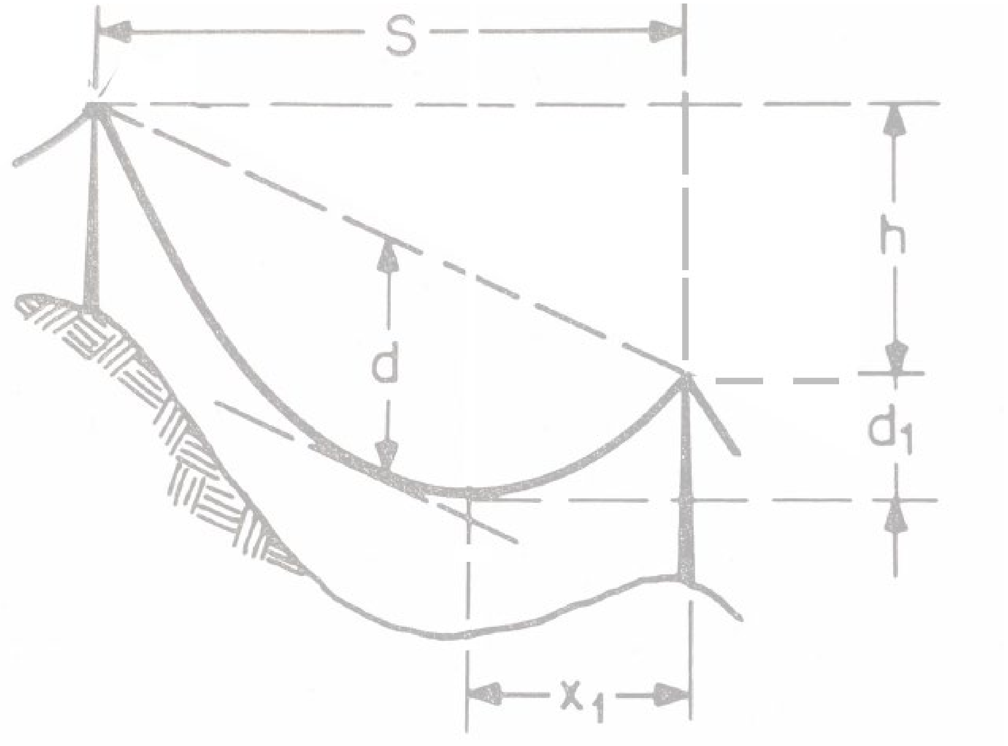
* - Or you can think of the low-point as being precisely at the lower attachment point = attached horizontally at the lower attachment point

Foundational Concepts

Cable Tension

OK. But, what if there is a low-point?

Recall:



Then the weight will be proportionally divided between the two supports

Going by this illustration:

- At lower: $\frac{W}{x_1}$
- At upper: $\frac{W}{x_2}$ where $x_2 = S - x_1$

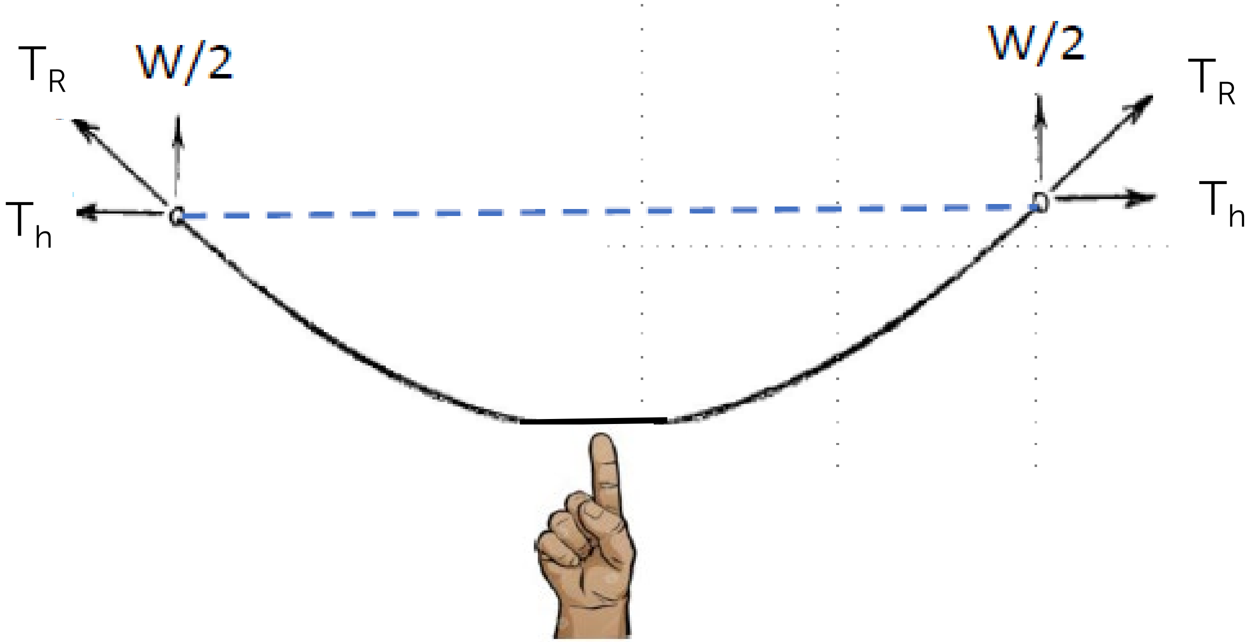
This is one reason why you should know how to calculate where the low-point is

Foundational Concepts

Cable Tension

We gave our fingers a rest for two slides, so let's return to our level span for two quick observations....

Observation #1



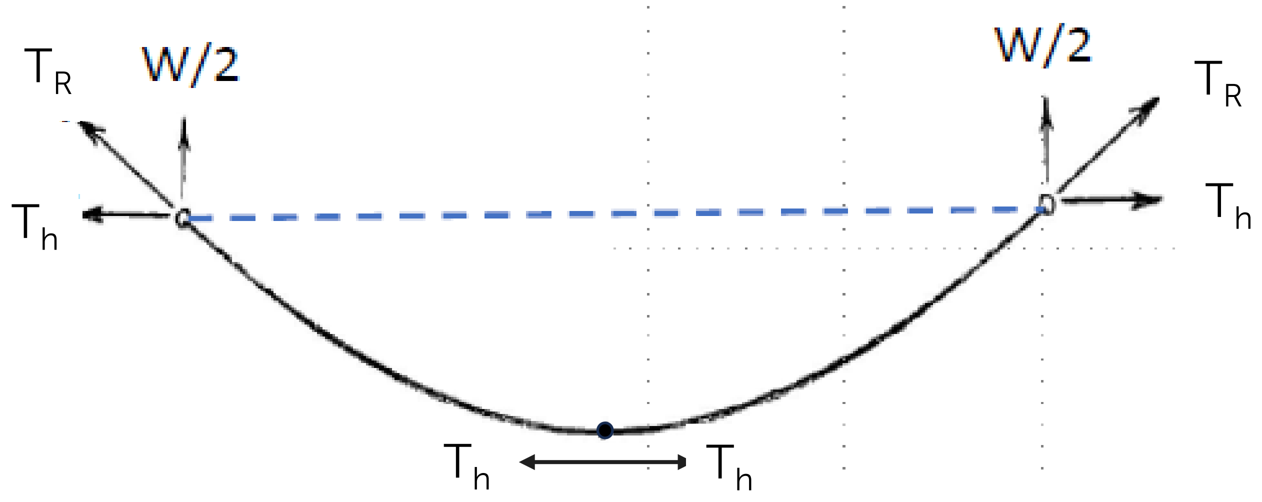
There is no significant weight at the low point

➔ You can move it up a bit with just a finger

Foundational Concepts

Cable Tension

Observation #2 – Recall that tension varied in our vertical hanging chain



At midspan, only T_h, no weight (W), no resultant tension (T_R)

Tension varies along the span

Foundational Concepts

Sag and Tension – Their Relationships

We have investigated the basic concepts of sag and the basic concepts of tension

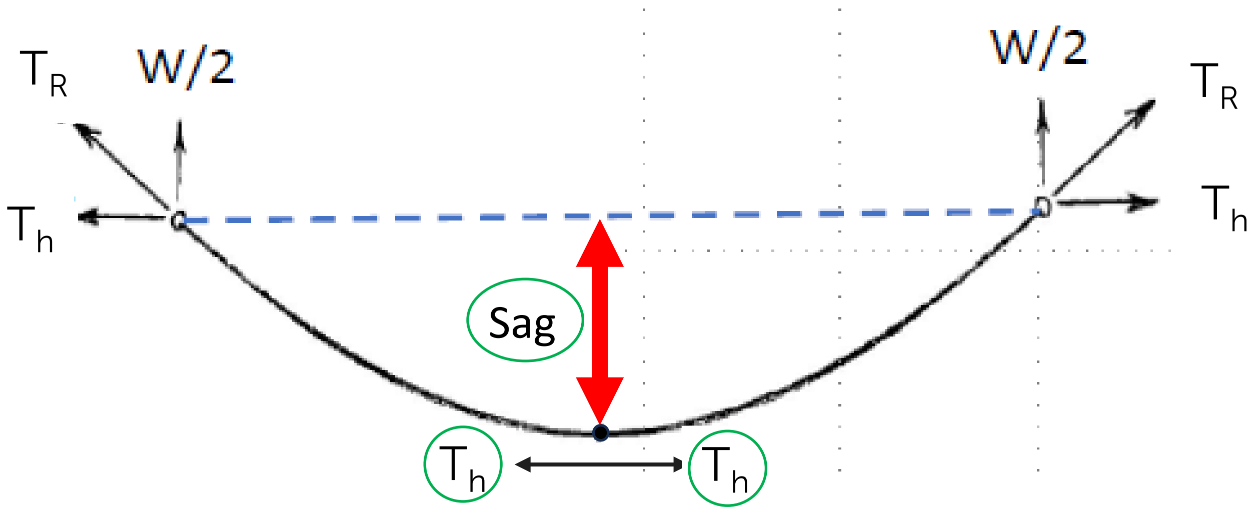
These concepts are essential to understanding our next step which is:

➔ Let's consider the relationships between the two…

Foundational Concepts

Sag and Tension – Their Relationships

Let's bring back our level span yet again…



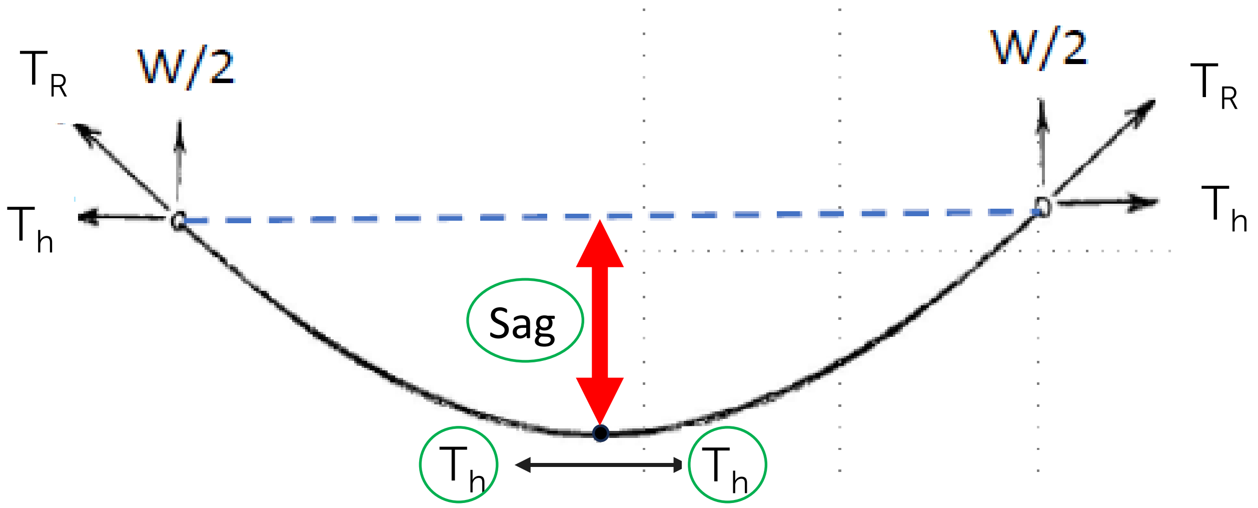
In a level span, **sag** is, **<u>generally</u>**, **inversely proportional** to the horizontal **tension** (T_h), so…

- **Increase tension**, and the **sag decreases**
- **Decrease tension**, and the **sag increases**
- There are **exceptions** which we will consider later

Foundational Concepts

Sag and Tension – Their Relationships

The "flip side" is also the case



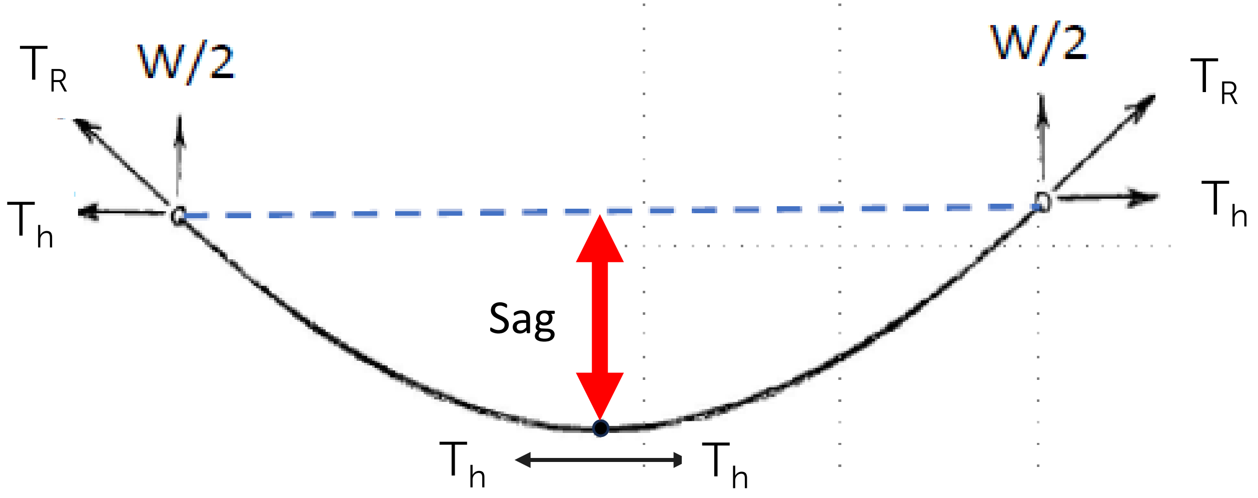
In a level span, **horizontal tension** is, **<u>generally</u>**, **inversely proportional** to the **sag**, so…

- **Increase sag**, and the **tension decreases**
- **Decrease sag**, and the **tension increases**
- Again, there are **exceptions** which we will consider later

Foundational Concepts

Sag and Tension – Their Relationships

And, let's note that…



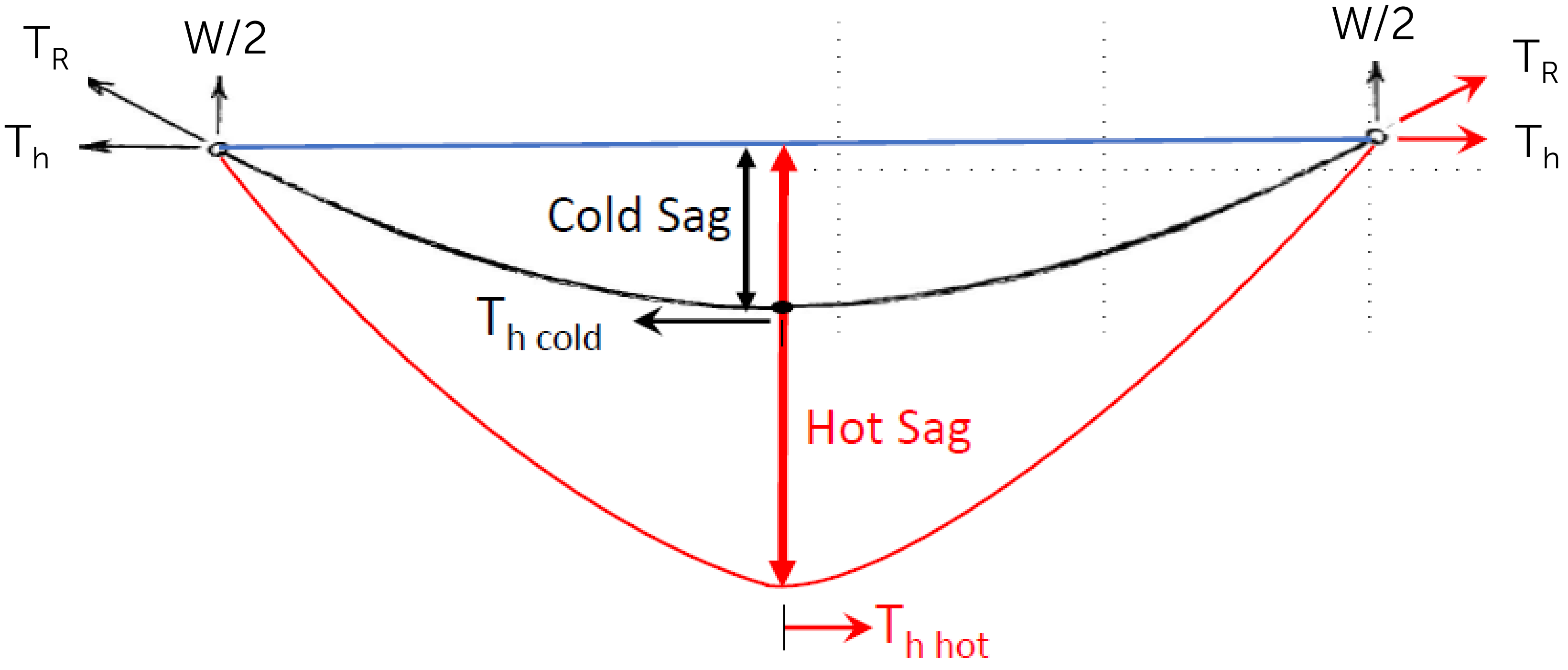
In a <u>level span</u>, at **midspan** there is **no weight** acting at that point

- This is because the weight is supported at the attachment points
- This may not be intuitive, but it is nevertheless true

Foundational Concepts

The Effects of Temperature Changes

As **cable temperature increases**, the cable material expands causing the **cable to elongate**



When the **cable length increases**, the **sag will increase,** and the **tension will decrease**

Foundational Concepts

The Effects of Temperature Changes

Conversely, as **cable temperature decreases**, the cable material contracts causing the **cable to contract**

- Accordingly, when the **cable length decreases**, the **sag will decrease,** and the **tension will increase**

The preceding is generally true, with exceptions that we will discuss in a moment

Foundational Concepts

The Effects of Temperature Changes

Recall that we said that **different materials** have different **coefficients of thermal expansion**

- **Coefficient of thermal expansion** = a material property expressed in units of 1/°F or 1/°C which indicates how much a material expands or contracts in response to temperature changes

- Using this coefficient, you can calculate the amount of expansion or contraction for a given temperature change

    - Don’t worry! We don’t need to do this today. Just remember that you can.

Foundational Concepts

The Effects of Temperature Changes

Just because we will not actually calculate elongation or contraction, does not mean that we will not say something about it!

General guidelines for metallic cables:

Metals expand or contract a lot (relatively speaking) in response to changes in temperature

- ➔ So, a lot of change in sag and tension, too
- ➔ No surprise: Thermal effects a significant factor in design for conductors which are affected by both environmental temperature changes and temperature increases caused by current flow

Foundational Concepts

The Effects of Temperature Changes

General guidelines for non-metallic cables

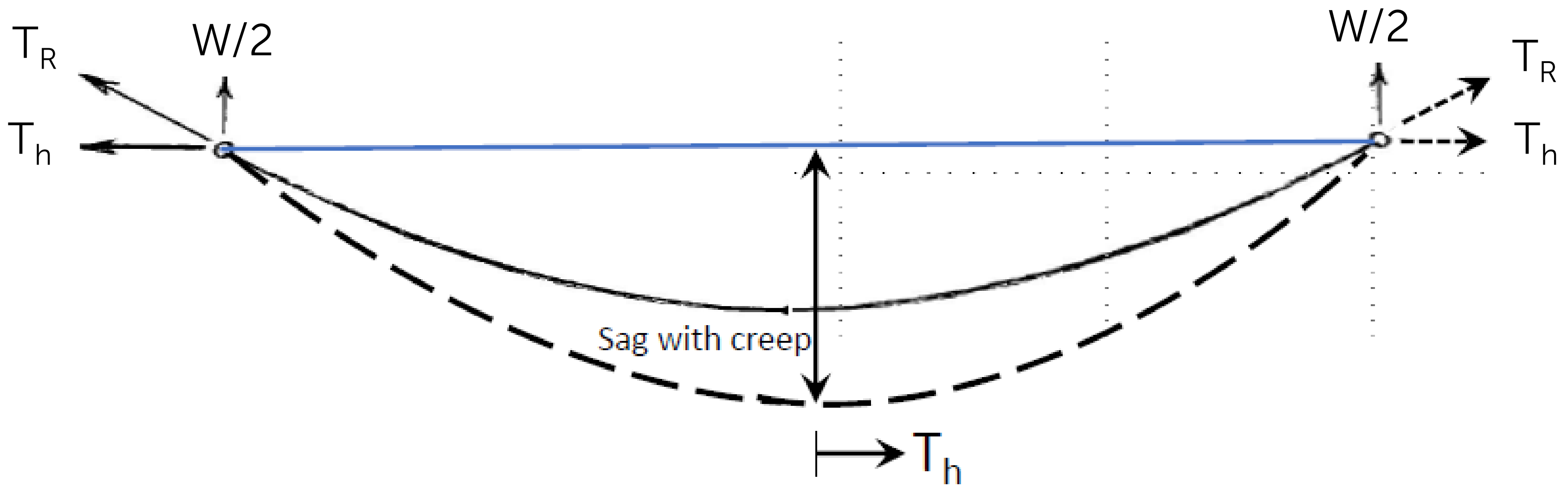
Plastics and other non-metallic materials expand or contract only a little (relatively speaking) in response to changes in temperature

- ➔ So, “low to no” change in sag and tension
- ➔ Mild surprise: Thermal effects on ADSS are so low that they are generally ignored when making sag and tension calculations
- ➔ Of Interest: Recall we mentioned “high temperature low sag” conductors earlier. They are possible because of the low thermal expansion properties of the composite materials used in their cores to carry the weight of the aluminum which is carrying the current

Foundational Concepts

The Effects of Creep

Creep is the **permanent** ("plastic") stretching (**elongation**) of a material **under tension over time**



Remember: When the **cable length increases**, the **<u>sag will increase</u>,** and the **<u>tension will decrease</u>**

Foundational Concepts

The Effects of Creep

Observations about Creep

1. We use "**plastic**" in this context to refer to **permanent elongation** of a material
    - That is, the elongation remains even if the tension is decreased to zero
    - Its opposite is "**elastic**" for **elongation that is temporary** – that is, elastic elongation "goes away" when the tension that caused it is removed
    - Generally, materials can endure some tension with elastic elongation (it may not be much), and beyond that point, the elongation is plastic
    - If the tension continues to increase after reaching the plastic point, then the material will soon break

Foundational Concepts

The Effects of Creep

More Observations about Creep

2. Aluminum conductor under tension for 10 years will stretch to about 97% of its maximum creep elongation

3. Because of (2), it is <u>generally</u> taken that after 10 years of hanging in the air, a cable has reached its maximum elongation

➔ So, 10 years is used in sag and tension calculations as the basis for the difference between "initial" (as installed) sag and tension and "final" sag and tension

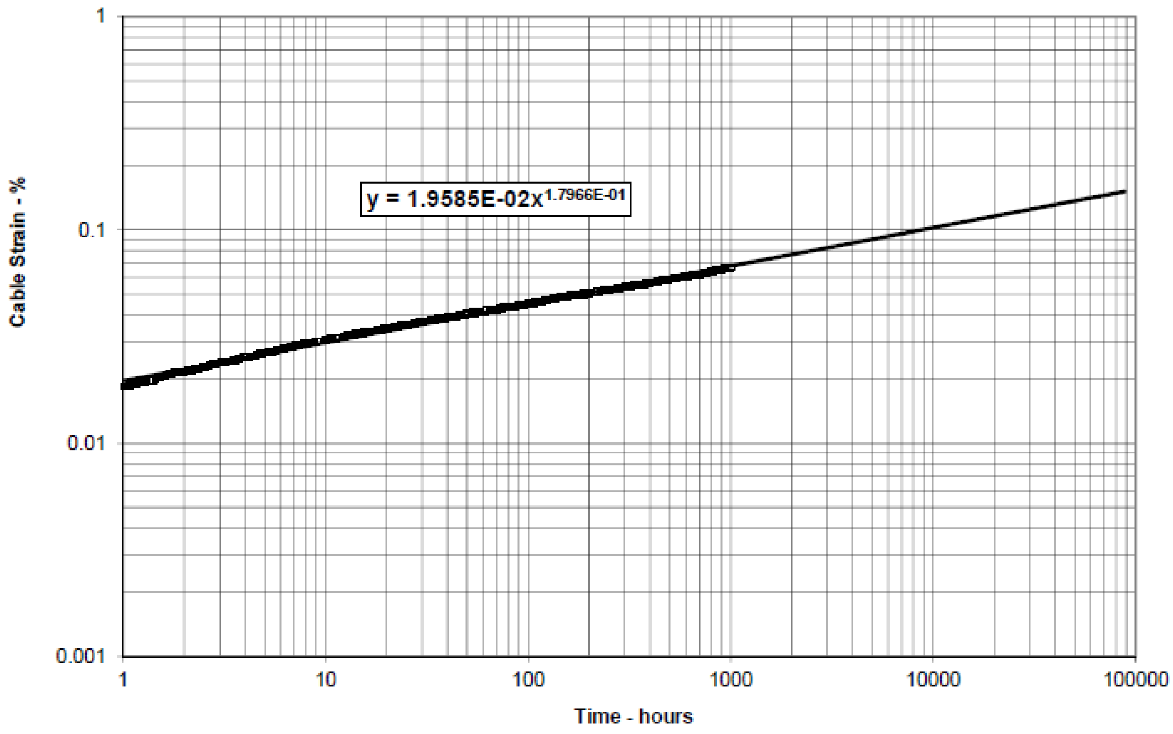
➔ "Generally"? Yes, creep can vary depending upon the actual loading that a cable experiences during operation

- But there is a limit to the maximum elongation, so changes in loading might either accelerate creep (higher loading) or slow it down (lighter loading), but it still ends up at about the same point
- Effectively then: 10 years works well

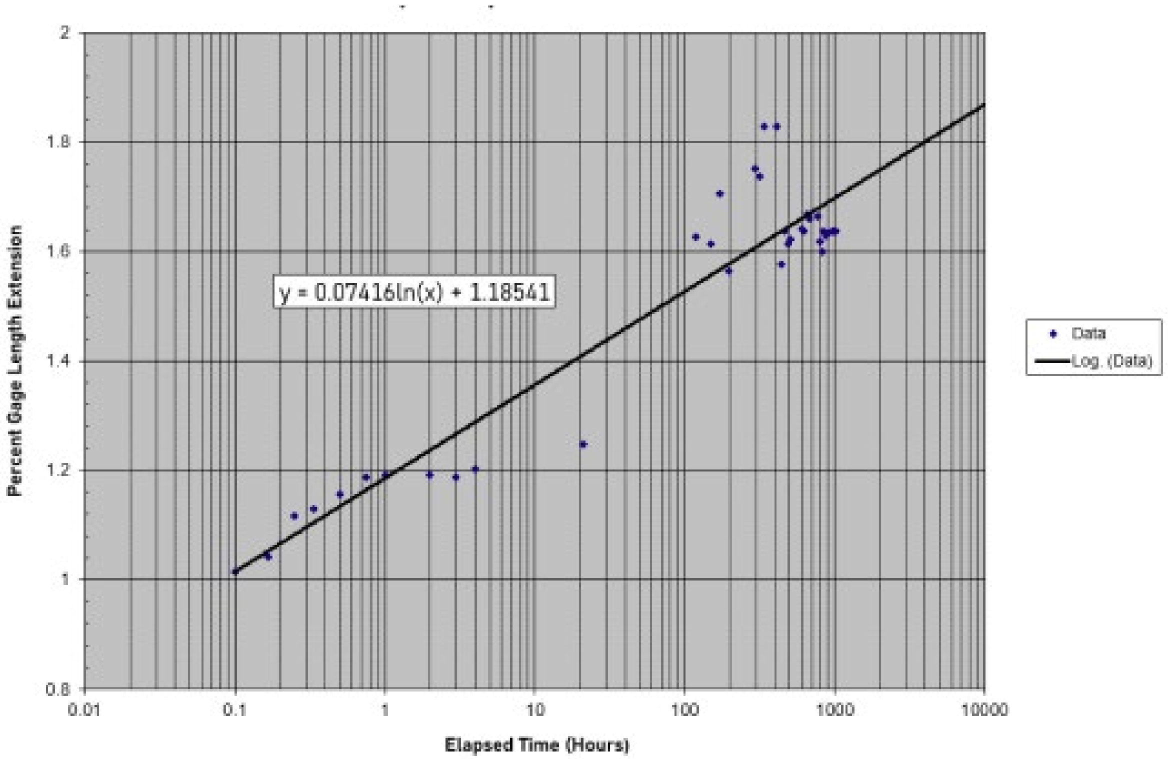
Foundational Concepts

The Effects of Creep

At the risk of creeping you out, here are two typical creep test results…



OPGW Creep Test per IEEE 1138



ADSS Creep Test per IEEE 1222

Foundational Concepts

The Effects of Creep

The test results lead to yet more observations about creep…

A. Creep progresses logarithmically

B. Notice that the creep of the metallic OPGW (about 0.15%) is much less than that of the non-metallic ADSS (just under 1.85%)

C. I have observed over the years that a rough guideline for creep of metallic cables is:
   - About 25% of creep elongation occurs in the two (2) days after installation
   - About 50% of creep occurs in the first two (2) months after installation
   - About 75% of creep occurs in the first two (2) years after installation
   - 10 years is taken as 100%

   Again, this is a rough guideline only - I call it the “2-2-2-10 Rule of Thumb.”

By now, I’m sure you are sick of creep and ready to move on

Aerial Cable Behavior

The Catenary

A **catenary** is the **curve** that a **hanging chain**, or a flexible cable, assumes under its own weight where the weight is uniformly distributed along the curve and is supported only at its ends

The resemblance to a smile ☺ shows that the cable gods meant this as a blessing

Aerial Cable Behavior

The Catenary

The word is derived from the Latin word “catēna” which means “chain”

An example of a catenary found in nature

Aerial Cable Behavior

The Catenary

OK. That last caption was a silly joke, but you really can find catenaries in nature

Note the attachment points are not at the same height

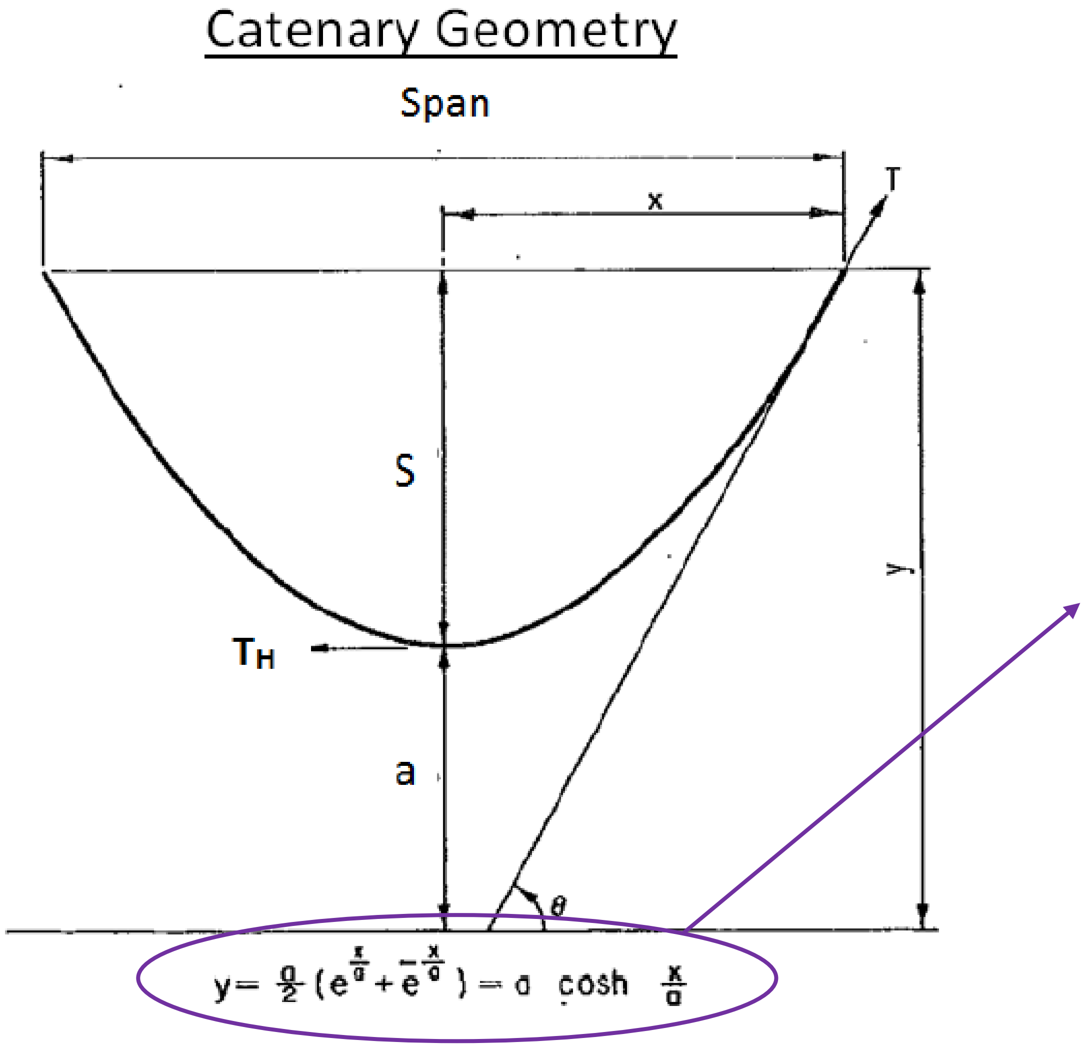
Aerial Cable Behavior

The Catenary

Refresher: Notice the max sag at midspan and low-point off to the left

Aerial Cable Behavior

The Catenary – Mathematics



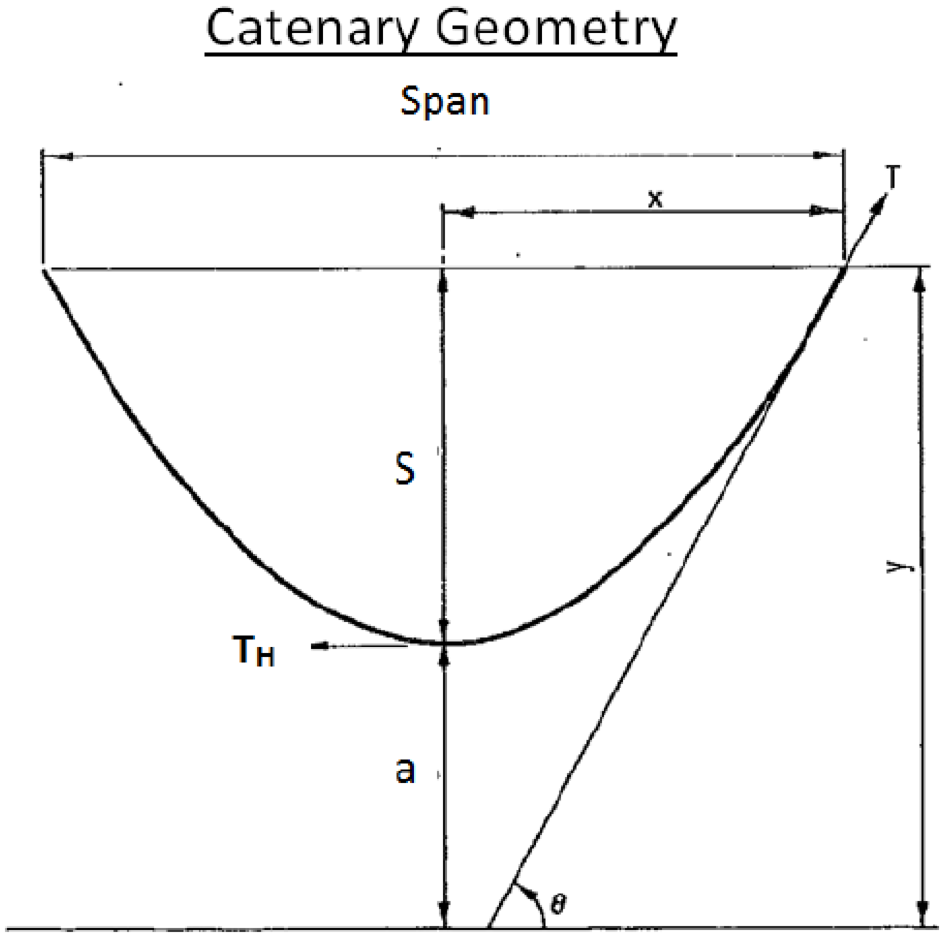
The catenary curve is a graph of a hyperbolic cosine function:

$$y = \frac{a}{2}\left(e^{\frac{x}{a}} + e^{\frac{-x}{a}}\right) = a \cdot \cosh\left(\frac{x}{a}\right)$$

Reference: **Standard Handbook for Electrical Engineers, McGraw Hill, 12th Edition, 1987, Fig. 14-20**

Aerial Cable Behavior

The Catenary – Mathematics



Plugging in the variables for an aerial cable span:

$$S = sag = \frac{T_h}{W_c} \cdot [\cosh\left(\frac{W_c}{T_h} + \frac{Span}{2}\right) - 1]$$

Where:

a $= \frac{T_h}{W_c}$

T_h = horizontal tension

W_c = cable unit weight (weight per foot)

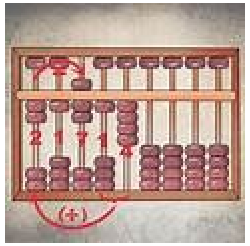
Aerial Cable Behavior

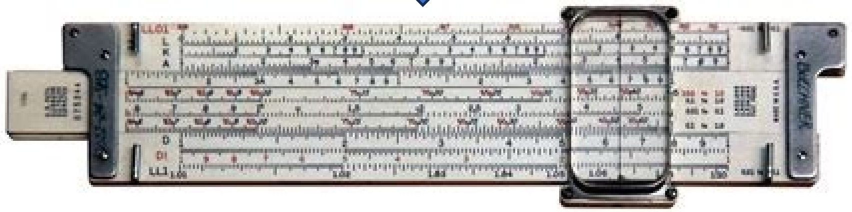
The Catenary to The Parabola

I don't know about you, but my day is not complete unless I've solved at least one hyperbolic cosine function! Today, with computers, it's easy!

But, that has not always been the case:

- When I was very little, we counted using piles of small rocks
- Then the abacas was invented (around middle school)
- And then, the slide rule! (high school, if I recall correctly)



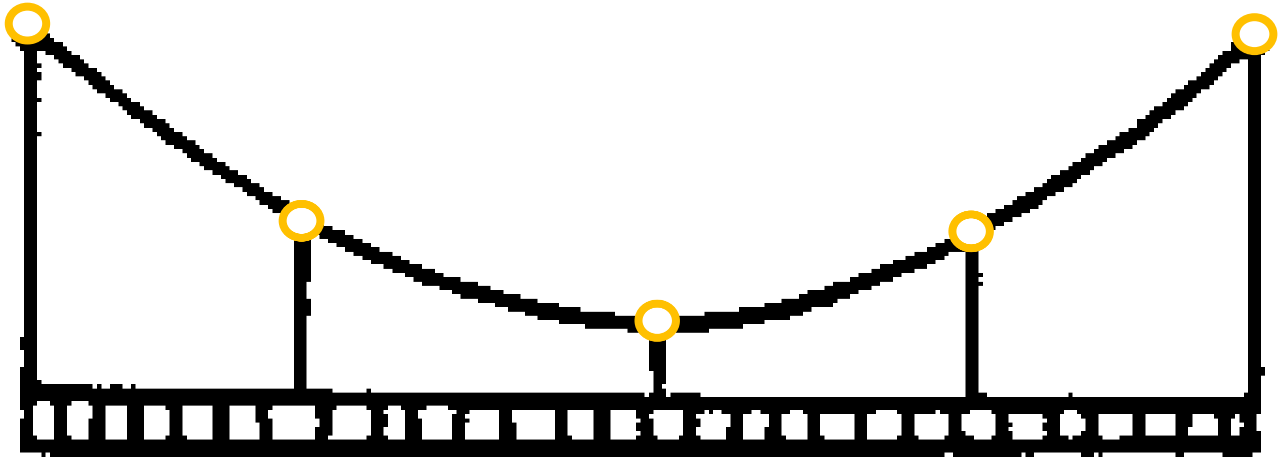


Slide rules were (are) amazing, but even with them, calculating hyperbolic cosines can be a bit tricky, so the Wise Ones of Transmission Line Design figured out that using a parabola was easier than using a catenary

Aerial Cable Behavior

The Parabola

A parabola describes the shape assumed by the suspension points (○) on a cable that supports a horizontally distributed weight



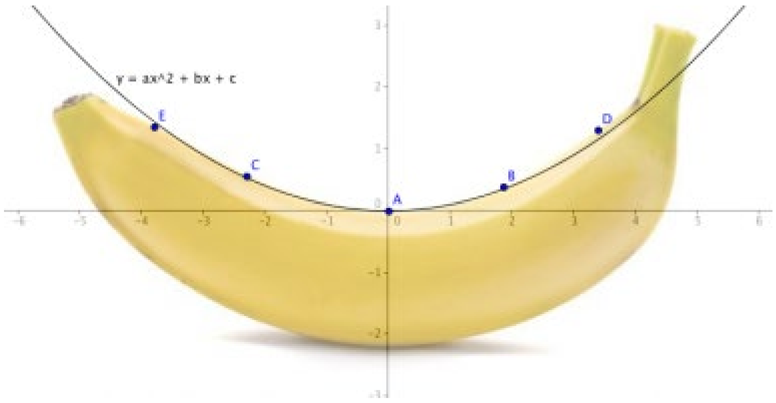
The repeated resemblance to a smile reinforces that the cable gods intended this as a great blessing

Note: In case you were wondering, the cable between the suspension points is in the shape of a catenary

Aerial Cable Behavior

The Parabola

Here again, we find parabolas in nature…



Aerial Cable Behavior

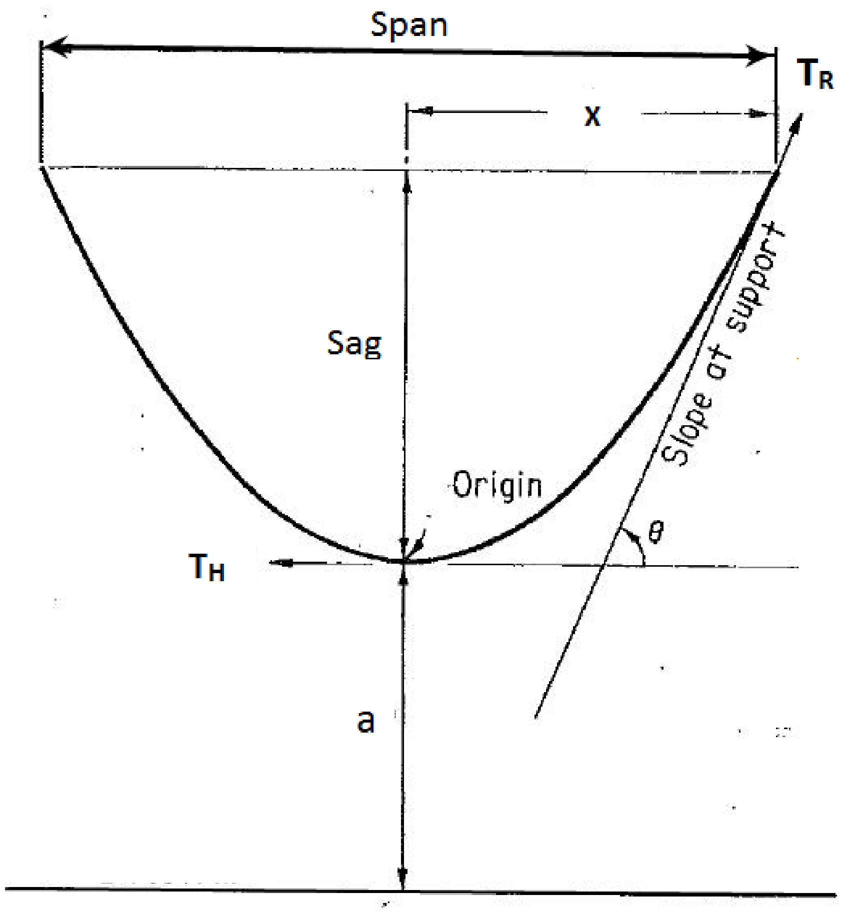
The Parabola

And man-made parabolas exist…

Aerial Cable Behavior

The Parabola – Mathematics

Parabolic Geometry



The parabolic curve is a graph of a simpler function:

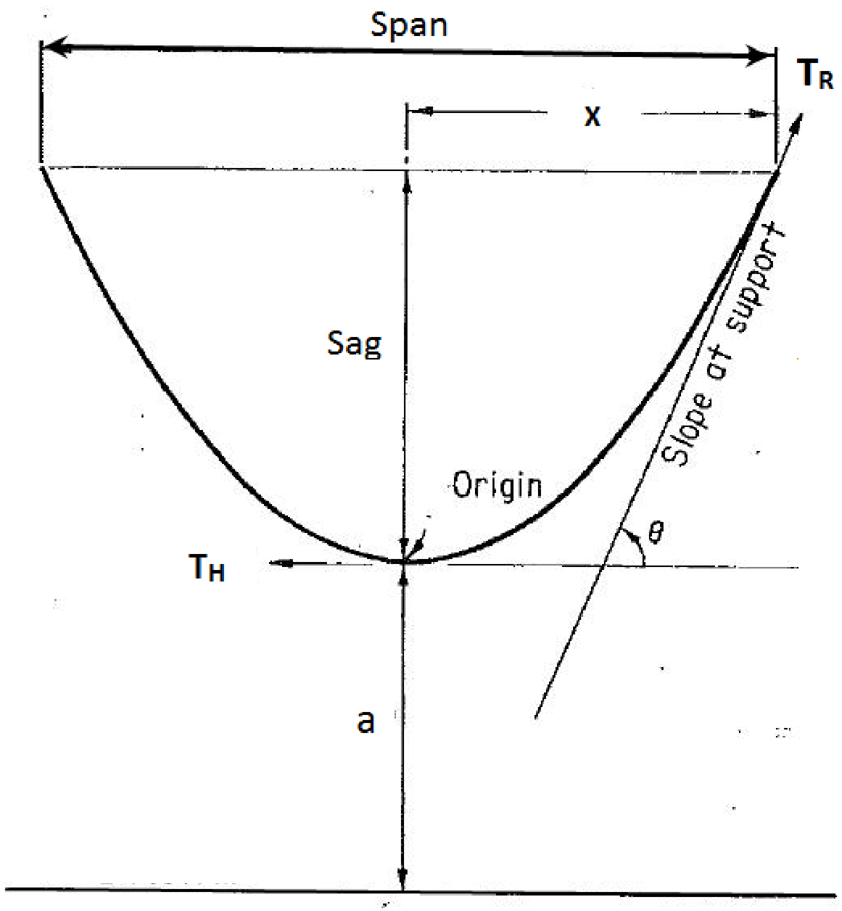
$$y = x^2$$

Reference: **Standard Handbook for Electrical Engineers, McGraw Hill, 12th Edition, 1987, Fig. 14-21**

Aerial Cable Behavior

The Parabola – Mathematics

Parabolic Geometry



Plugging in the variables for an aerial cable span:

$$S = sag = W_c \cdot \frac{Span^2}{8 \cdot T_h}$$

Where (again):

$a = \frac{T_h}{W_c}$

T_h = horizontal tension

W_c = unit weight (weight per foot)

Aerial Cable Behavior

The Catenary versus The Parabola

OK. So, computing a parabola is easier. But, how much accuracy do we lose using a parabola in lieu of a catenary?

Great question! Answer: Rule of Thumb[1] when using the parabolic approximation:

For sags up to 6% of the span length, the error in sag is less than ½% too small

This typically means the error is less than the cable diameter

1 – Reference: Standard Handbook for Electrical Engineers, McGraw Hill, 12 th Edition, 1987, Pg. 14 38

Aerial Cable Behavior

The Catenary versus The Parabola

Example (Customary Units - apologies to those outside the USA)

1590 kcmil 45/7 ACSR has diameter 1.504 inches, weight 1.792 lb/ft, and RBS = 42,220 lb

From realistic sag and tension calculations for this cable on an 800 ft span

- Initial tension, at 60°F ≈ 18% RBS = 7,600 lb
- Final sag at 212°F is 29.70 ft with horizonal tension at 4,835 lb

➔ Parabolic sag calculation based on the horizontal tension from the sag chart is:

$$S = sag = W_c \cdot \frac{Span^2}{8 \cdot T_h} = 1.792 \cdot \frac{800^2}{8 \cdot 4{,}835} = 29.65 \text{ ft}$$

➔ The sag error is: 29.70 - 29.65 = 0.05 ft = 0.6 inches less sag

Aerial Cable Behavior

The Catenary versus The Parabola

Example (Customary Units) – Additional Observations

- The actual sag of 29.70 ft is about 3.7% of span (29.70 ÷ 800 = 0.0371)
  ➔ So, the actual sag is well under the Rule of Thumb limit of 6%

- Recall that per the Rule of Thumb, the expected error is less than ½% too small
  ➔ The “error allowance” was 0.15 ft = 1.8 in.
  ➔ The actual error of 0.6 inch less sag is well under this

- And, the actual error of 0.6 inches < 1.504 inches (the conductor diameter) – In this case, less than ½ the cable diameter

Ergo ipso facto, **the parabolic approximation is darn good**!

Aerial Cable Behavior

Parabolic Error in Context

In fact, the parabolic error is one of the smallest errors in cable work in the real world

Consider:

- There is error in estimating the creep – This is because you do not know the actual history of temperature, tension, and ice-wind loading during operation

- There is error in stress-strain curves – There are several reasons for this which we do not have time to discuss today (we will next time)

- The largest source of error results from field installation techniques and, in particular, how cables are sagged (again, next time…maybe)

- These are the “Big 3” sources of sag error in the field – There are others

We must move on

Aerial Cable Behavior

Exceptions to Sag and Tension Relationship

Recall that we said that in a level span, sag and tension are <u>generally</u> inversely proportional (increase tension, sag decreases/increase sag, decrease tension)

There are **three exceptions**.

1. When **ice accumulates** on a cable, it **adds weight** which stretches the cable, **increasing both sag and tension**

2. When the **wind blows** transverse to the span, it **imparts a force** which stretches the cable, **increasing both sag and tension**

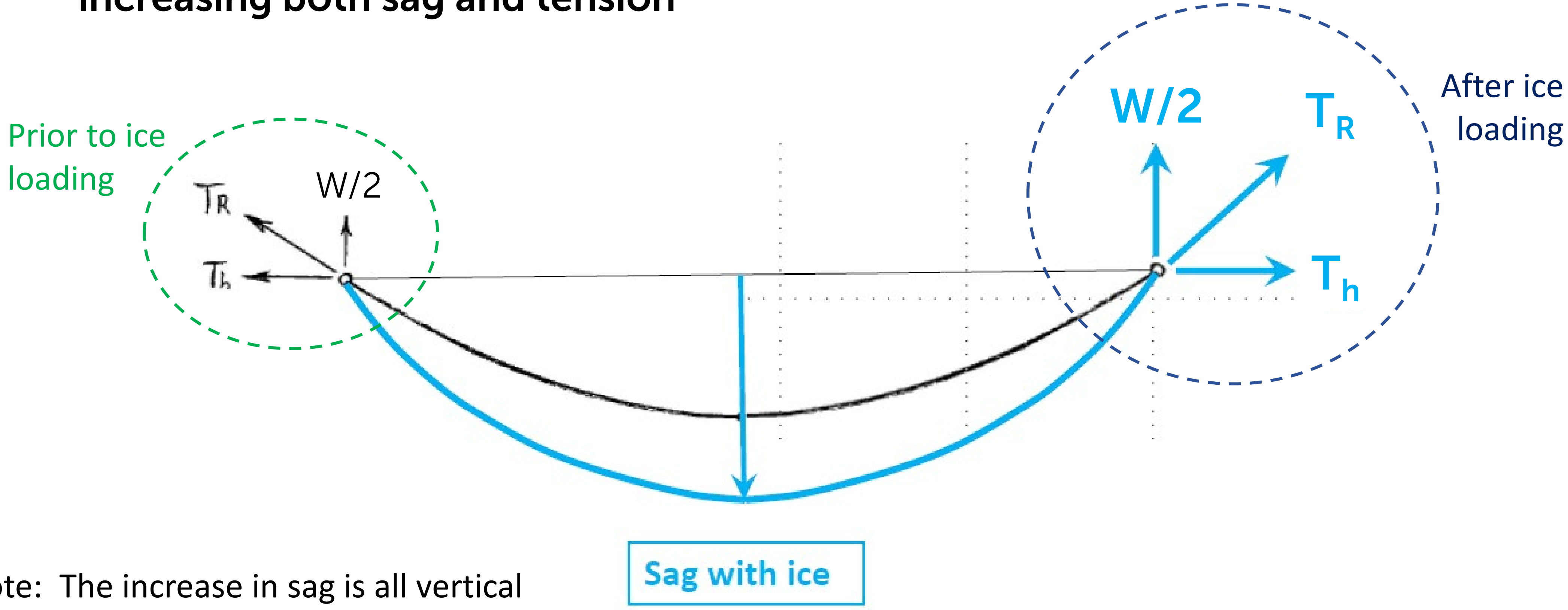
3. When there is **both ice and wind**

Let's look at these…

Aerial Cable Behavior

Effects of Ice Loading

1. When **ice accumulates** on a cable, it **adds weight** which stretches the cable, **increasing both sag and tension**

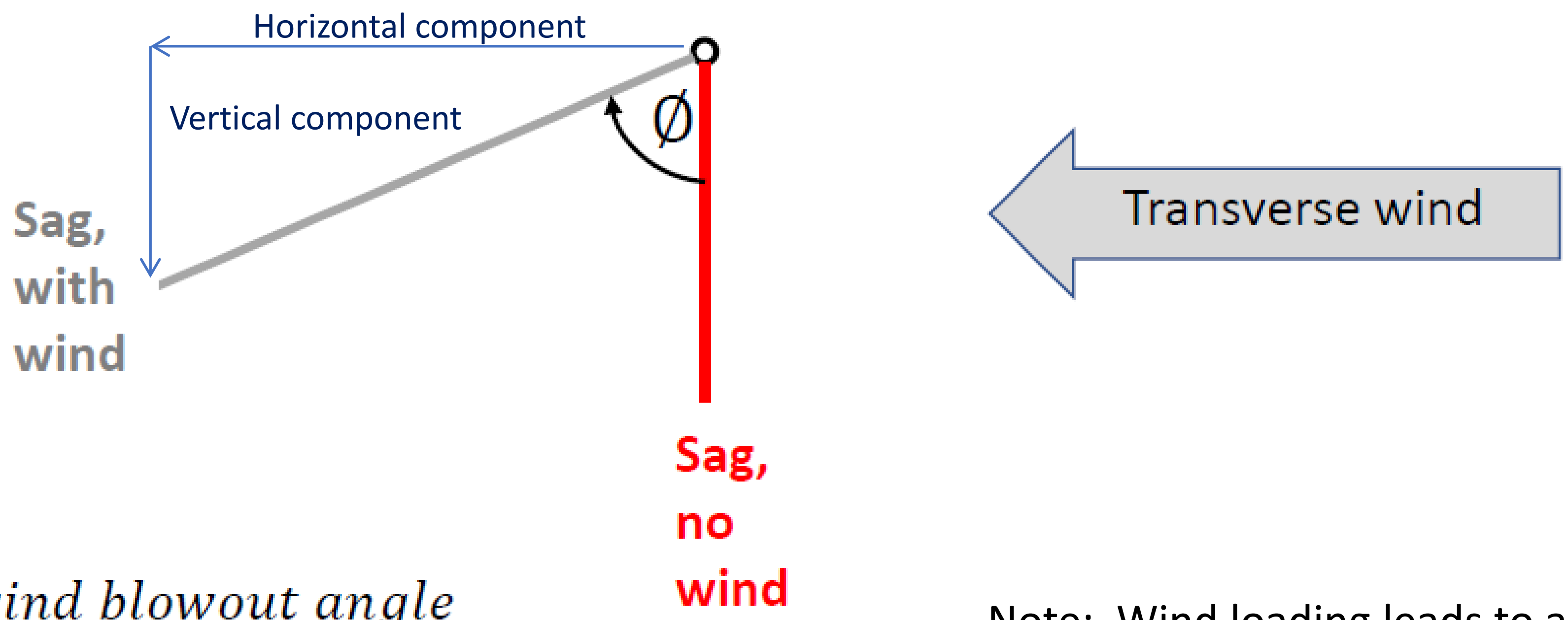


Note: The increase in sag is all vertical

Aerial Cable Behavior

Effects of Wind Loading

2. When the **wind blows** transverse to the span, it **imparts a force** which stretches the cable, **increasing both sag and tension**



$\emptyset = wind\ blowout\ angle$

Note: Wind loading leads to a "resultant sag"

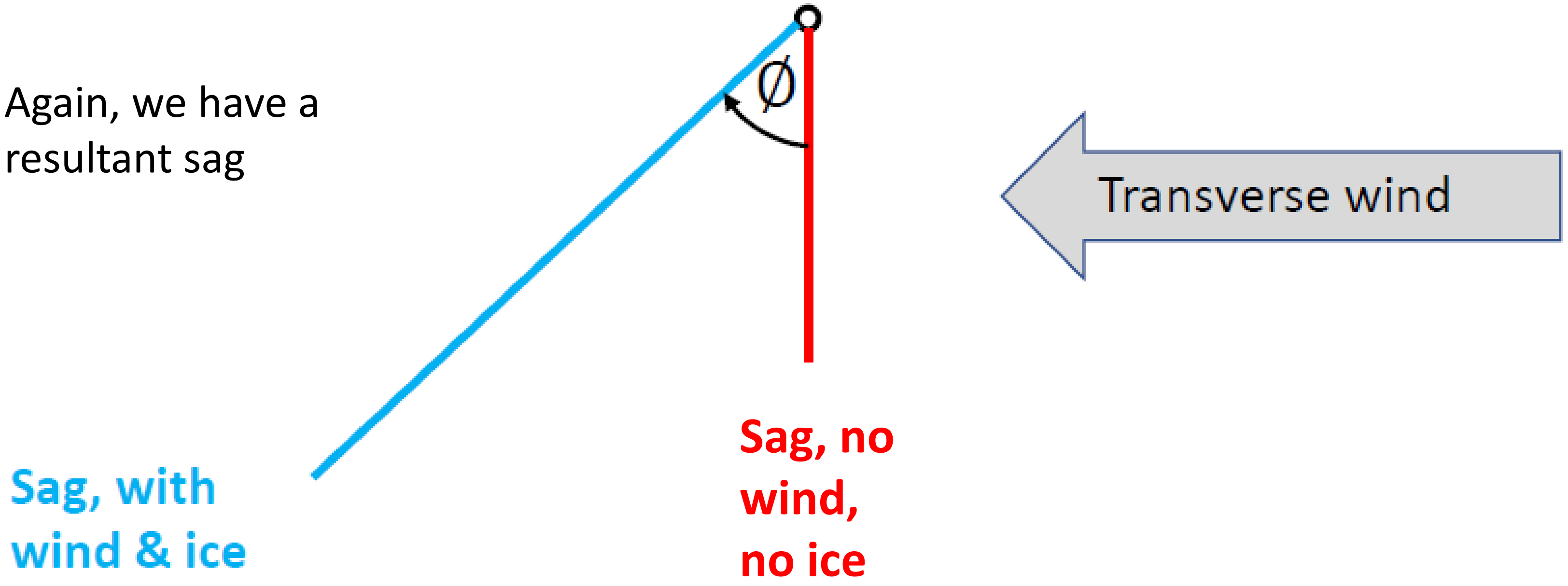
- Some is in the vertical plane
- Some is horizontal

Aerial Cable Behavior

Effects of Both Ice and Wind Loading

3. When there is **both ice and wind**

Again, we have a resultant sag



$\emptyset = wind\ blowout\ angle$

Aerial Cable Behavior

Exceptions to Sag and Tension Relationship

Keep in Mind: The effects of ice and wind must also be considered in conjunction with changes in temperature

Consider: When there is **ice**, it generally means that the temperature has dropped

- In metallic cables: decreased temperature = decreased cable elongation = decreased sag = increased tension
- And, the ice is increasing elongation = increasing sag and increasing tension
- So, where do you end up? Answer: Even more increased sag plus increased tension, too. You must run the calculations to find out exactly how much.

Aerial Cable Behavior

Exceptions to Sag and Tension Relationship

And…

- What about a conductor which gets heated by current flow?

  Answer: Again, cannot say. Depending on the details, the heating might counteract the environmental temperature change, or it might not. Must run the math.

- What about ADSS?

  Answer: Temperature effects are generally ignored because of the material properties, so you end up with only having to consider the ice loading itself

Sag Coefficients + Charts

And Related Concepts

By now, I'm sure that:

A. Your brain is full,

B. My voice is giving out, and

C. Our time is (more) than up

So, we will delve into these aspects of sag and tension concepts in a follow-on session next month

➔ Look for our announcement with the date and time!

Sag and Tension Theory 101 Recap

Today, we have learned:

1. What sag is and its relationship to the low point in a span.
2. What tension is.
3. The “everyday” relationship between sag and tension and the three exception to this relationship.
4. What creep is and how it changes sag and tension over time.
5. What a catenary is and how it relates to sag and tension.
6. What a parabola is, why it is used in lieu of a catenary, and how it relates to sag and tension.
7. What the approximate error in sag is using the parabolic approximation.
8. Three “big“ (3) sources of sag error in the field.
9. The difference between elastic and plastic changes in conductor length and their effect on sag and tension calculations.

Whew!

Follow-Up Information

Follow-up email contains:

Link to Video & Presentation Download

Link to Quiz for PDH Credits

Survey to give us feedback, including suggestions for topics we ought to cover

To receive PDH Credits:

Pass the quiz with 70% or higher

Please allow one business day for credits to be submitted to RCEP

Any questions, reach out to:

marketing@incabamerica.com

Incab

Thank you!
Questions?

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