

# Analysis of A Cable Loaded Uniformly Along the Horizontal Using MATLAB

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## ABSTRACT

Cables can be defined as a flexible structure which can only support tensile load and offers no resistance when compressed or bent in a curved shape. They have several applications in engineering structures for supporting and transmitting load from one point to another such as bridges, trolley wheels, supports suspension roofs and main load carrying cables in any structure. Hence it becomes necessary for extensive design and analysis study on cables. Therefore in the present paper work, cable of length 600m is uniformly loaded along the horizontal is been considered for the analysis with the mass of 18kg/m of its length and supports its own weight. The aim of the work is to determines mid length tension, maximum tension and total cable length for h= 10, 20, 30, 40, 50, 60, 70 and 80 meters using MATLAB. The result shows that as h increases, the tension in mid length and maximum tension is decreasing, whereas total length of the cable is found increasing.

**Keywords :** Cables, tension, MATLAB, uniformly loaded.

## I. INTRODUCTION

Cables can be of mild steel, high strength steel (drawn carbon steel), stainless steel, polyester or aramid fibres. Structural cables are made of a series of small strands twisted or bound together to form a much larger cable. Steel cables are either spiral strand, where circular rods are twisted together and "glued" using a polymer, or locked coil strand, where individual interlocking steel strands form the cable (often with a spiral strand core). Spiral strand is slightly weaker than locked coil strand. Steel spiral strand cables have a Young's modulus, E of 150±10 kN/mm<sup>2</sup> (or 150±10 GPa) and come in sizes from 3 to 90 mm diameter.

Spiral strand suffers from construction stretch, where the strands compact when the cable is loaded. This is normally removed by pre-stretching the cable and cycling the load up and down to 45% of the ultimate tensile load.

**Table 1:** Properties of different materials for cables

	<i>E</i> (GPa)	UTS (MPa)	Strain at 50% of UTS
Solid steel bar	210	400–800	0.24%
Steel strand	170	1550–1770	1%
Wire rope	112	1550–1770	1.5%
Polyester fibre	7.5	910	6%
Aramid fibre	112	2800	2.5%

Table 1 Reference:

[https://en.wikipedia.org/wiki/Tensile\\_structure#Cables](https://en.wikipedia.org/wiki/Tensile_structure#Cables)

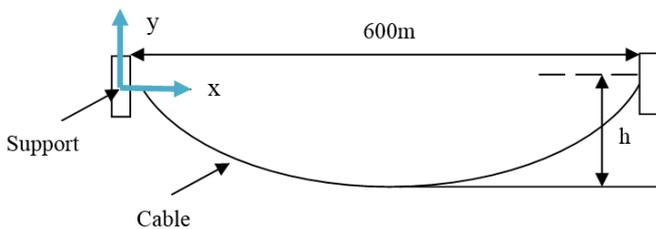
Locked coil strand typically has a Young's Modulus of  $160 \pm 10 \text{ kN/mm}^2$  and comes in sizes from 20 mm to 160 mm diameter. The properties of the individual strands of different materials are shown in the Table 1 below, where UTS is ultimate tensile strength, or the breaking load [5].

The cables are generally subjected to concentrated loads and distributed loads. In physics and geometry, a catenary is the curve that an idealized hanging chain or cable assumes under its own weight when supported only at its ends. The catenary curve has a U-like shape, superficially similar in appearance to a parabolic arch, but it is not a parabola [6].

MATLAB provides the platform for writing the mathematical programs with simple and ease. It is also a powerful graphical tool for producing 2D and 3D plots. Therefore in this current paper work the cable with uniform distributed load is considered and assumed to have a catenary shape for the cable. Analysis on cable is carried out using MATLAB.

## II. PROBLEM STATEMENT

The cable loaded uniformly along the horizontal as shown in Figure 2.1.



**Figure 2.1:** Cable loaded uniformly along the horizontal

The data for the cable is as below:

- Mass = 18kg/m
- Supports its own weight

- Variation of  $h = 10, 20, 30, 40, 50, 60, 70$  and  $80$  meters
- Assume to have catenary shape for the cable.

To determine:

1. Tension at the mid length ( $T_m$ )
2. Maximum tension ( $T_{max}$ )
3. Total cable length ( $L_T$ )

## III. MATHEMATICAL FORMULATION

For uniformly distributed load and catenary shape of the cable, the curve assumed by the cable  $y(x)$  is given by Eqn.1.

$$y = \frac{T_m}{w} \left( \cosh \frac{wx}{T_m} - 1 \right) \quad \dots \text{(Eqn.1)}$$

Where  $w$  = weight per unit length.

Weight per unit length ( $w$ ) can be calculated as below:

$$w = 18 \times 9.81 \times 10^{-3} = 0.17658 \text{ kN/m}$$

Taking  $y=h$  and  $x=300\text{m}$  for Eqn.1. The tension at the mid length is given by Eqn. 2.

$$h = \frac{T_m}{w} \left( \cosh \frac{300w}{T_m} - 1 \right) \quad \dots \text{(Eqn. 2)}$$

Rewriting the Eqn. 2 in terms of a function ' $f$ ', to ease the solution in MATLAB and the same is as shown in Eqn. 3.

$$f = h - \frac{T_m}{0.17658} \left( \cosh \frac{300 \times 0.17658}{T_m} - 1 \right) \quad \dots \text{(Eqn. 3)}$$

Roots of this Eqn.3 will be obtained for the specified values of  $h$ . if  $T_m$  is known,  $T_{max}$  and  $L_T$  can be found as in the Eqn. 4 and Eqn. 5.

$$T_{max} = T_m + wh \quad \dots \text{(Eqn. 4)}$$

$$L_T = \frac{2T_m}{w} \sinh \left( \frac{300w}{T_m} \right) \quad \dots \text{(Eqn. 5)}$$

#### IV. MATLAB PROGRAM

The MATLAB program is written as per the mathematical formulation shown in section 3 and is as below.

##### 4.1 Program

```
% This script finds the roots (Tm) of function f
%(see problem formulation) for h=
10,20,30,40,50,60,70 and
% 80 meters. the maximum tension and total cable
%length is then found for the same values of h.
f='h-Tm/0.17658*(cosh(0.17658*300/Tm)-1)'
f10=subs(f,'h',10);
Tm_10=solve(f10,'Tm')
f20=subs(f,'h',20);
Tm_20=solve(f20,'Tm')
f30=subs(f,'h',30);
Tm_30=solve(f30,'Tm')
f40=subs(f,'h',40);
Tm_40=solve(f40,'Tm')
f50=subs(f,'h',50);
Tm_50=solve(f50,'Tm')
f60=subs(f,'h',60);
Tm_60=solve(f60,'Tm')
f70=subs(f,'h',70);
Tm_70=solve(f70,'Tm')
f80=subs(f,'h',80);
Tm_80=solve(f80,'Tm')
% Now we find the maximum cable tension.
Tmax=inline('Tm+0.17658*h')
Tmax_10=Tmax(Tm_10,10)
Tmax_20=Tmax(Tm_20,20)
Tmax_30=Tmax(Tm_30,30)
Tmax_40=Tmax(Tm_40,40)
Tmax_50=Tmax(Tm_50,50)
Tmax_60=Tmax(Tm_60,60)
Tmax_70=Tmax(Tm_70,70)
Tmax_80=Tmax(Tm_80,80)
% Next we determine the total length of the cable.
LT=inline('2*Tm/0.17658*(sinh(0.17658*300/Tm))')
```

```
LT_10=LT(Tm_10)
LT_20=LT(Tm_20)
LT_30=LT(Tm_30)
LT_40=LT(Tm_40)
LT_50=LT(Tm_50)
LT_60=LT(Tm_60)
LT_70=LT(Tm_70)
LT_80=LT(Tm_80)
```

##### 4.2 Results

```
f =
h-Tm/0.17658*(cosh(0.17658*300/Tm)-1)
Tm_10 =
794.90412578891149524097326390836
Tm_20 =
397.89221082106894027670305045574
Tm_30 =
265.74823662107354135310243261986
Tm_40 =
199.81872805675426605669296976564
Tm_50 =
160.37227208754709371724095079346
Tm_60 =
134.16453333564736355675787561089
Tm_70 =
115.51898020059650565037687766668
Tm_80 =
101.59707127547397647689738539571
Tmax =
Inline function:
Tmax(Tm,h) = Tm+0.17658*h
Tmax_10 =
796.66992578891149524097326390836
Tmax_20 =
401.42381082106894027670305045574
Tmax_30 =
271.04563662107354135310243261986
Tmax_40 =
206.88192805675426605669296976564
Tmax_50 =
169.20127208754709371724095079346
Tmax_60 =
144.75933333564736355675787561089
```

### V. CONCLUSION

Tmax\_70 =  
127.87958020059650565037687766668  
Tmax\_80 =  
115.72347127547397647689738539571  
LT =  
Inline function:  
LT<sup>TM</sup> = 2\*Tm/0.17658\*(sinh(0.17658\*300/Tm))  
LT\_10 =  
600.44421423357429861445393152591  
LT\_20 =  
601.77410594966815056784072148905  
LT\_30 =  
603.9815077751840389764763812613  
LT\_40 =  
607.05308653416898604658117701575  
LT\_50 =  
610.97074115343839300275360069814  
LT\_60 =  
615.7121208772552861663778277023  
LT\_70 =  
621.25123065185363876799668455314  
LT\_80 =  
627.55908803247859413792411517784

The MATLAB analysis is carried out for cable of length 600m with uniformly load along the horizontal having the mass of 18kg/m of its length and supports its own weight. The conclusions drawn from the results obtained are as follows:

1. MATLAB is the powerful and effective mathematical tool for any complex numerical methods.
2. Work is a ready reckoner for beginning engineers in helping them on how to calculate tension at different locations under concentrated load or uniformly distributed load using MATLAB methods.
3. The results obtained showed that as *h* increases, the tension in mid length and maximum tension is decreasing, whereas total length of the cable is found increasing.

The present work in no means exhaustive, it can be further carried out for different values of *h*, mass and length of cables.

The summarization of the results obtained is as shown in Table 2.

**Table 2:** Results summarization

h(m)	T <sub>m</sub> (kN)	T <sub>max</sub> (kN)	L <sub>T</sub> (m)
10	794.904	796.669	600.444
20	397.892	401.424	601.774
30	265.748	271.045	603.981
40	199.818	206.882	607.053
50	160.372	169.201	610.970
60	134.164	144.759	615.712
70	115.518	127.879	621.251
80	101.597	115.723	627.559

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