FE Analysis of 2D Bridge Structure

me 477 fea project, fall 2015

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1 Problem and Overview

I choose the similar problem to example problem which can be found at ME 477 section at unilica[dot]com. The problem to deal with is how some arched bridge structure behaves under load which is applied at its peak point by finite element method. FEAP is used for its FE Analysis. In finite element truss method will be used.

The example geometry can be seen in Figure 1.

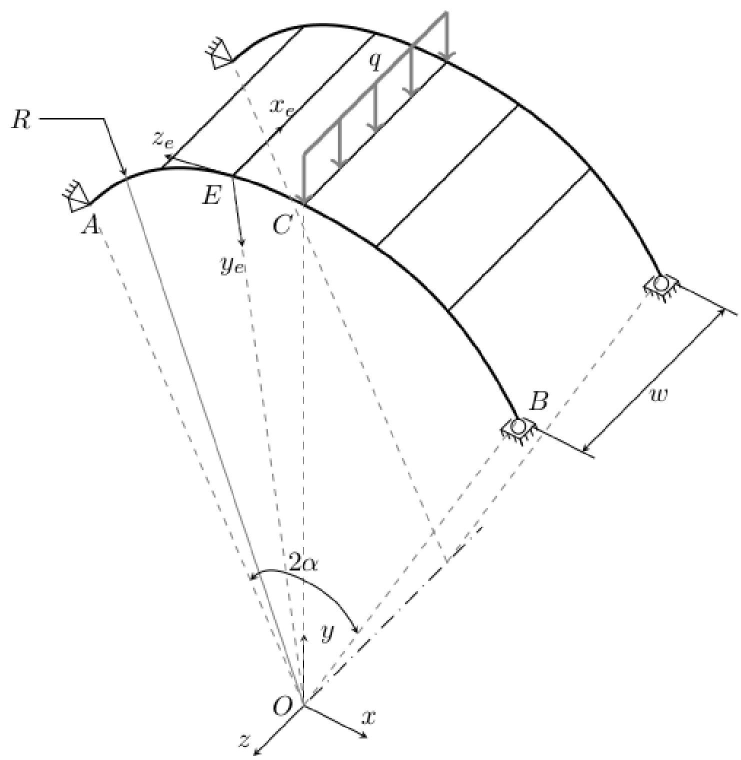


Figure 1: 3D Model

In these problem given parameters are $\alpha = 72^o$, $E\hat{O}C = \alpha/3$ and $R = 14m$. By knowing those properties the locations of points can be determined easily. And in case of interest the element lengths can be found from Law of Cosine(Eq. 1)

$$a^2 = b^2 + c^2 - 2\,b\,c\,cos(\alpha) \tag{1}$$

Location points in Cartesian Coordinates are found using Octave. Finding A and E point locations and |AE| length are demonstrated.

```
octave:1> A=[-14*cosd((180-72)/2);14*sind((180-72)/2)]
A =
   -8.2290
   11.3262
octave:2> E=[-14*cosd((180-72)/2+24);14*sind((180-72)/2+24)]
E =
   -2.9108
```

```
   13.6941
octave:3> AE=sqrt((14^2+14^2-2*14*14*cosd(24)))
AE =   5.8215
```

Structure is simplified as follows due to use the advantages of 2-D analysis. Figure 2 shows the simplified 2D model.

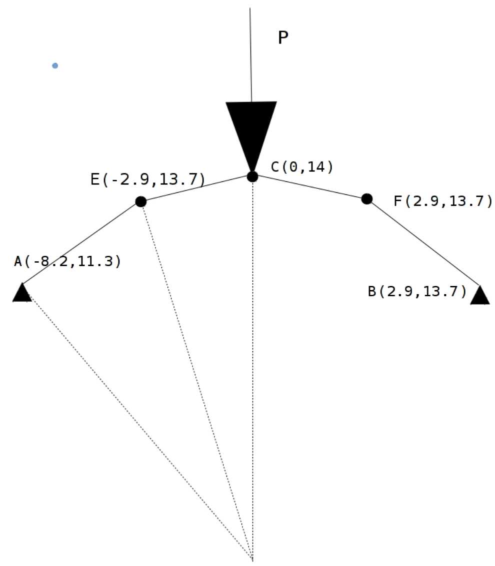


Figure 2: Simplified Model

As it can be seen from the figure 2 , this design have 5 nodes and 4 elements.

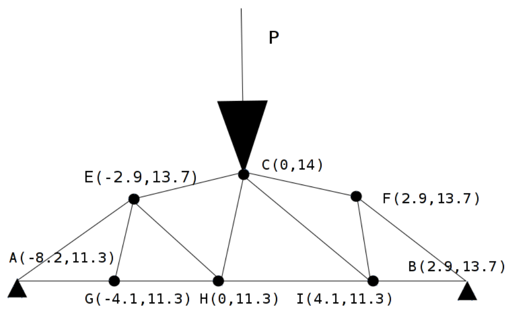
As a material A36 steel is chosen. Which has a Young's Modulus (E) 200 10^9[Pa]. Cross sectional area is chosen to be 0.1 meter-squared and squared profile, also applied force chosen to be 30kN to demonstrate heavy load on the bridge[1].

Also fixed points which are the beginning and the end of the bridge, will be used for boundary conditions of the problem.

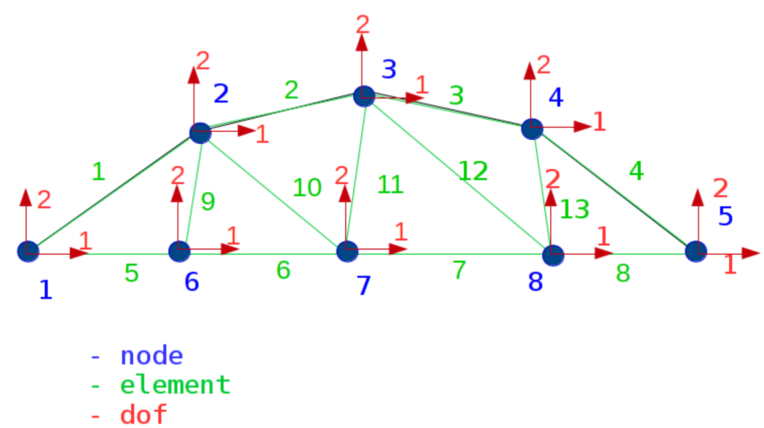
But with these force magnitude and material values, displacement values came out to be enormous. In this point I crossed with lowering the force or changing the design dilemma, and I went with changing the design under same material and force properties to get practical results.

As a modification 3 nodes and 9 elements are added. The coordinates of the nodes and the structure can be seen on Figure 3a. The modified design's nodes, elements and degree of freedoms are shown in Figure 3b.

[1]Maximum truck load is restricted with 27 metric tones by the law in Republic of Turkey.



(a)



(b)

Figure 3: Design v2

2 Pre-Process

To solve the problem input file is created in favorite text editor. Even though odd look of it, it just contains the info about its nodes coordinates, elements that are created between these nodes and material properties of those elements, applied force magnitude and its whereabouts, boundary conditions and lastly what we hope to get from analysis. The input file can be seen below.

```
FEAP * *  2-D Bridge Structure
  0 0 0 2 2 2


MATErial,1
  TRUSS
    ELAStic ISOTropic 200e9
    CROSs SECTion     0.1

COORdinates
  1 0 -8.2 11.3
  2 0 -2.9 13.7
  3 0 0.0 14.0
  4 0 2.9 13.7
  5 0 8.2 11.3
  6 0 -4.1 11.3
  7 0 0.0 11.3
  8 0 4.1 11.3

ELEMents
  1 0 1 1 2
  2 0 1 2 3
  3 0 1 3 4
  4 0 1 4 5
  5 0 1 1 6
  6 0 1 6 7
  7 0 1 7 8
  8 0 1 8 5
  9 0 1 6 2
  10 0 1 2 7
  11 0 1 7 3
  12 0 1 3 8
  13 0 1 8 4

BOUNdary restraints
  1 0 1 1
  5 0 1 1

FORCe
  3 0 0.0 -30000.0

END
TIE

BATCH
  TANG,,1
  DISPlacement ALL
  STRESs       ALL
```

```
  REACtion      ALL
  PLOT  MESH
  PLOT LOAD 1,-1
  PLOT  CONT    1
END


INTEractive
STOP
```

According to these input file mesh created by FEAP can be seen on Figure4.

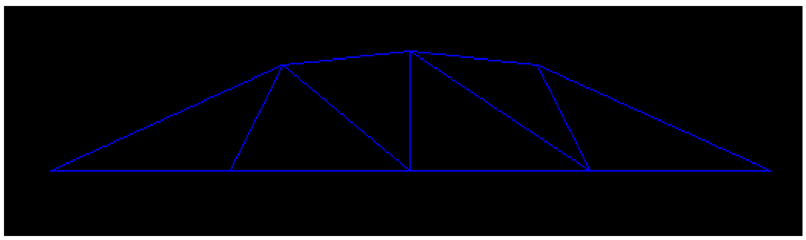


Figure 4: Mesh

3 Post-process & Conclusion

After the solution is run, output file file and colorized picture for displacements are created [Figure 5].

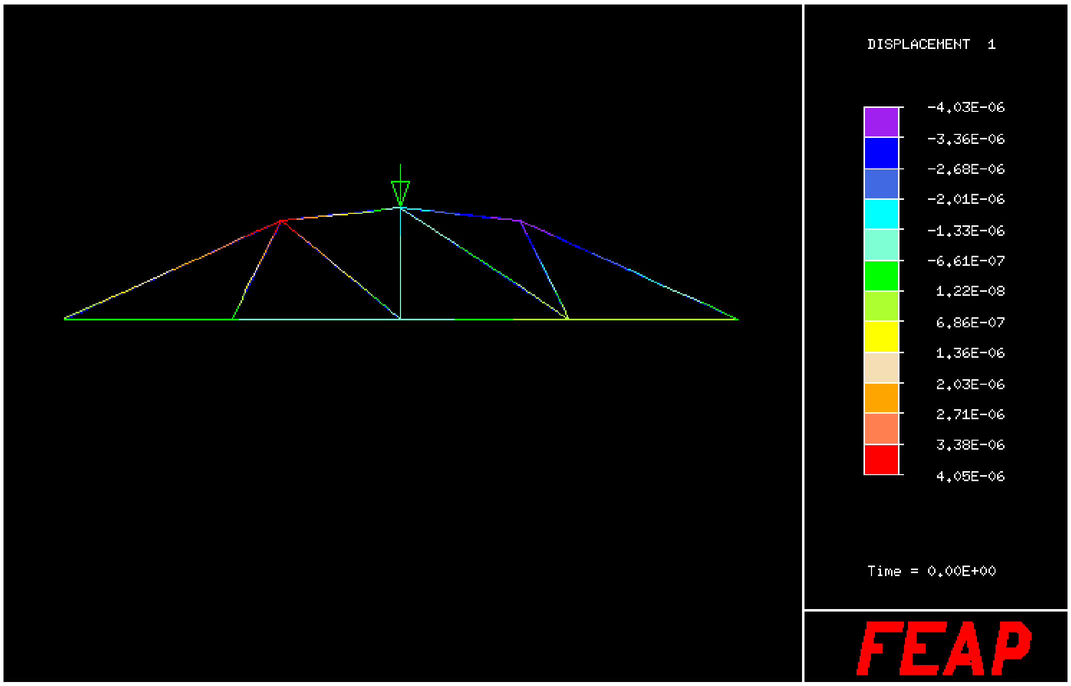


Figure 5: Colorized Displacement

Since output file is 228 lines long; only the interested sections of it is posted below. Full version can be found at `http://pastebin.com/tduNBxsi`.

Following section of output file contains information about nodal displacements. If results would be discussed they are practical since their very small values.

```
 FEAP * * 2-D Bridge Structure

  N o d a l   D i s p l a c e m e n t s     Time        0.00000E+00
                                            Prop. Ld.   1.00000E+00

    Node      1 Coord      2 Coord      1 Displ      2 Displ
       1  -8.2000E+00  1.1300E+01  0.0000E+00  0.0000E+00
       2  -2.9000E+00  1.3700E+01  4.0536E-06 -3.4595E-05
       3   0.0000E+00  1.4000E+01 -1.3559E-06 -4.7185E-05
       4   2.9000E+00  1.3700E+01 -4.0293E-06 -3.4542E-05
       5   8.2000E+00  1.1300E+01  0.0000E+00  0.0000E+00
       6  -4.1000E+00  1.1300E+01 -6.3707E-07 -3.2250E-05
       7   0.0000E+00  1.1300E+01 -1.2741E-06 -4.5796E-05
       8   4.1000E+00  1.1300E+01  6.3707E-07 -3.4255E-05
 *Command   3 * stre ALL            v:    0.00        0.00        0.00
                                                           t=     0.01      0.00
```

Following section of output file contains information about force and strain.

```
 FEAP * * 2-D Bridge Structure

         Truss Element

 Elmt Matl     1-coord     2-coord     3-coord      Force          Strain            Flux
    1    1  -5.550E+00  1.250E+01  0.000E+00  -3.63630E+04  -1.81815E-06   0.00000E+00
    2    1  -1.450E+00  1.385E+01  0.000E+00  -4.57987E+04  -2.28993E-06   0.00000E+00
    3    1   1.450E+00  1.385E+01  0.000E+00  -2.71669E+04  -1.35835E-06   0.00000E+00
    4    1   5.550E+00  1.250E+01  0.000E+00  -3.63630E+04  -1.81815E-06   0.00000E+00
    5    1  -6.150E+00  1.130E+01  0.000E+00  -3.10764E+03  -1.55382E-07   0.00000E+00
    6    1  -2.050E+00  1.130E+01  0.000E+00  -3.10764E+03  -1.55382E-07   0.00000E+00
    7    1   2.050E+00  1.130E+01  0.000E+00   9.32292E+03   4.66146E-07   0.00000E+00
    8    1   6.150E+00  1.130E+01  0.000E+00  -3.10764E+03  -1.55382E-07   0.00000E+00
    9    1  -3.500E+00  1.250E+01  0.000E+00   6.35275E-11   3.17637E-21   0.00000E+00
   10    1  -1.450E+00  1.250E+01  0.000E+00   1.61353E+04   8.06766E-07   0.00000E+00
   11    1   0.000E+00  1.265E+01  0.000E+00  -1.02874E+04  -5.14368E-07   0.00000E+00
   12    1   2.050E+00  1.265E+01  0.000E+00  -2.21905E+04  -1.10952E-06   0.00000E+00
   13    1   3.500E+00  1.250E+01  0.000E+00   1.36451E+04   6.82255E-07   0.00000E+00
 *Command    4 * reac ALL            v:    0.00        0.00        0.00
                                                          t=      0.01      0.00
```

It should be noted that force can lead to stress with easy algebra.

$$\sigma = \frac{F}{A}$$

Basic manipulation gives σ values as follows:

```
octave:2> Force/0.1
ans =

  -3.6400e+05
  -4.5800e+05
  -2.7200e+05
  -3.6400e+04
  -3.1100e+04
  -3.1100e+04
   9.3200e+04
  -3.1100e+04
   6.3500e-10
   1.6100e+05
  -1.0300e+05
  -2.2000e+05
   1.3600e+05
```

Which is safe since yield strength of A 36 steel is 260 MPa.

Following section of output file contains information about nodal reactions.

```
 FEAP * * 2–D Bridge Structure

  N o d a l   R e a c t i o n s

   Node        1 dof        2 dof
      1   3.6233E+04   1.5000E+04
      2  −4.9113E−11   6.0027E−11
```

```
       3   2.9104E-11  -3.0000E+04
       4  -5.0932E-11   1.2733E-11
       5  -3.6233E+04   1.5000E+04
       6  -4.1598E-11  -5.6821E-11
       7   7.2760E-12  -4.0018E-11
       8   1.2733E-11   3.0923E-11

 Pr.Sum  -7.0372E-12   1.3870E-12
    Sum  -7.0372E-12   1.3870E-12
  |Sum|   7.2465E+04   6.0000E+04
   Energy: Displacements * Reactions =      1.415548070137809E+00
```

Very small reactions except node 1 and 5 which are bridge's beginning and end points. It can be seen that nodal reactions are very small except node 1 and 5 which are bridge's beginning and end points and therefore fixed.

In conclusion modified bridge structure definitely can be considered safe since displacement, stress and node reactions are allowable. I choose FEAP over Pyfem for the analysis for practical reasons. FEAP was good enough to gave those results without too much struggle; but I would like to deal with Pyfem in future.