EG3111 Finite Element Analysis and Design

COMSOL Practical #2: Design of a Warren Truss Bridge

Aim

To simulate more complex frameworks and show how simulation tools can benefit the design process.

The video "COMSOL Practical #2" shows you how to set up this problem and analyse the solution. Try to do the simulation yourself and watch the video if you need some help.

Task

Geometry

This analysis will investigate the design of a Warren truss bridge which spans a distance of 40m. The framework is made up of N equilateral triangles, subject to the constraint that the height of the bridge is at least 5m, as shown in Figure 1 for $N = 8$.

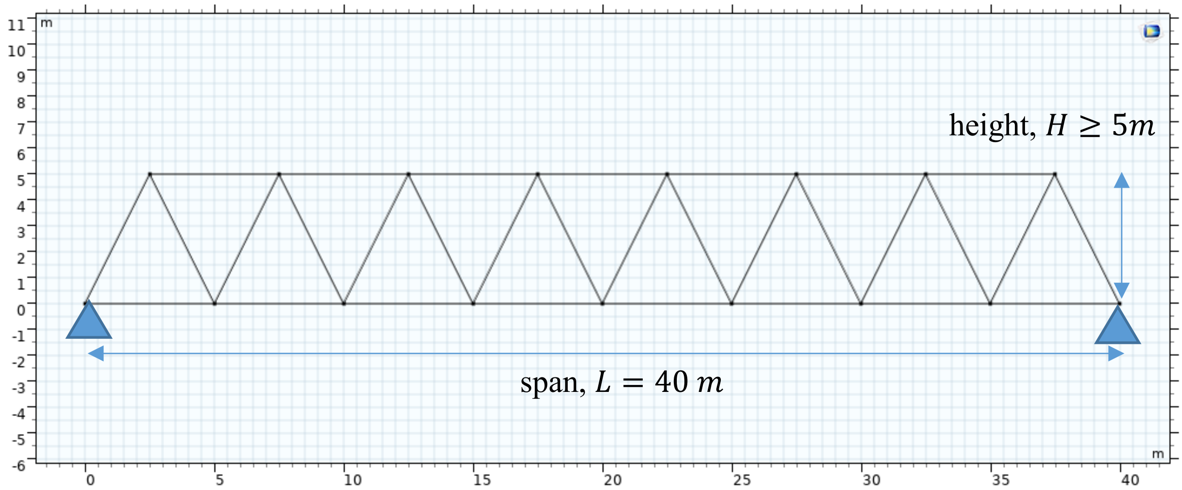

Figure 1 : Drawing of a Warren truss with $N = 8$.

Constraints

The points at the two ends of the bridge are pinned as shown in Figure 1.

Materials

The framework is constructed from steel with a Young's modulus of 200 GPa, Poisson's ratio 0.3 and density 7500 kg/m^3. Each truss has a cross-sectional area of 0.01 m^2.

Loading

The bridge is subject to a gravitational load due to its own weight as well as an additional distributed load due to the roadway and the vehicles on it. In two-dimensions, we are assuming that this framework represents one side of the bridge, and therefore carries one half of the total additional load. The two-lane roadway weights 6 tonnes/m. The maximum weight of a loaded lorry is 45 tonnes for a lorry of length 15m, i.e. 3 tonnes/m. For design purposes we consider the worst-case scenario where both lanes are covered with lorries. The total additional load is therefore $6 + 2 \times 3$=12 tonnes/m, which equates to 6 tonnes/m on this side of the bridge. Other loadings such as wind loading and ice/snow are neglected.

Problem

Conduct a COMSOL analysis of this bridge for this bridge for $N = 3, 5{,}8$ and fill in the following table:

	$N = 3$	$N = 5$	$N = 8$
Maximum axial stress (MPa)			
Minimum axial stress (MPa)			
Maximum displacement (mm)			
Length of steel used (m)			

Questions

1. Infer from this table which is the best design.
2. How might this bridge be expected to fail if the load was increased?
3. What other aspects can be changed to improve this design?

Solution

	$N = 3$	$N = 5$	$N = 8$
Maximum axial stress (MPa)	94	114	121
Minimum axial stress (MPa)	-95	-171	-247
Maximum displacement (mm)	23	40	66
Length of steel used (m)	147	152	164

1. The best design will have the smallest axial stresses, the smallest deflections and the lowest material cost (proportional to length of steel used). The table shows that $N = 3$ is the best design in all these respects. The solution $N = 1$ would be even better, although the height of the bridge would then become excessive.
2. The largest axial load is in the compressive trusses at the top and centre of the bridge. These could fail by buckling, and a separate calculation would need to be done to check the axial force is below the critical buckling load in these members. Recall from EG2111 that shorter members (higher N) will have a higher buckling load and hence are less prone to buckling.
3. The cross-sectional area of the members does not have to be the same for the whole framework. The area of members that carry the highest loads could be increased, and the area of the members that carry lower loads could be decreased. In practice, however, it is often simpler to use the same type of members for the whole bridge. The arrangement of the members can also be changed. In practice the Warren truss bridge geometry is not widely used in practise, with the Pratt truss bridge (below) being more popular as the force is distributed more evenly across the members. Note that the horizontal members are thicker than the vertical members.