Amanda Siciliano
CIVE 2000-03
Professor Saykin

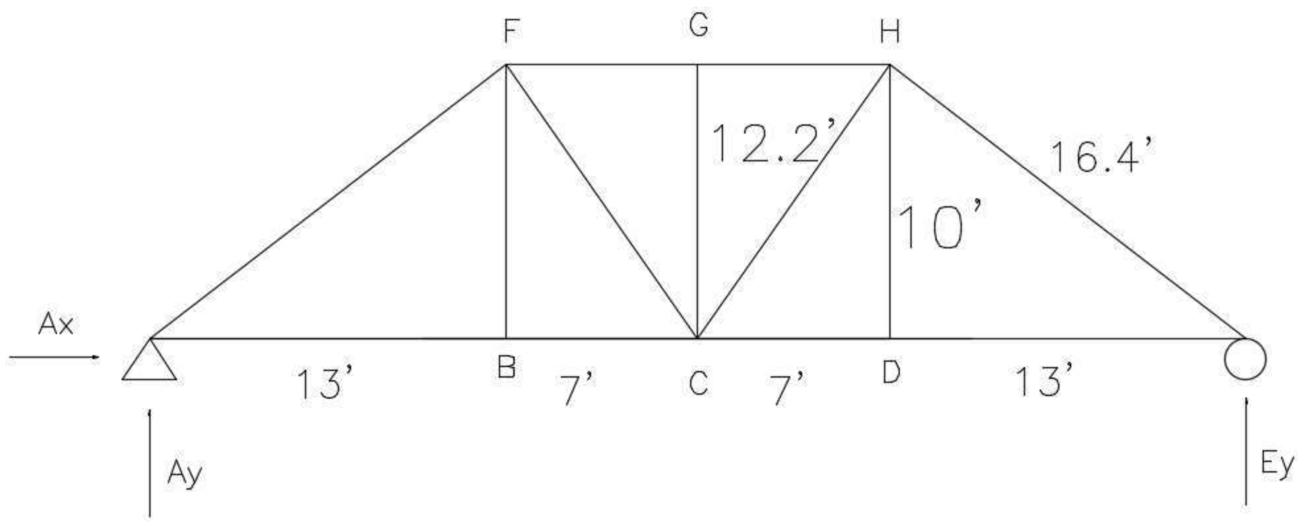
Truss the Design

First developed in 1844, the Pratt Truss bridge is one of the simplest yet strongest design for truss bridges. Designed by the American engineers Thomas Willis Pratt and his father Caleb Pratt, the Pratt Truss bridge was widely used for its remarkable ability to span long distances. In an age when steel and iron was becoming cheap, Pratt explored the idea of using metal connections between truss members. This advancement became revolutionary, leading to stronger and more stable bridges.

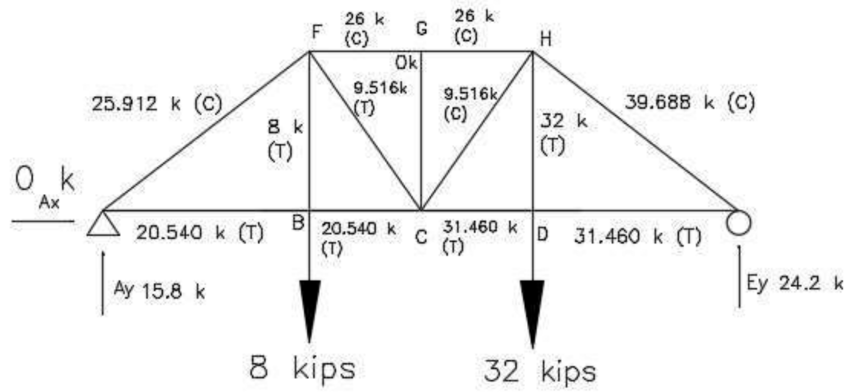
The Pratt Truss was selected due to its familiar nature. Because of its ability to span large distances while having a wide platform, this design is often used in railroad bridge construction. While cable-stayed/suspension bridges such as the Brooklyn Bridge or cantilever designs such as the Queensboro Bridge have a certain aesthetic appeal, the Pratt Truss is a classic, respectable design. Furthermore, while bridges such as the Warren and Parker Truss would be suitable, these bridges have a more complicated design that does not respond as well when load is placed at a single point. The timeless design of the Pratt Truss is remarkable with its simple design, wide span, cost effectiveness, and strong horizontal load capabilities.

Originally, bridges were designed using wood. While wood can be viewed as a competitive material, it is costly, susceptible, and ineffective. This type of material requires frequent maintenance in the form of chemical treatments to control moisture, bacteria, and corrosion. Pratt Truss bridges were a viable alternative option for their increased use of metal. New developments in 1855 made it possible for other metals to be explored, and introduced steel production. While other material options such as rope, fibers, stone, timber, and concrete exist, steel tends to be the modern-day preference due to its strength and pricing. For this reason, the new high performance A710 Grade B50 structural steel will be used to create this bridge. Research completed in 2014 by the Illinois Center for Transportation found that Grade B50 steel is outstanding for its resistance to corrosion, weldability, and ductility. Through analysis of the members after force is applied, it is evident that some of the diagonals and chords experience high values of compression and tension. For this reason, along with other factors such as strength, usability and environment weathering resistance, A710 grade B50 steel is the most efficient material to use for this Pratt Truss bridge.

Truss Bridge: No Applied Load

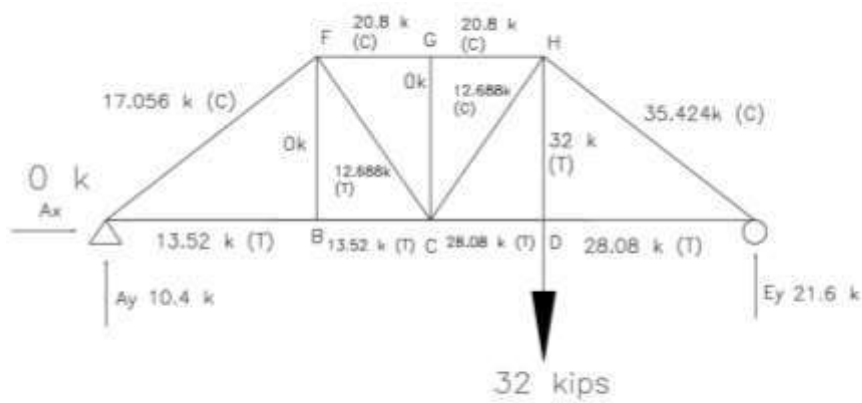


Scenario 1: 8 & 32 Kips Applied Loads (Front & Back Tire H-20 Truck)



This first scenario was chosen as one of the “worst case scenarios” because it applies large loads on the members. The right side of this bridge, which only has one support reaction, has members that experience forces up to about 39 kips. Because of the high forces, some recommendations include using a strong material or increasing the number of members to make this bridge more reliable.

Scenario 2: 32 Kips Applied Loads (Back Tire H-20 Truck)



In this second scenario, members also experience high forces up to about 36 kips. While this scenario has members experiencing less force, recommendations for this bridge also include a strong material, and an increased number of members. Other cost-effective recommendations include increasing the strength of the members where the largest load will be applied.

Scenario #1

Member	Force	Compression/Tension?
F_{AF}	25.912 k	C
F_{AB}	20.54 k	T
F_{BF}	8 k	T
F_{BC}	20.540 k	T
F_{EH}	39.688 k	C
F_{DE}	31.460 k	T
F_{DH}	32 k	T
F_{DC}	31.460 k	T
F_{CH}	9.516 k	C
F_{GH}	26 k	C
F_{GC}	0 k	-
F_{GF}	26 k	C
F_{FC}	9.516 k	T
E_y	24.2 k	-
A_x	0 k	-
A_y	15.8 k	-

Scenario #2

Member	Force	Compression/Tension?
F_{AF}	17.056 k	C
F_{AB}	13.52 k	T
F_{BF}	0 k	-
F_{BC}	13.52 k	T
F_{EH}	35.424 k	C
F_{DE}	28.08 k	T
F_{DH}	32 k	T
F_{DC}	28.08 k	T
F_{CH}	12.688	C
F_{GH}	20.8 k	C
F_{GC}	0 k	-
F_{GF}	20.8 k	C
F_{FC}	12.688 k	T
E_y	21.6 k	-
A_x	0 k	-
A_y	10.4 k	-

Scenario #1

$\Sigma M_A: 0 = (-8 \text{ kips})(13 ft) + (-32 \text{ kips})(27 ft) + (E_y)(40 ft)$

$-40E_y = -104 + -864$

$\boxed{E_y = 24.2 \text{ kips}}$

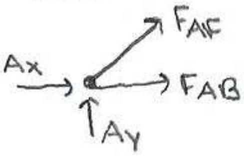
$\Sigma F_x: 0 = A_x$

$\boxed{A_x = 0 \text{ kips}}$

$\Sigma F_y: 0 = -8 \text{ kips} - 32 \text{ kips} + F_y + A_y$

$\boxed{A_y = 15.8 \text{ kips}}$

Joint A



$\Sigma F_y: 0 = A_y + F_{AF}\left(\frac{10}{16.4}\right)$

$F_{AF} = -\left(\frac{16.4}{10}\right)(15.8)$

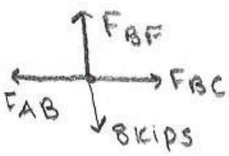
$\boxed{F_{AF} = -25.912 \text{ kips}}$

$\Sigma F_x: 0 = A_x + F_{AB} + F_{AF}\left(\frac{13}{16.4}\right)$

$-F_{AB} = 0 + (-25.912 \text{ kips})\left(\frac{13}{16.4}\right)$

$\boxed{F_{AB} = 20.540 \text{ kips}}$

Joint B



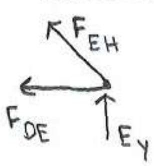
$\Sigma F_y: 0 = F_{BF} - 8 \text{ kips}$

$\boxed{F_{BF} = 8 \text{ kips}}$

$\Sigma F_x: 0 = -F_{AB} + F_{BC}$

$\boxed{F_{BC} = 20.540 \text{ kips}}$

Joint E



$\Sigma F_y: 0 = E_y + F_{EH}\left(\frac{10}{16.4}\right)$

$-F_{EH} = (24.2 \text{ kips})\left(\frac{16.4}{10}\right)$

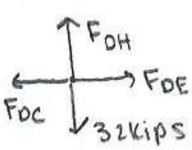
$\boxed{F_{EH} = -39.688 \text{ kips}}$

$\Sigma F_x: 0 = -F_{DE} - F_{EH}\left(\frac{13}{16.4}\right)$

$F_{DE} = -(-39.688 \text{ kips})\left(\frac{13}{16.4}\right)$

$\boxed{F_{DE} = 31.460 \text{ kips}}$

Joint D



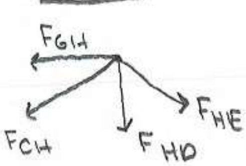
$\Sigma F_y: 0 = F_{DH} - 32 \text{ kips}$

$\boxed{F_{DH} = 32 \text{ kips}}$

$\Sigma F_x: 0 = -F_{DC} + F_{DE}$

$\boxed{F_{DC} = 31.460 \text{ kips}}$

Joint H



$\Sigma F_y: 0 = -F_{HD} - F_{CH}\left(\frac{10}{12.2}\right) - F_{HE}\left(\frac{10}{16.4}\right)$

$F_{CH} = \frac{12.2}{10}\left[-32 \text{ kips} - \left(-39.688 \cdot \frac{10}{16.4}\right)\right]$

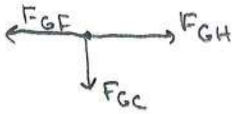
$\boxed{F_{CH} = -9.516 \text{ kips}}$

$\Sigma F_x: 0 = -F_{GH} - F_{CH}\left(\frac{7}{12.2}\right) + F_{HE}\left(\frac{13}{16.4}\right)$

$F_{GH} = -\left(-9.516 \cdot \frac{7}{12.2}\right) + \left(-39.688 \cdot \frac{13}{16.4}\right)$

$\boxed{F_{GH} = -26 \text{ kips}}$

Joint G



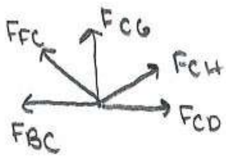
$\Sigma F_y : 0 = F_{GC}$

$\boxed{F_{GC} = 0 \text{ kips}}$

$\Sigma F_x : 0 = -F_{GF} + F_{GH}$

$\boxed{F_{GF} = -26 \text{ kips}}$

Joint C



$\Sigma F_y : 0 = F_{CG} + F_{CH}\left(\frac{10}{12.2}\right) + F_{FC}\left(\frac{10}{12.2}\right)$

$-F_{FC} = \frac{12.2}{10}\left[0 + -9.516\left(\frac{10}{12.2}\right)\right]$

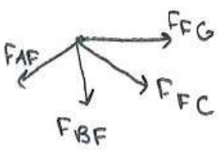
$\boxed{F_{FC} = 9.516 \text{ kips}}$

$\Sigma F_x : 0 = -F_{BC} + F_{CD} + F_{CH}\left(\frac{7}{12.2}\right) - F_{FC}\left(\frac{7}{12.2}\right)$

$F_{BC} = 31.460 + -9.516\left(\frac{7}{12.2}\right) - 9.516\left(\frac{7}{12.2}\right)$

$\boxed{F_{BC} = 20.540 \text{ kips}}$ → check ✓

Joint F



$\Sigma F_y : 0 = -F_{BF} - F_{AF}\left(\frac{10}{16.1}\right) - F_{FC}\left(\frac{10}{12.2}\right)$

$F_{FC} = \frac{12.2}{10}\left[-8 \text{ kips} - \left(-25.912 \cdot \frac{10}{16.4}\right)\right]$

$\boxed{F_{FC} = 9.516 \text{ kips}}$ → check ✓

$\Sigma F_x : 0 = F_{FG} + F_{FC}\left(\frac{7}{12.2}\right) - F_{AF}\left(\frac{13}{16.1}\right)$

$-F_{FG} = 9.516\left(\frac{7}{12.2}\right) - \left(-25.912 \cdot \frac{13}{16.4}\right)$

$\boxed{F_{FG} = -26 \text{ kips}}$ → check ✓

Member	Force	Compression / Tension
F_{AF}	-25.912 kips	C
F_{AB}	20.540 kips	T
F_{BF}	8 kips	T
F_{BC}	20.540 kips	T
F_{EH}	-39.688 kips	C
F_{DE}	31.460 kips	T
F_{DH}	32 kips	T
F_{DC}	31.460 kips	T
F_{CH}	-9.516 kips	C
F_{GH}	-26 kips	C
F_{GC}	0 kips	—
F_{GF}	-26 kips	C
F_{FC}	9.516 kips	T

Support Rxn	Force
E_y	24.2 kips
A_x	0 kips
A_y	15.8 kips

Scenario #2

$\Sigma M_A: 0 = (-32\,kips)(27ft) + (E_y)(40ft)$

$-E_y(40) = -864$

$\boxed{E_y = 21.6\,kips}$

$\Sigma F_x: 0: A_x$

$\boxed{A_x: 0\,kips}$

$\Sigma F_y: 0 = A_y + E_y - 32\,kips$

$-A_y = E_y - 32$

$= 21.6 - 32$

$\boxed{A_y = 10.4\,kips}$

Joint A

$\Sigma F_y = 0: A_y + F_{AF}\left(\frac{10}{16.4}\right)$

$-F_{AF} = \left(\frac{16.4}{10}\right)A_y$

$= \left(\frac{16.4}{10}\right)(-10.4)$

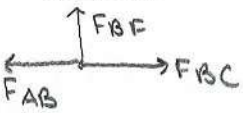
$\boxed{F_{AF} = -17.056\,kips}$

$\Sigma F_x: 0 = A_x + F_{AB} + F_{AF}\left(\frac{13}{16.4}\right)$

$-F_{AB} = 0 + (-17.056)\left(\frac{13}{16.4}\right)$

$\boxed{F_{AB} = 13.52\,kips}$

Joint B



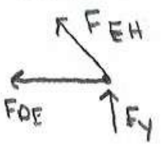
$\Sigma F_y: 0: F_{BF}$

$\boxed{F_{BF} = 0\,kips}$

$\Sigma F_x: 0 = -F_{AB} + F_{BC}$

$\boxed{F_{BC} = 13.52\,kips}$

Joint E



$\Sigma F_y: 0: E_y + F_{EH}\left(\frac{10}{16.4}\right)$

$-F_{EH} = \left(\frac{16.4}{10}\right)E_y$

$= \frac{16.4}{10}(21.6)$

$\boxed{F_{EH} = -35.424\,kips}$

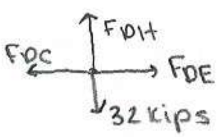
$\Sigma F_x: 0: -F_{DE} - F_{EH}\left(\frac{13}{16.4}\right)$

$F_{DE} = -F_{EH}\left(\frac{13}{16.4}\right)$

$= -(-35.424)\left(\frac{13}{16.4}\right)$

$\boxed{F_{DE} = 28.08\,kips}$

Joint D



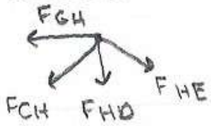
$\Sigma F_y: 0: F_{DH} - 32\,kips$

$\boxed{F_{DH} = 32\,kips}$

$\Sigma F_x: 0 = -F_{DC} + F_{DE}$

$\boxed{F_{DC}: 28.08\,kips}$

Joint H



$\Sigma F_y: 0: -F_{HD} - F_{CH}\left(\frac{10}{12.2}\right) - F_{HE}\left(\frac{10}{16.4}\right)$

$F_{CH} = \frac{12.2}{10}\left[-F_{HD} - F_{HE}\left(\frac{10}{16.4}\right)\right]$

$= \frac{12.2}{10}\left[-32 - (-35.424)\left(\frac{10}{16.4}\right)\right]$

$\boxed{F_{CH} = -12.688\,kips}$

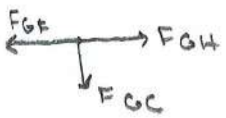
$\Sigma F_x: 0: -F_{GH} - F_{CH}\left(\frac{7}{12.2}\right) + F_{HE}\left(\frac{13}{16.4}\right)$

$F_{GH} = -F_{CH}\left(\frac{7}{12.2}\right) + F_{HE}\left(\frac{13}{16.4}\right)$

$= \left(-12.688 \cdot \frac{7}{12.2}\right) + \left(-35.424 \cdot \frac{13}{16.4}\right)$

$\boxed{F_{GH} = -20.8\,kips}$

Joint G



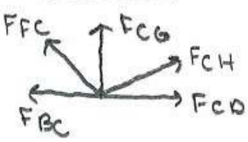
$\Sigma F_y = 0 : F_{GC}$

$\boxed{F_{GC} = 0 \text{ kips}}$

$\Sigma F_x = 0 : -F_{GF} + F_{GH}$

$\boxed{F_{GF} = -20.8 \text{ kips}}$

Joint C



$\Sigma F_y = 0 : F_{CG} + F_{CH}\left(\frac{10}{12.2}\right) + F_{FC}\left(\frac{10}{12.2}\right)$

$-F_{FC} : \frac{12.2}{10}\left[F_{CG} + F_{CH}\left(\frac{10}{12.2}\right)\right]$

$= \frac{12.2}{10}\left[0 + (-12.688)\left(\frac{10}{12.2}\right)\right]$

$\boxed{F_{FC} : 12.688 \text{ kips}}$

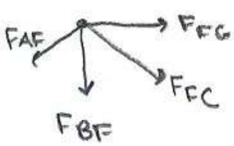
$\Sigma F_x = 0 : -F_{BC} + F_{CD} + F_{CH}\left(\frac{7}{12.2}\right) - F_{FC}\left(\frac{7}{12.2}\right)$

$F_{BC} : F_{CD} + F_{CH}\left(\frac{7}{12.2}\right) - F_{FC}\left(\frac{7}{12.2}\right)$

$= 28.08 + (-12.688)\left(\frac{7}{12.2}\right) - (12.688)\left(\frac{7}{12.2}\right)$

$\boxed{F_{BC} : 13.52 \text{ kips}}$ → check ✓

Joint F



$\Sigma F_y = 0 : -F_{BF} - F_{AF}\left(\frac{10}{16.4}\right) - F_{FC}\left(\frac{10}{12.2}\right)$

$F_{FC} : \frac{12.2}{10}\left[-F_{BF} - F_{AF}\left(\frac{10}{16.4}\right)\right]$

$= \frac{12.2}{10}\left[-0 - (-17.056)\left(\frac{10}{16.4}\right)\right]$

$\boxed{F_{FC} = 12.688 \text{ kips}}$ → check ✓

$\Sigma F_x = 0 : F_{FG} + F_{FC}\left(\frac{7}{12.2}\right) - F_{AF}\left(\frac{13}{16.4}\right)$

$-F_{FG} = F_{FC}\left(\frac{7}{12.2}\right) - F_{AF}\left(\frac{13}{16.4}\right)$

$= 12.688\left(\frac{7}{12.2}\right) - (-17.056)\left(\frac{13}{16.4}\right)$

$\boxed{F_{FG} : -20.8 \text{ kips}}$ → check ✓

Member	Force	Compression/ Tension
F_{AF}	-17.056 kips	C
F_{AB}	13.52 kips	T
F_{BF}	0 kips	—
F_{BC}	13.52 kips	T
F_{EH}	-35.424 kips	C
F_{DE}	28.08 kips	T
F_{DH}	32 kips	T
F_{DC}	28.08 kips	T
F_{CH}	-12.688 kips	C
F_{GH}	-20.8 kips	C
F_{GC}	0 kips	—
F_{GF}	-20.8 kips	C
F_{FC}	12.688 kips	T

Support Rxn	Force
E_y	21.6 kips
A_x	0 kips
A_y	10.4 kips