TAUBMAN COLLEGE
ARCHITECTURE & URBAN PLANNING
UNIVERSITY OF MICHIGAN

Arch314
STRUCTURES I

Fall 2024
Recitation

FACULTY: Prof. Peter von Bülow
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Welcome to Recitation session 10/18

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Office hours:

Room 3122
Wed: 11:30 – 12:30
Mon, Fri: 11:30 - 12:30
By appointment

Please feel free to ask questions.

Welcome to Recitation session 10/11

Outline:

- Quick **Recap** of the week
- Provide the solution for the assignment **(Homework 8)**
- Answering student's questions
- Lab: **3-Hinged Arches**
- **Bridge_1** project (providing feedbacks)

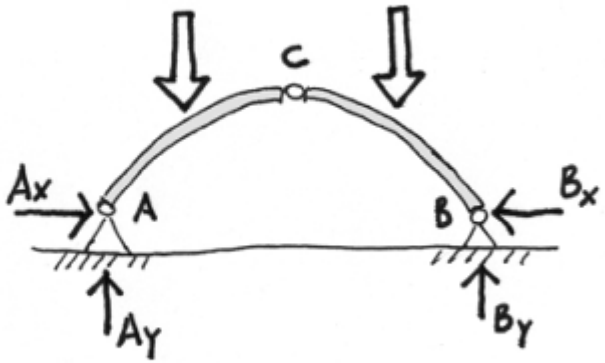
Please feel free to ask questions.

Contact: Mohsenv@umich.edu

Recap of the week

3-Hinged Arch

The 3-Hinged Arch has a “hinge” at each pinned support **plus one more internally**. The internal hinge provides one additional statics equation to be written since the moment at C is known ($M_C = 0$). This makes the system **statically determinate**.



3-HINGED ARCH

Characteristics of a 3-Hinged Arch

- Statically determinate – can be calculated with statics
- Movement or settling of foundations will not alter member stresses
- Small fabrication errors in length do not affect internal stresses
- Hinge placement can reduce internal stresses

Provide the solution for the assignment – **HW8**

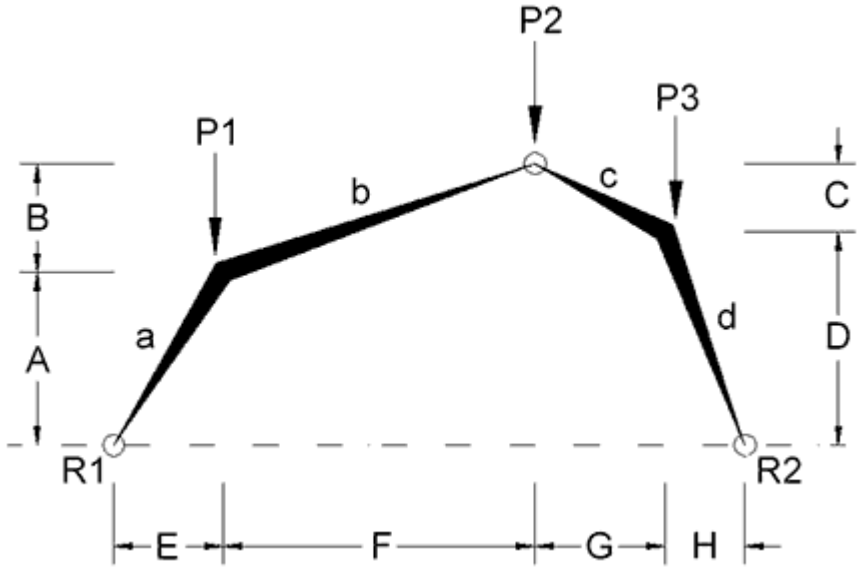
9. Three Hinged Arches

For the three-hinged arch shown, determine horizontal and vertical components of each reaction, and the moments at the knees.

DATASET: 1 -2- -3-

Height A	13 FT
Height B	8 FT
Height C	11 FT
Height D	10 FT
Length E	4 FT
Length F	17 FT
Length G	17 FT
Length H	4 FT
Force P1	6 KIPS
Force P2	20 KIPS
Force P3	20 KIPS

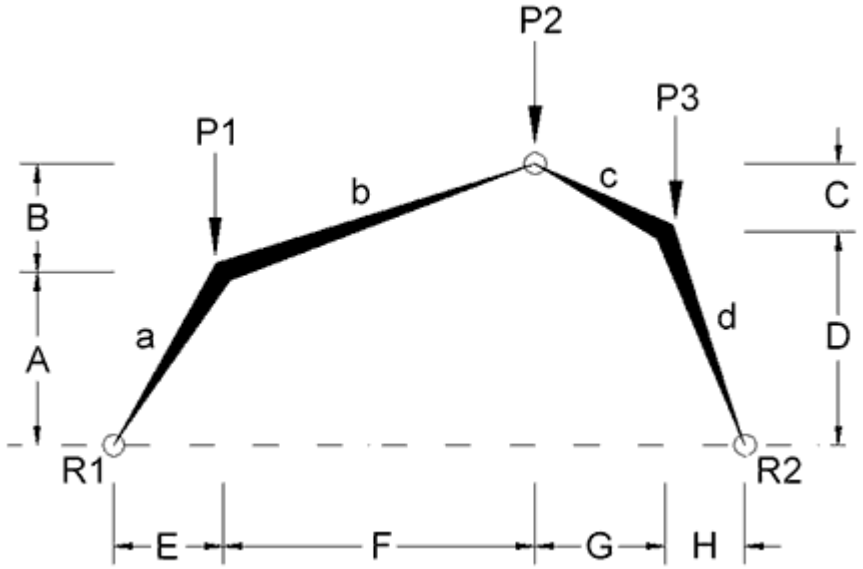
- Problem:



Provide the solution for the assignment – **HW8**

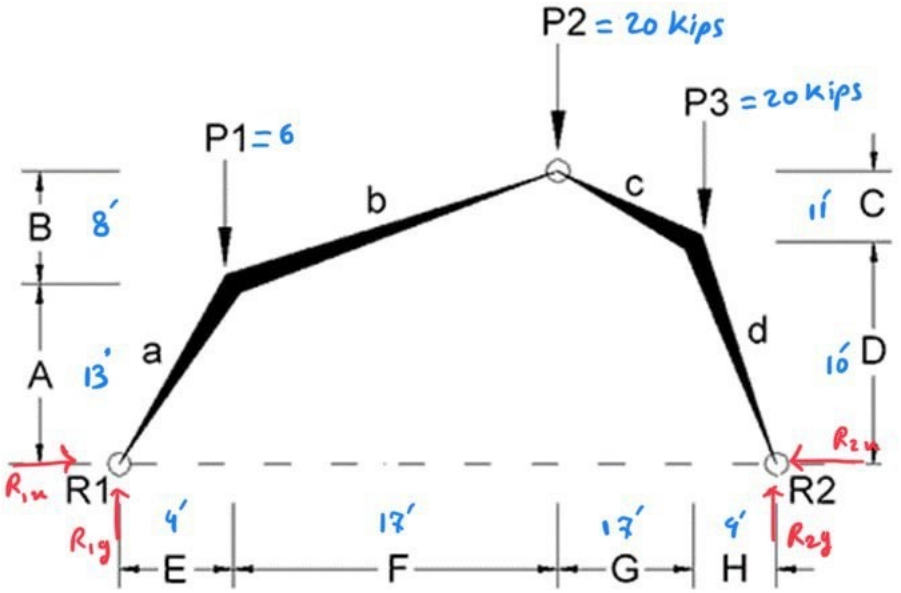
- Problem:

#	Question	Your Response	
1	HORIZONTAL component of R1 (+ = to the right)		KIPS
2	VERTICAL component of R1 (+ = upward)		KIPS
3	HORIZONTAL component of R2 (+ = to the right)		KIPS
4	VERTICAL component of R2 (+ = upward)		KIPS
5	Moment at M1 (+ = tension inside)		KIP-FT
6	Moment at M2 (+ = tension inside)		KIP-FT
7	Axial force in member "a" (+ is compression)		KIPS
8	Axial force in member "b" (+ is compression)		KIPS
9	Axial force in member "c" (+ is compression)		KIPS
10	Axial force in member "d" (+ is compression)		KIPS



Provide the solution for the assignment – **HW8**

- Solution:



FBD of whole structure:

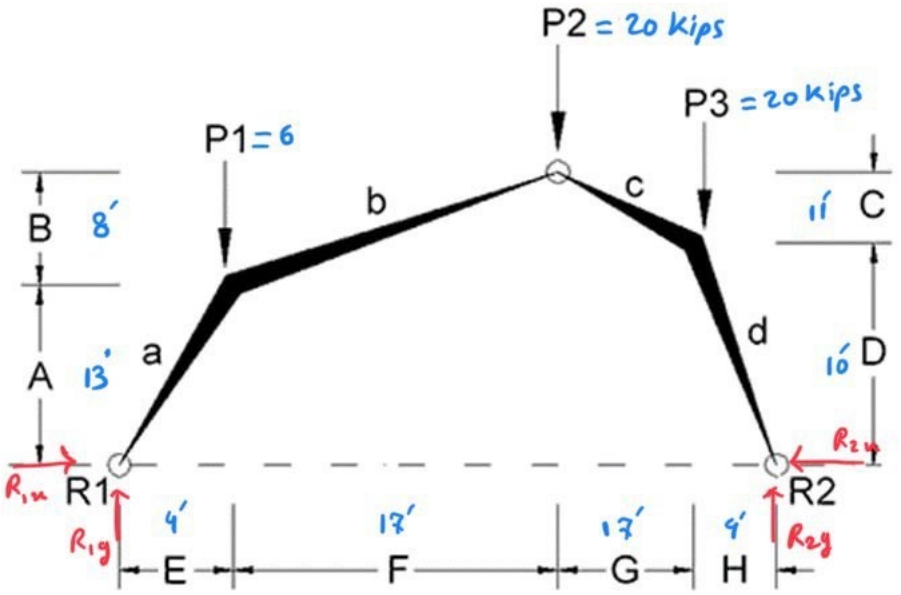
$\sum M_{@1} = 0$

$P_1 \times E + P_2 \times (E+F) + P_3 \times (E+F+G) - R_{2y} \times (E+F+G+H) = 0$

$6 \times 4 + 20 \times (4+17) + 20 \times (4+17+17) - R_{2y} \times (4+17+17+4) = 0$

$\rightarrow \underline{R_{2y} = 28.667 \text{ kips}}$

Provide the solution for the assignment – **HW8**



- Solution:

$\sum M_{@2} = 0$

$-P_3 \times H - P_2 \times (G+H) - P_1 (F+G+H) + R_{1y} (E+F+G+H) = 0$

$-20 \times 4 - 20 \times (17+4) - 6 \times (4+17+17) + R_{1y} (4+17+17+4) = 0$

$\rightarrow \boxed{R_{1y} = 17.334} \text{ kips}$

Check:

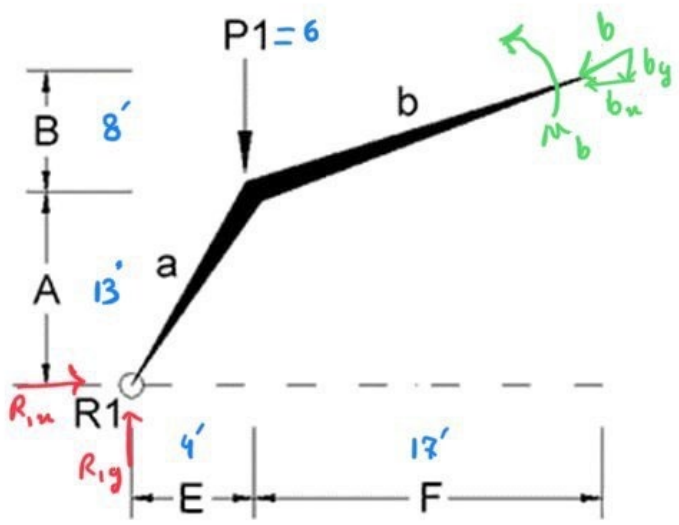
$\sum F_y = 0$

$R_{1y} - P_1 - P_2 - P_3 + R_{2y} \stackrel{?}{=} 0$

$17.334 - 6 - 20 - 20 + 28.667 \stackrel{?}{=} 0 \rightarrow$ O.K. ✓

Provide the solution for the assignment – **HW8**

- Solution:



FBD Left part :

$\sum M_{@k} = 0$

$-P_1 \times F + R_{1y} \times (E+F) - R_{1x} \times (A+B) = 0$

$-6 \times 17 + 17.334 \times (4+17) - R_{1x} \times (13+8) = 0$

$\longrightarrow \boxed{R_{1x} = 12.476}$ kips

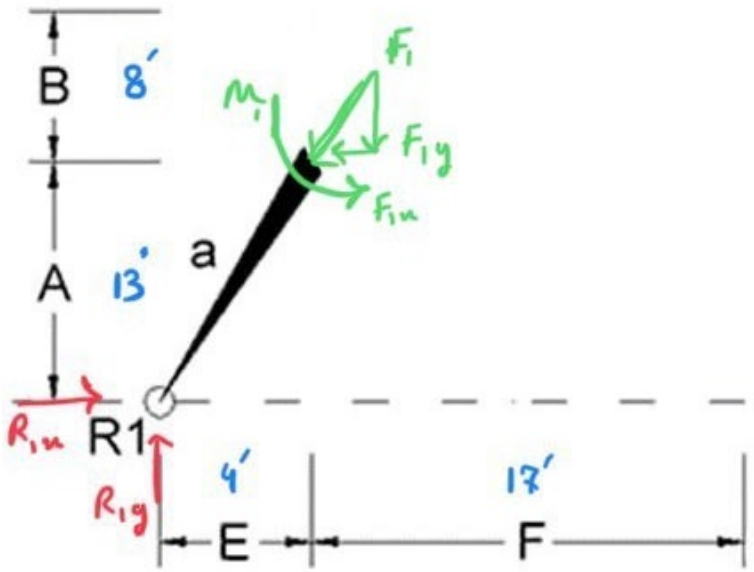
FBD of whole structure:

$\sum F_x = 0 \longrightarrow R_{1x} - R_{2x} = 0$

$\longrightarrow R_{1x} = \boxed{R_{2x} = 12.476}$

Provide the solution for the assignment – **HW8**

- Solution:



FBD:

$\sum F_x = 0 \longrightarrow R_{1x} - F_{1x} = 0 \longrightarrow F_{1x} = R_{1x} = \boxed{12.476}$ kips

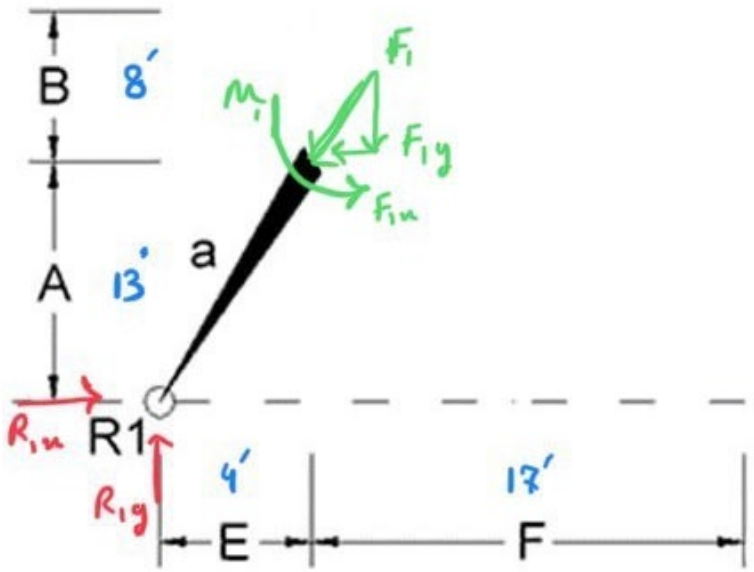
$\sum F_y = 0 \longrightarrow R_{1y} - F_{1y} = 0 \longrightarrow F_{1y} = R_{1y} = \boxed{17.334}$ kips

$F_1 = \sqrt{F_{1x}^2 + F_{1y}^2} = \sqrt{12.476^2 + 17.334^2} = \underline{\underline{21.35 \text{ kips}}}$

Axial Force in member: Compression

Provide the solution for the assignment – **HW8**

- Solution:



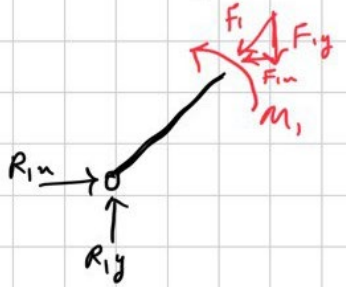
$\Sigma M_{@1} = 0$

$\rightarrow F_{1y} \times E - F_{1x} \times A - M_1 = 0$

$17.334 \times 4 - 12.476 \times 13 - M_1 = 0$

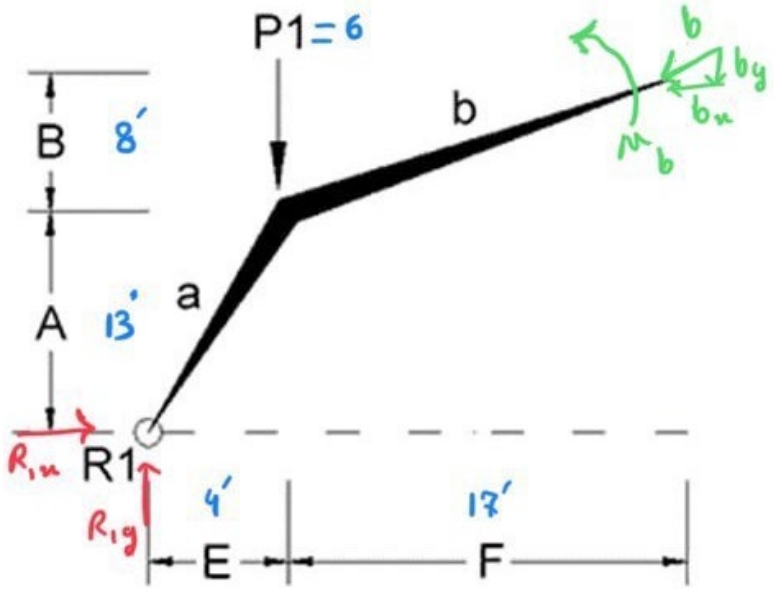
$\rightarrow M_1 = -92.852$ kips.Ft

The negative value indicates our initial assumption was not right, so we should flip the direction



Provide the solution for the assignment – **HW8**

- Solution:



FBD :

$\sum F_x = 0 \longrightarrow R_{1x} - b_x = 0 \longrightarrow b_x = R_{1x} = 12.476$ kips

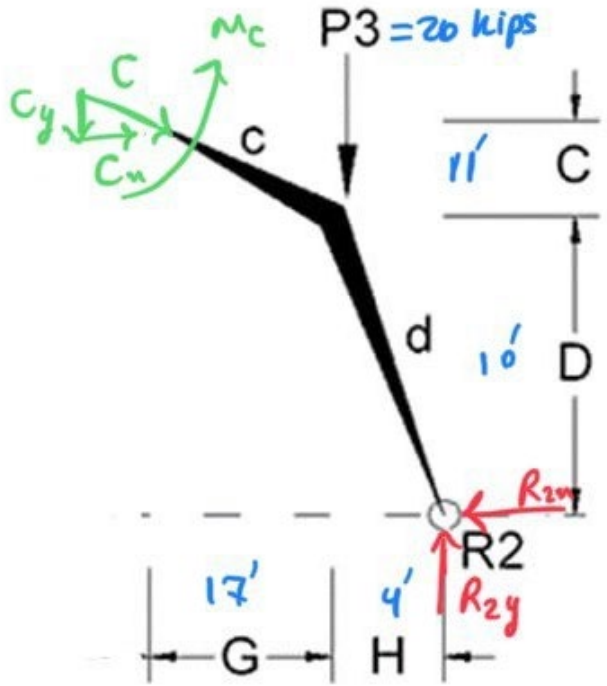
$\sum F_y = 0 \longrightarrow R_{1y} - P_1 - b_y = 0 \longrightarrow 17.334 - 6 - b_y = 0$

$\longrightarrow b_y = 11.334$ kips

$b = \sqrt{b_x^2 + b_y^2} = \sqrt{12.476^2 + 11.334^2} = 16.855$ kips

Compression

Provide the solution for the assignment – **HW8**



FBD Right part:

$\sum F_x = 0 \rightarrow \quad C_x - R_{2x} = 0 \rightarrow C_x = R_{2x} = \boxed{12.976}$ kips

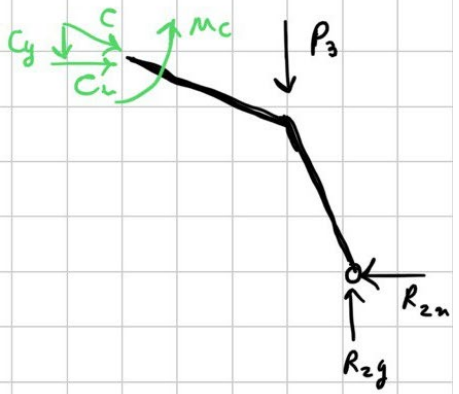
$\sum F_y = 0 \rightarrow \quad -C_y - P_3 + R_{2y} = 0 \rightarrow -C_y - 20 + 28.667 = 0$

$\rightarrow C_y = 8.667$

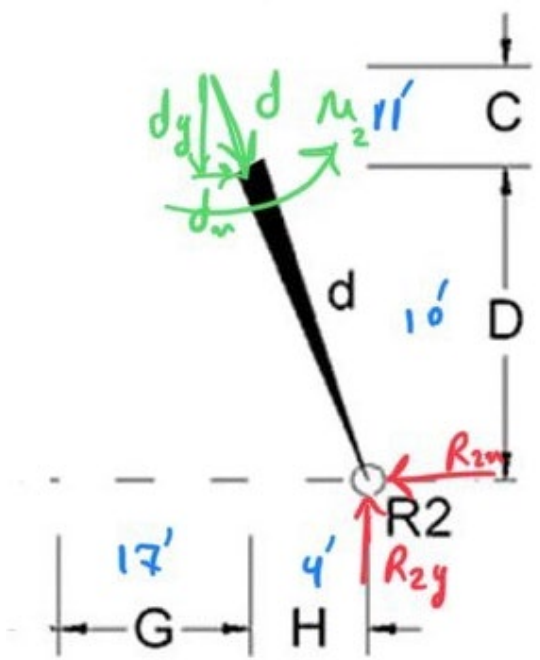
we should flip the direction

$C = \sqrt{C_x^2 + C_y^2} = \sqrt{12.976^2 + 8.667^2}$

$\rightarrow C = \boxed{15.19}$ kips



Provide the solution for the assignment – **HW8**



FBD:

$\Sigma F_x = 0 \longrightarrow d_x - R_{2x} = 0 \longrightarrow d_x = R_{2x} = \boxed{12.476}$ kips

$\Sigma F_y = 0 \longrightarrow R_{2y} - d_y = 0 \longrightarrow d_y = R_{2y} = \boxed{28.667}$ kips

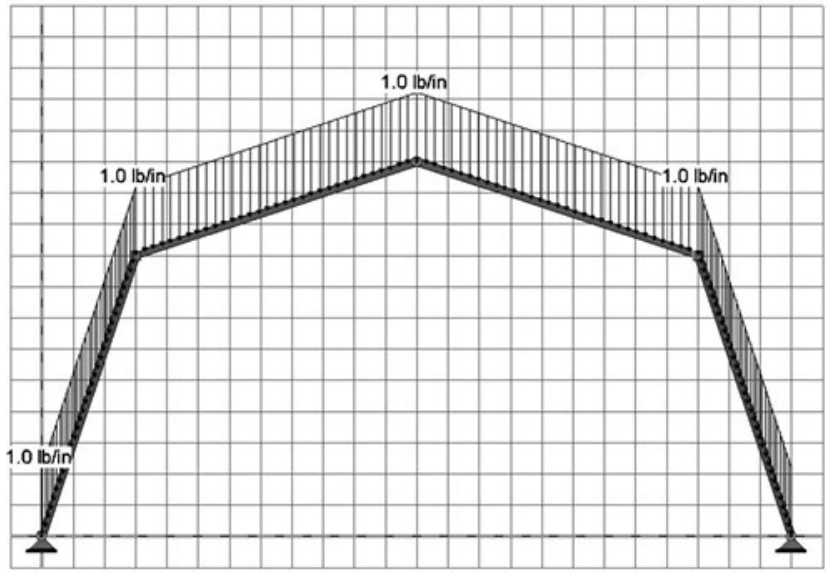
$d = \sqrt{d_x^2 + d_y^2} = \sqrt{12.476^2 + 28.667^2} = \boxed{31.26}$ kips

$\Sigma M_{@2} = 0 \longrightarrow d_x \times 10 - d_y \times 11 - M_2 = 0$

$12.476 \times 10 - 28.667 \times 4 - M_2 = 0$

$\longrightarrow \boxed{M_2 = 10.092}$ kips-Ft

Lab: 3-Hinged Arches



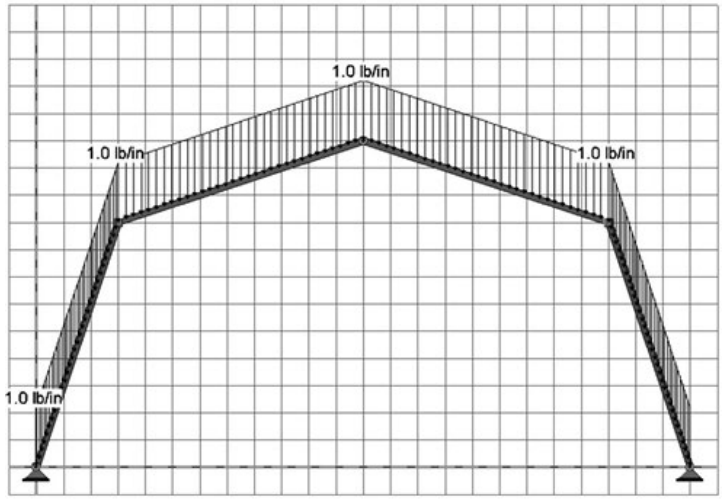
Description

This project finds the reactions and moments of a three-hinged arches.

Goals

To observe the end thrust behavior of a three-hinged arch.
To calculate the end reactions of the arch.
To calculate the moment at the knee.
To find the geometry of a catenary arch.

Lab: 3-Hinged Arches



Procedure

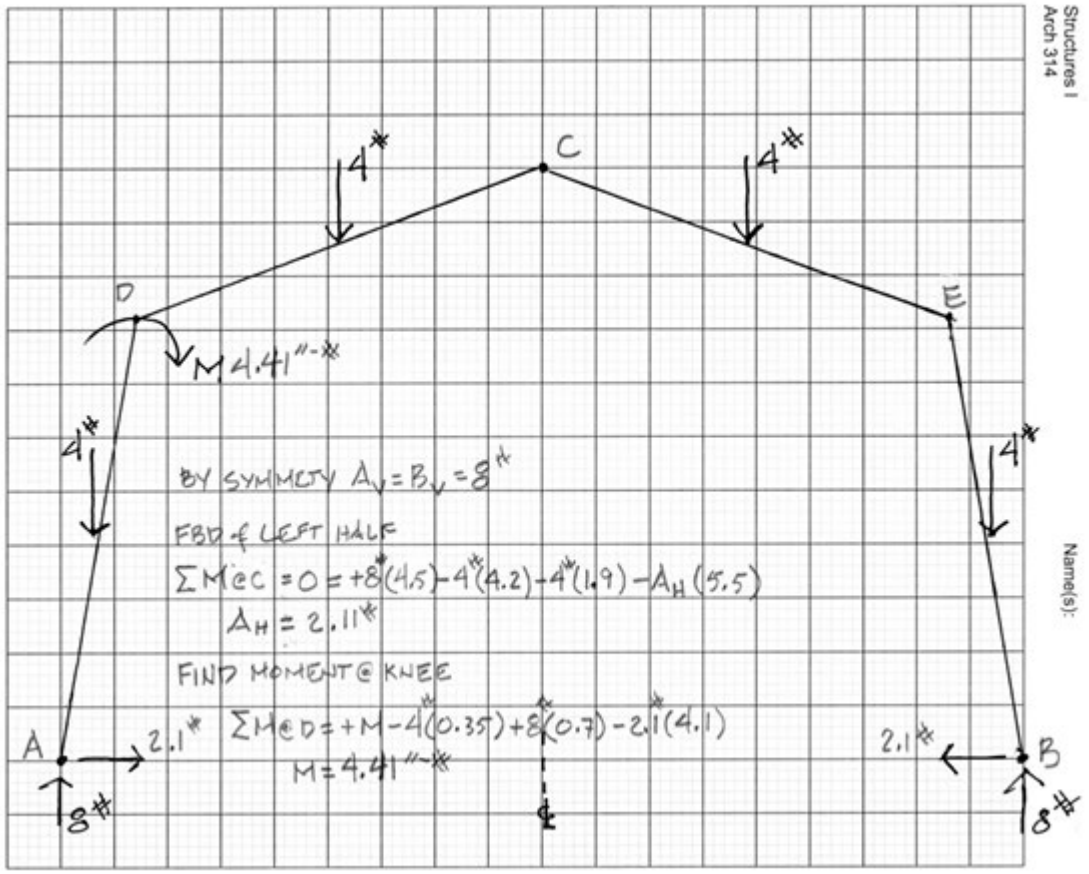
Part 1

1. Adjust the 3-hinged arch model on graph paper to have a 9” span.
2. Copy the geometry onto graph paper to determine the dimensions – the member lengths should be about 4” each.
3. Assume a uniform vertical load of 1 pound / inch on the length of each member (like a selfweight). Find and locate the resultant forces on your drawing.
4. Calculate the end reactions.
5. Calculate the peak moment at the knee.

Part 2

6. Next use the string to find a funicular shape with the same span.
7. Copy the new geometry onto the graph paper (overlaid on the original arch) to determine the dimensions.
8. Segment the arch into four symmetric sections.
9. Calculate the end reactions.
10. Calculate the peak moment at the knee.

Lab: 3-Hinged Arches



PART 1

VERTICAL REACTIONS - BY SYMMETRY

$\Sigma F_V = 16 - R_1 - R_2 = 0$

$R_1 = R_2 = \boxed{8^{\#}}$

FBD LEFT SIDE

$\Sigma M_{@} = 0 = 8^{\#}(4.5") - H(5.5) - 4(4.2) - 4(1.9)$

$H = \boxed{2.1^{\#}}$

RIGHT SIDE BY SYMMETRY

$M_{@\,KNEE} = 8(0.7) - 2.1(4.1) - 4(0.35) + M = 0$

$M = \boxed{4.41"\text{-}\#}$

PART 2

AGAIN VERTICAL REACTIONS BY SYMMETRY

$R_V = \boxed{8^{\#}}$

FBD LEFT SIDE

$\Sigma M_{@} = 0 = 8(4.5) - 5(3.5) - 3(1.2) - H(6.3)$

$H = \boxed{2.3^{\#}}$

$M_{@\,KNEE} = 8(2) - 2.37(4.6) - 5(1) - M = 0$

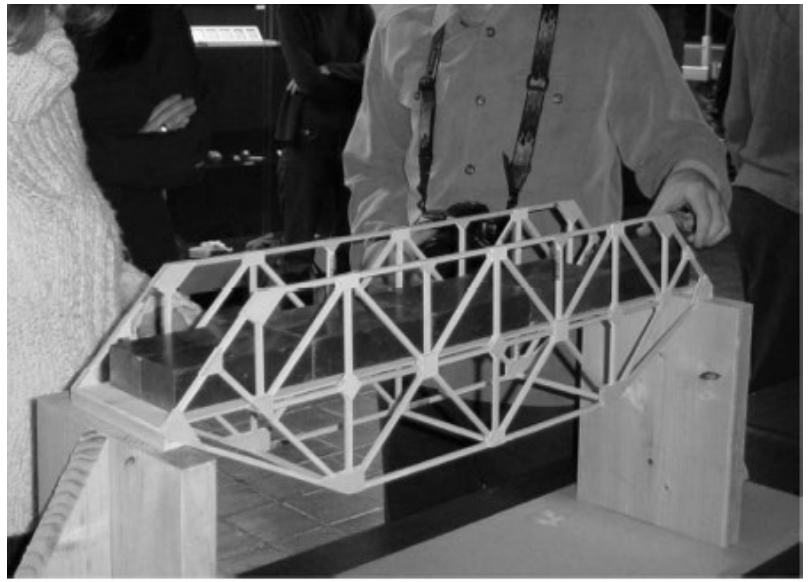
$M = \boxed{0.1 \approx 0}$

Bridge Project

FEEDBACKS + Challenges

Span=160 ft (scaled = 30 in)
Max. Depth = 53 ft (10 in)
Max. Deck = 8 in (1/8 in thick)

Max Weight = 68k (4 oz)
Material = wood + glue



Thank you.

Any question?

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