MECHANICS LAB
AM 317

EXP 9
TWO-PINNED ARCH

I. OBJECTIVES

I.1 To explore the relationship between the loads and the horizontal reaction force in a two-pinned arch.

I.2 To determine the horizontal thrust force and reaction influence lines for a point load moving across a two-pinned arch.

I.3 To determine the horizontal thrust force for a uniformly distributed load on a two-pinned arch.

Figure 1 St. Louis Arch

II. INTRODUCTION AND BACKGROUND

The main advantage an arch has over a beam, is that it can carry a much larger load. Historically arches were important because they could be constructed using small, easily carried blocks of brick or stone rather than using a massive, monolithic stone beam or lentil. Romans used the semicircular arch in bridges, aqueducts, and in large-scale architecture. In most cases they did not use mortar, relying simply on the precision of their stone finish. When an arch is loaded by gravity forces, the pressure acts downward on the arch and has the effect of compressing it together instead of pulling it apart. A free-body diagram of the arch supports shows the arch requires both horizontal and vertical reaction

forces (Figure 2). This horizontal reaction force, called thrust, can cause the arch to collapse if it is not properly restrained.

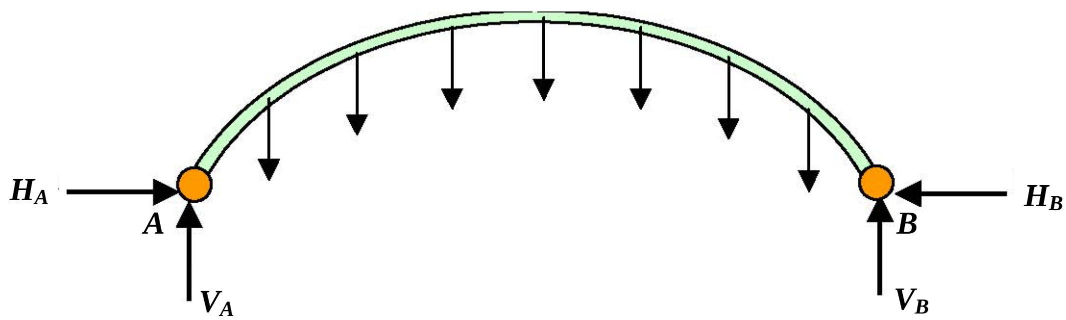

Figure 2 Free-Body Diagram of Two Hinged Arch

One of the disadvantages of the arch resisting loads in compression is the possibility that the arch may buckle. Any practical arch design would include analysis involving stress, deflection and buckling. To perform such analysis, reaction forces, shear and moment diagrams are needed for a given load case. Since the arch is indeterminate, having more unknown reactions forces than equilibrium equations, methods such as the flexibility method are required to determine the reaction forces.

III. EQUIPMENT LIST

Structures test frame

Digital force display and power supply

Aluminum arch

Hangers and weights (stored in the test station drawer)

Scale

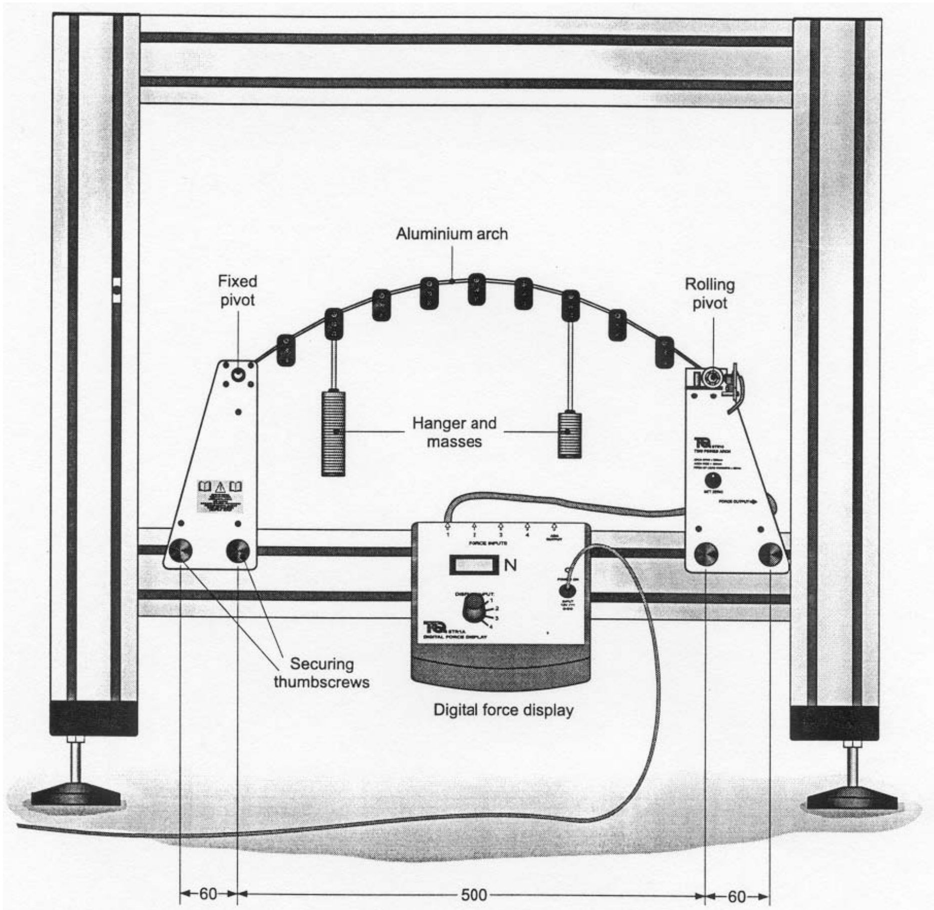

Figure 3 Test Frame and Two Hinged Arch Set-Up

IV. PROCEDURE

- **Visually inspect all parts of the test frame (including electrical leads) for damage or wear.**
- **Check that electrical connections are correct and secure.**
- **Check that all components are secured correctly and fastenings are sufficiently tight.**
- **Check the four securing thumbscrews are in the position shown in Figure 3 and the rolling pivot on the right is gently resting against the load cell.**
- **Make sure the digital force display is on and the force transducer is connected from the socket marked 'Force Output' on the right support, to the Digital Force Display 'Force Input 1'.**

- **Carefully zero the force meter using the dial on the right-hand side support. Gently apply a small load with a finger to the crown of the arch and release. Zero the meter again if necessary.**

  <u>NEVER</u> apply excessive loads to any part of the equipment.

PART A

The first experiment is to measure the horizontal thrust force H_B for a single load that is placed at increasing distances from the left support. A theoretical equation for the horizontal thrust force for a given load P at location x, is given below:

$$H_B = \frac{5Px}{8rL^3}(L^3 + x^3 - 2Lx^2) \qquad \textbf{9.1}$$

where:

- H_B **= the horizontal thrust reaction at B (N)**
- P **= the load (N)**
- L **= the span of the arch (m)**
- x **= the load location, distance from the left-hand side support (m)**
- r **= the Rise of the arch (m)**

IV.A1 Measure the necessary dimensions of the two-pinned arch and record the data.

IV.A2 Apply a 500-g pre-load in the mid-span.

IV.A3 Adjust the “set zero” control on the right support so that the digital force reads zero.

IV.A4 Apply a 100-g load to the left most hanger and record the thrust force. Moving the 100-g load to the remaining hangers and record the thrust force for each location. The horizontal thrust shown on the digital force display has units of Newton.

IV.A5 Repeat Steps A1 through A4 for a 500-g load.

PART B

The second part of the experiment involves determining the horizontal thrust force for a uniform or distributed load w. The equation for the thrust force is

given in Eq. (9.2).

$$H_B = \frac{wL^2}{8r} \qquad \textbf{9.2}$$

where:

- H_B **= the horizontal thrust reaction at B (N)**
- w **= the intensity of uniform distributed loads (N/m)**
- L **= the span of the arch (m)**
- r **= the Rise of the arch (m)**

IV.B1 Make sure the pre-load of Part A is removed.

IV.B2 Adjust the "set zero" control on the right support so that the digital force reads zero.

IV.B3 Apply 70 g on each of the nine hangers (total of 630 g) and record the thrust force. Repeat the procedure with 140 g on each hanger (1260 g total).

V. REPORT

V.1 Plot the experimental and theoretical thrust force determined in Part A of the experiment.

V.2 Compare the theoretical and experimental thrust force for the uniformly loaded arch. Present these results in the Results section.

VI. SELECTED REFERENCES

Megson, T.H.G., <u>Structural and Stress Analysis</u>, 2nd edition, Butterworth-Heinmann, 2005, pp. 133-149.

Timoshenko, S.P., Young, D.H., <u>Theory of Structures</u>, 2nd edition, McGraw Hill Co., New York, 1965.

Table I Arch data

Rise of arch, r (m)	
Length of arch, L (m)	

Table II Weight data

Added mass	100 g	500 g
Hanger mass		
Total mass		
Total load (N)		

Table III Data for a point load moving across a two-pinned arch

Load location x (mm)	Measured thrust force for 100 g load (N)	Measured thrust force for 500 g load (N)
0	0	0
50		
100		
150		
200		
250		
300		
350		
400		
450		
500	0	0

Table IV Data for a uniformly distributed load

Total mass (g)	Total mass of hangers (g)	Uniform distributed load (N/m)	Measured thrust force (N)	Calculated thrust force (N)	% Error
630					
1260					