Arch Structures

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ENCE 353, Fall Semester 2025

October 14, 2025

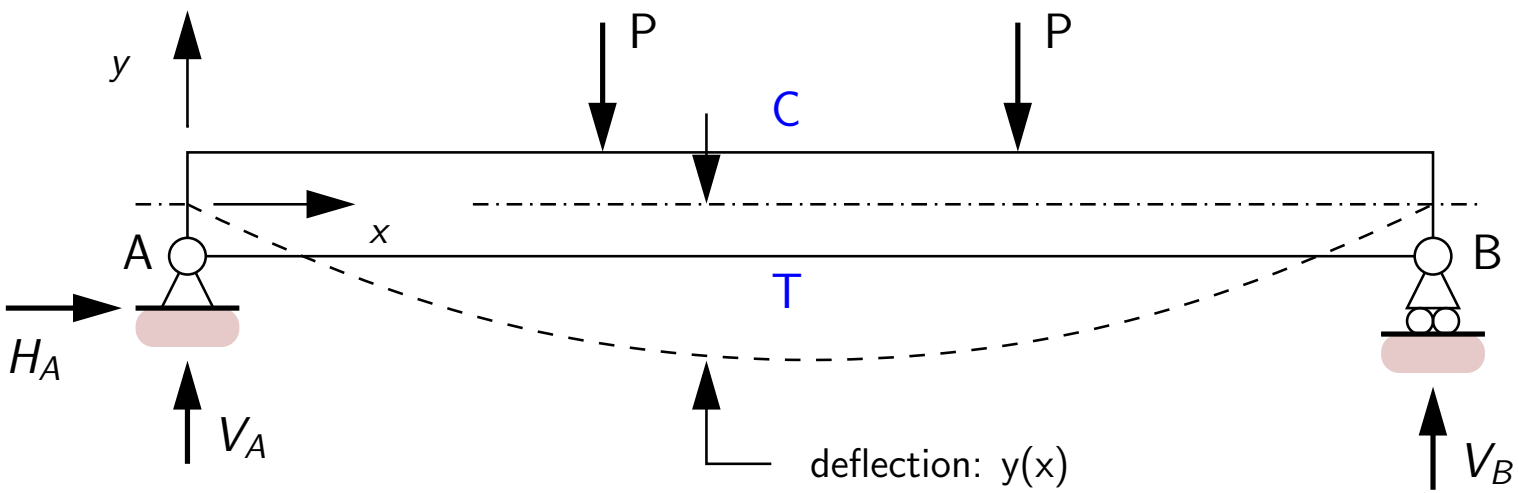
Overview

Motivation for Arch Structures

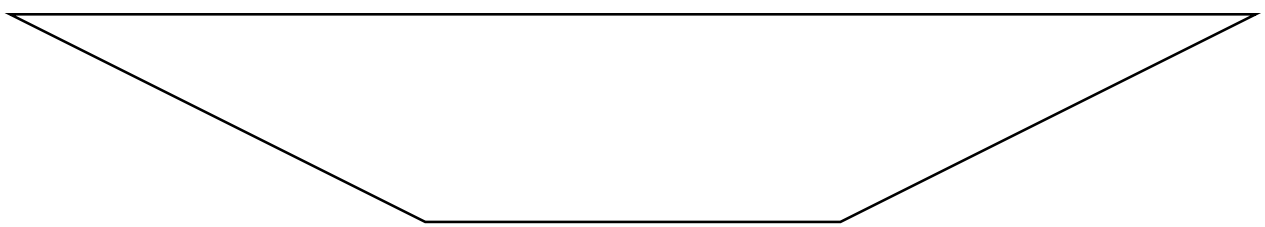
Motivation for Arch Structures

Reminder: Flexural behavior of simply supported beam ...

Experimental Setup

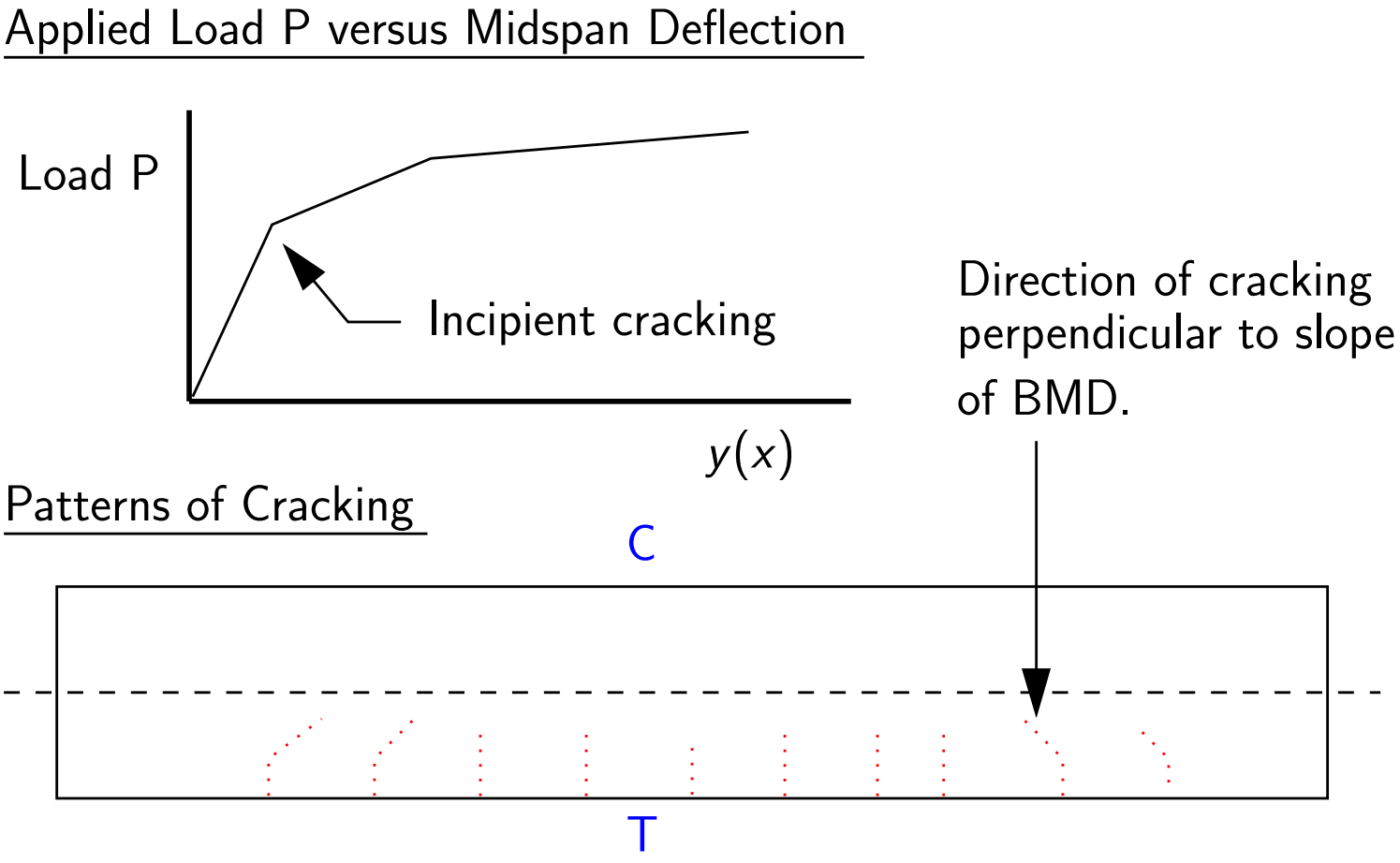


Bending Moment Diagram (BMD)



Motivation for Arch Structures

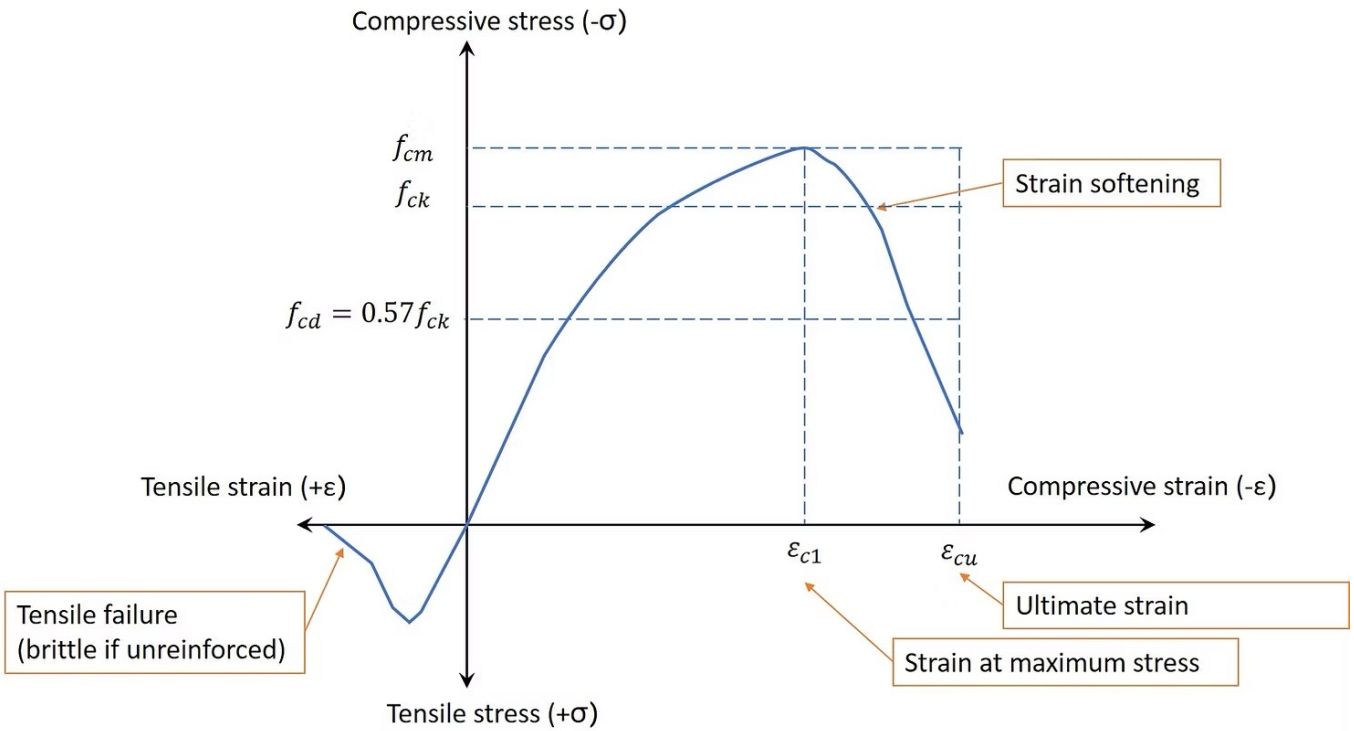
Reminder: Flexural behavior of simply supported beam ...



Motivation for Arch Structures

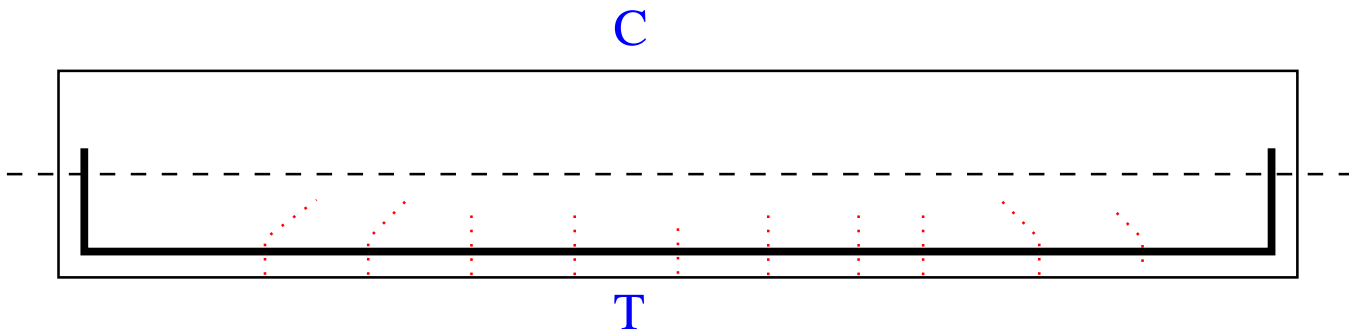
Stress-Strain Behavior of Concrete:

- Concrete materials have an ability to carry loads in compression but are very poor at carrying loads in tension.



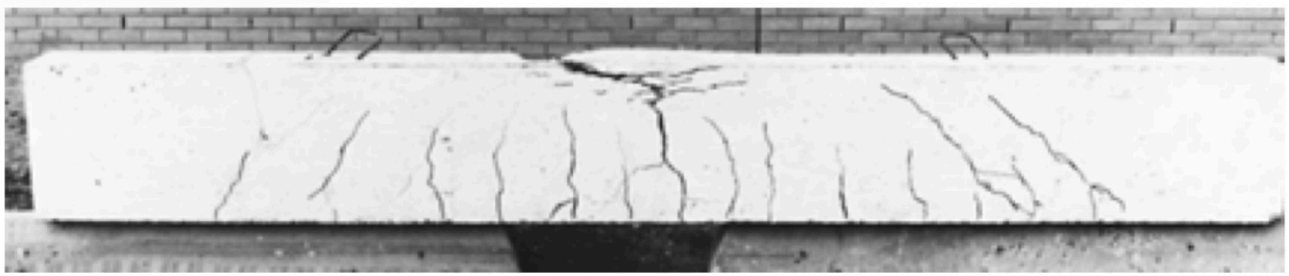
Motivation for Arch Structures

Strategy 1: Reinforced Concrete Beam (post- 1850)



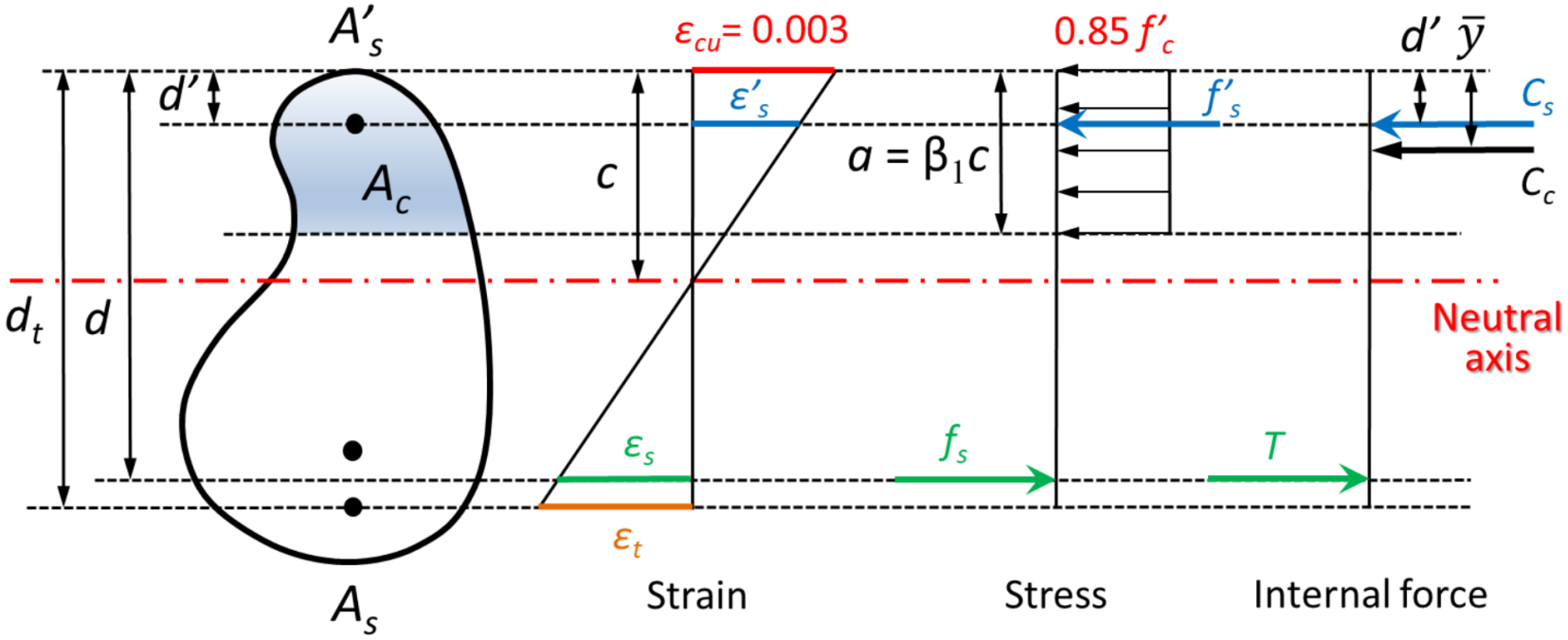
Steel bars strengthen concrete and resist tensile stress.

Compression and Tension Failure:



Motivation for Arch Structures

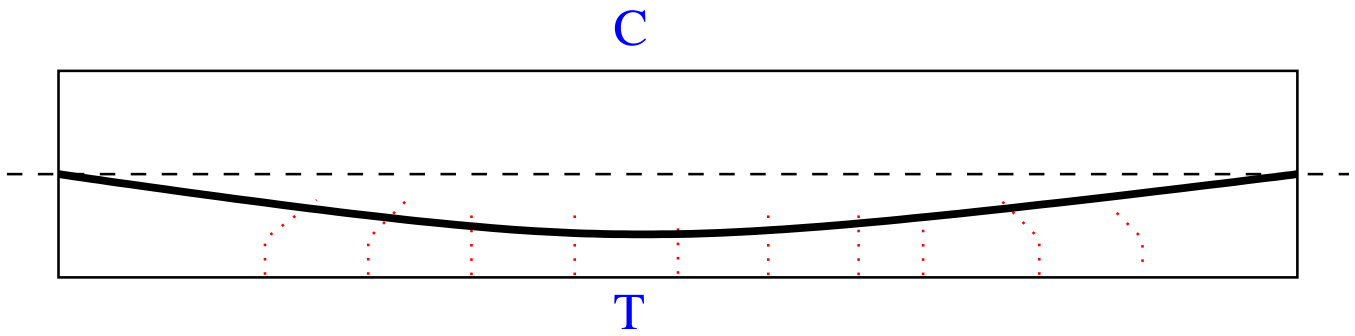
Preview to Analysis:



Maximum strain at the extreme concrete compressive fiber is assumed to be $\eta_c = 0.003$.

Motivation for Arch Structures

Strategy 2: Prestressed Beam (post-1960)

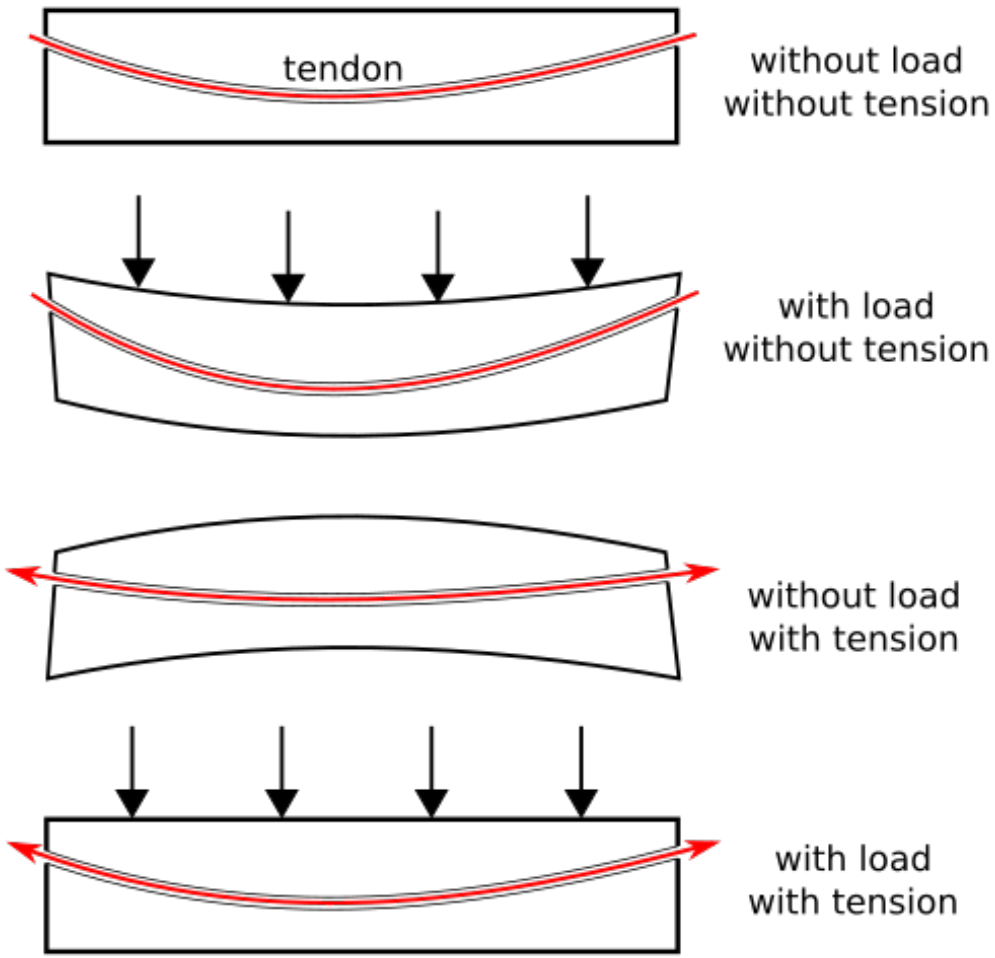


Design Procedure:

- High strength tendons are threaded through the concrete and then pulled tight.
- This puts the beam in compression (and reduces/eliminates the tensile stresses.
- Cable profiles can be designed to counter bending moments due to self weight.

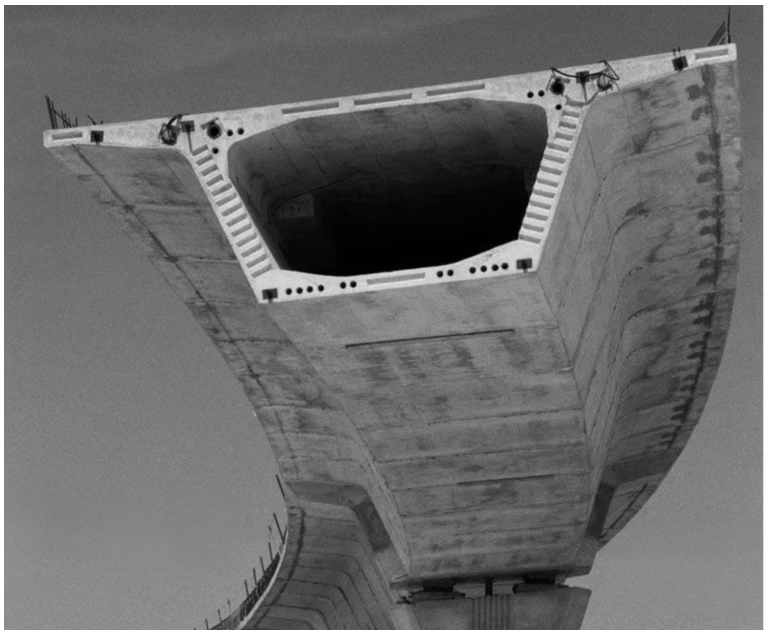
Motivation for Arch Structures

Post-Tensioned Concrete:



Motivation for Arch Structures

Application: Prestressed Concrete Box-Girder Bridge ...

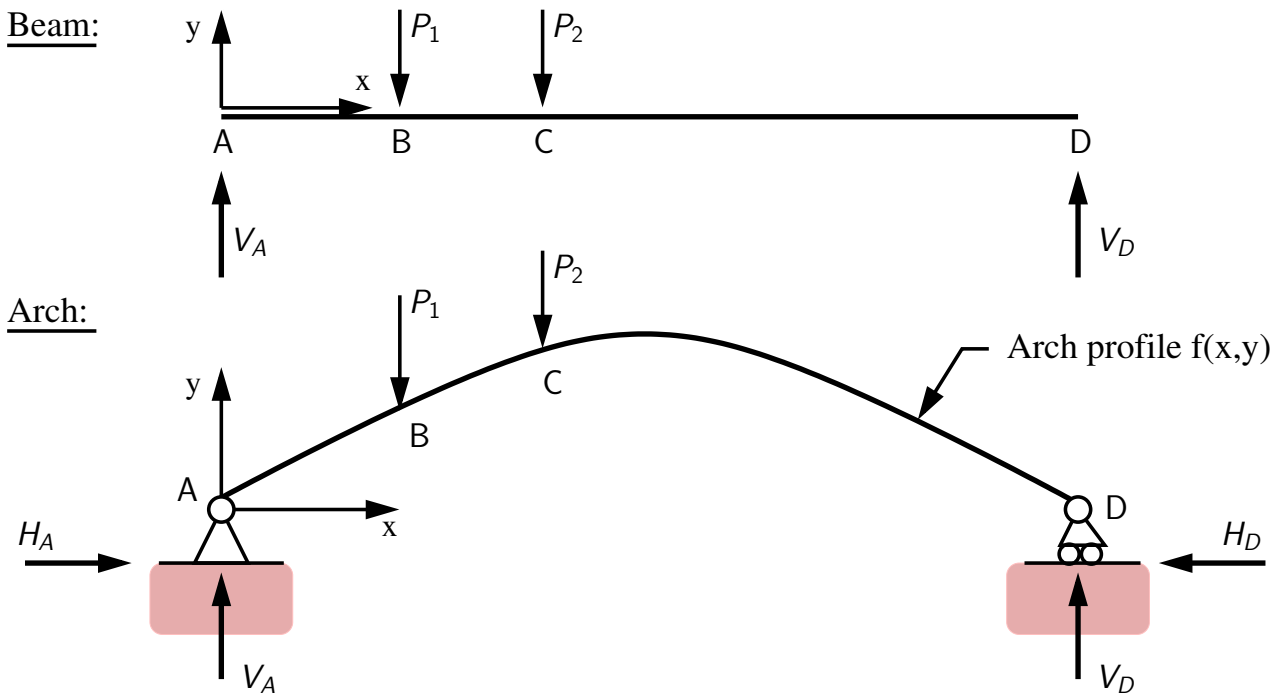


Benefits of Prestresssing:

- Increased load capacity; improved resistance to cracking.
- Longer beam spans are feasible.

Motivation for Arch Structures

Strategy 3: Remove constraint that beam element is straight !!!



Within the segment A-B:

- For the beam: $M(x) = V_A x$.
- For the arch: $M(x, y) = V_A x - H_A y$.

Motivation for Arch Structures

Main Takeaway:

- We can reduce bending moments by removing the constraint that beams are straight.
- But now we need to deal with the horizontal reactions H_A.

Implicit Assumption:

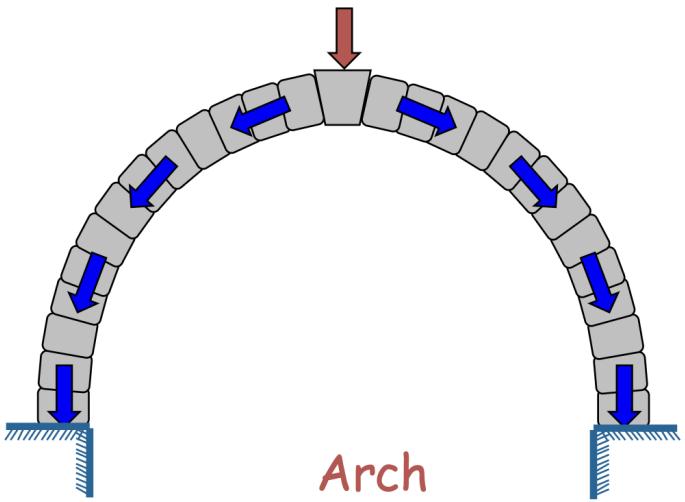
- Arch supports will not move ...

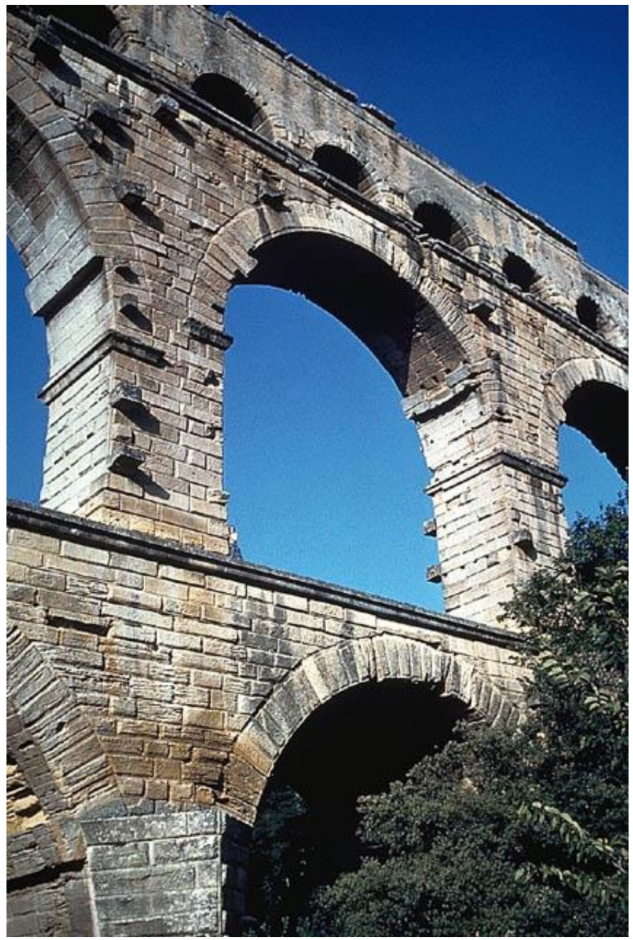
To see what happens when things go wrong:

- Google: bridge collapse taiwan.

Motivation for Arch Structures

Design and Analysis:



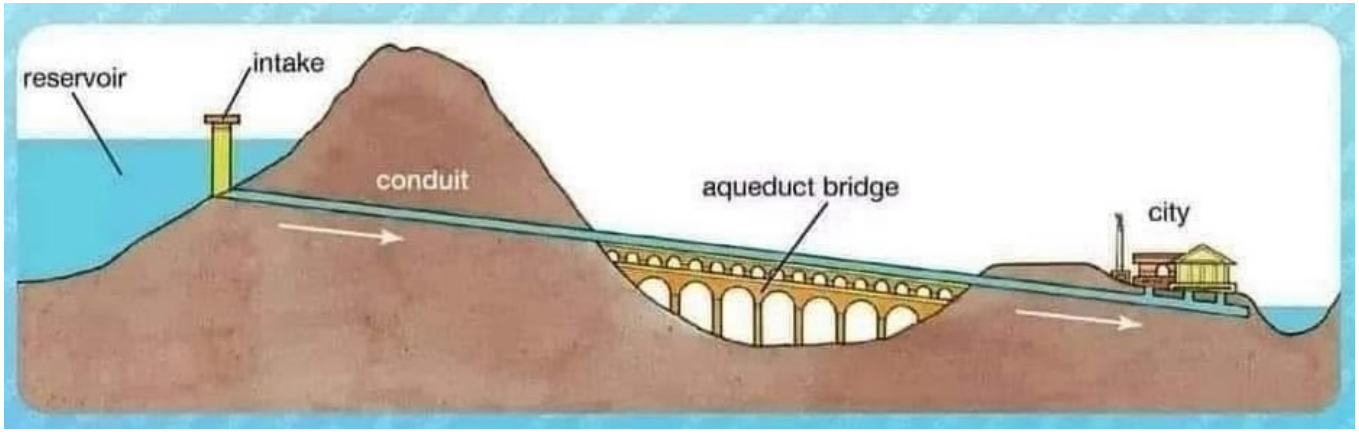


Design objective: Structure needs to work and be aesthetically pleasing!!
Analysis objective: What shape should the arch be so that forces can be transferred to the foundation through compression mechanisms alone?

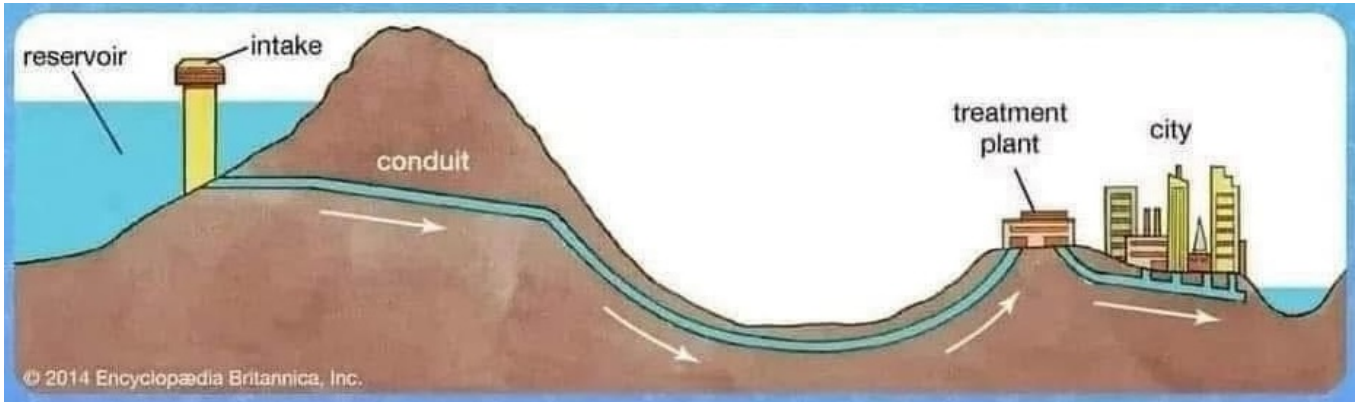
Brief History

History of Arch Structures

Basic Problem: Here's why the Romans built Aqueducts ...



Today we would use a pump to get the job done ...



History of Arch Structures

Aqueduct: Pont du Gard (circa first century) ...

Transported water approximately 50 km.

History of Arch Structures

Roman Aqueduct: of Segovia, Spain (circa 100-120 AD)

Transported water 10 miles during the first Century.

History of Arch Structures

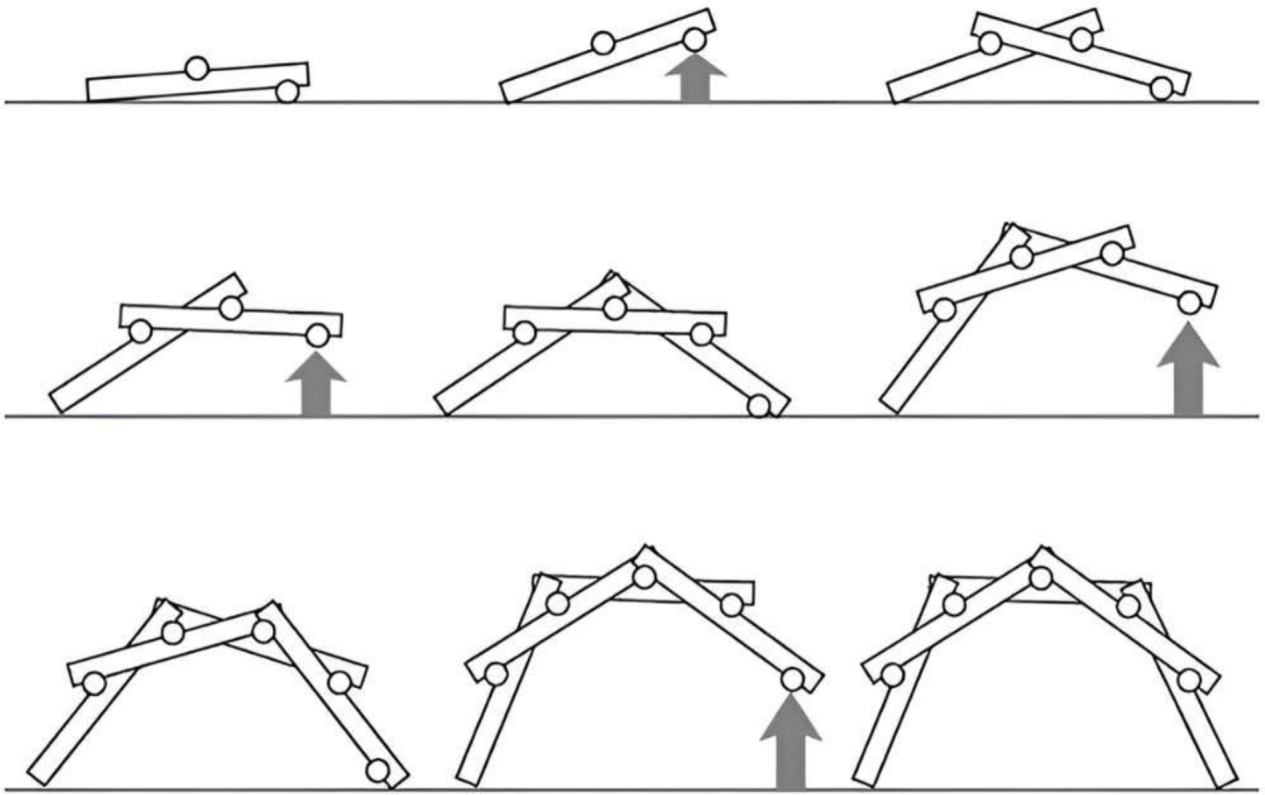
Example: Leonardo Da Vinci Bridge (1500s)

- Bridge is held together by its own weight without requiring any ties or connections.
- Bridge members interlock and tighten together through element shear and bending.

History of Arch Structures

Example: Leonardo Da Vinci Bridge (1500s)

Designed for Quick Assembly in Military Applications:



Case Studies

Key Bridge: Georgetown-Reston (1923)

Case Studies

Bixby Bridge: California Coastline (1932)

Case Studies

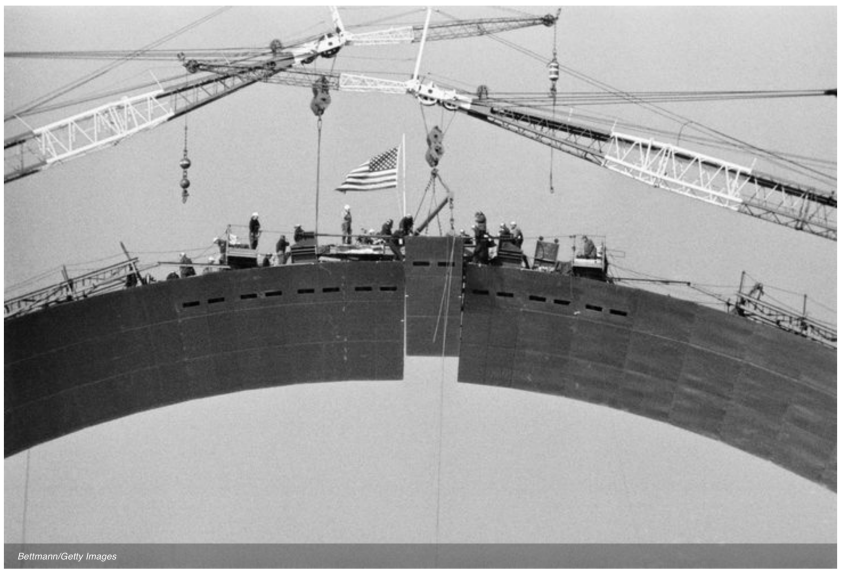
St Louis Gateway Arch:

Rough timeline of development:

- Initial planning occurred in the mid-1930s.
- Design competition held in the late 1940s and early 1950s.
- Construction began in 1963; completed 1965.

Case Studies

St Louis Gateway Arch: Construction ...



Case Studies

Principal Architect: Eero Saarinen (1910-1961)

Note: Saarinen also designed the terminal building at Dulles Airport.

Case Studies

Frederick Douglass Memorial Bridge: Washington DC (2017-2022).