Structural System in Architecture
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Lecture No -26
Introduction to Arch

Welcome to the NPTEL online certification course on Structural Systems in Architecture, we are in the module 6 i.e., week 6, lecture 26.

Concepts Covered

- Definition and Concept of an Arch
- Historical Examples
- Parts of a Masonry Arch
- Types of Arch
- Masonry Arch: Geometric Forms
- Classification of Arch: Structural Behaviour
- Function of an Arch

Learning Objectives

- To outline the various parts of an Arch.
- Illustrating the geometric formation of masonry arch.
- To classify the Arches based on the structural behavior.

Definition

In Engineering and Architecture, a curved member that is used to span an opening and to support loads from above is commonly known as an Arch**.**

In history of architecture, arches have been used as a main structural component. Due to its unique compressive mechanism of resisting load, arches can be categorized as special class of structural systems. They are capable of spanning long distances while supporting significant weight, which makes them highly efficient and visually powerful structural systems.

Concept of an Arch

Historically arches were built with masonry and were commonly used to span large distances. As stone is quite a durable material under compression. Many impressive examples of early masonry arches exist to this day

Figure 1 Stone arch

Figure 2 Brick arch

Historical Examples

Figure 3 Colosseum (70-80AD)

Colosseum

The Colosseum (70-80AD), horseshoe-shaped Roman Amphitheater is supported by a sequence of radial-vaulted structures capable of incorporating flights of steps for the incoming and outgoing row of spectators.

Pont du Gard

Figure 4 Pont du Gard (40-60AD)

Roman aqueduct Pont du Gard (40-60AD) shows the supporting system through three vertical layers of circular arches.

Roman Arch

Figure 5 Roman Arch (semi-circular)

Gothic arch (1100-1400AD)

Figure 6 Gothic Arch (pointed)

Parts of a Masonry Arch

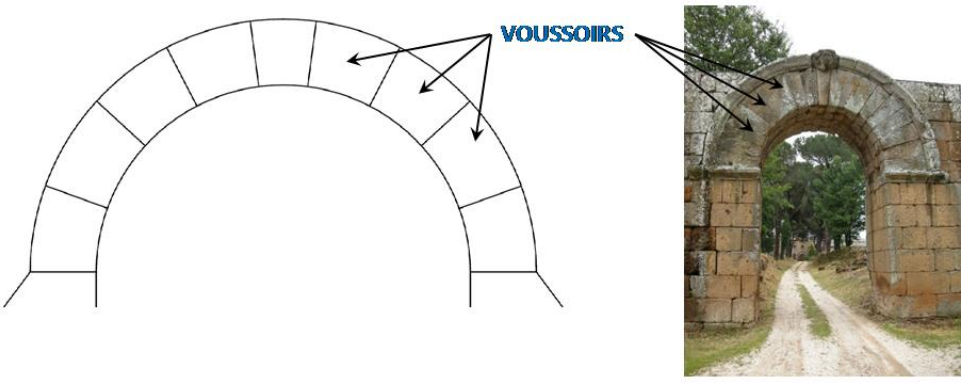


Figure 7 Voussoirs

Voussoirs are the wedge-shaped stones used in the construction of an arch.

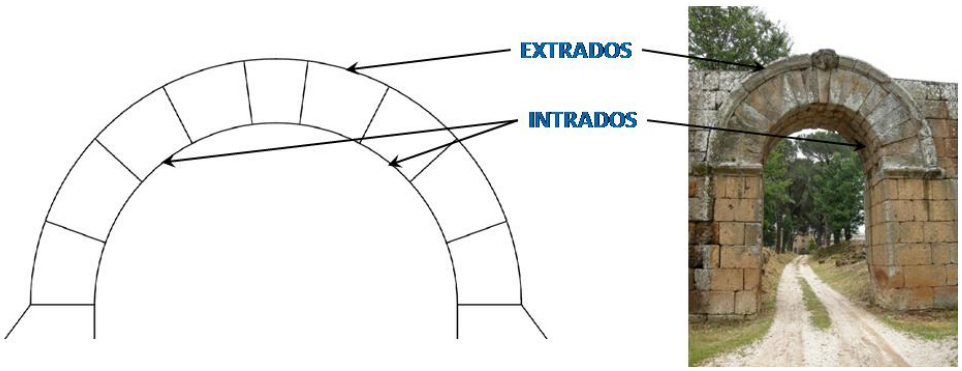


Figure 8 Extrados and Intrados

The lower or concave side of the voussoir is called the intrados whereas the upper or convex side is called the extrados of the arch.

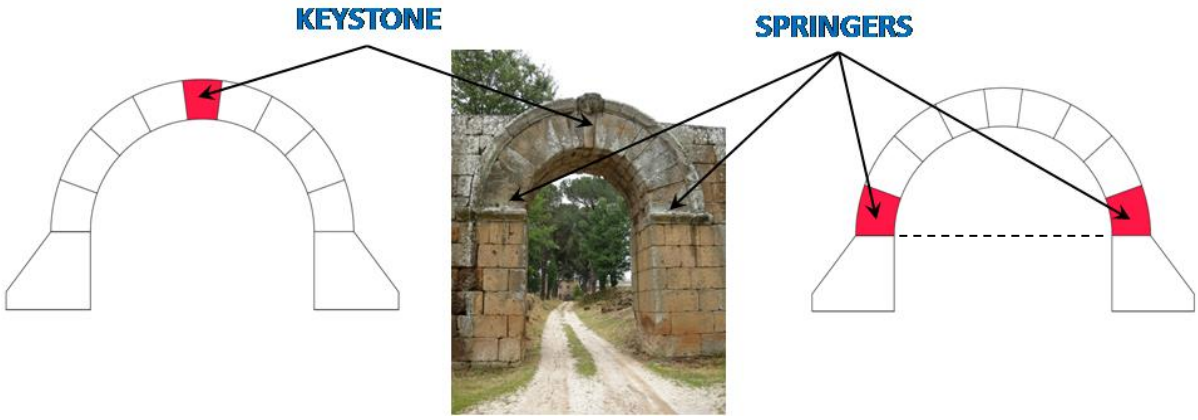


Figure 9 Keystone, springers, springer line

The central voussoir is called the keystone. The lowest voussoirs are called springers. The line between two opposite springers is known as the springing line.

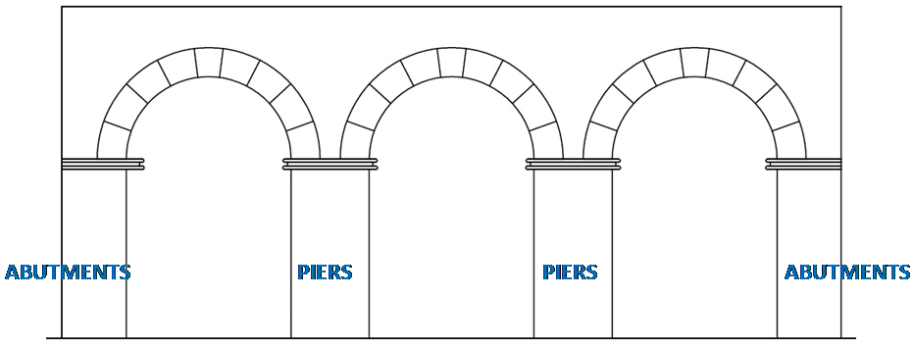


Figure 10 Abutments and piers

The end supports to which the load is transferred by the arch are called piers or abutments.

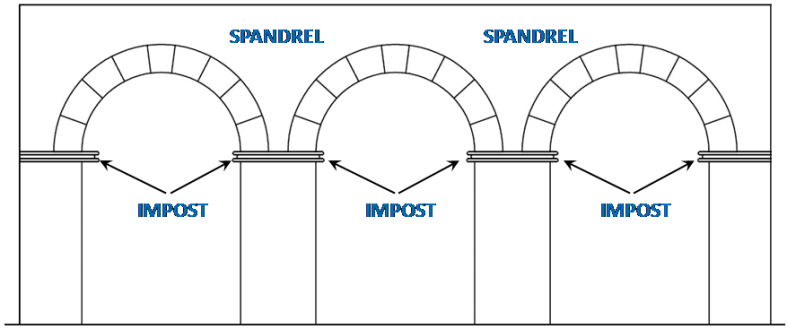


Figure 11 Spandrel and impost

The projecting block resting on top of the piers and serving as the base for the springer or

lowest voussoir is called impost. A triangular space, usually found above the pairs of two adjacent arches is called spandrel.

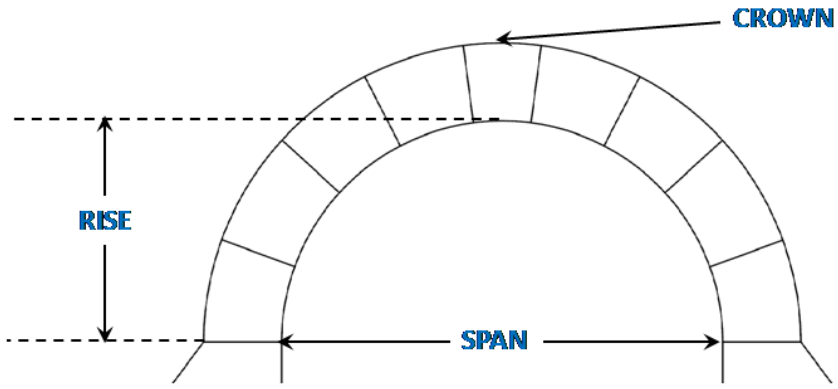


Figure 12 Rise, Span and Crown

The distance between the opposite springs is called the span of an arch. The height between the highest point of intrados above the line connecting the springer is called the rise of an arch. The highest point of the extrados is called the crown of the arch.

Types of Arch

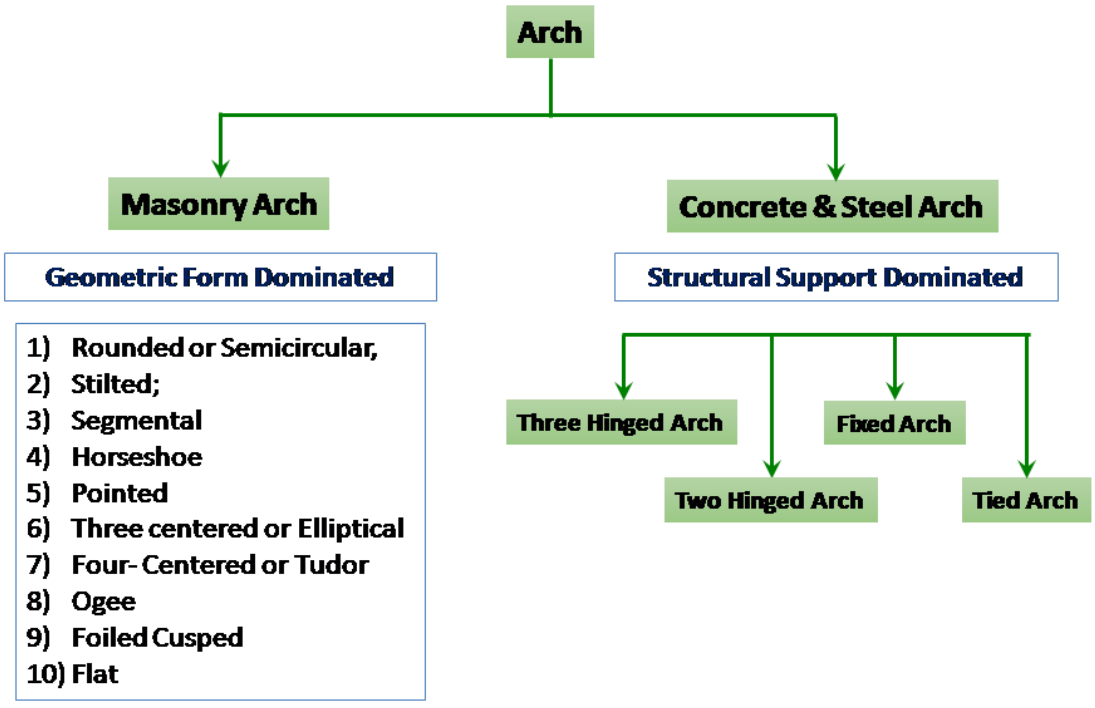
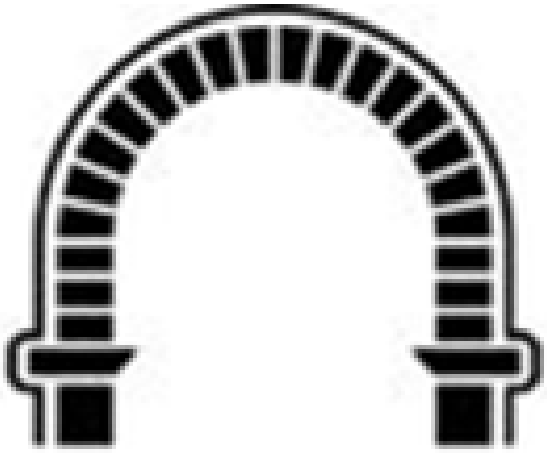


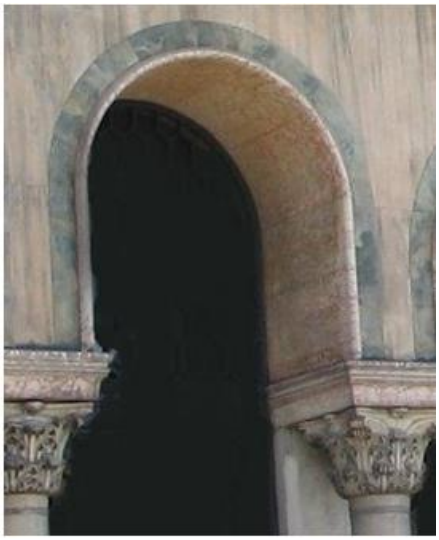
Figure 13 Types of arch

Masonry Arch: Geometric Forms

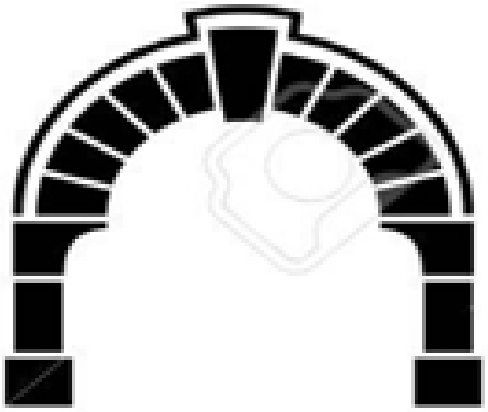
Rounded or Semi-circular

Stilted

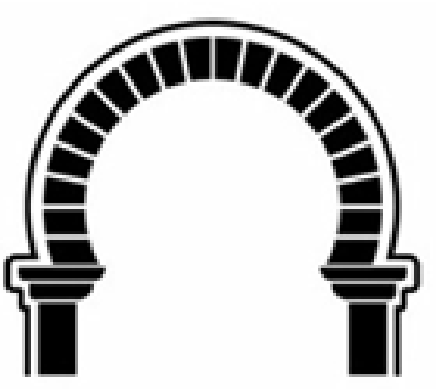




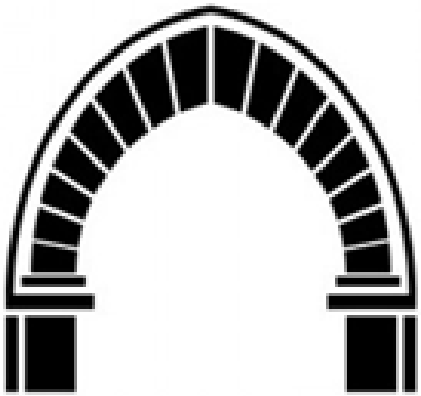
Segmental



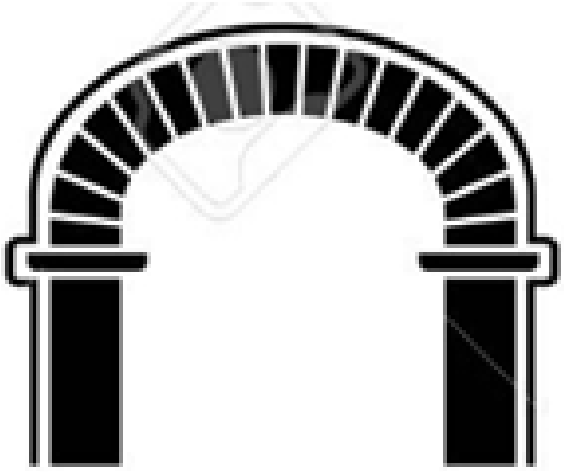
Horse-shoe



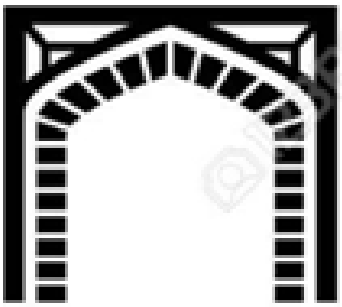
Pointed



Three-centered or Elliptical



Four-centered or Tudor

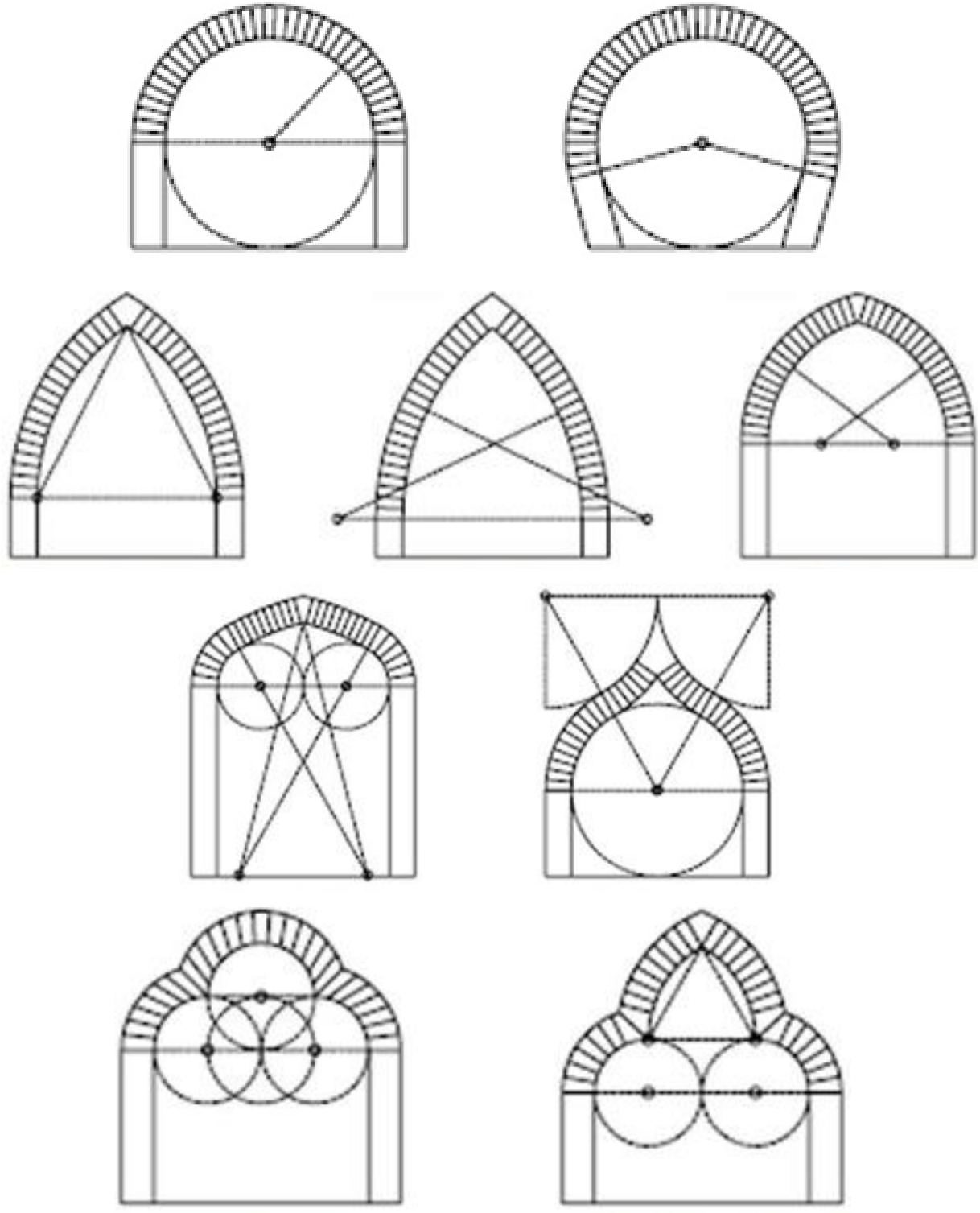


Ogee

Foiled Cusped

Flat

Masonry Arch: Geometric Forms



Classification of Arch as per Structural Behaviour

From the standpoint of the support conditions and structural behavior, arches are classified as follows:

(1) Three-Hinged - Hinges at the crown and abutment

(2) Two-Hinged - Hinges at the abutments only

(3) Fixed Arch- No Hinges, firmly fixed at the abutments

Three-Hinged Arches

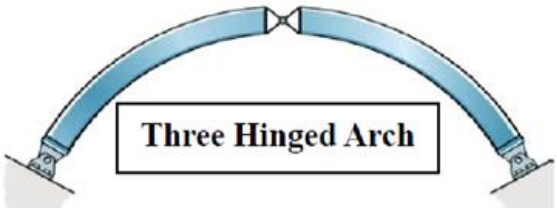


Figure 14 The Salginatobel Bridge, Schiers, Switzerland

Statistically Determinate structure: The elastic theory is not required for the analysis. Analysis of bending moment is much simpler. Appropriate for structures under slight horizontal movement. It is not affected by settlement or temperature changes. Mostly used in Bridges.

Two-hinged Arches

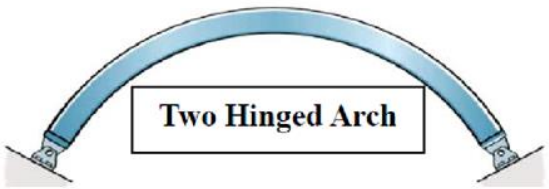
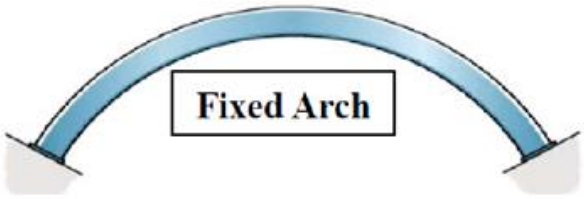


Figure 15 The Rainbow Arch at Niagara Falls

Statically Indeterminate structure: The elastic theory is essential for the analysis. It is indeterminate to the first degree. Interior stresses in the arch are dependent on its form and acts differently upon its various parts. These type of arches are more stiff w.r.t. three hinged

arches. It is not as rigid as a fixed arch; it is somewhat insensitive to settlement. Used in Bridges.

Fixed Arch



Statically Indeterminate structure: The elastic theory is essential for the analysis.
It is indeterminate to the third degree. Interior stresses in the arch are dependent in part on its change of form.

These type of arches are more stiff w.r.t. two-hinged arches. It is very insensitive to settlement. A fixed arch is often made from reinforced concrete. Used in Buildings.

Tied Arch

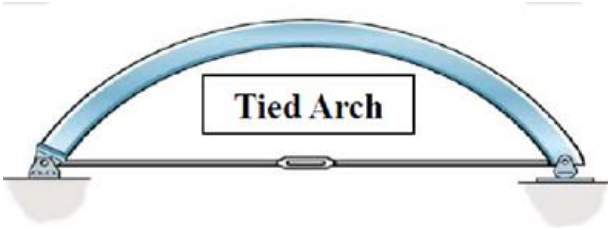


Figure 16 Toome Bypass, Northern Ireland

The springer level supports of two and three-hinged arches are tied. A tied arch allows the structure to behave as a rigid unit. The tie rod carries the horizontal component of thrust at the supports. It is also unaffected by relative settlement of the supports.

Functions of an Arch

- An arch is used to carry the weight of the portion of the structure above.
- The curvilinear arrangement of wedge-shaped masonry blocks mutually support each other and are finally supported at the end piers.
- Each part of an arch comes under pure compressive stress and eliminates tensile stress.
- It can span across a large area.

References

- **Structure as Architecture** By Andrew W. Charleson, Elsevier Publication
- **Basic Structures for Engineers and Architects** By Philip Garrison, Blackwell Publisher
- **Structure and Architecture** By Meta Angus J. Macdonald, Elsevier Publication

Conclusion

- Arch is one of the simple structural forms that can provide long-span solution.
- In history arch had been used in different geometry to support an opening.
- Introduction of hinge and fixity in concrete and steel arch provides various structural solutions.

Homework

Q1. Sketch a (i) Pointed Arch (ii) Segmental Arch (iii) Foiled Cusped Arch for a span 4 meter and rise 2 meter, by geometric construction