UNIT 4 MASONRY AND RCC ARCHES

Structure

4.1 INTRODUCTION

An arch is a curved structural component which bridges an opening in a structure and transfers superimposed loads through supports to the foundation.

Brick and stone masonry as well as plain cement concrete are very strong in compression whereas their flexural and tensile strength are nearly zero. Therefore, before the advent of steel and reinforced concrete, only wooden or bamboo straight beams were available for spanning an opening which were suitable for small spans because of their limited flexural strength.

Their durability was also limited due to environmental exposures.

Arch has an advantage over straight supporting member in the sense, that by dint of its shape, the transference of its superimposed load is mainly through compressive stresses – so much so that if the shape of an arch is the same as that of its bending moment diagram, the stress in the elements of the arch will be purely compressive.

About hundred years ago, masonry roofs were used to be arch shaped. The conical or spherical domes are nothing but three-dimensional curved or arch-shaped roofs, so that transmission of load is only through compression.

Another advantage of well bonded masonry arch is that a portion of load over an opening is transmitted to the foundation by arching action* through flanking walls.

* Explained in

Arches made of steel sections or of reinforced concrete may be of any shape and of any span as they are very strong in compression as well as in tension or in flexure.

Objectives

After studying this unit, you should be able to

- identify the different elements of a segmental arch,
- explain the types and detailing of brick masonry and stone masonry arches, and
- describe concrete and RCC arches.

4.2 GENERAL

The elements of an arch and its surroundings are denoted by various technical terms (Figure 4.1) as follows :

Figure 4.1 : Elements of a Segmental Arch

Voussoirs	**:**	Each wedge shaped unit of masonry forming an arch is called Voussoir.
Crown	**:**	It is the highest part of an arch.
Key	**:**	The voussoir at the crown is known as key.
Intrados	**:**	The internal surface of an arch is known as intrados or soffit.
Extrados	**:**	The external surface of an arch is known as extrados.
Spandril	**:**	This is a curved triangular space formed between the extrados and the horizontal surface through crown.
Springers	**:**	These are voussoirs at either ends of an arch.
Springing Line	**:**	A line joining the two ends (i.e. springing points) of an arch is termed as springing line.
Abutment	**:**	It is the end support of an arch.
Piers	**:**	The interior supports of an arch are called piers.
Skew Back	**:**	It is the surface of the abutment on which the arch rests.
Span	**:**	It is the clear horizontal distance between supports.
Rise	**:**	It is the vertical distance between the springing line and the highest point of intrados.

Other terms illustrated in Figure 4.1 are self explanatory.

SAQ 1

(a) Define an arch. What are the advantages in constructing arch in place of a lintel or a beam.

(b) Define the following : (i) Voussoirs, (ii) Extrados, (iii) Spandril, and (iv) Piers.

4.3 MASONRY ARCHES

A masonry arch is a mechanical arrangement of wedge shaped blocks, mutually supporting each other. These arches, depending on material of construction, may be brick, stone or concrete masonry arches. An axial load, *W*, on a wall over an arch may be assumed to be dispersed uniformly at an angle of 30^o to the vertical (Figure 4.2).

Figure 4.2 : Dispersal of Concentrated Load in Masonry

A certain portion of wall load or any other load over an arch gets directly transferred through the flanking walls to the foundation. This phenomenon is known as *arching action*. The proportion of the above mentioned loads carried by the arch depends upon support conditions, height of masonry above opening, location of concentrated or distributed gravity loads, width of flanking walls on both sides, etc. (Figure 4.3).

* l_c = clear span
** l_{ef} = effective span

Figure 4.3 : Diagrammatic Representation of Arching Action and Design Load when l_1 and $1_2 \geq l_{ef}/2$ and $h \geq 0.867\ 1_{ef} + 250$

4.3.1 Brick Masonry Arches

A brick masonry arch may be either a flat arch or a segmented arch according to its geometrical configuration.

A flat arch has horizontal extrados but slightly cambered (normally $\frac{1}{100}$ th of the span) intrados to ward off any sag due to loads. This type of arch is suitable for very small span (say up to 1 m) and light loads (Figure 4.4).

Figure 4.4 : Flat-Brick Arch

All other arches may be categorized as segmental arches. An arch constructed of plane bricks with *tapered* mortar joint is known as Rough Arch (Figure 4.5).

Figure 4.5 : Rough Brick Arch

If the brick units are wedge-shaped joined by uniform mortar joints for forming an arch it is known as Gauged Arch (Figure 4.6).

Figure 4.6 : Axed Brick Arch

Sometimes an arch is provided over a lintel or a beam for reducing masonry load on it. Such an arch is called Relieving Arch (Figure 4.7).

Figure 4.7 : Relieving Arch

Geometrical shape-wise an arch may be a semicircular arch, equilateral arch, elliptical arch, Bull's eye arch, etc. A few of them have been illustrated through Figure 4.8 to 4.11.

Figure 4.8 : Semi-circular Arch

Figure 4.9: Equilateral Arch

Figure 4.10 : Elliptical Arch

Figure 4.11 : Bull's Eye Arch

4.3.2 Stone Masonry Arches

Stone voussoirs for arches are cut and dressed from natural stone blocks. For ordinary works of smaller spans, where masonry wall including the arches are plastered hammer-dressed voussoirs are used for formation of arches. Such arches are called Rubble Arches (Figure 4.12). For aesthetic and exposed works of longer spans arches are made of fine-tooled voussoirs dressed to proper shapes and sizes. Such arches are called Ashlars Arches (Figure 4.13). Structural forms and functional requirements of stone masonry arches may be the same as those of brick masonry arches.

Figure 4.12 : Rubble Arch

Figure 4.13 : Ashlar Arch

4.3.3 Concrete Masonry Arches

Plain Concrete arches are suitable for smaller to moderate spans. Depending on the method of construction, they may be of the following two types :

(a) Precast Concrete Block Arches, and

(b) Monolithic Concrete Arches.

Precast Concrete Block Arches

In this method, voussoirs are made of concrete blocks, cast in moulds of proper shapes and sizes. The voussoirs are joined by mortar in-place to form an arch (Figure 4.14).

Figure 4.14 : Prescast Concrete Block Arch

Monolithic Concrete Arches

Such arches are cast at site in moulds of proper centering and shuttering (Figure 4.15).

Figure 4.15 : Monolithic Concrete Arch

SAQ 2

(a) How a concentrated load is distributed in a masonry wall?

(b) Define Rough, Gauged, and Relieving arch.

(c) Explain with sketches : (i) Rubble arches, and (ii) Ashlar arches.

4.4 RCC ARCHES

Reinforced cement concrete is a composite material composed of cement concrete and reinforcing steel. Concrete is very strong in compression whereas steel is strong in compression as well as in tension. Therefore, a properly designed RCC

arch of any shape and span can withstand flexural as well as direct stresses due to any type of loading.

RCC arches may be provided instead of lintels and beams for elegance, economy and structural considerations as follows :

Three hinged arches (Figure 4.16).

Figure 4.16 : Three Hinged Concrete Arch

Two hinged arches (Figure 4.17).

Figure 4.17 : Two Hinged Concrete Arch

Fixed arches with or without hinges (Figure 4.18).

Figure 4.18(a) : Fixed Concrete Arch **Figure 4.18(b) : Fixed Concrete Arch with Hinge**

A typical reinforcement detailing of hinges are shown in Figure 4.19.

Figure 4.19(a) : Reinforcement Details at Support

Figure 4.19(b) : Reinforcement Details at Crown

SAQ 3

(a) What is arching actions? Explain.

(b) What are the types of concrete masonry arch?

(c) Draw different types of hinges.

4.5 SUMMARY

An arch, like lintel or beam, is a structural component loaded transversely. Due to its curved shape, bending moment due to load is very much reduced in comparison to lintel or beam and the transference of loads is mainly through internal thrust. Masonry being strong in compression is suitable material for arches for small to moderate spans and light loads.

Categorization of arches is based on materials and method of construction, shapes of arches, functional requirements, etc. Properly designed RCC arches, being strong against compressive, tensile and flexural stresses are suitable for any span and loads.

4.6 ANSWERS TO SAQs

SAQ 1

(a) Refer to Section 4.1.

(b) Refer to Section 4.2.

SAQ 2

(a) Refer to Section 4.3.

(b) Refer to Section 4.3.1.

(c) Refer to Section 4.3.2.

SAQ 3

(a) Refer to Section 4.3.

(b) Refer to Section 4.3.3.

(c) Refer to Section 4.4.