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A Simple Inspection of Arches, Curved Beams, and Shells

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Abstract

Arches, curved beams and shells are important for structures. This article study provides information on arches, curved beams and shells. Arches, curved beams and shells were examined in sections and briefly explained. In fact, there is a lot of information that can be given about arches, curved beams and shells. In this article study, the terms are briefly explained and tried to be expressed by giving examples with shapes. The application of these terms in modern structures in Civil Engineering is quite common.

Keywords: Arches, Shells, Curved Beams.

1. Introduction

In recent years, many studies have been done on arches, curved beams and shells. In this article, we tried to provide information about arches, curved beams and shells. In Civil Engineering, many scientists have contributed to human history by doing important work on curved beams, arches and shells. Here, scientists have made applications that will make people's lives easier by contributing to human history. Each scientist has benefited from each other and brought these studies to the best place. The benefits of these studies continue to be obtained by obtaining new results. Scientists have done their own studies and have achieved positive results on arches, curved beams and shells. If we are to express what might be important from these studies; Kiselev emphasized the importance of the theory of curved rods and carried out intensive activities on two hinged arches [1]. When considering the three hinged arches, Rabinovich said that the vertical charge measured from the support is proportional to the coordinates of the vertical coordinate of the arch corresponding to the moment of tilt, and made calculations taking into account the elastic center [2]. Brockenbrough and Meritt compared the Shodek three-hinged arches with two hinged and non-hinged arches in terms of stiffness. As a result, he found that the three hinged arches had less stiffness than the other types of arches [3,4]. Maurizi et al., used the equations of tensile and kinetic energy in the case of non-uniform belt to obtain the bending vibration of the belt [5].

Qatu stated that the beams would be curved, and that they would be deep, shallow, open, closed in terms of curvature. He contributed to important studies by identifying the differences between straight and curved beams [6]. Qatu obtained equations by working on light curved beams. Using these equations, he applied on supported beams [7]. Qatu performed vibration analysis using thin and thick theories on laminated curved beams [8]. Tatemichi et al. they have done important work on viscoelastic layer curved sandwich beams [9]. Chidamparam and Leissa; Markus and Nanasi; Laura and Maurizi performed vibration analysis of curved beams and emphasized that the vibration analysis of curved beams is very important for engineering [10-12]. Morgaevsky, Kolesnik, Karnovsky, Flippov worked on the dynamic effect on shells as moving loads [16-19]. Karnovsky studied the effect of inertial loads on shells [20]. There are many studies on curved beams, arches and shells. The cumulative progress of these studies has been critical on arches, curved beams and shells. In general, the studies on arches, curved beams and shells described above have led to the work done today.

2. Arches

Arches are one of the important elements seen in construction applications from the past to the present. Mainly in historical artifact building applications, arches are seen in road structure applications. If we show the sections of the belt on Figure 1 in order to be better expressed;

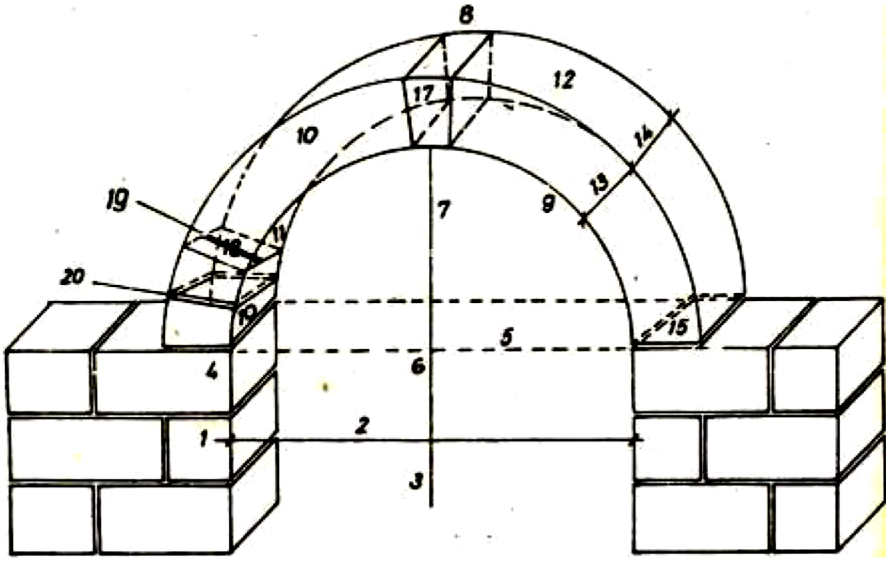

Fig. 1. Sections of the Arches [13]

The number 1 of the sections of the arch shown in Figure 1 are the feet of the arch. The opening of the ground arch expressed by number 2, the ground arch axis expressed by number 3, the ground angle point expressed by number 4, the ground angle level expressed by number 5, the center of the ground arch spring expressed by number 6, the ground arch height expressed by number 7, the floor mount or vertex expressed by number 8, the edge of the arch indicated by number 9, the forehead of the arch indicated by number 10, the abdomen of the arch indicated by number 11, the seat arch indicated by number 12, the thickness of the ground arch expressed by number 13, the width of the ground arch expressed by number 14, the bed of the ground extension expressed by number 15, the floor extension stone expressed by number 16, the place lock stone expressed by number 17, the ground referred to by number 18 is referred to as the arch stones. These sections are very important for the arch [13].

It is possible to see arch applications widely in the countries of the world from the first era to the present. Arch applications are widely seen in Turkey, especially in Ottoman architectures. In the structures where arch applications are seen, it should not be ignored that the structure supports in terms of robustness. This can be seen in some buildings in our country. The fact that they can stand without damage from the moment they are made in the structures supported by arch applications is one of the biggest proofs of this. The arches work in a certain way in the type of structure. The load transfer diagram in a arch is shown as in Figure 2. This diagram describes the exact working principle of the arch.

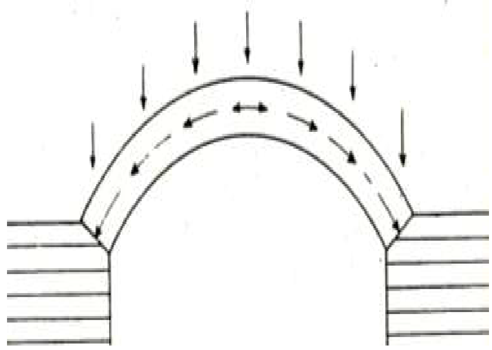

Fig. 2. Load Transfer Diagram in a Arch [13]

Arches are elements of a carrier structure that guide vertical and horizontal loads to specific points. Arches carry the weight they carry with them to the feet. This is why they are reacting to the backlash. The reactions that occur here are generally met with tension irons. But if the iron is corroded or loses its function, it causes damage to the joints. In cases where the tension bars are not used, the belt must be firmly seated on strong walls or the belts must be strengthened with the weight towers [14]. Thus, in Figure 3, an example of a carriage arch in a two-story structure is shown.

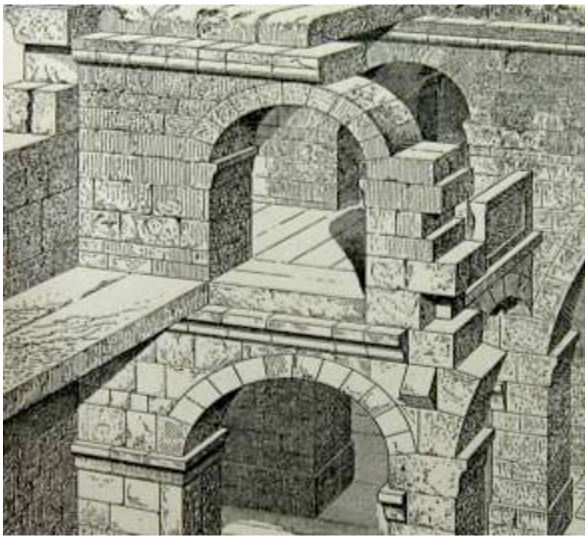

Fig. 3. Carriage Arches in a Two-Story Structure [13]

One of the most important arched structures known to everyone in the world is the Eiffel Tower. The Eiffel Tower was designed by Gustave Eiffel. The general appearance of the Eiffel Tower is shown in Figure 4.

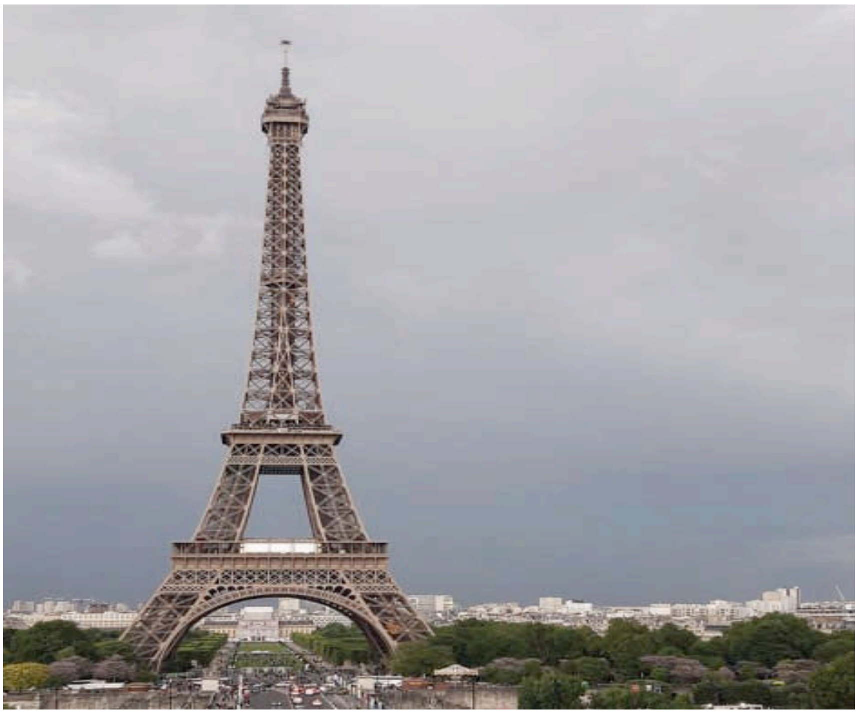

Fig. 4. Overview of the Eiffel Tower [15]

The Eiffel Tower is 300.65 meters high and weighs 7000 tons. Concrete is supported by basic reinforcements. There are approximately 18.000 different parts in this structure; about 2.500.000 rivets, 1.050.846 of which are in place. When this building was built, very skilled human power was used [15].

The Eiffel Tower is located in Paris, the capital of France. This building attracted visitors from many different parts of the world. Even the smallest details in the structure are considered and necessary controls are made both aesthetically and in terms of robustness. It is also possible to see steel construction applications in this structure. Together with the application of steel construction, the structure looks more aesthetically pleasing and at the same time has helped to be more statically sturdy.

There are many examples of structures in the world where arch applications are seen. The number of these buildings is quite large. In the article study, this section briefly gave information about the arches and tried to show them with shapes and the features of the Eiffel Tower, which is one of the most important structures in the world, were shown with the shape. Even in this article study, it was tried to emphasize how important arches are for structures. The sections of the arch are numbered and illustrated in shape and the load transfer principle of the arch is attempted to be illustrated. The features of the arch are briefly explained and the example of the carriage arches in a two-story structure is shown as a figure. Arches come to us in various ways. The most common types of belts; It can be expressed as Low Arch, Pointed Arch, Flat Arch, Horseshoe Arch, Overlap Arch, Kaş Arch, Bursa Arch, Water Arch, Tahfif Arch, Head Arch, Deaf Arch. Pointed Belt application, which is one of these arch types, is shown in Figure 5.

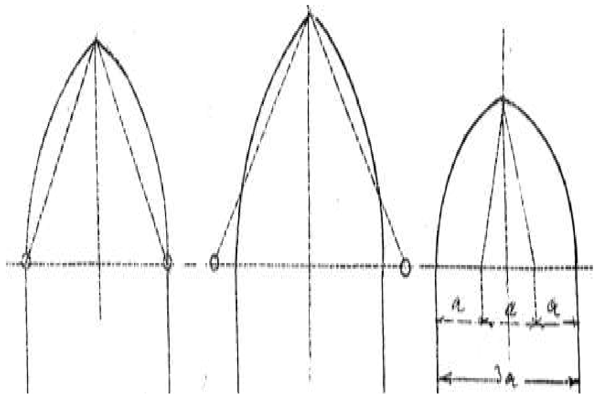

Fig. 5. Pointed Arch Types [13]

3. Curved Beams

Laminated composite materials are used to create components such as beams, plates, shells. It is often possible to find laminated beam applications. Beams can be straight or curved. The curved beams feature deep and shallow curvature. Curved beams also have the ability to be open and closed. Here closed beams can be defined as rings and open curved beams. The beams can vibrate at the curvature level and deform. These two features give information about some of the behavior of the beams in the structure and the effect of curvature on the beam vibration. By advancing these studies, scientists have obtained a number of mathematical expressions for straight beams and curved beams. Here the equations for a straight beam are derived by setting the curvature to zero. The radius of curvature that is meant to be described here is to say that it is gone forever [6].

Based on the above, two theories have been obtained for laminated curved beams. In the first theory, thin beams and rotary inertia, in which the effect of cutting deformation is examined, are neglected. This theory is called fine beam theory, or classical beam theory (CBT). To express the second theory, the designed cutting deformation and the rotating inertia effects are explained as follows. This beam theory (SDBT) is called thick beam theory or slip deformation. Figure 6 will show the parameters used for laminated curved beams [6].

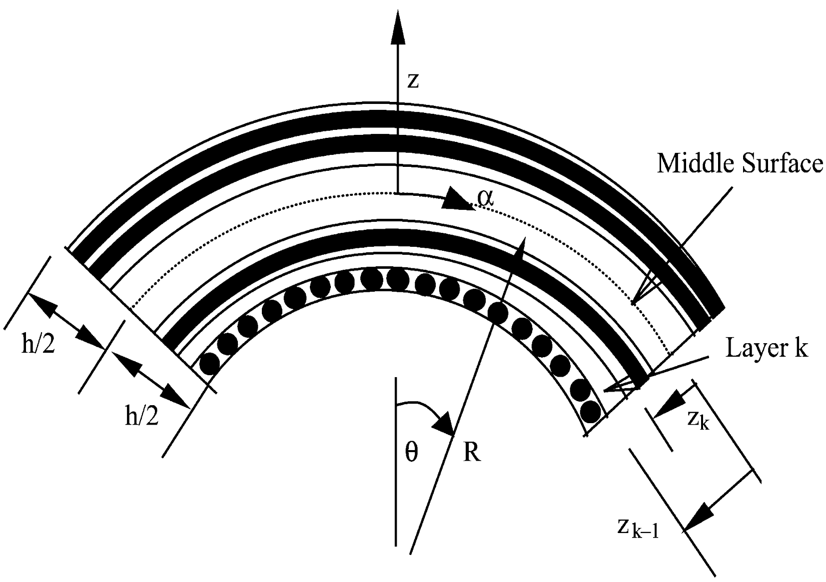

Fig. 6. Parameters Used for Laminated Curved Beams [6]

The basic theory of fine beams is also expressed as the classical beam theory. According to Figure 6, the laminated curved beam is characterized by its mid-surface, α defined by the polar coordinate. This can be explained mathematically as follows:

$$\alpha = R\theta \tag{1}$$

In Figure 6, R refers to the radius of curvature of the beam. Equation (1) has been made more special for curved beams. From here, equations for kinematic relations, equations for force and moment results, equations for motion, energy functions and boundary conditions can be obtained. İt is important for in-plane loading and vibration in the $\alpha - z$ plane [6].

The basic theory of medium-thickness beams will be obtained by developing thick beam theory (SDBT) to make thick beams more perfect. The equations obtained for the medium-thickness beam differ from the equations obtained from thin beams. In this theory, by including deformation and rotary inertia, equations for force and moment results, equations for motion equations, energy functions and boundary conditions can be obtained. An accurate mathematical expression can be obtained by incorporating the term z/R for the stress results of thick beams [6].

The theory of thin beams, using the theories of thick beams, can be obtained mathematical expressions for joists and closed rings that are simply supported. Here, when these equations are obtained, a number of solutions are made by taking into account the boundary condition. In the course of these studies, vibration analysis of fine beams and vibration analysis of thick beams were taken into account. From here, thin beams, medium-thickness beams, closed rings, a number of mathematical equations for numerical results are obtained. In this case, no definite solutions were found.

4. Shells

Shells are defined as a curved surface of a small thickness compared to the size of a structure. The shells carry their own weight, the loads coming from the outside and the loads coming in various forms. The principle of carrying the shell is very different according to the arch. While the amount of thickness is important in the arches, local compression sprain is important in the shells. The wall dome, which is one of the species found in shells, can be seen pressure stretches at very low scales. Figure 7 shows an example of a hemisphere shell. Here it is seen that support is carried out with a proper pressure tension on the shell floor [21].

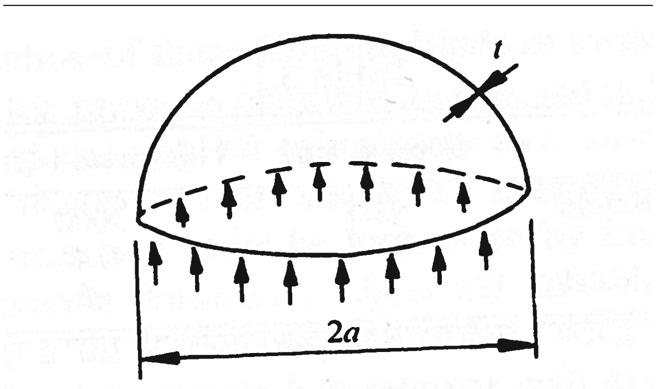

Fig. 7. Half Globe Shell under İts Own Weight Example [22]

Based on the above information, one of the most important methods of dome analysis is that if we express the membrane theory, the ground is weak against bends, therefore the forces cause complete stresses or compressions in the shell [22-32].

Stretches from the shell to the ground analyze the theory transmission. Here, using mathematical equations, Figure 8 and Figure 9 show that elements that occur as a result of stresses in the dome of an element cut from a small shell can be found [21].

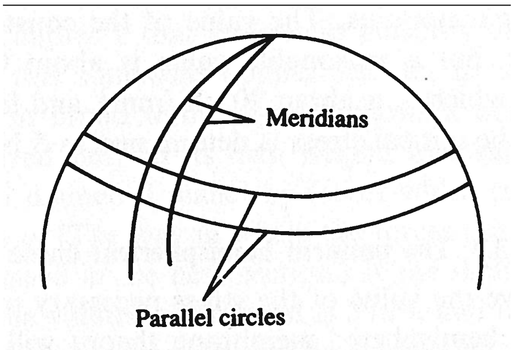

Fig. 8. Defining an Element of the Shell as Meridians and Parallels [22]

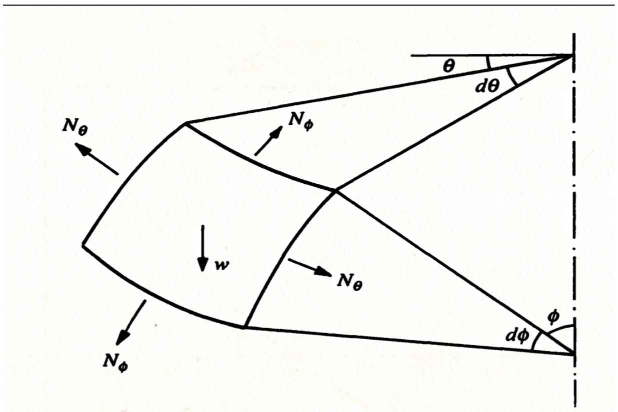

Fig. 9. Balance of a Small Shell Element [22]

Figure 10 illustrates the working principle of a semi-spherical shell balance system [22].

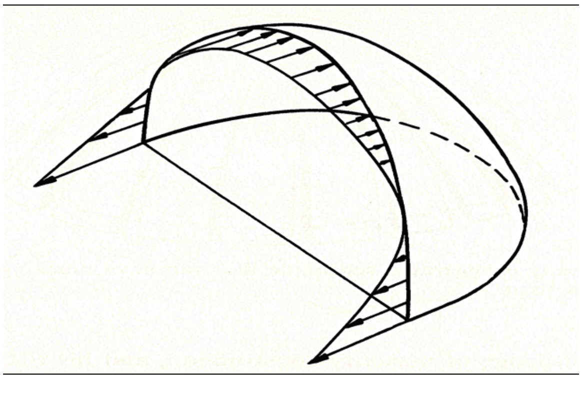

Fig. 10. A Semi-Spherical Shell Balance System [22]

Above, as much as possible, the principles of operation of shells are tried to be explained. Using these working principles, shell applications in modern structures have emerged. The shell applications in these modern structures have supported the robustness of the buildings. The external appearance of these applications looks aesthetically beautiful. Examples of modern structures can be seen predominantly in European countries. One of the modern shell applications in Europe is shown in Figure 11. The name of the structure shown in Figure 11 is the roof of the Zarzuela Hippodrome. The roof was designed by Eduardo Torroja.

Construction of the Zarzuela Hippodrome began in 1935. By making architectural aesthetics and the most appropriate structural solution, this structure took the form of a flat roof as simple as obtaining a hyperboloid. Here, it was seen that the thickness of the reinforced concrete shell changed by 65 cm. After this construction was completed, a modern structure emerged [15].

Fig. 11. Zarzuela Hippodrome by Eduardo Torroja [15]

5. Conclusions

Extensive work has been done on arches, curved beams and shells. In this article study, the sections of the arches were expressed in numbers and tried to be explained one by one. Then the exact working principle of the belt was expressed by showing the form. Examples of the arch structures are given and the characteristics of the Eiffel Tower are explained and shown with the shape. By expressing the types of arches, pointed arches, which is one of them, are shown in the figure. Curved beams are mentioned in this article. Two theories are mentioned for curved beams. Thin beam theory and Thick beam theory are explained. The parameters used for curved beams are shown in the figure. Finally, in this article, the shells are mentioned and the hemispherical shell example, the definition of one element of the shell as meridians, the balance of a small shell element and a hemispherical crustal balance system are shown in the figure. As an example of modern shell application, the Zarzuela Hippodrome is illustrated and its features are explained. In this article, it has been tried to be explained with examples by referring to arches, curved beams and shells. As a result, this article study was made with the thought that it would be useful for applications in Civil Engineering.

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