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Architectural and Structural Behavior Domes in Islamic Architecture (Case Study: Mosque of King Abdullah Ben Al-Hussein- Amman- Jordan)

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Abstract

This research aimed at tracking and investigating the evolution and development of domes construction, design, sizes, shapes, used materials, and functions of the domes during the different eras of the Islamic architecture. To achieve the research's objectives, the study used the descriptive, analytical and historical methods to deepen and enriching understanding the value and the aesthetic features of the domes, and the used instructional methods, how they were developed from bricks, stones, to reinforced concreted covering wider spans of the mosque to provide good view to the Mihrab and to see the speaker. In addition, the research used a case study dome of Mosque King Abdullah Ben Al-Hussein to learn useful lessons from some of the tumbles in the construction of the dome during the construction and after the usage, including sound distortion and echo resulting from lack of adherence with the golden percentage, between the dome's height and width of the mosque. Finally, the research based on the review of the previous domes construction introducing some recommendations to the designers of the domes, the most important to sustain the beauty and significance of the domes without imitation of other domes rather through carefully study the internal and external constraints to reach the optimal result at cost effectiveness.

Keywords: Islamic Architecture, Dome of the Rock, Engineering Philosophy. Construction, King Abdullah.

Introduction:

This research aims to shed light on the evolution and development of the domes in Islamic architecture, and to know forms of the domes in their appropriate structural position, either in the religious buildings or housing building. This requires following-up the historical buildings that have been found from the excavations in the previous eras and known civilizations which our Arabic and Islamic regions are rich of them. The Islamic domes are influenced by the architecture of these civilizations and nations, but at the end they took special feature specific to them. Forms and decorations of the domes were multiple in the Islamic countries, either inside or outside the dome. Multiple geometrical and plants drawings were used, in addition to the Kuranic verses. The Islamic domes have reached high level of superiority from the structured and the architectural sides and became important constructional element in covering the religious buildings.

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Figure. (1). Case study - Mosque King Abdullah Ben Al-Hussein in Amman –Jordan

Statement of the problem:

This study aims at answering the following question:

It is possible to benefit from the aesthetic values in the religious buildings and enriching and improving the local architecture in shadow of the similar conditions?

From this question branches the following sub questions:

1. What are the aesthetic architecture values in the religious building?
2. What is the architecture and engineering philosophy in the construction of the domes?
3. What is the secret behind the beauty of the domes in the mosque?
4. How to apply these aesthetic values in the local architecture to contribute to the establishment of a distinguish architecture feature?

Objective of the study:

1. This study aims at giving a quick view at the evolution and development of the domes in the Islamic architecture.
2. To show the features of the Islamic social and architecture heredity.
3. Understanding the architecture values in the domes.
4. Inserting the architecture aesthetic values in the modern architecture expression.

Significance of the study:

Significance of the study stems from the topic importance, and the importance of the religious, Significance, aesthetic and civilization importance and transforming it from one generation to another to sustain and develop by the future generation and applying them to local and city architecture. {1}.{2}.

Methodology of the study:

This study depended on the descriptive, analytical and historical methods to describe phenomenon of the spread of domes construction in the Islamic world to reach its reasons and the factors governing them, by collecting data, information and photos about the Islamic domes, including their shapes, classification, history, and aesthetic values, and the engineering analysis.

Limitation of the study:

It is limited to its theoretical research design by referring to historical data about the domes in different Islamic countries.

Prospects of the study:

- Opening the wide field in front of the researchers and the architecture to continue in finding new ways and modern technologies in domes' building in light of the available modern construction materials.
- Exploring and benefits from the aesthetic values presented by the ancient and hereditary buildings.

Theoretical Frame:

Forms of the Domes in the Islamic Architecture:

1- The Islamic Domes:

The first dome in Islam was the dome structured in the Ommayadi era known as (The Dome of the Rock) (year 72 BC/6911 AD). This dome has been influenced by the dome of the holly tomb church constructed in year 335 AD. The archeologist (Creswell) has carefully addressed this topic clarifying all the architectural, constructional and decoration influences from the Byzantine architecture on the construction of Dome of the Rock.Another example has been found a wooden dome in (Marneion) temple in Gaza (Palestine from the second century AD).

The presence of the Dome is an architectural confirmation about the place of the Mehrab, in addition, this place was designed for the Caliph at that time, then the dome have been moved in front of the Mihrab in the Fatimi Islamic architecture in Egypt through North Africa, it exists in (Al-Azhar Mosque) (361BD, 792AD). Also at the outside corners of these mosque there were small domes, while the dome in front of the Mihrab was characterized by its big size and the formation of its external surface in away differed from the other small domes. The dome has been found in some of the (Mammloaki Mosques) in Egypt, such as dome of (Ben-Tooloon Mosque) (265 BD, 878 AD) pertains to the end of the Thirteenth century AD.

The usage of the onion domes became popular in the Islamic architecture in India, Iran and Samarqand. This system has extended during the ottoman Caliph in Turkey and in Domes were found in (Amra palace) in Jordan, and Al-Mashta palace. (132 BD/ 750 AD).

Figure. (2). the Rock of al Aqsa in Jerusalem – Omayyad style.

Building of the Domes:

Domes were built of brick, stones and wood, but developed to be built of concrete, and the modern use of reinforced concrete. The domes were built by organizing rows of brick, or carved stones, their soldering was oriented towards the dome's center and in some cases, and rips were made to fill the vacuum between them by rows of bricks or stones. Some of the domes were found operating on two shells for the external shell to be differ from the internal shell, chains of steel or pieces of wood were used to resist the external pushing force of the domes. Domes in some of the Islamic countries were covered with colored glass or porcelains, qishani) such as in Iran and India. ({2}. {9}. {4}).

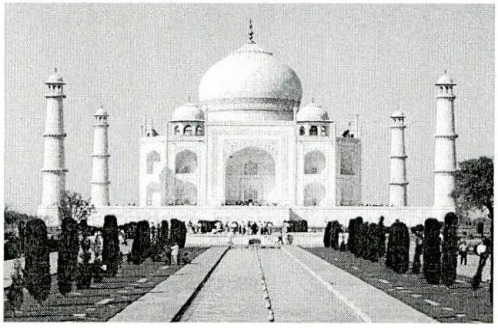

Figure. (3) Taj Mahal Mosque India – Indian style

Symbolism of the Dome:

- It links the earth with the sky, confirming the vertical movement upward.

- The spherical surface prevents the accumulation of rainwaters.
- From the structural side: The dome covers greater era for the praying hall without columns to give the prayers the opportunity to see the speaker while he is at the Mihrab.
- From the functional side: (1) It allows the natural light to inter the praying hall through the windows up of the dome.

(2) It helps the air interring during the summer months.
(3) It confirms the importance of the Mihrab.

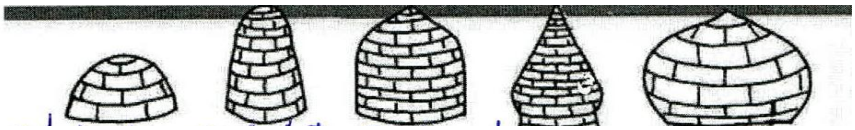

Figure. (4). Type the Islamic Dome.

The Dome in the Ommayadi and Iraqi Palaces:

Domes have been used in some of the palaces which were structured as rest places such as (Amra palace, Al-Sarkh Bath, Al-Mashta palace and Al-Akheeder palace, and other palaces, since Amra palace) is considered of the first Omayati palaces in the Northern Badia in Jordan, which used the domes in covering the bath's hot room, it is decorated from the inside with drawings with orbit of celestical bodies from the fresco.

The Dome at the doors and entrances of the cities:

The Abbasi era a domes are seen higher of the internal fence of Baghdad City built by Al-Mansour year (147 BD), while in Egypt the domes were seen at the doors entrances of Al-Fatimi Cairo walls, year (485 BD) at Al-Fotooh and Zwaila doors covered with circular dome made of carved stone, the two domes are considered the first evolution of this kind of domes in the Islamic Egypt.

The Dome in the Towers and the Defense Buildings:

The domes usage in the defense towers came in at (Ayooby era), since Al-Nasr Tower from the top was with a dome from outside. ({2}. {6}).

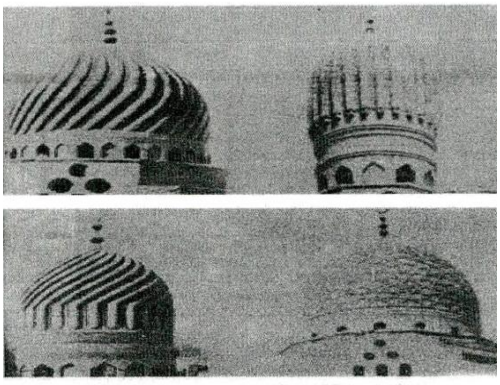

Figure. (5). Models from Cairo Mosques Domes – Fatimi style

The Dome in the Mosques:

Dome of the Rock in Jerusalem is considered one of the first domes in the Islamic architecture; it was built by the Ommayadi Caliph (Abdalmalek Ben Marwan) year (72 BD, 691 AD). It is diameter (20.44 m), it is built up wood and covered with lead plates above them copper plates. The Dome of the Rock consist of three parts: The neck made of ceramic, the two internal domes, their height reaches (34 m) made of wood and plaster, and gold, and the external dome made of copper, and nicks were casted with gold (24) caliper, when restoring the external dome it required (80 kg) of gold. It is an eight sides building, inside of it another eight sides structured on pillars and cylindrical columns. The Dome of the Rock and the neck contain (16) windows of glass and gold. Also, the domes were used to cover part of the mosque such as Al-motawada in the yard of Ibn Toloon Mosque, and also used at the end of some minarets. ({4}. {2}).

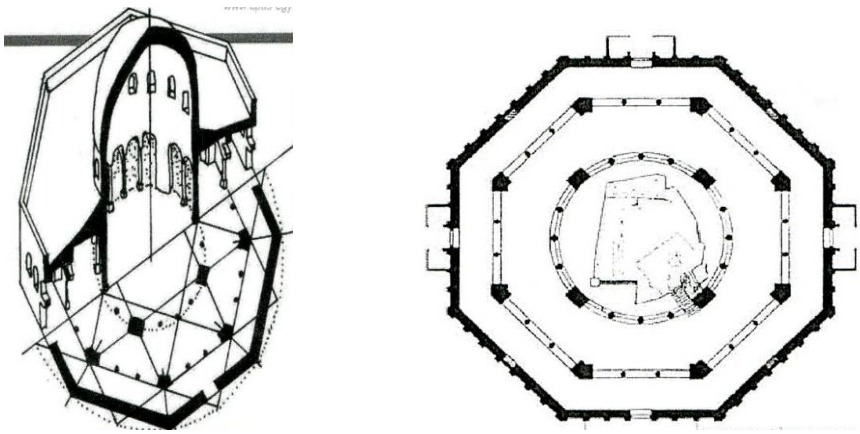

Figure.(6). Dome and plan of the Rock in Jerusalem.

Structural Behavior of Islamic Arches-Domes:

The dome is an important element in studying the architecture. To study the construction of the dome, it is very important to focus on its historical background and the characteristics of their basic architectural and structural behavior. The dome is an architectural form, Known in many civilizations as one of the most universal architectural aspect. It is good idea to have a look on the efficiency and strength of a structure, were required because a dome is the most practical construction system. The dome is the most practical construction system. It is so distinguish to minimize the weight of arch-dome. Firstly, a sphere requires the smallest amount of material surface area needed to enclose a given volume of space. Secondly, the dome has approximately one-third less surface to the outside. The shape of the dome provides an aerodynamic effect; wind passes over the dome with less resistance. Thirdly, the nature of the spherical design provides strength because all the points of the structure share the stress evenly. The dome shape allows environmental stress such as movement from an earthquake or wind or stress from snow loading to be evenly distributed throughout the structure. In the next pages there are two examples of structural analysis of the dome. ({11}{13}).

Example: 1

- Illustrative Example for semicircular arch:

A semicircular two hinged arch of constant cross section is subjected to a concentrated load as shown in Fig (1) below, Calculate reactions of the arch and draw bending moment diagram.

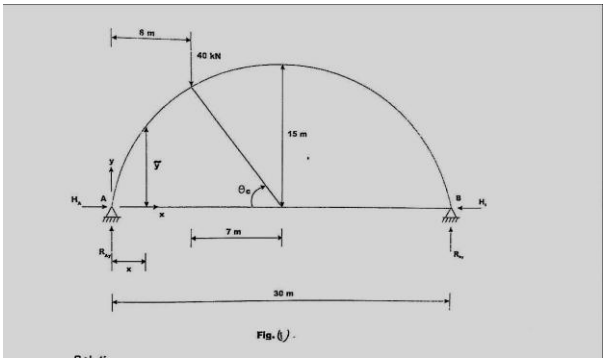

Fig (1) semicircular arch

Solution:

- Taking moment of all forces about hinge B leads to:

$$R_{ay}=\frac{50*22}{30}=36.7\ KN \quad (1)$$

$$\sum fy = 0$$

R_{by}=50-36.7=13.3 KN

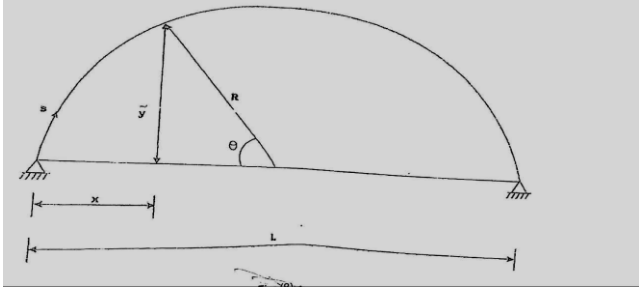

fig. 2. semicircular arch

Y=Rsin θ

X=r(1-cos θ).

Ds=Rd θ. (2)

Tan $\theta_{c=}\frac{13.267}{7}$ $= \theta_{c=62.18=}{}^{\pi}/_{2.895}{}^{rad}$

Now the horizontal reaction H may be calculated by the following expression.

$$H=\frac{\int_N^S MYDA}{\int_O^N Y2DZ} \quad (3)$$

Now M_o the bending moment at any cross section of the arch when one of the hinges is replaced by a roller support is given by.

$M_o=R_{ay}x=R_{ay\ R}$ (1- cos θ) $0 \leq \theta \leq \theta_c$

And, $M_o = R_{ay}$ R (1 – cos) - 5o (x-8).

= R_{ay} R (1- cos θ) – 5o R (x-8) $\theta_C \leq 0 \leq \pi$ (4).

Integration the numerator in equation (9).

$\int_o^s m_{oy}{}^2$ ds = $\int_0^{\theta c} R_{ay\ R}{}^3$ (1 – cos θ) sin θ d θ + $\int_{\theta c}^{\pi} R_{ay}$r(1 – cos θ) $40\{R(1-\cos\theta)-8\}Rsin\theta Rd\theta$

= $R_{ay}R \int_0^{xl2.295}(1-\cos\theta)\ Sin\theta d\theta + \int_{\pi l2.895}^{\pi}\{R_{ay}R(-\cos\theta)$ sin θ-5oR(-cosθ)-8}]dθ.

= $R_{ay}R^8$ [-cos θ]$_0\pi^{2.895+}R^2[[R_{ay}R(-\cos\theta)]_{n/2.895-}$[5OR(-cos$\theta$)]$\pi\frac{\pi}{2.895}$+[5o×8(-cos θ)]$\pi_{/2.985]}$

= $0.533R_{ay}R^3+R^2$[1,4667R_{AY}R]-[5Or(1,4667)]+[5O×8(1,4667)]

= 66159.5+225(868.5-S14.28]=132,242KN.

(5) The value of denominator in equation (3), after integration is,

$\int_0^2 y^2$ ds = $\int_0^{\pi}(Rsin\ \theta)^2$Rd θ

= $R^3\int_o^n(\frac{1-\cos 2\theta}{2})$ d θ=$R^3[\frac{\pi}{2}]$=5301.46.

Hence, the horizontal thrust at the support is (see equation 3)

H=$\frac{132,242}{5301.46}$=24,9kn.

Bending moment diagram.

Bending moment M at any cross section of the arch is given by.

$M=M_o-H_y$.

= R_{ay}R(1-cos θ)-HR sin θ.

= 551.3(1-cos θ) -374 sin θ $0 \leq \theta \leq \theta_0$ (5).

M = 551.3 (1 – cosθ) – 374 sin θ – so (15(1 – cos θ) – 8 $\theta_0 \leq \theta \leq \pi$ (9).

Using equations (5) and (6) bending moment any angle θ can be computed, the bending moment diagram is shown in fig (3) below.

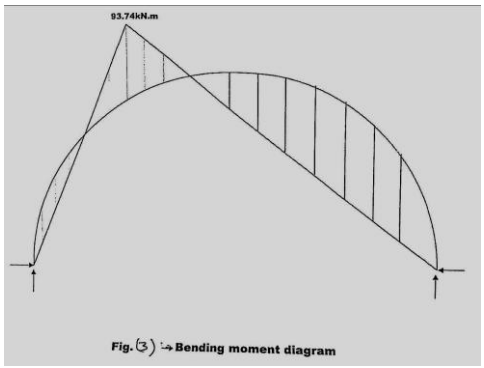

Fig. (3) Bending moment diagram

Two-hinged arch is the statically indeterminate structure to degree one. Usually, the horizontal reaction is treated as the redundant and is evaluated by the method of least work. Towards this end, the strain energy stored in the tow- hinged arch during deformation is given. The reactions developed due to thermal loadings are discussed. Finally, a few numerical examples are solved to illustrate the procedure. ({11}, {13},{12}).

(Case Study: Mosque of King Abdullah Ben Al-Hussein- Amman- Jordan). Attempts for Development between Success and Failure:

It is clear from the previously mentioned that there has been distinguished vision and methods in designing and building the domes in the Islamic architecture, this vision has been accompanied with originality in the design and the innovation of new architectural innovations, using an innovative and new method for treating the decorative aspects of the surfaces of these domes according to the used building materials, all of this in the frame of linkage with the dogmatic significances of each component of these domes.

In the new era with the advances in the building methods and using the reinforced concrete as construction materials have the great ability in dealing with ceiling with wide spans, some attempts have appeared to develop the use of the domes in the Islamic architecture especially in the mosques' building, such attempts ranged between success and failure.

One of the modern examples in using the dome to cover the prying hall of one of the Mosque is King Abdullah Ben Al-Hussein in Amman-Jordan . ({10}. {9}. {5}).

Figure (7). King Abdullah Ben Al-Hussein in Amman-Jordan – entrance

Illustrating this example is not for the purpose to evaluate it rather it is an attempt to explain the development of the domes in the Islamic architecture. The designer of this mosque is a Dutch architecture greatly influenced by the used octagonal idea in constructing (Al-mead dome) in (Ali Ben Yousef Mosque) in Morocco year 1220, BD in the form (b) by using eight concrete pillars, each pillar with two arms, each arm holds huge span inclines vertically upward and crosses with another span coming from the nearly pillar, and the cress of these pillars together at the base of the dome a multi diagonal is formed consists of (16) sides copying the dome, with diameter nearly (33m).

It is found from the phonic studies that there are phonic and echo problems in the prying hall, because of lack of consistency between the dome's height and the width of the mosque, this is clear from the mosque's section. To avoid this undesirable defect in the mosques, sound absorption materials were used and the wooden casting of the mosque's walls and the dome from inside, all of this at the expense of the huge costs to construct the mosque. By making a simple comparison, it is found that the diameter of the dome in this mosque is nearly eleven times the diameter of (Al-Meeda) dome in Ali Ben Yousef Mosque in which appeared the same used idea to hold dome of Martyr Abdulla Ben Al-Hussein's Mosque, regardless of the long time separating between the two domes. This is natural because of the great development in the construction methods with the use of reinforced concrete instead of the stones.

Despite of this, the designer of the mosque's dome has been successful in reaching the appropriate percentages for the mosque's vacuum by using this huge dome although he attempted to develop the used pillars idea in Al-Meeda Mosque's dome in Ali Ben Yousef Mosque in Morocco. So, the designer in the modern era should be careful that the domes in the Islamic architecture were designed based on clear architectural standards and principles, this is clear in figure (8) of one of the domes designed based on finding relationships between the dome's diameters, the height of its neck and the height of the octagonal holding it.

Even the height of the crescent above the dome has not been left to chance rather on the base of finding a percentage between its height and the dome's diameter. So, it is meant by the mindful development is the deep study of the traditional designs of the Islamic domes and methods of their construction and decoration, developing these designs relevant with the available developed construction materials. The development should not be by imitation, or by changing some of the existing traditional forms and giving it greater scale with the modern construction materials, or by adding some modifications that might be significance in the external form. ({8}.{7}.{6}).

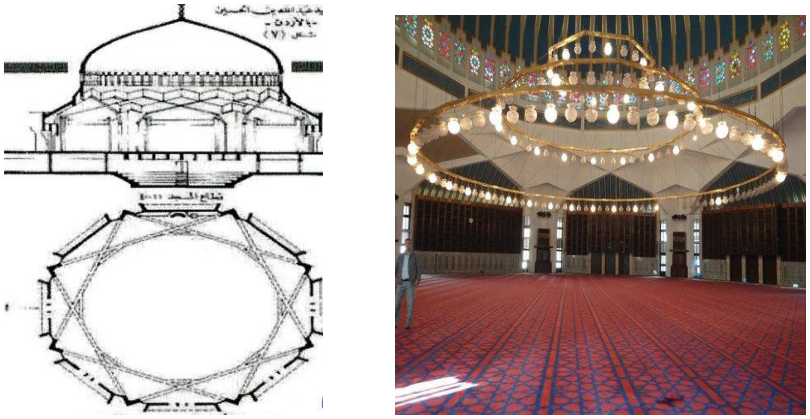

Figure (8). The plan Mosque of King Abdullah Ben Al-Hussein in Amman – internal photo.

Conclusions

1. Domes building is considered a genius resolution by using small brick size for wide span ceiling.
2. Domes building enjoys architecture and aesthetic values.
3. There has been an architecture and engineering philosophy used in structuring the domes, in the Islamic world from the old eras until the present time.
4. One of the most important secrets of beauty of Dome of the Rock, and reasons for its sustainable beauty and magnificence, and being distinguish from other buildings was the dependence on the golden percentage rule in the design and the implementation, and commitment to the aesthetic basics and principles.
5. It is possible to benefit from the architecture engineering and aesthetic values in building the domes by introducing an integrated proposal as project to be applied to the contemporary local architecture in the Islamic world, and transforming them from one generation to another.
6. The Islamic dome expresses philosophical, spiritual meanings and deep emotions regarding the form and the meaning.

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