KURDISTAN ENGINEERING UNION

The Role of

Dome's Shape on Acoustic Performance, thermal behavior and structural designs in The Main Hall inside Mosque

By

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October 2023

What is the mosque?

The phrase mosque alludes to a "place for prostration" that Muslims utilize as a religious building. A mosque in the early Muslim religion was more than just a house of worship. It served a variety of functions. It served as an education center and a propagation center for the Islamic Dawa "Islamic Call," and also a court center, a gathering place for the Shura Council, a place for conversation, a news transmission and publishing platform, and a place for hospitality and welcoming strangers. Muslims are required to perform (5) prayers every day, which are to be congregationally done in mosque. Masjids are definitely important structures inside each Muslim settlement. They are usually a specific size and placement with reference to the general public. In general, they could be classified as significant symbol architecture or landmark buildings, local visual elements, focal point, and tiny regional neighborhood.

The most important functional area in the mosque consists of the worship hall. This necessitates attaining suitable prayer needs in mosques, in line with the world trends to satisfy convenience in architecture (from thru sound performance better). Mosque Design Aspects and Uses Mosques share fundamental common design elements like prayer places. They usually take the form of a large rectangular building with a walled enclosure and a roofed worship space. The longer face of the rectangular is always faced towards Makah's sacred mosque, called as the 'Qibla.'

<u>First</u>

The Effect of Domes Shape on the Acoustics of Mosques

Abstract

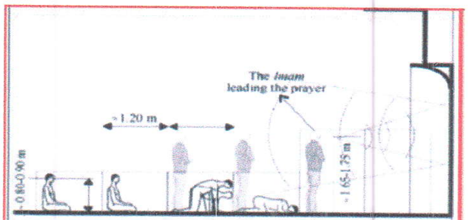
As an essential symbol and sign in Islam, a mosque is created with architectural magnificence and elegance. Among the features is its ceiling and it is usually built with a mainly shape of a spherical dome. It is one of the most important buildings for Muslim people, and they have developed and evolved to meet Islamic needs or requirements. Different worship activities take place within these public buildings, and these actions necessitate a variety of sound requirements. The layout and design of Masjid and their shape (Dome) ceiling is strongly influenced on the acoustic properties. Sound quality is a significant component in main hall (prayer) that was not neglected and disregarded during the design process. Finally, the significance of speech clarity became increasingly vital and important, with the incorporation of other functions within the prayer rooms, including the Quran Verses reading, lessons and teachings. The curved roof surface represented in domes is one of the key landmarks in the architectural style of mosques; as most of the mosques in different eras have a unique styled centralized dome as a part of the roof form and structure. The sound quality in contemporary mosques varies according to many variables such as geometric form of the building, internal finishing materials and roof shape. These three important variables have a great impact on the sound quality which can be enhanced and have direct positive impact in case of accurate calculations and conscious design solution.

INTRODUCTION

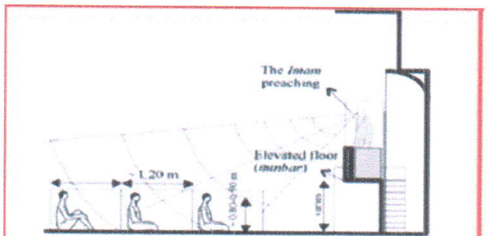
A dome that would be defined simply as "A hemispherical or semi-elliptical roof, built of stone, timber, metal or glass." Was considered one of the key features is Islamic architecture especially in mosques. Many civilizations prior to Islamic civilization adopted the dome as a roofing method in their important buildings such as the Romans, who used it in a monumental approach in the Pantheon, and the Byzantines who used the dome to cover their monumental buildings. Since the founding of Islam in 622 CE, a mosque has been a holy place where Muslims have gathered to pray in congregation. Besides, it is a public facility utilized by Muslims for multi-function which including Quran reading, Friday worship, and its teaching, in addition to being a space of worship

GEOMETRIC PARAMETERS OF MOSQUES

The dome shape and finishing materials of mosques differ from one country to another. Walls are sometimes covered with marble tiles or wooden boards or panels tongued and grooved to compose a vertical pattern. The floor area is always carpeted. Plastered and painted concrete ceilings with simple to elaborate decorations and /or inscriptions are commonly used. All these parameters directly affect the quality of the acoustical experience inside the mosques that could be measured in many aspects including clarity, reverberation time, speech transmission index and many other aspects. The research will study the Speech Transmission Index inside the prayer hall in relation to the dome form.

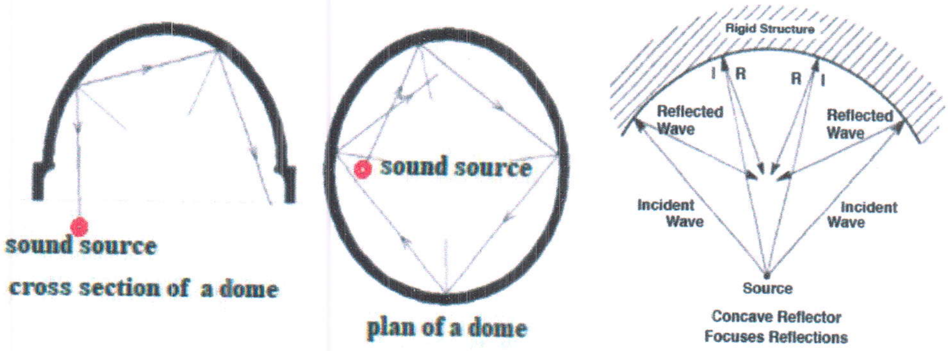


Congregation performing *Daily* individual or group prayers
Prayer-performing mode
(a)



Congregation listening to *Friday* speech
Preaching mode

In today's world, the Dome has become one of the most recognizable symbols of a mosque. The dome now not only sits physically on top of a concrete slab, but it is also a large element of the roof's construction. The spatial layout of a dome's structure or design details allows vibrations to be returned and echo to be generated. The material qualities and abilities of a dome are also significant for sound performance and should be regarded early in the design process. A dome can also build an impact named the "whispering gallery" and which occurs underneath a dome. The reverberation time in locations with huge volumes and weak absorbing floors is often lengthy, due to reduced speech clarity efficiency. Furthermore, because these elements normally have strong reflectors, the sidewalls, arches, and ceiling might lead to a prolonged echo period.



Represent –behavior of acoustic and sound power and energy in a dome

Architectural acoustics:

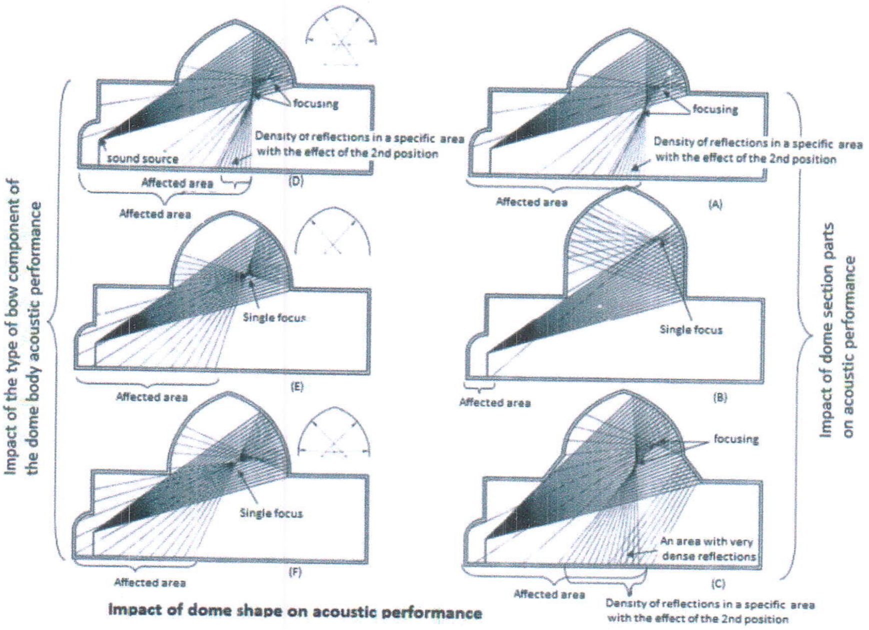
is about obtaining a high level of quality of sound (speech) in a public place (hall closed or theater), churches , mosque ,temple and other, improvise level and quality of tone of sound and the volume of hearing in a place, or diminishing noise in offices and homes to create them more pleasant and tranquil locations to live and work. In recent years, Designers have frequently concentrated on creating an attractive design for mosque. Sound design is a significant feature of a mosque. A high level or good quality of acoustics is required for all religious duties. Improper sound quality in a masjid will disturb the attention of the attendees. To ensure appropriate listening situations, soundproof requirements must be regarded throughout the design process.

Dome-shapes and sound Performance:

A dome is a hemispheric architectural structure that too many mosques use to symbolize the Islamic design language. Though the significance of domes in religious architecture has been acknowledged since antiquity, their sound efficiency has not been received the deserving study attention. The dome-shapes are amongst the most troublesome shapes in sounds. Because to the concave shape of the cupolas, the transmitted acoustic energy does not depart without bouncing numerous times in the cupola.

As a result, the reflected acoustic energy from the cupola returns to the hall with latency, causing repetitions or cacophony, as well as a decrease in Intelligibility. The behavior of acoustic pressure in a cupola in each of cross-section and plan is representing in Fig. As can be seen, reflection acoustic waves, that is increasingly retarded and delayed. Particularly in huge cupolas, is a cause of resonance and echo.

The utilize of cavity absorbers can prohibit acoustic waves from being reflected and re-radiate it throughout the space. Aside from providing a dispersed field, the audio from the cupola, which comes quickly after the direct sound, generates a heavenly impression in the prayer environment. In spite of negative impacts of delayed reflect and bounces, the cupola volume's connection to the rest of the space should lead in more complex activity. As an outcome, a thorough study of the sound behavior of various sorts of cupola is essential for selecting the right cupola shape for a specific mosque design.



Speech Transmission Index (STI)

A mosque typically performs activities involving a lot of speeches whether it is just having a small conversation or giving a talk in front of a crowd, clarity in the speeches is important. Intelligibility is the quality or condition of being understood, which means that speech intelligibility is the value of how clear the speech is in any condition, but should not be confused with speech quality [34-35]. Since reverberation time and sound reflection can affect speech intelligibility, this means that the type of the room, the room shape and volume can also affect speech intelligibility. To achieve 'good' speech intelligibility, the STI value must be within the value of 0.6 to 0.75; for a 'fair' speech intelligibility, the STI value must be within the value of 0.45 to 0.6; if the STI value were to be below 0.45 than it is considered 'poor'.

Table 5 shows the comparison of STI values in various dome shapes with their color contours of STI distribution. It can be observed that simulated models without a dome and those with a segmental dome have the highest average STI value of 0.56. However, all simulated models showed acceptable values based on the optimum limits adopted in this study even though the lowest STI averaged value found was 0.50 in the Arabic dome. The minimum STI value found in this study can be observed in the simulated model of the Arabic dome type. In general, all dome types including those without a dome have achieved a 'fair' performance of STI values within 5m range from the sound source, but the STI values gradually dropped to 'poor' performance when the distance between the sound source and the receiver exceeded approximately 15 m.

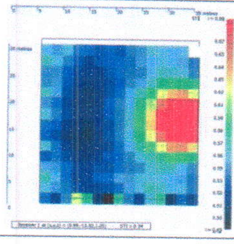
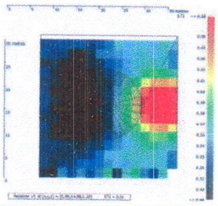
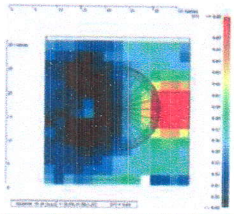
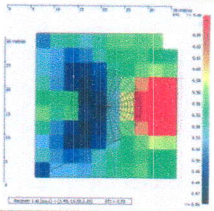
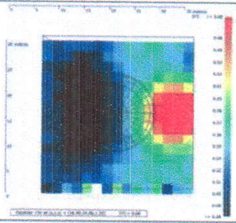
Type of dome	Grid Response	Speech Transmission Index. STI Min	Max	Avg.
No Dome		0.51	0.91	0.56
Arabic Dome		0.45	0.92	0.50
Onion Dome		0.48	0.92	0.55
Segmental Dome		0.48	0.92	0.56
Hemispherical Dome		0.46	0.91	0.54

Table 5. Comparison of minimum, maximum and average speech transmission index

With grid responses for each room model.

Based on the simulation, the shapes of dome affected the STI mean value as such - the larger the volume, the lower the STI means value. Taking into consideration the differences in the intensity of the color contour in the grid response, the certainty of the pattern on the grid response of the onion dome and segmental dome are nearly identical. The moment sound is transmitted through the respective dome shape; the sound was split-scattered by the sound reflection of the dome shape.

Table 6 presents the comparison of simulated STI values in three locations of dome for each type of dome shapes. The highest averaged STI value recorded for all dome shapes was located at the back with 0.56. Generally, compared to if it were in the middle or front positions. Even though the simulated STI values recorded show comparatively little substantial improvement, it can be concluded that changing the dome location contributes to some improvements in the STI values.

Table 6. Comparison of speech transmission index with respect to dome location.

Dome Type	Speech Transmission Index. STI, Dome Location: Front			Middle			Back		
	Min	Max	Avg.	Min	Max	Avg.	Min	Max	Avg.
Arabic	0.44	0.91	0.51	0.45	0.92	0.50	0.50	0.92	0.56
Segmental	0.47	0.91	0.54	0.48	0.92	0.56	0.48	0.92	0.56
Onion	0.45	0.93	0.53	0.48	0.92	0.55	0.50	0.92	0.56
Hemispherical	0.45	0.90	0.51	0.46	0.91	0.54	0.48	0.92	0.56

Summarize:

The cupola has always been a significant element of masjid architecture that has had a great influence on the acoustics within the main hall. This high acoustic quality might be investigated and recreated in the masjid utilizing different cupola shapes as a variable parameter in combination with the set mosque size and shape. The cupola sound impact was measured as per to each parameter (variable) in two primary factors: the first is the shape and size of dome and the the placement of the sound resource (Imam location). All results according to the different dome shape parameters and the various situations can be summarized in the following are some tips to assist designers in creating hearing-friendly environments in worship places, depending on these results (correlation between dome shapes and sound level performance within mosque):

- The dome's design and volume have a significant effect on sound and clarity of speech.

- The proximity between the dome and the acoustic source has an influence on the acoustic quality and word recognition.

- The material used to clad the dome's surfaces had an effect on word recognition and audio qualities, which could be verified using the materials' absorption coefficient.

- The major parameters used to evaluate sound quality are RT and clarity.

- Because the findings will vary depending on the structure's shape and architectural elements, a case-specific investigation is essential early in the design process.

It is clear from the findings that dome, as an Islamic architectural characteristic, could have a direct effect on audio quality. This influence could be favorable or unfavorable. The findings support the notion that appropriate cupola design in buildings is a critical component of a mosque's audio performance within the main hall.

CONCLUSION

In this study, a series of simulations have been performed with different shapes and their respective locations of mosque domes on the acoustical performance of reverberation time and speech transmission index by means of computer simulations. From the results obtained, it can be concluded that dome shape can affect reverberation time especially in low frequency regions. However, there is less significant changes in reverberation time that could be observed in the results when different locations of the dome were being simulated in this study. Meanwhile, the dome shape would affect speech transmission index adversely - the larger the volume is, the lower the STI becomes. However, it should be noted that while all models were simulated with fixed materials and similar size of prayer hall dimension, the positioning of the dome can also improve the speech transmission index value. Further investigations and analysis on other acoustical parameters are now being pursued intensively.

Second

Dome's thermal behavior (Heat and Ventilation)

Abstract

For centuries, dome roofs were used as a covering method of buildings` roof in traditional houses in hot regions such as the Middle East and Mediterranean basin, due to its thermal advantages, structural benefits and availability of construction materials ; so that it has been widely utilized in mosques, shrines, churches, bazaar and schools construction. On this account, the current research studies on the role of shape in roofs energy loss specifically in cold annual period to achieve the optimized form. About natural ventilation, the modeling was verified using grid sensitivity and flux balance analysis. In order to validate the modeling method used in the current study, additional simulation of a similar domed-roof building was conducted for comparison. For wind-induced ventilation, the dome building was modeled with upper roof vents. For buoyancy-induced ventilation, the geometry was modeled with roof vents and also with two windows open in the lower level. The results showed that using the upper roof openings as a natural ventilation strategy during winter periods is advantageous and could reduce the indoor temperature and also introduce fresh air. The results also revealed that natural ventilation using roof vents cannot satisfy thermal requirements during hot summer periods and complementary cooling solutions should be considered.

Introduction

Presently, energy demand, as a vital economic characteristic, plays an important role to increase energy price considering nonrenewable resources limitation and costs. Accordingly, parallel to efforts made to tackle the energy upgrading costs and absence, improving energy efficiency and conservation in buildings are considered as main solutions to address the problem. The increasing thermal comfort expectations, the availability of electricity generated by fossil fuels and the growth in the global average temperature have raised the energy requirements of mechanical systems (heating, cooling and ventilation) in a rather dramatic way in the building sector, which makes it responsible for 30%–40% of the global energy demand and 40%–50% of the world carbon emissions. Therefore, it is essential to replace the mechanical systems with passive techniques known to have low energy consumption and carbon emissions and provide good indoor air quality, Addition to applying thermal insulation in buildings, it is extremely significant to implement energy-efficient strategies and approaches to decrease energy transfer rate in construction sector

A. The role of domed shape roofs in energy loss in hot and dry climate.

This is an attempt to find the most efficient form of buildings which might be suitable for contemporary architecture of developing countries

1. Methodology and Inference Mechanism

Energy efficient design in building and its elements specifically roofs design plays an effective role to level down the rate of energy use in construction sector. Moreover, as previously mentioned, widespread application of domed roof in traditional vernacular buildings appeals many research workers to the issue to discover the most influential parameters. Many researchers have analyzed and studied dome employment on different aspects specifically thermal behavior.

Research Questions.

The article is to find following questions answer:

1- What is the role of roof shape in energy loss at night?

2- Is there any relation between the arch of dome and energy loss characteristics?

Applied techniques are numerical-comparative ones according to case study selection; so this paper uses computerized simulation methodology as an alternative to field-based research. Computerized simulation provides a virtual environment to survey the thermal behavior of building elements in details. The techniques of methodology, modeling and simulation by advanced numerical analysis software.

2. Buildings Form and Energy Loss

In the way of exploring sustainable solutions for energy efficiency construction, now building solutions plays the leading and exploring role in energy consumption. Combined with global experience and local knowledge, there is a large scope of solutions to decline the rate of energy loss in construction industry. To Increase the efficiency of heating and cooling equipment, the insulation increase for the building envelop and imposing buildings standards all are considered as contemporary solutions toward minimizing energy loss , however, there would be less tendency about pure architectural forms which leads to sustainability. Furthermore, in passive solutions toward energy saving, unlike the active ones, the architecture takes the most significant role according to creational design meeting energy conserving necessities. In this case, the first step inclines toward building volume and form. It means that if it is essential to use natural facilities to reduce energy loss, buildings type and envelope will be the first challenge to deal with. So that, the integration of the method and applying appropriate building design techniques contributes to green echo-friendly buildings and societies

3. Simulation Process

3.1. Mechanism of Case Studies Selection

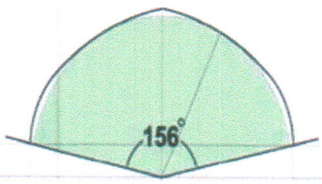
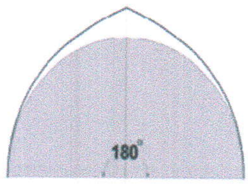
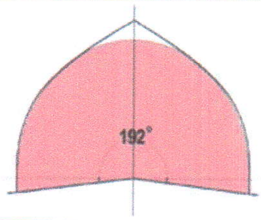
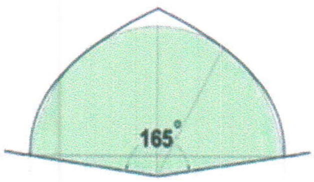
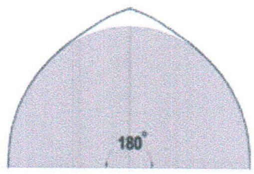
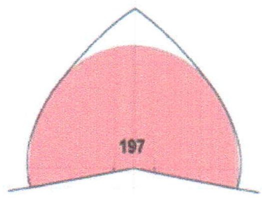
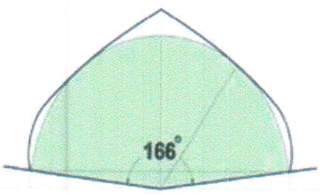
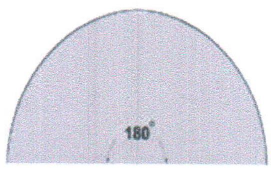
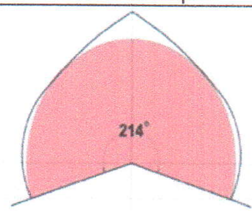
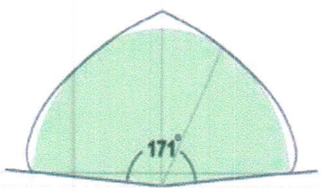
It is very important to clarify that in hot and dry regions of Iran, architects mostly used domed roofs to provide space coverage, particularly in dominant mosque constructions. Therefore, 10 survived samples of Esfahan mosques` dome are selected to study on. Case studies are provided for estimating heat loss through 4 types of roof including 3 types of domed roof and a flat one.

3.2. Roof types

All types are categorized in following groups:

Type 1. With an inscribed arc less than 180 degrees. **Type 2.** With 180 degrees inscribed arc.

Type 3. With an inscribed arc more than 180 degrees. **Type 4.** Slab roof.

Type1	Type2	Type3
		
Hakim Mosque	Jame Mosque	Sarutaqi Mosque
		
Agha Noor Mosque	Jame Mosque	Emam Mosque
		
Khan-Rahim Mosque	Khayatha Mosque	Rokn-ol-Molk Mosque
		
Lanban Mosque		

3.3. Identifying the Polygons

Three characteristic samples of each domed group are illustrated in table. These samples are: Hakim Mosque with an inscribed arc less than 180 degrees (Type1), Jame Mosque with a 180 degrees inscribed arc (type 2) and Imam Mosque with an inscribed arc greater than 180 degrees (type 3). To numerically calculate and analyze, the circle at the base of the dome is replaced with a hex decagon. The dome is placed on a cylinder which is 10 meters in diameter and 4 meters in height. The rise height is divided into 1 meter segments; hence, the outer layer consists of similar trapezoids. With this meshing method, the surface area of each dome can be numerically calculated and finally the simulation results for the domes will be compared with a flat surface. Thus, thermal performance of samples is evaluated by the numerical simulation method using commercially available software.

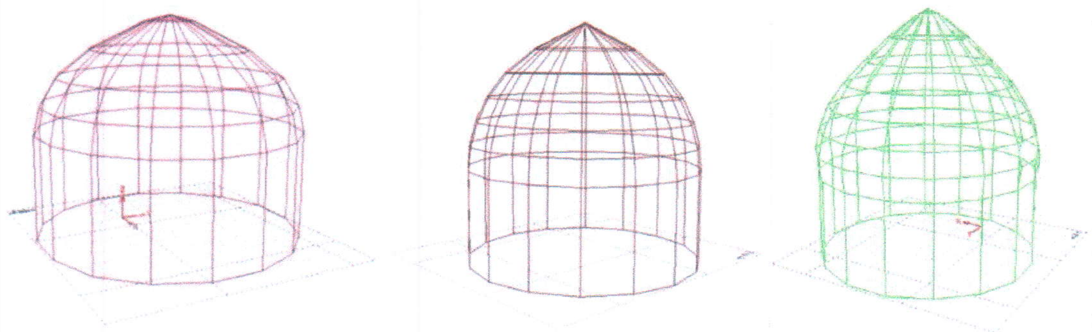


Table 2. Total area and total volume quantities in 4 types` roof, designed by authors

Roof Type	Total area/m2	Total volume/m3
Type 1	330.78	495.858
Type 2	366.78	582.826
Type 3	390.348	635.044
Type 4	277.989	307.193

4. Discussion

To achieve the goal, four roof models are calculated in software in terms of heating load emphasizing on the rate at. Numerical modeling is indicative of the thermal performance of domed roof buildings while comparing them in terms of energy efficiency. However there is more dictators can be effective on. As represented in table 3, the least total rate of heating load refers to type 4 flat roofs, which is about 46 kw/h in a daily calculation and 20.5 kw/h overnight times. Comparing all other type, furthermore, Hakim mosque roof, as type 1, has the most heating load rate both in day and night calculations which respectively is about 37.1 and 41.9 kw/h. It seems type 1 behaves as the least efficient shape of the roofs.

Table 3 . The comparison of heating load quantities in 4 type roofs

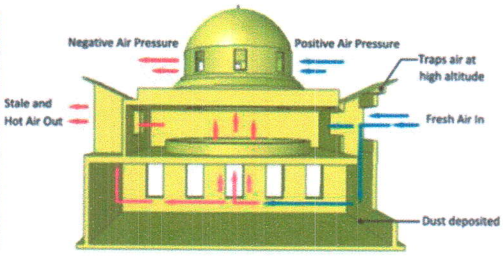
Heating Load (Kw/h)	Type 1	Type 2	Type 3	Type 4
Heating load (Night)	41.85	35.42	38.97	20.47
Heating load (Day)	37.12	31.5	35.093	25.59
Total Heating load	78.97	66.92	74.063	46.06

5. Summary

Comparing all four models together in graph 1, the result shows that the less external area is, the rate of heating load and the same the rate of heat transfer flux will be less. So that, flat roof in type one with the least side area ,which is about 278 m^2, behaves as the most efficient thermal performance due to a significant reduced volume over a daily period specifically with an emphasis on coldest night 21 December (Winter Solstice). Moreover, based on the analysis of three other modeling and roof types, it seems that however dome type 1, (Hakim mosque), gets lower side area with an inscribed arch less than 180 degrees, energy load negligibly increases in calculation; The graph also shows that type two presents more appropriate thermal behavior however the first one performs as the most inefficient type why it has the most heating load over a day.

B. Computational Analysis of Natural Ventilation of dome shape building

The reduction in energy consumption can be fulfilled by a wide range of factors, including appropriate building geometry, suitable building orientation, use of shading devices, vegetation, color and insulation . In terms of the building geometry, the lower the building surface area to volume ratio, the lower the heat gain would be, so for a given volume, building with a spherical shape is more energy efficient than a typical cubic building in terms of heating and cooling requirements. Accordingly, a dome house has 30% less surface area than a similarly sized box house, resulting in an average of 30% savings on the cooling and heating bill.



Several studies investigated the passive capabilities of dome roofs in keeping the internal spaces cool in summer with considerable low energy consumption due to several reasons such as:

(a) Thermal lag provision via applying masonry thermal mass such as stone and adobe, which abate the incredible temperature difference between day and night.

(b) Lowering exposed surface area to the direct solar radiation by one-third compared to the flat roof results in solar heat gain reduction

(c) Applying stack ventilation via roof vents, which let the rising hot air escape through and allow the cool fresh air to channel into the space from small peripheral openings at lower level

(d) Trapping the exhausted, hot air at the higher level compared to the flat roof, due to the increased height of the interior, which leaves the occupants in a cooler lower zone.

Results and Discussion

Wind-Induced Flows

During the windy period, ventilation is driven by wind-induced flows. In this case, two side windows were assumed to be closed and the entrance of fresh air and exhaust of stale air were by the top roof vents.

1. Velocity Distribution (Wind-Induced Flows)

Figure 10a shows the airflow velocity streamlines inside the dome house with the top vents open to ventilate the space. In this case, the windows were assumed to be fully closed. As observed, the wind enters from the left velocity-inlet wall and lower airflow speed can be observed towards the ground of the domain (atmospheric boundary layer flow). The airflow can be seen lifting up as it approaches the dome house and accelerates near the top where the vents are located. The top vents capture some of the airflow and recirculates it mainly in the upper floor area. The air that passed through the dome can be seen recirculating at the back side and then exits towards the right side of the domain where the pressure-outlet is located. The recirculating airflow pattern at the upper floor is positioned in the windward region of the building, which indicates a mainly positive vertical airflow in the most windward portion of the building and a negative vertical direction in the middle and leeward portion of the building.

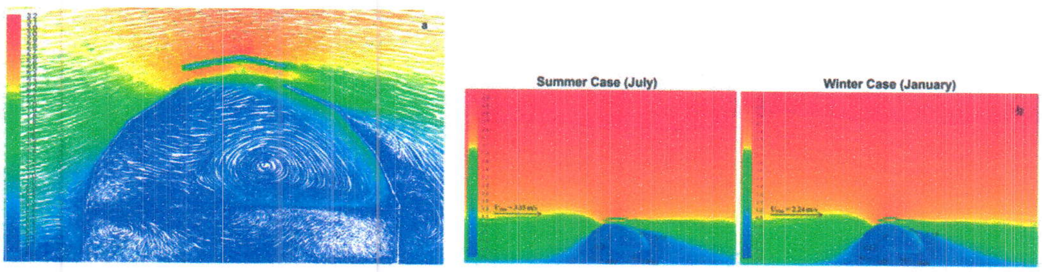
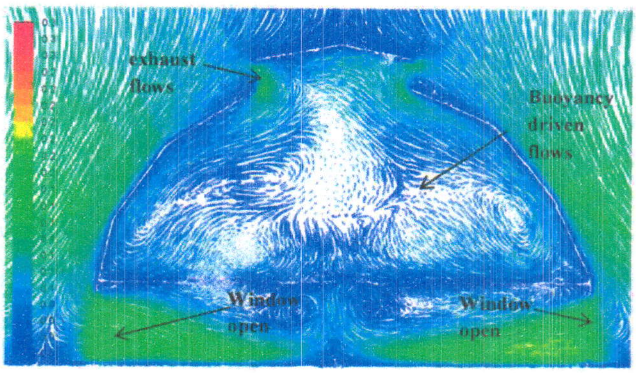


Figure 10. (a) Streamline plot of velocity inside the dome during summer with wind-induced flow; (b) Velocity contour results of the airflow distribution inside the dome (wind-induced flows).

2. Buoyancy-Induced Flows

During periods of very low to no wind, fresh outdoor air can still be induced inside the building using the buoyancy forces from heated air which creates flow from the lower floor to the upper floor. In this case, two side windows were assumed to be open to allow fresh air to enter from outside and replace the warm and stale air inside the dome house. The stale air is then exhausted by the top roof vents.



Streamline plot of velocity inside the dome during winter with very low or no wind speed

Third

Structure design of Dome and shell materials

Abstract.

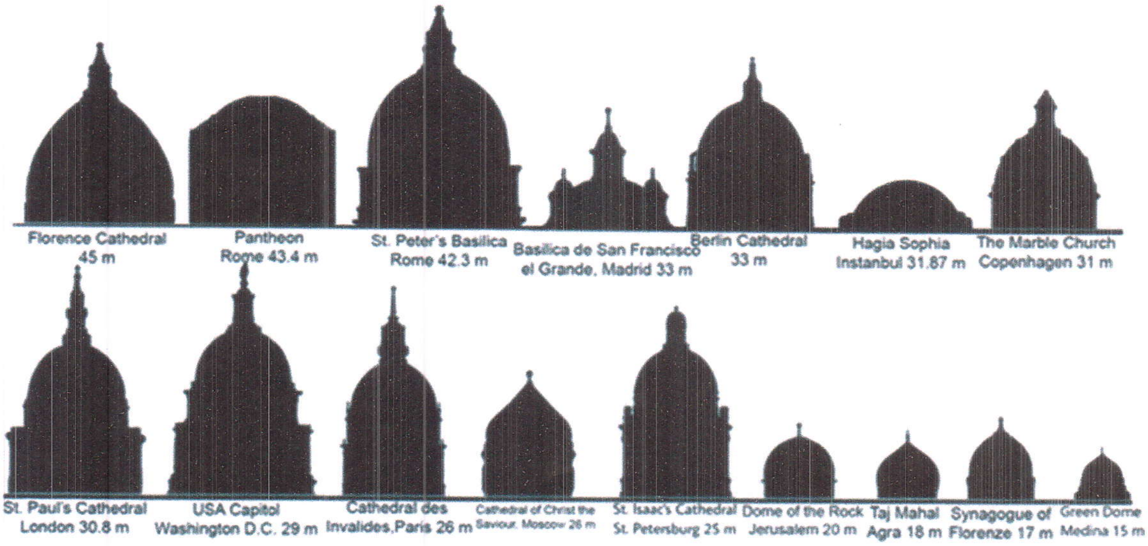
The developments of technology in realizing contemporary designs become a hot issue for the development of the mosque's appearance and shape. The development of the shell building in the mosque which is quite attractive to the public was the construction of the Cologne Central Mosque in Germany in 2017. For the point of view that shape of the building is a new era in the use of shell structures in the mosque. The shell structure commonly used as a dome of the mosque that is used as a symbol of the mosque buildings in general use and continues to this day which began from the era of the caliphate. This is a review of the structural designs and building materials on the shell structure of the mosque which has been developing from time to time. And can be used as a possible new reference in the future developments of mosque architecture.

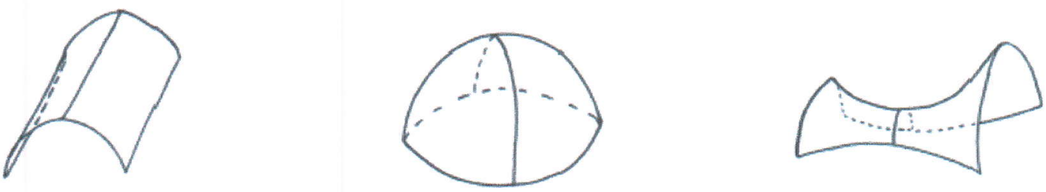
Introduction

The influence development form of the mosque with a dome was happened because of the effect of Christians building traditions (Greece and Roman). The famous dome formation in Roman times is the Pantheon which was founded in 27 BC that becomes a building with the use of a spectacular shell. With its well-known concrete shell affecting the development of the dome shape in general in the world, especially in the discussion of this article on the dome shape of the mosque. The first and most important mosque of Muslims in Medina, the second holiest place in Islam after Makah, did not have a tomb for more than 650 years after the Prophet, peace be upon him, passed away. The first one was built in 1279 by a Mamluk sultan and was made of wood .The dome of a mosque is very important both visually and in terms of quality. Therefore, dome construction is defined as one of the most difficult parts of mosque construction. Real construction experience is required as well as higher mathematical and architectural knowledge. Islamic culture that progressive developed begins when compiling the Umayyah caliphs' policy of shifting its power centre from Medina to Damascus in 661 AD and power up to 750 AD. From the association had been done before he became a caliph with the Romans, the caliphate produced mosque architecture with a dome shaped, so it became the early history of the development of the mosque until the next time. During the Roman and Persian conquests, Muslim rulers began to build cities, palaces, fortresses from the Persian lifestyle. Islamic architecture that is known today has started by Umayyah rulers and spread by Muslim rulers to this day. Umayyah (661-750) build the stone dome, the grand mosque of Kairouan and Damascus which are examples of Islamic Architecture in the Umayyad period. Formation of the dome from time to time is a symbol for the building of the mosque which is an architectural form and it is used as a marker of the existence of mosques in various places in the world. But lately the design of the mosque with a dome which is a shell structure not just to the top only (decoration), but more flexible so that the area inside the shell is also used as a space that is the prayer room and other functions. Especially in Seljuk and Ottoman architecture, large mosques have domes of enormous sizes. While expressing the rise of the earth with the dome in Islamic mosque architecture, it also indicates the power of the period and the intelligence of the architect. This article provides an overview of the above along with materials used both in the mosque in the past and its development.

Result and Discussion

Because, not only in mosques, in all architecture, domes were the only way of creating large spaces without pillars in the middle. Just like the arches were needed for empty spaces in walls. If you make it flat, it collapses. The dome creates a force like an egg shell. It is now easier to achieve that without a dome, thanks to the advanced concrete techniques of the 20th century. Shell structures must have thin, solid and curved. Shell behaves like a membrane that it receives the force of compressive, tensile, and shears on its surface. The thin of the shell makes a shell has little bending resistance. This shell distributing force spread all over the surface, unsuitable for center force. The ideas of this structure that it is inspired by nature are the most optimal and efficient structure. These structural examples in nature are turtle shells, eggshells, peanut shells, conch shells, etc. This shell with a curved surface can be categorized as a single curved, double curve or free from. The barrel vault is an example of a single curved that it is distributing force in one direction only. Whereas the double curved channel with a two-way system structure (it is distributing force in two directions), namely a synclastic and anticlastic. Like dome, a synclastic has an existence of the endpoints is in parallel places. Saddle-like shape and hyperbolic parabolic are examples of anticlastic that the curvature has a different sign and different directions. Whereas free-form surfaces are even more complicated that it cannot be determined by curvature.





Types of Shell [Single-curved, Double-curved (Synclastic and Anticlastic)].

Form-finding approaches

The efficiency of the shell if it is well designed, so it is a high level of the structure. There are several ways for form-finding approaches. They are analytical shapes described by mathematics, the evolution of two-dimensional structures, mechanical or funicular shapes, pneumatic shapes, free forms, and shapes obtained by numerical optimization. Analytical Shells using mathematical functions so this some shell shapes can be explained completely. The evolution of two-dimensional is obtained by rotating, extruding of two-dimensional elements. An example is the structure of barrels and domes obtained with this approach. One mathematical function that has been widely used in designing shell structures includes cylinder, coneoid, hyperbolic parabolic, spherical, torus and hyper structures. Free forms can be formed using digital computer-aided design with the architect's imagination. But its weaknesses may still find practical difficulties during their construction even if free forms can be more aesthetic Pneumatic shapes that this form is obtained with the help of the use of or gas pneumatics, by pumping gas in a balloon such that it is placed on a dynamic structure that will change shape according to the bubbling that occurs due to pumping gas. The model was built to adjust the computer model and to get a more realistic shape is mechanical or funicular shapes. This model of mechanical shape can be made using chains that are hung and interconnected. The model of mechanical shape is built on a special frame and a hanging chain freely under its weight. The interconnection of various chains allows for the development of forms as needed. After the required shape is obtained, the displacement along the chain is measured at a location corresponding to the computer model node. Then the displacement measurements are carried out by moving the coordinates in Excel and then compared to the computer model. The mosque dome design process cannot be separated from the mosque construction. We exchange views with you on every part of the mosque during the initial project design process of the mosque. This is how the process works in the design. Thus, the most suitable dome model for the mosque is found, Thanks to the developing software technologies and many modeling methods, we show different mosque domes and enable to make the right decision about the visual shape of the construction.

Mosque Dome Design Elements

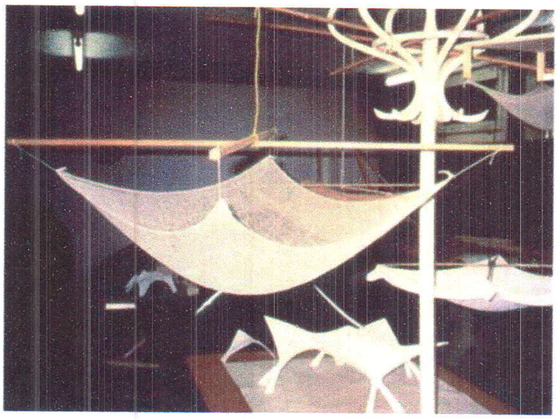
The difference in mosque dome design is shaped by the ties that belong to the mosques. These ties vary according to the characteristics of the region by being processed beforehand. Features that shape the mosque:

- Climate of the area
- Social structure
- Used materials
- Traditional architecture
- Environmental conditions

Building Shell's Material

1. Concrete

The shell with concrete became famous when the building of Pantheon was founded in Roman. The Romans were aware of the weight of the Pantheon dome shell, so the dome was made with lighter building materials at higher levels to reduce the weight of the dome itself. The concept of lightweight aggregates are used to produce lower density concretes, which are advantageous in reducing the self-weight of structures and also have better thermal insulation than normal-weight concrete. To make it lower density obtained with using aggregate materials that may have air voids. Pumice, naturally volcanic rock that occurs in nature, has been used since Roman times, but it is only available at few locations, and artificial lightweight aggregates are now widely available.



Hanging Cloth Model

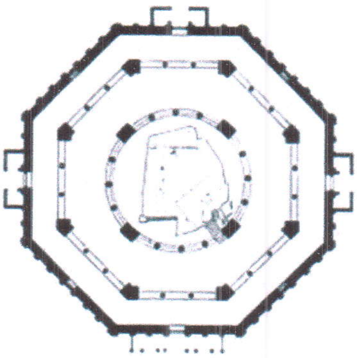
2. Steel Rebar and Lightweight Steel Rebar

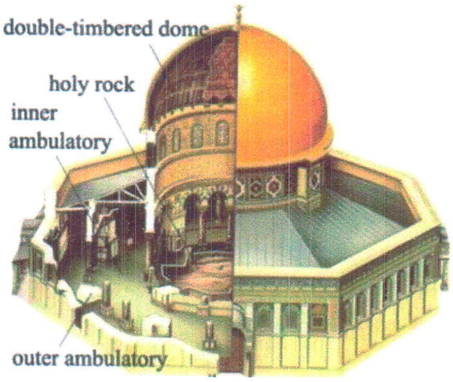
Use of rebar, so then the technic usually with formwork so it can be poured or sprayed with mortar or concrete. When shells with steel ribbed, it can be covered with glass-fiber reinforced concrete installed as fabrication elements. The lightweight steel rebar can be made for the dome when the cover does not weight material. It can be covered by enamel or another lightweight steel covered material

Structural Designs and Shell Materials of Recent Mosque

1. Al Sakhra Dome Mosque.

The Dome of the Rock was designed and built during the caliphate of Abdu al-Malik, the 5th Umayyad caliph of Islam (685–705 AD), and its construction was completed in 692 AD under the supervision of Raja ibn Haywa and Yazid ibn Sallam who are thought to have been in financial and administrative control. The building is octagonal with a wooden dome with a diameter of 20.44 m. A 9.5 m high octagonal-shaped like a drum has become the main building with a dome as a roof placed on it. The dome has a height that is approximately the same as its diameter.



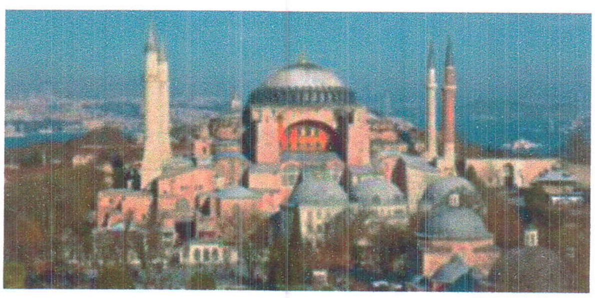


Using wood as material from its dome shell is a two-way structural system consisting of meredional and transverse ribbed that constructed as ribbed dome type. Structural design on the dome of the shell using a half-ball surface or synclastic with wooden ribbed domes, and covered up with coloured and gilded stucco. The first time this dome was originally roofed with lead covered in gold.

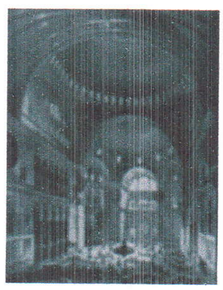
2. Hagia Sophia.

With the fall of Constantinople into the hands of the Ottoman Empire 1453 and the conquest of Hagia Sophia and turned into a mosque. Byzantine Hagia Sophia architecture became an inspiration for many Ottoman mosques at that time until now. The dome is carried on four spherical triangular pendentives, the pendentives are the corners of the square base of the dome, which curve upwards into the dome to support it, restraining the lateral forces of the dome and allowing its weight to flow downwards. The dome has a diameter of 32 m with a dome thickness of about 60 cm. The main building material for the dome is brick and mortar. Mortar from sand and ceramic pieces that are equivalent to concrete at that time. The dome construction weighed 150 pounds per cubic foot, the average weight of stone construction at the time. The dome was designed by Anthemios of Tralles and Isidoros of Miletos, this dome had repaired the collapse due to the earthquake in 558 AD and then was rebuilt with a height of 54.6 m. The dome is supported by four large arches on the four sides of the supporting wall.

Hagia Sophia Mosque

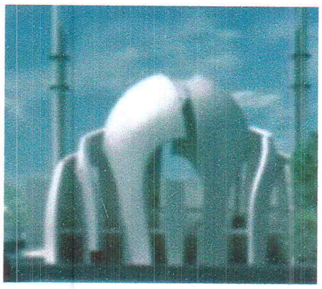


Hagia Sophia's dome



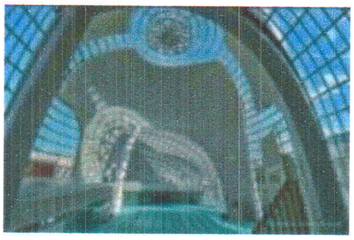
4. Cologne Mosques as Contemporary Mosque

- The span of the main shell 26 m
- The material: Exposed concrete
- The building shell is a two-way system shell
- Complex supporting structures and building state
- Special features: fire protection, earthquake certification and construction states certification
- Modern style blend with Ottoman Architecture style completion on 9 June 2017, architect: Paul Bohm
- Two-way system shell supported by meredional and longitudinal rebars steel



The global form of the solid shell system

Gives opened space



Steel rings connect the shell

Ribbed belt with glass wall material as heat bridges

Lightweight concrete

Mosque Dome Coating

The important thing in the covering of the mosque is durability that covers the dome. The mosque coating should remain intact for many years. The mosque dome cover provides durability and a strong structure.

Mosque dome covering is very important in terms of protecting the structure against external factors. When the dome coating is worn, it leaks into the mosque. This situation negatively affects both the mosque and the congregation who come to the mosque for worship. For this reason, it is extremely important to make the mosque dome coating in the best way and to renew the worn coating.

1. Aluminum Mosque Dome Covering

The aluminum dome covering has a very important place in mosque architecture. It is not only used to cover domes. It is also used to cover tombs and shadirvan domes. The aluminum covering that is made by our experienced staff is very durable in weather like snow and rain.

The other good thing about the aluminum covering is that it is the most economical material. The aluminum covering is waterproof and light. It can be used at the dome and elevations of all of the mosques.

Some Features of Aluminum Dome:

- It is light and durable.
- It provides a decorative appearance.
- It can be shaped easily.
- It is resistant to corrosion.
- It is long-lasting.
- It is easy to recycle.
- It is sensitive to the environment and human health.

2. Lead Mosque Dome Covering

Lead dome covering can be seen at most of the mosques. The lead material has a soft texture. In the first place, a lead dome covering is found. This material is used for many years – approximately since Ottoman time- because of the texture of lead that is soft and not affected by the weather.

The covering is very important because it can cause deterioration of calligraphy, embroidery, and workmanship like that. Mosquebuild is professional in covering domes. You can get done with a mosque that has detailed workmanship and durable covering.

Some Features of Lead Dome:

- Lead is a very soft substance.
- Lead is a material that can take shape very easily.
- Lead is a material that does not rust easily.
- Lead is a material that does not corrode easily.

3. Copper Mosque Dome Covering

Since copper sheets are soft, they can be easily shaped according to the structure of the covered area. There is no breakage or cracking in copper material, the processes are easier, and the coatings can be used for a long time after the process.

It is also worth remembering that copper dome coatings remain brightly colored and very striking for a long time. All coating materials should be handled with devotion and be sensitive about meticulousness. Mosque Build has sufficient knowledge and skills on how to do dome coating processes.

Some Features of Copper Dome:

- It has a striking and very bright appearance.
- It has a soft texture. Therefore, it is easy to handle.
- It provides good thermal conductivity.

What is a Dome Used for in a Mosque?

• We know that domes are roofs. In this way, it is normal to protect the mosque from adverse events such as rain and snow coming from outside.

• Dome is a shield against cold and heat with its roof quality.

• The dome gives a larger sanctuary atmosphere inside the mosque with its wide structure. It gives a very nice feeling.

• An authentic atmosphere is captured in the mosque with the art of calligraphy that will be skillfully embroidered on the inside of the dome.

• With the mosque, the voice of the imam can be more loudly and beautifully dispersed into the mosque. Architectural design is very important here.

Conclusion

The design of a building will form an artificial environment. Then we need both functional and aesthetic design. This is needed to be able to add value to the environment, in addition to providing challenges for the new design of a mosque. The shell structure itself is very interesting to get important characters can provide added value to the environment, structural efficiency, and function as a design producer. At present, the technologies (form-funding, formwork, and construction methods) are becoming increasingly easy. There is a new formation that opposes Islam itself. The most important thing is that the development without purely leaving the Islamic symbolism that has existed for thousands of years but can integrate it well.

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