STUDY OF ECHO FEATURE IN IMAM MOSQUE IN ISFAHAN AND ITS FUNCTION IN NEW BUILDINGS LIKE AMPHITHEATER

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ABSTRACT
The aim of this project is to acoustically investigate Imam Mosque in Isfahan. If anyone ever has seen Imam Mosque, one of the things that have to try is the reflection of sound in this mosque. There is an interesting feature alongside the beautiful architecture that could attract every tourist. The purpose of this design was not only to attract tourists. This is an excellent engineering that has been done purposefully. In the past, due to the lack of advanced audio technology, there were problems to voice one speaker to the audience. In the same period Sheikh Baha'i designed the dome of Imam Mosque to sound even when the speaker does not speak so easily reach to the whole audience. Accordingly, research with descriptive approach and the library methods of data collection (by reviewing historical documents and primary sources) tries to introduce the new perspective of the architectural features of the mosque in the area of innovative design in the architecture community. As a result, this research examined the dome to use technology in the design of today's conference halls.

Keywords:*Echo, acoustic, sound reflection, amplification*

İSFAHAN İMAM CAMİ'NDE EKO ÖZELLİĞİ VE AMFİ-TİYATRO FONKSİYONU

ÖZ
Bu projenin amacı, akustik İsfahan İmam Camii araştırmaktır. Hiç kimse gördü ise İmam Camii, denemek zorunda şeylerden biri bu camide ses yansımasıdır. her turist çekmek olabilir güzel mimari yanında ilginç bir özelliği vardır. Bu tasarımın amacı turist çekmek için tek değildi. Bu bilinçli yapılmış olan mükemmel bir mühendislik olduğunu. Geçmişte, gelişmiş ses teknolojisi eksikliği nedeniyle, dinleyicilere bir hoparlör sesli sorunları vardı. Aynı dönemde Şeyh Bahai konuşmacı kadar kolay konuşmak tüm hedef kitleye ulaşmak değil bile İmam Camii'nin kubbe ses için tasarlanmış. Buna göre, tanımlayıcı bir yaklaşım ve (tarihi belge ve birincil kaynaklar gözden geçirerek) veri toplama kütüphane yöntemleri ile araştırma mimarlık dünyasının yenilikçi tasarım alanında caminin mimari özellikleri yeni bir bakış açısı getirmek için çalışır. Sonuç olarak, bu araştırma günümüz konferans salonları tasarımında teknolojiyi kullanma kubbesi incelendi.

Anahtar Kelimeler: *Yankı, akustik, ses yansıması, amplifikasyon*

METHODOLOGY

Architectural History studies mostly with views as diverse as perceived history, architecture, art, aesthetic, archaeological, and metaphorical have been completed. In these attitudes and practices, interpretation, composition, monographs, typology, etc. information are analyzed and stated.
In this study that is accomplished by architectural attitude and in typology method, the method is descriptive and data are gathered by library (by reviewing historical documents and primary sources) and observation. First, a field survey and study of written sources related to the research has been done. In order to answer the questions, the achieved data are analyzed that the results are achieving the similar models in the geometry of space and acoustic examination of the structure.

Submit Date: 10.02.2016, Acceptance Date: 25.03.2016, DOI NO: 10.7456/1060ASE/022

INTRODUCTION

No nation can move in the path toward the bright future without depth look at his past and examining the life and work of artists, industrialists, politicians and the most important thinkers and scientists. Nowadays many experts have focused on matters relating to the welfare of citizens and reduce the cost of energy. Life is full of sound and we always want to hear good voices and sounds and we avoid unpleasant and abnormal sounds. Generally, it can be said that whatever we move forward, man has more focused on the hearing. Increasing development of sound technology such as telephone, radio, phonograph, tape recorders, etc., can be the good reasons. The purpose of this article is to study the sound and sound insulation and its role in the areas of architecture and energy consumption, after hearing descriptions, it studies sound reflection relationship with the capabilities to offer acoustic solutions in the design of architectural spaces. The site plan, architectural design, construction and design methods, barrier or fence are four main factors to improve the consistency of sound in any type of user or space activity. The physical techniques in many cases such as reducing noise, energy consumption and cost were effective, especially add to its circumstances. The aim of this study is to assess the current situation and provide a series of recommendations in order to achieve the highest quality of life, which may be in the process of planning, designing sustainable architecture, acoustic comfort and energy efficiency.

THEORETICAL PRINCIPLES

Sound which literally means the singing or exclaim (Dehkhoda, 1945) is one of the external phenomena that our senses perceive it and we feel it pleasant or ugly. When this beautiful sound tied with the spirit of the architecture, its effect is increased. It happens through twisting or reducing a voice response (Egan, 2009) that the artists in every period have done their best to achieve this goal.

In fact, the base of article is as a bridge between architecture and sound in the dome of Imam Mosque in Isfahan that leads to analyze patterns and geometric motifs of dome.

HISTORY OF SAFAVID

Safavid returned political unity to Iran after centuries and Iran's political and economic direction have blown breath, and to achieve the political objectives in the area of religion and Shiite, they create important change and recognize Shite that has rooted in Iran since Alebuyeh.

These changes in art and architecture were not ineffective and led to the rise and growth of the arts to the role of religion as well as the interest and support of the Safavid kings, and these changes caused the decline of some field of arts (Louis, 2004).

knows the Safavid state as the pure Aryan race (Sivori, 1945) that this state has formed in this way that Firouz Shah was a powerful and religious man who lived in Gilan, he had many followers and he lived in the early seventh century. After his death his son Eyvaz appears in the area of Ardabil (Asfaranjan) at age 14 with a spiritual character. He also had a sacred character enough to be his successor .Then the person on the 650 (AH) with the birth of his son, Sheikh Safi, the Safavid dynasty was entering a new phase.

Safi was looking for a coach, since he was twenty years that could help him and after passing through places like Fars, Mazandaran, and Gilan, he found Sheikh Zahed Gilani until his death at age 25, he was a disciple. Sheikh Zayed succeeded him as a leader and after that the dynasty was called as Safavid. He is the founder of Sheikh Safieddin Ardabili and successor of Shah Ismail Sheikh is the founder of the Safavid dynasty.

Ismail Shah's coronation date 970 AH Twelve Shia Safavid dynasty established and declared as state religion and consolidated his spiritual foundations of the state. After him Shah Tahmasb ruled and then, Shah Abbas ruled. The art and architecture flourished during the Safavid period. Because Abbas

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concerned the artistic issues such as tiling, painting, carpentry, etc. The pinnacle of urban public buildings was started in Iran in the same period.

THE HISTORY OF CONSTRUCTING IMAM MOSQUE

Building Abbasi Mosque (Imam) began in the southern side of the historical right of the world in the year 1020 AH Shah Abbas I and the twenty-fourth year of his reign and to decorate big right, in the year 1025 (AH) and, while still establishing other parts of the mosque, entrance exquisite mosaic tile work was finished.

The mosque is an immortal masterpiece of architecture and tile work of Iran in the eleventh century AH. (Sharden ,1993)

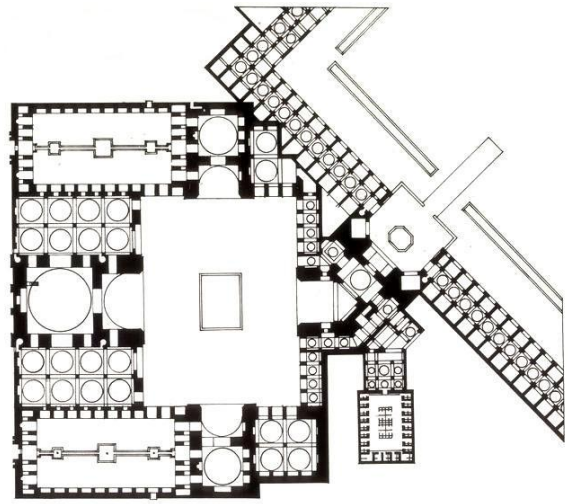
Inscriptions of the mosque, the famous calligraphers Safavid era and its main decoration of tiles and mosaic brick color is seven.

In school, southwest of the mosque, a simple piece of stone in the form of index embedded in a certain place on the afternoon of the real Four Seasons show and said that Sheikh Bahai has done its calculation. (Pirnia ,2004)

Interestingly, the great dome of the mosque in the southern sound reflection, the mosque is 52 m and its height is 48 meters and height of the prayer tower is 42 meters.

Large pieces of marble integrated precious stones, especially the precious stone of western yard of dome dated 1095 AH that it is the interesting parts of mosque. (Pope ,2009)

In order to enter the courtyard of the mosque had to pass left or right side of a covered corridor, which after passing through a semi-dark room, 45-degree angle until the mosque over them. (Sanson , 1987)



Map 1- Imam Mosque and its orbital plane relative to the axis Nqshjhan

In fact, these two paths as the tunnel for the passage of the transverse axis of the shaft failure of two of these fractures on the right and conceal the mosque was. In addition, this technique meets all goals of the mosque designer from the standpoint of maximum absorption of light and facing the Qiblah of the mosque.

A property of mosque has caused that without any sound amplifying devices such as microphones, the preacher was heard by the sound of a population of 15,000 people. This property is originated by the form of the dome which is built by the collaboration of the architect and mathematician. Function of dome is similar to the system of flashlight, as they are designed to strengthen the focus of the inside of

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the flashlight light. The dome reinforces the sound waves at a point just below the dome space and thus all clearly hear the voice of the preacher. (Hashemi ,2009)

Today, the property of the buildings can be designed as the amphitheater for lectures without having devices to amplify sound speaker voice to be heard clearly. This research led to the better introduction of Islamic-Iranian architecture, and it can be a model for contemporary architects.

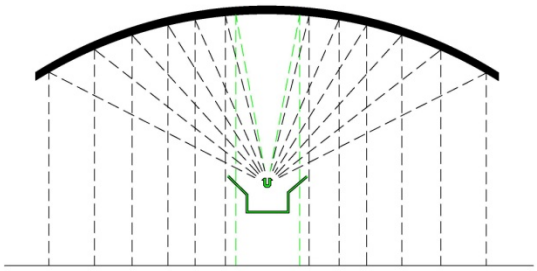

Figure 1- The manner of strengthening light in the center of flashlight

ACOUSTIC ARCHITECTURE

The sound quality of internal evaluation in humans that is of great importance and scope of human beings began to hear voices talking music continues. In both direct and indirect sound is received. Direct sound in a spherical form and has been transferred from the source directly to the listener and the spherical form of the motion will be moving in all directions at the same time. In the indirect mood, the sound is reflected by reaching to a surface and then return to the recipient. Sound is received simultaneously from different directions is removed. (Qyabklv ,2007)

In terms of physics, sound path from the source to the recipient in a confined space such as a music hall infinite number of different paths in their movement is possible (the spherical sound). And with regard to the levels at which the sound wave collides with one of them, there are Back (Reflect), refraction, diffusion or is absorbed by surfaces. In practice reflective and back, the sound wave returns but loses much of its energy.

When a sound wave hits a certain level, the materials in the amount of energy they absorb sound. Absorption coefficient determined for each of the materials that it determines absorption. (Hashemi ,2009)

In the design of spaces such as theaters and auditory environments in balance and the balance of the return and absorption try to create the environment in which the sound to flow competence. Another important factor in sound quality control related to Avast and the resonance or after the time when the reverberation continues.

It occurs when sound energy source will stop after his departure, continues. And that until that resonate through collisions with surfaces and circulating in the environment, leading to the loss of energy is lost. That it depends on the volume and duration of continuing resonance space and the type of materials. For example, if the reverberation is too long, it will be difficult to understand the words in a speech. The body has a natural alternative, and indeed is shaky. A music hall or like a gigantic resonator. One of the most interesting examples in this section discuss the dome that makes it so special is the distortion and transmission. (Qyabklv ,2007)

THE ACOUSTICS IN BUILDINGS

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The Greeks and Romans were the first known efforts to create the environment with good hearing. Epidaurus Theater Greece indicates this. The farthest seats from the theater listen to a voice that is clearly based on the current scene. (Farthest seat from age to run about 60 meters away). Interestingly, in the largest theaters in the world today are the last seat is the source of 50 meters. This form is oval and circular form of choice for Greeks who have good acoustic properties. Sound waves in this area if the sender is one of the foci of the ellipse spread through the interior walls inward reflection and focus on others are converging. (Bingley ,2009)

The theater seats with a slope of about 30 to 34 degrees as well. The steep sloping angle will be run full view of each point on age. In addition, it also helps to acoustics. The move also provides sound steep for a shorter route (the direct sound), the path that has the least interference. The resonance design brief that it increases sound clarity. The churches also usually desirable resonance is important and it is long. This will be satisfied by the dome .Parabolic dome systems will be the focus of the voice.Sound waves collide with the surface of the dome and the center of it are converging. (This depends on the curvature of the dome, as well as the type of material is different). (Bingley ,2009)

Domes can be designed to control echo and delay makes it actually prevents the return (using absorbent materials) or by the use of materials such as marble and mosaic resonator that are heavily reinforced. (Bingley ,2009)

In an auditorium of spectators to the venues is high if the sound is influenced by population and the hall can be used for any or all of the additional absorbent materials used and if the hall is empty. A huge difference arises. In this case, the variable absorptions are used in order to be in high or low volume based on the population. (Bingley ,2009)

The ideal for theaters is that the space should be absolutely silent to sound film without any change in broadcast quality, but in this case the source of the sound system must be extremely strong. This increases the number of speaker that is affordable and makes the sound is annoying to people close to the source. This makes acoustic design environment has been important and beneficial use of the voice. (Bingley ,2009)

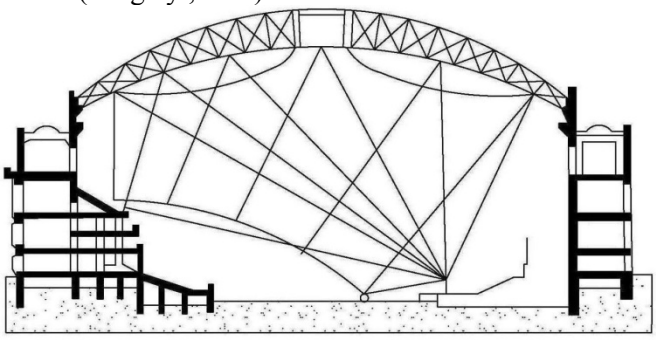

Figure 2 - Proper distribution of sound in a hall

THE RELATIONSHIP BETWEEN SOUND AND ARCHITECTURE

Sound propagation in open or closed depends on the different treatment. Sound waves in an open environment without hitting the barrier, the publication will continue to the point of ruin, If indoors, some of the waves hitting the walls and ceiling, absorbed, taken part and the other part after the transfer, overlapping waves produce. (Egan, 2009)

ECHO

Wave theory is based on the study of three-dimensional waves in an indoor space.

In theory, each chamber has fixed waves that can be used for countless three-dimensional hollow sound with specific frequency vibration that it can be calculated for simple geometric forms that it depends on the size and shape of the room.Thus, it can be concluded that the law into geometric

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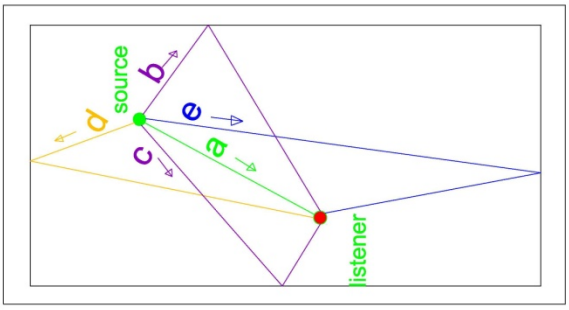
acoustic sound beams offensive and acoustic radiation at a level reflecting both the Provisional and the angle of incidence is equal to angle of reflection. (Qyabklv ,2007)

THE ACOUSTICS IN A ROOM

Imagine that there is an audio source in a green dot in the front of the speakers that can be a player, playing an instrument, or a singer and orchestra.

Simplicity, we assume that the ratio of the audio source in the room is so small that it can be considered a point source of sound.

Figure 3- diagram of audio sources and routes of the audio to the listener



The listener is in the red dot. Suppose that in a moment the sound source produces a sound, the shortest distance between the audio source and the listener is the green line that is displayed by *a* path. Obviously, the listener will hear this sound. Energy of sound reflection reduced due to the way it passes. (Mohammad kari & Khalili Jahromy ,2010)

When sound waves encounter obstacles angle of incidence with respect to the tangent to the point of impact will be reflected. So as you can see in Fig. Because the room has four walls, four reflections that the sound produced, after the long distance to bring the listener's ear .These reflections are displayed by the letters b, c, d and e.

The propagation of sound in the environment due to air resistance gradually causes less energy. In other words, the distant source causes less sound energy.

So it is clear that reflections of the main source of sound that travel farther to reach the audience, first, they arrive later to the listener's ear, and secondly they contain less energy.

THE FORM OF THE BUILDING

The form of the building is the first point that should be analyzed, it means the ratio of the length, width and height that the main issue was acoustic and acoustic proportions of old books described as 2-3-5.Today, measuring the local dimensions of halls is not unsolvable problems through theory of acoustic waves and according to the selected form. However, according to studies, the acoustic issue is not the definitive solution, but the size and form of Hall should be selected so as much as possible, especially dispersed waves and this requires avoiding the correct dimensions. (Liaqati ,2001)

Hearing spaces about a place close to the source of sound to the listener should be analyzed because the waves reflected from the walls and ceiling of the hall is not sufficient for understanding. The direct path is more important and the direct sound energy and sound energy is reflected in the good acoustic space. Observing this point in the construction of studios that listeners hear the sound from the microphone is very important.

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Radiation from the source of sound in different ways after reflection on the ceiling and walls to reach the listener's ear and, therefore, may be due to the way some reflections long time after the original sound to be heard. If this interval is more than 50 milliseconds on short reflected sound like drum or clap sound quite distinct from the original and be heard clearly that it is called echo. But if the sound is reflected back in less than 50 milliseconds are mixed with the original sound and the effect lasts only sound in the ear that does so much more defined sound.

It has been tried that the time difference between the original sound and sound reflections from 35 to 45 milliseconds, which corresponds to a difference not more than 12 to 15 m, usually less for lecture halls and classrooms, and the average value for concerts and more for churches and halls of the choir as well. (Liaqati ,2001)

DIFFUSIVITY

In addition to the dispersion of energy in the volume of another important point that must be considered in the design of such buildings damping is uniform special frequency that is to make it play materials Absorbent in all the zones of the assumptions. It is obvious that this is simply not possible for viewers who are absorbing the bulk materials or cannot be evenly distributed over the ceiling and the floor and walls. Due to the fact that, especially in the halls and studios with a weighted geometric form (cubic, etc.) that has flat walls are parallel and intensive radiation of varying intensities are high risk that reduces uniformity and hence it is necessary to make parallel walls and flat refused to make them homogenous sound field.The walls should be constructed so that they are reflected in a comprehensive and sound not to be diffused. (Qyabklv ,2007)

To homogenize the sound, rough areas with large roughness were used. Semi-cylindrical pieces of creatinine zones with large radius and flat diffuser plates that are installed with different distances from the walls and ceiling. (Irregular and with different dimensions and coating is selected with regard to the appropriate absorption factor)

REFLECTION FROM FLAT SURFACES

If the sound beam from a source that is located at a distance to reflective surface that is large enough to handle its dimensions and no changes will be reflected, this reflection is called echo. If the sound source is located near the flat reflective surface only for acoustic beam geometry is changed according to the law. The direction of the incident after the failure of the angle is equal to its previous angle. (Qyabklv ,2007)

REFLECTION OF THE CURVED SURFACES

Convex or concave Curved surfaces have a different behavior in the reflection of sound. When reflecting on a prominent convex surface, the angle of beam spread and beam divergence is sound and its direction is changed .In the reflection of a concave surface causing converging acoustic beam and change its direction. While the sound source is placed quite close to one side of a circular surface, reflection on surface waves and sound waves listener on the other side could easily get down to the lower level. (Qyabklv ,2007)

SOUND ABSORPTION

Sound design of a room is based on the impact of different sound absorption in the room. The concept of sound energy absorption is to degrade and convert it to heat. When the sound beam hits the surface, the amount of energy absorbed is that it reduces the noise level.

The inner surfaces of a room completely covered with absorbent, such as stereo sound, much reflection has occurred and the listener will receive only the direct sound. (Qyabklv ,2007)

FEATURES OF IMAM MOSQUE DOME

Northern Loggia of Mosque is a long space that is surrounded by a beautiful tile over it. Majestic and lofty dome of the mosque, which was built as two-layers located on the floor. The dome is the largest

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and busiest and most elaborate eleventh century AD architecture in general. (Hajighasemi & Associates ,1997).

The main dome of the Imam Mosque is the wall thickness of 5.4 meters and its internal dimensions of 6/22 m in 5/22 meters, on top of the dome is the floor of the dome to the sharp tips of its internal 38 meters and up Foreign sharp it is estimated at 52 meters.

In fact, the gap between the two domes can be as much as 13 meters (including one meter thick in sharp two domes) in the central region.

The dome weighs about 650 tons, which is assessed at such a height and weight certainly has the very precise and complex calculations of the instruments that the work attributes to Sheikh Bahai.
One of the acoustic properties of the dome is that if the visitor first enters the space of the dome and began to hit the floor and slowly move toward the center point, he can see that in his slow movement, at the beginning of each blow, 18 reflections were heard that the closer to the center, these numbers of reflection reduced to seven times. Instead, by decreasing the frequency of reflection, amplification of sound reflection is increased, and this proves that actually reflecting multiplying number (of any impact in any part of space under the dome) and the amplified sound is fixed and the added value of a factor, other factors will decrease the amount. (Hajighasemi & Associates ,1997).

An ideal acoustic hall has a certain number of natural reflection and action with equal intensity by creating Fractures in the flat wall and slope of the roof and floor, and the use of sound-absorbing material will be possible. Here, we should mention another focus of acoustic functions in the central dome is that prayer, Mokabber's voice for each part of the pillars of prayer should be reinforced to be hear in interior space of Mosque with the breadth of 15000 square meters, and it enables worshipers to follow the imam. However, with the passage of sound waves on a pond in the middle of the main floor area of 283 square meters, the voice can be heard easily because of the difference in the temperature above, the sound waves of Mokabber can be heard clearer and quickly, and by the presence of the other Mokabber in the main door of Mosque, the harmony is set among the worshipers.

Mokabber sound waves pass through the pool so more quickly and more clearly directed to the north entrance of the main door of the mosque with other Mokabber, tens of thousands of prayers coordinated with each other. (Kinzler,2003).

If you have gone to Imam Mosque in Naqsh Jahan, you know that you cannot hear the echo sound under the dome and you have to be on the floor below the top of the dome to hear the voice of applause or which this place is usually a half meters.
The person who built the dome may not be a mathematician, but mathematicians who are familiar hyperbolic mathematics of the height and diameter of the dome to know that you can rely on hyperbolic laws so calculated, which is part of a man standing inverse hyperbolic dome is the focal point of the interior wall and the dome is greater amplification will be more and more focused on that point,
If the dome is designed you can even make the sound at a specific location is much stronger.

What is interesting to know that at that point it will only sound if the property is repeated with energy, try another example, you can shine light on the entire dome to be stronger at that point because of the intersection reflect all light emitted from the surface of the hyperbolic or dome at that point.

And the same properties that are designed for satellite dish receiver or transmitter is used. Paced flashlight is also used.

Some may think that this property is the only property of Imam Mosque in Naqsh Jahan. This is not true and it is everywhere making. The inner dome is designed to be reckoned with, and it is not disproportionate to the dome of the dome's exterior walls to keep fit.

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Iraj Goudarznia is responsible for Technology and he is responsible for the project, he said:
"We've gone over to Imam Mosque in Naqsh Jahan.

We have softly spoken and heard the sound of the mosque. But we have never paid attention to the technology used in these places. This technology can easily be used. We can make modern all aboriginal technologies in past.

700 years ago one of the Iranian architects built a building that can be used at the present in the amphitheater and classrooms. The results of this study indicate that the wall was built based on mathematical equations to a form that reflects the sound on one of the walls leading to the reflection in all directions.

Curve of standoff Mosque is built with complex mathematical equations. Researchers are trying to learn exact extraction. In recognition of this equation, making similar places is possible. If the architecture used in the classroom, then the teacher in the class do not have to increase the sound.

ANALYZING THE RESULTS

By examining the implications of the findings, as has been mentioned, the clarity of sound under the dome of the mosque of Imam is associated with reaction time, the relationship between ECHO and the amount of adsorbent was assessed by quantitative measurements.Using the acoustic performance in the physics building to the acoustic parameters of historic buildings, including the magnificent dome of the Imam mosque covered in the tables, the geometric relationship with architecture is mentioned. As we know that time is the time it takes the echo to the sound intensity of 60 dB above the hearing threshold level is to reach the threshold level. The equation Sebayn, room volume V and capacity of energy absorption is a. Absorption is important, according to the findings outlined in Kaweck's findings, the roof plays the resonator role that refers to the used materials, including shells, porous materials that here the tiles are the dominant materials.

$$T = \frac{0/049V}{A}$$

According to German scientist Helmholtz results and formulas using data extracted Kawecki relations acoustic measurements of building housing research center, echo time of Imam Mosque dome is measured and it is shown in the table below.

2500	1000	5000	Frequency (s)
0/73	0/94	0/68	Reaction time T1
0/83	1/14	0/68	Reaction time T2
0/85	1/25	0/72	Reaction time T3

Table 1. Reaction time measurement in frequency

According to the results we can say that the rate of deterioration of acoustic energy under the dome is fast and echo time is shorter than other parts, while, soon damped waves are lost, respectively. This energy is gradually reduced with a longer reverberation time and acoustic absorption properties are well visible.
In order to prove the hypothesis about the effect of the institutional architecture of the sound we have prepared a table that sound coverage in any given area, the charts show the extent of absorption.

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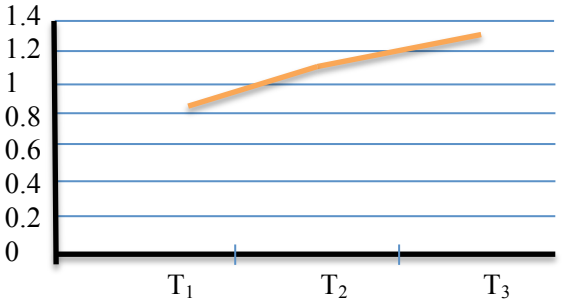

Diagram 1: frequency 1000 seconds

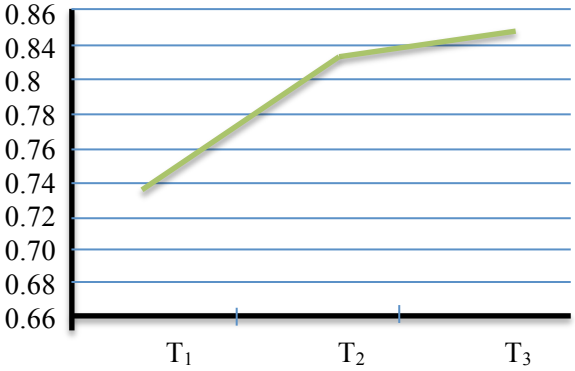

Diagram 2: frequency 2500 seconds

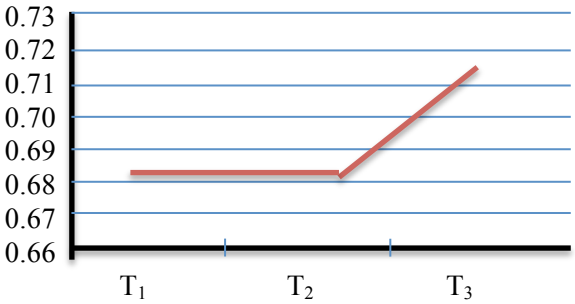

Diagram 3: frequency 5000 seconds

CONCLUSION

A property of mosque has caused that without any sound amplifying devices such as microphones, the preacher was heard by the sound of a population of 15,000 people. This property is originated by the form of the dome which is built by the collaboration of the architect and mathematician. Function of dome is similar to the system of flashlight, as they are designed to strengthen the focus of the inside of the flashlight light. The dome reinforces the sound waves at a point just below the dome space and thus all clearly hear the voice of the preacher.

Today, the property of the buildings can be designed as the amphitheater for lectures without having devices to amplify sound speaker voice to be heard clearly.

It will be more energy-saving design. In addition to the issue of saving, by designing self-sufficient buildings, there would be more attractive places for the users to enjoy being in a different environment.

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In this designing method, the building serves as the unified system that intelligently connect all its parts working together.

In the space under the dome of Imam Mosque, the tile materials that were used to reduce the reflection are not desirable materials for adjusting reflection if some materials such as bricks or stucco were used, the desired result is achieved more.

The new design for improving acoustic effect in this way, sound-absorbing materials indoor dome can be used to better sound quality and minimize sound reflection. This research led to the better introduction of Islamic-Iranian architecture, and it can be a model for contemporary architects.

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INTERVIEWS

- Interview with Dr. Iraj Goudarznia, faculty member of Sharif University
- Interview with Dr. Mehdi Sadvandi faculty member of Isfahan University of Arts

Submit Date: 10.02.2016, Acceptance Date: 25.03.2016, DOI NO: 10.7456/1060ASE/022