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The Echo of Voices in Qabus Tower

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Abstract: Qabus Tower was built during the King Qabus reign in Ziarian Dynasty. Regarding the time of its construction, it followed the Razistyle. There is a location 36 m from the Southern side of the tower, facing the construction with 4 degrees deviation toward the West on which making a sound will be associated with echo. The current study aimed to evaluate how this phenomenon happens and what is the cause of it.

Key words: Echo, superposition, muqarnas, papilla, deviation

INTRODUCTION

The historical buildings are each built with a specific goal. The past architectures avoided futility since they believed that beside capital, it is harmful to the time and even the eye. Therefore, understanding this issue, we can conclude that there was firm thinking behind the historical architecture which need precise studies to be revealed. The Qabus Tower is an example of these constructs with many hidden secrets in it. One of these secrets is the echo phenomenon happening outside the construct but directly related to the structure of the power.

MAJOR STUDIES

Gonbad-e Qabuscity with an area of 2,059 ha is locatedin the Eastern part of Golestan Province, bordered on the North by Turkmenistan, from the West to the cities of Aliabad, Gorgan and AqQala, from the East to the city of Kalala with a mountain and plain climate, between Turkmenistan border area and Gorgan Rood in Dashli Boroon area, having vast steppe areas.

INITIAL INTRODUCTION OF QABUS TOWER

Qabus Tower is one of the most important historical buildings of the 4th century and the world’s tallest brick building, located in the center of Gonbad-e Qabus City on a large artificial hill about 15 m above the surrounding lands. This building was built in 397 AH (1009 AD) as ordered by Shams Al-Maali Qabus Ibn-Vashngir (Fig. 1).

This magnificent Islamic building is constructed on a high soil hill. These tall buildings have always had two usages; besides being the symbol of the city, they have been the tomb of their founder. We can encounter such buildings in Iranian architecture beside the roads, named as bar, tower, copula which were intended to help the

Fig. 1: The location of the Qabus Tower in Gonbad-e Qabus City

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passengers and caravans find their path and to indicate the direction of the cities. Undoubtedly, the Qabus Tower also played this role, since it could be seen from very far distance in Turkmen Sahra plain. Most of the historians believe that Qabus has considered this tower as his tomb, however, some believe that the initial thought was a memorial and Qabus was buried there after his death (Saeidian, 2004).

Razi style: The Razi style was the fourth style of Iranian architecture well manifesting all the good characteristics of the previous architecture styles. The gentleness of Parsi style, the magnificence of the Parti style and the intricacy of the Khorasani style are well integrated in Razi style.

Although, it was initiated in Northern parts, it grew up in Shahr Ray and the best contsructs can be seen in this city, however, these constructs were demolished by Mahmud Ghaznavi raid. Constructs with various usage were built in this style such as the bar and tower monuments.

The construction of cupolae and vaults was well improved in Razi style and the sharp arch shapes were used for the cupola and vaults. The Charbaksh, Karbandi, Kalanbu and Chartork vaults were used in this style instead of simple Ahang vaults (which were prevalent in Khorasani style).

The cupola were also differently built. The discrete Rok cupola which was once built in Northern parts of Iran (such as Qabus Cupola) was also built in Ray City and then in the central parts of Iran. Also, the first example of the discrete Nar cupola was built in Kharghan Towers. Afterwards, the more improved types were built in Shiraz (Pirnia, 2009).

THE CONSTRUCTION ARCHITECTURE

The height of Qabus Tower is 52.72 m its diameter is 17.33 m. The entrance of the building is located in the Southern side. The body's height is 34.74 m and the cupola's height is 17.98 m. The plan of the construct is circular with 934 m of internal opening g. adding the thickness of the walls, the circular diameter of the construct reaches up to 14.89 m which is further increased to 17.33 including the papillae (Fig. 2).

Aside from the war thickness, 10 tangular papillae cover the tower's body. These papillae play the important role of neutralizing the propulsion which is changed by a huge torque. The architects' wit is that they have shown these papillae as a part of the building's facade (Memarian, 2013) (Fig. 3).

Qabus Tower's cupola is of two-shell broken rack type. The use of the rack inclined shield in the Northern

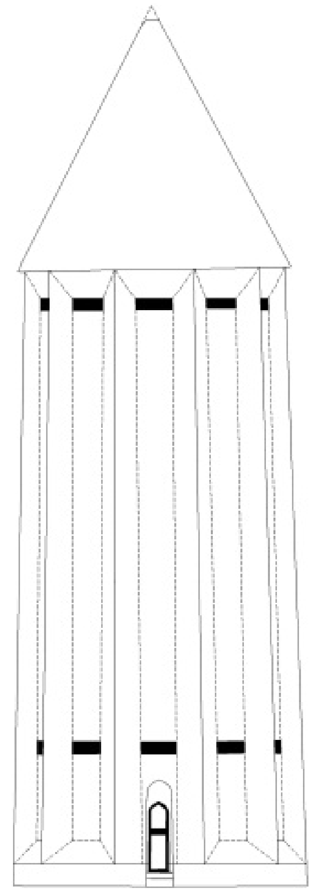

Fig. 2: The Southern facade of the tower

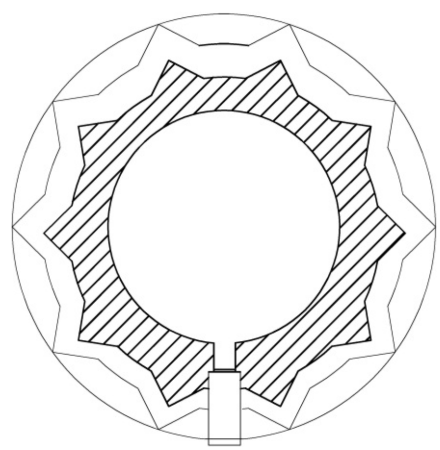

Fig. 3: The Qabus Tower plan

parts of Iran is consistent with the requirements of the area's climate and it has protected the building against the excessive rains (ibid, 508).

At a distance of 3.53 m from the edge of the cullis on the Eastern side of the roof, there is a window with a length of 2.13 m and width of 1.85 m which is the connection to the internal space. The structure from of the window is open with low width and vertical stretching from the bottom to the top (Nomination of Gonbad-e Qabus, Talebian, 75) (Fig. 4).

The Qabus Tower has a brick foundation. According to the story of Qabus Ibn Vashmgir burial in the Qabus Tower, it is probable some secrets can be revealed. Frist digging in the tower's foundation was done by Russians in 1899 AD but nothing was found except a brick foundation (ibid, 65) (Fig. 5).

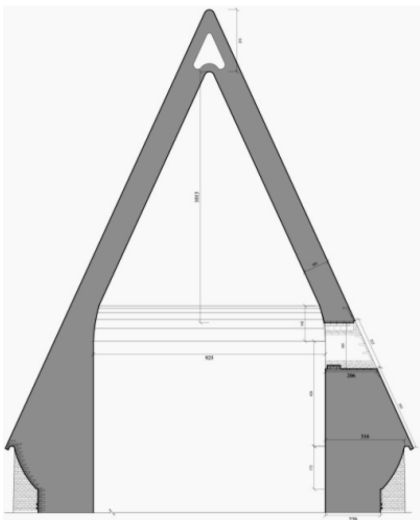

Fig. 4: The Qabus Tower copula (brick foundation)

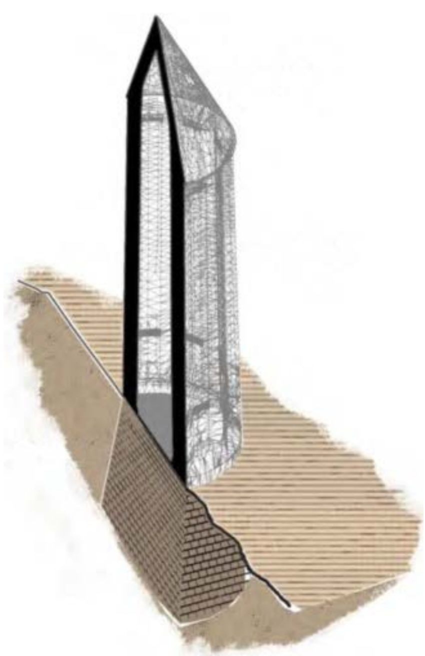

Fig. 5: The tower's foundation

THE TOWER'S GEOMETRY

The ratio of the copula to the body is 1 to 2, i.e., the construct's body is two times the copula. As it was mentioned, the tower has 10 papillae which are located around the cylindrical body of it (Fig. 6).

Each of these papillae form an isosceles triangle with the aid of cylindrical body of Qabus Tower; drawing the geometry Qabus Tower it is revealed that it is designed as two merged pentagons (Fig. 7). The asymmetry ratio can be found in two parts of the construct:

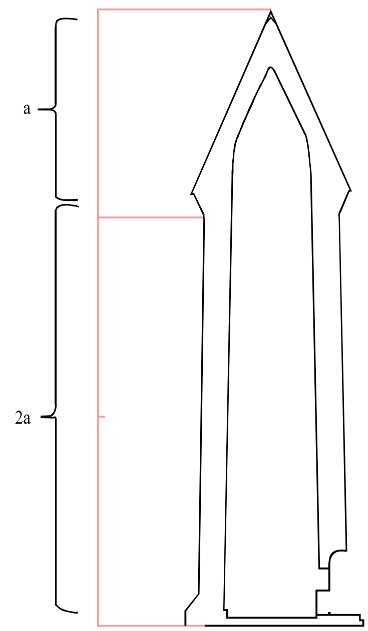

Fig. 6: The ratios of Qabus Tower

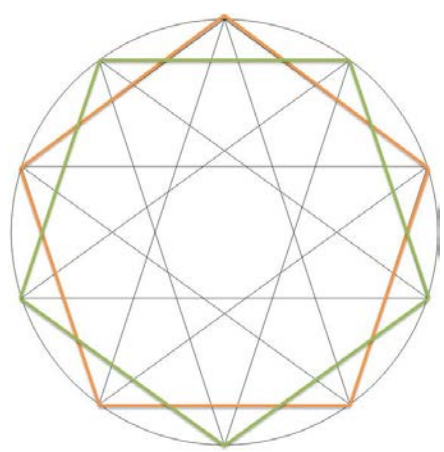

Fig. 7: The geometry of Qabus Tower

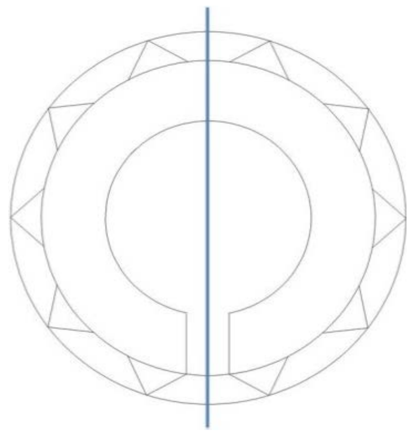

Fig. 8: The asymmetry figure (two equal parts)

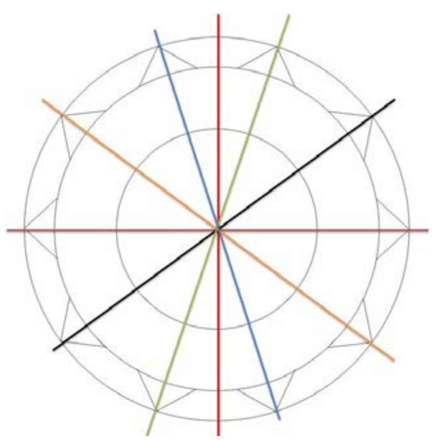

Fig. 9: The asymmetry figure (different direction)

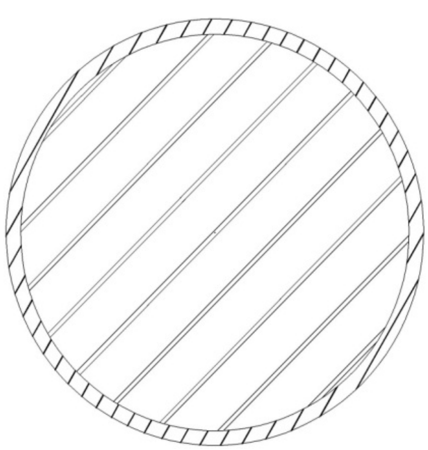

Fig. 10: The asymmetry figure

- In 4.90 m height, due to the existence of the construct's door, the asymmetry is from North to South and halves the construct into two equal parts (Fig. 8-10)

Fig. 11: The muqarnasses of the Qabus Tower

- In higher heights, the asymmetry can be seen in different directions

Decorations: The Qabus Tower was built in Razi style according to the requirements of its time and it was completely made of brick.

It does not have much decorations except two muqarnases on the entrance door which are among the first examples of the muqarnas in Iranian architecture, according to Pirnia (Fig. 11).

THE ECHO OF VOICES IN QABUS TOWER

The effective factors in creation of echo are as follows: smooth surfaces such as walls, cliffs, domeceilings reflect the sound well as well as materials such as brick and mortar (Talaei, M).

THE CREATION OF ECHO

Acoustic echo can be often heard in the mountains or against the large and tall buildings. Whenever, a sound is made in the mountain or against such buildings, this sound, after hitting the mountain or building or any other obstacle is reflected and again reaches our ears. It is called echo.

The condition for the voice to echo is that there should be an obstacle for sound reflection and the distance between the speaker and the obstacle should be at least to the extent that time interval between the original sound and the echo be at least 0.1 sec. For example in a normal weather that the sound speed is 340 m sec^{-1}, the sound round trip is 34 m.

$$\lambda = Ct = 340\times 0/1 = 34,\ 34/2 = 17$$

Where:

λ = The wavelength (the sound roundtrip)
C = Speed (340 m sec^{-1})
T = Time (sec)

Therefore, the distance between the wall and the speaker should be at least 17 m. In many buildings that have big saloons or copula, the echo can be found well. For example in Imam Masque of Isfahan, when we stand under the copula and make a sound, we will hear the echo of the original sound a couple of times. In the cinemas that the echo disturbing, the walls are covered with an anti-acoustic coating in order to prevent the echo (Motamedi).

In order for the echo or the reflected sound to be clear, the reflecting surface size should be bigger than then wavelength or the sound energy will be distributed in the whole space and reduce the echo making it unclear. Also, the more the reflecting surface is tense as compared to air and the sound frequency is higher and its interval is lower, the echo will be clearer.

In a small room with furniture, chairs, appliances and etc. if a sound wave is made by a source, after a maximum of 17 sec, it will be damped and lost. Thus, a remedy should be found for the big saloons which are used for concerts. The sound heard by man can remain in the mind for a maximum of 0.1 sec. If the distance of the hearer and the person who is intended to hear this sound needs the intensity of this time, the principles of building acoustics should be followed in terms of the wavelengths between the walls. Therefore, based on the previous information, the same formula ($T = C/\lambda$) can be obtained.

The obtained distance that is 34 m is the same distance if the hearer hears will be continued for 0.1 sec and since, the walls in the concert saloons are adjusted in a way that the voice is eliminated before reaching the ears of the hearer and the artificial voice is heard by the hearer, the interval between the artificial sound and the reflected sound is <0.1 sec (Fowrer, 1979).

According to the superposition theory, every spreading wave, without interrupting other waves, passes it and continues spreading just like there are no other waves spreading in the space. In the point two or more waves cross, the movement of a particle in the environment is equal to the total movements of each of the waves. Therefore, when an object is placed in a specific place and make a sound, its sound's wavelength reflects after hitting against the other object and returns to it (this kind of wavelengths is called mechanical wave) and increase its sound volume making it echo.

When the sound wave hit an obstacle, the sound returns to a point in the space and all the sounds that have hit the surface will be directed to a specific point which is its center. Thus, the sound is empowered in that point and gets much stronger. This happens due to concentration of all the energy of the waves in one pint. When reflecting from a convex surface, the spreading angle of the acoustic wave and its direction changes and it becomes divergent.

When reflecting from a concave width, the sound waves become convergent and their direction changes (Fowrer, 1979) (Fig. 12).

The sound also reveals itself in the connection between the centers, i.e., if we have two active sound centers in a given environment and these centers are placed in a specific distance from each other, the echo will be also heard in this place (Rasekh, M.).

The reason behind the change in the angle of the echo focal points: Based on what has been mentioned that the sound waves diverge hitting the convex or concave surface. Therefore, the waves after hitting with the tower and muqarnasses and inner wall of the tower, returning and reaching the primary center will undergo a 4-degree deviation in angle (Fig. 13). Based on the doppler effect, it can be stated that:

$$\lambda = CT$$

Where:

λ = The distance of the sound's roundtrip (the sound roundtrip)

C = The sound speed in the air (340 m sec^{-1})

T = The time of the sound's roundtrip (sec)

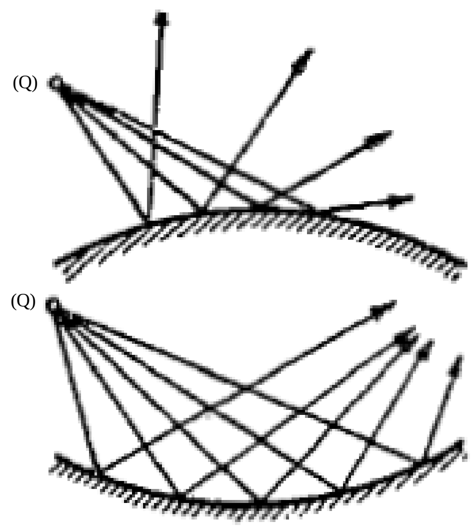

Fig. 12: The waves hitting the convex or concave surfaces

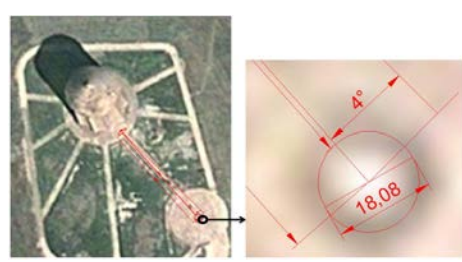

Fig. 13: 4-degree deviation from the echo focal point

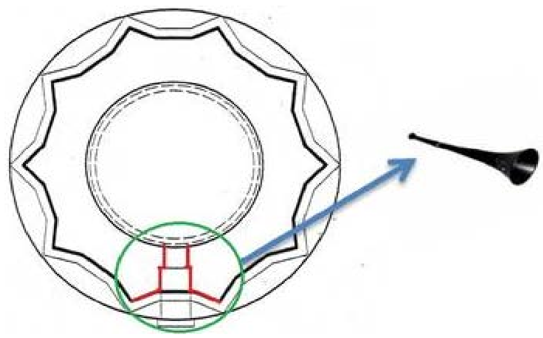

Fig. 14: The trumpet figure in the Qabus Tower

Based on the research conducted by the researchers, the effective factors on the echo from the Qabus Tower are as follows:

- The muqarnasses of the tower
- The papillae of the tower
- The inner wall of the tower

The muqarnasses of the tower: The distance between the center and the muqarnas x = 40.84 m:

$$\lambda = 2x = 81.68 \text{ m}, T = 0/2S \rightarrow \lambda = CT$$

The papillae of the tower: The distance between the center and papilla:

$$X = 39.84, \lambda = 2x = 79.68 \text{ m}, T = 0/2S \rightarrow \lambda = CT$$

The inner wall of the tower: The distance between the center and inner wall:

$$X = 52.07, \lambda = 2x = 104.14 \text{ m}, T = 0/3S \rightarrow \lambda = CT$$

According to the above data, all the obtained times are higher than 0.1 sec, so it can be said that the echo should be clear from the original sound, however it was actually low and its volume increased along side with the original sound.

It can be said that the tower's muqarnasses are the main factor in creation of echo in Qabus Tower and the reason behind the coincidence of the original sound and its echo and the low echo is that these muqarnasses have been ruined in the run of time. The papillae play the role of sound conductors to the muqarnasses or the reverse trumpet (Fig. 14).

The sound intensity is the amount of energy reaching to the surface perpendicular on the distribution direction per time. As a result, the sound intensity L in a place with surface A can be mentioned in the below equation:

$$L = E/AT$$

Where:

L = The sound intensity
E = The energy transferred by the wave
A = The area
T = Time

According to the sound intensity formula, the bigger the area is the sound intensity will be lower and vice versa. The more the sound intensity is the energy received by the ears will be higher and the sound is heard higher. The following test can be done for proving what has been mentioned.

If you put the bigger area of instruments such as trumpet or funnel beside your friend's ear and speak a sentence from the smaller area of the instrument, the voice will be heard with lower intensity but if we do the opposite, the voice will be heard by him with a higher intensity.

CONCLUSION

According to the research, it can be said that the only factor that cause echo outside the Qabus Tower (the echo focal point) is the muqarnasses; also, the papillae due to the convexity they make on the tower's body, concentrate the sounds in a point and cause a 4-degree deviation in the waves, creating the echo focal point. They play an important role in conducting the sound.

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