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# Comparing Reverberation Time in West Churches and Mosques of Qajar Era in Tabriz

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**ABSTRACT:** Worship places are psychologically evolved in human's mind, because his unconscious mind manifests evolution differently in such places. Every religion has its concerning style, while Islam and Christianity represent two different blazes in two separate places. Church and mosque are very important worship places and designers try to create a spiritual sense of place for the audience. Whereas acoustic induces the sense to the audience much more better; this paper investigates an acoustic variable in worship places, at reverberation time was selected as main audio measurement parameter. Three mosques in Tabriz pertaining to Qajar dynasty were assessed and evaluated for their specific construction development patterns and deductible module of RT variable and the obtained results were compared with churches and mosques in Turkey, Spain, Portugal and so forth. Thus, the historical records were identified and obtained through descriptive- research analysis style of RT comparison, measurement tools and devices belonged to B&K, Denmark. Obtained results have availed numerical outputs and quality concepts adopted from numerical factors. We concluded that reverberation time of the mosques is lower than that of the churches, and acoustic quality of the mosques is more effective for speech intelligence, although church is a desirable place for music performance and mosque for speech respectively.

**Key words:** Reverberation Time, Speech Intelligence, Religious Places.

## INTRODUCTION

Man has always loved evolution; his nature is perfection seeker as a divine gift. Everywhere he thinks on his entire belongings, also, he is trying to create perfect architecture designs, the divine creature, namely man has developed and constructed places since genesis; main objective is to build a place for worshiping Allah as well as perfection.

Mosques and churches have always been assessed for creating a desirable sense of worship in audience , the author tries to compare acoustic in the two places , hence, pertaining mosques to Qajar reign have definite structure types , they have been constructed almost uniform with the same materials: six historical samples of historical structures of Tabriz Bazaar were selected , all of them divided in three groups based on their volume , just one sample of a group assessed in the case study.

Three measurement tools were utilized to attain acceptable quality answers in acoustic including field study, simulation with EASE software, and precise calculation based on Sabine and Earring theories. This is just to explain measurement results of the utilized appliances of B&K Co made in Denmark. Acoustic test variables are RT, SPL, STI, ALCons and C50 Involved architecture parameters of form, geometry, material and joinery; quality of place has been assessed by focusing on 5 variables of speech intelligence and 3 parameters of architecture. Definite results and separated information obtained through investigation, thus, RT variance is the only assessment parameter in this paper. Reverberation time values are obtained through field study on three mosques in Tabriz during Qajar. Main objective of this

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paper is to compare obtained results with those of other researchers respective to worship countries and religion. 83 churches and 35 mosques were studied case by case by other investigators; therefore, the obtained investigation results were compared for better conclusion.

## METHODOLOGY

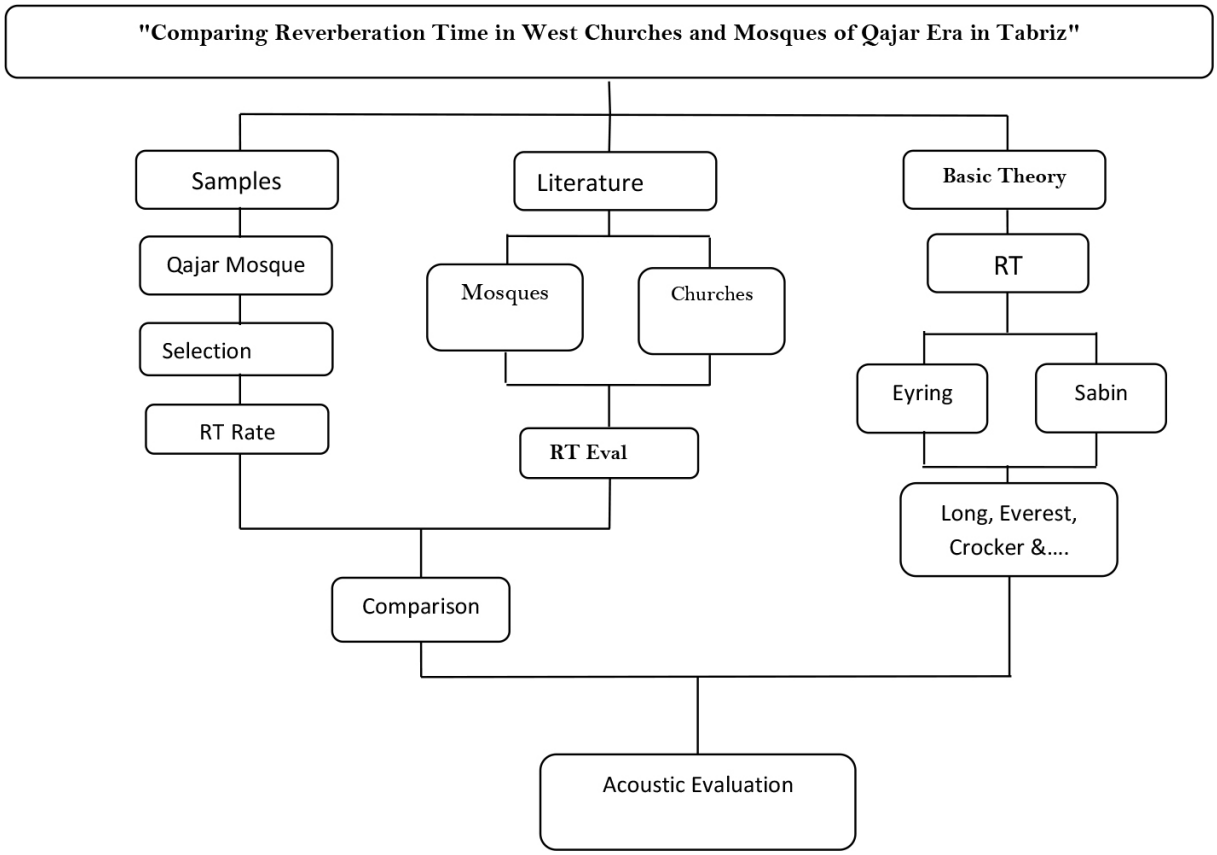



**Fig. 1. Assessment Methodology Diagram**

For comparative reverberation time of west churches and mosques of Qajar era, cognition of basic theories, literature and evaluation of samples are necessary. Selection of reverberation time is necessary for investigation based on basic theories, so, we need to study theories of thinkers. Churches and mosques as well as study the domain of reverberation time is selected to compare the results, so acoustic of Qajar Mosques is evaluated.

## RESEARCH METHOD

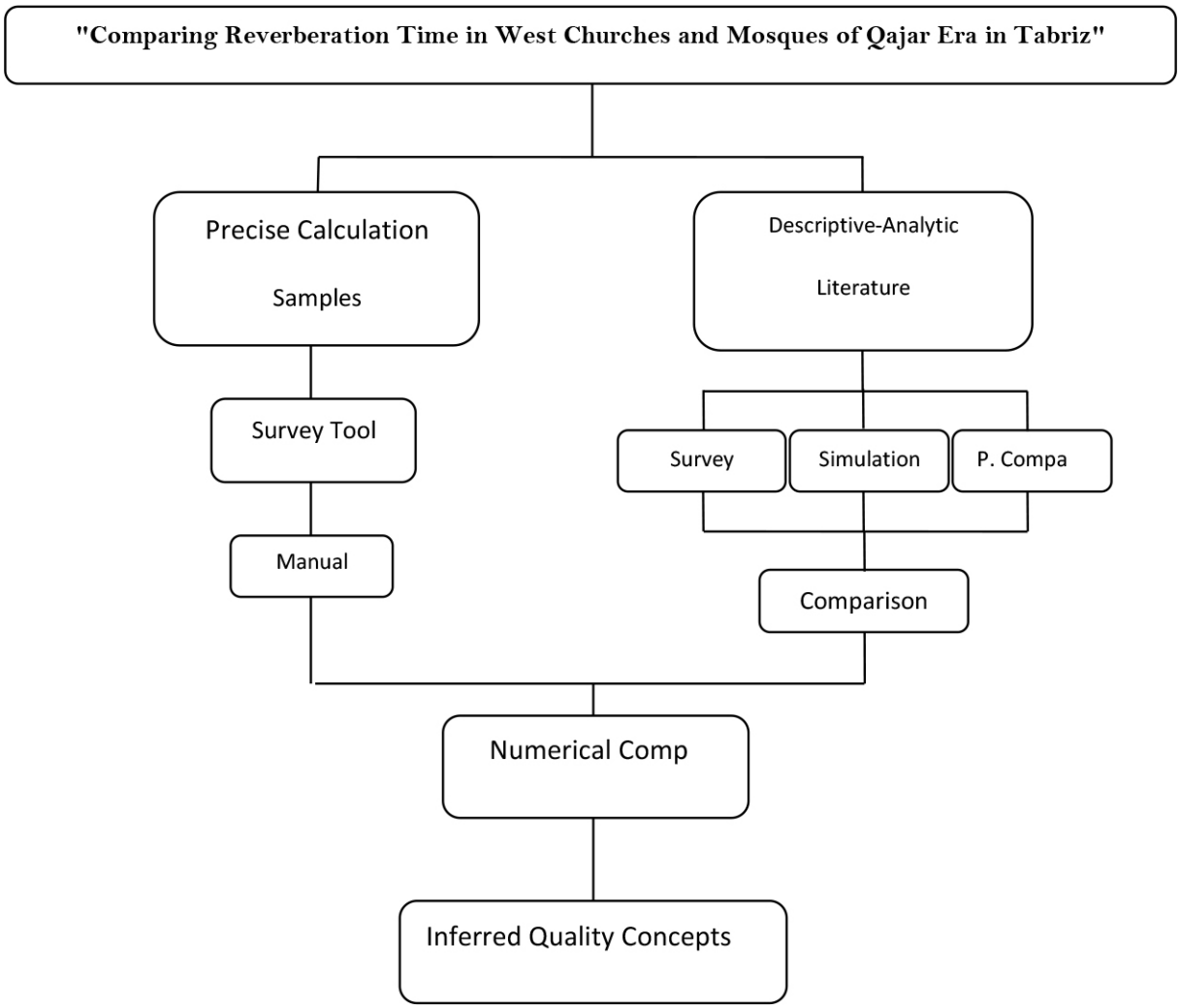



**Fig. 2. Evaluation of Research Results**

Reverberation time of comparative study of west churches and mosques of Qajar era is based on descriptive analytic literature, and precise calculations of samples evaluation. Research tools of other investigators are evaluated precise calculation, simulation and survey studies that have been utilized to compare the obtained results to assess reverberation time of the samples with survey tool and manually; numerical comparison and conceptual quality inferences have been more focused.

## LITERATURE

RT refers to a measure of acoustic properties of a room equal to the time taken for a sound to fall in intensity by 60 decibels (long , 2006; Alton, Everest & Pohl mann, 2009; Smith, Peters & Owen, 2001).

It is due to sound reflection to the walls, roofs and other available surfaces in a house, it is calculated by $T = r(0/012\sqrt[3]{V} + 0/107)$ where r is 4, 5, and 6 for speech, orchestra and symphony respectively (Bruel & Kjaer, 2010).

$T = \frac{KV}{\varepsilon A}$ is named Sabine formula that is to calculate reverberation time, where k is 0.163 in a metric system , V is volume of the room and A is area (Nasiri, 1996). Resonance or reverberation time or echo time have the same meaning, RT has various definitions according to Sabine, Earring, and Lung's theory (Long, 2006; Gholamali, 1991; Bruel & Kjaer, 2010).

Reverberation time studies have been commenced many years ago and acoustic study of the worship places firstly were begun in 70's. Spain and England have been pioneer states in church reverberation time study with 1-11.5 seconds interval (Maria, 1973). 90's decade is a prolific for acoustic studies in churches and mosques. Studied churches in Portugal and late 90's papers submitted on architecture acoustic and they have had interesting results on reverberation time in church and mosque (Algeria, 1997; Vadim, 1999).

Primarily, churches respectivly were studied acoustics but the mosques were evaluated since 2000 in this regard. Survey assessment and measurement are main tools of study; obtained results are the most dependable according to many researchers, variables are extensively utilized to test speech intelligence in such places, thus, STI, RASTI, SPL, ALCONS, and STC are studied. Reverberation time is mostly concerned to test speech intelligence that is main parameter of manual tools, hardware equipment made in Denmark by B&K Co (Make, 2009; Martellotta, 2003; Noxon, 2001).

Abasoufieh and Ghortabeh are the most important mosques in Islam where different acoustics has been accomplished. Field studies and simulation tools have been used to compare them as historical places since construction up to now (Suarez et al., 2005; Andreas et al., 2003).Volume and geometry of the buildings have been focused as the most effective factors. Mosques built in Othman rein have been impressed by peculiar worship elements in architecture (Alla, 2005). merit mentioning shows that researchers have progressed effectively in the study of acoustic conditions of religious places in Spain and Italy. Investigators of Civil university of Spain, architecture and Polyclinic urban development department are among them (Girón et al., 2008; Martellotta, 2008; Navarro et al., 2009).

There is a common view that church is a place for being better of music intelligence but mosque is for being better in speech. Lay-out of the seats in church and flooring of the mosque are the most effective elements for sound clarity of such places (Martellotta& Cirillo, 2009; Dewiyanti& Kusuma, 2012).

Design, size, and geometry of bedchamber or seraglio are main parameters, where materials affect sound distribution (Othman & Mohamed, 2012; Orfali, 2000). Studied samples have availed that desirable solutions for churches built in Edward Quick, Renaissance and Remank period, while mosques are divided to modern and traditional worship places by majority of investigators. (Karabiber, 2000; Orfali, 2000).

Henry and Jordan are pioneers of mosques' acoustics studies in recent years and after them researchers of other countries have remarkable studies (Abdou, 2008; Zamarreño et al., 2008), but the latest comparative project of RT variable on the mosques and churches delivered on a paper on 16th sound and resonance international conference in 2009, where variables of 41 churches in Portugal and 21 mosques in Saudi Arabia have been tested for the volume, height, and area including RT, RAST, C50, C80. Reverberation time of churches has been 2-5 second while that of mosque has been 1-3 second (Carvalho & Monteiro, 2009).

As mentioned, current paper is going to deduct from field studies on the mosques built during Qajar dynasty in Tabriz, Iran, while studies of other researches on western churches have logically linked reverberation time of these spaces for sound quality evaluation in Islamic and Christianity worship places.

## SAMPLES

Religious architectures of Tabriz city are very important; they built during Qajar reign, includes well known schools and mosques. These basic historical architectures are heritage which researchers are motivated to study various effective parameters on attractive aspects of each one.

There is pleasant, desirable and effective sound in historical mosques built during Qajar reign in Tabriz Bazaar which the current study is going to illustrate such places to compare their sound quality with that of the western mosques; hence, mosques are classified in three different groups of volume: low, medium and high. So the field measurement tool has been utilized as the most important and reliable technique for acoustic investigation. System 2260 of B&K made in Denmark was utilized with other tools in different points of the mosque to measure parameter. 3 different volumes selected where a mosque was evaluated as a sample.

Volume of the first, third, and second group was 2000 $m^3$, 2000-4000 $m^3$, 4000-8000 $m^3$ respectively. The mosques named Aharlilar , Imam Jomeh, and Saqhat Al Islam with 400 $m^3$, 400 $m^3$, and 5099 $m^3$ selected as the first, third and second samples respectively .

Measured noises in all samples field measurement

were 36-40db while their pre defined limit was 40db, so, intensity of distribution speakers increased 40db. Volume of the samples, interior form of the mosque; number of worshipers attended, utilized carpet or lack of carpet are effective measurement factors. For the number of measured points; eliminated probable error are utilized in measurement too. Accordingly, 2, 12, and 10 points were measured in the above mentioned mosques and minimum, maximum and mean values of the evaluated speech frequency was 500- 4000 hertz.

**Table 1. Measured Samples**

| | Samples | Volume in $m^3$ | Number of Measured Points |
|---|---|---|---|
| 1 | Aharlilar Mosque | 400 | 2 |
| 2 | Imam Jomeh Mosque | 4000 | 12 |
| 3 | Saqhat Al Islam Mosque | 5099 | 10 |

## INTRODUCTION TO THE MOSQUES

Aharlilar Mosque:" This is smaller than others; the mosque includes a dome and two secondary places, sanctuary is located at south". (Omrani & Esmaeili-pour, 2011)

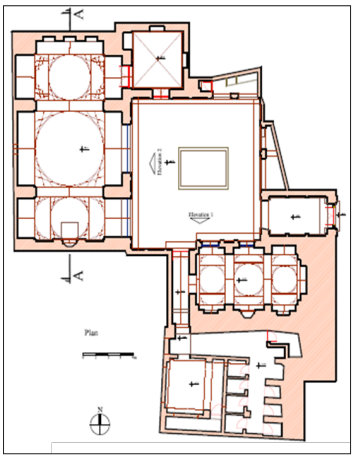


**Fig. 3. Plan of Aharlilar Mosque (Omrani & Esmaeili-pour, 2011)**

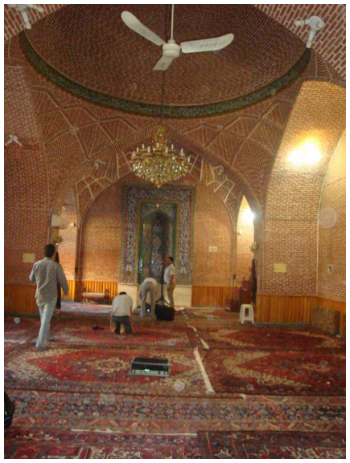


**Fig. 4. Aharlilar Mosque**

Imam Jomeh Mosque: It is located at the eastern side of bazaar, near seminary known as Green mosque, stone pillar based seraglio with Mogharnas bell and 30 brick dom (Ibid).

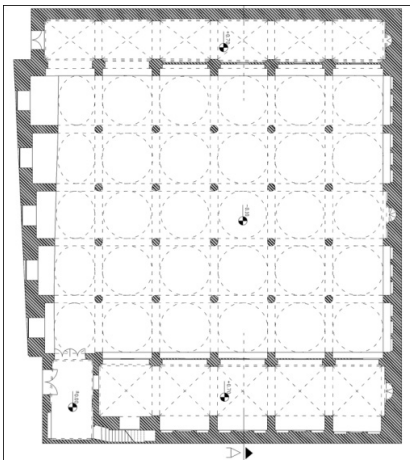


**Fig. 5. Plan of Imam Jomeh Mosque (Ibid)**

**Fig. 6. Imam Jomeh Mosque**

Saqhat Al Islam Mosque: The mosque is located at the southern side of Dehleez Saheb Al Amr and Akbarieh School. As written in a paper named "History of holy places and well-known men", in 1953, Late Mirza Ali Agha Saghat Al Islam, observed that area of the mosque equaled with two domes on the west; then he developed eastern and northern sides (Ibid).

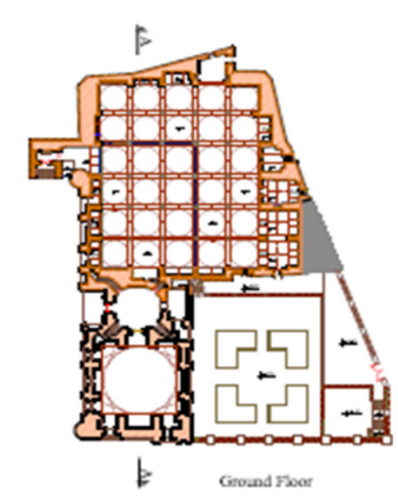
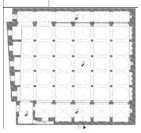
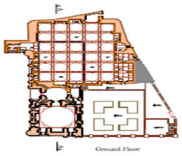



**Fig. 7. Plan of Saqhat Al Islam Mosque (Ibid)**

**Fig. 8. Saqhat Al Islam Mosque**

**Table 2. Specifications of the Evaluated Samples**

| Item | Name Of Mosque | No.of Doms | Height of plinth | Volume | Area | Height of Mosque | Plan |
|---|---|---|---|---|---|---|---|
| 1 | Aharlilar | 3 | 2.60 | 400 | 118.81 | 5.38 |  |
| 2 | Imam Jomeh | 35 | 2.20 | 4000 | 127.4 | 4.67 |  |
| 3 | Saqhat Al Islam Mosque | 33 | 2.60 | 5099 | 848.5 | 4.62 |  |

## EVALUATED SAMPLES

Aharlilar mosque: (400 m$^3$ small sample)

The least reverberation time of the mosque is 0.56 second, frequency is 4000hertz. Minimum reverberation time of this sample is increased 1.02 second at 500 hertz. Maximum reverberation time is 1.07 second but minimum value is 1.05 second based on evaluation.

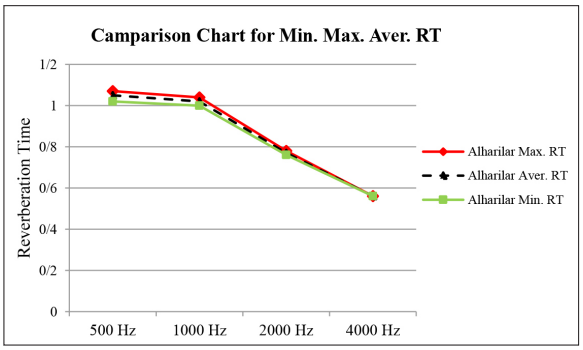



**Fig. 9. Maximum, Minimum and Mean Values of Aharilar Mosque**

Imam Jomeh Mosque (4000 m$^3$)

Minimum reverberation rate is 0.92 second but the Maximum is 2.07 for 4000 hertz and 500 hertz respectively. Both maximum and minimum reverberation rates are decreased, 1.11 - 2.34 maximum values but minimum values of 1.11 to 2.18 second.

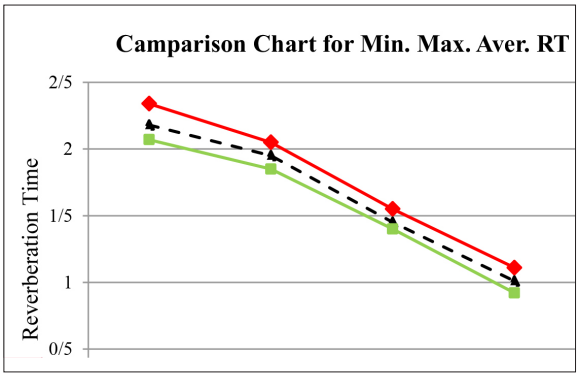



**Fig. 10. Maximum, Minimum and Mean Values of Imam Jomeh Mosque**

Saqhat Al Islam Mosque (5099 m$^3$ sample)

Minimum values have been decreased with frequency increase; reverberation time is 1.12 and 0.65 seconds for 500 and 4000 hertz frequency; reverberation time for 2000, and 4000 hertz frequencies are 1.1 and 1.44 seconds respectively while mean reverberation time values for 4000, 2000,and 1000, and 500 hertz frequencies are 0.78, 1.11, 1 and 1.15 seconds respectively.

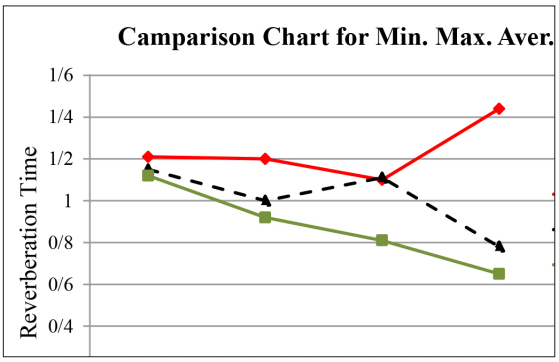
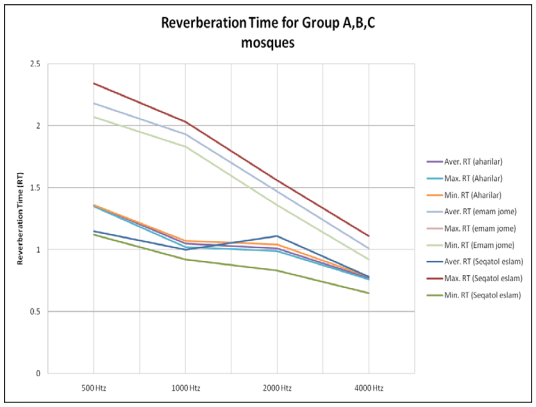



**Fig. 11. Comparison of Minimum, Maximum and Mean RT of All Samples**

**Table 3. RT Values of the Studied Samples**

| Reverberation Time of the Samples | | | | | |
|---|---|---|---|---|---|
|   | | | | | |
| Frequency Difference In second | RTmid (RT500+RT1000+RT2000+RT4000=RTmid) In second | Mean Frequency Values in Second | Max | Min | Sample |
| 0/56- 1/07 | 0/84 | 0/56,1/05 | 1/07 | 0/560 | Aharlilar |
| 0/92- 2/34 | 1/64 | 1/01- 2/18 | 2/34 | 0/92 | Imam Jomeh Mosque |
| 0/65- 1/21 | 1/01 | 0/78- 1/15 | 1/21 | 0/65 | Saqhat Al Islam Mosque |
| Evaluated Minimum, Mean and Maximum RT | | | | | |
| 0/56 | | | | | Min |
| 1/16 | | | | | Mean |
| 2/34 | | | | | Max |

Analysis of evaluated minimum, mean and maximum values of RT for three studied samples shows that RT has been 0.56 -2.34 Final limit of increased mean volume of RT was due to lack of carpet in the mosque. Although optimization process has improved through more measurements; uncarpeted places have increased the resonance more effectively. 1.15 RT is decreased to 0.56 to provide desirable acoustic conditions in religious places of Qajar era. Although ignored measurement conditions as well as absolute view on measurement results of desirable investigated through "Comparison of the acoustics of mosque and catholic churches" has shown that RT is less than 0.6 Second.

## SAMPLE CHURCHES

Several investigations and measurement of scientific and mind variables have clarified sense of worship in churches for audiences. Reverberation time has been the most basic scientific parameter in this domain. Compared investigation outputs with those of the studied samples of churches facilitated RT selection through dismissing of other parameters.

Aba Sufieh mosque has peculiar architecture style and had been utilized as mosque, church and museum. Team researchers from Denmark used ODEON software to calculate reverberation time, while RT-Frequency diagram, has evaluated the least reverberation time for the mosques (Andreas, Holger & Lynge, 2003).

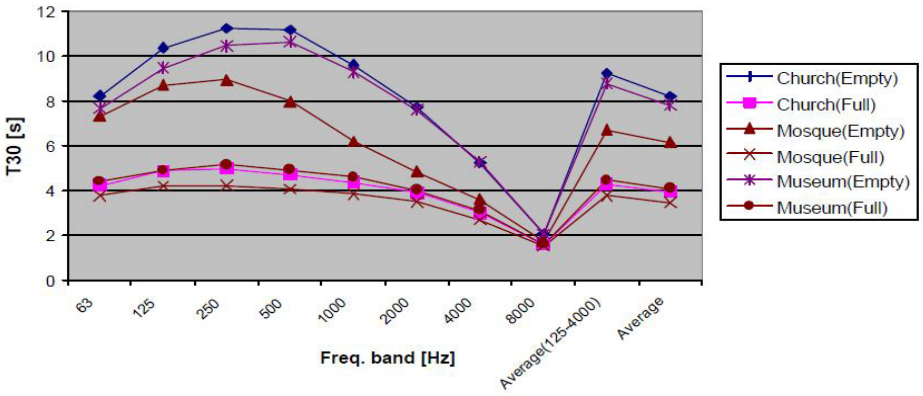



**Fig. 12. Calculated Reverberation Time (T30) As a Function of 1/1 Octave Frequency Band of Hagia Sophia Averaged Over all Positions. Also seen are Frequency Averaged Values from 125-4000 Hz and from 63-8000 Hz. (Andreas, Holger& Lynge, 2003)**

The team has evaluated the three places both in empty and full places, reverberation time for the mosque, church and museum has had minimum RT in500 to 4000 hertz. But the difference for the church and mosque is almost 2 seconds.

Two researchers of Italian University studied 9 churches of Romank era with 1500 $m^3$ to 33000 $m^3$ volumes respectively. Mean reverberation time of the churches was 2.1 seconds, for the larger volumes it was 6.8 seconds (Martellotta, 2003).

**Table 4. Basic Details of the Nine Churches Surveyed**

| Church | Volume ($m^3$) | Floor area ($m^2$) | Total area ($m^2$) | Length (m) | RTmid (s) |
|---|---|---|---|---|---|
| St. Nicholas Basilica, Bari | 32000 | 1530 | 10500 | 54 | 4.4 |
| Bari Cathedral | 30100 | 1274 | 9500 | 46 | 5.3 |
| Bitonto Cathedral | 16000 | 858 | 6500 | 42 | 4.3 |
| Barletta Cathedral | 15800 | 912 | 5500 | 46 | 6.8 |
| Bisceglie Cathedral | 10150 | 534 | 4660 | 29 | 3.5 |
| Ruvo Cathedral | 6400 | 445 | 3000 | 29 | 3.7 |
| Bovino Cathedral | 3840 | 452 | 2420 | 22 | 3.8 |
| Ognissanti church, Valenzano | 1800 | 258 | 1300 | 19 | 5.4 |
| Vallisa church, Bari | 1520 | 162 | 1130 | 15 | 2.1 |

**(Martellotta, 2003)**

In 2008, Francisco Martellotta evaluated audible conditions of the catholic churches in Italy; Almost RT of all samples was 5-8.9 seconds. (Martellotta, 2008)

**Table 5. Summary of Acoustical Parameters Measured in the Selected Sample of Irs**

| ID | S-R combin. | Style | Volume (m3) | Width (m) | S-R distance (m) | Δti (ms) | T30 (500-1 k) (s) | EDT (500-1 k) (s) | BR* | C80 (500-2 k) (dB) | Ts (500-1 k) (ms) | LF (500-2 k) (%) | I-IACCE (500-2 k) (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | A03 | Rm | 20000 | 22 | 9.5 | 20 | 5.4 | 5.6 | 1.09 | -4.2 | 342 | 31.1 | 79.0 |
| B | A05 | Rm | 10500 | 15 | 11.9 | 17 | 2.1 | 1.8 | 1.10 | 0.3 | 130 | 24.9 | 57.3 |
| C | A04 | Gt | 33100 | 26 | 18.1 | 16 | 5.7 | 6.3 | 0.96 | -9.2 | 489 | 28.9 | 76.0 |
| D | A02 | Rn | 19000 | 32 | 10.8 | 9 | 8.9 | 8.4 | 1.26 | -7.6 | 632 | 16.1 | 66.3 |
| E | A04 | Rn | 39000 | 36 | 20.6 | 25 | 5.1 | 5.4 | 1.07 | -7.4 | 389 | 18.9 | 48.0 |
| F | A03 | Ba | 8700 | 30 | 8.7 | 45 | 3.3 | 3.2 | 1.13 | -4.2 | 240 | 33.3 | 67.0 |
| G | A01 | Ba | 16400 | 34 | 9.9 | 34 | 7.2 | 7.5 | 1.03 | -5.4 | 500 | 15.2 | 38.3 |
| H | A03 | Mo | 5500 | 16 | 11.2 | 15 | 6.3 | 6.3 | 1.07 | -5.9 | 437 | 40.3 | 68.3 |
| I1 | A03 | } Mo | 9000 | 25 | 12.5 | 27 | 4.4 | 4.5 | 1.12 | -4.4 | 316 | 24.6 | 48.7 |
| I2 | A04 | | | 18 | 5 | 4.4 | 4.7 | 1.12 | -5.4 | 352 | 30.9 | 82.3 | |

**Style Abbreviation: Rm-romanesque, Gt-gothic, Rn-renaissance, Ba-Baroque, Mo-modern.**
***Bass Ration, Defined as (T30125-250/T30500-1 k) (Martellotta, 2008)**

Summarized Measured Acoustic parameters of the samples Martellotta and Sydilov studied laid- out seats of the churches and their effects on noise absorption as well as RT of the 3 studied samples in 2 modes of with seat and without seat (Martellotta, 2009).

**Table 6. Summary of the RT Measured in the Three Churches Surveyed with and Without the Pews**

| Type | T30 | | | | | |
|---|---|---|---|---|---|---|
| | 125 | 250 | 500 | 1000 | 2000 | 4000 |
| Church 1 w/o pews | 5.15 | 4.80 | 4.61 | 4.67 | 4.22 | 3.04 |
| Church 1 w/ pews | 5.02 | 4.45 | 4.14 | 4.10 | 3.78 | 2.77 |
| $\alpha_{site}$ for type B pews | 0.011 | 0.038 | 0.056 | 0.070 | 0.065 | 0.075 |
| Church 2 w/o pews | 2.68 | 2.63 | 3.24 | 4.48 | 5.11 | 4.00 |
| Church 1 w/all the pews | 2.61 | 2.53 | 3.10 | 4.18 | 4.76 | 3.82 |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\alpha_{site}$ for type D pews | 0.219 | 0.338 | 0.305 | 0.350 | 0.314 | 0.257 |
| Church 3 w/o pews | 3.09 | 3.39 | 3.51 | 3.29 | 3.16 | 2.48 |
| Church 3 w/ pews | 2.93 | 3.14 | 3.19 | 3.00 | 2.87 | 2.27 |
| $\alpha_{site}$ for type E pews | 0.044 | 0.060 | 0.073 | 0.075 | 0.080 | 0.096 |

**(Martellotta, 2008)**

Mean (500-1000) frequencies of human speech have the least 3 seconds reverberation time concerning to lain-out seats within the investigated church while the most reverberation time rate of 4.46 seconds is depending on 500-1000 hertz frequencies, arranged seats within the church reduced it to 4.10 seconds.

In 2010, contemporary churches of Brazil were studied and RT of the churches was 1.2 and 1.35 seconds, RT of the most modern Italian churches was 6.3 seconds , although the Italian churches are larger than the Brazilian churches but average volume of churches of Neo Gothic era is 5501m3 while its RT is 4.61 (Queiroz de Sant'Ana, Trombetta Zannin, 2011).

**Table 7. Reverberation Times of Old and Contemporary Churches.**

| Church | Country | Volume ($m^3$) | Architectural style | Mean (500Hz, 1000Hz) Reverberation time (s) |
|---|---|---|---|---|
| Sacra di San Michele | Italy | 7000 | Romanesque | 5.0 |
| Santi Luca e Martina | Italy | 10.000 | Baroque | 3.3 |
| Sant' Agnese in Agone | Italy | 14.500 | Baroque | 5.0 |
| San Lorenzo | Italy | 12.000 | Baroque | 4.1 |
| Fossanova Abbey | Italy | 17.000 | Gothic | 6.6 |
| Bom Jesus dos Perões | Brazil | 5501 | Neogothic | 4.61 |
| Messianic Church | Brazil | 933 | Modern/Contemporary | 1.20 |
| "Dives in Misericordia" jubilee church | Italy | 10.500 | Modern/Contemporary | 7.3 |
| Church of Santa Maria Assunta | Italy | 6300 | Modern /Contemporary | 6.3 |
| Church of Santa Giovanni Battista | Italy | 9000 | Modern/Contemporary | 7.7 |
| Church of São Carlos Borromeu | Brazil | 2100 | Modern/Contemporary | 1.35 |

**(Queiroz de Sant'Ana, Trombetta Zannin, 2011)**

Mentioned investigations and many others show that majority of the churches have different RT rates to the mosques, and RT of the churches with the same volume is more than that of the churches; moreover, investigations on other states support it. ADEL and A.ADDOU from Saudi Arabia had an acoustic study in 2003, Geometric form and configuration of the mosques simulated with ODEON software. RT of all samples is based on calculations of EYring theory, while RT of 500 to 4000HZ frequency was less than 1.5 second based on evaluations (International Conference, 2003).

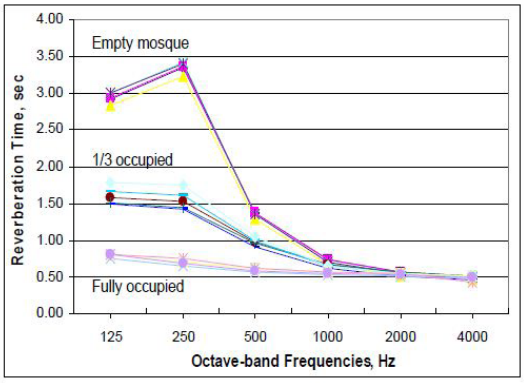



**Fig. 13.RT Vs. Octave-Band Frequencies for the Mosque Geometry Determined According to "Eyring" Formula When the Mosque is Assumed Empty, 1/3 Occupied and Fully Occupied (International Conference, 2003).**

RT is for fully empty mosque, while the mosque has worshipers and fairly $\frac{1}{3}$ of the mosque is full, RT is reduced to 1 second, but increased frequency reduces it to 0.5 second. $\frac{1}{3}$ Full mosque is for daily prayers but completely full is intended for Friday prayer and Ends. In another diagram, RT of all studied geometric configurations of the mosques with more than 500 Hertz frequencies was less than 1.75 (International Conference, 2003).

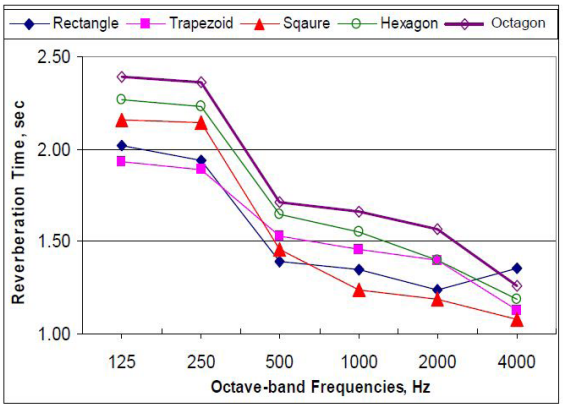



**Fig. 14. Evaluated RT of 5 Mosques with Different Geometric Configurations (International Conference, 2003)**

RT affects on human activities investigated in Malaysia, its main effect on construction materials separately, field study of the mosques, and its comparison with precise calculations was based on Sabine's Theory (Orfali, 2000).

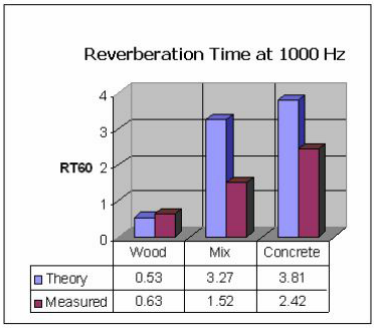



**Fig. 15. Reverberation Time Data for all Mosques at 1 kHz (Orfali, 2000)**

## ALL FIELD STUDIES

Measurements attain values less than the calculated ones, while RT frequency for separate materials is 2.42 to 5.63. Although, mosques with concrete materials have the highest rate of frequency, but for the churches, RT is 2.42 that is the most desirable RT.

A study on 16th international sound and vibration investigation In Portugal compared acoustic of mosques with catholic churches. 41 churches in Portugal with 21 mosques in Saudi Arabia were separately studied when they classified in 6 groups; all voluminous groups except for the first one that included mosque and church had a volume less than 1000 $m^3$ ; their Maximum RT was 2.7 seconds, that pertains to evaluated 10000 to 30000 $m^3$ and 500-1000 hertz frequencies (Carvalho & Monteiro, 2009).

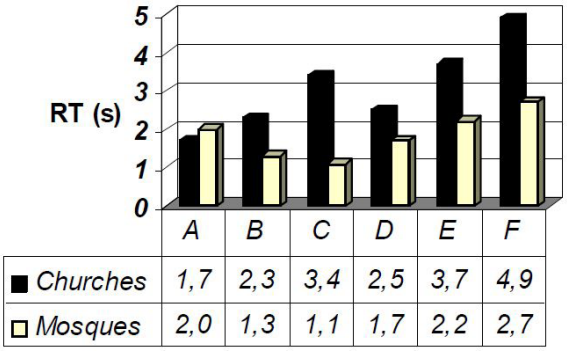



**Fig. 16. Reviewed RT of the Evaluated Samples (Carvalho & Monteiro, 2009).**

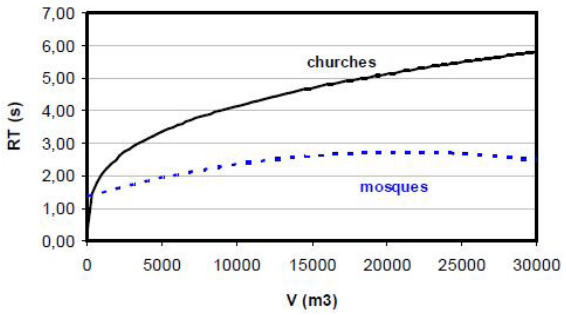



**Fig. 17. Different RT Rates Based on Volume of the Churches and Mosques (Ibid)**

He has investigated on C50, C80, RASTI and STI; also he has studied them based on architecture parameters including volume, area, wide, and height. Emphasized on volume in the investigation, RT of the mosques had been lower, their difference with that of the churches has been

1to 3 second while C50, C80, RASTI and ST are other sound variables that are measured in a building, RT was better for the mosques and more desirable than that of the churches, and according to the evaluations , their acoustic features are better (Ibid).

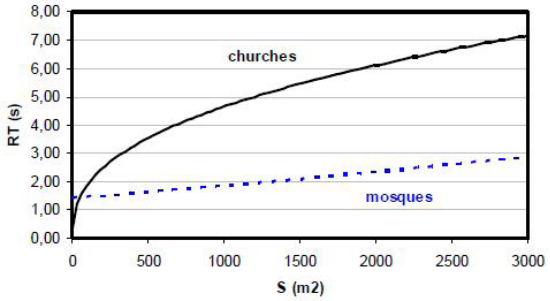



**Fig. 18. Different RT Rates Based on Area of the Churches and Mosques (Ibid)**

**Table 8. RT According to the Studies**

| Review of RT (Churches and Mosques) | | | | | |
|---|---|---|---|---|---|
| Descriptions | Difference of 500 -1000 Hertz RT Frequencies | Year | Researcher | Title | Samples |
| Usage of 3 Hagia Sophia churches was measured , the least usage allotted to mosque | 5 | | | The Acoustical History of Hagia Sophia revived through computer Simulation | Hagia Sophia church |
| Evaluated RT of all samples is higher than 3.5 seconds except one | 2/1- 6/8 | 2002 | E. Cirillo F. Martellotta | An improved model to predict energy-based acoustic parameters in Apulian-Romanesque churches | 4 Romanesque churches |
| RT of the samples is higher than 3.3 seconds except the Romanesque sample | 2/1-8/9 | 2008 | F. Martellotta | Subjective study of preferred listening conditions in Italian Catholic churches | 10 churches of Romanesque, Gothic, Renaissance, Baroque and Modern age |
| Objective of the investigation is to analyze the time effect | 2/27- 4/76 | 2008 | F. Martellotta E. Cirillo | Experimental studies of sound absorption by church pews | 3Modern churches |
| RT of the churches is higher than 3.3 second except the two modern churches in Brazil | 1/2- 7/7 | 2010 | David Queiroz de Sant'Ana, Paulo Henrique Trombetta Zannin | Acoustic evaluation of a contemporary church based on in situ measurements of reverberation time, definition, and computer-predicted speech transmission index | 8Italian churches of Romanesque, Gothic, Baroque and modern era as well as 3 Brazilian churches of Neo Gothic and Modern era |

| | | | | | |
|---|---|---|---|---|---|
| RT based on studied population | 0/4-1/1 | 2003 | Adel A. Abdou | COMPARISON OF THE ACOUSTICAL PERFORMANCE OF MOSQUE GEOMETRY USING COMPUTER MODEL STUDIES | 5 different geometric configurations including rectangular, Trapezoid ,Circular, hexagon, and Octagon |
| RT based on geometric configuration | 1/1-1/7 | | | | |
| Effect of material on evaluated RT | 0/63-2/42 | | Mohd Faiz bin Abd Halim1, Mohd Noor Arib bin Md Rejab 2, Fauziah bin Mat2 | Influences Reverberation Time to Human Activities: Method to Measure Reverberation Time for Different Mosque Structure | 3 wooden, concrete and mixed material mosques |
| Separated samples based on volume | 4/9-1/7 | 2009 | António P. O. Carvalho and Cândido G. Monteiro | COMPARISON OF THE ACOUSTICS OF MOSQUES AND CATHOLIC CHURCHES | 41 catholic mosques in Portugal |
| | 2/7-1/1 | | | | 21 mosques in Saudi Arabia |

**Table 9. Results of Studied Churches and Mosques**

| Results of Studied Samples of Churches and Mosques RT in Second | | | | |
|---|---|---|---|---|
| Average | Min | Max | No | |
| 4/1 | 1/2 | 8/9 | 83 | Sample of Studied Churches |
| 1/73 | 0/63 | 4 | 35 | Sample of Mosques in other Countries |

Studying the western churches shows different 1.2 to 8.9 RT. while investigated mosques of other countries had 0.63 to 4 second RT. It is concluded that RT of the third min, max, and average domain is decreased more than 50%.

## CONCLUSION

**Table 10. Evaluated RT of Samples of Churches and Mosques in Second**

| Evaluated RT of Samples of Churches and Mosques in Second | | | |
|---|---|---|---|
| Mean | Min | Max | |
| 4/1 | 1/2 | 8/9 | Sample Church |
| 1/73 | 0/63 | 4 | Sample Mosque |
| 1/16 | 0/56 | 2/34 | Studied Sample Mosques of Qajar Reign |
| Studied samples with lower RT time, both max, minimum and average rates were lower | | | Conclusion |

Three mosques located at old market of Tabriz Bazaar with min, max, and average volumes were chosen and their RT measured with equipment manufactured by B& K in Denmark. Obtained minimum and maximum RT has been 0.56 & 2.34 seconds, generally, mean RT is 1.16 second. Thus, it was compared with those of western churches, and sample mosques were utilized for comparison. Among 3 evaluated Messianic churches in Brazil, highest RT belonged to renaissance that is equal to 8.9 seconds. Mean evaluated RT of the studies has been 4.1 . Thus, RT of the mosques of other countries has been 0.63 to 4 second while the mean RT has been 1.73 second. Accordingly, the studied samples have the least RT; lower RT difference is an indication of desirable acoustic quality of the mosques.

Table-Compared Evaluated Samples of Mosques and Churches

RT is the basic quality evaluation parameter for speech intelligence; hence, Mosques of Qajar era in Tabriz had desirable quality according to the evaluations. Their difference was too high compared with those of studied churches; structure pattern and form of material have been effective for improvement of speech intelligence in mosques and churches. Similar investigations for optimum speech intelligence measured and simulated with EASE and ODEON software and other variables such as ALCons, C50, STI, and SPL. The results show that mosques have better qualities than the churches respective to speech intelligence that can be discussed in other articles.

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