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Field Study for Measuring the Architectural Acoustical Qualities of Abou El-Abass Mosque in Alexandria - Egypt

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Abstract: The Mosque of Abou El-Abass is one of the greatest and oldest mosques in Alexandria . It is constructed as a polygon structure. This architectural design introduces effects on the acoustical qualities of the mosque.

To achieve good acoustical environment inside a mosques, (i.e: speech clarity and intelligibility), the architectural acoustical parameters such as reverberation time and clarity factor, must be taken into consideration from the first stage of the design of the mosque, If not, acoustical defects which may arise will be difficult and costly to be treated.

In this paper the determination of the reverberation time (R.T) and the early reflections represented by the clarity factor (C50) for speech are presented.

A comparison between this objective measurements of the acoustical parameters and a subjective tests, which has been made to show the opinion of prayers about the sound quality in the mosque, will also be presented.

As a result of the study, it is found that (R. T) and C50 are considered out of range of satisfactory levels for such volume and activity. A good designed electro acoustic system is used which over come these acoustical problems with the help of the good designed polygon shape, which helped in avoiding much echo due to the absence of the concentration and focusing of sound inside the mosque.

Introduction

Mosques are used for praying, lecturing and similar activities. These activities start early in the morning and continue until midnight. It has been noticed that little attention has been given to the architectural acoustic design of mosques in general, although good acoustic qualities in mosques are very important in order to achieve clarity and intelligibility of speech inside the mosque. [1]

Acoustical problems arise from the fact that almost all mosques are usually located in the middle of residential areas with nearby noisy roads. Large windows and doors may be located on all walls, for lighting and ventilation during services, and they are open in some cases towards streets and courts. All floors are unfurnished, but carpeted. The internal surfaces are painted on cement plastering with gypsum and wood decorations. [2]

To ensure good acoustical qualities in mosques, it's important to achieve:

1- Optimum reverberation time (R. T.).

2- Clarity of speech (C_{50}). [3]

3- Spacious effects.

These parameters must be taken into consideration from the first stage of the architectural design of the mosque. If not, acoustical defects, which arise in already built mosques, may be treated by using special acoustic materials inside the enclosure and by controlling and isolation the outside noise.

Description

The Abou El-Abass Mosque, one of the most famous and well known mosque in Alexandria – Egypt, was built by an Italian architect in the year 1928. It took him 16 years (1928 – 1945) to finish this mosque. Since 1945 till now it has been used for praying and lecturing, with a capacity of approximately 4500 prayers.

The mosque, is a hall, polygon in shape, with a big dome located in the middle of the plan and four smaller ones in the four corners, as shown in (Figs. 1-3). The height of the mosque ranges between 19 and 24 meters and it's approximate volume is = 25000 mt3. It is located in the middle of a residential area with a nearby noisy main road. Windows and doors are located on all walls, closed most of the time except for the two main doors (north and west doors). The floor is heavily carpeted. This means that the measurements of the acoustical quality factors (R.T and C50) will not be affected by the capacity of the prayers because the heavey carpets have nearly the same absorption area as the prayers when the mosque is occupied.

The internal walls are covered with marble up to 5.80 meters the rest is painted on cement plastering. The inner ceiling is finished by cement and gypsum decorations.

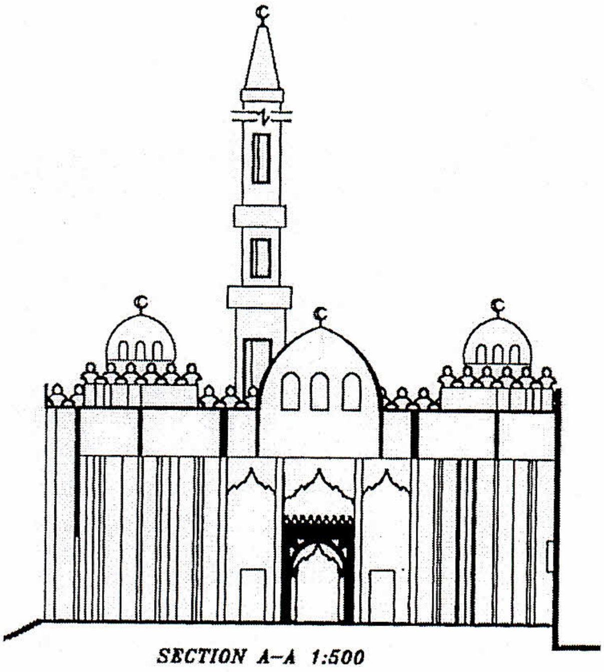

Fig. 1: Section of the Abou-El-Abas Mosque.

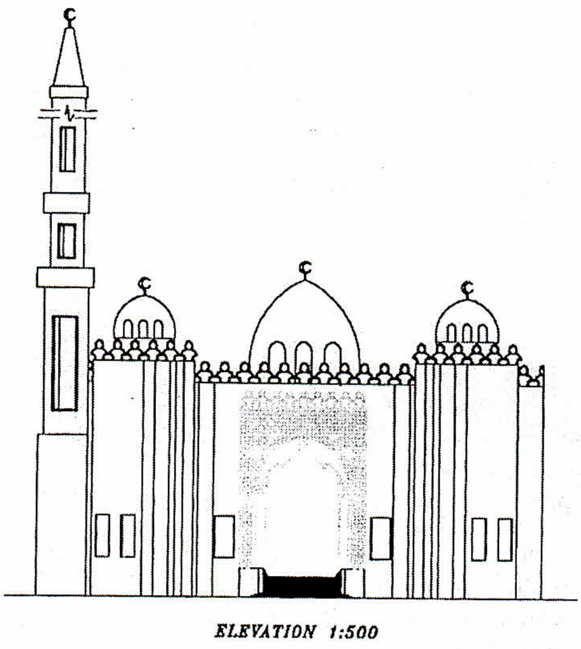

Fig. 2: Elevation of the Abou-El-Abass Mosque.

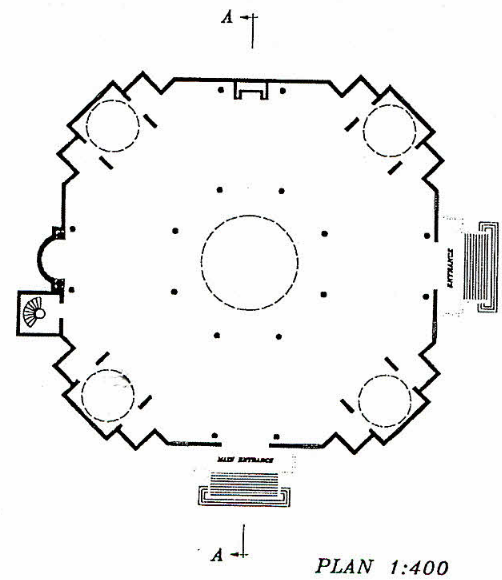

Fig. 3: Plan of the Abou – El-Abass Mosque.

Field Measurements

Objective Measurements

A portable recorder is used to record the sound inside the mosque in different locations, as shown in (Fig. 4), using an air balloon as an exciter, while the mosque was unoccupied.

A digital oscilloscope 500 Mc / s, Tektronix 2440, and a band pass filter type (R. F. T), are used to analyze the sound at different frequency bands (200-3200 Hz).

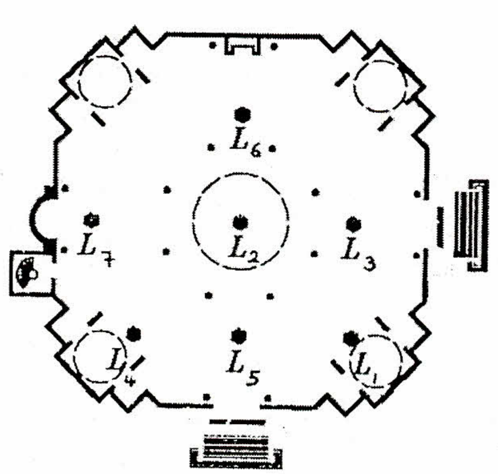

Fig. 4: The different locations of the objective measurements of sound inside the mosque.

The reverberation time and clarity factor (C_{50}) are measured and calculated using the following equations from the obtained sound decoy curves.

$$R.T = \frac{6.907}{Ln \frac{V1}{V2}} \; Sec \qquad (1)$$

$$C_{50} = 10 \; Log \frac{\int_{0}^{0.05} P^2 dt}{\int_{0.05}^{\infty} P^2 dt} \; dB \qquad (2)$$

Where:

V1 = is the value at the start point of the decay curve.

V2 = is the value at the limit of R. T.

P^2 = The squared values of the decay curve in the range determined by the limites of integration stated in the equation

The value of the measured (R.T) compared by the calculated (R.T) using Sabine's equation. [4]

$$R.T = \frac{0.163 \, V}{A} \; Sec \qquad (3)$$

V = Volume in mt^3

A = Total absorption area

Examples for the obtained sound decay curves are shown in (Figs. 5-8)

The calculated values of (R.T) and the measured values are both stated for the sake of comparison, which indicated a slate difference in almost all frequencies except for low frequencies were the difference was high.

The differences between the measured values of the reverberation time (R.T) and the calculated values are expected due to the fact that Sabine's equation depends on the values of the absorption coefficients which are taken as approximate values especially at low frequencies, and in case of improving the acoustical qualities at these frequencies, additional absorption materials are to be placed in proper positions facing the propagation of acoustic waves.

From the field measurements in the Mosque we obtained the impulse response (i. e. sound decay curve obtained from the storage oscilloscope), that is used for determining the reverberation and clarity factor, these two factors are considered the most important factors affecting the acoustical qualities in enclosures.

CH1 500mV A 1s 0.0. V VERT

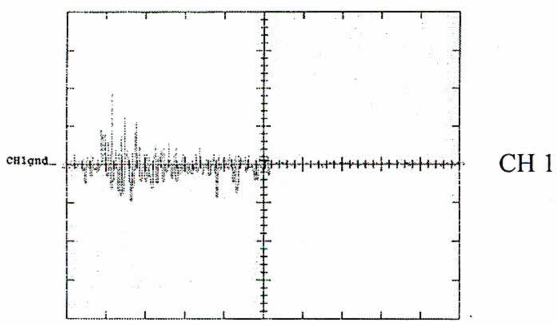

Fig. 5: The second decay curve in the frequency band (200-400).

CH1 1V A 1s 0.0 V VERT

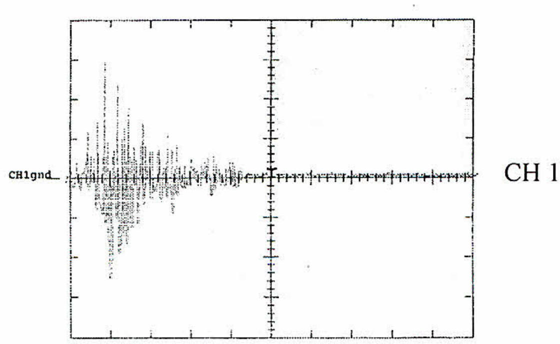

Fig. 6: The sound decay curve in the frequency band (400-800).

CH 1 1V A 1s 0.0 V VERT

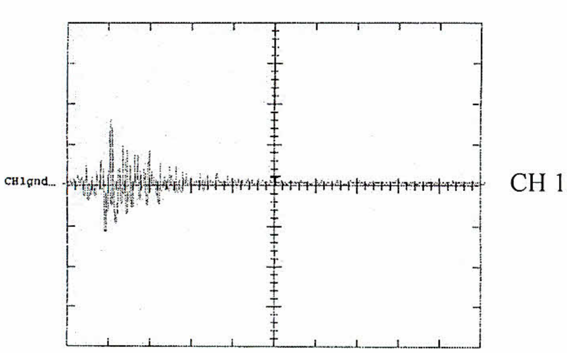

Fig. 7: The sound decay curve in the frequency band (800-1600).

CH1 500mV A 1s 0.0V VERT

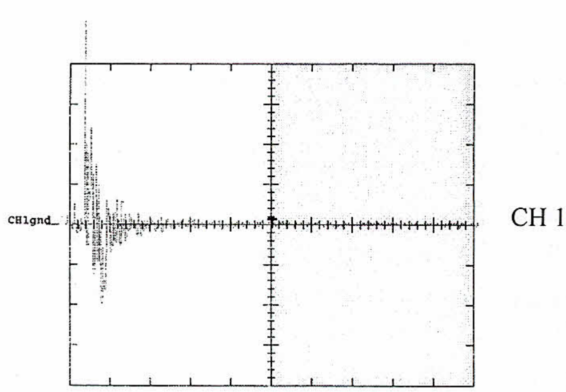

Fig. 8: The sound decay curve in the frequency band (1600-3200).

Subjective Tests

In this part a certain questioner, (Fig. 9), was prepared containing the opinion of the prayers, approximately 100 prayers were asked, about the acoustical quality of the sound inside the mosque. [1]

استطلاع رأس حول جودة الصوت

داخل مسجد المرسي أبو العباس

(١) صلاة الجماعة ظهرا يوم الجمعة

هل الصوت واضح	نعم ☐	لا ☐
هل يوجد رنين وصدي بالجامع	نعم ☐	لا ☐

(٢) الصلاة في أوقات مختلفة

هل الصوت واضح	نعم ☐	لا ☐
هل يوجد رنين وصدي بالجامع	نعم ☐	لا ☐

Fig (9): A sample of the questionair for the subjective tests .

Results

Results of the Objective Measurements

(Table 1) represents the results for the reverberation time (R. T) in the different locations at different frequencies from the decay curves calculated using equation (1).

(Table 2) shows the comparison between the calculated reverberation time using Sabine's equation (3) and the average measured (R. T) in the mosque.

(Table 3) displays the results for a (C50) in the different locations at different frequencies from the decay curves, calculated using equation (2).

(Table 4) shows the average clarity factor (C50) in the mosque at different frequencies.

[1] Results of the subjective test p will be displayed in section (4-2)

Table 1: Results of the measured reverberation time at different frequencies in different locations in the mosque (in sec.)

Frequency bands Locations	(200- 400) fo = 283 Hz	(400 – 800) fo = 566 Hz	(800 – 1600) fo = 1132 Hz	(1600-3200) fo= 2264 Hz
1	6.77	5.80	5.00	3.54
2	5.76	6.77	6.64	4.34
3	5.50	6.29	4.52	4.19
4	5.74	4.98	4.68	3.25
5	--	5.08	4.43	3.32
6	--	4.71	4.40	3.65
7	--	4.50	3.78	3.63

Table 2: Comparison between the calculated reverberation time and the average measured (R.T) in the mosque.

Frequency bands	(200- 400) Hz	(400 – 800) Hz	(800 – 1600) Hz	(1600-3200) Hz
Calculated R. T (sec)	8.56	6.61	4.90	3.45
Average measured R.T (sec)	5.94	5.44	4.78	3.72

Table 3: Results of the values of the clarity factor (C_{50}) at different frequencies in different locations in the mosque (in dB).

Frequency bands Locations	(200- 400) fo = 283 Hz	(400 – 800) fo = 566 Hz	(800 – 1600) fo = 1132 Hz	(1600-3200) fo= 2264 Hz
1	-9.6	-9.0	-8.2	-6.7
2	-8.9	-9.6	-9.6	-7.6
3	-8.8	-9.4	-8.6	-7.5
4	-9.0	-8.3	-8.0	-7.1
5	--	-8.3	-7.7	-7.1
6	--	-8.0	-7.7	-6.9
7	--	-7.8	-7.0	-6.8

Table 4: Average clarity factor (C_{50}) in the mosque.

Frequency Bands	(200- 400) Hz	(400 – 800) Hz	(800 – 1600) Hz	(1600-3200) Hz
Clarity factor C_{50} (dB)	-9.1	-8.6	-8.1	-7.1

Results of Subjective Tests

About 60% of the prayers, whom were asked about the sound quality inside the mosque, found that the sound is good but there is echo, while 40 % found good sound and no echo noticed.

Other comments from some prayers that the sound is not clear in the corners, while good at the middle of the mosque.

When asking the prayers about noticing any difference in sound quality while praying on Fridays (صلاة الجمعة) and other days, they all agreed that there is no difference in sound quality. This is due to the presence of the sound electric system in the mosque.

Discussion and conclusion

1. It was found that the reverberation time (R. T) is out of the range for acceptable values for such volumes. Where the values of R. T for such volume ranges from 1.3 sec. to 2.4 sec.
2. As it can be seen from the results, clarity factor (C50) is considered below the satisfactory levels Where the optimum range of the clarity factor (C50) for speech intelligibility are as follow:

   Less then - 2 dB bad, around O dB fair, more than O dB good

   Clarity factors are indicating the roles of the early reflections in affecting the acoustical qualities in the mosque. And since clarity factors are low, there must be a good sound system and a better distribution of loud speakers inside the mosque. This system seems to be good designed as indicated by the subjective tests.
3. The outside noise affects the quality of sound inside the mosque especially in religious occasions e.g.: Ramadan – fists ... etc. The analysis and the assessment of this point are considered in another research in the field of noise control and planning design of this Islamic district.
4. The polygon shape helped in avoiding echoes, due to the absence of the concentration and focusing of sound inside the mosque. As for the domes they are well designed, that is, the radius is smaller than the height of the mosque, which prevents any focusing of sound in the prayers' level.

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دراسة ميدانية لقياس الخواص الصوتية المعمارية لمسجد أبو العباس في الإسكندرية – مصر

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ملخص البحث: يعد مسجد أبو العباس من أكبر المساجد وأقدمها في الإسكندرية، وقد أثر التصميم المعماري وإنشاء المسجد على شكل مضلع متعدد الزوايا على الخواص الصوتيه المعماريه للمسجد.

ولتحقيق بيئة صوتيه جيده داخل المسجد (وضوح وجلاء الصوت) يجب الأخذ في الاعتبار زمن التردد ومعامل وضوح الصوت منذ مرحلة التصميم الابتدائي وإلا ظهرت عيوب صوتيه يصعب معالجتها إلا بتكاليف باهظة.

وحددت الدراسة زمن التردد وانعكاس الصوت المبكر بواسطة معامل وضوح الصوت (C50) وتمت مقارنة قياسات محددات الصوت الفعلية برد الأفعال للإحساس الشخصي للمصلين لمعرفة آرائهم حول جلاء الصوت داخل المسجد، وأظهرت النتائج عدم توافق زمن التردد ومعامل الوضوح (C50) لمستوى النشاط وحجم المسجد، لذلك صممت أنظمة الصوت كهربائيا لتصحيح مشكلة التصميم المضلع للمسجد، الشيء الذي ساعد على تجنب حدوث الصدى والبؤر الصوتيه داخل فراغ المسجد.