ACOUSTICAL PROBLEMS OF BAITUL MUKARRAM MOSQUE

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Baitul Mukarram mosque in Dhaka is the largest mosque in Bangladesh. The six-storied place of worship, raised on a eleven-foot high podium and veiled behind four massive walls, evolving in a cube is reminiscent of the form of Holy "Kaaba". It includes a mezzanine platform between the First and Second floors, and it can provide covered prayer space for about 15000 devotees. The eastern court or "shahan" is abutted on the North and South by roofed ablution facilities catering to 162 Muslims simultaneously. This court is exposed to the elements of the weather but it can accommodate another approximately 8000 respondents to the call of prayer. Because it can be extremely hot in summer and can be wet by rain, the "shahan" is protected by colourful flowing "shamianas" during important festivities and occasions calling for large gatherings.

The main approach from the south, previously overlooking a paved plaza and the scene of many a historical public meeting has been considerably redesigned one understands to prevent political gatherings. It now consists of a linearly laid out water body, sprinkled by fountains and juxtaposed with pretty gardens, climaxing at a 27-step entry portico under a tri-arched gateway. The approach from the north is similarly disposed *sans* the water body, fountains and gardens. The eastern approach ushering in "musallis" along a brick-paved walkway meets a plaza punched with a fountain before ascending up to the stepped podium. Both the latter approaches are lesser only in architectural hierarchy but are functionally as important as the

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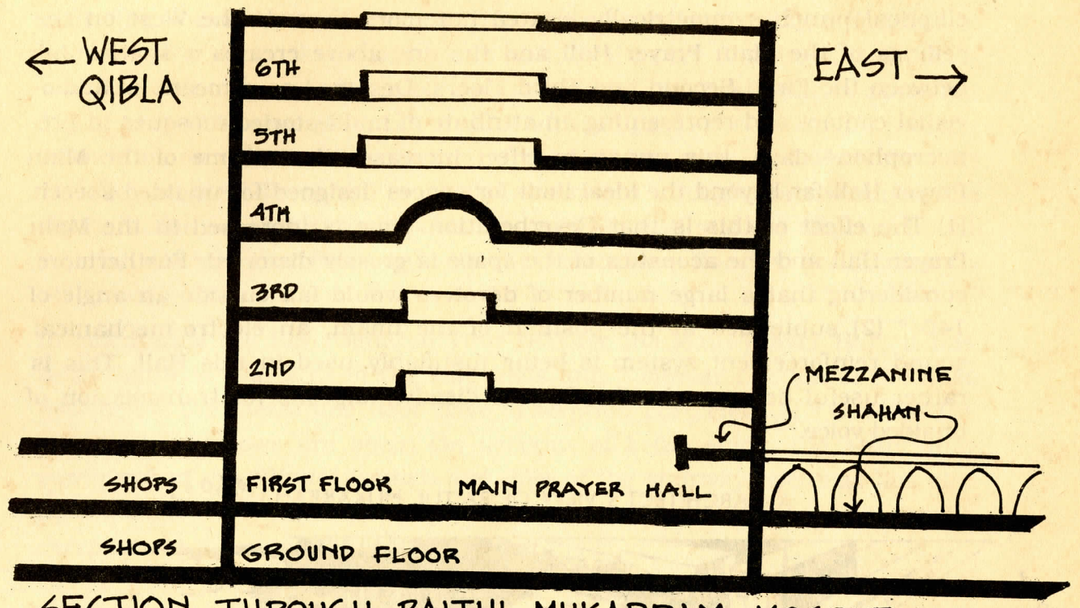
principal approach because the mosque is physically dominant over a busy urbanscape. The entire complex is guarded by high boundary walls pierced with arches latticed in concrete.

The mosque-in-the bazaar legacy is given credence by about 350 shops teeming with shoppers at any time of the day, extending along the Ground Floor and partly on the First of the West Block. There is so much of religious overtones at Baitul Mukarram that one hardly notices that this mosque has no minarets, This is hardly a folly but the failure of the designers to provide a congenial acoustical environment inside the mosque is a blunder of grave concern and consequences.

One of the primary functions of a mosque is to provide auditory communication between the Imam and the "Musallis". This vital transportation of the Imam's utterances to the avid audience is severely affected by the irritable and extremely poor acoustical conditions inside the mosque.

The top five floors, 2nd to 6th floors, and the open-to-sky eastern courtyard are occupied only during large congregations for Eid and Jumma prayers, the nights of Lailat-ul-Q'adr and Shab-e-Baraat, and on very special occasions. The lower three floors of the mosque, Ist to 3rd, are connected visually by a punch which is the central feature of the 4th floor, rather like a hump on the flat floor.



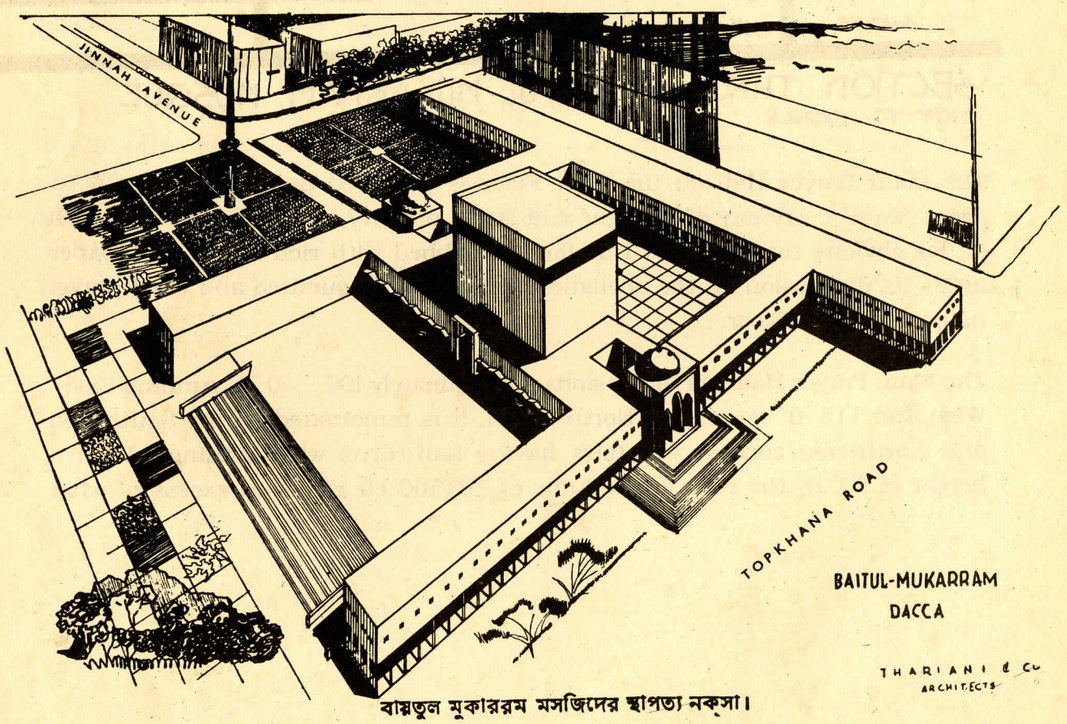
SECTION THROUGH BAITUL MUKARRAM MOSQUE
NOT TO SCALE

The Main Prayer Hall on the First Floor is occupied partially or wholly at every "waqt" every day of the year and is the primary centre of all activities. It is, for obvious reasons, that this floor is dabbed with rich decor. This paper limits its discussion on the acoustics of the most frequented and used prayer hall on the First Floor.

The Main Prayer Hall has dimensions approximately 100 ′ - 0 ′′ running East-West and 115'-0" measuring North-South. It is punctuated on the South-east and North-east corners by stairs having half-turns with landings. With a height of 23'-0" the resulting volume of 264500 cft is not in excess of what

would be the ideal size for design with unaided voice. However, a 580 sft. elliptical punch symmetrically located but more towards the West on the ceilings of the Main Prayer Hall and the one above creates a spatial link between the First, Second and Third Floors. Designed as a means of audio-visual contact and representing an attribute of multi-storied mosques in pre-microphone days, this punch in effect increases the volume of the Main Prayer Hall far beyond the ideal limit for spaces designed for unaided speech. (1) The effect of this is that Reverberation Time is increased in the Main Prayer Hall and the acoustics of the space is grossly distorted. Furthermore, considering that a large number of devotees would fall outside an angle of 140 ° (2) subtended at the position of the Imam, an electro-mechanical sound reinforcement system is being justifiably used in this Hall. This is rather useful because the flat floor is disadvantageous for transmission of unaided voice.

AN ARCHITECT'S VIEW OF BAITUL MUKARRAM (1960's)

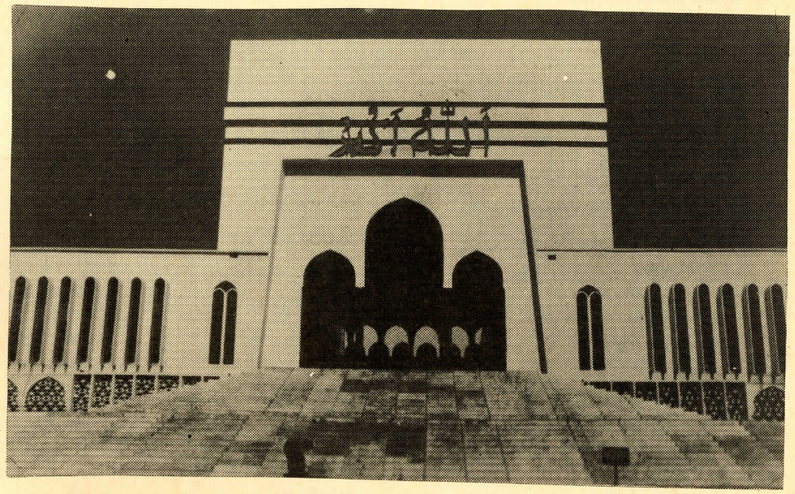


বায়তুল মুকাররম মসজিদের স্থাপত্য নক্সা।

Another factor responsible for increase in reverberation is the highly reflecting bounding surfaces. The floor of the Main Prayer Hall is finished in terrazzo. The West, North and South wall finishes are of marble. The ceiling and the columns are plastered concrete while the East wall is plastered brick. Very little absorption takes place in this space. The maximum possible absorption occurs when the doors and windows are open, and when the floor is fully occupied. There will be partial absorption through open windows and doors on the side walls, open doors on the East wall and the elliptical punch on the ceiling. The East wall on the mezzanine floor is predominantly reflective.

In calculating the Reverberation Time (RT) for the Main Prayer Hall, it has been assumed that 25% of the side walls and a similar fraction of the East wall below the mezzanine floor have absorption coefficient of I.O when the doors and windows are open. On account of being voids, the absorption coefficient of the elliptical punch and 25% of the stairway openings has also been assumed as I.O. A quarter of the West wall is glass; the rest is marble except two 11' X 5' wooden cabinets.

People absorb half as much as an open window at middle frequencies and at full occupancy this cumulates to be a major means of absorption. With absorption coefficients between. .02 to .05 very little is absorbed by the marble faced walls and the plastered surfaces. Although of negligible proportion, absorption by air has also been considered. (3)



Thus, the amounts of absorption in the space are as follows : (fractions ignored)

			Sabines
a.	North and South walls		
	100' X 23' X 2 walls	: 4600 sft	
	25% of above	: 1150 sft	
	Absorption (open)	: 1150 X 1	: 1150
	75% of above (marble)	: 3450 sft	
	Absorption	: 3450 X .02	: 69
b.	East wall 81' X 23'	: 1863 sft	
	Mezzanine is half	: 932 sft	
	Absorption (plaster)	: 932 X .05	: 47
	Ground floor is half	: 932	
	50% of this wall	: 466 sft	
	Absorption (open)	: 466 sft X 1	: 466
	50% of this wall	: 466 sft	
	Absorption (plaster)	: 466 X .05	: 23
c.	Staircases 15' X 23' x2	: 690 sft	
	33% of staircases	: 230 sft	
	Absorption (open)	: 230 X 1	: 230
	66% of staircases	: 460 sft	
	Absorption (plaster)	: 460 X .05	: 23
d.	West wall 115' X 23'	: 2645 sft	
	25% of above	: 661 sft	
	Absorption (glass)	: 661 X .05	: 33
	75% of above less wood	: 1666 sft	
	Absorption (marble)	: 1666 X .02	: 33
	Wooden surface	: 318 sft	
	Absorption (wood)	: 318 X .1	: 32
e.	Elliptical punch	: 580 sft	
	Absorption (open)	: 580 X 1	: 580
f.	Ceiling 84' X 115'	: 9660 sft	
	Minus punch (580 sft)	: 9080 sft	
	Absorption (plaster)	: 9080 X .05	: 454
	Ceiling below and above mezzanine floor		
	16' X 81' X 2	: 2592 sft	
	Absorption (plaster)	: 2592 X .05	: 130
g.	People		
	Total seating area	: 12252 sft	
	6 sft per person	: 2042 persons	
	Absorption (people)	: 2042 X .4	: 817
h.	Carpet area •	: 12252 sft	
	Assuming 50% remain exposed at full occupancy		
	Absorption (carpet)	: 6126 X .3	: 1838
i.	Terrazzo floor ••	: 12252 sft	
	Assuming 50% remain exposed at full occupancy	: 6126 sft	
	Absorption (terrazzo)	: 6126 X .02	: 123
j.	Air Volume	: 264500 cft (7406 m^3)	
	Absorption (air)	: 7406 X .02	: 148

• Used only during the Winter

•• The floor situation in Summer

The total absorption of the Main Prayer Hall is obtained by summing up the above absorptions, The values for summer and winter will vary (see h. and i. above) Carpet is used only in the winter.

Absorption for summer	:	4358
Absorption for winter	:	6073

Therefore, at full occupancy, the reverberation time, RT is given by

RT= .05 V/A, where A is room volume
and B is total absorption

For summer, RT =.05 (264500/4358)
= 3 .03 seconds

For winter, RT =.05 (264500/6073)
= 2 .18 seconds

Knudsen and Harris recommends just over 1.0 sec for a space volume as large as the Main Prayer Hall of the Baitul Mukarram mosque. (4) The values of RT obtained for both Summer and Winter are grossly over the mark. The RT will further increase at partial occupancies which is usually the case as mentioned earlier. The excessive RT in the Hall is a major acoustical problem of the space being considered.

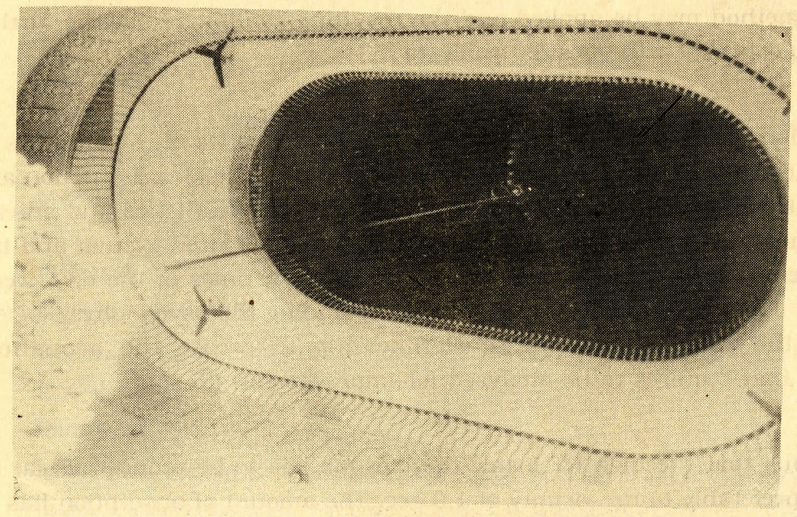
The high RT, echoes travelling more than 110'-0", multiple reflections from the hard surfaces, poorly disposed sound amplicication system, etc all culminate to produce a garble of words, totally unintelligible and barely comprehensible as speech. One can for reasons of familiarity and ritual comprehend *Allahu Akbar, Sura Fateha,* etc. However, *Khutba,* sermons, or any unfamiliar verse from the Holy Quran are not understood at all. This only comfirms Knudsen's view in 1929 that speech intelligibility suffers proportionately with the increase in reverberation time. (5)

Another factor contributing to the problem is that the columns and walls, reflective surfaces as they are, cannot possibly be equidistant from the listener and this obviously gives rise to echoes and delayed echoes, resulting in unintelligible sound. Flutter echoes may also be occuring between opposite parralel reflective surfaces, particularly between the mezzanine floor and the ceiling and also below the mezzanine floor.

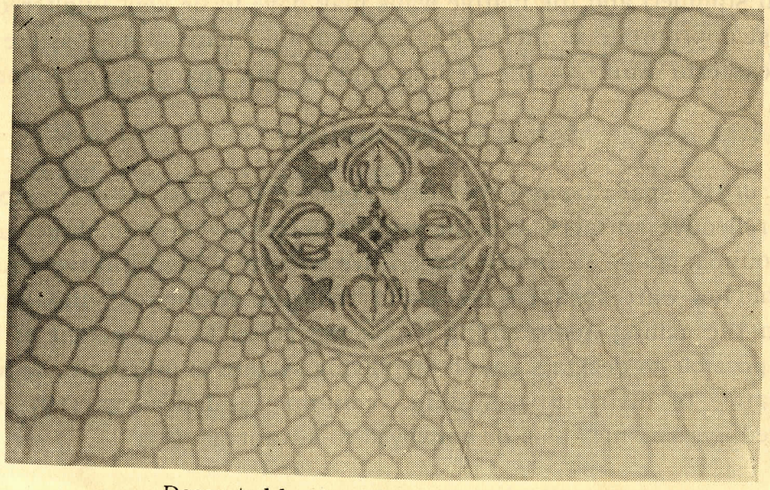
While designing for good acoustics inside a mosque it has to be borne in mind that the Imam Shaheb actually faces two directions in the course of his actions: he faces towards the direction of the Holy "Kaaba" (West in the case of Dhaka) while leading the prayer but he turns 180° to face the audience while reciting the *Khutba* or while addressing the assembly of devotees. It has already been discussed earlier why it is necessary for the Imam Shaheb to use an amplification system inside the Main Prayer Hall at the Baitul Mukarram.

In using a sound reinforcement system, the present distribution of speakers both laterally and vertically is inappropriate and inadequate. The sound cones of the two speakers mounted approximately 15'-0" high do not cover the entire gathering. "Box-type speakers mounted 10'-0" high on the columns are neither properly located, nor spaced. High frequency horns or "tweeters" and Low frequency boxes or "woofers" are being used separately. For best results, speakers should be placed above the audience when the height of the space is about 20'-0" and the distance between the speakers should be equal to the height for maximum coverage. (6) Also, clusters of woofers and tweeters should be used if central distributive system is opted for. The central system, if properly designed, may be marginally successful in the Main Prayer Hall because the height is just above the recommended limit of 20'-0". Under existing situation at the Baitul Mukarram it may be advisable to use a distributive system. (7)

It goes without saying that the existing situation in the Baitul Mukarram mosque is typical of large spaces with high reflectance of the bounding surfaces. Because the building is already constructed and in use, it cannot incorporate significant changes in size and shape. Moreover, the choice of major changes in the interior surface finish is also restricted. Considering



The punch in the ceiling of the Main Hall



Decorated hard surface of the ceiling.

the complexity of acoustics and the uncontrollable variables in this mosque, it is expected that the solution will not be a straight-forward one; rather a trial and test method may be applied and the resulting conditions may be further investigated to reach the desired goal. (8)

The solution of the problems associated with the acoustics of the Hall has to take into consideration the size and shape of the hall, use of construction and finish materials and their methods of application, the aesthetics and gravity of the space as a prayer hall, the use of sound amplification system and the use of the space at different occupancies at different times of the day, week and year. Each of the above factors, notwithstanding the psychophysiological state of the receiver, contribute significantly to create the acoustical condition that requires to be analysed for improvement. (9)

It is obvious that the high RT inside the mosque has to be reduced as far as possible, preferably to the vicinity of 1.0 sec. The amount of absorption has to be increased as adjusting the space volume is not feasible. Considering that the floor (in summer) and the marble walls may have to be kept unaltered, it will be most appropriate to increase absorption to a maximum possible on the rear (eastern) wall, on the ceiling and in the space by suspended absorbents.

The height of the space being considered being near about 23'-0", coupled with high reflective surfaces and the wide differences between direct and reflected sounds, make it almost imperative to use a disrtibutuve sound system. The low-watt speakers (to avoid reflected feed-back) should be installed in the ceiling, maintaining a spacing equal to the height of the room. It is possible to design s sound amplifying system to overcome the long RT. Alternative to distributive system, "column" loudspeakers (10) with Time-Delayed System, may also be employed to advantage. (11)

From the above discussion it will be clear that the solution to the severe acoustical problems of Baitul Mukarram is not a simple proposition. It is a complex task requiring high levels of technical and artistic skills that needs to be undertaken with a spirit of religious zeal.

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