The Original Acoustics of Sixteenth-Century Mughal Heritage of Burhanpur, India

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Conceptual background and research propositions

Acoustics of Asian worship spaces are not extensively researched & need multidisciplinary approach for comprehensive understanding (Jian, GE et al., 2012).
The acoustics of Asian cultural heritage and worship spaces in particular, have emerged on the basis of rites and rituals adopted in various cultures.

The cultures have evolved owing to the dynamism of philosophies, traditional knowledge systems, beliefs and religious concepts.

The architectural elements of the worship spaces also have a significant role in the acoustics apart from symbolism perceived and decoded by community.

This research, with Burhanpur; India as a case, explores the potential of acoustics of these worship spaces.

Conceptual background and research propositions
Burhanpur, a district in Madhya Pradesh having Historical Importance

From 1601 A.D Burhanpur city served as the second most important Deccan headquarters of the Mughals.
The Tomb of Shah Nawaz Khan

The Tomb of Shah Nawaz Khan of historic Burhanpur; amongst various sixteenth-century Mughal architectural heritage that served acoustical purposes; is unique, since it was used in the verse recitations from the Holy Quran and Qawwalies (Sufi song) during the holy days and festivals.

Its spatial configuration and sonic dimension associates the community emotionally, intellectually and spiritually.

Due to neglect, inappropriate interventions and vandalism its acoustical features are defaced, weakening communities’ association with the Tomb.

<table>
<thead>
<tr>
<th>Sr. no.</th>
<th>Name of Monuments / Sites</th>
<th>Physical attributes</th>
<th>Spatial variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Constructio materials</td>
<td>Openings</td>
</tr>
<tr>
<td>5</td>
<td>Tomb of Shah Nawaz Khan</td>
<td>Stone &amp; brick masonry, lime stucco plaster</td>
<td>1 Door, 2 Jalis, 4 Clearstory windows</td>
</tr>
</tbody>
</table>
To assess the consequences of resent restoration in the Tomb, this research was carried out to predict the acoustical performance of the structure based on the assumption that

the contemporary repairs were performed with **materials that were compatible with the original historical materials**

and the **virtual recreation or revival** helps analyze how the Tomb might have sounded some 395 years ago.

<table>
<thead>
<tr>
<th>measurement of the tomb</th>
<th>meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>extreme outside</td>
<td>26.72 m</td>
</tr>
<tr>
<td>total height</td>
<td>23.45 m</td>
</tr>
<tr>
<td>the exterior and interior diameter of the dome</td>
<td>9.87 and 9.12 m</td>
</tr>
<tr>
<td>the great hall (square plan)</td>
<td>9.69 m</td>
</tr>
<tr>
<td>interior height</td>
<td>19.4 m</td>
</tr>
<tr>
<td>area of the hall</td>
<td>93.89 m²</td>
</tr>
</tbody>
</table>

*Front View of the Tomb of Shah Nawaz Khan, Burhanpur.*
Schematic Plan, Elevation and Section of the Tomb of Shah Nawaz Khan, Burhanpur.
Research Method

Tomb of Shah Nawaz Khan
Research Method

3D view as rendered in EASE 4.3
Research Method

Overview of the Subjective and Objective Identification of the Acoustical Peculiarities of the Tomb of Shah Nawaz Khan, Burhanpur.
Research Method

Modelled Surfaces of the Tomb of Shah Nawaz Khan.

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Surface Material</th>
<th>Surface</th>
<th>Table 2 Material Code</th>
<th>Area (m²)</th>
<th>Percentage of total area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Concrete</td>
<td>Concrete</td>
<td>1</td>
<td>190.88</td>
<td>14.87</td>
</tr>
<tr>
<td></td>
<td>Plaster on Brick Substrate</td>
<td>2</td>
<td>901.84</td>
<td>70.26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Openings</td>
<td>3</td>
<td>15.32</td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stone lattices or Jali</td>
<td>4</td>
<td>30.70</td>
<td>2.39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marble</td>
<td>5</td>
<td>144.78</td>
<td>11.28</td>
<td></td>
</tr>
</tbody>
</table>

$I' = 1832.33 \text{ m}^2$

$\sum S = 1283.52 \text{ m}^2$


<table>
<thead>
<tr>
<th>Material Code</th>
<th>Surface Material</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100  125 160 200 250 315 400 500 630 800 1000 1250 1600 2000 2500 3150</td>
</tr>
<tr>
<td>1</td>
<td>Concrete</td>
<td>0.02 0.02 0.02 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.03 0.04 0.04 0.05 0.06</td>
</tr>
<tr>
<td>2</td>
<td>Plaster on Brick Substrate</td>
<td>0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10 0.10</td>
</tr>
<tr>
<td>3</td>
<td>Openings</td>
<td>1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00</td>
</tr>
<tr>
<td>4</td>
<td>Stone lattices or Jali</td>
<td>0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50 0.50</td>
</tr>
<tr>
<td>5</td>
<td>Marble</td>
<td>0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.02 0.02</td>
</tr>
</tbody>
</table>
Measured Versus Simulated Reverberation Time in the Tomb of Shah Nawaz Khan in the Non-occupied Mode (for the Present Acoustical Condition with Contemporary Repairs).

Early Decay Time (EDT) Measured and Simulated for the Tomb of Shah Nawaz Khan in the Non-occupied Mode (for the Present Acoustical Condition with Contemporary Repairs).
The acoustical performance and analysis of the Tomb was examined based on following three conditions:

1. **The present acoustical condition** of the structures with contemporary repairs;

2. **The compatible repair condition**, that is, the structure when repaired with materials compatible with the original historical materials;

3. **The original condition**, that is, features of the interior, such as the carpet on the floor of the Tomb in recitation mode, verse recitations from the Holy Quran, and singing Qawwalies and the virtual recreation or revival of the acoustical environment.
Results and Observations

Reverberation Time (RT) is the basic descriptor in the assessment of room acoustics.

RT characterizes the decay of sound for specifying the effectiveness of an enclosed environment in fulfilling the acoustical requirements, depending on the activity or function that occurs.

<table>
<thead>
<tr>
<th>Acoustical Parameters</th>
<th>Present acoustical condition with contemporary repairs</th>
<th>Compatible repair condition</th>
<th>Revival of Original condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-occupied at 500 Hz</td>
<td>Occupied at 1kHz</td>
<td>Average</td>
</tr>
<tr>
<td>RT</td>
<td>3.49</td>
<td>2.95</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
<td>2.94</td>
<td>2.91</td>
<td>2.92</td>
</tr>
<tr>
<td></td>
<td>2.99</td>
<td>2.50</td>
<td>2.74</td>
</tr>
</tbody>
</table>

The Calculated Values for RT in the Non-occupied and Occupied Mode of the Tomb of Shah Nawaz Khan for the Present Acoustical Condition with Contemporary Repairs, the Compatible Repair Condition and the Revival of Original Condition.

The optimum range 1.40 s to 3.40 s for both speech and music (Kleiner, M et al., 2010) (Egan, D., 2007) (Barron, M., 2010)
The Calculated Values for EDT in the Non-occupied and Occupied Mode of the Tomb of Shah Nawaz Khan for the Present Acoustical Condition with Contemporary Repairs, the Compatible Repair Condition and the Revival of Original Condition.
The Calculated Values for C80 in the Non-occupied and Occupied Mode of the Tomb of Shah Nawaz Khan for the Present Acoustical Condition with Contemporary Repairs, the Compatible Repair Condition and the Revival of Original Condition.
The Calculated Values for STI in the Non-occupied and Occupied Mode of the Tomb of Shah Nawaz Khan for the Present Acoustical Condition with Contemporary Repairs, the Compatible Repair Condition and the Revival of Original Condition.
**Ray Tracing:** In addition to the above acoustical parameters, ray tracing (an analytical tool in the EASE 4.3 acoustical simulation software) is implemented to model the propagation of sound rays and reflection patterns within the enclosed space by emitting rays whose reflection paths can be viewed and investigated.
**Ray Tracing** for the Tomb of Shah Nawaz Khan.
Conclusions

The main findings of the research may be summarized as follows:

In-situ measured reverberation times and sound distribution patterns were used to calibrate the digital simulation model of the Tomb and the model was used to predict the acoustical characteristics for two conditions - ‘compatible repair condition’ and the ‘revival of the original condition’.

The acoustical parametric analysis suggests that the Tomb originally had well-designed acoustical characteristics that provided optimal acoustical conditions for music and speech intelligibility.

The well-designed original acoustical characteristics of the Tomb is being changed and destroyed by improper conservation measures.

More information related to the sound absorption properties of the historic materials needs to be obtained to better understand and predict the original acoustical characteristics through simulations.

This will help protect intangible cultural heritage such as the acoustics of the built environment, a highly fragile and elusive quality attached to the heritage structures.
References


References


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