Analysis of Acoustical Environment in Temple Architecture of India: Built Form and Design Configuration

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Abstract: Even individuals can recall specific scents or aromas vividly. But in architectural practice, sound is a component that is frequently overlooked. When it comes to sound, architecture's soundscape are lacking in illumination up front. People who are deprived of their senses do not thrive. Our hearing is one of the senses that need good stimulation. Architects do not create visually quiet spaces. Colours, lighting, and textures are employed to improve the environment visually. Our auditory surroundings should also increase our happiness of life. This study aims to increase our awareness of the nuances and manifestations of the various sound waves and their frequencies that exist both inside and outside of us. The significance of the sounds and how they affect the Temple architecture's acoustics is covered in this essay. The goal of this study is to provide a useful framework for architects to leverage the connection between architectural aesthetics and soundscape. Additionally, this study helps to provide a structural framework that allows architects to include acoustic aspects into their designs for aesthetic rather than functional reasons.
***Keywords*:** soundscapes, acoustical environment, temple architecture, India

1. Introduction

In architecture, the visitor's visual experience is always considered to be the primary perception, and designers continue to prioritise this aspect of their work. Visualisation was most likely the first tool to be developed and is now the main application of design thinking (McLachlan, 2000). All people, however, use a variety of senses to give the world shape and definition. In order to feel, touch, and learn about the world, humans have ears, noses, and eyes. According to Rasmussen (1959), the author of Experiencing Architecture, people often get a general image of a building from their eyes but rarely become aware of all the senses that have influenced that impression. Soundscape is a new research topic that focuses specifically on the auditory experience as more modern architecture academics start to investigate people's multisensory experiences with buildings and other built environments. The term "soundscape" refers to the surrounding environment of noises, music, and noise. It was created in the late 1960s by Canadian composer and author R. Murray Schafer as a neologism by analogy with "landscape".

He noted that:

Soundscape is the sonic environment. Technically, any portion of the sonic environment regarded as field for study. The term may refer to actual environments, or to abstract constructions such as musical compositions and tape montages, particularly when considered as an environment.

Numerous studies on soundscape recommended seeing the natural soundscape as a whole, appreciating the acoustic experience, instead of removing the noises we do not want to hear. Motivated by this perspective, I am attempting to find a novel approach to enhancing the aesthetic expression of architectural or other environmental design through the use of electronic music composition, soundscape planning, and acoustic design. The research problem includes a systemically organized investigation on how the principles of soundscape architecture could enhance the formal aesthetics of architectural designs, in addition to offering architects a new approach in their design practice. Our built world can be experienced through architecture. Architecture has the power to recognize people's emotions, desires, and capacity for enjoyment. In this sense, multisensory architecture is relevant. With an eye towards aesthetic appreciation, the majority of architecture that is designed is ocular centric. However, our senses are always used to perceive architectural space. The senses of sight, hearing, touch, taste, and smell are the traditional five major senses. Vastu energies are formed through architecture, and they are expressed through music. Vastu energies become sensory perceptive through sound. Architectural design frequently overlooks the importance of the auditory experience, which should be considered early on in the process.

2. Literature Review

A soundscape is the entirety of the sounds produced by humans, the natural world, or both when they occur in different temporal and spatial dimensions within a specific environment. A variety of distinct objects, including tractors, birds, crickets, wind, fireworks, and waterfalls, could be the cause of the sound. Many subjects, including architectural acoustics, acoustic design, noise control, and vibration control, fall under the study spectrum that connects acoustic problems to building technology and architectural design when it comes to the realm of architecture and soundscape. According to Wrightson's description, soundscapes can be divided into two categories (Wrightson, 2000). Real Sounds: These are sounds found in the real world, such bird song and ocean waves; Virtual Sounds: These are sounds created purposefully by humans to create a unique virtual environment, like soundtracks from movies and music videos. The earlier studies on the subject of architecture and acoustics may be structured into such a structure if we split the architectural themes related to acoustics and soundscape into two categories based on their practical or aesthetic purpose (Figure 1). Using their initials — RA, RP, VA, and VP. Schafer began by noting how prevalent visual modality was in society — a phenomenon he dubbed "eye culture" — and realizing that children's listening skills were in risk of declining. Later, in 1977, Schafer published Tuning of the World, a book that summarized the findings of his observations and study on the historical development and current condition of the global auditory world. Schafer's research indicates that throughout the Renaissance, when the printing press and perspective painting were developed, the ear gave precedence to the eye. As the globe has grown, sound has become less important, and we are losing the chance to hear natural sounds with every generation, in part due to the destruction of natural ecosystems (Schafer, 1977). Under such circumstances, "*sound becomes something that the individual tries to block, rather than to hear*".

3. Research Objectives

Real Acoustics (RA) is the first of the two categories where the majority of the study is focused. My study's main focus will be on the issue of how people's perceptions of aesthetics can be influenced by real or natural sound in the built environment. When going through earlier studies on RA problems, such Schafer's Soundscape, it is rare to come across in-depth analyses of the connection between architectural aesthetics and acoustics. Nonetheless, there are several instances where the formal design of the visual quality of the architectural environment is aided by the auditory environment. Our enjoyment of the architectural environment's beauty is reinforced by the sounds of our footsteps, slamming doors, and the wind moving through the street's trees. There is a hope that this issue will receive greater attention by locating these cases and classifying how they are implemented. Prior research on Virtual Acoustics (VA), the second issue, is similarly restricted to a small scope. Martin's book, Architecture as a Translation of Music, did spark some thought-provoking conversations, however the most of them only addressed how music inspires architects rather than delving deeper into the more nuanced questions of how music may be used to the design process. The study concentrates on the usage of virtual acoustic environments in multimedia architectural presentation stages rather than establishing connections between music and architecture during the design stage. According to Martin (1995), a multimedia project that incorporates a virtual acoustic environment can provide the audience with an engaging experience while presenting the design works in a convincing and efficient manner.

4. Research Methodology

The evaluation of prior research in the fields of multimedia production, architectural aesthetic theory, and soundscape serves as the foundation for the entire research process. The internet and secondary data from pertinent published academic literature, including journal articles and research papers, have been used to investigate the systematic literature review. The information gathered for the qualitative research comes from several case study examples that are descriptively stated and have images and visuals to bolster the points made. In order to illustrate the formal aesthetics of soundscape and architecture, the discussion of acoustic issues and architectural forms in the sequence of point, line, plane, and space has been structured with the inclusion of personal observations.

5. Three-Dimensional Acoustic Environment

The majority of discussions surrounding recording technology centre on the concept of three-dimensional sound environments. The investigation of actual acoustic environments can benefit from these talks as well. People still have a tendency to visualize the apparent locations of sounds without really looking at the physical sources of sound. According to Copeland's study on blind people's aural perception, the blind person can perceive their surroundings by listening for typical sound patterns like traffic sounds because the acoustic environment shows them the world as it is outside of their body (Copeland, 1997). Copeland noted that:

The University of Birmingham has a huge clock tower that serves as an alternative illustration of how sounds capture the environment around one. Depending on one's location on campus, the sound of the clock tolling varies. This is caused by both the different ratios of direct to reflected sound and the physical separation between the bell and the listener. Additionally, the kinds of echoes and reverberations that can be heard in various outdoor settings as well as the effects of masking in specific locations are to blame. Each time the clock strikes, a separate individual is given a distinct auditory impression of what are typically thought of as silent, motionless structures. A demonstration of how sound captures both space and time in a single moment of existence occurs when the bell rings. Remarkably, the buildings contribute just as much to the composition of this photo as does the tolling bell.

6. Directivity and Distance of Sound

According to Lerner (2003), directivity refers to the angle at which sound is perceived in both the vertical and horizontal planes. Our two ears each hear sound events at different levels, which creates the illusion of directivity from the sound source. People are typically better at locating the sources of sound for left and right measurements than for front and rear. Additionally, we are able to determine a sound source's distance from us based on both its volume and the impression of space it gives us. Why the two? Assume for the moment that we are in a large outdoor square. The majority of the sounds we hear are either absorbed by receivers or sent to the sky and far-off locations, rarely being reflected by surfaces. We can determine a sound source's distance without significant reverberation by measuring its loudness in relation to the surrounding acoustic environment. However, when we are inside, as in an office building's foyer, we pick up sound waves both directly from the source and by reflections from the walls, windows, and other interior surfaces. The level variations among all the sound sources in the hall are, in this case, more subdued than the outdoor acoustic setting. If a sound event has less reverberation than other sound events with more reverberation, we perceive it to be closer to us.

The frequency spectrum is another element that influences how sound is perceived in space. In general, our ears are more sensitive to noises in the middle range of the frequency response, which falls within a smaller bandwidth. According to Schafer, the difference between a hi-fi and lo-fi soundscape truly lies in the frequency spectrum that influences how they seem to listeners. Schafer referred to the pre-industrial acoustic environment as hi-fi, or high fidelity, and the post-industrial one as lo-fi, or low fidelity. According to Schafer (1977), the former is characterized as a setting where sounds overlap less frequently and have a stronger sense of perspective, making the distinction between the foreground and background sounds more apparent.

7. Three Paradigm Systems of Soundscape Principles in Architecture

Three paradigm systems have been built from earlier research to illustrate the technical elements necessary in the recording technology to replicate the acoustic environment for the audience. The first one, dubbed "Soundscape Map," was created using a sound event map drawing by Michael Southworth that was published in Schafer's book, The Tuning of the World (Schafer, 1977). It may successfully illustrate how auditory identities blended with visual identities to provide a cohesive artistic experience for guests (Fig. 4).

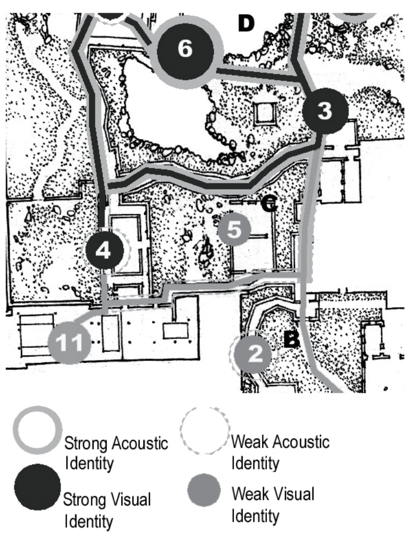

Figure 1. Soundscape Map in a Neighbourhood Setting

The second one is a technique for visualizing the acoustic environment surrounding an audience and is dubbed “Soundscape Perspectives.” Gibson’s research in The Art of Mixing: A Visual Guide to Recording, Engineering, and Production (Gibson, 1997) served as the basis for this development. When we use recording technologies to replicate the acoustic environment for soundscape design, it is really helpful. As previously said, soundscapes by themselves can provide those who are blind or visually impaired with a virtual aural environment. The acoustic world is recreated using a pair of speakers in front of us, displaying nearly every sound object in our immediate surroundings along with its direction, distance, height, and weight. Numerous physical characteristics of sound objects (spheres in the diagram) can be indicated using the Soundscape Perspective system, including directivity, loudness, and frequency (Fig. 5) (Table 6).

a) The size of the spheres, their height on the y-axis, their placement on the z-axis, their directivity on the x-axis, and their brightness on the y-axis are all ways that Soundscape Perspective can display volume, frequency, distance, and clarity.

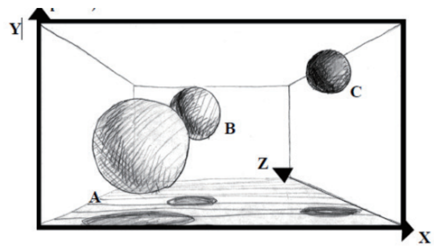

Figure 2. Soundscape Perspectibves for Visulaization of an Accoutical Space

b) In contrast to the foreground sound or sound signals (objects A and B in Figure 3), the plane in the back of the room represents background sound, also known as keynote sound. Usually, a noise wall that absorbs a large variety of frequencies is used.

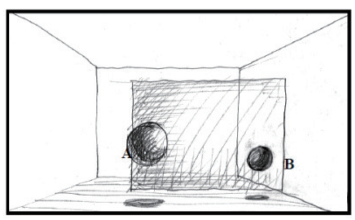

Figure 3. Keynote sound and Foreground sound in an Interior Space

c) Here, the pairs of spheres with arrows indicating the movement’s direction could be used to indicate the movement of sound items.

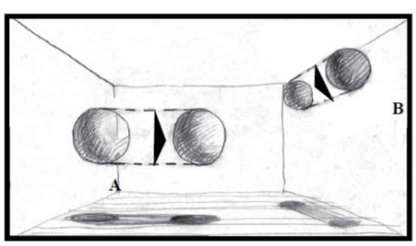

Figure 4. Movement of the Sound Object in an Interior Space

d) The diagram’s flattened spheres (items A and B) represent the sound objects that undergo some degree of transformation as a result of sound diffusion or reflection. They do not originate from audio sources directly. These items also symbolize the sound occurrences in recording technology that are subjected to effects like chorus, reverb, or flanger.

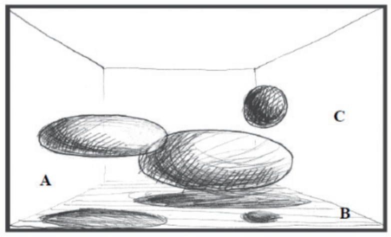

Figure 5. Transformation of Sound Objects due to Reflection or Diffusion

The third approach we developed is called "Soundscape Scores," which we created because the previous two couldn't account for the time component, which is crucial to soundscape designs. (Figure 6) If the sound objects are not continuous, as demonstrated in Figure 6, the density of object lines reveals the texture and rhythm of those sound things. The left end of the object line won't contact the left edge of the frame if the sound event, like object A in the picture, appears momentarily. Additionally, similar to the Soundscape Perspectives system, the separation between the arrows on the z-axis and the vertical grey strip on the right indicates the existence of sound objects; the arrangement of these items along the y-axis is determined by their fundamental frequency.

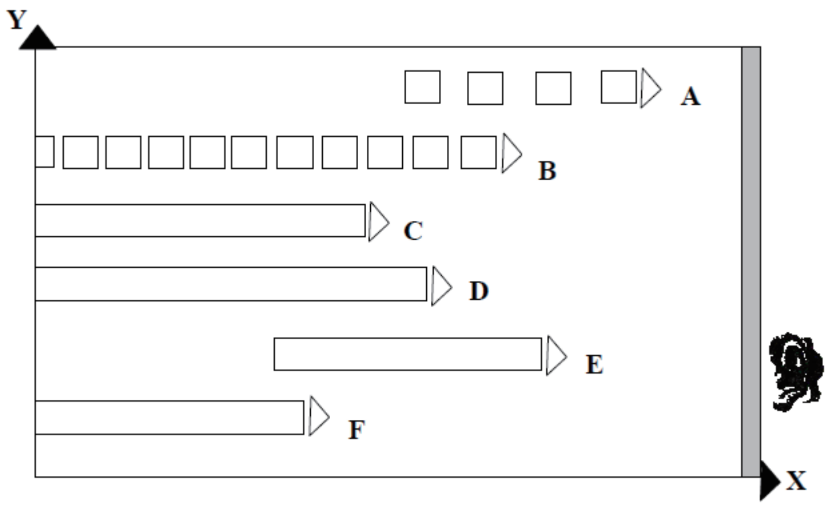

Figure 6. Soundscape scores of a space to evaluate the acoustical environment

A: high frequency, present, low density and temporary sound;
B: Higher density, enduring sound:
C, D: Continuous sound;
E: Temporary, continuous sound, present;
F: Low frequency, continuous background sound.

In the next section, these three graphic methods will be utilized in different ways to illustrate the case study talks. The majority of the time during the design phase, soundscape maps will be utilized to plan out the entire soundscape. Soundscape Scores and Soundscape Perspectives are more intricate issues that are typically utilized during the presentation stage to replicate the auditory environment.

8. Case Studies

In all world cultures and faiths, acoustics play a significant part in places of worship. This makes sense because one of the senses of perception that acoustics deals with is sound. In Hinduism, sound has a significant role in many facets of life, including spirituality, religion, culture, science, and the arts. It is often recognized that sound is extremely significant in Hindu places of worship, such as homes, community centres, and temples.

Vedic Chants

The Vedas are a collection of mantras sung with exact acoustical features from ancient times to the present, and they serve as the fundamental literature of Hinduism. It is often recognised that written communication cannot match the acoustic accuracy of oral Vedic chanting, music, and conversation.

Conch Shell

A conch shell's sound has an extremely high quality factor that reveals how sharply it resonates. Usually, the conch shell is used to usher in the worship. Because of the way it sounds, devotees are drawn to it and are able to concentrate their minds on the act of worship.

The Bell

At the start of worship, the bell is also used. A well-designed bell produces a ringing sound that lasts for a long time.

The Gong

A gong is a type of musical instrument that is hit with a mallet and looks like a flat, circular metal disc. They have a round shape and are composed of brass. It is also observed that the sounds of the conch shell and bell have an acoustic resemblance to the OM sacred sound chant. Temple sounds include bell ringing, mantra chanting, aarti recitation, and Strotram recital. Throughout ancient times, various types of bells have been utilized in Indian temples. Temples are made with the intention of allowing sound to echo within. Our awareness of the vibrating aspect of our existence is triggered by these direct and reverberating sounds, which interact with our internal frequencies.

8.1 Case Study 1: The Narayanaswami temple at Melukote, Mysore

The square, large-scale, plain Narayanaswami temple at Melukote, Mysore is devoted to Lord Cheluva-Narayana Swamy, also known as Thirunarayana (Figure 7). The goddess known as Shelvapillai, Cheluva Raya, and Cheluvanarayana Swamy is represented by the metallic utsavamurthi, whose original name seems to have been Ramapriya, which translates to "Rama's Favourite." It is thought that Lord Rama and the monarchs of the Surya Vamsa Dynasty revered and owned this utsavamurthi for many years. The same god was later bestowed to a monarch of Lord Krishna's Chandra vamsam dynasty, and Lord Krishna and numerous generations of people worshipped it. Because of his uniqueness, Cheluva Narayana was revered by both Rama and Krishna. The Floor Plan of the Narayanaswami temple at Melukote, Mysore is shown in Figure 8.

Figure 7. View of The Narayanaswami Temple at Melukote, Mysore, India

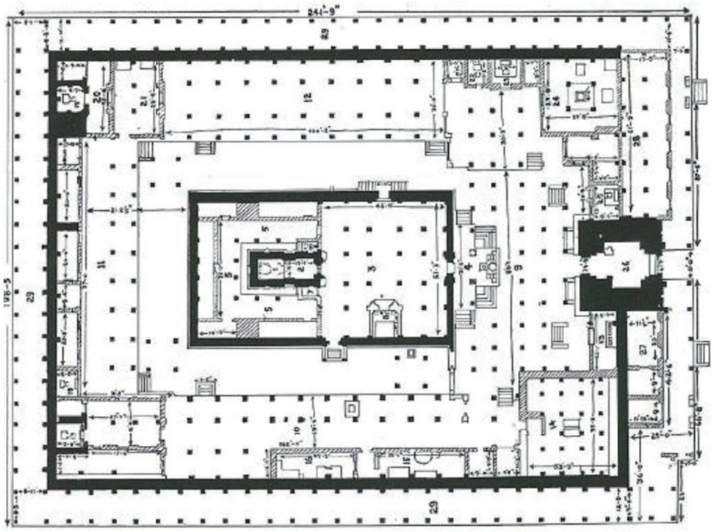

Figure 8. Floor Plan of the Narayanaswami temple at Melukote, Mysore, India

Acoustical Analysis

Analyses of the sounds produced by conch shells, bells, gongs, and mantra chanting were conducted in the Narayanaswami temple in Melukote, Mysore. Analogous recordings of similar sounds were also made in an anechoic chamber and a community hall.

Parameter

- The physical attributes of the sound source, such as bells, gongs, conch shells, and mantra chanting.
- The listener's and sound source's relative positions.
- The space's architecture (temple).
- The effect or sensation that devotees get from auditory stimuli

Process

- The audio recordings (.mp3) of different instruments were made in a community hall, an anechoic chamber, and the Hindu temple Ardha-Mantapa.
- The results show the ideal acoustical space in the three temples mentioned above based on an investigation of noises in various environments.

Result

- It has been noted that Ardha-Mantapa and Garbha-Griha both considerably improve the acoustical quality of the devotees' spiritual experiences.

Chanting The Mantras In Hindu Worship Spaces

Throughout the ceremonies or worship, the Vedas are recited by one priest at a time or by several priests together. Devotees occasionally participate in the Vedic recital. This study measures a single priest's recitation and performs sound spectral analysis on an Ardha-Mantapa of a temple, a community hall, and an anechoic room.

8.2 Case Study 2: Siddheshwar Temple Ahmednagar, India

The best example of Yadava architecture from the 12th and 13th centuries in the Marathwada region is the complex of temples dedicated to Shri Siddheshwar, located near Toka village. During the Peshwa dynasty, new temples were constructed following the founding of the Marathi state. There are many sculptures in existence. The temple is filled with sculptures depicting characters or stories from several epic tales, including the Ramayana, Mahabharata, Puranic, Surasundari, and Vyal-Sharbha. But it lacks the delicacy and variety of the Yadav period temple sculptures (Figure 9). Within the sanctum of the temple is a large Shivlingam, and the rear wall features an idol of Parvati and a brass serpent (Mandaar, 2015).

Figure 9. View of Siddheshwar Temple Ahmednagar, India

The main temple's spire, which is shaped like a sabhamandap, is composed of tiny peaks. The temple's pillars are in the Peshwa style. In front of the Shiva temple is a stunning Nandi that resembles Bhuleshwar Nandi a lot. Beautiful details may be seen in the chains, the snake's fence, the tiny bell vines, the embroidered stripes, and the exquisite rope carvings on Nandi's back. Yaksha is the carrier in the sanctuary and sabhamandap, whereas Jai Vijay guards the temple's entrance. The sculptures on the outer wall of the temple contain shrines on its side. All around the temple, there are carved images of characters from epics such as the Ramayana, Mahabharata, and other Puranic stories.

The facade of the temple is a beautifully sculpted Dashavatar plaque. You can view all ten of Lord Vishnu's incarnations here, including the Buddhavatar, Kurmavatar, Matsyavatar, Varaha Avatar, Nrusinhavatar, Vamana Avatar, Parashuram Avatar, Rama avatar, Krishna avatar, and Kalki avatar. The main temple's walls are carved with two sculptures: a lovely image of Draupadi is located on the right side, and a picture of the king is seen on the left. In addition, Ahmednagar (2020) mentions the events surrounding Balakrishna in Gokul, Krishna's leela with the Gopikas, Arjuna's pride, Bhim's pride, and Hanuman Sita's visitation to the Ashoka forest. There are also other intriguing sculptures that are engraved on the plaque depicting people playing different instruments, such as veenas, tal, mridang, women's bhavmudras, and nrityamudras, while also styling their hair and performing makeup (Figure 10).

Figure 10. Sculptures of Hindu deities carved on the wall of Siddheshwar temple at Ahmednagar, India

Acoustical Analysis

The sound produced by the bells of the Siddheswar Temple in the Pune district of India was analyzed using the sophisticated Wavanal and VizIR acoustic analysis programmes.

Parameter

- The physical attributes of the sound source, such as bells, gongs, conch shells, and mantra chanting.
- The listener's and sound source's relative positions.
- The space's architecture (temple).
- The impact or sensation that devotees experience from auditory stimuli.

Process

- The simulation's results indicate that a more diffused region is indicated by a ratio of Early Decay Time (EDT) to Reverberation Time (RT) that is close to unity since the decay curves in this instance are more linear.
- The resulting Clarity of Sound (C) values show whether or not worship areas are suitable for speaking or listening to music.

Result

- It has been noted that mean EDT values in Siddheshwar temples are shorter than RT. This indicates that massive surfaces, such as columns, that are closer to the source are producing the strongest reflections.
- Because EDT is somewhat smaller than RT, there is a certain level of "liveliness" in every temple.
- It has been noted that positive C80 is most appropriate for events like musical performances or prayer with musical accompaniments at the Siddheshwar Temple.

Conclusion Derived

- Creation of larger surface to get stronger acoustical reflections, thus enhancing the reverberation time.

Creating a reverse sound propagation in garbha griha and ardha mandapa which will project the sound to the rear *portion of the temple rather than flattening it to the front side, which enhances the reverberation time and gives the space a holy atmosphere*

9. Results and Discussion

Conch shells being sounded in Hindu worship areas

Conch shells are sounded at the start and finish of worship sessions as well as to announce the presence of the deity in numerous Hindu temple rites. It serves as a holy water bottle in addition to being a musical instrument. Additionally, it is employed to ward against evil spirits. It's noteworthy to note that conch shell sound has a distinct, strong, and crisp tone that may be heard when listening. The greatest acoustics can be found at Melukote's Narayanaswami Temple.

Gong Sounding at Hindu Places of Worship

A gong is a type of musical instrument that is hit with a mallet and looks like a flat, circular metal disc. The gong is struck three times in this investigation, and the resulting sound spectra are examined. For striking the gong at the centre (r=0), middle (r=R/2) and edge (r=R), spectral analyses are performed. The greatest acoustics can be found at Melukote's Narayanaswami Temple.

10. Conclusions

The droning thoughts of the devotees would be stilled by the sounds of these instruments and the Vedic chanting during the prayer.

One cannot turn off one's ability to hear. The earlids are absent. Our sense of sound is the last one to shut when we go to sleep and the first one to open when we wake up (Schafer, 1977).

Since sound and hearing affect the quality of space design, aural architecture should be seen as an essential part of basic design principles. The symmetrical Planning of the Temple, will greatly influence the acoustical quality of the space and moreover would help to achieve the Healing Frequency. The use of stones or building materials with rough textures would act as sound diffusers. The creation of larger surface to get stronger acoustical reflections, thus enhancing the reverberation time. Creating a reverse sound propagation in garbha griha and ardha mandapa which will project the sound to the rear portion of the temple rather than flattening it to the front side, this enhances the reverberation time and gives the space a holy atmosphere. The healing frequency of 432Hz should be achieved for the soundscape of the temple. The correct materials should be used, and during the prayer, the sound of bells, conch shells, and gongs combined with Vedic chanting can help devotees' wandering minds concentrate on the worship procedures. The importance of soundscapes and the aural environment as a highly useful tool for expressing architectural environments should be understood by designers. It is possible to effectively use soundtrack components to improve our perception of the built environment. Typically, designers ignore the aural component and only take into account the visual criteria that are part of the principles of basic design.

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