ACOUSTIC SIMULATIONS OF WORSHIP SPACES

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1. INTRODUCTION

Acoustic simulations of religious facilities need to focus on specific acoustic parameters, due to the different aural expectations of the congregations. In mosques, the main acoustic objective is speech intelligibility; whereas in churches and synagogues, the contrasting demand between adapted reverberance for music and clarity for intelligible speech is the main issue of the acoustical design. The nature of contemporary houses of worship is to serve more than one purpose. And hence due consideration for acoustical prediction should be taken alongside the development of sound system use. Galindo et.al. used simulation software to evaluate the acoustics of European churches[1].

In this investigation, acoustical simulations were applied to provide recommendations to the proposed design of the sanctuary of a United Church in Toronto. Since the existing sanctuary is seen to provide an acceptable and satisfactory sound environment, an evaluation of the acoustic performances of the existing sanctuary was carried out with measurements of the reverberation time. Simulations were conducted using CATT Acoustic software[2]. The calibration of the model was undertaken by comparing the results of the simulation and the measured data. Two main acoustical descriptors were used for the evaluations of the new sanctuary: Reverberation Time, RT and Speech Transmission Index, STI. Standard guidelines used for reverberation times were also applied in this investigation[3].

Different scenarios as to the placement of the speakers as well as to the acoustical materials used inside the sanctuary were evaluated with CATT Acoustic. Results of the above investigations are presented below.

1.1. Existing Sanctuary

The sanctuary, shown in Figure 1, has an overall volume of about 1850 m^3 and a floor surface of 255 m^2. The ceiling is vaulted with a highest point reaching 9.7 m in the nave and 6.3 m in the chancel. The floor is carpeted, the furnishings are finished plaster for the walls and the ceiling and a number of large stained glass windows. The seating is wooden pews with cushions. The measurements of the reverberation time of empty room show that the values across the frequency band are 1.6 seconds or less and the measured results are shown in Figure 2.

1.2. New Sanctuary

The proposed sanctuary, shown in Figure 3, will be a multipurpose space. The stage for the activities could vary depending on the program. For ease of analysis, two scenarios, chancel stage and the area along the west wall, are assumed for acoustic calculations. With an overall volume of 1390 m^3, the hall has a rectangular shape with a squared floor surface of 223 m^2 and a 6.2 m high ceiling. It will be able to accommodate up to 200 people in portable wooden chairs. The current building surfaces are painted concrete for the floor, drywall construction for the ceiling and walls with wooden doors and one window.

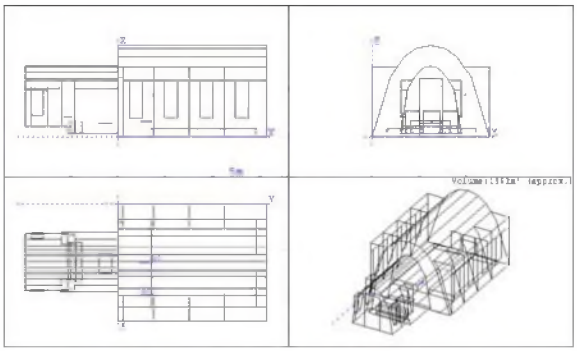

Figure 1. Details of the Existing Sanctuary.

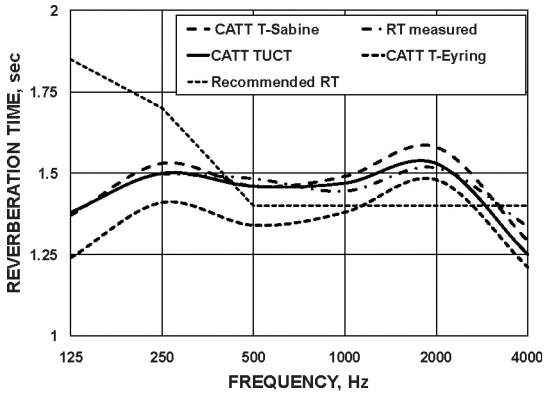

Figure 2. Reverberation Time in the Existing Sanctuary.

2. RESULTS AND DISCUSSION

2.1 Calibration Process

The process consists in an adjustment of the absorption and scatterings coefficients in order to match the simulated Reverberation time results to the measurements. The most adapted Scattering and absorption coefficients are chosen in the literature data for each existing material[4, 5, 6]. The CATT-ACOUSTIC Sabine and Eyring reverberation time predictions have been used in the calibration process but a

TUCT (The Universal Cone Tracer) module algorithm prediction have been launched at the end of the process to predict more accurately the simulation results.

Absorption coefficients values of "Unoccupied moderately upholstered chairs" at 1000, 2000 and 4000 Hz have been decreased to match with the characteristics of the empty wooden pews with thin cushion above a parquet floor[5]. The "Plasterboard ceiling on battens with large air-space above" absorption coefficient has been used for some parts of the ceiling and walls in order to take in consideration the absorption in low frequencies of ceiling mounted method[6]. Differences between measurements and simulated results at the 4 kHz values can be explained to be due to the importance of air absorption in this range of frequencies and the use CATT-Acoustic's pre-defined data.

2.2 Acoustical Simulations of the Proposed Sanctuary

CAD drawings and the interior surface materials of the proposed sanctuary, shown in Figure 3, were applied in the simulations by CATT-Acoustics. Appropriate absorption and scattering coefficient were assigned and reverberation time and STI simulations were carried out. Different scenarios were examined with the following audience parameters: empty, 100 people and 200 people. The main observation was that RT_{60} values of the sanctuary are high, especially with wooden chairs, for both speech and music. Speech and music will sound muddled and discoloured. It is clear, therefore, that the RT_{60} values must be reduced across the frequency bands. Different scenarios, such as reasonably upholstered chairs and adding absorbing panels, were attempted to reduce the RT_{60} values.

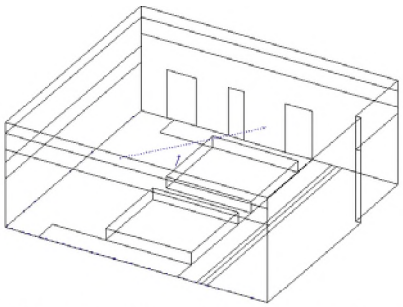

Figure 3. Interior View of the Proposed Sanctuary.

The acoustic panels were added along the long wall (East) in two different segments. The results of the simulation are shown in Figure 4.

Speech Transmission Index results were evaluated with a simple Yamaha speaker system with known characteristics. We assumed the speaker in the centre and the audience is distributed around the sanctuary. A slight global STI improvement due to the absorption has been noticed, as well as STI "fair" conditions. Improved STI in the range of fair to good are achieved with the use of two cluster of left-right speakers.

3. CONCLUSIONS

The proposed renovations of a United Church in Toronto were investigated as to their acoustic characteristics. Differences between the measured and the calculated data were found to be acceptable and hence validating the acoustical simulation method The bass absorption of the wall and ceiling plaster mounted technique, the absorption of carpeted floor and the diffusion due to the architectural details made the acoustics of the existing sanctuary more than satisfactory. Those acoustic characteristics have not been considered in the design of the new sanctuary. The lack of these aspects prevented the members of the church committee to have specific acoustics requirements and the architects to consider an acoustic design. The current simulations results were therefore provided the needed modifications of the sanctuary design.

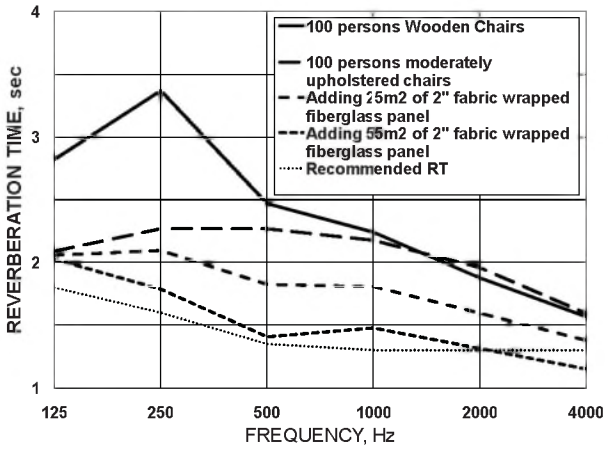

Figure 4. Reverberation Time in the Proposed Sanctuary.

The link between the acoustic corrections and the descriptors values can be studied and predicted even without measurements and calibration process. The main limitations of simulations that must be noted are: the lack of absorption and scattering coefficient data; and the bass frequencies prediction limitations caused by the range of prediction frequencies that are four times above Schröeder's frequency.

The main conclusion is that acoustical simulations with room acoustic software like CATT-ACOUSTICS are an effective tool to study and predict the acoustics of house of worship, where accurate prediction of reverberation times, STI evaluations and sound system studies can be performed.

4. REFERENCES

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