Acoustic effectiveness of pulpit reflector in churches

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Since the 12th century, pulpits and pulpit reflectors (canopies) were widely used in churches. This paper studies the acoustic effectiveness of such devices based on in site measurements (STI and D50) in four (unoccupied) churches with pulpits with and without the canopy. The pulpit reflector can remove the late reflection resulting from a high ceiling and makes possible to improve the listening conditions at medium distance from the pulpit. The pulpit reflector effectiveness decreases and becomes even unfavourable when the height of the ceiling drops ($h < 10$ m) and when the distance to the speaker increases. The absolute variations of speech intelligibility ratings are generally rather weak (average STI variation from +0.01 to -0.03), but can increase in the presence of an assembly.

INTRODUCTION

Since the 12th century, the use of pulpits, generally provided with a pulpit reflector (canopy) spreads in churches. A recent study \cite{1} showed that in Switzerland, about 76% of the churches still have pulpits and half of those are provided with a canopy. The use of the pulpits, which remains traditional for preaching in the Protestant churches, is now in disuse (about 32% of the Swiss pulpits are never used). This paper presents a study on the objective acoustic effectiveness of pulpits reflectors for the speech intelligibility ratings based on measurements in four standard churches.

METHOD

Two indices of objective evaluation of speech intelligibility (STI and D50) were calculated from the impulse response, established on the basis of two measuring devices (Symphony with dBBati32 of 01dB and MLSSA). The use of a MLS sequence makes it possible to reduce the duration of in site measurements and to provide instantaneously various evaluations of speech intelligibility ratings.

The measurements were carried out in unoccupied churches in two situations: initially, placing the sound source on the pulpit under its canopy at about 1.5 m (measurements named "with canopy"), then at the same height but on the side of the pulpit not to have the effect of its canopy (measurements named "without canopy"). Measurements were carried out in four churches in Lausanne (Switzerland) whose main room and pulpit characteristics are presented in tables 1 and 2. In each church four measuring points were studied (table 3).

RESULTS

The results obtained with 01 dB for speech intelligibility parameters, expressed by the STI and D50 with and without canopies, are presented in table 4. In the Cathedral (C) and in the church Allemande (A), that have a high ceiling, there is a beneficial effect of the canopy at medium distances (position 2). For the positions at long distance (positions 3 and 4) there is a slight deterioration. At short distances of the sound source (position 1) the speech intelligibility parameters are little influenced (C) or slightly underprivileged (A) by the presence of the canopy.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Church & Symbol & Volume \textsuperscript{m$^3$} & Nave high \textsuperscript{m} & Area \textsuperscript{m$^2$} & RT avr. \textsuperscript{s} \\
\hline
Cathedral & C & 35000 & 20.0 & 2400 & 6.5 \\
Allemande & A & 1680 & 11.5 & - & 3.0 \\
Terreaux & T & 3600 & 9.5 & 380 & 2.4 \\
St. Laurent & SL & 3150 & 10.5 & 300 & 2.5 \\
\hline
\end{tabular}
\caption{Main characteristics of the churches studied.}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
Church & Symbol & Pulpit Position & Pulpit high \textsuperscript{m} & Canopy height \textsuperscript{m} & Canopy width \textsuperscript{m} & Canopy length \textsuperscript{m} \\
\hline
C & lateral nave & 1.83 & 2.44 & 2.00 & 1.45 \\
A & lateral choir & 1.42 & 2.75 & 1.75 & 1.75 \\
T & central choir & 2.09 & 2.06 & 1.50 & 1.90 \\
SL & central choir & 2.15 & 2.00 & 1.00 & 1.00 \\
\hline
\end{tabular}
\caption{Pulpit and canopy main characteristics (m).}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|}
\hline
Church & Symbol & Position & Distance to source \textsuperscript{m} \\
\hline
C & 4.0 & 8.2 & 10.1 & 15.5 \\
A & 3.2 & 8.6 & 7.8 & 12.5 \\
T & 4.5 & 10.0 & 15.0 & 18.0 \\
SL & 4.4 & 4.8 & 8.2 & 10.1 \\
\hline
\end{tabular}
\caption{Measuring points - distance to sound source.}
\end{table}
This last case can be explained by the displacement of the sound source for the measurement "without canopy" (increase in the distance source/receptor).

On contrary in the Terreaux and St. Laurent churches, that have a lower ceiling (h < 10 m), the presence of the canopy deteriorates the speech intelligibility parameters at short and medium distances of the sound source. In these cases, the sound reflection from the ceiling is useful for the speech intelligibility (delay with direct sound lower than 35 ms). The positions located at medium distances or apart from the pulpit axis, are those that present the most significant loss of speech intelligibility because they do not profit any more from a ceiling reflection neither benefiting from those from the canopy. Such churches do not benefit by the presence of a canopy.

Table 4: STI and D50 values measured with and without canopy (%).

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<tr>
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<tbody>
<tr>
<td>with canopy</td>
<td>1</td>
<td>58</td>
<td>43</td>
<td>29</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>55</td>
<td>49</td>
<td>33</td>
<td>51</td>
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<td></td>
<td>3</td>
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<td>26</td>
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<td></td>
<td>4</td>
<td>38</td>
<td>19</td>
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<td>27</td>
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<tr>
<td>avg.</td>
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<td>37</td>
<td>46</td>
<td>28</td>
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<td>without canopy</td>
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<td></td>
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<td>avg.</td>
<td>48</td>
<td>35</td>
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<td>52</td>
</tr>
</tbody>
</table>

CONCLUSION

Based on in site measurements in four churches, we can separate the churches according to their ceiling height (h ≥ 10 m as in the cathedral of Lausanne and the Allemande church or h < 10 m as in the Terreaux and St. Laurent churches). When the height of the ceiling and the size of the canopy are significant, a beneficial effect of this one is noted, mainly for the listeners located at medium distances from the pulpit. On the other hand, the effect of the canopy is almost non-existent at long distances. For short distances from the pulpit, a weak effect is noted that can be explained by a modification of the distance source-receiver. For churches with lower ceilings (< 10 m), an unfavourable effect of the canopy is noted at short and medium distances. In this case the presence of a canopy removes the early reflections from the ceiling church that are favourable for the listener. The presence of a canopy is thus not favourable in a low ceiling church, but it is interesting at medium distances in the higher ceiling churches. Whatever the ceiling height, the canopy does not have an effect at long distances.

REFERENCES