



Acoustic evaluation of a contemporary church based on *in situ* measurements of reverberation time, definition, and computer-predicted speech transmission index

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ABSTRACT

An acoustic survey was conducted in a church with a modern architectural style in Curitiba, southern Brazil. The investigation used acoustic measurement methods to assess the acoustic quality of the nave and the results were compared with the NBR 12179 Brazilian National Standard, ISO 3382-1 international standard and IEC 60268-16 Standard. Integrated impulse responses were measured to determine two acoustic objective parameters: (1) Reverberation Time (RT), (2) Definition (D_{50}) according to the international ISO/3382 and ISO/3382-1 standards. The Speech Transmission Index (STI) inside the church was calculated by computer simulation. The measured and calculated values were consistent with those proposed by the standards for speech auditoria ($RT_{500\text{Hz}} = 1.18\text{ s}$, $D_{50} > 50\%$ and $STI > 0.45$), and are in line with the music and speech intelligibility requirements resulting from the Second Ecumenical Council of the Vatican in 1965, whose liturgical reforms involved the adoption of vernacular languages in place of Latin for religious service.

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1. Introduction

Churches have a unique architectural style and are of great social importance in city life. They are built with a very specific objective, namely, to serve as places of worship. Acoustically, churches have a complex mission. Their spaces must meet the requirements of both speech and music, which often seem incompatible.

Acoustics in religious buildings have been the focus of research groups in Portugal [1], Spain [2,3], Switzerland [4] and Italy [5–11]. Brazil's sacred architecture has also been the object of investigations [12–15].

These studies emphasize old buildings or buildings of great historical interest. Evaluations of this type of building assume the nature of a kind of acoustic archeology, and are a laudable effort to fill a gap in the scientific information about a type of room that has existed for centuries. The amount of available information on church acoustics is immeasurably less than that of concert halls. Even less data is available for research when it comes to contemporary Brazilian religious architecture.

The paucity of data on the acoustics of these buildings can be attributed, in part, to the lack of a complementary architectural

acoustics design or the misplaced belief in the unlimited possibilities of sound field correction through the adoption of reinforcement electro-acoustic systems. *In situ* evaluations and computational predictions of this type of space provide important information for the architectural production of ever more acoustically adequate spaces.

From the standpoint of church acoustics, the liturgical reforms introduced by the Second Ecumenical Council of the Vatican in 1965, involving the adoption of vernacular languages in place of Latin, meant a higher requirement for good speech intelligibility. Catholic churches call to mind highly reverberant spaces. It can be safely stated that modern church acoustics must be strongly inclined to meet the requirements of speech and that these acoustic requirements are not compatible with high reverberations.

In the present study, the Church of São Carlos Borromeu, a building with modern architecture in the city of Curitiba, was the object of an *in situ* acoustic survey and computer simulation to evaluate its acoustic quality with regard to speech intelligibility. The collection of data and computer simulations followed the recommendations of the international standards ISO 3382 [16] and 3382-1 [17]. The field measurements provided, among other data, information about the reverberation time (RT) and speech clarity (Definition, D_{50}) while the computer simulations served to evaluate the Speech Transmission Index (STI). The field investigation concentrated on the characteristics inherent to the interior of the

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