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ACOUSTIC DESIGN OF A CHURCH OF OUR LADY OF FATIMA IN POLAND

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ABSTRACT*

Most modern Catholic churches are designed without acoustic solutions, and good acoustics are often a matter of chance. Therefore, it is essential to address the subject of architectural acoustics of religious buildings. The paper presents the acoustic design of the Church of Our Lady of Fatima in Koziegłowy, which has a volume of 8,000 m³ and was inaugurated in 2022. The entire design process aimed at achieving optimal acoustic conditions was presented. Acoustic investigations in the interior were carried out during different stages of work. It is visible how the church's acoustics changed at each stage of construction, up to the final stage, where acoustic parameters were obtained following the recommendations. Acoustic parameters assessed include Reverberation Time (RT), Early Decay Time (EDT), Clarity (C80) and (C50), Definition (D50) and Speech Transmission Index (STI). Additionally, the acoustic properties of the church were compared with other churches of similar volume built in the last twenty years.

Keywords: *church acoustics*, *reverberance, contemporary church*

1. INTRODUCTION

The main problem that occurs in many Catholic churches is excessive reverberation, resulting in reverberant noise in the interior [1-4]. Among the works on church acoustics, many publications have been devoted specifically to contemporary Catholic churches, where most acoustic problems are related to excessive reverberation. Churches in Poland have been studied and acoustic corrections for problematic solutions have been proposed [5]. Excessively long reverberation time is typical in contemporary Catholic churches. Thus, the acoustic design of a church should be anticipated from the concept phase of its architectural design. This is the optimal situation as it allows the acoustic designer the freedom to realise the best possible acoustic concept for the interior.

Churches with reverberant noise were investigated, and then acoustic corrections were proposed. In the example of St. Paul's Church in Bochnia, the problem of reverberant noise was addressed and, based on measurements and acoustic simulations, a correction was proposed [6]. In the church of Santa Ana in Moratalaz in Madrid, a study was carried out and an acoustic correction was proposed to reduce the excessive reverberation time [7]. On the other hand, for the church of Maria Regina Della Pace in Perugia, built in 1993, where the RT reverberation time was 4.4 s, an acoustic correction was proposed based on simulations carried out in RAMSETE [8].

In the case of acoustic design, the proposed solutions need to be consistent with the interior design so that, visually, the adopted solutions are not perceptible as acoustic corrections but complement the designed architecture. Adding sound-absorbing materials as elements without stylistic relation to the designed interior is unacceptable. Unfortunately, visually disadvantageous solutions are used to improve the acoustic properties of a room.

This paper presents the results of the acoustic design process for a Catholic church, which began with the building's shell.

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2. STAGES OF WORK

The acoustic design of the Church of Our Lady of Fatima in Koziegłowy, which has a volume of 8,000 m³ and was inaugurated in 2022, was undertaken. Acoustic investigations inside the church were conducted at various stages of the design process. The changes in the church's acoustics at each stage are evident, culminating in the final stage, where the acoustic parameters met the recommended standards. Research was carried out during three main stages;

- first stage - church in raw state finished with brick lattice, reinforced concrete roofing, screed concrete floor, windows and no furnishings (Fig.1),
- second stage - walls covered with plaster, other elements as in the first stage (Fig.2),
- final stage - acoustic plaster in parts of the walls and choir banister, stretched ceiling, granite slabs, church fully equipped (Fig. 3).

It was imperative to do research before applying plaster to the lattice bricks from which the church is built. This is a building material often used in church buildings. Due to its structure, it has relatively good sound-absorbing properties. Many investors and architects give up on acoustic solutions, impressed by the good acoustics of the church in its raw state. However, once the plaster is applied, the acoustics deteriorate dramatically, causing annoying reverberation noise. Implementing acoustic solutions when the church has a finished interior can be a significant challenge and is very expensive.

The primary acoustic solution of choice is a stretch ceiling and acoustic plaster. Most often in public buildings, when a stretch ceiling system is chosen and a reduction in reverberation is required, perforated membranes are used. Depending on the system, either the perforated membrane is used, offset from the ceiling by a few centimetres, or a thin layer of mineral wool is added between the ceiling and the membrane. Two layers of perforated membrane with an air void between the layers are also used. The price of the perforated membrane is significantly higher than the non-perforated stretch ceiling membrane. In this case, a non-perforated membrane was used, and mineral wool was increased to 30 centimeters. The assumed thickness of the mineral wool layer is considerably greater than that in typical stretch ceiling acoustic systems, which usually range from 4 to 10 cm. This solution resulted in excellent sound absorption properties of the system. Additionally, a mineral wool-based plaster with a high sound absorption coefficient was applied on parts of the side walls, the balcony balustrade, and the upper parts of the rear wall as an extra acoustic solution.

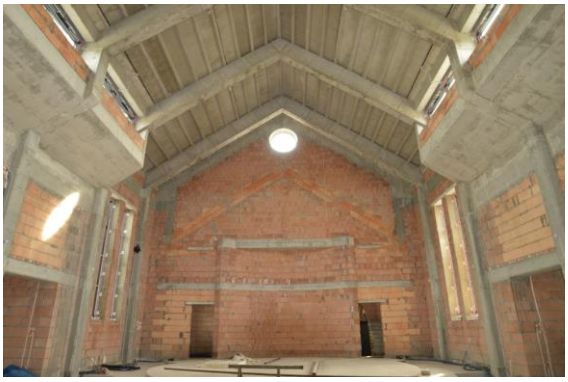

Figure 1. Church interior – first stage, view towards presbytery

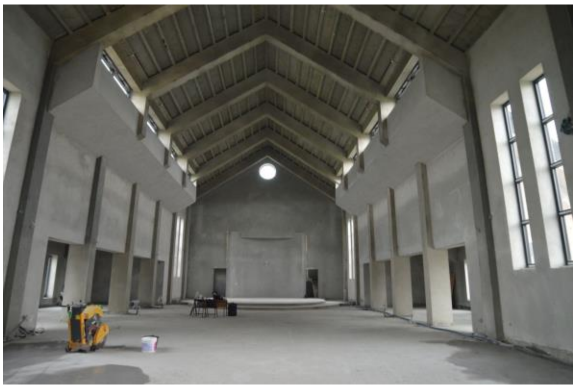

Figure 2. Church interior – second stage, view towards presbytery

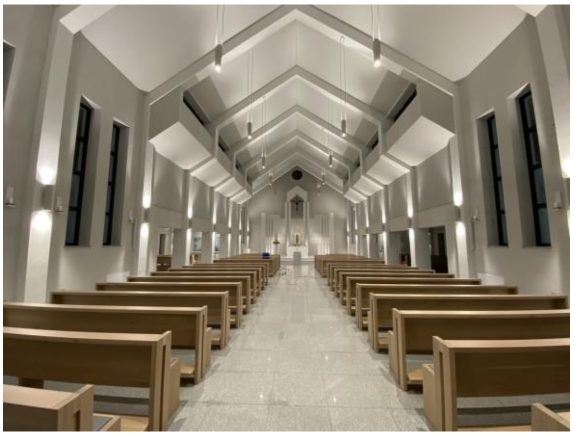

Figure 3. Church interior – final stage, view towards presbytery

3. DISCUSSION

Table 1 summarizes the results of acoustic measurements. Acoustic tests were conducted using an omnidirectional sound source, the DIRAC programme, and a Brüel & Kjær ZE-0948 USB sound card. A gunshot was used as the sound source, and the parameters crucial for assessing the acoustic properties of a sacred interior, as identified in the literature, were measured: RT, EDT, C80, C50, D50, and STI. All investigations were conducted in the absence of people. The values given in Table 1 refer to the measuring point in the central part of the church.

Table 1. Summary of acoustic parameters tested in the interior

Parameters	First stage	Second stage	Final stage
RT [s]	3.1	6.3	1.7
$RT_{500-1000}$ [s]	3.4	7.3	1.6
EDT [s]	3.2	6.2	1.5
C80 [dB]	-7.7	-8.8	-1.9
C50 [dB]	-2.8	-2,127	-1.9
D50	0.125	0.068	0.3
STI female	0.32	0.28	0.44
STI male	0.31	0.26	0.44

It is visible that at the final stage, the achieved parameters of reverberation time RT are satisfactory. The other parameters also achieve good results. The author analyzed 23 contemporary church interiors in Poznań and its vicinity [4]. Most examined churches do not have acceptable reverberation time. The acoustics of the Polish churches built between the 1970s and 1990s were not explicitly designed. Only two surveyed churches, built after 2000, used acoustic solutions as a stretched ceiling. Regarding reverberation time RT results, the designed church has a reverberation time comparable to those of these two churches.

4. CONCLUSION

Designing the acoustics of a church to suit both speech and music is challenging. It requires balancing the differing acoustic needs of each. The presented church project achieved the expected reverberation time parameters. Users perceive the acoustics as very good.

5. ACKNOWLEDGMENTS

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