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THE NEW MEGACHURCH FOR THE SANCTUARY OF FÁTIMA

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Abstract
The Sanctuary of Fátima (Portugal) is a world known Catholic pilgrimage center since 1917 when Holy Mary appeared to three children. The project for the 9,000-seat church of the Most Holy Trinity is in its final stage designed by the Greek architect A. Tombazis. This mega church will have a volume of about 130,000 m^3 and an average height of 15 m with two modes of use configurations (3,000 and 9,000 seats). Its seating capacity will make it the largest church in Portugal and one of the largest Roman Catholic churches in the world. This religious complex will also house four smaller churches and the construction will end on 2005. This paper presents and discusses the acoustical requirements set by the Owner's acoustical consultant as well as the main design considerations regarding Reverberation Time, RASTI, background noise, etc.

INTRODUCTION

The Sanctuary of Fátima (a 8,000 inhabitants town in the center of Portugal, about 120 km northeast of Lisbon, Fig. 1) is a world known Catholic pilgrimage center since 1917 when Holy Mary appeared several times to three children shepherds (Fig. 2). Since that revelation, millions of the faithful have made pilgrimages to the site where Our Lady of Fátima, appeared. It is now one of the greatest Marian shrines in the world. The Roman Catholic Church recognized the Fátima events as worthy of belief in 1930. The process of beatification of the Seers of Fátima was opened in 1952 and concluded in 1979. On 1988, the final documentation was given to the Holy Father, John Paul II, and the Congregation for the Causes of Saints. Meanwhile, they were declared "venerable" by a Decree of that Sacred Congregation on 1989. On 2000 John Paul II in his trip to Fátima beatified the two "little shepherds". During the beatification ceremony for Francisco and Jacinta the pope publicly credited Our Lady

of Fátima for saving his life (in the 1981 assassination attempt in Rome). The last step will be their canonization, by which they will be declared "saints".

Every year about four million persons visit Fátima and on the 13th of the months of May to October, there are international pilgrimages that can attract up to one million persons to the sanctuary (Fig. 3). The church that now dominates the pilgrimage arena (built in 1953) holds only a few hundred persons and is not suited for the majority of services that the Sanctuary needs to perform (about 2,500 masses and 5,800 other services a year [1]). Therefore a new much larger church is needed.

Fig. 1 (left) - Map of Portugal with the location of Fátima.
Fig. 2 (right) - The three seers of Fátima in 1917 [1].

Fig. 3 - A typical May 13th pilgrimage in Fátima [1].

THE NEW CHURCH

The project for the 9000-seat church of the Most Holy Trinity is in its final stage designed a team headed by the Greek architect Alexandros N. Tombazis (Fig. 4 to 6). This mega church will have a volume of about 130,000 m^3 and an average height of 15 m with two modes of use configurations (3,000 and 9,000 seats). Its seating capacity will make it the largest church in Portugal and one of the largest Roman Catholic churches in the world. This religious complex will also house four smaller churches and the construction will begin on October 2003 and will end on 2005.

The main dimensions of the church's interior are (approximated values):

- Surface area - 8,700 m^2;
- Volume - 130,000 m^3;
- Maximum height - 20 m;
- Average height - 15 m;
- Minimum height - 9 m;
- Maximum length - 95 m;
- Average length - 85 m;
- Maximum width - 115 m;
- Average width - 105 m.

The main characteristics of the church's interior are:

- Very large glassed ceiling area (with a shed-form shielded underneath with transparent screens that allow the light to enter the nave but been acoustically transparent to let the sound waves to reach the absorptive material on some parts of the ceiling) - Fig. 5;
- The almost circular shape is acoustically "destroyed" by the lateral walls (partly absorptive) - Fig. 6;
- The two modes for the church congregation area (3,000 and 9,000 persons) are achieved by using a movable wall that rises mechanically from the pavement (where it is "stored").

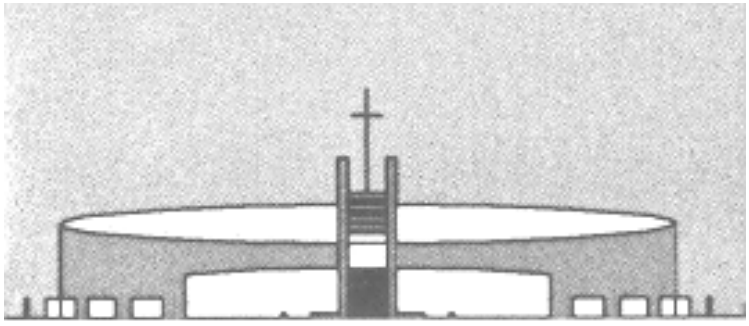

Fig. 4 - Frontal view of the new church of Fátima [2].

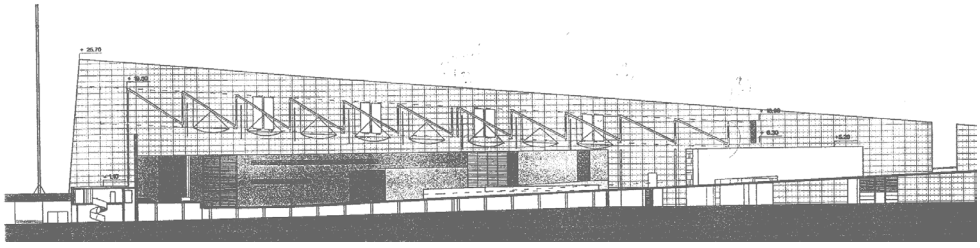

Fig. 5 - Interior longitudinal section of the new church of Fátima [2].

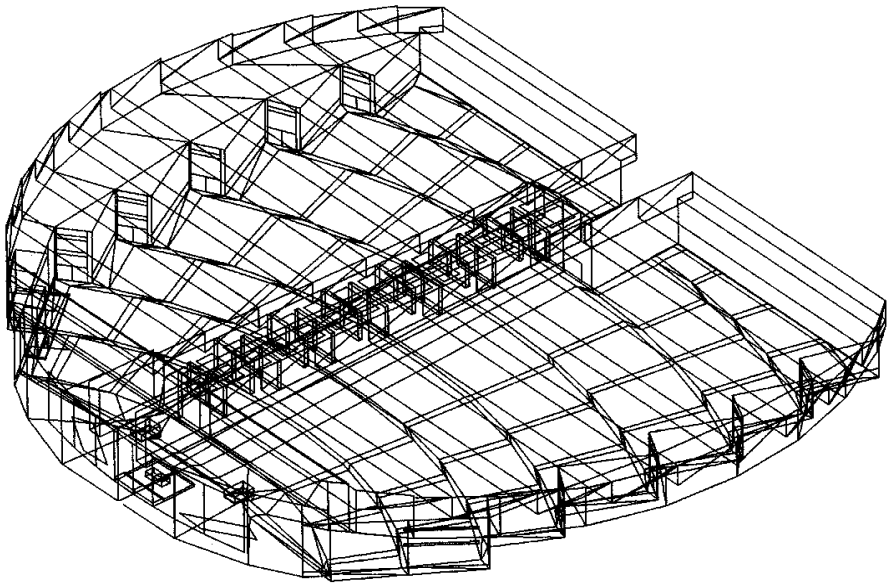

Fig. 6 - Axonometric view (interior plan) of the new church of Fátima.

Table 1 - Sample of large churches worldwide with mean reverberation times (*RT*) at 500/1000 Hz, unoccupied.

Church name, year [if 20th/21st cent.]	Town	Country	Seats	Volume (m^3)	RT (s)
St. Peter Basilica	Rome	Vatican	-	700,000	7.0
The Church of Jesus Christ of Latter-Day Saints, 2000	Salt Lake City	USA	21,000	226,000	2.0
St. Paul Outside the Walls	Rome	Italy	-	181,000	8.6
St. Paul's Cathedral	London	UK	-	152,000	10.7
St. John in Laterano	Rome	Italy	-	150,000	6.2
Klosterkirche	Ottobeuren	Germany		130,000	6.5
Most Holy Trinity, 2005	*Fátima*	*Portugal*	*9,000*	*130,000*	*(2.1)*
First Baptist Church, 1985	Orlando, FL	USA	6,000	115,000	2.9
Monastery	Santo Domingo de Silos	Spain	-	113,000	6.5
Marien church	Lubeck	Germany	-	100,000	5.5
Basilica Mariacka	Gdansk	Poland	-	97,000	11.4
Cathedral	Dresden	Germany	-	50,000	7.9
Munster	Weingarten	Germany	-	44,000	6.7
Assembly of God, 1985	Auckland	New Zealand	4,000	31,000	2.1

ACOUSTICAL REQUIREMENTS

Comparable churches in the world

The table 1 shows a comparative analysis of several large churches in the world with their volumes and *RT* mean values. As seen in that table, the new Fatima church stands as very typical regarding its Volume and desired *RT*. Its interior acoustic condition will be very distinct from almost all comparable size churches except for the ones built in the last 20 years, where acoustic requirements where also set.

The table 1 shows only the *RT* mean values because it is one of the most reliable indicators of a room's overall acoustic behavior. Other parameters can also be very important in a specific analysis of the acoustics of this room.

Limit values

The primary acoustic concern for this church is speech intelligibility but without putting in risk the minimum acoustical requirements concerning the music to support the religious services.

Table 2 - Limit conditions for the acoustical requirements (*RT* and *NC*) set by the Owner.

PARAMETERS	OBJECTIVES OF PROJECT [Ideal goals]	ACCEPTABLE LIMIT CONDITIONS
Main church (9,000 seats mode)		
RT 100% occupied (500-1k Hz)	≤ 1.6 s	≤ 2.0 s
100% occupied (250 Hz)	≤ 2.4 s	≤ 2.8 s
RT unoccupied (500-1k Hz)	≤ 2.1 s	≤ 2.6 s
unoccupied (250 Hz)	≤ 2.8 s	≤ 3.4 s
NC	≤ 25 dB	≤ 30 dB [1]
Main church (3,000 seats mode)		
RT 100% occupied (500-1k Hz)	≤ 1.5 s	≤ 2.0 s
100% occupied (250 Hz)	≤ 2.4 s	≤ 2.7 s
RT unoccupied (500-1k Hz)	≤ 2.0 s	≤ 2.6 s
unoccupied (250 Hz)	≤ 2.8 s	≤ 3.1 s
NC	≤ 20 dB	≤ 30 dB [1]

1 - at least on 95% of the seats

It was decided by the Owner that this church would not be acoustically designed mainly to music concerts or other type of public performances. For these reasons the limit on the reverberation time value was set on the 1.6 s. This value is supported by a large research program headed since 1991 by the Laboratory of

Acoustics of the University of Porto Faculty of Engineering (see http://www.fe.up.pt/~carvalho/igrejase.htm). It is a reasonable compromise (for such a large volume) for speech intelligibility and congregational singing.

The table 2 shows the numerical main acoustical requirements with two sets of values: objectives of project (design ideal goals), and acceptable limit conditions (refusal threshold).

Interior Noise

The requirement for background noise within the main church was set to a maximum *NC* of 25 (30 as the refusal limit) because this space can be used mainly for individual prayer where concentration and silence is necessary.

The step noise made by the pilgrims is also a concern in this church and specific care is taken to control this problem mainly related to the floor covering.

Electroacoustics and multimedia

Due to the large average distances of the audience to the presbytery and the shape of the hall, the electroacoustic sound reinforcement (PA) system design is very demanding. Nonetheless, taking speech intelligibility as the primer concern, a lowest *RASTI* limit value of 0.45 for at least 95% of the seats and a design goal value of at least 0.50 were fixed. Having in mind the intrinsic difficulty of achieving spatial uniformity of sound field in terms of sound pressure level at all frequencies and in terms of *STI*, the interest of these limit values, however, will concern a reduced percentage of seats. In most of the other seats, a good uniformity will be achieved.

The adopted criteria for the allowed variation range of sound pressure level in the hall were therefore organized in two categories. The first category is an average criterion for a wider frequency band, of interest to speech and religious music (45-11,200 Hz), limiting the maximum deviation of the average value amongst any two seats in the hall to a demanding design goal of 4 dB (limit of 6 dB).

As this frequency average constraint does not ensure a limit to the spot frequency deviations, not eliminating the risk of appearance of localized effects causing out-of-range sound pressure level values, and taking into account that these phenomena, would be harmful mainly to speech intelligibility, a second category of constraints was introduced, this time in reduced bandwidth, all over a speech centered frequency range. The second category is a criterion of peak deviation of not more than 6 dB (limit of 8 dB) between sound pressure level values in 1/3 octave bands, also taken amongst any two seats in the hall (in the frequency range of 141-5,620 Hz). Table 3 summarizes the aforementioned basic electroacoustic criteria.

The inter-relationship between the acoustical and the electroacoustical designs is very strong in every hall. In present-day technology, some solutions for the sound reinforcement problem exist that in a way allow alleviating the constraints and partially decouple the design tasks. An interesting example is the use of loudspeaker arrays powered by digital signal processing (DSP) beamforming systems. With such types of systems it becomes more feasible to acoustically cover, not only the most

distant locals but also some troublesome ones in the assembly, in better conditions of ratio of direct to reflected sound, therefore allowing better intelligibility values. In the present project the design team adopted this approach as the technical solution.

One practical limitation of loudspeaker arrays is the limited bandwidth, especially at low frequencies. Although this doesn't pose problems in speech transmission, for music it is not enough if the reproduction of orchestral material at realistic levels is desired. The basic system will therefore be complemented with additional devices for the purpose of eventual transmission of music. Taking in account the specified values of *RT*, the need for artificial reverberation during music transmission will be satisfied through adequate digital signal processing of the program material.

Another technological aspect considered for the design is the virtual system concept for the architecture of the electroacoustical system. The system will be based on computers with virtual interface software and interface devices controlling the whole multimedia system. The technical regie (control room) will allow full facilities for coverage of events by the media.

Image and film projection integrated with the sound system is another valence of the hall equipment. Multilingual sub-titling and text projection of the contents of speech or other materials is an important resource for the international pilgrims' comfort and an invaluable aid for those that are elder and, or, suffer from disabilities of hearing or understanding nature. For those attendees that are hearing-aid users an Assistive Listening System will be provided.

Table 3 - Limit conditions for the electroacoustical requirements set by the Owner for the main church (9,000 and 3,000 seats mode).

PARAMETERS	OBJECTIVES OF PROJECT [Ideal goals]	ACCEPTABLE LIMIT CONDITIONS
RASTI [1]	≥ 0.50	≥ 0.45 [2]
ΔL mean spectral (45-11,200 Hz) [1] (between any two seats in the congregation area)	≤ 4 dB	≤ 6 dB
ΔL maximum at 1/3 octave band (141-5,620 Hz) [1] (between any two seats in the congregation area)	≤ 6 dB	≤ 8 dB

1 - PA system; 2 - at least on 95% of the seats

Exterior Noise

One of the major acoustic concerns was the exterior environment noise that could penetrate into the church especially because a large glass ceiling area will be used. To check that problem measurements were held in the surrounding area where the church will be built in several typical conditions of use. The measured results of the environment noise levels are shown in table 4. These results were used to design the type of windows and glass to use in the shed-form ceiling area.

Table 4 - Exterior environment noise.

TIME PERIOD	L_{A95} (dB)	L_{Aeq} (dB)	L_{A05} (dB)
- NIGHT TIME CONDITIONS:			
standard surrounding environment	37	40	44
during main celebration in the pilgrimage area[1]	69	80	83
- DAYTIME CONDITIONS:			
standard surrounding environment	43	49	55
during main celebration in the pilgrimage area	72	77	84
with chants/organ music in the pilgrimage area	81	85	86
church bells	66	68	69

1 only present six times per year

Objective acoustical parameters predicted values

In the final stage of the design project, the range of predicted values for the objective acoustic parameters not listed in table 1 are shown in table 5 for several occupancy rates. These already show that the interior conditions will be suited for the main objective of the building: speech and religious services.

Table 5 - Predicted values (several rates of occupancy) for some objective acoustic parameters.

OBJECTIVE ACOUSTIC PARAMETER	RANGE OF PREDICTED VALUES
Center Time (*TS*)	100 to 120 ms
Definition (D_{50})	0.5 to 0.6
Clarity (C_{80})	+1 to +4 dB
Strength (G)	-5 to -10 dB

SUMMARY

The new 9,000 seats church of Fátima to be finished in 2005 will be the first mega church in Portugal and its acoustical requirements are very stiff concerning speech intelligibility without loosing grip to the minimum acoustical necessities for music to support the religious services. A 1.6 s maximum *RT* ideal value was set (occupied). So far, the acoustical design anticipates the fulfillment of all the main requirements.

REFERENCES

[1] http://www.santuario-fatima.pt/ [Accessed March 2003].

[2] Meletikiki - Alexandros N. Tombazis and Associates Architects Lda, design projects documents, Polydroso, Greece, 2000.