Engineer & Arquitecture La Salle
Arquitectural and Environmental Acoustics Master

Portuguese Theatres and Concert Halls Acoustics

Music and Acoustics

Francisco Santiago
Barcelona, 15th March of 2007

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Índex

Introdution

In the scope of the Tesis in the Architectural and Environmental Acoustics Master, of the Ramon Llull University - Engineer & Arquitectural La Salle, it was proposed the realization of a final work to develop a certain theme. Of the given proposal, I chose the theme about Architectural Acoustics, namely Portuguese Theatres and Concert Halls Acoustics.

The work consists, mainly, in describing the characteristics of these Theatres and Concerts Hall, all placed in Portugal, geographicaly separated with a fair occupation tax during the open seasons.

The first part of the paper is about the definitions of sound propagation in free field and in enclosure room, where properties like reflaction, difraction, absorption and difusion are describe. A brief description of Subjective and Objective Quality Acoustic Factors are given with their respectively mathematical equations, where its made a correlation between subjective definition with their physical characteristics that affects the defined acoustical parameters.

One second part is about the relation that should exist between the type of Hall and optim values and the objective acoustic parameters measured. It is shown a supose Merit Factor for each parameter and for different purposes for each hall. After it is describe the process and the equipment of measurements.

There is also presented some characteristics of hall elements that can influence the sound propagation and of course the qualitity of the hall acoustics, like as, the Acoustic Seating Area, Balconies, Chair Absorption and Orchestra Pits.

Before describing the acoustics measurements and present each Concert Hall/Theatre characteristics, it is describe a short Portuguese Theatres History with the first Roman Theatre established in Lisbon dated of the Ist Century D.C..

The last part describes the Theatres and the Concert hall it self: it is presented a brief history of the room, an architectural Plant and Cut, some fotographs of the Hall and its technical data details as the volume, audience and stage superficies, height, length, width and number of seats, among others. In the final part of each Theatre and Concert Hall it is presented the results of the measurements where is shown th TR60, EDT, C80, D50, G and STI.

To carry out this paper some research, that I consider necessary to this type of theme, had been done and is cited on the bibliography, namely from books of Acoustics and Architectural Acoustics, as well as in Internet sites. Books like BARRON, M., "*Auditoriun Acostics and Architectural Design*", London, y & FN Spon, 1993; ARAU, H., "*ABC de la Acústica Arquitectónica*", CEAC, Barcelona, 1999 and BERANEK, L., "*Concert and Opera Halls: How they sound*", Nova York, Acoustical Society of America, 1996 were extremely important to develop this work.

However, there was also another type of research related to the experiences and studies that were made in a recent past. From the last 30 years that Room Acoustic has been studied with special attention. Papers like "*Influence of reverberation room volume on measured absorption coefficients*" (A.C.C. Warnock; Ontario - Canada) in 1983 and "*Acoustical evaluation of halls for the performing arts using acoustical model*" (Kinsey and Siebein; Florida - EUA) and "*New room acoustics measurement software*" (Bradley and Halliwell; Ontario - Canada) in 1996 were important development items in this area.

In the decade of 1990 more progress had been developed in the Room Acoustics discipline: "*Ten years of newer auditorium acoustics measurements*" (Bradley; Ontario - Canada); "*Auditorium acoustics: What should we measure? What do we measure and what does it mean*?" (Vian and Pelorson; St. Martin d´Hères - France), "*Measurement of impulse response and its applications in room acoustics*" (Yano and Hidaka; Tokyo - Japan), "*Subjective and Objective evaluations of rooms for music*" (Cervone, Chiang and Siebein; Florida - USA) were papers that tried to conclude about acoustical criterias, subjective and objective parameters correlation and room measurements experiences (like type of source, receiver and processing that is used in room acoustic meaurements). The Impulse Response and the FFT analysis turned into one of the most important factors on room acoustics and its research.

In 1996 and 1998 two important studies were carried on, respectively, by Bradley with "*Comparisons of room acoustics measurements systems*", where were 23 different measurement systems were compared and Hidaka and Beranek with "*Objective and Subjective measurements of 15 opera houses in Europe and the USA*", where acoustical parameters were executed, under unoccupied conditions, like as, RT, EDT, C_{80}, D_{50} and G, common attributes needed for concert hall evaluation.

More recently, in 2004, some research was going on based on methods to quatify Opera houses and Concert hall acoustics: 1) Basic studies like "*Acoustical measurements of sound fields between the stage and the orchestra pit*" by Prodi (Ferrara – Italy) and Sakai (Kobe - Japan) and 2) Measurements, simulations and auralizations like "*An experimental comparative study of 20 Italian opera houses: Measurements techniques*" by A. Farina, Armelloni and Martignon (Parma – Italy) where it is focused mainly the development and specification of the measurements technique, describing the hardware equipment, the software, the electro-acoustic transducers (microphones and loudspeakers), measurements positions and the conditions of the room during the measurements.

Without the support of many persons this work was not possible. Among them I owe my deepest thanks to Sónia Raposo Santiago, my wife, for her pacience and help on critical moments, Octavio Inácio and Ivana Russel for their supervision on Work and dedicated time, my family for supporting me, João Valente (for his AUTOCAD help) and Catarina Duarte (for her supervision in English texts).

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1. Concert Hall Acoustics

In the broader sense, acoustics is the physics of sound, treated in all of its aspects. Up until the early 20th century, 'sound' and 'acoustics' referred to elastic vibrations and waves in the audible human range, but today, there are large fields of acoustics dealing with vibrations and waves not associated directly or indirectly with the hearing process, and often with frequencies and intensities above and below the human audible limits.

Architectural acoustics refers to the study and design of sound transmission in enclosed spaces. The acoustics of a room are its qualities related to sound transmission and reception.

Sound is a sequence of waves of pressure which propagates through compressible media such as air or water. (Sound can propagate through solids as well, but there are additional modes of propagation). During their propagation, waves can be reflected, refracted, or attentuated by the medium. The purpose of this experiment is to examine what effect the characteristics of the medium have on sound. [13]
All media have three properties which affect the behavior of sound propagation:

1. A relationship between density and pressure. This relationship, affected by temperature, determines the speed of sound within the medium.

2. The motion of the medium itself, e.g., wind. Independent of the motion of sound through the medium, if the medium is moving, the sound is further transported.

3. The viscosity of the medium. This determines the rate at which sound is attenuated. For many media, such as air or water, attenuation due to viscosity is negligible [21].

Sound behaviour characteristics:

- **Reflection**: If a sound is not absorbed or transmitted when it strikes a surface, it will be reflected. The law for reflection is the same as that for light, i.e. the angle of incidence of a sound wave equals the angle of reflection, just as if it were produced by a 'mirror image' of the stimulus on the opposite side of the surface. However, this law of reflection holds only when the wavelenght of the sound is small compared to the dimensions of the reflecting surface.
- **Diffraction**: The phenomenon in sound propagation whereby a sound wave moves around an object whose dimensions are smaller than or about equal to the wavelenght of the sound. When the wavelength is similar to the dimensions of the object, as with low frequencies and buildings, or mid-range frequencies and the head, the wave diffracts around the object, using its edges as a focal point from which to generate a new wavefront of the same frequency but reduced intensity.
- **Absorption**: The loss or dissipation of sound energy in passing through a material or on striking a surface, usually through conversion to heat energy.
- **Diffusion**: The comparative distribution of sound pressure variations throughout a given space, or the process by which a sound wave is distributed in the space. If sound pressure is uniformly distributed throughout the space, the sound is said to be well diffused. Good diffusion can be achieved by several methods of architectural design.
- **Reffraction**: The speed of sound in air is affected by the temperature of the medium, the wave moving faster at higher temperatures and slower at cool temperatures. When parts of a sound wave are in layers of a medium at different temperatures, and therefore are travelling at different velocities, the direction of propagation of the wave changes. This effect is called refraction [13].

In a room, there are a very large number of possible paths from the source to the receiver, involving various reflections off the room boundaries; the combination of all these paths determines how sound behaves in the room. As a result, sound levels in a room do not continue to decrease with increasing distance from the source for all distances.

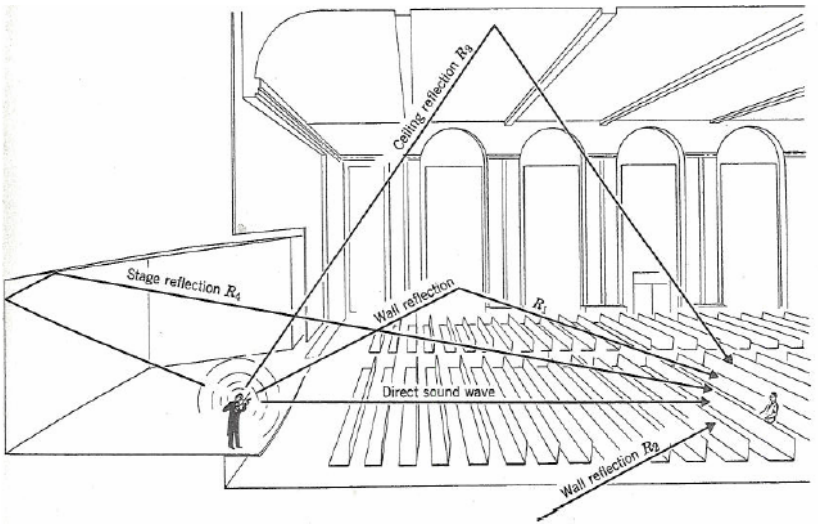


Image 1

An illustration of the paths that sound travels from the musician to the listener. (Direct sound and four early refleted sound waves out of many that may occur in the early time period of 80 msec.) - Image from BERANEK "*Concert and Opera Halls: How they sound*"

Although sound levels initially decrease with increasing distance from the source, as they would in the absence of reflections, after some distance from the source, sound levels become relatively constant as distance is further increased. Closer to the source, sound levels depend on the properties of the source and the distance to the source, but further away, sound levels are dominated by the reverberant sound energy, which depends on the properties of the room. The harder and more reflective are the room boundaries, the more reverberant sound energy there will be and the higher will be the reverberant levels in the room. Conversely, for a given room boundary material, reverberant field sound levels will decrease as the surface area is increased because more reverberant energy will be absorbed [3].

Until the turn of this century, auditorium acoustics owed very litlle to science. For a few designers before this century, the experience of building many auditoria inspired a fell for good acoustic design, but sadly they chose for their own reasons not to publicise their secrets. Valiant attemps at summaries of acoustic knowlegde by interested architects such as Vitruvius in the first century BC (1960) and much more recently Smith (1895) failed to fulfil their promise as serious guides to design.
"For most designers acoustic design was a matter of heavy reliance on precedents. The achievements of this trial-and-error approach have been considerable. The Greek classical theatre, the Roman arena, the Roman theatre, the Baroque theatre, the traditional Opera house, the English playhouse and the so called classical rectangular concert hall were developed with almost no science of auditorium acoustics". [3]

1.1.Quality Subjective Acoustics Factors

In recent years a commom language of acoustics has developed out of the dialogue between musicians and acousticians. Not every musician is familiar with all the terms. Nevertheless, the list compiled here results from a studied compromise from interviews with musicians and concert aficonados and from literature about Theatresand Concert Halls. Another group, music critics, provide a useful foil as they may describe a new concert hall with words that cannot serve as guides to succesful acoustical design. [3]
The terms below cover all the important aspects of music performed in the acoustics of a closed space:

- *Liveness or Reverberance*: Characterized by the reverberation time of primarily the high and medium frequency ranges. Determined by volume of room and effective surface area. Can be altered by changing area and nature of absorbing materials. Suitability depends on nature of sound or music.

- *Clarity vs Fullness*: Measure of intensity of the direct sound relative to the reverberant or reflected sound. The greater the reflected intensity, the more "full" the room is perceived and the less clear the spoken word or fast or highly articulated sections of music are perceived. Clarity is sacrificed in a "muddy" room but a lesser degree of clarity enhances slow passages of music from the romantic era. To achieve greater clarity or "definition" the entire audience should be close to the stage and have an unobstructed view.
- *Intimacy:* Connected to clarity. The time between the arrival of the direct sound and the first reflection determines the listener's perceived proximity to the performers. An intimate feeling occurs when the initial time delay is between 8 and 20ms.
- *Warmth vs. Brilliance:* This character is determined by the reverb time of the low frequencies relative to the medium and high frequency ranges. In general, the reverb time is a little longer for frequencies below 500Hz than those above. For a nearly constant reverb time as a function of frequency, the room may be classified as "bright" or "brilliant". The longer the lower frequency reverb time is the warmer the room.
- *Uniformity and Diffusion:* Uniform spatial distribution of both direct and reflected sounds throughout the audience. Uniformity in the direct sound can be achieved by minimizing the distance between first and last rows, e.g., a shallow hall with several balconies. Hot spots, caused by the focusing effect of curved walls or domed ceilings, reduce uniformity as well as do dead spots or "shadows" caused by physical obstructions or balcony openings.
- *Texture or Smoothness:* For a smooth room there should be no more than 20-30ms between successive reflections reaching a point in the audience and the intensity of the reflections should smoothly die away in time.
- *Envelopment:* Early reflections, those arriving in the first 100ms, should arrive from all directions in order to give the listener a sense of envelopment. Recent designs have given more attention to the importance of lateral reflections.

- *Balance or Blend:* Sound coming from different locations on the stage should have balanced intensities. Somewhat related to uniformity. This is generally a problem for seats close to a wide stage. This situation can be balanced with a low, irregularly shaped ceiling and appropriate onstage reflecting surfaces.
- *Sense of Ensemble or Performer Satisfaction:* The performers must be able to hear themselves and the other performers. There should be many reflections strong enough to be heard by the performers but the reflections should decay uniformly and in a time shorter than the shortest time between notes. Flutter echoes reflecting from parallel side walls must be avoided. Acoustic shells increase the sense of ensemble and helps to project more of the sound toward the audience. Ensembles in which members are separated by more than approximately 5 meters easily lose synchronicity and need a conductor to give visual cues [21].

1.2. Quality Objective Acoustics Factors

Reverberation Time (RT_{60})

RT60 is the time it takes for a loud sound to decay to inaudibility after its source is cut off. It is defined as the level difference of -60 dB. It is normally evaluated over the -5 to -35 dB (RT30) decay of sound and multiplied by the factor of 2 for conformity with RT60. These factors are necessary to make the measurements comparable with each other and with the more historical measurement of RT60, which is evaluated over a 60 dB sound decay.
Reverberation Time is the global quantitative criterion of the sound field in the room. Room reverberation gives fullness and singing tone to the music. The reverberation time must be in the proper range depending on the room size and the style of music [5].

Sabine TR60 Equation

$$T = \frac{0.162}{S\overline{a}_s}$$

where:

$$\overline{a}_s = \frac{a_1 S_1 + a_2 S_2 + ... + a_n S_n}{S}; \quad S = \sum_{i=1}^{n} S_i$$

Arau TR60 Equation:

$$T = \left[\frac{0.162V}{-S\ln(1-\overline{\alpha}_x)}\right]^{S_x/S}\left[\frac{0.162V}{-S\ln(1-\overline{\alpha}_y)}\right]^{S_y/S}\left[\frac{0.162V}{-S\ln(1-\overline{\alpha}_z)}\right]^{S_z/S}$$

where:

$$\overline{a}_x = -\ln(1-\overline{\alpha}_x) \qquad \overline{\alpha}_x = \frac{S_{x1}\overline{\alpha}_{x1} + S_{x2}\overline{\alpha}_{x2}}{S_x}$$

$$\overline{a}_y = -\ln(1-\overline{\alpha}_y) \qquad \overline{\alpha}_y = \frac{S_{y1}\overline{\alpha}_{y1} + S_{y2}\overline{\alpha}_{y2}}{S_y}$$

$$\overline{a}_z = -\ln(1-\overline{\alpha}_z) \qquad \overline{\alpha}_z = \frac{S_{z1}\overline{\alpha}_{z1} + S_{z2}\overline{\alpha}_{z2}}{S_z}$$

Eyring Norris TR60 Equation:

$$T = \frac{0.162V}{S\overline{a}} = \frac{0.162V}{-S\ln(1-\alpha)}$$

where:

$$\overline{\alpha} = \frac{\alpha_1 S_1 + \alpha_2 S_2 + ... + \alpha_n S_n}{S} \qquad \overline{\alpha} < 0.3$$

Millington y Sette TR60 Equation:

$$T = \frac{0.162V}{\sum_{i=1}^{n} S_i a_i}; \qquad a_i = \ln(1-\alpha_i)$$

where:

$$a_i = \ln(1-\alpha_i)$$

FitzRoy TR60 Equation:

$$T = \left(\frac{S_x}{S}\right)\left[\frac{0.162V}{-S\ln(1-\overline{\alpha}_x)}\right] + \left(\frac{S_y}{S}\right)\left[\frac{0.162V}{-S\ln(1-\overline{\alpha}_y)}\right] + \left(\frac{S_z}{S}\right)\left[\frac{0.162V}{-S\ln(1-\overline{\alpha}_z)}\right]$$

where:

$$\overline{a}_x = -\ln(1-\overline{a}_x);\ \overline{a}_y = -\ln(1-\overline{a}_y);\ \overline{a}_z = -\ln(1-\overline{a}_z)$$

Kutruff TR60 Equation:

$$T = 0.163\frac{V}{S\alpha''}$$

Early Decay Time EDT (sec)

The EDT is a reverberation time derived from the initial 10 dB of decay. It is the length of time that it takes for the sound to decay 10 dB after the sound source is turned off. EDT more closely corresponds to subjective evaluation of the reverberation time then RT. It affects principally the hall's support to the voice and adds definition to the higher tones of music [5].

The measurement is multiplied by the factor of 6 to make it comparable with RT60.

Clarity C_{80}, C_{50} (dB)

The measurement of Clarity is the ratio of the energy in the early sound compared to that in the reverberant sound, expressed in dB. Early sound is what is heard in the first 80 msec (C_{50} - 50 msec) after the arrival of the direct sound. It is a measure of the degree to which the individual sounds stand apart from one another.

If the clarity is too low, the fast parts of the music are not "readable" anymore. C_{80} is a function of both the architectural and the stage set design. If there is no reverberation in a dead room, the music will be very clear and C_{80} will have a large positive value. If the reverberation is large, the music will be unclear and C80 will have a relatively high negative value. C_{80} becomes 0 dB, if the early and the reverberant sound is equal. Often the values for 500Hz, 1000Hz and 2000Hz are averaged [5].

$$C_{80} = 10\log\frac{\int_{0ms}^{80ms} p^2(t)}{\int_{80ms}^{\infty} p^2(t)}$$

Definition - D_{50}

Definition is the ration of early sound energy to the total sound energy in Percent (%). It shows the difference of the level at the time range 0 - 50 ms as against the level at integration over the entire time range from zero to the end.

The larger this parameter, the more distinct the sound signal is felt, because it will then be less disturbed by later diffuse sound. In concert hall acoustics it refers to the degree to which individual strands in a musical presentation can be differentiated from each other [5].

- *Horizontal Definition* defines the degree to which sounds that follow one another stand apart.
- *Vertical Definition* defines the degree to which simultaneous sounds can be heard separately.

$$D_{50} = \frac{\int_{0ms}^{50ms} p^2(t)}{\int_{0}^{\infty} p^2(t)}$$

Centre Time (Tc)

It is the first-order momentum of the squared pressure impulse response, along the time axis, starting from the arrival of the direct wave. It is usually expressed in ms.

Strength - G (dB)

The strength G is defined as the difference between the sound level at listeners position in the hall and the level of the same source in free field in the reference distance 10 m from the centre of the source (in dB).

The strength of the sound, which is related to loudness, is a quantity that must be as uniform as possible throughout the hall [5].

$$G_{mid} = 10\log \frac{\int_{0}^{\infty} p^2(t)dt}{\int_{0}^{\infty} p_A^2(t)dt} \qquad \mathrm{G_{mid}} = \frac{G_{500Hz} + G_{1KHz}}{2}(dB)$$

Bass Ratio, Bass Strength – BR

BR is a measure of the support which the reverberation in the hall gives to the low notes of the music. The Bass Ratio is objective counterpart of the subjective criterion "Warmth". It is the ratio of the EDT between low frequencies (octaves 125 and 250 Hz) and medium frequencies (octaves 500 and 1000 Hz) [2].

The preferred values of the BR are between 1.1 to 1.25 for halls with high RT's, and 1.1 to 1.45 for halls with RT's of 1.8 sec or less.

$$I_{BR} = \frac{T_{125Hz} + T_{250Hz}}{T_{500Hz} + T_{1KHz}} = \frac{T_{LOW}}{T_{MID}} = \frac{(T_{125Hz} + T_{250Hz})/2}{(T_{500Hz} + T_{1KHz})/2}$$

Brightness, Bright Strength – Br

Br is a measure of the support which the reverberation in the hall gives to the high notes of the music. The Brightness Ratio is objective counterpart of the subjective criterion "Brightness". It is the ratio of the EDT between high frequencies (octaves 2000 and 4000 Hz) and medium frequencies (octaves 500 and 1000 Hz) [2].

$$I_{Br} = \frac{T_{2KHz} + T_{4KHz}}{T_{500Hz} + T_{1KHz}} = \frac{T_{HIGH}}{T_{MID}} = \frac{(T_{2KHz} + T_{4KHz})/2}{(T_{500Hz} + T_{1KHz})/2}$$

STI

For STI testing, a test signal with speech-like characteristics is used. STI employs a complex amplitude modulation scheme to generate the test signal. The received signal in the measurement system is compared with the test signal concerning the depth of modulation in a number of frequency bands. Reductions in the modulation depth represent a loss of intelligibility [5].

The Measurement of STI is defined by the standard IEC 60268-16.

$$STI = -0{,}1845 \ln(\%ALcons) + 0{,}9482$$

$$STI = \frac{(S/N)_{ap} + 15}{30}$$

RASTI

RASTI, Rapid Speech Transmission Index, is a more simplified version of STI.

A modulated test signal is fed to a loudspeaker at the talker's location. The receiver's microphone is positioned at the receiving listeners location. The system gives a direct read out of the measured RASTI value at the receiver position

RASTI can also take account of the effects of reverberation, as well as background noise. It tests in only two frequency bands, with the assumption that the response of the sound system is more than 100 Hz to 8 kHz or higher with a flat frequency response. A RASTI value is in the range 0 to 1.

Stage Support - ST1

Is a measure of strength of orchestral sound returned by nearby reflecting surfaces to the ears of each player in the orchestra, the acoustical support, that a hall gives a player on stage. Measured as the ratio of the arriving sound energy at the first 10 msec and the arriving sound energy between 20 and 100 msec.

Measurement source is an omnidirectional sound source in a distance of 1 meter. The sound arriving in the later interval has been reflected in the hall and the stage environment already. The measurements are made at several positions and the data are averaged.

Interaural Cross Correlation Coefficient IACC

To evaluate the spatial property of the sound field, it is the measure of the difference in the sounds arriving at two ears of listener facing the performing entity in a hall, measured for six octave bands between 125 and 4000 Hz. IACC is usually measured with a dummy head. IACC is defined as the maximum value of the cross-correlation function within ±1 msec.

Initial Time Delay Gap ITDG (msec)

The time difference between the arrival of the direct sound and the earliest and most significant reflection (at a listener's seat in the hall), excluding the reflections from the floor. It is measured in msec. It corresponds to the subjective impression of 'intimacy'. (*Preferred values don´t exceed 20 msec.*)

Lateral Fraction – LF

LF is determine by the ratio of the output of a figure-8 microphone with its null axis pointed to the source of the sound, divided by the output of a non-directional microphone at the same position. LF covers the time period of 0 to 80 msec and is the average of the LF´s in the four frequency bands – 125, 250, 500 and 1000 Hz.

(These last four parameters **ST1, IACC, ITDG** and **LF** were not measured in these work).

1.3. Acoustical Designs: Concert , Opera, Theatres and Speech

According to varius autors, there are some correlation between Objective Parameters and the types of room, due to her purpose: Concert Hall, Opera House, Theatre, Speech or Pop/Rock.

According to Arau, we can correlate some optim values for Acoustic Parameters with the type of music that is played in the room, like Theatres and Chamber Music:

Parameter	*Theatre*	*Chamber Músic*
Reverberation Time	O,87 < T_{Mid} < 1,33	1,32 < T_{Mid} <1.85
Bass Ratio (BR)	0,9 < I BR < 1,3	1 < I BR <1,3
Brightness (Br)	I Br > 0,8	I Br > 0,8
EDT	0,7 < EDT_{MID}* < 1,17	1,16 < EDT_{MID}*<1,29
Clarity Índex (C80)	C80 > 4 dB	-2 < C80 < 4 dB
Def. Índex (D50)	D50 > 60%	45% < D50 < 60%
Inteligibility	0,5	-
Echoes	No	No
Factor G	G > 0 dB	G > 0 dB

* Calculated from T_{Mid} = 1,29 s

Table 1

Aceptable Objective parameters for Theatre and Chamber Music.

From "*ABC de la Acústica Arquitectónica*" de H. Arau.

According to Carrión, the relation between RT_{mid} Occupied and the type of the room can be:

Room Type	TR_{mid} Room Occupied
Conferences Room	0,7 – 1,0
Cinema	1,0 – 1,2
Multi-Room	1,2 – 1,5
Theatre and Ópera	1,2 – 1,5
Concert Hall (Chamber Music)	1,3 – 1,7
Concert Hall (Sinfhonic Music)	1,8 – 2,0
Catedral Church	2,0 – 3,0
Radio	0,2 – 0,4

Table 2

RT_{mid} Occupied and type of room.

From "*Diseño Acústico de espacios arquitectónicos*" de A. Carrión

According to Barron, and other autors, the valorization of the parameter STI his given like:

%ALCons	*STI/RASTI*	*Subjetive Valorization*
1,4 % - 0 %	0,88 – 1	Excellent
4,8 % - 1,6 %	0,66 – 0,86	Good
11,4 % - 5,3 %	0,5 – 0,64	Fair
24,2 % - 12 %	0,36 – 0,49	Poor
46,5 % - 27 %	0,24 – 0,34	Bad

Table 3

Subjective valorization of STI parameter.

From "*Auditorium Acoustics and architectural design*" by M. Barron.

Carvalho achieve, in his work about *Portuguese Church Acoustics*, an equation between the differents objective acoustic parameters:

Equation	*Reference*
$EDT = 0{,}043 + 0{,}941\ TR$	0,98
$EDT = 0{,}219 + 0{,}013\ TS$	0,88
$C80 = 2{,}88 - 5{,}572\ ln\ (TR)$	0,56
$C80 = 2{,}78 - 5{,}735\ ln\ (EDT)$	0,61
$C80 = 30{,}94 - 6{,}422\ ln\ (Tc)$	0,86
$D50 = 0{,}357 + 0{,}048*C80 + 0{,}016(C80)^2$	0,88
$D50 = 1{,}562 - 0{,}25\ ln\ (TS)$	0,71
$Tc = 17{,}82 + 64{,}203\ TR$	0,83

Table 4

Relation between EDT, RT, C80 and D50.

From "*Acústica Ambiental e de Edifícios*" by A. Carvalho

According to Carrión, there are some correlation between the type of the room and the RT_{opt} (500Hz) and the C80:

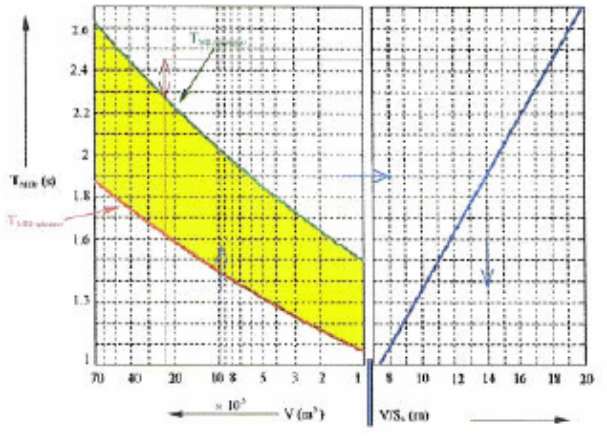
Function	*TR_{Opt} (500 Hz)*	*C_{80} (dB)*
Auditory	0,7 – 0,8	> 6
Theatre	0,7 – 0,9	> 5
Cinema	0,8 - 1	> 6
Recording Studio	0,4 – 0,6	> 6
Ópera (No Wagneriana)	1,3- 1,7	3 a 4
Ópera (Wagneriana)	1,8 – 1,9	1 a 2
Chamber Music	1,4 – 1,7	-1 a 1
Symphonic Barroc Music	1,4 – 1,6	0 a 2
Symphonic Classic Music	1,6 - 1,8	-1 a 0
Symphonic Romantic Music	1,9 – 2,2	-2 a -1
Symphonic Modern Music	1,4 – 1,9	-1 a 0
Pop Music	0,8 – 1	> 6
Organ Music	2,5 – 3,5	< -2
Gregorian Choir	3 - 4	-3 a -1

Table 5

Optim Reverberation Time at 500Hz, C80 and type of room.

From "*Diseño Acústico de espacios arquitectónicos*" de A. Carrión

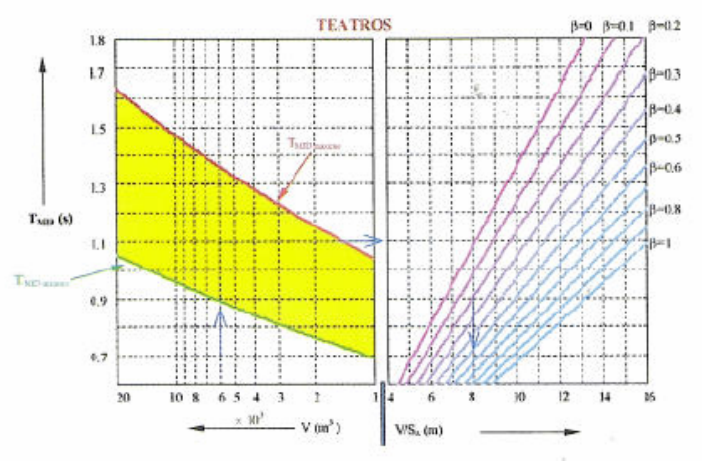
The relation between Volume and the Audience Area and the Reverberation Time, can be achieved in the architec project, according to the purpose of the hall. When the architec knows the medium hall size, the capacity of the hall and the purpose, he should follow some correlation between these parameters. H. Arau shows that, for concert hall, theatres and Opera Houses, the relation should be:



(A)

____ Wrong Projected Hall (the doble arrow (↔) shows the minimum absorption necessary to correct the excess of RT)

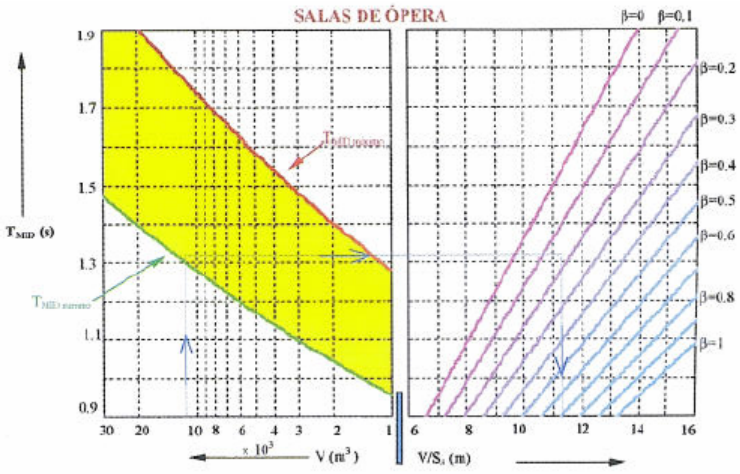
……. Good Projected Hall: V = 9700m^3; T_{mid} = 1,91seg; V/S_A = 14m; S_A = 692,8m^2



(B)

In this case there is no amphi-theatre audience shape (β=0)

____ Good Projected Hall: V = 6000m^3; T_{mid} =1,09seg; β=0; V/S_A= 8m; S_A=750m^2



(C)

In this case there is no amphi-theatre audience shape with a proportion of (β=0,16)

____ Good Projected Hall: V = 12000m^3; T_{mid} =1,33seg; β=0,16; V/S_A= 11,35m; S_A=1058m^2

Image 2

(A), (B) and (C): Correlation between the RT_{mid} and the Volume and the Audience Area (V/S_A).

From "*ABC de la Acústica Arquitectónica*" de H. Arau, fr Concert Hall, Theatre and Opera House respectively.

1.4. The Merit Factor (MF)

The Merit Factor (MF) for **Reverberation Time** - RT_{mid} – is:

M T_{mid}	0	to	$RT_{mid} \leq 0,9\ RT_{opt} - 0,5$
	$1 - (1,8RT_{opt} - 2RT_{mid})$	to	$0,9\ RT_{opt} - 0,5 < RT_{mid} < 0,9RT_{opt}$
	1	to	$0,9RT_{opt} \leq RT_{mid} \leq RT_{opt}$
	$1 - 2(RT_{mid} - RT_{opt})$	to	$RT_{opt} < RT_{mid} < RT_{opt}+0,5$
	0	to	$RT_{mid} \geq RT_{opt}+0,5$

RT_{mid} - Measured or Calculated value

RT_{opt} – Optim value for that kind of event

The MF for **Bass Ratio** – BR – parameter is:

<u>For Music:</u>

MF BR	0	to	IBR ≤ 0,85
	4 IBR – 3,4	to	0,85 ≤ IBR < 1,1
	1	to	1,1 ≤ IBR ≤ 1,3
	6,2 – 4 IBR	to	1,3 < IBR < 1,55
	0	to	IBR ≥ 1,55

<u>For Theatre</u>

MF BR	0	to	IBR ≤ 0,65
	4 IBR – 2,6	to	0,65 ≤ IBR < 0,9
	1	to	0,9 ≤ IBR ≤ 1,3
	6,2 – 4 IBR	to	1,3 < IBR < 1,55
	0	to	IBR ≥ 1,55

The MF for **Brightness** – Br – is:

MF Br	0	to	IBr ≤ 0,45
	2,86 IBr – 1,29	to	0,45 < IBr < 0,8
	1	to	0,8 ≤ IBr ≤ 1
	3,857 – 2,86 IBr	to	1 < IBr < 1,35
	0	to	IBr ≥ 1,35

The MF for **Early Decau Time** – EDT:

A Homogeneous Sound Difusion means an uniform distribution, where the sound pressure level fall is praticaly linear. In this case, there is no difference between the EDT and TR values. However, a No-Homogeneous Absorption Distribution which is the real case of all rooms, means the the distribution is not uniform. In general, the EDT values are smaller than TR60.

The EDT is more related with the subjective impression of a hall than RT60, which means that, one hall with an EDT with a smaller values than RT60 will be, aparentely, more "*dead*" to music but with a good intelegibility (STI).

To Theatres EDT_{mid} should be between $0,6RT_{mid}$ and $0,75RT_{mid}$, to Opera between $0,75RT_{mid}$ and RT_{mid}, and to Concert between $0,9RT_{mid}$ and RT_{mid}.

For Concerts:

MF EDT	0	to	$EDT_{mid} \leq 0,4T_{mid}$
	$2(EDT_{mid}/T_{mid})– 0,8$	to	$0,4T_{mid} < EDT_{mid} \leq 0,9T_{mid}$
	1	to	$0,9T_{mid} < EDT_{mid} \leq T_{mid}$
	EDT_{mid}/T_{mid}	to	$EDT_{mid} > T_{mid}$

For Opera:

MF EDT	0	to	$EDT_{mid} \leq 0,25T_{mid}$
	$2(EDT_{mid}/T_{mid})– 0,5$	to	$0,25T_{mid} < EDT_{mid} < 0,75T_{mid}$
	1	to	$EDT_{mid} \geq 0,75T_{mid}$

And for Theatre:

MF EDT	0	to	$EDT_{mid} \leq 0,35T_{mid}$
	$4(EDT_{mid}/T_{mid})– 1,4$	to	$0,35T_{mid} < EDT_{mid} < 0,6T_{mid}$
	1	to	$0,6T_{mid} \leq EDT_{mid} \leq 0,75T_{mid}$
	$1,75-(EDT_{mid}/T_{mid})$	to	$EDT_{mid} > 0,75T_{mid}$

The MF for **Definition - D50:**

For Concert halls, the D_{50} between 500 Hz and 1000 Hz, near to 0,5 is a good value. The more the Índex grow, the more the subjective acoustic perception gets worse to symphonic orchestra performance. If Definition grows it means that the room is more prepared/calculated to Speech – Theatre or Conferences. Any value bigger than 0,7 is adquate to Speech Rooms.

For Music Concert:

MF D_{50}	0	to	$D \leq 0,35$
	4D-1	to	$0,25 < D < 0,6$
	1	to	$0,5 < D \leq 0,75$
	1,93-1,43D	to	$D > 0,65$

For Theatre:

MF D_{50}	0	to	$D \leq 0,45$
	5D-2,25	to	$0,45 < D \leq 0,65$
	1	to	$D > 0,65$

The MF for **Clarity - C80:**

With a C_{80} high means that the first sound energy is bigger than the latest sound energy, which means that the sound is very clear. In the first 80 ms it is produced much more reflections that come from walls and ceillings near to the listener related to other surfaces of the room. When this happens we have an EDT much smalers than the TR_{60} measured.

For orchestral music a C_{80} of 0dB to -4dB is often preferred, but for rehearsals often conductors express satisfaction about a C_{80} of 1dB to 5dB, because every detail can be heard. For singers, all values of clarity between +1 and +5 seem acceptable. C_{80} should be generally in the range of -4dB and +4dB. For speech, in comparison to music, the Clarity will be measured as the ratio of the first 50 msec (C_{50}) instead of 80 msec (C80) for music. So, for

Concert Hall: $-2dB < C_{80} < 4dB$

Ópera House: $2dB < C_{80} < 6\ dB$

Theatre Room: $C_{80} > 6dB$

For Concert:

MF C_{80}	0	to	$C_{80} \leq -9$
	$1,62+0,18C_{80}$	to	$-9 < C_{80} \leq -4$
	$1,10+0,05C_{80}$	to	$-4 < C_{80} \leq -2$
	1	to	$-2 < C_{80} \leq 4$
	$1,6-0,16C_{80}$	to	$4 < C_{80} \leq 10$
	0	to	$C_{80} > 10$

For Opera:

MF C_{80}	0	to $C_{80} \leq 0$
	$C_{80}/2$	to $0 < C_{80} \leq 2$
	1	to $2 < C_{80} \leq 6$
	2- $C_{80}/6$	to $6 < C_{80} \leq 12$
	0	to $C_{80} > 12$

And for Theatre:

MF C_{80}	0	to $C_{80} \leq 0$
	$C_{80}/6$	to $0 < C_{80} \leq 6$
	1	to $C_{80} > 6$

The MF for **Factor Strenght - G:** (measured from 125 Hz to 4kHz)

It is convenient that the G values of the different points of the room and for the different range octaves band will be superior to 0 dB. This value is related to the room sonority impression and depends of the first reflections energy and the TR. Recently, itwas discovered that this parameter depend much more of EDT than TR.

The Merit factor for G parameter is:

MF G	0	to $(L-L_0) \leq -10$
	1+ $(L-L_0)$ /10	to $-10 < (L-L_0) \leq 0$
	1	to $(L-L_0) > 0$

The MF for **Inteligibility - STI:**

The Inteligibility Índex is not a fundamental parameter for Concert Halls, but for Theatres. In fact, inteligibility doesn´t have to be good for music, while for theatre it is crucial.

It is a mathematic function that depends of TR, signal/noise relation in the room and possible echoes.

The Merit factor for STI parameter is:

MF STI	0	to $0 \leq STI \leq 0,3$
	2,22*STI-0,67	to $0,3 \leq STI \leq 0,75$
	1	to $STI > 0,75$

Global Merit Factor

It is achieved by the arithmetic mean of all factors: **FMGlobal = ∑ FMi/n**

We should compare the Global value related to the minimiun FM that was obtained from the parameters measured. If the ERROR that exist between them and the mean is be superior to 0,2, and the values of FMGlobal inferior to 0,8, the room acoustic should be studied again in the parameters that are not correct [2].

2. Acoustic Hall Elements

2.1. Acoustic Seating Area

According to Barron, to calculate the effective absorving area of audience, allowence is made for the three-dimensional nature of chairs and people by a adding a perimeter strip round the seating area in plan.

A perimeter strip 0,5 metre wide is added to the true seating area, except where it abuts walls and along balcony fronts.

When aisles between seating are less than 1m wide, only the aisle area is taken. When this acoustic area is used, the appropriate coefficients are as given in tables in **1.6.** (according to Carrión), Absorption by seated audience is little influenced by the quality of the seating itself, whereas values vary depending on the degree of the upholstery [10].

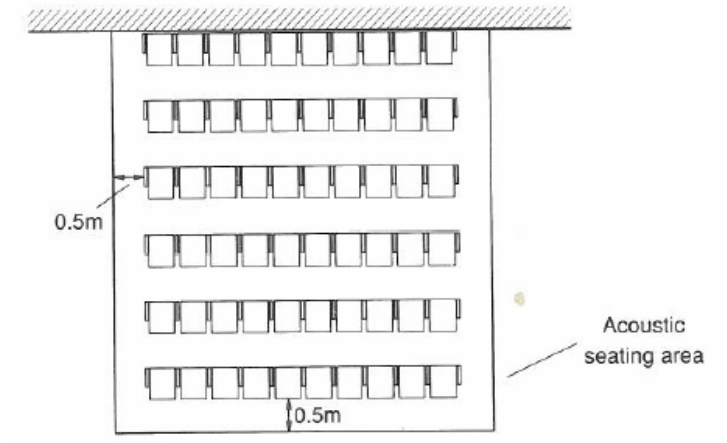


Image 3

Acoustic Seating Area based on adding a 0,5 perimeterstrip round thr true seating area. Image from "*Auditorium Acoustics and Architectural Design*" by M. Barron.

2.2. Chair Absorption

In the next tables is shown the results of a Beranek studies about the absorption of different types of chairs, realized on several kind of halls. The results are related to different type of chairs depending of the degree of upholstery. The three types are:

- Chairs with a maximum degree of upholstery (ChMaxUp)
- Chairs with a medium degrre of upholstery (ChMedUp)
- Chairs with a minimum degrre of upholstery (ChMinUp)

Freq. (Hz)	*125*	*250*	*500*	*1000*	*2000*	*4000*
ChMaxUp	0,76	0,83	0,88	0,91	0,91	0,89
ChMedUp	0,68	0,75	0,82	0,85	0,86	0,86
ChMinUp	0,56	0,68	0,79	0,83	0,86	0,86

Oc = Occupied Chairs

Table 6
Three different types of Occupied chair absorption from 125 Hz to 4000Hz .

Freq. (Hz)	*125*	*250*	*500*	*1000*	*2000*	*4000*
ChMaxUp	0,72	0,79	0,83	0,84	0,83	0,79
ChMedUp	0,56	0,64	0,70	0,72	0,68	0,62
ChMinUp	0,35	0,45	0,57	0,61	0,59	0,55

Un = Unoccupied Chairs

Table 7

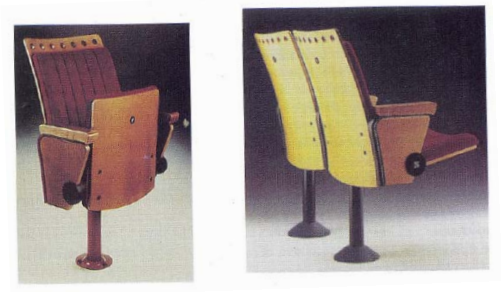
Three different types of Unoccupied chair absorption from 125 Hz to 4000Hz .
From "*Diseño Acústico de Espacios Arquitectónicos*" by A. Carrión.

The conclusions of the previous table are:

- Absorption grows in all frequencies from unnocupied to occupied chairs.
- Occupied chairs absorption grows with the percentage of upholstery chairs, specially on low frequencies.
- Absorption grows with the frequency until 1kHz. From this especific frequency in the case of unoccupied chairs, the aborption level falls, due to a shadow effect caused by chairs called the *Seat Dip Effect*. [10].

(A)

(B)



(C)

Image 4

(A) Chairs with a maximum degree of upholstery, (B) Chairs with a medium degrre of upholstery and (C)Chairs with a minimum degrre of upholstery. Image from Diseño acústico de espacios arquitectónicos by A. Carrión.

2.3. Balconies

The Reverberation Time, and more pertinentely early decay time, should take care of the temporal aspects of revrberant sound, providing adequate liveness and sufficient room response. However, the directional distribution of the reverberant sound is also important as our ears can respond to spatial effectsgenerated by early reflections and those produced by later reverberant sound [3].

Balconies which overhang audience seating are a feature of most large concert halls. Clearly, seats below overhangs are disadvantaged both visually and

acoustically. As a general principle, a balcony can cause, acoustically, a loss of intimacy and a sense of detachment from the acoustics of the main space. Hawever, this loss is not uniform with reflction delay. In a hall with balcony the early sound level is barely influenced by the presence of an overhang, where the side walls reflections are usually unaffected and the presence of a nearby rear wall probably compensates the obscured reflections caused by the surface [3].

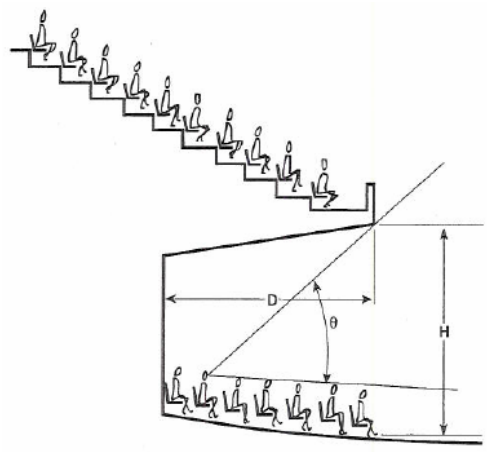


Image 5

Recommended designs for excellent balcony overhangs in concert halls. As a general principle, D should not exceed H. Angle ɵ should not be less than 45 degrees. The underbalcony rear wall should be shaped to reflect the direct sound toward the heads of the listeners [3]

In acoustic terms, the effect under a balcony is to both increase objective clarity and decreased the early decay time, resulting in a decreased sense of reverberation. Normally is this sense of reverberation that is perceived as lack of loudness. To mitigate, a little, this effect, in some cases, the existence of a gap behind the balcony can allow sound to filter round, giving a sense of some sound from behind for those below the overhang [3].

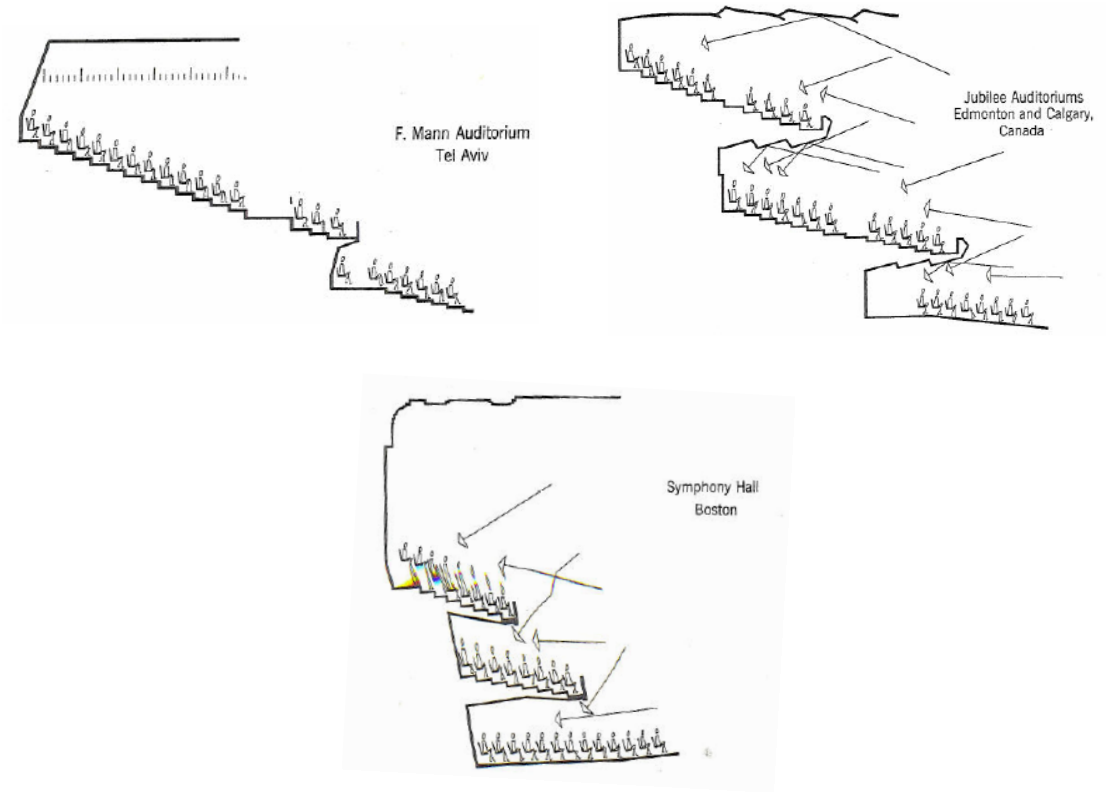


Image 6

Three relatively satisfactory balcony designs: F. Mann Audtorium (Tal-Aviv) with no overhang; Jubilee auditoriums (Edmonton and Calgary, Canada) with little overhang and wide openings; Symphony Hall (Boston) with a center balcony with good acoustics except for the last three rows of seats that do not receive sound from the upper part of the hall [3]

In order to provide extra reflections, the designer can profille the balcony soffit, however, as these are early reflections, this is only serve to increase further objective clarity. Maintaining a high opening at the overhang avoids the problem of lack of reverberance, but removes one of the main design gains of balcony. According to Beranek, the depth beyond the overhang should not exceed the height at the opening [5].

In this study there are six halls with balconies: Maria Matos Municipal Theatre, Gil Vicente Academic Theatre, Aveirense Theatre, Olga Cadaval Cultural Centre, Oporto Coliseum and S. Luiz Municipal Theatre.

2.4. Orchestra Pit

The ability of an instrumental player to play in time with a singer is obviously important, yet most performers commented that thay would like to. For the performer himself some sense of the sound he is producing returning from the auditorium is likewise a characteristic of most performing environments. The amount of sound returning to the back of the pit is generally very small. In acoustic terms the overhung section of a pit behaves like a coupled space to the auditorium, with double-slope reverberant decays. The initial slope of the decay is determined by the local acoustic conditions in th epit with decay rates corresponding to reverberation times of only 0,35 – 0,7 seconds. Thereafter the decay behaves as in the auditorium.

A solution to these various problems is not in most cases easy to achieve. The prinecipal non-acoustic variables are the physical dimensions of the pit, the degree of cover and the height of the opening.

Typical dimensions are given below. The top of the orchestra rail is generally in line with the stage. The degree of overhang extends in some houses considerably further than 2m mentioned in the figure. The depth of the opening should be a minimum of 2m but it should be higher for pits with larger overhangs to allow musicians to maintain some visual contact with the auditorium [3].

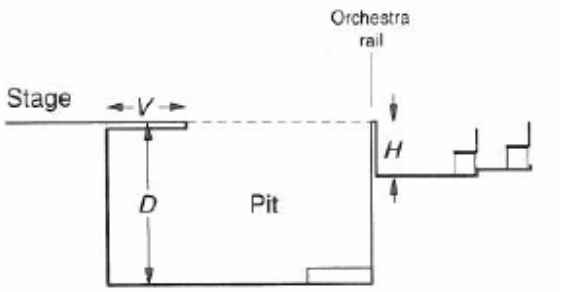


Image 7

Typical opera house pit dimensio: Stage overhang V, 1-2m; pit depth D, 2,5-3,5m; orchestra rail height H, 1m. Image from Auditorium Acoustics and architectural design by M. Barron.

3. Portuguese Theatres History

The first “portuguese” theatre was found in 1798 and comes from the time of Imperator *Augusto* in Roman Era and was remodelated by the Imperator Nero on the Ist Century D.C. : ***TEATRO ROMANO DE LISBOA***. However, it mus be said that since this discovery, in XVIIIth Century, all performing art halls hadn´t been treated or taken care by the Portuguese governement until the end of the XXth Century [15].

In fact, the portuguese theatres history had been a sucession of demolitions, with several damages to the social and cultural portuguese life, as an example of that the destruction of the primitive buildings after the XIXth century that represented great architectural references to the world theatres constructions.

This first Roman theatre is a singular case since the Ist Century to the XVIIth century when the portuguese cultur with her dramatic literature started to grow. The first concert halls/theatres appeared in that century constructed in order to serve Opera purposes:***TEATRO DA RIBEIRA*** (1755), the ***TEATRO S. CARLOS*** (1793) both in Lisbon and ***TEATRO. S. JOÃO*** (1798) in Oporto city.

It is after the inauguration of ***TEATRO D. MARIA II*** in 1846 that Portugal verifies a very huge and consistent movimentation on theatres construction and adaptations in order to provide performing arts halls, most of them similar to the Italian structure that had been stablished in all europe.

In the turn of the XXth century there were almost 150 theatres in activity in Portugal, but just after the 20´s, something new came up: the *CINE-TEATROS*, a second generation of theatres/concert hall buildings to serve mainly the boom of a new entertainment era: the Cinema.

Finally, it was in the end of the XXth century and in the beginning of this one that were constructed and projected theatres/concert halls that beside their specific function for performing arts, are unique points of cultural and social life. It´s in this period that almost every Town Halls, all around the country, after three centurys of demolitions and bad policy, are taking care (finally) the theatres and concert halls, the old and the new ones [15].

The first portuguese public art space appeared in 1590 by the hand of Fernão Dias de la Torre and was called ***PÁTIO DAS ARCAS*** in Rua Augusta and after 30 years, others like as ***PÁTIO DA FARINHA*** in 1619 both in down town of Lisbon.
In the beginning of the XVIIth century these kind of spaces, dedicated to performing arts, were in fact Theatres for the purposes of that time, like: ***PÁTIO DA MOURARIA*** and ***PÁTIO DAS HORTAS DO CONDE*** located at Rua do Condes, nowadays the actual localization of Recreios Coliseum and Politeama Theatre. The *TEATRO S. JOÃO* in Oporto city still remains in the same position as in 1798, the year of his construction and ***ACADEMIA DA TRINDADE*** in Lisbon placed on an ancient convent (nowadays in front of Trindade Theatre) was the first space in Portugal were Opera happened in1735.
However the first Portuguese Opera House was ***OPERA DO TEJO***, also called as *TEATRO DA RIBEIRA*, opened in 1755 and destroyed some months after his construction by the earthquake in the same year. TEATRO S. CARLOS took the place of *OPERA DO TEJO* in 1793 and until that year the performance of Opera was in several other spaces of art, like: ***TEATROS DO BAIRRO ALTO, ÓPERA DO CONDE DE SOURCE*** (1760-1771), ***TEATRO DO SALITRE*** and ***TEATRO CONDES.*** [15]

Image 8
Ruins of OPERA DO TEJO after the earthquake in 1755. Image from CRUZ, D.I., "Teatros de Portugal", Edições INAPA, Lisboa.

In the next image is shown the localization of the 32 Portuguese Theatres and Concert Halls that were studied in this work.

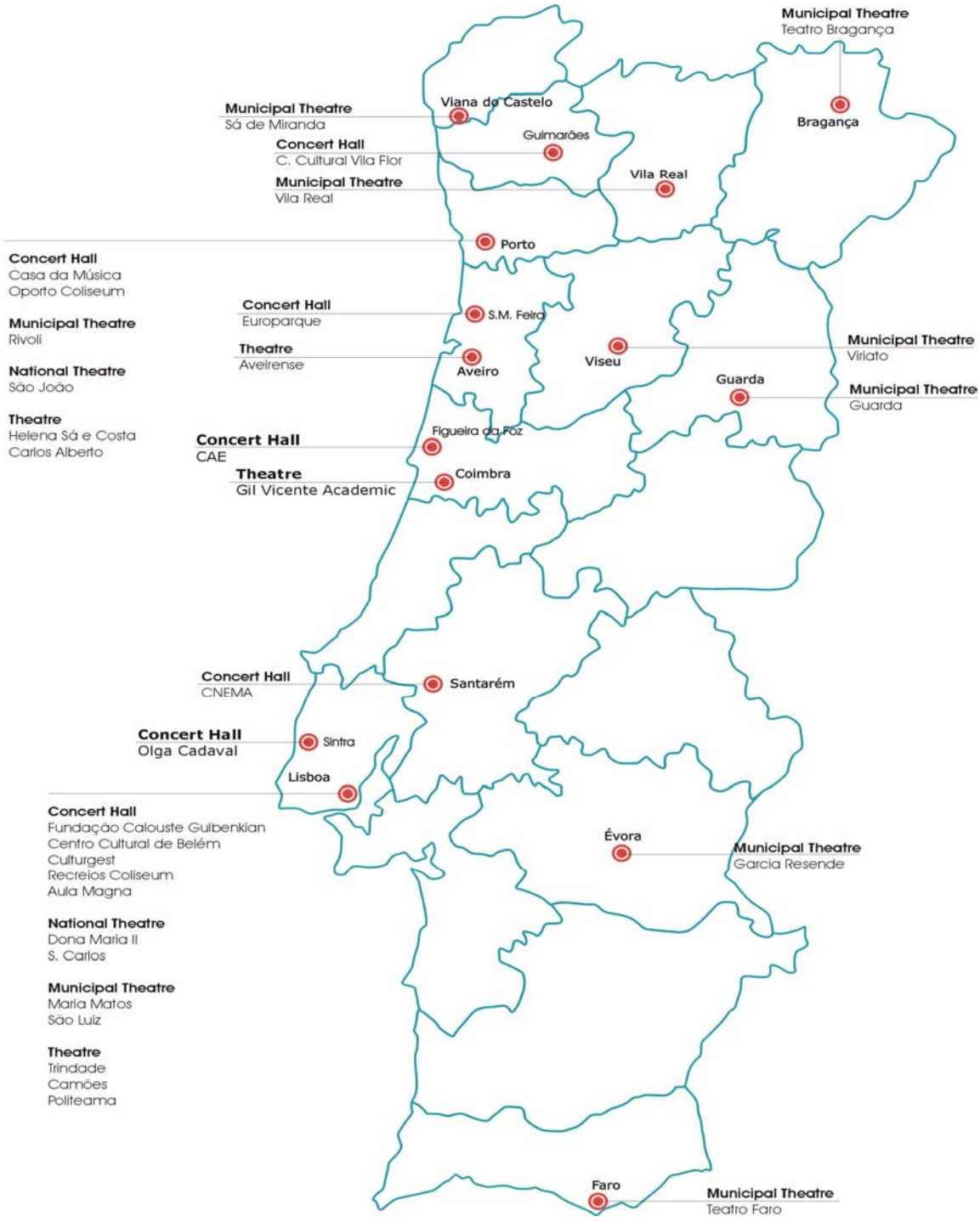


Image 9

Portugal Map and the localization of the studied Halls in this work.

4. XVIIIth Century Theatres

4.1. S. Carlos National Theatre

The S. Carlos National Theatre, in Lisbon, is among the small number of European lyric theatres with an almost uninterrupted activity through more than two hundred years, not having suffered any accident since it was inaugurated on July 30, 1793, even though it suffered some improvements and restorations in the interior of the room as well in the foyers, without any kind of alteration in the exterior.

Now days the theatre has the capacity to 404 people in the audience and 456 in the five rows of boxes. The history of opera in Portugal in the last two centuries and the S. Carlos history grow together, mainly after the fire that destructed the Oporto's S. João National Theatre in 1908.

The project author was the architect José da Costa e Silva, that had been studying in Italy and that inspired himself in the S. Carlo, in Napoli, and in the Scala, in Milan, to the façade. The first floor space, today known as Salão Nobre, was inaugurated in 1796.

In the XIX century last decades the Italian repertoire domination started to be partially dethroned by the Massenet, Gounod, Delibes and Wagner operas.

Between 1938 and 1940 the theatre was submitted to some major improvements. After the war and until the 60's some of the S. Carlos stage received some of the biggest singers, including Maria Caniglia, Ebe Stignani, Beniamino Gigli, Mario del Monaco,

Recently it has developed some co-productions with other European lyric theatres

In 1992 new lights and electronic subtitles equipment were installed. In 1993 and middle of 1998, the Theatre was, together with the Portuguese Symphonic Orchestra, under the charge of the S. Carlos Foundation, that joins the Culture State Secretary, RTP, RDP, Portugal Telecom and the Banco Comercial Português. Since May, 14, 1998, with the extinction of the Foundation, the Theatre became a public institute, under the supervision of the Culture Ministry.

Image 10
S. Carlos National Theatre stage view.

Image 11
S. Carlos National Theatre hall.

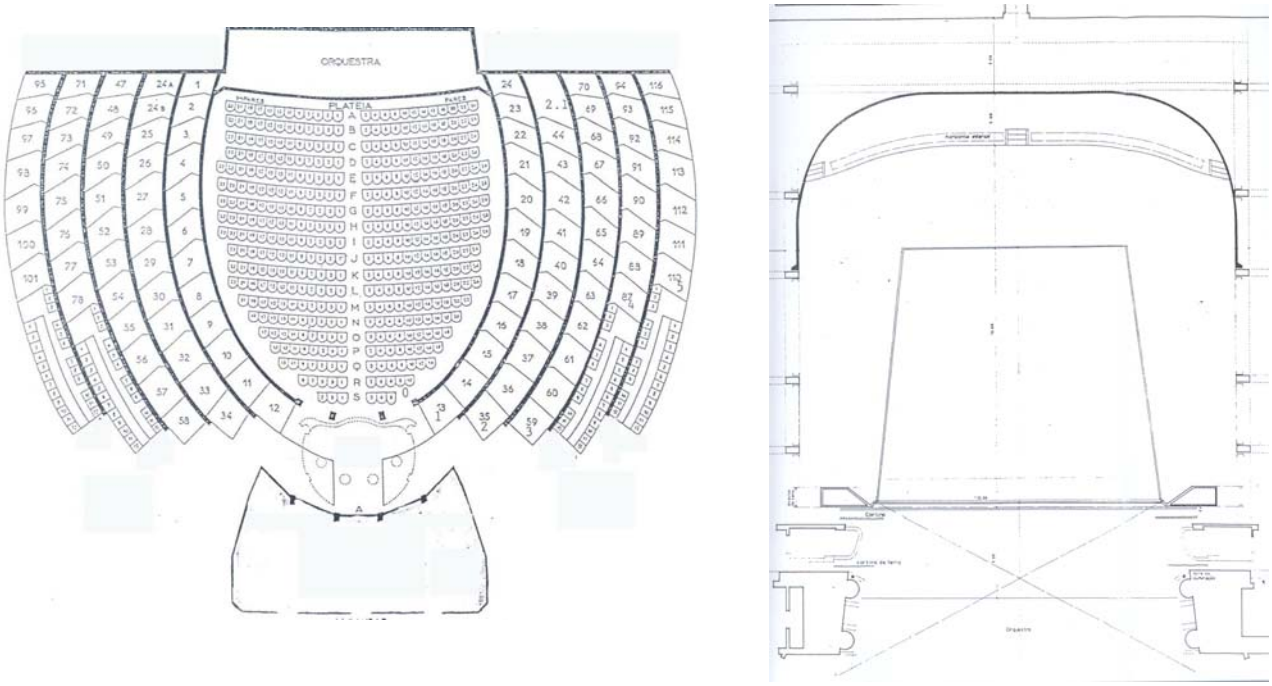


Image 12
S. Carlos National Theatre architectural plant, audience area and stage.

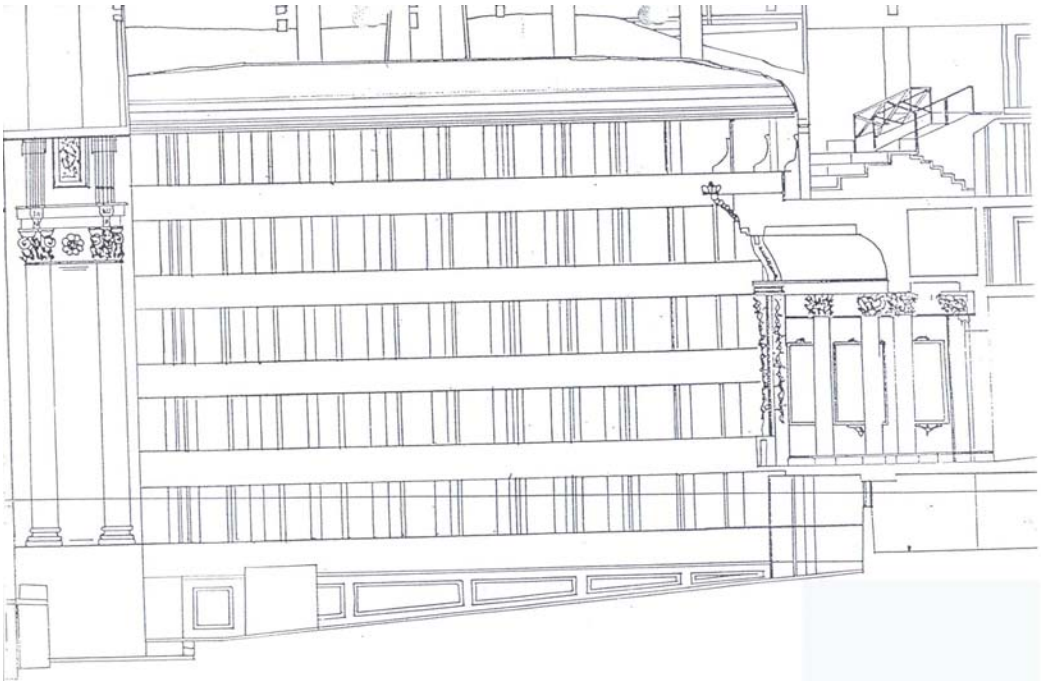
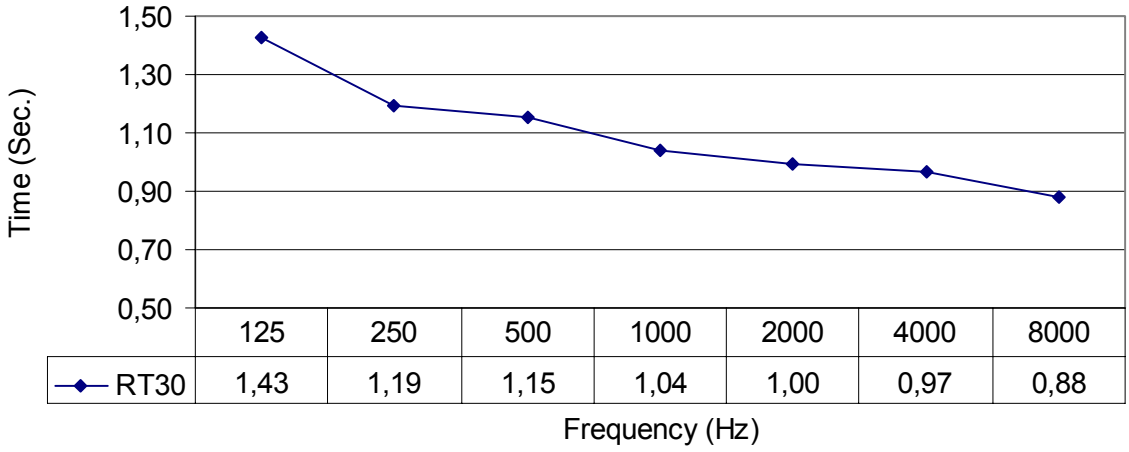


Image 13
S. Carlos National Theatre architectural cut.

		125	250	500	1000	2000	4000	8000
Audience	**TR30** (s)	1,43	1,19	1,15	1,04	1,00	0,97	0,88
	EDT (s)	1,27	1,23	1,26	1,17	1,17	1,19	1,11
	C80 (dB)	0,8	1,8	0,9	1,4	2,1	3,5	4,9
	D50 (%)	35	47	40	43	47	57	65
	Tc (ms)	104	87	92	85	80	65	53
	G (dB)	-	-	-	-	-	-	-
On Stage	**C50** (dB)	3,1	2,3	3,7	3,1	5,3	4,3	4,5
	D50 (%)	66	63	70	66	76	72	72

Seconds				
RT_{mid}	**EDT_{mid}**		**BR**	**Br**
1,10	1,20		1,19	0,90
V		**N**		**STI**
Volume		**Seats**		0,58
3729		600		
S_A	***S_0***	***S_{pit}***		**S_T**
230	180	85		495
V/N	**S_A/N**		**V/S_T**	**EDT/(Vx$10^{6)}$**
6,22	0,4		7,5	3,22 $^{-10}$

Reverberation Time



4.2. São João National Theatre

TNSJ – S. João National Theatre is one of the XVIII th century Portugal theatres, opened in 1798 located down town of Oporto city. It was first called as Real Teatro de S. João projected by the italian Architec Vicente Mazzoneschi (cenographe of S. Carlos National Theatre in Lisbon at that time).
Is interior is very similar to S. Carlos Theatre and had a near composition to all kind of italian theatres that were established with sucess until the born of french theatre.
After the fire of 1908, the theatre was projected by the Oporto Architec José Marques da Silva (1869-1947), extremely influenced by his visit to Paris, years before.

The new S. João Theatre was inaugurated in 7th March of 1920. In the beggining the theatre presented most performances related with theatre and opera, but after 1930 the hall had o progress and started a period of decadence, where the programming was based almost in cinema.
However, the S. João Theatre delivered his manegement to portuguese state in 8th October in 1992 and changed its designation to National Theatre. Until 1995 the theatre was under reconstruction by the architec João Carreira. The process was about to recovering all inside, maintaining the original structure and design and giving the theatre the essential profissional equipment for the performances.
After 1992, TeCA – Carlos Alberto Theatre delivered his manegement to S. João National Theatre, and both halls passed to be ruled only by a entity.

As main objective, S. João National Theatre tries to experiment contemporanean scenic languages exercise that are able to give to the audience classical or contemporanean dramaturge patrimonium texts.

Image 14
S. João National Theatre hall

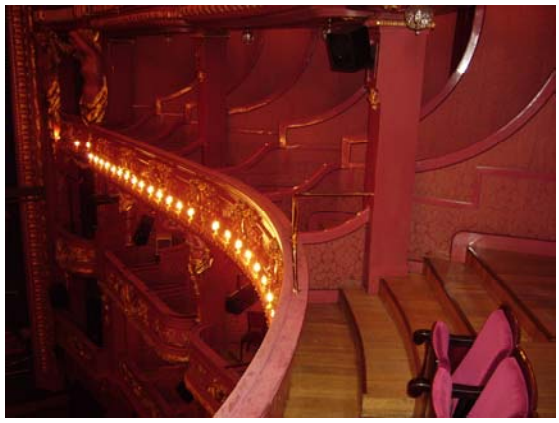


Image 15
S. João National Theatre boxes

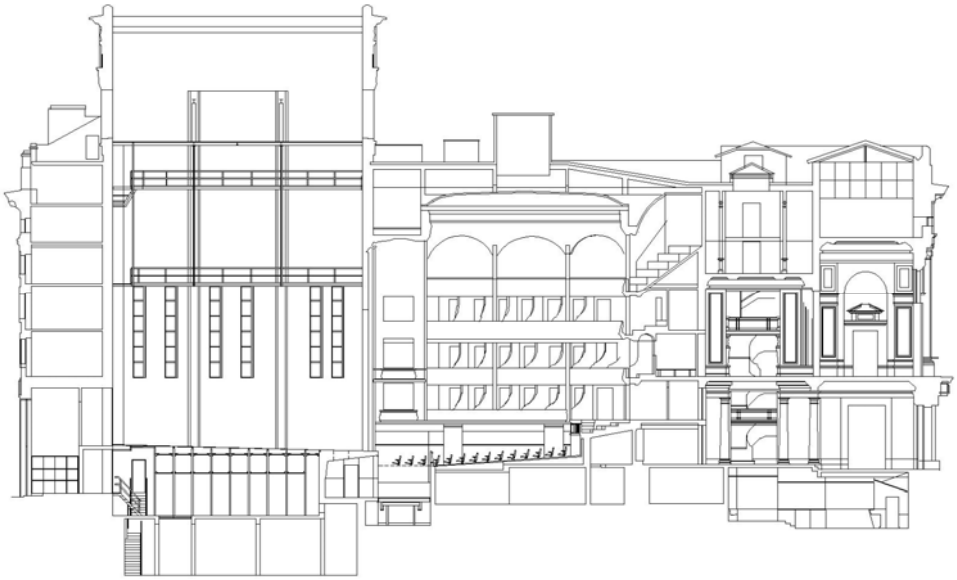


Image 16

S. João National Theatre architectural Cut.

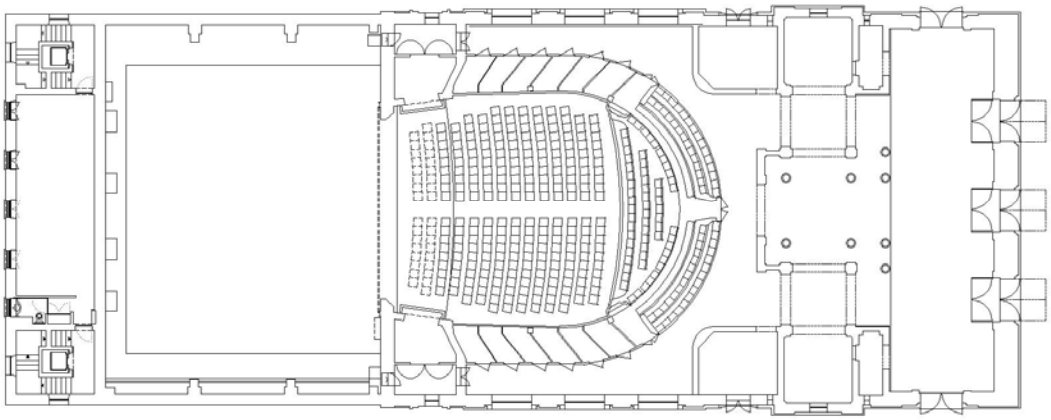


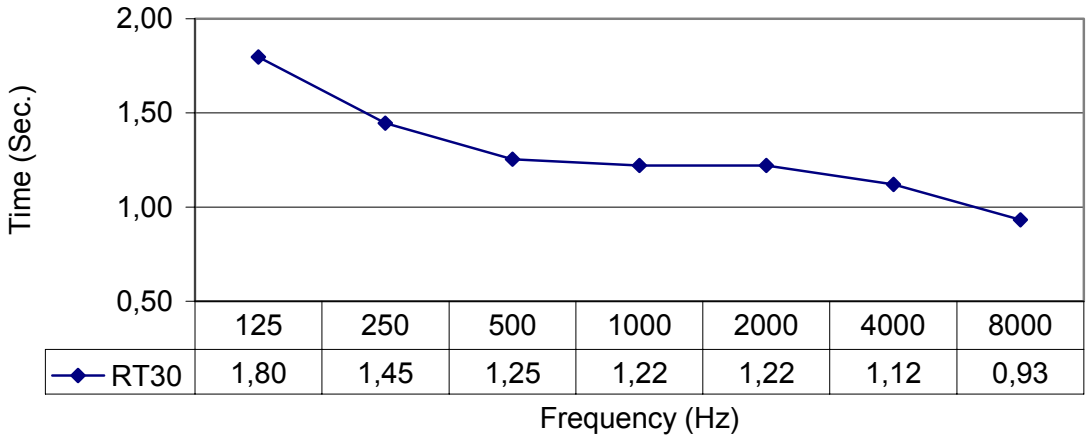
Image 17

S. João National Theatre architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,80	1,45	1,25	1,22	1,22	1,12	0,93
	EDT (s)	1,57	1,30	1,18	1,21	1,15	0,99	0,81
	C80 (dB)	1,4	2,3	2,9	2,4	3,8	3,6	5,0
	D50 (%)	36	47	49	43	55	54	59
	Tc (ms)	113	88	77	84	68	70	59
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	2,6	8,4	7,6	7,2	5,8	6,5	8,6
	D50 (%)	63	87	83	84	79	81	85

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,24	1,19		1,31	0,95
V		N		STI
Volume		Seats		0,58
2603		600		
S_A	S_0	S_{pit}		S_T
120	180	36		337
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6})$
4,3	0,2		7,7	$4,59^{-10}$

Reverberation Time



5. XIXth Century Theatres

5.1. D. Maria II National Theatre

The D. Maria II National Theatre opened at 13th April of 1846 during the Queen D. Maria II aniversary commemorations, which was presented the history drama of "*O Magriço e os doze de Inglaterra*" an original piece of Jacinto Aguiar de Loureiro.

The romantic ambience that was established, those days, all around europe, determined the urgency to find a model and a dramaturge national reportory, in order to define the national identity of Portugal. In other words, the forthcoming of a National Theatre (and his related reportory) was not only a cultural matter, but politic as well, related with the independence of portuguese nation.
The theatre was placed in the old leavings of Estaús Palace and had as Architec the italian Fortunato Lodi to project and execute it.

During a large period of time, D. Maria II National Theatre was ruled by artists societies. The longest manegement was by Amélia Rey Colaço/ Robles Monteiro from 1929 to 1964.

In that year the theatre was victim of a great fire that destroyed the main structure except the exterior walls. The building that we know today was totally reconstructed, according to neocalssic original style and opened his doors in 1978.
In March of 2004, the D. Maria II National Theatre passed to an Anonimous Society of the portuguese state supervisioned by the *Ministério da Cultura* and *Ministério das Finanças*.

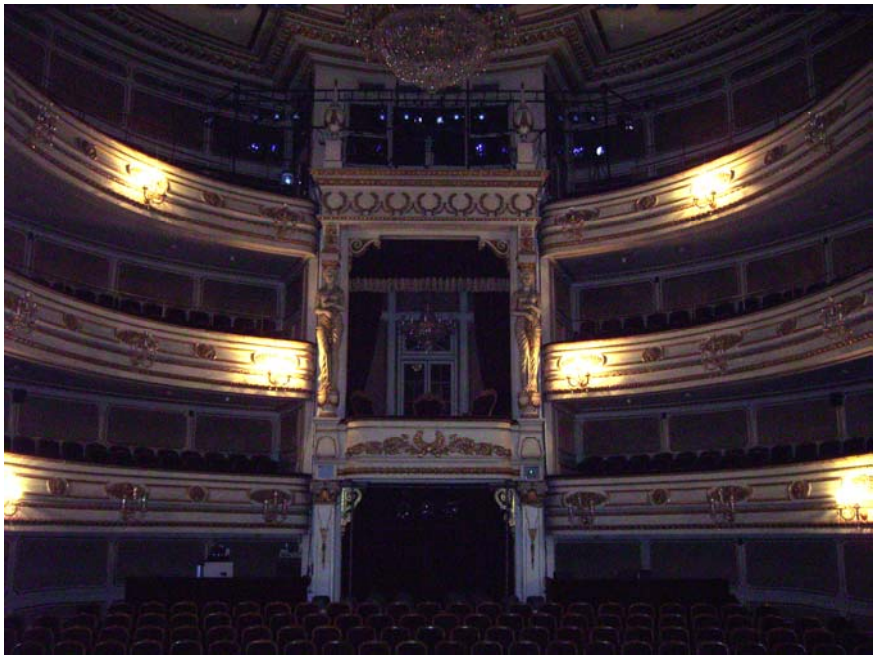


Image 18
D. Maria II National Theatre hall.

Image 19
D. Maria II National Theatre boxes

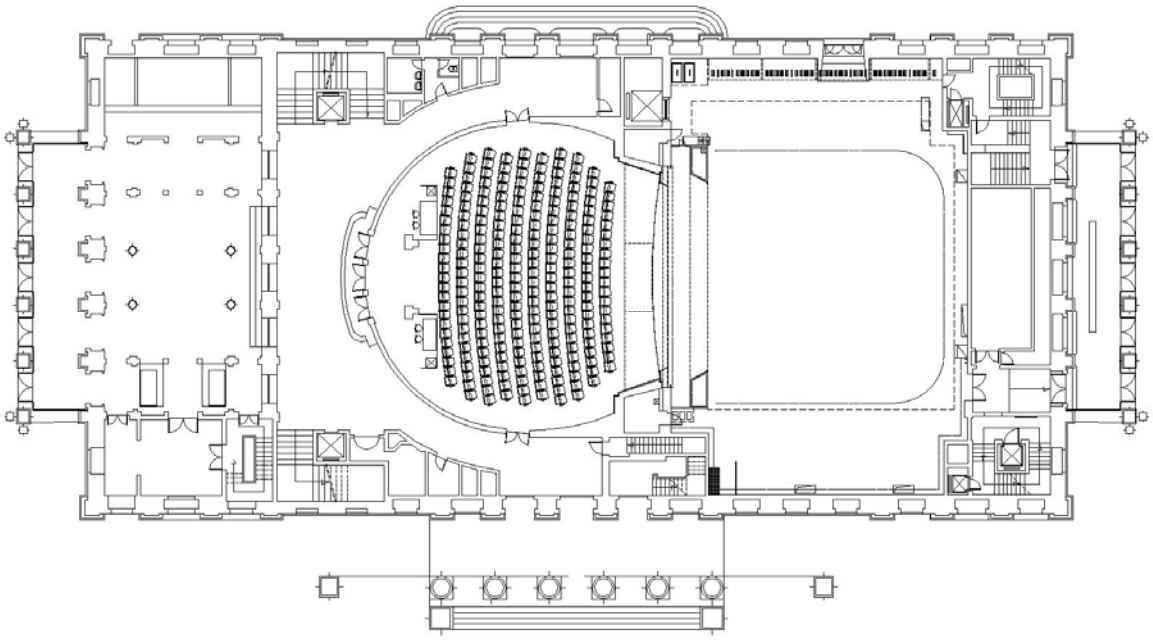


Image 20
D. Maria II Theatre architectural plant.

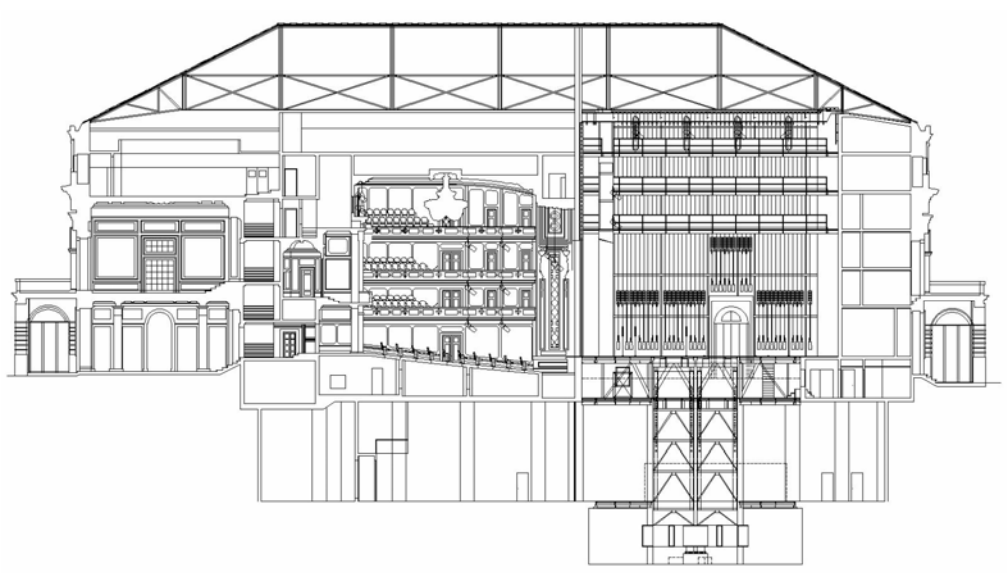
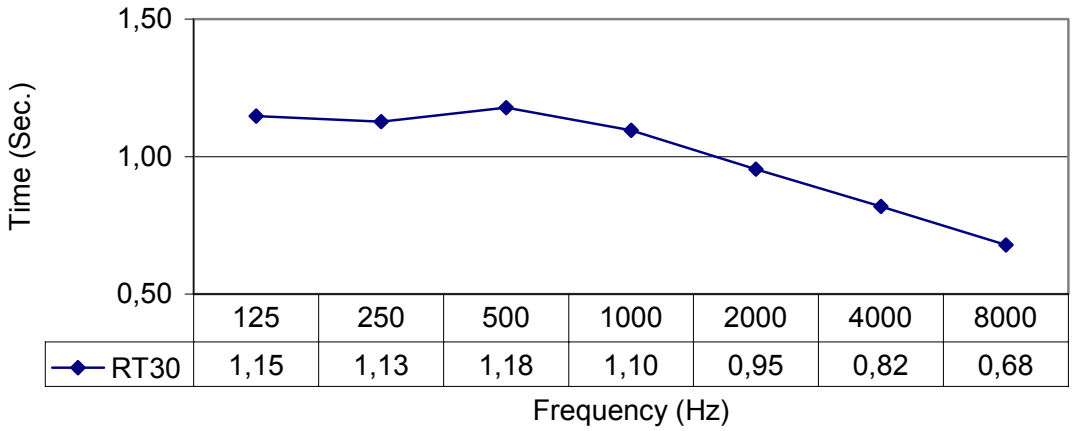


Image 21
D. Maria II Theatre architectural Cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,15	1,13	1,18	1,10	0,95	0,82	0,68
	EDT (s)	1,25	1,11	1,13	1,06	0,95	0,81	0,67
	C80 (dB)	1,0	3,9	3,1	3,6	4,8	7,7	9,6
	D50 (%)	40	55	51	51	60	74	79
	Tc (ms)	99	68	74	69	57	36	29
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	3,2	8,0	6,0	7,0	8,5	7,0	8,2
	D50 (%)	65	87	80	83	87	81	84

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,13	1,09		1	0,78
V		**N**		**STI**
Volume		**Seats**		0,63
2549		600		
S_A	S_0	S_{pit}		S_T
180	180	30		390
V/N	**S_A/N**		**V/S_T**	**EDT/(Vx$10^{6)}$**
4,25	0,30		6,53	4,28 $^{-10}$

Reverberation Time



5.2. Garcia Resende Theatre

Garcia Resende Theatre was opened on 1st of June of 1892 by the sponser Dr. Francisco Eduardo Fragoso and the Director Eng. Adriano de A. S. Monteiro, at that time.

The theatre´s architecture and decoration is italian Barroc. It present some anwsers to the scene traditions problems that were not resolved in the beggining of the XXth century. The hall axis, in horse-shoe shape, is perpendicular to the stage. Like the Recreios Coliseum and S. Carlos National Theatre (both in Lisbon) the most important seat is in front of the stage, below the arabean inspiration horse-shoe arc. From there, the hall is organized in hierarchic scale: the stalls, boxes and gallery (wich are not in use nowadays).

The capacity of this theatre is for 473 people. The floor inclination in the stalls area allows the principal actor to be seen in his totallity (all of his body), an innovation solution for a problem in that time. The mouth boxes were for special people use: in the opera performances, the singers usually come to the apron stage to interpretate principal arias.

What concerns to decoration, the stage curtain was painted “in four hands” by João Vaz (monuments and architecture) and António Ramalho (conception, drapery and figures). The ceilling, where the comedy and the tradegy are represented, surrounded by muses and genious, among clows, while in the center the name “*Garcia Resende*” remains in a Manueline armilar sphere, was painted by A. Ramalho.
The stage of Garcia Resende Theatre is one of the most biggest stages of old theatres in Portugal, predicted from the beggining to welcoming several national and forieg programmings.

Image 22

Garcia Resende Theatre Hall

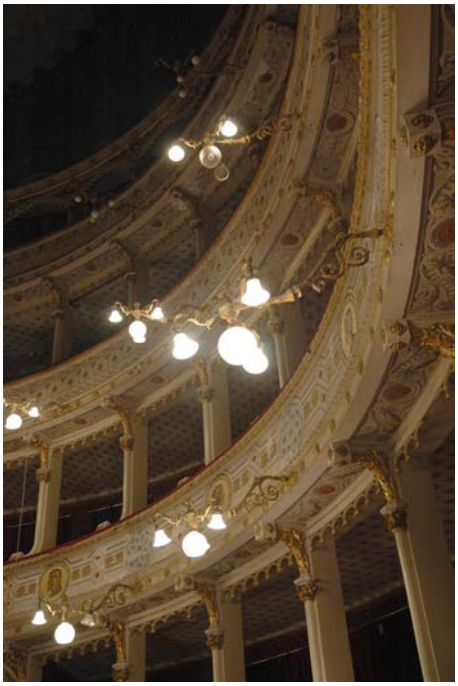


Image 23

Garcia Resende Theatre boxes and stage view.

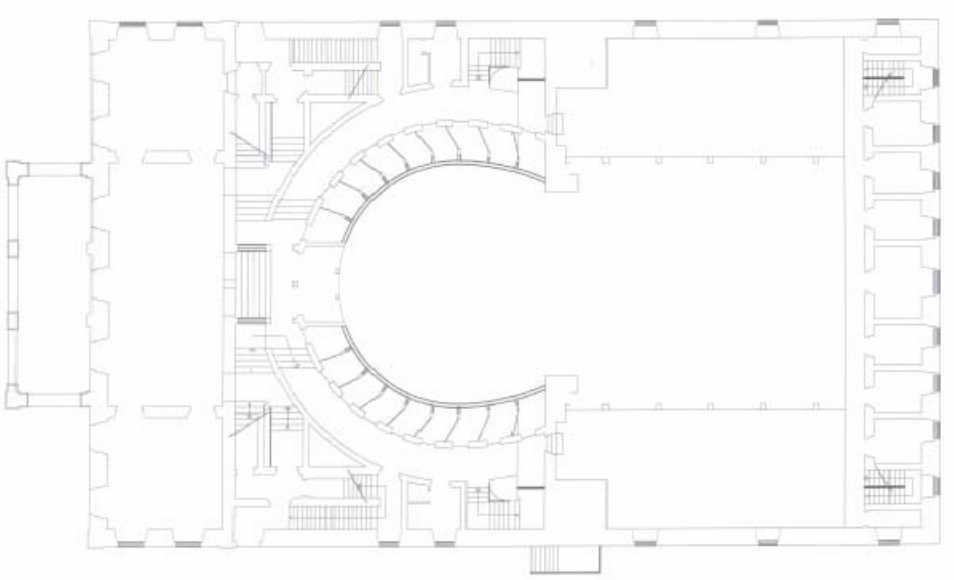


Image 24

Garcia Resende Theatre architectural plant.

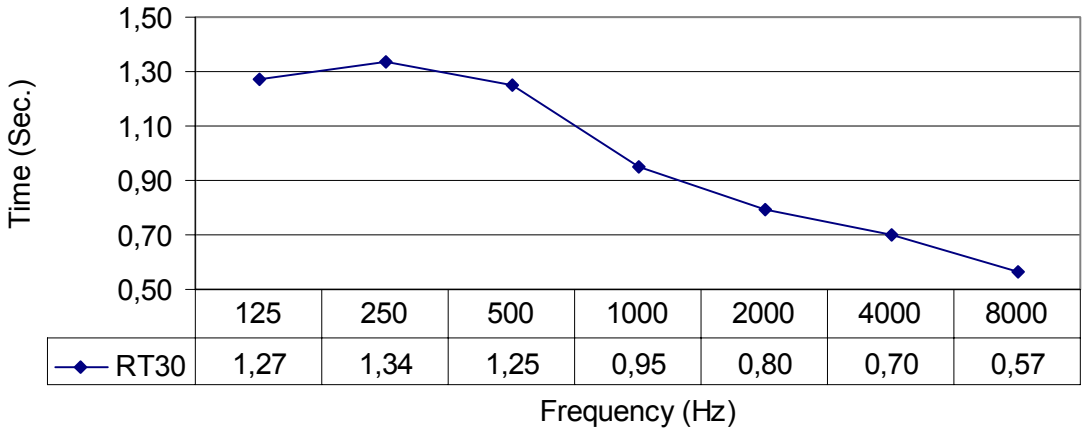
Image 25

Garcia Resende Theatre architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,27	1,34	1,25	0,95	0,80	0,70	0,57
	EDT (s)	0,99	1,03	0,94	0,71	0,70	0,56	0,47
	C80 (dB)	4,2	4,4	4,3	5,7	6,5	8,0	10,4
	D50 (%)	51	59	57	59	67	70	79
	Tc (ms)	77	68	66	58	50	43	33
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	4,1	7,7	8,4	9,5	10,5	11,9	13,1
	D50 (%)	72	85	85	88	91	93	94

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,10	0,83		1,19	0,68
V		N		STI
Volume		Seats		0,67
1577		500		
S_A	S_0	S_{pit}		S_T
98	143	-		241
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6})$
3,15	0,20		6,55	$5,23^{-10}$

Reverberation Time



5.3. Sá de Miranda Municipal Theatre

Sá de Miranda Municipal Theatre opened in 29th of April of 1885. The theatre construction started by the hand of several important persons of Viana do Castelo city in 1979 – Companhia Vianense.

Projected by the Architec José Geraldo da Silva Sardinha, the Sá de Miranda Municipal Theatre is an italian theatre with horse-foot shape, with na área of stalls and three levels of boxes. This hall has a capacity for 400 people.

The stage curtain was design by Luigi Manini and painted by Hercole Labertini, S. Carlos national Theatre scenographers. The ceilling, with the image´s sky in "*tromp l´oil*" with dramaturge portrait, was painted by João Baptista do Rio.

This theatre, a great ex-libris of Vianense and Alto-Douro cultur, has received the most important music, theatre, opera and dance performances.

Image 26

Sá de Miranda Theatre stage view.

Image 27

Sá de Miranda Theatre boxes.

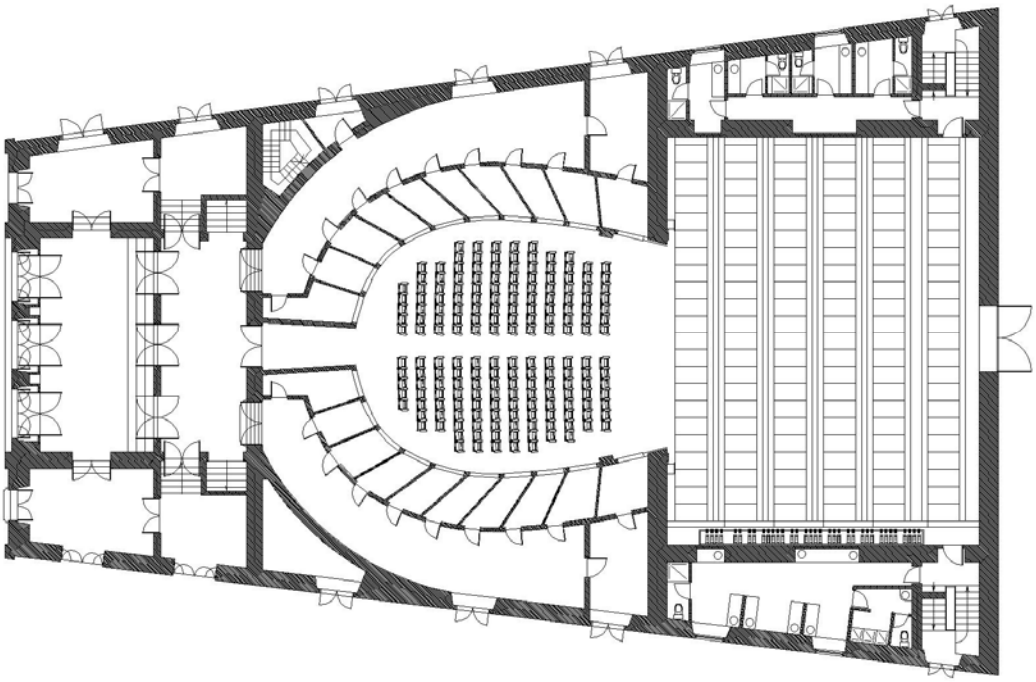


Image 28

Sá de Miranda Theatre architectural plant.

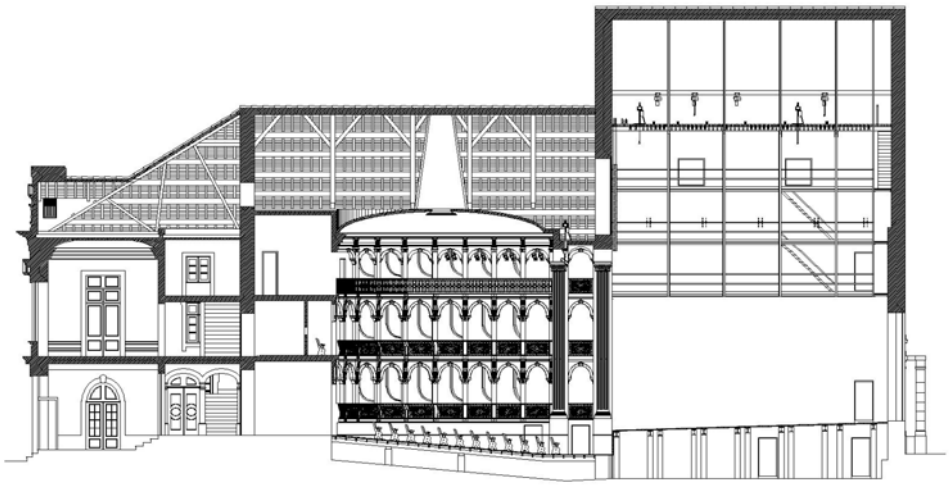
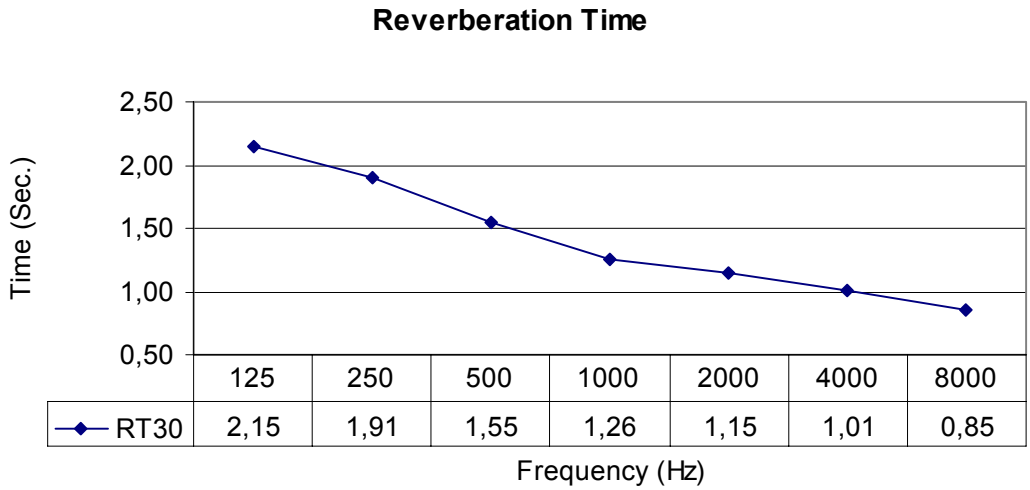


Image 29

Sá de Miranda Theatre architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,15	1,91	1,55	1,26	1,15	1,01	0,85
	EDT (s)	1,94	1,69	1,41	1,29	1,20	1,07	0,91
	C80 (dB)	0,3	0,7	1,9	3,5	3,4	5,3	7,7
	D50 (%)	42	42	49	58	55	66	77
	Tc (ms)	133	113	90	70	71	51	33
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	0,7	6,5	5,7	8,2	9,7	10,8	12,2
	D50 (%)	53	81	78	85	90	91	92

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,41	1,35		1,44	0,77
V		**N**		**STI**
Volume		**Seats**		0,58
1815		400		
S_A	S_0	S_{pit}		S_T
107,2	137,9	-		245,0
V/N	**S_A/N**		**V/S_T**	**EDT/(Vx$10^{6)}$**
4,54	0,27		7,41	7,42 $^{-10}$



5.4. São Luiz Municipal Theatre

S. Luiz Municipal Theatre opened in 22th May of 1894 and was first called Teatro D. Amélia, a tribute to the Portugal Queen in the end of the XIXth Century. At that time, the theatre received the most important art figure (persons) and theatre companies of europe.

After 1910, with the monarchy fall, the republic started in the theatre, a new art policy until 1930, where several important artists acted there, like: Eduardo Brazão, Rosa Damasceno, Ângelo Pinto, Adelina Abranches, Palmira Bastos and Amélia Rey Colaço. In those days the theatre discovered the modernism by the hand of the painter Almada Negreiros and the writer Fernando Pessoa.
In 1918, in tributte to a man that changed the theatre into a great cultural centre in Lisbon, the named changed to S. Luiz Theatre, where during the next years was the attraction of many great movies of XXth century.

After 1971, the Lisbon town council bought the theatre and started a serie of new performances by a resident company leadered by Eunice Muñoz and Luís Francisco Rebelo. Some years later, in 1980, one of the greatest portuguese FADO artist – Amália Rodrigues – returned to this hall to tributte the city of Lisbon.
However, the S. Luiz Municipal Theatre had to close his doors and after some reconstructions, maintaining the original design, opened in 2002. The main objective of this hall is to present a multidisciplinary and diversify performing arts: dance, theatre and music, among others.

Today, the theatre is a cultural centre dedicated to arts with 3 stage. Main hall, winter garden and Teatro-Estudio Mário Viegas.
In April of 2003, the manegement of S. Luiz Municipal Theatre passed to EGEAC E.M..

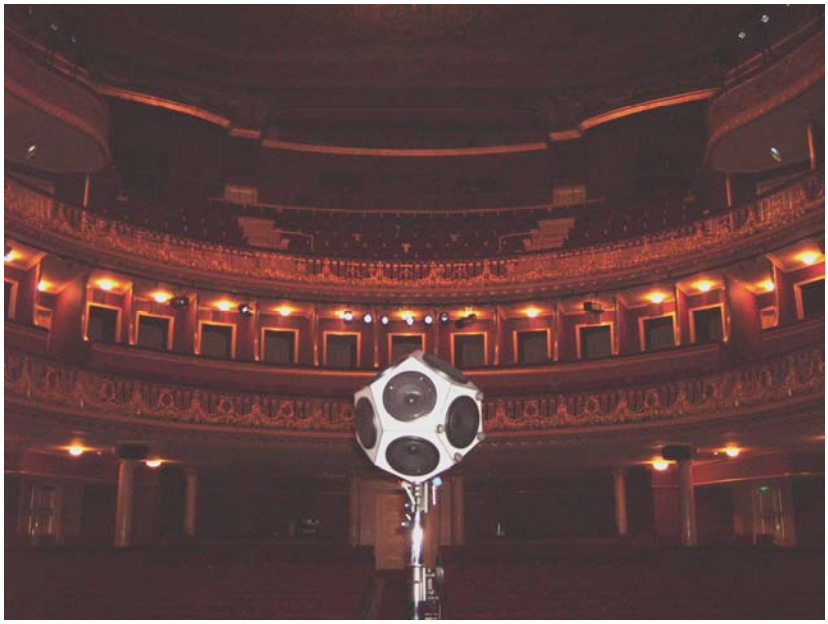


Image 30

S. Luiz Theatre stage view during the measurements.

Image 31

S. Luiz Theatre stage balcony view and boxes respectiely.

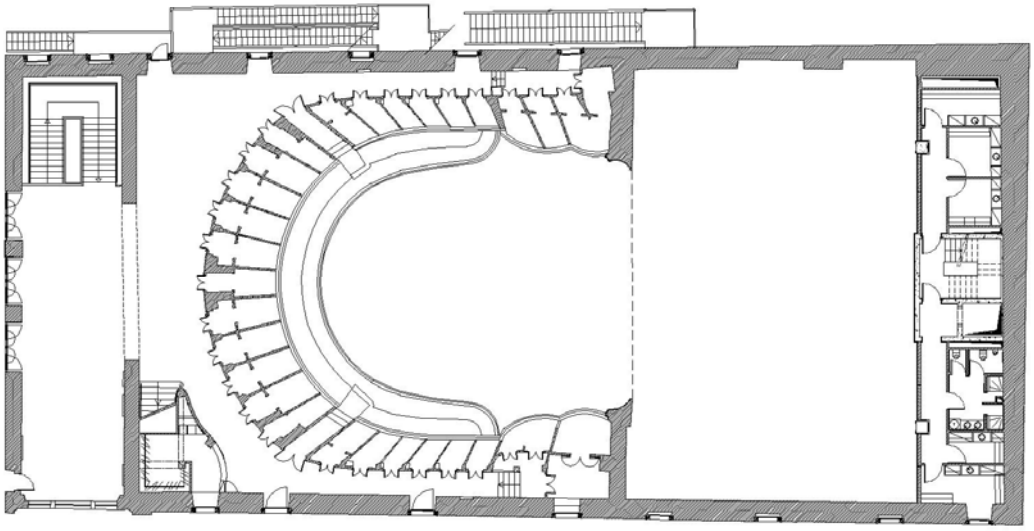


Image 32

S. Luiz Theatre architectural plant.

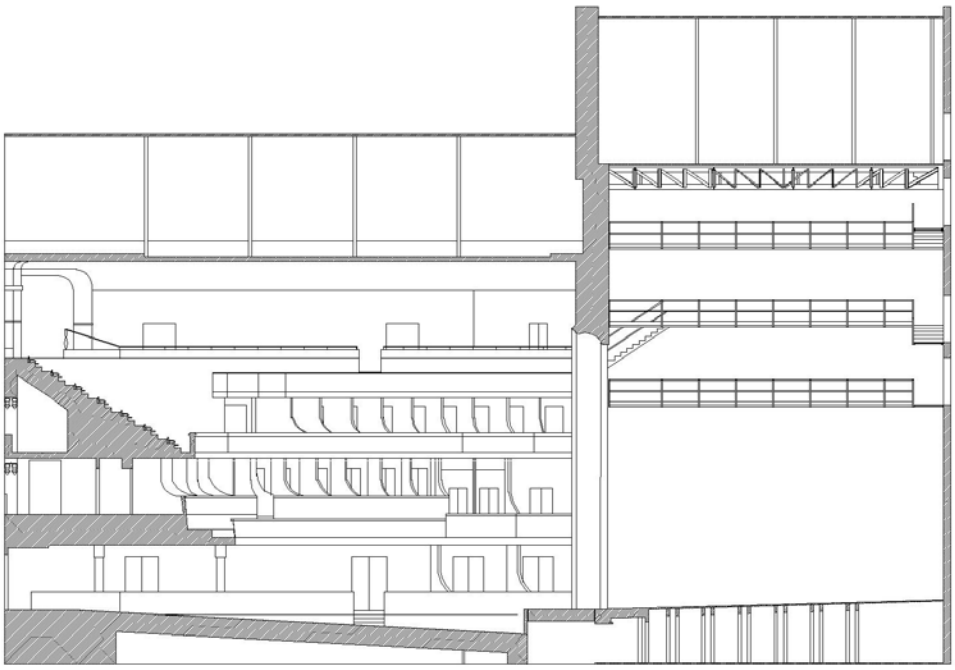


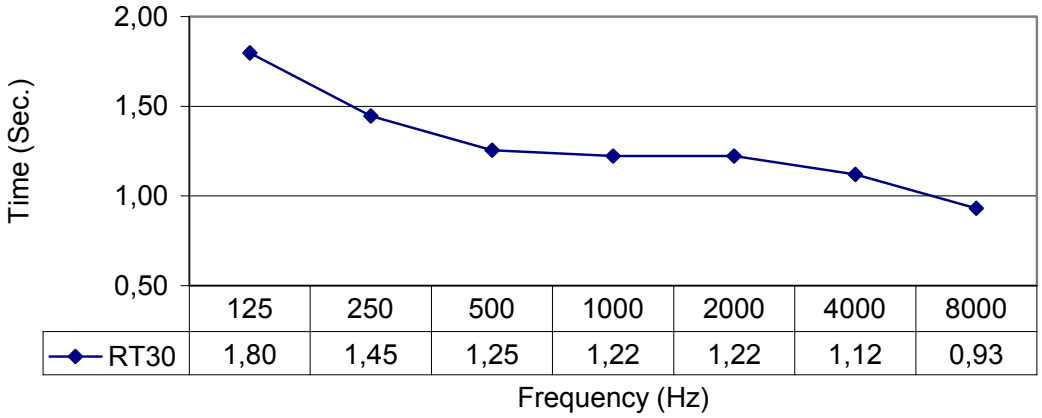
Image 33

S. Luiz Theatre architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,10	1,82	1,52	1,37	1,24	1,08	0,86
	EDT (s)	1,95	1,48	1,29	1,13	1,06	0,93	0,71
	C80 (dB)	-1,2	2,2	2,4	2,8	3,5	4,4	6,0
	D50 (%)	26	42	44	48	52	56	62
	Tc (ms)	143	101	89	83	73	65	54
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	1,4	9,1	8,9	9,9	8,9	8,2	10,1
	D50 (%)	58	89	88	90	88	84	88

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,44	1,19		1,37	0,80
V		N		STI
Volume		Seats		0,58
3630		730		
S_A	S_0	S_{pit}		S_T
140	160	30		330
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6)}$
4,9	0,2		10,9	$3,27^{-10}$

Reverberation Time



5.5. Trindade Theatre

Placed in one of the most ancient zones of Lisbon – between Chiado and Bairro Alto – the Trindade Theatre was built in the XIXth Century, where the social and cultural centre was placed exactly in that zone, as well as S. Carlos National Theatre and S. Luiz Municipal Theatre.
This theatre was the first in Portugal to have a balcony and an arena (stalls zone) that can elevate to the stage level, in order to organize state-balls. In the end of the XIXth century the Trindade Theatre was the most rich Lisbon hall.
It was Francisco Palha that ordered the theatre construction and the design by Architec Miguel Evaristo de Lima Pinto. The hall opened in 1867 with the "*A Mãe dos Pobres*" an Ernesto Biester piece and "*O Xerez da Viscondesa*" comedy.
From the beggining of his inauguration, Trindade Theatre is related to several Lisbon history cultural moments.

After 1930 the theatre, as well as many concert halls in the country, passed to perform cinema sessions. From the 40´s to 60´s the theatre received several national and foreign performing arts companies. In 1962 the Trindade Municipal Theatre is adquired by FNAT and it was completely remodelated and renovated. At that time, it was created the "*Companhia Portuguesa de Ópera*" directed by Dr. Serras Formigal.
Nowadays, the building of Trindade Theatre is divided in different points of performances exibition and other events: Main hall, *Sala Estúdio, Teatro Bar* and Noble Hall.

Today it has a capacity for 600 people and according to the theatre direction is one of the most conserved italian theatres in the country, with virgin concrete and iron structure elements and an unique scene machinery, this theatre belongs to the portuguese arqueology patrimonium theatres.

Image 34

Trindade Theatre hall.

Foto by Clementina Cabral.

Image 35

Trindade Theatre above the 1st Balcony and stage view.

Foto by Clementina Cabral.

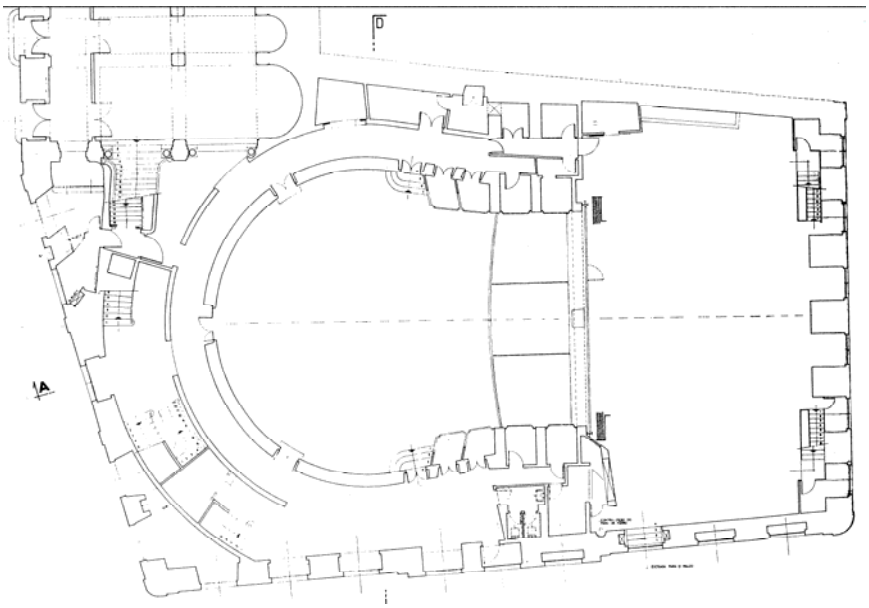


Image 36
Trindade Theatre lotation plant.

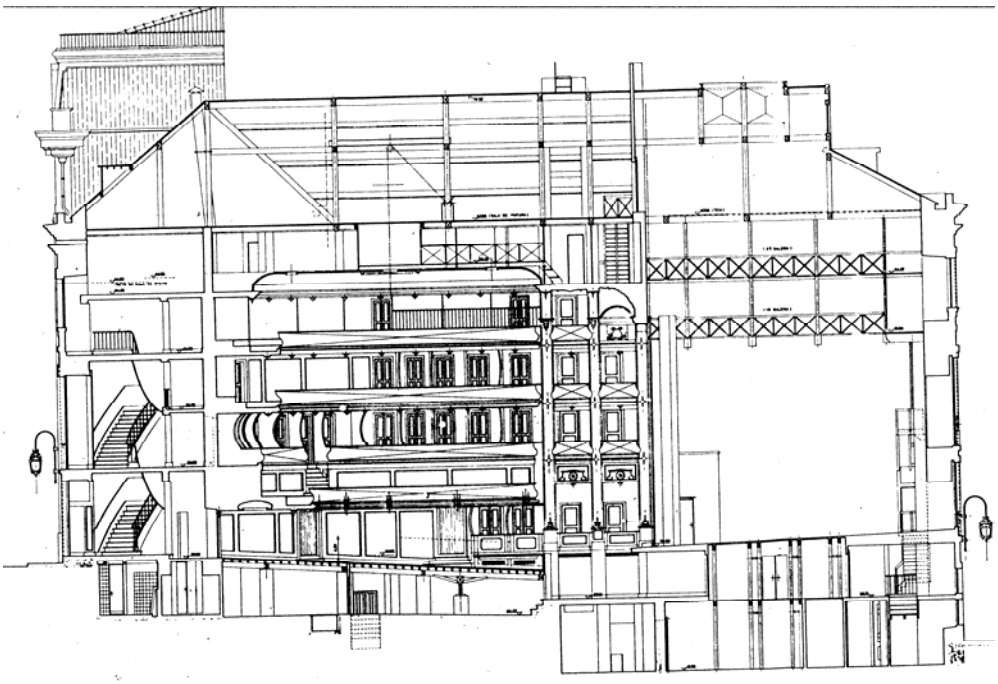
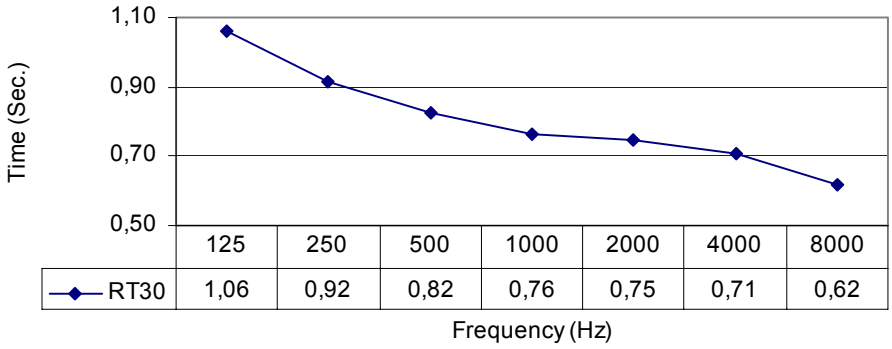


Image 37
Trindade Theatre architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,06	0,92	0,82	0,76	0,75	0,71	0,62
	EDT (s)	0,95	0,82	0,70	0,72	0,64	0,61	0,54
	C80 (dB)	5,0	6,0	6,8	6,5	8,5	8,7	9,3
	D50 (%)	58	61	63	66	74	72	70
	Tc (ms)	66	57	49	49	37	39	39
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	2,1	9,8	5,4	9,9	11,4	9,1	9,1
	D50 (%)	61	90	78	90	93	88	87

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
0,79	0,70		1,26	0,92
V		N		STI
Volume		Seats		0,69
2212		600		
S_A	S_0	S_{pit}		S_T
146,8	96	44,8		287,6
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6})$
3,69	0,24		7,69	$3,18^{-10}$

Reverberation Time



5.6. Viriato Theatre

The Viriato Theatre opened in the end of the XIXth century in 13th june of 1883 with the name of Theatro Boa União.
The performing piece at the openning cerimony was "*O Paralytico*" by the Oporto company "*Companhia de Teatro*". After 1889, the theatre passed the name to Viriato Theatre.
Some years later, the theatre served to received performing art pieces, but mainly cinema, to satisfy the Viseu audience.

After 1960, the theatre closed his doors, due to the sucess of another theatre in Viseu´s down town – *Avenida Teatro*. With a bigger capacity than Viriato theatre, *Avenida Teatro* soon became the most attractive cultural centre in Viseu.
Twenty five years later, Viriato Theatre opened for a single peformance of Ricardo Pais "Teatro de Enormidades apenas Críveis à Luz Eléctrica", with the support of *Fundação Calouste Gulbenkian*, Viseu Council and *Governo Civil de Viseu*. It was a glorious night, reminding the theatre past life.

After this moment, between 1989 and 1997, the Viseu Council adquire the hall and made deepest reconstructions in order to prepare the theatre to modern performing arts.

In 1996 Viriato Theatre re-opened again to Viseu audience with the direction of Paulo Ribeiro, after one century of his initial overture.
The hall offer to Viseu city a regular acess to performing arts, positioning the city in the national and international artistics performances rout.

Image 38
Viriato Theatre hall and boxes. Foto byJosé Alfredo

Image 39

Viriato Theatre stage view.

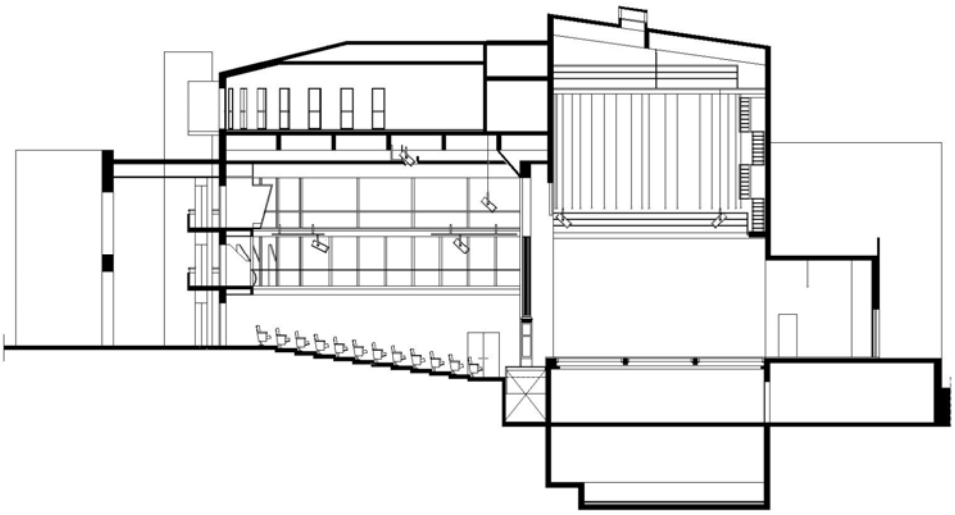


Image 40

Viriato Theatre architectural cut.

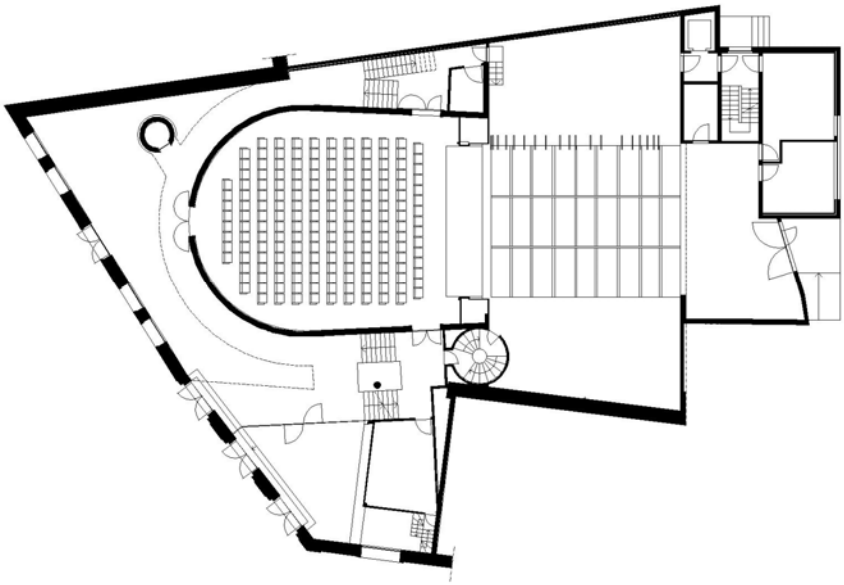


Image 41

Viriato Theatre architectural plant.

1. Orchestra Configuration: Acoustic Shell on Stage

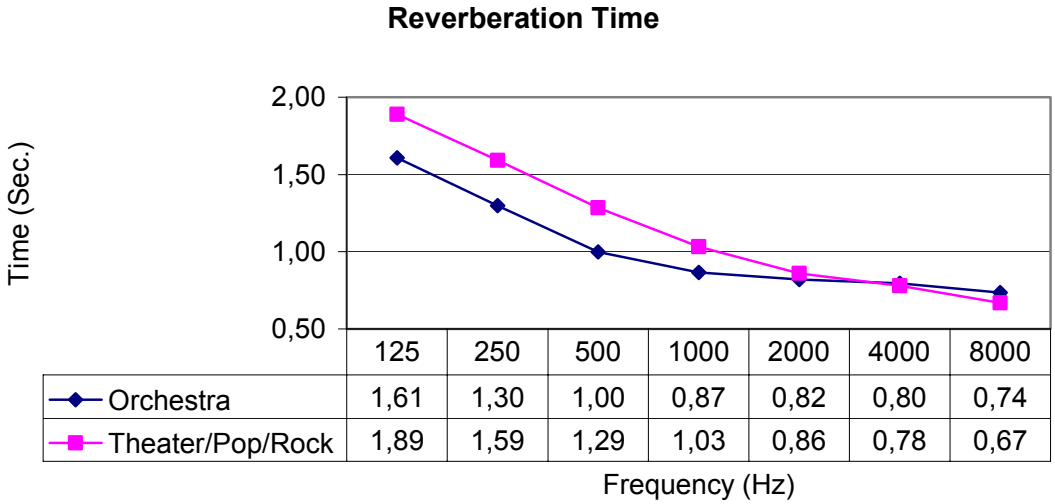
		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,61	1,30	1,00	0,87	0,82	0,80	0,74
	EDT $_{(s)}$	0,80	0,67	0,79	0,80	0,79	0,84	0,70
	C80 $_{(dB)}$	6,2	7,1	5,0	5,0	5,5	5,0	6,6
	D50 $_{(\%)}$	54	66	60	58	61	60	68
	Tc $_{(ms)}$	73	53	61	62	56	59	50
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	5,5	7,1	5,8	7,8	7,7	5,9	7,5
	D50 $_{(\%)}$	78	83	79	86	85	79	85

Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
0,93	0,76	1,55	0,86

2. Theatre Configuration:

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,89	1,59	1,29	1,03	0,86	0,78	0,67
	EDT $_{(s)}$	1,25	1,02	0,85	0,77	0,73	0,73	0,69
	C80 $_{(dB)}$	3,2	4,7	4,8	5,4	6,1	6,9	8,2
	D50 $_{(\%)}$	54	65	61	60	68	73	78
	Tc $_{(ms)}$	97	64	66	59	50	42	33
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	-2,0	5,4	3,9	5,0	6,1	7,4	10,2
	D50 $_{(\%)}$	39	77	70	75	80	84	91

Seconds				
RT_{mid}	**EDT_{mid}**		**BR**	**Br**
1,15	0,79		1,51	0,71
V		**N**		**STI**
Volume		**Seats**		0,65
1364		252		
S_A	***S_0***	***S_{pit}***		**S_T**
107,1	83,5	15		205,6
V/N	**S_A/N**		**V/S_T**	**$EDT/(Vx10^{6)}$**
5,41	0,4		6,64	$5,81^{-10}$



	125	250	500	1000	2000	4000	8000
Orchestra	1,61	1,30	1,00	0,87	0,82	0,80	0,74
Theater/Pop/Rock	1,89	1,59	1,29	1,03	0,86	0,78	0,67

6. XXth Century Theatres

6.1. Aveirense Theatre

The Aveirense Theatre opened in 1881 with the "*Companhia de Teatro Nacional D. Maria II*" after the constitution of "*Sociedade Construtora e Administrativa do Teatro Aveirense*", in 1879, in Aveiro city.
The theatre activity stoped in 1947 and after several and deepest contract jobs of remodelation and reconstruction the Aveirense Theatre re-started his activity in 1949.

In July of 1974, was born the "*Sociedade Teatro Aveirense*" and the interest of an aquisition by city council. However, the town hall aquisition just was possible on November of 1998. In June of 2000 the theatre close its doors and started another re-construction revolution in order to modernize its equipement and spaces. After 3 years, on 23th of October, the theatre re-opened with the supervision of Aveiro town hall (the actual owners and "*Rede Nacional de Teatro e Cine-Teatro*") and began a new age of cultural policy matter in the Aveiro city. At this time, the theatre is mainly a municipal space with excellent technical conditions and a profissional group of people in the art performances.

The main issue of this hall is to become a knowlege, wisdom and artistic cultural space and as an objective that the theatre allows the discovery of utopies and new imaginary and impulse the meeting of different comunities.
As a public service space, this theatre should present a diversity and regular programation to the Aveiro audience.

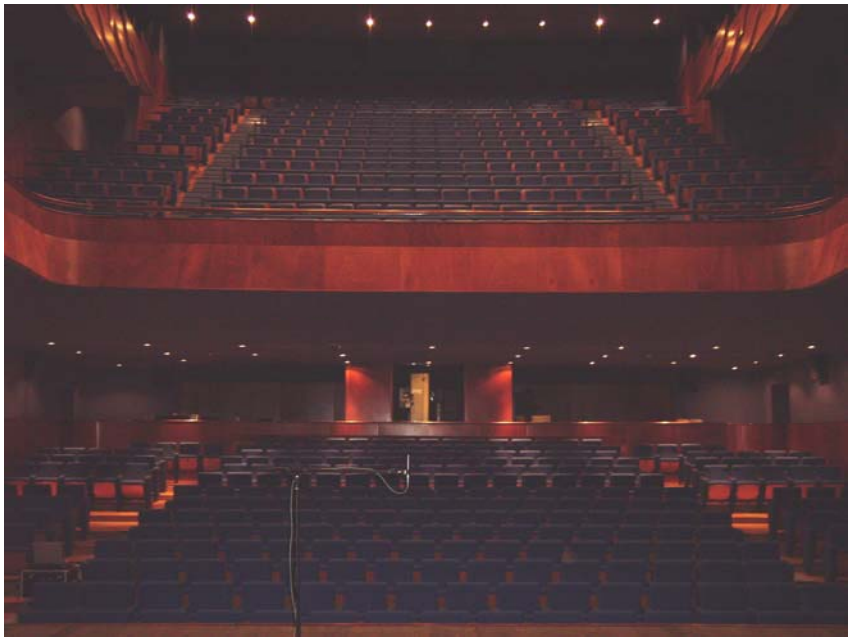


Image 42

Aveirense Theatre stage view during the measurements.

Image 43

Aveirense Theatre lateral balcony view.

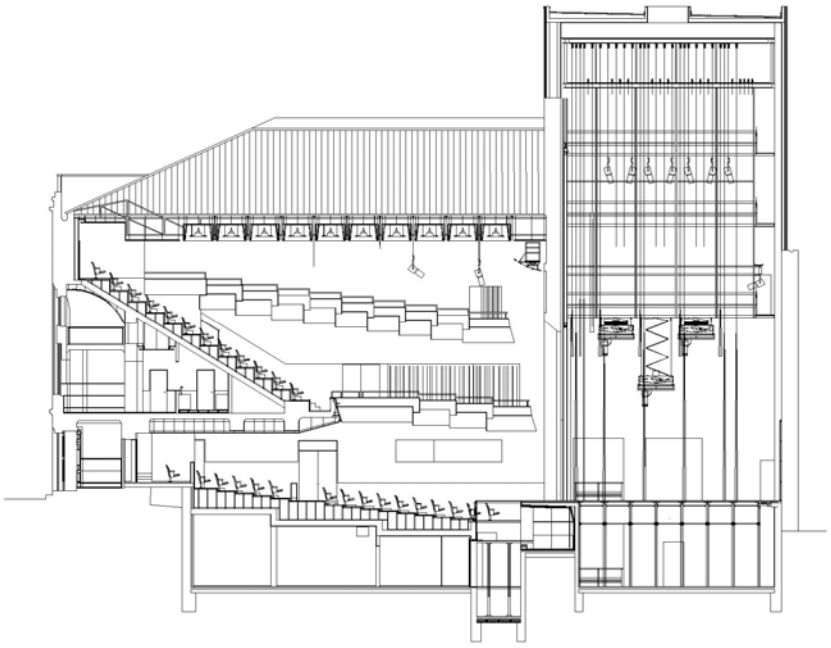


Image 44

Aveirense Theatre architectural cut.

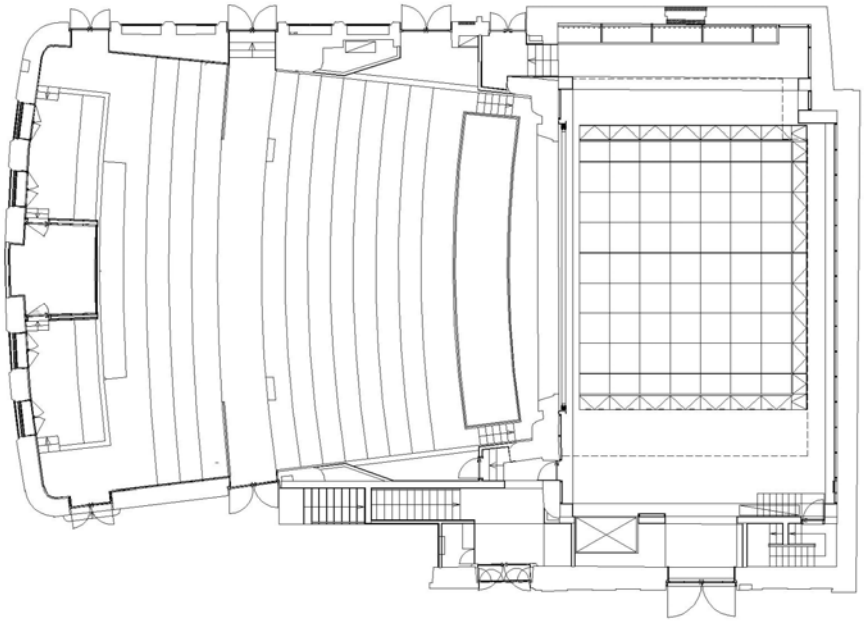


Image 45

Aveirense Theatre architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,41	2,23	1,90	1,42	1,13	1,00	0,86
	EDT (s)	1,89	1,56	1,21	0,91	0,85	0,76	0,63
	C80 (dB)	1,8	3,3	3,7	4,9	5,8	6,8	8,5
	D50 (%)	49	55	56	60	66	69	77
	Tc (ms)	115	89	77	63	53	46	38
	G (dB)	-	-	-	-	-	-	-
Balcony	C80 (dB)	2,8	3,3	2,9	3,8	3,4	4,9	6,1
	D50 (%)	48	51	52	58	53	60	65
On Stage	C50 (dB)	-2,0	4,7	4,6	6,2	7,5	8,5	9,6
	D50 (%)	38	73	74	79	84	87	89

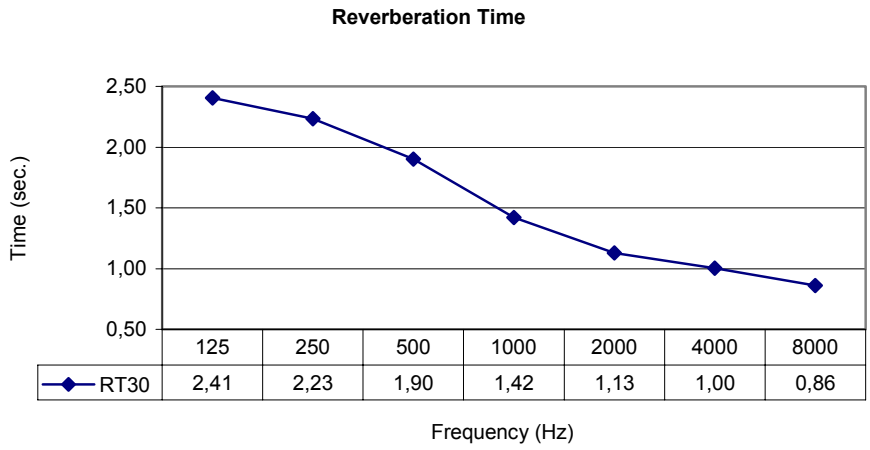
STI	
Audience	Balcony
0,63	0,60

Seconds			
RT_{mid}	EDT_{mid}	BR	Br
1,66	1,06	1,40	0,64

V	N
Volume	Seats
3422	663

S_A	S_0	S_{pit}	S_T
136	98,7	25	259,8

V/N	S_A/N	V/S_T	EDT/(Vx$10^{6)}$
5,16	0,2	13,17	$3,10^{-10}$



6.2. Bragança Municipal Theatre

Legend has it that the city of Bragança was founded by King Brigos, in 1906 b.C., giving it the primitive name of Brigância. Later on, it was dominated and rebuilt by the Romans, under the command of the emperor Augusto César, which changed its name to Juliobriga.

Bragança, a city of Trás-os-Montes, is located at 255km from Oporto and at 515 km from Lisbon. It is stuck between the northeastern mountains, at 700 metres of altitude, and the Spanish border, at 22 km.

Its location at the northeastern part of the country, forces Bragança to have a double geographic position, nationally and regionally. This position has been attenuated by the fact of being the region “capital”, what lead to a polarization about its external involvence as political, administrative and population centre. Bragança is the centre of some regional entities and associations and delegations and regional directions of the Central Administration.

Even tough, only with good accessibility and with the improvement of urban and environmental conditions, that promote its competitiveness, the localization of Bragança can stop being a constraint factor, to become a factor of potential development.

Image 46

Bragança Municipal Theatre stage view.

Image 47

Bragança Municipal Theatre hall.

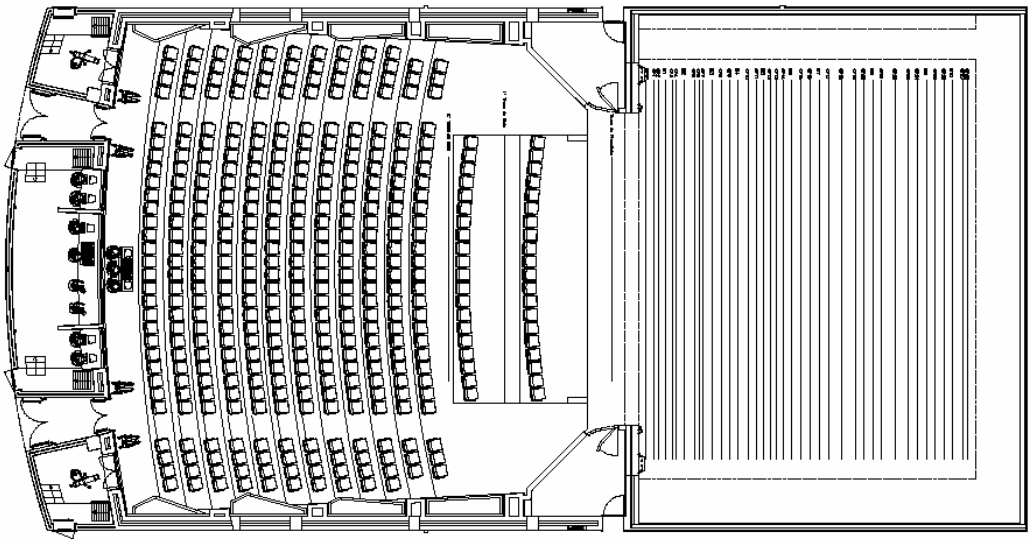


Image 48

Bragança Municipal Theatre architectural plant.

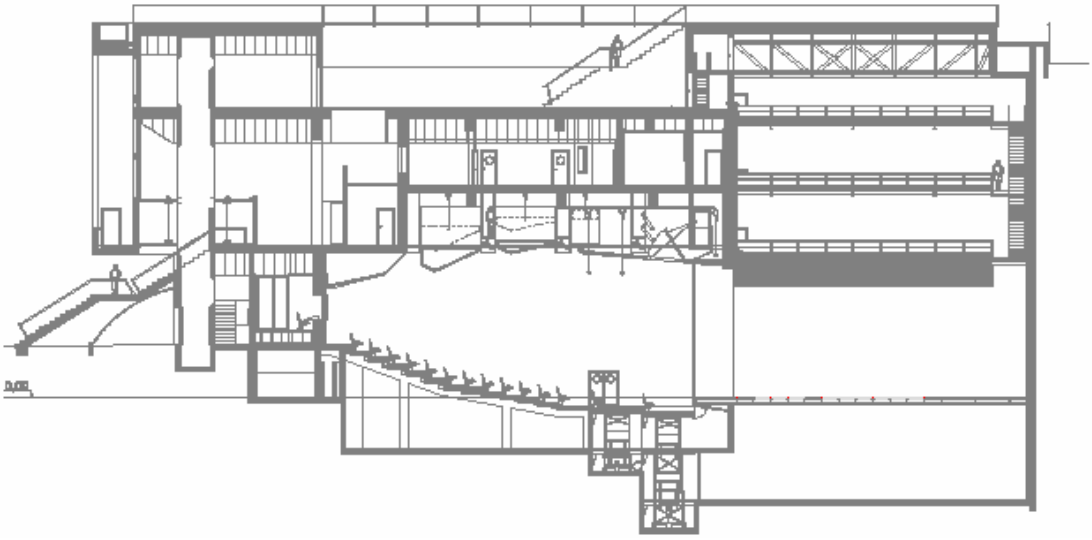


Image 49

Bragança Municipal Theatre architectural cut.

1. Small Orchestra Configuration: Saffety Curtain down

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,34	1,43	1,56	1,56	1,52	1,35	1,03
	EDT (s)	1,05	1,26	1,52	1,52	1,40	1,23	0,92
	C80 (dB)	2,3	2,7	1,9	2,6	1,7	2,3	5,1
	D50 (%)	40	45	46	50	43	47	62
	Tc (ms)	95	86	93	85	93	83	55
	G (dB)	-	-	-	-	-	-	-

2. Theatre Configuration - Unnocupied

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,29	1,25	1,37	1,35	1,34	1,19	0,94
	EDT (s)	0,99	1,10	1,29	1,30	1,23	1,12	0,88
	C80 (dB)	3,4	3,7	2,9	3,4	2,4	3,0	5,6
	D50 (%)	45	50	51	54	47	51	65
	Tc (ms)	86	75	77	72	82	73	50
	G (dB)	-	-	-	-	-	-	-

STI	Seconds			
	RT_{mid}	EDT_{mid}	BR	Br
0,57	1,37	1,29	0,94	0,93

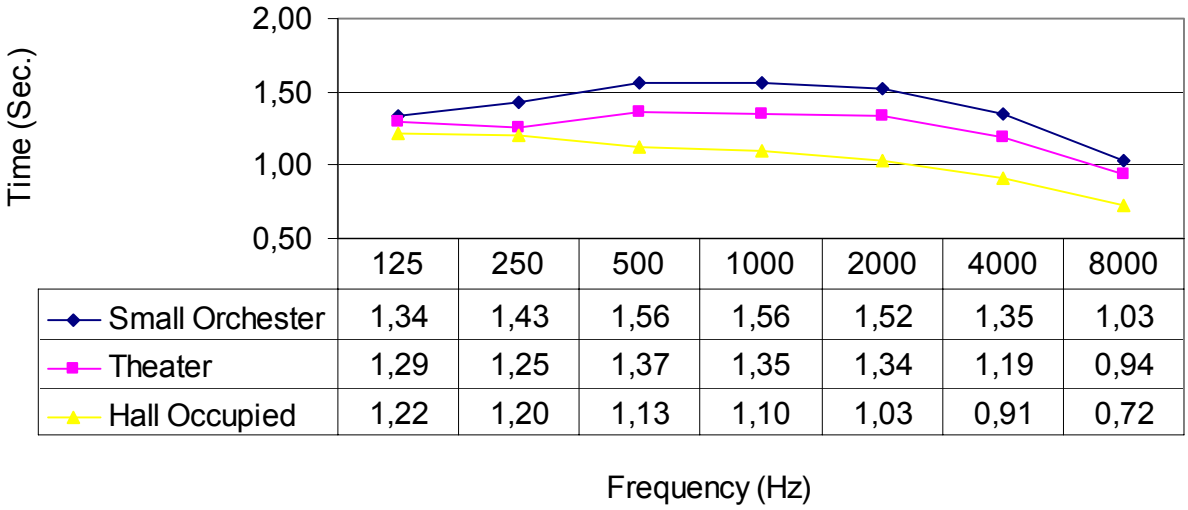
3. Saffety Curtain down – Hall Full Occupied

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,22	1,20	1,13	1,10	1,03	0,91	0,72
	EDT (s)	0,85	0,99	0,84	0,79	0,83	0,76	0,59
	C80 (dB)	3,5	3,2	4,7	4,8	5,1	5,1	7,1
	D50 (%)	55	50	56	56	60	54	59
	Tc (ms)	79	77	68	70	59	62	53
	G (dB)	-	-	-	-	-	-	-

STI	Seconds			
	RT_{mid}	EDT_{mid}	BR	Br
0,63	1,11	0,82	1,10	0,87

V			N	
Volume			**Seats**	
3274			400	
S_A	S_0	S_{pit}		S_T
282	180	72		534
V/N	**S_A/N**		**V/S_T**	**EDT/(Vx$10^{6)}$**
8,19	0,7		6,13	2,49 $^{-10}$

Reverberation Time



	125	250	500	1000	2000	4000	8000
Small Orchester	1,34	1,43	1,56	1,56	1,52	1,35	1,03
Theater	1,29	1,25	1,37	1,35	1,34	1,19	0,94
Hall Occupied	1,22	1,20	1,13	1,10	1,03	0,91	0,72

Frequency (Hz)

6.3. Camões Theatre

Camões Theatre appeared when the ideia of the realization of EXPO 98 came up in the new and reconstructed north area of Lisbon.

This theatre was, after his opening, offer to “Companhia Nacional de Bailado” (CNB). The “Companhia Nacional de Bailado” have presented since that year her regular programation in Camões Theatre, allowing the audience the opportunity to see in this hall classical productions as Gisele, A Dama das Camélias, the Nut-Cracker, among others.

The CNB presents also contemporanean program along the open seasons. Once the CNB develops a large and regular activity descentralization – by national tours, the theatre is also available for others dance companies.

The issue of Camões Theatre is to become in fact a dance space in Lisbon, consolidating the audience with the diversify programming. It is, also an objective, try to observe the young audience and assure a regular pedagogic programming.
In 2005 the theatre eceived *Companhia Olga Roriz, Companhia Portuguesa de Bailado Contemporâneo, Companhia de Dança Contemporânea (CDC), Companhia Benvindo Fonseca, Companhia Rui Lopes Graça, Companhia EgriBianco Danza* (Italia), among others.

The welcoming of portuguese dance companies it is considered very important and prescious to the portuguese culture.

The *Companhia Nacional de Bailado*/ Camões Theatre is a project in development with constant growing up, dinamic and quality.

Image 50

Camões Theatre Sound Technician view.

Image 51

Camões Theatre stage view.

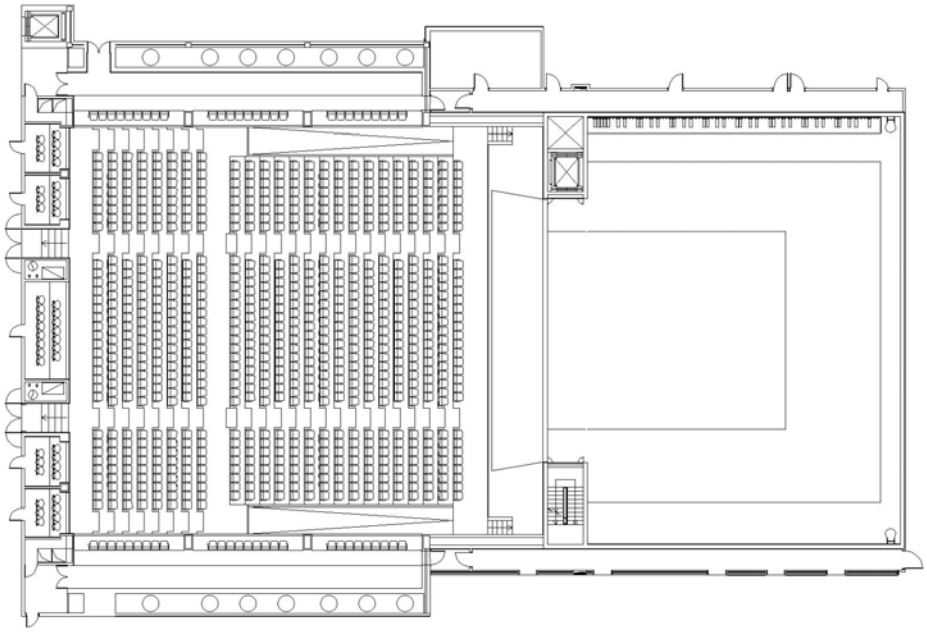


Image 52

Camões Theatre architectural plant.

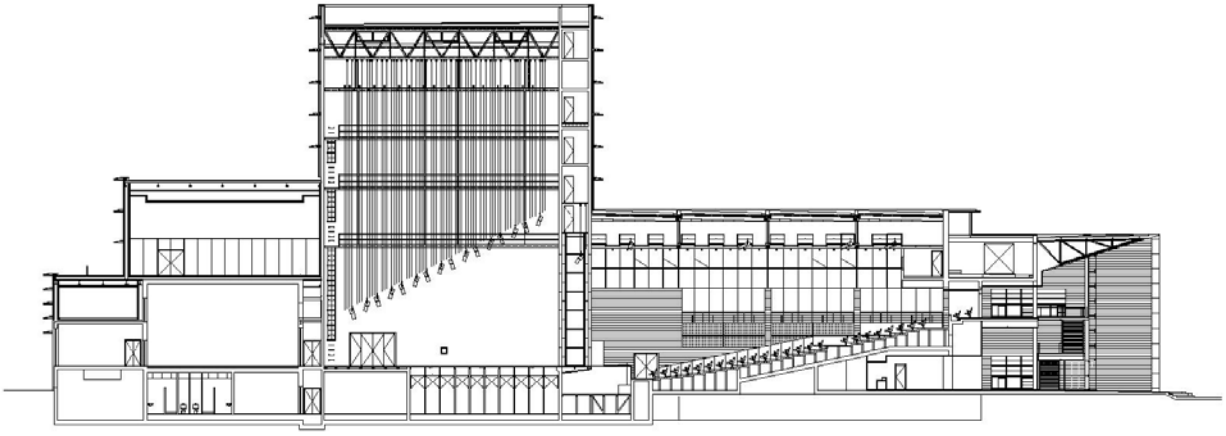


Image 53

Camões Theatre architectural cut.

1. Theatre Configuration

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	2,15	1,81	1,44	1,30	1,21	1,09	0,93
	EDT $_{(s)}$	1,09	1,19	1,19	1,03	0,99	0,84	0,73
	C80 $_{(dB)}$	3,5	2,7	1,7	0,5	3,6	3,2	3,3
	D50 $_{(\%)}$	52	52	48	40	57	51	49
	Tc $_{(ms)}$	85	81	82	85	63	67	65
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	0,8	1,9	5,0	8,1	7,8	6,2	4,6
	D50 $_{(\%)}$	54	60	75	86	86	79	71

STI	**Seconds**			
	RT_{mid}	**EDT_{mid}**	**BR**	**Br**
0,6	1,37	1,10	1,40	0,83

2. Conference Configuration: Saffety Curtain down.

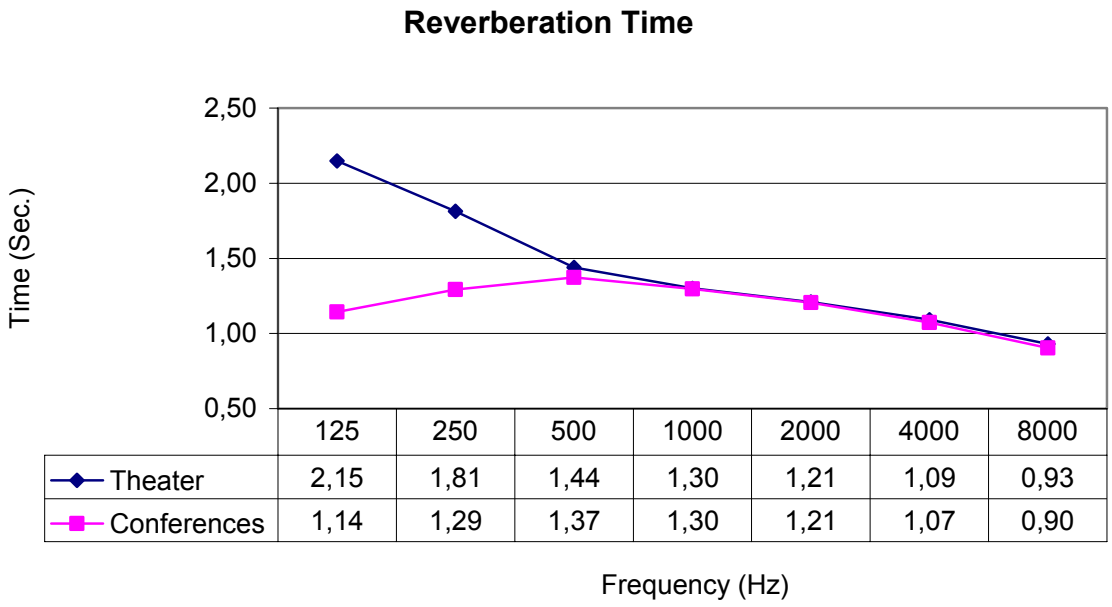
	Hz						
	125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
TR30 $_{(s)}$	1,14	1,29	1,37	1,30	1,21	1,07	0,90
EDT $_{(s)}$	1,13	1,29	1,27	1,10	1,05	0,95	0,77
C80 $_{(dB)}$	3,6	2,8	3,4	4,2	4,2	4,7	6,8
D50 $_{(\%)}$	50	51	51	59	59	60	71

STI	**Seconds**			
	RT_{mid}	**EDT_{mid}**	**BR**	**Br**
0,61	1,33	1,19	0,91	0,85

V	**N**
Volume	**Seats**
6295	890

S_A	**S_0**	**S_{pit}**	**S_T**
482	180	56	718

V/N	**S_A/N**	**V/S_T**	**EDT/(Vx$10^{6)}$**
7,07	0,5	8,77	1,75 $^{-10}$



	125	250	500	1000	2000	4000	8000
Theater	2,15	1,81	1,44	1,30	1,21	1,09	0,93
Conferences	1,14	1,29	1,37	1,30	1,21	1,07	0,90

6.4. Carlos Alberto Theatre

Since the inauguration in 14th of October, 1897, the Carlos Alberto Theatre (TeCA) was a witness of the Oporto years history culture, specially those of the XXth century.

By the hand of Manuel da Silva Neves, the theatre started, in the beggining of the last century, small theatre pieces, like the presentation of the “The Magic Devil”, one example of the popular genere: the magical. It was this kind of performances and others like *Revistas* and operetas, that until the beggining of the decade of 1920, were part of the hall programming.

After 1923 it was the art of Circus that gave the principal attraction to the Oporto audience. But it was just after the year of 1979, in order to have a hall for multi-pruposes, the governement allowed negociations with the owners of Carlos Alberto Theatre given to the hall several quality performances, of different artistic expressions areas: cinema, theatre, music, ballet and opera.

In the decade of 1990, a big fire destroyed a great part of Carlos Alberto Theatre, but with a total reconstruction in the beggining of this century, the theatre opened its doors and it still one of the most important cultural atraction in Oporto city.
Nowadays, the management of Carlos Alberto belongs to the S. João National Theatre (TNSJ).

Image 54

Carlos Alberto Theatre audience area.

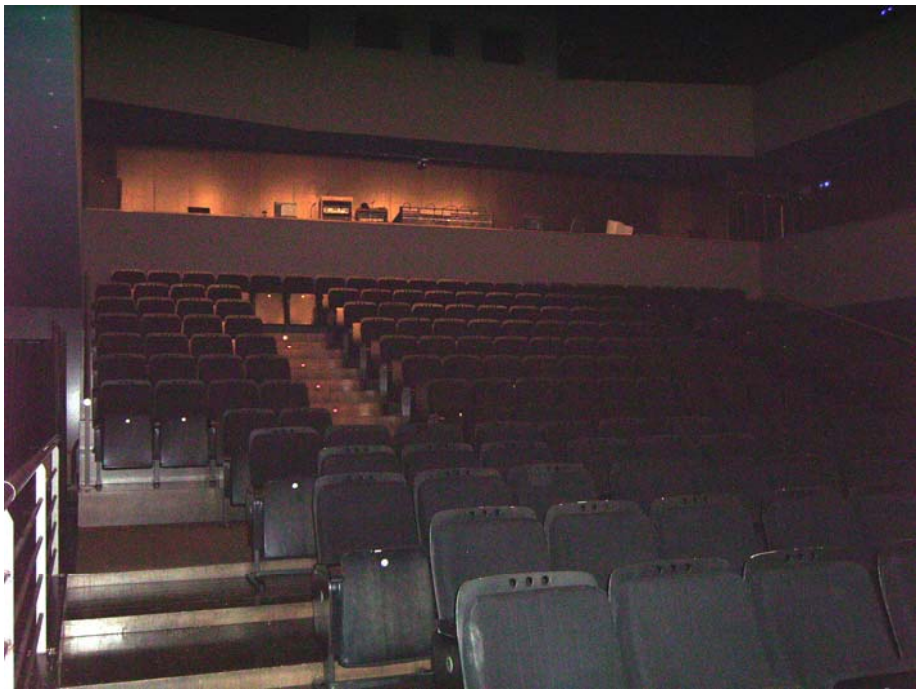


Image 55

Carlos Alberto Theatre left stage view.

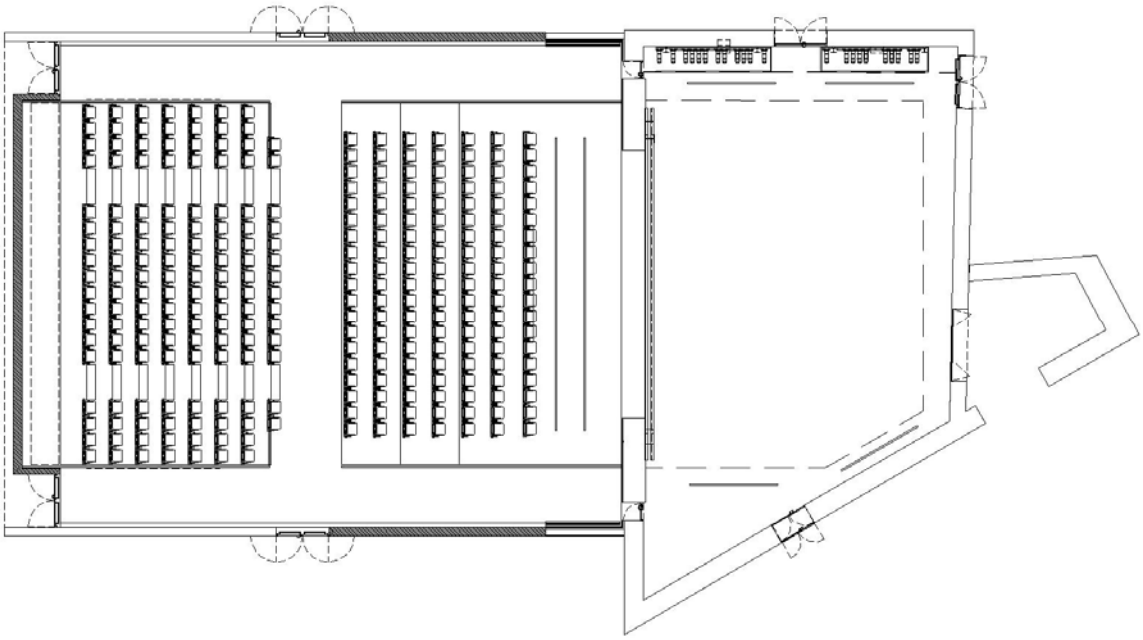


Image 56

Carlos Alberto Theatre architectural plant

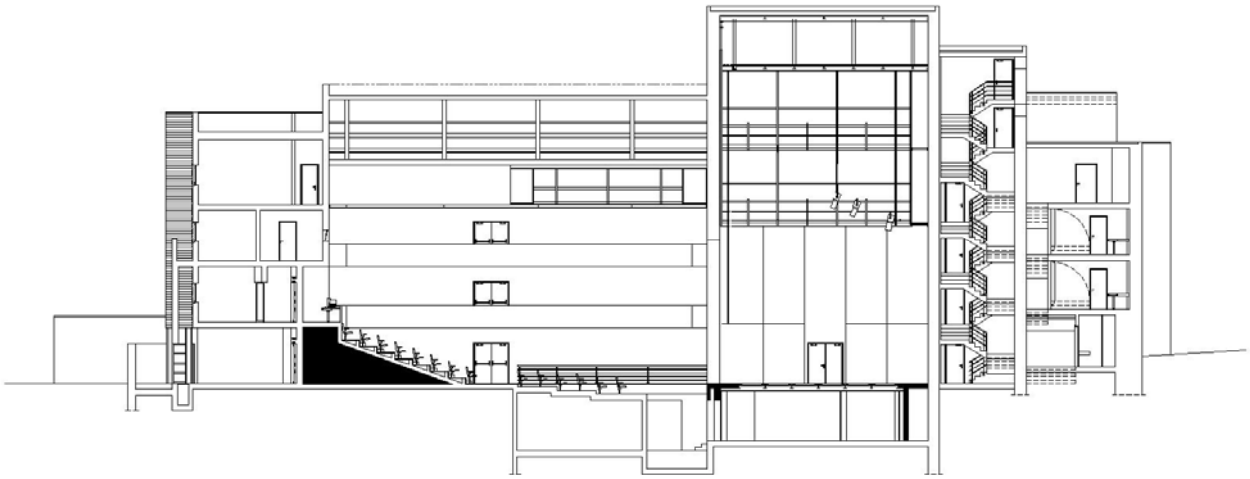


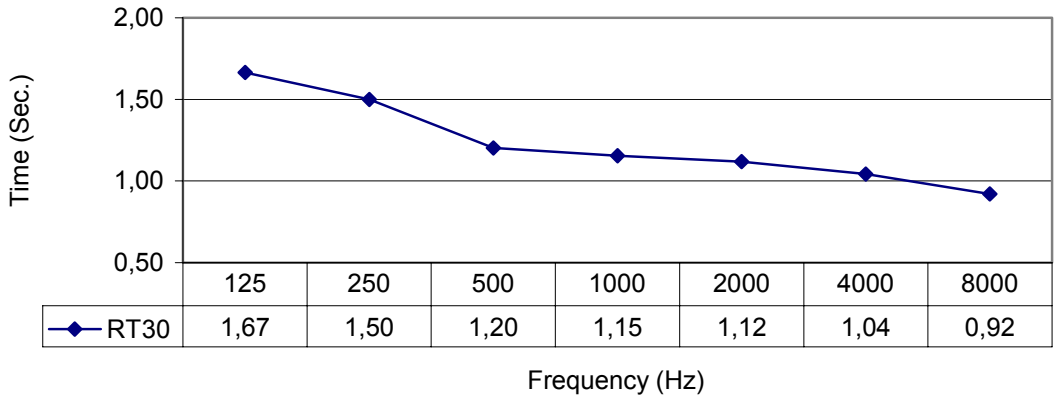
Image 57

Carlos Alberto Theatre architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,67	1,50	1,20	1,15	1,12	1,04	0,92
	EDT (s)	1,27	1,34	1,14	1,17	1,05	0,95	0,78
	C80 (dB)	2,3	2,2	2,7	1,8	3,7	3,8	5,2
	D50 (%)	48	47	48	41	55	53	59
	Tc (ms)	95	94	79	89	68	71	61
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	2,1	6,6	6,1	7,6	9,1	8,5	8,6
	D50 (%)	59	82	79	85	89	86	85

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,18	1,15		1,34	0,92
V		N		STI
Volume		Seats		0,59
2491		342		
S_A	S_0	S_{pit}		S_T
183	116	35		334
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6})$
7,28	0,53		7,46	$4,63^{-10}$

Reverberation Time



6.5. Faro Municipal Theatre

Opened in 2005, the Faro Municipal Theatre (nowadays called as *Teatro das Figuras*) is placed in Horta das Figuras, an area in constant progress and development near the Faro historic center.

The theatre is characterized, essential, by his big stage with top digital and analogue áudio/vídeo equipment, including an Acoustic Shell totally automatic and controlled by special stage technicians.

Besides the dimension of the stage, there is also, space to orqchestra rehearsals and scenery locals, allowing a great stage setting versatility.

The proscenium arcs has a maximum high of 4,4 meters, where it can be usefull to the Orchestra pit, which can receive 77 musicians. The audience access to the theatre is done by a slope which can serve also to outside productions, placed in *Praça da República*.

This theatre had as Architec Gonçalo Byrne and as acoustic consultant Higini Arau.

Image 58

Faro Municipal Theatre hall.

Image 59

Faro Municipal Theatre stage view.

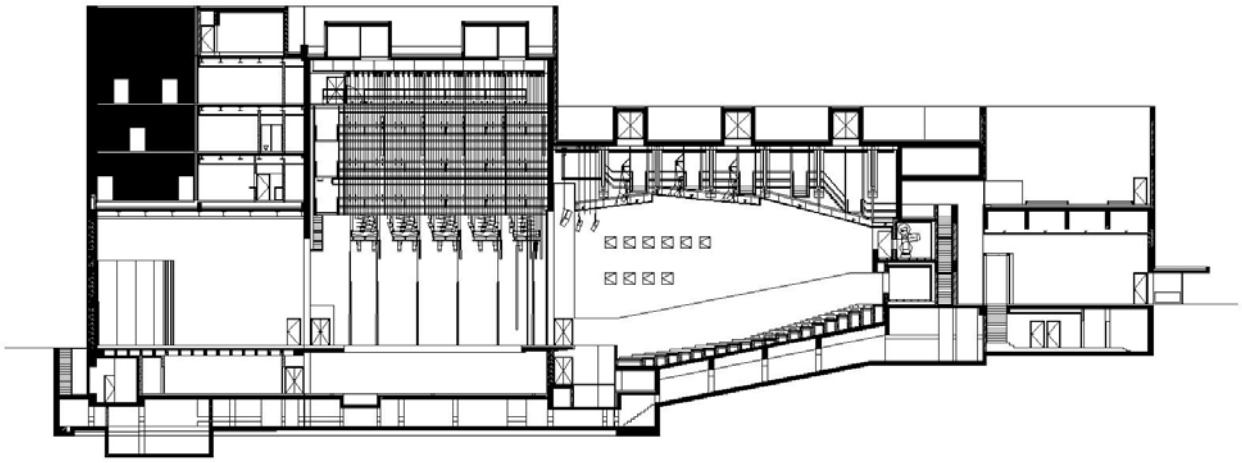


Image 60

Faro Municipal Theatre architectural cut.

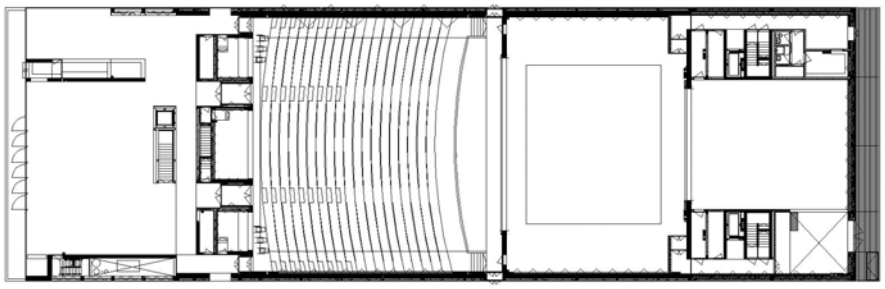


Image 61

Faro Municipal Theatre architectural plant.

1. Orchestra Configuration: Acoustic Shell on Stage

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** (s)	1,89	1,87	1,87	1,84	1,75	1,49	1,15
	EDT (s)	1,62	1,43	1,47	1,49	1,26	1,07	0,81
	C80 (dB)	-0,1	1,3	0,9	1,7	2,5	3,7	5,5
	D50 (%)	31	40	35	41	41	48	61
	Tc (ms)	129	111	113	103	94	77	57
	G (dB)	-	-	-	-	-	-	-
On Stage	**C50** (dB)	3,5	0,2	2,9	3,0	3,4	4,3	6,4
	D50 (%)	67	51	66	66	68	73	81

Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
1,85	1,48	1,02	0,88

2. Theatre and Pop/Rock Configuration:

3.

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** (s)	2,20	1,95	1,85	1,69	1,59	1,36	1,07
	EDT (s)	1,76	1,32	1,43	1,36	1,18	1,04	0,85
	C80 (dB)	2,0	2,3	1,7	2,9	4,5	4,2	5,4
	D50 (%)	48	47	48	55	61	59	63
	Tc (ms)	117	97	96	85	69	71	61
	G (dB)	-	-	-	-	-	-	-
On Stage	**C50** (dB)	3,2	2,5	6,7	8,5	7,8	8,0	10,4
	D50 (%)	67	64	82	87	85	84	89

STI
0,60

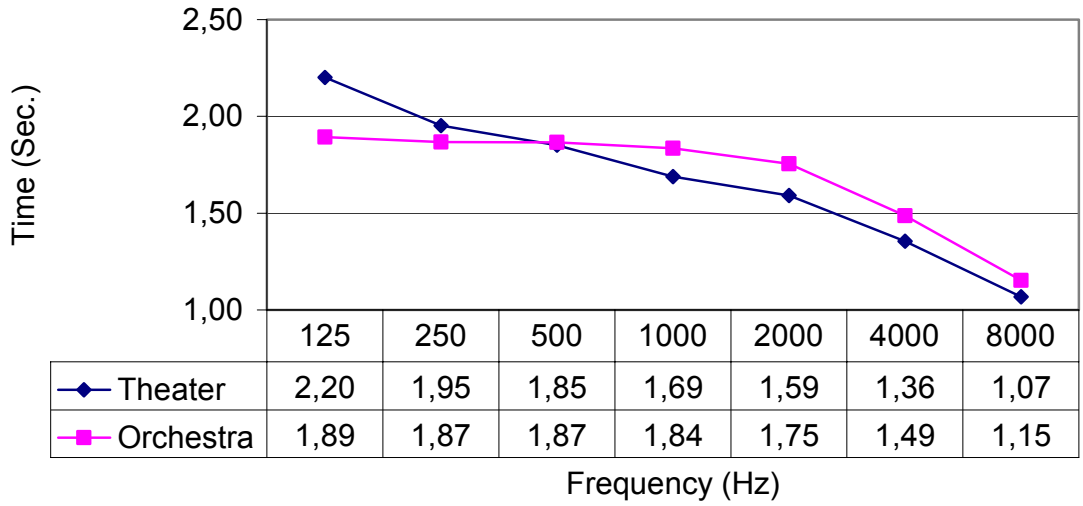
Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
1,77	1,39	1,17	0,83

V			N	
Volume			Seats	
5985			794	

S_A	S_0	S_{pit}		S_T
398	180	87		665

V/N	S_A/N		V/S_T	EDT/(Vx$10^{6)}$
7,54	0,5		9,00	2,47 $^{-10}$

Reverberation Time



	125	250	500	1000	2000	4000	8000
Theater	2,20	1,95	1,85	1,69	1,59	1,36	1,07
Orchestra	1,89	1,87	1,87	1,84	1,75	1,49	1,15

6.6. Gil Vicente Academic Theatre

Gil Vicente Academic Theatre belongs to Coimbra University and it has 42 years hold. Mainly, serves a strong support to artist and cultural creations of *Associação Académica de Coimbra*.

It was opened in 9th Setember of 1965 and besides theatre, dance and opera, the Gil Vicente Academic Theatre presented also a national and foreign quality musical landscape, focus in classic music.

After 1965, the hall starts the a programation of cinema, like many others theatres and concert halls of the country. However it is after the 80´s that Gil Vicente Academic Theatre intensify its program in several artistic theatre areas, but is after the second half of this decade that become a usual theatral representation.
As an example, the FITEI – *Festival Internacional de Teatro e Expressão Ibérica*; samples of Holland Theatre with ACARTE and *Fundação Calouste Gulbenkian* colaboration; the first Congresso Luso-Espanhol de teatro and the *Projecto de Itenerância da Secretaria de Estado da Cultura*.

In 1992 the Gil Vicente Academic Theatre becomes the oficial headquarter of Coimbra Culture Capital City. Besides the strong theatre presence, the hall goes on with another areas of interest as tematic organizations cicles, like cinema.

The Gil Vicente Academic Theatre one of the most important cultural and artistic center in Coimbra city, promoted and divulgated the Project Coimbra 2003, where had programated and received several national and international events, wich had many different artistic areas, given special attention to the stage performances.

Image 62

Gil Vicente Academic Theatre hall.

Image 63

Gil Vicente Academic Theatre balcony view.

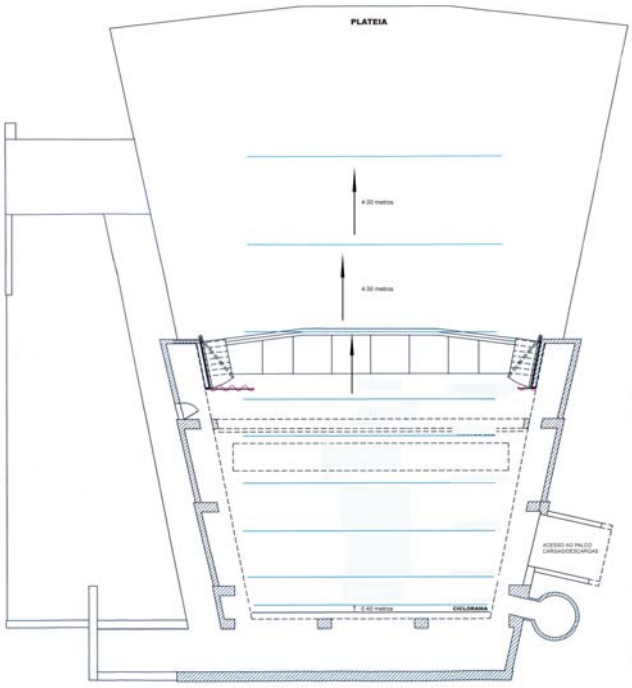


Image 64

Gil Vicente Academic Theatre architectural plant.

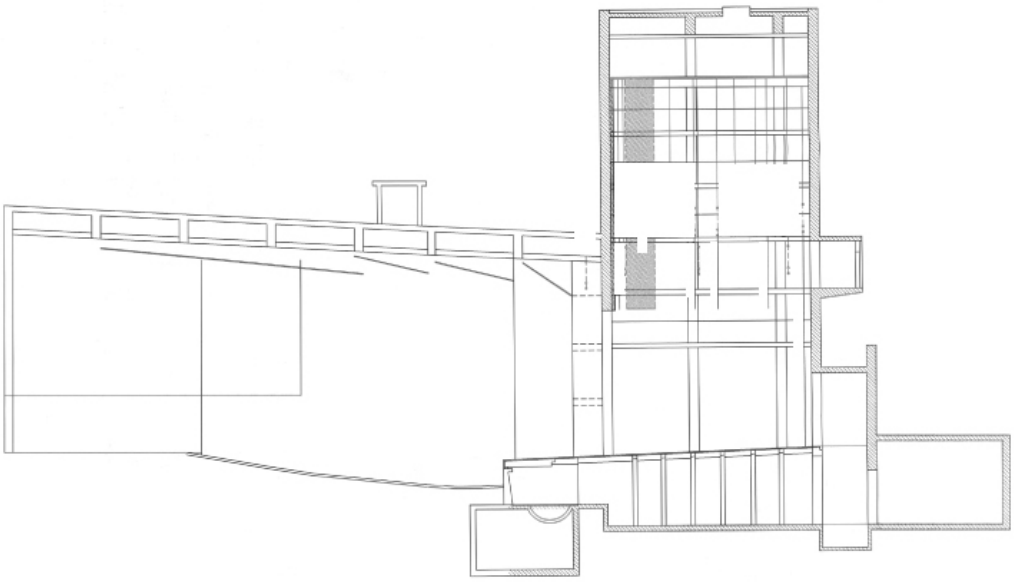


Image 65

Gil Vicente Academic Theatre architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,58	1,38	1,09	1,06	0,96	0,83	0,68
	EDT (s)	1,67	1,34	1,06	0,98	1,03	0,93	0,81
	C80 (dB)	0,1	2,1	4,9	4,3	5,7	4,8	6,4
	D50 (%)	36	49	60	50	63	54	61
	Tc (ms)	121	83	57	65	48	59	47
	G (dB)	-	-	-	-	-	-	-
Balcony	C80 (dB)	1,2	4,0	5,4	5,2	7,7	7,9	9,0
	D50 (%)	32	49	61	59	71	67	70
On Stage	C50 (dB)	1,7	6,8	6,3	7,8	9,0	8,3	10,6
	D50 (%)	60	82	81	84	89	85	89

STI	
Audience	Balcony
0,60	0,65

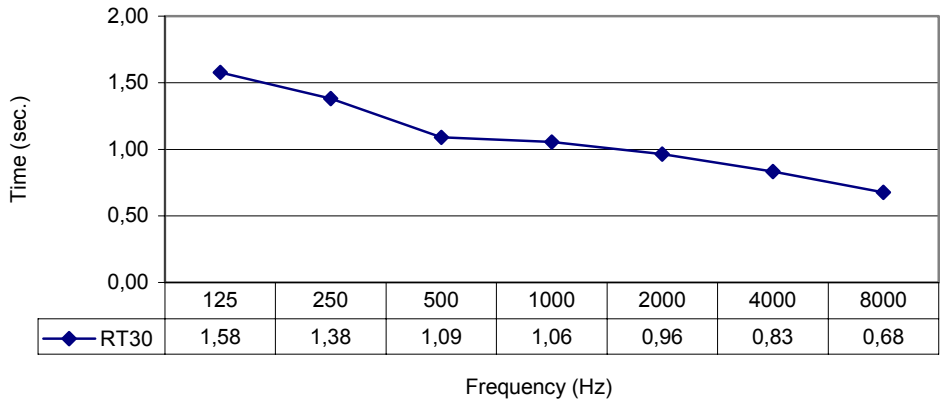
Seconds			
RT_{mid}	EDT_{mid}	BR	Br
1,08	1,01	1,38	0,84

V	N
Volume	Seats
3180	638

S_A	S_0	S_{pit}	S_T
200	141	45	386

V/N	S_A/N	V/S_T	EDT/(Vx$10^{6)}$
4,11	0,3	8,24	3,17 $^{-10}$

Reverberation Time



6.7. Guarda Municipal Theatre

In the last tem years the cultural life of the city has as main stage the City Hall Auditorium, a room with a small scenic space and other insufficiencies. Technical miracles were performed to make possible the presentation of shows, but, it became impossible to maintain a situation slightly limited to any more demanding program. Guarda needed a big show room, with all the conditions to receive the more diverse and complex proposals. But, Guarda deserved this equipment, since it was the interior city that, in a systematic way, invested in a cultural programming, seen as a development factor. The TMG has two auditoriums (a bigger one with 626 seats and a smaller one with 164 seats), a Concert- Café, an Art Gallery and a Rehearsal Room. In a small city as Guarda, this kind of equipment means a lot in what concerns to cultural fruition and new perspectives opening, with the countless proposals regarding plays, movies, music, dance and entertainment.

There is no cultural process that doesn't take risks and the TMG artistical direction chose to go for new things and permanent challenges. The TMG has a systematic attitude in the creation of new audiences, using the Educational Service. It organizes the program in circles and festivals, with unity and coherence. It tries to maintain a critical dialog with the creators and with the actions it promotes, and with the various cultural audiences. The TMG, didn't just brought a big transformation in Guarda's cultural life, as well as became a privileged intermediate in the cultural production of Salamanca's area (Spain)This space has the capacity to receive shows of a great technical complexity- becoming more appellative and mobilizing new audiences.

The auditoriums receive several shows: in the bigger one, we can usually see operas, ballet, music, plays among others; in the smaller one, we can also see music and plays, and also movie sessions, organized by the TMG together with the Guarda's Cineclube.

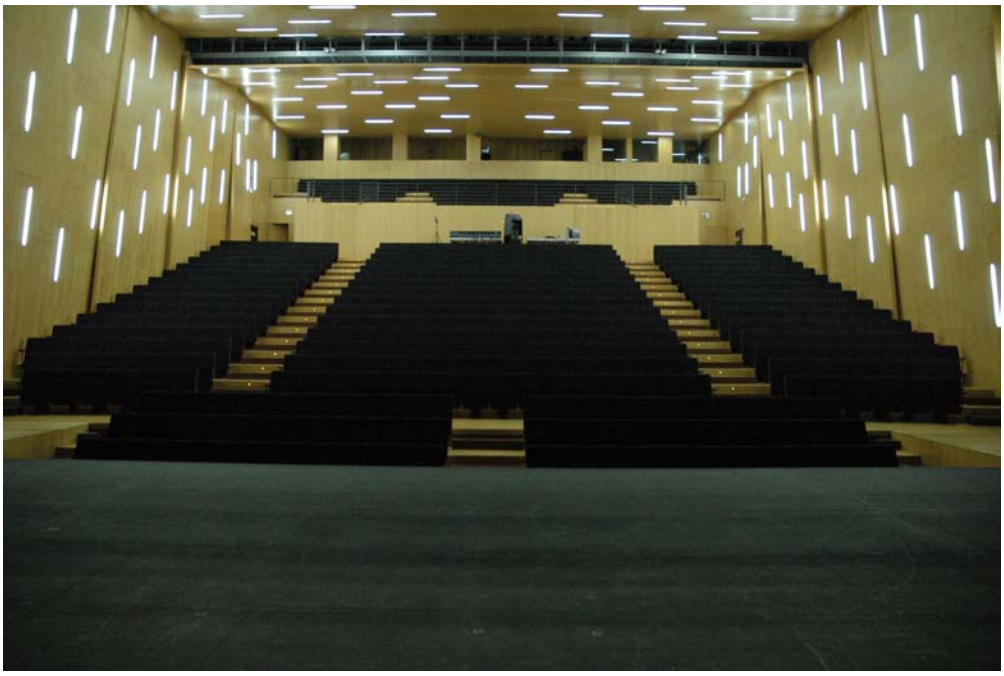


Image 66

Guarda Municipal Theatre hall.

Image 67

Guarda Municipal Theatre audience area view.

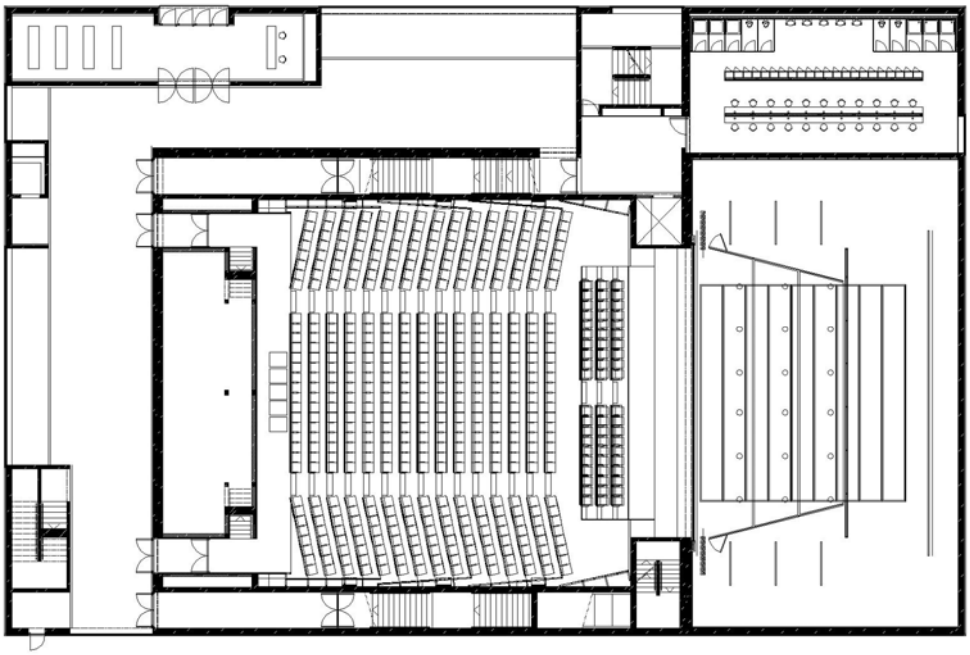


Image 68

Guarda Municipal Theatre architectural plant.

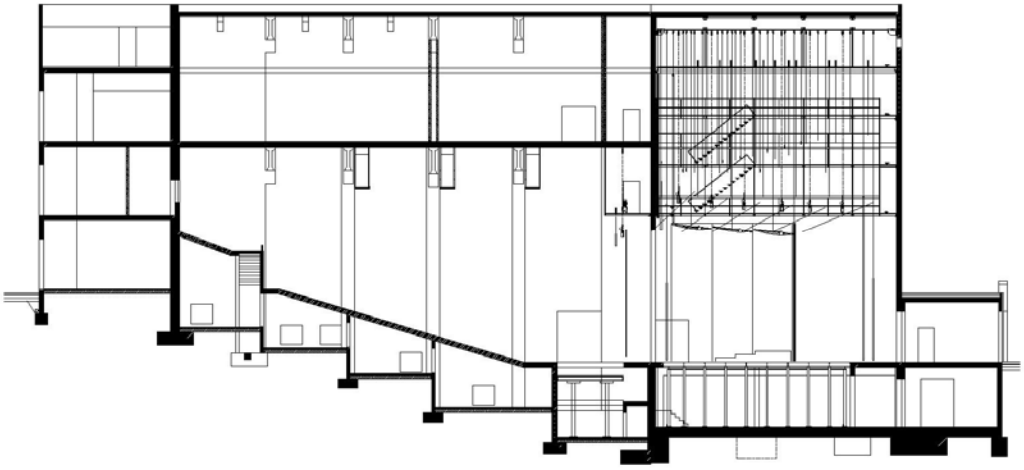


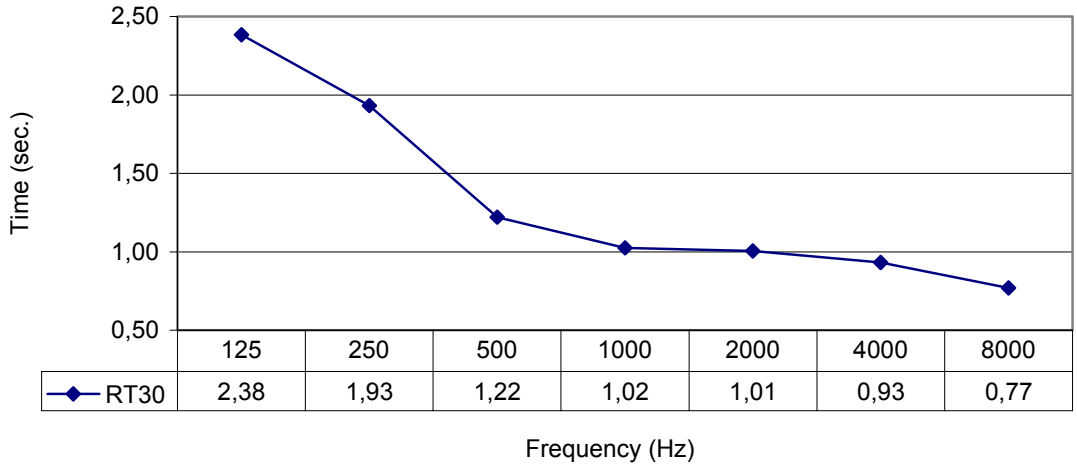
Image 69

Guarda Municipal Theatre architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,38	1,93	1,22	1,02	1,01	0,93	0,77
	EDT (s)	1,46	1,16	0,94	0,86	0,94	0,92	0,72
	C80 (dB)	2,2	3,8	5,7	4,7	4,4	4,1	5,1
	D50 (%)	47	55	62	50	52	50	53
	Tc (ms)	102	76	54	67	64	65	59
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	0,8	8,6	8,2	10,3	10,1	11,0	12,3
	D50 (%)	54	88	84	91	91	92	93

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,11	0,92		1,94	0,86
V		N		STI
Volume		Seats		0,61
6027		626		
S_A	S_0	S_{pit}		S_T
320	120	56		496
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6)}$
9,63	0,51		12,16	$1,52^{-10}$

Reverberation Time



6.8. Helena Sá e Costa Theatre

Helena Sá e Costa Theatre opened in 18th May of the year 2000 and belongs to the Oporto Polytechnic Institute (IPP) with its manegement handed over to IPP Foundation with no lucrative founds. This Theatre is licensed by the Cultural Activities general Inspection and is placed in the center of Escola Superior de Música e Artes do Espectáculo do Porto (High School of Music and Perfoming Arts of Oporto – ESMAE).

The main issue of Helena Sá e Costa Theatre is to promote and divulgate arts, as a tool of knowledge process and development of man in dance, music and theatre, given power to new tendencies, supporting embrionic atrs projects movements inside and outside the institution. Other objective is organizing artistic projects capable of getting new and faithfulness audience and give vitality to the Oporto historic center.

The strategic sucess is due to the presentation of new creations and new producers; the reception of external productions and the Escola Superior de Música e Artes do Espectáculo productions in dance, music and theatre. However, the direction of the theatre also rents the hall to external performing arts.

The architec project was Filipe Oliveira Dias, and the main question for the construction of this hall was study a way to recover an ancient garden/open space between the struture in the old primary school of Oporto city. The architec kept the windows design on the main walls of the building, that can been seen in the following pictures of the hall.

With a small capacity of 274 people and with a small volume, this theatre is one of the most equiped hall in Portugal, due to be located in the middle of a High School of Music and Perfoming Arts, with degrees in Music, Theatre and Prodution and Music Technologies. Actually, this theatre doesn´t need to depende of external instituions or resources, because it has their own musicians, actors and image and sound technicians.

Image 70

Helena Sá e Costa Theatre hall.

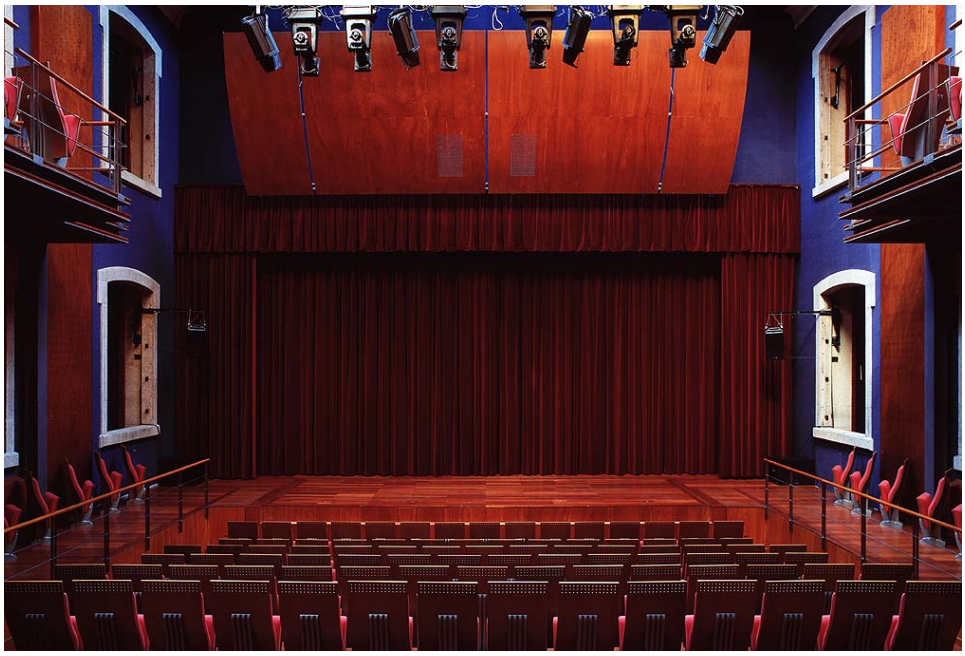


Image 71

Helena Sá e Costa Theatre sound Technician view.

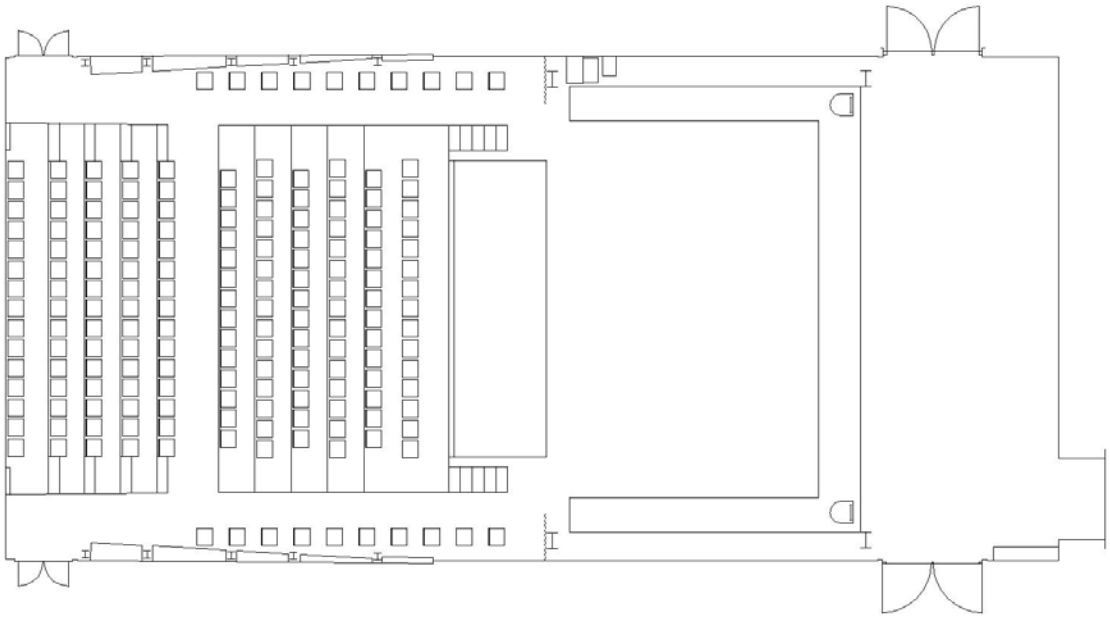


Image 72

Helena Sá e Costa Theatre architectural plant.

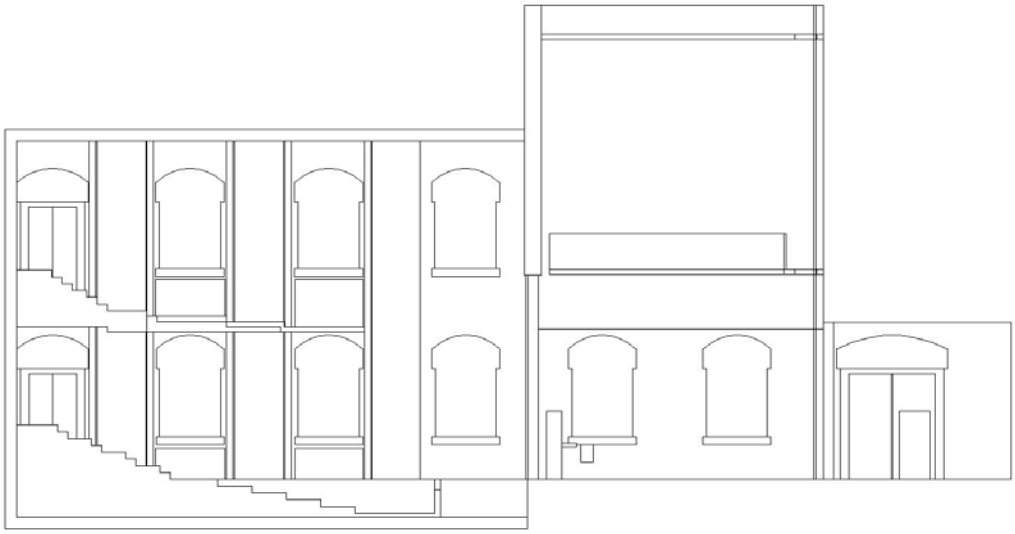


Image 73

Helena Sá e Costa Theatre architectural cut.

1. Small Orchestra: Acoustic Shell above the front Stage

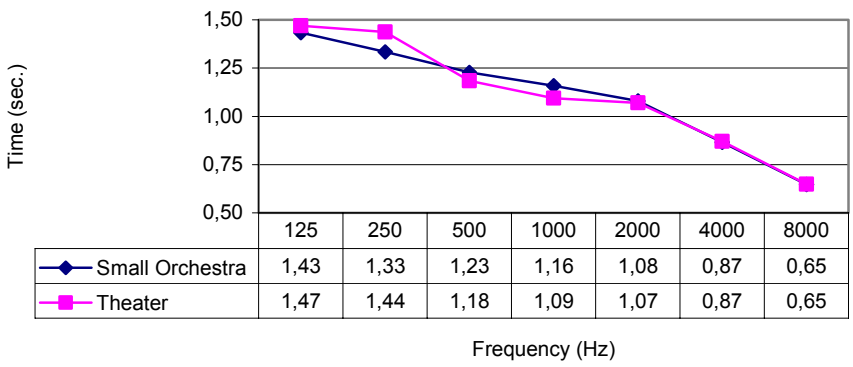
		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Hall	**TR30** (s)	1,43	1,33	1,23	1,16	1,08	0,87	0,65
	EDT (s)	1,20	1,22	1,05	1,07	1,02	0,82	0,59
	C80 (dB)	2,5	3,2	4,8	5,0	4,7	7,3	10,4
	D50 (%)	43	56	65	66	62	74	83
	Tc (ms)	92	74	57	51	55	37	23

2. Theatre and Pop/Rock Configuration

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Hall	**TR30** (s)	1,47	1,44	1,18	1,09	1,07	0,87	0,65
	EDT (s)	1,26	1,24	1,09	1,03	0,99	0,82	0,65
	C80 (dB)	1,5	1,9	3,8	4,2	3,8	6,0	9,3
	D50 (%)	38	50	60	61	58	70	82
	Tc (ms)	101	86	64	59	63	46	28
	G (dB)	-	-	-	-	-	-	-

Seconds				
RT_{mid}	**EDT_{mid}**		**BR**	**Br**
1,14	1,06		1,28	0,85
N		**V**		**STI**
Seats		**Volume**		0,62
272		1959		
S_A	**S_0**	**S_{pit}**		**S_T**
106	72	21		200
V/N	**S_A/N**		**V/S_T**	**$EDT/(Vx10^{6)}$**
7,8	0,4		9,8	$5,42^{-10}$

Reverberation Time



6.9. Maria Matos Municipal Theatre

The Maria Matos Municipal Theatre opened in 22th of October of 1969, almost in the end of conturbate years of the recent Portugal history and to tributte a great portuguese theatre actress of the first half of the XXth century – Maria Matos.
The structure construction was made by the Architec Fernando Ramalho in the beggining of the project and by Architec Barros da Fonseca a few years later.

In 24th of Setember of 1982 the theatre become part of Lisbon town hall. With a past loaded of popular and conventional portuguese expressions, the Maria Matos Theatre assumed in 1999 a will of change: to start a process in order to modernize and offer a better confort to artists and audience, as a diversify and professional programming, given to the theatre a space of new artistic experimentation language, trying to impose as an alternative space among the several audience of the city and country.

The theatre programming design is to serve the Lisbon city: from the Lisbon knowledge and the knowledge of theatre himself, from its past and tradition, his architectonic and technical characteristics, from his geographical localization in the Lisbon space and of course its artistics and cultural panorama.
For the city (their artists, their audience and another culture locals and cidadany) the present project respects the diversity of gender, stetic and intervenients.

The programming policy is done according to the international and national proposals, in the following areas: theatre, dance, music, new circus and as well transdisciplinarys projects. All the performing arts are attended by profissional formation (artistic and technical).
In April of 2003 the manegement of Maria Matos Municipal Theatre was delivered to EGEAC E.M..

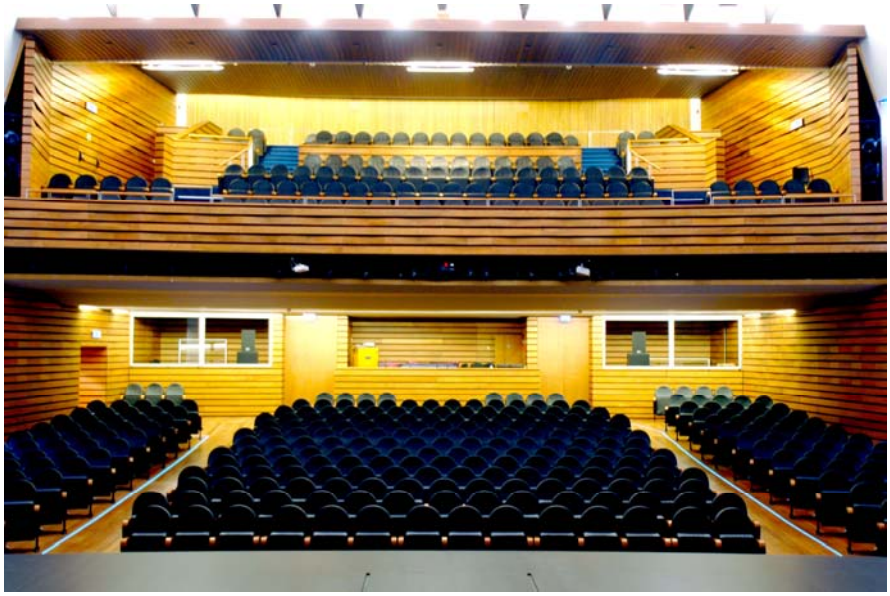


Image 74

Maria Matos Theatre hall. Foto by José Frade.

Image 75

Maria Matos Theatre audience view. Foto byJosé Frade.

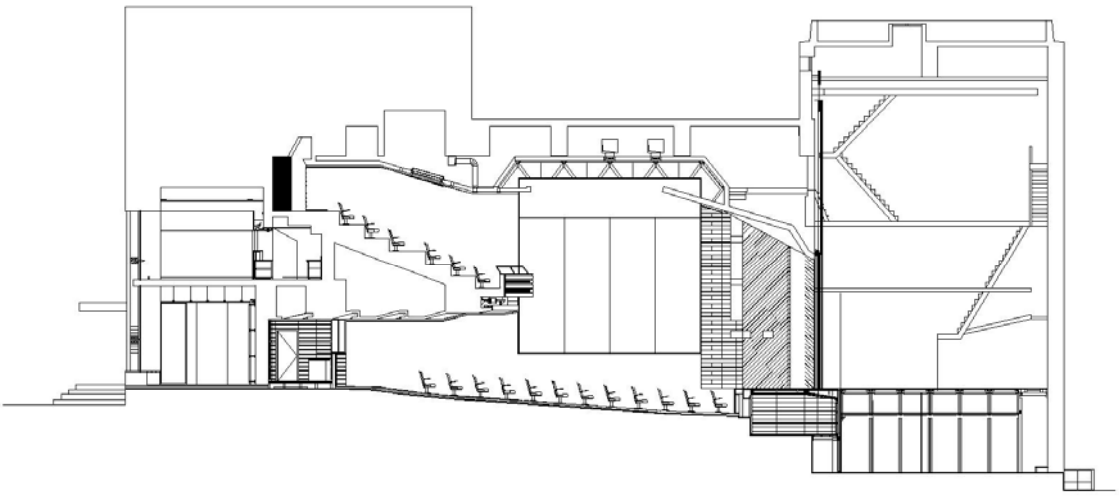


Image 76

Maria Matos Theatre architectural cut.

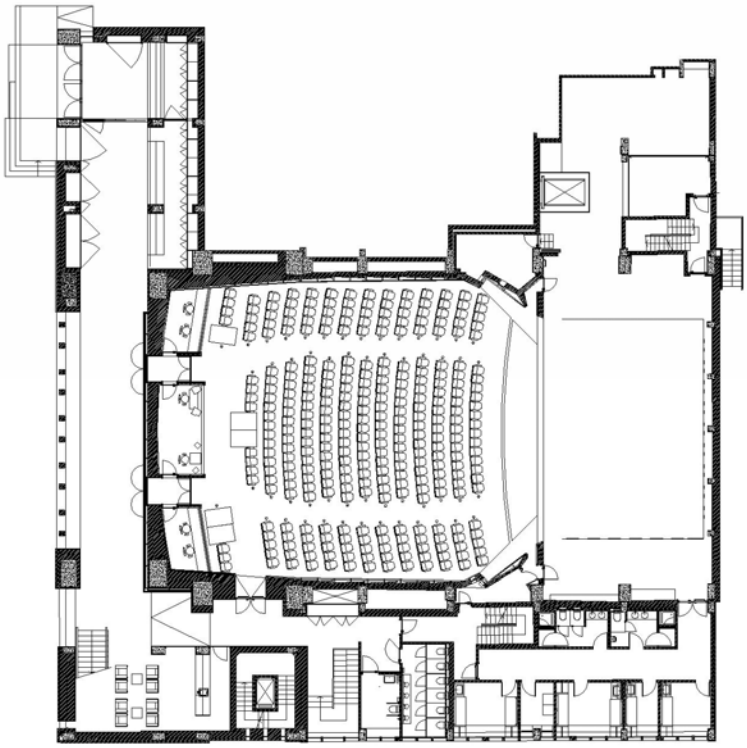


Image 77

Maria Matos Theatre architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,32	1,16	1,00	1,09	1,22	1,20	1,01
	EDT (s)	0,88	0,86	1,00	1,14	1,28	1,26	1,04
	C80 (dB)	5,1	5,2	3,6	2,5	1,8	2,6	3,9
	D50 (%)	57	62	51	48	45	51	55
	Tc (ms)	74	63	71	79	89	78	64
	G (dB)	-	-	-	-	-	-	-
Balcony								
	C80 (dB)	5,9	6,0	6,3	6,4	6,2	6,0	6,4
	D50 (%)	57	62	51	48	45	51	55
On Stage	C50 (dB)	0,2	7,2	6,0	5,5	5,8	6,8	8,5
	D50 (%)	52	84	80	77	79	82	87

STI	
Audience	Balcony
0,59	0,66

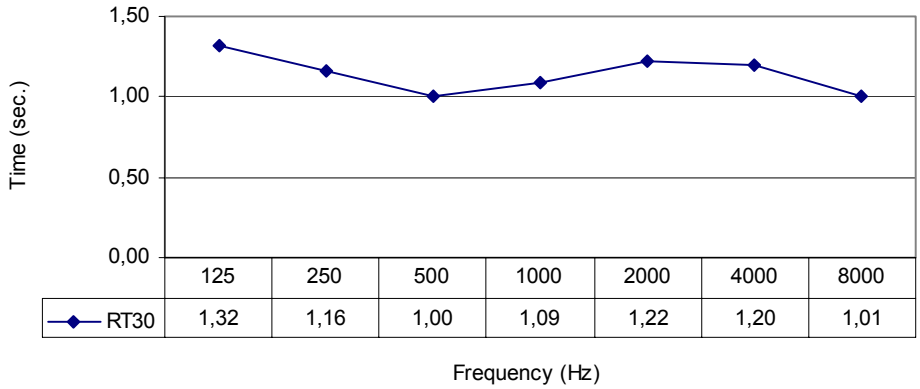
Seconds			
RT_{mid}	EDT_{mid}	BR	Br
1,04	1,07	1,19	1,16

V	N
Volume	Seats
2412	570

S_A	S_0	S_{pit}	S_T
234	116	24	374

V/N	S_A/N	V/S_T	EDT/(Vx$10^{6)}$
4,23	0,4	6,46	4,42 $^{-10}$

Reverberation Time



6.10. Politeama Theatre

The construction of Politeama Theatre was from Luís António Pereira ideia, a man in love with the performing arts, music and theatre in the first decade of the XXth century. The issue was to serve the lisbon audience with portuguese culture.
The project belongs to Architec Ventura Terra and the construction to José Barros Mesquita. The theatre decoration was by the sculptor Jorge Pereira and the painting by Benvindo Seia and Veloso Salgado.

The hall opened in 1913 with the opereta "*Valsa de Amor*" with Cremilde de Oliveira and Sofia Santos as main actress.
Several performing arts companies represented their shows in Politeama Theatre, like: Ângela Pinto, Palmira Bastos, Maria Matos, Companhia Rey Colaço, Alves da Cunha, Brumilde Júdice, Adelina Abranches, among others. In this theatre the most important portuguese actors of the XXth century like António Silva, Irene Isidro, Vasco Santana, Teresa Gomes, Raúl de Carvalho, Emília de Oliveira, Ruy de Carvalho, Varela Silva and Curado Ribeiro, acted.

During many years, this hall served the purposes of cinema, where exhibition of historic movies weas the main attraction, like "*Casablanca*" during the II th World War.

In 1991 Filipe La Féria rented for a long time period the theatre and did several reconstructions inside the hall in order to improve a better professional theatre conditions. After 1992, Filipe La Féria presented until now with sucess, "*Maldita Cocaína, Maria Cllas, Casa do Lago*" and the most important "*Amália*".

Image 78

Politeama Theatre stage view.

Image 79

Politeama Theatre boxes and 1st balcony.

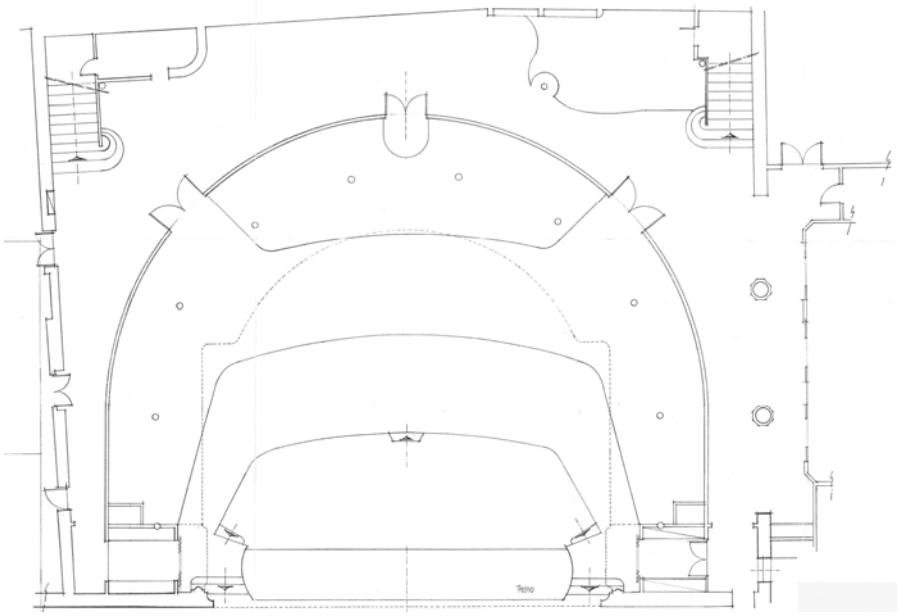


Image 80

Politeama Theatre architectural plant, without the stage.

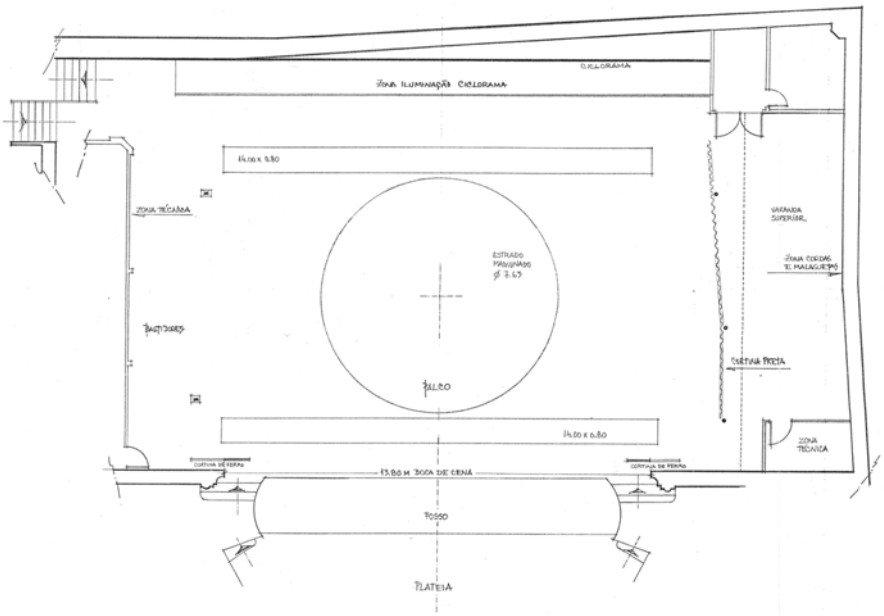


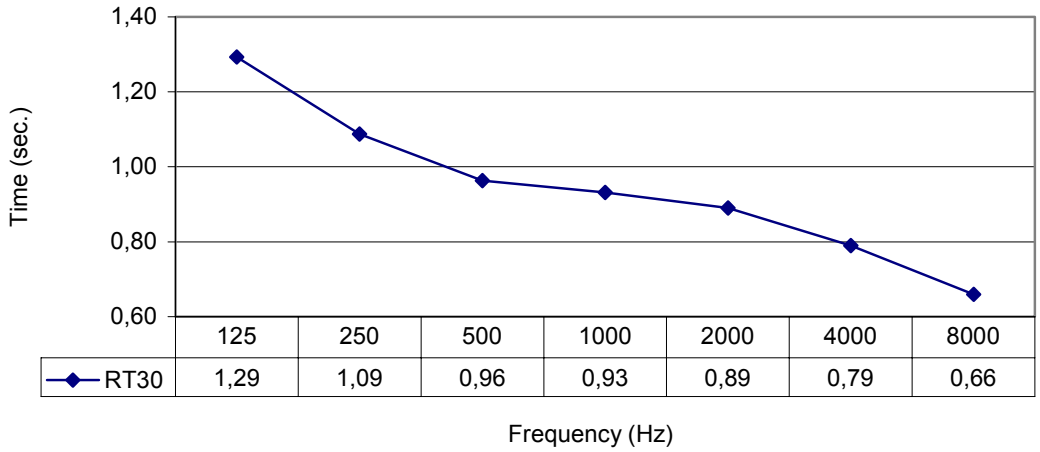
Image 81

Politeama Theatre architectural stage plant.

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,29	1,09	0,96	0,93	0,89	0,79	0,66
	EDT $_{(s)}$	1,16	1,14	1,00	0,90	0,87	0,79	0,64
	C80 $_{(dB)}$	1,5	3,5	3,5	4,7	5,9	9,0	10,3
	D50 $_{(\%)}$	34	52	53	54	63	80	84
	Tc $_{(ms)}$	98	73	65	60	48	27	23
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	1,8	8,8	6,0	7,1	9,5	10,7	11,7
	D50 $_{(\%)}$	59	88	81	84	90	91	93

Seconds				
RT_{mid}	**EDT_{mid}**		**BR**	**Br**
0,95	0,94		1,26	0,89
V		**N**		**STI**
Volume		**Seats**		0,67
3600		638		
S_A	**S_0**	**S_{pit}**		**S_T**
280	138	20		438
V/N	**S_A/N**		**V/S_T**	**$EDT/(Vx10^{6)}$**
5,6	0,4		8,2	$2,61^{-10}$

Reverberation Time



6.11. Rivoli Municipal Theatre

Teatro Nacional was the first name of Rivoli Municipal Theatre, placed in down town of Oporto in 1913. A great building, for that time, that become a cultural and social life point of interest in Oporto city.

In 1923, the theatre after some remodelations and modernizations was called Rivoli Theatre, totally adapted to cinema, with the best equipment for Opera, Dance, Theatre and Music concert, all performances with international reputation until 1970.

During the 70´s decade, the theatre suffered some finantial problems and closed his doors. With the design of the Architec Pedro Ramalho, the Rivoli Municipal Theatre opened in 1997, supervisioned by culturporto entity. The issue of the theatre and architec was to re-built a hall able to function for all kinds of audience and performances, producers and answer to the most diversify artistics expressions of multiple languages of arts.

Nowadays, this Rivoli Theatre, is now rented by Filipe La Féria, for a long time period, like Politeama Theatre in Lisbon.

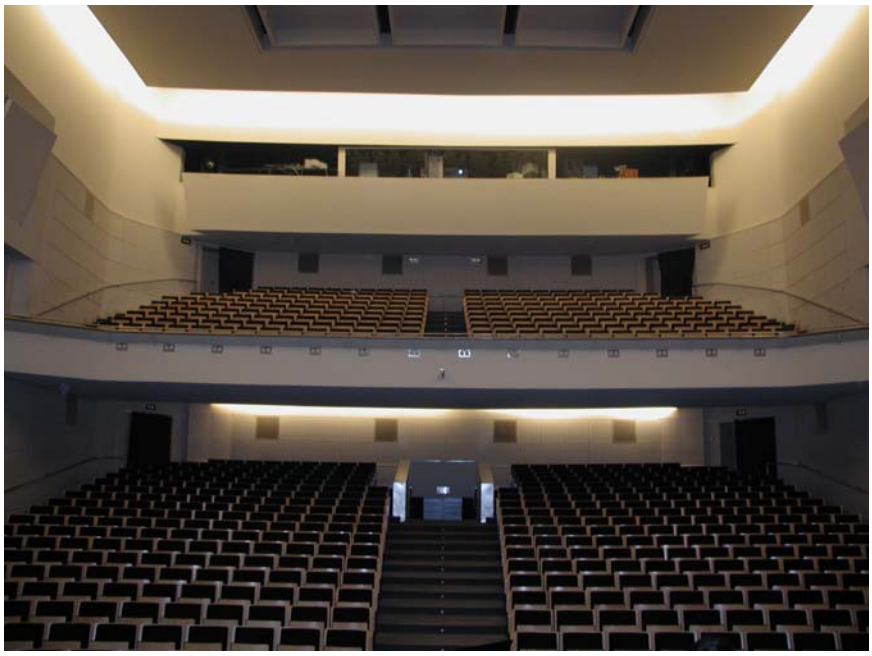


Image 82

Rivoli Theatre hall.

Image 83

Rivoli Theatre audience view.

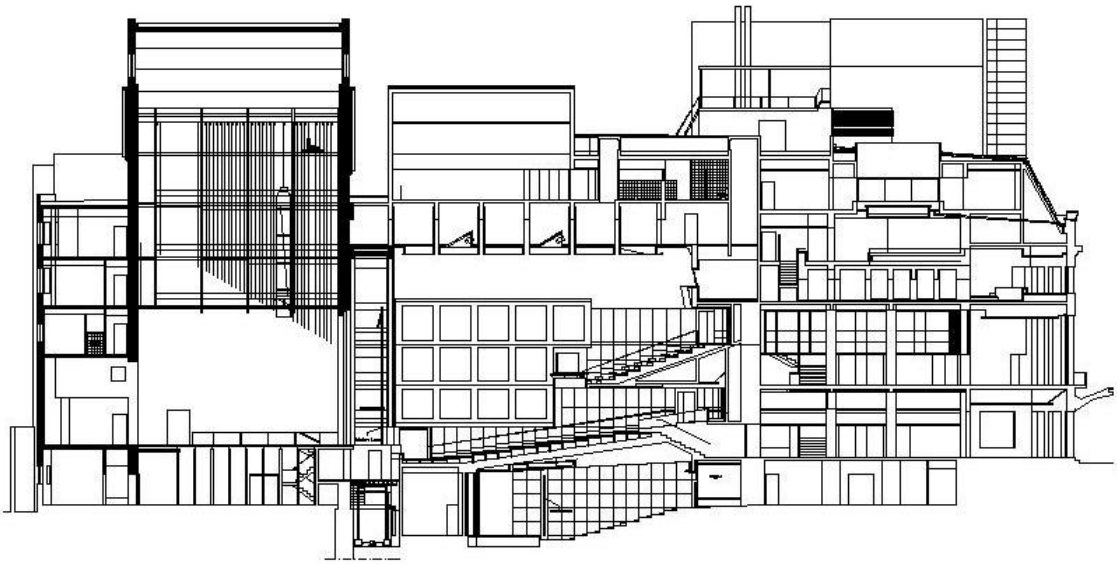


Image 84

Rivoli Theatre architectural cut.

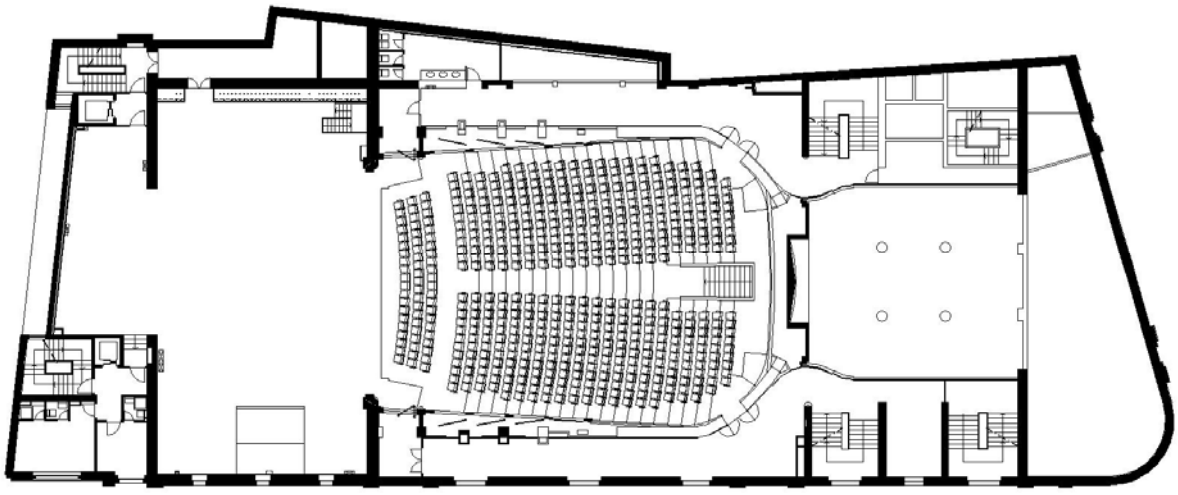


Image 85

Rivoli Theatre architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,75	2,27	1,60	1,36	1,17	0,94	0,60
	EDT (s)	1,29	1,30	1,08	1,02	1,02	0,82	0,58
	C80 (dB)	2,5	3,5	5,4	6,2	5,5	6,9	10,6
	D50 (%)	35	53	65	68	64	69	79
	Tc (ms)	109	83	58	52	55	44	29
	G (dB)	-	-	-	-	-	-	-
Balcony	C80 (dB)	-0,2	1,4	2,3	2,7	3,3	4,8	7,0
	D50 (%)	28	39	43	48	52	61	67

STI	
Audience	Balcony
0,64	0,59

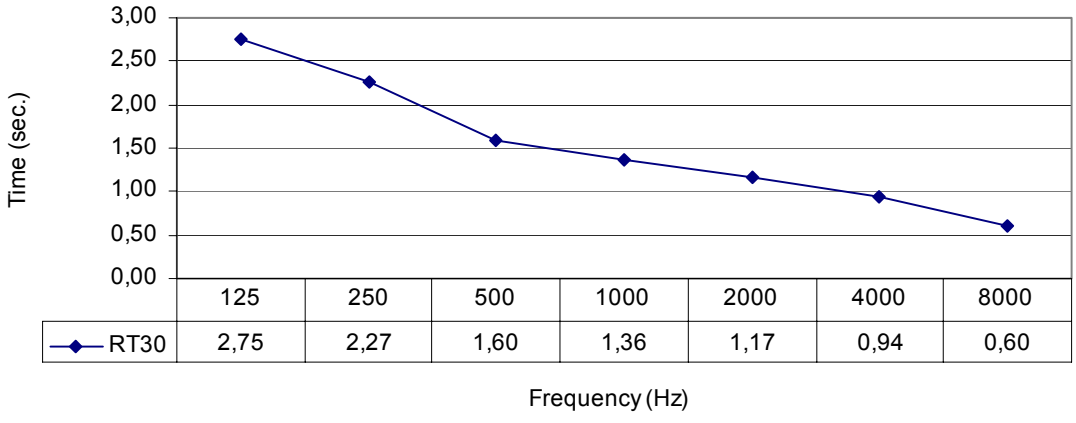
Seconds			
RT_{mid}	EDT_{mid}	BR	Br
1,48	1,05	1,70	0,72

V	N
Volume	Seats
4651	874

S_A	S_0	S_{pit}	S_T
274	180	39	493

V/N	S_A/N	V/S_T	EDT/(Vx$10^{6)}$
5,32	0,3	9,44	2,26 $^{-10}$

Reverberation Time



6.12. Vila Real Municipal Theatre

The Vila Real Municipal Theatre is located in Vila Real city in the North of Portugal, in a region called *Alto-Douro*, with a very beautiful landscape to the hills and fields.

This theatre opened in the year of 2005 and due to his new and excellent equipment conditions, the hall allows the presentation of great and quality performers and also innovates the region in what concerns to culture.

The complex is composed by the Great Auditorium (with the capacity of 500 people), the small auditorium (with the capacity of 150 people), exterior auditorium (for aproximately 200 people), the foyer, exposition hall, multi-purpose hall, Bar-Gallery, Café concert/restaurant, the Teatroteca and musical gardins.

The theatre activites are related with Rede Nacional de Teatros that deal with the principal national agency and producers. Beside the performances programming in theatre, dance, music, cinema, circense arts and expositions, there is also foreseen co-production performances with another regional, national and foreign enterprises.

From expositions to cinema, theatre festivals to music, there is every day strong reasons to use this point of interest in *Alto-Douro* region.

Image 86

Vila Real Municipal Theatre hall.

Image 87

Vila Real Municipal Theatre stage view.

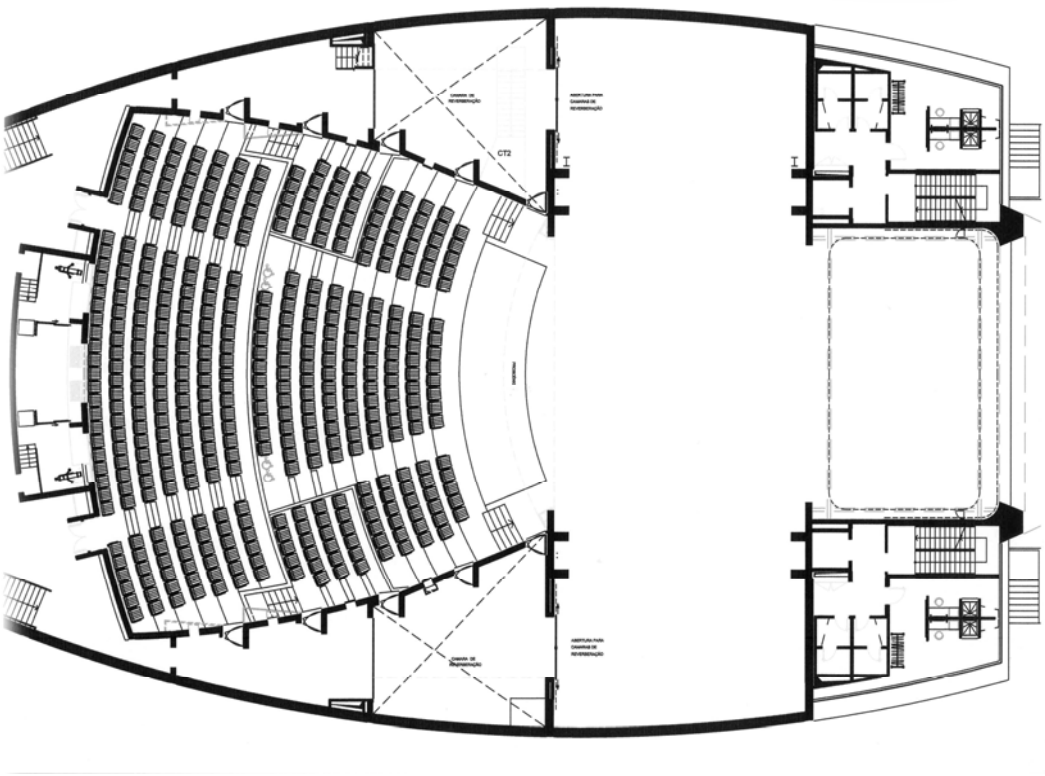


Image 88

Vila Real Municipal Theatre architectural plant.

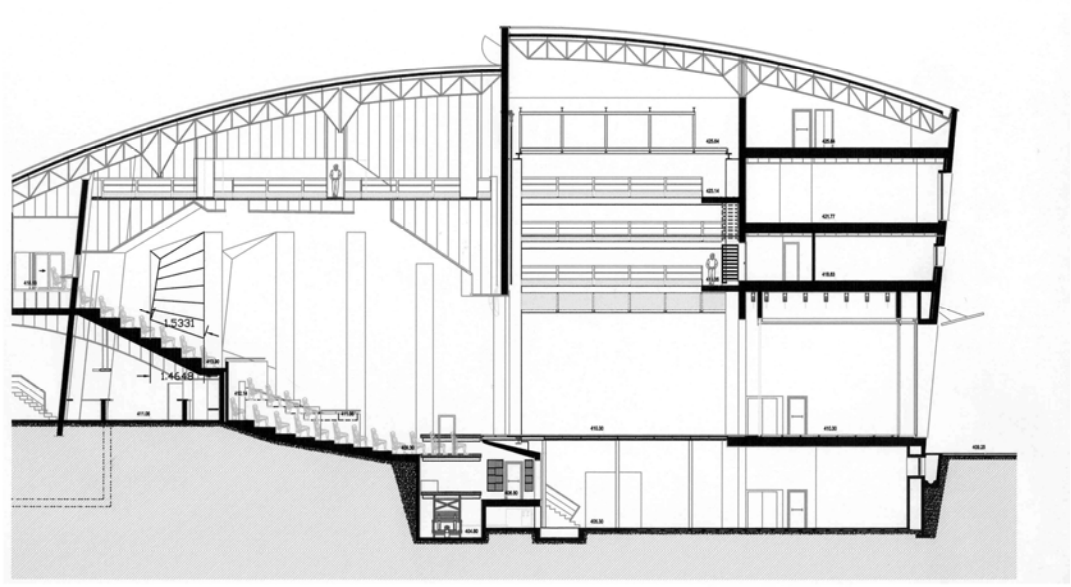


Image 89

Vila Real Municipal Theatre architectural cut.

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** (s)	1,85	1,44	1,21	1,16	1,15	1,14	0,95
	EDT (s)	1,72	1,43	1,41	1,39	1,32	1,41	1,10
	C80 (dB)	-0,8	2,3	2,1	1,8	3,0	3,2	5,2
	D50 (%)	36	53	53	50	59	60	66
	Tc (ms)	130	84	86	94	77	75	59
	G (dB)	-	-	-	-	-	-	-
Balcony	**C80** (dB)	3,3	5,0	5,3	6,4	6,4	5,4	6,2
	D50 (%)	43	53	56	64	65	61	66
On Stage	**C50** (dB)	-1,1	6,6	7,5	8,8	6,4	7,0	9,7
	D50 (%)	43	82	84	88	80	82	87

STI	
Audience	**2th Audience**
0,56	0,65

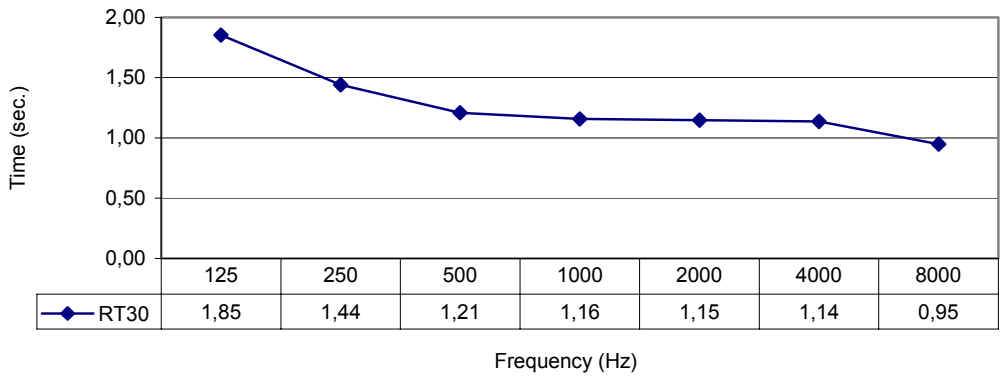
Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
1,20	1,40	1,39	0,96

V	**N**
Volume	**Seats**
5324	500

S_A	**S_0**	**S_{pit}**	**S_T**
336	144	33	513

V/N	**S_A/N**	**V/S_T**	**EDT/(Vx$10^{6)}$**
10,6	0,7	10,4	2,62 $^{-10}$

Reverberation Time



7. Concert Halls

7.1. Aula Magna

After several years in construction, the Lisbon University was opened in 1961, with a population of about 7000 students at that time. The University will become one of the most important studies centre of Portugal. Aula Magna is placed in the midle of University´s Rectory, and has the capacity for 1597 people. As architect this concert/conference hall had António Pardal Monteiro and as engineers José Marecos and João d`Arga e Lima.

According to the Amphi-theatre shape, with an isosceles trapeze form, there was the need to do the hall structure in radial sense and not the transversal sense. So, the main structure of the amphi-theatre consists on a serie of longitudinal metallic beam with a radial disposition.
Two characteristics were treated with special care: form (which is related to the sound propagation) and materials (related with the Reverberation Time and Inteligibility of Word).
With a volume of 14000 m^3 and with a fan shape, the project authors applied to the medium and rear halls smoth and hard superfícies in order to lead the sound rays to the poor zones of the hall.

The shape of the back hall is concave, which is not advisable by the acoustics experts because it can cause sound focalizations. However, it was constructed with an inclination of 6% to avoid completely the origin of any echoes.
The shape of the ceilling was studied in order to allow a convenience sound rays orientation to the hall rear, and besides that fact the geometric shape project of the hall lead to guide a convenient ceilling reflectors plan, regarding the phonic level compensation in the far zones of the sound origin, according to the quadratic square law.

Image 90

Aula Magna concert/conference hall.

Image 91

Aula Magna concert/conference hall stage view.

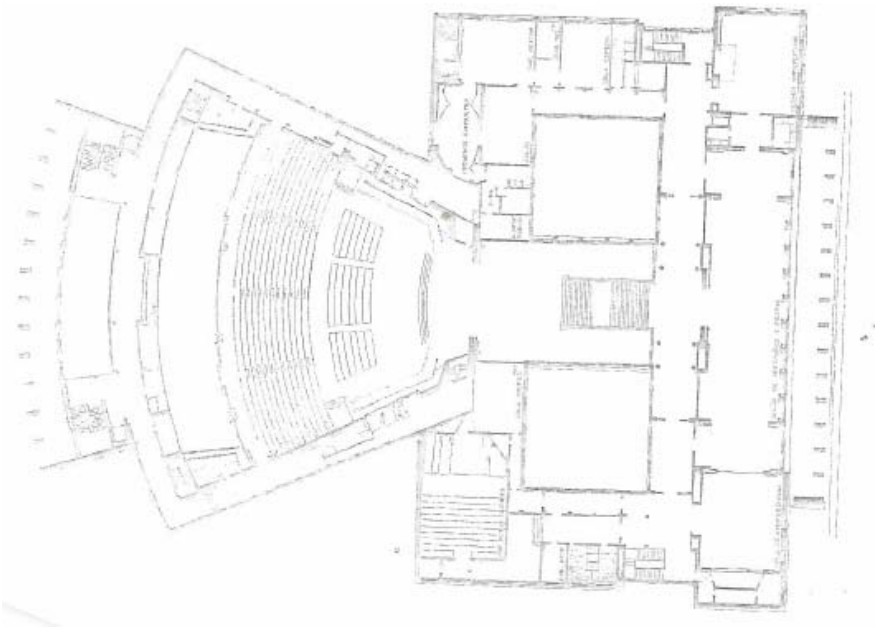


Image 92

Aula Magna concert/conference hall architectural plant.

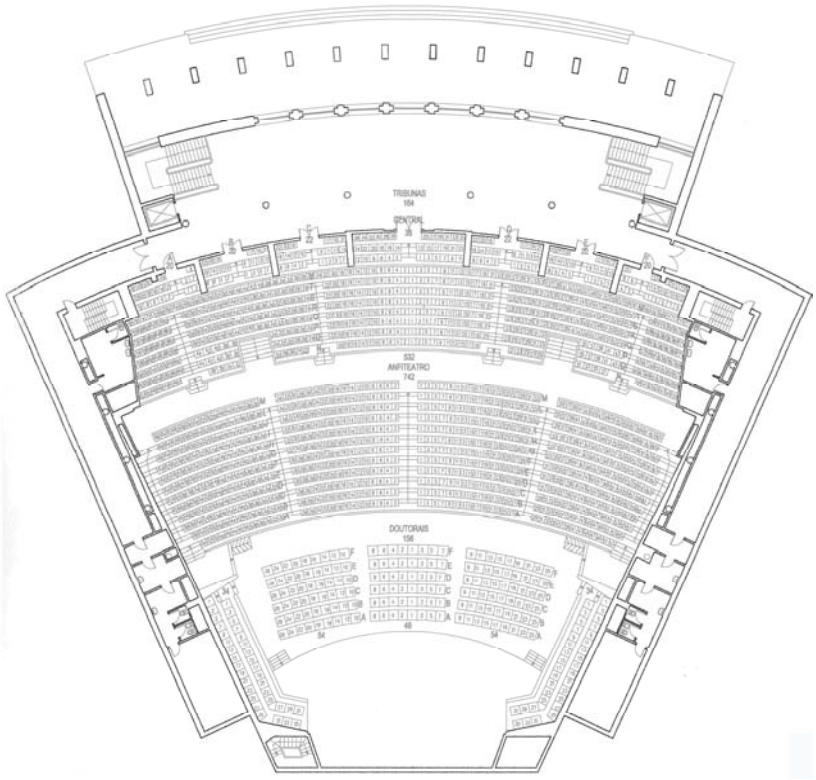
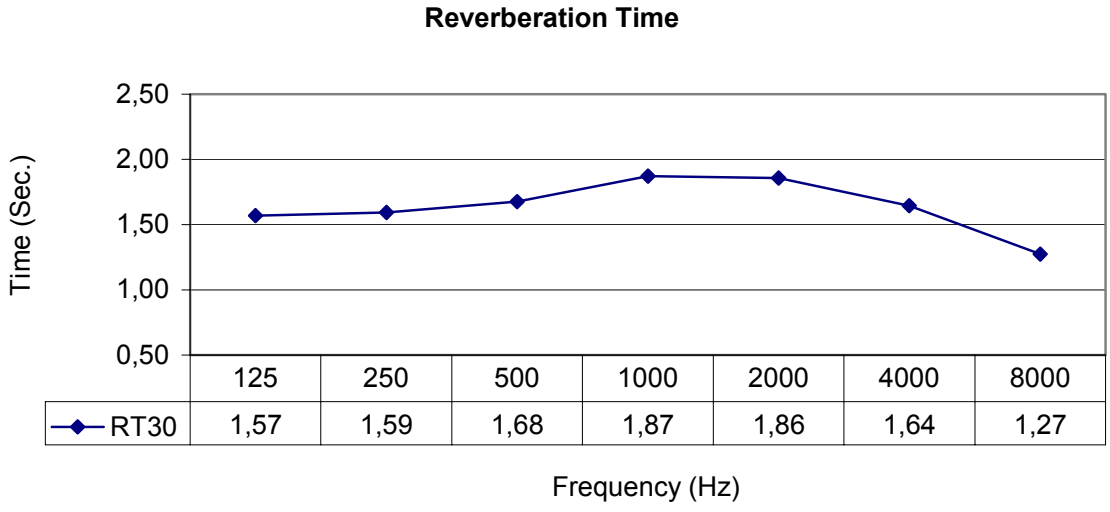


Image 93

Aula Magna concert/conference hall architectural lotation plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,57	1,59	1,68	1,87	1,86	1,64	1,27
	EDT (s)	1,46	1,62	1,77	1,96	1,94	1,71	1,27
	C80 (dB)	1,5	0,9	0,0	-0,6	-0,1	0,2	2,1
	D50 (%)	45	42	35	31	37	37	46
	Tc (ms)	109	111	125	140	129	117	88
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	2,9	2,6	3,7	2,2	2,9	4,7	7,4
	D50 (%)	64	65	69	61	66	74	84

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,77	1,88		0,88	0,98
N		V		STI
Seats		Volume		0,51
1800		14018		
S_A	S_0	S_{pit}		S_T
879,8	180,0	-		1060
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6)}$
8,78	0,55		13,23	1,34 $^{-10}$



7.2. CCB

Its construction was decided in 1988. The idea was to have a building able to receive, in 1992, the Portuguese Presidency of the EU (European union), remaining as an important (dinamizador) of cultural and leisure activities.

This remarkable building was built in Belém, this choice seems obvious, it was the place of departure of maritime discoveries and the magnificent Belém Tower and "*Padrão dos Descobrimentos"*.

After the international contest, there were 57 projects. The chosen one was the proposal of the Italian architect Vittorio Gregotti and the Portuguese architect Manuel Salgado, which comprehended 5 modules: reunion, show and exhibition centres, a hotel area and complementary equipment.

The big Auditorium has 1429 seats, the small Auditorium sits 310 people and the rehearsal room sits 85. In this structure, we can find the supporting rooms to the production and preparation of shows.

Even without two of the five modules initially foreseen, CCB has today a construction area of 97 thousand square meters, divided in 6 ha (hectares). There are two interior streets united by a footway which creates continuity to the Império Square. It's like a small city, with gardens, lakes, bridges, ramps, nooks and crannies. The Praça do Museu is in the limelight for its nobility.

It's a unique work , aesthetically, but this construction was a true challenge to engineering.

The CCB three modules have a rather complex structure with an electrical supply system, electrical nets, telecommunications, computer science, security and conditional air.

Image 94

CCB concert hall.

Image 95

CCB concert hall stage view.

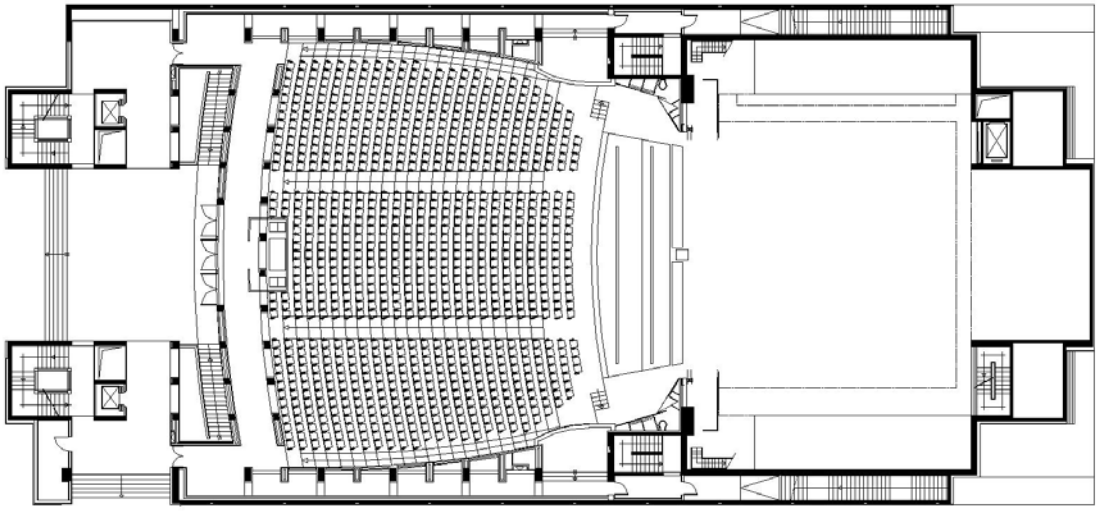


Image 96

CCB concert hall architectural plant.

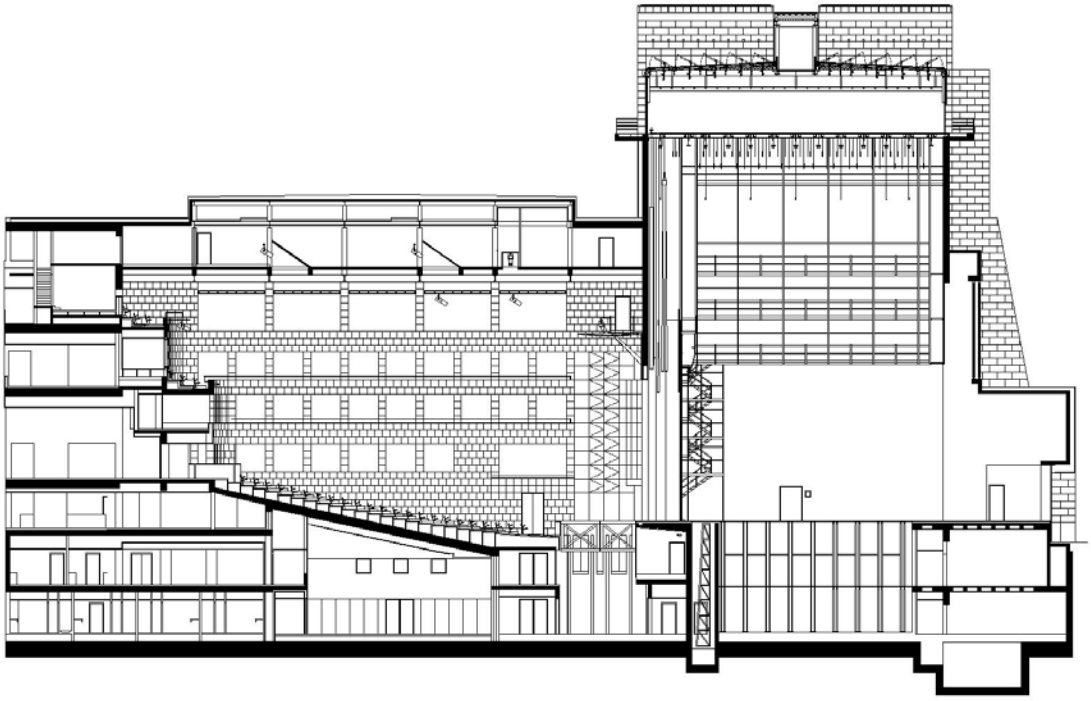
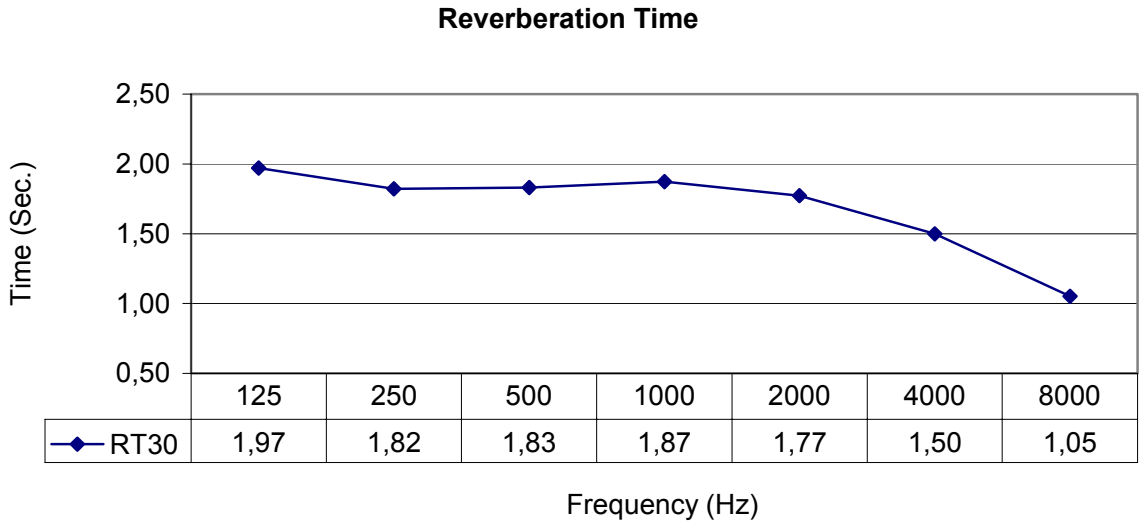


Image 97

CCB concert hall architectural cut

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,97	1,82	1,83	1,87	1,77	1,50	1,05
	EDT (s)	1,53	1,65	1,82	1,84	1,59	1,27	0,80
	C80 (dB)	-0,3	1,1	1,5	2,1	2,3	3,6	6,7
	D50 (%)	27	43	44	48	45	53	66
	Tc (ms)	126	110	108	101	97	77	46
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	3,30	0,93	5,77	4,87	4,30	4,93	7,30
	D50 (%)	67	54	79	75	73	75	84

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,85	1,83		1,02	0,88
N		V		STI
Seats		Volume		0,55
1200		13395		
S_A	S_0	Spit		S_T
538	325	77		940
V/S_T	S_A/N		V/N	$EDT/(Vx10^{6)}$
11,2	0,4		14,2	$1,37^{-10}$



7.3. CAE

The city of Figueira da Foz is located in the Portuguese Atlantic coast, at just about 180 km from Lisbon, 120 km from Oporto and 40 km from Coimbra. The sun and the beach are it's main touristy resources. 4 km of fine golden sand and sea give all the necessary to a relaxing fun, and pleasant vacations.

Inaugurated in July 1, 2002, the Centro de Artes e Espectáulos- a Luís Marçal Grilo project- stated as an important mark of a cultural intervention politics, becoming an attraction and projecting a city regionally and nationally.

Under the tutee of Figueira Grande Turismo - Em, the actions that lead to the valorisation of this cultural patrimony, shows, science reunions and others, have been intensified.

The general character of the auditorium will be evident from plants showed after. The audience area is rectilinear in main plan and cross-section, with the stage embodied in the hall rather than in a proscenium recess.

The audience area slopes, the floor is solid and carpeted and the walls have two especies of wood type and marmol. The audience area is composed by chairs with a maximum degree of upholstery, which means that absorption grows (in the case of occupied chairs) with the percentage of upholstery chairs, especially on low frequencies. (Beranek).

Image 98

CAE concert hall stage view.

Image 99

CAE concert hall sound technician view.

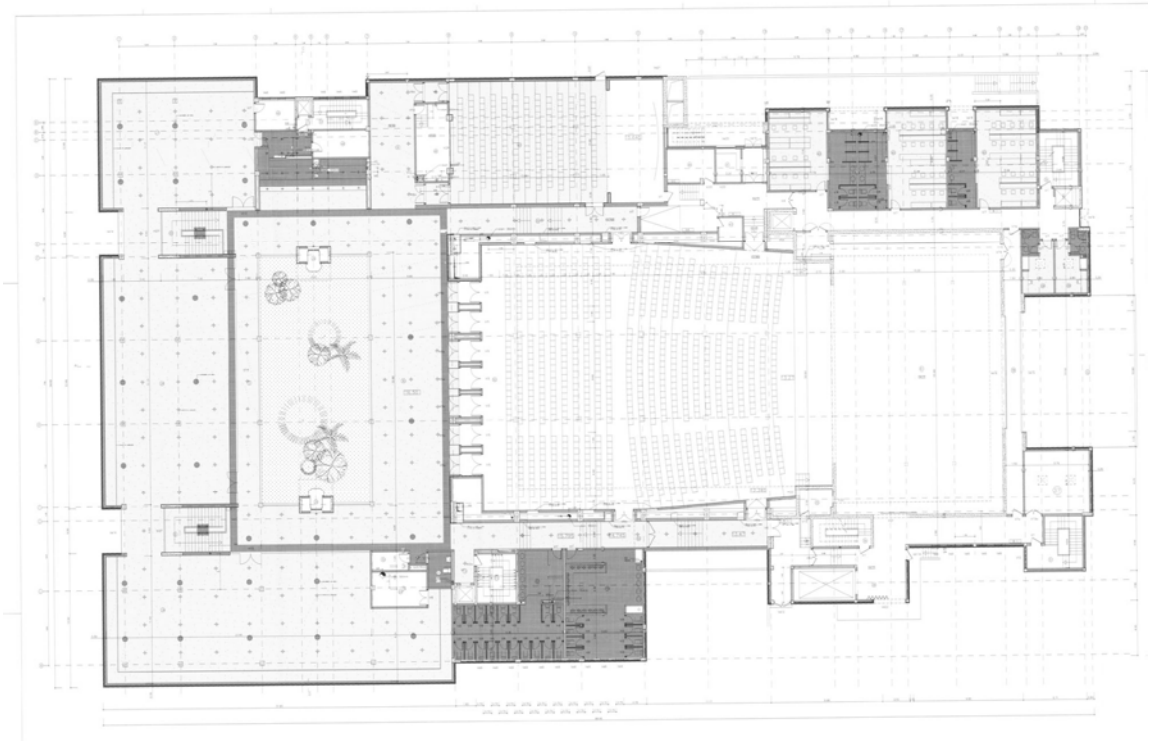


Image 100

CAE concert hall architectural plant.

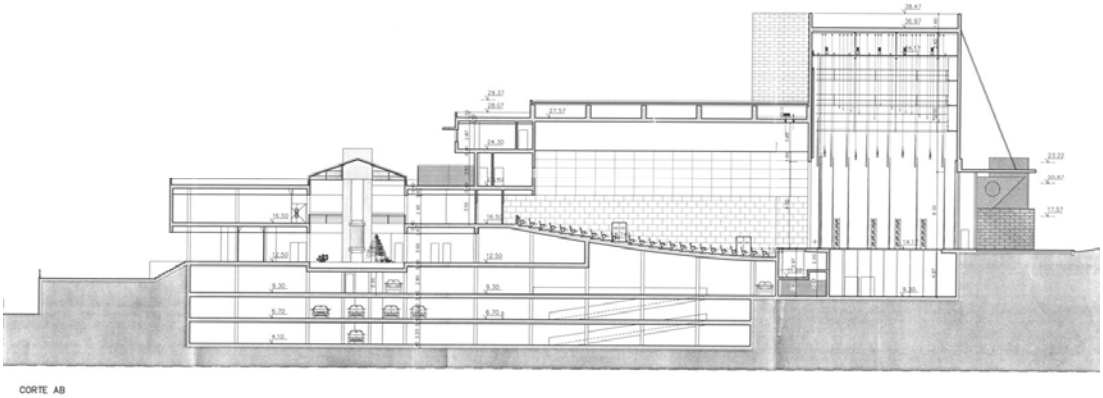


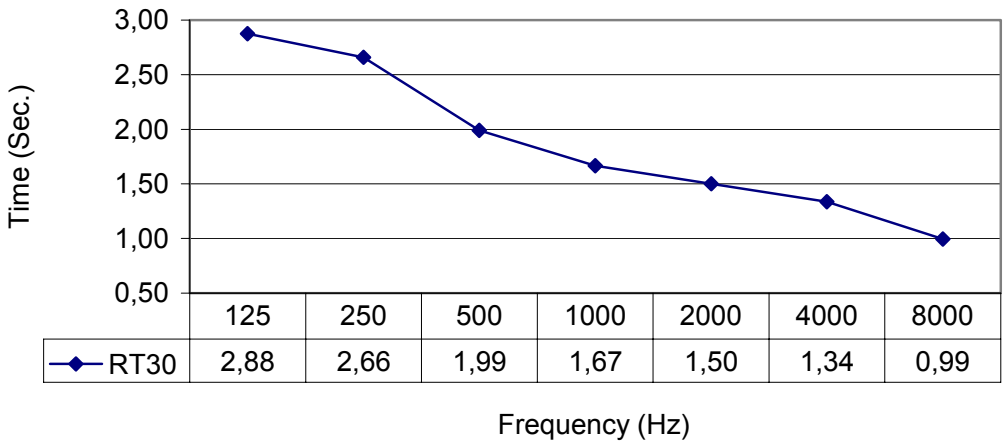
Image 101

CAE concert hall architectural cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Hall	TR30 (s)	2,88	2,66	1,99	1,67	1,50	1,34	0,99
	EDT (s)	2,09	1,89	1,55	1,48	1,38	1,16	0,97
	C80 (dB)	-0,5	0,5	0,9	0,9	2,5	3,6	5,6
	D50 (%)	34	41	41	38	50	53	61
	Tc (ms)	154	129	111	108	86	72	53
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	-1,4	7,1	5,8	6,6	8,7	9,6	10,8
	D50 (%)	41	83	78	81	88	89	91

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,79	1,51		1,50	0,79
N		**V**		**STI**
Seats		**Volume**		0,54
800		7488		
S_A	S_0	**Spit**		S_T
481	224	56		717
V/N	S_A/N		V/S_T	EDT/(Vx$10^{6)}$
9,4	0,7		10,4	$2,02^{-10}$

Reverberation Time



7.4. Casa da Música

The idea of building Casa da Música came up in the extent of Oporto 2001 – The European Capital of Culture and it was shown to the public as a paradigm of the transformations to raise to power in town at the time of this event. Conceived by the Dutch arquitect Rem Koolhaas, Casa da Música is a multidiscipline and polyvalent space, with undercarriages, spaces, extraordinary technical and acoustic means to the production and shelter of various musical shows and other events.
Its action will certainly mark the Portuguese cultural scenery as a centre of production, divulging and a privileged musical formation, through the interpreter's improvement, new audience's creation, innovation and as recording centre, for its technical and acoustics improved conditions.

The Big Auditorium will be the neuralgic centre and the public heart of the House of Music. With a total area of 1100 m2 and the capacity for 1238 seats, it is gifted with the most demanding acoustics and technical conditions to the welcoming of medium and big productions. It also has all the needed structures for recording, filming and show's transmission in ideal conditions. With the shape of a huge rectangle, it has laterally and in its ends, glazed areas which allow the visual communication with other public areas of the building. Behind the pit (audience) and the stage, two glass walls complete the principle of transparency which presided at its conception. The pit in slope has also two small lateral dress-circles for 26 people. The stage, with a capacity for 110 musicians, divides itself in several sections equipped with elevators. It can still be amplified by the removability of the first four rows of the pit, allowing the creation of an orchestra ditch. The back side of stage can still take a choir of 143 elements. The installation of two organ pipes of different features will be a rare value in world-wide terms. In the inside decoration, the silver and golden colours prevail, opposing intentionally with light movements proportionate by its glassed spaces.

Image 102

Casa da Música chorus view.

Image 103

Casa da Música concert hall.

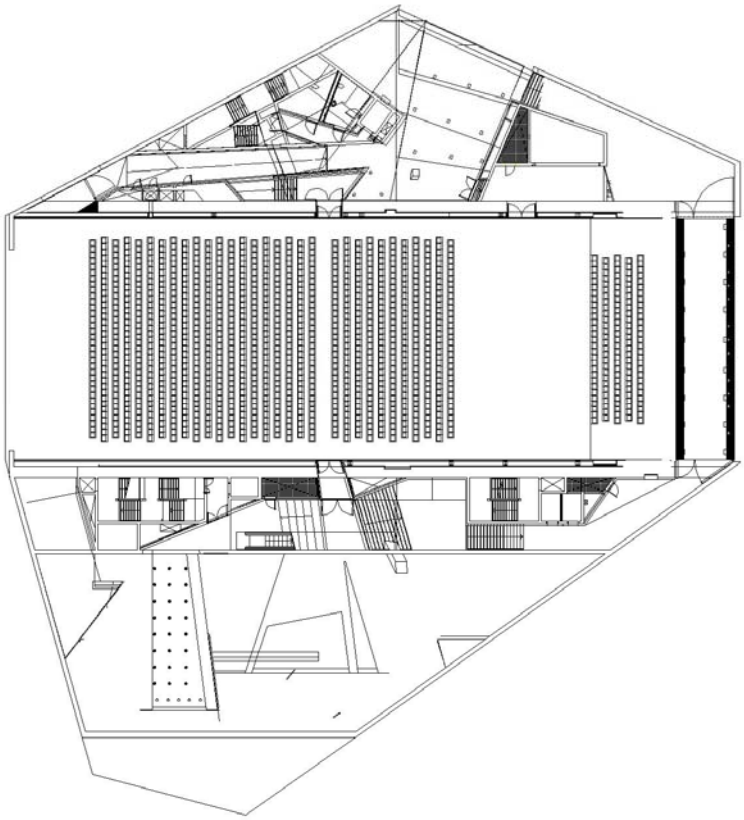


Image 104

Casa da Música architectural plant.

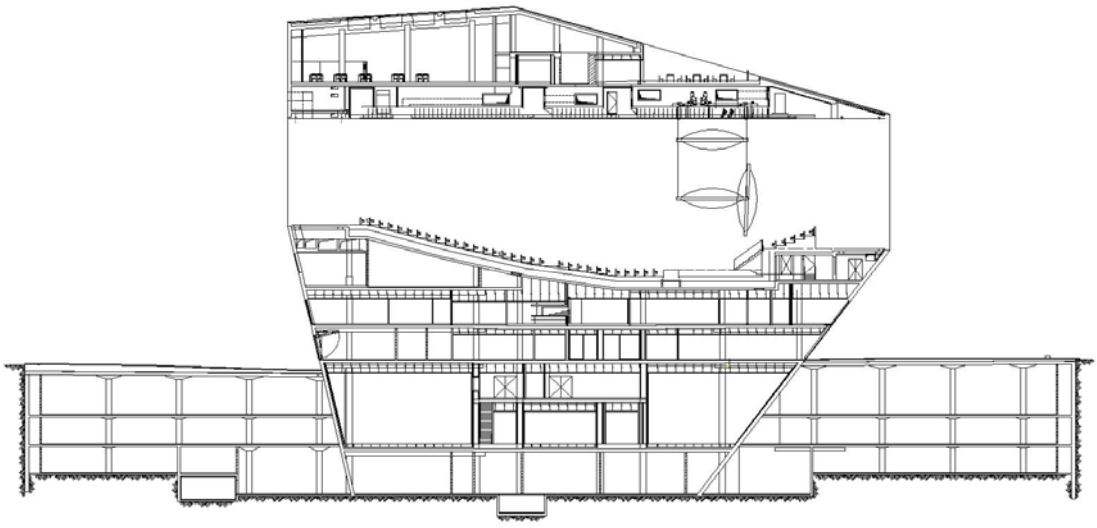
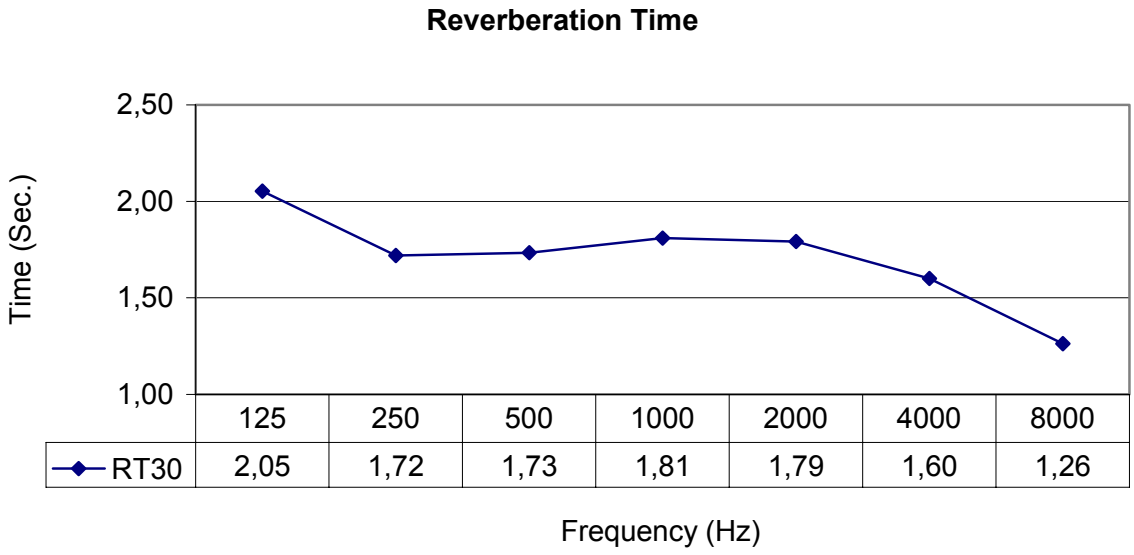


Image 105

Casa da Música architectural cut.

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	2,05	1,72	1,73	1,81	1,79	1,60	1,26
	EDT $_{(s)}$	1,94	1,74	1,68	1,60	1,69	1,51	1,19
	C80 $_{(dB)}$	-2,4	-0,5	0,3	0,7	0,7	1,2	3,1
	D50 $_{(\%)}$	21	33	35	36	39	42	50
	Tc $_{(ms)}$	157	124	117	109	109	97	71
	G $_{(dB)}$	-	-	-	-	-	-	-

Seconds				
RT_{mid}	**EDT_{mid}**		**BR**	**Br**
1,77	1,64		1,07	0,96
N		**V**		**STI**
Seats		**Volume**		0,50
1238		13376		
S_A	**S_0**	**Spit**		**S_T**
653	180	-		833
V/N	**S_A/N**		**V/S_T**	**EDT/(Vx$10^{6)}$**
10,80	0,53		16,06	1,22 $^{-10}$



7.5. CNEMA – Exposition National Centre

Located at only 2 km from the centre of the city, the National Exhibitions Centre was inaugurated in 1994, being the result of an extreme necessity of constructing a modern and adequate exposition centre facing the demandings of the evolution of the National Agriculture Fair/ Ribatejo Fair, an annual event that gave world wide prestige to the name of this city. The necessity of changing started to be felt at the end of the seventies decade. The posterior editions of this fair are more and more focused on the agriculture technical aspects and problems as well as on the Portuguese entry in CEE. At the beginning of the eighties same lands are bought and in 1989 the constitution of the "CNEMA" society, that brings live to the now existing National Centre of Exhibitions, is signed.

In 1994 the fair already took place in this centre. Modern, functional, and polyvalent, this centre brought a lot of improvements to the fair, to the exhibitioners as well as to the visitors, which number has grown up year after year, thanks to the space and facilities they now have.

The Main Auditorium disposed in an amphitheatre, with 1200 seats, it's equipped with the most modern sound, light and video projection systems. It has two dressing rooms (in the basement) with capacity for 50 people, with wc's, shower and make up room, stage, six cabins of simultaneous translation an four VIP boxes.

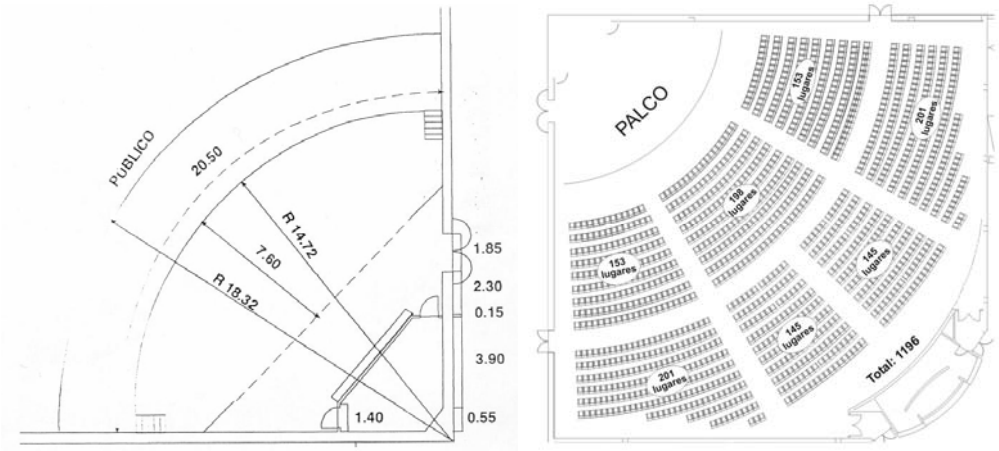


Image 106

CNEMA concert/conference hall stage and lotation plant.

Image 107

CNEMA concert/conference hall stage view during the measurements.

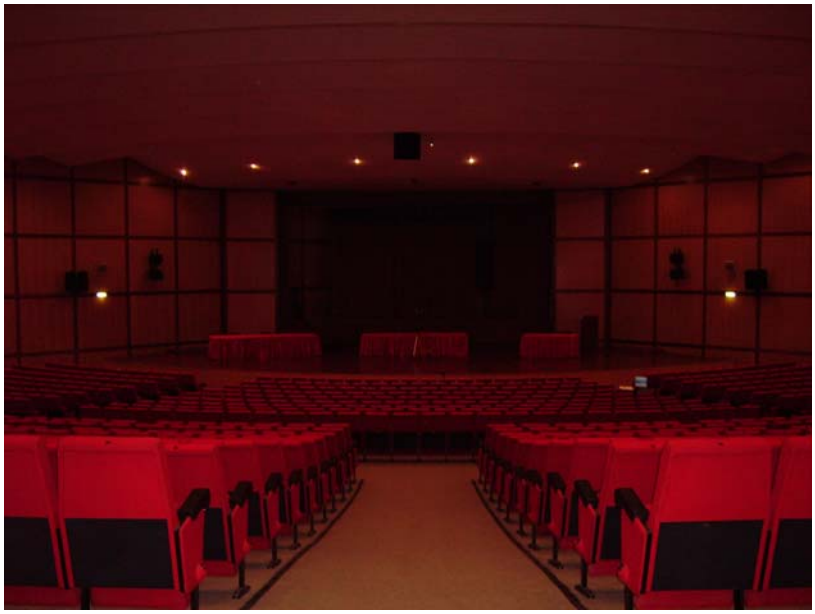


Image 108

CNEMA concert/conference hall.

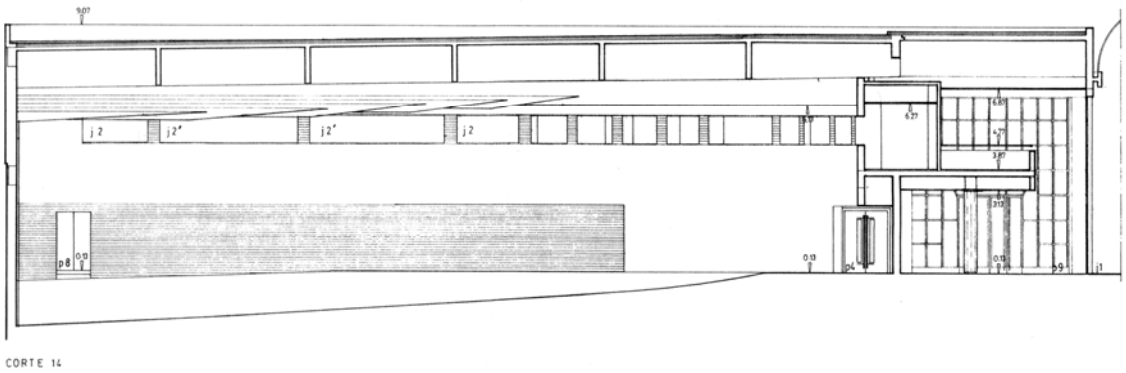


Image 109

CNEMA concert/conference hall architectural cut.

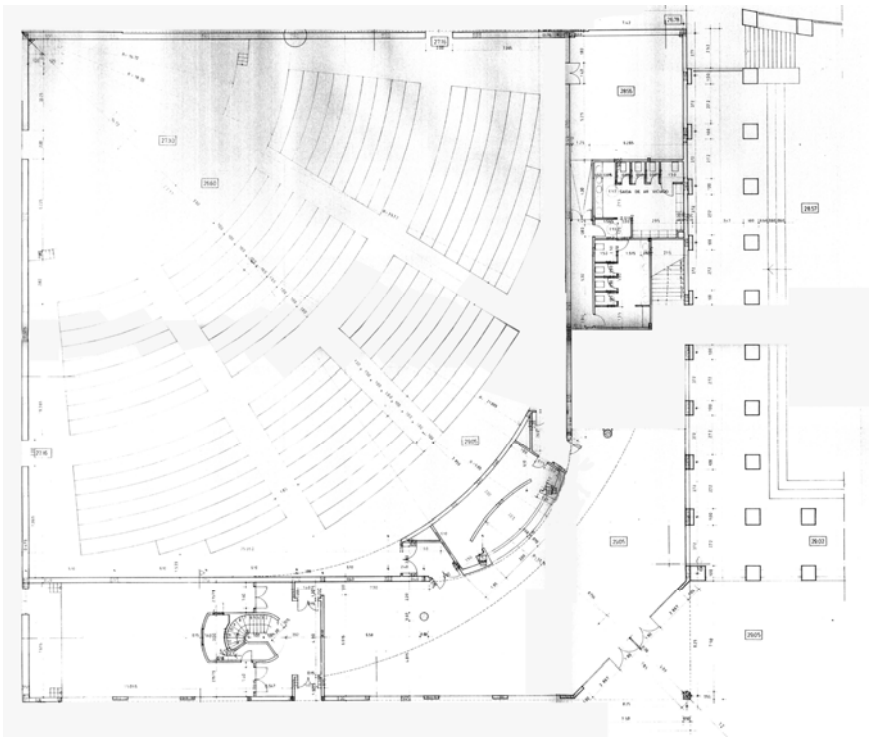
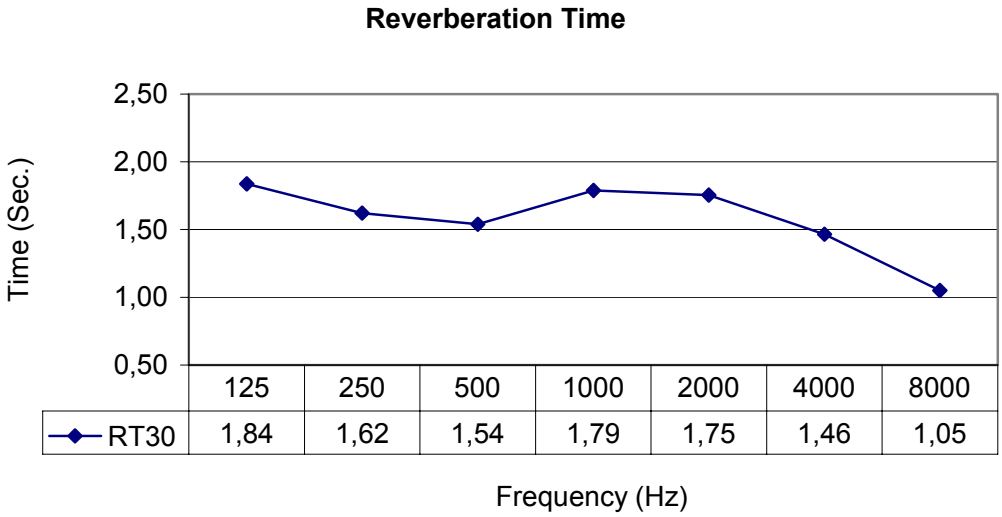


Image 110

CNEMA concert/conference hall architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,84	1,62	1,54	1,79	1,75	1,46	1,05
	EDT (s)	1,67	1,54	1,48	1,64	1,52	1,34	1,05
	C80 (dB)	0,3	1,3	0,4	0,9	2,0	3,2	6,5
	D50 (%)	39	46	41	47	52	57	73
	Tc (ms)	123	102	103	99	86	70	43
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	0,3	0,2	3,4	1,0	4,1	4,7	6,4
	D50 (%)	51	51	67	55	70	74	80

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
1,65	1,56		1,04	0,97
N		V		STI
Seats		Volume		0,56
1200		7776		
S_A	S_0	Spit		S_T
606	169	-		775
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6)}$
6,48	0,51		10,03	2,00 $^{-10}$



7.6. Oporto Coliseum

In 1911, the Salão Jardim Passos Manuel (now known as Coliseu do Porto), suffered some improvements and was extended, having also a garden esplanade, a party room, a restaurant, an hall and a small theatre. By the end of the 1920's, trying to keep up with the society cultural habits, the room becomes a polyvalent space that received cinematography successes, social evenings, cultural reunions and conferences. By the end of the 1930's, its activity started to decay, partly due to the rising of other entertainment forms. It was in this mythical place that Oporto saw its coliseum being born.

Unexpectedly, it's in a season where the world is leaving under an extreme insecurity that the project starts moving on. The Coliseu do Porto took 22 months to be built and cost a lot more than what was usual back then.

In 1937, the building starts to rise but it is only in 1939 when Cassiano Branco takes charge as head- architect, with the collaboration of Júlio Brito, with whom he would later have a conflict. After various events and after several architects, engineers and contractors, the coliseum is finished in 1941, in a modern style that immediately became an architectonical reference. A modern building that marks in an undeniable way Oporto's downtown as well as the heart of every citizen.

For several decades, the coliseum had a glamorous life, bringing to the Oporto citizens all kinds of shows: opera, dance, classical music, pop music, variety shows, musicals, circus, carnival parties, new year parties, movies, social evenings and congresses. After a big fire in November 28th of 1996, the coliseum opened its doors, after an impressive recovery, in November 24th of 1998, with the presentation of the opera Carmen, by Bizet, in a co-production with the Oporto Opera's Circle and the Oporto National Orchestra.

At the same time, the equipments and technologies were modernized, and the coliseum has now all the conditions to receive all kind of shows, including large dimensions shows. These improvements made the coliseum a polyvalent room able to recover its "golden years".

In 2001, Oporto was the european cultural capital, a great opportunity to show the world what an excellent cultural property the coliseum is.

Image 111

Oporto Coliseum concert hall.

Image 112

Oporto Coliseum concert hall audience view.

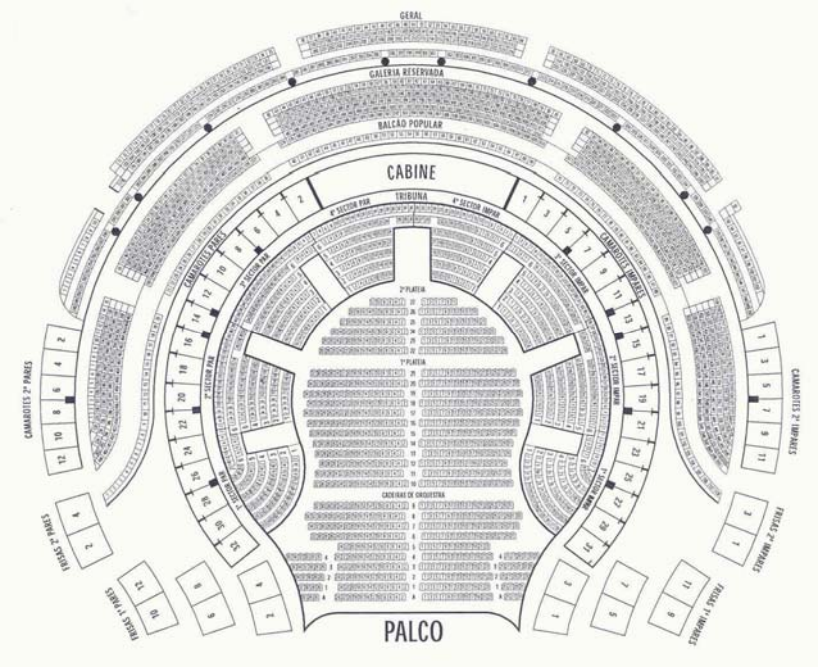


Image 113

Oporto Coliseum concert hall lotation plant.

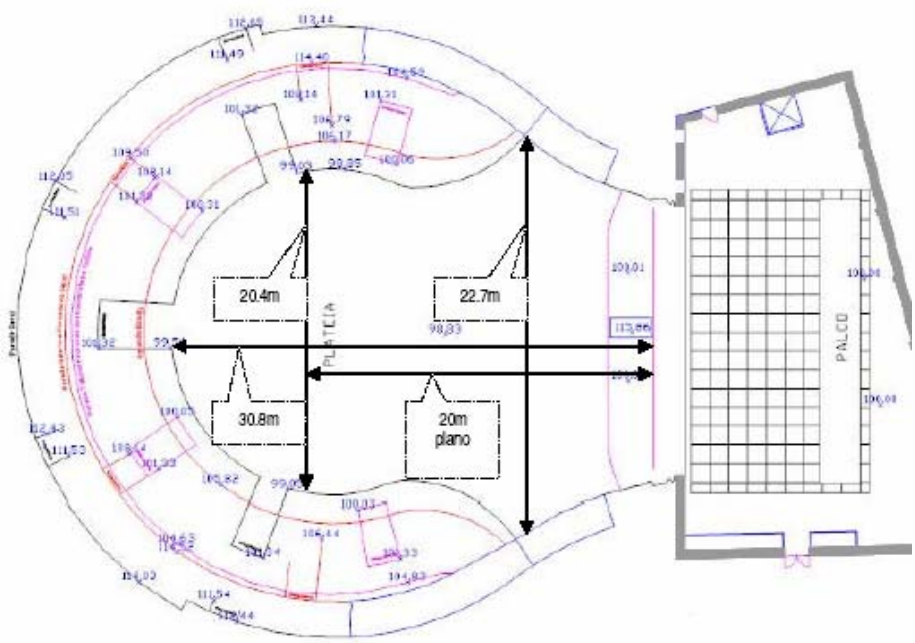


Image 114

Oporto Coliseum concert hall architectonic plant and main dimensions.

1. Orchestra Configuration: Acoustic Shell on Stage

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,46	2,34	2,45	2,51	2,65	2,42	1,77
	EDT (s)	2,47	2,33	2,39	2,51	2,65	2,24	1,50
	C80 (dB)	-1,5	-1,7	-0,9	-0,6	-0,4	1,0	2,9
	D50 (%)	28	27	29	34	35	44	54
	Tc (ms)	178	167	158	156	163	128	87
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	1,6	5,6	6,3	6,4	6,1	7,9	9,3
	D50 (%)	59	78	80	79	79	85	89

Seconds			
RT_{mid}	EDT_{mid}	BR	Br
2,48	2,45	0,97	1,02

2. Theatre/Pop/Rock Configuration

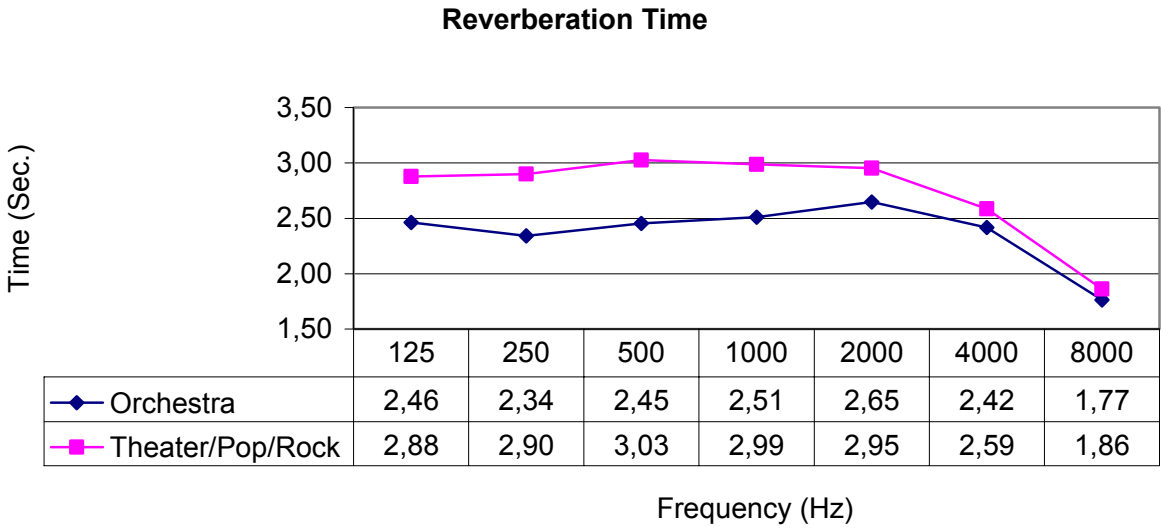
		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,88	2,90	3,03	2,99	2,95	2,59	1,86
	EDT (s)	2,57	2,83	3,09	3,08	3,05	2,66	1,69
	C80 (dB)	-0,2	-1,3	-2,2	-0,7	-0,8	1,8	4,5
	D50 (%)	36	33	28	37	33	50	64
	Tc (ms)	165	180	205	181	183	122	72
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	-0,7	5,4	7,3	7,2	8,7	10,3	12,7
	D50 (%)	46	77	84	82	88	91	94

Seconds			
RT_{mid}	EDT_{mid}	BR	Br
3,01	3,08	0,96	0,92

N		V		STI
Seats		Volume		0,47
3500		12566		

S_A	S_0	S_{pit}		S_T
628	180	87		896

V/S_T	S_A/N		V/N	$EDT/(Vx10^{6)}$
6,47	0,32		14,03	$1,94^{-10}$


Reverberation Time
Time (Sec.)
3,50
3,00
2,50
2,00
1,50
125
250
500
1000
2000
4000
8000
Orchestra
2,46
2,34
2,45
2,51
2,65
2,42
1,77
Theater/Pop/Rock
2,88
2,90
3,03
2,99
2,95
2,59
1,86
Frequency (Hz)

7.7. Recreios Coliseum

On August 14, 1890, a big show room opened in Lisbon, the newest Coliseu dos Recreios. Several motifs lead to the closure of other show rooms, what became urgent the construction of this new space, located in Rua das Portas de Santo Antão and opened to the public even before being finished. Having the collaboration of foreign artists, the coliseum was an innovation in what concerns to the introduction of iron in the architecture, what was rare in Portugal, trough the spectacular iron copula, with 25 metres of width and 100 tons of weight, that imported from Berlin. The engineer Lacombe installed the roof, also in iron, in 1889. The engineers Goulard, father and son, and the portuguese Manuel Garcia Júnior were the responsible by the line of the project; the metallic construction was under the care of Castanheira das Neves and the paintings and decoration were due to the painter António Machado. The architect Cesare Ianz took care of the project of the 3 storey-building facade, with decorative motifs in plaster and a few figure-head, that give and increase its graciosity, being the last part finished. It's construction is due to four daring enterprisers (the solicitor José Frederico Ciríaco, the philosophy professor Pedro António Monteiro, the warehouse owner António Caetano Macieira and the meat tradesman João Baptista G. de Ahneida), that thought in building the biggest covered building in the world in the show context and which the capacity would rise above the 4000 seats.

Several exterior and interior restoration works were performed in this show room. Inside the showroom, the most significant changes took place in the gallery and in the reserved gallery that are now continuous, and in the narrow balcony above the central entrance that simply was removed. In the ceiling, a massive globe was put in the middle of the room, surrounded by others through 2 concentric circumferences.

These works were concluded in February of 1994 and the room was opened at the end of the same month with a concert that marked the beginning of the cultural events of "Lisboa 94".

Image 115

Recreios Coliseum stage view.

Image 116

Recreios Coliseum concert hall.

Image 117

Recreios Coliseum architectural cut.

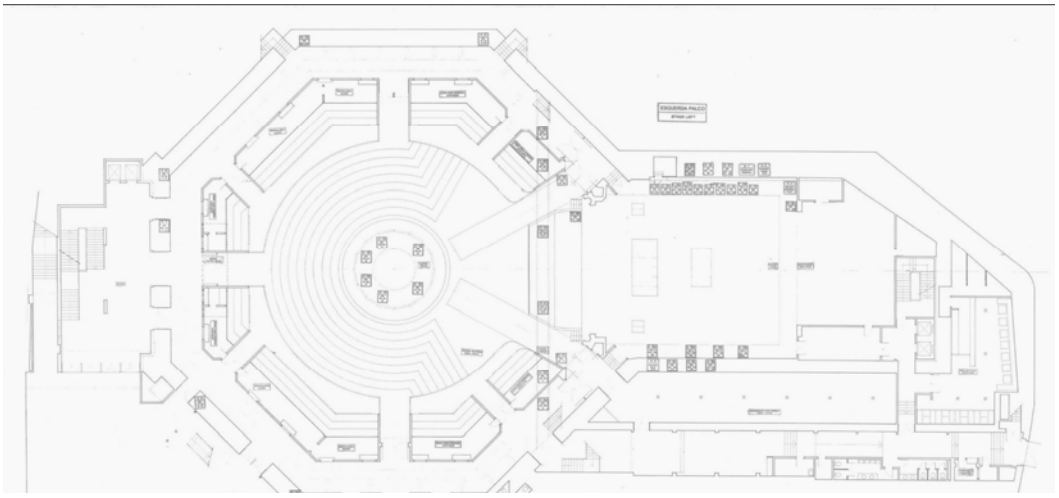


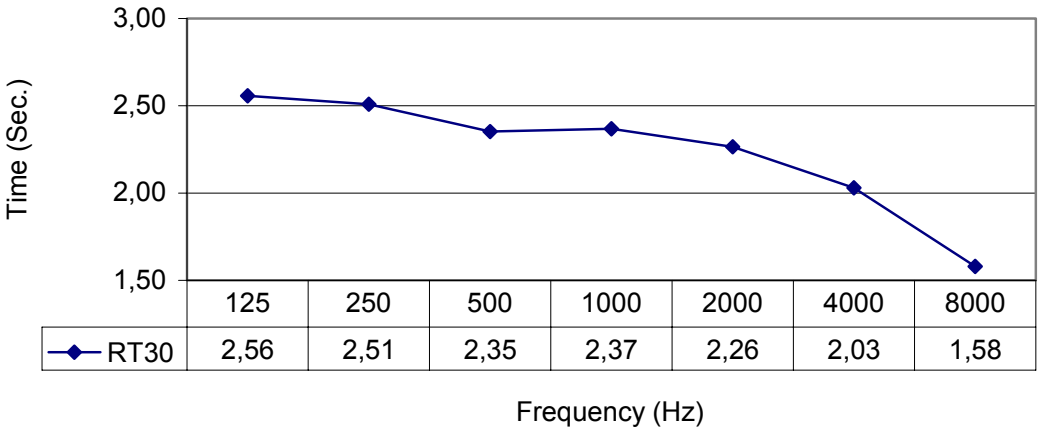
Image 118

Recreios Coliseum architectural plant.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	2,56	2,51	2,35	2,37	2,26	2,03	1,58
	EDT (s)	2,88	3,04	2,54	2,48	2,36	2,14	1,65
	C80 (dB)	-0,1	-1,1	-2,0	-3,7	-0,8	-1,6	0,0
	D50 (%)	42	37	32	21	37	31	38
	Tc (ms)	161	178	170	194	144	148	112
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	1,5	8,3	6,4	7,7	8,7	7,5	7,8
	D50 (%)	58	87	81	85	88	83	81

Seconds				
RT_{mid}	EDT_{mid}		BR	Br
2,36	2,51		1,07	0,91
N		**V**		**STI**
Seats		**Volume**		0,44
2500		25817		
S_A	S_0	**Spit**		S_T
695	180	62		937
V/N	S_A/N		V/S_T	$EDT/(Vx10^{6)}$
13,66	0,37		27,55	9,73 $^{-11}$

Reverberation Time



7.8. Culturgest

Caixa Geral de Depósitos had it's first main building in Calhariz, in 1987. Since then, the institution expansion, around Lisbon, in what concerns to central support services, lead to the necessity of occupying about 29 buildings and to the communication difficulties that came with this dispersion.

So, a land located between Campo Pequeno and London Square, where at the end of the 50's the Companhia das Fábricas de Cerâmica Lusitana was installed and that presented all the necessary characteristics was chosen.

The selected Project, from the architect Arsénio Cordeiro, then began. At the end of 1989 it suffered several changes, due to the modernization politics, regionalization and consequent rationalization of effectives.

Culturgest it's a cultural space that integrates two auditoriums for congresses, seminars, conferences, concerts, theatres, ballet and two galleries for exhibitions, reunions rooms, press room and other support structures.

According to the Amphi-theatre shape, with a trapeze form, two characteristics were treated with special care: form (which is related to the sound propagation) and materials (related with the Reverberation Time and Inteligibility of Word), like Aula Magna concert hall.

The shape of the back hall is concave, which is not advisable by the acoustics experts because it can cause sound focalizations. However, it was constructed with an inclination of > 6% to avoid completely the origin of any echoes.

Image 119

Culturgest concert/conference hall stage view.

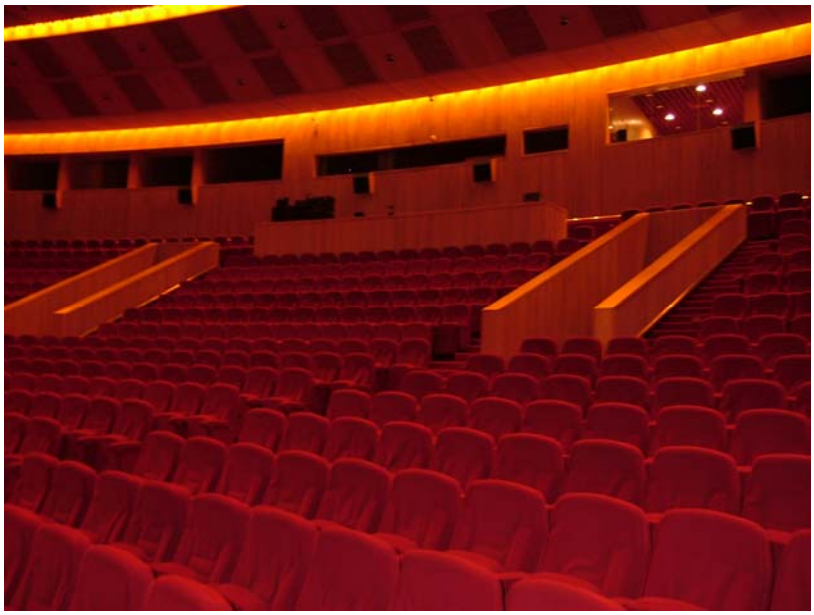


Image 120

Culturgest concert/conference hall.

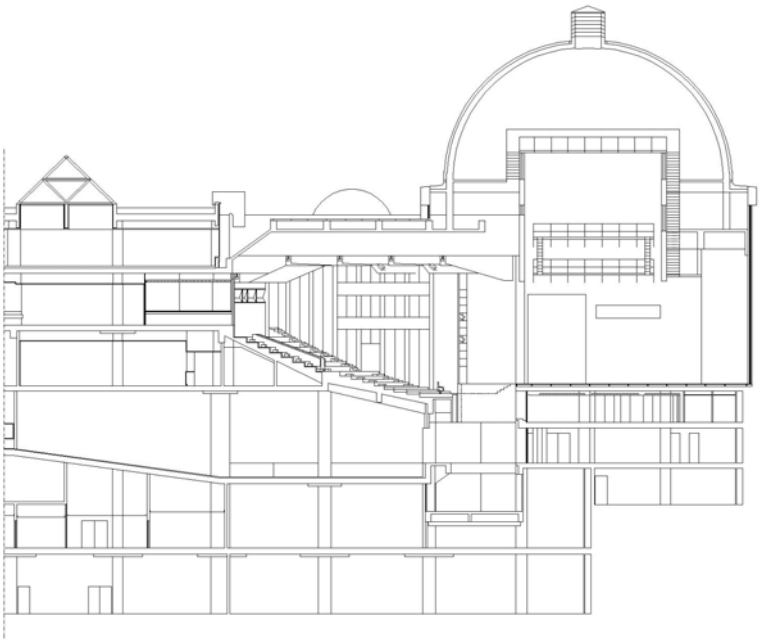


Image 121

Culturgest concert/conference hall architectural cut.

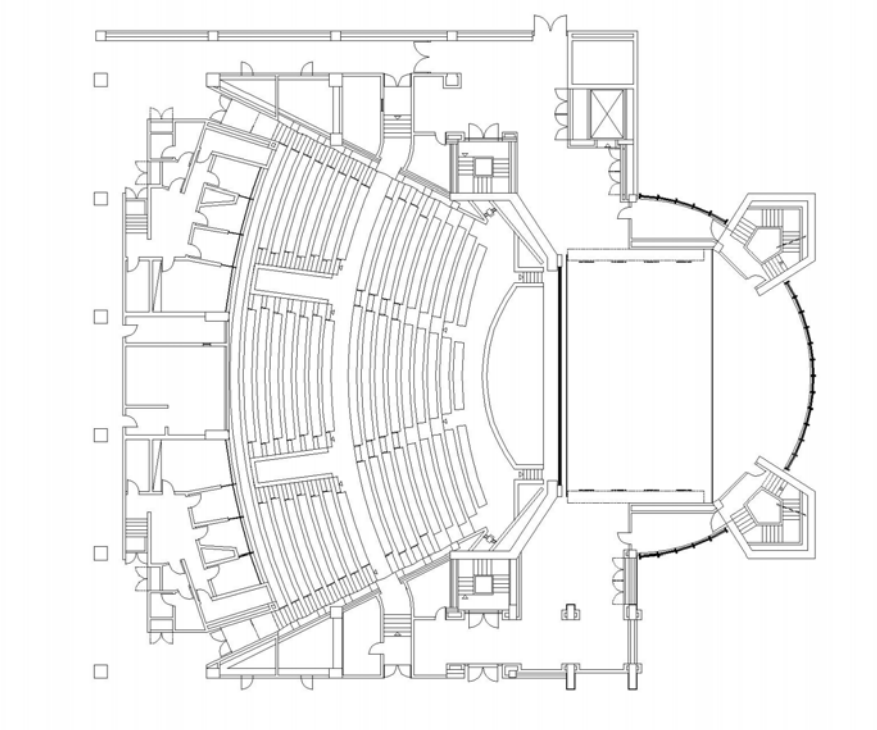


Image 122

Culturgest concert/conference hall architectural plant.

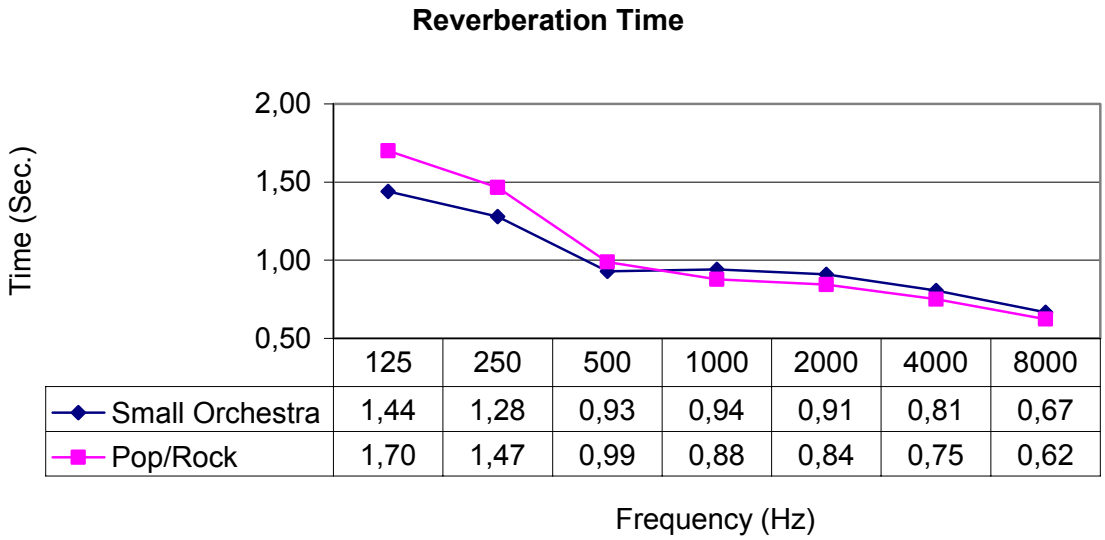
1. **Small Orchestra Configuration: Half Acoustic Shell on Stage**

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,44	1,28	0,93	0,94	0,91	0,81	0,67
	EDT $_{(s)}$	0,93	0,85	0,92	1,05	0,95	0,86	0,80
	C80 $_{(dB)}$	3,0	5,2	4,0	3,9	4,7	6,4	7,7
	D50 $_{(\%)}$	50	63	57	57	62	68	73
	Tc $_{(ms)}$	78	59	62	62	55	42	35
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	5,5	7,4	6,4	6,8	5,6	6,3	8,8
	D50 $_{(\%)}$	75	84	81	80	78	77	82

2.**Conferences and Pop/Rock Configuration:**

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,70	1,47	0,99	0,88	0,84	0,75	0,62
	EDT $_{(s)}$	0,95	0,77	0,80	0,87	0,82	0,78	0,65
	C80 $_{(dB)}$	3,6	6,5	5,2	4,6	5,7	6,8	8,5
	D50 $_{(\%)}$	51	72	60	59	66	69	75
	Tc $_{(ms)}$	76	49	56	59	49	41	33
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	5,5	6,1	8,0	6,6	6,9	8,4	10,6
	D50 $_{(\%)}$	79	77	84	79	80	85	91

Seconds				
RTmid	**EDTmid**		**BR**	**Br**
0,93	0,84		1,70	0,85
N		**V**		**STI**
Seats		**Volume**		0,66
652		4646		
S_A	S_0	S_{pit}		S_T
371	151	40		562
V/N	S_A**/N**		**V/**S_T	**EDT/(Vx10**$^{6)}$
7,13	0,57		8,26	1,80 $^{-10}$



	125	250	500	1000	2000	4000	8000
Small Orchestra	1,44	1,28	0,93	0,94	0,91	0,81	0,67
Pop/Rock	1,70	1,47	0,99	0,88	0,84	0,75	0,62

7.9. Europarque

Europarque – Economical and Cultural Center is in Santa Maria da Feira, located 30 Km south of Oporto, next to main motorway axis Lisboa-Oporto.

Only recently, for events like conferences and commercial exhibitions, the only equipped infrastructures was Exponor. Europarque´s program seeks the development and the organisation of cultural, commercial and social events of high standard quality in the attempt of pushing the main sectors of Portuguese society to European levels. In this location it will concentrate, a congress centre, a performing arts centre (the one that is studied in this work), a technological centre, a leisure centre and a wildlife centre.

One can easily understand the enormous versatily and polyvalence required by the program, project and building of this centre. All spaces, systems and equipments have been built with one common goal: performing many different types of events: for Live Performances (Opera, Theatre and dance; Concerts and Fashion Show), Projection (Cinema and Video) and for Presentations like Congress, Conferences, Seminars and Marketing presentations.

The official inauguration was held on April 8th 1995. On April 11th Europarque opened to the grater public to present the 1st World Voice Congress.

A grand concert was held to conclude the congress works that gathered, on the same stage, four of the most magnificient "*Bel Canto*" voices: José Carreras, Agnes Balsa, Oleana Cotrubas and Ferrucio Furlanetto, accompanied by the Orquestra Sinfónica Portuguesa directed by maestro Manuel Ivo Cruz.

During the first season the polyvalence of this performing arts centre was tested by presenting several different types of events in areas like politics, commerce and performing arts.

In his architectural project, Europarque had ARSUNA, Lda with the coordenation of Arq. Flavio Tirone and the colaboration of Arqs. Cidália C. Worm, Paulo Ramos, Nuno Dias and Pedro Pereira.

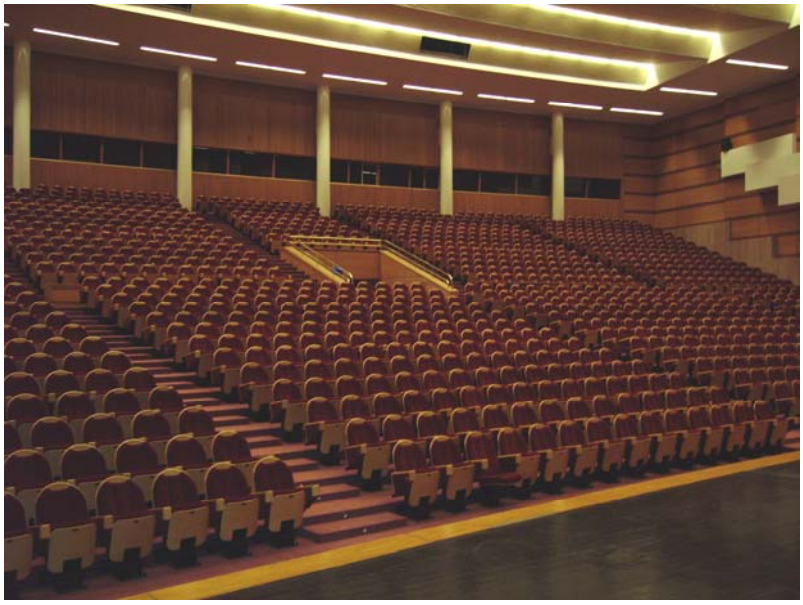


Image 123

Europarque concert/conference hall.

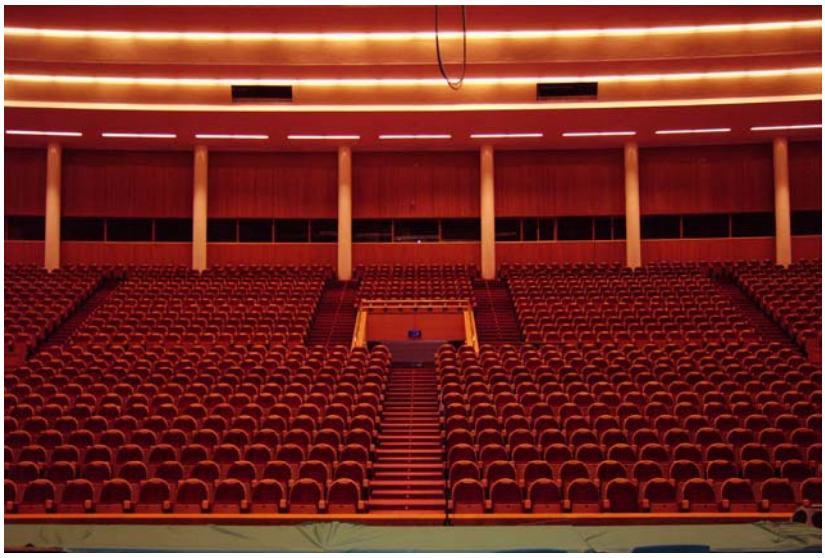


Image 124

Europarque concert/conference hall stage view.

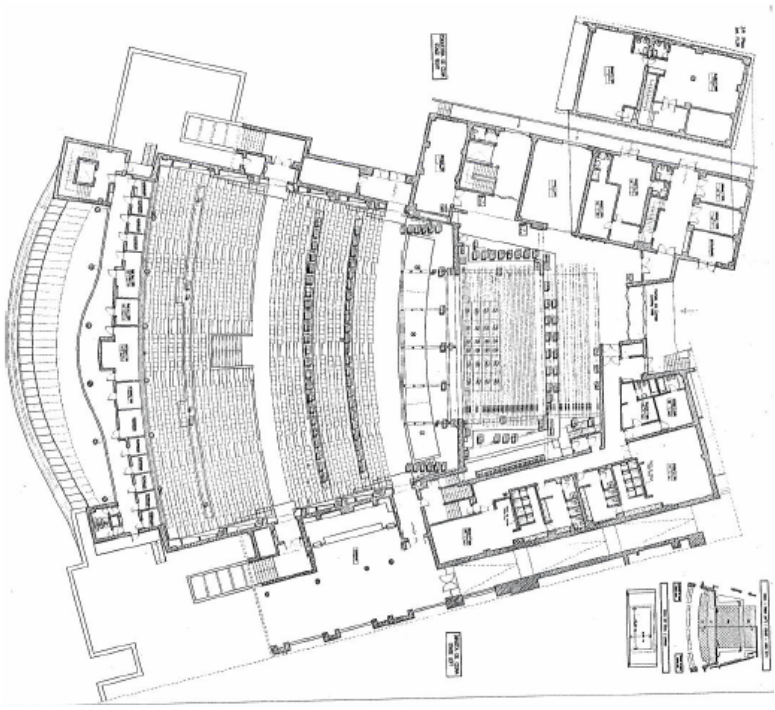


Image 125

Europarque concert/conference hall architectonic plant.

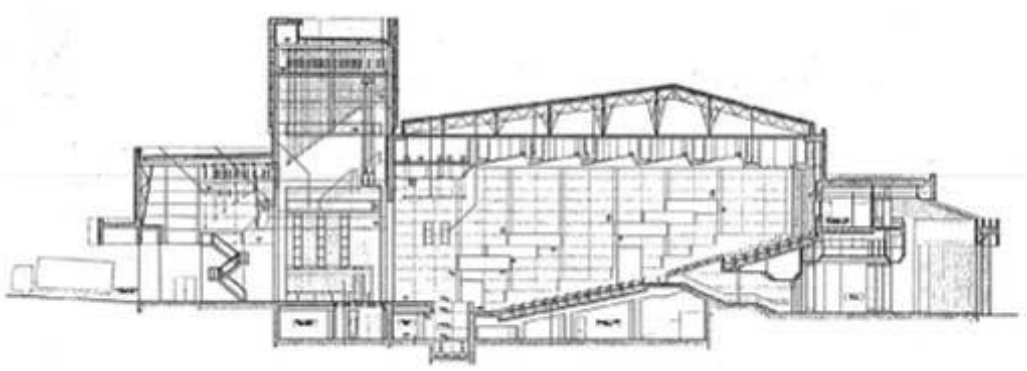
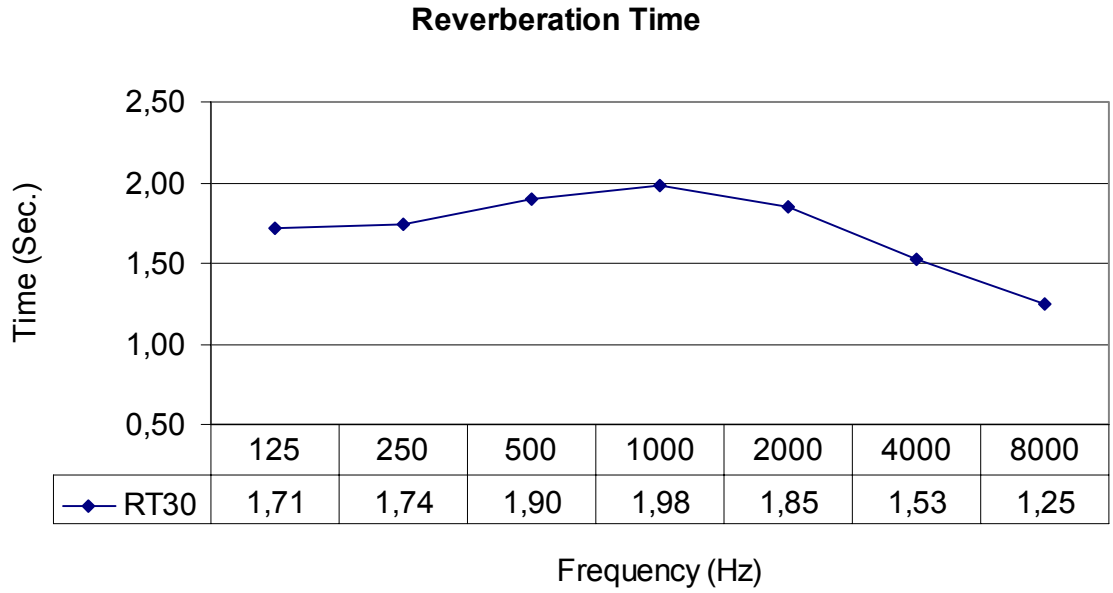


Image 126

Europarque concert/conference hall architectonic cut.

		Hz						
		125	250	500	1000	2000	4000	8000
Audience	TR30 (s)	1,71	1,74	1,90	1,98	1,85	1,53	1,25
	EDT (s)	1,56	1,72	1,76	1,82	1,71	1,53	1,29
	C80 (dB)	0,3	-0,1	-0,5	-1,9	0,0	-0,7	-0,8
	D50 (%)	36	37	36	28	39	36	36
	Tc (ms)	123	125	128	141	117	112	100
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	0,8	2,4	4,7	5,8	4,3	4,3	6,4
	D50 (%)	53	62	73	78	73	73	81

Seconds				
RTmid	EDTmid		BR	Br
1,94	1,79		0,89	0,87
N		V		STI
Seats		Volume		0,50
1414		12730		
S_A	S_0	S_{pit}		S_T
822	162	20		1004
V/N	S_A/N		V/S_T	EDT/(Vx10$^{6)}$
9,00	0,58		12,68	1,41 $^{-10}$



7.10. Gulbenkian

The Headquarters of the Calouste Gulbenkian Foundation in Lisbon were opened in October 1969. They include a concert auditorium (the Great Hall), a conference suite, and a museum, a library and an Office block.

The auditorium was to be designed primarily for music, but a subsequent requirement arose for ballet, and it had to be usable for lectures and films. Seating was to be provided for about 1300 people.

The general character of the auditorium will be evident from plants showed after. The audience área is rectilinear in main plan and cross-section, with the stage embodied in the hall rather than in a proscenium recess. The audience área slopes, and the stage can be set either flat, or raked in a variety of arrangements.

The design of the complex had been won in a limited competition by three Portuguese architects Cid, d´Atoughia and Pessoa, working as a temporary partnership. As acoustic and noise consultant throughout the Project was William A. Allen.

The desire approximate volume of the auditorium had been determinated initially by assuming that the audience and performers should provide almost the entire absorption requirements. It was thought at that date, 1959, that a Reverberation Time of 1,6 or 1,7 seconds at 500 Hz should be the aim for a hall of this size, and a initial target of about 9 m^3 per person was set for the volume. In the event architectural constraints reduced this, but not severely.

The floor is solid and carpeted, the walls have a lining 5 cm thick in wood and the ceilling dense flaxboard panels, also 5 cm thick, with a bronze metal face.

The stage area is large for a hall of this size, but is particullary unique in its flexibility. The hall was originally conceived as a concert hall, but at a relatively late stage in the design a more multi-purpose role was foreseen, with a particulary requirement of use for ballet. Since a flytower was considered architecturally undesirable, the necessary flexibility was achieved by making the stage a series of surfaces on lifts, by making the satge side-panels rotable and enclosing the stage rear with full-height lifts or curtain.

Image 127

Gulbenkian Concert hall stage view side walls during the measurements.

Image 128

Gulbenkian Concert hall stage view during the measurements.

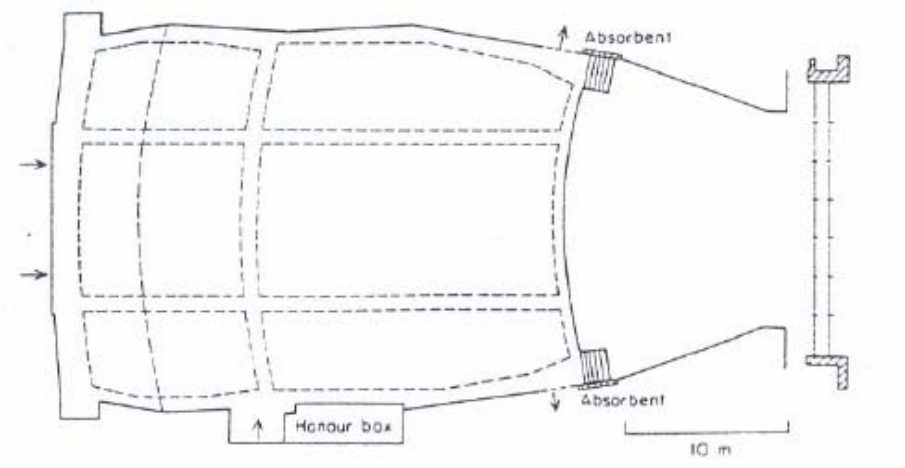


Image 129

Gulbenkian Concert hall architectonic plant.

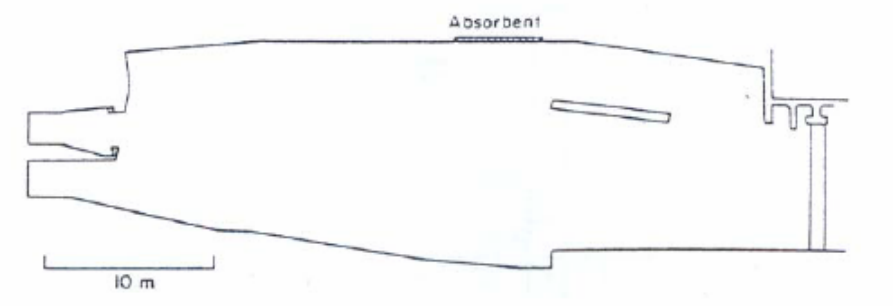


Image 130

Gulbenkian Concert hall architectural cut.

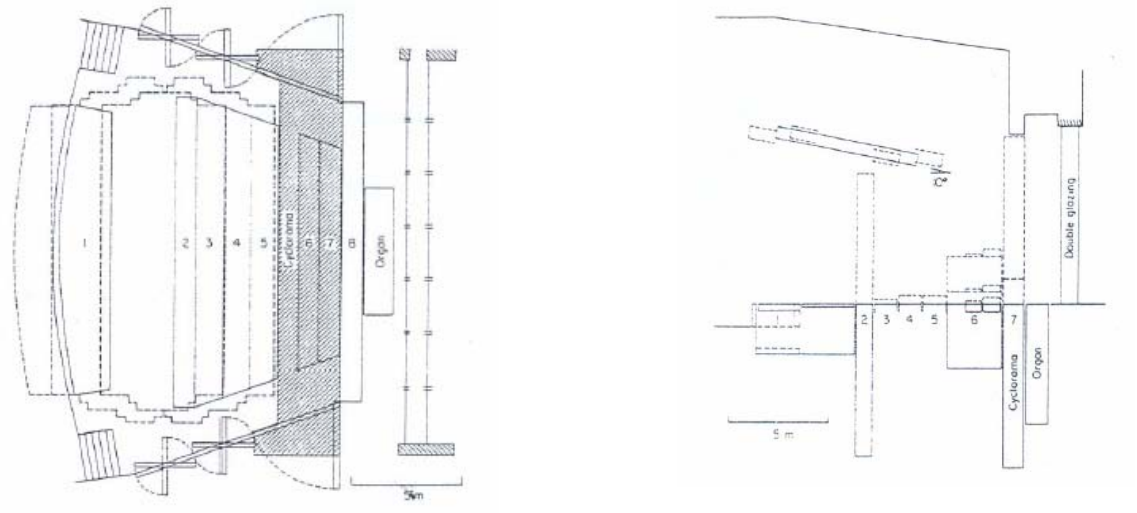


Image 131

Gulbenkian Concert hall stage lifts design.

1. **Orchestra Configuration: Acoustics Shell on Stage**

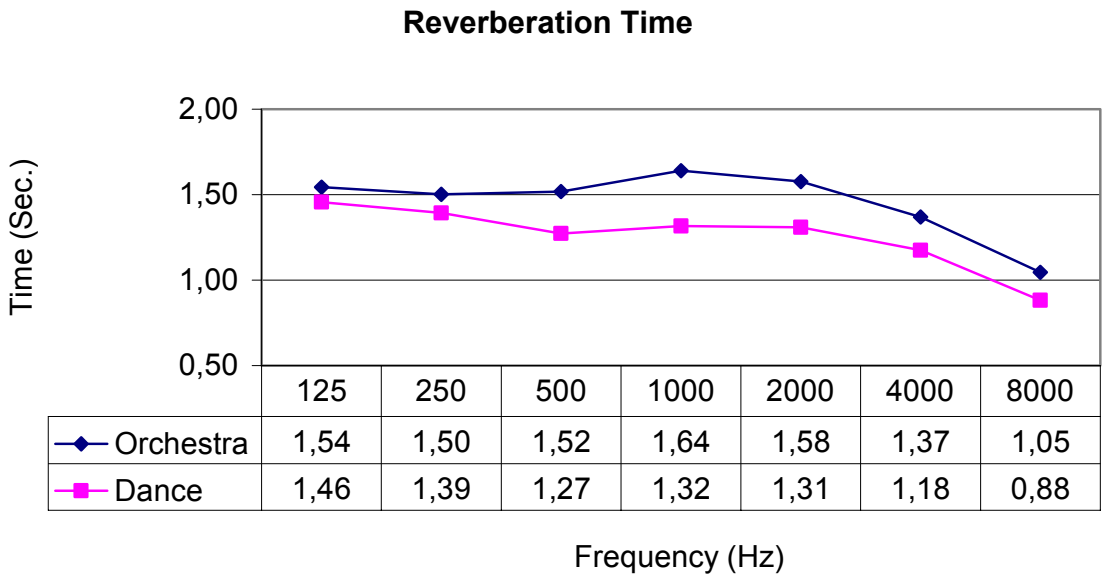
		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,54	1,50	1,52	1,64	1,58	1,37	1,05
	EDT $_{(s)}$	1,17	1,28	1,30	1,42	1,35	1,15	0,88
	C80 $_{(dB)}$	0,3	0,4	1,0	0,7	2,0	2,2	3,7
	D50 $_{(\%)}$	33	33	39	38	46	46	52
	Tc $_{(ms)}$	113	107	98	104	89	82	66
	G $_{(dB)}$	-	-	-	-	-	-	-
On Stage	**C50** $_{(dB)}$	4,5	4,5	6,6	6,9	5,7	5,7	8,2
	D50 $_{(\%)}$	72	73	80	82	78	77	84

Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
1,58	1,36	0,96	0,93

2. **Theatre/Dance Configuration:**

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Audience	**TR30** $_{(s)}$	1,46	1,39	1,27	1,32	1,31	1,18	0,88
	EDT $_{(s)}$	1,46	1,29	1,20	1,30	1,18	0,99	0,72
	C80 $_{(dB)}$	-3,5	-2,2	0,3	1,7	2,2	2,2	3,6
	D50 $_{(\%)}$	32	39	51	59	61	60	68
	Tc $_{(ms)}$	116	95	72	64	61	56	43

Seconds				
RT_{mid}	**EDT_{mid}**		**BR**	**Br**
1,30	1,25		1,10	0,96
N		**V**		**STI**
Seats		**Volume**		0,61
1300		8221		
S_A	**S_0**	**S_{pit}**		**S_T**
607	180	54		841
V/N	**S_A/N**		**V/S_T**	**$EDT/(Vx10^{6)}$**
6,32	0,47		9,77	$1,65^{-10}$



	125	250	500	1000	2000	4000	8000
Orchestra	1,54	1,50	1,52	1,64	1,58	1,37	1,05
Dance	1,46	1,39	1,27	1,32	1,31	1,18	0,88

7.11. Olga Cadaval Cultural Centre

The Centro Cultural Olga Cadaval is part of the country's cultural revitalization policy in which the recovery of the existing performing arts spaces is of extreme importance.

Included in the boom of cinemas construction, and after several changes to the original project, the Cine Teatro Carlos Manuel was built in 1945 with the project signed by the architect Joaquim Norte Junior. Despite the most significant work of this architect, it was considered representative of a late modern style with Art Deco elements, also belonging to the classic functional typology for theatres.

Having been a landmark of Sintra's social and cultural life for 40 years, the fire of 1985 would destroy not only the physical space but also the region's aesthetical rhetoric reminiscence. A great part of the building was destroyed. The stage, the backstage, the orchestra pit, the stalls and almost the whole balcony burned.

Three years after the fire, the first studies that intended to give the building a wider range of uses were started. Given that Sintra is already known as home to various cultural events, the presence of a space capable to provide a proper answer to those event's demands would become very useful.

The first results of these studies lead towards the creation of a 1200-seat auditorium for Opera, Theatre, Concerts and Dance, and a smaller 200 to 300-seat multifunctional auditorium, mainly for cinema and congresses. However these results would be evaluated and changed to honour the original design.

The main Auditorium would have its capacity reduced, but its functionality increased. The available 1000-seats were not only distributed by the stalls and balcony, but also by two new levels of interior galleries.

This hall gained not only the possibility of holding congresses, now supported by translation booths, but also better scenic conditions overall. The apron, the link between the hall and the scenic tower, was increased to 14m in width and 9m in height. Rehearsal rooms and technical support spaces, capable of giving an answer to the scheduling demands, were also designed as part of the Center.

Image 132

CCOC concert hall stage view.

Image 133

CCOC concert hall

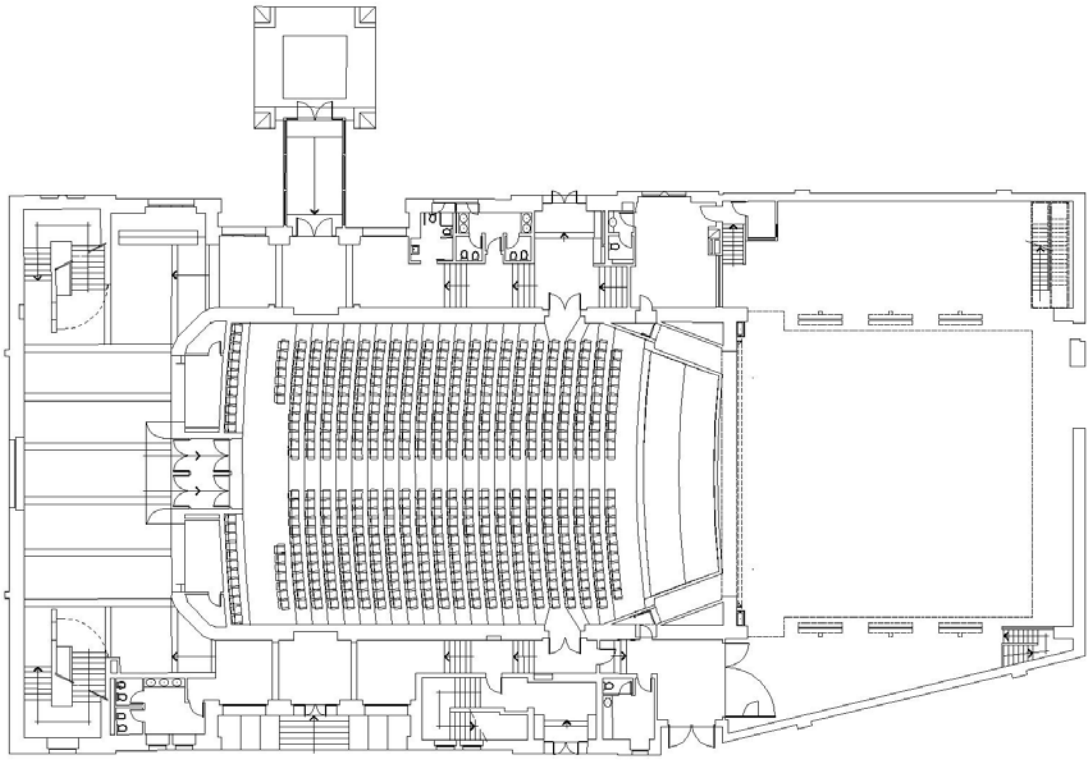


Image 134

CCOC concert hall architectural plant.

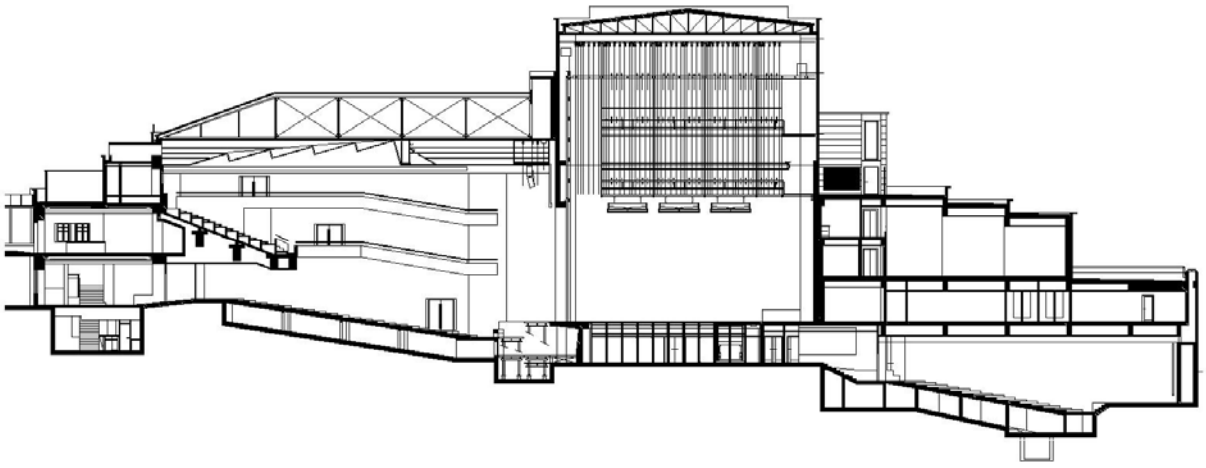


Image 135

CCOC concert hall architectural cut.

1.Orchestra Configuration: Acoustics Shell on Stage

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Hall	**TR30** (s)	1,50	1,21	1,11	1,22	1,25	1,16	0,98
	EDT (s)	1,21	0,89	0,88	1,02	0,98	0,94	0,77
	C80 (dB)	1,3	3,8	4,3	4,3	3,7	4,0	6,0
	D50 (%)	40	53	49	52	46	50	62
	Tc (ms)	101	75	70	69	76	71	53
	G (dB)	-	-	-	-	-	-	-
Balcony	**C80** (dB)	1,8	3,5	3,7	3,7	2,8	3,5	4,2
	D50 (%)	37	45	50	51	47	50	56
On Stage	**C50** (dB)	6,1	5,5	4,6	5,1	3,7	3,9	5,7
	D50 (%)	78	77	74	75	70	70	78

Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
1,17	0,95	1,16	1,03

2.Theatre/Dance Configuration:

		Hz						
		125	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Hall	**TR30** (s)	1,81	1,47	1,19	1,15	1,15	1,01	0,85
	EDT (s)	1,39	1,11	0,91	0,94	0,92	0,81	0,63
	C80 (dB)	3,6	4,4	6,4	7,6	6,1	7,2	9,3
	D50 (%)	51	60	71	77	67	69	79
	Tc (ms)	98	71	47	38	52	44	32
	G (dB)	-	-	-	-	-	-	-
Balcony	**C80** (dB)	2,2	4,2	6,6	6,8	6,7	7,4	8,3
	D50 (%)	49	60	71	73	71	73	77
On Stage	**C50** (dB)	2,85	1,275	6,4	6,125	7,3	8,8	9,6
	D50 (%)	65	56	80	78	85	88	90

Seconds			
RT_{mid}	**EDT_{mid}**	**BR**	**Br**
1,17	0,93	1,40	0,92

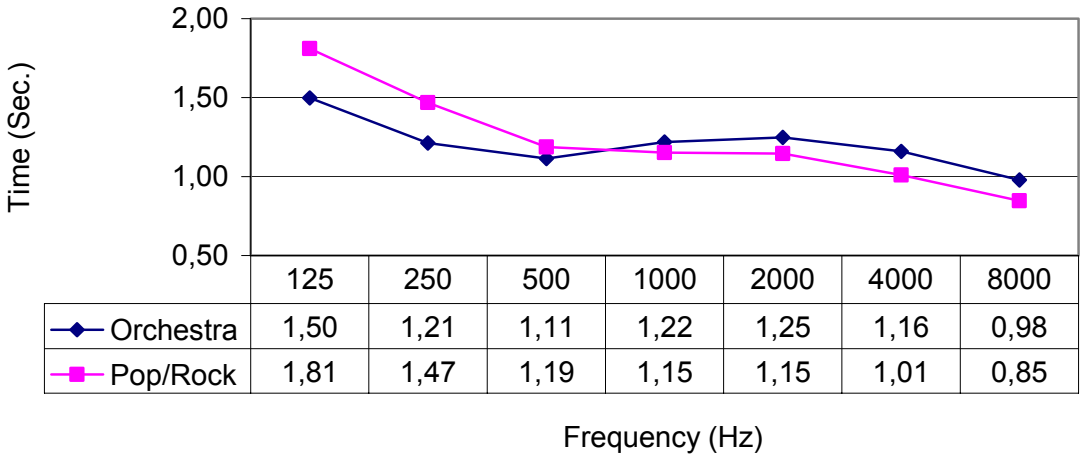
STI	
Audience	**Balcony**
0,66	0,7

V	N
Volume	**Seats**
8674	1000

S_A	S_0	S_{pit}	S_T
314	235	50	600

V/N	S_A/N	V/S_T	EDT/(Vx$10^{6)}$
8,6	0,3	14,4	1,09 $^{-10}$

Reverberation Time



	125	250	500	1000	2000	4000	8000
Orchestra	1,50	1,21	1,11	1,22	1,25	1,16	0,98
Pop/Rock	1,81	1,47	1,19	1,15	1,15	1,01	0,85

7.12. Vila Flor Cultural Centre

In the centre of a town which is World Heritage, a cultural area was created, it marks and refines the excellency of Guimarães: the Cultural Centre Vila Flor, inaugurated in September 17th, 2005. With the purpose of giving the town an equipment capable of getting (with the appropriate conditions) a large variety of artistically and cultural events and at the same time, assures a suitable equipment to receive several activities. The Palace Vila Flor was classified as patrimonial interest and a theatre was built in its surrounding area, so we now have a public area. Equipped with two auditoriums, four meeting rooms, an area for exhibitions, a restaurant, a concert coffee, car parking and magnificent gardens. The Cultural Centre of Vila Flor reinforces the culture vocation of Guimarães.

The Palace Vila Flor was built in the 18th century by a member of the local nobility: Tadeu Luís António Lopes de Carvalho de Fonseca e Camões. It was later purchased by the family of the Counts of Arrochela who received the Queen D. Maria II, in the visit where the village of Guimarães was established as town. Sold again, in 1884, there was the first Industrial and Commercial exhibition of Guimarães. Later, the new owner was the Jordão family, who finished the work first initiated by Tadeu Luís, except for the sequence of Portugal King's statues on the north and East fronts of the Palace.

The Palace was afterwards purchased by the Town Hall of Guimarães in 1976,with its inside destroyed.

None of these works foresaw the reconstruction and rehabilitation of the Palace as a whole, so its inside was in ruins and it was constantly changed not respecting the original style.

In Vila Flor farm, boxwood gardens were kept intact, in front of the north side of the Palace and they are considered the best gardens of the country.

It's in this Palace of the 18th century that one can find the Vila Flor Cultural Centre.

Image 136

Vila Flor concert hall stage view.

Image 137

Vila Flor concert hall sound technician view.

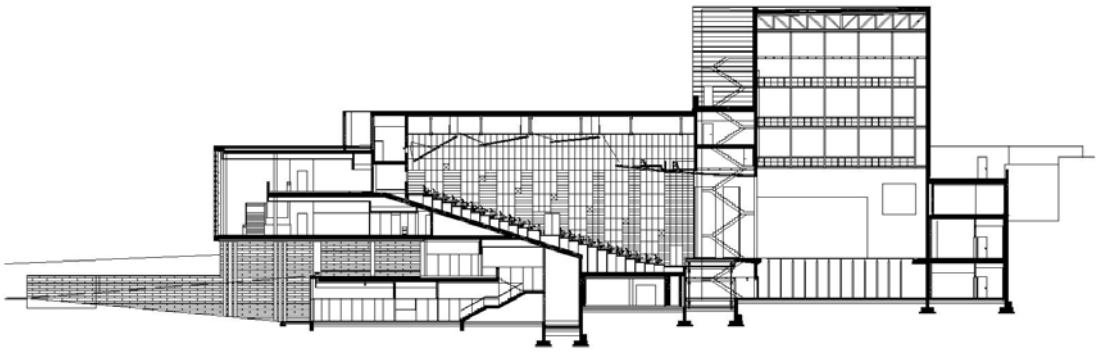


Image 138

Vila Flor concert hall architectural cut.

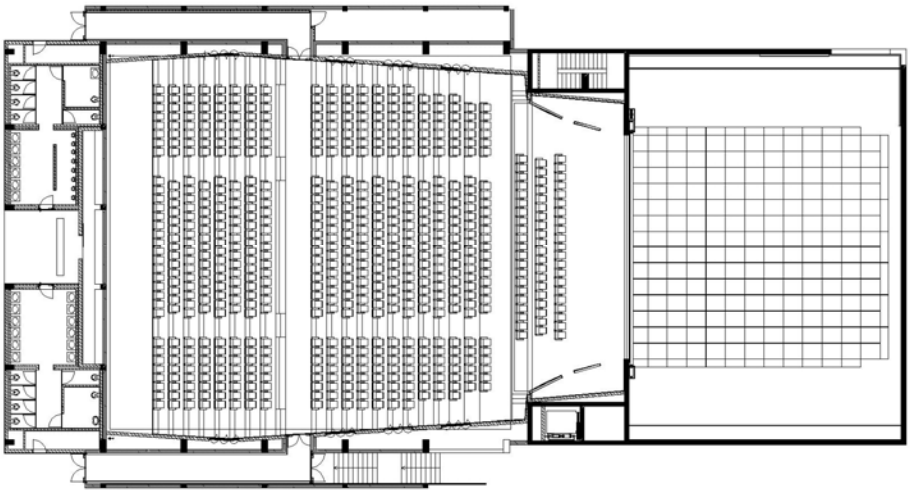


Image 139

Vila Flor concert hall architectural plant.

1.Orchestra Configuration: Acoustics Shell on Stage

		Hz						
		125	250	500	1000	2000	4000	8000
Hall	TR30 (s)	1,96	1,57	1,39	1,32	1,25	1,15	0,91
	EDT (s)	1,55	1,37	1,24	1,07	1,06	1,02	0,88
	C80 (dB)	-1,0	0,0	0,4	1,3	2,2	1,3	2,0
	D50 (%)	27,7	31,9	33,8	38,6	45,9	37,1	36,4
	Tc (ms)	131,9	112,2	104,6	93,5	82,0	86,8	79,6
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	-4,0	0,4	0,1	2,1	2,0	2,6	3,9
	D50 (%)	28	52	51	61	61	64	69

Seconds			
RT_{mid}	EDT_{mid}	BR	Br
1,36	1,15	1,30	0,88

2.Theatre/Dance Configuration:

		Hz						
		125	250	500	1000	2000	4000	8000
Hall	TR30 (s)	2,27	1,73	1,22	1,05	1,02	0,94	0,79
	EDT (s)	1,58	1,23	0,85	0,70	0,71	0,68	0,58
	C80 (dB)	1,2	3,3	5,4	6,3	6,8	6,9	7,9
	D50 (%)	42,3	52,6	56,4	54,2	65,2	65,6	68,1
	Tc (ms)	116,1	82,6	61,2	55,8	47,5	48,6	43,4
	G (dB)	-	-	-	-	-	-	-
On Stage	C50 (dB)	-2,4	6,2	6,9	8,7	6,6	6,5	8,3
	D50 (%)	36,0	80,7	83,0	87,7	81,3	80,3	86,0

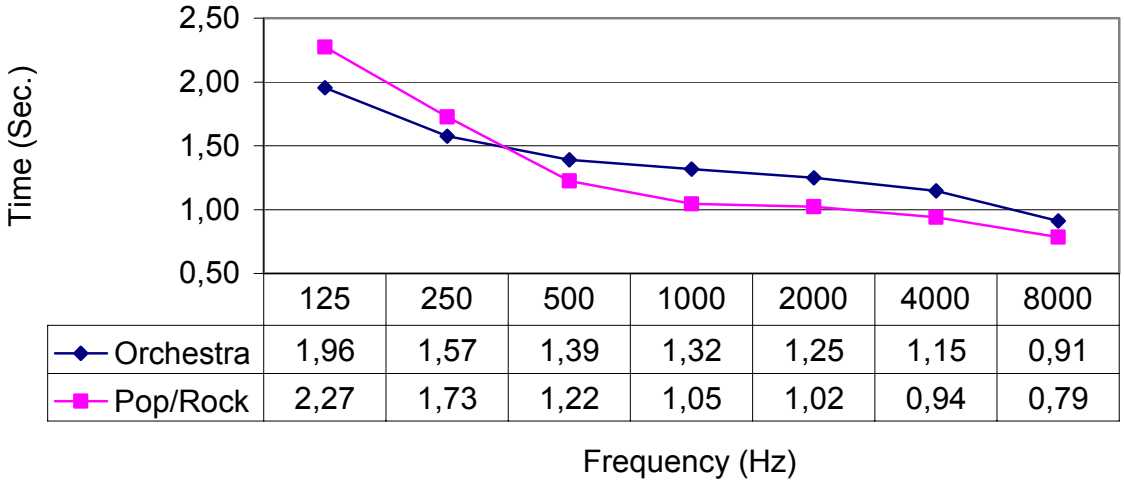
Seconds			
RT_{mid}	EDT_{mid}	BR	Br
1,14	0,77	1,76	0,87

N	V	STI
Seats	Volume	0,64
800	4319	

S_A	S_0	Spit	S_T
415	180	91	686

V/N	S_A/N	V/S_T	$EDT/(Vx10^{6)}$
5,40	0,52	6,30	$2,67^{-10}$

Reverberation Time



	125	250	500	1000	2000	4000	8000
Orchestra	1,96	1,57	1,39	1,32	1,25	1,15	0,91
Pop/Rock	2,27	1,73	1,22	1,05	1,02	0,94	0,79

Frequency (Hz)

8. Reveberation Time

Reverberation Time is the global quantitative criterion of the sound field in the room. The reverberation time must be in the proper range depending on the room size and the style of music.

In the next tables it is shown the **Reverberation Time** of each hall studied in this work, in 7 Center Frequencies of Filter Octave Bands (Hertz).

The halls which have "*Orchester*" or "*Conference*" names means that the objective room measurements were done with or without (respectively Orchester or Conference) an Acoustics Shell on stage, properly to be use by a Symphonic Orchestra.

	TR_{30}(Seconds)						
Name of Hall	Center Frequencies of Filter Bands - Hz						
Concert Halls	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aula Magna	1,57	1,59	1,68	1,87	1,86	1,64	1,27
CCB	1,97	1,82	1,83	1,87	1,77	1,50	1,05
CAE	2,88	2,66	1,99	1,67	1,50	1,34	0,99
Casa da Música	2,05	1,72	1,73	1,81	1,79	1,60	1,26
CNEMA	1,84	1,62	1,54	1,79	1,75	1,46	1,05
Oporto Coliseum (Orchester)	2,46	2,34	2,45	2,51	2,65	2,42	1,77
Recreios Coliseum	2,56	2,51	2,35	2,37	2,26	2,03	1,58
Culturgest (Conference)	1,70	1,47	0,99	0,88	0,84	0,75	0,62
Europarque	1,71	1,74	1,90	1,98	1,85	1,53	1,25
Gulbenkian (Orchester)	1,54	1,50	1,52	1,64	1,58	1,37	1,05
Olga Cadaval (Orchester)	1,50	1,21	1,11	1,22	1,25	1,16	0,98
Vila Flor Cultural Centre	1,96	1,57	1,39	1,32	1,25	1,15	0,91

Name	Center Frequencies of Filter Bands - Hz						
XVIIIth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
São João National Theatre	1,80	1,45	1,25	1,22	1,22	1,12	0,93
S. Carlos National Theatre	1,43	1,19	1,15	1,04	1,00	0,97	0,88

	Center Frequencies of Filter Bands - Hz						
XIXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
D. Maria II National Theatre	1,15	1,13	1,18	1,10	0,95	0,82	0,68
Garcia Resende Theatre	1,27	1,34	1,25	0,95	0,80	0,70	0,57
Sá de Miranda Municipal Theatre	2,15	1,91	1,55	1,26	1,15	1,01	0,85
São Luiz Municipal Theatre	2,10	1,82	1,52	1,37	1,24	1,08	0,86
Viriato Theatre	1,89	1,59	1,29	1,03	0,86	0,78	0,67
Trindade Theatre	1,06	0,92	0,82	0,76	0,75	0,71	0,62

	Center Frequencies of Filter Bands - Hz						
XXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aveirense Theatre	2,41	2,23	1,90	1,42	1,13	1,00	0,86
Bragança Municipal Theatre	1,29	1,25	1,37	1,35	1,34	1,19	0,94
Camões Theatre	2,15	1,81	1,44	1,30	1,21	1,09	0,93
Carlos Alberto Theatre	1,67	1,50	1,20	1,15	1,12	1,04	0,92
Faro Municipal Theatre (Orchester)	1,89	1,87	1,87	1,84	1,75	1,49	1,15
Gil Vicente Academic Theatre	1,58	1,38	1,09	1,06	0,96	0,83	0,68
Guarda Municipal Theatre	2,38	1,93	1,22	1,02	1,01	0,93	0,77
Helena Sá e Costa Theatre	1,47	1,44	1,18	1,09	1,07	0,87	0,65
Maria Matos Municipal Theatre	1,32	1,16	1,00	1,09	1,22	1,20	1,01
Politeama Theatre	1,29	1,09	0,96	0,93	0,89	0,79	0,66
Rivoli Municipal Theatre	2,75	2,27	1,60	1,36	1,17	0,94	0,60
Vila Real Municipal Theatre	1,85	1,44	1,21	1,16	1,15	1,14	0,95

9. Early Decay Time

The EDT is a reverberation time derived from the initial 10 dB of decay. It is the length of time that it takes for the sound to decay 10 dB after the sound source is turned off. EDT more closely corresponds to subjective evaluation of the reverberation time then RT.

In the next tables it is shown the **Early Decay Time** of each hall studied in this work, in 7 Center Frequencies of Filter Octave Bands (Hertz).

The halls which have "*Orchester*" or "*Conference*" names means that the objective room measurements were done with or without (respectively Orchester or Conference) an Acoustics Shell on stage, properly to be use by a Symphonic Orchestra.

	EDT (Seconds)						
Name of Hall	Center Frequencies of Filter Bands - Hz						
Concert Halls	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aula Magna	1,46	1,62	1,77	1,96	1,94	1,71	1,27
CCB	1,53	1,65	1,82	1,84	1,59	1,27	0,80
CAE	2,09	1,89	1,55	1,48	1,38	1,16	0,97
Casa da Música	1,94	1,74	1,68	1,60	1,69	1,51	1,19
CNEMA	1,67	1,54	1,48	1,64	1,52	1,34	1,05
Oporto Coliseum (Orchester)	2,47	2,33	2,39	2,51	2,65	2,24	1,50
Recreios Coliseum	2,88	3,04	2,54	2,48	2,36	2,14	1,65
Culturgest (Conference)	0,95	0,77	0,80	0,87	0,82	0,78	0,65
Europarque	1,56	1,72	1,76	1,82	1,71	1,53	1,29
Gulbenkian (Orchester)	1,17	1,28	1,30	1,42	1,35	1,15	0,88
Olga Cadaval (Orchester)	1,21	0,89	0,88	1,02	0,98	0,94	0,77
Vila Flor Cultural Centre	1,55	1,37	1,24	1,07	1,06	1,02	0,88

Name	Center Frequencies of Filter Bands - Hz						
XVIIIth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
São João National Theatre	1,57	1,30	1,18	1,21	1,15	0,99	0,81
S. Carlos National Theatre	1,27	1,23	1,26	1,17	1,17	1,19	1,11

	Center Frequencies of Filter Bands - Hz						
XIXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
D. Maria II National Theatre	1,25	1,11	1,13	1,06	0,95	0,81	0,67
Garcia Resende Theatre	0,99	1,03	0,94	0,71	0,70	0,56	0,47
Sá de Miranda Municipal Theatre	1,94	1,69	1,41	1,29	1,20	1,07	0,91
São Luiz Municipal Theatre	1,95	1,48	1,29	1,13	1,06	0,93	0,71
Viriato Theatre	1,25	1,02	0,85	0,77	0,73	0,73	0,69
Trindade Theatre	0,95	0,82	0,70	0,72	0,64	0,61	0,54

	Center Frequencies of Filter Bands - Hz						
XXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aveirense Theatre	1,89	1,56	1,21	0,91	0,85	0,76	0,63
Bragança Municipal Theatre	0,99	1,10	1,29	1,30	1,23	1,12	0,88
Camões Theatre	1,09	1,19	1,19	1,03	0,99	0,84	0,73
Carlos Alberto Theatre	1,27	1,34	1,14	1,17	1,05	0,95	0,78
Faro Municipal Theatre (Orchester)	1,62	1,43	1,47	1,49	1,26	1,07	0,81
Gil Vicente Academic Theatre	1,67	1,34	1,06	0,98	1,03	0,93	0,81
Guarda Municipal Theatre	1,46	1,16	0,94	0,86	0,94	0,92	0,72
Helena Sá e Costa Theatre	1,26	1,24	1,09	1,03	0,99	0,82	0,65
Maria Matos Municipal Theatre	0,88	0,86	1,00	1,14	1,28	1,26	1,04
Politeama Theatre	1,16	1,14	1,00	0,90	0,87	0,79	0,64
Rivoli Municipal Theatre	1,29	1,30	1,08	1,02	1,02	0,82	0,58
Vila Real Municipal Theatre	1,72	1,43	1,41	1,39	1,32	1,41	1,10

10. Clarity (C80)

Clarity means the ratio of the energy in the early sound compared to that in the reverberant sound, expressed in dB. Early sound is what is heard in the first 80 msec after the arrival of the direct sound. It is a measure of the degree to which the individual sounds stand apart from one another.

In the next tables it is shown the **Clarity** of each hall studied in this work, in 7 Center Frequencies of Filter Octave Bands (Hertz).

The halls which have "*Orchester*" or "*Conference*" names means that the objective room measurements were done with or without (respectively Orchester or Conference) an Acoustics Shell on stage, properly to be use by a Symphonic Orchestra.

	C80 (dB)						
Name of Hall	Center Frequencies of Filter Bands - Hz						
Concert Halls	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aula Magna	1,46	0,92	0,02	-0,60	-0,10	0,20	2,12
CCB	-0,3	1,1	1,5	2,1	2,3	3,6	6,7
CAE	-0,5	0,5	0,9	0,9	2,5	3,6	5,6
Casa da Música	-2,4	-0,5	0,3	0,7	0,7	1,2	3,1
CNEMA	0,3	1,3	0,4	0,9	2,0	3,2	6,5
Oporto Coliseum (Orchester)	-1,5	-1,7	-0,9	-0,6	-0,4	1,0	2,9
Recreios Coliseum	-0,1	-1,1	-2,0	-3,7	-0,8	-1,6	0,0
Culturgest (Conference)	51	72	60	59	66	69	75
Europarque	0,3	-0,1	-0,5	-1,9	0,0	-0,7	-0,8
Gulbenkian (Orchester)	0,3	0,4	1,0	0,7	2,0	2,2	3,7
Olga Cadaval (Orchester)	1,3	3,8	4,3	4,3	3,7	4,0	6,0
Vila Flor Cultural Centre	-1,0	0,0	0,4	1,3	2,2	1,3	2,0

Name	Center Frequencies of Filter Bands - Hz						
XVIIIth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
São João National Theatre	1,4	2,3	2,9	2,4	3,8	3,6	5,0
S. Carlos National Theatre	0,8	1,8	0,9	1,4	2,1	3,5	4,9

	Center Frequencies of Filter Bands - Hz						
XIXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
D. Maria II National Theatre	1,0	3,9	3,1	3,6	4,8	7,7	9,6
Garcia Resende Theatre	4,2	4,4	4,3	5,7	6,5	8,0	10,4
Sá de Miranda Municipal Theatre	0,3	0,7	1,9	3,5	3,4	5,3	7,7
São Luiz Municipal Theatre	-1,2	2,2	2,4	2,8	3,5	4,4	6,0
Viriato Theatre	3,2	4,7	4,8	5,4	6,1	6,9	8,2
Trindade Theatre	5,0	6,0	6,8	6,5	8,5	8,7	9,3

	Center Frequencies of Filter Bands - Hz						
XXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aveirense Theatre	1,8	3,3	3,7	4,9	5,8	6,8	8,5
Bragança Municipal Theatre	3,4	3,7	2,9	3,4	2,4	3,0	5,6
Camões Theatre	3,5	2,7	1,7	0,5	3,6	3,2	3,3
Carlos Alberto Theatre	2,3	2,2	2,7	1,8	3,7	3,8	5,2
Faro Municipal Theatre (Orchester)	-0,1	1,3	0,9	1,7	2,5	3,7	5,5
Gil Vicente Academic Theatre	0,1	2,1	4,9	4,3	5,7	4,8	6,4
Guarda Municipal Theatre	2,2	3,8	5,7	4,7	4,4	4,1	5,1
Helena Sá e Costa Theatre	1,5	1,9	3,8	4,2	3,8	6,0	9,3
Maria Matos Municipal Theatre	5,1	5,2	3,6	2,5	1,8	2,6	3,9
Politeama Theatre	1,5	3,5	3,5	4,7	5,9	9,0	10,3
Rivoli Municipal Theatre	2,5	3,5	5,4	6,2	5,5	6,9	10,6
Vila Real Municipal Theatre	-0,8	2,3	2,1	1,8	3,0	3,2	5,2

11. Definition (D50)

Definition is the ration of early sound energy to the total sound energy in Percent (%). It shows the difference of the level at the time range 0 - 50 ms as against the level at integration over the entire time range from zero to the end.
The larger this parameter, the more distinct the sound signal is felt, because it will then be less disturbed by later diffuse sound.

In the next tables it is shown the **Definition** of each hall studied in this work, in 7 Center Frequencies of Filter Octave Bands (Hertz).

The halls which have "*Orchester*" or "*Conference*" names means that the objective room measurements were done with or without (respectively Orchester or Conference) an Acoustics Shell on stage, properly to be use by a Symphonic Orchestra.

	D50 (dB)						
Name of Hall	Center Frequencies of Filter Bands - Hz						
Concert Halls	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aula Magna	45	42	35	31	37	37	46
CCB	27	43	44	48	45	53	66
CAE	34	41	41	38	50	53	61
Casa da Música	21	33	35	36	39	42	50
CNEMA	39	46	41	47	52	57	73
Oporto Coliseum (Orchester)	28	27	29	34	35	44	54
Recreios Coliseum	42	37	32	21	37	31	38
Culturgest (Conference)	51	72	60	59	66	69	75
Europarque	36	37	36	28	39	36	36
Gulbenkian (Orchester)	33	33	39	38	46	46	52
Olga Cadaval (Orchester)	40	53	49	52	46	50	62
Vila Flor Cultural Centre	28	32	34	39	46	37	36

Name	Center Frequencies of Filter Bands - Hz						
XVIIIth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
São João National Theatre	36	47	49	43	55	54	59
S. Carlos National Theatre	35	40	47	43	47	57	65

	Center Frequencies of Filter Bands - Hz						
XIXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
D. Maria II National Theatre	40	55	51	51	60	74	79
Garcia Resende Theatre	51	59	57	59	67	70	79
Sá de Miranda Municipal Theatre	42	42	49	58	55	66	77
São Luiz Municipal Theatre	26	42	44	48	52	56	62
Viriato Theatre	54	65	61	60	68	73	78
Trindade Theatre	58	61	63	66	74	72	70

	Center Frequencies of Filter Bands - Hz						
XXth Century Theatres	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Aveirense Theatre	49	55	56	60	66	69	77
Bragança Municipal Theatre	45	50	51	54	47	51	65
Camões Theatre	52	52	48	40	57	51	49
Carlos Alberto Theatre	48	47	48	41	55	53	59
Faro Municipal Theatre (Orchester)	31	40	35	41	41	48	61
Gil Vicente Academic Theatre	36	49	60	50	63	54	61
Guarda Municipal Theatre	47	55	62	50	52	50	53
Helena Sá e Costa Theatre	38	50	60	61	58	70	82
Maria Matos Municipal Theatre	57	62	51	48	45	51	55
Politeama Theatre	34	52	53	54	63	80	84
Rivoli Municipal Theatre	35	53	65	68	64	69	79
Vila Real Municipal Theatre	36	53	53	50	59	60	66

12. Other Data Evaluation

In the next tables it is shown several evaluation parameters of each hall studied in this work, in 7 Center Frequencies of Filter Octave Bands (Hertz), like as:

1. Number of seats (N)
2. Volume (V)
3. Reverberation Time mid (an average between the 500Hz and 1000Hz values of RT)
4. Early Decay Time mid (an average between the 500Hz and 1000Hz values of EDT)
5. Bass Ratio and Brightness Ratio (BR and Br)
6. STI (Speech Transmission Index)

The following data, due to the autor of this essay not having the exactly room plants (with scales), are aproximated values, what can lead to miscalculation of some parameters, like, High, Width and Length (and of course the Volume). These are marked with an *.

Name	Year	N	V	Seconds				
Concert Halls		**Seats**	**Volume**	**RT_{mid}**	**EDT_{mid}**	**BR**	**Br**	**STI**
Aula Magna	1961	1597	14018 *	1,77	1,88	0,88	0,98	0,5
CCB	1992	1200	13395	1,85	1,83	1,02	0,88	0,55
CAE	2002	800	7488	1,79	1,51	1,50	0,79	0,54
Casa da Música	2005	1238	13376	1,77	1,64	1,07	0,96	0,50
CNEMA	1994	1200	7776 *	1,65	1,56	1,04	0,97	0,56
Oporto Coliseum (Orchester)	3000	1941	12566 *	2,48	2,45	0,97	1,02	0,47
Recreios Coliseum	2500	1890	25817 *	2,36	2,51	1,07	0,91	0,44
Culturgest (Conference)	1993	652	4646	0,93	0,84	1,70	0,85	0,66
Europarque	1995	1414	12730 *	1,94	1,79	0,89	0,87	0,50
Gulbenkian (Orchester)	1969	1300	8221 *	1,58	1,36	0,96	0,93	0,61
Olga Cadaval (Orchester)	1945	1000	8674	1,17	0,95	1,16	1,03	0,66
Vila Flor Cultural Centre	2005	800	4319	1,36	1,15	1,30	0,88	0,64

Name	Year	N	V	Seconds				
XVIIIth Century Theatres		**Seats**	**Volume**	**RT_{mid}**	**EDT_{mid}**	**BR**	**Br**	**STI**
São João National Theatre	1798	600	2603	1,24	1,19	1,31	0,95	0,58
S. Carlos National Theatre	1793	600	3729 *	1,10	1,20	1,19	0,90	0,58

Name	Year	N	V	Seconds				
XIXth Century Theatres		**Seats**	**Volume**	**RT_{mid}**	**EDT_{mid}**	**BR**	**Br**	**STI**
D. Maria II National Theatre	1846	600	2549	1,13	1,09	1	0,78	0,63
Garcia Resende Theatre	1892	500	1577 *	1,10	0,83	1,19	0,68	0,67
Sá de Miranda Municipal Theatre	1885	400	1815	1,41	1,35	1,44	0,77	0,58
São Luiz Municipal Theatre	1894	730	3630	1,44	1,19	1,37	0,80	0,58
Viriato Theatre	1883	252	1364	1,15	0,79	1,51	0,71	0,65
Trindade Theatre	1867	600	2212 *	0,79	0,70	1,26	0,92	0,69

Name	Year	N	V	Seconds				
XXth Century Theatres		**Seats**	**Volume**	**RT_{mid}**	**EDT_{mid}**	**BR**	**Br**	**STI**
Aveirense Theatre	2003	663	3422	1,66	1,06	1,40	0,64	0,63
Bragança Municipal Theatre	2004	400	3274	1,11	0,82	1,10	0,87	0,63
Camões Theatre	1998	890	6295	1,37	1,10	1,40	0,83	0,6
Carlos Alberto Theatre	2003	342	2921	1,18	1,15	1,34	0,92	0,59
Faro Municipal Theatre (Orchester)	2005	794	5985	1,85	1,48	1,02	0,88	0,60
Gil Vicente Academic Theatre	1961	773	3180 *	1,08	1,01	1,38	0,84	0,60
Guarda Municipal Theatre	2005	626	6027	1,11	0,92	1,94	0,86	0,61
Helena Sá e Costa Theatre	2000	254	686	1,14	1,06	1,28	0,85	0,62
Maria Matos Municipal Theatre	1969	570	2412	1,04	1,07	1,19	1,16	0,59
Politeama Theatre	1913	638	3600 *	0,95	0,94	1,26	0,89	0,67
Rivoli Municipal Theatre	1913	874	4651	1,48	1,05	1,70	0,72	0,64
Vila Real Municipal Theatre	2005	500	5324 *	1,20	1,40	1,39	0,96	0,56

Other evaluation parameters are shown in the next tables, such as:

1. Volume / Number of seats (V/N)
2. Volume / Total Area (V/ S_T)
3. Effective Acoustic Area (S_A)
4. Stage Area (S_0)
5. Pit Area (S_{pit})
6. Total Area (S_T)
7. Effective Acoustic Area / Number of seats (S_A / N)
8. Early Decay Time / Volume x 10^6 (EDT/(Vx10^6))
9. Hall Length (L)
10. Hall Width (W) - Average
11. Hall High (H) – Average

Name			**m^2**						**m**		
Concert Halls	**V/N**	**V/S_T**	**S_A**	**S_0**	**S_{pit}**	**S_T**	**S_A/N**	**EDT/(Vx10^6)**	**W**	**L**	**H**
Aula Magna	8,8	13,2	880*	180*	-	1060*	0,6	1,34 $^{-10}$	44,5	35	9*
CCB	11,2	14,2	538	180	77	940	0,4	1,37^{-10}	28,1	27	17,6
CAE	9,3	7,9	481*	180	56	717	0,7	2,02 $^{-10}$	24	31,2	10
Casa da Música	10,8	16,1	653	180	-	833	0,5	1,23 $^{-10}$	21,9	40,6	15,1
CNEMA	6,48	10	606*	169	-	775*	0,5	2,00 $^{-10}$	36	36	6*
Oporto Coliseum	6,47	14	628*	180	87	896	0,3	1,95 $^{-10}$	20,4	30,8	20*
Recreios Coliseum	13,7	27,6	695*	180	62	937*	0,4	9,73 $^{-10}$	34,7	31	24
Culturgest	7,13	8,26	371	151	40	562	0,6	1,80 $^{-10}$	24,8	22,5	8,3
Europarque	9	12,7	822*	162	20	1004*	0,6	1,41 $^{-10}$	39	34	9,6*
Gulbenkian	6,3	9,7	607*	180	54	841*	0,5	1,65 $^{-10}$	23,8	31,4	11
Olga Cadaval	8,6	14,4	314	180	50	600	0,3	1,09 $^{-10}$	18,7	31,9	7,3
Vila Flor Cultural Centre	5,4	6,3	415	180	91	686	0,5	2,67 $^{-10}$	18,7	31,9	7,3

Name			m^2						m		
XVIIIth Century Theatres	**V/N**	**V/S_T**	**S_A**	**S_0**	**S_{pit}**	**S_T**	**S_A/N**	**EDT/(Vx10^6)**	**W**	**L**	**H**
São João National Theatre	4,3	7,7	120	180	36	337	0,2	$4,59^{-10}$	11,2	17,4	13,3
S. Carlos National Theatre	6,2	7,3	230*	180	85	495*	0,4	$3,22^{-10}$	15,3	16,2	15

Name			m^2						M		
XIXth Century Theatres	**V/N**	**V/S_T**	**S_A**	**S_0**	**S_{pit}**	**S_T**	**S_A/N**	**EDT/(Vx10^6)**	**W**	**L**	**H**
D. Maria II National Theatre	4,25	6,5	180	180	30	390	0,3	$4,28^{-10}$	13,7	18,4	10,1
Garcia Resende Theatre	3,15	6,5	98*	143	-	241*	0,2	$5,23^{-10}$	12,4*	10,6*	12*
Sá de Miranda Municipal Theatre	4,5	7,4	107	138	-	245	0,3	$7,42^{-10}$	10,4	14,6	12
São Luiz Municipal Theatre	4,9	10,9	140*	160	30	330*	0,2	$3,27^{-10}$	11,6	15,9	19,6
Viriato Theatre	5,4	6,6	107	83	15	206	0,4	$5,81^{-10}$	10,2	15	8,9
Trindade Theatre	3,7	7,6	147*	96*	45*	288*	0,2	$3,18^{-10}$	16*	14,4*	9,6*

Name			m^2						m		
XXth Century Theatres	**V/N**	**V/S_T**	**S_A**	**S_0**	**S_{pit}**	**S_T**	**S_A/N**	**EDT/(Vx10^6)**	**W**	**L**	**H**
Aveirense Theatre	5,1	13,2	136	100	25	260	0,2	$3,11^{-10}$	15	18,3	12,5
Bragança Municipal Theatre	8,1	6,1	282	180	72	534	0,7	$2,49^{-10}$	18,5	23,4	7,6
Camões Theatre	7	8,7	482	180	56	718	0,5	$1,75^{-10}$	24,4	28,9	8,9
Carlos Alberto Theatre	7,3	7,4	183	116	35	334	0,5	$4,63^{-10}$	15,2	20,5	8
Faro Municipal Theatre	7,5	9	398	180	87	665	0,5	$2,47^{-10}$	25	24,4	9,8
Gil Vicente Academic Theatre	4,1	8,2	200*	141	45	386*	0,3	$3,17^{-10}$	21,6*	18,4*	8*
Guarda Municipal Theatre	9,6	12,2	320	120	56	496	0,5	$1,52^{-10}$	20	24	12,7
Helena Sá e Costa Theatre	7,8	9,8	106	72	21	200	0,4	$5,42^{-10}$	13,6	15,7	9,2
Maria Matos Municipal Theatre	4,2	6,4	234	116	24	374	0,4	$4,42^{-10}$	16,6	19,4	7,5
Politeama Theatre	4,6	8,2	280*	138	20	438*	0,4	$2,61^{-10}$	20	15	12*
Rivoli Municipal Theatre	5,3	9,4	274	180	39	493	0,3	$2,26^{-10}$	16,4	25,6	11
Vila Real Municipal Theatre	10,6	10,4	336	144	33	513	0,7	$2,63^{-10}$	22	22	11*

According to Beranek [5], it is desirable to have a simpler equation than Sabine´s, in the preliminary design of a hall. "*A possible simplification is to assume that the total room absorption is attributable to tha audience and restrict the calculation to the midle frequencies (500Hz to 1000Hz), in order to eliminate the air absorption term and to avoid the greater irregularities found in sound absorption at low frequencies*".

The simplification leads to:

$$RT_{mid} = 0{,}161V/[S_T(\alpha_T + (S_R\alpha_R/S_T))] = K1 * (V/S_T)$$

So that:

$$K1 = 0{,}161 /[\alpha_T + (S_R\alpha_R/S_T)]$$

According to the same author, K1 "*is not highly accurate because the accuracy of the reverberation data, mostly from a few stop-chords at a limited number of seats, is unknown, and perhaps more important the halls have different audience absorptions owing to the type of seats, and* $(S_R\alpha_R/S_T)$ *varies from one hall to another*".

Thus:

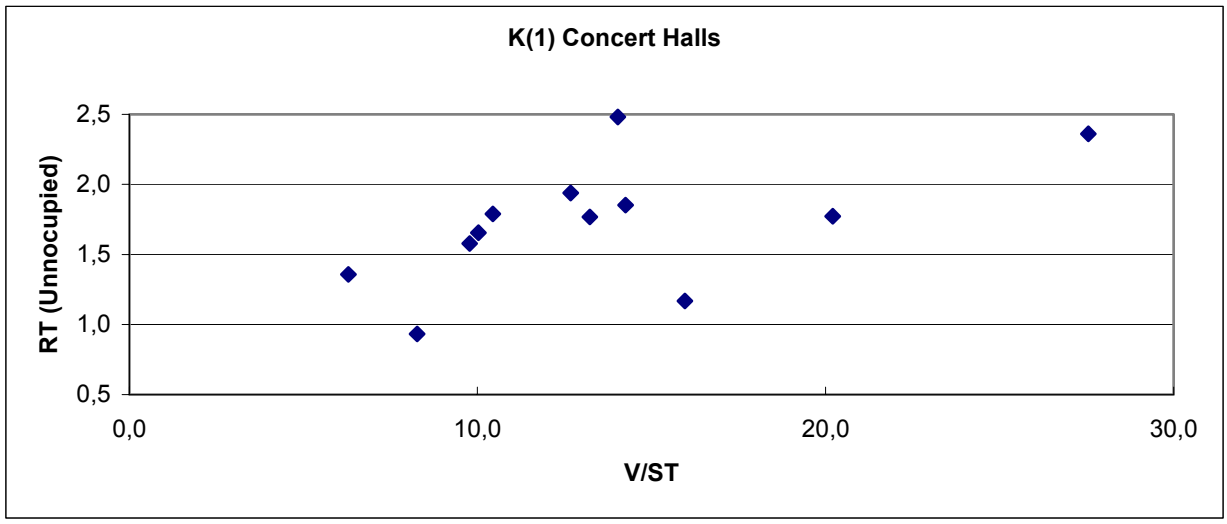
$$\mathbf{K1 = RT/(V/ S_T)}$$

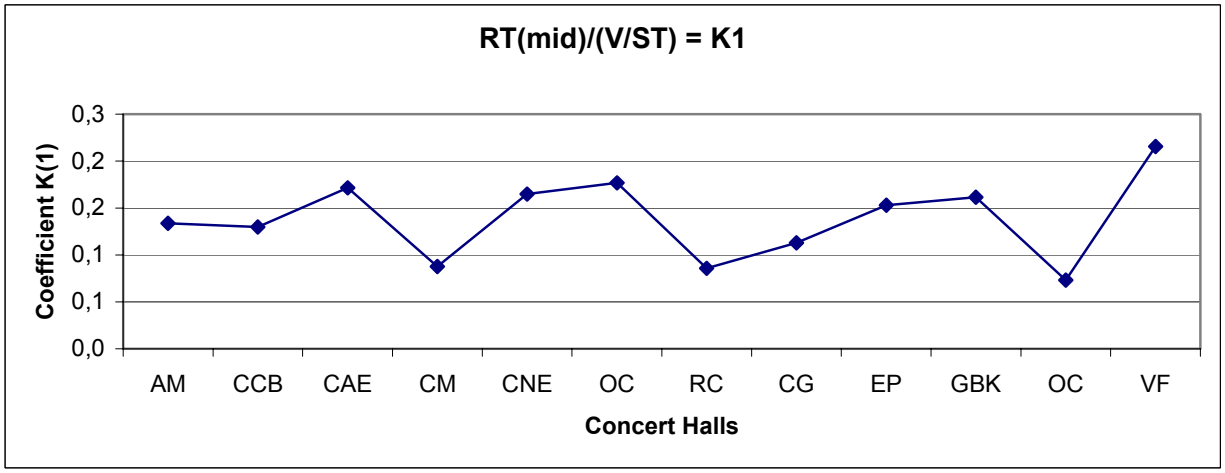
To preent the results of the 32 measured halls, a division were made between Concert halls, XVIIIth, XIXth and XXth Century Theatres.

Concert Halls	**AM**	Aula Magna
	CCB	CCB
	CAE	CAE
	CM	Casa da Música
	CNE	CNEMA
	OC	Oporto Coliseum
	RC	Recreios Coliseum
	CG	Culturgest
	EP	Europarque
	GBK	Gulbenkian
	OC	Olga Cadaval
	VF	Vila Flor Cultural Centre
XVIIIth Century Theatres	**TNSJ**	São João National Theater
	TNSC	S. Carlos National Theater
XIXth Cenury Theatres	**TNDM**	D. Maria II National Theater
	TGR	Garcia Resende Theater
	TSM	Sá de Miranda Municipal Theater
	TSL	São Luiz Municipal Theater
	TV	Viriato Theater
	TT	Trindade Theater
XXth Century Theatres	**TA**	Aveirense Theater
	TMB	Bragança Municipal Theater
	TC	Camões Theater
	TeCA	Carlos Alberto Theater
	TMF	Faro Municipal Theater
	TAGV	Gil Vicente Academic Theater
	TMG	Guarda Municipal Theater
	HSC	Helena Sá e Costa Theater
	TMM	Maria Matos Municipal Theater
	TP	Politeama Theater
	TMR	Rivoli Municipal Theater
	TMVR	Vila Real Municipal Theater

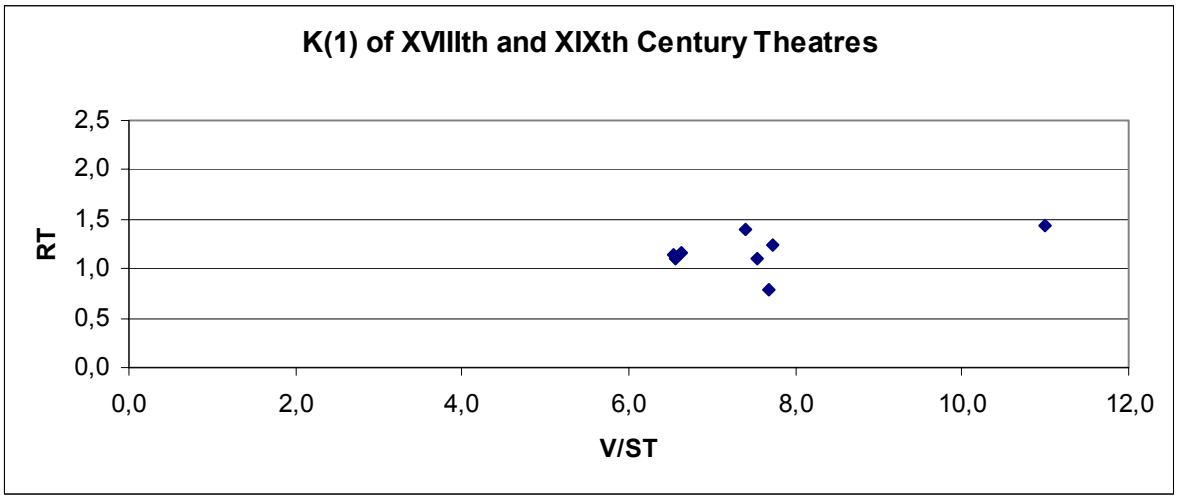
Plot of the midle-frequency Reverberation Time, RT, hall unnocupied, vs V/ S_T , where V is the Volume and S_T is the acoustical area (see Terminology and Definitions).

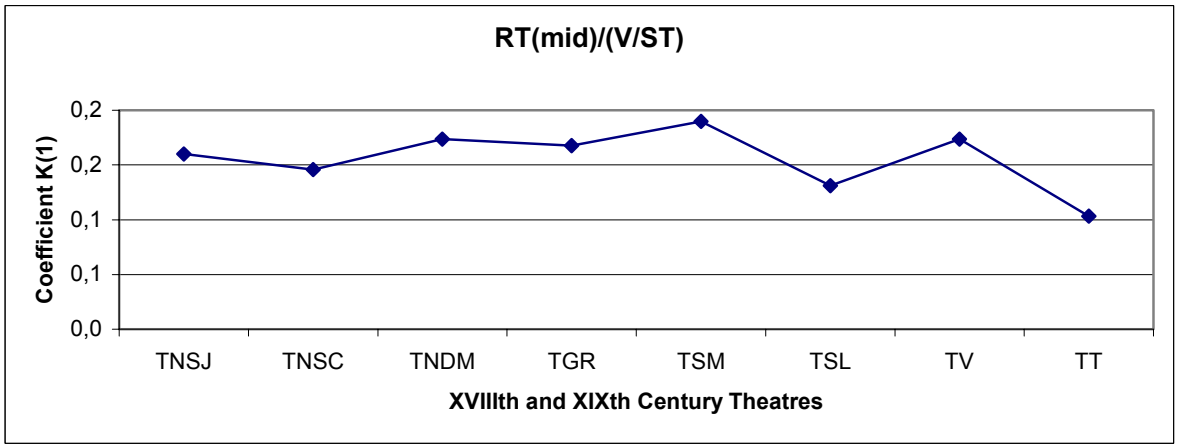
For Concert halls:



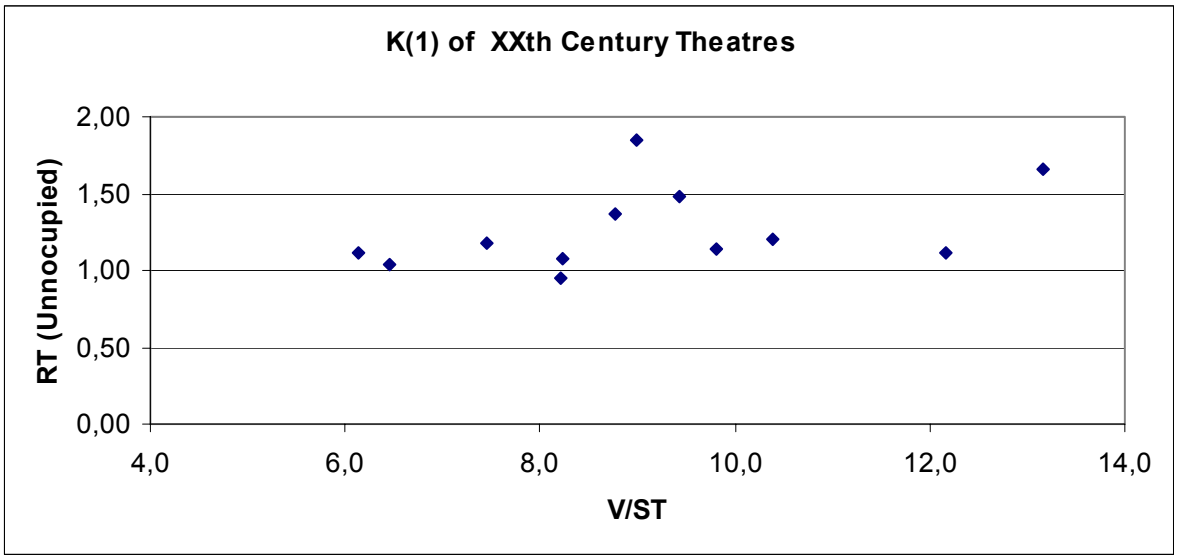


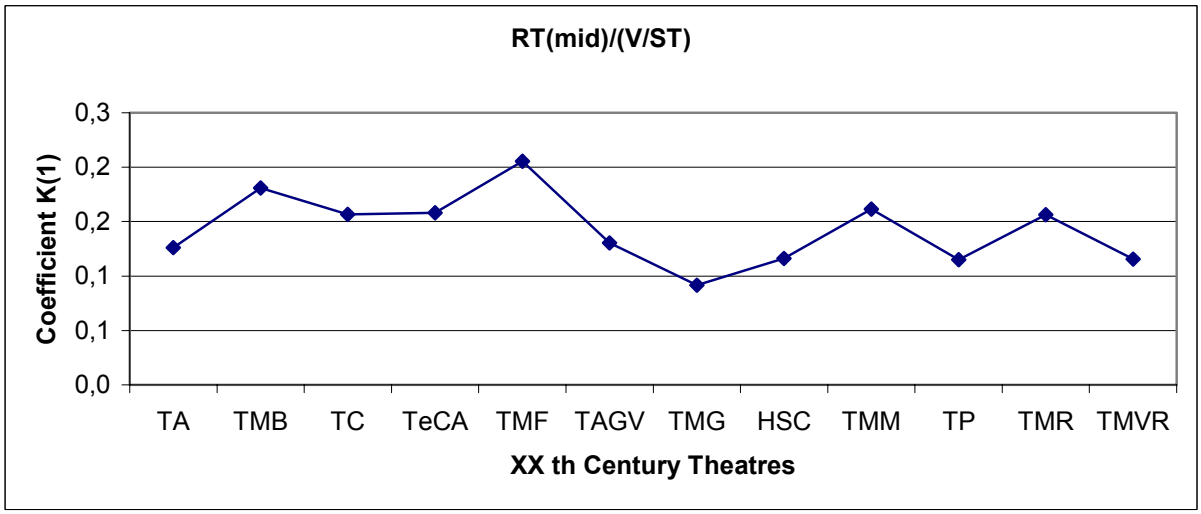
For XVIIth and XIXth Century Theatres:





And for XXth Century Theatres:





Bibliography

[1] ALLEN, W., "*The Gulbenkian Great Hall, Lisbon, I: Acostic Design*", Jornal of Sound and Vibration 59(4), pag. 469-479, Acadenic Press, London, 1978.

[2] ARAU, H., "*ABC de la Acústica Arquitectónica*", CEAC, Barcelona, 1999.

[3] BARRON, M., "*Auditorium Acoustics and Architectural Design*", London, y & FN Spon, 1993.

[4] BARRON, M., "*The Gulbenkian Great Hall, Lisbon, II: An acostic study of a concert hall with variable stage*", Jornal of Sound and Vibration 59(4), pag. 481-502, Acadenic Press, London, 1978.

[5] BERANEK, L., "*Concert and Opera Halls: How they sound*", Nova York, Acoustical Society of America, 1996

[6] BERANEK, L., "*Music, acoustics & architecture*", Nova York, Wiley, 1962;

[7] BROOKS, C., "*Architectural Acoustics*", Ed. McFarland, USA, 2003

[8] CARVALHO, A., " *Acústica Ambiental e de Edifícios*", Apuntos de la Disciplina de AAE del Departamento de Ingenieria Civil de la FEUP, Porto, 2004.

[9] CARVALHO, A., "*Influence of architectural features and styles on varios acoustical measures in churches*", Ph.D.Dissertação, Universidade da Flórida, EUA. 1994.

[10] CARRIÒN, A., "*Diseño acústico de espacios arquitectónicos*", EdicionsUPC, Barcelona, 2003.

[11] EVEREST, F., "*Master Handbook of Acoustics*", 4th Edition, McGrawHill, 2001.

[12] GLEN, M., "*Handbook for Sound Engineers – The new audio encyclopedia*", Boston, Focal Press

[13] HENRIQUE, Luís., "*Acústica Musical"*, 1ª edição, Fundación Caloste Gulbenkian, Lisboa, 2003

[14] HENRIQUE, Luís., "*Instrunentos Musicais"*, 3ª edição, Fundación Caloste Gulbenkian, Lisboa, 1999;

[15] CRUZ, Ivo D., "*Teatros de Portugal*", Edições INAPA, Lisboa

[16] KNUDSEN, V., "*Architectural Acoustics*", Scientific American, 1963

[17] MEYER, E., NEUNANN, E., "*Physical and apllied acoustics: An Introduction*", Nova York, Acadenic Press.

[18] MORFEY, J., ""*Dictionary of Acoustics*", San Diego, Acadenic Press, 2001.

[19] PATRICIO, J., "*Acústica de Edifícios*", *2*ªEdición, Lisboa, 2004.

[20] QUIVY, R., "*Manual de Investigação en Ciências Sociais*"**,** Lisboa, Gradiva, 1998

[21] ROSSING, T.D., "*The science of sound*", Addison-Wesley, reading, Massachussets.

Terminology and Definitions

N = Number of seats in the hall (usually wheelchair is not included)

V = Volume of the hall in cubic feet (cubic meters).

In concert halls, V includes the volume of air in the main hall and in the orchestra enclosure. If there is a stagehouse, the volume V does not include that volume, that lies outside the Orchestra enclosure and the volume occupied by the solid balcony structures.. In Operas houses, V includes the volume of air contained in the house forward of the main curtain. It does not include the volume of air in the stagehouse or the

S_A = Acoustical Audience Area. It includes the sum of the area of floor space over which the audience chairs are located and the area of strips (0,5m) wide around the separated blocks of the seating area, except that such strips are neither included at the front edge of a balcony where the audience is seated against a balcony rail nor where the seats abut a wall.

S_0 = Area of stage. When the stage área exceeds 180 m^2, S_0 is limited to that value. This numerical is deemed the acoustical area of a 100 piece orchestra. No side strips are added.

S_{pit} = área of the open surface of the pit.

$S_T = S_A + S_{pit} + S_0$

H = Average room height, measured from main floor to ceilling in that part of the main-floor not covered by balconies. Is needed to determine the time delay of the first ceiling reflection.

W = Average width, measured between side walls in the audience área on the main floor, disregarding any balcony overhang. The W is an indication of the “intimacy” of the hall.

L = Average room length, measured from the stage front to the average of the back wall position at all levels. This length is a general indication of the magnitude of the fall-off loudnes with distance from the stage. The maximum fall-off is determinated by D. It is not intended that H*W*L should be the exact cubic volume of the auditorium.

Apendix

Acoustic Equipment for measurements

All measures in this work where made with he following equipment:

- Sonometer Bruel & Kjaer 2260
- Dodecaedrical Sound Source DO 12 – AWS
- Microphone GRAS
- RAD Inter M 700 Amplification (two channels)
- Laptop Asus
- Software WinMLS 2004
- Microphone Pre-amplification Opus 01 dB:

  - 200 *volts* microphone polarization signal
  - Linear Ponderation
  - 10 Hz Low Cut Filter
  - *Gain* + 20 dB

Measurements Method – MLS

MLS is an abbreviation for Maximum Length Sequence. It is basically a pseudo-random sequence of pulses. Nowadays Maximum Length Sequence measurements are quite standard in many different application fields. One of them is acoustics. The maximum length sequence (MLS) technique is established in various acoustic measurements for fast and accurate broadband determination of acoustic quantities. This technique uses a self-generated periodic, pseudo-random noise signal, which is cross-correlated with the measured signal to give the impulse response, and hence transfer function, of the monitor.

The MLS signal sounds a bit like, and has similar energy content properties to, white noise. Using MLS techniques, it is possible to perform quasi-anechoic measurements of a loudspeaker without having to place it inside an anechoic chamber (a room free from echoes and reverberations). The impulse response can be easily windowed in the time domain, in order to analyze the signal and reject the reflections from the walls of the room. Moreover the room impulse response itself (and all the related parameters such as reverberation time) can be measured. The MLS method can also be used to analyse and obtain information about the impedance or the absorption coefficient of a surface. The MLS technique has many advantages when compared with other methods of measuring the response of a system. Among them the following:

- The MLS has a quasi-flat power spectrum. The spectrum envelope follows a square(sin(x)/x) law and falls by about 1.6 dB at 1/3 of the sampling rate.
- MLS technique rejects the DC component of the sampled signal.
- MLS measurements have a very high Signal/Noise ratio. The cross-correlation used to compute the impulse response reduces all background noise (uncorrelated with MLS), so that measurements can be performed also in noisy environments. The use of averaging techniques can furhter increase the S/N ratio.
- The measured distortion of the system is spread throughout the computed impulse response. Every MLS sequence has his own characteristic distorsion pattern: more measurements on the same system with different MLS sequences (of the same order) allow an easy recognition of the distortions.