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"Comparative evaluation of room acoustical modeling software in Hoftheater Kreuzberg, Berlin"

TRABAJO FINAL DE CARRERA

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ENGLISH

Clarity, loudness, intelligibility and reverberation time are basic characteristics to consider when designing a speech room or theater. The physical characteristics of the room –location, size and function– are defined variables where the engineer must adjust. This project aims to evaluate, through room acoustical modelling software –EASE and CATT-Acoustic–, acoustic parameters and binaural simulations data contrasting their differences between the three programs, applied to a medium-sized theatre as "Hoftheater Kreuzberg Berlin".

DEUTSCH

Klarheit, Lautstärke, Verständlichkeit und Widerhall sind die klaren Charakteristika über die man sich bewusst sein sollte wenn man den Hörsaal für ein Theater designt. Die Physikalischen Eigenschaften von Raumwahl, –größe und –funktion sind meist unklare variablen die ein Akustiktechniker kennen lernen sollte. Dieses Projekt verwendet die Raumakustik-Software –EASE and CATT-Acoustic–, für die Akustischen Informationen und binären Simulationsdaten wurde ebenfalls mit den selben Softwareprogrammen gearbeitet, dabei handelt es sich um ein mittelgroßes Theater wie das "Hoftheater Kreuzberg Berlin".

ESPAÑOL

Claridad, sonoridad, inteligibilidad y tiempo de reverberación son características básicas a tener en cuenta a la hora de diseñar una sala para la palabra. Las características físicas del recinto –localización, dimensiones y función– son variables definidas donde el ingeniero debe adaptarse. Este proyecto trata de evaluar, a través del software de diseño acústico de recintos –EASE y CATT-Acoustic–, parámetros acústicos y datos de simulaciones binaurales contrastando sus diferencias entre los tres programas, aplicadas a un teatro de tamaño medio como es "Hoftheater Kreuzberg Berlin".

CATALÀ

Claredat, sonoritat, intel·ligibilitat i temps de reverberació són característiques bàsiques a tenir en compte a l'hora de dissenyar una sala per a la paraula. Les característiques físiques del recinte –localització, dimensions i funció– són variables definides on l'enginyer deu adaptar-se. Aquest projecte tracta d'avaluar, mitjançant software de disseny acústic de recintes –EASE i CATT-Acoustic–, paràmetres acústics i dades de simulacions binaurals contrastant les seves diferències entre els tres programes, aplicades a un teatre de tamany mitjà com és el "Hoftheater Kreuzberg Berlin".

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Introduction

For several centuries, the acoustic has developed a very important role in the construction of theaters. In fact, it's a science that has been consolidated through the development of new technologies and the evolution of electronic measuring equipment. Thanks to them, it has been possible to relate subjective parameters such as reverberation, speech intelligibility, acoustical intimacy, sound clarity or special surround sound with objective parameters obtained under *in situ* measurements.

In recent years, within the field of acoustic simulation, the software programs have gained ground, both in the design phase and in the analysis phase, as they are useful tools to improve the enclosure and reliably predict the acoustic behaviour of the room. These software are a qualitative enhancement of the forecasts compared to the final results (enclosure built), calculating room acoustical parameters, binaural planning simulations, as well as creating virtual sound (also called "auralization").

Therefore, it's a fast, effective and economical way to model a 3D space and acquire their acoustic parameters, adjusting them according to the use of the place, ignoring in most cases the scale models building for simulation.

That's why this project is intended to compare acoustic simulation programs such as EASE and CATT-Acoustic, in order to assess Hoftheater Kreuzberg (Berlin) through their results and differences.

1. Hoftheater Kreuzberg, Berlin

1.1 Description

Just five minutes walking from the U-Kottbusser Tor subway station, in Berlin, is Hoftheater Kreuzberg. A theater coordinated by Naunyn Ritze cultural association, responsible for providing a platform where actors and artists develop their ideas and put them into practice.

Over these years, this organization focused on educational theater to assist children and young people in the district of Kreuzberg. At this time, these young people have done several productions always oriented to the life-worlds of them.

Regarding the preconditions of the place, the theater has balanced environmental conditions. It's located in a quiet street, without traffic, surrounded by buildings that isolate outside sound. Moreover, it's a closed building, oriented to the southwest, built of concrete and bricks reinforcing the isolation of the room. The building has a gas heating system, which raises the temperature of the theater. The temperature is usually between 18-22 ºC. The five large windows that make up the front of the building are responsible for air-cooling and natural lighting, using also artificial light.

Fig 1.1. – Hoftheater Kreuzberg, Berlin

Thus, the geometry of the theater is based on a rectangular room, or also called “Shoe-Box Hall”. It’s a relatively narrow room, without balcony, where the loudness and acoustical intimacy are high. It has a good spatial impression due to the vision and inclination of the stalls. Normally, these rooms have a high degree of sound diffusion by ornamentation and irregular surfaces, as well as top and side reflections.

Therefore, this room has an own acoustic treatment of a speech room. Reverberation time is adapted to the use of the room, given that acoustical materials are installed. In addiction, Hoftheater has an area of 133 m^2, including backstage and dimmers room. But, as optimal area is 96 m^2 divided between audience area, stage and downstage. The sound and light technicians are at the center of the room, to the back, where you have a good visual angle and stereo sound.

1.2 Location

Fig 1.2. – Location Hoftheater Kreuzberg

Hoftheater Kreuzberg is located in Naunynstraße 63, district of Kreuzberg, in the *Hof* [1] of Naunyn Ritze cultural center.
A few meters from this place is Civilipark, which is a children’s center near Mariannen Platz.

Nevertheless, arrive by public transport isn’t complicated. The nearest subway stations are U-Kottbusser Tor and U-Görlitzer Bahnhof, or with BVG bus service 129, 140, 141 stopping at Oranienstraße.

1.3 Performances

The association organizes a schedule that includes performances by theater companies, dance groups, actors, artists, as well as musicians and composers.

A theater company that has performed several times at this place is Kazibaze Theater. It’s a young company founded in Berlin 2011 by Clara García and Marina Rodríguez (Familie

[1] Hof: German word that means courtyard, area wholly or partly surrounded by walls or buildings.
http://dict.tu-chemnitz.de

Flöz component), two actresses formed in the *Institut del Teatre de Barcelona* specialists in physical theater. Beside them, collaborating different dancers, musicians, puppeteers and artists. Two shows premiered: *Zwei Omas und ein Buch* inspired by the "Town musicians of Bremen" story and *Someone has jumped into my bubble*, a solo dance drama based on the novel by Sylvia Plath "The Bell Jar".

Fig 1.3.1. – Kazibaze Theater in Hoftheater Kreuzberg.

Another company that has recently performed at Hoftheater Kreuzberg is Theater am Tisch. Born as a new theater project in Berlin, May 2012, concept drawn from ComunicaMente cultural association (Italy). A theatrical menu of monologues and dialogues is delivered to the guests in bar and restaurants. There are nine actors who perform in English, German, Spanish and Italian. These actors come to the table and perform their works for a small group, which brings together friends and strangers in this unusual event.

Fig 1.3.2. – Theater am Tisch in Hoftheater Kreuzberg.

2. Modeling and design

2.1 3D modeling with AutoCAD 2012 and Sketch Up 8

First of all, AutoCAD is a software application for computer-aided design and drafting, supporting 2D and 3D formats. An international recognized software employed by engineers, architects, project managers and industrial designers, amongst other professions.

Secondly, to start with the theater's design, it's absolutely essential to consult the room plans (attached in Annex) because it reports all measures necessary for the identical construction of the enclosure. So in order to work faster and visual, the theater is designed under layers of different colors and line weights. In this case, the layers differ between structure, carpentry, heights, stairs, audience area, seats, technicians, stage, proscenium, floor and ceiling.

In addition, 3D solids are used to draw on the XYZ coordinates because otherwise, export the file to other programs that work with three-dimensional spaces, there may be problems of open enclosure, empty blocks, faces corrupt or 2D lines and polylines that aren't detected. Also it happens with visible layers. It should reduce the number of layers because many programs don't allow a large number of them.

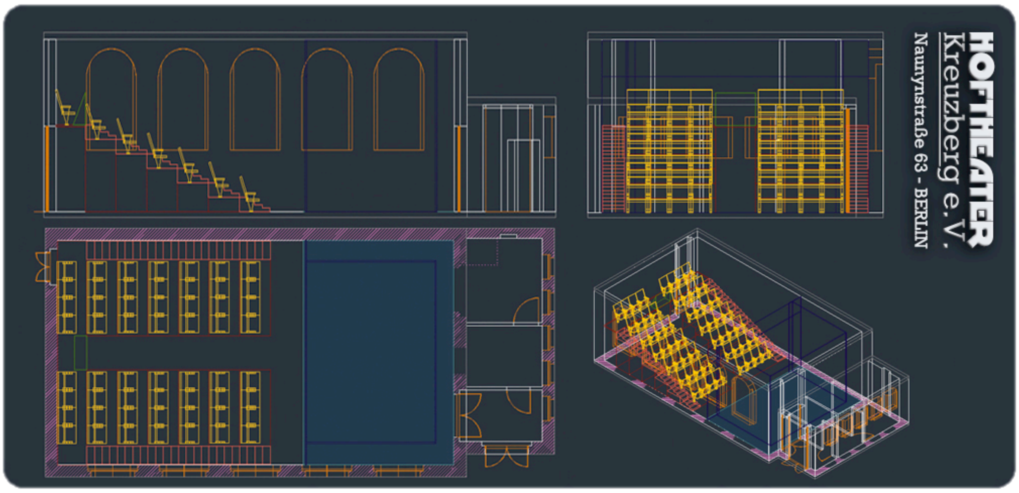

Fig 2.1.1. – AutoCAD modeling

An additional matter is that in order to model the room, as close to reality, there's an option to render the design adding materials. It's possible adjust shadows, lights and even the sunshine condition on a specific date.

The files are recommended to save in .dxf or .dwg format for use in other softwares.

Moreover, Sketch Up is graphic design software and three-dimensional modelling focused on faces for a broad range of applications. Easy, simple and intuitive, designed to be a viable tool for conceptualizing and modelling 3D images. The program has a freeware[2] license and available in free as well as professional versions. It includes a drawing layout functionality, an online repository of model assemblies, allows surfaces rendering and plugin programs to enable other capabilities, besides importing image files, designs in AutoCAD, 3D Studio and Google Earth.

As AutoCAD, this software allows to add materials, shadows and sunshine conditions. The company *Rahe Kraft* has designed an application to Sketch Up, processing and transforming the design directly as EASE or CATT file, including layers and absorption coefficients of the materials.

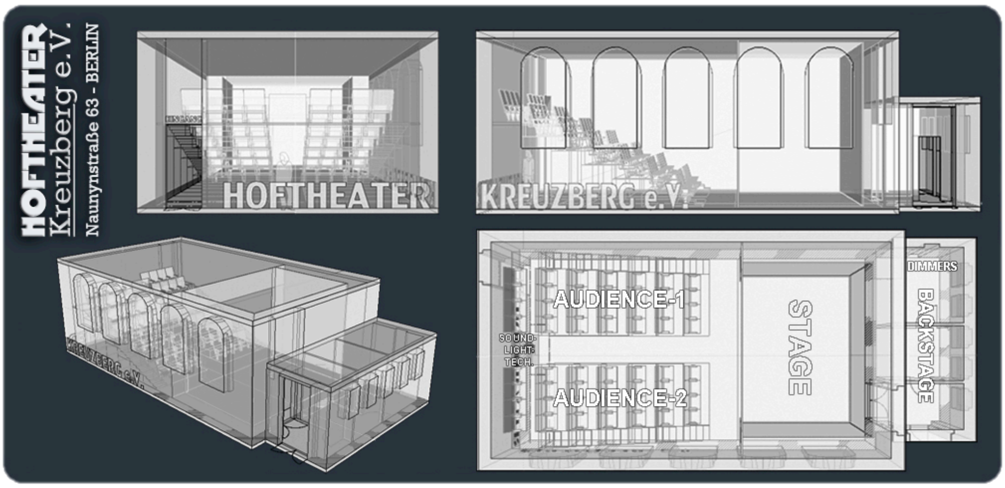

Fig 2.1.2. – Sketch Up modeling

2.2 EASE design

[2] Freeware: software that is provided without charge.

AFMG, located in Berlin, is a company dedicated to the software development for the professional audio industry. Among other programs that are on the market stands EASE[3], standard acoustic simulation software for engineers. It offers an extensive set of professional tools for the study rooms, from detailed, realistic modeling and acoustics simulation in open and closed spaces, sound system performance to informative presentations, as well as professional data assessment and verification.

EASE allows defining the rooms through a CAD module. Graphically displays real world accurate acoustic predictions, and easily assign absorption coefficients at the surfaces, creating sound sources and listening posts.

Previously, the designs have been made in AutoCAD and Sketch Up. So, just import the file DXF/SKP. When the format is *.dxf* (AutoCAD), the program asks metric units that have been designed. If this file is *.skp* (Sketch Up), just ask if the new design should also include invisible structures.
Then, according to CAD format layers developed in the project, the materials are annotated on site. The software has a detailed database of available materials, although it's also possible to create materials from the absorption and scattering coefficients corresponding to a frequency range between 100 and 10000 Hz on third octave band.

If there is a problem importing the file, also can be done the room's design with this software, creating an empty project or using prototypes base that containing, for fast and convenient use, auditoriums, operas, churches, theaters and stadiums, among others. In this case, the multipurpose prototype fits with Hoftheater Kreuzberg. The measures must be defined to load the design. Therefore, the sizes of the audience and stage area are indicated in Table 2.2.1.

Piece	Length (m)
Room length	8.06
Room breadth	7.34
Room height	4.76
Stage depth	4.90
Stage breadth	5.74
Stage height	3.96
Step height	0.10

Table 2.2.1. – Theater's measures

The theater is symmetric about the long axis. The audience area is divided into two parts, with dual side access to the stalls and a central aisle of 1.10 m width regulated by law. Faces, specifying the materials in each, create the inclined structure audience area. The stalls consist of 56 seats, separated into seven distinct rows in blocks of four seats on each side. The maximum height in this area is 2.40 m.

[3] EASE: Enhanced Acoustic Simulator for Engineers.

After defining all the faces, it has to check that there aren't holes or openings in the room. Thus, there is an option called "Check Holes" in the tools menu. If the program detects an error, it's not possible continue with the acoustic enclosure because it's not defined the entire structure.

When the theater's structure is developed, the materials elements are added to determine acoustically the room. In addition to conditioning the enclosure faces, can be obtained values as the reverberation time.

The materials appearing at the carpentry and flooring finishes belonging to the theater project execution is shown in Table 2.2.2. These materials have been used in the acoustic simulations performed.

Surface	**Material**	**EASE Name**
Floor	Parquet wood flooring	Parquet FL
Ceiling and rear wall	Wood paneled wall 16 mm on 4 cm air	WDPanel 16
Sidewalls	Black thin curtain for theater	Drape THIN
Unoccupied Seats	Seats unoccupied upholstered in fabric	MTSeat Fab.
Occupied Seats	Seats occupied upholstered in fabric	Public TNC
Stalls, stairs and stage floor	T&G Hardwood floor on beams	Wooflr HWD
Proscenium arch and tormentors	Thin dark curtain for theater	Drape THIN
Stage sidewalls	Thin black velvet curtain for theater	Velour LT
Stage ceiling	Scored beveled tegular cirrus 400 mm backspace assumed. Armstrong Ceiling tile	SBV Cirrus

Table 2.2.2. – Materials used in the acoustic simulation

In relation to the equipment, both in lighting and sound reinforcement, this software allows to display graphically and visually the sound and light result of the building. It features an updated database of speakers and lamps. In this theater, CQ2 Meyer Sound loudspeakers have been used as models for sound reinforcement, as well as dodecahedron speaker for sound absorption measurements, reverberation time and soundproofing. Also, there are eight lamps in the audience area, besides spotlights placed on the stage trussing system.

Finally, it should define the public area and create listener seats for acoustic simulation. The minimum number of positions and measurements to engineering, according to ISO 3382, is six source-microphone combinations with two or more source positions. The microphones positions shouldn't be near to the source position, to avoid strong influence of the direct sound.

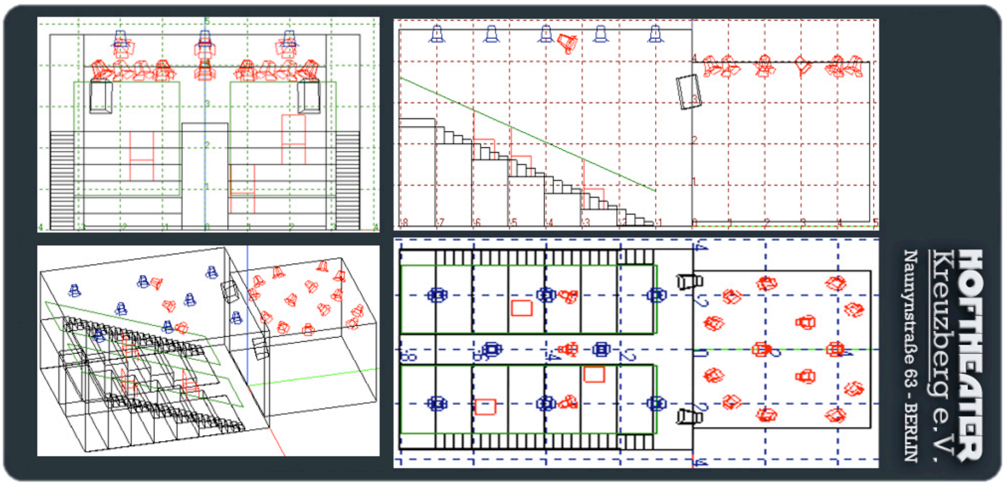

Fig 2.2.3. – EASE design

2.3 CATT-Acoustic design

From Gothenburg (Sweden), Dr. Bengt-Inge Dalenbäck -CRAG[4] group- developed the world's first professional software for room acoustics metrics prediction and auralization, in 1998. CATT-Acoustic software is developed for analysis and acoustic simulation, with great calculation potential given its processed algorithms. Allows acoustic prediction of rooms, process where by geometrical acoustics algorithms are deduced echograms in octave-band based on 3D CAD model. Geometrical surfaces of the rooms have assigned material properties depending of the frequency.

Another function, as EASE, is the sound's auralization in the enclosure, digital signal process where the echograms in octave-band are converted into binaural impulse responses. That can be convolved with music or speeches recorded in anechoic form, perceiving the listening feeling to this audio as if reproduced into the created hall.

Regarding the design methodology, in the first place, work with this software can be difficult. The enclosure should be defined through corners and planes within the ASCII file CATT preprocessing. Also, it's recommended to create the structure of the theater trying to simplify the faces to be used. There are simple commands that facilitate the design, as well as variables or parameters that modify values once built the room.

[4] CRAG: The Chalmers Room Acoustics Group (CRAG) was formed in 1989 to unite both senior and junior researchers, and to create a body of critical mass for excellence.
http://www.ta-chalmers.se

The software has three basic files for a new model's creation:

- The **.geo* model file reports the enclosure's geometric modeling, points and planes. These points or corners, when joining together, create rectangular or triangular planes figures of specific material.
  The materials are also defined by their absorption and scattering coefficient, along with distribution in each enclosure. In this case, the materials are implemented at the beginning of the code using the command ABS, but they can be created in another model file.
- The *src.loc* sound sources file specifies the characteristics such as directivity, frequency response, levels and position of the sound sources.
- The *rec.loc* receivers file indicates on the receiver's position.

A complex room to program by CATT can be designed in simple independent models and then, integrate them into a *master.geo* file.

As discussed in the previous section 2.1, from Sketch Up can export the room's layout with SU2CATT application. The demo version limited to export the design only 50 layers.
On the other hand, it's also possible to export the 3D model from AutoCAD using *AutoLISP* command series. But first, it is recommend to know that CATT-Acoustic just represents planar geometries, defined by walls and corners. In fact, only the objects 3Dface can be exported and the curvilinear structures must be approximated to planar geometries.

The theater's main model is a multipurpose room. The room is composed of different parts including stage, proscenium, main hall, audience area, technical area and stairs. Being a symmetrical room, *mirror* function saves time and does not draw all the points in the plane.

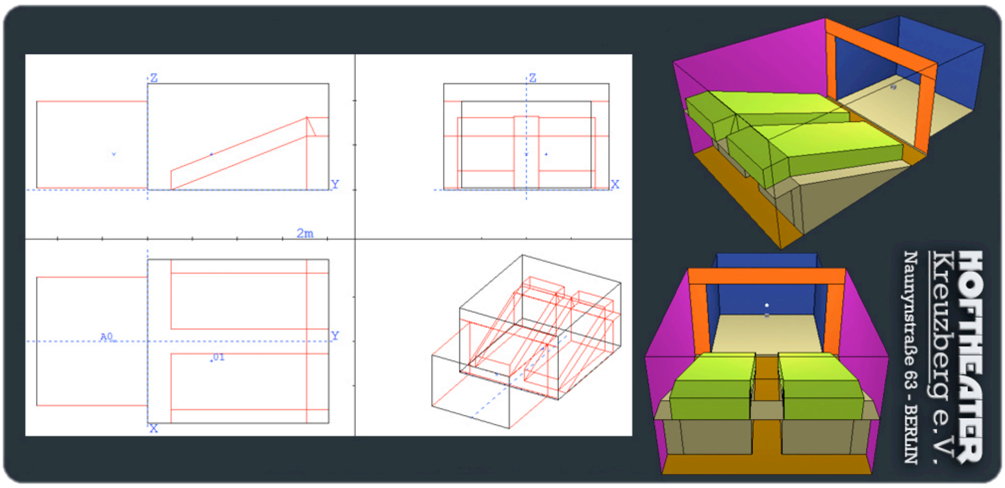

Fig 2.3. – CATT-Acoustic design

The implemented code in Appendix A.2 contains the main program file, master.geo, followed by the location of sources and listeners. CATT-Acoustic offers three independent prediction or acoustic simulation based on geometrical acoustics:

- *Audience area mapping* utilizes standard ray-tracing with a spherical receiver. The audience plane is defined in the range 39-40 and 47-48.
- *Early part detailed ISM* uses the Image Source Model with added first-order diffuse reflection. This method is meant for qualitative reflection path analysis and does not estimate any room acoustic parameters.
- *Full detailed calculation* utilizes Randomized Tail-corrected Cone-tracing (RTC) that combines features of both specular cone-tracing, standard ray-tracing and the ISM.

3. Test report for showrooms

The measurement procedure mentions the regulation UNE-EN ISO 3382. Acoustics. Measurement of room acoustic parameters in performance spaces (part 1) and reverberation time measurement in ordinary rooms (part 2).

- Data of the test chamber:
  - Name: Hoftheater Kreuzberg e.V.
  - Location: Naunynstraße 63, 10997 Berlin, Germany.
  - Contact: Karin Liersch
  - Email: info@hoftheater-kreuzberg.de
  - Phone: +49 30 347458930

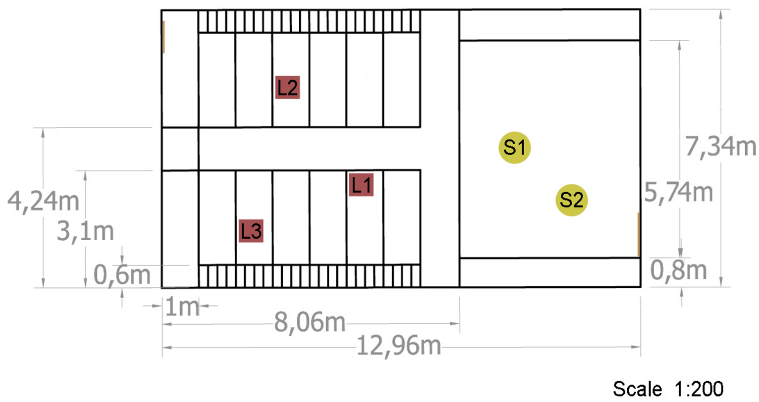

Fig 3.1. – Sketch of theater

- Geometric data of the enclosure:
  - Rectangular-shaped room completely closed.
  - Volume: 452.80 m^3
  - Volume available: 392.70 $m^3 \approx 393$ m^3
  - Volume without stage: 281.60 m^3
  - Useful stage area: 28.13 m^2
  - Main room area: 59.16 m^2
  - Effective audience area: 37.61 m^2

- Total area: 87.29 m^2
- Number of seats (N): 56 seats
- V/N: 5 m^3/seat

▪ Measurements conditions:
    - Unoccupied and occupied room
    - Empty stage
    - Temperature: 20ºC
    - Relative Humidity: 50%

▪ Acoustic objectives:
    - Reverberation Time (occupied room): $0.70 \leq RT_{mid} \leq 1.20$ s
    - Speech Average (occupied room): $C_{50} > 2$dB
    - Definition (occupied room): $D \geq 0.50$
    - Speech Intelligibility STI/RASTI (occupied room): RASTI ≥ 0.65
    - Articulation Loss of Consonants (occupied room): $AL_{cons} < 5\%$

The stalls or seating area has a maximum height of 2.40 m, accessing the seats thought the side stairs. Each row has four seats from Seating Concepts company, BW 220 Contour model of 20'' inches. Inside, the seats contain cold molded foam for superior comfort and cushion lifespan, four-inch foam crown on seat foam and serpentine spring support. The rear surface is an injection molded with texture surface for ease maintenance. Also, the surface is contoured for optimal comfort, adding a counterbalance mechanism that provides seat return.

Proscenium is composed of porous and rough drapes. They are situated as stage curtains on the sides, called tormentors, and proscenium arch. There is not front curtain, that is, a curtain between acts does not close the proscenium. The area between the wings[5] and the tabs[6] has a width of 0.80 m and is accessible through the rear door that communicates with the backstage and storage area.

In the main room, the ceiling and rear wall are covered with wood paneled 16 mm on 4 cm air. Its sidewalls are coated with dark thin fabric, which prevents the light's entry and acts as an absorbent, complicating the reflections. The floor uses wood parquet flooring of light colored.

On stage, the ceiling is made by scored beveled tegular cirrus from Armstrong brand. Provides excellent sound absorption, light reflectance and resistant to shocks, scratches and

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[5] Wings: Areas that are part of a stage deck but offstage (out of sight of the audience), typically masked with legs. This space is used for performers preparing to enter, storage of sets for scenery changes and as stagehand work area. Wings also contain technical equipment, such as the fly system.

[6] Tabs: Drapes that hang at the sides of the stage perpendicular to the proscenium opening to mask the wings, as shown in the drawing at the top of this page.

stain. Its visual representation is a medium texture. Suspended from the ceiling hang the batten or fly system, a long metal pipes that supports the lighting fixtures, theatrical scenery, theater drapes and stage curtains.

The floor material is dark hardwood. As tabs and backdrop are used large and thin drapes, current standard in the textile industry for theatrical productions. They are made with black velvet, light-absorbing material to mask areas that should not be visible to the public. Each side of the stage has a speaker Meyer Sound CQ-2 acting as sound reinforcement.

According to the DIN-18041, referring to statistical theory to calculate the reverberation time using Sabine's formula (3.2), the reverberation time obtained in this room is 0.70 seconds:

$$T = 0{,}163\,\frac{V}{A} \qquad (3.2)$$

clearing

V is the volume of the room, in cubic meters. In this case, 393 m^3;

A is the total absorption area, in square meters. In this case, 90.86 m^2;

T is the reverberation time, in seconds.

The measurement positions in the theater to obtain adequate coverage are made using the engineering method to verify building performance with respect to the reverberation time of the enclosure, being a medium-sized room. The method is based on placing two points source inside the room and three microphone positions for each point source with two falls or reverberation time calculations at each point.

The locations of the sound sources and the calculation points or listeners are described below and are shown in Figure 3.1.

- Sound source:
  - Source type: Omnidirectional
  - Signal used: Pink Noise
  - Number of points of the source location: 2
    (named A1, A2 or S1, S2)
  - Height of the source from the stage's floor: 1.50 m
  - Locations of the points:
    S1: on the longitudinal axis of the room, 1.50 m away from the front of the stage
    S2: 1.44 m on the longitudinal axis of the room, 3 m away from the front of the stage

- Microphones or calculation points:
  - Number of microphones: 3 (named L1, L2, L3 or P1, P2, P3)
  - Height of the microphones from the main room’s floor: 1.60 m, 2.40 m, 2.80 m, respectively

- Location of the points:
  P1: 0.90 m on the longitudinal axis of the room, 2.70 m away from the front of the stage
  P2: 1.50 m on the longitudinal axis of the room, 4.70 m away from the front of the stage
  P3: 2.10 m on the longitudinal axis of the room, 5.70 m away from the front of the stage

In addition, the minimum distance between source-microphone is 2.56 m, using 0.70 seconds as reverberation time.

$$d_{min} = 2\sqrt{\frac{V}{cT}} \quad (3.3)$$

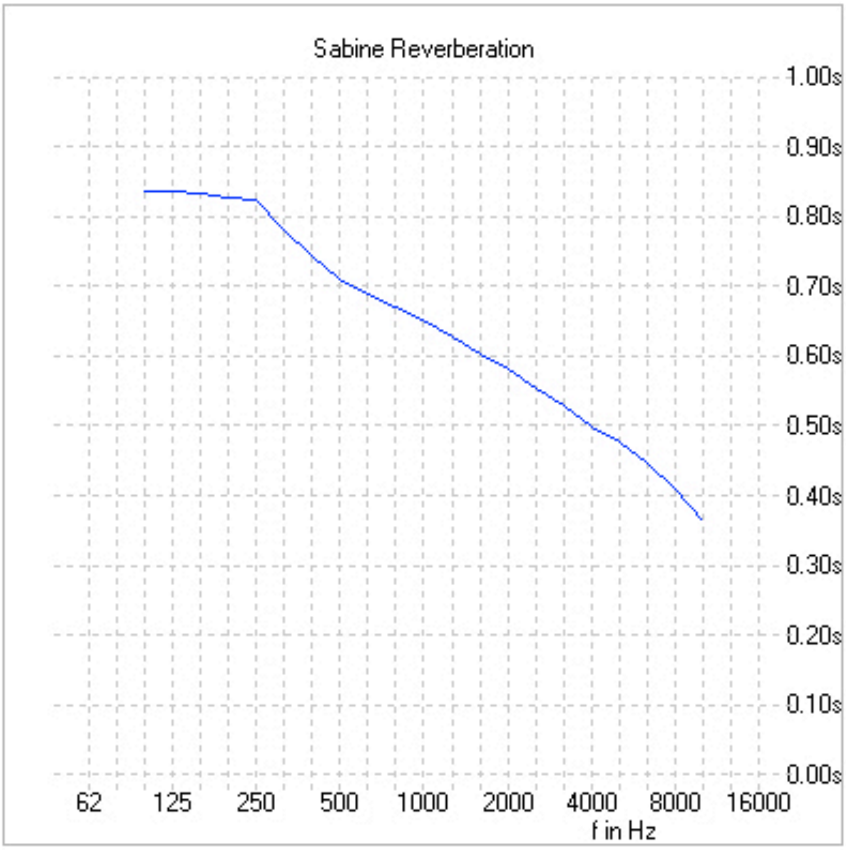
where
V is the volume, in cubic meters;
c is the speed of sound, in meters per second;
T is an estimate of the expected reverberation time, in seconds.

4. Acoustic simulation software

The acoustic parameters necessary to achieve the project objectives are represented below as graphics and mapping of the audience area, extracted from the acoustic simulation with both software. Furthermore, as discussed in section 3, the parameters are evaluated in occupied and unoccupied room.

4.1 EASE

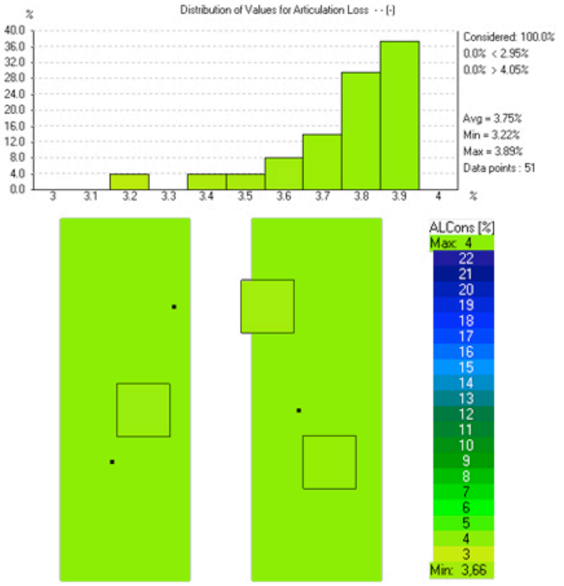
4.1.1 Occupied room



Band	RTime [s]
100 Hz	0,84
125 Hz	0,84
160 Hz	0,83
200 Hz	0,83
250 Hz	0,82
315 Hz	0,78
400 Hz	0,74
500 Hz	0,71
630 Hz	0,69
800 Hz	0,67
1000 Hz	0,65
1250 Hz	0,63
1600 Hz	0,6
2000 Hz	0,58
2500 Hz	0,56
3150 Hz	0,53
4000 Hz	0,5
5000 Hz	0,48
6300 Hz	0,45
8000 Hz	0,41
10000 Hz	0,36

Fig 4.1.1.1. – Reverberation time in occupied room

- Source 1



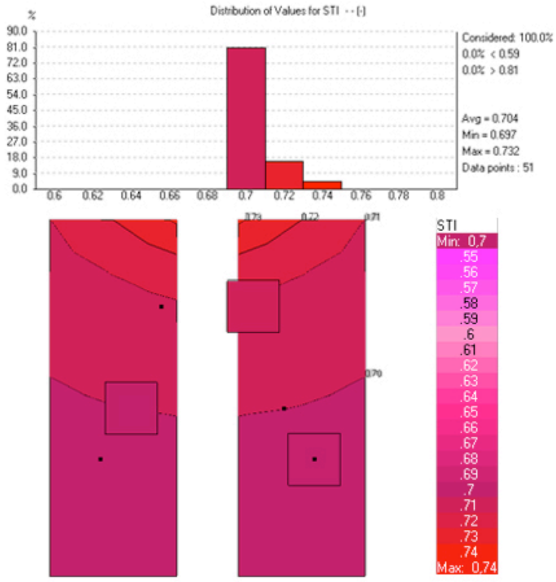
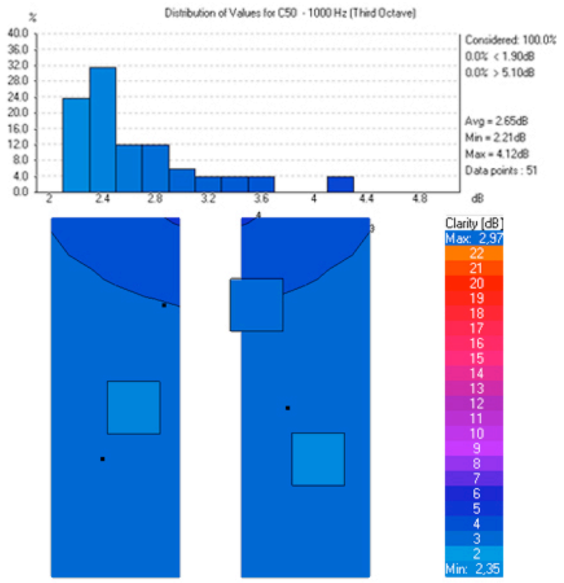


Fig 4.1.1.2. – Percentage Articulation Loss of Consonants %ALcons in occupied room (S1)

Fig 4.1.1.3. – Speech transmission index STI/RASTI in occupied room (S1)



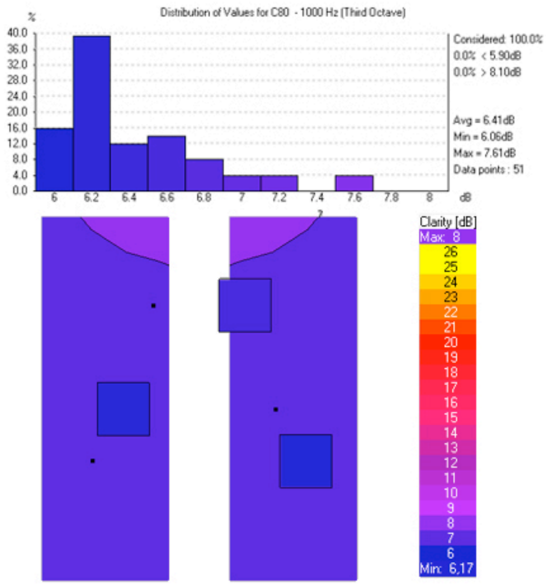


Fig 4.1.1.4. – Speech Average C_{50} in occupied room (S1)

Fig 4.1.1.5. – Speech Average C_{80} in occupied room (S1)

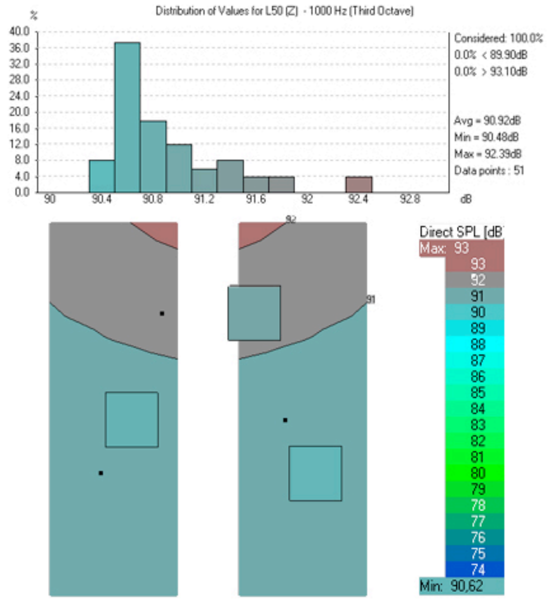


Fig 4.1.1.6. – Pressure Level L_{50} in occupied room (S1)

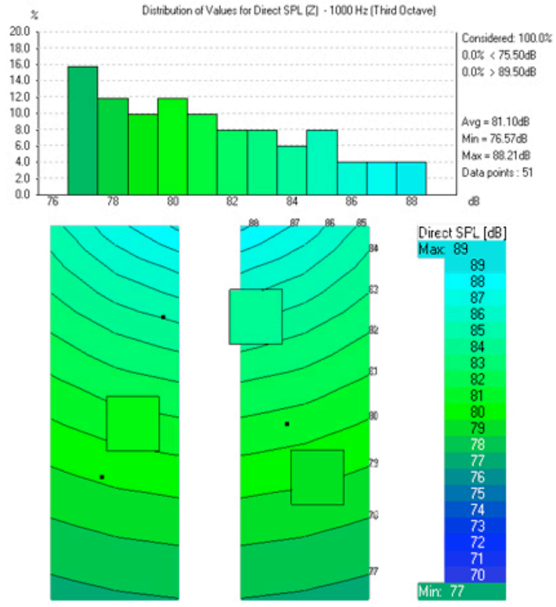


Fig 4.1.1.7. – Direct Sound Pressure Level in occupied room (S1)

▪ Source 2

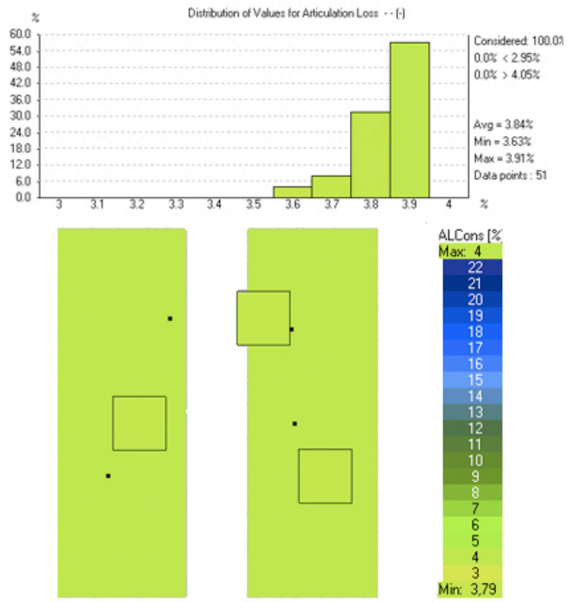


Fig 4.1.1.8. – Percentage Articulation Loss of Consonants %ALcons in occupied room (S2)

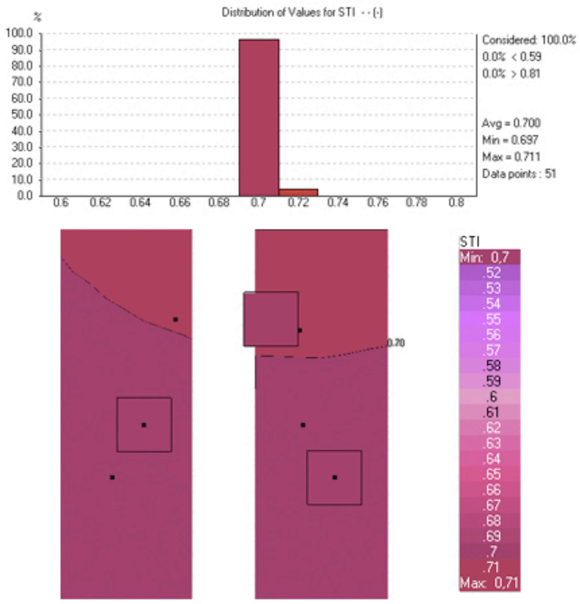


Fig 4.1.1.9. – Speech transmission index STI/RASTI in occupied room (S2)

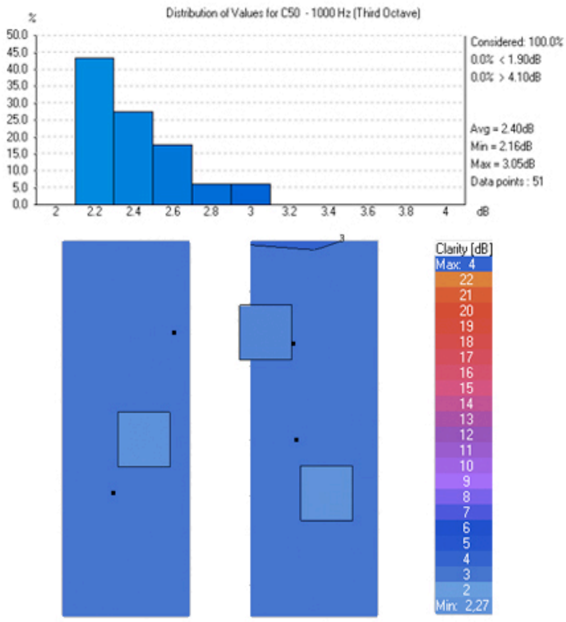


Fig 4.1.1.10. – Speech Average C_{50}
in occupied room (S2)

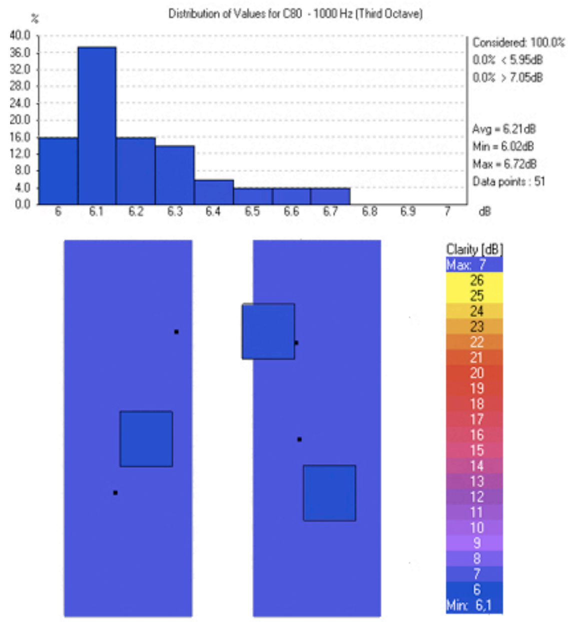


Fig 4.1.1.11. – Speech Average C_{80}
in occupied room (S2)

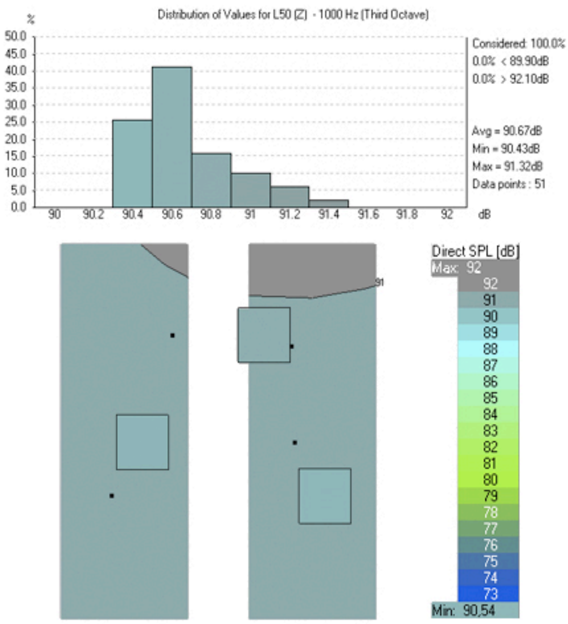


Fig 4.1.1.12. – Pressure Level L_{50}
in occupied room (S2)

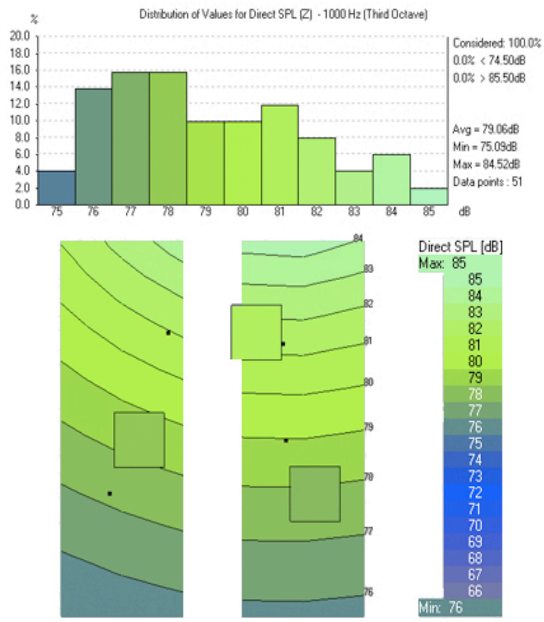
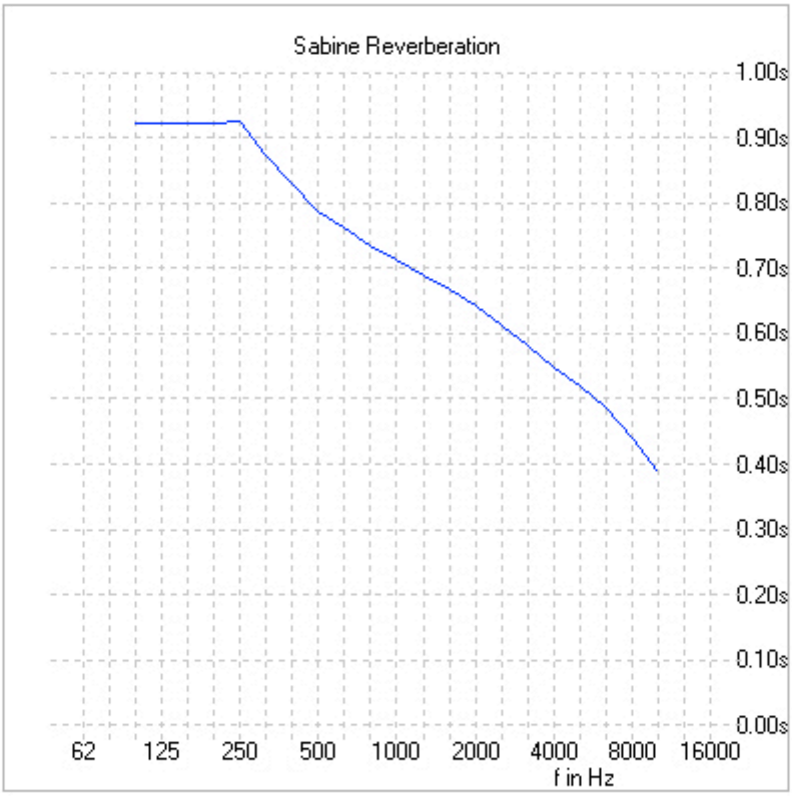


Fig 4.1.1.13. – Direct Sound Pressure Level
in occupied room (S2)

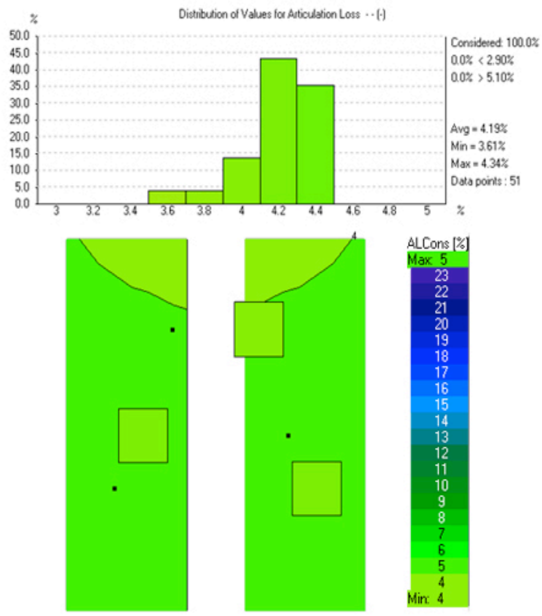
4.1.2 Unoccupied room



Band	RTime [s]
100 Hz	0,92
125 Hz	0,92
160 Hz	0,92
200 Hz	0,92
250 Hz	0,92
315 Hz	0,87
400 Hz	0,83
500 Hz	0,79
630 Hz	0,76
800 Hz	0,74
1000 Hz	0,71
1250 Hz	0,69
1600 Hz	0,67
2000 Hz	0,64
2500 Hz	0,61
3150 Hz	0,58
4000 Hz	0,55
5000 Hz	0,52
6300 Hz	0,49
8000 Hz	0,44
10000 Hz	0,39

Fig 4.1.2.1. – Reverberation time in unoccupied room

- Source 1



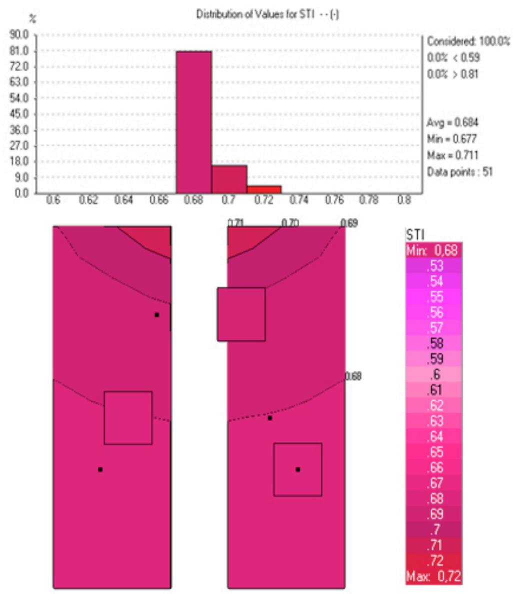


Fig 4.1.2.2. – Percentage Articulation Loss of Consonants %ALcons in unoccupied room (S1)

Fig 4.1.2.3. – Speech transmission index STI/RASTI in unoccupied room (S1)

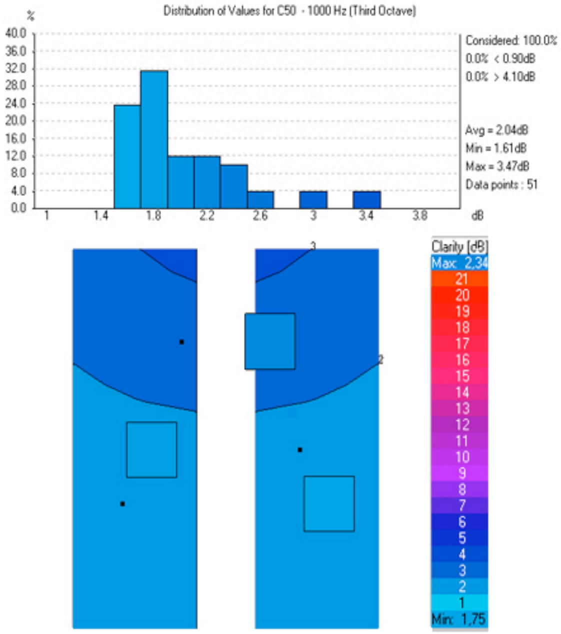


Fig 4.1.2.4. – Speech Average C_{50} in unoccupied room (S1)

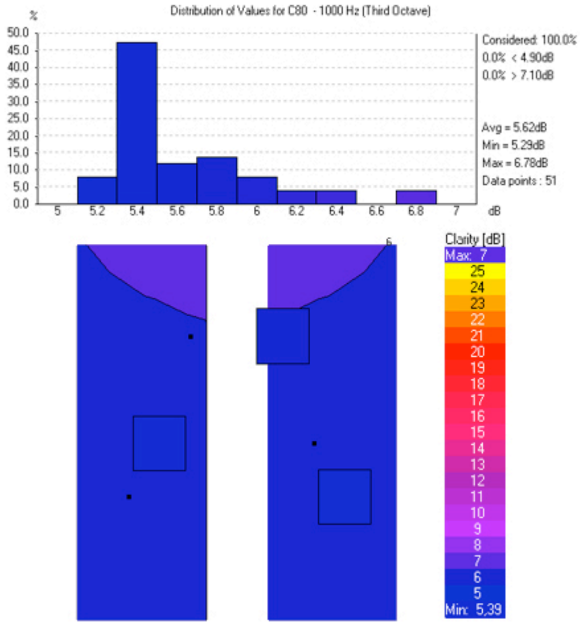


Fig 4.1.2.5. – Speech Average C_{80} in unoccupied room (S1)

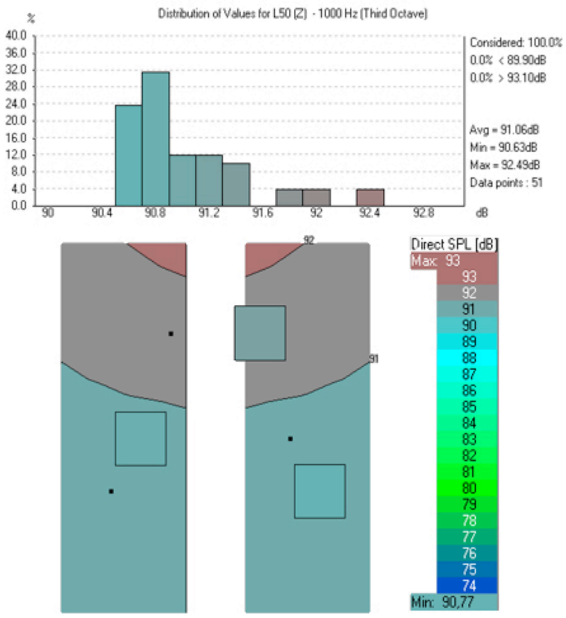


Fig 4.1.2.6. – Pressure Level L_{50} in unoccupied room (S1)

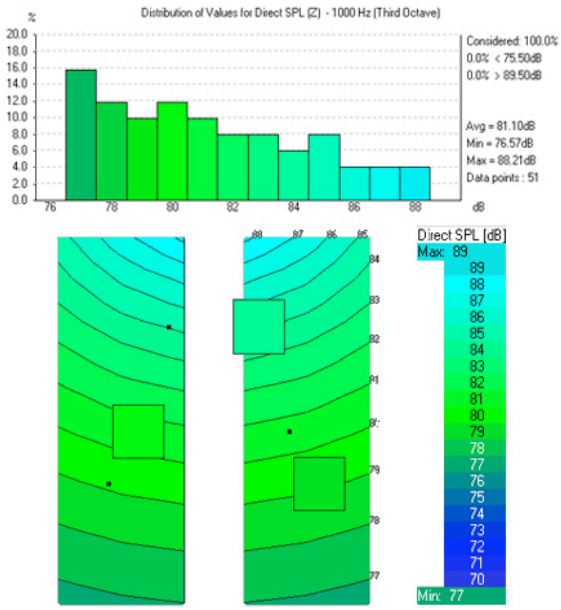


Fig 4.1.2.7. – Direct Sound Pressure Level in unoccupied room (S1)

- Source 2

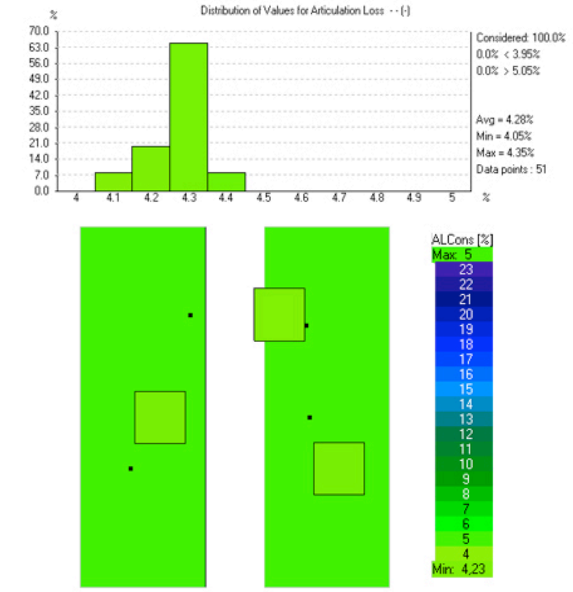


Fig 4.1.2.8. – Percentage Articulation Loss of Consonants %ALcons in unoccupied room (S2)

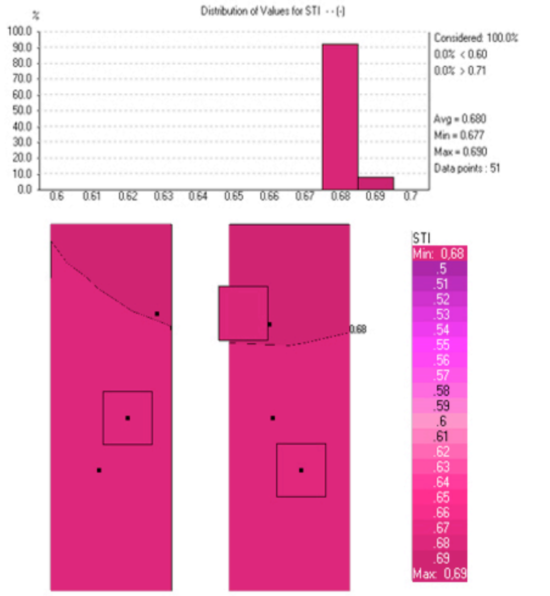


Fig 4.1.2.9. – Speech transmission index STI/RASTI in unoccupied room (S2)

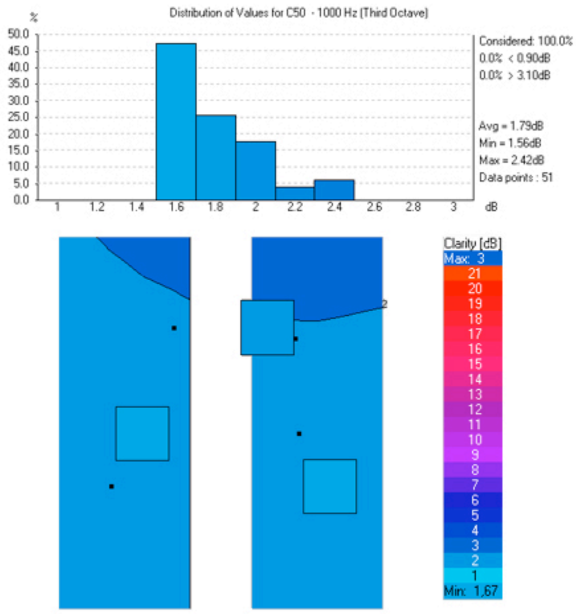


Fig 4.1.2.10. – Speech Average C_{50} in unoccupied room (S2)

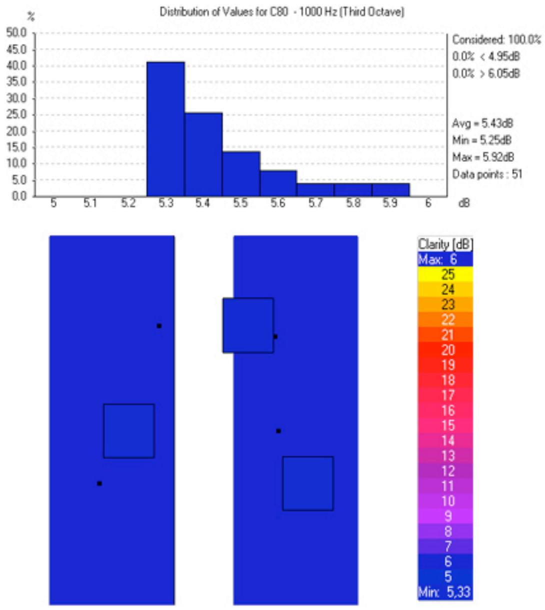


Fig 4.1.2.11. – Speech Average C_{80} in unoccupied room (S2)

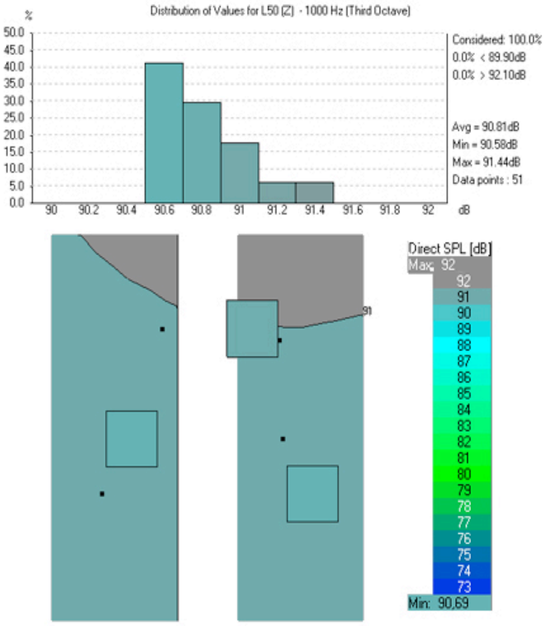


Fig 4.1.2.12. – Pressure Level L_{50} in unoccupied room (S2)

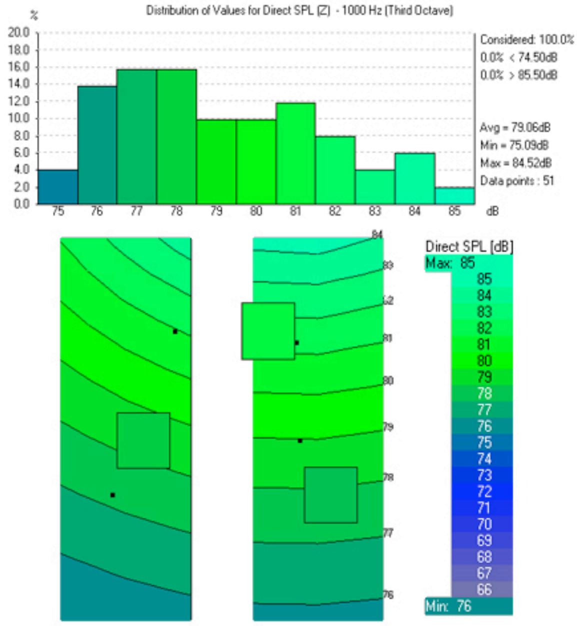


Fig 4.1.2.13. – Direct Sound Pressure Level in unoccupied room (S2)

4.2 CATT-Acoustic

4.2.1 Occupied room

- Source 1

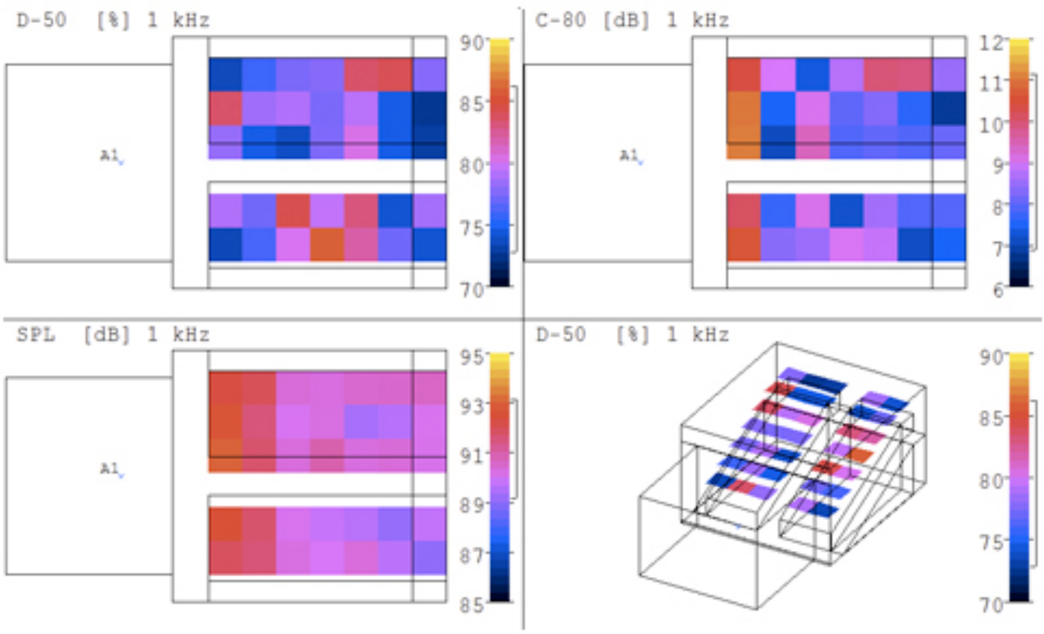
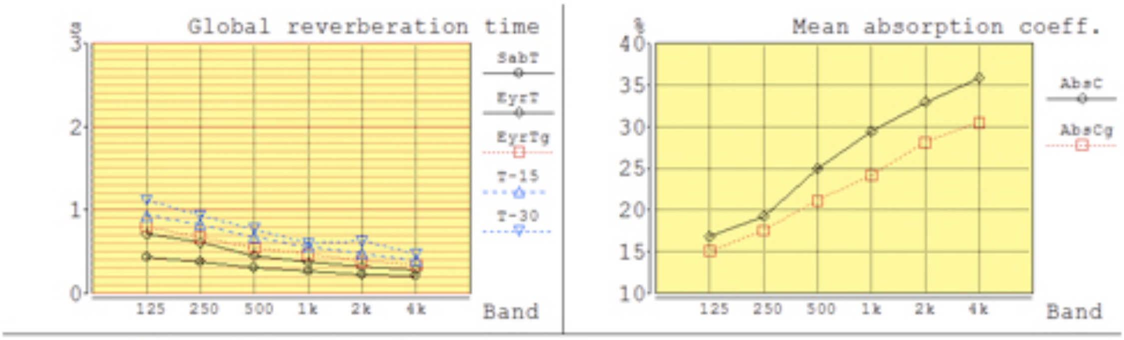


Fig 4.2.1.1. – D_{50}, C_{80} and SPL in occupied room (S1)



	125	250	500	1k	2k	4k	
EyrT	0,71	0,61	0,45	0,37	0,32	0,28	s
EyrTg	0,80	0,67	0,54	0,47	0,39	0,34	s
SabT	0,43	0,37	0,31	0,27	0,23	0,21	s
T-15	0,93	0,83	0,67	0,56	0,48	0,39	s
T-30	1,12	0,93	0,77	0,60	0,63	0,47	s
AbsC	16,79	19,21	24,95	29,41	32,93	35,84	%
AbsCg	15,03	17,53	21,13	24,13	28,08	30,48	%
MFP	3,24	3,24	3,24	3,24	3,24	3,25	m
Diffs	10,01	10,05	10,13	10,05	10,06	10,07	%

Trunc 1000,0 ms
Rays 10088 (used/oct)
0 (lost/oct)
0 (absorbed/oct)
Angle 2,02 degrees

Fig 4.2.1.2. – Reverberation time in occupied room (S1)

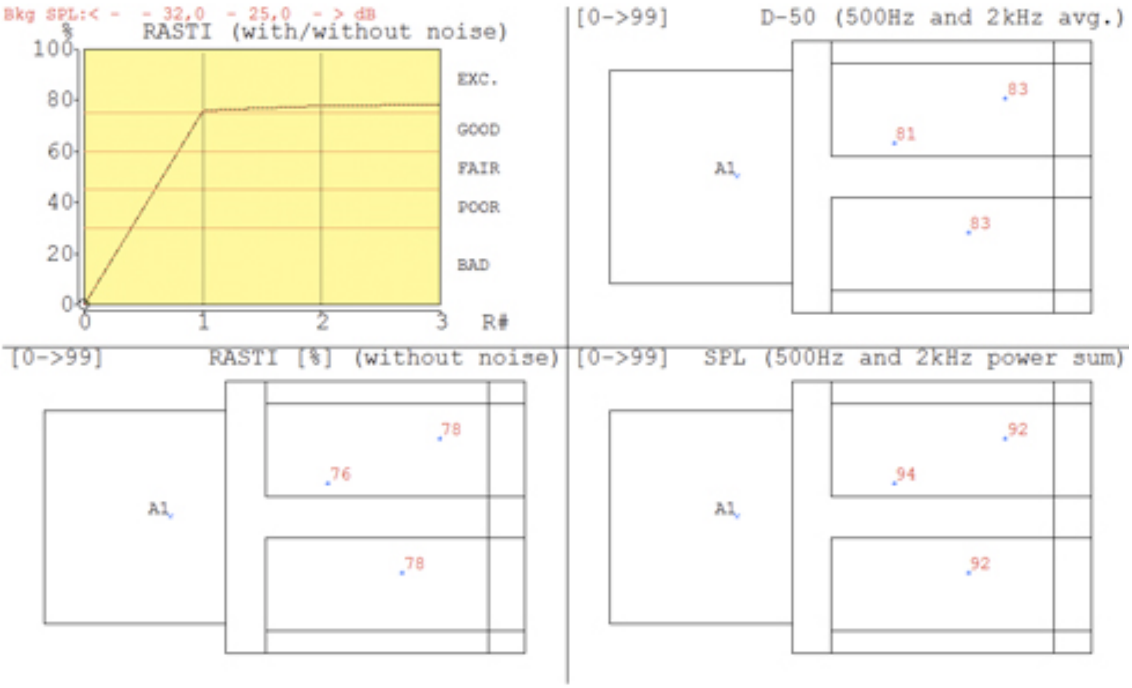


Fig 4.2.1.3. –RASTI, D_{50} and SPL in occupied room (S1)

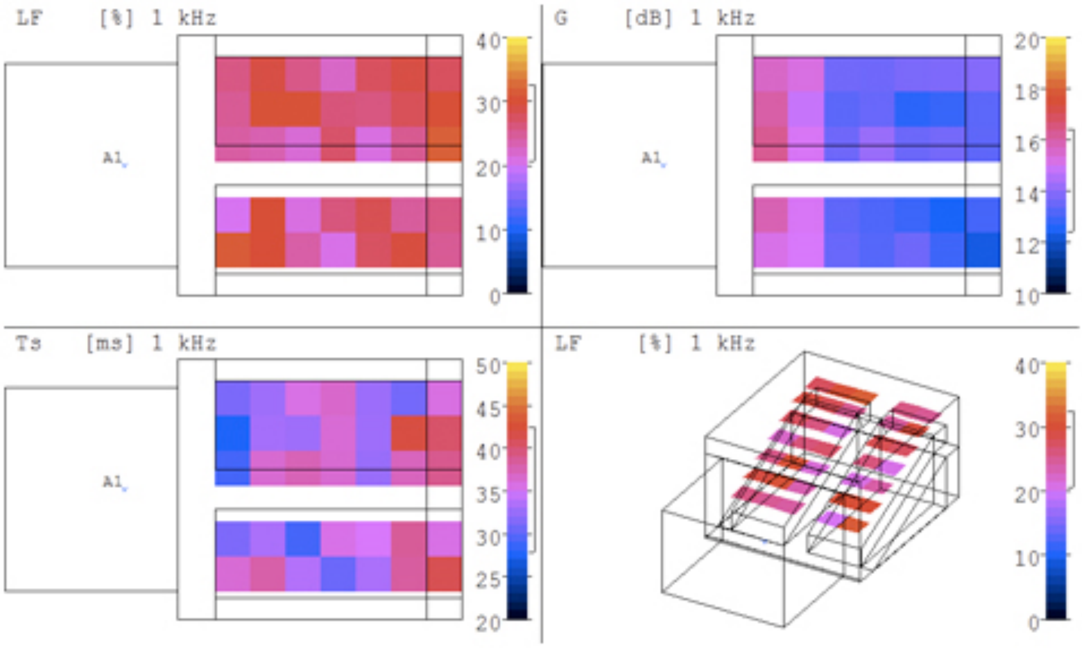


Fig 4.2.1.4. – LF, G and Ts in occupied room (S1)

- Source 2

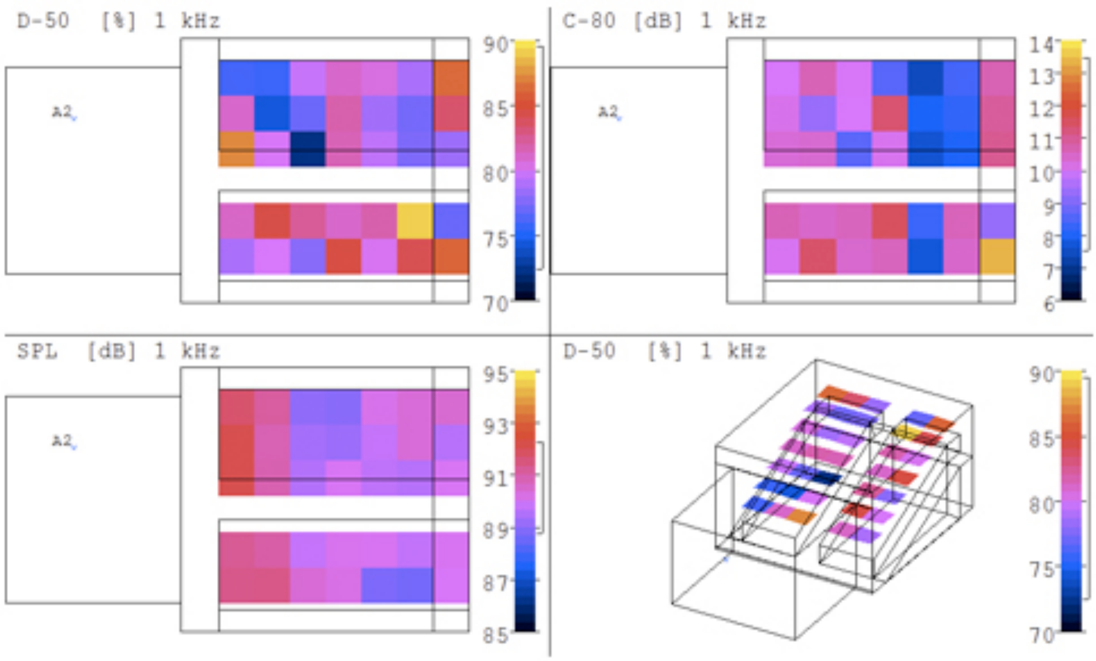
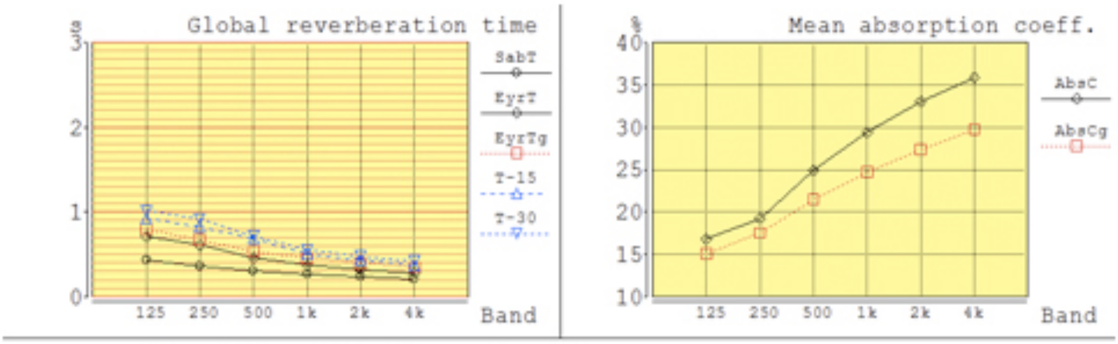


Fig 4.2.1.5. – D_{50}, C_{80} and SPL in occupied room (S2)



	125	250	500	1k	2k	4k	
EyrT	0,71	0,61	0,45	0,37	0,32	0,28	s
EyrTg	0,80	0,67	0,54	0,45	0,40	0,35	s
SabT	0,43	0,37	0,30	0,26	0,23	0,21	s
T-15	0,92	0,83	0,68	0,50	0,44	0,37	s
T-30	1,01	0,92	0,72	0,56	0,48	0,42	s
AbsC	16,81	19,25	24,92	29,37	32,97	35,85	%
AbsCg	15,03	17,53	21,50	24,70	27,35	29,71	%
MFP	3,24	3,24	3,25	3,24	3,25	3,25	m
Diffs	10,09	10,11	10,08	10,14	10,08	10,06	%

Trunc	1000,0	ms
Rays	10088	(used/oct)
	0	(lost/oct)
	0	(absorbed/oct)
Angle	2,02	degrees

Fig 4.2.1.6. – Reverberation time in occupied room (S2)

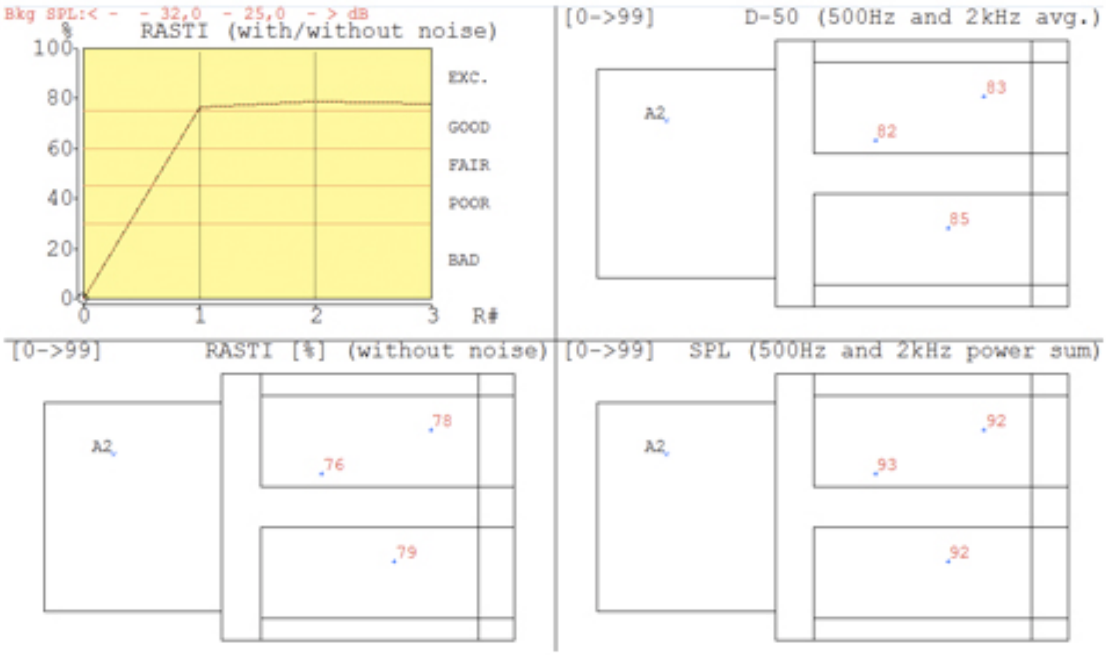


Fig 4.2.1.7. – RASTI, D_{50} and SPL in occupied room (S2)

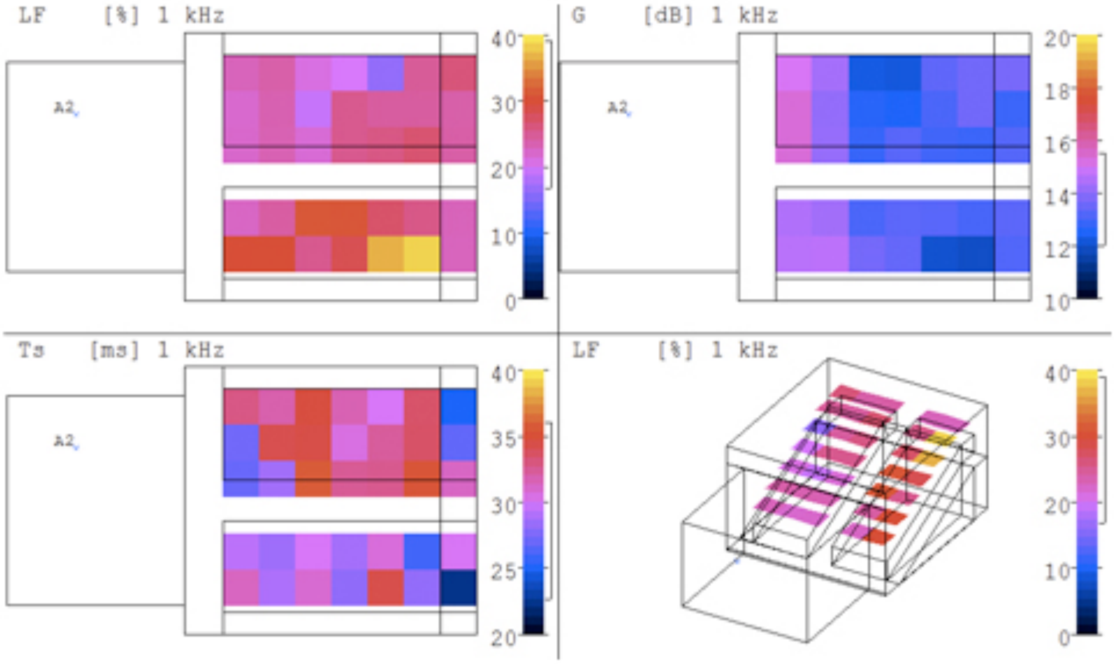


Fig 4.2.1.8. – LF, G and Ts in occupied room (S2)

4.2.2 Unoccupied room

- Source 1

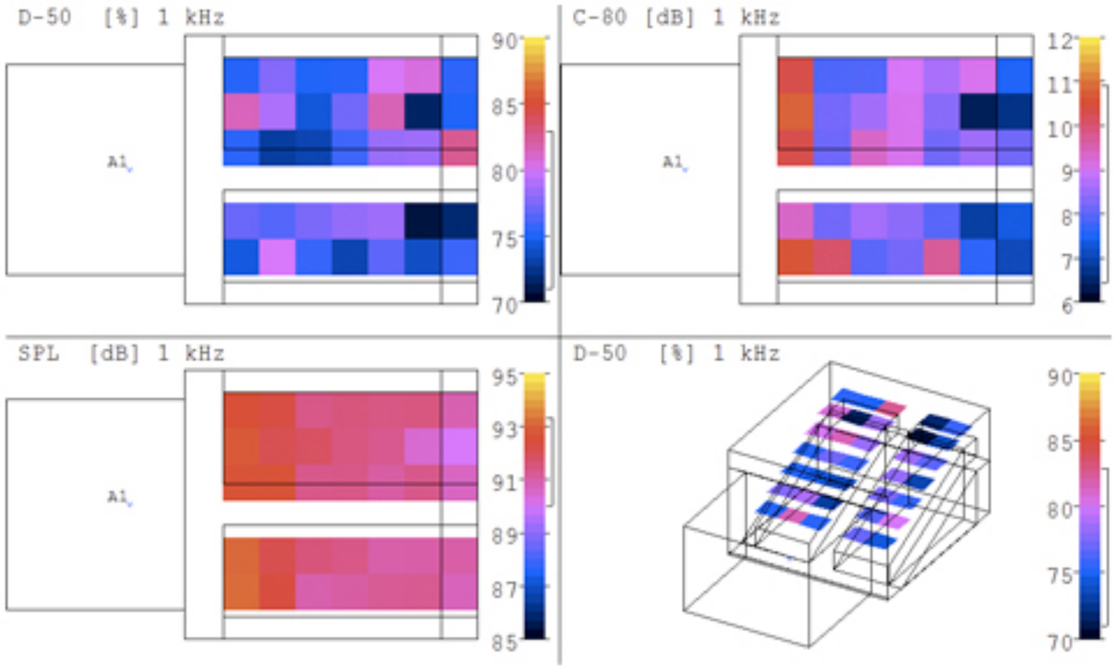
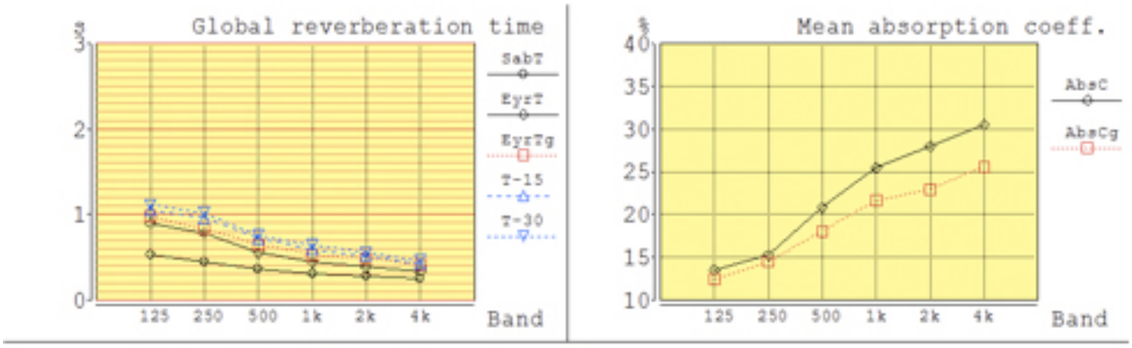


Fig 4.2.2.1. – D_{50}, C_{80} and SPL in unoccupied room (S1)



	125	250	500	1k	2k	4k	
EyrT	0,90	0,78	0,55	0,44	0,39	0,34	s
EyrTg	0,98	0,83	0,65	0,53	0,49	0,41	s
SabT	0,53	0,45	0,36	0,30	0,28	0,24	s
T-15	1,05	0,96	0,72	0,59	0,52	0,42	s
T-30	1,12	1,02	0,76	0,64	0,55	0,46	s
AbsC	13,54	15,28	20,84	25,47	27,99	30,49	%
AbsCg	12,41	14,46	18,03	21,63	22,91	25,57	%
MFP	3,24	3,24	3,24	3,24	3,24	3,25	m
Diffs	10,08	10,07	10,08	10,06	10,12	10,10	%

Trunc 1000,0 ms
Rays 10088 (used/oct)
0 (lost/oct)
0 (absorbed/oct)
Angle 2,02 degrees

Fig 4.2.2.2. – Reverberation time in unoccupied room (S1)

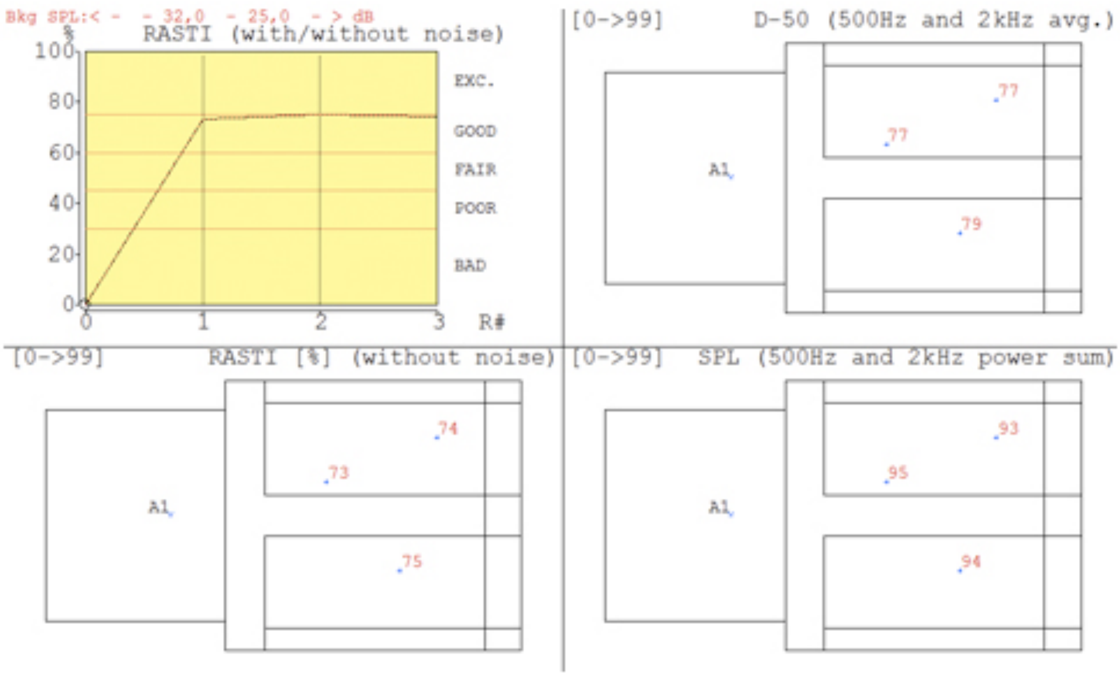


Fig 4.2.2.3. – RASTI, D_{50} and SPL in unoccupied room (S1)

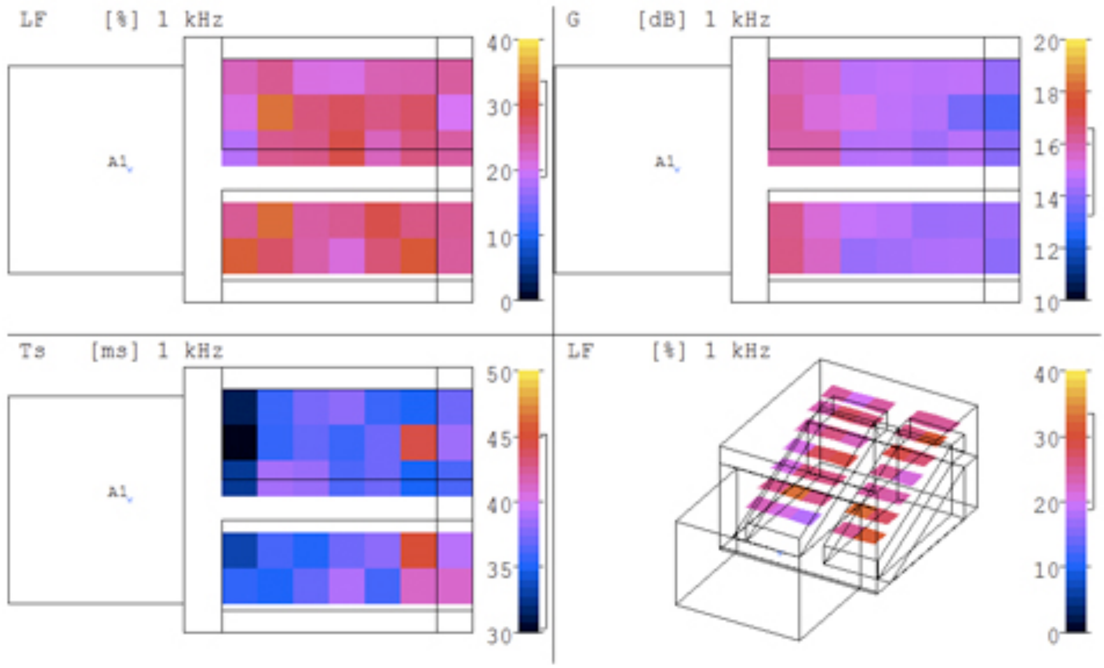


Fig 4.2.2.4. – LF, G and Ts in unoccupied room (S1)

- Source 2

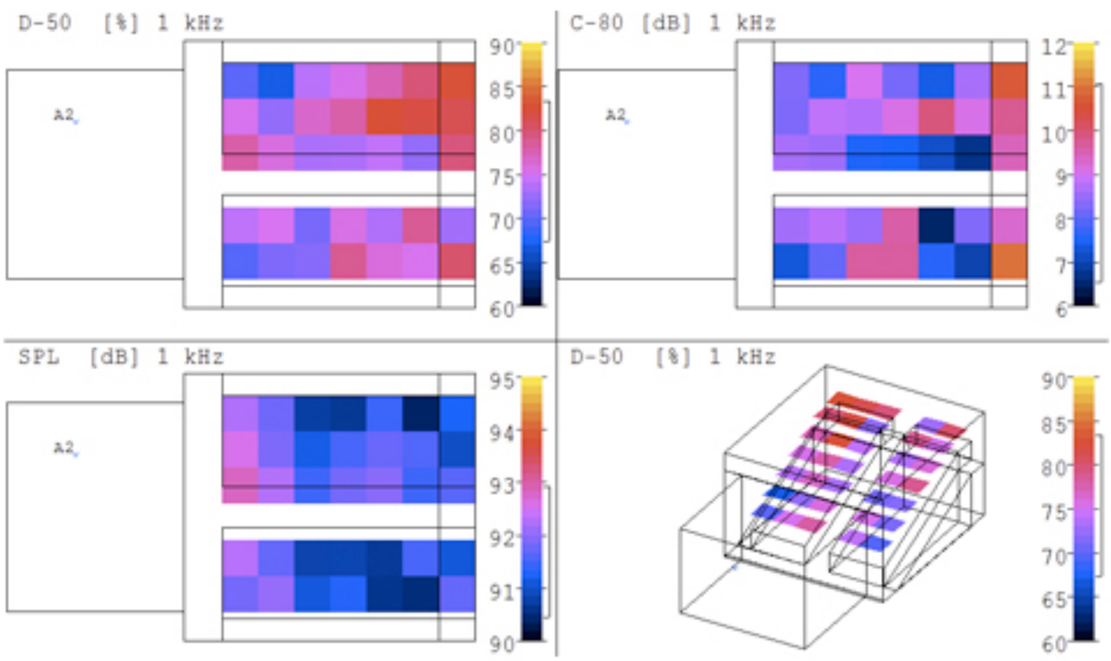
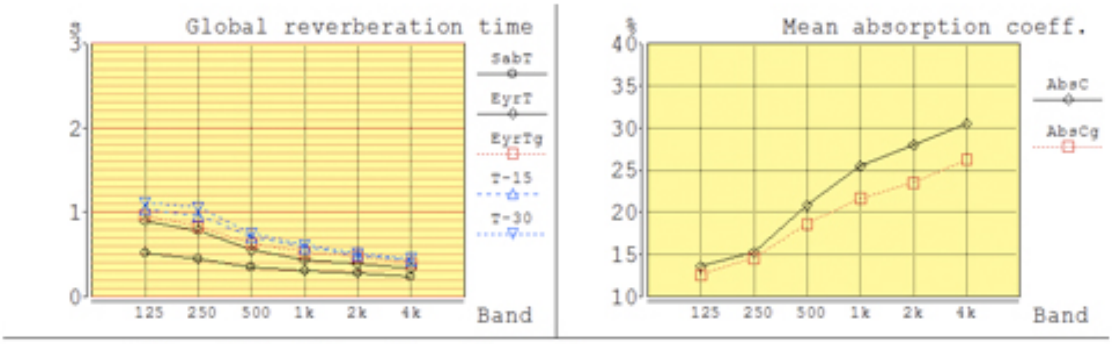


Fig 4.2.2.5. – D_{50}, C_{80} and SPL in unoccupied room (S2)



	125	250	500	1k	2k	4k	
EyrT	0,89	0,78	0,55	0,44	0,39	0,34	s
EyrTg	0,97	0,82	0,63	0,53	0,47	0,40	s
SabT	0,52	0,45	0,35	0,30	0,28	0,24	s
T-15	1,04	0,96	0,71	0,58	0,49	0,43	s
T-30	1,12	1,05	0,75	0,61	0,51	0,45	s
AbsC	13,56	15,26	20,84	25,48	27,98	30,47	%
AbsCg	12,58	14,58	18,58	21,63	23,47	26,20	%
MFP	3,25	3,24	3,24	3,24	3,24	3,25	m
Diffs	10,06	10,11	10,06	10,09	10,03	10,07	%

Trunc	1000,0	ms
Rays	10088	(used/oct)
	0	(lost/oct)
	0	(absorbed/oct)
Angle	2,02	degrees

Fig 4.2.2.6. – Reverberation time in unoccupied room (S2)

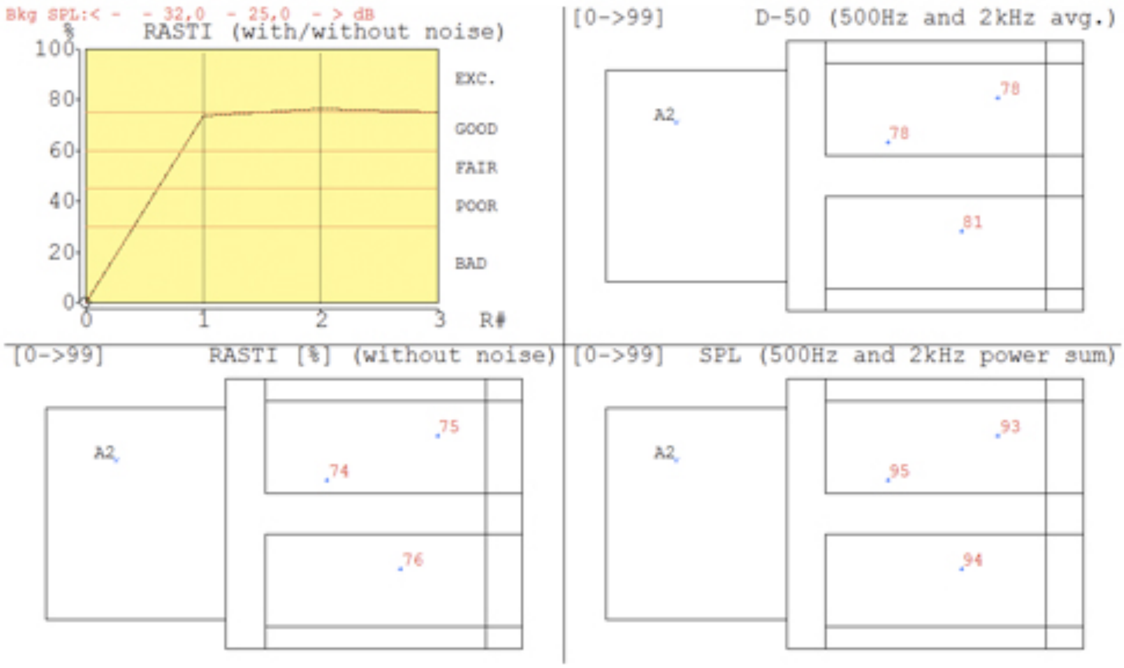


Fig 4.2.2.7. – RASTI, D_{50} and SPL in unoccupied room (S2)

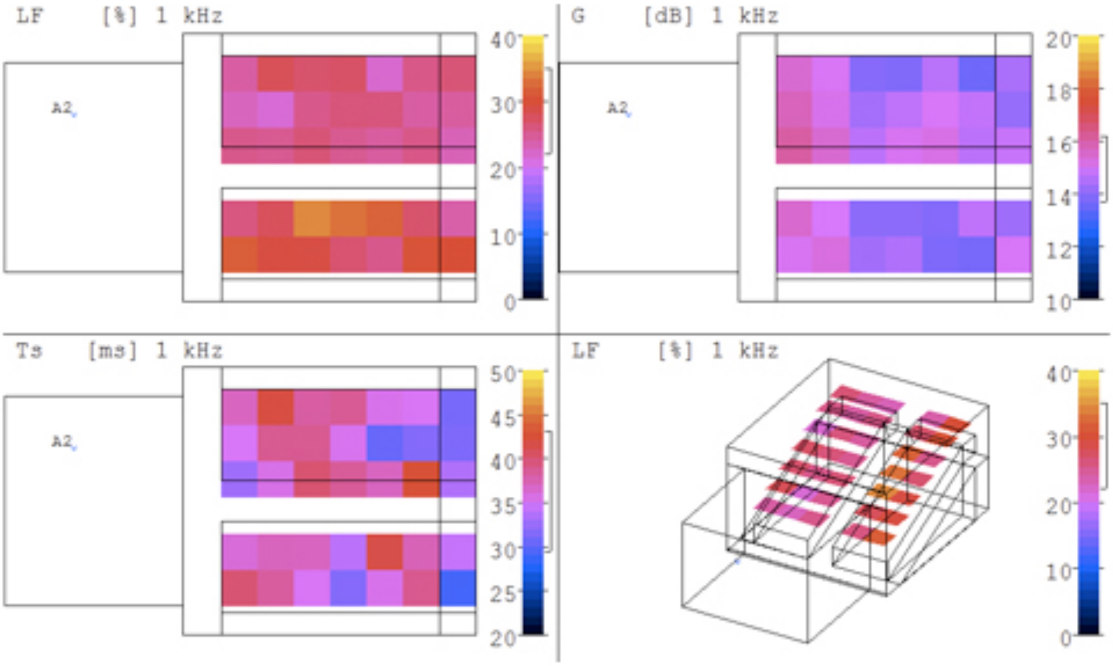


Fig 4.2.2.8. – LF, G and Ts in unoccupied room (S2)

5. Results

5.1 Input parameters

EASE and CATT-Acoustic are acoustic simulation software. This definition does not mean that the features to enter the input data are equal.

On the one hand, EASE offers data input in simple menus, graphics and intuitive. The values or properties are stored in tables that report the location of the point in XYZ space, as well as the aiming and orientation especially in speakers, lamps and listeners. If the room is symmetrical, as in this case, it would be advisable to do mirror images of the points to save time designing.
Moreover, this software includes a CAD function to create, edit or change vertexes, lines, surfaces, objects or prototypes of room. It also has a database of materials, speaker models and lamps, which can always be added or modified with new items. In this function, there is a tool to optimize the reverberation time graphically or numerically, modifying material used in the enclosure in order to obtain an adequate reverberation time.

On the other hand, the input parameters for CATT-Acoustic are stated in text format. It is necessary to know the specific code using their expressions, calling functions and adding new constants and symbols.
As has been mentioned in section 2.3, this software must read three files created in the input folder. These files describe the geometric model of the room, the positions and properties of the sources, and the positions of the receivers. The points or corners are plotted on the XYZ coordinates.

5.2 Simulation algorithms

Both programs utilize the geometric theory as simulation algorithms. This theory respects the principle of Fermat as the law of reflection in sound waves, affecting the direct and reflected ray at the receiver.

The geometric theory applications analyze the direct field and the first reflections individually. Also detect echoes and focalizations caused by the surfaces of the room and seek the guidance of the useful sound.

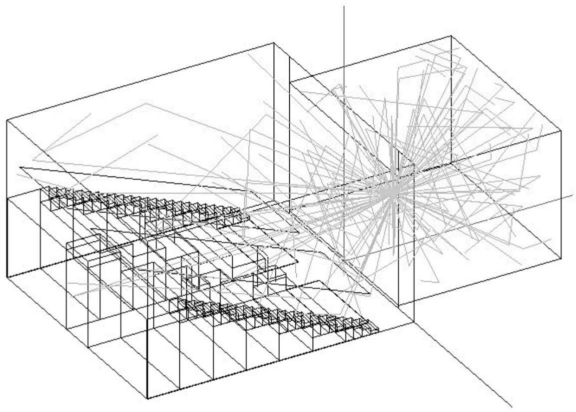


Fig 5.2.1. – EASE ray-tracing

As shown in Fig. 5.2.1, this theater does not have a good guidance of the useful sound because there are not reflective surfaces on the sidewalls. Meanwhile, Fig 5.2.2 shows the same ray-tracing but with the echogram produced by the room.

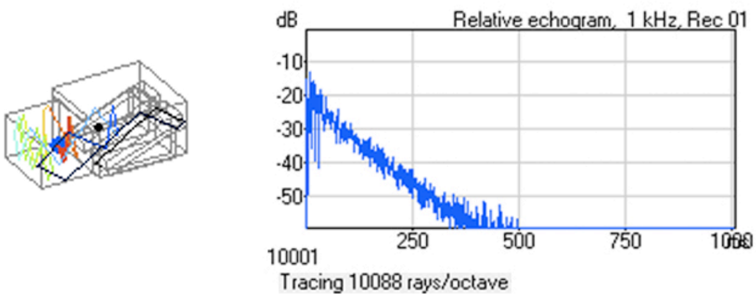


Fig 5.2.2. – CATT-Acoustic ray-tracing

5.3 Evaluation results

a) Reverberation Time (RT)

The measured values of reverberation time are shown in Table 5.3.1.1 and Figure 5.3.1.2 for the octave bands located between 125 Hz and 4 kHz, corresponding to the occupied and unoccupied room. These values are obtained using EASE software.

The average value of reverberation time RT_{mid} corresponding to the occupied room is:

$$RT_{mid}^{occ} = 0.68 \text{ s}$$

This value is close to the range of recommended values for the room, according to its volume (between 0.7 and 1.2 s).

Freq. (Hz)	RT_{occ} (s)	RT_{unocc} (s)
125	0.84	0.92
250	0.82	0.92
500	0.71	0.79
1000	0.65	0.71
2000	0.58	0.64
4000	0.50	0.55

Table 5.3.1.1. – Measured values of RT_{occ} (occupied room) and RT_{unocc} (unoccupied room)

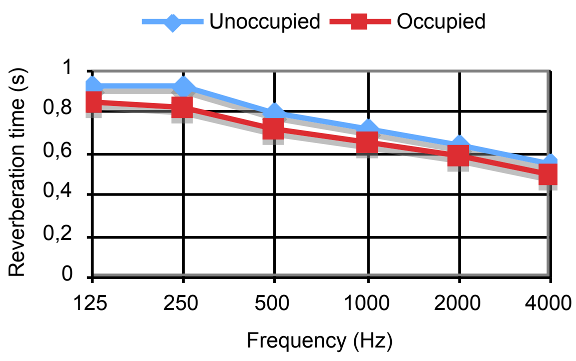


Fig 5.3.1.2. – Measured values of RT_{occ} and RT_{unocc}

The measured values of reverberation time are shown in Table 5.3.1.3 and Figure 5.3.1.4 for the octave bands located between 125 Hz and 4 kHz, corresponding to the occupied and unoccupied room. These values are obtained using CATT-Acoustic.

The average value of reverberation time RT_{mid} corresponding to the occupied room is:

$$RT_{mid}^{occ} = 0.69 \text{ s}$$

This value is really close to the range of recommended values for the room, according to its volume (between 0.7 and 1.2 s).

Freq. (Hz)	RT_{occ} (s)	RT_{unocc} (s)
125	1.12	1.12
250	0.93	1.02
500	0.77	0.76
1000	0.60	0.64
2000	0.63	0.55
4000	0.47	0.46

Tabla 5.3.1.3. – Measured values of RT_{occ} (occupied room) and RT_{unocc} (unoccupied room)

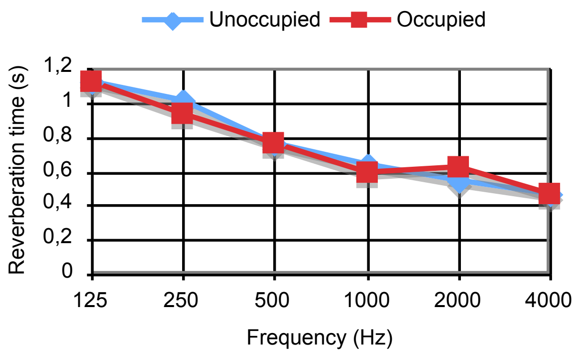


Fig 5.3.1.4. – Measured values of RT_{occ} and RT_{unocc}

b) Clarity (C_{50})

The measured values of speech clarity C_{50} are shown in Table 5.3.2.1 and Figure 5.3.2.1 for the octave bands located between 500 Hz and 4 kHz, corresponding to the occupied and unoccupied room. These values are obtained using EASE software.

The value of speech average C_{50} corresponding to the occupied room is:

$$C_{50}^{occ} \text{ ("speech average")} = 3.31 \text{ dB}$$

This value is clearly above the recommended minimum of 2 dB, indicating that the speech intelligibility and loudness are correct.

Freq. (Hz)	C_{50}^{occ} (dB)	C_{50}^{unocc} (dB)
500	2.05	1.35
1000	2.65	2.02
2000	3.47	2.72
4000	4.62	3.88

Table 5.3.2.1. – Measured values of C_{50}^{occ} (occupied room) and C_{50}^{unocc} (unoccupied room)

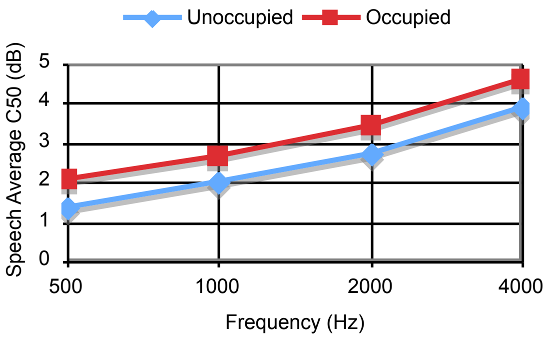


Fig 5.3.2.2. – Measured values of C_{50}^{occ} and C_{50}^{unocc}

The measured values of speech clarity C_{50} are shown in Table 5.3.2.4 and Figure 5.3.2.5 for the octave bands located between 500 Hz and 4 kHz, corresponding to the occupied and unoccupied room. CATT-Acoustic does not show C_{50}. These values are obtained by the conversion of D50 to C50 shown in Table 5.3.2.3.

D_{50} (%)	0	10	20	30	40	50	60	70	80	90	100
C_{50} (dB)	-30	-9.5	-6.0	-3.7	-1.8	0	1.8	3.7	6.0	9.5	30

Table 5.3.2.3. – Conversion between D_{50} (%) and C_{50} (dB)

The value of speech average C_{50} corresponding to the occupied room is:

$$C_{50}^{occ} \text{ ("speech average")} = 15.95 \text{ dB}$$

This value is considerably above the recommended minimum value, $C_{50} > 2$dB.

Freq. (Hz)	C_{50}^{occ} (dB)	C_{50}^{unocc} (dB)
500	5.10	4.35
1000	7.20	5.75
2000	8.80	7.95
4000	21.50	9.12

Table 5.3.2.4. – Measured values of C_{50}^{occ} (occupied room) and C_{50}^{unocc} (unoccupied room)

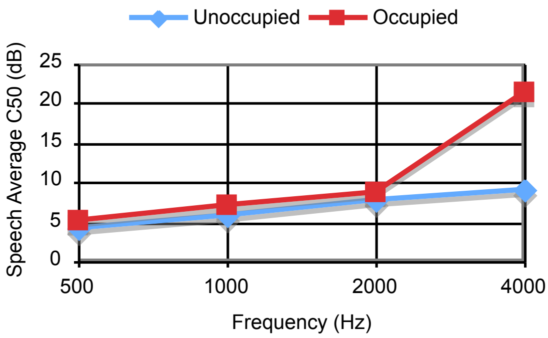


Fig 5.3.2.5. – Measured values of C_{50}^{occ} and C_{50}^{unocc}

c) Definition (D)

This value is obtained quickly by CATT-Acoustic. EASE also allows to obtain this value using the subprogram AURA. This characteristic is used only for speech rooms. The measured values of definition D are shown in Table 5.3.3.1 and Figure 5.3.3.2 for the octave bands located between 500 Hz and 4 kHz, corresponding to the occupied and unoccupied room.

The average value of definition D corresponding to the occupied room is:

$$D_{occ} = 0.775$$

This value is considerably above the recommended minimum value, D ≥ 0.5.

Freq. (Hz)	D_{occ}	D_{unocc}
125	0.612	0.544
250	0.663	0.589
500	0.765	0.710
1000	0.829	0.795
2000	0.878	0.840
4000	0.918	0.882

Table 5.3.3.1. – Measured values of D_{occ} (occupied room) and D_{unocc} (unoccupied room)

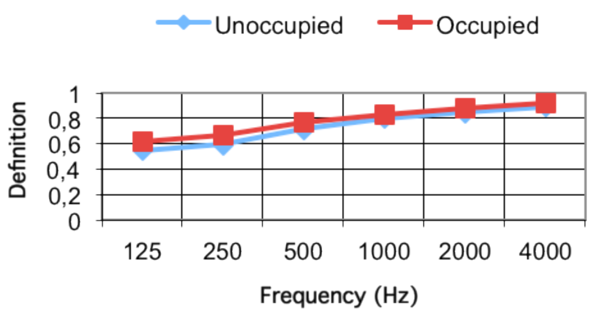


Fig 5.3.1.4. – Measured values of D_{occ} and D_{unocc}

d) Speech intelligibility (RASTI/STI)

In EASE, as shown the bar chart of the previous Fig. 4.1.1.3 for the source S1, the average value of RASTI corresponding to the occupied room is:

RASTI = 0.704

Regarding CATT-Acoustic, as shown the previous graph Fig 4.2.1.3 for the source S1, the average value of RASTI corresponding to the occupied room is:

RASTI = 0.775

In both cases, this value is higher than the recommended minimum value, RASTI≥ 0.65. Therefore, the speech intelligibility will be quite good.

e) Articulation Loss of Consonants (AL_{cons})

This value has been obtained only by EASE. The bar chart of Fig. 4.1.1.1 shows that the value of average percentage through the source S1 to the occupied room is:

AL_{cons} = 3.75%

The result obtained is within the recommended value, AL_{cons} <5%. Thus, articulation loss of consonants is correct.

5.4 Comparison of results in relation to DIN-18041

The DIN-18041 regulation reports of the acoustical quality in small to medium-sized rooms, in this case with volume between 250 and 5000 m3 for small auditoriums, theaters and conference rooms.

The expected reverberation time for these rooms is calculated with eq. (5.4.1). In this case, the time is 0.66 seconds, approaching the real value.

$$RT_{exp} = \left(0.32 \log \frac{V}{m^3} - 0.17\right) \qquad (5.4.1)$$

This regulation also shows the necessary acoustics parameters that must achieve the room with sound reinforcement. Hoftheater Kreuzberg uses two speakers Meyer Sound CQ-2 as sound reinforcement. The acoustic parameters to meet are:

Speech Clarity (C_{50})	≥ 0 dB
Common Intelligibility Scale (CIS)	≥ 0,75
Speech Transmission Index (STI)	≥ 0,56
Articulation Loss of Consonants (%Alcons)	< 8%

CIS factor is obtained by STI, as shown in equation (5.4.2).

$$CIS = 1 + \log(STI) \quad (5.4.2)$$

The parameters obtained quickly by EASE to meet current regulation using sound reinforcement are:

Speech Clarity (C_{50})	2.79 dB
Common Intelligibility Scale (CIS)	0.85
Speech Transmission Index (STI)	0.71
Articulation Loss of Consonants (%Alcons)	3.58 %

Therefore, the theater meets perfectly the necessary acoustic parameters of DIN-18041 for sound reinforcement system.

As regards the generation of useful reflections, the room do not have reflective elements to generate a good guide of useful sound.

5.5 Assessment of Hoftheater Kreuzberg

- The overall assessment of the enclosure is satisfactory as theater.
- The measured reverberation times are slightly low but adequate for performances where the understanding speech is essential.
- Speech clarity and definition provide increased intelligibility and loudness.
- The speech intelligibility in all measured points in the room is pretty good.
- Separate audience area is not recommended in this room because there is a good direct sound in its center. It is also a small theater and could place two seats per row, reaching a number of seats between 60 and 70.
- As acoustic elements, the theater need reflective materials on walls and reflection areas on ceiling, avoiding focalizations in the audience area and improving the direct sound guidance.

6. Conclusions

It has carried out a comparative analysis of acoustic simulation software such as EASE and CATT-Acoustic in Hoftheater Kreuzberg, Berlin.

In both simulations there is a lack of accuracy at low frequencies, characteristic of simulation programs based on geometrical acoustics. In them, the sound field is calculated using the ray tracing method, involving the propagation of rays launched from the source and subsequent reflection on the surfaces of the room. It can be seen as a discretized simulation of the sound field: the higher the number of rays used, the better the approximation to the real case. Processing time required to calculate the ray-tracing simulation increase significantly in both programs when is more complex.

The simplifications made in the geometric model, starting point for all calculations made by the simulation, affect the final results. There are differences in the reverberation time and clarity. That could be because CATT audience area has reduced to simplify the modeling of the enclosure. It may also be due to the scattering coefficient of the materials.

The graphical representations in EASE are considerably more quick and easy. It has more acoustic parameters to calculate and represent.

In short, these two powerful tools are simple and comfortable, processing large amounts of information in a relatively short time. However, you should possess a deep knowledge of their configurable parameters to be reliable in their results.

7. References

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[17] CATT; *CATT-Acoustic.* <http://www.catt.se>

A. Appendix

A.1. CATT-Acoustic code

```
; ===========================================================
; MAIN Program: MASTER.GEO
; ===========================================================
; constant declarations  ==========================================

GLOBAL hd = 8.06            ;hall depth
GLOBAL hw = 7.34/2          ;hall width/2
GLOBAL hh = 4.76            ;hall height

GLOBAL pbh =0.10            ;prosc bottom wall height
GLOBAL psw =0.80            ;prosc side wall width

GLOBAL sd = 4.90            ;stage depth
GLOBAL sw = 5.74/2          ;stage width/2
GLOBAL sh = 3.96            ;stage height

GLOBAL as = 1.06            ;pit audience-stage
GLOBAL ah = 2.40            ;max. stalls height
GLOBAL ccr = 1.1/2          ;central corridor/2
GLOBAL aud = 0.85           ;audience height

; ==========================================================
; absorption and scattering coefficients 125Hz to 4kHz [%], RGB-color

ABS mtseat_fab = <19 37 56 67 61 59>            { 153 214 41 }
ABS public_tnc = <38 60 80 90 90 90>            { 153 214 41 }
ABS wood     = <15 11 10 7 6 7>                 { 159 152 96 }
ABS parquet  = <2 15 10 8 5 5>                  { 126 82 0 }
ABS cirrus   = <30 31 42 54 64 66>              { 228 179 27 }
ABS drape_thin = <4 5 11 18 30 35>              { 0 74 126 }
ABS drape_thin2 = <4 5 11 18 30 35>             { 244 85 22 }
ABS velour_LT = <3 4 11 17 24 35>               { 24 35 87 }
ABS woodpanel_16 = <20 12 10 10 8 7>            { 126 0 120 }
ABS resonador_TRR9 = <95 65 20 19 17 16>        { 94 119 162 }

;matt assignements ============================================

ABS ceilstage = cirrus
ABS ceilhall = woodpanel_16
ABS audience_unocc = mtseat_fab
ABS audience_occ = public_tnc
ABS floor = parquet
ABS stageflr = wood
ABS wallstage = velour_LT
ABS prosc = drape_thin2
ABS wallhall = drape_thin
ABS wallrear = woodpanel_16
ABS back = resonador_TRR9
; ==========================================================
CORNERS

; HALL ===========================
; floor corners
 1     -hw     0      0
 2     -hw     hd     0
 3      hw     hd     0
```

```
 4      hw        0       0

; ceiling corners
11     -hw        0       hh
12     -hw        hd      hh
13      hw        hd      hh
14      hw        0       hh

; STAGE ==========================
; floor corners
21     -sw        0       pbh
22     -sw        -sd     pbh
23      sw        -sd     pbh
24      sw        0       pbh

; ceiling corners
31     -sw        0       sh
32     -sw        -sd     sh
33      sw        -sd     sh
34      sw        0       sh

; PROSC ==========================
; left corners
41     -hw        0       pbh
51     -hw        0       sh

; right corners
44      hw        0       pbh
54      hw        0       sh

; STALLS =========================
; right stalls
5      -hw+0.6    as      0
6      -hw+0.6    hd-1    0
7      -ccr       hd-1    0
8      -ccr       as      0
9      -ccr       hd-1    ah
10     -hw+0.6    hd-1    ah

; left stalls
15     hw-0.6     as      0
16     hw-0.6     hd-1    0
17     ccr        hd-1    0
18     ccr        as      0
19     ccr        hd-1    ah
20     hw-0.6     hd-1    ah


; STAIRS =========================
; right stairs
35     -hw        as      0
36     -hw        hd-1    0
37     -hw        hd-1    ah

; left stairs
46     hw         as      0
47     hw         hd-1    0
48     hw         hd-1    ah
```

```
; TECHNICIANS ===================
; technicians and public
25      -hw         hd          ah
26      -ccr        hd          ah
27      ccr         hd          ah
28      hw          hd          ah
29      -hw+0.6     hd          ah
30      hw-0.6      hd          ah

; technicians wall
55      -ccr        hd-1        ah+0.9
56      ccr         hd-1        ah+0.9
57      ccr         hd-0.6      ah
58      -ccr        hd-0.6      ah

; AUDIENCE ======================
; right side
60      -hw+0.6     as          aud
61      -hw+0.6     hd-1        ah+aud
62      -hw+0.6     hd          ah+aud
63      -ccr        hd          ah+aud
64      -ccr        hd-1        ah+aud
65      -ccr        as          aud

; left side
66      hw-0.6      as          aud
67      hw-0.6      hd-1        ah+aud
68      hw-0.6      hd          ah+aud
69      ccr         hd          ah+aud
70      ccr         hd-1        ah+aud
71      ccr         as          aud

; ========================================================
PLANES

; HALL ====================================
[1 floor / 4 3 2 1 / floor ]
[2 ceiling / 11 12 13 14 / ceilhall ]
[3 rear wall / 3 13 12 2 / wallrear ]
[4 left wall / 2 12 11 1 / wallhall ]
[5 right wall / 4 14 13 3 / wallhall ]

; STAGE ===================================
[6 floor stage / 23 24 21 22 / stageflr ]
[7 ceiling stage / 32 31 34 33 / ceilstage ]
[8 rear wall stage / 22 32 33 23 / wallstage ]
[9 left wall stage / 21 31 32 22 / wallstage ]
[10 right wall stage / 23 33 34 24 / wallstage ]

; PROSC ===================================
[11 floor prosc / 1 41 44 4  / stageflr ]
[12 top prosc / 51 11 14 54 / prosc ]
[13 left prosc / 41 51 31 21 / prosc ]
[14 right prosc / 24 34 54 44 / prosc ]

; STALLS ==================================
;right stalls
[15 floor right stalls \ 8 7 6 5 \ wood ]
[16 ceiling right stalls / 8 9 10 5 / wood ]  ;Right-Audience
[17 rear right stalls / 10 9 7 6 / wood ]
```

```
[18 leftwall right stalls / 6 10 5 / wood ]
[19 rightwall right stalls / 8 7 9 / wood ]

;left stalls
[20 floor leftt stalls / 18 17 16 15 / wood ]
[21 ceiling left stalls / 15 20 19 18 / wood ] ;Left-Audience
[22 rear left stalls / 17 19 20 16 / wood ]
[23 leftwall left stalls / 16 20 15 / wood ]
[24 rightwall left stalls / 18 19 17 / wood ]

; STAIRS ===================================
;right stairs
[25 floor right stairs \ 6 36 35 5 \ wood ]
[26 ceiling right stairs \ 35 37 10 5 \ wood ]
[27 rear right stairs / 10 6 36 37 / wood ]
[28 leftwall right stairs \ 37 35 36 \ wood ]

;left stairs
[29 floor left stairs / 16 47 46 15 / wood ]
[30 ceiling left stairs / 15 46 48 20 / wood ]
[31 rear left stairs / 48 47 16 20 / wood ]
[32 rightwall left stairs / 47 48 46 / wood ]

; TECHNICIANS ================================
[33 floor tech / 48 28 25 37 / wood ]
[34 floor right stalls / 29 10 9 26 / wood ] ;Audience
[35 floor left stalls / 20 30 27 19 / wood ] ;Audience

;panel protector tech
[36 wall tech / 19 56 55 9 / back ]        ;Wall with absorption
[37 left wall tech / 9 58 55 / wood ]
[38 right wall tech / 19 57 56 / wood ]

; AUDIENCE ===================================
; audience_occ = Occupied
; audience_unocc = Unoccupied

;right side
[39 top rs / 65 64 61 60 / audience_occ ]
[40 top2 rs / 62 61 64 63 / audience_occ ]
[41 front rs / 65 60 5 8 / audience_occ ]
[42 rear rs / 63 26 29 62 / audience_occ ]
[43 left rs / 5 60 61 10 / audience_occ ]
[44 left2 rs / 10 61 62 29 / audience_occ ]
[45 right rs / 65 8 9 64 / audience_occ ]
[46 right2 rs / 64 9 26 63 / audience_occ ]


;left side
[47 top ls / 66 67 70 71 / audience_occ ]
[48 top2 ls / 67 68 69 70 / audience_occ ]
[49 front ls / 71 18 15 66 / audience_occ ]
[50 rear ls / 68 30 27 69 / audience_occ ]
[51 left ls / 18 71 70 19 / audience_occ ]
[52 left2 ls / 69 27 19 70 / audience_occ ]
[53 right ls / 66 15 20 67 / audience_occ ]
[54 right2 ls / 67 20 30 68 / audience_occ ]
```

```
; ============================================================
; Sources file: src.loc
; ============================================================
; variable list ================================================

LOCAL src_z = 1.6                    ; source height 0.1 + 1.5 m

; source list  ==================================================

SOURCEDEFS
; A1 is natural OMNI source
; id     x0      y0      z0            direct          aim_x aim_y aim_z
A1      0       -1.5    src_z   OMNI                   0.0            0.0            0.0
 Lp1m_a = <96.78 96.78 96.78 96.78 96.78 96.78>

; A1 is natural OMNI source
; id      x0      y0      z0             direct          aim_x aim_y aim_z
A2     -1.44  -3.0     src_z       OMNI              0.0            0.0            0.0
 Lp1m_a = <96.78 96.78 96.78 96.78 96.78 96.78>
```

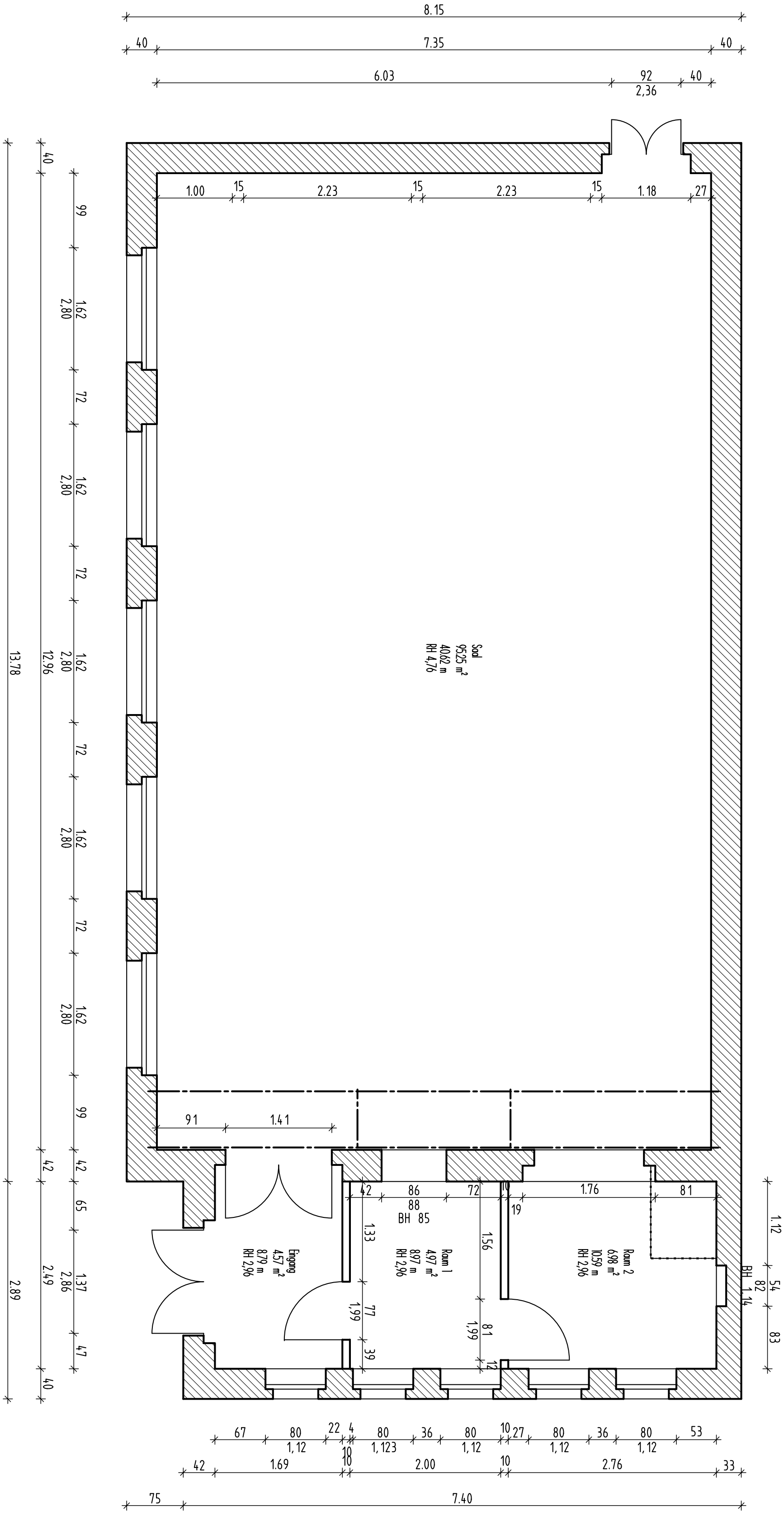
```
; ============================================================
; Receivers file: rec.loc
; ============================================================
; receivers list  ===============================================

RECEIVERS
1  -0.9               as+1.7              1.2+0.4
2  1.50               as+3.7              1.2+1.2
3  -2.10              hd-2.3              1.2+1.6

; ============================================================
```

B. Annex

B.1. Plan of Hoftheater Kreuzberg



Hofsaal Naunynritze 1 : 50 28.05.2012

B.2. Materials

- ### Cirrus Tegular Ceiling

OPTIMA®
Tegular
fine texture

Items with Breakthrough Plant-based Binder have a PB Suffix

Optima Tegular 24" x 24" panels with Sonata® 9/16" suspension system (Pg. 265)

Visit Armstrong.com Photo Gallery to view more installation photos

SEARCH: optima

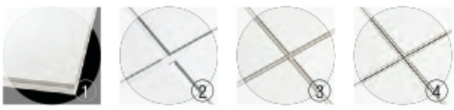
KEY SELECTION ATTRIBUTES

- Outstanding acoustical performance for open plan areas, both Articulation Class (180-200) and NRC (0.90-1.00)
- Smooth, clean, durable finish – Washable, Impact-resistant, Scratch-resistant, Soil-resistant
- Energy-saving high light-reflective finish
- Non-directional visual reduces installation time and scrap
- Items with PB suffix are manufactured with a plant-based binder
- Sag-resistant large size panels
- Compatible with TechZone™ Ceiling Systems (Pgs. 235-241)
- 30-Year Limited System Warranty against visible sag, mold/mildew, and bacterial growth

TYPICAL APPLICATIONS

- Open plan offices
- Computer rooms
- Corridors (walls-to-deck)
- Auditoriums
- Waiting rooms/nurses' stations – assists in addressing HIPAA and FGI acoustical requirements
- Areas with indirect lighting systems

DETAIL (Other Suspension Systems compatible. Refer to listing on page 200.)



1. Optima Square Tegular
2. Optima Tegular with Prelude® 15/16" suspension system
3. Optima Tegular with Interlude® XL® 9/16" suspension system
4. Optima Tegular with Silhouette® 9/16" suspension system with 1/8" reveal

COLOR

White

OPTIMA®
Tegular
fine texture

Items with Breakthrough Plant-based Binder have a PB Suffix

UP TO 71% RECYCLED CONTENT | EPD AVAILABLE

LEED® ✓ acoustics ✓ energy ✓ daylight & views ✓ indoor air quality ✓ renewable materials ✓ recycled content ✓ waste mgmt ✓ local* materials

$$ $$

Calculate LEED contribution at armstrong.com/greengenie *LOCATION DEPENDENT

VISUAL SELECTION — PERFORMANCE Dots represent high level of performance.

Edge Profile	Susp. Dwg. Pgs. 273-277 armstrong.com/catdwgs		Item No.	Dimensions (Inches)	Acoustics NRC	Acoustics CAC	Acoustics AC	Fire Rating	Light Reflect	Anti-Mold & Mildew	Sag Resist	Certified Low VOC Emissions	Durability Wash	Durability Impact	Durability Scratch	Durability Soil	Primary (Embodied) Energy	Recycled Content♦	Recycle Program	Warranty†
OPTIMA Tegular					UL Classified					Inherent	Humi-Guard+		Wash	Impact	Scratch	Soil	Below 11MJ/SF		Yes	No. of Years
15/16" Square Tegular	8		1402	6 x 48 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		1406	6 x 60 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3264	12 x 24 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3278	20 x 60 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3250 3250PB	24 x 24 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– •	•	•	•	•	•	High	•	30
	8		3354	24 x 24 x 1"	0.90 •	26	200 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	–	30
	8		3253	24 x 24 x 1-1/2"	1.00 •	N/A	200 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3252 3252PB	24 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– •	•	•	•	•	•	High	•	30
	8		3281	24 x 72 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3282	24 x 96 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3258	30 x 30 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3286	30 x 60 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	8		3255 3255PB	48 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– •	•	•	•	•	•	High	•	30
	8	NEW	FastSize™	W: 4" - 48" / L: 4" - 120" 1" Thick	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	–	High	•	30
	8		Other Sizes	W: 4" - 36" / L: 4" - 120" W: 4" - 42" / L: 4" - 102" W: 4" - 48" / L: 4" - 90" 1-1/2" Thick	1.00 •	N/A	200 •	Class A	0.90 •	•	•	–	•	•	•	•	–	High	•	30
9/16" Square Tegular	26, 43, 47, 51, 55, 59		1410	4 x 48 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1411	4 x 60 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1412	6 x 6 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1413	6 x 12 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1415	6 x 42 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1403	6 x 48 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1417	6 x 54 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1407	6 x 60 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1409	6 x 96 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		3263	12 x 24 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		3290	12 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		1414	12 x 96 x 1"	0.90 •	N/A	180 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		3276	20 x 54 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59		3266	20 x 56 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30

FIBERGLASS

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OPTIMA®

Tegular

fine texture

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*LOCATION DEPENDENT

VISUAL SELECTION

PERFORMANCE Dots represent high level of performance.

FIBERGLASS

Edge Profile	Susp. Dwg. Pgs. 273-277 armstrong.com/catdwgs	Item No.	Dimensions (Inches)	Acoustics NRC (UL Classified)	Acoustics CAC	Acoustics AC	Fire Rating	Light Reflect	Anti-Mold & Mildew (Inherent)	Sag Resist (Humi-Guard+)	Certified Low VOC Emissions	Durability Wash	Durability Impact	Durability Scratch	Durability Soil	Primary (Embodied) Energy (Below 11MJ/SF)	Recycled Content*	Recycle Program (Yes)	Warranty† (No. of Years)
OPTIMA Tegular																			
9/16" Square Tegular	26, 43, 47, 51, 55, 59	**3277**	20 x 60 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3279**	21 x 24 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3251** **3251PB**	24 x 24 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– / •	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3355**	24 x 24 x 1"	0.90 •	26	200 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	–	30
	26, 43, 47, 51, 55, 59	**3254**	24 x 24 x 1-1/2"	1.00 •	N/A	200 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3280**	24 x 42 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3257** **3257PB**	24 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– / •	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3265** **3265PB**	24 x 60 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– / •	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3261** **3261PB**	24 x 72 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– / •	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3262** **3262PB**	24 x 96 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– / •	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3283**	27 x 30 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3268**	28 x 30 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3269**	28 x 60 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3259**	30 x 30 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3284**	30 x 54 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3289**	30 x 56 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3285**	30 x 60 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3287**	42 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3288**	44 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3256** **3256PB**	48 x 48 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	– / •	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**3249**	48 x 54 x 1"	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	NEW **FastSize™**	W: 4" - 48" / L: 4" - 120" 1" Thick	0.95 •	N/A	190 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30
	26, 43, 47, 51, 55, 59	**Other Sizes**	W: 4" - 36" / L: 4" - 120" W: 4" - 42" / L: 4" - 102" W: 4" - 48" / L: 4" - 90" 1-1/2" Thick	1.00 •	N/A	200 •	Class A	0.90 •	•	•	–	•	•	•	•	•	High	•	30

OPTIMA®

Tegular

fine texture

Items with Breakthrough Plant-based Binder have a PB Suffix

UP TO 71% RECYCLED CONTENT | EPD AVAILABLE

LEED® acoustics | energy | daylight & views | indoor air quality | renewable materials | recycled content | waste mgmt | local* materials

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$$$$

VISUAL SELECTION

PERFORMANCE

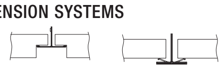
Dots represent high level of performance.

Edge Profile	Susp. Dwg. Pgs. 273-277 armstrong.com/ catdwgs	Item No.	Dimensions (Inches)	Acoustics NRC	Acoustics CAC	Acoustics AC	Fire Rating	Light Reflect	Anti-Mold & Mildew	Sag Resist	Certified Low VOC Emissions	Durability Water Repel	Durability Wash	Durability Scrub	Durability Impact	Durability Scratch	Durability Soil	Primary (Embodied) Energy	Recycled Content◆	Recycle Program	Warranty†
OPTIMA Health Zone™				UL Classified					Inherent	Humi-Guard+		Water Repel	Wash	Scrub	Impact	Scratch	Soil	Below 11MJ/SF		Yes	No. of Years
15/16" Square Tegular	8, 10	**3214**	24 x 24 x 1"	0.95 ●	N/A	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	●	30
	8, 10	**3316**	24 x 24 x 1-1/2"	0.95 ●	29**	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	–	30
	8, 10	**3215**	24 x 48 x 1"	0.95 ●	N/A	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	●	30
	8, 10	**3317**	24 x 48 x 1-1/2"	0.95 ●	29**	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	–	30
	8, 10	**Other Sizes**	W: 4" - 48" / L: 12" - 48" 1" Thick	0.95 ●	N/A	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	●	30
9/16" Square Tegular	26, 43, 47, 51, 55, 59	**3216**	24 x 24 x 1"	0.95 ●	N/A	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	●	30
	26, 43, 47, 51, 55, 59	**3217**	24 x 48 x 1"	0.95 ●	N/A	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	●	30
	26, 43, 47, 51, 55, 59	**Other Sizes**	W: 4" - 48" / L: 12" - 48" 1" Thick	0.95 ●	N/A	190 ●	Class A	0.86 ●	●	●	–	●	●	●	●	●	●	●	High	●	30

** CAC 29 achieved with Clean Room™ suspension system, not UL classified for acoustics.

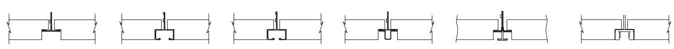
SUSPENSION SYSTEMS

15/16"



Prelude® | Clean Room (Steel or Aluminum)

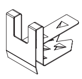
9/16"



Suprafine® | Silhouette® 1/4" Reveal | Silhouette 1/8" Reveal | Interlude® | Sonata® | Trimlok®

ACCESSORIES (not included; ordered separately)

435

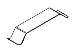


Stabilizer Clip (3/4" & 1")

Recommended for panels 60" and greater in length

Note: Panels 60" up to 96" – One clip near mid-point of each long edge.
Panels 96" and over – Two clips at 1/3 points of each long edge.

7870



Spring Border Clip

(For installations with the panel resting on the wall molding)

PHYSICAL DATA

Material
3316, 3317, 3354, 3355 – Fiberglass with DuraBrite® acoustically transparent membrane; CAC backing
All other items – Fiberglass with DuraBrite acoustically transparent membrane

Surface Finish
DuraBrite with factory-applied latex paint

Fire Performance
ASTM E84 and CAN/ULC S102 surface burning characteristics. Flame Spread Index 25 or less. Smoke Developed Index 50 or less. (UL labeled)

ASTM E1264 Classification
Type XII, Form 2, Pattern E
Fire Class A

Sag Resistance
HumiGuard® Plus – superior resistance to sagging in high humidity conditions up to, but not including, standing water and outdoor applications.

Anti Mold/Mildew & Bacteria
Fiberglass substrate is inherently resistant to the growth of mold, mildew, and bacteria.

VOC Emissions (PB items only)
Third party certified compliant with California Department of Public Health CDPH/EHLB/Standard Method Version 1.1, 2010. This standard is the guideline for low emissions in LEED, CalGreen Title 24, ANSI/ASHRAE/USGBC/IES Standard 189; ANSI/GBI Green Building Assessment Protocol.

Primary (Embodied) Energy
See all LCA information on our EPD's.

High Recycled Content◆
Contains greater than 50% total recycled content. Total recycled content based on product composition of post-consumer and pre-consumer (post-industrial) recycled content per FTC guidelines.

Acoustical Details
Some items have CAC backing. CAC backing may be available as a special order. A CAC value of 37 can be achieved by backloading fiberglass products with Item 769 or 770.

Insulation Value
3253, 3254 –
R Factor – 6.0 (BTU units)
R Factor – 1.05 (Watts units)
3281, 3282 –
R Factor – 3.0 (BTU units)
R Factor – 0.53 (Watts units)
All other items –
R Factor – 4.0 (BTU units)
R Factor – 0.70 (Watts units)

30-Year Performance Guarantee & Warranty†
When installed with Armstrong Suspension System. Details at armstrong.com/warranty

Weight; Square Feet/Carton
1402, 1403 – 0.55 lbs/SF; 24 SF/ctn
1406, 1407 – 0.55 lbs/SF; 30 SF/ctn
1409, 3249, 3250, 3250PB, 3251, 3251PB, 3252, 3252PB, 3257, 3262, 3262PB, 3282 – 0.55 lbs/SF; 96 SF/ctn
1410 – 0.55 lbs/SF; 16 SF/ctn
1411 – 0.55 lbs/SF; 20 SF/ctn
1412 – 0.55 lbs/SF; 6 SF/ctn
1413 – 0.55 lbs/SF; 12 SF/ctn
1414, 3263, 3264, 3290 – 0.55 lbs/SF; 48 SF/ctn
1415 – 0.55 lbs/SF; 21 SF/ctn
1417 – 0.55 lbs/SF; 27 SF/ctn
3214 – 0.45 lbs/SF; 128 SF/ctn
3215, 3216, 3217 – 0.45 lbs/SF; 96 SF/ctn
3253, 3254 – 0.78 lbs/SF; 64 SF/ctn
3255, 3255PB, 3256, 3256PB – 0.55 lbs/SF; 128 SF/ctn
3258, 3259, 3276 – 0.55 lbs/SF; 75 SF/ctn
3261 – 0.55 lbs/SF; 72 SF/ctn
3265PB, 3277, 3278, 3285, 3286 – 0.55 lbs/SF; 100 SF/ctn
3266 – 0.55 lbs/SF; 62.22 SF/ctn
3268 – 0.55 lbs/SF; 70 SF/ctn
3269 – 0.55 lbs/SF; 93.33 SF/ctn
3279, 3280 – 0.55 lbs/SF; 84 SF/ctn
3281 – 0.55 lbs/SF; 72 SF/ctn
3283 – 0.55 lbs/SF; 67.5 SF/ctn
3284 – 0.55 lbs/SF; 90 SF/ctn
3287 – 0.55 lbs/SF; 112 SF/ctn
3288 – 0.55 lbs/SF; 117.33 SF/ctn
3316, 3317 – 0.75 lbs/SF; 64 SF/ctn
3354, 3355 – 0.57 lbs/SF; 96 SF/ctn

Minimum Order Quantity
1 carton

Metric Items Available
3250M, 3251M, 3252M, 3253M, 3254M, 3256M, 3257M, 3354M, 3355M – Metric items are subject to extended lead times and minimum quantities. Contact your representative for more details.

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(search: optima)
BPCS-4648-413

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Armstrong®

200

FIBERGLASS

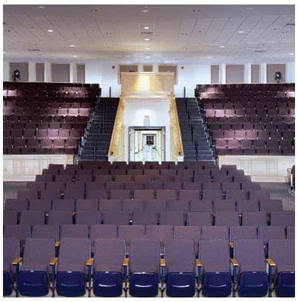
- Seats

SEATING CONCEPTS

200 SERIES

BW 220 CONTOUR
BA 205 PERFORMER
BU 207 ENCORE

BW 220 CONTOUR



LYNNFIELD MIDDLE SCHOOL

CHURCH OF BROOKHILLS

EAGLE SAGINAW HIGH SCHOOL

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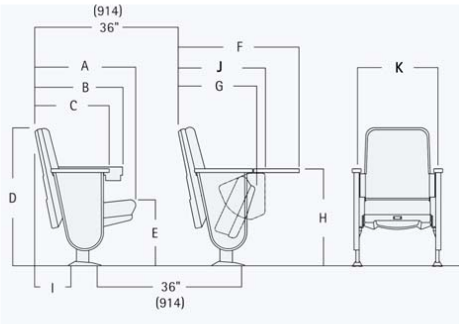
200 SERIES

BW 220 CONTOUR
BA 205 PERFORMER
BU 207 ENCORE



Recommended row spacing	36″	(914 mm)
Minimum row spacing	33 7/8″	(860 mm)

BACK PITCH

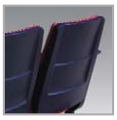
	24°		20°		16°	
	INCHES	MM	INCHES	MM	INCHES	MM
A	28 1/4″	718	27″	686	25 3/4″	654
B	24″	610	22 3/4″	578	21 5/8″	549
C	21 3/4″	552	20 1/2″	521	19 3/8″	492
D	33 1/4″	845	34″	864	34 1/2″	876
E	18 1/2″	470	18 1/2″	470	18 1/2″	470
F	33 5/8″	854	32 3/8″	822	31 1/4″	794
G	23 1/8″	587	21 7/8″	556	20 5/8″	524
H	23 1/2″	597	23 1/2″	597	23 1/2″	597
I	12″	305	10 3/4″	273	9 1/2″	241
J	26 3/8″	670	25 1/8″	638	24″	610

CHAIR WIDTHS

	INCHES	MM	INCHES	MM	INCHES	MM
K	19″	482	20″	508	21″	533
	22″	559	23″	584		

Note: Inclusion of chair accessories may affect final dimensions.

FEATURES AND BENEFITS



- Injection molded outerback with textured surface for ease of maintenance (Models BW 220 Contour and BK 206 Composer)
- Outerback surfaced with wood veneer or plastic laminate material (Model BA 205 Performer)
- Upholstered outerback (Model BU 207 Encore)



- Optional two vertical upholstery pleats
- Optional horizontal upholstery pleat
- Optional upholstered headrest (Model BZ 220 Ariel. Contact Seating Concepts for information on product)


- Cold molded foam for superior comfort and cushion lifespan
- Contoured surface for optimal comfort
- Industry exclusive four-inch foam crown on seat foam and serpentine spring support



- Counterbalance mechanism provides lifetime of quiet seat return
- Serpentine springs for superior comfort
- Vented pans allow cushion to breathe and extend life of foam


- Free miscellaneous overrun of spare parts for owner's attic stock purposes
- Five year warranty on seating product
- 1, 3 and 5 year warranty inspection reports provided

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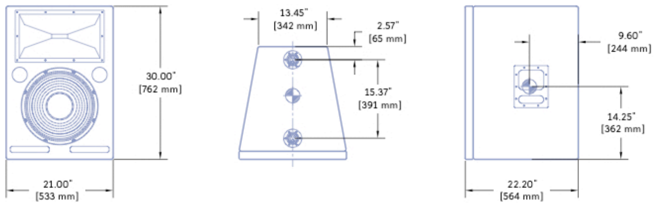
- **Speakers**

DATASHEET CONCERT SERIES

CQ-2 : Narrow Coverage Main Loudspeaker



Dimensions	21.00" w x 30.00" h x 22.20" d (533 mm x 762 mm x 564 mm)
Weight	130 lbs (58.97 kg); shipping 150 lbs (68.04 kg)
Enclosure	All birch multi-ply
Finish	Black textured
Protective Grille	Perforated hex metal grille frame with charcoal-grey foam
Rigging	Ring and stud pan fittings, two on both top and bottom. Working load for each fitting is 500 lbs (226.80 kg), which is 1/5 the cabinet breaking strength (with straight tensile pull); 3/8" or metric M10 nut plates optional

The CQ-2 narrow coverage main is a self-powered, phase-corrected reinforcement loudspeaker offering precise, high-Q coverage. The CQ-2 features a patented constant-Q horn design — the result of extensive research using Meyer Sound's calibrated anechoic chamber. The frequency response of 40 Hz to 16 kHz is uniform over the entire coverage area in both the horizontal and vertical axes, with no side lobes even when measured at a one-sixth octave frequency resolution.

The CQ-2 loudspeaker's unique combination of arrayability, precise pattern control, compact size, low distortion and high power make it suitable for a wide variety of installed and rental applications. As stand-alone or in arrays, the CQ-2 is perfect as the main PA in small to mid-sized auditoriums, houses of worship, clubs and hotel ballroom settings, and is highly effective in delayed fill applications for arenas and outdoor concert systems.

The CQ-2 loudspeaker's low-frequency section comprises a single 15-inch Meyer Sound cone driver, and the high-frequency section utilizes a 4-inch diaphragm compression driver coupled to a 50-degree by 40-degree constant-Q horn.

The sophisticated MP-2/CQ-1 power amplifier is integrated into an accessible, lightweight rear module. The amplification, processing and protection circuitry produces consistent and predictable results in any system design. The proprietary two-channel amplifier employs Meyer Sound's proven class AB/H design with complementary MOSFET output stages, and delivers 1240 watts burst power (620 watts per channel). Audio is processed through an electronic crossover and correction filters for phase and frequency response, as well as driver protection circuitry.

Each amplifier channel has TruPower® limiting technology which maximizes loudspeaker reliability, minimizing power compression and extending component life. TruPower also affords higher continuous SPL capability at all frequencies with maximum headroom and regulates voice coil temperature. Limiter activity is easy to monitor with the limit LEDs on the rear panel.

The MP-2/CQ-2 amplifier's power supply incorporates Meyer Sound's Intelligent AC™ system, which performs automatic voltage selection, EMI filtering, soft current turn-on and surge suppression. Intelligent AC allows fail-safe operation worldwide, with no need to manually select the AC mains voltage.

The compact CQ-2 system is housed in an all-birch multi-ply enclosure with a textured, hard shell black finish. It is flyable and arrayable using standard ring and stud pan fittings on top and bottom rated at 500 lbs (226.80 kg) with a 5:1 safety factor. Optional 30- and 40-degree arraying rigging frames and mounting yoke allow fast, flexible installation and easy aiming in any application.

Options for the CQ-2 cabinet include weather protection and finishes in custom colors for fixed installations and other situations requiring specific cosmetics.

The CQ-2 integrates with the optional RMS™ remote monitoring system, which displays signal and power levels, driver status, limiter activity, and amplifier temperature on a remote Windows® computer.

FEATURES & BENEFITS

- Extremely smooth horizontal pattern for consistent sound
- Ultra-low distortion yields remarkable fidelity
- Extraordinarily flat amplitude and phase response for tonal accuracy and precise imaging
- Extended low-frequency response for stand-alone applications
- Constant-Q horn affords uniform response throughout the coverage area.
- Predictable performance ensures system design flexibility
- Narrow pattern enables precisely controlled coverage and arrayability and increases efficency at high frequencies

APPLICATIONS

- Concert halls, theatres and houses of worship
- Downfill and delays in large-scale reinforcement
- Stage monitoring side fill
- Paging and announcing

CQ-2 SPECIFICATIONS

ACOUSTICAL	
Operating Frequency Range[1]	35 Hz – 18 kHz
Frequency Response[2]	40 Hz – 16 kHz ±4 dB
Phase Response	50 Hz – 16 kHz ±90°
Maximum Peak SPL[3]	139 dB
Dynamic Range	›110 dB
COVERAGE	
	50° Horizontal x 40° vertical
CROSSOVER[4]	
	900 Hz
TRANSDUCERS	
Low Frequency	One 15" cone driver Nominal impedance: 8 Ω Voice coil size: 3" Power-handling capability: 600 W (AES)[5]
High Frequency	One 4" compression driver Nominal impedance: 8 Ω Voice coil size: 4" Diaphragm size: 4" Exit size: 1.5" Power handling capability: 250 W (AES)[5]
AUDIO INPUT	
Type	Differential, electronically balanced
Maximum Common Mode Range	±15 V DC, clamped to earth for voltage transient protection
Connectors	Female XLR input with male XLR loop output or VEAM all-in-one (integrates AC, audio and network)
Input Impedance	10 kΩ differential between pins 2 and 3
Wiring	Pin 1: Chassis/earth through 220 kΩ, 1000 pF, 15 V clamp network to provide virtual ground lift at audio frequencies Pin 2: Signal + Pin 3: Signal – (Polarity can be changed on user panel) Case: Earth ground and chassis
DC Blocking	None on input; DC blocked through signal processing
CMRR	›50 dB, typically 80 dB (50 Hz – 500 Hz)
RF Filter	Common mode: 425 kHz; Differential mode: 142 kHz
TIM Filter	‹80 kHz, integral to signal processing
Nominal Input Sensitivity	0 dBV (1 V rms, 1.4 V pk) continuous average is typically the onset of limiting for noise and music.
Input Level	Audio source must be capable of producing a minimum of +20 dBV (10 V rms, 14 V pk) into 600 Ω to produce maximum peak SPL over the operating bandwidth of the loudspeaker
AMPLIFIER	
Type	Two-channel complementary MOSFET output stages (class AB/H)
Output Power[6]	1240 W (620 W/channel)
THD, IM, TIM	‹.02%
Load Capacity	8 Ω each channel
Cooling	Forced air cooling, two fans total (one ultrahigh-speed reserve fan)
AC POWER	
Connector	250 V AC NEMA L6-20 (twistlock) inlet, IEC 309 male inlet, or VEAM
Voltage Selection	Automatic, two ranges, each with high-low voltage tap (uninterrupted)
Safety Agency Rated Operating Range	95 V AC – 125 V AC; 208 V AC – 235 V AC; 50/60 Hz
Turn-on and Turn-off Points	85 V AC – 134 V AC, 165 V AC – 264 V AC; 50/60 Hz
Current Draw: Idle Current	0.640 A rms (115 V AC); 0.320 A rms (230 V AC); 0.850 A rms (100 V AC)
Max Long-Term Continuous Current (›10 sec)	8 A rms (115 V AC); 4 A rms (230 V AC); 10 A rms (100 V AC)
Burst Current (‹1 sec)	15 A rms (115 V AC); 8 A rms (230 V AC); 18 A rms (100 V AC)
Ultimate Short-Term Peak Current Draw	22 A pk (115 V AC); 11 A pk (230 V AC); 25 A pk (100 V AC)
Inrush Current	7 A pk (115 V AC); 7 A pk (230 V AC); 10 A pk (100 V AC)
RMS NETWORK (OPTIONAL)	
	Equipped for two conductor twisted-pair network, reporting amplifier operating parameters to system operator's host computer.

NOTES:

1. *Recommended maximum operating frequency range. Response depends on loading conditions and room acoustics.*
2. *Free field, measured with 1/3-octave frequency resolution at 4 meters.*
3. *Measured with music at 1 meter.*
4. *At this frequency, the low- and high-frequency transducers produce equal sound pressure levels.*
5. *Power handling is measured under AES standard conditions: transducer driven continuously for two hours with band-limited noise signal having a 6 dB peak-average ratio.*
6. *Amplifier wattage rating is based on the maximum unclipped burst sine-wave rms voltage the amplifier will produce into the nominal load impedance. Both channels 70 V rms (100 V pk) into 8 ohms*

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N775

3K59 COMMERCIAL AUDIO SYSTEM
US LISTED

CQ-2 — 04.046.011.01 A

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ARCHITECT SPECIFICATIONS

The loudspeaker shall be a self-powered, full range system. The transducers shall consist of a 15-inch diameter cone driver and a 1.5-inch throat, 4-inch diaphragm compression driver on an 50-degree horizontal by 40-degree vertical constant-Q horn.

The loudspeaker system shall incorporate internal processing electronics and a two-channel amplifier. Processing functions shall include equalization, phase correction, driver protection and signal division for the high- and low-frequency sections. The crossover point shall be 900 Hz. Each amplifier channel shall be class AB/H with complementary MOSFET output stages. Burst capability shall be 620 watts each channel (1240 watts total) with nominal 8-ohm resistive load. Distortion (THD, IM, TIM) shall not exceed 0.02 percent. Protection circuits shall include TruPower limiting.

Performance specifications for a typical production unit shall be as follows: Operating frequency range shall be 35 Hz to 18 kHz. Phase response shall be ±90 degrees from 50 Hz to 16 kHz. Maximum peak SPL shall be 139 dB at 1 meter. Beamwidth shall be 50 degrees horizontal from 800 Hz to 16 kHz and 40 degrees vertical from 1500 Hz to 12 kHz.

The audio input shall be electronically balanced with a 10 kOhm impedance and accept a nominal 0 dBV (1 V rms, 1.4 V pk) signal (+20 dBV to produce maximum peak SPL). Connectors shall be XLR (A-3) type male and female or VEAM all-in-one (integrates AC, audio and network). RF filtering shall be provided. CMRR shall be greater than 50 dB (typically 80 dB 50 Hz – 500 Hz).

The internal power supply shall perform automatic voltage selection, EMI filtering, soft current turn-on and surge suppression. Powering requirements shall be nominal 100 V, 110 V or 230 V AC line current at 50 Hz or 60 Hz. UL and CE operating voltage ranges shall be 95 to 125 V AC and 208 to 235 V AC. Current draw during burst shall be 15 A at 115 V AC and 8 A at 230 V AC. Current inrush during soft turn-on shall not exceed 7 A at 115 V AC. AC power connectors shall be locking NEMA L6-20 connector, IEC 309 male or VEAM.

The loudspeaker system shall provide facilities for installing the optional RMS remote monitoring and control system.

All loudspeaker components shall be mounted in an acoustically vented trapezoidal enclosure constructed of birch plywood with a hard black textured finish. The front protective grille shall be perforated hex metal covered by charcoal gray foam. Dimensions shall be 21.00" wide x 30.00" high x 22.20" deep (533 mm x 762 mm x 564 mm). Weight shall be 130 lbs (58.97 kg). Rigging points shall be four ring and stud pan fittings, two each top and bottom, rated at 500 lbs (226.80 kg) per fitting at a 5:1 safety factor; 3/8-inch or metric M10 nut plates are optional.

The loudspeaker shall be the Meyer Sound CQ-2.