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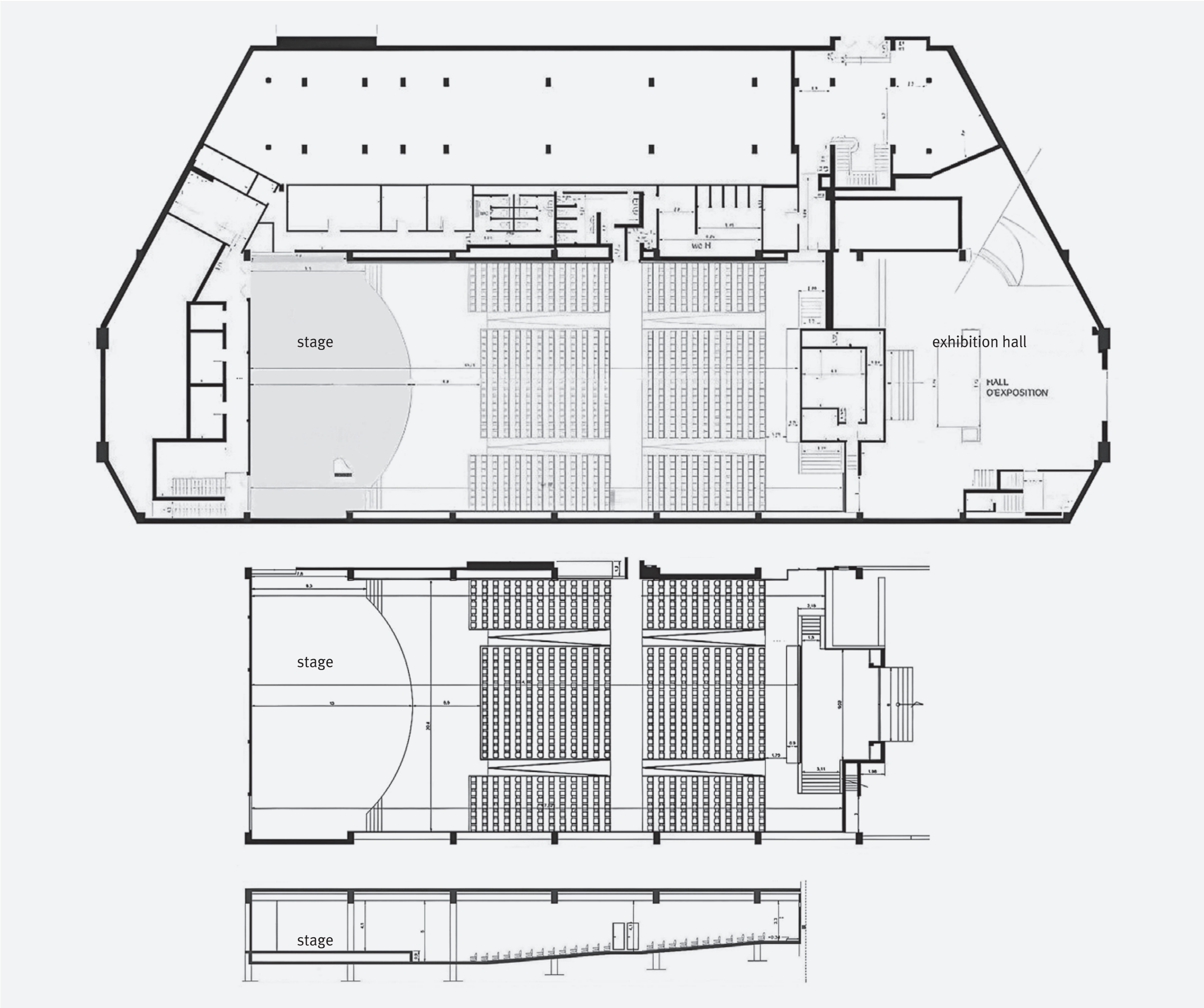

Fig. 1 Floor plans and longitudinal section of El Khalifa Cultural Center

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Reflectors Impact on Acoustic Correction of the Conference Hall at the El Khalifa Cultural Center in Constantine

acoustic quality
auditory comfort
conference rooms
El Khalifa Cultural Centre, Constantine, Algeria
plywood reflectors
sound diffusers

In Algeria, the field of acoustics has garnered limited attention from researchers, predominantly focusing on physical acoustics. Architectural acoustics, which deals with controlling auditory comfort and listening criteria within buildings, remains largely underexplored. The acoustic quality of spaces is a significant concern for physicists, architects, and researchers alike. The application of architectural acoustics in public spaces, such as conference rooms, greatly enhances the exchange of oral information and supports learning processes that require intensive verbal communication. This research aims to improve the acoustic quality of the existing conference room at the El Khalifa Cultural Centre in Constantine, Algeria. It has been noted that the centre experienced a reduction in reverberation time and sound diffusion due to an acoustic rehabilitation that introduced wall coverings of mixed panels composed of heavily perforated MDF and a layer of foam (8 cm thick). However, this rehabilitation resulted in the conference room becoming overly "deaf", diminishing its acoustic quality. In order to address this issue, we proposed the installation of a network of six plywood reflectors, each 12 mm thick, placed on the ceiling of the room in the xy plane, with dimensions of 3×2.67 m^2 each. Subsequently, the acoustic characteristics of the plywood reflectors were incorporated into the material database of the Olive Tree Lab Suite software to evaluate their impact on the room's acoustic performance and the quality of sound diffusion. The results for reverberation time (TR60), clarity (C80), strength (G), definition (D50), and speech transmission index (STI) were highly satisfactory and aligned perfectly with the recommended values. Therefore, the acoustic correction significantly improved the listening conditions.

Introduction

The acoustics of conference rooms is a very specific discipline that has not always integrated optimized acoustic principles, despite being in the focus of standard and relatively general studies (Farid et al., 2021). In particular, older designs and even some modern designs of these rooms do not take into account essential principles aimed at optimizing intelligibility and achieving an adequate reverberation time (Barron, 2010; Economou and Charalampous, 2016).

The reflection of surfaces in a room is crucial for the acoustic quality of space. To address this scientifically, it is necessary to define concepts that characterize diffusion and to perform corresponding measurements on sound-reflective materials. In recent years, several coefficients have been developed to measure the degree of diffusion of a surface, catering to the needs of diffuser manufacturers, room designers, and geometric acoustic modelers.

These coefficients provide a frequency-dependent measure analogous to the absorption coefficient, with two of them set to be included in international standards. However, there is a lack of publications directly comparing these coefficients, making it challenging to assess their relative merits.

Recent Research

Rindel (2001) emphasized that, alongside acoustic absorption, the diffusion of sound from surfaces plays a vital role in all aspects of room acoustics, such as in concert halls, sound studios, industrial halls, and reverberation rooms. Over a century ago, Wallace Sabine[1] intuitively recognized the importance of sound diffusion while contributing to the design of the Boston Symphony Hall. Sound diffusion can be achieved through isolated elements like columns or statues, surfaces with coarse structures such as diffusers, or through diffraction effects at the edges of panels.

Expanding on the role of reflective surfaces, Yan and Chen (2012) conducted research on high-precision reflective panels with a sandwich-type construction. These panels consisted of a coating plate and an aluminum support structure combined with a structural adhesive. The flexible skin-plate adapts well to the module, while the adhesive compensates for gaps between the skin-plate and the backup structure. The research utilized finite element method simulations (ANSYS) to analyze internal stresses and optimize processing parameters for manufacturing these high-precision panels.

Suspended reflectors, particularly in concert and audition halls, are critical for enhancing acoustic properties. Well-designed raised awnings on stage direct initial sound reflections towards the audience, ensuring equal spatial distribution of sound and improving communication among musicians. These awnings also address acoustic issues like parallel walls and excessively high ceilings. Hongisto et al. (2021) highlighted that an effective awning should allow sound reflections within a frequency range of 250 Hz to 4 kHz (ISO 3382). To cover a wider frequency range, larger panels are effective for lower frequencies, while smaller elements or modified panel shapes improve high-frequency reflections.

In this context, Szelag et al. (2020) proposed a design modification for reflective panels intended to extend the upper frequency limit of awnings without compromising the lower limit. By incorporating Schroeder diffusers on the edges of flat panels, the design maintains a large reflection area for low frequencies

1 Wallace Clement Sabine was an American physicist and Harvard professor who became known as a founder of the field of architectural acoustics. Around 1900 he was involved in designing the acoustics for Boston Music Hall (now Boston Symphony Hall), considered one of world's best concert halls for acoustics. (http://waywiser.fas.harvard.edu/people/3338/wallace-c-sabine)

while enhancing high-frequency performance through diffusion. The effectiveness of this modified design was validated through numerical simulations, mathematical modeling, and measurements. Comparative analysis demonstrated that the proposed design outperformed traditional flat or curved-edge panels.

Jo & Jeon (2022) further explored the optimization of sound diffusion in concert halls through scale-model measurements and simulations. Their study analyzed the effects of reflectors (canopies and clouds) and diffusers on both stage and auditorium acoustics. Key parameters such as stage support (STEarly and STLate), reverberation time (RT), early decay time (EDT), clarity (C80), and center time (TS) were evaluated. The results indicated that canopies reduced reverberation and increased stage support, while diffusers decreased some acoustic parameters but reduced seat-to-seat deviations. The research underscores the importance of considering both auditorium and stage acoustics and suggests placing diffusers near the sound source to optimize early reflections and achieve uniform sound distribution.

Shtrepi et al. (2017) examined the impact of distance from diffusive surfaces on acoustic parameters and sound perception in a small simulated variable-acoustics hall. Using numeric simulation software, the study evaluated two modeling approaches for diffusive surfaces to assess their influence on acoustic predictions. Parameters such as early decay time (EDT), reverberation time (T30), clarity (C80), definition (D50) (Farid Ibrir and Debache Benzagouta, 2017), and interaural cross-correlation (IACC) were analyzed. Calibration involved aligning simulation results with in-field measurements by adjusting surface absorption and scattering coefficients. The study found that diffusive surfaces significantly altered acoustic parameters, increasing EDT and T30 while reducing clarity and definition. Subjective tests showed that listeners could detect differences between reflective and diffusive conditions at distances greater than 7.5 meters. This research highlights the importance of accurate diffusion modeling in simulations to optimize both objective acoustic performance and listener experience.

Continuing this line of investigation, Shtrepi, Di Blasio and Astolfi (2020) studied the effect of diffusive surface location in performance spaces on acoustic parameters and sound perception. Conducted in a real shoebox concert hall, the study explored six configurations by varying the location of diffusive surfaces on lateral walls while keeping other surfaces absorptive or reflective. Conventional ISO 3382 acoustic parameters were measured, and results indicated minimal variation with surface location. However, subjective tests revealed that some listeners noticed differences in reverberance, coloration, and spaciousness, providing valuable insights for the strategic placement of diffusive surfaces in concert halls.

Finally, Labia, Shtrepi and Astolfi (2020) focused on improving the acoustic quality of medium-sized meeting rooms by optimizing the configuration of sound-absorptive and sound-diffusive panels. Their study combined in-field acoustic measurements with numeric simulations to evaluate various acoustic treatment configurations. The findings showed that placing absorptive materials on the ceiling or around its perimeter, as well as on the upper parts of one lateral wall, yielded the best acoustic results. Interestingly, diffusive panels did not significantly improve conditions compared to absorptive panels alone. This research offers a practical design workflow for optimizing acoustic material placement in meeting rooms, balancing sound quality improvement with cost efficiency.

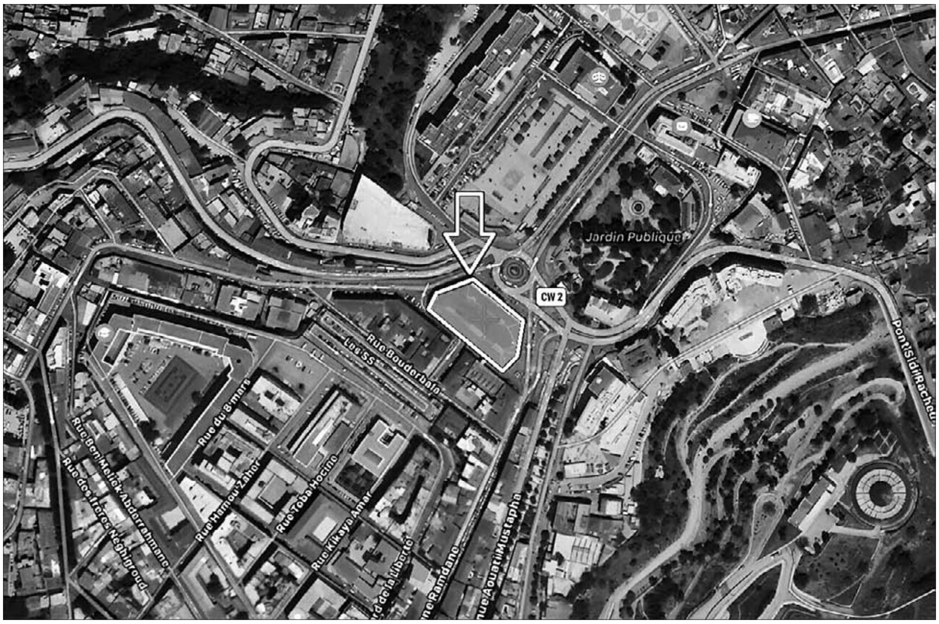


Fig. 2 Location plan of El Khalifa Cultural Center

Applied Methodology

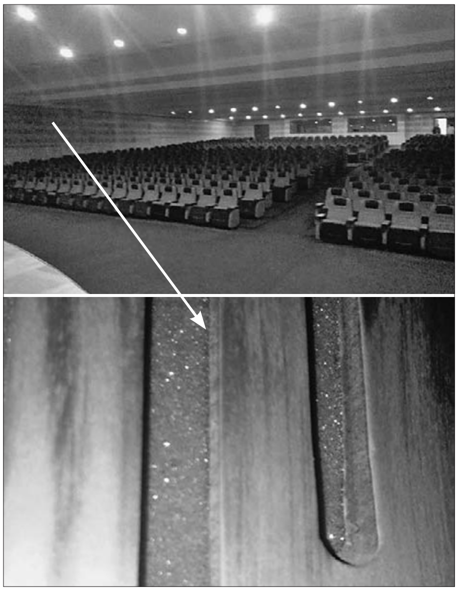
In this study, an acoustic analysis of the conference room of the El Khalifa Cultural Center was conducted using the Olive Tree Lab SUITE software (Farid, 2021). This investigation aimed to assess acoustic performance before and after rehabilitation, focusing on key parameters such as reverberation time (TR60) and intelligibility indices (C80, G, D50 and STI). The results obtained were com-

Table I Architectural and Geometric Data of the Conference Room at El Khalifa Cultural Center

1 - Surface and perimeter							
Stage	Alone	Balcony	Total (floor + balcony	Surface clean audience		perimeter	Sh_f [a]
				Balcony Floor			m^{-1}
223.3	661.4		661.4	595.26		129	0.15
2 - Volumes [b] in m^3				capacity of pers.		D_{MAX} [d] (m)	
Stage	Whole room	Total	F_f [c]	Ground	Balcony	Ground	Balcony
781.55	2314.9	3096.45	3.50	704	0	23	
Geometric data							
Surface area/ person m^2				Volume / person m^3			
Net		Raw					
Ground	Balcony	Ground	Balcony	Ground	Under the balcony	Balcony	$T_{OPT-500}$ s
0.85		0.94		3.29			**0.74**

a – Shape factor (mainly the perimeter-to-area ratio).
b – Under the suspended ceiling.
c – For the considered room, the height of the room is taken as the average height, calculated as follows: total volume of the room / net area = 7.82 m.
d – The distance between the sound source (located in the middle of the stage) and the farthest listener.
e – Calculation (gross area / person × average height of the room, under the balcony or the balcony).

Fig. 3 Perforated MDF panels and foam (sponge) used for the rehabilitation of the room



pared to the optimal values prescribed by the ISO/DIS 3382-1 standards, making it possible to identify acoustic deficiencies and sound problems specific to the room. Olive Tree Lab SUITE, an advanced tool designed for acoustic simulations, provided a precise and efficient virtual environment, allowing complex acoustic scenarios to be modeled and analyzed. Suitable for professionals such as acoustics consultants, engineers and urban planners, this software helped predict noise levels, compare different configurations and ensure regulatory compliance through 3D visualizations and sound contour maps. Based on the results of the analysis, recommendations have been made to optimize the acoustic quality of the room and achieve international standards.

Architectural Analysis of the Conference Room at El Khalifa Cultural Center

El Khalifa Cultural Center is a prominent cultural venue in the heart of Constantine, located on Place du 1er Novembre 1954 (formerly La Brèche; Fig. 2). The former Citroën garage, built during the colonial period in 1933, was converted into a cultural center in 1980. Like the Malek Hadad Cultural Palace, El Khalifa Cultural Center underwent a rehabilitation operation in 2014, initiated as part of the event “Constantine, Capital of Arab Culture 2015” by the Nasri Salim design office. The building includes several offices, two conference rooms, a library, and a performance hall, as well as an honors lounge reserved for welcoming city guests (Fig. 1 up).

– **Architectural description** – The conference room at El Khalifa Cultural Center is rectangular in shape (Fig. 1). It consists of two parts: the stage and the seating area. The total area is 884.7 m^2. The total volume of the room is approximately 3096.45 m^3. The total capacity of the room is 704 spectators. Table I presents the most important architectural and geometric data of the room.

Acoustic Rehabilitation

The conference room at the El Khalifa Cultural Center underwent a specific rehabilitation operation aimed at improving its acoustic quality as well as its general condition. The rehabilitation work involved covering all the walls of the room with perforated MDF panels combined with foam (sponge) to enhance acoustic quality without altering the shape (Fig. 3).

Determination of Optimal Values for Acoustic Quality Indices

Determining optimal values for acoustic quality indices in conference rooms is based on several essential criteria to ensure an optimal sound experience. Reverberation time (RT), considered the most critical acoustic criterion, ensures that speech sounds remain undistorted. According to Galbrun and Kitapci (2016), the optimal value of TR, calculated using the formula TOPT-500 = 0.3 log(V), is 0.85 seconds. Sound clarity (C80), expressed in dB, measures the ratio between the sound energy arriving in the first 80 milliseconds and that arriving thereafter, thus influencing sound perception. Likewise, the sound force (G) corresponds to the difference between the observed sound pressure level and the sound power level, also expressed in dB. The D50 index, for its part, makes it possible to assess speech clarity by analyzing the ratio between the sound energy of the first 50 milliseconds and the total impulse energy, with reference values at 500 and 1000 Hz for frequencies ranging from 63 Hz to 8,000 Hz. Finally, speech intelligibility (STI) provides an objective percentage assessment, making it possible to judge effective understanding speeches (Galbrun and Kitapci, 2016). These different indices, taken as a whole, contribute to optimal acoustics for conference spaces, validated by scientific criteria and the specialized community.

Results and Interpretation of Measurements Obtained for the Conference Room

– **Results for the TR60 Criterion** – The introduction of wall cladding with mixed panels

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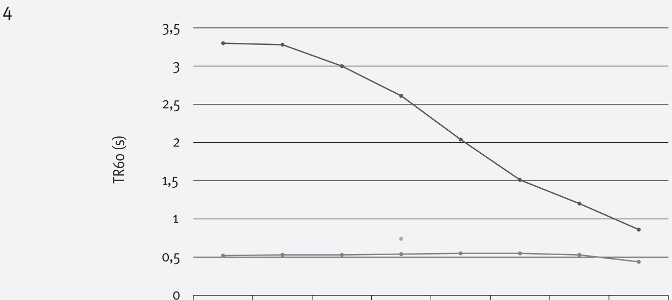
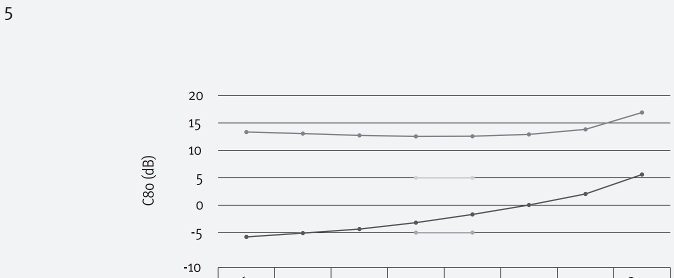


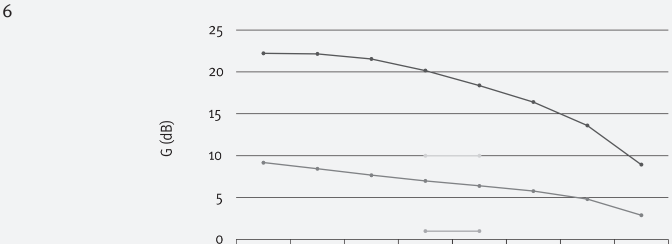
frequency (Hz)	63	125	250	500	1000	2000	4000	8000
Tr60 before rehabilitation	3,3	3,28	3	2,61	2,04	1,51	1,2	0,86
Tr60 after rehabilitation	0,52	0,53	0,53	0,54	0,55	0,55	0,53	0,44
optimal TR60				0,74				

5



frequency (Hz)	63	125	250	500	1000	2000	4000	8000
corrected C80	-5,79	-5,08	-4,36	-3,19	-1,67	0,04	2,06	5,62
current C80	13,36	13,08	12,75	12,56	12,59	12,93	13,86	16,94
Minmum C80 according to ISO/DIS 3382-1				-5	-5			

6



frequency (Hz)	63	125	250	500	1000	2000	4000	8000
G before rehabilitation	22,23	22,16	21,55	20,16	18,39	16,41	13,61	8,93
G after rehabilitation	9,18	8,45	7,68	7	6,4	5,78	4,83	2,9
Minmum G according to ISO/DIS 3382-1				1	1			
Maximum G according to ISO/DIS 3382-1				10	10			

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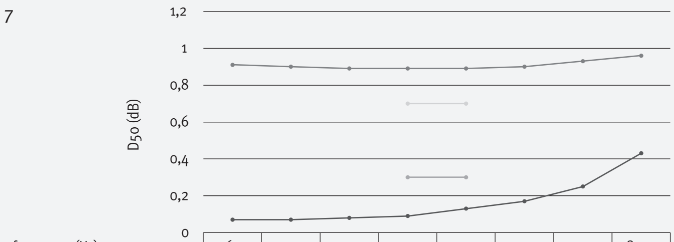


frequency (Hz)	63	125	250	500	1000	2000	4000	8000
D50 before rehabilitation	0,07	0,07	0,08	0,09	0,13	0,17	0,25	0,43
D50 after rehabilitation	0,91	0,9	0,89	0,89	0,89	0,9	0,93	0,96
Minimum D50 according ISO/DIS 3382-1				0,3	0,3			
Maximum D50 according ISO/DIS 3382-1				0,7	0,7			

composed of heavily perforated MDF and a layer of foam (thickness 8 cm) significantly reduced the reverberation time values across all frequencies. The reduction after the rehabilitation work is estimated at -84% for the 125 Hz frequency, -73% for the 1000 Hz frequency, and -44% for the 4000 Hz frequency. Comparing the reverberation time after rehabilitation with the optimal reverberation time shows that Tr60500, which was 0.54 s, decreased, compared to the optimal Tr60500 value of 0.74 s. This makes the room acoustically dead, significantly reducing its acoustic quality (Fig. 4).

– **Results for the C80 Criterion** – It can be observed from these results that the acoustic rehabilitation influenced the values of the C80 spectrum. It produced an increase in the level, ranging from 19 dB for the 63 Hz frequency to 11 dB for the 8000 Hz frequency. It is important to note that the C80 index values after rehabilitation do not fall within the optimal range (Fig. 5).

– **Results for the G Criterion** – The rehabilitation had a significant impact on the energy strength G, with an average decrease of -13 dB, which is particularly notable in acoustics. According to ISO 3382, the optimal values of the G index fall within the range of -2 to 10 dB for frequencies of 500 Hz and 1000 Hz. Comparing the G strength values after rehabilitation with these optimal values, it is evident that the rehabilitation has considerably improved the G indices (see Fig. 6). This improvement demonstrates the effectiveness of the interventions carried out, aligning the room's acoustic performance with the recommended standards.

– **Results for the D50 Criterion** – The value of D50 is 0.90 across all frequencies, indicating a significant increase of 0.84 dB after the rehabilitation work. However, it is important to note that these D50 values have exceeded the optimal range defined for this index (see Fig. 7).

– **STI Intelligibility Criterion** – The final STI intelligibility index improved from a very poor state to a good state (Table II).

Fig. 4 Comparison between TR60 before rehabilitation, TR60 after rehabilitation, and the optimal TR60

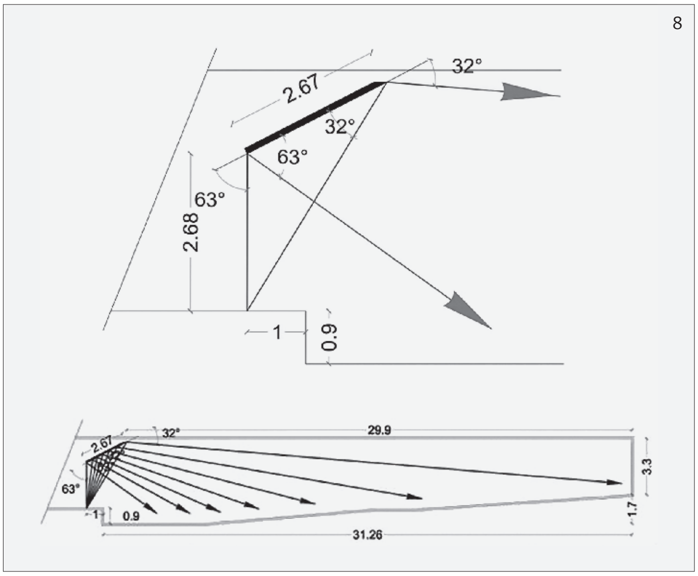
Fig. 5 Comparison between C80 before rehabilitation, C80 after rehabilitation, and the optimal C80

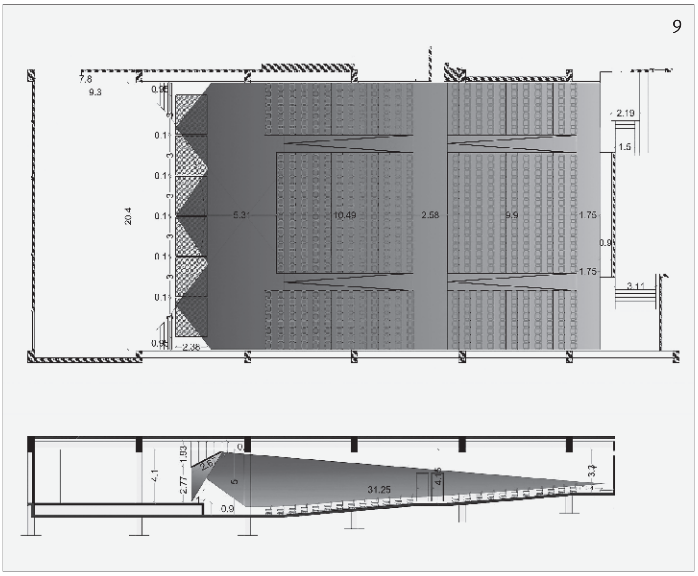
Fig. 6 Comparison between G before rehabilitation, G after rehabilitation, and the optimal G

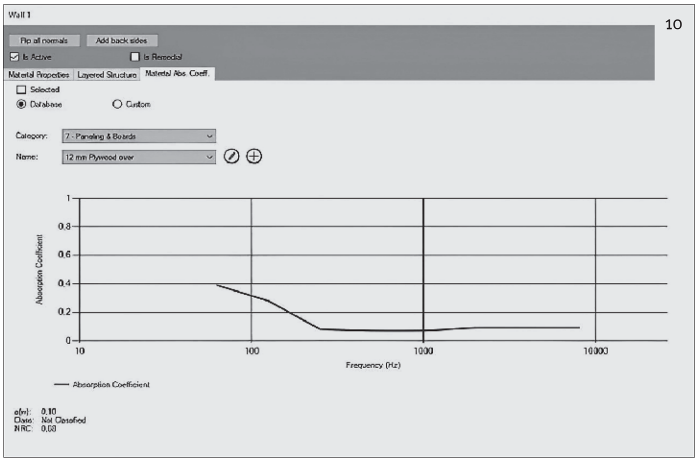
Fig. 7 Comparison between D50 before rehabilitation, D50 after rehabilitation, and the optimal D50

Table II Comparison of STI before rehabilitation, STI after rehabilitation, and optimal STI

	STI before rehabilitation	STI after rehabilitation	optimal STI according to ISO/DIS 3382-1
STI	0.38 very bad state	0.66 good condition	0 to 0.30 very bad 0.30 to 0.45 bad 0.45 to 0.60 satisfactory 0.60 to 0.75 good 0.75 to 1 very good







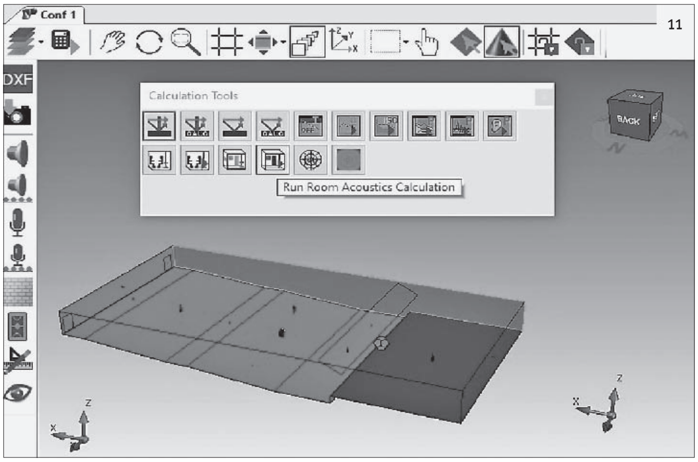


Fig. 8 Position of the reflectors on the section

Fig. 9 Direct and indirect sound field after the insertion of reflectors

Fig. 10 Introduction of the acoustic characteristics of reflectors into the software program

Fig. 11 Acoustic simulation on Olive Tree Lab

Proposed Corrections

– **Application of reflectors** – For better sound diffusion and improved acoustic quality in the conference room at El Khalifa, we opted to insert reflective plywood surfaces on the ceiling. Several calculations were made to identify the number of reflectors and their dimensions to ensure the sound reaches all the audience members. A network of six plywood reflectors, 12 mm thick, is placed on the ceiling of the room on the xy plane, each with a dimension of $3\times2.67\ m^2$. The projection of the geometric reflection point on the plane is represented as shown in the section (Fig. 8).

The reflection angle for the lowest point of the reflectors is 63°, which reaches the first row of the audience. The highest point has an angle of 32°, which reaches the last row of the audience (Rindel, 2004). The direct and indirect sound fields after the insertion of reflectors are shown in the figure below (Fig. 9).

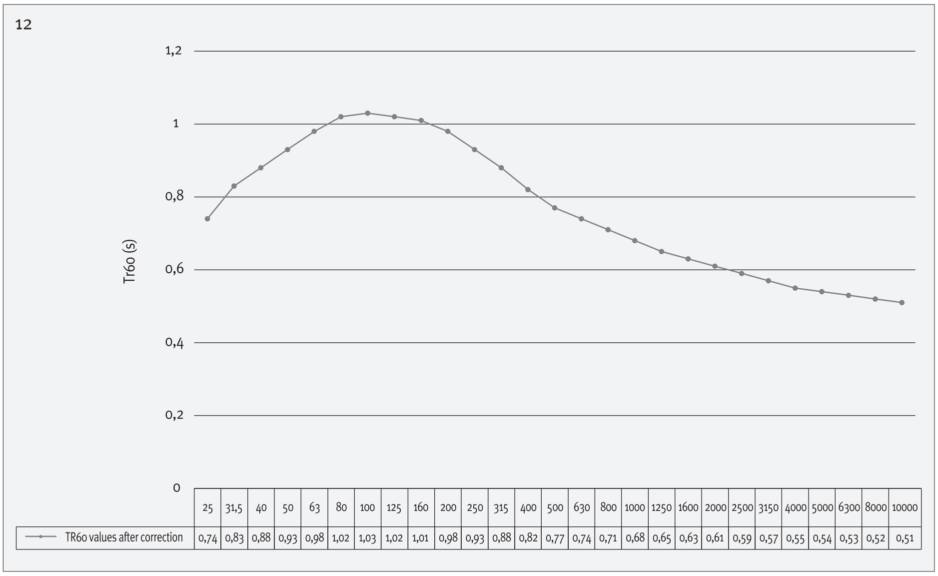
– **Modeling and simulation** – We introduced the acoustic characteristics of the plywood reflectors into the material database of the Olive Tree Lab Suite software (Fig. 10) to evaluate the impact of these reflectors on the acoustic performance of the room and the quality of sound diffusers (Fig. 11).

Table III The STI values after correction, compared with the current STI and the optimal STI

Indication	Current State	After Correction	Optimal Values
STI	0.67 on the STI scale – the quality is good	0.87 on the STI scale – the quality is very good	from 0 to 0.30 – very poor from 0.30 to 0.45 – poor from 0.45 to 0.60 – satisfactory from 0.60 to 0.75 – good from 0.75 to 1 – very good

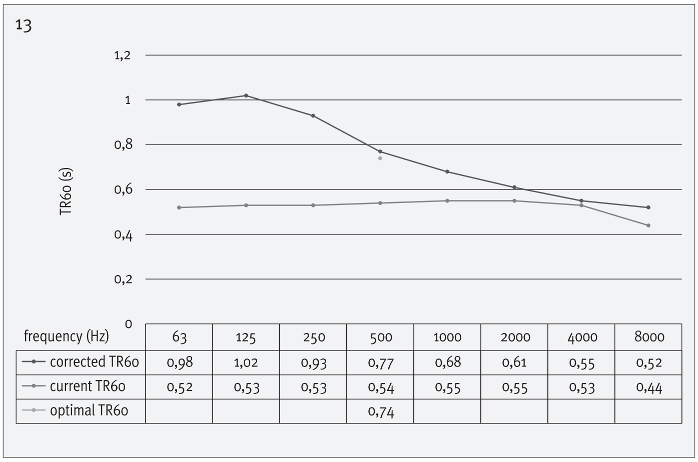
Results and Interpretation

The results for the reverberation time TR60, clarity C80, strength G, D50, and speech transmission index (STI) were highly satisfac-



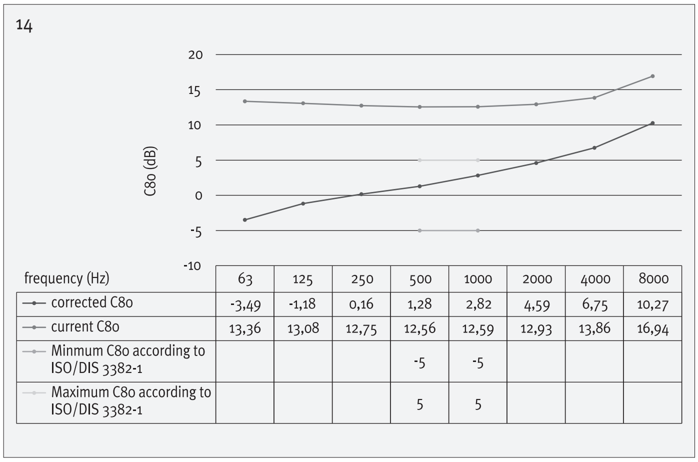
	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
TR6o values after correction	0,74	0,83	0,88	0,93	0,98	1,02	1,03	1,02	1,01	0,98	0,93	0,88	0,82	0,77	0,74	0,71	0,68	0,65	0,63	0,61	0,59	0,57	0,55	0,54	0,53	0,52	0,51

FIG. 12 TR60 VALUES AFTER CORRECTION

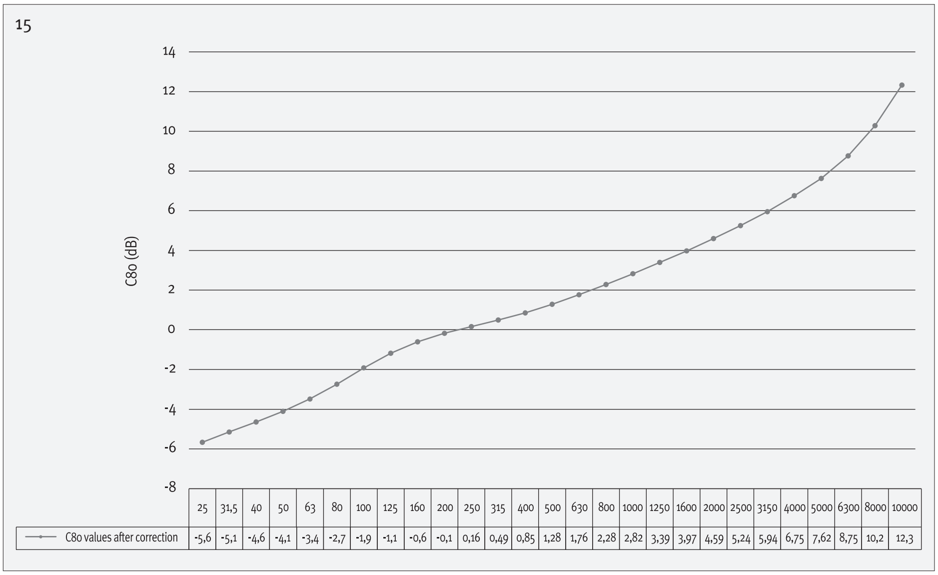


frequency (Hz)	63	125	250	500	1000	2000	4000	8000
corrected TR6o	0,98	1,02	0,93	0,77	0,68	0,61	0,55	0,52
current TR6o	0,52	0,53	0,53	0,54	0,55	0,55	0,53	0,44
optimal TR6o				0,74				

FIG. 13 COMPARISON BETWEEN THE CORRECTED TR60, THE CURRENT TR60, AND THE OPTIMAL TR60



frequency (Hz)	63	125	250	500	1000	2000	4000	8000
corrected C8o	-3,49	-1,18	0,16	1,28	2,82	4,59	6,75	10,27
current C8o	13,36	13,08	12,75	12,56	12,59	12,93	13,86	16,94
Minmum C8o according to ISO/DIS 3382-1				-5	-5			
Maximum C8o according to ISO/DIS 3382-1				5	5			



	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
C8o values after correction	-5,6	-5,1	-4,6	-4,1	-3,4	-2,7	-1,9	-1,1	-0,6	-0,1	0,16	0,49	0,85	1,28	1,76	2,28	2,82	3,39	3,97	4,59	5,24	5,94	6,75	7,62	8,75	10,2	12,3

FIG. 14 COMPARISON BETWEEN THE CORRECTED C80, THE CURRENT C80, AND THE OPTIMAL C80

FIG. 15 C80 VALUES AFTER CORRECTION

Fig. 16 G values after correction

Fig. 17 Comparison between the corrected G, the current G, and the optimal G

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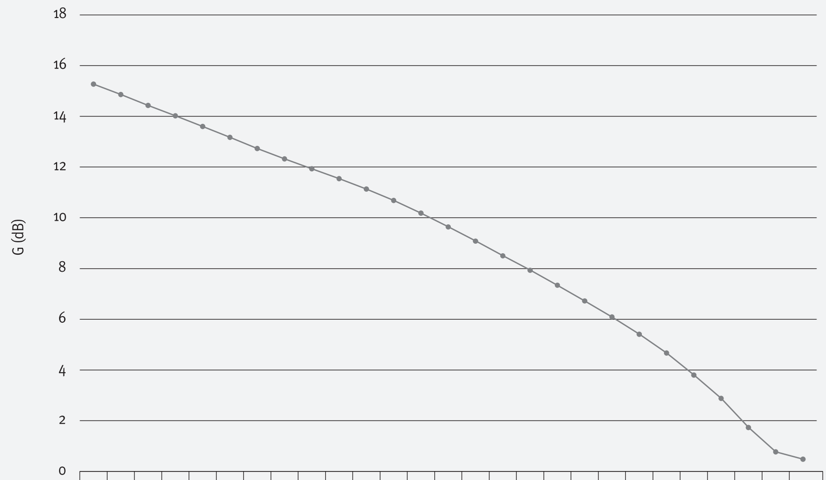

	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
G values after correction	15,2	14,8	14,4	14,0	13,6	13,1	12,7	12,3	11,9	11,5	11,1	10,6	10,1	9,64	9,08	8,5	7,93	7,34	6,72	6,09	5,41	4,67	3,8	2,88	1,73	0,77	0,48

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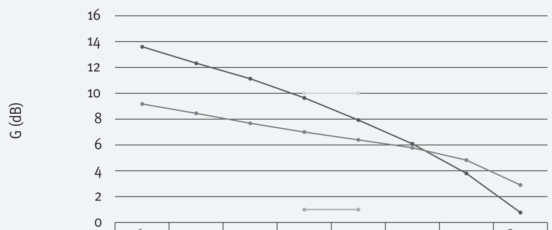
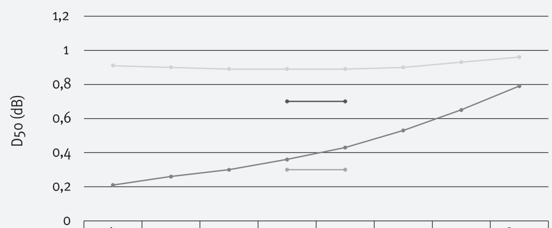


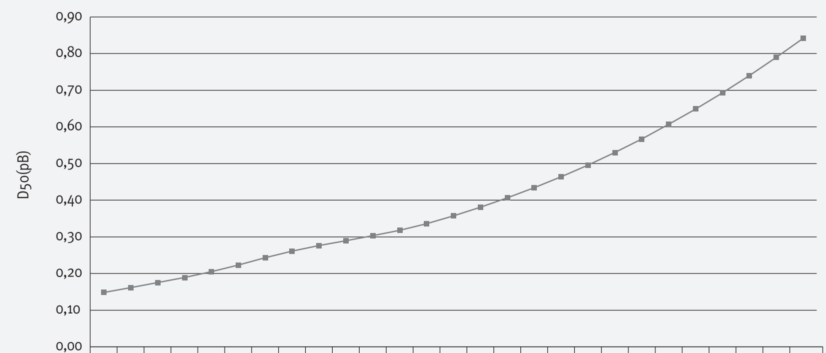
frequency (Hz)	63	125	250	500	1000	2000	4000	8000
corrected G	13,6	12,32	11,13	9,64	7,93	6,09	3,8	0,77
current G	9,18	8,45	7,68	7	6,4	5,78	4,83	2,9
Minmum G according to ISO/DIS 3382-1				1	1			
Maximum G according to ISO/DIS 3382-1				10	10			

18



frequency (Hz)	63	125	250	500	1000	2000	4000	8000
D50 before rehabilitation	0,21	0,26	0,3	0,36	0,43	0,53	0,65	0,79
D50 after rehabilitation	0,91	0,9	0,89	0,89	0,89	0,9	0,93	0,96
Minmum D50 according to ISO/DIS 3382-1				0,3	0,3			
Maximum D50 according to ISO/DIS 3382-1				0,7	0,7			

19



Frequency(Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000
D50 values after correction	0,15	0,16	0,18	0,19	0,21	0,22	0,24	0,26	0,28	0,29	0,30	0,32	0,34	0,36	0,38	0,41	0,43	0,46	0,50	0,53	0,57	0,61	0,65	0,69	0,74	0,79	0,84

Fig. 18 Comparison between the corrected D50, the current D50, and the optimal D50

Fig. 19 D50 values after correction

tory. In Figures 12-19 the nominal TR60 value is 0.77 seconds, which is perfectly compatible with the recommended value of 0.74 seconds. In Fig. 14 the C80 values fall within the standard margin, and the same is true for the other indices: G (Figs. 16 and 17), D50 (Fig. 19), and STI (Table III).

Overall, the results for the various acoustic criteria are very satisfactory. We can conclude that our correction strategy yielded good results. It is noteworthy that the correction significantly improved the listening conditions.

Conclusion

The acoustic simulation conducted on various indices allowed for a detailed acoustic diagnosis of the studied conference hall. This analysis revealed that despite the improvement in acoustic conditions following the rehabilitation work, the hall still exhibits notable acoustic problems and deficiencies. The results indicated a reduction in reverberation time below the optimal threshold, which significantly reduced sound diffusion and, consequently, the acoustic quality of the hall. This reduction in reverberation time compromises the clarity and intelligibility of speeches. To remedy this problem, we introduced reflectors in strategic locations. The simulation results showed that the proposed modifications to the acoustic corrections were largely significant.

These results provide a valuable basis for guiding our methodological approach. They allow us to propose solutions aimed at improving the listening quality in the studied conference hall. Furthermore, these results will guide us in developing a comprehensive strategy to generalize the recommended solutions to all similar conference halls, in order to optimize their acoustic performance.

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Illustration sources

Fig. 1	BET Nasri Salim
Fig. 2	Google Earth, 2023
Fig. 3	Authors 2019
Figs. 4-19	Olive Tree Lab Suite software, 2019
Tables I-III	Authors, 2024

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Leading role: D.F.; conceptualization: D.F. and A.N.; methodology: D.F. and A.N.; software: D.F. and K.Z.; validation: A.N.; formal analysis: D.F. and A.N.; investigation: D.F.; resources management: D.F. and K.Z.; data curation: D.F., A.D. and K.Z.; writing – original draft preparation: D.F.; writing – review and editing: D.F., A.N. and Y.N.B.; visualization: D.F., A.N. and K.Z.; supervision: D.F.; project administration: D.F.; funding acquisition: D.F. and A.N. All authors have read and agreed to the published version of the manuscript.