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ACOUSTICAL ADAPTATION OF THE THESSALONIKI MUSIC-THEATRE

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Acoustical adaptation design for a musical theatre situated in a residential building at Thessaloniki downtown is described. Peculiar details of the completed adaptation are discussed and some conclusions derived, stressing the importance of a high sound insulation level as a factor of the good acoustical quality of concert halls.

1. Introduction

Adaptations of existing buildings to new requirements due to altered building destination, cause very often troublesome problems. They are especially difficult in the domain of acoustical adaptations, when a high quality concert-hall or theatre-hall is foreseen as an adaptation aim.

The problems are of various kinds and of different degrees of difficulty depending on adaptation design assumptions and on their conditions of realization. Thus, no general solution is available and every case has to be studied, designed, and realized on its own way. The character of designers' tasks is, however, restricted to a few specific areas of concepts. They may be mentioned, grouped in the following way.

A. The correction of the hall shape, the positioning of the stage and the distribution of audience; the geometrical study of sound reflections to secure uniform sound distribution.

B. The acoustical design of the interior; placement of sound absorbing and of sound reflecting materials and diffusing elements; correction of frequency characteristics.

C. The design of sound systems; recording, reinforcement, monitoring, pageing, reverberation, etc.

D. The design of improved sound insulation, in order to suppress extraneous noise penetrating the hall, and to prevent radiation of sounds out of the hall adjacent dwellings.

As problems concerning solutions of tasks quoted in items A, B, and C are rather often described in acoustical literature, so appropriate concepts are commonly known. On the contrary, those encountered in item D are very seldom described. Moreover, as they belong to building acoustics rather than to room acoustics domain so they are, as a rule, presented separately. However, those problems are often to be solved by sound-engineers or by acoustical consultants working on room acoustics designs.

Thus, a presentation of design considerations and of the results obtained in the course of adaptation undertaken at the new music-theatre in Thessaloniki, may turn out to be a useful hint for designers of similar projects, and may be of interest as practical example for acousticians and sound-engineers. The more so, because the most essential task of the design consisted of sound insulating constructions separating acoustically the hall interior and the outer part of the building.

2. Object data

A part of the building constructed in the fifties, situated in the busy district of Thessaloniki eastern downtown, at the crossing of Vasilissas Olgas and M. Botsari streets, occupied earlier by a cinema, has been destinated to be converted into a music-theatre, named REX. The building adaptation design was consigned to an outstanding architect Nikos Gortsios, while the present author was charged with the acoustical design of the object. The adaptation enterprise began to be realized in January 1989. Designs had to be ready for implementation immediately. All decisions had to be undertaken without any delay because of urgent deadlines for their execution. The whole adaptation work has been completed within 64 days.

Two sectional views of the object are shown in Fig. 1. It should be explained that four floors of the building situated above the depicted part, lodge numerous residential flats. Such situation demands very high transmission loss of sound penetrating through separating barriers, walls and floors of the hall, into the residential part of the building.

On the other hand, the sound insulation requirements imposed by the level of traffic noise prevailing nearby, are also very difficult to be fulfilled.

3. Traffic noise conditions

Measurements of the traffic noise levels have been recently carried on for the Thessaloniki downtown [4]. A map section is shown in Fig. 2, where the theatre site is marked encircled with dashed line. Numbers along streets denote traffic intensities. The measured equivalent level for Vasilissas Olgas street in the theatre neighborhood $L_{\mathrm{eq}} = 78$ dB(A), i.e. the highest level of traffic noise observed in the whole downtown area. Unmeasured were, however, ground vibrations caused by the traffic.

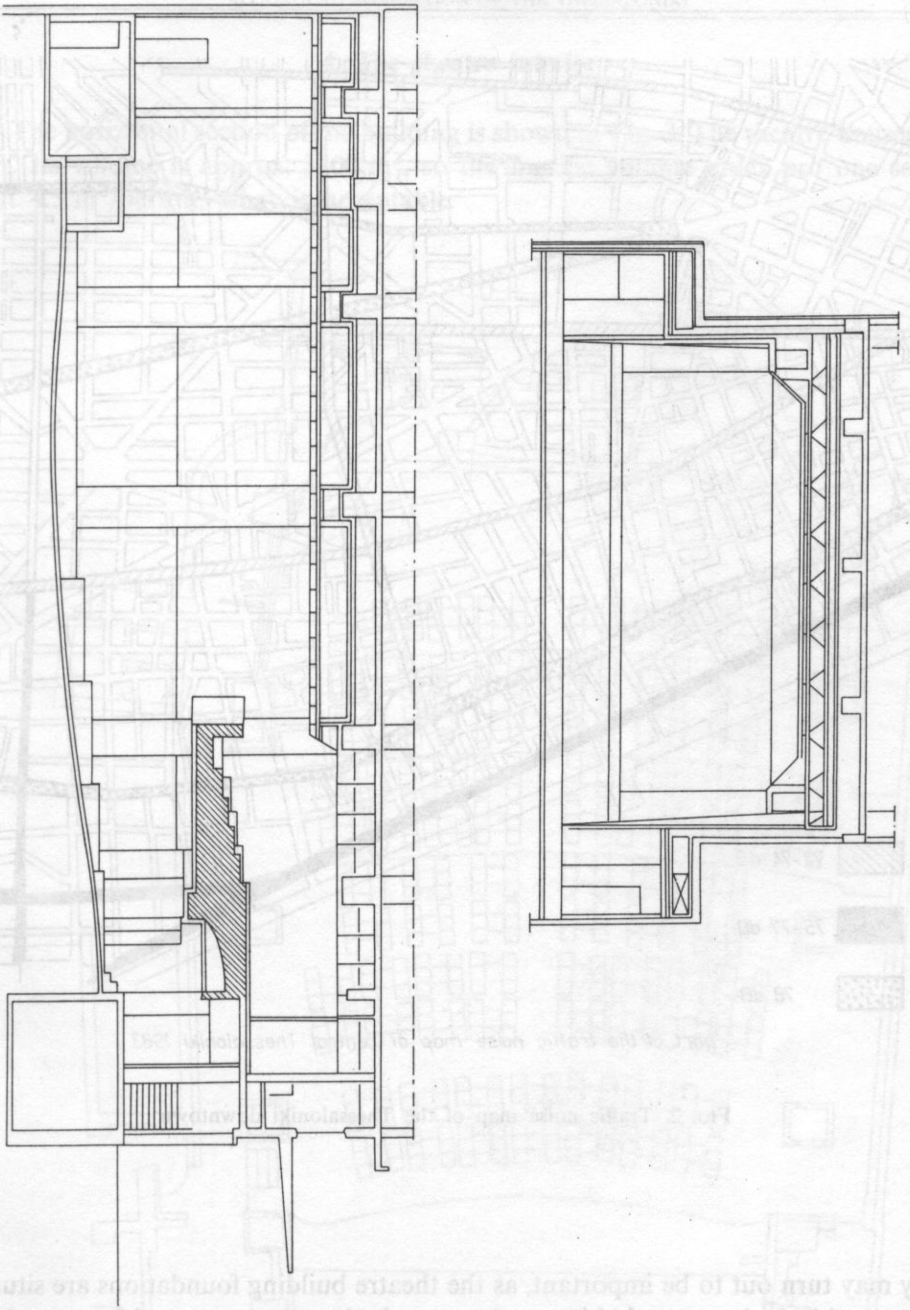
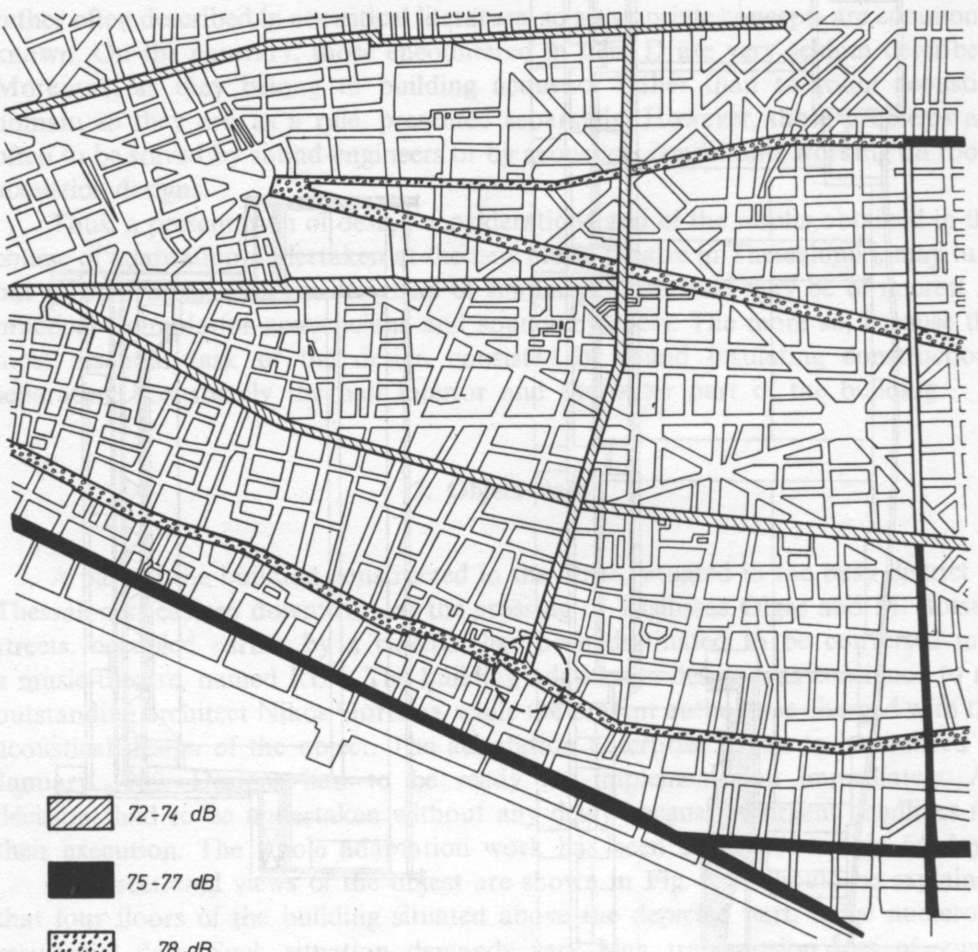


FIG. 1. Cross sections of the theatre hall



part of the traffic noise map of central Thessaloniki 1983

FIG. 2. Traffic noise map of the Thessaloniki downtown

They may turn out to be important, as the theatre building foundations are situated near an old rivulet, now hidden underground, then on an unstable ground.

Thus, conditions for a design of appropriate insulation against the mentioned level of noise and vibrations were severe. Moreover, a constant tendency to augmentation of the traffic noise in the city will aggravate the conditions soon. Then, the design must take it into account.

4. The theatre interior

The horizontal section of the building is shown in Fig. 3. The theatre houses 850 seats. Its volume is approx. 3800 m^3, so the specific volume index pro one seat is aboit 4.5 m^3/person, what is acceptable.

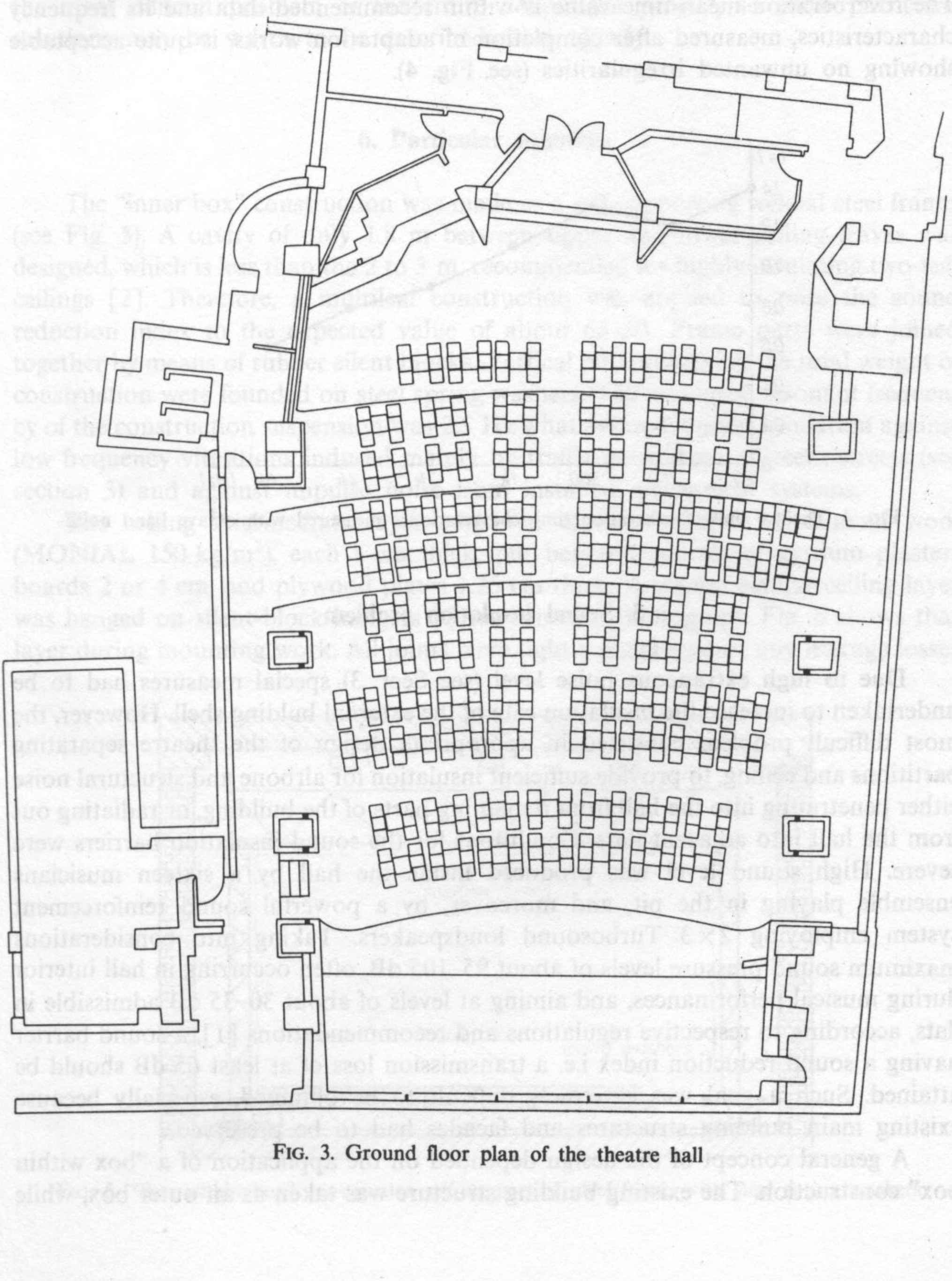


FIG. 3. Ground floor plan of the theatre hall

The shape of the interior has been redesigned so as to obtain good visibility towards the stage from all seats, however their distribution depends mainly on the presence of side pillars designed to support an inner shell of the ceiling and partitions. Due to such unusual interior construction some problems of sound distribution arise, yet generally the listening conditions in all seats are favourable. The reverberation mean-time value is within recommended data and its frequency characteristics, measured after completion of adaptation works, is quite acceptable showing no unwanted irregularities (see Fig. 4).

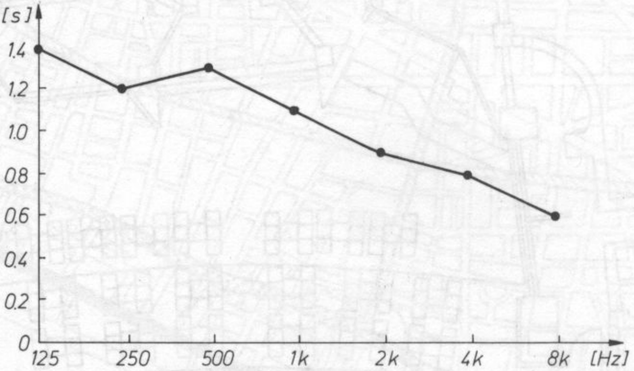


FIG. 4. Theatre hall reverberation time characteristics measured with octave band noise

5. Sound insulation problem

Due to high extraneous noise level (see Sect. 3) special measures had to be undertaken to increase the insulation rate of the external bulding shell. However, the most difficult problem consisted in appropriate design of the theatre separating partitions and ceiling, to provide sufficient insulation for airbone and structural noise either penetrating into the hall from remaining parts of the building, or radiating out from the hall into adjacent flats. Conditions for the sound insulation barriers were severe. High sound level was produced inside the hall by a sixteen musicians ensemble playing in the pit, and moreover, by a powerful sound reinforcement system employing 2 × 3 Turbosound loudspeakers. Taking into considerations maximum sound pressure levels of about 95–105 dB, often occurring in hall interior during musical performances, and aiming at levels of about 30–35 dB admissible in flats, according to respective regulations and recommendations [1], a sound barrier having a sound reduction index i.e. a transmission loss of at least 65 dB should be attained. Such a goal was extremely difficult to be obtained, especially because existing main building structures and facades had to be preserved.

A general concept of the design depended on the application of a "box within box" construction. The existing building structure was taken as an outer box, while the inner one was to be build. A very thick intermediate insulating layer was to be put between. Besides of high insulation introduced by the material selected for intermediate layer, it should be mounted as tight as possible in order to reduce eventual leakage of sound through holes and cracks [1].

As the above presented concept turned out to be an efficient tool for resolving the most difficult problem of the entire adaptation project, so some particular solutions may be worth to be described more closely.

6. Particular solutions

The "inner box" construction was made as a self-supporting welded steel frame, (see Fig. 5). A cavity of only 1.8 m between upper and lower ceiling leaves was designed, which is less than the 2 to 3 m, recommended for highly insulating two-leaf ceilings [2]. Therefore, a multileaf construction was applied to raise the sound reduction index to the expected value of about 65 dB. Frame parts were joined together by means of rubber silent blocks. Vertical pillars carrying the total weight of construction were founded on steel spring washers. The measured resonant frequency of the construction suspension was 2.5 Hz what assured a good insulation against low frequency vibrations induced mainly by traffic noise from adjacent streets (see section 3) and against impulse noise from installed mechanical systems.

The ceiling intermediate layer consisted of three courses of mineral wool (MONIAL 150 kg/m^3), each 8 cm thick, put between courses of gypsum plasterboards 2 or 4 cm, and plywood plates 1.25 cm thick. A second similar ceiling layer was hanged on silent-block-hangers 35 cm beneath. Photograph Fig. 6 shows that layer during mounting work. All joints were tightly glued against any leakage losses

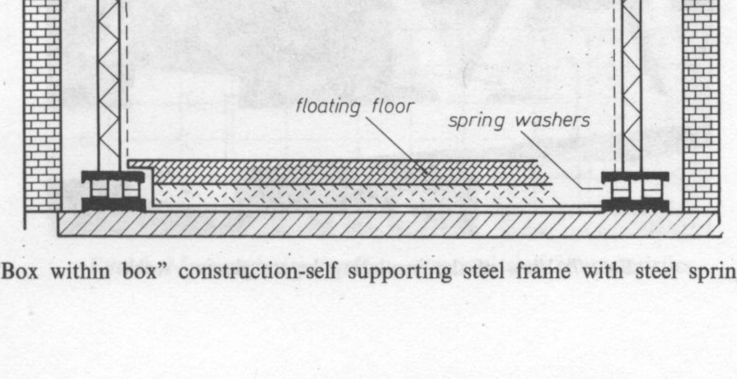


FIG. 5. "Box within box" construction-self supporting steel frame with steel spring washers

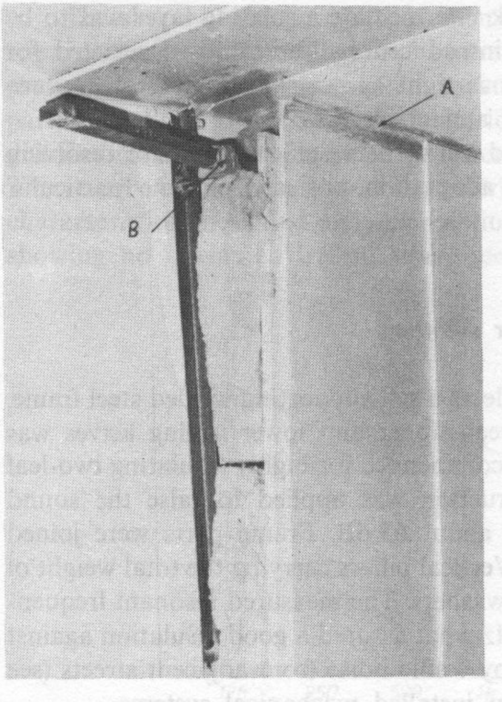


FIG. 6. Mounting of the mineral wool insulating layer

of insulation. The total thickness of the inner ceiling, including a 35 cm spacing from the outer one, was 120 cm. Side partitions of similar construction were spaced only 15 cm from outer walls. Another view of mounting work showing part of steel frame construction and spaced supporting battens and trusses in is shown in Fig. 7.

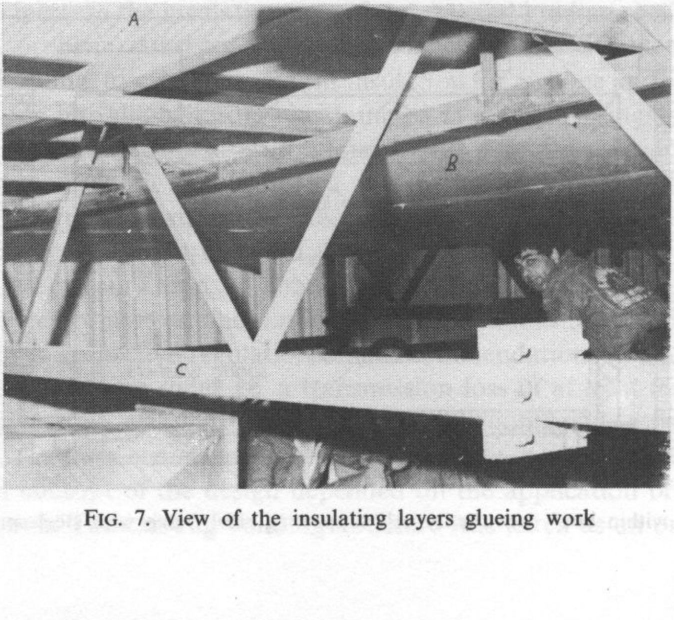


FIG. 7. View of the insulating layers glueing work

7. Obtained results

Several test were made in order to check the efficiency of the implemented solutions.

The first test consisted of noise level measurements made in residential flats situated directly above the theatre ceiling. A block diagram of the measuring equipment is shown in Fig. 8. During a performance when the sound level on stage was at about 100 dB, the weighted noise level measured in flats reached from 28 dB (A) to 38 dB(A), depending on frequency band. Detailed results plotted as normalized level difference vs. midfrequency of tierce-bands are shown in Fig. 9, while same results obtained from a printer are listed in Table 1. The normalized level difference R, i.e. the transmission loss, was calculated by Building Acoustic Analyzer B and K 4417, the equations (after ISO 140):

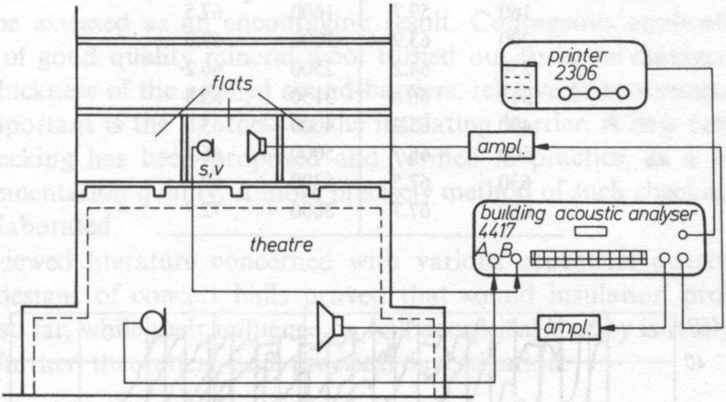


FIG. 8. Block diagram of the instrumentation used for transmission loss measurements of the ceiling

$$D = L_1 - L_2; \qquad R = D + 10\log(6{,}15ST/V)\mathrm{dB}$$

where S and V denote surface and volume of the flat room, in square and cubic metres respectively, while T means reverberation time of the flat room, in seconds (see Fig. 10) also measured by the Building Acoustic Analyzer.

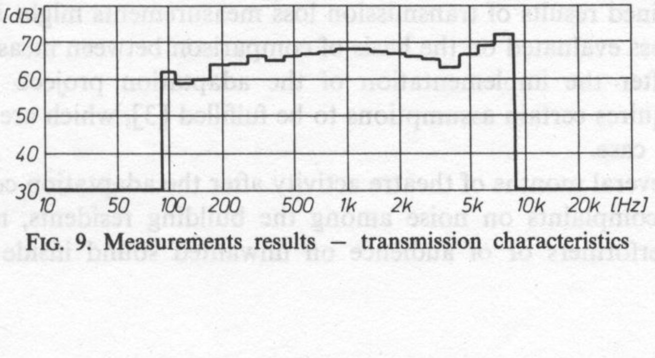


FIG. 9. Measurements results — transmission characteristics

Table 1. Measurements results — table of transmission loss values

00:00:45
NRM. LEVEL DIFF.
V = 36 S = 11,5

HZ	CODES DB	HZ	CODES DB
100	62.2	1000	68.0
125	58.5	1250	68.2
160	59.7	1600	67.5
200	63.9	2000	67.0
250	64.2	2500	66.2
315	66.5	3150	65.5
400	65.2	4000	63.2
500	66.7	5000	66.7
630	67.5	6300	69.5
800	67.7	8000	72.2

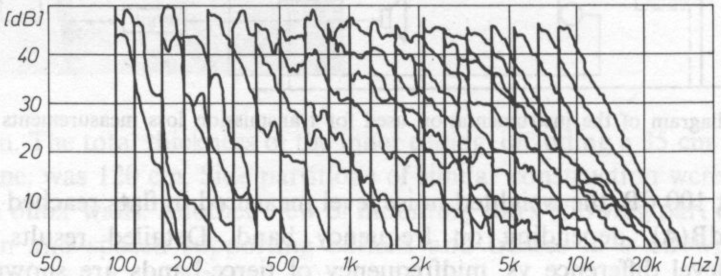


FIG. 10. Decay curves measured in a flat above theatre ceiling

Beside of transmission loss measurements a tightness test was executed. Ventilation system was used to check the tightness of the mounted sound barriers. All doors were shut and door slits were sealed up with glue-tapes. After the blow-in system was switched in, while the exhaust system was switched out, the static pressure rose quickly to 0.5 at above the normal level, thus showing very good tightness of the implemented sound-barriers.

The obtained results of transmission loss measurements might be compared to an insertion loss evaluated on the basis of comparison between measurements made before and after the implementation of the adaptation project. However, such evaluation requires certain assumptions to be fulfilled [3], which are not satisfied in the presented case.

During several months of theatre activity after the adaptation completion there were neither complaints on noise among the building residents, nor any critical remarks of performers or of audience on unwanted sound inside the hall.

8. Conclusions

A brief description of an acoustical adaptation design was given. The presented information seems to be sufficient to derive conclusions useful for acoustical designers dealing with similar problems, which may be relatively often met in practice.

The concept of "box within box" insulating construction gained a successful application example, applied to an existing building, not a newly built one. The attained degree of insulation expressed by the more than 65 dB sound reduction index may be assessed as an encouraging result. Courageous application of very thick layers of good quality mineral wool turned out to be advantageous, despite small total thickness of the applied sound-barriers, relative to recommended values.

Very important is the tightness of the insulating barrier. A new concept of the tightness checking has been proposed and verified in practice, as a proof of the barrier implementation quality. A more precisely method of such checking should be of course, elaborated.

The reviewed literature concerned with various acoustical questions met in adaptation designs of concert halls proved that sound insulation problems were disregarded so far, while their influence on hall acoustical quality is really important and worth further theoretical and practical investigation.

References

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