Investigation of the acoustical influence of lighting equipment in performing spaces

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ABSTRACT

The characteristics of lighting equipment were investigated to know the acoustical influence in the hall. The absorption coefficients were measured in reverberation chamber with the representative lighting equipment of 1 kW and 2 kW according to ISO 354. Based on the absorption coefficients, laboratory tests using 1:10 scale model of test specimens were carried out to identify the scattering characteristics. As a result, it was derived that the averaged absorption coefficients were increased from 0.04 to 0.10 in 1 kW and 0.05 to 0.13 in 2 kW as the density varies from 5 to 15 % and 5 to 16 %, respectively and the averaged scattering coefficients were ranged from 0.19 to 0.25 in 1 kW and from 0.18 to 0.22 in 2 kW as the density varies from 5 to 15 % and 5 to 16 %, respectively.

Keywords: lighting equipment, absorption, scattering coefficients
I-INCE Classification of Subjects Number(s): 51.1

1. INTRODUCTION

The acoustical characteristics of a space are affected by diverse elements, including walls, ceiling, seats, floor, audience, musicians, and stage elements. Diverse research papers have addressed the acoustical characteristics of the musicians. Barron and Lee (1) found that the sound pressure level decreased by 1.3 dB when the hall was occupied. Jeon and Barron (2) observed that musicians, when present, reduced acoustic reflections from the stage wall and, in a scale model, provided reflections of their own. In addition to musicians, both chairs and the audience also affect a room’s acoustic characteristics. Previous studies on audience absorption of sound in concert halls include ones by Beranek (3–5), who studied the effects of seats and the audience occupying the space. Wall materials, such as diffusers, are also an important factor affecting the acoustics of concert halls (6). In the case of ceiling materials, Kim et al. used a scale model to investigate the absorption characteristics of open ceilings in multi-purpose halls. They found the absorption coefficients of equipped ceilings ranged from 0.19 to 0.61, mostly at high frequencies (7). Variable stage elements also have a significant influence on reverberation times in the audience area (8).

These elements—walls, ceiling, seats, audience, and musicians—are essential elements affecting a space’s acoustical environment. Moreover, all elements are considered to be elements fixed in the space while the performance is taking place. In addition to these elements, in performing spaces such as multi-purpose halls, opera houses, and drama theaters, lighting equipment is installed over the stage, on the side walls, from the ceiling of the audience area, and sometimes on the stage floor. This equipment also works like fixed materials during a performance in the hall, despite variations in the position and density of the various pieces of lighting equipment. Jeon et al. investigated multipurpose halls, which have more complicated absorption characteristics; without information about ductwork and lighting equipment, predicting accurate results from a computer simulation proved difficult (9).

This study aims to investigate the influence of lighting equipment in a performance hall. Absorption coefficients of 1 kW and 2 kW lights were measured in a reverberation chamber according to ISO-354 (10). Based on the absorption coefficients, scattering coefficients were measured in a 1:10 scale model.

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2. Methodology

2.1 Absorption coefficients of the lighting equipment

The absorption coefficients of the lights were measured in a reverberation chamber with total volume of 325 m^3 according to ISO 354 (10), as shown in Fig. 1. The equipment used to perform the measurements included the following elements: a JBL SRX-725 loudspeaker and 6.5" free-field microphones (G.R.A.S.). The sound source was MLS (Maximum Length Sequence).

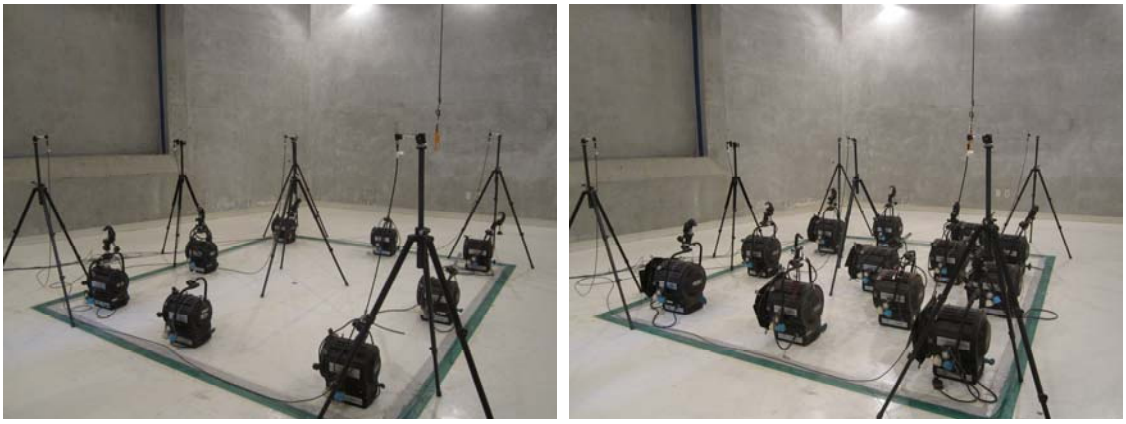

Figure 1 – 1 kW and 2 kW lighting equipment in the reverberation chamber.

The measured absorption coefficients of the two sizes of lights appear in Fig. 2. As the occupying density increased, the absorption coefficient also increased for both the 1 kW and 2 kW lights.

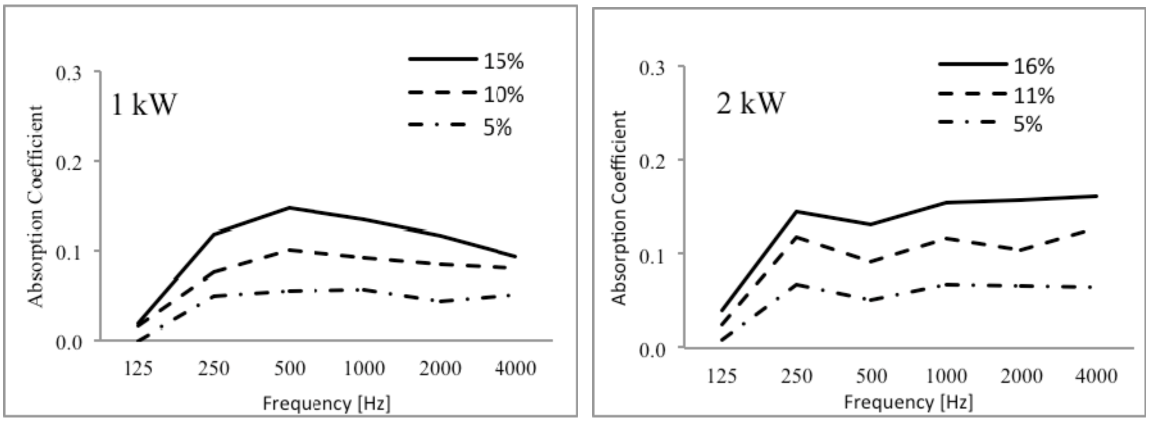

Figure 2 – The absorption coefficients for 1 kW and 2 kW lights in the octave band as the density varies.

The light equipment consisted of metal, glass, and lamps, which are mostly reflective materials. Thus, acrylic plates were chosen as the materials for fabricating the scale-model specimens, which were made to be cylinders with diameters of 2.5 cm and lengths of 3.0 cm in the case of the 1 kW lights and diameters of 3.0 cm and length of 3.5 cm in the case of the 2 kW lights. These dimensions were based on the size of the lights. The absorption coefficients of the scale model were measured in a 1:10 reverberation chamber using A-type mounting, according to ISO 354, to match the in situ measurement. The absorption coefficients were calculated for the octave bands using the difference in the absorption power caused by the presence of the test specimens. The absorption coefficients of the scale-model specimens matched the absorption coefficients of in situ measurements at less than 0.05 in the octave bands, as shown in Fig. 3.

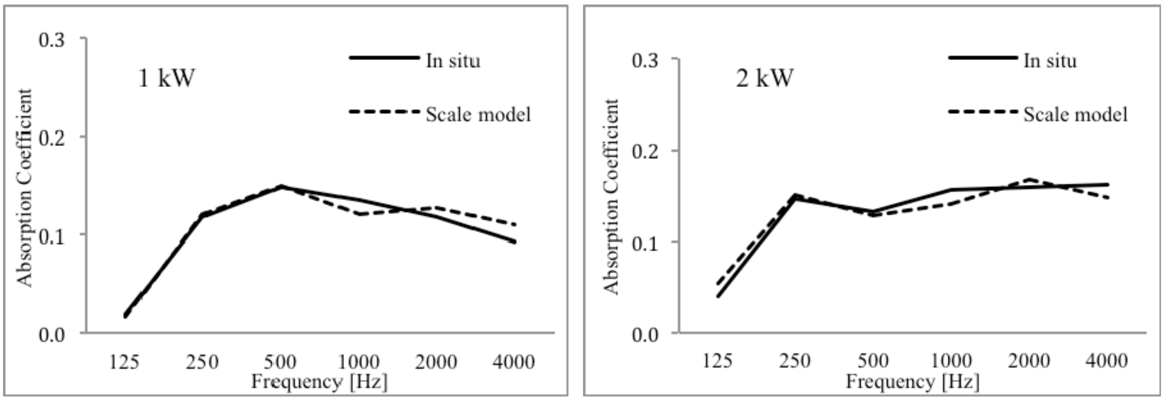

Figure 3 – The absorption coefficients of the 1:10 scale models of 1 kW and 2 kW lights.

2.2 Scattering coefficients of the lighting equipment

The scattering coefficients were measured in the 1:10 scale reverberation chamber using a moving electric turntable with a 420 mm-diameter circular plate and two tweeter speakers located in the corner of the reverberation chamber according to ISO 17497-1 (11). Impulse responses were taken in 88 different directions in a rotation cycle using a multi-MLS signal. The signals were measured at two source positions and four receiver positions using a 1/8-in microphone. Environmental conditions like temperature and relative humidity were measured for correction of air absorption with regard to the ISO 9613-1 (12). In order to measure the scattering coefficients, four averaged reverberation times (T15) were calculated according to the presence of the test specimens and the rotation of the turntable. The results are shown in Fig. 4.

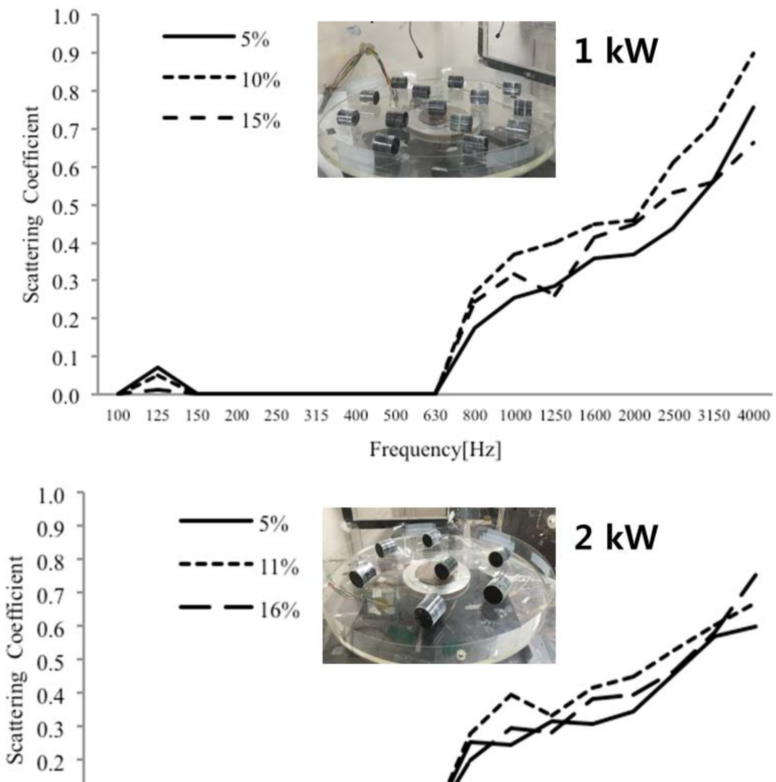

Figure 4 – The scattering coefficients of the 1 kW and 2 kW scale model specimens at varying densities.

3. Discussion

In this study, two fundamental coefficients of the lighting equipment were investigated. The absorption coefficient was increased as the density and the size of the lighting equipment increases. When the scale model light was put in the vertical, the absorption coefficient was decreased up to 0.03 in the averaged octave band. According to the ISO 354, it was recommended to put the discrete objects not closer than 0.75 m to any other boundary. In this study, the absorption coefficient was measured from the density of 5 % to 28 %. In the closest case, the distance between the lighting equipment was shorter than 0.75m, but the absorption coefficient was increased linearly as the density increases. In case of the scattering coefficient, it was increased linearly in accordance with the density, but decreased as the size increases.

4. Summary

In the present study, the essential coefficients of lighting equipment were measured to ascertain the equipment's characteristics. The averaged absorption coefficients (100 Hz–4 kHz) were increased from 0.04 to 0.10 with the 1 kW lights and 0.05 to 0.13 with the 2 kW lights as the density varied from 5 % to 15 % and 5 % to 16 %, respectively. The averaged scattering coefficients (100 Hz–4 kHz) varied from 0.19 to 0.25 for the 1 kW lights and from 0.18 to 0.22 for the 2 kW lights as the density varied from 5 % to 15 % and 5 % to 16 %, respectively. In the future, both the simulation and scale model methods will be conducted with the results of present measurements in order to determine the acoustical influence of lighting equipment in the performance hall.

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REFERENCES

1. Barron M. Energy relations in concert auditoriums . I. 2013;618–28.
2. Jeon JY, M B. Evalustion of Stage Acoustics in Seoul Arts Center Concert Hall by Measuring Stage Support. J Acoust Soc Am. 2005;117:232.
3. Beranek LL. Audience and Seat Absorption in Large Halls. J Acoust Soc Am. 1960;32(6):661–70.
4. Beranek LL, Hidaka T. Sound absorption in concert halls by seats, occupied and unoccupied, and by the hall's interior surfaces. J Acoust Soc Am. 1998;104:3169.
5. Hidaka T, Nishihara N, Beranek LL. Relation of acoustical parameters with and without audiences in concert halls and a simple method for simulating the occupied state. 2001;109(3):1–5.
6. Barron M. Auditorium Acoustics and Architectural Design. Spon Press; 2009.
7. Kim YH, Lee HM, Seo CK, Jeon JY. Investigating the absorption characteristics of open ceilings in multi-purpose halls using a 1:25 scale model. Appl Acoust. 2010;71:473–8.
8. Jeon JY, Kim H, Ryu JK. The effects of stage absorption on reverberation times in opera house seating areas. J Acoust Soc Am. 2015;15:1099–107.
9. Jeon JY, Ryu JK, Kim YH, Sato S. Influence of absorption properties of materials on the accuracy of simulated acoustical measures in 1:10 scale model test. Appl Acoust. 2009;70(4):615–25.
10. ISO 354. Acoustics-measurement of sound absorption in a reverberation room. Geneve. 2006.
11. ISO 17497-1. Acoustics-sound scattering properties of surfaces. Part 1: measurement of the random-incidence scattering coefficient in a reverberation room. Geneve. 2004.
12. ISO 9613-1. Acoustics-attenuation of sound during propagation outdoors. Part1: Calculation of the absorption of sound by the atmosphere, Geneve. 1993.