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ACOUSTICAL MODELLING OF TROY MUSIC HALL

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INTRODUCTION

An acoustical model built to a scale of 1:16 was utilized in evaluating the acoustics of Troy Music Hall, Troy, New York. Temporal energy measurements were made at eight locations in the model. Different energy ratios such as early (0-50ms) to late (50ms-∞) were compared with the preferred values. The results are based on the initial assumption that Troy Music Hall has superior acoustical quality.

MODEL CONSTRUCTION

The model scale was set at 1:16, considering the fact that the maximum frequency intended was 2000 Hz (to avoid the problems of air absorption) and the highest octave filter available was 31,500 Hz. The model was constructed of 3/4" (1 cm) particle board with adequate support to avoid vibrations, and all the major details such as organ pipes and stage shell were modelled with care. It is believed that for objective model tests, precise selection of materials with absorption equal to that of prototypes in the increased frequencies was not necessary. The reflecting surfaces of the model were simulated by several coats of varnish and smooth plaster. The audience, the major source of absorption, were simulated with rows of egg cartons whose height correspond to the height of a seated audience. Several rows of egg cartons were placed on the stage representing the musicians. Fig. 1 shows a view of the model.

EXPERIMENTAL METHOD

A spark source was utilized to emit a loud signal from the stage and the impulse was recorded on magnetic tape at octave center frequencies from 2000 Hz to 31,500 Hz which correspond to frequencies at prototype from 125 Hz to 2000 Hz. Fig. 2 shows the eight test locations. The recorded signal was played back into a storage scope to obtain echograms. An upper limit of 280ms was set on the horizontal time scale because of technical limitations. Each pulse in the echogram was converted into decibel units and the levels were integrated as per different temporal energy criteria.

EXPERIMENTAL RESULTS

a. Ratio of 0-50ms (early) to 50ms-∞(late) energy. This ratio is based on Sukharovskii's assumption that the useful sound is the total components of sound arriving within 50ms.[1] Fig. 3 shows the results at all the eight selected test locations. The ratio ranges from +5 dB to -8 dB. Except for positions 4 and 14, all other positions are dominated by the late energy. Schultz defines the tolerable range for this ratio as 5 dB, and a ratio of 10 dB causes excessive liveness. Only at position 13, which is under the first balcony, the ratio has a value of -8 dB which shows that this location gets more than adequate amount of late energy, and the early reflections are shielded by the overhanging balcony. Except for this position, Troy Music Hall has the acceptable range of reverberant energy.

b. Ratio of 0-80ms (early) to 80-∞ (late) energy. According to Reichardt, etal,[2] this ratio is more valid than the previous one. Fig. 4 shows the ratio at eight test locations. In general, Position 4 is dominated by early energy, whereas positions 3 and 13 are dominated by late energy at lower frequencies. Results of Reichardt, etal, suggest a difference limen of -2 dB for a highly diffused hall. Except for locations closer to the stage, the ratios do not have a great difference from the published limit of 2 dB. At mid and high frequencies, Position-10 maintains a ratio in the range of +2 dB emphasizing the strong early sound. At mid and high frequencies the ratios for Position 10 are between +2 dB and 0 dB. This could explain that this position has clarity as well as having its ratios stay within the preferred limit of 2 dB.

c. Ratio of 0-50ms (early) to 0-∞ (total) energy. This ratio, otherwise called "Definition" (Deutlichkeit) is the ratio between the early to the total energy.[3] Fig. 5 shows the ratios at the eight test positions. The values in the graph stay within the -8 dB limit. At mid frequencies, the values do not exceed -6 dB in the graph. Thiele's measurements showed that this ratio varied only 3-5 dB in any one theater and only 8 dB in all the theaters and studios he measured. Since Thiele measured only well-liked spaces, this enables us to take this range as preferred value for the quantity "Definition" (D). The ratios in the graph stay within the preferred range and this indicates the existence of 'Definition' and liveness.

d. Rise Time and Inversion Index. V. L. Jordan defines this as the time interval within which half the sound energy of the complete process arrives. This is associated with the idea that the rise period of musical sound must not be too long and that the arrival of 50% of the energy indicates the rapidity of room response.[3] Subsequently, "Inversion Index" was calculated by the relationship, Rise Time,Aud/Rise Time, Stage. The preferred value of Inversion Index in terms of Rise Time is 1 or more than 1. The values of the Inversion Index averaged over the six test locations (except Position 4 which is closer to the stage) are more than 1.0 and this would imply that the musical notes rise faster on the stage than in the auditorium.

e. Steepness and Inversion Index. V. L. Jordan defines this criteria as the interval of time after the source is switched on, when the sound energy is 5 dB less than the steady state level. Subsequently he formulates a relationship, $\sigma = d/dt\,(10 \log I_0/I{\div}5)$ dB/msec, which is the rise of the sound energy in dB/msec.[3] The rise in dB/msec is utilized to derive the relationship of the "Inversion Index" which is steepness, auditorium/steepness, stage. The preferred value of the Inversion Index is 1 or less than 1. This is based on the fact that sound should rise at the stage faster than at the auditorium. Except at position 4 which is closer to the stage, the value of Inversion Index is less than or equal to 1, and this shows that sound rises faster at the stage than in the auditorium.

f. Envelopment and Clarity. Veneklasen defines the importance of lateral reflections for providing "envelopment" and this is enhanced by a minimum of three lateral reflections, with the initial reflection coming within 50ms after the direct sound.[4] Veneklasen also prefers one co-planar reflection occurring less than 40ms after the direct sound to aid the direct sound for clarity. Only positions 10 and 11 in the first and second balconies get a co-planer reflection within 40msec. All the test locations get an "envelopmental reflection " within 50msec. The balcony positions are the most preferred positions among the concert goers because of the subjective acoustical quality. The arrival of a co-planar reflection within the time period as preferred by Veneklasen implies that the balcony locations provide "clarity".

SUMMARY

The study assumes the accepted high quality of the Troy Music Hall and it takes into account that the objective qualities prior to the reverberation process can be measured in an acoustical model without matching the model materials with the prototypes in terms of absorption at the increased frequencies. Comparison of results obtained in the model study with the published data are in full agreement. The preferred ratios in terms of various early and late time periods coincide well with the model results. These objective results in the model coincide with different subjective qualities of Troy Music Hall.

ACKNOWLEDGEMENTS

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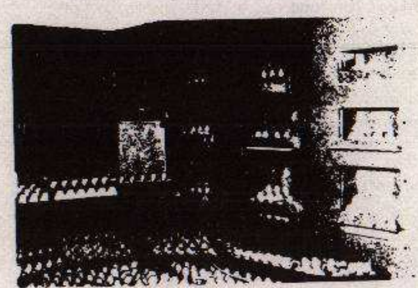


Fig. 1 Acoustical Model of Troy Music Hall

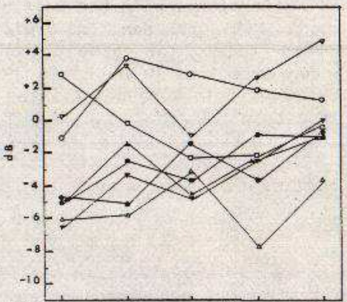


Fig. 3 Ratio of 0-50ms to 50ms energy

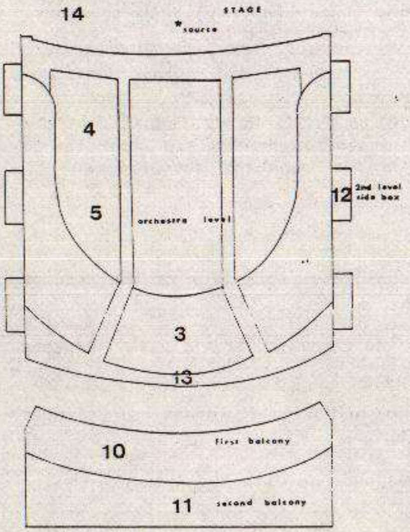
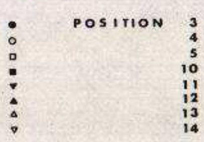


Fig. 2 Model Test Locations



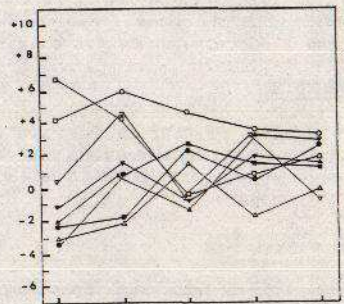


Fig. 4 Ratio of 0-80ms to 80ms-energy

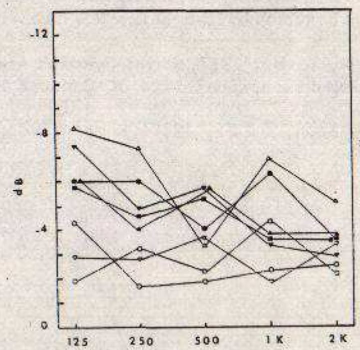


Fig. 5 Ratio of 0-50ms to 0ms-energy