ICA 11 BEIJING 1992

F5-6

THEATRES AND OPERA HOUSES IN THE CITY OF BOLOGNA

Massimo GARAI, Angelo FARINA, Giovanni SEMPRINI

Istituto di Fisica Tecnica, Eng. Faculty, Bologna University, Viale Risorgimento 2, 40136 Bologna, Italy

1. MEASUREMENT TECHNIQUE AND METHODOLOGY

In situ measurements were made using a system composed by: 1) a loudspeaker, located on the stage; 2) a two-microphones dummy head; 3) a PC with a special analysis board, controlling the loudspeaker and the dummy head; 4) an FM transmitter, connecting the dummy head to the PC; in this way the dummy head could be quickly moved to several positions.

The PC-board drove the loudspeaker with pseudo-random binary sequences of maximum length (MLS); the signals picked up by the dummy head were processed with a fast algorithm to obtain the in situ impulse responses [1]. The cross-correlation implied in the computation rejected unwanted noise, improving the final S/N ratio.

From the impulse response, the following basic quantities were computed: 1) listening level L; 2) ITDG (initial time-delay gap) Δt_1; 3) reverberant-to-direct energy ratio R/D; 4) reverberation time T_{15}; 5) early-to-late energy ratio E/L (*early* means < 5 ms); 6) IACC (inter aural cross-correlation); 7) Clarity C_{50}; 8) Clarity C_{80}; 9) baricentric time t_s; 10) EDT (early decay time); 11) RASTI (rapid speech transmission index).

A subset of this ensemble was used to compute the four orthogonal preference indices of the Ando's theory [1]. Linearly superposing the four preference indices, the total preference was obtained at each seat of the halls under test.

The weight α_3 for the reverberation time preference depends on the *equivalent amplitude of the reflections* A_r [1], that has been evaluated from the R/D energy ratio. Many authors compute A_r choosing a fixed value for the time instant assumed for the beginning of the reverberant contribution (e.g. 5 ms), but we prefer to select it by visual inspection of the (squared) impulse response.

The listening level was assumed to reach its optimum value in the center of the audience at about 20 m from the source. The preferred values for the ITDG and for the reverberation time were referred to music samples with an effective duration of the autocorrelation function equal to: τ_e= 38 ms (Mozart, KV 551, IV mov.) and with τ_e= 127 ms (Gibbons, Royal Pavane).

2. RESULTS FOR AN ITALIAN OPERA HOUSE

The "Comunale" theatre of Bologna is a typical Italian opera house of the 18th century. It is a horseshoe in plan with high balcony faces and a vaulted ceiling. It has 540 seats on the main floor and 466 seats in the boxes and in the gallery. The seats are upholstered.

2.1 Audience Floor

The preference for the listening level has a nearly constant value, with a slight diminishment just in front of the stage. On the other hand, the ITDG preference is better in a central strip-shaped zone, covering about one third of the main floor, and then decreases approaching the lateral sides, where a reflecting plaster strip lyes just under the first order of boxes. The reverberation time preference (depending on A_r) for the fast music decreases toward the rear of the audience, while for the slow music it becomes better. The IACC preference is of course better out from the center of the audience. Thus, three partial preference indices have considerable variations over the main floor, although the final superposition partly balances these effects, revealing design rules founded on past experience.

The best listening conditions for the fast music are reached in the rear seats of the audience (Fig.1), and the most relevant parameter for this judgment is the IACC (Fig.2). The same seats are still the less unsuitable for listening to slower orchestral music, but - as expected - the global preference is lower, owing to a non-optimal value of the ITDG (Fig.2).

2.2 Lateral Boxes

The dummy head was placed in the opening of the boxes, because in the rear of them the listening - and the looking - quality is compromised. The preference indices for the listening level and for the reverberation time are close to those obtained on the main floor. The ITDG preference evaluation is altered by the early reflections on the box walls, which arrive before the *true* stronger reflection, that mostly comes from the ceiling. The IACC preference values suggest that the lateral boxes, apart those just on the side of the stage, are better than the rear ones; on the other hand, looking at the values of clarity, a meaningful parameter for the opera listeners, it seems that the boxes near the stage and in the rear wall should be preferable (Fig.3).

3. RESULTS FOR A MULTIPURPOSE HALL

The "Europa" hall is a modern multipurpose hall with a polygonal shape. It has 967 seats on the main floor, and 512 seats in two elevated enlargements of the main floor. The seats are upholstered.

The preference for the listening level grows slightly going to the rear of the audience. The ITDG preference is almost constant in the central zone of the main floor but diminishes in the "lateral halls". For τ_e = 127 ms the values are clearly worse. The reverberation time

preference has fairly good values in almost all the the room. The IACC preference is of course better out from the center of the audience. The regularity of the level and of the reverberation time preferences mirrors a design inspired to the classical Sabine's theory.

The best listening conditions for the fast music are reached in the central zone of the audience (Fig.4), and the most relevant parameter for this judgment is the IACC (Fig.5). The same seats are still the less unsuitable for listening to slower orchestral music, but in this case the ITDG maintains a non-optimal value (Fig.5).

4. REFERENCE

[1] Ando Y., *Concert Hall Acoustics*, Springer-Verlag, Berlin (1985).

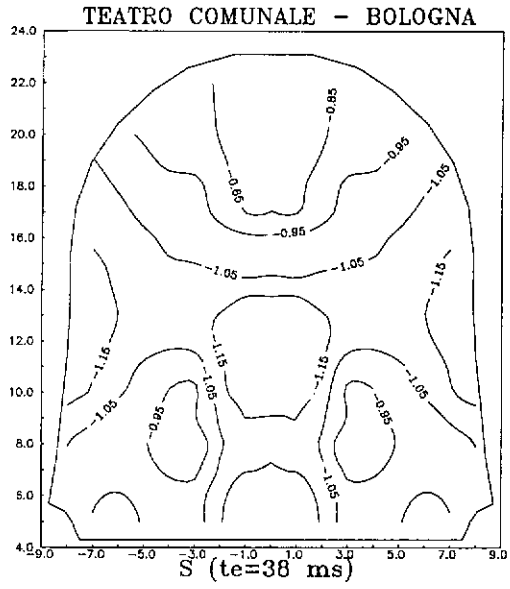

Fig. 1. Teatro Comunale. Contour lines of total subjective preference (τ_e=38 ms).

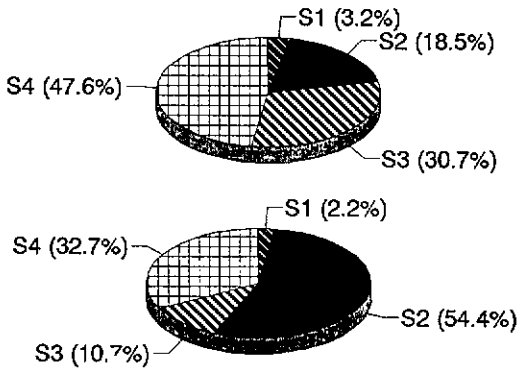

Fig. 2. Teatro Comunale. Partial preferences contributions to the total preference. Average values over the main floor. Up: τ_e = 38 ms; down: τ_e = 127 ms.

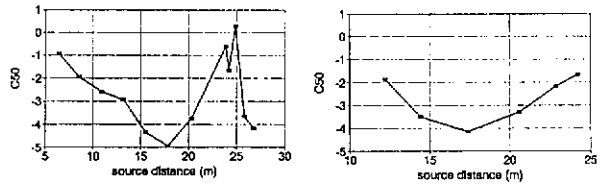

Fig. 3. Teatro Comunale. Plots of the clarity C_{50} values on a vertical section of the theatre (stage on the left) and in plan along the 2nd order of boxes.

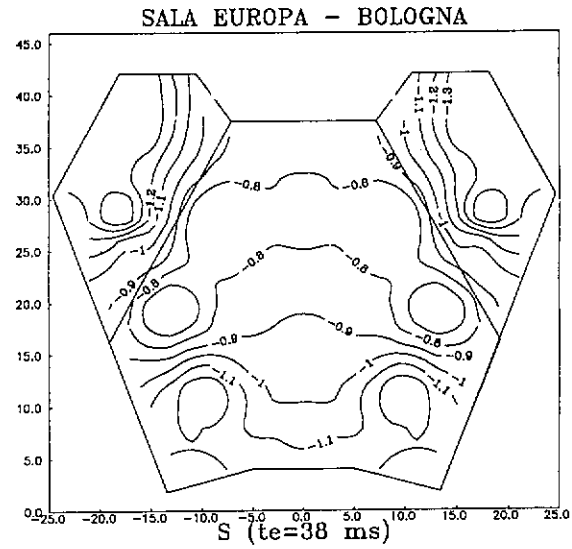

Fig. 4. Sala Europa. Contour lines of total subjective preference (τ_e=38 ms).

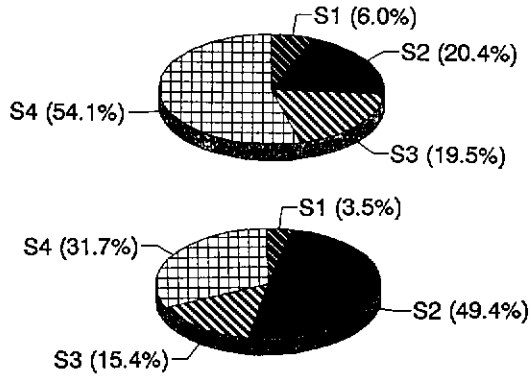

Fig. 5. Sala Europa. Partial preferences contributions to the total preference. Average values over the main floor. Up: τ_e = 38 ms; down: τ_e = 127 ms.