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THE ACOUSTIC DESIGN OF THE YORK BARBICAN

N F Spring

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1. INTRODUCTION

The York Barbican Centre opened in September 1991. It was planned in 1983 as a sports centre for the City of York, but as the plan developed, it was decided that the cer'^re would provide facilities for high quality live entertainment as well as indoor sports. The architect prepared his design to satisfy the requirements of international badminton and excellent acoustics for symphonic performance. The initial design was accepted and the City of York calculated that, by selling some assets, they could afford to spend about £8m on the scheme. With the prospect of engagement to scheme design, the architect then took the step of seeking professional acoustic advice, which we provided at a modest cost to the client.

2. THE BRIEF

The Director of Leisure, representing the client, explained that York did not have a satisfactory auditorium suitable for symphonic performance and an audience of about 1500. He hoped that the new auditorium would meet this requirement as well as being an attractive venue for recording companies.

2.1 Usage

The forecast usage of the centre included football, basketball, archery, pistol shooting, aerobics and roller-skating. About 100 entertainment events were expected each year.

2.2 Comparison with other halls

UK multi-purpose halls having similar usage to that envisaged for York were visited in Carlisle, Newport (Gwent) and Warwick. The Butterworth Hall at the University of Warwick impressed the Director of Leisure, and this was taken as a benchmark for the acoustic design [1].

3. SIZE AND SHAPE

The plan shape as originally conceived is shown, together with a longitudinal section, in Figure 1. The basic plan for the auditorium is a circle of diameter 40 m. At the stage end, the plan becomes rectangular in order to accommodate international badminton. The stage and wings were intended to be demountable for sports events. The seats at the lower level are retractable for sports events.

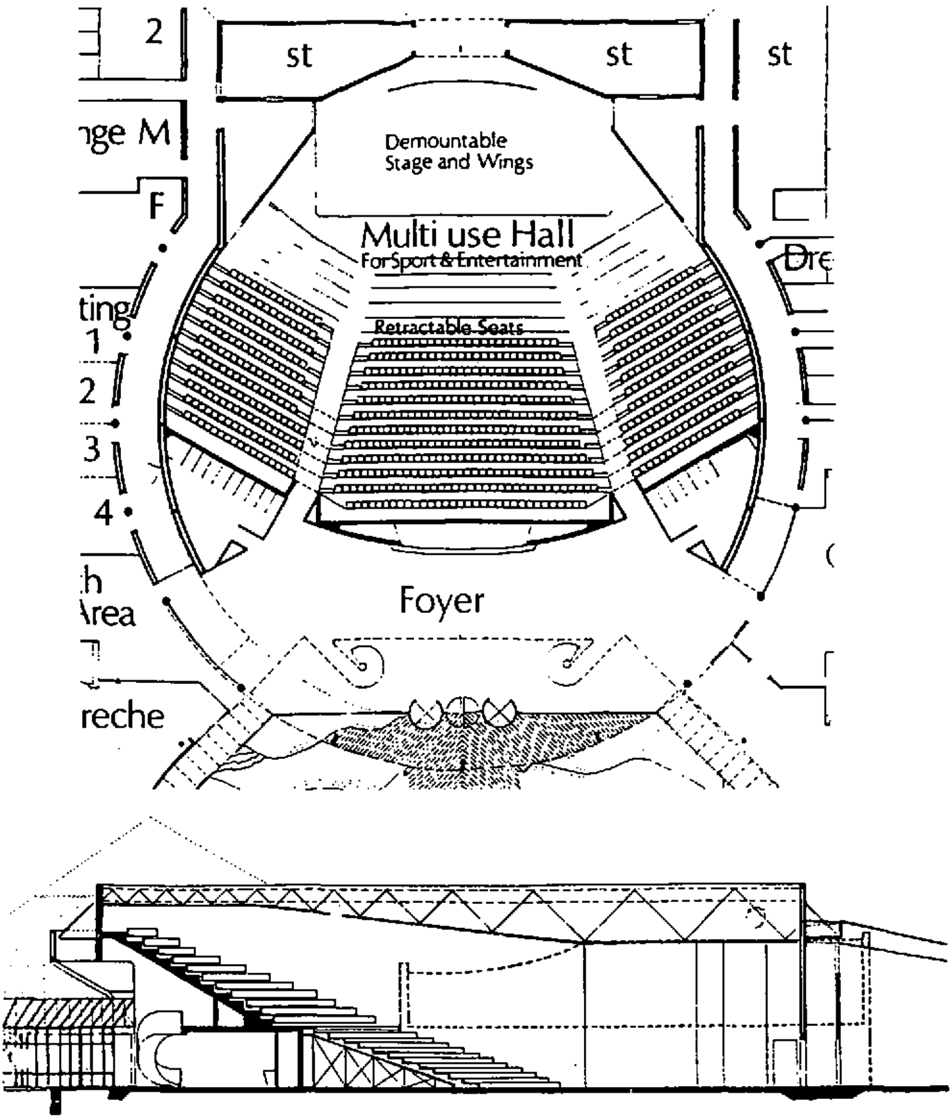

Figure 1. Plan and longitudinal section of initial design.

4. ACOUSTIC CONSIDERATIONS

4.1 Noise Intrusion

4.1.1 *External sources.* The site is in the middle of a circulatory road system bounded by Paragon Street, Barbican Road and Fishergate. Traffic noise was thought to be a likely problem with the lightweight sheet metal roof originally proposed.

The proposal for a sheet metal roof also gave rise to concern that rainfall noise would be a problem for symphonic, choral and solo performance.

4.1.2 *Internal sources.* The main hall was surrounded by a corridor which formed a useful buffer zone against noisy activities in other areas of the building. Weight lifting and roller skating were a potential noise hazard.

For concerts, a ventilation noise level of NR 20 was specified. It was recognised that a relaxation to NR 25 might be acceptable with a consequent reduction in costs. In the early stages of design, it was intended to explore this possibility by arranging a demonstration of the two noise levels in the Quiet Listening Room at the Building Research Establishment. However, it proved impracticable to slot the demonstration into the design programme.

4.2 Neighbourhood Noise

Noise emission from the building was seen as a potential problem. There is a housing estate to the north of the site, behind the city wall. Although the wall shields the estate from much of the noise, there is an unobstructed line of sight between the roof of the auditorium and the upper floors of the houses.

4.3 Acoustic Quality

4.3.1 *Loudness.* The loudness is determined, among other things, by the distance from the source and the early reflected sound energy. It was intended that local reflectors would be provided around the stage area to enhance the latter. The distance from the front of the stage to the furthest listener is approximately 34 m which compares with 30 m at Warwick.

4.3.2 *Reverberation time.* In view of the client's wish that the acoustics be biased towards good conditions for symphonic music, it was decided to design for maximum reverberation time. For those other entertainment uses of the hall, for which a less reverberant acoustic is usually preferred, it was considered that a well designed sound reinforcement system would provide satisfactory conditions.

The maximum reverberation time is limited by the cubic volume and the area of audience. For concert mode, the volume of the York Barbican is about 14,500 m^3. This is very satisfactory for concert hall use, providing a volume of 9.7 m^3 per seat. For comparison, the concert hall at Warwick has a volume of 9.2 m^3 per seat.

In order to provide warmth, it was decided to allow the low-frequency reverberation to rise.

4.3.3 *Ensemble*. Ensemble is enhanced by the provision of reflecting surfaces near to the performers. These were allowed for in the early acoustic design.

4.3.4 *Avoidance of echoes and focusing*. No particular problems with echoes were expected. The circular plan form gave rise to some concern that undesirable focusing effects would occur, especially as the front portion of the stage area was within the extended circle of curvature [2]. The risk of focusing was reduced to some extent by altering the internal walls to a series of plane surfaces.

5. CONSTRUCTION

In order that the reverberation be adequate for symphony concert use, no acoustic absorbents as such were deliberately introduced. It was expected that the audience and seating would provide most of the absorption at mid-frequencies.

In order to provide warmth, no additional low-frequency absorption as such was deliberately introduced. However, it was recognised that gratuitous low-frequency absorption would be provided by elements such as the seating (both fixed and retractable), ventilation ducting, the demountable stage and the movable partition.

5.1 Floor

The main floor is made of Granwood, a hard durable floor designed for sports use. The floor in the permanent seating area (balcony) is carpet on concrete, and for the retractable seating, carpet on timber.

5.2 Walls

The walls of the auditorium are of two leaves of dense concrete blocks (shot-blasted York Stone Forticrete), separated by an air space of approximately 300 mm.

5.3 Ceiling and roof

Initially, a lightweight roof combined with a plasterboard ceiling had been considered as sufficient sound insulation for sound transmission into and out of the building. However, doubts that this would be adequate at low frequencies and the difficulty of ensuring that the ceiling be imperforate led to the rejection of this arrangement. Instead, the roof was made of pre-cast concrete planks 200 mm thick, painted on the underside. The ceiling was omitted, providing the benefits of maximum cubic volume for the hall and a sound field exposed to the diffusing elements of ventilation ducting and structural steelwork.

5.4 Reflectors

Overhead reflectors, similar to those at Warwick, were provided above the stage area (Figure 2). Most of the reflectors are adjustable in height . For best acoustical effect they are probably best lowered to about 8 m above the stage. However, at this height they can be visually intrusive and may well interfere with the stage lighting.

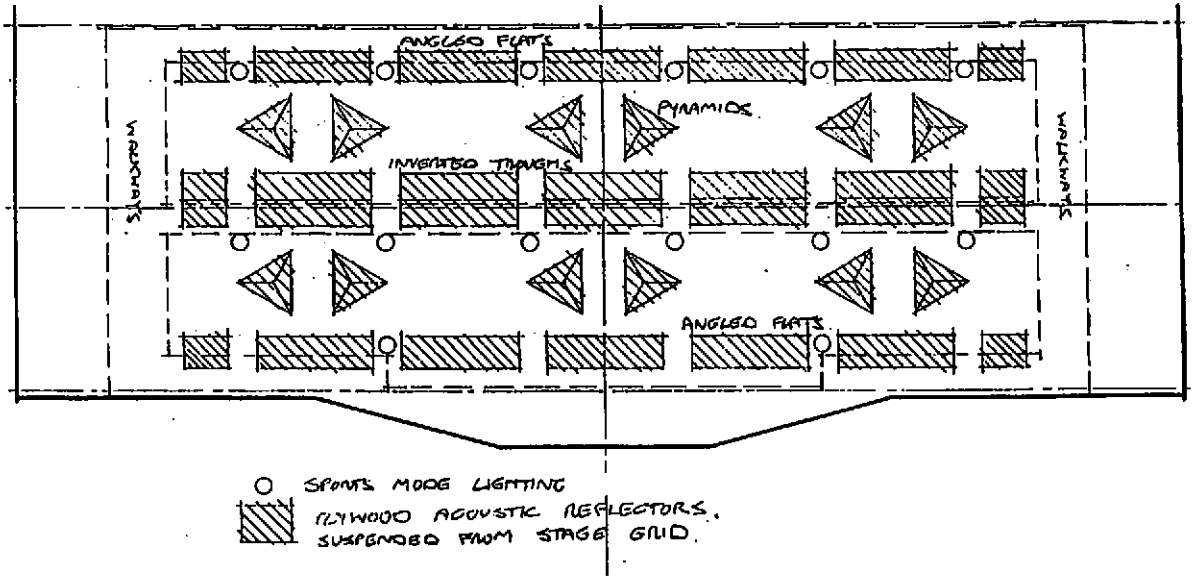

Figure 2. Reflected ceiling plan of overhead reflectors.

Demountable side reflectors were allowed for in the original design, but they were one of the casualties of a cost-cutting exercise.

6. RESULTS

6.1 Flutter echo

One of the most pronounced characteristics of the auditorium is a very prominent flutter echo between the two parallel side walls (32 m apart) either side of the stage. A single handclap in this area produces a very impressive repetition of the original sound, rather like the burst of a machine gun. The installation of the missing angled side reflectors would eliminate the flutter echo, but, in practice, the flutter has not been a problem requiring urgent remedial treatment. A relatively small amount of absorbent, for example a few chairs in the space between the walls, reduces the effect very markedly and it was estimated that a small number of performers would have a similar effect.

6.2 Royal Gala Concert

The centre was formally opened on 17 September 1991 and a Royal Gala Performance with the London Concert Orchestra and the Hallé Choir was held in the evening. At the rehearsal on the day of the concert, the timpanist was asked what he thought of the sound, in the expectation that he, of all the performers, would be most sensitive to the destabilising effects of a flutter echo. To the relief of the questioner, the timpanist thought the sound was very good and he only hoped that those out there in the audience would find it as good as he did.

The soprano seemed to have no difficulty at all, but the tenor was very worried that all the sound from his voice seemed to be lost 'up there', pointing to the black void of the ceiling. It was pointed out that although it could not be seen, the ceiling was very reflective and there were no acoustical absorbents up there. The actual performance in the evening by the soloists, orchestra and choir was a great success.

6.3 Broadcasting

It is reported that the BBC find the acoustics generally very satisfactory for broadcasting, but consider that side screens would be highly desirable to reduce bounce off the side walls.

6.4 Reverberation time

The reverberation time was measured at the first practicable opportunity during the construction period, that is when the doors had been installed. The measurements were made before the seating was installed and are shown in Figure 3. After the seats were installed, the reverberation time was again measured and the results are also shown in Figure 3. At two subsequent live concerts attempts were made to determine the occupied reverberation times from analysis of recordings of the performances but the results are not sufficiently reliable to present here.

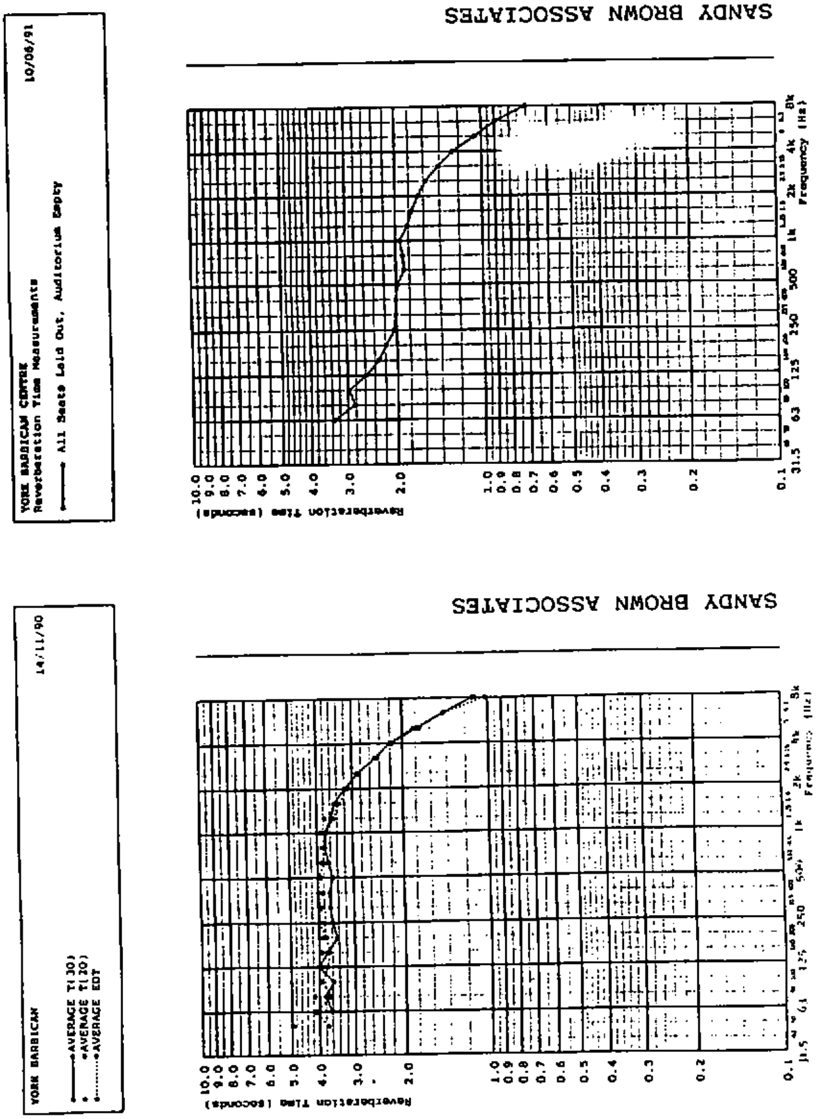

Figure 3. Reverberation time of auditorium before (14/11/90) and after seats installed (10/06/91).

6.5 Effect of reflectors

Dr James Angus of the University of York has carried out experiments on the effects of re-orienting the reflectors. He reports that they have a very noticeable effect on the perceived acoustic.

6.6 Noise level

After some initial difficulties, the noise level of the ventilation system was brought down to NR 20 in concert mode. For sports mode, the ventilation system is designed to move the air at greater speed and the noise level is consequently greater.

7. ACKNOWLEDGEMENT

I am grateful to the architect FaulknerBrowns* for the use of the drawings for Figure 1.

8. REFERENCES

[1] CHARLES, J. G., FLEMING, D.B. AND MILLER, J. (1985) The hall of the University of Warwick. *Applied Acoustics*, **18**, 195-234.

[2] BARRON, M (1993) Auditorium acoustics and architectural design. E & FN Spon. London