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MORE MEASUREMENTS ON AUDIENCE AND SEAT ABSORPTION

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INTRODUCTION

Two medium sized auditoria are nearing completion in the north of England; namely at the Town Hall in Bolton and at the Sands Centre in Carlisle.

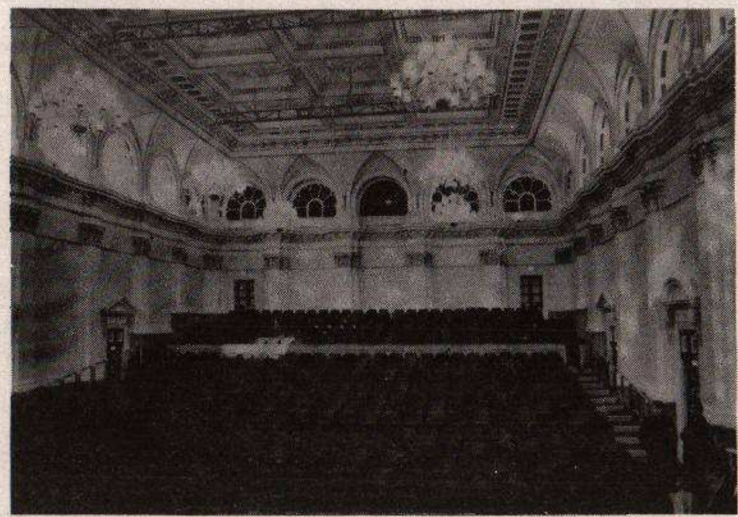
Samples of seating for both auditoria were supplied by the manufacturer for sound absorption measurements in the large (225m^3) reverberation chamber at Salford University. Fortunately, it was possible to retain the seating for experimental measurements so that various alternative configurations could be tested in addition to the usual central sample layout. This opportunity, in conjunction with the possibility of comparing the results with measurements in the auditoria themselves before and after the installation of seating, provided the incentive to take another overall look at seating absorption and its measurement. The data collected has been compared with absorption figures for seating from other laboratories and auditoria.

DESIGN FEATURES OF THE AUDITORIA AT BOLTON AND CARLISLE

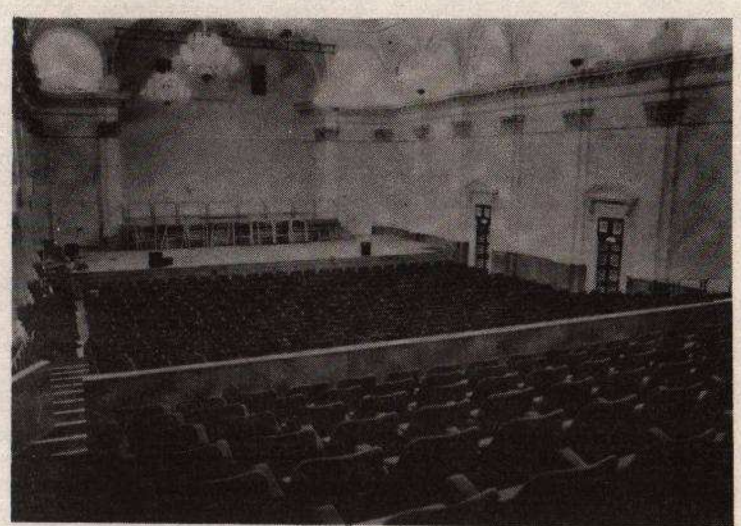
Before discussing the results of the seating absorption measurements, it is worth outlining the general design features of the Bolton and Carlisle auditoria where the two types of seating are now installed.

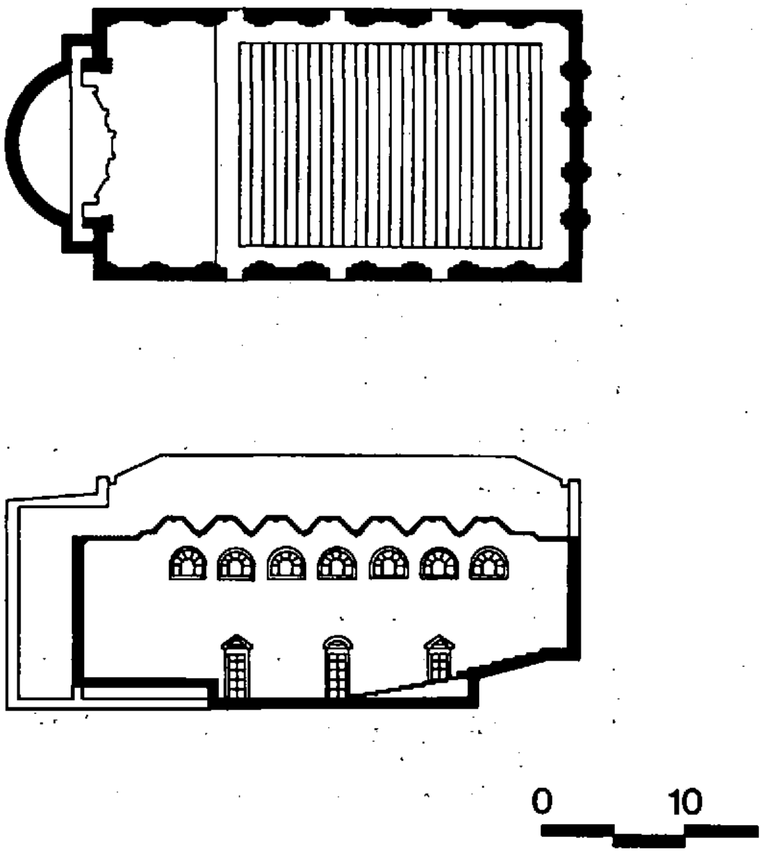
Bolton Town Hall is a grand Victorian building which originally housed a traditional 'shoe-box' shaped auditorium typical of many 19th century halls. The 17m high ceiling of the auditorium ensured a long reverberation time which was suitable for then-fashionable organ recitals. Unfortunately the building, in particular the roof, was badly damaged by fire in 1981. Plans for rebuilding were strongly influenced by the need for the new hall to serve a broad base of cultural activities and also to be profitable. This policy gave rise to a design in which the original hall was split into two; forming an upper and lower hall. The upper hall, shown in Figure 1, has the higher ceiling and remains as an auditorium with a seating capacity of 700. All the seats, except those on the balcony, can be mounted on bleachers or on the flat floor thus giving a variety of seating arrangements; for example, the performing area can be in the centre of the hall instead of at one end. This flexibility means that the hall is suitable for multipurpose use although good acoustics for musical performance has been a dominant factor in the design.

The Sands Centre in Carlisle is a modern civic building which houses a multi-purpose hall with a maximum seating capacity of 1400; Figure 2. Here again the seating is mounted on bleachers so that activities ranging from sport to music can be accommodated. The design policy emphasised the need for the hall to be suitable for the performance of music including orchestral concerts. This has determined the criteria for reverberation and background noise level. To underline the management's intention of promoting concerts, the hall is scheduled to open in April, 1985 with Beethoven's ninth symphony performed by the Scottish National Orchestra and Chorus.



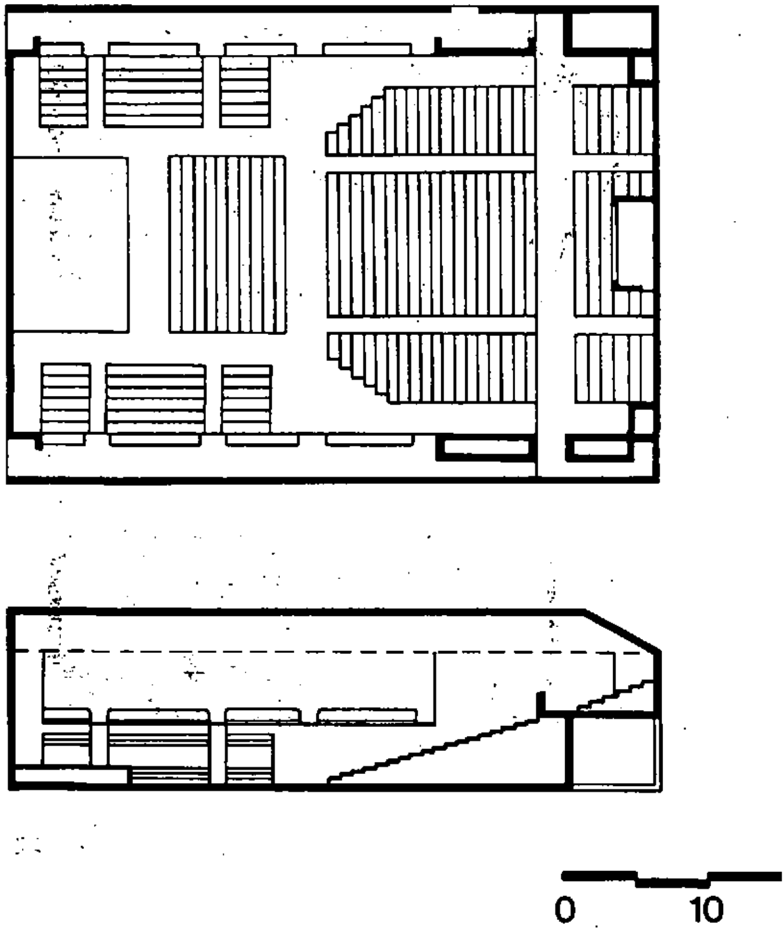
BOLTON TOWN HALL





BOLTON TOWN HALL

Fig. 1



SANDS LEISURE CENTRE, CARLISLE

Fig. 2

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SEATING ABSORPTION MEASUREMENTS

Sample arrangements

Measurement of the absorption of an array of seating is complicated by the extra absorption of exposed edges. This is particularly relevant in reverberation chamber measurements because of the inevitably small sample size and the high ratio of edge length to plan area; in effect one row out of every 3 or 4 in the sample is an exposed 'front' row giving greater absorption. Therefore measurement of a small seating sample in the centre of a reverberation chamber tends to give higher values of absorption than when the seating is in a large array. Although corrections can be applied, they tend to vary with seating type and there is no common agreement on which values should be used.

An alternative method has been proposed by Kath and Kuhl [1] which involves placing the seating in the corner of the chamber with a barrier obscuring the side and exposed front as shown in Figure 3. This method clearly aims at eliminating edge effects by completely boxing in the seating to represent a sample from the centre of a large seating area. Minor errors can occur at low frequencies due to the doubling of sound pressure at reflective walls; however these effects have not been accounted for in the present results.

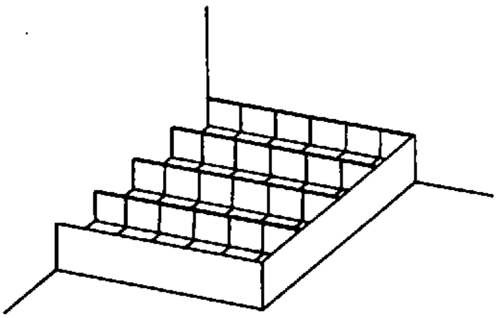

Fig. 3 Arrangement of Seating in Reverberation Chamber after Kath and Kuhl

Seating at Bolton Town Hall

The absorption of the seating for Bolton Town Hall was measured in the reverberation chamber using an array of four rows of six seats. The inter-row spacing was 82cm, the same as in the auditorium, and the seat squabs were in the upright position to correspond with conditions in the unoccupied hall.

For the first measurement the seats were placed in the centre of the chamber in the usual sample position; the resulting absorption coefficient is shown as curve a in Figure 4. Secondly, the seats were placed in the corner of the chamber with a plywood barrier around the front and side edges after the method proposed by Kath and Kuhl. This arrangement gave results as shown in curve b in Figure 4. As expected, the absorption was significantly lower when the edges of the seating were obscured from the sound field.

To evaluate whether one of these test configurations gives absorption values which correspond with those of seating once installed in the auditorium, measurements were carried out at Bolton Town Hall with and without two thirds of the seating installed: this being the number that are removeable. The measurements were carried out on the same day so that all other conditions were unchanged. The absorption coefficient calculated from the reverberation times is shown as curve c in Figure 4. No correction was applied for edge effect. The agreement

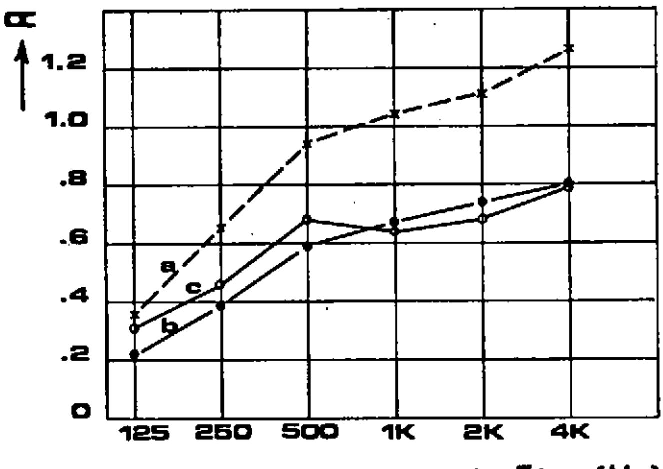

Fig. 4 Absorption coefficient of seating at Bolton Town Hall

a. Measured in reverberation chamber in central position.
b. As a, but in corner position with barriers.
c. Measured in auditorium.

with the results from the reverberation chamber measurements using a corner arrangement with barriers is remarkably good. This encouraging first result supports the use of Kath and Kuhl's method and justified undertaking further measurements.

Seating absorption at Sands Centre, Carlisle

The absorption of the seating for the Sands Centre was measured in the same two configurations as for the Bolton seating, namely 24 seats in a central arrangement and the same arrangement in a corner with surrounding barriers. The results are shown in Figure 5. Here again the absorption with the corner arrangement is lower although the difference is less marked than with the Bolton seating. A

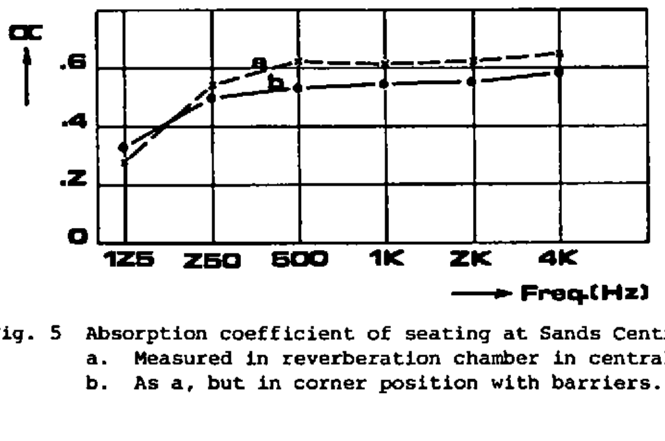

Fig. 5 Absorption coefficient of seating at Sands Centre, Carlisle
a. Measured in reverberation chamber in central position.
b. As a, but in corner position with barriers.

comparison with absorption measurements in the auditorium with and without seating installed is not yet available although it is hoped to present the figures when the paper is presented.

Seating at St David's Hall, Cardiff

The acoustic consultants of St David's Hall* measured the reverberation time before and after the installation of seating thus enabling the seating absorption to be evaluated. In addition, the seating absorption was measured in the Salford reverberation chamber in two configurations, a central position and a corner position with barriers. The results are shown in Figure 6.

It is again evident that a corner arrangement, shown as curve b, gives less absorption than a central one, curve a. Also curve b shows much better agreement with curve c, the results from the measurements in the auditorium. The agreement is not as impressive as in the case of Bolton, but it is possible that the conditions in the auditorium before and after seating installation were not identical.

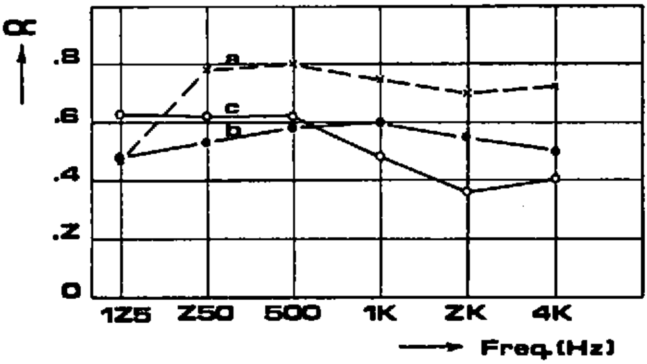

Fig. 6 Absorption of seating at St David's Hall

a. Measured in reverberation chamber in central position.
b. As a, but in corner position with barriers.
c. Measured in auditorium.

Summarizing the results to date, measurement of seating absorption in a corner arrangement with barriers gives, as expected, lower results than a central arrangement. Kath and Kuhl proposed that the corner arrangement simulated the absorption of an infinitely large seating area. The evidence so far is that using their method gives absorption results which correspond reasonably well with measurements in auditoria. It is hoped that further measurements will confirm this.

GENERAL DATA ON SEATING ABSORPTION

During this study, data on seating absorption has been collected from various sources, in particular we are grateful to AIRO Ltd and Arup Acoustics. Some of this data is presented in Figure 7 in terms of absorption per seat, in all cases the seating has been measured in the centre of a reverberation chamber with the

*We are grateful to Sandy Brown Associates for being able to include these results in the present survey.

seat squabs in the upright position unless they are permanently fixed.

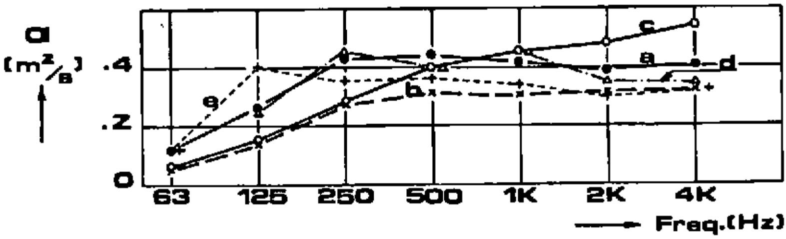

Fig. 7 Absorption of unoccupied seats in several halls in square metres per seat, evaluated from reverberation chamber measurements

All the curves exhibit broadly similar characteristics although it is worth noting that curve e, for example, shows substantially more absorption than the rest at 125Hz and curve c continues to increase at high frequencies whilst others reach an approximately constant level. The possibility of these untypical characteristics occurring suggests that the absorption of seating should always be measured if designers wish to ensure accurate prediction of reverberation time.

AUDIENCE ABSORPTION

Less data is available for the absorption of seated audience than for seating alone because of the obvious difficulties of arranging measurements. Three results are given in Figure 8 together with the figures proposed by Beranek [2] for comparison. In all cases measurements were made in the centre of a reverberation chamber. Generally, the curves agree with Beranek's figures although the results given by the large dots again indicate that characteristics can deviate appreciably from the norm.

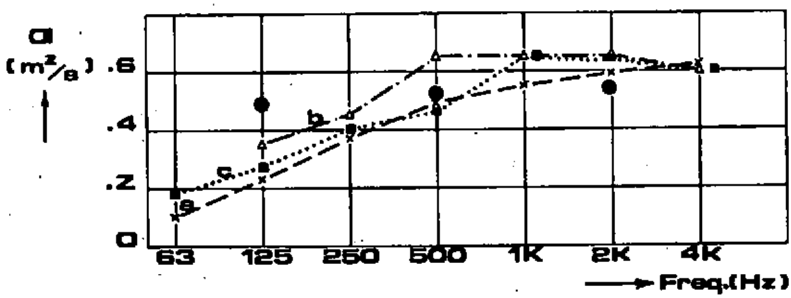

Fig. 8 Absorption of occupied seats in several halls in square metres per seat, evaluated from reverberation chamber measurements

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CONCLUSIONS

Designers of today's auditoria are expected to create spaces for an increasing number of uses, each having its own acoustical requirements. This means that the choice of Reverberation Time is inevitably a compromise. However, having proposed a particular value, the acoustician is expected to ensure that this value is achieved. The absorption of the seating and audience is the single most influential factor in determining Reverberation Time and accurate figures are necessary for accurate prediction. Measurements in a reverberation chamber are clearly the first step but there is little evidence to indicate how accurately the results correlate with the absorption of installed seating. By making measurements in auditoria before and after seating installation it has been possible to guage the accuracy of reverberation chamber measurements. The results so far indicate that the absorption of a sample of seating can correspond with auditorium conditions if the method proposed by Kath and Kuhl is adopted, namely by placing the seats in a corner with a barrier around the exposed edges. If this trend is confirmed by further measurements, it seems reasonable to adopt this method generally for measuring seating absorption. Ultimately seating manufacturers may be persuaded to quote absorption figures based on a standardised test method; this would undoubtedly be of great benefit to all auditorium designers.

REFERENCES

[1] U. Kath and W. Kuhl, 'Messungen zur Schallabsorption von Polsterstuhlen mit und ohne Personen', Acustica, Vol. 15, 127-131, (1965).

[2] L.L. Beranek, 'Audience and chair absorption in large halls, II', J.A.S.A., Vol. 45, 13-19, (1969).

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