SEGERSTROM HALL IN ORANGE COUNTY - DESIGN, MEASUREMENTS AND RESULTS AFTER A YEAR OF OPERATION

Jerald R. Hyde

Consultant on Acoustics, Box 55, St. Helena, CA 94574 USA

INTRODUCTION

The purpose of this paper is to show how a 3000 seat "fan-shaped" hall has been acoustically designed to compare favorably with smaller classically-designed rectangular halls, accommodating performances from full symphony and chorus, chamber music and opera, to recitals and musical theater. The success of Segerstrom Hall's acoustical design is seen not only in the objective data derived from extensive testing but also by the response of musicians and performers, audiences and critics after over a year of operation.

From the objective measures and subjective correlates has come a determination of proposed ranges and maximum values for the following objective parameters: Clarity Index - C_{80}, total sound level - $L_T(10)$, lateral energy fraction - LE_{80}, and early decay time (0-10 dB) - EDT. A summary is given of measured data, energy/distance relationships, a discussion of "intimacy," with comments on general issues derived from practical experience since the opening in September 1986.

DESIGN EVOLUTION, A REVIEW

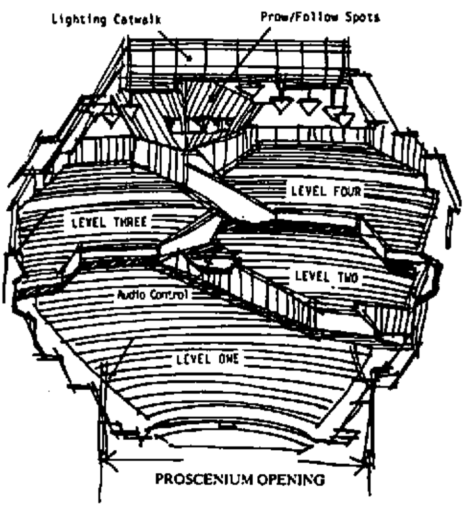


Fig. 1 - 3000 Seat Segerstrom Hall Schematic View from Stage

Design precedents and principles leading to the acoustical design of Segerstrom Hall have already been presented. [1][2][3] The first set of requirements imposed upon the design team by the client was that a multipurpose "theater" must be designed with excellent sight-lines and 3,200 seats. After rigorous design sessions and analysis of balcony overhangs, lateral sightlines and maximum distances, the number of seats required was revised to 3,000. The theater criterion meant in part that the minimum average distance to the stage would be obtained with a fan shaped room. Diligently fitting the 3000 seats within walls, aisles and building codes required 3/4 m^2 per seat yielding a total floor area of around 2,250 m^2. Restrictions on maximum visual distances forced the use of balconies in the design. [1] The result is a fan shaped "footprint" which is 52 m across at the widest point.

Discussions on acoustical criteria over the past 15 years have centered on the desirability of providing the necessary amount of early energy for clarity and intimacy with a good deal of that energy being incident laterally relative to the frontal plane. [4][5][6][7] With the fan walls significantly far from a large number of seats near the middle, it was clear that adequate early lateral reflections would be difficult to achieve with traditional solutions for at least 1/3 of the seats. Knowing that the hall would be primarily judged by its success when used for symphonic/music presentations, it was also clear that adequate reverberation would also need to be provided, in contradiction to a theater's need for high C_{80} values.

The acoustical music/theater related conflicts and the associated so called "problems" were seen as an opportunity to create a new solution which was found fundamentally in two major architecturally significant approaches.

Subdivided seating plane
First, the seating planes were subdivided in a way which provides interior boundaries and their associated shorter and earlier delays. The wall created in the "mid-fan" zone as seen in Fig. 1 provides the aural impression of a narrower room of from 20 to 25 m in width. By staggering the levels as shown, a series of surfaces are created which on each seating level provide the temporally and directionally desired reflections. The large "cleavage" surfaces, where the gallery fronts cut back to the "prow," open up the center and under-gallery positions to a unified view of the front and provide an acoustical connection of those seats with the reverberant field. Highly faceted walls and truncated back corners in each of the four seat planes complete the trend.

Large interior reflectors
The unmistakable design feature common to DRS (directed reflection sequence) halls [8][9] has been the use of large reflectors which float within the volume, independent of the sidewalls which define the reverberant boundary as seen in Fig. 2. Along with the lower sidewalls and subdivision seating planes, these are the source of early lateral reflections which, because they are easily aimed, can be used to balance the spread of early energy across the audience. Most of these DRS reflectors have been made diffusing by applying linear QRD surfaces, which not only spread the early energy out, but provide an expanded source image at any given receiver position. [These diffusors are based on the prime number N=7. The design frequency was chosen at f_o=500 Hz, yielding a diffraction bandwidth of 3.1 octaves. Wellington's Michael Fowler Centre is the first hall in the world to use these surfaces as prominent acoustical and visual elements. Segerstrom Hall is the first such hall in the US.] [9] [10] In line with Segerstrom Hall's use as a theater, all reflectors were positioned to provide reflections with the first delays within the first 50 msec to ensure clarity for speech and high articulation sources.

Acoustical curtains
The large reflectors provide an opportunity to add variable absorption to the volume in a way which in no way interferes with the early reflection sequence, as seen in Fig. 2. The "early" sound level remains essentially the same, independent of the added absorption, and C_{80} is found to increase an amount greater than would be predicted statistically. [See Fig. 6, Ref. 1]

Scale Modelling
Acoustical models scaled at 1:50 and 1:10 were an important part of the design process. The smaller model resulted in significant architectural improvements; the larger model resulted in a confirmation of the objective measure goals, a change in the angle of several first order reflectors and provided an increased level of confidence in the design. The objective measures at both scales correlate well with those measured in the full scale as shown in Table II.

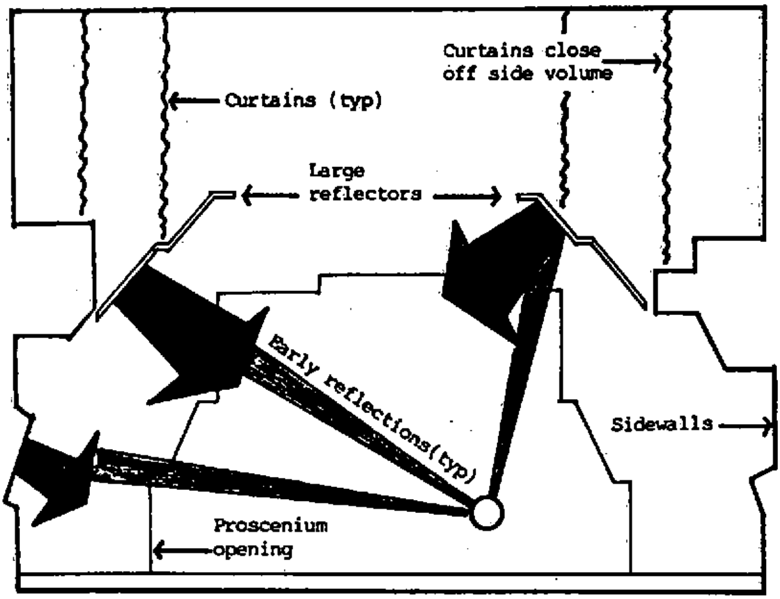


Fig. 2 - Transverse Section Showing Large Interior Reflectors Absorption is added to the Upper Volume

Physical results

Part of the acoustical design was a requirement that the performing area be extremely flexible in terms of the location of side and overhead surfaces. The proscenium opening was made so high and wide that the orchestra enclosure represents the visual and acoustical termination of the room on the whole; the musicians are in the hall, rather than in the shell. The shell is highly faceted and diffusing, and large "ensemble reflectors" hang within the volume over the performing area at varying heights of from 6 to 10 m depending upon the type of performance. Because of the disinterest in ceiling shaping and frontal reflections, the non-diffusing flat ceiling is high allowing for the necessary large volume needed to keep the reverberation time high. A tabulation of physical dimensions is given in Table I.

TABLE I - Segerstrom Hall Physical Measures	
Volume = 27,800 m^3	Opening below balc. = 4.9 m
Ceiling ht.(re:stage) = 26 m	Seat area = 2,230 m^2
Ht. last row (") = 20 m	Curtain area = 840 m^2
d_{max}(top level) = 49 m	Volume/Seat = 927 m^3
d_{ave} = 26 m	Volume/Seat Area = 12.46 m
Proscen. ht. = 12.8 m	Solo stage area = 60 m^2
Proscen. width = 20.7 m	Symph. stage area = 220 m^2
Max. hall width = 52 m	Max. stage area = 285 m^2

SEGERSTROM HALL - DESIGN, MEASUREMENTS & RESULTS

OBJECTIVE RESULTS

The DRS hall

Although never fully achieved in a hall, the concept of a diffuse or "statistical" sound field is an essential point of reference in room acoustics as representing an acoustical baseline. The transient time signature of a DRS hall is clearly different from that of a classical or "statistical" hall of the same volume. When large interior reflectors aim first and second order reflections at the audience, the impulse density in the early field becomes greater than would be the case with the volume dependent statistical prediction [11]. As would be expected when "deflecting" energy into the early time frame, the impulse response is observed to drop off rapidly in the first 50 to 100 msec.

A statistical space predicts that reflected energy will be constant and independent of distance relative to the source. Measurements in most halls instead show that this is not the case and that the total sound level and the early/late ratio drop off significantly with source-receiver distance. Barron has suggested a "revised theory" [12][13] which models different impulse responses as a function of distance from the source and which fairly accurately accounts for the deviation of the early reflections and related impulse responses from statistical predictions. Early reflected energy is therefore found to be higher at positions closer to the source and to drop off toward the back of the hall. From this, the values of C_{80} and total sound level can also be shown through known mathematical relationships to vary with distance from the source. An inverse relationship between C_{80} and EDT is therefore derived. [13] In other words, the price paid for perturbing the "natural" or statistical reflection sequence in order to achieve higher early energy is that the drop-off in level over the first 100 to 150 msec. as expressed by the measure EDT, becomes greater than the statistical RT.

With EDT being most highly correlated with the subjective sense of reverberation [15], the design goal to compensate for this would be to increase the volume of the room and along with it, the RT. Increasing the volume by adding ceiling height has less architectural consequences if the early sound field is provided from lateral directions, which is another of our design goals. It also has a tendency to slightly reduce the total sound level, so our criteria are in conflict. The question is therefore whether a satisfactory balance is possible between our criteria in the case of a large volumed space with RT's in the 2+ sec. range.

Measurement results

Table II gives the mean value results of measurements taken at 15 positions evenly distributed throughout the hall, excluding locations which are well under balcony overhangs unless otherwise noted. The results show that with such a large volume, the DRS design approach can provide good C_{80}, $L_T(10)$ and EDT values simultaneously.

Discussion

The EDT was found to be at 10% below the RT values yielding an EDT = 1.8 sec. for full occupancy. This is considered to be at the lower limit established for music presentations.

Calculated on the basis of total statistical conditions, a C_{80} value of -2.2 dB is derived. A small decrease with distance of 0.5 dB/10 m is calculated although the correlation coefficient of the regression line is quite low because of two high values measured in the two most distant seats.

SEGERSTROM HALL - DESIGN, MEASUREMENTS & RESULTS

TABLE II - Segerstrom Hall
Mean Value Results of Objective Measurements

CONDITION	RT(s)	EDT(s)	C_{80}(dB)	LE_{80} (a)	$L_T(10)$(dB)
Hall (Unocc.)	2.35 (b)	2.15	0.0	0.23	3.2
Standard Dev. (c)	-	-	1.6	0.06	1.3
Hall (Occupied)	2.0 (d,e)	1.8 (f,e)	1.0 (g)	0.23 (h)	2.5 (g)
1:10 Model (Occ.)	2.0	-	1.2	0.23	3.0
Model Std. Dev.	-	-	0.92	0.10	0.67

Notes: (a) Average for 20 meas. positions including under-balc.
(b) Acoustical curtains provide RT=2.05 sec. when unocc.
(c) For measurements of unoccupied hall condition.
(d) Calculated from the empty hall measurements.
(e) Acoustical curtains reduce to RT=1.7 sec. & EDT=1.5 sec.
(f) Estimated using the relationship between RT and EDT for the empty condition.
(g) Calculated using the RT for the occupied condition.
(h) Assumed to be the same as for the empty condition.

As seen in Fig. 3, the total sound level L_T is found to drop off at 1.06 dB/10 m and to have its mean value 1.3 dB below the theoretical calculated value of $L_T(10)_{th}$=4.5 dB. The net drop-off in L_T between 10 and 40 m is found to be 3.1 dB, which is considered to be quite low for hall of this capacity.

When considering the extremely wide fan dimensions of Segerstrom Hall, the average value of LE_{80}=0.23 is found to be exceedingly high as shown in Fig. 4 from work by Gade [14]. The actual hall fan width of around 50 m would predict LE_{80} values in the 0.04 to 0.10 range. When plotting the LE_{80} values measured for each of the four seating areas against the average width of each area, we find an extremely good correlation with Gade's results. Segerstrom Hall, which in its "footprint" is fan-shaped, behaves acoustically as predicted for classical halls.

DISCUSSION OF OBSERVATIONS

A broad cross-section of performances, from soloists and string quartets to full symphony were subjectively evaluated in the hall prior to the opening (with the acoustical curtains exposed simulating the full occupancy condition). Since then, the Center has presented every sort of performance including full symphony and choir, grand opera, ballet, chamber orchestras, light opera (amplified), and soloists in recital. The following comments, briefly touch on several of the acoustical issues which have become apparent through a good deal of listening by the author, plus the remarks and observations of performers, critics and other musically astute people.

Pianissimos - One of music's toughest critics has described the hall as creating what he calls "shimmering pianissimos." The softest sound made on stage is easily heard at the most distant seats. Coupled with this effect is the sense of a full dynamic range which is a result of the ability to project the pianissimos (high C_{80} and a quiet hall) along with the high $L_T(10)$ values.

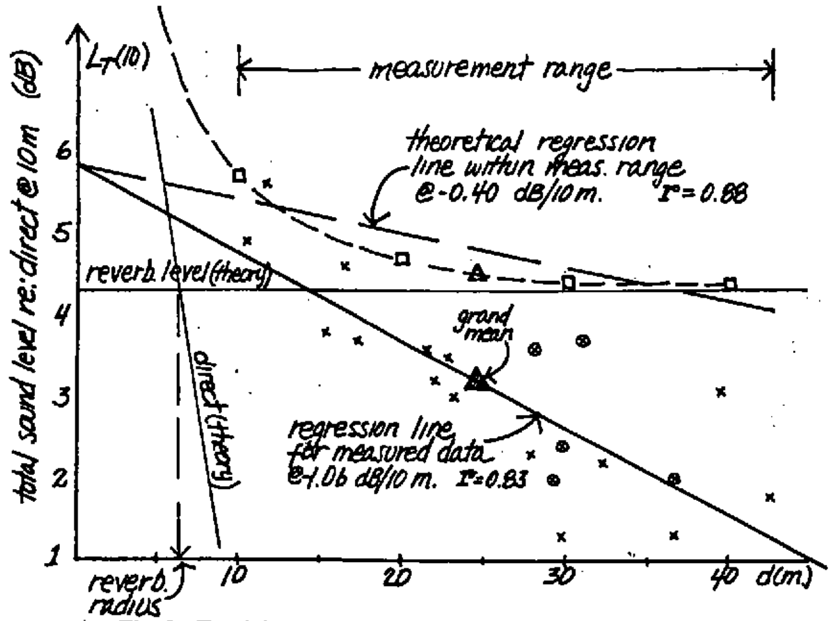


Fig. 3 - Total Sound Level L_T(10) versus Source-Receiver Distance

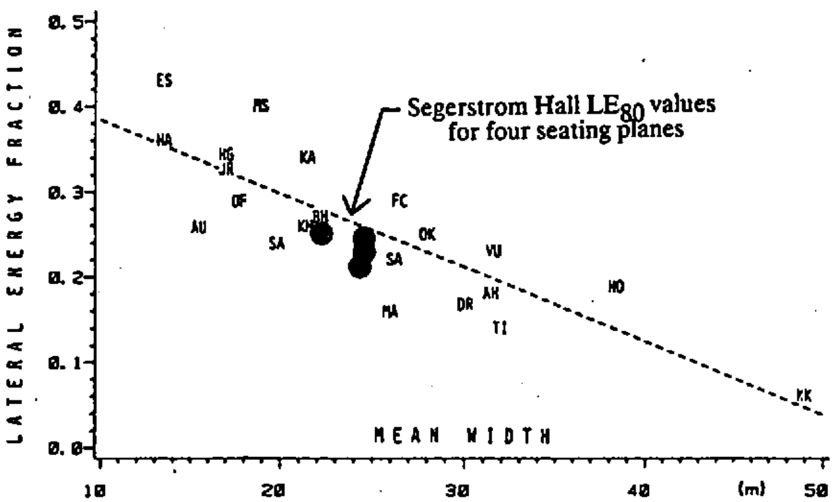


Fig. 4 - Lateral Energy Fraction LE_{80} versus Mean Hall Width [From Gade] [14]

SEGERSTROM HALL - DESIGN, MEASUREMENTS & RESULTS

Loudness, sound strength, dynamic range - Orchestras unaccustomed to the hall, tend to play too loudly. It can be a problem for touring groups who don't get an opportunity to rehearse in the space. With time, musicians easily adjust to the dynamic range. Recitalists are able to perform through the full range of expression and to easily announce their encore pieces, unamplified, at normal voice effort.

Spatial impression - There is good image broadening apparent at mezzo forte passages. At the highest sound levels, the spatial impression is at the maximum desirable.

Fidelity to the source - Many comment that the sound is "true" and unforgiving. High C_{80} values do indeed "expose" the performers. Part of this effect is that musicians have not yet adjusted to the ease at which loudness can be achieved; they tend to force the sound when it isn't necessary.

Performer satisfaction - Musicians are uniformly pleased by the "ensemble" conditions. Surfaces in sidewalls and overhead provide good "support" for soloists at the front of the stage.

Quadratic Residue Diffusors - These are found to be absolutely necessary when used on large DRS reflectors. The diffusion adds texture and helps soften the tone of the music. There are two locations where large specular surfaces provide harsh early reflections, and additional diffusion is being considered.

Pavarotti's recital - On his usual tour of 15,000 seat sports arenas, Pavarotti arrived at Segerstrom Hall with a full sound system. In a hall that clearly registers a whisper at 45 m, he proceeded to blast the patrons with amplified sound. The result was appalling!

THE ISSUE OF INTIMACY

For those who move around the hall and listen from varied positions, perhaps the most consistent comment, usually in amazement, is about how "close" and "intimate," or "strong" the sound is. The overriding impression is that the sound is stronger than one would expect for the distances involved. While the dense pattern of early reflections may well be a factor, it is the author's contention that this is due primarily to two factors. First, the total sound level is indeed high in the back of both balconies. In fact, the five most distant test positions had $L_T(10)$ values in the 1.3 to 3.1 dB range with an average of $L_T(10)=2.1$ dB (subtract 0.7 dB from these to obtain full occupancy values). When considering the regression line drop-off of levels from the center of the orchestra section at 20 m, to the farthest test position at 42 m, the drop-off is 0.4 dB/10 m or a total of only 0.9 dB difference over that particular 22 m.

Second, the sense of acoustical intimacy appears to be enhanced by the distance as if the visual perception of distance feeds the sense of intimacy the moment one hears an event which is so much more loud and clear than one would normally expect when so remote from the source. Listeners usually include some description of the distance, or "how far" away the source looks when discussing the seemingly relatively high sound level which they experience. Barron has shown that "louder" sound is perceived as more "intimate" and further that perceived "loudness" does not vary significantly with distance [16]. In other words, people may tend to compensate for the visual perception of the distance.

SEGERSTROM HALL - DESIGN, MEASUREMENTS & RESULTS

SUGGESTED OBJECTIVE MEASURE LIMITS

Extensive listening experience in Segerstrom Hall, along with the two other DRS halls in New Zealand [8][9], have lead the author to some acoustical design guidelines on objective measure ranges and limits as given in Table III below. Variation of each measure from the mean should generally be kept low. Some is inherent in C_{80} and $L_T(10)$. A total variation of 4 to 5 dB would be considered excellent.

TABLE III - Proposed Design Objective Measures for DRS Halls [Music Source, Hall Occupied]

Objective Measure	Mean Value Range	Maximum Value
C_{80}	-1.0 to +1.0 dB [(a)]	2.0 to 2.5 dB [(b)]
$L_T(10)$	0.0 to 2.5 dB [(c)]	3.5 to 4.0 dB [(d)]
LE_{80} [(e)]	0.40 to 0.20 [(f)]	(g)

Notes:
(a) This is for classical symphonic music.
(b) For music, ratios greater that this tend to mask the perception of the reverberation.
(c) This range puts Segerstrom Hall at the upper limit
(d) Other than at the very front of the hall, levels exceeding these values are generally too loud for a large orchestra.
(e) The degree of spatial impression is level dependent
(f) These LE_{80} values are established relative to the $L_T(10)$ given above. They are based upon the author's judgment that the degree of spatial impression significantly more than those obtained in the 3 DRS halls would be too great.
(g) The maximum value depends on $L_T(10)$ as noted above.

REFERENCES

1. Jerald R. Hyde & John von Szeliski 1986 Proc. 12th ICA, Vancouver, Symposium. Acoustics and theater design: Exploring new design requirements for large multipurpose theaters.
2. A.H. Marshall 1986 J. Acoust. Soc. Am. 80, Paper A1. Segerstrom Hall - A review of concept, design process, and results. Anaheim Conf.
3. J.R. Hyde 1986 J. Acoust. Soc. Am. 80, Paper A2. Segerstrom Hall - Evaluation of measurements and design details. Anaheim Conf.
4. M.F.E. Barron 1971 J. Sound Vib. 15(4), 475-494. The subjective effects of first reflections in concert halls - the need for lateral reflections.
5. W. Kuhl 1978 Acustica (40), Spatial impression as a component of total room impression.
6. Y. Ando & M. Imamura 1979 J. Sound Vib. 65(2), 229-239. Subjective preference for sound fields in concert halls simulated by the aid of a computer.
7. J.R. Hyde & A.H. Marshall 1980 Proc. IEEE Int'l Conf. on Acoustics, Speech and Signal Processing. Requirements for successful concert hall design: Need for lateral and ensemble reflections.
8. A.H. Marshall 1979 J.A.S.A. (65), 591. Acoustical design and evaluation of Christchurch Town Hall.
9. A.H. Marshall & J.R. Hyde 1982 (Sept) Proc. Inst. of Acoustics, Edinburgh. The acoustical design of Wellington Town Hall: design origins, research review and acoustical objectives.
10. A.H. Marshall & J.R. Hyde 1980 Proc. 10th ICA, Sydney, E-7.3. Some practical considerations in the use of quadratic residue diffusing surfaces.
11. L. Cremer & H.A. Muller 1978 Principles and Applications of Room Acoustics, Vol. 1. (Applied Sciences Publishers) p. 504.
12. M. Barron & L-J.Lee 1984, submitted to J. Acoust. Soc. Am. for publication. Energy relations in concert auditoria, I.
13. M. Barron 1986 Proc. 12th ICA Vancouver. Objective measures in concert halls and their use in acoustic scale models.
14. A.C. Gade 1985 Proc. Inst. of Acoustics, Vol. 7, Part 1. Objective measures in Danish concert halls.
15. B.S. Atal, M.R. Schroeder & G.M. Sessler 1965 Proc. 5th ICA, Liege, Paper G-32.
16. M. Barron 1986 Proc. 12th ICA, Toronto, E4-3. Intimacy, loudness and sound level in concert halls.

Proceedings of The Institute of Acoustics

HONGKONG AND SHANGHAI BANKING CORPORATION HEADQUARTERS ASPECTS OF ARCHITECTURAL ACOUSTICS

Richard Cowell

Arup Acoustics, 10a Stephen Mews, London W1P 1PP

Redevelopment of the headquarters of the Hongkong and Shanghai Banking Corporation in Hong Kong Central took just over 5 years including demolition of the old headquarters, temporary annexe facilities, construction of a sea water tunnel (from Star Ferry to the site) and construction of the new building.

The 47 storey structure (178m high, gross area 100,000m²) was constructed on a 5000m² site to house office accommodation, conference, staff training, central atrium, and executive restaurant and kitchen facilities.

The building is supported on eight steel masts, carrying trusses from which floors are hung - this arrangement encourages maximum free floor area. The building was assembled with an emphasis on off-site fabrication, with consequent implications for the acoustic design.

Acoustic design was carried out as a collaborative consultancy by Arup Acoustics (Architectural Acoustics) and Tim Smith Acoustics (Building Services Noise & Vibration Control), environmental noise aspects being tackled jointly. This consultancy covered an unusual variety of disciplines (even for a major and innovative office building).

This paper describes aspects of the architectural acoustics selected as potentially of particular or unusual interest:-

- o protection of the building from MTR railway vibration.
- o atrium acoustics
- o fit-out component testing
- o board room speech assistance system.

MTR Railway Vibration

At the time of building design, the new MTR Short Island Line was only a proposal. The line of tunnels, in very close proximity to the NW masts (<2m), and the relatively lightweight construction of the building engendered some concern at the potential for disturbance of the building by the new railway.

With reference to measurements elsewhere in Hong Kong, estimated local noise levels higher than NR40 were anticipated and local perceptible vibration predicted. Estimates of amplification in the superstructure also suggested that attenuation was justified. Although MTR designs for the tunnels were well developed, with the assistance of Prof. Peter Grootenhuis and in cooperation with the MTR (advised by George Wilson of Wilson Ihrig) we were able to develop an isolation system which could be integrated within the tunnel section (see Fig.1). Use was made of natural rubber bearings designed to achieve a system natural frequency of 14Hz and adjustable lateral restraint pads. These were installed over a length extending 30m (top tunnel), 50m (lower tunnel) beyond the ends of the site. A target attenuation between 15 and 20dB at 40Hz upwards was intended. Whereas in the absence of a 'before' situation, attenuation performance cannot be ascertained accurately, following this installation, the building is not disturbed by the railway. The trains are just audible in the NW stairwell adjacent to the masts and vibration just perceptible in the stair handrail.

Atrium Acoustics

The atrium space (Fig. 2) runs from a full floor area Banking Hall at level 3 as a rectangular E-W shaft rising from a glazed "underbelly" up to level 11 where a concave sunscoop mirror (incorporating convex mirror panels) is located. The sides of the atrium are open, exposing the sound absorptive material of the open offices to the atrium space.

There is a natural instinct to introduce sound absorbing material within public atria as a safe means of limiting occupational noise. But the aural 'life' of the space would suffer if sound absorbing treatment were excessive. The target mid-frequency RT range of 1.5 - 2.0 seconds (met by a final measured value of 1.9 seconds) and, as important, the volume of the space, provide a balance between noise control and aural sense of space.

The sun mirror at the top of the atrium represented potential for focussing of sound - this has been countered by use of convex profiles for the mirrors encouraging dispersion of the sound. In evaluation of the atrium acoustics, the extent of enclosure of the office floors connected to the atrium was a particularly important factor.

Distribution of sound in the atrium was checked in terms of dB(A) using pink noise directed vertically on to the stone-faced floor of level 3 from a cabinet loudspeaker set 450mm above f.f.l. From a source position close to the long central axis from the cross central axis, sound levels were measured at higher levels and at positions retreating into the offices at 2.4m centres (2x floor module) at 1.5m above f.f.l. These were compared with levels 2.4m on plan from the source at 1.5m above f.f.l.

This data illustrates even distribution less than 2dB(A) variation with height, a useful fall-off in level into the offices (a 5dB(A) drop with a retreat of 2.4m and a further 3dB(A) drop after a further 2.4m) and some local influence of the sunscoop (which is however limited).

Fit-out Component Testing

It is unusual to have the opportunity to carry out tests on virtually all of the major elements of a fit-out likely to affect room to room sound insulation for partitioned areas. For the Bank project, major tests included:-

A.	Raised Floors (Geiger Hamme, USA)	Airborne sound insulation Room to room transmission under partitions (Panel 'ringing' tests) (Surface noise radiation)
B.	Ceilings (JTCCM, Tokyo)	Sound absorption (rev. room method) Room to room transmission over partitions
C.	Light fittings (IBP W.Germany)	(Noise emission) Transmission loss testing
D.	Partitions (JTCCM, Tokyo)	Transmission loss testing
E.	Face Panels (JTCCM, Tokyo)	Room to room transmission loss

Raised flooring achieved between 40 and 47dB mean normalised level difference between rooms, the difference being mainly the position of panel joints. Partitioning set on the joint was clearly better, although, in practice, the continuity across the joint is affected by the partition base fixing.

Ceiling construction (incorporating panels of perforated metal with plasterboard backing) achieved 42dB normalised level difference with a sound absorbent structural soffit over. Face panels achieved a similar performance. Light fittings offered 18dB nominal transmission loss - with the absorption in the void, this proved just adequate.

A range of partitions was designed to meet a target range of Rw performances as shown in Fig.3. The combined performance across a Type B partition (this was mid floor and excludes influence by face panels) was within 1dB nominal of target 34dB nominal mean level difference over the standard range.

It is important to note that the 'package' system of construction prevents a particular challenge to acoustic specification. It was noted during this project that room to room insulation at the perimeter of the building depended on the performance of ten separate packaged elements. A final test on site could not be used as a control on sub-contract performance. Consequently, prior testing and tight QA/QC procedures are essential.

Board Room Speech Assistance System

The board room is not very large and good acoustic design allows clear natural speech with careful projection and good diction. However, it was decided that support for voices should be arranged to aid clarity of communication, to assist less able speakers and improve intelligibility where the speaker is turned away from the listener.

An amplified sound was not sought, but rather gentle assistance. Priority controlled voice-activated microphones are set in the table. These feed only remote loudspeakers set in to the light fitting (See Figs. 4 and 5). The loudspeakers are on delay and carefully equalised. There are no user controls and the system is designed to be essentially passive.

The system, developed with Peter Barnett and John Oliver of AMS, has proved very effective and the Bank has been asked for permission by others for the concept to be pursued elsewhere in Hong Kong.

Reference: Cowell J.R. and Smith T.J.B. (1985) "The acoustic design of the new headquarters for the Hong Kong and Shanghai Banking Corporation, 1 Queens Road Central, Hong Kong". Paper to WESTPAC II Hong Kong.

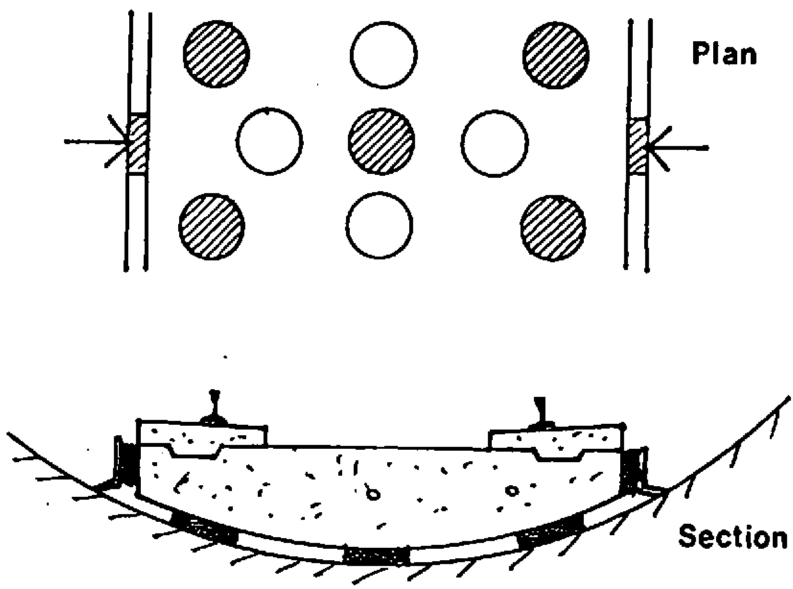


FIG. 1. CROSS SECTION AND PART PLAN OF ISOLATED TRACK SLAB.

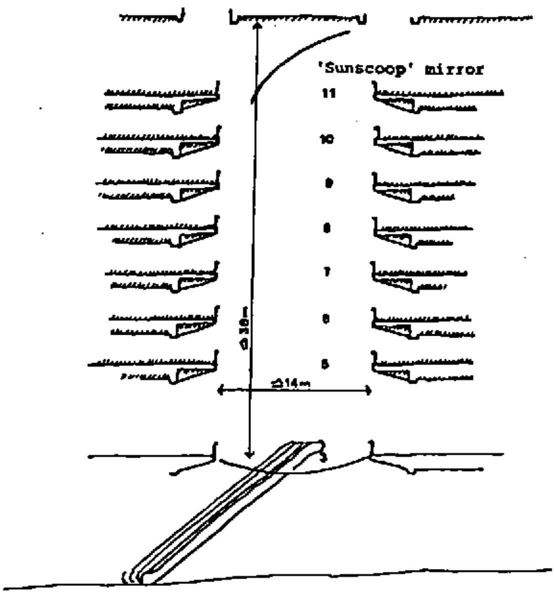
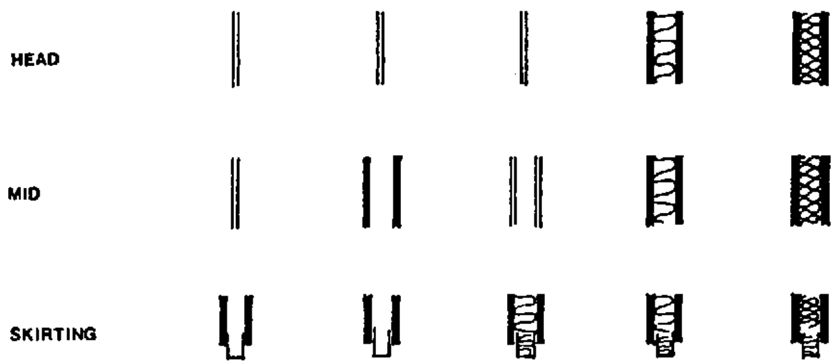


FIG. 2. SECTION THROUGH ATRIUM - SHADED AREAS SHOW ABSORPTIVE MATERIAL.



AIM R_W min	28	32	33	38	42
ACHIEVED	29	36	35	40	42

FIG. 3. RANGE OF PARTITIONING AND COMPARISON OF TARGET AND ACHIEVED R_w.

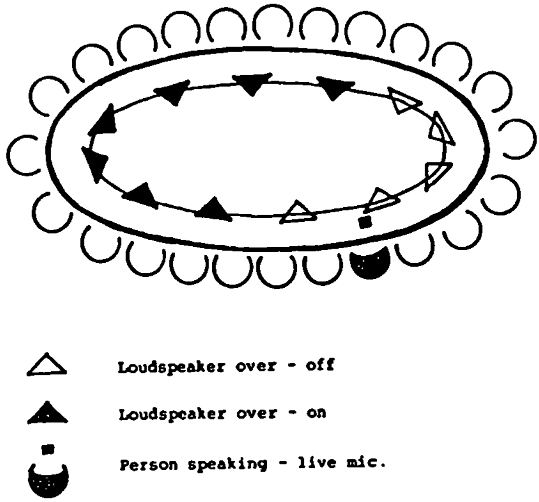


FIG. 4. PLAN OF BOARD ROOM TABLE AND EXAMPLE OF SWITCHING

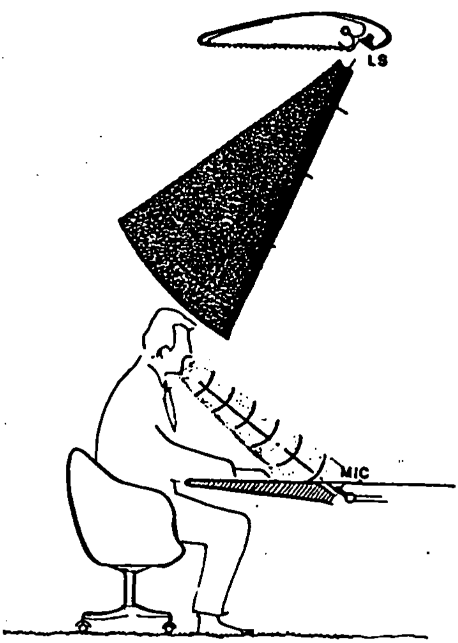


FIG. 5. SECTION SHOWING LOUDSPEAKER IN LIGHT FITTING, MICROPHONE RECESSED IN TABLE (NB. NOT OPERATING SIMULTANEOUS AT ONE LOCATION).