# ARCTIC TRANSFORMATION: A FULLY FLEXIBLE CONCERT HALL/THEATRE IN BODØ, NORWAY

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## 1 INTRODUCTION

A wind-swept harbour in the Arctic Circle is an unlikely setting for a new arts centre, particularly one that has attracted international attention for its quality and versatility. Yet ‘Stormen’ (roughly translated into English as “tempest”) – comprising a library, a theatre that converts into a concert hall, bars, clubs, reading rooms and various performance spaces - has brought unexpected fame to the small town of Bodø in Norway. The Architects Journal selected Stormen as its ‘Building of the Year’ for 2014, and it also won the Norwegian State Prize for Building of the Year.
Designed by DRDH Architects, working in close collaboration with Arup on acoustic, venue and theatre design, Stormen is actually two buildings: Bibliotek and Kulturhus. Bibliotek with its library, reading rooms and performance spaces, is located on the waterside edge of the site, its huge windows affording the visitor a panoramic view across the fjord. The Kulturhus on the inland side of the plot, has a 944 seat theatre/concert hall; a 250 seat multi-purpose drama and recital hall and a 400-seat basement jazz and rock music club.

## 2 BRIEF

Developments in the regional music scene emerged that had significant implications for the design of the multi-functional concert hall, Store Sal. Two local orchestras were combined to form a new regional orchestra – the Arctic Philharmonic – and the local annual music festival, already gaining in national importance, was expanded. It became apparent that the client required both a first-rate concert hall, which could be a base for the Arctic Philharmonic, and a theatre of equal international quality. They needed an exceptional multi-functional venue capable of rapid conversion between concert hall and theatre.

A traditional orchestra shell installed on a theatre stage was neither practical - because space limitations precluded its storage - nor suitable because it would fail to deliver a concert hall acoustic. Potential issues with temporary orchestra shells include directing sound onto the stalls resulting in excessive clarity in these locations, and often being too low to provide good ensemble conditions for the musicians. Electro-acoustic enhancement fell short of the client’s aspirations so a bespoke solution was required. The hall had to be physically transformed.

The volume of the audience end of the room was to remain unchanged between modes – and designed for sufficient volume to achieve concert hall reverberance. The following modifications were needed to change between the two modes of operation

• The stage flytower and wings had to be closed off with suitably stiff reflective surfaces to create a concert hall ‘shoe-box’ geometry by obscuring absorption and defining temporary room boundaries appropriate for orchestral playing/ensemble conditions;

• A suspended reflector array was required over the orchestra platform to achieve the early reflections necessary for performers to communicate clearly with each other;

• Surfaces finishes and materials needed to achieve dual functionality;

• Spatial transformation systems would have to change the venue’s geometry to reveal or hide acoustic finishes and specialist technical systems as required.

The Arup team is expert in multi-functionality using spatial transformation technology. So the efficient design concept and competitive procurement strategy subsequently devised meant the complex, novel, moving-shell system could be built for similar cost to a traditional shell with an acoustic enhancement system. The following sections outline the acoustic and technological concepts involved.

# 3 ACOUSTIC TRANSFORMATION

The client required an audience capacity of about 1000. In symphony orchestra concert mode, a reverberation time (RT) of about two seconds was targeted. For 1000-person capacity this suggested a room volume of approximately 11,000 $m^3$ and an ideal width (for appropriate lateral energy) of not less than 18m with a height of >18 m. In theatre mode, however, such a volume is excessive - the ideal RT being closer to one second, which for a given audience size corresponds to half the spatial volume. The desired reduction in RT was achieved by:

• Exposing absorption in the stage area and flytower

• Deploying variable acoustic drapes at technical balcony level

• Deploying a system of bespoke sliding unity-absorbing sliding wall panels that cover more than a third of the auditorium side and rear wall areas.

To prevent excessive low frequency absorption, panel storage enclosures were carefully designed and lab-tested to ensure that, in orchestral mode, the absorptive panels themselves were effectively isolated from the room. This was achieved by providing suitable mass and stiffness to the enclosures and by ensuring that all gaps into the enclosures are sealed when the panels are retracted.

# 4 SPATIAL TRANSFORMATION

An array of innovative technologies enables Store Sal to be truly dual-purpose.

The orchestra is enclosed within the flytower by a system of suspended movable wall and ceiling panels. The 14m high wall panels can be moved easily by a single person on an overhead track system and store tightly against a side stage wall behind the theatre fly galleries. Acoustic reflectors and motorised ceiling panels can be flown or hinged into place above the stage and, together with the wall panels, these dramatically change the acoustics and aesthetics of the space. In theatre-mode a pair of the side wall panels hinge around to form the sides of the proscenium arch with the top completed by folding down one of the ceiling panels. The total transformation can be achieved in less than a couple of hours.

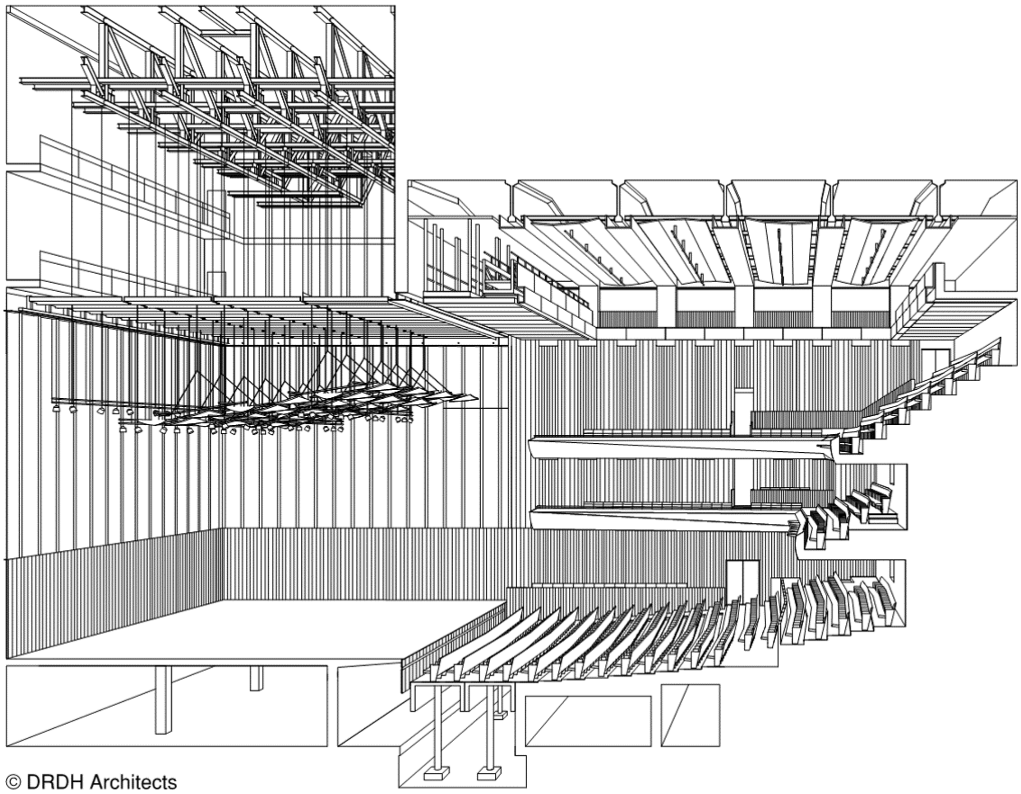



Figure 1: Concert mode

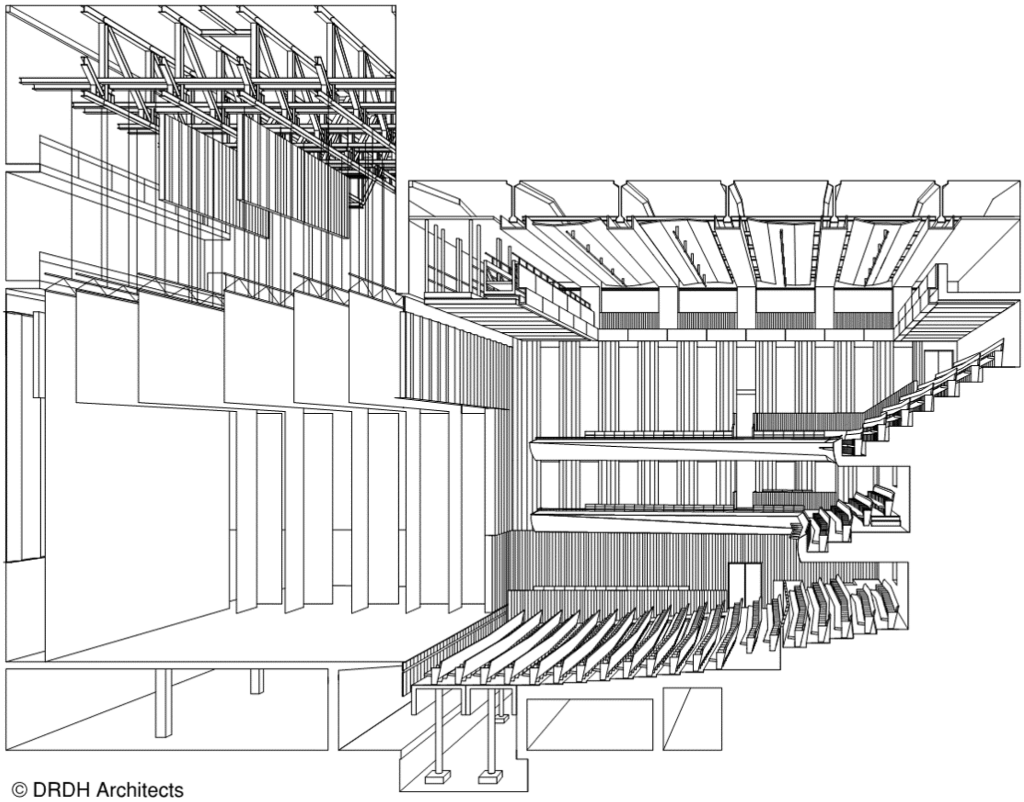



Figure 2: Theatre mode

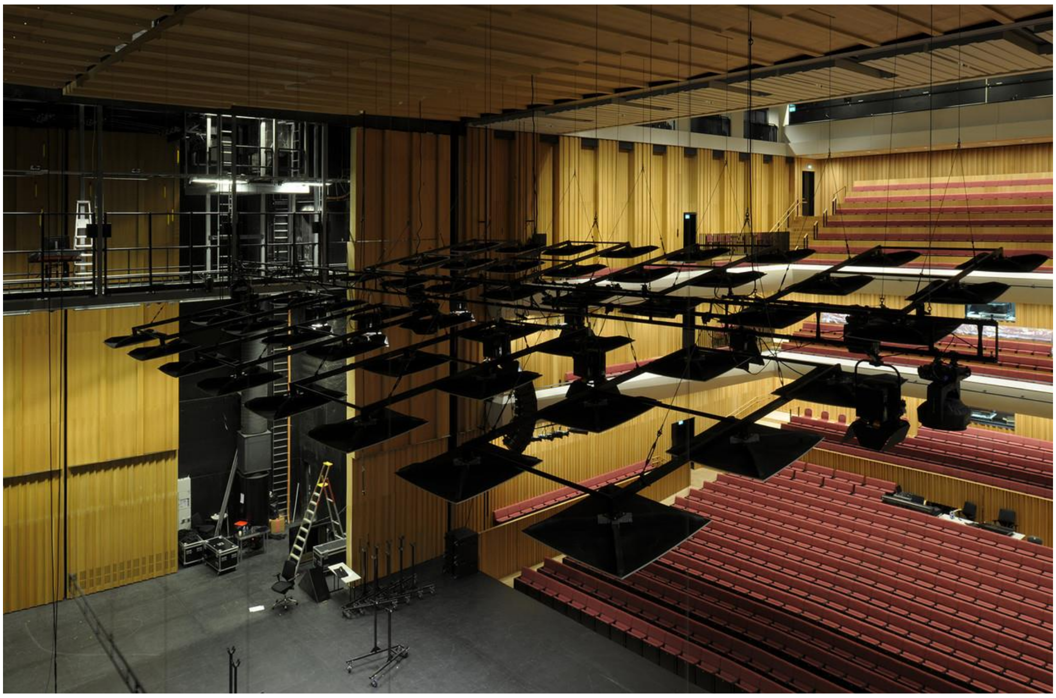

Figure 3: Room transforming elements

## 5 CEILING AND BALCONY FRONTS

Having established the acoustic and theatrical concept for the room, various elements of detailed design were undertaken to optimise the room's performance.

Rhino add-in modules (Grasshopper and Galapagos) were used to optimise the profiles of the ceiling and balcony fronts to ensure even coverage of early energy to the two balcony levels. The geometric optimization was performed using three on-stage source positions (downstage, mid-stage and upstage) as shown in the image below.

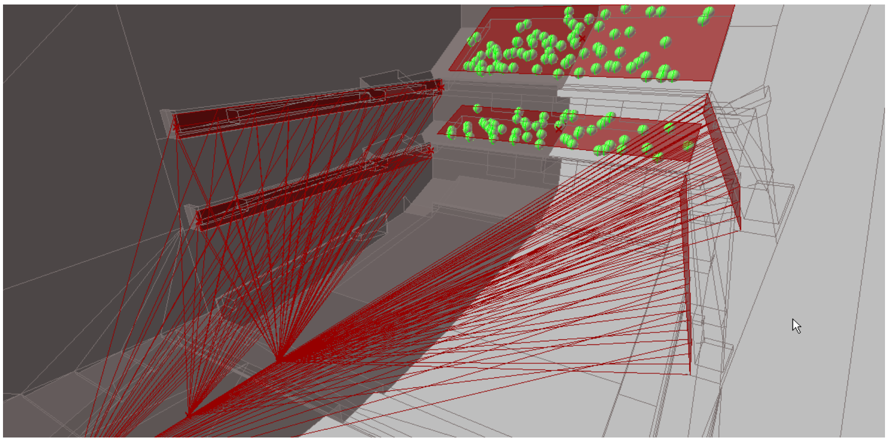

Figure 4: Screen shot of the optimisation of the balcony front shape

Ceiling and balcony soffit panels were designed to scatter sound in order to prevent strong specular reflections or image shifts, and to provide an even distribution of appropriate early energy.

Using similar techniques, side-balcony fronts were optimised both to maximise sound reflections from stage towards the audience on the first and second rear balconies and to ensure even coverage with no 'hot' or 'cold' spots (Figure 4 includes a screen shot of the optimisation process).

The initial balcony-front design was a vertical profile, the optimisation routine changed the surface calculating the optimum warp/twist to be applied to the surface.

The optimisation performed in Grasshopper is based purely on ray-tracing to calculate the specular reflections of incident sound paths. Reaction to incidence on a surface depends on a number of factors including the surface finish, geometry and panel size. So in order to check the resultant acoustic parameters, the results from the geometric ray-tracing optimisation were incorporated into Odeon models of the hall.

To achieve the precision engineered surfaces resulting from the optimisation exercise, the ceiling and balcony fronts were constructed from calcium sulphate panels. These were chosen both for the high density of the material and its ability to be accurately machined.

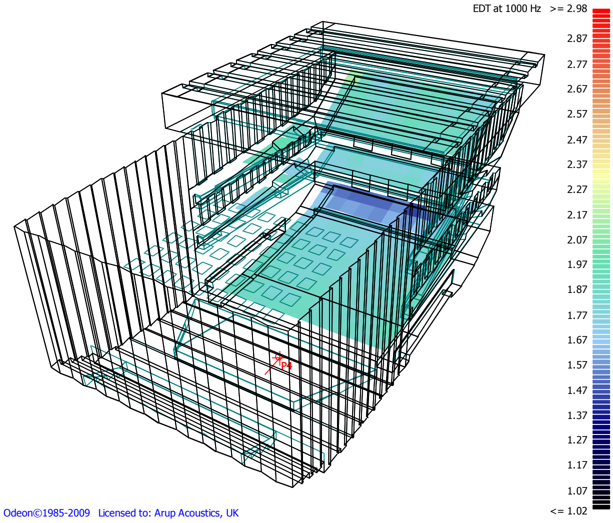


Figure 5: Odeon modelling

# 6 ORCHESTRAL REFLECTOR ARRAY

Orchestral ensemble reflectors are essential elements in concert halls where the platform-to-ceiling height is significant and the orchestra is large. The surface used to closed off the flytower is 14m above the platform and too high to provide ideal overhead ensemble reflections. Such reflections are necessary for the musicians to hear themselves and other sections of the orchestra. The suspended reflector array is variable in height and provides appropriate surfaces for those reflections, assisting the musicians with their timing, tuning and ensemble.

Ensemble reflectors also provide some high frequency early reflections to the audience, especially from the string section. The design of the reflector array is a complex matter. Five main design criteria were addressed:

- Number of reflector panels
- Location of reflector panels relative to the platform
- Size of each reflector panel
- Curvature of the reflector panels
- Height of the reflector array over the platform

The frequency response and coverage was optimized through consideration of the size, height and distribution of the panels, again using optimization routines developed in Grasshopper

The following figures show the optimised designs for the reflector, balancing openness of the array layout, coverage and cut-off frequency.

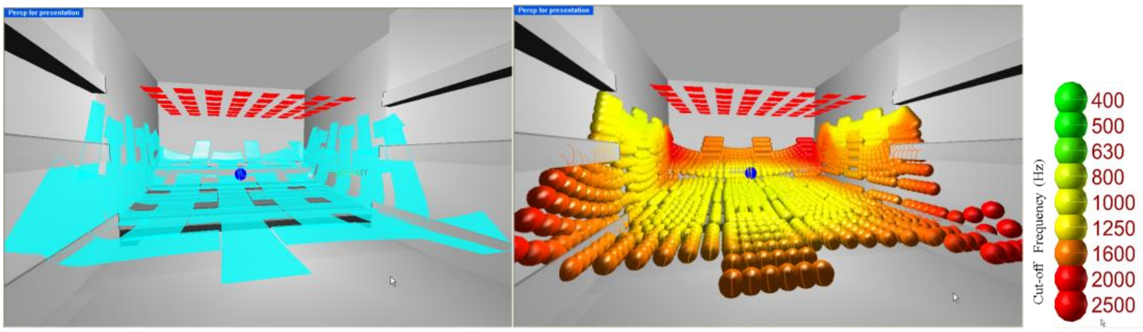


Figure 6: Coverage and cut-off frequency of overhead reflector panels

The ensemble reflectors are suspended above the orchestra at about 10m above the platform. They are suspended through slots in the ceiling panels. The array was adjusted in collaboration with the orchestra to optimise the ensemble on the platform and assist in providing a beautiful string tone in the auditorium.

## 7 AUDITORIUM WALLS

To assist with room acoustic control, bespoke tracked timber panels in the auditorium walls reveal semi-rigid 100mm thick glass fibre panels behind acoustically transparent fabric. These materials are used because their full bandwidth acoustic absorption properties are more tonally balanced than soft drapes or banners. Various areas of the wall panels can be exposed to suit the performance and programme type.

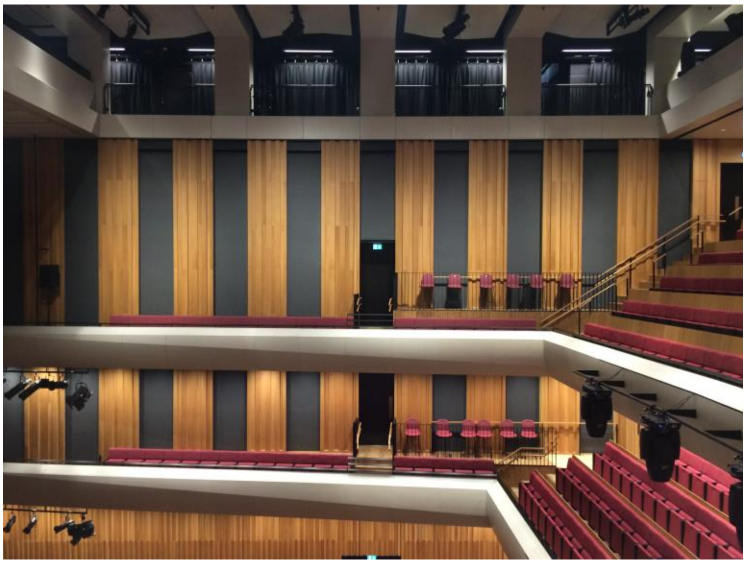

Figure 7: Deployed variable absorption

## 8 PLATFORM SIDE WALLS, PROSCENIUM AND CEILING PANELS

Tracking side-wall panels (14m high) move from their parked position to one side of the stage and complete the side-wall enclosure to the orchestral platform. These are sufficiently stiff and diffusing to provide adequate ensemble reflections to the performers and are shaped to balance orchestral sound across the platform with that reflected into the auditorium. The saw-tooth profile also prevents flutter-echoes across the platform between the parallel walls. To make the system simple to use and to avoid the need for motorisation (thus reducing maintenance and complexity) they are hung from low friction steel wheels and may be hand-rolled (by one person) into their parking position.

The proscenium is formed by large vertical and horizontally hinged panels. The proscenium header hinges upwards into a horizontal position covering the front part of the flytower. The side panels (10m high) hinge through 90° forming the front part of the orchestra enclosure when stored.

Three more ceiling panels close off the flytower visually and acoustically: two rotate and are stored vertically in the flytower, while the upstage panel is hinged so that it hangs down against the back wall.

The upstage wall itself is timber clad to match the side walls and ceiling panels, and is the only fixed element on the platform. Although unintended during design, this surface has also proved very effective for projection of scenic video during concerts despite its uneven, oak veneered finish.

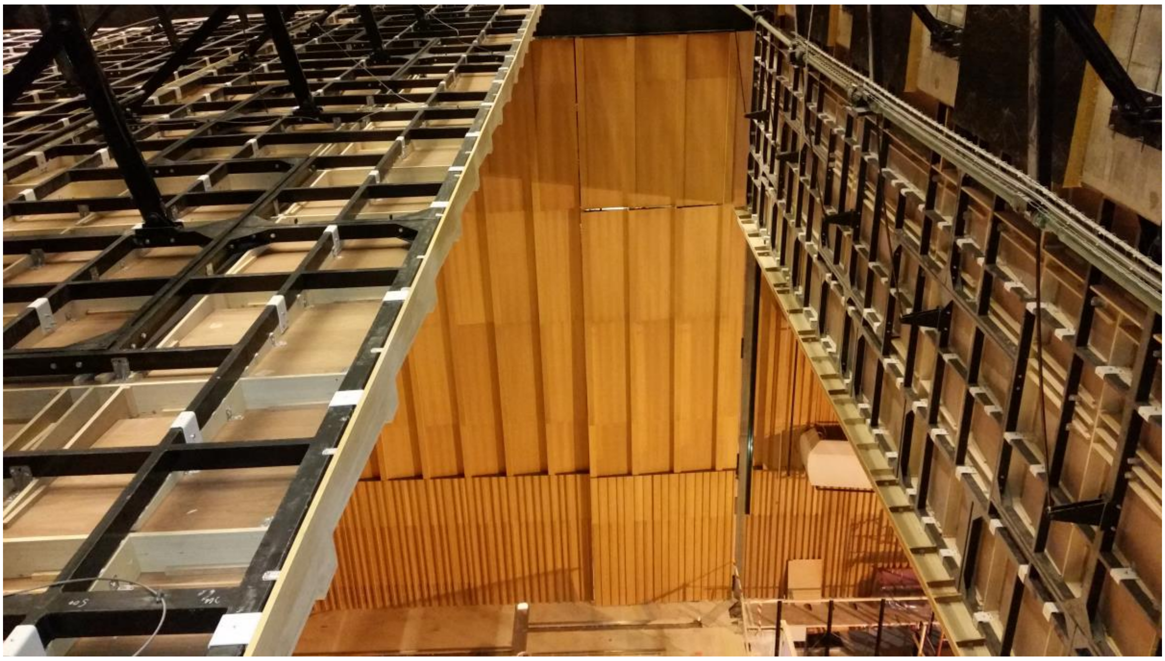

Figure 8: Tracked wall panels and hinged ceiling panels

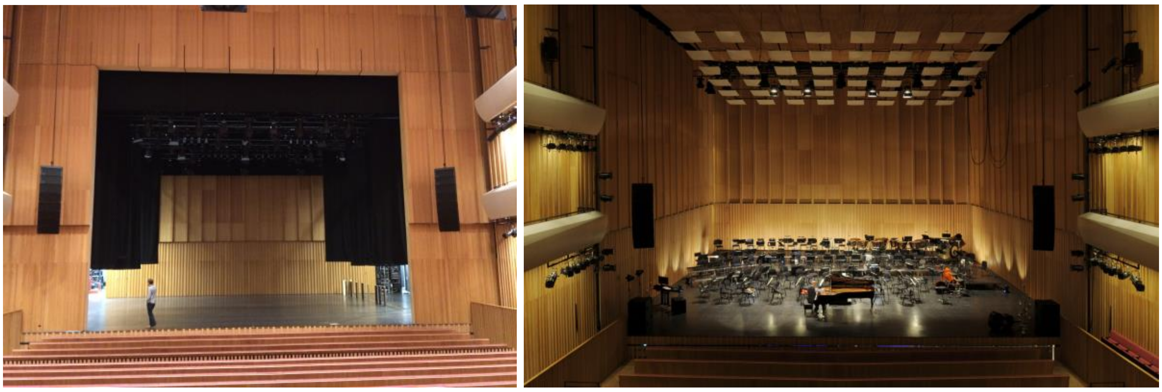

Figure 9: Panels deployed in theatre and concert mode

# 9 ROOM ACOUSTIC MEASUREMENT RESULTS

Commissioning measurements in the room in its two performance conditions and with and without an audience have been performed. The results of these measurements are presented graphically below.

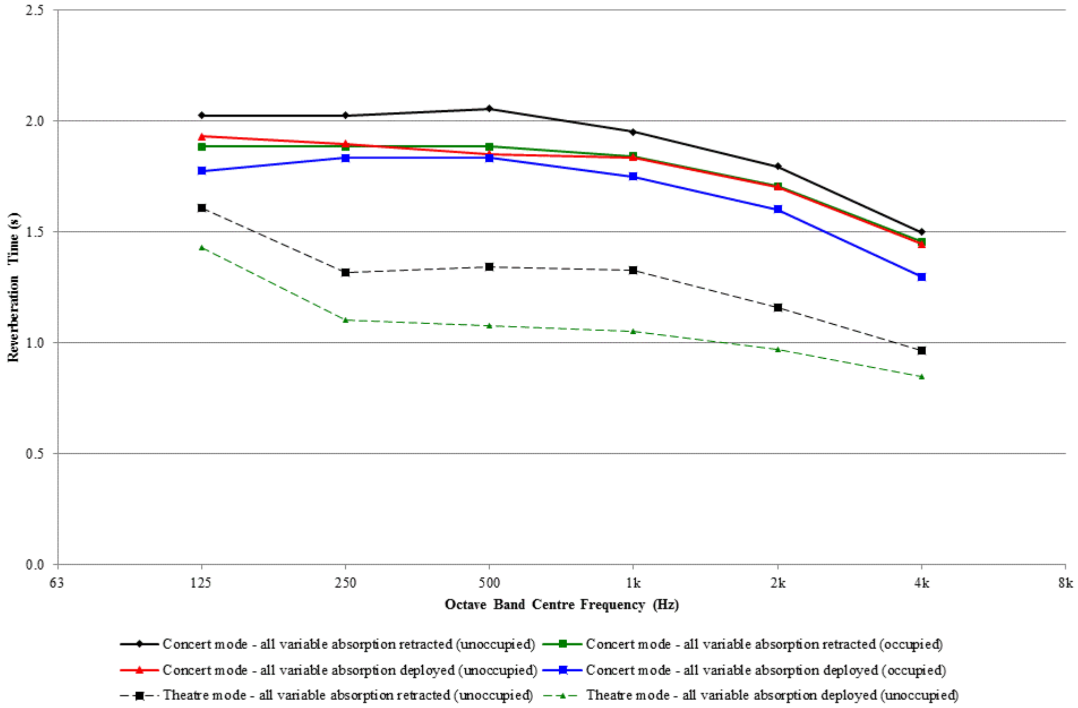


Figure 10: Spatially averaged measured reverberation time across all seating areas

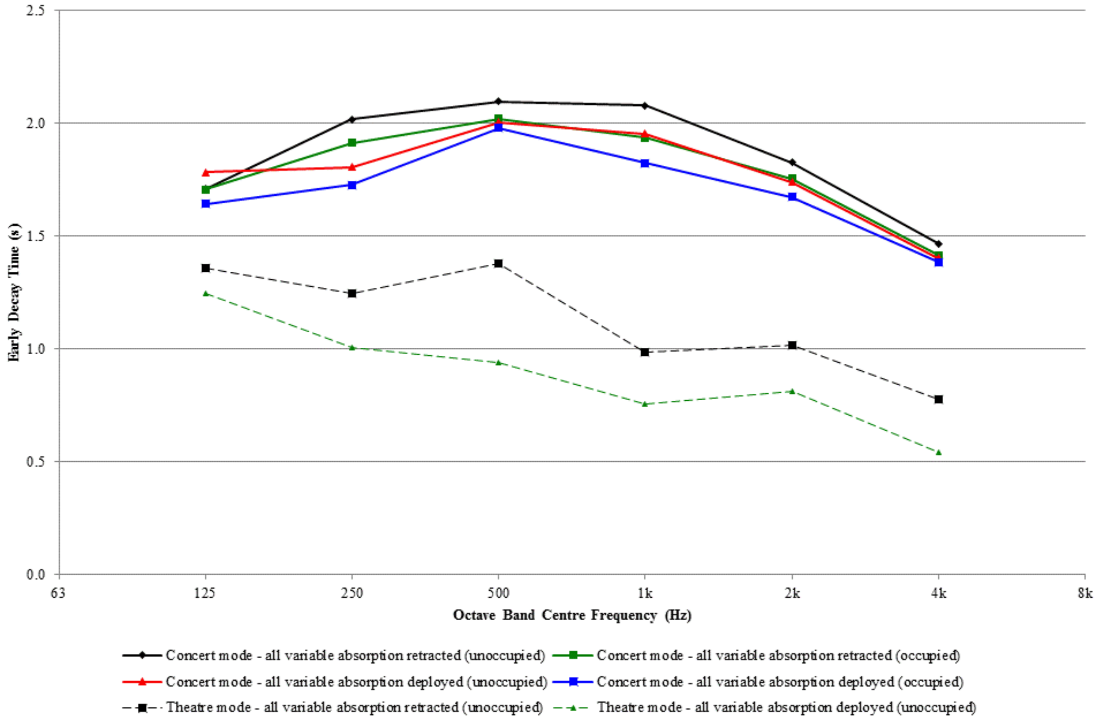


Figure 11: Spatially averaged measured early decay time across all seating areas

The results above demonstrate the wide variety of room acoustic that can be achieved in Store Sal. The low frequency roll-off in the EDT is almost certainly due to the lightweight stage surround panels (a necessary component of the transformable hall) and interestingly does not affect the reverberation time. The reduction in early bass energy is not apparent in the audience area where the bass sounds rich and balanced. This over-riding subjective impression is possibly due to the direct and first reflections being substantially full bandwidth.

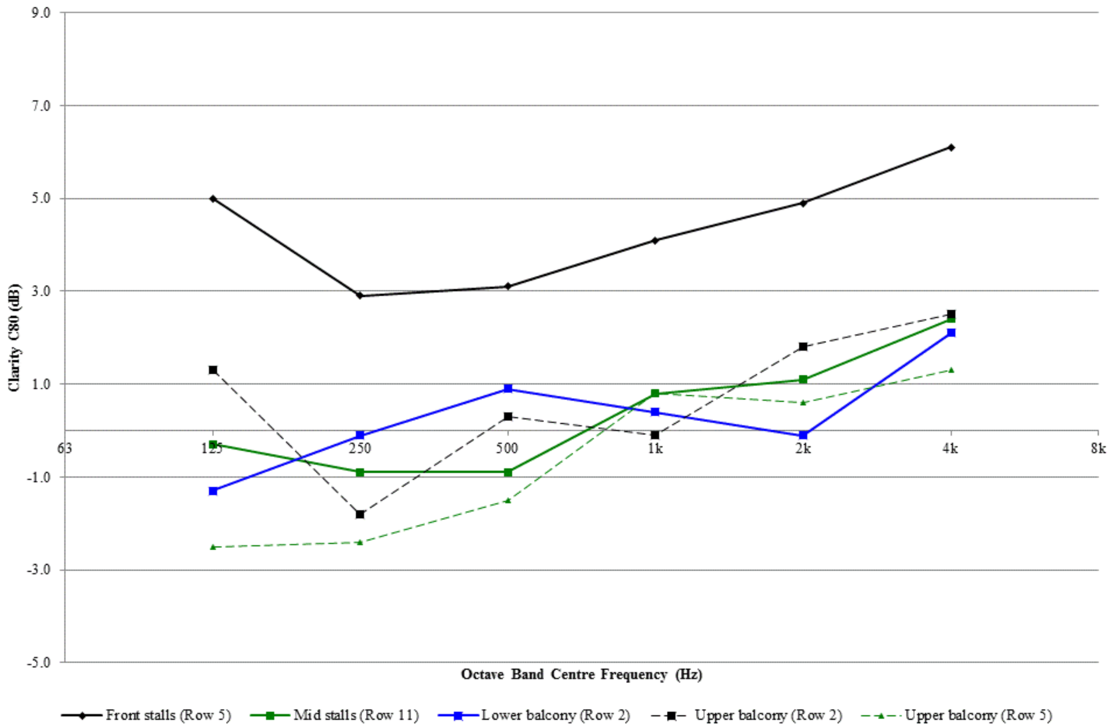


Figure 12: Clarity in occupied concert mode (all variable absorption retracted)

Figure 12 demonstrates that clarity remains appropriate right through to the upper balcony due to the carefully directed early energy.

# 10 REVIEWS

During its first year of operation, Store Sal at Stormen has proved to be hugely successful, making full use of its flexible system to accommodate a wide variety of performances. In theatre mode, it has hosted many amplified shows and in orchestral concert mode it has already built up a reputation as an international quality concert hall.

*The acoustics in Stormen Concert Hall are brilliant, ….. the room has intimacy, warmth in the sound, it sounds transparent and spatial.....it feels intimate and that everything one does is perceived in the audience, if one whispers or shouts. For me, the acoustics of Stormen Concert Hall is up there with the very best around the world.*
Leif Ove Andsnes - Concert Pianist

*A highly successful and well-functioning increment in the series of great new halls around the country. It was a pleasure to play there!*
Jan Garbarek, Saxophonist

*This is the best hall in the world. There are none better*
Christian Lindberg – Conductor of the Arctic Philharmonic and Trombonist

## 11 REFERENCES AND ACKNOWLEDGEMENTS

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Venue consultant – Arup
Lars Strand - Brekke Strand