

Acoustic isolation of: **CONCERT HALLS**



Concert Halls, Lyric Theatres and Performing Arts Venues

Concert halls are an important and popular part of arts and leisure culture where cutting edge technologies are used to provide the best possible acoustics for the music and theatre to be performed.

They tend to be constructed in urban environments to allow accessibility which can lead to challenging scenarios where externally induced noise and vibration from road, rail, general urban noise and tightly spaced venues can dramatically affect the critical acoustic experience.



Design Consideration:

Acoustics, Control of Noise and Vibration

Vibration control may be required in a concert hall design due to;

- Externally induced disturbing vibration from transport etc.
- Internal noise transfer between performance, rehearsal / practice and public spaces

It is important to characterise the disturbing vibration in terms of frequencies, amplitudes etc. and then to establish whether the intended design will might need vibration control to be incorporated. Often cost can actually be saved by reducing the mass of the structure and incorporating vibration control.

The principles of concert hall design are similar to those adopted in cinemas but tend to be on a much larger scale owing to the size of the auditoria and the very high acoustic requirements of the performance spaces.

There are two main approaches to concert hall vibration control;

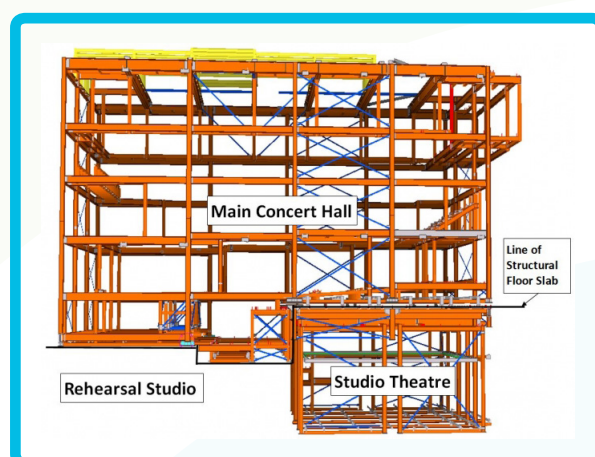
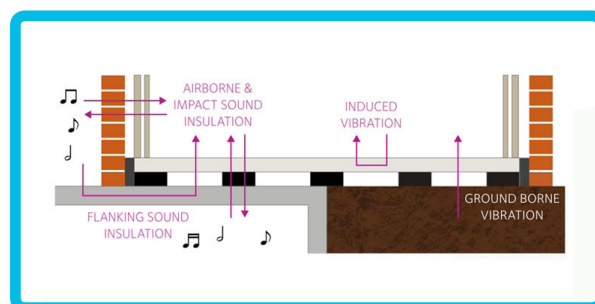
- › Full building / Base isolation has been used in many concert halls around the world to prevent any structure borne vibration from entering the structure in the first place. See separate 'Full Building Isolation' section for more details on this.
- › Box in Box Systems have the benefit, if space within the concert hall is constrained (as it often is), of isolating each internal part of the building (main concert hall, second hall, studio theatres, rehearsal studios and gyms etc) from one another.

A modern construction method for concert halls is to build the main shell out of in-situ concrete and then construct all the noise critical areas as independent 'boxes' supported by high performance acoustic bearings.

For large spaces such as main concert hall auditoria and studio theatres the walls and ceiling are supported by a steel frame which is supported at the base of each column by a resilient bearing. That way anything within that space (seating, stage, fly tower etc) is decoupled.

Such a method will provide high levels of airborne noise attenuation in each space whilst the structure borne vibration levels can be controlled through selecting an appropriate frequency dependent on the disturbing frequency and building structure design. Using steel as the internal frame also facilitates the use of longer spans, complex shapes whilst at the same time minimising weight and cost.

Such designs require intensive design coordination between the structural engineers, acoustic consultants, the contractors and the isolation product supplier which in Farrat's case use a multi-disciplined team of engineers to form an informed link between all parties. As a manufacturer we can produce standard and bespoke products to meet the specific project requirements.



Design Consideration:

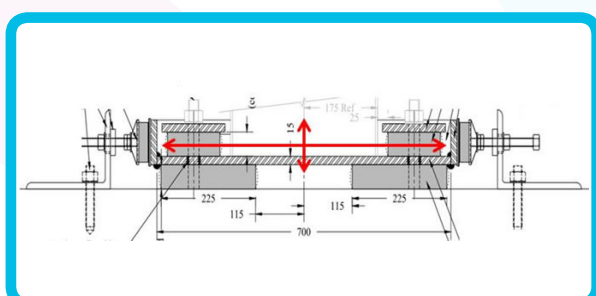
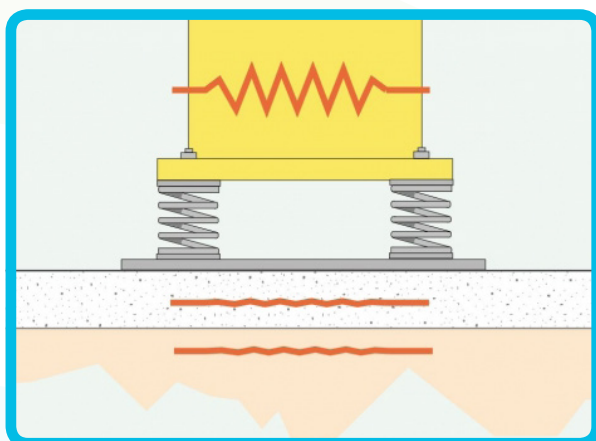
Acoustics, Control of Noise and Vibration

Solution 01

Acoustic Bearings for main structural frame

The design implications for the incorporation of Acoustic Bearings into a structure can vary significantly depending on the intended design of the structure.

A recommended design is to create a freely supported mass where the room (internal box consisting of: floors, columns, walls, ceiling and internals) is supported only by isolation bearings with no lateral or vertical restraints such as fixing bolts. To achieve this there must only be vertical loads transmitted to the isolators (i.e. no horizontal or moment loads) and the steel frame should have sufficient stiffness to be self-supporting.



If this is not achievable due to the need for raked steelwork then lateral and uplift restraints will have to be incorporated into the bearing assemblies to restrain and isolate the multi-directional loads.

Information Farrat require to design a suitable vibration control system for steelwork;

- › Required natural frequency
- › Un-factored loads to ensure we achieve the required performance at realistic loads:
 - › Structure Dead Load (DL)
 - › Super Imposed Dead Load (SDL) – screeds and floor finishes, walls, partitions, ceilings etc.
 - › Live Loads (LL)
 - › Vertical
 - › Lateral
- › Proportion of live load to be included in the isolation design (ADL) which can be added to the DL & SDL when designing the isolation system. Concert halls tend to require the design natural frequency to be at Dead load only as it should perform as well with one person in it as it would if it were full.
- › Factored loads to ensure that the isolation system will withstand the maximum anticipated loads
- › Future load variations due to future change in use of the building
- › Amount of rotation anticipated in the structure
- › What area is available to accommodate the isolation system
 - › Baseplate sizes
 - › Perimeter space constraints such as acoustic voids
- › Proposed mounting arrangement
 - › E.g. Bolt through connections
 - › Bolt sizes
 - › Number of bolts per connection

Design Consideration:

Acoustics, Control of Noise and Vibration

Acoustic Bearings for main structural frame (Cont)

A feature of concert hall design is that the loading of each column will vary significantly and there will be cases where the live load is higher than the dead load whilst the overall system requirements tend to demand a similar natural frequency and deflection of all bearings. At Farrat we pride ourselves on being able to overcome all these constraints through involved design and in-house manufacture.

Structural design

Using the natural frequency, loadings and space constraint information, Farrat provide a detailed schedule of performance for each column / connection. The structural engineer can then add the spring constants provided by Farrat to their structural model to ensure that the steel frame has sufficient stiffness under all load scenarios across different parts of the structure to demonstrate long term structural integrity. A stiffer structure will improve the isolation bearing performance and retain its design intent under differential loadings but this has to be balanced against additional cost and mass to the construction.

Factors to consider for construction;

-)] For safety and so as not to overload individual bearings the steel frame needs to be constructed very carefully
-)] Farrat can provide the bearings in various forms including with mechanisms to 'lock' the bearing during construction but temporary bracing is usually required to support the individual structural parts until it becomes a self-supporting structure.
-)] Isolating the steel structure can lead to longer construction times as bolted connections may need to be carefully designed and installed
-)] Bearing can be same size as baseplate or smaller
-)] Baseplates need to be designed to have sufficient strength to resist bending

Design Consideration:

Acoustics, Control of Noise and Vibration

Solution 02

Lateral Restraints, Shear Keys

Ideally an acoustically isolated building should be constructed as close to the concept of a 'freely supported mass' as possible. In reality this is not practical due to;

- › Construction tolerances
- › Wind and possibly earthquake loads causing lateral forces in the structure
- › Low frequency vibration isolators have very low lateral stiffness but when under high vertical load they should not be subjected to significant lateral forces.

Acoustic bearings cannot be considered exactly as bridge bearings since the thicker rubber layers mean that they do not have the same stability under shear or rotation. This means that lateral restraints usually need to be incorporated as a critical part of the structural and acoustic design. They can either be;

- › Part of the bearing assembly
- › Constructed next to the bearing but built off adjoining structural elements such as floor slabs
- › Incorporated in other parts of the building as shear keys or slab buffers

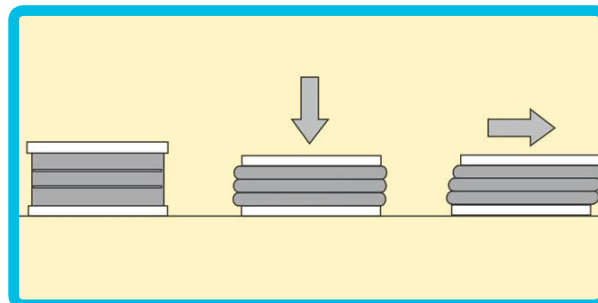
Solution 2a

Lateral restraints as part of the bearing assembly

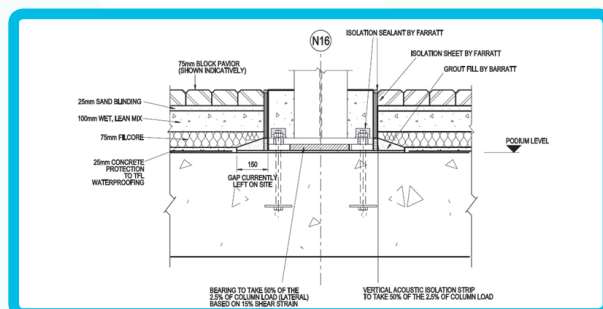
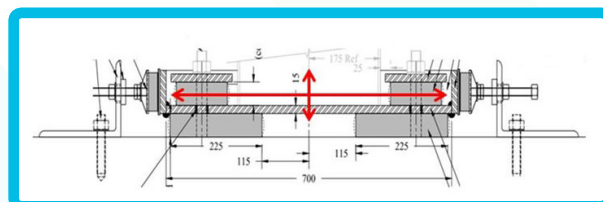
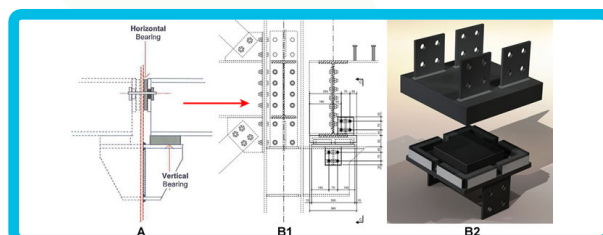
There are various ways of incorporating lateral restraints into bearing assemblies but the exact design will depend on the actual project and connection requirements.

As an example of what can be achieved Diagram A shows the original design where the lateral restraint was designed to be a separate connection. Such designs need to be assembled on site and tend to be difficult to erect and control. Diagram B shows a Farrat alternative where the bearing was supplied as a pre-assembled unit with the lateral restraints integrated into the design. This alternative offered the following advantages;

- › Easier and faster construction
- › A more resilient connection
- › Ability to rotate with the beam without overstressing the lateral restraint bearings
- › Fail-safes incorporated
- › Can be supplied with pre-compressed lateral restraints



It is also possible to incorporate lateral restraints by adding fixtures such as resin anchored brackets to the building or using the existing structures such as floor slabs.



Design Consideration:

Acoustics, Control of Noise and Vibration

Solution 01

Lateral restraints as part of the bearing assembly (Cont)

Solution 2b

Lateral restraints away from the bearing assembly

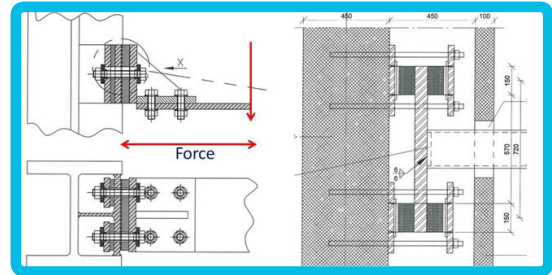
If lateral restraints are to be incorporated at other parts of the structure, such as higher up the building then push-pull connections are usually required to restrict movement in two directions. Push-pull connections may also be required to prevent noise and vibration from external facades and structured from infiltrating the building.

It is important in such connections to allow vertical deflection in the structure from the main isolation bearings. This can be achieved with:

- › Slide faces
- › Slotted holes

Pre-compression may be required to ensure that as load is applied in one direction tension is maintained throughout the connection without unloading the opposite pad. For steel connections Farrat can provide pre-compressed assemblies or for concrete structures flat jacks can be used to generate compression in the bearings during construction.

Shear loads can also be handled by using an acoustic slide bearing where a PTFE slide face is incorporated onto the top of the bearings which slides against a specially designed slide surface on the connecting structure.



Design Consideration:

Acoustics, Control of Noise and Vibration

Solution 03

Acoustic Floating Floors

The isolated steel frame either needs to be designed as one integrated unit where the steel frame columns, floating floors, walls, seating and ceiling structure etc. are created as one unit. In such scenarios steel beams will span the floor allowing a metal-deck (Holorib) concrete slab to be constructed.

A disadvantage of such a design is that loadings can vary significantly across the structure (audience seating section, stage, stage equipment mechanisms etc.) so the structure needs to be designed with sufficient stiffness to resist all load scenarios.

An alternative solution is to construct the main steel frame independently from the floors. This approach allows significant differential loading from different audience levels, stage equipment in the fly tower, performers on the stage etc. without necessarily putting undue stress on the structure.

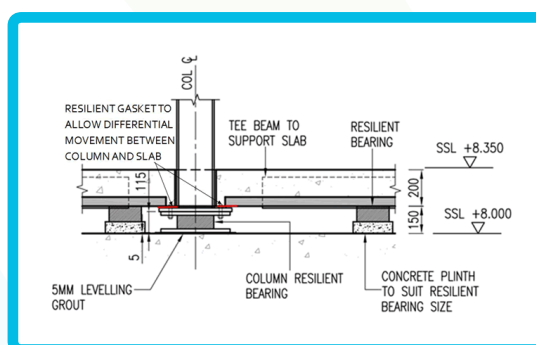
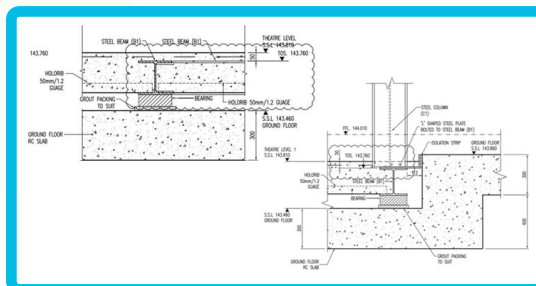
The overall design needs to consider all load combinations to ensure that clashes do not occur between independent elements.

For example if the floor were loaded (and therefore were to deflect) but the seating structure was

empty (dead load deflection only) there may be a chance that the floor and seating structure may clash.

Farrat has designed a range of floating floor which have been successfully used in concert halls. There are various options to accommodate specific design requirements and construction constraints.

- ▶ Isomat
- ▶ Jack Up
- ▶ Pre-cast



Design Consideration:

Construction

- › The building structure must be constructed evenly to avoid differential deflections
- › Avoid excessive bearing loading
- › Temporary ties / bracing may be required
 - › Bearing assemblies can be fitted with temporary holding down bolts
- › Avoid bridging (short circuiting) isolation system;
 - › All debris to be cleared from around bearings
 - › All services to be flexibly connected to the building
 - › Retained facades to be flexibly connected to new structure
 - › Consider lift shafts and stairwells which pass through the isolation break
 - › Internal & external cladding must not bridge isolation region

Care must of course be taken to ensure that there are no mechanical couplings between the main and isolated structures. Such couplings can occur at any part of the construction process.

Hybrid constructions like this can lead to overlaps between steel and concrete trades as well as later fit out works which have to be carefully planned and coordinated.





Global experts in
Vibration Control, Thermal Isolation &
Precision Levelling Solutions
for Construction, Industry & Power Generation

Farrat Isolevel Ltd Balmoral Road, Altrincham, Cheshire, WA15 8HJ, England, UK
T. 44 (0) 161 924 1600 F. +44 (0) 161 924 1616
E. ales@farrat.com www.farrat.com

Company Registration Number (England): 635283
VAT Registration Number: GB 145 9515 50
Company Directors: O. Farrell, A. Farrell, R.J. Farrell, H.J. Farrell, G.H. Farrell