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The isolation from railway vibration of the BBC Egton Wing, Portland Place, London

Peter Henson[a]
Bickerdike Allen Partners, 121 Salusbury Road, London NW6 6RG, United Kingdom

1. INTRODUCTION

Egton Wing forms a key part of Phase 1 of the BBC Broadcasting House redevelopment project in Portland Place, London. This recently completed new building was constructed on spring anti-vibration bearings (AVB) to protect studios from the effects of the Victoria Line which runs directly underneath. The brief required the building to perform acoustically when almost empty and also when full of TV and radio studios. The isolation design therefore had to take account of variable loads arising from a phased approach to studio fit-out.

This paper details the results of vibration measurements taken in the original Egton building before demolition, those taken in the new Egton Wing when constructed but with bearings installed but unreleased (rigid or "locked"), and those taken after release of the bearings. The results show the order of magnitude of isolation attainable from spring bearings placed beneath a concrete framed building of this type.

In addition, this paper describes some of the special measures that were deployed in the vibration isolation design to account for the fact that the building, on opening, would be of a significantly lower weight than on full occupation with heavy studios installed. This required the deployment of dummy bearings for later release as well as special head and movement details to account for significant variations in building deflection, over and above the norm.

The paper compares the final vibration levels achieved in the building with those required to ensure compliance with BBC criteria for structure-borne noise in studios.

2. EGTON WING VIBRATION ISOLATION

This section of the paper describes the range of vibration measurements obtained in:-

- the original building prior to demolition;

- the new building prior to AVB release

- the new building after AVB release

The isolation of the new Egton Wing was undertaken to ensure that vibrations induced by passing trains in the first floor plate and in higher floors would be sufficiently controlled to

[a] Email address. phenson@bickerdikeallen.com

ensure stringent noise criteria could be achieved within Radio and TV studios. Table 1 sets out the vibration limits that were deduced as applicable to the first floor (and higher floors) to ensure compliance with the studio noise criteria.

Table 1: *First floor train vibration acceleration limits (L_{eq})*
dB re 10^{-6} ms^{-2}

	Octave Band Centre Frequency (Hz)		
	31.5	63	125
First Floor Vibration Limit	62	70	62

These criteria were applied by adopting a measurement procedure where, during a train passby, the vibration was monitored and the meter set to record once the train event was well established. Recording ceased prior to the vibration level falling significantly.

Vibration measurements were obtained at various locations around each floor plate under investigation. At each position, measurements of at least three train events were recorded. Background vibration levels were also recorded and train event measurements corrected where necessary.

A. The Original Building Prior To Demolition

The original Egton Wing Building comprised a steel frame with concrete floors. Basement areas were of in-situ concrete construction. A series of vibration measurements were taken in various areas around the building to assess existing conditions and establish the need for and extent of isolation required in the new building. The concrete floor of the basement car park, which was located on grade, formed a useful surface for baseline vibration measurements.

Table 2: *Mean train vibration acceleration levels (L_{eq})- original building*
dB re 10^{-6} ms^{-2}

	Octave Band Centre Frequency (Hz)		
	31.5	63	125
Basement Car Park	71	77	70
Basement & Lower Ground			
(Floor Edge)	68	80	77
(Floor Centre)	73	89	93

B. The New Building Prior To AVB Release

The new Egton Wing Building was built on the same site as the original building. Unlike its lighter weight predecessor, it was built with a reinforced concrete frame. The basement and ground floors remained unisolated. The AVBs were installed at the top of the columns supporting the first floor plate. The results presented in Table 3 below were obtained when the superstructure of the building was substantially complete but external cladding and internal fit-out was not well advanced. The AVBs were present but not yet released therefore the upper floors were unisolated.

Table 3: *Mean Train Vibration Acceleration Levels (L_{eq})- New Building Prior to AVB Release*
dB re 10^{-6} ms^{-2}

	Octave Band Centre Frequency (Hz)		
	31.5	63	125
Basement 3	70	80	76
Ground	69	79	73
First Floor	67	77	71
Third Floor	66	75	68

C. The New Building After AVB Release

The AVB installation was designed to operate with a system resonant frequency of 3.5 Hz under a spring deflection of 20 mm. Since the building would experience variable loads from the commencement of its operation to full fit-out, the AVB deflections would vary. Some variation around the "target deflection" of 20 mm could be accommodated with little impact on isolation efficiency.

During the construction of the building, measurements were taken to review how vibration levels were varying with spring deflection. Measurements were also taken just prior to hand-over when the springs would theoretically have been operating close to their design deflection (although this was not recorded). The results of vibration measurements taken at these different stages are given in Tables 4 to 6 below.

Table 4: *Mean Train Vibration Acceleration Levels (L_{eq})- New Building Prior to AVB Release*
dB re 10^{-6} ms^{-2}
AVB Deflection – 14.6 mm average

	Octave Band Centre Frequency (Hz)		
	31.5	63	125
Ground	71	81	75
First Floor	62	70	63

Table 5: *Mean Train Vibration Acceleration Levels (L_{eq})- New Building Prior to AVB Release*
dB re 10^{-6} ms^{-2}
AVB Deflection – 16.4 mm average

	Octave Band Centre Frequency (Hz)		
	31.5	63	125
Ground	74	82	79
First Floor	61	67	60
Third Floor	53	62	54

Table 6: *Mean Train Vibration Acceleration Levels (L_{eq})- New Building Prior to AVB Release*
dB re 10^{-6} ms^{-2}
AVB Deflection – Unknown (18.0 mm estimated prior to hand-over)

	Octave Band Centre Frequency (Hz)		
	31.5	63	125
Ground	73	81	74
First Floor	61	69	60
Third Floor	58	65	55

Comparing the results in Table 6 for the first floor and third floor with the vibration limits in Table 1 shows that, at the time the building was completed (but not fully fitted out with studios), the required level of vibration isolation in the floor plates had been achieved.

3. VARIABLE LOADS ARISING DURING STUDIO FIT-OUT

For a typical building project where the structure will be supported on springs, the following general steps are followed (Strategy A):-

i) AVBs are delivered to site when foundations are sufficiently prepared.
ii) AVBs are positioned on top of columns, shear walls, or ground beams, etc.
iii) Superstructure is constructed on top of the "locked" AVBs.
iv) On completion of the superstructure, prior to the major fit-out of the building, the AVBs are unlocked. Access to the bearings is required for this purpose.
v) The fit-out of the building proceeds to completion of the project.

The BBC required the flexibility to install studios within technical areas of the building in a phased manner. On opening, the building might contain no studios but may, in the future, accommodate many heavy studios. Any AVB installation, building services, structural or architectural design requirements had to take account of this.

On opening, the AVBs would have to deflect sufficiently to acoustically protect the initial "0% studio (or office) accommodation scenario". This would ensure that when the first studio is built, train noise and vibration is adequately controlled. For the 100% studio load, the AVBs will deflect further, with implications for the building structure, finishes, services, and structural acceptability of the AVBs.

The design deflections adopted on the project for areas are given in Table 7.

Table 7: *AVB Design Deflections*

Case		Deflection
Office Accommodation Only (No studios present)	Design	19 mm
	Min. Deflection Permissible	16 mm
Building with Studio Accommodation	Design	23 mm
	Max. Deflection Permissible	25 mm

The minimum deflection was set to ensure adequate levels of vibration isolation would be achieved. The maximum deflection was set to avoid over-stressing the bearing.

With these deflection guidelines, it was possible to establish for each AVB cluster a minimum and maximum permissible load.

The ideal scenario is to have a strategy (Strategy A) where springs are installed at the time of construction of the building with sufficient load capacity to cater for the expected variation in studio loads. This was not always possible however due to the large fluctuation in loads that arose at a particular column, buttress or shear wall.

When load fluctuations during the life of the building are too large to be accommodated by a single AVB arrangement a different strategy must be followed (Strategy B). This could involve the insertion of spare AVBs at the time of building construction. These remain “inactive” or "locked" until the load warrants their activation. Alternatively, an AVB could be replaced with one of greater load carrying capacity. Whereas Strategy B provides increased flexibility in load carrying capacity, it has the disadvantage that after completion of the building, access is required to "unlock" or replace these bearings when building services and finishes are already installed.

When the building is complete and subsequent access is required to an AVB arrangement under Strategy B, the design woud have to take account of the following key factors:-

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- access would be required to each end of the AVB to adjust locking bolts.
- ceilings in the vicinity of the AVB would require provision for access by one man.
- building services in front of the AVB would need to be capable of isolation and removal (or diversion) to allow access with back-up systems available where necessary.
- fire protection would need to be removeable.

4. ACCOMMODATING DEFLECTIONS AT STRUCTURAL ISOLATION INTERFACE

To accommodate variable loads over the life of the building, partition head details and building services connections that occur at the interface of the unisolated and isolated structure must be carefully designed.

The ground floor of Egton Wing is unisolated but partitions are still required to provide adequate sound insulation between spaces. Partition head details must not only accommodate the usual structural deflections associated with concrete floor spans but also the additional movement arising from spring deflections caused by future studio loading. Furthermore, any connection between the top of the "unisolated "ground floor partitions and the "isolated" first floor slab must be sufficiently flexible to avoid the transmission of vibration from underground train movements while also retaining the required sound insulation performance. Figure 1 shows a typical fire rated partition head detail adopted on the project for this purpose.

Figures 2 and 3 provide an option for accommodating the required deflections at the AVB cluster location and also for providing fire protection and sound insulation. Figure 2 demonstrates the general arrangement of the treatment in the absence (for clarity) of any acoustic and fire cladding. Figure 3 depicts the final detail with acoustic and fire cladding applied. The detail can be provided on one side or both sides of a wall depending on the level of fire protection and sound insulation performance required.

To avoid any structural bridging caused by building services passing across the structural isolation joint, each service run must be considered on its own merits. Flexible connections offering sufficient movement capacity were used to isolate ductwork. For pipework, resilient spring hangers were used to ensure that the services were isolated on one or the other side of the isolation joint. Under some circumstances, conflicts can arise between thermal and acoustic requirements, such as where pipework must be connected rigidly to the structure to control thermal movement. Under these circumstances, a compromise solution is sometimes necessary.

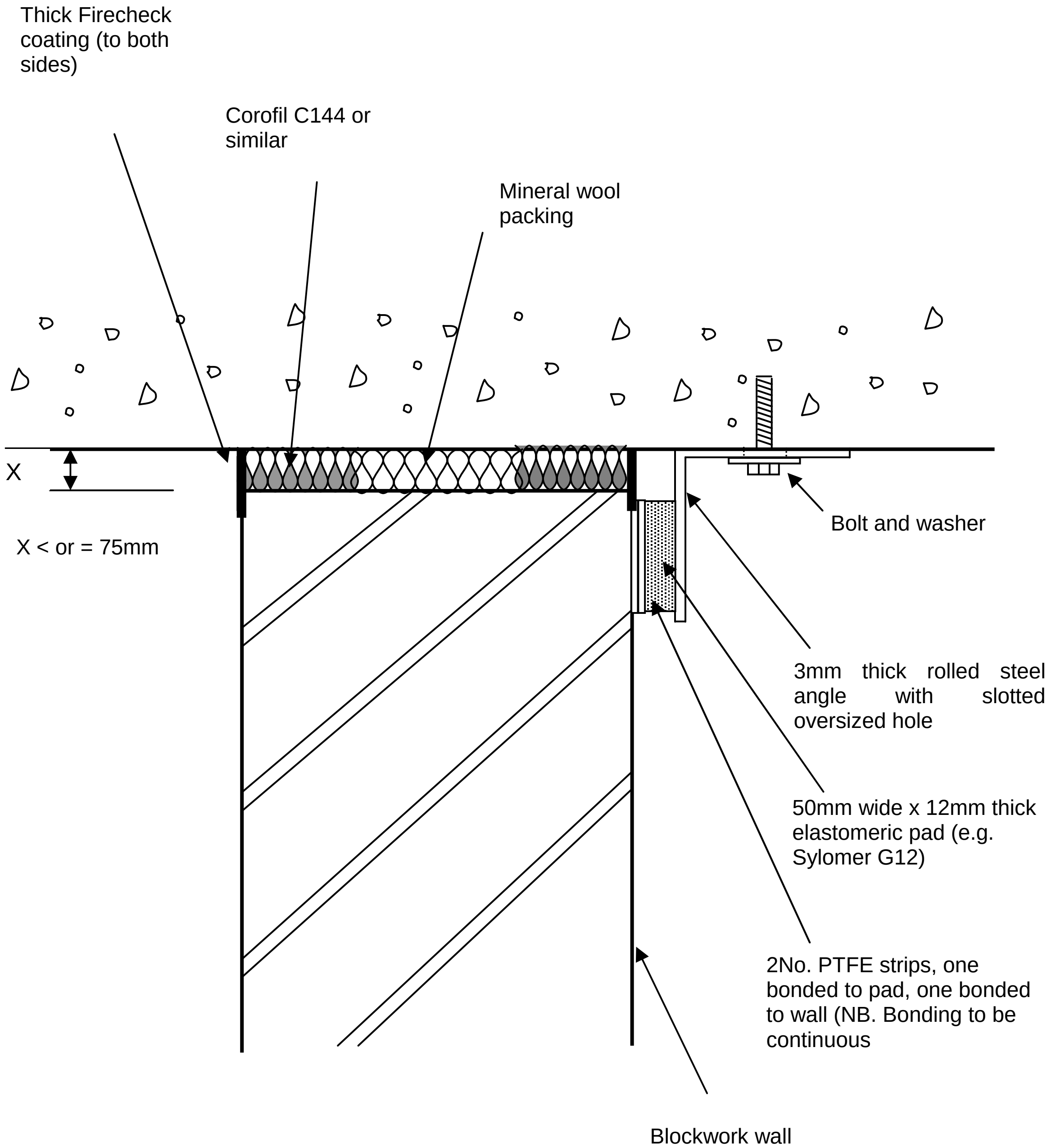
The attention given to details of this type will affect the isolation achieved from the anti-vibration bearings supporting the structure. This was particularly true on this project due to the highly serviced nature of the BBC building. When comparing vibration measurements presented in Table 5 obtained when the building was empty yet virtually complete against those in Table 6 obtained once the building had been fitted out with services, a slight rise in vibration levels is evident on the isolated floors. This may be due to the many service connections required across the structural isolation joint.

5. SUMMARY

This paper details the results of vibration measurements taken in the original Egton building before demolition, those taken in the new Egton Wing when constructed but with bearings installed but unreleased (rigid or "locked"), and those taken after release of the bearings. The results indicate a reduction in vibration acceleration at first floor level of the order of around 10 dB at spring release (at the low frequencies typical of those excited during a train passby) as compared to when the springs were in place but "locked". A reduction of around 13 dB was obtained at third floor level.

Some of the special measures that were deployed in the vibration isolation design to account for the fact that the building, on opening, would be of a significantly lower weight than on full occupation with heavy studios installed have been described, such as the deployment of dummy bearings for later release as well as special head and movement details to account for significant variations in building deflection.

The final vibration levels produced in the isolated section of the building during underground train movements were in compliance with those required to ensure that BBC studio structure-borne noise criteria would be achieved.



N.B. Angle, pad and PTFE strips to be continuous along length of wall.

Lengths of angles to be butt jointed and carefully sealed with mastic.

Note: Only acceptable where walls are restrained at either end, otherwise utilize angle bracket and pads on both sides of wall.

Figure 1: Partition Head Detail

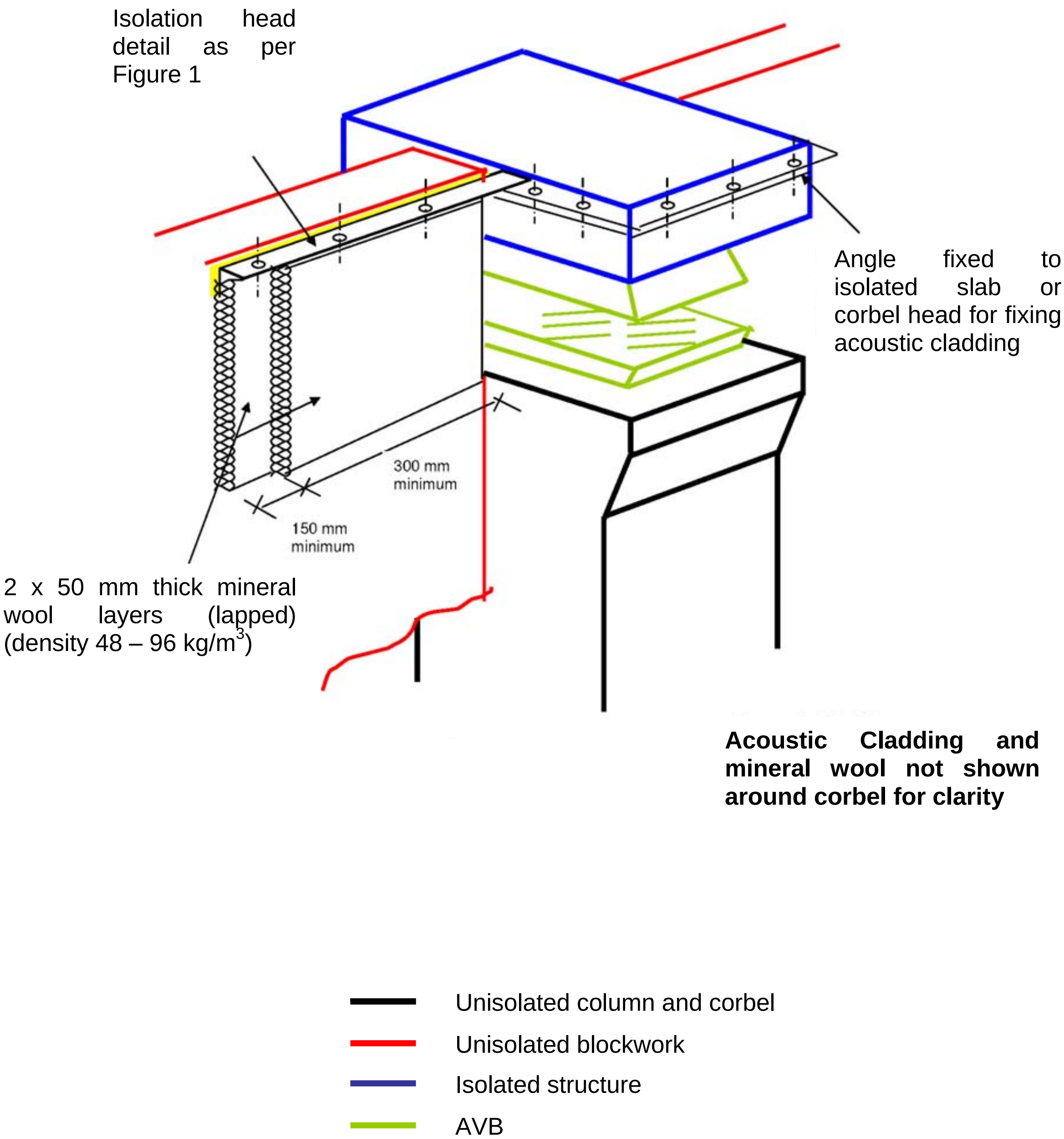


Figure 2: Partition Head Detail at AVB

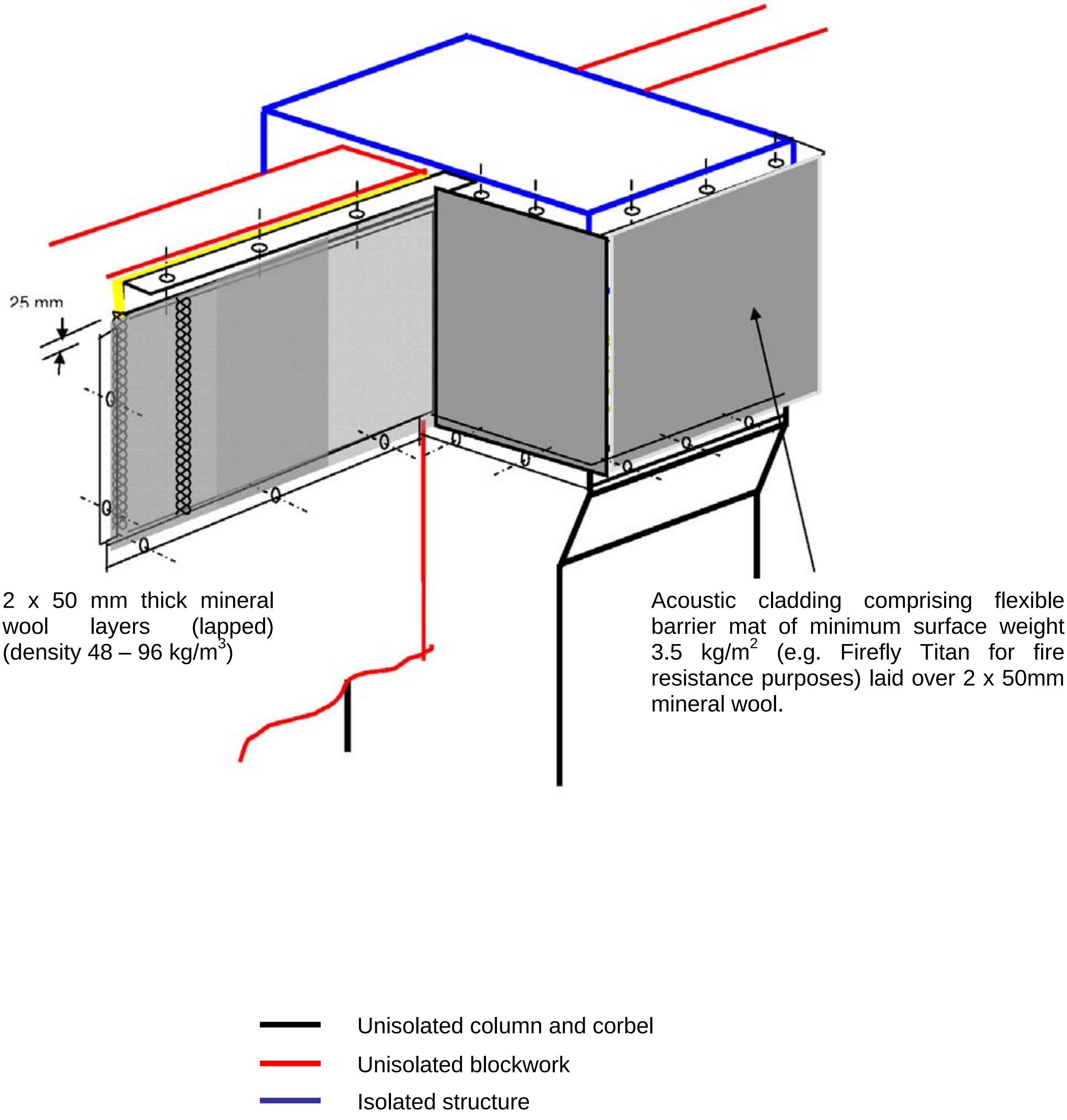


Figure 3: AVB Cladding Detail