SOUND CONTROL IN BELL TOWERS - GUIDANCE NOTES

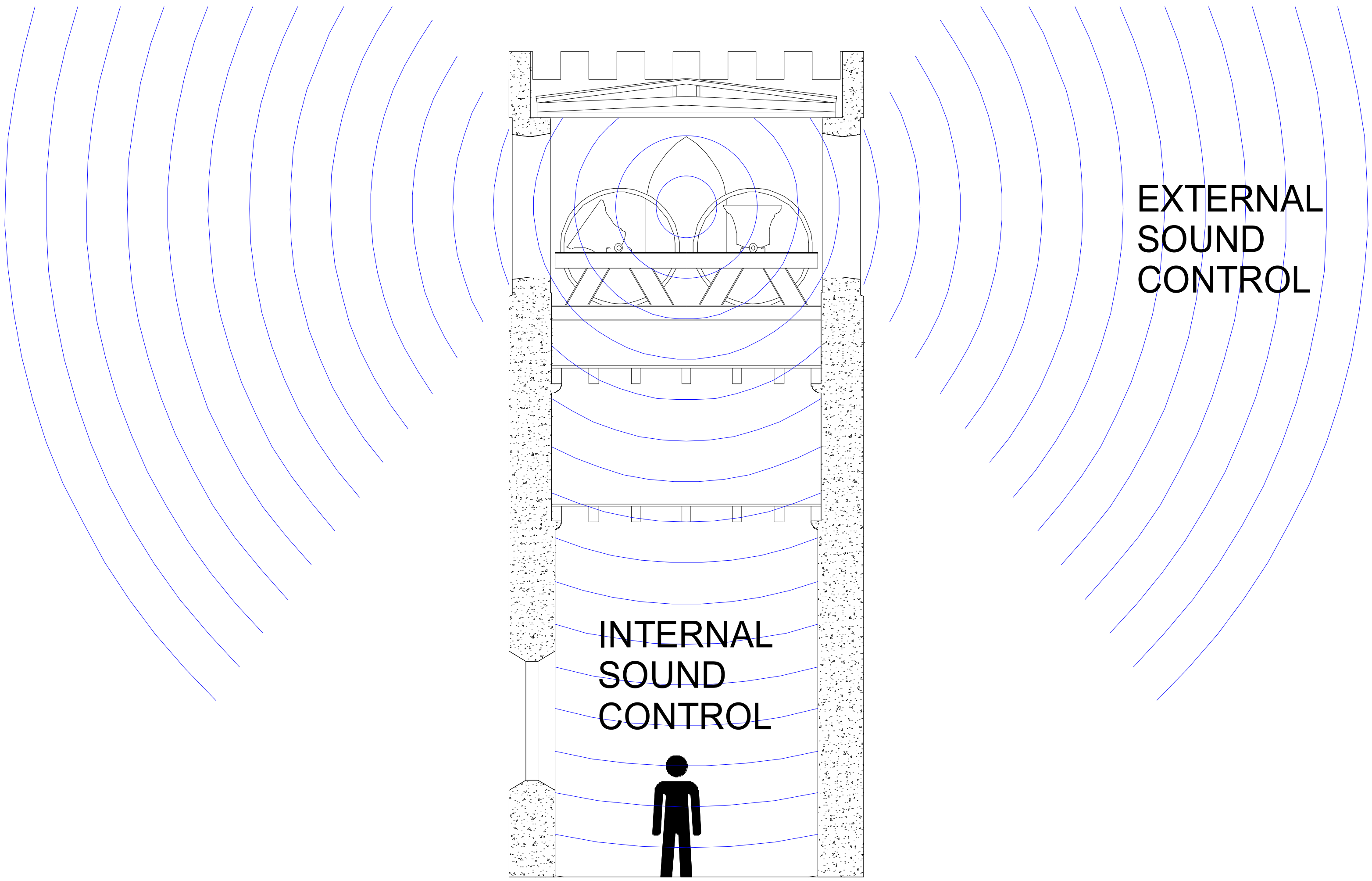
These guidance notes offer:

- a basic understanding of the technical requirements for church bell sound control
- sufficient information to avoid problems in the first place
- sufficient information to investigate problems and instigate effective solutions.

Further advice is always available from the Towers & Belfries Committee and firms of bell hangers.

Note: acoustics is a very complex subject. Simplifying assumptions are made in these notes (e.g. graphs showing sound transmission losses are not corrected for frequency), however useful and relevant conclusions are shown to be possible.

These Notes Cover both Internal & External Sound Control



Acoustics Basics

Sound is:

- **vibration** transmitted through a solid, liquid or gas
- composed of **frequencies** within the range of hearing
- at a **level** sufficiently strong to be heard.

Noise is:

- unwanted sound which may be distracting, annoying or cause temporary or permanent hearing damage.

Acoustics Basics - Vibration

Sound is transmitted through air as longitudinal (pressure or compression) waves. In a longitudinal wave the oscillations occur in the direction of sound travel.

Acoustics Basics - Frequency

- The frequency of a sound wave is the number of complete back-and-forth vibrations of a particle of the sound-carrying medium, per unit of time.
- If a particle of air undergoes 1000 longitudinal vibrations in 2 seconds, then the frequency of the wave would be 500 vibrations per second.
- A commonly used unit for frequency is the Hertz (abbreviated Hz), where

1 Hertz = 1 vibration/second

Frequencies of Sound Emitted by Bells

- When struck by its clapper, the body of a bell vibrates in several modes, each mode vibrating at a different frequency or partial.
- Some partials predominate in loudness and largely define the perceived bell sound. These partials are known as the:
  - hum
  - prime (also known as the fundamental)
  - tierce
  - quint
  - nominal.
- The high frequency partials (nominal, quint) tend to be high-intensity and short duration whereas the low frequency partials (hum, prime, & tierce) are generally lower intensity but of long duration.
- The nominal is used as the reference for tuning of church bells and most lie in the range 500 – 1200 Hz.

Acoustics Basics - Sound Pressure Level

- For the human ear, the perceived loudness of any sound correlates logarithmically with actual sound level.
- The Bel is the logarithm of the ratio of one quantity to a reference quantity and the decibel is one tenth of a Bel. The decibel (dB) scale is used as a means of defining sound levels.
- The smallest change in sound pressure level that can be detected by the human ear is about 3 dB.

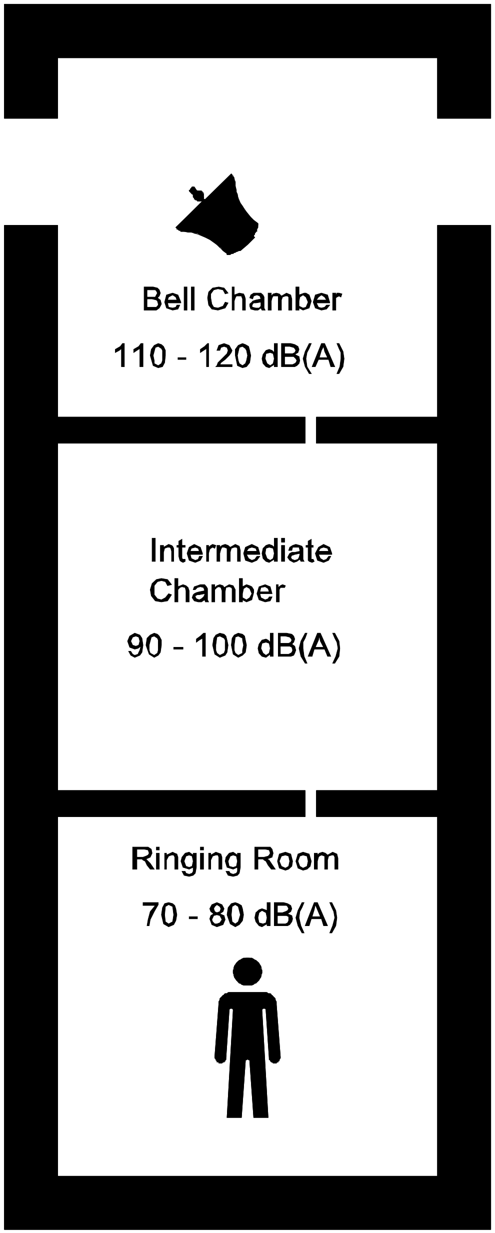
Measuring Sound Pressure Levels

- The human ear is most sensitive to sounds in the 500 Hz - 8 kHz range.
- Sound level meters incorporate electronic filtering to correspond with the varying sensitivity of the ear. This filtering is called A-weighting and measured sound pressure levels are signified as dB(A).
- There are two settings: the FAST setting attempts to catch peaks of sound whereas the SLOW setting averages sound levels over a longer time period.
- Ringers' perceptions of bell sound levels correlate well with use of dB(A) and a SLOW setting.
- Sound level meters are available at low cost (< £100).

Target Sound Levels For Ringing Chamber

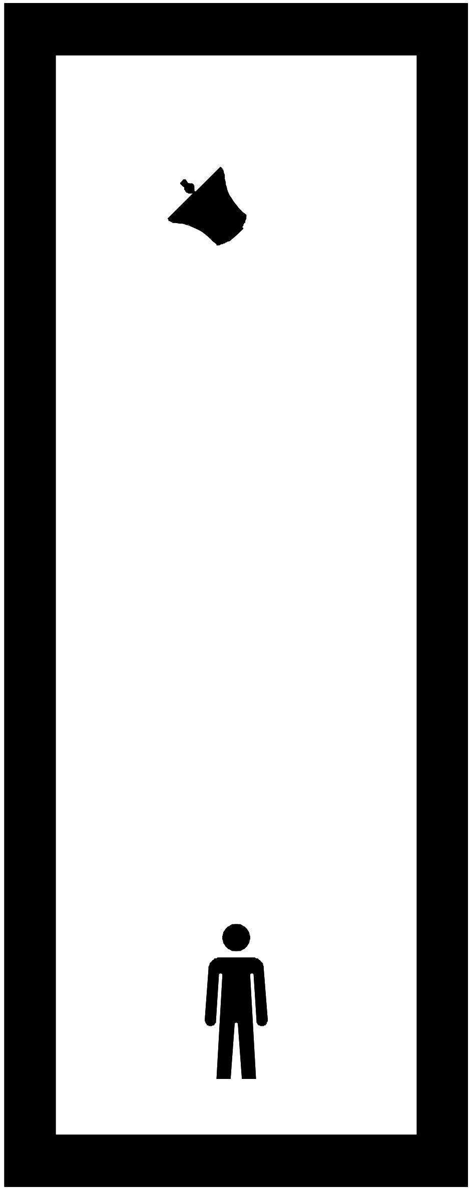
The ear will be the final judge of sound level acceptability, but the following are good guidelines.

- The bells must be sufficiently loud for ringers to clearly hear their own and the other bells to ensure good striking.
- The bells must not be too loud since:
  - ease of verbal communication is essential for ringers to clearly hear commands from the conductor or from a tutor
  - the ringers risk hearing damage if sound levels exceed 85 dB(A), recommended levels are <80 dB(A).
- Experience has shown the following sound levels to be ideal:
  - all bells ringing 70 – 75 dB(A)
  - each bell rung individually 68 – 72 dB(A)



Typical Sound Levels in a Tower with All or Most of the Bells Ringing.

- A typical sound attenuation of 35 - 45 dB(A) is required between bell chamber and ringing room.
- Note: ear protection is strongly advisable in the intermediate room and essential in the bell chamber when the bells are ringing.



Acoustics Basics
- Reverberation

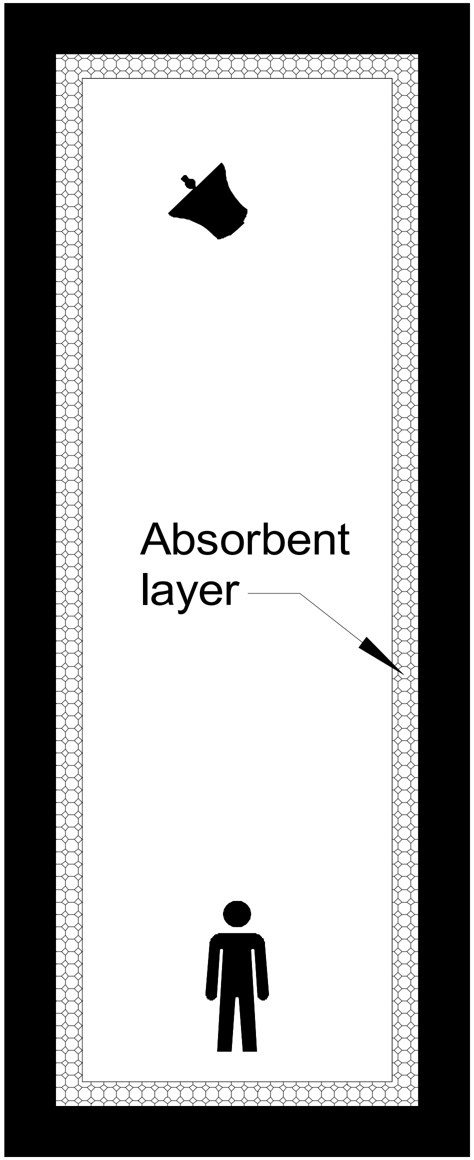
- When a bell is struck in a bell chamber, a significant amount of the radiated sound energy is reflected at the chamber surfaces, so augmenting the intensity of the sound in the chamber.
- Only a fraction of this sound energy is absorbed at any one reflection and so the sound does not die away instantaneously, giving rise to **reverberation**.

Acoustics Basics - Sound Attenuation

The mechanism for sound attenuation in a space depends on the sound source.

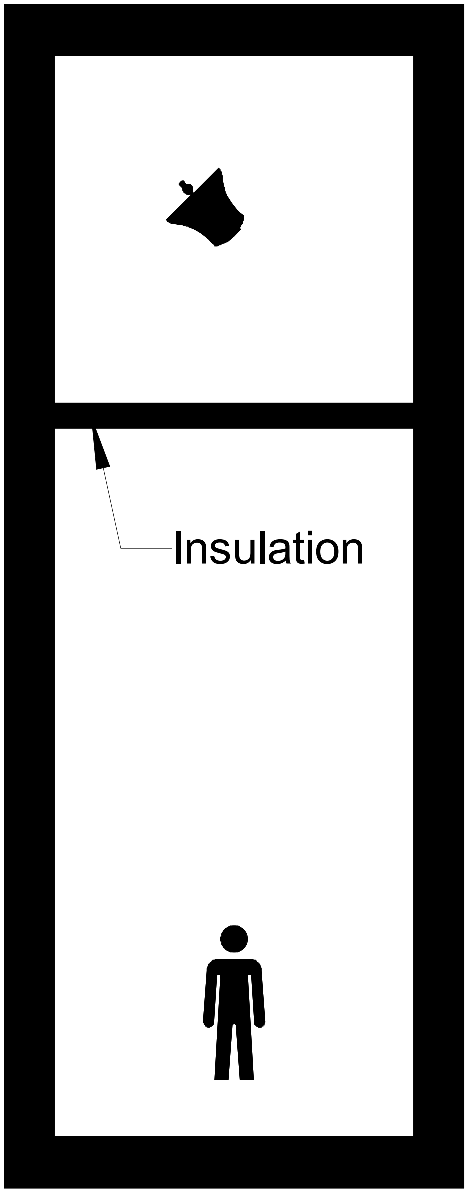
- If sound is generated within the space then it must be **absorbed**.
- If it is airborne, originating outside the space, it is necessary to **insulate** the space.
- If it is transmitted to the space through a structure, then the structure needs to be **isolated** from the source of vibration.
- Sound barriers may employ one or all of these mechanisms.

Sound Attenuation - Absorption



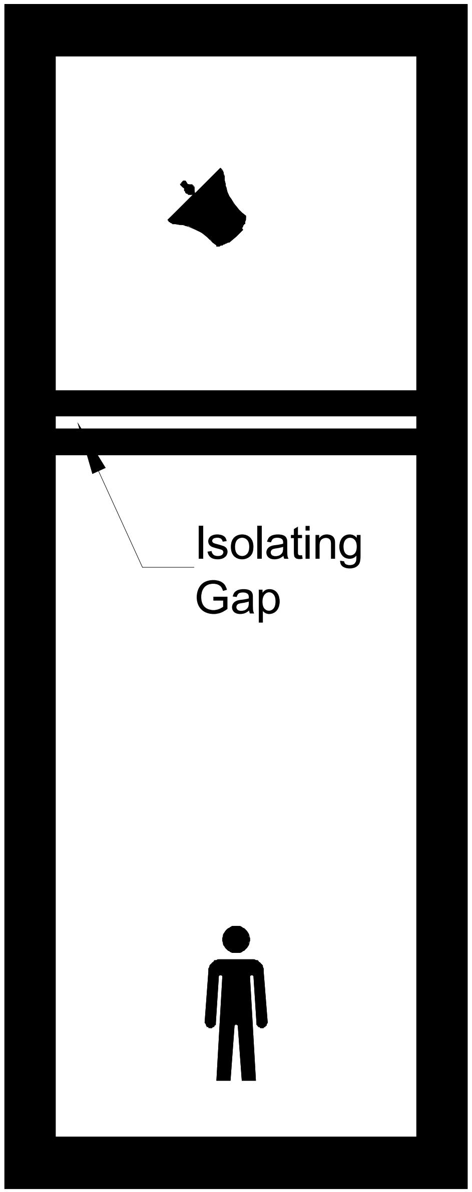
- Absorbent materials dissipate energy from an incident sound wave.
- They work best in association with hard reflective surfaces which cause reflected sound to pass through the material many times.
- They can be used to reduce reverberation.
- Commonly available absorbent materials (such as carpets, draperies, fibrous mineral wool, glass wool, and open cell foam) are highly porous and of **low mass per unit area**.

Sound Attenuation - Insulation



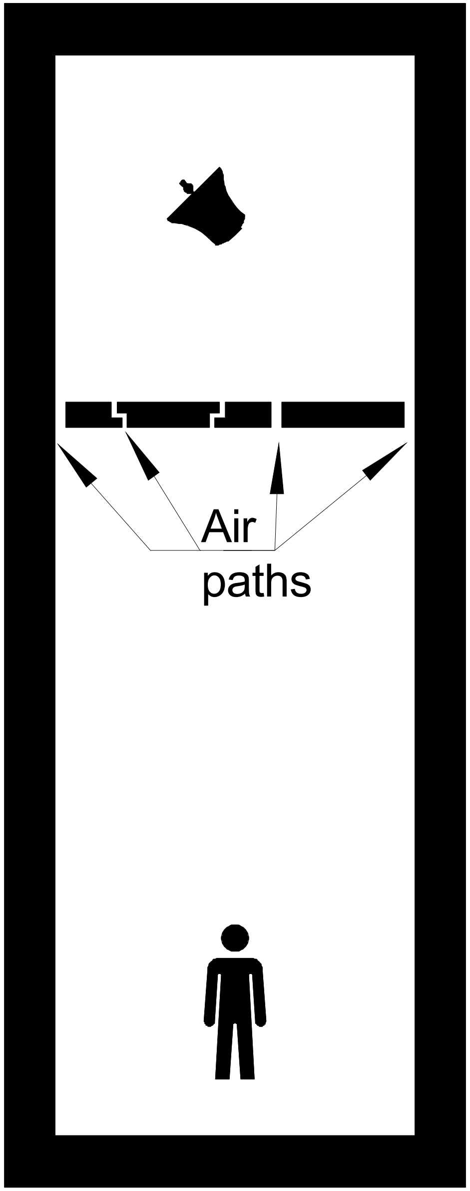
- Insulation requires materials with **high mass per unit area** such as concrete, bricks or thick timber panels.
- Many insulating materials are good sound reflectors and so do not significantly dissipate sound energy.

NB In general, commonly available sound absorbing materials are poor sound insulation materials.



Sound Attenuation - Isolation

Isolation is achieved by ensuring there are no mechanical sound paths between the sound source and the isolated space.



Air Paths Through Sound Barriers

- Air paths breaching or bypassing sound barriers, **even very small air paths**, act as intense sources of sound and seriously erode the effectiveness of the sound barrier.
- Unwanted air paths transmit flanking sound (more later).
- Rope holes offer a challenge – but we need them!

Practical Applications – Control of Sound Levels in the Ringing Room

Sound levels may be:

- too loud or too quiet
- uneven
- lacking in clarity.

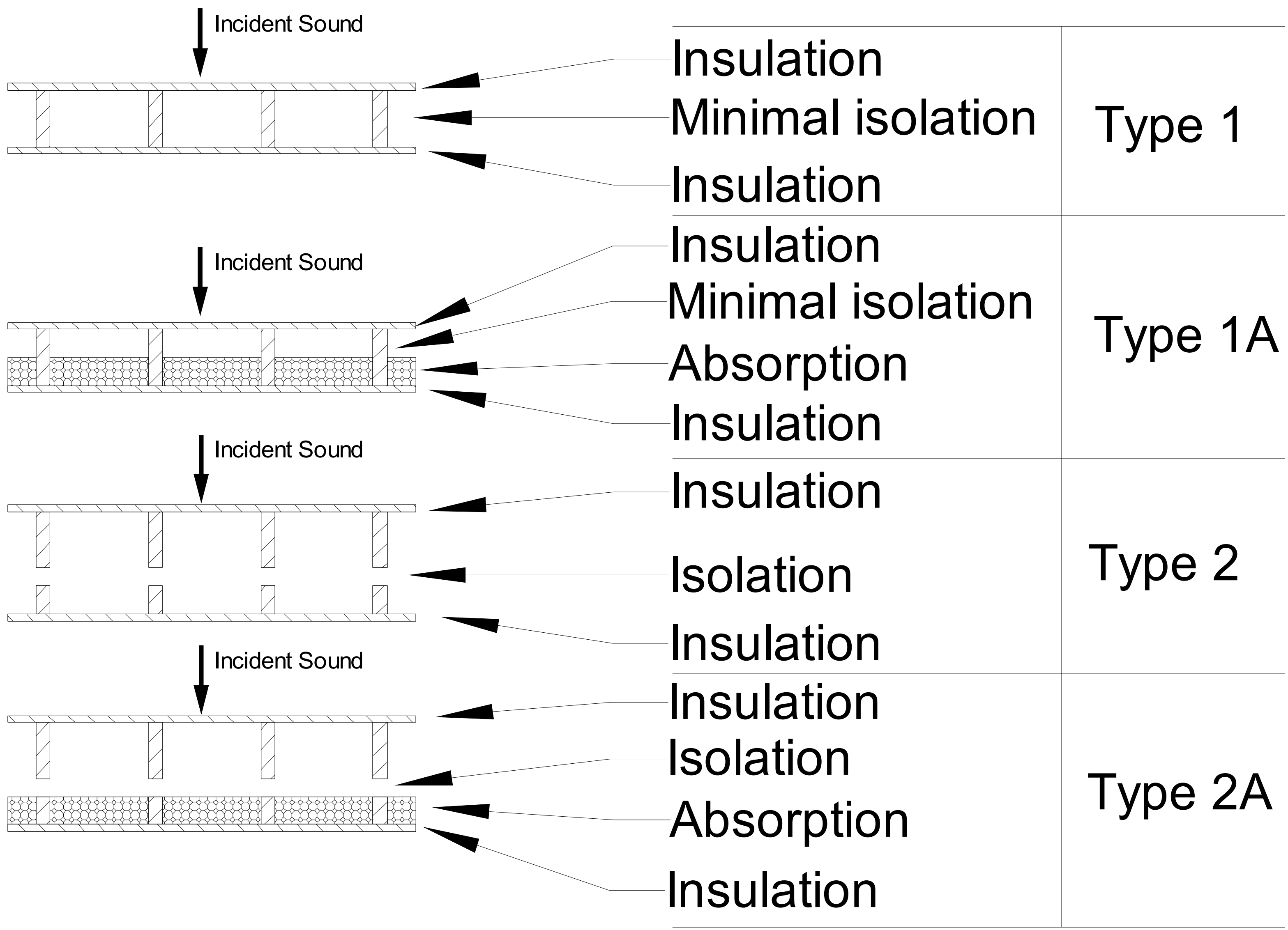
Control of Sound Levels in the Ringing Room

- Attenuation of bell chamber sound levels heard in the ringing room is achieved by installing one or more sound barriers between the bells and the ringers.
- Two types of sound barrier are used:
  - **a simple barrier** comprising a single layer and employing insulation as the means of attenuation
  - **a composite barrier** comprising several layers and employing various combinations of insulation, isolation and absorption as the means of attenuation.

Sound Barrier Construction

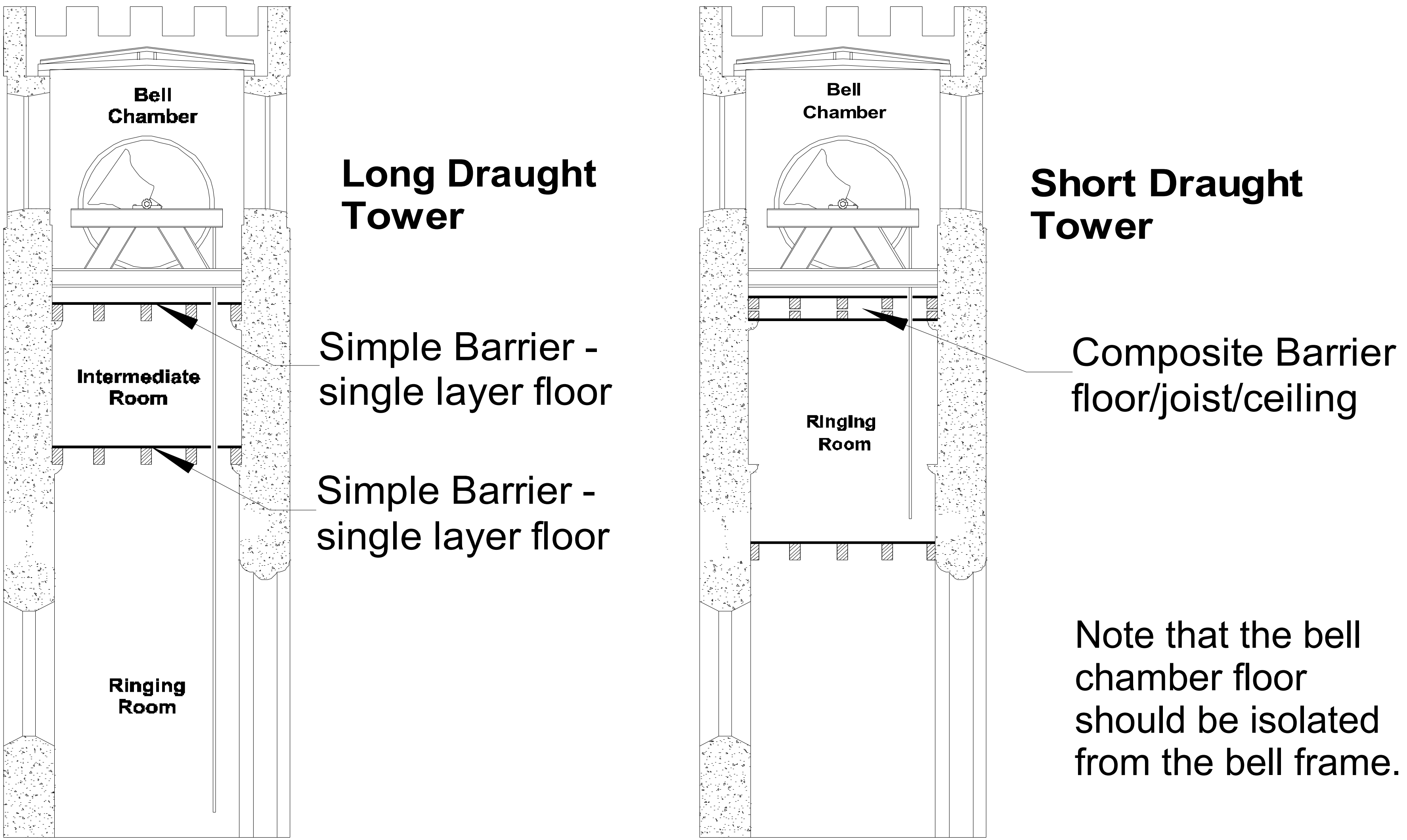
- **A simple sound barrier** may comprise:
  - a tongue & groove wooden floor resting on joists
  - a reinforced concrete floor.
- **A composite sound barrier** typically comprises a tongue & groove wooden floor resting on joists, with a ceiling of tongue & groove boarding below either attached to the underside of the joists or structurally independent. The cavity may contain mineral / glass wool sound absorbent material.

Types of Composite Sound Barrier



Towers & Belfries Committee - **SOUND CONTROL IN BELLTOWERS**

Typical Sound Barriers Inside Tower to Give 35-45 dB(A) Attenuation for Ringing Room

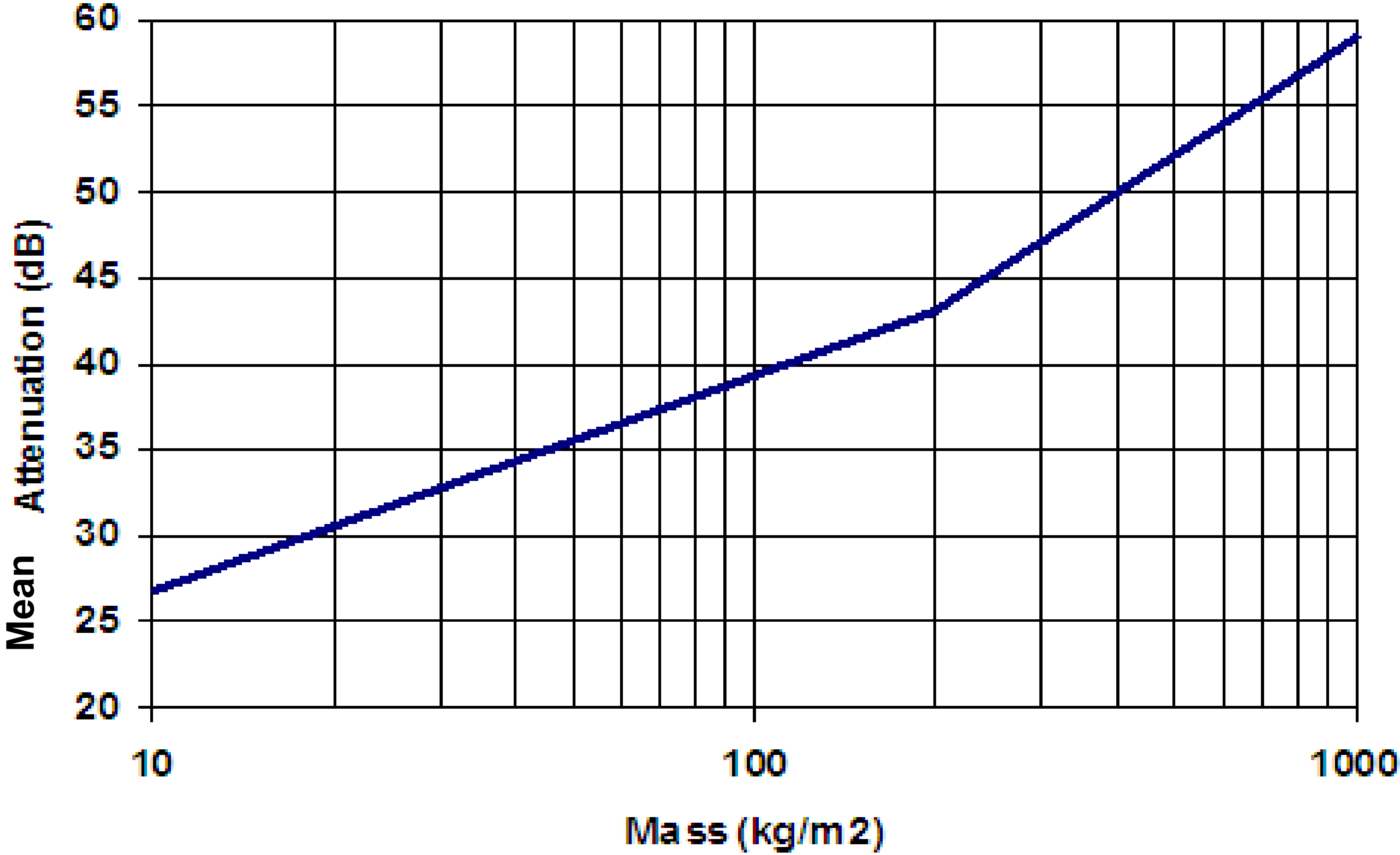


Note that the bell chamber floor should be isolated from the bell frame.

Sound Barriers – Estimated & Achieved Attenuation

- **The estimated attenuation** of a sound barrier is considered, for the purposes of this seminar, as the maximum possible attenuation for a particular specification.
- **The achieved attenuation** is what remains after the estimated level is degraded by:
  - sound transmitted through the rope holes
  - flanking sound transmitted through unwanted air paths.

Estimated Sound Attenuation for Simple Barriers



Estimated Sound Attenuation for Simple Barriers – Sample Calculations

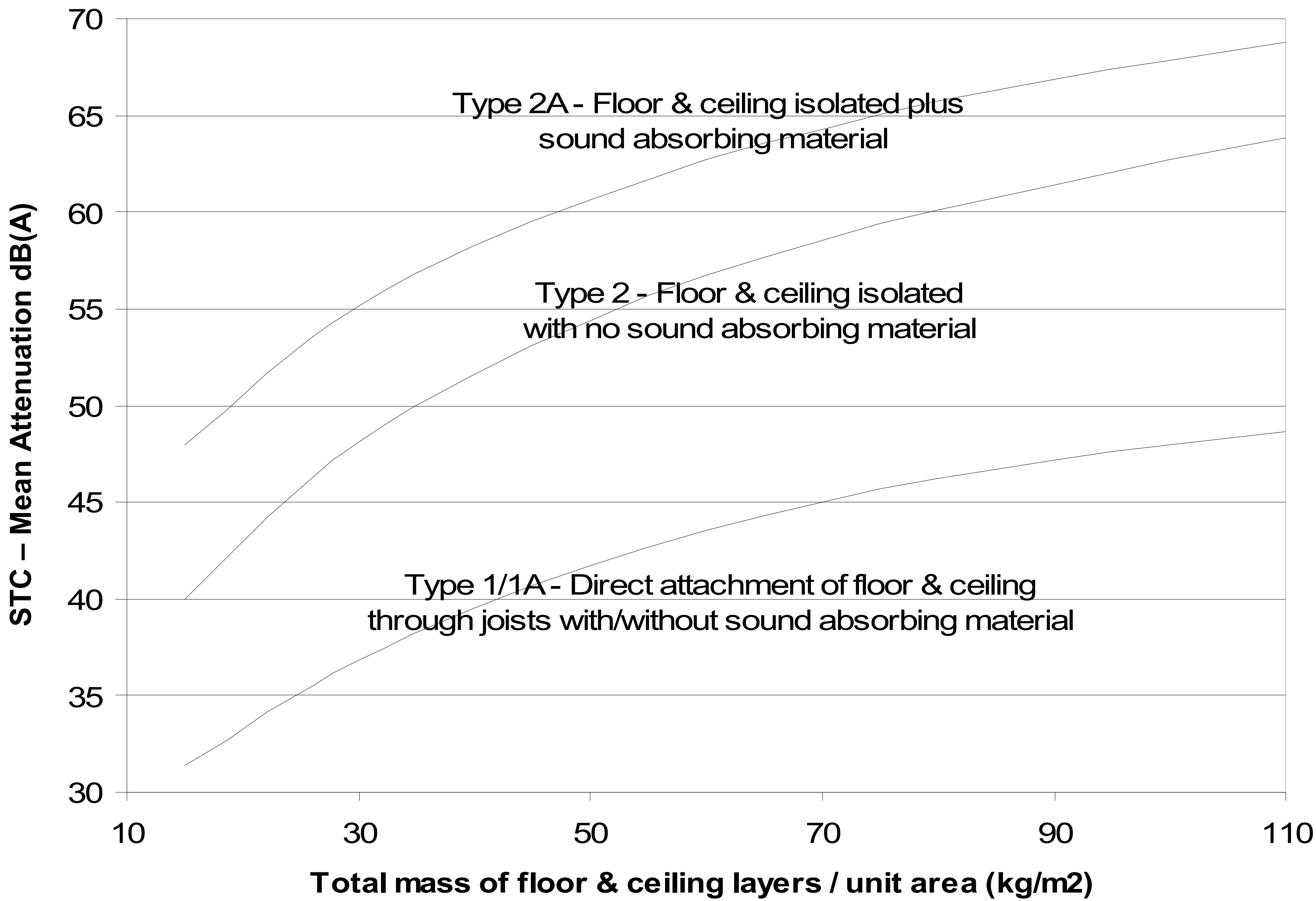
Wooden Floor

- The mass of a wooden floor 25 mm thick is approximately 12 kg/m^2 (ignore mass of joists).
  - Using the graph, the estimated sound attenuation for the floor is 28 dB.
- The mass of a wooden floor 50 mm thick is approximately 24 kg/m^2 (ignore mass of joists).
  - Using the graph, the estimated sound attenuation for the floor is 32 dB.

Concrete Floor

- The mass of a concrete floor 200 mm thick is 460 kg/m^2.
  - Using the graph, the estimated sound attenuation for the floor is 52 dB.

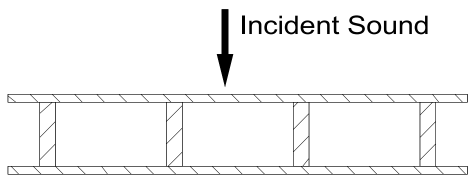
Estimated Attenuation - Composite Barriers



Estimated Sound Attenuation for Composite Barriers - Sample Calculations

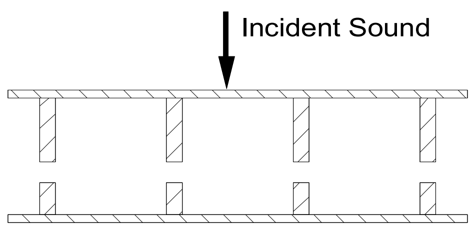
- Assume the floor and ceiling comprise 25 mm tongue and groove timber boards. The mass of the floor plus ceiling is 24 kg/m^2 (ignore mass of joists).
- From the graph, the estimated sound attenuation for barrier types 1, 2, and 2A are:

(Type 1) 35 dB(A)



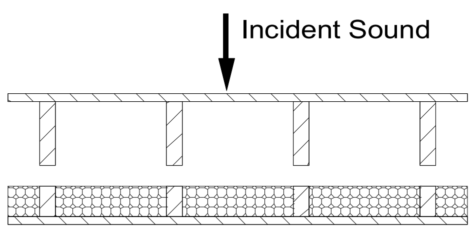
Floor and ceiling acoustically connected through joists

(Type 2) 46 dB(A)



Floor & ceiling acoustically isolated

(Type 2A) 53 dB(A)



Floor & ceiling acoustically isolated plus sound absorbing material

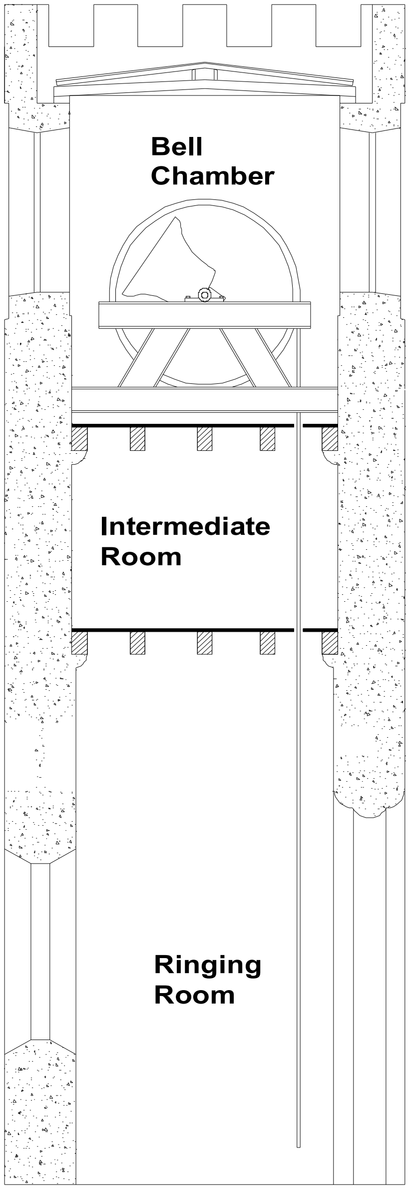
Estimated Sound Attenuation for Composite Barriers

- For type 1 barriers (floor and ceiling not isolated) most of the sound is transmitted through the joists and:
  - attenuation is a little better than a simple barrier comprising material of the same mass / unit area
  - sound absorbent material does not particularly increase estimated attenuation but significantly reduces rope hole noise – see later.
- For type 2 barriers, acoustic / mechanical isolation of the floor and ceiling makes a big improvement to attenuation since sound can pass only via the air in the cavity. Sound undergoes reflections inside the cavity providing conditions in which sound absorbing materials work at their best.
- Composite barriers find greatest use in short draught towers where there is only one barrier between ringers and bells.

Rope Holes – Sound Attenuation

- Rope holes form air paths through barriers and function as sound transmitters providing ringers with essential acoustic information for good striking.
- In many towers excessive ringing room sound levels require rope-hole transmitted sound to be controlled.
- Control of rope-hole sound is achieved by causing the rope to pass through an acoustically insulated chamber which preferably contains some form of sound absorption.
- The chamber may be large, as in the case of an intermediate room, or small as in the case of the void within a composite barrier. Rope-hole mufflers are also small chambers and function in the same way.

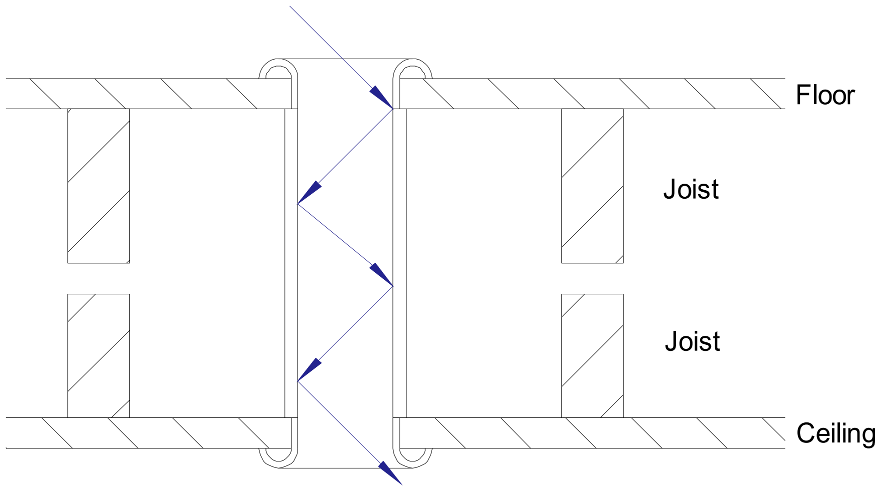
The Intermediate Room



- The primary function is to attenuate sound levels by:
  - acoustically isolating the bell chamber floor from the ringing room ceiling
  - diffusing sound coming through the bell chamber floor rope holes
  - providing a degree of absorption for sound.
- Other functions are:
  - to more evenly mix bell sounds
  - provide space to draw ropes into a better circle
  - protect ringers from a clapper failure
  - provide space for a tower clock mechanism.

Rope Holes in Composite Barriers – Effect of Tube

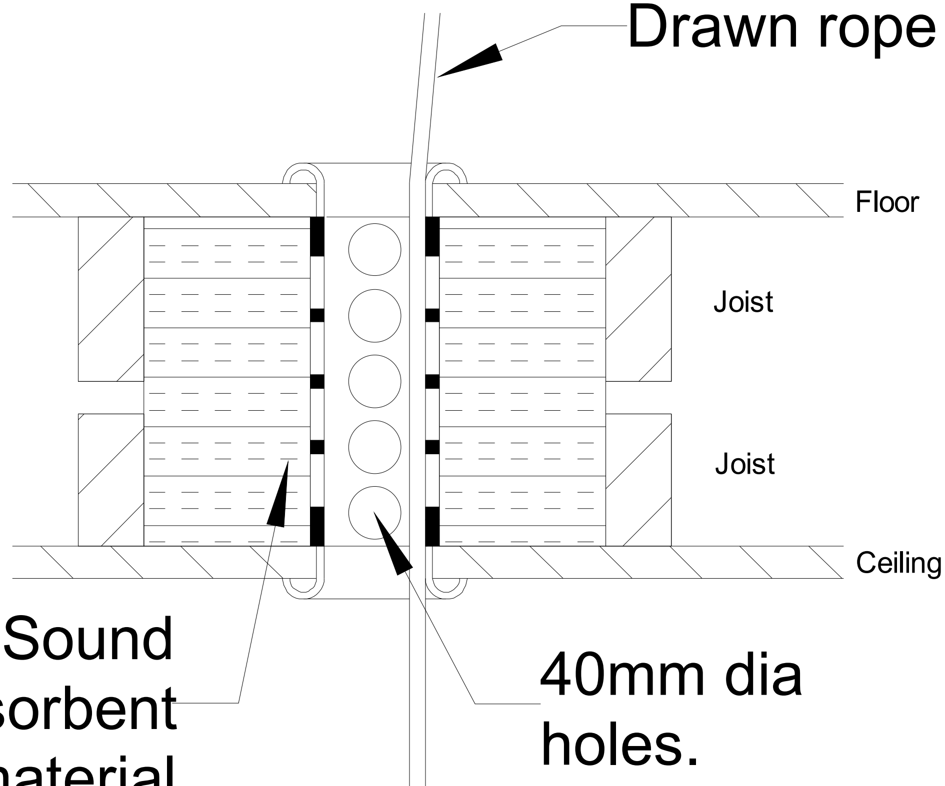
Rope hole
with tube



Sound reflected down tube giving little attenuation of rope hole sound

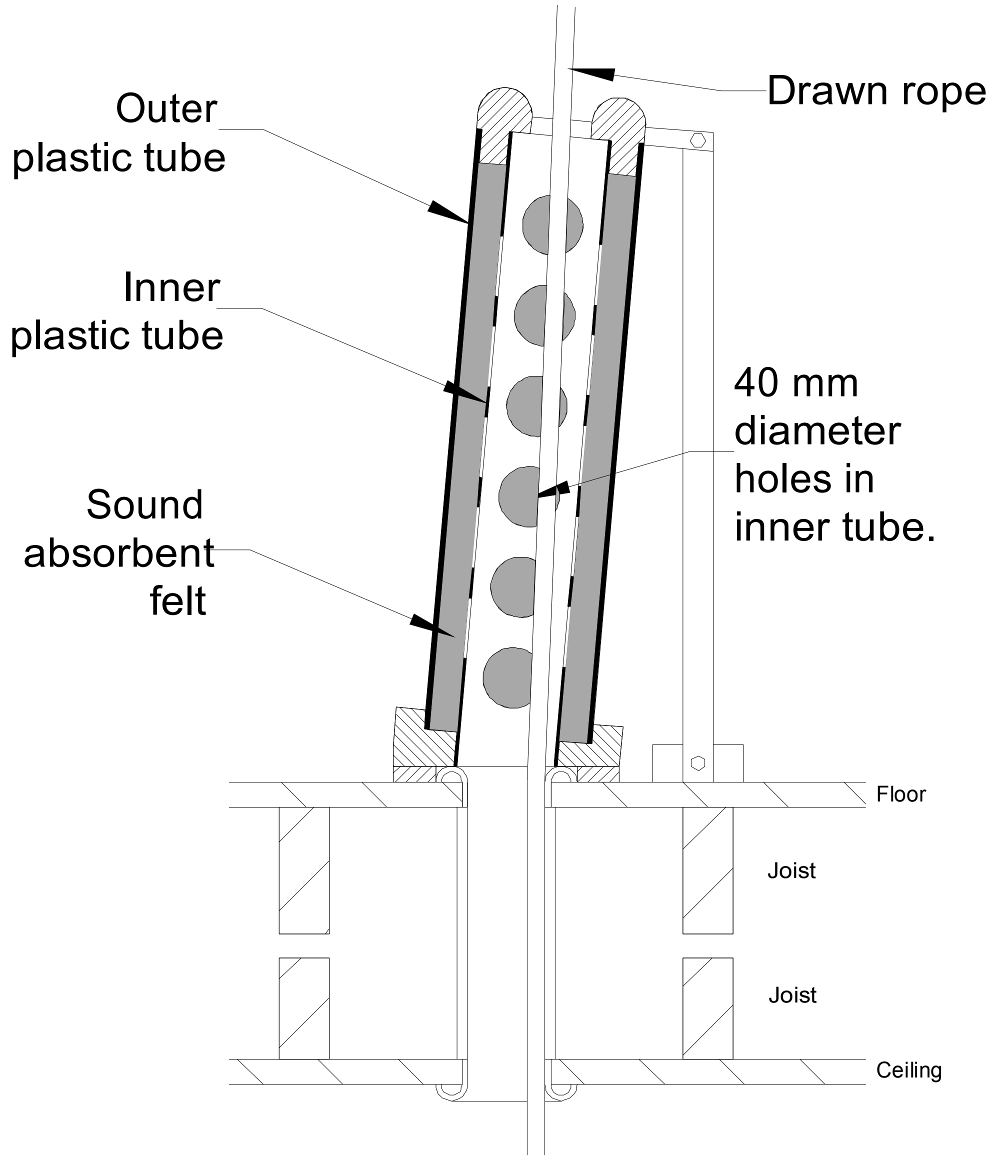
- Use of plain rope-hole tubes or boxes through composite floors causes maximum rope hole sound transmission.
- If the sally enters the tube it will mute rope-hole sound causing sound to come and go in the ringing room.
- In cases where the rope is drawn above the barrier, tubes **are sometimes necessary** to ensure free rope movement through the barrier.

Rope Holes in Composite Barriers – Tube Modified to Attenuate Sound



In cases where the rope is drawn above the barrier and the cavity depth permits, incorporate 40 mm diameter perforations in the walls of the tube and surround with sound absorbent material.

Rope Holes in Composite Barriers – Rope Guide Muffle

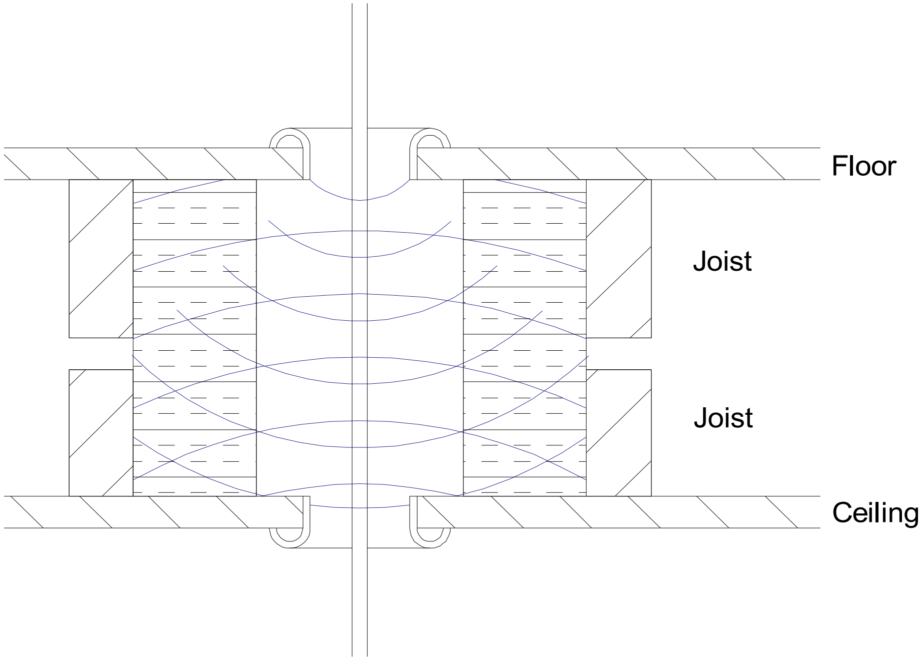


In situations where there is already a rope-hole tube or box and the rope is drawn above the barrier, use a muffled rope guide above the barrier.

This can also be used with simple barriers.

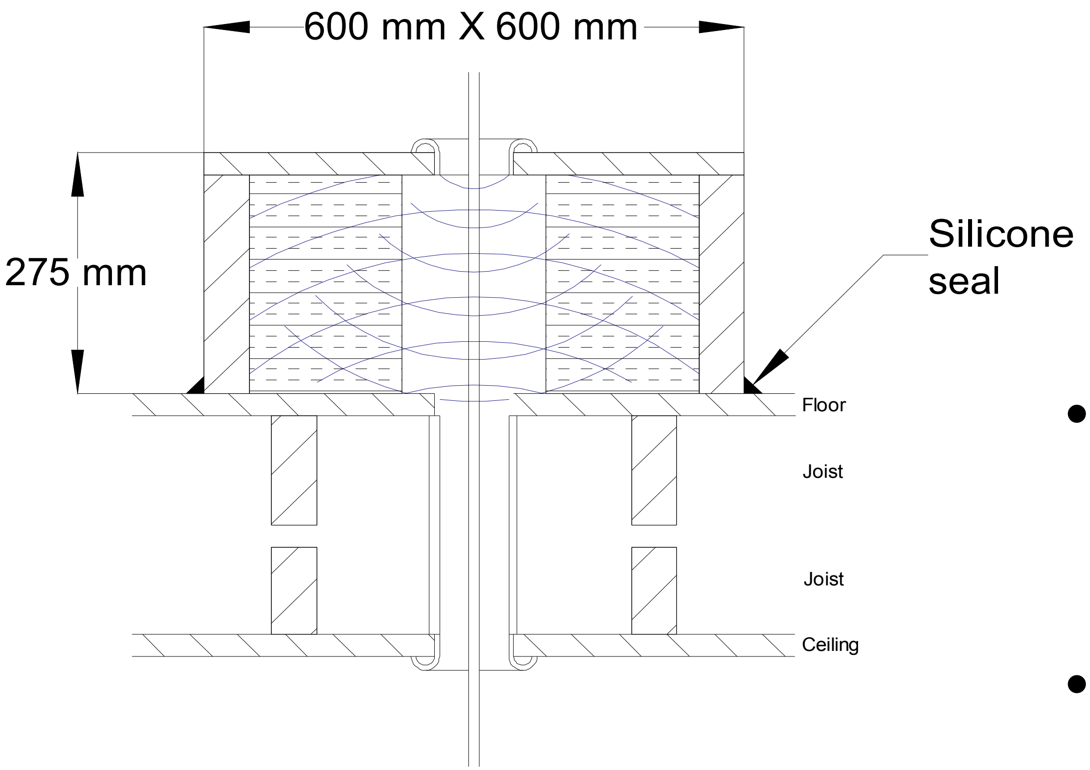
Rope Holes in Composite Barriers – Preferred Design

Rope hole with sound absorbent material in cavity and no tube



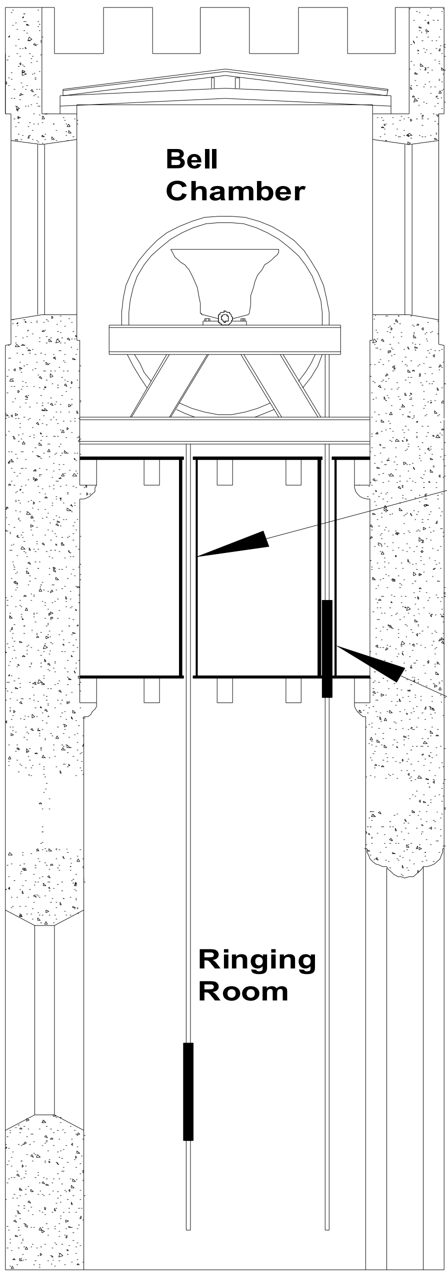
This is the preferred form of rope-hole construction and should be used in all situations where the rope falls vertically and maximum sound attenuation is required.

Rope Holes in Composite Barriers – Muffler Box



- Use of a muffler box is a variation on the previous slide and can be used where the rope falls vertically and where there is already a rope-hole tube or box.
- Great care is needed to seal all joints in the box or it will be ineffective!
- This can also be used with simple barriers.

Conventional Rope Guides (i.e. without Sound Attenuation Incorporated)



Fully enclosed rope guides act as sound conduits between bell chamber and ringing room

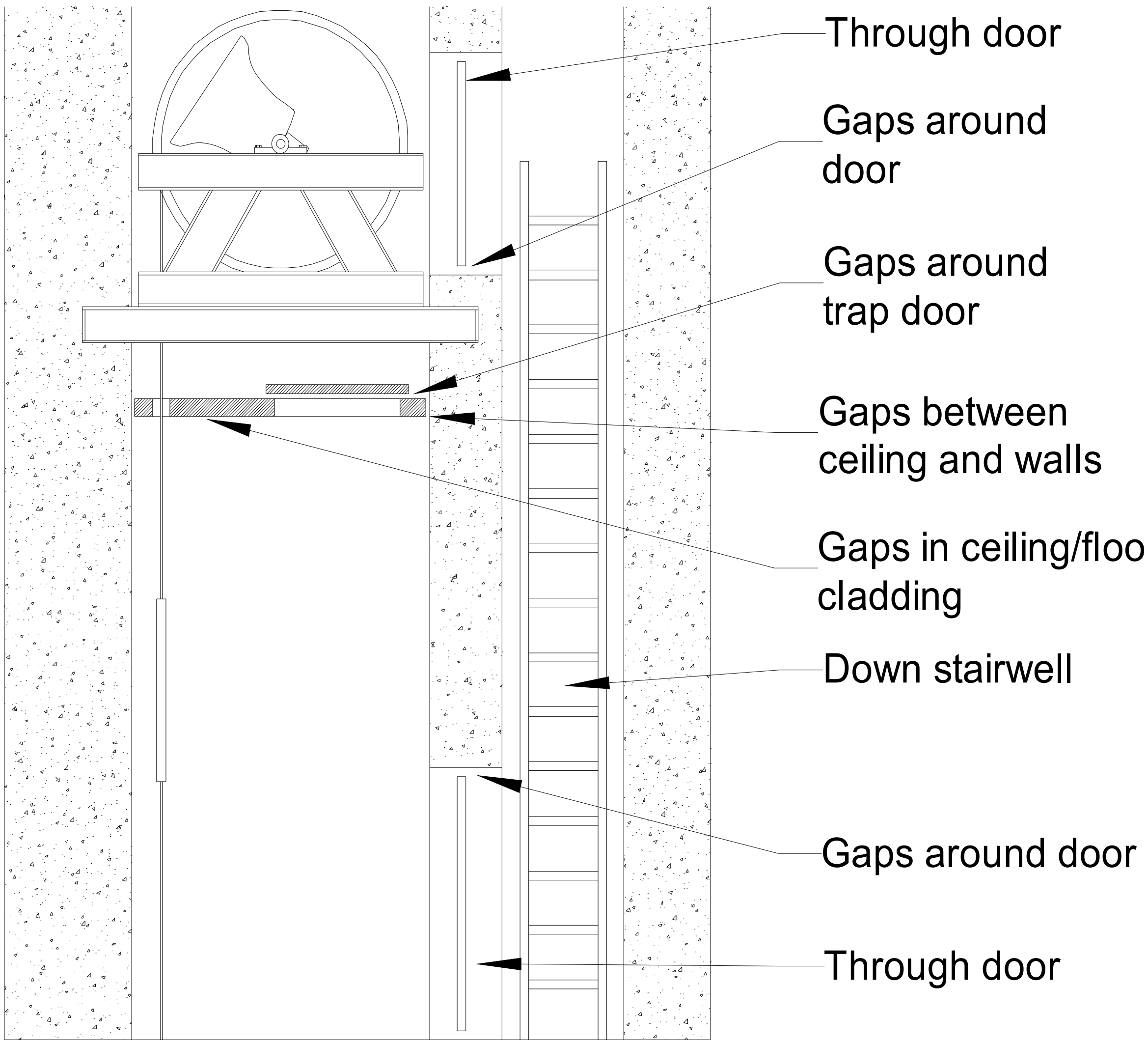
If sally enters fully enclosed rope guide, it mutes the sound following a hand stroke.

Avoid fully enclosed rope guides unless there is a need to increase ringing room sound levels.

Flanking Sound

- Flanking sound is sound which bypasses the sound barriers.
- It blurs the sound of the bells in the ringing room.
- It can be employed to augment ringing room sound levels where these are too quiet.
- It is often the main contributor to excessive sound levels in a ringing room.
- Reduction of flanking sound levels generally requires **fastidious** attention to details – all flanking sound paths must be identified and sealed – if one is missed it will largely negate all the good work done on the other paths!

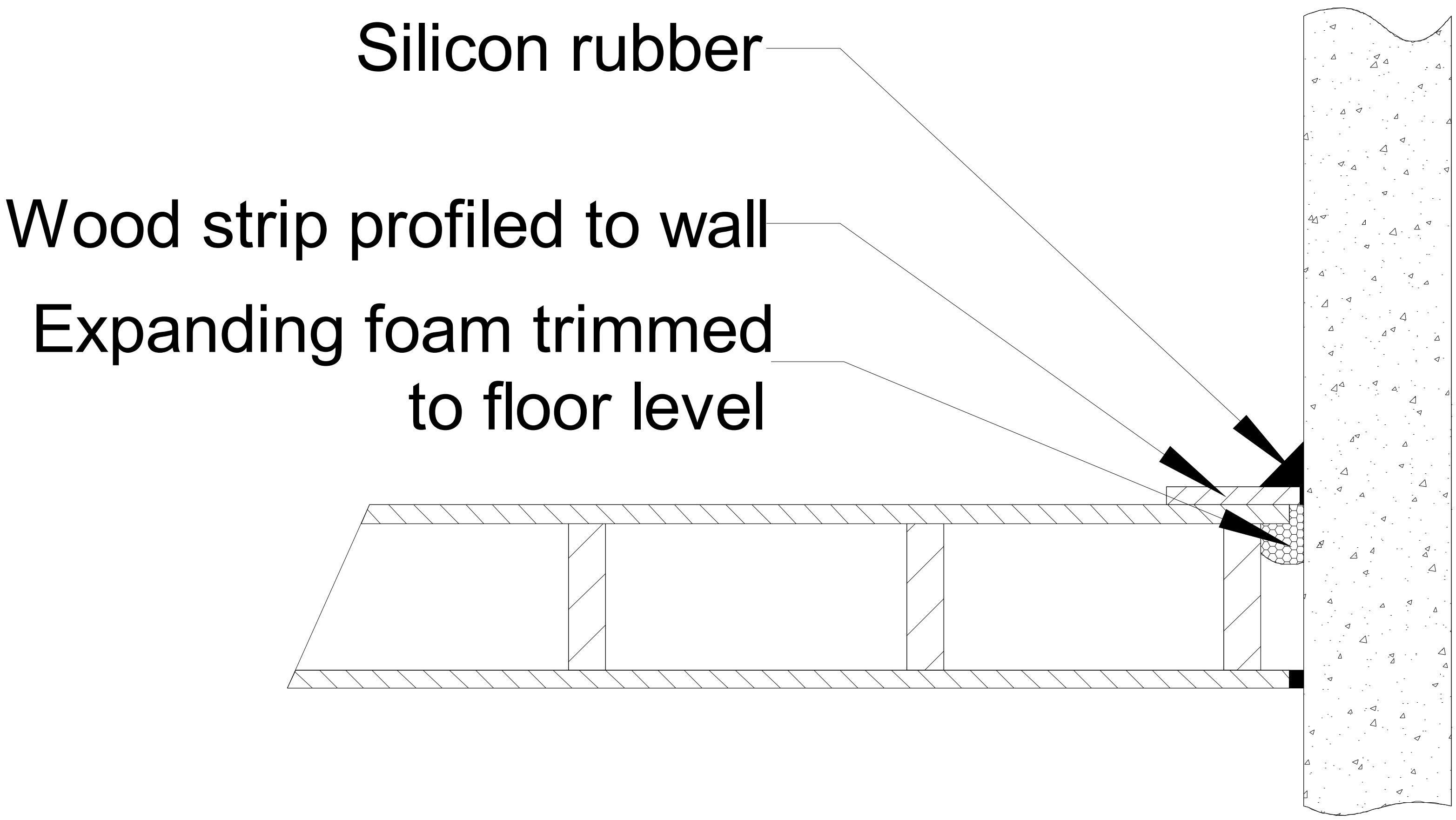
Sources of Flanking Sound in Ringing Rooms



Other sources of flanking sound are:

- clock weight chutes made from lightweight materials and with unsealed joints
- clock pendulum box made from lightweight materials and unsealed
- holes for clock drive shafts, chiming wires etc.
- ringing room window.

Reducing Flanking Sound – Sealing Floor to Wall



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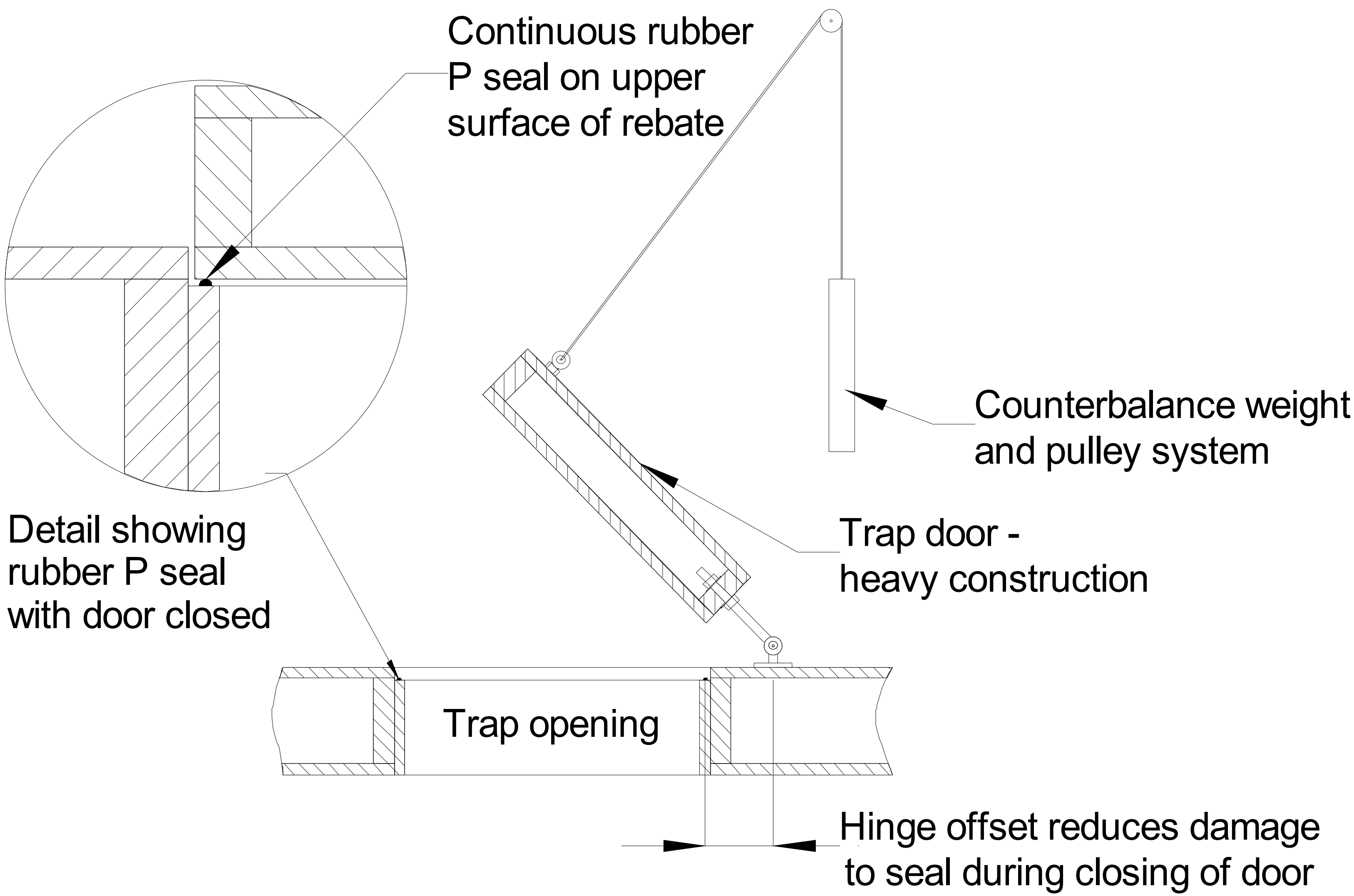
Reducing Flanking Sound –
Design of Bell Chamber Access Trap Door



Reducing Flanking Sound – Sealing Bell Removal Trap Door

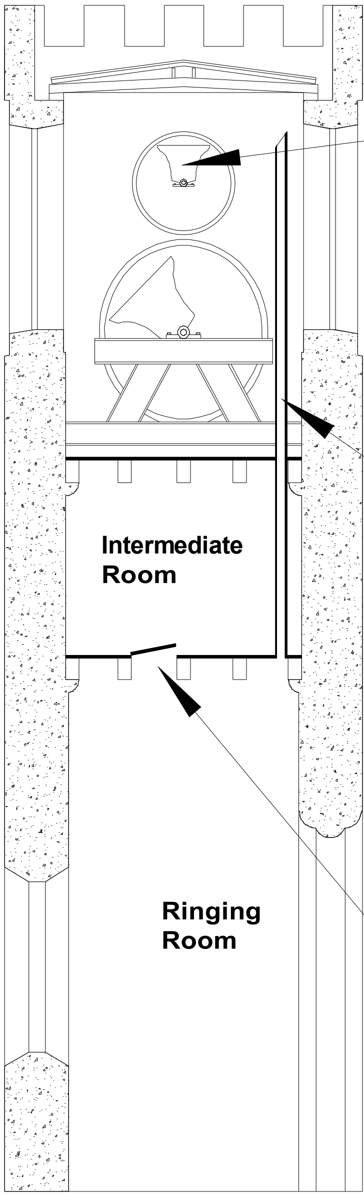
The bell removal trap doors are seldom used and may be screwed down (using stainless steel screws) and the edges sealed with silicone rubber.

NB Do not use nails since these are difficult to remove, particularly 50 years later!

Reducing Flanking Sound – Clock Weight Chutes

- Ensure clock weight chutes are made from 25 mm thick boarding with all edges sealed, particularly where they meet the tower walls and ceilings. Use the same approach for the pendulum box.
- If the clock has been converted to auto-wind it is most likely the chutes can be removed altogether and the ringing room and intermediate room ceilings made good.
- If the clock is not auto-wound, consider having it modified.

Increasing Flanking Sound – Making Individual Bells Sound Louder in Ringing Room



Bell giving insufficient sound level in ringing room.

Sound tube/box augments individual bell sound in ringing room. Preferably made as 150X150 mm wooden box since tube acts as a low pass filter. Route as far as possible from direct sound of other bells.

Trap door opening controlled to give required increase in sound level for all bells. (Warning: take appropriate steps to prevent this becoming a safety hazard).

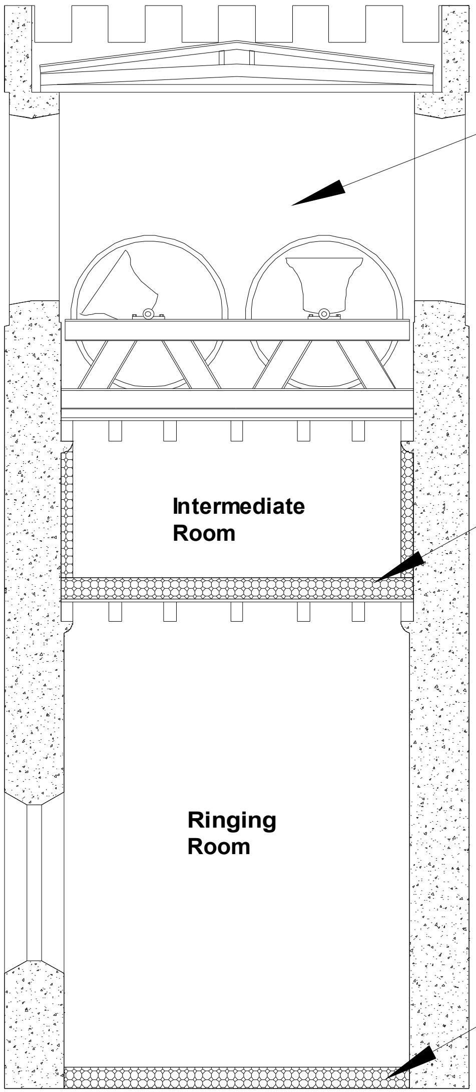
Clarity of Sound

- Clarity of sound refers to the degree to which the sound of each bell perceptually stands apart from the others.
- Direct sound reaches the listener by the shortest route (usually through the rope holes) and provides greatest clarity.
- Indirect sound reduces clarity if it reaches the listener more than 50 ms later than the direct sound.
- Indirect sound is produced by:
  - flanking sound – as already discussed, its paths are often longer than direct sound paths
  - reverberation
  - echoes.

Clarity – Reverberation Time

- **Reverberation Time (RT)** is the time taken for sound intensity to decay to one millionth of its original value.
- A short RT is preferred to enable ringers to strike accurately.
- Any reverberation in the ringing room or intermediate chamber further reduces the clarity of the bell sounds heard by the ringers. In practice the RT here should be less than or equal to the RT in the bell chamber.
- Measurement of RT and its interpretation is beyond the scope of this seminar and must involve professionals.

Reducing Reverberation



Reduction of reverberation in bell chamber requires professional advice

Reduce reverberation in intermediate room using sound absorbent material on floor and walls as necessary e.g. carpet.

Reduce reverberation in ringing room using sound absorbent material e.g. carpet on floor and curtains on windows and walls.

Clarity – Initial Time Delay Gap

- Sound reflections can enhance or detract from the clarity of the direct sound – a measure of this is the **Initial Time Delay Gap (ITG).**
- If a reflection has an ITG > 50 milliseconds and is of sufficient amplitude it will be heard as an echo resulting in poor perceived clarity of sound.
- Echoes can occur in towers with high volume bell chambers, sometimes with steeples open to the bells.
- Measurement and interpretation of ITG is beyond the scope of this seminar and must involve professionals.

Ideal Barrier Design (Vertical Rope Falls) - Summary of Main Features

- **Towers with an intermediate room**. Bell chamber and intermediate room floors should be simple barriers with no rope-hole mufflers.
- **Towers with a single barrier between bells and ringers.** Barrier should be a type 2 composite, i.e. the ringing room ceiling acoustically isolated from the bell chamber floor and no widespread use of sound absorbent (or thermal insulation) material in the cavity. Rope-holes should not have tubes but the cavity which the rope passes through **should** contain mineral/glass wool sound absorbing material arranged to give rope clearance.
- All installations to be free from flanking sound paths.
- Timber rope bosses should be avoided since they often result in drumming, excited by passage of the rope.

INTERNAL SOUND CONTROL CASE STUDIES

Three case studies are presented with as-found ringing room sound levels above 80 dB(A). All are short draught towers in Derbyshire with a single barrier of **non-ideal design** and each case demonstrates the need to raise the achieved attenuation to the optimum in order to create (just) acceptable sound levels.

- Case 1 – St Michael, Pleasley with a simple barrier.
- Case 2 – Ss George & Mary, Church Gresley with a type 1A composite barrier fitted with rope-hole tubes/boxes.
- Case 3 – Ss Peter & Paul, Old Brampton.

Measurement Procedures

- In towers with up to 6 bells, the peak sound level of the tenor bell rung by itself is close to the average sound level with all bells ringing. This fact is useful in situations where there are few ringers available during lengthy sound reduction trials, as in the case studies.
- A minimum of two people is necessary for sound level measurements – one to ring each bell in turn and one to read and record the levels keeping a full log of all acoustic changes and their consequences.
- Consistent, repeatable ringing is essential. The ringer must be competent at bell handling and all ringing carried out by one person since different ringing styles produce slightly different sound levels.
- Sound level readings should be taken for both hand and backstroke.
- Ear protection is essential in the bell chamber.
- Hold the sound level meter away from the body.

St Michael Pleasley

Case Study (1)

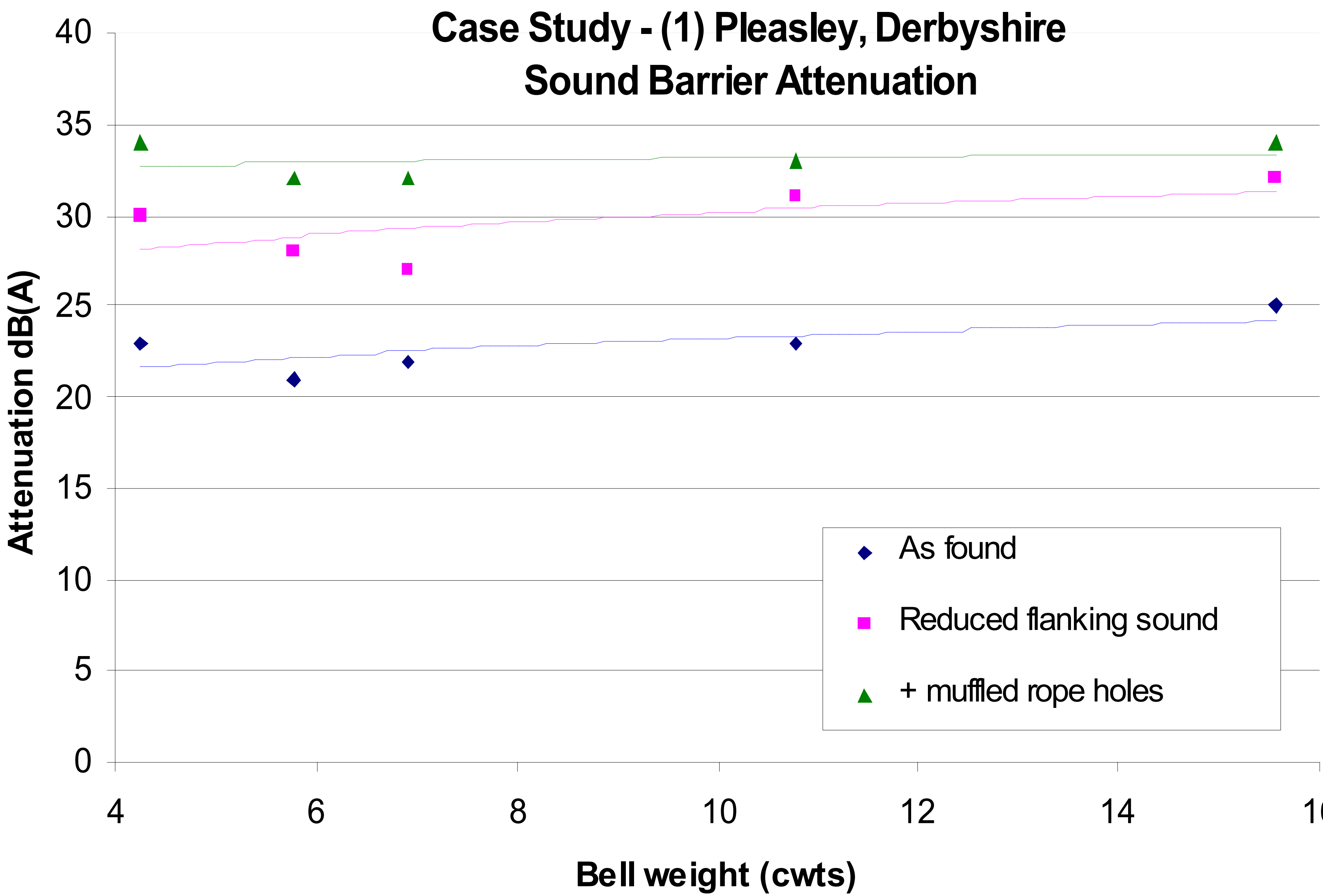
Case Study (1) – Pleasley, Derbyshire

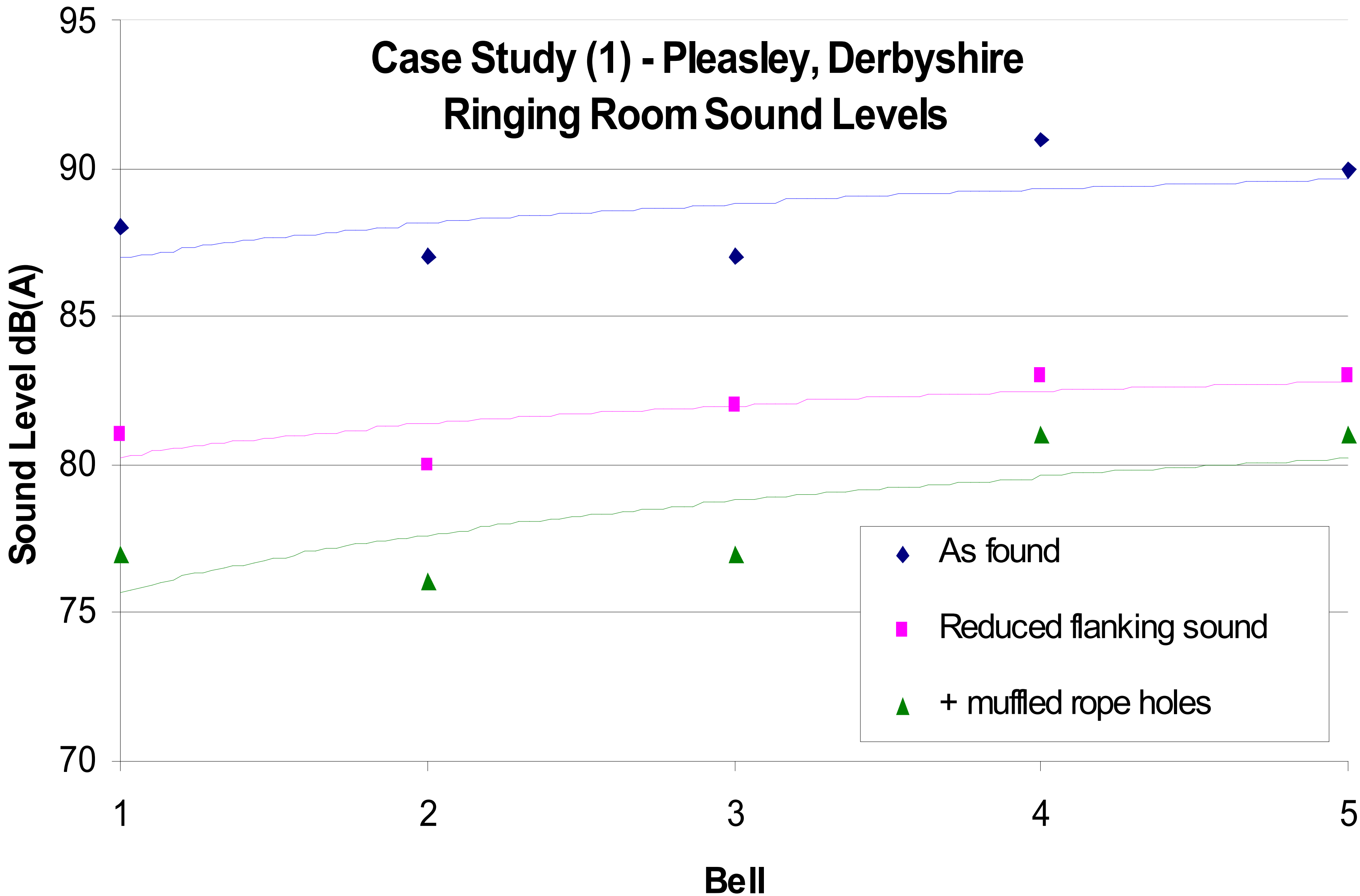
- **Problem** – sound levels in ringing room too high (all bells above 85 dB(A)); limited funding available to rectify.
- **Number of bells:** 5
- **Tenor weight:** 15-2-7
- **Draught:** short
- **Sound barrier:** single simple – approx 50 mm thick wooden boarding on joists with some ropes drawn above in boxes.
- **Estimated sound attenuation** – 50 mm timber boarding has a mass of 24 kg/m^2. From graph, estimated attenuation should be <u>32 dB</u>.
- **Sources of flanking sound:**
  - gaps between barrier and walls
  - gaps around edges of bell removal trap door
  - down stairwell - no bell chamber door and gaps around ringing room door.

Case Study (1) – Pleasley, Derbyshire

Remedial work

- Gaps sealed between wall and edge of barrier.
- Bell removal trap door sealed with silicone rubber.
- New bell chamber door fitted.
- Improved, better fitting ringing room door fitted.
- Rope-guide mufflers fitted to each rope.


Case Study - (1) Pleasley, Derbyshire
Sound Barrier Attenuation
Attenuation dB(A)
40
35
30
25
20
15
10
5
0
4
6
8
10
12
14
16
Bell weight (cwts)
As found
Reduced flanking sound
+ muffled rope holes


Case Study (1) - Pleasley, Derbyshire
Ringing Room Sound Levels
95
90
85
80
75
70
Sound Level dB(A)
1
2
3
4
5
Bell
As found
Reduced flanking sound
+ muffled rope holes

Case Study (1) – Pleasley, Derbyshire

Summary of Achieved Levels

- **The final achieved attenuation** of 33 dB(A) is equal to the estimated value and so little more is possible without redesign.
- **Attenuation** was increased from 23 to 33 dB(A) comprising:
    - a flanking sound reduction of 7 dB(A)
    - a rope-hole sound reduction of 3 dB(A).
- **Final achieved sound levels** for individual bells in the ringing room are marginally adequate with a spread between bells of 76 – 81 dB(A).
- It is now possible to ring without ear protection.
- If more funding were available, the underside of the joists could have been clad with 25 mm T&G, bringing ringing room sound levels within 80 dB(A).

Towers & Belfries Committee - SOUND CONTROL IN BELLTOWERS

Ss George & Mary, Church Gresley Case Study (2)

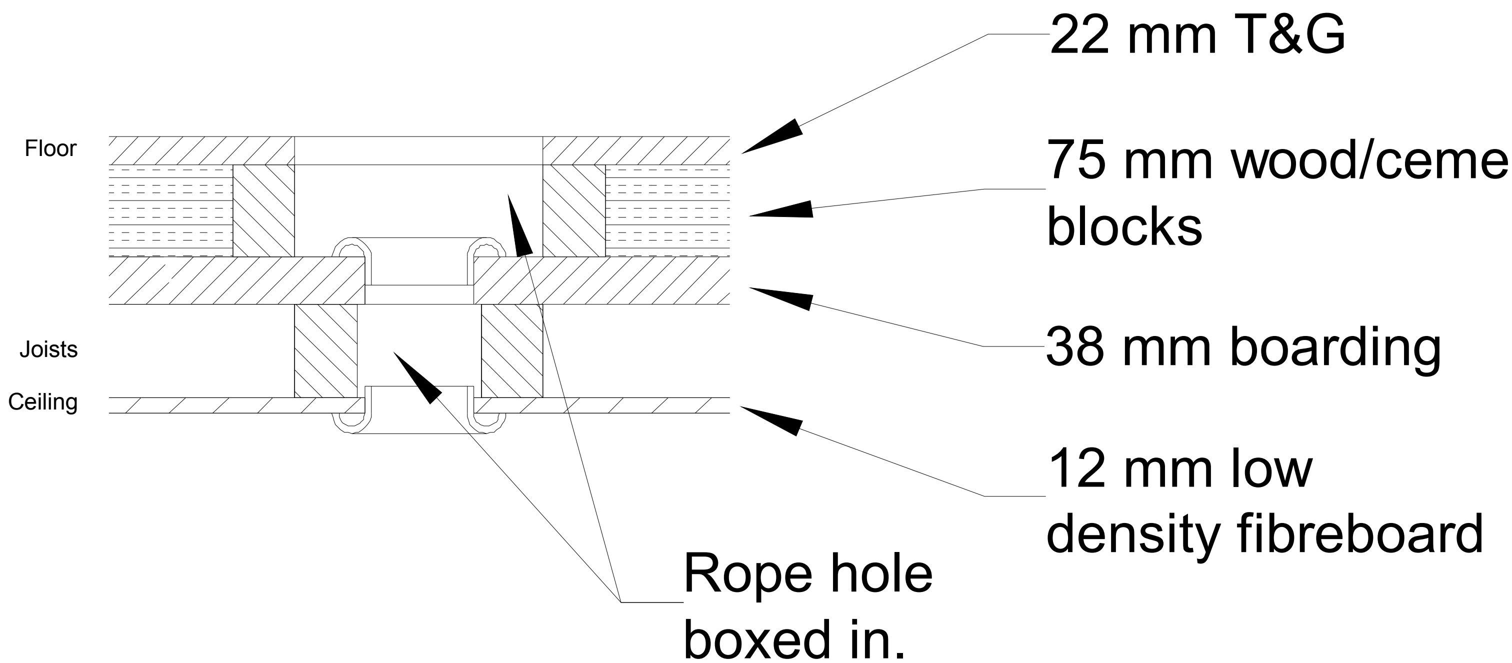
Case Study (2) – Church Gresley, Derbyshire

- **Problem** – sound levels in ringing room too high (all bells above 80 dB(A)).
- **Number of bells:** 6
- **Tenor weight:** 8-0-3
- **Draught:** short
- **Sound barrier:** single composite type 1A with boxed-in rope holes.
- **Sources of flanking sound:**
  - gaps between barrier and walls
  - gaps around edge of access trap door
  - low mass / unit area trap door construction.

Case Study (2) – Church Gresley, Derbyshire

Sound Barrier Construction – As Found

The 22 mm T&G layer is directly supported by and nailed through the wood/cement blocks providing poor isolation and a degree of absorption. It behaved as a type 1A barrier.



Case Study (2) – Church Gresley, Derbyshire

Remedial Work

- Gaps around edge of bell chamber floor sealed.
- New trap door (type 1 construction).
- Fit of trap door improved and edges sealed with self adhesive “P” sealing strip.
- Rope-hole mufflers fitted to all ropes.

Case Study (2) – Church Gresley, Derbyshire

Estimated Sound Attenuation

Mass of 22 mm T&G boarding	10.6 kg/m^2
Mass of 75 mm wood/cement blocks	13.5 kg/m^2
Mass of 38 mm T&G boarding	18.2 kg/m^2
Mass of 12 mm low density fibreboard	5.1 kg/m^2
Total mass of barrier layers	47.4 kg/m^2

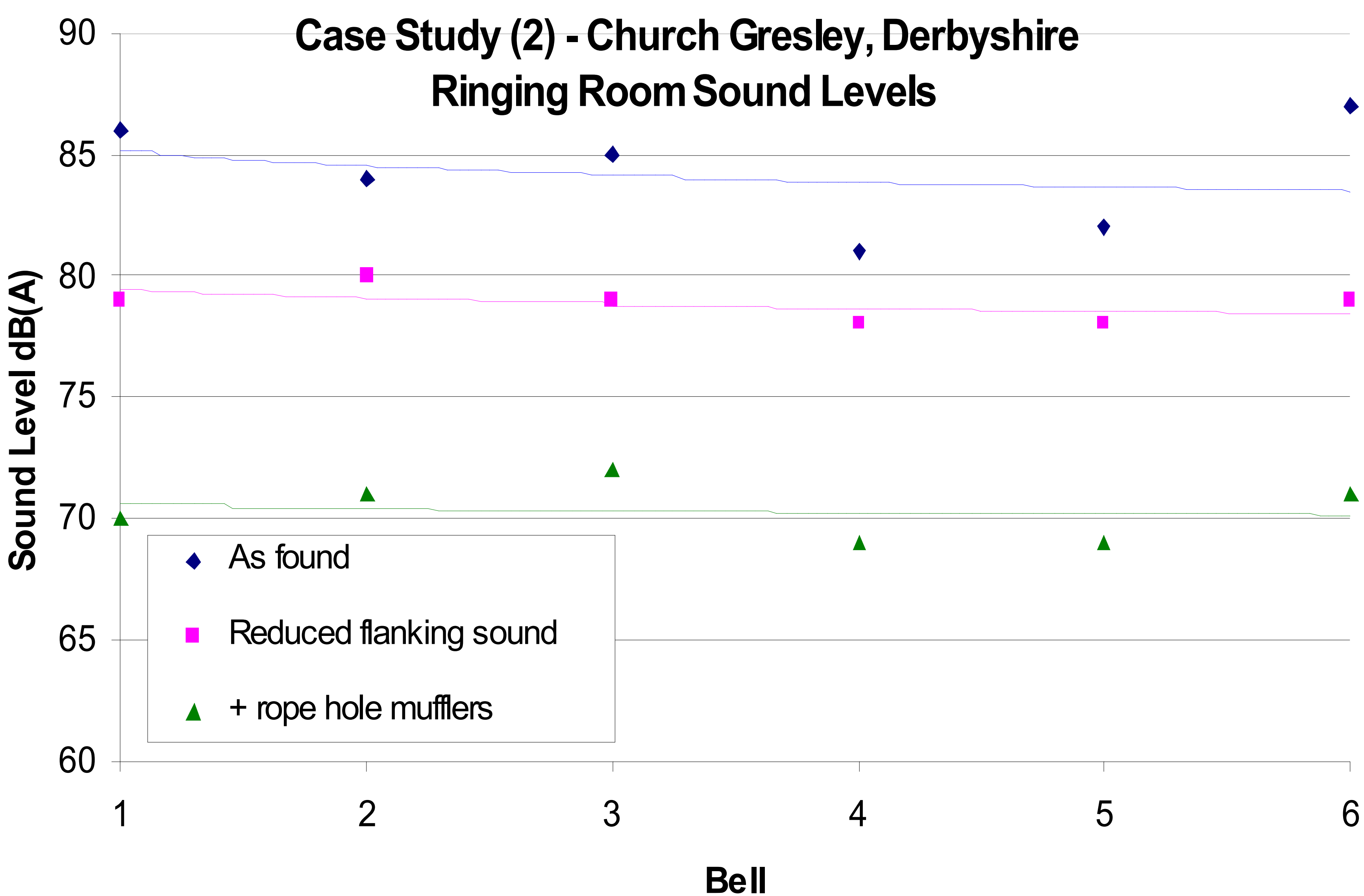
From graph of type 1A barrier:

Estimated sound attenuation is 41 dB

Case Study (2) – Church Gresley, Derbyshire

Attenuation with Tenor Bell Ringing

Bell Chamber	111 dB(A)	
Ringing Room as found	87 dB(A)	
Attenuation as found		**24 dB(A)**
Flanking sound reduced	79 dB(A)	
Attenuation		**32 dB(A)**
+ rope hole mufflers	71 dB(A)	
Final achieved attenuation		**40 dB(A)**


Case Study (2) - Church Gresley, Derbyshire
Ringing Room Sound Levels
Sound Level dB(A)
90
85
80
75
70
65
60
1
2
3
4
5
6
Bell
As found
Reduced flanking sound
+ rope hole mufflers

Case Study (2) – Church Gresley, Derbyshire

Summary of Achieved Levels

- **The final achieved attenuation** is equal to the estimated level and so little more is possible.
- **Attenuation** was increased from 24 to 40 dB(A) comprising:
  - a flanking sound reduction of 8 dB(A)
  - a rope-hole sound reduction of 8 dB(A).
- **Final achieved sound levels** for individual bells in the ringing room are ideal, lying between 68 and 72 dB(A).

Ss Peter & Paul, Old Brampton Case Study (3)

Case Study (3) – Old Brampton, Derbyshire

- **Problem** – sound levels in ringing room too high (five bells at or above 80 dB(A)) and sound barrier in poor structural condition.
- **Number of bells:** 6
- **Tenor weight:** 12-0-9
- **Draught:** short
- **Sound barrier:** single composite type 1, no rope-hole tubes.
- **Sources of flanking sound:**
  - gaps between barrier and walls
  - gaps around edge of access trap door
  - unsealed clock weight chutes
  - low mass / unit area trap door construction.

Case Study (3) – Old Brampton, Derbyshire

Remedial Work

- New type 1A composite barrier installed, replacing existing.
- Gaps between barrier and walls sealed.
- Bell removal trap door screwed shut and edges sealed with silicone rubber.
- New type 1 personnel access trap door fitted with edges sealed by rubber “P” seal.
- Clock weight chutes removed (clock is autowound).
- Sound absorbent material incorporated in cavities with clearance around ropes.
- No rope-hole tubes.

Case Study (3) – Old Brampton, Derbyshire

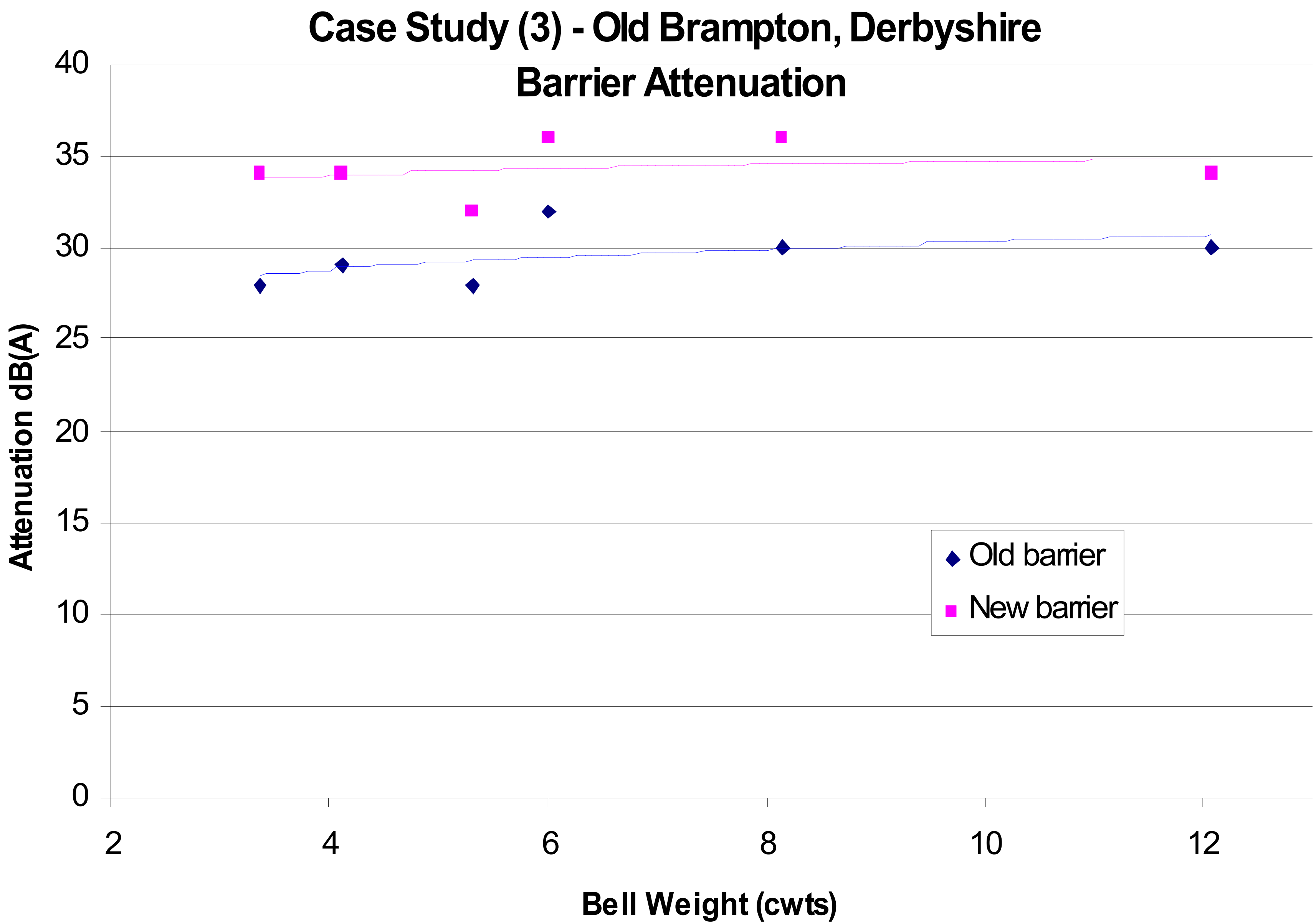
Estimated Attenuation for New Barrier

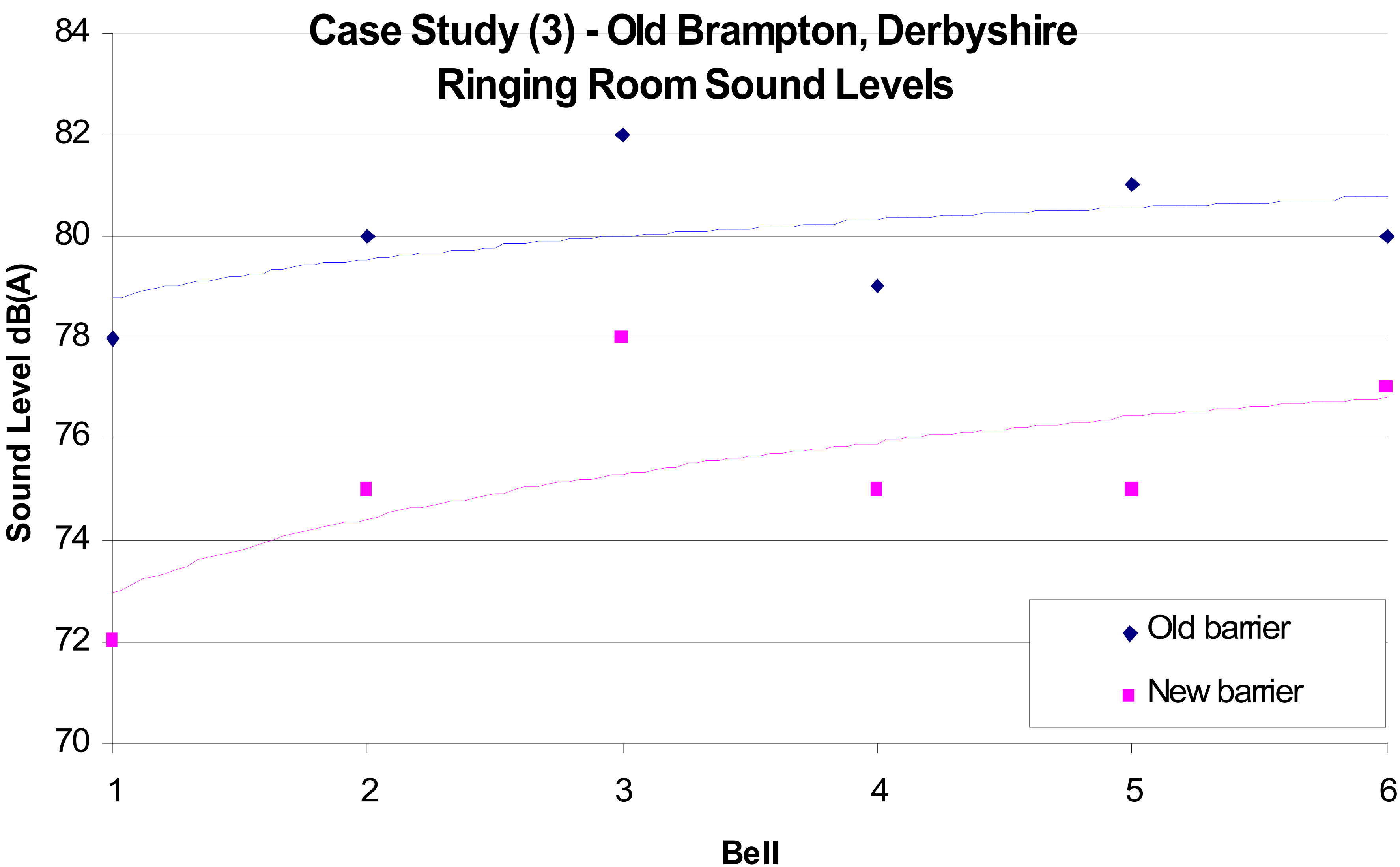
Barrier comprises 22 mm T&G wood boarding, top and bottom layers.

Mass of layers is 2 X 10.6 kg/m^2 = 21.2 kg/m^2

From the graph for a type 1A barrier:

<u>estimated attenuation is 34 dB(A)</u>


Case Study (3) - Old Brampton, Derbyshire
Barrier Attenuation
Attenuation dB(A)
0
5
10
15
20
25
30
35
40
Bell Weight (cwts)
2
4
6
8
10
12
Old barrier
New barrier


Case Study (3) - Old Brampton, Derbyshire
Ringing Room Sound Levels
Sound Level dB(A)
84
82
80
78
76
74
72
70
1
2
3
4
5
6
Bell
Old barrier
New barrier

Case Study (3) – Old Brampton, Derbyshire

Summary of Achieved Levels

- **The final achieved attenuation** is equal to the estimated level and so little more is possible with this configuration.
- **Attenuation** was increased from 30 to 34 dB(A) due to a reduction in flanking sound of 4 dB(A).
- **Final achieved sound levels** for individual bells in the ringing room are below 80 dB(A) and so acceptable, but at 72 to 78 dB(A) not ideal.
- A further 22 mm of T&G boarding on top of the barrier would have brought these levels closer to ideal.
- The absence of flanking sound improved the quality of the bell sound in the ringing room.

Practical Applications - Control of Sound Levels Outside the Tower

- Avoiding complaints about bell noise.
- Use of variable geometry sound barriers to reduce sound levels when appropriate.
- Use of partial sound barrier to prevent bells from shouting.
- Use of sound shadows cast by sound lanterns to maintain distant carrying power but reduce local sound levels.
- Use of sound reflector to increase carrying power.

External Sound - Tips on How to Avoid Complaints

It is far better to avoid complaints about the noise of your bells than to drift into a situation where external sound control becomes unavoidable.

- Ensure that the bells are rung regularly and at fixed times.

- Most people **can** tell the difference between good ringing and bad and are more likely to complain about the latter. Poor quality ringing is most likely to occur when too many novices are ringing at the same time - one popular solution is to install a simulator.

- When special ringing is necessary, make sure local residents know about it by broadcasting the fact in a door-to-door circular or by publication in the parish magazine or local newspaper.

- If you believe your bells may be noisy, restrict the amount of ringing particularly at unsocial times or during hot weather when neighbours have their windows open.

- Many complaints arise where new houses are built close to a bell tower. It is important that the local authority planning department is made aware of the church bells at an early stage in the planning process.

- Advice can be obtained from the CCCBR Public Relations Advisory Committee.

Control of Sound Levels Outside the Tower - Sound Levels too High

- Bell sound levels outside the tower will be unobtrusive if they are no higher than ambient noise levels.
- Bell sound levels at the extremity of church yards can typically be 70 - 73 dB(A) with ambient sound levels of 50 - 55 dB(A).
- From the above it follows that, in general, the maximum attenuation required of a sound control system will be about 20 dB(A).
- On-site measurement of sound levels both with and without the bells ringing are therefore necessary to establish an appropriate design of sound control.

Control of Sound Levels Outside the Tower
- Sound Levels too High

- The bell installation and its ability to radiate sound out to the parish has cost the PCC tens of thousands of pounds. In most cases it would be inappropriate to employ sound absorbent materials in the bell chamber as part of external sound control.
- There are three principal methods of external sound control:
  - barriers with variable control using opening doors
  - creation of a sound shadow by use of a sound lantern
  - use of a simulator with tied clappers (not discussed).
- **It is very important that ventilation of the tower is not adversely affected by external sound control systems.**

Control of Sound Levels Outside the Tower - Variable Control Using Doors

- Since sound attenuation of about 20 dB(A) will be required, this can be achieved using simple barriers.
- Two types of installation are possible:
  - installation of sound barriers in each bell chamber sound window
  - construction of a horizontal sound barrier between the bells and sound window sills (for bell installations set well below the sound windows).
- In both cases design requirements are to:
  - use high mass per unit area materials
  - eliminate flanking sound paths.

Control of Sound Levels Outside the Tower - Flanking Sound

- **Fastidious** elimination of flanking sound paths is essential to avoid compromising the effectiveness of any sound barrier.
- Some sources of flanking sound are:
  - through cracks in sound barriers
  - around the edges of sound barriers.

NB Flanking sound can also pass via spire lights – these are difficult to seal and are vital to spire ventilation. They are best ignored unless other measures prove inadequate.

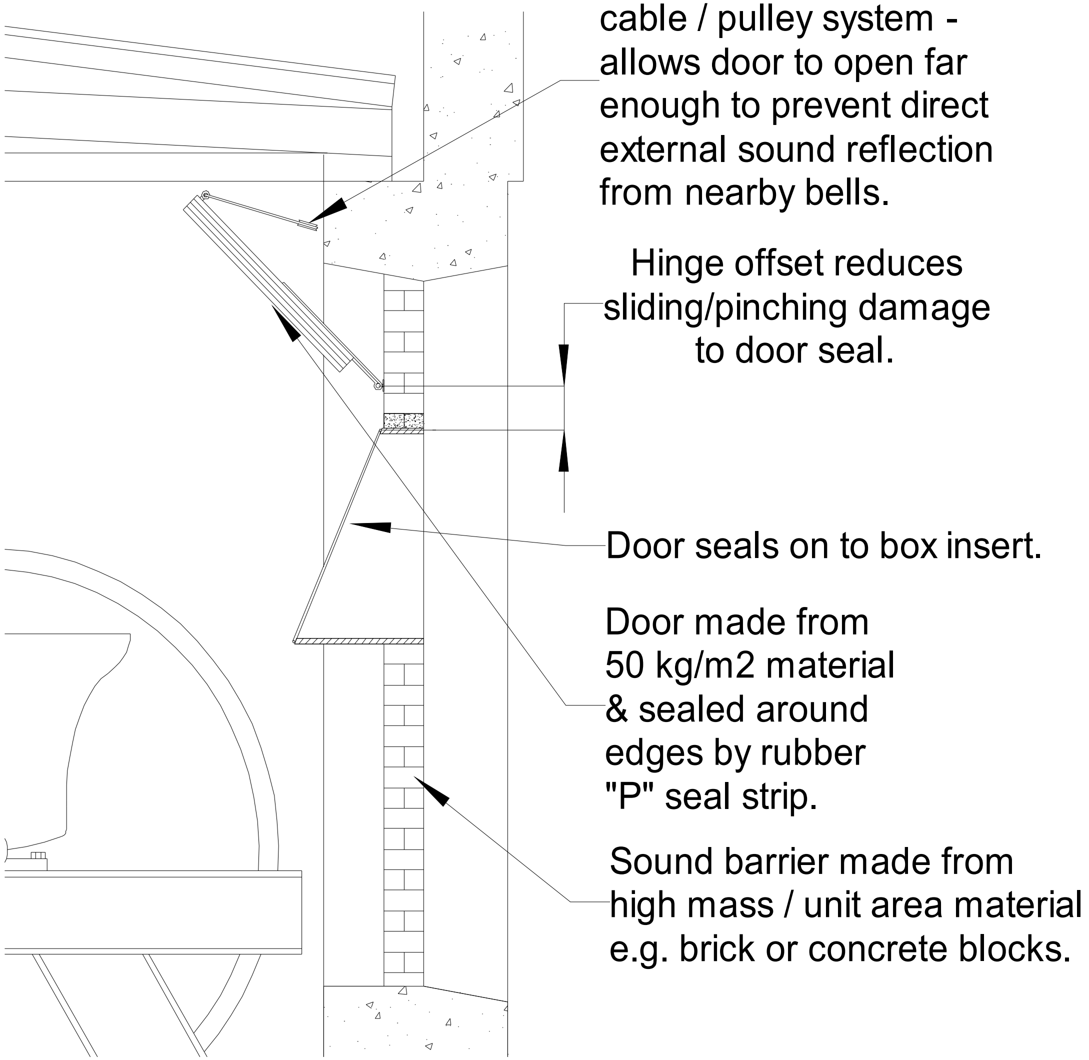
Control of Sound Levels Outside the Tower
- Variable Control in Bell Sound Windows

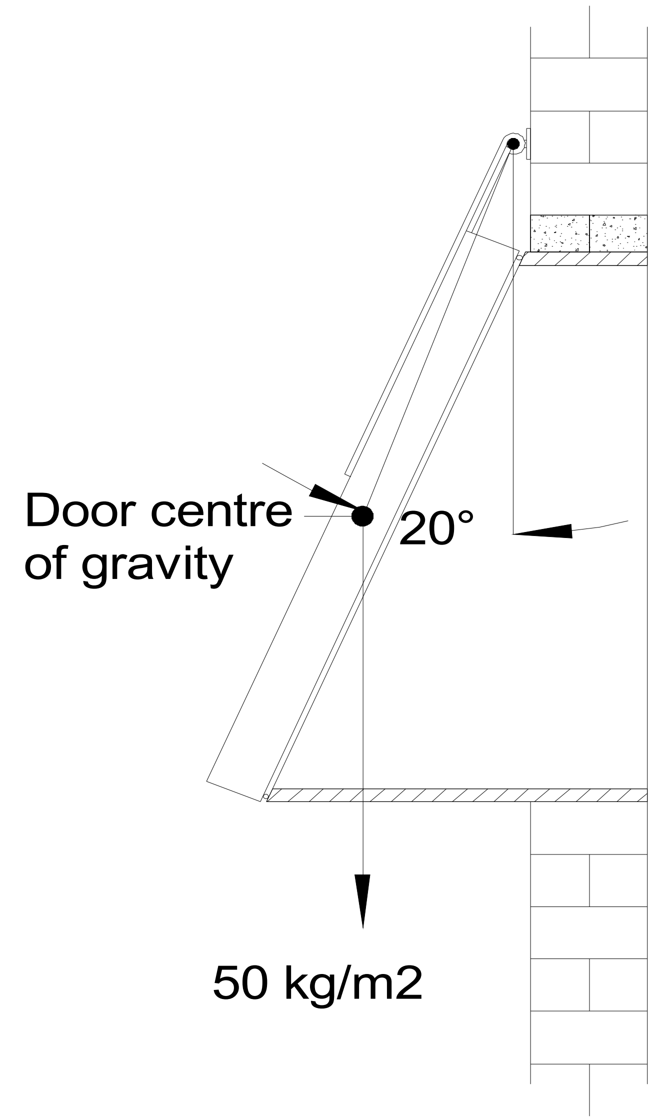
- Tower sound outlet areas can be small – a total for all outlets of 4 m^2 is adequate for a 24 cwt ring of 12 bells and 2 m^2 for a 17 cwt ring of 10.
- 20 dB(A) sound attenuation can be easily achieved, in the absence of flanking sound, using a simple barrier of 22 mm wooden board.
- Due to wind loading, **vertical doors** only succeed if the doors are held closed on their peripheral seals. This can be achieved by:
    - using latches manually operated from within the bell chamber
    - using electric actuators or tensioned cable systems remotely operated from the ringing room.

Inclined doors of sufficient weight can be held shut by gravity and remotely opened from the ringing room via a winch, cables and pulleys. A closed angle of 20° and weight of 50 kg/m^2 is adequate.

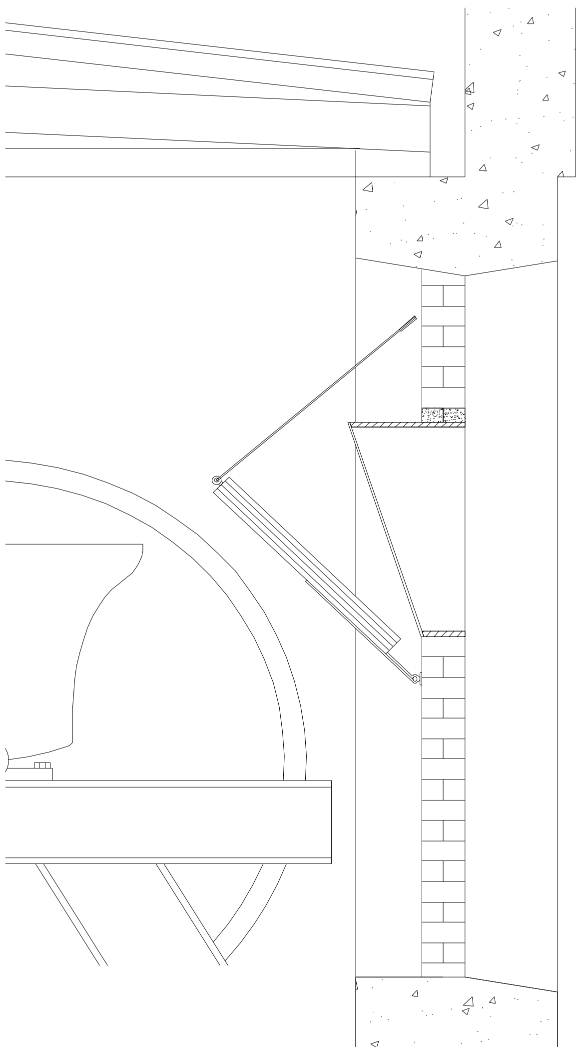
- <u>**For tower ventilation, all doors must be left open when not ringing.**</u>

Control of Sound Levels Outside the Tower-
Variable Sound Control in Bell Sound Windows



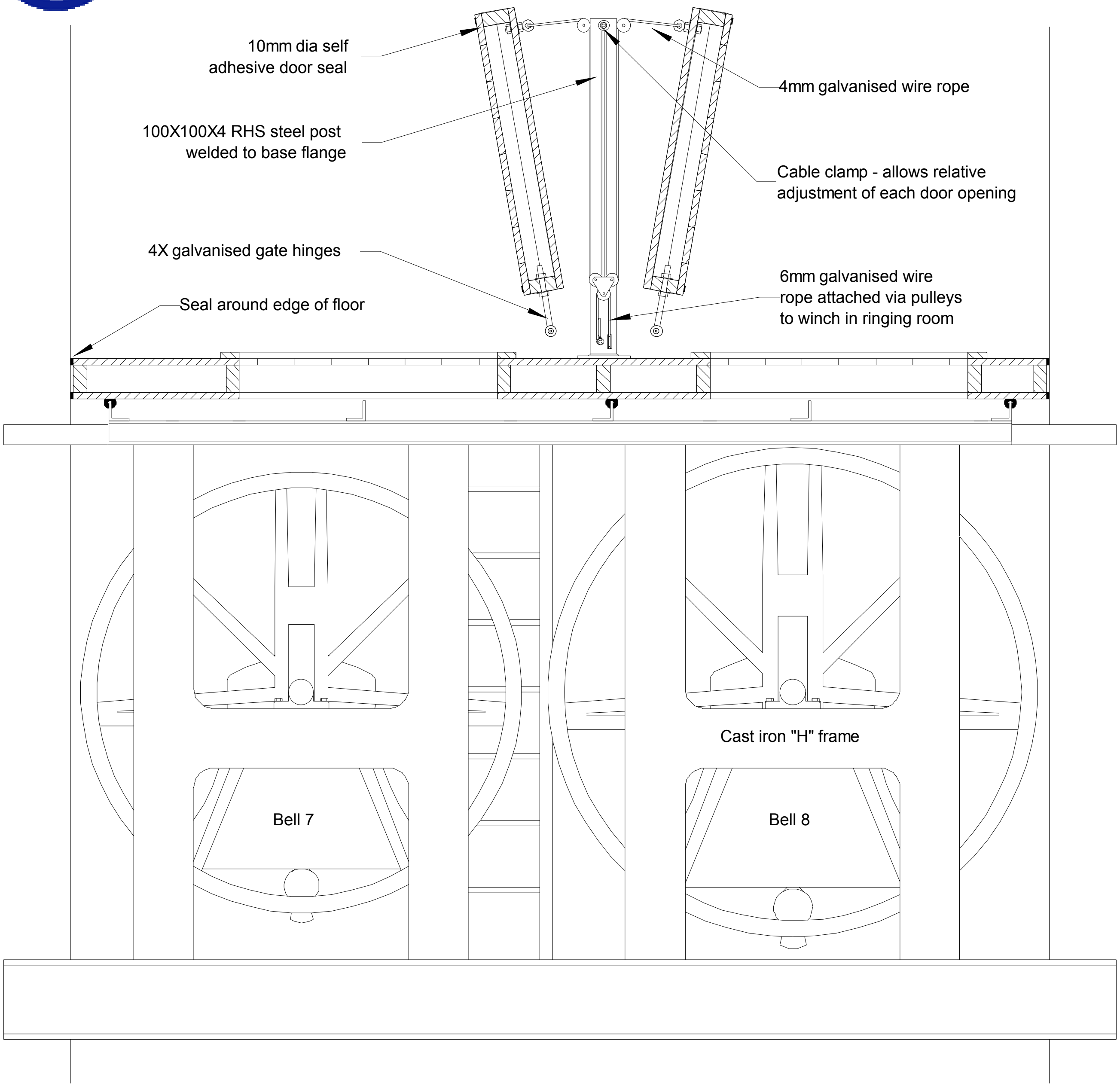


Control of Sound Levels Outside the Tower- Variable Sound Control in Bell Sound Windows



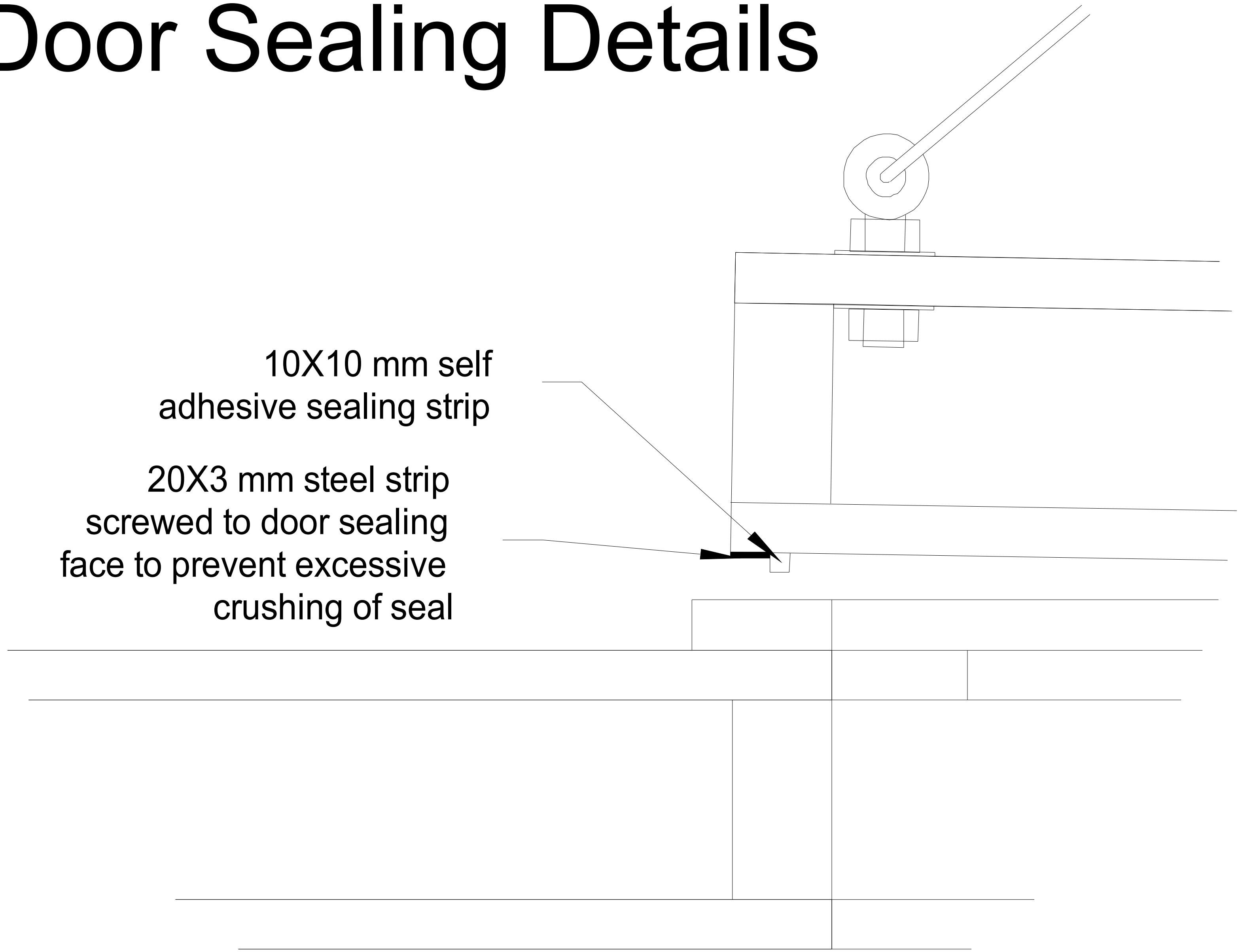
Alternative bottom
hinged door
held shut by
tension in cable.

Door angle avoids
preferential external
reflection of sound
from nearby
high level bells.

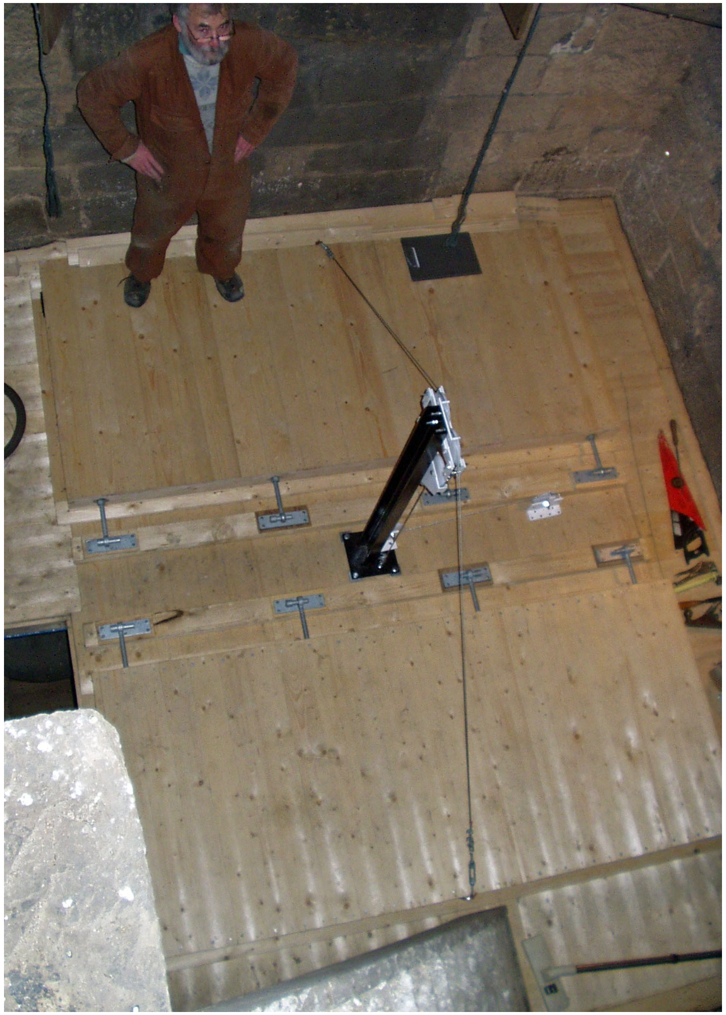


Control of Sound Levels Outside the Tower - Horizontal Variable Sound Control Above Bell Frame

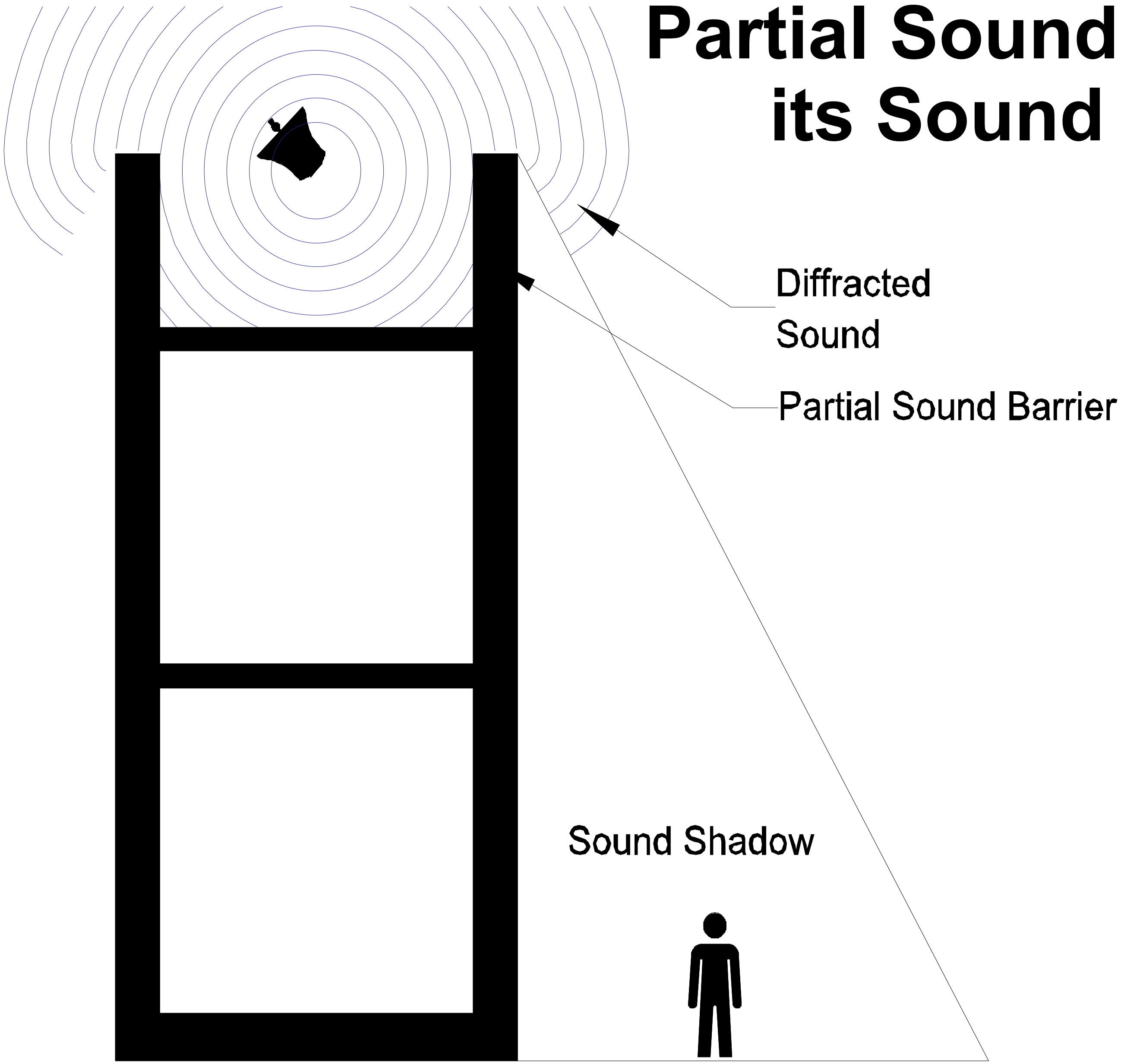
Door Sealing Details



Horizontal Variable Sound Control

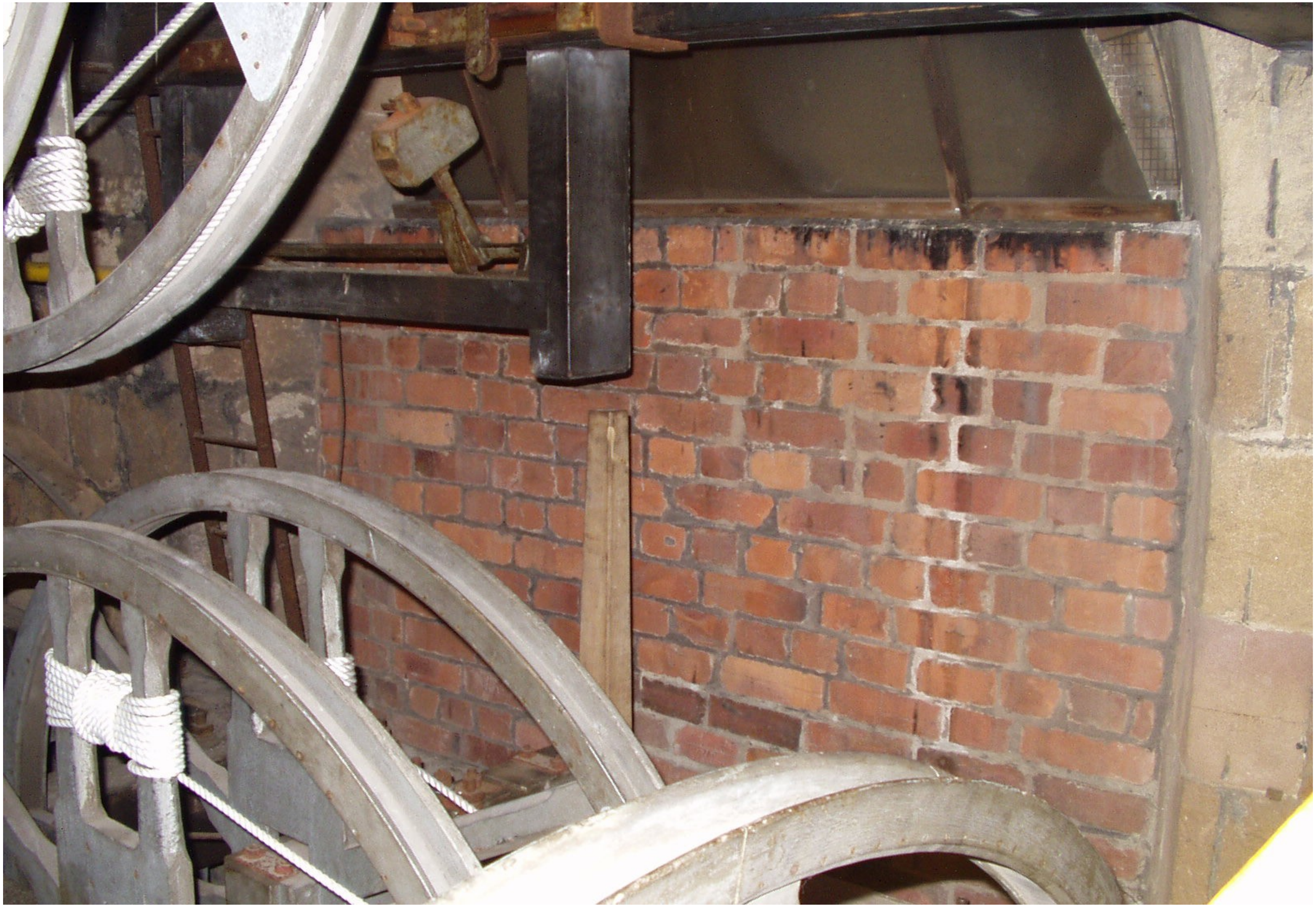


Partial Sound Barrier and its Sound Shadow



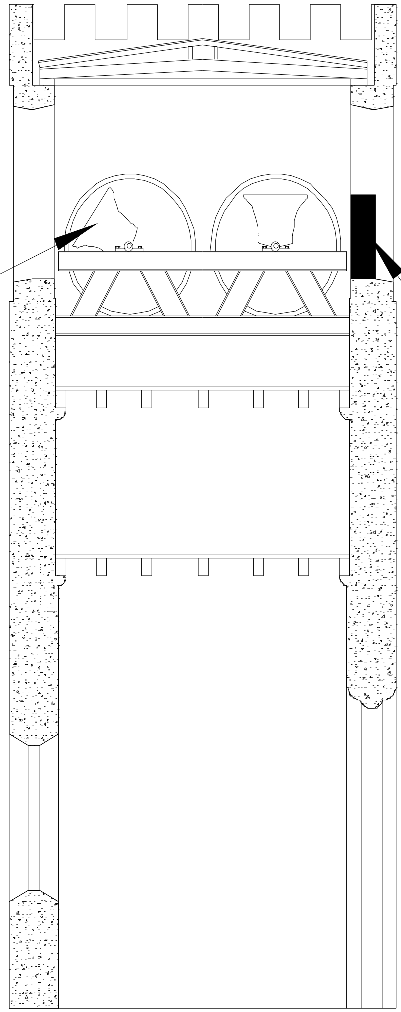
Low frequency sounds diffract more than high frequency sounds. Thus the sound reduction in the sound shadow is less for the heavier bells than for the lighter bells.

Partial Sound Barrier



External Sound Control – Bells that Shout

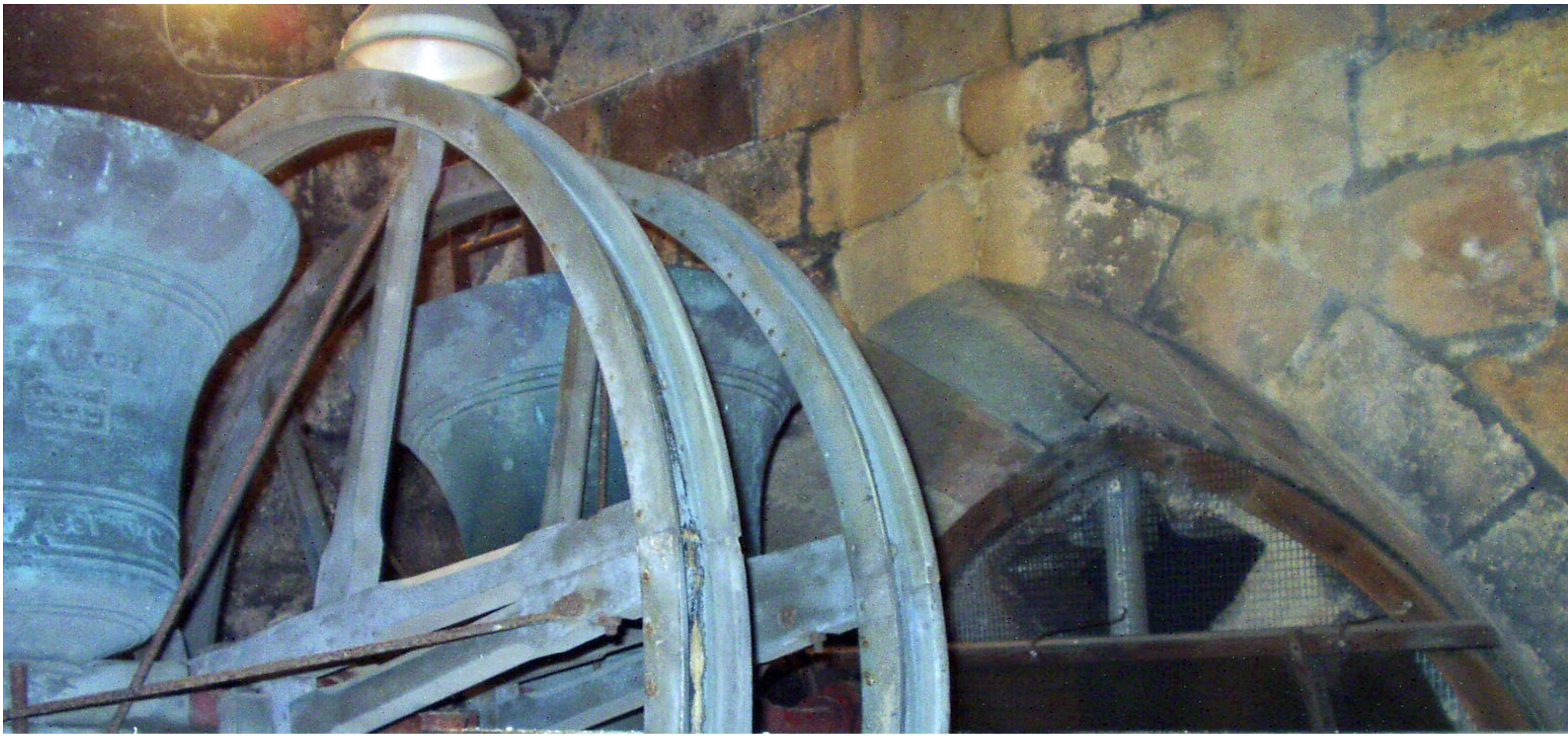
Since this bell is above the sill of the tower sound opening, direct sound from the bell will cause it to "shout" i.e. be heard louder on this side of the tower than the other bells.



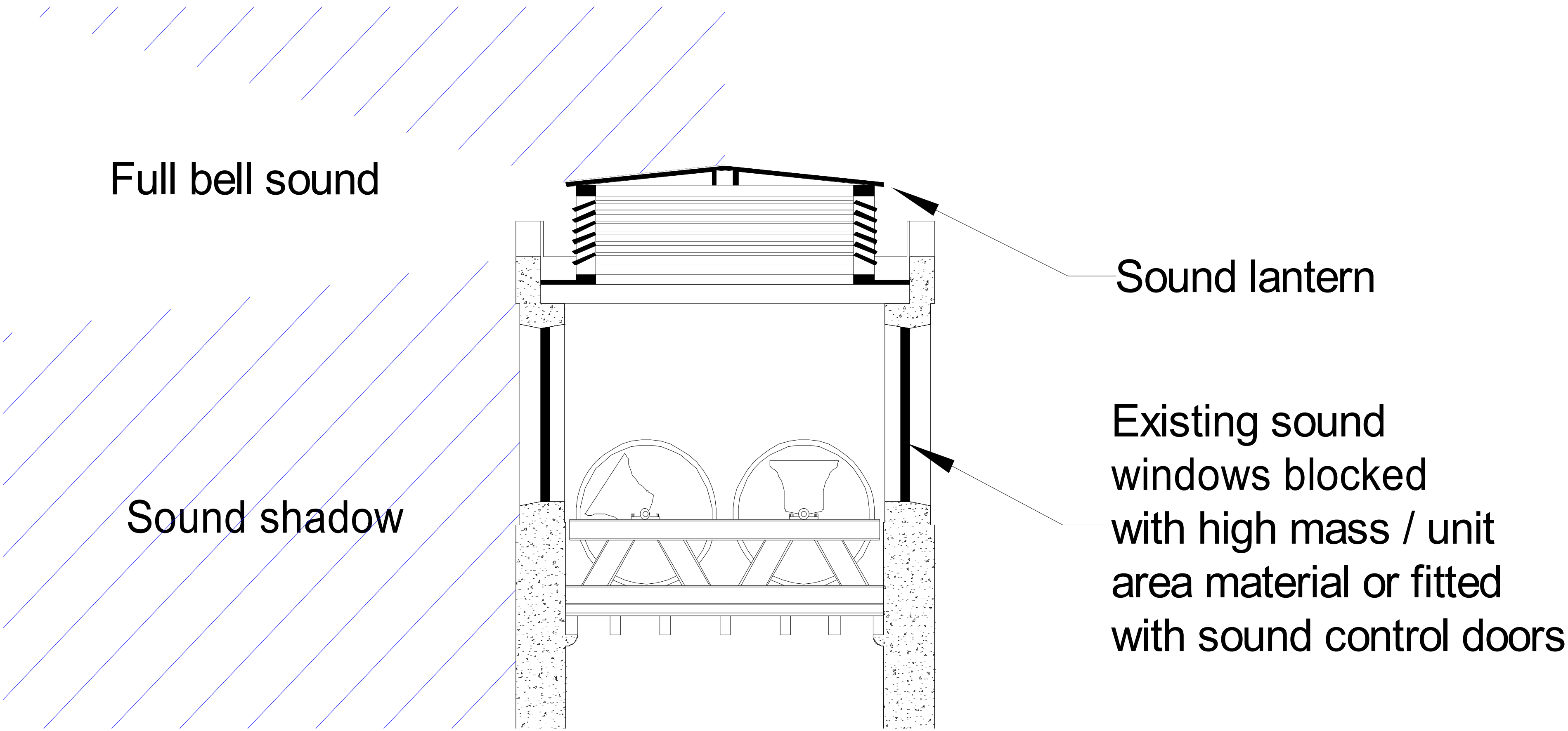
Partial sound barrier installed to the lip height of the heaviest bell when upturned.
The barrier allows only reflected sound to be heard ensuring an even mix of sound levels from all bells.

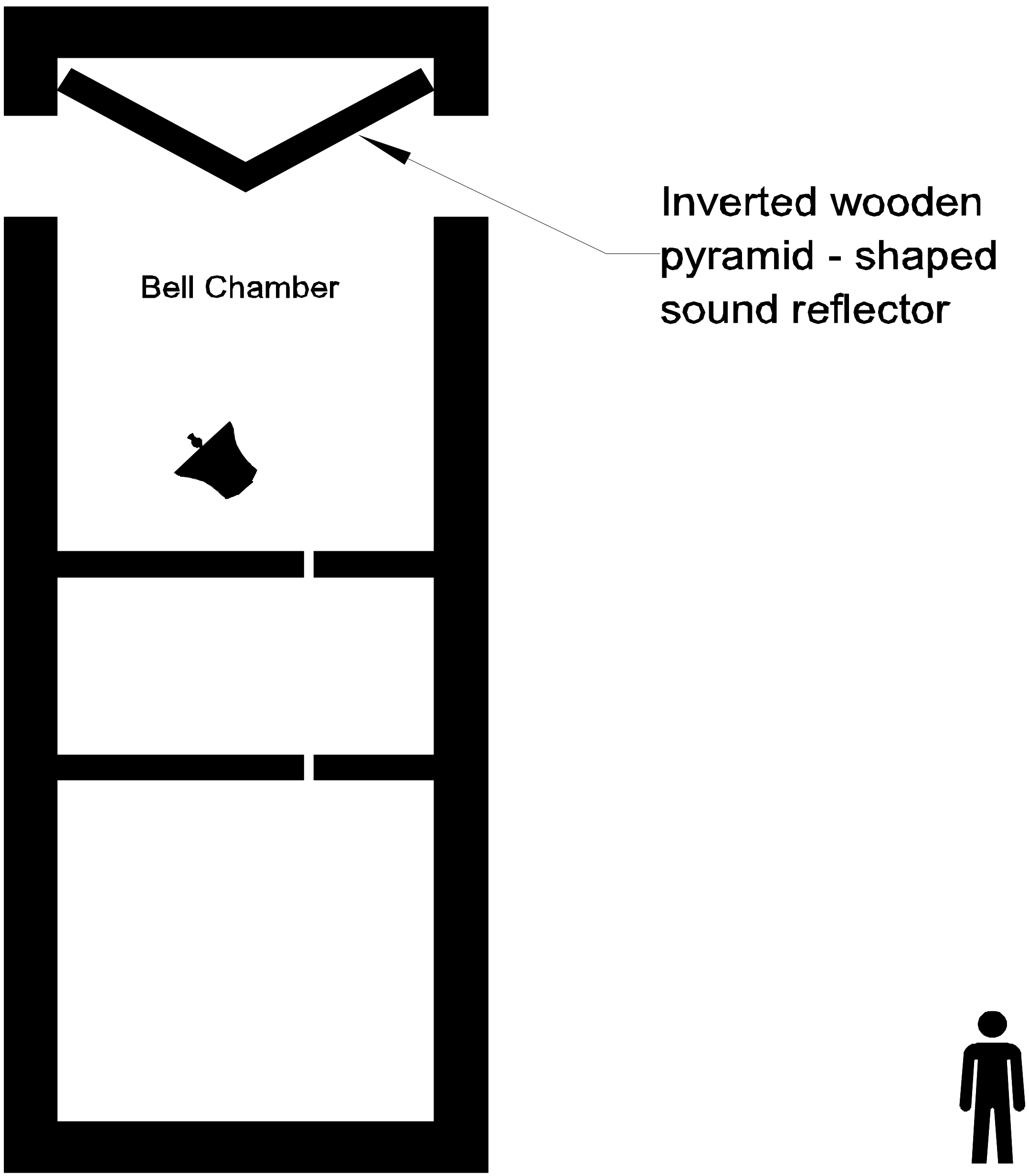
Partial sound barrier to be made from high mass per unit area material such as bricks or concrete blocks and sealed on the sides and base.

External Sound Control – Bells that Shout



Control of Sound Levels Outside the Tower -
Sound Lantern Reducing Local Sound Levels





Control of Sound Levels Outside the Tower -

Use of Sound Reflector to Increase Sound Carrying Power

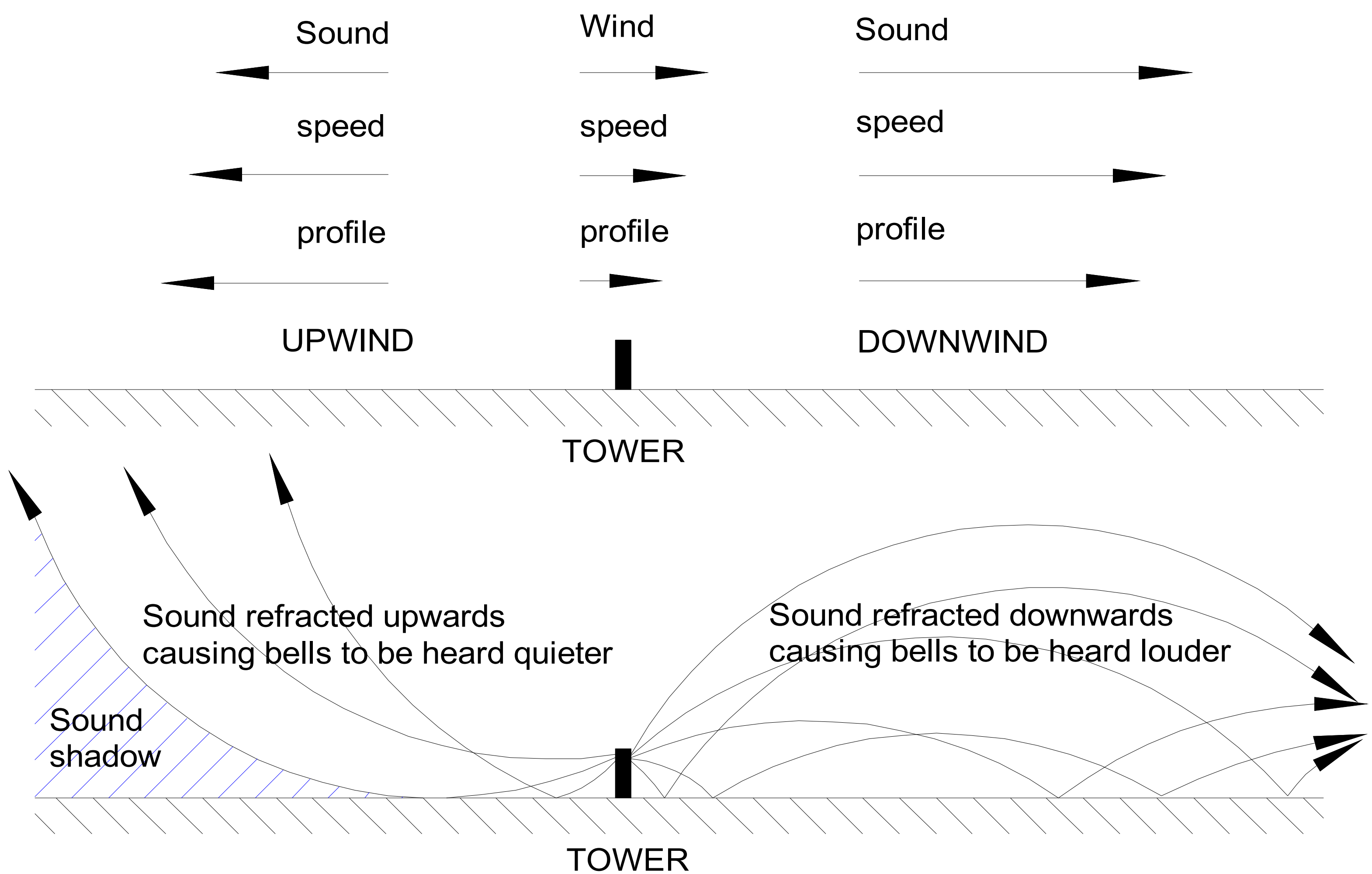
Sound Reflector Cone – Westminster Abbey

Sound Reflector Cone – Westminster Abbey

External Sound Measurement Procedures

- Choose a day when wind speeds are low.
- Select measurement locations and times of day when bell external sound levels may be considered by non ringers to be obtrusive.
- Set the meter to “A” weighting and SLOW.
- Measure ambient noise levels with the bells silent.
- Measure sound levels with all bells ringing.
- The difference between these readings gives the required attenuation for a sound control system.

Effects of Wind Speed on Sound Levels



EXTERNAL SOUND CONTROL CASE STUDY

Case 4: variable sound control in a village church, St Alkmund's, Duffield, Derbyshire.

Case Study (4) – Duffield, Derbyshire

- **Problem –** external sound levels for residents on Duffield Bank to the east, and in church hall to the south of the tower intrusive when peals rung.
- **Number of bells:** 10
- **Tenor weight:** 17-2-11
- **Tower configuration -** stone spire surmounting substantially built stone tower with one sound window to each of the four aspects. No spire openings other than ventilation opening at base of west side.
- **Remedial work –** brick sound barriers, incorporating gravity-closing sound control doors, fitted to south and east sound windows only. Each door opening size 860 X 570 mm.

Variable Sound Control - Duffield

Case Study (4) – Duffield, Derbyshire
Summary of Results

Sound level at south east corner of the churchyard

- Ambient sound levels: <50 dB(A)
- With doors closed and all bells ringing: <50 dB(A)
- With doors open and all bells ringing: 74 dB(A)

Sound level at north west corner of the churchyard

- Ambient sound levels: <50 dB(A)
- With all bells ringing: 75 dB(A)

Organisations Involved in Sound Control Projects

- **The Parochial Church Council (PCC)** is responsible for the management of all aspects of the church fabric including the bell installation. Any work on sound control can only be done with the PCC's full knowledge and authority.
- **The Church Architect** may not necessarily have a detailed understanding of the technical requirements for effective sound control but nevertheless will have a professional view on any proposal and should at least be satisfied there are no risks to the fabric of the church. Conversely he/she may be the principal design authority.
- **The Churches Buildings Council, English Heritage, The Society for the Protection of Ancient Buildings and The Victorian Society** may need to be satisfied that the sound control proposal does not adversely affect the historical context of the church building or its contents.
- **Diocesan Advisory Committee (DAC)**. Major sound control projects will require a Faculty, which is the church equivalent of “planning permission”. The relevant DAC will advise on the necessary procedures.
- **Local Planning Authority.** External alterations such as a sound lantern will require planning permission in addition to a Faculty.