Historic England

Building and Landscape Conservation

Rain Noise: Acoustic Tests on Terne-Coated Stainless-Steel Roofing

Roberts Consulting

Discovery, Innovation and Science in the Historic Environment

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RAIN NOISE: ACOUSTIC TESTS ON TERNE-COATED STAINLESS-STEEL ROOFING

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SUMMARY

Where lead or copper has been stolen from a roof, we recognise that it may be unwise to replace it like-for-like. Historic England has found that, in many cases, terne-coated stainless steel (TCSS) is an appropriate alternative material. It is a good colour match for lead and can be installed with similar detailing, such as timber batten rolls, which minimises the impact on the significance of the building. Furthermore, it is durable and, therefore, cost-effective in the long run. TCSS is unlikely to be stolen because it is of little scrap value. However, in some churches where TCSS has been installed recently, there have been reports that the noise of rain drumming on the new roof seems louder than on the previous lead roof.

To investigate these concerns, Historic England commissioned laboratory testing to compare simulated rain noise on a lead roof and various TCSS roof assemblies (standing seam, batten roll joints and batten roll joints with two different proprietary sound insulation materials). This report presents an analysis of the data recorded.

The results confirmed that the TCSS roof assemblies tested transmitted more noise from simulated rainfall than the traditional lead roof test panel. However, noise levels were lower when joints in the TCSS roof covering were made with a traditional batten roll detail than when they were made with a standing seam. There was further noise reduction when proprietary sound insulation products were installed beneath the TCSS. We have updated our guidance on Church Roof Replacement Using Terne-coated Stainless Steel to reflect these results.

It is important to remember that the results obtained are comparative and relate to laboratory conditions; they are not necessarily representative of the actual noise that would be experienced inside a building. Factors such as the shape of the building, surface finishes and occupancy will all have an effect on the levels of noise experienced by building users. To obtain more realistic data, Historic England plans to carry out site monitoring in a selection of lead-roofed and TCSS-roofed churches to record noise levels under different conditions.

AUTHOR
Keith Roberts BSc CEng MICE MIStructE
Roberts Consulting, 2 Gardiner Close, Abingdon, Oxfordshire, OX14 3YA

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JTC Roofing Contractors, Narborough, Leicestershire
SRL Technical Services, Sudbury, Suffolk

ARCHIVE LOCATION
Historic England, Swindon

DATE OF RESEARCH
Experimental work was carried out in February 2021.

CONTACT DETAILS
Email: NationalSpecialistServices@HistoricEngland.org.uk

CONTENTS

1 INTRODUCTION

1.1 This report has been prepared for Historic England by Keith Roberts of Roberts Consulting. It presents the results of acoustic tests of terne-coated stainless steel (TCSS) roofing when subjected to heavy rainfall. Roberts Consulting is an independent firm of consulting engineers, specialising in roofing and cladding.

1.2 The theft of lead from church roofs in England continues to be reported, despite active preventative measures. Like-for-like replacement with lead roofing is the preferred remediation, although this presents a risk of further theft. An alternative is to use a thin TCSS sheet, which is durable, can be configured to form a similar appearance to lead roofing and has little salvage value to a potential thief.

1.3 For more than 40 years, stainless steel coverings have been used on church roofs. When correctly installed, these roofs have generally been successful. However, a recurring concern is the reports of significant noise during heavy rainfall, caused by droplets of rain falling onto the thin metal roofing.

1.4 Traditional fully supported metal roofing on churches generally has no thermal insulation within the depth of the roof. Instead, the metal roofing is laid over a thin underlay and supported directly by timber boards, often with gaps to provide ventilation. Consequently, the drumming noise created by rain falling onto the metal roofing transfers directly to the church below.

1.5 To address the noise issue, the metal roofing industry has developed several different products that can be laid below TCSS roofing. One option is to use a spiral mesh underlay, placed on top of the wooden deck and directly below the TCSS sheet. This comprises an open fibre mat, up to 8mm thick, with a breather membrane underneath. Concerns have been raised that the air within the mesh can act as a sound box, potentially amplifying the drumming noise.

1.6 An alternative is to use a thick acoustic mat that is adhered to the underside of the flat pan of the roofing. The bonded mat increases the stiffness of the metal, thus reducing the rain noise.

1.7 In 2006, the British Standards Institution published a new standard for the laboratory measurement of noise made by rainfall on roofs: BS EN ISO 140-18. Several independent laboratories developed facilities for carrying out this test. A short review of the standard is given in Appendix D.

1.8 After discussions with the Federation of Traditional Metal Roofing Contractors (FTMRC), it was clear that there was a lack of independent test data comparing the acoustic performance of the different fully supported TCSS roof assemblies. Historic England decided to commission acoustic tests at an independent laboratory. The various metal roof samples would be prefabricated in an FTMRC member workshop and delivered to the laboratory.

1.9 It is recognised that most ancient churches that need a replacement roof after lead theft have no thermal insulation in the roof. Accordingly, the five samples tested for this report were all uninsulated.

2 ACOUSTIC TEST METHOD

2.1 SRL Technical Services is an independent test laboratory based near Sudbury, Suffolk, with more than 50 years' experience of acoustic testing. Within its external laboratory, it has a special test room that is used for measuring impact noise caused by rainfall on roof constructions.

2.2 More than 15 years ago, SRL was actively involved in the development of the relevant British Standard: BS EN ISO 140-18 'Acoustics – Measurement of sound insulation in buildings and of building elements – Part 18: Laboratory measurement of sound generated by rainfall on building elements'.

2.3 In December 2020, Historic England commissioned SRL to carry out acoustic tests on different metal roof constructions.

2.4 The test arrangement comprises a test room with an opening in the roof for installing test samples. Artificial raindrops are generated from a water tank with a perforated base suspended above the roof sample. Droplets of water fall onto the sample and the sound pressure levels are measured within the test room below. A cross-section through the test arrangement is given in Figure 1.

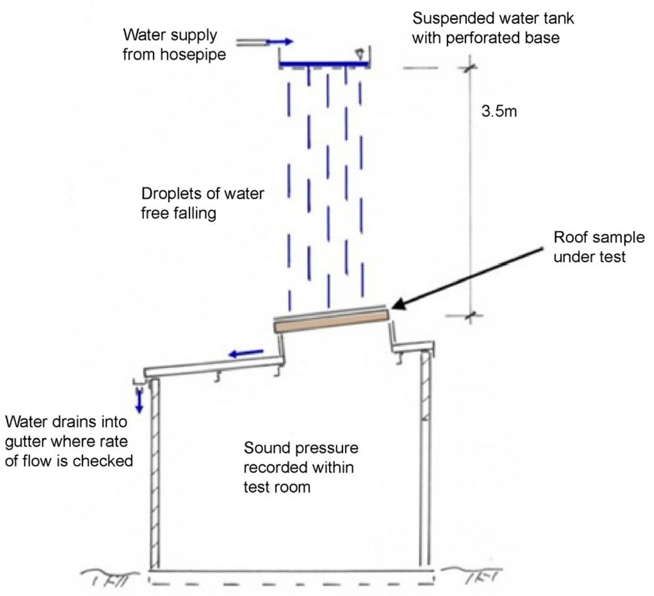

Figure 1: Rain noise test arrangement

2.5 Paragraph 5.2.1 of the British Standard calls for the size of a standard test panel to be between 10m² and 20m². However, it would not be practical to prefabricate metal roof assembles of this size in a workshop and deliver them to the laboratory. Building the large samples at the laboratory would have been expensive. The decision was made for the samples to be the size of a standard skylight opening, as given in paragraph 5.2.1, which is 1.5m by 1.2m in plan. The samples were installed at an angle of 5° to allow for drainage.

2.6 SRL produced a written test procedure for the laboratory measurement of sound generated by rainfall on small samples of building elements to BS EN ISO 140-18: 2006. A copy is given in Appendix C.

2.7 The British Standard identifies two different types of rainfall: intense rainfall, with 2mm-diameter drops falling at 4 metres per second (m/s), and heavy rainfall, with 5mm-diameter drops falling at 7m/s. For the test at the SRL laboratory, heavy rainfall water drops were applied to the roof samples.

2.8 SRL technicians measured the sound intensity level within the test room in decibels (dB) across the audible frequency range. They recorded it using Brüel & Kjær equipment. For comparative purposes, typical sound intensities for different everyday functions are given in Appendix E.

2.9 During the testing, the sound pressure levels of background noise were also recorded. The sound pressure levels due to the rain impact noise were then corrected by SRL using a standard equation given in the British Standard to obtain the A-weighted sound intensity levels (L_{IA}) which produces an average value.

2.10 In 2016, the standard test method was updated to ISO 10140-1: 2016 Annex K. It is understood that details of this test method are identical to the earlier BS EN ISO 140-18.

3 ROOF SAMPLES

3.1 The samples of metal roofing were prefabricated in the workshops of JTC Roofing Contractors, based in Narborough, Leicestershire. Trevor Corser, the managing director, is an active member of the FTMRC. The company has many years' experience installing TCSS roofs on churches following lead theft.

3.2 Each roof sample was built on a softwood frame using 22mm-thick by 150mm-wide softwood sarking boards, glued and screwed to the frame with 5mm gaps between the boards. The fully supported metal roofing and different underlays were then assembled on top of each frame. A sketch showing a plan and cross-section of a sample is given in Figure 2.

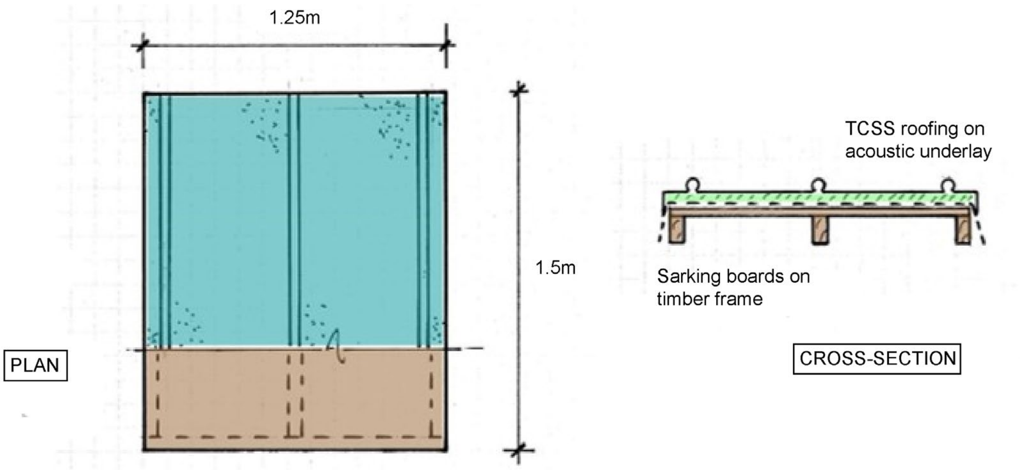

Figure 2: Plan and cross-section of sample

3.3 Five different uninsulated roof assemblies were chosen for testing, as summarised in Table 1. Photographs of the samples are given in Appendix A.

Sample	Roof material	Seam	Joint spacing	Underlay	Self weight		Photo
					Metal	Sample	
1	Code 7 lead	Batten roll	540mm	None	36kg/m²	120kg	1, 2
2	0.5mm TCSS	Standing seam	510mm	None	4kg/m²	70kg	3
3	0.5mm TCSS	Batten roll	540mm	None	4kg/m²	70kg	4
4	0.5mm TCSS	Batten roll	540mm	Spiral mesh[1]	4kg/m²	70kg	5
5	0.5mm TCSS	Batten roll	540mm	Adhered acoustic mat[2]	4kg/m²	70kg	6
[1] VAPOZINC®, manufactured by RHEINZINK® [2] ROOFINOX ACUSTIC, manufactured by ROOFINOX®							

Table 1: Summary of roof assemblies tested

3.4 Lead sample 1 was included as a reference to compare the basic acoustic performance of fully supported lead and TCSS roofing. Once assembled, the sample would be too heavy to transport to the laboratory. Consequently, JTC Roofing Contractors installed the lead at the laboratory.

3.5 Standing seam joints are often used in TCSS roofing. The double-locked seams (25mm high) for sample 2 were formed in accordance with detail D25 in the FTMRC UK Guide to Good Practice in Fully Supported Metal Roofing and Cladding, 3 edition, FTMRC (2018).

3.6 Historic England prefers batten roll seams for church roofs as they more closely match historic detailing. The capped batten roll detail adopted in samples 1, 3, 4 and 5 was similar to detail D30 in the FTMRC good practice guide.

3.7 The first three samples –1, 2 and 3 – were all formed with no underlay. For samples 4 and 5, the two different proprietary acoustic underlays were used as described in Table 1.

4 TESTING AT ACOUSTIC LABORATORY

4.1 The tests were carried out on 18 and 19 February 2021 at the SRL headquarters and laboratories near Sudbury. The weather conditions were generally dry, with an occasional light shower, sunny spells and a light to moderate gusty breeze.

4.2 The roof testing was undertaken by Richard Calvert of SRL, assisted by his colleague Allen Smalls. Mark Weston and Sam Sidwell of JTC Roofing Contractors helped with installing the samples on top of the test roof and laying the lead sheet on sample 1. Keith Roberts was present on 18 February to witness the first test. The SRL site-operating procedures to protect personnel during the coronavirus pandemic were followed.

4.3 Photographs showing the roof sample mounted on the test roof and the general test arrangement are given in Appendix B.

4.4 On the first day of testing, the gusty breeze affected the amount of free-falling water droplets landing on the roof sample, 3.5m below the water tank. The SRL technicians advised that they would only record sound levels when the wind speeds had dropped.

4.5 When testing was complete, JTC Roofing Contractors removed the five samples from the SRL laboratory site and returned them to the workshop in Leicestershire.

5 RESULTS

5.1 Richard Calvert of SRL produced a technical report (reference 24779-SRL-RP-XT-001-P1), dated 10th May 2021. This records the results of the tests, supported by data sheets.

5.2 The A-weighted sound intensity levels (L_{IA}) derived by SRL are given in Table 2.

Sample	Material	Seam	Underlay	SRL data-sheet	Sound intensity L_{IA}	Sound increase compared to sample 1
1	Code 7 lead	Batten roll	None	6	59.6dB	-
2	0.5mm TCSS	Standing seam	None	1	72.2dB	+12.6dB
3	0.5mm TCSS	Batten roll	None	4	70.9dB	+11.3dB
4	0.5mm TCSS	Batten roll	Spiral mesh[1]	3	70.5dB	+10.9dB
5	0.5mm TCSS	Batten roll	Adhered acoustic mat[2]	2	68.7dB	+9.1dB
[1] VAPOZINC®, manufactured by RHEINZINK® [2] ROOFINOX ACUSTIC, manufactured by ROOFINOX®						

Table 2: Results of rain noise acoustic tests

6 CONCLUSIONS

6.1 The independent acoustic tests for rain noise on fully supported metal roofing clearly demonstrate that fully supported lead roofing, with no underlay, is the quietest of the five samples tested under heavy rainfall, with a recorded sound intensity of 59.6dB.

6.2 Changing from lead roofing to 0.5mm-thick TCSS roofing, with no underlay, causes an increase in sound intensity of more than 11dB. This test result supports the reported increase in rain noise experienced by building users after a lead roof has been replaced with TCSS.

6.3 For fully supported TCSS roofing, changing from standing seam to batten roll joints, with no underlay, reduces rain noise by 1.3dB. The recorded sound intensity for the batten roll construction was 70.9dB.

6.4 Adding acoustic underlays further reduces rain-induced noise transmission. The SRL test report suggests that adding spiral mesh underlay reduces noise transmission by 0.4dB (recorded sound intensity of 70.5dB). Alternatively, adding an adhered acoustic mat reduces noise transmission by 2.2dB (recorded sound intensity of 68.7dB). It is recognised that these results are based on single tests of small roof samples.

7 RECOMMENDATIONS

7.1 When fully supported TCSS roofing is specified on a church roof following lead theft, from an acoustic perspective, it is preferable to use batten roll seams rather than standing seams.

7.2 Based on the SRL test results, from an acoustic perspective, it is preferable to use a proprietary acoustic mat adhered to the underside of fully supported TCSS roofing rather than a spiral mesh underlay.

APPENDIX A

Photographs of roof samples produced by JTC Roofing Contractors

Photo A1: Sample 1 – lead batten roll, no underlay

Photo A2: Sample 1 – as laid on top of test roof

Photo A3: Sample 2 – TCSS standing seam, no underlay

Photo A4: Sample 3 – TCSS batten roll, no underlay

Photo A5: Sample 4 – TCSS batten roll, spiral mesh underlay

Photo A6: Sample 5 – TCSS batten roll, adhered acoustic mat

Photographic record of test set-up

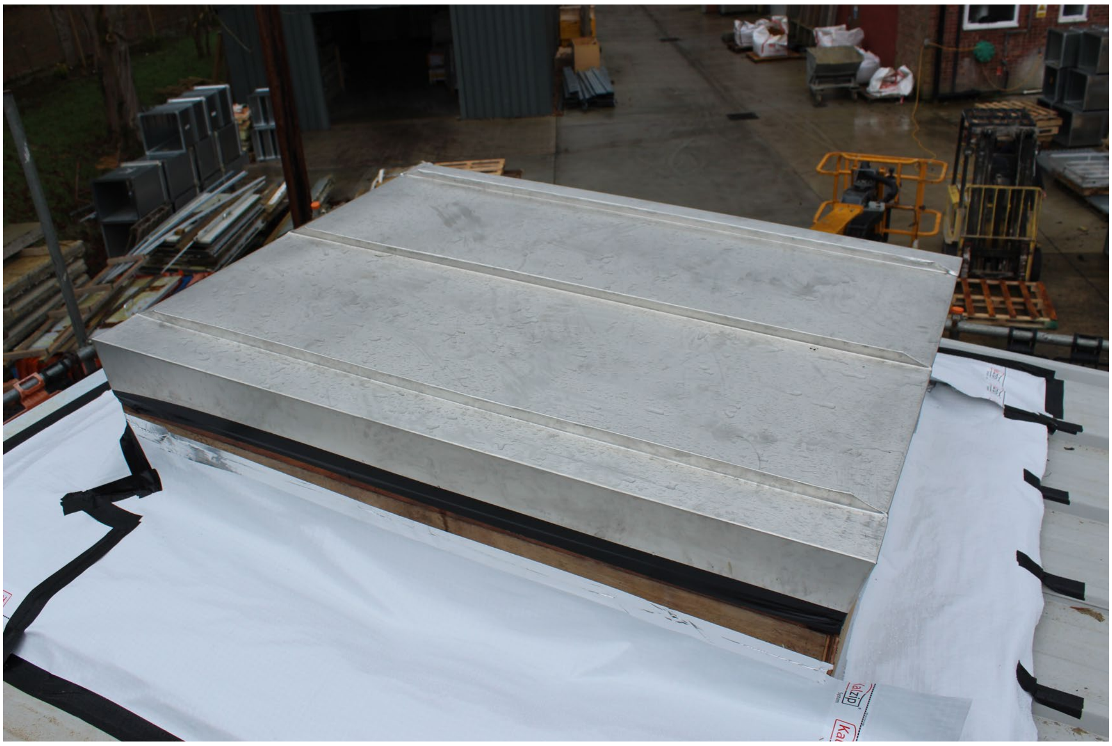

Photo B1: TCSS roof sample mounted on roof of acoustic test room

Photo B2: Underside of roof sample with timber deck, seen from within acoustic test room

Photo B3: Water tank suspended below mobile platform before being put in position

Photo B4: Water tank being manoeuvred into position

Photo B5: Water tank suspended 3.5m above roof sample, water supplied by hosepipe

Photo B6: Rate of water flow is checked by collecting water as it drains from test room gutter

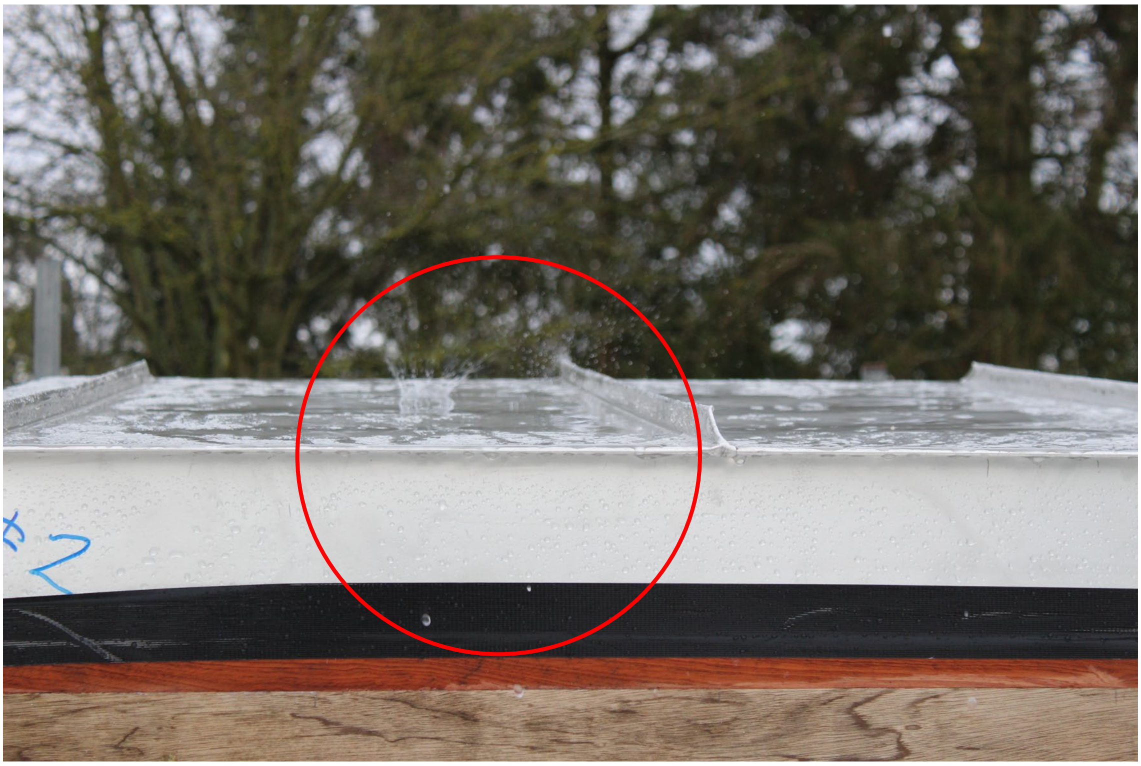

Photo B7: Test in progress, droplets of water falling onto roof sample

Photo B8: Follow-on roof sample, ready for testing on 19 February 2021

APPENDIX C

Technical Report
24779-SRL-RP-XT-002-P1

Project

The Laboratory Determination of Sound Generated by Rainfall on Five Sample Roof Constructions

Prepared for

Historic England

By

Richard Calvert

Published

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Telephone +44(0)1787 247595
Website www.srltsl.com
London, Birmingham, Manchester, Sudbury

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Client	Historic England
Client Address	The Engine House Fire Fly Avenue Swindon SN2 2EH
Author	Richard Calvert
Checker	Allen Smalls
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P1	10/05/2021	

R Calvert

Richard Calvert
Tester
For and on behalf of
SRL Technical Services Limited
Tel: 01787 247595
Email: rcalvert@srltsl.com

Quality Manager

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Contents

1.0 Description of Test

1.1 Description of Sample

Tests were done on five different sample roof constructions measuring 1250x1500mm to determine the sound generated by rainfall. For details of each construction, please see Section 2 and Drawing 1 and Photograph 1.

Due to size of the samples, they do not meet the requirement of the standard and are not UKAS accredited tests. They were tested to give comparable results between the five samples and not as full constructions.

The test samples sit on a wooden upstand which is sealed to a supporting roof. The supporting roof system was mounted on three equispaced steel purlins spanning the test room. The Purlins sit flush with the top of the test room wall.

Sampling plan:	Enough for test
Sample condition:	New
Details supplied by:	Historic England
Sample installed by:	SRL Technical Services Ltd

1.2 Sample Delivery Date

17 February 2021

1.3 Test Procedures

The sample was mounted/located and tested in accordance with the relevant standard. Details of measurement are given in Appendix A. The method and procedure are described in Appendix B

2.0 Results

The results of the measurements and subsequent analysis are given Data Sheets 1 to 5 and summarised below.

Results relate only to the items as received and tested.

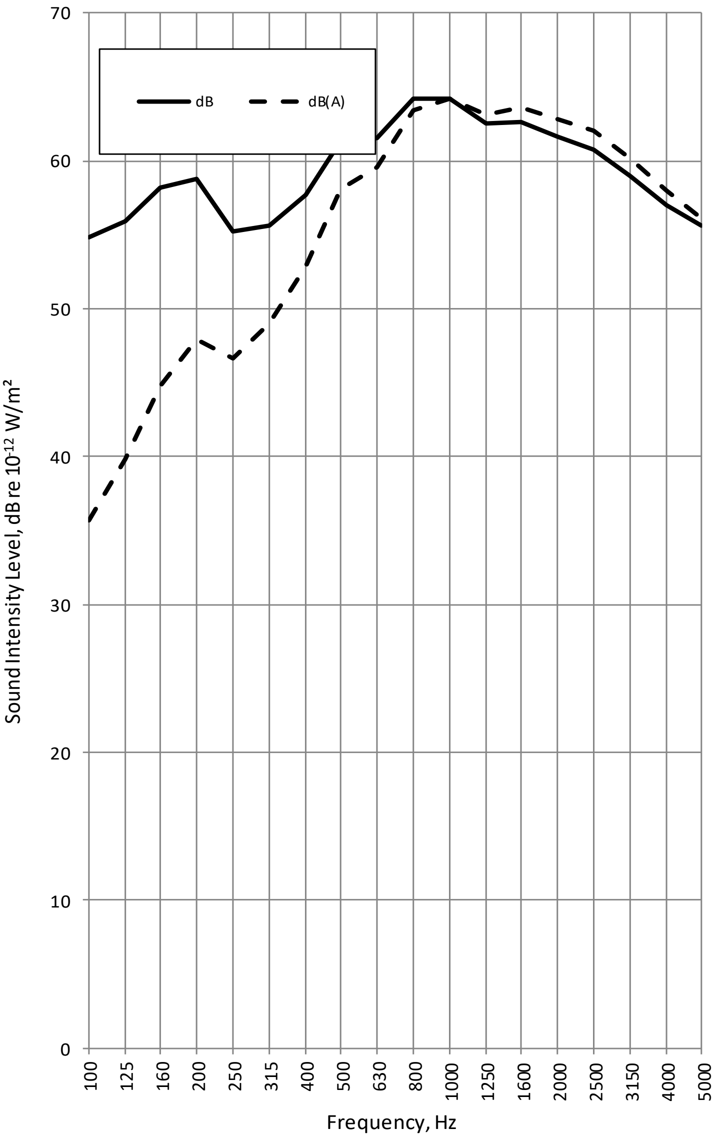
SRL Test No.	Description in Brief	L_{IA} (dB)
1	Sample No 2 0.5mm TCSS, Standing Seam 25mm sarking boards with 5mm gap	72.2
2	Sample No 5 0.5mm TCSS, Batten Roll Seam Adhered Acoustic Mat underlay 25mm sarking boards with 5mm gap	68.7
3	Sample No 4 0.5mm TCSS, Batten Roll Seam Spiral Mesh underlay 25mm sarking boards with 5mm gap	70.5
4	Sample No 3 0.5mm TCSS, Batten Roll Seam 25mm sarking boards with 5mm gap	70.9
6	Sample No 1 Code 7 Lead, Batten Roll Seam 25mm sarking boards with 5mm gap	59.6

Datasheet 1 – Not UKAS accredited due to small sample size

SOUND INTENSITY LEVEL GENERATED BY ARTIFICIAL RAINFALL

Test Number:	1	**Rainfall Type:**	Heavy	**Room Air temperature:**	9.5 °C
Client:	Historic England	**Rainfall Rate:**	39.9 mm/h	**Room Air humidity:**	88 %
Test Date:	18/02/2021	**Water Temperature**	7 °C	**Room volume:**	55.8 m³
Type of Sample:	Small	**Slope of Sample:**	5 deg.	**Area of Sample Excited:**	1.57 m²
Surface Mass:	36.3 kg/m^2				
Sample Description:	Sample No 2, 0.5mm TCSS, Standing Seam, 25mm sarking boards with 5mm gap				

Freq f Hz	Sound Intensity Level dB 1/3 Oct	dB 1/1 Oct	dBA 1/3 Oct
50+	*50.2*		*20*
63+	*48.3*	*54.0*	*22.1*
80+	*49.1*		*26.6*
100	54.8		35.7
125	55.9	61.3	39.8
160	58.2		44.8
200	58.8		47.9
250	55.2	61.6	46.6
315	55.6		49
400	57.7		52.9
500	61.3	65.3	58.1
630	61.5		59.6
800	64.2		63.4
1000	64.2	68.5	64.2
1250	62.5		63.1
1600	62.6		63.6
2000	61.6	66.5	62.8
2500	60.7		62
3150	59		60.2
4000	57	62.2	58
5000	55.6		56.1



L_{IA} = **72.2** dB

Notes: # designates limit of measurement due to background

+ designates frequency beyond range covered by the Standard & not UKAS accredited

v2.0

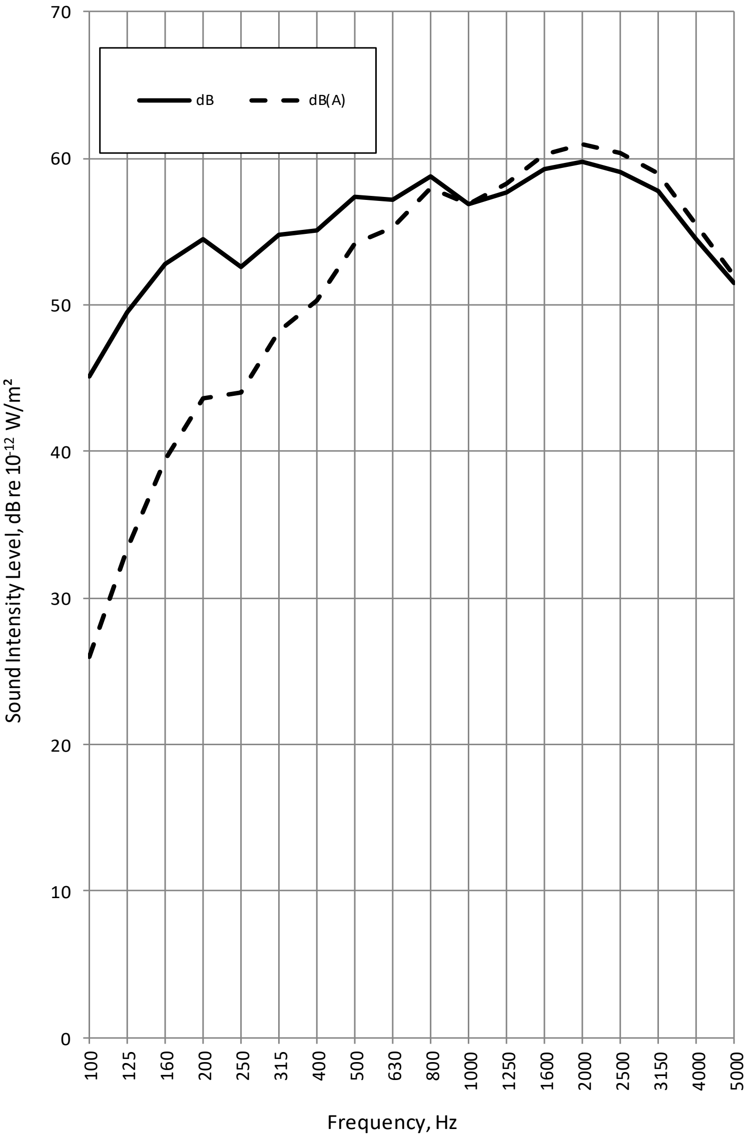
Datasheet 2 – Not UKAS accredited due to small sample size

SOUND INTENSITY LEVEL GENERATED BY ARTIFICIAL RAINFALL

Test Number:	2	**Rainfall Type:**	Heavy	**Room Air temperature:**	9.5 °C
Client:	Historic England	**Rainfall Rate:**	40.6 mm/h	**Room Air humidity:**	88 %
Test Date:	18/02/2021	**Water Temperature**	10 °C	**Room volume:**	55.8 m³
Type of Sample:	Small	**Slope of Sample:**	5 deg.	**Area of Sample Excited:**	1.57 m²
Surface Mass:	38.9 kg/m^2				

Sample Description: Sample No 5, 0.5mm TCSS, Batten Roll Seam, Adhered Acoustic Mat underlay, 25mm sarking boards with 5mm gap

Freq f Hz	Sound Intensity Level dB 1/3 Oct	dB 1/1 Oct	dBA 1/3 Oct
50+	*42.6 #*		*12.4 #*
63+	*39.8 #*	*47.5*	*13.6 #*
80+	*44.6*		*22.1*
100	45.1		26
125	49.5	54.9	33.4
160	52.8		39.4
200	54.5		43.6
250	52.6	58.8	44
315	54.8		48.2
400	55.1		50.3
500	57.4	61.5	54.2
630	57.2		55.3
800	58.8		58
1000	56.9	62.6	56.9
1250	57.7		58.3
1600	59.3		60.3
2000	59.8	64.2	61
2500	59.1		60.4
3150	57.8		59
4000	54.5	60.1	55.5
5000	51.5		52



L_{IA} = **68.7** dB

Notes : # designates limit of measurement due to background

+ designates frequency beyond range covered by the Standard & not UKAS accredited

v2.0

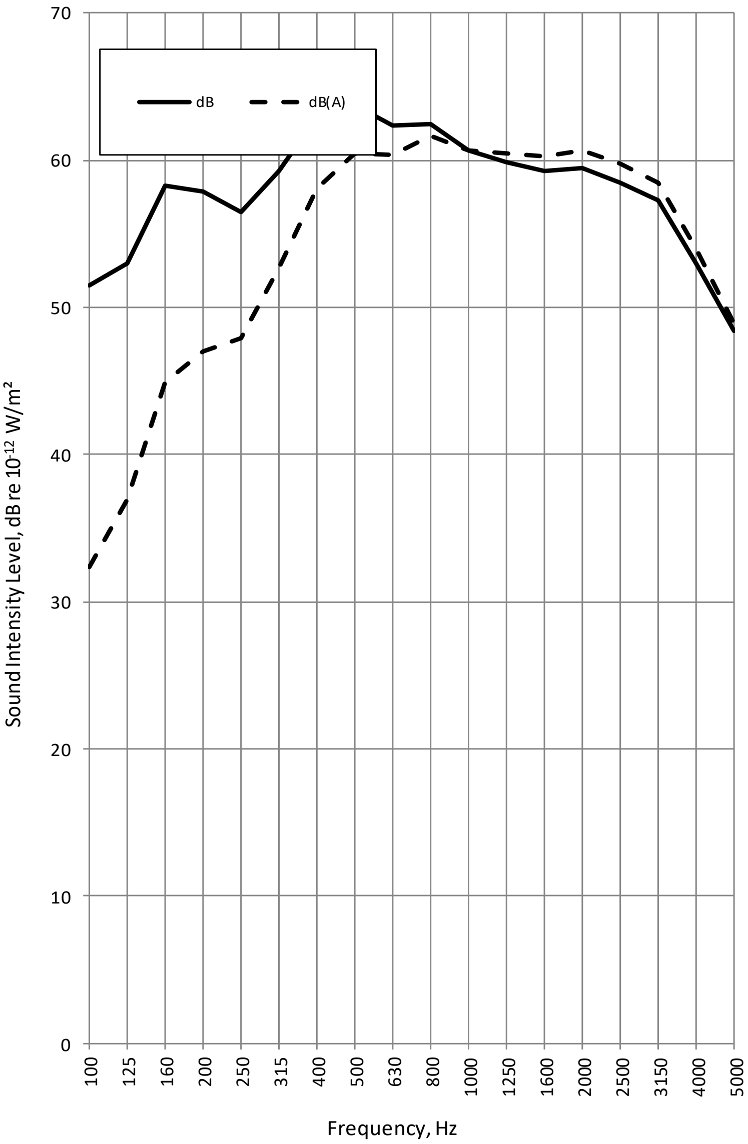
Datasheet 3 – Not UKAS accredited due to small sample size

SOUND INTENSITY LEVEL GENERATED BY ARTIFICIAL RAINFALL

Test Number:	3	**Rainfall Type:**	Heavy	**Room Air temperature:**	4.5 °C
Client:	Historic England	**Rainfall Rate:**	41.4 mm/h	**Room Air humidity:**	86 %
Test Date:	19/02/2021	**Water Temperature**	4.5 °C	**Room volume:**	55.8 m³
Type of Sample:	Small	**Slope of Sample:**	5 deg.	**Area of Sample Excited:**	1.57 m²
Surface Mass:	37.3 kg/m²				

Sample Description: Sample No 4, 0.5mm TCSS, Batten Roll Seam, Spiral Mesh underlay, 25mm sarking boards with 5mm gap

Freq f Hz	Sound Intensity Level dB 1/3 Oct	dB 1/1 Oct	dBA 1/3 Oct
50+	*48.3*		*18.1*
63+	*49.3*	*54.0*	*23.1*
80+	*49.9*		*27.4*
100	51.5		32.4
125	53	60.1	36.9
160	58.3		44.9
200	57.9		47
250	56.5	62.8	47.9
315	59.3		52.7
400	62.9		58.1
500	63.7	67.8	60.5
630	62.3		60.4
800	62.4		61.6
1000	60.7	65.9	60.7
1250	59.9		60.5
1600	59.3		60.3
2000	59.5	63.9	60.7
2500	58.5		59.8
3150	57.3		58.5
4000	53	59.1	54
5000	48.4		48.9



L_{IA} = **70.5** dB

Notes : # designates limit of measurement due to background
+ designates frequency beyond range covered by the Standard & not UKAS accredited

v2.0

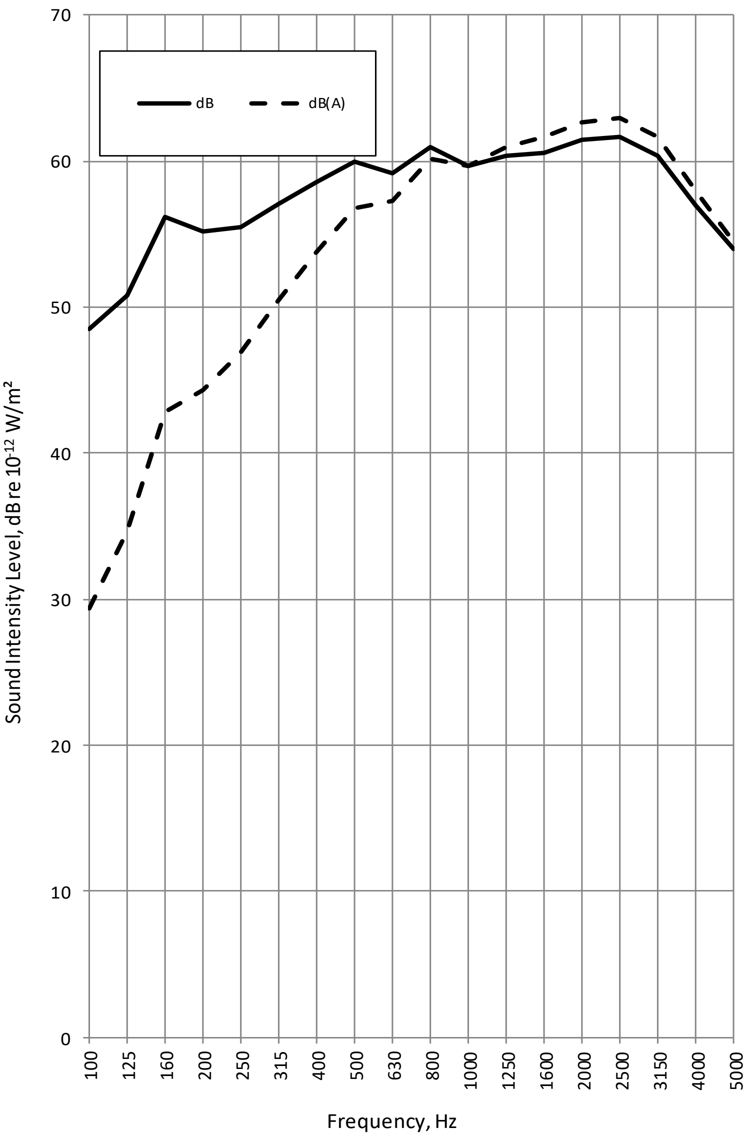
Datasheet 4 – Not UKAS accredited due to small sample size

SOUND INTENSITY LEVEL GENERATED BY ARTIFICIAL RAINFALL

Test Number:	4	**Rainfall Type:**	Heavy	**Room Air temperature:**	5 °C
Client:	Historic England	**Rainfall Rate:**	41.4 mm/h	**Room Air humidity:**	87 %
Test Date:	19/02/2021	**Water Temperature**	5 °C	**Room volume:**	55.8 m³
Type of Sample:	Small	**Slope of Sample:**	5 deg.	**Area of Sample Excited:**	1.57 m²
Surface Mass:	39.5 kg/m²				

Sample Description: Sample No 3, 0.5mm TCSS, Batten Roll Seam, 25mm sarking boards with 5mm gap

Freq f Hz	Sound Intensity Level dB 1/3 Oct	dB 1/1 Oct	dBA 1/3 Oct
50+	*40.8 #*		*10.6 #*
63+	*41.7 #*	*48.6*	*15.5 #*
80+	*46.6*		*24.1*
100	48.5		29.4
125	50.8	57.8	34.7
160	56.2		42.8
200	55.2		44.3
250	55.5	60.8	46.9
315	57.1		50.5
400	58.6		53.8
500	60	64.1	56.8
630	59.2		57.3
800	61		60.2
1000	59.7	65.2	59.7
1250	60.4		61
1600	60.6		61.6
2000	61.4	66	62.6
2500	61.6		62.9
3150	60.4		61.6
4000	57	62.7	58
5000	54		54.5



L_{IA} = **70.9** dB

Notes: # designates limit of measurement due to background

+ designates frequency beyond range covered by the Standard & not UKAS accredited

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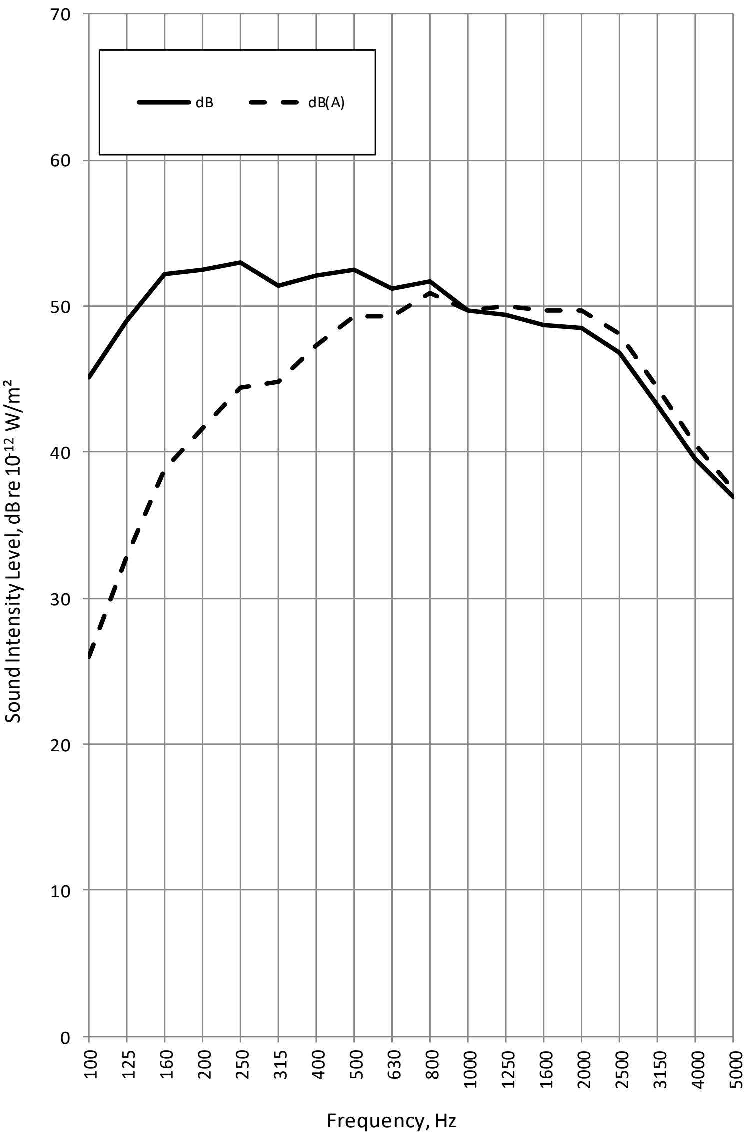
Datasheet 5 – Not UKAS accredited due to small sample size

SOUND INTENSITY LEVEL GENERATED BY ARTIFICIAL RAINFALL

Test Number:	6	**Rainfall Type:**	Heavy	**Room Air temperature:**	5 °C
Client:	Historic England	**Rainfall Rate:**	38.4 mm/h	**Room Air humidity:**	87 %
Test Date:	19/02/2021	**Water Temperature**	5 °C	**Room volume:**	55.8 m³
Type of Sample:	Small	**Slope of Sample:**	5 deg.	**Area of Sample Excited:**	1.57 m²
Surface Mass:	83.7 kg/m²				

Sample Description: Sample No 1, Code 7 Lead, Batten Roll Seam, 25mm sarking boards with 5mm gap

Freq f Hz	Sound Intensity Level dB 1/3 Oct	Sound Intensity Level dB 1/1 Oct	Sound Intensity Level dBA 1/3 Oct
50+	*38.0 #*		*7.8 #*
63+	*36.3 #*	*46.2*	*10.1 #*
80+	*44.9*		*22.4*
100	45.1		26
125	49	54.4	32.9
160	52.2		38.8
200	52.5		41.6
250	53	57.1	44.4
315	51.4		44.8
400	52.1		47.3
500	52.5	56.7	49.3
630	51.2		49.3
800	51.7		50.9
1000	49.7	55.2	49.7
1250	49.4		50
1600	48.7		49.7
2000	48.5	52.9	49.7
2500	46.8		48.1
3150	43.2		44.4
4000	39.5	45.4	40.5
5000	36.9		37.4



L_{IA} = **59.6** dB

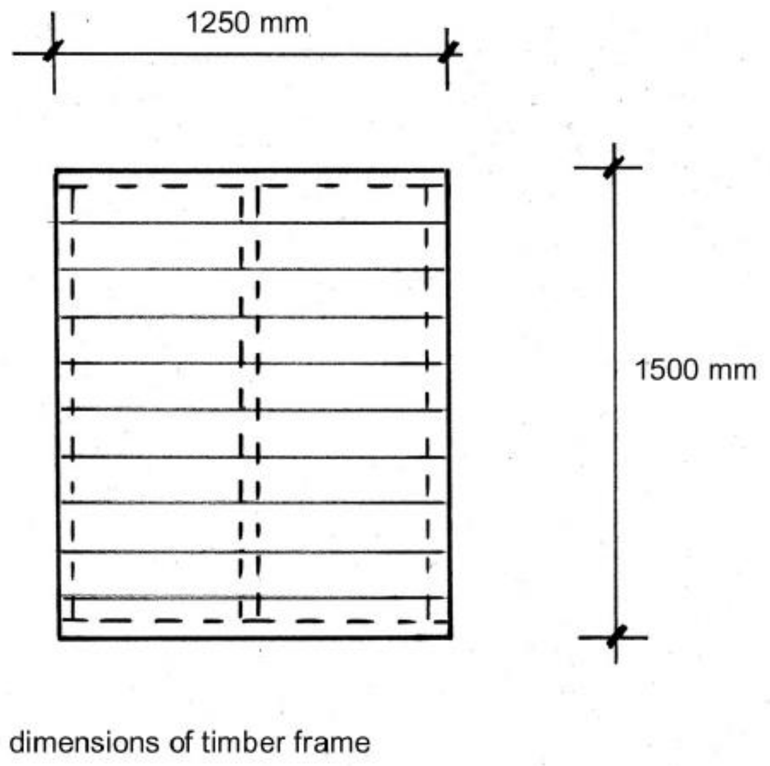
Notes : # designates limit of measurement due to background
+ designates frequency beyond range covered by the Standard & not UKAS accredited

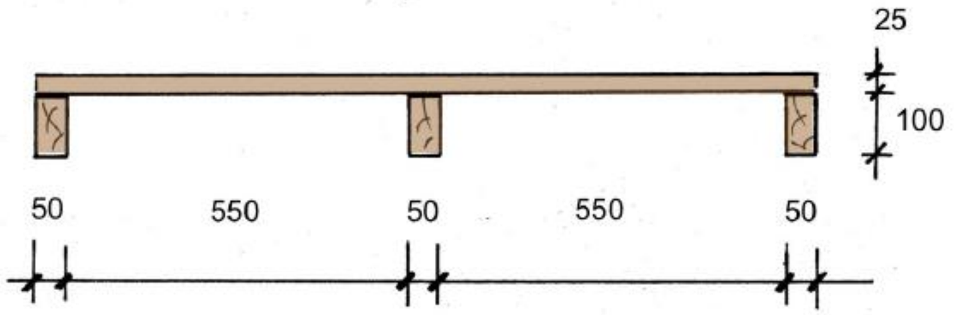
v2.0

Drawing 1

Timber base 6 no. required

50 x 100 softwood frame.
25 x 150 softwood sarking boards, glued and screwed to frame, 5mm gaps between boards





Photograph 1

View of 0.5mm TCSS Batten Roll Seam sample

Appendix A - Details of Measurements

A1. Location

Sound Research Laboratories

Holbrook House

Little Waldingfield

Sudbury

Suffolk

CO10 0TF

A2. Test Dates

18 & 19 February 2021

A3. Tester

Richard Calvert of SRL Technical Services Limited

A4. Instrumentation and Apparatus Used

Description	Location	SRL No.	Make	Type	S/N
Sound Level Analyzer	Holbrook	850	Brüel & Kjær	2250	3007898
Preamplifier	Holbrook	852	Brüel & Kjær	ZC0026	19790
Microphone	Holbrook	951	Brüel & Kjærl	4189	3130789
Calibrator	Holbrook	692	Brüel & Kjær	4231	2438805
Active Speaker	Holbrook	718	JBL	EON10G2	14075
Hygrometer	Holbrook	369	Brannan	Whirling	No S/N
Thermometer	Holbrook	772	Brannan	Bulb	No S/N
Measuring Cylinder	Holbrook	771	Azlon	1 litre	No S/N
Stopwatch	Holbrook	713	na	na	na
Rain Tank	Holbrook	770	SRL	na	na

A5. References

BS EN ISO 140-18:2006 Laboratory measurement of sound generated by rainfall on building elements

Appendix B – Test Procedure

Laboratory Measurement of Sound Generated by Rainfall on Building Elements to BS EN ISO 140-18:2006 (small samples)

Test Procedure

Rain was simulated and measured on a rig built based on that described in BS EN ISO 140-18.

The rain droplets were formed through holes in a polycarbonate plate 1cm thick in a specially constructed tank.

Tank size 1.25 by 1.3m
Holes spread out over 1.25 by 1.3 m = 1.625m^2
Nominal diameter of holes in tank = 1mm
Number of holes = 60/m^2

This produced a measured rainfall rate of 38 to 42 mm/h

A roof is constructed with a 5 degree slope over a room with an internal volume of 53.8m^3. The sample skylight is installed over an opening in the roof. The room is constructed with 100mm blocks and dimensions are chosen so that the natural frequencies at low frequency are spaced as uniformly as practicable.

Height	2.76 to 3.10m
Width	3.69m
Length	4.62m

The tank is suspended 3.5m above the test sample; one tank position is used, so the rain impacts on the skylight sample.

The sound pressure levels are measured in the room at a minimum of five microphone positions, with minimum separating distances as follows:

0.7m between microphone positions
0.7m between any microphone position and room boundaries or diffusers
1.0m between any microphone position and the test sample

A minimum of 6 seconds averaging time for each microphone position is used.

The background noise level is also measured to see if the measurements are affected by extraneous noise, if so the noise levels are corrected according to ISO 140-18.

The sound pressure levels corrected for background noise are converted into sound intensity levels using the following equation:

$$L_I = L_{pr} - 10\lg(T/T_0) + 10\lg(V/V_0) - 14 - 10\lg(S_e/S_0)dB$$

where

L_{pr} is the averaged sound-pressure level in the test room, in decibels;

T is the reverberation time of the test room, in seconds;

T_0 is the reference time (=1s);

V is the volume of the test room, in cubic metres (m^3);

V_0 is the reference volume (=1m^3);

S_e is the area of the test specimen directly excited by the rainfall, in square metres; it corresponds to the specimen size for smaller specimens;

S_0 is the reference area (=1m^2).

Laboratory
Holbrook House
The Street
Little Waldingfield
Sudbury
Suffolk
CO10 0TF
Tel: +44 (0)1787 247595

Website: www.srltsl.com
e-mail: srl@srltsl.com

Registered Name and Address:
SRL Technical Services Limited
Holbrook House
Little Waldingfield
Sudbury
Suffolk
CO10 0TF

Registered Number: 907694 England

BS EN ISO 140-18:

the new British Standard for measuring rain noise on roofs

Photo: Underside of water tank with perforated base of the new BRE rain noise measurement rig. (Source: BRE)

The noises heard inside a building from rain falling onto a lightweight roof or a rooflight can lead to complaints, particularly in quiet rooms such as bedrooms, libraries and health buildings. To help designers specify new roofs and compare alternative products, a standard test method has been agreed for the laboratory measurement of sound generated by rainfall, BS EN ISO 140 Part 18, which is reviewed in this RCi Technical Note.

In November last year a new international standard for the laboratory measurement of noise made by rainfall on roofs (BS EN ISO 140 Part 18:2006) was published after several years in development.

Noise problems

There are some types of buildings where there is a requirement for peace and quiet, including theatres, rehearsal rooms, recording studios, schools, examination rooms, churches, hospitals and convalescent homes. The building design may require rooflights to provide natural lighting or, alternatively, a lightweight roof construction. During periods of heavy rainfall, the impact noises from raindrops falling onto a glass or profiled metal roof can create a nuisance to the users of the rooms below, with noise levels as high as 70dB.

For some building types, there are now requirements that limit the amount of rain-induced noise that is permissible. For example, in the *Building Bulletin 93* for the acoustic design of schools, introduced in 2003, there is a need to demonstrate to Building Control "that the roof has been designed to minimise rain noise". The intensity of the rain-induced noise will depend upon the size of the rooflight and its sound insulation capabilities, which can be selected by the designer.

Artificial raindrops

Externally there are many different types of rain. The induced noise will depend upon – among other things – the size of the raindrop, its velocity on hitting the roof, and the rainfall rate. BS EN ISO 140 Part 18 describes, in detail, different rainfall types and the generation of artificial raindrops. This includes information on measuring raindrop size and velocity which may be of assistance for other building envelope performance studies. Hail stones are not considered. Two types of rainfall are specified for use in the test method, which is helpful, as there is now an agreed standard measure which can be used for comparing the results of testing different products and systems.

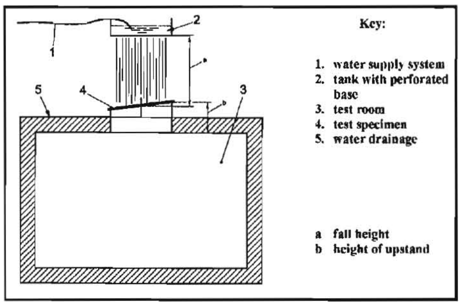


Figure: Typical test arrangement (taken from figure A2 of BS EN ISO part 18).

Test method

At the BRE, bespoke facilities for measuring sound generated by rainfall on roofs have been developed in accordance with the new Standard. The tests can be conducted at any time of the year, in closely controlled conditions, allowing manufacturers and designers to rank different types of roof and rooflights in terms of their resistance to noise generated by rain falling on them.

The acoustic test room has an opening in the roof of between 10 and 20m^2 for the installation of the test specimens, as shown in the Figure above. The preferred dimensions of a rooflight under test are 1.5m x 1.25m and laid to a slope of 30°. It is important that the background noise level in the test room is very low to ensure accurate measurement of the noise generated by the drumming of the rain.

A water tank with 25 or 60 holes in the base is suspended at a height of up to 3.5m above the test specimen. Water is supplied to the tank such that there is a constant head of water flowing in a steady state condition. The BRE rig allows for the water tank to be moved to at least three different areas of the test specimen.

The artificial rain falling on the test specimen is run for at least five minutes before starting to measure the sound pressure levels. The Standard gives details of the setting out of the microphones and the conversion of the measured sound pressure levels to the sound intensity level for each grouped frequency. These in turn are converted to the A-weighted sound intensity level, which is recorded in the acoustic test report. This is necessary for demonstrating that rain noise has been adequately controlled in, for example, schools and health premises.

Concluding remarks

The works carried out by the research teams in developing the new British Standard have helped to develop an internationally accepted method for measuring rain-induced drumming noise on roofs. This will be a helpful reference for designers and manufacturers alike. Now the Standard has been published and facilities developed at the BRE, it will be important for the industry to commission appropriate testing and for designers of special 'quiet' buildings to use this information in designing and specifying buildings that meet client requirements.

References

1. BS EN ISO 140-8: 2006, *Acoustics – measurement of sound insulation in buildings and of building elements – Part 18: Laboratory measurement of sound generated by rainfall on building elements*, December 2006, BSI (£114)

Keith Roberts, who compiled this Technical Note exclusively for RCi, is an independent roofing consultant.

Contact him at:
Roberts Consulting
2 Gardiner Close
Abingdon
Oxon OX14 3YA
Tel/fax: 01235 529 693

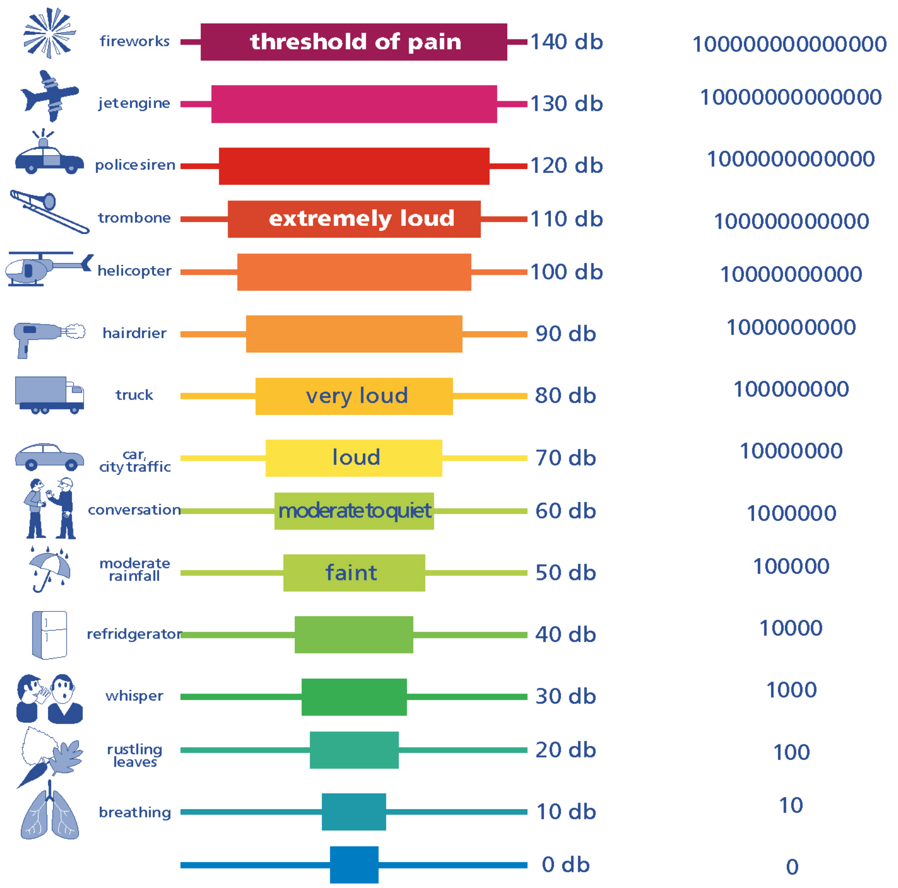
www.robertsconsulting.co.uk

	Intense	Heavy
Raindrop diameter	2mm	5mm
Rainfall rate	15mm/hr	40mm/hr
Full height	approx. 1m	approx. 3.5m
Velocity at impact	4m/s	7m/s

Table: Specifications for artificial rainfall used in acoustic tests.

SOUND INTENSITIES OF EVERYDAY FUNCTIONS

dB	Function
100	Very loud passing truck, home lawn mower, car horn at 5m, wood saw, boiler factory
90	Very loud. Noisy factory. Decibels at or above 90 regularly cause ear damage.
80	Loud noisy office, electric shaver, alarm clock, police whistle
70	Loud average radio, normal street noise
60	Moderate conversational speech
50	Moderate normal office noise, quiet stream
45	Moderate to awaken a sleeping person
40	Faint average residence, normal private office
30	Faint recording studio, quiet conversation
20	Very faint whisper, empty theatre, ticking of watch
10	Very faint threshold of good hearing
0	Threshold of excellent youthful hearing



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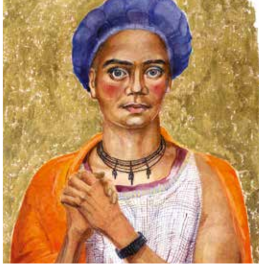



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