DAY DESIGN PTY LTD

A.B.N. 73 107 291 494

CONSULTING ACOUSTICAL ENGINEERS

MEASUREMENTS OF SOUND ABSORPTION

TIMBERCRETE

100 mm "ANCIENT STONE" BRICK

REPORT NUMBER: **4546-2**

PREPARED FOR: Timbercrete Pty Ltd
2628 Bells Line Of Road
Bilpin NSW 2758

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1.0 INTRODUCTION

Day Design was commissioned by Timbercrete Pty Ltd to measure the sound absorption coefficient of their 100 mm "Ancient Stone" brick.

The tests were conducted in a reverberation chamber at the National Acoustic Laboratories in accordance with Australian Standard AS ISO 354-2006: *"Acoustics – Measurement of sound absorption in a reverberation room"*.

The measurement results are to be rated in accordance with AS ISO 11654-2002" *"Acoustics – Rating of Sound Absorption – Materials and Systems"*.

2.0 SOUND SURVEY INSTRUMENTATION

Noise level measurements and analysis were made with instrumentation as follows in Table 2.1:

Table 2.1 Instrumentation

Description	Serial No.
Brüel and Kjær Two Channel Pulse Analyser (assembly 2825, 7521, 2 x 3015)	2005502
Brüel and Kjær Cathode Follower type 2669	1888716
Brüel and Kjær Microphone type 4144	2118354
Brüel and Kjær Sound Level Calibrator type 4231	2095415
Yamaha Professional Sound Sources type S500 (2x units)	1068 & 1069
Murray 100 Watt Amplifier type MA534	15
Vaisala Digital Barometer type PTB201AD	R3330001
Testo Temperature/Humidity Logger, type 177-H1	00886924

All acoustic instrument systems have been laboratory calibrated using instrumentation traceable to Australian National Standards and certified within the last two years thus conforming to Australian Standards. The acoustic measurement system was also calibrated prior to and after the noise level measurements.

3.0 ACOUSTIC TEST LABORATORY

Location:	National Acoustic Laboratories 126 Greville Street, Chatswood, NSW.
Room Construction:	The Receiving Reverberation Room was used for the acoustical measurements with the dividing steel doors closed. The room is of concrete and masonry construction having an internal volume of 202 cubic metres. The floor is pentagonally shaped and the ceiling is inclined so that no two surfaces are parallel. The room is vibration and sound isolated from the enclosing building, being floated on steel springs and rubber dampers below the concrete floor. Large panels of 19 mm thick plywood, heavily coated with an epoxy resin are suspended inside the test room in random orientation to aid in the diffusion of the sound field.
Room Surface Area:	231 m^2
Atmospheric Conditions:	The relative humidity inside the reverberation room throughout testing was between the ranges of 65 to 75%. The temperature was between the ranges of 20 to 25^{o}C.
Test Specimen:	- Timbercrete 100 mm “Ancient Stone” bricks (approximate density 1000 kg/m^3) each with dimensions of 440 mm (L) x 240 mm (H) x 100 mm (D) were placed directly on the floor to form a 14 x 7 array (10.5 m^2) test sample. - The 100 mm “Ancient Stone” brick has a rough finish on one side and smooth finish on the other side of the brick. The bricks were placed on the floor with the rough finish exposed. - The perimeter edges of the test sample were covered up using strips of 7.5 mm thick fibre cement.
Date of Test:	Monday 14th February, 2011

4.0 MEASUREMENT PROCEDURE

Before testing commenced, the reverberation room temperature, relative humidity and barometric air pressure were noted. The measurement microphone was acoustically calibrated and the acoustical noise floor of the room checked.

All reverberation rooms have small space variations of the sound field distribution and time variations in sound field decay (of reverberation time) during the measurement period. The gathering of meaningful results therefore requires multiple measurements to determine the extent of these variations. The testing procedure uses 48 sets of data to determine the spread of results around the estimate of the mean, each set containing eighteen measurements of one-third-octave reverberation times.

Sound levels generated in the reverberation room for this test were at least 48 dB above the combined background noise level in the reverberation room and the recording equipment electrical noise level for each one-third-octave band. Thus these tests provide a minimum 33 dB evaluation range for measurement of sound decay starting from 5 dB below the initial sound pressure level and with a margin of at least 10 dB between the background noise level and the lowest level of measurement. Item 7.4.1 of AS ISO 354-2006 requires a minimum evaluation range of 20 dB.

The suite of data is divided into two sets of 24 measurements; the first set for the empty reverberation room with the fibre cement frame; and the second set for the reverberation room with the test specimen. The difference between the two measurement data sets is used to determine the absorption characteristics of the test specimen.

These 24 sets of data for each of the two measurement suites consists of a spatial average of six different combinations of two loudspeakers and three microphone positions, and four measurements taken at each combination for a time average to obtain an estimate of the reverberation time precision.

At all times care was taken to ensure that the microphone was separated by at least one metre from the test specimen and room surfaces or diffusers and at least two metres from a sound source as required by AS ISO 354-2006.

This space-time measurement data was computer processed on a pre-configured Excel spreadsheet to obtain a final average and standard deviation for the test specimen results. The calculations provide sound absorption coefficients and precision level of the measurements to a 95% confidence level.

The complete measurement data, calculated sound absorption coefficients and the precision of each coefficient to the 95% confidence level is shown on the attached spreadsheet and is tabulated in Table 2 of this report.

Note: The first measurement of empty room reverberation time can be used for measurements involving more than one test specimen since the temperature and humidity are stable over long periods of time in all of the test facility measurement rooms. However, re-measurement of the empty room reverberation time is always undertaken if the data is suspect or multiple samples are to be evaluated over a long period of time.

4.1 Sound Absorption Coefficients (α_s)

The sound absorption coefficient (α_s) in one-third-octave bands (centre frequencies of 100 to 500 Hz inclusive) is the ratio of the equivalent sound absorption area of a test specimen divided by the area of the test specimen. It should be noted that a sound absorption coefficient evaluated from reverberation time measurements can have values larger than 1.00 due to edge effects. Sound absorption coefficient results were rounded to the nearest 0.01 as required by AS ISO 354-2006, item 8.3.

4.2 Practical Sound Absorption Coefficients (α_p)

The practical sound absorption coefficient (α_p) is given in octave bands (centre frequencies of 125 to 4000 Hz inclusive) based on the arithmetic mean value of the three corresponding one-third-octave sound absorption coefficients, with the mean value calculated to the second decimal, rounded in steps of 0.05.

4.3 Weighted Sound Absorption Coefficient (α_w)

The weighted sound absorption coefficient (α_w) is calculated from the practical sound absorption coefficients (α_p) using the reference curve as shown in Table 1 below. The reference curve is shifted in steps of 0.05 towards the measured α_p value, until the sum of the unfavourable deviations is less than 0.10. An unfavourable deviation occurs at a particular frequency when the measured value is less than the value of the reference curve. The weighted sound absorption coefficient α_w is defined as the value of the shifted reference curve at 500 Hz.

Table 1 Reference curve for evaluation of weighted sound absorption coefficient, α_w

Frequency (Hz)	250	500	1000	2000	4000
Value	0.80	1.00	1.00	1.00	0.90

The single number rating, α_w, obtained by the method of this standard does not convey enough information when products are to be used in environments requiring specialist acoustical design. In such cases, complete sound absorption data, α_s, as a function of frequency are needed.

4.4 Shape Indicators

Whenever α_p exceeds the value of the shifted reference curve by 0.25 or more, one or more shape indicators are added in parentheses, to the single number α_w rating. If the excess absorption occurs at 250 Hz, "(L)" notation is used. If the excess absorption occurs at 500 Hz or 1000 Hz, "(M)" notation is used. If the excess absorption occurs at 2000 Hz or 4000 Hz, "(H)" notation is used. A "shape indicator" means the sound absorption coefficient at one or more frequencies is considerably higher than the values of the shifted reference curve and therefore, the complete sound absorption coefficient curve should be examined.

4.5 Noise Reduction Coefficient (NRC)

The noise reduction coefficient (NRC) is a commonly used descriptor determined by arithmetically averaging the sound absorption coefficients measured in octave bands centred on 250 – 2000 Hz inclusive, as defined in the American Standard ASTM C 423–89: *"Standard test method for sound absorption and sound absorption coefficients by the reverberation room method"*. The calculated NRC is rounded to the nearest 0.05.

The NRC is not defined by Australian Standards. However, we have included the NRC rating in this report, for comparison with other test data.

5.0 TEST SPECIMEN DESCRIPTIONS AND RESULTS

The test specimen comprised of 98 Timbercrete 100 mm "Ancient Stone" bricks to form a 14 x 7 array giving a total test area of 10.5 m^2. 100 mm wide strips of 7.5 mm thick fibre cement was used to construct a frame covering the perimeter edges of the test specimen so that only the top surface was exposed.

Figure 1: "Ancient Stone" bricks set-up in reverberation room.

Figure 2: Fibre cement frame left in the reverberation room as part of the empty room.

The Timbercrete 100 mm "Ancient Stone" bricks achieved an NRC rating of 0.15 and α_w rating of 0.2.

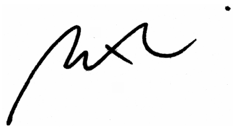
Sound absorption coefficients (rounded to the nearest 0.01) are tabulated for each one-third-octave band tested and presented in Table 2. Formulae used in deriving results are presented in the attached Appendix A.

Reverberation times at one-third octave centre frequencies 100 to 5000 Hz were measured and sound absorption coefficients calculated by the methods and procedures of AS ISO 11654-2002: *"Acoustics – Rating of Sound Absorption – Materials and Systems"*.

Table 2 Measured Sound Absorption Coefficients

1/3 Octave Band Centre Frequency (Hz)	Sound Absorption Coefficient (α_s)	Practical Sound Absorption Coefficient (α_p)
100	0.00	
125	0.00	0.00
160	0.03	
200	0.05	
250	0.14	0.10
315	0.14	
400	0.18	
500	0.15	0.15
630	0.14	
800	0.14	
1000	0.15	0.15
1250	0.20	
1600	0.24	
2000	0.22	0.25
2500	0.23	
3150	0.23	
4000	0.23	0.25
5000	0.31	
Weighted Sound Absorption Coefficient (α_w)	**0.20**	
Noise Reduction Coefficient (NRC)	**0.15**	

Test measurements and calculations were conducted by the undersigned.



Alex Li, BE (Mech) Hons

Consulting Acoustical Engineer

for and on behalf of Day Design Pty Ltd.

AAAC MEMBERSHIP

Day Design Pty Ltd is a member company of the Association of Australian Acoustical Consultants, and the work herein reported has been performed in accordance with the terms of membership.

Attachments:

- Test Certificate 4546-2 – Timbercrete 100 mm "Ancient Stone" Brick
- Appendix A: Method of Calculation of Sound Absorption Coefficients

DAY DESIGN

SOUND ABSORPTION COEFFICIENT TEST CERTIFICATE

Test 4546-2

Manufacturer:

Timbercrete Pty Ltd

2628 Bells Line of Road

Bilpin NSW 2758

Test Specimen:

100 mm "Ancient Stone" Brick

440 mm (L) x 240 mm (H) x 100 mm (D) per brick

Approximate density 1000 kg/m^3

Frequency - Hz	Sound Absorption Coefficients α_s	Sound Absorption Coefficients α_p
100	0.00	
125	0.00	0.00
160	0.03	
200	0.05	
250	0.14	0.10
315	0.14	
400	0.18	
500	0.15	0.15
630	0.14	
800	0.14	
1000	0.15	0.15
1250	0.20	
1600	0.24	
2000	0.22	0.25
2500	0.23	
3150	0.23	
4000	0.23	0.25
5000	0.31	
Weighted Sound Absorption Coefficient, α_w		**0.20**

Noise Reduction Coefficient, **NRC**	**0.15**

Australian Standards:

Measured according to AS ISO 354-2006

Rated according to AS ISO 11654-2002

Specimen Area:

10.5m^2 (3.385m x 3.11m)

Type-A Mounting (floor mounted)

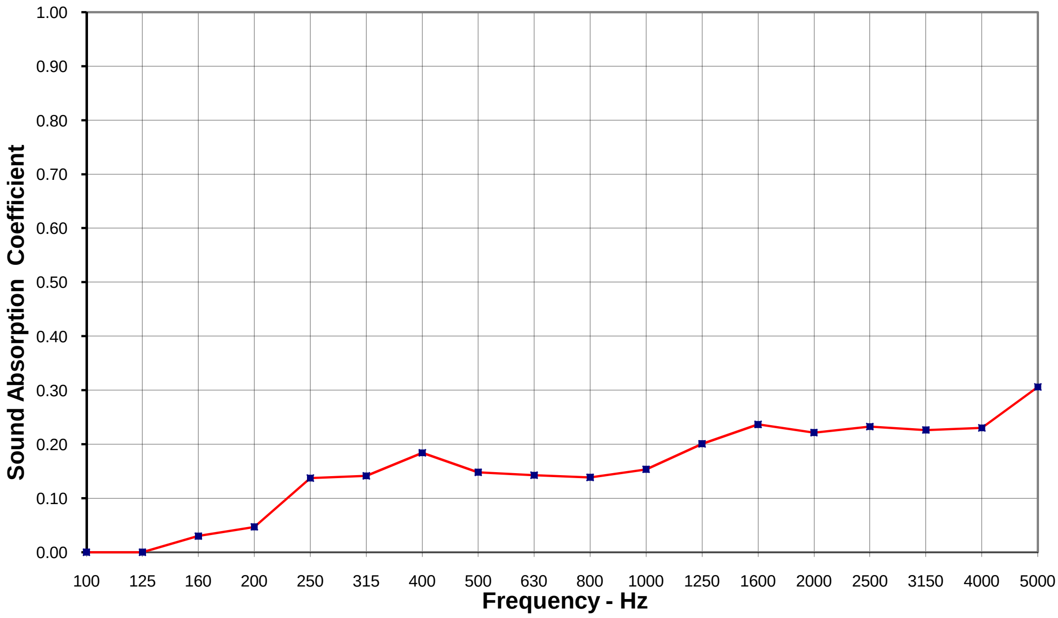
Test Location:

National Acoustic Laboratories

126 Greville Street, Chatswood NSW

Instrumentation:

- Brüel and Kjær "Pulse" Data Acquisition System type 3560-C
- Brüel and Kjær Cathode Follower type 2669
- Brüel and Kjær Microphone type 4144
- Brüel and Kjær Sound Level Calibrator type 4231
- Yamaha Professional Sound Sources type S500
- Vaisala Digital Barometer type PTB201AD
- Testo Temperature/Humidity Logger type 177-H1



Date of Test: Monday, 14 February 2011

Project Number: 4546-2

Test Engineer: **Alex Li, BE(Mech) Hons, MAAS**

For and on behalf of Day Design Pty Ltd

The absorption coefficient is calculated from the change in reverberation time between the empty room and the room with the test specimen.

Calculations have been carried out in accordance with the Australian Standard AS ISO 354-2006: *"Acoustics – Measurement of sound absorption in a reverberation room"* in conjunction with Australian Standard AS ISO 11654-2002: - *"Acoustics Rating of sound absorption – Materials and systems"*, as outlined below:

The equivalent sound absorption area, A_T of the test specimen, in square metres, is calculated using the following formula:

$$A_T = A_2 - A_1$$

$$= 55.3 \times V\left(\frac{1}{c_2 T_2} - \frac{1}{c_1 T_1}\right) - 4 \times V(m_1 - m_2)$$

Where

A_T	=	Equivalent sound absorption area of only the test specimen (m^2)
A_1	=	The equivalent sound absorption area of the empty reverberation Room (m^2)
A_2	=	The equivalent sound absorption area of the reverberation room including the test specimen (m^2)
V	=	Room volume (m^3)
C_1	=	propagation of sound in air at temperature T_1 ie. $C_1 = (331 + 0.6 \times T_1)$ in (m/sec) for temperatures in the range of 15 ^{o}C to 30 ^{o}C
C_2	=	propagation of sound in air at temperature T_2 ie. $C_2 = (331 + 0.6 \times T_2)$ in (m/sec) for temperatures in the range of 15 ^{o}C to 30 ^{o}C
m_1, m_2	=	The power attenuation coefficient, in reciprocal metres calculated according to ISO 9613-1 using climatic conditions that have been present in the empty reverberation room and the reverberation room with the test specimen respectively, during the measurement. The value of m can be calculated from the attenuation coefficient, α (not the absorption coefficient) which is used according to the formula:

$$m = \frac{\alpha}{10\mathrm{Log(e)}}$$

The sound absorption coefficient of the test specimen, α_s, in square metres, is calculated using the following formula:

$$\alpha_s = \frac{A_T}{S}$$

Where

α_s	=	The sound absorption coefficient
A_T	=	Equivalent sound absorption area of only the test specimen (m^2)
S	=	the area, in square metres, covered by the test specimen