ASSESSMENT OF SOUND TRANSMISSION CHARACTERISTICS OF TRADITIONAL TIMBER FRAMED DWELLINGS IN ANKARA, TURKEY

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ABSTRACT

ASSESSMENT OF SOUND TRANSMISSION CHARACTERISTICS OF TRADITIONAL TIMBER FRAMED DWELLINGS IN ANKARA, TURKEY

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Sound transmission characteristics of traditional timber dwellings in Turkey have become a serious issue due to the increase in complaints of residents about noise problems in those structures. There is a necessity to examine sound transmission problems in these dwellings with an emphasis on configuration of their timber frame components. Such a study is needed to suggest proper repair solutions to eliminate the existing sound transmission problems while keeping authentic features of those traditional structures.

Three traditional timber framed dwellings in Ankara, original one and repaired ones, were examined in terms of impact and airborne sound transmission characteristics of their floor and wall components by in-situ measurements and simulation analyses. Sound absorption and transmission loss characteristics of laboratory mudbrick samples were determined by using the impedance tube. Some supportive laboratory tests were conducted to characterize material properties of the original mudbrick samples collected from traditional houses.

The sound insulation performances of timber framed wall and floor components under examination, both repaired and non-repaired ones, were below the acceptable values. The presence of door/window openings, air leakages and poor detailing such as direct fixing of any cladding layers to the structural elements, are the main reasons that reduce the overall sound insulation performance of the original wall and floor components. Presence of voids for the running of pipework or door/ window openings existed in the composition of timber framed wall and floor components was found to reduce their sound insulation performances in the range of 12-22dB. Air/sound leakages through the openings should be sealed properly and the openings need to be replaced with the solid/insulated door or insulated window components in order to provide the required Rw and Lnw values for dwellings. In case that the dwelling units/spaces are used as exhibition, meeting, office or hotel rooms, some acoustical improvements in existing wall and floor components can be provided by demountable attachments with sound insulation infill and sound breaks. The 50mm-thick and 100mm-thick mudbrick samples were determined to have STC values of 28dB±2 dB and 35dB±2 dB, respectively. The sound absorption coefficient at mid frequencies and NRC of one representative mudbrick sample were determined to be 0.31 and 0.23, respectively. The performance of several wall/floor configurations suggested in the study was summarized to be guiding particularly for the improvement of airborne and impact sound insulation of traditional timber frame wall and floor sections and their repairs.

Keywords: Traditional timber frame dwellings, airborne sound reduction index, impact sound level, in-situ acoustical measurements, mudbrick.

ÖZ

ANKARA’DAKİ GELENEKSEL AHŞAP KONUTLARIN SES İLETİM ÖZELLİKLERİNİN DEĞERLENDİRİLMESİ

Erdil, Meltem
Yüksek Lisans, Yapı Bilimleri, Mimarlık Bölümü
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Türkiye’deki geleneksel ahşap çatkı konutlarda yaşayanlar tarafından katlar ve odalar arasında ciddi boyutta gürültü sorunlarının olduğu dile getirilmektedir. Bu sebeple, söz konusu yapılarda iç duvar ve döşemelerinin ses iletim/yalıtım özelliklerinin incelenmesi; bu incelemeler esnasında da özgün ve onarım görmüş yapım detaylarının/sistemlerinin dikkate alınması gerekli görülmektedir. Bu tür bir çalışma, geleneksel ahşap yapıların özgün niteliklerini koruyacak nitelikte ve bu yapılarda ortaya çıkan gürültü geçişi problemlerini en aza indirebilecek/ortadan kaldırabilecek nitelikte uygun onarım önerilerinin geliştirilmesinde faydalı olacaktır.

Ankara’da onarım geçirmiş ve geçirmemiş üç geleneksel ahşap konutun akustik niteliklerini belirlemek amacıyla saha ölçümleri ve simülasyon analizleri yapılmış; iç duvar ve döşemelerinden darbe gürültüsü ve havada yayılan sesin geçişi incelenmiştir. Geleneksel yapılarda dolgu amaçlı kullanılan özgün kerpiç bloklardan hazırlanan laboratuvar örneklerinin ses yutma ve ses iletim kaybı özellikleri, empedans tüp ile belirlenmiştir. Özgün kerpicin temel fiziksel ve hammadde/bileşim özellikleri, laboratuvar ortamında yapılan malzeme analizleriyle tanımlanmıştır.

Onarım geçirmiş ve geçirmemiş iç duvar ve döşeme bileşenlerinin ses yalıtım özellikleri kabul edilebilir eşik değerlerin altında bulunmuştur. Kapı veya pencere gibi açıklıklar, duvar/döşeme/tavan kaplama levhalarının dikme ya da kirişleme gibi ana çatkı elemanlarına arada bir ses kesici/tutucu olmadan doğrudan sabitlenmesi gibi detay sorunları, özgün duvar ve döşeme elemanının ses yalıtım performansını düşüren başlıca nedenlerdir. Döşemelerde tesisat borularının geçtiği yerlerde bulunan veya duvarlardaki kapı ve pencere açıklıkların neden olduğu boşluklar ses yalıtım performansını 12-22 dB aralığında düşürmektedir. Konutlarda gerekli Rw ve Lnw değerlerini sağlayabilmek için boşluklardan oluşabilecek hava/ses sızıntılarının giderilmesi ve açıklıklarda masif dolgulu/yalıtımlı kapı veya yalıtımlı pencere elemanlarının kullanılması gerekmektedir. Konut mekanlarının sergi, toplantı, ofis veya hotel odalarına dönüştürülmesi durumunda, varolan duvar ve döşeme elemanlarının akustik özellikleri ses yutucu dolgu malzemesi ve ses kesici ara elemanların kullanıldığı sökülüp takılabilir duvar/döşeme panellerinin eklenmesi ile geliştirebilmektedir. 50mm ve 100mm kalınlığındaki kerpiç dolgunun STC değerleri, sırasıyla 28dB±2 dB ve 35dB±2 dB bulunmuştur. Çalışılabilen tek kerpiç örneğin orta frekans aralığındaki ses yutma katsayısı ve NRC değeri, sırasıyla 0.31 ve 0.23 bulunmuştur. Geliştirilen bazı duvar/döşeme detay önerileri/kurguları, geleneksel ahşap çatkı duvar /döşemelerin havada yayılan ses ve darbe sesi yalıtımlarını arttırmak ve onarımları için yol gösterici olabilmeleri bakımından her bir önerinin sağladığı performans tartışılmıştır.

Anahtar kelimeler: Geleneksel ahşap konutlar, havada yayılan sesin yalıtım indeksi, darbe sesi seviyesi, yerinde akustik ölçümler, kerpiç tuğla.

to freedom and equality…

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ABBREVIATIONS

Hz Hertz

dB Decibel

α Sound absorption coefficient

NRC noise reduction coefficient

TL Transmission loss

R Sound reduction index

R_w Weighted sound reduction index

Lnw Weighted impact sound level

STC Sound transmission class

IIC Impact insulation class

D_{ntw} Weighted standardised level difference

CHAPTER 1

INTRODUCTION

The 19th century traditional timber dwellings representing the traditional timber frame structures commonly built in Anatolia, in fact, reflect the experience of the past on timber construction techniques and traditional building materials. They are mostly composed of mudbrick or stone masonry at the ground floor and timber frame structure at the upper level(s). Several studies on architectural and structural features of those structures have shown the achievements of timber construction technology in Anatolia. However, there is a lack of knowledge on inherent acoustical features of those traditional structures in terms of traditional building materials and construction detailing as well as their impact to the acoustical features. Due to the increase in complaints of residents about noise problems in those structures after they underwent repairs, comprehensive studies are needed to better understand their inherent acoustical features and problems occurred in time and to suggest proper repairs and/or maintenance programs.

The acoustical problems mainly originate from transmission of airborne sound and structure borne sound through the wall and floor components of timber frame structure. Airborne sound may arise from daily speaking and musical activities of occupants, voices of television, wind, etc. while structure borne sound, in other words impact sound, may occur due to the footsteps, moving furniture, rainfall, etc. Within a structure, the airborne and/or impact sounds are transmitted to the adjacent spaces mainly by two transmission modes: directly or indirectly (flanking). The transmission of sound occurs through the unintended openings/clearances or sound flanking paths due to wrong/inadequate material selection and improper detailing of building construction components/configurations. Such failures may cause significant sound transmission problems within those structures and acoustical discomfort conditions for the occupants.

Considering all, the correct diagnosis of these problems in terms of sound sources, sound transmission patterns in relation to the construction detailing and materials use and the extent of sound transmission within the structure is essential for planning proper repairs and measures to eliminate them. In this regard, the study deals with the assessment of acoustical features of traditional timber frame structures, still keeping their original construction techniques and materials, and repaired ones with an emphasis on sound transmission characteristics of building components, such as floor and wall cross-sections. The study is conducted on structures selected in Ankara region that represent the authentic architectural and construction features of traditional timber framed structures in central Anatolia and the repaired ones.

1.1 PROBLEM STATEMENT

The noise problems originated from sound transmission through floors and walls were observed at traditional timber framed structures in Turkey after they underwent repairs. However, there is no comprehensive study in the literature that defines sound insulation features of traditional timber framed dwellings and examines sound transmission problems by taking into consideration the materials used in their floor and wall sections and construction detailing. In addition, there is lack of knowledge on acoustical properties of traditional mudbrick infill material and its role to sound reduction through floor or wall section. A study, therefore, is needed (i) to discover the sound transmission characteristics of the timber-framed floor and wall sections as well as the original mud-based infill material, (ii) to identify possible sound transmission problems of those sections, (iii) to suggest proper repair solutions for the elimination of the sound transmission problems while keeping authentic features of the traditional structures.

1.2 AIM AND OBJECTIVES

Traditional timber framed structures representing the original architectural features and the repaired situation was examined in terms of their impact and airborne sound transmission characteristics through interior wall and floor components.

In particular, this study intends to achieve the following objectives:

- To assess direct and flanking transmission of airborne and impact sound through traditional timber-framed wall and floor sections.
- To determine sound transmission problems and their reasons.
- To propose some remedies, in other words some repair/renovation configurations that can be attached to the existing wall/floor components
- To point out the key concerns/comments for the improvement of their sound insulation performances in the form of “guiding remarks”.
- To determine the sound transmission loss and sound absorption properties of traditional mudbrick in contact with the structural timber frame.
- To define the compositional properties of original mudbrick and mudmortar infill materials in order to prepare mudbrick samples in laboratory for acoustical properties assessment.

1.3 PROCEDURE

The study starts with literature survey about sound transmission characteristics of timber frame walls and floor components. The study focuses on acoustical assessment of the traditional timber framed dwelling by in-situ measurement and simulation analyses by“ INSUL” and “BASTIAN” software and laboratory tests on mudbrick infill materials in contact with structural timber frame to determine their physical, compositional/raw material properties and sound transmission loss (TL) characteristics.

Firstly, in-situ measurements were conducted in timber framed dwellings, namely Ankara Bağ Evi, Boyacızade Konağı and Tahtacıörencik Village house. Later, the wall and floor sections in dwellings were analysed by “INSUL” and “BASTIAN” and the mudbrick samples were analysed by laboratory tests.

1.4 DISPOSITION

The study is composed of six chapters. The first chapter is introduction, where the purpose and content of the study is introduced and the procedure is briefly described. In the second chapter, general information about sound transmission paths, traditional timber framed dwellings, acoustical parameters and measurements, design parameters and timber framed floor and wall components. In the third chapter comprises the material and method of the study. In the fourth chapter, results of the study are submitted. In the fifth chapter, the results are discussed and conclusions are outlined in the sixth chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 SOUND TRANSMISSION PATTERNS THROUGH WALLS AND FLOORS

The noise problems originate from airborne or/and impact sound transmission through floors and walls

- Airborne sound travels through air before reaching a partition. Typical sources of airborne sound include voices, radios, musical instruments, and traffic and aircraft noise (Warnock & Birta, 2000).
- Impact sound is generated by bows or vibration on a partition and transmitted by the vibrations within a structure. Typical sources of impact sound include footsteps, slammed doors and windows, noisy pipes and vibrating machinery (Warnock & Birta, 2000).

Depending on the path of sound can be stated as following:

- Direct Sound Transmission: Sound is transmitted directly through a wall or floor from one of its side to the other. It occurs where a structure's element is excited by an airborne or a structure-borne sound source on one side, and radiates sound from the other side without any flanking transmission.
- Flanking Sound Transmission: Sound is transmitted from one room to another indirectly, through adjoining parts of the structures. These indirect sound paths can be numerous and complex (Hassan, 2009). Continuous walls between floors, columns or any other continuous element behave like flanking path for impact sound. It is caused by improper installation of construction elements as well as building construction components and configurations not providing sufficient sound insulation (Hassan, 2009). Total of the flanking and direct transmission refers like apparent transmission.

2.2 TRADITIONAL TIMBER FRAMED STRUCTURES

Traditional timber frame structures have basic structural elements such as main post, stud, tie beam, brace, wall plate and foot plate as shown in Figure2.1.

Main posts installed on the corners of the walls are basic load bearing structural elements. These posts are placed on the footplate and floor joists are set on the wall plates also named as beam. Studs are secondary load bearing elements used for creating the openings and separating distance between main posts. The main posts and studs are connected to each other with brace and tie beams. The intervals between studs are filled by mud brick, stone or timber. The other system is timber skeleton (wood lathing) also known as "*Bağdadi*" technique. Lath coverings in 2-3 cm width were nailed on both inner and outer wall surfaces horizontally in this technique. The spaces between surfaces are filled with stone, mudbrick, brick and timber or left empty" (Ozyer, 2008).

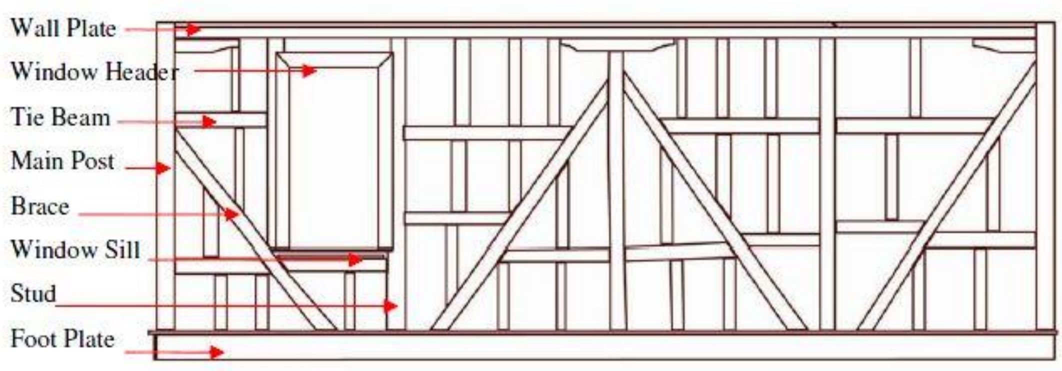

Figure 2.1 Detail of timber framed construction on Hisar Evi ,in Taraklı

(Özyer, 2008, pp 87)

Kandemir (2010) stated that timber floors were built by placing the floor joists on the wall plates. Kandemir (2010) also asserted that the floor configuration named as '*bulgurlama'* was constructed with double layer and earth used as infill material for insulation at the space between the layers and this floor type could be encountered in early Ankara houses.

Eraslan (2009) stated that mudmortar was used as insulation material between joists and timber floor finishing within floor sections of the traditional timber framed hoses in Safranbolu (Figure 2.2). The insulation materials such as mineral wool and expanded polystyrene foams were used instead of mudmortar after repairs at those dwellings (Eraslan, 2009).

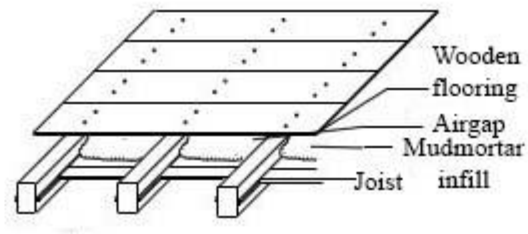

Figure 2.2 Floor details of houses in Safranbolu (Eraslan, 2009, pp 47).

2.3 ACOUSTICAL PARAMETERS FOR AIRBORNE AND IMPACT SOUND

A sound wave that encounters a surface of a partition is reflected, absorbed or transmitted. While sound wave is transmitted through the partition it causes to vibrate it and the vibration induced by the sound wave makes the wall /floor to radiate the sound waves to other side of the partition (Peters *et al.*, 2011). The fraction of transmitted energy to the incident is called the transmission coefficient, τ. As values of the transmission coefficient are mainly small the logarithmic index of sound transmission, the transmission loss (TL) by American Society of Testing Materials (ASTM) and also referred as the sound reduction index (R), dB by International Standards Organization (ISO) is used to quantify transmitted energy., TL and R are defined as (Praščevič *et al.*, 2012; Peters *et al.*, 2011):

$$R/TL = -10\log\tau \quad (\text{Eq. 2.1})$$

where "R" is the sound reduction index and "TL" is sound transmission loss in dB; "τ" is transmission coefficient ,unitless.

Several single number ratings are used to identify the sound insulation performances of building components such as walls, floors, doors and windows. Those ratings differ in determination of airborne sound and impact sound insulation performances of the components. For airborne sound insulation of the building components, the single number ratings of weighted sound reduction index, R_w (dB) based on ISO and sound transmission class, STC (dB) based on ASTM are used (Hassan, 2009; Long, 2006). The higher rating numbers indicate the higher the sound insulation performances. STC and R_w define sound reduction performance measured in a laboratory. R_w is estimated between 100 Hz and 3150 Hz in the 1/3 octave bandwidth. To calculate $R_{w,}$ firstly sound reduction index data versus frequency is plotted as shown in Figure 2.3. The reference curve defined by standards is shifted upward or downward to get the best fit position with the measured data, defined also by the relevant standards 100-3150Hz. The single number parameter value is then the shifted reference value at 500 Hz. STC also is determined with the help of a reference curve on the measured data between 125 Hz and 4000 Hz.

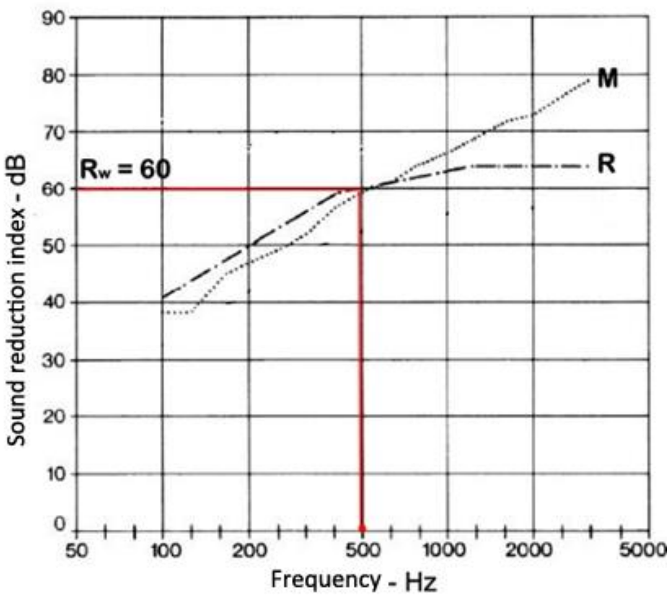

Figure 2.3 Weighted sound reduction index Rating (Rw). (Calıskan, 2012)
(M: Measured data, R: Reference curve).

Weighted sound reduction index (Rw) and sound transmission class (STC) values of some wall, floor, window and door components are given in Table 2.1.

Table 2.1 Rw and STC values of some wall, floor, window and door components (Hassan.2009; Long, 2006; Team IMI, 2010).

Construction type	**Thickness, mm**	**Weight**	**STC, dB**	**Rw, dB**
Walls				
Autoclaved aerated concrete	100	NA	38	
Autoclaved aerated concrete	200	NA	45	
Hollow clay block, plaster one side	90	75		35
Terracotta	90	NA		35
Lightweight block work, fair faced	100	125		40
Lightweight block work, fair faced	200	240		48
Dense block work	100	190		44
Concrete brick	110	110		38
Dense Concrete	100	230		50
Reinforced concrete	100	230		47

Table 2.1(continued)

Floors				
Timber board connected with tongue and groove, wood joists joints sealed	21	13		26
Concrete slab	100	250		49
Single glazed windows				
6 mm glass in sealed frame	6	15		27
6 mm glass in heavy frame	6	15		32
6 mm glass set in gaskets in wooden frame	6	15		31
19 mm glass	19	40		40
Double glazed windows				
4/150/4 mm with absorbent reveal	158	20		45
9/340/9 mm sealed frame with absorbent reveal	358	NA		53
Doors				
Flush panel, hollow core, normal gaps at edges	49	9		18
Solid core wood door no seals around perimeter	NA	24		25
Solid core wood door with drop seals and gaskets	NA	NA		34
Acoustic door, double heavy sheet steel skin absorbent in airspace and double seals in heavy steel frame	100			48

For the field measurement data, the single number ratings of R'w (Apparent Sound Reduction Index) and FSTC (Field Sound Transmission) and D_{nTw}, (Weighted sound level difference) are used. D_{nTw} is also obtained with the help of the reference curve (Hassan, 2009; ISO 140-4:1998). According to an approximate relationship between D_{nTw} and Rw, while in-situ sound insulation performance (D_{nTw}) of a partition is converting to laboratory performance level (Rw), 5 dB, for heavy constructions, and 7 dB, for lightweight construction, are added to in-situ performance level of the partition (Littlefield, 2015).

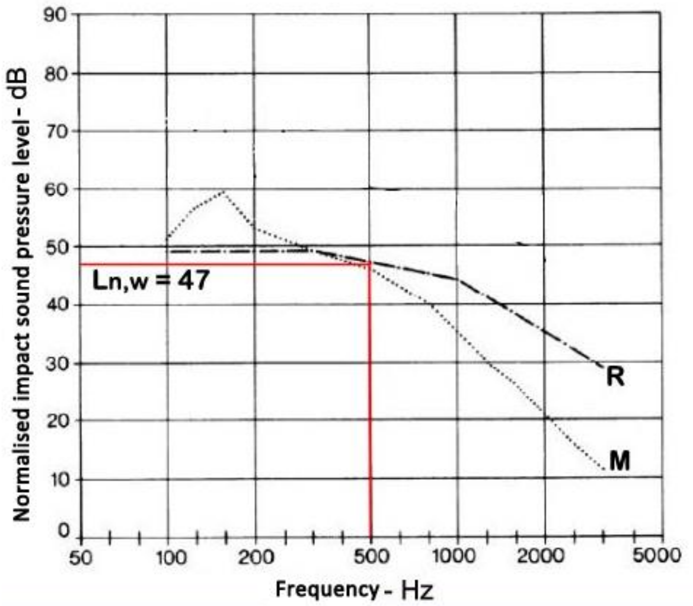

Figure 2.4 Weighted normalised impact sound pressure level Rating (Lnw), M: Measured data, R: Reference curve (Calıskan, 2012).

For impact sound insulation of the building components, the single number ratings of weighted normalized impact sound pressure level (L_{nw}) (dB) and impact insulation class (IIC) (dB) are used. The L_{nw} and IIC are obtained by laboratory measurements without considering flanking transmission by standards of ISO and ASTM respectively. Apparent weighted impact sound pressure level (L'_{nw}) and field impact insulation class (FIIC) and are used for in-situ impact sound measurement. The calculations of L_{nw} and IIC are conducted with reference curve as R_w and STC (Figure 2.4). There is an inverse relation between IIC and L_{nw}. Lower L_{nw} values indicate better impact insulation performance while higher IIC values indicate higher insulation performance. Sum of those ratings give 110 dB. The conversion for the impact sound insulation from IIC to L_{nw}; IIC =110dB-Lnw, is the general acceptance. Since the measurement of FIIC is comparable to the measurement of L'_{nw}, the same relationship is expected to hold as for IIC and L_{nw} (Mahn, 2014).

The minimum requirements for sound insulation performance of multi-storey dwellings in Europe are shown in Table 2.2. The minimum value of: R'_w is 50 dB in Italy; $D_{nT,w}$+Ctr is 45 dB in UK; $L'_{nT,w}$ is 65 dB in Spain.

Table 2.2 The minimum requirements for sound insulation performance of multi-storey dwellings in Europe (Ingelaere, 2012; ISO 717:2013).

Country	Descriptor (dB)	Multi-storey housing	Descriptor (dB)	Multi-storey housing
Austria	D_{nTw}	≥55	L'_{nTw}	≤48
Belgium	D_{nTw}	≥54	L'_{nTw}	≤58
Czech Rep.	R'_w	≥52	L'_{nw}	≤58
Denmark	R'_w	≥55	L'_{nw}	≤53
Estonia	R'_w	≥55	L'_{nw}	≤53
Finland	R'_w	≥55	L'_{nw}	≤53
France	D_{nTw}+C	≥53	L'_{nTw}	≤58
Germany	R'_w	≥53	L'_{nw}	≤53
Hungary	R'_w +C	≥51	L'_{nw}	≤55
Iceland	R'_w	≥52	L'_{nw}	≤58
Ireland	D_{nTw}	≥53	L'_{nTw}	≤62
Italy	R'_w	≥50	L'_{nw}	≤63
Latvia	R'_w	≥54	L'_{nw}	≤54
Lithuania	D_{nTw} or R'_w	≥55	L'_{nw}	≤53
Norway	R'_w	≥55	L'_{nw}	≤53
Poland	R'_w +C	≥50	L'_{nw}	≤58
Portugal	D_{nTw}	≥50	L'_{nw}	≤60
Slovakia	R'_w	≥52	L'_{nw}	≤58
Slovenia	R'_w	≥52	L'_{nw}	≤58
Spain	$D_{nTw}+C_{100-500}$	≥50	L'_{nTw}	≤65
Sweeden	$D_{nTw}+C_{50-3150}$	≥53	$L'_{nTw}+C_{I50-2500}$	≤56
Switzerland	D_{nTw}+C	≥52	$L'_{nTw}+C_{I}$	≤53
UK	$D_{nTw}+C_{tr}$	≥45	L'_{nTw}	≤62

According to the data in Table 2.3, the minimum requirements for sound insulation performance for airborne and impact sound are STC ≥55-60 dB and IIC ≥50 dB.

Table 2.3 Acoustic requirements for airborne and impact sound insulation according to ASTM. (Çalışkan, n.d.; Warnock,1990; Warnock,1999).

Rating	STC (dB)	FSTC (dB)	IIC (dB)	FIIC (dB)
Minimum requirement	50	45	50	45
Minimum quality	55	50	55	50
Medium quality	60	55	65	60
High quality	65	60	75	70

2.4 SOUND ABSORPTION CHARACTERISTICS OF MATERIALS

Sound absorption is the loss or dissipation of sound energy in passing through a material or on striking a surface, usually conversion of acoustical energy into thermal energy as a result of some sort of frictional process (Hassan, 2009). Sound absorption coefficient (α) is the fraction of the intensity of sound wave that is absorbed to the intensity of the incident sound wave (Hassan, 2009; Peters *et al*, 2011). The α value is found to be between 0 and 1;1 being a perfect absorber and 0 being a perfect reflector. (Hassan, 2009; Peters *et al*,2011). The α value varies with the frequency and the angle of incidence of the sound and the values are usually given in octave or one third octave (Hassan, 2009; Peters *et al*,2011). Sound absorbing materials, such as acoustical tile, wall panels and other porous absorbers are often characterized by their noise reduction coefficient (NRC), which is the average of absorption coefficients over the speech frequencies, 250 Hz to 2 kHz, rounded to the nearest 0.05 (Long, 2006). Sound absorption coefficients (α) and noise reduction coefficient (NRC) of some construction materials are given in Table 2.4.

Table 2.4 Sound absorption coefficients in 1/1 octave band frequency centre and noise reduction coefficients (NRC) of some construction materials (Hassan, 2009; Varghese, 2011).

Material	Thickness (mm)	Octave band frequency centre, Hz						NRC
		125	250	500	1000	2000	4000	
Walls								
Brick, unglazed, unpainted		0,03	0,03	0,03	0,04	0,05	0,07	0,04
Brick, unglazed, painted		0,01	0,01	0,02	0,02	0,02	0,03	0,02
Rough concrete		0,02	0,03	0,03	0,03	0,04	0,07	0,03
Concrete block, painted		0,1	0,05	0,06	0,07	0,1	0,08	0,07
Concrete block, unpainted		0,36	0,44	0,31	0,3	0,4	0,25	0,36
Smooth unpainted concrete		0,01	0,01	0,02	0,02	0,02	0,05	0,02
Smooth concrete, poured concrete painted or glazed		0,01	0,01	0,01	0,02	0,02	0,02	0,02
Autoclaved aerated concrete		0,08	0,1	0,12	0,15	0,2	0,22	0,14
Standard brickwork		0,05	0,04	0,02	0,04	0,05	0,05	0,04
Porous concrete blocks, unpainted		0,05	0,05	0,05	0,08	0,14	0,2	0,08
Ceramic tiles with smooth surfaces		0,01	0,01	0,01	0,02	0,02	0,02	0,02
Plaster, lime/gypsum on tile/brick		0,013	0,015	0,02	0,03	0,04	0,05	0,03
Plaster, lime /gypsum on wood lath		0,14	0,1	0,06	0,05	0,04	0,04	0,06
Cement plaster		NA	NA	NA	NA	NA	NA	0,02
Plywood panelling	10	0,3	0,22	0,17	0,09	0,1	0,11	0,15
Wood panelling on 25 mm battens	12	0,3	0,33	0,14	0,1	0,1	0,12	0,17
Plasterboard on 25 mm battens		0,3	0,33	0,14	0,1	0,1	0,12	0,17
Gypsum board, 18 mm airspace on studs		0,3	0,1	0,06	0,05	0,04	0,04	0,06

Table 2.4 (continued)

Floors								
Wooden floor on joists		0,15	0,11	0,1	0,07	0,06	0,07	0,09
Floors, wooden platform +w/airspace		0,4	0,3	0,2	0,17	0,15	0,1	0,21
Carpet, thin over thin felt on concrete		0,1	0,15	0,25	0,3	0,3	0,3	0,25
Carpet, thin over thin felt on wood floor		0,2	0,25	0,3	0,3	0,3	0,3	0,29
Floor tiles ,plastic or linoleum		0,03	0,03	0,03	0,04	0,05	0,05	0,04
Pile carpet bonded to open-cell foam underlay		0,03	0,1	0,2	0,54	0,7	0,72	0,39
Glazed tile /marble		0,01	0,01	0,01	0,01	0,02	0,02	0,01
Mineral wool and foams								
Glass wool, 24 kg/m^3	50	0,27	0,54	0,94	1	0,96	0,96	0,86
Rockwool, 33 kg/m^3	50	0,15	0,6	0,9	0,9	0,9	0,85	0,83
Rigid polyurethane foam	50	0,2	0,4	0,65	0,6	0,7	0,7	0,59
Expanded polystyrene	13	0,05	0,05	0,1	0,15	0,15	0,2	0,11
Ceilings								
Gypsum plaster tiles(17% perforated, 22mm mineral wool backing)		0,45	0,7	0,8	0,8	0,65	0,45	0,64
Mineral wool tiles, glued to soffit		0,06	0,4	0,8	0,95	0,96	0,83	0,67

2.5 ACOUSTICAL MEASUREMENTS TO DETERMINE THE ACOUSTICAL CHARACTERISTICS OF WALL AND FLOOR COMPONENTS

Sound insulation measurements for the assessment of impact and airborne sound insulation characteristics of floor and wall sections are standardised in ISO 140 and ISO 717 .The standards of ISO 140-3 and 140-8 are used for laboratory measurements, while ISO 140-4 and ISO 140-7 are used for in-situ measurements of airborne and impact sound transmissions between rooms. For airborne sound transmission measurements, the basic idea is to create a loud sound in one of the rooms (called as source room) using a loud speaker and measure the sound pressure level in both of the source room (L_1) and in receiving room (L_2) (Hassan, 2009; Peters *et al*,2011). The basic parameter to be measured in the test is the difference between these two levels (Hassan, 2009; Peters *et al*, 2011). The quantity that results is the transmission loss or sound reduction index in decibels (dB). A test method to rate the transmission of impact sound insulation test through floors uses a standardised tapping machine to simulate the impact noise such as footsteps or the moving furniture on a floor (Hassan, 2009; Peters *et al*,2011). The machine has five metal hammers which are lifted and dropped onto the floor at a total rate often times per second. The average sound pressure level (L_i), called as impact sound level, is measured in the room below the floor (Hassan, 2009; Peters *et al*,2011). The measurements in building acoustics are commonly made in one-third octave band in the range from 100 Hz to 3150 Hz but it can be extended upwards to include 4000 and 5000 Hz and may be extended downwards to include the 50 Hz, 63 Hz and 80 Hz (Hassan, 2009; Peters *et al*,2011).

2.6 ACOUSTICAL MEASUREMENTS TO DETERMINE THE ACOUSTICAL CHARACTERISTICS OF MATERIALS

The acoustical properties of the materials such as sound absorption coefficient (α) and transmission loss (TL) are measured using by impedance tube (also called standing wave tube) consisting of a complete set of hardware and software tools as acoustic driver, standard tube, microphones, amplifier, sound receiver and acoustic analyser of operation (ISO 10534-2:1998; ASTM E1050–12). The impedance tube calculates the normal incidence absorption coefficient and transmission loss by generating plane sound waves that pass by microphone and are reflected back along the tube by the specimen (Fukuta *et al*., 2012; Collings & Stewart 2011; Seddeq, 2010). The pair tube set up of sound absorption and transmission loss measurements include small and large tubes. The set-up of small tube having inner diameters of 28mm/29 mm/30mm is composed of the small sized devices for acoustic properties measurements in the high frequency range (1600Hz-6400Hz/ 800Hz-6300Hz), while the set-up of large diameter tube having inner diameters of ø100mm is for the measurements in the low frequency range (50Hz-1600Hz/50Hz-1200Hz).(Jung, 2008; Brüel &Kjær 2014;Mezzo studio,2014). The sound source, typically a high-output acoustic driver, is connected at the opposite end of the tube and the microphones are mounted in special holes drilled through the sidewall of the impedance tube (Seddeq, 2009).

Sound absorption coefficient is determined using, "*Kundt Tube"* with a configuration composed of two microphones - transfer function method (ASTM E1050 – 12; ISO 10534-2). Transmission loss (Sound reduction index (R)) is also measured by using a "TL tubes" configuration representing the tube arrangement scheme, which allows transmission loss measurements (4 microphone method) (ASTM C384 – 04, 2011). Test specimen is mounted in the sample holder at one end of the straight tube and a rigid plunger with an adjustable depth is placed behind the sample to provide a reflecting surface at the two microphone method (Seddeq, 2009). The pair of microphones is mounted flush with the inner wall of the tube near the sample end of the tube(Seddeq, 2009). In the case of four microphone method, the specimen is inserted in the middle of the test tube and an absorbent material is put behind the sample or anechoic termination is applied to bottom of the tube so as to cancel the reflected waves and to obtain the accurate measurement values (Seddeq, 2010; Zhao *et al.,2010*). By measuring the sound pressure at four specified locations, two in the receiver and two in the source region, it is possible to calculate the normal transmission loss of the material (Collings & Stewart, 2011).

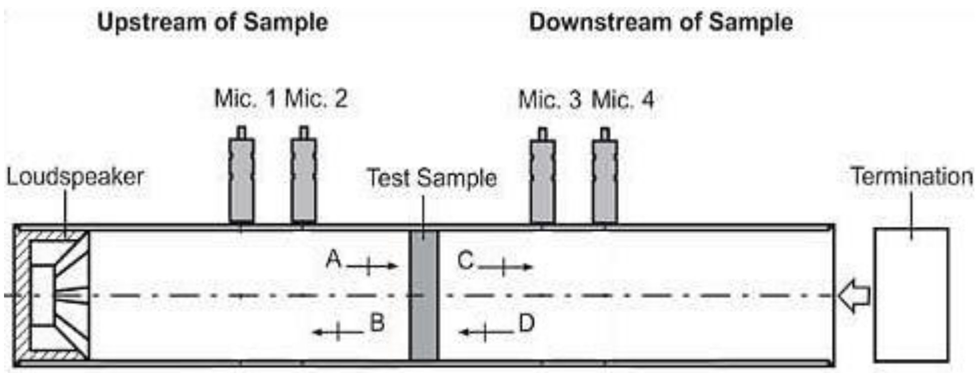

Figure 2.5 Schematic view of a four-microphone impedance tube for normal incident transmission loss measurement (Collings & Stewart, 2011,pp 1).

2.5 DESIGN PARAMETERS TO CONTROL SOUND TRANSMISSION IN TIMBER FRAMED FLOOR AND WALL COMPONENTS

Sound transmission through the partitions such as wall and floor between two rooms can be controlled by improving the insulation and absorption characteristics of the components.

2.5.1 Timber Framed Wall

Timber framed walls shows poor sound insulation performances unless treated with additional mass or decoupling techniques (Byrick, 2011). On the other hand, cavity constructions can have sound transmission loss of 5dB to 10 dB higher than an equivalent mass solid wall (Ballagh, 2003). Because timber framed constructions are inherently cavity constructions it is important to understand the basic behaviour of cavity constructions to able to develop high performance timber frame constructions (Ballagh, 2003).

2.5.1.1 Single Panel Partition

The prediction of the sound transmission loss for single panel structures utilizes the ‘mass law’ theory. The theory assumes that for homogeneous single panels, the sound reduction index/transmission loss is influenced by the factors of stiffness, mass and damping (Fred &Rudder,1985; Peters,2011; Long, 2006; Hassan,2009). It gives an information on the characteristic frequency ranges which are effective on sound transmission in relation to the stiffness, mass or damping features of the panel structure.

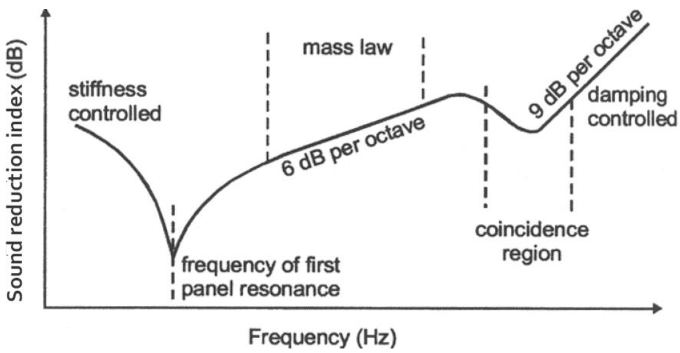

Figure 2.6 Typical single panel transmission loss as a function of frequency (Praščevič *et al.,* 2012, pp 157).

An illustration of typical sound reduction index/transmission loss of a single panel is shown in Figure 2.6, in which various characteristic frequency ranges are indicated (Peters *et al*, 2011; Long, 2006; Hassan, 2009; Praščevič *et al.,*2012). In "stiffness controlled" region, at very low frequencies the panel/plate can be considered as very thin and so the panel/plate vibrates as whole. The sound transmission through the panel depends mainly on the stiffness of the wall, while damping features and mass of the panel have effect on sound transmission a little. The stiffness of the panel is critical especially for low-frequency sound transmission problems in long-span of floor structures, therefore particularly in lightweight construction where the bending stiffness of the panel structure is not great. The lowest value of sound transmission in low frequency range that indicates the first panel resonance can be significantly controlled by improving the damping feature of the panel structure. In other words, amplitude of the vibrations at resonance frequencies is reduced by increasing the damping features of the panel. At mid frequency ranges, above the first resonant frequency, the sound transmission is controlled depending on the mass of the panel and its surface density while its stiffness does not any effect on sound transmission through the panel structure (Peters *et al*, 2011, Long, 2006; Hassan,2009). In the frequency range of mass law, sound reduction index increases with a rate of 6 dB per octave (Peters *et al*, 2011, Long, 2006; Hassan, 2009). According to the mass law, the sound reduction index can be predicted with the Eq.2.2 by using the data on surface density, “m”, of a partition, which is related to the density and partition thickness, and the sound frequency, “f” (Long,2006):

$$R = 20\log(fm) - 47 \qquad \text{(Eq . 2.2)}$$

where “R” is the sound reduction index in dB; “f” is the sound frequency in Hz; “m” is the surface density of the panel in kg/m^2; “47” is the numerical constant in dB.

In the coincidence region, the wavelengths of sound in air and bending wave in the panel coincide and the sound reduction index collapses (Praščevič *et al.,* 2012; Long, 2006). Because of this matching, the panel offers very little resistance to the sound transmission and the wall would, thus, radiate a sound wave into the receiving room, which has about the same amplitude as that of the incident wave. Consequently, the resulting panel vibration causes dip at the frequency which is termed as critical frequency. The depth of the notch is controlled by damping. In damping control region, for frequencies above the critical frequency, the sound reduction index is strongly dependent on the frequency of the incident sound waves, surface density, stiffness of plate and the damping of the plate material. Therefore, this region is also called the upper stiffness region.

STC and Rw values obtained from laboratory tests and simulation analyses for some single panel walls screwed wood studs were given in Table 2.5 (Warnock, 1985; Ingelaere, 2012). If panels are thickened, the critical frequency and the coincidence dip shifts towards the lower frequencies (Warnock, 1985; Ingelaere, 2012). That is less advantageous for the sound insulation such as is seen in hardboard panel. When two hardboards are screwed together, the coincidence dip remains at the same place as for the individual hardboard as the boards still reacts independently (Warnock,1985; Ingelaere, 2012). If the boards are rigidly glued, they behave as single hardboard of 36 mm and the critical frequency shift towards the lower frequencies. According to mass law, the surface mass of the panel such as gypsum board and hardboard is doubled, the sound reduction index for each frequency increases with a maximum of 6 dB.

Table 2.5 STC and Rw values of some single panel walls (Warnock, 1985; Ingelaere, 2012).

Panel	STC,dB (Warnock,1985)	Rw,dB (Ingelaere,2012)
16 mm-thick plywood	21	
13 mm-thick wallboard	28	
12,5 mm-thick gypsum board		27
2 layers of 12,5 mm-thick gypsum boards (screwed to each other)		33
18 mm-thick hardboard		34
36 mm-thick hardboard		37
2 layers of 18mm-thick hardboards (screwed to each other)		40

2.5.1.2 Double Panel Partition

The sound reduction characteristics of double panel partition composed of timber frame covered both sides with thin panels differ significantly from the characteristics of single panel construction (Praščevič *et al.,* 2012). The differences, if properly utilized, a sound insulation performance of double panel wall is considerably higher than of an equivalent mass single panel wall (Fred & Rudder, 1985; Hassan, 2009). The impinging sound waves from a sound source make one surface of the partition vibrate. The airspace between the boards serves as "spring" transmitting the oscillating motion to the other surface (Peters *et al*., 2011; Hassan, 2009). In effect the structure behaves like a mass-spring-mass vibrating system with each of the leaves acting as mass connected to the other leaf by the air in the cavity acting as spring (Peters *et al*., 2011; Hassan, 2009). Such system has natural frequency at which resonance occurs, when sound is transmitted efficiently between the leaves resulting in a poor sound insulation performance and a dip in the sound reduction index value. The natural frequency, f_0, is given by the equation (Peters *et al*.,2011):

$$f_0=60\sqrt{(m_1+m_2)/m_1\,m_2\,d} \qquad \text{(Eq . 2.3)}$$

where m_1 and m_2 are the superficial masses kg/m^2 of the panels and d (in m) is the thickness of the airspace between panels.

At low frequencies, below the resonant frequency, the two panels act as one mass. If the individual panels are mass controlled, then the transmission loss follows the mass law of the composite structure. At frequencies above the mass-air-mass resonance, the effect of the cavity is to increase the sound reduction significantly. At high frequencies, constructions having multiple panels with intervening air spaces can provide significant increases in transmission loss over that achieved by single panel (Long, 2006).

The sound energy is transmitted by two major paths through a double panel: the first involves radiation from the first panel into the airspace, where it excites the second panel; the second involves structure borne transmission of vibrational energy from the first panel to the second panel through mechanical connections between the panels. (Hassan, 2009; Praščevič *et al.*, 2012).

The ways to increase the sound insulation performance of the double panel wall are:

- to attempt to separate the two panels from the building structure and hence from each other , using resilient materials.
- to put sound absorbing material into the cavity to suppress acoustic resonances of the airspace.
- to widen the cavity gap so that the natural frequency is no longer at subjectively sensitive frequency range.

When the board in a wall is solidly fastened to the wood studs on both sides, much of the sound is transmitted through the studs. Therefore, it is significant for the two wall surfaces to be supported independently from one another in order to control sound transmission. This can be done by fastening the board on each side of the wall to different lines of studs (Hassan, 2009). The mechanical connection between the layers of wallboard can be reduced by the use of single wood studs with resilient metals and furring strips, staggered wood studs, or double wood studs, or to support the wallboard layers independently to each other (Hassan, 2009).

2.5.1.2.1 Single Stud Wall

The use of single lightweight metal studs is more effective at sound insulation performance of the wall than the use of wood studs by means of inherently flexibility of metals. The studs themselves act as vibration isolations and decouple one side from another, thereby reducing impact noise transmission. The method of attachment also affects the transmission loss. Panels that are glued continuously to studs yield lower transmission loss values than panels that are attached with screw. The gluing apparently increases the stiffness of the flange, which then increases transmission via the studs.

Resilient channel a flexible strip of metal is designed to mechanically decouple the partitions on either side of the framing for providing a measure against vibrations. It is important to note that the resilient channel should be installed with the resilient leg up, which allows gravity and the weight of the panel to pull the channel away from the structure. Also screws should be carefully placed as not to be driven through the channel to the structural studs. Both of these installation errors result in resilient channel commonly being “short-circuited”. Short circuited resilient channel results in up to STC value of 10 dB reduction (Byrick, 2011). Resilient channel is not effective when it is installed between two layers of gypsum board, the air gap is small and the trapped air creates an air spring, which makes an additional mass air mass resonance (Long, 2006). When the panels are already separately or flexibly supported, the addition of resilient channel does little to improve the transmission loss (Long, 2006).

2.5.1.2.2 Staggered Stud Wall

Staggered wall construction represents a compromise between single-stud and double-stud construction. The use of staggered wood studs can provide some mechanical decoupling between the panels on either side of a wall (Long, 2006).. If a higher transmission loss is required and the width is limited, this construction type is preferable.

2.5.1.2.3 Double Stud Wall

Double wood stud construction with multiple layers of board or heavy plaster, is preferred when high transmission loss values are desired (Long, 2006). According to the study of Byrick (2011), the double wood stud wall composed of 15.9 mm gypsum boards screwed to studs, two frames constructed with 50 mmx100 mm wood studs spaced 406 mm, 25 mm gap between two frame and 89 mm-thick un-faced mineral wool installed between both stud space yield STC value of 61 dB that is highest value among the single and staggered stud partitions in test series.

The losses are limited by flanking transmission through the structure, which can be improved by setting one or both sides of the wall on a floating floor or isolated stud supports in specialized applications such as studios (Long, 2006).

The air gaps or holes in the wall can lead to significant reductions in sound transmission loss because of the poor sealing applications on double panel walls (Ballagh, 2003).The most critical point for sealing is the perimeter where a gap under a plate permits the transmission directly from the source room to receiver room (Ballagh, 2003). However, gaps in one lining alone often do not cause a significant loss. Gaps are closed off with a non-hardening caulk that should not be used to span more than a 6 mm gap. Larger openings should be filled with drywall mud or board (Long, 2006). Similar openings can be left by electrical box penetrations, pipe penetrations, cut-outs for medicine cabinets, light fixtures, and duct openings (Long, 2006). Some simple precautions can be taken to avoid leaks around electrical and other wiring outlets. One way is to offset the boxes when the wall is filled with sound absorbing material. Forcing high frequency sound that leaks permits only pass through to travel along path through sound absorbing material is an effective way to attenuate sound leakage. The other way is to use the blocking panel while still having back to back boxes.

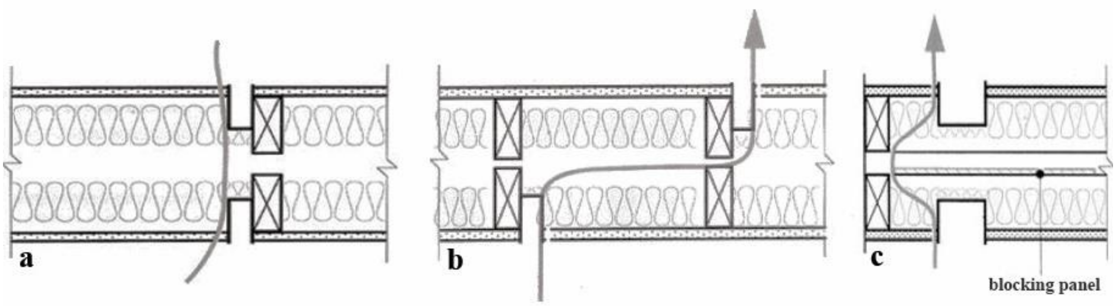

Figure 2.7 a) Leakage through electrical boxes; b) Offset boxes make the sound path longer; c) Blocking panels force the sound to travel through sound absorbing material.

Double wood stud wall may consist of areas of different materials such as partly glazed walls, façades with individual windows, the composite weighted sound reduction index R_{wc} is calculated by Eq 2.4, in the case of sound reduction index of door or window is at least 15 dB lower than the sound reduction value of wall component (Eckard &Müller, 2009).

$$R_{WC} = R_{W2} + 10\log(1 + S1/S2) \qquad \text{(Eq.2.4)}$$

where R_{WC} is the composite sound reduction index of wall including door/window (dB), R_{W2} is the sound reduction index of door/window (dB), S_1 is the surface area of the wall excluding the area of door/window opening (m^2), S_2 is the surface area of the door/window (m^2).

2.5.2 Timber Framed Floor

The floor components such as floor topping, joist, subfloor, ceiling board and sound absorbing infill material are the main parameter effecting the direct and flanking transmission of airborne sound and impact sound. The effect of construction details and the material selection on direct and flanking sound transmission were examined by laboratory measurements on the Reference A and B floors as shown in Figure 2.8.

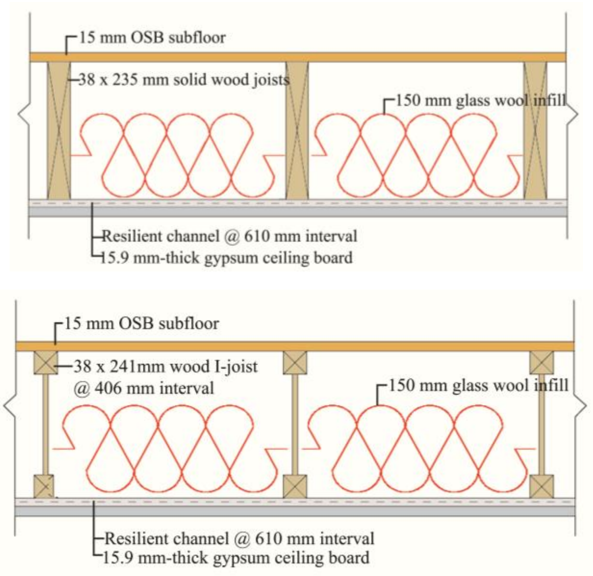

Figure 2.8 Floor configurations of Reference A (above) and Reference B (below) (Reassembled by author).

Table 2.6 Single number rating values of the Reference A and Reference B.

Floor	STC (dB)	IIC (dB)	Rw (dB)	Lnw (dB)
Reference A	52	46	51	64
Reference B	52	45	50	65

While traditional solid wood joist (38x235 mm) was used within the Reference A floor, lighter wood I-joist common in the modern buildings was used within the Reference B section. 15 mm OSB subfloor was fixed to the joists @406 mm spacing on floor side, 15.9 mm gypsum ceiling board was fixed with resilient channels @610 mm spacing on the ceiling side. 150 mm-thick glass wool infill material was used between joists.

2.5.2.1 Floor Topping

Floor topping is the most effective factor for controlling o propagation of sound vibration on surface of the timber frame floor (Warnock, 1999; Schonewall & Gover, 2010). While the sound on the bare floor tends to propagate towards the connection parts of the load bearing wall and floor, the propagation towards the non-load bearing connection parts is prevented (Schonewall & Gover, 2010). When the topping is added, the sound propagates in a more homogenous and isotropic way (Schonewall & Gover, 2010). The decrease at impact sound transmission through timber frame floor especially at low frequencies can be supplied by increasing the surface density of the floor upper layers. On the other hand, the impact sound insulation at high frequency is increased significantly when the surface hardness of flooring is reduced (Emms *et al*, 2006; Warnock, 1999a; Quirt *et al*., 2006). Reference A floor having IIC value of 46 dB was examined with laboratory measurements by forming various floor configurations composed of different toppings in the studies of Warnock (1999a) and Quirt *et al*. (2006). IIC values achieved were given in Figure 2.9. When hard surfaced toppings such as ceramic and concrete were directly applied on sub-floor without using any resilient layers, 5 dB decrease in IIC value was observed (Warnock, 1999a; Quirt *et al*., 2006). The floor configurations including toppings such as vinyl, hardwood floorings applied on resilient layers provided improvement at performance of impact sound reduction at only high frequency but not at lower frequencies. The improvement only 2 dB in IIC value was observed (Warnock, 1999a). The use of concrete layer on OSB subfloor and under the resilient layer provided much more effective performance (Warnock, 1999a). While IIC high value of 80 dB was obtained by usage of resilient flooring like carpet with underlay, the noise problem was still observed. The impact sound at low frequencies under frequency range specified for the single number rating system caused noise problems (Emms *et al.*, 2006; Warnock, 1999a; Quirt *et al*., 2006).

The mass of the flooring was the dominant factor to control of the sound transmission but total mass of those light and resilient floorings were very low (Warnock, 1999a; Quirt *et al*, 2006). Adding sand and concrete layers under the floor covering such as carpet having soft surface provided an increase at the mass and rigidity of floor so that improvement at the impact sound insulation performance of the component at low and high frequencies was provided to increase performance of Reference A floor up to 86 dB in IIC value. (Emms *et al*, 2006; Warnock, 1999a; Quirt *et al.*, 2006; Lahtela, 2005).

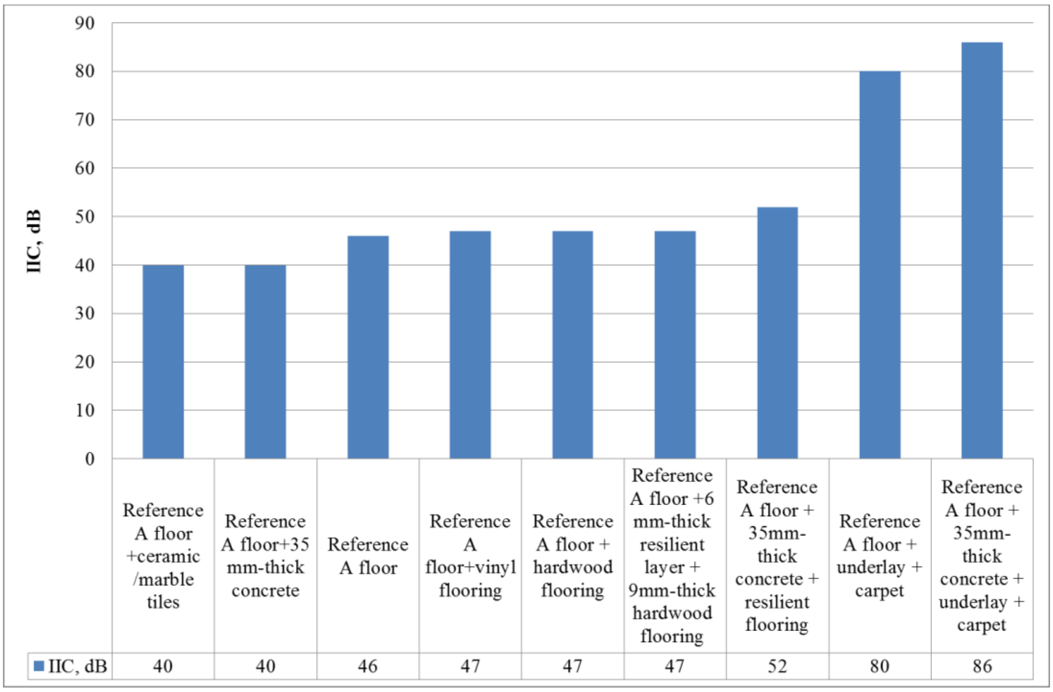

Figure 2.9 IIC values of Reference A floor with different toppings.

2.5.2.2 Floor Joists

Cross section of the timber framed floor joists has no impact on the horizontal or vertical direct sound transmission in the single number rating system. (Warnock, 1999a; Warnock, 2000; Halliwell *et al.* 2002).

According to laboratory measurements conducted on Reference A with solid wood joist by Warnock & Birta (2000), when the height of joist was changed from 235 mm to 184 mm, the values of STC, R_w and IIC decreased 2 dB, while Lnw decreased 1 dB. No difference was observed in those values by increasing the joist height from 235 to 286 mm. The tests on Reference B floor indicated that 216 mm increase at the height of joists provided 2 dB increase in values of R_w and IIC, while 1 dB increase was observed in STC value (Warnock & Birta 2000). According to another measurement on Reference A floor, 102 mm increase at height of the joist yielded to increase about 2 dB in values of STC and IIC (Warnock, 1998).

Massively increasing at stiffness of the floor joists substantially improves the sound insulation performances of the floor (Emms *et al.,* 2006). On the other hand, the bending stiffness of the joists is needed to increase at least four- fold in order to obtain significant increase in the performance of the basic floor configuration (Emms *et al.*, 2006). The stiffness of joists can be increased by addition of transverse wood stiffeners in the form of blocking board and tie rod (Emms *et al*., 2006). Those applications in timber frame floors provide improvement at high-frequency impact sound insulation performances (Emms *et al*., 2006). The effect of increasing the spacing between joists on sound transmission which has also negative impact on floor rigidity was observed with laboratory measurements conducted on Reference A. When the spacing between joists was increased from 305mm to 500 mm, airborne and impact sound insulation performances of the floor increased about 2 dB and when the increase at joists was made from 305mm to 610 mm provided improvement at airborne sound insulation was about 4 dB-5 dB and at impact sound insulation was about 2 dB -3 dB (Warnock & Birta, 2000). the increase at intervals between joists yielded continuous increase at Rw and STC values parallel with each other and also increases of IIC value at rise of joist interval from 305mm to 500 mm as shown in Figure 2.10 (Warnock & Birta 2000).

According to the regression analysis conducted by Warnock, increase in intervals between joists leaded to increase in STC value while it had negative effect on IIC value (Warnock, 2000).the studies showed that increase at intervals between joists had a positive effect on airborne transmission while there were both negative and positive effects obtained for impact sound transmission. In order to determine the particular tendency for the effect of joists arrangement on impact sound transmission, further studies are needed to be investigated.

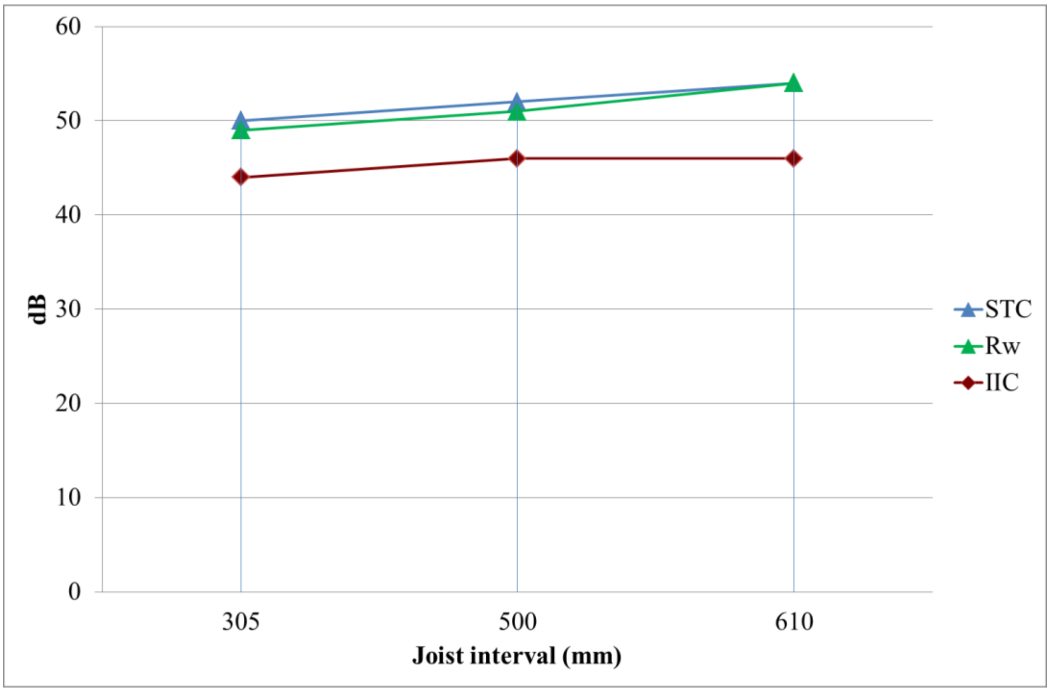

Figure 2.10 The values of STC, Rw and IIC according to different joist intervals (Warnock & Birta 2000; Warnock, 2000).

2.5.2.3 Subfloor and Ceiling Board

The dominant factor for the reduction of the impact sound transmission is the increase of the total mass of the subfloor and ceiling board. The sound insulation performance of two different sections of Reference A floor; one of them included one layer subfloor, the other one was composed of one layer plywood subfloor, were compared in the studies of Warnock and Birta (Warnock, 1999b; Warnock & Birta, 2000). The STC value of the floor configuration composed of OSB heavier and more rigid layer was found higher than one composed of plywood subfloor (Warnock, 1999b; Warnock & Birta, 2000). When the mass of the subfloor layer was doubled, the increase was about 2 dB in IIC value; as the mass of the ceiling board was doubled the increase was about 4 dB in IIC value; when both subfloor layer and ceiling board were doubled, the increase was about 7 dB in IIC value. (Warnock, 1999b). On the other hand, when the number of OSB subfloor layer was doubled, the increase was about 3-5 dB in STC value; as the number of plywood subfloor layer was doubled, the increase was 3 dB-4 dB in STC value; when the number of gypsum ceiling board layer was doubled, the increase was 5 dB-6 dB in STC value; as the numbers of gypsum ceiling board and subfloor layer were doubled, the increase was about 8 dB in STC value (Warnock, 1999b; Warnock & Birta, 2000).

Emms *et al.* (2006) indicated that the increase at the number of the ceiling board improved the performance of the timber framed floor especially at the low frequencies. Two different sections of Reference A floors including two different subfloors configuration in equal mass; one of them included one layer plywood subfloor, the other one was composed of two layers plywood subfloor, were compared (Warnock & Birta, 2000). The higher values at airborne and impact sound insulation performance especially between 250-2500 Hz was obtained at the floor including two layers plywood subfloor. The performance of that floor section was higher than 2 dB at STC value and 5 dB at IIC value than the other one composed of one layer subfloor (Warnock & Birta, 2000).

2.5.1.4 Infill Material

The studies showed when the thickness of the sound absorbing infill material used between the joists was increased, the performance of the timber framed floor at impact and airborne sound insulation linearly enhanced (Warnock, 1999a; Warnock, 1999b;

Warnock & Birta, 2000). The effect of the increase at the thickness of the rock wool and glass wool within Reference B floor section was given at Table 2.7 (Warnock & Birta, 2000). The floor section composed of rock wool infill material having denser physical characteristics showed better sound insulation performance than one including glass wool infill (Warnock & Birta, 2000). When the thickness of glass wool within the section of Reference A floor was increased from 90mmm to 270 mm, improvement about 2 dB at airborne sound and about 1 dB at impact sound insulation performance was provided (Warnock & Birta, 2000).

Table 2.7 Changes at the values of single number ratings when the thickness of glass wool and rock wool were increased within the Reference B floor section.

Type of the sound absorbing material	Changes at thickness of the sound absorbing infill material within Reference B floor (mm)	The improvement at values of single number rating			
		STC (dB)	Rw (dB)	IIC (dB)	Lnw (dB)
Glass wool	From 90mm to 152mm	+1	-	+1	+1
	From 90mm to 456mm	+5	+4	+3	+2
Rock wool	From 90mm to 456mm	+6	+6	+4	+5

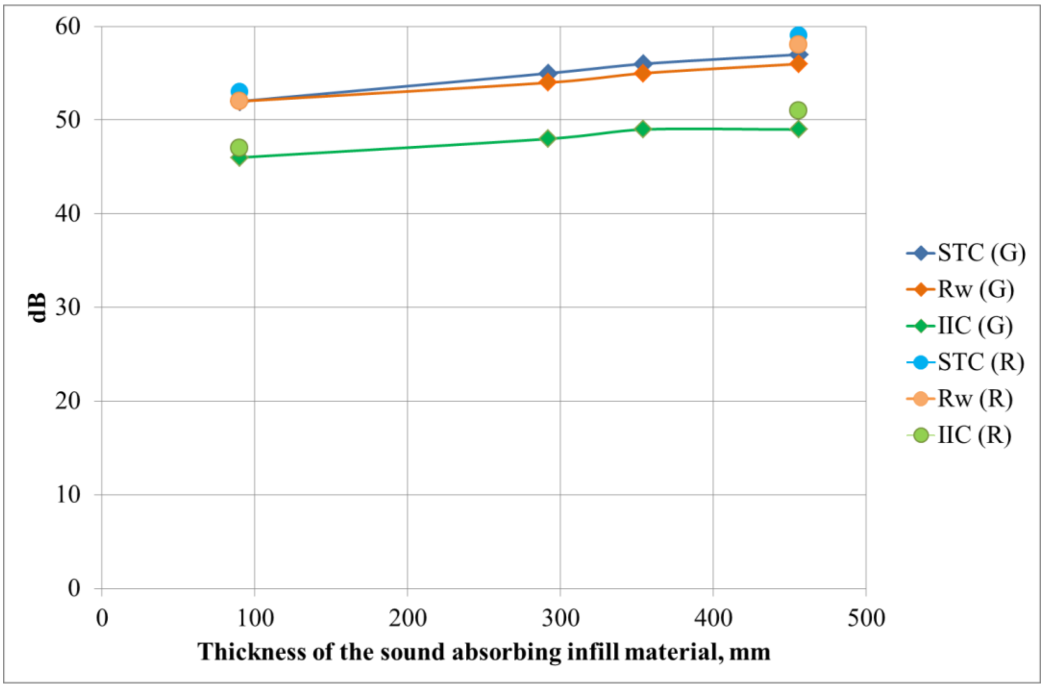

Figure 2.11 The values of STC, R_W and IIC Reference B timber frame floor including various thicknesses sound absorbing infill materials; glass wool (G) and rock wool (R) within the section (Warnock & Birta 2000).

Lahtela (2005), Warnock and Birta (1998) indicated that the sound insulation performance of timber framed floors decreased as the ratio of the infill material in the cavity within floor section was decreased in the case of the thickness of infill material was kept constant and the depth of the joists was increased. They also asserted that the excessive use of the sound absorbing infill material within the cavity was found to be ineffective for the airborne and impact sound insulation performance (Lahtela, 2005; Warnock &Birta, 1998).

The use of the granular materials such as sand, ash and sawdust as the infill materials within the timber frame floor section, one of the traditional method and also applied at the contemporary structures, improves the sound insulation performances of the floor because of their positive impact on the mass and damping of the partition (Lahtela, 2005; Chung *et al*, 2006; Hassan, 2009). The contributions of those materials are the characteristics of vibration absorbing by the friction of the particles in it and the providing of increase at floor mass (Lahtela, 2005; Chung *et al*, 2006; Hassan, 2009).

2.5.2.5 Decoupling of Layers within Floor Section

Decoupling of floor toppings and ceiling layers are the most effective methods to minimize the sound transmission through the floor. The use of floating floor application and the separating the ceiling board are the decoupling methods (Damme *et al*, 2007; Hiramitsu *et al*, 2009; Hassan, 2009).

Timber framed floating floor is constituted by putting of rigid floor coverings such as wood and concrete on resilient intermediate layer on the subfloor without use of any joining by bonding method or with nails. The system is the most effective way to decrease the airborne and impact sound transmission (Warnock, 1999a; Damme *et al*, 2007; Hiramitsu *et al*, 2009; Hassan, 2009).

The separating of floor from the other structural element provides to prevent impact sound energy to transmit through the structural element (Hassan, 2009). The floating floor on timber frame floor can be set up on the sound absorbing materials or resilient layers such as resilient cushion, plastic isolation, rock wool as shown in Figure 2.12 (Warnock, 1999a; Lahtela, 2005; Hiramitsu *et al* 2009). Lahtela (2005) indicated while material were selecting for the appropriate detailing for floating floor, the loading onto them should have been considered. He also added the increase at the elasticity of those materials improved impact sound reduction performance. The use of isolation strip at the connection parts of the floor and walls provides to block to sound transmission from the floating floor to the walls. The use of resilient caulk at the connection detail also prevents path for the sound energy to bypass the floating floor by the contact breaking of the baseboard and flooring as shown in Figure 2.12 (Warnock, 1999a).

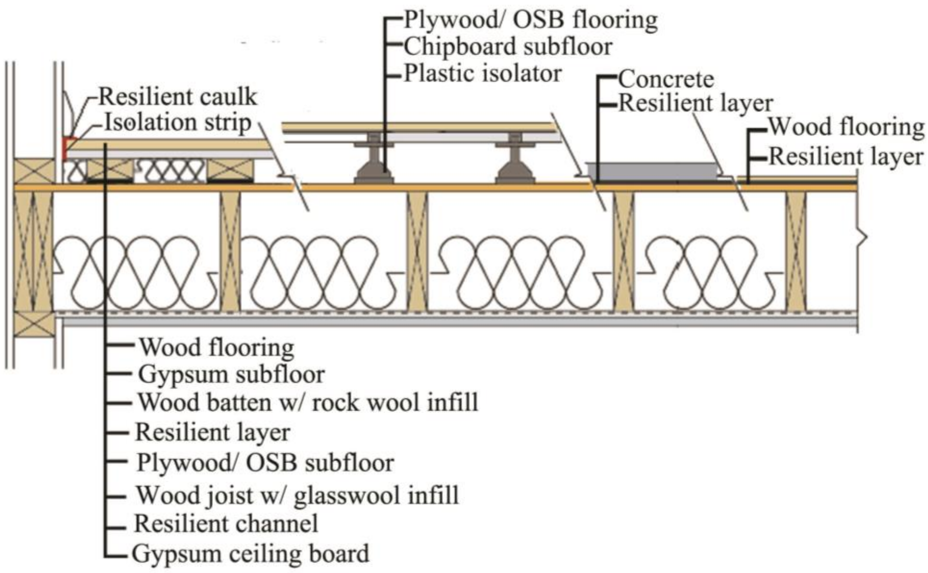

Figure 2.12 Various details of the floating floors designed for the timber frame floor (Reassembled by author).

The IIC value of 45 dB of Reference A floor reached up to 55 dB-65 dB when the floor was formed into the floating floor configurations as shown in Figure 2.12 (Warnock, 1999a; Lahtela, 2005). Hiramitsu *et al.* (2009) asserted that the floating floor was the considerably effective system enhancing insulation performance of impact sound generated from various forces especially light weight impact source such as a person walk.

The fixing of ceiling boards directly to the wood joists decreases impact sound insulation performance. On the other hand, decoupling of the ceiling board provides to decrease direct sound transmission (Warnock, 2000). One of the methods to separate the ceiling boards is the use of the separate joists as shown in Figure 2.13 (King *et al*, 2010). The floor sections having that system named as independent ceiling has inferior performance at heavy weight impact sources such as running and jumping than the floor sections including directly connected ceiling boards because of the resonance of that section at 63 Hz (Hiramitsu *et al*, 2009). The use of the resilient channels with independent ceilings provides only little improvement (Figure 2.13) (Hiramitsu *et al*, 2009). Hiramitsu *et al*, (2009) stated the reason as the use of resilient channels caused vibration amplification in the floor component. The rigidity of the independent ceiling is lower than the direct mounted ceiling. Independent ceiling could be prone to flanking sound transmission, therefore, the joists and ceiling board should be insulated to prevent the vibration transmission through the edge of floor and to increase the low frequency sound insulation performance (Emms *et al*, 2006). In addition, the resonance at 30 Hz caused negative impact on the sound insulation performance of the timber frame floor composed of the separated ceiling board (Emms et al, 2006). The second method to separate the ceiling board was the use of the resilient channel to improve the impact and airborne sound insulation performance as shown in Figure 2.13 (Hiramitsu *et al*, 2009). When the resilient channels are not used within the floor section, sound energy is transmitted through joists one surface of the floor to another face. The adding of sound absorbing material into the cavity within the section composed of no resilient channel provides too little improvement and causes no change at STC value (Warnock, 2000).

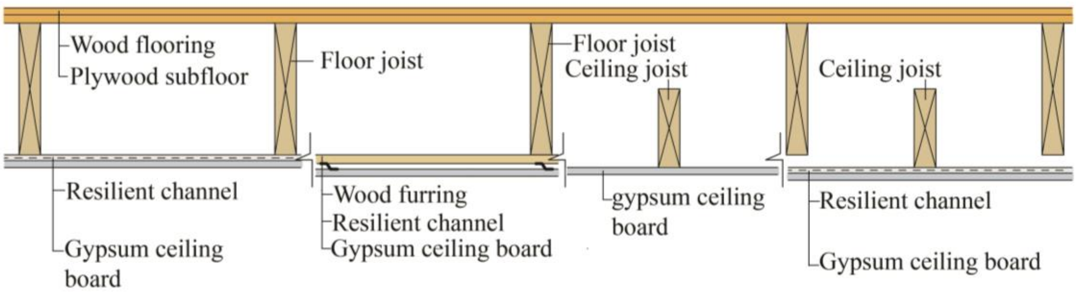

Figure 2.13 Decoupling of the ceiling boards **(**Reassembled by author).

The increase at interval between resilient channels placed on the ceiling boards provides to increase the airborne and impact sound insulation performance of the floor (Warnock, 2000). As the intervals between resilient channels within Reference B floor section was increased from 406 mm to 610 mm while STC and Rw values increased 1 dB, no change was observed in IIC and Lnw values (Warnock & Birta, 2000). For Reference A floor, the increase at the spacing of the resilient channel from 406 mm to 610 mm improved STC and IIC values 5 dB and 6 dB, respectively (Warnock, 1999b;Warnock&Birta,2000). The support types used between ceiling boards and joists within the Reference A floor section were compared as shown in Table 2.8 (Warnock & Birta, 2000). The most effective way was to use the resilient channels for mounting the ceiling board to joists instead of the use of wood furring strip or directly fixing of the board with screws.

Table 2.8 Single number rating values of Reference A floor according to support type of the ceiling board.

Support type of the ceiling board to joists	Single Number Rating			
	STC(dB)	Rw(dB)	IIC(dB)	Lnw(dB)
Direct fixing w/screw	34	35	30	80
19 mm wood furring strip @610 mm spacing	42	41	35	74
Resilient channel @610 mm spacing	52	51	46	64

CHAPTER 3

MATERIAL AND METHOD

The study was conducted on three traditional timber framed dwellings located in Ankara. The dwellings were Bağ Evi and Boyacızade Konağı and Tahtacıörencik Village House. The plan and section schemas of the dwellings and floor and wall details of those structures were drawn for acoustical measurements. The study was composed of (i) the in-situ measurements and simulation analyses to assess impact and airborne sound transmission characteristics of these structures through the floors and walls (ISO 140-7:1998; ISO 140-4:1998; ISO 717-1:20013; ISO 717-2:2013), (ii) laboratory tests to determine the sound transmission loss (TL) and sound absorption characteristics of the mudbrick samples prepared in laboratory (ASTM C384-04:2011; ASTM E1050-12; ISO 10534-2:2009). Supportive laboratory analyses were also done for the material characterization of mud-based materials collected from traditional timber frame structures.

3.1 THE DWELLINGS STUDIED

Three dwellings; Ankara Bağ Evi, Boyacızade Konağı and Tahtacıörencik Village House were examined. Ankara Bağ Evi in Keçiören and Boyacızade Konağı in Altındağ underwent repairs, while Tahtacıörencik Village House in Güdül is keeping the original architectural features. Keçiören, Güdül and Altındağ Distircts were shown in Ankara map in Figure 3.1.

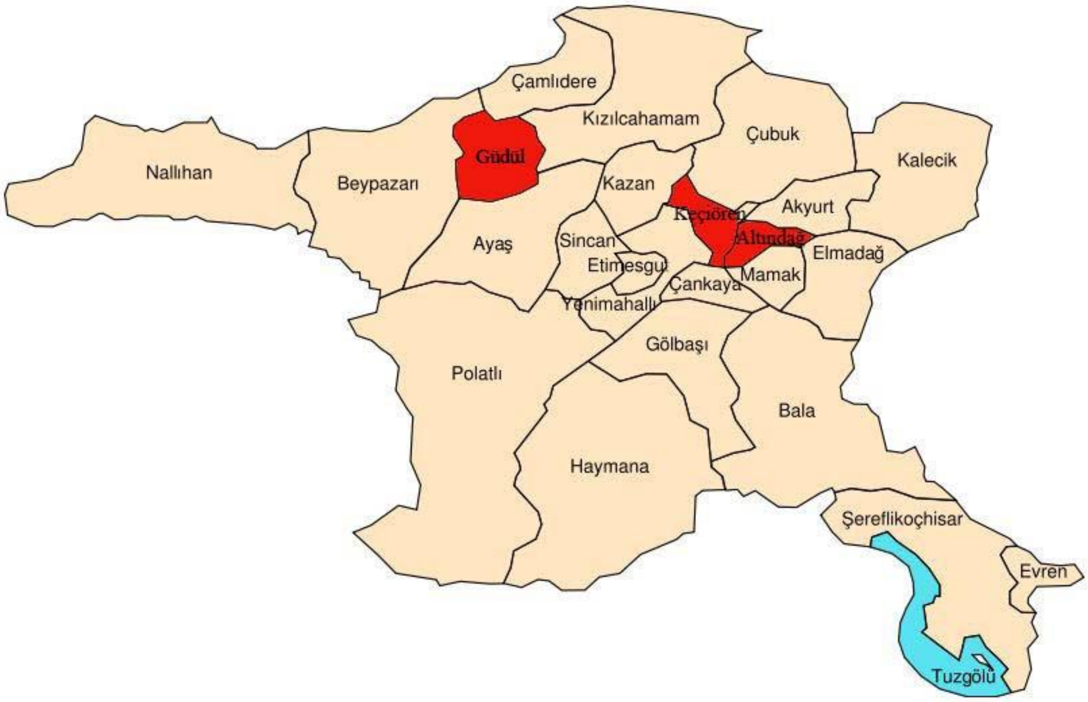

Figure 3.1 Keçiören, Altındağ and Güdül Districts in Ankara.

3.1.1 Ankara Bağ Evi

Ankara Bağ Evi is an orchard house named also Gedikoğlu Orchard. The building one of the example of repaired traditional dwelling located in Pınarbaşı Quarter, Şehit Hakan Turan Street No:18, Keçiören. The original house was constructed in early 1900s by Ali Gedikoğlu aunt's husband of trader Vehbi Koç. Opened in 2007 as museum exhibiting the room spaces including the authentic furniture, textiles and domestic accessories in Ankara traditional houses, It is also hosting various conferences and meetings. The caretaker of the museum, Ertuğrul Avcı mentioned that after twice fire exposure in early 1900s, the destroyed house was bought by Vehbi Koç then it was restored between 2004 and 2006 years by Foundation of Vehbi Koç. He also indicated that while the restoration of house was carried out according to its original plans, its all construction materials were replaced with the new ones by using recent construction methods except andesite and Ankara stones that were used at masonry exterior walls of ground and mezzanine floors. He also added that the noise of the footsteps at first floor was perceptible at ground floor.

According to visual experiments and the restoration project of the building taken from the Foundation of Vehbi Koç, the building consists of rubble stone masonry at ground and mezzanine floors and timber frame structure at the upper floor (Figure 3.3 and Figure 3.4). The façade of building was unpainted but polished by a liquid insulation material. One interior wall and one floor components examined by the in-situ acoustical measurements were shown on the plans and section schemas in 1/100 scale between Figure 3.4 and Figure 3.7. The interior wall, as indicated Reconstructed-Wall 1 (W1-BE-FR1/R2) the panelled door (D1) positioned on is between BE-FR1 and BE-FR2, two neighbouring exhibition rooms. Reconstructed-Floor 1 namely F1-BE-FR1/MR3 is between the exhibition room on the first floor and meeting room on the mezzanine floor.

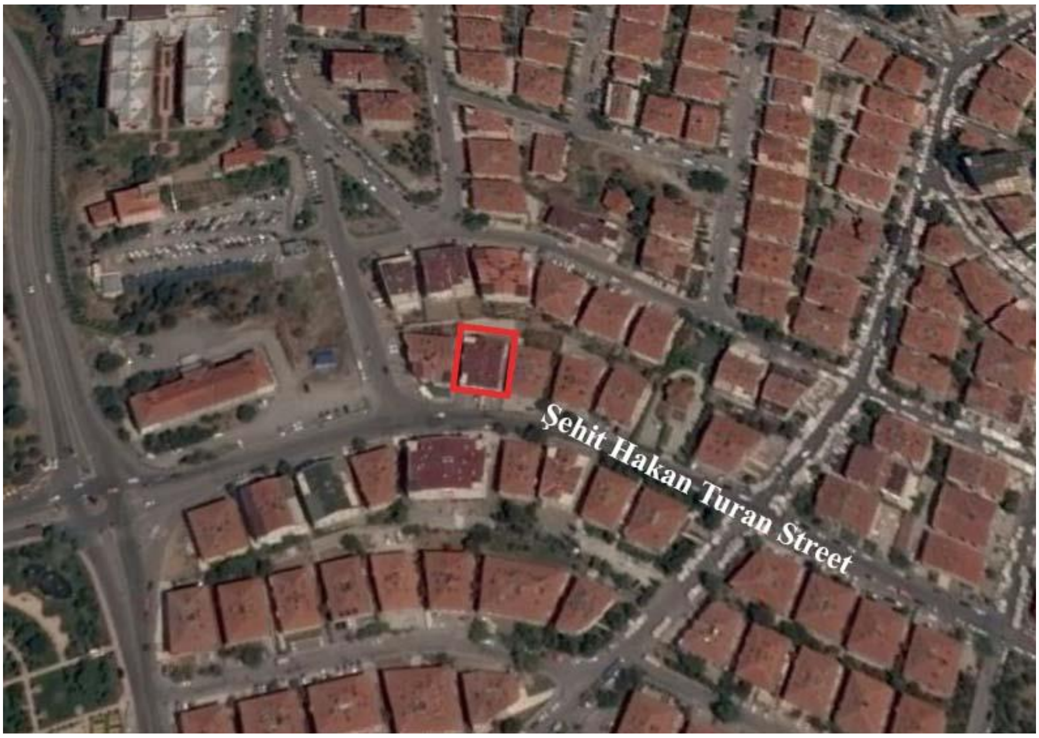

Figure 3.2 Location of Ankara Bağ Evi.

Figure 3.3 General and interior views of Ankara Bağ Evi. A: general views of the dwelling; B: interior view of BE-FR2; C: interior view of BE-MR3.

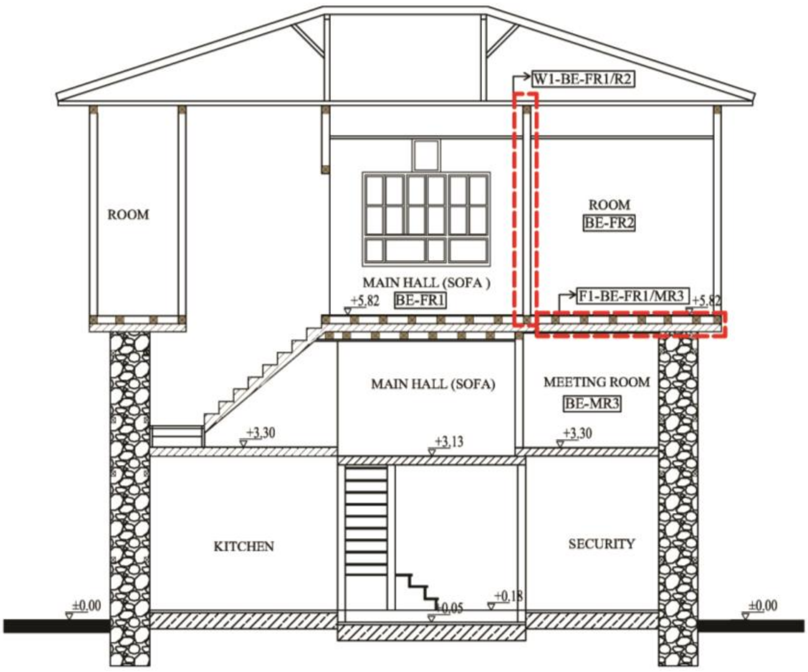

Figure 3.4 A-A section of Ankara Bağ Evi in1/100 scale (Redrawn by author).

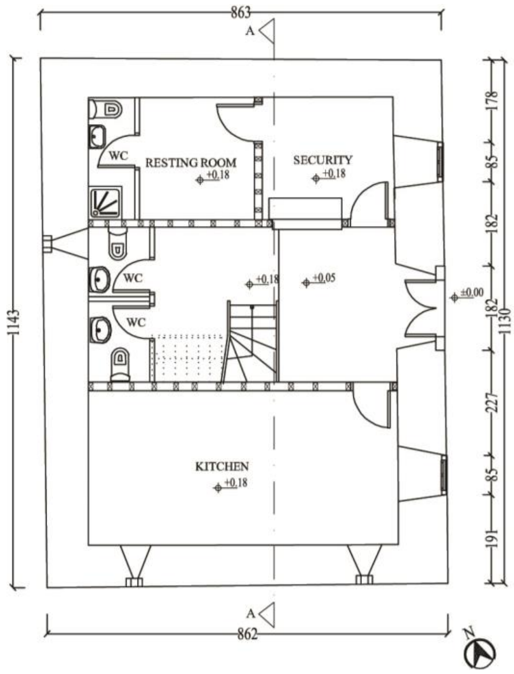

Figure 3.5 Ground floor plan of Ankara Bağ Evi in 1/100 scale (Redrawn by author).

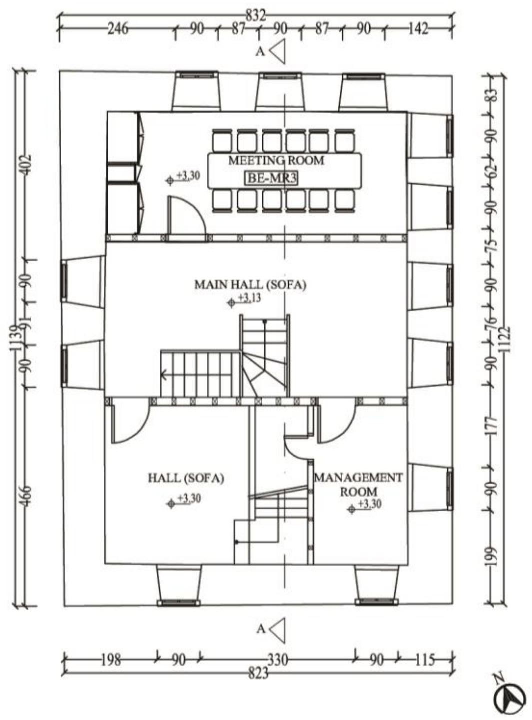

Figure 3.6 Mezzanine floor plan of Ankara Bağ Evi in 1/100 scale (Redrawn by author).

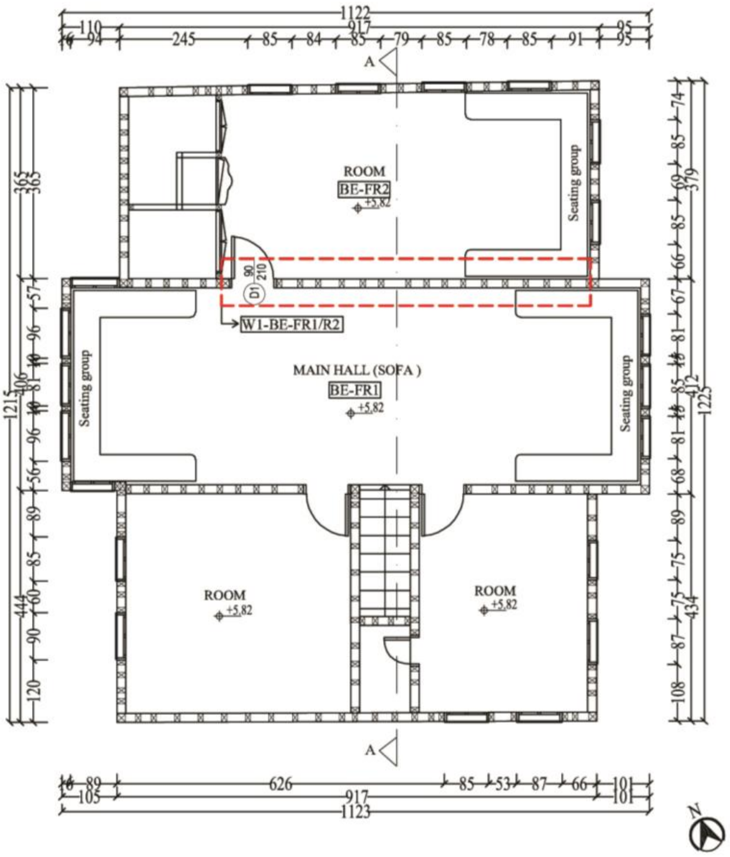

Figure 3.7 First floor plan of Ankara Bağ Evi in 1/100 scale (Redrawn by author).

The details of the construction components examined by the in-situ acoustical measurement was drawn according to the information got from foreman İlyas worked at the construction site and restoration project taken from the Foundation of Vehbi Koç (Figure 3.8 and Figure 3.9). The configurations of the floor and the wall are as follows:

- The Reconstructed-Wall 1 was composed of impregnated pine wood structural elements such as 150x150 mm main post, 100x150 mm bracings, 100x150 mm studs and 300x150x50mm solid fired bricks as an infill material in herringbone pattern and khorasan mortar as a binder. The studs were spaced at various intervals.
- The wall was coated with the lime and gypsum plasters and paint.

- The Reconstructed-Floor 1 was composed of two way joists of 150x200 mm impregnated pine wood; one way joists were spaced at 500 mm interval, the other way joists were spaced with 450 mm interval.
- Cavity between joists was fully filled with 200 mm-thick rock wool.
- 17 mm-thick wood parquet (pine) flooring mounted on two layers of 20 mm plywood, underneath it, 40 mm batten and extruded polystyrene were placed.
- 17 mm-thick pine wood as a ceiling board was mounted directly to the joists.

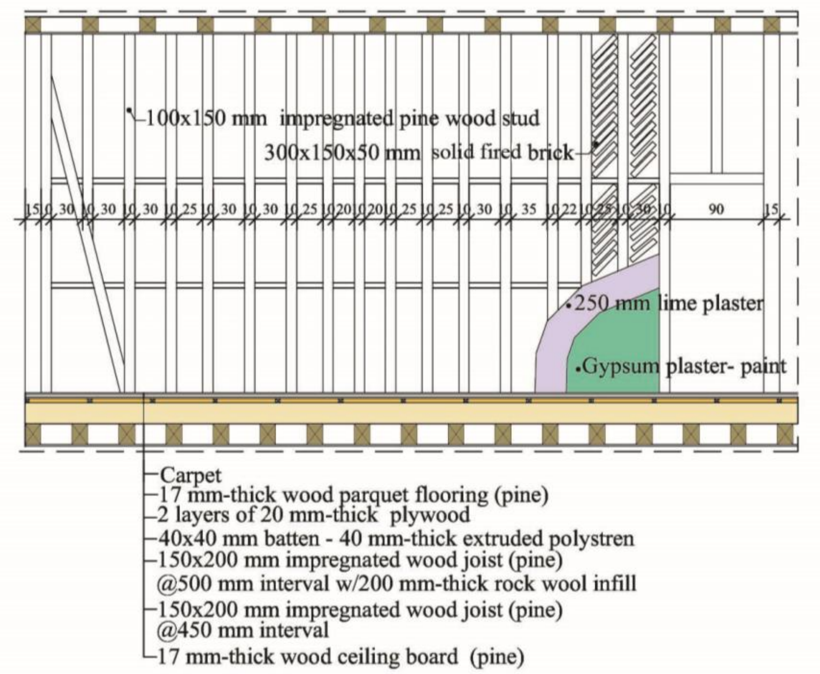

Figure 3.8 Elevation of Reconstructed-Wall 1 & section of Reconstructed-Floor 1 in 1/50 scale (Drawn by author).

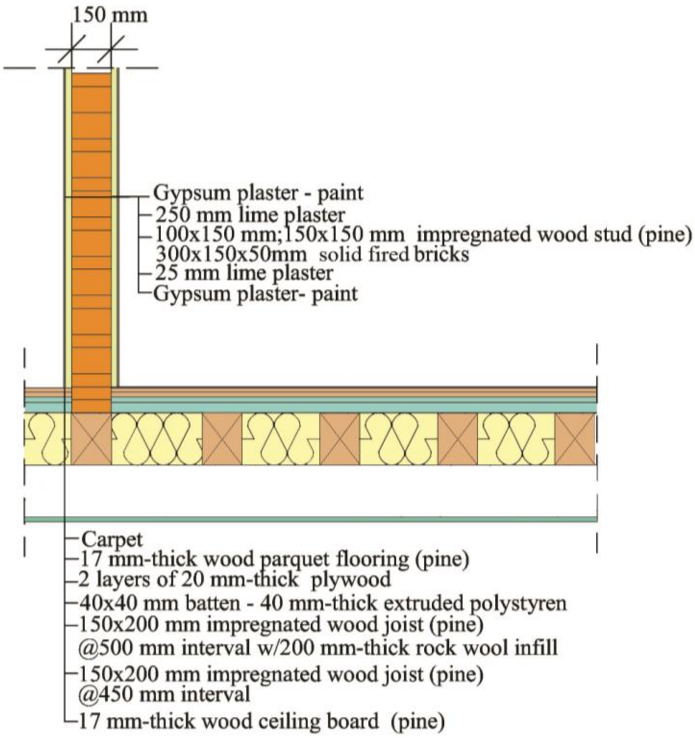

Figure 3.9 Sections of Reconstructed-Wall 1 & Reconstructed-Floor 1 in 1/20 scale (Drawn by author).

3.1.2 Boyacızade Konağı

Boyacızade Konağı is one of the repaired mansions located in Kale Quarter, Altındağ, Ankara. The mansion is used as restaurant and exhibition of the room spaces including the authentic furniture, textiles and domestic accessories in Ankara traditional houses as Ankara Bağ Evi. The owner of the Boyacızade Konağı, Ali Atilla Boyacıgil, mentioned that the dwelling belonging to early 1800s have been repaired forth times since this year. Ahu Yağcı, the architect of the last restoration project of it in 2012, indicated that the first repair was applied on the building between 1940-1960 years, the second one in 1989 and then in 1999. No information was found about the first intervention. Ali Atilla Boyacıgil indicated that the intervention in 1989 included the repairs of the partially collapsed floors and walls, replacement of cement based infill mortar within the floor section, renewal of some floor joists and the treatment of the mortar and painting. During the third repair in 1999, the architect of this restoration project, Sahure Ertürk Atak determined that the partition walls both side of entrance door at the ground floor were removed and wood studs were set on instead of those walls. The roof plan was changed by adding the terrace and covering the terrace by the fenestration unit. The last repair on the mansion in 2012 was composed of the repair of the hair cracks on the exterior wall and façade painting.

According to visual experiment and the restoration project, the dwelling consists of a stone masonry ground floor and timber framed two floors. The timber framed walls were constructed from timber pine studs, bracings and the timber lathing (bagdadi) with brick infill material. The floor structures are timber frame composing of wood flooring on wood joists at first and second floors and concrete at ground floor (Figure 3.12 and Figure 3.12).

Two interior wall and two floor components examined by the in-situ acoustical measurements were shown on the plans and sections schemas between Figure 3.12 and Figure 3.15 in 1/100 scale. The interior walls, indicated as W2-BK-FR2/R3 (Semi-Repaired-Wall 2) the panelled door (D2) positioned on is between BK-FR2 and BK-FR3,W3-BK-FR2/R3 (Semi-Repaired-Wall 3) the panelled and glazed door (GD3) positioned on between BK-FR3 and BK-FR4, two neighbouring exhibition rooms. The Semi-Repaired-Floor 2 namely F2-BK-FR3/GR1 is between the exhibition rooms on the first floor (BK-FR3) and on the ground floor (BK-GR1). The Semi-Repaired- Floor 3, F3-BK-FR2/GR1, is also between the exhibition rooms on the first floor (BK-FR2) and on the ground floor (BK-GR1). The details of those walls and floors sections were shown between Figure 3.17 and Figure 3.19.

Figure 3.10 Location of Boyacızade Konağı.

Figure 3.11 General and interior views of Boyacızade Konağı. A: general view of the dwelling; B: interior view of BK-GR1; C: interior view of BK-FR2; D: interior view of BK-FR3; E: interior view of BK-FR3.

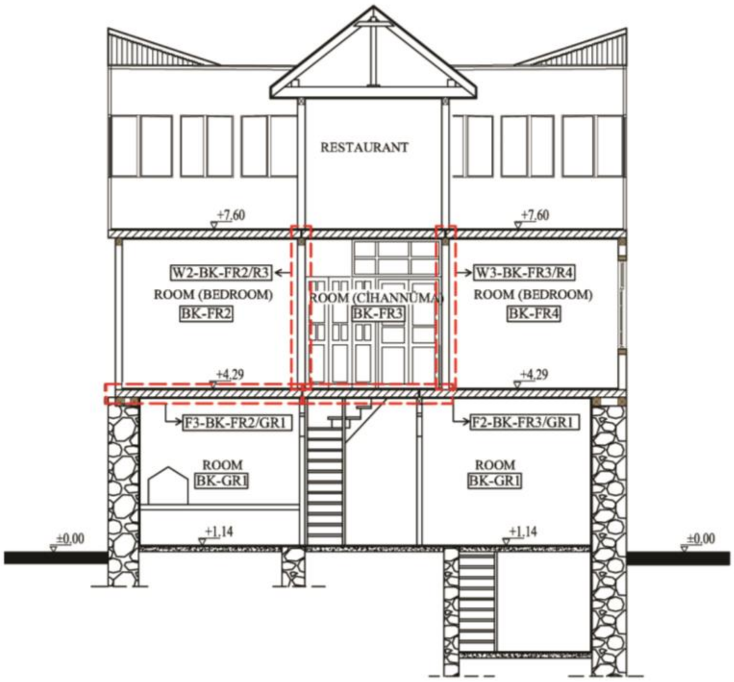

Figure 3.12 A-A section of Boyacızade Konağı in 1/100 scale (Redrawn by author).

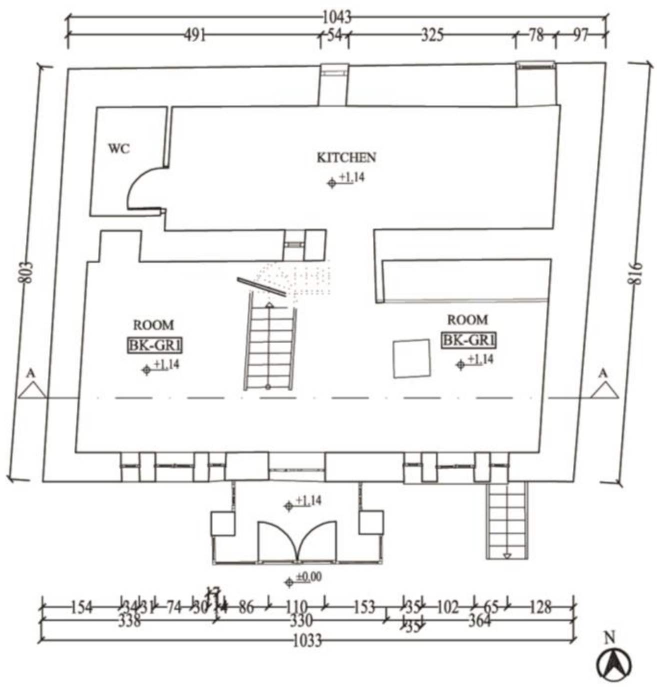

Figure 3.13 Ground floor plan of Boyacızade Konağı in 1/100 scale (Redrawn by author).

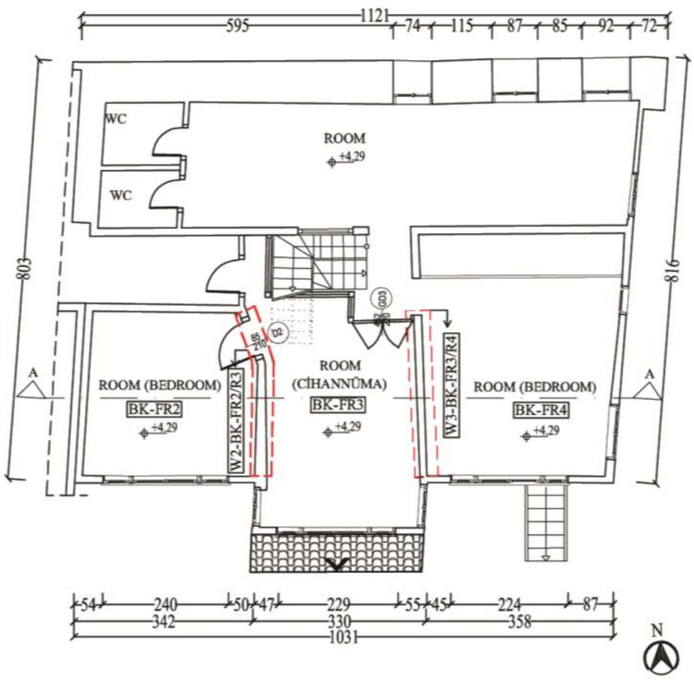

Figure 3.14 The first floor plan of Boyacızade Konağı in 1/100 scale (Redrawn by author).

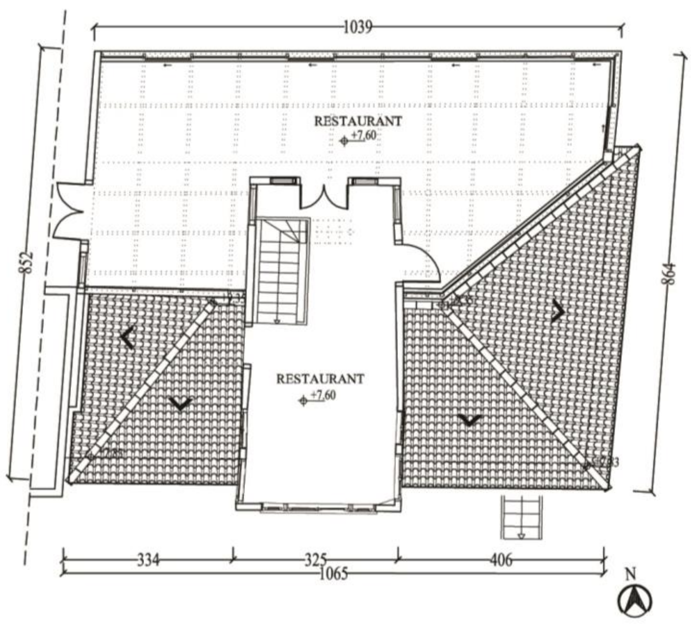

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Figure 3.15 The second floor plan of Boyacızade Konağı in 1/100 scale (Redrawn by author).

The Infrared thermography camera, FLIR thermacam E65, was also used to uncover the hidden timber frame structures of the walls not indicated in the restoration projects. IR thermography measurement in qualitative way was conducted to examine timber structures of two interior walls (Semi-Repaired-Wall 2, Semi-Repaired-Wall 3) shown in BK-FR2 and BK-FR3 in Figure 3.16. While the measurement was conducting, there was no difference between the temperatures of the rooms, therefore the timber structure of the walls could not be observed with the camera directly. IR camera measuring thermal radiation emitted by the walls could display the hidden structure after the rooms were heated up by a heater approximately one and a half hour. The images of the results were obtained from the software, Thermacam reporter 2000 professional, the various parameters such as ambient temperature, humidity, distance from the target and emissivity were entered as input. The ambient temperatures in BK-FR2 and BK-FR3 were between, respectively 23.6Cº- 26.4Cº and 25.7 Cº-27.6Cº, relative humidity were between, respectively 43.8 %- 60.5% and 42.1 % -45% and the emissivity value was defined as 0.95.

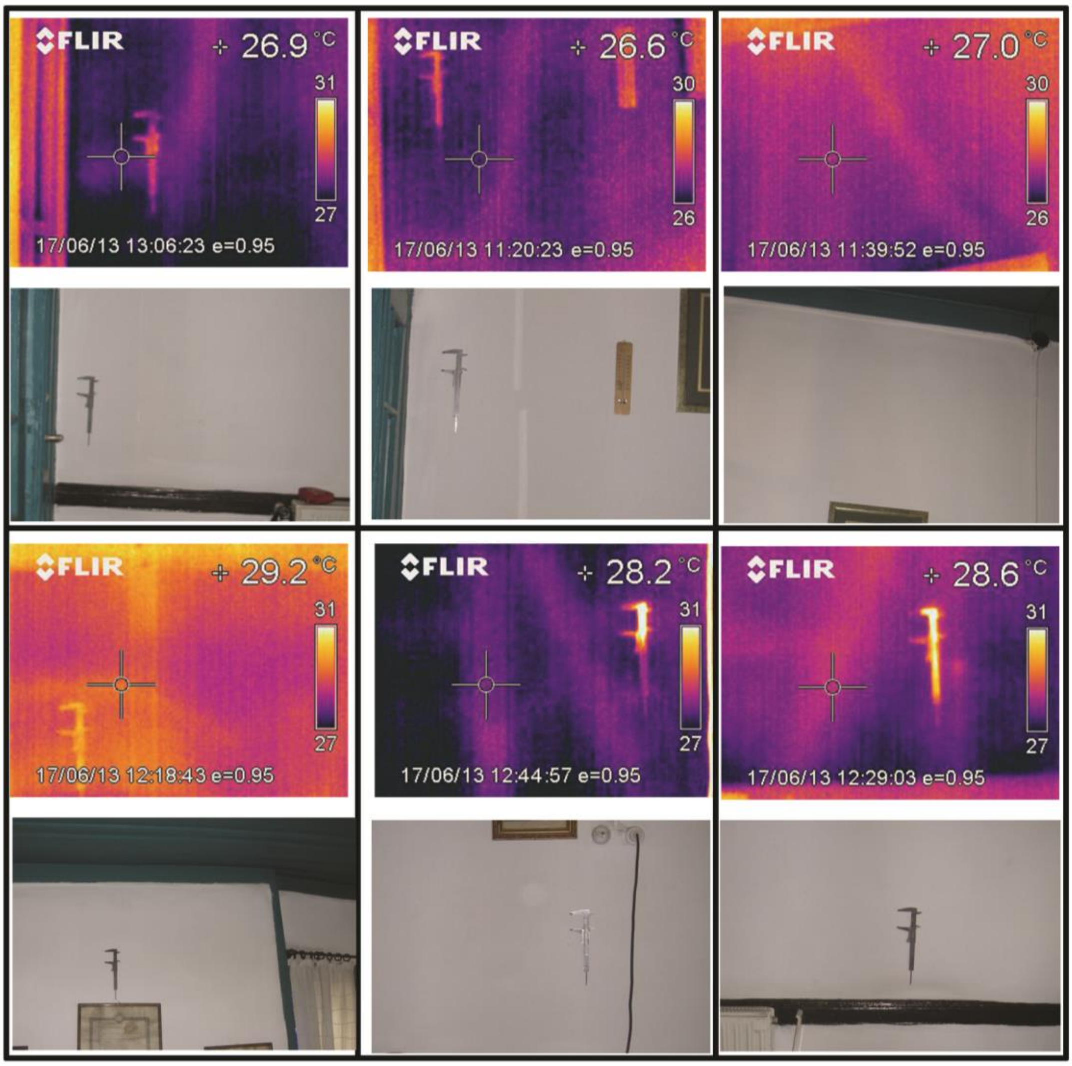


Figure 3.16 Images of the Semi-Repaired-Wall 3 taken by IR camera.

According to information obtained from Ali Atilla Boyacıgil, the restoration projects conducted at 1999 and 2014 and the IR camera measurement results, the configurations of the floors and the walls examined by the in-situ acoustical measurements are as follows:

- The Semi-Repaired-Wall 2 and Semi-Repaired-Wall 3 were composed of pine wood structural elements such as 150x150 mm main post, 100x100 mm bracing, 100x100 mm and 70x100 mm studs and the wooden lath (bagdadi) with solid fired brick infill material.

- The walls were coated with the plaster and paint.
- The Semi-Repaired-Floor 2 and Semi-Repaired- Floor 3 were composed of 50x150 mm pine wood joists with 450 mm spacing.
- 25 mm-thick pine wood strip flooring was fixed with nails to the joists.
- Two layers of carpet were attached onto the Semi-Repaired-Floor 2 with nails.
- 25 mm wood ceiling board was directly mounted to the joists with nails.
- The height of cement based infill mortar within the Semi-Repaired-Floor 2 and Semi-Repaired-Floor 2 sections was approximately 75 mm, half of the cavity height.

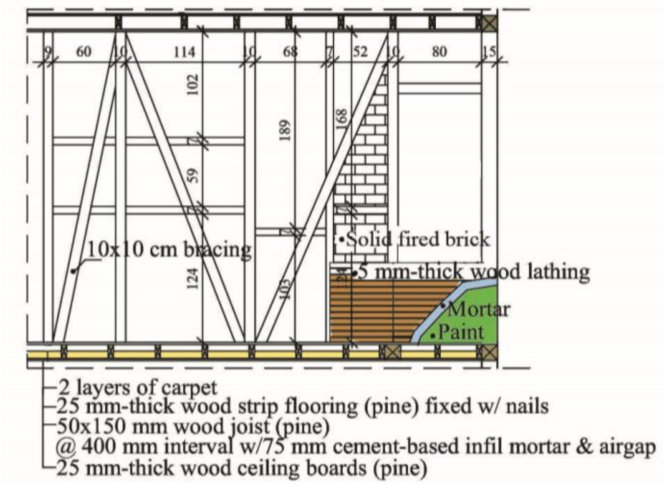


Figure 3.17 Elevation of Semi-Repaired-Wall 2 & Section of Semi-Repaired-Floor 2 in 1/50 scale (Drawn by author).

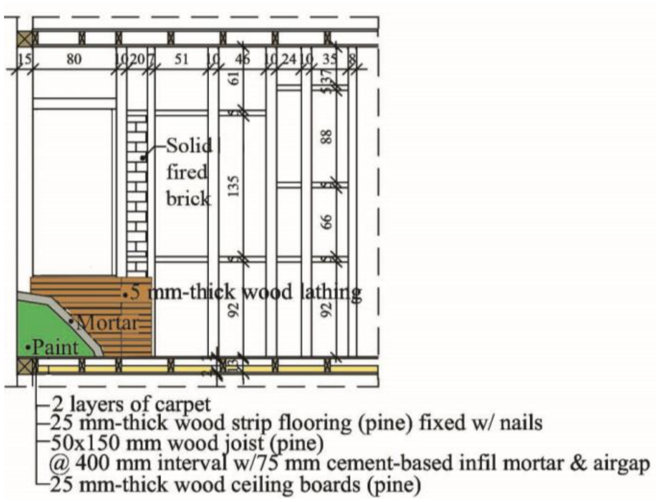


Figure 3.18 Elevation of Semi-Repaired-Wall 3 & section of Semi-Repaired-Floor 2 in 1/50 scale (Drawn by author).

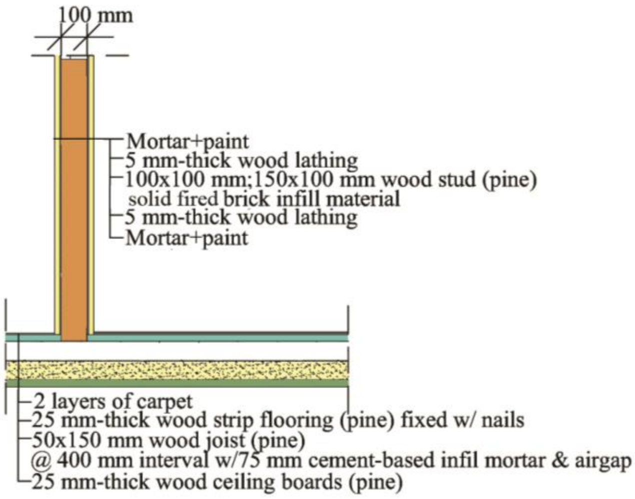


Figure 3.19 Section of Semi-Repaired-Wall 3 & Semi-Repaired-Floor 2 in 1/20 scale (Drawn by author).

3.1.3 Tahtacıörencik Village House

The house with no: 70/2 located in Tahtacıörencik Village of Güdül District in Ankara, belongs to 1920. The dwelling keeping the authentic features techniques is the rescued part of grater building from the fire in 1950s. The damaged part of the building was destroyed at that time. The resident indicated that the repairs on the house were composed of renewal of two rooms at upper floor shown in Figure 3.24, the replacement of the wood flooring with newly ones on the floor in the kitchen, alteration of roof tile with metal sheet and the repair of façade mortar and painting. The ground floor is used as barn and storage; the first floor includes living and bed rooms, kitchen, toilet and bathroom (Figure 3.21 and Figure 3.22).

According to visual experiments, the dwelling is composed of rubble stone masonry ground floor and timber framed upper floor. The timber framed walls were constructed from pine wood studs, bracings and the wooden lath (bagdadi) with mud mortar infill by hımış construction technique. The floor structures are timber frame composing of wood flooring on wood joists at first floor and earth at ground floor.

One interior wall and one floor component examined by the in-situ acoustical measurements were shown on the plans and sections schemas between Figure 3.22 and Figure 3.24 in 1/100 scale. The interior wall, indicated as Original- Wall 4 (W4-TV-FR1/R2) the panelled door (D4) positioned on is between TV-FR1 and TV-FR2. The Original- Floor 4 namely F4-TV-FR2/GR1 is between the room (TV-FR2) on the first floor and the entry (TV-GR1) on the ground floor. The details of the walls and floors sections were shown between Figure 3.25 and Figure 3.26.

Figure 3.20 Location of Tahtacıörencik Village House with no: 70/2.

Figure 3.21 General and interior views of Tahtacıörencik Village House. A: general view of the dwelling; B: interior view of TV-GR1; C: interior view of TV-FR1; D: interior view of TV-FR2.

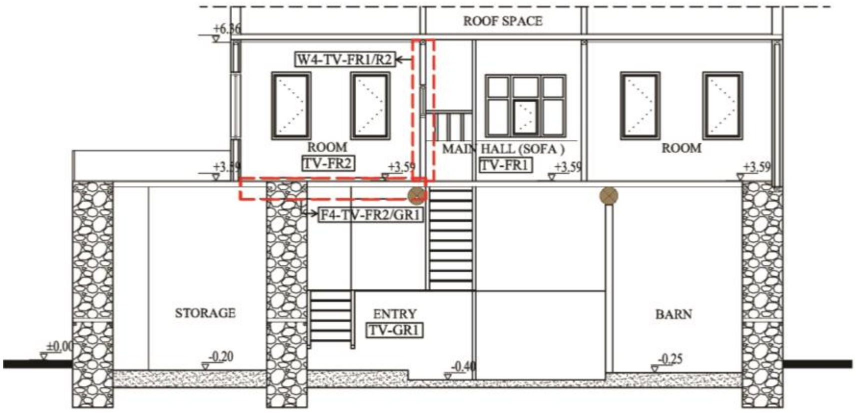


Figure 3.22 A-A section of Tahtacıörencik Village House in 1/100 scale (Drawn by author).

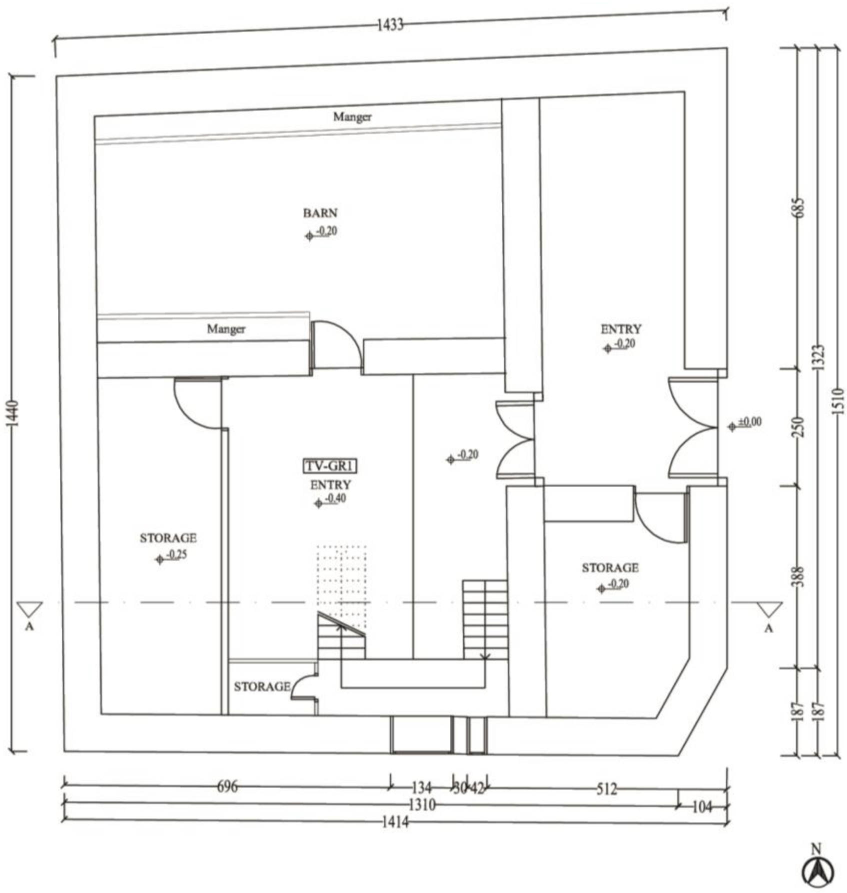


Figure 3.23 Ground floor plan of Tahtacıörencik Village House in 1/100 scale (Drawn by author).

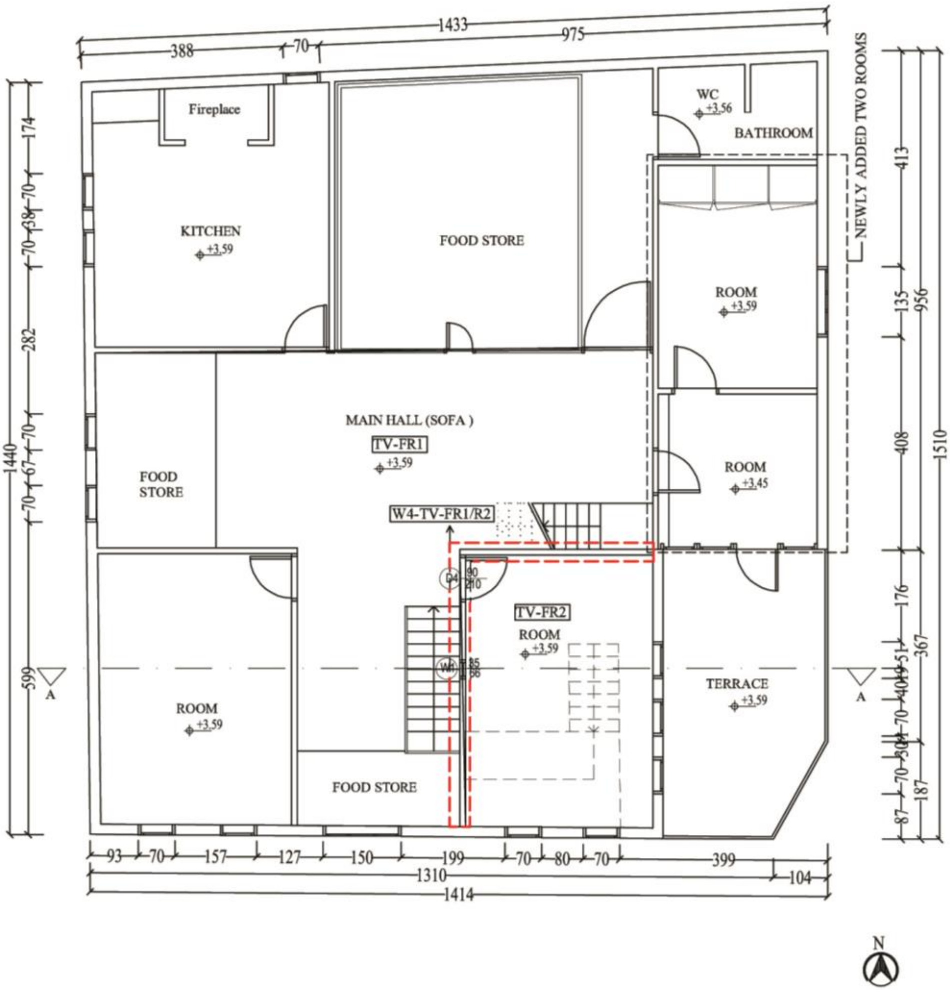


Figure 3.24 First floor plan of Tahtacıörencik Village House in 1/100 scale (Drawn by author).

According to information obtained from the residents and the visual experiments, the configurations of the floors and the walls examined by the in-situ acoustical measurements are as follows:

- The Original-Wall 4 was composed of pine wood elements such as 100x100 mm main post, 50x100 mm studs and 5 mm-thick wooden lath (bagdadi) with 100 mm-thick mudbrick infill material.

- The wall was coated with the lime plaster and paint at only one surface of the partition.
- The Original- Floor 4 was composed of Ø100 mm and 100x100mm pine wood joists at various intervals.
- 20 mm-thick and 16 mm-wide pine wood strip flooring fixed with nails on the joists.

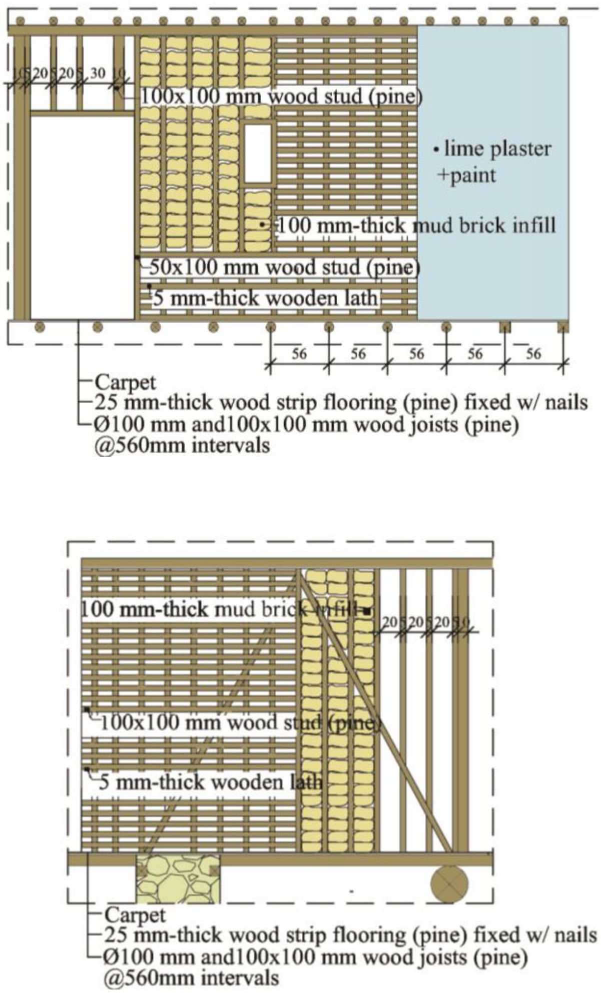


Figure 3.25 Elevations of Original-Wall 4 & sections of Original-Floor 4 in 1/50 scale (Drawn by author).

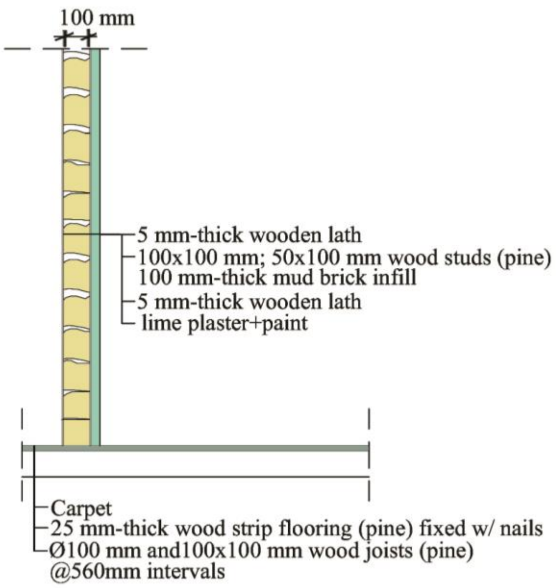


Figure3.26 Sections of Original-Wall 4 & Original-Floor 4 in 1/20 scale (Drawn by author).

3.1.4. Abbreviations for Wall and Floor Components Under Examination

BE: Ankara **B**ağ **E**vi

BK: **B**oyacızade **K**onağı

TV: **T**ahtacıörencik **V**illage House

GR1: **R**oom **1** at **G**round Floor

MR3: **R**oom 3 at **M**ezzanine Floor

FR1: **R**oom **1** at **F**irst Floor

FR2: **R**oom **2** at **F**irst Floor

FR3: **R**oom **3** at **F**irst Floor

FR4: **R**oom **3** at **F**irst Floor

W: **W**all

F: **F**loor

The nomenclature of walls and floors studied is given below:

Reconstructed-Wall 1: W1-BE-FR1/R2

- FR1/R2 — The component is between **room 1** and **room 2**
- BE — The component is at **Ankara Bağ Evi**
- W1 — **Wall 1**

Semi-Repaired-Wall 2: W2-BK-FR2/R3

- FR2/R3 — The component is between **room 2** and **room 3** at **first floor**
- BK — The component is at **Boyacızade Konağı**
- W2 — **Wall 2**

Semi Repaired -Wall 3: W3-BK-FR3/R4

- FR3/R4 — The component is between **room 3** and **room 4** at **first floor**
- BK — The component is at **Boyacızade Konağı**
- W3 — **Wall 3**

Original- Wall 4: W4-TV-FR1/R2

- FR1/R2 — The component is between **room 1** and **room 2** at **first floor**
- TV — The component is at **Tahtacıörencik Village** House
- W4 — **Wall 4**

Reconstructed-Floor 1 : F1-BE-FR1/MR3

- FR1/MR3 — The component is between **room 1** at **first floor** and **room 2** at
- BE — The component is at **Ankara Bağ Evi**
- F1 — **Floor 1**

Semi-Repaired-Floor 2: F2-BK-FR3/GR1

The component is between **room 3** at **first floor** and **room 1** at **ground floor**

The component is present at **Boyacızade Konağı**

Floor 2

Semi-Repaired-Floor 3: F3-BK-FR2/GR1

The component is between **room 2** at **first floor** and **room 1** at **ground floor**

The component is present at **Boyacızade Konağı**

Floor 3

Original- Floor 4: F4-TV-FR2/GR1

The component is between **room 2** at **first floor** and **room 1** at

The component is at **Tahtacıörencik Village** House

Floor 4

Table 3.1 Nomenclature and configuration of the wall and floor components examined.

Wall &Floor Components Examined	Configuration of Components	Short Name	Explanatory drawings of cross section
W1-BE-FR1/R2	Reconstructed timber framed wall w/ infill of new fired clay brick coated with gypsum and lime based plaster	Reconstructed-Wall 1	Figure 3.9
W2-BK-FR2/R3 & W3-BK-FR3/R4	Semi-repaired timber framed wall w/ infill of fired clay brick coated with wooden lathes and mortar and paint	Semi-Repaired-Wall 2 & Semi-Repaired-Wall 3	Figure 3.19
W4-TV-FR1/R2	Original timber framed wall w/ infill of mud brick coated with wooden lathes mortar and paint at one surface of wall	Original-Wall 4	Figure 3.26
F1-BE-FR1/MR3	Reconstructed timber framed floor composed of two way joists, sound absorbing infill, three layers of flooring and ceiling board.	Reconstructed-Floor 1	Figure 3.9
F2-BK-FR3/GR1 & F3-BK-FR2/GR1	Semi-Repaired timber framed floor composed of one way joists, a flooring layer and ceiling board.	Semi-Repaired-Floor 2 & Semi-Repaired- Floor 3	Figure 3.19
F4-TV-FR2/GR1	Semi-Repaired timber framed floor composed of one way joists and a flooring layer.	Original - Floor 4	Figure 3.26

3.2 IN-SITU ACOUSTICAL MEASUREMENTS

The actual sound transmission features of the floor and wall sections in Bağ Evi, Boyacızade Konağı and Tahtacıörencik Village House were examined by in-situ measurements for the assessment of impact and airborne sound insulation characteristics (ISO 140-7:1998; ISO 140-4:1998; ISO 717-1:2013; 717-2:2013).The actual impact sound transmission through the floors were measured on site by using a standard tapping machine as the impact sound source, Tapping Machine B&K Type 3207, (ISO 140-7:1998) and defined in normalised impact sound pressure level, L'_n (dB) and weighted normalised impact sound pressure level, L'_{nw} (dB) (ISO 717-2:2013). The actual airborne sound transmission through the walls was measured by using an Omni directional sound source, Omni Power™ Sound Source B&K Type 4292-L. As a receiver, sound level meter, Hand-held Analyser B&K Type 2250-A was used, (ISO 140-4:1998) and defined in terms of sound reduction index, R' (dB) and weighted sound reduction index, R'_W (dB) (ISO 717-1:2013)(Figure 3.25). The values given in Table 2.3 were accepted as the minimum requirements; $R'w \geq 50$ dB, $L'_{nT,w} \leq$ 65 dB. The results of measurement conducted by using white noise were recorded in sound level meter obtained by software of BZ 5503 measurement partner suit.

Figure 3.27 Instruments of in-situ acoustical measurements. A: omnidirectional sound source; B: sound level meter; C: tapping machine.

3.2.1 Case 1: Ankara Bağ Evi

The in-situ measurements conducted in Ankara Bağ Evi on 28th February 2014 included two impact and one airborne sound transmission tests for the Reconstructed-Floor 1 and one airborne transmission test for the Reconstructed-Wall 1 section (Figure 3.24). The impact sound transmission through the floor was measured with carpet on the wood flooring and also without carpet.

The measurement were conducted in the rooms; BE-FR1, BE-FR2 and BE-MR3, shown in Figure 3.24. Those furnished rooms had regular shaped plans. The door (D1) on Wall1 was functioning properly and no holes or cavity was present on the wall and floor components. The locations of the sound source in the source rooms and the receiver in the receiving rooms were indicated in the plan schemas of the rooms as shown in Appendix B. Those measurement instruments were placed the way that the minimum distance between; receiver and room boundary was 0.56m, the source and the room boundary was 0.56 m, source positions was 1.58 m, receiver and source was 1.1 m and receiver positions were 0.86 m. The least distance between the omnidirectional sound source, sound level meter and ceiling were respectively 0.74 m and 0.5 m. According to ISO140-4:1998 and ISO 140-7:1998, the minimum requirements for distances of all source and receiver positions were provided by taking into account the large-sized furniture in rooms. The three measurements were summarized below:

- RECONSTRUCTED-WALL 1-Airborne sound transmission measurements: The source room was BE-FR1 and the receiving room was BE-FR2. The measurement of Reconstructed-Wall 1 was done with one source and three receiver positions in BE-FR1 and one source and eight receiver positions and two source positions for the reverberation time measurement in BE-FR2.
- RECONSTRUCTED-FLOOR 1 -Airborne sound transmission measurement: The source room was BE-FR2 and the receiving room was BE-MR3. The measurement was done on the carpet surface by using one source and four receiver positions in the room BE-FR2, one source and three receiver positions in the room BE-MR3.

- RECONSTRUCTED-FLOOR 1 -Impact sound transmission measurement: The source room and the receiving room were decided to be the rooms of BE-FR2 and BE-MR3, respectively. The measurements were repeated for two cases -with and without carpet layer on parquet flooring- by using one source position in the room BE-FR2 and three receiver positions in the room BE-MR3 for each measurement. A special care was given to the direction of joists while placing the tapping machine.

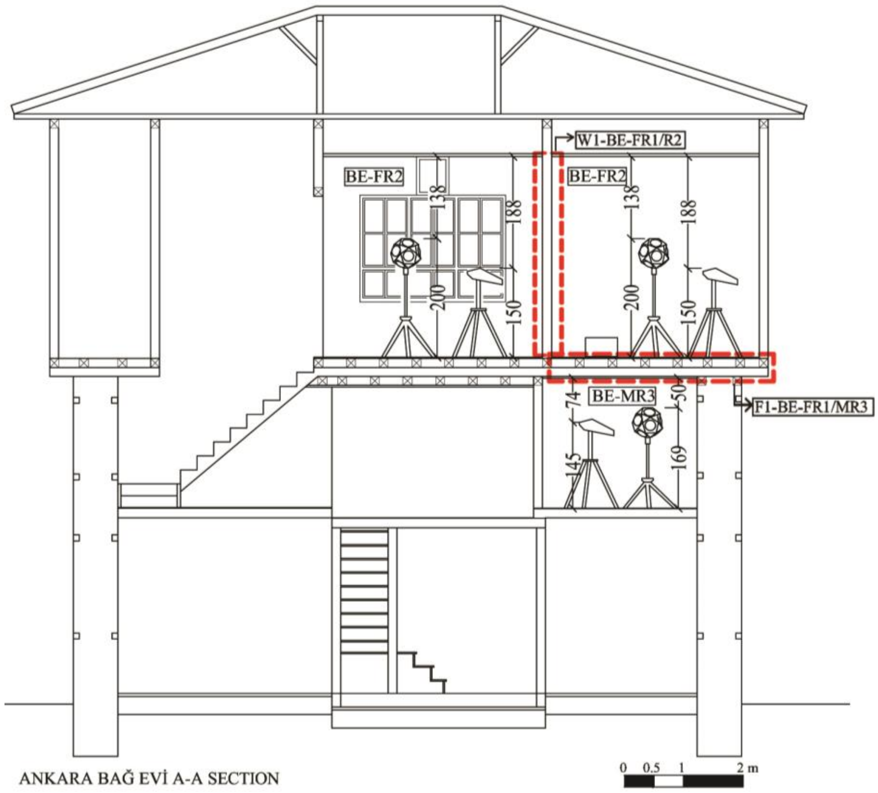


Figure 3.28 Locations of the sound level meter, omnidirectional sound source and tapping machine in the section of Ankara Bağ Evi.

3.2.2 Case 2: Boyacızade Konağı

The in-situ acoustical measurements performed in Boyacızade Konağı on 05th April 2014 were composed of two impact sound transmission tests for two floor (Semi-Repaired-Floor 2 and Semi-Repaired- Floor 3) sections and four airborne sound transmission tests for the same two floors and two walls (Semi-Repaired-Wall 2 and Semi-Repaired-Wall 3) sections (Figure 3.25).

The measurements were conducted at the ambient temperature between 10.3 C^{o}-12.8 C^{o} and the relative humidity between 35%-41% in the rooms; BK-GR1, BK-FR2, BK-FR3 and BK-FR4. Those furnished rooms had irregular shaped plans. The panelled and glazed door positioned on the Semi-Repaired-Wall 3, shown as GD3 shown in Figure 3.11 as the part of a fenestration were not functioning properly and was suffering from the gap at the level of top rail. A hole with size of approximately 10cmx10cm in square was positioned on Semi-Repaired-Floor2. The gap for the run of heating system piping in vertical was filled with kind of wool sponge.

The locations of the sound source in the source rooms and the receiver in the receiving rooms were indicated in the plan schemas of the rooms as shown in Appendix B. The measurement instruments were placed the way that the minimum distance between; receiver and room boundary was 0.7 m, the source and the room boundary was 0.7 m, source positions was 0.7 m, receiver and source was 1m and receiver positions were 1m. The least distance between the omnidirectional sound source, sound level meter and ceiling were respectively 1.15 m and 1.45 m. According to standards, the minimum requirements for distances of all positions were provided (ISO140-4:1998, ISO 140-7:1998) by taking into account the smallness of the rooms and furnishings in rooms. The six measurements were summarized below:

- SEMI-REPAIRED-WALL 2 and SEMI-REPAIRED-WALL 3-Airborne sound transmission measurements: The source room was BK-FR2 for Semi-Repaired-Wall 2 and BK-FR4 for Semi-Repaired-Wall 3. The receiving room for both of them was BK-FR3. The measurement of Semi-Repaired-Wall 2 was done with one source and three receiver positions in BK-FR2 and one source and four receiver positions in BK-FR3. The measurement of Semi-Repaired-Wall 3 was done one source and four receiver positions in BK-FR4 and one source and four receiver positions in BK-FR3.

- SEMI-REPAIRED-FLOOR 2 and SEMI-REPAIRED- FLOOR 3-Airborne sound transmission measurements: The source room was BK-FR3 for Semi-Repaired-Floor 2 and BK-FR2 for Floor3. The receiving room for both of them was BK-GR1. The measurement of Semi-Repaired-Floor 2 was done with one source and four receiver positions in BK-FR3, one source and five receiver positions in BK-GR1. The measurement of Floor3 was done with one source and three receiver positions in BK-FR2, by one source and four receiver positions in BK-GR1.
- SEMI-REPAIRED-FLOOR 2 and SEMI-REPAIRED- FLOOR 3-Impact sound transmission measurements: The source room was BK-FR3 for Semi-Repaired-Floor 2 and BK-FR2 for Semi-Repaired-Floor 2. The receiving room for both of them was BK-GR1. The measurement of Semi-Repaired-Floor 2 was done with four source positions in BK-FR3 and four receiver positions in BK-GR1. The measurement of Floor3 was done with one source in BK-FR2 and four receiver positions in BK-GR1. A special care was given to the direction of joists while placing the tapping machine.

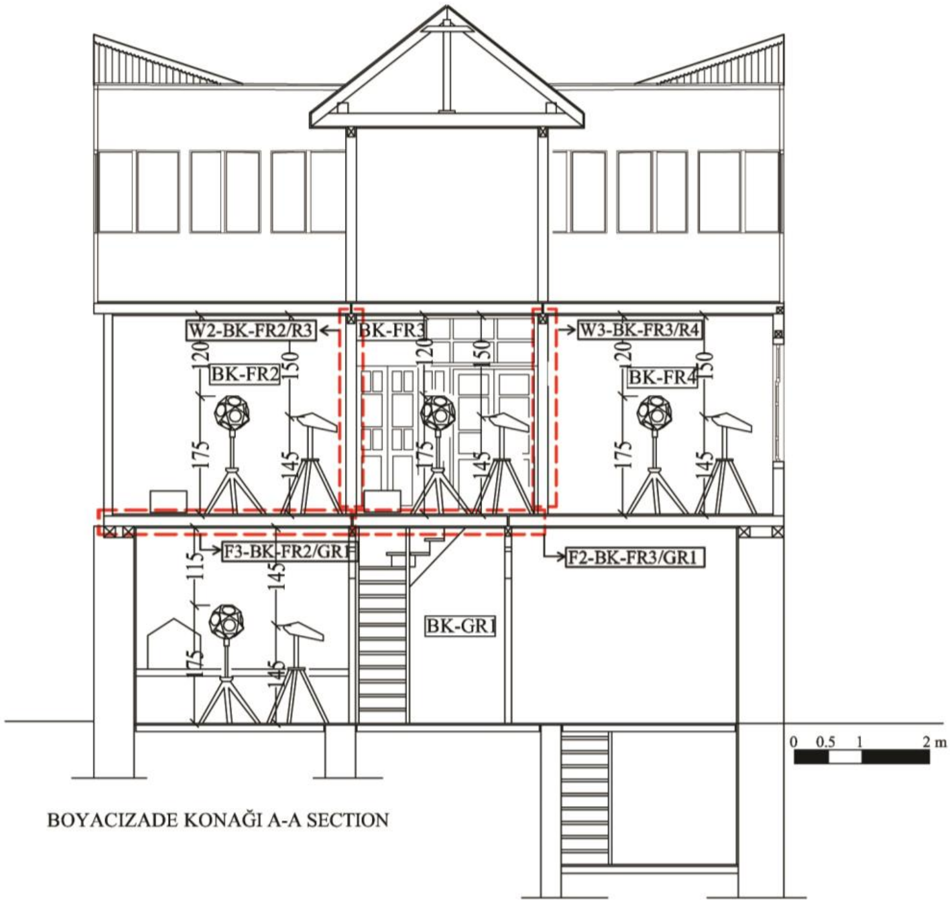


Figure 3.29 Locations of the sound level meter, omnidirectional sound source and tapping machine in the section of Boyacızade Konağı.

3.2.3 Case 3: Tahtacıörencik Village House

The in-situ acoustical measurements performed in the dwelling with no:70/2, Tahtacıörencik Village on 14th December 2014 were composed of one impact sound transmission test for the Original- Floor 4 section and two airborne sound transmission tests for the same floor and the Wall4 section (Figure 3.26).

The measurements were conducted in the rooms; TV-GR1, TV-FR1and TV-FR2 (Figure 27). Those furnished rooms had regular shaped plans. The panelled door and the single pane window positioned on the Original- Wall 4, shown as respectively, D4 and W1 shown in Figure 3.11.

The locations of the sound source in the source rooms and the receiver in the receiving rooms were indicated in the plan schemas of the rooms as shown in Appendix B. The measurement instruments were placed the way that the minimum distance between; receiver and room boundary was 0.52 m, the source and the room boundary was 1.16 m, receiver and source was 1.13 m and receiver positions were 1.14 m. The least distance between the omnidirectional sound source, sound level meter and ceiling were respectively 0.97m and 1.09 m. According to standards, the minimum requirements for distances of all positions were provided by taking into account the smallness of the rooms and furnishings in rooms. The three measurements were summarized below(ISO140-4:1998, ISO 140-7:1998):

- ORIGINAL-WALL 4- Airborne sound transmission measurement: The source room was TV-FR2 and the receiving room was TV-FR1. The measurement of Semi-Repaired-Wall 2 was done with one source and four receiver positions in TV-FR2 and two source and eight receiver positions in TV-FR1.
- ORIGINAL-FLOOR 4- Airborne sound transmission measurement: The source room was TV-FR2 and the receiving room was TV-GR1. The measurement of Original-Floor 4 was done with one source and four receiver positions in TV-FR2, one source and four receiver positions in TV-GR1.
- ORIGINAL-FLOOR 4-Impact sound transmission measurement: The source room was TV-FR2 and the receiving room was TV-GR1. The measurement of Semi-Repaired-Floor 2 was done with four source positions in TV-FR2, one source and four receiver positions in TV-GR1.

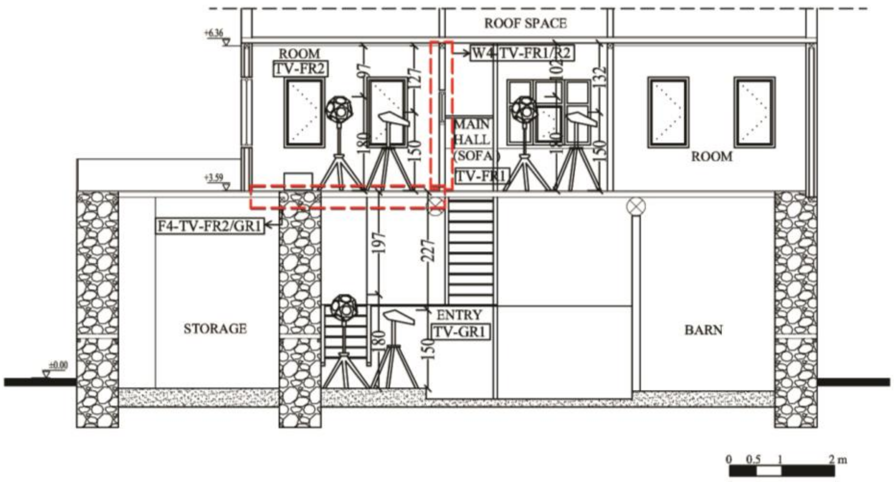


Figure 3.30 Locations of the sound level meter, omnidirectional sound source and tapping machine in the section of Tahtacıörencik Village House.

3.3 ACOUSTICAL MODELLING AND SIMULATION ANALYSES

Sound insulation performance of the floor and wall components in the traditional timber framed dwellings and the overall structure was also assessed by making their acoustical modelling and simulation analyses with the software named "INSUL" and "BASTIAN". Sound transmission through the wall and floor sections were examined by software, namely, "INSUL", developed by Marshall Day Acoustics. The analyse allow to estimate sound insulation performance in one-third octave band center frequencies for the airborne and impact sound in terms weighted sound reduction index, R_W (dB), and weighted impact sound pressure level, L_{nw} (dB); (EN 12354-3:2000; ISO 717-1:1996; ISO 717-2:1996). The other software that was used for assessment of sound insulation performance of the overall building is "BASTIAN" developed by Datakustik (ISO 717-1:1996; ISO 717-2:1996; EN 12354-1:2000; EN 12354-2:2000; EN 12354-3:2000; ASTM E 413-87; ASTM E 989-89). The airborne and impact sound transmission between rooms in a building was estimated in one-third octave band centre frequencies with single number ratings: Apparent Sound Reduction Index (R'_w); apparent impact sound pressure level L'_{nw}. The achieved data could be exported into MS-Excel and PDF format. The INSUL allowed calculating analytically the sound insulation performance of building components individually without considering the effect of flanking transmission while BASTIAN was able to calculate the influence of flanking transmission on the resulting sound transmission performance since it allowed modelling the junctions of flanking elements.

3.3.1 Sound Transmission Loss Analyses for Floor &Wall Cross Sections by INSUL

The representative models were produced both for the timber-framed wall and floor components of existing dwellings under examination and for the interventions proposed for the sound reduction improvement of those components by using the archive of INSUL software. The mudbrick infill, which was not involved in this archive, was included in the models by giving the inputs of “modulus of elasticity, MoE” in the range of 0.7 GPa -7 GPa and density in the range 1073 $kg.m^{-3}$-1206 $kg.m^{-3}$ (Houben & Guillaud,1994; Meriç *et al*, 2013, Meriç *et al*, in press). The models of the existing wall and floor components and the proposed ones were then examined in terms of Lnw and Rw values by using by INSUL software.

The configuration of the models representing the existing wall and floor components are summarized below and their schematic sketches are given in the Figure 3.31 and Figure 3.32, respectively:

- *Reconstructed-Wall 1* which is composed of 150 mm-thick fired brick infill.
- *Semi-Repaired-Wall 2 and Wall3*, both of which are composed of 100 mm-thick fired brick infill with double layers of wooden sheathing (pine).
- Original-Wall 4 which is composed of 100 mm-thick mudbrick infill with double layers of wooden sheathing (pine).
- *Reconstructed-Floor 1* composed of two-way solid wood joist system with 200mm-rockwool infill used at the first level and 200mm air gap at the second level of the joist framing. The joists were covered with 17 mm-thick wooden flooring (pine parquet) and 20 mm-thick plywood subfloor at the floor side while covered with 17 mm-thick wooden boards (pine) at ceiling side.

- *Semi-Repaired-Floor 2 and Floor 3* composed of one-way solid wood joist system without infill material. The joists were covered with 25 mm- thick wood strip flooring (pine) at floor side while covered with 25 mm-thick wooden boards (pine) at ceiling side.
- *Original-Floor 4* composed of one-way solid wood joist system without infill. The joists were covered with 25 mm- thick wood strip flooring (pine) at the floor side while the joists were exposed (not covered with a material) at the ceiling side.

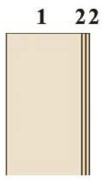
WALL SECTIONS	SECTION DESCRIPTION
	Reconstructed-Wall 1
	1- 150 mm-thick fired clay brick
	Semi-Repaired-Wall 2/Wall 3
	1- 100 mm-thick fired clay brick 2- 5mm-thick pine board
	Original-Wall 4
	1-100 mm-thick mudbrick 2- 5mm-thick pine board

Figure 3.31 The configuration of the models representing the existing wall components.

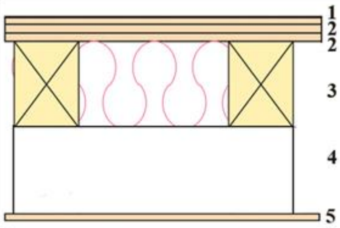
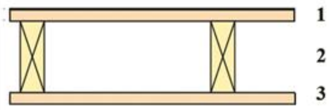
FLOOR SECTIONS	SECTION DESCRIPTION
	1- 17 mm-thick pine flooring layer 2- 20 mm-thick plywood 3-150 mm x 200 mm solid wood joist @ 500 mm w/ 200 mm-thick mineral fibre infill 4-150 mm x 200 mm solid wood joist @ 450 mm 5-17 mm-thick pine ceiling board
	1-25 mm-thick pine flooring layer 2-50 mm x 150 mm solid wood joist @ 400 mm 3-25 mm-thick pine ceiling board
	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm

Figure 3.32 The configuration of the models representing the existing floor components.

The configuration of the models representing the proposals in the form of demountable drywall attachments on the existing wall components and interventions to the existing floor configurations are summarized in the following paragraphs, respectively.

Several types of single-sided dry wall applications were proposed as interventions to provide sound insulation improvements in existing wall components. These applications are demountable interventions that form a separate 60mm-thick dry wall attached behind the existing wall surface (see Figures 4.5 to 4.7) and supported with metal or wood framing. Some sound break elements, such as resilient channel, rubber isolation channel or resilient layer, are introduced within the wall section in order to separate some layers from the others or to make an indirect mechanical fixing of a layer to the other (Figure 3.33). The capital letters are used to label the interventions applied with wood framing while " ' (apostrophe)" is added to the labels for the interventions applied with metal framing. The configurations of the models representing those interventions are summarized below:

- A_W: composed of wood framing with one layer of gypsum board and without sound insulation infill (positioned behind all types of wall sections).
- B_W & B_W’: composed of wood /metal framing with one layer of gypsum board and sound insulation infill (positioned behind all types of wall sections).
- C_W, D_W & C_W’, D_W’: composed of resilient channel/rubber isolation clip acting as a sound break between gypsum board facing and backing metal/wood framing with sound insulation infill (positioned behind all types of wall sections).
- E_W & E_W’: composed of separate wood /metal framing with one layer gypsum board and sound insulation infill (positioned behind all types of wall sections).
- F_W: composed of a sound insulation board with gypsum board facing which is directly sticked on existing wall surface without framing (positioned behind the Reconstructed-Wall 1).
- G_W& G_W’: composed of separate wood /metal framing with double layer gypsum board and sound insulation infill (positioned behind all types of wall sections).
- H_W: composed of resilient layer acting as a sound break between double layer of gypsum boards in double wall system including wood framing and sound insulation infill (positioned behind all types of wall sections).

Figure 3.33Views of a resilient layer applied on wood studs (at the left) and a rubber isolation clip connecting the gypsum board to the wooden frame (at the middle) and a resilient channel applied on a wood stud (at the right).

Some techniques in which the layers forming the floor component are separated from each other were proposed as interventions (Figures 3.33). The models of the proposed configurations for the floor components are given in Figures 4.12-4.13 for Reconstructed-Floor 1, Semi-Repaired Floor 2/3 and Original-Floor 4, respectively. Some demountable sound resistive layers were suggested to attach to the original timber-framed floor section (Original-Floor4) while renewal/ renovation works introducing sound breaks within the floor sections were proposed to the existing floors of Reconstructed-Floor 1, Semi-Repaired Floor 2/3. Each floor type were labelled in Roman numbers and capital letters were used to indicate a specific intervention proposed. The configurations of the models representing those interventions are defined below.

The Reconstructed-Floor 1:

- I_{F-}A: addition of resilient layer between wood subfloor and wood joists.
- I_{F-}B: addition of resilient channel separating three layers of ceiling board from joist layer at the bottom.
- I_{F-}C: addition of resilient channels separating ceiling board from joist layer. The sound absorbing infill is also used between the joist layer at the bottom.
- I_{F-}D: addition of rubber isolation clips separating three layers of ceiling board from joist layer at the bottom. The sound absorbing infill is also used between the joist layer at the bottom.

The Semi-Repaired Floor 2/3:

- II_{F-}A: addition of resilient channel separating the ceiling board from joists
- II_{F-}B: addition of resilient channel separating the ceiling board from joists. The sound absorbing infill is also used between joists
- II_{F-}C: addition of resilient channel separating two layers of ceiling board from joists. The sound absorbing infill is also used between joists.
- II_{F-}D: addition of rubber isolation clip separating two layers of ceiling board from joist. The sound absorbing infill is also used between joists.
- II_{F-}E: addition of rubber isolation clip separating two layers of ceiling board from joist and resilient layer between wood subfloor and joists. The sound absorbing infill is also used between joists.

- $II_{F-}F$: addition of separate joists decoupling two layers of ceiling board from joist and resilient layer between wood subfloor and joists. The sound absorbing infill is also used between joists.

The Original-Floor 4:

- $III_{F-}A$: addition of ceiling board with direct mounting to joists.
- $III_{F-}B$: addition of ceiling board with direct mounting to joists. The sound absorbing infill is also used between joists.
- $III_{F-}C$: addition of resilient channel separating the ceiling board from joists. The sound absorbing infill is also used between joists.
- $III_{F-}D$: addition of resilient channel separating two layers of ceiling board from joists. The sound absorbing infill is also used between joists.
- $III_{F-}E$: addition of separate joists decoupling two layers of ceiling board from joists. The sound absorbing infill is also used between joists.

The sound insulation performances of those proposal configurations for wall and floor sections were discussed in terms of simulated Rw and Lnw values in order to suggest the most appropriate intervention technique(s). The sound reduction performance of each proposal was examined by only using the software INSUL. The simulation analyses of flanking sound transmission on those proposals could not be done by using the software BASTIAN due to some restrictions. The new building components could not adapted to the standard building components assigned by the software and the acoustical data of new materials as inputs could not be integrated into the software.

3.3.2 Sound Transmission Loss Analyses in Timber Framed Dwellings by BASTIAN

Reconstructed-Wall 1, Semi-Repaired-Wall 2 and Wall3, Original-Wall 4 and Semi-Repaired-Floor 2 and Floor 3, Original-Floor 4 were analysed by BASTIAN to determine the influence of flanking transmission on the resulting sound transmission performance of the partitions. Reconstructed-Floor 1 could not be analysed because of the lack of an appropriate floor section in the archive of the software for this floor.

The special care was given to model the junctions between the floor and wall components for the simulation analyses. While the type of conjunctions were determined as between lightweight wall and floor construction elements for all partitions examined, various wall and floor configurations including similar or different sections were analysed. Different wall and floor configurations used for evaluation of the Original-Wall 4 and Original-Floor 4 were given between Table 3.2 and Table 3.8.

As shown in Figure 3.34 and Figure 3.35, the examined floor and wall components were defined as “d” and the other ones were identified as “f1”, “f2”, “f3” and “f4”. Source room was indicated as “SR”and receiving room was shown as “RR”.

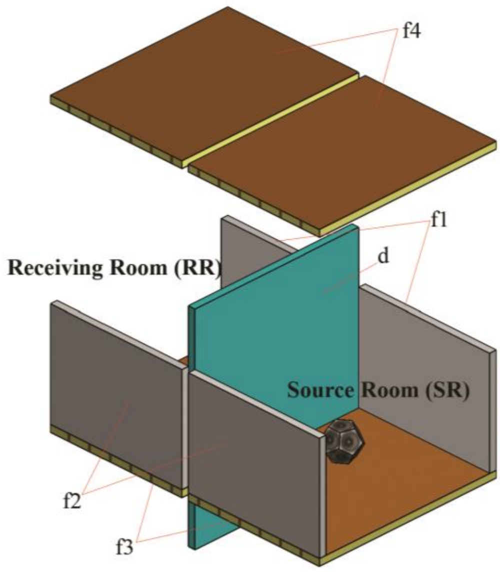


Figure 3.34 A modelling of TV-FR2 as a source room and TV-FR1 as receiving room in Tahtacıörencik Village House analysed by BASTIAN to determine airborne sound transmission characteristics of Original-Wall 4.

Table 3.2 Section description of wall and floor sections used for the simulation analyses of the Original-Wall 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f3	SR	timber floor with wooden joists	wooden flooring on wooden joists
f3	RR	timber floor with wooden joists	wooden flooring on wooden joists
f4	SR	timber floor with wooden joists	wooden flooring on wooden joists
f4	RR	timber floor with wooden joists	wooden flooring on wooden joists

Table 3.3 Section description of wall and floor sections used for the simulation analyses of the Original-Wall 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	lightweight wall, composite construction	40 mm-thick foamglas, 2x9,5 mm gypsum board
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f3	SR	timber floor with wooden joists	wooden flooring on wooden joists
f3	RR	timber floor with wooden joists	wooden flooring on wooden joists
f4	SR	timber floor with wooden joists	wooden flooring on wooden joists
f4	RR	timber floor with wooden joists	wooden flooring on wooden joists

Table 3.4 Section description of wall and floor sections used for the simulation analyses of the Original-Wall 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	lightweight wall, composite construction	75 mm-thick paper honeycomb (ø 4 mm) , 2x 12,5 mm gypsum board
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f3	SR	timber floor with wooden joists	wooden flooring on wooden joists
f3	RR	timber floor with wooden joists	wooden flooring on wooden joists
f4	SR	timber floor with wooden joists	wooden flooring on wooden joists
f4	RR	timber floor with wooden joists	wooden flooring on wooden joists

Table 3.5 Section description of wall and floor sections used for the simulation analyses of the Original-Wall 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	lightweight wall, composite construction	75 mm paper honeycomb (ø 4 mm), 2x triplex board
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f3	SR	timber floor with wooden joists	wooden flooring on wooden joists
f3	RR	timber floor with wooden joists	wooden flooring on wooden joists
f4	SR	timber floor with wooden joists	wooden flooring on wooden joists
f4	RR	timber floor with wooden joists	wooden flooring on wooden joists

Table 3.6 Section description of wall and floor sections used for the simulation analyses of the Original-Wall 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	lightweight wall, composite construction	30 mm-thick polyurethane foam (50 kg/m³) , 2x 5 mm-thick fibre concrete board
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f3	SR	timber floor with wooden joists	wooden flooring on wooden joists
f3	RR	timber floor with wooden joists	wooden flooring on wooden joists
f4	SR	timber floor with wooden joists	wooden flooring on wooden joists
f4	RR	timber floor with wooden joists	wooden flooring on wooden joists

Table 3.7 Section description of wall and floor sections used for the simulation analyses of the Original-Wall 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	lightweight wall, composite construction	30 mm-thick polyurethane foam (50 kg/m³) , 2x 9,5 mm-thick gypsum board
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x 5 mm- thick fibre concrete board
f3	SR	timber floor with wooden joists	wooden flooring on wooden joists
f3	RR	timber floor with wooden joists	wooden flooring on wooden joists
f4	SR	timber floor with wooden joists	wooden flooring on wooden joists
f4	RR	timber floor with wooden joists	wooden flooring on wooden joists

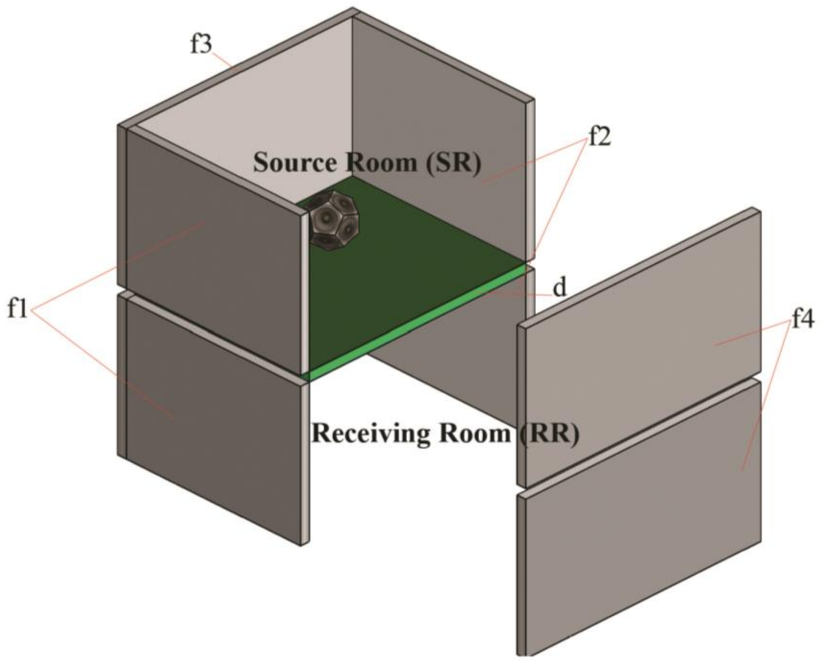


Figure 3.35 A modelling of TV-FR2 as a source room and TV-GR1 as a receiving room in Tahtacıörencik Village House analysed by BASTIAN to determine airborne and impact sound transmission characteristics of Original-Floor 4.

No difference was observed at performance of the floor when the wall components were changed, therefore one wall configuration was used for analysing of Original-Floor 4.

Table 3.8 Section description of wall and floor sections used for the simulation analyses of the Original-Floor 4 in BASTIAN.

	Room	Wall /Floor Element	Section Description
d	SR	timber floor with wooden joists	22 mm-thick chipboard on wooden joists
f1	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f1	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f2	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f2	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f3	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f3	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f4	SR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board
f4	RR	lightweight wall, composite construction	45 mm-thick expanded cork, 2x5 mm-thick fibre concrete board

3.4. LABORATORY ANALYSES

The laboratory analyses were conducted on original mud based materials collected from the non-repaired traditional buildings in Ankara and laboratory mudbrick samples prepared by remixing of the original mudbrick samples. The analyses were done to determine the basic physical properties, composition and raw material properties of the original samples and acoustical properties of the laboratory mudbrick samples in compatible with the original ones.

The sample preparation for the original mud-based materials and representative ones as well as the methods for the laboratory analyses are described under respective headings.

3.4.1 Sample Preparation

The original mud-based materials, such as mudbrick and mudmortar as infill material, were collected from the non-repaired traditional buildings. Two mudbrick samples were taken from two houses located in Kavaközü village in Güdül district (Ankara) which is three km away from Tahtacıörencik village. One mud infill sample was taken from the house in the centre of Beypazarı district (Ankara). The samples collected from those houses were labelled as shown in Table 3.9 and their positions are shown in Figure 3.36.

Table 3.9 The description of material samples with their codes collected from the traditional timber framed houses (The italic codes in parenthesis correspond with the ones given in Figure 3.36 and show the location where the samples were taken).

Sample Description	Beypazarı (By)	Güdül (Kavaközü village) (Kv)
Mud Brick (MB)	-	KvMB1(*p1*), KvMB2(*p2*)
Infill Mud Mortar (IM)	ByIM1(*p3*)	-

Figure 3.36 The locations where the material samples were taken from the traditional timber frame houses (A) and (B): in the village of Kavaközü with the door numbers 15 and 39 respectively; (C) in Beypazarı.

The laboratory samples were prepared by remixing the original mudbrick samples of KvMB1 and KvMB2 with water, and then were put into cylindrical moulds of 28mm diameter for the acoustical measurements in mid and high frequencies and 100mm diameter for the acoustical measurements of low frequencies. The set of samples in different diameters were moulded in varying thicknesses of 50mm and 100mm as shown in Figure 3.37 and Figure 3.38. Those thicknesses were determined in accordance with the layer thickness mudmortar, mudbrick infill within the timber framed wall and floor sections. The prepared samples were named as MB1 and MB2. In short, two sets of mudbrick samples, MB1 and MB2 in varying diameters and thicknesses, were prepared for the acoustical measurements. They were dried in the laboratory environment during three weeks. The dry state of the samples was controlled by the protimeter *Survey master* in terms of moisture content within the material. The compatibility of laboratory samples was checked in terms of their basic physical properties. The representative ones were selected among those laboratory samples which had physical properties compatible with the original ones, and then examined in terms of their sound transmission properties. For the analyses of sound absorption coefficient, the surface roughness of the sample should also be similar with the surface of original mudbrick. According to the similarity of macro views, among the representative samples, only the sample MB1-50 was representative the surface of original mudbrick and could be used for the analyses of sound absorption coefficient. The representative samples prepared in the laboratory for the acoustical analyses were listed in the Table 3.10.

Table 3.10 The number of the samples in varying thickness.

Diameter (mm)			28		100	
Thickness (mm)			50	100	50	100
		Samples				
Number of samples	Sound transmission analyses	MB1	2	2	2	2
		MB2	1		1	
	Sound absorption coefficient analyses	MB1	1		1	

Figure 3.37 MB1and MB2 samples.

The list of samples, their codes and the laboratory test conducted were given in Table 3.11. The materials characterization of original mudbrick samples collected from the traditional timber framed houses were done in terms of their basic physical, compositional/raw materials characteristics The mudbrick samples reproduced from the original material by remixing the sample with water were examined in terms of their basic physical properties, compositional and raw properties, acoustical properties.

Table 3.11 The list of samples, their codes and the laboratory test conducted.

Sample code	Sample Description	Basic Physical Properties					Compositional & Raw Properties		Acoustical Properties	
		Bulk density	Particle density	Porosity	Water vapour permeability	Grain size distribution	Silt clay content	Mineralogical composition	Sound transmission loss	Sound absorption coefficient
KvMB1	Mudbrick sample collected from the traditional timber framed house with no: 15 in Kavaközü village, Güdül.	+	+	+	+	+	+	+		
KvMB2	Mudbrick sample collected from the traditional timber framed house with no: 39 in Kavaközü village, Güdül.	+	+	+	+	+	+	+		
BYIM1	Mud infill mortar collected from the traditional timber framed house in Beypazarı.	+	+	+	+	+	+	+		
MB1	Mud sample prepared by remixing of KvMB1 sample with water.	+		+					+	+
MB2	Mud sample prepared by remixing of KvMB2 sample with water.	+		+					+	+

3.4.2 Determination of Basic Physical, Compositional & Raw Characteristics of Original Mud Based Samples

Some supportive laboratory analyses were done to determine physical and compositional characteristics of the mud based samples. Some basic physical characteristics of those samples were examined in terms of particle density (the density of solid particles only), bulk density (the density of the material including air voids), and porosity (ϕ), resistance to water vapour permeation (μ) and equivalent air layer thickness to water vapour permeation (SD). The raw materials analyses for the materials were carried out mainly to determine the silt-clay content, particle size distribution, and clay type, fibre content and mineralogical compositions.

The study on the material characterization of mud based samples of KvMB1, KvMB2 and ByIM with two related papers contributed to national project supported by METU Research Grant No. BAP-02-01-2013-003: Technological properties of building materials used in traditional timber framed in Ankara: Mud and Plaster (Meriç *et al.*, in press, Meriç *et al.*, 2013, Tavukçuoğlu *et al.*, 2013).

Particle density and bulk density values of samples were determined by using ASTM C127:2012 and ASTM D7263: standards respectively. The porosity values of samples were calculated according to following formula (RILEM,1980).

$$P = \frac{D_{Particle} + D_{Bulk}}{D_{Particle}} \quad \text{(Eq. 3.1)}$$

where P is porosity (%), $D_{Particle}$ is particle density and D_{Bulk} is bulk density in g cm^{-3}.

Water vapour permeability characteristics of mud brick and mortar were determined by using the standards Turkish Standard TS-prEN 7783-2:1999 in terms of equivalent air thickness of water vapour permeability (SD) and water vapour diffusion factor (μ). SD values below 0.14 m indicate high water vapour permeability of a material while SD values above 1.4 m indicate low water vapour permeability of a material. The SD values for the medium vapour permeability are defined in the range between 0.14m – 1.4m (TS-prEN 7783-2:1999).

For the determination of binder-aggregate ratio of earthen materials, clay and silt content of mud brick and infill mortar samples were examined with sieve analysis. The samples were kept in water. The fibre ingredient suspended in water was separated. After the drying out of the samples, they were sieved by using a set of sieves with specific sizes of 16mm, 8mm, 4mm, 2mm, 1mm, 0.500mm, 0.250mm, 0.125mm and 0.063mm. Particle size distribution of aggregates was evaluated according to the Udden and Wentworth scale (Tucker, 2009). After weighing the mass of the aggregate retained on each sieve, those aggregates were washed until clay and silt particles which might be adhered to their surfaces were removed. The weight losses for the aggregates sieved above 63μm size were added to the mass of the silt and clay content previously sieved below 63μm size. The mineralogical compositions of the mud brick, infill mortar, samples in powder were investigated by X-ray diffraction (XRD) instrument, *Bruker D8 Advance Diffractometer* with Sol X detector, using CuKα radiation, at 40 kV and 40 mA. The XRD traces and peak intensities were recorded at 2θ (incident ray angle) values from about 2º to70º by using the *DIFFRACT.SUITE software*. The fine aggregates with the diameters below 125μm and 63μm for infill mortar and mud brick samples, respectively, were examined to identify clay and silt minerals in them. For this purpose, the oriented samples of the clay constituents were prepared by wetting the powders below 125μm and 63μm with distilled water and then keeping it on the sample holder of XRD for its drying out at room temperature.

3.4.3 Determination of Sound Transmission Loss and Sound Absorption Characteristics of Mudbrick Samples Prepared in Laboratory

The prepared mud based samples of MB1 and MB2 were analysed to determine the values of the sound absorption coefficient (α) and transmission loss by using an impedance tube, also namely, "*Kundt Tube"* with a configuration composed of 2 microphones - transfer function method and transmission loss (TL) by using an impedance tube also stated as "TL tubes" configuration representing the tube arrangement scheme (4microphones method) (ASTM C384 – 04:2011; ASTM E1050 - 12; ISO 10534-2:2009; Hassan, 2009). The measurements were conducted by white noise generator in the frequency range from between 63Hz to-6300Hz in 1/3 octave bandwidth.

3.5 DETERMINATION OF OPENING EFFECT ON WALL

The composite sound reduction performances (Rwc) of the Reconstructed-Wall 1, Semi-Repaired-Wall 2 and Semi-Repaired-Wall 3 Original-Wall 4 walls with doors (D1, D2 and GD3) were calculated by using Eq.2.3 given in Section 2.5.1.2. The values of sound reduction index of door/window (Rw2), the surface area of the wall not including door/window (S1) and the surface area of the door (S2) were summarized in Table 3.12.The calculation was done in case that the type of the doors were accepted to be the hollow-core door without any gasket at the edge where the main frame and swing come together has 18dB of Rw value (Eagen, 1988; Hassan, 2009).

Table 3.12 S_1 values of the walls and R_{w2} and S_2 values of the doors.

Wall/ Door	Reconstructed –Wall 1	D1	Semi-Repaired-Wall 2	D2	Semi-Repaired-Wall 3	GD3	Original -Wall 4	D4
R_{w2} (dB)		18		18		18		18
S_1 (m^2)	28		23.3		10.8		25.4	
S_2 (m^2)		1.89		1.7		5.5		1.89

CHAPTER 4

RESULTS

4.1 IN-SITU DATA ON AIRBORNE SOUND TRANSMISSION CHARACTERISTICS THROUGH WALL AND FLOOR COMPONENTS

The in-situ weighted sound reduction index (R'w) data obtained for the floor and wall components were summarized in Table 4.1. According to the in-situ measurements, R'w values for Reconstructed-Wall 1, Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original-Wall 4 were found to be 28dB, 23dB, 24dB and 26dB, respectively. The Reconstructed-Wall 1 which had the thickest wall cross-section presented the highest R'w value .Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original-Wall 4 which had equal-thick sections indicated similar sound reduction performances. The in-situ R'w values for Reconstructed-Floor 1, Semi-Repaired-Floor 2, Semi-Repaired-Floor 3 and Original-Floor 4 were found to be 47 dB, 25 dB, 37 dB and 29 dB, respectively. The Reconstructed-Floor 1 which had the thickest cross-section presented the highest sound reduction performance while the lowest Rw value was found for the Semi-Repaired-Floor 2 which had the hole within the section. The presence of hole was estimated to reduce sound insulation performances about 12 dB.

Table 4.1 The in-situ R'w data of Reconstructed-Wall 1, Semi-Repaired-Wall 2, Semi-Repaired-Wall 3and Original- Wall 4; Reconstructed-Floor 1 , Semi-Repaired-Floor 2, Semi-Repaired- Floor 3 and Original- Floor 4.

In-Situ Acoustical Measurement		
Analysis	Airborne Sound Transmission	
Component	Wall	Floor
Single number ratings (ISO717:2013)	R’w (dB)	R’w (dB)
W1-BE-FR1/R2	28	
W2-BK-FR/R3	23	
W3-BK-FR3/R4	24	
W4-TV-FR1/FR2	26	
F1-BE-FR1/MR3 w/carpet		47
F2-BK-FR3/GR1 w/carpet		25
F3-BK-FR2/GR1 w/carpet		37
F4-TV-FR2/GR1 w/carpet		29

The in-situ, sound reduction index (R’) data obtained for the wall and floor components were indicated in Figure 4.1 and Figure 4.2. According to the in-situ measurement, R’ values for Reconstructed-Wall 1, Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original-Wall 4 were found to be between 12 dB and 29 dB. The Reconstructed-Wall1 presented the highest sound reduction between 100Hz and 1250 Hz. Above 1250 Hz, Original- Wall 4 continuously increasing presented the highest performance. According to the in-situ measurement, R’ values for Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original-Wall were found to between 13 dB and 64 dB. The Reconstructed-Floor 1 presented the highest R’ values above 160 Hz.

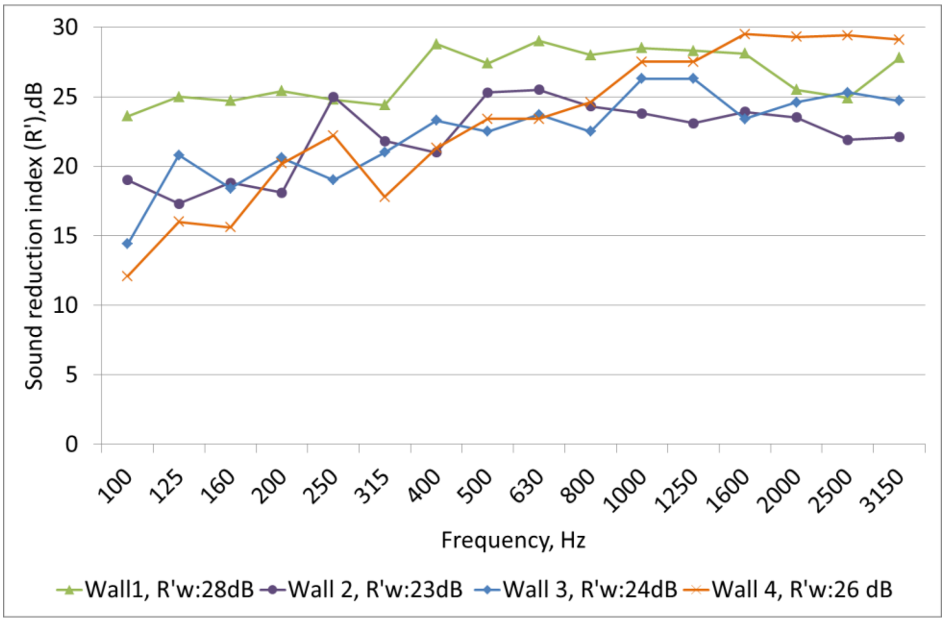


Figure 4.1 The in-situ R' data of Reconstructed-Wall 1, Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original- Wall 4

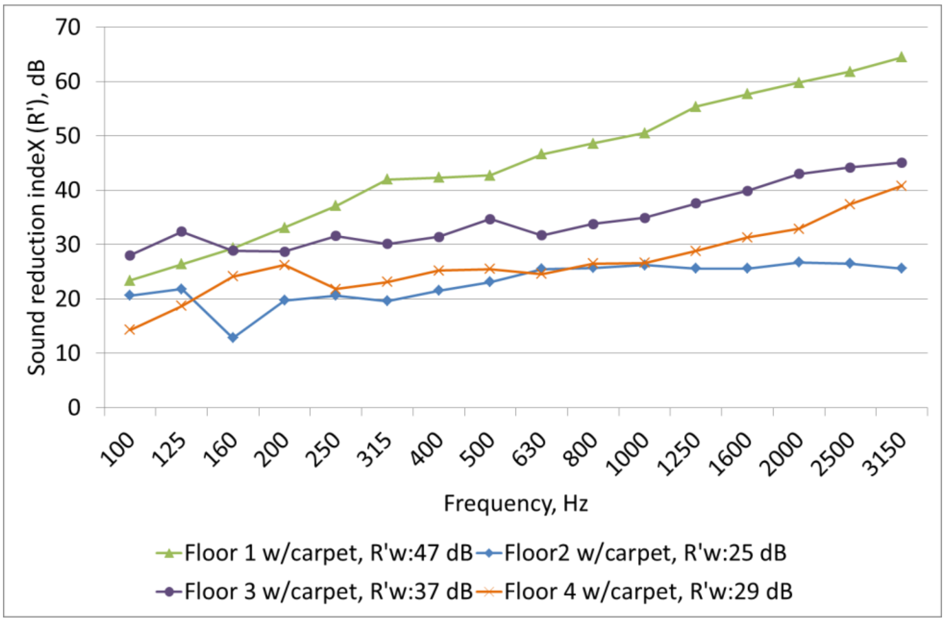


Figure 4.2 The in-situ data R' values of Reconstructed-Floor 1, Semi-Repaired-Floor 2, Semi-Repaired- Floor 3 and Original- Floor 4.

4.2 IN-SITU DATA ON IMPACT SOUND TRANSMISSION CHARACTERISTICS THROUGH THE FLOOR COMPONENTS

The in-situ weighted impact sound pressure level sound level (L'nw) data obtained for the floor components were summarized in Table 4.2 Impact insulation class (IIC) values were also added to the table. According to the in-situ measurements, L'nw values for Reconstructed-Floor 1 w/carpet, Reconstructed-Floor 1 w/out carpet, Semi-Repaired-Floor 2 w/carpet, Semi-Repaired- Floor 3 w/carpet and Original-Floor 4 w/carpet were found to be 68dB, 76dB, 75 dB and 77 dB and 69 dB, respectively. Reconstructed-Floor 1 w/carpet which has the thickest floor section and Original-Floor 4 w/carpet which has the thinnest floor section indicated similar L'nw values. The presence of carpet was estimated to improve sound insulation performances about 7 dB.

Table 4.2 The in-situ L'nw and IIC data of Reconstructed-Floor 1, Semi-Repaired-Floor 2, Semi-Repaired- Floor 3 and Original- Floor 4.

In-Situ Acoustical Measurement		
Analysis	Impact Sound Transmission	
Component	Floor	
Single number ratings (ISO717:2013)	L'nw (dB)	IIC (dB)
F1-BE-FR1/MR3 w/carpet	68	42
F1-BE-FR1/MR3 w/out carpet	75	35
F2-BK-FR3/GR1 w/carpet	76	34
F3-BK-FR2/GR1 w/carpet	77	33
F4-TV-FR2/GR1 w/carpet	69	41

The in-situ, impact sound level (Ln') data obtained for the floor components were indicated in Figure 4.3 and Figure 4.4. According to the in-situ measurements, Reconstructed-Floor 1 w/carpet and Original-Floor 4 w/carpet indicated similar performance between 250 and 630 Hz. The contribution of the carpet to Reconstructed-Floor 1 was observed at L'n values above 200 Hz.

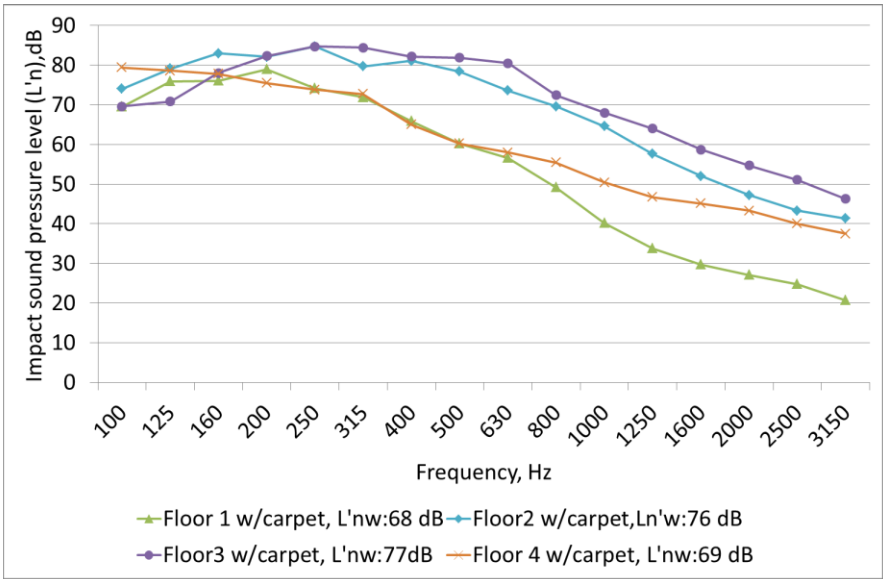


Figure 4.3 The in-situ L'n data of Reconstructed-Floor 1, Semi-Repaired-Floor 2, Semi-Repaired- Floor 3 and Original- Floor 4.

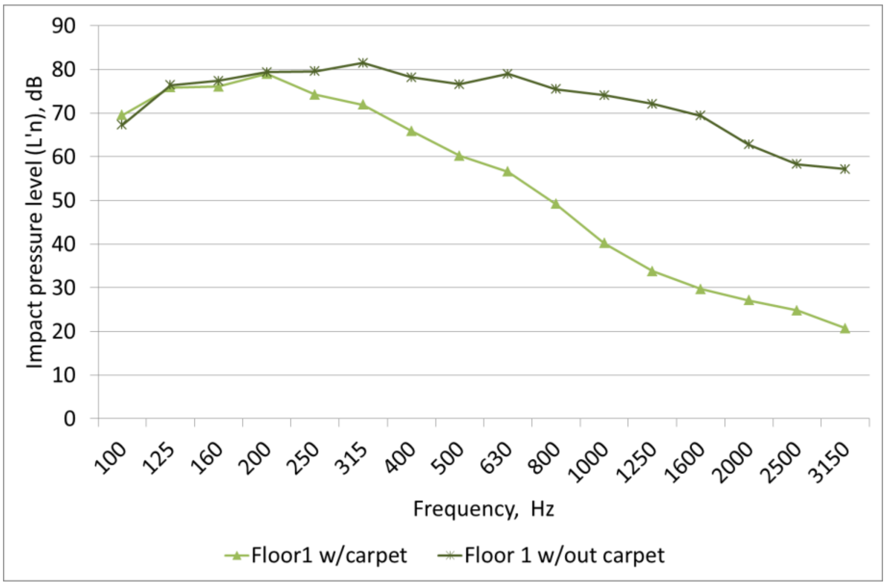


Figure 4.4 The in-situ L'n data of Reconstructed-Floor 1 w/carpet and Reconstructed-Floor 1 w/out carpet.

4.3 ESTIMATED DATA ON SOUND TRANSMISSION CHARACTERISTICS OF WALL AND FLOOR COMPONENTS

The estimated Rw and Lnw data obtained by the INSUL and BASTIAN analyses for the existing wall and floor components and the proposed configurations as well as the calculated Rw values for the existing walls with and without openings are given under respective subheading.

4.3.1 The Estimated Rw and Lnw Data Obtained for Existing Wall and Floor Components

The simulation results on Rw and R'w, data obtained for the existing wall are summarized in Table 4.3. According to the INSUL analyses, the estimated Rw values for Reconstructed-Wall 1, Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original-Wall 4 were found to be 50dB, 45dB, 45dB and 42-44dB, respectively. Rw values for the same walls together with openings were found to be 27dB, 24dB, 25dB and 28dB, respectively. The presence of door and window openings decreased the sound insulation performance of wall section in the range of 13dB and 23dB. According to the BASTIAN analyses, the estimated R'w values for Reconstructed-Wall 1, Semi-Repaired-Wall 2, Semi-Repaired-Wall 3 and Original-Wall 4 were found to be 29-37dB, 28-38dB, 29-36dB and 28-35dB, respectively. The occurrence of flanking transmission was estimated to reduce sound insulation in wall section in the range of 6dB and 21dB.

Table 4.3 The estimated R'w and Rw data obtained from the INSUL and BASTIAN simulation analyses for Reconstructed-Wall 1, Semi-Repaired-Wall 2 Semi-Repaired-Wall 3 and Original- Wall 4.

Analyses	Simulation Analyses		
	INSUL		BASTIAN
Component	SOLID WALL	COMPOSITE WALL (SOLID WALL +OPENINGS)	SOLID WALL
Single number ratings (ISO717:2013)	Rw (dB)	Rw (dB)	R'w (dB)
W1-BE-FR1/R2	50	27	29-37
W2-BK-FR/R3	45	24	28-38
W3-BK-FR3/R4	45	25	29-36
W4-TV-FR1/FR2	42-44	28	28-35

The simulation results on Rw, R'w, Lnw and L'nw data obtained for the existing floor components are summarized in Table 4.4. According to the INSUL analyses, the estimated Rw values for Reconstructed-Floor 1, Semi-Repaired-Floor 2, Semi-Repaired-Floor 3 and Original-Floor 4 were found to be 46dB, 39dB, 39dB and 32dB, respectively. Lnw values for the same floors were found to be 74dB, 76dB, 76dB and 85dB. According to the BASTIAN analyses, the estimated R'w values for Semi-

Repaired-Floor 2, Semi-Repaired-Floor 3 and Original-Floor 4 were found to be 34 dB, 35 dB and 28 dB, respectively. Lnw values for the same floors were found to be 80dB, 80dB, and 91dB respectively. The occurrence of flanking transmission was estimated to reduce sound insulation in wall section in the range of 2dB and 5dB. The outputs of the INSUL and BASTIAN simulation analyses are given between Appendix D and Appendix G.

Table 4.4 The estimated R'w, Rw, Lnw and L'nw data obtained from the INSUL and BASTIAN simulation analyses for Reconstructed-Floor 1 , Semi-Repaired-Floor 2, Semi-Repaired- Floor 3 and Semi-Repaired- Floor 3.

Analyses	Simulation Analyses			
	INSUL		BASTIAN	
Component	FLOOR		FLOOR	
Single number ratings (ISO717:2013)	Rw (dB)	Lnw (dB)	Rw (dB)	Ln'w (dB)
F1-BE-FR1/MR3 w/out carpet	46	74	NA	NA
F2-BK-FR3/GR1 w/out carpet	39	76	34	80
F3-BK-FR2/GR1 w/ out carpet	39	76	35	80
F4-TV-FR2/GR1 w/out carpet	32	85	28	91

4.3.2 The Calculated Rw Data Obtained for Composite Walls

The composite sound reduction (Rwc) performances of the Reconstructed-Wall 1, Semi-Repaired-Wall 2/3 and Original-Wall 4 were calculated by using Eq.2.3 and the values given in Table3.12. The results were given in Table 4.5. The adverse effect of the door openings to solid wall performances was found be to in the ranges of 15-21dB.

Table 4.5 The composite sound reduction (Rwc) performances of the walls.

Wall	Reconstruted-Wall 1	Semi-Repaired-Wall 2	Semi-Repaired-Wall 3	Original-Wall 4
Rwc, dB	30	24	26	29

4.3.3. The Estimated Rw and Lnw Data Obtained for Proposed Wall and Floor Configurations

The sound reduction index values of the proposals with 60mm-thick single-sided dry wall configurations were summarized in Figures 4.5 to 4.7. Improvements at sound reduction performance provided by the proposals of the walls were given in Figures 4.8 to 4.10 .The outputs of the INSUL simulation analyses for the all proposal of the walls are given in Appendix 4-5. The results of proposals for the infill part of timber-framed wall sections were summarized below:

- All interventions suggested here (B to H) provided timber-framed wall sections with Rw value above 50dB, in the range of 54dB to 76dB. This meant that the treated walls have sufficient sound reduction performances.
- The A_W interventions including single wood framing with one layer gypsum board without sound insulation infill provided the improvement about 3 dB. The adding of the 60 mm–thick sound absorbing infill material increased the performance of the walls about 6 dB as shown in B_W interventions (see Figures 4.5 to 4.10).
- The highest performance among dry-wall application methods was provided by separate wood /metal framing. The improvement at Rw value of the walls was with an average 18 dB. Adhesive attachment system without any use of fixing material between gypsum board facing and sound insulation infill also showed similar performance to double wood /metal framing (see the proposals of E_W, E_W' and F_W in Figures 4.5 to 4.10).

- The second highest performance was provided by resilient channel or rubber isolation clip and the lowest performance was supported by single metal/wood framing (see the proposals of B_{W}, B_{W}', C_{W}, C_{W},' D_{W} and D_{W}' in Figures 4.5 to 4.10).
- The single metal framings indicated higher sound reduction performance than single wood framings. (see the difference between the proposals of B_{W}&,B_{W}' in Figures 4.5 to 4.10).
- The use of resilient channel and the rubber isolation clip between panel and the wood/metal framing provided similar sound reduction performance to each other (see the difference between the proposals of C_{W}& D_{W}, C_{W}'&D_{W}').
- The use of resilient channel or the rubber isolation clip with single wood framing performance provided higher sound reduction than with single metal framing system The use of resilient channel and rubber isolation clip together with single wood framing provided with an average of 7dB improvement (see the difference between the proposals of B_{W} and C_{W}, D_{W}), the use of them together with single metal framing increased about 2 dB (see the difference between the proposals of B_{W}'and C_{W}, D_{W}').
- Doubling of the gypsum board layer at wall sections composed of double wood/metal framing systems provided significant improvement 6 dB at Rw value (see the difference between the proposals of E_{W}&G_{W}; E_{W}'&G_{W}').
- The use of resilient layer between double layers of gypsum boards provided 5dB improvement (see the proposals of G_{W} and H_{W}).

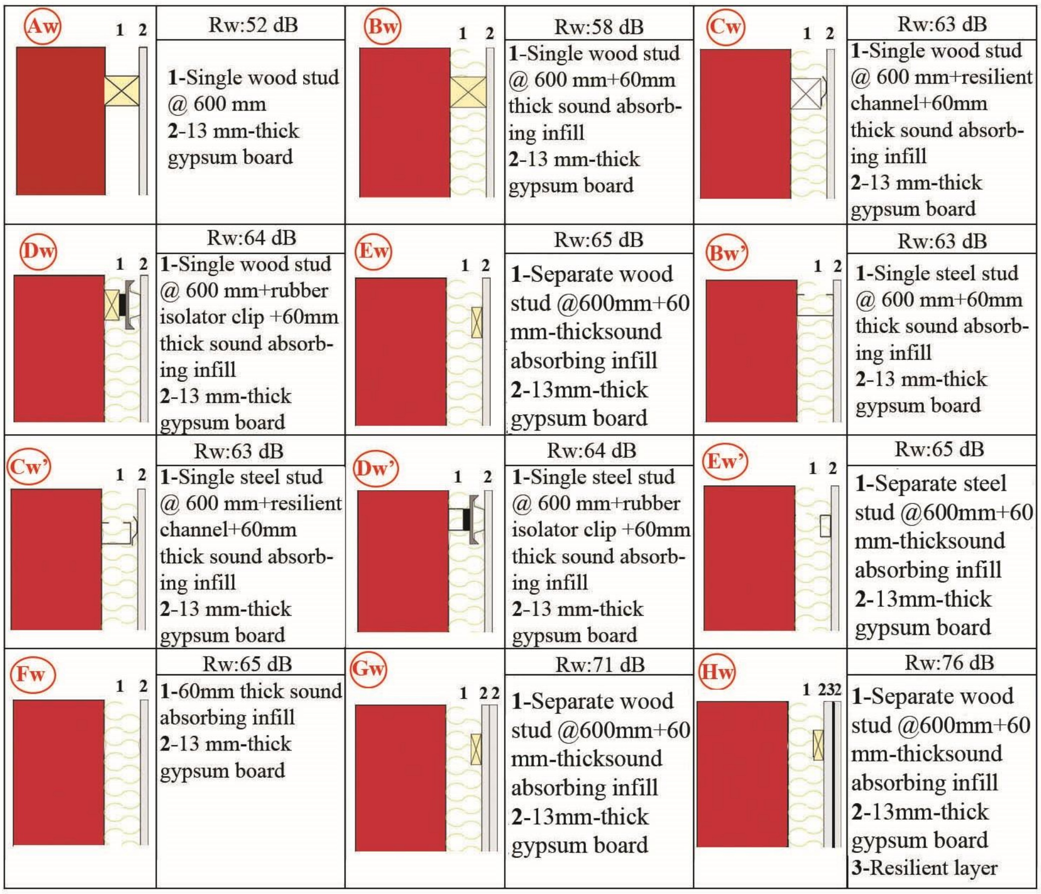


Figure 4.5 The sound reduction index (Rw) values of the proposals with 60mm-thick single-sided dry wall configurations for Reconstructed-Wall 1.

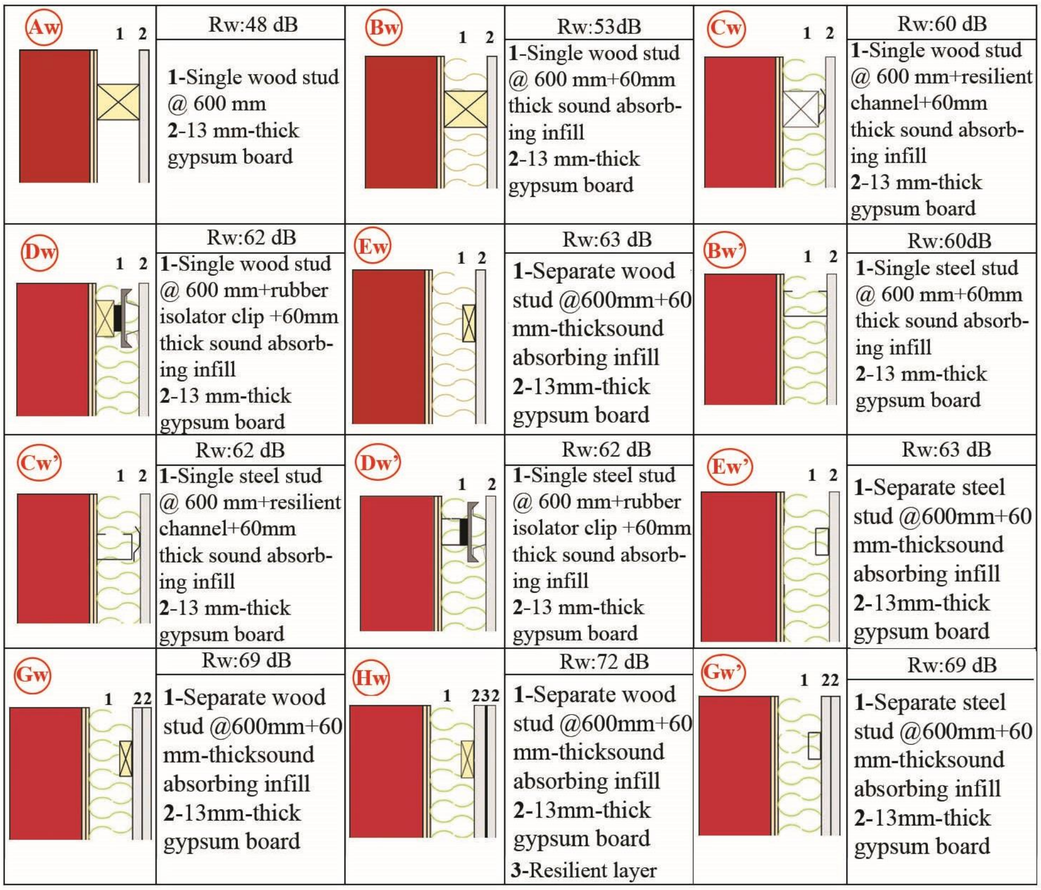


Figure 4.6 The sound reduction index (Rw) values of the proposals with 60mm-thick single-sided dry wall configurations for the Semi-Repaired-Wall 2 /Wall 3.

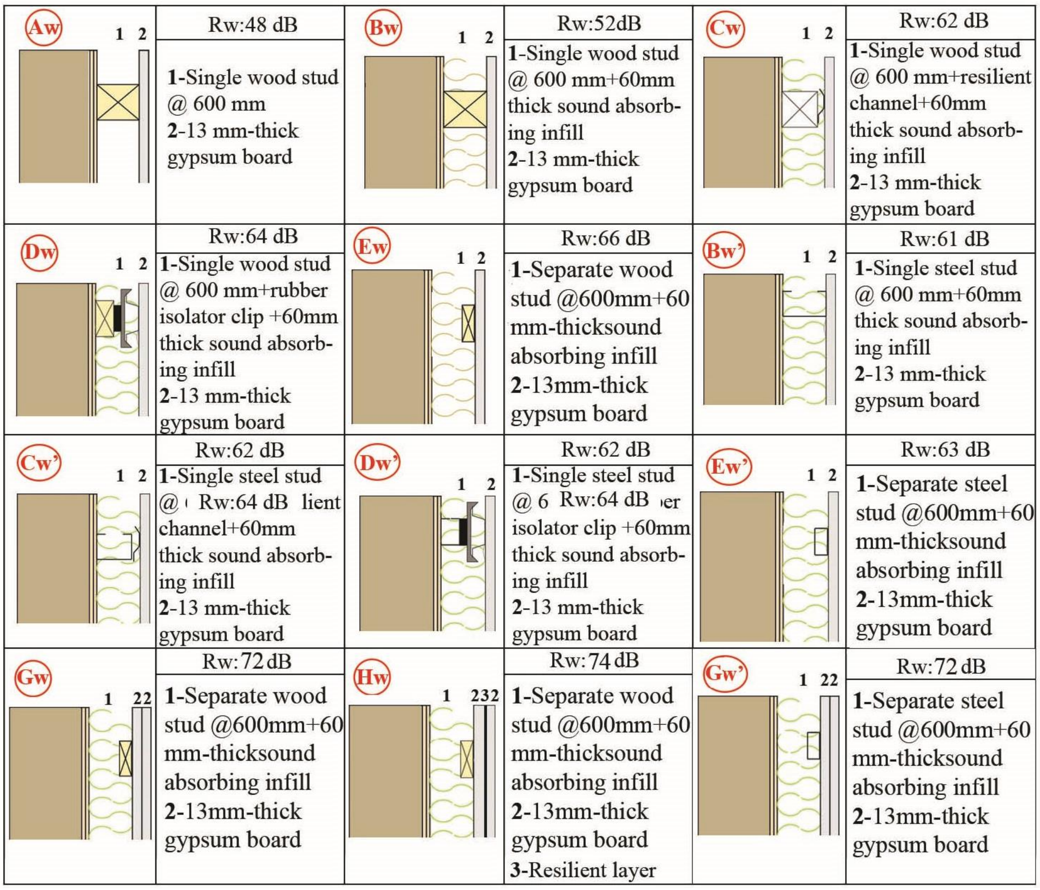


Figure 4.7 The sound reduction index (Rw) values of the proposals with 60mm-thick single-sided dry wall configurations for Original-Wall 4.

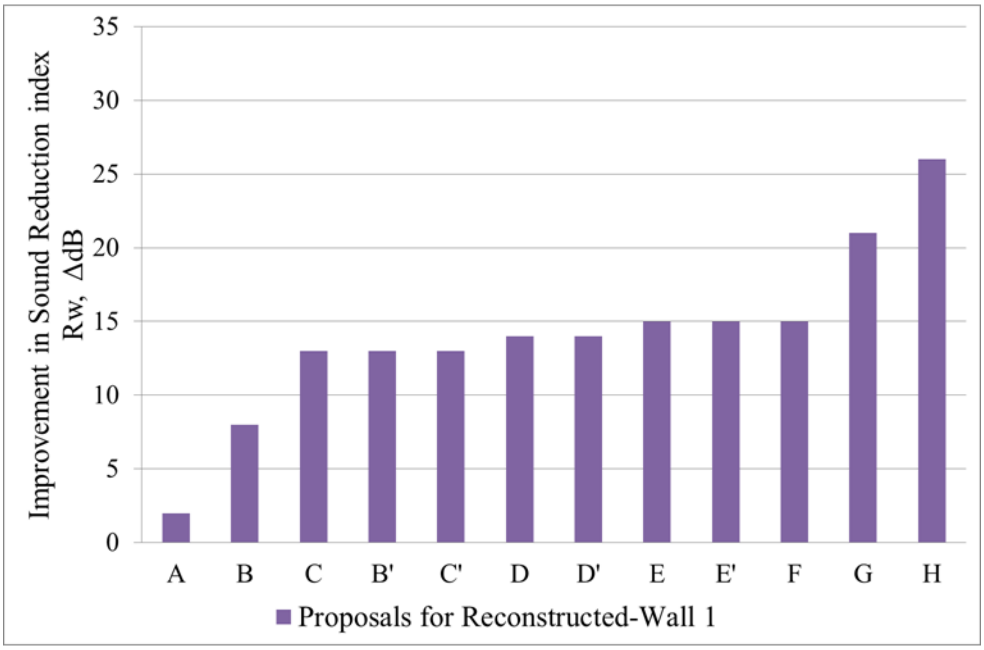


Figure 4.8 Improvement in sound reduction index of the proposals for Reconstructed-Wall 1.

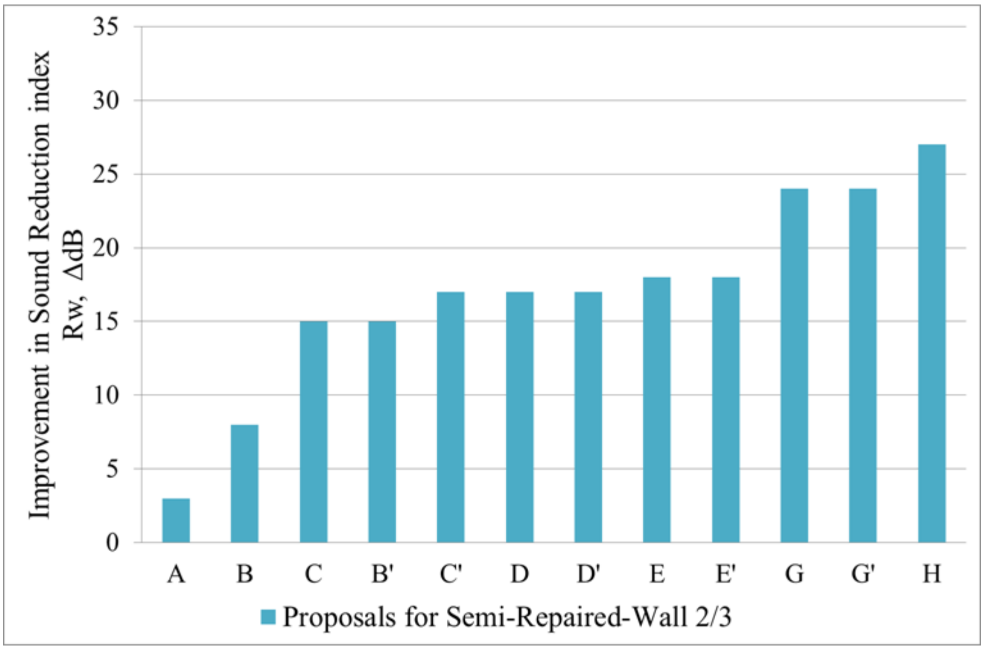


Figure 4.9 Improvement in sound reduction index of the proposals for Semi-Repaired Wall 2/3.

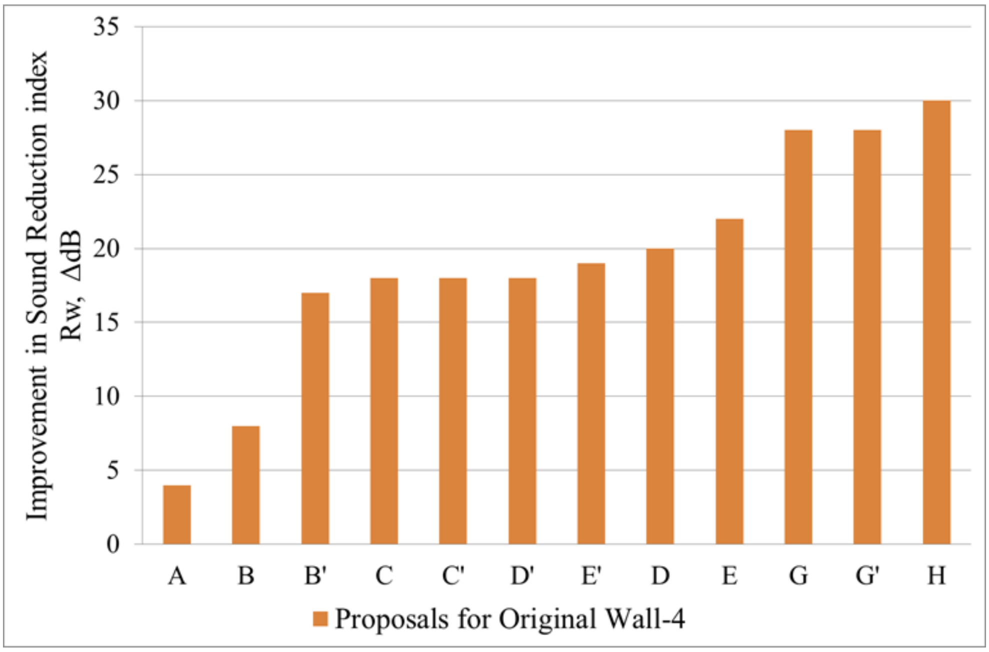


Figure 4.10 Improvement in sound reduction index of the proposals for Original-Wall 4.

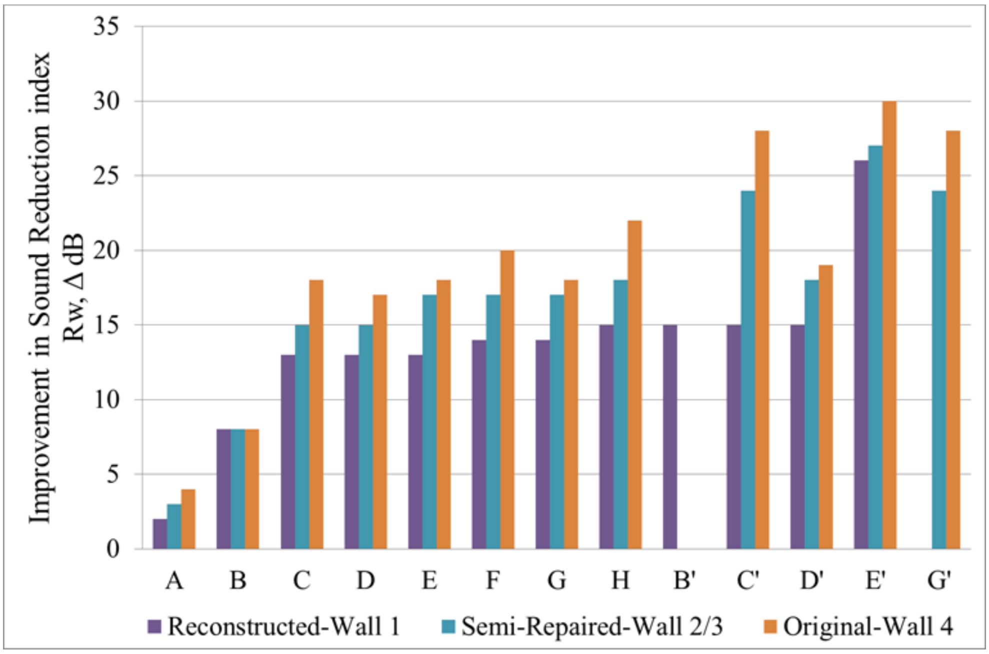


Figure 4.11 Improvement in sound reduction index of the proposals for Reconstructed-Wall 1, Semi-Repaired Wall 2/3 and Original-Wall 4.

The sound reduction index (Rw) and impact sound level (Lnw) values of the floor proposals were summarized in Figures 4.12 to 4.14.

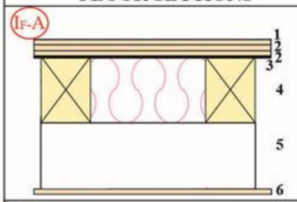
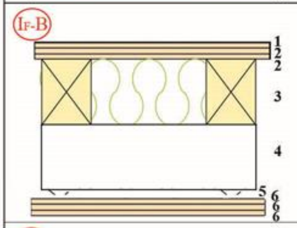
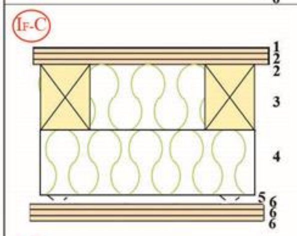
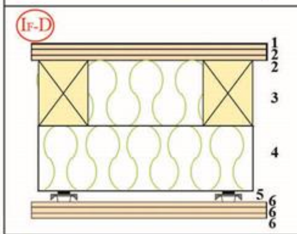
FLOOR SECTIONS	SECTION DESCRIPTION	Rw, dB	Lnw,dB
	1- 17 mm-thick pine flooring layer 2- 20 mm-thick plywood 3-2.8 mm-thick resilient layer 4-150 mm x 200 mm solid wood joist @ 500 mm w/ 200 mm-thick mineral fibre infill 5-150 mm x 200 mm solid wood joist @ 450 mm 6-17 mm-thick pine ceiling board	49	62
	1- 17 mm-thick pine flooring layer 2- 20 mm-thick plywood 3-150 mm x 200 mm solid wood joist @ 500 mm w/ 200 mm-thick mineral fibre infill 4-150 mm x 200 mm solid wood joist @ 450 mm 5- Resilient channels @ 500mm 6-17 mm-thick pine ceiling board	53	63
	1- 17 mm-thick pine flooring layer 2- 20 mm-thick plywood 3-150 mm x 200 mm solid wood joist @ 500 mm w/ 200 mm-thick mineral fibre infill 4-150 mm x 200 mm solid wood joist @ 450 mm w/ 200 mm-thick mineral fibre infill 5-Resilient channels @ 500mm 6- 17 mm-thick pine ceiling board	53	63
	1- 17 mm-thick pine flooring layer 2- 20 mm-thick plywood 3-150 mm x 200 mm solid wood joist @ 500 mm w/ 200 mm-thick mineral fibre infill 4-150 mm x 200 mm solid wood joist @ 450 mm w/ 200 mm-thick mineral fibre infill 5-Rubber isolation clip @ 450 mm 6-17 mm-thick pine ceiling board	53	63

Figure 4.12 The sound reduction index (Rw) and impact sound level (Lnw) values of the proposals for Reconstructed-Floor 1.

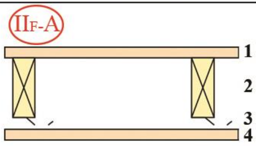
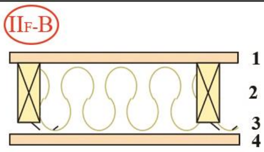
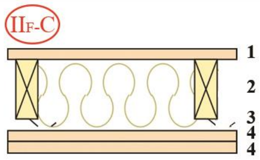
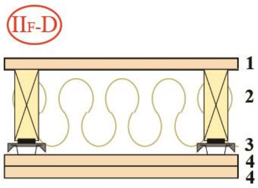
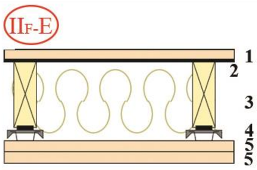
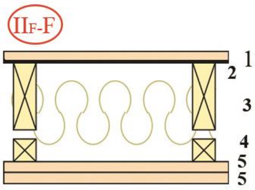
FLOOR SECTION	SECTION DESCRIPTION	Rw, dB	Lnw, dB
IIF-A 	1- 25 mm-thick pine flooring layer 2- 50 mm x 150 mm solid wood joist @ 400 mm 3-Resilient channel @ 400 mm 4-25 mm-thick pine ceiling board	46	72
IIF-B 	1- 25 mm-thick pine flooring layer 2- 50 mm x 150 mm solid wood joist @ 400 mm w/ 150 mm-thick mineral fibre infill 3-Resilient channel @ 400 mm 4-25 mm-thick pine ceiling board	54	62
IIF-C 	1- 25 mm-thick pine flooring layer 2- 50 mm x 150 mm solid wood joist w/ 150 mm-thick mineral fibre infill @ 400 mm 3-Resilient channel @ 400 mm 4-25 mm-thick pine ceiling board	58	61
IIF-D 	1- 25 mm-thick pine flooring layer 2- 50 mm x 150 mm solid wood joist w/ 150 mm-thick mineral fibre infill @ 400 mm 4-Rubber isolation clip @ 400 mm 4-25 mm-thick pine ceiling board	57	59
IIF-E 	1- 25 mm-thick pine flooring layer 2- 2.8 mm-thick resilient layer 3- 50 mm x 150 mm solid wood joist @ 400 mm w/ 150 mm-thick mineral fibre infill 4-Rubber isolation clip @ 400 mm 5-25 mm-thick pine ceiling board	61	47
IIF-F 	1- 25 mm-thick pine flooring layer 2- 2.8 mm-thick resilient layer 3- 50 mm x 150 mm solid wood joist @ 400 mm w/ 150 mm-thick mineral fibre infill 4-50 mm x 50 mm separate wood joist @ 400 mm 5-25 mm-thick pine ceiling board	72	35

Figure 4.13 The sound reduction index (Rw) and impact sound level (Lnw) values of the proposals for Semi-Repaired-Floor 2/3

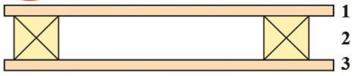
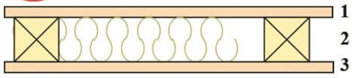
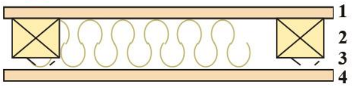
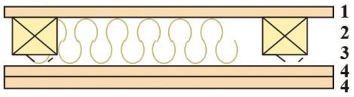
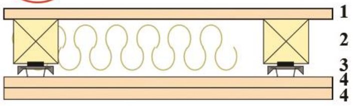
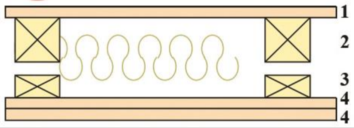
FLOOR SECTION	SECTION DESCRIPTION	Rw,dB	Lnw,dB
IIIF-A 	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm 3-25 mm-thick pine ceiling board	40	77
IIIF-B 	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm w/ 100 mm-thick mineral fibre infill 3-25 mm-thick pine ceiling board	41	74
IIIF-C 	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm w/ 100 mm-thick mineral fibre infill 3- Resilient channel @ 400 mm 4-25 mm-thick pine ceiling board	53	63
IIIF-D 	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm w/ 100 mm-thick mineral fibre infill 3- Resilient channel @ 400 mm 4-25 mm-thick pine ceiling board	57	61
IIIF-E 	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm w/ 100 mm-thick mineral fibre infill 3- Rubber isolation clip @ 400 mm 4-25 mm-thick pine ceiling board	61	59
IIIF-F 	1- 25 mm-thick pine flooring layer 2-100 mm x 100 mm solid wood joist @ 560 mm w/ 100 mm-thick mineral fibre infill 3- 50 mm x 50 mm separate wood joist @ 560 mm 4-25 mm-thick pine ceiling board	67	49

Figure 4.14 The sound reduction index (Rw) and impact sound level (Lnw) values of the proposals for Original-Floor 4.

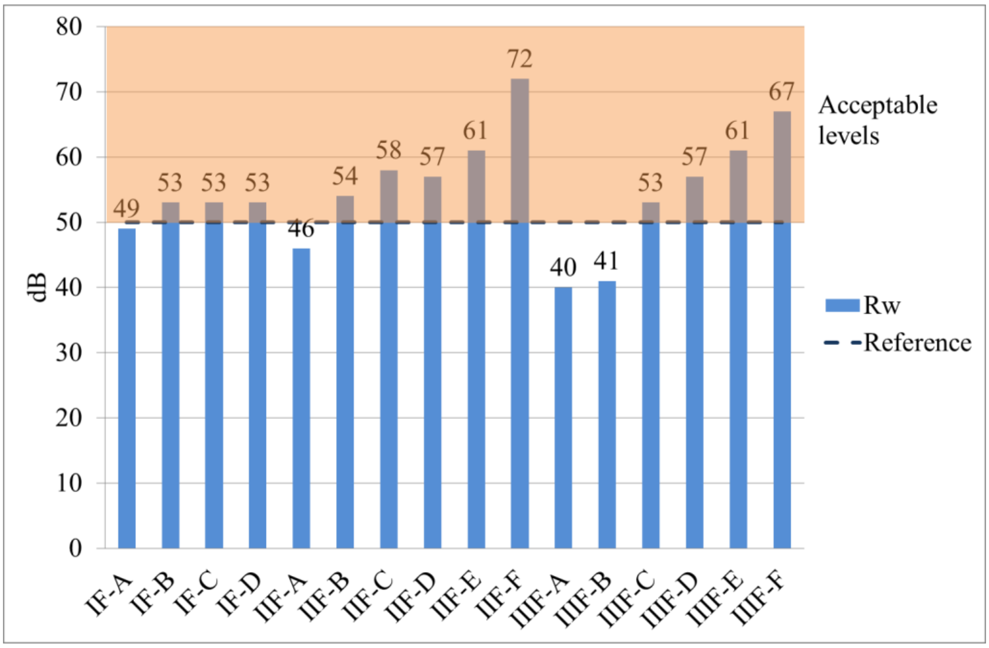


Figure 4.15 Sound reduction index (Rw) values of the proposals for Reconstructed-Floor 1, Semi-Repaired-Floor 2/3 and Orginal-Floor 4.

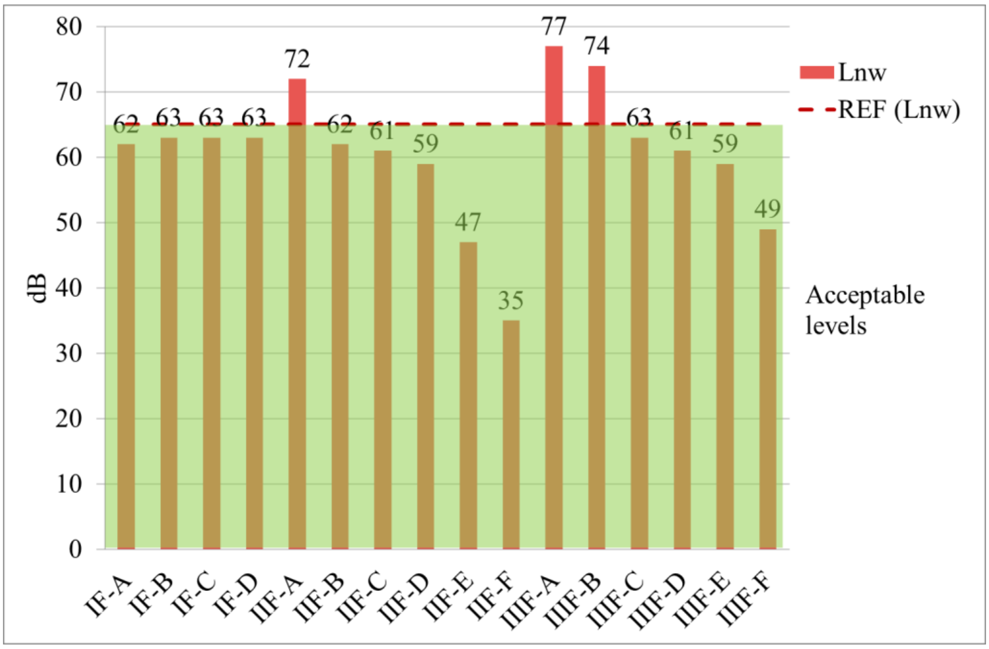


Figure 4.16 Weighted impact sound level (Lnw) values of the proposals for Reconstructed-Floor 1, Semi-Repaired-Floor 2/3 and Original-Floor 4.

Improvements in sound reduction performance provided by the proposals for the floors were given in Figures 4.17.and in Table 4.6.

Table 4.6 Improvement in Rw and Lnw values of the proposals for Reconstructed-Floor 1, Semi-Repaired-Floor 2/3 and Orginal-Floor 4.

Intervention		Improvement in dB		Cases in comparison
		Rw	Lnw	
APPLICATION OF SEPARATED JOISTS (within the floor section w/ 100 mm-thick or 150 mm-thick sound absorbing infill, respectively)	**Ab+i**	**20**	**19**	III_F-B & Figure F.47-48
	Ab+i	**23**	**23**	Figure F.23-24 & Figure F.27-28
APPLICATION OF SEPARATED JOISTS (within the non-insulated floor section)	**Bb**	**9**	**7**	Semi-Repaired-Floor 2/3& Figure F.25-26
	Bb	**7**	**5**	III_F-A & Figure F.45-46
USE OF RESILIENT LAYER underneath the wooden subfloor (added to the insulated floor section)	**Cb**	**3**	**12**	I_F-A & Reconstructed-Floor 1
	Cb	**4**	**12**	II_F-D & II_F-E
ADDITION OF THE CEILING BOARD (directly attached to the joists w/out sound absorbing infill in between)	**D**	**10**	**8**	III_F-A & Original-Floor 4
DOUBLING THE WOOD CEILING BOARD (attached w/ resilient channel to the insulated floor section)	**Ei+b**	**4**	**1**	II_F-B & II_F-C
	Ei+b	**4**	**2**	III_F-C & III_F-D
USE OF RUBBER ISOLATION CLIPS (for fixing the ceiling board to the floor section w/ 100 mm-thick or 150 mm-thick sound absorbing infill, respectively)	**Fb+i**	**13**	**12**	III_F-A & Figure F.43-44
	Fb+i	**13**	**14**	Figure F.23-24 & Figure F.29-30
USE OF RUBBER ISOLATION CLIPS (for fixing the ceiling board to the non-insulated floor section)	**Gb**	**7**	**5**	Semi-Repaired-Floor 2/3- Figure F.21-22
	Gb	**5**	**3**	III_F-A & Figure F.49-50
USE OF RESILIENT CHANNEL (for fixing the ceiling board to the floor section w/ 100 mm-thick or 150 mm-thick sound absorbing infill, respectively)	**Hb+i**	**12**	**11**	III_F-B & III_F-C
	Hb+i	**14**	**13**	Figure F.23-24 & II_F-A
USE OF RESILIENT CHANNEL (for fixing the ceiling board to the non-insulated floor section)	**Ib**	**7**	**4**	II_F-A & Semi-Repaired-Floor 2/3
USE OF SOUND ABSORBING INFILL (150 mm-thick – within the floor section w/resilient channel	**Ji+b**	**8**	**10**	II_F -A and II_F -B
USE OF SOUND ABSORBING INFILL (150 mm-thick – within the floor section w/out resilient channel)	**Ki**	**1**	**1**	Semi-Repaired-Floor 2/3 & Figure F.23-24

Improvement Scale in dB	**1-3**	**4-6**	**7-9**	**11-12**	**13-15**	**16-18**	**19-21**	**22-24**

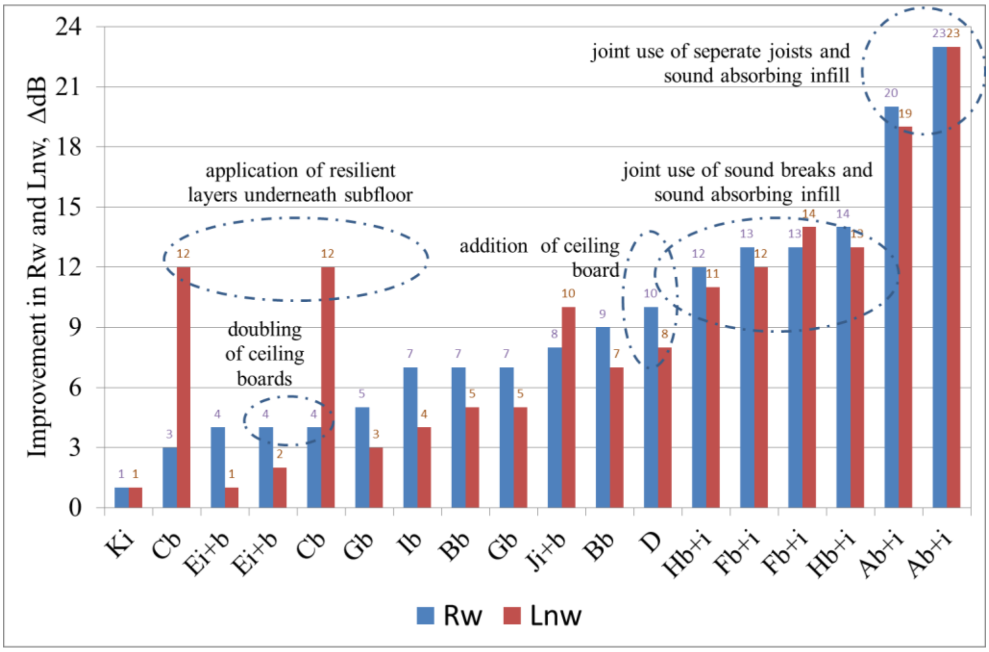


Figure 4.17 Improvement in Rw and Lnw values of the proposals for Reconstructed-Floor 1, Semi-Repaired-Floor 2/3 and Original-Floor 4.

4.4 SOUND TRANSMISSION LOSS AND SOUND ABSORPTION PROPERTIES OF MUDBRICK SAMPLES PREPARED IN LABORATORY

Here, the sound transmission properties of the mudbrick laboratory samples were given in terms of sound transmission loss (TL) in 1/3 octave frequency band, sound transmission class (STC), mass law frequency ranges and noise reduction coefficient (NRC) in 1/1 octave frequency band.

The sound transmission loss (TL) and sound transmission class (STC) values of laboratory samples were summarized in Figures 4.18 to 4.20. The sound transmission loss values of the samples shown in Figure 4.18 were between 18 dB and 43 dB. Below 1600 Hz, 100mm-thick MB samples presented the higher transmission loss, while above 1600Hz, 50mm-thick MB1 samples presented the higher transmission loss. Sound transmission class (STC) values were calculated to be within the range of 27 dB and 36 dB by using similar calculation method to find Rw value that was given in Section 2.3.The STC values for the 50mm-thick and 100mm-thick mudbrick samples were found to be 28 dB ±2 dB and 35 dB ±1dB, respectively. The 100mm-thick samples provided higher sound reduction than 50mm-thick mudbrick samples.

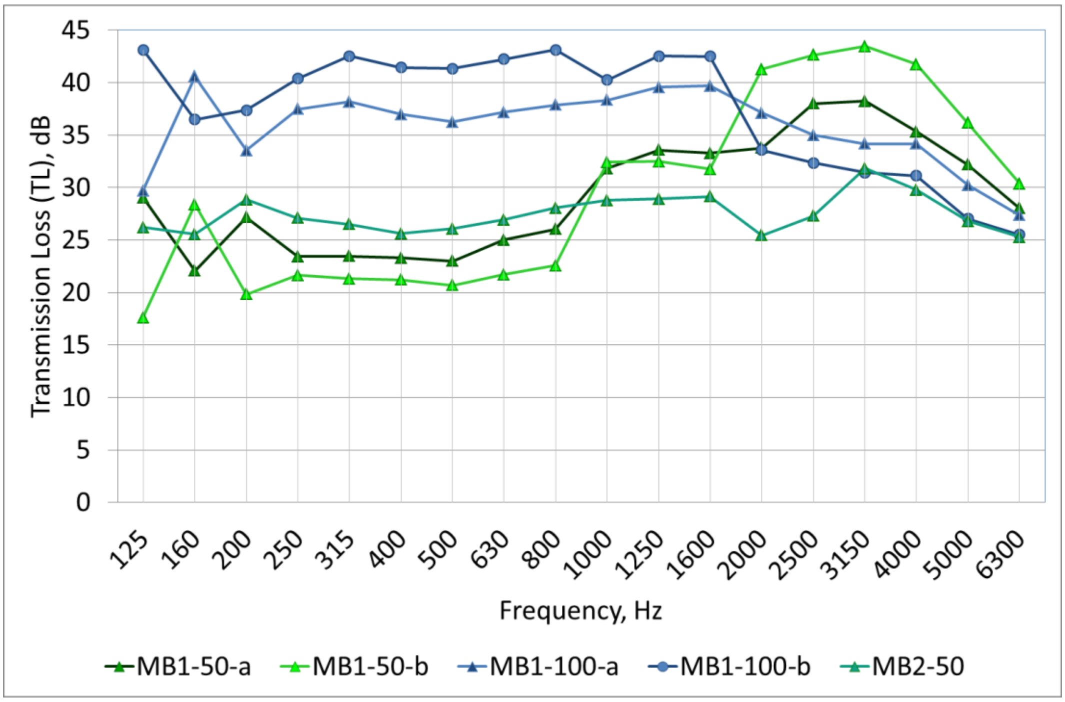


Figure 4.18 TL values of MB1-50-a, MB1-50-b, MB1-100-a, MB1-100-b and MB2-50.

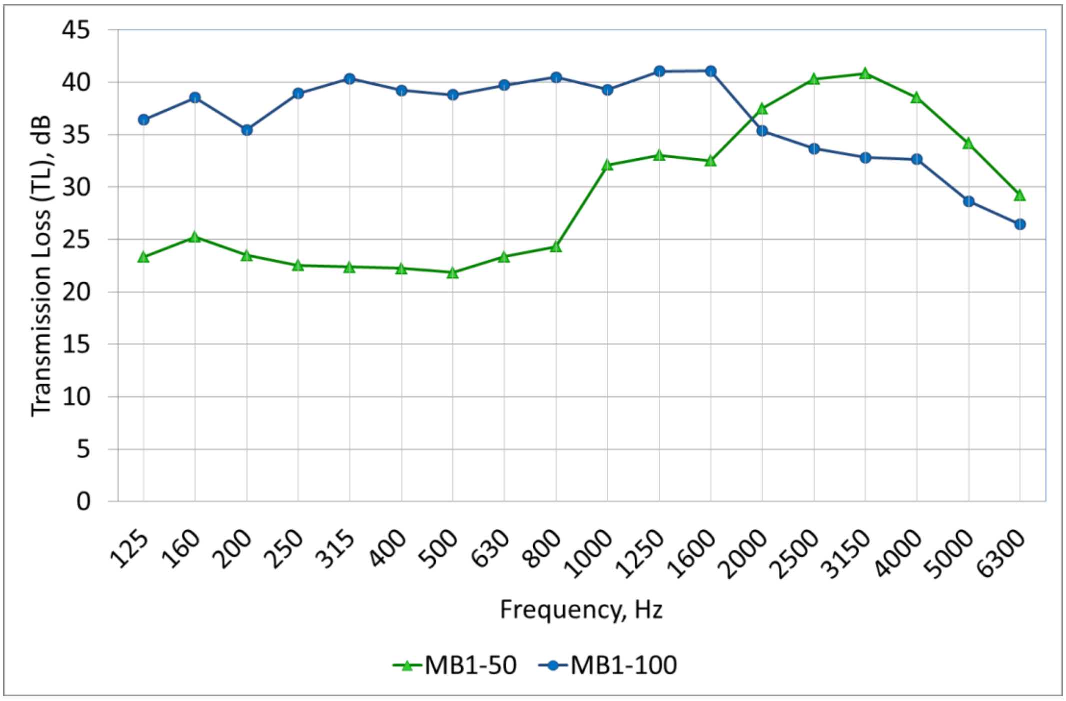


Figure 4.19 TL values of MB1-50 and MB1-100.

The mass law ranges of MB1-50 and MB1-100 samples were calculated for the frequency ranges of 125Hz-6300Hz by using the Eq.2.2 given in Section 2.3. The mass law range for the sample of MB1-100 were found to be in the ranges of 125-250 Hz. The mass law frequency range could not be achieved for the sample MB1-50.

Table 4.7 The mass law ranges for the MB1-50 and MB1-100.

Samples	MB1-50	MB1-100
Mass law frequency range	NA	125 – 250 Hz

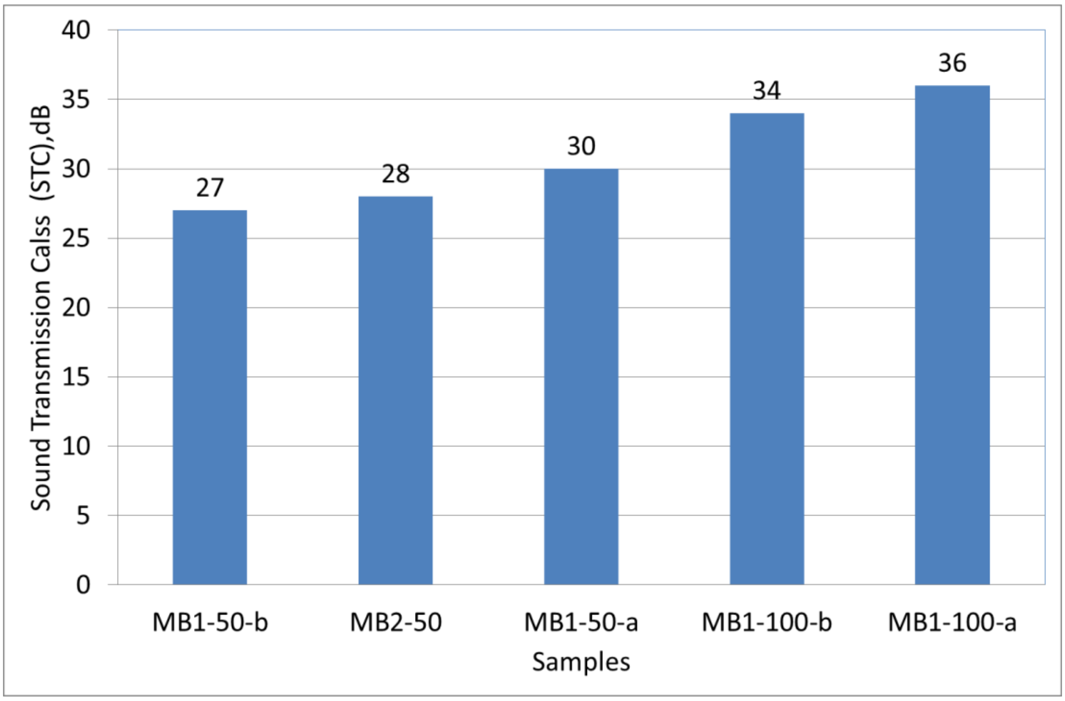


Figure 4.20 STC values of MB1-50-a, MB1-50-b, MB1-100-a, MB1-100-b and MB2-50.

The sound absorption properties of the mudbrick laboratory sample, MB1-50a, was given in terms of sound absorption coefficient in 1/3 and 1/1 frequency ranges, noise reduction coefficient (NRC) and average sound absorption coefficient values at low-, mid-, and high frequency ranges (Figures 4.21and Table 4.8). The sound absorption (α) values of MB1 were in the range of 0.08 and 0.41. The peak α value was around 1000 Hz. The average sound absorption coefficient was found between 125-250 Hz about 0.09; between 500-1000Hz about 0.31; between 2000-4000Hz about 0.25. The NRC was found to be 0.23.

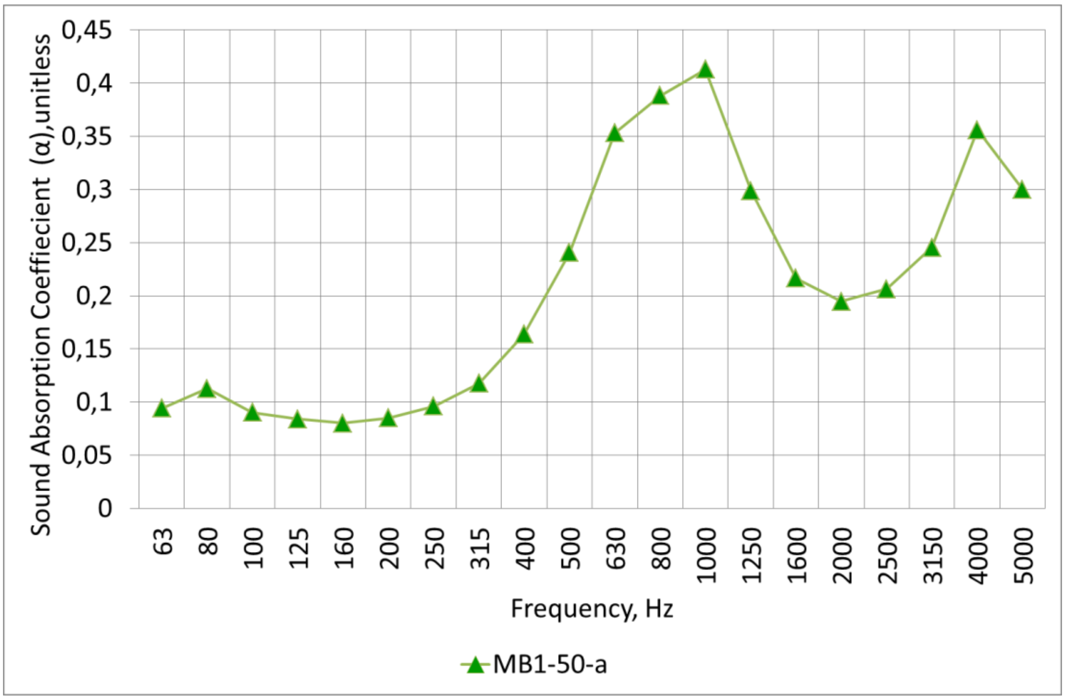


Figure 4.21 Sound absorption values of MB1-50-a.

Table 4.8 The sound absorption, sound transmission loss, NRC and STC values of MB1-50-a.

Sample	Sound Absorption Coefficient (α), unitless						NRC (α), unitless, average of 250 Hz,500 Hz,1000 Hz, 2000 Hz
	Octave Band frequency center ,Hz						
MB1-50-a	125	250	500	1000	2000	4000	
	0.08	0.1	0.25	0.37	0.21	0.30	0.23
	$\alpha_{125\text{-}250}$ = 0.09		$\alpha_{500\text{-}1000}$ = 0.31		$\alpha_{2000\text{-}4000}$ = 0.25		
	Sound Transmission Loss, dB						
	Octave Band frequency center ,Hz						STC, dB
MB1-50-a	125	250	500	1000	2000	4000	
	29	23	23	32	34	35	30

4.5 BASIC PHYSICAL, COMPOSITIONAL & RAW CHARACTERISTICS OF MUD-BASED SAMPLES

The values of particle density, bulk density and porosity of the original mud based samples collected were shown in Figure 4.22. While the bulk densities of mud based samples were in the range of 1.07-1.3 g/cm^3 the particle density of the samples were in the range of 2.01 -2.32 g/cm^3.The porosity of the samples were between 40%-47%.

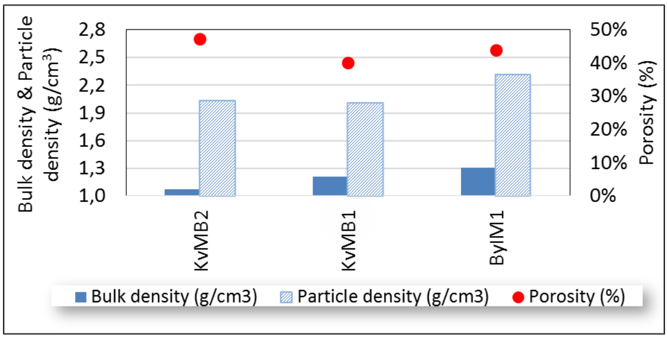


Figure 4.22 Bulk density, particle density and porosity values of the samples.

The values of the bulk density and porosity of MB1 and MB2 samples, representative ones, which had physical properties compatible with the original mudbased samples were in the range of 1.15-1.31g.cm^{-3} and of 35-43%, respectively as shown in Table 4.9.

Table 4.9 Bulk density, particle density and porosity values of mudbrick samples prepared in laboratory.

		Bulk density (g/cm3)				Particle density (g/cm3)		Porosity %			
Sample		MB1	MB2	MB1	MB2	MB1	MB2	MB1	MB2	MB1	MB2
Diameter(mm)		28		100				28		100	
Thickness	50	1,30	1,30	1,31	1,19	2,01	2,03	35	36	35	41
	100	1,15	-	1,30	-	2,01	2,03	43	-	35	-

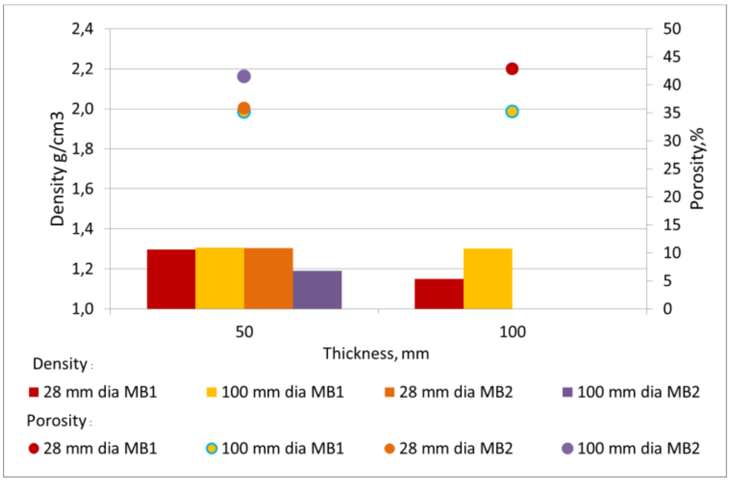


Figure 4.23 Bulk density, particle density and porosity values of mudbrick samples prepared laboratory.

The water vapour permeability data are summarized in Figure 4.24. The SD values for the mud bricks were found to be 0.04. Their µ values for the same samples were calculated to be 1.5. SD values below 0.14 m indicate high water vapour permeability of a material while SD values above 1.4 m indicate low water vapour permeability of a material. The SD values for the medium vapour permeability are defined in the range between 0.14m – 1.4m (TS prEN 7783-2:1999). Those SD values below 0.14m presented high water vapour permeability characteristics of the mud-based samples.

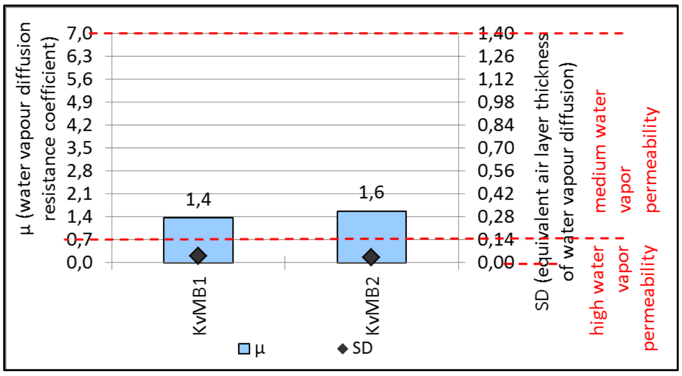


Figure 4.24 Water vapour permeability characteristics of the samples in terms of SD and μ values.

The mud brick samples, KvMB1 and KvMB2 were found to have 24.9% and 31.1% silt-clay content (below 63µm) by mass, respectively (Figure 4.25). Silt-clay content in mud infill mortar, ByIM1, was 16%, lower than the silt-clay content of mud brick samples.

The grain size distribution of aggregates is shown in Figure 4.25. The percentage of aggregates above 63µm (above silt-clay size) were found to be 75.1% and 68.9% by mass for the mud brick samples of KvMB1 and KvMB2, respectively while that percentage was 84% for the mud infill mortar ByIM1. The particles above 8mm (pebble content) and below 63µm (silt-clay content) were observed only at those mud brick and mud infill mortar samples in the range of 0.5-4.6% and 16-31%, respectively. For the mud brick samples, the aggregates above 1mm (very coarse particles) and below 0.125mm (very fine particles) had the largest content with the ratios of 18-28% and 29-36%, respectively while the medium and fine sand content (in the range of 30-34% in total) was comparable with the very fine particles. For the mud infill mortar, the aggregates above 1mm (very coarse particles) had the largest content with the ratio of 55% while the portion of very fine particles (below 0.125mm) was 18%. The mass percentage of fibres was 2% and 5.8% of the total weight for the mud brick samples of KvMB1 and KvMB2, respectively.

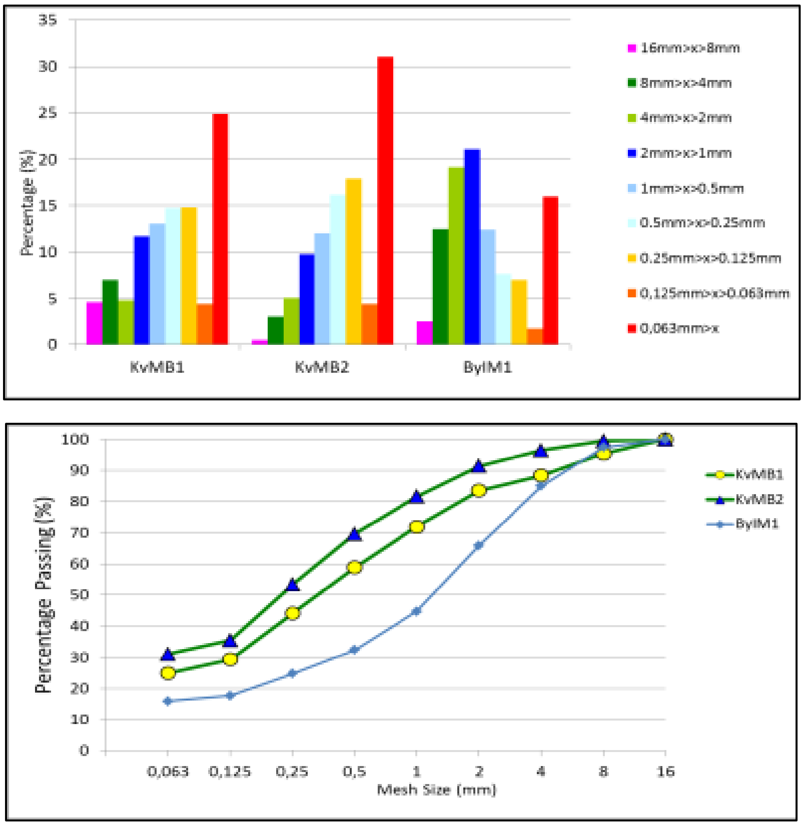


Figure 4.25 Grain size distribution of aggregates for the mud brick, mud infill mortar in percentages (at above) and curves showing their cumulative passing percent (at the below).

The XRD results of the oriented and non-oriented silt-clay samples indicated the presence of feldspar (albite), quartz and calcite together with some clay minerals in the mud which are illite-clay mica and mixed layer smectites (see XRD traces of KvMB1 in Figure 4.26). Non-clay minerals like quartz and feldspars are generally exist in clay materials and usually in the particle size of silt. Illite-clay mica, gypsum and calcite minerals were identified in the oriented and non-oriented sample of ByIM1 (Figure 4.26).

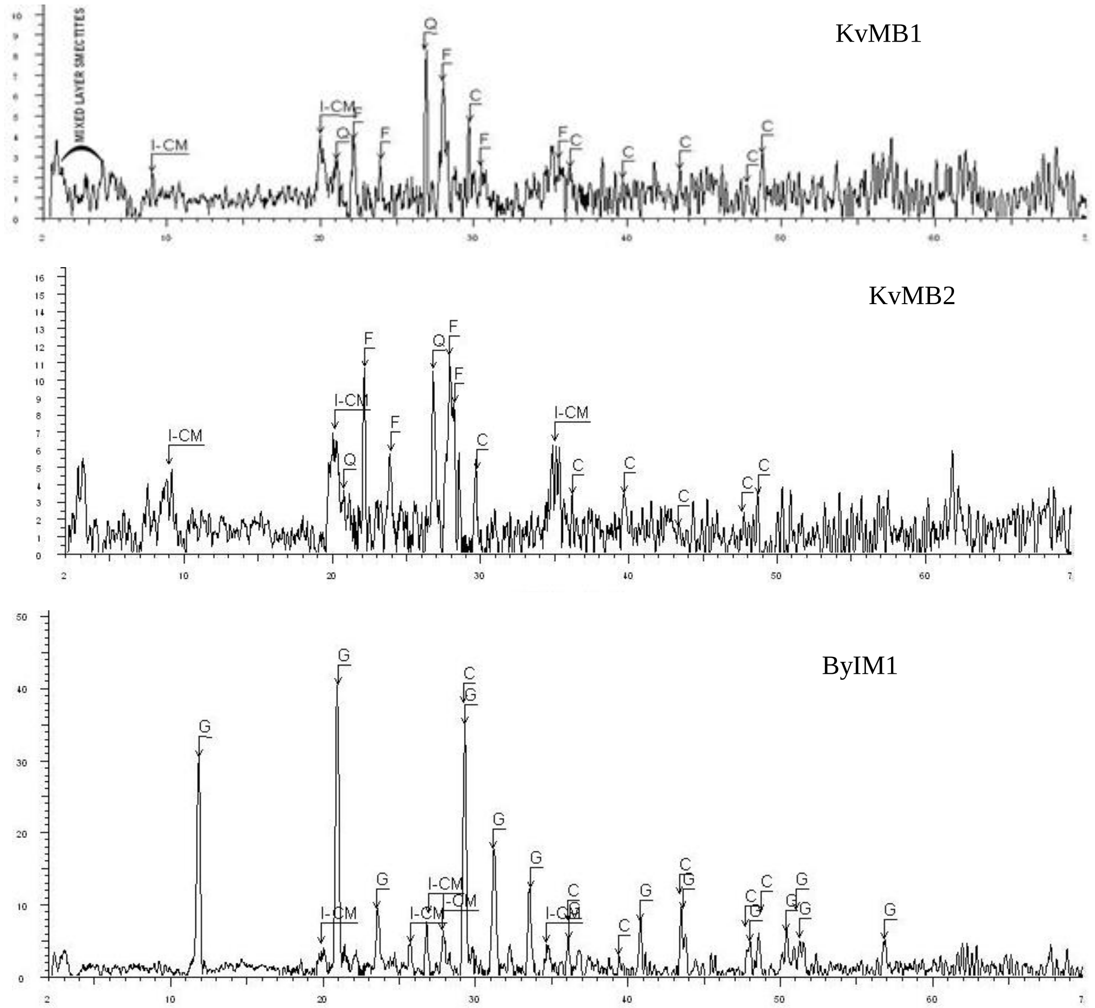


Figure 4.26 XRD traces of the mudbrick sample KvMB1, infill mud mortar ByIM1, (I-CM: Illite-clay micas, C: Calcite, G: Gypsum, Q: Quartz, F: Feldspar, Mixed layer smectites peaks).

CHAPTER 5

DISCUSSION

The data obtained from the in-situ measurements, simulation analyses and laboratory tests were interpreted together in order to assess the sound transmission properties of mud-based infill materials in comparison to contemporary ones used in repairs, sound transmission characteristics of original floor and wall components in traditional timber-framed dwellings in comparison to the repaired ones. The in-situ measurements and acoustical simulation methods used in the study were also evaluated in terms of difficulties, restrictions, and potentials met during the study.

5.1 ASSESSMENT OF SOUND TRANSMISSION PERFORMANCE OF ORIGINAL WALL AND FLOOR SECTIONS IN TRADITIONAL TIMBER FRAMED DWELLINGS

The in-situ R'w data of 26dB obtained for the Original Wall-4 (Tahtacıörencik Village, Güdül, Ankara) have shown the poor sound reduction performance of the original configuration of the wall. That wall is composed of 100x100 mm wood stud system with mud brick infill and covered with wooden lath at both sides while the wooden lath at the interior side is coated with lime-based plaster. Its in-situ R'w value is considerably below than the acceptable minimum R'w value of 50dB (Ingelaere, 2012). Such a poor performance measured during the in-situ tests is attributed to the presence of door opening along the wall. A panelled door was used to cover the opening. Since no gaskets are used at the edges where the main frame and swing come together as well as poor sound insulation quality of the door swing, it seemed to be the weakest part of the wall. In such composite wall surfaces composed of wall section and opening units, the weakest surfaces are expected to act dominant during the in-situ measurements and to disturb the sound insulation capacity of the overall wall section (Eagen, 1988). In presence of an opening, such as door or window along the wall length, the R'w performance of the wall section should be designed/provided more than the required levels, depending on the proportion of opening-to-solid wall area (Littelfield, 2015). For instance, R'w of a partition wall positioned between a cinema hall and corridor is required to be above 60-62dB in absence of door while the R'w value of 71dB, in other words 11dB higher performance, is required in presence of door (Littelfield,2015).

The simulation analyses also supported the in-situ measurements. The sound reduction performance of the wall section was estimated by the INSUL analyses while the sound transmission due to the flanking effect through the wall section was determined by the involvement of BASTIAN. Due to the lack of data to represent the original mudbrick in INSUL software, the relevant data was given as input for the simulation analyses. The input data on modules of elasticity (MoE) and the density values of mudbrick was accepted to be in the ranges of 0.7GPa-7GPa and 1073kg/m^3 -1206kg/m^3, respectively (Houben & Guillaud, 1994; Meriç *et al*, 2013, Meriç *et al*, in press). The Rw value estimated by INSUL analyses for the timber framed wall section with mudbrick infill is used as the criterion for adapting/simulating the same wall section during BASTIAN analyses.

The INSUL analyses on the Original-Wall 4 without and with openings have shown that the Rw values of its solid part (without any opening) were found to be between 42dB and 44dB while that Rw performance of the solid wall reduced to 28 dB in presence of the door D4. The decrease of 16dB in Rw performance of the solid part of the wall was also determined, therefore supported, by the results of the numerical calculations. The calculation defined in Eq.2.4 is used for the calculation of sound reduction performance for a composite wall (Table 4.5; Eckard &Müller, 2009). The calculated Rw value of the Original-Wall 4 was found to be 29dB. The in-situ R'w data of 26dB which is similar with the calculated and simulated Rw values of Original-

Wall 4 proves the dominant role of an opening in a wall section and also presents the consistency between in-situ, simulated and calculated Rw values.

The BASTIAN analyses on the Original Wall 4 have shown the presence and effect of flanking transmission through the wall component. The estimated R'w values in the range 28dB and 35dB presented that the effect of flanking might increase the overall sound transmission through the wall component in the range of 6-16dB with an average of 11 dB±4dB.

In short, the two factors which are "the presence of door/window openings" and "the poor detailing that accelerates flanking sound transmission" are the main critical reasons, all of which are determined to reduce the overall sound insulation performance of the original wall component (Original-Wall 4) around 16dB and 11dB, respectively.

The in-situ R'w and L'nw data obtained for the Original-Floor 4 (Tahtacıörencik Village, Güdül, Ankara) have shown the insufficient impact and airborne sound insulation performance of the original configuration of floor. The Original-Floor 4 fully-keeps its original the traditional construction techniques and authentic materials. It is composed of one-way wood (pine) joist system covered with wood (pine) strip flooring and carpet at floor side while fully-exposed at ceiling level, without any infill and ceiling boards. Its in-situ R'w and L'nw performances with the values 29dB and 69dB, respectively exhibited that the sound reduction index is considerably below the acceptable minimum level of 50dB while the impact sound level is not enough to satisfy the acceptable level above 65dB (Ingelaere, 2012). The presence of carpet layer on the original floor surface might have contributed to the performance of impact sound level while its presence is not expected to improve the sound reduction index (Emms *et al.,* 2006; Warnock,1999a; Quirt et al.2006).

The sound reduction performance of the original floor component was estimated by INSUL and BASTIAN analyses to interpret the in-situ R'w data. For INSUL analyses, the structural timber elements used in the simulation of original floor configuration were accepted to have the density of 630kg/m^3 belonging to sound old pine (Kandemir, 2010). The simulated Rw value of the original floor was found to be 30dB that is slightly higher than the in-situ R'w data of 29 dB. That supported the insufficient airborne sound insulation capacity of the original floor section. The simulated Rw data of 28 dB obtained by BASTIAN analyses also supported the result of poor airborne sound transmission performance the original floor section without mudbrick infill. However, it seemed that flanking through the original floor component is effected the overall sound transmission slightly due to the decrease of only 4dB in estimated R'w data.

The resistance of the original floor component against impact sound transmission was estimated in terms of weighted impact sound level (Lnw). The simulated Lnw data obtained by INSUL and BASTIAN analyses were found to be 85dB and 91dB, respectively. Those values are 16-21dB lower than in-situ Lnw data. One of the reason of those better results showing the real impact sound insulation performance of the existing original floor may be due to the presence of the carpet on floor surface. However, the contribution of the carpet to the impact sound level is expected to be 7-8dB (Emms *et al.,* 2006; Warnock,1999a; Quirt et al.2006). Therefore, the noticeable and better performance of the original floor component may be attributed to the inherently-better density and durability characteristics of old timber in comparison to the newly-grown ones (Ridout, 2000; Kandemir *et al*, 2007; Long,2006), as well as traditional construction detailing and techniques. Here, the contribution of the traditional timber-frame construction techniques to the direct and flanking transmissions of impact sound, particularly the contribution of material characteristics of structural timber elements and nails used for joining those timber elements, need to be investigated with further studies.

5.2 ASSESSMENT OF SOUND TRANSMISSION PERFORMANCE OF RECONSTRUCTED/REPAIRED FLOOR AND WALL SECTIONS IN TIMBER FRAMED DWELLINGS

The in-situ R'w data of 28dB, 23 dB and 24dB obtained for the Reconstructed-Wall 1 (Ankara Bağ Evi, Keçiören, Ankara), Semi-Repaired-Wall 2 and Semi-Repaired-Wall 3 (Boyacızade Konağı,Altındağ, Ankara), respectively, have shown the poor sound insulation performance of the renewed wall configurations. The Reconstructed-Wall 1 is composed of 100-150mmx150 mm wood stud system with fired solid brick infill covered with contemporary lime-based plaster layers while Semi-Repaired-Walls 2 and 3 are composed of 100x100mm wood stud system with fired solid brick infill covered with wooden lath coated with plaster and paint. Their in-situ R'w data are considerably below than the acceptable minimum R'w value of 50dB (Ingelaere, 2012). Reconstructed-Wall 1 has the slightly better sound reduction performance than Semi-Repaired-Wall 2 and Semi-Repaired-Wall 3 by means of its thicker wall section. Such poor performances measured during the in-situ tests are attributed to the presence of door opening along the wall as Original-Wall 4. A panelled door was used to cover the opening. Since no gaskets are used at the edges where the main frame and swing come together as well as poor sound insulation quality of the door swing, it seemed to be the weakest part of the wall.

The INSUL analyses on the existing walls without and with openings have shown that the Rw values of their solid parts (without any opening) were found to be in the range of 45-50dB (Table 4.3) while those performances reduced to the range of 24-27dB (Table 4.3), respectively, in presence of the doors of D1, D2 and GD3 along the wall. A similar decrease in their Rw performances were also determined, by the numerical calculations in the range of 19-20dB (Table 4.5, Eckard &Müller, 2009). The calculated and simulated Rw data which are similar with the in-situ performances of those walls proves the dominant role of an opening in a wall section and also presents the consistency between in-situ, simulated and calculated Rw values.

The BASTIAN analyses on the Reconstructed-Wall 1,Semi-Repaired-Wall 2 and Semi-Repaired-Wall 3 have shown the presence of flanking transmission problem through the wall components. The estimated R'w values in the ranges of 29-37dB, 28-38dB and 29-36dB, respectively, exhibited that the adverse effect of flanking might increase the overall sound transmission through the wall component in the range of 13-21dB with an average of 16dB, 7-17dB with an average of 12dB and 9-16dB with an average of 12dB, respectively.

In short, the two factors which are "the presence of door openings" and "the poor detailing that accelerates flanking sound transmission" are the main critical reasons, all of which reduce the overall sound insulation performance through the existing walls in the ranges of 20-23dB and 12-16dB, respectively.

The in-situ R'w and L'nw data obtained for the Reconstructed-Floor 1 (Ankara Bağ Evi, Keçiören, Ankara) Semi-Repaired-Floor 2 and Semi-Repaired-Floor 3 (Boyacızade Konağı,Altındağ, Ankara) have shown the insufficient impact and airborne sound insulation performance of those existing floors. The Reconstructed-Floor 1 was built as two way joist system with 200mm-rockwool infill and the joists were covered with wood parquet flooring and carpet at floor side and with wooden boards at ceiling side. The Semi-Repaired-Floor 2 and Semi-Repaired- Floor 3, on the other hand, were composed of one-way joists with an infill of 7.5 cm-thick cement-based mortar together with air cavity, and the joists were covered with wood strip flooring and carpet at floor side and with wooden boards at ceiling side. Their in-situ R'w performances with values of 45dB, 25dB and 37dB, respectively, and their in-situ L'nw performances with values of 68dB, 76dB and 77dB, respectively exhibited that the sound reduction indexes are considerably below the acceptable minimum level of 50dB while the impact sound level is not enough to satisfy the acceptable level above 65dB (Ingelaere, 2012). Their low sound insulation performances can be due to their insufficient insulation properties and the direct fixing of cladding boards to the structural timber elements without using any sound break. Due to the thicker cross section and higher surface density (kg/m^2) of Reconstructed-Floor 1, its airborne and impact sound insulation performances, expectedly, was found to be better than the others.

Although the Semi-Repaired-Floor 2 and 3 have the same floor section, the Floor 3 presented more resistivity to sound transmission than the Floor 2 with a difference of 12dB in R’w value. There was a square-shaped hole with the sizes of approximately 10cmx10cm which is positioned in the Semi-Repaired-Floor 2 area and used for the run of heating system piping in vertical. Although the cavity is observed to be filled with a kind of wool sponge, it causes considerable sound transmission through the floor section.

The in-situ examination has shown that the presence of carpet provides an improvement of 7 dB in L’nw value and increases the impact sound resistance, especially at higher frequencies (Figure 4.4). Doubling the carpet layers on Semi-Repaired-Floor 2 provided a slight improvement with a difference of 1dB in L’nw value when compared with the performance of one layer of carpet laid on Semi-Repaired- Floor 3.

According to the INSUL and BASTIAN simulation analyses, the estimated Rw and Lnw values obtained for the existing floor sections were found to be supporting the in-situ measurements. That proved the insufficiency of the existing floor section in terms of airborne sound insulation capacity as well as clarified the adverse effect of the hole located in the Semi-Repaired Floor 2, accelerating the sound transmission through its section. In addition, the comparison of INSUL and BASTIAN results have shown that the decrease of 5dB and 4dB in estimated Rw and Lnw values, respectively, signalled the adverse effect of flanking to the overall sound reduction performance of the Semi-Repaired-Floor 2/3.

5.3 DISCUSSION ON ACOUSTICAL PROPERTIES OF MUDBRICK PREPARED IN LABORATORY

The mudbrick samples prepared in various diameters and thicknesses were provided density and porosity values in the ranges of 1.15-1.31g.cm^{-3} and 35-43%, respectively. These values fell into the ranges of original mudbrick samples collected from non-repaired traditional timber-framed dwellings; therefore, those samples were appropriate for the determination of sound transmission properties of mudbrick. On the other hand, among those samples, only the MB1-50-a could be used for the analyses of sound absorption coefficient since its surface represented the surface of original mudbrick.

The presence of aggregates in coarse diameters and fibres establish an heterogeneous fabric in the bulk of mudbrick. Therefore, mudbrick samples in varying thickness were found to exhibit sound reduction performances in a wider range of 27 dB-36 dB with an average of 32 dB ± 4 dB. On the other hand, 100mm-thick mudbrick samples seemed to provide higher sound reduction performance than 50mm-thick mudbrick samples with a difference of 7dB.The noise reduction coefficient (NRC) of the representative sample MB1-50a is 0.23 and its sound absorption coefficient (α) in average is 0.31 at mid frequencies (Table 4.8). Its sound reduction performance is also 31dB within the range of the data obtained for mudbrick samples.

In comparison with some building materials that are used as an infill material during repairs instead of original mud brick infill, 100 mm-thick mudbrick infill has similar sound reduction performance with 100mm-thick clay brick while 100 mm-thick light-weight concrete units, such as autoclaved aerated concrete (AAC) and pumice block with STC values of 38 dB, and 40 dB respectively, have slightly higher than the mudbrick (Hassan, 2009;Team IMI,2010).

In addition, the original mudbrick has higher NRC values than the others, such as autoclaved aerated concrete (AAC), brick or expanded polystyrene (EPS), having NRC values of 0.15, 0.037, 0.11, respectively. On the other hand, glass wool and rock wool infill material, with NRC values of 0.83 and 0.86 respectively, seems to have considerably-higher sound absorbing performances than mudbrick infill (Hassan, 2009; Long,2006; Tayabiji *et al*, 2010)

In comparison with some building materials that are used as finishing layers during repairs instead of original mud plasters, the sound absorption performance of mud plaster is noticeably higher than gypsum-based/lime-based and cement-based plasters. For instances, the NRC values of gypsum-based/lime-based plasters applied on brick surface, applied on wood lath and cement-based plasters are 0.03, 0.06 and 0.02, respectively (Hassan, 2009; Varghese,2001). The mudplaster seems to have sound absorption performance 4 to 10 times higher than the contemporary ones applied on wall surfaces.

Some contemporary infill materials, such as light-weight concrete blocks, may have similar or better sound reduction performances while they have low sound absorption characteristics as well as while are not appropriate to be used as repair materials due to their incompatible physical/mechanical properties and necessity of plastering their surfaces with cement-based finishing layers. Contemporary gypsum/lime-based plasters may be compatible with the original mudplaster in terms of their breathing capacities (TS EN 12086;2013; TS 825:2008) while they have sound absorptive and reduction performance lower than the original ones. Among the contemporary insulation materials ,the mineral wools (glass wool and rock wool) has density between 0.025 $g.cm^{-3}$ cm and 0.23 $g.cm^{-3}$and porosity higher than 0.95 (Be´cota, *et al*,2011; Voronina,1994). It can be preferable to be used as infill material within wall and floor sections due to their good acoustical and physical performances and fire-resistivity properties while expanded polystyrene boards are not recommended due to their poor acoustical performances and very low fire-resistivity characteristics (Hassan, 2009; Long, 2006;TS EN 13501-1). It should be mentioned that the acoustical properties of building materials can be considered as one of the compatibility parameter in addition to the compatibility properties of water vapour permeability, modulus of elasticity and dilatation characteristics.

5.4 GUIDING REMARKS FOR IMPROVEMENT OF SOUND TRANSMISSION PROPERTIES OF WALL & FLOOR COMPONENTS

Here, the results of the study are summarized in the form of guiding remarks for the improvement of sound insulation features of timber-famed wall and floor components as well as for the repair works traditional timber-framed houses. Those remarks, in fact, are the hints for the architects, engineers and practitioners let them to suggest proper construction details and interventions for repair works.

The guiding remarks are summarized below under the individual subheadings for wall and floor components.

5.4.1 Wall Components

The guiding remarks are summarised below:

- *The sound insulation performance of a partition wall is expected to provide airborne sound reduction index above 50dB* (Ingelaere, 2012). Therefore the interventions are proposed here to achieve that criterion.
- *For residential dwellings, the proposals providing Rw performance above 50-62dB are acceptable for the walls while the proposals provide higher Rw values are preferable for the walls where doors are present.*
- *During the refunctioning of a timber-framed dwellings, the proposals providing Rw performance above 50-52dB are acceptable for the walls of offices (Littelfield,2015), above 55-57dB for the walls of private offices/meeting rooms (Littelfield,2015), above 60dB for the walls of a classroom (Littelfield,2015),*
- *The flanking sound transmission through the wall sections is one of the critical problems at the adjoining part of the wall and ceiling/ floor components for timber framed structures.*
- *Any precaution that provides discontinuity between the wall and floor components is the main solution* to eliminate/minimize the sound flanking problem. Several treatments, such as to provide resilient caulks for filling gaps at the lower/upper parts of a wall where the wall is in touch with the floor/ceiling, (see Figure 2.12)

and/or to use resilient channels between the wood studs and wallboards, are needed to provide such a discontinuity, in other words, sound breaks. The precautions that can eliminate the flanking transmission at floor-wall connections are described in the following subsection 5.4.2.

– *The two interventions are recommended for the improvement of timber-framed wall sections:* Replacement of existing door with the ones having higher resistance to sound transmission and improvement of sound insulation capacity of the walls section.
– *The recommended first intervention is to take precautions to minimize the sound transmission through the edges of door and cross section of door.* The existing panelled door was recommended to be replaced with a solid core door (solid with particle board/MDF or fibercore) with door stop and drop seals/gaskets. For instance, such a door replacement provided a significant increase in sound insulation performance of 16 dB in Reconstructed-Wall 1, 14 dB for the Semi-Repaired-Wall 2/ Wall 3, and Original-Wall 4 (Figure E.1-E.4).
– *The second intervention is suggested to use additional sound insulation layers within the cross-section of timber-framed wall*.
– *The cladding of wall surfaces with one- or double-layer of gypsum/wooden board*, in other words sticking the boards directly on wall surface, *was determined to slightly reduce the sound transmission within the range of 1 dB-2 dB* (see Figure E.5-E.6). That supports the information given in literature (Long, 2006).
– *Most types of single-sided dry wall application which provide sound insulation improvements in various ranges are demountable interventions* that form a separate dry wall behind the existing wall surface (see Figures 4.5 to 4.7).
– *The attachment of a single-sided dry wall system composed of metal/wood framing with an infill of mineral wool and gypsum board facing is an intervention much more effective than gypsum board lining/cladding of wall surfaces*. Therefore, an intervention in the form of single-sided dry wall is a necessity to improve the sound insulation characteristics of existing walls. On the other hand, such a dry wall attachment results in thickening the wall, in other words, reduction in effective floor area.

- *The mineral wool board with gypsum board facing which is directly adhered/sticked to existing wall surface without framing is suggested only for newly-constructed walls*. Such an intervention is not appropriate for the existing original wall sections since its removal may damage the original wall surface.
- *The mineral wool is suggested to be used as sound absorbing infill material within the cavity of attached dry wall*. Due to the poor fire rating and less sound insulation characteristics of polystyrene boards, mineral based rigid insulation boards are preferred to be used for improvements (Hassan, 2009; TS EN 13501-1:2007).
- *The interventions applied above the existing wood lath (as observed in wall sections of Semi-Repaired-Wall 2/3 and Original Wall 4) are more effective than interventions applied directly on fired-brick infill (Reconstructed-Wall 1*) (see Appendix E).
- *It is recommended to make demountable interventions on the original timber-framed wall section by keeping its original mudbrick infill.* Any intervention applied on the original timber-framed wall with mudbrick infill provides higher sound reduction than the performance of the same intervention when applied on reconstructed/repaired timber-framed wall with contemporary clay-brick infill (see Figure 4.11).
- *The attachment of single-sided dry wall with sound absorbing infill provides significant improvement in sound reduction performance.* For instance, such as attachment composed of 60mm-thick insulated dry wall construction provides 6dB improvement while the same intervention without sound absorbing infill provides only 3dB improvement in the sound reduction performance. This meant that the presence of sound absorbing infill suppresses acoustic resonances that might occur within the air cavity of dry wall system (see the difference between the proposals of Aw and Bw in Figures 4.5 to 4.7 and Figure 4.11).
- *The involvement of any sound break, such as use of resilient channel/resilient layer/rubber isolation clip, into the wood/metal frame wall section provides a significant improvement in its sound reduction performance*, in the range of 4-10dB. The staggered stud application presents similar improvement in sound

reduction with the use of any sound break within the wall section (see Figures 4.5 to 4.7).

- *The construction of separate wood/metal framing or sticking of sound insulation board* with gypsum board facing *are more effective interventions than the use of sound breaks within the single stud application*, with an improvement of 7-12dB in sound reduction performance. (see the proposals of Ew, Ew' and Fw in Figures 4.5 to 4.11).
- *In case that selection of wood or metal for the construction of wall framing is critical for repair works, the metal stud framing has higher sound reduction performance than the wood stud framing, with an improvement of 1-3dB.* That might be due to the more flexible characteristics of metal stud walls (see the difference between the proposals of B_W and B_W' in Figures 4.5 to 4.11).
- *Increasing the mass of the wall by doubling of the gypsum board layer provides an improvement reaching 6 dB in Rw value* (see difference between the proposals of E_W&$G_{W;}$ E_W'&G_W'in Figures 4.5 to 4.11).

5.4.2 Floor Components

The guiding remarks are summarised below:

- *The sound insulation performance of an intermediate floor is expected to provide impact sound insulation performance (Lnw) below 65dB and airborne sound reduction index (Rw) above 50dB* (Ingelaere, 2012). These are the acceptable minimum ranges defined in the Building Regulations of various European countries. For any intervention, the Rw and Lnw performance of a floor component is advised to achieve at least those criteria.
- *On the other hand, the acceptable criteria defined in Austria Building Regulations are given as above 60dB and below 48dB for Rw and Lnw performances of floor components, respectively.*
- *The sound insulation performances of floor components in timber-framed dwellings need to be designed in case of refunctioning of those structures.* For instances: in offices, the floors is required to provide Rw and Lnw performances above 52dB and below 53dB, respectively; for the floors between offices and

music rooms, the Rw and Lnw values are required to provide above 57-78dB and Lnw below 46-28 dB; in classrooms, the floors should provide Rw and Lnw values above 55dB and below 53dB; for the floors between workshop room and classroom, the Rw and Lnw performances are expected to be above 55dB and below 46dB, respectively according to the DIN norm (Eckard &Müller, 2009).

- *The presence of air gaps, such as slits, holes, blanks/voids on floor surfaces is one of main reason that reduce the sound insulation of the floor component. In case of its/their presence, it is recommended to seal the gaps with appropriate sealants/gaskets or to fill the gap with timber boards.*
- *Among the timber-framed floor sections examined here, the direct fixing of any floor cladding layer to the structural floor system without any sound break in between is the main reason for poor sound insulation performance.* Therefore, there is a necessity to provide a sound break to prevent the direct and flanking sound transmission.
- *Decoupling of flooring layers from wall and floor structure and separating the floor and wall structure from each other are the main solutions to break/eliminate/minimize the flanking transmission at floor-wall connections.* The construction of "floating floors" in which resilient layers/pads are used to break the connections at the edges/corners where flooring layer comes together with the wall surface, is one of the commonly-used technique to prevent flanking sound transmission (Figure 2.12). Since this is a demountable application and no wet materials are used, it can be recommended for the repair/maintenance works in traditional timber framed dwellings.
- *It is recommended to make such demountable interventions on the original timber-framed floor section (Original-Floor 4) in such a way that "attaching sound resistive additional layers while keeping its existing/original floor section layers".* For instance, the placement of any resilient layer between wooden floor board and joist requires the removal of original wooden board, therefore such an intervention is not acceptable due to its destructive nature.

– The interventions recommended for the improvement of direct sound transmission through timber-framed floor sections and sound insulation capacity are listed below:
  - *The use of sound breaks, such as resilient layer/pad/channel, rubber isolation clips to separate joists from each other, to decouple floor/ceiling layers from joists/sleepers.* Such as barrier would damp the vibration of impact sound and hinder its transmission to the neighbouring layers (Warnock,1999a;Quirt *et al*.2006).
  - *The use of sound absorbing infill (mineral fibre infill), such as mineral wool and mudbrick with sufficient thicknesses, within the floor section.*
  - *The use of double/thicker/heavier flooring layers or ceiling boards covering the floor structure.* That would increase the surface density, in other words the ratio of the weight of floor to its surface density (kg.m^{-2}), which is an effective parameter for the improvement of sound reduction performance of a floor (Warnock,1999a;Quirt *et al*.2006).

– *All interventions recommended here, in one way or another, provide a certain sound insulation improvement in floor sections and reaches the acceptable minimum criteria.* However, only the configurations composed of "separation of joists within the insulated floor section (I_F-C, I_F-D, II_F-F and III_F-F)" and "separation of joists within the insulated floor section together with the application of resilient layer underneath the subfloor (II_F-E)" are the most satisfactory interventions in accordance with the Austrian building Regulations and DIN norms.

– *The most effective technique to eliminate the problem of airborne and impact sound transmission through the floor section is the separation of joist layers from each other within the insulated floor section* (Figure 4.12 to 4.14 and Table 4.6). The improvement is considerable in impact sound level and sound reduction index within the ranges of 19-23dB and 20-23dB, respectively (see Table 4.6).

– *For the control of both airborne and impact noise transmission through the floor section, there is necessity for the joint use of sound break, such as resilient channel or rubber isolator clip, and sound absorption infill within the floor section* (Figure

4.12 to 4.14 and Table 4.6).. It seemed that sound absorbing infill supports the sound breaks' performance. The improvement expected from such interventions varies in the ranges of 10-14dB for both Lnw and Rw, respectively (see Table 4.6).

- *The use of resilient layers underneath wooden subfloor allows separation of flooring layers from the structural floor, therefore provides a significant improvement, particularly in impact sound insulation.* Such a treatment is expected to provide an improvement of 12 dB in Lnw value while only an increase of 4 dB can be provided in Rw value of the floor section (see Table 4.6).
- The addition of ceiling board by direct-fixing to the joists provides an improvement in the range of 10dB and 8dB in Rw and Lnw values of the exposed wooden floor section (see Table 4.6). On the other hand, the effect of doubling the ceiling layers lower than the covering the bottom surface of floor section with one layer of wooden ceiling board with an improvement of 4dB and 2dB in Rw and Lnw performances, respectively.

CHAPTER 6

CONCLUSIONS

In the study, sound transmission characteristics of the wall and floor components in the two repaired (Ankara Bağ Evi and Boyacızade Konağı) and one non-repaired (Tahtacıörencik Village House) traditional timber framed dwellings were examined in terms of airborne and impact sound insulation performances. The original mudbrick infill used within timber-framed wall and floor components was analysed to uncover its acoustical characteristics. Some configurations were proposed for the acoustical improvement of existing wall and floor sections.

The existing wall and floor components under examination were found to have insufficient sound insulation performances due to their Rw values below 50dB and Lnw values above 65dB. The two factors which are "the presence of non-insulated door/window openings and air/sound leakages through their edges" and "the poor construction detailing which accelerates flanking sound transmission" are the main critical reasons, all of which are determined to significantly-reduce the overall sound insulation performance of the original wall component.

The presence of door/window openings and voids for the running of pipework are the main reasons that reduce the overall sound insulation performance of the existing wall and floor components in the range 12-22dB. The poor detailing and poor sound insulation features of those openings cause air leakages through the edges of openings and considerable sound transmission through their cross section. For instance, the 50dB sound reduction performance of a partition wall (Reconstructed-Wall 1) decreased to 27 dB, only due to the poor fixing detail of the door to the wall (Table 4.3). Air/sound leakages through the openings, therefore, should be sealed/eliminated properly by using stoppers, sealants, gaskets, mud or board fillers. and the openings need to be replaced with the solid/insulated door or insulated window components in order to provide the required Rw and Lnw values for dwellings and achieve sufficient sound reduction performance.

The other critical problem is the flanking sound transmission through the adjoining parts of wall and ceiling/ floor components for timber framed structures. Any precaution that provides discontinuity between the wall and floor components as well uses sound breaks to separate the cladding layers from wall/floor structure are the main solutions to eliminate/minimize the sound flanking problem. The simulated data have shown that the flanking sound transmission through repaired floor components (between the floors) may decrease the overall sound insulation performance (R'w) around 5dB while the flanking sound transmission through repaired wall components (between rooms) may decrease the sound insulation performance (R'w) in the range of 11-16dB. That signals that the adverse effect of flanking transmission through the walls is more noticeable/distinguishable than through floors.

On the other hand, the real impact sound insulation performance of the original timber-framed floor component, even without mudbrick infill, is better than the simulated performance with a 16-21dB difference between the in-situ and simulated Lnw values. In addition, the real impact sound insulation performance of original floor without any sound insulation infill is measured to be similar with the real impact sound insulation performance of reconstructed floor although it has 10cm-thick insulation infill, thicker section and higher surface density than the original one. The data show that the inherent materials and construction features contribute to the overall sound insulation performance of original floor component and those features cannot be adapted to, therefore represented in, simulation analyses. The contribution of the traditional timber-frame construction techniques to the direct and flanking transmissions of impact sound, particularly the contribution of material characteristics of structural timber elements and nails used for joining those timber elements, need to be investigated with further studies.

The 50mm-thick and 100mm-thick mudbrick samples were determined to have STC values of 28dB±1.5dB and 35dB±1.5dB, respectively. The 100mm-thick mudbrick samples seemed to provide higher sound reduction performance than 50mm-thick mudbrick samples with a difference of 7dB. The sound absorption coefficient at mid frequencies and NRC of one representative mudbrick sample were determined to be 0.31 and 0.23, respectively. The 100 mm-thick mudbrick infill seemed to have similar sound reduction performance with 100mm-thick fired-clay brick while having slightly lower sound reduction performance than 100 mm-thick autoclaved aerated concrete (AAC) and pumice block. In addition, the original mudbrick seemed to have higher NRC values than the AAC block, fired-clay brick or expanded polystyrene (EPS) while glass wool and rock wool infill material have considerably-higher sound absorbing performances than mudbrick infill. In addition, the sound absorption performance of mud plaster is noticeably higher than contemporary gypsum-based/lime-based and cement-based plasters, reaching to sound absorption coefficients at mid-frequency range 4 to 10 times higher than the contemporary ones applied on wall surfaces.

There is the necessity of keeping the inherent/original wall/floor construction details together with the original mudbrick infill. The inherent acoustical properties of the mudbrick infill and mudplasters seems to provide sound insulation to a certain extent. In case that air/sound leakages through the wall and floor components are eliminated and the existing openings are replaced with the solid core/insulated door or insulated window components, a significant improvement is expected to have been achieved in their sound reduction performances. In the context of refunctioning the traditional dwellings, when dwelling units/spaces are used as exhibition, meeting, office or hotel rooms, some acoustical improvements in existing wall and floor components can be provided by demountable attachments including sound absorbing infill and sound breaks within the wall/floor components. Attachment of single-sided and insulated dry wall together with sound breaks within the attached wall section provides significant improvement in Rw value of timber-framed wall section, especially when the original mudbrick infill and wooden lath are kept. Keeping the original structural floor section and the application of floating floor or ceiling layers with indirect fixing provide considerable improvement in sound reduction through the floor section and minimize sound transmission. The effectiveness of any remedy provided by sound breaks within the wall/floor section increases when sound absorbing insulation infill is added. The mineral wool can be used for infill in absence of mudbrick infill.

The in-situ examinations, simulation analyses and specific calculations used for the building components with openings seemed to complement each other, especially for the interpretation of the real situation in the dwellings. The estimated data obtained by the simulation analyses and specific calculations on the performance of composite components are very useful to interpret the in-situ data, especially for the identification of the local defects which fails the sound insulation performance of the wall and floor component significantly. The joint interpretation of data obtained by INSUL and BASTIAN analyses allowed examining the performances of direct and flanking sound transmission through wall and floor components individually. It should be mentioned that software used for the simulation analyses need to be improved to produce acoustical models of building components which represent their real characteristics. Special care should be given to enrich the library on materials for INSUL analyses and the library on section models for BASTIAN analyses in order to be able to simulate the real performance properties of materials and construction configurations of building components. That would enhance the accuracy of the simulation analyses. In the study, the necessity of simulating mudbrick infill layer within the wall and floor section was solved by introducing the input data to the INSUL software in terms of its MoE and density properties.

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APPENDIX A

FORMULAS OF SOME ACOUSTICAL PARAMETERS

$R' = D + 10 \log S/A$ (dB)

R': Apparent sound reduction index

D: level difference ,$D=L_1-L_2$

L_1: average sound pressure level in the source room

L_2: average sound pressure level in the source room

S: area of the test specimen (m^2)

A: Equivalent sound absorption area of the receiving room (m^2)

$D_n=D-10\log A/A_0$

D_n: Normalized sound level difference

D: level difference

A_0:Reference absorption area in square meters (10 m^2)

$D_{nT}=D-10\log T/T0$

D: level difference

T: reverberation time in receiving room

T_0:Reference reverberation time 0.5 seconds for dwellings

$L_n=Li+10\log A/A0$

L_i: the average sound pressure level in receiving room.

$L_{nT}=Li-10\log T/T0$

APPENDIX B

LOCATIONS OF SOUND SOURCE AND RECEIVERS

According to ISO140-4:1998, ISO 140-7:1998, during the field measurements of airborne and impact sound insulation between rooms the microphone sound level meter and omnidirectional sound source and tapping machine positions should be as follows:

- the minimum distance between receiver positions should be 0.7 m.
- the minimum distance between any receiver position and room boundaries or diffusers should be 0.5 m.
- the minimum distance between the sound source centre and room boundaries or diffusers should be 0.5 m.
- the minimum distance between sound source positions should be 0.7 m.
- the minimum distance between any receiver position and the sound source should be 1 m.
- the minimum number of receiver position should be five per each measurement.
- the minimum one sound source position and three receiver positions with two reading in each should be to carry out measurement of reverberation time.
- the minimum distance between any border of floor and the tapping machine should be 0.5 m.
- the minimum number of tapping machine positions should be four.

The measurements conducted in-situ is shown below:

- L1=Level1 refers to the sound level measurements made in the Source Room (1) – these are used in airborne sound insulation calculations.

- L2=Level 2 refers to the sound level measurements made in the Receiving Room (2) – these are used in airborne and impact sound insulation calculations.
- B2= refers to the background sound level measurements in the Receiving Room (2) – these are used for background level corrections in airborne and impact sound insulation calculations.
- T2= T2 refers to the reverberation time measurements made in the Receiving Room (2) – these are used in airborne and impact sound insulation calculations.

The positions of the receivers and sound sources are shown between Figure B1 to B12 (The receiver is indicated as “R” and sound sources are shown as “S”).

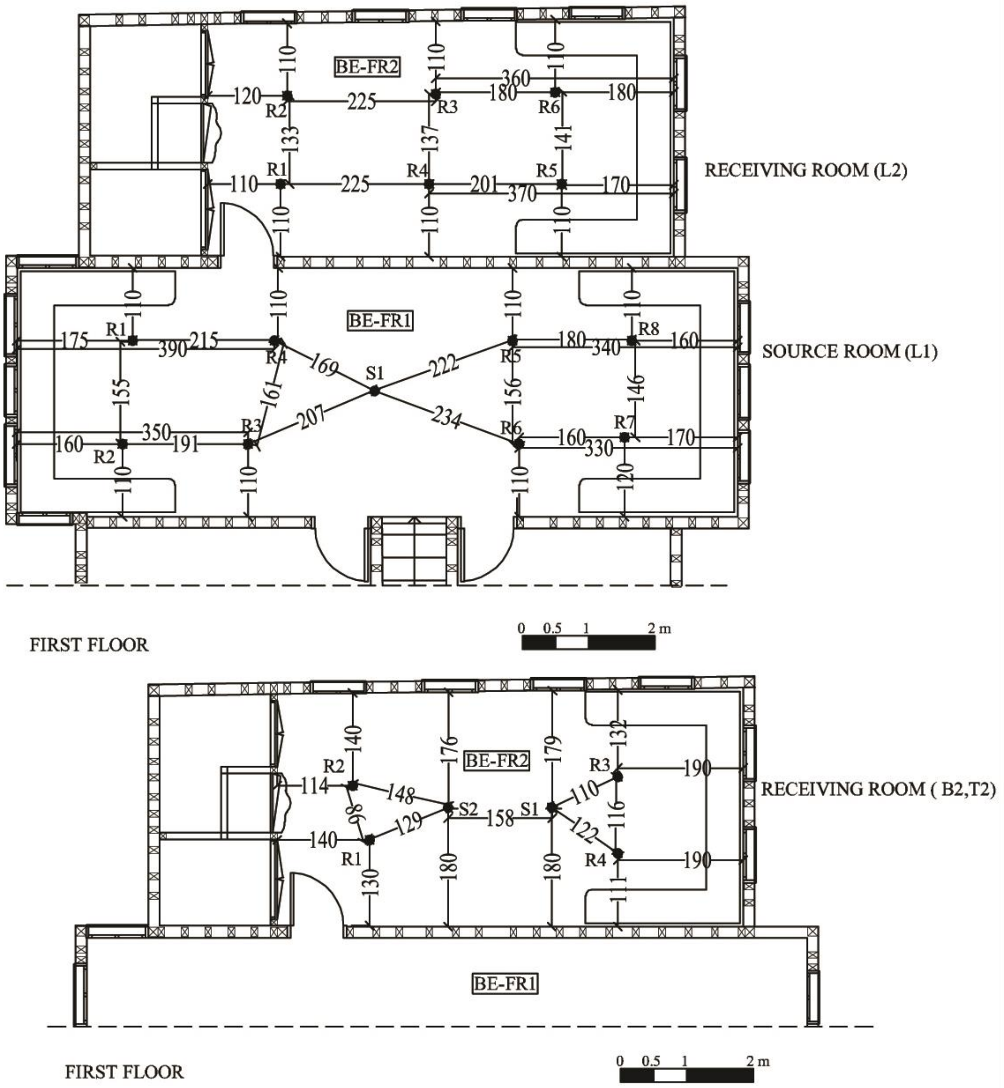


Figure B.1 Measurement of airborne sound transmission through Reconstructed-Wall 1(W1-BE-FR1/R2).

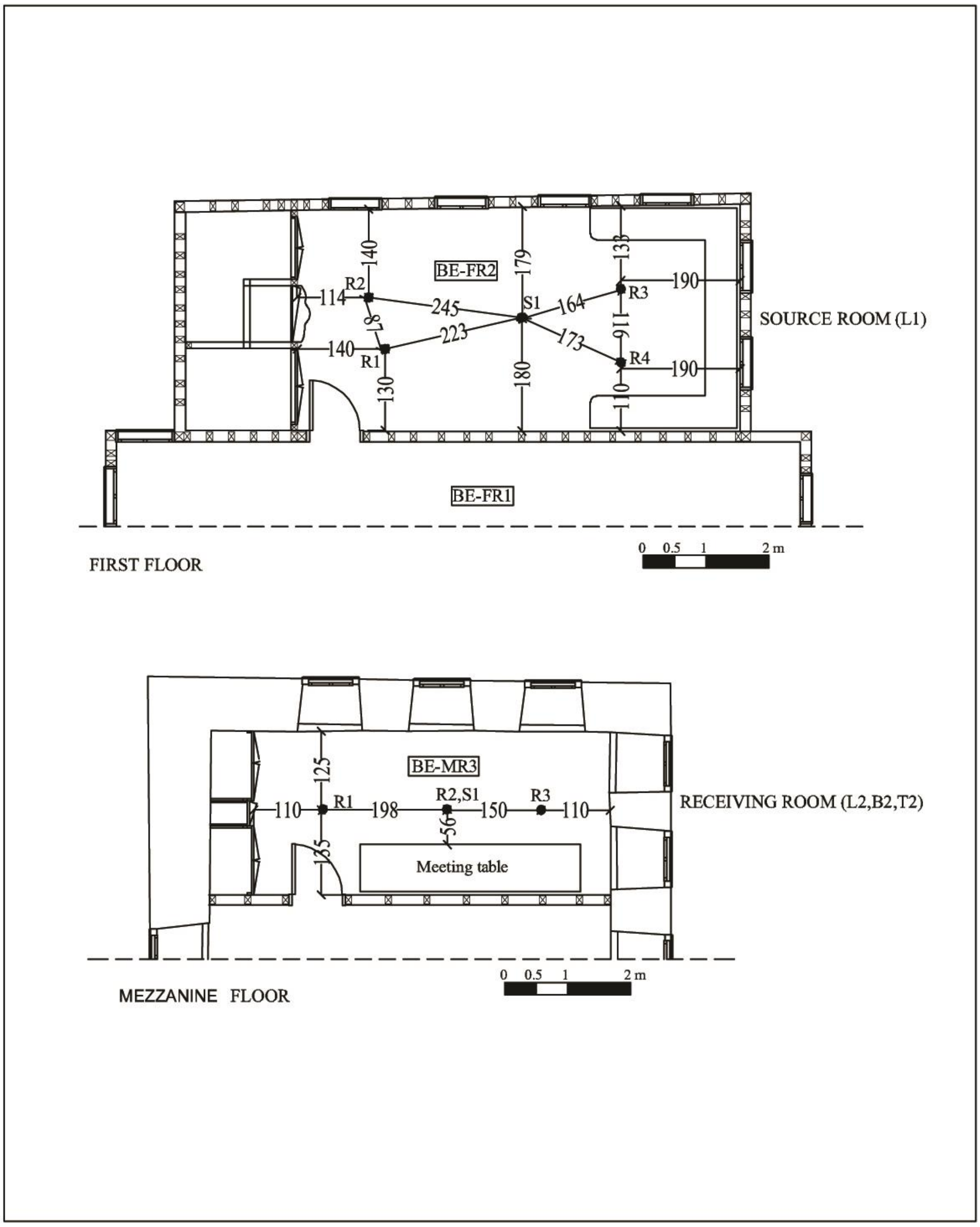


Figure B.2 Measurement of airborne sound transmission through Reconstructed-Floor 1 (F1-BE-FR1/MR3)

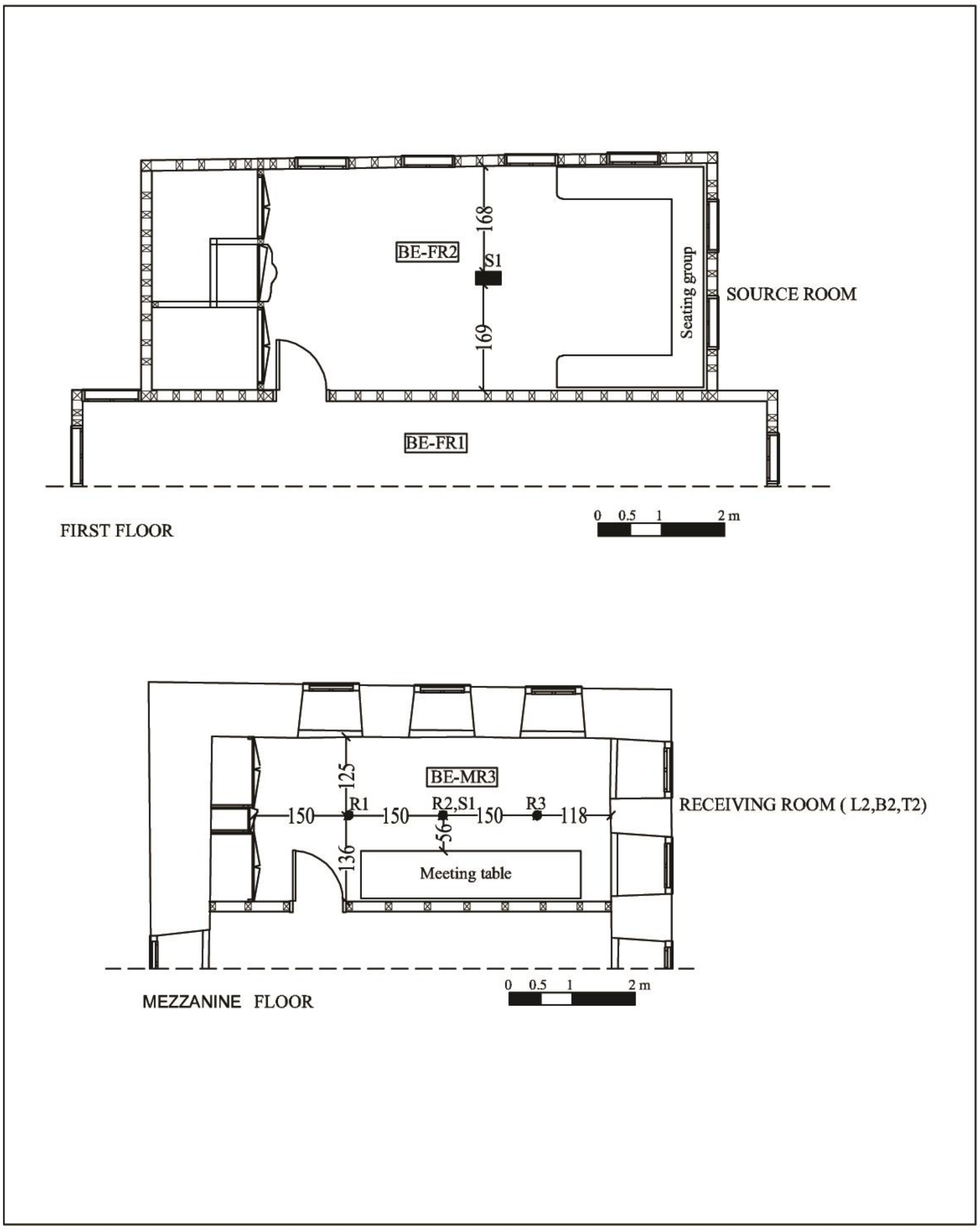


Figure B.3 Measurement of impact sound transmission through Reconstructed-Floor 1 w/ carpet and without carpet (F1-BE-FR1/MR3).

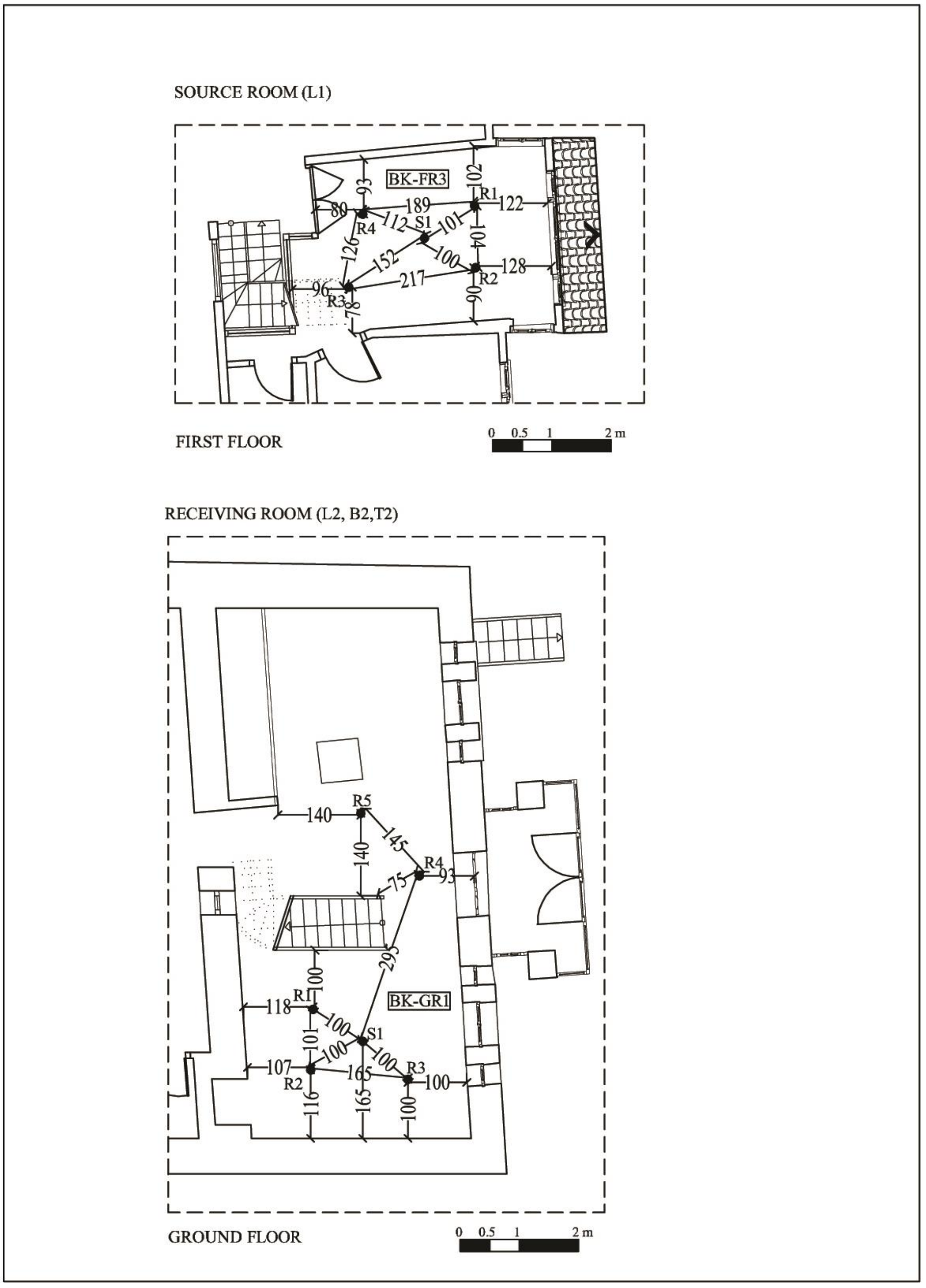


Figure B.4 Measurement of airborne sound transmission through Semi-Repaired-Floor 2 (F2-BK-FR3/GR1)

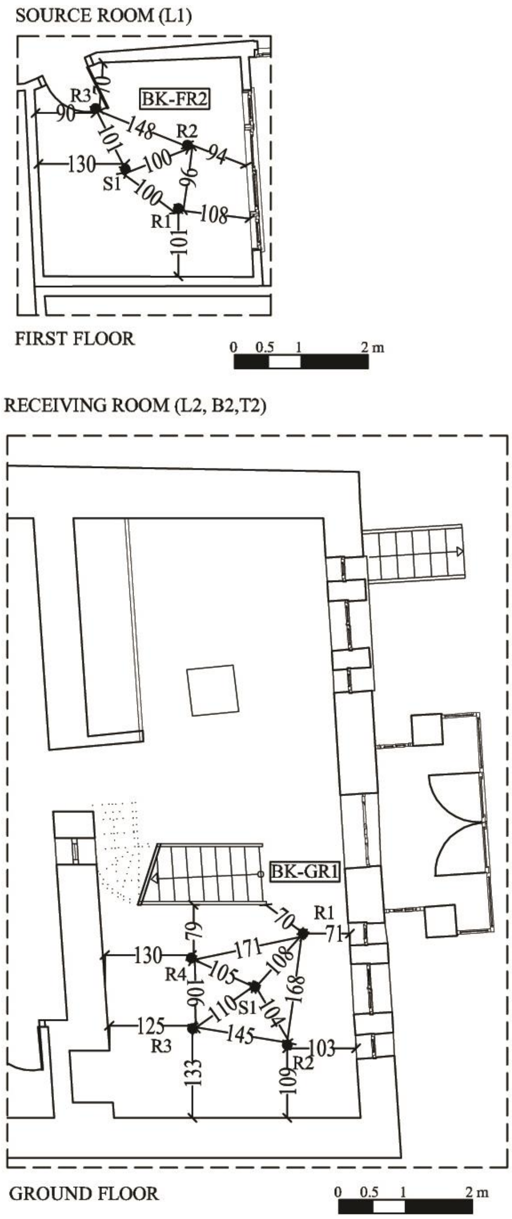


Figure B.5 Measurement of airborne sound transmission through Semi-Repaired- Floor 3 (F3-BK-FR2/GR1).

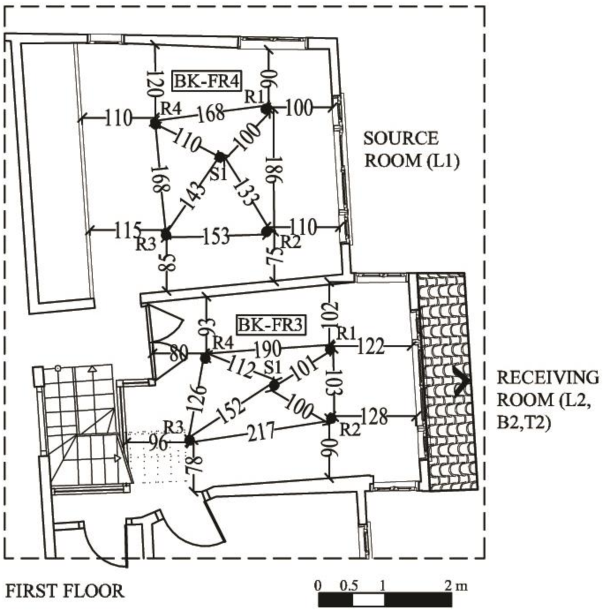


Figure B.6 Measurement of airborne sound transmission through Semi-Repaired-Wall 3 (W3-BK-FR3/R4).

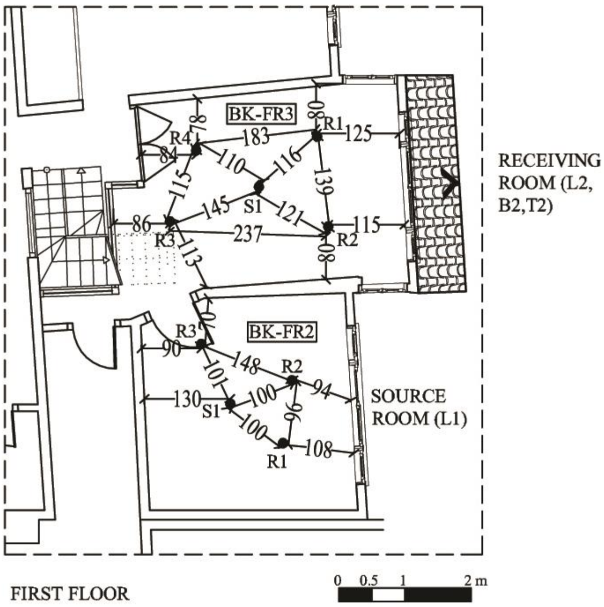


Figure B.7 Measurement of airborne sound transmission through Semi-Repaired-Wall 2 (W2-BK-FR2/R3).

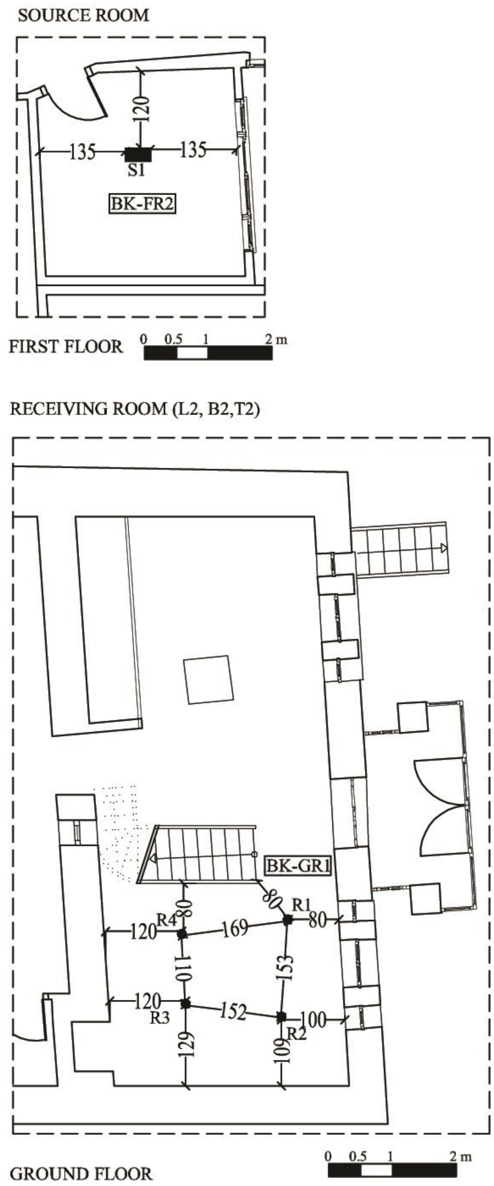


Figure B.8 Measurement of impact sound transmission through Semi-Repaired-Floor 3 (F3-BK-FR2/GR1).

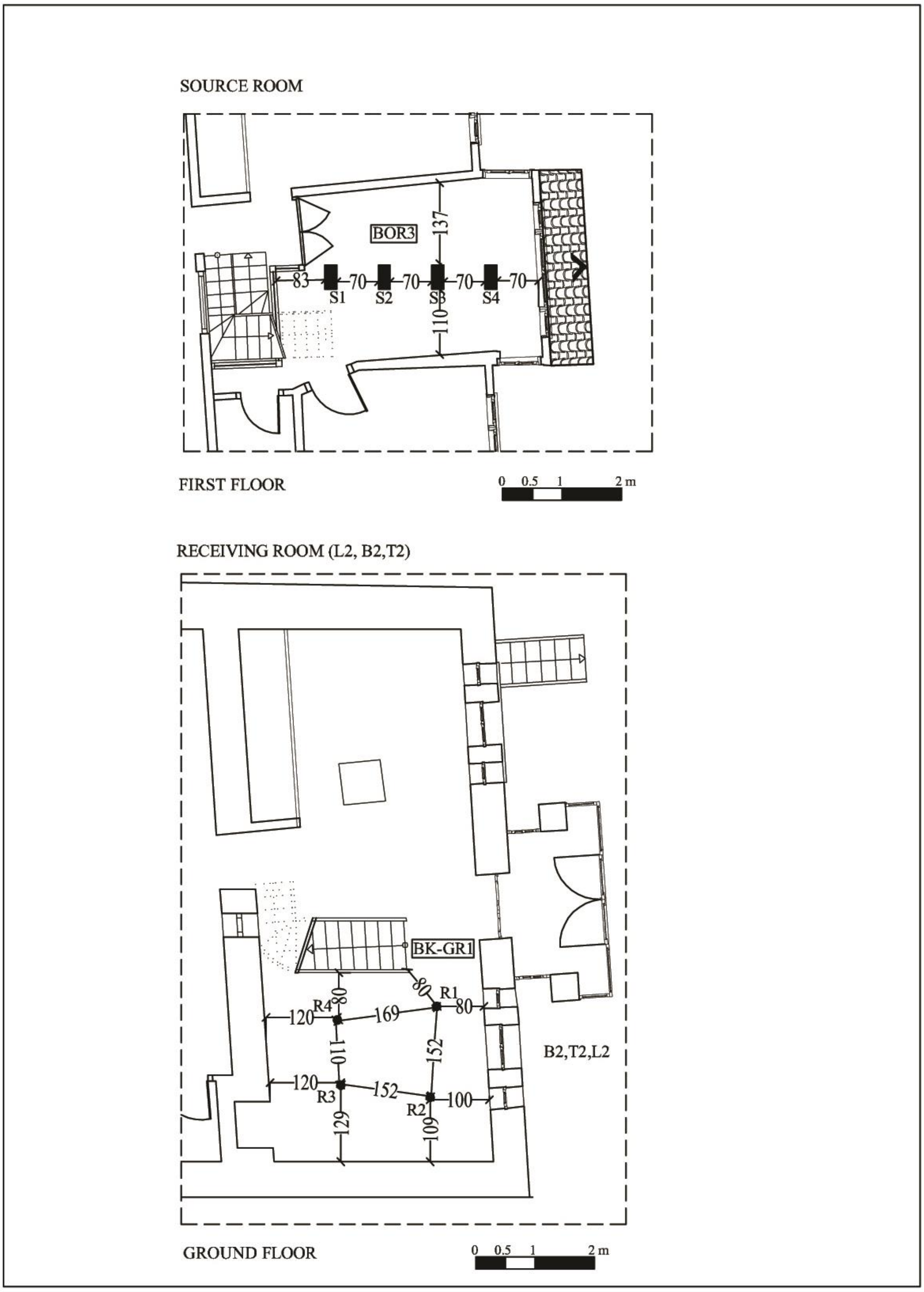


Figure B.9 Measurement of impact sound transmission through Semi-Repaired-Floor 2 (F2-BK-FR3/GR1).

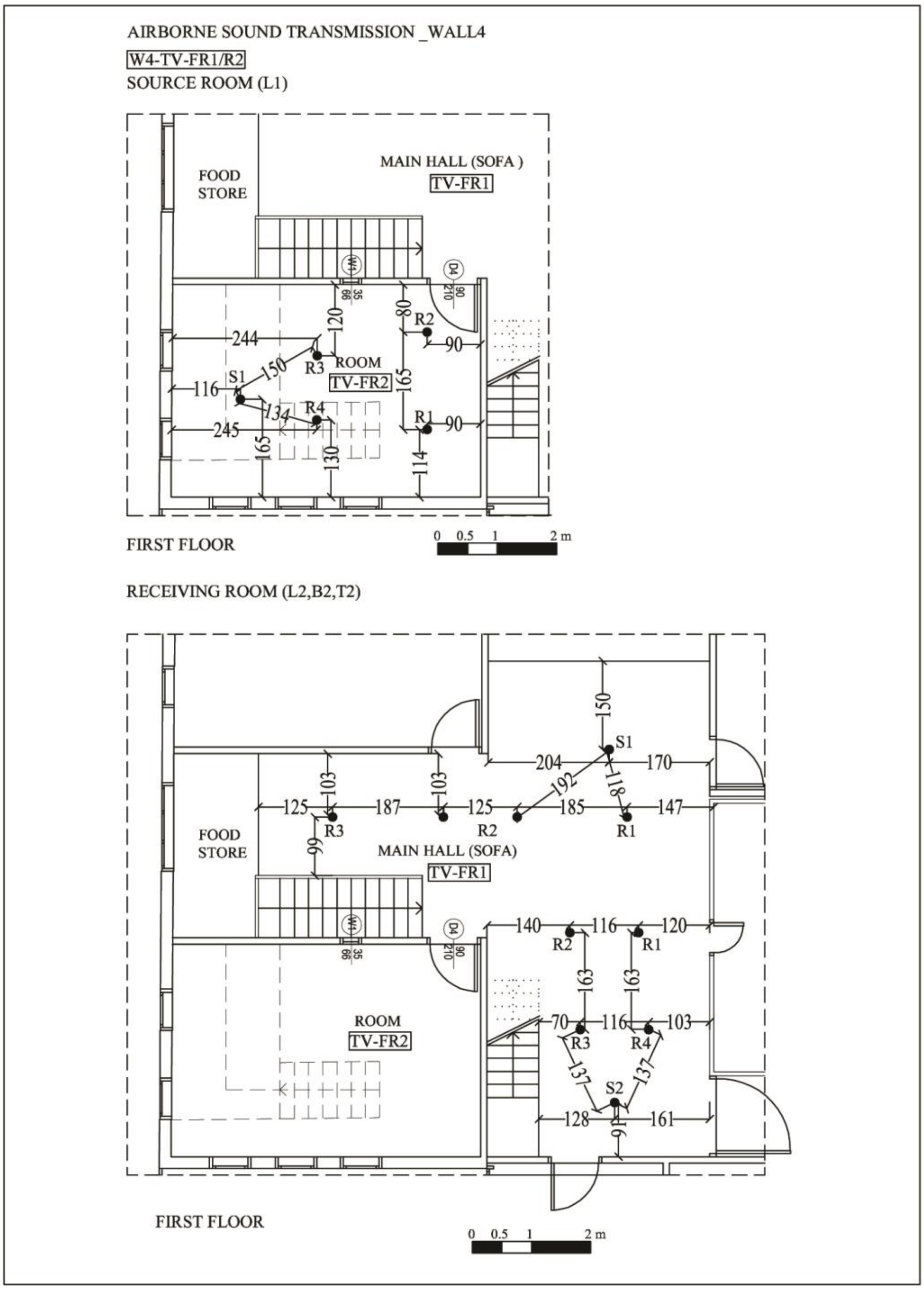


Figure B.10 Measurement of airborne sound transmission through Original-Wall 4 (W4-TV-FR1/ FR2).

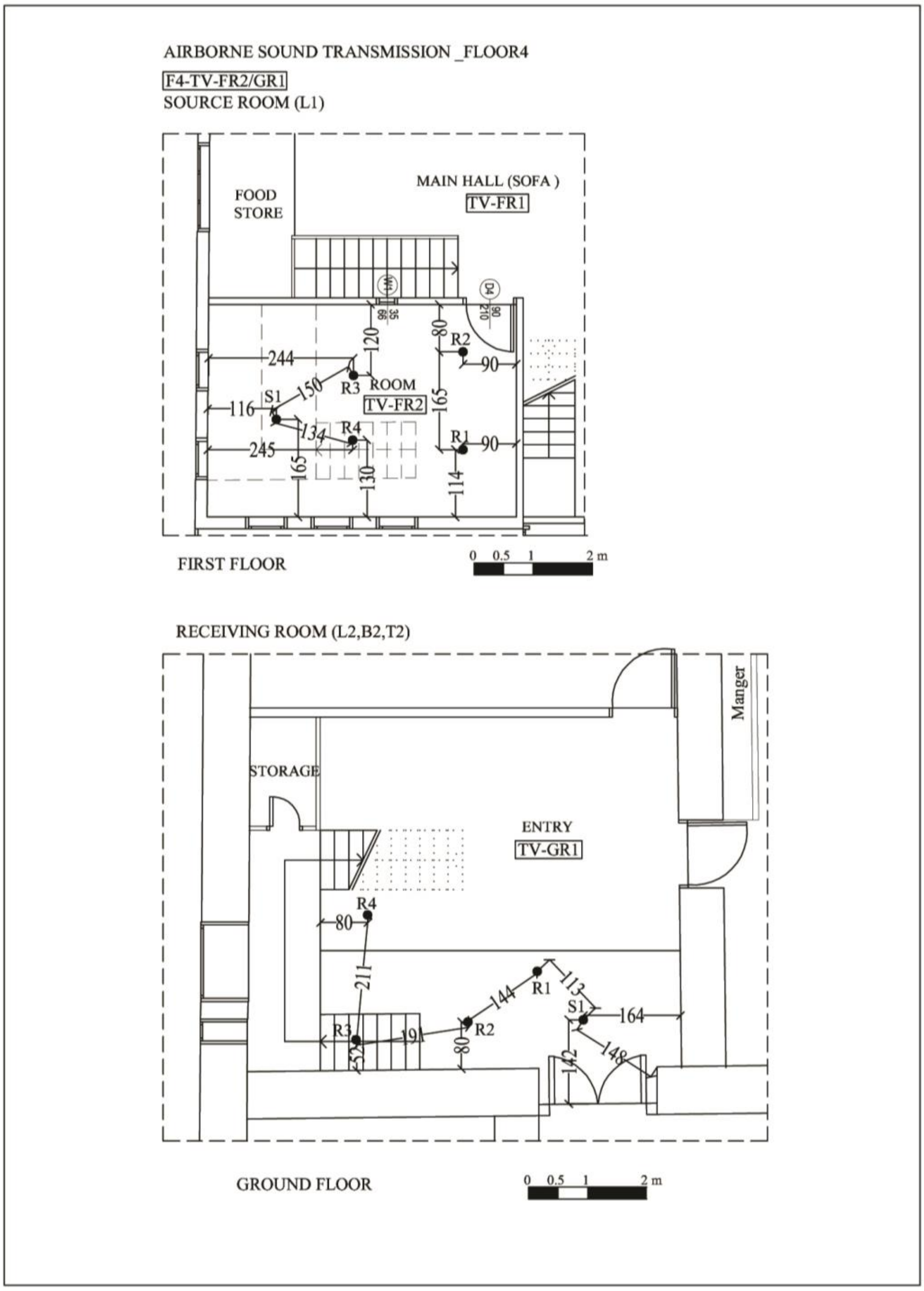


Figure B.11 Measurement of airborne sound transmission through Original- Floor 4 (F4-TV-FR2/ GR1).

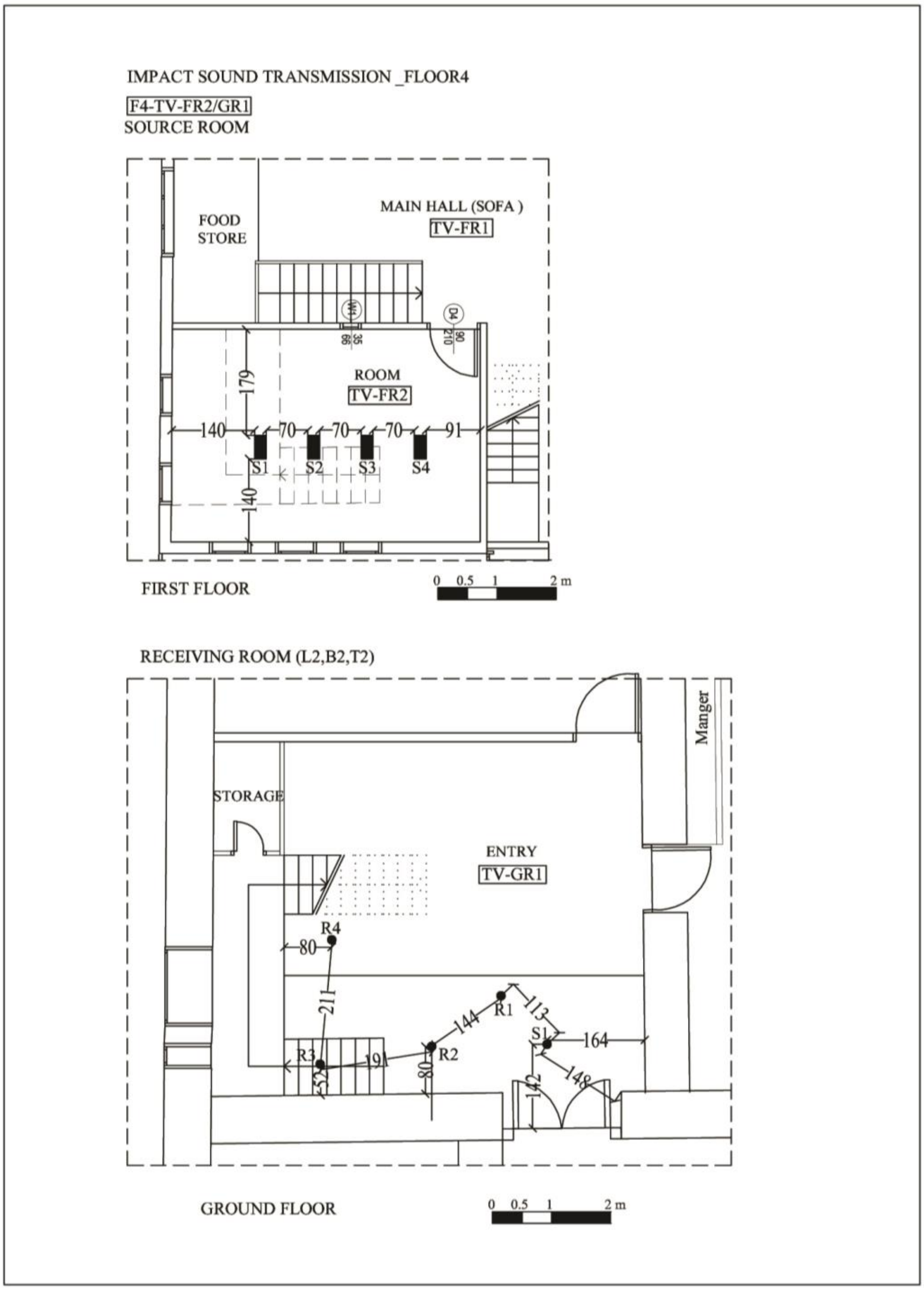


Figure B.12 Measurement of impact sound transmission through Original-Floor 4 (F4-TV-FR2/ GR1).

APPENDIX C

SOUND TRANSMISSION LOSS AND SOUND ABSORPTION COEFFICIENT VALUES OF MUDBRICK SAMPLES

Table C.1 Sound transmission loss (TL) values of MB1-50-a, MB1-50-b, MB1-100-a, MB1-100-b and MB2-50 (in 1/3 octave frequency band).

		Sound Transmission Loss (TL), dB				
Sample		MB1-50-a	MB1-50-b	MB1-100-a	MB1-100-b	MB2-50
1/3 octave band frequency centre, Hz	125	29	18	30	43	26
	160	22	28	41	36	26
	200	27	20	34	37	29
	250	23	22	37	40	27
	315	23	21	38	43	27
	400	23	21	37	41	26
	500	23	21	36	41	26
	630	25	22	37	42	27
	800	26	23	38	43	28
	1000	32	32	38	40	29
	1250	34	32	40	43	29
	1600	33	32	40	42	29
	2000	34	41	37	34	25
	2500	38	43	35	32	27
	3150	38	43	34	31	32
	4000	35	42	34	31	30
	5000	32	36	30	27	27
	6300	28	30	27	25	25

Table C.2 Sound absorption coefficients (α) of, MB1-50-a (in 1/3 octave frequency band).

		Sound Absorption Coefficient (α), unitless
Sample		MB1-50-a
1/3 octave band frequency centre, Hz	63	0,09
	80	0,11
	100	0,09
	125	0,08
	160	0,08
	200	0,09
	250	0,10
	315	0,12
	400	0,16
	500	0,24
	630	0,35
	800	0,39
	1000	0,41
	1250	0,30
	1600	0,22
	2000	0,19
	2500	0,21
	3150	0,25
	4000	0,36
	5000	0,30

APPENDIX D

ESTIMATED DATA OF EXISTING WALL & FLOOR COMPONENTS

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick-
(m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile

frequency (Hz)	R(dB)	R(dB)
50	37	
63	38	38
80	39	
100	38	
125	39	37
160	35	
200	35	
250	38	37
315	40	
400	43	
500	46	45
630	48	
800	51	
1000	53	53
1250	56	
1600	59	
2000	60	60
2500	62	
3150	63	
4000	65	65
5000	67	

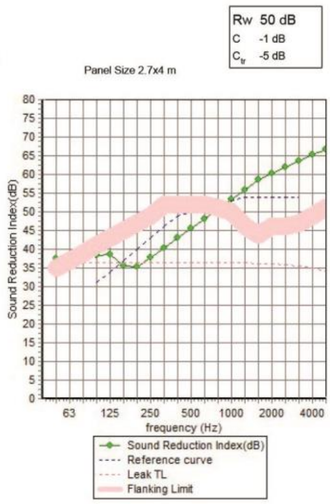


Figure D.1 Estimated data of Reconstructed-Wall-1.

System description

Panel 1 Outer layer: 1 x 100,0 mm Brick-
(m=160,0 kg/m2, fc=275 Hz, Damping=0,00) Profile
Panel 1 Inner layer: 2 x 5,0 mm Pine (m=4,9 kg/m2, fc=4082 Hz,Damping=0,04)

frequency (Hz)	TL(dB)	TL(dB)
50	35	
63	36	36
80	37	
100	38	
125	38	38
160	37	
200	37	
250	34	35
315	34	
400	37	
500	39	39
630	42	
800	45	
1000	47	47
1250	50	
1600	53	
2000	55	55
2500	58	
3150	60	
4000	61	61
5000	63	

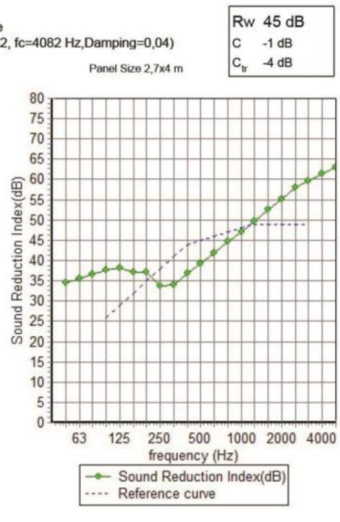


Figure D.2 Estimated data of Semi-Repaired-Wall 2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=254 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)

frequency (Hz)	R(dB)	R(dB)
50	31	
63	32	32
80	33	
100	34	
125	35	34
160	33	
200	33	
250	29	31
315	31	
400	34	
500	37	36
630	40	
800	42	
1000	45	45
1250	48	
1600	51	
2000	54	53
2500	57	
3150	59	
4000	61	60
5000	63	

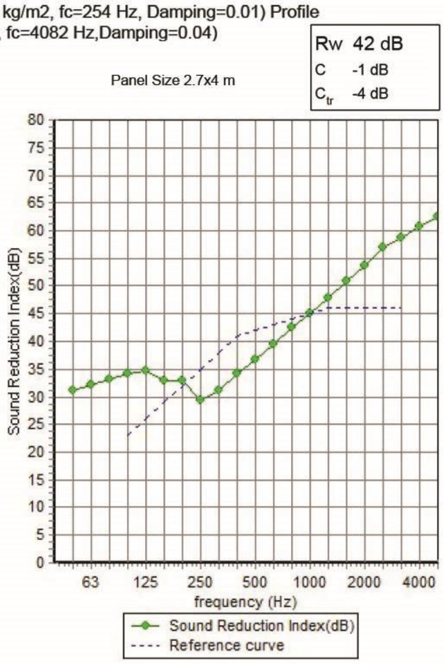


Figure D.3 Estimated data of Original-Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)

frequency (Hz)	R(dB)	R(dB)
50	32	
63	33	33
80	34	
100	35	
125	37	37
160	38	
200	40	
250	41	41
315	42	
400	43	
500	41	42
630	41	
800	38	
1000	40	40
1250	43	
1600	45	
2000	47	47
2500	49	
3150	51	
4000	53	52
5000	55	

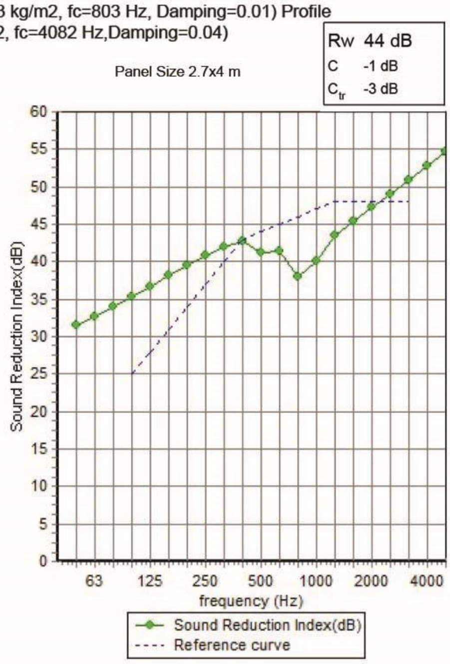
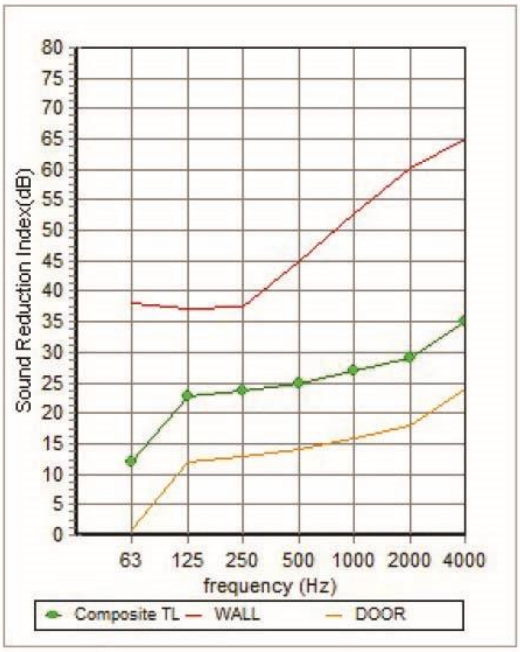


Figure D.4 Estimated data of Original-Wall 4.



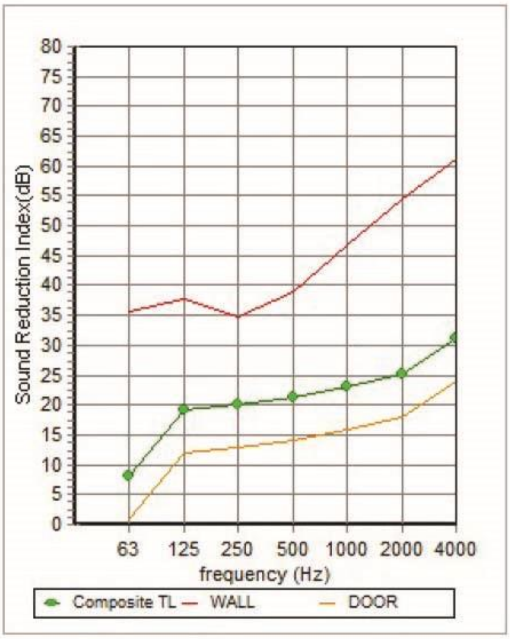
Rw 27 dB

C 0 dB

C_{tr} -1 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
12	23	24	25	27	29	35

Figure D.5 Composite sound reduction index of Reconstructed-Wall 1.



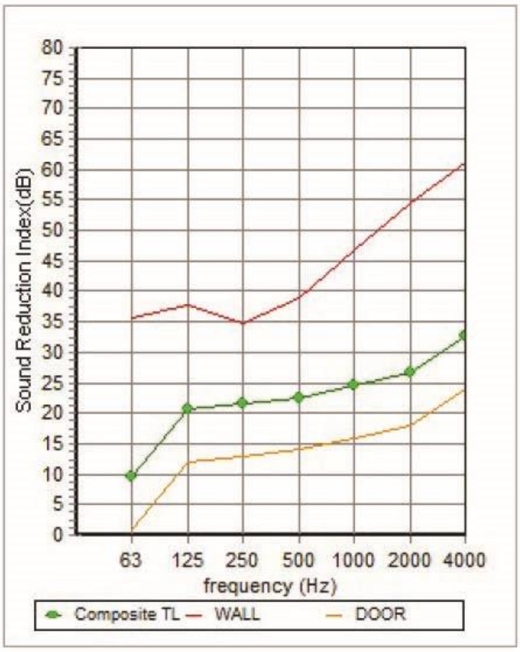
Rw 24 dB

C 0 dB

C_{tr} -2 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
8	19	20	21	23	25	31

Figure D.6 Composite sound reduction index of Semi-Repaired-Wall2.



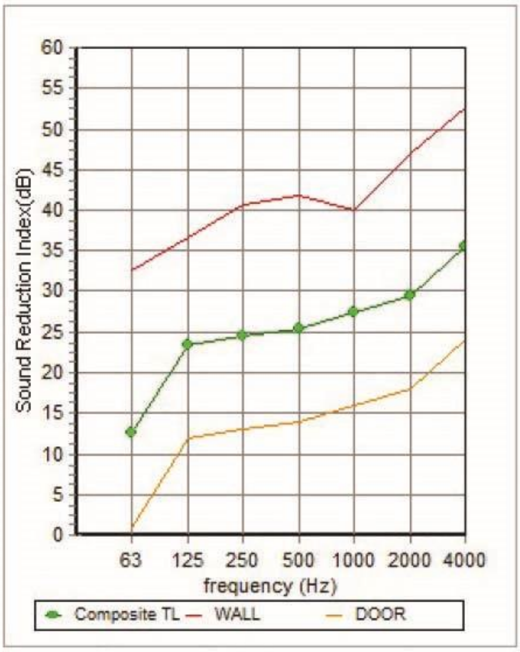
Rw 25 dB

C 0 dB

C_{tr} -1 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
10	21	21	23	25	27	33

Figure D.7 Composite sound reduction index of Semi-Repaired-Wall3.



Rw 28 dB

C 0 dB

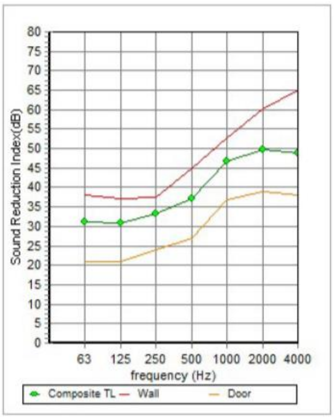
C_{tr} -1 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
13	23	24	25	27	30	35

Figure D.8 Composite sound reduction index of Original-Wall 4.

APPENDIX E

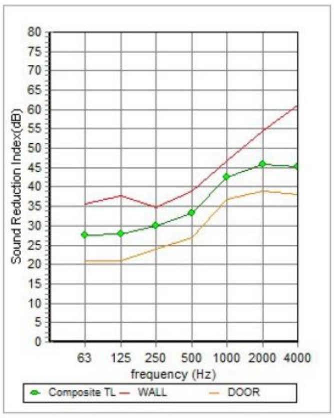
PROPOSALS OF WALL COMPONENTS



Rw 43 dB
C -1 dB
C_{tr} -4 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
31	31	33	37	47	50	49

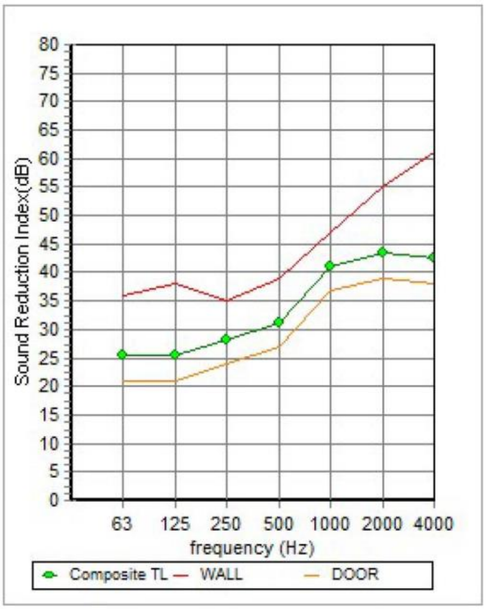
Figure E.1 Composite sound reduction index of Reconstructed-Wall 1 with a solid core door.



Rw 39 dB
C -1 dB
C_{tr} -4 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
28	28	30	33	43	46	45

Figure E.2 Composite sound reduction index of Semi-Repaired-Wall 2 with a solid core door.



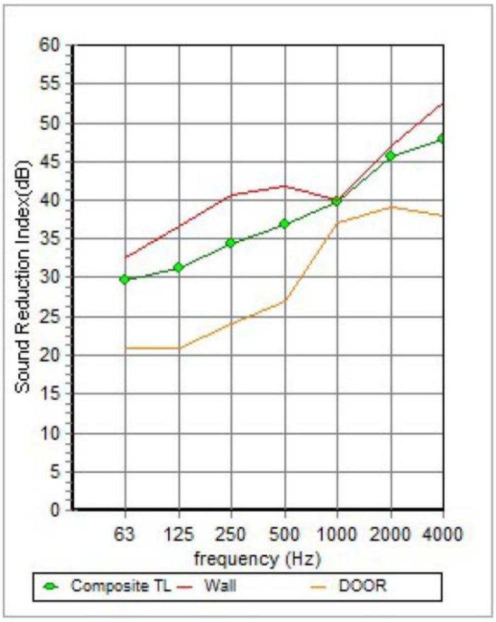
Rw 38 dB

C -2 dB

C_{tr} -5 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
25	26	28	31	41	44	43

Figure E.3 Composite sound reduction index of Semi-Repaired-Wall 3 with a solid core door.



Rw 41 dB

C -1 dB

C_{tr} -3 dB

Composite TL per Frequency(Hz))						
63	125	250	500	1k	2k	4k
30	31	34	37	40	46	48

Figure E.4 Composite sound reduction index of Original-Wall 4 with a solid core door.

System description

Panel 1 Outer layer: 1 x 200.0 mm Brick- (m=320.0 kg/m2, fc=137 Hz, Damping=0.00) Profile

Rw 54 dB
C -1 dB
C_{tr} -5 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	39	
63	40	39
80	39	
100	40	
125	37	38
160	38	
200	40	
250	43	42
315	45	
400	48	
500	50	50
630	53	
800	56	
1000	59	58
1250	61	
1600	62	
2000	64	64
2500	65	
3150	67	
4000	69	68
5000	70	

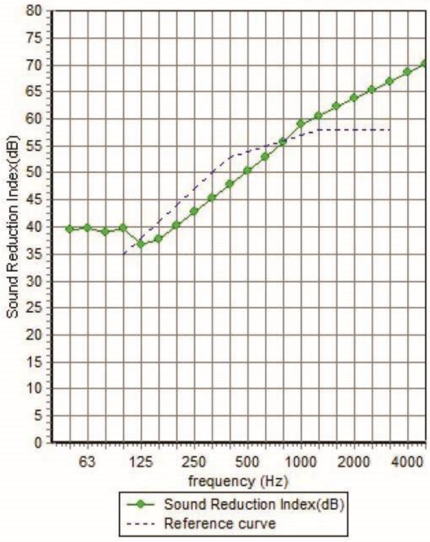


Figure E.5 Sound reduction index of 200mm-thick brick.

System description

Panel 1 Outer layer: 1 x 200.0 mm Brick- (m=320.0 kg/m2, fc=137 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)

Rw 54 dB
C -1 dB
C_{tr} -5 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	40	
63	40	40
80	39	
100	40	
125	37	38
160	38	
200	40	
250	43	43
315	45	
400	48	
500	51	50
630	53	
800	56	
1000	58	58
1250	61	
1600	63	
2000	64	64
2500	66	
3150	67	
4000	69	69
5000	71	

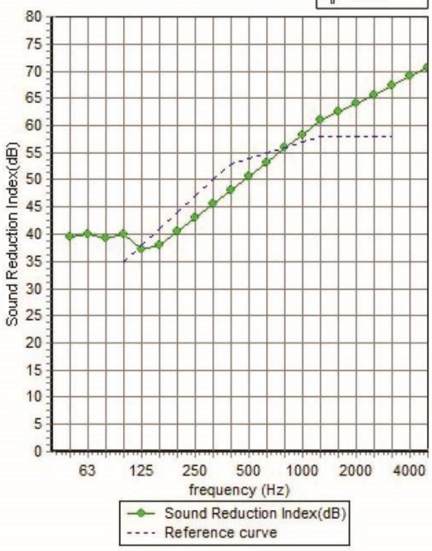


Figure E.6 Sound reduction index of 200mm-thick brick with two layers of board.

System description

Panel 1 Outer layer: 1 x 150,0 mm Brick- (m=240,0 kg/m2, fc=183 Hz, Damping=0,00) Profile
Cavity: Timber stud @ 600 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile
Mass-air-mass resonant frequency =83 Hz

frequency (Hz)	TL(dB)	TL(dB)
50	36	
63	35	34
80	32	
100	37	
125	35	35
160	34	
200	36	
250	39	39
315	43	
400	47	
500	51	50
630	55	
800	58	
1000	62	61
1250	64	
1600	68	
2000	69	68
2500	69	
3150	71	
4000	73	73
5000	75	

Panel Size 2,7x4 m

Rw 52 dB
C -2 dB
C_{tr} -6 dB

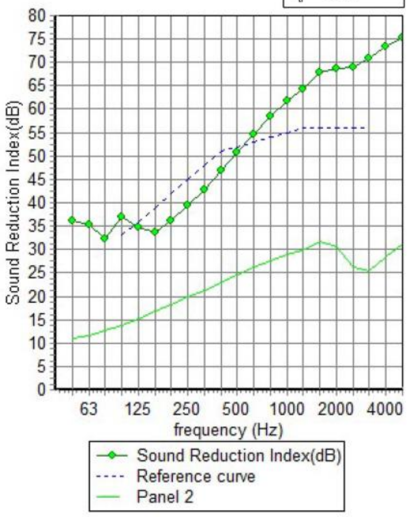


Figure E.7 Estimated data of Aw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150,0 mm Brick- (m=240,0 kg/m2, fc=183 Hz, Damping=0,00) Profile
Cavity: Timber stud @ 600 mm , Infill Sound absorber Thickness 60 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile
Mass-air-mass resonant frequency =70 Hz

frequency (Hz)	TL(dB)	TL(dB)
50	35	
63	33	34
80	36	
100	38	
125	42	40
160	41	
200	43	
250	46	45
315	49	
400	52	
500	55	54
630	58	
800	60	
1000	63	62
1250	65	
1600	68	
2000	70	69
2500	71	
3150	71	
4000	73	73
5000	75	

Panel Size 2,7x4 m

Rw 58 dB
C -2 dB
C_{tr} -6 dB

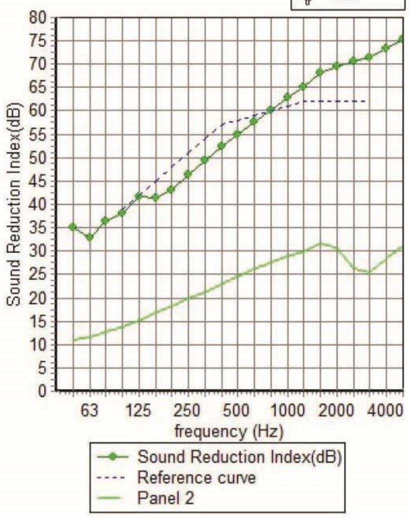


Figure E.8 Estimated data of Bw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Timber stud + resil. rail/bar @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

Panel Size 2.7x4 m

Rw 63 dB
C -3 dB
C_{tr} -8 dB

frequency (Hz)	R(dB)	R(dB)
50	35	
63	33	34
80	37	
100	40	
125	43	42
160	43	
200	46	
250	51	50
315	56	
400	60	
500	63	62
630	66	
800	69	
1000	71	71
1250	74	
1600	77	
2000	78	78
2500	80	
3150	81	
4000	83	83
5000	85	

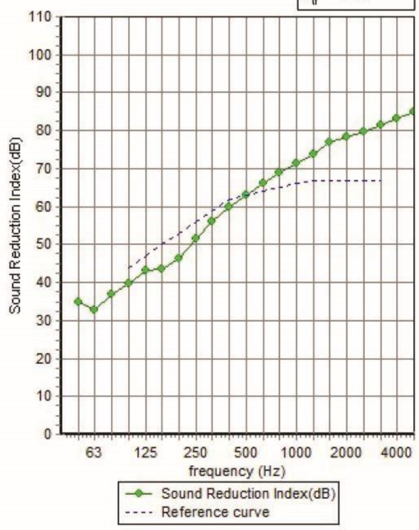


Figure E.9 Estimated data of Cw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Rubber Isolation Clip timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

Panel Size 2.7x4 m

Rw 64 dB
C -3 dB
C_{tr} -9 dB

frequency (Hz)	R(dB)	R(dB)
50	35	
63	33	34
80	37	
100	40	
125	43	42
160	44	
200	47	
250	53	51
315	59	
400	64	
500	69	67
630	73	
800	76	
1000	79	78
1250	81	
1600	84	
2000	86	85
2500	86	
3150	88	
4000	91	90
5000	93	

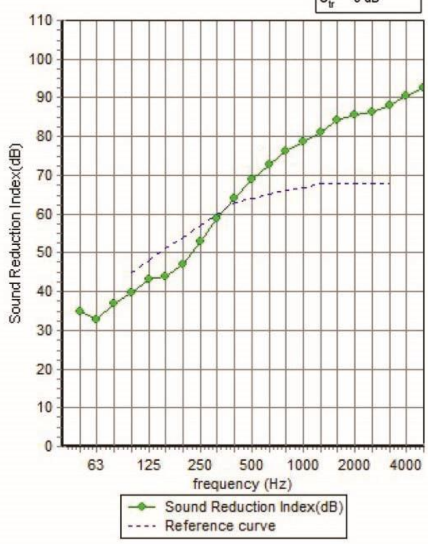


Figure E.10 Estimated data of Dw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Rubber Isolation Clip timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

frequency (Hz)	R(dB)	R(dB)
50	35	
63	33	34
80	37	
100	40	
125	43	42
160	44	
200	47	
250	53	51
315	59	
400	64	
500	69	67
630	73	
800	76	
1000	79	78
1250	81	
1600	84	
2000	86	85
2500	86	
3150	88	
4000	91	90
5000	93	

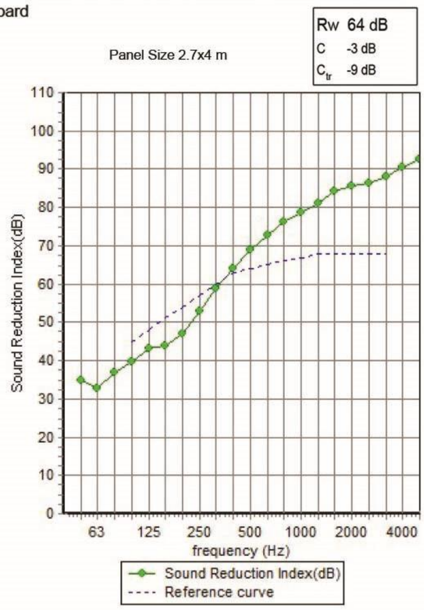


Figure E.11 Estimated data of Ew proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Steel stud (0.55mm) @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

frequency (Hz)	R(dB)	R(dB)
50	35	
63	33	34
80	37	
100	40	
125	43	42
160	44	
200	46	
250	52	50
315	56	
400	61	
500	64	63
630	67	
800	70	
1000	72	72
1250	75	
1600	78	
2000	79	79
2500	81	
3150	82	
4000	84	84
5000	86	

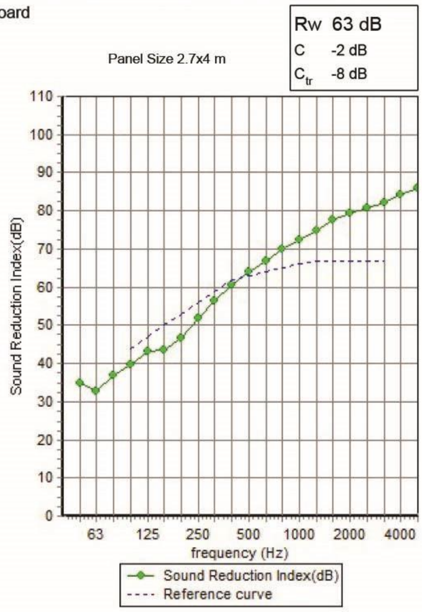


Figure E.12 Estimated data of Bw’ proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Steel stud + resil. rail @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

frequency (Hz)	R(dB)	R(dB)
50	35	
63	33	34
80	37	
100	40	
125	43	42
160	44	
200	47	
250	53	51
315	59	
400	64	
500	69	67
630	73	
800	76	
1000	79	78
1250	81	
1600	84	
2000	86	85
2500	86	
3150	88	
4000	91	90
5000	93	

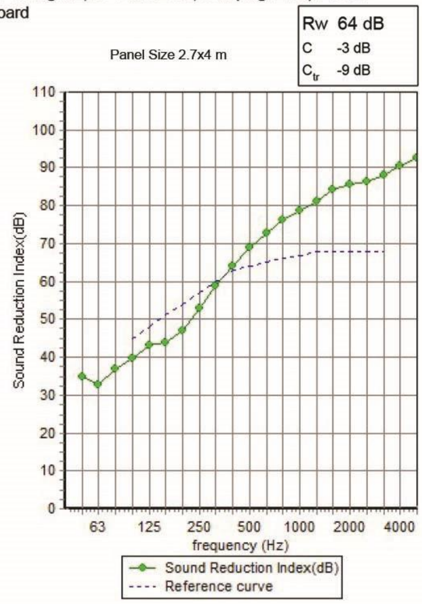


Figure E.13 Estimated data of Cw’ proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Rubber Isolation Clip Steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

frequency (Hz)	R(dB)	R(dB)
50	35	
63	33	34
80	37	
100	40	
125	43	42
160	44	
200	47	
250	53	51
315	59	
400	64	
500	69	67
630	73	
800	76	
1000	79	78
1250	81	
1600	84	
2000	86	85
2500	86	
3150	88	
4000	91	90
5000	93	

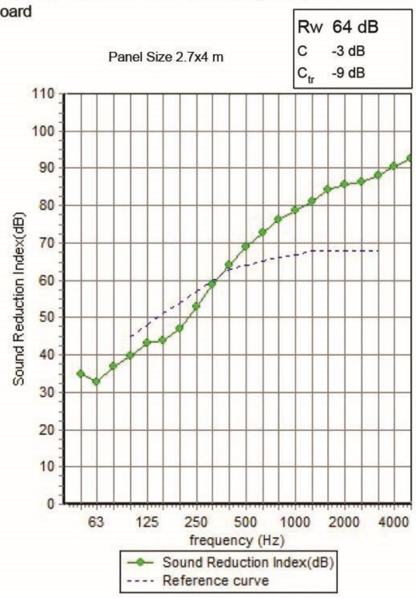


Figure E.14 Estimated data of Dw’ proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile

Cavity: Double steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile

Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

Panel Size 2.7x4 m

Rw 65 dB
C -2 dB
C_{tr} -8 dB

frequency (Hz)	R(dB)	R(dB)
50	34	
63	32	33
80	34	
100	41	
125	45	43
160	45	
200	48	
250	54	52
315	60	
400	67	
500	73	70
630	79	
800	85	
1000	86	86
1250	89	
1600	92	
2000	93	92
2500	91	
3150	93	
4000	98	96
5000	103	

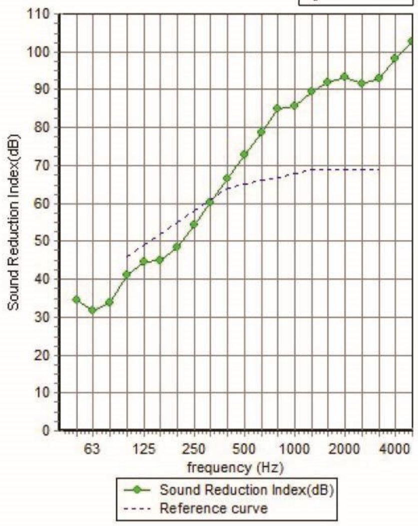


Figure E.15 Estimated data of Ew’ proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile

Cavity: None @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 0 x 2.8 mm Acoustiblok 16- (m=0.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile

Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =70 Hz

Panel Size 2.7x4 m

Rw 65 dB
C -2 dB
C_{tr} -8 dB

frequency (Hz)	R(dB)	R(dB)
50	34	
63	32	33
80	34	
100	41	
125	45	43
160	45	
200	48	
250	54	52
315	60	
400	67	
500	73	70
630	79	
800	85	
1000	86	86
1250	89	
1600	92	
2000	93	92
2500	91	
3150	93	
4000	98	96
5000	103	

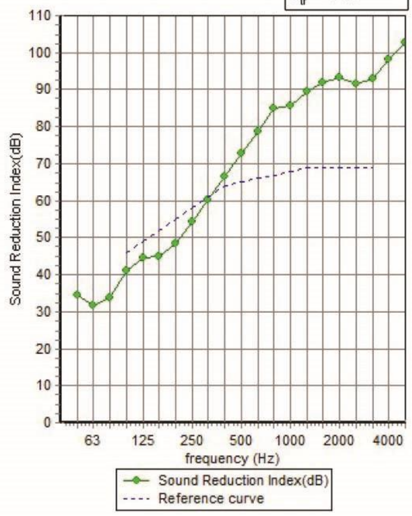


Figure E.16 Estimated data of Fw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 2 x 13.1 mm Gypsum plasterboard
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =51 Hz

Panel Size 2.7x4 m

Rw 71 dB
C -2 dB
C_{tr} -8 dB

frequency (Hz)	R(dB)	R(dB)
50	29	
63	38	33
80	46	
100	47	
125	50	49
160	51	
200	54	
250	60	58
315	66	
400	73	
500	79	76
630	85	
800	91	
1000	92	92
1250	96	
1600	98	
2000	99	98
2500	98	
3150	99	
4000	104	102
5000	109	

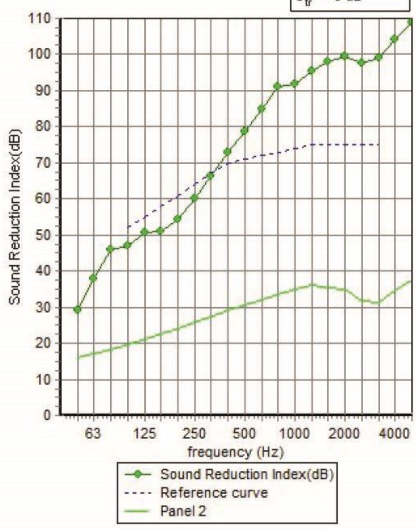


Figure E.17 Estimated data of Gw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 150.0 mm Brick- (m=240.0 kg/m2, fc=183 Hz, Damping=0.00) Profile
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 1 x 2.8 mm Acoustiblok 16- (m=5.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 2 x 13.1 mm Gypsum plasterboard
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =45 Hz

Panel Size 2.7x4 m

Rw 76 dB
C -3 dB
C_{tr} -9 dB

frequency (Hz)	R(dB)	R(dB)
50	33	
63	42	37
80	47	
100	50	
125	54	52
160	56	
200	60	
250	66	64
315	73	
400	79	
500	85	83
630	92	
800	98	
1000	100	100
1250	104	
1600	108	
2000	113	111
2500	120	
3150	124	
4000	129	127
5000	134	

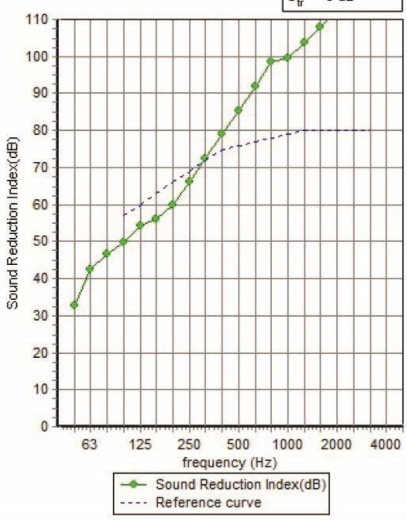


Figure E.18 Estimated data of Hw proposal of Reconstructed-Wall 1.

System description

Panel 1 Outer layer: 1 x 100,0 mm Brick- (m=160,0 kg/m2, fc=275 Hz, Damping=0,00) Profile
Panel 1 Inner layer: 2 x 5,0 mm Pine (m=4,9 kg/m2, fc=4082 Hz,Damping=0,04)
Cavity: Timber stud @ 600 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile

Mass-air-mass resonant frequency =84 Hz

Panel Size 2,7x4 m

Rw	48 dB
C	-2 dB
C_{tr}	-5 dB

frequency (Hz)	TL(dB)	TL(dB)
50	33	
63	33	32
80	30	
100	37	
125	36	37
160	36	
200	35	
250	33	35
315	36	
400	40	
500	44	43
630	48	
800	52	
1000	55	54
1250	58	
1600	61	
2000	63	63
2500	64	
3150	66	
4000	69	68
5000	71	

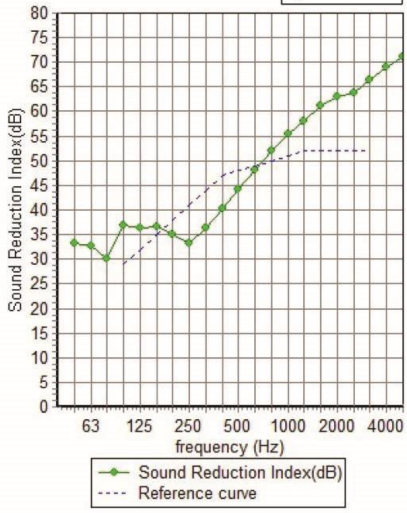


Figure E.19 Estimated data of Aw proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 50 mm
Panel 2 Inner layer: 1 x 13.1 mm Gypsum plasterboard-
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01) Profile
Mass-air-mass resonant frequency =71 Hz

Panel Size 2.7x4 m

Rw	53 dB
C	-1 dB
C_{tr}	-4 dB

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	32
80	34	
100	38	
125	41	40
160	43	
200	44	
250	42	43
315	42	
400	45	
500	48	47
630	50	
800	53	
1000	56	55
1250	58	
1600	61	
2000	63	63
2500	65	
3150	66	
4000	68	68
5000	70	

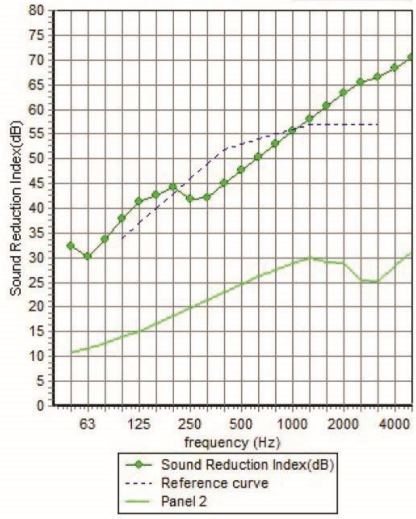


Figure E.20 Estimated data of Bw proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Timber stud + resil. rail/bar @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 1 x 13.1 mm Gypsum plasterboard-
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01) Profile
Mass-air-mass resonant frequency =71 Hz

Rw 60 dB
C -2 dB
C_{tr} -6 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	32
80	34	
100	39	
125	43	41
160	45	
200	48	
250	48	48
315	50	
400	54	
500	57	56
630	60	
800	63	
1000	65	65
1250	68	
1600	71	
2000	73	73
2500	76	
3150	76	
4000	78	78
5000	80	

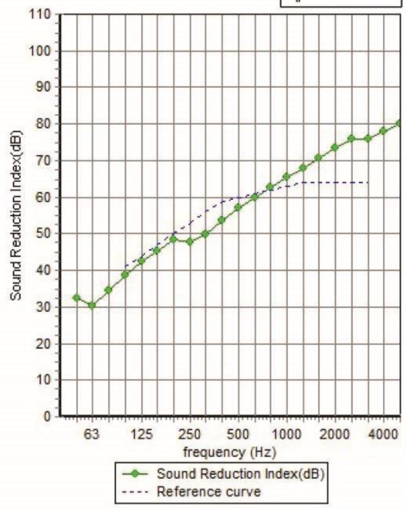


Figure E.21 Estimated data of Cw proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Rubber Isolation Clip timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =71 Hz

Rw 62 dB
C -2 dB
C_{tr} -7 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	32
80	35	
100	39	
125	43	41
160	46	
200	49	
250	49	50
315	52	
400	58	
500	63	61
630	67	
800	70	
1000	72	72
1250	75	
1600	78	
2000	81	80
2500	83	
3150	84	
4000	87	86
5000	89	

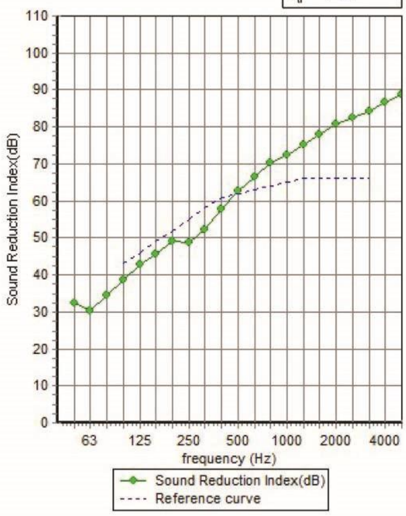


Figure E.22 Estimated data of Dw proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100,0 mm Brick- (m=160,0 kg/m2, fc=275 Hz, Damping=0,00) Profile
Panel 1 Inner layer: 2 x 5,0 mm Pine (m=4,9 kg/m2, fc=4082 Hz,Damping=0,04)
Cavity: Double timber stud @ 600 mm , Infill Sound absorber Thickness 60 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile
Mass-air-mass resonant frequency =71 Hz

frequency (Hz)	TL(dB)	TL(dB)
50	32	
63	30	31
80	31	
100	40	
125	44	43
160	47	
200	50	
250	50	51
315	54	
400	60	
500	66	64
630	72	
800	78	
1000	79	80
1250	83	
1600	88	
2000	89	88
2500	88	
3150	89	
4000	94	92
5000	98	

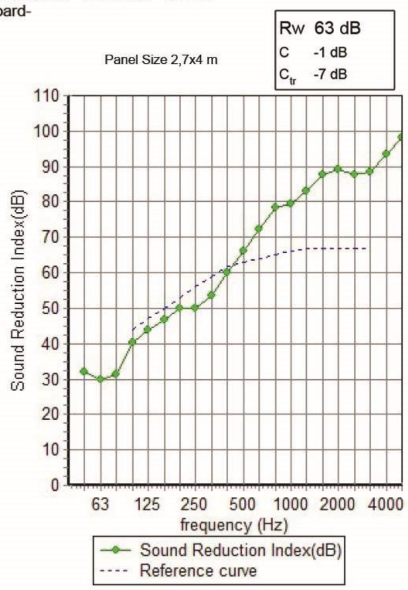


Figure E.23 Estimated data of Ew proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Steel stud (0.55mm) @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =71 Hz

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	32
80	34	
100	39	
125	43	41
160	45	
200	48	
250	48	49
315	50	
400	54	
500	58	57
630	61	
800	64	
1000	66	66
1250	69	
1600	72	
2000	74	74
2500	77	
3150	79	
4000	81	80
5000	82	

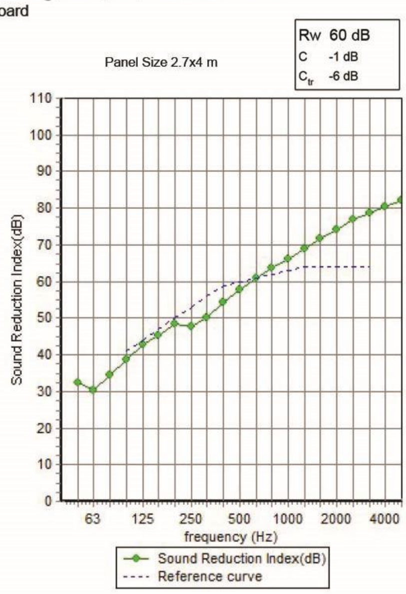


Figure E.24 Estimated data of Bw' proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Steel stud + resil. rail @ 600 mm . Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =71 Hz

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	32
80	35	
100	39	
125	43	41
160	46	
200	49	
250	49	50
315	52	
400	58	
500	63	61
630	67	
800	70	
1000	72	72
1250	75	
1600	78	
2000	81	80
2500	83	
3150	84	
4000	87	86
5000	89	

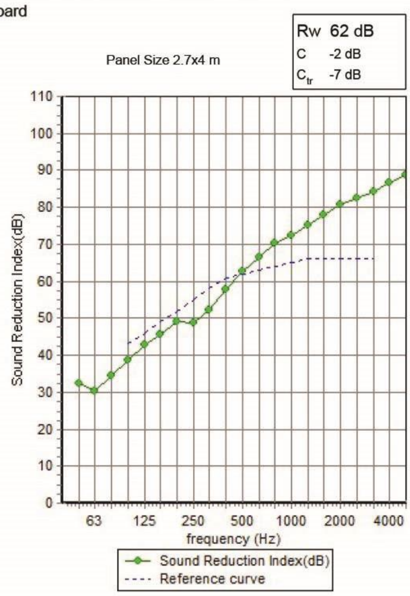


Figure E.25 Estimated data of Cw' proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Rubber Isolation Clip Steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =71 Hz

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	32
80	35	
100	39	
125	43	41
160	46	
200	49	
250	49	50
315	52	
400	58	
500	63	61
630	67	
800	70	
1000	72	72
1250	75	
1600	78	
2000	81	80
2500	83	
3150	84	
4000	87	86
5000	89	

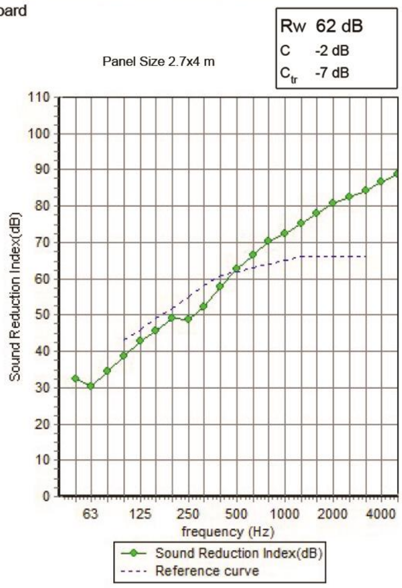


Figure E.26 Estimated data of the proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =71 Hz

Panel Size 2.7x4 m

Rw 63 dB
C -1 dB
C_{tr} -7 dB

frequency (Hz)	R(dB)	R(dB)
50	32	
63	30	31
80	31	
100	40	
125	44	43
160	47	
200	50	
250	50	51
315	54	
400	60	
500	66	64
630	73	
800	79	
1000	80	80
1250	83	
1600	86	
2000	88	87
2500	88	
3150	89	
4000	94	92
5000	99	

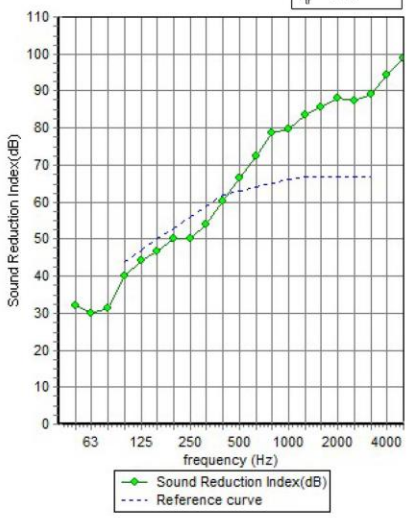


Figure E.27 Estimated data of Ew' proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 2 x 13.1 mm Gypsum plasterboard-
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01) Profile
Mass-air-mass resonant frequency =51 Hz

Panel Size 2.7x4 m

Rw 69 dB
C -1 dB
C_{tr} -7 dB

frequency (Hz)	R(dB)	R(dB)
50	27	
63	35	31
80	43	
100	46	
125	50	49
160	53	
200	56	
250	56	57
315	60	
400	66	
500	72	70
630	79	
800	85	
1000	86	86
1250	89	
1600	92	
2000	94	93
2500	94	
3150	95	
4000	100	99
5000	105	

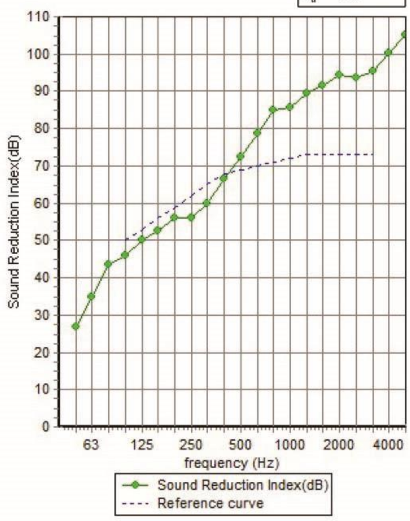


Figure E.28 Estimated data of Gw' proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 1 x 2.8 mm Acoustiblok 16- (m=5.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 2 x 13.1 mm Gypsum plasterboard
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =46 Hz

frequency (Hz)	R(dB)	R(dB)
50	29	
63	39	33
80	44	
100	48	
125	52	51
160	55	
200	58	
250	58	59
315	62	
400	69	
500	75	72
630	81	
800	87	
1000	88	89
1250	92	
1600	96	
2000	102	100
2500	110	
3150	113	
4000	118	116
5000	123	

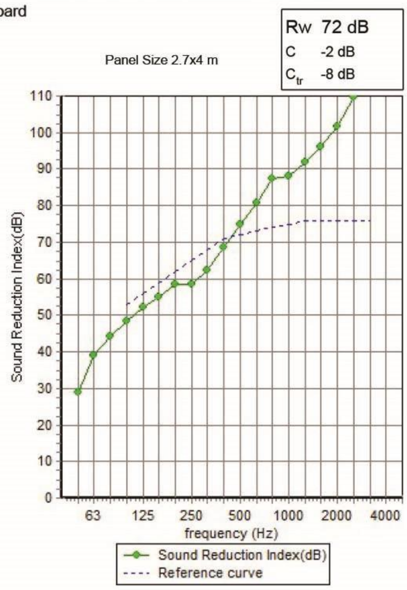


Figure E.29 Estimated data of Hw proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm Brick- (m=160.0 kg/m2, fc=275 Hz, Damping=0.00) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 2 x 13.1 mm Gypsum plasterboard-
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01) Profile
Mass-air-mass resonant frequency =51 Hz

frequency (Hz)	R(dB)	R(dB)
50	27	
63	35	31
80	43	
100	46	
125	50	49
160	53	
200	56	
250	56	57
315	60	
400	66	
500	72	70
630	79	
800	85	
1000	86	86
1250	89	
1600	92	
2000	94	93
2500	94	
3150	95	
4000	100	99
5000	105	

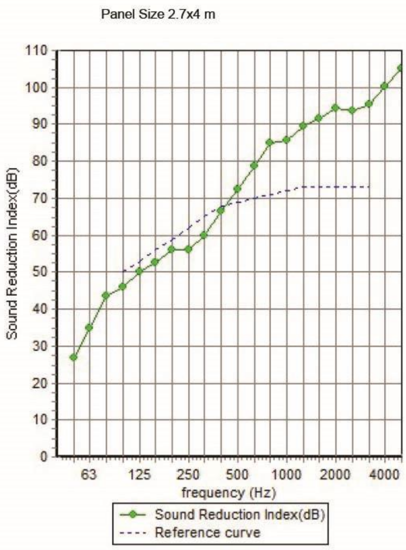


Figure E.30 Estimated data of Gw' proposal of Semi-Repaired-Wall2/3.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Timber stud @ 600 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile

Mass-air-mass resonant frequency =84 Hz

frequency (Hz)	TL(dB)	TL(dB)
50	33	
63	33	32
80	30	
100	37	
125	36	37
160	36	
200	35	
250	33	35
315	36	
400	40	
500	44	43
630	48	
800	52	
1000	55	54
1250	58	
1600	61	
2000	63	63
2500	64	
3150	66	
4000	69	68
5000	71	

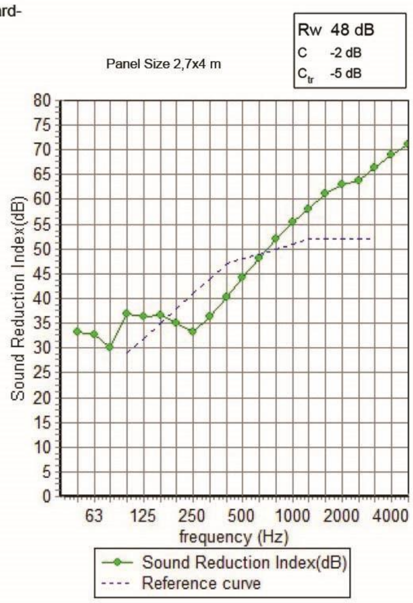


Figure E.31 Estimated data of Aw proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100,0 mm MUD- (m=107,3 kg/m2, fc=803 Hz, Damping=0,01) Profile
Panel 1 Inner layer: 2 x 5,0 mm Pine (m=4,9 kg/m2, fc=4082 Hz,Damping=0,04)
Cavity: Timber stud @ 600 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile

Mass-air-mass resonant frequency =66 Hz

frequency (Hz)	TL(dB)	TL(dB)
50	29	
63	27	29
80	34	
100	33	
125	36	35
160	38	
200	41	
250	44	43
315	47	
400	49	
500	50	49
630	50	
800	47	
1000	49	49
1250	52	
1600	55	
2000	56	56
2500	57	
3150	59	
4000	61	61
5000	63	

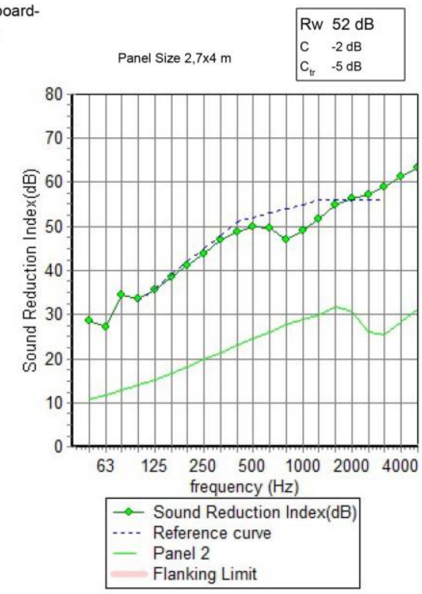


Figure E.32 Estimated data of Bw proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100,0 mm MUD- (m=107,3 kg/m2, fc=803 Hz, Damping=0,01) Profile
Panel 1 Inner layer: 2 x 5,0 mm Pine (m=4,9 kg/m2, fc=4082 Hz,Damping=0,04)
Cavity: Timber stud + resil. rail/bar @ 600 mm , Infill Sound absorber Thickness 60 mm
Panel 2 Inner layer: 1 x 13,1 mm Gypsum plasterboard-
(m=9,0 kg/m2, fc=2901 Hz, Damping=0,01) Profile
Mass-air-mass resonant frequency =56 Hz

Panel Size 2,7x4 m

Rw 62 dB
C -2 dB
C_{tr} -6 dB

frequency (Hz)	TL(dB)	TL(dB)
50	27	
63	31	30
80	36	
100	41	
125	45	44
160	50	
200	54	
250	57	56
315	59	
400	61	
500	62	61
630	61	
800	57	
1000	58	58
1250	61	
1600	64	
2000	66	66
2500	68	
3150	68	
4000	70	70
5000	72	

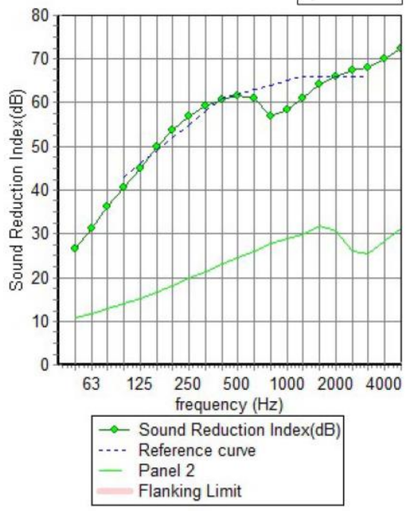


Figure E.33 Estimated data of Cw proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Rubber Isolation Clip timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =72 Hz

Panel Size 2.7x4 m

Rw 64 dB
C -3 dB
C_{tr} -10 dB

frequency (Hz)	R(dB)	R(dB)
50	29	
63	28	29
80	32	
100	36	
125	41	39
160	46	
200	51	
250	56	54
315	60	
400	64	
500	65	65
630	67	
800	64	
1000	66	66
1250	69	
1600	71	
2000	73	73
2500	74	
3150	76	
4000	79	78
5000	81	

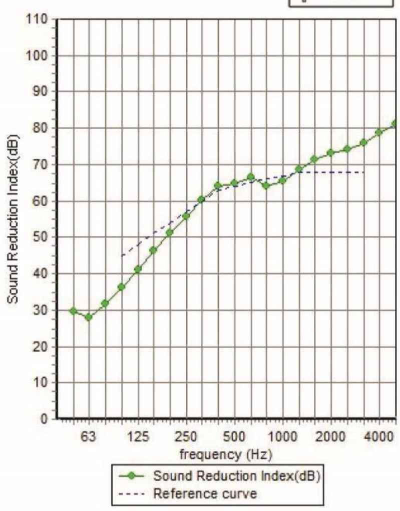


Figure E.34 Estimated data of Dw proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard (m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =72 Hz

frequency (Hz)	R(dB)	R(dB)
50	29	
63	28	28
80	28	
100	38	
125	43	41
160	48	
200	52	
250	57	56
315	62	
400	66	
500	68	68
630	72	
800	72	
1000	73	73
1250	77	
1600	78	
2000	80	79
2500	79	
3150	80	
4000	86	84
5000	90	

Panel Size 2.7x4 m

Rw 66 dB
C -3 dB
C_{tr} -10 dB

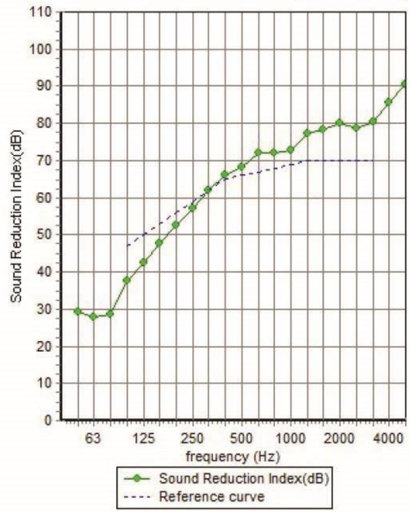


Figure E.35 Estimated data of Ew proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Steel stud (0.55mm) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =72 Hz

frequency (Hz)	R(dB)	R(dB)
50	29	
63	28	29
80	31	
100	36	
125	41	39
160	46	
200	51	
250	54	53
315	58	
400	60	
500	60	60
630	60	
800	57	
1000	59	59
1250	61	
1600	64	
2000	66	66
2500	68	
3150	70	
4000	72	71
5000	74	

Panel Size 2.7x4 m

Rw 61 dB
C -3 dB
C_{tr} -8 dB

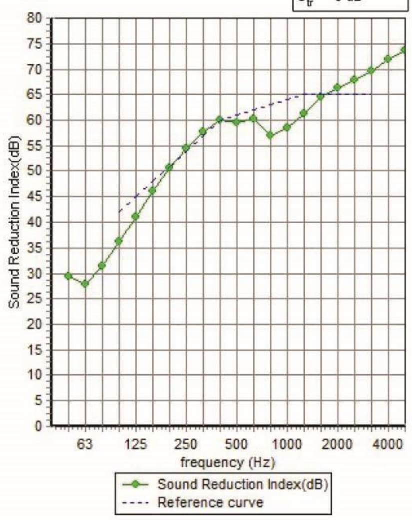


Figure E.36 Estimated data of Bw’ proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Steel stud + resil. rail @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard (m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =72 Hz

Rw 64 dB
C -3 dB
C_{tr} -10 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	29	
63	28	29
80	32	
100	36	
125	41	39
160	46	
200	51	
250	56	54
315	60	
400	64	
500	65	65
630	67	
800	64	
1000	66	66
1250	69	
1600	71	
2000	73	73
2500	74	
3150	76	
4000	79	78
5000	81	

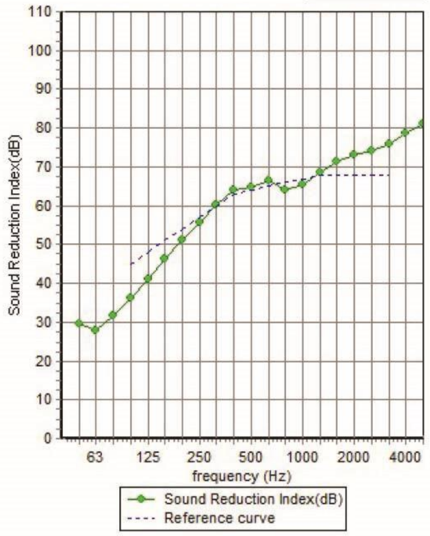


Figure E.37 Estimated data of Cw’ proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Rubber Isolation Clip Steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =72 Hz

Rw 64 dB
C -3 dB
C_{tr} -10 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	29	
63	28	29
80	32	
100	36	
125	41	39
160	46	
200	51	
250	56	54
315	60	
400	64	
500	65	65
630	67	
800	64	
1000	66	66
1250	69	
1600	71	
2000	73	73
2500	74	
3150	76	
4000	79	78
5000	81	

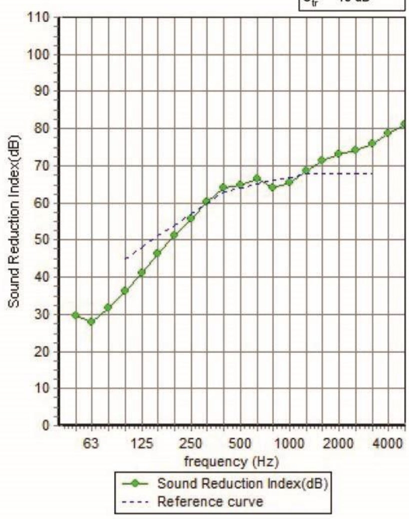


Figure E.38 Estimated data of Dw’ proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Outer layer: 1 x 13.1 mm Gypsum plasterboard
(m=9.0 kg/m2, fc=2901 Hz, Damping=0.01)

frequency (Hz)	R(dB)	R(dB)
50	29	
63	28	28
80	28	
100	38	
125	43	41
160	48	
200	52	
250	57	56
315	62	
400	66	
500	68	68
630	72	
800	72	
1000	73	73
1250	77	
1600	78	
2000	80	79
2500	79	
3150	80	
4000	86	84
5000	90	

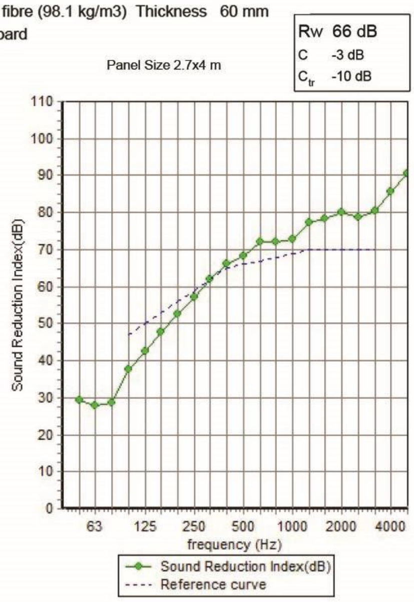


Figure E.39 Estimated data of Ew’ proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 2 x 13.1 mm Gypsum plasterboard-
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01) Profile
Mass-air-mass resonant frequency =53 Hz

frequency (Hz)	R(dB)	R(dB)
50	25	
63	31	29
80	40	
100	44	
125	48	47
160	54	
200	58	
250	63	62
315	68	
400	72	
500	74	74
630	78	
800	78	
1000	79	80
1250	83	
1600	85	
2000	86	85
2500	85	
3150	87	
4000	92	90
5000	97	

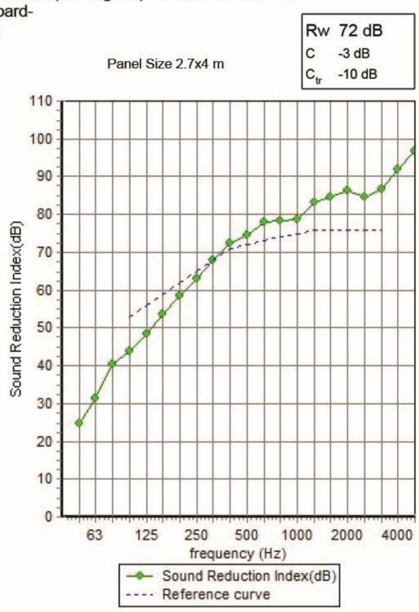


Figure E.40 Estimated data of Gw proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double timber stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 1 x 2.8 mm Acoustiblok 16- (m=5.0 kg/m2, fc=347482 Hz, Damping=2.00) Profile
Panel 2 Outer layer: 2 x 13.1 mm Gypsum plasterboard
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01)
Mass-air-mass resonant frequency =47 Hz

Panel Size 2.7x4 m

Rw 74 dB
C -3 dB
C_{tr} -10 dB

frequency (Hz)	R(dB)	R(dB)
50	25	
63	36	29
80	41	
100	46	
125	51	49
160	56	
200	61	
250	65	64
315	70	
400	75	
500	77	77
630	80	
800	81	
1000	81	82
1250	86	
1600	89	
2000	94	92
2500	101	
3150	104	
4000	110	108
5000	114	

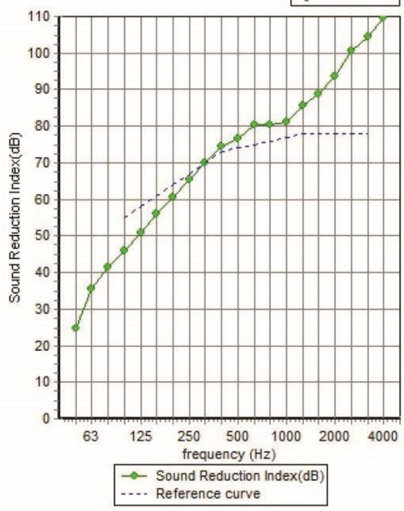


Figure E.41 Estimated data of Hw proposal of Original Wall 4.

System description

Panel 1 Outer layer: 1 x 100.0 mm MUD- (m=107.3 kg/m2, fc=803 Hz, Damping=0.01) Profile
Panel 1 Inner layer: 2 x 5.0 mm Pine (m=4.9 kg/m2, fc=4082 Hz,Damping=0.04)
Cavity: Double steel stud @ 600 mm , Infill mineral fibre (98.1 kg/m3) Thickness 60 mm
Panel 2 Inner layer: 2 x 13.1 mm Gypsum plasterboard-
(m=18.1 kg/m2, fc=2901 Hz, Damping=0.01) Profile
Mass-air-mass resonant frequency =53 Hz

Panel Size 2.7x4 m

Rw 72 dB
C -3 dB
C_{tr} -10 dB

frequency (Hz)	R(dB)	R(dB)
50	25	
63	31	29
80	40	
100	44	
125	48	47
160	54	
200	58	
250	63	62
315	68	
400	72	
500	74	74
630	78	
800	78	
1000	79	80
1250	83	
1600	85	
2000	86	85
2500	85	
3150	87	
4000	92	90
5000	97	

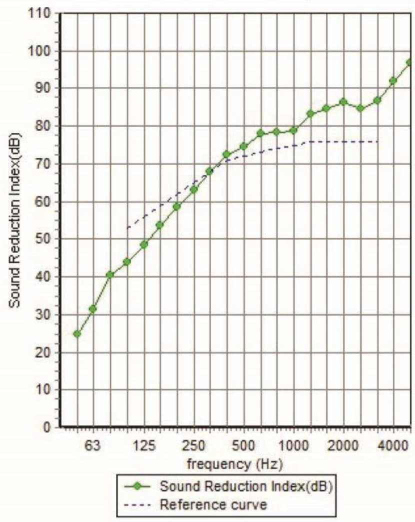


Figure E.42 Estimated data of Gw’ proposal of Original Wall 4.

APPENDIX F

PROPOSALS OF FLOOR COMPONENTS

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Panel 1 Inner layer: 1 x 2.8 mm Acoustiblok 16 (m=5.0 kg/m2, fc=347482 Hz,Damping=2.00)
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 450 mm
Panel 3 Inner layer: 1 x 17.0 mm Pine- (m=8.3 kg/m2, fc=1200 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =39 Hz , 829 Hz

frequency (Hz)	R(dB)	R(dB)
50	16	
63	23	19
80	27	
100	30	
125	33	32
160	36	
200	38	
250	40	39
315	42	
400	44	
500	46	46
630	47	
800	47	
1000	48	48
1250	49	
1600	53	
2000	56	55
2500	58	
3150	61	
4000	65	64
5000	67	

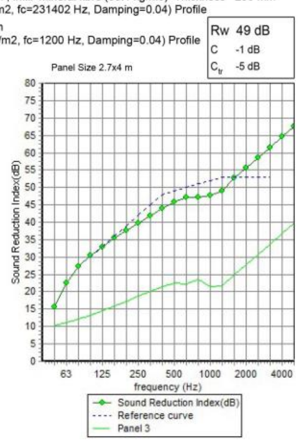


Figure F.1 Estimated data of I_F-A proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Panel 1 Inner layer: 1 x 2.8 mm Acoustiblok 16 (m=5.0 kg/m2, fc=347482 Hz,Damping=2.00)
Joists: 150.0 mm x200.0 mm @ 500 mm (490.0 (kg/m3), Youngs Modulus =5(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 450 mm
Panel 3 Inner layer: 1 x 17.0 mm Pine- (m=8.3 kg/m2, fc=1200 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =39 Hz , 829 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	66	
63	62	68
80	61	
100	61	
125	61	66
160	60	
200	61	
250	62	67
315	63	
400	63	
500	63	69
630	65	
800	63	
1000	65	68
1250	58	
1600	56	
2000	53	59
2500	50	
3150	46	
4000	43	49
5000	40	

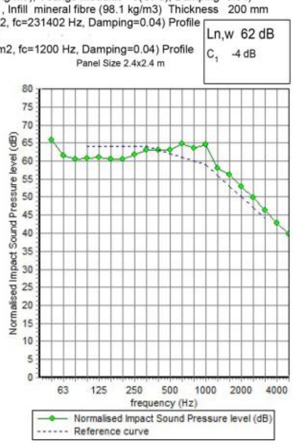


Figure F.2 Estimated data of I_F-A proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile
Cavity: Resilient clip or channel @ 450 mm
Panel 3 Inner layer: 3 x 17.0 mm Pine-
(m=25.0 kg/m2, fc=1200 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =27 Hz , 817 Hz

Panel Size 2.7x4 m

Rw	53 dB
C	-1 dB
C_{tr}	-4 dB

frequency (Hz)	R(dB)	R(dB)
50	26	
63	31	29
80	34	
100	36	
125	38	38
160	41	
200	43	
250	45	45
315	47	
400	49	
500	51	50
630	52	
800	52	
1000	52	52
1250	51	
1600	53	
2000	56	55
2500	59	
3150	62	
4000	65	64
5000	68	

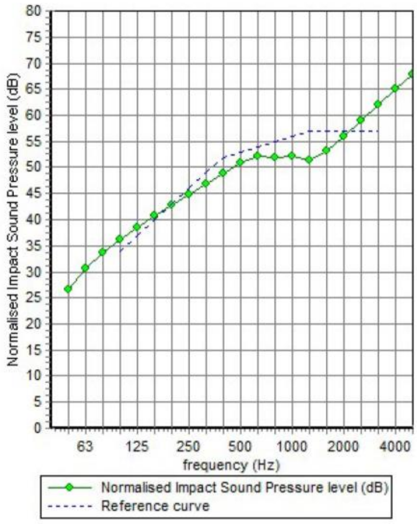


Figure F.3 Estimated data of I_F-B proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Joists: 150.0 mm x200.0 mm @ 500 mm (490.0 (kg/m3), Youngs Modulus =5(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile
Cavity: Resilient clip or channel @ 450 mm
Panel 3 Inner layer: 3 x 17.0 mm Pine- (m=25.0 kg/m2, fc=1200 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =27 Hz , 817 Hz

Panel Size 2.4x2.4 m

Ln,w	63 dB
C_I	-2 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	61	
63	59	65
80	60	
100	61	
125	62	67
160	63	
200	67	
250	64	70
315	64	
400	65	
500	69	72
630	67	
800	65	
1000	66	69
1250	61	
1600	54	
2000	51	57
2500	48	
3150	44	
4000	40	46
5000	36	

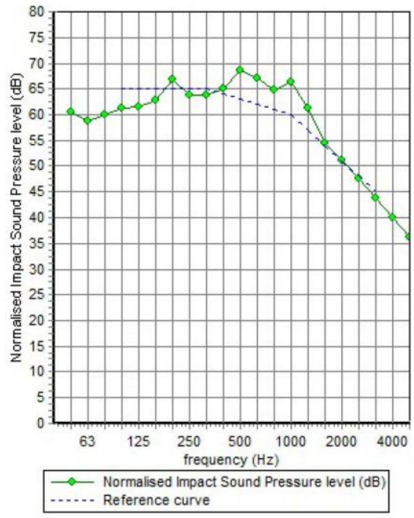


Figure F.4 Estimated data of I_F-B proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile
Cavity: Resilient clip or channel @ 450 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 3 Inner layer: 3 x 17.0 mm Pine- (m=25.0 kg/m2, fc=1200 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =25 Hz , 747 Hz

Panel Size 2.7x4 m

Rw 53 dB
C -1 dB
C_{tr} -4 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	27	
63	31	30
80	34	
100	36	
125	39	38
160	41	
200	43	
250	45	45
315	47	
400	49	
500	51	50
630	52	
800	52	
1000	52	52
1250	51	
1600	53	
2000	56	55
2500	59	
3150	62	
4000	65	64
5000	68	

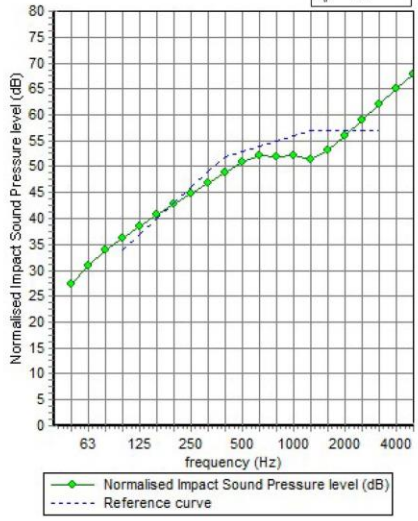


Figure F.5 Estimated data of IF-C proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Joists: 150.0 mm x200.0 mm @ 500 mm (490.0 (kg/m3), Youngs Modulus =5(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile
Cavity: Resilient clip or channel @ 450 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 3 Inner layer: 3 x 17.0 mm Pine- (m=25.0 kg/m2, fc=1200 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =25 Hz , 747 Hz

Panel Size 2.4x2.4 m

Ln,w 63 dB
C_I -2 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	60	
63	58	64
80	60	
100	61	
125	62	67
160	63	
200	67	
250	64	70
315	64	
400	65	
500	69	72
630	67	
800	65	
1000	66	69
1250	61	
1600	54	
2000	51	57
2500	48	
3150	44	
4000	40	46
5000	36	

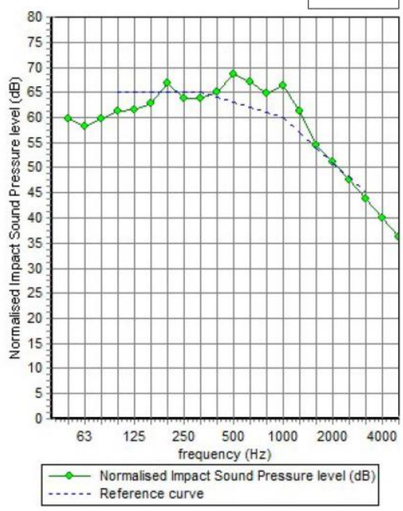


Figure F.6 Estimated data of I_F-C proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile

Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile

Cavity: Rubber Isolation Clip @ 450 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 3 Inner layer: 3 x 17.0 mm Pine- (m=25.0 kg/m2, fc=1200 Hz, Damping=0.04) Profile

Rw 53 dB
C -1 dB
C_{tr} -4 dB

Mass-air-mass resonant frequency =24 Hz , 731 Hz

frequency (Hz)	R(dB)	R(dB)
50	28	
63	31	30
80	34	
100	37	
125	39	39
160	41	
200	43	
250	45	45
315	47	
400	49	
500	51	51
630	53	
800	52	
1000	52	52
1250	52	
1600	54	
2000	56	56
2500	59	
3150	62	
4000	65	65
5000	68	

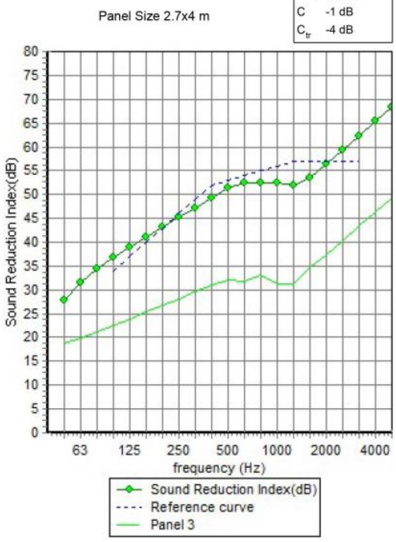


Figure F.7 Estimated data of I_F-D proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 3 x 17.0 mm Pine- (m=32.1 kg/m2, fc=1361 Hz, Damping=0.04) Profile
Joists: 150.0 mm x200.0 mm @ 500 mm (490.0 (kg/m3), Youngs Modulus =5(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 500 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 2 Inner layer: 1 x 0.1 mm Pine- (m=0.1 kg/m2, fc=231402 Hz, Damping=0.04) Profile

Cavity: Rubber Isolation Clip @ 450 mm , Infill mineral fibre (98.1 kg/m3) Thickness 200 mm
Panel 3 Inner layer: 3 x 17.0 mm Pine- (m=25.0 kg/m2, fc=1200 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =24 Hz , 731 Hz

Ln,w 63 dB
C_I -2 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	59	
63	58	64
80	59	
100	61	
125	61	66
160	62	
200	66	
250	64	69
315	63	
400	65	
500	68	72
630	67	
800	64	
1000	66	69
1250	61	
1600	54	
2000	51	56
2500	47	
3150	43	
4000	40	45
5000	36	

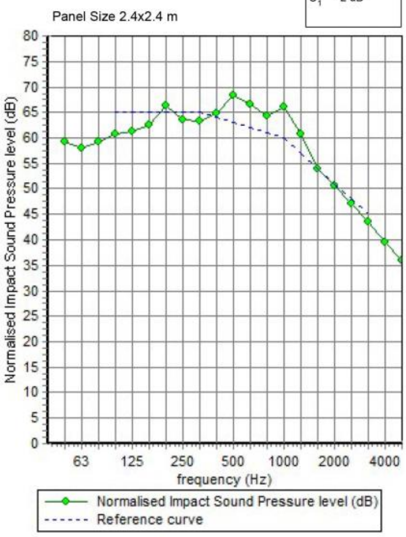


Figure F.8 Estimated data of I_F-D proposal of Reconstructed-Floor 1.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Resilient clip or channel @ 400 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =54 Hz

Panel Size 2.7x4 m

Rw 46 dB
C -2 dB
C_{tr} -8 dB

frequency (Hz)	R(dB)	R(dB)
50	15	
63	21	18
80	20	
100	23	
125	25	25
160	28	
200	32	
250	35	34
315	39	
400	44	
500	48	46
630	48	
800	51	
1000	50	48
1250	46	
1600	51	
2000	56	54
2500	60	
3150	63	
4000	66	65
5000	69	

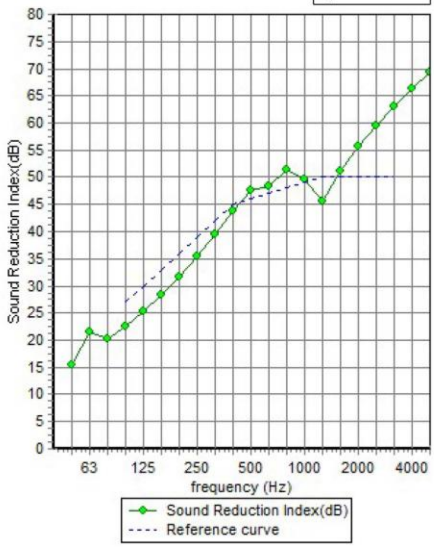


Figure F.9 Estimated data of II_F-A proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)

Cavity: Resilient clip or channel @ 400 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =63 Hz

Panel Size 2.4x2.4 m

Ln,w 72 dB
C_I -1 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	80	
63	84	86
80	79	
100	76	
125	78	82
160	78	
200	77	
250	76	82
315	77	
400	73	
500	76	79
630	74	
800	64	
1000	64	70
1250	68	
1600	55	
2000	48	56
2500	39	
3150	29	
4000	33	38
5000	34	

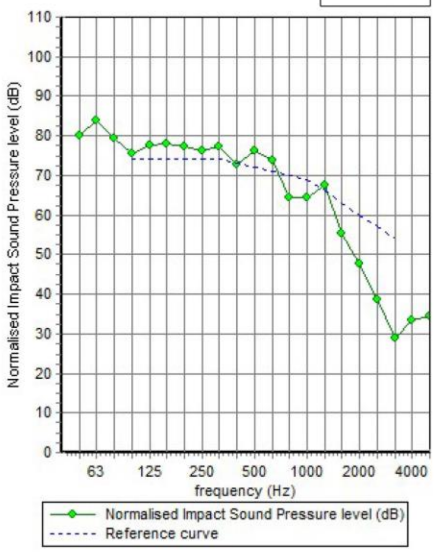


Figure F.10 Estimated data of II_F-A proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Resilient clip or channel @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Ln,w 62 dB
C_1 -2 dB

Mass-air-mass resonant frequency =54 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	79	
63	77	81
80	67	
100	65	
125	64	69
160	63	
200	62	
250	61	67
315	64	
400	62	
500	67	71
630	67	
800	62	
1000	62	69
1250	66	
1600	54	
2000	47	55
2500	38	
3150	29	
4000	33	37
5000	34	

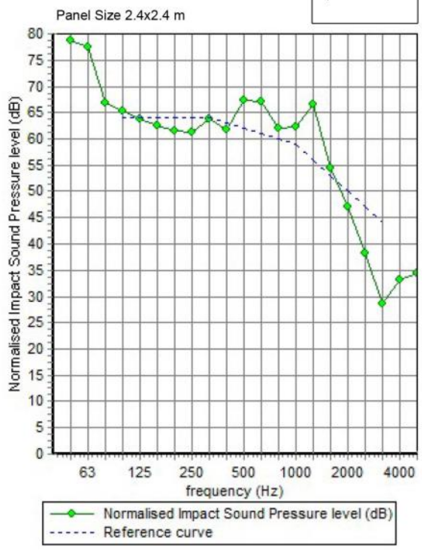


Figure F.11 Estimated data of II$_F$-B proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Resilient clip or channel @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Ln,w 62 dB
C_1 -2 dB

Mass-air-mass resonant frequency =54 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	79	
63	77	81
80	67	
100	65	
125	64	69
160	63	
200	62	
250	61	67
315	64	
400	62	
500	67	71
630	67	
800	62	
1000	62	69
1250	66	
1600	54	
2000	47	55
2500	38	
3150	29	
4000	33	37
5000	34	

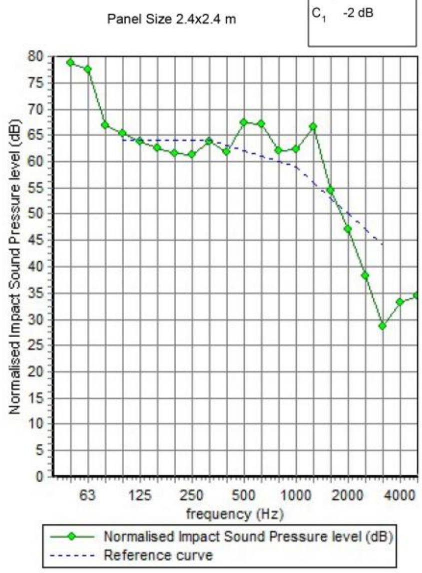


Figure F.12 Estimated data of II$_F$-B proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Resilient clip or channel @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =39 Hz

frequency (Hz)	R(dB)	R(dB)
50	23	
63	29	26
80	34	
100	38	
125	42	41
160	46	
200	49	
250	52	51
315	53	
400	55	
500	56	56
630	57	
800	56	
1000	58	56
1250	55	
1600	58	
2000	61	60
2500	64	
3150	67	
4000	70	69
5000	73	

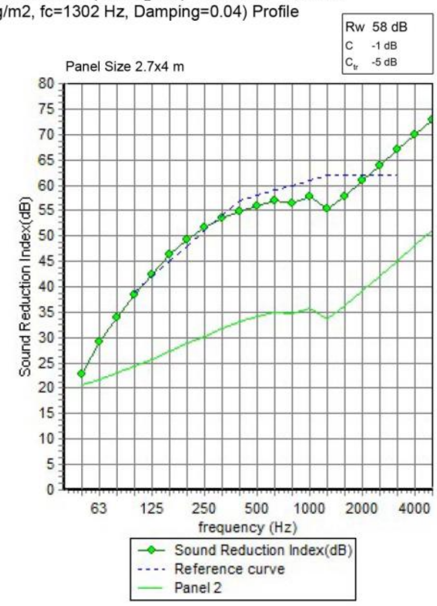


Figure F.13 Estimated data of II_F-C proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Resilient clip or channel @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =46 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	75	
63	58	76
80	62	
100	61	
125	60	65
160	60	
200	60	
250	60	66
315	63	
400	61	
500	67	71
630	67	
800	62	
1000	60	67
1250	65	
1600	53	
2000	45	53
2500	36	
3150	27	
4000	31	36
5000	33	

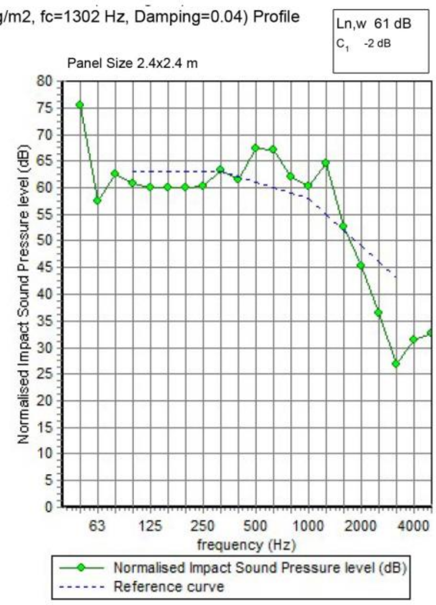


Figure F.14 Estimated data of II_F-C proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Rubber Isolation Clip @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =37 Hz

frequency (Hz)	R(dB)	R(dB)
50	25	
63	30	28
80	35	
100	39	
125	43	42
160	46	
200	49	
250	51	51
315	52	
400	54	
500	55	55
630	56	
800	56	
1000	57	56
1250	55	
1600	57	
2000	60	59
2500	63	
3150	66	
4000	69	68
5000	72	

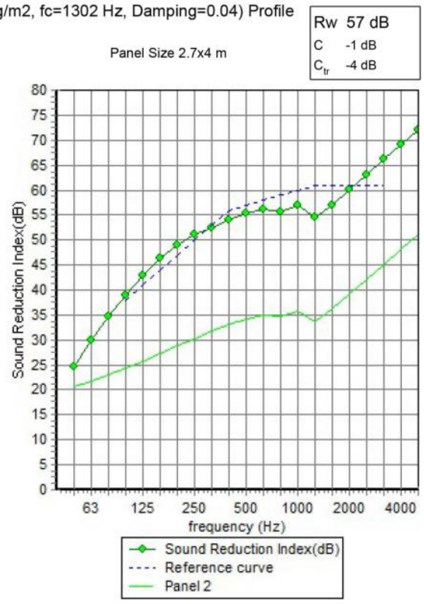


Figure F.15 Estimated data of II$_F$-D proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Rubber Isolation Clip @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =44 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	75	
63	63	76
80	61	
100	59	
125	59	64
160	59	
200	58	
250	59	65
315	62	
400	60	
500	66	69
630	65	
800	60	
1000	59	66
1250	63	
1600	51	
2000	44	52
2500	35	
3150	25	
4000	30	34
5000	31	

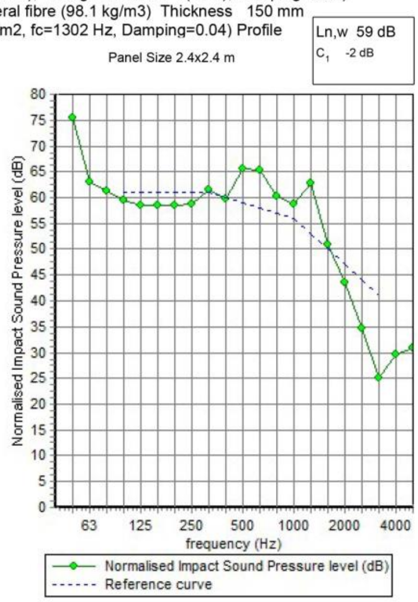


Figure F.16 Estimated data of II$_F$-D proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Panel 1 Inner layer: 1 x 2.8 mm Acoustiblok 16 (m=5.0 kg/m2, fc=347482 Hz,Damping=2.00)
Cavity: Rubber Isolation Clip @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =34 Hz

Rw 61 dB
C -1 dB
C_{tr} -5 dB

frequency (Hz)	R(dB)	R(dB)
50	28	
63	32	31
80	37	
100	41	
125	45	44
160	48	
200	51	
250	52	52
315	54	
400	55	
500	57	57
630	58	
800	59	
1000	63	61
1250	64	
1600	66	
2000	69	69
2500	72	
3150	75	
4000	78	78
5000	81	

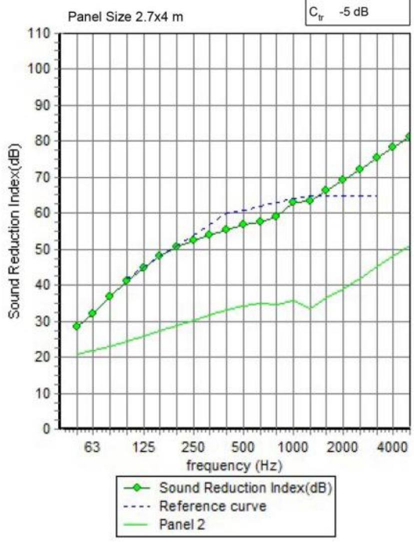


Figure F.17 Estimated data of II$_F$-E proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Panel 1 Inner layer: 1 x 2.8 mm Acoustiblok 16 (m=5.0 kg/m2, fc=347482 Hz,Damping=2.00)
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Rubber Isolation Clip @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =40 Hz

Ln,w 47 dB
C_I -1 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	65	
63	51	65
80	51	
100	50	
125	49	54
160	49	
200	49	
250	49	54
315	49	
400	50	
500	51	57
630	54	
800	50	
1000	45	52
1250	46	
1600	41	
2000	35	43
2500	28	
3150	19	
4000	15	23
5000	20	

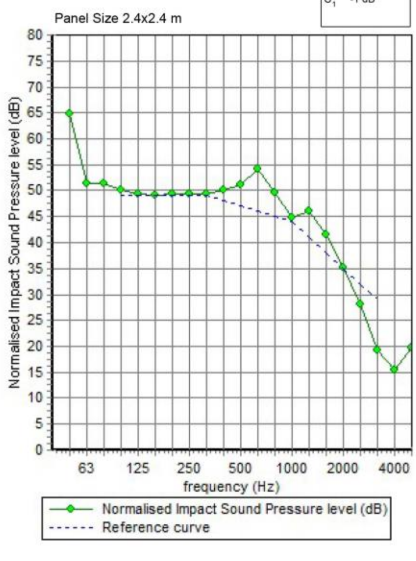


Figure F.18 Estimated data of II$_F$-E proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Panel 1 Inner layer: 1 x 2.8 mm Acoustiblok 16 (m=5.0 kg/m2, fc=347482 Hz,Damping=2.00)
Cavity: Separate joists @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =31 Hz

frequency (Hz)	R(dB)	R(dB)
50	32	
63	36	35
80	41	
100	46	
125	51	49
160	56	
200	61	
250	62	62
315	65	
400	68	
500	71	70
630	73	
800	74	
1000	81	77
1250	80	
1600	87	
2000	93	90
2500	99	
3150	105	
4000	112	109
5000	118	

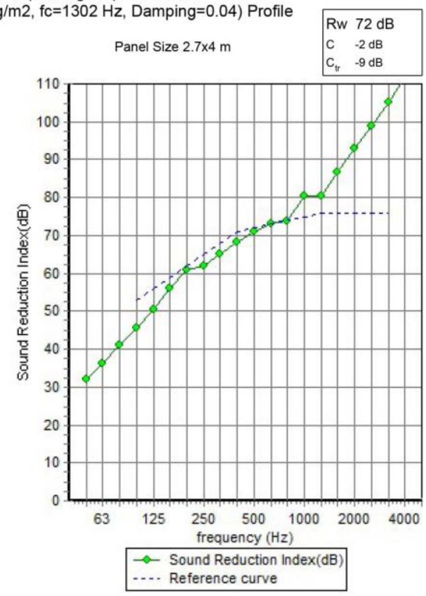


Figure F.19 Estimated data of II$_F$-F proposal of Semi-Repaired-Floor 2/3.

System description

Floor Cover: Custom floor covering
Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Panel 1 Inner layer: 1 x 2.8 mm Acoustiblok 16 (m=5.0 kg/m2, fc=347482 Hz,Damping=2.00)
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Separate joists @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 2 x 25.0 mm Pine- (m=31.5 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =36 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	49	
63	51	54
80	49	
100	47	
125	45	50
160	42	
200	40	
250	37	42
315	35	
400	35	
500	35	40
630	37	
800	33	
1000	28	35
1250	29	
1600	25	
2000	17	25
2500	8	
3150	-4	
4000	-11	-2
5000	-9	

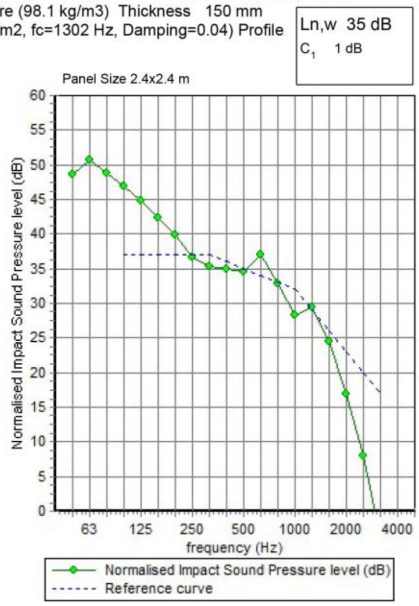


Figure F.20 Estimated data of II$_F$-F proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Rubber Isolation Clip @ 400 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =50 Hz

Rw 46 dB
C -2 dB
C_{tr} -7 dB

frequency (Hz)	R(dB)	R(dB)
50	16	
63	24	19
80	20	
100	23	
125	26	25
160	29	
200	32	
250	36	35
315	40	
400	44	
500	48	47
630	49	
800	51	
1000	50	49
1250	46	
1600	51	
2000	55	54
2500	59	
3150	62	
4000	66	65
5000	69	

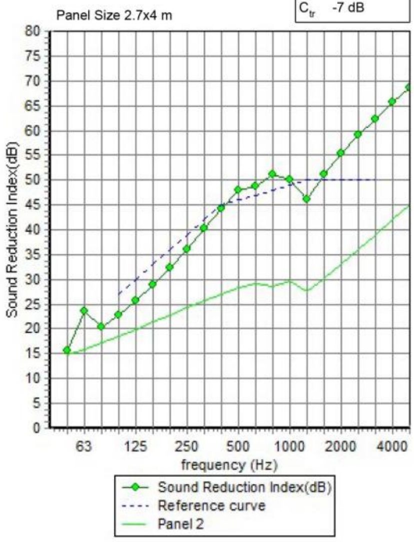


Figure F.21 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)

Cavity: Rubber Isolation Clip @ 400 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =60 Hz

Ln,w 71 dB
C_1 0 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	81	
63	78	83
80	74	
100	77	
125	77	82
160	78	
200	77	
250	75	81
315	76	
400	72	
500	75	78
630	73	
800	63	
1000	63	69
1250	66	
1600	54	
2000	46	55
2500	37	
3150	27	
4000	32	36
5000	33	

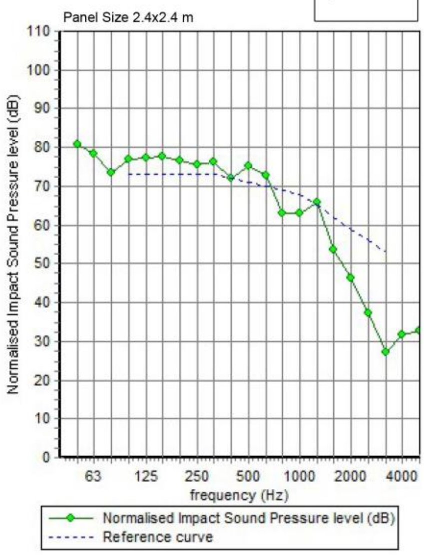


Figure F.22 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Rw 40 dB
C -1 dB
C_{tr} -3 dB

Mass-air-mass resonant frequency =47 Hz

frequency (Hz)	R(dB)	R(dB)
50	16	
63	20	19
80	24	
100	27	
125	29	29
160	31	
200	32	
250	34	34
315	35	
400	37	
500	38	38
630	39	
800	38	
1000	39	38
1250	37	
1600	39	
2000	43	42
2500	45	
3150	49	
4000	52	51
5000	55	

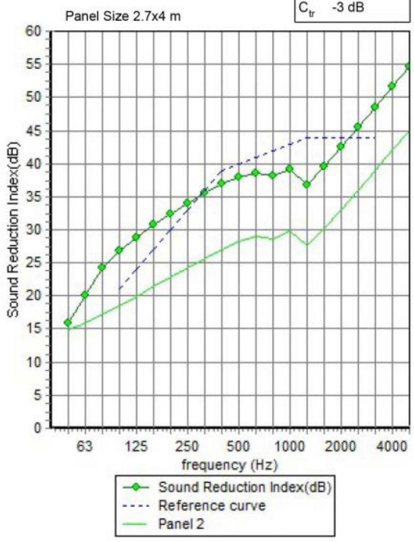


Figure F.23 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Ln,w 75 dB
C_1 -3 dB

Mass-air-mass resonant frequency =55 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	79	
63	78	82
80	71	
100	71	
125	71	76
160	72	
200	73	
250	73	79
315	76	
400	74	
500	80	84
630	80	
800	75	
1000	75	82
1250	79	
1600	67	
2000	60	68
2500	51	
3150	41	
4000	46	50
5000	47	

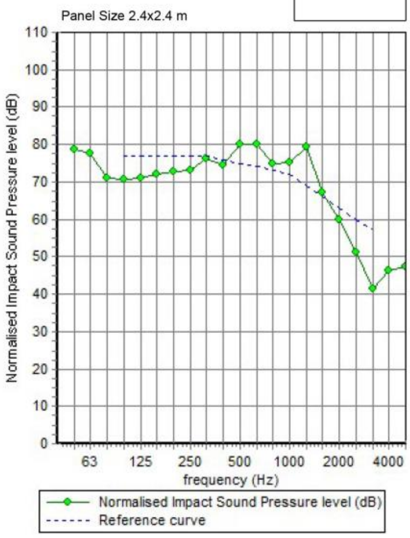


Figure F.24 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Separate joists @ 400 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =46 Hz

Rw 48 dB
C -2 dB
C_{tr} -8 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	16	
63	19	18
80	21	
100	24	
125	26	26
160	30	
200	34	
250	38	37
315	42	
400	47	
500	52	50
630	53	
800	59	
1000	54	53
1250	49	
1600	57	
2000	64	61
2500	70	
3150	77	
4000	85	81
5000	92	

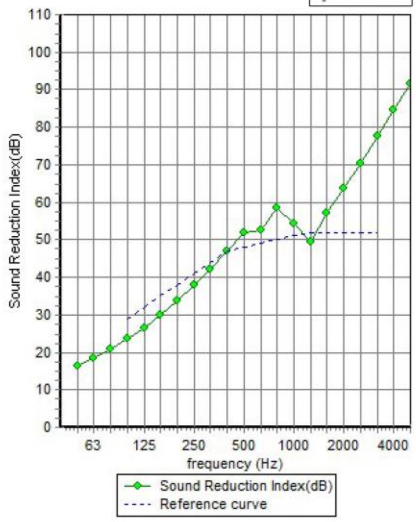


Figure F.25 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Separate joists @ 400 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =54 Hz

Ln,w 70 dB
C_I -1 dB

Panel Size 2.4x2.4 m

frequency (Hz)	Ln(dB)	Ln(dB)
50	80	
63	74	82
80	76	
100	76	
125	77	81
160	77	
200	75	
250	74	80
315	75	
400	70	
500	73	76
630	70	
800	58	
1000	58	63
1250	59	
1600	46	
2000	37	47
2500	27	
3150	14	
4000	15	19
5000	14	

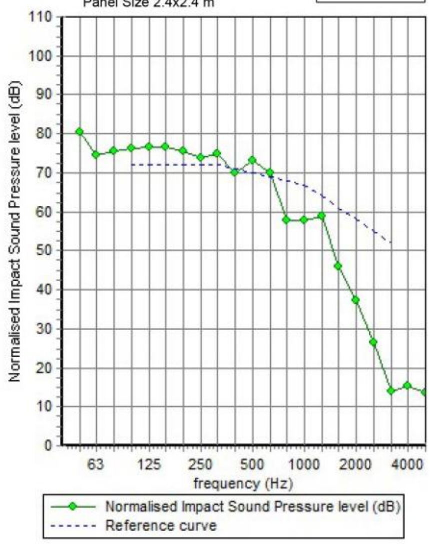


Figure F.26 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Separate joists @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =39 Hz

Rw 63 dB
C -3 dB
C_{tr} -8 dB

Panel Size 2.7x4 m

frequency (Hz)	R(dB)	R(dB)
50	22	
63	28	26
80	33	
100	37	
125	42	40
160	47	
200	52	
250	53	54
315	56	
400	59	
500	62	61
630	64	
800	63	
1000	66	63
1250	62	
1600	67	
2000	73	71
2500	79	
3150	86	
4000	92	89
5000	98	

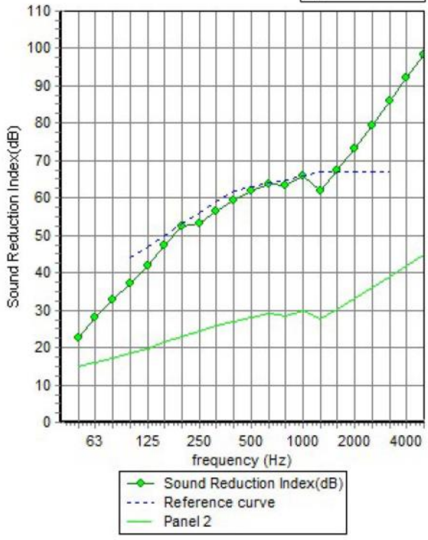


Figure F.27 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Separate joists @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm
Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =46 Hz

Ln,w 52 dB
C_I 0 dB

Panel Size 2.4x2.4 m

frequency (Hz)	Ln(dB)	Ln(dB)
50	68	
63	63	71
80	65	
100	62	
125	60	65
160	58	
200	55	
250	52	58
315	54	
400	50	
500	55	58
630	54	
800	49	
1000	49	56
1250	53	
1600	41	
2000	32	41
2500	21	
3150	9	
4000	10	14
5000	9	

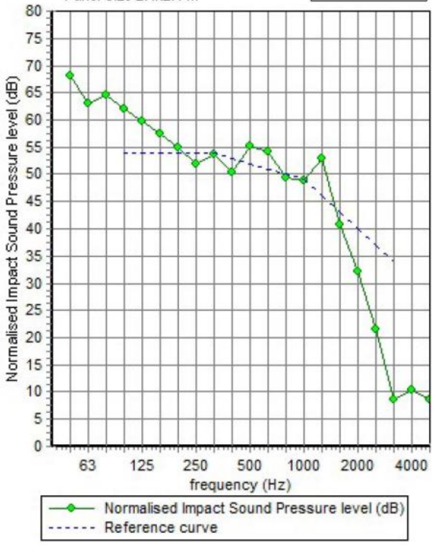


Figure F.28 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Rubber Isolation Clip @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =43 Hz

frequency (Hz)	R(dB)	R(dB)
50	20	
63	25	23
80	29	
100	33	
125	38	36
160	42	
200	45	
250	47	47
315	49	
400	50	
500	52	51
630	52	
800	52	
1000	53	52
1250	51	
1600	53	
2000	56	56
2500	59	
3150	63	
4000	66	65
5000	69	

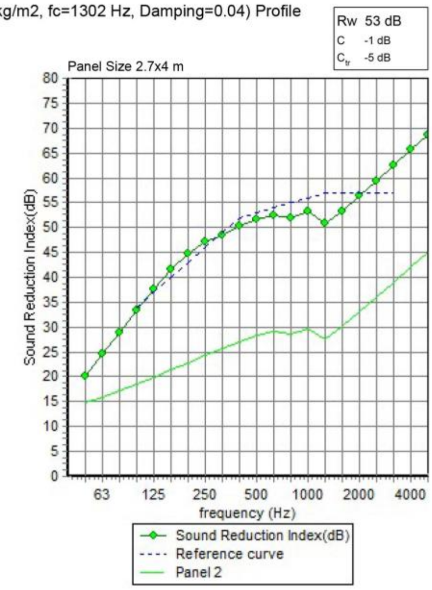


Figure F.29 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Joists: 50.0 mm x150.0 mm @ 400 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)

Cavity: Rubber Isolation Clip @ 400 mm , Infill mineral fibre (98.1 kg/m3) Thickness 150 mm

Panel 2 Inner layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =50 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	79	
63	77	81
80	65	
100	64	
125	63	68
160	61	
200	60	
250	60	66
315	62	
400	60	
500	66	69
630	65	
800	60	
1000	61	67
1250	65	
1600	53	
2000	45	54
2500	37	
3150	27	
4000	31	36
5000	33	

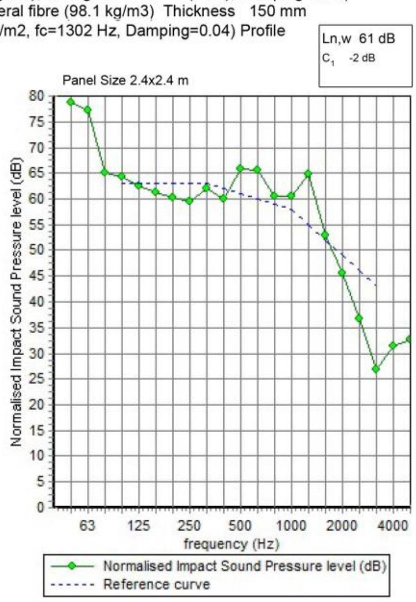


Figure F.30 Estimated data of the proposal of Semi-Repaired-Floor 2/3.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 560 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine-
(m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =67 Hz

frequency (Hz)	R(dB)	R(dB)
50	17	
63	16	18
80	21	
100	21	
125	23	23
160	26	
200	29	
250	31	31
315	34	
400	37	
500	39	38
630	39	
800	39	
1000	40	39
1250	37	
1600	41	
2000	44	43
2500	47	
3150	50	
4000	53	52
5000	56	

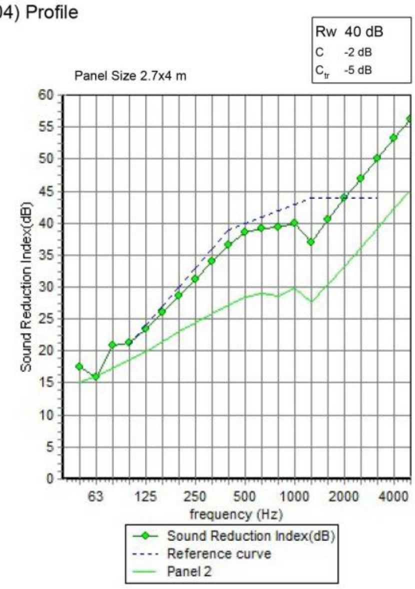


Figure F.31 Estimated data of III$_F$-A proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 560 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =80 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	78	
63	82	86
80	82	
100	77	
125	79	86
160	84	
200	81	
250	79	84
315	79	
400	78	
500	85	87
630	81	
800	75	
1000	73	81
1250	79	
1600	66	
2000	59	67
2500	50	
3150	40	
4000	45	49
5000	46	

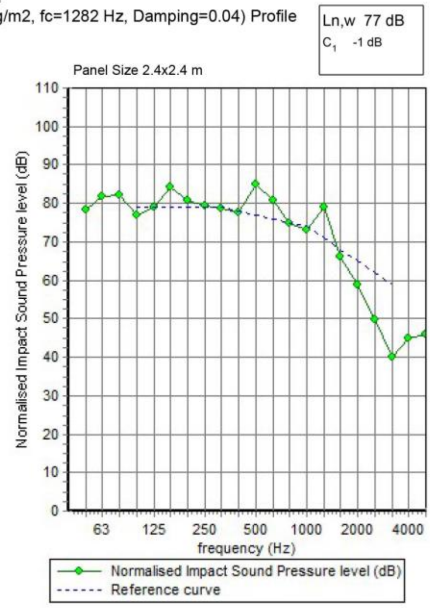


Figure F.32 Estimated data of III$_F$-A proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Solid joist(timber or Twinaplate) @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =57 Hz

frequency (Hz)	R(dB)	R(dB)
50	16	
63	17	18
80	23	
100	26	
125	29	28
160	32	
200	34	
250	35	35
315	37	
400	38	
500	39	39
630	40	
800	40	
1000	41	39
1250	38	
1600	41	
2000	44	43
2500	47	
3150	50	
4000	53	52
5000	56	

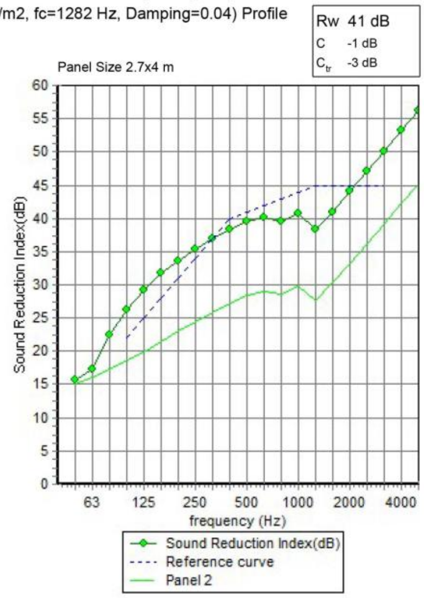


Figure F.33 Estimated data of III$_F$-B proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Solid joist(timber or Twinaplate) @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =67 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	78	
63	81	84
80	79	
100	72	
125	72	78
160	76	
200	72	
250	72	77
315	72	
400	73	
500	82	84
630	79	
800	74	
1000	73	81
1250	79	
1600	66	
2000	59	67
2500	50	
3150	40	
4000	45	49
5000	46	

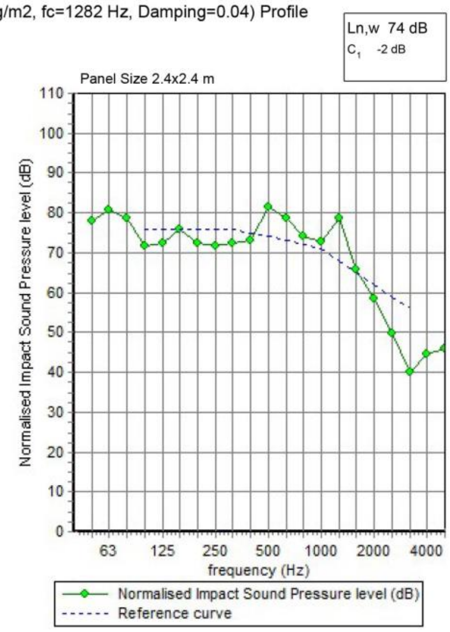


Figure F.34 Estimated data of III$_F$-B proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Resilient clip or channel @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm

Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =54 Hz

frequency (Hz)	R(dB)	R(dB)
50	15	
63	21	18
80	25	
100	29	
125	34	33
160	39	
200	43	
250	46	45
315	49	
400	51	
500	52	52
630	53	
800	53	
1000	54	52
1250	51	
1600	54	
2000	57	56
2500	60	
3150	63	
4000	67	66
5000	69	

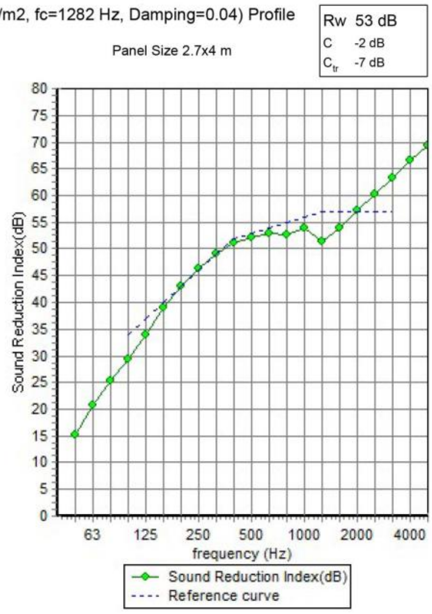


Figure F.35 Estimated data of III$_F$-C proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)

Cavity: Resilient clip or channel @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm

Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =64 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	78	
63	81	84
80	78	
100	68	
125	68	73
160	69	
200	64	
250	61	67
315	61	
400	61	
500	69	71
630	66	
800	62	
1000	60	68
1250	66	
1600	53	
2000	46	54
2500	37	
3150	27	
4000	32	36
5000	33	

Figure F.36 Estimated data of III$_F$-C proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Resilient clip or channel @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 2 x 25.4 mm Pine- (m=32.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =47 Hz

Rw 57 dB
C -1 dB
C_{tr} -6 dB

frequency (Hz)	R(dB)	R(dB)
50	19	
63	25	23
80	31	
100	35	
125	40	38
160	44	
200	48	
250	51	50
315	53	
400	55	
500	56	56
630	57	
800	56	
1000	58	56
1250	55	
1600	58	
2000	61	60
2500	64	
3150	67	
4000	70	69
5000	73	

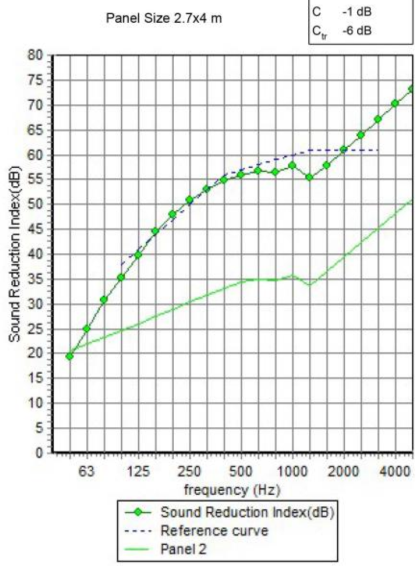


Figure F.37 Estimated data of III_F-D proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Resilient clip or channel @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 2 x 25.4 mm Pine- (m=32.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =56 Hz

Ln,w 61 dB
C_1 -2 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	77	
63	77	80
80	65	
100	63	
125	63	69
160	65	
200	61	
250	59	65
315	60	
400	60	
500	69	71
630	66	
800	61	
1000	58	67
1250	64	
1600	51	
2000	44	52
2500	35	
3150	25	
4000	30	34
5000	31	

Figure F.38 Estimated data of III_F-D proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Rubber Isolation Clip @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 2 x 25.4 mm Pine- (m=32.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =43 Hz

frequency (Hz)	R(dB)	R(dB)
50	23	
63	28	26
80	32	
100	37	
125	41	40
160	46	
200	49	
250	52	51
315	54	
400	56	
500	57	56
630	57	
800	57	
1000	58	57
1250	56	
1600	58	
2000	62	61
2500	65	
3150	68	
4000	71	70
5000	74	

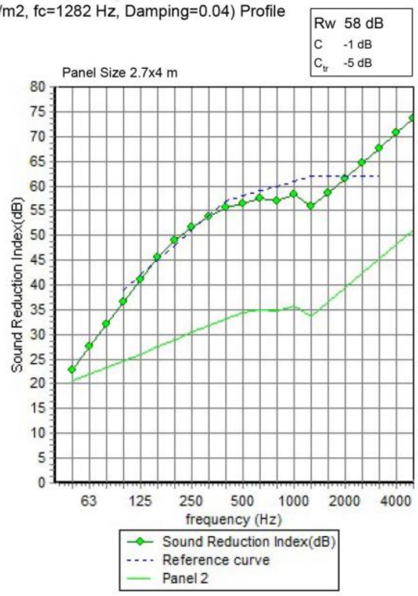


Figure F.39 Estimated data of III_F-E proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Rubber Isolation Clip @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 2 x 25.4 mm Pine- (m=32.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =51 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	77	
63	77	80
80	63	
100	62	
125	61	67
160	63	
200	59	
250	58	63
315	58	
400	58	
500	67	69
630	64	
800	60	
1000	56	65
1250	62	
1600	49	
2000	42	50
2500	33	
3150	24	
4000	28	32
5000	29	

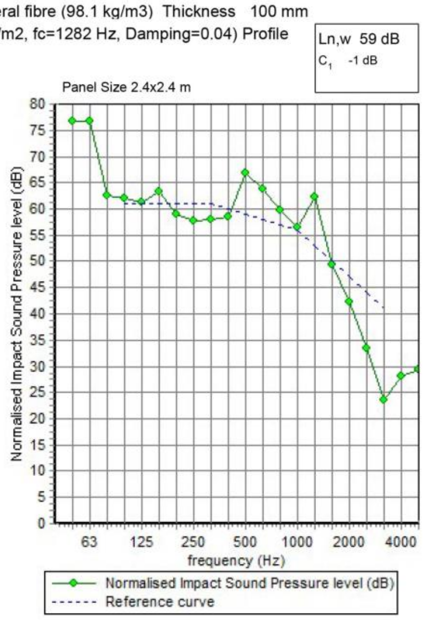


Figure F.40 Estimated data of III_F-E proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Separate joists @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm

Panel 2 Inner layer: 2 x 25.4 mm Pine- (m=32.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =37 Hz

frequency (Hz)	R(dB)	R(dB)
50	27	
63	32	30
80	37	
100	41	
125	46	44
160	51	
200	56	
250	61	59
315	62	
400	64	
500	67	66
630	69	
800	68	
1000	71	68
1250	66	
1600	72	
2000	78	76
2500	84	
3150	90	
4000	97	94
5000	103	

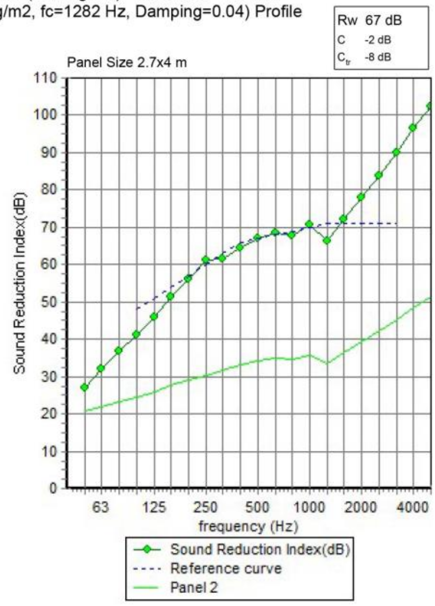


Figure F.41 Estimated data of III_F-F proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)

Cavity: Separate joists @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm

Panel 2 Inner layer: 2 x 25.4 mm Pine- (m=32.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =44 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	58	
63	62	65
80	61	
100	58	
125	57	62
160	58	
200	51	
250	48	54
315	45	
400	44	
500	52	54
630	48	
800	44	
1000	42	50
1250	48	
1600	34	
2000	26	35
2500	15	
3150	2	
4000	4	8
5000	2	

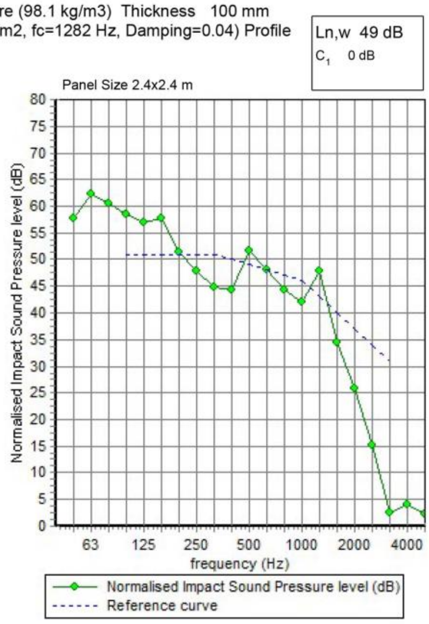


Figure F.42 Estimated data of III_F-F proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Rubber Isolation Clip @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =50 Hz

Rw 54 dB
C -2 dB
C_{tr} -7 dB

frequency (Hz)	R(dB)	R(dB)
50	15	
63	19	18
80	26	
100	31	
125	35	34
160	40	
200	44	
250	47	46
315	50	
400	52	
500	53	53
630	54	
800	53	
1000	55	53
1250	52	
1600	55	
2000	58	57
2500	61	
3150	64	
4000	67	66
5000	70	

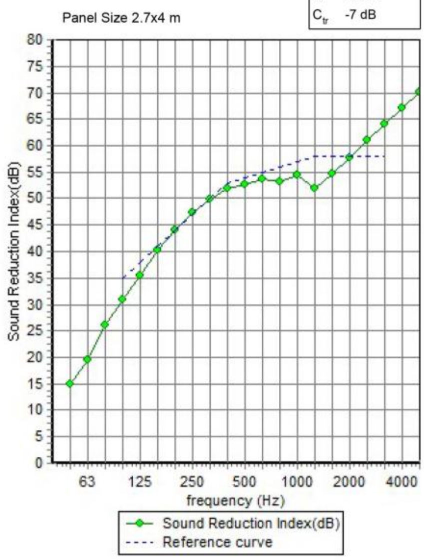


Figure F.43 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Rubber Isolation Clip @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =59 Hz

Ln,w 62 dB
C_I -2 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	78	
63	78	81
80	66	
100	67	
125	66	72
160	67	
200	62	
250	60	65
315	59	
400	59	
500	67	69
630	64	
800	60	
1000	58	66
1250	64	
1600	51	
2000	44	52
2500	35	
3150	25	
4000	30	34
5000	31	

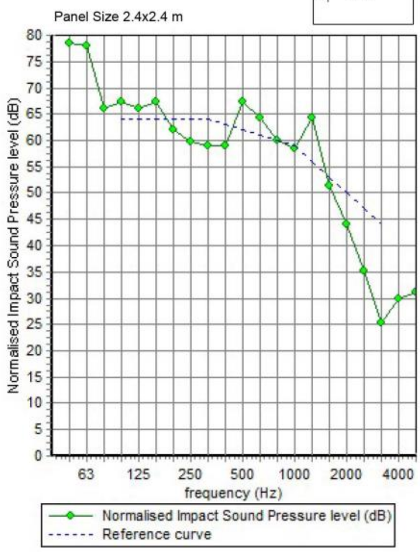


Figure F.44 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Separate joists @ 560 mm

Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =50 Hz

Rw 47 dB
C -2 dB
C_{tr} -8 dB

frequency (Hz)	R(dB)	R(dB)
50	21	
63	18	20
80	21	
100	23	
125	26	25
160	29	
200	33	
250	37	35
315	41	
400	46	
500	50	48
630	51	
800	57	
1000	53	51
1250	48	
1600	55	
2000	62	59
2500	69	
3150	76	
4000	83	80
5000	90	

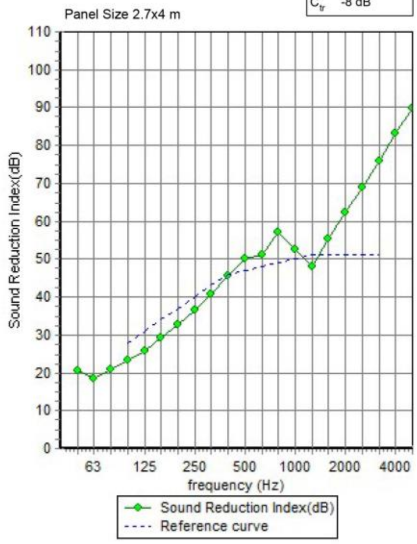


Figure F.45 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)

Cavity: Separate joists @ 560 mm

Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =59 Hz

Ln,w 72 dB
C_I 0 dB

frequency (Hz)	Ln(dB)	Ln(dB)
50	79	
63	73	81
80	73	
100	77	
125	79	84
160	82	
200	77	
250	75	80
315	73	
400	72	
500	77	79
630	72	
800	60	
1000	59	65
1250	61	
1600	48	
2000	39	48
2500	28	
3150	15	
4000	17	21
5000	15	

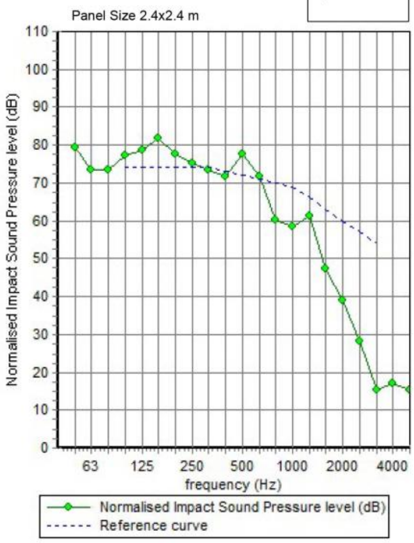


Figure F.46 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Cavity: Separate joists @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =43 Hz

frequency (Hz)	R(dB)	R(dB)
50	19	
63	27	23
80	31	
100	35	
125	40	38
160	45	
200	50	
250	55	53
315	55	
400	58	
500	61	60
630	63	
800	62	
1000	64	62
1250	60	
1600	66	
2000	72	69
2500	78	
3150	84	
4000	90	88
5000	96	

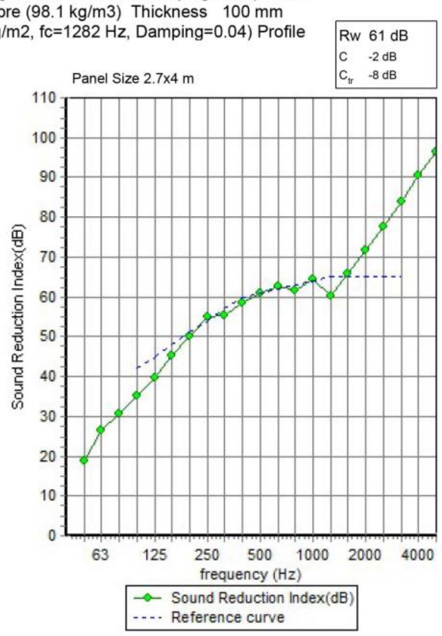


Figure F.47 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Separate joists @ 560 mm , Infill mineral fibre (98.1 kg/m3) Thickness 100 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =50 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	76	
63	66	77
80	65	
100	64	
125	63	68
160	64	
200	57	
250	54	60
315	51	
400	50	
500	58	60
630	54	
800	50	
1000	48	56
1250	54	
1600	41	
2000	32	41
2500	21	
3150	8	
4000	10	14
5000	8	

Figure F.48 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile

Cavity: Rubber Isolation Clip @ 560 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine-
(m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile

Mass-air-mass resonant frequency =59 Hz

frequency (Hz)	R(dB)	R(dB)
50	16	
63	18	18
80	20	
100	22	
125	25	24
160	28	
200	31	
250	34	34
315	38	
400	43	
500	47	45
630	47	
800	51	
1000	49	47
1250	44	
1600	51	
2000	56	54
2500	60	
3150	64	
4000	67	66
5000	70	

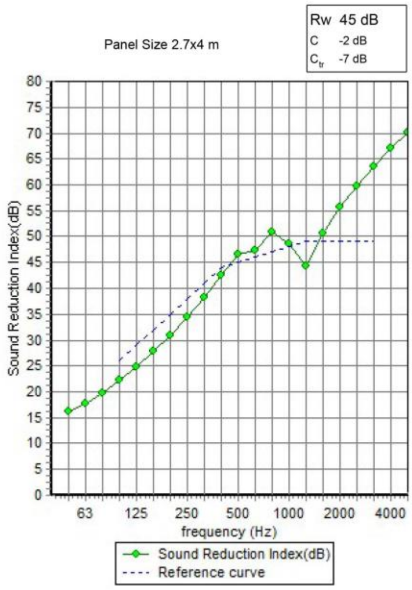


Figure F.49 Estimated data of the proposal of Original-Floor 4.

System description

Panel 1 Outer layer: 1 x 25.0 mm Pine- (m=15.8 kg/m2, fc=1302 Hz, Damping=0.04) Profile
Joists: 100.0 mm x100.0 mm @ 560 mm (630.0 (kg/m3), Youngs Modulus =3(GPa), Damping=0.04)
Cavity: Rubber Isolation Clip @ 560 mm
Panel 2 Inner layer: 1 x 25.4 mm Pine- (m=16.0 kg/m2, fc=1282 Hz, Damping=0.04) Profile
Mass-air-mass resonant frequency =70 Hz

frequency (Hz)	Ln(dB)	Ln(dB)
50	79	
63	84	86
80	80	
100	78	
125	79	85
160	83	
200	79	
250	77	82
315	76	
400	74	
500	80	82
630	75	
800	65	
1000	63	70
1250	67	
1600	54	
2000	46	54
2500	36	
3150	26	
4000	30	35
5000	31	

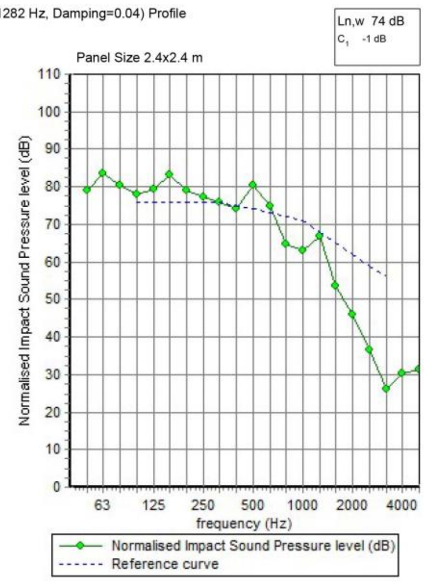


Figure F.50 Estimated data of the proposal of Original-Floor 4.

APPENDIX G

ESTIMATED DATA OF WALL & FLOOR COMPONENTS

Estimated data taken from BASTIAN for existing wall&floor components is given below:

Table G.1 Types of the junction used between the wall and floor components.

Type 19	Cross-junction, double leaf lightweight elements, continuous separating element
Type 20	T-junction, double leaf lightweight elements, continuous separating element

Table G.2 Estimated data of Alternative 1 section for Reconstructed-Wall-1.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm					35,5	94	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		51,2	3	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		51,2	3	0	0
f3	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		19	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		71,3	0	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		54,6	1	0	0
					Total:	35,2	100	0	0

Table G.3 Estimated data of Alternative 2 section for Reconstructed-Wall-1.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Addition	Type-No.	Basic Element	Addition	dB	%	dB	%
d	GELUI: foamglas 40 mm, 2x gypsum board 9,5 mm					31,9	96	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50,8	1	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50,7	1	0	0
f3	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		19	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		68,3	0	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		51,3	1	0	0
					Total:	31,7	100	0	0

Table G.4 Estimated data of Alternative3 section for Reconstructed-Wall-1.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Addition	Type-No.	Basic Element	Addition	dB	%	dB	%
d	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x gypsum board 12,5 mm					28,5	98	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		49,2	1	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		49,2	1	0	0
f3	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		19	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		67,8	0	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		51,5	0	0	0
					Total:	28,4	100	0	0

Table G.5 Estimated data of Alternative 4 section for Reconstructed-Wall-1.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additiona	Type-No.	Basic Element	Addition	dB	%	dB	%
d	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x triplex					38,4	92	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		52,7	3	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		52,7	3	0	0
f3	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		19	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		72,4	0	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		56,4	1	0	0
					Total:	38	100	0	0

Table G.6 Estimated data of Alternative 5 section for Reconstructed-Wall-1.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additional	Type-No.	Basic Element	Additional	dB	%	dB	%
d	GELUI: polyurethane foam (50 kg/m³) 30 mm, 2x fibre concrete board 5 mm					32,8	96	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		51,1	1	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		51,1	1	0	0
f3	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		19	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		69	0	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		52,1	1	0	0
					Total:	32,6	100	0	0

Table G.7 Estimated data of Alternative 6 section for Reconstructed-Wall-1.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: polyurethane foam (50 kg/m³) 30 mm, 2x gypsum board 9,5 mm					30	97	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50,3	1	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50,3	1	0	0
f3	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		19	ISOV: carpet, chipbrd. 22 mm, Akustic EP 2 27/25, chipbrd. 19 mm, Integra ZKF 1-040 120 mm, gypsum brd. 12.5 mm		66,8	0	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50,8	1	0	0
					Total:	29,8	100	0	0

Table G.8 Estimated data of Alternative 1 section for Semi-Repaired-Wall-3.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm					35	72	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	4	0	0
f2	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		20	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		40	22	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		52	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		53	1	0	0
					Total:	34	100	0	0

Table G.9 Estimated data of Alternative 2 section for Semi-Repaired-Wall-3.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x triplex					38	64	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		49	5	0	0
f2	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		20	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		42	28	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		54	2	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		55	1	0	0
					Total:	36	100	0	0

Table G.10 Estimated data of Alternative 3 section for Semi-Repaired-Wall-3.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: polyurethane foam (50 kg/m³) 30 mm, 2x fibre concrete board 5 mm					32	75	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	2	0	0
f2	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		20	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		38	21	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		51	1	0	0
					Total:	31	100	0	0

Table G.11 Estimated data of Alternative 4 section for Semi-Repaired-Wall-3.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: polyurethane foam (50 kg/m³) 30 mm, 2x gypsum board 9,5 mm					30	94	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	2	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	2	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50	1	0	0
					Total:	30	100	0	0

Table G.12 Estimated data of Alternative 5 section for Semi-Repaired-Wall-3.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x gypsum board 12,5 mm					28,3	89	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		45,5	2	0	0
f2	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		20	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		38,7	8	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49,5	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50,2	1	0	0
					Total:	27,8	100	0	0

Table G.13 Estimated data of Alternative 6 section for Semi-Repaired-Wall-3.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: foamglas 40 mm, 2x gypsum board 9,5 mm					31	76	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	2	0	0
f2	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		20	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x fibre concrete board 4 mm		37	20	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50	1	0	0
					Total:	30	100	0	0

Table G.14 Estimated data of Alternative 1 section for Semi-Repaired-Wall-2.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm					35	88	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	5	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	5	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		52	2	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		53	1	0	0
					Total:	35	100	0	0

Table G.15 Estimated data of Alternative 2 section for Semi-Repaired-Wall-2.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: foamglas 40 mm, 2x gypsum board 9,5 mm					32	92	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	2	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	2	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49	2	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50	1	0	0
					Total:	31	100	0	0

Table G.16 Estimated data of Alternative 3 section for Semi-Repaired-Wall-2.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x gypsum board 12,5 mm					28	95	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		46	2	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		46	2	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50	1	0	0
					Total:	28	100	0	0

Table G.17 Estimated data of Alternative 4 section for Semi-Repaired-Wall-2.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: paper honeycomb (ø 4 mm) 75 mm, 2x triplex					38	84	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50	6	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50	6	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		54	2	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		55	2	0	0
					Total:	37	100	0	0

Table G.18 Estimated data of Alternative 5 section for Semi-Repaired-Wall-2.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: polyurethane foam (50 kg/m³) 30 mm, 2x gypsum board 9,5 mm					30	94	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	2	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	2	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49	1	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		49	1	0	0
					Total:	30	100	0	0

Table G.19 Estimated data of Alternative 6 section for Semi-Repaired-Wall-2.

	Sending Room		Junction	Receiving Room		R'w		L'n, w	
t	Basic Element	Additional Layer	Type-No.	Basic Element	Additional Layer	dB	%	dB	%
d	GELUI: polyurethane foam (50 kg/m³) 30 mm, 2x fibre concrete board 5 mm					33	92	0	0
d1	GELUI: 38 mm Merbau, wood					0	0	0	0
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	3	0	0
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48	3	0	0
f3	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		50	2	0	0
f4	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		19	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)		51	1	0	0
					Total:	32	100	0	0

Table G.20 Estimated data of Semi-Repaired-Floor-2.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additional	Type-No.	Basic Element	Additional	dB	%	dB	%
d	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)					35,8	80	78,9	93
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	6	63,6	3
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		47	6	63,6	3
f3	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		49,1	4	58,9	1
f4	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		49,1	4	58,9	1
					Total:	34,8	100	79,3	100

Table G.21 Estimated data of Semi-Repaired-Floor-3.

	Sending Room		Junction	Receiving Room		R'w		L'n,w	
t	Basic Element	Additional	Type-No.	Basic Element	Additional	dB	%	dB	%
d	GELUI: wooden floor on wooden joists with susp. ceiling (gypsum board)					35,8	85	78,9	95
f1	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48,5	5	62,1	2
f2	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		19	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		48,5	5	62,1	2
f3	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50,6	3	57,4	1
f4	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		20	GELUI: expanded cork 45 mm, 2x fibre concrete board 5 mm		50,6	3	57,4	1
					Total:	35,1	100	79,2	100

GLOSSORY OF ACOUSTICAL TERMS

This glossary is taken from the glossary section of the book "Acoustics and Noise Control" (Peters *et al* ,2011).

Acoustics (1) the science of sound; (2) of a room: those factors which determine its character with respect to the quality of the received sound.

Airborne sound sound or noise radiated directly from a source, such as a loudspeaker or machine, into the surrounding air.

Airborne sound insulation the reduction or attenuation of airborne sound by a solid partition between source and receiver; this may be a building partition.

Centre frequency the centre of a band of frequencies; in the cases of octave or one-third octave it is geometric mean of the upper and lower limiting frequencies of the band.

Coincidence effect an effect which leads to increase the transmission of sound by panels and partitions when the speed of flexural waves in the panel coincide with the speed of the sound waves exciting the panel.

Critical frequency the lowest frequency at which the coincidence effect takes place for a particular panel or a partition, and which the sound insulation performance starts to deteriorate.

Decibel (dB) the decibel is a scale is a scale for comparing the ratios of two powers, or of quantities related to power such as sound intensity; on the decibel scale the difference in level between two power,W_1 and W_2 N dB, where N=10 log (W_1/W_2); the decibel scale may also be used to compare quantities, whose squared values may be related to powers, including sound pressure, vibration displacement, velocity or acceleration, voltage and microphone sensitivity.

Direct sound sound which arrives at the receiver having travelled directly from the source, without reflection.

Flanking transmission the transmission of sound between two adjacent rooms by paths other than via the separating partition between the rooms via floors, ceilings and walls.

Frequency of a sinusoidal varying quantity such as sound pressure or vibration displacement; the repetition rate of cycle i.e. the reciprocal of the period of the cycle, the number of cycles per second; measured in Hertz (Hz).

Hertz (Hz) the unit of the frequency; the number of the cycles per second.

In-situ measurements measurements carried out on-sit, away from controlled laboratory conditions; the results of in-situ tests of sound insulation may include the effects of flanking paths as well as direct sound transmission which would not be the case for laboratory tests.

Impact sound sound resulting from the impact between colliding bodies.

Impact sound insulation the resistance of a floor to the transmission of impact sound: measured according to BS EN 140-7.

Mass law an approximate relationship for the predicting the sound reduction index of panels and partitions, based only on the surface density of the panel and the frequency of the sound.

Noise reduction coefficient a single number sometimes used to describe the performance sound absorbing materials, based on a combination of its absorption coefficient at various frequencies.

Sound pressure fluctuations in a fluid medium within the (audible) range of amplitudes and frequencies which excite the sensation of hearing; (2) the sensation of hearing produced by such pressure fluctuations.

Sound absorbing material material designed and used to maximize the absorption of sound by promoting frictional processes; the most commonly used materials are porous, such as mineral fibre materials or certain types of open-cell foam polymer materials.

Sound absorption (1) the process whereby sound energy is converted into heat, leading to a reduction in sound pressure level; (2) the property of a material which allows it to absorb sound energy.

Sound absorption coefficient a measure of the effectiveness of materials as sound absorbers; it is the ratio of the sound energy absorbed or transmitted by a surface to the total sound energy incident upon that surface; the value of the coefficient varies from 0 to 1.

Sound reduction index (R) & apparent sound reduction index (R') Terms relating to the sound insulation performance of partitions defined in BS EN ISO 140-4, measured in octave or third octave frequency bands.

Sound transmission the transfer of sound energy across a boundary from one medium to another.

Standardised level difference (D_{nT}) a measurement of airborne sound insulation, corrected according to BS EN ISO 140-4 for receiving room characteristics(reverberation times); a complete set of measurements consists of 16 third octave band values, from100 to 3150 Hz.

Standardized impact sound pressure level (L_{nT}) a measurement of impact Sound insulation, corrected according to BS EN ISO 140-7, for room characteristics; a complete set of measurements consists of 16 values, one for each third octave frequency band from100 Hz to 3150 Hz.

Weighted sound reduction index (Rw) & apparent weighted sound reduction index (Rw') a single figure value of sound reduction index, derived according to procedures given in BS EN ISO 717-1, used for rating and comparing partitions and based on the values of sound reduction index at different frequencies.

Weighted standardised level difference (D_{nTw}) a single figure value of airborne sound insulation performance derived according to procedures in BS EN ISO 717-1 used for rating and comparing partitions.

Weighted standardized impact sound pressure level (L_{nTw}) a single figure value of impact sound insulation performance, derived according to procedures BS EN ISO 717-2 used for rating and comparing floors and based on the values of L'_{nT} reduction index at different frequencies.