Design Guide –
Silent Timber Build – WWN+
Summary

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SILENT
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BUILD

Table of Contents

Summary

This report summarizes the results from the project “Silent Timber Build”, a Wood Wisdom Net+ project granted in the 4th joint call of WoodWisdom-NET research programme, 2014 – 2017. The aim has been to develop prediction tools and to verify that the results from the modelling is according to expected values. Additionally the aim has to broadcast the results and to make them accessible and understandable for users in general. For that results are displayed in the ATLAS hosted by Lignum (www.lignumdata.ch) which also comprises an auralization tool for aural understanding of various figures. The database is now available in many languages for easier access.

For full understanding and deeper knowledge we refer to the Work Package reports as is also available on line, in total three additional reports describing:

1. The modelling prerequisites and the software used
2. The verification of models and the grouping that has done in order to simply model verification
3. The ATLAS and the basic principles for the auralization tool

The project results are satisfactory and the confidence in modelling is far better today compared to prior to the project. There are still obstacles to overcome, however a far better understanding is achieved and the wooden industry can look forward for more safe prediction of sound insulation implying more scientific development of new buildings as well as opening up for new products and building systems. Preconditions that will open the doors for more competitive wooden industry and an increased number of buildings with wooden structural components in future.

More information is found in this design guide and www.silent-timber-build.com

Acknowledgements

We would like to acknowledge all participants in the Silent Timber Build project, scientists as well as industrial representatives. They are all displayed in the website www.silent-timber-build.com.

Furthermore we would like to acknowledge Wood Wisdom Net for recommending funding for this important project and also all the national funding organizations for finally funding the project, and not least CEI-Bois for their invaluable contribution. Additionally all industrial representatives from the countries involved.

Klas Hagberg
Silent Timber Build

1. Introduction

Sound insulation and vibration characteristics of buildings represent the design parameters always deciding the structural dimensions and build-up of the floor- and wall assemblies in a building, no matter what is the structural material. It is not the statics, not the fire regulations, not energy requirements or any other technical aspect, it is always the sound insulation and / or the vibration characteristics that state the dimensions, at least for multi-family houses where requirements adapted to subjective evaluation are effectual. As soon as the design criteria of sound insulation and vibration are fulfilled, then the predicted sound insulation and vibration are expected to be satisfactory, e.g. the main structural dimensions in the building should then be decided since they are normally big enough to cover the needs for other technical aspects. This is at least valid for normal high rise multifamily buildings. Therefore the results from this research project is of vital importance for the further development of wooden structures. Calculating and optimizing the structural components will imply further development of wood in buildings and make the production reduce in cost. This guide is prepared as a results from recent research and it comprises an extensive description of possibilities to facilitate prediction of and optimization of the sound insulation characteristics concerning floor and wall assemblies comprising wood as bearing structural element.

This guide is the result from the project WWN+ project “Silent Timber Build”, granted in the 4th joint call of WoodWisdom-NET research programme. Its results comprises guidelines regarding sound insulation and vibrations that can be used as designing wooden floor and wall assemblies and their connections, in order to develop a completed building that can correspond to habitants expectations in each specific case. The results from the research are broadcasted in several different ways, amongst those (see also detailed specification in annex A):

a) This report series (design guide).

b) Certain measurement data useful as input to future standardization.

c) A commercial SEA software aimed for wood constructions SEAWood.

d) A European on line Atlas with various floor and wall assemblies, partly developed within Silent Timber Build. It also comprises an online auralization tool, developed in order to listen to the different floor partitions prior to choose the final solution. The atlas also comprises a certain section with Silent Timber Build floor structures and a verified solution from the parallel WWN+ project HCLTP.

e) All is available on www.Silent-Timber-Build.com

1.1 Layout of the design Guide

The present design guide is divided into various parts based on the Working Groups included in the project.

1. This Summary report

2. WG 1 report with the content

    a. Modelling prerequisites FEM/SEA – Impact and Airborne sound insulation and vibration modelling. The report shows modelling results from typical setups within the “Silent Timber Build” project. The modelling is carried out by using

FEM for vibrations and low frequencies and in addition the SEA software SEAWood. Tested floor assemblies corresponds to the measured assemblies as described in report no 2, bullet point 3 below.

3. WG 2 report

    a. Validation of prediction tools and constructions – grouping, verification measurements and trend analysis

        i. Comprising acoustic solutions for floor assemblies throughout Europe and a grouping of these based on their acoustic performance. The grouping that finally was carried out can be used to find some rough conformity between the impact sound level single number value and the mass per unit area (mpua). Hence, as designing or calculating a floor, note first which group it belongs to, in order to make a rough estimate. From that it is possible to optimize the assembly by changing modelling characteristics.

4. WG 3 report

    a. A description of the layout of floor and wall assemblies in the European atlas (EATSI) comprising calculated and/or measured airborne and impact sound insulation values and in addition experienced sound insulation by using an auralization tool. The report also gives an overview on the basic theory for the auralization tool.

This summary report (Bullet point 1. above) gives an overview of the projects main results and how these can be applied in reality. The report also comprises a proposal regarding a hybrid floor assembly that might be further developed in order to become highly competitive compared to any other floor assembly. The floor structure is developed within the parallel WWN+ project HCLTP taking many aspects into consideration, such as:

1. Material usage
2. Conceivable production ability
3. Stiffness / floor span length (to increase design flexibility)

and then the structure is optimized and verified in this research project (Silent Timber Build) regarding its sound insulation performance.

1.2 History

Multifamily residential houses using wood in the structural bearing components have been erected over the last 20-25 years and is currently increasing in numbers, not only in Europe but also in other continents. Today wood has a benefit in terms of environmental aspects compared to other structural materials. However, originally, it was the change in fire regulations all over Europe that opened up for structural material in wood also in high rise residential buildings. Unfortunately, it was only the fire regulations that were adapted to the new building technique, no changes were made in the sound insulation requirements (they stayed unchanged) in spite of the fact that the regulations were not at all adapted to wood as structural bearing material.

It is well known that light material such as wood is less resistant to vibrations and low frequency noise, it is following the physical laws. Hence, prevailing acoustic and vibration requirements that was adapted to traditional buildings erected with stiff and heavy material such as concrete, now could be applied also for buildings with structural material in wood. An overview of the acoustic regulations were not even considered prior to the change in fire regulations and therefore acoustic regulations adapted to wood buildings are still not implemented in building codes in European countries (or any other country in the world). That is a problem since development of building structures are always optimized in order to fit the regulations, not in order to optimize for the experienced sound insulation.

After the changes in fire regulations were completed and in use in building regulations, there were some research project carried out where full residential buildings with wood were finalized. They included considerations regarding sound insulation, e.g. the design was made by applying adapted sound insulation requirements based on early investigations regarding annoyance in residential buildings. However, as the development continued and the market for wooden buildings slowly increased the structural design more and more became adapted to prevailing “old” minimum requirements. Nevertheless, due to several research projects throughout Europe and research networking (COST for example) over the latest 5-10 years, the awareness has increased. As a result from all this common work, there exists now a European agreement (at least amongst researchers) regarding the main design principles as follow below:

a) Vibrations has to be part of early stage design of the floor assembly
b) Low frequencies should be considered for impact sound levels, at least from 50 Hz
c) Airborne sound insulation might be satisfactory in the ordinary frequency range (100 – 3150 Hz)
d) Flanking transmission and junctions are of main interest and have to be designed carefully.

The numbers and results in detail are summarized in the next section.

1.3 Legal requirements in Europe

The legal minimum requirements in Europe vary a lot between countries. The huge variations are described in several articles [1, 2]. Apart from different requirements within the standard range, there are a number of specific national adaptations outside the normal single number values complicating trade between countries if not aware of the differences. Some national adaptations are described in [3].

Sweden is still the only country in the world considering the frequency range from 50 Hz to 3150 Hz in the minimum requirements (building code). Many other countries have introduced an extension to low frequencies, but still only optional and in higher sound classes (above legal requirements). For wooden structures and other light structures it is essential to include low frequencies for multifamily houses / dwellings, especially concerning impact sound. If not there is no doubt that the experienced sound insulation might be bad even if the requirements are fulfilled. For certain special housing / small flats (for example student rooms and dwellings for elderly), it might be acceptable to exclude the low frequencies due to lower impact loading, however more information is needed to collect to make judgments based on scientific results. The legal requirements in the countries participating in the project Silent Timber Build are summarized in table 1 and table 2 below.

Table 1; Impact sound insulation requirements in dwellings in multifamily houses

Country	Requirements found in	Impact sound level, ISO 717 [dB]	National additional rule	Comments
Finland (SF)	Both in BC and CS (identical limits)	$L'_{n,w} \leq 53$	Receiving room volume limitation in the evaluation, $V_{r,max}$ 60 m^3.	
France (F)		$L'_{nT,w} \leq 58$		
Germany (D)		$L'_{n,w} \leq 53^{3,6}$, $L'_{n,w} \leq 48^{3,6}$		3) Row houses, 6) Should be compared to results with no **soft** floor covering that can be easily removed and changed
Austria (A)		$L'_{nT,w} \leq 48$, $L'_{nT,w} \leq 43^{6}$		6) Row houses
Italy (I)		$L'_{n,w} \leq 63$		
Sweden (S)	BC	$L'_{nT,w}+C_{I,50\text{-}2500} \leq 56$ $L'_{nT,w} \leq 56^{1}$	$C_{I,50\text{-}2500}$ is not allowed to be below 0	1) Homes for elderly
Switzerland (CH)	SIA 181:2006 Schallschutz im hochbau	$L'_{nT,w}+C_{I} \leq 53$, 50^{5}		5) Row houses and owned flats
Norway (N)		$L'_{n,w} \leq 53^{4}$	For sound class A and B, $L'_{n,w} + C_{I,50\text{-}2500}$ have to be applied (with lower values). Receiving room volume limitation in the evaluation, $V_{r,max}$ 100 m^3.	4) $L'_{nw}+C_{I,50\text{-}2500} \leq 53$ is recommended
Spain (E)				

Table 2; Airborne sound insulation requirements in dwellings in multifamily houses

Country	Requirements found in	Airborne sound insulation, ISO 717 [dB]	National additional rule	Comments
Finland (SF)	Both in BC and CS (identical limits)	$R'_{w} \geq 55$	Receiving room volume limitation in the evaluation, $V_{r,max}$ 60 m^3.	
France (F)		$D_{nT,w}+C \geq 53$		
Germany (D)		$R'_{w} \geq 53$ / $(52)^{9}$ / $(54/55)^{5}$, 57^{6}		5) Vertical (55 to garage) 6) Row houses 9) walls to staircases
Austria (A)		$D_{nT,w} \geq 55$, $D_{nT,w} \geq 60^{7}$		7) Row houses
Italy (I)		$R'_{w} \geq 50$		
Sweden (S)	BC	$D_{nT,w}+C_{50\text{-}3150} \geq 52$, $D_{nT,w} \geq 52^{1}$	-	1) Homes for elderly
Switzerland (CH)	SIA 181:2006 Schallschutz im hochbau	$D_{nT,w}+C \geq 52$, $D_{nT,w}+C \geq 55^{8}$		8) Row houses and owned flats
Norway (N)		$R'_{w} \geq 55$	For sound class A and B, $R'_{w} + C_{50\text{-}5000}$ have to be applied (with higher values). Receiving room volume limitation in the evaluation, $V_{r,max}$ 100 m3.	
Spain (E)				

In the tables above additional national rules are included. Rules hidden in the regulations that complicate the comparison between countries and of course also complicate the use of one unified building system in different countries, adaptations are always needed. Adding other types of buildings to the table above complicate the use even more.

In a COST action finalized in 2013 (COST TU 0901) a proposal for a common European regulation framework was presented, comprising new single number quantities and a classification scheme, see table 3 and table 4 below. For full information see ref [4, 5]

Table 3; Airborne sound insulation requirements as proposed in COST TU 0901 (summary – for full info see ref 4)

Type of space	Class A $D_{nT,50}$ (dB)	Class B $D_{nT,50}$ (dB)	Class C $D_{nT,50}$ (dB)	Class D $D_{nT,50}$ (dB)	Class E $D_{nT,50}$ (dB)	Class F $D_{nT,50}$ (dB)
Between a dwelling and premises with noisy activities (3)	≥ 68	≥ 64	≥ 60	≥ 56	≥ 52	≥ 48
Between a dwelling and other dwellings and rooms outside the dwelling	≥ 62	≥ 58	≥ 54	≥ 50	≥ 46	≥ 42

Note: $D_{nT,50} = D_{nT,w}+C_{50\text{-}3150}$

Table 4; Impact sound level requirements as proposed in COST TU 0901 (summary – for full info see ref 4)

Type of space	Class A $L'_{nT,50}$ (dB)	Class B $L'_{nT,50}$ (dB)	Class C $L'_{nT,50}$ (dB)	Class D $L'_{nT,50}$ (dB)	Class E $L'_{nT,50}$ (dB)	Class F $L'_{nT,50}$ (dB)
In dwellings from premises with noisy activities(4)	≤ 38	≤ 42	≤ 46	≤ 50	≤ 54	≤ 58
In dwellings from other dwellings	≤ 44	≤ 48	≤ 52	≤ 56	≤ 60	≤ 64
In dwellings: – from common stairwells and access areas – balconies, terraces, bath, toilet not belonging to own dwelling	≤ 48	≤ 52	≤ 56	≤ 60	≤ 64	≤ 70

Note: $L'_{nT,50} = L'_{nT,w} + C_{I,50\text{-}2500}$

Regarding floor vibrations, to our knowledge, the vibration magnitudes are not precisely regulated in national regulations. However, the design rules for floor vibrations are set in Eurocode 5 (EN1995-1-1) together with country specific national application documents (NAD). Reference [6] (Zhang et al, 2013) gives an overview of how the Eurocode 5 related national application rules varies in 13 European countries currently. The variation of acceptance levels is very wide and in addition many countries have altered their vibration design rules significantly. At present, the Eurocodes are under development and it is anticipated that these rules will become more uniform in the next code version.

1.4 Verification of requirements

Historically, sound insulation characteristics of wooden structures are difficult to predict with high accuracy, hence optimizing the structures with regard to their sound insulation are connected to severe difficulties, often full scale test houses has been built to secure the solutions. It is both expensive and time consuming, and reducing the competitiveness for wood as structural material. Additionally, the diversity of regulations might complicate trade since the various regulations aggravate the verification procedure even more (see table 1 and table 2). For other structural material such as concrete or combined steel and concrete a series of standardized calculation models, EN 12354 [7, 8] exist and they are also verified and tested over decades. The structural elements and junctions for these structures are also more clearly defined and easier to describe compared to wooden elements and junctions. Slowly the standardized models are adapted to wooden structures as well [9], and Silent Timber Build provides additional input for further development, but still there are a long way to go until the accuracy for these future standardized methods is similar to heavy structures. These uncertainties imply that increased knowledge regarding prediction models for wooden structures is a key factor in order to increase the use of wood in future buildings. The models have to be “safe enough” in order to encourage developer to use wood as structural material.

In order to optimize the structural elements properly, low frequencies (below 100 Hz) have to be included even if the vast majority of the countries in the world still are using the same acoustic requirements, originally developed for typical heavy structures, e.g. starting from 100 Hz. In Silent Timber Build modelling are developed considering the frequency range from 50 Hz to 3150 Hz. Additionally FEM models are used for evaluating vibrations and hence, even lower frequencies are covered and considered.

1.4.1 Acoustics

Acoustic verification of sound insulation comprises both airborne and impact sound insulation. The frequency range considered are from 50 Hz to 3150 Hz in both cases. However, it is not yet clarified to full extent if it is really needed for dwellings in general for airborne sound insulation, the traditional frequency range, 100-3150 Hz, might be sufficient in most cases. By contrast, for impact sound level it exists a European consensus that the frequency range for "normal" dwellings should be extended to 50 – 3150 Hz. There are also indications that it could be of benefit to extend it even lower, to 20 Hz for impact sound levels. Research from Sweden implies that it is of certain importance to include frequencies from 20 Hz [9, 10], however careful considerations and more work is needed [10]. The results should be limited to comprise only "ordinary" dwellings, dwellings with families (kids). In order to emphasize the importance of including low frequencies in the verification procedure a comparison is shown below in figure 1.1, the left diagram indicating correlation including frequencies from 50 Hz to 3150 Hz and the right diagram indicating correlation including only a sum of the frequencies from 20 Hz to 50 Hz, e.g. all other frequencies excluded in the evaluation. The correlation increases significantly when the focus is directed to the low frequencies.

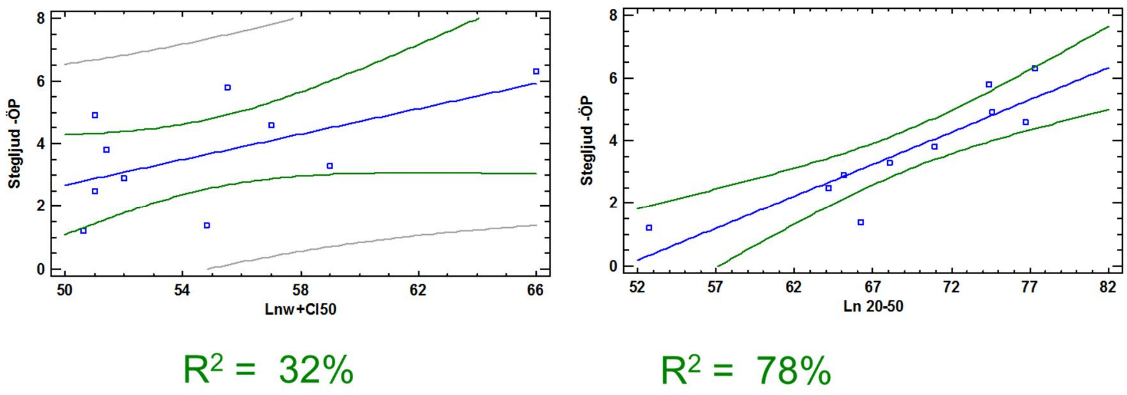


Figure 1.1. Determination coefficient for; 1. (left) experienced impact sound level (vertical axis) compared to objective measured impact sound level $L'_{n,w}+C_{i,50-2500}$; 2. (right) experienced impact sound level (vertical axis) compared to objective measured impact sound level, $L'_{n,20-50}$.

Similar findings were detected in the European project *AcuWood*, however not necessarily resulting in better correlation if the frequency range is extended below 50 Hz [13].

Nevertheless, when designing and verifying a light timber structure low frequencies have to be considered according to following:

- For impact sound
- For normal "several room" dwellings comprising "families"

For other applications there might still be sufficient to consider the traditional frequency range. However, for full understanding of future needs a more specified investigation regarding future living habits and expectations has to be carried out. Such an investigation should be carried out on a European basis.

1.4.2 Vibrations

Considering the verification of floor vibrations, there does not exist a test standard currently for this. There is at present an EN test standard under preparation on methods to measure deflections and the natural frequency of a floor. This will however not be sufficient for floor assessments. Tests and verifications are carried out in various ways, either in laboratory conditions or in the building site. Also the applied dynamic loads are different, typically the application of an impact hammer, a walking person or a heal-drop. The measured vibration accelerations are usually compared with the human perception curve presented in the international standard ISO 2631-2 (1989) [14].

As a role of thumb a floor structure should comply with a lowest natural frequency bigger than > 16 Hz and a declination equal to maximum 1 mm when the floor is loaded with 1 kN point force.

2. Methods

The aim of current research project has been to develop a general approach for the design of any available wooden floor and wall assembly existing in Europe today and in addition use the methods developed in the project in order to optimize new future structural components in wood. A specific SEA software has been used and developed further during the project (SAEWOOD), in combination with FEM modelling. For the further development of new floor assemblies, cooperation has also been carried out with the parallel WWN+ project HCLTP. The modelling have been verified by measurements within Silent Timber Build but also by collecting existing data from different countries.

The results are then broadcasted in a database, European Atlas, comprising wood constructions, hosted by Lignum in Switzerland. In the database the user can also listen to the different examples of floor and wall assemblies. The development of the listening tool has been part of Silent Timber Build and the work was carried out in order to translate the acoustic objective numbers into sound files in a manner that makes it far much easier for the users to understand and subjectively evaluate the impact of various measures changing the characteristics of the actual partition.

The work was carried out in cooperation between a number of researchers and industrial partners within different Work Packages (WP:s). A schematic picture of the different Work Packages and their mutual interactions is shown in figure 2.1 below:

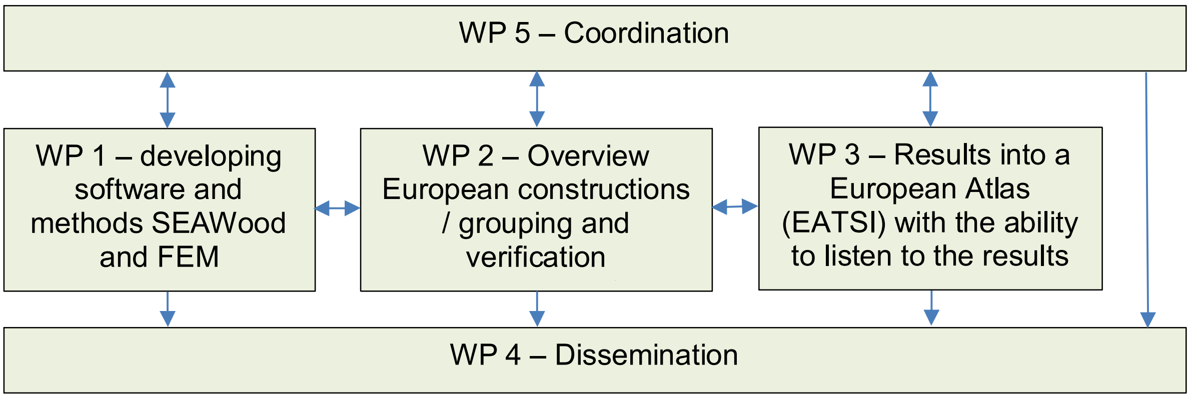
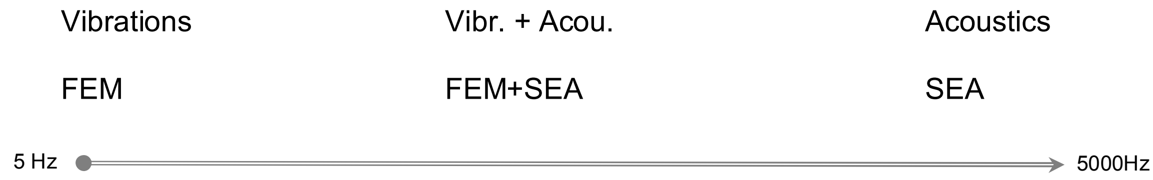


Figure 2.1. Overview of the project Work Packages and their mutual interactions

In terms of frequency range the work might be divided into two parts, one part considering the vibrations and one part considering the acoustics. The vibrations are normally appearing in very low frequencies and then the vibrations turn into acoustics as the frequency increases. In current project acoustic calculations are carried out from the frequency 50 Hz which is rather low from a legal point of view. As mentioned in previous sections, the legal acoustic requirements normally start at 100 Hz and up to 3150 Hz. Designing for vibrations imply far more low frequencies. The methods used in the research project are Finite Element Methods (FEM) and Statistical Energy Analysis (SEA). The methods are complementary and applicable in different frequency ranges. Suitable methods for the design are



The frequency range between 20 – 50 Hz are then not really part of the calculation, however if designing the floor structure with respect to both vibrations and acoustics the missing range are still considered to some extent.

2.1 Acoustics

The acoustics in this research project comprises development of calculation prerequisites and models for impact sound insulation and airborne sound insulation between different spaces. The focus within acoustics regarding lightweight structures, e.g. wooden structures, is often directed towards impact sound insulation in floor assemblies. Impact to the floor, such as walking noise produces more energy in low frequencies than airborne sound and if this is considered and satisfactory, the airborne sound insulation normally becomes sufficient. However, other building parts such as wall partitions between dwellings, should be designed in order to meet an airborne sound insulation that corresponds to experienced impact and airborne sound insulation for the floor assemblies. Hence, in terms of optimizing the entire structure, and in order to reduce costs in the overall design, both aspects always have to be considered and carried out.

The work in current project is divided into some different tasks. Due to the importance of impact sound in the design process the work started to collect European floor assemblies and their impact sound insulation performance have been identified, aiming at a grouping of different existing floor assemblies. The grouping was carried out in order to facilitate prediction of new floor assemblies in future. The aim is to use the grouping as a helpful tool for further refining of a model and then optimizing the floor assembly. Hence the grouping gives a rough idea of expected sound insulation of various floor assemblies. Any floor assembly that is supposed to be calculated can be compared to the groups and normally it belongs to one of them. From that expected sound insulation can be estimated and hence, it will indicate whether there are any severe errors in the basic model of the actual floor assembly.

In parallel, modelling of wall assembly airborne sound insulation characteristics has been carried out by using the software SEAWOOD. Wall assemblies are slightly less complicated in their composition compared to floor assemblies and the prediction software is generally more reliable in these cases. The software SEAWOOD has been further updated during the project, in order to better fit to typical wall assemblies and the accuracy is now shown to be satisfactory in most cases.

2.2 Vibrations

Modelling vibrations has been done in some specific cases by using FEM, however main focus has still been to go low in frequencies regarding acoustics.

3. Results

3.1 WP 1 – Modelling prerequisites – FEM/SEA

The aim from this WP was to develop prediction methods applied for wooden constructions as they might appear, no matter if it is joist constructions, CLT or any other structural bearing solution. Included in this is also to create necessary basis for enough accuracy for any European wood construction. It implies development of new methods but also to understand how input forces primarily from the tapping machine affects the results of impact sound levels, specifically in the low frequency region. The WP also describes how models are developed, in order to provide expected accuracy and then how to further improve the models in order to optimize floor and wall assemblies. The Work Package has been closely linked to WP 2 (section 3.2) but also WP3 (section 3.3). Using the results from WP 2, the prediction model results can be compared to expected values for any European construction, see below in section 4. From that optimization of floor assemblies and refining of the model is possible.

For details regarding theory and modeling prerequisites, see report from WP 1; "*Modelling prerequisites – FEM/SEA, Impact and Airborne Sound*".

In WP 1 a number of data is also collected to provide input to future standardization by measuring damping through junctions. One extensive measurement series is carried out by the project partner Rothoblaas (annex 2 in this report) and another by FCBA in Bordeaux in France, see report from WP 1.

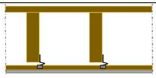
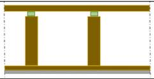
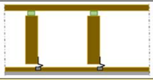
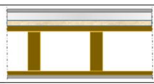
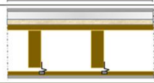
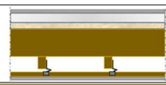
3.2 WP 2 – Validation of prediction tools and constructions – grouping, verification measurements and trend analysis

Current existing European wooden floor- and wall assemblies comprises a huge number of variables. The building materials involved in various solutions are numerous. All these variables make it difficult to predict and really identify what is most essential in order to optimize the structure in terms of acoustics and vibrations. When modelling, how can we really be sure that the correct assumptions are carried out and in the extension, that the results are trustable? That is the reason why this project started with collection of current data available in different countries but also additional laboratory measurements within the project and then a grouping of the building systems (floor assemblies primarily), followed. The grouping was made in order to detect any relations between important variables that might be used in order to make rough estimations of the floor assembly sound insulation characteristics. This estimation can then be used in order to verify the model. Hence, as a new wooden floor assembly is modelled, the grouping can be helpful to use as comparison with "measured" values, even if the modelled floor assembly itself is not measured.

The grouping does not cover all systems in spite of trying to collect as many data as ever possible during the project. Hence the grouping and its results have to be used carefully, it is as mentioned in the heading a "trend analysis". Nevertheless, it is a safety for the engineers creating acoustical models that their floor assembly is properly modelled. As changes are carried out in the model in order to improve a floor assembly the grouping can be used yet again in order to estimate if the results are probable and reliable, a minor confirmation for the engineer.

The grouping is not fully completed, but it is a first attempt. It might need future updates in the further development of the wooden building sector. Table 1 below shows the grouping as it I carried out in this project, Silent Timber Build. The results from the grouping indicate that it is far more efficient to use wood joist floor assemblies compared to homogeneous CLT structures. The floor assemblies become less heavy, still performing better in terms of acoustics. Consequently, the use of structural material is more efficient in a wood joist construction. The entire data collection and the basis for the grouping is shown in the report from WP 2; "*Validation of prediction tools and constructions – grouping, verification measurements and trend analysis*".

Table 5: Main groups and subgroups as they are used for the summary in this report. In the cases where pictures are missing, it implies that there is no results within this report but they might exist in reality.

Floor Assembly group	Name	Assembly	
Group A	Wood Joist	FS-CS	
		FS-CR	
		FS-CN	
		FR-CS	
		FR-CR	
Group B	Hybrid Wood Joist	FS-CS	
		FS-CR	
		FR-CS	
		FR-CR	
Group C	Massive wood	FS-CS	
		FS-CR	
		FS-CN	
		FR-CS	
		FR-CR	
Group D	Hybrid Massive element	FR-CS	
		FR-CR	

3.3 WP 3 – European ATLAS

A European ATLAS is available as a complement to the grouping above. The ATLAS is hosted by the project partner LIGNUM at www.lignumdata.ch . The ATLAS is not developed as a whole during this project but it has been completed with a complex listening tool which is now available on line, see report from WP 3; *European Timber Sound Insulation Atlas*“. The listening tool has been part of WP 3 and implies that it is possible to listen to the results of a floor assembly facilitating for the user to understand the objective numbers that is given in the ATLAS. During the project floor assemblies have been added to the database and in particular one floor assembly is now available and it is a floor developed within the parallel project, HCLTP. Hence, it is possible to create a floor assembly, develop a model based on SEA or FEM and calculate, compare with grouping values in order to secure the model, refine the model, put it online in the database, listen to the results.

For the careful designer it is a possibility that could be of great benefit. During the project the ATLAS has been translated into several languages facilitating the use of the results for the industry in many countries.

4. Analysis

In figure 2.2 below, a procedure for designing wooden structures is shown. The boxes (groups and subgroups) in the bottom shows a simple way to estimate expected impact sound level for various groups of floor assemblies. The grouping is based on the build up and the assembly mass per unit area (mpua). The grouping focuses only on impact sound levels since it is well defined and is also considered as the main parameter to secure for buildings with wood. Also for more heavy material it might be the main parameter, however it is easier to carry out structural measures if the floor assembly is heavy since it often becomes a high frequency problem in those cases. Hence it can be annoying, but if mistakes are done, it is easy to "repair". Wooden structures are far more complicated and sensitive and therefore they require a much more careful design and critical considerations during the design phase. The modelling itself is also more complicated for the impact sound level since the impact force hitting the structure can vary depending on its location, on a beam or on a field between two beams. All this together makes it important to model with some sort of certainty by comparing with measured values.

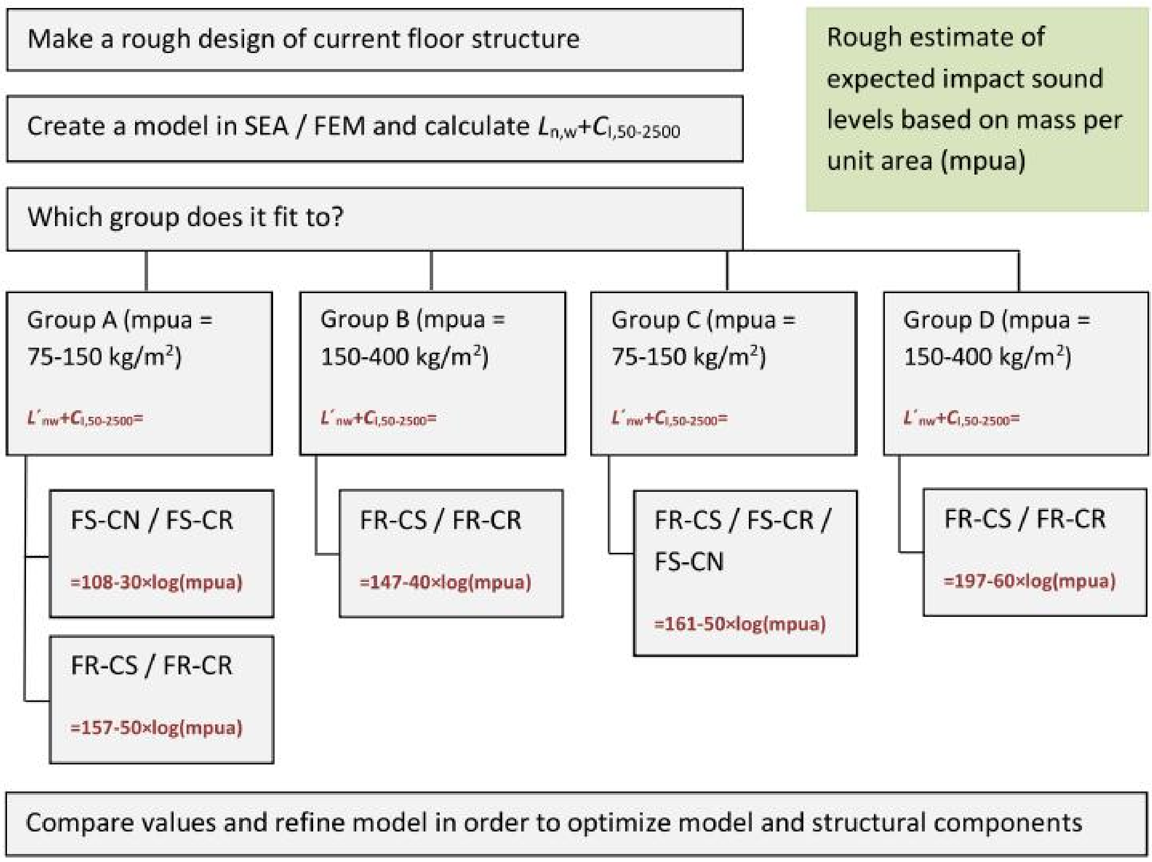


Figure 2.2. Hybrid CLT floor as proposed by the project HCLTP

4.1 HCLTP Floor

To prepare for optimization and future productive and competitive floor assemblies close cooperation have been carried out with the parallel project HCLTP (www.hcltp.com).

They developed a floor assembly optimized for production ability, stiffness, flexibility, floor span etc. Within “Silent Timber Build” it was further optimized in terms of its acoustic performance without affecting its characteristics regarding other technical aspects. The proposal from HCLTP project is shown below. After calculations some minor adaptations were done to further optimize the floor structure according to the following:

a) use of material (minimize the use)
b) Annoyance regarding impact sound (adapt to modern and future requirements)

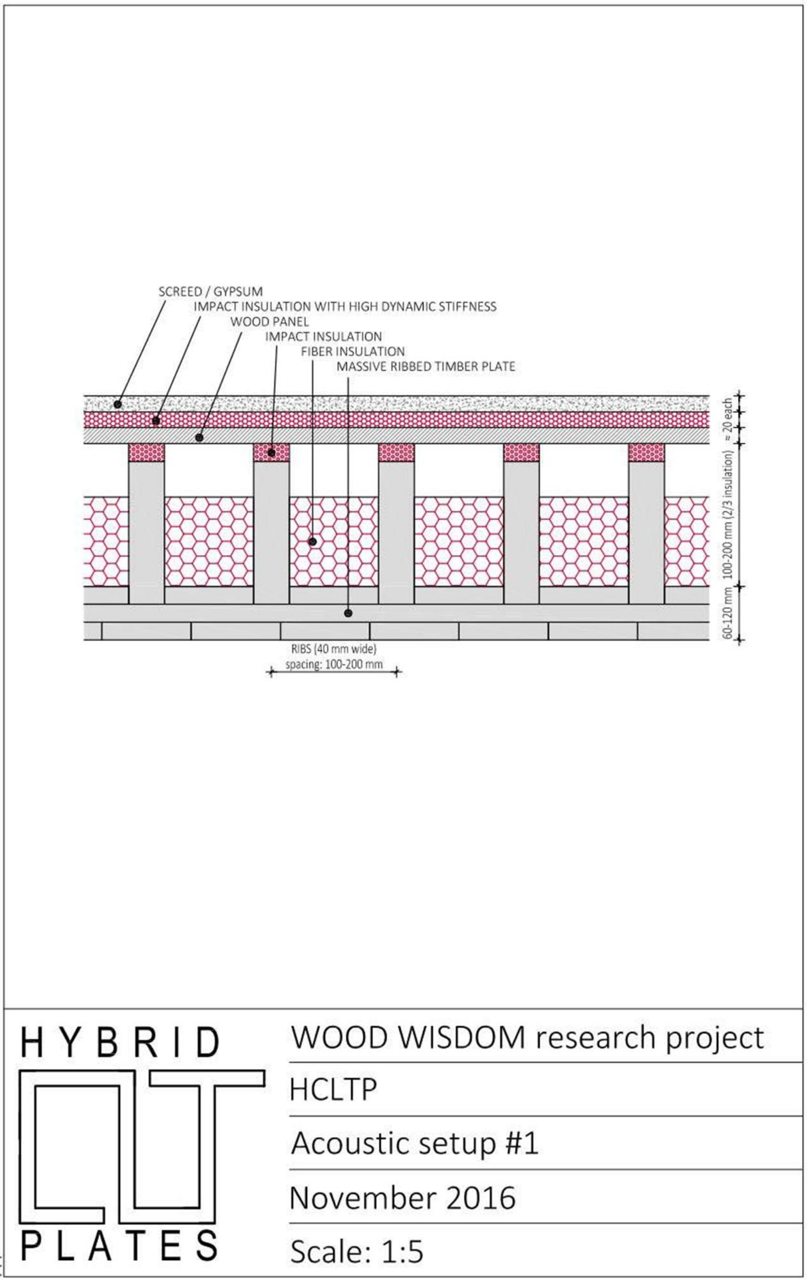


Figure 2.3. Hybrid CLT floor as proposed by the project HCLTP

The weight of the floor structure is approximately using a spacing between the beam equal to 200 mm and a 100 mm thick CLT in the bottom is approximately 120 kg / m^2. For the user it might be confusing since this floor not clearly belongs to a specific group since it comprises both massive wood and joists. However, the group that corresponds best is Group A (FR-CS). So a good start is to use this as a reference, and it shows that this structure exhibit an impact sound level corresponding to

$L_{nw} + C_{I,50\text{-}2500} = 53$ dB

The floor was then modelled in SEAWOOD and the results are shown in figure 2.4 below. It ended up in $L_{nw} + C_{I,50\text{-}2500} = 57$ dB which is on “safe side”.

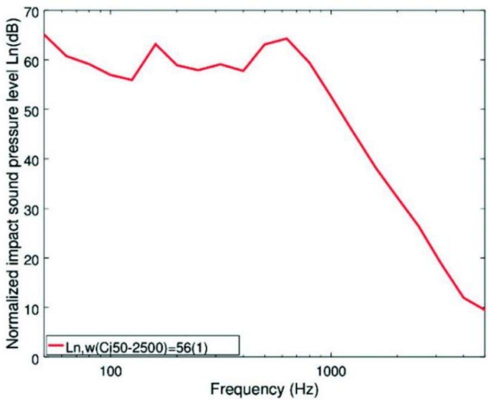


Figure 2.4: Result after modelling the HCLTP floor in the software SEAWOOD. The single number value of the impact sound level is calculated to $L_{nw} + C_{I,50\text{-}2500} = 57$ dB.

4.2 Improved HCLTP Floor

What can then be improved in order to further improve this floor without changing the weight? The height was increased and the beams were separated by a distance of 400 mm instead and one of the impact sound layers was removed, see figure 2.5 below.

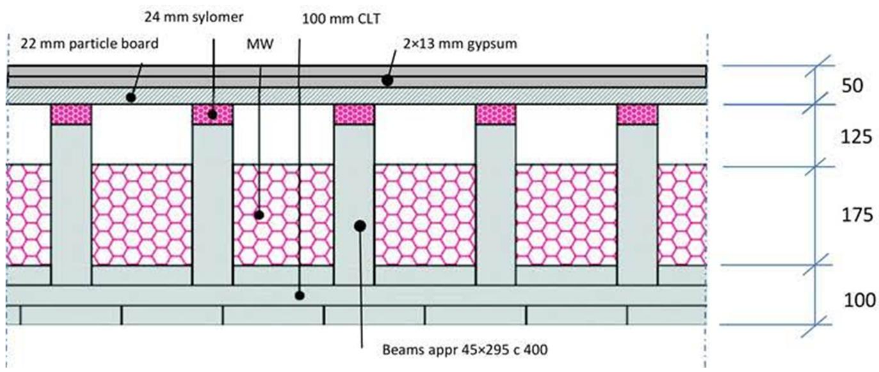


Figure 2.5: Acoustically optimized hybrid CLT floor as proposed by “Silent Timber Build”. Measures are not exact.

After that, the calculations of the optimized floor using FEM and SEAWOOD, exhibited a result as shown in figure 2.6 below, $L_{nw} + C_{I,50\text{-}2500} = 53$ dB. Still the expected sound insulation was 53 dB since the weight remained the same. Hence the structure will fulfill “normal” and / or high requirements at a European level. The savings of material and weight compared to a “normal CLT floor assembly” and still maintain same acoustical quality is noticeable.

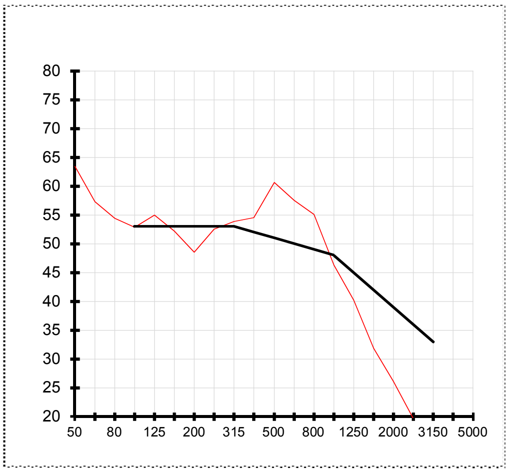


Figure 2.6. Hybrid CLT floor as proposed by the project HCLTP

5. Conclusions

The results from this project will facilitate modelling of acoustic and vibration characteristics of wooden buildings. We provide an efficient software, SEAWOOD, and in addition we describe how to use FEM in order to predict the lowest frequencies (including vibrations). All developed within Work Package 1 and described more in detail in report no 1. Furthermore, the project results provide a simplified method in order to verify the modelled results by comparing with similar floor assemblies from the grouping based on measurements, carried out within the project Work Package no 2 and in detail described in report no 2. The grouping comprises measured results from a huge number of floor assemblies within all European countries.

The grouping and the project as a whole focuses on floor assemblies and impact sound levels at any frequency that might appear in order to create models that can be used to compare with future building regulations and requirements from habitants. Nevertheless, the software has been verified also for wall assemblies and it has been shown to be far more easy and straightforward to model airborne sound than impact sound and vibrations.

Results and a huge number of floor assemblies, wall assemblies and some other building parts are broadcasted in the European ATLAS called in this project for “EATSI” (European Atlas for Sound Insulation). This ATLAS has been completed during Silent Timber Build. The completion implies that an auralization module has been developed within Silent Timber Build and is now introduced into the online database. It is a magnificent help in order to understand any measures that is proposed for improvement of a floor structure. By using headphones you can immediately “listen to” the expected impact sound level and compare different floor assemblies. All details regarding the ATLAS and the listening tolls are described in report no 3 provided by Work Package no 3. The database is available on www.lignumdata.ch and a link is provided from the project website www.silent-timber-build.com.

Finally the project provides input for further development of the European Standard EN 12354. Some simplified junctions for wood assemblies are introduced in the new updated standard (2017), and by further collecting measurement data and add to the collected data from this project and also from what was delivered within COST FP 0702 the standard can become even more useful in future.

6. References (2 p)

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[2] Rasmussen, B.; Sound Insulation between Dwellings – Overview of the Variety of Descriptors and Requirements in Europe, *Conference proceeding Forum Acousticum,* Aalborg, Denmark (2011).

[3] Hagberg, K.; Bard, D.; Sound Insulation Descriptors in Europe – Special Rules Complicate Harmonization within Lightweight Industry, *Building Acoustics, Volume 17, Number 4 (2010), p. 277–290*.

[4] Rasmussen, B.; Machimbarrena, M. et.al.; Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe, *COST Action TU 0901 ISBN: 978-84-697-0158-4* (2014)

[5] Rasmussen, B. Machimbarrena, M.; Fausti, P. et.al.; Building acoustics throughout Europe. Volume 2: Housing and construction types country by country, *COST Action TU 0901 ISBN: 978-84-697-0159-1* (2014)

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[7] EN 12354, part 1; Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 1: Airborne sound insulation between rooms, *CEN* (2000)

[8] EN 12354, part 2; Building acoustics – Estimation of acoustic performance of buildings from the performance of elements – Part 2: Impact sound insulation between rooms, *CEN* (2000)

[9] COST FP 0702, “Net-Acoustics for Timber based lightweight buildings and elements” e-book

[10] Ökvist, R; Measurement and perception of Sound Insulation from 20 Hz between Dwellings. Doctoral Thesis; ISBN 978-91-7583-869-4 (pdf) (2017)

[11] Ljunggren, F; Simmons, C; Hagberg, K; Correlation between sound insulation and occupants’ perception – proposal of alternative single number rating of impact sound. *Applied Acoustics 85 (2014), p 57-68.*

[12] Ljunggren, F; Simmons, C; Öqvist, R.; Correlation between sound insulation and occupants’ perception – Proposal of alternative single number rating of impact sound, part II. *Applied Acoustics 123 (2017), p 143-151.*

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Annexes

A. Dissemination of the project Silent Timber Build

B. Measurement report from Rothoblaas

Updated 2017-11-24

Silent Timber Build dissemination 2014 – 2017

Working partners: FCBA, CSTB, InterAC, LTH, Sintef, TU Graz, IBP Fraunhofer, Lignum, Tecnalia, Finnish Wood etc				
Dissemination, how and where	***Titel, description***	***Author / presenter***	***Made by /Planned by When?***	***Uploaded to website?***
Working reports (without official search numbers)				
Interims report for FNR Germany	Zwischenbericht ERA-WoodWisdom: Leise Holzgebäude für den europäischen Markt (Silent Timber Build) from 13.05.2015	M. Späh, P. Leistner	05/2015	No
Internally	Force identification of Shock Machine - Test campaigns in FCBA for Silent Timber Build project	G. Borello	2015-11-01	No
STB	Grouping of constructions. Working report from WP2	A. Homb	Oct 2015	No
Official report for the Austrian government	Official intermediate report	Ferk	08/2015	No
Interims report for FNR Germany	Zwischenbericht: Ergebnisse und Stand des Vorhabens; ERA-WoodWisdom: Leise Holzgebäude für den europäischen Markt (Silent Timber Build) from 28.04.2016	M. Späh	04/2016	No
Interim report for Norgeshus	Vibration transmission measurements of the "Kvartett" building concept	A.Homb	11/2016	No
Interim report for Norgeshus	Sound insulation measurements of the "Kvartett" building concept	A.Homb	05/2016	No
European J. Wood and Wood Prod.,74(3): 353–67. http://dx.doi.org/10.1007/s00107-015-0976-z	Vibration serviceability performance of timber floors.	Weckendorf, J., Toratti, T., Smith, I., & Tannert, T	2015	No
DAGA 2016	A Contribution concerning Boundary Condition Effects that need to be considered using SEA for Calculation of Direct Sound Transmission	W. Hauer H. Ferk	03/2016	
BauSIM 2016	Numerical calculation of the direct sound transmission using a combined finite element -	W. Hauer H. Ferk	09/2016	

	statistical energy analysis approach			
DAGA 2017	Zum Einfluss der modalen Kopplung von Prüfräumen und Prüfobjekten auf Messungen des Schalldämm-Maßes einer Brettsperrholzplatte im tieffrequenten Bereich	W. Hauer H. Ferk	03/2017	

Dissemination, how and where	*Titel, description*	*Author / presenter*	*Made by /Planned by When?*	*Uploaded to website?*
Popular publications				
Bygg&Teknik nr 3 2015	Silent Timber Build – för Framtidens trähus (In swedish)	K.Hagberg	2015	Yes
Bygg&Teknik nr 3 2016	Silent Timber Build – beräkning av ljudisolering i träkonstruktioner rycker allt närmare	K.Hagberg	2016	Yes
Bygg&Teknik nr 3 2016	FEM beräkningar av ljudiolering i byggnader med trästomme (In Swedish)	D. Bard; N. Vardaxis	2016	Not yet
Bygg&Teknik nr 3 2017	Beräkning av ljudisolering i trästommar med SEAWood (in Swedish)	K.Hagberg; T.Augustsson	2017	
Adresseavisen 23.4.2014	Fremtid i tre (in Norwegian)	Time, B., Homb, A., Malo, K.A., Haugen, T.	2014	No

Dissemination, how and where	*Titel, description*	*Author / presenter*	**Made by /Planned by** *When?*	*Uploaded to website?*
Product development in connection to companies / industrial partners				
	Activities have been ongoing, however not public			

Dissemination, how and where	*Titel, description*	*Author / presenter*	*Made by /Planned by When?*	*Uploaded to website?*
Handbooks				
SINTEF Building & Infrastructure: Building detail sheet	No. 522.511 Lydisolerende etasjeskillere med trebjelkelag i boliger (in Norwegian)	A.Homb	09-2016	Subscription needed
SINTEF Building & Infrastructure: Building detail sheet	No. 522.512 Lydisolerende etasjeskillere med trebjelkelag. Målte verdier (in Norwegian)	A.Homb	09-2016	Subscription needed

Dissemination, how and where	***Titel, description***	***Author / presenter***	***Made by /Planned by When?***	***Uploaded to website?***
	Seminars, workshops			
Presentation at specific low frequecy workshop, Paris France	SILENT TIMBER BUILD Presentation of the project and more specifically prediction in the low frequency range	C. Guigou-Carter J.L. Kouyoumji	CIDB,CINOV-GIAC and SFA	Yes
Presentation at SP day 2015	Massivträhusens akilleshäl på väg att botas	K. Hagberg	2015-04-15	Yes
Forum Holz|Bau|Nordic 2014	*Timber and sound – what works well and what does not.* Presentation at Nordic Wood Building Conference: Forum Holz|Bau|Nordic Trondheim 14. Trondheim 24.-26.09.2014	Homb, A.		
NAL-kurs, Oslo 2014	*Lydoverføring i trebygninger med flere etasjer.* Foredrag ved NAL-kurset "Prosjektering av urban trearkitektur". Norske arkitekters landsforbund, Oslo 17.10.2014	Homb, A.		
NTF-kurs, Gardermoen 2015	*Gitterbjelkelag og lyd. Løsninger og utfordringer.* Foredrag på kurs "Trekonstruksjoner". NTF i samarbeid med Treteknisk, Gardermoen, 3. og 4. februar 2015.	Homb, A.		
STB-seminar, Stochholm 2015	Seminar "Silent Timber Build". In cooperation with Swedish Wood and Swedish Wood Building Council, Stockholm 28-29. April 2015 – see www.silent-timber-build.com	Project team	28-29 April 2015	Yes
NTNU workwhop, Trondheim 2015	*Etasjeskillere; Dagens løsninger og framtidens optimaliserte konstruksjoner.* Workshop Trekonstruksjoner. Institutt for konstruksjonsteknikk, NTNU, 3. juni 2015	Homb, A.		
SP "Trähusdagar" 2016, Skövde Sweden	Silent Timber Build – prediction models for wooden structures	K. Hagberg	March 2016	Not yet
TEKNA-kurs, Trondheim 2016	Krav og anbefalinger til lydisolasjon i trekonstruk-sjoner. Lyd og vibrasjoner til gitterbjelkelag. Foredrag ved kurset "Lyd og brannprosjektering av trekonstruksjoner"	A.Homb	Jan 2016	No

SILENT TIMBER BUILD

Dissemination, how and where	*Titel, description*	*Author / presenter*	*Made by /Planned by When?*	*Uploaded to website ?*
Conference papers				
Internoise 2014 Malbourne	Challenges for acoustic calculation models in "Silent Timber Build", Part 2	J-L KOUYOUMJI, D. Bard, G Borello, C GUigou	Nov 2014	Yes
Internoise 2014 Malbourne	Challenges for acoustic calculation models in "Silent Timber Build", Part 1- FEM	D. Bard, J Negreira, J-L KOUYOUMJI, G Borello, C GUigou	Nov 2014	Yes
Internoise 2014 Malbourne	Challenges for acoustic calculation models in "Silent Timber Build", Part 2	J-L KOUYOUMJI, D. Bard, G Borello, C GUigou	Nov 2014	Yes
Internoise 2014 Melbourne	Low frequency sound transmission in multifamily wooden houses	K. Hagberg, D. Bard	Nov 2014	Yes
Internoise 2014 Melbourne	Acoustic Solutions for Wooden Intermediate Floors	A Liebl, O Bartlomé	Nov 2014	Yes
Internoise 2014 Melbourne	Comparison of the results of a laboratory experiment and a field study with regard to acoustic quality in wooden buildings and recommendations for classification of acoustic quality	A Liebl, M Spaeh, O Bartlomé, M Kittel	Nov 2014	Yes
Internoise 2014 Melbourne	Laboratory facilities for sound transmission measurements – validation by measurement and simulation methods	M. Meissnitzer B Buchegger H. Ferk	Nov 2014	Yes
InterNoise 2014, Melbourne	Measurements of junction vibration level differences of timber framed constructions. *Proceedings Inter.noise 2014.* Melbourne 16-19. november 2014, Austalia.	A.Homb	Nov 2014	Yes
InterNoise 2014, Melbourne	Dynamic Laminate Model for Broadband Frequency Prediction	G Borello, A Duval	Nov 2014	Yes
Internoise 2014 Melbourne	Determination of vibration acceptability and annoyance design indicators for human response to wooden-floor vibrations.	J. Negreira, A. Trollé, K. Jarnerö, L-G. Sjökvist, D. Bard.	Nov 2014	NO
ICSV Beijing 2014	NEW RESEARCH CREATE BASIS FOR FUTURE COMPETETIVE WOODEN STRUCTURES	K. Hagberg	July 2014	Yes
ICSV Beijing 2014	Challenges for acoustic calculation models in "Silent Timber Build"	D Bard, G. Borello, C. Guigou, J. Negreira, J-L Kouyoumji	July 2014	
ICSV Beijing 2014		O Bartlomé	July 2014	
Internoise2015 San Francisco	Predicting Sound Transmission Loss of timber framed walls and floors using SEA, in "AcouBois" project of the French wood industry	J-L KOUYOUMJI	August 2015	

Internoise2015 San Francisco	Prediction of the acoustic performance of lightweight wood-based floor	C. Guigou C. Coguenanff	August 2015	Yes
Internoise2015 San Francisco	Vibration response of lightweight building elements under structural excitation	S. Bailhache M. Villot	August 2015	Yes
Harrogate 2015 – Institute of Acoustics	ACOUSTICS IN TALL WOOD BUILDINGS, RECENT RESEARCH AND FUTURE CHALLENGES	K Hagberg, D Bard	October 2015	Yes
Les Rencontres Acoustique et Techniques, Paris	Développement de modèles prédictifs basses fréquences pour les constructions bois dans le cadre du projet européen Silent Timber Build	C Guigou, JL Kouyoumji	June 2015	No
DAGA 2016, Aachen, GER	The determination of radiation efficiencies of plates used for timber constructions in reverberation chambers	Wolfgang Hauer	03/2016	Not yet
WCTE 2016, Vienna	Experimental analysis of flanking transmission of different connection systems for CLT panels	A. Speranza, L. Barbaresi, F. Morandi	August 2016	No
WCTE 2016, Vienna	Modelling guidelines for simulating low frequency vibroacoustic performance in wooden T-junctions	J., Negreira, A. Sjöström, D. Bard	August 2016	No
WCTE 2016, Vienna	Silent Timber Build – Development of low frequency vibroacoustic prediction tools for lightweight wooden constructions.	D. Bard, C. Guigou-Carter, C. Coguenanff, J. Negreira	August 2016	No
WCTE 2016, Vienna	Frequency spectra of typical European wooden joist constructions. Proceedings World Conference on Timber Engineering	A.Homb, C. Guigou-Carter, K. Hagberg, H. Schmid	August 2016	Not yet
IMAC XXXIII Orlando	Numerical prediction tools for low-frequency sound insulation in lightweight buildings	J., Negreira, D. Bard	February 2015	No
ICA 2016, Buenos Aires	Modelling of the tapping machine for finite element prediction tools – Preliminary parametric studies.	J., Negreira, D. Bard	Sept 2016	No
ICA 2016, Buenos Aires		K. Hagberg	September 2016	
ICA 2016, Buenos Aires	Reverse sea to predict flanking transmission in timber framed constructions (Silent Timber Build, special session)	J-L Kouyomji G Borello H Ferk	September 2016	
ICA 2016, Buenos Aires	Hybrid cross-laminated timer floors. Comparison of measurements and calculations. Proceedings 22nd International Congress on Acoustics	A.Homb	September 2016	Not yet
ICA 2016, Buenos Aires	Experimental analysis of flanking transmission in CLT structures	L. Barbaresi, F. Morandi, M. Garai, A. Speranza	September 2016	
ICSV 2017, London	Acoustic performance prediction for wood frame based floors	C. Guigou C. Coguenanff	July 2017	No
ICSV 2017, London	Multi-criteria optimization of a wood based floor	C. Coguenanff C. Guigou	July 2017	No
ICSV 2017, London	Lightweight floor: step by step comparisons between	C.	July 2017	No

	measured and simulated quantities	Coguenanff C. Guigou, M. Spaeh		
Internoise 2017, Hong Kong				

Dissemination, how and where	*Titel, description*	*Author / presenter*	*Made by /Planned by When?*	*Uploaded to website?*
Other international presentations				
Mass Timber Session in Harrogate UK	ACOUSTICS IN TALL WOOD BUILDINGS, RECENT RESEARCH AND FUTURE CHALLENGES	K Hagberg	October 2015	Yes
Mass Timber Workshop in Madison USA	Acoustic prediction models create basis for future competetive wooden structures http://www.woodworks.org/	K Hagberg	Nov 2015	Yes
Forum Wood Building Nordic Espoo 2016	Silent Timber Build – WWN+	K. Hagberg	June 2016	No
WCTE 2016	Arranging a session in the conference WCTE	D.Bard	August 2016	
ICA 2016 Buenos Aires, Argentina	Arranging a session regarding ´Calculation models for wooden structures – Silent Timber Build´	K. Hagberg; J-L Koujoumji	Sept 2016	
AIA; Symposium Advanced research in timber construction, Bolzano Italy	Silent Timber Build – WWN+	J-L Kouyomji; K. Hagberg	March 2017	
WWN+ seminar, Edinburgh, UK		K. Hagberg	April 2017	
Acoustics'17, Boston. Joint meeting JASA & Euronoise	Analysis of impact sound insulation properties of wooden joist and cross laminated timber (CLT) floor constructions.	A. Homb	June 2017	No
Final seminar Woodrise Bordeauz			Sept 2017	
ECCOMAS MSF 2017			Sept 2017	

Dissemination, how and where	*Titel, description*	*Author / presenter*	*Made by /Planned by When?*	*Uploaded to website ?*
Scientific articles				
Journal Paper, Building Acoustics	Impact sound insulation of wooden joist constructions. Collection of laboratory measurement and trend analysis.	A.Homb, C. Guigou, K. Hagberg, H. Schmid	Vol. 23(2), p 73-91 2016	No
Journal Paper	Evaluation methods for sound transmission in numerical calculations, especially at lower frequencies	Ferk, Hauer	Under prep. Planned 2017	Noy yet
Journal Paper, Building Acoustics	Impact sound insulation of cross-laminated timber/massive wood floor constructions. Collection of laboratory measurement and result evaluation.	A.Homb, C.Guigou-Carter, A.Rabold	Vol. 24(1) 2017	No
Journal Paper, Applied Acoustics, 105:1–12	Low frequency vibroacoustic investigation of wooden T-junctions	J. Negreira, A. Sjöström, D. Bard	2016	No
Journal Paper, Journal of Sound and Vibration, 340: 383–408	Psycho-vibratory evaluation of timber floors – Towards the determination of design indicators of vibration acceptability and vibration annoyance	J. Negreira, A. Trollé, K. Jarnerö, L-G. Sjökvist, D. Bard	2015	No
Journal Paper, Engineering Structures, 83: 7–16	The effect of modelling acoustic media in cavities of lightweight buildings on the transmission of structural vibrations.	O. Flodén, J. Negreira, K. Persson, G. Sandberg.	2015	No
Journal Paper, Building Acoustics, 21(4): 251–276	Characterisation of an elastomer for noise and vibration isolation in lightweight timber buildings.	J. Negreira, P-E. Austrell, O. Flodén, D. Bard	2014	No
Submitted to Applied Acoustics	Airborne sound insulation between dwellings, from 50 Hz – Twenty years of experience in Sweden	F. Ljunggren, C. Simmons, R. Öqvist	2017	No
Journal paper, Applied Acoustics	Correlation between sound insulation and occupants' perception – Proposal of alternative single number rating of impact sound, part II	F. Ljunggren, C. Simmons, R. Öqvist	2017	No
Acoustical Society of America - POMA-D-17-	Experimental analysis of flankng transmission in CLT structures	L. Barbaresi,		

00015		F. Morandi, M. Garai, A. Speranza		
Journal Paper	Evaluation methods for sound transmission in numerical calculations, especially at lower frequencies	H. Ferk, Hauer	Under prep. Planned 2017	Noy yet

Dissemination, how and where	*Titel, description*	*Author / presenter*	*Made by /Planned by When?*	*Uploaded to website?*
Master thesis works and dissertations				
WSP	FEM modelling for a CLT structure	N. Verdaxis	2014-09	Yes
Master Thesis GRAZ	Calculation of the sound reduction index of a simplified timber construction using an SEA-environment	Wolfgang Hauer	07/2016	
PhD Thesis	Vibroacoustic Performance of Wooden Buildings - Perception and Prediction	Juan Negreira	May 2016	Not yet
Master Thesis NTNU	Beregning og måling av lavfrekvent trinnlydisolasjon til bjelkelag. Masteroppgave ved Institutt for bygg- og miljøteknikk, IVT-Fakultetet (in Norwegian)	E.Lundgrenn	February 2017	No
Master Thesis NTNU	Beregning av trinnlydnivåer fra trebjelkelag ved bruk av FEM-analyse	Sondre Utmo Vikøren	June 2017	No
WSP		T Augustsson	2016	

Dissemination, how and where	***Titel, description***	***Author / presenter***	***Made by /Planned by When?***	***Uploaded to website?***
Web page / Newsletters				
Web	www.silent-timber-build.com	STB		
Web	European Atlas http://bauteilkatalog.lignum.ch/	Lignum		
Laboratory for Building Physics Web page	”A new way to test and calculate wood based constructions.”	GRAZ		
Träguden (Swedish)	Updating a design web page in Sweden www.traguiden.se	Swedish Wood		

SOUNDPROOFING SOLUTIONS

FLANKSOUND PROJECT

SUPPLEMENT

rothoblaas

ACOUSTICS AND LIVING

Acoustic comfort in the living environment

SOUND OR NOISE?

Sound propagates in air as a pressure wave. When this pressure wave reaches our ear, the signal and is translated through a complex series of organs into a nervous stimulus and finally becomes the feeling of sound we experience everyday.

Noise is related to a subjective judgment of a listening experience; it is commonly defined as an unwanted sound that disturbs the performance of our standard living activities.

ACOUSTIC DESIGN OF BUILDINGS

Acoustic comfort can be achieved through the control of noise transmission; it is a key factor to guarantee a high quality living experience in our homes and offices.

This is why it is important to care about acoustics from the early stage of the design to the final realisation of the work, so that a good acoustic design can translate into the best living experience.

AIRBORNE AND STRUCTURE BORNE SOUND INSULATION

Sound transmission between a "source room" and a "receiving room" can be related to two kinds of excitation: airborne or structure-borne.

AIRBORNE EXCITATION

In the first case, a sound source generates a sound field inside the source room that induces a vibrational state into the wall that separates the rooms. The wall itself radiates sound energy into the receiving room. Annoying airborne sounds are for instance the television of the neighbours, people talking loud or traffic noise.

STRUCTURE-BORNE EXCITATION

Structure-borne sounds are generated by a mechanical excitation of the partition. The separating wall is excited for instance by an impact; the vibration propagates through the structure and is finally radiated in the receiving environment. A typical structure-borne sound is the noise of heels or furniture dragged on the floor.

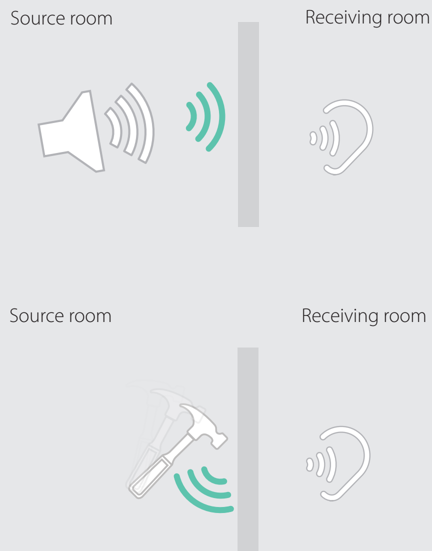


Figure 1.1 Airborne and structure-borne excitation.

In the acoustic design of a building, it is important to consider both kind of excitations as potential annoyance factors.

SOUND INSULATION AND ABSORPTION

ABSORPTION, TRANSMISSION AND REFLECTION

When a sound wave impinges on a partition, part of the sound power is reflected into the source room (W_r); part of it is transmitted into the receiving room (W_t) and a third component is absorbed by the wall (W_a). Thus the incident sound power can be expressed as:

$$W_i = W_r + W_t + W_a$$

The absorption, reflection and transmission coefficients (α, r, τ) are defined as the ratio between the absorbed, reflected and transmitted sound power to the incident sound power.

$$\alpha = W_a / W_i \qquad r = W_r / W_i \qquad \tau = W_t / W_i$$

Therefore the relation holds:

$$\alpha + r + \tau = 1$$

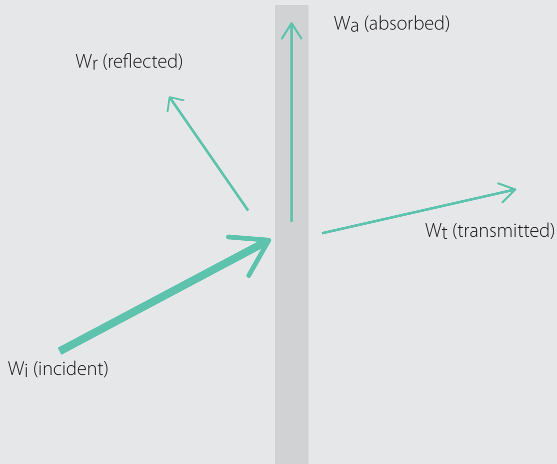


Figure 1.2 Absorption, reflection and transmission.

It is crucial to distinguish between two different concepts and interventions: sound insulation and sound absorption.

SOUND INSULATION

Sound insulation deals with the transmission of sound between adjacent rooms through the minimisation of τ.

SOUND ABSORPTION

Sound absorption aims at controlling the sound field inside a room by maximising α, i.e. decresing the energy content of multiple order reflections inside a room. Sound absorption in an enclosed space is closely related to the reverberation time of that room.

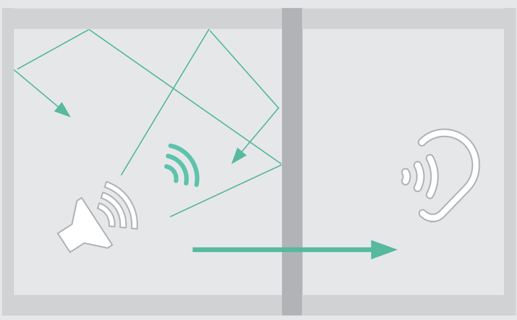


Figure 1.3 Sound insulation and sound absorption.

REVERBERATION TIME T_{60}

It is the time required by a stationary sound field to decay by 60 dB after the sound source has been switched off.
It can be estimated from Sabine's law:

$$T_{60} = 0.161V/A$$

where V is the volume of the room (m^3) and A is the equivalent absoprion area (m^2), which can be obtained by multiplying each surface of the room S by its absorption coefficient α.

THE METRICS IN BUILDING ACOUSTICS

Building acoustics is a branch of acoustics that deals with the control of noise propagation in buildings. It specifically deals with the verification and optimisation of airborne sound insulation and impact sound insulation.

D. Normalised Level Difference

The normalised level difference D_n is the difference in the space and time average sound pressure level produced in two rooms corresponding to the reference equivalent absorption area in the receiving room.

$$D_n = L_1 - L_2 - 10 \log (A/A_0) \quad \text{(dB)}$$

where L_1 is the sound pressure leve in the source room (dB), L_2 is the sound pressure level in the receiving room (dB), A is the equivalent absorption area in the receiving room (m^2) and A_0 is a reference area of 1 m^2.
The level difference can be alternatively normalised with respect to the reverberation time of the receving room (Standardised Level Difference D_{nT}).

R. Sound Reduction Index

The Sound Reduction Index R (or Tranmsission Loss TL) is defined as minus 10 times the logarithmic ratio of the sound power transmitted into the receiving room to the sound power which is incident on the separating element. It is commonly determined from measurements as:

$$R = L_1 - L_2 + 10 \log (S/A) \quad \text{(dB)}$$

where L_1 is the sound pressure level in the source room (dB), L_2 is the sound pressure level in the receiving room (dB), S is the area of the separating element (m^2) and A is the equivalent absorption area in the receiving room (m^2).

L. Impact Sound Insulation

The normalised impact sound pressure level L_n is the impact sound pressure level measured in the receiving room L_i when a standardised tapping machine is active in the source room, corresponding to the reference equivalent absorption area in the receiving room.

$$L_n = L_i + 10 \log (A/A_0) \quad \text{(dB)}$$

The impact sound pressure level can be alternatively normalised with respect to the reverberation time of the receving room (standardised Impact Sound Insulation L_{nT}).

Each of these parameters is expressed as a frequency dependent quantity. To describe the behaviour of a partition with a single number, a special procedure is used (EN ISO 717 series) that relates the frequency behaviour to a reference curve. The weighted index takes the subscript W.

DIRECT AND FLANKING TRANSMISSION

IN SITU vs LABORATORY MEASUREMENTS

Sound insulation measurements return significantly different results when performed ***in situ*** or in certified laboratories. This is mainly due to two factors: first, when partitions are mounted in the laboratory, it is easier to control the quality of the installation. Second, ***in situ*** measurements are affected by the presence of flanking transmission paths.

LABORATORY MEASUREMENTS

In the laboratory, the test wall is installed in test chambers expressly designed for the purpose which are structurally decoupled one from the other. Therefore the laboratory measurements characterise the transmission through the separating wall only (direct transmission), which is generally referred to as **sound reduction index R.**

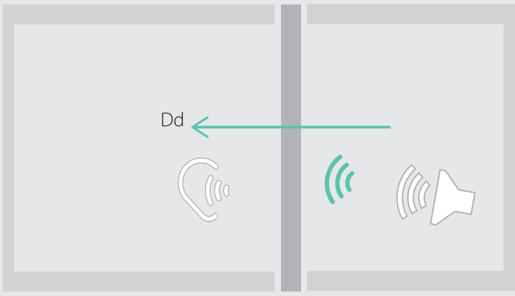


Figure 1.4 Laboratory measurement of the sound reduction index R: direct transmission path.

IN SITU MEASUREMENTS

When this quantity is measured ***in situ***, its value is smaller than the value measured in laboratory for the same wall. This occurs because the sound transmission between the rooms is characterised not only by the direct transmission but also by the flanking transmission, i.e. the contribution of the lateral walls to the propagation of sound into the receiving room.

NOTE: In Figure 1.1 and 1.2 "D" stands for direct while "F" stands for flanking.; capital letters represent the wall excited in the source room while lower case letters represent the wall that radiates sound into the receiving room. Thus the direct transmission path is identified as Dd, while for instance the transmission paths that involve the separating wall as source wall and the side walls as radiating walls in the receiving room are labelled Df.

FLANKING TRANSMISSION PATHS

When a sound source is switched on in the so-called "source room", sound induces a vibrational state into the separating wall. Part of the sound power is radiated directly into the receiving room by the wall itself (direct transmission, path Dd).
The separating wall transmits vibration also to the adjacent walls, which in turn radiate energy into the receiving room (path Df).

The sound source that excites the source room induces a vibrational state also in the side walls. From the side walls, sound energy can be radiated in to the receiving room through two other transmission paths: through the separating wall (Fd) or through the side walls of the receiving room (Ff), completing the first order transmission paths.

All these flanking quantities add up to the direct sound transmission and return to a lower value of sound insulation of the partition. When R is measured in situ, it is generally referred to as **apparent sound reduction index R'**.

The contribution of the flanking paths can be quite significant thus it is crucial for the acoustic designer to estimate properly the entity of the flanking transmission.

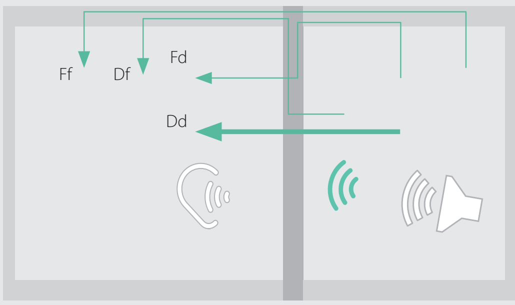


Figure 1.5 In situ measurement of the apparent sound reduction index R': direct and flanking transmission paths.

THE EN 12354 CALCULATION MODEL

The CEN models proposed in the EN 12354 series provide a powerful tool to predict the acoustic performance of a partition from the characteristics of the construction elements. The EN 12354 series is currently under revision and the updated version (2017) has been expanded to provide more exhaustive information relative to timber frame and CLT structures.

EN 12354-1
Airborne sound insulation between rooms

EN 12354-2
Impact sound insulation between rooms

APPARENT SOUND REDUCTION INDEX

The EN 12354 series provide two methods to calculate the acoustic performance of a partition: the detailed method and the simplified method. According to the simplified calculation model and disregarding the presence of small technical elements and airborne transmission paths, the apparent sound reduction index can be calculated as the logarithmic sum of the direct component R_{Dd} and the flanking transmission components R_{ij}.

$$R'_w = -10\log\left[10^{-\frac{R_{Dd,w}}{10}} + \sum_{i,j=1}^{n} 10^{-\frac{R_{ij,w}}{10}} + \frac{A_0}{S_s}\sum_{j=1}^{n} 10^{-\frac{D_{n,j,w}}{10}}\right] (dB)$$

(Eq. 1)

where $R_{Dd,w}$ is the sound reduction index due to the direct transmission only and $R_{ij,w}$ is the sound reduction index due to flanking transmission. The flanking paths R_{ij} can be estimated as:

$$R_{ij,w} = \frac{R_{i,w}+R_{j,w}}{2} + \Delta R_{ij,w} + K_{ij} + 10\log\frac{S}{l_0 l_{ij}} \; (dB)$$

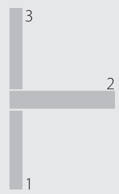
(Eq. 2)

where R_{ij} is the weighted flanking sound reduction index for transmission path i-j; R_i and R_j are the weighted sound reduction indices for the flanking elements i and j respectively; ΔR_i, ΔR_j are the sound reduction index improvements by additional layers for element i in the source room and/or element j in the receiving room; S is the area of the separating element and l_{ij} is the coupling length of the junction between separating elements and the flanking elements i and j, l_0 being the reference coupling length of 1 m.

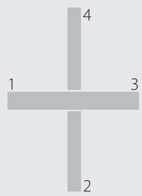
Among the input parameters required by the model, the sound reduction indices can be easily reached from accredited laboratory measurements; several databases provide freely available certified data, and often the data are provided by the manufacturers of the partitions themselves.
The ΔR_{ij} can be estimated modelling of the system as a mass-spring-mass system (EN12354 annex D).

The most critical parameter to estimate is the **vibration reduction index K_{ij}.** This quantity is related to the structural coupling of the elements and represents the vibration energy damped by the junction, thus the highest K_{ij} generates the highest performance of the junction. The standard EN ISO 12354 provides some predictive estimates of two standard T and X junctions, which are reported to the right, but still few measured data are available.

JUNCTIONS FOR CLT ELEMENTS (EN 12354-1:2016)



$K_{13} = 22 + 3.3 \log f/f_k$
$K_{23} = 15 + 3.3 \log f/f_k$



$K_{13} = 10 - 3.3 \log f/f_k + 10\,M$
$K_{24} = 23 + 3.3 \log f/f_k$
$K_{14} = 18 + 3.3 \log f/f_k$
$f_k = 500$ Hz
$M = \log (m'_{perp,i} / m'_i)$

THE FLANKSOUND PROJECT

Determination of the flanking transmission in CLT buildings

EXPERIMENTAL MEASUREMENTS OF THE K_{ij} IN CLT JUNCTIONS

Therefore rothoblaas funded a measurement campaign aimed at measuring the vibration reduction index K_{ij} for a variety of junctions for CLT panels with the twofold aim of providing specific data suitable for the acoustic design of CLT buildings and to contribute to the development of the calculation method.

The vibration reduction index measurements have been conducted according to the EN ISO 10848 standard.

EN ISO 10848

L, T and X junctions were tested. CLT panels were provided by seven different manufacturers and therefore underwent different production processes, showing different characteristics - among all, the number and thickness of the lamellas, the side gluing of the lamellas, the vacuum gluing or the standard gluing. Different kinds of screws and connectors were tested, as well as different resilient interlayers at the wall-floor junction.

The test setup was arranged in the warehouse of the rothoblaas headquarters in Cortaccia (BZ).

PRODUCTS TESTED

- HBS partially threaded screws
- VGZ totally threaded screws
- TITAN N angle brackets
- TITAN F angle brackets
- WHT hold down
- XYLOFON resilient interlayer
- ALADIN STRIPE resilient interlayer
- CONSTRUCTION SEALING airtight profile

HIGHLIGHTS

- 7 different CLT manufacturers
- L, T, X vertical and horizontal junctions
- influence of kind and number of screws
- influence of kind and number of angle brackets
- influence of kind and number of hold-downs
- use of resilient interlayers

TEST SETUP

MEASUREMENT SETUP: EQUIPMENT AND DATA PROCESSING

The vibration reduction index K_{ij} is evaluated as:

$$K_{ij} = \frac{D_{v,ij} + D_{v,ji}}{2} + 10\log\frac{l_{ij}}{\sqrt{a_i a_j}} \ (dB)$$

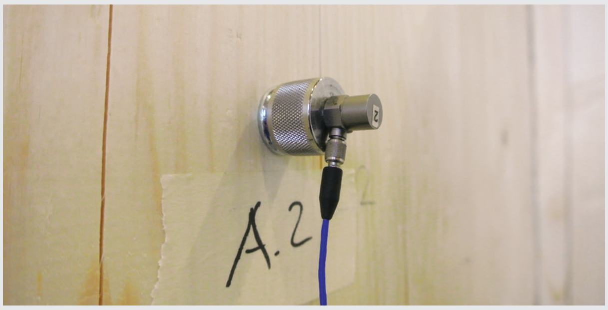
(Eq. 3)

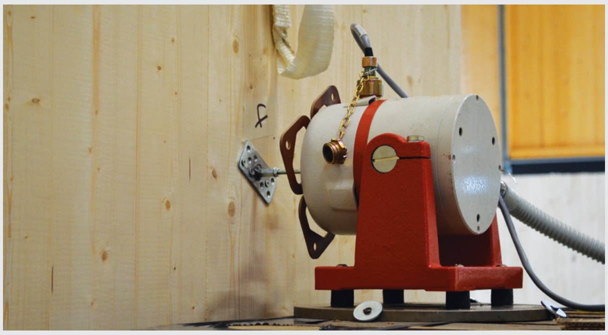
where $D_{v,ij}$ ($D_{v,ji}$) is the velocity level difference between elements i and j (j and i) when element i (j) is excited (dB), l_{ij} is the common element junction between elements i and j and a are the equivalent absorption lengths of elements i and j, expressed as a function of frequency f and of the structural reverberation time T_S:

$$a = \frac{2.2\pi^2 S}{c_0 T_s}\sqrt{\frac{f_{ref}}{f}} \ (m)$$

(Eq. 4)

The source consisted of an electrodynamic shaker with sinusoidal peak force of 200 N, which was mounted on a heavy-weight base and screwed to the CLT panels using a plate.





The velocity levels were measured using a pink noise source signal, filtered at 30 Hz in order to get reliable results from 50 Hz on. Structural reverberation times were calculated from impulse responses acquired using ESS test signals. The accelerometers were fixed to the panels using magnets. Eyelets were screwed to the panels with screws whose length was at least half of the thickness of the panels, in order to reach the innermost layer of lamellas. The vibration reduction indices are reported in the one-third of octave bands ranging from 100 to 3150 Hz, together with the value averaged over the one-third octave bands from 200 to 1250 Hz.

THE SIMPLIFIED METHOD

A calculation example using the EN 12354

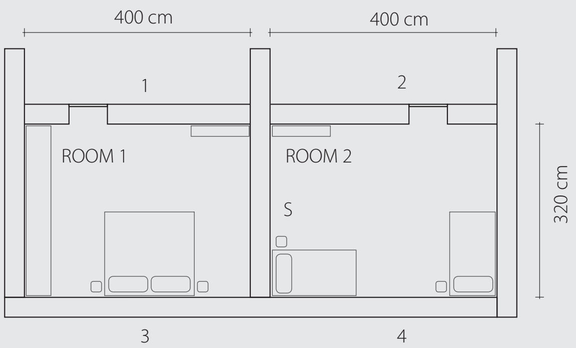
INPUT DATA

As anticipated, the EN 12354 series provide two methods to calculate the acoustic performance of a partition: the detailed method and the simplified method.
The simplified calculation model predicts the weighted apparent sound reduction index on the basis of the weighted sound reduction indices of the elements involved. In the following, a calculation example evaluated the apparend sound reduction index between two adjacent rooms.

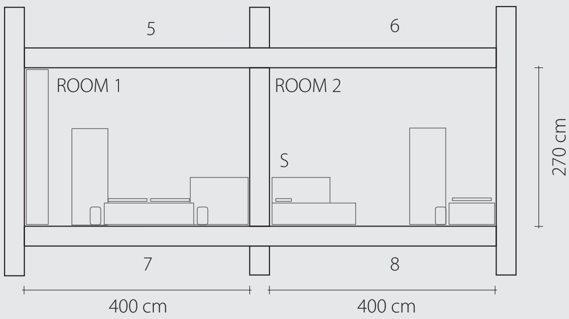
In order to determine the acoustic performance of a partition from the acoustic performance of its components, it is important to determine:

- The geometry of the partition (S)
- The acoustic properties of the partition (R_W)
- The coupling between structural elements (K_{ij})
- The characteristics of each layer composing the partition

PLAN



SECTION



CHARACTERISATION OF THE PARTITIONS

- SEPARATING WALL (S)

25 mm	gypsum plasterboard
50 mm	mineral wool
75 mm	CLT
50 mm	mineral wool
25 mm	gypsum plasterboard

- EXTERNAL WALLS (3, 4)

6 mm	plaster
60 mm	wood fibre insulation board
160 mm	mineral wool
90 mm	CLT
70 mm	spruce wood battens
50 mm	mineral wool
15 mm	gypsum plasterboard

- FLOORS (5, 6, 7, 8)

70 mm	cement screed
0.2 mm	PE membrane
30 mm	soft impact sound insulation
50 mm	backfill (loose)
140 mm	CLT panels
60 mm	mineral wool
15 mm	plasterboard

- INTERNAL WALLS (1)

12.5 mm	gypsum fire board
78 mm	CLT
12.5 mm	gypsum fire board

- INTERNAL WALLS (2)

75 mm	CLT
50 mm	mineral wool
25 mm	gypsum plasterboard

The data relative to the acoustic characterisation of the partitions were retrieved from the DataHolz database (www.dataholz.com).

ACOUSTIC DESIGN STEP BY STEP

Flanksound catalogue: how to use it

CALCULATION OF THE DIRECT AND FLANKING COMPONENTS

The apparent sound reduction index is given from the contribution of the direct component and the flanking transmission paths (Eq. 1). Since only first order propagation systems are considered, for each i-j combination of walls there are three paths to be considered, for a total of 12 R_{ij} evaluated according to Eq. 2.

1. ACOUSTIC CHARACTERISTICS OF THE PARTITIONS

Transmission path	S (m^2)	R_w (dB)	m' (kg/m^2)
S (separating wall)	8.64	53	69
1	10.8	38	68
2	10.8	49	57
3	10.8	55	94
4	10.8	55	94
5	12.8	63	268
6	12.8	63	268
7	12.8	63	268
8	12.8	63	268

Table 1.1 Geometrical and acoustical characteristics of the partitions.

2. CHARACTERISATION OF THE JUNCTIONS

JUNCTION 1-2-S X junction with soundproofing profile, detail 11 (page 21)

JUNCTION 3-4-S T junction with soundproofing profile, detail 5 (page 18)

JUNCTION 5-6-S X junction with soundproofing profile, detail 42 (page 37)

JUNCTION 7-8-S X junction with soundproofing profile, detail 42 (page 37)

3. CALCULATION OF THE R_{ij}

Transmission path	R_{ij} (dB)
1-S	60
3-S	68
5-S	83
7-S	75
S-2	66
S-4	68
S-6	83
S-8	75
1-2	64
3-4	77
5-6	75
7-8	75

Table 1.2 Evaluation of the flanking transmission paths.

4. DETERMINATION OF THE APPARENT SOUND REDUCTION INDEX

Though the sound insulation for direct transmission only would provide a R_W of 53 dB, considering the flanking transmission, R'_W goes down to 51 dB.

The simplified model has the unquestioned advantage of providing an easy-to-use tool to predict the sound insulation. On the other side, its application is quite critical for CLT structures because the damping of each structural element is strongly affected by the assembly and should deserve a dedicated modelling. Moreover, CLT panels provide poor insulation at low frequencies, thus the use of frequency weighted indices might return results which lack of representativeness of the real behaviour in the low frequency region. Therefore the use of the detailed method is strongly suggested.

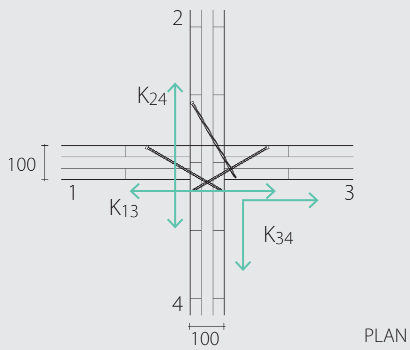
$R_W = 53$ dB $R'_W = 51$ dB

EXPRESSION OF THE RESULTS

Flanksound catalogue: notes

EXPERIMENTAL MEASUREMENTS OF THE K_{ij} IN CLT JUNCTIONS

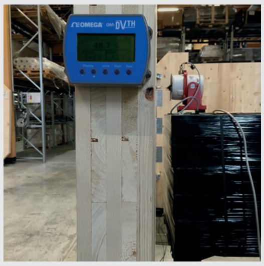
The following pages report the results of the measurement campaign for a selection of junctions. For each junction, the vibration reduction indices relative to the transmission paths involved are reported in1/3 octave bands in the range 100- 3150 Hz. Moreover, the K_{ij} is also averaged in the frequency range 200-1250 Hz; these values can be used as inputs when using the simplified method reported in the EN 12354, being careful and aware of the limitations of the use of such method.



Most of the data were directly measured. The results reported here are not often the result of one measurement only, but the average over sets of measurements performed with the same fixing systems.

One example is given by the vertical X junctions reported to the left. It has been observed that there are slight differences between transmission paths 1-2 and 2-3 due to the fact that the screws that are fixed into panel 2 reach panel 3 too. Anyway, given the uncertainties related to the installation (which can be hardly controlled ***in situ***), an average value between the transmission paths 1-2 (K_{12}) and 2-3 (K_{23}) is given in this catalogue.

Another example can be related to the analysis of different CLT manufacturers. Given the great difference of K_{ij} values measured in configurations with the same nominal fastening system but diffferent CLT manufacturers, in this catalogue the values which are provided represent the average value of each configuration.



This choice has been done in order to return stable data that can take into account mounting tolerances and other variability factors, the aim of the catalogue being the development of a powerful tool for the acoustic design of buildings. For a detailed discussion about the results, please refer to the references reported at the end of the page.

LEGEND


Data calculated starting from the measurements

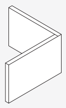
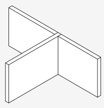
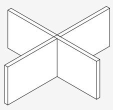
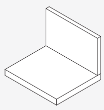
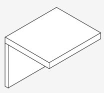
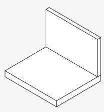
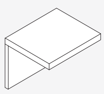

Additional configurations tested for acoustical purposes, with small structural relevance

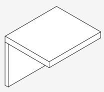
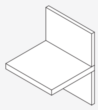
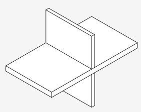
FOR FURTHER INFORMATION

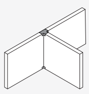
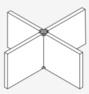
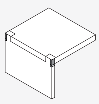
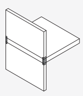
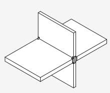
- A. Speranza, L. Barbaresi, F. Morandi, " ***Experimental analysis of flanking transmission of different connection systems for CLT panels*** " in Proceedings of the World Conference on Timber Engineering 2016, Vienna, August 2016.
- L. Barbaresi, F. Morandi, M. Garai, A. Speranza, " ***Experimental measurements of flanking transmission in CLT structures*** " in Proceedings of the International Congress on Acoustics 2016, Buenos Aires, September 2016.

SYNOPTIC TABLE

A brief summary of the tested configurations

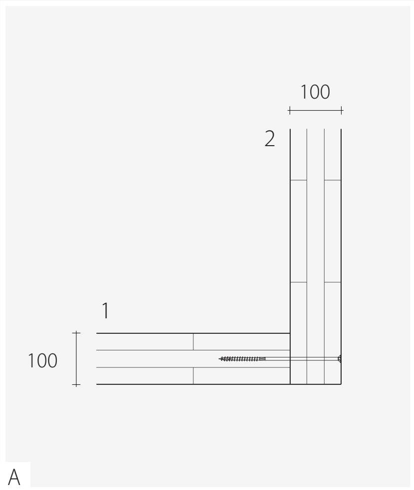
			FIXING SYSTEM					SOUNDPROOFING SOLUTION			
		DETAIL	HBS	VGZ	WHT	TITAN	LVB	CONSTRUCTION SEALING	XYLOFON	ALADIN STRIPE	TITAN SILENT
WALL - WALL JUNCTIONS		1	Ø8 x 240 step 200	-	-	-	-	-	-	-	-
		2	Ø8 x 240 step 400	-	-	-	-	-	-	-	-
		3	-	Ø7 x 260 step 600	-	-	-	-	-	-	-
		4	-	Ø9 x 400 step 300	-	-	-	-	-	-	-
		5	Ø8 x 240 step 400	-	-	-	-	-	-	-	-
		6	Ø8 x 240 step 400	-	-	-	-	●	-	-	-
		7	-	Ø7 x 260 step 400	-	-	-	-	-	-	-
		8	-	Ø7 x 260 step 400	-	-	-	●	-	-	-
		9	Ø8 x 240 step 400	-	-	TTF200 step 600	-	-	-	-	-
		10	-	Ø7 x 260 step 600	-	TTF200 step 600	-	-	-	-	-
		11	Ø8 x 240 step 400	-	-	-	-	-	-	-	-
		12	Ø8 x 240 step 400	-	-	-	-	●	-	-	-
		13	-	Ø7 x 260 step 400	-	-	-	-	-	-	-
		14	-	Ø7 x 260 step 400	-	-	-	●	-	-	-
WALL - FLOOR JUNCTIONS		15	-	-	-	TTN240 step 1000	-	-	-	-	-
		16	-	-	-	TTF200 step 1200	-	-	-	-	-
		17	Ø8 x 240 step 300	-	-	-	-	-	-	-	-
		18	-	Ø9 x 400 step 600	-	-	-	-	-	-	-
		19	Ø8 x 240 step 300	-	-	-	-	-	●	-	-
		20	-	Ø9 x 400 step 600	-	-	-	-	●	-	-
		21	-	-	-	TTN240 + TCW240 step 1400	-	-	-	-	-
		22	-	-	340	-	-	-	-	-	-
		23	-	-	620	-	-	-	-	-	-
		24	-	-	2 x 620	-	-	-	-	-	-
		25	Ø8 x 240 step 300	-	440	-	-	-	-	-	-
		26	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	-	-	-
		27	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	●	-	-
		28	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	●	-	●
		29	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	-	●	-
		30	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	-	●	-

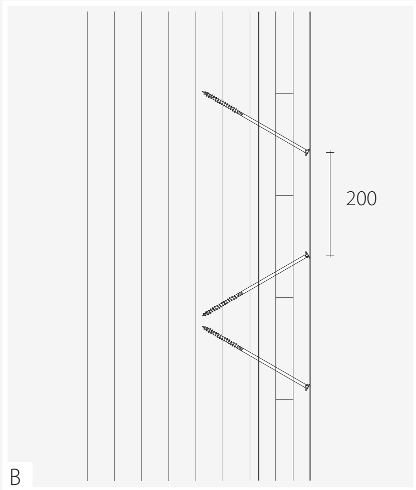
	DETAIL	FIXING SYSTEM					SOUNDPROOFING SOLUTION			
		HBS	VGZ	WHT	TITAN	LVB	CONSTRUCTION SEALING	XYLOFON	ALADIN STRIPE	TITAN SILENT
	31	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	-	●	●
	32	-	Ø9 x 400 step 600	440	-	-	-	-	-	-
	33	-	Ø9 x 400 step 600	440	TTN240 step 800	-	-	-	-	-
	34	-	Ø9 x 400 step 600	440	TTN240 step 800	-	-	●	-	-
	35	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	-	-	-
	36	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	●	-	●
	37	-	-	440	TTN240 step 800	-	-	-	-	-
	38	-	-	440	TTN240 step 800	-	-	●	-	●
	39	Ø8 x 240 step 400	-	-	TTN240 step 800	●	-	-	-	-
	40	Ø8 x 240 step 300	-	-	TTN240 step 800	●	-	●	-	●
	41	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	-	-	-
	42	Ø8 x 240 step 300	-	440	TTN240 step 800	-	-	●	-	●
	43	-	-	440	TTN240 step 800	-	-	-	-	-
	44	-	-	440	TTN240 step 800	-	-	●	-	●

		DETAIL	FIXING SYSTEM						SOUNDPROOFING SOLUTION			
			X-PLATE BASE T	X-PLATE TOP T	X-PLATE BASE X	X-PLATE TOP X	X-PLATE BASE O	X-PLATE MID O	CONSTRUCTION SEALING	XYLOFON	ALADIN STRIPE	TITAN SILENT
X-RAD		45	●	●	-	-	-	-	-	-	-	-
		46	-	-	●	●	-	-	-	-	-	-
		47	-	-	-	-	●	-	-	-	-	-
		48	-	-	-	-	●	-	-	●	●	-
		49	-	-	-	-	●	●	-	-	-	-
		50	-	-	-	-	●	●	-	●	-	-
		51	-	-	-	-	●	●	-	-	-	-
		52	-	-	-	-	●	●	-	●	-	-

L JUNCTIONS

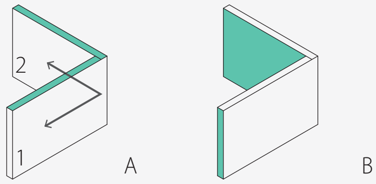
DETAIL 1





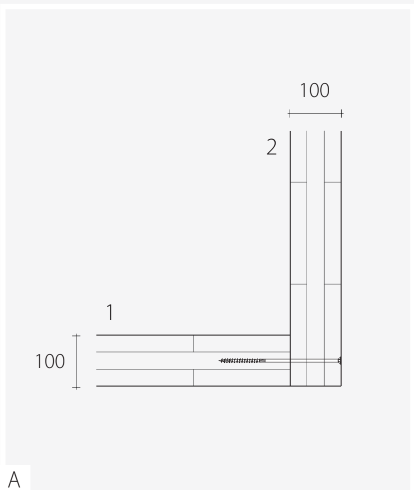
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 200 mm)

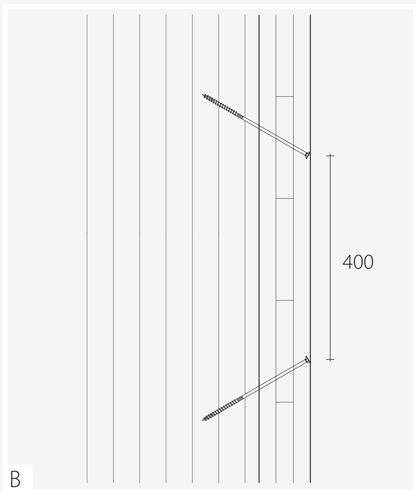
RESILIENT INTERLAYER
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	12.8	9.4	3.9	2.3	2.3	0.2	3.7	4.6	6.6	8.1	9.6	11.7	15.0	15.4	15.9	16.8	**5.5**

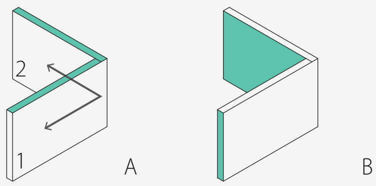
DETAIL 2





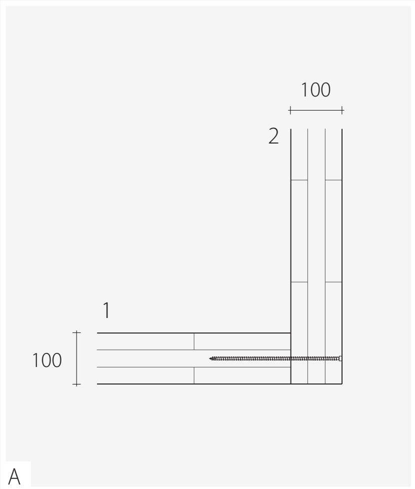
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 400 mm)

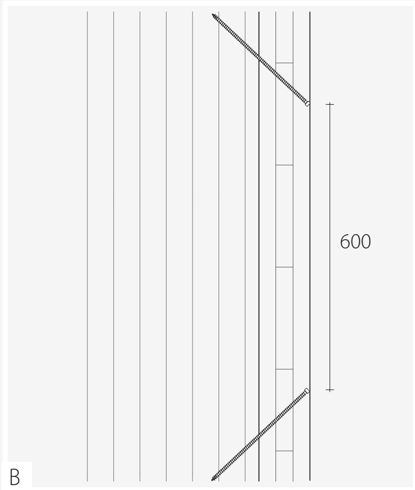
RESILIENT INTERLAYER
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	11.4	9.8	2.9	2.1	2.7	1.8	6.3	8.3	10.1	12.6	12.9	16.1	18.3	16.9	19.6	22.2	**8.1**

DETAIL 3



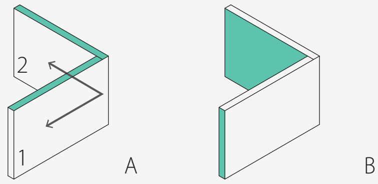


FIXING SYSTEM

VGZ screws Ø7 x 260 mm (step 600 mm)

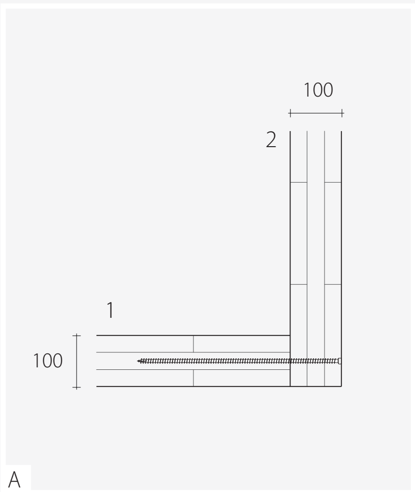
RESILIENT INTERLAYER

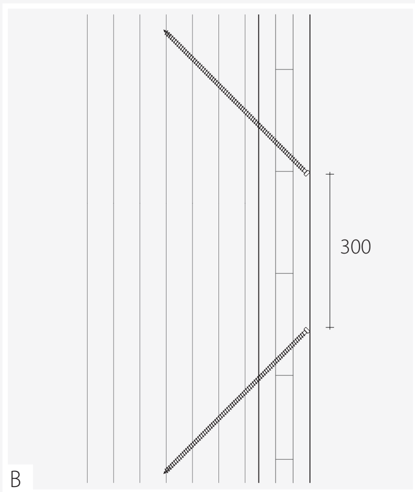
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	16.5	15.1	6.4	11.5	11.3	9.8	11.7	12.8	15.0	15.5	16.0	19.7	18.8	19.8	22.5	23.0	**13.7**

DETAIL 4



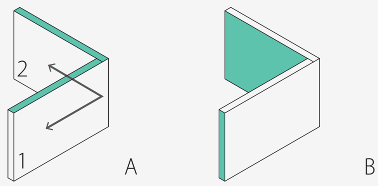


FIXING SYSTEM

VGZ screws Ø9 x 400 mm (step 300 mm)

RESILIENT INTERLAYER

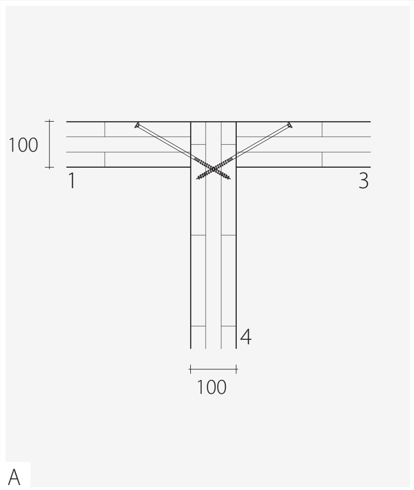
no

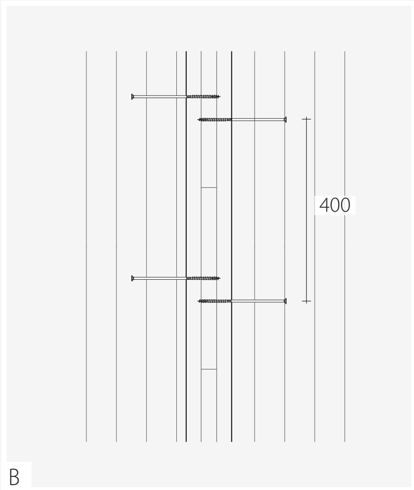


Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	19.0	16.7	9.6	14.5	12.0	10.8	8.7	11.2	10.2	13.9	14.3	16.1	17.9	17.7	18.5	19.9	**12.4**

T JUNCTIONS

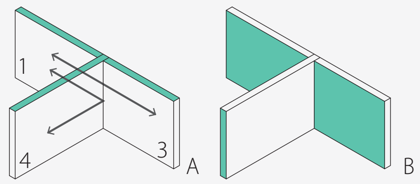
DETAIL 5





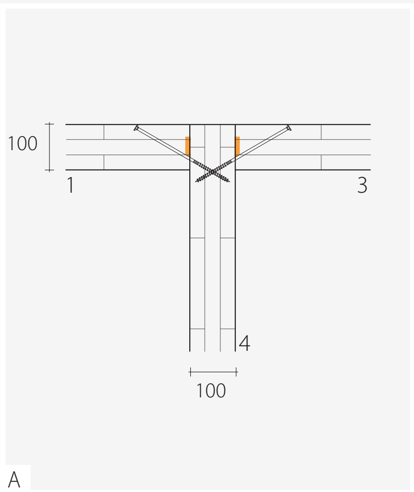
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 400 mm)

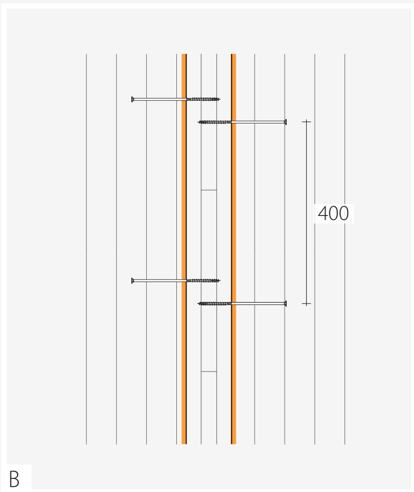
RESILIENT INTERLAYER
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	AVG$_{200-1250}$
K_{14} (dB)	6.9	7.6	5.9	5.5	5.9	5.9	7.3	8.0	11.0	10.8	12.8	12.6	14.6	16.0	18.2	19.2	**8.9**
K_{13} (dB)	8.6	9.2	7.2	7.7	10.3	9.8	12.6	16.0	20.9	21.2	25.6	28.1	29.6	33.4	34.9	37.8	**16.9**

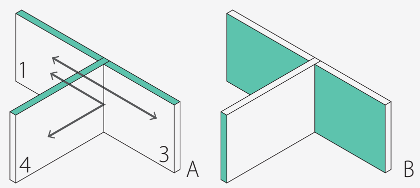
DETAIL 6





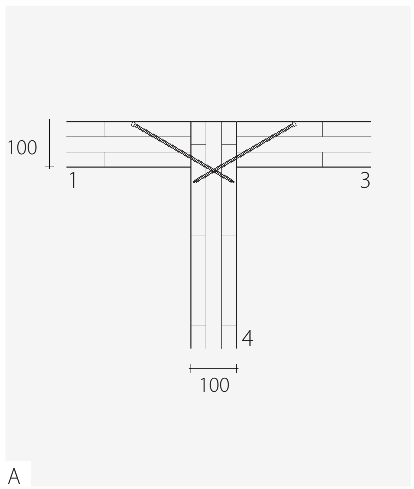
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 400 mm)

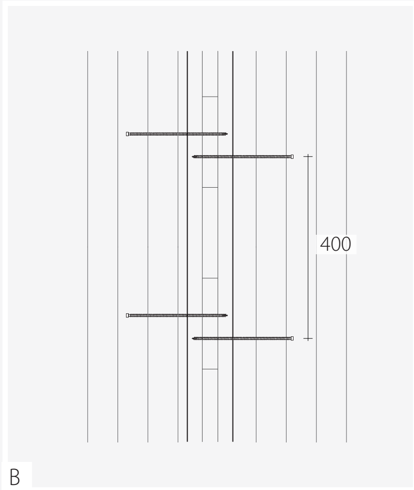
RESILIENT INTERLAYER
CONSTRUCTION SEALING



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	AVG$_{200-1250}$
K_{14} (dB)	4.4	4.3	3.5	5.8	7.4	3.7	7.6	12.4	12.0	15.9	16.7	18.4	19.1	20.5	24.3	26.2	**11.1**
K_{13} (dB)	10.3	8.2	2.6	3.3	9.8	7.3	15.0	18.6	18.3	27.9	25.9	30.6	30.7	37.4	39.7	41.2	**17.4**

DETAIL 7



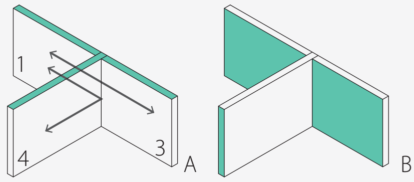


FIXING SYSTEM

VGZ screws Ø7 x 260 mm (step 400 mm)

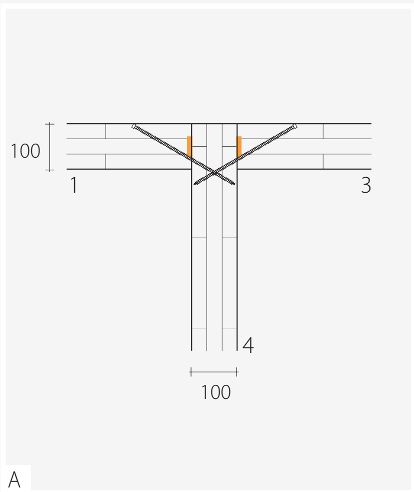
RESILIENT INTERLAYER

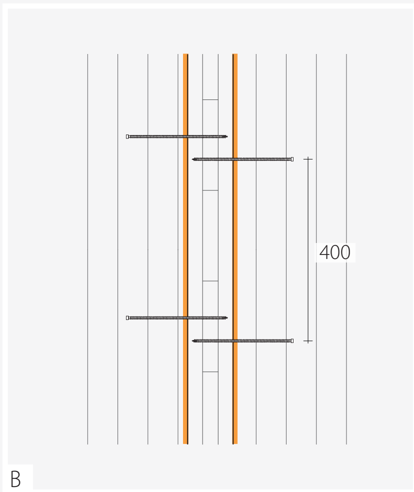
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{14} (dB)	1.3	4.7	4.2	5.1	5.8	1.3	9.5	9.5	12.0	12.9	14.8	16.5	16.5	20.8	24.0	25.6	**9.7**
K_{13} (dB)	3.7	4.3	7.5	5.2	5.6	4.3	14.9	15.4	17.6	19.5	26.4	27.8	27.8	34.2	38.8	43.8	**15.2**

DETAIL 8



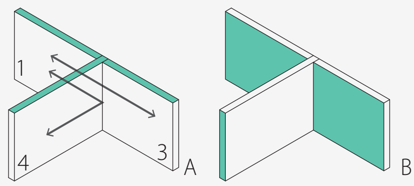


FIXING SYSTEM

VGZ screws Ø7 x 260 mm (step 400 mm)

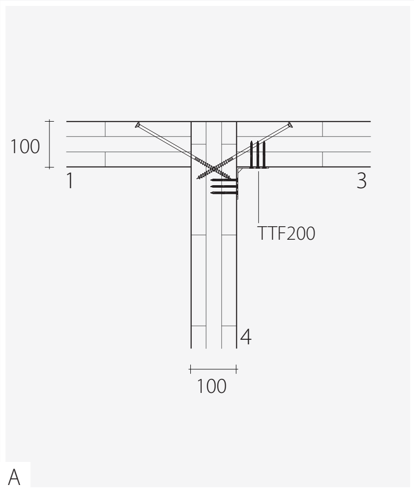
RESILIENT INTERLAYER

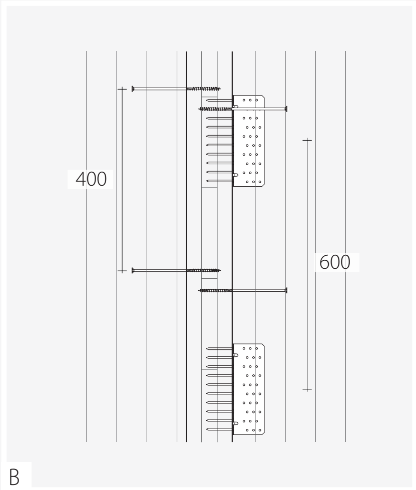
CONSTRUCTION SEALING



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{14} (dB)	4.6	2.6	2.0	4.3	4.8	4.1	10.2	11.0	13.2	15.3	15.3	17.4	17.2	21.7	24.7	25.8	**10.6**
K_{13} (dB)	7.3	5.1	3.3	6.7	6.9	7.2	14.5	18.0	17.9	20.2	25.6	30.8	31.4	37.4	39.3	41.1	**16.4**

DETAIL 9



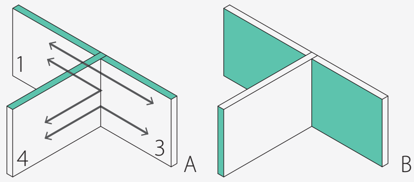


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 400 mm)
TTF200 (step 600 mm)

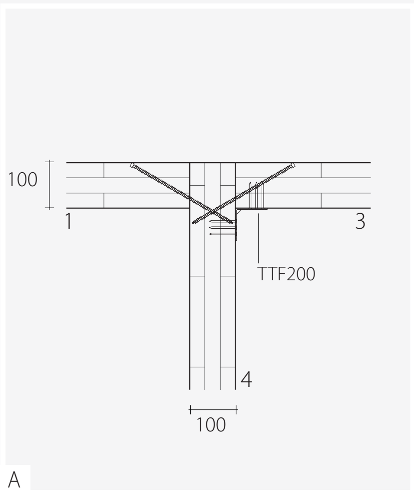
RESILIENT INTERLAYER

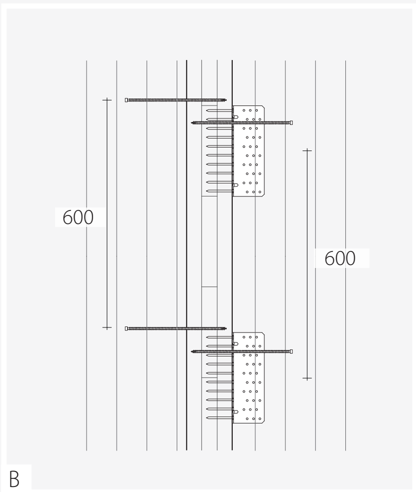
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{14} (dB)	8.1	12.6	6.2	8.7	11.0	8.4	10.0	13.2	18.9	16.7	16.2	13.4	16.2	24.5	23.5	28.3	**12.9**
K_{13} (dB)	4.4	-0.2	2.9	7.9	14.6	13.4	9.4	13.7	16.5	14.7	16.7	20.0	23.4	27.1	28.4	29.6	**14.1**
K_{34} (dB)	3.2	-1.7	-2.0	0.4	3.8	2.7	0.9	6.7	7.4	6.4	6.1	10.5	10.7	10.8	11.3	13.3	**5.0**

DETAIL 10



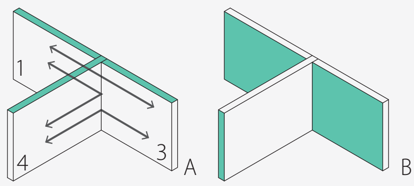


FIXING SYSTEM

VGZ screws Ø7 x 260 mm (step 600 mm)
TTF200 (step 600 mm)

RESILIENT INTERLAYER

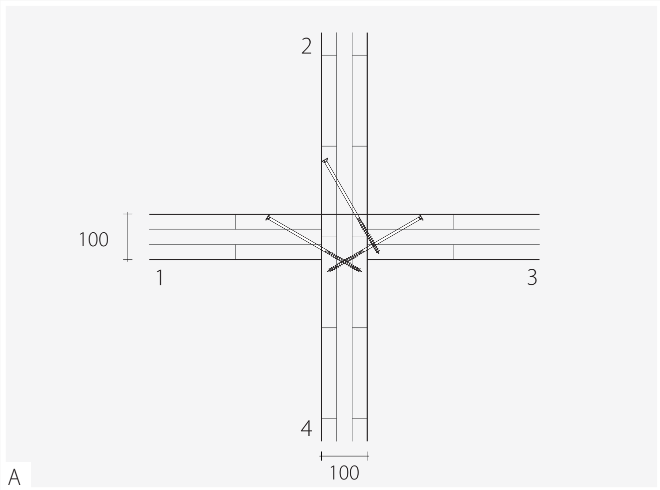
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{14} (dB)	6.3	9.3	9.6	9.9	9.8	5.7	8.7	11.5	12.6	12.1	14.5	15.1	15.2	20.1	24.1	22.6	**11.1**
K_{13} (dB)	7.4	9.8	12.1	11.9	13.4	9.9	14.5	15.4	16.1	18.5	22.2	21.0	21.8	26.2	28.7	29.2	**15.9**
K_{34} (dB)	7.9	12.0	7.3	6.6	8.2	4.3	6.3	7.8	8.4	9.4	11.2	11.0	11.2	14.9	16.0	15.5	**8.1**

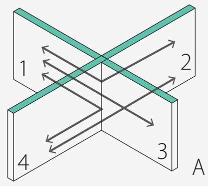
X JUNCTIONS

DETAIL 11



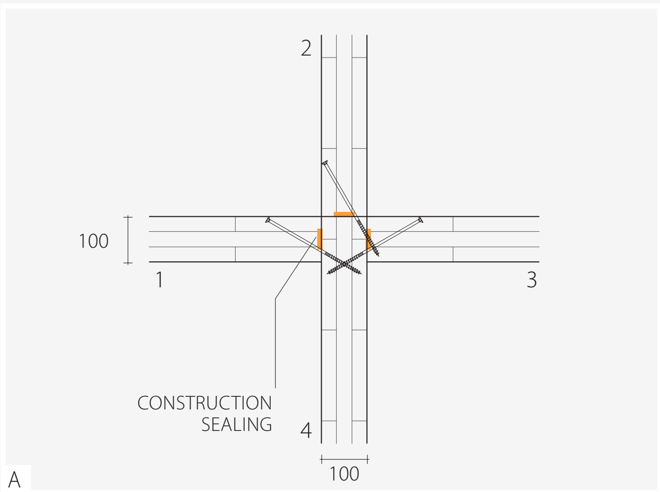
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 400 mm)

RESILIENT INTERLAYER
no



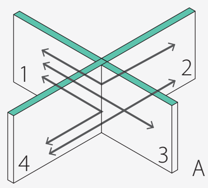
Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	13.1	12.4	13.7	10.8	13.2	12.2	12.8	14.4	15.9	17.0	19.7	21.2	25.0	27.9	29.7	32.6	**15.2**
K_{14} (dB)	9.9	10.4	8.7	8.0	9.8	7.7	8.4	9.4	11.2	10.1	11.5	12.3	15.0	16.8	18.0	21.2	**9.8**
K_{13} (dB)	12.5	12.1	12.7	12.3	14.6	13.3	11.9	14.0	16.8	16.8	20.5	21.7	23.9	27.5	28.3	31.6	**15.8**
K_{24} (dB)	12.9	11.2	11.6	9.8	12.7	12.5	11.6	11.9	13.8	12.6	13.4	13.9	16.8	18.6	20.7	22.9	**12.5**

DETAIL12



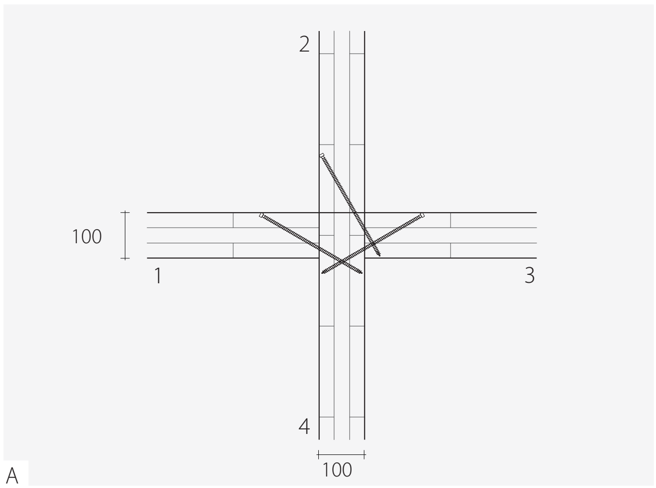
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 400 mm)

RESILIENT INTERLAYER
CONSTRUCTION SEALING



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	11.4	8.5	6.9	10.1	14.1	10.9	14.6	17.1	16.9	20.9	22.0	22.8	28.7	33.4	37.2	39.3	**16.6**
K_{14} (dB)	5.9	6.3	7.3	6.3	8.4	6.1	8.5	11.6	12.2	13.6	12.8	16.5	17.6	19.6	23.6	25.1	**10.7**
K_{13} (dB)	13.4	12.3	11.0	12.9	15.5	14.6	17.0	17.5	19.7	26.4	25.1	28.1	27.4	35.4	39.9	39.6	**19.6**
K_{24} (dB)	9.5	8.1	9.0	8.2	12.7	11.5	14.3	13.3	17.1	18.5	17.3	20.5	23.9	24.4	29.2	32.8	**14.8**

DETAIL 13

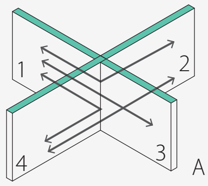


FIXING SYSTEM

VGZ screws Ø7 x 260 mm (step 400 mm)

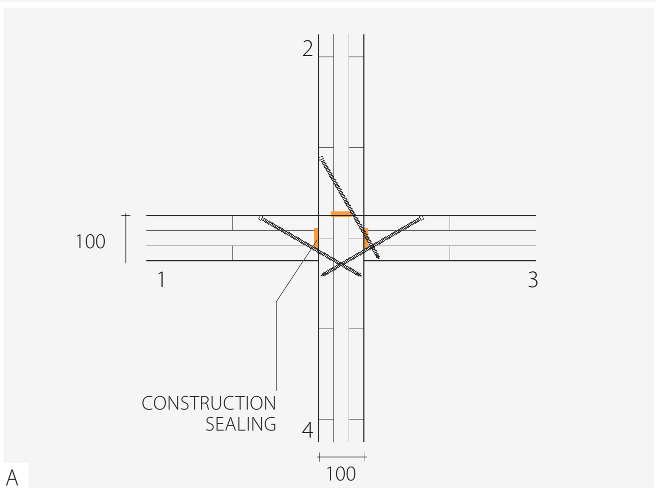
RESILIENT INTERLAYER

no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	11.0	8.6	8.9	9.7	10.1	7.1	12.3	13.4	15.1	17.8	19.8	23.3	24.9	30.8	33.7	37.3	**14.3**
K_{14} (dB)	7.8	8.7	7.1	6.5	6.7	3.3	8.7	10.0	13.1	12.5	16.1	17.0	17.2	21.2	20.2	24.3	**10.4**
K_{13} (dB)	9.8	9.6	13.6	12.0	9.5	8.7	15.9	17.5	18.7	20.8	26.7	28.2	27.9	35.7	36.4	42.6	**17.5**
K_{24} (dB)	13.0	9.8	5.5	5.6	7.8	8.0	11.8	9.6	13.6	17.6	18.3	20.8	19.8	27.4	30.3	29.1	**12.6**

DETAIL 14

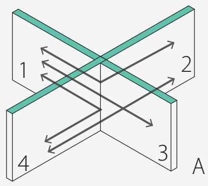


FIXING SYSTEM

VGZ screws Ø7 x 260 mm (step 400 mm)

RESILIENT INTERLAYER

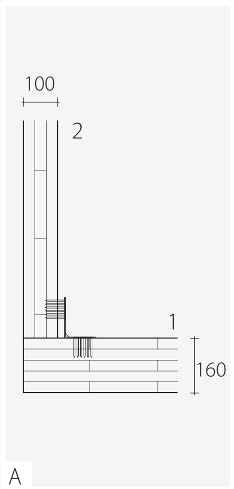
CONSTRUCTION SEALING

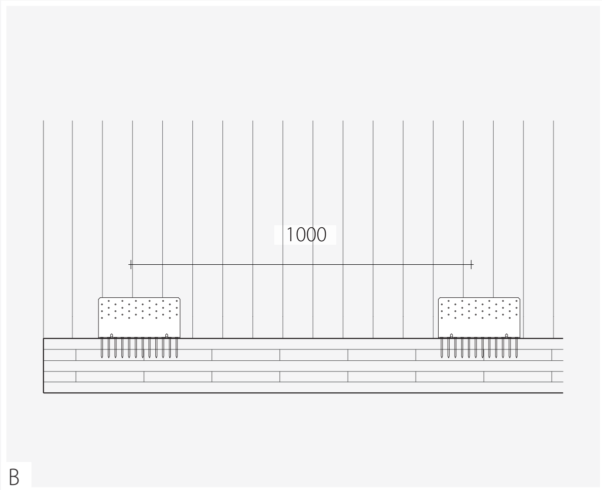


Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	10.5	7.2	5.1	6.0	9.9	8.1	11.5	14.3	16.8	18.4	22.0	25.1	27.5	33.5	36.1	36.4	**14.7**
K_{14} (dB)	7.4	5.1	1.7	4.3	5.1	4.4	9.8	11.8	12.9	14.2	15.8	17.5	16.9	22.2	26.1	25.4	**10.7**
K_{13} (dB)	10.2	9.9	2.5	9.9	12.2	10.1	14.1	18.5	19.8	21.8	26.1	31.8	31.9	38.6	42.7	42.0	**18.3**
K_{24} (dB)	10.1	7.9	9.0	5.7	11.0	11.1	15.1	16.5	19.4	19.2	21.7	23.8	24.4	32.7	34.7	35.3	**15.9**

L JUNCTIONS

DETAIL 15



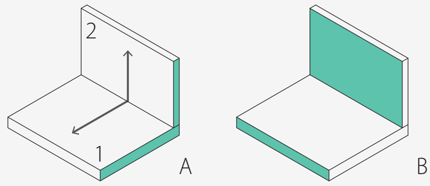


FIXING SYSTEM

TTN240 angle brackets (step 1000 mm)

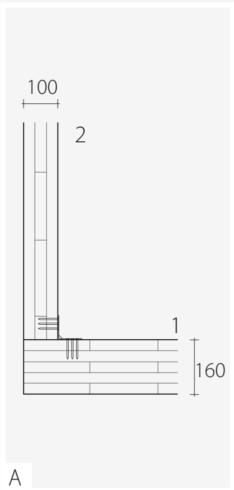
RESILIENT INTERLAYER

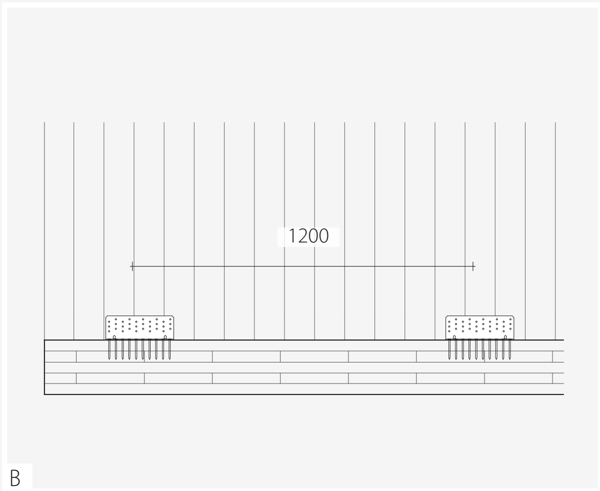
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	9.7	8.0	11.8	7.5	10.0	7.6	11.4	11.1	10.4	10.0	9.8	12.3	15.9	16.5	17.4	13.3	**10.0**

DETAIL16



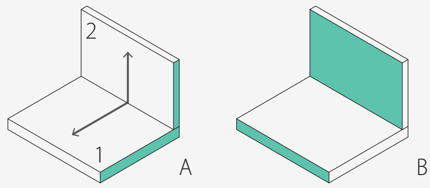


FIXING SYSTEM

TTF200 angle brackets (step 1200 mm)

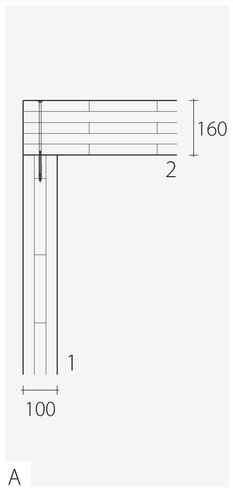
RESILIENT INTERLAYER

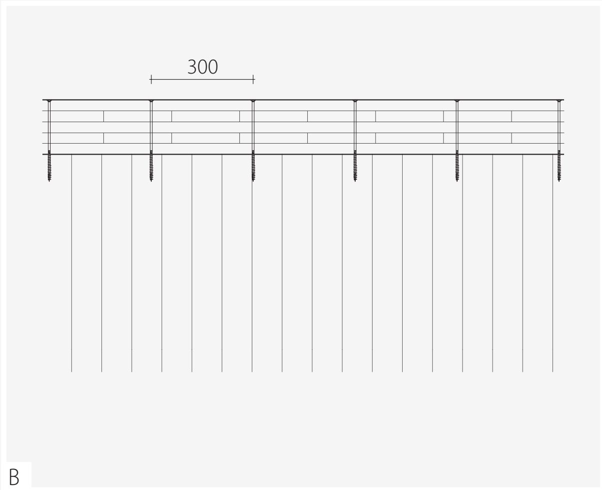
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	8.4	10.0	12.1	6.5	11.3	6.0	10.3	10.1	8.6	7.7	8.3	11.3	15.2	15.9	16.4	14.2	**8.9**

DETAIL 17



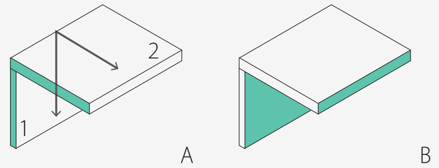


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)

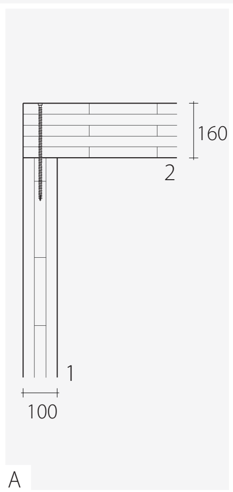
RESILIENT INTERLAYER

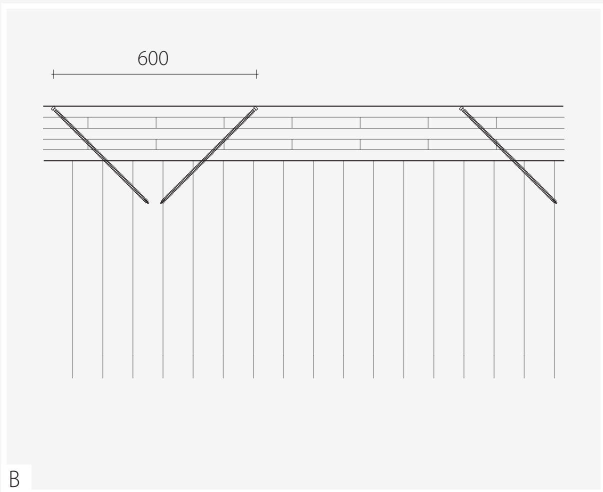
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	11.7	15.6	12.1	9.4	11.9	10.1	9.5	11.0	7.0	10.1	9.9	12.8	14.8	15.4	17.3	18.6	**10.2**

DETAIL 18



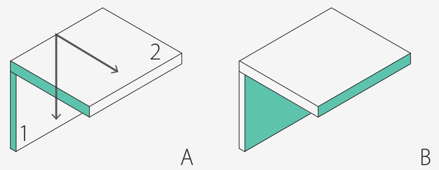


FIXING SYSTEM

VGZ screws Ø9 x 400 mm (step 600 mm)

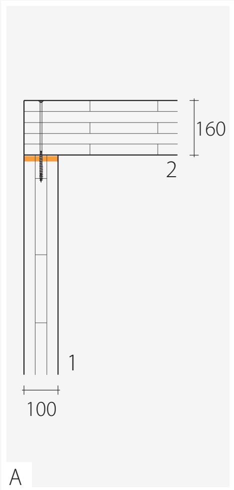
RESILIENT INTERLAYER

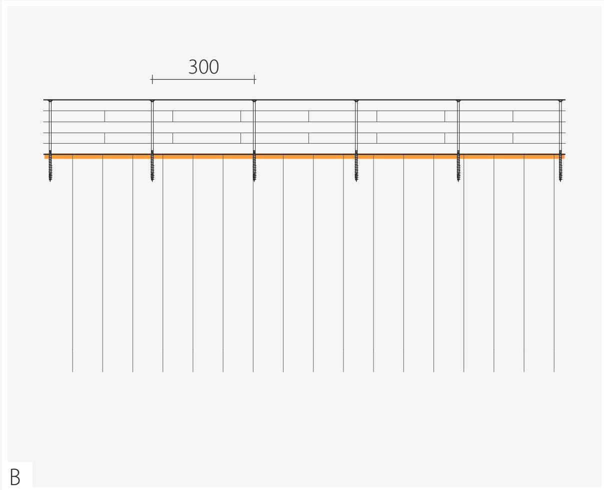
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	18.5	10.8	12.3	11.5	12.8	10.1	12.0	12.9	10.4	10.0	8.7	14.8	16.9	21.3	21.2	23.2	**11.5**

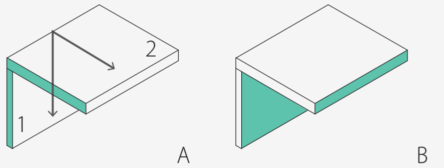
DETAIL 19





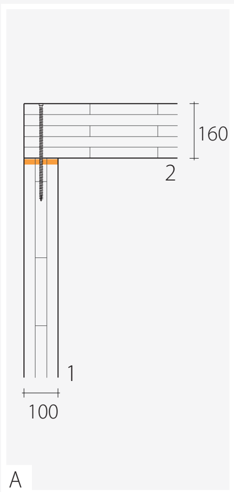
FIXING SYSTEM
HBS screws Ø8 x 240 mm (step 300 mm)

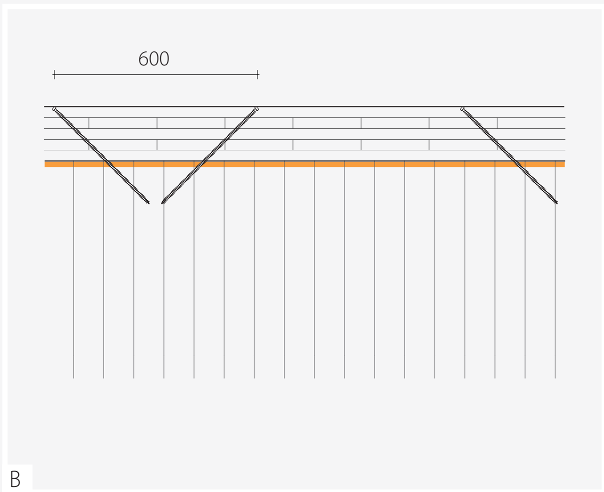
RESILIENT INTERLAYER
XYLOFON



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	12.6	10.8	13.6	11.1	9.2	13.3	11.3	16.5	10.2	14.6	14.9	17.4	19.6	25.0	28.5	25.1	**13.2**

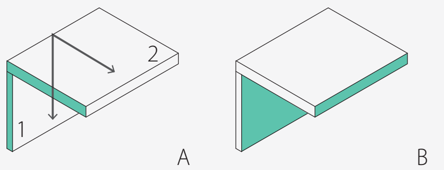
DETAIL 20





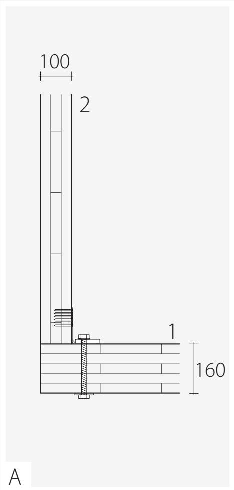
FIXING SYSTEM
VGZ screws Ø9 x 400 mm (step 600 mm)

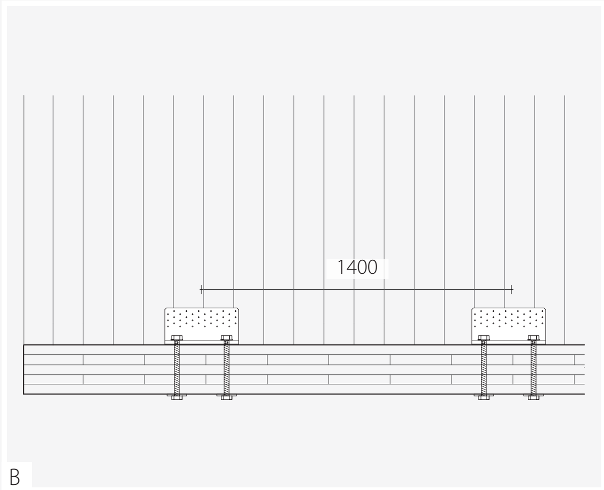
RESILIENT INTERLAYER
XYLOFON



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	15.3	11.2	10.6	9.5	11.7	11.5	13.8	15.1	12.0	14.5	13.0	18.6	21.6	22.0	20.8	23.7	**13.3**

DETAIL 21



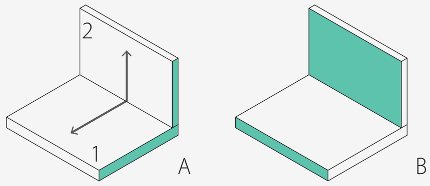


FIXING SYSTEM

TCN240 angle brackets + TCW240 (step 1400 mm)

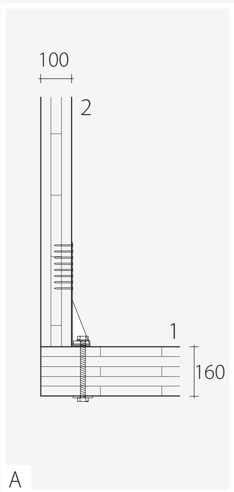
RESILIENT INTERLAYER

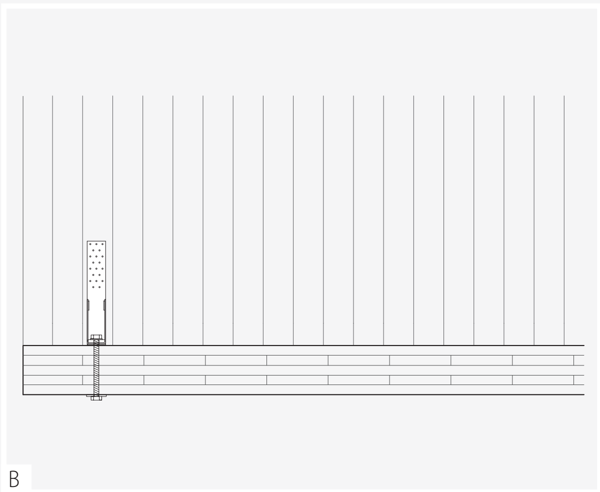
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	8.6	11.6	11.5	6.8	9.9	6.8	9.7	10.0	9.0	10.5	9.8	11.4	14.1	17.0	18.5	15.5	**9.3**

DETAIL 22



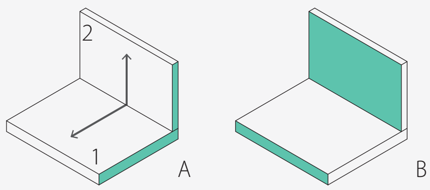


FIXING SYSTEM

WHT340 hold-down

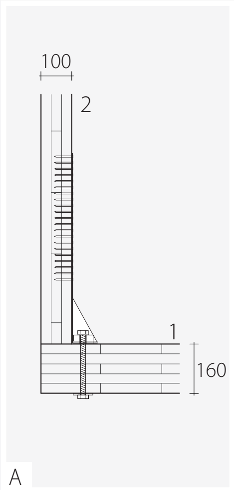
RESILIENT INTERLAYER

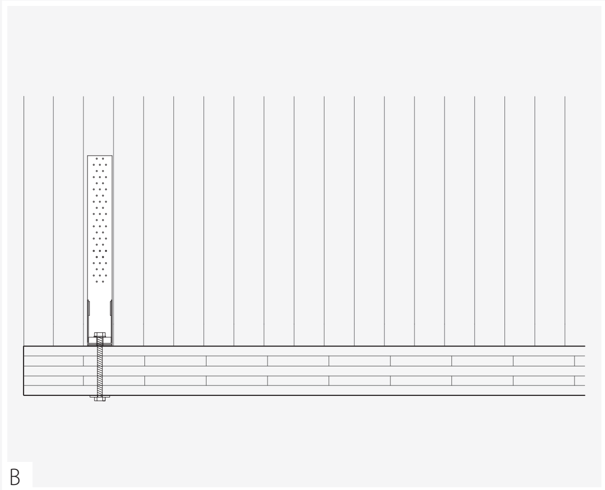
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	9.0	11.5	13.7	9.3	9.3	8.5	9.7	8.7	10.6	11.0	11.3	11.9	12.8	14.3	15.0	16.5	**10.0**

DETAIL 23



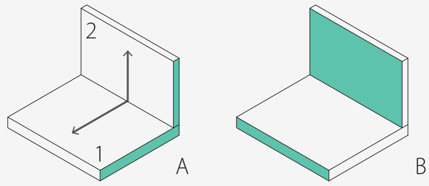


FIXING SYSTEM

WHT620 hold-down
* partial fixing (33 screws)
** total fixing (55 screws)

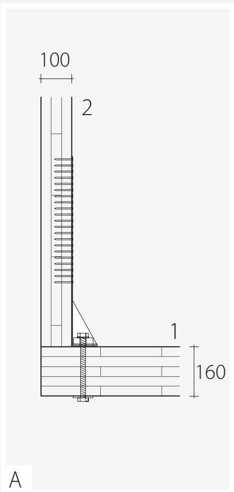
RESILIENT INTERLAYER

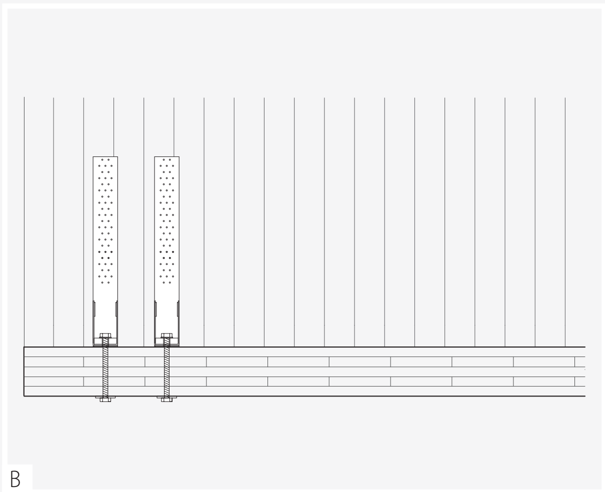
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB) *	9.1	15.8	9.4	9.3	9.2	7.1	14.7	11.5	13.5	10.7	13.4	11.7	14.4	14.4	16.8	18.2	**11.3**
K_{12} (dB) **	15.6	11.7	12.4	8.7	10.2	8.0	13.2	12.5	9.2	10.8	10.3	12.5	13.8	14.6	15.1	16.7	**10.6**

DETAIL 24



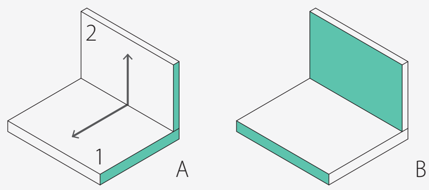


FIXING SYSTEM

2 WHT620 hold-down

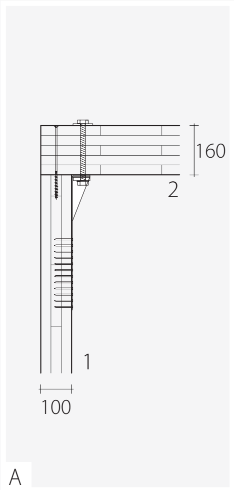
RESILIENT INTERLAYER

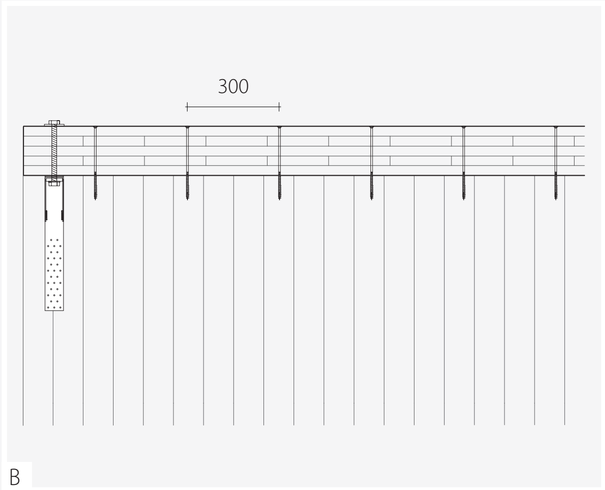
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	12.3	11.6	10.1	8.4	7.9	7.2	10.0	8.8	9.4	11.1	11.9	11.8	13.7	13.5	16.7	15.4	**9.6**

DETAIL 25



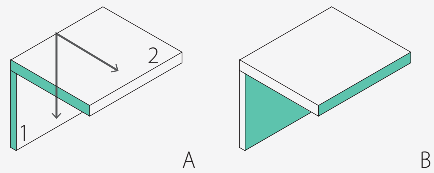


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
WHT440 hold-down

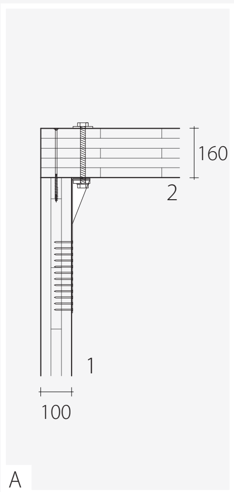
RESILIENT INTERLAYER

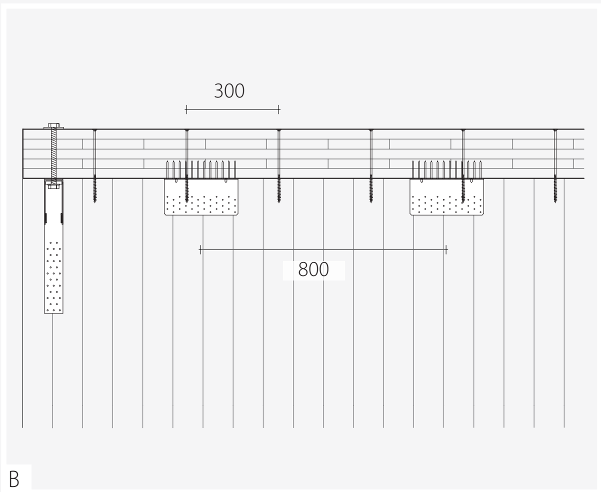
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	8.4	15.5	9.8	9.2	9.6	9.3	6.2	7.3	7.2	10.4	11.5	12.1	14.6	14.2	18.9	17.3	**9.2**

DETAIL 26



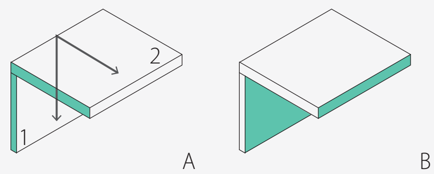


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

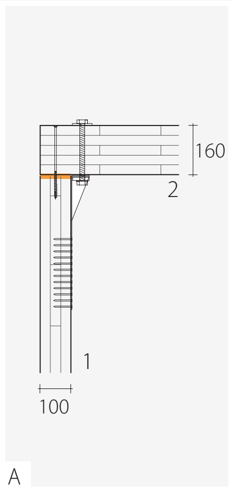
RESILIENT INTERLAYER

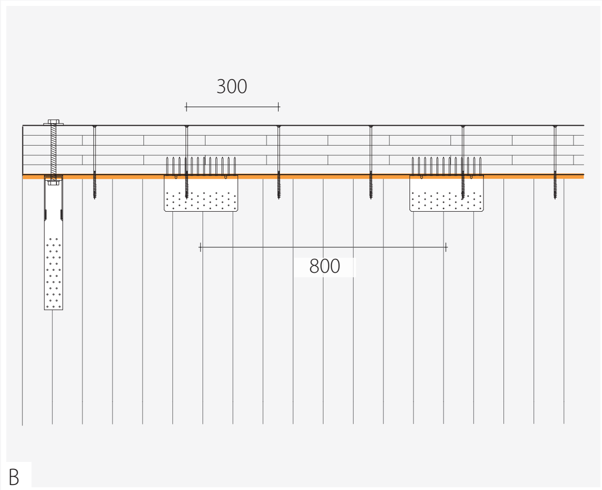
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	10.6	14.2	10.0	10.3	9.9	7.8	8.5	8.3	8.7	10.5	10.6	12.1	13.1	12.6	14.4	15.6	**9.6**

DETAIL 27



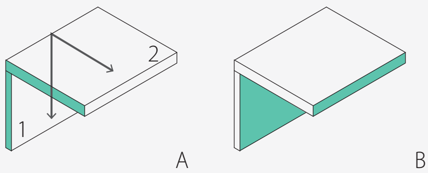


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

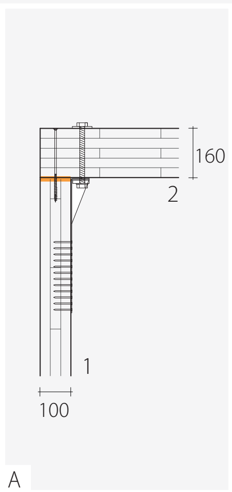
RESILIENT INTERLAYER

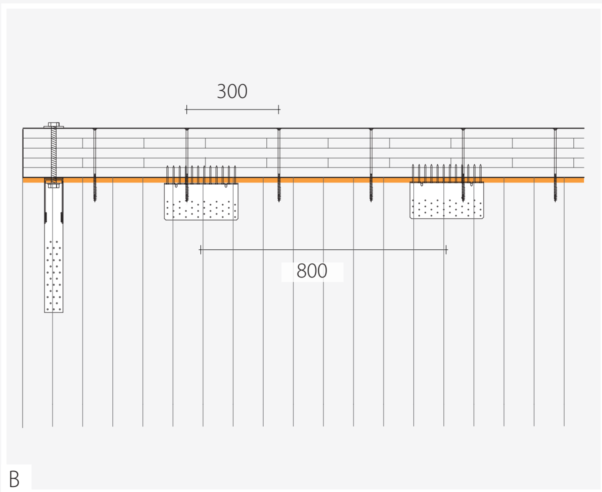
XYLOFON



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	10.9	8.9	7.1	10.6	7.4	9.6	10.2	12.5	11.8	14.1	14.8	15.3	17.1	17.4	21.5	21.2	**11.8**

DETAIL 28



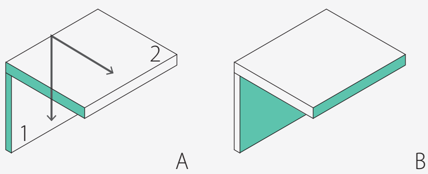


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

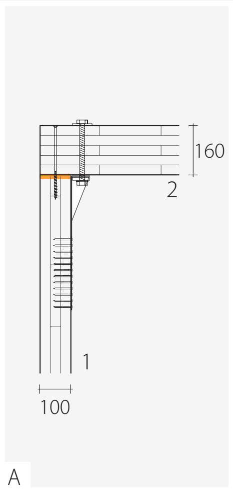
RESILIENT INTERLAYER

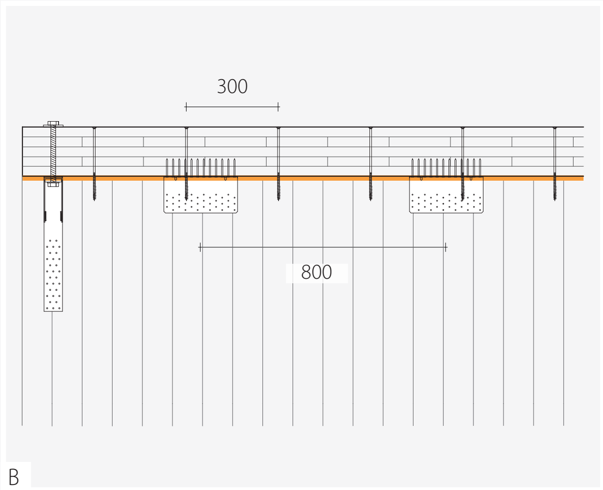
XYLOFON + TITAN SILENT



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	11.6	9.4	11.6	12.0	7.2	11.0	10.3	13.7	11.9	15.1	15.6	16.7	17.9	22.2	25.6	22.1	**12.6**

DETAIL 29



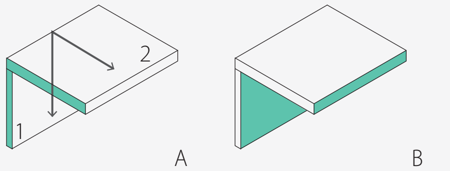


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

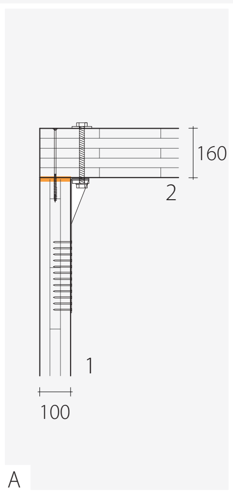
RESILIENT INTERLAYER

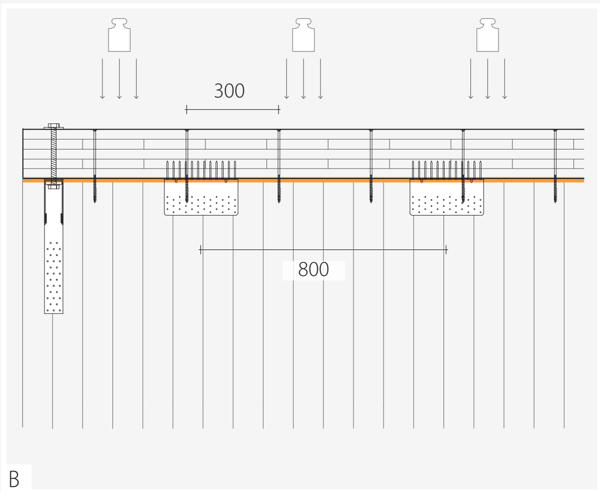
ALADIN STRIPE



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	8.7	14.4	8.7	10.0	10.7	9.5	6.1	9.8	9.4	14.1	16.1	18.1	18.1	17.8	21.3	19.1	**11.5**

DETAIL 30



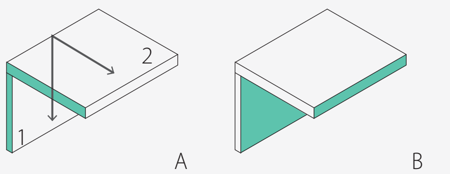


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

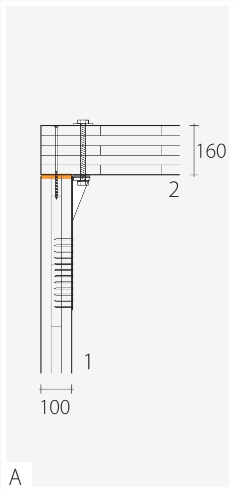
RESILIENT INTERLAYER

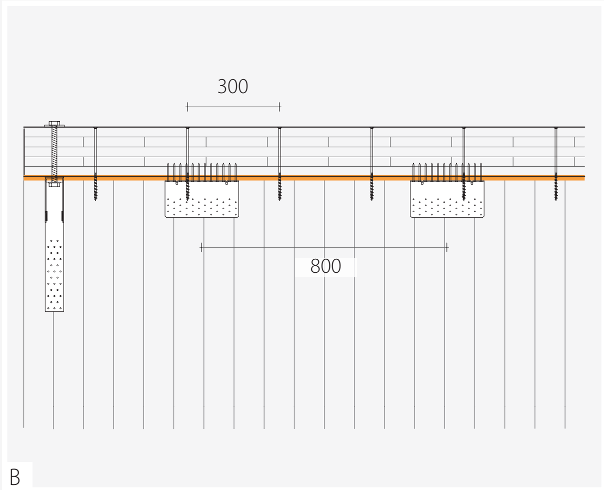
ALADIN STRIPE + 2 kN/m static load



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	9.5	13.6	8.7	11.8	9.0	10.1	7.2	8.7	10.4	14.2	17.0	16.5	18.4	20.0	23.1	19.7	**11.7**

DETAIL 31



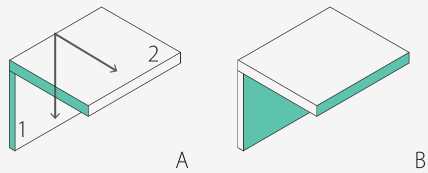


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

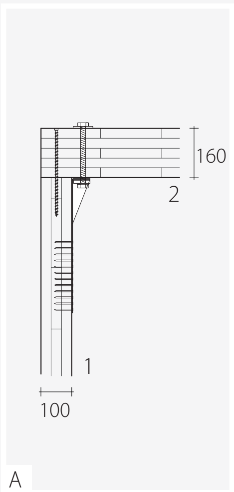
RESILIENT INTERLAYER

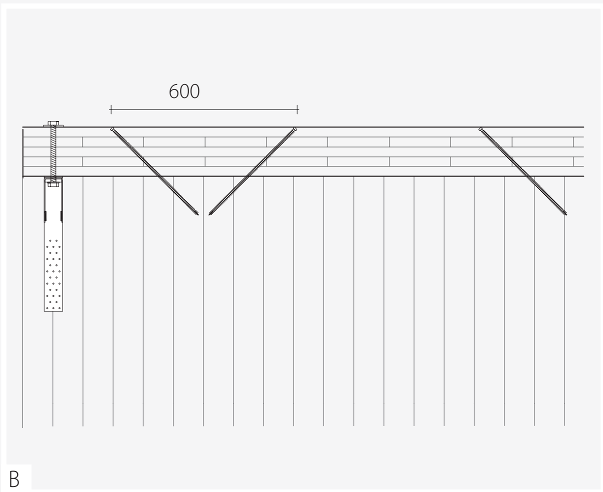
ALADIN STRIPE + TITAN SILENT



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	9.7	15.3	9.0	11.2	9.2	9.3	6.6	10.6	9.7	14.0	16.3	15.8	16.7	17.8	22.1	21.8	**11.4**

DETAIL 32



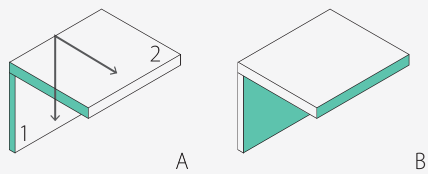


FIXING SYSTEM

VGZ screws Ø9 x 400 mm (step 600 mm)
WHT440 hold-down

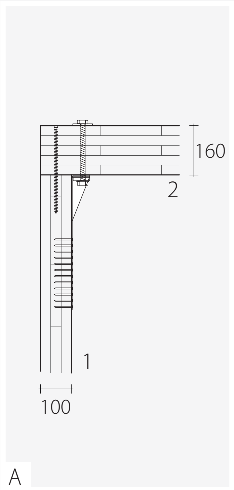
RESILIENT INTERLAYER

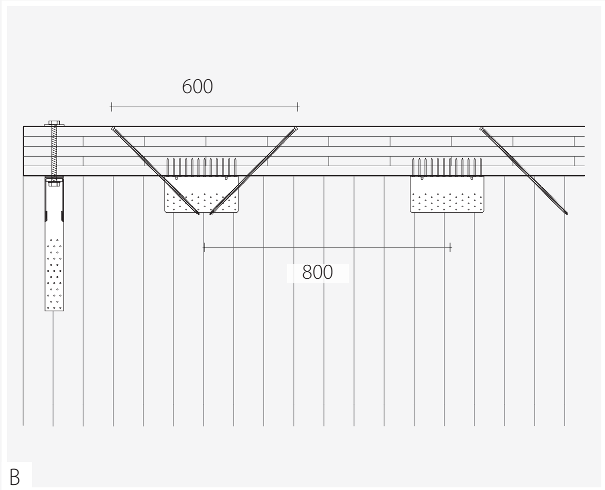
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	15.2	10.6	10.1	11.2	10.5	9.3	8.7	9.2	10.6	10.3	10.3	14.1	16.7	20.2	22.8	21.9	**10.5**

DETAIL 33



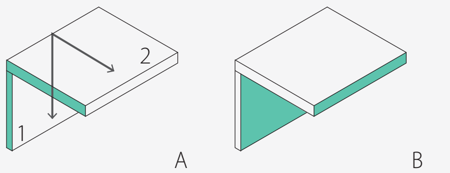


FIXING SYSTEM

VGZ screws Ø9 x 400 mm (step 600 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

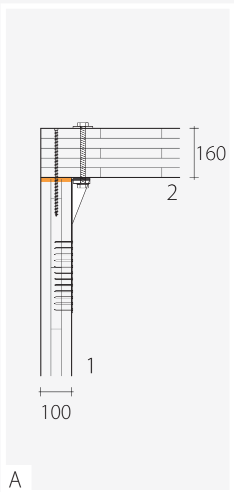
RESILIENT INTERLAYER

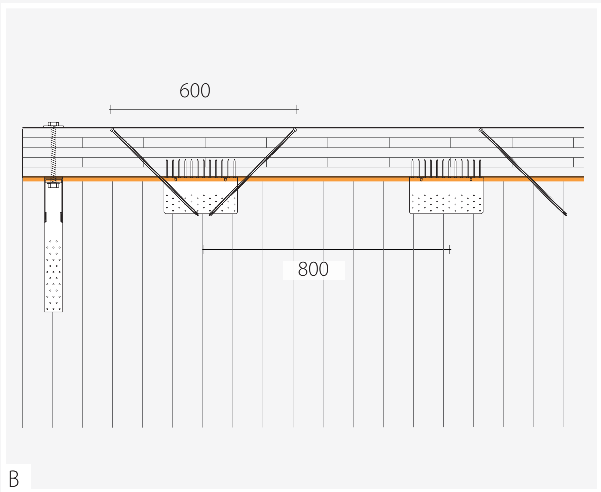
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	13.8	14.6	10.6	11.5	10.4	7.0	5.9	7.7	9.7	9.7	10.0	12.6	15.2	18.0	21.2	18.2	**9.4**

DETAIL 34



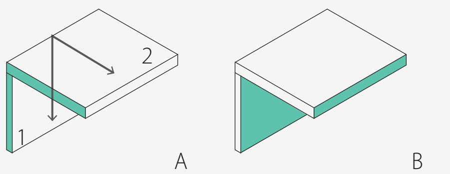


FIXING SYSTEM

VGZ screws Ø9 x 400 mm (step 600 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

RESILIENT INTERLAYER

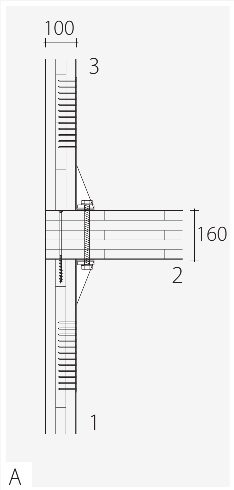
XYLOFON

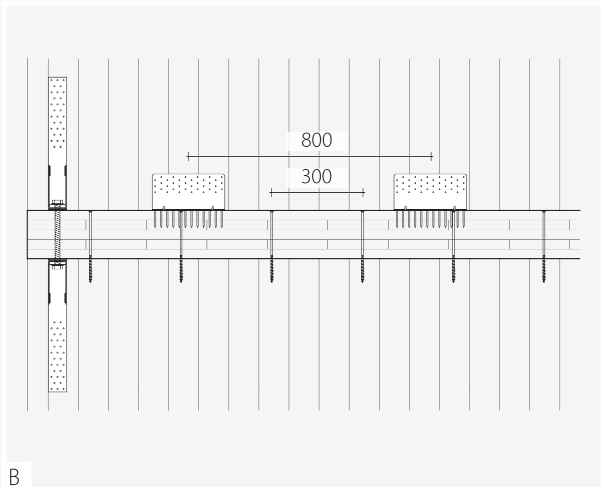


Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	10.6	15.0	8.8	9.6	9.2	8.4	7.7	10.0	11.3	14.3	14.2	16.3	20.0	18.6	20.8	18.7	**11.2**

T JUNCTIONS

DETAIL 35



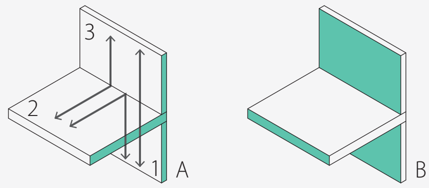


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

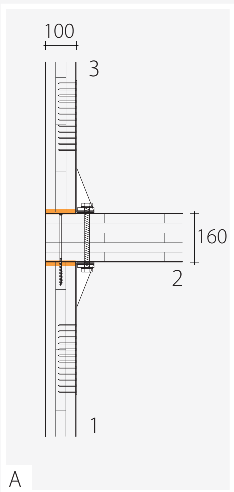
RESILIENT INTERLAYER

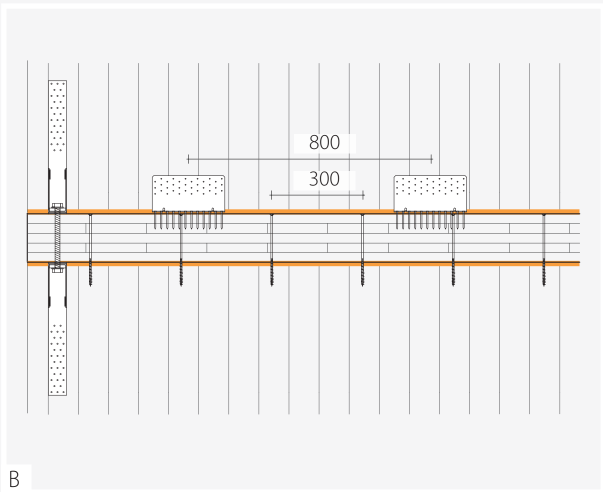
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	16.8	19.9	9.6	14.5	14.5	10.8	8.1	11.4	17.6	18.5	18.3	17.8	20.5	27.9	28.1	35.1	**14.6**
K_{13} (dB)	23.8	26.9	16.6	21.5	21.5	17.8	15.1	18.4	24.6	25.5	25.3	24.8	27.5	34.9	35.1	42.1	**21.6**
K_{23} (dB)	11.9	5.6	1.4	6.3	7.2	5.0	-1.0	4.9	6.0	8.2	8.2	14.9	15.1	14.2	15.9	20.2	**6.6**

DETAIL 36



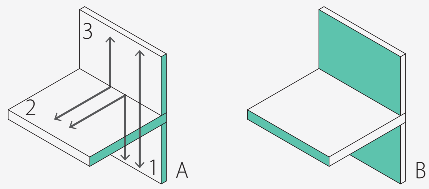


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

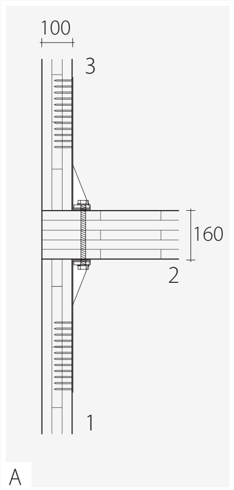
RESILIENT INTERLAYER

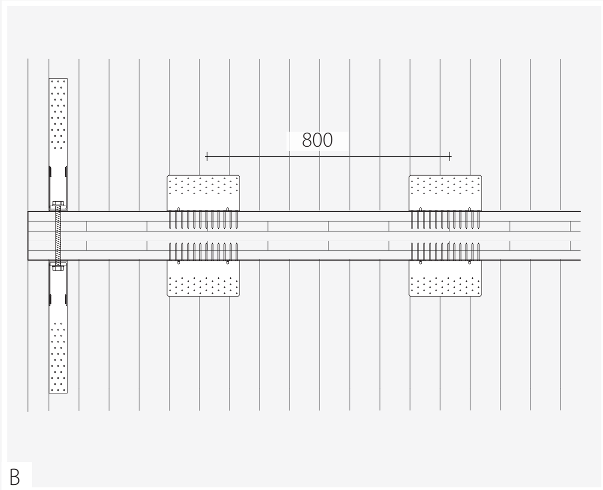
XYLOFON + TITAN SILENT



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	17.4	14.8	9.0	15.5	11.9	13.2	9.9	16.2	20.6	22.5	22.9	21.7	24.9	35.1	37.3	41.2	**17.2**
K_{13} (dB)	24.4	21.8	16.0	22.5	18.9	20.2	16.9	23.2	27.6	29.5	29.9	28.7	31.9	42.1	44.3	48.2	**24.2**
K_{23} (dB)	12.5	0.5	0.7	7.2	4.6	7.5	0.7	9.7	9.1	12.3	12.8	18.8	19.5	21.3	25.1	26.3	**9.2**

DETAIL 37



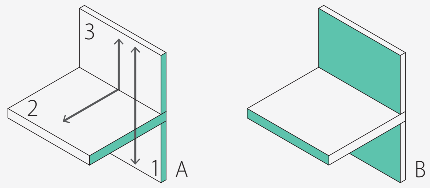


FIXING SYSTEM

TTN240 angle brackets (step 800 mm)
WHT440 hold-down

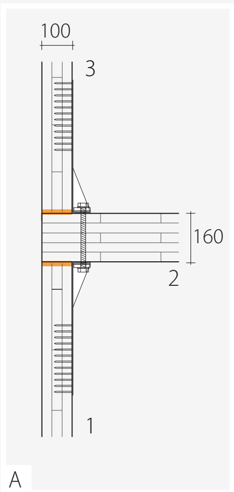
RESILIENT INTERLAYER

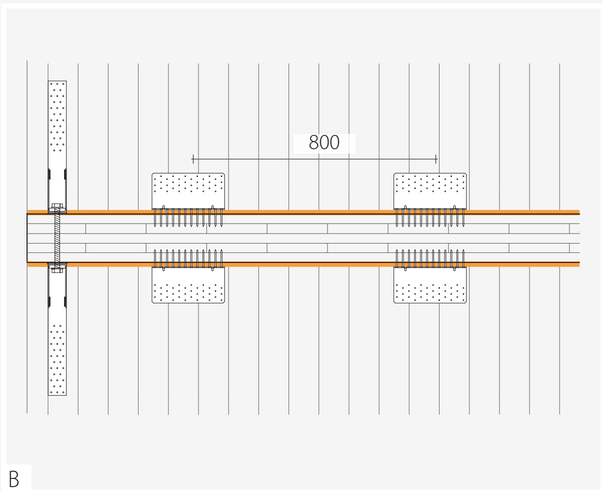
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{13} (dB)	26.9	26.7	18.3	20.6	19.1	12.9	8.8	12.4	15.1	17.5	19.7	22.8	24.6	30.7	34.3	32.0	**16.5**
K_{23} (dB)	19.9	19.7	11.3	13.6	12.1	5.9	1.8	5.4	8.1	10.5	12.7	15.8	17.6	23.7	27.3	25.0	**9.5**

DETAIL 38



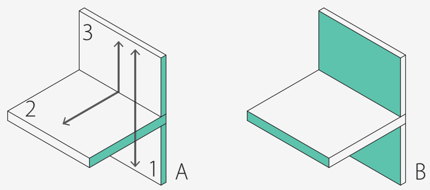


FIXING SYSTEM

TTN240 angle brackets (step 800 mm)
WHT440 hold-down

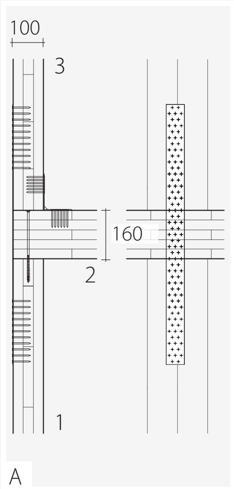
RESILIENT INTERLAYER

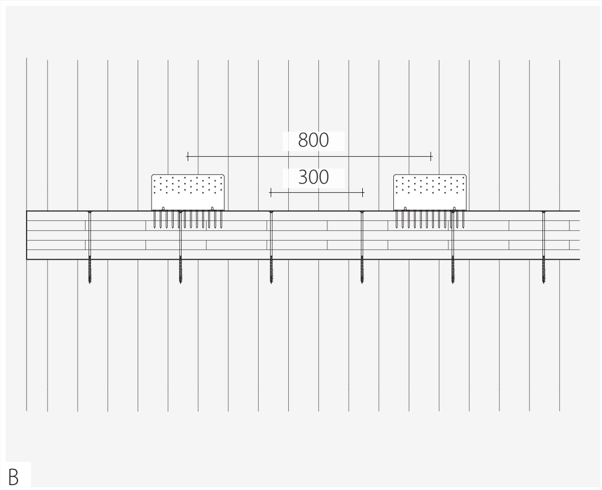
XYLOFON + TITAN SILENT



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{13} (dB)	23.6	27.1	16.5	18.7	18.0	14.2	10.6	14.6	16.7	22.0	24.0	26.6	29.4	31.4	34.0	32.5	**18.4**
K_{23} (dB)	16.6	20.1	9.5	11.7	11.0	7.2	3.6	7.6	9.7	15.0	17.0	19.6	22.4	24.4	27.0	25.5	**11.4**

DETAIL 39



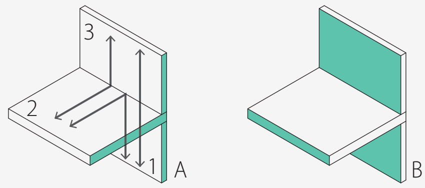


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 400 mm)
TTN240 angle brackets (step 800 mm)
LBV perforated plate

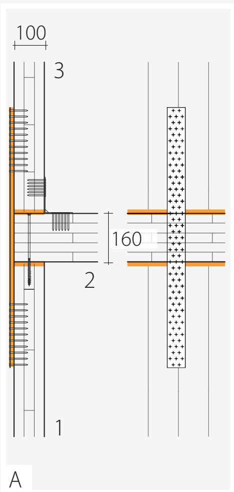
RESILIENT INTERLAYER

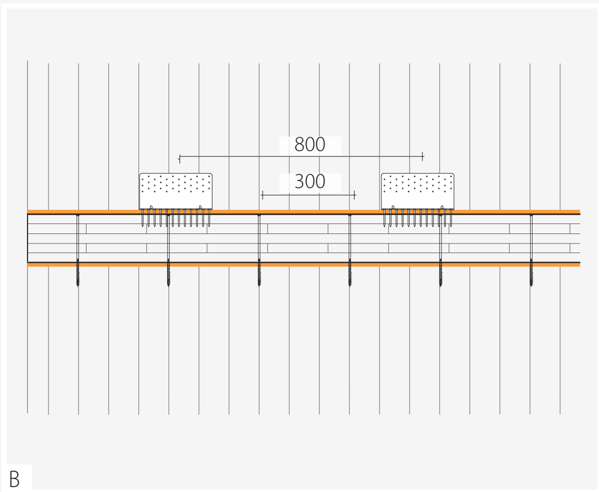
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	13.6	14.9	4.4	9.4	11.4	7.0	8.9	9.0	14.5	18.2	17.4	20.2	21.9	28.9	28.3	36.7	**12.9**
K_{13} (dB)	22.5	25.3	15.7	16.5	15.0	12.6	13.4	15.8	21.1	18.6	19.3	18.8	23.5	29.0	27.5	32.3	**16.8**
K_{23} (dB)	4.8	-1.3	-4.1	4.7	5.7	1.2	-3.7	2.2	6.5	8.5	9.0	17.5	16.0	16.6	17.3	22.7	**5.7**

DETAIL 40



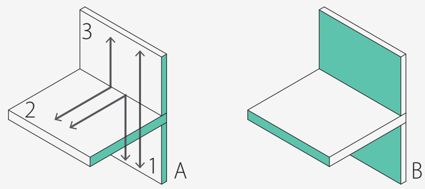


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
LBV perforated plate

RESILIENT INTERLAYER

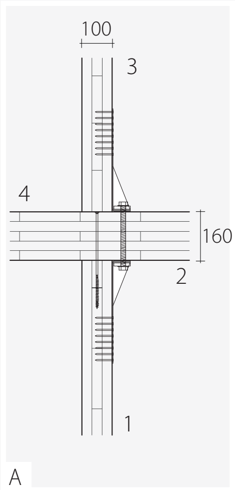
XYLOFON + TITAN SILENT

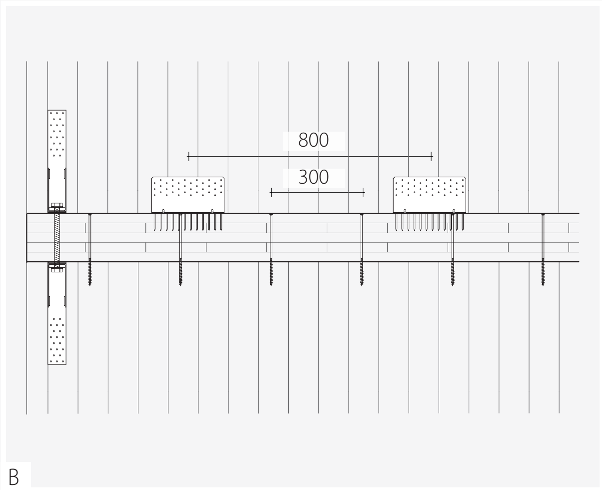


Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	17.4	13.1	7.0	11.1	10.8	11.5	10.5	15.6	20.4	22.4	21.9	24.7	24.5	38.4	38.6	41.0	**16.6**
K_{13} (dB)	23.9	24.5	18.3	20.6	16.3	18.2	19.4	19.6	25.7	27.2	25.6	21.9	24.5	41.7	44.9	49.0	**21.6**
K_{23} (dB)	7.1	-3.1	-2.5	6.2	6.0	6.4	0.7	9.7	9.5	12.5	12.7	19.3	16.8	21.8	25.2	27.2	**9.2**

X JUNCTIONS

DETAIL 41



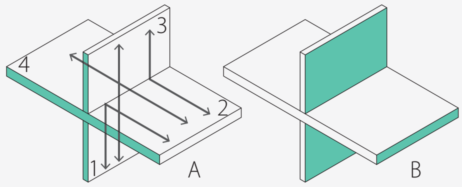


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

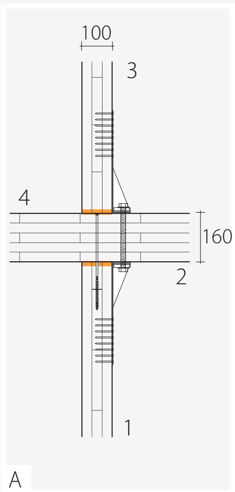
RESILIENT INTERLAYER

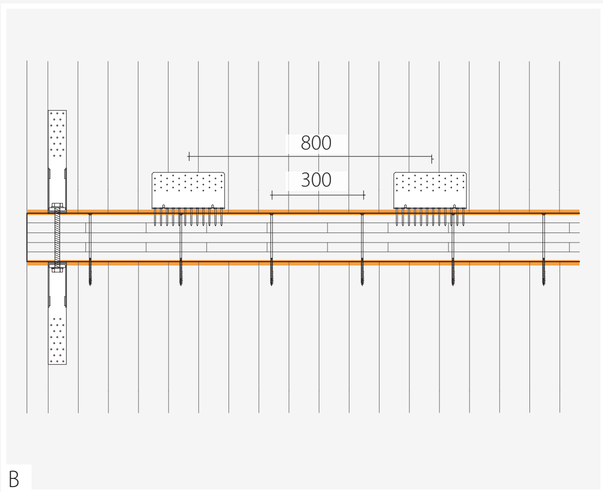
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	19.8	22.9	12.6	17.5	17.5	13.8	11.1	14.4	20.6	21.5	21.3	20.8	23.5	30.9	31.1	38.1	**17.6**
K_{23} (dB)	14.9	8.6	4.4	9.3	10.2	8.0	2.0	7.9	9.0	11.2	11.2	17.9	18.1	17.2	18.9	23.2	**9.6**
K_{13} (dB)	24.8	27.9	17.6	22.5	22.5	18.8	16.1	19.4	25.6	26.5	26.3	25.8	28.5	35.9	36.1	43.1	**22.6**
K_{24} (dB)	10.3	10.0	9.6	9.3	9.0	8.6	8.3	8.0	7.6	7.3	7.0	6.7	6.3	6.0	5.7	5.3	**8.0**

DETAIL 42



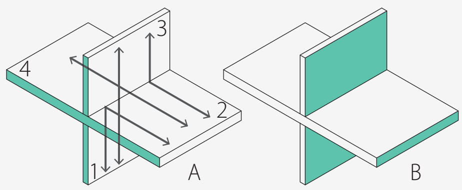


FIXING SYSTEM

HBS screws Ø8 x 240 mm (step 300 mm)
TTN240 angle brackets (step 800 mm)
WHT440 hold-down

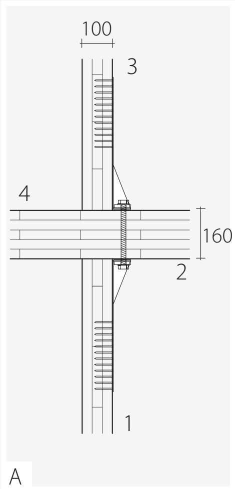
RESILIENT INTERLAYER

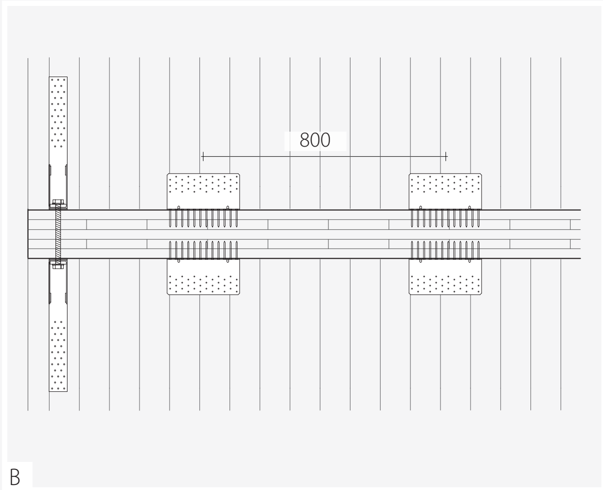
XYLOFON + TITAN SILENT



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	20.4	17.8	12.0	18.5	14.9	16.2	12.9	19.2	23.6	25.5	25.9	24.7	27.9	38.1	40.3	44.2	**20.2**
K_{23} (dB)	15.5	3.5	3.7	10.2	7.6	10.5	3.7	12.7	12.1	15.3	15.8	21.8	22.5	24.3	28.1	29.3	**12.2**
K_{13} (dB)	25.4	22.8	17.0	23.5	19.9	21.2	17.9	24.2	28.6	30.5	30.9	29.7	32.9	43.1	45.3	49.2	**25.2**
K_{24} (dB)	10.3	10.0	9.6	9.3	9.0	8.6	8.3	8.0	7.6	7.3	7.0	6.7	6.3	6.0	5.7	5.3	**8.0**

DETAIL 43



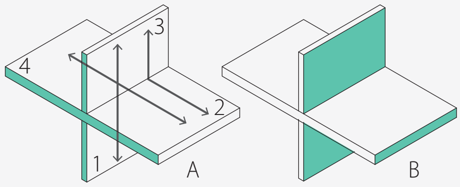


FIXING SYSTEM

TTN240 angle brackets (step 800 mm)
WHT440 hold-down

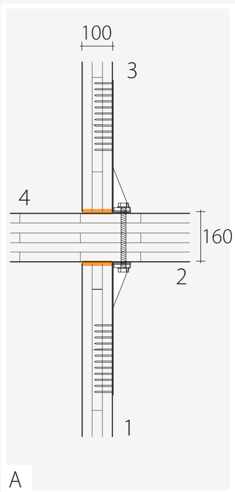
RESILIENT INTERLAYER

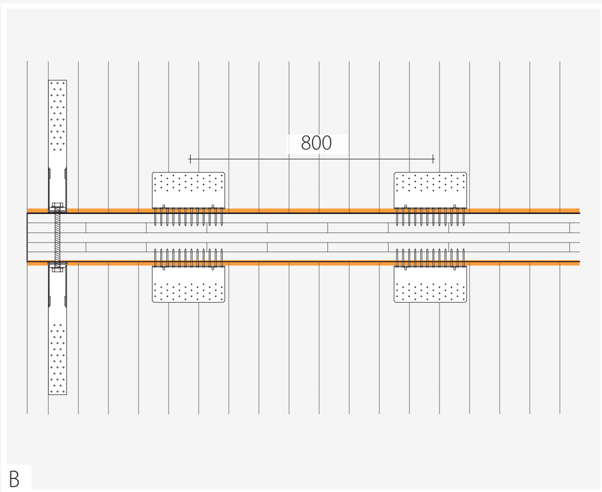
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{13} (dB)	27.9	27.7	19.3	21.6	20.1	13.9	9.8	13.4	16.1	18.5	20.7	23.8	25.6	31.7	35.3	33.0	**17.5**
K_{23} (dB)	22.9	22.7	14.3	16.6	15.1	8.9	4.8	8.4	11.1	13.5	15.7	18.8	20.6	26.7	30.3	28.0	**12.5**
K_{24} (dB)	10.3	10.0	9.6	9.3	9.0	8.6	8.3	8.0	7.6	7.3	7.0	6.7	6.3	6.0	5.7	5.3	**8.0**

DETAIL 44



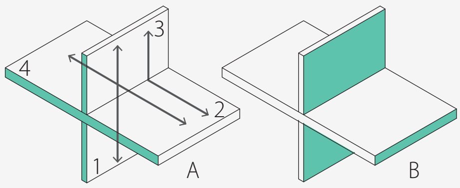


FIXING SYSTEM

TTN240 angle brackets (step 800 mm)
WHT440 hold-down

RESILIENT INTERLAYER

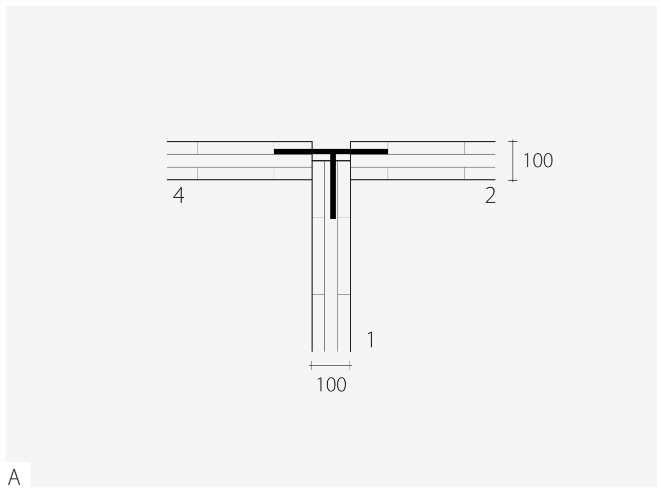
XYLOFON + TITAN SILENT



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{13} (dB)	24.6	28.1	17.5	19.7	19.0	15.2	11.6	15.6	17.7	23.0	25.0	27.6	30.4	32.4	35.0	33.5	**19.4**
K_{23} (dB)	19.6	23.1	12.5	14.7	14.0	10.2	6.6	10.6	12.7	18.0	20.0	22.6	25.4	27.4	30.0	28.5	**14.4**
K_{24} (dB)	10.3	10.0	9.6	9.3	9.0	8.6	8.3	8.0	7.6	7.3	7.0	6.7	6.3	6.0	5.7	5.3	**8.0**

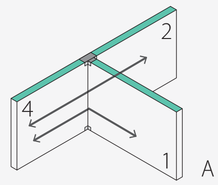
X-RAD: WALL-WALL JUNCTIONS

DETAIL 45 | T vertical junction



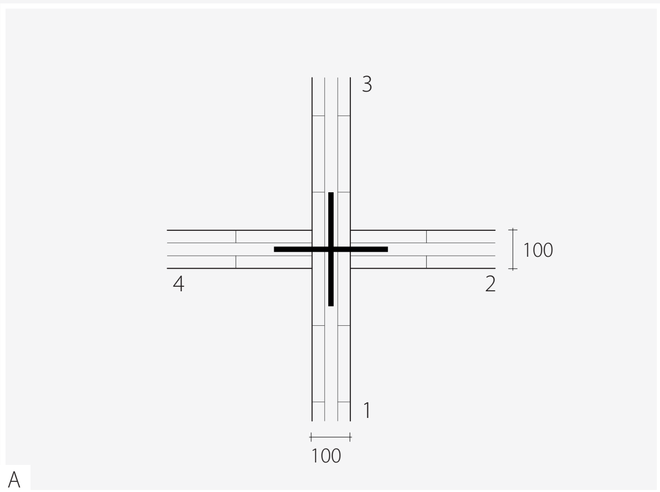
FIXING SYSTEM
X-PLATE BASE T, X-PLATE TOP T

RESILIENT INTERLAYER
no



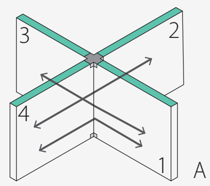
Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{14} (dB)	10.2	7.0	8.1	6.4	6.4	5.1	6.7	7.6	7.3	7.9	8.2	9.7	12.7	12.9	12.6	15.5	**7.3**
K_{24} (dB)	15.7	16.0	13.6	6.5	6.4	8.8	9.5	15.2	18.4	17.7	20.2	18.9	24.7	24.7	23.4	28.5	**13.5**

DETAIL 46 | X vertical junction



FIXING SYSTEM
X-PLATE BASE X, X-PLATE TOP X

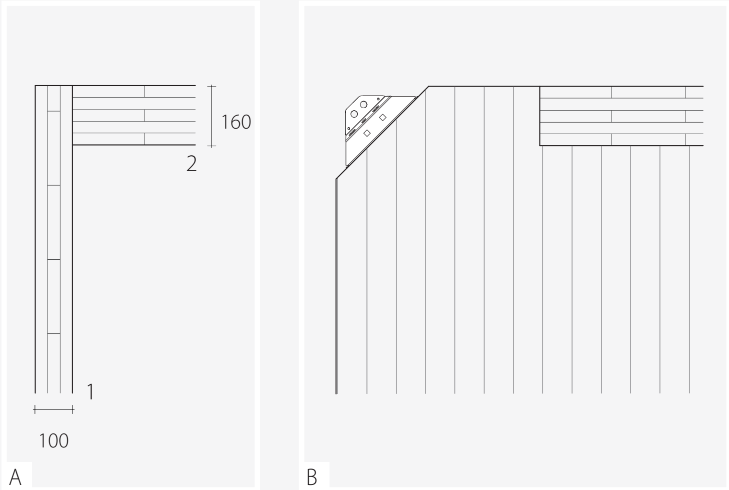
RESILIENT INTERLAYER
no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{14} (dB)	12.7	11.4	10.2	8.5	8.5	7.0	8.1	10.7	11.5	9.5	11.1	12.5	15.8	17.5	17.5	21.6	**9.7**
K_{24} (dB)	18.9	12.0	13.3	9.7	8.7	8.8	6.6	11.1	13.1	11.7	13.4	12.6	13.8	14.4	12.4	16.9	**10.6**
K_{13} (dB)	15.0	13.7	13.6	12.0	11.8	9.3	8.2	12.6	15.4	13.3	12.6	13.2	19.0	21.6	24.0	31.4	**12.0**

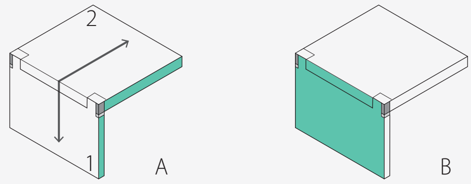
X-RAD: WALL-FLOOR JUNCTIONS

DETAIL 47 | L horizontal junction



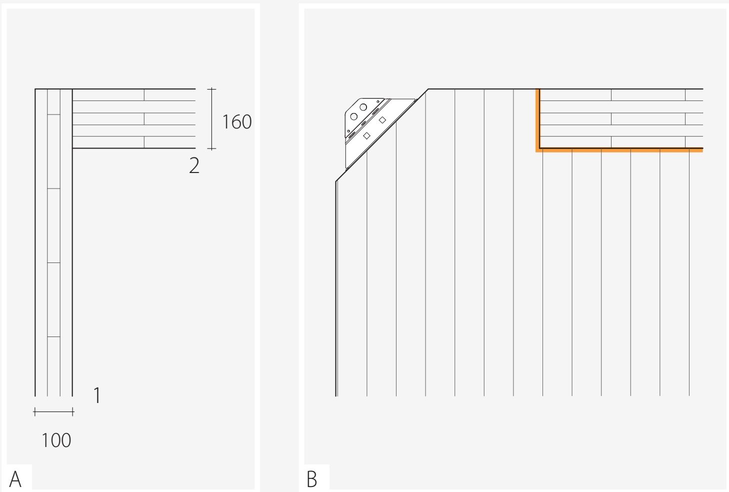
FIXING SYSTEM
X-PLATE BASE O

RESILIENT INTERLAYER
no



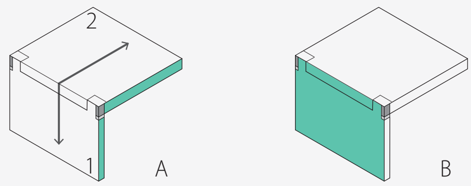
Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB)	13.1	13.8	14.2	10.6	11.6	12.8	12.2	10.6	12.2	9.7	8.1	11.2	9.9	10.2	11.2	13.5	**11.0**

DETAIL 48 | L horizontal junction



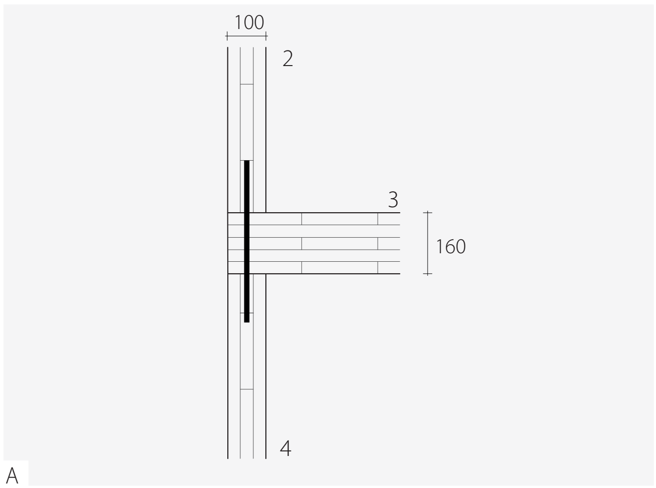
FIXING SYSTEM
X-PLATE BASE O

RESILIENT INTERLAYER
XYLOFON*, ALADIN STRIPE**



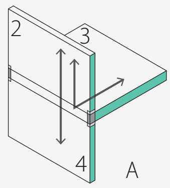
Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{12} (dB) *	12.0	14.6	11.8	13.2	12.8	15.2	15.9	14.9	15.7	15.9	13.9	12.6	16.2	18.5	17.8	17.5	**14.4**
K_{12} (dB) **	16.3	13.7	14.4	13.8	13.4	12.7	11.4	10.0	13.3	14.3	13.3	14.3	15.9	13.9	16.2	21.9	**13.0**

DETAIL 49 | T horizontal junction



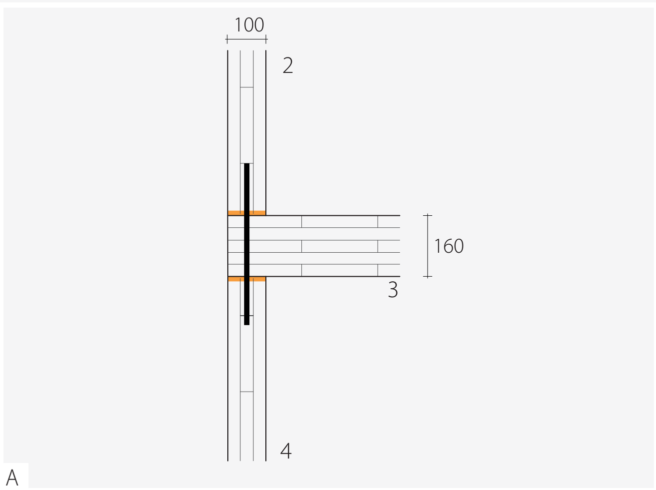
FIXING SYSTEM
X-PLATE BASE O, X-PLATE MID O

RESILIENT INTERLAYER
no



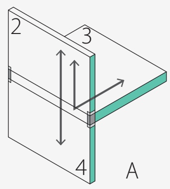
Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{23} (dB)	17.2	13.0	13.1	10.4	9.5	7.1	7.7	7.6	8.3	9.9	11.3	13.7	17.8	18.9	19.6	23.5	**9.5**
K_{24} (dB)	24.2	20.0	20.1	17.4	16.5	14.1	14.7	14.6	15.3	16.9	18.3	20.7	24.8	25.9	26.6	30.5	**16.5**

DETAIL 50 | T horizontal junction



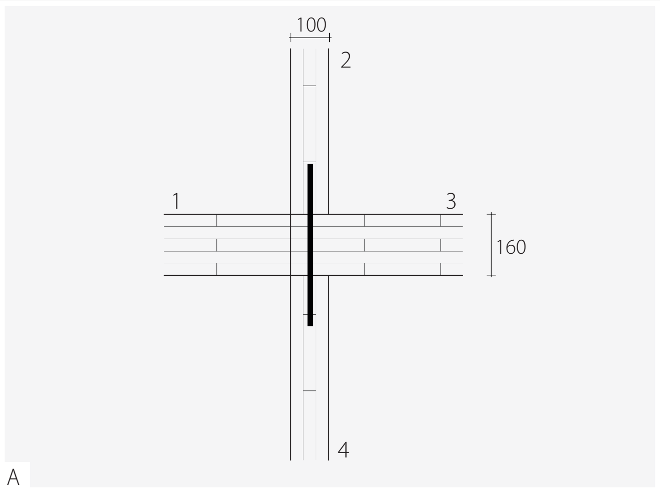
FIXING SYSTEM
X-PLATE BASE O, X-PLATE MID O

RESILIENT INTERLAYER
XYLOFON



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	$AVG_{200-1250}$
K_{23} (dB)	16.0	13.8	10.7	13.0	10.6	9.5	11.4	11.9	11.9	16.1	17.1	15.0	24.1	27.2	26.3	27.4	**12.9**
K_{24} (dB)	23.0	20.8	17.7	20.0	17.6	16.5	18.4	18.9	18.9	23.1	24.1	22.0	31.1	34.2	33.3	34.4	**19.9**

DETAIL 51 | X horizontal junction

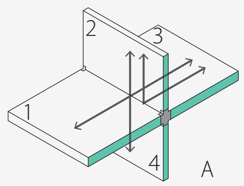


FIXING SYSTEM

X-PLATE BASE O, X-PLATE MID O

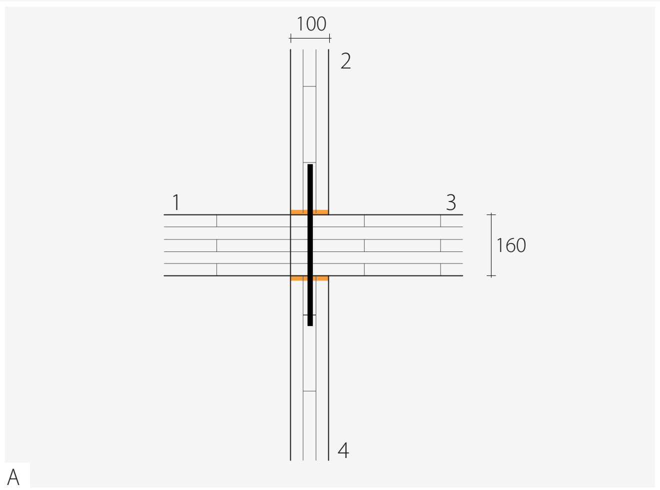
RESILIENT INTERLAYER

no



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	AVG
K_{23} (dB)	19.7	17.4	15.1	12.4	11.5	9.0	9.1	10.7	12.5	11.6	14.1	16.5	20.8	23.5	24.5	29.6	**11.9**
K_{13} (dB)	13.0	11.7	11.5	10.0	9.7	7.2	6.2	10.6	13.4	11.3	10.6	11.1	17.0	19.6	22.0	29.3	**10.0**
K_{24} (dB)	19.9	13.0	14.3	10.7	9.7	9.8	7.6	12.1	14.1	12.7	14.4	13.6	14.8	15.4	13.4	17.9	**11.6**

DETAIL 52 | X horizontal junction

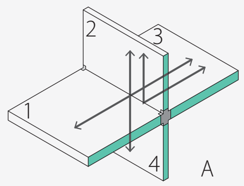


FIXING SYSTEM

X-PLATE BASE O, X-PLATE MID O

RESILIENT INTERLAYER

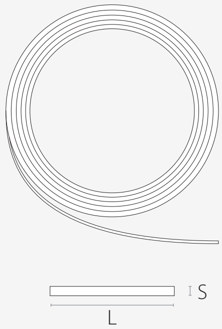
XYLOFON



Frequency (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	AVG
K_{23} (dB)	18.6	18.2	12.7	15.1	12.7	11.4	12.8	15.1	16.0	17.8	19.9	17.8	27.1	31.8	31.1	33.5	**15.4**
K_{13} (dB)	13.0	11.7	11.5	10.0	9.7	7.2	6.2	10.6	13.4	11.3	10.6	11.1	17.0	19.6	22.0	29.3	**10.0**
K_{24} (dB)	18.8	13.8	11.9	13.4	10.8	12.2	11.3	16.4	17.7	18.9	20.2	15.0	21.2	23.7	20.1	21.8	**15.1**

XYLOFON

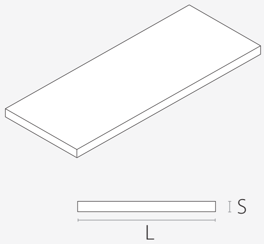
CODES AND DIMENSIONS



CODE	EX CODE	version	length	width (L)	thickness (S)	pcs/pack
XYL35100	D82411	35	3.66 m	100 mm	6 mm	1
XYL50100	D82412	50	3.66 m	100 mm	6 mm	1
XYL70100	D82413	70	3.66 m	100 mm	6 mm	1
XYL80100	D82414	80	3.66 m	100 mm	6 mm	1
XYL90120	D82415	90	3.66 m	120 mm	6 mm	1

XYLOFON MEGA

CODES AND DIMENSIONS

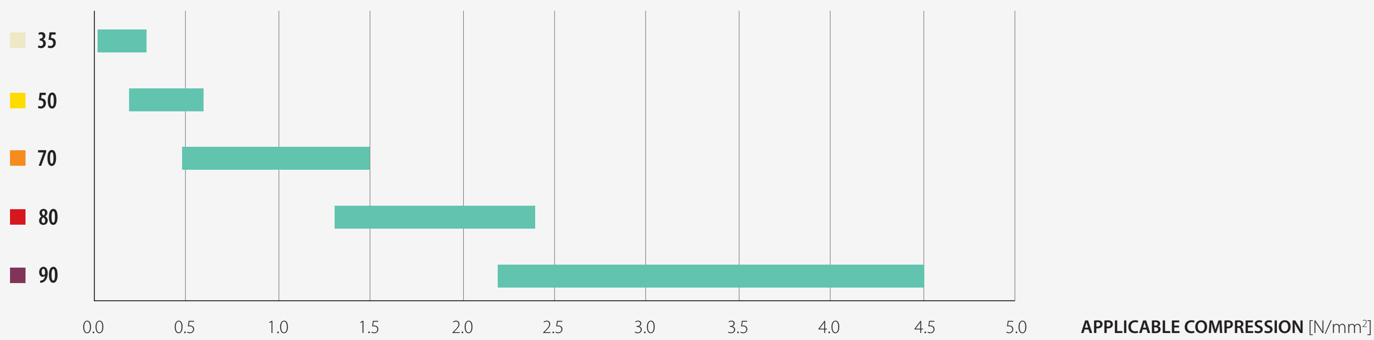


CODE	EX CODE	version	length	width (L)	thickness (S)	pcs/pack
XYL351000	D82421	35	3.66 m	1000 mm	6 mm	1
XYL501000	D82422	50	3.66 m	1000 mm	6 mm	1
XYL701000	D82423	70	3.66 m	1000 mm	6 mm	1
XYL801000	D82424	80	3.66 m	1000 mm	6 mm	1
XYL901000	D82425	90	3.66 m	1000 mm	6 mm	1

TABLE OF USE

In table of use ("Soundproofing solutions" product catalogue) the loads are optimized with respect to the dynamic behaviour of the material and considering a deflection within the range 1-10%.
The preferred loads reported here are optimized with respect to the static load, evaluated in compression and considering the effect of friction, and the resonance frequency, chosen to range between 20 and 30 Hz, with a maximum deflection of 12%.

	APPLICABLE COMPRESSION [N/mm^2]		DEFORMATION [mm]		APPLICABLE LINEAR LOAD [kN/m]		
VERSION	from	to	min	max	CODE	from	to
35	0.027	0.275	0.06	0.60	**XYL35100** (100 mm)	2.7	27.5
50	0.180	0.605	0.16	0.62	**XYL50100** (100 mm)	18.0	60.5
70	0.455	1.500	0.13	0.44	**XYL70100** (100 mm)	45.5	150.0
80	1.300	2.400	0.32	0.59	**XYL80100** (100 mm)	130.0	240.0
90	2.200	4.500	0.30	0.62	**XYL90120** (120 mm)	264.0	540.0

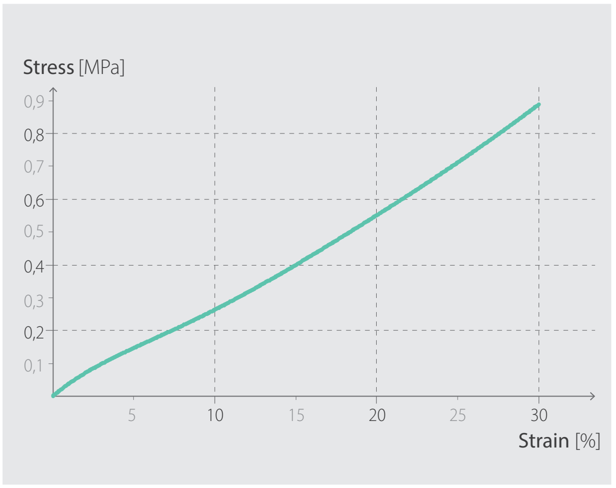


35 SHORE

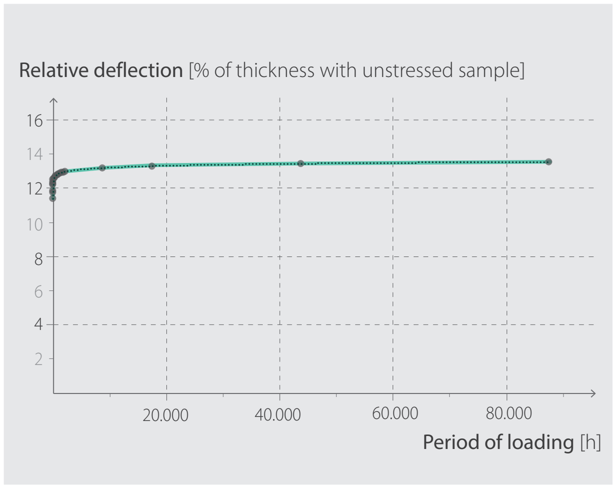
PROPERTY	STANDARD	XYL35100 XYL351000
Hardness	-	35 shore
Elastic modulus 10% (compression)	ISO 604	2.74 MPa
Dynamic stiffness s'	ISO 9052	1262 MN/m³
Creep	EN 1606	< 0.5 %
Compression deformation DVR	ISO 1856	1.5 %
Dynamic elasticity modulus E', 10 Hz (DMA)	ISO 4664	2.16 MPa
Dynamic shear modulus G', 10 Hz (DMA)	ISO 4664	1.13 MPa
Damping factor Tan δ	ISO 4664	0.177
Max processing temperature (TGA)	-	200 °C
Reaction to fire	EN 13501-1	class E

LEGEND	CHART 4 - 6	CHART 3	CHART 5
	tan d (1,0 Hz)	E' (1,0 Hz/MPa)	G' (1,0 Hz/MPa)
	tan d (5,0 Hz)	E' (5,0 Hz/MPa)	G' (5,0 Hz/MPa)
	tan d (10,0 Hz)	E' (10,0 Hz/MPa)	G' (10,0 Hz/MPa)
	tan d (20,0 Hz)	E' (20,0 Hz/MPa)	G' (20,0 Hz/MPa)
	tan d (33,3 Hz)	E' (33,3 Hz/MPa)	G' (33,3 Hz/MPa)
	tan d (50,0 Hz)	E' (50,0 Hz/MPa)	G' (50,0 Hz/MPa)

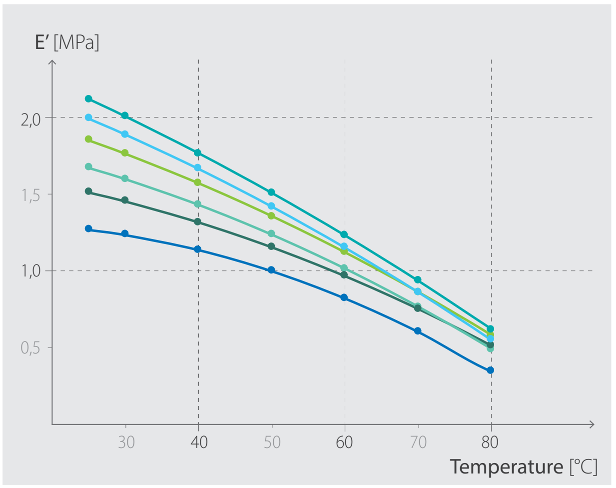
1 | STRESS STRAIN (COMPRESSION)



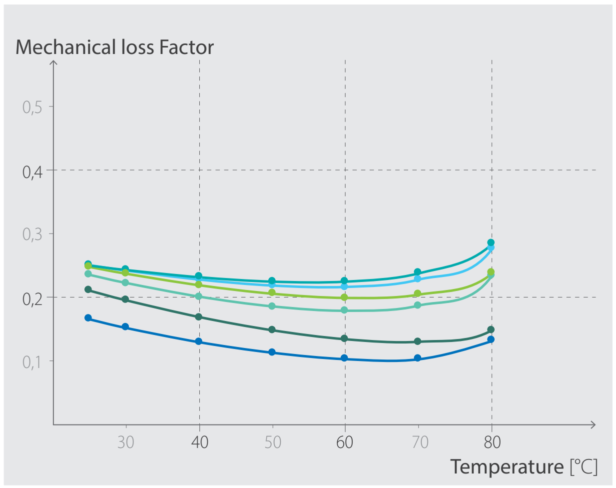
2 | CREEP



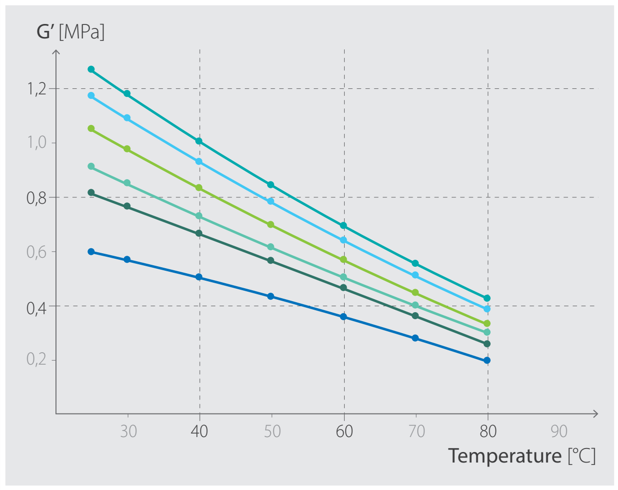
3 | DYN E-MODULUS TENSIL MODE DMTA



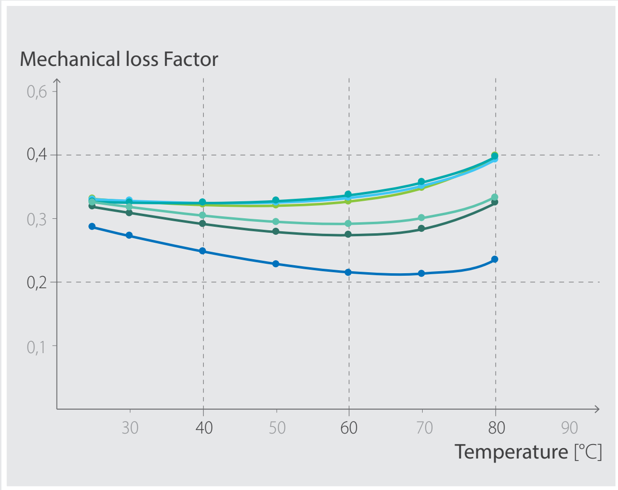
4 | TAN δ TENSIL MODE DMTA



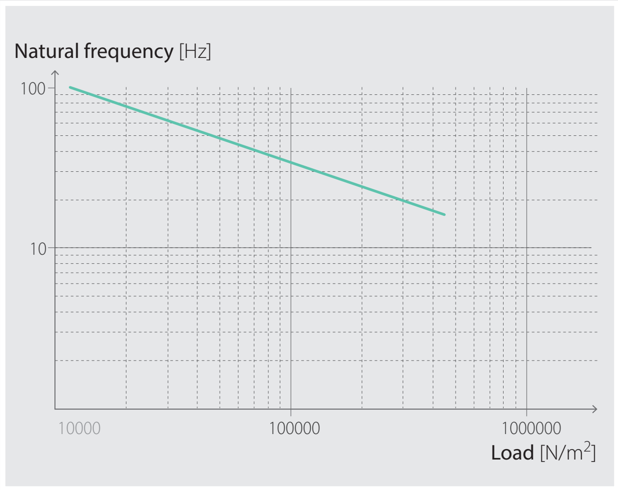
5 | DYN G-MODULUS SHEAR MODE DMTA



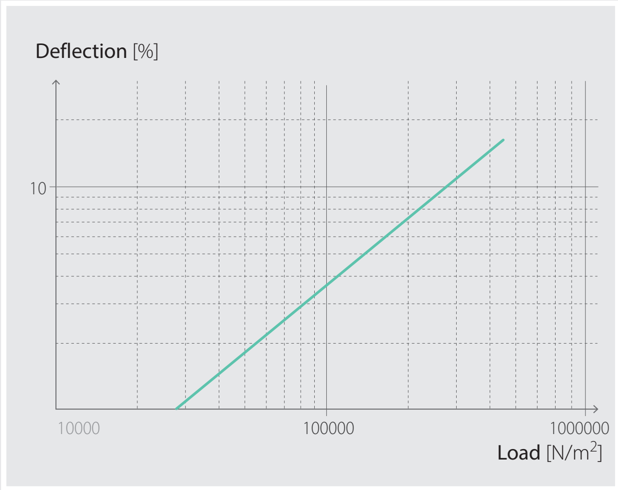
6 | TAN δ SHEAR MODE DMTA



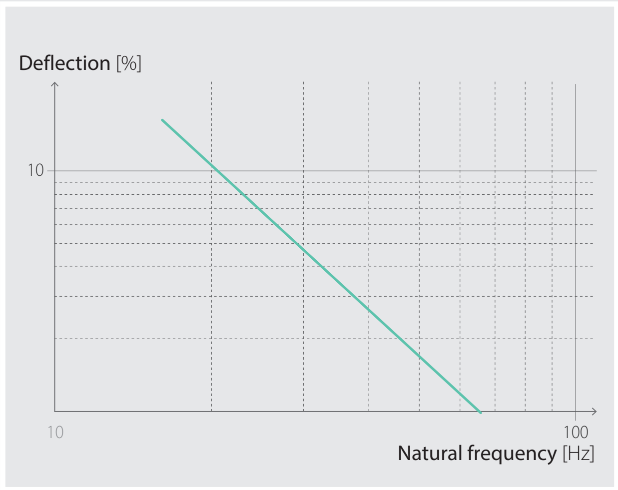
7 | NATURAL FREQUENCY AND LOAD



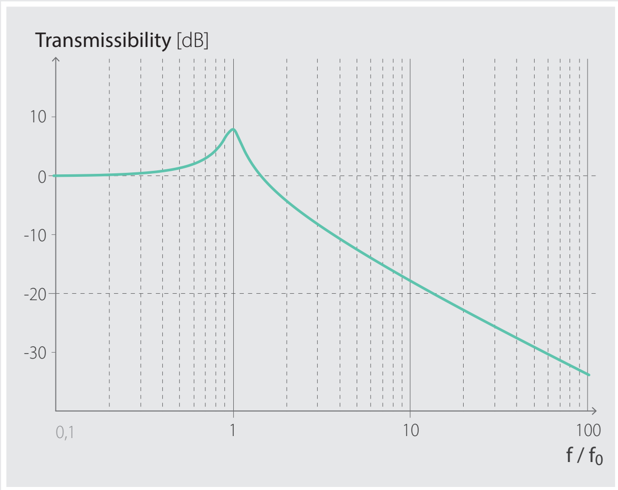
8 | DEFLECTION AND LOAD



9 | DEFLECTION AND NATURAL FREQUENCY



10 | TRANSMISSIBILITY



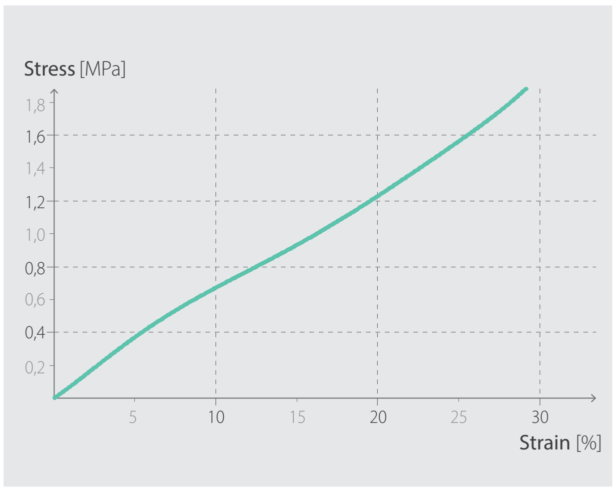
Normalized respect to the resonance frequency.
Elastic modulus from compression tests with 10% deflection.

50 SHORE

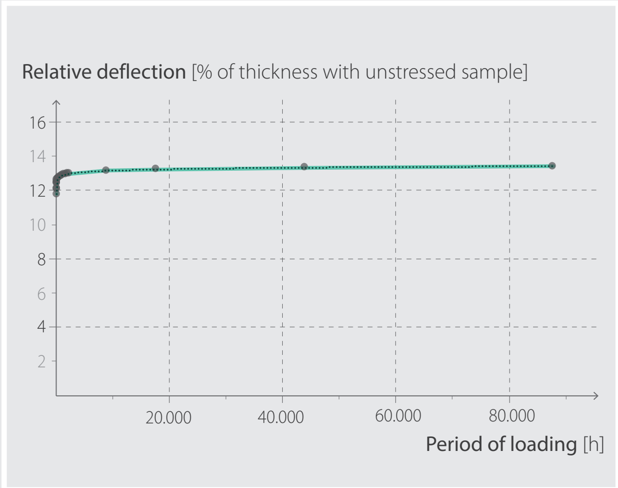
PROPERTY	STANDARD	XYL50100 XYL501000
Hardness	-	50 shore
Elastic modulus 10% (compression)	ISO 604	6.74 MPa
Dynamic stiffness s'	ISO 9052	1455 MN/m^3
Creep	EN 1606	< 0.5 %
Compression deformation DVR	ISO 1856	0.5 %
Dynamic elasticity modulus E', 10 Hz (DMA)	ISO 4664	3.53 MPa
Dynamic shear modulus G', 10 Hz (DMA)	ISO 4664	1.18 MPa
Damping factor Tan δ	ISO 4664	0.132
Max processing temperature (TGA)	-	> 200 °C
Reaction to fire	EN 13501-1	class E

LEGEND	CHART 4 - 6	CHART 3	CHART 5
	tan d (1,0 Hz)	E' (1,0 Hz/MPa)	G' (1,0 Hz/MPa)
	tan d (5,0 Hz)	E' (5,0 Hz/MPa)	G' (5,0 Hz/MPa)
	tan d (10,0 Hz)	E' (10,0 Hz/MPa)	G' (10,0 Hz/MPa)
	tan d (20,0 Hz)	E' (20,0 Hz/MPa)	G' (20,0 Hz/MPa)
	tan d (33,3 Hz)	E' (33,3 Hz/MPa)	G' (33,3 Hz/MPa)
	tan d (50,0 Hz)	E' (50,0 Hz/MPa)	G' (50,0 Hz/MPa)

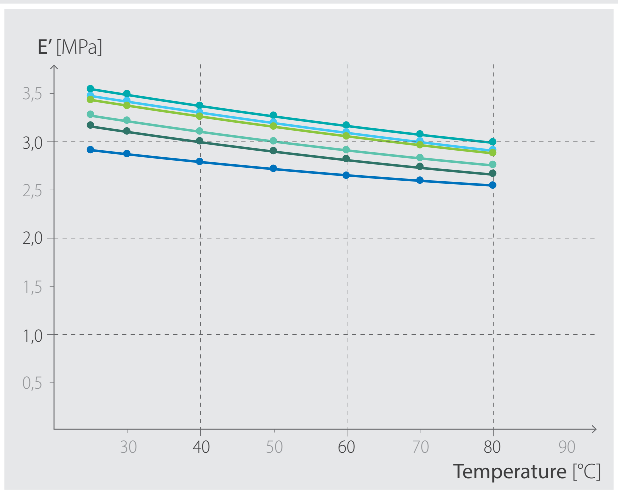
1 | STRESS STRAIN (COMPRESSION)



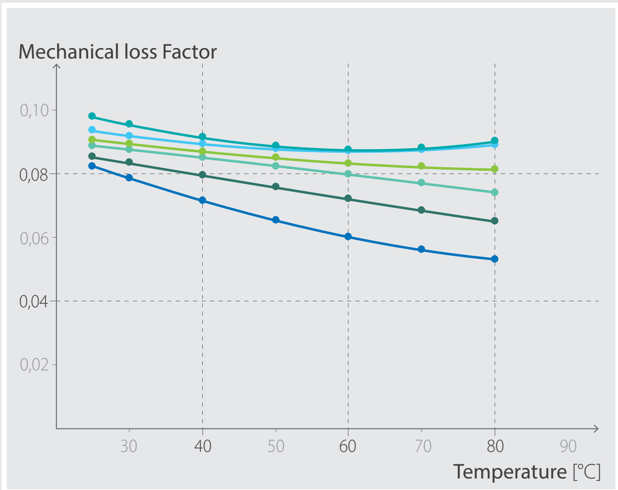
2 | CREEP



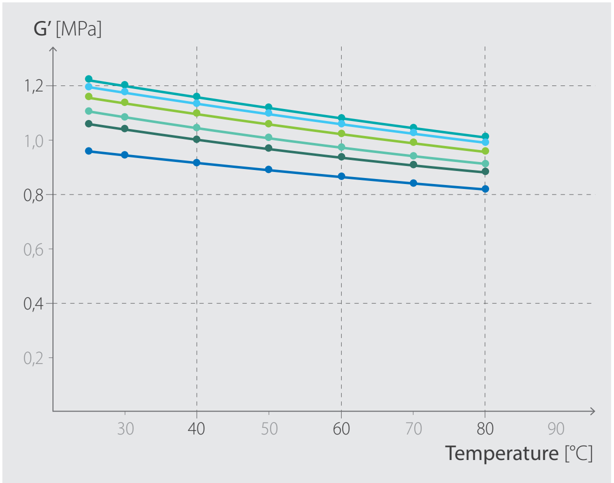
3 | DYN E-MODULUS TENSIL MODE DMTA



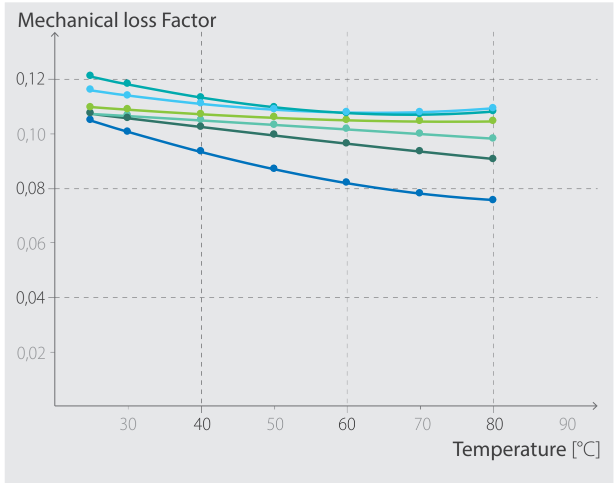
4 | TAN δ TENSIL MODE DMTA



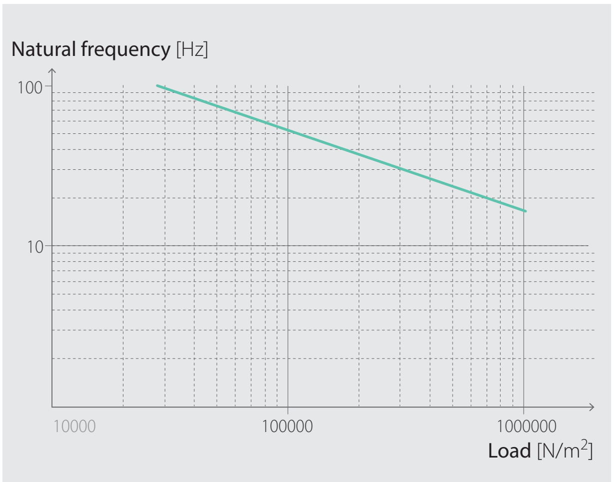
5 | DYN G-MODULUS SHEAR MODE DMTA



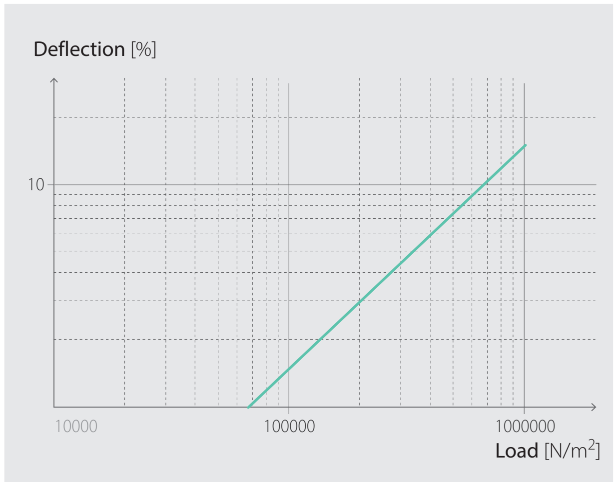
6 | TAN δ SHEAR MODE DMTA



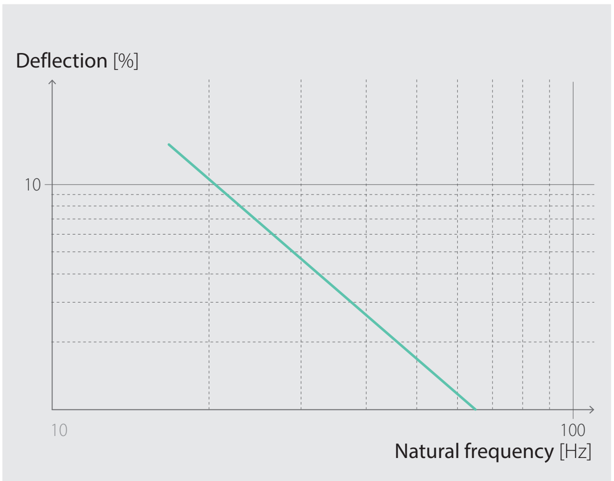
7 | NATURAL FREQUENCY AND LOAD



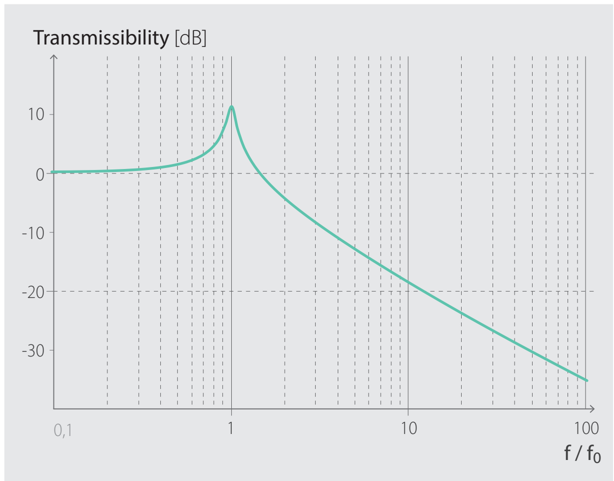
8 | DEFLECTION AND LOAD



9 | DEFLECTION AND NATURAL FREQUENCY



10 | TRANSMISSIBILITY



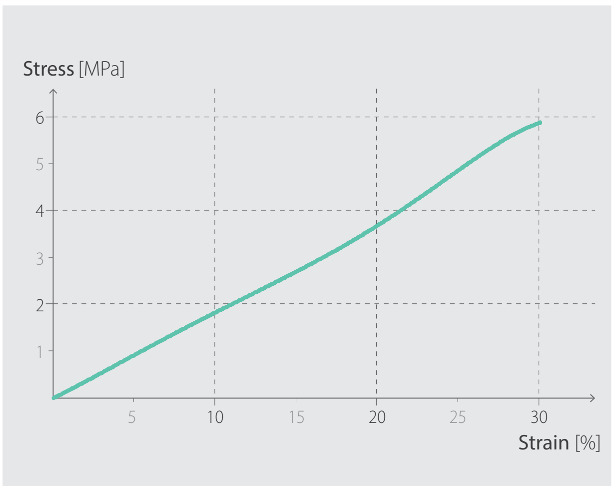
Normalized respect to the resonance frequency.
Elastic modulus from compression tests with 10% deflection.

70 SHORE

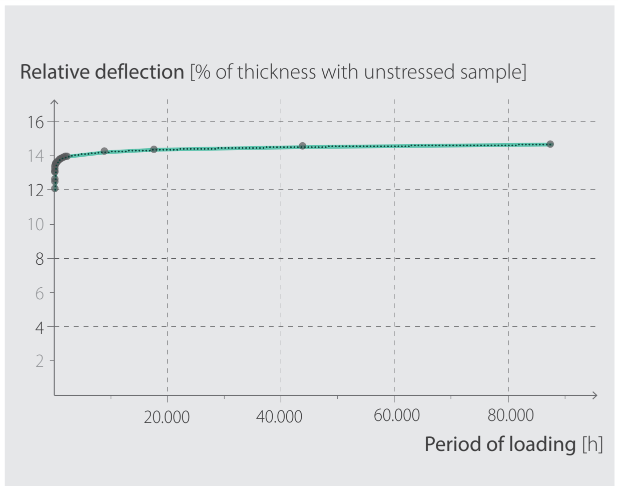
PROPERTY	STANDARD	XYL70100 XYL701000
Hardness	-	70 shore
Elastic modulus 10% (compression)	ISO 604	20.5 MPa
Dynamic stiffness s'	ISO 9052	1822 MN/m³
Creep	EN 1606	< 0.5 %
Compression deformation DVR	ISO 1856	0.3 %
Dynamic elasticity modulus E', 10 Hz (DMA)	ISO 4664	10.1 MPa
Dynamic shear modulus G', 10 Hz (DMA)	ISO 4664	3.24 MPa
Damping factor Tan δ	ISO 4664	0.101
Max processing temperature (TGA)	-	> 200 °C
Reaction to fire	EN 13501-1	class E

LEGEND	CHART 4 - 6	CHART 3	CHART 5
	tan d (1,0 Hz)	E' (1,0 Hz/MPa)	G' (1,0 Hz/MPa)
	tan d (5,0 Hz)	E' (5,0 Hz/MPa)	G' (5,0 Hz/MPa)
	tan d (10,0 Hz)	E' (10,0 Hz/MPa)	G' (10,0 Hz/MPa)
	tan d (20,0 Hz)	E' (20,0 Hz/MPa)	G' (20,0 Hz/MPa)
	tan d (33,3 Hz)	E' (33,3 Hz/MPa)	G' (33,3 Hz/MPa)
	tan d (50,0 Hz)	E' (50,0 Hz/MPa)	G' (50,0 Hz/MPa)

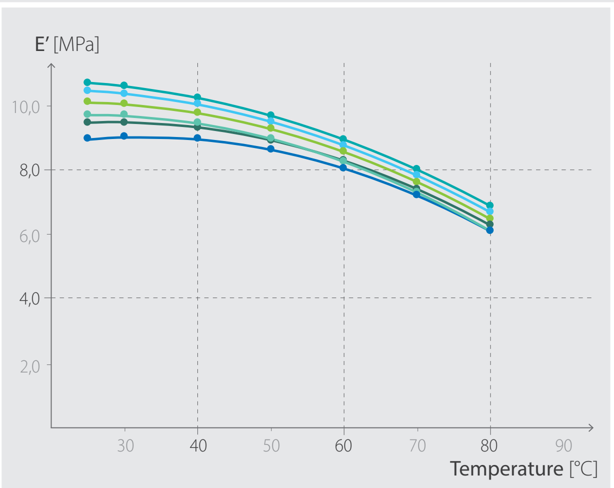
1 | STRESS STRAIN (COMPRESSION)



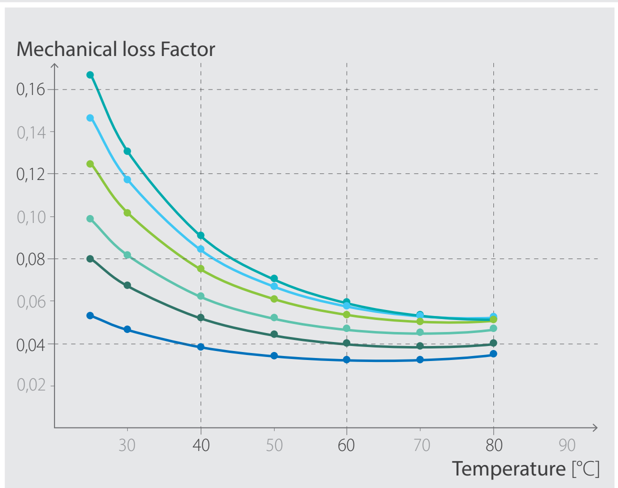
2 | CREEP



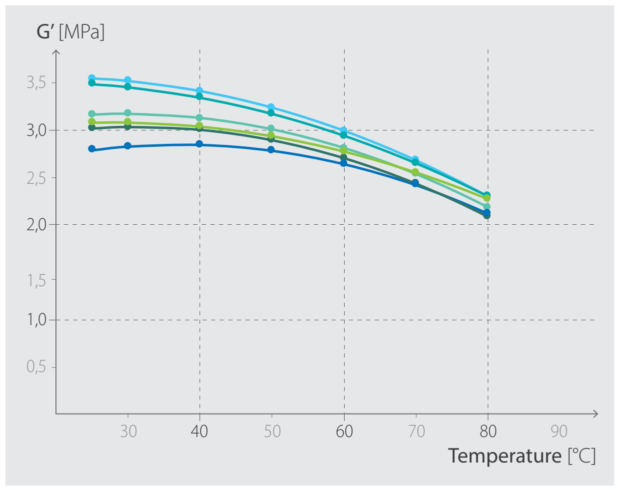
3 | DYN E-MODULUS TENSIL MODE DMTA



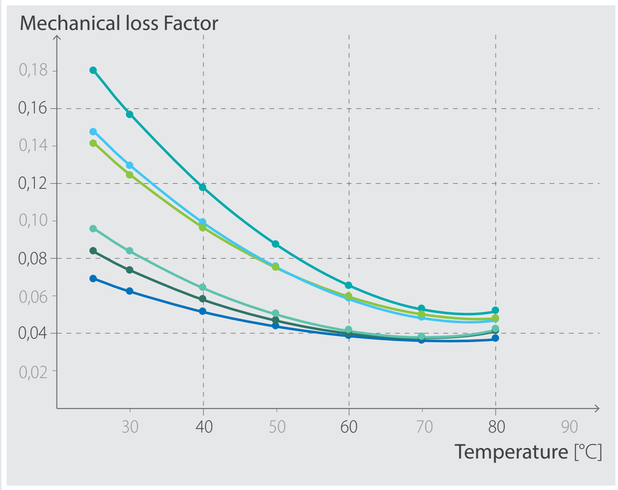
4 | TAN δ TENSIL MODE DMTA



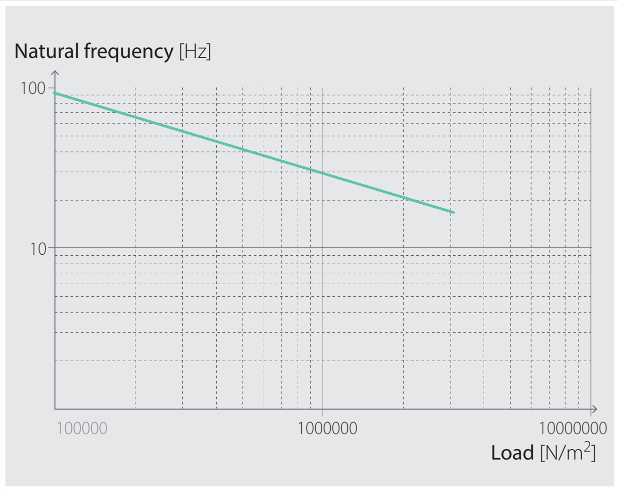
5 | DYN G-MODULUS SHEAR MODE DMTA



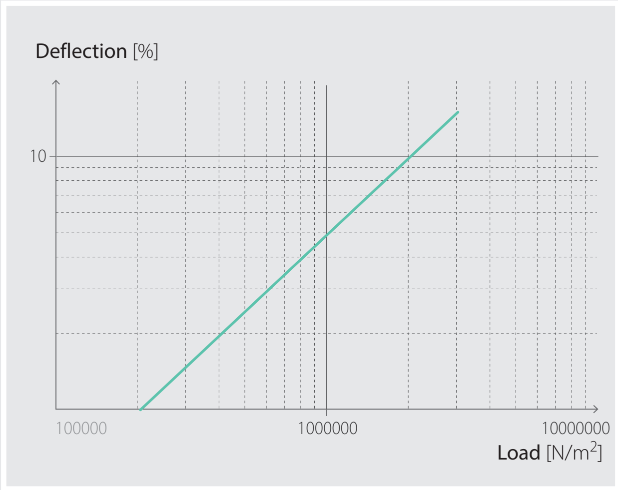
6 | TAN δ SHEAR MODE DMTA



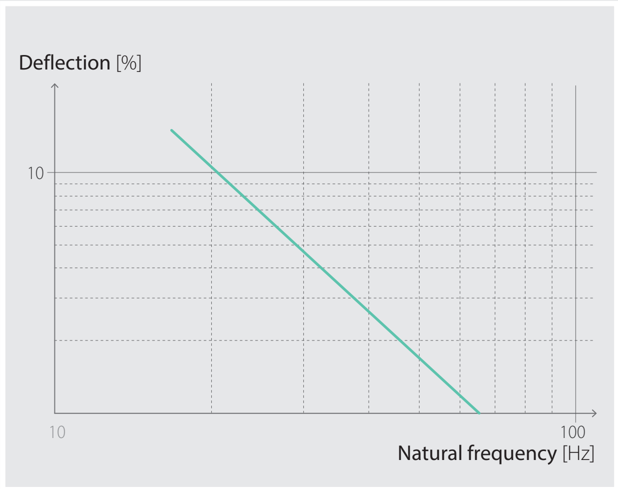
7 | NATURAL FREQUENCY AND LOAD



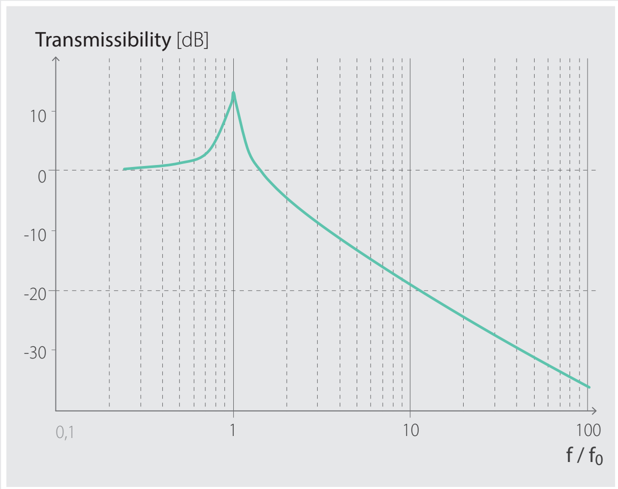
8 | DEFLECTION AND LOAD



9 | DEFLECTION AND NATURAL FREQUENCY



10 | TRANSMISSIBILITY



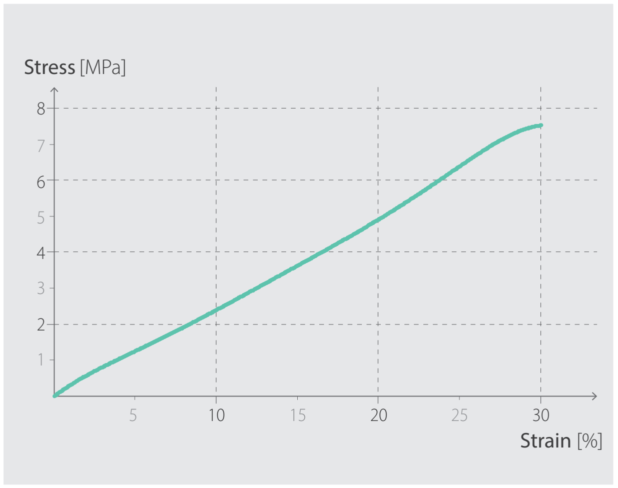
Normalized respect to the resonance frequency.
Elastic modulus from compression tests with 10% deflection.

80 SHORE

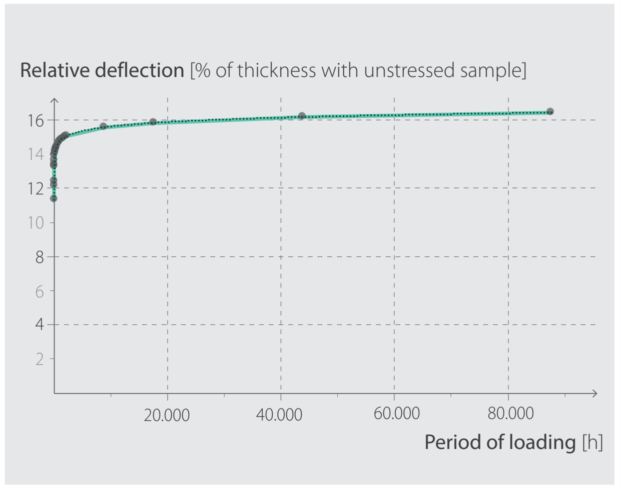
PROPERTY	STANDARD	XYL80100 XYL801000
Hardness	-	80 shore
Elastic modulus 10% (compression)	ISO 604	24.3 MPa
Dynamic stiffness s'	ISO 9052	2157 MN/m³
Creep	EN 1606	< 0.5 %
Compression deformation DVR	ISO 1856	0.9 %
Dynamic elasticity modulus E', 10 Hz (DMA)	ISO 4664	19 MPa
Dynamic shear modulus G', 10 Hz (DMA)	ISO 4664	6.5 MPa
Damping factor Tan δ	ISO 4664	0.134
Max processing temperature (TGA)	-	> 200 °C
Reaction to fire	EN 13501-1	class E

LEGEND	CHART 4 - 6	CHART 3	CHART 5
	tan d (1,0 Hz)	E' (1,0 Hz/MPa)	G' (1,0 Hz/MPa)
	tan d (5,0 Hz)	E' (5,0 Hz/MPa)	G' (5,0 Hz/MPa)
	tan d (10,0 Hz)	E' (10,0 Hz/MPa)	G' (10,0 Hz/MPa)
	tan d (20,0 Hz)	E' (20,0 Hz/MPa)	G' (20,0 Hz/MPa)
	tan d (33,3 Hz)	E' (33,3 Hz/MPa)	G' (33,3 Hz/MPa)
	tan d (50,0 Hz)	E' (50,0 Hz/MPa)	G' (50,0 Hz/MPa)

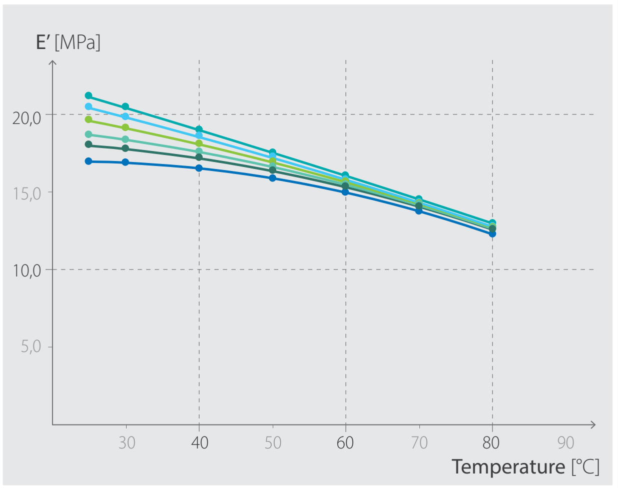
1 | STRESS STRAIN (COMPRESSION)



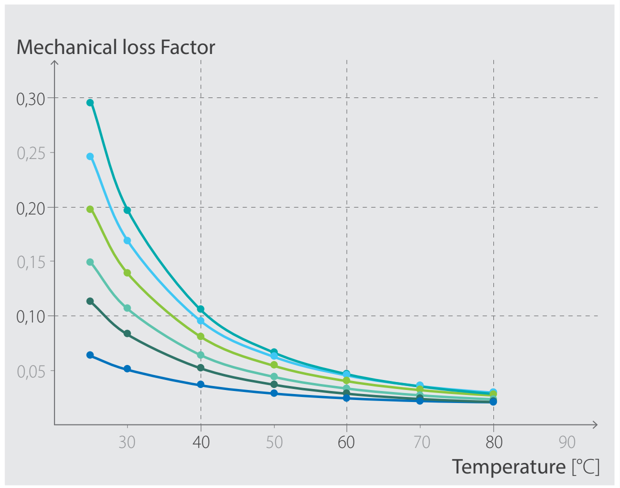
2 | CREEP



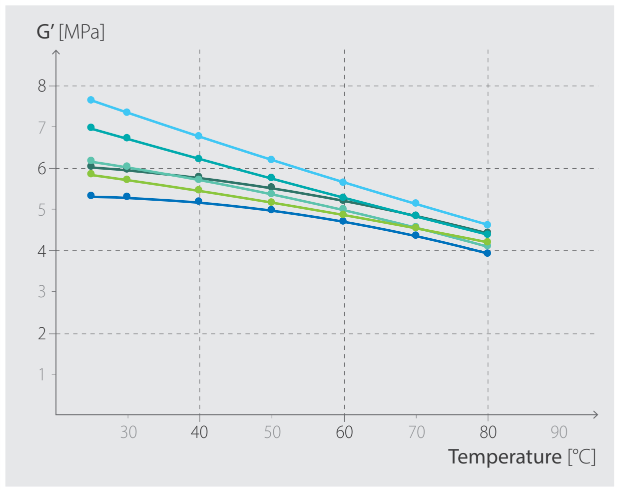
3 | DYN E-MODULUS TENSIL MODE DMTA



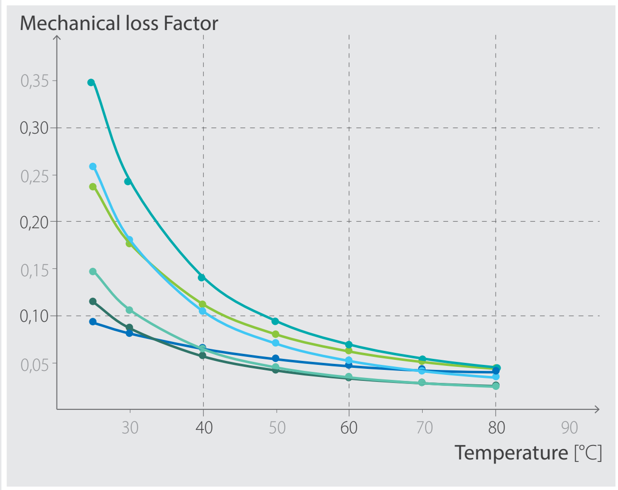
4 | TAN δ TENSIL MODE DMTA



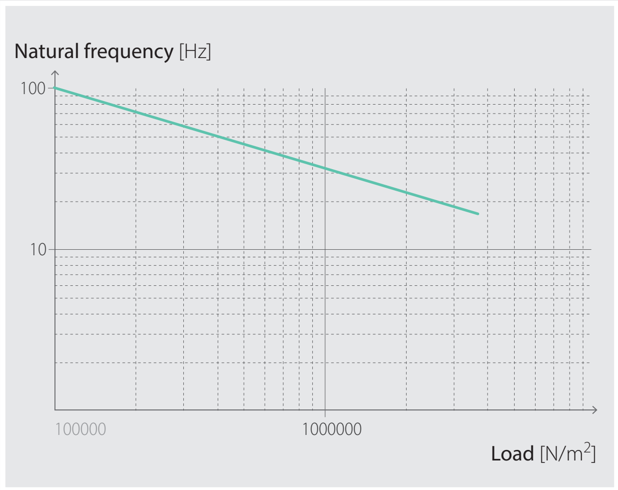
5 | DYN G-MODULUS SHEAR MODE DMTA



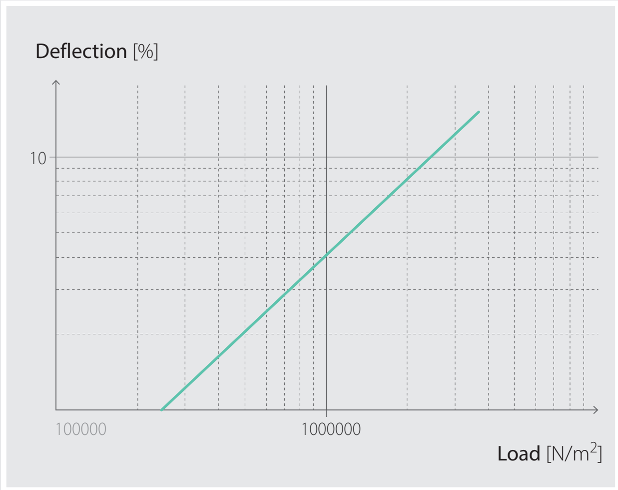
6 | TAN δ SHEAR MODE DMTA



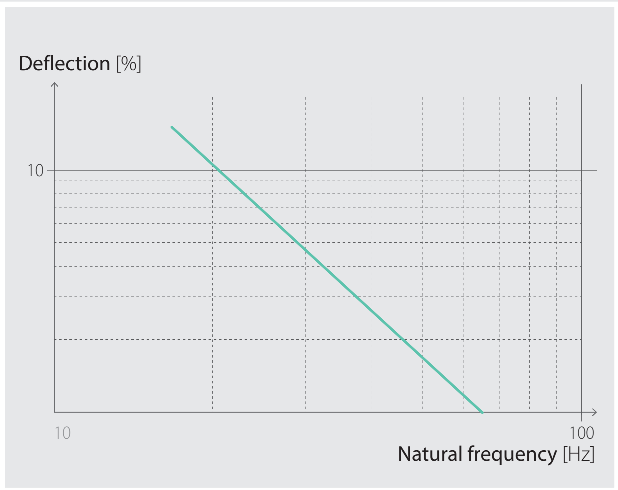
7 | NATURAL FREQUENCY AND LOAD



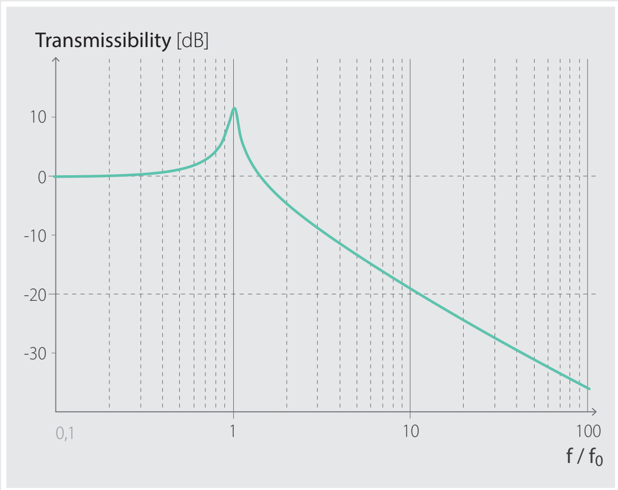
8 | DEFLECTION AND LOAD



9 | DEFLECTION AND NATURAL FREQUENCY



10 | TRANSMISSIBILITY



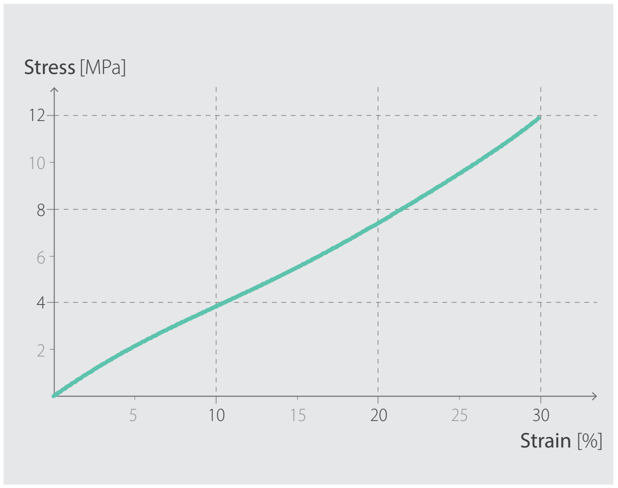
Normalized respect to the resonance frequency.
Elastic modulus from compression tests with 10% deflection.

90 SHORE

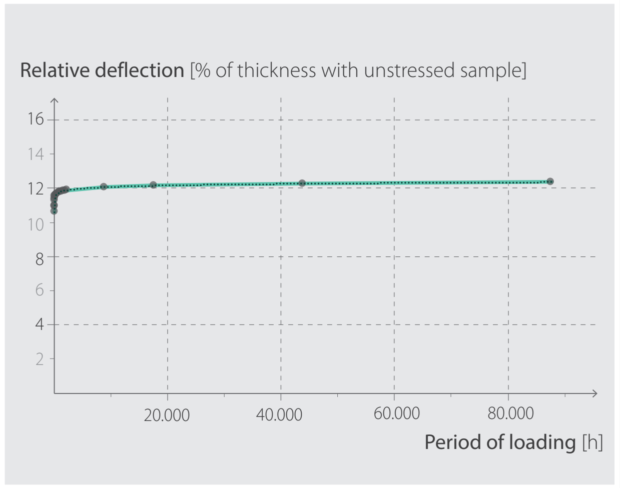
PROPERTY	STANDARD	XYL90120 XYL901000
Hardness	-	90 shore
Elastic modulus 10% (compression)	ISO 604	43.5 MPa
Dynamic stiffness s'	ISO 9052	> 2200 MN/m³
Creep	EN 1606	< 0.5 %
Compression deformation DVR	ISO 1856	3.7 %
Dynamic elasticity modulus E', 10 Hz (DMA)	ISO 4664	43 MPa
Dynamic shear modulus G', 10 Hz (DMA)	ISO 4664	16.7 MPa
Damping factor Tan δ	ISO 4664	0.230
Max processing temperature (TGA)	-	> 200 °C
Reaction to fire	EN 13501-1	class E

LEGEND	CHART 4 - 6	CHART 3	CHART 5
	tan d (1,0 Hz)	E' (1,0 Hz/MPa)	G' (1,0 Hz/MPa)
	tan d (5,0 Hz)	E' (5,0 Hz/MPa)	G' (5,0 Hz/MPa)
	tan d (10,0 Hz)	E' (10,0 Hz/MPa)	G' (10,0 Hz/MPa)
	tan d (20,0 Hz)	E' (20,0 Hz/MPa)	G' (20,0 Hz/MPa)
	tan d (33,3 Hz)	E' (33,3 Hz/MPa)	G' (33,3 Hz/MPa)
	tan d (50,0 Hz)	E' (50,0 Hz/MPa)	G' (50,0 Hz/MPa)

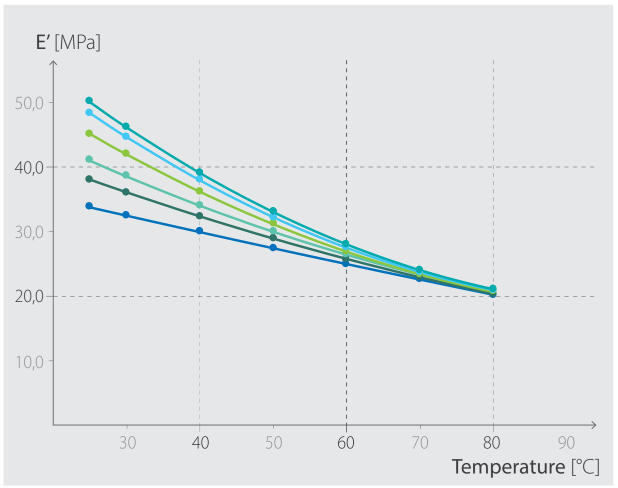
1 | STRESS STRAIN (COMPRESSION)



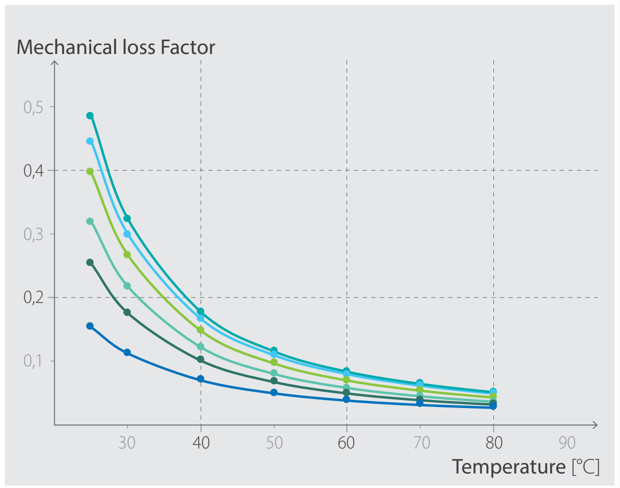
2 | CREEP



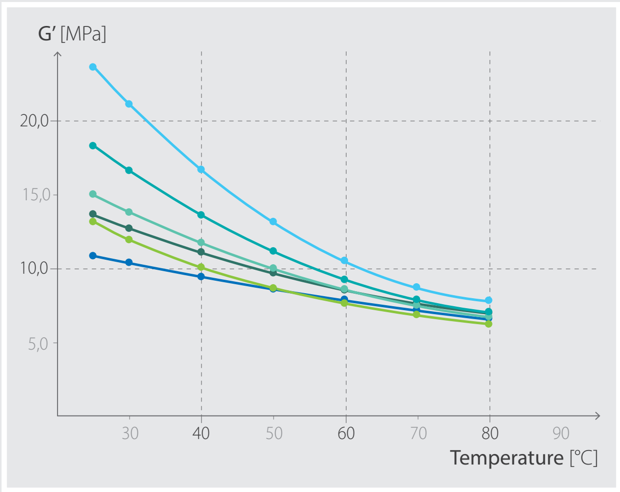
3 | DYN E-MODULUS TENSIL MODE DMTA



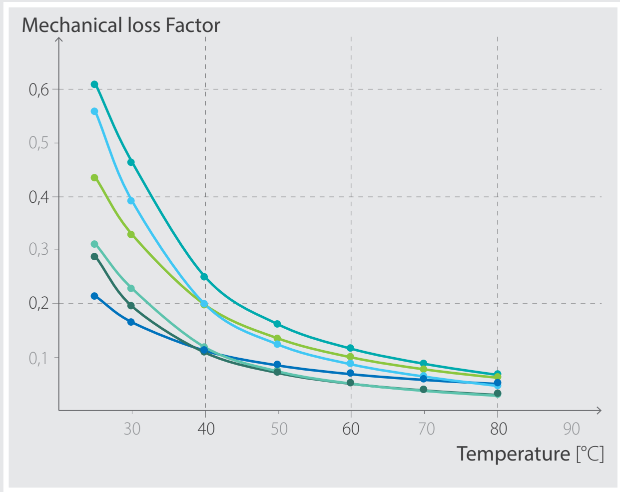
4 | TAN δ TENSIL MODE DMTA



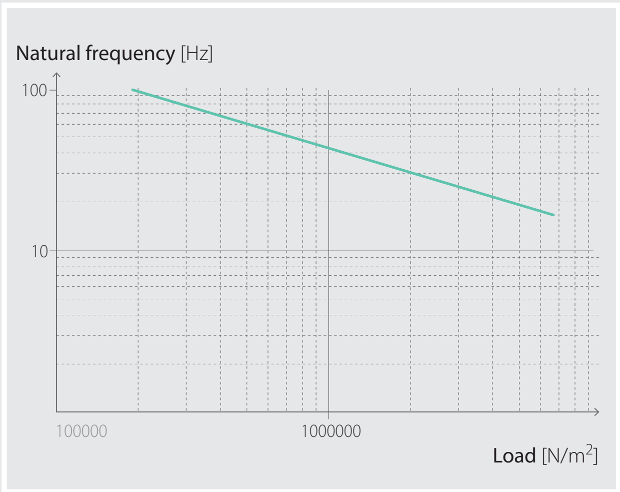
5 | DYN G-MODULUS SHEAR MODE DMTA



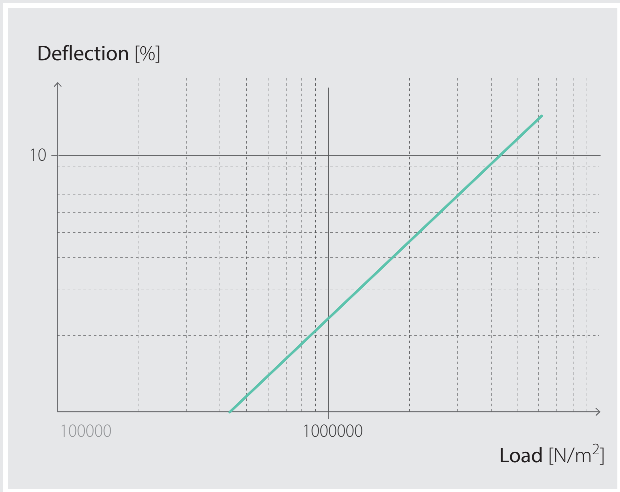
6 | TAN δ SHEAR MODE DMTA



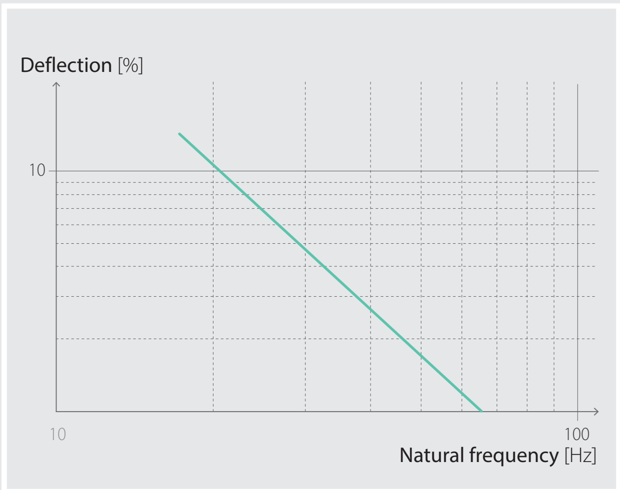
7 | NATURAL FREQUENCY AND LOAD



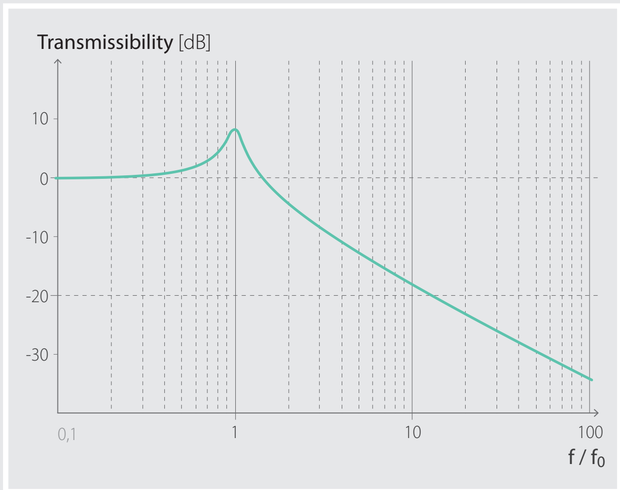
8 | DEFLECTION AND LOAD



9 | DEFLECTION AND NATURAL FREQUENCY



10 | TRANSMISSIBILITY



Normalized respect to the resonance frequency.
Elastic modulus from compression tests with 10% deflection.

NOTES

rothoblaas

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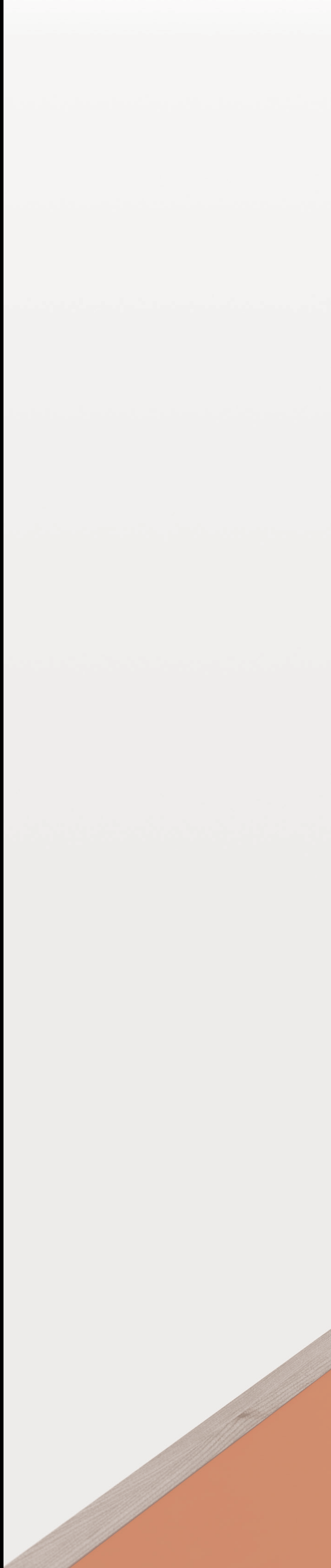

Silent Timber Build

The overall objectives of Silent Timber Build project are to develop prediction models for multi storey buildings using various wooden floor and wall assemblies in the structural elements.