COMPARING PREDICTED AND ON SITE PERFORMANCE OF CLT PARTITIONS AND FLANKING ELEMENTS

N Conlan AECOM, Nottingham
J Casey AECOM, Manchester

1 INTRODUCTION

This paper will address whether predicted sound insulation values for Cross-Laminated Timber (CLT) constructions and built up CLT systems compare well to tested constructions. It is based on two completed projects where the sound insulation measurements on site can be compared to the predicted values, using prediction software.

The paper includes a review of available data for CLT constructions, from both previous papers and suppliers information; and these will also be compared to predicted sound insulation values.

A benefit of using CLT is that it provides a nice surface finish if left exposed, however when exposed the flanking performance of the constructions must be sufficient to maintain the sound insulation performance. A discussion of flanking is included, based on site measurements of constructions with exposed CLT forming a flanking element.

2 CROSS-LAMINATED TIMBER

Cross-Laminated Timber is an engineered timber product with good structural properties and low environmental impact (when sustainably sourced timber is used)[1]. It can be used for constructing large elements off-site which reduces the build time and operations required on site.

The CLT panels are formed by bonding together small sections of timber with a permanent adhesive. The grains in the layers of timber are bonded perpendicularly resulting in improved strength, integrity and stability. Figure 1 shows a three layer panel and a five layer panel.

Figure 1: 3 layer and 5 layer CLT Panels

The panels can be manufactured up to around 18m x 4m as single panels and are generally limited by transportation sizes. The overall weight of constructions is less than other traditional build systems and the onsite construction process requires less skilled operatives than more traditional construction methods such as masonry or light-weight stud partitions.

3 LITERATURE REVIEW

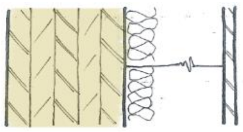
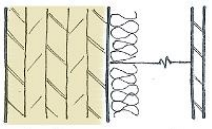
3.1 Past Papers

The following papers have been presented at recent conferences and they include measured values of sound insulation for various CLT based constructions.

3.1.1 Experiences with sound insulation for cross-laminated timber floors

Experiences with sound insulation for cross-laminated timber floors[2] provides measured airborne sound insulation performance for various floor constructions. It includes laboratory test data for 180mm thick CLT panels and raised floor systems. The constructions do not include a ceiling so that the underside of the CLT could be exposed within the spaces below. The tested constructions and sound reduction index are shown in Table 1.

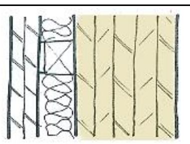
Table 1

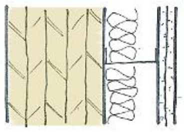
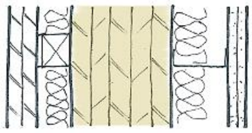
Ref	Section	Description	R'_w dB
1		180mm CLT 123-200 void c/w mineral wool Raised floor with single point isolation Floor boarding and finishes	61
2		160mm CLT 128 void c/w mineral wool Raised floor with continuous isolation Floor boarding and finishes	55

3.1.2 Experimental approach on sound transmission loss of cross-laminated timber floors for building

Experimental approach on sound transmission loss of Cross Laminated Timber floors for building[3] provides the sound insulation performances for various floor constructions, tested in 2006 and 2009. Table 2 shows the results of the measurements which are presented as STC values. In practice these can assumed to be approximately equal to the R_w value. Where two values are shown, these are for the values measured in 2006 and 2009 respectively.

Table 2

Ref	Section	Description	STC dB
3		146mm CLT Panel	39; 38
4		2 x 22mm Particle board Isolated Timber Battens 53mm void c/w mineral wool 146mm CLT Panel	55

5		146mm CLT Panel 87mm void c/w mineral wool 2 x 13mm Gypsum boards on resilient supports	64; 63
6		Constructions 4 and 5 combined	67

3.1.3 Sound insulation performance of cross laminated timber building systems

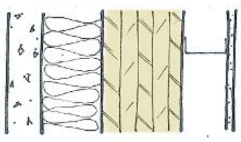
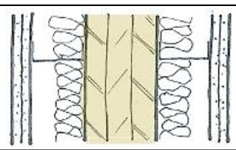
Sound insulation performance of cross laminated timber building systems[4] provides test data of the sound insulation and flanking contribution of CLT panels.

The paper includes the measured loss factors and Vibration reduction index associated with continuous and non-continuous junction details. These are then used to predict the flanking transmission across the junctions.

3.1.4 Acoustic performance of cross-laminated timber system (CLT): In situ measurements of airborne and impact sound insulation for different configurations

Acoustic performance of cross-laminated timber system (CLT): In situ measurements of airborne and impact sound insulation for different configurations[5] provides details of CLT constructions which meet suitable standards for residential buildings. The measured apparent sound reduction index of the constructions is shown in Table 3.

Table 3

Ref	Section	Description	R'_w ($C;C_{tr}$) dB
7		50mm sand and cement screed 130mm lightweight infill 144mm CLT Panel 87mm void c/w mineral wool 12.5mm plasterboard	64 (-4;-10)
8		2 x 12.5mm plasterboard 75mm void c/w mineral wool 95mm CLT Panel 75mm void c/w mineral wool 2 x 12.5mm plasterboard	64 (-2;-6)

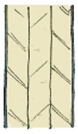
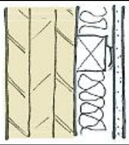
3.2 Suppliers Literature

Various suppliers include sound insulation performances of their products on the company websites.

3.2.1 Storo Ensa

Stora Ensa[6] have various brochures and technical documents available to download including a sample of constructions suitable for internal partitions with weighted sound reduction indexes for each. These are reproduced in Table 4.

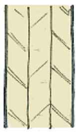
Table 4

Ref	Section	Description	R_w (C;C_{tr}) dB
9		100mm CLT	34 (-1;-3)
10		100mm CLT 50mm void c/w mineral wool 12.5mm Fireboard on isolated studs	51 (-2;-8)
11		100mm CLT 50mm void c/w mineral wool 12.5mm Fireboard on timber studs	45 (-1;-5)

3.2.2. KLH

KLH produces a technical characteristics document[7] which provides the sound reduction of unlined CLT panels and these are shown in Table 5.

Table 5

Ref	Section	Description	R_w dB
12		94mm CLT 3 layer panels	33
13		145mm CLT 5 layer panels	37

4 PREDICTED SOUND INSULATION

To compare the measured values of CLT constructions with predicted values, the predictions have been made using industry standard prediction software. The unlined CLT has been modelled as a single thickness of plywood, with the density changed to 500kg/m^3 to reflect the density of CLT.

When additional linings have been added, the method of fixing the lining can have a considerable effect on the predicted performance depending on the degree of isolation that the lining method provides. This can be affected by the properties of the fixings and the separation distances between fixings.

For some comparisons, two values of prediction have been provided with different fixing method.

Table 6 shows the measured performance values for the constructions 1 to 13 detailed in the previous section. It then shows the predicted weighted sound reduction index of the constructions and comments are included to show the assumptions used for the predictions.

Table 6: Comparison of measured and predicted performance of CLT

Construction reference	Measured R_w, R'_w or STC	Predicted $R_w(C{:}C_{tr})$	Comments
1	61	62 (-4;-10)	Assumed boarding of 14.5kg/m^2 and 150mm void
2	55	57 (-2;-7)	Assumed 14.5kg/m^2 board and 300mm spacing of supports
3	39 38	38 (-2;-6)	
4	55	58 (-3;-8)	
5	64 63	59 (-2;-8) 62 (-3;-10)	Variation of performance depends on the degree of isolation from supports
6	67	73 (-4;-11)	
7	64 (-4;-10)	63 (-1;-6)	Predicted without lightweight insulation
8	64 (-2;-6)	67 (-2;-7) 66 (-1;-6)	With steel stud connections With timber stud and resilient bar
9	34 (-1;-3)	33 (-1;-4)	
10	51 (-2;-8)	48 (-2;-8)	Assumed 10kg/m^2 board
11	45 (-1;-5)	42 (-1;-6) 47 (-2;-7)	Timber stud and 10kg/m^2 board Steel stud and 10kg/m^2 board
12	33	32 (0;-3)	
13	37	38 (-2;-6)	

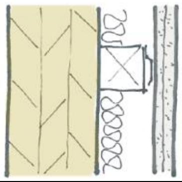
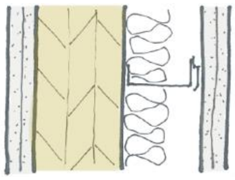
The difference between the measured and predicted single figure values for the unlined CLT was no more than 1dB for constructions 3, 9, 12 and 13. The largest variation was for construction 6, which was a triple panel construction and this would be expected to have the greatest tolerance as a result.

For the two panel systems the margin of error was within the ±3dB range that the software suggests for the tolerance of the predictions.

5 MEASURED ON-SITE SOUND INSULATION

This section compares the on-site performance and predicted performance of two different CLT constructions, which have been measured in two or more separate locations. The details of the constructions and the measured and predicted values are shown in Table 7.

Table 7: Comparison of on-site measured and predicted sound reduction indexes

Ref	Section	Description	Measured R'_w (C;C_{tr}) dB	Predicted R_w (C:C_{tr}) dB
A		95mm CLT 66mm void c/w mineral wool 2 x 12.5mm wall board on resilient bars	53 (-1;-6) 50 (-1;-6)	51 (-1;-6)
B		2 x 15mm Sounbloc board 95mm CLT 85mm void c/w mineral wool 2 x 15mm Soundbloc board on independent wall liner system	59 (-3;-8) 59 (-2;-7) 59 (-3;-8)	62 (-1;-5)

A review of the 1/3rd octave band measurements and predicted levels are shown in Figure 2 for construction reference A and in Figure 3 for construction reference B.

Frequency f Hz	Predicted R (one-third octave) dB	R' (one-third octave) dB	R' (one-third octave) dB
50	21.0	24.4	29.2
63	23.0	22.7	27.2
80	29.0	26.9	28.1
100	33.0	35.7	30.8
125	35.0	35.1	34.8
160	38.0	38.7	33.1
200	37.0	38.6	35.3
250	38.0	42.4	36.8
315	41.0	44.3	41.6
400	45.0	47.9	44.4
500	48.0	50.4	48.9
630	51.0	52.7	52.1
800	54.0	56.3	55.0
1000	57.0	54.8	58.1
1250	60.0	56.9	59.7
1600	63.0	58.0	63.0
2000	65.0	62.3	65.5
2500	69.0	64.5	67.0
3150	70.0	65.7	68.6
4000	72.0	67.2	69.4
5000	74.0	71.4	69.3

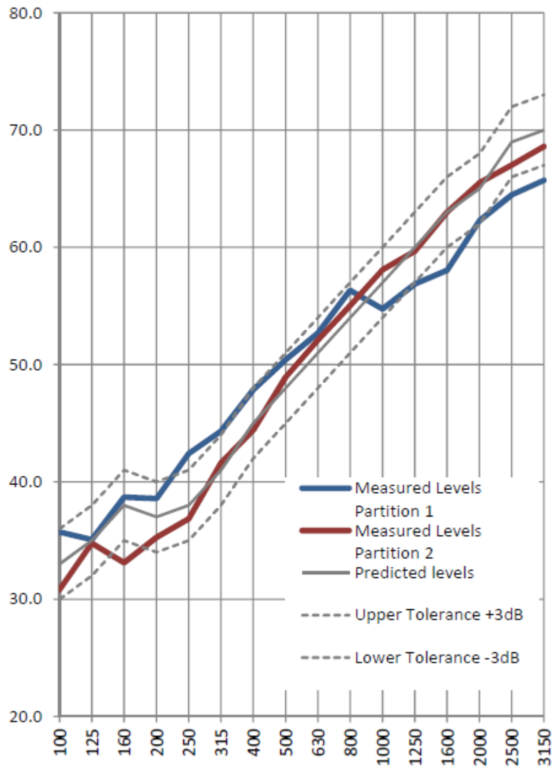


Figure 2: Predicted and measured sound insulation values for construction A

For construction A, the tested construction had good detailing at the wall junctions and a separated floating screed, which should have controlled the flanking paths to below the contribution through the separating walls.

The single figure measured performances are within 3dB of the predicted level and the 1/3rd octave band levels are also very similar to the predicted values, with only a small number of values outside of the ±3dB tolerance.

Frequency *f* Hz	Predicted R (one-third octave) dB	R' (one-third octave) dB	R' (one-third octave) dB	R' (one-third octave) dB
50	31.0	28.2	23.4	26.4
63	36.0	34.4	34.5	33.9
80	39.0	32.8	30.6	30.7
100	43.0	34.8	35.7	33.8
125	47.0	36.5	37.5	39.8
160	50.0	44.5	42.5	46.7
200	52.0	48.2	46.3	46.3
250	52.0	50.2	51.1	47.8
315	51.0	52.6	54.3	48.6
400	54.0	56.0	57.9	56.0
500	57.0	58.7	59.5	57.4
630	60.0	60.1	61.2	59.8
800	63.0	59.3	61.4	60.0
1000	65.0	63.0	63.6	62.4
1250	68.0	62.9	63.0	64.2
1600	71.0	61.0	61.9	62.9
2000	73.0	60.5	61.8	61.4
2500	74.0	60.8	61.6	62.2
3150	77.0	63.5	65.2	65.6
4000	80.0	66.4	71.6	70.6
5000	82.0	71.6	75.8	74.7

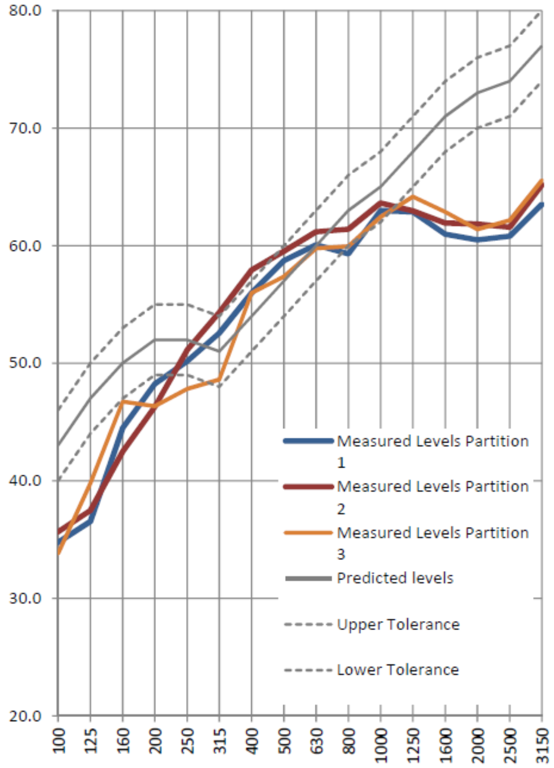


Figure 3: Predicted and measured sound insulation values for construction B

For construction B, the tested partitions initially failed to meet the required sound insulation performance due to cross talk via common ductwork. The test data shown is following the remedial work, however there is still a drop in performance below the predicted values at high frequencies. This is probably due to remaining cross talk transmission between the rooms.

There is also an over predication in performance at low frequency, which can occur for some constructions. Within the middle frequencies the measured and predicted levels are very similar. The measured single figure performance was 3dB worse than the predicted value, and the C_{tr} correction was a further 2-3dB worse than the predicted value.

6 STRUCTURAL FLANKING CONTRIBUTION

On one of the projects undertaken, it was an architectural request to have the CLT exposed at the soffit. We highlighted the risk of structural flanking and originally felt that an exposed soffit would not be possible, particularly between two music classrooms. The contractor for the project had recently completed another CLT school and suggested we undertake some research measurements to see if we could quantity the flanking performance.

To do this we selected a source and receiver room, in a non-sensitive area of the school, which had an exposed CLT flanking wall. The panels had vertical joints, parallel to the separating partition, so we could measure the vibration levels in the separate CLT panels and determine the loss at each of the panel joints.

We measured the vibration levels on the separating wall, flanking wall and floor. We could then use the velocity levels at each panel to determine the sound power contribution from each element. The contribution from the flanking element was predicted and indicated that, provided the CLT panels had a junction close to the separating wall , flanking transmission through it should not impact on achieving the required sound insulation.

On the basis of these research measurements, the school proceeded with an exposed CLT soffit. Testing at completion showed that the partition to music rooms (shown in Figure 4) achieved 55 dB $D_{nT,w}$ on site.

Figure 4: Classroom with exposed CLT soffit; which achieve 55dB D_{nTw} on site

7 REFERENCES

1. BRE Information Paper IP 17/11 Cross-laminated Timber 'An introduction to low-impact building materials. Andy Sutton and Daniel Black, BRE & Pete Walker, University of Bath
2. Experiences with sound insulation for cross laminated timber floors Anders Homb, Jan Arne Austnes, Proceedings of BNAM 2010, Bergen 2010
3. Experimental approach on sound transmission loss of CLT floors for building Jean-Luc Kouyoumji; Sylvian Gagnon Proceedings of Internoise 2010; Lisbon 2010
4. Sound insulation performance of cross laminated timber building systems
5. Acoustic performance of cross-laminated timber system (CLT) :In situ measurements of airborne and impact sound insulation for different configurations
6. http://www.clt.info/en/wp-content/uploads/sites/6/2013/07/Soundproofing-of-CLT-internal-wall-structures.pdf
7. http://www.klhuk.com/media/29233/technical%20characteristics.pdf