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DEVELOPMENT OF TWO LIGHT FRAME WALL SYSTEMS FOR DWELLINGS

K. McGunnigle

Prendos Ltd, 36 Cumberland Avenue, 1002, Auckland, New Zealand

Tel.: +64 9 486 1973 / Fax: +64 9 486 1963 / Email: kenm@kiwilink.co.nz

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ABSTRACT
In New Zealand the predominant form of construction for dwellings is light timber frame, with plasterboard wall linings and particle board floors. Many of the competing system manufacturers believe that plasterboard enjoys a unique technical and economic advantage, which is unassailable. The New Zealand Building Code (NZBC) is performance based and there are significant barriers to any new forms of construction entering the market. The minimum NZBC sound insulation performance between abutting occupancies is a laboratory result of STC 55. However, two recent developments have provided sound insulation laboratory performances in excess of STC 60 without the use of plasterboard. Firstly, A modification of the traditional, double timber frame wall system; substituting James Hardie fibre cement sheets in lieu of plasterboard. The acoustic absorber in the cavity is a mineral fibre blanket designed specifically for fire resistance. Secondly, A particle board, panellised double skin system which replaces the traditional double frame timber wall. The high performance of the particle board panels is intended to offset the significant flanking which is expected to occur at the simple joints to the wall/floor junctions. Further on site measurement and investigation of junction performance is planned.

1 - JAMES HARDIE 9 MM VILLABOARD ON BOTH SIDES OF DOUBLE FRAME

Fibre cement wall linings within New Zealand homes are primarily promoted in water proofing systems to wet areas such as showers and bathrooms. Therefore the wall system under consideration had to have a multi-functional capability, including water resistance, structural load bearing, wind and earthquake bracing, fire resistance, impact resistance, smooth finish, economic, simple to construct, use readily available manufactured products as well as possessing a satisfactory sound insulation performance. A further consideration is that James Hardie fibre cement is resistant to inclement weather during the building phase.

The first phase of this development was in regard to the fire rated performance of the fibre cement panel system because it would have been pointless to carry out any acoustic work if the fire criteria could not be met. A fire rating of one hour was attained with a 9 mm fibre cement lining on timber studs with a heavy double layer of mineral wool bulk insulation in the cavity.

There was scant previous acoustic performance history for wall systems using fibre cement as the only lining material. Therefore, prior to commencing any laboratory tests in 1999, a prediction programme, based on Ben Sharps work [1], was used to model and estimate the performance of various combinations of fibre cement panels. The choices were based on perceived economy, simplicity of construction, availability of manufactured product as well as performance. A number of single steel stud possibilities were considered and their sound insulation performance was good, but they were discounted due to the lack of fire resistance capability and consequently the traditional double timber stud framing was selected as the most favoured wall construction. The lining options are set out in Table 1 as follows.

Performance Prediction STC	**Cavity width (mm)**	**Construction of fibre cement Panels**		**Comment**
		Panel 1 (mm)	**Panel 2 (mm)**	
50	92	2 × 4.5	2 × 4.5	Failed NZ Building Code requirement
54	144	2 ×4.5	2 × 4.5	Failed NZ Building Code requirement
57	215	2 ×4.5	2 × 4.5	Costly
50	215	1 × 6	1 × 6	Failed NZ Building Code requirement
52	313	1 × 6	1 × 6	Failed NZ Building Code requirement
55	215	1 × 6 compressed	1 × 6 compressed	A promising innovation but this board was not normally manufactured
54	215	1 × 9	1 × 6	Failed NZ Building Code requirement
57	215	1 × 9	1 × 9	Provides a simple solution

Table 1: Inter tenancy wall options for wet areas.

Note 1: The estimate is ± 3 and is from a prediction model. To give greater certainty laboratory results are necessary.
Note 2: The predictions are based on a bulk fibreglass absorber in the cavity equivalent to a flow resistance of 120 rayls.

2 - ANALYSIS

It is apparent from table 1 that the double layers of 4.5 mm sheet perform quite well, but the cost of labour required to fix two sheets instead of one makes this system unattractive. A narrow wall would be desirable but only the wider cavity of 215 mm provided a satisfactory result. A single layer system using 6 mm sheets failed to meet the STC 55 requirement except for a higher density board such as 6 mm compressed fibre cement. However this product is not normally manufactured and consequently could not be tested, although it may be used in future. The next higher thickness of board available was 9 mm and a simple solution was provided with an estimated performance of STC 57. This system was attractive because it was simple, used traditional framing methods, had only one layer of fibre cement sheet with the same thickness on each side and was perceived to be cost effective. Furthermore it had proven capability in the other functional areas including structural load bearing, bracing, fire, water resistance, impact resistance and surface finish.
The prediction software includes a bulk absorber in the cavity equivalent to one layer with a flow resistance of about 120 rayls. The fire performance of the fibre cement system required a double layer of high density mineral fibre bulk insulation in the cavity. This fire requirement to fill the cavity with a heavy bulk absorber had advantages for the acoustic performance, which would not normally be considered due to cost. Consequently the laboratory result of STC 61 was 4 STC points higher than the prediction estimate. Refer to figure 1.
Rating according to ISO 717-1: $\boldsymbol{R}_{\mathrm{w}} = \mathbf{60}$
Rating according to ASTM E413: **STC = 61**
Description and identification of the test specimen and test arrangement:
James Hardie 9 mm Villaboard on both sides of double frame. Frame: 90 × 45 mm dry frame offset studs at 600 mm centres; nogs at 800 mm centres; cavity fit tightly with 38 mm (820° 120 kg/m^3) mineral fibre insulation; Villaboard fixed with 40 × 2.8 Hardiflex nails at 200 mm centres to studs and plates only; stopped with villaboard bedding compound and paper tape, finished with villaboard finishing compound.

3 - PARTICLE BOARD 36 MM WITH 100 MM CAVITY AND ABSORBER AND 2 X 18 MM LAMINATED MEDIUM DENSITY FIBREBOARD

The market for this system is aimed at dwellings to compete with light timber frame methods and in particular plasterboard systems. It may also have other applications in schools and commercial buildings. It is a whole building approach; the structural design and surface finish is based on Particle

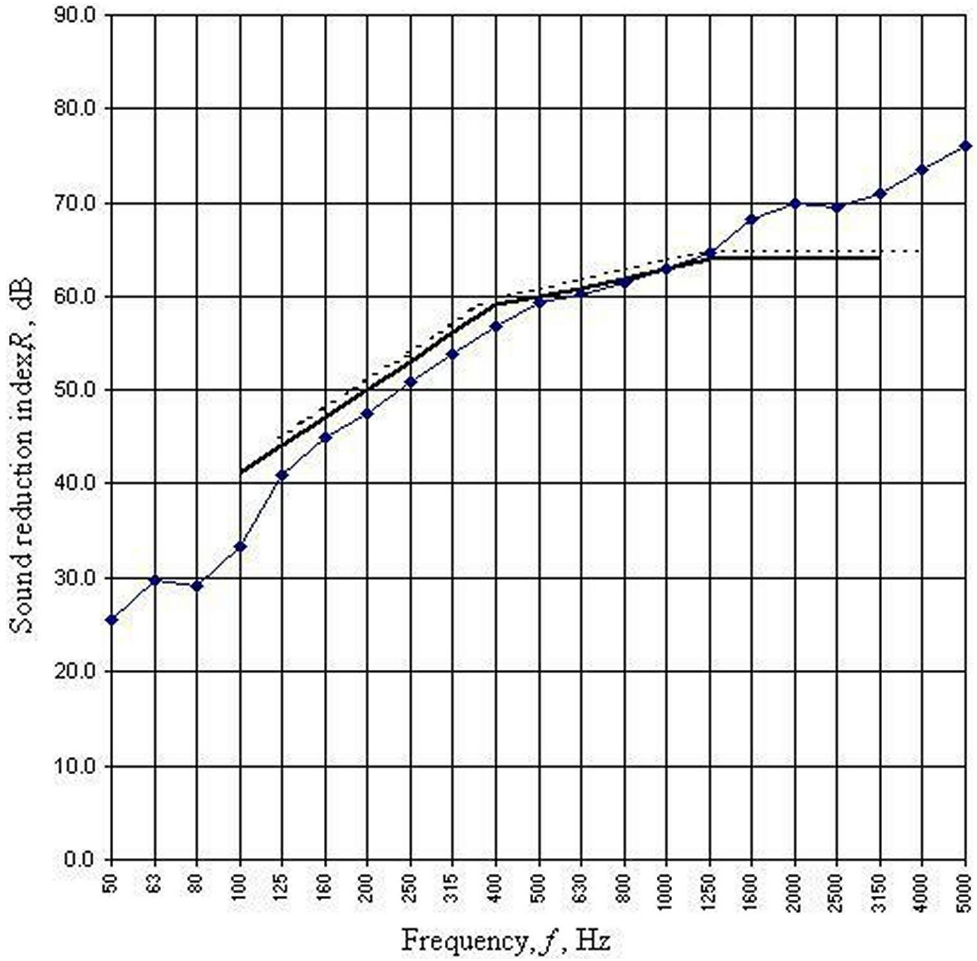

Figure 1: Laboratory result for fibre cement wall lining system (dash: curve of ASTM E413 reference values; curve of ISO 717−1 reference values).

board, including walls, floors and ceilings. The benefits are off site detailing and prefabrication, quick construction period and economy.

A double panel 36 mm Particle board wall with a bulk fibreglass absorber in the 94 mm cavity was tested on site in 1997 with a performance of STC 37. An on-site performance of STC 37 for a double panel system is quite poor and at this stage the panel system did not show much promise for use in multi-unit apartment buildings. The test report did not consider the development of a laminated panel to improve the performance of the double panel wall system. The most likely reason for the poor performance was flanking around the wall due to the junction details at the floor, ceiling and side walls.

Prior to commencing any laboratory tests in 1999, a prediction programme was used to estimate the performance of various combinations of Particle board panels. The choices were based on perceived economy, simplicity of construction and manufacture as well as performance. These are tabulated as follows.

Performance Prediction STC	Construction of particle board Panels		Comment
	Panel 1 (mm)	Panel 2 (mm)	
51	36	36	Failed NZ Building Code requirement
54	18 × 2	18	Not structurally adequate
54	36	24	Uses a non-standard 24 mm thickness
56	36	36+18	Complex and costly
60	18 × 2	36	Provides a simple solution
60	24+18	36	Uses non standard 24mm thickness

Table 2: Inter tenancy wall options.

Note 1: The estimate is ± 3 and is from a prediction model. To give greater certainty laboratory results are necessary.
Note 2: All walls have a 100 mm gap between panels and a bulk fibreglass absorber equivalent to a flow resistance of 120 rayls in the cavity.

4 - ANALYSIS

It is immediately apparent from Table 2 that two separate panels of 36 mm particle board only gave a performance of STC 51. Furthermore, the substitution of a laminated 18 mm sandwich panel gave a predicted performance of STC 60. This was chosen for the laboratory test because it was simple, easy to build and gave a performance well in excess of the STC 55 laboratory requirement of Clause G6 in the New Zealand Building Code.
Furthermore, a high performing wall enables the wall/floor junctions to be simplified with some direct connection and yet still attain the minimum field performance of STC 50 required by the New Zealand Building Code. The laboratory test for this wall construction gave a performance of STC 61. Refer to figure 2.
Description and identification of the test specimen and test arrangement:
36 mm Particleboard with 50 × 50 mm timber battens fixed vertically at 600 mm centres within cavity and fixed to the test opening collar by 34 × 34 × 1.2 mm steel angle at bottom, nominal 150 mm angle at top. Sealed by 10 mm sealant gap between perimeter and collar at sides and top. Vertical joint in centre of Particleboard covered by 150 mm wide joint plate. R 1.8 (75 mm) Pink Batts in 100 mm cavity. Other panel consists of 2 × 18 mm Medium Density Fibreboard with 0.5 mm gap between sheets using a resilient adhesive and fixed to collar as before described with 150 mm wide joint plate within cavity between panels.
Rating according to ISO 717-1: $\boldsymbol{R}_{\mathrm{w}} = \mathbf{60}$
Rating according to ASTM E413: **STC = 61**

5 - FUTURE RESEARCH

The specific investigation of floor/ceiling junctions is not possible in the laboratory facilities that are available in New Zealand. However, this is the most important factor in the successful application of light frame sound insulation systems, including both particle board panels and timber frame with fibre cement linings. The adequate performance of whole buildings and their room spaces is the critical issue. The on-site test with Particle board panels in 1997 clearly indicates the importance of flanking at junctions. Therefore, it is essential that on site tests are carried out so that the field performance of alternative junction details can be investigated. Otherwise a high performing wall system with a laboratory performance of STC 61 could be reduced to a field performance of less than STC 50 and fail the Building Code requirements if inappropriate junction details are used.
Floor systems may also be an application for both James Hardie fibre cement and Particle board systems. The acoustic characteristics of the absorber used to improve the fire resistance in the fibre cement system could be given closer attention both in regard to flow resistance and the issue of filling the whole cavity.

6 - CONCLUSION

The development of new high performance acoustic systems by manufacturers cannot be done solely by acousticians. The other functional requirements of the system must be considered in full and solved prior to the commencement of substantial acoustic development.

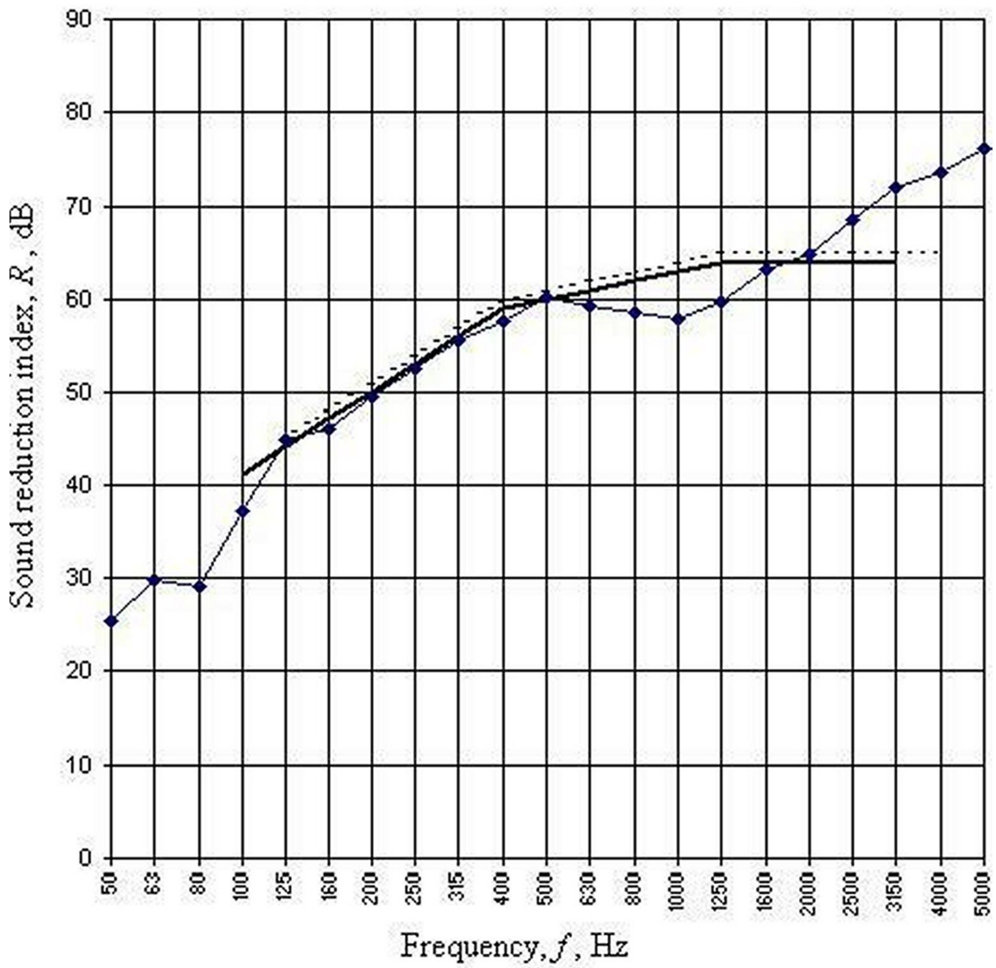

Figure 2: Laboratory result for particle board wall panel system (dash: curve of ASTM E413 reference values; curve of ISO 717−1 reference values).

In the case of the fibre cement system there was neither laboratory nor on site acoustic tests to provide guidance as to the expected performance. The success of the outcome was mainly due to the various options considered to achieve the desired performance using the prediction estimate model. Nevertheless other negative aspects must be considered and non-technical criteria also apply such as simplicity, width of wall, cost effectiveness, availability of traditional trade skills and products.
The fibre cement system has yet to be launched into the market but it is expected to be readily accepted by specifiers and builders alike.
In regard to the Particle board wall system the initial on-site test indicated such a poor performance of STC 37 that future development was delayed for over a year. It was only by using the prediction estimate model that it was apparent that the reason for the poor on-site result was most probably flanking. Furthermore the process of using a model to make predictions allows an alternative idea such as a laminated panel to be tried out with consummate ease. The laminated 2 × 18 mm panel acts as two separate panels from an acoustics viewpoint but structurally it acts as one 36 mm panel.
This wall system has been launched into the market place and has been readily accepted. However, standard junction details have not been fully developed. On-site tests remain a priority to ensure that flanking is kept to a minimum and the process of erection respects the need for careful installation of junction details.

REFERENCES

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