ABSTRACT

Framed walls that require high acoustic performance often need structurally separate frames to avoid bridging. This leads to designs incorporating staggered and parallel arrays of studs. Currently, common methods of framing walls using “C” section studs which carry linings on one side only of the stud present problems with the torsional rigidity of the stud under pressure loadings. The use of “tophat” section as studs overcomes many of these problems.

Systems have been derived and tested utilising “tophat” section to provide walls with acoustic, structural and fire resistant properties. Development of the system is outlined including full-scale fire, acoustic and structural testing, and detailing for specific jobs.

Applications include inter-tenancy, inter-cinema, external and shaft wall situations. Performance enhancement was achieved in the following areas:

- Construction efficiency due to the system's lightweight and simplicity.
- Acoustic isolation due to the inherent frame separation

Several cinema projects have been successfully completed in Australia. Field acoustic testing has revealed superior results. The system, in its low rise form, has been used in several projects for separating walls in office-to-residential building refurbishments.

KEYWORDS

Walls; Structure; Acoustics; Construction.

INTRODUCTION

The increasing importance of acoustics in building design has created the need for more flexible and economical ways of building acoustic separating walls. prevailing technology includes the use of masonry, of twin stud drywall, of reinforced concrete tilt up and of acoustically isolated structural frames amongst others.

When enhanced noise isolation is required in a wall system, one of the simplest methods to achieve this is to separate the wall linings on each side of the wall by running two sets of studs offset, as in a staggered stud configuration, so there is no direct physical connection between the linings. This is shown in Figure 1. When linings are fixed to only one side of the stud, the traditional "C" stud section experiences height restrictions caused by its torsional instability under lateral loadings. Effective structural bridging between adjacent studs to overcome this is difficult to achieve in a staggered stud array without putting its acoustic isolating properties in jeopardy.
In seeking to overcome these problems, a system was developed utilising light gauge steel tophat sections as studs. This system, shown in Figure 2, will be referred to here as the D Stud system.

The D Stud system uses the composite action of plasterboard and stud, resulting in a wall possessing several unique features contributing to its performance including:

- The creation of a box section using the plasterboard and stud. The linings become part of the wall structure providing lateral and torsional stability to the studwork.
- The resulting enhanced stud torsional rigidity allows the removal of all nogging or bridging between studs

The benefits accruing from these are:

- Elimination of acoustic bridging.
- Absence of nogging allows for a thinner overall wall width.
- Enhancement in achievable wall heights of up to 13m or more.
- Lower installed costs stemming from reductions in material and installation time.

The system is protected by several patents, has been successfully implemented on a number of cinema projects in Australia and also in the United Arab Emirates and on several multi-residential projects, and has been specified on several others.

BACKGROUND

Boral Australian Gypsum, an Australian based manufacturer of plasterboard and gypsum based products, has a systems development group based in Port Melbourne whose brief includes the development of plasterboard systems to meet fire resistance, acoustic and structural requirements. The authors are both from within this group.

The D Stud Wall System is a plasterboard and steel stud drywall construction system used where plasterboard linings are attached to one side of the stud only (as distinct from most partition walls where plasterboard is fixed to both sides of the wall frame). This is shown in Figure 3.
Typically these walls are used in specialist applications such as cinema and multi-residential party walls where two separate leaves (or wall frames) are constructed to achieve the required acoustic isolation. The studs are placed in a staggered format with plasterboard attached to one side only. Some of these applications, especially inter-cinema walls, require wall heights beyond the limitations of existing un-nogged C stud systems.

The C Stud metal section is essentially the same shape that has been used since the early 1950’s although modifications to gauge and profile have been made to make the section more efficient. However where the back flange is unrestrained, the stud is free to twist, reducing its sectional properties and leading to premature failure under load. This failure mode may be by ultimate strength before serviceability, i.e. little warning is given.

Methods available for improving the stud stability in staggered stud wall frames include the following:-

- Noggings between the studs are acceptable for a twin stud or chase wall but are inappropriate for a staggered stud wall where they may contact the stud supporting the other leaf of the wall, thus degrading the acoustic performance. Overcoming this requires increasing wall widths which is often not desirable.

- Running strapping along the back flanges has been used in the past as an alternative to noggings for staggered stud walls. The strapping is fed through holes in the web of the studs down one side of the wall and fixed to the back flange of the studs supporting the other side of the wall and vice versa. It is a time consuming process for the contractor with the ever present possibility of degradation in the acoustic performance of the wall should the strapping passing through the hole in the stud acoustically bridge across the wall.

- End clips have in the past been used to provide end restraint for the stud at the base and the head of the wall. These clips have improved the stability of the stud ends markedly but do add to the construction time of the wall and must be fixed at the head. There remains a limitation on the stud due to its torsional behaviour at mid height. With the back flange of the stud in compression under an incident negative pressure loading on the wall, rotation of the web about its junction with the front flange will still occur limited largely by the gauge of the stud.

- Enhancing the torsional and lateral stability of the stud over its entire length.

Consideration of ways to effect the latter method revealed the possibility of mutual support between the plasterboard and its “supporting” steel section and ultimately to the D Stud concept, the low rise version of which is depicted in Figure 4.
SYSTEM DEVELOPMENT

Fire Resistance Assessment
A vertical 3020 x 3020 mm specimen of the low rise D stud system was fire tested to Australian standard AS1530.4 1987 at CSIRO Division of Building, Construction and Engineering, North Ryde, NSW, Australia on the 8th of January 1997. It was lined on each side with 1 layer of 16 mm thick fire grade plasterboard sheets with their joints horizontal. This specimen included a deflection head; pipe, tap set, damper and electrical outlet penetrations; access hatch; two stud types (61 deep x 0.75mm base metal thickness (BMT) and 61 x 1.00mm BMT); stud joint; plasterboard butt joint; and temperature gradient thermocouples through the wall thickness. Insulation failure of the wall was recorded at 80 minutes but no integrity or structural adequacy failure of the wall was noted before the test was terminated at 107 minutes.

Subsequent evaluation of this and previous fire test results allowed assessment of the system in various plasterboard configurations for fire resistance levels (FRL’s) of -/30/30, -/60/60, -/90/90 and -/120/120, i.e. up to 120 minute fire resistance as a non load bearing wall. The 3 and 4 layer systems using 16mm Boral Firestop plasterboard used for cinema walls were assessed by CSIRO as having a fire resistance of at least 120 minutes.

Acoustic Assessment
Between 22nd of April and 15th of May 1997, airborne sound transmission loss testing was carried out on the low rise D stud system at CSIRO Division of Building, Construction and Engineering, Highett, Vic., Australia. This was performed to the requirements of Australian standard AS 1191 1985 on a specimen 3 metres high simulating a typical staggered stud party wall configuration. This specimen had 1 layer of 16mm fire grade plasterboard on each side of a staggered array of 61mm x 1.0 BMT D studs in 92mm head and base track. The results provided sound transmission class (STC) values of 40 without insulation, 49 with 50 mm x 14 kg/m3 glass wool insulation, and by adding a 10mm layer of standard core plasterboard to one side only of this wall the STC value increased to 55.

Acoustic testing of the cinema wall system was performed at the National Acoustic Laboratories (NAL), Chatswood, NSW, Australia on the 10th of December 1997. This testing resulted in an STC
value of 72 and a performance as shown below thus exceeding the current requirements for cinemas in the industry. (Refer also to Figure 5 below).

**Results of Tests Performed at NAL**

![Graph showing sound transmission loss](image)

Notes :- Points shown as diamonds represent minimum specification (at octave band centre frequencies) for “Hoyt’s” fitted out cinemas
Wall incorporated 75 mm x 14 kg/m³ “PinkPoly” polyester insulation each side between 200 mm deep x 1.5 mm gauge D studs spaced at 1200 mm centres, linings were 4 x 16 plasterboard to each side, and overall wall width was 500 mm.

**Figure 5: Cinema Wall Sound Transmission Loss Results (third octave readings)**

Recent field acoustic testing of new cinemas at Chadstone shopping centre, Melbourne, Victoria achieved a value of field sound transmission class (FSTC) of 69-70. Sound transmission loss figures (dB) for this test are tabled below :-

<table>
<thead>
<tr>
<th>Octave Band Centre Frequency</th>
<th>63 Hz</th>
<th>125 Hz</th>
<th>250 Hz</th>
<th>500 Hz</th>
<th>1000 Hz</th>
<th>2000 Hz</th>
<th>4000 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall A</td>
<td>41</td>
<td>52</td>
<td>63</td>
<td>72</td>
<td>82</td>
<td>&gt;82</td>
<td>N/A</td>
</tr>
<tr>
<td>Wall B</td>
<td>42</td>
<td>53</td>
<td>64</td>
<td>74</td>
<td>79</td>
<td>88</td>
<td>N/A</td>
</tr>
<tr>
<td>Specification</td>
<td>35</td>
<td>42</td>
<td>55</td>
<td>65</td>
<td>70</td>
<td>75</td>
<td>75</td>
</tr>
</tbody>
</table>

Note :- N/A indicates not able to be accurately determined but found to be in excess of specification. Specification is as required by “Hoyt’s” for fitted out cinemas.
Wall incorporated 100 mm x 20 kg/m³ polyester insulation each side, linings were 4 x 16 plasterboard and overall wall width was 500 mm.

**Structural Assessment**

Structural testing of the D Stud system took place at the NATA registered laboratories of Boral Australian Gypsum Limited at Port Melbourne, Vic., Australia and at VIPAC in Port Melbourne.

Initial testing was performed to determine the capacity of the wall head connection. When the wall is subjected to a negative pressure the flanges of the D stud bear on the flange of the head track and previous experience with C studs in this area could be applied. However, when the wall was subjected to a positive pressure, the strength of the connection was dependent on the resistance of the
uppermost plasterboard fixing screw head pulling through the plasterboard. It should be noted here that the purpose of the D clip was purely as an aid to construction and not to react stud forces into the top track.

Testing was performed and demonstrated, as expected, that the connection capacity varied with the board thickness and composition, that is, a specimen lined with a layer of 16mm fire grade plasterboard failed at a higher load than a specimen with a layer of 10mm standard core plasterboard. With a standard allowance for vertical head deflection the resulting allowable head track reaction capacities with fire grade plasterboard were derived to be:

<table>
<thead>
<tr>
<th>Plasterboard</th>
<th>1 x 13</th>
<th>1 x 16</th>
<th>2 x 16 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (kN)</td>
<td>0.35</td>
<td>0.38</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Serviceability tests were then performed to determine the behaviour of the studs under load with combinations of D studs of different depths and gauges, of specimen heights and of plasterboard linings. Specimens were loaded, in accordance with the Building Code of Australian (BCA) requirements, at quarter points along their height in both directions simulating pressures of +/- 250Pa and +/- 350Pa on the wall surface. In all cases walls using D studs failed serviceability criteria before reaching ultimate load. Load deflection curves were plotted and used to calculate maximum wall heights of similar sections, based on load/deflection limits from the BCA specification C 1.8 of L/240 or 30 mm @ 250 Pa pressure. Using commonly available one piece top hat sections, walls up to 7.4 metres in height are possible.

The cinema wall D stud system was also tested to confirm its behaviour under combined lateral loading and shelf loading situations such as basin loads.

The cinema wall D stud system was tested under lateral pressure as a specimen 8.6 metres high x 5.5 metres wide in the Sirowet rig at VIPAC in Port Melbourne. It used D studs comprising paired Zed sections 150 mm deep x 1.2 mm BMT at 1200 mm centres and was lined with 4 x 16 mm fire grade plasterboard layers. The specimen withstood a 1.0 kPa pressure loading, reaching a lateral load of -1.1kPa before the compression flanges of three of the studs were crippled. Were the stitch screws connecting the lapped flanges of the Zed sections closer than their 1000 mm, it is believed that the crippling load would very likely have been greater. This was considered to be a considerable margin on the lateral design load required for most cinema walls of 0.25kPa. The loaded specimen demonstrated significant torsional stability of the stud section indicating that noggings are unnecessary in D Stud walls.

**Buildability**

Ease of assembly of the system on site was a very important consideration during its development. Anecdotal evidence pointed to labour costs being a substantial portion of building costs, so any means where the contractor could save time were seriously considered.

For low rise staggered stud applications the D Clip was a further development. This clip is fixed to the top end of the stud whilst on the ground and, when erected increases the depth of the stud holding it securely in the top track by friction whilst the plasterboard is being permanently secured. The contractor benefits by being able to install the stud from ground level without the need for scaffolding or a scissor lift to fix a top connection.

In the development of the cinema D stud wall system due to the tall wall heights involved and possibly adverse site conditions it was deemed imperative that construction was simple, safe and straightforward. Thought was given to the head and base details and the method of applying the plasterboard.

As shown in Figure 6 below, the head connection of the cinema wall D studs uses a simple box section with slotted holes, welded to the roof beam during its fabrication and allowing for rapid
erection of the pre punched studs which house the box and are bolted to it through its slotted holes in order to allow for roof movement.

A wide base track or independent fixing angles were the obvious options for the cinema wall base and both have been used although the angle is considered the more preferable. The studs, after being connected at their top, stand hard onto the floor slab and are screwed to a 50 x 50 x 3 mm hot rolled mild steel angle fixed down to it.

![Figure 6: Cinema Wall Frame System](image)

To avoid the multiplicity of plasterboard-to-steel screws it was proposed that the first and third layers of cinema wall linings be screwed to the distal flanges of the D studs at 300 mm centres in a staggered array. Recent successful usage of plasterboard-to-plasterboard screw lamination suggested that the second and fourth layers could be fastened to their preceding layers using laminating screws in a 600 x 600 pattern. For ease of construction the plasterboard sheets were oriented horizontally with the butt joints at the sheet ends fastened at 200 mm centres along the butt. This method of plasterboard attachment proved in the Vipac test and in practice to be adequate and construction friendly.

Also, due to the large mass required in these wall linings to achieve adequate acoustic isolation between cinemas, three or four layers of 16 mm plasterboard were used on each side of the wall. With this thickness of linings having significant spanning capability and the need to minimise on framing costs, the spacing of studs at up to 1200 mm was investigated and found to be satisfactory.
SYSTEM RELEVANCE

The boxed section was found to be efficient and not to be subject to twisting failure. The joint action of the plasterboard and stud working compositely results in a stiffer wall with reduced deflection.

The elimination of noggings or bridging preserves the acoustic integrity of the wall.

The system retains the staggered stud format thus maintaining reduced wall widths.

Estimates of construction costs place D stud wall costs competitively in the market.

The increased stud spacing in cinema walls to up to 1200mm and the revision of screwing details reduces installation time.

Both the top hat and Zed section are sourced from common building sections and are readily available from a number of national suppliers.

Cinema projects incorporating D Stud
- Highpoint, Maribyrnong, Melbourne.
- Peninsular Fair, Kippa Ring, Brisbane.
- Jam Factory, Prahran, Melbourne.
- Chadstone, Melbourne.
- Abu Dhabi Trade Centre, Dubai, U.A.E.
- Carousel, Perth.
- Belmont, Perth.

Building Refurbishments
- Anne Street, Brisbane
- Surry Hills, Sydney
- Civic Hotel, Sydney
- GPO Refurbishment, Sydney
- Port Authority Building, Melbourne

CONCLUSION

A novel system was developed suitable for use as a separating wall for multi-residential refurbishment, cinema wall and other one sided wall construction. It represents a significant advance in wall system capability where enhanced acoustics or higher achievable wall heights are required. Several cinema projects have been successfully completed in Australia and elsewhere. Field acoustic testing has revealed superior results. The system, in its low rise form, has been used successfully in several projects for separating walls in office-to-residential building refurbishments.

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