ASSESSMENT OF FIRE PERFORMANCE OF POLYPHEN STEEL CLAD SANDWICH PANELS IN ISO 9705 ROOM CORNER TEST

Report to

Polyphen International Pty Ltd

N. White, G. P. Bradbury and A. D. Bicknell

CSIRO MIT Fire Science and Technology Laboratory

October 2003
CONFIDENTIAL Doc CMIT-(C)-2003-041

ASSESSMENT OF FIRE PERFORMANCE OF POLYPHEN STEEL CLAD SANDWICH PANELS IN ISO 9705 ROOM CORNER TEST

CSIRO CMIT Specimen ID 03/14

by

N. White, G. P. Bradbury and A. Bicknell

In confidence to:
Polyphen International Pty. Ltd.
Level 5, 45 William St
Melbourne, VIC, 3000

October 2003

This document has been prepared for the sponsor and is confidential. It may not be cited in any publication without the agreement of the authors and the sponsor.

Please address all enquiries to:

The Chief
CSIRO Manufacturing and Infrastructure Technology
Private Bag 33
Clayton South, Victoria 3169

i
DISTRIBUTION LIST

Polyphen International Pty. Ltd  3
V P Dowling   1
N White   1
G. P Bradbury  1
A. Bicknell  1

Registry (Original)

www.cmit.csiro.au

© CSIRO 2003
ASSESSMENT OF FIRE PERFORMANCE OF POLYPHEN STEEL CLAD SANDWICH PANELS IN ISO 9705 ROOM CORNER TEST

(CSIRO-MIT-FSTL-HR Specimen ID 03/14)

1. INTRODUCTION

This report describes an ISO 9705 room corner test conducted on Polyphen steel clad sandwich panels. The test was performed under contract to Polyphen International Pty Ltd, Level 5, 45 William St Melbourne, 3000. This test was performed according to ISO 9705–1993. The test was conducted on 16th April 2003 at CSIRO FSTL’s Hightt Laboratory, by a team lead by Nathan White. It was observed by Nicholas Hughes, Ingmar Quist and Anthony John of Polyphen International Pty Ltd and Andre J. Mierzwa and Trevor Clayton of FM Insurance Company Ltd.

2. SPECIMEN DESCRIPTION

The specimens were 2400×1200mm steel clad sandwich panels constructed of a 100mm thick Polyphen foam core faced on both sides with 0.6mm colorbond steel sheets. Polyphen is phenolic/polystyrene composite foam and has a density of 60 kg/m³. The steel sheets are factory bonded to the foam with two-part polyurethane glue ex Huntsman (Part A = Suprasec 5005, Part B = Daltofoam MR 40106) at an application rate of 370 g/m² per sheet. The colorbond steel sheets are off white in colour. The Polyphen foam is a white/brown colour. The panels are constructed with rolled tongue-and-groove slip joints at the edges, as shown in Figure 1.

3. SPECIMEN INSTALLATION

The Polyphen sandwich panels were mounted within the existing lined fire test room as required by ISO 9705 (see Figure 2). The installation method may have a significant effect on the fire performance of sandwich panels, therefore the specimens have been mounted, as far as possible, in the manner as recommended by Polyphen International Pty Ltd. However, the presence of the existing lining did not allow access to the non-exposed rear side panel joints for sealing or bracing.

Specimen panels were installed in the fire test room by contractors provided by Polyphen International 24 hrs prior to testing to ensure curing of the adhesive.

In all, eleven sandwich panels were installed on the ceiling and three walls of the fire test room. First, three panels spanning the 2.4m width of the enclosure were installed in the ceiling. Each ceiling panel was secured to the roof with one 10mm steel bolt through the panel centre. Panels were then mounted on the three walls so that the
ceiling panels fully overlapped the top of the wall panels. The base of the wall panels was mounted within C section steel channel of 40 mm wall height. This channel was riveted to wall panels at 300 mm spacings on the exposed side. Each wall panel was secured to the enclosure wall with one 10 mm steel bolt through the panel centre, 300 mm below the ceiling. At the corners the wall panels were overlapped as shown in Figure 12. Each connecting panel edge (except corners) was firmly jointed with tongue-and-groove slip joints. The overlapping facings at these joints were secured with steel rivets at 300 mm spacings on the exposed side (Figure 2). All wall/ceiling and wall/wall corner joints were secured using 40mm steel angle riveted to the panels at 300 mm spacings on the exposed side. All panel joints were sealed with silicon sealant, grade Siliglaze II manufactured by GE Silicones.

4. FIRE TEST ROOM AND EXHAUST SYSTEM

The fire test room consists of four walls at right angles, with a floor and a ceiling and has dimensions of 3.60 x 2.40 x 2.40 m high. It has a door in the centre of one of the 2.40 x 2.40 m walls, 0.8 m wide and 2 m high. It is constructed inside an essentially draught free building large enough to ensure that there is no influence of the enclosure on the test fire, in accordance with Section 5 of ISO 9705. The room has a steel frame clad in 12 mm plywood and 16 mm glass reinforced paper faced gypsum plasterboard on all surfaces. The density and thickness of this material does not comply with the Standard, but it is the opinion of this laboratory that the use of this material would not have an effect on the results, considering the thickness and thermal properties of the panels under test.

The room doorway opens under a smoke collection hood and exhaust duct system which meets the requirements of ISO 9705. The exhaust duct contains instrumentation for measuring the flow rate and temperature of the exhaust gases, an optical smoke measurement system to determine optical density of the combustion gases and a gas sampling probe. Sampled gases are continuously analysed for concentrations of O\(_2\), CO and CO\(_2\). This instrumentation is installed in accordance with ISO 9705.

A Gardon-type water-cooled radiometer was mounted at floor level at the centre of the fire test room, facing upwards. The radiometer has a range of 0 - 50 kW/m\(^2\).

5. IGNITION SOURCE

The ignition source was the alternative ignition described in Annex A of ISO 9705. It consisted of a sandbox burner as shown in Figure A2 of ISO 9705. The heat output was 100 kW during the first 10 minutes of the test and 300 kW for the remaining 10 minutes. The burner was placed in one corner of the room, opposite the doorway. For safety reasons this burner is equipped with a pilot flame and flame sensor (see Figure 2).
6. CALIBRATION

A calibration test was carried out prior to the test. The burner heat outputs used in the calibration were the same as those used in the test. Additionally a check was carried out on the day of the test as required by ISO 9705, to confirm the correct working of the exhaust instrumentation.

7. PROCEDURE

Specimens were conditioned to constant mass in a conditioning room maintained at 23 °C and 55% RH prior to installation. During the installation period, temperature and humidity conditions of the test room were monitored.

Data recording equipment logging at 5 s intervals and video recorders viewing the burner corner of the fire test room and a side wall through the doorway were turned on three minutes prior to ignition. The burner output was set to 100 kW for 10 minutes, after this period the burner output was increased to 300kW for a further 10 minutes. Visual observations of specimen behaviour were made through the doorway, and still photographs were taken of significant events. At 20 minutes the burner was turned off and the test was terminated. After the test a fire hose was used sparingly to ensure no further smouldering or flaming of the specimens. When the fire test room had cooled, video and still photographs of specimen damage were taken. The specimens were carefully disassembled and weighed. The steel facing sheets were removed to allow observation of foam charring.

8. RESULTS AND OBSERVATIONS

The results are shown in Figures 3-17.

The maximum measured heat release rate including the contribution of the ignition source was 340 kW.

The material did not go to flashover

The maximum rate of smoke production was 1.4 m$^2$/s. The smoke production was not excessive.

8.1 Test Conditions

The ambient conditions in the laboratory were 17°C, 60.5 % RH and 1033 mbar atmospheric pressure. Conditions in the fire test room were 17°C and 61% RH

8.2 Calibration

A graph of rate of heat release versus time for the calibration burn is shown in Figure 12.
### 8.3 Test Observations

The test observations are given in Table 1. The complete test can be seen on the videotape, which accompanies this report. The log of this videotape is included in Appendix A.

#### Table 1. Test Observations

<table>
<thead>
<tr>
<th>Time (min:s)</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00</td>
<td>Burner established at 100 kW output. Flames occasionally impinge ceiling at room corner.</td>
</tr>
<tr>
<td>2:00</td>
<td>Charring and buckling of colorbond where flames impinge. Small amounts of smoke and gas are emitted from corner joint. There is no significant fire growth or spread. Light smoke and hot gases are observed to form a layer approximately 0.5m below the ceiling. See Figure 3.</td>
</tr>
<tr>
<td>8:00</td>
<td>There is no significant flame growth or spread however a small intermittent flame is observed to be seated at the wall corner joint.</td>
</tr>
<tr>
<td>10:00</td>
<td>No significant flame spread or excessive smoke production is observed during the first 10 minutes. The burner output is increased to 300 kW. Flames are observed to impinge on the ceiling and intermittently radiate out to 1m along the ceiling from the corner.</td>
</tr>
<tr>
<td>11:00</td>
<td>Production of smoke and hot gases increases but is not excessive. The layer of light smoke and hot gases is observed at 1m below the ceiling. A small amount of flaming is observed at the base of the corner (possibly flaming molten material). Otherwise no significant fire spread is observed.</td>
</tr>
<tr>
<td>12:00</td>
<td>Silicon sealant covering through bolts on both corner wall panels ignite and produce small flames. Blackening and slight buckling of the ceiling colorbond on the ceiling where flames directly impinge is observed. See Figure 4.</td>
</tr>
<tr>
<td>14:00</td>
<td>This material ignites and produces a 1m line of flame along the rear edge of the fire test enclosure (other side of ply/plasterboard lining). This may be due to inability to properly joint and seal panel surfaces covered by the fire test enclosure. The flaming at the rear of the enclosure is estimated not to have exceeded 50 kW. The contribution of this fire to the total heat release rate is not measured, as the exhaust hood did not collect the combustion gases. See Figure 5.</td>
</tr>
<tr>
<td>14:30</td>
<td>Flaming of silicon sealant covering through bolts ceases.</td>
</tr>
<tr>
<td>20:00</td>
<td>No significant flame spread or excessive smoke production is observed during the previous 10 minutes of 300kW burner exposure. The burner is turned off and the test completed. Upon turning the burner off a flame of approximately 40mm length is observed in the wall corner and small amounts of smoke and gas are emitted from the ceiling corner joint. A hose is used to wet and cool the panels to reduce the fire size at the rear of the enclosure. The fire at the rear of the enclosure goes out within 1 minute after the test.</td>
</tr>
</tbody>
</table>
8.4 Instrumentation Records

The rate of heat release for the room fire test is plotted against time in Figure 13. It shows that there was no significant contribution to total heat release rate from the material.

The radiant heat flux at the centre of the floor is given in Figure 14. This reached a maximum of 7 kW/m$^2$ indicating that the fire test enclosure was not close to a flashover condition.

The volume flow rate in the exhaust duct is shown in Figure 15. Volume rate of carbon monoxide and carbon dioxide production and standard pressure and temperature is shown in Figure 16. The smoke production versus time is shown in Figure 17. This shows that production of both smoke and carbon monoxide was not excessive.

8.5 Post Test Observations

After the test was completed the specimens were inspected for damage.

All colorbond was still in place with no significant delamination. The colorbond panels had buckled outwards in the burner corner where there was direct flame contact however they were held in place by the riveted angle sections. Buckling of the colorbond between rivets had produced small gaps exposing the foam. Damage and burning of the painted colorbond surface was evident up to 600 mm from the corner along the walls and 1m radially along the ceiling from the corner. The colorbond surface was sooted and blackened on the ceilings and uniform ally to a height of approximately 1m below the ceiling on all walls. This is in agreement with the observed hot layer depth. See Figures 6 and 7.

The sandwich panels were removed from the test enclosure and the Colorbond steel sheets were removed to inspect damage to the foam core. In general the sheets were still adhered to the foam core. It was found that where the panels had received direct flame contact the EPS beads near the surface were no longer visible. As polystyrene softens at 100 °C and melts and flows at about 180 °C this is not surprising. Considering that EPS has a density of 13-16 kg/m$^3$, compared with solid polystyrene's density of ca 900 kg/m$^3$, there is very little polystyrene in the beads (approximately 1.5%), the rest being air. The EPS had completely melted and either been pyrolysed or, formed a very thin film on the phenolic matrix. There was no evidence that the EPS has flowed or formed pools of molten material. The phenolic matrix showed various stages of charring or discolouration from pyrolysis (see Figures 8 and 9), but there was no evidence of flame spread inside the panels. On panels that had not received direct flame contact the region of panel exposed to the hot layer had been affected. For all panels down to 1 m below the ceiling the EPS had melted and/or pyrolysed down to a depth of 20-25 mm, leaving the discoloured or charred phenolic matrix. Below 1 m the degree of discolouration was much less (see Figure 10). This charring or discolouration is due to hot layer exposure rather than direct flame spread. Charring is an integral part of fire retardant mechanism and the phenolic matrix that is left behind forms an insulating barrier against further attack.
Where significant charring of the foam had occurred the bonding of the colorbond to the foam had been reduced, see Figure 11.

9. DISCUSSION AND ASSESSMENT

The ISO 9705 Room Corner Test is used by regulatory and insurance authorities to certify a materials fire performance. This report does not provide certification however may be presented to specific authorities to demonstrate the materials performance.

9.1 BCA Criteria

The proposed Building Code of Australia (BCA) amendment for fire hazard properties of building materials and assemblies\cite{2} classifies wall and ceiling material into four different grouping based on ISO 9705 Room Corner Test performance.

The criteria for the 4 material groups are as follows.

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The material is not expected to result in flashover</td>
</tr>
<tr>
<td>2</td>
<td>The material is expected to result in flashover after 10 minutes but before 20 minutes</td>
</tr>
<tr>
<td>3</td>
<td>The material is expected to result in flashover after 2 minutes but before 10 minutes</td>
</tr>
<tr>
<td>4</td>
<td>The material is expected to result in flashover in less than 2 minutes</td>
</tr>
</tbody>
</table>

Based on the test results stated in this report Polyphen steel clad sandwich panels meet the criteria for a Group 1 material classification as stated in the proposed BCA amendment for fire hazard properties of building materials and assemblies.

9.2 Factory Mutual Criteria

Acceptance criteria (pass/fail) is defined in the published 4880 Approval standard as one of three options depending on which of the three optional room tests are conducted. The Approval standard allows for the use of one of the following procedures to satisfy the room test requirement:

1. UBC Standard 17-5 (new designation 26-3)
2. UBC Standard 42-2 fully lined protocol
3. ISO 9705

The results outlined in this report may be used by Factory Mutual to determine acceptance of the material.

9.3 Euro Code Criteria

Annex A of EN 13501-1:2002 “Fire Classification of Construction Products and Building Elements Part 1: Classification using test data from reaction to fire tests”\cite{3} provides a relationship between classes as defined by the “Euro Code” and ISO 9705 test results. This relationship states that materials achieving class A1 or A2 rating by EN 13501-1 are not expected to go to flashover in the ISO 9705 test. The Polyphen
material did not go to flashover. Materials achieving Class B or lower by EN 13501-1 would be expected to go to flashover in the ISO 9705 test.

To demonstrate performance to a given classification a series of tests as described in EN 13501-1:2002 must be performed.

10. CONCLUSIONS

Polyphen steel clad sandwich panels have been tested in the ISO 9705 room corner test with installation as stated. There was no excessive flame spread or smoke production. The room did not reach a flashover condition.

11. REFERENCE


.....................................................  .....................................................
N. White                          V. P. Dowling
Mechanical Engineer              Leader, Material Flammability and
                                 Fire Protection Project
Date:                            Date:
Figure 1. Polyphen™ steel clad sandwich panels

Figure 2. Specimens installed in ISO 9705 test enclosure
Figure 3. Test in progress with 100 kW burner output.

Figure 4. Test in progress with 300 kW burner output.
Figure 5. Small fire at rear side of test enclosure

Figure 6. Damage to corner specimens
Figure 7. Damage to ceiling corner

Figure 8. Rear wall panels with colorbond removed
Figure 9.  Charring of foam in region of direct flame contact

Figure 10.  Side wall panels opposite burner corner with colorbond removed
Figure 11. Rear face of colorbond sheet from side wall panel.
Figure 12. Installation Schematic
Figure 12. Oxygen consumption calorimetry calibration

Figure 13. Rate of heat release including ignition source output.
Figure 14  Heat flux incident on meter at the centre of the floor.

Figure 15.  Volume flow rate in exhaust duct.
Figure 16. Volume rate of CO and CO$_2$ production at 25°C and atmospheric pressure.

Figure 17. Extinction coefficient and volume rate of light-obscurring smoke production.
APPENDIX A  Log of videotape accompanying this report.

hh:min:sec

0:00:00 – 0:00:40    Titles
0:00:40 – 0:01:20    Pre Test
0:01:20 – 0:22:00    Room Test

*Please Note : The lab clock on the test video footage is 20 seconds slow.