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# Assessment of the CSR AFS REDIWALL® polymer-based permanent formwork system for resistance to water penetration, tested to parts of ASTM E514/E514M-14a and AS/NZS 4347.1-1995

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*Client*
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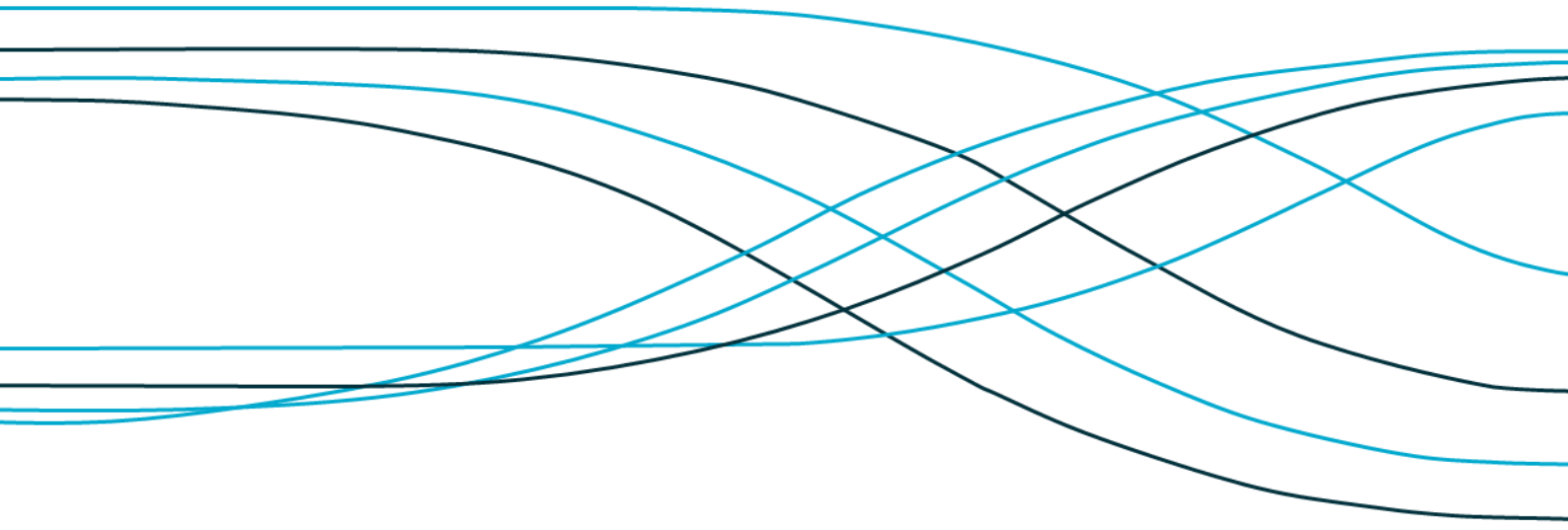
Commercial-in-confidence



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The results reported herein relate only to the item(s) tested.

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# Assessment of the CSR AFS REDIWALL® polymer-based permanent formwork system for resistance to water penetration, tested to parts of ASTM E514/E514M-14a and AS/NZS 4347.1-1995

# 1 Summary

CSR Building Products Limited engaged CSIRO to undertake evaluation of their CSR AFS Rediwall polymer-based permanent formwork system. The walling system was made up of 250 mm wide extruded casings interlocked together, with each casing having internal punched slots for meshing of reinforcing rods and allowing flow of concrete mix for core-fill. CSR supplied two configurations to the CSIRO Laboratory at North Ryde, as representative specimens for assessing resistance to water penetration performance. The first was a single leaf wall panel 1810 mm (length) by 1280 mm (height) and 150 mm (thick). The second was a sample block section of wall panel 500 mm square by 150 mm thick. Both specimens were assembled and then core-filled at the CSIRO facility. All the test Standards, methods, and test parameters were specified by the test sponsor, CSR Building Products Limited.

The following is a summary of all tests, by test Standard, and the resultant test outcomes:

*Test 1 - ASTM E514/E514M-14a – Water Penetration and Leakage through Masonry*

Water penetration and leakage resistance (WPLR) of a representative specimen of the Rediwall polymer-based permanent formwork system was assessed under the test procedure for water penetration by wind-driven rain, in accordance with the Standard ASTM E514/E514M-14a, '*Standard Test Method for Water Penetration and Leakage through Masonry*'. The wall panel was assembled at CSIRO's facility by the sponsor, with the sides and base capped while the top was left open for core-filling. The specimen was covered with an impervious plastic sheet for part of the conditioning period, as per the Standard. Once the conditioning period was completed, the test chamber was installed on the wall specimen, before being subjected to a water flow rate of 138 L/m$^2$/min, while the chamber was simultaneously being subjected to an air pressure of 500 Pa. Testing was conducted over a four (4) hour period, where observations and any water collections were made at 30 minute intervals. Under testing, the test specimen demonstrated no water penetration.

*Test 2 - AS/NZS 4347.1 – Water Permeability*

Water permeability (WP) of a representative specimen of the Rediwall permanent formwork system was assessed under the test procedure for water permeability through the material due to a head of water, in accordance with the Australian Standard AS/NZS 4347.1:1995, 'Method 1: *Determination of Water Permeability*'. The block section of wall panel was assembled at CSIRO's facility by the sponsor, with three of the four sides capped and one left open for core-filling. The specimen was covered with an impervious plastic sheet for part of the conditioning period. The exposed test area for the water pressure test was 50 mm diameter on one face of the block section (underside), which included the interlocking joint between the 250 mm box casing. The test specimen was installed on the flanged water permeability test rig and subjected to a 6 metre hydrostatic head for duration of 100 hours. No water penetration was observed to the top surface of the test specimen.

A full description of the testing and test results are provided within this report.

# 2 Background

The CSR AFS Rediwall polymer-based permanent formwork system by CSR Building Products Limited is primarily an alternative to other floor to floor walling systems; using a polymer-based permanent formwork. The polymer-based permanent formwork is also seen to offer a water proof barrier, negating the use of waterproofing membranes, compounds, or other systems, as is standard practice in similar construction. The test sponsor, CSR Building Products Limited, engaged CSIRO to assess the performance of the CSR AFS Rediwall walling system for its capacity to resist such water penetration. Performance was assessed under the relevant nominated Standards for: penetration and leakage and water permeability to demonstrate or reveal deficiencies in water resistance of the polymer-based permanent formwork walling system in sub-surface applications.

# 3 Introduction

This report details the performance of two representative specimens of the polymer-based permanent formwork panel system, under simulated conditions for resistance to water penetration.

The following testing was conducted to the test sponsor's specified parameters:

- ASTM E514/E514M-14a, 'Standard Test Method for Water Penetration and Leakage through Masonry'; and,
- AS/NZS 4347.1:1995, 'Method 1: Determination of Water Permeability'.

**Table 1 CSIRO Job number, test specimens, tests and timeline information**

| | | |
|---|---|---|
| CSIRO JOB No: | R-90006-01-001 HI 2970 | |
| SPECIMEN DESCRIPTION: | REDIWALL PVC permanent formwork panel system | |
| TEST SPONSOR: | CSR Building Products, AFS Walling Systems Pty Ltd | |
| SPECIMENS PRODUCED BY: AFS WALLING SOLUTIONS AT CSIRO FACILITY, NORTH RYDE: | REDIWALL polymer-based single wall concrete system configurations:<br>1810 x 1280 x 150 mm single wall reinforced panel<br>500 x 500 x 150 mm single block of reinforced panel<br>Core filling of all wall panel specimens | <br>19 March 2015<br>19 March 2015<br>19 March 2015 |
| TEST DATES: | ASTM Designation E514/E514M-14a, 'Standard Test Method for Water Penetration and Leakage through Masonry'<br>Preconditioning<br>Specimen performance test<br>AS/NZS 4347.1:1995, 'Method 1: Determination of Water Permeability'<br>Preconditioning<br>Specimen performance test | <br>19 March to 10 May 2015<br>13 May 2015<br><br>19 March to 10 May 2015<br>14 May to 18 May 2015 |

# 4 System description

The CSR AFS Rediwall polymer-based permanent formwork panel system is comprised of 250 mm wide PVC extruded box casings interlocked together to form a concrete formwork. The box casings were fabricated with punched internal slots for fitting reinforcing rods and allowing the flow of concrete mix for the core filling. The available wall thicknesses indicated by the sponsor are: 100 mm, 150 mm and 200 mm. The reinforcing rods within the box casings were positioned as detailed by the structural engineer.

Figure 1 shows the Rediwall polymer-based permanent formwork system supplied to CSIRO.

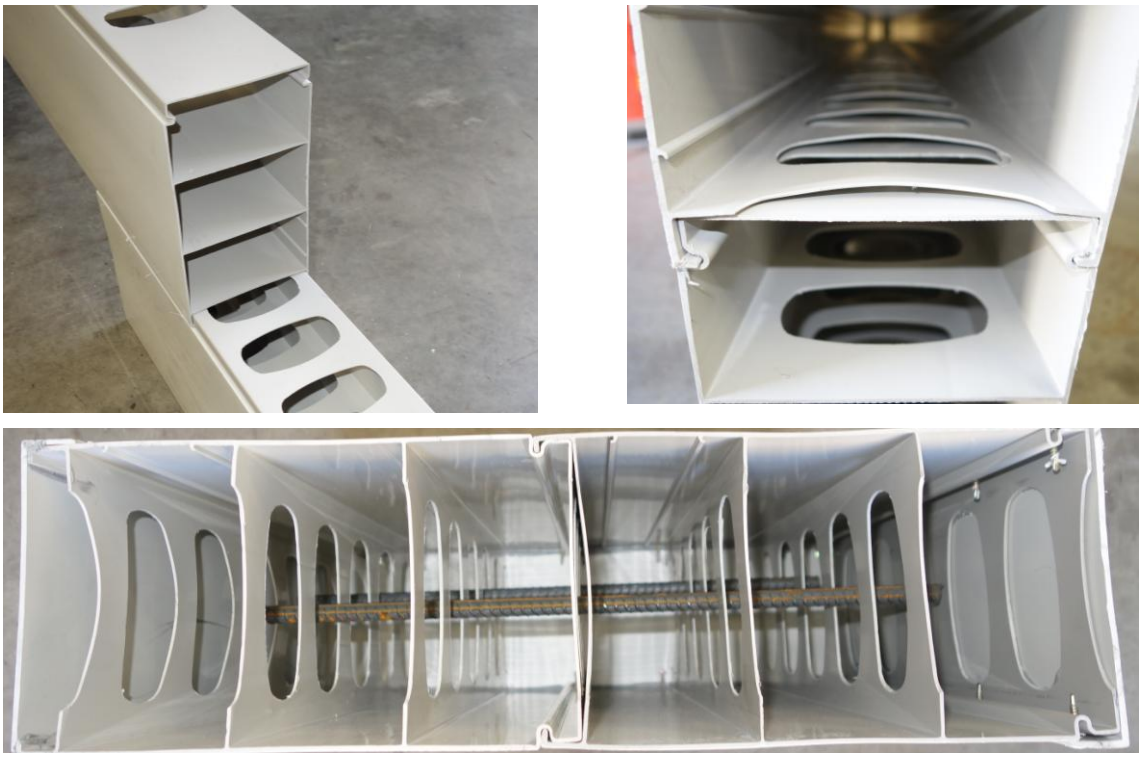


**Figure 1 Rediwall polymer-based permanent formwork system, 150 mm thickness**

# 5 Test specimen description and preparation

## 5.1 Polymer-based permanent formwork system – Wall Panel

The following describes the preparation of the representative specimen for the polymer-based permanent formwork system.

The single leaf wall panel was constructed by the sponsor at CSIRO's test facility for the water penetration and leakage test. The wall panel's configuration was 1810 mm in length, 1280 mm in height and 150 mm thick. The 1810 mm length of the specimen was made up of four 250 mm interlocking cases including two end stops. The base of the wall panel assembly was also fitted with an end stop to contain the concrete pour of the core-fill. The wall panel assembly was then set upright on a steel channel and fixed between two columns for stability.

The reinforcing rods used in the test wall panel were 12 mm in diameter. The spacing of the reinforcing rods in the test wall panel were at 400 mm centres for the horizontal (4 off), and at 300 mm centres for the vertical (2 off).

The premix concrete detailed by the sponsor was 1 part cement and 4 parts aggregate (1:4 ratio). The aggregate size was 10 mm, slump of 160 to 180 mm and a compressive strength of 32 MPa.

The premixed concrete was poured down into each of the wall panel cavities. Once all cavities were filled, a 40mm needle vibrator was used to compact the mix.

Refer to Figure 3 below for the wall panel's preparation.

**Figure 2 Preparation of wall panel for water penetration and leakage test**

## 5.2 Polymer-based permanent formwork system – Block section of wall panel

A block section of the wall panel was constructed by the sponsor at CSIRO's test facility for the water permeability test. The block panel configuration was 500 $mm^2$ and 150 mm thick. The specimen was made up of two 250 mm interlocking casings, with three of the sides having end stops fitted to contain the concrete.

The reinforcing rods used in the test wall panel were 12 mm in diameter. The spacing of the reinforcing rods in the test wall panel were at 85 mm centres for the horizontal (2 off), and at 85 mm centres for the vertical (2 off).

The premix concrete detailed by the sponsor was 1 part cement and 4 parts aggregate (1:4 ratio). The aggregate size was 10 mm, slump of 160 to 180 mm and a compressive strength of 32 MPa.

The premixed concrete was poured down into each of the wall panel cavities. Once all cavities were filled, a 40mm needle vibrator was used to compact the mix.

Refer to Figure 4 below for the block section's preparation.

**Figure 3 Preparation of Rediwall block section of the wall panel for water permeability testing**

# 6 Test methodologies

## 6.1 Water penetration and leakage test – ASTM E514/E514M-14a

The prepared wall panel specimen, as described in section 5.1 above, was tested in accordance with the Standard ASTM E514/E514M-14a, '*Standard Test Method for Water Penetration and Leakage through Masonry*'.

During installation of test specimen, flashing (a trough) was installed at the base between the steel channel and wall panel base end stop to collect any water penetrating through the wall panel during the test period. The Rediwall wall panel was cured by wrapping it in an impervious membrane over a 7 day period. After this period had finished, the plastic was removed and left for a further 21 days under ambient laboratory conditions, which gave a total 28 days curing period prior to testing.

The Rediwall wall panel specimen was tested by mounting a test chamber on the front face, held by clamps (Figure 6, overleaf) and sealed by a gasket around the perimeter of the chamber, which gave an exposed test area of at least 1.08 $m^2$. The exposed wall surface area was subjected to a water spray supplied through a sparge pipe at the top of the chamber, delivering a flow rate of 138 $L/m^2$ of wall per hour (approximately 2.3 L/min). At the same time, the chamber was pressurized with air supplied at 500 Pa. The test period was maintained for 4 hours, with observations made every 30 minutes to monitor areas of dampness on the rear face of the test wall panel, and, as well, any water collection from the flashing (trough) at the base.

**Figure 4 Curing with the use of impervious plastic over the wall panel**

**Figure 5 Flashing located at the base of the Wall panel**

**Figure 6 Test chamber fitted to the wall panel**

## 6.2 Water permeability test – AS/NZS 4347.1

The prepared block section of the single leaf wall panel, as described in section 5.2 above, was tested in accordance with Australian Standard AS/NZS 4347.1:1995, 'Method 1: *Determination of Water Permeability*'.

The block section of wall panel was conditioned by wrapping it in an impervious membrane and then cured for 7 days; at the completion the plastic was removed and left for a further 21 days under ambient laboratory conditions, giving a total 28 days curing period prior to testing

The block section of wall panel was fixed with one part of the flange plate and rubber gasket test apparatus. The flange was a DN40 size, which was bored out to a diameter of 50 mm. The bore exposed the base of the test specimen to a water head at the interlocking joint during testing. The flange assembly included a 6 metre high pipe, measured from the rubber gasket of the flange. The pipe, when filled, subjected the underside face of the block section to a 6 metre head of water for duration of 100 hours. The specimen was observed for any water penetration coming from the underside face through to the top face.

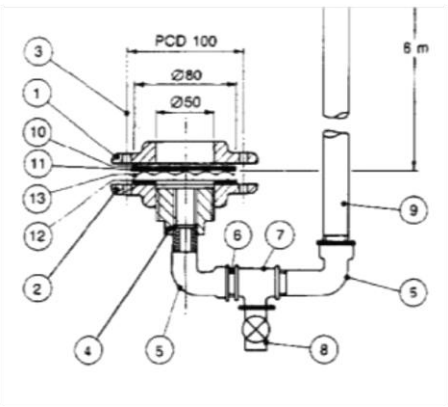



**Figure 7 Testing apparatus schematic and specimen under test**

# 7 Results

The results from all test methods described in Section 6 above, are detailed in the relevant sections below.

## 7.1 Water penetration and leakage test results

Water penetration and leakage resistance (WPLR) for the single leaf wall panel was tested in accordance with the Standard ASTM E514/E514M-14a, '*Standard Test Method for Water Penetration and Leakage through Masonry*'.

The apparatus and procedure used for testing the water penetration of the wall panels complied with ASTM E514/E514M-14a. The test apparatus enclosed an area 1070mm x 1600mm on the test face of the specimen. As described in section 6.1, the test chamber was positioned and fixed onto the specimen for a water and air tight seal. Water was sprayed from a sparge pipe near the top of the test area which sprayed water directly onto the test face. The water flow rate of 138 L/m$^2$/hour was maintained constant throughout the test. The water flow rate was measured with the aid of a calibrated flow meter. Air pressure inside the chamber was maintained at 500 Pa using an inclined water manometer. Observations were made for the appearance of damp patches on the back face of the wall at 30 minute intervals throughout the 4 hour test duration.

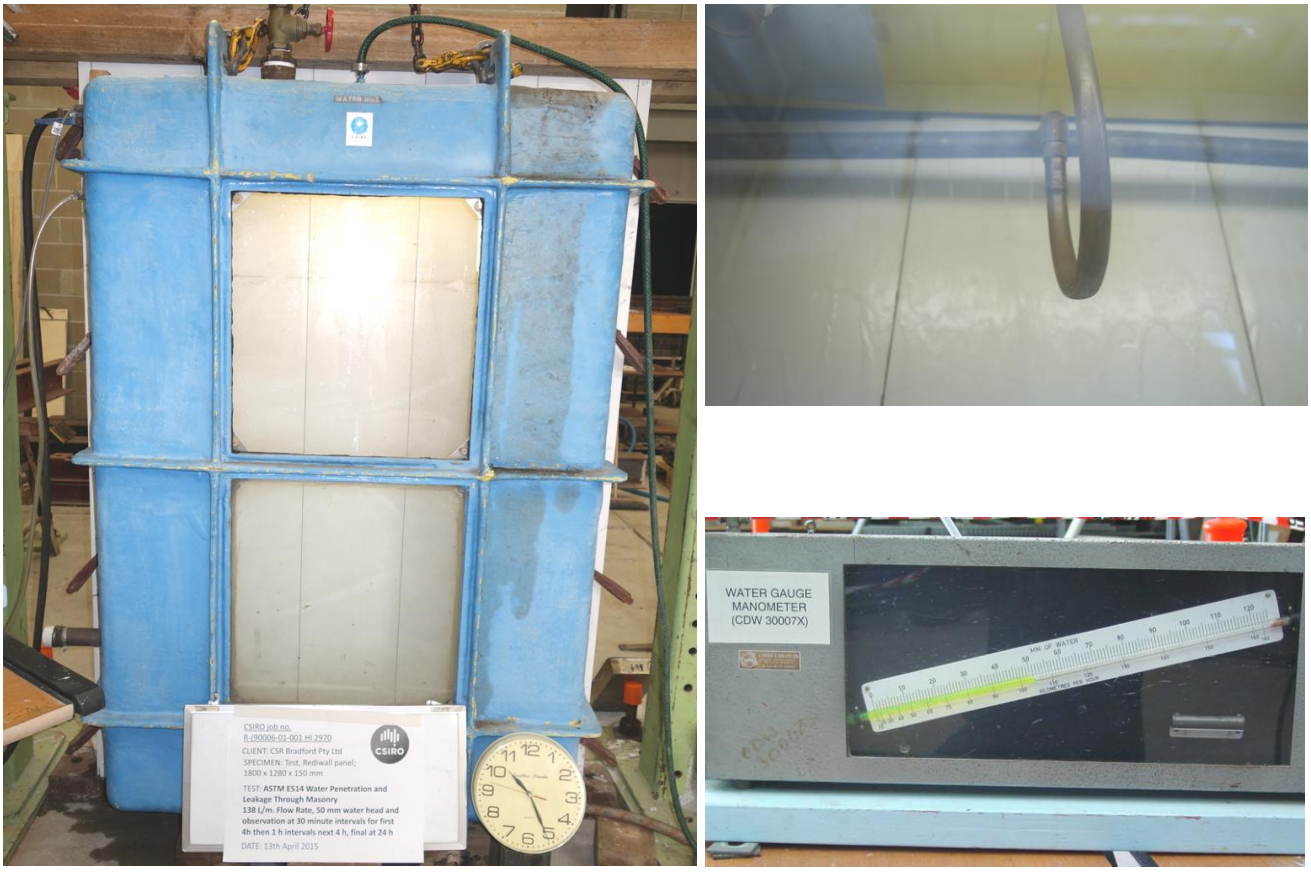



**Figure 8 Water penetration test apparatus attached to single leaf wall panel**

Refer to Table 2 for results of water penetration testing.

### Table 2 Observations and results for water penetration test of single leaf wall panel

| Specimen | Exposure area | Test period Start | Test Period Finish | Conditions |
|---|---|---|---|---|
| Single leaf Wall panel | 1070mm x 1600mm | 13 April 2015 | 13 April 2015 | Temperature 20 ± 1°C |
| 1810 x 1280 x 150 mm | Area = 1.712 $m^2$ | 9:55 am | 1:55 pm | Relative humidity 76 % |

| Test duration | Observation | Collection of water |
|---|---|---|
| **30 minutes** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **1 hour** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **1 hour 30 minutes** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **2 hours** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **2 hours 30 minutes** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **3 hours** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **3 hours 30 minutes** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Water observed at end stop |
| **4 hours** | Water penetration through to outer face | No water collected |
| | Water penetration through to base of wall panels | Total 0.18 L water collected |

### Figure 9 Observation for water penetration at wall panel's base (end stop)

### 7.1.1 COMMENT

Water was observed weeping over the lip of the end stop at the wall panel's base. There was no evidence of any water penetrating through the rear wall face opposite the area exposed to the water spray and air pressure test. It was concluded that the water spray had penetrated through the exposed area where the interlocking joints of the casings were, then travelled down to the end stop at the base of the wall panel. The water welled-up in the end stop until it reached the lip and began weeping out the front and rear of the base of the wall panel.

The end stop was not part of the normal installation of the CSR AFS Rediwall polymer-based permanent formwork system. The end stop at the base of the wall panel specimen was there for containment of the core-fill process for the test. Therefore, the water collected at the base of the wall panel can be ignored in the test results.

## 7.2 Water permeability test results

Water permeability (WP) of the block section of the wall panel, as described in section 5.1, was tested in accordance with the Australian Standard AS/NZS 4347.1:1995, 'Method 1: *Determination of Water Permeability*'.

Table 3, below, details the block section of the wall panel, test conditions, and observations, whilst subjected to the test conditions.

**Table 3 Test conditions and exposure area of the specimen**

| Specimen | Specimen size | Exposed test area | Test period | Test conditions | Observations |
|---|---|---|---|---|---|
| block section of the Wall panel | 150 mm thick x 500 $mm^2$ | 50 mm diameter | 100 hours | 6 metre head of water<br>Temperature +20 °C ±1 °C | Water did not penetrate top surface |

**Figure 10 Water permeability test observations of the block specimen under test**

## 7.3 Summary of results

The tested polymer based permanent formwork system, in a 150 mm thick core-filled configuration, when subjected to the test methods described herein, performed in general as summarised in Table 4.

**Table 4 Summary of the test results**

| # | ASSESSMENT METHOD | SPECIMEN | TEST PARAMETERS | RESULTS/OBSERVATIONS |
|---|---|---|---|---|
| 1 | ASTM E514/E514M-14a; Standard test method 'Water penetration leakage through masonry' | Wall panel - Polymer based permanent formwork system | Water penetration and or leakage at rear of exposed test chamber surface; compared with reference wall | Specimen wall showed no penetration through the rear wall panel |
| 2 | AS/NZS 4347.1:1995 Standard test method 'Damp-proof courses and flashings – Method of test – Determination of water permeability' | Block section of the Wall panel - Polymer based permanent formwork system | Water penetration through specimen due to 6 m water head pressure | Water did not penetrate through the top face of the specimen |

Note: Item 1 - Water collected at base of the wall panel was due to the end stop. This was not considered part of the test criteria, since the wall stop was for containment of the core-file process for the test, and therefore not part of the normal installation of the CSR AFS Rediwall polymer-based permanent formwork system.

S J Smith
Project Leader/Technical Manager
13 October 2015

G Williams
Technical Officer
13 October 2015

# Appendices

# Appendix A Rediwall System information, as provided by sponsor

## A.1 Rediwall Construction Process Overview

AFS WALLING SOLUTIONS we put you in front

# REDIWALL CONSTRUCTION PROCESS OVERVIEW

1. **Place Order (Rediwall Orderform)**

Client completes Rediwall order form, listing lineal metres of each wall height required along with a listing of the required accessories. The completed order form is submitted to Rediwall production electronically or by fax.

2. **Production**

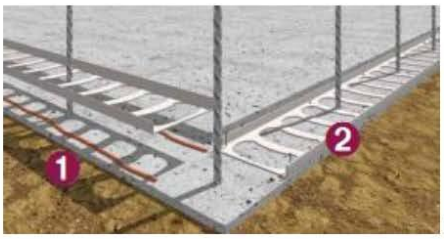
AFS Rediwall is manufactured in a state of the art factory with precision processes, manufacturing large volumes of quality product with short lead times.

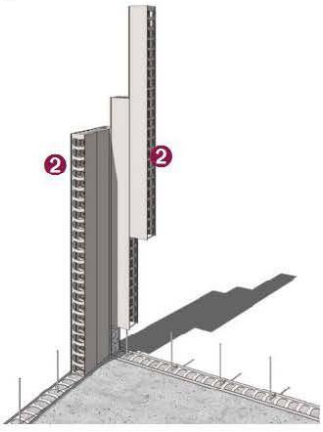
3. **Delivery**

AFS's in house transportation and logistics team ensures that orders are shipped with care, arriving on site in a timely manner. Panels are packed in packs of up to 20 panels which are easily delivered to site and craned onto the floor slab or deck ready for placement.

4. **Site Erection**

Once set out is complete, Rediwall floor track is installed followed by the Rediwall panels being lifted into place by hand over the reinforcement starter bars. In some cases it is simply installed off the formwork deck of the next floor level. The panels are then braced using temporary braces or fixed to the formwork deck.

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### 5. Openings & Services

Smaller penetrations may be cut out once a wall is installed and then caped off using the Rediwall End Cap. Doorway and window openings are formed using sill and lintel panels (which can be supplied cut to size). Steel door frames can be installed to suit or the openings can simply be capped off using the Rediwall End Cap.

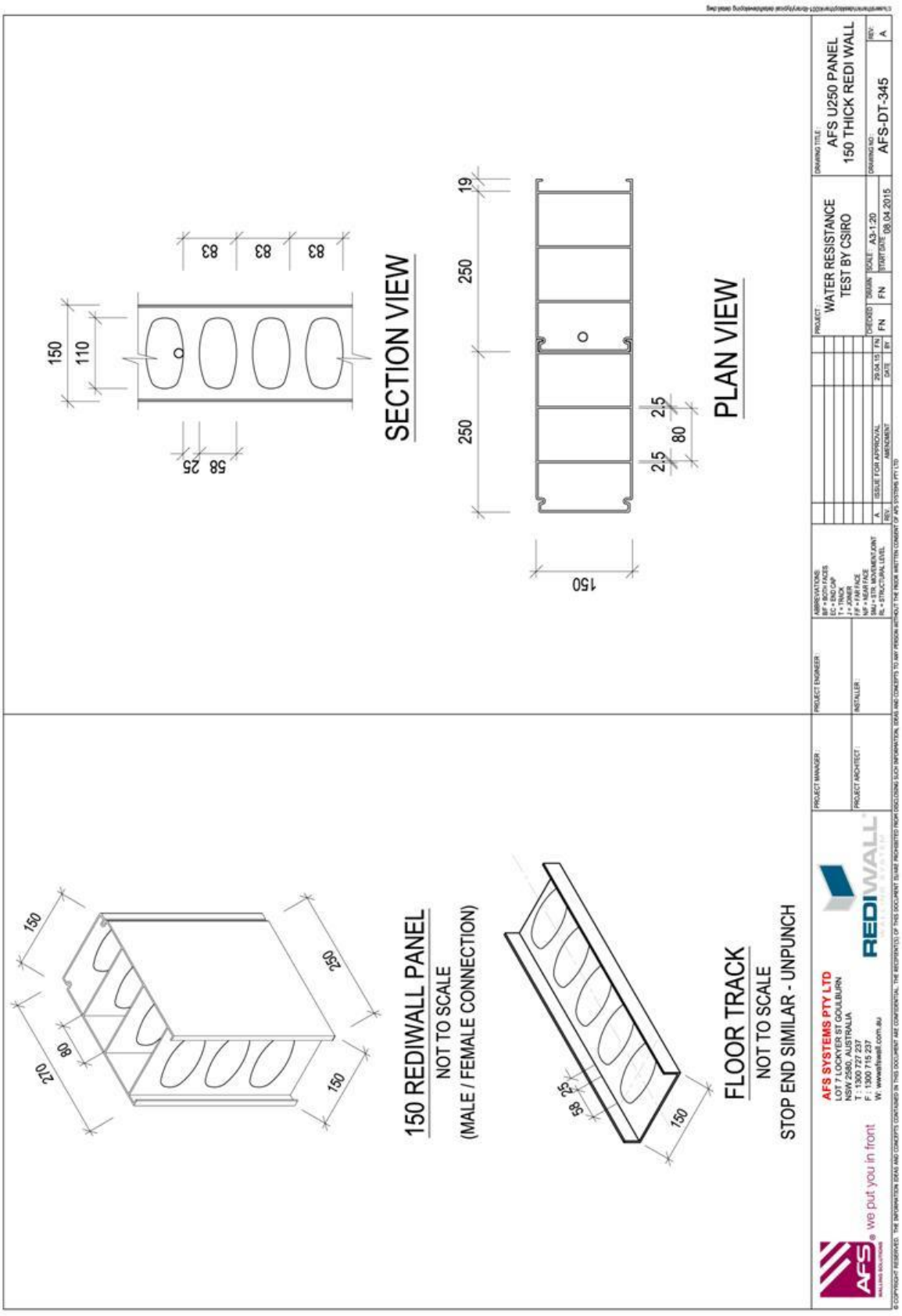

### 6. Concrete Core Fill

The erected panels are then core filled with concrete using a mix design that is suitable for filling Rediwall delivered into the wall via a concrete pump. This is mostly done from the formed deck. Of the next slab or off a scaffold. The concrete walls are then ready to serve as load bearing structure.

### 7. Finishing of Walls

Once the concrete core fill has gained strength and the walls are permanently braced by the floor or roof structure at the top of the walls the temporary bracing is removed. The smooth, white finish of the Rediwall panels is a suitable finish for many applications; however suitable acrylic renders can be applied to the surface if required.

## A.2 AFS U250 Panel 150 mm Thick Rediwall



# End of report

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