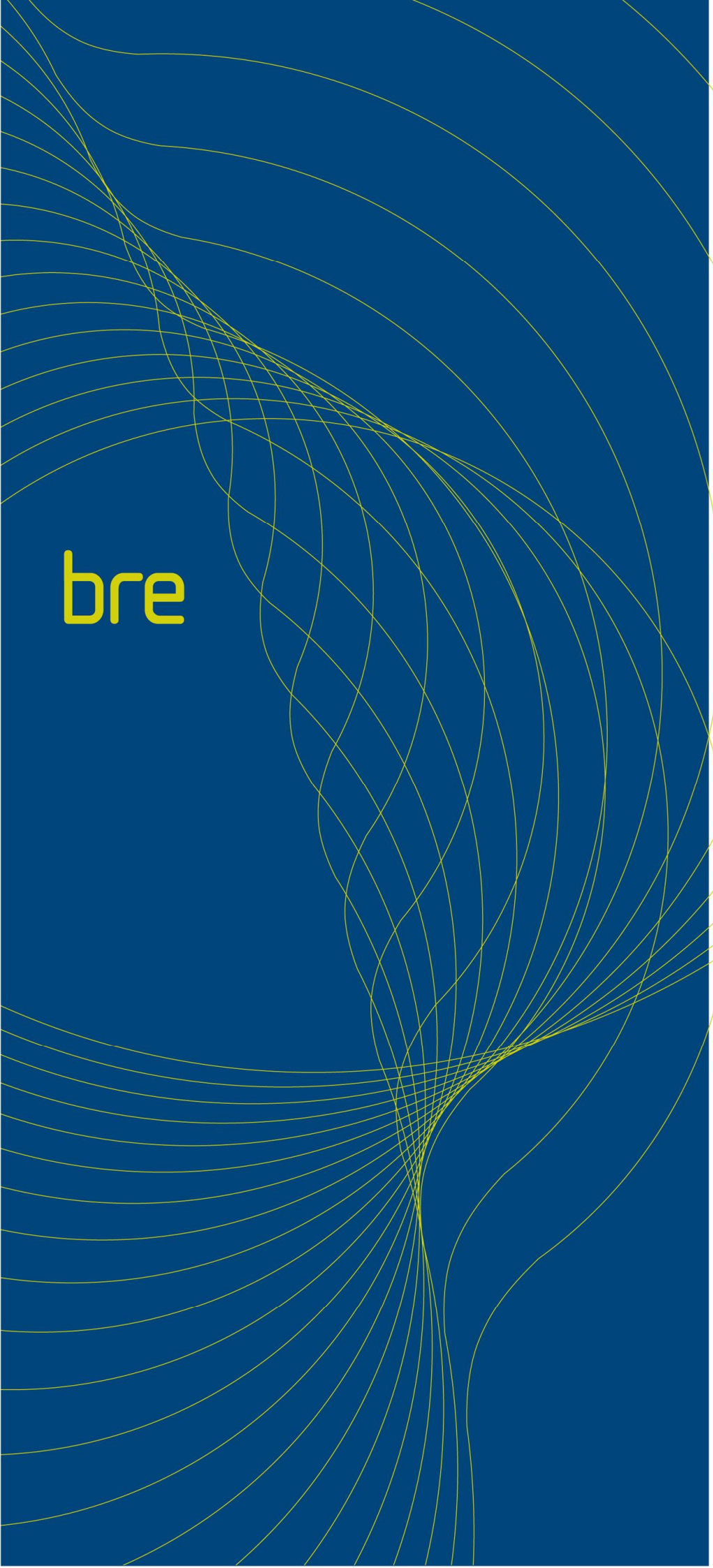


Comparative Freeze-Thaw Testing of Affresol TPR

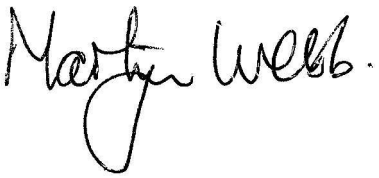
Prepared for: Scott Phillips
Affresol Ltd
Unit 3 Queensway
Swansea West Business Park
Swansea
SA5 5DJ

29 February 2012

Test report number 267194/R1

Prepared by

Name	Dr Martyn Webb
Position	Principal Consultant, Building Technology Group, BRE
Date	29/02/12



Signature

Approved on behalf of BRE

Name	Dr Rupert Pool
Position	Principal Consultant, Building Technology Group, BRE
Date	29/02/12

Signature

BRE
Garston
WD25 9XX
T + 44 (0) 1923 664000
F + 44 (0) 1923 664010
E enquiries@bre.co.uk
www.bre.co.uk

Contents

1 Introduction

At the request of Scott Phillips of Affresol Ltd, BRE have undertaken a programme of comparative freeze-thaw testing on the product described as Affresol TPR.

Two different test methods were used for the assessment; DD CEN/TS 12390-9: 2006 to investigate external 'scaling' effects and PD CEN/TR 15177: 2006 to examine internal effects. For the latter test, the 'beam' test option was followed.

As a means of benchmarking the performance of the TPR product, two different concrete mixes were exposed to the test regimes – a C25/30 concrete meeting the requirements of Class XF1 in BS 8500-1: 2006/BS EN 206-1: 2000, and the same concrete mix but without the addition of an air entraining agent. Exposure Class XF1 could be considered typical of vertical surfaces such as façades and columns exposed to rain and freezing, and/or non-vertical surfaces not highly saturated, but exposed to freezing and to rain or water. This exposure class does not include exposure to de-icing agents.

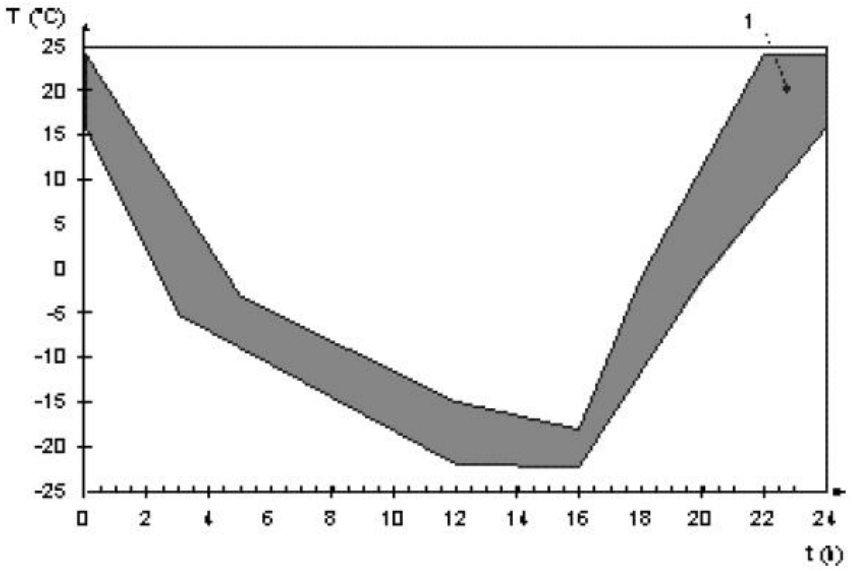
Details of the reference concrete mix designs are given in Section 2.3.

An internal audit of the test programme was undertaken which confirmed that the work carried out was completed in accordance with the requirements of BS EN ISO 17025: 2005. Evidence of the audit is given in Appendix A.

2 Details of tests carried out

2.1 Testing to DD/CEN/TS 12390-9: 2006

Affresol Ltd provided BRE with four 150 mm cubes of the TPR product for testing, with these being identified as specimens 267194/1/1 to 4. The reference concrete cubes were cast and cured by BRE at their Garston laboratories, with these being given the identifications 267194/2/1 to 4 for the non-air-entrained specimens and 267194/3/1 to 4 for the XF1 concrete. A total of 56 exposure cycles were completed, with the freeze-thaw exposure profile being shown in Figure 1. The method used was the slab method (listed as the reference method) and the freezing medium used was deionised water.



Key
1 Temperature range at the centre of the test surface

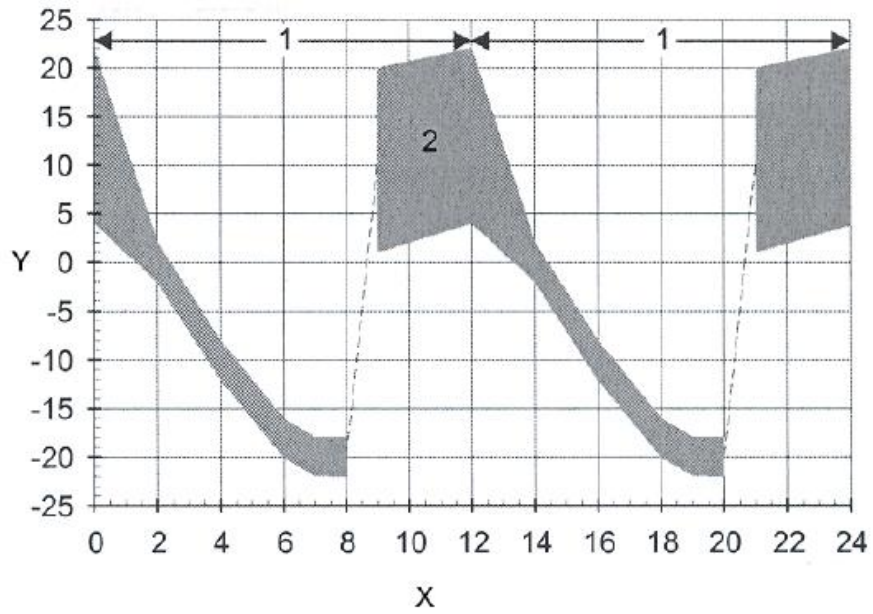
Figure 1. Diagram showing the temperature/time profile in DD/CEN/TS 12390-9: 2006.

The results of the test are presented in Section 3.1 and discussed in Section 4.

2.2 Testing to PD/CEN/TR 15177: 2006

Affresol Ltd provided BRE with four beams (and one spare) of the TPR product, each measuring 400 mm x 100 mm x 100 mm. These were given specimen numbers 267194/1/5 to 8. The reference concrete beams were cast and cured by BRE at their Garston laboratories, with these being given the identifications 267194/2/5 to 7 for the non-air-entrained specimens and 267194/3/5 to 7 for the XF1 concrete.

A total of 56 exposure cycles were completed with the exposure profile for this test being shown below:



Key

1	freeze-thaw cycle
2	temperature range in the reference prism
Y	temperature in °C
X	time in h

Figure 2. Diagram showing the temperature/time profile in PD/CEN/TR 15177: 2006

The results of the test are presented in Section 3.2 and discussed in Section 4.

2.3 Reference concrete mix designs

2.3.1 Class XF1 concrete (267194/3)

This concrete was designed against the requirements for exposure Class XF1, with this exposure environment being typical of vertical surfaces such as façades and columns exposed to rain and freezing, and/or non-vertical surfaces not highly saturated, but exposed to freezing and to rain or water. This exposure class does not included exposure to de-icing agents. This mix design was identified as 267194/3, and would provide a 'satisfactory/good' performance benchmark during the tests. The mix details are as follows:

	kg/m^3
Cement	330
20 – 10 mm aggregate	684
10 – 4 mm aggregate	342
4 mm down	684
Air entraining agent	0.693
Added water	189.307

Table 1. Mix design for Class XF1 reference concrete (267194/3)

The mean compressive strength at 28 days for this mix design was 33.5 MPa.

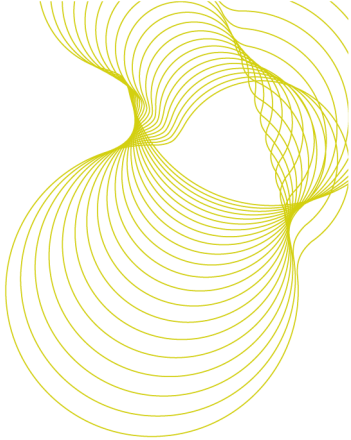
2.3.2 Non air-entrained concrete (267194/2)

This concrete design did not include an air-entraining agent, and as such would be expected to perform less well during freeze-thaw tests. This mix design was identified as 267194/2, and would provide a 'less good' performance benchmark during the testing. The mix details are as follows:

	kg/m^3
Cement	330
20 – 10 mm aggregate	736
10 – 4 mm aggregate	368
4 mm down	736
Air entraining agent	None
Added water	190

Table 2. Mix design for non air-entrained reference concrete (267194/2)

The mean compressive strength at 28 days for this mix design was 49.5 MPa.



3 Test results

3.1 Results for testing to DD/CEN/TS 12390-9: 2006

The results (weight of scaled material per unit area) from each freeze-thaw cycling stage for each specimen are given in Tables 3 to 5. A mean value for each cycling stage for each specimen is also given.

	267194/1/1	267194/1/2	267194/1/3	267194/1/4	**Mean**
	kg/m^2				
S_7	0.0004	0.0010	0.0004	0.0009	**0.0007**
S_{14}	0.001	0.001	0.001	0.002	**0.001**
S_{28}	0.003	0.002	0.001	0.002	**0.002**
S_{42}	0.006	0.002	0.001	0.004	**0.003**
S_{56}	0.007	0.002	0.001	0.006	**0.004**

Table 3. Summary of test results for TPR Product

	267194/2/1	267194/2/2	267194/2/3	267194/2/4	**Mean**
	kg/m^2				
S_7	0.0004	0.0041	0.0003	0.0010	**0.001**
S_{14}	0.009	0.012	0.023	0.003	**0.012**
S_{28}	0.032	0.024	0.038	0.008	**0.026**
S_{42}	0.038	0.027	0.064	0.009	**0.035**
S_{56}	0.038	0.031	0.070	0.010	**0.037**

Table 4. Summary of test results for the non air-entrained reference concrete

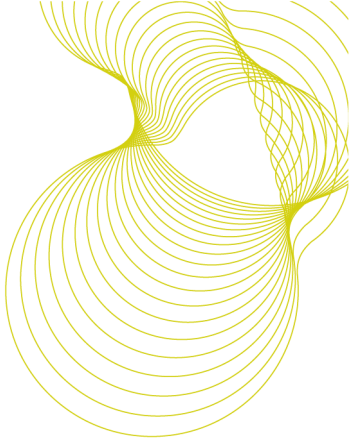
	267194/3/1	267194/3/2	267194/3/3	267194/3/4	**Mean**
	kg/m^2				
S_7	0	0.0004	0.0002	0.0003	**0.0002**
S_{14}	0.0001	0.0004	0.0010	0.005	**0.0018**
S_{28}	0.001	0.012	0.007	0.006	**0.0066**
S_{42}	0.003	0.013	0.012	0.007	**0.0087**
S_{56}	0.003	0.013	0.013	0.008	**0.010**

Table 5. Summary of test results for the XF1 reference concrete

3.2 Results for testing to PD/CEN/TR 15177: 2006

The weight of each specimen was recorded after 7, 14, 28, 42 and 56 cycles, with the results summarised in Tables 6 to 8.

The modulus of elasticity (E) of each specimen was calculated before exposure and at each of the weighing intervals described above, using a Grindosonic instrument in longitudinal resonance mode. The E values for each specimen at each measurement interval are summarised in Tables 9 to 11.



Specimen	Weight loss (%)				
	7 Cycles	14 Cycles	28 Cycles	42 Cycles	56 Cycles
267194/1/5	0.4	0.2	0.2	0.2	0.4
267194/1/6	0.5	0.3	0.3	0.3	0.6
267194/1/7	0.6	0.4	0.4	0.4	0.6
267194/1/8	0.5	0.3	0.3	0.3	0.5
Mean	**0.5**	**0.3**	**0.3**	**0.3**	**0.5**

Table 6. Summary of weight changes from initial value for TPR Product

Specimen	Weight loss (%)				
	7 Cycles	14 Cycles	28 Cycles	42 Cycles	56 Cycles
267194/2/5	0.2	0.1	0.1	0.1	0.1
267194/2/6	0.1	0.1	0.1	0.1	0.2
267194/2/7	0.1	0.1	0.1	0.1	0.2
Mean	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**

Table 7. Summary of weight changes from initial value for the non air-entrained reference concrete

Specimen	Weight loss (%)				
	7 Cycles	14 Cycles	28 Cycles	42 Cycles	56 Cycles
267194/3/5	0.2	0.1	0.1	0.2	0.3
267194/3/6	0.2	0.1	0.1	0.1	0.3
267194/3/7	0.2	0.2	0.2	0.2	0.4
Mean	**0.2**	**0.1**	**0.1**	**0.2**	**0.3**

Table 8. Summary of weight changes from the initial value for the XF1 reference concrete

Specimen	E Value (kN/mm^2)					
	Initial	7 Cycles	14 Cycles	28 Cycles	42 Cycles	56 Cycles
267194/1/5	17	3	11	6	15	13
267194/1/6	8	5	4	15	15	15
267194/1/7	14	3	2	6	3	12
267194/1/8	10	13	4	15	15	16
Mean	**12**	**6**	**5**	**10**	**12**	**14**

Table 9. Summary of calculated E values for the TPR Product

Specimen	E Value (kN/mm^2)					
	Initial	7 Cycles	14 Cycles	28 Cycles	42 Cycles	56 Cycles
267194/2/5	53	137	86	45	186	47
267194/2/6	87	90	167	167	182	43
267194/2/7	47	45	94	44	92	43
Mean	**53**	**90**	**116**	**85**	**154**	**44**

Table 10. Summary of calculated E values for the non air-entrained reference concrete

Specimen	E Value (kN/mm^2)					
	Initial	7 Cycles	14 Cycles	28 Cycles	42 Cycles	56 Cycles
267194/3/5	57	119	68	41	103	153
267194/3/6	108	39	36	119	49	21
267194/3/7	118	88	88	135	163	135
Mean	**95**	**82**	**64**	**98**	**105**	**103**

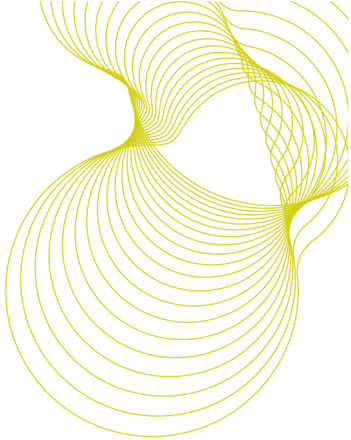
Table 11. Summary of calculated E values for the XF1 reference concrete

4 Discussion

The results of the DD CEN/TS 12390-9 ‘scaling’ test have shown the TPR product to perform well, with the loss of material through scaling being less than the material lost by the XF1 reference concrete after completion of the 56 freeze-thaw cycles. This reference concrete was designed following guidance given in BS 8500-1: 2006, and is classed as being suitable for XF1 applications (moderate water saturation without de-icing salts) – typically these could be vertical surfaces such as façades and columns exposed to rain and freezing, and/or non-vertical surfaces not highly saturated, but exposed to freezing and to rain or water. It does not include environments where de-icing agents may be present.

The results of the PD CEN/TR 15177 tests are less definitive in their outcome due to variability within the results of the reference concrete specimens. Overall they show the TPR product has suffered minimal internal damage after completion of 56 freeze-thaw cycles – as indicated by a virtually unchanged E (modulus of elasticity) value and only 0.5 % weight loss overall. The XF1 reference concrete showed a slight increase in E value associated with a 0.3 % weight loss after 56 cycles. The E value of the non air-entrained concrete showed a slight decrease at the conclusion of the testing.

When the results of the test programme are considered as a whole, it is BRE’s opinion that the TPR product has demonstrated a similar level of performance in these tests to concrete designed to Class XF1 in BS 8500-1: 2006 – a concrete designed to withstand moderate water saturation without de-icing salts.



5 Standards

BS 8500-1:2006. Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier

BS EN 206-1: 2000 Concrete. Specification, performance, production and conformity

BS EN ISO 17025: 2005 General requirements for the competence of testing and calibration laboratories

DD CEN/TS 12390-9: 2006 Testing hardened concrete, Freeze-thaw resistance, Scaling

PD CEN/TR 15177: 2006 Testing the freeze-thaw resistance of concrete. Internal structural damage

Appendix A ISO 17025 Audit Record

BRE
Garston, Watford, Herts WD25 9XX
T +44 (0)1923 664000 F +44 (0)1923 664010 E enquiries@bre.co.uk

21 September 2011

To whom it may concern,

Ref: Project/Job Number – CV3701/267194

I have completed an audit of the above referenced Project/Job Number which covered test work on samples supplied by Affresol Ltd and I am satisfied that the work carried out by BRE was done so in accordance with ISO 17025: 2005.

Yours faithfully,

John Noonan

BRE Quality Manager

==========REPORT ENDS==========