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Resin cube testing for Millfield

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1 Introduction

This report presents the results for testing which was undertaken on resin cubes supplied to TTI Testing by Millfield Enterprises Ltd (Job reference 17235) for their client Arcelormittal. It was requested to test the cubes in accordance with DNV-OS-E304 to determine the Barcol hardness, density, failure stress and Young's modulus.

The mechanical testing was witnessed by a DNV GL Surveyor.

This document sets out the measurements and results of the testing undertaken by TTI Testing Ltd. and witnessed by DNV GL for Millfield Enterprises Ltd. in assessment of the cube properties.

2 Samples

A set of six samples (nominal cube side length 40 mm) was supplied to TTI Testing by Millfield Enterprises Ltd. The cubes had previously been conditioned by heating in an oven at 80°C for 2 hours. They were numbered arbitrarily (by TTI Testing) 1 to 6 inclusive.

3 Test Procedure

3.1 General preparation

On receipt, the cubes were machined to reduce the resin rich layer and to provide parallel faces suitable for compression testing.

3.2 Barcol hardness

Barcol hardness testing was conducted in accordance with ASTM D 2583. Figure 3.1 shows a resin cube being tested with a Barcol Hardness tester.

Six readings were taken from each sample. If one of the readings was inconsistent with the other five data points this reading could be dropped and an average value taken of the remaining five points.

Figure 3.1: Use of a Barcol Hardness tester on a resin cube.

3.3 Specific gravity

The specific gravity of the mix was determined for each of the cubes (after machining). The linear dimensions of the cube were measured using digital callipers accurate to 0.01 mm, and the mass of the cube using digital scales accurate to ±0.01 g.

3.4 Compressive strength and Modulus of elasticity

TTI Testing's 250 kN machine (serial number 80184) was used for the compression tests. This machine is a universal testing machine, with main parameters listed in Table 3.1. A copy of the calibration certificate for this machine is presented in Appendix A.

Parameter	
Load capacity (kN)	± 250
Actuator stroke (mm)	150
Adjustable cross head for slack removal	Y
Maximum 'day light' below crosshead (mm)	1250
Controller	M9500 SERIES
Fatigue rated	Y

Table 3.1: Main parameters of the 250 kN testing machine.

- The ultimate compressive strength was calculated from the captured maximum compressive load displayed on the machine controller and the cross sectional area of the cube.
- The Young's modulus was determined from the load-stroke data collected by proprietary software on a computer connected to the machine controller. Data was gathered at 0.1 s intervals.

Figure 3.2 presents a typical load-stroke plot for a compression test on a resin cube. The Young's Modulus, E, may be derived using this graph and in accordance with equation 3.1.

$$E = \frac{F}{\Delta l} \times \frac{l_0}{A} \tag{3.1}$$

Where F is Load applied over which the strain is measured [N];

Δl is the change in specimen length over the load range [mm];

l_0 is the initial specimen length [mm]; and,

A is the specimen area [mm^2]

The gradient of the load-stroke relationship (Figure 3.2) gives F / Δl, and l_0 and A are the measured length and cross-sectional area for each cube determined before testing.

Each load-stroke plot was corrected for the machine stiffness to give the intrinsic behaviour of the resin cube.

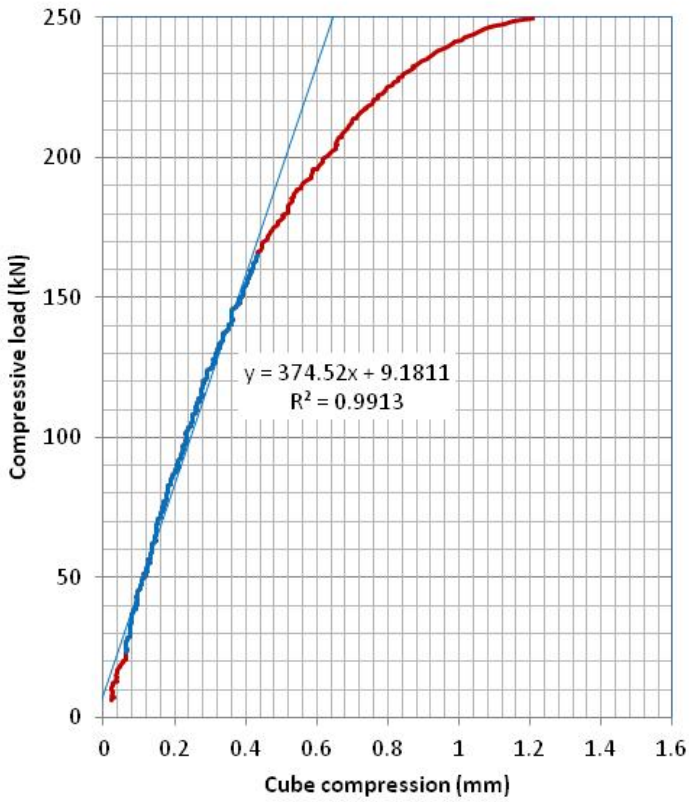

Figure 3.2: Example load-stroke relationship for a compression test on a resin cube used to determine the material Modulus of Elasticity.

4 Results

4.1 Compression testing and Modulus of Elasticity

Table 4.1 summarises the results of the compression strength and modulus of elasticity tests which were undertaken on the cubes.

Appendix B presents these results witnessed by the DNV GL surveyor (without the results of the E-modulus which was determined later from an analysis of the data collected during the witnessed tests).

Appendix C presents the load-stroke plots for each of the cubes from which the Modulus of Elasticity, E, was determined in accordance with equation 3.1.

4.2 Barcol Hardness and Specific Gravity

Table 4.2 presents the measurements and results for the Barcol Hardness testing. Appendix B presents these results witnessed by the DNV GL surveyor.

	sample dimensions							
sample no.	width A	breadth B	height C	weight	relative density	compressive failure load	Nom. Failure stress	Modulus of Elasticity
(-)	(mm)	(mm)	(mm)	(g)	(-)	(kN)	(N/mm^2)	(N/mm^2)
1	39.65	39.67	40.37	109.26	1.72	205.6	130.7	7,970
2	39.65	39.65	40.34	109.64	1.73	208.1	132.4	7,887
3	39.66	39.67	40.15	108.26	1.71	203.9	129.6	7,567
4	39.65	39.67	40.36	109.97	1.73	206.9	131.5	8,011
5	39.67	39.65	40.10	108.65	1.72	207.2	131.7	7,550
6	39.65	39.64	40.47	109.96	1.73	202.8	129.0	7,723
Average					**1.72**		**130.8**	**7,785**
Standard Dev.					**0.007**		**1.30**	**201**

Notes: for ease of reference, the lowest values obtained for the failure stress and Modulus of Elasticity have been highlighted by the blue shading. These figures are well in excess of the values of 100 N/mm^2 and 6,000 N/mm^2 resp. stipulated by DNV-OS-304.

Table 4.1: Summary of the results and measurements taken during the compression and E-modulus testing of the resin cube samples (17235).

Sample No.	width	breadth	height	weight	Specific Gravity	Barcol hardness						
					(SG)	1	2	3	4	5	6	Average
(-)	(mm)	(mm)	(mm)	(g)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
1	39.65	39.67	40.37	109.26	**1.72**	54	62	55	56	55	54	**56**
2	39.65	39.65	40.34	109.64	**1.73**	46	56	58	51	51	56	**53**
3	39.66	39.67	40.15	108.26	**1.71**	59	57	59	53	53	57	**56**
4	39.65	39.67	40.36	109.97	**1.73**	52	48	57	51	55	56	**53**
5	39.67	39.65	40.10	108.65	**1.72**	59	61	50	60	60	63	**59**
6	39.65	39.64	40.47	109.96	**1.73**	57	58	59	52	52	58	**56**
Average					**1.72**							
Standard Dev.					**0.007**							

Note, for ease of reference, the lowest values of Barcol hardness obtained for each of the cubes have been highlighted by the blue shading. These figures are all in excess of the minimum value of 36 stipulated by DNV-OS-304.

Table 4.2: Summary of results for the Barcol hardness and Specific Gravity testing of the resin cube samples (17235).

5 Discussion and Conclusions

1. The relative density of the cubes was measured over the range of 1.71 to 1.73. The DNV-OS –E304 (§D101 Table 1) specifies a range of 1.55 – 1.95. Therefore the cubes may be said to satisfy the requirement of the standard in this respect.
2. Measurements of the Barcol hardness of the six cubes were in the range 48 – 63. All readings were in excess of the minimum value of 36 specified in DNV-OS –E304 (§D101 Table 1). Therefore the cubes may be said to satisfy the requirement of the standard in this respect.
3. The compressive strength for the six cubes were in the range 129.0 – 132.4 N/mm^2, with an average value of 130.8 N/mm^2. This value is well in excess of the 100 N/mm^2 specified in DNV-OS –E304 (§D101 Table 1). Therefore the cubes may be said to satisfy the requirement of the standard in this respect.
4. The Young's Modulus for the six cubes was in the range 7,550 – 8,011 N/mm^2. All values were well in excess of the min. 6,000 N/mm^2 specified in DNV-OS –E304 (§D101 Table 1). Therefore the cubes may be said to satisfy the requirement of the standard in this respect.

6 References

[1] **Offshore Standard DNV–OS–E304** Offshore moorings steel wire ropes, April 2009, Det Norske Veritas, Høvik, Norway.

[2] **ASTM D2583-07** Standard test method for indentation hardness of rigid plastics by means of a Barcol impressor, ASTM International, West Conshohocken, PA, 2007, DOI: 10.1520/D2583-07, www.astm.org.