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Compression Testing of Cork

Report to Croft Associates Ltd

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Title	Compression Testing of Cork
Customer	Croft Associates Ltd
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	Name	Signature	Date
Author(s)	Paul Hutchinson	P Hutchinson	23/10/08
Reviewed by	George Melvin	G Melvin	23/10/08
Approved by	George Melvin	G Melvin	23/10/08

Executive Summary

This report details the results of a series of compression tests on cork, which have been conducted by Serco Technical and Assurance Services (TAS) on behalf of Croft Associates Ltd. The experimental programme was carried out as specified in Croft document CTN 2008/02 Issue A(1) and in accordance with the procedures described in test standard BS ISO 844:2001(2).

The tests were performed at temperatures of 20, 100, and -29°C using samples of material provided by Croft Associates. These samples were manufactured from a material conforming to specification Amorim 8113i, as per inspection report Croft GRC 1550 (3).

The work was carried out within the Serco Materials and Component Research Laboratory during August 2008 under contract number PO5607TC.

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1 Introduction

Croft Associates Ltd. has a requirement to determine the behaviour of rigid cellular material (cork) when it is subjected to a compressive force. In order to provide the necessary data, Serco TAS conducted a series of compression tests on specimens prepared from a material conforming to specification Amorim 8113i, as per inspection report Croft GRC 1550. The experimental programme was carried out as specified in Croft Associates document CTN 2008/02 Issue A and generally in accordance with the procedures described in Test Standard BS ISO 844:2001. Five samples were tested at each of the specified temperatures; 20, 100, and -29°C.

Croft Associates Ltd provided the samples. These comprised cylindrical coupons of material, nominally 76mm in diameter and 45mm in length. The samples were conditioned at the required temperature prior to testing. They were then placed in a cylindrical pot, to provide radial constraint, and crushed axially at a controlled rate up to a load of 50kN. Measurements of applied force and deformation were recorded continuously during the test.

The data were analysed to provide values of applied stress and relative deformation (strain) and the compressive modulus of elasticity was evaluated. The results are presented in the form of test certificates, and are included in the Appendices of this report.

2 Quality Assurance and Control

Serco TAS Quality Management arrangements have been assessed by Lloyds Register Quality Assurance (LRQA) against the requirements BS EN ISO 9001:2000 and certificate number LRQ 0964988 has been issued.

The overall scope of testing is defined in Croft Associates Test Specification CTN 2008/02 Issue A. The tests were conducted generally in accordance with British Standard BS ISO 844:2001 with the following permitted deviations:

i) The test specimens were radially constrained.
ii) The humidity of the environment during conditioning and testing of the samples was not controlled or measured.
iii) Testing was terminated at a maximum load of 50kN.
iv) Tests were conducted at temperatures other than 20°C.

Tests were performed in accordance with a Serco TAS Local Working Instruction(4) prepared specifically for compression testing of rigid plastic materials and cork. This was prepared for a previous experimental programme conducted on behalf of Croft Associates(5). This has been entered in the Serco TAS Quality Assurance register and has been approved by Croft Associates Ltd.

3 Test Details.

Details of the specimens, the equipment used and testing procedure are described below.

3.1 Test Specimens

A total of 20 cork specimens were prepared by Croft Associates Ltd. and were identified as samples GRC 1550/1 to GRC 1550/20. These were delivered to Serco TAS in July 2008 and registered within the laboratory QA system. The specimens were cylindrical and were nominally 76 mm in diameter and 45mm in length.

Prior to testing, the specimens were conditioned by storing them for a minimum period of 6 hours at the required test temperature. The dimensions of individual samples were recorded both at 20°C and at temperature immediately prior to installation into the testing machine.

3.2 Test Machine

The tests were carried out using a conventional servo-electric testing machine with a maximum load capacity of 250kN although the tests were terminated at a load of 50kN for consistency with data generated during a previous programme[5]. The machine was equipped with a fan-assisted environmental enclosure allowing tests to be conducted at temperatures from -170°C to 350°C to an accuracy of ± 2°C.

Radial constraint was a requirement of the test specification. This was achieved by placing the specimens into a cylindrical pot and applying the compressive force through a piston inserted into the top. The design of the pot included a removable base to simplify the extraction of the specimen on completion of the test. A detailed drawing of the containment is shown in Figure 1.

In order to ensure good axial alignment of the specimen during the test, the pot was supported on a platen incorporating a self-aligning spherical bearing.

A photograph illustrating the key elements of the complete testing arrangement is shown in Figure 2.

3.3 Instrumentation

The applied force was measured using the integral test machine load cell, which had been calibrated by a UKAS accredited authority to ISO 7500-1:1999 and ascribed a grade 1.0 classification.

The displacement of the test machine crosshead, and hence the deformation of the sample, was measured using a linear encoder, the calibration of which was checked using a traceable reference and found to be accurate to within +/- 0.15% over the range used during the test (40mm).

Data from the load and displacement instrumentation were recorded using a high-resolution PC based data acquisition system.

The temperature of the samples during conditioning and testing was checked using a hand-held digital thermometer with either two type 'T' thermocouples (20° and -29°C) or two type 'K' thermocouples (100°C). One thermocouple was attached to the outer surface of the containment pot, the other located in a hole drilled into the centre of one of the 'spare' specimens, placed inside the environmental enclosure.

3.4 Test Procedure

The specimens were conditioned in batches of five at the required temperature for a minimum period of 6 hours prior to testing. Meanwhile, the pot was placed into the environmental enclosure and allowed to stabilise at the same temperature as the specimens. After conditioning, the specimen to be tested was measured, placed into the pot, and the complete assembly was then installed into the test machine. The temperature was again allowed to stabilise for a minimum period of 1 hour before testing was carried out.

The crushing force was applied by displacing the piston at a controlled rate of approximately 4.5 mm/minute. This continued until a load of 50kN was attained. The load and displacement data were recorded continuously during the test at a rate of 20 readings/second. On completion the test specimen was removed and the recorded data were analysed as described in Section 4.

4 Data Analysis

The computer records were analysed to provide the required data using the procedure described below. At all test temperatures values of displacement were calculated from the "zero-deformation point" as specified in BS ISO 844.

The terms used in the calculation of these results are illustrated in Figure 3.

4.1 Applied Stress and Compressive strength

The applied stress (**σ**) in MPa was calculated as follows:

$$\sigma = \frac{F}{A_0}$$

where:

$\boldsymbol{F}$ = Applied force (N)
$\boldsymbol{A_0}$ =Initial cross-sectional area of the test specimen (mm^2)

Note that a value for compressive strength was not applicable as crushing did not occur hence no peak load was determined.

4.2 Relative Deformation

The relative deformation (**ε**) was calculated from:

$$\varepsilon = 100 \times \frac{x}{h_0}$$

where:

$\boldsymbol{x}$ = displacement (mm) from the "zero-deformation point"
$\boldsymbol{h_0}$ = initial thickness of the specimen (mm)

The compressive stress has been calculated at a range of relative deformations from 1% to 65%. These results are tabulated in the test certificates provided in the Appendices.

4.3 Compressive Modulus of Elasticity

The Compressive Modulus of Elasticity (***E***) was calculated for the linear portion of the force-displacement curve (elastic zone) from:

$$E = \frac{\sigma_e}{\varepsilon_e} \qquad \text{(MPa)}$$

where:

$$\sigma_e = \frac{F_e}{A_0}$$

$\boldsymbol{\sigma_e}$ = Stress at end of elastic region (MPa)
$\boldsymbol{F_e}$ = force at the end of the elastic region (N).
$\boldsymbol{A_0}$ = Initial cross-sectional area of the test specimen (mm^2).

and

$$\varepsilon_e = \frac{x_e}{h_0}$$

where:
$\boldsymbol{\varepsilon_e}$ = strain at force F_e
$\boldsymbol{X_e}$ = displacement (mm) at force F_e measured from the “zero-deformation point”
$\boldsymbol{h_0}$ = initial thickness of the specimen (mm)

Plots of the relative deformation as a function of applied stress have been produced for each test.

5 Results and Discussion

Test certificates were compiled containing details of each specimen tested, the results of the analyses described in Section 4, and plots of stress vs. relative deformation. These are presented in Appendices 1 to 3 for temperatures of 20, 100 and -29°C respectively.

5.1 Test Temperature of 20°C

At a test temperature of 20°C, the curve generally showed a reduction in slope at approximately 1% relative deformation. There was then a gradual increase in stress as the material was compacted, with the slope of the curve becoming increasingly steep after 40% relative deformation. The final load of 50kN was reached at a relative deformation of approximately 70%.

5.2 Test Temperature of 100°C

The results from the tests at 100°C showed a gradual increase in stress with the slope of the curve increasing significantly at about 45% relative deformation. The final load of 50kN was reached at a relative deformation of approximately 74%.

5.3 Test Temperature of -29°C

At a test temperature of -29°C the curve showed a reduction in slope at approximately 5% relative deformation. The stress then increased gradually, with the increase in slope occurring at approximately 35% relative deformation. The final load of 50kN was reached at approximately 60-65% relative deformation.

The tests at -29°C exhibited significantly more experimental scatter than the tests at 20°C and 100°C.

At -29°C all test traces exhibited a very steep gradient up to an applied load of approximately 1000N. Beyond 1000N the gradient of each curve became much shallower. It is this second part of the curve that was used in the calculation of the compressive modulus of elasticity. This is illustrated graphically in Figure 4.

The average results are summarised in the table below and the stress versus relative deformation data from all the specimens tested at each temperature are plotted for comparison in Figures 5-7.

Test Temperature (°C)	Compressive Modulus of Elasticity E, calculated from Initial Deformation (MPa)	Compressive Stress at 10% relative deformation (MPa)
20	15.0	0.57
100	4.6	0.34
-29	23.4	1.60

Table 1 – Average Compressive Modulus of Elasticity and Compressive Strength at 10% Relative Deformation for each Test Temperature

6 Conclusions

Compressive tests have been conducted at temperatures of 20, 100 and -29°C on samples manufactured from cork. Plots of applied stress versus strain have been produced and the relative moduli calculated.

7 References

1. Low Strain Rate Test Specification for Amorim Cork. - Croft Report CTN 2008/02 Issue A. June 2008.
2. BS ISO 844:2001. Cellular plastics - Compression Test for Rigid Materials - Specification
3. Specification for Manufacture of Cork Blocks - Croft Report GRC 1550 for Cork Amorim 8113i
4. SA/QA/LWI/SUS/212. Compression Testing of Rigid Plastic Materials and Cork.
5. SA/RJCB/RD04970/R002 Issue 1: Compression testing of Cork: July 2002

8 Distribution

Name	Organisation	Copies
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Mr. P. Hutchinson	Serco TAS	1
Mr. G. Melvin	Serco TAS	1

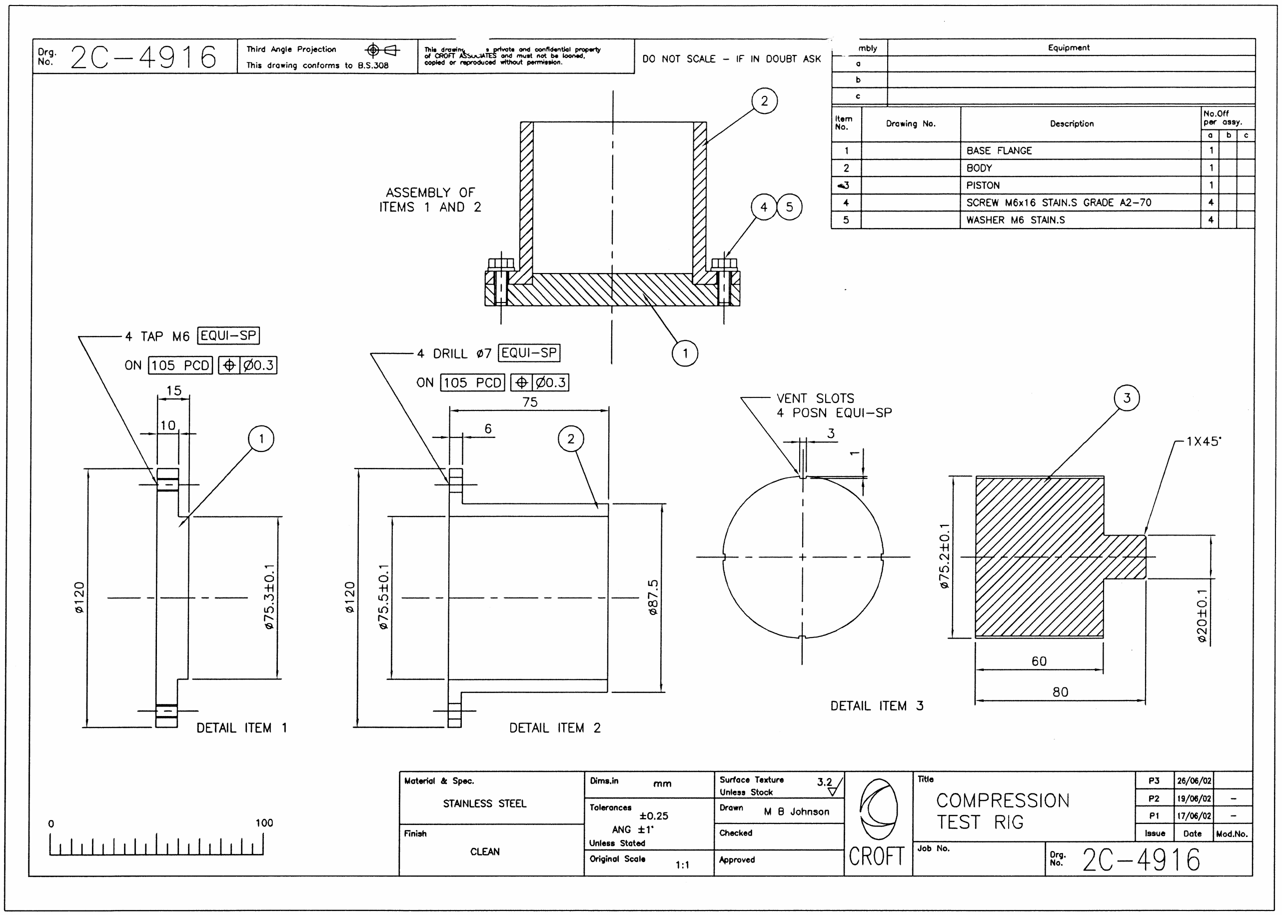

Figure 1 – Design of Pot used to Provide Radial Constraint during Compression Tests

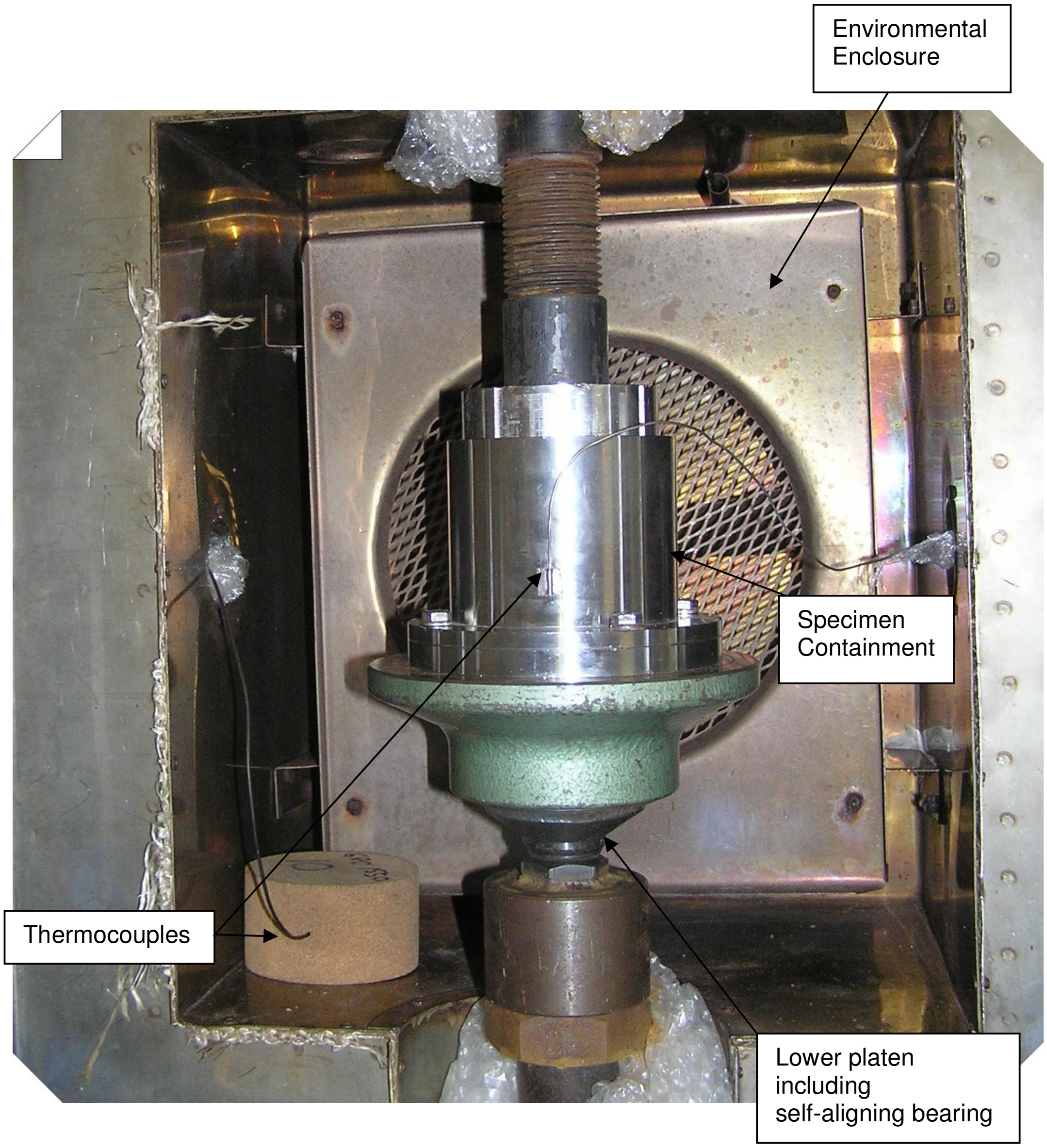

Figure 2 - Photograph of Test Assembly in Test Machine

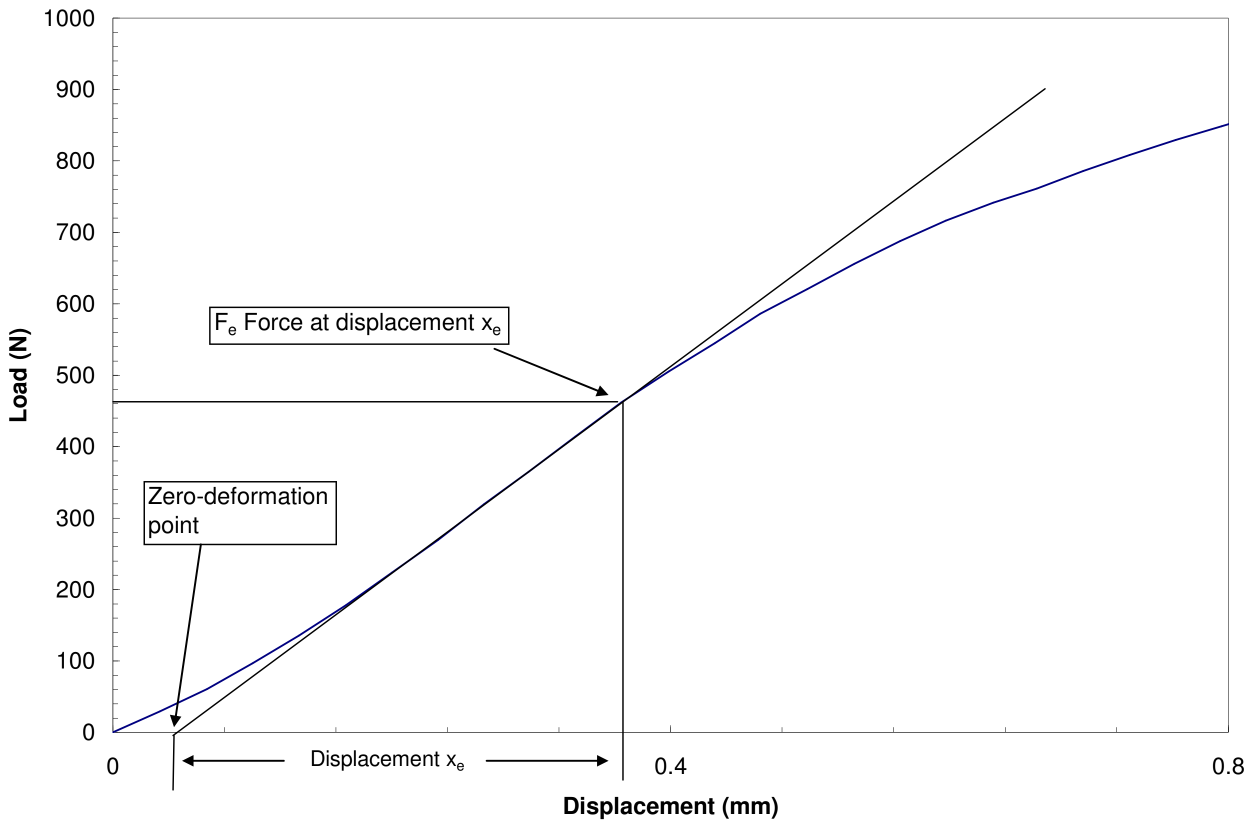

Figure 3 – Force-Displacement Curve: Illustration of terms used for analysis of data in accordance with BS ISO 844:2001

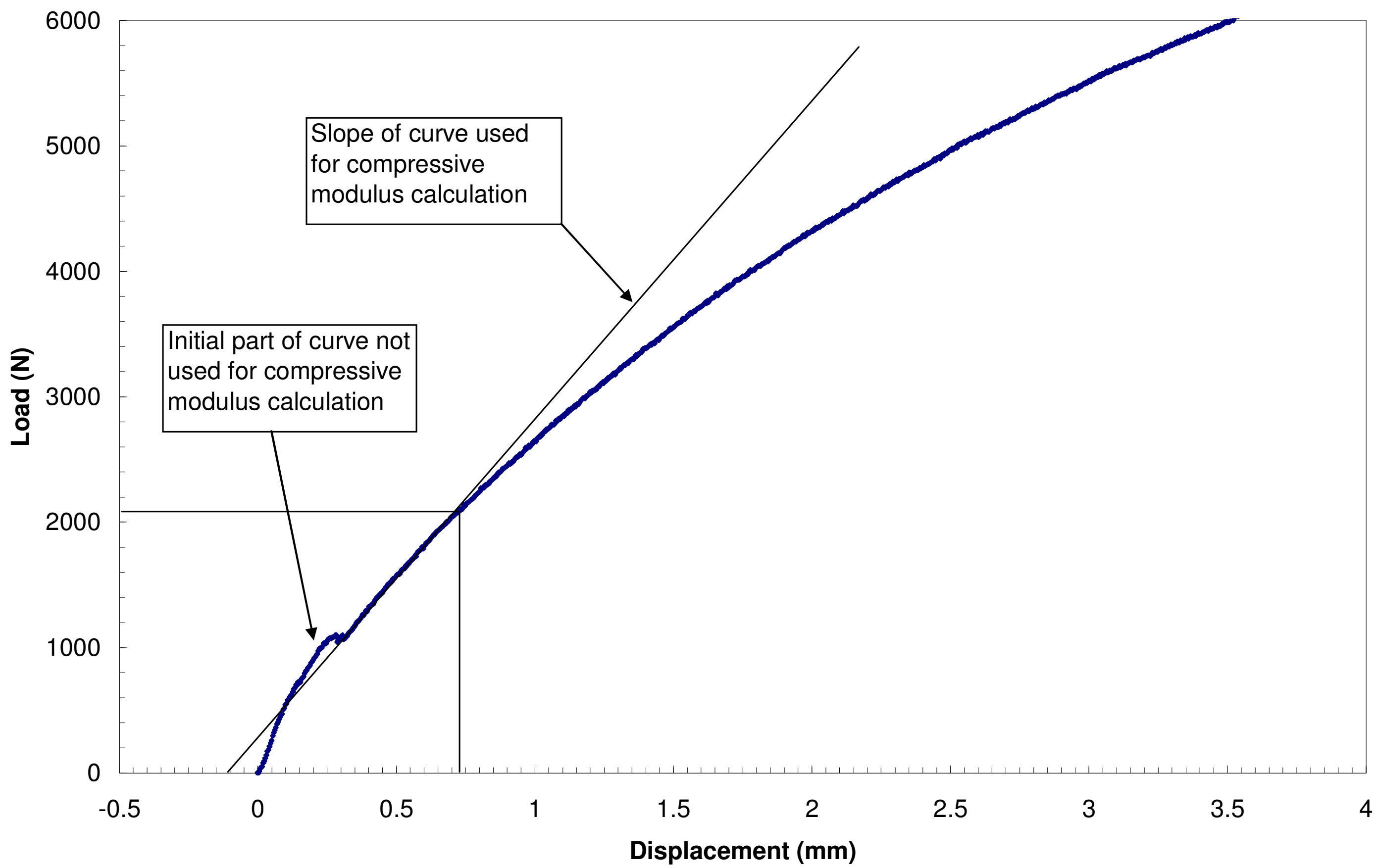

Figure 4 – Illustration of Slope of Curve used for Modulus Calculation at -29°C (Specimen GRC 1550-1)

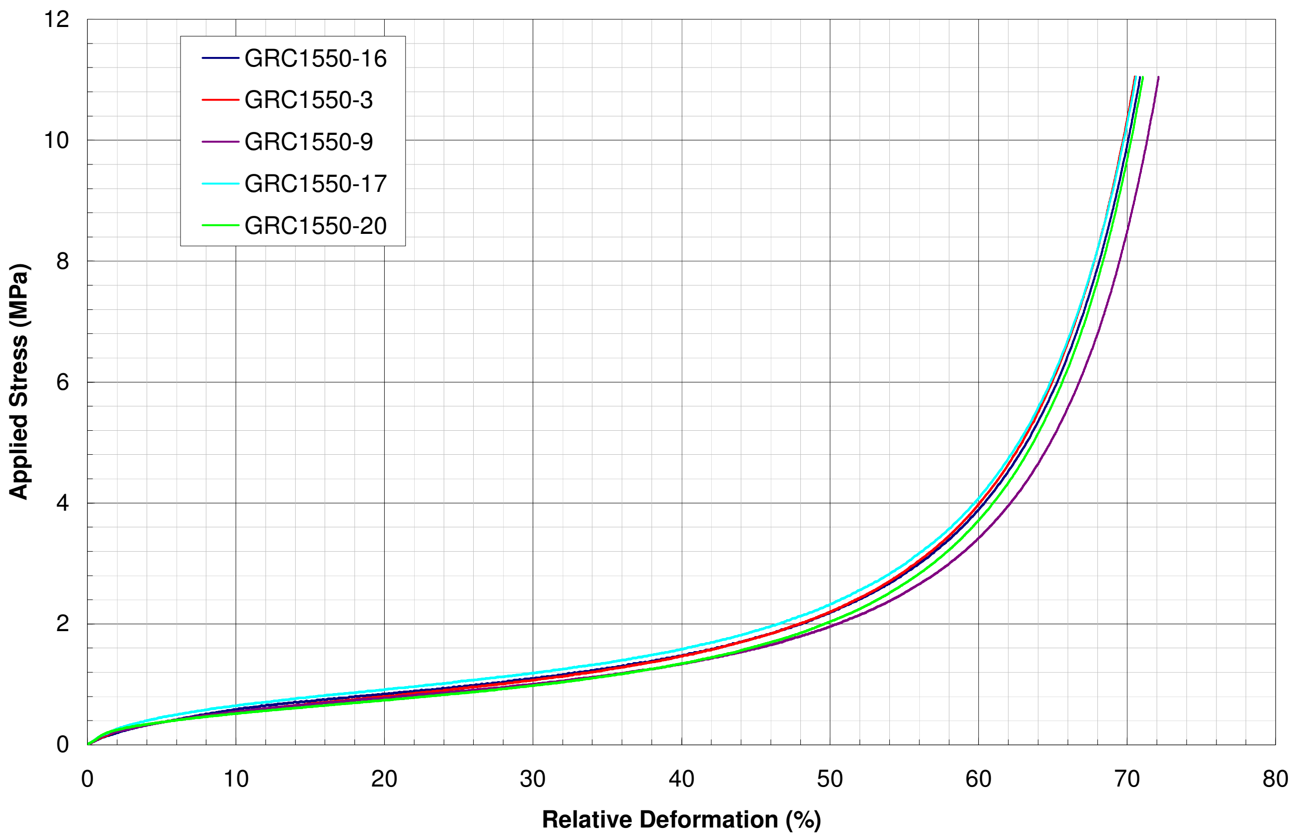

Figure 5 – Stress vs. Relative Deformation plot for Cork Samples Tested at 20°C

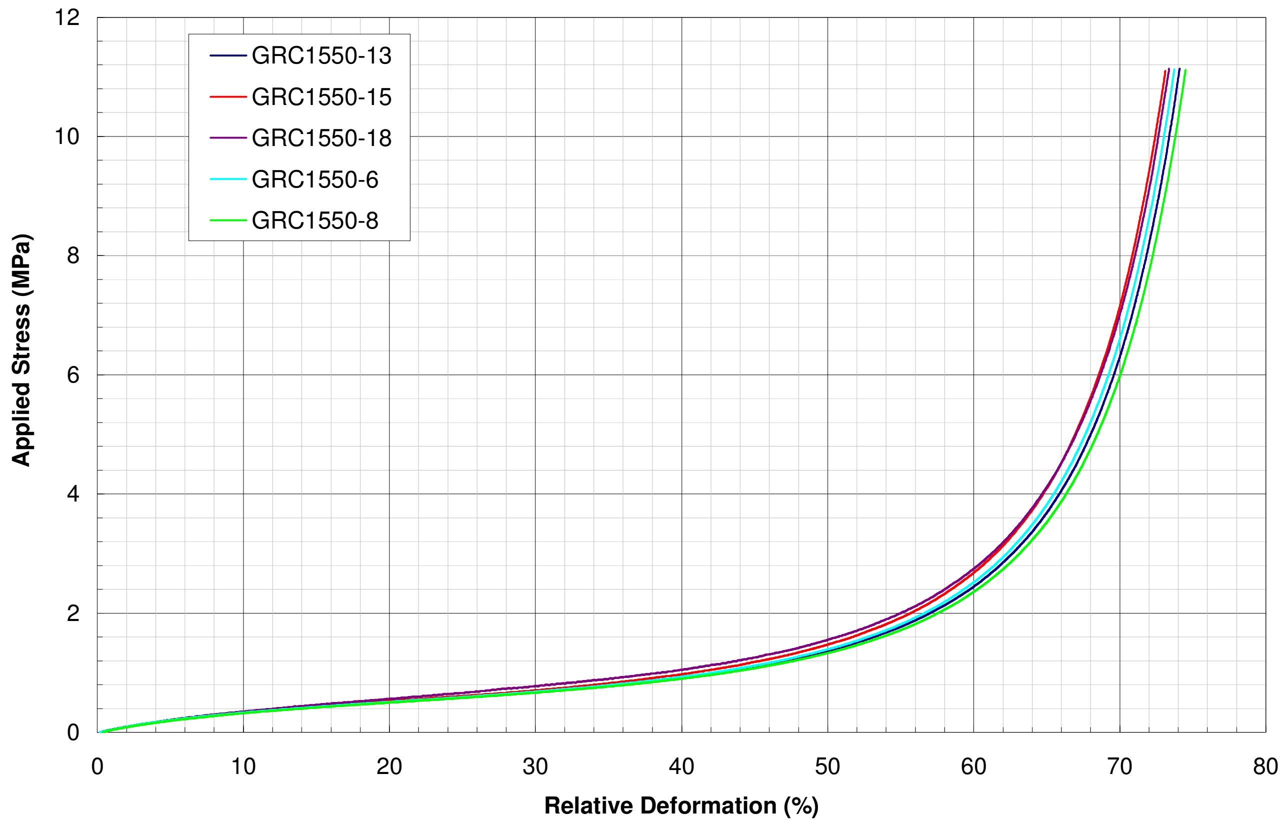

Figure 6 – Stress vs. Relative Deformation plot for Cork Samples Tested at 100°C

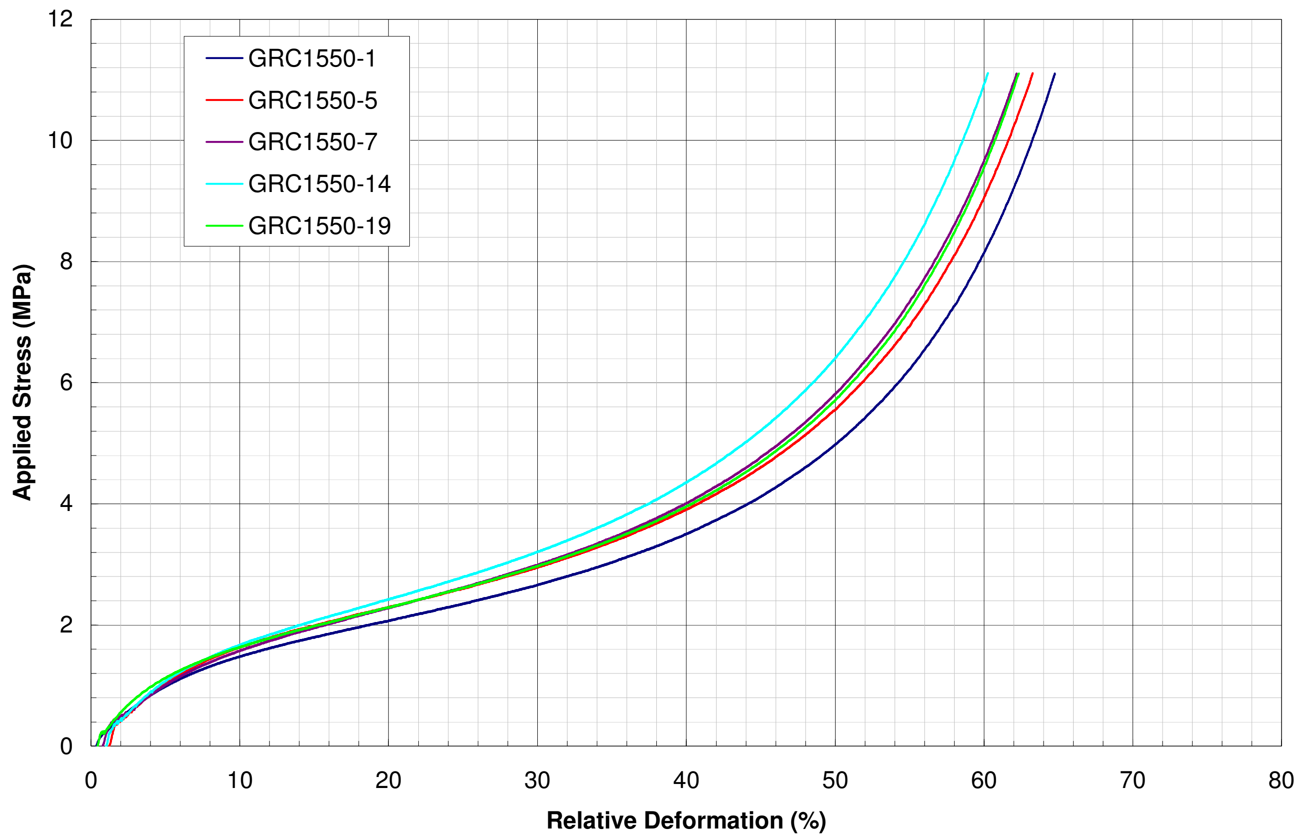

Figure 7 – Stress vs. Relative Deformation plot for Cork Samples Tested at -29°C

Appendices

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