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Testing. Advising. Assuring.

Physical Testing on Adjustment Ring Samples

A Report to:

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1.0 INTRODUCTION

At the request of Ipex Management Inc. (Ipex), Exova performed Physical Testing on Adjustment Ring samples, according with specifications provided by the client.

Ipex submitted three (3) full size adjustment ring specimens for testing. Nine samples of 12 in length were cut off from the full size specimens and allocated with Exova Sample Numbers below:

| <u>Exova Sample #</u> | <u>Samples Description</u> |
|-----------------------|---|
| 13-06-C0157-1 to 9 | Samples of 12 in (304.80 mm) length, 4.875 in (123.82 mm) depth and 1.9685 in (50 mm) thickness |

2.0 OBJECTIVES

The objective of the proposed work was to provide information needed to evaluate the properties of the adjustment ring samples, when subjected to a series of compression load applications.

3.0 INSTRUMENTATION

The following instruments were used to measure and record the load values:

| | |
|----------------------------|--------------|
| 10 Kip load cell | MII # B06835 |
| MTS 407 signal conditioner | MII # B06081 |
| Environmental chamber | MII # B04271 |
| Temperature probe | MII # B07887 |
| Calibrated caliper | MII # B00095 |

4.0 TEST PROCEDURE

The compression test set-up was designed using a servo-hydraulic actuator and a calibrated load cell installed in vertical orientation on a super structure. Each sample was seated on the bottom steel plate which was placed on the test bed and the compression load was applied using an additional steel plate attached to the load cell (support and loading fixtures designed and fabricated by Exova).

The photos of the compression test set-up are presented in Figures 1 to 3.

Three samples were tested at three different temperatures as described in Table 1 below.

Table 1: Environmental Test Conditions

| Sample Number | Pre-test Temperature Conditioning (°C) |
|----------------------|---|
| 13-06-C0157-1 to 3 | + 23 |
| 13-06-C0157-4 to 6 | - 20 |
| 13-06-C0157-7 to 9 | + 30 |

Prior compression load application each sample was maintained in the environmental at the specified test temperatures for a period of minimum two (2) hours. The compression test was started within one (1) minute after sample removal from environmental chamber.

The photo with example of one batch of samples into the environmental chamber and the shape of the mini specimens are presented in Figures 4 and 5.

The test was performed using smaller samples cut off from full size adjustment ring specimens. The required compression loads were calculated based on full load design of 166.6 KN (for a full size specimen) to develop the same stress on the smaller size samples as explained below.

- Full size specimen area $A_f = 558.1875$ sq-in
- Load bearing surface area of the mini specimens $A_{ms} = 58.5$ sq-in
- Initial stress on the adjustment unit $S_i = 14 \text{ KN}/A_f = 38.8541 \text{ KPa}$
- Final stress on the adjustment unit $S_f = 166.6 \text{ KN}/A_f = 462.3632 \text{ KPa}$
- Initial load on the mini specimens $L_{mi} = S_i \times A_{ms} = 1,466.95 \text{ N}$ (329.8 lbs)
- Final load on the mini specimens $L_{mf} = S_f \times A_{ms} = 17,458.84 \text{ N}$ (3,925.1 lbs)

The compression load test sequence, measurements and calculations are described below.

- Measure sample thickness at four locations prior compression and calculate average D_0
- Apply initial constant load $L_{mi} = 1,466.95 \text{ N}$, measure the thickness of the sample at the same four locations and calculate initial thickness of the sample prior compression D_1
- Apply final load $L_{mf} = 17,458.84 \text{ N}$ in 20 seconds (using a ramp rate of 800 N/sec), measure the thickness of the sample at the same four locations and calculate initial compression deformation of the sample D_2
- Calculate the initial compression deformation $Cd1 = D_1 - D_2$
- Maintain final load L_{mf} for a period of 30 minutes then measure the thickness of the sample at the same four locations and calculate the average final compression deformation thickness D_3
- Calculate average final compression deformation $Cd2 = D_1 - D_3$
- Remove the load and allow the sample to rest undisturbed for a period of 30 minutes
- Apply initial constant load L_{mi} , measure the thickness of the sample at the same four locations and calculate the average compression set thickness D_4
- Calculate average compression set $Cs = D_1 - D_4$
- Calculate average initial compression deformation = $(Cd1/D_1) \times 100 \%$
- Calculate average final compression deformation = $(Cd2/D_1) \times 100 \%$
- Calculate allowable average compression set = $(Cs/D_1) \times 100 \%$

Maximum allowable percentage compression deformation and compression set for each sample are presented in Table 2 below.

Table 2: Maximum Allowable Compression Deformation and Compression Set

| Pre-test Temperature Conditioning (°C) | Maximum Average Initial Compression Deformation (%) | Maximum Average Final Compression Deformation (%) | Maximum Allowable Average Compression Set (%) |
|--|---|---|---|
| + 30 | 3.3 | 7.4 | 1.3 |
| + 23 | 1.9 | 3.0 | 0.8 |
| - 20 | 1.1 | 0.8 | 0.5 |

5.0 RESULTS

The calculated deflections for each sample/temperature condition are presented in the Tables 3 to 5 below.

Table 3: Results for + 23°C Test Samples

| Description of Measured/Calculated Thickness | Sample Number | | |
|---|---------------|---------------|---------------|
| | 13-06-C0157-1 | 13-06-C0157-2 | 13-06-C0157-3 |
| Initial average sample thickness Do (mm) | 49.76 | 49.51 | 49.51 |
| Sample average thickness prior compression D1 (mm) | 49.63 | 49.39 | 49.37 |
| Initial average compression deformation thickness D2 (mm) | 49.36 | 49.13 | 49.12 |
| Initial compression deformation Cd1 (mm) | 0.27 | 0.26 | 0.25 |
| Final average compression deformation thickness D3 (mm) | 49.31 | 49.06 | 49.05 |
| Final compression deformation Cd2 (mm) | 0.32 | 0.33 | 0.32 |
| Average compression set thickness D4 (mm) | 49.55 | 49.31 | 49.24 |
| Average compression set Cs (mm) | 0.08 | 0.08 | 0.13 |
| Average initial compression deformation (%) | 0.54 | 0.53 | 0.51 |
| Average final compression deformation (%) | 0.64 | 0.67 | 0.65 |
| Allowable average compression set (%) | 0.16 | 0.16 | 0.26 |

Table 4: Results for - 20°C Test Samples

| Description of Measured/Calculated Thickness | Sample Number | | |
|---|---------------|---------------|---------------|
| | 13-06-C0157-4 | 13-06-C0157-5 | 13-06-C0157-6 |
| Initial average sample thickness Do (mm) | 49.60 | 49.55 | 49.49 |
| Sample average thickness prior compression D1 (mm) | 49.45 | 49.40 | 49.35 |
| Initial average compression deformation thickness D2 (mm) | 49.27 | 49.20 | 49.17 |
| Initial compression deformation Cd1 (mm) | 0.18 | 0.20 | 0.18 |
| Final average compression deformation thickness D3 (mm) | 49.22 | 49.15 | 49.12 |
| Final compression deformation Cd2 (mm) | 0.23 | 0.25 | 0.23 |
| Average compression set thickness D4 (mm) | 49.40 | 49.34 | 49.29 |
| Average compression set Cs (mm) | 0.05 | 0.06 | 0.06 |
| Average initial compression deformation (%) | 0.36 | 0.40 | 0.36 |
| Average final compression deformation (%) | 0.46 | 0.51 | 0.47 |
| Allowable average compression set (%) | 0.10 | 0.12 | 0.12 |

Table 5: Results for + 30°C Test Samples

| Description of Measured/Calculated Thickness | Sample Number | | |
|--|---------------|---------------|---------------|
| | 13-06-C0157-7 | 13-06-C0157-8 | 13-06-C0157-9 |
| Initial average sample thickness Do (mm) | 49.68 | 49.72 | 49.84 |
| Sample average thickness prior compression D1 (mm) | 49.48 | 49.58 | 49.69 |
| Initial average compression deformation thickness D2 (mm) | 49.18 | 49.30 | 49.39 |
| Initial compression deformation Cd1 (mm) | 0.30 | 0.28 | 0.30 |
| Final average compression deformation thickness D3 (mm) | 49.06 | 49.21 | 49.29 |
| Final compression deformation Cd2 (mm) | 0.43 | 0.37 | 0.40 |
| Average compression set thickness D4 (mm) | 49.39 | 49.49 | 49.61 |
| Average compression set Cs (mm) | 0.09 | 0.09 | 0.08 |
| Average initial compression deformation (%) | 0.61 | 0.56 | 0.60 |
| Average final compression deformation (%) | 0.78 | 0.75 | 0.80 |
| Allowable average compression set (%) | 0.18 | 0.18 | 0.16 |

The compression test was performed at Exova Mississauga facility on between September 03 and September 06, 2013.

6.0 CONCLUSIONS

The average initial compression deformation, average final compression deformation and allowable average compression set for all tested samples are below the maximum percentage stated in the Table 2 of the present report (Table 1 from "EPS and HDPE Test Procedure 24 Dec 2012 – Maximum Allowable Percentage Compression Deformation and Compression Set for a Single 50 mm Thick Adjustment Unit or Equivalent Sample"). The tested samples meet the "EPS and HDPE Test Procedure 24 Dec 2012, Section TBD.03.03.05 Compression Deformation and Set".

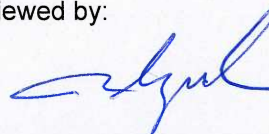
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Figures

(3 Pages)



Figure 1 : Compression test set-up – General view

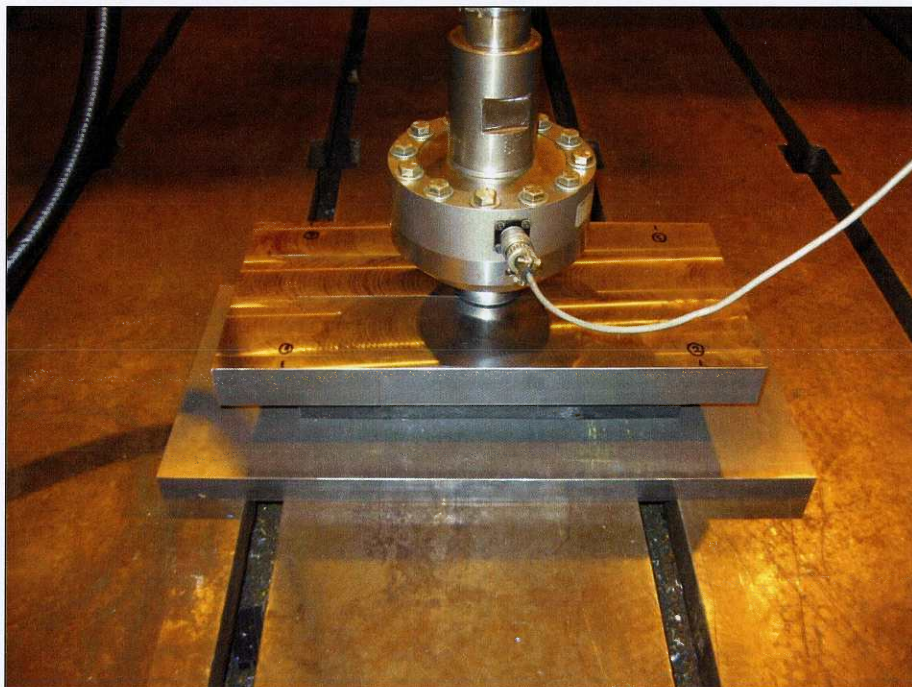


Figure 2 : Compression test set-up – Load cell, support and loading fixtures



Figure 3 : Compression test set-up – Example of sample installed between fixtures



Figure 4 : Example of samples in the environmental chamber



Figure 5 : Shape of mini specimens used as test samples