

EXOVA REPORT

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REGRESSION ANALYSIS ACCORDING TO ASTM D2837

Regression analysis according to ASTM D2837 of the PE material HD4600U from Braskem S.A.

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REGRESSION ANALYSIS ACCORDING TO ASTM D2837

Regression analysis according to ASTM D2837 of the PE material HD4600U from Braskem S.A.

ABSTRACT

The aim of this project was to perform a regression analysis, according to ASTM D2837 of the hydrostatic pressure test data of PE material HD4600U, in order to obtain an HDB-classification for the material.

The extrapolation method ASTM D2837 was used to fit the data obtained for the PE material HD4600U at 22.8°C (73°F). Exova performed the hydrostatic pressure testing.

MATERIAL	T	HDB	VALIDATION OF HDB
HD4600U	22.8°C (73°F)	1 250 psi (8.62 MPa)	Successful

The HDB at 22.8°C (73°F) is 1 250 psi for the PE material HD4600U. The validation of the HDB was successful.

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1 EVALUATED MATERIAL

A short presentation of the evaluated material is presented in Table 1 below. Detailed information about the material is given in Appendix B.

Table 1 *Evaluated material*

MATERIAL NAME	HD4600U
PIPE COLOUR	Natural
PIPE MATERIAL	PE
NOMINAL PIPE DIMENSION	32 x 3 mm
EXOVA CODE	5652

2 EXPERIMENTAL PROCEDURE

The hydrostatic pressure testing is performed at Exova according to ASTM D1598. The pressure testing at 22.8°C (73°F) is performed using deionised water on the inside and on the outside of the samples. The accuracy for temperature¹ and pressure¹ is better than $\pm 1^\circ\text{C}$ and $\pm 2\%$ respectively. The measurements of the wall thickness¹ are accurate within ± 0.01 mm and the diameter¹ within ± 0.1 mm.

3 RESULTS FROM THE HYDROSTATIC PRESSURE TESTING

The results obtained from the hydrostatic pressure testing are presented in Appendix B and shown in Appendix C. Table 2 gives a summary of the observations.

Table 2 *Summary of the results from the hydrostatic pressure testing*

T	TOTAL NO OF SAMPLES	BURST SAMPLES	ONGOING SAMPLES	STOPPED SAMPLES	LONGEST BURST TIME	LONGEST TEST TIME
	[1]	[1]	[1]	[1]	[h]	[h]
22.8°C (73°F)	25	13	12	0	4 260	10 004

¹ The expanded uncertainty of measurement has been calculated as the standard uncertainty of measurement multiplied by the coverage factor K=2, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with EA Publication EA-4/16:2003 and is documented at EXOVA.

4 EVALUATION OF THE HYDROSTATIC DESIGN BASIS (HDB)

The HDB of the material is done by performing regression analysis on the generated test data in Appendix B. The diagrams in Appendix C show the observations and lines for σ_{LCL} and σ_{LTHS} for the selected analysis.

4.1 Distribution of stress rupture data

Table 3 presents the distribution of observations for the data set that was used in the ASTM D2837-evaluation.

Table 3 *Distribution of observations*

T	TOTAL	DISTRIBUTION OF OBSERVATIONS ¹⁾				
		<1 000 h [6]	10- 1 000 h [3]	1 000- 6 000 h [3]	>6 000 h [3]	>10 000 h [1]
22.8°C (73°F)	20	6	6	10	4	1

1) Numbers between brackets [] indicate the required number of observations in ASTM D2837

4.2 Linear regression analysis

The linear regression analyses are performed on the creep rupture data obtained at the test temperature 22.8°C (73°F). The results are presented in Table 4 below.

Table 4 *Linear regression coefficients and M-values*

T	LINEAR REGRESSION COEFFICIENTS		M ¹⁾
	a	b	
22.8°C (73°F)	134.857	-41.053	1 658.825

1) M must be positive and b negative; otherwise the data are unsuitable for evaluation.

Equation 1 *Regression equation*

$$\text{Log}(t) = a + b \cdot \text{Log}(\sigma)$$

Where

a, b	regression coefficients
t	time to failure (h)
σ	Hoop stress (psi)

M Statistical quantity defined in ASTM D2837, X3.2.4
 If M is negative or zero, the slope of log cycles versus stress is not significantly different from zero. In this case, the lower confidence limit cannot be calculated, and the data are unreliable for the evaluation of the material.

4.3 Extrapolated strength values

Using the results from linear regression analyses in 4.2 the strength values in Table 5, corresponding to 100 000 h and 50 years at 22.8°C (73°F).

Table 5 *Extrapolation results*

T	TIME	σ_{LCL}	σ_{LTHS}	$\sigma_{LCL}/\sigma_{LTHS}$
22.8°C (73°F)	100 000 h	1 438 psi	1 461 psi	0.984
22.8°C (73°F)	50 yrs	1 381 psi	1 409 psi	0.980

Table 5a *Extrapolation results*

T	TIME	σ_{LCL}	σ_{LTHS}	$\sigma_{LCL}/\sigma_{LTHS}$
22.8°C (73°F)	100 000 h	9.91 MPa	10.07 MPa	0.984
22.8°C (73°F)	50 yrs	9.52 MPa	9.71 MPa	0.980

According to part 5.4 in ASTM D2837 the σ_{LTHS} value at 100 000 h shall be used to determine HDB if the value is less than 125% of the 50 years value. In order for the data to be suitable for evaluation the ratio $\sigma_{LCL}/\sigma_{LTHS}$ at 100 000 h shall exceed 0.90 according to PPI TR-3. This is fulfilled.

Table 6 *Extrapolation results*

T	TIME	σ_{LTHS}	$\sigma_{LTHS(100\ 000\ h)}/\sigma_{LTHS(50\ yrs)}$
22.8°C (73°F)	100 000 h	1 461 psi	104 %
22.8°C (73°F)	50 yrs	1 409 psi	

Table 6a *Extrapolation results*

T	TIME	σ_{LTHS}	$\sigma_{LTHS(100\ 000\ h)}/\sigma_{LTHS(50\ yrs)}$
22.8°C (73°F)	100 000 h	10.07 MPa	104 %
22.8°C (73°F)	50 yrs	9.71 MPa	

4.4 Determination of the HDB

The HDB is determined by calculating the strength at LTHS (100 000 h) using single linear regression on the test data in accordance with ASTM D2837. The result is shown in table 7 below.

Table 7 *Determined HDB*

T	$\sigma_{LTHS(100\ 000\ h)}$	σ_{HDB}
22.8°C (73°F)	1 461 psi (10.07 MPa)	1 250 psi (8.62 MPa)

5 VALIDATION OF THE HDB AT 22.8°C (73°F)

Six samples were tested at the given conditions ASTM D2837, Table 3, for the validation of the HDB in 4.4. The validation was successful.

Table 8 *Validation of the HDB at 22.8°C (73°F)*

T	STRESS	REQUIRED TIME ¹⁾	TEST TIME ¹⁾	RESULT
176°F	645 psi (4.45 MPa)	200 h	>200 h	PASS

1) Logarithmic average time of six samples

6 HDB FOR HD4600U

The HDB at 22.8°C (73°F) for the PE material HD4600U is 1 250 psi with successful validation.

Table 8 *Summary of HDB*

MATERIAL NAME	T	HDB	VALIDATION OF HDB
HD4600U	22.8°C (73°F)	1 250 psi (8.62 MPa)	Successful

7 ADDITIONAL COMMENTS

The delivered material showed no defects. No unusual behaviour was observed during the testing.

The circumferential expansion in accordance with 5.3 in the ASTM D2837 document has not been performed. This is not necessary for the presently used stress rated thermoplastic pipe materials in North America, the 5% expansion strengths are not the limiting factor. Hence circumferential expansion is not required for PE pressure pipe materials.

The testing has been performed using the units; Pressure [Bar], Stress [MPa], Temperature [°C]. For his report the values have been converted to psi and °F respectively.

REFERRED DOCUMENTS

- ASTM D2837-11
Standard Test Method for - Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products
- ASTM D1598-02 (2009)
Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
- ASTM D2837 evaluation software
Pipeson Analyzer® 3.2.3
Pipeson AB, SE-11152 Stockholm, Sweden, www.pipeson.se

Plastic Pipes

2014-05-26

CLIENT INFO

Client	Braskem S.A.
Department	Competitividade & Inovação - Unidade de Polímeros
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MATERIAL INFO

Exova code	5652
Trade name	HD4600U
Material	PE
Colour	Natural
Nominal dimension	32 x 3 mm (SDR 11)
Arrival date at Exova	2013-02-25
Amount	44 x 0.35 m
Consignor	Braskem S.A.
Condition of material at arrival	No visual defects
Marking	No commercial marking
Resin producer	Braskem S.A.
Resin production site	-
Resin production batch no	-
Resin production date	-
Pipe producer	-
Pipe production site	-
Pipe production batch no	-
Pipe production date	-
Method of manufacturing	Rotomolded

TEST INFO

Test laboratory	Exova Plastic Pipes, ISO/IEC 17025 Swedac accreditation no. 0067
Responsible	Joakim JANSSON - Technical Manager
Test method	ASTM D1598
Length (total/free)	350/310 mm
Fittings	Brass fittings and type A, unless remarked
Internal medium	Water
External medium	Water
Conditioning time	3 h
Situation on	2014-05-25

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TABLE REMARKS

Code	Exova internal code
T	Test temperature
Start date	Date when the pipe sample was started
Reg date	Date when the sample was stopped or registered as failure.
e_{\min}	Minimum wall thickness
d_{em}	Mean outside diameter
p	Internal pressure
σ	Circumferential stress (hoop stress)
->	The sample is under test

PIPE REMARKS

1 The sample is for validation of the HDB

 The sample is included in the ASTM D2837 regression analysis

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HYDROSTATIC PRESSURE TESTING

Code	T [°C]	Start date [yyymmdd]	Reg date [yyymmdd]	d_{em} [mm]	e_{min} [mm]	p [bar]	σ [psi]	σ [MPa]	Failure time [h]	Failure mode	Test time [h]	Remark
5652-16	22.8	130603	130605	32.05	2.92	24.81	1 796	12.38	26	Ductile		
5652-17	22.8	130603	130605	32.05	2.96	24.81	1 768	12.19	31	Ductile		
5652-18	22.8	130603	130607	32.05	2.94	24.22	1 739	11.99	68	Ductile		
5652-19	22.8	130603	130607	32.05	2.96	24.03	1 713	11.81	89	Ductile		
5652-41	22.8	140401	140414	32.05	2.97	23.73	1 685	11.62	271	Ductile		
5652-1	22.8	130404	130429	32.05	2.97	23.05	1 636	11.28	549	Ductile		
5652-28	22.8	131002	131230	32.05	2.94	22.65	1 627	11.22	2 083	Ductile		
5652-29	22.8	131002	140221	32.05	2.92	22.26	1 610	11.10	3 402	Ductile		
5652-30	22.8	131002	140109	32.05	2.97	22.65	1 608	11.09	2 364	Ductile		
5652-31	22.8	131002	140331	32.05	2.94	22.26	1 598	11.02	4 260	Ductile		
5652-2	22.8	130404	130909	32.05	2.95	22.26	1 593	10.98	3 793	Ductile		
5652-20	22.8	130619	130821	32.05	2.95	22.26	1 593	10.98	1 511	Ductile		
5652-32	22.8	131002		32.05	2.96	22.26	1 587	10.94	->		>5 660	
5652-21	22.8	130619	130903	32.05	2.97	22.26	1 581	10.90	1 823	Ductile		
5652-33	22.8	131002		32.05	2.98	22.26	1 575	10.86	->		>5 660	
5652-22	22.8	130619		32.05	2.94	21.87	1 571	10.83	->		>8 179	
5652-34	22.8	131002		32.05	2.91	21.58	1 566	10.80	->		>5 660	
5652-23	22.8	130619		32.05	2.92	21.58	1 561	10.76	->		>8 179	
5652-24	22.8	130619		32.05	2.94	21.58	1 549	10.68	->		>8 179	
5652-25	22.8	130619		32.05	3.00	21.87	1 536	10.59	->		>8 179	
5652-26	22.8	130619		32.05	2.94	21.18	1 521	10.49	->		>8 179	
5652-27	22.8	130619		32.05	2.98	21.38	1 513	10.43	->		>8 179	
5652-3	22.8	130404		32.05	2.87	20.50	1 511	10.42	->		>10 004	
5652-4	22.8	130404		32.05	2.95	19.03	1 360	9.38	->		>10 004	
5652-5	22.8	130404		32.05	2.92	18.63	1 347	9.29	->		>10 004	

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HYDROSTATIC PRESSURE TESTING

Code	T [°C]	Start date [yyymmdd]	Reg date [yyymmdd]	d_{em} [mm]	e_{min} [mm]	p [bar]	σ [psi]	σ [MPa]	Failure time [h]	Failure mode	Test time [h]	Remark
5652-35	80	131120	131204	32.05	2.96	9.06	645	4.45	->		>200	1
5652-37	80	131120	131202	32.05	2.96	9.06	645	4.45	->		>200	1
5652-38	80	131120	131202	32.05	2.96	9.06	645	4.45	->		>200	1
5652-40	80	131120	131202	32.05	2.96	9.06	645	4.45	->		>200	1
5652-36	80	131120	131129	32.05	2.93	8.96	645	4.45	->		>200	1
5652-39	80	131120	131209	32.05	2.92	8.92	645	4.45	->		>200	1





