ENGLISH TRANSLATION OF IMPACT REPORT LCP06-000079

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OS: 20975.

MMA Sheet testing

Objective:

Verify if 1 (one) sample of poly methyl methacrylate is in accordance to some of the tests described on the regulation NBR ISO-7823-2 – "Plastic Sheets of poly methyl methacrylate) – Types dimensions and characteristics – Part 2 extruded and calendered sheets.

Analysis Methods:

Tensile strength: test made in accordance to the item 6.5.2 of the norm ISO 7823-2. Test made according to ISO 527-1 – "*Determination of tensile properties".* This method is utilized to investigate the behavior of the sample under stress, to determine the tensile strength, module under stress and other aspects involving the relation stress/ deformation under tension under defined conditions. These data are useful for qualitative evaluation, and research and development.

The properties under tension can vary as a function of the method of preparation of the test corps, the environment and the velocity of the test. Therefore, if an accurate comparison of the tests results is necessary, these variables should be properly controlled. The properties encountered can be useful information for the design of engineer products. Due to the great sensibility of the majority of the plastic materials, the deformation rate and environmental conditions, data obtained on these tests are not valid for application involving different scales of time/load and a different environment than used on the tests. In the test, the sample is tensioned on its longer longitudinal shaft at a constant speed until either the sample is torn or the tension applied reaches a pre-determined value. During this process the load supported by sample and its elongation are registered.

The tension under stress expressed in megapascal (MPa) was calculated according to equation 1

$$\sigma = \frac{F}{(h \cdot W)} \qquad (1)$$

Where:

F is the strength applied (in Newton);

W is the used width of the proof corps (in mm)

H is the thickness of the proof corps (in mm)

The elasticity module is calculated by equation 2:

$$E_t = \frac{\sigma_2 - \sigma_1}{\varepsilon_2 - \varepsilon_1} \qquad (2)$$

Where:

E_t is the elasticity module (Young) expressed in MPa

σ_1 is the tension, in MPa, measured at deformation ε_1= 0,0005

σ_2 is the tension, in MPa, measured at deformation ε_2= 0,0025

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Poisson rate is given by equation 3:

$$\mu_n = -\frac{\varepsilon_n}{\varepsilon} \qquad (3)$$

Where:

μ_n is the Poisson rate expressed dimensionless with *n*= *b* (width) or *h*= (thickness) indicating the normal direction selected

ε is the longitudinal deformation

ε_n is the normal deformation that can be *n*= *b* (width) or *h*= (thickness).

Equipment used have the characteristics below:

Brand: EMIC

Model: DL10000

The test was run in proof corps type 1-B according to ISO 527-2 - “Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics”, machined and prepared from the acrylic sheets received.

The proof corps were taken perpendicular to the extrusion direction. The speed of the test was 1 mm/min the determination of the elastic module and 5 mm/min for the other properties. Tests were run on March 3, 2006.

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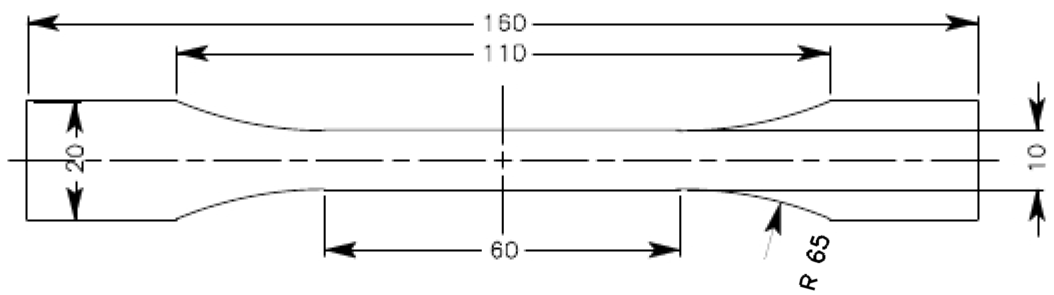

Figure 1 – Proof corps ISO 527-2 1B used on the tensile test.

Flexural strength: made in accordance to item 6.5.1 of norm NBR ISO 7823-2. Tests were run as described on ISO 178 – "*Plastics – Determination of fflexural properties"*. Flexural tests are used to investigate the mechanical behavoir of the materials under flexion. By this method it is possible to obtain information about the tension under flexion, flexural module and other properties of interest. Tests were run on three proof corps under load in three different points. The maximum load was applied exactly on the half distance between the two fixed supports ("span").

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The approximate dimensions of the proof corps used on this test were as below:

- length: 80,0 mm;
- width: 10 mm e
- thickness: 4 mm.

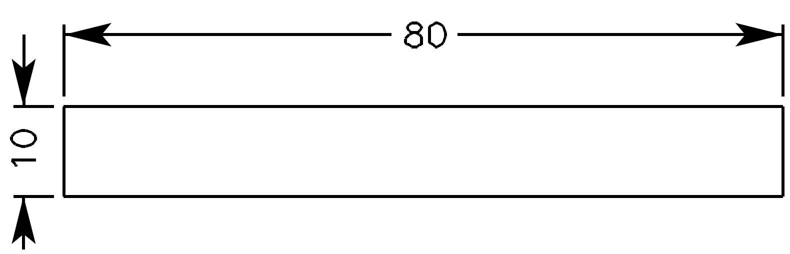

Figure 2 – Proof corps used on flexural tests according to ISO 178.

Proof corps with this thickness requires that the distance between the two fixed supports (“span”) be equal to 64,0 mm, as:

:

$$L = (16 \pm 1)\bar{h} \qquad (4)$$

where L= distance between the fixed supports and $\bar{h}$ is the average thickness of the proof corps used.

The real tension expressed in megapascal (MPa), is calculated in accordance to equation 5.

$$\sigma_f = \frac{3FL}{2bh^2} \qquad (5)$$

Where:

F is the strength applied (in Newton);

L is the distance between the fixed supports, (in mm);

b is the width of the proof corps (in mm) e

h is the thickness of the proof corps (in mm).

For the calculation of flexural module it is necessary to determine first the individual deformation s_1 e s_2, that corresponds to the arrow in the initial linear region of the curve tension x deformation. The values of s_1 and s_2 are calculated in accordance to equation 3.

$$s_i = \frac{\sum_{fi} L^2}{6h} \text{ (i=1,2)} \qquad (6)$$

Where: s_i is the individual deflection;

$\sum_{fi}$ individual values of deformation ($\sum_{f1}$= 0,0005 e $\sum_{f2}$= 0,0025);

L distance between fixed supports

h thickness of the proof corps.

By this way the flexural module can be determined in accordance equation 7:

$$E_f = \frac{\int_{f2} \square \int_{f1}}{\sum_{f2} \square \sum_{f1}} \qquad (7)$$

where $\int_{f1}$ e $\int_{f2}$ are the tensions measured on the deflection points s_1 e s_2 respectively.

The tests were run in an universal testing machine model DL10000 da EMIC, operating with a load cell of 500 Kgf. The velocity of the test was of 2 mm/min, as it is suggested by the norm. As there were no suggestion for the direction to be taken the proof corps, they were taken perpendicular to the extrusion direction. Tests were run on February 23, 2006.

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Charpy Impact Resistance*:* test is run in accordance to item 6.5.3 of norm NBR ISO 7823-2. The property was determined according to norm ISO 179 – *Plastics – Determination of Charpy impact strength"*, using a proof corps of 80 mm x 10 mm by the proof corps thickness unknotted (ISO 179/1fU), a pendula of 2J e and a span of 62 mm. This test was run on February of 2006. The equipment used has the following characteristics:

Brand: CEAST

Model: RESIL 25R

This method is used to investigate the behavior of specific proof corps under well defined impact conditions and to evaluate the fragility or tenacity of the samples within the limitations established by test conditions. This method is more applicable than the one defined by norm ISO 180 (izod impact) and is more adequate for testing materials that may present lamellar shear fracture or material that can present surface defects due to environmental aspects.

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Different proof corps can be used to Charpy impact tests, depending on the initial shape of the sample and the desired characteristic to be analyzed. The types of proof corps to be used can be found in table 1.

The choice of the testing method to be used depends upon the type of the proof corps, the knot and direction of the impact as can be observed on table 2.

Table 1 – Types of proof corps, dimensions and Span.

Type of P.C.	Length [mm] (l)	Width [mm] (b)	Thickness [mm] (h)	Span [mm] (L)
1	80 ± 2	10,0 ± 0,2	4,0 ± 0,2	$62_{0}^{0,5}$
2	25 h	10 ou 15	3	20^{+} h
3*	(11 ou 13) h			(6 ou 8) h

* To materials, that may present lamellar shear fracture.

Table 2 – Methods specifications

Method Designation	Type of proof corps	Impact Direction*	Knot Type	Ray at the Knot basis [mm]	Extra width, b_n, At the knot basis [mm]
ISO 179/1eU	1	Edgewise	unknotted		
ISO 179/1eA			A	0,25 ± 0,05	8,0 ± 0,2
ISO 179/1eB			B	1,00 ± 0,05	8,0 ± 0,2
ISO 179/1eC			C	0,10 ± 0,02	8,0 ± 0,2
ISO 179/1fU		Flatwise	unknotted		

* see figure 3

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The result of the impact resistance calculation to unknotted proof corps is expressed in kilojoules per square meter and determined using the following formula:

$$a_{cU} = \frac{W}{h \cdot b} \cdot 10^3 \qquad (8)$$

To knotted proof corps the formula to use is the below:

$$a_{cU} = \frac{W}{h \cdot b_N} \cdot 10^3 \qquad (9)$$

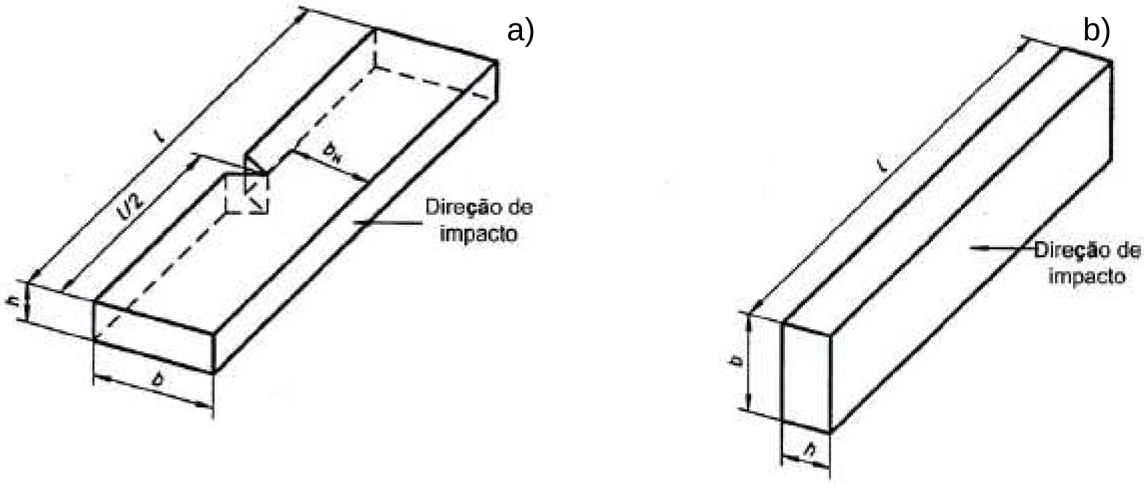

Figura 3 – Direção de impacto (impact direction) : a) edgewise e b)flatwise.

VICAT softening temperature: made in accordance to item 6.6.1 of norm NBR ISO 7823-2. This property was determined following norm ISO 306 - "*Plastics – Thermoplastic materials – Determination of VICAT softening temperature*", method B50.

In the test, a flat tipped needle (area $1.000 \pm 0.015\ mm^2$) and pressed by a determined weight is put in direct contact with the sample. The weight over the needle and the heating rate are defined using the following methods:

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Method A50: strength (10 ± 0,2) N and rate of (50 ± 5) ºC/h

Method B50: strength (50 ± 0,2) N and rate of (50 ± 5) ºC/h

Method A120: strength (10 ± 0,2) N and rate of (120 ± 5) ºC/h

Method B120: strength (10 ± 0,2) N and rate of (120 ± 5) ºC/h

The VICAT softening temperature is the temperature that was reached when the needle penetrates (1±0,01 mm) into the sample.

The samples thicknesses must vary between 3 and 6.5 mm and the area must be at least 10 mm x 10 mm or a circle with 10 mm of diameter.

The heat transfer mean is a silicon oil bath in one calibrated equipment with the following characteristics

Brand: CEAST

Model: HDT 6 VICAT P/N 6921

Before the test, the proof corps were kept 16 hours at 80º C and allowed to cool naturally in a desiccator. This test was in March 8, 2006.

***Sheet Thickness**:* made according to items 4.4.2, 5.2 e 6.4 of norm NBR ISO 7823-2. The sheet was kept at 23ºC and 50% relative humidity – norm ISO 291. The test was run in February 22, 2006.

Appearance evaluation: made in accordance to item 4.2 of norm NBR-ISO 7823-2. Surface and embedded defects were observed.

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Sample was identified according to table 3.

Table 3 – Sample Identification.

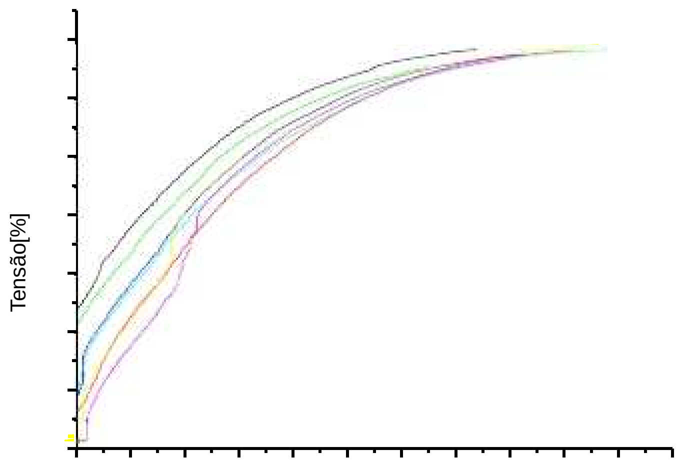
Customer's identification*	Sample code - CCDM
Clear sheet 1.016 x 2.007 x 4.00	LCP060158
* Identification supplied by customer.	

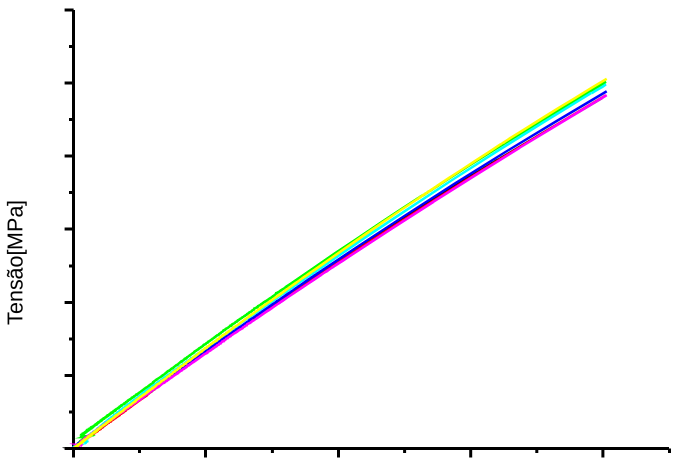
Results:

The result of tensile strength is presented on table 4. The value of elastic module was obtained in a test made at 1 mm/min. The other results were obtained at 5 mm/min. The thickness of the proof corps used are equal to the thickness of the sample sheet sent by customer. In figure 4 it is possible to observe the curves tension x deformation. The outliers were not considered on the calculation.

Table 4 – Tensile strength test results.

Sample	Elasticity Module (MPa)	Tensile strength (MPa)	Deformation under traction (%)
	3205	68,55	3,68
LCP060158	3244	68,30	4,53
	3302	65,46	3,23
	3257	67,66	4,14
	3315	68,37	4,85
	3159	67,31	4,02
	3385	69,06	4,79
Average	3267	67,81	4,18
Standard deviation	75	1,19	0,59


Tensão[%]


Tensão[MPa]

The flexural strength result obtained is present on table 5. On figure 6 it is possible to observe the curves tension x deformation to the samples tested under flexion. The proof corps were taken with the same thickness of the sheet sent by customer.

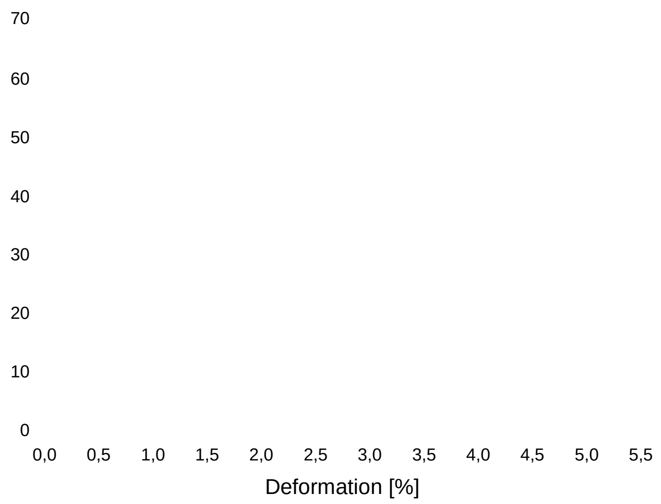


Figure 4 – Curve Tension x Deformation of sample LCP060158 under traction at 5 mm/min.

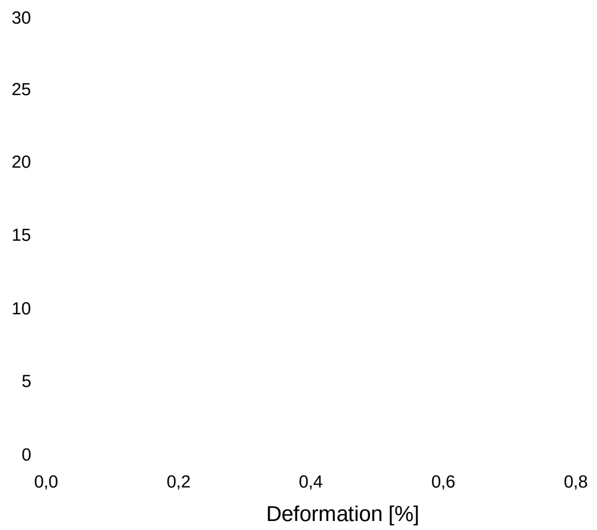


Figure 5 – Curve Tension x Deformation of sample LCP060158 under traction at 1 mm/min.

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Table 5 – Results of flexural strength tests.

Sample	Flexural Strength [MPa]
LCP060158	111,77
	111,21
	109,92
	110,94
	108,15
Average	110,4
Standard deviation	1,4

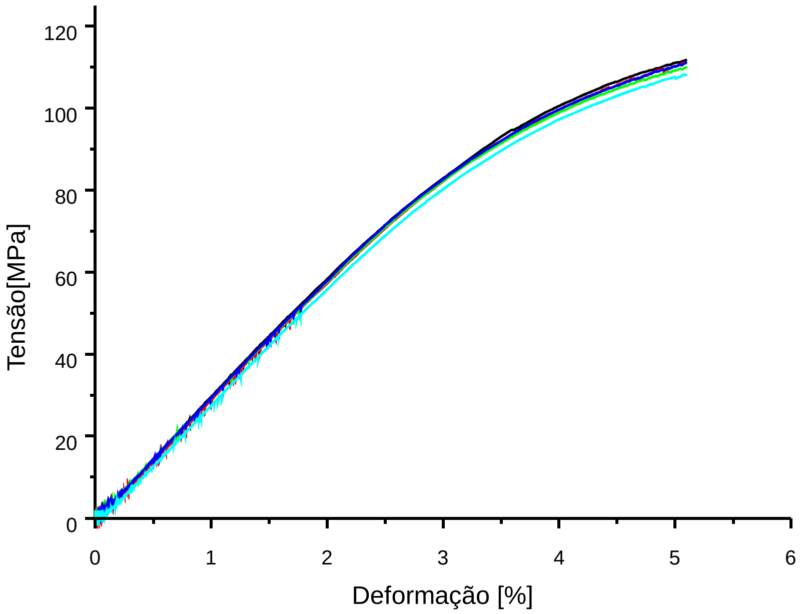

Figure 6 – Curve Tension x Deformation of sample LCP060158 under flexion.

The values of energy absorbed during the Charpy test are presented on table 7. The results of Charpy impact resistance are presented on table 6

Tabela 6 – Impact resistance results.

Sample	kJ/m² Average	Std. Deviation
LCP060158	14,32	1,77

The results of VICAT softening temperature are presented on table 8.

Table 8 – Individual results of absorbed energy.

LCP060158		
Impact [J]	Residual Energy [J]	Result [J]
0,576	0,016	0,560
0,628	0,016	0,612
0,560	0,016	0,544
0,628	0,016	0,612
0,624	0,016	0,608
0,400	0,016	0,384
0,608	0,016	0,592
0,628	0,016	0,612
0,616	0,016	0,600
0,552	0,016	0,536
	Average:	0,566
	Std. Deviation:	0,070

Table 8 – Results of VICAT softening temperature

Sample	**VICAT softening temperature [ºC]**	**Average VICAT softening temperature [ºC]**
LCP060158	101,8	101,9
	101,9	
	102,1	

The thickness of the sheet was measured with a millesimal micrometer and presented on table 9. There were made 10 measurements around the sheet.

Table 9 – Sheet thickness in millimeters.

LCP060158	
3,971	3,944
4,000	3,965
4,006	3,959
3,966	3,991
3,953	3,956
Average:	3,971
Standard deviation:	0,021

No surface or embedded defects were observed on the analyzed area of sample LCP060158.

Conclusion

The table below presents a summary of the results obtained as well as the specifications for each test.

Sample LCP060158

Property	Unit	Norm Item	Specified Value	Value Obtained
Flexural strength	MPa	6.5.1	110 a115	110,4
Tensile strength	MPa	6.5.2	> 60	67,81
Deformation under traction	%	6.5.2	>2	4,18
Elasticity module under traction	MPa	6.5.2	> 2900	3267
Charpy impact resistance	KJ/m^2	6.5.3	>8	14,32
VICAT softening temperature	ºC	6.6.1	> 88	101,9
Thickness of sheet	mm	6.6.3	$4 \pm 0,4$	3,971
Appearance	-	4.2	Classification negligible/ acceptable Acceptable distribution	OK

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Therefore the sample LCP060158 complies the requests of norm NBR ISSO 7823-2 – “Plastic – Sheets of poly (methyl methacrylate) – types, dimensions and characteristics – Part 2 – Extruded and calendered sheets”.

São Carlos, March 8 2006.

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