Title: Physics and mechanical properties of Wood Polymer Composite decking Envirodeck™

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SHR
"Het Cambium"
Nieuwe Kanaal 9b
PO Box 497
6700 AL Wageningen

Tel: + 31 317 467366
Fax:. + 31 317 467399

E-mail: b.tjeerdsma@shr.nl

Principal: Fiberplast B.V.
Mr. W. Wieten
Postbus 525
9200 AM Drachten

Appendices: 2

Project number: 7.375

Authors:

Ir. B.F. Tjeerdsma
Project manager

A. van Hunnik
Technical assistant

Entries: Density, waterab sorption, bending strength, MOR, bending stiffness, MOE, linear thermal expansion

Summary

Fiberplast BV has commissioned SHR to perform testing of two types of wood polymer composite (WPC) decking products, regarding the physics and mechanical properties. The testing has been performed from September 17th, 2007 to November 15th, 2007, with the exception of the testing of the samples which have been exposed in outdoor conditions for 1 year. These samples were tested in November 2008.

The determined physical and mechanical properties of Envirodeck™ HB (cedar) and Envirodeck™ HA (coffee) are summarised in the table below.

Property				**Test method/ standard**
		Envirodeck™ HB (cedar)	**Envirodeck™ HA (coffee)**	**ASTM standard EN standard**
Density	kg/m^3	1226	1301	ASTM D792-00
Water absorption 24 h 23℃	%	1.09	1.11	ASTM D570-00
Modulus of Rupture (MOR) at - 20 ℃	N/mm^2	18.7	20.6	ASTM D790-03 EN 408
Modulus of Elasticity (MOE) at - 20 ℃	N/mm^2	2252	2710	
Modulus of Rupture (MOR) at 20 ℃	N/mm^2	14.9	16.3	
Modulus of Elasticity (MOE) at 20 ℃	N/mm^2	1559	1857	
Modulus of Rupture (MOR) at 60 ℃	N/mm^2	9.2	10.4	
Modulus of Elasticity (MOE) 1 year outdoor	N/mm^2	1544	1832	
Modulus of Rupture (MOR) 1 year outdoor	N/mm^2	14.3	16.9	
Modulus of Elasticity (MOE) at 60 ℃	N/mm^2	673	834	
Coefficient of linear thermal expansion (-20 to + 60 ℃)	℃$^{-1}$	5.34 x 10^{-5}	4.50 x 10^{-5}	ASTM D696-03

Contents

1 Assignment

Fiberplast BV has commissioned SHR to perform testing of two types of wood polymer composite (WPC) decking products, regarding the physics and mechanical properties. SHR is recognised by the European Union as a notified test laboratory under the number 1686. Detailed information can be found on the website http://ec.europa.eu/enterprise/newapproach/nando/.

2 Execution of the test

2.1 Identification and description of the samples

On September 17th 2007, two types of WPC decking boards have been delivered to SHR by Fiberplast BV. Of each type, Envirodeck™ HB (colour cedar) and Envirodeck™ HA (colour coffee brown), 20 boards of 2, 2 meter length have been delivered. The boards have a hollow profile and two types of profile on the sides (see appendix A). The sampling of the test material for the different tests has been performed by SHR.

2.2 Period of the test

The testing has been performed from September 17th, 2007 to November 15th, 2007, with the exception of the testing of the samples which have been exposed in outdoor conditions for 1 year. These samples will be tested in October 2008.

2.3 Procedure

In the table below the determined properties and the corresponding standards are listed.

Property		*Test conform*	
	Unit	**ASTM standard**	**NEN standard**
Density	kg/m^3	ASTM D792-00	
Water absorption 24 h 23℃	%	ASTM D570-00	
Bending strength (MOR) at 20 ℃	N/mm^2	ASTM D790-03	EN 408
Bending stiffness (MOE) at 20 ℃	N/mm^2	ASTM D790-03	EN 408
MOR en MOE at 60 °	N/mm^2	ASTM D790-03	EN 408
MOR en MOE at -10 ℃	N/mm^2	ASTM D790-03	EN 408
MOR en MOE after 1 year of outdoor exposure	N/mm^2	ASTM D790-03	EN 408
Linear thermal expansion	℃$^{-1}$	ASTM D696-03	BRL 1309

Density

The density has been determined on 5 independent samples by immersion in water and measuring the water displacement on an analytical balance. The density in kg/m^3 is calculated based on the weight of the sample and the weight of the displaced water with known volume.

Water absorption

The water absorption has been determined on 5 independent samples by immersion in water of 23 ℃ durin g 24 hours. The water absorption in % is calculated based on the (conditioned) weight before and after immersion.

Bending strength (MOR) and bending stiffness (MOE)

The MOR and MOE have determined on a bending machine in 3-point bending test. The used span (hart on hart) was 500 mm. The sample has been loaded in the middle until failure. The speed of the load increase by the machine has been adjusted resulting in failure of the samples within 60 seconds (± 30 seconds).

The MOE is calculated by the measured values in the 3-point bending test, according to the following formula:

$$E_m = \frac{l_1^3 (F_2 - F_1)}{4bt^3 (a_2 - a_1)}$$

In which:

E_m = Modulus of elasticity (MOE) in N/mm²
l_1 = Span in mm
b = Width of the sample in mm
t = Thickness (height) of the sample in mm
$F_2 - F_1$ = Difference of force in the elastic area (between 10% and 40 % of the failure load) in N
$a_2 - a_1$ = Difference in deflection in mm corresponding to $F_2 - F_1$.

MOR has been calculated using the following formula:

$$f_m = \frac{3F_{max} l_1}{2bt^2}$$

In which:

f_m = Bending strength (MOR) in N/mm²
F_{max} = Maximum load at failure in N
l,b,t = As used in calculation of MOE

MOE and MOR are determined on the material after different conditionings:

- At a temperature of 20 ± 2 ℃ and relative humidit y of 65% ± 5%
- After conditioning at – 10 ℃
- After conditioning at + 60 ℃
- After 1 year of outdoor exposure

For each condition 10 samples are tested.

Linear thermal expansion

The linear thermal expansion has been determined on three independent samples with dimension: 300 mm x 20 mm x 25 mm (length x width x thickness). The changes in length of the samples conditioned in the different climates are measured with a specific Mitutoya measuring device (to the nearest 0,0001 mm).

3 Results of the test

Density

The mean results of the density measurements are demonstrated in the table below. Detailed results of all individual measurements can be found in appendix B.

	Property	Weight	Volume	Density
		[N/mm²]	[N/mm²]	[N/mm²]
Type				
Envirodeck™	**Mean**	63.22	51.55	1226
HB (cedar)	**Stdev**	1.23	0.66	15.3
Envirodeck™	**Mean**	67.75	52.09	1301
HA (coffee)	**Stdev**	1.80	1.28	9.3

Water absorption

The mean results of the water absorption measurements are shown in the table below. Detailed results of all individual measurements can be found in appendix B.

	Property	Weight	Weight after 24 h. immersion	Water absorption
		[g]	[g]	[%]
Type				
Envirodeck™	**Mean**	63.22	63.91	1.09
HB (cedar)	**Stdev**	1.23	1.19	0.13
Envirodeck™	**Mean**	67.75	68.50	1.11
HA (coffee)	**Stdev**	1.80	1.73	0.29

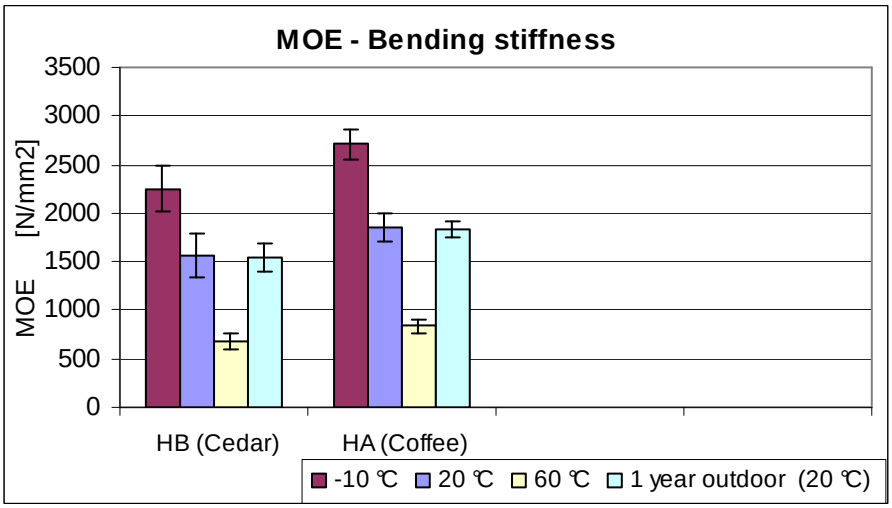
Bending strength (MOR) and bending stiffness (MOE)

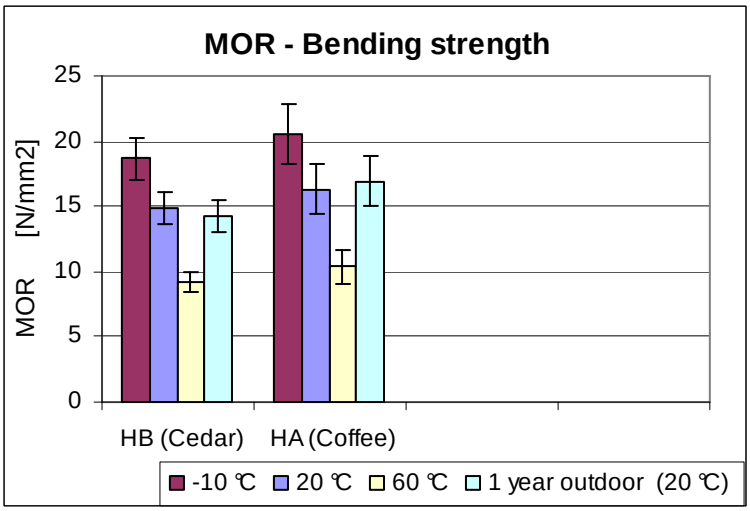
The mean results of the MOE and MOR measurements are demonstrated in the table below. Detailed results of all individual measurements can be found in appendix B

	Test condition	20 ℃		-10 ℃		60 ℃		1 year outdoor exposure*)	
	Property	**MOE**	**MOR**	**MOE**	**MOR**	**MOE**	**MOR**	**MOE**	**MOR**
		[N/mm²]	**[N/mm²]**	**[N/mm²]**	**[N/mm²]**	**[N/mm²]**	**[N/mm²]**	**[N/mm²]**	**[N/mm²]**
Type									
Envirodeck™	Mean	1559	14.9	2252	18.7	673	9.2	1544	14.3
HB (cedar)	Stdev	230	1.2	234	1.6	85	0.7	134	1.2
Envirodeck™	Mean	1857	16.3	2710	20.6	834	10.4	1832	16.9
HA (coffee)	Stdev	141	1.9	151	2.3	62	1.3	83	1.9

* Results available October 2008

The mean results of the MOE and MOR measurements are graphically in the figure below.





Linear thermal expansion

The mean results of the linear thermal expansion measurements are demonstrated in the table below. Detailed results of all individual measurements can be found in appendix B.

	Test condition	Change of length* per temperature range			Coefficient of linear thermal expansion		
	change of temperature	20 to -20	-20 to 20	20 to 60	20 to -20	-20 to 20	20 to 60
		[mm]	[mm]	[mm]	[℃$^{-1}$]	[℃$^{-1}$]	[℃$^{-1}$]
Type							
Envirodeck™	**Mean**	-0.658	0.651	0.632	-5.48 x 10^{-5}	5.42 x 10^{-5}	5.27 x 10^{-5}
HB (cedar)	**Stdev**	0.041	0.041	0.050	3.45 x 10^{-6}	3.43 x 10^{-6}	7.17 x 10^{-6}
Envirodeck™	**Mean**	-0.608	0.607	0.472	-5.07 x 10^{-5}	5.06 x 10^{-5}	3.93 x 10^{-5}
HA (coffee)	**Stdev**	0.037	0.037	0.079	3.12 x 10^{-6}	3.08 x 10^{-6}	6.58 x 10^{-6}

* L_0 = 300 mm

4 Conclusion

The determined physical and mechanical properties of Envirodeck™ HB (cedar) and Envirodeck™ HA (coffee) are summarised in the table below.

Property				**Test method/ standard**
		Envirodeck™ HB (cedar)	**Envirodeck™ HA (coffee)**	**ASTM standard EN standard**
Density	kg/m^3	1226	1301	ASTM D792-00
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Modulus of Elasticity (MOE) at - 20 ℃	N/mm^2	2252	2710	
Modulus of Rupture (MOR) at 20 ℃	N/mm^2	14.9	16.3	
Modulus of Elasticity (MOE) at 20 ℃	N/mm^2	1559	1857	
Modulus of Rupture (MOR) at 60 ℃	N/mm^2	9.2	10.4	
Modulus of Elasticity (MOE) 1 year outdoor	N/mm^2	1544	1832	
Modulus of Rupture (MOR) 1 year outdoor	N/mm^2	14.3	16.9	
Modulus of Elasticity (MOE) at 60 ℃	N/mm^2	673	834	
Coefficient of linear thermal expansion (-20 to + 60 ℃)	℃$^{-1}$	5.34 x 10^{-5}	4.50 x 10^{-5}	ASTM D696-03

Appendix A Picture of the profile of the test sample

Appendix B Detailed results of the measurements

Density

	Property	Weight	Volume	Density
		[N/mm²]	[N/mm²]	[N/mm²]
Type				
		64.37	52.42	1228
		63.87	52.00	1228
		61.36	50.77	1209
		62.60	51.40	1218
		63.91	51.14	1250
Envirodeck™	**Mean**	**63.22**	**51.55**	**1226**
HB (cedar)	**Stdev**	**1.23**	**0.66**	**15.3**
		67.47	52.37	1288
		70.12	53.87	1302
		68.99	52.52	1314
		65.76	50.72	1297
		66.40	50.96	1303
Envirodeck™	**Mean**	**67.75**	**52.09**	**1301**
HA (coffee)	**Stdev**	**1.80**	**1.28**	**9.3**

Water absorption

	Property	Weight	Weight 24 h. immersion	Waterabsorption
		[g]	[g]	[%]
Type				
Envirodeck™		64.37	64.99	0.96
HB (cedar)		63.87	64.60	1.14
		61.36	62.15	1.29
		62.60	63.24	1.02
		63.91	64.58	1.05
	Mean	**63.22**	**63.91**	**1.09**
	Stdev	**1.23**	**1.19**	**0.13**
Envirodeck™		67.47	68.16	1.02
HA (coffee)		70.12	70.65	0.76
		68.99	69.91	1.33
		65.76	66.72	1.46
		66.40	67.04	0.96
	Mean	**67.75**	**68.50**	**1.11**
	Stdev	**1.80**	**1.73**	**0.29**

Bending strength (MOR) and bending stiffness (MOE)

Code	Fmax	L1	b	d	modulu	ƒm		MOE E mod.	MOR ƒm
	N	mm	mm	mm	N/mm²	N/mm²		N/mm²	N/mm²
Evirodeck™ HB Cedar 20°								***Major axis***	
HB-1	1790	500	149.4	24.2	1392	15.4	*Mean*	1559.1	14.9
HB-2	1993	500	148.7	24.8	1833	16.4	*St.Dev.*	230.3	1.2
HB-3	1837	500	149.6	24.8	1489	15.0	*VC (%)*	14.8	8.1
HB-4	1627	500	150.5	25.0	1466	13.0			
HB-5	1850	500	149.3	24.8	1351	15.1			
HB-6	1848	500	150.5	25.0	1462	14.8			
HB-7	1652	500	149.5	24.9	1279	13.4			
HB-8	1719	500	149.6	24.7	1604	14.1			
HB-9	2049	500	149.2	24.7	2015	16.9			
HB-10	1784	500	149.7	24.8	1702	14.5			
Evirodeck™ HA Coffee 20°								***Major axis***	
HA-1	2179	500	150.4	24.6	1976	18.0	*Mean*	1856.8	16.3
HA-2	2170	500	151.3	24.9	2019	17.4	*St.Dev.*	141.4	1.9
HA-3	2182	500	150.4	24.5	1990	18.1	*VC (%)*	7.6	11.5
HA-4	2058	500	151.5	24.9	1817	16.5			
HA-5	1870	500	150.5	23.8	1795	16.4			
HA-6	1513	500	151.5	23.5	1840	13.6			
HA-7	1736	500	150.6	24.0	1783	15.0			
HA-8	1549	500	151.2	23.6	1680	13.8			
HA-9	2338	500	150.8	24.7	2032	19.1			
HA-10	1905	500	150.3	25.0	1637	15.3			
Evirodeck™ HB Cedar 60°								***Major axis***	
HB-11	1178.08	500	150.5	24.7	775	9.6	*Mean*	673.1	9.2
HB-12	1160.84	500	150.0	25.0	620	9.3	*St.Dev.*	85.4	0.7
HB-13	1268.77	500	149.3	24.6	827	10.5	*VC (%)*	12.7	8.1
HB-14	1191.33	500	150.1	25.2	625	9.4			
HB-15	1035.19	500	150.8	25.0	617	8.2			
HB-16	1186.2	500	149.7	24.8	614	9.6			
HB-17	1144.08	500	150.7	25.0	637	9.1			
HB-18	975.96	500	150.3	25.0	655	7.8			
HB-19	1151.13	500	150.2	25.0	586	9.2			
HB-20	1129.8	500	150.1	24.8	776	9.2			
Evirodeck™ HA Coffee 60°								***Major axis***	
HA-11	1068.0	500	151.2	24.0	811	9.2	*Mean*	833.9	10.4
HA-12	1144.8	500	151.3	24.7	821	9.3	*St.Dev.*	61.5	1.3
HA-13	1026.3	500	151.5	24.0	727	8.8	*VC (%)*	7.4	12.4
HA-14	1493.0	500	151.0	24.9	868	12.0			
HA-15	1158.6	500	151.0	24.4	811	9.7			
HA-16	1538.2	500	151.0	24.8	876	12.4			
HA-17	1381.6	500	150.9	24.7	917	11.3			
HA-18	1202.7	500	150.7	24.9	797	9.7			
HA-19	1390.2	500	150.8	24.5	923	11.5			
HA-20	1235.6	500	150.7	25.0	787	9.9			

Code	Fmax	L1	b	d	modulu	fm		MOE E mod.	MOR fm
	N	mm	mm	mm	N/mm²	N/mm²		N/mm²	N/mm²
Evirodeck™ HB Cedar -10°								***Major axis***	
HB-21	2236.4	500	149.9	24.8	2414	18.1	*Mean*	2252.4	18.7
HB-22	2306.9	500	149.2	24.9	2123	18.7	*St.Dev.*	233.6	1.6
HB-23	2620.6	500	149.7	24.9	2404	21.2	*VC (%)*	10.4	8.6
HB-24	2300.0	500	149.6	25.1	2182	18.3			
HB-25	2324.2	500	149.3	24.9	2037	18.9			
HB-26	2107.1	500	149.3	24.7	2348	17.3			
HB-27	2016.9	500	149.6	25.0	1983	16.2			
HB-28	2560.7	500	148.5	24.6	2667	21.5			
HB-29	2299.2	500	149.4	25.1	1947	18.4			
HB-30	2223.9	500	149.4	24.9	2417	18.0			
Evirodeck™ HA Coffee -10°								***Major axis***	
HA-21	2740.7	500	150.1	24.6	2869	22.7	*Mean*	2709.5	20.6
HA-22	2767.2	500	151.0	24.8	2947	22.4	*St.Dev.*	151.2	2.3
HA-23	2039.7	500	150.8	23.4	2762	18.5	*VC (%)*	5.6	11.0
HA-24	2064.9	500	150.3	24.6	2542	17.0			
HA-25	2821.9	500	150.3	24.8	2706	22.9			
HA-26	2639.0	500	150.0	24.4	2677	22.2			
HA-27	2805.1	500	150.2	24.6	2852	23.1			
HA-28	2137.3	500	150.5	23.5	2586	19.3			
HA-29	2253.9	500	150.2	24.2	2678	19.2			
HA-30	2071.6	500	150.4	23.4	2475	18.9			

Code	Fmax	L1	b	d	modulu	fm		MOE E mod.	MOR fm
	N	mm	mm	mm	N/mm²	N/mm²		N/mm²	N/mm²
Evirodeck™ HB Cedar (1 year outdoor)								***Major axis***	
HB-31	1845,0	500	150,6	25,0	1622	14,7	*Mean*	1543,7	14,3
HB-32	1702,4	500	150,8	25,0	1494	13,6	*St.Dev.*	134,5	1,2
HB-33	1867,3	500	150,8	25,0	1486	14,9	*VC (%)*	8,7	8,7
HB-34	1736,4	500	149,9	25,1	1445	13,8			
HB-35	1740,8	500	150,3	25,0	1541	13,9			
HB-36	1651,3	500	150,3	25,1	1486	13,1			
HB-37	1763,0	500	149,7	25,4	1648	13,7			
HB-38	2171,5	500	151,2	24,9	1856	17,4			
HB-39	1843,9	500	150,3	25,0	1388	14,7			
HB-40	1694,1	500	150,8	25,2	1471	13,3			
Evirodeck™ HA Coffee (1 year outdoor)								***Major axis***	
HA-31	2192,7	500	150,4	24,5	1929	18,2	*Mean*	1831,5	16,9
HA-32	2220,3	500	150,8	24,8	1724	17,9	*St.Dev.*	83,1	1,9
HA-33	2223,6	500	150,5	24,6	1922	18,3	*VC (%)*	4,5	11,1
HA-34	1826,5	500	151,4	24,8	1828	14,7			
HA-35	2295,0	500	150,7	24,8	1896	18,6			
HA-36	2233,8	500	150,8	24,8	1749	18,1			
HA-37	1674,2	500	150,8	23,7	1909	14,8			
HA-38	2235,5	500	150,9	24,7	1792	18,2			
HA-39	1576,7	500	151,8	24,1	1713	13,5			
HA-40	2014,0	500	151,1	24,5	1852	16,7			

Linear Thermal expansion

	Test condition	Change of length* per temperature range			Coefficient of linear thermal expansion		
	change of temperature	20 to -20	-20 to 20	20 to 60	20 to -20	-20 to 20	20 to 60
		[mm]	[mm]	[mm]	[℃ $^{-1}$]	[℃ $^{-1}$]	[℃ $^{-1}$]
Type		-0.632	0.635	0.669	-0.0000527	0.0000529	0.0000558
Envirodeck™		-0.659	0.642	0.575	-0.0000549	0.0000535	0.0000479
HB (cedar)		-0.633	0.631	0.605	-0.0000528	0.0000526	0.0000504
		-0.722	0.721	0.628	-0.0000602	0.0000601	0.0000524
		-0.599	0.588	0.605	-0.0000499	0.0000490	0.0000504
		-0.677	0.668	0.658	-0.0000564	0.0000557	0.0000548
		-0.664	0.655	0.602	-0.0000553	0.0000546	0.0000502
		-0.711	0.702	0.697	-0.0000593	0.0000586	0.0000581
		-0.676	0.662	0.712	-0.0000563	0.0000552	0.0000593
		-0.604	0.601	0.568	-0.0000503	0.0000501	0.0000473
	Mean	**-0.658**	**0.651**	**0.632**	**-5.48 x 10^{-5}**	**5.42 x 10^{-5}**	**5.27 x 10^{-5}**
	Stdev	**0.041**	**0.041**	**0.050**	**3.45 x 10^{-6}**	**3.43 x 10^{-6}**	**7.17 x 10^{-6}**
Envirodeck™		-0.627	0.627	0.553	-0.0000522	0.0000522	0.0000461
HA (coffee)		-0.615	0.613	0.432	-0.0000514	0.0000513	0.0000361
		-0.547	0.541	0.534	-0.0000455	0.0000450	0.0000445
		-0.609	0.605	0.385	-0.0000508	0.0000504	0.0000321
		-0.622	0.627	0.507	-0.0000518	0.0000523	0.0000423
		-0.568	0.572	0.379	-0.0000473	0.0000476	0.0000316
		-0.686	0.68	0.587	-0.0000572	0.0000567	0.0000489
		-0.589	0.589	0.362	-0.0000491	0.0000491	0.0000302
		-0.604	0.603	0.509	-0.0000503	0.0000503	0.0000424
		-0.612	0.61	0.471	-0.0000511	0.0000509	0.0000393
	Mean	**-0.608**	**0.607**	**0.472**	**-5.07 x 10^{-5}**	**5.06 x 10^{-5}**	**3.93 x 10^{-5}**
	Stdev	**0.037**	**0.037**	**0.079**	**3.12 x 10^{-6}**	**3.08 x 10^{-6}**	**6.58 x 10^{-6}**

* L_0 = 300 mm