




SICOMIN

FORMULATION OF EPOXY SYSTEMS

PB170,250,400 and 600kg/m^3

FOAMING EPOXY SYSTEMS

USER MANUAL

Two component foaming epoxy PB

The foaming epoxy PB is a two-component formulation, designed to manufacture structural core and fill hollow parts by casting.
This closed cell foam is rot proof, with a negligible water absorption.
After post-cure the PB foam is non-friable and has excellent behaviour when submitted to static and dynamic loads.

The **PB** is available in several densities:

- **170** kg per cubic meter
- **250** kg per cubic meter
- **400** kg per cubic meter
- **600** kg per cubic meter

You can do in one step:

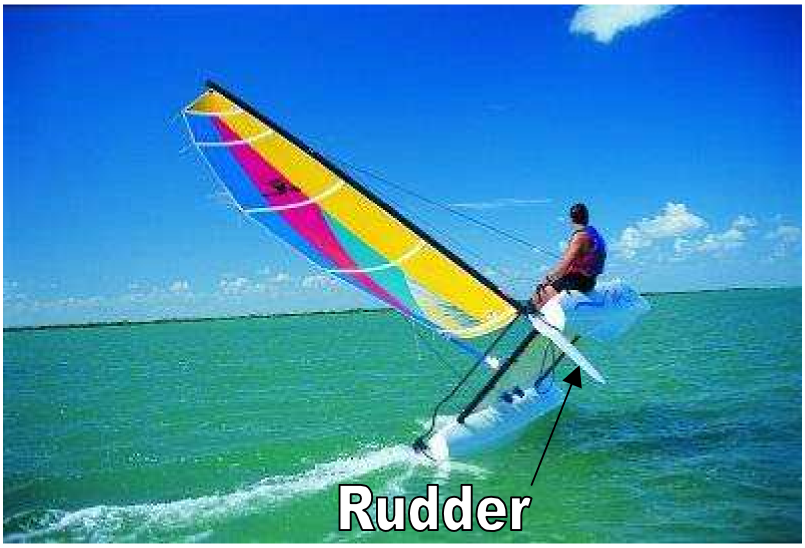
- ► The filling of hollow parts
- ► Complex shapes without machining and with low waste
- ► Embedding of inserts
- ► Local densification of foam core material
- ► Creation of rot proof areas in wooden core
- ► Bonding of spaced laminates
- ► Structural prototyping

The expansion of PB system happens in a liquid state, the cavity is filled entirely, curing occurs after, depending on the chosen hardener. For this reason the induced pressure or "push" of the liquid PB is extremely low, avoiding the investment of a reinforced tooling as with other type of foams.
An air-vent is required to let the air away while the PB is expanding.
PB can be applied directly onto a gelcoat and can be pigmented with epoxy compatible pigments. Pigment are mixed in the resin part first.

User guide to cast foaming epoxy PB

Summary

The part made in the mould below is a catamaran rudder



1- Preparation of components

Before using the PB, mix thoroughly the resin part in order to obtain homogeneous liquid and consistent density of foam

Stir thoroughly the resin before adding the hardener.

2- Workshop environment

The foaming resin and hardener should be stored between 18℃ and 23℃, for a minimum of 12h before use.
Long term storage should be below 28℃.

If the resin and hardener are at 28℃ or over, mind the exothermic peak.
A rise of the temperature is accompanied by a decrease of the viscosity of the two components. Furthermore it will have an influence on the final density of the foam.
Heat will increase the expansion, cold will decrease it.
All densities on the technical data sheet are given at 20℃.

3- Determination of volume to fill

If the volume of the part is unknown, use some fine sand or equivalent to fill the cavity.
Pour the sand into a graduated cup to measure the volume.

Do not forget to double the volume if it's a symmetrical part made in two half moulds (rudder, foil...)

To know the quantity of PB to prepare, divide the volume of the cavity by the expansion ratio of chosen PB. When working in cubic cm or ml for the volume unit, the weight of material to mix will be in grams.

Example:

PB 250/ DM 03

Volume to fill:	468ml
Expansion ratio PB 250 @ 20°C:	4
Mixed quantity to prepare :	468/4 =117g

Important: Prepare 10% more of mix by weight to allow for waste

Waste of 10% :	117 + 11.7 = 128.7g so 129g approx.
Mixing ratio by weight :	100g of PB 250 for 31g of DM03
Mix Resin/ Hardener (131) =	129 g
Resin (100) = 129 x 100 / 131 =	98.5 g
Hardener (31)= 129 x 31 / 131 =	30.5 g

4- Compatibility and interface

Foaming epoxy PB is compatible with most of polyester, vinylester (check by a preliminary test) and epoxy resins.
It can be applied directly on wet epoxy resin and onto gelled or still liquid polyester and vinylester resins.

If applied onto a cured laminate, remove the peel ply and sand the surface.
To increase the shear strength between the laminate and the PB foam, prime the surface with a fast laminating epoxy system just before casting.

This operation allows the foam to slide on the wet resin film, it avoids also the formation of macro-bubbles between foam and laminate.

Laminates primed with fast epoxy system

Casting of PB in the two half moulds while the resin film is still liquid

5- Choice of hardener

When choosing the hardener, 2 major parameters are taken into account:

- The exotherm generated by the hardening reaction.
- The insulation of the foam due to its cellular structure

The thickness to be cast and the density of PB chosen will highly influence these two parameters.
The thicker the casting is and /or the higher the density of foam is, the more you will have to use a slow hardener to avoid a high exothermic peak.

Several hardeners are available, in relation with the volume of casting, density and the Tg required.

Maximum Tg reached with the appropriate hardeners:

PB 170 = 115°C
PB 250 =137°C
PB 400 = 135°C
PB 600 = 142°C
(For more details, consult the Technical Data Sheet)

6- Casting

In the case of a two part mould (example: a rudder mould), pour half the required quantity in each half mould, wait one minute for the PB to start its expansion and increase its thixotropy, then close the mould.
Use clamps to hold the mould properly closed during the expansion.
Depending on the shapes to fill, we advise tilting the mould slightly with an air-vent at the top, to let the PB foam push the air out.
The event is necessary because PB does not consume the air contained in the cavity.
The foaming system PB has a very low "push" in comparison with PU foam, it does not require a mould reinforced with a steel frame. A simple monolithic mould is normally enough.
In order to obtain very regular cells, without macro bubbles due to the mixing operation, you can use a sieve and cast the mixed PB through it, breaking the macro bubbles.

Casting through a sieve to eliminate the macro bubbles of the mix

Closure of the mould

7- Hardening and post-curing

Definition of Tg: The Tg (Glass transition) of a polymer is the temperature where this polymer goes from a hard, glass like state to a rubber like state.

When the part is completely filled, wait for the PB to cure at ambient temperature. Keep aside a sample of PB cast as a witness. When cured, start the post cure at 40℃ with the part inside the mould.
After several hours at 40 ℃ (see TDS) you can :

- Ramp it up till 60℃ in the mould.

or

- Let it cool down, release the part before putting the part on self standing post cure at 60℃.

or

- Let it cool down, release the part and finish it. The mechanical properties will be of course less than if post cured at 60℃, but enough for a many of applications, where cycle time must be as short as possible.

The stage at 40℃ is the minimum post-cure.
Don't put directly the PB at 60℃ if not in the mou ld, it may expand again and break apart on the split line.

8- Reminder of parameters to check

⇒ Before each use, mix the resin part in its original container, until you obtain a homogeneous consistency

⇒ Determinate the quantity to cast plus 10% for waste allowance.

⇒ Compatible with polyester, vinylester and of course epoxy resins. Check by preliminary test. If the laminate is cured take off the peel ply and sand with 40 or 60 grit, then apply a coat of fast epoxy as primer before casting the PB.

⇒ Cast through a sieve to break macro bubbles of mix.

⇒ Wait 1 min for the thixopropy to increase before turning over the mould to close it (PB should have the consistency of shaving foam).

⇒ Minimum post-cure at 40℃ in the mould. If the part requires the maximum mechanical properties, carry on post curing at 60℃ . (After cool down from 40℃ stage and release, the part can have a self standing post-cure at 60℃)

⇒ Workshop and products temperatures should be controlled , ideally at 20℃. Heat will increase expansion and cold will decrease. All densities are given at 20℃ on technical data sheet.

9- Examples of parts made with PB

Front light of Paris/Dakar 4 wheel drive
Epoxy gel coat and PB 250

Local densification of foam for inserts of fins

Carbon pedal crank stiffened with PB 250

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PB 170, PB 250, PB 400, PB 600

Cellular foam production epoxy system

PB products are 2 component epoxy foaming formulations developed for “in situ” low density epoxy foam production. Foam final density depends only on the choice of the resin. These systems are white but can be coloured by adding any epoxy compatible pigments.
PB 170, **PB 250**, **PB 400** and **PB 600** respectively provide approximately 170, 250, 400 and 600 kg/m^3 foams. The hardener has only an influence on the curing time and thus the potential thickness of the one shot cast part.
The mixes evolve in two separate steps:

1. Fast expansion of the casting.
2. Slow hardening of the mass.

Performances

“in situ” low density foam manufacturing.
No hollow microspheres handling.
Good adhesion onto all type of materials.
PB can be cast onto prepregs and wet epoxy resins curing.
Homogeneous density.
Very low water absorption.

Applications

Production of epoxy foam.
Casting “in situ” of epoxy core materials.
Floating volume.
Increasing density of foam cores and honeycomb.
Thermal insulation.
Machinable blocks for models.

Mixing ratios

	PB 170	PB 250	PB 400	PB 600
DM 03 (standard)	100 g / 31 g	100g / 31g	100g / 32g	100g / 30g
DM 02 (slow)	100 g / 36 g	100g / 36 g	100g / 37g	100g / 35 g

Exothermic parameters

Thermal conductivity of substrate.
Open or closed moulding.
Temperature of components and ambient temperature.
Geometry, thickness, volume and mass of the casting.
For casting onto a laminate that is curing, the heat produced by the laminating resin can influence the reactivity of the foaming system, particularly with a thick laminate.

Recommendations for use

In order to homogenise the PB resins, mix thoroughly with a helicoidal agitator before quantity determination(take a special care to scrape the sides and bottom of the container).
The quantity determination have to be done by weight, with a precise scale adapted to the quantity used .
The expansion is much faster than the polymerisation: mixing and casting operations must be done as quick as possible, specially with the low density foaming systems.
The maximum working time of mixes is 4 minutes.

While mixing PB resin and hardener, air is usually included.
Most of these bubbles can be eliminated by simply passing the blend trough a 1 to 2 mm stainless steel sieve.

Expansion ratios

	Finale density after free expansion @ 20℃	Expansion ratio @ 20℃
PB 170	170 ± 20 kg / m^3	x 6.2
PB 250	250 ± 25 kg / m^3	x 4
PB 400	400 ± 30 kg / m^3	x 2.5
PB 600	600 ± 40 kg / m^3	x 1.7

For example, if the volume to fill up is 10 litres, you need :
- 10 / 6.2 = 1.62 kg **PB 170** mix
- 10 / 4 = 2.5 kg **PB 250** mix
- or 10 / 2.5 = 4 kg **PB 400** mix
- or 10 / 1.7 = 5.9 kg **PB 600** mix

Prepare 10 % more of mix for the waste.
Be aware of the problem of exothermal peak with large volume (see graph: Measure of the exothermal peak of the casting relative to the thickness @ 20°C, page 3 & 4.

Curing

For medium to large volume wait until every parts of the casting is hard.
If possible leave in the mould.
A minimum post cure of 6 hrs @ 40℃. is required to get a dimensional stability.

Post cure cycle:

-For small volume:
You can put directly the casting in the oven after pouring, according the schedule described below.
-For large volume:
6 - 24 hours after the mix of the two components at ambient temperature (18 - 23°C), this will limit the exothermal peak and the risk of "burning" the material.
+ 6 hrs. at 40°C Achieving a Tg1 of above 50°C
+ 12 hrs. at 60°C Achieving a Tg1 of above 70°C

Other versions

PB 350 S / **SD 1249.17** : Sprayable version for lightened laminates.
Requires a machine with 2/1 pump ratio by volume with mixing in the nozzle
PB 270 I : Fire retardant version.

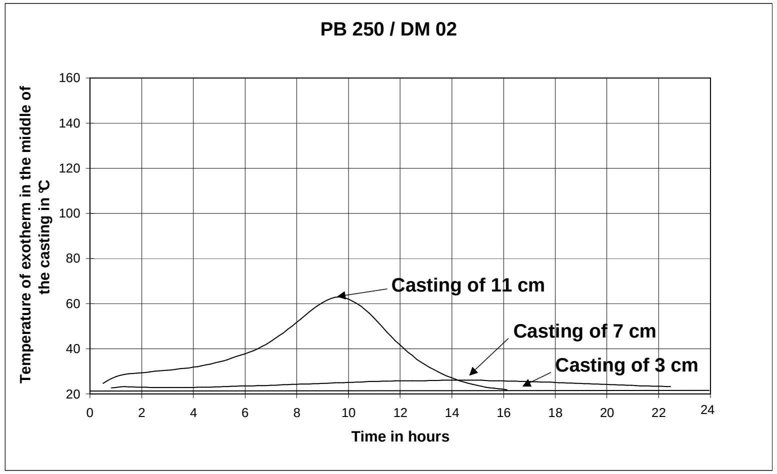
Other blends

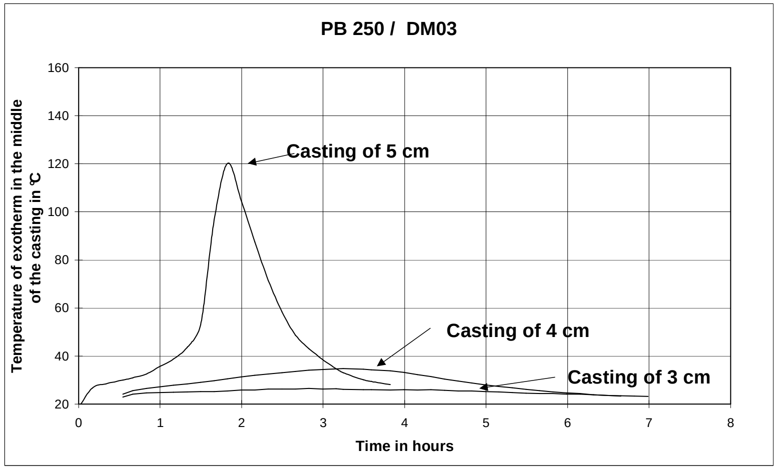
PB	SD	Weight ratios	Tg 1 max in ℃
PB 170	**SD 2505**	100 / 30	97
	SD 8203	100 / 30	115
PB 250	**SD 8205**	100 / 27	96
	SD 7820	100 / 30	125
	SD 2630	100 / 27	137
PB 400	**SD 7820**	100 / 28	133
	SD 2630	100 / 27	135
PB 600	**SD 7820**	100 / 27	137
	SD 2630	100 / 26	142

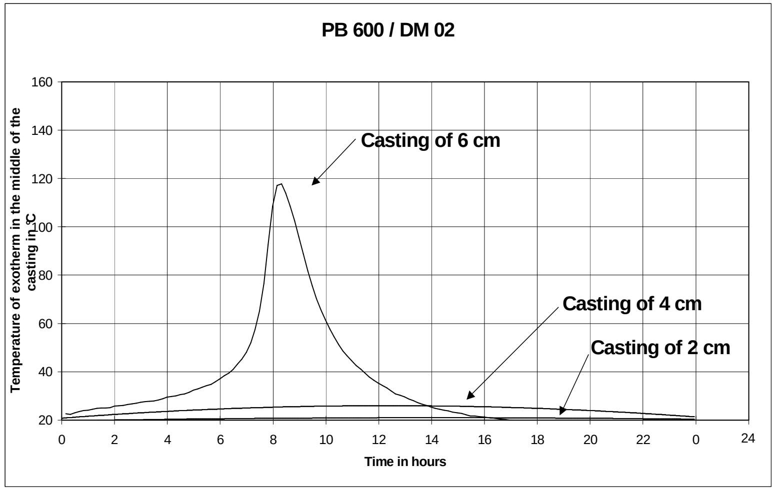
Material thermal conductivity

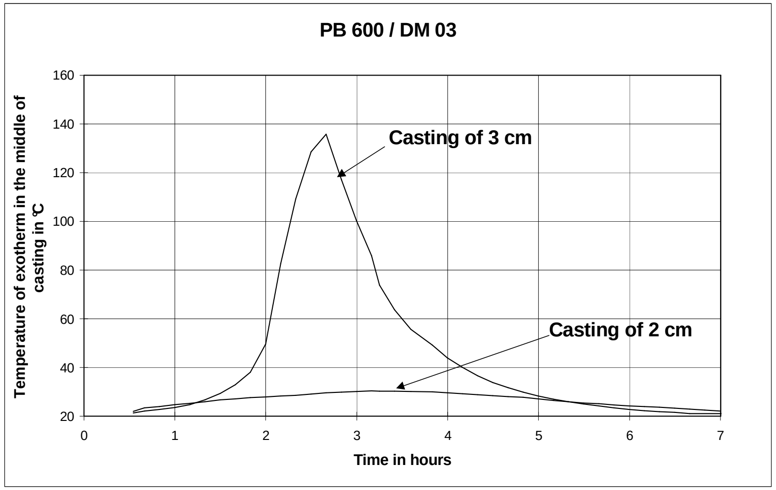
Materials	Density **(kg / m^3)**	**Thermal Conductivity @ 20 ℃ (W / m x ℃)**
Copper	8800	380
Composite Carbon / carbon	1700 – 2000	300
Aluminium (AU 4G)	2800	140
Steel	7800	20 to 100
Carbon fiber: HR or HM	1800	200
E glass fiber	2600	1
Aramid fiber	1450	0.03
Concrete	2000 to 2500	1 to 1.5
Plaster		0.37
Expanded polycarbonate (Forex)	650	0.12
PB 600 epoxy foam	**600**	**0.157**
PB 400 epoxy foam	**400**	**0.130**
PB 250 epoxy foam	**250**	**0.065**
Extruded polyethylene foam	35 to 150	0.05
Herex C70.33 C70.75 C70.200	33, 80 and 200	0.030, 0.033 and 0.048
Airex R82.80 R 82.110	80 and 110	0.037 and 0.040
Airex R63.80 R63.140	90 and 140	0.034 and 0.039
Kapex C51	60	0.036
Non-filled thermoset resins Epoxy, polyester, phenolic	1100 to 1300	0.2
Polyethylene LD / HD	960	0.25 to 0.34
Laminate E glass / epoxy		0.3 to 0.8
Wood	400 to 700	0.12 to 0.2
Balsa	100 to 250	0.051 to 0.090
Expanded Polystyrene	20	0.035
Extruded Polystyrene	28 to 45	0.033 to 0.025
Air		0.021

Exothermal of cast relative to thickness at 20°C , open mould 480x 480 mm

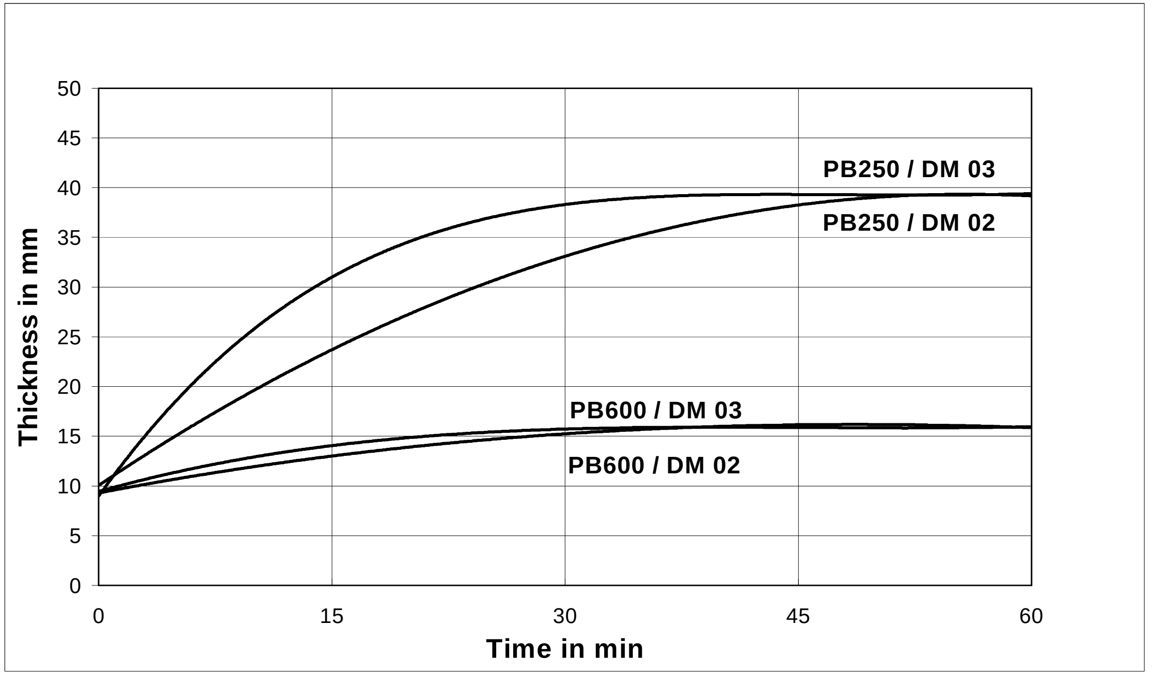








Expansion speed of a 10 mm. Cast at 20 °C



Mechanical Properties of cured foam

		PB 170* / DM 02		**PB 170* / DM 03**	
Curing cycle		48 h Tamb + 24 h 40 ℃	48 h Tamb + 6 h 40 ℃ +16 h 60 ℃	48 h Tamb + 24 h 40 ℃	48 h Tamb + 6 h 40 ℃ + 16 h 60 ℃
Compressive strength					
Modulus of elasticity	N/mm²	75	61	90	100
Compressive yield strength	N/mm²	2	1.8	2.4	2.4
Offset compressive yield	%	3.9	4.7	4.8	5.7
Flexion					
Modulus of elasticity	N/mm²	128	115	122	105
Maximum resistance at break	N/mm²	1.7	1.4	1.9	2.3
Elongation at maximum load	%	2	1.8	2.4	1.7
Shear strength					
Modulus of elasticity	N/mm²	82	72	79	85
Shear load at break	N/mm²	1.3	1.1	1.5	1.6
Elongation at break	%	5.8	5.7	6.2	6.7
Glass transition					
Tg1	℃	64	85	69	85
Tg1 max.	℃		90		92

Tests carried out on samples of pure cast resin, without prior degassing, between steel plates.
Measures undertaken according to the following norms :
Flexion : NF T 51-001
Compression: NF T 51-101
Shear strength ASTM 1041
Glass transition DSC : ISO 11357-2 : 1999 -5℃ t o 180℃ under nitrogen gaz
Tg1 or Onset : 1st point at 20 ℃/mn
Tg1 maximum or Onset : second passage

Mechanical Properties of cured foam

		PB 250 / DM 02				PB 250 / DM 03			
Curing cycle		48 h Tamb + 6 h 40 ℃	48 h Tamb + 6 h 40 ℃ + 48 h water	48h Tamb + 6 h 40 ℃ +16 h 60 ℃	48 h Tamb + 6 h 40 ℃ + 16 h 60 ℃ + 48 h water	48 h Tamb + 6 h 40 ℃	48 h Tamb + 6 h 40 ℃ + 48 h water	48 h Tamb + 6 h 40 ℃ + 16 h 60 ℃	48 h Tamb + 6 h 40 ℃ +16 h 60 ℃ + 48 h water
Compressive strength									
Modulus of elasticity	N/mm²	205	155	135	140	240	160	180	175
Compressive yield strength	N/mm²	6	6	5	5	6	6	6	7
Offset compressive yield	%	3.6	6.1	4.5	4.7	3.7	6.1	5.3	5.8
Flexion									
Modulus of elasticity	N/mm²	275		240		255		235	
Maximum resistance at break	N/mm²	5		6		5		5	
Elongation at maximum load	%	1.9		2.3		1.8		2.0	
Shear strength									
Modulus of elasticity	N/mm²			100				120	
Shear load at break	N/mm²			3				3	
Elongation at break	%			16				13	
Water absorption	%weight		+ 0.69		+ 1.0		+ 0.98		+ 1.0
Glass transition									
Tg1	℃	60	95	76	93	59	83	75	95
Tg1 max.	℃			94				88	

Tests carried out on samples of pure cast resin, without prior degassing, between steel plates.
Measures undertaken according to the following norms :

Flexion :	*NF T 51-001*
Compression:	*NF T 51-101*
Shear strength	*ASTM 1041D*
Glass transition DSC :	*ISO 11357-2 : 1999 -5℃ t o 180℃ under nitrogen gaz*
	Tg1 or Onset : 1st point at 20 ℃/mn
	Tg1 maximum or Onset : second passage

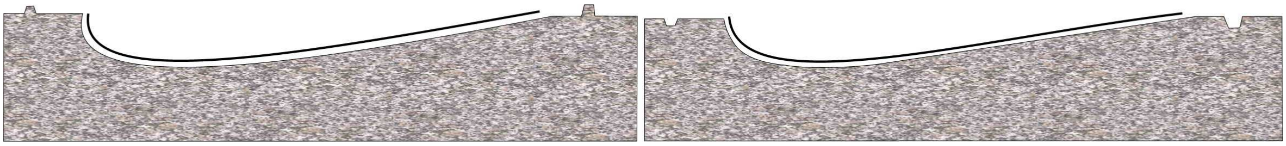
Mechanical Properties of cured foam

		PB 400 / DM 03		PB 600 / DM 02				PB 600 / DM 03			
Curing cycle		48 h Tamb +24 h 40℃	48 h Tamb +6h 40 ℃ +16h 60℃	48 h Tamb +6 h 40 ℃	48 h Tamb +6h40℃ +48h water	48 h Tamb + 6h 40 ℃ +16h 60℃	48 h Tamb + 6h 40 ℃ +16h 60 ℃ + 48h water	48 h Tamb + 6h40℃	48 h Tamb + 6h 40℃ +48h water	48h Tamb + 6h 40 ℃ +16h 60 ℃	48h Tamb + 6h 40 ℃ +16h 60 ℃ + 48h water
Compressive strength											
Modulus of elasticity	N/mm²	290	290	620	425	580	460	670	445	630	435
Compressive yield strength	N/mm²	11	12	26	28	27	28	27	28	30	28
Offset compressive yield	%	7.7	8.0	6.4	13	8.1	11.2	6.3	11.2	8.6	11.6
Flexion											
Modulus of elasticity	N/mm²	470	460	1160		1085		1230		1150	
Maximum resistance at break	N/mm²	12	11	19		21		21		21	
Elongation at maximum load	%	3.0	2.9	1.8		2.0		1.8		2.0	
Shear strength											
Modulus of elasticity	N/mm²	225	240								
Shear load at break	N/mm²	6.9	7.1								
Elongation at break	%	12	12								
Water absorption	%weight				+ 0.44		+ 0.46		+ 0.61		+ 0.61
Glass transition											
Tg1	℃	62	79	62	92	77	93	59	82	74	81
Tg1 max.	℃		84			97				90	

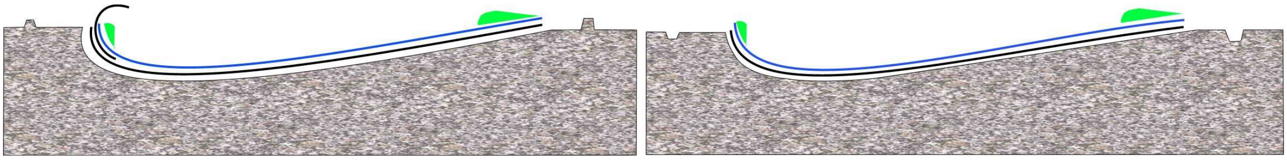
Tests carried out on samples of pure cast resin, without prior degassing, between steel plates.
Measures undertaken according to the following norms :

Flexion :	*NF T 51-001*
Compression:	*NF T 51-101*
Shear strength	*ASTM 1041D*
Glass transition DSC :	*ISO 11357-2 : 1999 -5℃ t o 180℃ under nitrogen gaz*
	Tg1 or Onset : 1st point at 20 ℃/mn
	Tg1 maximum or Onset : second passage

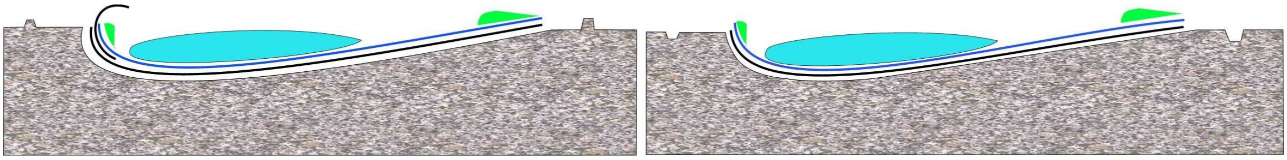
Use of PB epoxy foam for daggerboard or foil manufacturing



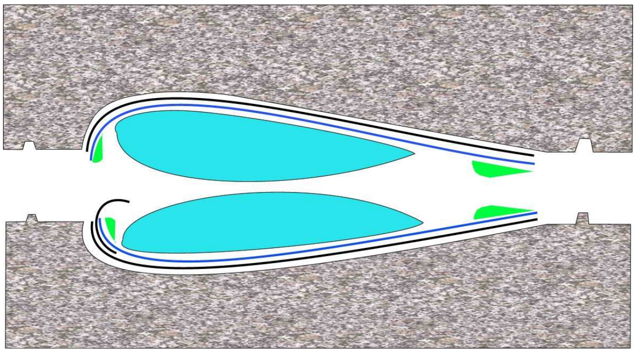
Hand laminating of the skins in the mould or bulking of the prepreg layers under vacuum.
After cure of the laminate take the peelply off
With polyester skins, finish the laminate with a dry CSM (mechanical key), post cure the skins in the mould to fully complete the cure of polyester.



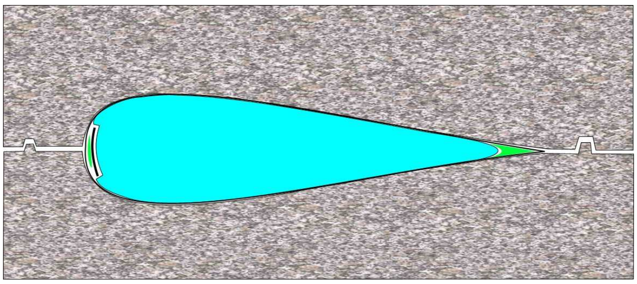
Front edge :
Application of film of bonding paste on the whole laminate, laminating of biaxial fabric.
For polyester skins : wet the csm out with laminating epoxy system.
Rear edge : apply a thixotropic epoxy resin .



Casting of PB in both halves. Wait till the foam raise up to the level of flanges



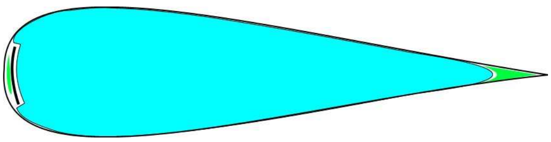
Assembling of the two parts mould.



Curing at ambient temperature.
Minimum post-cure of 6 hours @ 40 °C

Or

Post-curing @ 80 to 130°C for prepregs.



Release is then possible when back to ambient temperature.

Part finished.

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www.alm-inter.com

AUSTRALIA
LAVENDER CE Pty Ltd
10/10 Miltiadis Street
Acacia Ridge
QLD 4110
Tel : + 61 (7)3255 6924
Fax : + 61 (7)3255 6923
rsteinbush@lavender-ce.com
www.lavender-ce.com

BELGIUM/LUXEMBOURG
FINRES GROUP
Rue J.Van Hovestraat,35
B-1950 KRAAINEM
Tel : + 32 (0)2 720 23 56
Fax : + 32 (0)2 720 16 00
info@vulga.be
www.vulga.be

CHINA
FRP SERVICES & CO
(SHANGHAI) LTD.
He Chuang Bldg, 8th Floor, 801
No. 450, Caoyang,
200063 SHANGHAI, CHINA
Tel : + 86 21 61072600
Fax : + 86 21 61072666
luyingjie@frpchina.cn
www.frpservices.com

FINLAND
KG Enterprise Oy
PL 2, Vaiskinkuja 2
04 500 KELLOKOSKI
Tel : + 358 92 82 660
Fax : + 358 92 82 616
kenneth.gauffin@kolumbus.fi
www.kgenterprise.fi

FRENCH WEST INDIES
GUYANE, GUADELOUPE, MARTINIQUE
MULTICAP CARAÏBES
B.P. 898 - Quai Ouest
97 245 FORT DE FRANCE Cedex
Martinique
Tel : + 33 (0)5 96 71 41 81
Fax : + 33 (0)5 96 71 41 83
mcm@multicapcaraibes.com
www.multicapcaraibes.com

GERMANY/NETHERLANDS
TIME OUT COMPOSITE
Ottostrasse 119
D-53 332 BORNHEIM-SECHTEM
Tel : + 49 (0)22 27 90 810
Fax : + 49 (0)22 27 90 81 29
service@timeout.de
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ALVIN PLAST
H 2040 BUDAORS GYAR U2
H 2041 BUDAORS PF 254
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Fax : + 36 23 44 55 24
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Fax : + 33 (0)2 62 42 36 28
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ITALY
G. ANGELONI s.r.l.
Via A. Tommaso 72/A5
30020 QUARTO D'ALTINO (VE)
Tel : + 39 04 22 78 05 80
Fax : + 39 04 22 78 27 82
info@g-angeloni.com
www.g-angeloni.com

PACIFIC OCEAN
COPRODEX
B.P. 24
Chemin du grand pin vert
13 671 AUBAGNE Cedex
Tel : + 33 (0)4 42 18 56 20
Fax : + 33 (0)4 42 03 61 69
info@coprodex.fr

PORTUGAL
REBELCO, Lda
Rua Gil Vicente 69
2775-198 PAREDE
Tel : + 351 2 14 56 63 35
Fax : + 351 2 14 56 63 38
geral@rebelco.pt
www.rebelco.pt

SLOVENIJA
MPI KRANJ d.o.o
Bristof 126
4000 KRANJ
SLOVENIJA
Tel : 00386 4 234 0650
Mobile : 00386 41 70 90 18
mpi.rok@gmail.com

SOUTH AFRICA
AERONTEC cc
PO Box 683
HOWARD PLACE 7450
Cell : + 27 82 45 83 379
Tel/Fax : + 27 21 67 12 114
blyth@cinet.co.za

SPAIN
DMS / EURORESINS
La Llacuna, 161 planta 2ª
08 018 BARCELONA
Tel : + 34 93 489 99 02
Fax : + 34 93 473 63 73
ramon.fontanals@dms.com

SWITZERLAND
COMPOSITE SOLUTIONS AG
Freiburgstrasse 251
CH-3018 BERN
Tel : +41 (0)3 16 88 40 40
Fax : +41 (0)3 16 88 40 41
info@compositesolutions.ch
www.compositesolutions.ch

TUNISIA
CIREX
30 rue ali ben guedahen
1001 TUNIS
Tel : + 216 71 34 02 24
Fax : + 216 71 33 46 34
cirex@gnet.tn

TURKEY
DERYA MARINE
Sariana MAH
27. sokak NO : 2/3
48 700 MARMARIS-MUGLA
Tel : + 90 252 412 52 25
Fax : + 90 252 413 66 30
deryamarine@superonline.com

UNITED ARAB EMIRATES
LOGISTICS COMPANY LIMITED
P.O. box: 17134,
Jebel Ali Free Zone,
DUBAI, UNITED ARAB EMIRATES
Tel : + 971 6 5430995
Fax : + 971 6 5430996
logistic@emirates.net.ae

UNITED KINGDOM
MATRIX COMPOSITE MATERIAL
CO.LTD
Unit 5.5 paintworks
Bath road BRISTOL BS4 3EH
ENGLAND
Tel : + 44 (0) 117 971 5145
Fax : + 44 (0) 117 977 8388
info@mcmc-uk.com
www.mcmc-uk.com

USA / BRESIL
NIDA-CORE CORP.
541 NW Interpark Place
Port St Lucie,
Florida 34986
USA
tel : 1.7723437300
Fredromier@aol.com