# SONOBOARD™ - THE NEXT GENERATION FORMWORKS BOARD

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## ABSTRACT

This paper presents research, design and prototype testing for a composite formworks board. The aim is to produce a board with the wooden based boards' advantages, but without its disadvantages. Therefore the board shall have similar stiffness and weight, but longer life, water resistance and permanence of size.

Water absorption is tested with a standard for rigid cellular plastics. The thermal expansion is estimated theoretically and experimentally in four different temperatures and a linear regression is made for the differential coefficient. Stiffness is tested by three or four point bending tests.

The water absorption is low, <1%; the thermal expansion coefficient is equal to steel, ~11µstrain/°C. A co-extruded thermoplastic sheet is chosen as surface material, which is durable and resistant to strong alkalis and UV-light. The desired stiffness is hard to achieve for thicker boards than 20mm. With unbalanced biaxial Non-Crimp Fabric (NCF) the stiffness is 90% of the preferred value. For thinner boards balanced biaxial NCF can be used.

## 1. INTRODUCTION

Sonoform AB has a new patent pending on a glass fibre reinforced sandwich panel used for concrete formworks. The material will revolutionize the formworks industry, which almost exclusively use wooden based materials. Sonoboards™ mechanical and physical properties remain over time. The sandwich panel is produced in one step, with fibre reinforcement and surface material in the mould which gives an efficient process and a low-cost product.

Today a standard formworks board has a life-time of 5 – 20 moulds, the aim is to stretch it to 50 moulds with Sonoboard™.

## 2. MANUFACTURING

The manufacturing process is simple but smart. The principle is to use the core material as the matrix in the fibre layers as well, thereby; the production can be made in one step. The advantages are that it is high-efficient compared to ordinary sandwich production, and there is no joining between the layers and the core. A disadvantage is though, that a high density core is needed for good bonding to the fibre.

The core material that is used is a rigid closed cell polyurethane, PUR. A schematic sketch of a PUR mixing machine is shown in Figure 1; PUR is a mix of polyol and isocyanate.

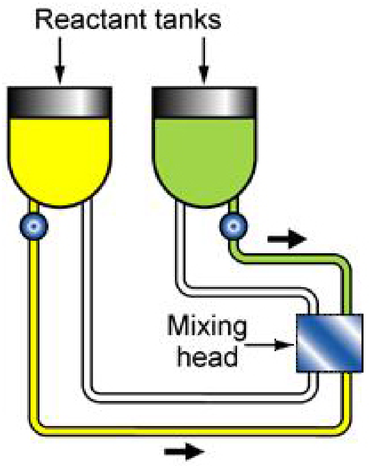


Figure 1: Polyurethane mixing machine [1]

One glass fibre mat and a spacing material are placed in a simple mould die, which is then filled with polyurethane and on top the last fibre layer is placed. The mould is closed by the over half of a hydraulic press, figure 2. Pores in the foam are formed when the blowing agent reacts and produces carbon dioxide. When the material swells it fills out the mould and presses through the glass fibre layers. Remaining air evacuates through out-lets in each corner of the mould.

If a board with a different surface is needed, sheets of desired material can be placed outside each glass fibre layer. The surface will stick to the sandwich structure directly in the mould, due to the good adhesive properties of PUR.

Figure 2: Production process

## 3. MATERIALS

A board produced with a thermoplastic surface sheet will have a cross sectional area according to figure 3.

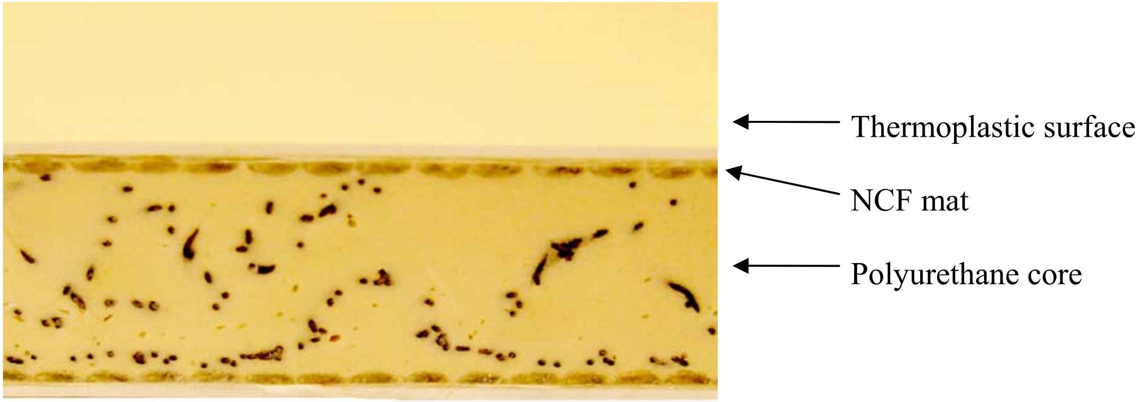


Figure 3: Materials in the sandwich structure

For reinforcement a stitch bonded biaxial Non-Crimp Fabric (NCF) of glass fibre is used. The fabric provides both good mechanical and wetting properties.

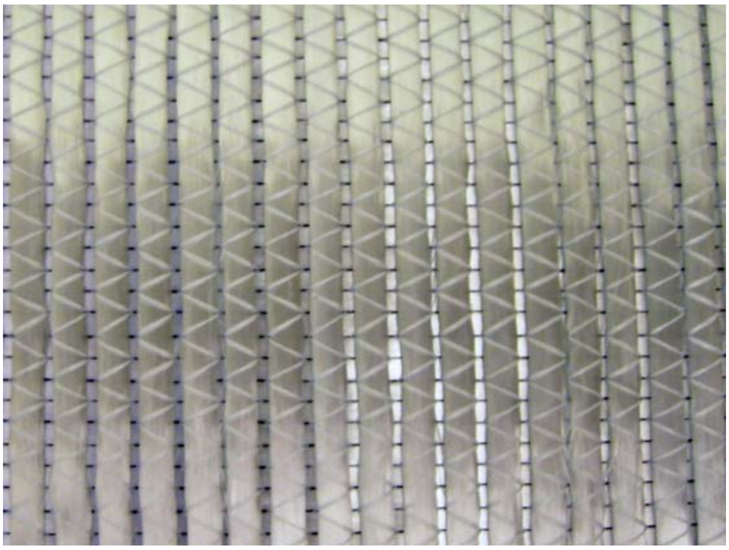

Figure 4: Stitch bonded biaxial non-crimp fabric.

The core material needs to be light-weight and have moderate shear stiffness. Therefore a PUR foam with a high functionality is used. Functionality is the ability for each monomer to crosslink when polymerizing or how many free radicals the monomer has. The polyol has functionality 5.0 and the isocyanate 2.7. The foam is then stiff but brittle, a lower functionality will provide a more flexible material.

Because the core material will bond to the fibre, a low density will give a poor bond and with that a low bending stiffness. With a higher density the bond gets better but the structure gains weight. A matrix to give optimal specific bending stiffness is therefore chosen. A cellular plastic can have different microstructure even though the density is the same, as shown in figure 5. The left hand foam is preferred, small cells collapse to a greater extent in the surface and have a better flow through the mat and thereby gives a denser matrix in the reinforcement.

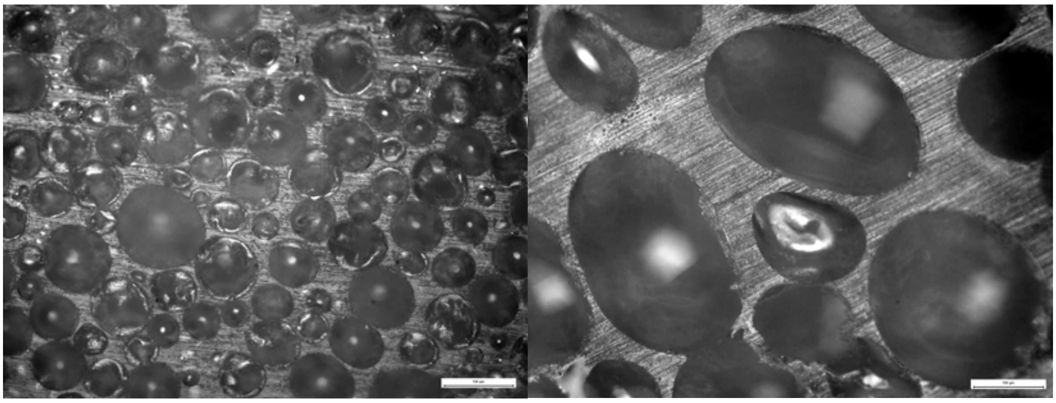

Figure 5: Two different polyurethane systems for closed cell foams with the same density.

When the foam expands though the fibre bunches, pores collapse because of the pressure, which makes the porosity in surface lower than in the core.

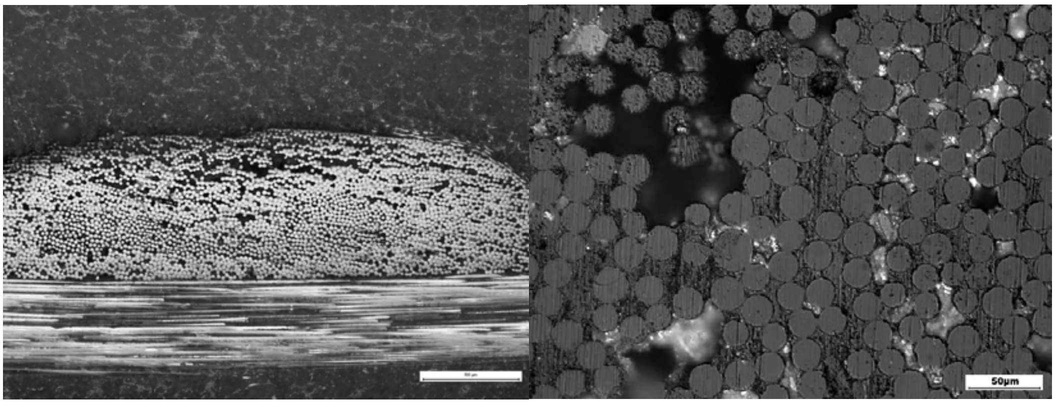


Figure 6: When foam is used in a fibre reinforced composite, the wetting is not optimal.

## 4. FORMWORKS

Formworks is the efficient way for concrete molding. Boards are mounted in frames, which are easy to connect to each other, figure 7. Two walls are built facing each other, reinforcement bars are placed in-between and cement is dispersed. A vibrator evacuates air and makes the cement homogeneous.

Frames are rented and then taken back for cleaning and repair. Therefore, the boards' lifetime is more critical than a customer made form, which is often disposed after one mould.

In formworks wooden based boards are almost exclusively used. On the market there are a few composite boards, all sandwich, but none established. The competitors use either twintex or aluminum and polypropylene. A normal plywood board has a life-time of 5-20 moulds.

Figure 7: Formworks [3]

**Formworks demands on a composite board**

| | |
|---|---|
| Bending stiffness | // 7.3 GPa* |
| | ⊥ 5.6 GPa* |
| Water absorption | Low |
| Weather resistance | -20 to +60°C |
| Strong alkali resistance | pH 13.5 |
| Moulding life-time | 50 times |
| Surface voids or cavities | Minimal |

| Thickness | Weight [kg/m2] |
|---|---|
| 11 mm | 8.6* |
| 16 mm | 11.2* |
| 22 mm | 15.4* |

## 5. EXPERIMENT AND RESULTS

**Bending stiffness**

Flexural properties are determined with 3-point bending tests. Though Sonoboard™ is a sandwich structure the shear stresses cannot be neglected, eq. (1). [4]

* Properties for conifer plywood with 1,4mm veneers [2]

$$\delta = \delta_{bend} + \delta_{Shear} = \frac{PL^3}{48D} + \frac{PL}{4S} \qquad (1)$$

The bending stiffness is determined by eq. (2). [4]

$$D = \frac{E_f t_f^3}{6} + \frac{E_f t_f d^2}{2} + \frac{E_c t_c^3}{12} \qquad (2)$$

The modulus of elasticity in the fibre layer, $E_f$, cannot be determined separately and it is impossible to produce just the fibre layer in the process or separate it from the structure. $E_f$ will therefore be determined by tests of the structure and the core material. From eq. (1) and (2) $E_f$ is determined by eq (3). [4]

$$E_f = \frac{\dfrac{PL^3}{48\left(\delta - \dfrac{PL}{4S}\right)} - \dfrac{E_c t_c^3}{12}}{\dfrac{t_f^3}{6} + \dfrac{t_f d^2}{2}} \qquad (3)$$

In figure 8, a bending test is performed. The fracture appears on the compression side. The structure is linear elastic until it breaks.

Figure 8: 3-point bending testing according to EN ISO 141 25 – Fibre reinforced plastic composites – Determination of flexural properties.

With an unbalanced bi-axial glass fibre mat of 1.9 kg/m$^2$ (3.8kg/m$^2$ both sides), the desired bending stiffness is almost achieved. In the parallel fibre direction the flexural modulus is 6.5 GPa and in the transversal 4.0 GPa. In comparative concrete mould testing with new and used form plywood, Sonoboard™ proved to have less deflection than both the plywood's. This is assumed to depend on the decrease of stiffness plywood gets with a high moist content.

With 1.9 $kg/m^2$ reinforcement the weight is 2.6$kg/m^2$ (12.8 $kg/m^2$ totally) lighter than the maximal weight for a 22mm board.

**Water absorption**

Water absorption testing is performed according to *SS-ISO 2896 – Cellular plastics rigid – Determination of water absorption.* The standard is chosen because the main material volumevise is a cellular polyurethane. The absorption is low due to a closed cell core material, approximately 0.5 – 0.8 %.

**Thermal expansion coefficient**

The wooden based competitive materials have a very low thermal expansion coefficient, α, but the moist content can be up to 30 - 40%. When that is the case the material swells. Because Sonoboard™ has low water absorption; moisture will not be the driving force for instability in dimension. On the other hand, polymers have generally a high thermal expansion. The board should not be exposed to thermal stress, when mounted in an aluminum or steel frame. The thermal expansion is examined in the fibre direction, both theoretically and experimentally.

The α- value for the frames and plywood are as follows.

$\alpha_{Al} = 24 * 10^{-6}/°C$ [1]

$\alpha_{Steel} = 13 * 10^{-6}/°C$ [1]

$\alpha_{Plywood} = 2 * 10^{-6}/°C$ [3]

If α for Sonoboard™ is very different from the frame, thermal stress will occur and the board will not be plane. Theoretically α is determined by *the rule of mixture* with the surface material and transversal fibre layer neglected. α for glass and PUR are:

$\alpha_{Glass} = 5 * 10^{-6}/°C$ [1]

$\alpha_{PUR} \approx 140 * 10^{-6}/°C$ [1]

The theoretical value for a 19mm thick plate with 3,4$kg/m^3$ glass fibre is:

$\alpha_{Theoretical} \approx 19 * 10^{-6}/°C$

The experimental value is taken from a linear regression of 10 specimens measured in four different temperatures, -30, 22, 40, 60°C

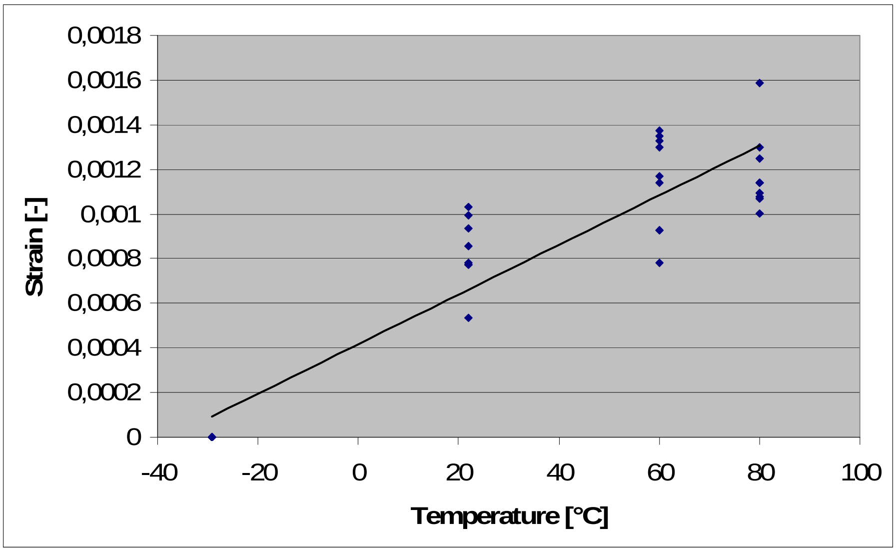

Figure 9: Measurements of thermal expansion

$\alpha_{Experimental} \approx 11 * 10^{-6}$/°C

The glass fibre does not let the structure expand by heat and as a result it will work well together with steel or aluminum.

**Surface**

The surface needs to withstand the environment affect, such as UV-light, strong alkalis, temperature; but also handling and cleaning. It is also important that the surface is thin for low-weight and minimal affect on the structure stiffness. A thick surface will provide a lower sandwich effect and a weaker board. During testing and prototyping many surfaces were examined, several thermoplastics extruded and foil, phenol papers and thermosets. With all demands considered the best alternative was a co-extruded thermoplastic sheet. The inner layer is cheap and has good adhesion to PUR. The outer layer contributes with a smooth surface, are easy to clean and have good weather resistance. Because it is co-extruded it is hard to produce for thicknesses thinner than 0,7mm.

## 7. CONCLUSIONS

Sonoboard™ presents a new alternative as a formworks board. Generally the board fulfils desired mechanical- and physical properties. The chosen materials have good durability which should have a long life. It is easy to clean and lighter to handle. If the moulding life-time is reached there will be a less expense per mould for the customer.

But there are some thresholds to overcome. Each board are more expensive. The construction industry is rather conservative and is reluctant to accept new materials.

## 8. FUTURE APPLICATIONS

The composite board provides a good alternative to plywood, where moisture affect the material and thereby the life-time. Other possible applications/markets for the Sonoboard™ concept could be:

- Scaffoldings
- Boards in environment with moisture, bathrooms
- Linings in tunnels
- Floor boards in boats
- Partition boards in trains
- Staircases
- Barge boards
- Subterranean lining

## ACKNOWLEDGEMENTS

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