Course on Classification and Certification of Yacht

Lloyd's Register Rules and Regulations for the Classification of Special Service Craft

“GLASSES”

Simone Parizzi
Surveyor
Viareggio Office
THE RAW MATERIAL TO PRODUCE GLASS

The base material to obtain glass is the silica $\text{SiO}_2$. This material is present in nature under many forms in particular silicate, otherwise is extremely difficult to extract it because combined with other elements. The only forms easily suitable to be overworked are the quartz and some varieties of sand which arrive to have to be constituted until 98% of quartz.

Due to the very strong chemical links it is extremely difficult to smelt the silica alone because the temperature required are close to 1700°C. To overcome this problem especially in the past when there are no refractory materials able to survive to this temperature some other elements were added to reduce the melting point. These elements are Na, Ca, Mg, K, Pb.

\begin{align*}
\text{SiO}_2 (\text{Silica}) + \text{Na}_2\text{CO}_3 (\text{Soda or Natron}) + \text{CaO} (\text{Calce}) \\
\text{SiO}_2 (\text{Silica}) + \text{K}_2\text{CO}_3 (\text{Potassa}) + \text{CaO} (\text{Calce})
\end{align*}
THEORETICAL STRENGTH OF GLASS

The intrinsically glass strength is extremely high reaching values of 5 – 10 GPa.

In absolute vacuum a pristine glass (=no imperfections) obtained by quartz (SiO₂) reaches a strength of 14 000 MPa. This value is very close to the theoretical glass strength which depend on the potential of atomic bonding.

Despite the high theoretical strength, float glass currently manufactured is about 40 Mpa.

Reason: micro-cracks are located at the surface of glass producing stress concentration at the corner.

Glass Strength \( \leftrightarrow \) cracks extension & radii
SAMPLE OF MICRO CRACK AND GRIFFITH THEORY

\[ \sigma_d = \sigma \cdot 2 \cdot \sqrt{\frac{c}{r_0}} \]
Glass Pane (Cristallo): flat piece of glass, edge worked, to size and shape ready glazing. May be monolithic or laminated (2 or more glass panes bonded), or made of other material.

Safety Glass: Glass which, if fractured, gives fragments which are less liable to cause severe cuts than fragments of ordinary glass.

Toughened Safety Glass: Glass which has been converted to safety glass by subjection to a process of heating and rapid cooling, so that if fractured, it disintegrates in small pieces and, in addition, increase its strength properties.

TSG is the glass generally required by the Rules and International Standards
Thermal toughening
(industrially applied after 1930)

Rapid cooling of glass pane from a temperature $> T_g$

Different cooling rate between the outer surface and core produces a state of compression on the surfaces and tension in the core.

The state of compression on the surface acts in way to close the cracks.
Toughened Safety Glass

With the production of stress field elastic energy is stowed in the material. When the glass is broken the energy is released, for this reason thermally toughened glass breaks in small non sharp pieces therefore they are safety glasses.

Other types of glasses breaks in big sharp fragments ➔ to be of safety type they are to be laminated.

Require a minimum thickness to be treated of 4 mm

Strength increases from 40 N/mm\(^2\) to about 250 N/mm\(^2\)
Toughened Safety Glass

Thermally toughend glasses **can not** be cut (in conventional way), therefore production process is the following:

CUT → GRINDING → STAMP → THERMAL TREAT → TESTING
CHEMICAL STRENGTHENING PROCESS

It is a process of **diffusion** (thermally activated) that increases glass strength replacing some of the alkaline ions on the glass surface with other ions of greater size.

**First method:** (Schottky process) a surface layer with a lesser $\alpha$: a surface layer is created with a smaller coefficient of elongation $\alpha$. This is obtained by ions exchange at temperature $> T_g$. (not used due to distortion and surface crystallisation)

1. **Surface layer with less coeff. of elongation**
   - Ions Exchange process
   - Surface crystallisation

   **Example:**
   - Li$^+$ or Cu$^+$ $\leftrightarrow$ Na$^+$ in sodium calcium glass
   - $T > T_g$ (distortion, loss of shape)

   **Glass compositions:**
   - $\text{Li}_2\text{O} - \text{Al}_2\text{O}_3 - \text{SiO}_2$ at $900^\circ \text{C} \Rightarrow \beta$-eucryptite
   - ZnO- Al$_2$O$_3$-SiO$_2$ at $800^\circ \text{C} \Rightarrow \text{willemite, albite, keatite}$
CHEMICAL STRENGTHENING PROCESS

Second method: surface strengthening by ions exchange (glass ceramics) at temperature $< T_g$:
Glasses in annealed condition are immersed in a potassium salt melted.

Parameters:
- Temperature
- Time
- Concentration

\[ \overline{A}_{glass} + B_{salt} = \overline{B}_{glass} + A_{salt} \]
More is the time and / or greater is the concentration of KNO₃ deeper is the penetration

More time → less surface compression

Stress induced in the surface is much more higher than the thermal treatment but the penetration is generally maximum 50 µm
A COMPARISON BETWEEN PROPERTIES OF DIFFERENT TYPES OF GLASSES

Chemically treated glass

1. Very high bending breaking strength (300 – 600 N/mm²) for applications where high performances are required.
2. Thin layers (min. 0.5 mm) can be treated.
3. The glass can have the most strange shape with high curvature.
4. Easy to couple with PVB.
5. Impact strength higher than thermal glasses.
6. High optical performances: no or very low distortions also curved shape.
7. No deformation or distortion.
**BASIC PARAMETERS TO EVALUATE THE QUALITY OF CHEMICAL TREATMENT**

- **CD** = depth of chemical treatment process (mm) to be > 30 mm
- **Sc** = surface compression N/mm\(^2\)
- **σc** = characteristic breaking strength N/mm\(^2\)

The Glass ply Manufacturer must declare the above data and is responsible to guarantee the conformity of the production to the declared values.

Sc: compression on the surface may be measured with double refraction methods and photoelasticity, stress profiling or DSR.

σc: is derived on the basis of breaking full scale tests or four point bending stress (EN 1288-3) *the two methods gives different results!!!* Due to boundary effects.

CD = polarizing microscopy or stress profiling (also based on calibrated weight gain)
TYPES OF GLUE AND INTERLAYER

Polivinil-butirrale PVB
SGP Sentry Glass Pluss®
PC Policarbonate