MEST SHIPYARD

ROOT CAUSE ANALYSIS

WINDOWS FAILURE

VESSEL	: ERLA KONGSDÓTTIR
IMO	: 9905526
DNV GL id	: 40921
CASE NO.	: 38359
DOCUMENT NO.	: 1353-515-011-A

REV.	DATE	DESCRIPTION	ISSUED	CHECKED
A	25-03-2021	FIRST ISSUE	BH	SJ

Contents

Introduction

Two of the large windows in the salon broke during sailing on the 11'th of December 2020, without any apparent excessive force or load. SSL decided to replace three of the largest windows on each side, six in total, with polycarbonate windows.

On the 23'rd of February another of the original windows broke, also without any apparent excessive force or load.

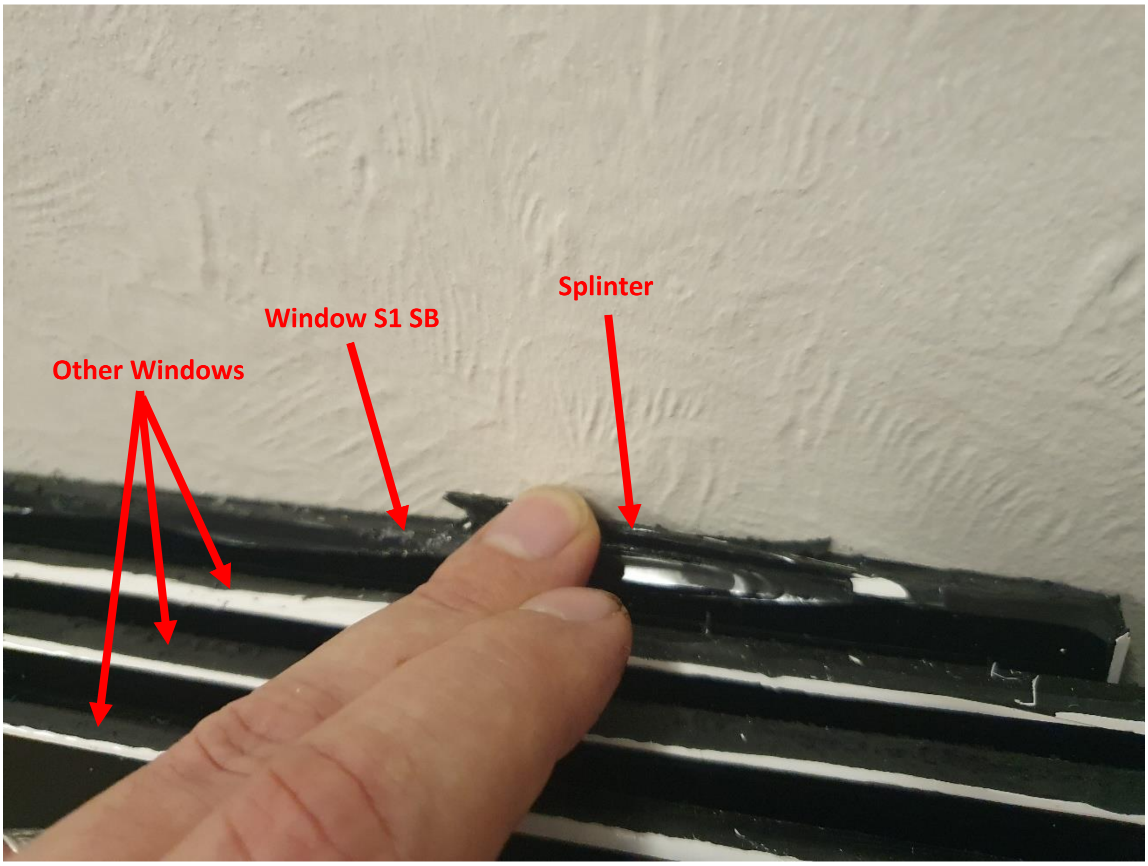
The weather conditions on both occasions was well within the limitation stated in the class certificate for the vessel.

Because of safety concerns, the ferry has not been in service since.

Observations during dismounting of the windows

When dismounting the windows, everything seemed to be according to the documentation provided. The documentation was produced according to DNV-GL's "Rules for High Speed Light Craft", Part 3, Chapter 6, Section 3.

We did however notice that there was some damage to the upper edge of one of the windows, shown in this photo:



Thoughts on possible causes of the failures

As we see it, there are three main suspected causes for the failing of the windows, or possibly any combination of them.

- Fault in glass production and/or heating process.
- Weather conditions / Excessive deformation of the hull.
- Lack of joint flexibility.

Fault in glass production and/or heating process.

Most cases of spontaneous shattering of tempered glass, happens when there is a defect or a minor damage in the edge of the tempered glass or if there is a small nick or chip of the glass surface, caused during the transportation or installation of the glass.
A combination of these minor and often unseen damages could deteriorate the glass, along with the glass units' movements, caused by winds and temperature changes, could lead to a spontaneous shatter of the glass.
As already mentioned, there was clear damage to the edge of at least one of the glasses that were removed in December 2020.
After the first two windows broke in December, a laminate was installed on the inside of the remaining windows, to ensure that in case another window broke, splinters would not fall onto any passengers. This laminate also enabled us to see the window that broke in February in its place after it broke. Se pictures:

It is clear that the initial fracture was from the top edge, and all the remaining fractures propagate out from there.

The windows that broke in December did not have a laminate inside, so part of the window fell down when it shattered, making it harder to see the form of the cracks. But there is the same indication on this picture:

It is also a well know, although quite rare, phenomenon that tempered glass can spontaneously shatter. This happens when a Nickel Sulphide molecule is embedded in the glass. The molecule will be trapped in the glass in a contracted state.
Some glass manufacturers use a “Heat Soak Test” to check for this fault. The glass is heated in an oven, forcing the Nickel Sulphide molecule to expand to its original size, causing the glass to shatter.

This test can of course not be performed on the glasses that have already shattered, but we have sent two of the windows that we took out in December, to a glass manufacturer in Denmark to perform a Heat Soak Test on them. The results are still pending.
We have also sent two other glasses that we took out in December to DMI (Dansk Teknologisk Institutt), to test for strength (ISO 614) and chemical composition (EN 572-1). These results are also pending.

Weather Conditions / Excessive deformation of the hull.

An excessive deformation of the hull where the glass was attached would of course cause the glass to shatter, since toughened glass is a very brittle material.
The sailing conditions during the first incident on the 11'th of December, was 10-12 m/s wind, approximately 2 m waves and the speed was 10 Kn.
During the second incident on the 23'rd of February, there was 12 m/s wind, approximately 1,5 m waves and the speed was 9 Kn.
On both occasions the wind and the waves were coming from forward portside, meaning the windows that broke were on the lee side.
The class certificate for the ship states the following restrictions to operating speed with respect to significant wave height:

Significant Wave Height (m)	Maximum Speed (knots)
0,0 – 2,0	24
2,0 – 3,0	21
3,0 – 4,0	19
> 4,0	Slow speed to shelter

So, the weather- and sailing conditions were well within the limits.

Whether or not the hull was excessively deformed at the time of the incidents, is impossible for us to determine. But we can conclude that the ship is designed for the conditions in which it was operating, the design was approved by DNV, and that two similar ships do not have this problem.

Lack of joint flexibility.

All three windows that have failed so far, have been fastened with a 18mm wide and 9mm thick joint, as calculated in DNV's "Rules for High Speed Light Craft", Part 3, Chapter 6, Section 3.
They were also mounted with two support blocks along the lower edge of the glass, carrying the weight of the glass (Rule 7.3.1) and securing it against in-plane movement (Rule 7.3.3).

In our experience, when a material as brittle as hardened glass, mounted on a structure as flexible as a fibre hull, flexibility of the joint is paramount. Restricting flexibility in one plane with the support blocks, does seem counterproductive, especially considering that the weight of the glass would only give a very small tension on the joint (Less than 0,02 N/mm^2).

Also, in rule 7.3.3 in the formula for thickness of the glue, there is a factor *k*, which is 1,5 for glass and 8 for polycarbonate. This also seems counterintuitive, considering that a glass window would need more flexibility in the joint than a polycarbonate window would.

In our opinion, the 9mm thickness of the joints on the large glass windows also seems quite small, considering the size of the windows and flexibility of the structure.

Conclusion

Since we do not have the results from the tests of the glass, and we do not have the documentation for the hull, or sufficient documentation for the glass, our conclusion should not be considered definite or final. But it seems to us, with the information available to us at this time, that the cause of the failure of the windows was a combination of some of the mentioned factors.

With the shape of the fractures in mind, it looks like the windows had damages and/or imperfections on the edges from the start. And combined with a lack of joint flexibility and possibly hull flexibility, the tension on the glass surpassed what the damaged parts of the windows could withstand, resulting in a shattering of the glass.