Älvsbacka Bridge – A Bridge in Cold Climate

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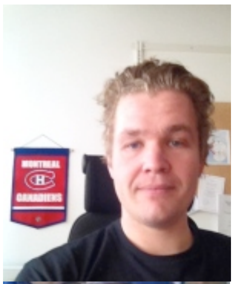

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Summary

Älvsbacka Timber Bridge was erected during the summer of 2011. The bridge is equipped with a health monitoring system with GNSS-receivers, accelerometers, MC-sensors, weather station. The timber bridge is situated in Skellefteå, Sweden close to the artic circle. The location and the monitoring system of Älvsbacka Bridge gives us a unique opportunity to study the behavior of glulam and the bond of glulam in a cold climate. The bond of the adhesives is usually more brittle than wood. Bond line performance at elevated temperatures is well documented, but little information is reported on the behavior on sub zero temperatures. The bond line performance is of concern for outdoor timber constructions in regions such as: the Nordic countries, northern US, Canada, Russia and northern Japan. The monitoring system of the bridge gives us opportunities to study the effect of cold climate on timber constructions. Together with lab tests on pine and spruce and the bond stability of the glue line down to -60° we will have a better understanding on how engineered wood products and timber constructions behave at extreme temperatures.

Keywords: Glue line, Engineered wood, Cold climate, Timber bridge

1. Introduction

Engineered wood is increasingly used in large structures in Europe, though little is known of its behavior in cold climate. This paper presents the structural health monitoring system of Älvsbacka Bridge, a newly built suspension timber bridge with a deck of glulam timber, as well as a bond stability study regarding cold climate performance of engineered wood. The bridge is located in Skellefteå in northern Sweden, and connects two parts of the city situated on opposite shores of the

Skellefteå river. In an ongoing study of the timber-bridge, a structural health monitoring system is employed to verify structural design and long-term performance.
Wood construction is increasingly using engineered wood products. Engineered wood application in bridges, sports centers and timber buildings are common in Europe and North America. Adhesives are the key part of these engineered wood products and play an important role in the performance of engineered wood products. How do the bond lines of engineered wood behave under extreme cold climate? The concern is stronger in regions like Scandinavia, Canada, Alaska, Russia, and North China and Japan etc. The bond of most adhesives is more brittle than wood. The performance of bond lines at elevated temperatures is well documented [1, 2, 3], but not much information is available on the stability of bond lines at low temperatures and especially under extremely cold temperatures, although some studies of timber bridges in cold climates have been reported [4, 5, 6].
The main objective of this project is to determine how engineered wood behaves when exposed to temperatures between 20 °C to -60 °C, and study how these features should be described and measured in an objective way. Bond stability of glulam structures in cold climate is also examined in a range of experiments ranging from small glued wood joints to full size glulam bridge performance over time. In this paper the first test on small specimens is presented.

1.1 Älvsbacka Bridge

Älvsbacka timber footbridge was built over the Skellefteå River in Sweden 2011. It is a cable-stayed bridge with a span of 130 m. In general today the health of the bridges is assessed at regular intervals by visual inspections and if necessary some minor local tests. Continuous measurements could complement the inspections and provide a better basis for planning maintenance activities and evaluating the remaining service life. An ongoing project is developing monitoring tools for timber structures to guide the planning of maintenance and to evaluate the performance of the bridge. The monitoring of the bridge contributes to wood research on specific areas such as durability of timber bridges and vibrations of wooden deck plates, research on measurement and data transmitting techniques as well as performance of timber structures in cold climate. The Älvsbacka Bridge is monitored using GNSS receivers, MEMS accelerometers, wireless moisture content sensors, strain gauges and a weather station. Data from the monitoring systems is analyzed regarding accuracy, complexity, costs and reliability for long time use. In this way, the measurements deliver complete and unique data from long-term monitoring. Wireless sensor networks are tested for the bridge monitoring. Temperature, wind and rain are measured at the site. The bridge is monitored for temperature, moisture, movements, deflections and vibrations at different points enabling analyses of the bridge health. Vibration measurements using accelerometers, natural frequencies and modes will be used to evaluate the structure.

1.2 Wood in cold climate

The wood constructions are increasingly using engineered wood products (such as glued-laminated timber (glulam), laminated veneer lumber (LVL), structural-composite lumber (SCL), or cross laminate timber (CLT)) [1]. Adhesives are the key part of these engineered wood products and play an important role in the performance of engineered wood products. The response of glue line to temperature changes and extreme temperatures as regularly occurs in normal use raise some concerns on the integrity of wood structure. It is believed that the most commercial wood adhesives are vulnerable to the extreme temperatures and temperatures changes. The concern is stronger in the regions having extreme weather like Scandinavia, Canada, Alaska, Russia, and North Japan etc. Wood constructions in these areas are exposed to low temperatures during a quite long period each year. Despite this, thermal effects are usually not a consideration in the design of wood constructions. Wood and adhesives are very different in terms of swelling and shrinkage coefficients. Glue line of most adhesives is also more brittle than wood. If not compensated for, any differential between wood and adhesives thermal properties can lead to performance problems

when the construction is exposed to large temperature changes. In these cases, the design needs to compensate for differential movement of components while preserving structural integrity.
This research project takes advantage in that the Älvsbacka Bridge is located where temperatures varies from 30° to -35° during the year together with temperature data from the health monitoring system.

2. Materials and method

2.1 Materials

The wood used was Norway spruce (*Picea abies*). The equilibrium moisture content was 12% and the average density 450kg/m^3
The adhesives used were: One-component polyurethane (PUR), polyvinyl acetate (PVAc), emulsion-polymer-isocyanate (EPI), melamine-formaldehyde resin (MF), melamine-urea-formaldehyde resin (MUF) and phenol-resorcinol-formaldehyde resin (PRF).

2.2 Methods

The boards were conditioned at 20°C and 65%RH until EMC of 12% was reached.
The specimens were made of two lamellas glued together, after gluing the lamellas together the specimens where cut to correct size, 150mm x 20mm x 10 mm. For each of the six adhesives and for each of the six temperatures 15 specimens were produced. 15 reference specimens of solid wood were also produced.

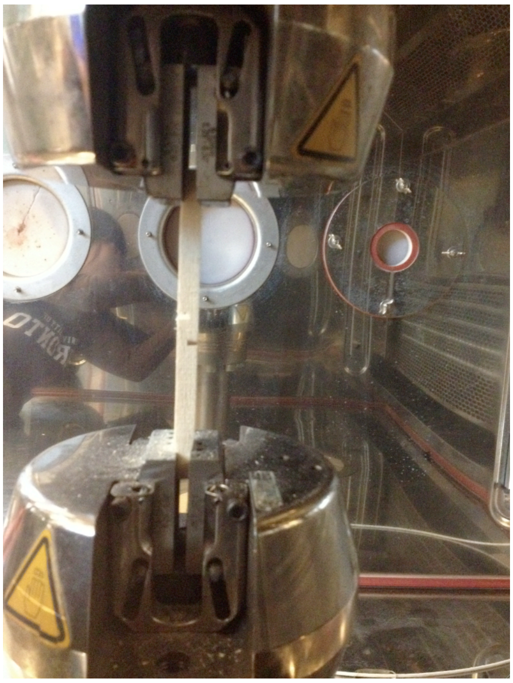

Figure 1. Universal testing machine with wood specimen, in climate chamber.

The specimens were tested for shear strength according to European Standard EN302-1. The tests were done with a universal testing machine inside a Vötsch industrietechnik vcv7120-5 climate chamber (Figure 1). The feed speed was 2mm/min. the whole test procedure was conducted as recommended in EN 302-1. Data were analysed with IBM SPSS Statistics 20. An analysis of variance with 5% level of significance was conducted on the data. When significant differences were found a Duncan's multiple-range test were conducted to find differences caused by different adhesives at different temperatures.

3. Results

From the data presented in table 1 it can be seen that the trend is when temperature is decreased so is the shear strength of both specimens with adhesives and solid wood specimens. PUR showed the strongest shear strength of the tested adhesives. PRF and PVAc was the adhesives that had the lowest change in shear strength, both just below 20% while the other adhesives lost 25-27% in shear strength. However the shear strength of PVAc decreases a lot between 20°C and -20°C and then behaves rather homogenous between -20°C to -60°C. MUF showed the lowest shear strength of the tested adhesives. Shear strength of solid wood decreased from 10,1 to 8,0 going from 20°C to -60°C.

Table 1 Shear strength data (in MPa)

Temp./Glue	1-PUR	2-PVAc	3-EPI	4-MF	5-PRF	6-MUF	7-Wood
20°C	10.9 (1.0) [1] A [2]	9.6 (0.6) A	10.0 (1.1) A	9.8 (0.9) A	9.8 (1.0) A	8.7 (0.7) A	10.1 (0.9) A
-20°C	10.8 (2.3) A,B	8.1 (1.2) B	8.3 (1.6) B	9.4 (2.3) A	9.7 (1.8) A	7.9 (1.1) A,B	9.5 (1.1) A,B
-30°C	10.2 (2.9) A,B	8.2 (1.2) B	8.3 (2.0) B	8.1 (2.5) A,B	9.2 (2.0) A,B	7.2 (1.9) B,C	9.0 (0.9) A,B,C
-40°C	9.9 (1.5) A,B	7.9 (1.9) B	7.3 (1.5) B	7.7 (1.4) B	9.3 (1.4) A,B	7.2 (1.3) B,C	8.7 (1.3) B,C
-50°C	9.2 (1.3) B,C	7.9 (1.8) B	7.8 (1.4) B	7.5 (1.2) B	8.4 (1.7) A,B	6.6 (0.9) C	8.8 (1.5) B,C
-60°C	7.9 (1.4) C	7.7 (1.1) B	7.2 (1.5) B	7.3 (1.7) B	8.0 (1.4) B	6.6 (1.3) C	8.0 (0.9) C
Total shear strength change (%) [3]	27.1	19.3	27.5	25.0	18.7	24.5	27.1

[1] Values in parentheses are standard deviations based on 15 specimens.
[2] Values in the same capital letter in each column are not statistically different at the 0.05 significance level.
[3] Total shear strength change (%)=(Shear Strength $_{20°C}$ - Shear Strength $_{-60°C}$)/ Shear Strength $_{20°C}$*100.

4. Discussion

Specimens of Norway spruce and PUR, PVAc, EPI, MF, PRF and MUF adhesives were tested for shear strength at 20°C, -20°C,-30°C,-40°C,-50°C and -60°C. The shear strength of the tested adhesives at room temperature is relatively stable. As the temperature drops the variation of the shear strength increases. All tested specimens except for PUR have a shear strength below 10 MPa already at -20°C, not meeting the EU requirement (EN 301). This calls for more attention on how low temperature impacts solid wood and engineered wood products.

Next step of this project is to study how glued finger joints behaves in cold climate.
Data acquired in this ongoing project will be used to model temperature behavior in the glue line and compare with bridge data.

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