Conference Proceedings 4th ICTB (2022)
https://doi.org/10.24451/pe83-p237

ICTB 2021 PLUS
4th International Conference on Timber Bridges
Biel/Bienne, Switzerland, 9 -12 May 2022

Direct trafficable waterproofing and wearing courses for timber decks

Dirk Uebelhoer[1], Mareike Vogel, Thomas Volkmer, Adrian Willi Wick

1 Introduction

Sustainability is becoming a more and more important topic in the construction industry. Climate change is the most important environmental global threat, so the use of environmentally friendly products with a low carbon footprint gets very popular [1].

The use of timber in the bridge construction is common for more than 3000 years. After using step stones, to cross small rivers approx. 6000years back the next step was using felled trees to cross rivers. One of the oldest piled timber bridges has been found in the Zurich Lake/ Switzerland, dated back to approx. 1500 BC [2].

Timber, a natural renewable construction material, requires less energy than other construction materials, i.e. concrete and stores CO_2.

Timber decks made of planks have space between the planks and a certain slope to get the water running off, so the deck can dry easily. This deck design is often used for pedestrian and bicycle bridges.

Decks exposed to vehicular traffic are often made from Cross-Laminated-Timber (CLT) because of the flat and uniform surface. The closed deck protects the load beams underneath the deck from moisture and ensures a dry supporting structure. The state of the art is to apply bitumen sheets as a waterproofing layer followed by an asphalt overlay. Because of the movement of the timber structure this waterproofing technology has been proven as in-adequate due to crack forming, which allows the ingress of water to the timber deck. This happens due to the lox flexibilty of bituminous deck waterproofing system that can´t cope with the movement of the structure. Sometimes the hairline cracks are not visible, and the ingress of water remains unremarked This leads to a permanent humid environment at the timber structure, which leads to deterioration caused by attack of microbes and growth of fungi. This could be prevented using a loose laid waterproofing system, but this would not work well with shear foces applied to the deck by breaking and accelerating vehicles and slide on the deck panels.

2 The idea

Due to the movement of timber beams and panels under dynamic load the currently used solution for deck waterproofing and wear protection does not provide satisfactory results. A more flexible system, providing sufficient wear resistance should perform better on the CLT-deck. The system shall be fully bonded to the substrate to prevent ingress of moisture and water caused by delamination. An already approved and used system for concrete decks, based on hot-spray-applied Polyurea, has been detected as a promising solution.

An additional advantage of this technology would be a reduction of the deck load. An asphalt pavement with thickness of 7cm has a weight of approx. 168kg/m², the waterproofing and wearing course made of Polyurea counts for approx. 5kg/m². This would allow more filigree bridges design and will reduce the carbon footprint of the structure notably. Possible necessary repair works on the deck will be much easier using the spray applied technology, compared to ashpalt pavement.

3 Test programme

Adhesion and shear strength are important measurements when it comes to Bridgedeck waterproofing. The protective system must develop a good bond to the substructure to prevent delamination and ingress of water. High shear strength ensures, that the waterproofing and protection layer doesn´t delaminate from the deck when vehicles break and accelerate. Water vapour diffusion and change of physical properties, after artificial weathering are also important indicators for the suitability of the chosen system.

Wood has the nature, that wood moisture is not constant and changes frequently due to ambient conditions, therefore the applied system needs to develop perfect adhesion to the substrate at different levels of wood

[1]Dirk Uebelhoer, Sika Services AG, Switzerland, uebelhoer.dirk@de.sika.com

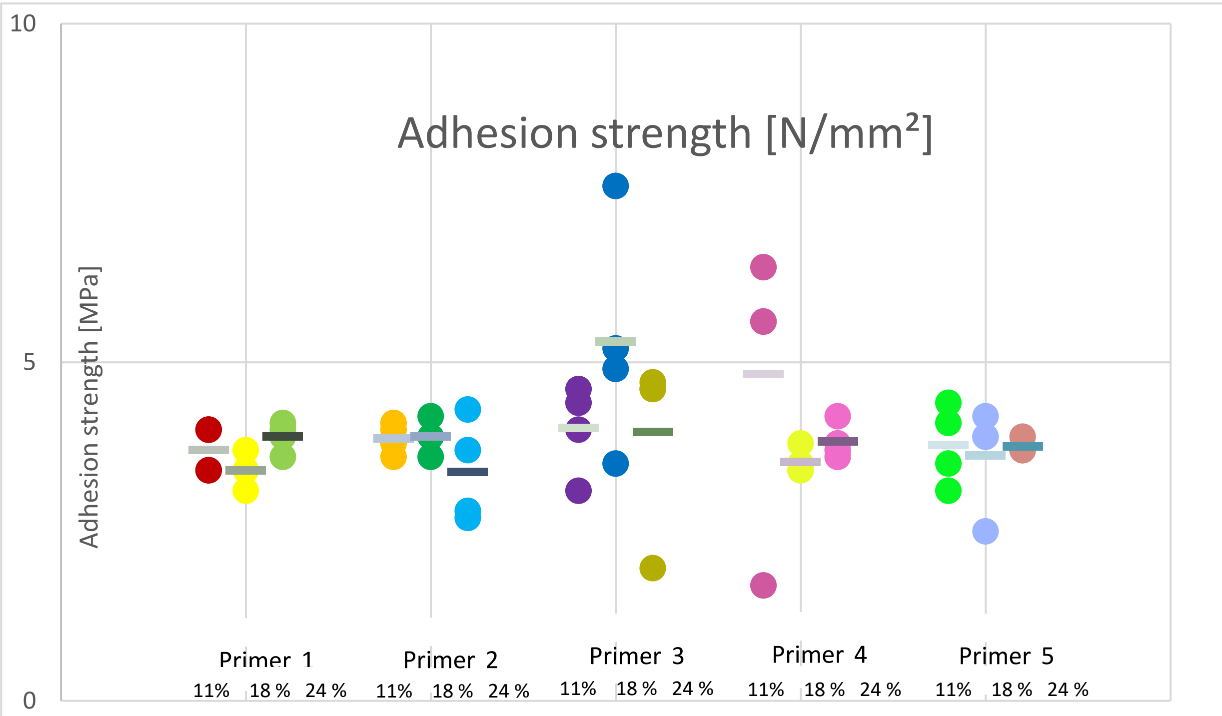
moisture. For the preliminary testing 3 levels of moisture have been agreed, approx. 11%, approx. 18% and approx. 25%.

3.1 Primer testing, tensile adhesion strength

The test series has been started with a prelimary primer testing program to reduce the possible systems for testing.

Table1: Primer Overview

Primer 1:	epoxy resin, solvent free, unfilled, 2nd generation
Primer 2:	epoxy resin, solvent free, pre-filled, 2nd generation
Primer 3.	epoxy resin, solvent free, unfilled, 1st generation, approved for bridge application on concret
Primer 4:	epoxy resin, solvent free, unfilled, fast curing, 1st generation, approved for bridge application onconcret
Primer 5:	epoxy resin, solvent free, pre-filled, low odour



Graph 1: Adhesion strength, primers, acc. EN ISO 4624, 20mm dolly

Due to the thin layer resulting for the primer the determination of shear strength, according to SIA 281-2:2011 was not possible. The test has been postponed to the system testing part.

3.2 System testing

All tested primers worked well and fulfilled the requirements. Having a closer look at the result the variation in adhesion values for Primer 1 was less than others. To reduce workload the involved parties decided to perform system testing only with Primer 1, an unfilled solvent free epoxy resin. Testing was agreed for four systems to screen possible combinations of product. The four systems are described in the table below:

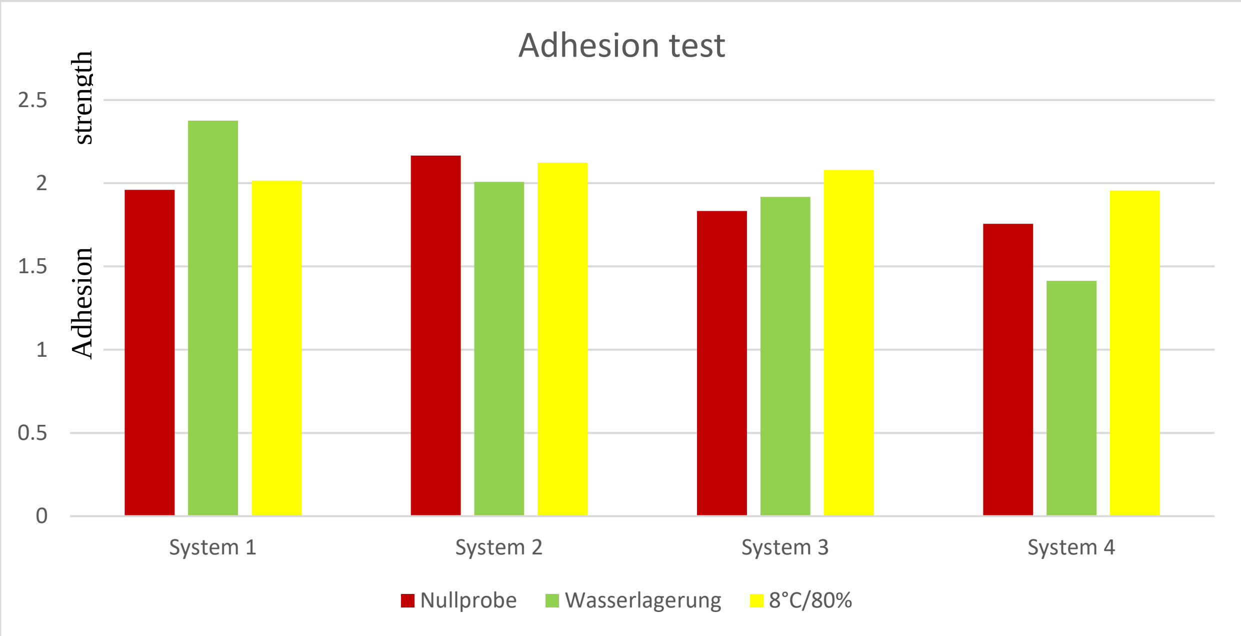
Table2: System Overview

Technology	System 1	System 2	System 3	System 4
Primer, epoxy solvent free, unfilled	X	X	X	X
Membrane pure Polyurea	X	X		
Membrane Polyurea- Polyurethane-Hybrid			X	X
Topcoat, solvent based aliphatic Polyurethane	X		X	
Topcoat, solvent free, aliphatic Polyaspartic		X		X

3.2.1 Adhesion test

All four systems have been applied on CLP-Panels with the dimension 300 x 300 x 26mm. The adhesion strength has been determined under 3 different conditions,

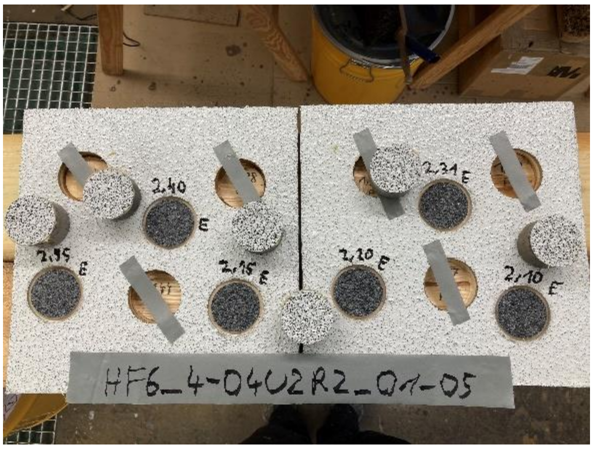
1. Wood moisture approx. 12%
2. Stored 14 days under water after application, before testing
3. Stored in +8°C/ 80% relative air humidity before application



Graph 2: Adhesion strength, systems with different stress, 50mm dolly

System 2 and 4 showed failure between wearing layer and topcoat, after strorage in water. Systems 1 and 3 had the failure level in the CLT.

Pic.1: Adhesion test sys-

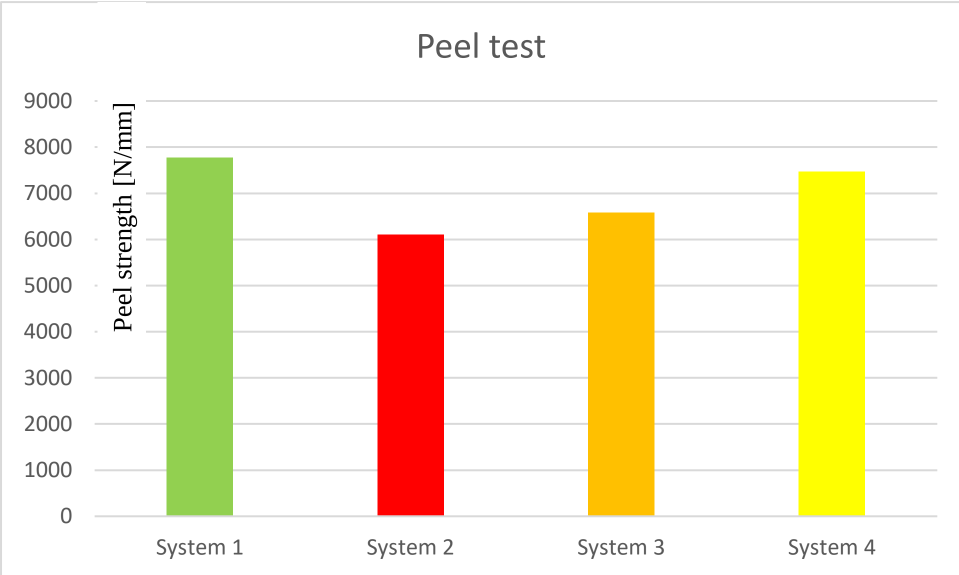


Pic 2: Adhesion test sys-

The preferred failure level is in the substrate. This indicates that the adhesion strength and the cohesion strength of the protective system is higher than the cohesive strength of the substrate.

3.2.2 Peel test

The peel test had been performed in accordance with the Swiss Standard SIA-281-2:2011, method B. Peel resistance gives a good indication to the shear force resistance of the applied waterproofing and protection system, especially when vehicles brake or accelerate on the bridge. The measured values can be found in graph 3.



Graph 3: Peel resistance, system performance

Also with the peel test the preferred failure level is failure in the substrate. If the failure level is between protective system and substrate the system shear strength needs to be evaluated as inadequate.

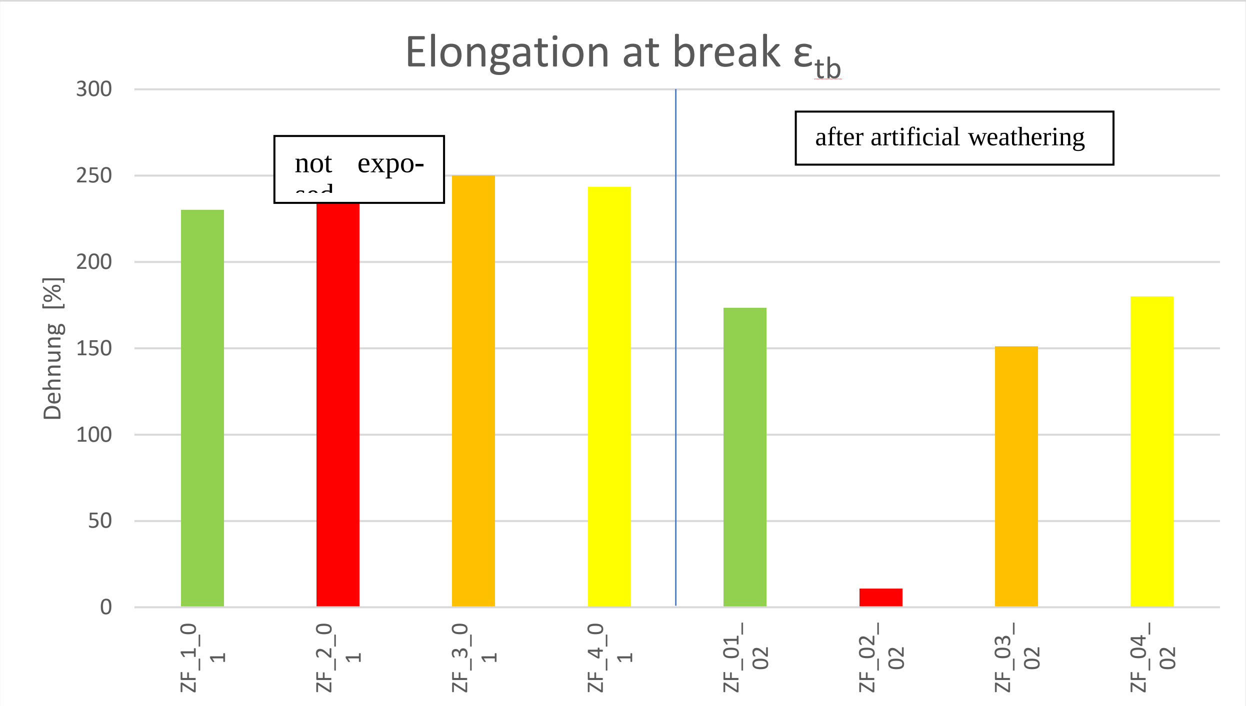
Pic.3: Peel test, System 1

Pic.3: Peel test, System 4

Even if both systems show almost the same peel resistance System 1 is the preferred technology, due to the failure level in the CLP plate.

3.2.3 Elongation at break

Elongation at break is an indicator of the flexibility of the used system. The target is to find a system, which is flexible enough to handle the movement of a timber structure, caused by temperature and variation of wood moisture over the year. The waterproofing and protection system will be exposed to weathering; therefore a comparison has been made with unstressed samples and test specimens exposed to artificial weathering. Testing has been in accordance with EN 527-1.



Graph 4: Elongation at break before and after weathering

System 1 has the lowest difference between the two test results. System 1 is less affected from artificial weathering than the other 3 systems. System 2 has lost almost the whole flexibility, degraded under the weathering exposure, and had the strongest impact.

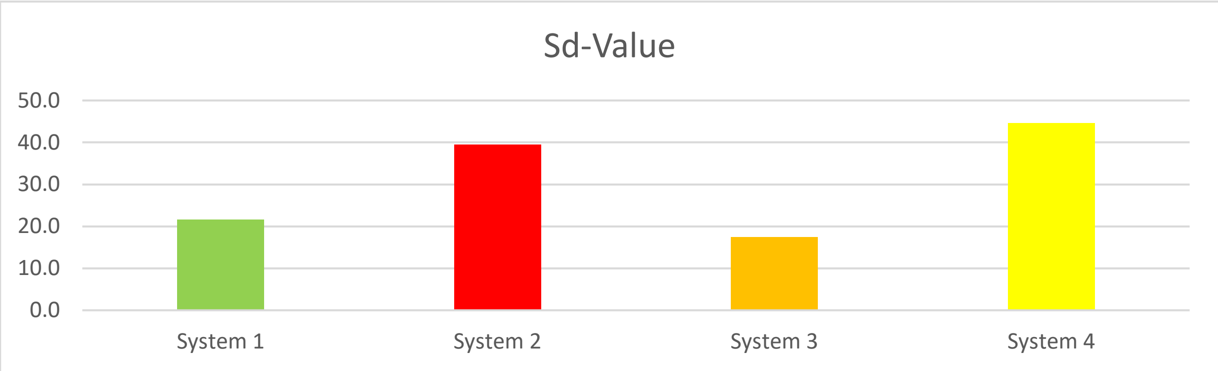
3.2.4 Water vapour Diffusion

Moisture control is the simplest, most economical method of reducing the decay in timber bridge structures [3]. To prevent ambient relative moisture to penetrate the timber and to keep the construction dry, the protective system needs to block water vapour diffusion. DIN EN ISO 10456 contains tables with the µ-value of most used construction materials. Multiplication of the µ-value by the thickness of the related layer [m] leads to the s_d-Value. The classification in accordance to DIN 4108-3 is:

Table 3: evaluation scheme water vapour diffusion acc. DIN 4108-3

s_d-value	**evaluation of tightness**	**Resistance to water vapour diffusion**
$s_d \leq 0.5$m	open to water vapour diffusion	Low
$0.5 < s_d < 1500$	inhibitive to water vapour diffusion	middle
$s_d \geq 1500$	blocking water vapour diffusion	high

The following results have been optained:



Graph 5: Water vapour diffusion; s_d-value

All systems are in the same range, to be classified as inhibitive to water vapour diffusion.

4 Summary

The results shown above are an overview of test performed to determine the most promising waterproofing and protection system for timber bridges with the approach to be directly exposed to pedestrian, bicycle and car traffic at low frequency. The rating was made by evaluating the test results with numbers 1 (best in class) to 4. The system with the lowest overall number is the best performing and shall be used for further evaluation and for field test applications on real projects.

System 1, made of a solvent free epoxy primer, a pure polyurea waterproofing membrane, a pure polyurea wearing course and a solvent borne PU topcoat had the best performance and is the system which is already often used for the waterproofing and protection of concrete bridges.

Currently the project team is in process to finish the planned testing, find a trial bridge for the system application, which will be necessary to make a step forward with the project.

Acknowledgement

The author acknowledges the following individuals, universities, and companies for the substantial contribution they made to this publication:

- Prof. Dipl. Ing Andreas Müller; University of Applied Science Bern of Architecture, Timber and Construction, Project Initiator and Senior Consultant
- Thomas Volkmer; University of Applied Science Bern of Architecture, Timber and Construction, Project Co-Lead and Senior Consultant
- Dipl. Ing. Mareike Vogel, University of Applied Science Bern of Architecture, Timber and Construction, Project Co-Lead and Documentation for Innosuisse Program
- B.Sc. Adrian W. Wick, University of applied Science Bern of Architecture, Timber and Construction, Test planning, Testing and Evaluation
- Patrik Barmettler and Conradin Huerlimann, Sika Schweiz AG, Project partner and Sponsoring Roland Jaeggi, Sika Schweiz AG, peel testing
- Christoph Goy, Sika Services AG, application of est specimen and pull-off testing

References

[1] Timber: Trends in Availability, Sustainability and Durability for Bridges Mick Stephens*, Chief Executive Officer, Timber Queensland, 30 Boothby Street, Kedron, Queensland 4031 Rob McGavin, Queensland Department of Agriculture and Fisheries, Horticulture and Forestry Science, Salisbury Research Facility, 50 Evans Road, Salisbury, Queensland 4107

[2] Ritter, Michael A., 1990, Timber Bridges: Design, Construction, _Inspection, and Maintenance; Washington, D.C. 944.

[3] EM-7700-8, AASTHO 1996.