Wearing Surface Testing and Screening:

Yukon River Bridge

INTERM FINAL REPORT

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Summary

Since the summer of 2011, static and dynamic traction tests including chain dragging, rolling and lashing tests have been conducted on several products sent by companies in order to qualify as an alternative wearing surface for the Yukon River Bridge. Unlike the YRB research in 2006/2007, the companies are encouraged to provide a revision of their product in order to further meet the specific requirements of the bridge. The tests were conducted at room temperature using a custom apparatus designed by Wilhelm Muench, a graduate student at the University of Alaska Fairbanks. Out of the tested products Product 2, Product 3, Product 6, Product 8a, Product 8b, Product 9b, and Product 10 have provided potential as a substitute for the current wood decking on the bridge. Yet to come in the YRB research is 3-point flexural testing at cold temperatures and data analysis of chain rolling and lashing on wearing surfaces.

1. Introduction

The Yukon River Bridge is a two lane highway bridge with an orthotropic steel deck structure located about 50 miles North of Fairbanks on the Dalton Highway. The bridge was designed to carry highway traffic and the oil pipeline across the Yukon River. When it was built in the early 1970's, a two layer temporary timber wearing surface was installed over the steel deck. Because the bridge is on a 6% grade, trucks typically use tire chains to provide traction. The chains tend to cause serious wear on the timber surface over time. Due to the severe climate changes and intense loading from passing trucks, the timber surface deteriorates at a rapid rate.

Over a thirty year period, the timber surface was replaced in 1981, 1992, 1999 and 2007. As the quality of the timber wood decreased, the time between replacements also decreased which resulted in an increase in material costs. Therefore the Alaska Department of Transportation became interested in finding an alternative wearing surface that provide longer life, be relatively lightweight, offer flexible and improve traction. The alternative wearing surface must also be easy to install and maintain, and overall be a more economic option compared to timber.

Figure 1. Yukon River Bridge 1

1.1 Yukon River Bridge Project 2006

In 1992, the Alaska Department of Transportation installed panels of alternative wearing surfaces that were produced by participating companies. These included Transonite, which is a fiber-reinforced plastic surface that was supplied by Martin Marietta Composites, Ultra High Density Polyethylene by Ultra Poly, Inc. and Super Panel which is a fiber-reinforced polymer supplied by Creative Pultrusions, Inc. and Compositech, Inc. The AKDOT also installed Cobra-X, which was a high-density polyethylene panel with a contoured surface. These wearing surface panels were subjected to service conditions from 1992 to 2006. The only test surface that did not suffer from intense damage and meet the weight requirements of the Yukon River Bridge was the Cobra-X. However, the Cobra-X was no longer manufactured at the time and was reported by truckers to provide lower traction than the existing timber deck.

Dr. Leroy Hulsey, a professor at the University of Alaska Fairbanks in the Civil Engineering Department, became interested in the AKDOT's search for an alternative wearing surface and began a collaborative study. The purpose of this study was to develop a laboratory testing procedure to determine the traction and wear resistance of wearing surface materials. These results would then be used for ranking the wearing surface materials based on eligibility for replacing the wood surface of the Yukon River Bridge. The study's mission statement was as follows:

> *An ideal wearing surface for the Yukon River Bridge must be flexible, durable, ductile, and lightweight. It must also have sufficient traction to accommodate winter truck chains on a 6% grade. Connections between the wearing surface and the orthotropic steel deck should be designed to accommodate differential thermal strains between the wearing surface and the orthotropic steel deck.*

With the research being funded by the Alaska Department of Transportation and the Alaska University Transportation Center, Dr. Hulsey hired two UAF graduate students, Wilhelm Muench and Zackary Jerla, to carry out the research and produce laboratory procedures for testing alternative wearing surfaces. Zachery focused on the structural durability of the wearing surface system. Five experimental bridge-deck panels were tested at room and cold temperatures and evaluated the structural behavior and stiffness. Zach's studies provided a basis for ranking the panels based on structural durability and applicability for the Yukon River Bridge.

Wilhelm's work focused on test equipment and procedures that would provide a reliable scientific method for finding the coefficient of friction of a wearing surface and to assess the amount of damage caused by tire chains. Once the apparatus was designed and built by Wilhelm, tests for measuring the traction and wear of four alternative wearing surface panels. These panels included the Transonite, Ultra High-Density Polyethylene, Super Panel and Cobra X which were tested by AKDOT on the Yukon River Bridge. These results were used as a basis for ranking the various wearing surfaces for possible use on the Yukon River Bridge.

1.2 Yukon River Bridge 2011

Although test procedures were developed to test alternative wearing surfaces, the AKDOT did not replace the timber surface on the Yukon River Bridge in 2007. In the summer of 2011, Dr. Hulsey hired Ty Wardell, an undergraduate student, to continue the research using the same test equipment and procedures developed by Wilhelm. Instead of the focus being on developing test procedures, the new objective of this study was to find an alternative wearing surface by cooperating with and providing feedback to interested companies.

2. Methodology

The Yukon River Bridge wearing surface has two layers of 63 mm wood planking on top of an orthotropic steel deck. The bottom layer of the planks is bolted to the steel deck and the top layer is lag bolted to the layer underneath. This wood wearing surface has been used by the AKDOT since the bridge was constructed in 1976. Depending on the age of the timber, the top layer deteriorates rapidly due to a combination of decay, traffic and tire chain damage. Not only must an alternative wearing surface provide longer life under these conditions, but must also accommodate the 6% grade by providing traction for heavy trucks. The alternative wearing surface must also be relatively lightweight, provide flexibility for the bridge and require a more economic operation.

2.1 Traction and Chain Wear Test Equipment

Since there was no known laboratory test equipment found to determine wear due to tire chains, an apparatus was developed by Wilhelm. This testing apparatus consists of a lower and upper steel frame with a 14 ply 235/85R16 tire attached to the upper frame and spins on an axle. A tray is placed underneath the tire on the lower frame which is attached to a hydraulic ram that pushes and pulls the tray back and forth over a distance of 20 cm. The upper steel frame is attached to another hydraulic ram which elevates one end of the upper frame on a pivot. This in turn raises or lowers the tire onto the tray which contains a wearing surface panel that is to be tested. Electric load cells are attached to each hydraulic ram to measure the vertical and horizontal force on the tire as the tray moves in a direction. These readings are recorded by a data collector which is then displayed on a nearby laptop. The laptop uses proprietary software designed to work with the data collector to allow for calibration and corrected readings. The apparatus is approximately 60 cm wide and 230 cm long with a weight of around 4500 N. For test samples to fit in the tray, they must have dimensions of 45 cm wide by 61 cm long by 15 cm thick.

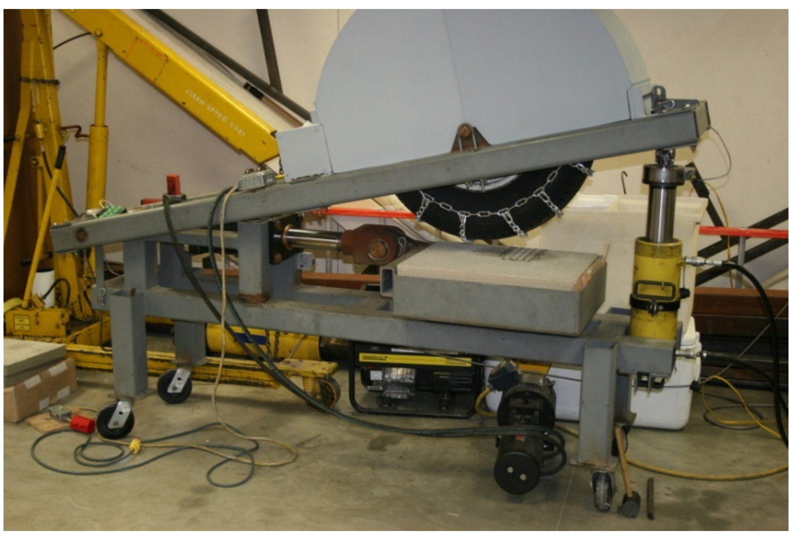

Figure 2. Test Equipment 1

2.2 Test Procedures

The study hypothesizes that wear on the surface of the Yukon River Bridge is caused by three different factors as vehicles drive over the bridge with tire chains:

- When loose chains lash against the surface, the impact causes damage;

- As the tire rolls over the chain, the individual chains will place a load over a small surface area;
- When a vehicle applies their break, the chains drag over the surface and causes wear;

Since it is impossible to conduct a test that covers all of these factors, each factor is tested and analyzed separately. To test for traction, the tire is loaded onto the sample panel in the tray with a force of 4500 N (which was determined as an average value for the weight of trucks that pass over the Yukon River Bridge). With the tire locked at its axle, the hydraulic ram moves the tray back and forth, resulting in traction between the tire and the sample panel. The horizontal forces caused by the traction are measured by the load cell attached to the hydraulic ram. These measurements are then recorded by the data collector and are used to approximate a value for the coefficient of friction that the sample panel offers. This value is taken after the tray has moved back and forth for five to six cycles, which gives a more accurate approximation for what traction the alternative wearing surface has to offer after long term wearing.

To test for wear that is caused by dragging chains over the alternative wearing surface, the tire is locked at its axle with the tray moving back and forth. However, tire chains are attached as tight as possible to the tire. Instead of finding the coefficient of friction, the displacement in the surface of the sample panel caused by the tire chains is measured. This is done by using a profiler before the chain dragging test to measure the relative heights of the surface, then measuring the displacements in the surface after the test using the same profiler.

Tire chains that roll over a surface can cause punctures in small areas. These tiny displacements can be measured by unlocking the tire from its axle and moving the tray back and forth with the sample panel. A pre-profile is required before the rolling test is performed. To account for loose chains that lash against the surface, the apparatus is modified such that an edge of the sample panel is exposed to the lashing tire chains. With the top steel frame unattached from the hydraulic ram, the top frame is lifted and lowered by an attached lever that is controlled manually by the operator. A motor spins the tire up to 45 miles per hour (which was determined as an average speed for trucks to pass over the Yukon River Bridge), which causes the loose tire chains to lash against the sample panel. This is done for two seconds which simulates long term wear. Once again, a pre-profile is required before the test in order to measure the displacement in the surface.

(The description of the 3-point flex test will be included here)

3. Test Results and Data

3.1 Test Samples

The products samples tested in the laboratory are required to have the dimensions of 18 x 24 x 2 inches (note however that the thickness of the panel may be adjusted). The tested products were as follows:

- Product 1: Anti-Slip Polymer Coating on Fiberglass
  The fiberglass panel is about an inch thick with a polymer coating that is typically used on docks to prevent slippage for pedestrians. The sample was prepared by Company 1, allowing the coating to cure and bond to the fiberglass for a period of time.
- Product 2: Polyester Polymer Concrete
  The product was prepared in the university laboratory with special training provided by the owner of the company. The aggregate mix (which Company 2 makes specific) is a polymer resin which is activated by 30% peroxide. Once activated, the resin hardens within 20 – 30 minutes (during this timeframe, the aggregate and resin are mixed together to produce the final product). The PPC sample panel was prepared to be 2 inches thick and the mix was bonded to a steel plate using a zinc metal solution.
- Product 3: Epoxy for Surface Coating
  This product was also prepared in the university laboratory with a relatively simple procedure. The resin consists of a Part A and a Part B; once combined, the resin begins to cure within 45 minutes (however the company recommends a whole day for the resin to fully cure). Two layers of resin and basalt were applied to one side of a fiberglass panel (which was provided by Company 1). The final product was around 0.75 inches thick.
- Product 4: Wood Panel
  The product consists of wood blocks with the grains facing outward to provide better traction. The blocks were glued to a wood panel, resulting in a thickness of 2.5 inches.
- Product 5: Ultra High Molecular Weight Polyethylene
  Shares the same qualities as the UHMW sample tested in 2006/2007. However, a crystalline coating is applied to the surface rather than an aggregate cast. The thickness is around 1.5 inches.
- Product 6: Polymer Concrete
  The composition of the product is unknown (possibly consisting of a special polymer solution) and was prepared by the company. The roughness of the surface was produced when the product was curing. The company prepared the panel with a thickness of 2 inches.

- Product 7: Epoxy Concrete Product
  This product is claimed by Company 7 to perform well in cold climates (they also claim that it has already been used in Alaska). The thickness of the product was an inch, and the surface was rough and partially crystalline.
- Product 8a & Product 8b: Epoxy Concrete Product
  These are two revisions of the previous submission (Product 7), with the thickness increased to 2 inches and the surface much more crystalline. The difference in composition between Product 8a and Product 8b is unknown.
- Product 9a & Product 9b: Epoxy Concrete Product
  Another revision to their products was provided by Company 7. The only apparent difference from Product 8a and Product 8b was the surface was no longer crystalline but instead just rough from curing. Also the same thickness from Product 8a and Product 8b was preserved.
- Product 10: Fiberglass Panel
  A preliminary sample of this product was provided before actual testing, which consisted of multiple fiberglass layers bonded together with a rough surface produced from curing. The preliminary sample was half an inch thick and then was later increased to 0.75 inches with the second version.
- Product 11: Epoxy Asphalt
  The product consisted of asphalt that was partially bonded and reinforced by an epoxy solution. The sample was also bonded to a wood panel. The thickness of the asphalt sample (not including the wood panel) was an inch.

3.2 Product Results

Product	Result
Product 2	Passed
Product 3	Passed
Product 6	Passed
Product 8a	Passed
Product 8b	Passed
Product 9b	Passed
Product 10	Passed
Product 1	Failed
Product 4	Failed
Product 5	Failed
Product 7	Failed
Product 11	Failed
Product 9a	Failed

3.3 Product Pros & Cons

- Product 1: Anti-Slip Polymer Coating on Fiberglass
  - Pros: Fiberglass made sample lightweight and flexible
  - Cons: Anti-Slip coating experienced extreme wear during wet traction and chain dragging tests, exposing smooth fiberglass panel and reducing traction
- Product 2: Polyester Polymer Concrete
  - Pros: Preparation is very simplified, provided good traction in dry and wet conditions, experienced little wear during chain dragging test, effectively bonds to steel plating
  - Cons: Relatively heavy, however the thickness can be adjusted without compromising the performance of the product
- Product 3:
  - Pros: Very simple two part solution preparation, epoxy solution effectively bonds to fiberglass, sample lightweight and flexible, provided very good traction
  - Cons: Basalt that is not properly bonded can be dragged off of the panel easily from tire chains
- Product 4: Wood Panel
  - Pros: Lightweight, provides the same advantages that the current wood decking has to offer
  - Cons: Suffers intense wear during chain dragging test, spaces present between wood blocks which allow water to seep through, making the panel subject to freezing and thawing, adhesive was not effective in holding blocks to panel underneath
- Product 5:
  - Pros: Lightweight and flexible, provide good traction
  - Cons: Tire chains easily dug through the surface coating, subjecting the UHMW underneath to intense wear which resulted in extreme changes in coefficient of friction values
- Product 6:
  - Pros: Provided good traction in wet and dry conditions, did not experience much wear during chain dragging test, provided very consistent coefficient of friction values
  - Cons: Relatively heavy, however the thickness can be adjusted without compromising the performance of the product

- Product 7:
  - Pros: Lightweight, claimed to be resistant to cold temperatures, provided good traction in dry and wet conditions
  - Cons: Two panels broke into pieces when 4500 lbs was loaded onto the panels
- Product 8a:
  - Pros: Provided very good traction in wet and dry conditions, claimed to be resistant to cold temperatures
  - Cons: Experienced slightly more wear during chain dragging test compared to other products that passed, surface coating easily brushed off
- Product 8b:
  - Pros: Provided very good traction in wet and dry conditions, claimed to be resistant to cold temperatures
  - Cons: Experienced slightly more wear during chain dragging test compared to other products that passed, surface coating brushed off easily
- Product 9a:
  - Pros: Provided very good traction in wet and dry conditions, claimed to be resistant to cold temperatures
  - Cons: Experienced severe wear during chain dragging test
- Product 9b:
  - Pros: Provided very good traction in wet and dry conditions, claimed to be resistant to cold temperatures, experienced very little wear during chain dragging test
  - Cons: None
- Product 10:
  - Pros: Provided very good traction in wet and dry conditions, very lightweight, very flexible, experienced very little wear during chain dragging test
  - Cons: None
- Product 11:
  - Pros: Provided good traction, was relatively lightweight
  - Cons: Experienced severe wear during chain dragging test, cracks and voids present which makes product subject to freezing and thawing of seeping water

3.4 Passed Products – Traction Data

Product	**Dry Traction**	**Wet Traction**	**Dry Traction**	**Wet Traction**
	Static	Static	Dynamic	Dynamic
Product 2	0.67	0.59	0.64	0.58
Product 3	0.68	0.64	0.65	0.61
Product 6	0.63	0.64	0.61	0.63
Product 8a	0.66	0.59	0.64	0.57
Product 8b	0.64	0.61	0.62	0.57
Product 9b	0.67	0.63	0.63	0.59
Product 10	0.64	0.61	0.60	0.58

3.5 Passed Products – Chain Drag Ranking

1. Product 10
2. Product 3
3. Product 2
4. Product 6
5. Product 9b

6. Product 8b
7. Product 9a

Note: The difference in wear between the top five ranked products is very small, whereas the two lowest ranked products received slightly more wear than the top five.

3.6 Passed Products – Densities

- Product 2 – 171 lbs/ft^3
- Product 6 – 181.8 lbs/ft^3
- Product 8a – 111.4 lbs/ft^3
- Product 8b – 119.2 lbs/ft^3
- Product 9b – 118.2 lbs/ft^3
- Product 10 – 85.6 lbs/ft^3
- Product 3 – 131.2 lbs/ft^3

3.7 Chain Lashing Data Analysis

Product	Displacement			
	Path 1	Path 2	Path 3	Average
Product 2	-0.094	-0.098	0.000	-0.064
Product 3	-0.033	-0.007	-0.248	-0.096
Product 6	-0.181	-0.162	-0.085	-0.143
Product 8a	-0.052	-0.022	-0.023	-0.032
Product 8b	-0.078	-0.054	-0.060	-0.064
Product 9b	-0.275	-0.289	-0.286	-0.283
Product 10	-0.031	-0.043	0.001	-0.024
Product 1	0.087	0.115	-0.075	0.042
Product 4	0.100	0.018	0.106	0.075
Product 5	0.033	0.081	-0.394	-0.093
Product 7	0.012	0.007	-0.007	0.004
Product 11	0.732	0.680	0.681	0.698
Product 9a	-0.089	-0.071	-0.011	-0.057

References

- Evaluation of Wearing Surfaces for the Yukon River Bridge. Prepared by J. Leroy Hulsey, Zachary Jerla and Wilhelm Muench. Prepared for the Alaska Department of Transportation, July 2009
- Tire Chain Damage on Bridge Deck Wearing Surfaces. Prepared by J. Leroy Hulsey and Wilhelm Muench. Prepared for the Alaska Department of Transportation and the Alaska University Transportation Center.