TIRE CHAIN DAMAGE ON BRIDGE DECK WEARING SURFACES

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Abstract

A light weight, durable, and damage-resistant material is needed as a wearing surface replacement for a two-lane bridge deck that is on a 6% grade. The wearing surface to be replaced is 9.2-m wide and is attached to an orthotropic closed cell steel deck that supported by two 155.9- cm wide by 414.0-cm deep steel box girders. This is a 699.5-m long six span bridge over the Yukon River located near the Arctic Circle on the gravel road section of the Dalton Highway. The bridge is located approximately 80 km north of Fairbanks, Alaska.

The structure was designed in the early 1970's with a 127-mm two-layer timber deck wearing surface. Since then, the timber deck wearing surface has been replaced in 1981, 1992, 1999, and 2007. Future decking material may be composites. Factors to be considered in the selection of a new decking material include: thermal cracking, abrasion, durability, flexural strain, traction, weight, and fastening methods to the steel deck. Moreover, the material must retain its structural properties in temperatures that range from -50C to 40C..

For a majority of the year, the driving surface is covered with ice and snow. Because of the steep grade, trucks typically use tire chains during the winter. These tire chains damage the current timber wearing surface and are a major factor in its deterioration. Further, the more traffic the less traction. Owing to the damage tire chains cause on the current timber wearing surface, other wearing surface materials are being considered. The purpose of this project was to evaluate possible wearing surface in the laboratory for punching shear, structural strain, modulus, traction, and resistance to tire chains. In this paper, preliminary test results for traction, and wear by tire chains are presented.

*This is an updated version of a paper that was first presented at ISCORD 2007, Proceedings of the 8th International Symposium on Cold Region Development, Tampere, Finland, September 25-27, 2007, with co-author, J. Leroy Hulsey.

1. Introduction

It is the purpose of this study to evaluate alternative wearing surface materials that may be applied to the Yukon River Bridge, an orthotropic steel deck on a 6% grade. The material of choice must be lightweight - no more than 1.44 Kpa (30 psf), durable, ductile, and have a surface that will provide winter traction and perform well under the use of truck tire chains for a number of years; winter exposure can reach temperatures below -46C(-50F).

A series of laboratory tests were developed specifically for the project. Specialized equipment was designed and manufactured to measure traction, surface damage and structural flexibility and strength for alternative wearing surfaces for this application. This paper will focus on the results from the laboratory traction tests.

The Yukon River Bridge is a 2-lane highway bridge with a width of 9.2 m. The structure is located about 50 miles north of Fairbanks on the Dalton Highway carrying a low volume of heavy truck traffic. The structure was designed to carry the highway traffic, the oil pipeline and a future gas pipeline. The superstructure consists of two closed steel box girders that support an orthotropic steel deck. The structure was built in the early 1970's and at that time, a 127-mm two-layer a temporary timber wearing surface was placed over the steel deck. The bridge has 6 spans and it is on a 6% grade, see Figures 1 and 2 [1, 2, 3]; Because of the steep grade, in the winter trucks typically use chains and this has caused several problems. Chains tend to plane the timber deck causing loss of section and reduced traction with time. Subsequently, timber deteriorates rapidly under the severe climate and loads.

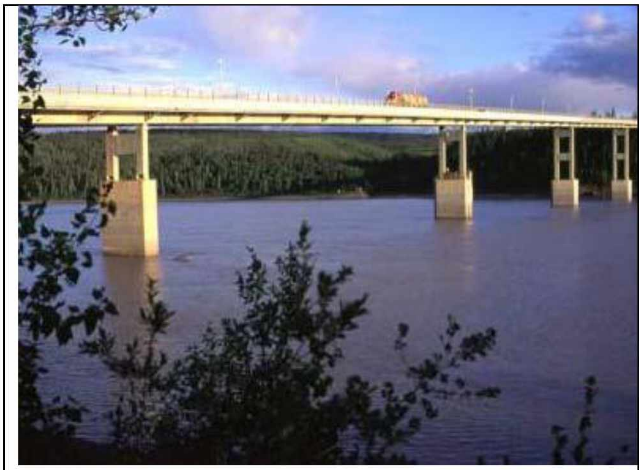

Figure 1. Yukon River Bridge

Figure 2. Yukon River Bridge in Winter

Over a 30-year period, the temporary timber solution has been replaced several times. It was replaced in 1981, 1992, 1999 and in 2007. As timber quality decreases, time between replacements decrease and material costs increase. Thus, cost effective lightweight alternatives are needed. Currently the Alaska Department of Transportation (ADOT) is looking to find a replacement for the timber wearing surface, which it is hoped will offer longer life, no increase in weight, improved traction, and more economic operation.

In 1992, AKDOT installed Cobra-x as an experimental feature on a small portion of the bridge Cobra-x is a high density polyethylene (HDPE) with a contoured surface. In 1999 AKDOT installed a test section consisting of Portland cement concrete cast-in-place into a steel grate. In the summer of 2005, AKDOT installed other types of test sections. These include Transonite, a fiber reinforced polymer (FRP) and foam composite with 10 mm epoxy and aggregate wearing surface, and a hollow core FRP with 19 mm epoxy aggregate wearing surface. The only test surface on the bridge that did not suffer heavy damage and meets weight requirements was the Cobra-x with a contoured surface. The Cobra-x, however, is no longer manufactured and it was reported by truckers to have lower traction than the existing wood deck.

This study is an attempt to develop a laboratory testing procedure to determine traction and wear resistance of alternative wearing surface materials that might be used on this structure. A general specification will be stated:

> *The ideal wearing surface 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. The connections between the wearing surface and the orthotropic steel deck shall be designed to accommodate differential thermal strains between the wearing surface and the orthotropic steel deck.*

2. Literature Review

An attempt was made to find methods for traction and damage caused by tire chains through other studies. A search was conducted using the National Transportation Library (NTL) Integrated Search Online, for previous tests of tire chain wear. While much research suggests that chain wear is a known issue, no methods to duplicate or measure that wear in the laboratory could be found. One study "Investigation of Durability of Wearing Surfaces for FRP Bridge Decks" was engaged in wear testing using a tire in a testing frame [4]. However, tests did not include tire chains. The laboratory testing reported here is limited to traction testing and the evaluation of our testing apparatus and methods.

3. Methodology

The Yukon River Bridge wearing surface has 2 layers of 63 mm wood planking on top of an orthotropic steel deck. The lower layer of planks is bolted to the steel deck and the top layer is lag bolted to the lower layer of planks. Lower planks run perpendicular to traffic and the upper are parallel to the traffic. This two layer wood wearing surface has been in use since the bridge was constructed in 1976. This system, while functional, has several problems. Most notably, the upper layer planks rapidly degrade, and need to be replaced with increased regularity. Deterioration is caused by a combination of decay, vehicle traffic, and damage by tire chains on heavy trucks traveling over the bridge during the winter months. Further, traction on the 6% grade is a major concern. Currently the Alaska Department of Transportation (ADOT) is looking to find a replacement for the wood wear deck which it is hoped will offer: longer life, no increase in weight, improved traction, and more economic operation.

Subsequently, we developed test methods and equipment to measure traction and the amount of wear caused by tire chains. A Findlay Irvine Grip Tester machine was used to calibrate laboratory traction data with field data on the existing bridge deck.

3.1 Traction test equipment

Tire chains on heavy trucks are considered to be a major source of damage to the Yukon River Bridge deck wearing surface. Since no known laboratory test could be found to determine wear due to tire chains, test equipment and a testing procedure was developed. The testing apparatus consists of a tray which contains the sample to be tested; this tray maybe moved horizontally over a distance of 20 cm by use of a hydraulic ram. Located over the sample tray is a 14 ply 235/85R16 tire through which downward force many be applied to the sample by means of a second hydraulic ram. The tire is located on an axle and that may be allowed to rotate in the direction of motion of the sample, or locked depending on the requirements of a given test. Electric load cells are provided to measure vertical and horizontal force on the tire in the direction of motion of the sample. Test samples maybe up to 45 cm wide by 61 cm long by 15 cm thick. The entire apparatus is approximately 60 cm wide 230 cm long and weighs around 4500 N. The small size is required to fit within the low temperature testing room available, see Figure 3.

Figure 3. Traction Equipment

It is hypothesized that wear of the wearing surface due to tire chains as vehicles drive over the bridge at highway speeds is caused by three mechanisms. Consider a tire with chains:

- As the chain strikes the surface there is an impact which causes some damage;
- As the tire rolls over the chain, it will cause the chain to place load over a small contact area on the surface; and
- While on the bridge, there is slipping or dragging of the chain due to a vehicle either climbing or braking.

Since it is nearly impossible to conduct a laboratory test in a small area featuring all three of these actions, they were tested and analyzed separately. Impact damage was measured by rotating a tire with chains over the sample. The speed of rotation was equivalent to a vehicle moving at 65 kph. Links of chain were allowed to impact the surface for several seconds. The amount of material removed was measured by profiling the surface before and after the test.

Rolling damage was tested by placing a tire with chains on the test sample. A vertical load was applied to the wheel that was equivalent to the force of a standard axle load of 80 kN (18,000 lbs). The tire was free to rotate as the test sample was moved under the tire for a given number of cycles. Depth of indentation formed by the chains was measured.

Slipping or dragging damage caused by tire chains was measured by placing a vertical load on the wheel which imposed load to the test sample. This was similar to the rolling test. However, in this case, the wheel was prevented from rotating while that sample was moved under the tire and chain. This test was developed to measure damage caused by drag between a tire chain and the wearing surface. The amount of material removed was measured by profiling the surface before and after the test.

In addition to tests for surface damage, samples were also tested for traction. This was done by loading the tire, without chains but with rotation of the tire prevented. A vertical load was applied to the wheel. With the vertical load acting on the wheel, the force required to move the sample was measured (this was the friction force). Normal force was measured indirectly and friction force was measured directly. The coefficient of friction was then calculated. Traction tests were conducted for varying surface conditions, including: dry, wet, and lightly ice covered. Here we report our initial room temperature tests, as well as cold room tests reported by other in our laboratory. Test Samples

The laboratory tests samples are described herein for review and consideration. These are:

- Timber

  Samples are 610 mm long, 300mm wide, and 64mm thick, Douglas Fir #2 grade rough cut.

- Transonite – a Proprietary product, manufactured by Martin Marietta [5].

  Samples are 610 mm long, 460mm wide, and 100 mm thick, with an additional 10mm wear surface of epoxy and aggregate. Material is a foam core with top and bottom surfaces of fiber reinforced polymer (FRP). The top and bottom are connected together through the foam with columns of FRP bonded to the top and bottom surface. Details may be found on the referenced web site.

- Ultra High Molecular Weight Polyethylene (UHMW) – Provided by Ultrapoly [6]

  Samples are solid blocks. 610mm long, 460mm wide and 127mm thick. The top 610mm by 460mm surface has an aggregate cast into the surface of the UHMW, approximately 3mm thick.

- Cobra-x

  Samples are 610mm long, 410mm wide and 64mm thick. A small section of Cobra-x was placed on the bridge deck in 1992 and it has performed well. It is a no longer manufactured Polyethylene product for use at railroad crossings. It is molded with a contoured top surface and relieved on the bottom to reduce weight and materials. The top is also coated with a ~1mm thick grit layer. The exact makeup of this layer is unknown.

- Compositech Panels – Custom Super panel manufactured by Creative Pulltrusions [7] with a surface coating applied by Compositech [8] (a local Fairbanks company).

  Samples are 610mm long, 410mm wide, and 64mm thick, Fiber Reinforced Polymer (FRP) hallow core panel, See Figure 4 The panel was topped with 8 to 15mm of basalt aggregate in a binder of Methyl Methacrylate (MMA). Mechanical properties for the FRP were provided by the supplier and these are A=1787 mm^2, I=6.41x$10^6$$mm^4$, E= 24 Gpa, G=345 Gpa. This panel is shown in Figure 4.

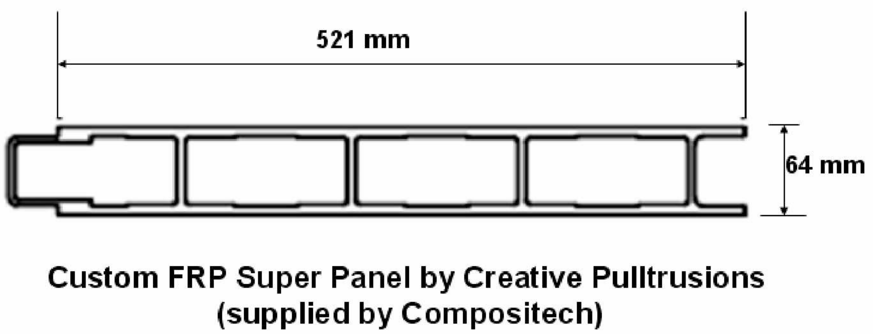

Figure 4. FRP Compositech Panel

4. Test Results

4.1 Wear Tests at room temperature:

Prior to testing, surface of the sample was measured using a rolling linear variable displacement transducer (LVDT). This procedure was used to define the surface topography prior to testing. The sample was placed under the tire and either dragging, rolling or lashing was implemented for a given number of cycles. After a number of cycles, the sample was removed from the test frame and the surface and the surface topography was once again measured to evaluate the level of damage. These beginning and ending conditions are used to evaluate surface damage.

4.1.1 Dragging. - Samples were exposed to 11 dragging cycles. Both Wood and Cobra-x samples showed very uneven wear during these tests. The wear presented is an approximate average and may need to be adjusted slightly as more tests are conducted. Martin Marietta and UHMW samples wore more evenly but only lost a small amount of surface making accurate measurement difficult. Tests were conducted at room temperature.

4.1.2 Rolling. - Rolling tests resulted in very little wear after 60 cycles. The number of cycles will be increased to try to gain more accurate values. The Wood and Cobra-x lost very little material during these tests, and showed little overall change in surface profile. The surface deformed around the V-bars of the chains resulting in small indentations and not in loss of surface material. Martin Marietta and UHMW samples lost a small amount of surface Aggregate. Tests were conducted at room temperature.

4.1.3 Lashing. - A lashing chain wear test was only conducted on one sample of Cobra-x. This was because the lashing test resulted in scraping rather than impact damage and therefore the testing procedure will be adjusted to correct this. Subsequently, wear results on the Cobra-x due to lashing are not useable. In order to have sufficient sample data, additional samples will not be tested until the test is modified. All tests were conducted at room temperature.

4.1.4 Lessons Learned - Wear measurements are taken by profiling the surface before and after testing. The surface of the panel is in contact with a disk 19.05 mm in diameter and 9.53 mm wide. The position of the disk is recorded in the horizontal and vertical directions as it is moved over the panel in the long direction of the panel. Values listed are for the largest change in surface as recorded by the profiler. Rolling tests failed to show significant damage in rolling tests. This was due to the tendency of the tire chains to cause highly local damage to the panel in the form of depressions about 8mm in diameter. The chains then returned to these damaged locations on subsequent cycles of the test. This resulted in the panels' depressions forming to the shape of the chain, resulting in little increase in damage on subsequent cycles. The profile disk will not enter these small depressions, see figure 5.

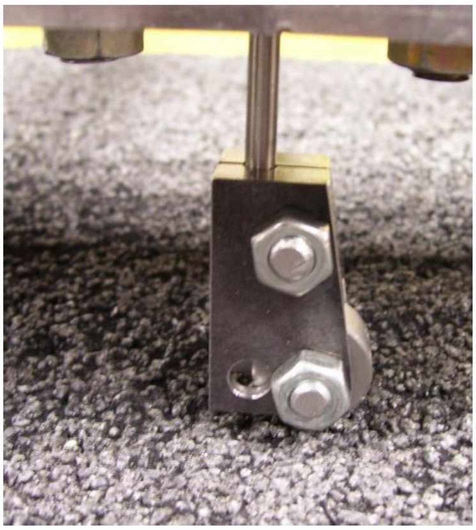

Figure 5. Profile meter disk on Transonite panel

The rolling testing procedure will be adjusted to address this problem. Panels will now be measured at random locations with a depth gage to find an average surface depression depth. The tire will then be rolled over the panel and the depth of local damage measured. The increase in depth of the damaged minus the average depression depth will be counted as the depth of damage. Currently no results are available for this new testing procedure.

4.1.5 Drag Test Results

As with any new testing procedure many problems have been encountered, and testing procedures were adjusted to compensate. Testing procedures were adjusted and changed from the original plans as testing progressed. This necessary adjustment significantly affected tests for rolling and lashing damage, therefore results of these tests are not presented at this time. Limited test results showing damage caused by braking or dragging are presented in Table 1. Based on the samples tested to date, the wood experienced the most damage and the Cobra-x the least. All other products showed similar wear characteristics.

Table 1 . Wear Test Results at 20 Degrees Celsius

Damage Measurements are in (mm)

Samples	Dragging Wear after 11 cycles	Rolling Wear after 60 Cycles	Lashing Wear after about 6000 Cycles
Cobra-x	0.38	NA	NA
Transonite	1.27	NA	NA
UHMW	1.27	NA	NA
Wood	2.54	NA	NA
Compositech	NA	NA	NA

4.2 Traction Tests

Testing has been done for 20, -7, and -29 degrees Celsius. This report covers test results for room temperature (20 degree Celsius). Results from traction tests at room temperature are presented in Table 2. The Compositech panel has the highest coefficient of friction of all samples tested. Traction for wood was lower than the Cobra-x when dry but higher when conditions are wet. In all cases, traction for the UHMW did not seem to vary with surface moisture.

Table 2. Traction Test Results

20 degrees Celsius Coefficient of Friction (unit less)

Dry Dynamic

Test sample	# of Samples	Average	Standard Deviation	95% Confidence Interval
Cobra-x	4	0.58	0.01	0.54 to 0.62
Martin Marietta	3	0.62	0.02	0.55 to 0.70
UHMW	3	0.54	0.02	0.49 to 0.59
Uncoated UHMW	3	0.50	0.05	0.33 to 0.67
Wood	3	0.54	0.00	0.53 to 0.55
Compositech	4	0.66	0.03	0.58 to 0.75

Wet Dynamic

Test sample	# of Samples	Average	Standard Deviation	95% Confidence Interval
Cobra-x	4	0.45	0.02	0.39 to 0.51
Martin Marietta	3	0.63	0.01	0.60 to 0.66
UHMW	3	0.55	0.02	0.50 to 0.60
Uncoated UHMW	4	0.47	0.01	0.43 to 0.51
Wood	1	0.61	NA	NA
Compositech	4	0.70	0.01	0.66 to 0.74

Dry Static

Test sample	# of Samples	Average	Standard Deviation	95% Confidence Interval
Cobra-x	4	0.65	0.02	0.59 to 0.70
Martin Marietta	3	0.67	0.03	0.57 to 0.77
UHMW	3	0.56	0.01	0.52 to 0.60
Uncoated UHMW	3	0.55	0.07	0.31 to 0.79
Wood	3	0.58	0.01	0.56 to 0.60
Compositech	4	0.76	0.03	0.68 to 0.83

Wet Static

Test sample	# of Samples	Average	Standard Deviation	95% Confidence Interval
Cobra-x	4	0.52	0.02	0.46 to 0.58
Martin Marietta	3	0.69	0.01	0.67 to 0.70
UHMW	3	0.57	0.02	0.50 to 0.63
Uncoated UHMW	4	0.50	0.01	0.48 to 0.53
Wood	3	0.64	0.02	0.59 to 0.69
Compositech	4	0.75	0.01	0.73 to 0.78

Table 3 is the traction test results carried out using the testing apparatus and procedures outlined in this paper, that were reported by Hulsey, Jerla, and Muench [9] as table 1.2.

Table 3. Traction Test Results

20 degrees Celsius Coefficient of Friction (unit less)

Wearing Surfaces Ranked by Traction Performance at -20°F (Dry and Icy)							
		70°F/20°C		20°F/-7°C		-20°F/-29°C	
Ranking	Sample	Dry	Wet	Dry	Icy	Dry	Icy
Ranked for dynamic friction at -20°F and icy:							
1	Wood	0.54	0.61	0.69	0.05	0.47	0.38
2	Super Panel[a]	0.66	0.7	0.78	0.65	0.70	0.34
3	Cobra X	0.58	0.45	0.65	0.53	0.55	0.33
4	Transonite[b]	0.62	0.63	0.75	0.51	0.63	0.29
5	Uncoated UHMW	0.5	0.47	0.37	0.13	0.37	0.18
6	UHMW	0.54	0.55	0.60	0.25	0.48	0.12
Ranked for static friction at -20°F and icy:							
1	Super Panel[a]	0.76	0.75	0.89	0.6	0.75	0.47
2	Cobra X	0.65	0.52	0.77	0.61	0.64	0.43
3	Wood	0.58	0.64	0.71	0.21	0.53	0.41
4	Transonite[b]	0.67	0.69	0.82	0.57	0.69	0.37
5	Uncoated UHMW	0.55	0.5	0.47	0.25	0.44	0.30
6	UHMW	0.56	0.57	0.62	0.28	0.51	0.19

a. Same as Martin Marietta in Table 2
b. Same as Compositech in Table 2

5. Summary and Conclusions

Preliminary test results for traction at room temperature show that the Cobra-x has more traction than wood when the material is dry but has less traction when wet. It appears that the surface coating on the UHMW does not provide as much traction as rough sawn Douglas fir. The Composittech super panel provided the most traction and the Martin Marietta product was next. At – 29 C, wood yielded the most traction under wet/icy conditions, while the Martin Marietta (Transonite) and Cobra-x were second and third. Only limited wear test results are available. Based on the information to date, the Cobra-x seems to have the best resistance to wear caused by braking.

The search goes on for a wearing surface that is durable under stress from tire chains and cold temperatures and that still provides traction in wet and icy weather. [9] Recent research has provided some interesting avenues that need to be tested. [10,11] However the testing apparatus described in this report coupled with cold room environment enables an important first step in testing and will save time and expense in future field testing.

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