CONTAMINATION OF WEATHERING STEEL DURING CONSTRUCTION

Final Report
KLK484
N07-07
ITD Project SPR-0004(022)

National Institute for Advanced Transportation Technology
University of Idaho

NIATT

E.R. Schmeckpeper, P.E., Ph.D.
Department of Civil Engineering
University of Idaho
Moscow, Idaho, 83844-1022

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Contamination of Weathering Steel during Construction		5. Report Date May 2007 6. Performing Organization Code
7. Author(s) Schmeckpeper, Edwin		8. Performing Organization Report No. N07-07
9. Performing Organization Name and Address National Institute for Advanced Transportation Technology University of Idaho PO Box 440901; 115 Engineering Physics Building; Moscow, ID 83844-0901		10. Work Unit No. (TRAIS) 11. Contract or Grant No. SPR-0004(022)
12. Sponsoring Agency Name and Address Idaho Transportation Department PO Box 7129 Boise, ID 83707-1129		13. Type of Report and Period Covered Final Report 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Idaho Transportation Department (ITD) Standard Specifications for Highway Construction requires that all steel surfaces of unpainted weathering steel structures are to be blast cleaned in the shop. Despite precautions taken to protect faying surfaces during the fabrication, transportation, and erection processes, some rusting or contamination of the faying surfaces, by oil, dust, road salts, or cleaning fluids may occur.

The effects of the accumulation of small amounts of rust have been documented. Yura, et al. (1981) found that when subject to normal atmospheric exposures, a Class B (blast-cleaned) slip coefficient could be maintained for up to one year prior to joint assembly. However, the effects of contaminates on the faying surfaces are not known. In addition, the effects of attempts at removing the contaminates are not known. It is hypothesized that the residues remaining from attempts at removing contaminates from the faying surface might reduce the slip coefficient more than the presence of the original contaminates.

The objective of this project was to provide guidance to ITD inspectors for judging the acceptability condition of steel faying surfaces. This would include guidelines to determine when the accumulation of contaminates on the faying surface has reached objectionable levels, and appropriate methods for removing contaminates from faying surfaces. These guidelines and methods could be incorporated into the ITD specifications.

17. Key Word	18. Distribution Statement
Steel structures; bridges; construction management; surface treating; rehabilitation (maintenance)	Unrestricted. This document is available to the public at NIATT.org

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unrestricted	Unrestricted	30	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

Background Information:

The Idaho Transportation Department (ITD) Standard Specifications for Highway Construction requires that all steel surfaces of unpainted weathering steel structures are to be blast cleaned in the shop.

Despite precautions taken to protect faying surfaces during the fabrication, transportation, and erection processes, some rusting or contamination of the faying surfaces, by oil, dust, road salts, or cleaning fluids may occur.

The effects of the accumulation of small amounts of rust have been documented. Yura, et al. (1981) found that when subject to normal atmospheric exposures, a Class B (blast-cleaned) slip coefficient could be maintained for up to one year prior to joint assembly.

However, the effects of contaminates on the faying surfaces are not known. In addition, the effects of attempts at removing the contaminates are not known. It is hypothesized that the residues remaining from attempts at removing contaminates from the faying surface might reduce the slip coefficient more than the presence of the original contaminates.

1Figure 1. Bridge girder at construction site.

Project Objectives:

The objective of this project is to provide guidance to ITD inspectors for judging the acceptability condition of steel faying surfaces. This would include guidelines to determine when the accumulation of contaminates on the faying surface has reached objectionable levels, and appropriate methods for removing contaminates from faying surfaces. These guidelines and methods could be incorporated into the ITD specifications.

Test Specimens

The following blast cleaned test specimens are covered in this report:

Uncontaminated Specimens

- tested within 24 hours of blast cleaning
- tested more than 24 hours after blast cleaning
- tested after exposure to 100 percent humidity for 48 hours

Specimens Contaminated by Dust, Clayey-Mud, or De-Icing Chemicals

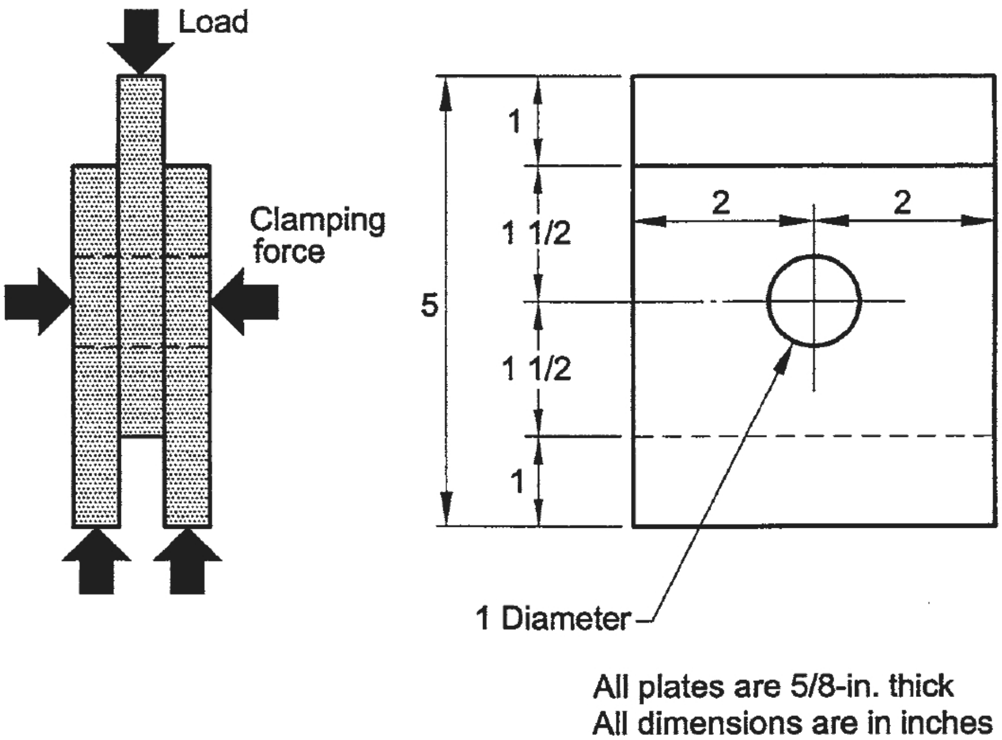
- contaminated by dust
- contaminated by clayey-mud
- contaminated by de-icing chemicals and exposed to 100 percent humidity for 48 hours

Specimens Contaminated by Chip Seal Oil (CRS-2P)

- no attempt at cleaning faying surface
- unleaded automotive gasoline used to clean faying surface
- 100 percent mineral spirits (paint thinner) used to clean faying surface
- 100 percent acetone used to clean faying surface
- household all-purpose cleaner (Simple Green®) used to clean faying surface
- liquid organic solvent (De-Solv-It®) used to clean faying surface
- aerosol organic solvent (Orange Supreme®) used to clean faying surface
- aerosol inorganic brake parts cleaner (CRC Br□kleen®) used to clean faying surface
- wire brush used to clean faying surface
- mechanically powered wire brush used to clean faying surface
- compressed air used to clean faying surface
- blast cleaned faying surface

Test Specimens

The slip test specimens are fabricated from 5/8 inch thick ASTM A588 steel plates. The dimensions of the test specimens are shown in Figure 2.



2Figure 2. Compression slip test specimen.

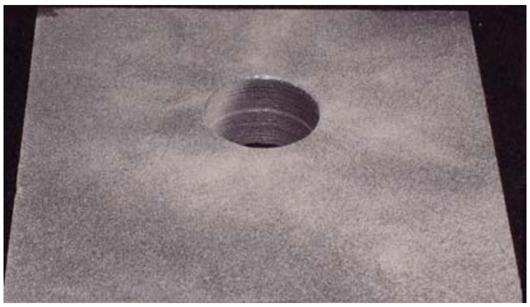
Test Specimens (continued)

The test specimens were blast cleaned at a local fabrication shop in accordance with SSPC Specification for Commercial Blast Cleaning (SSPC-SP-6) using combination of 25 percent grit and 75 percent steel shot .The blast cleaned appearance, as shown below, was intended to be equal to, or better than, BSa2 as shown in the pictorial standards of SSPC-VIS 1. The surface profile was tested at random and yielded a 2.4 to 2.5 mils peak to valley profile

3Figure 3. Compression slip test specimen, blast cleaned surface.

Contaminated Specimens
Specimens Contaminated by Dust, Clayey-Mud, or De-Icing Chemicals

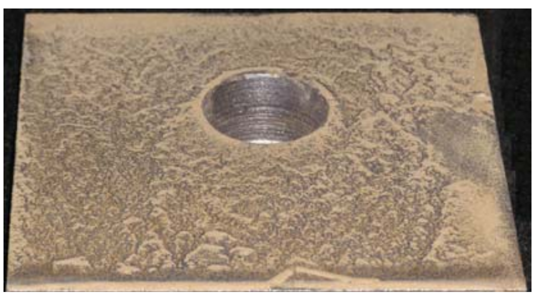
Despite precautions taken to protect faying surfaces during the fabrication, transportation, and erection processes, some rusting or contamination of the faying surfaces, by oil, dust, road salts, or cleaning fluids may occur. In order to determine the effects of these contaminates, specific quantities of different types of these materials were applied to the faying surface of test specimens. Consistent amounts of these materials were applied to each specimen tested.



4Figure 4. Dust from Road Base Material.

The dust material was obtained from basalt aggregate used in road construction projects in Latah County, Idaho. The dust was obtained by sieving road base material and collecting the material that passed a #200 sieve, approximating the size of material that would be wind deposited. Approximately one gram of dust was applied to each test specimen.

The Clayey-Mud mixture was obtained by mixing 100 grams of clay obtained from a road construction project in Latah County with 1000 ml of water. The steel specimens were submerged in the clay-water mixture and air-dried prior to testing.



5Figure 5. Clayey-Mud.

Some specimens were dipped in a Magnesium Chloride solution and then subjected to 100 percent humidity.

Additional specimens were dipped in the Magnesium Chloride solution, subjected to 100 percent humidity, dipped in the clayey-mud mixture, and then air-dried prior to testing.

6Figure 6. Clayey-Mud and Magnesium Chloride.

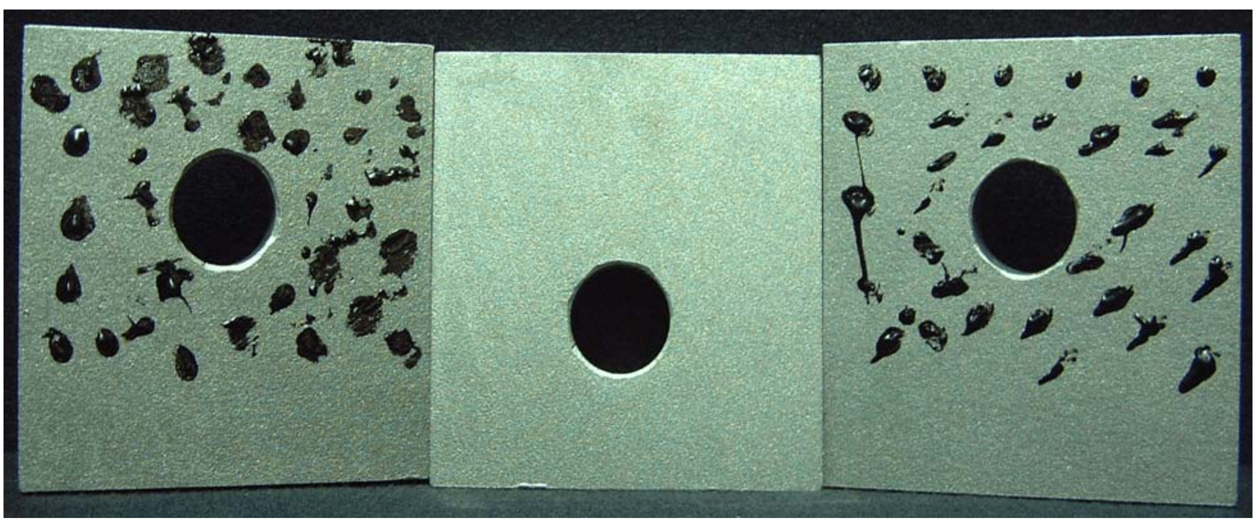
Contaminated Specimens
Specimens Contaminated Chip Seal Oil (CRS-2P)

7**Figure 7**. Specimen Contaminated with Chip Seal Oil (CRS-2P).

These specimens were treated with the oil based emulsion commonly used in chip sealing operations. The weight of the chip seal oil applied to the specimen was approximately one gram.

Generic Category:	Polymer Modified Emulsions
Product Name:	CRS-2P
Company Name:	Idaho Asphalt Supply Inc. Coeur d`Alene, Idaho

The chip seal oil was applied to only one side of each faying surface. The inside faces of the left plate and the right plate were contaminated with the chip seal oil. The center plate was not contaminated.



8**Figure 8.** Specimens Contaminated with Chip Seal Oil (CRS-2P).

Cleaning of Contaminated Surfaces

Several methods were used in attempts to remove the contaminates from the faying surfaces of the test specimens.

These methods included:

1. Wiping the faying surface with a clean cotton rag soaked in unleaded automotive gasoline.
2. Wiping the faying surface with a clean cotton rag soaked in 100 percent mineral spirits (paint thinner).
3. Spraying the faying surface with 100 percent acetone, followed by wiping the faying surface with a clean cotton rag.
4. Spraying the faying surface with a household all-purpose cleaner (Simple Green®), followed by wiping the faying surface with a clean cotton rag. Simple Green® is a citrus based cleaner. It is advertised as being able to clean mild oils, grease, and is intended to be used as a natural alternative to petroleum based degreasers.
5. Spraying the faying surface with a liquid organic solvent (De-Solv-It®), followed by wiping the faying surface with a clean cotton rag. De-Solv-It® is a degreaser utilizing citrus based acids, aloe, Vitamin E, and is claimed to be biodegradable and organic.
6. Spraying the faying surface with an aerosol organic solvent (Orange Supreme®), followed by wiping the faying surface with a clean cotton rag. Orange Supreme® also claims to be organic and biodegradable. It contains citrus based acids which were formulated to remove tar, oil and grease.
7. Spraying the faying surface with an aerosol inorganic brake parts cleaner (CRC Br□kleen®), followed by wiping the faying surface with a clean cotton rag. CRC Br□kleen® is formulated to clean brake fluid, grease and oil from automotive brake parts.
8. Manually cleaning the faying surface using a steel brush
9. Mechanically cleaning the faying surface using an angle grinder with a wire brush attachment.
10. Spraying the faying surface with compressed air to remove the contaminate.
11. Shot blast cleaning the surface using same equipment as was used to originally blast clean the surface prior to contamination.

Notes on the Effectiveness of the Various Methods:

Gasoline – Dissolved the CRS-2P chip seal oil but left the samples a brown color, and there was still a "shadow" of where each blot of CRS-2P chip seal oil was on the specimens. This could be due to residue from the gas, CRS-2P or a combination of the two as the gas evaporated.

100 percent Mineral Spirits – This material was not odorless. The mineral spirits dissolved the CRS-2P chip seal oil. However after the specimens were wiped clean and the mineral spirits evaporated, there was still a "shadow" of where each blot of CRS-2P chip seal oil was on the specimens. Unlike the specimens cleaned with gasoline, there seemed to be no discoloration

100 percent Acetone – The use of this material required special precautions, such as the use of a forced air fume hood. The acetone did not completely dissolve the CRS-2P chip seal oil.

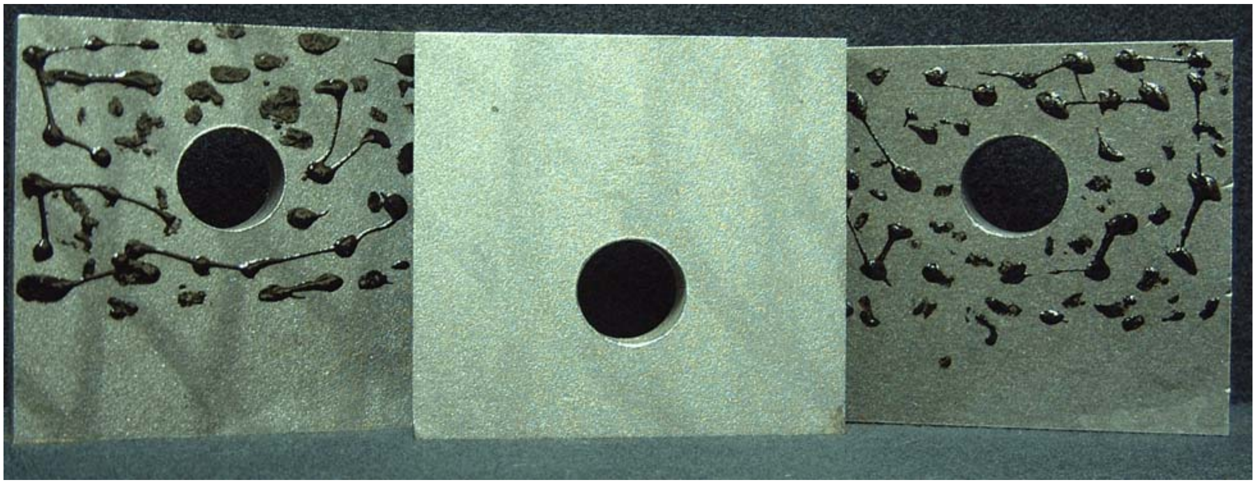
Simple Green® – This did not dissolve the CRS-2P chip seal oil. It left sticky residue on sample.

De-Solv-It ®– This dissolved the CRS-2P chip seal oil, but only after the cleaner had been allowed at least 10-20 minutes to penetrate the CRS-2P chip seal oil.

Orange Supreme® – The manufacturer 's instructions directed that the material should be wiped 10-20 minutes after application. This cleaner was very effective, and started to dissolve the CRS-2P chip seal oil almost immediately upon application.

Brake Parts Cleaner - CRC Brākleen® – This material was not odorless. The Brake parts cleaner dissolved the CRS-2P chip seal oil. However after the specimens were wiped clean and the brake parts cleaner evaporated, there was still a thin film of residue on the surface of the specimens.

Some of the methods used to attempt to clean the faying surfaces were completely ineffective. For example, as shown in the following figure, the household all-purpose cleaner *Simple Green*® was completely unable to remove the chip seal oil.



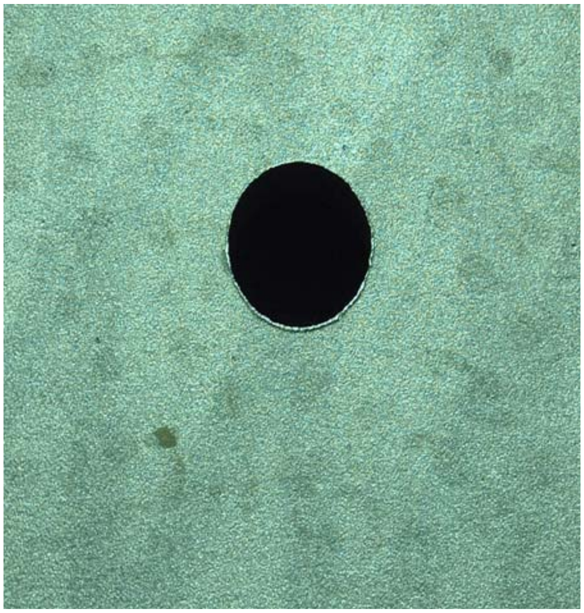
10Figure 9. Specimens contaminated with chip seal oil,
after attempt at cleaning using household all-purpose cleaner.

9Figure 10. Effects of using wire brush in attempt to clean faying surface contaminated with chip seal oil.

11Figure 11. Effects of using 100 percent Acetone in attempt to clean faying surface contaminated with chip seal oil.

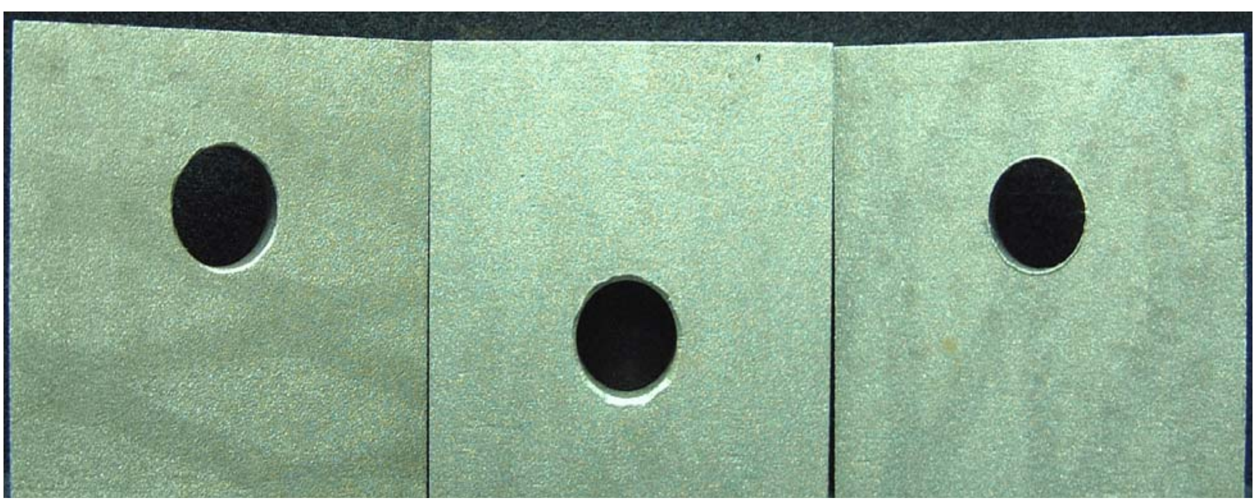
As shown in Figure 10, the use of manual or mechanical wire brushes resulted in the spread of the contamination across the faying surface. In a similar manner, Figure 11 shows that the use of 100 percent acetone also resulted in the spread of the contamination across the faying surface.

Gasoline dissolved the CRS-2P chip seal oil but left the samples with a slight brown tint and there was still a “shadow” of where each blot of CRS-2P chip seal oil was on the specimen (Figure 12).



12Figure 12. Specimen contaminated with chip seal oil, after cleaning with gasoline.

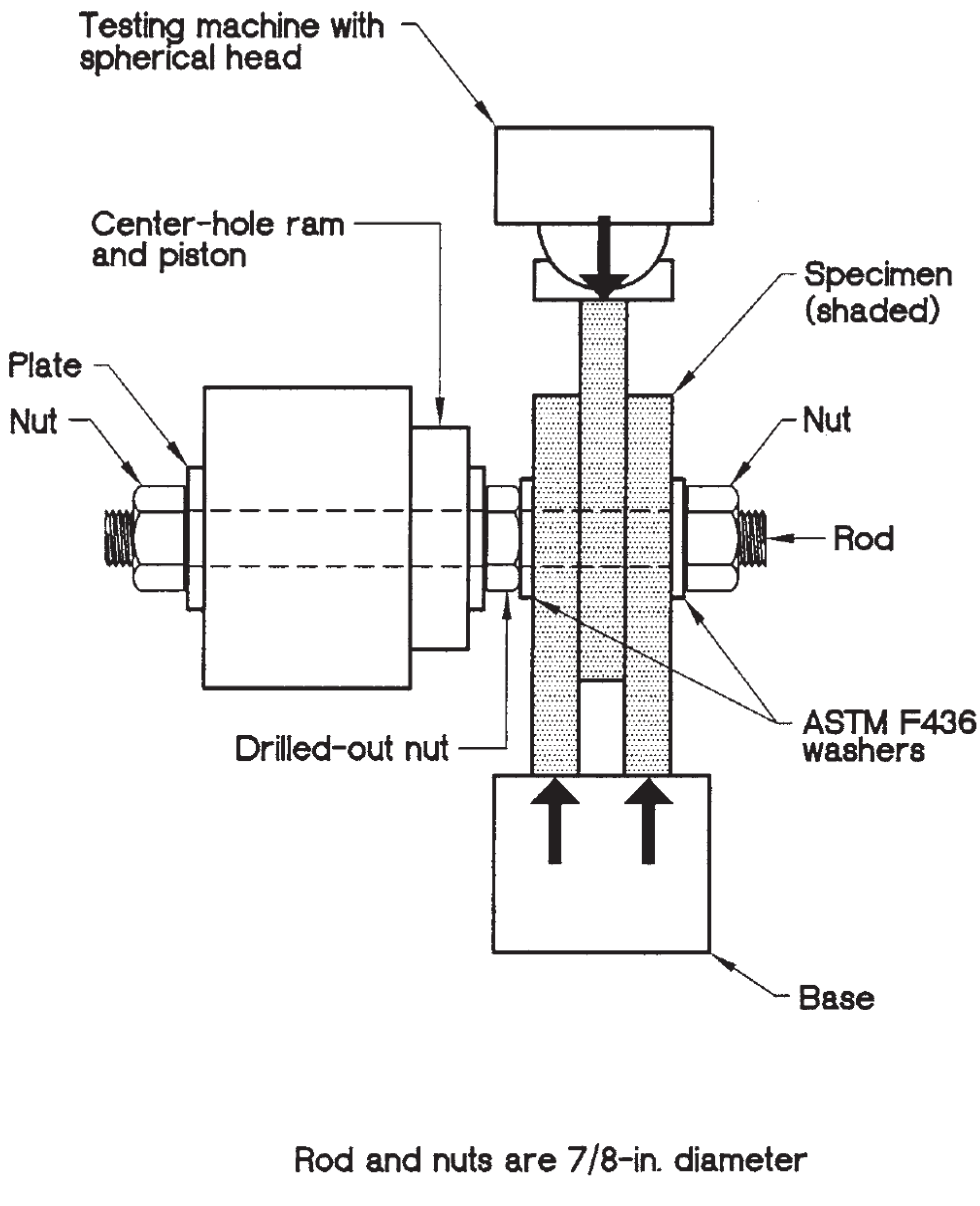
The spray liquid organic solvent and the aerosol organic solvent removed the majority of the chip seal oil contaminates, only leaving behind some slight staining of the steel surface (Figure 13).



13Figure 13. Specimens contaminated with chip seal oil, after cleaning with spray liquid organic solvent.

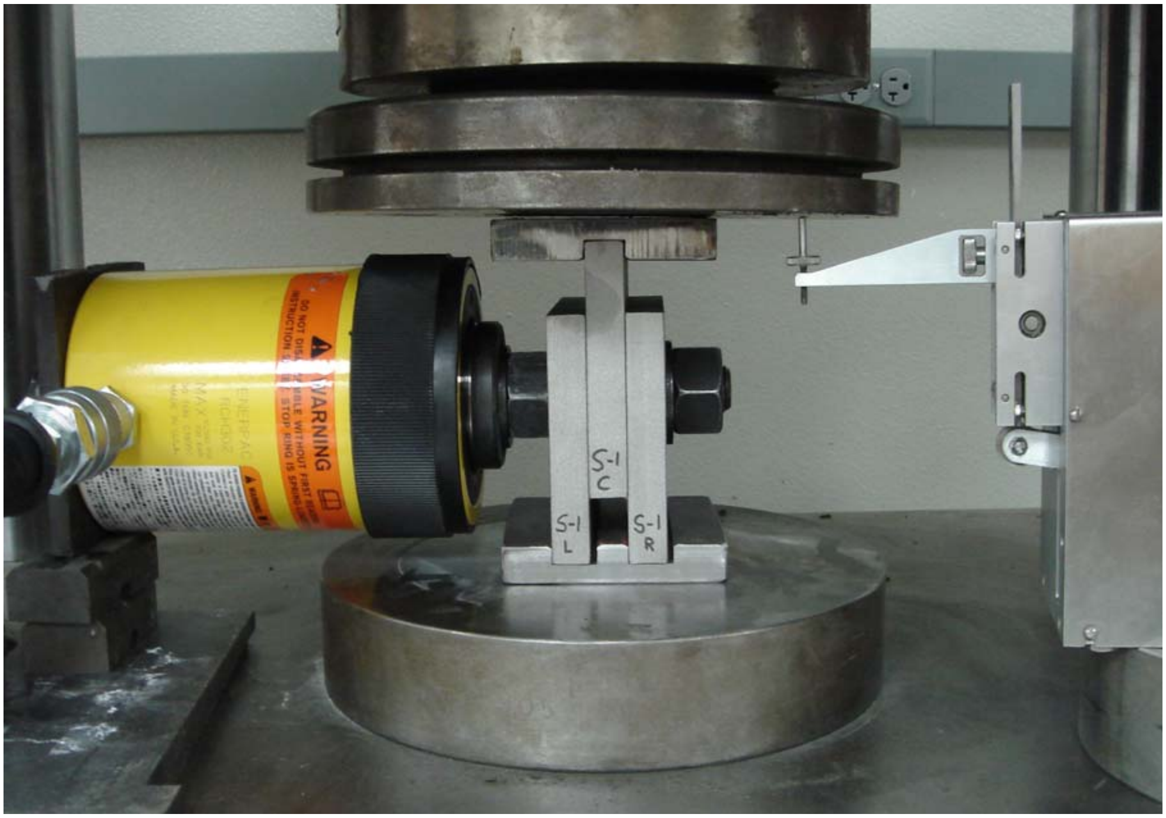
Test Apparatus

The test setup has two major loading components. The first is used to apply a clamping force to the specimen plates. The second is used to apply a compressive load to the specimen plates so that the load is applied to the faying surfaces by friction.



14Figure 14. Compression Slip Test Setup (RCSC Page 64).

Test Apparatus (continued)



15Figure 15. Compression Slip Test Setup

Clamping Force System:

The clamping force system consisted of a center-hole hydraulic jack, load cell and load cell indicator. A $^{7}/_{8}$ inch diameter threaded rod passes through the specimen plates, the center-hole hydraulic jack, and the load cell. An ASTM A563 grade DH nut was used at both ends of the rod, with a hardened washer placed on each side of the test specimens. Between the hydraulic jack and the specimen plates was a specially modified $^{7}/_{8}$ inch diameter ASTM 563 Grade DH nut in which the threads have been drilled out so that it will slide with little resistance along the rod.

The extension of the hydraulic jack forces the special nut against one of the outside plates of the specimen, places tension in the threaded rod, and results in a clamping force being applied to the specimen. This clamping force simulates the effect of a pretensioned $^{7}/_{8}$ inch diameter ASTM A325 bolt.

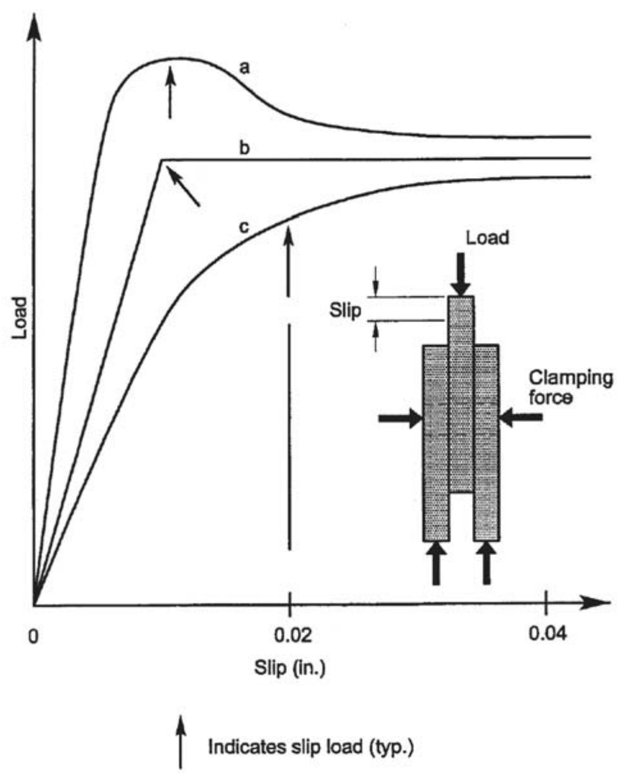
Enerpac RCH302, 30 ton center-hole hydraulic jack
OMEGADYNE LCWD-100K Load Cell
Transducer Techniques PHM-100 Load Cell Indicator

A 500K MTS universal testing machine with a MTS 442 controller was used to apply compressive loads to the test specimens.

Determination of Slip Load

Based upon the specifications for ASTM A325 bolts (RCSC), typical load-slip response is shown in the following figure. Three types of load-slip responses are typically observed.

Curve (a) Slip load is the maximum load, provided this maximum occurs before a slip of 0.02 in. is recorded.
Curve (b) Slip load is the load at which the slip rate increases suddenly.
Curve (c) Slip load is the load corresponding to a deformation of 0.02 in. This definition applies when the load vs. slip curves show a gradual change in response.



16Figure 16. Definition of slip load (RCSC page 66).

The slip coefficient for an individual specimen k_s is calculated using the following equation:

$$k_s = \frac{slip\ \ load}{2 \times clamping\ \ force}$$

Slip Coefficient Test Results

Slip Coefficient tests were conducted on the following specimens:

Uncontaminated Specimens

- blast cleaned specimens tested within 24 hours of blast cleaning
- blast cleaned specimens tested more than 24 hours after blast cleaning
- blast cleaned specimens exposed to 100 percent humidity for 48 hours

- Specimens Contaminated by Dust, Mud or De-Icing Chemicals
- blast cleaned specimens contaminated by dust
- blast cleaned specimens contaminated by clayey-mud
- blast cleaned specimens contaminated by road salts and exposed to 100 percent humidity for 48 hours

Specimens Contaminated by Chip Seal Oil (CRS-2P)

- blast cleaned specimens contaminated by chip seal oil (CRS-2P)
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned using unleaded automotive gasoline
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned using 100 percent mineral spirits (paint thinner)
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned using a liquid organic solvent (De-Solv-It®)
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned using an aerosol organic solvent (Orange Supreme®)

blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned using an aerosol inorganic brake parts cleaner (CRC Brākleen®)

- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then blast cleaned

Since the attempts at cleaning only spread the contaminates further across the faying surface, slip coefficient tests were not conducted for the following specimens:

- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then attempted cleaning using a wire brush
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then attempted cleaning using a mechanical grinding wheel with a wire brush attachment
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then attempted cleaning using 100 percent acetone

Similarly, since the attempts at cleaning failed to remove any of the contaminates, slip coefficient tests were not conducted for the following specimens:

- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then attempted cleaning using household all-purpose cleaner (Simple Green)
- blast cleaned specimens contaminated by chip seal oil (CRS-2P) then attempted cleaning using compressed air

Test Results

Uncontaminated Specimens

The test results for the uncontaminated specimens are shown below. The first set was tested within 24 hours of blast cleaning. The second set was tested more than 24 hours after blast cleaning. This set of specimens was stored at approximately 75 degrees Fahrenheit, 25 percent humidity until tested. The third set was tested after exposure to 75 degrees Fahrenheit, 100 percent humidity for 48 hours

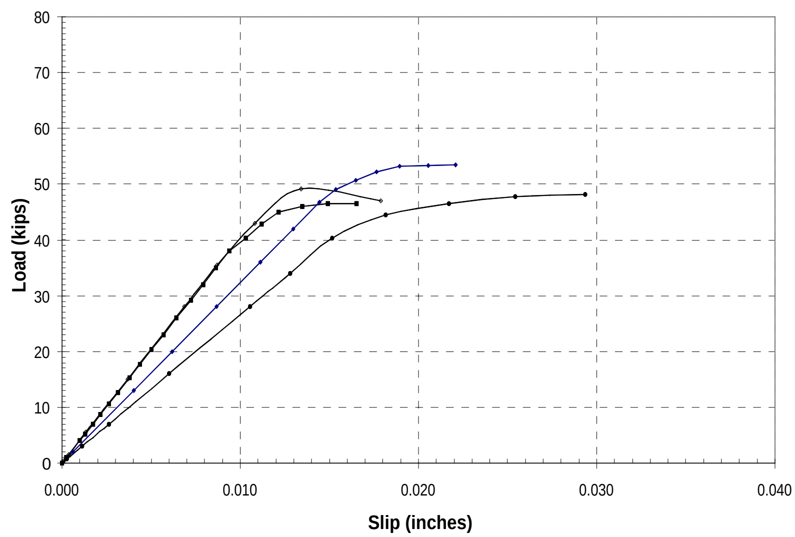


Figure 17. Compressive Load vs Slip for specimens tested within 24 hours of blast cleaning. μ=0.49.

Slip Coefficient Results for Specimens Tested Within 24 Hours of Blast Cleaning

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	46.5	49.2	0.47
2	53.2	49.1	0.54
3	49.2	49.0	0.50
4	43.5	49.0	0.44
		mean slip coefficient (μ)	0.49

The slip coefficient for the specimens tested within 24 hours of blast cleaning was determined to be μ =0.49, which compares reasonably well with the value of 0.50 used in the AASHTO Bridge Design specifications.

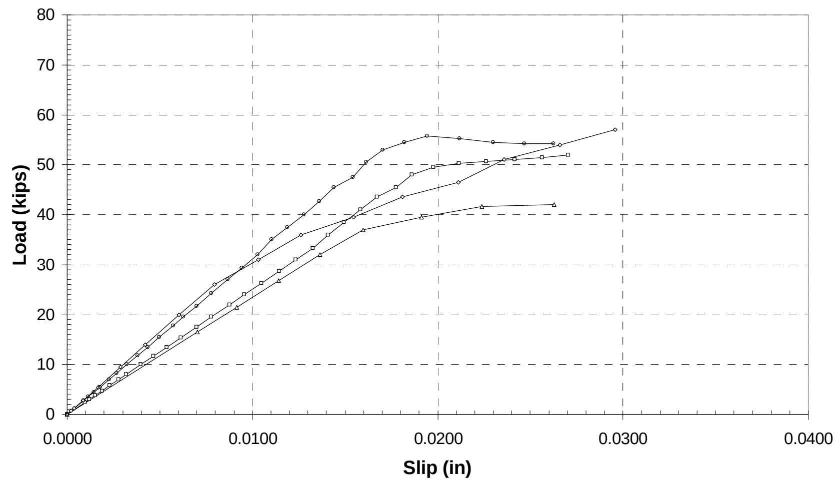


Figure 18. Compressive Load vs Slip for specimens tested more than 24 hours of blast cleaning. μ=0.49.

Slip Coefficient Results for Specimens Tested more than 24 Hours after Blast Cleaning

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	55.7	49.2	0.57
2	49.6	49.1	0.51
3	40.1	49.0	0.41
4	45.4	49.0	0.46
		mean slip coefficient (μ)	0.49

The slip coefficient for the specimens tested more than 24 hours after blast cleaning was also determined to be μ =0.49, which compares reasonably well with the value of 0.50 used in the AASHTO Bridge Design specifications.

Slip Coefficient Results for Specimens Subjected to 48 hours of 100% humidity

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	47.7	49.0	0.49
2	72.1	49.1	0.73
3	62.0	49.1	0.63
4	45.0	49.0	0.46
5	65.4	49.1	0.67
		mean slip coefficient (μ)	0.60

The slip coefficient for the specimens subjected to 48 hours of 100% humidity, was determined to be μ =0.60, showing an increase in slip resistance compared to the value of 0.50 used in the AASHTO specifications.

Specimens Contaminated by Dust, Mud or De-Icing Chemicals

The test results for the specimens contaminated by dust, mud, or de-icing chemicals are as follows:

Slip Coefficient Results for Specimens Contaminated by Dust

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient ks
1	54.5	49.5	0.55
2	72.7	49.9	0.73
3	60.7	49.3	0.62
4	77.6	49.1	0.79
5	65.2	48.6	0.67
6	56.8	49.0	0.58
mean slip coefficient (μ)			0.66

Slip Coefficient Results for Specimens Contaminated by Clayey-Mud

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	72.5	48.6	0.75
2	53.2	49.3	0.54
3	74.4	48.6	0.77
4	43.8	48.9	0.45
mean slip coefficient (:μ)			0.63

Slip Coefficient Results for Specimens Contaminated by Magnesium Chloride Then Exposed to 100 percent Humidity for 48 Hours

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	56.7	49.9	0.57
2	38.2	49.3	0.39
3	43.5	48.1	0.44
4	63.6	48.6	0.65
5	62.0	49.0	0.63
mean slip coefficient (μ)			0.54

Note that the slip coefficient for all three of these cases is higher than that of the uncontaminated specimens.

Specimens Contaminated by Chip Seal Oil (CRS-2P)

The following figures show the test data for the specimens contaminated by chip seal oil, those cleaned using gasoline, and those cleaned using mineral spirits. Note that the slip values for specimens cleaned using gasoline or brake parts cleaner are worse than those of the specimens which had no attempt at cleaning. The specimens cleaned with mineral sprits, or organic solvents, or blast cleaning, all showed an increase in slip resistance compared to those that were not cleaned.

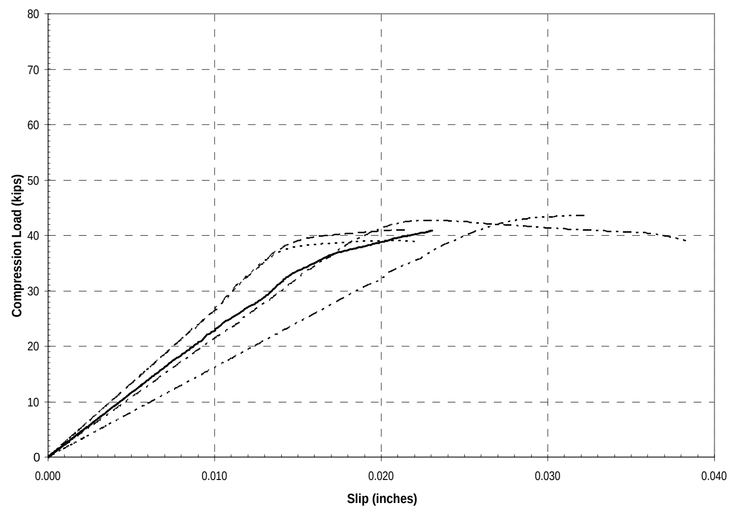
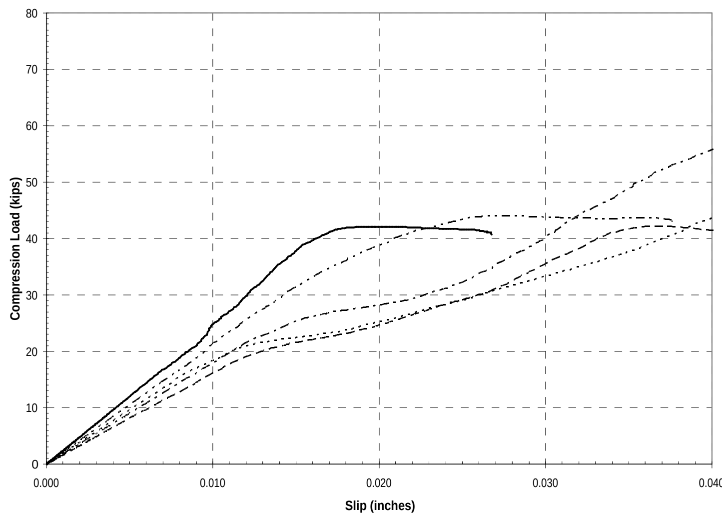


Figure 1917: Compressive Load vs. Slip for Specimens Contaminated with Chip Seal Oil.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P)

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	41.3	49.0	0.42
2	32.3	49.3	0.33
3	38.0	49.7	0.38
4	39.0	49.5	0.39
5	37.4	49.5	0.38
		mean slip coefficient (μ)	0.38



18.**Figure 20:** Compressive Load vs Slip for specimens cleaned using automotive gasoline.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned with gasoline

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	28.4	49.8	0.29
2	38.8	49.7	0.39
3	25.3	49.5	0.26
4	24.6	49.8	0.25
5	42.0	49.8	0.42
		mean slip coefficient (μ)	0.32

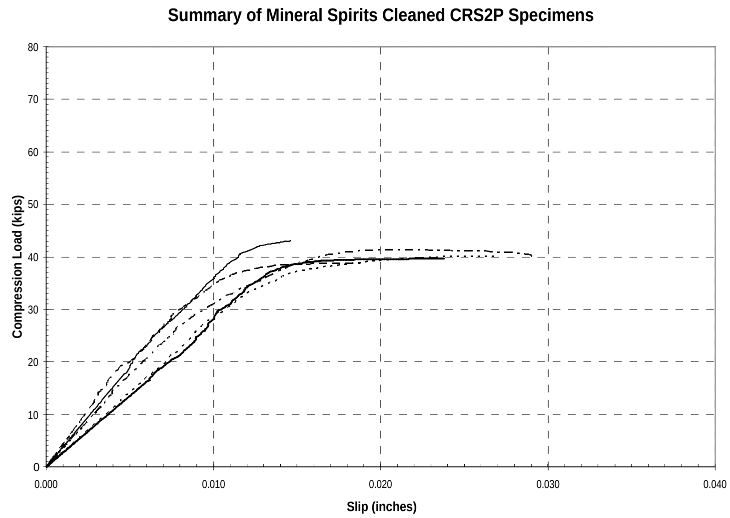


Figure 2119. Compressive Load vs Slip for specimens cleaned using 100 percent Mineral Spirits.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned with 100 percent mineral spirits (paint thinner)

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	41.3	48.7	0.42
2	39.3	49.3	0.40
3	38.8	49.4	0.39
4	39.5	49.6	0.40
5	43.0	49.5	0.43
		mean slip coefficient (μ)	0.41

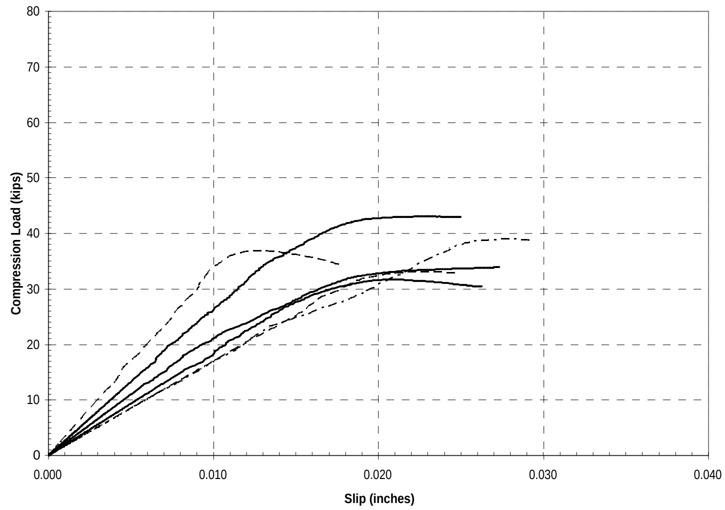


Figure 2220. Compressive Load vs Slip for specimens cleaned using Brake Parts Cleaner.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned with an aerosol inorganic brake parts cleaner (CRC Brākleen®)

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient ks
1	30.7	49.7	0.31
2	31.7	49.7	0.32
3	36.9	49.8	0.37
4	32.6	50.0	0.33
5	32.9	50.0	0.33
6	42.8	49.9	0.43
mean slip coefficient (μ)			0.35

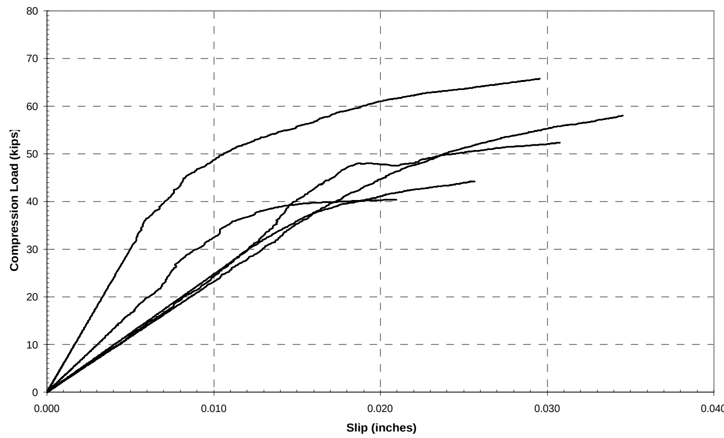


Figure 23.21. Compressive Load vs Slip for specimens cleaned with liquid organic solvent.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned with a spray-on liquid organic solvent (De-Solv-It)

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	60.1	49.6	0.61
2	40.3	49.2	0.41
3	48.1	49.0	0.49
4	41.1	49.6	0.41
5	44.7	50.0	0.45
		mean slip coefficient (μ)	0.47

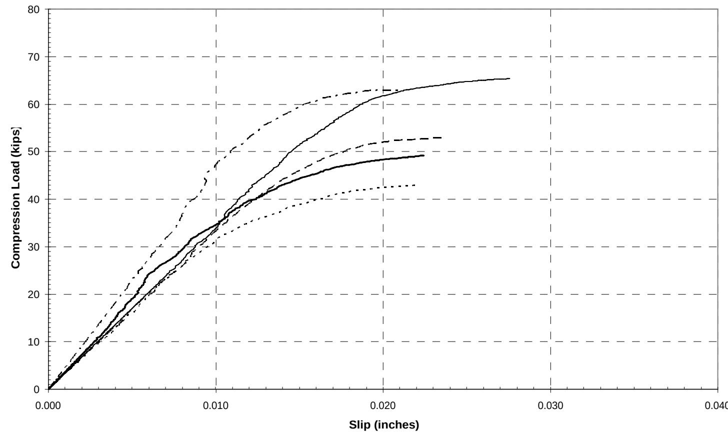


Figure 2422. Compressive Load vs Slip for specimens cleaned with Aerosol Organic Solvent.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P) then cleaned with an aerosol organic solvent (Orange Supreme)

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient ks
1	63.0	49.9	0.63
2	42.5	49.8	0.43
3	52.1	49.6	0.53
4	48.4	49.7	0.49
5	61.6	49.5	0.62
6	33.2	49.8	0.33
mean slip coefficient ( )			0.50

The aerosol organic solvent (Orange Supreme) was the only product tested that resulted in a slip coefficient value that was equal to or greater than the value of 0.50 used in the AASHTO specifications.

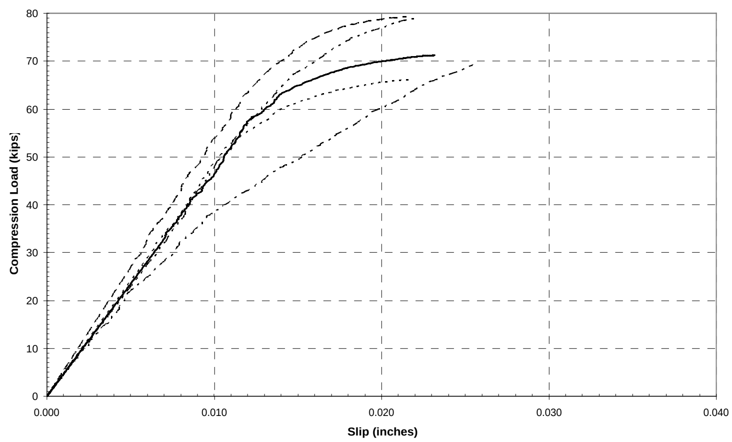


Figure 2523. Compressive Load vs Slip Coefficient Testing for specimens which were blast cleaned after contamination.

Blast cleaned specimens contaminated by chip seal oil (CRS-2P) then blast cleaned

Specimen	Compressive Load (kips)	Clamping Force (kips)	Slip Coefficient k_s
1	69.8	49.6	0.70
2	78.8	50.0	0.79
3	65.6	49.8	0.66
4	60.1	49.7	0.61
5	77.1	49.6	0.78
		mean slip coefficient (:)	0.71

The blast cleaned specimens consistently resulted in a slip coefficient values that were greater than the value of 0.50 used in the AASHTO specifications.

Specimens After Slip Coefficient Testing

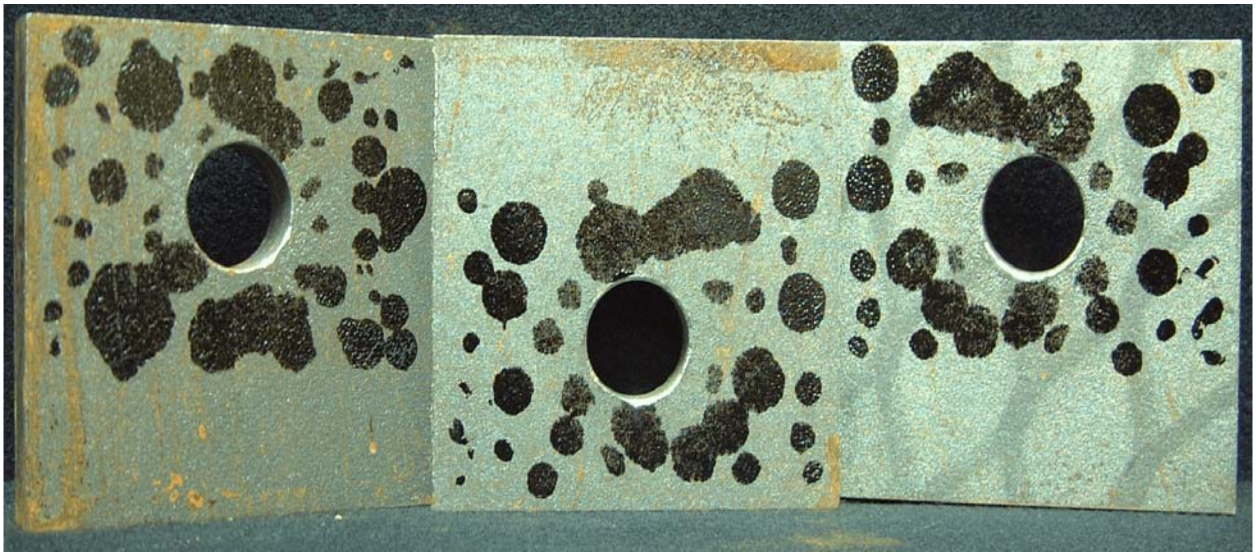
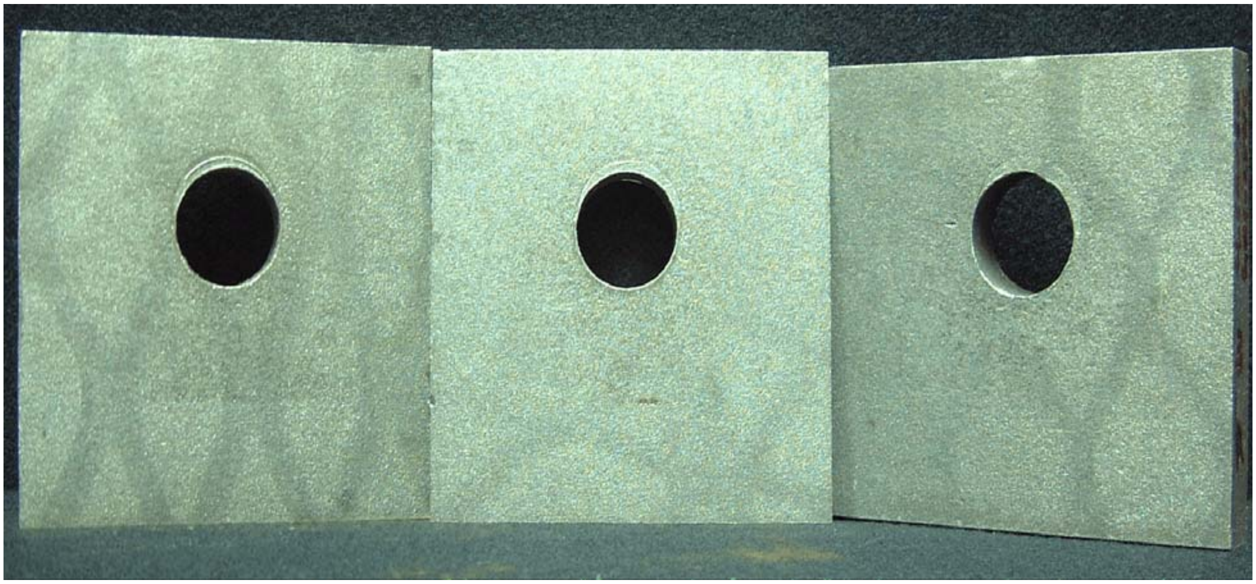


Figure 2624: Specimens Contaminated with Chip Seal Oil (CRS-2P) after slip coefficient testing



25**Figure 27** Specimens Contaminated with Chip Seal Oil (CRS-2P) which have been cleaned with spray liquid solvent, after slip coefficient testing

Summary of Test Results

These results indicate that there was no significant difference in slip coefficient between the specimens that have been blast cleaned within 24 hours and those that were tested more than 24 hours after blast cleaning.

The specimens with faying surfaces contaminated by dust, clayey-mud, or de-icing chemicals exhibited slip coefficient values which were higher than those obtained from tests on uncontaminated blast cleaned surfaces.

Attempts at using the household all-purpose cleaner, compressed air, 100 percent acetone, manual wire brushing, or mechanical wire brushing were completely ineffective in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P). The first two of these methods failed to remove any of the contaminate, while the use of acetone or wire brushing only served to distribute the contamination over a wider portion of the faying surface.

The use of automotive gasoline was ineffective in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P). The use of gasoline as a cleansing agent worsens the conditions, and actually resulted in a lower value for slip coefficient than was obtained originally from tests on the contaminated surfaces.

Similarly, the use of aerosol brake parts cleaner was ineffective in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P). The use of the aerosol brake parts cleaner as a cleansing agent worsened the condition, and actually resulted in a lower value for slip coefficient than was obtained originally from tests on the contaminated surfaces.

The use of 100 percent mineral spirits was slightly more effective than automotive gasoline, or brake parts cleaner, but did not fully succeed in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P). This method resulted in a slight increase in slip coefficient compared to the test results on contaminated surfaces.

The use of spray-on liquid organic solvents was much more effective than the use of mineral spirits or gasoline in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P). This method achieved a slip coefficient (μ) of 0.47, which was a considerable increase compared to the previously mentioned methods. While this is 6 percent under the specified value of 0.50, the method is probably acceptable with less severely contaminated faying surfaces.

The use of aerosol organic solvents was effective in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P) The aerosol organic solvent achieved a slip coefficient (μ) of 0.50, equaling the minimum slip coefficient values assumed in the AASHTO Bridge design Specifications.

The use of blast cleaning was completely effective in cleaning the faying surface after the surface had been contaminated with chip seal oil (CRS-2P), achieving values for the slip coefficient (μ) which were greater that the slip coefficient values assumed in the AASHTO Bridge design Specifications.

Conclusions

Based upon these test results, it appears that the passage of 24 hours, or the minor accumulation of rust, dust, mud, or a de-icing chemical does not adversely affect the slip resistance of the connections. Attempts at cleaning these materials might actually cause the slip resistance of connections to be reduced. If it is desired to remove these contaminates, it is suggested that these contaminates be removed with clean water only.

If chip seal oils or other contaminates need to be removed from the faying surface, blast cleaning was most effective method of cleaning the faying surface. The use of aerosol organic solvents was just barely effective, achieving the minimum slip coefficient values assumed in the AASHTO Bridge design Specifications. Environmental considerations on the use of the aerosol organic solvents would need to be addressed on a case by case basis. All the other methods tested for removing chip seal oils from the faying surfaces were shown to be completely ineffective.

REFERENCES

American Association of State Highway and Transportation Officials. *Standard Specifications for Highway Bridges.* 17th Ed. Washington, D.C.

American Association of State Highway and Transportation Officials. *LRFD Bridge Design Specifications.* 3rd Ed. Washington, D.C., 2004.

Idaho Transportation Department. *Standard Specifications for Highway Construction*. 1999.

Idaho Transportation Department. *Standard Specifications for Highway Construction*. 2004.

Kulak, G. L., J. W. Fisher, and J. H. Struik. *Guide to Design Criteria for Bolted and Riveted Joints*. 2nd Ed. New York: John Wiley & Sons, 1987.

Research Council on Structural Connections (RCSC). *Specifications for Structural Joints Using ASTM A325 or A490 Bolts*.Chicago: AISC, 2004.

SSPC: The Society for Protective Coatings. *SSPC-VIS 1, Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning*. SSPC Publication 02-12, Pittsburgh, PA, 2002.

SSPC: The Society for Protective Coatings. *SSPC Specification for Commercial Blast Cleaning*. (SSPC-SP-6) Pittsburgh, PA, 2000 (with editorial changes in 2004).

Yura, Frank, and Cayes, "Bolted Friction Connections with Weathering Steel," *Journal of the Structural Division*, Vol 107, No. ST11, Nov. 1981, pages 2071-2087.