Texas Transportation Institute

A METHOD FOR FRICTION TESTING OF OPEN GRATED STEEL BRIDGE DECKS

by

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Contract No. BC-857
Project No. 474160-1

Sponsored by
Florida Department of Transportation

January 2002

TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A & M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS 77843

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ACKNOWLEDGMENT

The author would like to thank the Florida Department of Transportation for support in obtaining friction data for use in this study. Gratitude is expressed to Bob Daniels and Larry Hewett for their involvement in providing those data and for assistance to the author while in Jacksonville.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
A METHOD FOR FRICTION TESTING OF OPEN GRATED STEEL BRIDGE DECKS	January 2002
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Richard A. Zimmer	474160-1
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. BC-857
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Florida Department of Transportation State Materials Office, Pavement Systems Evaluation 5007 NE 39th Ave. Gainesville, FL 32609	Final Report January 2001 - January 2002 14. Sponsoring Agency Code

15. Supplementary Notes

Research Study Title: “Development of a Standard Method for Friction Testing of Steel Grated Bridge Decks”

Name of Contacting Representative: Bouzid Choubane

16. Abstract

The primary objective of this work was to develop a standard method of determining the surface friction or skid resistance of open grated steel bridge decks. Standard methods of measuring pavement friction have been used for more than 40 years as means of judging the quality of pavement surfaces, as controls for new construction and as criteria for repair or reconstruction. The standardization of those methods led to the development of the American Society of Testing and Measurement (ASTM) Committee E17 on skid resistance in 1960. Since that time to the present, friction standards have been concerned primarily with roadway pavements such as concrete and asphaltic concrete. Hundreds of studies have been conducted on the measurement of the friction and texture of pavements with very few on other types of roadway surfaces.

In 1965, ASTM adopted Committee E17's standard E-274, Standard Method of Test for Skid Resistance of Paved Surfaces Using a Full-Scale Tire, which remains the primary method for evaluating roadway pavements in the United States to the present time.

The findings of this study showed that the E-274 test method, with an E-501 ribbed tire, produces friction values similar to those of a radial passenger car tire, E-1136, on either a paved surface or open grated steel bridge. Based on these results it was recommended to ASTM committee E17.21, during the December 2001 meeting, to include open grated steel bridges into ASTM Standard E-274, as a road surface that may be measured by this method, without modification, but with proper documentation as to the type of surface. It was also recommended that states be allowed to determine acceptable Friction Number values for the open grated steel bridge deck maintenance, just as they now do for pavements.

In addition to the friction of bridge decks, steering stability was investigated and was found to have no adverse effects while on the bridges tested. Also during the study a coating was located and evaluated that could increase the friction of steel bridges if needed.

17. Key Words	18. Distribution Statement
Bridge decks, friction, steel bridges, steering stability	Copyrighted. Not to be copied or reprinted without consent from Sponsor.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	31	

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I. INTRODUCTION

The primary objective of this work was to develop a standard method of determining the surface friction or skid resistance of an open grated steel bridge deck, an example of which is shown in Figure 1. Standard methods of measuring pavement friction have been used for more than 40 years as means of judging the quality of pavement surfaces, as controls for new construction and as criteria for repair or reconstruction. In 1958 the First International Skid Prevention Conference in Charlottesville, Virginia was convened to standardize commonly used measuring methods. The standardization of those methods led to the development of the American Society of Testing and Measurement (ASTM) Committee E17 on skid resistance in 1960. Since that time to the present, friction standards have been concerned primarily with roadway pavements such as concrete and asphaltic concrete. Hundreds of studies have been conducted on the measurement of friction and texture of pavements with very few on other types of roadway surfaces.

Figure 1. An Open Grated Steel Bridge Deck.

In 1965, ASTM adopted Committee E17's standard E-274, Standard Method of Test for Skid Resistance of Paved Surfaces Using a Full-Scale Tire, which remains the primary method used in the United Stated to the present time. Every jurisdiction surveys its road system using method E-274 to obtain the friction characteristics to input to its pavement management program.

Since method E-274 was originally conceived with the measurement of paved roads being the primary concern throughout the country, other road surfaces were overlooked or simply not addressed directly. As road safety and accident causation is becoming more important to state agencies, it is imperative to include the atypical road surfaces, such as bridges with open grated steel decks, in a measurement program. To do this properly, it must be shown that a standardized test method, such as ASTM E-274 is applicable to measuring the roadway surfaces of steel bridge decks as well as pavements. This study will attempt to show that measuring either pavements or steel bridge decks, with method E-274, will produce results that may be used in a state road management program to assist in determining maintenance requirements.

This study will address only the measurement of friction on open grated steel deck bridges and not what those values should or should not be. Just as with the friction measurement of pavements, the maintenance criteria should be left up to each state or local agency.

Other objectives of the study were to determine if open grated steel bridge decks contributed to vehicle instability by producing lateral forces at the tire interface. If these forces existed, they would produce lateral oscillations in the vehicle which could be detected by acceleration recording equipment.

Methods of improving the friction of steel bridges would also be investigated during this project.

II. STUDY APPROACH

To determine the best method for friction testing of open grated steel bridge decks, a review of several pavement friction techniques was made. The first to be considered was ASTM method E-274, which uses a trailer pulled by a truck and is the most widely used highway friction measurement method in the United States. The E-274 method measures drag force of one of the trailer wheels after it is braked to a stop, with water applied ahead of it. This method was the primary consideration since most state agencies have at least one of these systems.

Other methods considered were the MuMeter E-670, Diagonal Braked Vehicle E-503, and several European devices. These devices were subsequently rejected due to their inappropriateness to bridge testing or the burden on the states to acquire a new device to test only bridge decks.

Once the ASTM E-274 method was determined to be the prime candidate for steel bridge deck testing, the task at hand was to determine if any undesirable, unpredictable, or unexplainable data were generated by using this method on open grated steel bridge decks. Also an automobile type radial test tire, ASTM E-1136 would be used to judge the results of the results of the pavement and steel bridge deck testing.

Steel Deck Bridge Testing with a Single Wheel, Two Wheel E-274 Systems, and an Automobile

Test data were reviewed from two recent studies in the state of Florida. The friction testing part of the first study(1) was conducted with the ASTM E-274 friction measurement system, the Penn State University single wheel friction tester and an automobile using an accelerometer. Eight bridges were tested in both the traffic and passing lanes. Upon reviewing this work, a summary has been developed and is presented in Figure 2. The friction testing and stopping tests have been normalized to reflect friction numbers (FN) for comparison in this graph. The sixteen sets of data have been averaged in the last set of bars. This average shows that the highest friction values go to the automobile at FN47. Close behind that number are the two E-274 systems at FN42 and FN43. The single wheel friction tester produced an average friction value of FN34. These numbers are reasonable since the automobile tire tread contains more rows and groves than the E-501 test tires and would provide additional friction from the interaction with the vertical steel sections of the deck. The lower numbers of the single wheel tester could be due to the location of the test wheel during the lockup, which could be found in an oil contaminated area between the traffic wheel paths. The automobile and E-274 two wheel tester numbers show that these bridges, which range from FN35 to over FN50, are within an acceptable friction range.(2) The difference in friction values of the travel lanes and the passing lanes was also looked at and appears to be insignificant, averaging one friction number difference.

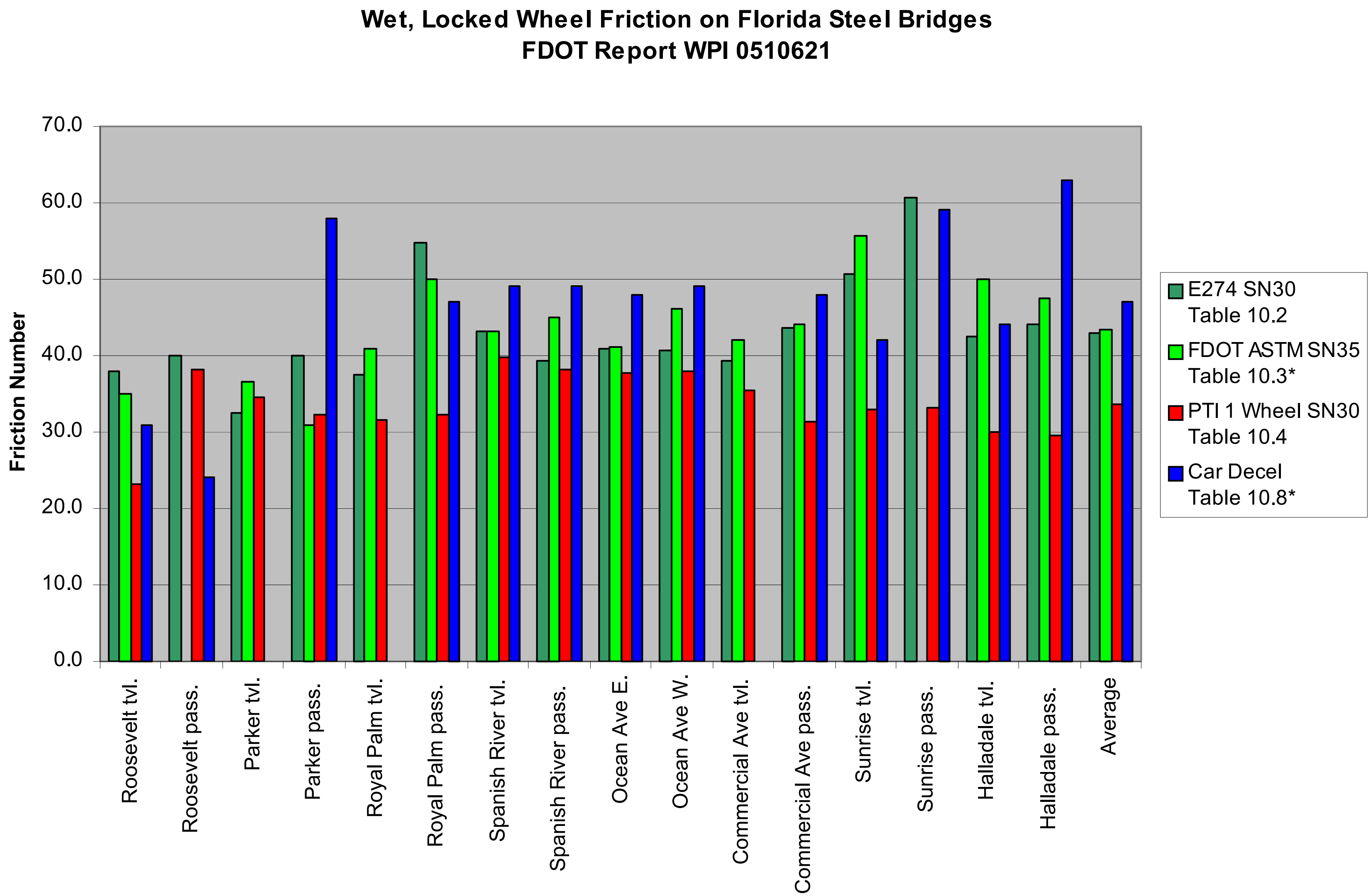


Figure 2. Wet, Locked Wheel Friction on Florida Steel Bridges.

The Jacksonville, Mathews and Main Street bridges were friction tested by CDRM in March of 2000.[3] This testing was done with the E-274, two wheel, tester and an automobile with accelerometer conducting wet, locked wheel, stops (ASTM E-445). The results of this study are summarized in Figure 3a and 3b. Again the automobile with radial tires produced the higher friction numbers in the range of 55 to 60 whereas the ASTM trailer with the E-501 tire showed friction numbers from 33 to 37 on both bridges. Again there is more available friction for the vehicles with radial tires than the E-274 system reports.

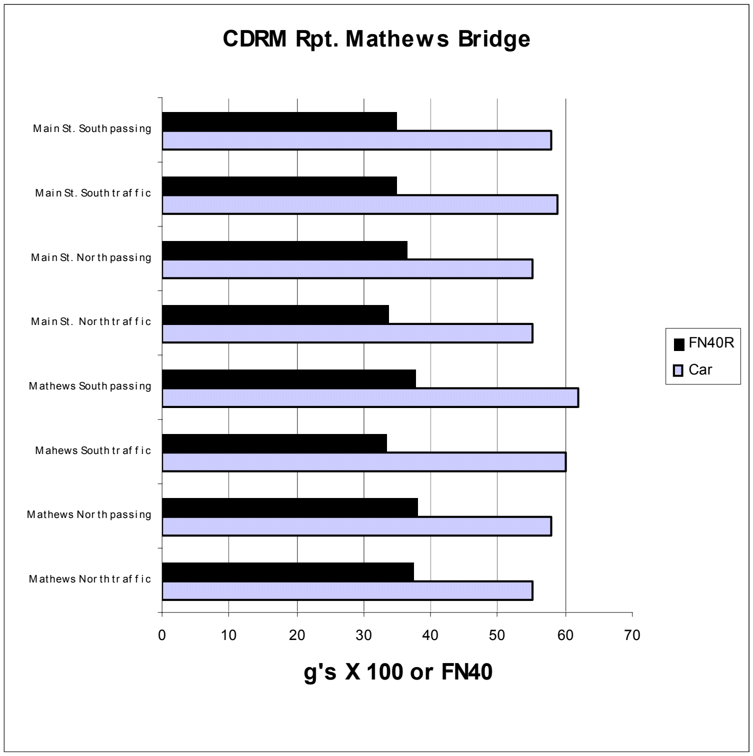


Figure 3a. Friction Testing by CDRM on the Mathews Bridge.

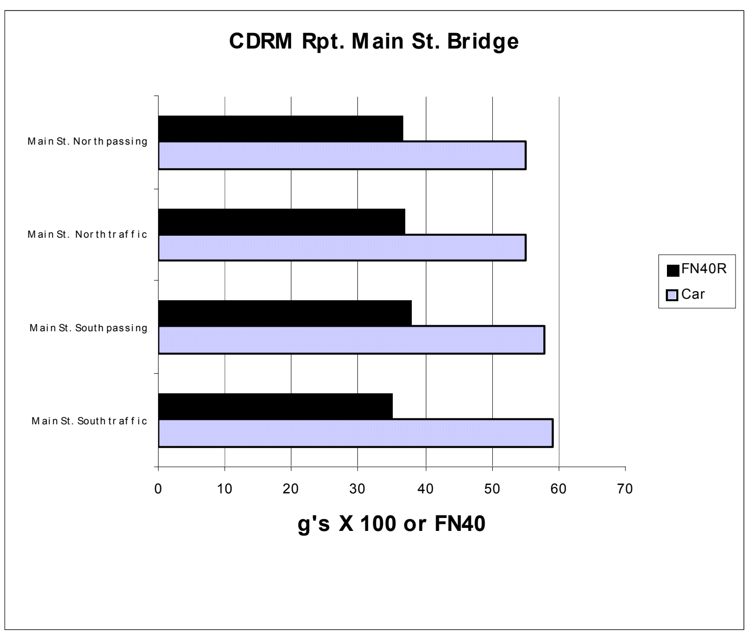


Figure 3b. Friction Testing by CDRM on the Main Street Bridge.

FDOT Testing of Open Grated Steel Bridge Decks

To provide additional data for this study, the Florida Department of Transportation (DOT) friction group assisted in the collection of real world data using one of their E-274 systems. They friction tested four, open grated steel deck bridges and the approach pavement to each in the Jacksonville area. Three of the decks were the newer 5-way design: the Main Street, Shands, and Sisters bridge. The Matanzas bridge was the 4-way type. Testing was done with three ASTM standard tires: the E-501, E-524, and the E-1136, to discover any anomalies with the deck/tire combinations. The E-1136 closely represents the tires found on automobiles and was included to insure we have a relationship back to the friction levels motoring public finds on the steel bridges as we now do on pavements. The runs were made at 10, 20, and 40 mph to investigate any speed gradient issues. Three repeats were made at each test condition and averaged.

The data matrix then consisted of four bridges, three tires, three speeds, and three repeats (108 runs). All runs were made with internal water. Two runs were made with no water (dry) on the Main Street bridge with an E-501 tire. The results of the dry runs were friction numbers of 98 and 103 and the driver had trouble holding speed because of the drag. These were unexpectedly high numbers. Examples of these steel bridge decks are shown in Figures 4 and 5.

In addition to friction testing, the effects of open grated steel deck bridges on vehicle stability was investigated. Lateral stability of a full size automobile was recorded on the same bridges in the Jacksonville area that were tested for friction. This was done with a precision electronic accelerometer whose data were digitally recorded and later saved to a laptop computer. This research will be discussed further in section IV.

At the 40-mph test speed it appears that all bridges, with all tires, run between SN30 and SN40, with the E-524 smooth tire typically running 2 to 3 SN below the E-501 rib tire. These data are shown in Figures 6, 7, 8, and 9 for the four bridges. This would indicate that it should not matter which test tire is used to evaluate the bridge decks. It was initially thought that the E-1136 car tire would produce noticeably higher numbers due to the tread design interacting with the steel deck ribs, but an increase of only a few friction numbers was observed.

Using the E-501 and E-1136 tires, the four approach pavements produced slightly higher friction values than the bridges in all cases. Importantly, the differences between the radial tire and the E-501 test tires were very small for the pavements and also for the bridge decks. In other words there was close agreement between the radial tire and the E-501 tire on the pavements and there was close agreement between the radial automobile tire and the E-501 tire on the steel bridge decks. This information and data from previous studies show that using the ASTM E-274 method to obtain friction numbers on open grated steel bridge decks is comparable to those obtained on pavements as they related to the E-1136 radial tire.

The E-524 smooth tire, on the other hand, showed that the steel bridge had higher friction than the pavement in three of the four sites. This was due to the friction numbers of the pavement being lower for the smooth tire than the radial or the E-501 test tire due to texture. Also, the

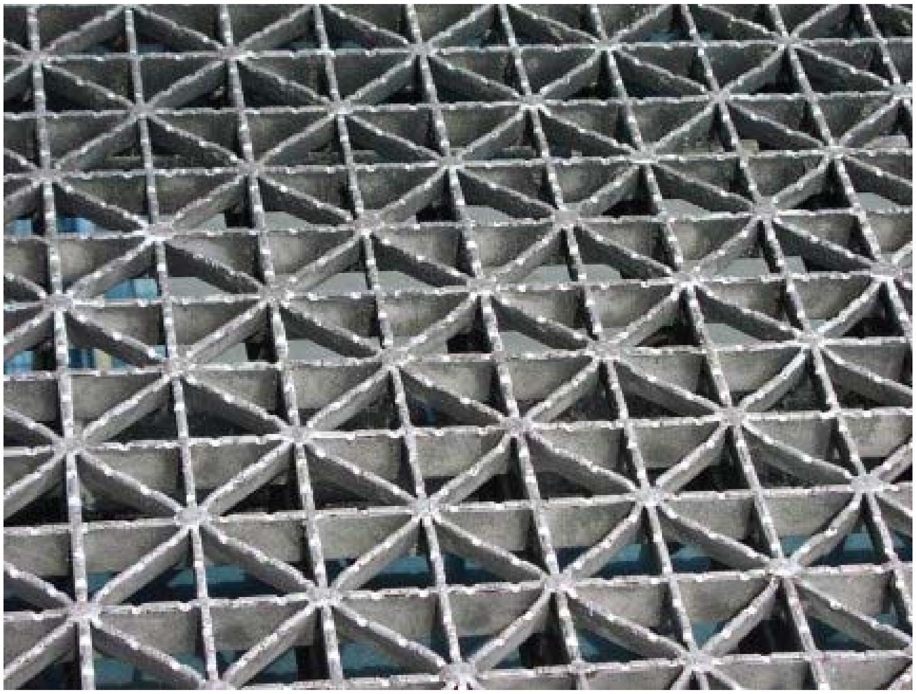


Figure 4. 5-way Steel Bridge Deck.

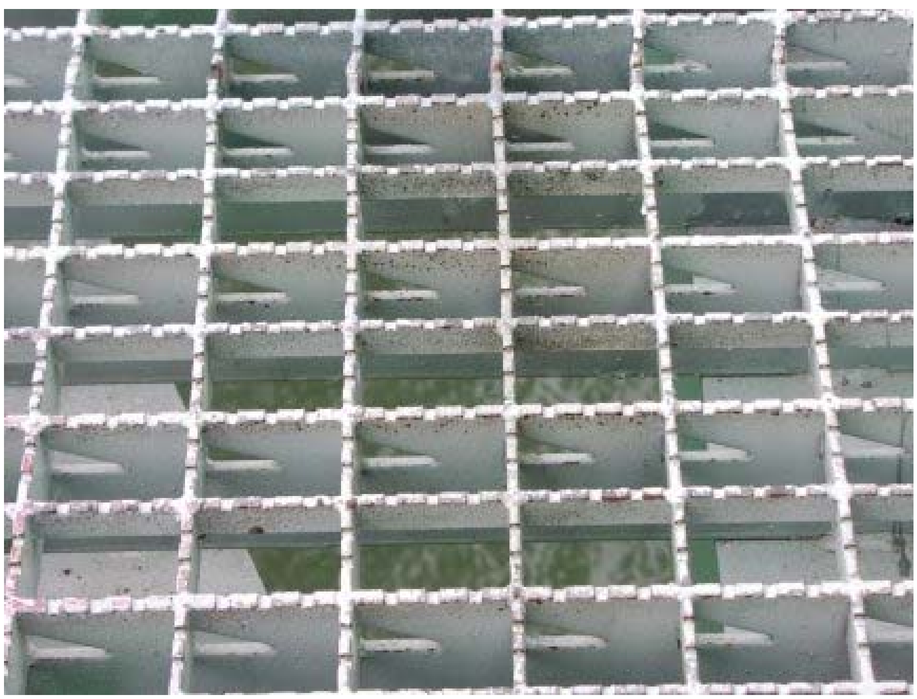


Figure 5. 4-way Steel Bridge Deck.

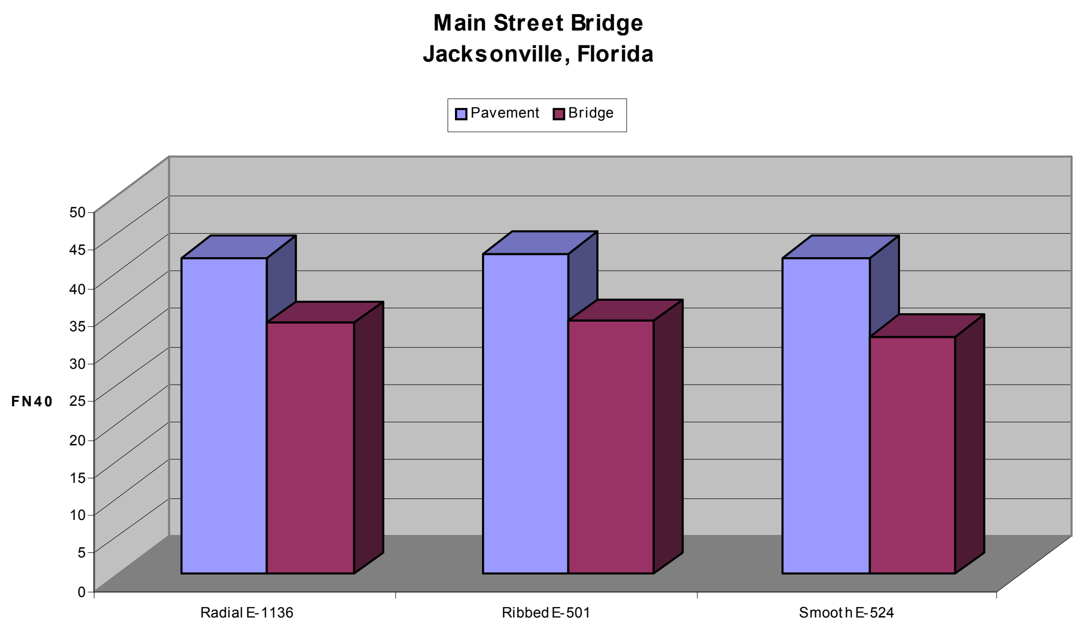


Figure 6. Comparison of SN for Tires on Main Street Bridge.

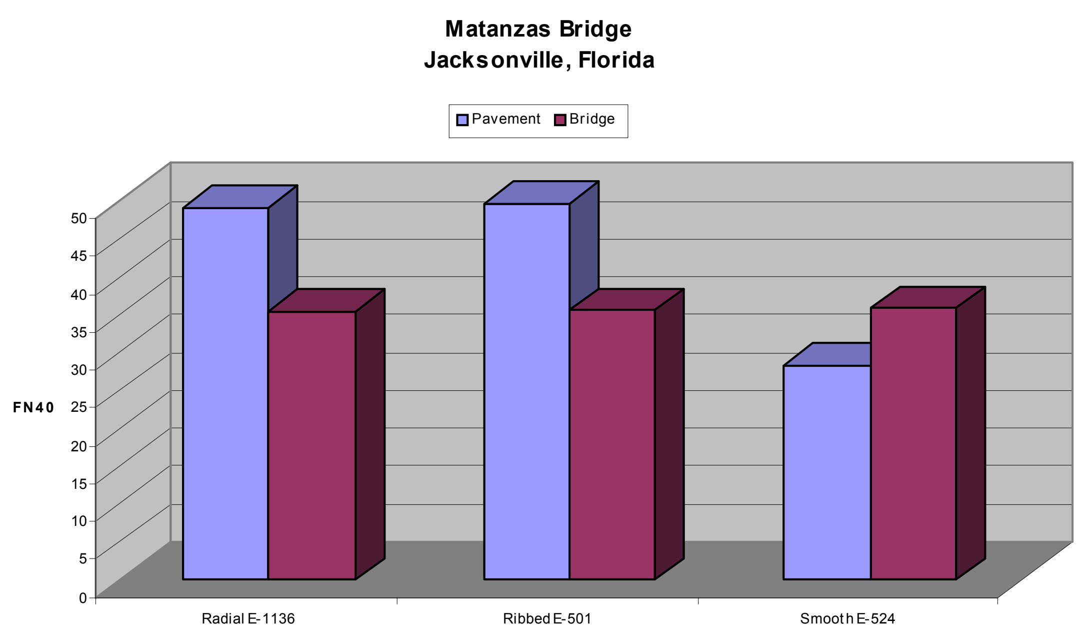


Figure 7. Comparison of SN for Tires on Matanzas Bridge.

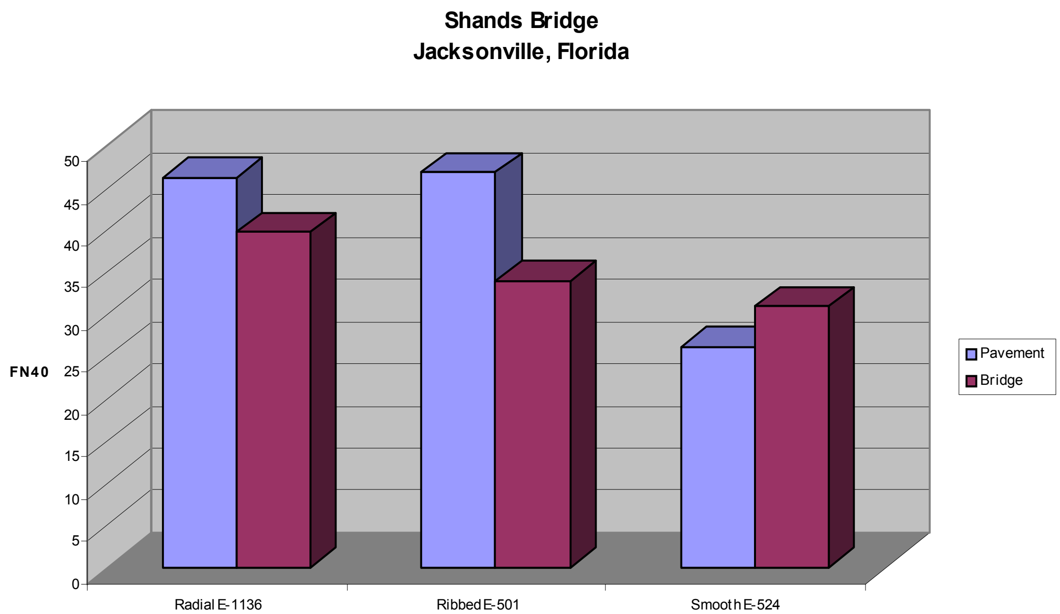


Figure 8. Comparison of SN for Tires on Shands Bridge.

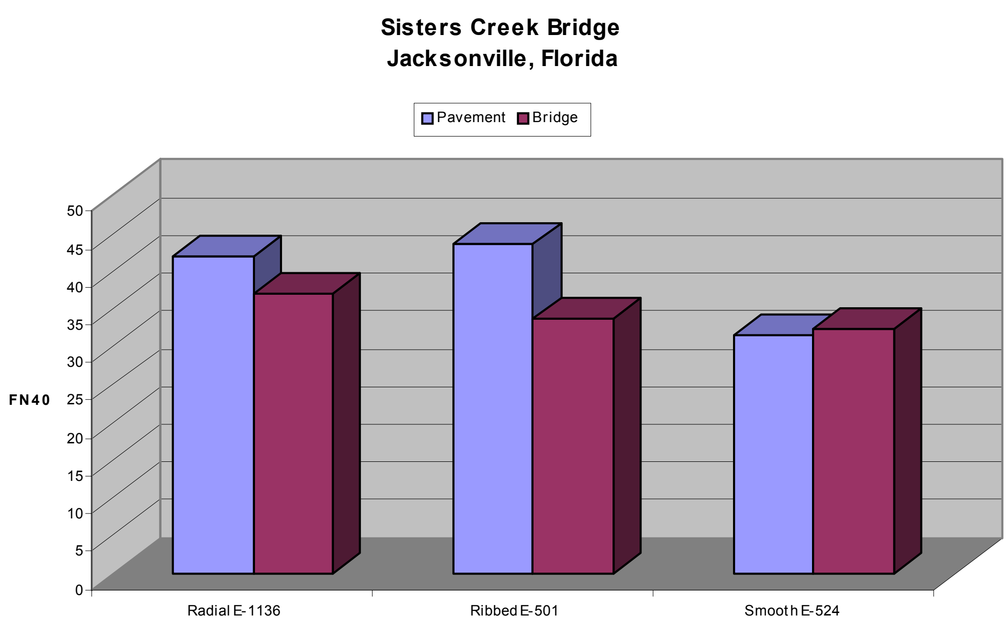


Figure 9. Comparison of SN for Tires on Sisters Creek Bridge.

friction numbers obtained on the bridge decks with the smooth tire were close to the numbers using the other two test tires. This effect is described more fully in the section on Texture and Speed Gradient.

E-274 Friction Trailer Stability on Steel Bridge Decks

To investigate the possible instability or yaw of the two-wheel trailer during a single wheel lockup on the steel bridge, an experiment was conducted on the Main Street Bridge in Jacksonville to document the magnitude of any yaw of the trailer. Should the test trailer move sideways or yaw while the left test tire is braked, a cosine error would be produced in the reported drag force. This means that an eight degree yaw would produce a 1% measurement error.

While following the FDOT Friction Measurement System, a series of photos was taken from directly behind the trailer before and during locked wheel friction tests. Two of those photos are shown in Figures 10 and 11. By scaling the photos and taking measurements between the left trailer jack and the truck's left tail light, it appears that the rear of the trailer moved to the right by 3 inches when the left wheel was locked. With a typical distance of 14 feet from the ball hitch to the rear of the trailer, an angular change of about one degree is produced. This angle then shows up in the friction data as a cosine error of 0.02 percent, which is insignificant. This amount of yaw is similar to that measured at the Texas Transportation Institute (TTI) Proving Ground on several pavements. It appears that the very high dry friction values of the steel deck contribute to considerable side friction of the unbraked trailer wheel maintaining the trailer in a straight path.

Figure 10. FDOT Friction Measurement System on Main Street Bridge Before Testing.

Figure 11. Rear of FDOT Friction Measurement System During a Locked Wheel Friction Test.

III. TEXTURE AND SPEED GRADIENTS

The roadway texture of an open grated steel deck bridge is unique and unlike any pavement. With road surfaces, friction is a function of both microtexture and macrotexture. Microtexture has been defined by ASTM as the deviation from a true planer surface with heights less than 0.5 mm. Macrotexture is defined as surface deviations greater than 0.5 mm. Clearly the open grated steel bridge deck has very high macrotexture and low microtexture. In addition to the edges of the steel grate, additional macrotexture has been added to the steel by adding semicircular notches, several millimeters deep, in the top edge during manufacturing. These notches can be seen in Figures 4 and 5.

The relationship between wet friction and speed is clearly based on the drainage capability of the tire-pavement contact patch. With pavements, this drainage capability is related to the surface texture. With the multitude of pavement types and wear it is important that this drainage effect be measured on road pavements. This is done several ways by use of static and dynamic texture measurement devices and indirectly by the use of a smooth E-524 tire on the E-274 Friction Measurement System. Water drainage is not a problem with the open grated steel decks since the majority of the water applied to the surface passes through the open portion of the grating. What water remains is a thin film on the top of the steel grate. Microtexture could exist on the top of the steel grate if a coating of galvanize is present or a coating is applied which contains fine grain particles such as sand or ceramic grit to the steel that would resist traffic wear. The latter is discussed later in this report under "Methods of Increasing Friction of Open Grated Steel Bridges."

Friction that develops between a tire and roadway has two components, adhesion and hysteresis. Hysteresis reflects the energy loss that occurs as the rubber is alternately compressed and expanded. Thus as the tire slides over the irregularities of a high macrotexture surface, such as the steel grate, friction develops even if the surface is perfectly lubricated. The hysteresis contribution usually is fairly independent of speed and because the adhesive friction component on wet surfaces tends to decease with speed, the hysteresis component provides a friction benefit at the higher speeds.[4]

If hysteresis is the primary contributor to friction, on open grated steel deck bridges, then the measured friction values should be fairly independent of speed. The Speed Gradient is a measure of locked wheel friction as the speed is changed. This is the slope of the line when plotting friction numbers versus speed. Speed gradient plots were produced on each of the four test bridges on both the open grated steel deck and the approach pavement adjacent to the bridge. This was done with the three ASTM test tires, E-501, E-524, and the E-1136 at test speeds of 10, 20, and 40 miles per hour. Figures 12 through 19 show the results of this study. The results are consistent with the theory that the major contribution to friction on these bridges is the rubber hysteresis due to the large amount of macrotexture. Between 20 and 40 mph on the steel deck, the friction numbers drop very little except for some cases with the smooth E-524 tire. It could be expected that with speeds above 40 mph the friction numbers would continue at or near these levels where a pavement would continue to decrease. The Matanzas bridge produced an atypical

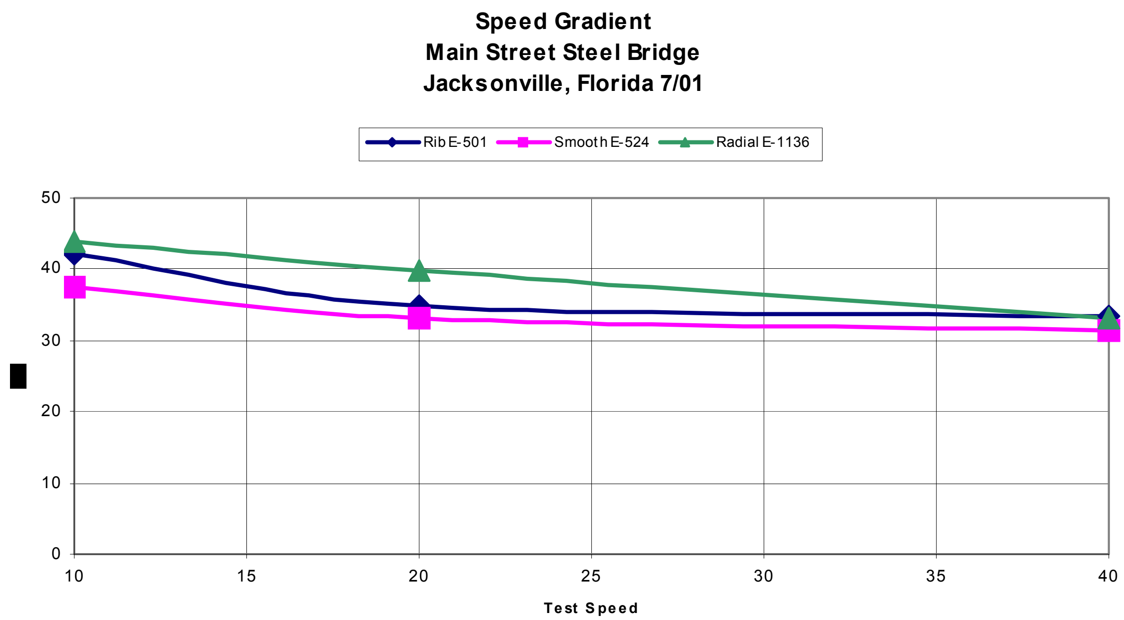


Figure 12. Speed Gradient for Main Street Steel Bridge.

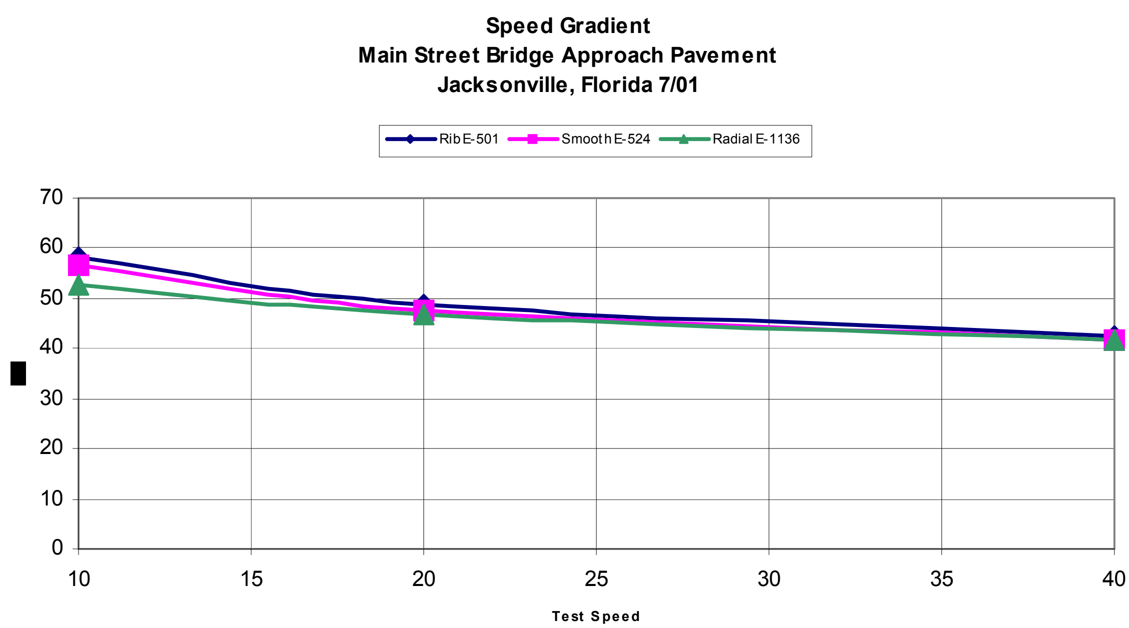


Figure 13. Speed Gradient for Main Street Bridge Approach Pavement.

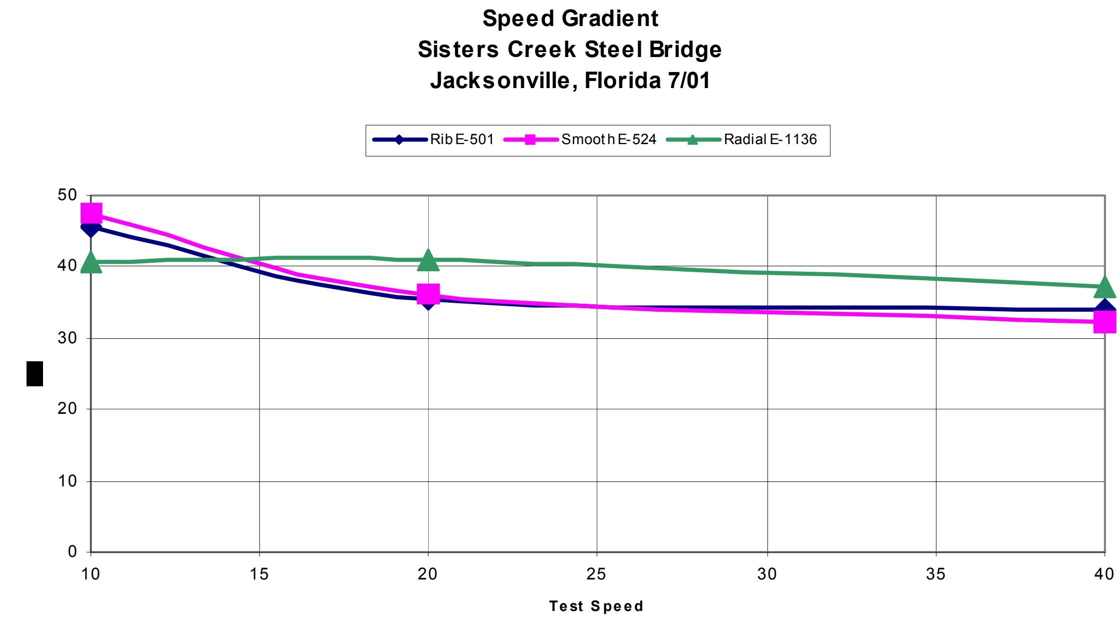


Figure 14. Speed Gradient for Sisters Creek Steel Bridge.

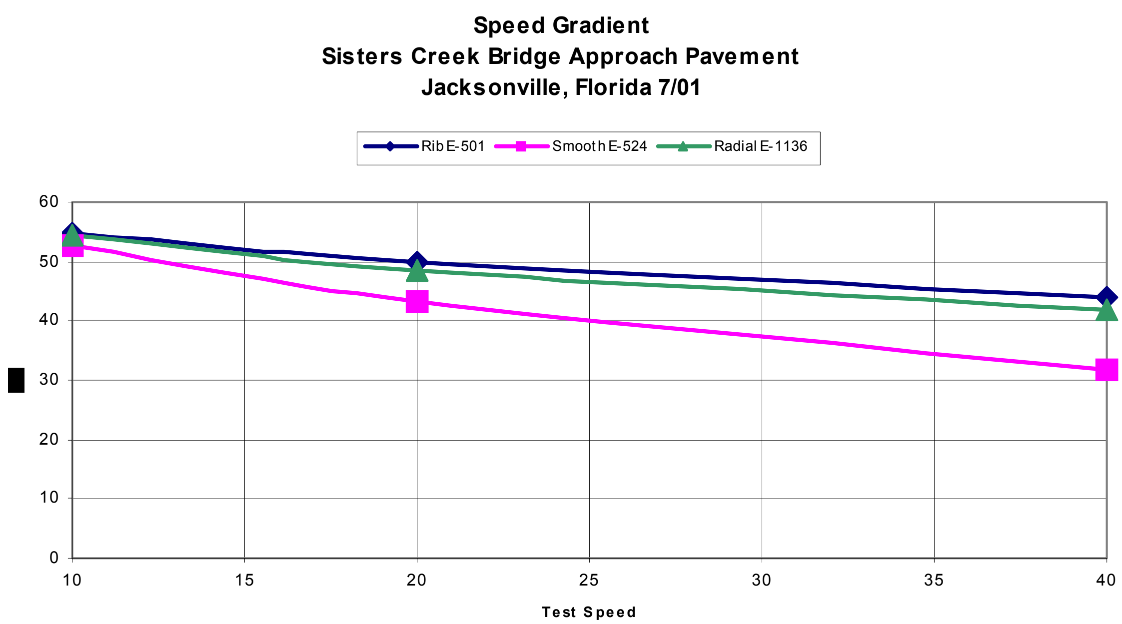


Figure 15. Speed Gradient for Sisters Creek Bridge Approach Pavement.

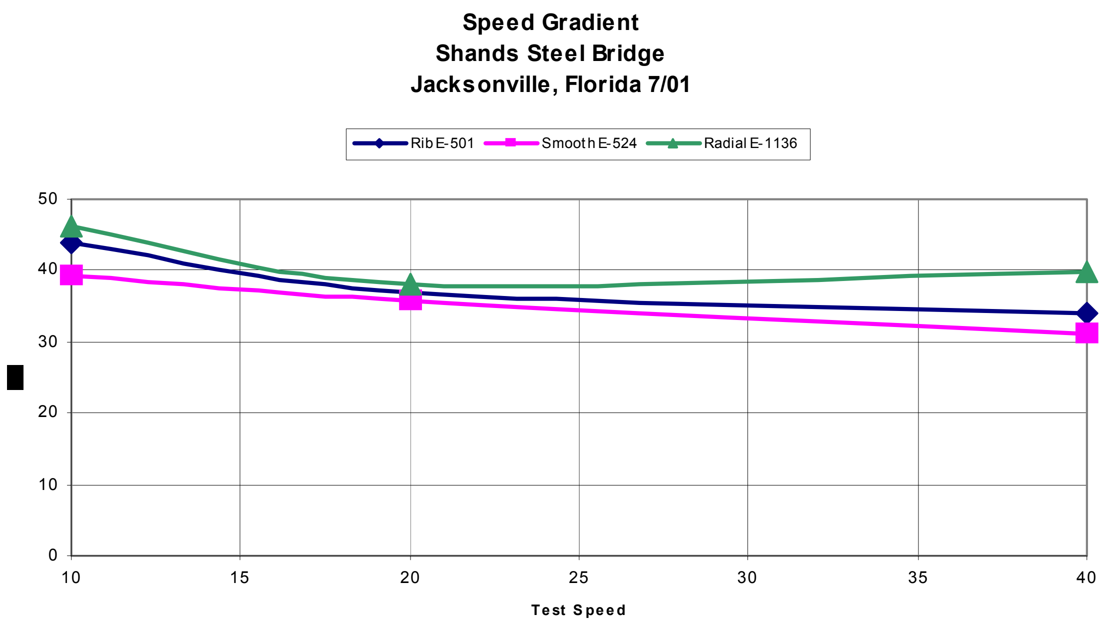


Figure 16. Speed Gradient for Shands Steel Bridge.

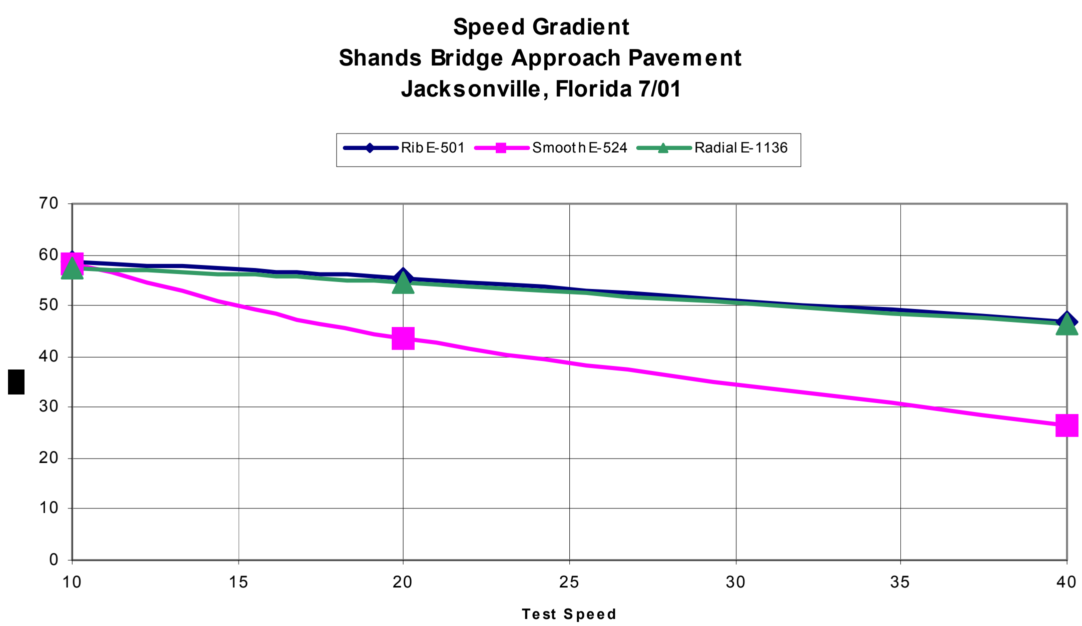


Figure 17. Speed Gradient for Shands Bridge Approach Pavement.

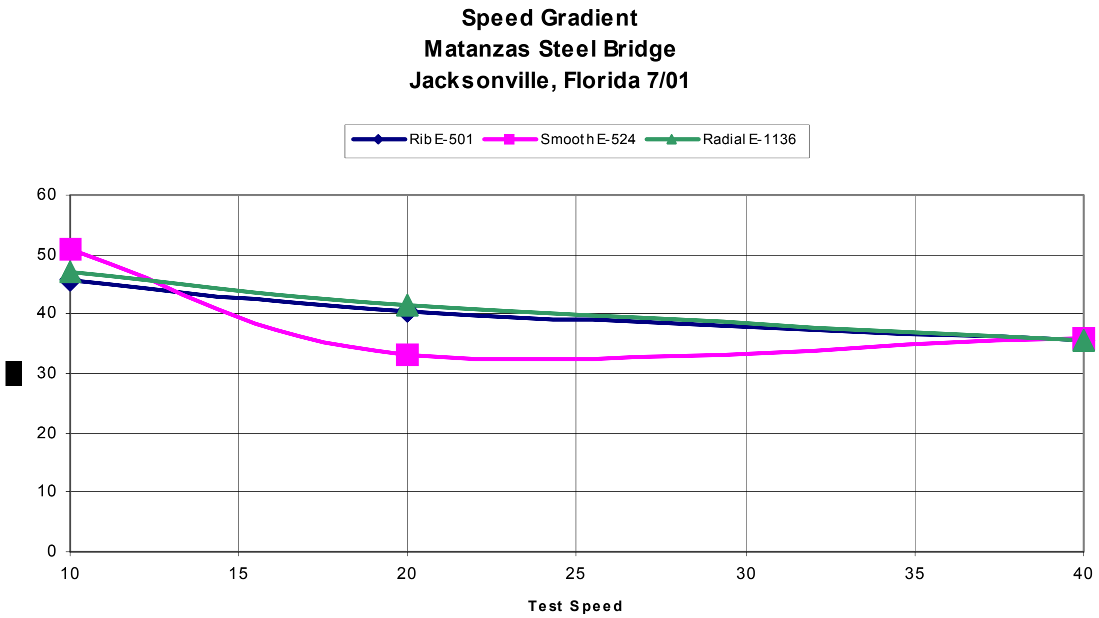


Figure 18. Speed Gradient for Matanzas Steel Bridge.

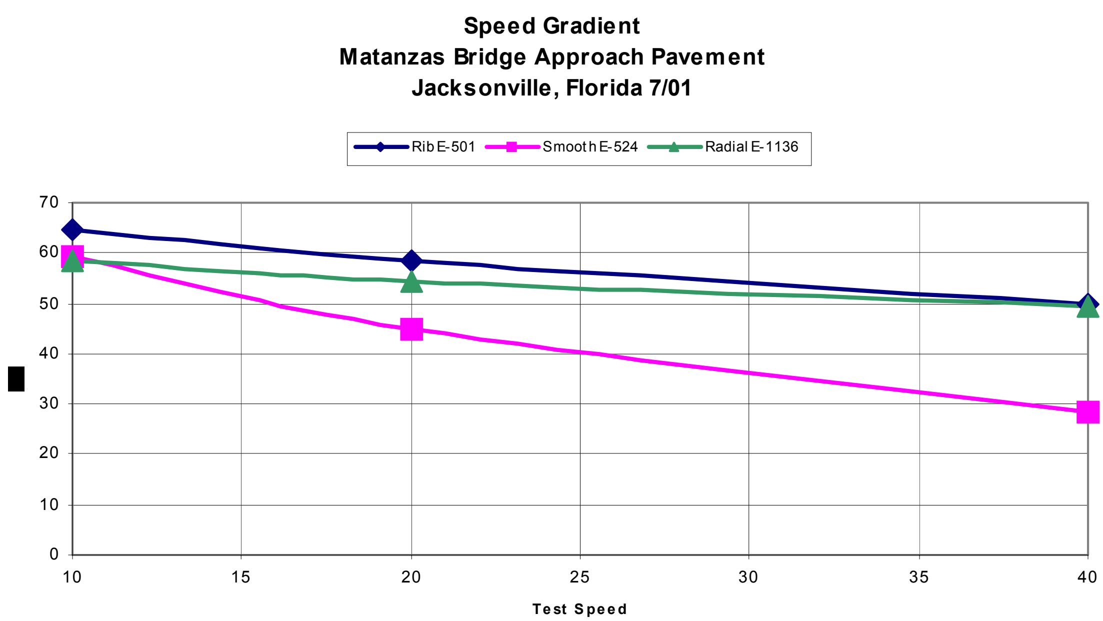


Figure 19. Speed Gradient for Matanzas Bridge Approach Pavement.

speed gradient with the smooth tire, where the friction value increased slightly between 20 and 40 mph, which could be attributed to the 4-way design of this particular bridge.

The measurements of the approach pavements to these bridges, made with the same three reference tires at the same speeds of 10, 20 and 40 mph, show similar gradient curves between the radial and ribbed test tires. The E-524 smooth test tire produces dramatically lower friction numbers between 20 and 40 mph on three of the four approaches. This effect is due to macro and micro texture differences in these pavements and has nothing to do with the bridge decks.

Since drainage is not a problem with open grated steel bridges and speed gradient testing has shown comparable values between the ribbed E-501 and the smooth E-524 tires, and both of those tires compare favorably to a radial passenger tire, it is not recommended that either of these tires be used exclusively for testing on open grated steel bridge decks but the decision be left up to the testing agency to which standard tire to use. Use of either the E-501 or the E-524 test tire is consistent with the current specifications of ASTM Standard E-274.

IV. VEHICLE STABILITY ON OPEN GRATED STEEL BRIDGES

When people move there are many visual and non-visual clues that can inform them about their movement. Physical force turns out to be a particularly potent cue: not only does it evoke an exaggerated sensation of motion, but it also tends to dominate other cues.[5] Any movement of the body that changes its velocity induces forces on the body itself and on the structures within it. The inner ear is made up of semicircular canals and the otoliths which detect angular and linear accelerations of the head. For whole-body linear accelerations, the threshold seems to be around 0.1 m/s^2 and extends upward to 0.25 m/s^2. [6] This equates to a threshold range of acceleration from 0.01 g to 0.026 g, where a driver begins to notice a side motion.

If a driver encounters lateral or side-to-side accelerations somewhere above this threshold and their vision shows no reason for this, they could perceive that some corrective measure needs to be taken but not sure why. This happens in everyday driving with common external forces acting on the vehicle. Wind would be one of these forces that if blowing on the side of a vehicle would cause it to move or accelerate slightly to one side. This would then require an equal and opposite force in the other direction, by the driver moving the steering wheel, to maintain a straight path. Road grooving has been known to produce unexpected lateral accelerations, or wobble, of motorcycle wheels. This is due to the motorcycle tire tread aligning itself in the grooves and once aligned, opposing forces to break that alignment. As the motorcycle driver exerts forces to move across the pavement, a jerk is encountered as the side force finally exceeds the groove alignment force and the new path may exceed that which the driver had planned on, requiring more steering corrections. Since the motorcycle has only two tires, groove tracking can become a serious problem.

It has been suggested that this same effect could be taking place with automobiles on open grated steel deck bridges. To investigate this possibility, very sensitive accelerometers were used in passenger cars to attempt to measure any abnormal lateral oscillations or jerks caused by the open grated steel bridges. The first testing was done in Jacksonville, Florida in July of 2001 in conjunction with the FDOT friction testing. The same four bridges involved in friction testing were driven, in a dry condition, with a 2001 Chevrolet Lumina with P205/70R15, B.F. Goodrich tires at a nominal speed of 30 to 40 mph. The results of 17 test runs showed that none of the bridges produced a wobble or unstable feeling to either the driver or the passenger in the car. Also, none of the recorded accelerometer readings showed significant oscillations much above the threshold level. Typical graphs from these measurements are shown in Figures 20 and 21. Figure 20 is a nine and a half second run across the Jacksonville, Main Street bridge deck. No pattern of oscillation or instability is observed. One perturbation at two seconds is believed to be a small driver correction, using the steering wheel. For comparison, the second graph shows data that were taken on the paved approach road to the bridge. Again a small single sine wave is apparent at the end of the run and is probably driver input. The majority these runs are similar to each other in frequency and amplitude and should be considered normal background road noise and quite controllable. The open grated steel bridge and the pavement produced very low levels of lateral acceleration, near the human threshold levels of detection, but nothing that should cause a driver to make a drastic steering correction.

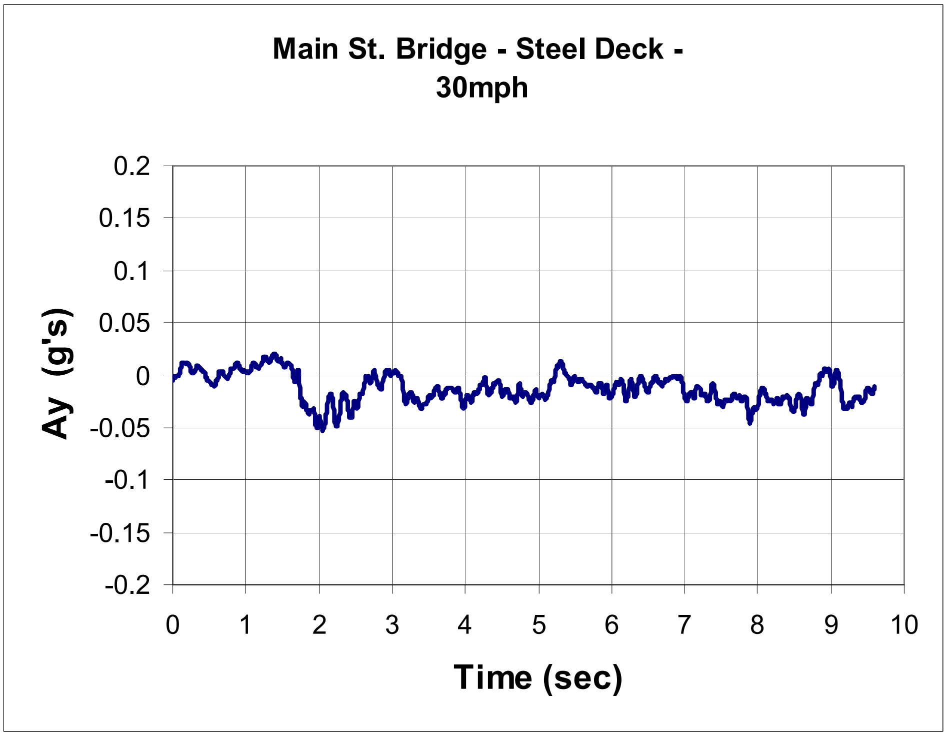


Figure 20. Lateral Acceleration Measured on Main Street Bridge.

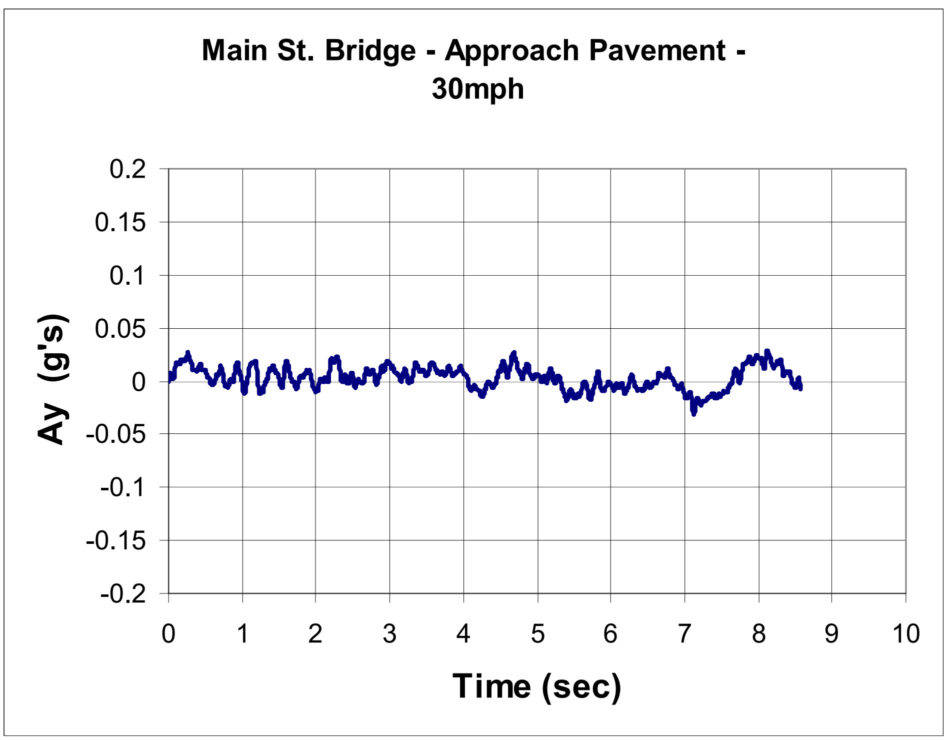
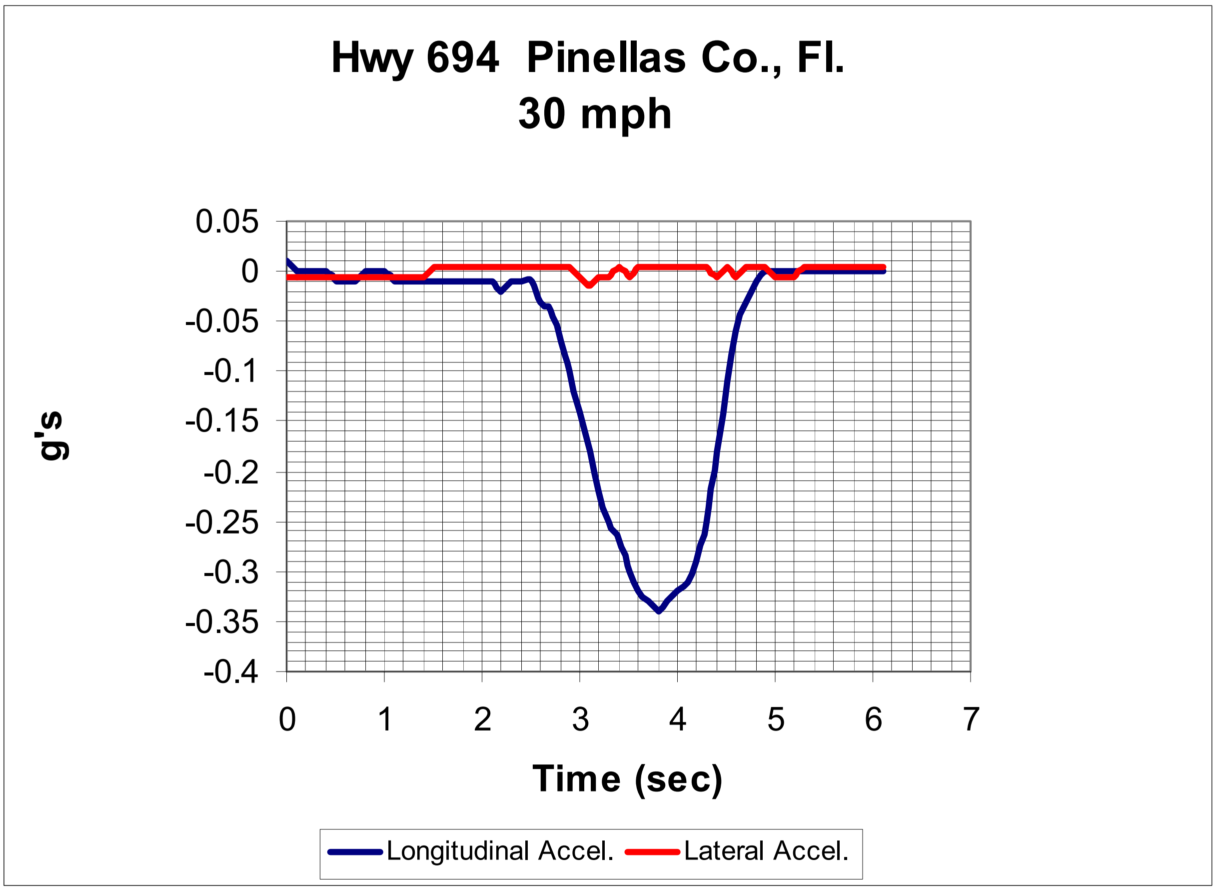


Figure 21. Lateral Acceleration Measured on Paved Approach Road to Main Street Bridge.

After the Jacksonville data were reduced and analyzed, finding no problems, a question was raised about the effect of applying brakes on lateral stability on the open grated steel bridges. To resolve this question a trip was made to Pinellas County, Florida where six open grated steel bridges along the Intracostal Waterway were measured using a 2002 Chevrolet Malibu and a Valentine Research, g-analyst recording accelerometer system. The g-analyst is a two-axis unit that will record both lateral, side-to-side acceleration and longitudinal acceleration, which is acceleration due to braking. These bridges ranged from 110 feet to 140 feet in length and were tested at 30 and 40 mph. Figure 22 shows the lateral acceleration in red and the longitudinal in blue. Brakes were applied briefly and vigorously to attempt to produce a lateral effect. Another reason for the pulse brake was because the traffic flow would not allow braking to a complete stop. As can be seen, the braking produced no significant change in the lateral



acceleration.

Figure 22. Longitudinal and Lateral Accelerations Measured in Pinellas County, Florida.

Another experiment conducted on these bridges was a lane change maneuver to observe any anomalies in tracking while turning to the left, to the right, and then back to center. This maneuver will normally produce a sine wave, or a near sine wave with human inputs. Any instability would start to show itself as a jagged lateral acceleration line rather than smoothly following the input of the driver. Figure 22 shows the typical results of these lane change trials that do show the vehicle, rather smoothly, following the steering input.

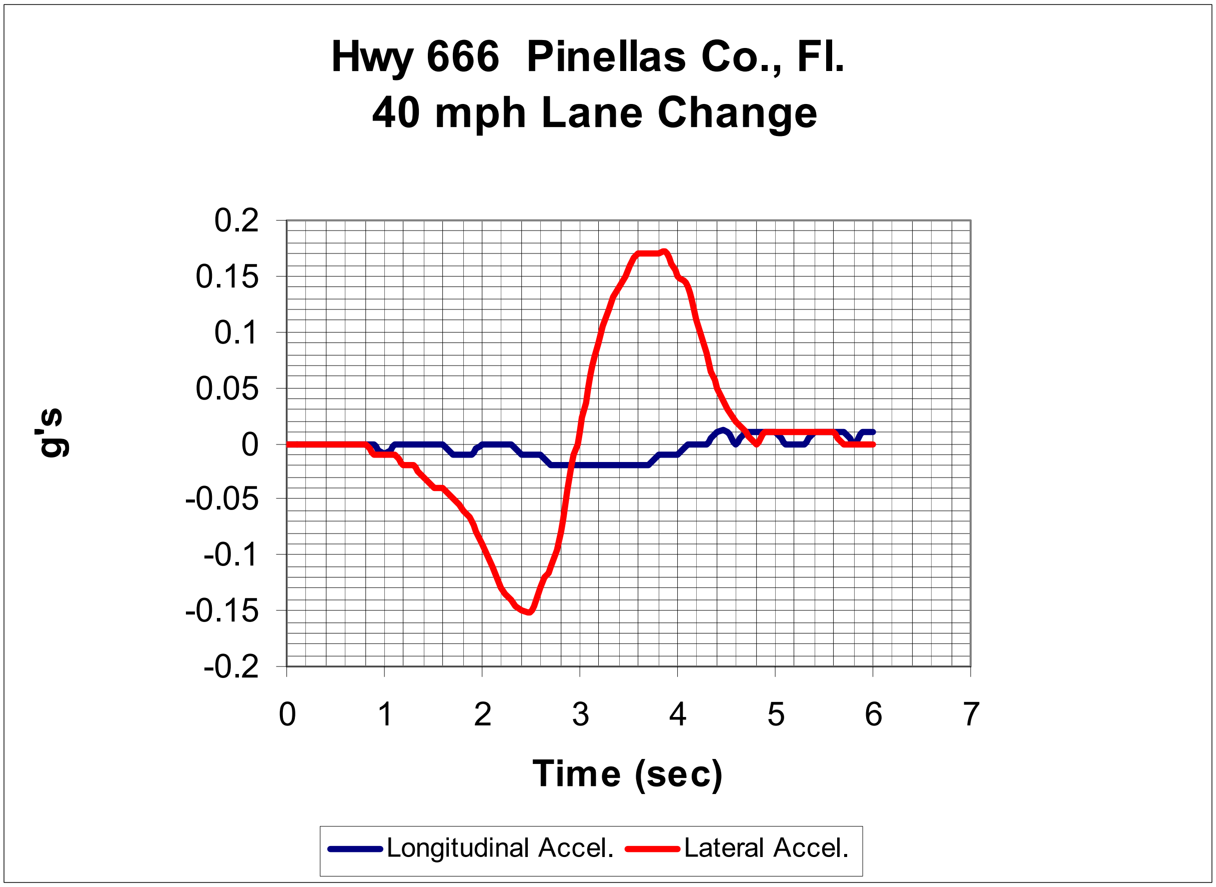


Figure 23. Lane Change Maneuver Tracking Steering Input.

After driving or riding over ten steel grated steel bridges as part of this project, and taking objective and subjective measurements while traveling straight, braking and turning, no instability was detected at any time. Only a limited number of vehicles and tires were tested on these decks and perhaps a different vehicle/tire combination could have produced different results but is unlikely. Testing all passenger vehicles and tire combinations was outside the scope of this project.

In an effort to gain more insight into a driver's response to lateral disturbances as relates to loss of control, Dr. Walter Wierwille with Virginia Polytechnic Institute and State University was contacted. Dr. Wierwille is a renowned human factors researcher in the field of transportation. One of his conclusions was "I believe based on all of the research results we have with lateral disturbances, that there are no dry conditions under which an automobile driver might lose control. Basically, a driver tries to keep the longitudinal axis of the vehicle roughly aligned with the direction of travel. Therefore, if there were rapid buildup of yaw, the driver would quickly correct this resulting in a stable trajectory."

Unlike grooved pavement, the open grate is made up of longitudinal, lateral, and diagonal grates within inches of each other, that are covered by the footprint of the tire which should, as the data suggests, alleviate the problem of groove tracking. With the lack of hard evidence that open grated steel deck bridges produce uncontrollable or significant steering forces on vehicles combined with the statement from Dr. Wierwille, it appears unlikely that these bridges, by the nature of their construction, contribute to dry weather accidents.

Methods of Increasing Friction of Open Grated Steel Bridges

The final task in this project was to investigate methods of increasing the friction levels of the open grated steel bridges. This would be either a treatment of the steel itself or a coating that could be applied to the steel grates in an effort to increase the microtexture of the roadway. As can be seen from Figures 4 and 5, the top edge of the grating has been cut or formed to produce a series of closely spaced sharp edges. This treatment produces more areas for the tire rubber to conform into, increasing resistance to sliding via the hysteresis effects. But this treatment is still in the range of macrotexture and adds little to the adhesion component of friction. This is shown by comparing the typical wet values obtained, which were around FN40 to the dry values of $FN_{dry}98$. To increase the microtexture of the steel, a coating should be applied that increases the microroughness to a peak-to-peak distance between 40 microns and 0.5 mm.[4]

Pavement coatings to increase the microtexture are available and were considered. These coatings have drawbacks that do not lend themselves to the open grated steel bridge decks. The primary problem with many of these coatings is lack of longevity under continuous traffic impacts where applied to steel. Other negative points have to do with toxicity and use near waterways.

One product was located that appears to have qualities that could lend itself to use on steel grated bridges where a friction increase is desired. It is a flexible ceramic coating that goes under the trade name of Ceram-Kote 54 produced by Freecom, Inc. Ceram-Kote 54 is a thin-film one coat, air-cured ceramic epoxy coating. The coating is naturally smooth and used in marine and offshore applications, on steel, but may be mixed with a grit to provide good micro texture.

A sample of 5-way bridge deck was sent to Freecom, Inc. to be coated with Ceram-Kote 54. Photos of the returned piece are shown in Figures 24 and 25. Subjective tests with a grinder, file and hammer, on the material, proved that it was very strong, durable, and firmly bonded to the steel decking. The sample was forwarded to Florida DOT for further testing and possible insertion into a roadway for long-term traffic tests.

Neither the author, TTI, nor Texas A&M University has any affiliation with the Freecom company and does not endorse or guarantee this product in any way. This product is being suggested as a possible solution to particular friction needs and requires further research and investigation.

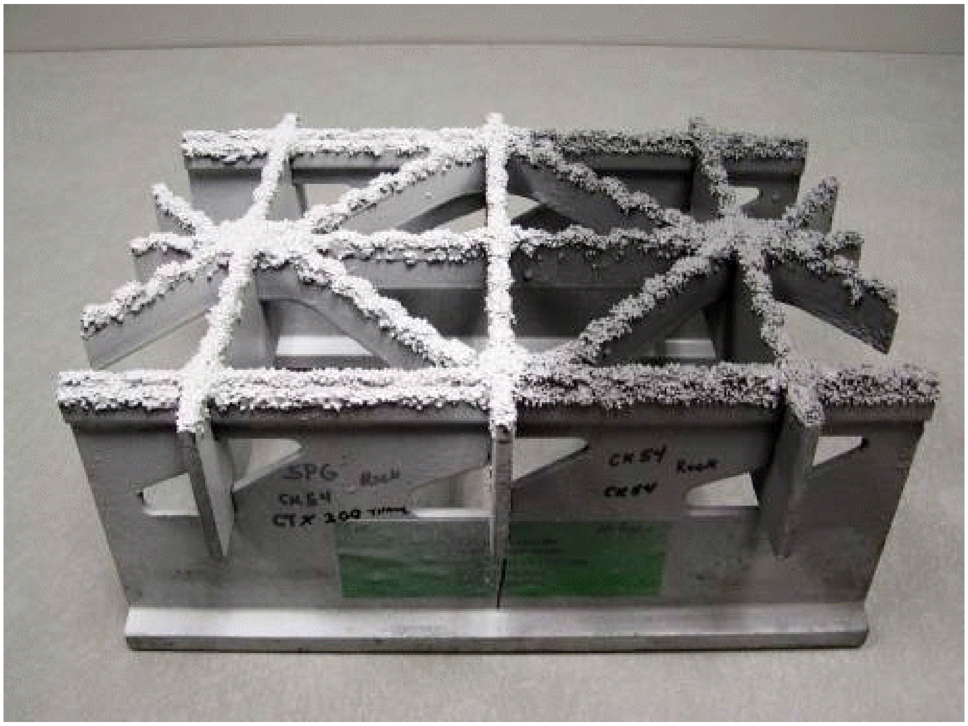


Figure 24. Sample of 5-way Bridge Deck Coated with Ceram-Kote.

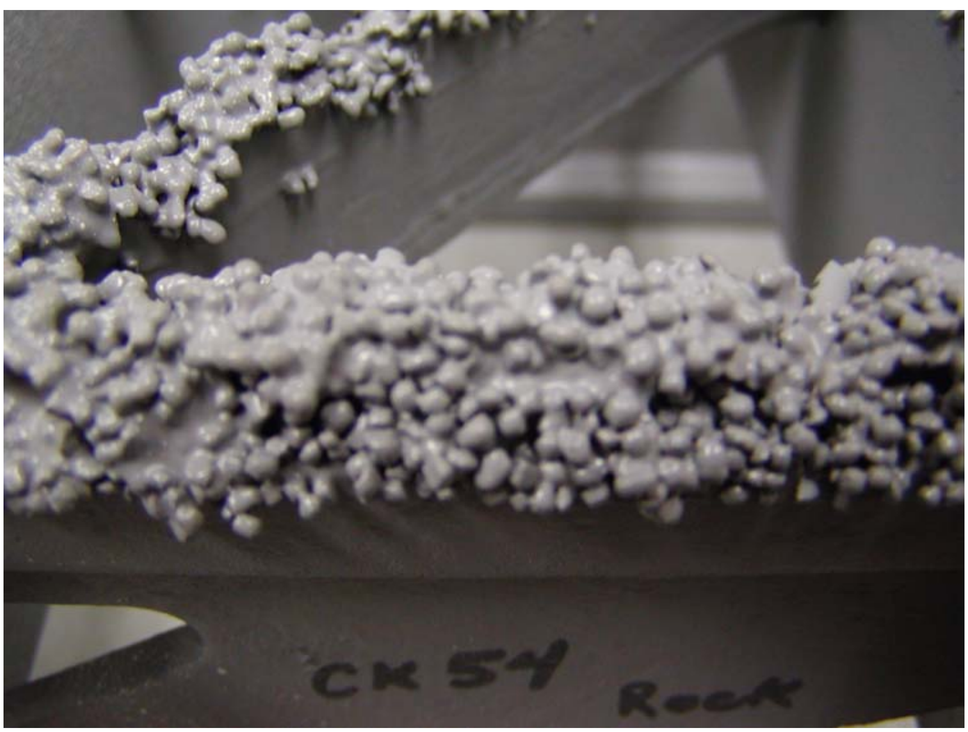


Figure 25. Close-up View of Ceram-Kote Applied to Bridge Deck Sample.

V. SUMMARY

Friction Testing of Open Grated Steel Bridge Decks

This report documents the development of a standard test method to properly measure the surface friction of open grated steel deck bridge roadways. It was determined that among all of the various devices and methods for measuring pavement friction, the ASTM Test Method E-274 “Skid Resistance of Paved Surfaces Using a Full-Scale Tire” provided the most logical candidate for achieving the desired results. Method E-274 uses an automobile size test tire on a trailer, that is momentarily braked to a stop in a wet condition, with the resulting force of that action measured and recorded. Also since this method is being used by most state agencies for their pavement maintenance programs, it is only logical to determine if this method may be used on steel deck bridges as well as pavements to eliminate the cost and maintenance of additional test devices.

Throughout this project, the foremost objective was to discover any significant differences between the quality of friction measurements taken on pavements and those taken on open grated steel bridges as they may relate to the traveling public. Even though ASTM E-274 is a maintenance tool and states that “The values are insufficient to determine the distance required to stop a vehicle on either a wet or dry pavement,” a correlation between pavements, steel bridge decks, and automobiles was investigated. This was done by friction testing both the paved approach to the bridge and then the steel bridge deck with three ASTM test tires on the friction trailer. The ASTM E-1136 test tire, which is a full tread, Uniroyal Tiger Paw radial, was included to represent the locked wheel friction of a passenger car on the different surfaces. The other tires were the standard ASTM E-501 ribbed, the E-524 smooth tire. All testing was done using unmodified E-274-97 procedures at 40 mph.

After testing five bridges and approaches it was found that the ratios and absolute values between radial and ribbed test tires on the pavements were similar to the ratios and absolute values between radial and ribbed test tires on the steel bridges.

This affirms that the E-274 test method, with an E-501 ribbed tire, produces friction values similar to those of a radial passenger car tire, E-1136, on either a paved surface or open grated steel bridge. Previous studies also showed a good correlation between an automobile and a 2-wheel E-274 system on seven different bridges, with an average difference of three friction numbers.

In the case of the E-524 smooth test tire, friction values on the steel bridge deck were very similar to those of the other two test tires but varied considerably on the paved surfaces. With the smooth tire, some bridges showed higher friction on the steel deck while others showed higher friction on the pavement.

It was recommended to ASTM committee E17.21 during the December 2001 meeting to include open grated steel bridges into ASTM Standard E-274, as a road surface that may be measured by this method, without modification, but with proper documentation as to the type of surface. It was also recommended that states be allowed to determine acceptable Friction Number values for the open grated steel bridge deck maintenance, just as they now do for pavements. This recommendation has been incorporated into a draft revision of E-274 that should go out soon for ballot. Work will continue to implement these changes to E-274.

Steering Stability on Open Grated Steel Bridges

After evaluating the steering stability of automobiles crossing ten open grated steel bridges by both instrumentation and subjective measures, it was determined that no adverse effects could be detected. Over the thirty-two test runs, several maneuvers were investigated such as maintaining a straight path, light braking, and light steering while on the bridge deck. None of the test runs produced any hint of instability on the instruments or to the driver.

Increasing Friction of Open Grated Steel Bridges

The final portion of the study was to locate a surface treatment that may be applied to open grated steel bridge decks, which may require an increase in friction values. A product called Ceram-Kote 54 was located and a sample of decking was treated. The result was positive with the coating being firmly bonded to the steel and initially immune to abrasion. Further research is needed to determine if this is a suitable coating for steel deck bridges.

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