

Dry Pavement Friction Reductions Due to Sanding Applications

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ABSTRACT

The importance of friction applications in the field of collision reconstruction is well recognized in published research [1, 2]. However, tire-road frictional drag values (μ -values) are partially dependent on the surface on which the tire is travelling. One such variable may be the intentional presence of sand upon a particular roadway. Sand is sometimes applied to dry pavement in an effort to absorb liquid debris that may have been accidentally spilled onto the surface. Once the sand has been applied, it may be left for a measureable time until the fluid has been absorbed. If a collision were to occur on that particular surface while the sand is in place, it may be difficult to determine an appropriate μ -value for the given scenario.

In an attempt to examine the extent of friction reduction for both a passenger vehicle and a commercial truck on such a surface, testing was performed in a like condition. For both vehicle types, full braking with an active Anti-Lock Brake System (ABS) was used to measure the respective average and dynamic μ -values. For the testing, a 2006 Freightliner Century Class tractor pulling a fully loaded semi-trailer was compared with a 2007 Ford Crown Victoria automobile.

Test conditions consisted of a baseline dry asphalt surface, a surface of loose sand, a surface of packed sand, and finally a surface whereon there was a residual amount of sand. During the test runs, the vehicles were instrumented with recording devices to measure the relative acceleration and test speeds. In performing these tests, it was found that the application of sand did reduce the pavement friction as suggested in prior research concerning similarly covered road surfaces [3]. However, it was also found that while the performance results varied significantly between the tractor semi-trailer and the passenger vehicle on dry pavement, their net braking abilities were much closer after the sand was applied.

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INTRODUCTION

Many highway departments and local governmental authorities use dry sand applications to clean non-hazardous liquid spills on roadway surfaces. From a practical perspective, the majority of the liquid is absorbed by the fine sand material. In time, the sand is removed or swept from the roadway surface and disposed of appropriately.

Traffic collisions occasionally occur in areas where sand is present over an asphalt or concrete surface. This condition causes issues of reduced friction properties between the vehicle tires and roadway surface. It can also affect a vehicle's ability to decelerate by splitting friction between various tires or axles. The objective of this research was to measure the effect of sand placement on a dry roadway surface relative to the ABS braking on a loaded commercial truck and a typical passenger car.

BRIEF LITERATURE SURVEY

Probable μ -values for various surfaces have been characterized in numerous research documents. Published tables such as those provided separately by Collins and Baker in 1967 and 1975, respectively, provide a qualitative description of a roadway surface with a corresponding range of μ -values [4, 5]. With respect to sanding applications, Collins does include values associated with vehicle braking maneuvers on sand surfaces. However, a description of the exact testing conditions used to obtain these values is not available. It is further noted that the tables were originally developed using vehicles with standard braking systems and bias-ply tires.

In 1983, Warner, et al. described the fundamental properties of friction [1]. In a discussion concerning the effects of water on the roadway surface, the author suggested that "soft sand" will reduce tire/road frictional drag. However, there is no specific discussion about vehicles braking on sanded surfaces. In terms of specific μ -values for

various surfaces and conditions, Warner provided a reproduction of the table(s) presented previously by Collins.

Contemporary research into the reduction of friction due to roadway contaminants was presented in 2007 by Hall and Painter [6]. Through a series of 12 tests, surfaces were covered with either clay or a lime dust material. With respect to the clay surface, a short brake application of approximately 1.0 seconds was analyzed. Tests conducted on the lime dust surface involved a full brake application until the vehicle was brought to a stop. The authors concluded that during dry conditions, any reduction in friction was slight and unlikely to affect traffic operations. However, under wet conditions, the available surface friction was reduced significantly.

In a 2010 compilation of deceleration tests completed on gravel surfaces, Bartlett & Wright looked at vehicles with standard braking systems and those with ABS [7]. The data sets that were examined showed a mean μ -value of .62 for locked wheels and .495 for vehicles equipped with ABS. This is similar to Baker Materials Engineering, LTD, data that were also illustrated in the compilation. Here, an average of .58 was observed for vehicles with a standard braking system while a lower average of .48 was recorded for vehicles having ABS.

Testing specific to a sanded roadway was published in 2006 by Lambourn and Viner [3]. The surfaces were described as being asphalt or concrete that was "covered with coarse sand." Two vehicles with standard braking systems and one with ABS were tested once at three different speeds. The passenger cars with standard braking systems were found to achieve locked wheel coefficients of friction exceeding .50 with "slightly lower" results for the ABS-equipped vehicle.

With respect to heavy trucks, Reed & Keskin reported in 1989 that such vehicles will develop about 70% of the deceleration rate of a passenger car [2]. This conclusion appears to be with respect to vehicles braking on dry pavement, without reference to other surface types. A 1991 study by Heusser expanded on this previous research in an attempt to better evaluate heavy vehicle braking with air-mechanical brake systems [8]. Through regression analysis, a mathematical model was developed by the National Highway Traffic Safety Administration (NHTSA) at the Vehicle Research and Test Center (VRTC) to evaluate the braking abilities of a limited number of air-mechanical brake systems. Heusser, in turn, developed an additional algorithm that could be applied to a broad range of such vehicles. This methodology allows reconstructionists to measure the braking efficiency of air braked vehicles under different loading conditions.

In Heusser's methodology for calculating the efficiency of an air-mechanical braked truck, it is necessary to determine the truck tire coefficient of friction. In his publication, he indicates that this is obtained by reducing the μ -value for a passenger vehicle tire by 85 percent. This, however, is based on testing performed on dry roadway conditions. In later testing completed at the 2000 World Reconstruction Exposition (WREX), research performed by Stopper, et al.

suggests that on a reduced-friction surface, the μ -value for a truck tire may actually be close to that for a passenger car [9].

TEST OBJECTIVES

As was stated previously, sanding applications have been used as a methodology for cleaning nonhazardous roadway spills. In such an operation, the sand is placed on the surface and allowed time to absorb the liquid or chemical. During this time, the possibility exists for a collision to occur on the sanded surface. The intent of this research involves an examination of the reduction in friction associated with sanding applications. In particular, the primary objectives are as follows:

1. Examination of tire/road μ -value variation between a dry asphalt surface and one having the presence of sand.
2. Comparison of a passenger car and a heavy air braked vehicle under similar test conditions with ABS.
3. Review average vehicle deceleration values with a comparison to a dynamic value (peak to peak).

METHODOLOGY

To evaluate the reduction in friction associated with a sanding application, two vehicles were tested by initiating full brake applications on a sanded surface. For safety purposes, the testing was completed on a closed driving course at Fox Valley Technical College (FVTC) in Appleton, Wisconsin. The driving range is used for training professional truck drivers, and is composed of bituminous concrete. The vehicles, which consisted of a commercial heavy truck and a passenger car, are identified below.

VEHICLE NO. 1a AND 1b

The first vehicle that was used was a 2006 Freightliner Century Class tandem axle truck tractor (1FUJBCK56LV78618). The vehicle is owned by FVTC and is used for on-highway driving instruction. All of the unit's brakes were inspected by the Wisconsin State Patrol's Motor Carrier Section and found to be within Commercial Vehicle Safety Alliance (CVSA) regulatory limits. Individual wheel weights were measured during the inspection as follows:

Axle 1 Left: 5650 lbs Axle 1 Right: 5450 lbs
 Axle 2 Left: 7300 lbs Axle 2 Right: 7100 lbs
 Axle 3 Left: 7300 lbs Axle 3 Right: 7100 lbs

The Freightliner was equipped with a Meritor ABS having four sensors and four modulators. For the testing, the truck was attached to a loaded 2004 Stoughton tandem axle semi-trailer (1DW1A53234S701423) also having a Meritor system with two sensors and one modulator. Like the Freightliner tractor, the brakes on this vehicle were also found to be within CVSA specifications. Wheel weights for the trailer were measured at:

Axle 4 Left: 7200 lbs Axle 4 Right: 7650 lbs

Axle 5 Left: 7700 lbs Axle 5 Right: 7300 lbs

In total, the unit weighed 69,750 pounds, which is typical for many similar sized commercial motor vehicles. The Freightliner and Stoughton are shown during a test run [Figure 1](#).



Figure 1. Test Vehicle(s) 1a and 1b

VEHICLE NO. 2

The passenger car used for this testing was a 2007 Ford Crown Victoria sedan loaded with approximately 200 pounds of equipment (2FAFP71WX7X109200). The vehicle is used by the Wisconsin State Patrol as a police cruiser, and is maintained per departmental policy. Published data suggest that the car, which is shown during a test run in [Figure 2](#), has a gross weight of 4137 lbs. and a front to rear weight ratio of 56% to 44% [10].



Figure 2. Ford Crown Victoria in Test Run

TEST PROCEDURE

In analyzing the effects of sand on the available roadway friction, initial baseline braking runs were completed over the dry asphalt surface used for the testing. Four runs were completed with the Freightliner while three runs were

completed with the Crown Victoria. The passenger vehicle was driven by a veteran law enforcement officer, while the tractor semi-trailer was operated by a professional driving instructor. For all test runs, the drivers were instructed to maintain throttle input until entering the test area, then to provide a full brake application such that the ABS system was activated. The operators were further directed to maintain this brake application until the vehicle had been brought to a stop.

Following the baseline tests, three test conditions were prepared using sand obtained from a nearby supplier. Agencies tasked with highway maintenance use materials readily available to them through area quarries or suppliers. In terms of guidance, a typical recommendation is that the sand be at least 0.5 mm in size, but not so large as to create a dangerous condition. Furthermore, as an example of typical guidance, the Wisconsin Traffic Information Center suggests that agencies use angular particles as opposed to ones that are round [11]. In choosing sand for this testing, attempts were made to abide by this guidance. [Figures 3](#) and [4](#) show a sample of the sand used in comparison with a scale in millimeters. As is visible in the images, the sand grains are in compliance with the stated recommendations.

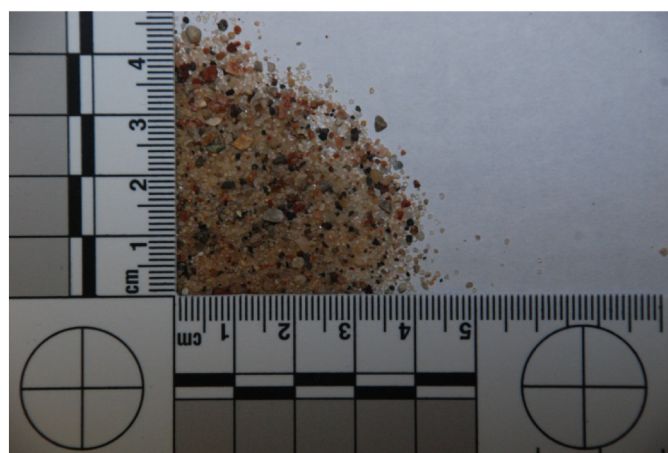


Figure 3. Sample of Sand Used in Testing

In each test condition, runs were alternately completed with each vehicle. For the first test group, $\frac{1}{4}$ inch of sand was raked on the pavement for a sufficient longitudinal distance (approximately 250 feet) to enable the entire braking tests to be completed on the prepared surface. Following each run, the sand was raked back to a loose condition and uniform depth. Depth was maintained using a parallel series of steel rods having a $\frac{1}{4}$ inch diameter. When the rods were in place, excess sand could be scraped off the top by sliding the back side of a large metal rake over the top (similar to a concrete screed). The final sand condition at $\frac{1}{4}$ inch after raking is shown in [Figure 5](#).



Figure 4. Magnified View of Sand Used in Testing

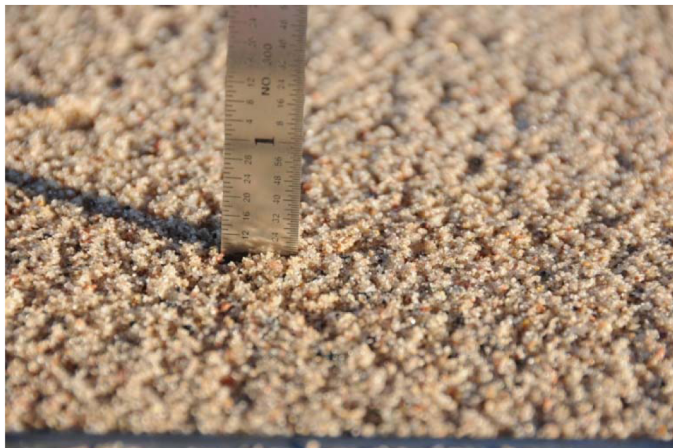


Figure 5. Sand Texture at 1/4 Inch Depth

Following the loose sand testing, the sand was allowed to become packed down without raking between test runs. Again, six tests were completed under this condition with each vehicle. Finally, the majority of the sand was scraped from the roadway using flat shovels, brooms, and a frontend loader. This left only a minimal amount of sand covering the macro-texture of the asphalt. The residual sand after scraping and sweeping is shown in [Figure 6](#). Each vehicle was then run through three additional tests on this surface.

For each test run, data concerning vehicle position, velocity, acceleration, and time were captured using a Vericom® VC4000 DAQ recording system. This unit samples acceleration on the X, Y, and Z axes at 100 Hz, and also allows for a Global Positioning System (GPS) receiver to sample at 5 Hz. Similar Vericom instruments (VC2000 and VC3000) have been recognized in past research for their accuracy and use in measuring tire-road frictional drag values [[12](#), [13](#), [14](#)].



Figure 6. Asphalt Surface with Residual Sand

TEST RESULTS

For reporting purposes, the results of the testing are broken down by condition. These include the dry asphalt (baseline) runs, and the runs completed on the surface having loose sand, packed sand, and residual sand. Tabular and graphical data shown herein include the speed at brake application, the overall mean μ -value obtained during the test, and the dynamic “peak to peak” mean value. The test runs for the condition are then examined collectively.

With respect to dynamic friction, the mean value from the initial maximum normalized force to the final peak was used. This is in comparison to the overall mean, which refers to start of the vehicle's deceleration to the end of the phase. These are shown graphically in [Figure 7](#), which represents a Crown Victoria test on the dry asphalt (baseline) surface.

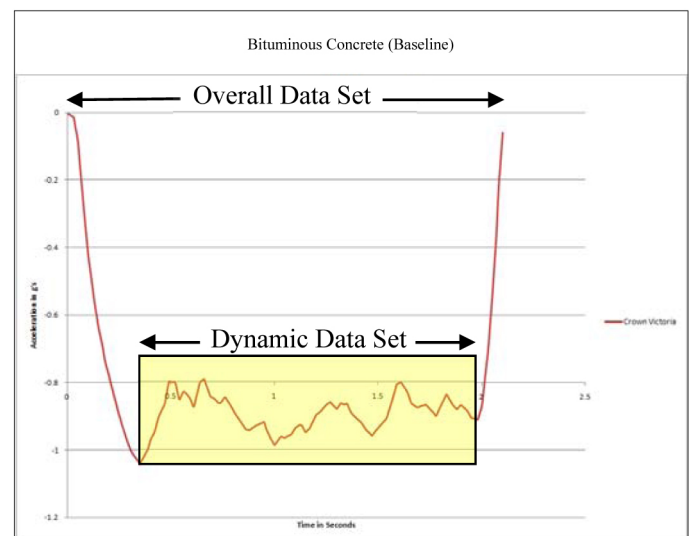


Figure 7. Overall and Dynamic Data Sets

For all braking tests, while GPS speeds do indicate that the vehicles have stopped or have nearly stopped, accelerometer data showed continued movement in the