

## **SASKATCHEWAN'S CENTRAL TIRE INFLATION SYSTEMS (CTIS) RESULTS FROM THE YEAR 2000 FIELD TRIAL**

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### **ABSTRACT**

*This paper documents the results of the Central Tire Inflation System (CTIS) field experiments conducted in Saskatchewan in the summer of 2000 as a follow up to a field demonstration of CTIS technology conducted in the fall of 1999. A paper had been presented on the results from the 1999 field demonstration at the 6<sup>th</sup> International Symposium on Heavy Vehicle Weights and Dimensions held in Saskatoon, CANADA. The objective of the 2000 field experiment was to investigate the potential benefits of CTIS technology in more detail and specifically to determine to what extent the technology can offset incremental road damage when hauling in excess of regulated weights. The experiment used the same truck configurations as in the 1999 field demonstration trials. The research was sponsored by Saskatchewan Highways and Transportation, Manitoba Highways and Government Services, Agriculture and Agri-food Canada through the Canada Agri-Infrastructure Program (CAIP) and the Saskatchewan Wheat Pool. The authors wish to acknowledge and thank the Rural Municipality of Big Quill for allowing the use of their roads for the field experiment. The experiments were conducted in the vicinity of Wynyard, Saskatchewan and comprised of two separate test sites, one site to assess the benefit of CTIS for reducing road damage at equal gross vehicle and axle weights, and the other to assess whether the use of CTIS can offset any incremental damage caused by hauling the same tonnage at higher axle and gross vehicle weights than those specified by regulations.*

## **1.0 INTRODUCTION**

### **1.1 Background**

In the fall of 1999, Saskatchewan Highways and Transportation conducted a field demonstration near Walpole, Saskatchewan to explore the difference in road damage that would occur from using trucks equipped with Central Tire Inflation Systems (CTIS)<sup>1</sup>. The demonstration utilized fourteen 9-axle B-Trains, all loaded to the legal maximum primary axle weights allowed in Saskatchewan for a maximum gross vehicle weight of 70500 kg. Half of the trucks were operated at normal, highway (standard) tire pressures and the other half at optimised (reduced) tire pressures. The test trucks were run on two separate earth road test circuits joined by a common test road on which each group of 7 trucks passed each other in opposing lanes. Two modes of failure were investigated: washboarding and surface rutting. The results of the demonstration indicated that the use of optimised tire pressures reduced wash boarding by two-thirds. The rutting results were not conclusive; however, an analysis of the change in surface deflection, using data gathered before and after the demonstration, indicated that the strength of the surface crust on the standard-tire-pressure lane decreased significantly more than the opposing reduced-tire-pressure lane. This demonstration project is described in detail in a paper entitled "Field Demonstration Comparing Damage to Rural Saskatchewan Roads Caused by Optimised and Normal Highway Truck Tire Pressures" published in the proceedings from the 6<sup>th</sup> International Symposium on Heavy Vehicle Weights and Dimension. A review of related literature found no reference to the effect of variable tire pressures on damage to

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<sup>1</sup> Central Tire Inflation Systems for commercial truck applications are often called Tire Pressure Control Systems.

low-volume roads constructed with a clay-capped or thin bitumen running surfaces, as are common in rural Saskatchewan.

### 1.2 Objectives

SHT offers an enhanced weight program to qualified trucking firms in the interest of improving truck efficiency and stimulating economic activity in Saskatchewan. In exchange for the granting of these weight privileges SHT requires enhancements in truck safety and operator qualification, payment for incremental pavement damage caused by the higher weights and a sharing of the haul cost savings from the granting of the weight privilege. SHT policy with respect to this program is that truck hauls utilizing CTIS technology do not cause incremental road damage and thus the company is not charged for any road damage. The basis for this policy position is research work done by the United States Forest Service, Forest Engineering Institute of Canada and undocumented research done in SHT Test Track facilities. The value of the benefits arising from the use of CTIS technology has been very controversial causing the results of the 1999 field demonstration project to be strongly debated. The stakeholder groups in Saskatchewan feel the extrapolation of results from research conducted in the United States and in the forestry industry were not applicable to Saskatchewan rural roads.

The significant reduction in the strength of the earth road surface crust caused by the trucks operating at normal tire pressures, as opposed to those operating at reduced tire pressure, prompted Saskatchewan Highways and Transportation (SHT) to conduct a second, more detailed, field experiment to further explore the potential benefits of CTIS in reducing road damage on rural roads. The purpose of the follow up research was two-fold:

- 1) to determine the magnitude of the benefit arising from the use of reduced tire pressures for equal axle loading conditions and
- 2) to determine whether the use of reduced tire pressures offsets the incremental road damage from using higher-than-regulated weights for an equal quantity of payloads hauled.

The work was conducted over a period of seven days in late July and early August of 2000. The details of this research will follow below.

### 1.3 Participants

The research was funded by SHT, the Canada-Saskatchewan Agri-Infrastructure Program (CAIP) with contributions in kind from Manitoba Highways and Government Services. The Saskatchewan Wheat Pool provided the trucks for the test. The Rural Municipality of Big Quill allowed the use of their roads to conduct the experiments. SOO Navigational Systems Inc. supplied and monitored the GPS-navigational systems used to track, in real-time, the movements of the vehicles over the test roads. Tire Pressure Control International Ltd. supplied the CTIS and provided technical assistance with the test including CTIS re-programming and gathering tire footprint measurements. Michelin (North America) approved the test tire pressures and evaluated the resultant tire heat build-up.

An advisory committee comprised of members from the Saskatchewan Association of Rural Communities, two Area Transportation Planning Committees, Saskatchewan Trucking Association, University of Regina, Saskatchewan Wheat Pool, the Forest Engineering Research Institute of Canada, Tire Pressure Control International Ltd., Manitoba Highways and Government Services, and the Saskatchewan Department of Highways & Transportation was established to provide advice and guidance for the 1999 CTIS Demonstration Project near Walpole, Saskatchewan. This committee was retained to monitor and advise on the progress of the research on the CTIS Field Experiments.

## **2.0 METHODOLOGY**

The field study location was in the vicinity of Wynyard, Saskatchewan, Canada (see Figure 1). Two separate sets of earth roads were used to conduct the research: the Equal Axle Weight Experiment on Circuits 1 and 2 and the Equal Payload Experiment on Circuits 3 and 4 (see Figure 2). The two experiments were conducted simultaneously. The north-south roads common to Circuits 1 and 2, and Circuits 3 and 4 were the test sections. A

total of 17 test vehicles were used to conduct the experiments (ten 9-axle B-trains, four 8-axle B-trains and three 6-axle semi-trailers).

The test roads were low-volume earth roads constructed with the local clay-type soils of medium plasticity (Average Plasticity Index = 17.5, and Average Group Index = 8.3). The road surfaces were comprised of a compacted crust, 140–200 mm thick, overlain with a thin layer of gravel for wet weather traction. The pre-trial test road strengths were very similar, with the average surface deflection being 2.0 mm and 1.9 mm for the Equal Axle Weight Experiment test road and the Equal Payload Experiment test road, respectively. The principle difference between the test roads was running surface width—the width was approximately 8.0 m and 7.0 m for the Equal Axle Weight Experiment test road and the Equal Payload Experiment test road, respectively. The test roads were selected because they were representative of many rural roads in Saskatchewan, and because they were very similar in construction to the road used in the 1999 CTI demonstration project. Figure 3 illustrates a typical cross-section of the test roads.

Each test road included a thinly paved test section that was representative of the thin membrane surfaced (TMS) roads used as rural collector highways in Saskatchewan. Prior to paving the traction gravel was bladed away and the surface crust sprayed with an asphalt emulsion. A thin layer of bituminous cold mix (40 mm thick across the entire road surface) was placed in a 300 m-long section located at approximately the midpoint of each test road.

### 2.1 Equal Axle Weight Experiment

The purpose of this experiment was to determine the effect that reducing tire pressures will have on road damage, given identical gross vehicle and axle weight conditions.

**Vehicle Description.** The vehicles used in the Equal Axle Weight Experiment were five 9-axle B-Trains equipped with CTIS, air ride suspensions, 11R22.5 Michelin tires, and GPS-based navigational systems. Each vehicle was loaded with 5500 kg on the steer axle, 17000 kg on the tandem drive axles, and 24000 kg on each trailer tridem axle group, for a Gross Combination Vehicle Weight (GCVW) of 70500 kg. The cold tire inflation pressures of the test vehicles cycling on Circuit 1 were reduced to 550 kPa (80 psi) in the steering tires, 414 kPa (60 psi) in the drive axle tires and 345 kPa (50 psi) in the trailer tires. All tires of the vehicles cycling on Circuit 2 were set to a normal, highway cold inflation pressure of 690 kPa (100 psi). The reduced tire pressure trucks cycled in the southbound lane of the test road and the standard tire pressure trucks cycled in the northbound lane. A description of the test vehicles is given in Figure 4.

**Data Collection.** The data collection on the test road consisted of taking samples for soil moisture and density, Atterberg Limits and the soil Group Index values as well as Dynamic Cone Penetrometer readings, surface rut measurements and surface deflections using a Benkelman beam. Data samples were taken before, during, and after trafficking. An analysis of the data collected indicated that the soil strength properties of the north and southbound lanes of the test road were the same. Relative changes in surface deflection were taken as a proxy for changes in strength of the road structure. Although deflections were gathered on the bituminous mix test sections, surface deflection within the bituminous mats confounded the results.

Dynamic Cone Penetrometer readings and Benkelman deflections were taken on all of the connecting roads. Benkelman beam readings were gathered on the test road two to three times every day of trafficking, at 400 m intervals on the earth sections and 100 m intervals on the bituminous mix sections. The readings were taken at approximately the same locations, however, variations in measurement location likely occurred and were accounted for by averaging all of the test road deflections together. Beam reading variability on the earth road was not very great; a limited sampling found a standard deviation of 0.05 mm for eight deflections taken on the same spot.

The test roads and connecting roads were videotaped during the experiment to record the test procedure and the road condition before, during and after trafficking.

**Test Procedure.** The five vehicles trafficked Circuits 1 and 2 on alternate days commencing with Circuit 2 (tire inflations set to standard tire pressures). The trucks cycled together and the lead truck maintained a pace of no more than 80 km/h. Every half-day (i.e., after approximately 70 passes) trafficking was halted while data was collected from the cycled lane. This alternating procedure was continued for the duration of the Equal Axle Weight Experiment.

Trafficking was continued on the test lanes until one of the two lanes failed. Once a test lane was considered failed, no more test trucks were cycled around the failed circuit. Trafficking was continued on the opposing lane until its average surface deflection was comparable to that of the failed lane (that is, it had approximately equivalent structural damage). Throughout the trafficking, video record was kept of the visual appearance of the test lanes.

## 2.2 Equal Payload Experiment

The purpose of this experiment was to determine whether a reduction in tire pressures would compensate for the incremental road damage caused by operating at higher axle weights. In this experiment, the two lanes of the test road were trafficked by five 9-axle B-trains, and a combination of four 8-axle B-trains and three 6-axle tractor/semi-trailers collectively carrying an equal payload to the five 9-axle B-trains. The resulting road damage in each lane was compared at given quantities of payload hauled.

**Vehicle Description.** Two groups of commercial trucks were used to conduct this experiment: five 9-axle B-trains (the high efficiency fleet), and a combination of four 8-axle B-trains and three 6-axle tractor/semi-trailers (the conventional fleet). All of the vehicles were equipped with CTIS, 11R22.5 Michelin tires, air ride suspensions and GPS-based navigational systems. Each high efficiency fleet truck was loaded to maximum legal primary axle weights—5500 kg on the steer axle, 17000 kg on the tandem drive axle group, and 24000 kg on the trailer tridem axle groups. The GCVW of the 9-axle B-trains was 70500 kg. The cold inflation pressures used by the high efficiency fleet were 550 kPa in the steering tires, 414 kPa in the drive tires, and 345 kPa in the trailer tires. Each of the conventional fleet trucks was loaded to maximum legal secondary axle weights—5500 kg on the steering axle, 14500 kg on tandem axle groups, and 20000 kg on tridem axle groups. The GCVW of the 8-axle B-trains and the 6-axle units was 54500 kg and 40000 kg, respectively. All of the 8 and 6-axle units utilized (standard) cold tire inflation pressures of 690 kPa. The high efficiency fleet cycled on the southbound lane of the test road whereas the conventional fleet cycled on the northbound lane. A description of the test vehicles used in the Equal Axle Weight Experiment is presented in Figure 5.

**Data Collected.** The data collected for the Equal Payload Experiment was identical to that of the Equal Axle Weight Experiment.

**Test Procedure.** The experiment was designed so that the combined payload hauled by the five high efficiency fleet trucks was approximately equal to that carried by the seven conventional fleet trucks. In a single cycle, the high efficiency fleet carried 236.5 t of payload whereas the conventional fleet carried 205.7 t of payload. Extra cycles were completed when necessary, by some or all of the conventional fleet, to keep the payload over the northbound lane of the test road equal to that over the southbound lane. The high efficiency fleet cycled around Circuit 3 while the conventional fleet cycled around Circuit 4. Cycling on Circuits 3 and 4 occurred simultaneously, with the fleet location coordinated so that only one fleet occupied the test road at a time. The trucks in each fleet cycled together and the lead truck maintained a pace of no more than 80 km/h. Trafficking was stopped twice daily to allow data to be collected from the test road.

Trafficking was continued on the test road until one of the two lanes failed. Once failed, no more test trucks were allowed to traffic that lane. Trafficking was continued on the opposing lane until its average surface deflection was comparable to that of the failed lane (that is, it had approximately equivalent structural damage). Throughout the trafficking, video record was kept of the visual appearance of the test lanes.

## 3.0 RESULTS

### 3.1 Equal Axle Weight Experiment (Circuits 1 and 2)

The northbound lane of the test road was declared failed after 200 passes (9350 t payload) by the trucks utilizing standard tire pressures. Cycling on the northbound lane had to stop because of the large shear areas that were threatening to damage or upset the test trucks. The southbound lane of the test road sustained 721 passes (33800 t payload) by the trucks utilizing reduced tire pressures before the experiment was stopped. The southbound lane never reached the level of damage observed in the northbound lane.

**Comparison of Test Road Properties.** A comparison of road properties was done prior to the commencement of testing to insure the test results were not biased by physical differences between the test lanes. Changes in road properties resulting from the application of the trucks onto the test road are documented below.

**Comparison of Soil Properties.** A comparison of the physical properties (e.g., moisture, density, plasticity (Atterberg Limits), and strength (Group Index)) of the subgrade soils in the north and southbound lanes prior to the experiment indicated no significant differences that might bias the test results.

**Comparison of Benkelman Beam Deflections.** The average Benkelman beam deflection values on the test road were monitored for a period of nine weeks (data collected every two weeks) prior to the commencement of the experiment. No significant differences in the average deflection values were observed between the north and southbound lanes of the test road (Figure 6).

At the start of the experiment, both lanes of the earth test section had an average deflection value of approximately 2.0 mm. After approximately 140 truck passes over each lane, the average deflection value observed on the northbound (standard tire pressure) lane was 4.7 mm whereas the average deflection value observed on the southbound lane was only 3.2 mm. After 200 truck passes, the average deflection of the northbound lane was 5.0 mm, the lane was declared impassable, and no further truck passes were made on it. After 200 passes, the average deflection on the southbound lane was 3.6 mm.

At the conclusion of the trafficking (i.e., 721 truck passes), the average deflection value of the southbound lane was 3.5 mm. This lane never reached an impassable condition. The average deflection observed on the southbound lane fluctuated from a low of 3.2 mm to a high of 4.4 mm during the test.

**Comparison of Observed Road Damage.** The northbound lane was declared impassable and cycling was stopped on this lane after 200 passes by the trucks utilizing standard tire pressures. The middle and northernmost sections of the northbound lane sustained the greatest amount of damage. It was estimated from the video records that 50% of the length of the northbound lane's earth section had sustained shear failure in the outer wheel path (Figure 7). The entire 300 m-length of bituminous mix completely failed in shear over, at least, half of its width (Figure 8). In many places, the shear failures resulted in the displacement of the outer wheel path crust by more than 30 cm. This raised concerns about damage to the test vehicles and led to the termination of the truck cycling on the lane.

After 200 passes by the trucks utilizing reduced tire pressures, the southbound lane sustained significantly less damage than the northbound lane. From the video record, it was estimated that only 7% of the earth section of the test road sustained shear failure in the outer wheel path. The video record also indicated that only 10% of the length of the bituminous section was observed to have failed in half the lane after the 200 truck passes. After 721 truck passes (33900 t payload), the video record indicated that approximately 10% of the length of the earth section and 40% of the length of the bituminous mix section of the test road had failed from the shearing of the outer wheel path.

### 3.2 Equal Payload Test (Circuits 3 and 4)

In this experiment, an effort was made to obtain the same payload on each lane of the test road over the duration of the testing. To accomplish this it was often necessary to stop cycling the trucks to allow for the repair of serious shear failures to prevent damage to the test vehicles. The requirement for subgrade repairs was far more extensive on the northbound lanes (cycled by the trucks utilizing standard tire pressures) than for the southbound lanes (cycled by the trucks utilizing reduced tire pressures). A total of 17970 t payload (380 truck passes), was hauled over the southbound lane and 13634 t payload (478 truck passes) was hauled over the northbound lane before the experiment was terminated.

**Comparison of Test Road Properties.** A comparison of the road properties was done prior to the commencement of the test to insure no bias existed in the test from differences in the physical properties of the road. The changes in the road properties resulting from the application of the trucks on to the test road are documented below.

**Comparison of Soil Properties.** A comparison of the moisture, density, plasticity (Atterberg Limits) and strength (Group Index) properties of the subgrade soils in the north and southbound lanes prior to the application of the trucks to the road indicated no significant differences to cause a skewing of the test results.

**Comparison of Benkelman Beam Deflections.** As was the case for the Equal Axle Weight test road the average Benkelman beam deflection values on the Equal Payload test road were similarly monitored for a period of nine weeks prior to the commencement of the experiment. No significant differences in the average deflection values were observed between the north and southbound lanes of the test road.

Prior to the start of the experiment, both lanes of the earth road section had an average deflection value of approximately 1.88 mm (Figure 9). After approximately 3400 t payload had been carried over each lane, the average deflection value observed on the northbound (conventional fleet) increased to 4.0 mm whereas the average deflection value on the southbound lane (high efficiency fleet) increased to only 3.2 mm. As the payloads continued to increase, the average deflection values ranged between from 3.73 mm to 4.61 mm on the northbound lane and ranged from a low of 3.70 mm and a high of 4.05mm on the southbound lane. Deflection measurements continued to be taken until payloads of 13634 t and 17970 t had been carried over the north and southbound lanes, respectively.

**Comparison of Observed Road Damage.** A review of the video record indicated that shear failures started to appear on the earth section of the northbound lane of the test road after the movement of approximately 3500 t payload. No shear failures were observed on the southbound lane at this payload. At a payload of 10300 t, shear failures were observed on 40% of the length of the northbound lane compared to 6% of the length of the southbound lane (Figure 10). After 10000 t payload had been moved, significant repair effort was necessary on the northbound lane in order to continue trafficking. After 13634 t payload, the poor condition of the northbound lane, and the extensive effort and delays required to prolong trafficking, resulted in the termination of the experiment. At the end of the experiment, 10% of the southbound lane length and 60% of the northbound lane length had sustained shear failures in the outer wheel path.

The video record indicated that failure of the bituminous mix section on the northbound lane of the test road began after the movement of approximately 200 t payload. Failure of the bituminous mix surface on the southbound lane progressed more slowly with first indications of damage appearing after approximately 500 t payload. After approximately 1000 t payload had been moved over the bituminous mix surface, shear failures were observed on 5% of the length on the southbound lane compared to approximately 50% of the length of the northbound lane. After approximately 13000 t payload had been moved, both lanes of the bituminous mix surface had completely failed.

## 4.0 DISCUSSION ON THE TEST RESULTS

### 4.1 Effect of Reduced Tire Pressure on Road Performance

The results from both experiments clearly indicate that damage to earth roads and thin bituminous surfaces can be reduced with the use of CTIS. For the 9-axle trucks tested at common axle weights, the effect of using optimised tire pressures was to reduce road damage by an order of magnitude (i.e., 1/10 the amount observed for the standard tire pressure trucks). It was also noted that, for equal payloads hauled, the high efficiency fleet (operating at enhanced weights and reduced tire pressures) did less road damage than the conventional fleet (operating at regulation weights and standard tire pressures). In both experiments, the use of reduced tire pressure significantly reduced road damage for an equal quantity of payload hauled.

### 4.2 Other Factors Observed to Affect Road Performance.

**Road Width.** The Equal Axle Weight test road was approximately 0.6 m wider than the Equal Payload test road. A comparison of surface deflections versus payload on the two southbound test lanes (lanes cycled by identically configured 9-axle trucks operating at reduced tire pressure) suggests that width did not have a large effect for these trucks (Figure 12). A similar conclusion can be drawn from a comparison of the road damage versus payload (Figure 13).

On the connecting roads used to complete the loading cycles the test vehicles typically drove down the centre part of the road because of the narrowness of the running surface (typically 7.4 meters in width). It is interesting to note that the video record from these roads indicates little or no damage done by either the reduced or standard tire pressure trucks. This observation would suggest that road performance is related to the distance between the outer wheel path track and the edge of the road surface. This distance was 0.5 - 0.9 m for the Equal Axle Weight experiment and 0.3 - 0.6 m for the Equal Payload experiment. (The range of distances is due to the drivers steering closer to centreline as the outer edge of the lanes failed and the road's 4% cross slope causing the trailers to track towards the road edge.) In the case of the connecting roads, the distance was in the order of 2.3 m. This suggests that, for the conditions tested, outer wheel path shearing can be reduced if an outer wheel path-to-edge of road offset distance of greater than 1.0 m exists.

Damage to the connecting roads also may have been reduced because they followed well-established, densified wheel paths in the centre of the road and, by straddling centreline, they remained level instead of leaning with the cross slope of the surface. Based on measurements made with the same test trucks during the 1999 CTI Demonstration, the outer wheel loads were increased by approximately 13% during these trials when driving on test lanes having a 4% cross slope.

**Vehicle Configuration.** Comparisons of the average surface deflections, and of the visual estimates of damage, for the two northbound test lanes indicate a significant difference in road performance. This suggests that, for an equivalent payload, the five 9-axle units operating at enhanced axle weights and standard tire pressures did more damage to an earth road than the conventional trucks operating at regulation axle weights and standard tire pressures (Figures 14 and 15). Assuming road width did not affect road performance, as discussed above, this observation supports the Highways & Transportation Department's ESAL damage model that predicts, for equal payloads hauled, trucks operating at higher axle weights will cause approximately 16% more road damage. The Department's ESAL model does not directly account for differences in tire inflation, however, and was not suitable for estimating damage potential of the test trucks utilising reduced tire pressures.

**Accelerated Testing.** The experiments were completed in an accelerated fashion on account of time and budget considerations. The effect of accelerated testing is uncertain however it is believed that failure is accelerated because of the insufficient time provided for pore water pressure to stabilize prior to the application of the next loading cycle. This effect is not considered to be critical in the comparison of the results from the experiments given that the experiments were all carried out in an accelerated environment however careful consideration needs to be given to the application of the results to actual in-service conditions to adjust for the acceleration effects that are built into the results.

The effect of accelerated testing also needs to be considered in the context of a road's exposure to seasonal strength variations and the effect this will have on the pavement components. This is particularly important in northern countries that are reliant on frost susceptible glacial lacustrine soil deposits in the construction of road subgrades.

## 5.0 CONCLUSIONS

The purpose of the CTI Road Experiments was two-fold:

- 1) to determine the magnitude of the benefit arising from the use of reduced tire pressures for equal gross vehicle and axle loading conditions and
- 2) to determine whether the use of reduced tire pressures offsets the incremental road damage caused by using higher-than-regulated weights for an equal quantity of payload hauled.

The results from both experiments clearly indicate that damage to the earth roads and thin bituminous surfaces tested was significantly reduced with the use of reduced tire pressures – as controlled by a CTIS. It was also noted that, for equivalent payloads carried, the high efficiency fleet (operating at enhanced weights and reduced tire pressures) did less road damage than the conventional fleet (operating at regulation weights and standard tire pressures). In both experiments, the use of reduced tire pressure significantly reduced road damage for an equal quantity of payload hauled. The rate of damage observed on the test roads did not appear to be influenced by the 0.6 m difference in test road widths, however, road damage was dramatically reduced when the offset from outer wheel path to edge of road exceeded 1.0 m. The results from the lanes trafficked by test vehicles using standard tire pressures appear to support the ESAL damage model for equal payload hauled.

The test road, subgrade soil types, 9-axle test vehicles, and test procedures were common to both the Equal Axle Weight Experiment and the 1999 CTI Field Demonstration. However, because of seasonal differences the CTI Field Demonstration test road was dryer and stronger, and the resultant differences in observed road performance were significantly less.

Opportunities for further research with the data collected from these trials include:

- an analysis of pre- and post-trial deflection data to determine if the results can be extrapolated to other seasons in a meaningful way;
- an analysis of deflection data taken in 2001 and 2002 to determine the rate of damage recovery in the earth road as it is subjected to climatic processes;
- analyses of rutting and gravel loss rates to estimate potential surface maintenance benefits; and,
- extrapolation of the results to other road types and travel speeds using pavement-road performance models calibrated with the data.

## 6.0 REFERENCES

"Field Demonstration Comparing Damage to Rural Saskatchewan Roads Caused by Optimised and Normal Highway Truck Tire Pressures" in Proceedings from the 6<sup>th</sup> International Symposium on Heavy Vehicle Weights and Dimension – Past, Present, Future. International Forum for Road Transport Technology. Regina, Saskatchewan. June 2000. pp 237-251.



Figure 1. Location of CTI Road Experiment near Wynyard, Saskatchewan, Canada.

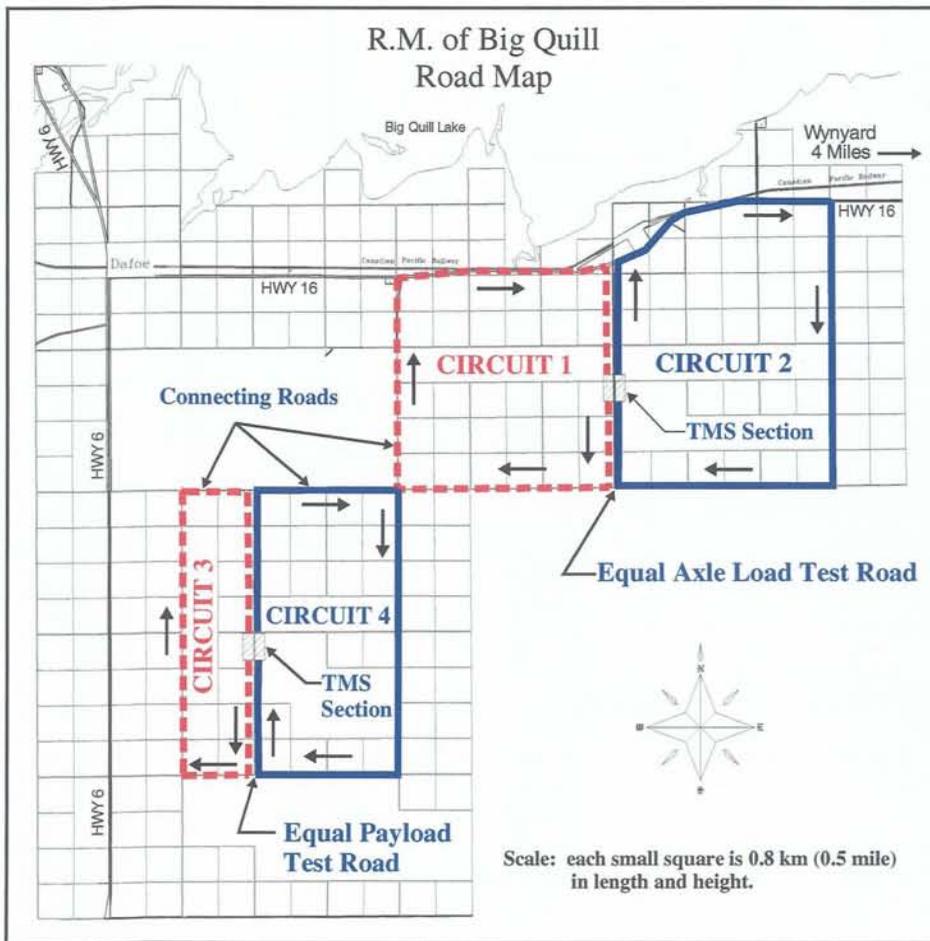


Figure 2. Equal Axle Weight Experiment (Circuits 1 and 2) and Equal Payload Experiment (Circuits 3 and 4).

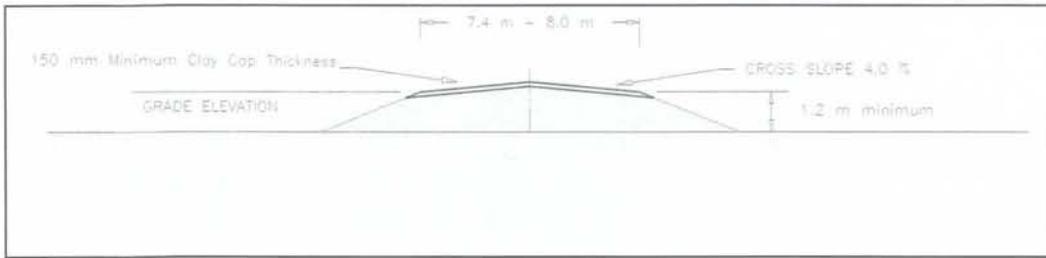


Figure 3. Typical test road cross-section.

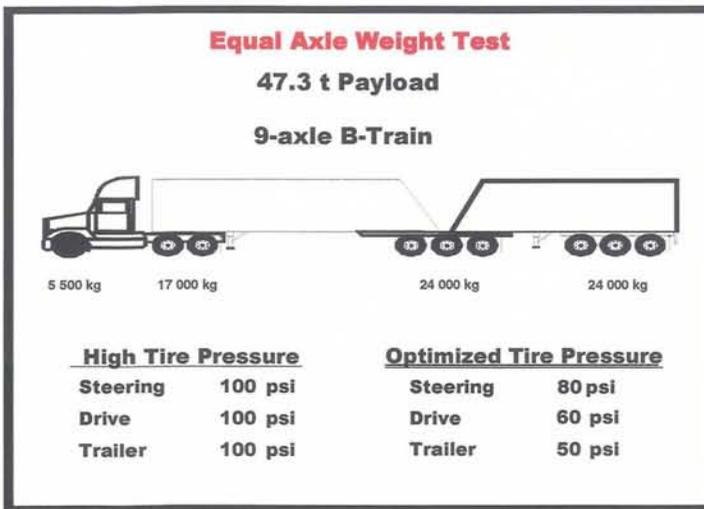


Figure 4. Test vehicle used for the Equal Axle Weight Experiment.

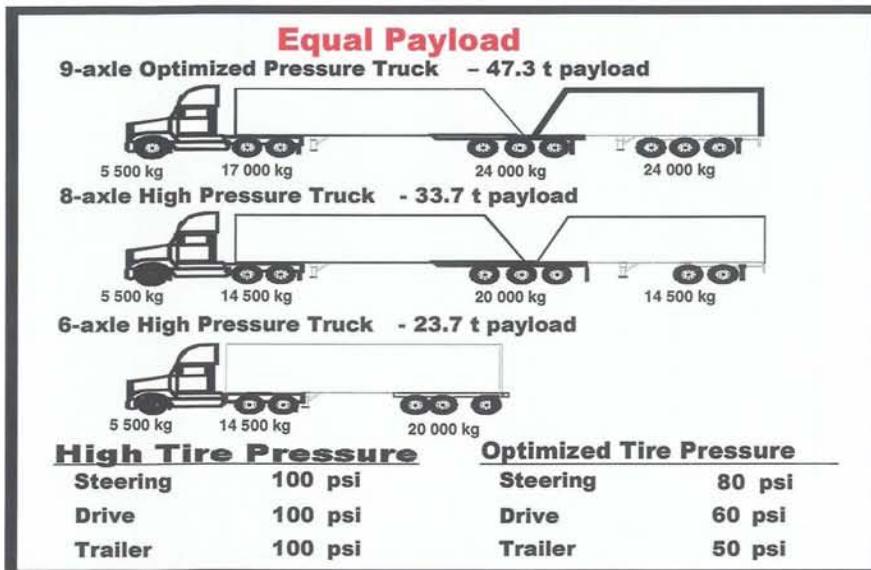


Figure 5. Test vehicles used for the Equal Payload Experiment.

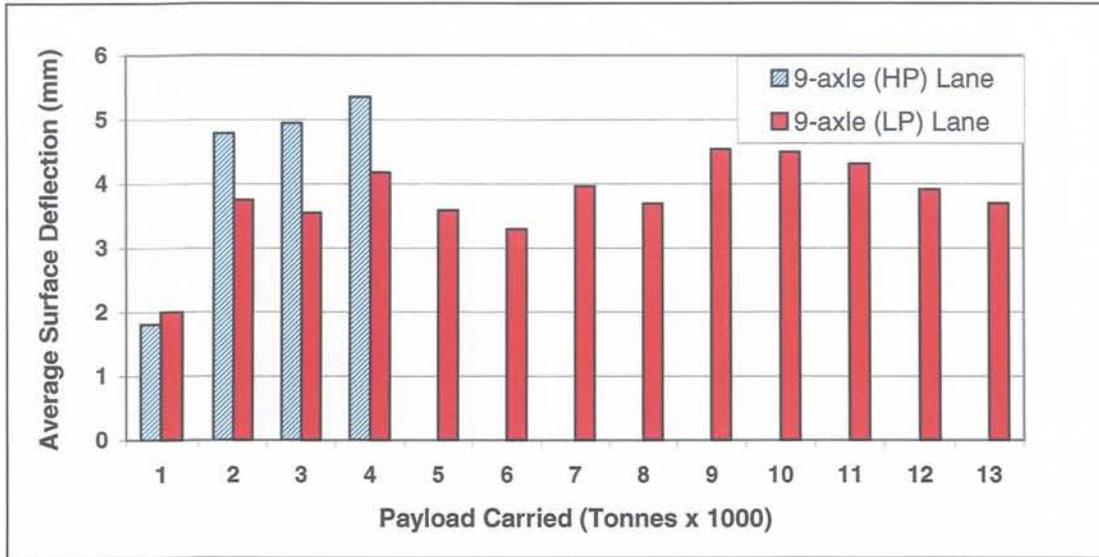


Figure 6. Comparison of the average surface deflections of the reduced tire pressure (LP) and standard tire pressure (HP) test lanes on the earth section of the Equal Axle Weight test road.

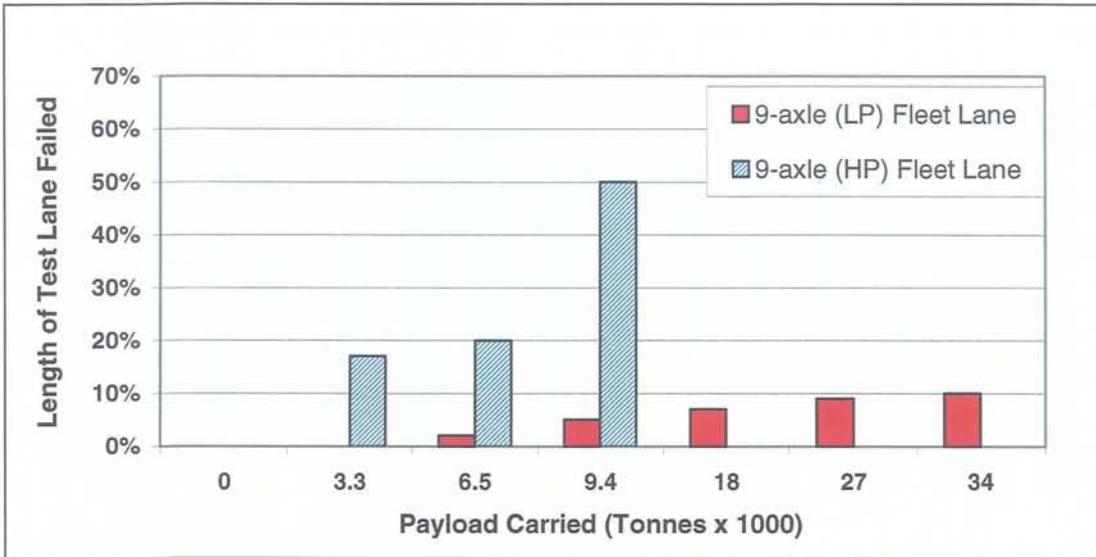


Figure 7. Comparison of the failed length of the reduced tire pressure (LP) and standard tire pressure (HP) test lanes on the earth section of the Equal Axle Weight test road.

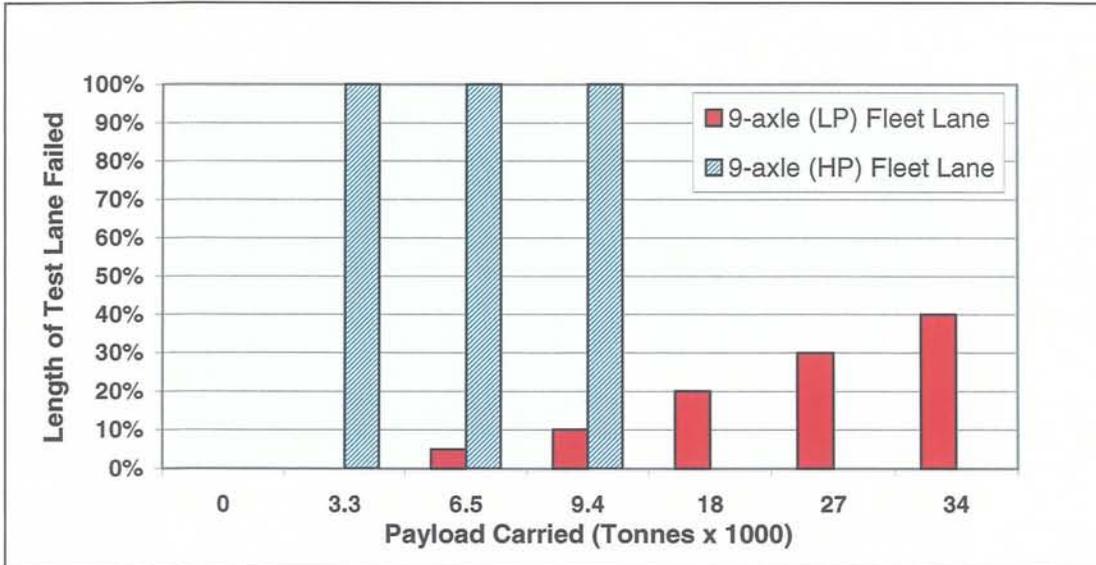


Figure 8. Comparison of the failed length of the reduced tire pressure (LP) and standard tire pressure (HP) test lanes on the bituminous mix section of the Equal Axle Weight test road.

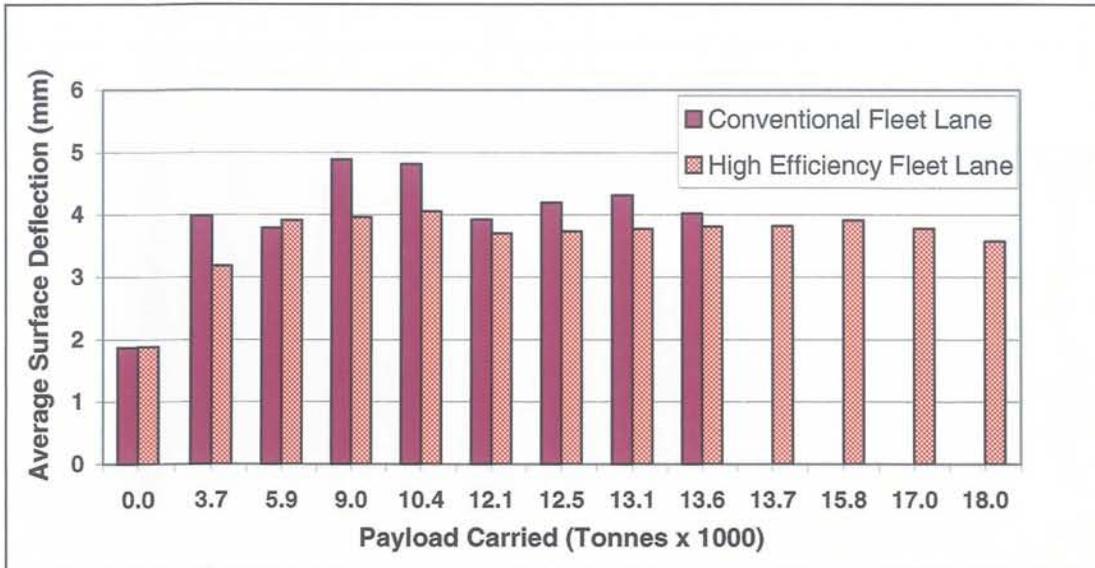


Figure 9. Comparison of the average surface deflections of the high efficiency fleet and conventional fleet test lanes on the earth section of the Equal Payload test road.

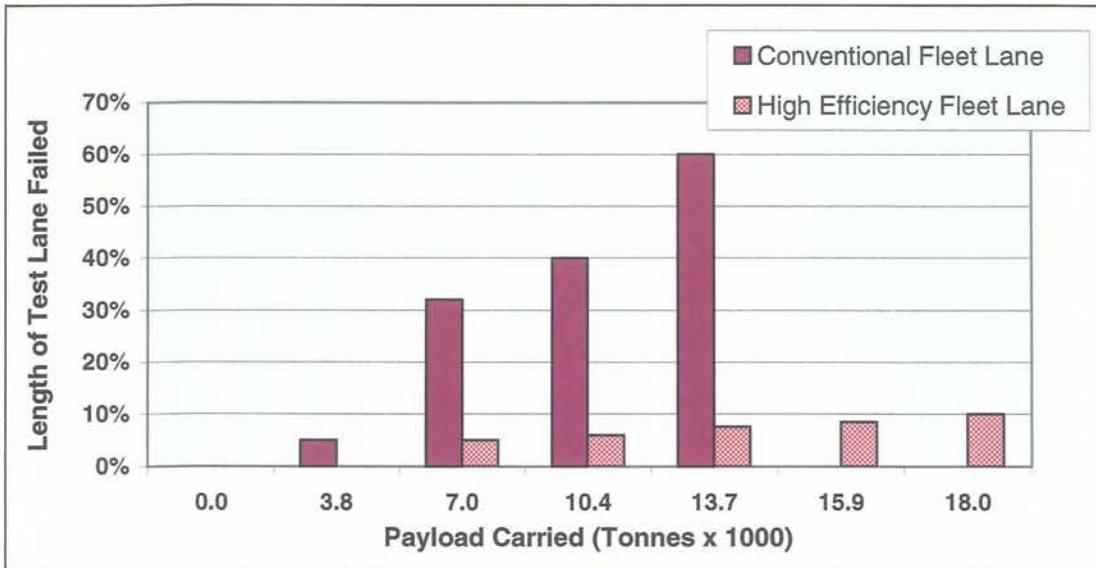


Figure 10. Comparison of the failed length of the high efficiency fleet and conventional fleet test lanes on the earth section of the Equal Payload test road.

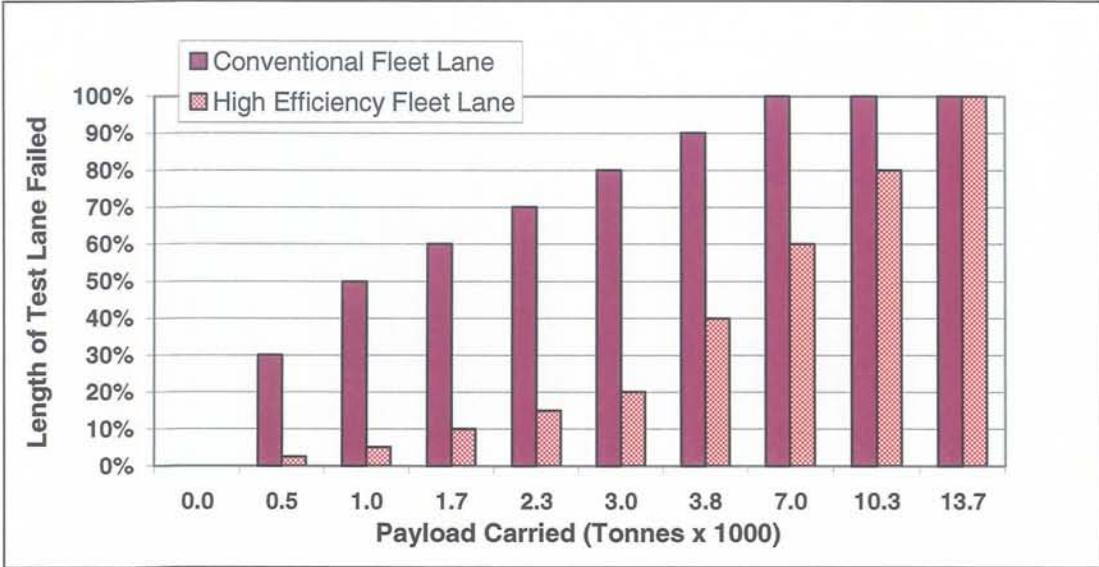


Figure 11. Comparison of the failed length of the high efficiency fleet and conventional fleet test lanes on the bituminous mix section of the Equal Payload test road.

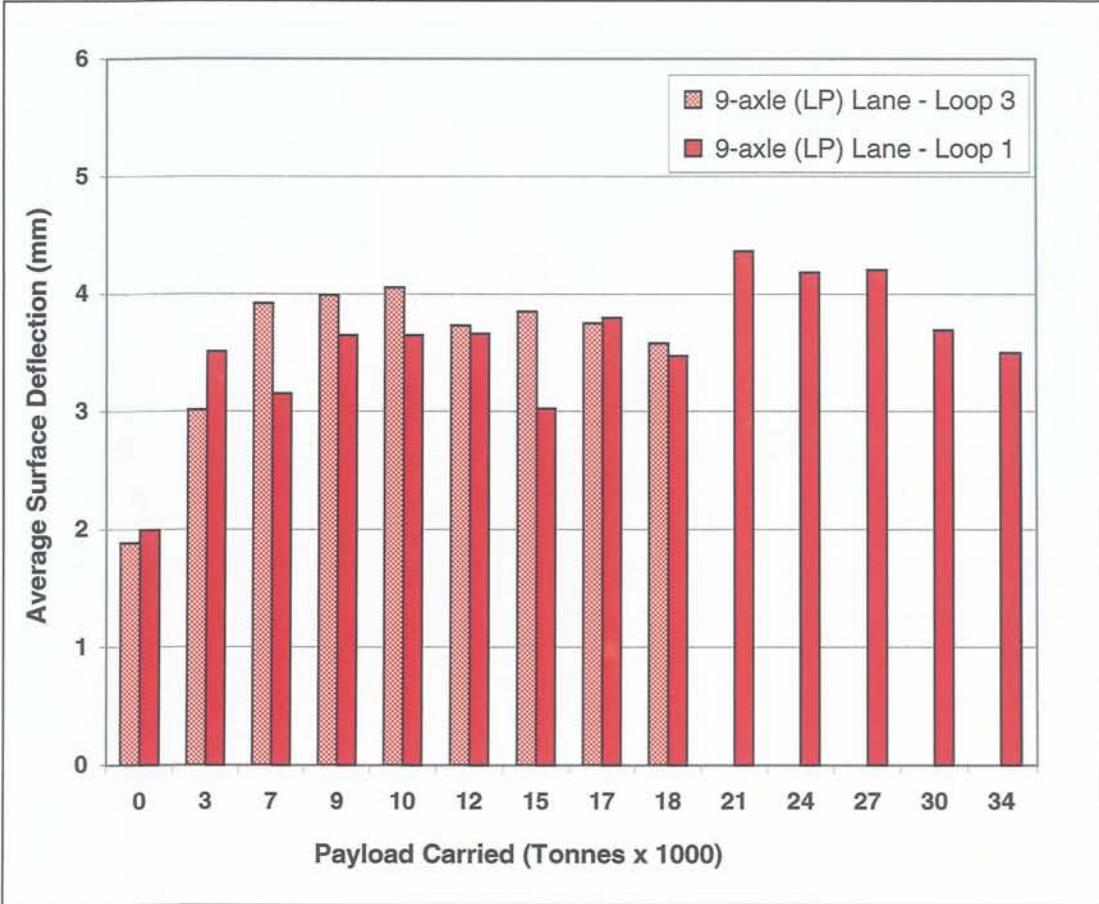


Figure 12. Comparison of the average surface deflections of the two earth road test lanes subjected to 9-axle B-train trucks loaded to primary highway (enhanced) axle weights and utilizing reduced tire pressures (LP).

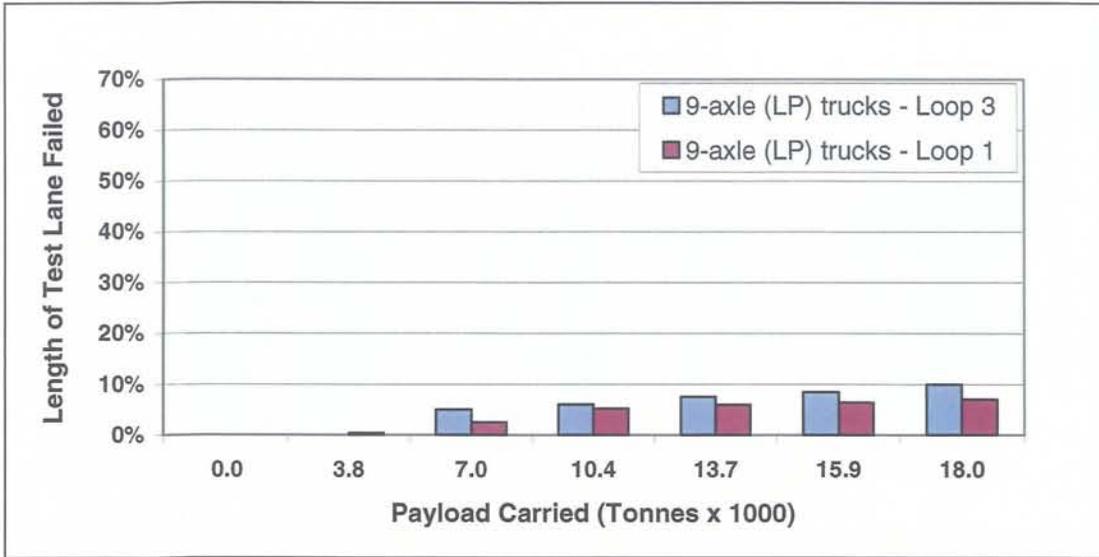


Figure 13. Comparison of the failed lengths of the two earth road test lanes subjected to 9-axle B-train trucks loaded to primary highway (enhanced) axle weights and utilizing reduced tire pressures (LP).

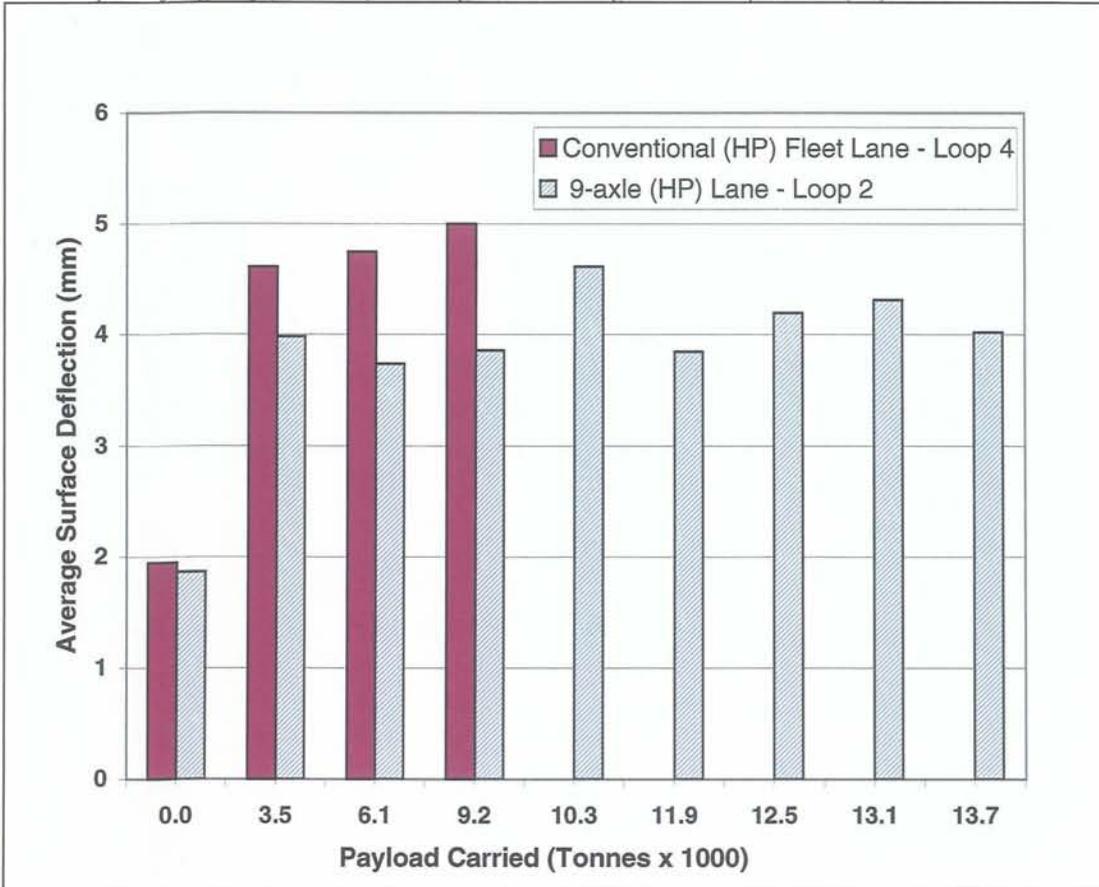


Figure 14. Comparison of the average surface deflections of the two earth road test lanes subjected to trucks utilizing standard tire pressures: Conventional 6 and 8-axle trucks loaded to Secondary Highway Axle weights and 9-axle B-train trucks loaded to Primary Highway Axle weights.

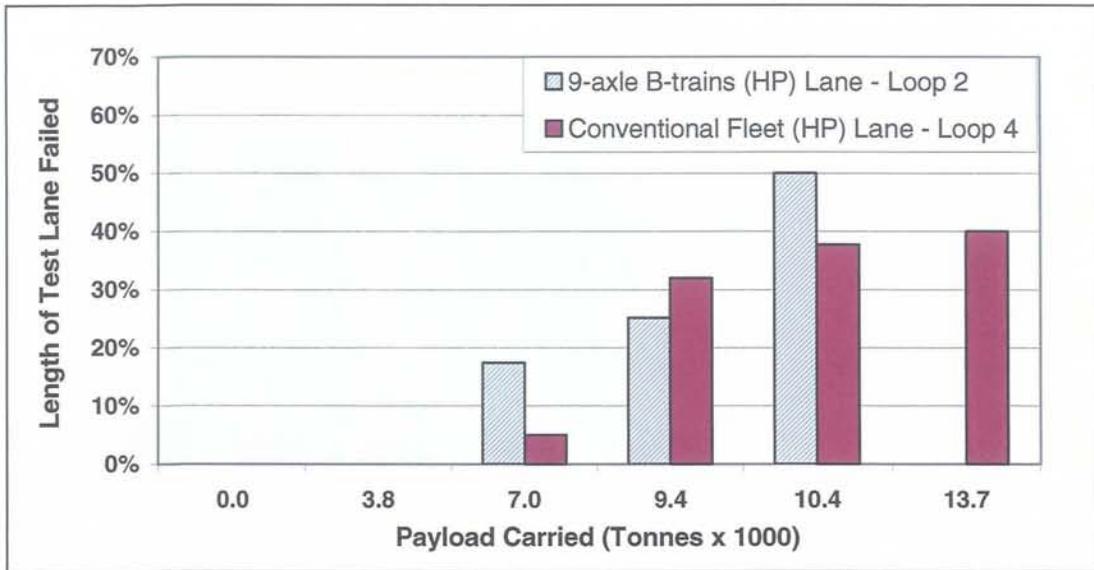


Figure 15. Comparison of the failed lengths of the two earth road test lanes subjected to trucks utilizing standard tire pressures: 9-axle B-train trucks loaded to Primary Highway Axle weights and conventional 6 and 8-axle trucks loaded to Secondary Highway Axle weights.