SEVEN YEAR PERFORMANCE EVALUATION OF A CPR PROJECT IN CANADA

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ABSTRACT

In the summer of 1989, the Ministry of Transportation of Ontario (MTO) undertook the rehabilitation of an exposed concrete pavement exhibiting various distress manifestations. Highway 126 in Southwestern Ontario is a four-lane divided arterial with 25,000 AADT and 15% commercial traffic. The existing pavement, constructed in 1963, consisted of 230 mm mesh reinforced Portland Cement Concrete pavement with dowelled joints at a spacing of 21.3 m.

The rehabilitation of the highway in the northbound lanes consisted of using the latest developments in portland cement concrete (PCC) rehabilitation design techniques, material specifications and construction methods. The southbound lanes received an unbonded PCC overlay.

The rehabilitation techniques include full depth repair, partial depth repair, diamond grinding and joint sealant replacement on the northbound lanes which had experienced moderate deterioration. The southbound lanes received a 180 mm thick plain jointed unbonded PCC overlay to address the severe 'D' cracking and spalling at all the joints and cracks.

This paper will discuss the seven year performance of this rehabilitated pavement in terms of roughness measurements using the Portable Universal Roughness Device, frictional resistance measured with the ASTM brake-force trailer, Pavement Condition Ratings and crack surveys. Also included will be a discussion on subsequent localized concrete pavement repair work completed on the highway during the seven years.

INTRODUCTION

Until 1989 the traditional method of rehabilitating concrete pavements in Ontario was to remove the distressed concrete full depth or partial depth and replace it with asphaltic concrete. Although these repairs performed well in the short-term, in the long-term the hot mix patches would begin to distort and crack resulting in a rough ride. During the mid to late 1980's, significant advances in concrete pavement rehabilitation (CPR) techniques were achieved allowing the restoration of rigid pavements with concrete. This maintained the integrity of the PCC slabs and the long-term benefits of concrete. A site was selected in the late 1980's to demonstrate various restoration techniques, including methods that had not previously been utilized in Ontario.

At the time of construction, this project utilized the most comprehensive CPR techniques undertaken in Canada. The demonstration site is located on a 5 km urban arterial facility in London, Ontario, Highway 126. The highway was assumed by the City of London and is now known as Highbury Avenue. Rehabilitation techniques included partial and full depth repairs and diamond grinding on the northbound lanes and an unbonded overlay on the southbound lanes. Construction was completed late in the summer of 1989.

BACKGROUND

General

Highbury Avenue is located approximately 200 kilometres west of Toronto. It is a four-lane divided arterial, with an AADT of 25,000, with 15% commercial vehicles.

The original pavement was constructed in 1963 with 225 mm of mesh reinforced PCC (JRCP) on 300 mm of granular base and subbase materials. The pavement was constructed with a 21.3 m joint spacing with dowel bars. The joints were sealed with preformed neoprene seals.

The pavement serviceability varied dramatically between the northbound and southbound lanes. The general pavement condition of the northbound lanes was considered better than average considering the 26-year service life. The distresses on these lanes consisted of approximately three transverse cracks per slab, with one being a severe working crack and two slight cracks, spalling at joints and cracks, and a moderately polished surface. Typically the transverse contraction joints had seized, leading to the severe working cracks. Minimal stepping was exhibited at the joints. The joint seals were approximately 85% intact, although there was significant bond failure between concrete and sealant throughout.

The pavement on the southbound lanes was in much poorer condition, with full and partial width transverse cracks in each slab, severe D-cracking, spalling of all joints throughout, and moderate pavement edge break-up.

The variance in the 26-year pavement performance was attributed to the different concrete aggregate types used in the concrete on the opposing lanes. The quarried aggregate used on the southbound lanes exhibited absorptive characteristics and was highly susceptible to D-cracking under freeze/thaw conditions. A pit run gravel source was used for the coarse aggregate on the northbound lanes. Three rehabilitation strategies were considered:

- crack and seat with an asphalt overlay;
- repair of the PCC pavement with hot mix and a multiple lift asphalt overlay; and
- full depth and spall repairs with concrete and diamond grinding on the northbound lanes and placement of an unbonded concrete overlay on the southbound lanes.

The estimated initial construction costs for the three options varied from $1.5 to $1.8 million, however, the total life cycle costs over 30 years were similar. The option of concrete repairs with PCC, diamond grinding and an unbonded concrete overlay was selected, as it best addressed the actual performance deficiencies exhibited by the pavement and provided the longest anticipated service life.

Design

The PCC rehabilitation techniques utilized on the northbound lanes incorporated the latest designs and construction procedures. The design of the full depth repairs included a minimum repair width of 2.0 m with epoxy coated dowel bars epoxied into drilled holes spaced at 300 mm on both transverse faces. Also, the existing concrete had to be removed in such a manner as not to disturb the underlying granular base.

The partial depth repair requirements included sawcutting the perimeter to a depth of 50 mm, removal of loose concrete, and sandblasting of the final exposed surfaces. A cement paste was applied immediately prior to concrete placement. The designs used are fully detailed in [1].

The design of the unbonded concrete overlay on the southbound lanes included the placement of a 20 mm asphaltic sand hot mix bondbreaker over the existing pavement surface. This was then overlain by a 180 mm thick unreinforced plain jointed concrete pavement. Slipforming of the concrete overlay used revised specifications based on experience gained on an earlier MTO demonstration project on Highway 3N, which placed and monitored four types of experimental concrete pavements [2, 3]. Skewed randomized joints were utilized with no effort made to avoid matching the underlying joints.

Construction

There were some initial difficulties with the removal of the existing concrete for the full depth repairs without disturbing the granular base. Once this was resolved the construction of the concrete repairs, diamond grinding, and the unbonded overlay went smoothly. Details of the construction procedure and material testing have been published in the earlier report [1].

PAVEMENT PERFORMANCE

Pavement Distress Survey

The visible distresses in the pavement surface were surveyed using the ministry's Rigid Pavement Evaluation Procedure [4] to provide an overall indication of performance.

Northbound Lanes

In 1992, after three years, seven of the 266 full depth repairs were typically exhibiting a very slight longitudinal cracking in the right wheelpath of the driving lane. In a few locations, these cracks are beginning to propagate into the adjacent slabs. No signs of movement or faulting of the repairs were observed.

At that time, approximately half of the 75 partial depth repairs were exhibiting distress. The majority of the failures were in the driving lane and in the outside third of the slab. This is likely due to higher stress levels at the outside of the pavement as there are no integral shoulders.

In 1992 a limited investigation of a few partial depth repairs was undertaken. The investigation revealed that the partial depth repairs had extended to the level of the dowel bars, with associated joint movements resulting in rapid deterioration (cracking and spalling) occurring at the repairs. This reaffirms the generally accepted practice of not undertaking partial depth repairs for depths greater than one third the slab depth or where shallow dowel bars/reinforcing mesh are encountered [5]. This was also confirmed by cores taken through some slabs where the partial depth repairs did not exhibit any cracking. In these uncracked repairs the replacement did not exceed a third of the slab depth and bond between the old and new concrete was excellent. Bond between the old and new concrete was also very good in the deteriorated repairs, indicating the weakness or spalling in the slab extended below the repair level. These findings reaffirm the importance of critical assessment of where partial depth repairs are used.

In 1994 a detailed distress survey was also carried out indicating that further full depth repairs were required. A total of 96 areas requiring full depth repairs (including 13 of the original repairs) and 16 new partial depth repairs were identified. The majority of the full depth repair locations required the minimum one lane width by 2.0 m long repair. The partial depth repairs were all one-half a square metre in size. Also identified was the need to remove and reseal an additional 46 cracks that at the time of original construction did not exist or were not wide enough to require sealing.

In the summer of 1994, the City of London completed 96 full depth and 16 partial depth repairs along with limited resealing. The repairs were completed in the same manner as the original repairs as detailed in [1], except that the surface of the repairs was not diamond ground but tined longitudinally by hand, while the concrete was plastic.

A recent survey of the northbound lanes indicates that a few of the new repairs have cracked in the wheelpath of the driving lane, as happened with the original repairs. These cracks are slight in severity. There is also some slight spalling of the repairs and original concrete at the joints and cracks.

Southbound Lanes

The only distress observed in the southbound lanes is slight longitudinal cracking in 11 of the driving lane slabs. This can probably be attributed to inadequate longitudinal joint construction (i.e., delayed saw cutting) as the cracks were visible soon after construction. No transverse or reflection cracking has been observed, which correlates with other agencies' experience [6]. There was no additional construction on these lanes during the work undertaken by the City of London on the northbound lanes.

Roughness Measurements

Roughness was measured just after construction, and prior to opening to traffic, and on a yearly basis since construction. The California Profilograph was used after construction and the Portable Universal Roughness Device (PURD) for ongoing monitoring..

The profilograph measurements were taken on the new concrete overlay with readings taken in both wheelpaths of the driving and passing lanes. For details on the function and operation of a profilograph see [7]. The average profilograph reading, profile index, for the length of the project in the driving lanes was 175 mm/km and 169 mm/km in the passing lanes. These readings were taken prior to diamond grinding the 21 locations where the roadway did not meet the surface tolerance specifications of 3 mm in 3 m. Since 1994 the MTO has incorporated a ride specification on all concrete paving contracts based on profilograph readings. The specification allows for bonuses and penalties based on the profile index. For 100% payment the profile index must be between 110 mm/km to 180 mm/km. For this demonstration project, the initial ride measured with the profilograph indicated that it met the smoothness requirements expected of a new exposed concrete pavement.

Roughness measurements using the PURD have also been taken over the last seven years. The PURD is a trailer-mounted, accelerometer-based mechanical measuring device operated at constant highway speed, that uses the root mean square vertical acceleration of the trailer axle to measure roughness. PURD measurements are converted into a ride comfort rating (RCR) using a transfer function for application in Ontario's Pavement Management system. RCR is based on a scale from 0-10, with 10 considered a smooth and pleasant ride. Testing for roughness was undertaken using the PURD prior to rehabilitation, after rehabilitation just prior to opening to traffic, and on an annual basis since.

Northbound Lanes

The ride improved significantly after construction on the diamond ground surface, with an improvement in RCR from 5.4 and 6.5 to 9.1 and 9.3 in the driving and passing lanes respectively. The ride data over the first six years for the diamond ground surface indicates that this high ride value in the driving lane dropped to a value of 7.5 after one to two years but has remained fairly constant over the last five years. The passing lane also remained constant over the last six years at a ride value of 7.7. These RCR values are in the comfortable range of the ride categories. The 1996 survey indicates that the ride has dropped to 6.6 in the driving lane while remaining at 7.6 in the passing lane; both lanes still fall within the comfortable category. See Figure 1 for a summary of the RCR values in the northbound lanes.

Southbound Lanes

The unbonded overlay on the southbound lanes resulted in an improvement in ride from 5.1 and 6.1 to 7.7 and 7.8 in the driving and passing lanes respectively; see Figure 2. The newly tined surface texture on the unbonded overlay was very aggressive and may have contributed to some of the initial roughness. The ride in both the passing and driving lanes in the southbound direction have had fairly constant RCR values over the last seven years, ranging from 6.9 to 7.9 (averaging 7.5) in the driving lanes and from 7.1 to 8.1 (averaging 7.6) in the passing lanes. Again, all readings are in the comfortable category.

Skid Testing

The skid resistance of the pavement was measured with a brake-force trailer conforming to ASTM Standard E274. The measured friction force is described as a skid number (SN) at a specific speed; for example, SN 80 is the skid number at 80 km/h.

Northbound

On the diamond ground surface the skid numbers improved just after construction, from an average of 25 and 35 to 48 and 49 for the driving and passing lanes respectively. Skid numbers of this magnitude indicate a good friction factor and are similar to numbers obtained on premium hot mix surface courses [8]. Over the last six years the skid resistance has dropped to levels between 26 to 30 in the driving lane and between 34 to 38 in the passing lane, see Figure 3.

These values are approximately 10 units lower than the results of the tined and burlap finish in the southbound lanes. These results in the NBL are somewhat unexpected as the corduroy type of texture with fractured concrete between the diamond cuts visually indicates a high frictional resistance. It is assumed that the fractured ridges have worn away fairly quickly under high traffic and heavy snowplowing conditions. The micro-texture created with diamond grinding may not be as durable as that created by burlap drag resulting in an earlier reduction in measured frictional properties.

Southbound

The skid numbers in the southbound lanes increased to an average SN 80 of 55 for both lanes after the overlay, from an SN 80 of 18 and 29 in the driving and passing lanes respectively. The skid resistance has stayed fairly consistent for the last seven years with the driving lanes ranging from 35 to 37 and the passing lanes ranging from 39 to 45. See Figure 4 for a summary of the skid resistance in the southbound lanes.

As anticipated, in the first year the initial sharp projections of the drag/tined surfaces have been worn, polished or sheared off by traffic and snow removal operations, but it appears that this is happening at a higher rate on the diamond ground surface when compared to the tined and burlap dragged surface texture.

Sound Level Measurements

Sound level measurements were undertaken prior to and following rehabilitation to provide data for future projects. The procedure used to measure pavement noise on this project was to measure noise from individual vehicle pass-bys at a 15 m distance from the travelled lane. The results indicated that the diamond ground surface was approximately 1 dBA quieter than the old worn concrete and the MTO sample. The diamond ground surface was only 1 dBA louder than an open graded asphalt friction course which is used for its low noise characteristics and good skid resistance. The MTO sample is obtained from [9] and was derived by testing several hundred vehicles on a variety of pavement surfaces, predominantly asphaltic concrete, across the province.

The burlap dragged and transversely tined concrete surface was approximately 1 dBA noisier than the old worn concrete and MTO sample. For further details on the sound measurements see [1].

CONCLUSIONS

1. A comfortable and acceptable ride is attainable with surfaces that have been diamond ground or tined and burlap dragged.

2. Visual observation in conjunction with core analysis of partial depth repairs confirms the importance of not only observing quality construction procedures but also of critical selection of repair locations.

3. Pavement monitoring has revealed that where existing pavement joints are seized (non-working) and full depth repairs are constructed at mid-slab working cracks future deterioration of secondary minor transverse cracks may occur. Consideration should be given to repairing them at the time of initial rehabilitation or planning for further repairs at a staged time interval.

4. Performance of the unbonded overly has been excellent to date with no indication of reflection cracking or other distress manifestations.

5. Measured friction/resistance of the diamond ground surface is approximately 10 units lower than that measured on the burlap drag/tined surface over the last five years of service. Although the frictional numbers are still at an acceptable level, this difference in comparative performance will continue to be monitored.

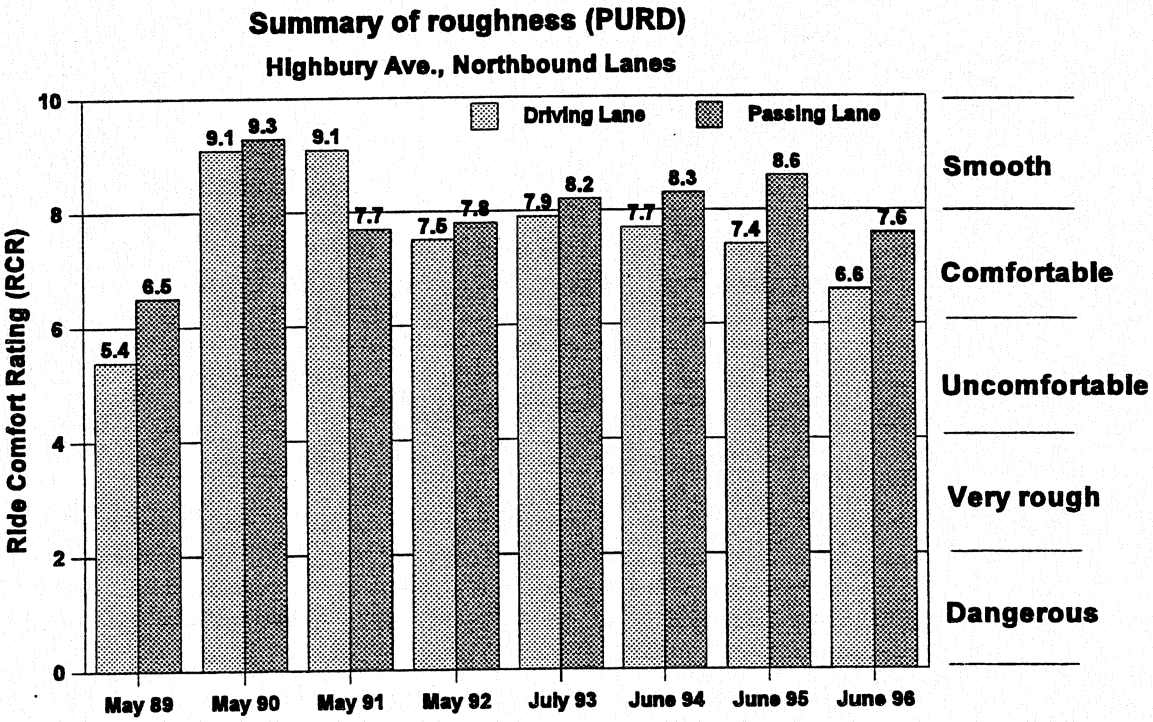


FIGURE 1

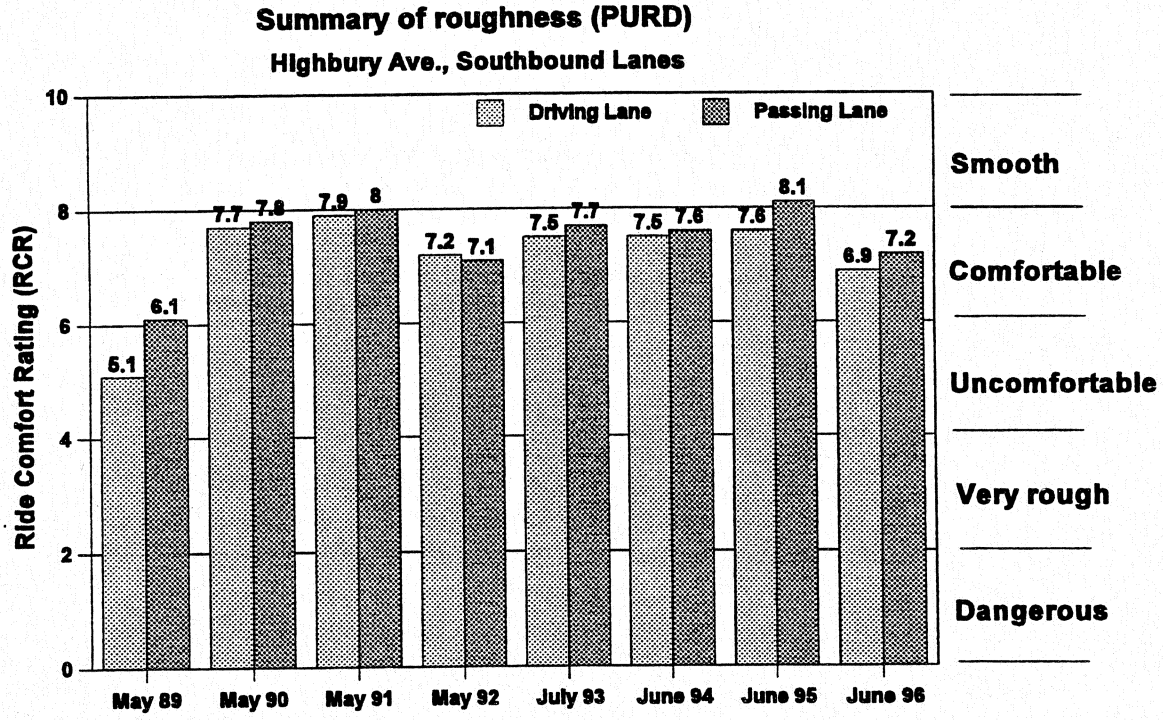


FIGURE 2

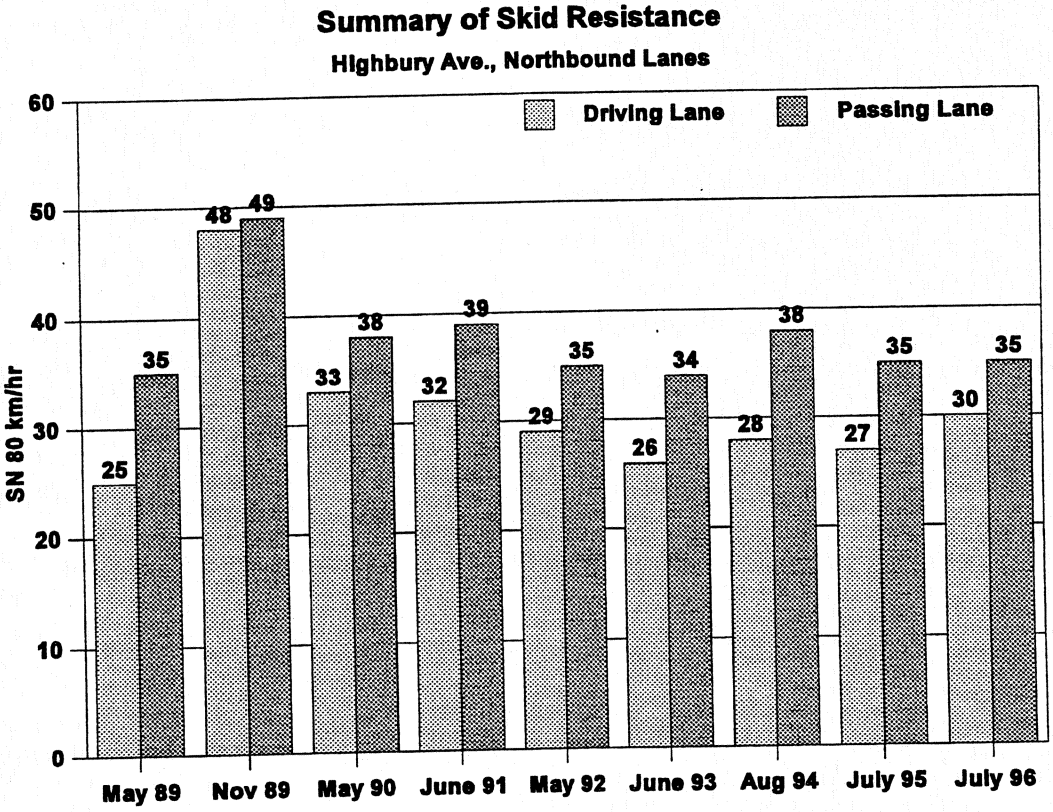


FIGURE 3

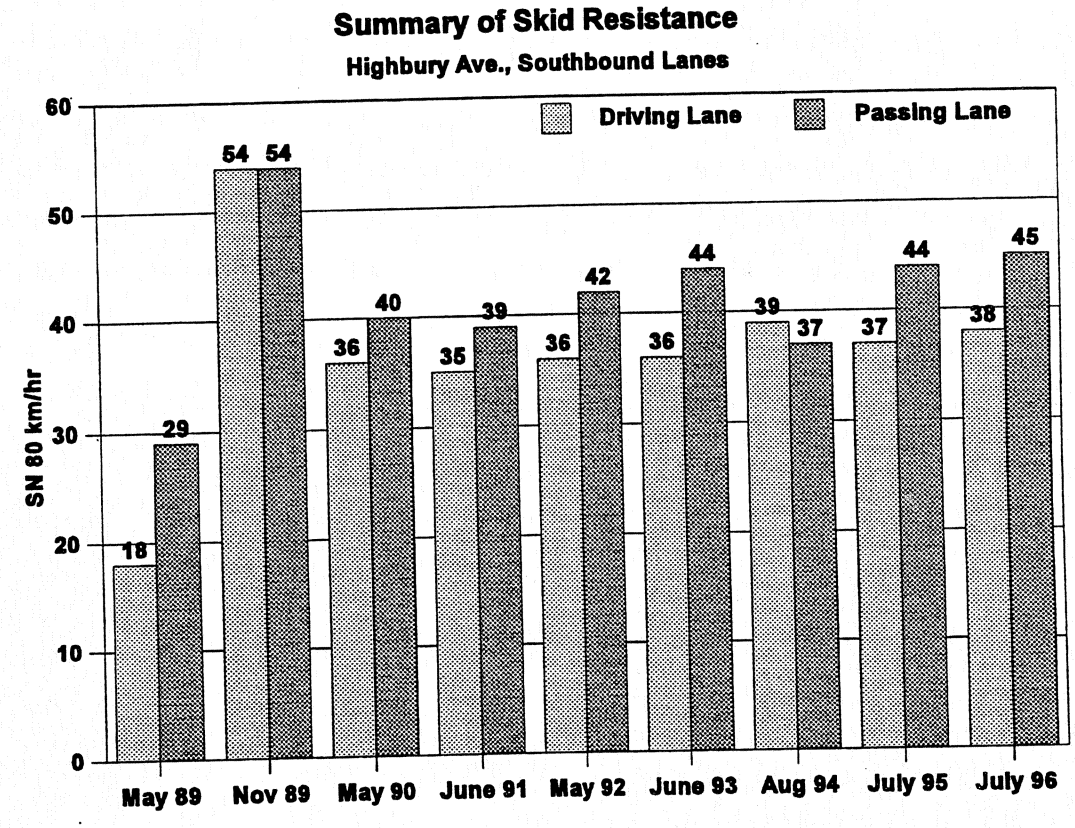


FIGURE 4

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