ALGUNOS ASPECTOS RELEVANTES DEL MICROFRESADO DE PAVIMENTOS DE CONCRETO HIDRÁULICO

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RESUMEN

El estado de la superficie de un pavimento es un factor que puede variar debido a la influencia del tráfico y de los procedimientos constructivos, es una característica funcional que afecta el considerablemente al usuario de la carretera. Para pavimentos de concreto hidráulico con un desempeño estructural competente, el microfresado puede ser una opción muy eficaz y económica para la dejar en condiciones aceptables el estado superficial. El microfresado es la remoción de una fina capa de concreto (generalmente alrededor de 6 mm [0.25 pulg.]) De la superficie del pavimento. Esto se logra usando equipo especial equipado con una serie de picas espaciados estrechamente. Las principales aplicaciones para la el empleo del microfresado son para eliminar irregularidades de la superficie, restaurar una superficie de rodadura lisa, para aumentar el coeficiente de fricción del pavimento, y para reducir el ruido pavimento. El microfresado produce valores de lisura muy aceptables, y en algunos casos superiores a las que normalmente se obtiene para la nueva construcción del pavimento, también proporciona una mejora inmediata en la fricción de la superficie del pavimento. La intención de este este trabajo es caracterizar y analizar el comportamiento de la primera intervención de esta técnica en México, misma que se llevó a cabo en la autopista México - Querétaro, que se considera como uno de los principales corredores viales de México, tiene un TDPA de 43,626 vehículos, mismo que consisten principalmente de los vehículos pesados (30 % aprox).

Palabras clave: microfresado, pavimentos de concreto hidráulico, condiciones superficiales y rehabilitación.

ABSTRACT

The surface condition of a pavement is a factor that may vary due to the influence of traffic and construction methods, and is a functional characteristic that impacts the road user considerably. For concrete pavements in good structural condition, diamond grinding can be a highly effective and economical choice for rehabilitation. Diamond grinding is the removal of a thin layer of concrete (generally about 6 mm [0.25 in.]) from the surface of the pavement. This is accomplished using special equipment fitted with a series of closely-spaced diamond saw blades. Major applications for diamond grinding are to remove surface irregularities, to restore a smooth riding surface, to increase pavement surface friction, and to reduce pavement noise. Diamond grinding produces smoothness values approaching (and in some cases exceeding) those typically obtained for new pavement construction, and also provides an immediate improvement in the surface friction of the pavement. The aim of this paper is characterize and analyze the behavior of the first diamond-ground road in México, namely the 057D, one of México's main highway corridors with an AADT of 43 626 vehicles, consisting primarily of heavy vehicles (30 % approx.).

Keywords: diamond grinding, concrete pavement, surface conditions and rehabilitation.

RESUMO

A condição da superfície de um pavimento é um fator que pode variar devido à influência de métodos de tráfego e de construção, e é uma característica funcional que impacta o usuário estrada consideravelmente. Para pavimentos de concreto hidraulico em boas condições estruturais, de moagem de diamante pode ser uma escolha altamente eficaz e

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econômica para a reabilitação. Diamond grinding é o remoção de uma fina camada de betão (geralmente cerca de 6 mm [0.25 pol.]) A partir da superfície do pavimento. Isto é conseguido usando um equipamento especial equipado com uma série de lâminas de serra de diamante estreitamente espaçados. As principais aplicações são para rectificação com diamante para remover irregularidades da superfície, para restaurar uma superfície de tráfego lisa, para aumentar a superfície de atrito do pavimento, e para reduzir o ruído do pavimento. Diamante moagem produz valores lisura aproximando (e em alguns casos superiores a) aqueles normalmente obtidas para a construção nova calçada, e também fornece uma melhoria imediata na fricção da superfície do pavimento. O objetivo deste trabalho é caracterizar e analisar o comportamento da primeira estrada de terra de diamantes no México, ou seja, o 057D, um dos principais corredores rodoviários do México com um TMDA de 43 626 veículos, consistindo principalmente de veículos pesados (30 % aprox).

Palavras chave: microfresado, pavimentos de concreto hidraulico, condições do superfície y reabilitação.

1. INTRODUCTION

With both the rising costs of pavement construction and delays to road users during construction or rehabilitation, more attention is being given to simpler but effective measures of pavement rehabilitation that can be carried out on our CAPUFE system while minimizing the impact of rehabilitation on road users.

The pavement must be smooth for the driving public, but must also be strong and cost-effective, while meeting many other specifications required by the road's owner – the Mexican state highway agency – and ultimately road users. As an incentive to encourage contractors to optimize these competing objectives, the Mexican Government began offering bonuses to contractors able to resolve the technical problems associated with the task while still achieving a smooth ride surface. As a necessary counterpart to these bonuses, the Government also issued penalties for rough pavements. The Mexican Government has thus recognized the benefit of offering incentives for smoother pavements.

A primary responsibility of state transportation departments is to maintain their highway network (Toth 2000). Of all the desired surface qualities, road smoothness (ride quality) has a strong influence on the public judgment of its serviceability (Janoff 1982, 1983; Hudson 1991; NQI 2001).

Longitudinally ground PCC pavements were found to have better overall crash rates (measured in crashes per 100 million vehicle-km of travel) than transversely tined PCC pavements (Drakopoulos *et al.*, 1998).

Diamond grinding is the removal of a thin layer of concrete (generally about 6mm [0.25in]) from the surface of the pavement. This is accomplished using special equipment fitted with a series of closely-spaced diamond saw blades. Major applications for diamond grinding are to remove surface irregularities (most commonly joint faulting), to restore a smooth riding surface, to increase pavement surface friction and to reduce pavement noise (ACPA 2000; Correa & Wong 2001; Hoerner et al., 2001; Peshkin *et al.*, 2004).

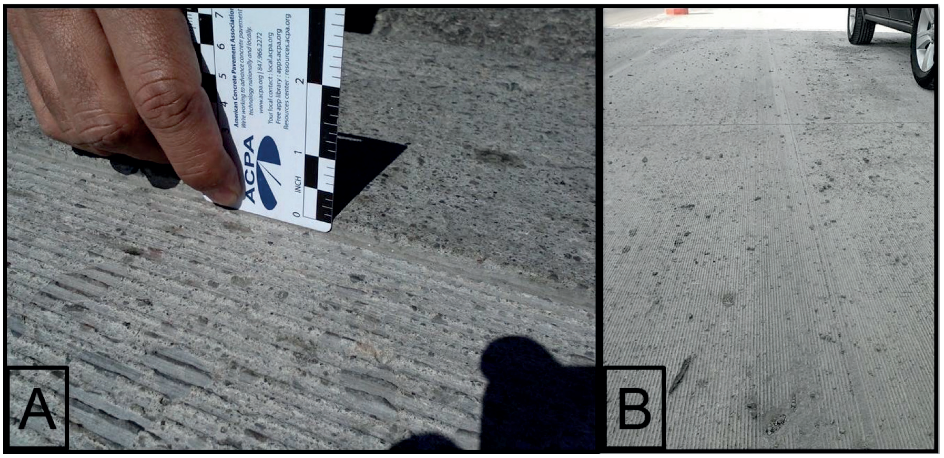

Fig. 1: (A) Close-up of diamond grinding; (B) Longitudinal diamond grinding.

Figure 1(A) shows a close-up of diamond grinding on the 057D highway running from México City to Queretaro, with a thin layer of approximately 5.0 mm of concrete removed. Figure 1(B) shows this longitudinal grinding in the direction of highway.

The history of continuous diamond grinding for pavement restoration dates back to 1965, when the technique was first used on a 19-year-old section of the San Bernardino Freeway (I-10) in southern California to eliminate excessive faulting (Neal & Woodstrom, 1976).

It is important to recognize that diamond grinding only addresses serviceability problems: diamond grinding should not be used on pavement sections with a material problem such as D-cracking or reactive aggregate (Rao et al., 1999).

Diamond grinding also brings two other major advantages: improved texturing and skid resistance, and reduced noise levels at the tire/pavement interface. Based on current experience, it is possible to diamond-grind candidate concrete pavements up to three times before major reconstruction is needed (Stubstad *et al.,* 2005).

This paper describes the first trial of diamond grinding in México, which has a total of 230 km of concrete roads. The road under study is the 057D highway running from México City to Queretaro, a total distance of 176 kilometers (109 miles). This road was renovated in 1998 and has three lanes in each direction. The road surface design includes 28 cm (11in) of non-reinforced Portland Concrete Cement Pavement (PCCP). This is the main highway through the country.

2. METHODOLOGY

There are no objective criteria (such as maximum joint faulting, maximum percent of cracked slabs or maximum roughness value) available for the selection of any given concrete pavement as a candidate for diamond grinding. Nevertheless, multiple factors were considered for the present study in order to decide which slabs should be ground.

The present field investigation was carried out using efficient, systematic procedures to minimize both disruption to traffic and the risk of missing out any sections of road.

2.1. PROFILE INDEX

The PIC (profile index) is a nonlinear transform of a longitudinal profile statistic of the Ride Number (RN). The RN was developed (NHI 2001) to agree with mean panel rating (MPR) of roughness using a scale from 0 to 5 where 5 is a perfect ride. This scale was select to be similar to the present serviceability index (PSI) that was introduced during the American Association of State Highway & Transportation Officials (AASHTO), Road Test (Highway Research Board 1962).

2.1.1 PROFILE MEASUREMENT

A California Profilograph was used for profile measurement. The California Profilograph consists of a 7.6m (25 ft) long aluminum truss supported by bogey wheels with a centrally-located, pneumatic measuring wheel secured to a moveable arm. The arm moves up and down as the device is pushed down the road, tracing the surface profile. As such, the device can only measure one wheel path at a time and measurements are taken at a relatively slow pace (around 4 km per hour).

A standard procedure was used to operate the profilograph. The start and end points of the pavement section to be measured are marked out. The operator is responsible for starting the profilograph with the measuring wheel on the mark and ending on the mark at the end of the run. Ride quality is then measured by operating the profilograph over the section of pavement in question, with the location within the lane and number of runs determined by applicable specifications, and with the equipment being operated within the speed range specified for data collection by the manufacturer. Linear measurement is continued over areas excluded from ride quality measurement where these areas still lie within the overall limits of pavement being measured. The pavement surface must be clean to obtain accurate measurements.

2.2. INTERNATIONAL ROUGHNESS INDEX

An inertial profiler is used to determine International Roughness Index. Inertial profiling devices were originally developed for highway use and measurements with these devices are typically made at a constant travel speed. A typical inertial profiler, as used in the present study, consists of three major components: a sensor to measure the distance from a point on the test vehicle to the pavement surface; an accelerometer to measure the vertical acceleration of the test vehicle; and a sensor for measuring the distance traveled along the pavement.

The profiler used in the present study has a distance measuring sensor based on laser triangulation with a nominal spot size of 1 mm (0.04 in), a measurement range of ± 100 mm (4 in), a resolution of 12 bits (0.049 mm, 0.002 in) and a sample rate of 32 kHz. The normal test speed is 100 km/h (62 mi/h) and the maximum spatial sampling distance is therefore 0.52 mm/sample (0.02 in/sample), or one-half the spot size per sample.

Vertical acceleration of the test vehicle is measured via a high quality servo accelerometer while distance traveled is measured via a contact-free incandescent light distance sensor (output is one pulse every 2.5 mm [0.1 in]).

3. RESULTS AND ANALYSIS

Figure 2 shows a plot of Profile Index taken in the direction Mexico City - Queretaro before and after diamond grinding. The Profile Index values obtained were in the range 1.3 to 128.8 cm/km (1.0 to 81 in/mi), with the highest measurements lying in the kilometers between 171 + 000 and 172 + 000. Likewise, the graph shows that the profile is very heterogeneous. This is possibly due to previous pavement rehabilitation having taken place involving the replacement of slabs in the absence of strict standards.

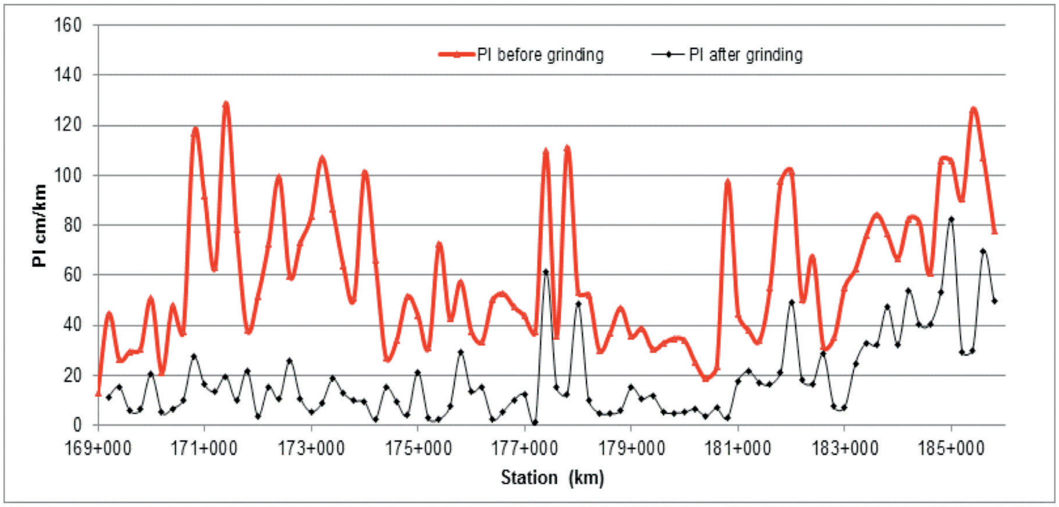

Fig. 2: Profile Index in the direction Mexico City - Queretaro before and after diamond grinding.

Figure 3 shows that over almost all sections, a greater than 50 % reduction in PI is observed, providing evidence that diamond grinding is a successful technique for reducing Profile Index.

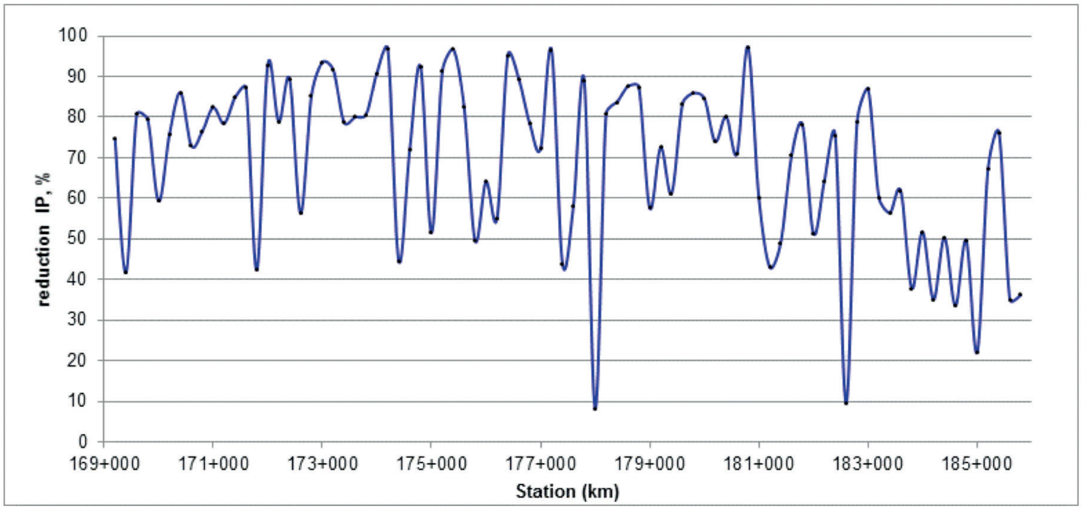

Fig. 3: Percentage reduction in Profile Index.

Throughout the section studied, mean PI was reduced from 60.0 cm/km/200 m (38 in/mi/0.12 m) prior to grinding to 18.6 cm/km/200m (12 in/mi/0.12 m) post grinding. According to Table 1, these results are considered acceptable even for new pavements. It would be possible to reduce the PI further. However, this could lead to damage or deterioration of the road's structural capacity.

Table 1: Profile Index values reported in the literature.

(SCT 2008)		(CTDOT 2044)	
PI cm/km/200m	**Action**	**PI cm/km/200m**	**Action**
< 14	Incentives	< 12	Incentives
14	Threshold	over 10 - 12	Threshold
> 14	Disincentives	> 12	Disincentives
	Corrective work		Corrective work
> 24	Required	> 20	Required

Turning to International Roughness Index (IRI), figure 4 shows that IRI values follow a similar trend after grinding to those observed prior to grinding. Overall, IRI values were observed in the range 1.68 to 3.74 m/km (106.5 to 237 in/mi).

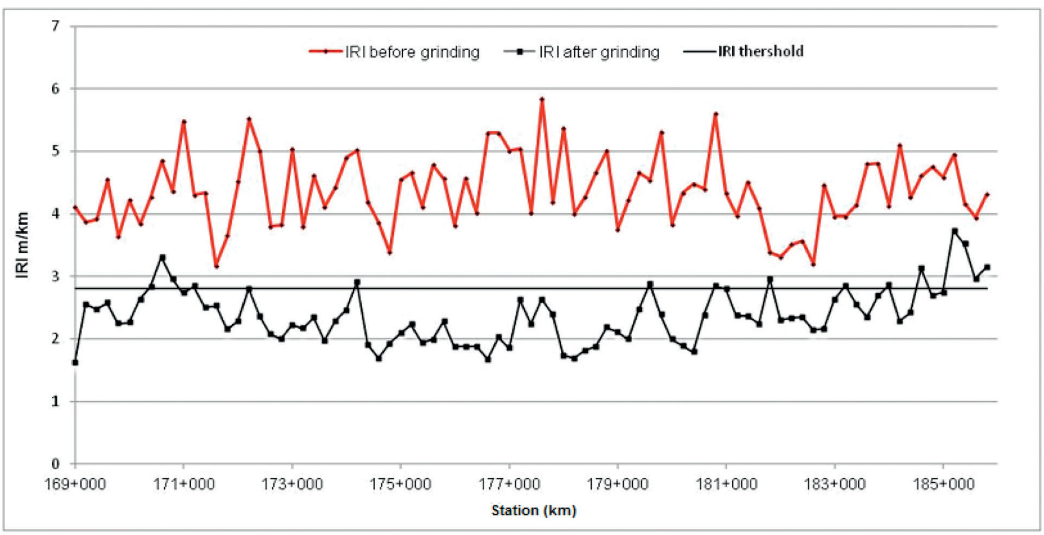

Fig.4: International Roughness Index in the direction Mexico City - Queretaro before and after diamond grinding.

The Mexican Ministry of Communications and Transportation (SCT 2013) stipulates an acceptable IRI threshold of 2.81 m/km (178 in/mi) for new roads. This threshold is marked in figure 4, showing that observed values exceed the limit for new roads in most cases. However, there is still a significant reduction in PI and excessive faulting is eliminated. This percentage reduction in IRI is plotted in figure 5.

Table 2 lists IRI classification ranges reported in the literature. According to these criteria, the observed case would be classified as a "Rough" surface and according to New Mexico DOT would require corrective work. Moreover, this road is more than 20 years old.

4. CONCLUSIONS

Based on the observations and results of the study, we conclude that diamond grinding is a viable method for providing surface smoothness on both recently laid and older PCCP.

In almost all cases, the observed reduction in PI was above 50 %, with an average of around 69.2 %, a maximum of 97.2 % and a minimum of 8.3 %. The reduction in IRI was less than 30 % (average value 27.5 %), with a maximum of 81.1 % and a minimum of 0.2 %. Over all sections tested, PI and IRI were reduced, as expected.

Diamond grinding extends the service life of an old concrete pavement to around twice the normal design life through the use of two or three diamond grinding operations in addition to normal routine maintenance, none of which should disrupt the flow of traffic during peak hours.

All results obtained from the México City-Queretaro highway will serve as a benchmark for the rehabilitation of Hydraulic Cement Concrete Pavement exhibiting clear distress problems in Mexico.

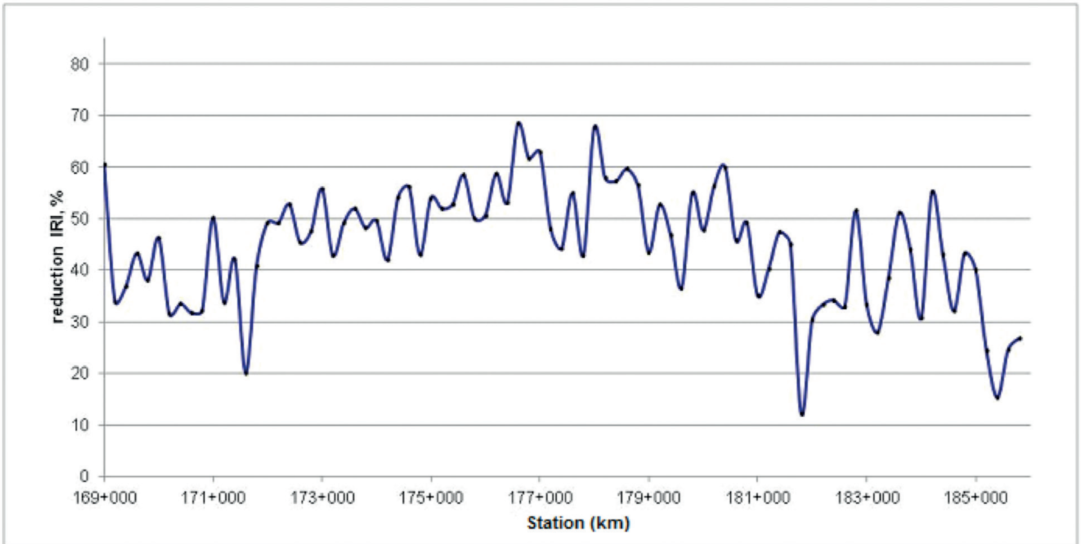

Fig. 5: Percentage reduction in International Roughness Index.

Table 2: Pavement Roughness classification reported in the literature.

(SCT 2008)		(CTDOT 2044)	
Approximate IRI (m/km)	**Roughness Classification**	**Approximate IRI (m/km)**	**Roughness Classification**
0.0 – 1.5	Smooth	< 0.97	Incentives
1.5 – 2.1	Moderatey rough	0.97 to 0.98	Threshold
> 2.1	Rough	> 0.98	Disincentives
			Corrective work
		> 1.15	Required

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