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Field and Laboratory Studies of AMIR II Compacted Asphalt Pavement

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***Abstract*—The early results of using the Asphalt Multi-Integrated Roller (AMIR) roller have shown improved qualities of the finished hot asphalt mixes. Various field studies have been carried out to in Egypt, Canada and Australia comparing between the conventional drum rollers combination and the AMIR roller. In this research, AMIR II compactor was used in Canada, specifically in Ontario, to construct several highway section and bridge lanes throughout Ontario. This paper report results of test section constructed on a MTO Highway-28 and another in-house section where both AMIR and the conventional rollers train were used in order to evaluate the quality of the AMIR compaction method in relation to the current one. Measurements of field Permeability, degree of compaction, density of recovered asphalt cores and periodical deflection tests were carried out on the paved sections. The results supported the findings of earlier AMIR Field trials and showed that hot mix asphalt mixes that are compacted with the AMIR II had superior properties in terms of lower permeability values and equivalent or better density achieved with fewer roller passes. Also the results of using Falling Weight Deflectometer (FWD) to measure the deflections of the surface of the finished asphalt sections showed that surface deflections were 10 to 15 % less in the case of AMIR compacted section compared to the section that were compacted using current rollers.**

Keywords— Asphalt Pavement; Compaction; Permeability; Bulk Relative Density; Roads & highways; Field Testing & Monitoring; Quality Assurance & Quality Control.

I. INTRODUCTION

In Ontario, most asphalt pavements are designed to have an expected service life in the range of 15 to 20 years [1] [2]. However, this design objective is rarely met because of the uncertainty of many design and construction variables that leads to early failures and premature failure of newly laid asphalt surfaces. Ministry of Transportation Ontario (MTO) launched several research initiatives in the field of asphalt binders, material selection and handling, testing procedure, mix design method. These attempts are carried out in order to find effective and reliable solutions to address old problems that are still unsolved until today such as early cracking, rutting, stripping and other similar pavement distresses leading to early failures.

The Hot Mix Asphalt pavement (HMA) Community introduced some solutions for the existing pavement problems. The introduced solutions are more based on the materials used in the asphalt mixes. The main course of action remained, modification to asphalt mix design as well as selection of different materials. Majority of predicted solutions deals in part with the characterization of asphalt materials and their performance under a wide range of in-service conditions, and the adoption of gyratory compaction as the main laboratory device for designing asphalt mixes. Also the use of advanced materials such as polymer modified asphalt binders with improved tensile and shear strengths to reinforce asphalt layers. The introduction of end-result specifications [3] and performance based specifications have contributed to an improvement in pavement performance. These and other initiatives are expected to have a significant impact on the performance of asphalt pavements both in the short and long term. However, in spite of these efforts long term performance of pavement has not met its expectation. A very important factor remain broadly unaddressed which has a potential to affect performance of asphalt pavement is technology of asphalt compaction.

II. INFLUENCE OF COMPACTION

Compaction has been recognized by HMA community as one of the most important factors affecting quality and the least expensive element in extending the service life of asphalt pavement. Asphalt pavements have been compacted since their early introduction with the same technique which is mainly the steel drummed rollers. Unfortunately, no significant improvement had been made to study the interaction problem between the rollers and the compacted asphalt mat. HMA community assumes that base stability, operator error, temperature during compaction and/or the asphalt mix itself attribute to compaction problems. One such problem is construction induced cracks also known as “check cracks” [4]. Check Cracks are mainly caused by the compaction equipment used. These cracks may propagate through the asphalt layer providing a path for water to enter inside the body of the mat. The existence of water within the asphalt layers can potentially lead to negative and undesirable results by weakening the bond between the asphalt binder and aggregates leading to stripping and other types of distress. As an example, with the change of temperature during winter seasons, the trapped water inside the pavement layers freezes and expands leading to initiation of internal stresses which in turns lead to premature failure of the newly constructed pavement. In the early 90s, development of a new compaction concept led to the introduction of a new compaction technique termed Asphalt Multi-Integrated Roller or AMIR. The AMIR roller has a totally different compaction principle than the current drum or pneumatic rollers. AMIR roller applies a uniformly distributed pressure through a special endless rubber belt on the Asphalt, over a longer period of time as depicted in Figure 1. In contrast to the very high pressure over a very short contact duration with the asphalt mat as in the current compaction equipment as demonstrated in Figure 2, the lower uniform pressure applied for a very long contact period with the mat ensured the higher quality and crack free surface of the asphalt mat when compacted by AMIR technique. The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

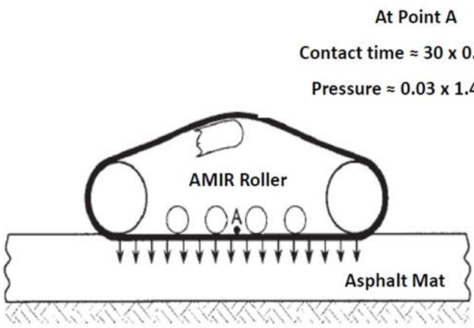

Fig. 1. *Schematic AMIR Compactor*

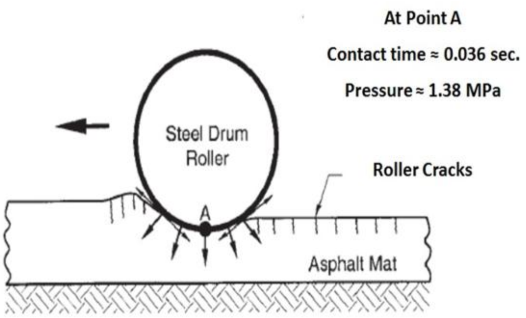

Fig. 2. *Schematic of Conventional Steel Drum Rolling*

Furthermore, traditionally HMA community compaction procedures are carried out with three different types of compactors. The construction of asphalt pavements is carried out by placing the hot mix asphalt over a base course or an existing road surface, and the first operation in the compaction procedure uses a heavy vibratory steel roller that induces greater compactive effort to obtain the desired density. Greater compactive effort is necessary, as Superpave design method results in higher required density at lower asphalt content with a higher aggregate percentage and aggregate contact compared to traditional mixes. Another reason for the greater compactive effort is to achieve higher density soon after the initial lay down because some binders are much stiffer at a higher temperature. Smoothing out the surface is accomplished with a multi wheeled rubber roller followed by a light steel roller. The finished product is assumed to be structurally sound and free of defects. The AMIR method replaces the three rollers and achieves the specifications in less number of passes as reported by several research reports [5-7].

In 2012, the Ministry of Transportation of Ontario, MTO, initiated a research program to upgrade the original AMIR roller. The modified roller was given a name AMIR II roller. The original AMIR roller was a prototype built to demonstrate the scientific principle leading to its unique design. Therefore, it was able to move in straight lines with limited ability to manoeuvre or turn sideways since it lacks steering capabilities. Subsequently, the primary modifications planned for the AMIR roller included upgrading its steering abilities, replacing its rubber belt and improve its hydraulics. A steering unit was added to the original AMIR roller as shown in Figure 3. The steering unit was able to allow the improved AMIR II to steer and change its directions with ease. It should be noted that the steering unit is only used for the steering purpose and not for any compaction purposes.

Fig. 3. *Modified AMIR II roller*

Secondary enhancements were incorporated by necessity through the course of the project. These enhancements consisted of various mechanical repairs, and safety and mechanical upgrades. The most significant mechanical enhancement was the addition of a self-regulating hydraulic system for maintaining the proper tension on the compaction belts. In addition, a new belt was replaced on the roller and was used in the field test at a commercial project on Highway 28.

III. PREVIOUS TESTS

Previous research investigations were carried out to study the performance of AMIR roller in the compaction of Asphalt in comparison to that of the conventional steel and pneumatic rollers [5-11].The previous research work showed that conventional compaction equipment are the main cause of surface cracks leading to finished asphalt mats with permeability rates as high as 3 to 10 times those achieved by using AMIR compactor. Also, it was reported that permeability rates can range across the width of the conventionally compacted mat by a factor of 2 to 5 higher rates at the edge of the HMA layer when compared to the rates at the centreline of the same compacted HMA layer. The high rates as well as the variation of the permeability rates can lead to non-uniform performance across the width of the lane and accelerating the deterioration of unsupported lane edges where higher rates of permeability were reported. Subsequently, the non-uniformity of the permeability rates between the edges and the middle of the paved lanes will likely result in the potholes and other premature surface cracks and/or distresses which can be observed on many sections of the highways.

IV. OBJECTIVES

The main objectives of this paper is to report on the results of field data obtained from planned cooperative projects with the Ministry of Transportation of Ontario and presents the results and main findings of the evaluation of the use of the upgraded AMIR compactor.

V. SITE LOCATIONS

The permeability tests were carried out on the same day after the fresh HMA was placed and compacted on roads in two site locations in Eastern Region of Ontario. The first test sections were completed on a commercial project on Highway 28 while the second one was carried out on the contractor firm yard (Tomlinson Yard) in the city of Ottawa. The AMIR section on Highway 28 was 2-lanes 250 meter each and received between 4 to 6 roller passes. The conventional rolling train in the control section required approximately 12 to 14 passes to complete compaction. Nuclear density meter was used to determine compaction acceptance. For the Highway 28 test location, permeability measurements, compaction, and smoothness, were carried out while for the Tomlinson Yard location, field permeability, compaction and falling weight deflectometer tests were carried out. The details of test sections and their site locations are given below. It should be mentioned that in all field tests both conventional and AMIR II compaction equipment were used to compact similar asphalt mixtures having the same mix design, mix temperature and road characteristics. Therefore, any differences to be observed or reported can be directly related to the change in compaction method.

A. *First Test Section – Highway 28*

Highway 28 is a Provincial Highway, which runs southwest–northeast from Highway 7 east of Peterborough, to Highway 41 in Denbigh, Ontario, Canada. The field test section was a part of 2012 MTO paving projects near the town of Bancroft. The test section layout was 250 m long, both lanes and hot mix asphalt was placed end-to-end same day. The project feature consisted of laying HMA 40 mm Superpave 12.5 Surface over 60 mm SP 19 over pulverized base; PGAC 58-40 Trial – highly polymer-modified and 0.5m single lift partial paved shoulders. The test sections were compacted using AMIR II on one section while the other section was completed using conventional compaction methods utilizing the three typical rollers of steel vibratory, pneumatic rubber and static steel rollers.

B. *Second Test Section – Tomlinson Yard*

In-house asphalt layer was HL-3 provided by Tomlinson groups Ltd. from their Rideau Plant in Ottawa. This section consisted of 60 meter long by 9-meter width and 50 mm thickness and was compacted using AMIR II side by side with the conventional steel roller. The asphalt mat was laid over a well compacted finished subgrade.

For the two road test sections, the permeability tests were carried out on the finished surface of the pavement sections after the compaction was completed. The field measurements were performed on randomly selected points on the paved lanes to examine the variability in permeability with the change of lateral location of the testing location. The test locations were identified according to their respective distance off the outer edge of the paved lane and were termed as “outer edge”, “centreline” and “inner edge”. Figure 4 shows a typical layout for the locations where the field measurements were carried out.

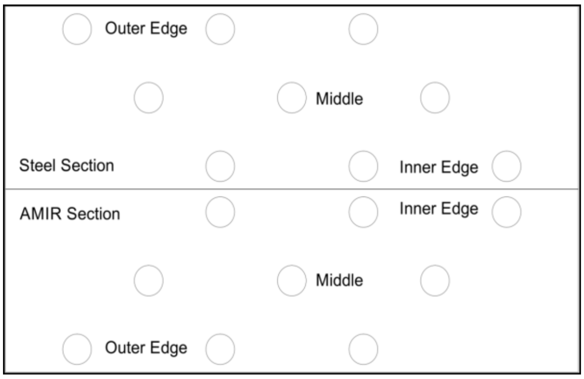

Fig. 4. *Typical location of permeability tests*

VI. GENERAL OBSERVATIONS

Clearly, the construction induced cracks caused by the use of the conventional steel rollers lead to several defects that influence the overall performance of the finished pavement. As shown in Figure 5 and Figure 6, the advantage of utilizing the AMIR compaction method produces a surface texture that is tighter and crack free. This superior surface reduces the permeability of the finished pavement in contrast to the surfaces resulted from the use of current rollers. The Asphalt that was compacted with the conventional steel roller experienced numerous surface cracks perpendicular to the direction of rolling.

Fig. 5. *Asphalt finish using AMIR II roller*

Fig. 6. *Asphalt finish using conventional roller*

In addition, the AMIR compaction method demonstrated an advantage when compacting the unsupported edges of the paved lanes as opposed to the inability of current roller to achieve the same task as shown in Figure 7. The AMIR II compactor was also used to finish longitudinal joints between old cold lane and fresh hot asphalt lane as well as between two newly laid HMA lanes and the results met the MTO specifications.

Fig. 7. *AMIR II roller compacting unsupported edges*

VII. PERMEABILITY TESTS

To evaluate the in-situ permeability of each compaction method, the National Centre for Asphalt Technology (NCAT) field Permeameter test was used. The NCAT field Permeameter has gained wide acceptance by several researches because of its practicality, ease of use, short time of the test, and non-destructive nature [12, 13]. The NCAT field Permeameter shown in Figure 8, is a falling head device used to record the drop in water level in the standpipe over a given time interval. The standpipe will be filled up to a specific mark, and the drop in water will be noted for a specified duration of time based on how fast the water permeates through the asphalt layer (ten to thirty minutes). However, the more permeable the pavement is, the faster the rate of drop of the water head. The Permeameter is divided into four sections with the base being the largest, and the top is the smallest; from the top to the bottom, the first level is used when the asphalt layer is a low permeable pavement, while the second or third levels are used for asphalt pavement mixes that are relatively more permeable.

Fig. 8. *Field permeability using the NCAT permeameter*

The Permeameter is typically filled to the top and the drop in water is measured at predetermined time intervals. Because of the increasing diameter in the lower levels, the drop in the level will be slow enough for efficient and more accurate recording of measurements in the case of highly permeable pavements. For each of the test sites, 5 to 6 measurements were taken and recorded per test location. For the 5-6 readings or measurements, the mean of the measurements are used in the analysis. The coefficient of permeability is calculated based on the falling head principal as follows [14]:

$$K = \frac{aL}{\mathrm{At}} \ln\left(\frac{h_1}{h_2}\right) t_c \quad (1)$$

K is the coefficient of permeability (cm/sec),

a is the internal cross-section area of standpipe (cm^2),

L is the thickness of the asphalt layer (cm),

A is the cross-sectional area that in contact with water during the test (cm^2),

h_1 is the initial head (cm),

h_2 is the final head (cm), and

t_c is the temperature correction for viscosity of water (20°C is used as the standard).

It is worth mentioning that the thickness of the asphalt layer (L) was estimated by measuring the thickness of the field-recovered cores, while the t_c was measured using a water thermometer.

A. Permeability Test Observations

Several observations were reported during the performance of the permeability tests. In general, water was much faster penetrating the asphalt lanes compacted by the conventional equipment than the same asphalt when compacted by AMIR II. The lane edges where conventional compaction equipment was used had an average permeability of four times higher than that for lane edges compacted by the AMIR. An important observation was noted on several test locations of conventionally compacted asphalt lanes where the water penetrated the surface into the body of the asphalt mix and appears to have moved sideways within the layer and returned upward outside the test region (Figure 9). This observation suggested that air voids within the finished paved lane were interconnected with surface cracks to form a channel leading the water back again to the surface.

Fig. 9. *The water penetrated the asphalt surface under the permeameter and returned back to the surface outside the test location*

B. Permeability Test Results

Results of the permeability tests carried out at the two locations; Highway 28 and Tomlinson Yard are shown in Table I and Table II, respectively. The tables show the description and locations of the test points, raw data obtained in the field tests, and the calculated permeability of the asphalt layer using the Equation 1.

The calculated permeability for the paved lanes on Highway 28 showed much superior performance achieved by the improved AMIR II compactor. As can be seen from Table I, the overall average permeability of the AMIR II compacted lanes was 1.08×10^{-3} cm/sec compared to the overall average of 3.28×10^{-3} cm/sec achieved using the conventional compactors. The use of AMIR II has significantly reduced the permeability of the same asphalt mix by more than 70%. Also, the highest permeability value on the AMIR II lanes was 3.77×10^{-3} cm/sec while on the control section was 7.06×10^{-3} cm/sec which is twice as much that of the AMIR compacted surface.

TABLE I. RESULTS FROM TESTS AT HIGHWAY 28

Field Compactor	Test No.	Tier No.	h_1	h_2	Time (Sec)	Permeability (cm/sec)	Avg. (cm/sec)	Std. Dev.	COV
AMIR II	1	1	64	53	105.9	2.50×10^{-4}	1.08×10^{-3}	0.0011	1.02
	2	1	63	53	45.2	5.66×10^{-4}			
	3	2	50	47	47.0	1.06×10^{-3}			
	4	2	49	45	26.5	2.59×10^{-3}			
	5	2	49	44	86.6	9.50×10^{-4}			
	6	2	49	38	52.9	3.77×10^{-3}			
	7	2	50	46	83.4	7.64×10^{-4}			
	8	1	63	58	71.9	1.66×10^{-4}			
	9	1	64	58	167.6	8.24×10^{-5}			
	10	1	49	37	68.7	5.63×10^{-4}			
Conventional Steel	1	3	33	27	60.7	6.41×10^{-3}	3.28×10^{-3}	0.0025	0.76
	2	2	49	45	69.0	9.69×10^{-4}			
	3	3	32	27	64.0	4.92×10^{-3}			
	4	2	49	39	54.6	3.14×10^{-3}			
	5	2	49	37	120.0	1.76×10^{-3}			
	6	3	33	27	52.7	7.06×10^{-3}			
	7	2	49	43	109.1	8.98×10^{-4}			
	8	1	63	52	60.1	4.40×10^{-4}			
	9	2	49	41	111.1	1.20×10^{-3}			
	10	3	33	28	50.9	5.98×10^{-3}			

Avg.: Average; Std. Dev.; Standard Deviation; COV: Coefficient of variation

Table I also shows the standard deviation as well as the coefficient of variation for the permeability results at Highway 28. It can be seen that the standard deviation for the permeability values is equal to 0.0011 in case of AMIR compactor in comparison to 0.0025 in case of the results obtained at the section compacted using the steel compactor. This illustrates that AMIR II compaction achieved about 40% (0.0011/0.0025) more consistent compaction in comparison to the steel roller. However, the two rollers achieved the same coefficient of variation in case of Tomlinson Yard as shown in Table II.

TABLE II. RESULTS FROM TESTS AT TOMLINSON YARD

Field Compactor	Test No.	Tier No.	h_1	h_2	Time (Sec)	Permeability (cm/sec)	Avg. (cm/sec)	Std. Dev.	COV
AMIR II	1	1	63	52	55.7	3.52×10^{-4}	1.72×10^{-4}	0.00011	0.65
	2	1	62	52	97.5	1.84×10^{-4}			
	3	1	63	58	67.9	1.24×10^{-4}			
	4	1	63	55	111.4	1.42×10^{-4}			
	5	1	63	60	100.2	5.65×10^{-5}			
Conventional Steel	1	1	63	52	6.4	3.63×10^{-3}	2.39×10^{-3}	0.00156	0.66
	2	2	50	45	74.3	9.36×10^{-4}			
	3	2	50	46	61.0	8.74×10^{-4}			
	4	3	33	28	59.9	4.35×10^{-3}			
	5	2	49	37	83.1	2.16×10^{-3}			

Avg.: Average; Std. Dev.; Standard Deviation; COV: Coefficient of variation

The results in Table II show the comparison between the permeability values achieved by AMIR II and Vibratory compacted asphalt sections side-by-side at Tomlinson Yard site. In this test the HMA was placed on top of pre-prepared subgrade and no pneumatic roller was used with the vibratory steel roller. Both paved lanes were subjected to the same number of passes by each roller. As shown in the table, the AMIR II produced overall average permeability value of 1.72×10^{-4} cm/sec compared to overall average value of 2.39×10^{-3} cm/sec achieved by the vibratory steel roller. Clearly, this is an improvement of a factor of 10 which is very significant in terms of the amount of water penetrating the surface of the finished pavement. The effects of cracks are much more apparent in this test section due to the absence of the pneumatic roller which may help covering the surface of the cracks caused by the earlier passes of the steel roller.

Table III shows a comparison between the permeability values of HMA for the paved sections using the conventional steel compactor and AMIR II compactor. It can be seen from the table that the permeability of the paved Asphalt at the inside edge lane was improved up to 9 times when compacted using AMIR II compactor in comparison to that of that paved using the steel compactor. While for the centre line and the outside edge of the lane, AMIR roller showed 6 times improvement in the permeability of the asphalt.

TABLE III. COMPARISON BETWEEN PERMEABILITY VALUES OF PAVED ASPHALT AT TOMLINSON YARD

Sample location	Conventional Steel	Sample location	Conventional Steel
Inside edge Lane	3.20	0.35	9.14
Centerline edges	0.90	0.15	6.00
Outside edge Lane	0.90	0.14	6.34
Avg.	**1.67**	**0.21**	**7.16**

VIII. Relation between Permeability, Compaction and Density of Paved Asphalt

The Permeability and level of compaction were measured immediately after compaction process was completed. Field Cores were then recovered from the asphalt sections and transported to be tested in the laboratory to measure the bulk relative density (BRD) of the asphalt. The field-recovered cores were divided for laboratory tests performed by an independent consultant (hired by the MTO) and Carleton University.

Table IV shows the each individual measurement as well as the average density for each of the two field test sections. The results shown in the table illustrate the abilities of the AMIR II compaction method to meet current Quality assurance (QA) and Quality control (QC) specified by MTO standards. It should be noted that the reported densities were achieved by fewer passes of the AMIR II in comparison to number of passes using the conventional steel roller.

TABLE IV. BRD AND COMPACTION LEVEL FOR PAVED ASPHALT

	AMIR II		**Conventional Steel**	
Site	***BRD***	***Compaction[1] (%)***	***BRD***	***Compaction[1] (%)***
1	2.401	94.16	2.311	90.63
2	2.364	92.71	2.237	87.72
3	2.358	92.47	2.325	91.19
4	2.348	92.08	2.279	89.38
5	2.357	92.43	2.332	91.44
6	2.354	92.31	2.308	90.49
7	2.345	91.96	2.305	90.38
8	2.305	90.39	2.320	90.99
9	2.318	90.90	2.341	91.81
10	2.217	86.94	2.341	91.81
Avg.	**2.337**	**91.635**	**2.310**	**90.583**
1	2.357	93.47	2.313	91.72
2	2.332	92.47	2.369	93.95
3	2.363	93.69	2.282	90.47
4	2.385	94.57	2.307	91.46
5	2.386	94.62	2.354	93.33
6	2.389	94.71	2.354	93.34
7	2.437	96.63	2.320	92.00
8	2.423	96.09	-	-
9	2.463	97.65	-	-
10	2.465	97.73	-	-
Avg.	**2.400**	**95.162**	**2.328**	**92.326**

(1) Measured as percentage of maximum theoretical density

It is important to note the correlation achieved by the density and lower permeability of the AMIR II method in contrast to the discrepancy noted between both measurements for the conventional compaction method, with and without the pneumatic rollers. Table V summarizes the density, compaction (%) and permeability for the both sections compacted by the two rollers.

TABLE V. AVERAGE COMPACTION LEVEL, DENSITY AND PERMEABILITY FOR PAVED ASPHALT

	AMIR II			***Conventional Steel***		
Site	***Avg. BRD***	***Avg. Compaction (%)***	***Avg. Permeability***	***Avg. BRD***	***Avg. Compaction (%)***	***Avg. Permeability***
Highway 28	2.337	91.635	1.08×10^{-3}	2.310	90.583	3.28×10^{-3}
Tomlinson Yard	2.400	95.162	1.72×10^{-4}	2.328	92.326	2.39×10^{-3}

IX. SURFACE SMOOTHNESS

Table VI shows the IRI (International Roughness Index) surface smoothness results for the two sections, the asphalt section compacted by the conventional steel roller and the one compacted by AMIR II roller of Highway 28. Each roller was used to compact the north bound and south bound of a section of the highway. The results show that both rollers; conventional steel and AMIR II roller achieved the current Quality assurance (QA) and Quality control (QC) specified by MTO standards with IRI less than 1 M/KM.

TABLE VI. ASPHALT-IRI SMOOTHNESS USING AMES ENGINEERING PROFILER

Highway Direction	**Length**	**SURFACE SMOOTHNESS MEASUREMENTS – IRI (M/KM)**			
		Run 1	**Run 2**	**Run 3**	**Average**
AMIR II Section					
North Bound	115	0.66	0.67	0.655	0.662
North Bound	140	0.93	0.91	0.91	0.917
South Bound	140	0.885	0.885	0.88	0.913
South Bound	90	0.86	0.855	0.85	0.682
Avg.					**0.79**
Conventional Steel Section					
North Bound	90	0.705	0.715	0.74	0.72
North Bound	140	0.635	0.63	0.64	0.635
South Bound	140	0.91	0.91	0.92	0.883
South Bound	115	0.675	0.69	0.68	0.855
Avg.					**0.77**

X. Falling Weight Deflectometer (FWD)

The Falling Weight Deflectometer (FWD) is used to measure the response of a given pavement structure to its working load [15]. The measurements include the vertical deflection of the pavement surface to application of a falling weight simulating the effect of a dynamic load. The recorded pavement response is analysed using software to compute the elastic modulus and other properties of the specific structure. The software can identify the weakest layer in the pavement, residual life and used to determine the optimum rehabilitation alternatives. The FWD is available as a trailer or a truck mounted version meeting all FWD standards worldwide. The surface modulus is calculated using Boussinesq's equation and the measured surface deflections. The surface modulus is obtained using Equation 2 below:

$$E_0 = \frac{2P(1-\mu^2)}{\pi\, r\, d_r} \qquad (2)$$

E_0 is the surface modulus (MPa),

P is the applied load (N),

u is the Poisson's ratio and is usually assumed to be 0.35,

r is the distance from the centre of the applied load (mm), and

d_r is the deflection at distance r from the centre of the applied load (mm).

The FWD tests were performed on the sections paved at Tomlinson Yard. The tests were carried out by Stantec Consulting Ltd; a Canadian firm. The measurements were carried out along the centre lane of each paved section. Two lanes were compacted by AMIR II, while only one lane was compacted using the steel roller. The FWD test was performed one year after of the construction of the test sections. The distance between the points where the tests were carried out was 5 meters. Figure 10 and Figure 11 show a picture for the falling weight deflectometer while applying its test at the Tomlinson Yard site. The figure shows the location of the sensors at which the deflections are recorded and thus the surface moduli is calculated as well. The sensors are located at 0, 300, 450, 600, 900, 1200, 1500, 1800, 2100 mm from the point where the load was applied, respectively. The loading sequence was set to be 40 kN (Drop 1), 55 kN (Drop 2) and 70 kN (Drop 3). The load was normalized to 40 kN that represents the equivalent single axle load (ESAL).

Fig. 10. *FWD truck at Tomlinson Yard*

Fig. 11. *Falling Weight Deflectometer (FWD)*

Figure 12 through Figure 14 and Figure 16 through Figure 18 show the normalized deflections at each sensor as well as the surface moduli for the results obtained from the Drop 1, Drop 2 and Drop 3 loading case, respectively. In addition, the average normalized deflections and the average surface moduli of the three drops are presented in Figure 15 and Figure 19, respectively. It should be noted that the values closer to or under the centreline (sensor 1) represents the strength of the compacted surface while the values further away reflect the strength of the subgrade under the asphalt layer. The results at each sensor are the average readings at that sensor along the 25 m of the whole section. As can be seen from the figures, the surface modulus for each of the two lanes compacted with AMIR II roller was higher, by about 10%, than that of the lane compacted using the steel roller. This illustrates the enhancement that was achieved by AMIR II to the properties of the paved asphalt. Another important result that can be seen in the figures is that values at the sensor number 6 and further, there was no significant difference between the two rollers since the data reflect the strength of the subgrade which is the same under both lanes. Finally, the slope of the deflected bowels of the two AMIR II compacted lanes (Lane 1 and Lane 2) are relatively less steeper compared with that of the steel compacted lane suggesting that the steel compacted asphalt layer was more stressed under the same applied load.

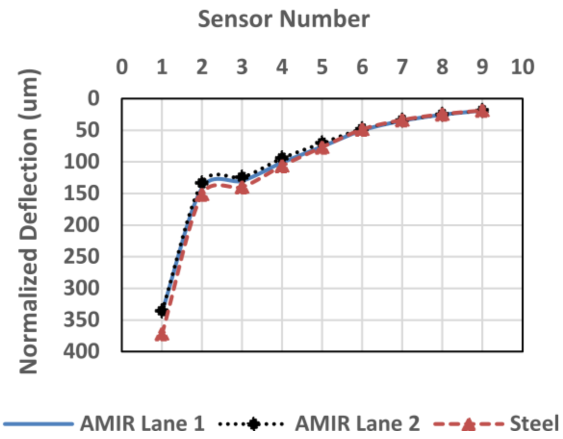

Fig. 12. *Normalized deflection (Drop 1)*

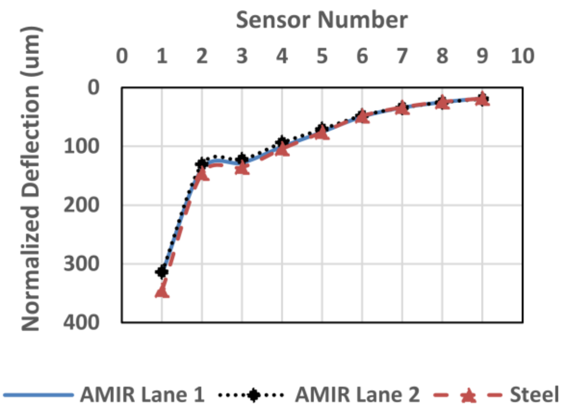

Fig. 13. *Normalized deflection (Drop 2)*

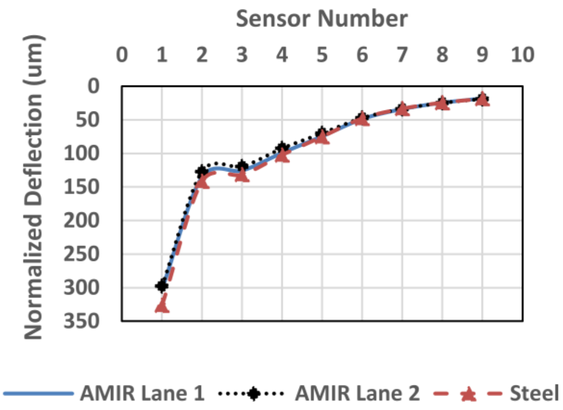

Fig. 14. *Normalized deflection (Drop 3)*

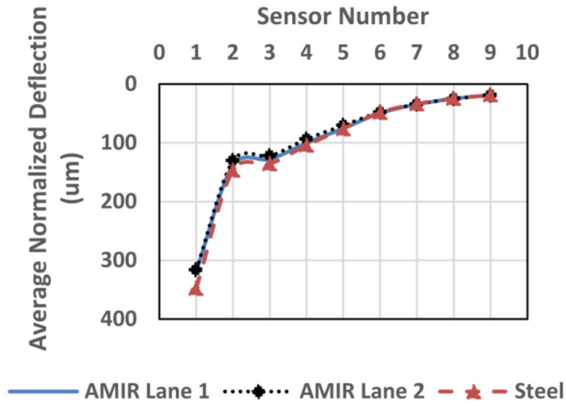

Fig. 15. *Average normalized deflection of the three drops*

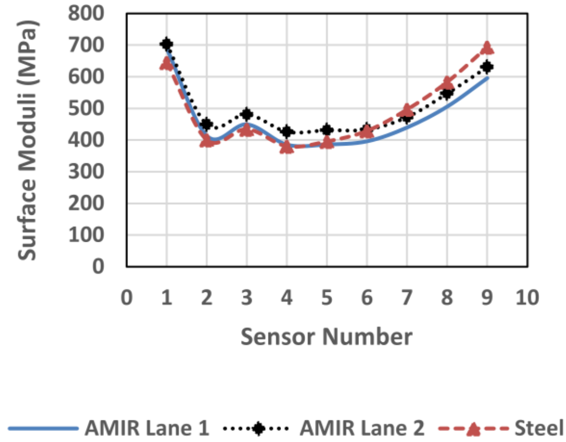

Fig. 16. *Surface moduli (Drop 1)*

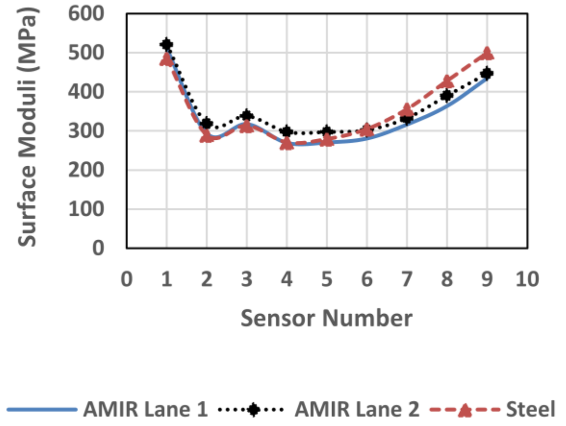

Fig. 17. *Surface moduli (Drop 2)*

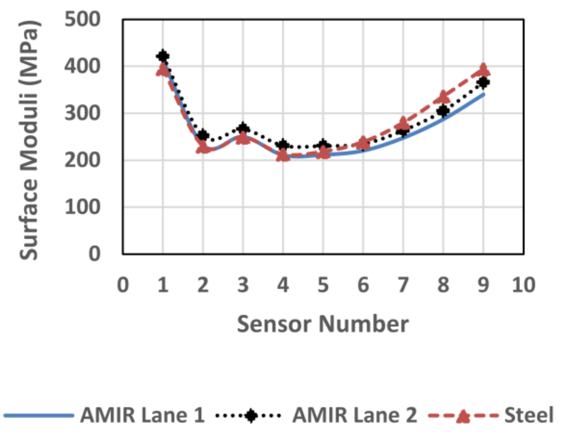

Fig. 18. *Surface moduli (Drop 3)*

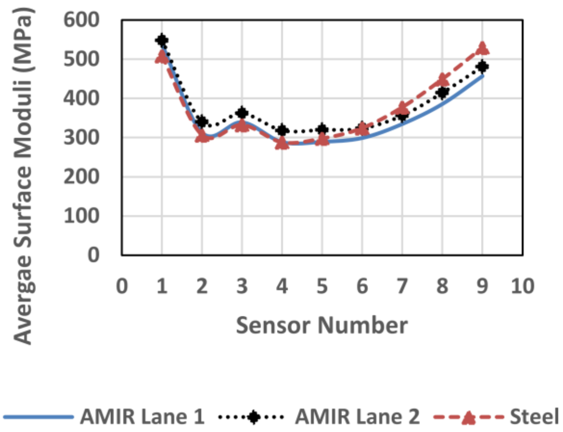

Fig. 19. *Average surface moduli of the three drops*

XI. CONCLUSIONS AND RECOMMENDATIONS

This paper presented a summary of a research work carried out to evaluate the quality of paved roads using two different methods of compaction. The first method is using the conventional steel roller and the other is using AMIR II roller that is a modified version of AMIR roller. The tests were performed on MTO paving projects during the summer and fall of 2012. Field permeability, compaction, surface smoothness and deflection tests were carried out on site while the density tests were performed at Carleton University laboratory on field-recovered cores obtained from the paved sections. The results of the field and laboratory tests showed that the AMIR II compactor was able to achieve a better compacted HMA with less permeability and higher density. Also the deflection measurements of the HMA compacted by the AMIR II displayed an overall average of 10% lower deflection compared to that of that the conventional compacted sections which suggests a longer service life at no extra cost. These better qualities were achieved on the same hot asphalt mixture and with less number of passes. Additionally, AMIR II roller was able to provide surface texture that tight and crack free leading to significant reduction of the permeability of the asphalt layer. Less permeability will lead to less water penetrating the asphalt layer which will result in less potholing and protection against stripping. As a future research, the field trials will be monitored on seasonal basis with additional field and laboratory measurements.

Finally, in order to meet the full potential of the AMIR compaction technology a number of challenging issues remain to be solved. The most urgent one has to do with the recent use of higher polymers content in current asphalt mixes which required more attention to the type of rubber belt used on the AMIR compactor. A research investigation has been initiated with the MTO to deal with the pick-up problem since it is recognized as a general problem and not limited to the AMIR method only.

SIGNIFICANCE AND PRACTICALITY OF THE PRESENTED WORK

This paper presents a new and innovative compactor for asphalt pavements. The findings of presented research and other publications have proven that the new compaction technology (AMIR II) provides a promising potential to solve many of the existing problems known for decades in the asphalt industry. The practical gain of deploying AMIR roller is to preserve the initial capital investment of new roads as well as to reduce the maintenance and rehabilitation costs through extending the service life of the pavements. This is because asphalt pavements compacted by AMIR II roller have shown significant improvement in surface texture, quality of finished pavement, and much less permeability rates. In addition, the new roller does the job of the current three different rollers, and in less number of passes.

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