Eight Years Superb Performance of a Motorcycles Race Track Pavement – A Design and Construction Review

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The primary purposes of this paper are to review the special pavement design and construction activities employed in construction of the Calabogie race track after a visual conduction survey to the surface conditions and interaction with the operation personnel and users to verify the performance of the track during the eight years' service, and the effectiveness of the construction strategies, materials and mix designs used in the asphalt paving eight years ago. It was found that the pavement demonstrated good condition after eight years' service including hosting numerous racing and competition events. Special construction methods, material designs and quality control and quality assurance procedures are the major factors contributing to the success of the track. This paper reviews the hot mix asphalt design, and special construction techniques employed during the construction including the project specifications, special paving techniques, field quality control and assurance, hydrated lime application in the mix and during paving. The review of the construction of the race track surface paving will have referential value for asphalt paving activities in highway construction.

Key Words: Pavement Construction, Asphalt, Hydrated Lime, Paving, Race Track.

Introduction

Pavement surface characteristics such as surface texture, skid resistance and smoothness are critical for highway pavement. This is no more evident than race track surfaces, where racing cars and motorcycles may run as fast as over 200 kilometers per hour. It is a challenging task to construct an asphalt motor race track. Especially the owner wanted to reduce curing time to "zero" while the conventional practice and general specifications require several month or over a winter. It took approximately two years to complete the material selection, testing, mix design, and construction methods for the subject race track. The design process and construction methods adopted was innovative and can be a salutary lesson for general highway paving to eliminate premature distress which is not uncommon, for horizontal paving companies. The race track in Calabogie Motorsports Park opened in September 2006 immediately after the asphalt paving was completed. Customary stringent construction procedures were employed during the construction to reduce the curing time which normally takes several months. A site visit and visual inspection to the track was conducted in 2014. Calabogie Motorsports Park (CMP) is a 5.05-kilometre (3.14-mile) race track located in Renfrew County, eastern Ontario near the Ottawa metropolitan area in Canada. The track opened in September 2006, immediately after the asphalt paving completion. The Park has hosted numerous Canadian and international racing events including Castrol Canadian and Canadian Superbike Championship, and for club level car and motorcycle competition. It has also been used by major automobile manufacturers for testing track, for the Harley-Davidson XR1200, for instance.

The layout and design of the track was conducted by Wilson Motorsport Inc. The track consists of 20 turns, measuring 40 feet wide, and featuring a 2,000 ft. long straightaway. The design plan considered all operational and safety elements for race events and professional level events with their accompanying large paddock, operational facilities and spectator amenities.

The asphalt paving was conducted by Lafarge Paving and Construction. Contract was administrated by LVM with bid and specification documents preparation; materials review, selection, and testing; quality assurance (QA) activities. Figures 1 and 2 present the geometric shape of the track circuit and the aerial view of the site.

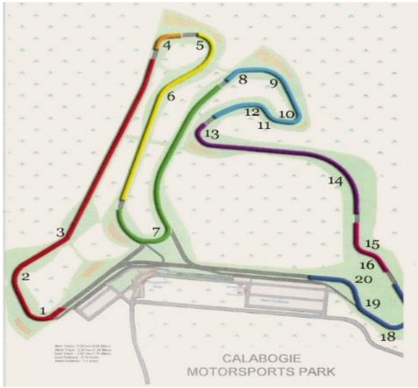

Figure 1: Geometric shape of the track circuit. *Figure 2:* Aerial view of Calabogie Motorsports Park track on the outset of the earthwork construction.

Since new race track asphalt pavement is more susceptible to surface deformation, typically, after hot mix asphalt (HMA) being placed and compacted, race tracks are required to be cured for at least three months or, in cold areas, after one winter season before open to public. In Calabogie Motosports Park race track project, innovative methods were employed to increase the initial stiffness and setting of asphalt pavements including polymer modified asphalt (PMA) and hydrated lime which was used in the mixes and applied to the surface of newly paved asphalt pavement.

As the paving project contract administrator and bid and specifications documents writer, the first author visited the track eight years after asphalt paving completion, accompanied by the second author in July 2014. This paper reviews and summarizes the special aspects of paving related activities and identifies the causes for the excellent performance of the track during the eight years' service.

General Requirements for Race Track Surface

Strength, durability, safety and smoothness are the paramount important factors in highway pavement design and construction, this is no more evident for rack track pavement. Although the International Automobile Federation (FIA, 2015) provides general guidelines for race track surface, typically technical requirements for highway pavement are adopted with more rigorous criteria. In selecting materials, preparing mix design, selecting construction methods and conducting quality control (QC) and quality assurance (QA), all the special requirements by race track must be considered (Wright and Dixon, 2004; NCAT, 1991; AI, 2011)

Since race track surfaces are subject to extremely high lateral forces, with load factors in excess of 1 G being common, it is imperative that the surface of the track be strong enough to withstand these forces at all temperatures and in all conditions.

Skid resistance for race track surface is incorporated into the material selection and hot mix asphalt (HMA) design to achieve a practical balance between grip and tire wear. Approximate typical highway characteristics would work properly, even if they have a slightly less than optimum grip character which will be offset by the greater adhesion capabilities of race tires and extended use.

Smooth surface is extremely important and the final wear course should be as smooth as possible and an extremely high level of QC is required to ensure the smoothness. A final tolerance of 1/16th in. over 10 ft is typically required for oval tracks in North America (Steenbakkers, 2004). The FIA recommends that track smoothness can be assessed by laying a 12 meter (40 ft) straightedge along any section of the surface (longitudinal, diagonal, crossways). The surface should maintain contact with the lower plane of the straightedge uniformly along its entire length. A maximum tolerance of 3 mm (0.15 in.) can be permitted in a few isolated instances. Checks should be made at 100 m (300 ft.) intervals all around the track.

Being different from highway pavement, all surface water on track should flow off the surface (not conducted through the asphalt layer vertically in porous manner). This is because the wide and slick tires for racing can cause hydroplaning on the thin film of water in the surface layer.

Seamless surface in longitudinal and horizontal directions should be maintained throughout the track surface. This is to be implemented by continuous and multiple pavers echelon paving and compaction.

Materials Selection and Mix Design

Two types of mixes, i.e., stone mastic asphalt (SMA) and high stability hot laid asphalt Type 1 (HL1) mixes were the two candidate mix types to consider. It was found that the City of Toronto HL1 (High Stability) mixes for heavy duty highway pavement met race track requirements with slight modifications including introducing rigorous Superpave HMA asphalt binder and aggregate requirements.

The track pavement thickness design include 50 mm HMA binder course and 50 mm HMA surface course. City of Toronto Transportation Services Standard Construction Specifications were referred in the HMA mix design (specially the aggregate gradation requirements) in paving project including TS 1003 Material Specification for Aggregates Hot Mixed, Hot Laid Asphalt Concrete; TS 1150 Material Specification for Hot Mixed, Hot Laid Asphalt Concrete; and TS 310 Construction Specification for Hot Mixed, Hot Laid Asphalt Concrete Paving (City of Toronto, 2001; 2004). City of Toronto hot laid asphalt Type 8 (HL8) mix was selected for the binder course mix.

Materials

The HMA aggregate was quarried from local pit and crushed and processed near CMP site. The processed quarry rock was also used as the base and subbase aggregate. The types of quarry rock were dolomitic, traprock, and meta-Arkose. Polymer modified asphalt cement was selected for HL1 surface course.

Aggregate
Tables 1 and 2 present the physical properties and test results of the surface course (HL1) and binder course (HL8) aggregates. Petrographic analyses were conducted for HL1 aggregates and it indicated that the aggregates possess good petrographic numbers. Figures 3 and 4 show the quarry rock processing site and aggregate base and subbase using the aggregate from the same source being constructed.

For this project, multiple crushed faces was required for HL1 aggregate to maximize retention in the mix and increased the Marshall stability. Round, polished or flat and elongated aggregate particles were not allowed to use. The HL1 mix contained larger sized aggregates, in the range of 60% to 70%, and coarse sand was used.

Table 1: Specified Physical Properties and Test Results of HL1 Coarse Aggregate

Laboratory Test	Types of quarry rock and criteria			Test results, maximum
	Dolomitic Sandstone	Traprock Diabase & Andesite	Meta-Arkose & Gneiss	
Wash Pass 75 μm Sieve, % Maximum	1.0	1.0	1.0	0.7
Absorption, % Maximum	1.0	1.0	1.0	0.69
Flat and Elongated, % Maximum	15	15	15	3.7
Petrographic Number, Maximum	145	120	145	103
Freezing and Thawing, % Loss Maximum	6	6	6	5.1
2-Face Crushed, % Minimum	80	80	80	99.3
Micro-Deval abrasion	15	10	15	13.6

Table 2: Specified Physical Properties and Test Results of HL8 Coarse Aggregate

Laboratory Test	Types of quarry rock and criteria	Test results, maximum
Wash pass 75 µm sieve, % Maximum	2.0	0.90
Absorption, % Maximum	2.0	0.49
Magnesium Sulfate Soundness, 5 cycles, % Loss Maximum	15	2.0
Percent Crushed Particles, % Minimum	60/80	97.9
Flat and Elongated, % Maximum	20	3.1
Micro-Deval Abrasion	21	13.1

Asphalt Cement

Superpave performance graded asphalt cement PGAC 58-34 was selected for HL8 binder course asphalt. Polymer modified asphalt cement PGAC-E 70-34 (Koch Stylink PMAC) was selected for HL1 (High Stability) surface course asphalt. According to the temperature and viscosity relationship curve, the recommended mixing temperature and compaction temperature for PGAC-E 70-34 by manufacturer are 165 ºC and 150 ºC respectively.

Figure 3: Quarry rock mined near the construction site is processed. *Figure 4:* Aggregate base course is constructed.

HMA Mix Design

Marshall Mix Design Method was used to conduct the mix designs. Superpave asphalt binder and aggregate requirements were referenced and followed.

Special Considerations

Most race track damage occurs when aggregate is stripped from the surface by high lateral forces. To increase the anti-stripping and anti-sheer properties of the HMA, as indicated, polymer modified asphalt was used in HL1 mix. For the same reason, hydrated lime was also used as anti-stripping additive. Based on the immersion Marshall tests, 1% hydrated lime was found to be appropriate which resulted in 99.5% retained stability.

Marshall Properties

Optimum asphalt continent (AC) was selected based on Marshall physical properties (Figures 5 and 6). Aggregate job mix formula is presented in Figure 7 which conforms to City of Toronto TS 1003 (City of Toronto, 2001).

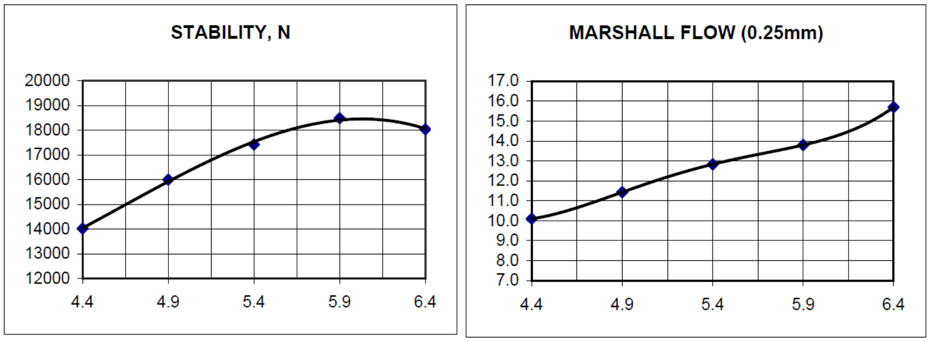

Figure 5: HL1 Marshal stability and flow.

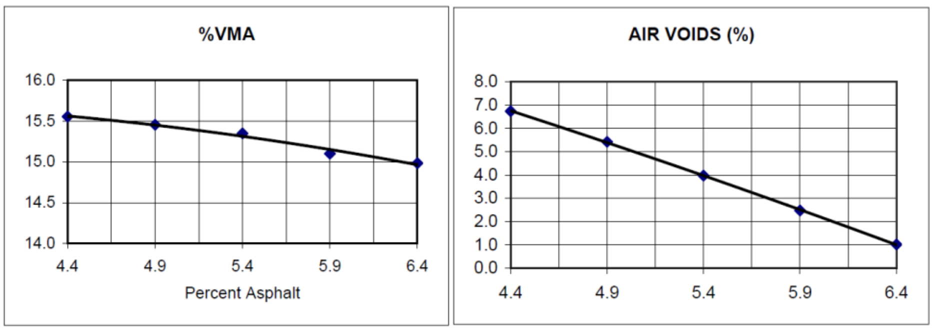

Figure 6: HL1 mix voids in mineral aggregate and air voids.

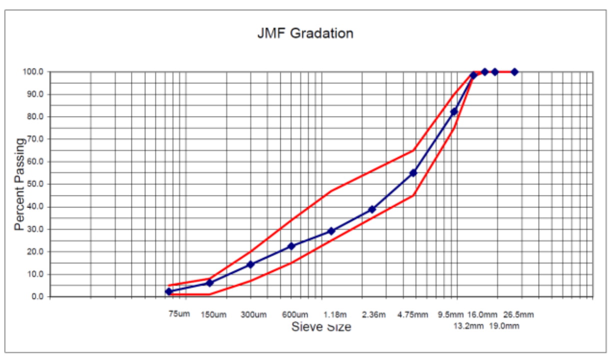

Figure 7: HL1 aggregate gradation.

Table 3 presents the HL1 and HL8 aggregate gradation and Table 4 presents the Marshall physical properties. Table 5 presents the results for resistance to stripping of HL1 by Marshall immersion test.

After careful review, it was found that it is noted that HL1 had 17,417 N stability which was in the similar level with most of SMA mixes. The optimum asphalt cement selected was 5.4%. HL1 HS and HL8 asphalt mix designs were approved for use on the above noted project (Lafarge, 2006).

Table 3: Gradation of HMA Aggregate of HL8 and HL1 Mixes

	26.5	19.0	16.0	13.2	9.5	4.75	2.36	1.18	600	300	150	75
HL8 JMF	100.0	98.4	85.5	67.4	54.7	49.9	44.6	37.4	25.2	12.0	4.6	2.0
HL1 JMF	100.0	100.0	100.0	98.5	82.3	55.0	38.8	29.2	22.5	14.3	6.1	2.3

Table 4: Marshall Properties of HL8 Mixes

	Binder Course (HL8)		Surface Course (HL1, high stability)	
	Required	Selected	Required	Selected
% AC	-	4.8	-	5.4
% Voids	3.5-4.5	4.0	3.0-5.0	4.0
Flow (min.)	8.0	8.5	8.0	12.8
Stability (min.)	8,000	9,517	14,000	17,417
%VMA	13.5	14.9	14.5	15.3

Table 5: Resistance to Stripping of HL1 by Marshall Immersion Procedure

Tests	Sample Test Results	
	Control	1.0% Hydrated Lime
Dry Stability, N	38,982	43,711
Wet Stability, N	24,376	43,497
Retained Stability, %	62.5	99.5
Stripping rating	7	6
Coarse Aggregate (CA)	2	1
Fine Aggregate (FA)	1	1
Coating Rating	Medium	Medium

Coating and Stripping Rating

Coating rating of air cured briquettes:
Heavy; Medium; Light; Heavy Stain; Medium Stain or Light Stain

Stripping rating: R = P + C + F
P = 3 when no stripping evident; P = 4 when some stripping is evident;
C = % coarse aggregate stripping: 0 = less than 10%; 1 = 10% to 30%;; 2 = 31% to 60%; 3 = >60%;
F = % fine aggregate stripping: 0 = less than 10%; 1 = 10% to 30%;; 2 = > 30%

Construction and Quality Control Measures

The customary construction specifications was prepared by the first author and reviewed by the second author. In the document, detailed construction methods and QC/QA procedures were enunciated which were implemented throughout the construction process. The quantity of the paving include 5.60 km bottom track, 5.05 km top track, and 12.2 m in width. For the special requirements of the track and the owner, construction methods were used to reduce the cure time significantly and ensure the smoothness.

General requirements

A high degree of quality control was to be maintained by the HMA producer with particular attention given to aggregate, fines returned and asphalt cement content. Samples of the HMA were to be taken at the start of production for full compliance testing, including Marshall properties, extraction and gradation. Where production extends beyond one day for any mix, additional samples should be taken to verify asphalt cement content, gradation and Marshall properties. Figures 8 and 9 show binder and surface courses paving.

Figure 8: HL8 binder course paving. *Figure 9:* Echelon paving and material transfer vehicle were employed for surface paving and temperatures were checked constantly.

The wear course was required to be compacted to extremely high levels at least 98% of Marshall density, and 4% air voids as a recommended goal. Nuclear gauges were used throughout the paving process. Due to the sensitivity of PMA, HMA with lower temperatures was not allowed to be used and must be returned to the plant.

Special Construction Methods

Seamless constant paving on top layer was required that involved three pavers wide, echelon seamless paving, and extra ready to go equipment on site in the event of a breakdown, and portable asphalt plant via shuttle buggies.

Hydrated Lime Application

Although there is not a proper method to effectively measure the cure rate of fresh HMA pavement, it is generally agreed hardening normally last 12 months after paving (Chen and Huang, 2000). While ordinary vehicles can be driven at reasonable speed on a fresh HMA surface, no race cars or motorcycles should be run on the newly paved surface. It was recommended minimum cure time of 60 day is necessary after paving, depending on temperature, thickness, mix type and other conditions. Note that motorcycles are as damaging as any race car due to the high power/tire footprint ratio, which causes bike tires to cut through the surface more easily than a wider car tire. In cold areas in Canada, it is recommend that the track surface be allowed a full winter of cure time. To reduce the cure time, hydrated lime was spread after HMA was placed and rolled. The application rate for the hydrated lime was 80 to 100 grams/m^2 of pavement surface area. The hydrated lime should meet the requirements in ASTM 0207: Specifications for Hydrated Lime for Masonry Purposes. Mete-R-Matic XL top dresser, with an extra-large capacity hopper, was used to apply hydrated lime. This equipment has been known for its uniform application of top dressing and its simple, easy-to-use design. Other similar equipment can also be used. Application rate can be set and go with confidence that each pass will be the same as the last. The hydrated lime should be brushed into the surface with hard brushes so that the lime gets into the open pores of the mix where it will react with liquid asphalt cement to help dry it out. Rubber tired rollers were used to draw excess asphalt cement from the surface. This rolling took place for several days after paving was complete. The applied hydrated lime was consistently rolled into the asphalt pavement surface with multiple passes of light, unballasted, rubber-tired rollers. The hydrated lime application and rolling process was repeated, as necessary, to achieve a uniform “off-white” surface color condition.

The pavement stiffness was significantly improved by this operation. As a result, the race car track was opened approximately one week after the completion of paving, approximately six months earlier than originally scheduled. Figures 10 and 11 show the hydrated lime was uniformly spread onto the surface of the asphalt pavement and the tire mark made to test the strength and stiffness of the fresh pavement. The circle in the middle of the picture shows the tire mark left by the strength test, turning the front wheel of a fully loaded 18 thousand pounds truck several times on the newly paved surface. The lime-modified pavement successfully passed the strength test.


Figure 10: Hydrated lime is applied and rolled. *Figure 11:* tire mark generated by heavy loaded truck to check the stiffness of HMA surface after approximate one week of paving.

Continuous Paving

Laser paving systems was used to ensure track smoothness was constantly verified. Continuous paving was generally followed. According to the project specification, no paving activity was allowed to end between the beginning of the braking and the end of the acceleration areas in any corner zone. That means: (i) a corner must always be paved along each laying path in its entirety at one time to avoid surface changes or bumps in an area where racing vehicles are at the limits of their road holding; (ii) wherever segments join, every effort must be made to ensure that no bumps are created; (iii) bumps can also be expected to develop in areas at the end of long straights where hard braking occurs. The occurrence of these will be minimized if an adequate base is properly laid and compacted and if polymerized asphalt is used. The aggregate base course was redressed prior to the binder course paving.

Compacting

Three pavers, materials transfer vehicle (MTV) and echelon paving were employed. Multiple rollers and two pneumatic-tired rollers were used. Breakdown rolling with steel wheel rollers was immediately commenced following rolling of longitudinal joint and edges. Vibratory rollers and pneumatic-tired rollers followed breakdown rolling as closely as possible; three tandem axle steel wheel rollers were used for finish rolling while material was still warm enough for removal of roller marks.

Finish Tolerances

Finished asphalt surface was within 5 mm of design elevation but not uniformly high or low. Finished asphalt surface was ensured not to have irregularities exceeding 3 mm when checked with a 12 m straightedge placed in any direction.

Construction Inspection and Quality Insurance by the Consultant (Owner)

A full time field engineer was on site to represent the owner to monitor the construction activities on daily basis and conduct quality assurance (QA) testing. On the daily report, the following questions to be answered by the inspector: (i) Does the previous hot mix asphalt lift have any dragging, segregation or other visual defects? (ii) Has paving been carried out to full width to essentially the same station and ramping completed as specified at the end of the day? (iii) Is the air temperature above the minimum requirement for placement and have they been recorded in the Hot Mix Inspection Summary form? (iv) Does the mix temperature meet the project specifications and have they been recorded in the Hot Mix Inspection Summary form? (v) Does the Contractor utilize the minimum equipment required by the specifications: Pavers, rollers, lighting system, etc. (vi) Have the joints been properly constructed? (vii) Has the tack coat been applied and allowed to properly cure? (viii) Is the specified distance between pavers being met for paving in echelon? (ix) Were all required samples taken at correct locations? (x) Were plate sample locations correctly reinstated? (xi) Is the thickness of the HMA above the minimum requirements? (xii) Has all the staff worked safely at all times? Detailed compaction and QA reports were sent to the file engineer's home office for review. Figures 12 and 13show checking smoothness and the compaction of the asphalt.

Figure 12: Checking smoothness in a horizontal joint. *Figure 13:* Compaction in the edge by portable tamper plate.

Eight Year Site Visit and visual Inspection

The eight year performance review was conducted by the authors on July 10, 2014. It was noted that some tracks may have distress beginning with raveling (lose aggregate) very quickly under the loads imposed by race cars and motorcycles. The site inspection indicted that the CMP track pavement demonstrated good condition after eight years' service when inspected. The site showed no raveling, cracking and settlements and unevenness. The users of the track reported that the track had been performed very well and no minor and major repairs had been conducted. Figures 14 and 15 show the site condition during the site visit in 2014.

Figure 14: Racing cars lined up during the site visit. *Figure 15:* Surface texture view of the track surface in July 2014.

Conclusion

The materials, mix designs, construction methodology and QC/QA procedures used in Calabogie Motorsports Park race track paving have been proved to be effective after eight years services. High stability surface mix for highway pavement can be used for race track wear course. Proper hydrated lime application with paving and compaction can reduce the cure time significantly without future raveling. Addition of lime in the mix can enhance the anti-stripping property. The standard of QC/QA were very high however they were attainable.

The hydrated lime can also be applied dry using a common rotary type garden fertilizer spreader (not a broadcast spreader) to keep the hydrated lime as close to the asphalt pavement surface as possible). The gate opening on the spreader should be sufficient to apply a consistently uniform, light application. Care must be taken to avoid creation of "dusty" conditions.

Drum plant should be used in preparation of the HMA if possible. It is crucial that, if batch plant is selected, the plant be capable of providing high quality, consistent product throughout the paving process. Shift changes is necessary for continuous paving which continues unbroken for more than 24 hours. Under these circumstances such variables as worker experience and skills, tiredness, equipment breakdowns, weather changes and traffic problems may become negative effects on the process.

A polymer surfaced track can be more stable during its early life, therefore reduce potential raveling and other damage during the crucial few months after paving before the surface is fully cured. PMA can effectively increases the strength of the bitumen and enhances its ability to prevent the aggregate from being raveled out of the wear surface during high lateral loads and under extreme temperature conditions. The polymer also adds elasticity to the surface allowing it to accommodate extreme temperature fluctuations without developing the radial cracks often found in conventional highway asphalt surfaces.

If pavement is not laid simultaneously, the edge of the hot second paving section butts up against the cold and hardened edge of the previously laid one and longitudinal seams between two or more paving sections are likely occur which is the cause of many long term problems. The best solution is to use two or more paving machines operating in tandem one behind the other in such a way that each machine's paving path merges directly into the other's while the bitumen is still hot. Immediate rolling of both paving sections will then eliminate the seam and ensure a smooth cohesive final surface. If this is not possible always ensure that longitudinal seams in the wear surface are offset from those in the leveling course. Horizontal seams may occur if the entire track is not paved in one continuous operation. If it is the case, the beginning and end of paving sections must be considered.

To sum up, the methods used were unique, for general HMA paving, also motor race track paving in the US and internationally. The methods used included using hydrated lime immediately after HMA placement and rolled and compacted with hot HMA (different from using lime as an additive, antistripping agent, in mixing plant). This resulted in a significantly reduced curing time from specified for minimum three months to less than one week. Continuous echelon multiple-paver paving is another feature, which eliminated joint crack and other premature failure which could happen in many highway pavement in about 5 - 8 years.

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