A paving solution to minimize airport down time while providing resistance to surface deformation: Calgary Airport

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PAVING SOLUTION FOR THE CALGARY AIRPORT

ABSTRACT

In the spring of 2015 the Calgary Airport Authority was looking for a paving solution to resolve a recurring surface deformation issue in the holding area of two taxiways leading to runway 17/35. The paving solution needed to satisfy two requirements: rapidity of execution to minimize airport down time, and resistance to rutting and shoving to alleviate surface deformation.

Standard General Inc. - Calgary (SGIC), a subsidiary of Colas Canada Inc. proposed the usage of a paving material marketed as Betoflex™, based on the long history of successful applications within the Colas group. The binder was formulated using the Multiple-Stress Creep-Recovery (MSCR) test to achieve a PG58E-28 binder. The paving material was engineered as a 0-16 mm material to facilitate placement in one 100 mm lift layer and to reduce placement time. The mixture was development using the French Level 2 methodology to ensure mixture workability and rutting resistance.

This paper provides an overall perspective of the engineering of asphalt mixtures to achieve “in service” performance. It also discusses the differences between the French and the North-American approaches in mix-design methodologies and why in the context of the two taxiways at the Calgary Airport, the French approach was used.

RÉSUMÉ

Abstracts provided in English will be translated to French and vice versa.

1.0 INTRODUCTION

The Calgary Airport is the third busiest airport in Canada after Toronto and Vancouver with over 15 million passengers every year. In the spring of 2015 the Calgary Airport Authority (CAA) with Tetra Tech as their technical advisor interacted with Standard General Inc. - Calgary (SGIC), a subsidiary of Colas Canada Inc., to find a paving solution to resolve a recurring permanent surface deformation issue in the holding area of two taxiways leading to the takeoff areas of Runway 17/35. Concrete and cement grout percolated bituminous materials, such as Colas Rodal™, were considered but the associated operational disruption of the airport negated their use. Accordingly, the paving solution needed to satisfy two important requirements: rapidity of execution to minimize airport down time, and resistance to rutting to alleviate surface deformation.

After discussions with the Colas S.A. Campus for Science and Techniques (CST), Betoflex™ quickly emerged as a viable paving material solution for this particular application. The long history of successful applications of this paving material within the Colas group [1] and the recent experience at the Toulouse airport [2, 3] provided solid references. Furthermore, the paving material allowed SGIC to propose a rapid placement method to avoid any down time for the airport operation, which in this particular application was as critical as the technical performance of the paving material. Incidentally, Tetra Tech as technical advisor to CAA actively participated in the selection of the paving solution as well as planning of the paving operations, field inspection and technical review. Through review of available technical information and previous experiences, Tetra Tech endorsed the approach proposed by SGIC.

The formulation of the binder was carried out at the Colas Canada Inc. GECAN laboratory in Acheson, Alberta while the mixture design was developed at the CST. The binder formulation was carried out using the Multiple-Stress Creep-Recovery (MSCR) test [4] as reference to achieve a PG 58E-28 binder. The development of this high performance binder, while maintaining viscosities for mixing and compaction at achievable temperatures was a challenge. The Betoflex™ paving material was engineered as a 0-16 mm material to facilitate placement in one 100 mm lift layer and to reduce placement time. Laboratory rutting performance needed to be less than 5.0 % of a 100 mm thick specimen at 30,000 cycles using the French rut testing device [5] to ensure resistance to surface deformation.

Taxiways Alpha and Charlie waiting areas were rehabilitated using the method proposed by SGIC with nearly 3000 tonnes of Asphalt Concrete Pavement. The Airport Authority was satisfied with the initial results considering that pavement surface temperature was above 50 °C on a regular basis during the summer of 2015 with no signs of deformation.

2.0 CALGARY AIRPORT TAXIWAY ALPHA & CHARLIE

Taxiway Alpha: Taxiway Alpha waiting area is located at the south end of Runway 17/35 as shown in Figure 1. It was constructed in 1958, and overlaid with asphalt materials in 1972, 1977, and 1994. The last rehabilitation of Taxiway Alpha waiting area was carried in 2009 and consisted of 90 mm milling operation followed with placement of 90 mm of hot mix asphalt concrete (HMAC). Based on construction history and core results from 2008, the pavement structure is: 330 mm HMAC overlaying 305 mm a granular base course (GBC) material and 1120 mm of a granular sub-base course (GSBC) material [6].

Taxiway Charlie: Taxiway Charlie waiting area is located at the north end of Runway 17/35 and it was built in 1976 as shown in Figure 1. The original structure consisted of 380 mm of concrete overlaying 200 mm of GSB and 230 mm of GSBC [6]. It was overlaid with 38-75 mm asphalt in 1993; then milled and overlaid with 75-100 mm asphalt in 1999. Since 1999, multiple areas were replaced with HMAC and with

a composite paving material consisting of an open graded asphaltic mixture filled with cement based grout.

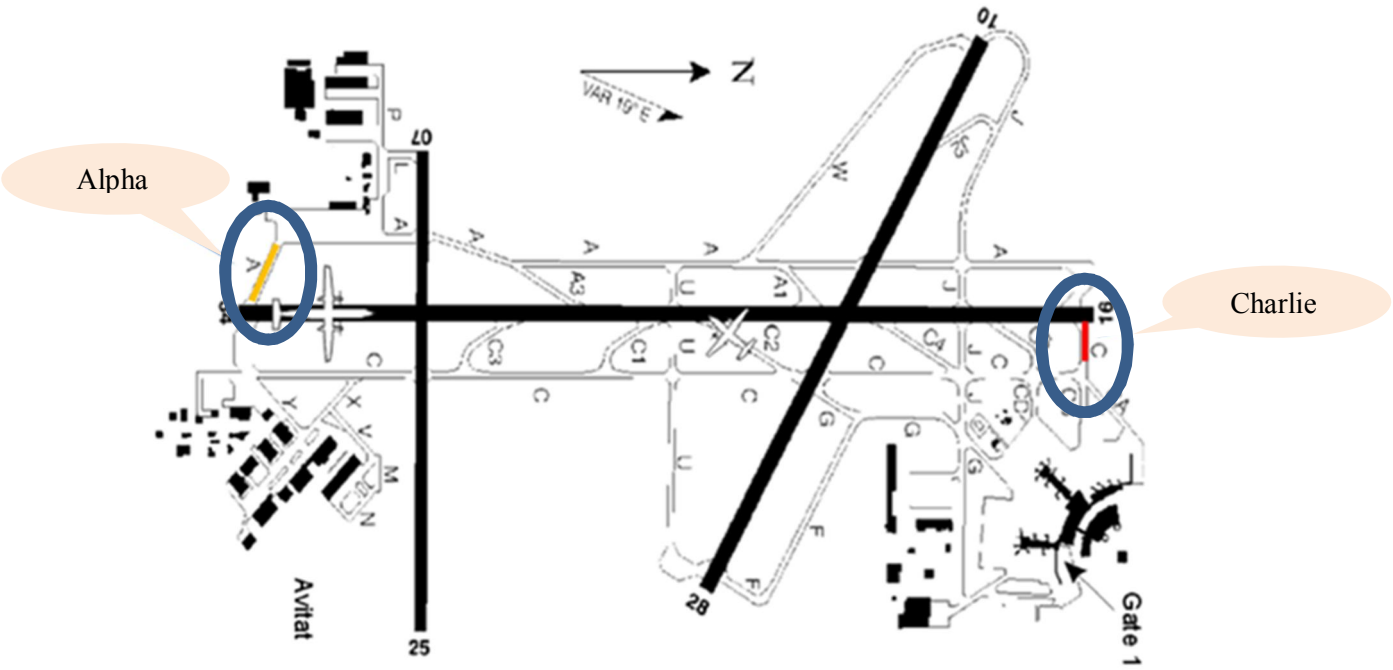

Figure 1. Calgary Airport

Photo 1. Taxiway Charlie in the spring of 2015

Photo 2. Taxiway Charlie, HMAC shoving

Holding areas within taxiways are prone to surface deformation as airplanes are at their heaviest i.e. fully loaded with fuel; engines are running increasing surface temperature and standing still waiting to get authorization to take-off. During sunny and warm summer temperatures the pavement surface can easily exceed 50°C even reaching 60°C. Furthermore, aircraft tire pressure can exceed 1.52 MPa (220 psi) for long-range wide- body aircraft such as Boeing 777-300ER which have been in operation at the Calgary Airport for the Asian market for a few years now. Each tire of the main two six-wheel landing gear of a Boeing 777-300ER can carry up to almost 27 tonnes.

Hot Mix Asphalt Concrete (HMAC) used in the past on each taxiway utilized Performance Graded (PG) 70-28 binder in an attempt to address the difficult loading conditions. Although this paving material served to control permanent deformation associated with the frequent passage of heavy aircraft, performance in holding areas continued to be an issue. The HMAC on Taxiway Charlie was placed directly on top of concrete creating an anvil/hammer type effect with each aircraft passage. Furthermore, Taxiway Charlie serves as the main taxiway for commercial flights including the long-range wide-body heavy aircrafts. The HMAC surface deformations were diverse including: rutting, shoving and shearing. Accordingly, as shown on Photo 1 and 2, recent repairs were carried out with limited success. As for Taxiway Alpha, it is mainly used for private flights and smaller aircraft. The surface deformations were not as severe as the ones on Taxiway Charlie.

The challenge with respect to the HMAC performance was the resistance to deformation i.e. rutting, shoving and shearing. The reliability and rapidity of construction were also crucial factors in the selection of the pavement solution. Accordingly, a Colas Betoflex™ [7] asphalt concrete pavement solution was proposed and specifically engineered to resist permanent deformation and to minimize airport operations inconveniences during construction. Tetra Tech as technical and operational advisor to CAA also participated in setting guidelines as to how the paving solution needed to be conducted to meet the requirements of CAA.

3.0 BETOFLEX™

Through its connection with the Colas Group, SGIC has access to a wide range of technologies and know-how specific to airport pavement in Canada and abroad. As such, the work carried out at the Toulouse Airport in France in 2013 [2, 3] was instrumental in determining the type of HMAC mixture that would be appropriate for the paving work needed on Taxiway Alpha and Charlie. In 2013, Colas Sud-Ouest was involved in the development of a specific paving material that would resist permanent deformation in regards to not only the Airbus A380, which is assembled at the Toulouse Airport, but also the future development of the Airbus A350, which is, in part, similar to the Boeing 777-300ER in terms of size and configuration.

After discussions with the Colas S.A. research facility, Betoflex™ quickly emerged as a viable paving material solution for this particular application. Betoflex™ is a range of paving materials manufactured using bituminous binders highly modified with SBS type polymers and possibly other viscosity reducing additives. The Colas Group has been using this type of paving materials for a wide range of applications for more than 25 years worldwide [1]. Mechanical characteristics are excellent which make this product ideal for surface course and binder course application on new construction and rehabilitation. In the case of Taxiway Alpha and Charlie the focus is on resistance to permanent deformation i.e. rutting and shoving. Betoflex™ was selected for Taxiway Alpha and Charlie, and engineered to resist rutting.

This paving material may be produced as a 0-10 mm or 0-14 mm mixture and placed at thicknesses ranging from 50 to 90 mm depending on mixture gradation. The different types of Betoflex™ are graded based on their mechanical characteristics i.e. permanent deformation, dynamic modulus and fatigue [7]. The mixture performance in regards to rutting needed to be verified in the laboratory using a wheel track device [5]. As per the Toulouse airport, the development of the mixture was focused on the binder and complemented with a conventional mix-design development using the French mix-design procedure.

The formulation of the binder was carried out at the Colas Canada Inc. GECAN laboratory in Acheson, Alberta while the main mix-design development was performed at the Colas S.A. Campus for Science and Techniques research facility in Europe. The binder formulation was carried out using the Multiple-Stress Creep-Recovery (MSCR) test [4] as reference to achieve a PG 58E-28 binder. The binder used for the mixture development was very similar to a Colas Colflex™ type binder [8]. The Betoflex™ paving material was engineered as a 0-16 mm material using the French mix-design development system Level 2 [9]. A slightly larger top size aggregate was selected to facilitate placement in one 100 mm lift layer and reduce placement time. The maximum laboratory rutting was 5 % at 60°C for 30,000 cycles tested as per the European Standard NF EN 12 697-22 [5].

3.1 Binder Formulation

The binder was developed using the Multiple-Stress Creep-Recovery (MSCR) test. The MSCR test is in the process of being implemented in many regions in North-America. It is a test that supplements the existing PG (Performance Grade) grading system to better characterise the rut resistance contribution of a binder. The MSCR test is based on a J_{nr} parameter that represents the ratio of unrecovered shear strain over the applied shear stress at higher levels of stress and strain that better represent what's occurring in pavement. The MSCR J_{nr} values were found to correlate well with rutting found at full scale Accelerated Loading Facilities (ALF) [10].

The work carried out at the Toulouse Airport served as starting point for the initial binder formulation. It was a highly modified binder formulated using the European approach based on binder penetration, ring

ball test and Fraass test [11]. The initial formulation based on the Toulouse binder formulation met the PG58E-28 specification but the viscosities for mixing and compaction at achievable temperatures were very high. The challenge in the binder development for this particular application was not the PG58E-28 specification per se, but rather achieving the PG58E-28 with a viscosity that would allow proper mixing and compaction at realistic temperatures.

Table 1 shows the J_{nr} values and the associated Brookfield Viscosities for the two different formulation tested. Formula 2 was used for the mixture development even though the Brookfield Viscosity remained higher compared to the values of 320 and 670 cP of conventional and modified binders used in Alberta. The higher binder viscosity was specifically mentioned in the Toulouse airport project review report as it was a concern for that particular job site as well. The report indicated that no issues, related to mixing or compaction, were reported providing the assurance that the viscosity of Formula 2 would not be a concern in the case of the Betoflex™ for the Calgary Airport.

Table 1. PG58E-28 Binder Formulations

Formula	Brookfield Viscosity (cP)	$J_{nr\ 3.2}$, max. E designation (kPa^{-1})	$J_{nr\ 3.2}$ (kPa^{-1})	$J_{nr\ diff.}$ max. E designation (%)	$J_{nr\ diff.}$ max. (%)
1	3100	0.500	0.207	75	14.01
2	1280		0.361		32.82

Photo 3. French gyratory compactor

3.2 Paving Material Mixture Development

The various aggregates available at Standard General Inc. - Calgary were shipped to the CST in France and the mixture was developed as per the Level 2 French mix-design process. Level 2 includes Level 1, which refers to compaction in the field and moisture resistance while the level 2 refers to resistance to

rutting/permanent deformation. Level 1 mix-design process is carried out using a gyratory compactor as shown in Photo 3 which differs slightly from the Superpave gyratory compactor (mainly angle and revolutions per minute) [12]. The moisture susceptibility is performed using a test nearly identical to the Lottman test [13]. Incidentally, it was decided to perform the test at the Colas Canada Inc. GECAN facility in Acheson Alberta. The level 2 mix-design process involves the usage of a rutting simulator device as shown in Photo 4 and the test is performed in accordance with NF EN 12697-22+A1:2007 [5].

Photo 4. French wheel tracking device

The French mix-design process differs significantly from the North-American mixture development approach as the French process is much more *performance-based* [9] rather than the *performance-related*, which may relate more to the North-American approach. The French system focuses on the desired levels of fundamental engineering properties, e.g., compaction (Level 1), rutting (Level 2), complex modulus (Level 3), and fatigue (Level 4) properties, while the North-American system put more emphases on properties that relate to performance such as gradation, air voids, and voids in the mineral aggregates. In North-America rutting devices are also used, but it is not yet a common practice.

Again the differences between the two mix-design approaches are quite significant and a comparative review of the two methods could likely be the subject of several papers. The purpose of this paper is to highlight some of these differences in a practical application using common materials used in Alberta and in the Calgary region. The aim of the Level 1 mix-design method is to establish a mixture that may be compacted to the desired compaction level for a given thickness. The selected number of gyration relates to thickness that the mixture is placed at i.e. not traffic as it is the case for Superpave. As a general rule the compaction achievable in the field relates to a given number of gyrations closely equivalent to the mix placement thickness in millimetres [14]. The European standard specifies three levels of gyrations for surface mixes i.e. 40, 60 and 80 for level of compaction ranging from 91 to 96 % [15]. As a starting point the target compaction level selected was 95 % i.e. 5 % air voids at 80 gyrations the Calgary Airport Betoflex™ paving mixture. The high level of 95 % compaction at 80 gyrations was selected to ensure increased mixture density in the field even though the mix was to be placed at 100 mm. Again, this was

only a starting point, for an application such as the Calgary Airport, the mixture service viability is always confirmed with a Level 2 mix-design i.e. rutting test.

The Level 1 mix-design exercise using SGIC's aggregates allowed highlighting a few significant practical differences between what would be expected for Superpave type mixture and the Betoflex™. In Level 1 mix-design process, the nature of the binder did not have a significant impact. In fact, a different binder was used to produce the gyratory compactor specimen simply because the PG58E-28 available was only sufficient to produce the specimen to be tested with the rutting machine. What is considered important in the level 1 mix-design is not the binder per se but the viscosity of the binder at the expected field compaction temperature. The proposed gradation was also significantly different from what would have been expected for a Superpave type design. Crucial and more expensive aggregates, free of minus 80 µm particles, such as washed sands, natural or crushed were not used in the Betoflex™ mixture. In actual fact, mineral filler was added to the mixture which is rarely done in Canada with Superpave mixtures. Yet, as shown in Table 2, the Betoflex™ aggregate gradation proposed to Tetra tech and CAA fits within the Alberta Transportation Superpave 20 mm specification.

Table 1. Superpave 20 mm (SP-20) gradation band vs. the BETOFLEX gradation (% passing)

Sieve Size (µm)	SP-20	BETOFLEX™ 0/16 mm
25,000	100	100
20,000	90-100	100
12,500	Max. 90	86
2,500	23-49	29
80	2-8	7.9

As indicated above, any type of work such as the Calgary Airport requires a Level 2 type mix-design, which includes the Level 1 i.e. workability of the mixture and the level 2 which serves to verify the viability of the mixture in regards to rutting and permanent deformation. The French rutting test is now part of the European standard and it was first used in the early 70's. The test was designed to simulate the worst condition for rutting in France i.e. pavement at 60 °C, tire pressure and axle load simulating a 13 tonnes single axle moving at slow speed. As indicated in the introduction, the target maximum rutting for Betoflex™ is less than 5 % rutting of the 100 mm thick specimen at 30,000 passages. The rutting performance achieved in the laboratory for the 0-16 mm Betoflex™ proposed to Tetra Tech and CAA was 3.0 % at 30,000 cycles, providing the assurance that the mixture would resist permanent deformation.

4.0 PAVEMENT CONSTRUCTION

The pavement construction was carried out in three phases i.e. a test pad in a refueling area to ensure the paving material met expectation, Taxiway Charlie holding area and then Taxiway Alpha holding area. In all cases the work consisted of a mill and inlay type intervention i.e. milling 100 mm of existing HMAC, tack-coating and then placement and compaction of Betoflex™ paving material. The paving work for the test pad and the Taxiway Charlie was performed in early July 2015, while the work for Taxiway Alpha was accomplished at the end of August 2015. Both Taxiway Charlie and Alpha paving material installations (milling, tack-coating and paving) were undertaken during a limited runway shutdown period.

Photo 5 shows the placement of the test pad with a long-haul wide-body Boeing 777 aircraft in the background. Photo 6 shows the placement of the Betoflex™ mixture on Taxiway Charlie. Photo 7 shows the texture of the mat a few weeks after placement.

Photo 5. Betoflex™ test pad with Boeing 777 in background

Photo 6. Placement and compaction of paving material on Taxiway Charlie

Photo 7. Texture of the mat shortly after placement

4.1 Quality Control/Quality Assurance

As the paving material mix-design development was carried out at the CST, testing in parallel was performed in Canada using the Superpave gyratory method to establish testing correlation with North American laboratory equipment. The parallel testing was to allow developing corresponding parameters and create Quality Assurance (QA) criteria for volumetric data that can be verified using local testing capabilities. The testing showed significant differences between the French gyratory compactor compared to the Superpave gyratory compactor in terms of compaction effort per gyration as illustrated in Figure 2.

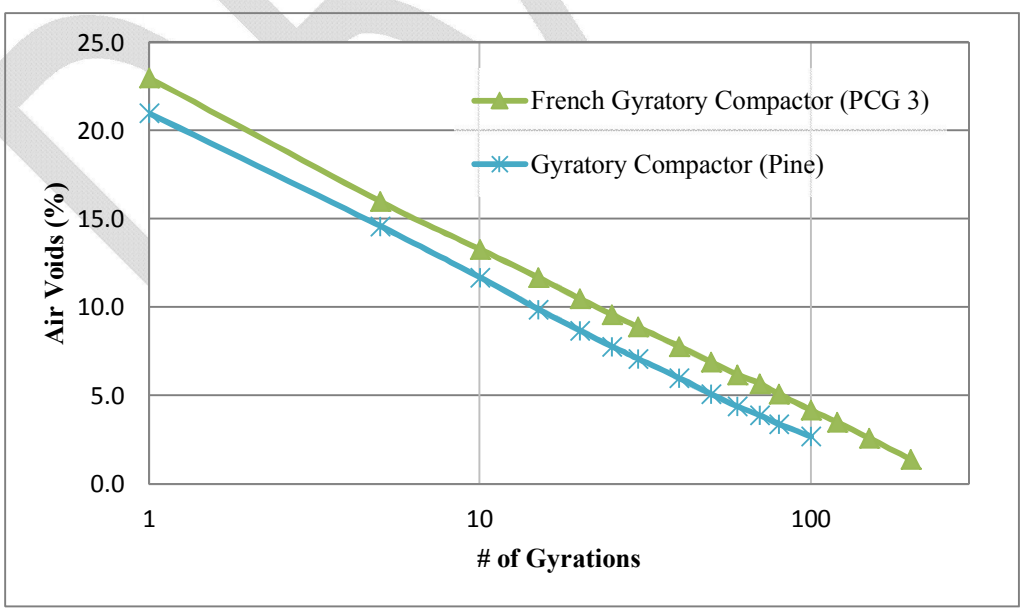

Figure 2. Comparative Compaction Efforts of Results (Pine vs. PCG 3)

For this particular paving material, using the French gyratory compactor, voids of 5.1 % were obtained at 80 gyrations, while equivalent voids were obtained at 50 gyrations using the Superpave gyratory compactor.

The Quality Control (QC) was focused on gradation and binder content and field compaction. Gradation and binder content were within normal production tolerance. Compaction was monitored using a nuclear gauge and compaction averaged 94.5% on Taxiway Charlie and 95.5% on Taxiway Alpha. Marshall specimens were also produced with field mix; the Marshall air voids were less than 1.0 % creating concerns even thought it was not totally unexpected. Betoflex™ is designed to be both compactable and rut resistant and finding lower Marshall air voids was expected but not as low as what was found. Rather than producing Superpave gyratory compacted specimen to further evaluate air voids it was decided to perform additional rut testing using the French rutting device. The results obtained using the field mix indicated rutting less than 2.5 % of the 100 mm thickness of the laboratory specimens indicating that the mixture produced and place on Taxiway Charlie complied with the performance of the mix-design.

Photo 8. Final result Taxiway Charlie holding area

5.0 CONCLUSIONS

The usage of a paving material designed using a European approach rather than a North-American design method is a significant departure from the existing practice for CAA or any Canadian airport for that matter. The teaming of SGCI, Tetra Tech and CAA focused on risk management, given this new technical approach and the challenging operations considerations. As for Taxiway Alpha and Charlie, a program has been put in place to monitor the performance of the paving material as it is considered a viable alternative to the HMAC typically used at the Calgary Airport for special conditions such as holding areas. Photo 8 shows the final result of the strip of Betoflex™ placed on Taxiway Charlie.

As indicated in the paper, Betoflex™ has been used in Europe for decades and as such this paving material does not constitute a real novelty. The innovation associated with this exercise was the usage of

the French mix-design approach to create a paving material that would provide field performance based on mechanistic properties i.e. rutting test rather than empirical properties i.e. air voids.

What constitutes the new finding with this technology transfer is the possibility to formulate a paving material easy to densify in the field at compaction temperature but that would also be rut resistant at service temperature. Based on air voids criteria for Marshall or Superpave mix-design processes a Betoflex™ type mixture would be rejected, yet the rutting tests provided excellent results. Additionally, as demonstrated Betoflex™ may be produced with commonly produced aggregates and does not require the use of minus 80µm particle free sands.

The compaction obtained in the field may be considered high and potentially lead to mixture instability, and /or flushing yet the rutting test provides the assurance that the mixture locks-up and will remain stable over time. Furthermore, in a wet and cold environment there are many benefits associated with paving materials compacted at low (5 to 6 %) field air voids in regards to pavement durability particularly in regards to ingress of water and the associated moisture damage.

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