Performance-Based Specifications for HMA Pavements on Airfields

AAPTP Project 06-03

Final Report

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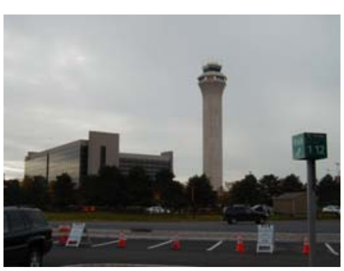

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1. Carlton Lambiasi
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ABSTRACT

The ultimate objective of this project is a framework for development and implementation of performance-based specifications for hot-mix asphalt (HMA) airfield pavements. Because the function of airfield pavements is to safely and smoothly carry aircraft traffic, the specifications must be related to and driven by aircraft operational performance characteristics (OPCs). In addition, the specifications require the ability to predict performance based on material properties measured at the time of construction, also known as Acceptance Quality Characteristics (AQCs).

This report documents the results of AAPTP Project 06-03 which included a literature review and series of interviews with airport operators, aircraft manufacturers, and experts. These tasks provided the means to identify the key OPCs of interest on HMA airfield pavements: braking capability, directional control, dynamic effects related to aircraft damage and pilot control, static load carry capability, and traffic flow disruptions.

These OPCs were then related to a variety of pavement performance characteristics such as cracking, surface friction, raveling, rutting, and roughness. Given the prior research conducted on highway pavements it is possible to identify the appropriate AQC to control the pavement performance characteristics that relate to the OPC.

This report also identifies research that needs to be performed to provide a sufficient basis for developing and implementing a performance-based specification and recommended revisions to the existing P-401 specification used by the FAA for asphalt mixtures on airfield pavements. These recommended revisions include measurement of initial levels of friction and macrotexture on new pavements; changes in measurement method used for evaluating

smoothness on new pavement surfaces; and measurement of the volumetric properties of HMA materials as part of construction acceptance.

CHAPTER 1

OVERVIEW OF THE PROJECT

BACKGROUND AND PROBLEM STATEMENT

Highway and airfield pavements are engineering structures designed and constructed to carry traffic from one point to another in as safe and smooth a manner as possible regardless of climate conditions. Perhaps this definition is an over-simplification, but it highlights the key pavement requirements – structural (load-carrying capacity) and functional (smoothness and safety). This definition could also be expanded to add other requirements such as appearance (aesthetics).

The above definition of a pavement highlights the requirements placed on all highway and airfield pavements. Differences between airfield pavements and highway pavements are primarily due to differences in the type of traffic using the pavements and their operational requirements. Highway pavements have to accommodate the geometric characteristics of personal and commercial vehicles and provide a safe and comfortable ride at the posted highway speed limits. In comparison, airfield pavements have to accommodate large and small aircraft; commercial, personal or military. Unlike vehicles, aircraft have more unique characteristics as far as geometry and loading. Airbus 380 for example has a wing span of over 260 feet and a length slightly less than 240 feet. Tire configurations (landing gear) vary from one aircraft to another and tire pressures can reach 300 psi for military aircraft. Total loads also vary greatly from one aircraft to another and are usually considerably higher than those seen on highway pavements. Additionally, the smoothness requirements of aircraft occur over a greater range of speeds and are affected by the vastly different tire sizes and gear configurations. Therefore, the operational characteristics of airfield pavements and highway pavements are similar but with different nuances that have to be understood.

OBJECTIVE

Although the operational requirements related to airfield and highway pavements are different, the materials used for both types of pavements are the same. Therefore, the mechanistic relationships established between the material characteristics and the pavement performance characteristics are the same.

Construction specifications are intended to control the construction of the pavement to facilitate production and placement of the pavement materials meeting a minimum level of performance. Most construction specifications perform their function by requiring measurement of material characteristics that are believed to influence pavement performance.

The objective of this study is to develop comprehensive guidance that ties the operational requirements of airfield pavements to the technical specifications and notes provided in Federal Aviation Administration (FAA) Specifications P-401 *Plant Mix Bituminous Pavement* and EB-59A *Plant Mix Bituminous Pavement (Superpave)*, for mixes designed by the Marshall and Superpave methods, respectively. To satisfy this objective, a framework is to be developed to provide guidance on implementation of a performance-based specification (PBS) for airfield pavement construction using hot-mix asphalt (HMA).

Unlike most construction specifications which perform their function by requiring that certain material characteristics are met at the time of construction, a performance-based specification requires that predicted performance characteristics like pavement distress or ride quality meet certain acceptance criteria. The concept of PBS is discussed in more detail in the next section of this report.

This report documents the results of the project which included the following tasks:

- Task 1 – Literature Review and Interviews
- Task 2 – Identification of Aircraft Operational Characteristics
- Task 3 – Identification of Pavement Performance Measures
- Task 4 – Interim Report
- Task 5 – Identification of Test Methods
- Task 6 – Research Problem Statements
- Task 7 – Draft Final Report
- Task 8 – Final Report

BASIC CONCEPTS OF PERFORMANCE-BASED SPECIFICATIONS

Prior to discussing the various phases of work that have been completed, it is important to establish some basic concepts associated with performance-based specifications. In addition, the following sections provide definitions associated with the terms used in this report.

Basic Elements of Performance Specification

The basic elements of a performance specification are shown in Figure 1.

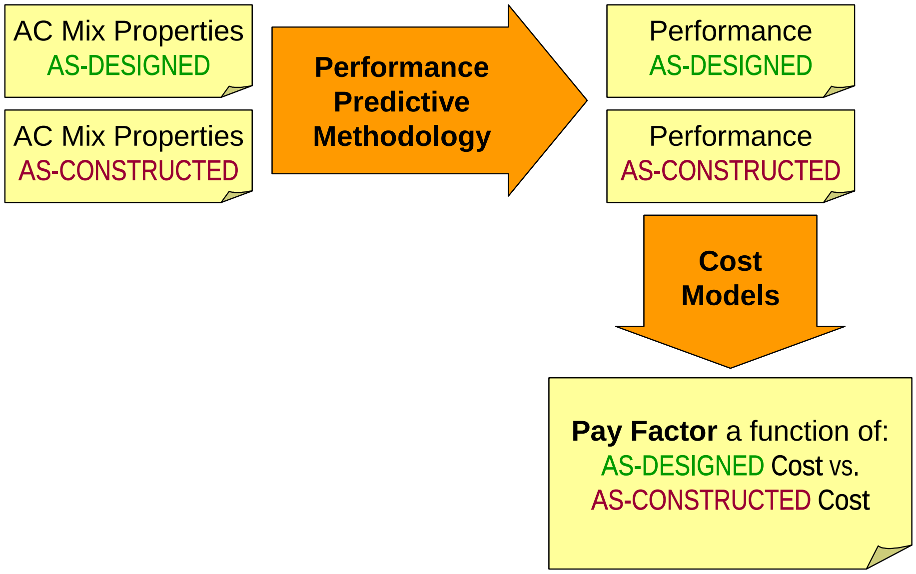

Figure 1. Typical Elements of a Performance Specification

As shown in Figure 1, a predictive methodology is used to predict the performance of a pavement structure according to two scenarios: one is the hypothetical "as-designed" scenario, which assumes that the material perfectly meets all design specifications; the second is the realistic "as-constructed" scenario where the asphalt concrete mix actually used on the project is sampled and tested, and its properties are used to predict as-constructed performance. Finally, cost models are used to estimate the cost to the Agency specific to each scenario. The difference between the as-designed and as-constructed life cycle cost is then used as a basis for calculating a pay factor (i.e. a bonus or penalty). The deviations in the mix design may result in either a decrease or an increase in the estimated life cycle cost which should result in either a penalty or a bonus in the contractor's pay.

Definitions

A few notions commonly used in Performance Specifications will be introduced in the following paragraphs. These notions are used frequently throughout the report, and a clear understanding of each is necessary.

- ***Acceptance Quality Characteristics*** (AQC) are basic HMA properties, measured at the time of construction; these may include: asphalt content, air voids, aggregate gradation, initial roughness, initial friction, etc.
- In a ***Performance-Related Specification*** (PRS), the desired levels of AQCs are specified.
- More advanced HMA properties like stress-strain relationships (e.g. Dynamic Modulus, Creep Compliance) or fatigue relationships are referred to as ***Fundamental Engineering Properties*** (FEPs). FEPs can also be measured *at the time of construction*.
- In a ***Performance-Based Specification*** (PBS), the desired levels of FEPs are specified as opposed to PRS which is based on AQCs.
- HMA properties measured *during the performance life of the pavement* are referred to as ***Performance Characteristics*** (PCs). Examples include: roughness, friction, deflection, distress, etc.
- ***Operational Performance Characteristics*** (OPC) are measures of pavement performance from the perspective of the *user*. OPCs are often subjective and, in very general terms, include Safety, Comfort and Appearance. The project team have identified and defined OPCs specific to HMA airfield pavements. These are

discussed in more detail in the Operational Performance Characteristics section of this report.

CHAPTER 2

LITERATURE REVIEW

A literature review was conducted to identify work that has already been performed in the development of PBS or PRS for highway and airfield pavements. The work was separated into two categories: highway and airfield. The following sections summarize the results of this review.

PERFORMANCE SPECIFICATIONS FOR HIGHWAY PAVEMENTS

Introduction

The first task of the research plan was to assemble a bibliography of documents which may provide insight into the relationships between the key elements of a performance specification. Of interest were the following items: AQCs, FEPs, PCs, and OPCs – all of which were defined in the previous chapter.

Most of the available literature on this subject is pertinent to highway pavements as opposed to airfield pavements. While the research team understands the distinctly different nature of the operational and performance requirements of airfield pavements and highway pavements, some of these documents written towards highway pavements may provide key understanding in the relationships between the key elements of a performance specification.

This section presents a summary of findings resulting from reviews of highway-related documents. Similar reviews, for airfield pavements, are presented in the next section.

References 1 through 9 were assembled for the highway literature review. The documents listed address different aspects of performance specifications for HMA roadways.

Rather than discussing each resource on an individual basis, several common issues have been identified and are presented in the following paragraphs.

Performance-Based Specifications versus Performance-Related Specifications

It is important to note that there is a difference between PRS and PBS. The following definitions were found in the Guideline developed by the Quality Construction Task Force of the AASHTO Subcommittee on Construction (*1*): *"Performance Related Specifications are ... specifications that use quantified Quality Characteristics and Life Cycle Cost (LCC) relationships that are correlated."* In other words, in a PRS, AQCs measured at the time of construction (e.g., asphalt content, air voids, and initial ride quality) are used with pavement performance predictive models to establish the desired levels acceptance levels. The performance predictive models used in these specifications are generally empirical in nature.

In comparison, "*Performance Based Specifications are ... specifications that describe the desired levels of fundamental engineering properties (e.g. Resilient Modulus, creep properties, and fatigue) that are predictors of performance and appear in primary prediction relationships (i.e. mathematical models) that can be used to predict stress, distress, or performance from combinations of predictors that represent traffic, environment, supporting materials, and structural conditions)."(1)* In other words, a PBS uses a more mechanistic approach to establishing the performance prediction for defining the acceptance levels of the fundamental engineering properties used to evaluate the construction quality.

It is important to distinguish between the different nuances of a PRS and a PBS because the ultimate scope of this project, as outlined in the request for proposals, is to set the stage for the development of a PBS. In comparison with PRS, a PBS is likely to be more sophisticated and more costly to implement requiring more advanced field and laboratory testing, as well as eventually developing more robust performance models. However, it should be remembered that because a PBS is based on FEPs, this type of specification will be applicable to more different types of materials and would be expected to provide a more reliable estimate of the performance of these materials.

Need for Comprehensive Pavement Performance Database

As already mentioned, the availability of pavement design data, initial construction data (AQCs / FEPs) as well as performance data (distress, ride quality, friction) is crucial to the development of a performance specification. The data should include as a minimum elements like: traffic loading, pavement condition at different times, construction date, climate, materials, layer thickness, material properties, etc.

In addition, the specification will be used to penalize or give bonuses to contractors based on the predicted performance and life cycle costs (*2*). When not to their advantage, contractors will likely challenge the accuracy and reasonableness of the performance and cost predictions (*3*). This is why a thorough, well-documented effort and a fair amount of performance and cost data will be necessary to defend the specification. It has been documented that a minimum of 15 years of performance data is required for the development of a PBS for highway pavements.(*4*)

For the same reasons, contractors should be invited to participate in the specification development process to become familiar with the specification and will eventually feel comfortable participating in the bid process when the Agency wishes to use a performance specification (*3*).

Candidate Acceptance Quality Characteristics

Several asphalt pavement design parameters have been identified in the highway literature as playing a major role in predicting HMA performance (*2,3,4,5,6,7*):

- Traffic: Load, Speed, Wander
- HMA: Thickness, Stiffness, Air voids, Asphalt content, Percent fines, Mat density, Joint density, Texture, Initial IRI, Permeability
- Base: Stiffness, Thickness
- Subgrade stiffness
- Depth to bedrock
- Mean Annual Air Temperature (MAAT)
- Surface and subsurface drainage

Some of these design parameters are relevant to airfield pavements and some are not. Additionally, some of these parameters are not suitable for use with a construction acceptance specification for HMA, such as traffic loading or subgrade stiffness; however, this list provides a good basis for initial development of a list of AQCs for consideration in a PBS.

Of these, the design parameters listed under HMA are candidate AQCs for a performance specification. The performance of the considered pavement is influenced not only by the quality of the HMA but also by the quality of the base, subbase and subgrade. This will only become an issue if the specification is used as a warranty where the contractor is held responsible for the performance level of the pavement over a multi-year warranty period. It must be recognized that a PRS does not take into account the actual performance of the constructed pavement – instead, bonuses and penalties are calculated based on measurements, assumptions, and predictions made at the time of construction. Other issues that need to be considered when establishing a PBS include:

- How can one differentiate between the effects of base quality versus asphalt quality?
- What if the contractor achieves the required HMA characteristics but the aggregate base characteristics are deficient? Should the contractor be penalized for the inferior

overall pavement performance when only the HMA specification is a "performance-related" one?

Performance Characteristics

As found in the reviewed literature (*2,3,4,5,6,7*), the highway pavement design parameters listed in the previous section are related to the following PCs:

- Alligator (Fatigue) Cracking
- Longitudinal Cracking
- Permanent Deformation (Rutting)
- Ride Quality
- Surface Friction

The relationship between AQCs and PCs can be quite complex. For example, traffic and subgrade stiffness may have a significant impact on the HMA performance even though they are not HMA characteristics. As another example, the AQC of asphalt content has a significant impact on both permanent deformation and cracking. Too much asphalt cement will result in an increased risk of permanent deformation while too little asphalt cement will result in an increased risk of premature cracking. Therefore, it is important to develop a specification that applies an appropriate balance for the AQCs to optimize the overall performance of the material.

These relationships identified that construction of the subgrade and base can have a significant impact on the pavement performance. Hence, any PBS developed for the HMA will have to equalize the impact of the base and subgrade. Further, consideration of the development of a PBS for these materials may be considered in future research.

Predicting Highway Pavement Performance

Two avenues have been traditionally used to predict highway pavement performance: empirical and mechanistic-empirical (*8*). In the first approach, empirical correlations are sought between initial design parameters (which include AQCs) and observed pavement performance, over the service life of the pavement. Examples include the American Association of State Highway Officials (AASHO) Road Test and the predictive equation used in the American Association of State Highway and Transportation Officials (AASHTO) Design Guide, Westrack models, and others. The main disadvantage of this "observational" approach is that extrapolating outside the range of conditions used in developing the model/methodology may yield incorrect, irrational and erroneous results.

The second approach, *mechanistic-empirical*, introduces an intermediate step in the prediction process. Design inputs are used to calculate stresses and strains within the pavement structure and the final performance prediction models include the calculated stresses and strains as model parameters. Although a more scientifically sound approach, it is also a more sophisticated and costly alternative. The main advantage of the mechanistic-empirical method is that new materials and non-conventional pavement structures could be introduced and, theoretically, the mechanistic part of the model should still function (i.e. produce correct, rational and reasonable results). For this reason, HMA performance prediction models that include stress or strain as inputs to the model may be applicable to airfield pavements: HMA will perform similarly under the same state of stress/strain regardless of whether the loading is induced by a tractor-trailer or an aircraft. However, due to the difference in the size of loading, the mechanistic models should be thoroughly reviewed prior to implementation.

As an example, National Cooperative Highway Research Program (NCHRP) project 9-22 considered use of the Mechanistic-Empirical Pavement Design Guide (MEPDG) software to provide a mechanistic-empirical prediction of pavement performance (*9*). This project identified that the mechanistic-empirical approach provided a good estimate for performance; ultimately, the MEPDG was not a good option for completing the calculations for the highway pavements due to the time involved with this particular software.

Regardless of the approach, verification of the predictive methodology is necessary. The need for a comprehensive pavement construction and performance database is again emphasized.

Summary and Conclusions

In summary:

- It was apparent from the highway literature that the backbone of a performance specification is the predictive methodology whether it is empirical or mechanistic-empirical.
- Predicting highway pavement performance is a complex and sophisticated process and a wealth of good quality data is necessary to develop and calibrate distress prediction models as well as to validate the predictive methodology as a whole.
- Several approaches are possible to predict performance, each with its advantages and disadvantages.
- Existing AQC-PC models and relationships established for highway pavements can be of value to an airfield specification; however, given the different loading conditions specific to airfield pavements (e.g., higher wheel loads, tire pressures and contact

areas), these relationships should be re-evaluated before adoption into an airfield pavement performance specification.

There is a difference between PRS and PBS and most likely a “hybrid” approach can be used in developing a performance specification; the use of the MEPDG in NCHRP 9-22 is a good example.

PERFORMANCE SPECIFICATIONS FOR AIRPORT PAVEMENTS

Introduction

As already mentioned, the objective of this study is to develop comprehensive guidance that ties the operational requirements of airfield pavement to the technical specification and discussions provided in FAA Specifications P-401 and EB-59A Plant Mix Bituminous Pavement (Superpave). To achieve this objective, one of the most important tasks is to identify those aircraft operational requirements that are influenced by the quality of airfield asphalt pavements, recognizing that the HMA mix will play a key role in achieving pavement quality. A thorough literature search and review in the area of airport asphalt pavement will serve the following purposes:

1. Identify similar or related research in the area of performance-based HMA design;
2. Identify aircraft OPCs that relate to pavement conditions;
3. Review current FAA HMA design procedures and investigate relationships between the current HMA specification and the operational pavement performance;
4. Review current HMA mixture and pavement acceptance characteristics.

Documents identified as references 10 through 32 were assembled for the airport pavement literature review.

Literature Review Results

In comparison with highway pavements, limited research has been conducted to date on pavement performance-related or performance-based HMA specifications for airport pavement. However, the FAA's P-401 specification does share elements common to PRS *(10)* and flexible pavements properly designed and constructed to FAA standards perform well *(11)*. Most of the references listed discuss the relationship between aircraft operational performance and the quality of the airport pavements. The following discussion will concentrate on these results.

Operational Performance Characteristics

Most of the airport pavement references describe typical aircraft OPCs that are influenced by the quality of the airfield pavements. These include directional control, foreign object damage (FOD), turning control, aircraft vibration, dynamic shock, and acceleration and deceleration control.

Depending on the function of the aircraft pavement (i.e., runway, taxiway, apron), different operational characteristics may be of concern. For example, on runways, directional control becomes critical due to the high take-off speed of the aircraft. On the other hand, foreign object debris should be avoided on all airport pavement types because it may cause damage to aircraft engines.

FAA Advisory Circular No. 150/5380-5B *(12)* lists typical foreign objects on an airfield pavement as "aircraft and engine fasteners (nuts, bolts, washers, safety wire, etc.); mechanics' tools; flight line metal (nails, personnel badges, pens, pencils, etc.); stones and sand; paving materials; pieces of wood; plastic and/or polyethylene materials; paper products; and ice formations in operational areas." Among these, stone, sand, and paving materials that exist on pavement surface as foreign object debris may be directly caused by pavement distresses. For the measurement of FOD, Air Force Engineering Technical Letter (ETL) 04-9 introduces the use of the FOD Index *(13)*. The index can be estimated as a function of the PCI calculated by considering only the distress/severity levels capable of producing FOD.

Aircraft vibration and dynamic shock are influenced by pavement roughness. These can lead to fatigue in the landing gear, accelerations experienced in the cockpit, and passenger discomfort from pitch and roll motions *(14,15,16,17,18)*. In some cases, the roughness can lead to on-board vibration which prevents the pilot from accurately reading on-board instruments during take-off. The Boeing Company (Boeing) has taken steps to quantify this roughness to assist airport managers to identify problem roughness before it creates safety issues *(17)*. The Boeing Bump Index will assist in identifying if a section of pavement contains a bump or dip that causes an unacceptable shock on the aircraft (*17*). However, the Index does not quantify the total impact from multiple events and how they influence operation of the aircraft.

Pavement Performance Characteristics

Most pavement distresses will impact aircraft operational performance. For example, loose aggregate from the pavement surface can create FOD potential causing damage to the airframe or aircraft engine. Excessive rutting may make directional control difficult. A pavement that is too rough or does not have sufficient skid resistance may make acceleration and deceleration difficult and dangerous. Excessive roughness, excessive cracking, raveling, potholes and shoving may cause vibration and dynamic shock to the aircraft in the vertical direction. Transport Canada provides a description of some of the most basic types of distresses that can be found on airport pavements and what types of OPCs they will impact (*19*).

According to the Code of Federal Regulations, Section 139.305 *(20)*, "The pavement must have no hole exceeding 3 inches in depth nor any hole the slope of which from any point in the hole to the nearest point at the lip of the hole is 45 degrees or greater, as measured from the pavement surface plane, unless, in either case, the entire area of the hole can be covered by a 5-inch diameter circle." Also, "The pavement must be free of cracks and surface variations that could impair directional control of air carrier aircraft, including any pavement crack or surface." Airfield asphalt pavement may exhibit the following distresses or undesirable characteristics *(14, 15,16,17,19,20,21,22,23,24,25,26, and 27)*:

- Cracking (linear, block, reflection, etc.),
- Rutting (permanent deformation),
- Shoving,
- Bleeding,
- Patch,
- Pothole,
- Rough surface,
- Low skid resistance.

Therefore, any specification developed would need to control the quality characteristics of the HMA to preclude development of these distresses to unacceptable levels during the design life whether they result from traffic loading or environmental factors. For example, rutting on airfield pavements has been shown to result from either static or dynamic loading. While rutting from dynamic loading may be related to the pavement thickness design and HMA mix properties, plastic deformation from static loading is primarily related to the HMA mix properties *(27)*.

Acceptance Quality Characteristics

One measurement that can be incorporated in construction acceptance is the roughness of the finished surface. Pavement roughness can be evaluated in a number of ways including surface deviations measured by a straight-edge *(28,29)*, or a profile device *(15,18)*. Other measures attempt to relate the surface deviations to aircraft response *(16)* or potential damage to the airframe *(17)*. The International Roughness Index (IRI), which was developed for use on highways can also be used to evaluate airport pavement roughness *(16,18)*; although this index is primarily related to identifying roughness as it relates to cars and trucks. Another option would be to use the IRI as a model for development of an index more closely related to the behavior of aircraft.

Gerardi proposes a method of tracking deviations to a pavement profile by measuring the pavement baseline profile of a runway or taxiway after the pavement is constructed (*15*). As the author suggests, the baseline profile can be used as an acceptance criterion. The author also suggests that the pavement design should be evaluated against ride quality before the pavement is constructed, especially when the pavement needs to tie into the grade of other pavement sections.

While the current HMA specifications for airport pavements described in references 28 and 29 contain performance-related elements, the trend towards a more complete, performance-related HMA specification has been a goal of the FAA for some time *(10)*. For example, the existing FAA Marshall and Superpave specifications *(28,29)* both recommend the use of Performance-Graded (PG) asphalt binders, and as discussed below, the choice of the acceptance characteristics in these FAA specifications was an attempt to rely less on a "means and methods" approach and to make the specifications more performance-related.

FAA's P-401 specification (*28*) contains requirements for the design, production and placement of HMA. These include the preliminary material acceptance criteria, mixture composition and laboratory design, construction methods, equipment, quality control testing, and final mixture and pavement acceptance criteria. The acceptance criteria are based on the following characteristics of bituminous mixture and completed pavement:

- Marshall Stability
- Marshall Flow
- Air voids
- Mat density
- Joint density
- Thickness
- Smoothness
- Grade

As discussed in reference 10, the choice of stability, flow and air voids as acceptance criteria, in lieu of aggregate gradations and asphalt content, was an attempt by the FAA to steer their specification towards a more performance-related basis. Aggregate gradation and asphalt content were then considered as contractor quality control characteristics.

Reference 29 is FAA's Plant-Mix Bituminous Pavement specification for the Superpave mix design method. The acceptance criteria for Superpave airport asphalt mixes (*29*) are similar to the P-401 Marshall mix specification (*28*) and include the following characteristics of bituminous mixture and completed pavement:

- Air voids
- Mat density
- Joint density
- Thickness
- Smoothness
- Grade

The P-401 specifications (*28,29*) were developed by the FAA to satisfy several key pavement PCs for HMA: strength, (i.e., resistance to plastic deformation); durability (i.e., sufficient asphalt binder for coating and low in-place air voids); fatigue resistance; and resistance to bleeding and oxidation (optimized voids) (*10*). These considerations influenced the structure of both the Marshall and Superpave P-401 specifications.

The importance that FAA places on skid resistance is highlighted by the fact that an entire Advisory Circular (*22*), FAA AC 150/5320-12C, is devoted to this topic. Table 3-2 of the advisory circular contains criteria for minimum coefficient of friction of the pavement surface as measured by different continuous friction measuring equipment (CFME). The minimum texture depth of a newly constructed HMA surface is also recommended as 0.045 inch (1.14 mm) in Chapter 4. A measurement method for texture depth (NASA Grease Smear Test) is also referenced. There is anecdotal evidence that the coarse nature of the FAA P-401 gradation bands helps to achieve the minimum texture depth for new construction. Guidelines for aggregate quality, shape, and blending are included in Chapter 2 of the advisory circular. Finally, the advisory circular discusses methods to decrease hydroplaning potential through the use of grooving or application of a porous friction course. Conceivably, the criteria for texture depth and/or coefficient of friction could be included in a performance-based specification for airport HMA.

Summary and Conclusions

Although the amount of research performed in the area of PRS and PBS is limited for airfield pavements, it is possible to discern from the literature some characteristics that should be considered in developing any such specification. In summary:

1. Typical aircraft OPCs that can be considered related to mix design include:
    a. Aircraft directional control (skid resistance, plastic deformation)
    b. FOD (fatigue behavior, joint construction)
    c. Aircraft vibration and dynamic response of the aircraft (plastic deformation, grade control)
    d. Aircraft acceleration and deceleration (skid resistance)
2. Pavement distresses or undesirable characteristics that may cause aircraft operational performance problems include:
    a. Cracking (linear, block, reflection, etc.)
    b. Rutting
    c. Shoving
    d. Bleeding
    e. Patching
    f. Pothole
    g. Roughness
    h. Low skid resistance
3. Current mixture acceptance criteria that can be considered as performance-related include:
    a. Air voids
    b. Marshall stability and flow
4. Current pavement acceptance criteria that can be considered as performance-related include:
    a. Mat and joint density

b. Thickness

c. Smoothness

d. Grade

e. Frictional characteristics.

HIGHWAY/AIRPORT LITERATURE REVIEW SUMMARY AND CONCLUSIONS

In the area of highway pavements, past and ongoing research produced the voluminous data and the analytical and software tools necessary to develop a PRS/PBS (*5,6*). Even so, at the time of this report, the use of PRS by public agencies in the US and the world is still in the experimental stages. NCHRP Project 9-22 is expected to produce software that could be used by public agencies to implement a performance-related specification (*9*). The software used in Project 9-22 relies heavily on the research and findings of NCHRP Project 1-37A, "Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures." Project 1-37A was an impressive research effort that used a wealth of pavement performance and laboratory testing data, including data from the Long-Term Pavement Performance Data Base, the Federal Highway Administration Accelerated Loading Facility, the MnRoad test track, and the Westrack test track, to calibrate and validate the predictive methodology (*30*).

In contrast, in the area of airfield pavements, the available software tools and construction/performance data are limited, as discussed in the previous sections of this chapter. The backbone of a performance specification, be it either a PRS or a PBS, is the predictive methodology. Without the necessary data, predictive models cannot be developed, calibrated and validated. With the limited data available at this time for airfield asphalt pavements, the pursuit of a PRS seems to be the first logical step in the development of a performance specification. As more data becomes available, a PBS could be developed. However, a significant amount of research and time will be necessary to generate the ingredients necessary for a PBS.

The predictive methodology used in the MEPDG, for example, allows the user to input a combination of AQCs and/or FEPs to predict performance (*7*). The MEPDG can therefore be used as a "hybrid" between a PRS and a PBS. Most likely a similar approach will be viable for airfield pavement performance specifications.

The FAA has developed some tools to provide some of the functionality provided by the MEPDG. The FAARFIELD software provides for pavement design and allows the user to identify the effect of changes in thickness on expected pavement life. However, it does not provide a means to evaluate the effect of changes in other AQCs on the pavement performance. Additionally, FAApro allows the user to evaluate the pavement roughness of the pavement structure.

CHAPTER 3

INTERVIEW SUMMARY

INTRODUCTION

Within AAPTP Project 06-03, part of the first task was to conduct a series of interviews of various personnel involved with the design, construction, and management of airport pavements. The objective of these interviews was to capitalize on the experience of airport operators, manufacturers, and airport pavement experts across the nation in support of the development of a framework for PBS.

Interview Process and Statistics

A list of 57 interview candidates was developed by the project team including aircraft manufacturers, airport operators, military, consultants, government personnel, experts, and contractors. A breakdown of the candidates by agency type is provided in Table 1. Eight (8) of the interview candidates were from international agencies and included an aircraft manufacturer, airport operators, government agency personnel, and consultants.

Of the 57 people contacted for an interview, 26 people (~45%) provided responses, 5 people (~9%) declined to participate, and the remaining 26 people (~45%) did not respond. The number of responses are identified by agency type in Table 1 and further illustrated by percentage in Figure 2.

Table 1. Interviews by Agency Type

Contact Type	Number Contacted	Number Responding
Aircraft Manufacturers	4	2
Airport Operators (Small Airports)	10	4
Airport Operators (Large Airports)	10	4
Military Airport Operators	5	1
Consultants	15	8
Government Agents	11	7
Contractors	2	0
Totals:	57	26

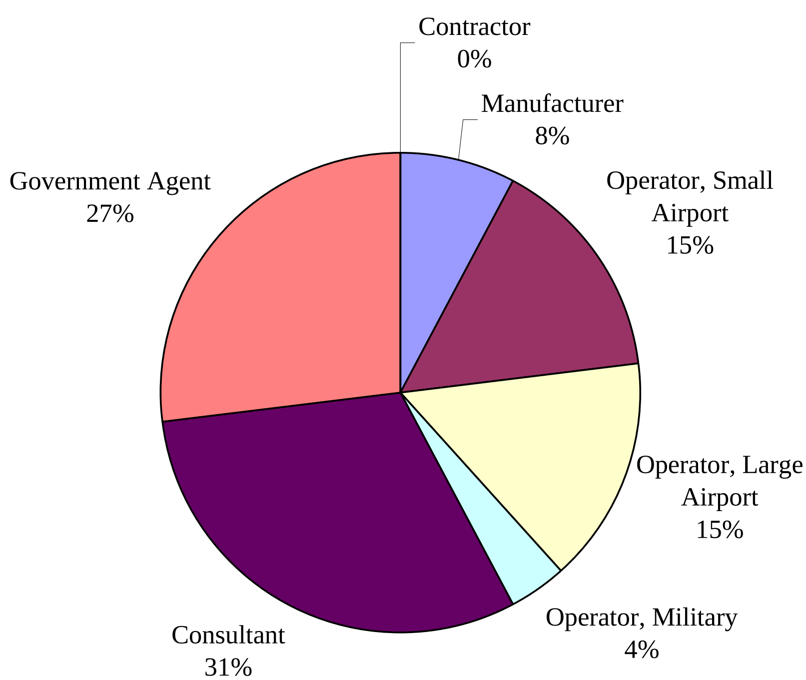

Figure 2. Interview Responses by Agency Type

The candidates were assigned to individual members of the project team for interview based primarily on convenience with some consideration given to existing personal relationships. For instance, if a member of the team was going to be attending a conference or other meeting that several potential interview candidates would also be attending, then these interviews were assigned to that team member.

Interviews were conducted via one of three methods: face-to-face, telephone, or by e-mail. The face-to-face interviews were limited to only those interviews where both a team member and a candidate would coincidentally be in the same place at the same time. The remaining interviews were conducted either over the telephone or by e-mail. The 26 responses obtained were from 17 face-to-face interviews, 6 telephone interviews, and 3 e-mail interviews as illustrated by Figure 3. Note that in some cases, the face-to-face interviews and telephone interviews were supplemented with e-mail communication.

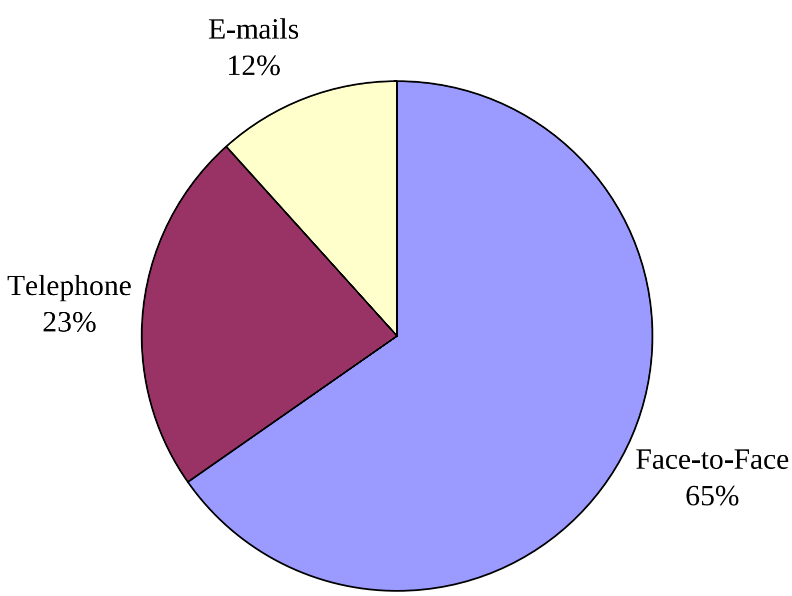

Figure 3. Interview Responses by Type of Contact

The interview candidates responding to the request for an interview came from fairly diverse geographic locations across the U.S. as indicated in Figure 4. The figure shows that experience from the eastern, mid-western, and western states were included within the interview pool.

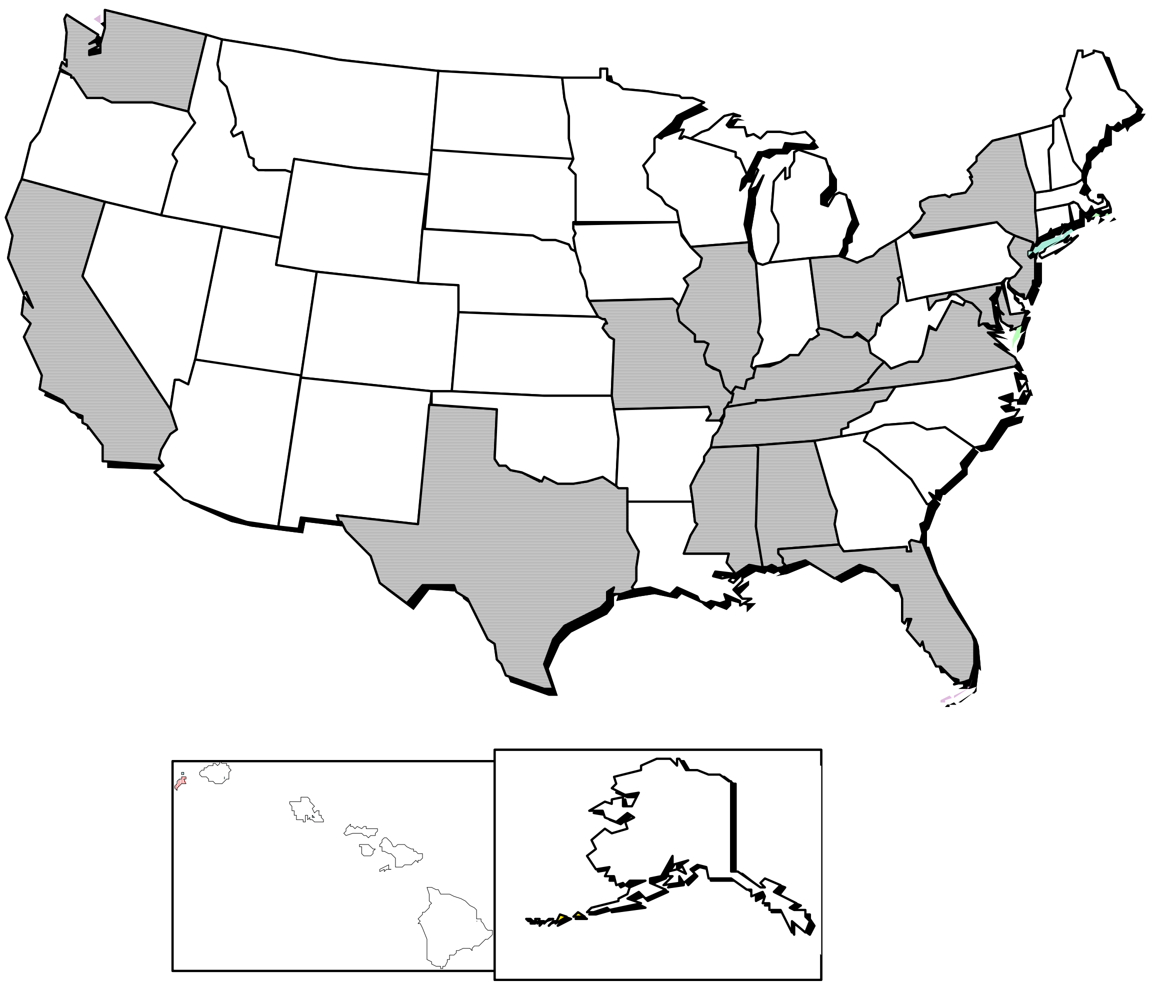

Figure 4. Geographic Distribution of Responding Interview Candidates

The list of responding candidates is provided in Appendix A. The list identifies the type of contact (airport operator, aircraft manufacturer, or expert) and form of interview (face-to-face, telephone, or e-mail).

Two questionnaires were developed for conducting the interviews. The first questionnaire was for use with airport operators. The initial set of questions within this first questionnaire assisted in identifying the size of the airport(s) being maintained by the operator by identifying the number of runways, the primary types of aircraft using those runways, and the number of operations per runway. The next set of questions was intended to identify the types of issues experienced by the aircraft at the airport and the types of pavement distresses observed. A set of questions was also included to identify the potential relationships between the aircraft operational issues, pavement distresses, and asphalt specification used in construction based upon the operator's experience. The final set of questions included a means for identifying how the pavement smoothness has been measured and any suggestions for improvement in smoothness specifications the operator may have. The completed questionnaires from the airport operators are provided in Appendix B.

The second questionnaire developed was used for conducting interviews with the aircraft manufacturers and airport pavement experts included in the interview candidate list. This questionnaire did not incorporate any of the questions about a specific airport as they are not applicable to these interview candidates. The remaining questions were very similar to those asked of the airport operators with the intent of identifying the candidate's opinion regarding the most prevalent aircraft operational issues, how these issues relate to pavement distresses, and, in the opinion of the candidate, how these operational issues and distresses may be impacted by the HMA specifications. The completed questionnaires from the aircraft manufacturers and other experts are provided in Appendix C.

INTERVIEW RESULTS

The objective of the interviews, as noted earlier, was to capitalize on the experience of airport operators, manufacturers, and airport pavement experts across the nation in support of the development of a framework for PBS.

The specific information pursued in the interviews relate to the three key elements of pavement PBS. They are:

- Aircraft OPCs,
- Pavement PCs influencing the aircraft OPCs,
- AQCs measured at the time of construction to predict pavement performance.

The input received from the interviews relative to these three key elements is detailed over the remainder of this section.

OPERATIONAL PERFORMANCE CHARACTERISTICS

The aircraft OPCs identified by the interviews include:

- Braking – Surface Friction
- Braking – Hydroplaning
- Dynamic Effects – Aircraft Damage
- Dynamic Effects – Pilot Control
- Dynamic Effects – Passenger Comfort
- Load Carrying Capability – Dynamic Loads
- Load Carrying Capability – Static Loads
- Directional Control
- Foreign Object Damage (FOD) Potential
- Traffic Disruptions
- Appearance

The number of interviews identifying each of these OPCs as important by type of pavement (runway, taxiway, or apron) is summarized in Table 2. This table shows that braking, as impacted by surface friction on runways, appears to be the performance characteristic of greatest concern across the airport pavement industry. Dynamic effects, FOD potential, and braking, as affected by hydroplaning, were the next three performance characteristics of greatest concern. Two of the PCs were identified for apron pavements and taxiway pavements, but not for runway pavements – static load carrying capability and appearance.

Table 2. Number of Interviews Identifying Each OPC as Important

Operational Performance Characteristic	**Runway**	**Taxiways**	**Aprons**
Braking – Surface Friction	19	7	4
Braking – Hydroplaning	15	6	2
Dynamic Effects – Aircraft Damage	16	6	2
Dynamic Effects – Pilot Control	16	6	2
Dynamic Effects – Passenger Comfort	3	8	3
Load Carrying Capability – Dynamic	1	1	1
Load Carrying Capability – Static	0	0	8
Directional Control	5	8	3
Foreign Object Damage (FOD) Potential	13	12	8
Traffic Disruptions	5	2	2
Appearance	0	1	1

For runways, the percentage of interviews identifying each OPC is further broken down in Table 3 according to agency type. There is only one interview falling into the military airport operator category; hence, the percentages in that category are either 100 or 0. The percentages are fairly consistent across agency type with the exception of the airport operators, who identified dynamic effects as being a greater concern on runways than braking.

Table 3. Runway OPCs by Agency Type

Operational Performance Characteristic	Consultant, %	Government, %	Large Airport, %	Small Airport, %	Manufacturer, %	Military, %*
Braking – Surface Friction	100	86	40	0	100	100
Braking – Hydroplaning	75	86	20	0	50	100
Dynamic Effects – Aircraft Damage	75	57	60	67	0	100
Dynamic Effects – Pilot Control	75	57	60	67	0	100
Dynamic Effects – Passenger Comfort	38	0	0	0	0	0
Load Carrying Capability – Dynamic	13	0	0	0	0	0
Load Carrying Capability – Static	0	0	0	0	0	0
Directional Control	50	14	0	0	0	0
Foreign Object Damage (FOD) Potential	88	43	0	33	50	100
Traffic Disruptions	38	14	0	33	0	0
Appearance	0	0	0	0	0	0

*Only one interview was completed with someone from a military agency; hence percentages are either 0 or 100

Table 4 provides the percentages of interviews identifying each OPC according to agency type for taxiways. As shown, the OPC of greatest concern is FOD potential. Like runways, the percentages are fairly consistent across agency type with the exception of the airport operators, who identified dynamic effects and braking as being of greater concern on taxiways.

Table 4. Taxiway OPCs by Agency Type

Operational Performance Characteristic	**Consultant, %**	**Government, %**	**Large Airport, %**	**Small Airport, %**	**Manufacturer, %**	**Military, %***
Braking – Surface Friction	38	29	20	0	0	100
Braking – Hydroplaning	50	29	0	0	0	0
Dynamic Effects – Aircraft Damage	38	14	20	0	0	100
Dynamic Effects – Pilot Control	38	14	20	0	0	100
Dynamic Effects – Passenger Comfort	63	14	20	0	50	0
Load Carrying Capability – Dynamic	13	0	0	0	0	0
Load Carrying Capability – Static	0	0	0	0	0	0
Directional Control	50	29	0	0	50	100
Foreign Object Damage (FOD) Potential	88	43	0	0	50	100
Traffic Disruptions	13	14	0	0	0	0
Appearance	13	0	0	0	0	0

*Only one interview was completed with someone from a military agency; hence percentages are either 0 or 100

Table 5 provides the percentage of interviews identifying each OPC according to agency type for aprons. The OPCs of greatest concern on aprons are FOD potential and static load carrying capability.

Table 5. Apron OPCs by Agency Type

Operational Performance Characteristic	Consultant, %	Government, %	Large Airport, %	Small Airport, %	Manufacturer, %	Military, %*
Braking – Surface Friction	25	14	0	0	0	100
Braking – Hydroplaning	25	0	0	0	0	0
Dynamic Effects – Aircraft Damage	13	0	20	0	0	0
Dynamic Effects – Pilot Control	13	0	20	0	0	0
Dynamic Effects – Passenger Comfort	25	14	0	0	0	0
Load Carrying Capability – Dynamic	0	0	20	0	0	0
Load Carrying Capability – Static	38	43	20	0	50	0
Directional Control	13	14	0	0	0	100
Foreign Object Damage (FOD) Potential	75	29	0	0	0	0
Traffic Disruptions	13	14	0	0	0	0
Appearance	13	0	0	0	0	0

*Only one interview was completed with someone from a military agency; hence percentages are either 0 or 100

PAVEMENT PERFORMANCE CHARACTERISTICS

Table 6 lists the pavement PCs that, according to the interviews, are expected to influence the aircraft OPCs.

Table 6. Pavement Performance Characteristics Influencing OPCs

Operational Performance Characteristic	Runway	Taxiways	Aprons
Braking – Surface Friction	Friction, groove closure, surface texture	Friction, groove closure, surface texture	Friction, groove closure
Braking – Hydroplaning	Drainage, rutting, surface texture, groove closure	Rutting, groove closure	None given
Dynamic Effects – Aircraft Damage	Roughness, reflection cracking, transverse joints, grade control	Roughness, reflection cracking, transverse joints, grade control	Roughness, reflection cracking, transverse joints, grade control
Dynamic Effects – Pilot Control	Roughness, reflection cracking, transverse joints, grade control	Roughness, reflection cracking, transverse joints, grade control	Roughness, reflection cracking, transverse joints, grade control
Dynamic Effects – Passenger Comfort	Roughness, reflection cracking, transverse joints, grade control	Roughness, reflection cracking, transverse joints, grade control	Roughness, reflection cracking, transverse joints, grade control
Load Carrying Capability – Dynamic	None given	None given	None given
Load Carrying Capability – Static	None given	None given	None given
Directional Control	Rutting, drainage, potholes, friction, cracking, roughness, shoving, patching, raveling, groove closure, bleeding, bumps, surface texture, joint deterioration	Rutting, drainage, potholes, friction, cracking, roughness, shoving, patching, raveling, bleeding, groove closure, lack of crown	Rutting, drainage, potholes, friction, cracking, shoving, roughness, bleeding, static indentation, fuel spills
Foreign Object Damage (FOD) Potential	All	All	All
Traffic Disruptions	All	All	All
Appearance	None given	None given	None given

Three of the OPCs were not related back to any pavement PCs. They are the dynamic load carrying capacity (generally seen as being related primarily to the pavement design), static load carrying capacity (generally related to the mix characteristics) and appearance (only identified in one interview and not related back to any of the pavement PCs).

In addition, braking, as related to hydroplaning, was not related to any pavement PCs for apron pavements. Many of the interviews identified this OPC, but most of them indicated that aircraft travel at very slow speeds on apron pavements and hence it is not considered an issue on this pavement type.

The interview questions also attempted to identify the pavement PCs that are believed to be important to aircraft operations on airfields. Table 7 identifies each of the pavement PCs and the number of times these characteristics were identified according to pavement type.

Table 7. Pavement Performance Characteristics

Pavement Performance Characteristic	Runway	Taxiway	Apron
Roughness	10	6	4
Friction	9	1	1
Joint Cracking/Raveling	7	7	3
Raveling	16	11	6
Drainage	5	3	4
Groove Closing	6	2	0
Fuel Spills	0	0	12
Rutting	12	14	9
Cracking	13	10	7
Bleeding	3	3	2
Stripping	2	1	1

The pavement PCs most frequently identified for runways include raveling, cracking, and rutting. These same characteristics were also most frequently identified for taxiway pavements. While rutting and cracking were also in the top three pavement PCs for apron pavements, fuel spills was the most frequently identified pavement PC.

ACCEPTANCE QUALITY CHARACTERISTICS

Table 8 presents the AQCs and the number of times each was identified within the interviews. As shown, the mix design and control of the mix parameters are considered the key components in HMA pavement performance.

Table 8. Acceptance Quality Characteristics by Pavement Type

Acceptance Quality Characteristic	Runway	Taxiway	Apron
Asphalt Content	14	13	11
Air Voids	13	12	11
Compaction	11	10	8
Voids in Mineral Aggregate	11	9	8
Aggregate Gradation	11	11	10
Binder Grade / Quality	11	10	10
Smoothness	4	3	4
Joint Compaction	4	3	1
Fractured Faces	3	3	3
Natural Sand Content	2	2	2
Angularity	1	1	2
Aggregate Polishing	1	0	0
Grade Control	1	0	1
Asphalt Temperature Control	1	1	1
Stability	4	3	3
Surface Texture	2	1	1
Stripping	3	3	2
Mineral Filler	2	2	2
Film Thickness	4	4	4
Friction	3	3	2

Each interview attempted to identify the AQCs that most influence the durability and structural performance of the HMA. These results are summarized in Table 9. According to the interviews, the AQCs that most impact the durability of the mix are related to the percentage of air voids in the mix, the asphalt content, and the compaction of the mix, while those that most impact the structural performance of the mix are related to the aggregate (fractured faces, aggregate angularity, and gradation), the percentage of air voids in the mix, and the compaction of the mix.

Table 9. Acceptance Quality Characteristics Affecting Durability and Structural Performance

Acceptance Quality Characteristic	**Durability**	**Structural**
Asphalt Content	10	5
Air Voids	14	7
Compaction	9	7
Voids in Mineral Aggregate	6	3
Aggregate Gradation	5	8
Binder Grade / Quality	9	5
Smoothness	1	0
Joint Compaction	1	0
Thickness	0	2
Fractured Faces	4	9
Natural Sand Content	1	1
Aggregate Angularity	3	8
Flow	1	2
Asphalt Temperature Control	2	1
Stability	1	1
Stripping	3	1
Film Thickness	2	0
E*	0	2

SUMMARY

A series of interviews were held with airport operators, aircraft manufacturers, consultants, and government agents across the nation to capitalize on their experience in support of the development of a framework for PBS.

To begin with, the interviews yielded a list of aircraft OPCs which were summarized in Table 2. The OPCs most frequently recognized by those interviewed included braking, dynamic effects, and FOD potential, but their priority order depends on pavement type (runway, taxiway, or apron).

Next, the interviews identified pavement PCs influencing the aircraft OPCs. These pavement PCs were summarized in Table 6. The most frequently identified characteristics were raveling, rutting, cracking, fuel spills, and roughness, but their priority order depends on pavement type.

Finally, the interviews identified the AQCs of HMA mixes that can be measured at the time of construction to predict pavement performance. The AQCs identified were summarized in Table 8. The mix design and control of the mix parameters were considered the key AQCs. The percentage of air voids in the mix, the asphalt content, and the compaction of the mix were identified as having the greatest impact on durability, while the aggregate (fractured faces, aggregate angularity, and gradation), the percentage of air voids in the mix, and the compaction of the mix were identified as having the greatest impact on structural performance.

The key information and priorities obtained from these interviews will be used in identifying priorities in future research efforts. Additionally, any specification must balance the needs of the pavement being developed. For instance, additional asphalt cement may make the HMA more resistant to cracking and at the same time increase the potential for permanent deformation. Using the priorities of the operators and experts will provide a means for developing an appropriate balance in the AQCs.

CHAPTER 4

OPERATIONAL PERFORMANCE CHARACTERISTICS

INTRODUCTION

Airport OPCs are an extension of the key desirable features of a pavement structure: safety, comfort, appearance and structural integrity. Based on the findings of the literature review and interviews described in the previous chapter, the following OPCs have been identified:

Safety:
- Braking Capability
- Directional Control
- Aircraft Damage – due to poor ride quality
- Aircraft Damage – due to foreign object debris

Comfort:
- Pilot and Passenger Comfort

Appearance:
- Aesthetics

Structural Integrity:
- Load Carrying Capability – Static (Aprons and Taxiways)
- Load Carrying Capability – Dynamic (Runways and Taxiways)
- Traffic Flow Disruptions

Each of theses OPCs are described in more detail in the following section.

DEFINITIONS

Braking Capability – Surface Friction and Hydroplaning

This aircraft OPC relates to the ability of any given aircraft to safely reduce its speed (i.e., decelerate) and/or come to a complete stop while operating in direct contact with the airfield pavement surface. References 13, 22, and 31 were used in developing this definition.

There are a number of factors that affect aircraft braking capability, including atmospheric conditions (e.g., rainfall rate and wind velocity and direction), aircraft parameters (e.g., aerodynamics, speed, engine thrust, brake systems, landing gear geometry, tire inflation pressure, and tread design and wear), pilot inputs (e.g., technique for applying brakes and using directional control), and runway geometry (e.g., length and orientation).

For purposes of this study dealing with PBS for HMA pavements, however, the primary factor of interest is the pavement itself. There are two pavement-related elements that affect aircraft braking capability: pavement surface texture (friction) and drainage (hydroplaning). Both of these elements affect the aircraft tire-pavement surface interaction (i.e., “where the rubber meets the pavement”) and hence aircraft braking capability.

From a pavement design viewpoint, the objective is to maximize surface friction and to minimize conditions that may permit water build-up on the surface that can lead to hydroplaning and loss of traction and directional control. Hydroplaning can be controlled over the design life of the pavement with the use of porous friction courses, slurry seals, or pavement grooving.

Surface friction from the pavement perspective is controlled primarily by the surface texture which is generally described in terms of its micro- and macro-texture. Micro-texture, which provides frictional properties for aircraft operating at low speeds, refers to the fine scale roughness contributed by small individual aggregate particles on the pavement surfaces that are not readily discernible to the eye but are apparent to the touch, i.e., the feel of fine sandpaper. Macro-texture, which provides frictional properties for aircraft operating at high speeds, refers to visible texture of the pavement surface as a whole.

Surface drainage, as it relates to this OPC, is the ability of water to flow away from the aircraft tire-pavement surface interaction area and it is affected by the macro-texture and porosity of the pavement surface (e.g., porous friction course versus dense HMA surface). In order to promote drainage, grooves are cut into the pavement surface; however, over time, rubber from aircraft tires will deposit into the grooves preventing the intended effect of drainage. Therefore maintenance of these grooves is an on-going effort.

Either of these factors can contribute to hydroplaning. In addition, there are other factors such as permanent pavement deformations (i.e., rutting) that can lead to the retention of water on the surface and therefore contribute to hydroplaning. Both the surface texture and drainage characteristics of a pavement can be affected by other factors beyond those listed above, such as grooving of the pavement surface, painted areas on the pavement surface and pavement geometry (e.g., slope in longitudinal and transverse direction). These factors are beyond the scope of this study as it relates to PBS for HMA pavements. However, the specification should include guidance on how to address these additional factors.

Several factors concern the pavement designer in selecting the appropriate design mix relative to surface micro- and macro-texture. They include the blending of aggregate sources, aggregate size and gradation, aggregate characteristics (resistance to polish and wear, texture and shape), selection of an optimum asphalt content to prevent bleeding, and the use of quality construction methods to obtain the required surface properties. Poor quality construction techniques can lead to segregation or a non-homogeneous mix resulting in areas of poor surface texture. All of these same factors also play an important role with regards to surface drainage and the rutting potential of the pavement; however, the influence of other pavement layers and subgrade will also affect rutting potential.

On the basis of the above discussion, the aircraft OPC in question has been subdivided into the following OPCs:

- Braking Capability – Surface Friction (related to micro- and macro-texture of pavement surface)
- Braking Capability – Hydroplaning (related to macro-texture of pavement surface as well as permanent deformation or rutting potential of pavement structure)

These two aircraft OPCs are considered applicable to runways and high-speed taxiways only and may be dependent on aircraft type – large commercial (new versus old, i.e. changes in tire pressures, landing gear configuration, etc.), general aviation or military aircraft.

Directional Control

This aircraft OPC relates to the pilot's ability to maintain steering control of the aircraft while in direct contact with the airfield pavement surface. References 19 and 22 were used in developing this definition.

Directional control can be affected by a number of elements. For instance, on a grooved pavement surface, the closing of the grooves will increase the potential for hydroplaning which could make it more difficult for the pilot to maintain steady control of the aircraft as it lands or takes off. Other factors that can influence the directional control of the aircraft include environmental factors such wind, precipitation, etc.; aircraft inputs such as speed, landing gear geometry, tire tread design and wear; and pilot inputs.

However, for the purpose of this study, two conditions are of primary interest. The first is related to friction and hydroplaning. As with braking, the objective from the pavement design perspective is to maximize surface friction and to minimize conditions that may permit the build-up of water on the surface over the design life of the pavement using proper materials and construction techniques. The second is related to roughness and permanent deformation occurring on the pavement surface.

Water build-up on the pavement surface or surface drainage is related to both surface texture and vertical pavement distresses (i.e., distresses resulting in vertical deviations in the pavement surface). The surface drainage is affected by the surface texture and porosity of the pavement (i.e., porous friction course versus dense-graded HMA). Surface drainage is also impacted by vertical distresses such as depressions, rutting and shoving which with sufficient water depth and spray can lead to flame-outs and subsequently directional control problems with even very large aircraft.

If the vertical distresses become sufficiently large, they will impact the ability of the pilot to control the steering mechanism of the aircraft on dry pavements leading to issues with directional control. This directional control issue would primarily occur with smaller aircraft and/or on runways and high speed taxiways.

This aircraft OPC is applicable to runways, taxiways, and aprons, although it is most likely to occur on runways and high-speed taxiways. The OPC may be dependent upon aircraft type.

Dynamic Effects – Aircraft Damage, Pilot Control, Passenger Comfort

This aircraft OPC relates to the vertical movement of the aircraft as it traverses the airfield pavement surface. The vertical movement is caused by the dynamic interaction of the aircraft with the pavement surface. References 15, 16, 17, 18, and 25 were used in developing the definition of this OPC.

These dynamic interactions can have three specific impacts on aircraft operations. The first is *damage to the aircraft*. The pavement roughness can cause increased pitch on the nose gear and increased loading on the strut. Ultimately, this increased loading will cause increased wear and tear on the nose strut and other systems associated with the nose strut. Increases in g-forces from dynamic interaction can also cause damage to other components of the airframe. These increases in vertical movement and loading will result in the requirement for increased maintenance on the aircraft and subsequently higher cost of operation by the airliner and shortens the useful life of the aircraft.

The second dynamic effect is related to *pilot control*. This effect is closely related to the directional control OPC. The roughness of the pavement can cause undue accelerations that are felt in the cockpit and affect the pilot's ability to control the steering of the aircraft or affect the pilot's ability to process the visual cues used in landing the aircraft. This aircraft OPC is more likely to occur on runways and high speed taxiways when the aircraft is operating at higher speeds and/or with smaller aircraft.

The third dynamic effect is related to *passenger comfort*. Passenger comfort represents how the aircraft passengers feel about the ride as the aircraft traverses the airfield pavements. This comfort is dependent upon the roughness present on these pavements and the length of the area. It is also dependent upon the speed of the aircraft and the type of aircraft. Passenger comfort is generally less important on airfield pavements than on highway pavements as the length of time spent traversing these pavements is much less for a given trip.

Based on these different impacts, this OPC has been subdivided into the following OPC:

- Dynamic Effects – Aircraft Damage
- Dynamic Effects – Pilot Control
- Dynamic Effects – Passenger Comfort

The main pavement factor which obviously contributes to these OPCs is pavement roughness. All of the pavement performance characteristics which impact roughness will impact these OPCs.

These three aircraft OPCs are considered applicable to runways and taxiways. Due to slow operational speeds, these OPCs are not considered to be particularly important for apron pavements. Only those pavements which more routinely receive high speed traffic, i.e. runways and high speed taxiways, are more likely to have issues with dynamic effects. The dynamic effects are also dependent to some extent upon aircraft type.

Foreign Object Damage (FOD) Potential

This aircraft OPC relates to the potential damage to any given aircraft resulting from foreign object debris on or around an aircraft. References 12 and 13 were used in developing this definition.

Foreign object debris includes a substance, debris or article alien to the aircraft that does not belong in or near the aircraft, which could potentially cause damage to it. Examples of foreign object debris include bird strikes, rocks or other metal parts, hail, ice on the wings, and dust or ash clogging the air intakes. Other examples include catering supplies, building materials and pieces of luggage. Also, most aircraft occasionally lose small metal parts during takeoff and landing, which remain on the pavement. All of these foreign objects can cause damage through direct contact with aircraft, such as by cutting aircraft tires or being ingested into engines, or as a result of being thrown by jet blast and damaging other aircraft or injuring people.

For purposes of this study dealing with PBS for HMA pavements, however, the primary foreign object debris of interest is that resulting from the pavement itself, and more specifically fragments resulting from pavement deterioration due to climate, loading and tire abrasion and scuffing.

From a pavement design viewpoint, the objective is to minimize conditions that may result in the breakup of the pavement into fragments during its planned design life, which in turn can lead to the potential for foreign object damage. These conditions include the development of cracks (alligator, longitudinal and transverse, joint reflection, block and slippage), jet blast erosion, oil spillage, raveling and weathering, and shoving.

Factors of concern to the pavement designer include not only those associated with the selection of the appropriate HMA design mix(es) and thickness(es), but also the appropriate selection of the remaining pavement structural layers (material types, properties and thicknesses) and preparation of the subgrade soil given the anticipated environmental conditions and traffic.

This aircraft OPC is considered applicable to all airfield pavements (runways, taxiways and aprons) and all aircraft types.

Load Carrying Capability – Dynamic and Static

This aircraft OPC relates to the pavement's ability to withstand the loading by the various aircraft using the airfield pavement. References 23, 26, and 27 were used in developing the definition of this OPC.

There are a number of factors that affect the ability of the airfield pavements to withstand aircraft loading and climatic conditions, including layer thickness, mechanical properties, and drainage. The driving condition affecting which of these parameters control the load carrying capability of the pavement is the time of loading.

Dynamic loading of the airfield pavement is the loading applied by the aircraft as it moves across the apron, taxiway, and runway pavements prior to take-off and after landing. This type of loading is generally expected to be related to the pavement design; although, certain poor construction practices or the use of poor paving materials can theoretically affect the structural capacity of the pavement. However, for the purposes of this study, the dynamic load carrying capability is believed to be primarily a function of the pavement thickness design that is typically characterized by limiting vertical strain in the subgrade.

Static loading occurs when the aircraft sits on the apron for loading and unloading of passengers and/or cargo. The nose and main gears sitting for long periods in a single location can cause an extreme loading condition on the asphalt pavement and lead to a failure termed "static indentation." The ability of the pavement to withstand the static loading of the aircraft is generally expected to be controlled by ambient temperatures, the asphalt mix and construction techniques. In particular, factors related to the aggregate skeleton and grade of the asphalt cement of the asphalt concrete will impact the static load carrying capability of the pavement.

Traffic Flow Disruptions

This aircraft OPC relates to the ability of the airfield to provide continuous operation thus limiting disruptions in traffic flow. Reference 32 was used in developing the definition of this OPC.

There are a number of factors that may cause traffic flow disruptions including issues related to the pavement maintenance requirements, climatic conditions, general air traffic, and delays in other operations. For the purposes of this study dealing with PBS for HMA pavements, the primary traffic flow disruption of interest is related to the requirement to close an area of pavement for the purposes of performing maintenance repairs on the pavement.

From a pavement design and construction viewpoint, the objective is to minimize conditions that result in the failure of the pavement to perform as required. These conditions include the development of cracks (alligator, longitudinal and transverse, joint reflection, block and slippage), jet blast erosion, oil spillage, raveling and weathering, shoving, rutting, roughness or any other distress.

Factors of concern to the pavement designer include not only those associated with the selection of the appropriate HMA design mix(es) and thickness(es), but also the appropriate selection of the remaining pavement structure layers (material types, properties and thicknesses) and preparation of the subgrade soil given the anticipated environmental conditions and traffic.

This aircraft OPC is considered applicable to all airfield pavements (runways, taxiways and aprons), but may be dependent on aircraft type – large commercial (new versus old), general aviation or military aircraft.

Aesthetics

This aircraft OPC has to do with the aesthetics of the airfield. As with the previous OPCs, because this project is dealing with PBS for HMA pavements, further discussion will be limited to the aesthetics as they pertain to the HMA pavement.

The pavement aesthetics deal with providing the airfield pavement users including both pilots and passengers with a pavement that is pleasing in appearance. Generally, aesthetic pavements will be uniform in appearance with no irregularities in color or elevation.

The factors affecting the pavement aesthetics include the development of cracks (alligator, longitudinal and transverse, joint reflection, block and slippage), jet blast erosion, oil spillage, raveling and weathering, shoving, rutting, roughness or any other distress. Irregular mix types such as porous pavements or large stone mixes will impact the opinion of the traveling public regarding the appearance of the pavement.

This aircraft OPC is applicable to all pavement types (runways, taxiways, and aprons). It will not be impacted by the aircraft type.

PRIORITIES

Once the OPC definitions were established, the next step was to develop a prioritized list. The list needs to reflect the information obtained from the reviews of the airport literature and the highway literature as well as the interviews conducted for the project.

The airport literature review identified the OPCs of directional control, FOD potential, dynamic effects related to pilot control, dynamic effects related to aircraft damage, as well as speed control. FOD potential was identified as being very important on all airport pavements.

The interview results were also used to establish a set of priorities. As illustrated in Table 2 of Chapter 3, braking, as impacted by surface friction on runways, appears to be the performance characteristic of greatest concern across the airport pavement industry. Dynamic effects, FOD potential, and braking, as affected by hydroplaning, were the next three performance characteristics of greatest concern. Table 10 provides the priorities based on the number of interviews in which each OPC was identified by pavement type, e.g., the lower the number the higher the priority. The priorities are distinctly different for each pavement type.

Table 10. Prioritized List of OPCs

Operational Performance Characteristic	Runway	Taxiways	Aprons
Braking – Surface Friction	1	7	10
Braking – Hydroplaning	3	8	12
Dynamic Effects – Aircraft Damage	2	8	12
Dynamic Effects – Pilot Control	2	8	12
Dynamic Effects – Passenger Comfort	11	6	11
Load Carrying Capability – Dynamic	13	13	13
Load Carrying Capability – Static	14	14	6
Directional Control	9	6	11
Foreign Object Damage (FOD) Potential	4	5	6
Traffic Disruptions	9	12	12
Appearance	14	13	13

It is believed that the dynamic load carrying capability falls lower in the priority list than might be expected because the dynamic load carrying capability is believed to be primarily related to the pavement design. This relationship outweighs its dependence upon the asphalt mix and construction techniques. While poor mix design or construction can impact the ability of the pavement to carry the load, the pavement design has a much bigger impact on this OPC.

These items were used to develop the priorities identified in Table 11. In this table, the large commercial airport priorities and military airport priorities are combined because these two types of airports are believed to have very similar priorities.

Three of the OPCs are identified as a level 3 priority regardless of pavement type or airport type: dynamic effects resulting in passenger discomfort, dynamic load carrying capability and aesthetics. Based on these low priorities and difficulties in establishing objective quantitative ratings for passenger comfort and aesthetics, we recommend that these OPCs not be included in a performance specification.

By not considering these three OPCs, the only differences in priorities between the large commercial/military airports and the general aviation airports are the FOD potential and traffic flow disruptions. The lower priority for FOD potential at the general aviation airports is in part due to the lesser volume of jet engine aircraft at these locations. As it is likely that these types of aircraft could become more frequent users of the general aviation airports, it is also likely that the development of FOD potential on these pavements will become a higher priority. A similar argument can be made for the traffic disruptions at these types of airports. Therefore, the priority lists have been combined into a single set, shown in Table 12, with different priorities maintained for different pavement types.

Table 11. Operational Performance Characteristic Priorities by Airport

Aircraft Operation Performance Characteristics	**Large Commercial and Military Aircraft**			**General Aviation Aircraft**		
	Runway	**Taxiway**	**Apron**	**Runway**	**Taxiway**	**Apron**
Directional Control						
Foreign Object Damage (FOD) Potential						
Dynamic Effects – Passenger Comfort						
Dynamic Effects – Pilot Control						
Dynamic Effects – Aircraft Damage						
Braking Capability – Surface Friction						
Braking Capability – Hydroplaning						
Traffic Flow Disruptions						
Load Carrying Capability – Dynamic						
Load Carrying Capability – Static						
Aesthetics						

Priority level 1
Priority level 2
Priority level 3

SUMMARY

As illustrated in Table 12, all OPCs are important to runway pavements except for static load carrying capability, while the only OPCs that are important to apron pavements are FOD potential and static load carrying capability. Taxiways are similar to runways, but other than directional control and FOD potential, the remaining OPCs are of lower priority.

Table 12. Final Operational Performance Characteristic Priorities

Aircraft Operation Performance Characteristics	**All Aircraft/Airports**		
	Runway	**Taxiway**	**Apron**
Directional Control			
Foreign Object Damage (FOD) Potential			
Dynamic Effects – Pilot Control			
Dynamic Effects – Aircraft Damage			
Braking Capability – Surface Friction			
Braking Capability – Hydroplaning			
Traffic Flow Disruptions			
Load Carrying Capability – Static			

Priority Level 1
Priority Level 2
Priority Level 3

The project team felt it was important to maintain separate priorities for runways, taxiways and aprons. First, the FAA has set a higher safety standard for runway pavements due to operational speeds on these pavements. Second, the same pavement distress could manifest differently given the different types of loading on each pavement type. For instance, hydroplaning on a taxiway should be a lesser issue than for runways because of the lower operating speeds while rutting and shoving may be more likely to occur on taxiways than on runways because of the generally lower operating speeds. Note that in some areas such as high-speed exit taxiways, the consideration of hydroplaning may be a bigger issue than with other taxiways. Finally, the importance placed on these pavements by the various airport operators interviewed was distinctly different for each of the three pavement types.

CHAPTER 5

PAVEMENT PERFORMANCE MEASURES

INTRODUCTION

The basic concepts of a PBS were outlined in Chapter 1. In this particular case, the specification is expected to control the interface of the airport operations with the key pavement operational requirements as identified and prioritized in Chapter 4. In order to fully investigate how these operational characteristics should be controlled by a PBS, the general flow of a PBS is presented in Figure 5. Note that the life-cycle cost approach used for developing the pay factors as shown in Figure 5 is just one of several potential approaches that could be taken.

This flow chart illustrates the steps taken to identify the required limits on a particular AQC for a given project to control a pavement performance characteristic. In order to understand which OPCs are affected by which pavement PCs it is necessary to further review these OPCs.

The following sections discuss how the OPCs are manifested and the interrelationships between pavement PCs and OPCs.

PAVEMENT PERFORMANCE CHARACTERISTICS

Having identified the OPCs, the next step is to identify how the various pavement performance measures relate to these OPCs. This chapter identifies each of the pavement PCs typically measured in evaluating pavement performance and how these characteristics relate to the OPC. Further, it identifies the acceptance quality characteristics which are used in the current specification to control the development of the OPC.

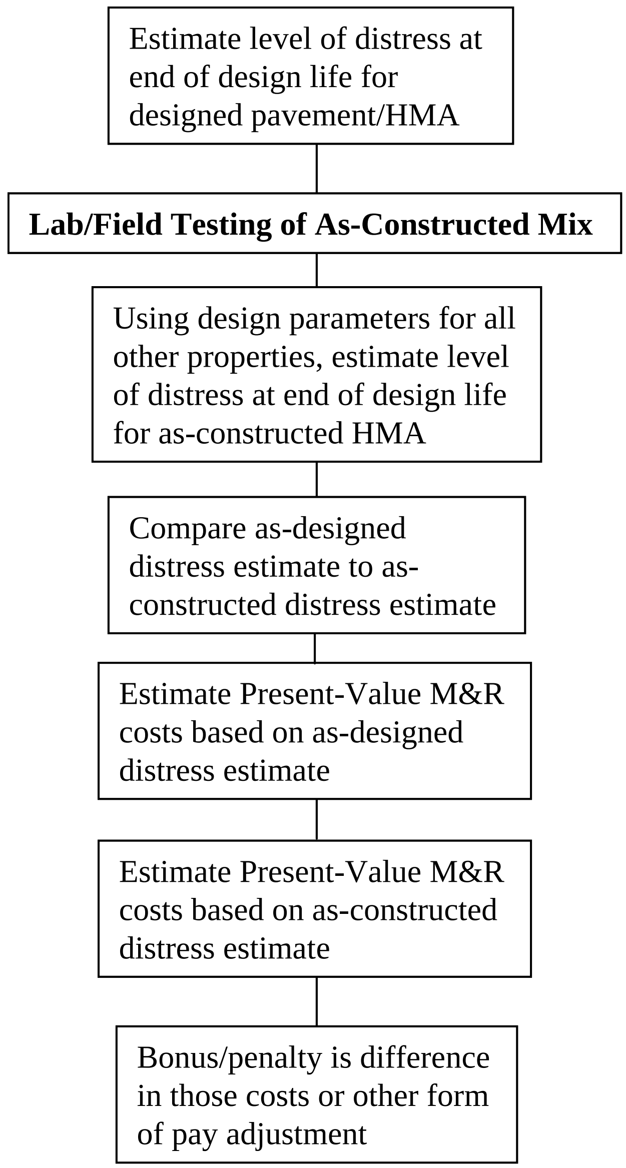

Figure 5. Flow Chart for Developing Acceptance Levels for a Performance Based Specification

CRACKING

Cracking may occur on a pavement surface for a variety of reasons and takes a variety of forms in HMA pavements. These forms include longitudinal and transverse cracking which may progress to block cracking and fatigue or alligator cracking. Additionally, cracking may be observed as joint reflection cracking caused by movement of underlying portland cement concrete (PCC) slabs.

Generically speaking, cracking occurs when the tensile stresses in the HMA exceed the tensile strength of the material. These tensile stresses occur due to both loading of the pavement and due to environmental factors which can impact the stress being applied and the materials' strength. There are a variety of reasons for the HMA material to have insufficient strength to withstand the stresses from applied load and environmental factors.

Affected OPCs

Cracking primarily affects the OPC of FOD potential. As identified above, the basic process of crack development is due to tensile stresses in the HMA exceeding the tensile strength of the material. Without maintenance to inhibit crack propagation, the cracks will become wider over time and develop adjacent cracking and spalling which lead to pieces of material that may easily become dislodged and provide potential for FOD.

Cracking will also affect the Traffic Flow Disruptions OPC. Cracking will require maintenance to inhibit continued growth. In performing this type of activity, it will be necessary for airport personnel to halt operations on various portions of the airport pavements in order to complete the maintenance activities. In some cases, there may be only minimal disruption to airport operations; however, as the cracking becomes more extensive and the maintenance/repair requirements become more extensive, the disruptions to operations will likely increase.

Current Procedures

One current procedure used for controlling cracking on HMA airfield pavements relates to the selection of the binder. The lower temperature specified by the binder grade should be at least as low as the lowest temperature expected. This low temperature value indicates the binder's ability to withstand low temperature values without significant cracking. This type of asphalt grading is intended to control the thermal cracking in the HMA mix.

Other procedures used to control cracking include the pavement design. A frost penetration layer may be used to control the development of cracking as a result of frost action.

Joint reflection cracking is controlled by a variety of means. Approaches such as break and seat or crack and seat where the PCC layer is fractured may be used to mitigate reflection cracking. In other cases, a "saw and seal" approach is used where the HMA layer is sawed directly above the PCC joint and the "joint" in the HMA layer is sealed can inhibit crack propagation from movement of the underlying PCC material. Other techniques such as the use of interlayers directly above the PCC layer have also been successfully used to retard reflection cracking.

The proper pavement design is also critical in controlling the fatigue cracking the pavement exhibits. Placing the HMA layer with sufficient thickness to withstand the load applied is critical to controlling the fatigue cracking exhibited by the pavement surface. Additional steps for controlling fatigue cracking include providing a base material of sufficient quality and thickness.

Joint density is currently the only means for controlling the cracking/fraying of the pavement along the longitudinal joint. The P-401 specification currently calls for evaluation of the density along the joint by coring the compacted pavement with a minimum of one core for each sublot.(*28*) The cores are evaluated for bulk specific gravity to identify that adequate compaction was achieved along the joint.

Current acceptance criteria from the P-401 specification include mat density, air voids, Marshall stability and flow, thickness, smoothness, and grade. Additionally, the contractor is expected to maintain a quality control program covering mix design, aggregate grading, quality of materials, stockpile management, proportioning, and mixing and transportation. These items cover the basic material properties related to the development of cracking assuming that the job-mix formula has been reviewed with respect to its ability to limit crack development.

SURFACE FRICTION

Affected OPCs

Surface friction affects two of the OPCs identified: braking capability and directional control. The loss of surface friction may be the result of bleeding or polish of the surface aggregates. This surface friction is controlled by the micro-texture and macro-texture of the pavement surface. If surface friction is insufficient, the safety of operations at the airport is significantly impacted.

Current Procedures

The required maximum aggregate size and gradation will be designated to produce a higher quality surface texture to maintain skid resistance.

There are other items associated with construction and maintenance that lead to improved performance of the pavement related to braking. For example, use of surface treatments and proper maintenance of the surface grooving can both lead to improvements in skid resistance and drainage over time. Other important maintenance activities include tire rubber removal, crack sealing, and other standard maintenance practices each lead to improved performance of the pavement structure. However, these items are not directly related to the specifications associated with initial construction or re-construction of the pavement section.

There are several other items that are used over the life of the pavement to improve surface friction properties of the pavement surface. These items include:

- Grooving requirements (time = 0 and over life of pavement)
- Grade control requirements (time = 0)
- Tire-rubber and contaminant removal requirements (over life of pavement)
- Surface renewal/rejuvenation requirements

PERMANENT DEFORMATION

Permanent deformation results from issues related to pavement design, subgrade soil characteristics (swell), pavement type disparities such as where HMA abuts PCC (resulting in shoving), HMA mix properties, and HMA construction. Additionally, a pavement section that is not sufficient to meet the actual traffic demands will also result in the development of permanent deformation.

Affected OPCs

Permanent deformation is related to issues associated with braking capability and directional control. The permanent deformation impacts these two OPCs in two distinct ways. The first is due to the roughness caused by the permanent deformation itself. The permanent deformation may be exhibited on the pavement surface in the form of rutting, depressions, or shoving. Should any of these distresses become sufficiently large, they will inhibit operations of the aircraft just as any type of pavement roughness would impact the aircraft.

The other way in which permanent deformation impacts the OPCs of braking and directional control is related to the surface friction and hydroplaning. Permanent deformation will inhibit drainage of the pavement surface resulting in water retention after precipitation events. The retained water will first result in a loss of surface friction as it fills in the micro-texture of the pavement surface. As water retention builds ponding may occur resulting in hydroplaning of the aircraft (particularly at high speeds). Both the loss of surface friction and hydroplaning will impact the ability of the pilot to control the aircraft.

Current Procedures

There are multiple methods for handling these issues at present. The P-401 specification bases payment primarily on acceptance test results for mat density, thickness, and air voids. For mixes designed with the Marshall mix design method, acceptance testing is also performed to determine the stability and flow of the in-place mix. Aggregate properties are restricted by several difference characteristics such as soundness, abrasion loss, flat and elongated pieces, fractured faces, and percent of natural sand. By the specification, the contractor is required to have a quality control program in place for checking the material as it is mixed and placed to ensure that minimum levels of conformity to specifications are obtained.

In addition to the specification requirements, individual projects may address some of the pavement PCs that lead to issues with drainage and hydroplaning potential by requiring the use of rut-resistant mixes such as using polymer modified asphalt, stone-mastic asphalt or a resin-modified pavement surface. The required maximum aggregate size and gradation will be designated to produce a higher quality surface texture to maintain material strength.(*33*) Additionally, binder selection plays a critical part in developing a mix that meets the requirements of airfield pavements and use of a performance-graded binder with an upper temperature level one or two levels higher than the required high temperature for environment alone may help limit the development of material distortions that result in problems with drainage.

There are a number of performance-related tests for evaluating the permanent deformation characteristics of an HMA mix. Several of these tests are more complex to run and would not be useful in evaluating the as-placed material in production mode; although, the information they provide is quite useful in evaluating a job-mix formula. For example, the asphalt pavement analyzer (APA) encompasses a test procedure which requires more than 2 hours to test a set of samples where a set may include up to 9 samples at a time.(*34*) This procedure has been identified by a growing number of State highway agencies in evaluating job-mix formulas for roadways but is generally not used in evaluating the as-placed material. These agencies are using this “torture” test to evaluate the susceptibility of a given mix to permanent deformation. The exact methodology used differs between the various agencies.(*35*) Due to the differences in loading, tire pressures, and speed of loading between airfield and highway pavements, FAA should evaluate the appropriate test method for use in evaluating mixes for placement before this test method becomes a routine part of mix evaluation.

One of the key factors in the development of permanent deformation is related to the binder characteristics used in the HMA layer. As with the APA testing, evaluating the binder characteristics alone does not necessarily provide suitable assurance that permanent deformation will not occur. However, evaluating the characteristics of the binder to be used in the HMA layers prior to production is an important part of the quality control procedure used in construction. Further, additional evaluation of these characteristics over the course of the construction project may be needed depending upon the size of the paving job and the consistency of the supplier being used.

Complex modulus is used for evaluating the high temperature performance of the asphalt binder for highway pavements. AAPTP project 04-02 identified that the Multiple Stress Creep and Recovery (MSCR) test as a specification test for binders at high temperature.(*36*) This test involves application of a constant creep stress for 1.0 second followed by a 9.0-second recovery period. Ten loading cycles are run at each of two stress levels – 100 Pa and 3,200 Pa. While Project 04-02 identified that this test had a good relationship with high temperature performance of the asphalt mix, it also identified that much work needs to be done to incorporate this type of test in the binder specification.(*36*)

Project NCHRP 9-19 evaluated various test methods that could be used in combination with the Superpave mix design method to evaluate permanent deformation.(*37*) The objective of this portion of the research study was to identify a simple test for confirming key performance characteristics of asphalt mixes. The study identified three response parameter combinations to be used for evaluating permanent deformation. These parameters are the dynamic modulus/phase angle determined from the triaxial dynamic modulus, the flow time determined from the triaxial static creep test, and the flow number determined from the triaxial repeated load test. These tests are intended to provide an indication of the susceptibility of the mix to rutting in terms of one-dimensional densification, lateral displacement of the mix, and tertiary flow. Although the objective of NCHRP 9-19 was to identify tests that could be incorporated into the Superpave mix design procedure, these tests could also be incorporated in the Marshall mix design procedure as well.

Another test has been used in the past to evaluate the permanent deformation performance of an asphalt mix is the repeated simple shear test at constant height. The testing protocol for this test was developed as part of the Strategic Highway Research Program.(*38*) However, others have identified this test as being complicated to run with highly variable results and the equipment required is very expensive.(*39*)

One final test that has been identified for testing asphalt mixes to evaluate their susceptibility to permanent deformation is the creep compliance test. In general, this type of test has been identified as simple to run. However, the National Center for Asphalt Technology (NCAT) has identified that the relationship between these test results and the actual permanent deformation performance of the pavement is questionable.(*39*)

Note that most of the test procedures discussed in this section involve testing with expensive equipment and the tests themselves take a great deal of time and effort. Few of these are suited to the type of testing required for production-level evaluation of HMA construction.

Surface drainage characteristics may be evaluated based on pavement cross slope and local depressions using detailed profile testing. This is a complex approach based on assessment of the surface, modeling and predicting drainage. This is likely an approach that will require automated equipment and significant processing capabilities.

The current specifications review items that are expected to be related to permanent deformation. With proper enforcement, these specifications should prove to be moderately acceptable at controlling permanent deformation until further research can be performed to improve the existing specifications.

RAVELING AND WEATHERING

Affected OPCs

Raveling and weathering are related to the development of FOD potential. Raveling and weathering is defined by ASTM D5340 as the wearing away of the pavement surface due to loss of binder and resulting in dislodged aggregate particles. Any small particulate matter on the pavement surface in an area regularly traversed by aircraft provides FOD potential.

Current Procedures

The P-401 specification specifies a number of items related to the aggregate and mix characteristics. In particular, as part of material acceptance prior to construction, the specification identifies that the aggregate should be tested for soundness, wear, sand equivalency and asphalt-aggregate mixture for stripping potential. The job mix formula report is expected to incorporate the gradation, percent natural sand, percent fractured faces, and percent of flat and elongated particles. The job mix formula requirements identify limits for various aspects of the mix volumetrics and in some cases film thickness. Each of these items provides a recipe approach to limiting the development of the pavement performance characteristics that result in FOD potential.

ROUGHNESS

Affected OPCs

Roughness can be described as the deviations of the pavement surface from a true planar surface that impacts ride quality. Roughness impacts the OPCs of directional control, dynamic effects – aircraft damage, and dynamic effects – pilot control.

Current Procedures

The current FAA P-401 specification controls unacceptable levels of pavement roughness by grade control and straight edge testing. For the straight edge requirement, Section 401-5.2.b.(5) states:

> *The finished surfaces of each course of the pavement, except the finished surface of the final course, shall not vary more than ⅜ inch when evaluated with a 16-foot straightedge. The finished surface of the final course of pavement shall not vary more than ¼ inch when evaluated with a 16-foot straightedge. The lot size shall be [ ] square yards (square meters). Smoothness measurements shall be made at 50-ft intervals and as determined by the Engineer.*

The specification also allows an optional method for smoothness based on a California Profilograph and a Profile Index (PI) computed with a 0.2-inch blanking band. Full payment is identified for a PI of 7 in/mile or less, with payment adjustments permitted for non-compliance down to a rejectable quality level of 15 in/mile.

For grade control, Section 401-5.2.b(6) states:

The finished surface of the pavement shall not vary from the gradeline elevations and cross sections shown on the plans by more than ½ inch (12.70 mm). The finished grade of each lot will be determined by running levels at intervals of 50 ft (15.2 m) or less longitudinally and all breaks in grade transversely (not to exceed 50 ft) to determine the elevation of the completed pavement.

STATIC INDENTATION

Affected OPCs

Static indentation occurs under extreme loading conditions as discussed in the definitions of the OPCs. While this distress leads to additional roughness in the pavement surface, the primary OPC affected by it is the static indentation.

Current Procedures

Where static indentation is a problem, e.g., at major airports accommodating heavy, high tire pressure wheel loads, HMA is typically not used at the parking positions. Rather, "hard stand" parking positions are constructed with PCC. Other materials, such as surfaces constructed with concrete block, stone matrix asphalt (SMA), or resin modified materials, have potential for use, but, by far, the overwhelming choice for hard stand surfacing material at major airports in the U.S. is PCC. However, many General Aviation or smaller regional airports may utilize flexible pavement for apron parking. Therefore, while static indentation problems can occur at any airport, the problem is typically confined to smaller General Aviation and regional airports with HMA apron pavements.

SUMMARY

The distresses of primary interest for controlling the aircraft OPCs previously identified include cracking, surface friction, permanent deformation, raveling and weathering, roughness, and static indentation. The P-401 specification addresses some component of the HMA mix which is affected by each of these distresses. However, the specification primarily addresses the control of the mixture in the form of a recipe-based specification.

The in-service pavement performance will be a result of material (HMA) properties and the effects of subgrade and base strength and volume stability (resistance to swell). Temperature and moisture conditions vary seasonally and temporally; therefore, the effects on pavement stress state must be included in the modeling of performance indicators.

CHAPTER 6

MODELING OF PAVEMENT PERFORMANCE CHARACTERISTICS

INTRODUCTION

The current P-401 specification provides a means for controlling most of the pavement performance characteristics identified in the previous chapter. However, all of the AQCs identified in the P-401 specification are empirically related to these AQCs. In order to advance the specification towards a performance-based version, it is necessary to identify AQCs that are mechanistically related to the PCs. This chapter is concerned with identifying potential models to be used in identifying and developing the PBS.

CRACKING

Cracking develops in response to stresses applied to the HMA mix. However, these stresses are not dependent only on the mix, but also on the traffic loads and thermal cycling, as well as the pavement structure as a whole. Poor subgrade support, inadequate thickness of base, movement of an underlying PCC slab, increased loading, inadequate drainage and softening of the subgrade, for example, all can lead to an increase in the stresses applied to the HMA layer and cause cracking. These factors should all be addressed in the design of the pavement structure.

The binder properties will also influence the occurrence of cracking in the HMA material. At lower temperatures the mix will shrink resulting in the build-up of tensile stresses which results in thermal cracking that generally appear as either longitudinal or transverse cracks. This type of cracking will be most likely to occur when the asphalt binder does not meet the strength requirements at the low temperatures that are expected to occur at the paved site. Additionally, the asphalt binder will become brittle over time making the material more prone to cracking.

Segregation can also lead to increased cracking of the HMA material. Segregation occurs with improper construction techniques and leads to areas of weakness within the HMA material. These areas may be expected to break up and exhibit cracking more quickly than a non-segregated mix.

A more common construction related distress is cracking along the construction joint. This type of cracking is frequently related to issues with bonding of the adjacent mat due to inadequate compaction along the edges of the paving lane.

Predictive Model

The appropriate model for use in forecasting traffic will depend upon the type of cracking the user wishes to forecast. The FAARFIELD software program developed by FAA already incorporates a predictive model for fatigue cracking. The software does not enforce the use of the model but provides it as an alternative for review. The model is not enforced as part of the pavement design process because the rutting model nearly always provides the limiting constraint for design. This fatigue cracking model may require some refinement to improve its ability to forecast fatigue cracking.

A second cracking model is required for forecasting thermal cracking. This type of model has not been developed specifically for HMA pavements on airfields; however, the MEPDG does incorporate a thermal cracking model.(*7*) This model is reliant on the material properties and should be relevant for use with airfield pavement structures. Calibration may be necessary as the boundary conditions of an airfield pavement are significantly different from those on highway pavements. In other words, the geometric configuration of airfield pavements is vastly different from highway pavements and may influence the development of thermal cracking.

A third model may be considered for predicting the amount of cracking at each level of severity. The development of FOD potential occurs as cracking develops from low severity to moderate or high severity levels. Generally, as-constructed pavements meeting the assumed design values for subgrade support, layer thicknesses and layer densities would be expected to perform approximately as the PAVER deterioration model as shown in Figure 6.(*40*) That is, distress propagation will commence almost immediately but at a very slow rate. This rate will increase gradually over the service life and as a consequence predictions for distress conditions may be made with some degree of confidence.

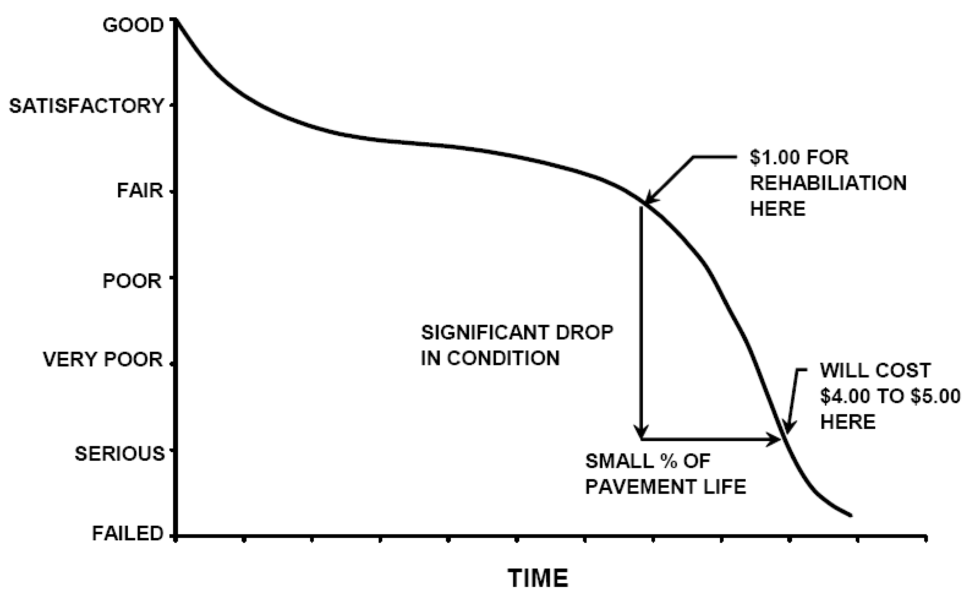

Figure 6. Pavement Performance Life Cycle

Since pavement derived FOD is primarily a function of distresses that link to overall pavement condition, the PAVER Pavement Condition Index (PCI) concept may be useful in predicting FOD potential. A more specific FOD Index was developed from the PAVER set of distresses to directly address this operationally critical parameter.

In addition to the cracking models identified above, a fourth model to forecast joint reflective cracking is required. Reflection cracking is one of the primary distresses observed in HMA materials placed on portland cement concrete. A model is currently being developed for highway pavements under NCHRP project 01-41. The results of this study should be examined for potential use on airport pavement when it is completed.

SURFACE FRICTION

Aggregate that is prone to polish or wear may result in the loss of macrotexture of the pavement and subsequently loss of friction.

Predictive Model

There are no known models related to forecasting friction on a pavement surface. Additionally, the development of such a model is likely to be quite complex. Friction is not only related to the breakdown of the surface texture but also to the development of other distresses which may cause the pavement to retain water. Any model used to forecast friction must address both types of friction. Also, surface friction can increase over time, but this may be an undesirable result of other forms of pavement distress, e.g., weathering/raveling.

PERMANENT DEFORMATION

Permanent deformation results from issues related to pavement design, subgrade soil characteristics (swell), pavement type disparities such as where HMA abuts portland cement concrete (resulting in shoving), HMA mix properties, and HMA construction. Additionally, a pavement section that is too thin to meet the actual traffic demands will also result in the development of permanent deformation.

However, permanent deformation resulting from issues associated with the HMA mix properties; as well as layer compaction, is of primary concern for this project. For instance, an improper aggregate gradation or aggregate of an improper shape may result in the development of permanent deformation in the pavement surface and subsequently surface distortion such as rutting and shoving. Both the Marshall and the Superpave mix design method are, in part, based on the use of volumetrics to appropriately proportion the material components. A mix with too much asphalt or too many voids may result in compaction and shoving of the material. An inappropriate binder selection may result in a mix that is prone to permanent deformation.

Improper mix delivery, such as when the trucks delivering material from the mix plant bump the paver, can result in segregation in the asphalt mix and segregation can lead to surface distortions including rutting and shoving. Other construction irregularities may be caused by the roller resulting in an uneven pavement surface or poor rolling practices that lead to insufficient density in the mix. Poor control on the density may also result in surface distortions. Poor compaction of the HMA lift(s) will also result in permanent deformation similar to that resulting from poor mix design characteristics. Both mix and construction related deficiencies can be prevented and controlled with good construction quality control processes.

Predictive Model

The FAA design procedure as implemented in the FAARFIELD pavement design software incorporates the use of a model to evaluate permanent deformation. However, this structural design model is based primarily on the computed strain at the top of the subgrade. Although the model does include a fatigue component based on horizontal asphalt strain, it does not directly incorporate any deformation experienced by the HMA material. As the purpose of this study is to develop a specification that targets the performance of the HMA material, this model will not suffice for use with a performance-related specification.

The FAA design procedure primary failure criterion is shear failure in the subgrade sufficiently large enough to result in 1 inch of upheaval in the pavement surface. For the purposes of designing airfield pavements, this approach works quite well resulting in flexible pavement surfaces that rarely develop structural failure – failure, when experienced, more commonly occurs as a result of durability. However, the objective of this portion of this study is to identify a permanent deformation model that is sufficiently accurate for the prediction of permanent deformation in the asphalt layer so that it may be used in allocating monies to construction contractors. As such, the FAA's structural model does not meet this need.

Because permanent deformation may occur as a result of either a materials-related problem or a structural issue, it is important that the model used in the PRS be capable of accurately predicting the permanent deformation resulting from issues related to both the materials and the as-placed pavement structure.

Secondly, from a design perspective, the permanent deformation model use in the FAA design procedure works very well because 1 inch of permanent deformation is rarely observed on an airfield pavement. The model used in a PRS must be sufficiently accurate in its ability to predict permanent deformation that it is defensible in a court of law given that it will be used to allocate bonuses and penalties applied to a contract fee. Because the model used in the design procedure does not incorporate the HMA materials component, it cannot be used for this purpose. Therefore, while the FAA design procedure model for permanent deformation is quite appropriate for use in successfully designing airfield pavement structures, it does not contain an asphalt materials component suitable for use in a PRS.

RAVELING AND WEATHERING

Raveling on flexible pavements can be caused by both mix and construction related deficiencies. Mix-related causes include such items as inadequate film thickness, poor volumetrics and improper gradations. A tender mix will also result in a less durable surface.

It is also important to achieve proper compaction at paving joints to prevent raveling in these areas. Poor construction practices may also result in mix segregation which in turn results in areas of pavement with excessive asphalt cement and areas with excessive air voids and is then exhibited as raveling of the pavement surface. Another construction-related cause is related to poor bonding of the HMA layers which may result in debonding and break-up of the HMA surface.

Other causes relate to the operating environment of the final pavement. Oil spillage will result in break-down of the asphalt cement and cause a loss of integrity of the HMA mix creating loose material. Jet blast causes burned spots of pavement material and will result in break-down of the surface materials. Finally, distress is expected on an aging HMA surface and inadequate maintenance may hasten the breakup of the pavement materials.

Predictive Model

No models are known which can be used to forecast raveling of HMA materials. The development of this type of model could be quite complex as with friction. Highway researchers have not considered raveling and weathering in distress modeling efforts as the cost of developing these models is expected to reap very little benefit. The same may not be true for airfield pavements where raveling presents FOD potential.

ROUGHNESS

Pavement roughness on flexible pavements can be caused by both mix and construction related deficiencies. Common causes include the following:

- Construction Related Causes:
  - Poor equipment (e.g., paver, roller, mill)
  - Poor grade control
  - Poor compaction
  - Poorly constructed patches
  - Improper temporary ramps constructed during off-peak construction projects (re: FAA AC 150/5370-13)
  - Improper permanent transitions at interfaces to abutting facilities
- Mix Related Causes:
  - Rutting due to mix problems
  - Shoving/corrugation due to mix problems
- Other:
  - Potholes

- o Faulty design

Of these, the construction related defects that cause single event or profile roughness would be most applicable to PBS. Mix related causes may best be handled by other pavement PCs, such as permanent deformation.

Potholes and design deficiencies, of course, are causes beyond a contractor's control, and as such, should not be included in a PBS.

Predictive Model

The BBI and vertical acceleration simulations can most likely be used for performance-based or performance-related measures that encompass single event and profile roughness on airport pavements as they impact aircraft damage. Limiting criteria will be needed for each measure for new construction. Since the pavement is expected to deteriorate over time, the criteria for new construction should be significantly less than the "unacceptable" criteria, albeit within industry capability to construct. Although a predictive deterioration model for deterioration of the profile with loading and environment and consequent effect on aircraft damage would be desirable, there are no known models in existence for the BBI.

The highway industry has developed a model for predicting the IRI on highway pavements as part of the MEPDG.(*7*) The limitation with this model is that it is not known if the IRI accurately reflects the roughness on airfield pavements as that roughness relates to pilot control or aircraft damage. However, the approach taken in predicting roughness on highway pavements may be useful in developing a predictive model.

The model uses the fact that the roughness present on the pavement surface is due directly to the presence of various distresses along with the influence of various environmental factors such as freeze-thaw cycling and precipitation. Therefore, to predict roughness over time, it is necessary to predict the occurrence of other distresses over time and the roughness at a particular point in time is a function of the predicted distress at that time. This approach for predicting pavement roughness should be considered in developing a model for airfield pavements.

STATIC INDENTATION

Static indentation on flexible pavements can be caused by both mix and construction related deficiencies. Common causes include the following:

- Construction Related Causes:
  - Poor compaction
- Mix Related Causes:
  - Tender mix
  - Poor gradations (e.g., over-sanded, or excessively gap-graded)
  - Poor volumetrics (e.g., low air voids)
  - Improper binder selection (e.g., binder too soft for climate)

Predictive Model

A predictive model addressing static load carrying capability does not currently exist. However, since static indentation is a secondary OPC that is a problem primarily at smaller airports, it is probable that performance tests and predictive models for rutting and plastic deformation would also encompass static indentation. That is, if the mix meets the performance criteria for rutting, it may also provide adequate protection against static indentation, at least for smaller airports.

SUMMARY

Predictive models are available for both permanent deformation and fatigue cracking. However, based on prior experience with these models, they require review and re-calibration to provide more accurate estimates of distress on the asphalt pavement surface. Models have been developed for highway pavements for thermal cracking and roughness. These models are not directly applicable to airfield pavements, but provide a starting point for development of these types of models for airfield pavements. Models do not currently exist for raveling and weathering and surface friction. In order to incorporate performance related to these types of distresses into a PBS, models will need to be developed.

CHAPTER 7

ACCEPTANCE QUALITY CHARACTERISTICS

INTRODUCTION

Identifying the predictive models to be used with each pavement PC identifies the appropriate AQCs to be measured as part of a PRS or PBS. As identified in the previous chapter, very few of the PPCs have existing predictive models that are relevant for airfield pavements; however, using the models developed for highway pavements and evaluating potential causes of each PPC can lead to the identification of appropriate AQCs to consider. Ultimately to establish appropriate levels for the specification without a predictive model may prove difficult.

This chapter considers each of the AQCs and identifies appropriate test methods to be used in evaluating these AQCs.

FRICTION

Friction has been identified as one of the PCs and is directly related to braking capability and directional control OPCs. Identifying the initial friction of the finished pavement surface should provide an indication of the potential for deterioration of the surface friction.

Test Methods

Several methods are available for evaluating pavement friction. One approach is using CFME which is based on ASTM E1551-08 “Standard Specification for Special Purpose, Smooth-Tread Tire, Operating on Fixed Brake Slip Continuous Friction Measuring Equipment.” Skid testing is governed by ASTM E274-06 “Standard Test Method for Skid Resistance of Paved

Surfaces Using a Full-Scale Tire." These systems both perform testing as the system moves down the pavement and allow for more surface area to be measured in less time.

Another approach to friction evaluation is using a dynamic friction tester as described in ASTM E1911-09ae1 "Standard Test Method for Measuring Paved Surface Frictional Properties Using the Dynamic Friction Tester." Unlike the previously mentioned methods, this system measures a single location on the pavement surface and must be physically moved for measurements at other locations.

Analysis

Once the data have been collected, it is important to reduce the data into meaningful information that can be used to make decisions. The skid number resulting from skid testing or the CFME data can be used to develop the International Runway Friction Index. Both of these test procedures are speed dependent and a change in speed will provide a different result. The International Runway Friction Index is defined in ASTM E2100-04 "Standard Practice for Calculating the International Runway Friction Index." This standard provides a consistent means for evaluating data from different devices.

Another option for evaluating skid is through the use of the International Friction Index. The International Friction Index is defined in ASTM E1960-07 "Standard Practice for Calculating International Friction Index of a Pavement Surface" and is based on the coefficient of friction as measured at different speeds using the dynamic friction tester.

MACROTEXTURE

The macrotexture directly influences the friction of the pavement surface. Subsequently, this AQC will affect the OPCs of directional control and braking capability.

Test Methods

There are several potential methods for measuring the macrotexture. The NASA Grease Smear and sand patch test methods involve using a known volume of some substance and filling in the voids. A measurement is taken of the surface area covered by the substance which is then used to determine the mean texture depth.

The circular texture meter has been developed to provide the mean profile depth which is highly correlated to the mean texture depth. Additionally, the testing device has been developed to operate over the same path as the dynamic friction tester such that these two measurements together can be used to provide a more complete picture of the friction characteristics of a pavement area. The test method associated with the circular texture meter is ASTM E2157-01(2005) “Standard Test Method for Measuring Pavement Macrotexture Properties Using the Circular Track Meter.”

DENSITY

Density provides a measurement of compaction and subsequently durability of the completed pavement section.

Test Methods

The nuclear gauge is commonly used to evaluate the density of the completed surface. The nuclear gauge can be manipulated to provide different results as part of the testing process indicating that the device is not always repeatable. The correlations between the nuclear gauge results and density obtained from cores are less than excellent. Further, cores must be taken from each mix placed to develop appropriate correlations between the measured density and the nuclear gauge measurements. One of the reported benefits of the nuclear gauge is that it reduces the need for destructive evaluation; however, it should be remembered that coring is necessary in order to obtain accurate results from the nuclear gauge.

There are other gauges that operate in a similar manner without the difficulty encountered when dealing with a radioactive substance. As an example, the Pavement Quality Indicator (PQI) uses non-radioactive materials to perform the same testing as a nuclear density gauge. However, the other issues that exist for a nuclear gauge are also common to these gauges. The gauges can be manipulated as part of the testing process and do not provide data as reliable as coring.

Determining density from a core provides the most precise and accurate measure possible, even though coring requires a destructive evaluation of the newly constructed asphalt layers. The amount of destructive evaluation can be limited using an optimized evaluation plan.

It should be noted that the P-401 specification requires acceptance testing to be performed on cores of the asphalt mixture. On the other hand, it identifies that quality control monitoring performed by the contractor may be accomplished using a nuclear density gauge. The contractor must accept the risk that the density gauge may not provide the same results obtained from a core when evaluating the data obtained from the gauge.

Analysis

Once the decision has been made, it is important to identify how density will be represented – percent of maximum theoretical or percent of Marshall. Evaluating the density based on the percent of the Marshall mix design density can lead to inconclusive results regarding the quality of the pavement. As part of the mix design process, pavement engineers have established required levels of density. Therefore, in trying to evaluate pavement quality, reviewing the AQCs based on the actual value rather than a percentage of that actual value can lead to an overall improvement in understanding of where issues may exist with the as-constructed quality of the asphalt mix.

The other benefit of using cores for evaluating density is that it provides opportunity to evaluate all of the mix volumetrics of the in-place material including the voids in mineral aggregate (VMA), voids filled with asphalt (VFA), asphalt content, and other characteristics. Each of these parameters will affect the durability of the asphalt mixture and should be considered in a PRS.

AGGREGATE PROPERTIES

There are a variety of aggregate properties that may be used to evaluate the aggregate as part of a PRS. Most of these properties are related to the friction and permanent deformation properties of the constructed mix. These properties include such items as particle shape soundness, gradation, angularity, percentage of fractured faces, and sand equivalency.

Test Methods

Table 13 identifies the appropriate methods for determining each of these parameters. Some of these parameters are better suited for use in construction acceptance than others. The assumption has long been held that once an aggregate stockpile has been approved for use in a particular mix design then all of the aggregate in that stockpile meet the standards set forth as part of the mix design. Therefore, the primary property that is tested as part of construction quality control is gradation.

Table 13. List of Aggregate Test Methods

Parameter	Test Method
Soundness	ASTM C131-06 "Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine" and ASTM C88-05 "Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate"
Gradation	ASTM C117 "Standard Test Method for Materials Finer than 75-µm (No. 200) Sieve in Mineral Aggregate by Washing," ASTM C136-06 "Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates" and ASTM D5444-08 "Standard Test Method for Mechanical Size Analysis of Extracted Aggregate"
Fine Aggregate Angularity	ASTM C1252-06 "Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading)

Fractured Faces	ASTM D5821(2006) "Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate"
Sand Equivalency	ASTM D2419-02 "Standard Test Method for Sand Equivalent Value of Soils and Fine Aggregate"
Particle Shape	ASTM D4791-05e1 "Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate"

SMOOTHNESS

Smoothness is one of the pavement performance characteristics identified in the prior chapters. Smoothness is directly related to the OPCs of dynamic effects – pilot control and dynamic effects – aircraft damage. Smoothness is indirectly related to the OPC of directional control.

Similar to friction, smoothness can be evaluated as part of the construction acceptance process.

Measurement

There are several methods for evaluating the pavement smoothness that may be considered. First, grade control is part of the current P-401 specification. The specification requires the grade be checked by "running levels at intervals of 50 feet." Performing an elevation survey can provide the information required for evaluating the grade, but the data required to evaluate pavement smoothness is generally much more detailed than can be reasonable collected using typical survey equipment.

However, in recent years, laser scanners have been developed which provide a means for collecting much more data on a much quicker basis. These devices collect elevation data and may be used to evaluate up to 4000 ft of pavement in an 8-hour day.(*41*) In other words, these devices collect the data at a much faster pace than other types of standard survey equipment. However, the accuracy of the elevation data are not sufficient for roughness evaluation with a reported accuracy on the order of 0.25 inch over 333 ft.(*42*) ASTM E950-98(2004) "Standard Test Method for Measuring the Longitudinal Profile of Traveled Surfaces with an Accelerometer Established Inertial Profiling Reference" identifies that this level of accuracy is insufficient for collection of longitudinal profile data for the purpose of evaluating pavement roughness.

Another approach to evaluation of the pavement smoothness at the completion of construction is using a straightedge. P-401 calls for evaluation of pavement smoothness using a 16-ft straightedge requiring that no deviations greater than 0.25 inch exist in the final surface. However, this approach to evaluation is cumbersome and slow. Further, this approach can miss some of the roughness features which have a negative impact on operations on the airfield.

Operating on a similar principal, the profilograph provides another option for evaluating pavement smoothness. The profilograph is identified as an option for evaluating pavement smoothness in P-401. Similar to the straightedge method, this approach to smoothness evaluation is cumbersome and slow. Additionally, the profilograph can distort the measurements by attenuating some wavelengths of roughness and amplifying others. The appropriate test method for use with the profilograph is ASTM E1274-03(2008) "Standard Test Method for Measuring Pavement Roughness Using a Profilograph."

Inertial profilers are capable of collecting true profile over a range of wavelengths from approximately 2 ft to 300 ft. There are a couple of concerns with these devices. First, although they have been shown to collect true profile within the range of wavelengths identified, they do not do a good job of collecting true profile for wavelengths longer than 300 ft. Further, no study has been completed to identify that the cutoff wavelength of 300 ft is sufficiently long for consideration on airfield pavements.

The second concern is related to the operational aspects of the inertial profilers. These devices require some distance of pavement prior to the area to be evaluated. This lead-in distance is required for bringing the device up to operational speed and to initialize the data collection filters. Evaluation of the end of the airfield pavement is difficult given the need for the lead-in distance. The FAA has developed a means for removing the error in the accelerometer signal that occurs in the lead-in portion of the profile data collection. Reducing this error makes these devices a more viable option for profile data collection on airfields.

One last group of devices that may be used for obtaining longitudinal profile data has been defined as reference devices such as the SurPRO. References devices are used in highway operations to evaluate and/or certify inertial profilers. These devices often run at much slower speeds than inertial profilers, but are capable of collecting detailed longitudinal profile data with great precision. In some cases, the devices may be used to collect true elevation while other devices collect relative changes in elevation. Additionally, several new reference devices are under development under the Federal Highway Administration profile pooled fund study TPF-5(063). While these devices operate at slower speeds than inertial profilers, they may be of sufficient speed for data collection on the shorter projects generally encountered on airfield pavements.

Analysis

Data collected using an inertial profiler or a reference device may be used to evaluate roughness using a variety of methods. These data allow the analyst to review the pavement roughness as it pertains to short wavelength content, long wavelength content, or some combination. They also allow the analyst to identify specific roughness events that may be repaired. This section identifies some of the methodologies that may be used in evaluating roughness data.

A straightedge simulation may be used to evaluate the roughness. This analysis will identify deviations greater than a specified height based on a reference line established by the endpoints of the straightedge. This analysis combines the speedier data collection with a simplistic model for evaluating the data. In addition, the analyst may evaluate the pavement roughness using straightedges of varying lengths. The straightedge simulation is subject to the same problems as the actual straightedge measurements. This analysis will attenuate wavelengths that are half the length of the straightedge and amplify wavelengths equal to the length of the straightedge. In other words, it is necessary to conduct this analysis using straightedges of varying lengths to consider the impact of the wavelengths of roughness that may be important to the aircraft operational concerns.

Another approach for reviewing these data is to simulate a profilograph on the profile. However, like the straightedge, the profilograph will attenuate some wavelengths and amplify others without proper consideration of which wavelengths most impact the operational concerns of the aircraft.

The IRI has been used for evaluation of roadways in terms of both construction acceptance and pavement management for a number of years. The IRI has been shown to provide a value that is well correlated to user opinions of roadway smoothness. However, it has been established that the operational characteristics of roadways and airfields are quite different. Therefore, the IRI cannot be expected to provide a good indication of user satisfaction on airfield pavements nor can it be expected to provide any indication of potential aircraft fatigue due to pavement roughness. Therefore, while the idea behind the IRI may be relevant, the IRI itself is not a practical approach for use in evaluating roughness on airfield pavements.

Profile roughness can be defined as surface profile deviations which cause airplanes to respond in a manner that may increase fatigue on aircraft components. The response of an aircraft to profile deviations is dependent upon aircraft type, size, weight, and operational speed. Roughness may or may not cause discomfort to passengers or affect pilot control, but may still affect the fatigue life of airplane components. Boeing has reported that short wavelength roughness (~ 2 to 7 meters) at certain speeds can cause resonance in 2D and 3D truck beams resulting in overstress and fatigue failure. Likewise, depending upon airplane characteristics and operating speed, an airplane can also be excited into harmonic resonance due to long wavelength profile roughness, with consequent damage to various components of the airframe and/or landing gear.

The Boeing Bump Method discussed in Reference 18 is based on the effect of a single event (bump, or other discontinuity) on aircraft landing gear. The basis of the Boeing Bump method is to construct a virtual straightedge between two points on the elevation profile and measure the deviation from the straightedge to the pavement surface. The procedure reports “bump height” as the maximum deviation (positive or negative) from the straightedge to the pavement surface. The longest distance from either end of the straightedge to the location where the bump event is measured is known as the bump length. The procedure plots bump height and bump length against the acceptance criteria shown in Figure 7 as originally developed by the Boeing Aircraft Company. The accuracy of the Boeing Bump procedure, or its ability to represent field conditions, increases as the survey interval decreases. Because the accuracy of the procedure changes if the survey interval changes, the FAA requires a survey interval of 0.25 meters (0.82 feet) for evaluation of the Boeing Bump.

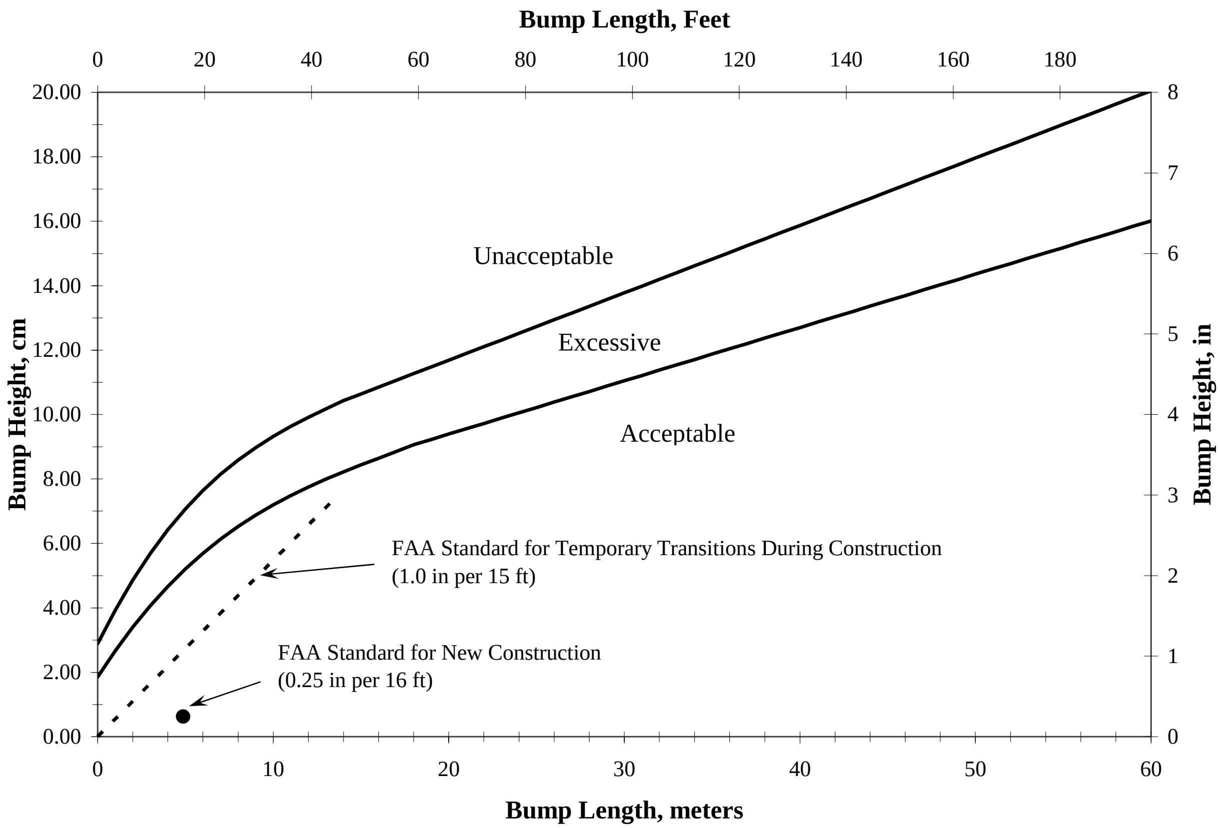

Figure 7. Single Event Bump – Roughness Acceptance Criteria

While the BBI is a useful index, it only addresses one component of the airplane, (the landing gear) based on a single event. Both short wavelength and long wavelength roughness can also affect other components of the airframe. Therefore, another measure(s) will be necessary to address damage to other parts of the airframe. As discussed, this can be extremely complex process dependent upon analysis of the effects of roughness at different locations on the airframe for different aircraft operating at different speeds for the same profile. Therefore, for practical application, simplifying assumptions will be necessary.

The BBI has been shown to provide an evaluation of unacceptable single event roughness as it relates to the airframe. There is still one important aspect of roughness to consider – pilot control. Researchers have identified a means to simulate the forces felt at the center of gravity of the aircraft and in the cockpit as a result of the pavement roughness. Studies have shown that the forces felt in the cockpit are more sensitive to pavement roughness than those felt at the center of gravity. The one drawback to this sort of evaluation is that different aircraft are expected to have different responses to various wavelengths of roughness. Therefore, it may be necessary to simulate more than one aircraft to complete an evaluation of the pavement smoothness for construction.

PERFORMANCE TEST

Mechanistic-empirical pavement design criteria have shown the need to incorporate a performance-related test in order to develop realistic estimates of pavement distress. In other words, these quality characteristics are more directly related to pavement performance. There are a variety of test procedures available for this type of evaluation.

One set of potential performance-related tests include torture tests. These tests subject the material to extensive loading under harsh environmental conditions to evaluate performance. One specific example of a torture test is the asphalt pavement analyzer. This test subjects the mix to repeated loading to evaluate its susceptibility to rutting. This test was mentioned previously in Chapter 5. This test may take up to 2 hours to complete and as such, is not suitable for use as part of a construction acceptance process.

Other performance related tests involve evaluation of the modulus of the mix. For example the shear modulus of the mix can be obtained using ASTM D7312-07 "Standard Test Method for Determining the Permanent Shear Strain and Complex Shear Modulus of Asphalt Mixtures Using the Superpave Shear Tester (SST)." Other tests evaluate the complex modulus or the dynamic modulus and the phase angle. These tests are quite sensitive and require great precision in running.

Other tests include MSCR; flow time through triaxial static creep; flow number through triaxial repeated load; repeated simple shear at constant height; or creep compliance. As with the other tests, these types of tests may be quite lengthy and require great precision in running.

In general, these tests are not suitable for use with construction acceptance. As noted previously, by necessity, tests associated with construction acceptance are simple to run and provide quick results. The current specification uses the Marshall stability and flow values to provide an estimate of the mix stiffness and subsequently expected performance. This type of testing meets the requirements for construction acceptance and/or quality control. However, these values are limited in their ability to actually identify the expected performance of the in-place mix.(*43*)

MIX VOLUMETRICS

A more realistic approach to evaluating performance of the in-place pavement structure is to evaluate the HMA volumetrics. The volumetrics include determining the asphalt content, VMA, and VFA.

Test Methods

A volumetric analysis using the information gathered as part of the density testing and performing an extraction of the asphalt cement using ASTM D2172-05 "Standard Test Methods for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures" can provide a more complete picture of the mixture properties. Just evaluating the mix volumetrics as part of construction quality control assumes that the structural and mixture design meets the performance requirements of the traffic using the pavement.

SUMMARY

Testing can be performed to ascertain many different types of attributes of the as-placed asphalt mixture. However, in order for the testing to be suitable for construction quality control, those tests must be precise, quick, and simple to perform. Additionally, the parameter being evaluated needs to be directly related to the performance of the as-constructed mix. There are very few tests which meet all of these required characteristics. In some cases, it may be necessary to rely on tests that do not necessarily identify the performance of the mix but rather can be used to estimate the performance of the mix such as with the case of determining the mixture volumetrics.

CHAPTER 8

RECOMMENDATIONS FOR FUTURE RESEARCH

Although the amount of research performed in the area of PRS and PBS is limited for airfield pavements, interviews and literature reviews caused the team to adopt the following tenets as a basis for further development in the area of PRS/PBS.

Typical aircraft OPCs that can be considered related to HMA mix properties include:

- Aircraft braking capability
- Aircraft directional control (skid resistance, plastic deformation)
- Foreign object damage (climatic effects, fatigue behavior, joint construction)
- Aircraft vibration and dynamic response of the aircraft (plastic deformation, grade control)
- Static load carrying capability
- Traffic flow disruptions

Pavement distresses or undesirable characteristics that may impact these OPCs include:

- Cracking (linear, block, reflection, etc.)
- Surface Friction
- Permanent Deformation
- Raveling and Weathering
- Bleeding
- Roughness
- Static Indentation

Current HMA mixture acceptance criteria that can be considered as performance-related include:

- Air voids
- Marshall stability and flow
- Mat density
- Joint density

Current pavement acceptance criteria that can be considered as performance-related include:

- Thickness
- Smoothness
- Grade

Additional potential AQCs have been identified for both the pavement structure and the asphalt mixture. Relationships between the acceptance criteria (including both the criteria being used and the suggested additional criteria) and the pavement PCs would lead to the development of a PRS. As identified in Chapter 1, a PRS uses typical AQC and empirical relationships between these characteristics and the pavement PCs to establish appropriate pay factors for the as-constructed pavement. In order to fully develop a PBS it will be necessary to develop relationships between FEPs of the HMA to the pavement PCs.

In the previous chapters, a list of research needs was developed which identifies efforts that need to be completed to meet the objective of developing a PBS. These research needs have been used to develop a series of eight research needs statements which are provided in Appendix D. The topics of each of the eight statements are listed below:

- Development of long-term performance database for airfield pavement data

- Study of roughness on airfield pavements
- Development and/or refinement of models to estimate cracking including fatigue, thermal, and joint reflection
- Refinement of permanent deformation model to estimate contribution of each layer in the pavement structure
- Simple performance test to evaluate as-constructed mix as part of construction acceptance
- Development of model for forecasting cracking severity to estimate FOD potential
- Development of model to estimate friction deterioration
- Development of modeling for raveling and weathering

The first item in the list is the development of a pavement performance database for airfield pavements. The work following this first item is fairly comprehensive and will require significant volumes of data to complete. The airports that would participate in this type of data collection effort maintain pavement management systems (PMS) and the data in these systems can be used in part for these research efforts. These systems provide a good location to identify construction history and traffic information on the airport pavements. The pavement performance information collected for pavement management purposes is not generally representative of the detailed information that would be required for these types of research efforts. Further, reliance on current condition reporting would be a first step but significant data are needed relative to HMA characteristics, as-built pavement structures, climate and traffic conditions that are not currently available.

Validation of extensions to the FAA's structural models can be accomplished under accelerated controlled conditions at the FAA's Technical Center, coupled with establishment of instrumented pavements at select airports. The airport PMS databases could also be expanded by establishing performance monitoring locations, either in conjunction with or in addition to the instrumented pavement sites.

The efforts required to collect the type of data that should be used in these projects will require a well designed and managed research initiative. This would include detailed data for materials, construction, traffic, environment, and in-service performance measurements. In essence, a long term aviation pavement performance program would incorporate FAA research efforts, detailed data collection, storage and availability to researchers and performance monitoring potentially extending over the thousands of airfields eligible for Airport Improvement Program (AIP) funding.

The remainder of the list identifies models and test procedures required to complete a performance-based specification for airfield pavements. These statements include developing enhanced models for cracking and permanent deformation. Enhanced cracking models for FAARFIELD based on the MEPDG and extended (validated and calibrated) to aviation would improve structural design reliability (and by definition reduce the rate of distress propagation). Similarly, enhanced permanent deformation models based on the MEPDG models extended to airport pavements would also improve structural design reliability and improve performance related to braking capability, directional control, and dynamic effects.

A better understanding of the relationship between pilot control, aircraft dynamics, and airfield pavement roughness are required to develop a PBS related to roughness. The first step in developing a more complete model to establish the fundamental engineering properties related to dynamic effects is to identify the wavelengths of roughness that are most related to aircraft effects and pilot control. Once these wavelengths are identified, the appropriate criteria for evaluating pavement smoothness can be selected along with limits for construction acceptance. Finally, a model can be developed to estimate the development of roughness over time for use in a PBS.

The development of a performance-related test to evaluate the as-constructed mix would provide a better indication of expected performance than using models that rely on such items as mix volumetrics. Tests which result in improved ability to identify a material that is susceptible to permanent deformation will also result in a test that is susceptible to static indentation. However, the mechanisms are not identical as permanent deformation is closely related to shear stresses/strains in the HMA material and static indentation is primarily related to compressive stresses/strains.

The last three statements provide for model development related to raveling and weathering, loss of friction and FOD potential. Very little work has been performed in this area, possibly because the return on investment is expected to be minor, particularly for highway pavements. However, raveling is closely related to the development of FOD potential on airfield pavements and such a model could be a key factor in controlling FOD. A model for FOD potential will require forecasting the development and progression of distress severity levels.

CHAPTER 9

RECOMMENDED CHANGES TO EXISTING SPECIFICATION

INTRODUCTION

The work completed for this project has identified that there is still much research required in order to develop a PBS. However, it also illustrates that there are some immediate improvements that can be made to the existing P-401 specification which improve its relationship with expected HMA performance.

RECOMMENDATIONS

Four revisions to the P-401 specification have been identified. These are as follows:

- Measurement of initial friction
- Measurement of initial macrotexture
- Method of measuring smoothness
- Measurement of mix volumetrics – air voids, VMA, VFA, and asphalt content

These revisions in and of themselves do not suddenly transform the P-401 specification into a PBS, but they provide a first step in that direction. These revisions are discussed in more detail below.

Measurement of Initial Friction

Initial friction should be added to the contractor's quality control plan and these data maintained by the airport as part of their pavement management program. The various pavement characteristics that contribute to loss of friction are not known; however, initial friction is almost certainly one of the key parameters in estimating future values of friction. Hence initial friction is important to the future performance of the pavement surface.

A model used to estimate loss of friction would almost certainly be developed at a national level meaning that the model could be applied to any airport in the nation. These national models provide the appropriate model structure, but the calibration of these models may lead to more error than desired for use at a local level. Developing a database of information over time which includes the data elements contained in the model provides the information necessary to calibrate models for a particular location or agency.

Most importantly, friction is key to runway safety and making sure that the initial level of friction meets minimal standards. FAA AC 150/5320-12C provides recommended levels of friction for new runway pavement surfaces at the different test speeds and based on different devices. These values range from 0.69 to 0.82 for testing at 40 mph and from 0.63 to 0.74 for testing at 60 mph. As suggested in the advisory circular, testing of new pavement surfaces should be performed based on a 500-ft lot basis.

Measurement of Initial Macrotexture

As with the measurement of initial values of friction, initial values of macrotexture provide a key indication of the performance of the pavement surface with respect to friction. Macrotexture provides a good indication of the surface drainage characteristics of the pavement, is related to friction, and subsequently provides an indication of the performance of the pavement with respect to the OPCs of directional control and braking capability.

FAA AC 150/5320-12C recommends a minimum texture depth on new pavements of 0.045 in. The advisory circular identifies that measurement of the texture depth is not required unless the minimum levels of friction are not met. Given that measurement of friction is not required on new pavements, it is unlikely that the texture depth is measured.

Measurement of texture depth should be completed as part of the contractor's quality control testing process. Measurement should be completed prior to grooving of new pavement. A minimum of three tests should be conducted per construction lot.

Method of Measuring Smoothness

The current P-401 specification requires smoothness to be measured with a 16-ft straightedge. The specification identifies that a California profilograph is an acceptable approach in some cases. As noted in prior chapters of this report, these methods may not accurately measure some roughness features that are important to aircraft dynamics and pilot control.

It is recommended that the P-401 specification be revised to require construction acceptance evaluation of pavement smoothness with either an inertial profiler or with a reference-type profile collection device that allows for collection of true elevation. Until further research can be completed to identify the appropriate indices to be used with these data, the profile index can be calculated using the longitudinal profile data collected.

The purpose of making the transition in data collection devices before making the transition in analysis is to allow airport operational staff and contractor staff to become familiar with the equipment. Staff will be familiar with the range of numbers to expect from the analysis process while making the transition with the equipment. Subsequently, changes in the analysis of the profile data should be simpler than requiring staff to become familiar with new analysis and new equipment at the same time.

The smoothness evaluation approach used for construction acceptance should be the same as that used for pavement management purposes. Although the index may be the same, the index limits defining when it is necessary to correct a rough area will be different for new construction and for pavement management. The purpose of this is to provide a single standard for evaluating pavement smoothness over the full life of the pavement. The construction acceptance data may be stored with the pavement management data and provide a means for evaluating performance over the full life of a pavement section.

Measurement of Mixture Volumetrics

Construction acceptance testing in the existing P-401 specification is based primarily upon density of the as-constructed mixture. The specification requires that density be evaluated based on a core of the constructed layer and the air voids of the mixture are evaluated as part of this process as well. The contractor’s quality control process is required to evaluate the mixture for compliance with the job mix formula including air voids, asphalt content, and aggregate gradation.

A complete evaluation of the mixture volumetrics would include determining the VMA and VFA in addition to the asphalt content and air voids. Any one of these properties by itself cannot be relied upon to provide an exact indication of the mixture performance. However, these properties together with information about the asphalt binder can be used to estimate the overall mixture stiffness and, subsequently, performance. Therefore, it is recommended that measurement of these properties be incorporated into the testing for construction acceptance.

SUMMARY

As has been discussed, there is insufficient information available to fully develop a performance-based specification for airfield asphalt pavements. However, the recommendations provided here are a first step in that direction.

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APPENDIX A

INTERVIEW CONTACTS

Name	Agency	Type of Contact	Form of Interview
Phil Becker	Reynolds, Smith and Hills	Expert	Face/E-mail
Lorrin Bird	Office of Program Development & Management, Aviation Bureau	Airport Operator	Mail/E-mail
Bob Boyer	Independent Consultant	Expert	Mail/E-mail
Dr. Ray Brown	Corps of Engineers	Expert	Mail/E-mail
Samuel Hautequest Cardoso	ICAO	Expert	Face/E-mail
Ron Corun	Citgo	Expert	Face
Gary Fuselier	Metropolitan Washington Airports Authority	Airport Operator	Face
Jeff Gagnon	FAA William J. Hughes Technical Center	Expert	Phone
Toni Gerardi	APR Consultants, Inc	Expert	Phone
Ed Gervais	Boeing	Aircraft Manufacturer	Face
Dr.Gordon Hayhoe	FAA William J. Hughes Technical Center	Expert	Face/E-mail
Frank Holt	Dynatest USA	Expert	Face/E-mail
Bob Humer	Asphalt Institute	Expert	Face
Joel Jenkinson	Addison Airport	Airport Operator	Face
Rodney Joel	Federal Aviation Administration	Expert	Face
Ryan King	FAA William J. Hughes Technical Center	Expert	Phone/E-mail

Name	Agency	Type of Contact	Form of Interview
Bill Lewis / Steve Howerton	Ennis Municipal Airport	Airport Operator	Face
Roy D. McQueen	Roy D. McQueen & Associates, Ltd.	Expert	Face
Bill Mohler	John Wayne Airport	Airport Operator	Face
Scott Murrell	PANY&NJ	Airport Operator	Phone
Joe Polk	Memphis-Shelby County Airport Authority	Airport Operator	Phone
Jeff Rapol	FAA (HQ Washington)	Expert	Face
Mike Roginski	Boeing	Aircraft Manufacturer	Face
Jack Scott	FAA Northwest Region	Expert	Face
John Slone / Mark Day	Lexington Bluegrass	Airport Operator	Phone/E-mail
Monte Symons	AAPTP	Expert	Face

APPENDIX B

COMPLETED AIRPORT OPERATOR QUESTIONNAIRES

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Gary Fuselier*

2. Agency: *Metropolitan Washington Airports Authority*

3. Date of Interview: *6 November 2007*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Braking (friction)*
   Ride quality
   Groove integrity

   b. Taxiways *Ride quality*
   Braking (less than runway)

   c. Aprons *Ability to withstand static loading (lack of static indentation)*
   Ability to make tight turns without deforming pavement

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?
   Friction influences braking
   Internal stability will influence ride quality

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *12*
   b. Taxiways? *10*
   c. Aprons? *15-20*

   However, pavement life at DCA approaches 20-years.

7. What are the key **runway** pavement characteristics/distresses? Please list:
   a. *Cracking*
   b. *Rutting / shoving*
   c. *Bleeding*
   d. __________
   e. __________

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      Rutting / Shoving
      Bleeding
   b. Development of Foreign Object Damage potential?
      Cracking
      Extreme rutting / shoving
   c. Development of pavement maintenance needs?
      Cracking
      Rutting / shoving

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

% AC; Air voids; density (compaction); VMA; aggregate gradation

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    Same as Runway
    a. ____________________
    b. ____________________
    c. ____________________
    d. ____________________
    e. ____________________

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?
       Same as Runway
    ____
    ____
    ____
    b. Development of Foreign Object Damage potential?
       Same as Runway
    ____
    ____
    ____
    c. Development of pavement maintenance needs?
       Same as Runway
    ____
    ____
    ____

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?
    ____
    Same as Runway
    ____
    ____
    ____

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Same as Runway*
    b. *Fuel resistance*
    c.
    d.
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?
    Same as Runway
    b. Development of Foreign Object Damage potential?
    Same as Runway
    c. Development of pavement maintenance needs?
    Same as Runway

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?
Same as Runway; also binder grade will influence static indentation (stiffer on hot side)

16. What HMA characteristic(s) do you believe are most important in affecting durability?

% AC

Air voids (most important)

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

% AC; air voids and VMA; aggregate structure

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Straight edge good for all facilities, but it is a "localized" measurement

Profilograph & profilers will give long wave roughness

RWs & TWs: use profilers due to long pull lengths; Apron: use straight edge (short pulls)

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Smoother you start, smoother pavement will stay

Transverse & longitudinal joints are a problem, need to adhere to grade at joints

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

No

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Smoothness; lack of FOD; braking action

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Density

Smoothness

Quality construction joints

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Don't need to "invent" anything new.

Implement and enforce "tried and true practices

AIRPORT INTERVIEW FORM

1. Operator Name: Steve Howerton

2. Airport or Agency: Ennis Municipal Airport

3. Date of Interview: October 29, 2007

4. Identify typical aircraft using the airport: Designed for Beech King Air, will be building new airport to accommodate light jet traffic with single wheel load up to 20,000 lbs

5. What is the average number of takeoffs per runway at the airport? (An approximate value is sufficient) 6,846 per year

6. How many runways are at the airport? 1

7. How many of these runways are portland cement concrete, how many are asphalt concrete, and how many are asphalt surfaces on portland cement concrete? asphalt runway that is 3600 ft, new airport will have 5000 ft runway but pavement type has not been selected yet

8. What are the approximate thicknesses of the pavement layers?4 inch HMA over lime stabilized base over lime stabilized subbase

9. What are the typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway/taxiway/apron pavements? unstable soil has been the biggest problem at the airport. A section of the runway is on fill material that has exhibited shrink/swell problems.

10. How does the quality of the pavement influence these operational/performance characteristics? Affected braking distance of aircraft and cause wear and tear on the aircraft.

11. Are you using the P-401 construction specification contained in AC 150/5370-10A or the Superpave specification contained in Engineering Brief EB-59A? TXDOT highway spec

12. How was the selection made? Based on runway length, it fits the FAA loophole for using state spec.

13. Describe any modifications to FAA standards that were required to meet the local conditions? none known

14. Can we obtain a copy of the standard HMA specification used at your airport? Yes If yes, please return with completed questionnaire to:

Gonzalo Rada, Ph.D., P.E.
MACTEC Engineering and Consulting, Inc.
12104 Indian Creek Court, Suite A
Beltsville, MD 20705

15. What acceptance tests are performed according to your HMA specification? See spec
16. What asphalt binder is primarily used at the airport? How was it selected? not sure

17. What is the average life of an asphalt surface or overlay for:
    a. Runways: 10-12 years
    b. Taxiways: no response
    c. Aprons: no response
18. What are the key **runway** pavement characteristics/distresses at your airport? Please list:
    a. raveling/weathering have been other distress issued
    b. most important distress is hump
    c.
    d.
    e.

19. How do these distresses relate to the following:
    a. Directional control of the aircraft? see first page
    b. Development of Foreign Object Damage potential? The raveling/weathering have caused a few dings on propellers but not caused any FOD yet
    c. Development of pavement maintenance needs? no resposne

20. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **runways**? no response

21. What are the key **taxiway** pavement characteristics/distresses at your airport? Please list:
    a. no response
    b.
    c.
    d.
    e.

22. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response

23. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **taxiways**? no response

24. What are the key **apron** pavement characteristics/distresses at your airport? Please list:
    a. no resposne
    b.
    c.
    d.
    e.

25. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response
26. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **aprons**? no resposne

27. What HMA characteristic(s) do you believe are most important in affecting durability? From Steve's perspective, the thickness has been the most important factor in how t he pavement wears

28. What HMA characteristic(s) do you believe are most important in affecting structural performance? see above

29. How do you measure smoothness for compliance to specifications? Are you using different methods on runways, taxiways, and aprons? no

30. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications? no response

31. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications? no resposne

32. Do you have any additional comments to make regarding pavement performance or performance-based specifications? no response

AIRPORT INTERVIEW FORM

1. Operator Name: Joel Jenkinson, Aaron Russell, Dave Foster

2. Airport or Agency: Addison Airport

3. Date of Interview: 11/2/07

Background info – Airport was built in 1957. At that time there was also a cross-wind runway but it was turf. That runway was removed early within the airport operations. The airport was privately owned and operated. The primary aircraft were piston engine, small. In the mid-1970's the aircraft was turned over to the city of Addison; however, the former owner maintained operational control. On 1/1/2001, control was turned over to the city who has hired a contractor to provide that service. Maintenance history prior to 2001 is sketchy at best.

Many of the old asphalt pavements were have minimal major maintenance or reconstruction based on a visual review. The last major rehabilitation on the runway occurred in 1972. However, the gentlemen that I met with were certain that it had received an overlay sometime since 1972, they just weren't sure when.

They are planning a series of rehabilitation projects across the airport over the next few years. As the airport is very busy, they do not believe that reconstruction to change pavement type is feasible. So, the operators feel "stuck" with an asphalt runway and taxiway. They are very interested in seeing our project succeed and getting the benefit of what we learn.

The airport is "one of the few" that actually makes money. They hired KSA Engineers to assist in developing an improvements plan which has been provided to TX DOT and the FAA to attempt to get some assistance in carrying out these improvements. Many of the answers are based on experiences at other airports and their opinions rather than what has been observed at the Addison Airport.

4. Identify typical aircraft using the airport: Aircraft receives a variety of traffic ranging from helicopters and small props to an occasional 737. This week they had 2 C130s land. Primarily see small jets like the Lears. Jet traffic constitutes 40% of the traffic. Other traffic includes Gulfstreams and Challenger aircraft.

5. What is the average number of takeoffs per runway at the airport? (An approximate value is sufficient) 130,000 operations per year

6. How many runways are at the airport? 1 runway

7. How many of these runways are portland cement concrete, how many are asphalt concrete, and how many are asphalt surfaces on portland cement concrete? asphalt surface

8. What are the approximate thicknesses of the pavement layers? Asphalt is ~ 10 inches over 18 inches of granular base

9. What are the typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway/taxiway/apron pavements? ride quality and friction; the biggest problem they are seeing currently developing is FOD potential from raveling and weathering of the surfaces

10. How does the quality of the pavement influence these operational/performance characteristics? Ride quality was observed on an airport in the New Orleans area. The specification had a bonus on compaction (the more the better) with little to no control on grade or smoothness. The contractor did everything possible to achieve maximum compaction without considering what happened to smoothness. Result was "waffle pattern" of bumps on runway.

11. Are you using the P-401 construction specification contained in AC 150/5370-10A or the Superpave specification contained in Engineering Brief EB-59A? Expect to be using P-401 in the future. Have no idea what was used previously. In some areas believe that TXDOT specification was used.

12. How was the selection made? no response

13. Describe any modifications to FAA standards that were required to meet the local conditions? no response

14. Can we obtain a copy of the standard HMA specification used at your airport? No If yes, please return with completed questionnaire to:

    Gonzalo Rada, Ph.D., P.E.
    MACTEC Engineering and Consulting, Inc.
    12104 Indian Creek Court, Suite A
    Beltsville, MD 20705

15. What acceptance tests are performed according to your HMA specification? no response
16. What asphalt binder is primarily used at the airport? How was it selected?
    unknown

17. What is the average life of an asphalt surface or overlay for:
    a. Runways: Expect 10-12 years
    b. Taxiways: 10-12 years
    c. Aprons: 10-12 years
18. What are the key **runway** pavement characteristics/distresses at your airport? Please list:
    a. Oxidation
    b. Cracking on edges of pavement - due to small traffic in those areas
    c.
    d.
    e.

19. How do these distresses relate to the following:
    a. Directional control of the aircraft? none - blown tires the only issue observed at the airport
    b. Development of Foreign Object Damage potential? They are expecting this to become more of a problem in the near future
    c. Development of pavement maintenance needs? covered in prior discussions

20. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **runways**? Haven't really considered

21. What are the key **taxiway** pavement characteristics/distresses at your airport? Please list:
    a. cracking and ponding
    b. poor drainage
    c. lack of design and poor quality base
    d.
    e.

22. How do these distresses relate to the following:
    a. Directional control of the aircraft? See runway
    b. Development of Foreign Object Damage potential? some weathering observed which may become FOD potential
    c. Development of pavement maintenance needs? See background section

23. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **taxiways**? no response

24. What are the key **apron** pavement characteristics/distresses at your airport? Please list:
    a. same as taxiway
    b.
    c.
    d.
    e.
25. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response
26. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **aprons**? no response

27. What HMA characteristic(s) do you believe are most important in affecting durability? Using a mix and pavement design that is appropriate to traffic expected to observe. A heavy structural mix should be used in an area receiving this type of traffic. Their feeling is that overdesign can result in cracking and wearing issues from lack of use just like underdesign can lead to early fatigue

28. What HMA characteristic(s) do you believe are most important in affecting structural performance? see above - also for some of their lighter use pavements, the design vehicle is not the airplane but rather the fuel trucks

29. How do you measure smoothness for compliance to specifications? Are you using different methods on runways, taxiways, and aprons? All smoothness questions answered here - Based on prior experience, ride quality is important to this airport. The group wants to see a good smoothness requirement put into place for all pavements. Recently constructed a new fuel farm. They surveyed the area using a Lidar survey approach. The Lidar is a laser system and it can survey an area up to a 360 degree circumference over a 100 or 200 ft radius. The survey is accurate up to 0.028 inches. The Lidar also sees color. They intend at this point to try and use the Lidar on the entire runway.

30. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications? no response

31. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications? no response

32. Do you have any additional comments to make regarding pavement performance or performance-based specifications? They believe that the specifications should be regionalized as they do not believe that the needs of a pavement in Texas are the same as the needs of a pavement in Michigan.

AIRPORT INTERVIEW FORM

1. Operator Name: Lexington Fayette Urban County Airport Board

2. Airport or Agency: LEX

3. Date of Interview: November 20, 2007

4. Identify typical aircraft using the airport: Commercial RJs

5. What is the average number of takeoffs per runway at the airport? (An approximate value is sufficient) 80,699 operations in 2006

6. How many runways are at the airport? 2

7. How many of these runways are portland cement concrete, how many are asphalt concrete, and how many are asphalt surfaces on portland cement concrete? 2 concrete on asphalt

8. What are the approximate thicknesses of the pavement layers?Commercial runway - 14" asphalt on 6" concrete; GA runway - 1" asphalt on 8" concrete

9. What are the typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway/taxiway/apron pavements? Seriously? Whole papers and books are written on this.

10. How does the quality of the pavement influence these operational/performance characteristics? Same as 9.

11. Are you using the P-401 construction specification contained in AC 150/5370-10A or the Superpave specification contained in Engineering Brief EB-59A? P-401 and P-403

12. How was the selection made? Necessary for FAA funding.

13. Describe any modifications to FAA standards that were required to meet the local conditions? None.

14. Can we obtain a copy of the standard HMA specification used at your airport? No If yes, please return with completed questionnaire to:

    Gonzalo Rada, Ph.D., P.E.
    MACTEC Engineering and Consulting, Inc.
    12104 Indian Creek Court, Suite A
    Beltsville, MD 20705

15. What acceptance tests are performed according to your HMA specification? Per P-401 and P-403 spec
16. What asphalt binder is primarily used at the airport? How was it selected? SS-1h; selected by the contractor from an approved list

17. What is the average life of an asphalt surface or overlay for:
    a. Runways: 12 yrs
    b. Taxiways: 30
    c. Aprons: NA
18. What are the key **runway** pavement characteristics/distresses at your airport? Please list:
    a. Asph - Reflective cracking
    b. Asph - Alligator cracking
    c.
    d.
    e.

19. How do these distresses relate to the following:
    a. Directional control of the aircraft? None
    b. Development of Foreign Object Damage potential? Minor - due to preventative maintenance
    c. Development of pavement maintenance needs? Directly

20. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **runways**? Mix quality

21. What are the key **taxiway** pavement characteristics/distresses at your airport? Please list:
    a. Asph - Reflective cracking
    b. Asph - Alligator cracking
    c.
    d.
    e.

22. How do these distresses relate to the following:
    a. Directional control of the aircraft? None
    b. Development of Foreign Object Damage potential? Minor - due to preventative maintenance
    c. Development of pavement maintenance needs? Directly

23. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **taxiways**? Mix quality

24. What are the key **apron** pavement characteristics/distresses at your airport? Please list:
    a. Conc - Crazing
    b. Conc - Joint spalling
    c. Conc - Corner spalling
    d. Asph - Reflective cracking
    e. Asph - Block cracking

25. How do these distresses relate to the following:
    a. Directional control of the aircraft? None
    b. Development of Foreign Object Damage potential? Minor with preventative maintenance
    c. Development of pavement maintenance needs? Directly
26. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **aprons**? Placement and workmanship

27. What HMA characteristic(s) do you believe are most important in affecting durability? Mix quality

28. What HMA characteristic(s) do you believe are most important in affecting structural performance? Compaction

29. How do you measure smoothness for compliance to specifications? Are you using different methods on runways, taxiways, and aprons? Straightedge per the specs.

30. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications? No

31. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications? No

32. Do you have any additional comments to make regarding pavement performance or performance-based specifications? No

AIRPORT INTERVIEW FORM

1. Operator Name: Bill Molher, Ambi Thurai

2. Airport or Agency: John Wayne Airport (SNA)

3. Date of Interview: October 11, 2007

4. Identify typical aircraft using the airport: 80% of airplanes are B737; also have 757, Airbus 320, 318, 340 - Fedex; also have smaller aircraft trainer/school

5. What is the average number of takeoffs per runway at the airport? (An approximate value is sufficient) see Statistics.doc, Repetitions.pdf

6. How many runways are at the airport? 2: Comercial and GA

7. How many of these runways are portland cement concrete, how many are asphalt concrete, and how many are asphalt surfaces on portland cement concrete? Commercial is grooved AC; GA is porous friction course

8. What are the approximate thicknesses of the pavement layers?Commercial is 22 inch AC over 14 inch base, GA is 6 inch AC over 6 inch base

9. What are the typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway/taxiway/apron pavements? Smoothness

10. How does the quality of the pavement influence these operational/performance characteristics? a smooth pavement will last longer, experience less loading, have less impact on planes

11. Are you using the P-401 construction specification contained in AC 150/5370-10A or the Superpave specification contained in Engineering Brief EB-59A? using AC 150/5370-10B; contractor has hard time getting VMA 15%

12. How was the selection made? no info

13. Describe any modifications to FAA standards that were required to meet the local conditions? none

14. Can we obtain a copy of the standard HMA specification used at your airport? Yes If yes, please return with completed questionnaire to:

    Gonzalo Rada, Ph.D., P.E.
    MACTEC Engineering and Consulting, Inc.
    12104 Indian Creek Court, Suite A
    Beltsville, MD 20705

15. What acceptance tests are performed according to your HMA specification? what is required in spec
16. What asphalt binder is primarily used at the airport? How was it selected? AR-8000, PG 70-11 for local repairs

17. What is the average life of an asphalt surface or overlay for:
    a. Runways: 10-12yrs
    b. Taxiways: 10-12yrs
    c. Aprons: no info
18. What are the key **runway** pavement characteristics/distresses at your airport? Please list:
    a. skewed grooves because of heavy breaking; grooves are 3/8" instead of 1/4"
    b. have all other types of distress except polished aggregate
    c.
    d.
    e.

19. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? crew is driving on runway morning and afternoon to inspect for FOD
    c. Development of pavement maintenance needs? PMS used to identify needs, however they generally do worst first; they do crack sealing

20. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **runways**? binder properties: not too soft, keep VMA up

21. What are the key **taxiway** pavement characteristics/distresses at your airport? Please list:
    a. Rutting on taxiway used for take-off, where aircraft is standing
    b.
    c.
    d.
    e.

22. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response

23. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **taxiways**? no response

24. What are the key **apron** pavement characteristics/distresses at your airport? Please list:
    a. all commercial aprons are PCC; GA aprons are slurry sealed when in bad shape
    b.

c.
d.
e.

25. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response
26. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **aprons**? no response

27. What HMA characteristic(s) do you believe are most important in affecting durability? smoothness, VMA, gradation, binder

28. What HMA characteristic(s) do you believe are most important in affecting structural performance? air voids

29. How do you measure smoothness for compliance to specifications? Are you using different methods on runways, taxiways, and aprons? 16' straight edge, profilograph

30. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications? no response

31. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications? no response

32. Do you have any additional comments to make regarding pavement performance or performance-based specifications? no response

AIRPORT INTERVIEW FORM

1. Operator Name: Scott Murrell

2. Airport or Agency: PANY/NJ

3. Date of Interview: October 24, 2007

4. Identify typical aircraft using the airport: primarily narrow body aircraft. At EWR and JFK there is significant wide-body traffic including 777, 747, Airbus, and they will be getting A380s

5. What is the average number of takeoffs per runway at the airport? (An approximate value is sufficient) Annual basis - >50,000

6. How many runways are at the airport? 11 to expanding to 13 in near future

7. How many of these runways are portland cement concrete, how many are asphalt concrete, and how many are asphalt surfaces on portland cement concrete? all AC surfaced with exception of a small stretch of runway at EWR. Additionally, plans do not park on asphalt pavement, they park on concrete pads though the apron pavements are primarily AC

8. What are the approximate thicknesses of the pavement layers? no response

9. What are the typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway/taxiway/apron pavements? No1 issue is maintaining grooves. When the grooves disappear in wet weather, there is a stopping distance issue and they are limited on aircraft that can land. Also, aircraft response to pavement surface based on quality of ride and can affect stopping distance.

10. How does the quality of the pavement influence these operational/performance characteristics? Both affect stopping distance

11. Are you using the P-401 construction specification contained in AC 150/5370-10A or the Superpave specification contained in Engineering Brief EB-59A? approval to use modified P-401 - Marshall mix design targeting 4% voids

12. How was the selection made? The modification was based on their experience and an extensive research study performed in the 90s. Study involved review of various mixes in triaxial compression testing machine. The research was looking for how AC performed with queuing aircraft. Based on this study, PANY/NJ went to a more stone-rich design prior to Superpave implementation. Validated with some Superpave info.

13. Describe any modifications to FAA standards that were required to meet the local conditions? Modifications identified above will e-mail a copy of spec

14. Can we obtain a copy of the standard HMA specification used at your airport? Yes If yes, please return with completed questionnaire to:
    Gonzalo Rada, Ph.D., P.E.
    MACTEC Engineering and Consulting, Inc.
    12104 Indian Creek Court, Suite A
    Beltsville, MD 20705

15. What acceptance tests are performed according to your HMA specification? done by PANY/NJ - mat air voids, long joint density, mat density, profilometer smoothness testing, test to make sure that getting modifier asking for (ask for specific modifiers that meet PG grade) - TSR testing, plant air voids - check in-place air voids to not exceed 8%
16. What asphalt binder is primarily used at the airport? How was it selected? PG76-22 in 64-22 region in some locations go to PG82-22 based on traffic. Because it's really our concern about plastic deformation, it doesn't hurt these planes carry jet fuel which so these higher viscosities were more resistant to fuel spills

17. What is the average life of an asphalt surface or overlay for:
    a. Runways: 8 to 12 years
    b. Taxiways: 10-12 years
    c. Aprons: 10 year (seal coats) aprons with concrete parking pads don't park on AC aprons. Have concrete ring or put concrete pads for gear to sit in.
18. What are the key **runway** pavement characteristics/distresses at your airport? Please list:
    a. longitudinal joint cracking and secondary associated cracking
    b. rubber removal on runways is problematic for asphalt
    c.
    d.
    e.

19. How do these distresses relate to the following:
    a. Directional control of the aircraft? End up patching and patchwork adds roughness which affects pilots ability to control
    b. Development of Foreign Object Damage potential? certainly long joint failure proceeds right into FOD issue - alligator along long joint and then FOD
    c. Development of pavement maintenance needs? into a lot of cracking sealing and patching

20. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **runways**? long joint density requirement

21. What are the key **taxiway** pavement characteristics/distresses at your airport? Please list:
    a. long cracking at joint
    b.
    c.
    d.
    e.

22. How do these distresses relate to the following:
    a. Directional control of the aircraft? same not as big of an issue
    b. Development of Foreign Object Damage potential? same
    c. Development of pavement maintenance needs? same

23. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **taxiways**? same, runways are just wider so have more

24. What are the key **apron** pavement characteristics/distresses at your airport? Please list:
    a. more an issue with fuel spills or hydraulic fluid spills taking binder out
    b.
    c.
    d.
    e.

25. How do these distresses relate to the following:
    a. Directional control of the aircraft? softening pavement - aircraft can get stuck in a spot and have to tug it out
    b. Development of Foreign Object Damage potential? loose aggregate
    c. Development of pavement maintenance needs? into patching, pain in the neck not getting same asphalt as when doing a big job. For patching get state mix.
26. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **aprons**? Most important fuel resistant seal coating - another step and time costs seal coat doesn't set up at 50 and on damp night

27. What HMA characteristic(s) do you believe are most important in affecting durability? Void structure

28. What HMA characteristic(s) do you believe are most important in affecting structural performance? Gradation

29. How do you measure smoothness for compliance to specifications? Are you using different methods on runways, taxiways, and aprons? inertial profiler and simulating profilograph

30. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications? inertial profiler is best in general okay

31. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications? it can't be profile index, can't be quarter car model, could be longer (100-ft) straight edge review - simple and doable for runways. May not be as applicable for taxiways but should work because of wheelbase

32. Do you have any additional comments to make regarding pavement performance or performance-based specifications? it would be good to come up with something for rubber removal - big issue, if there were perf criteria or indication of pavement ability to withstand - further research

AIRPORT INTERVIEW FORM

1. Operator Name: Joe Polk

2. Airport or Agency: Memphis-Shelby County Airport Authority

3. Date of Interview: October 24, 2007

4. Identify typical aircraft using the airport: Airport is classified as a D5 or 5D. They get a lots of different types of aircraft including MD11s, DC10s, A300s, 310s, the occasional 747 and all smaller regionals and mid-size aircraft including 737s, and the occasional 757

5. What is the average number of takeoffs per runway at the airport? (An approximate value is sufficient) On the average day, operations sees 282 passenger flights and approximately the same number of cargo flights

6. How many runways are at the airport? 4

7. How many of these runways are portland cement concrete, how many are asphalt concrete, and how many are asphalt surfaces on portland cement concrete? 3 PCC and 1 asphalt, no asphalt taxiways or aprons

8. What are the approximate thicknesses of the pavement layers?Asphalt is 24 inches thick

9. What are the typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway/taxiway/apron pavements? Operations uses the asphalt runway the same as the PCC runway. I tried re-phrasing the question but Joe still insisted that there was no influence. They do regular checks of the ACN and PCN values.

10. How does the quality of the pavement influence these operational/performance characteristics? no response

11. Are you using the P-401 construction specification contained in AC 150/5370-10A or the Superpave specification contained in Engineering Brief EB-59A? P-401

12. How was the selection made? The have been using the P-401 specification for quite some time. And at the time of the last construction operation, the SuperPave spec had not been fully approved by FAA

13. Describe any modifications to FAA standards that were required to meet the local conditions? have used polymer modified AC in last work which was re-surfacing job

14. Can we obtain a copy of the standard HMA specification used at your airport? No If yes, please return with completed questionnaire to:

    Gonzalo Rada, Ph.D., P.E.
    MACTEC Engineering and Consulting, Inc.
    12104 Indian Creek Court, Suite A
    Beltsville, MD 20705

15. What acceptance tests are performed according to your HMA specification? standard FAA required - Marshall tests, density in-place, joint density, gradation, ac content and voids
16. What asphalt binder is primarily used at the airport? How was it selected? P-401 binder

17. What is the average life of an asphalt surface or overlay for:
    a. Runways: expect 10-15 yrs actually got 3 yrs from last surface, previous surface lasted 12 yrs
    b. Taxiways: none
    c. Aprons: none
18. What are the key **runway** pavement characteristics/distresses at your airport? Please list:
    a. stripping, grooves closing, ruts forming in wheelpaths particularly at breaking points and high stress areas where fully loaded aircraft sit. The runway is occasionally used as taxiway at high traffic times
    b.
    c.
    d.
    e.

19. How do these distresses relate to the following:
    a. Directional control of the aircraft? Has not received any reports that the rutting is affecting directional control but believes this is inevitiable and that repairs for drainage will be required soon. Rutting is causing water to pond on the surface and the grooving is no longer facilitating the drainage.
    b. Development of Foreign Object Damage potential? none to this point
    c. Development of pavement maintenance needs? have to look at re-surfacing much sooner than anticipated or possibly an interim mill and replace in areas of significant rutting. Tried to re-groove but apparently this led to more problems than it helped.

20. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **runways**? Joe believes that the cause of the problems he is observing are due to the use of the polymer-modified asphalt. This asphalt is the only difference between the prior construction spec and the most recent spec.

21. What are the key **taxiway** pavement characteristics/distresses at your airport? Please list:
    a. no response
    b.
    c.
    d.
    e.

22. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response

23. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **taxiways**? no response

24. What are the key **apron** pavement characteristics/distresses at your airport? Please list:
    a. no response
    b.
    c.
    d.
    e.

25. How do these distresses relate to the following:
    a. Directional control of the aircraft? no response
    b. Development of Foreign Object Damage potential? no response
    c. Development of pavement maintenance needs? no response

26. What key aspects of your construction specification do you believe are most important in controlling the development of the distresses identified for your **aprons**? no response

27. What HMA characteristic(s) do you believe are most important in affecting durability? density of the material, air voids, and the stripping characteristics

28. What HMA characteristic(s) do you believe are most important in affecting structural performance? same as durability - structural performance is will it support load - thickness has a lot to do, but key is surface is where load is most intense

29. How do you measure smoothness for compliance to specifications? Are you using different methods on runways, taxiways, and aprons? run profilographs and very constrained areas still use straightedge - aprons don't bother

30. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications? profilograph has served them well, have very smooth pavements and can't think of much that can be changed. In concrete slab tightening of edge slump characteristic. For asphalt just controlling grades and rolling patterns to maintain uniformity

31. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications? no response

32. Do you have any additional comments to make regarding pavement performance or performance-based specifications? we in current specs don't have performance criterion. Looking at these but don't know how to get around constraints in FAA system to make use of performance spec. if it doesn't perform not going to know want to know at the beginning if not going to perform. Look for some way to tell at the beginning and give confidence/assurance of performance then would consider more seriously.

APPENDIX C

COMPLETED EXPERT INTERVIEW QUESTIONNAIRES

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Philip C. Becker, P.E.

2. Agency: Reynolds, Smith & Hills, Inc. – Consulting Engineer

3. Date of Interview: November 8, 2007

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways Directional stability during landing and take-off , effective braking, smoothness of landing/travel to the gate, run-up to rotational speed, hydroplaning if water not effectively removed from runway surface, FOD issues for engines if pavements are not maintained.

   b. Taxiways Directional stability during taxi, effective braking, smoothness of ride for passengers, pavement edge geometry such that pilot is not distracted by narrow pavements or tight turns, FOD issues for engines if pavement are not maintained, drainage of pavements to ensure that hydro-planing does not occur.

   c. Aprons Concerns over concentrated stain in the asphalt pavements by high ambient temperatures, poor quality control of placement and careful consideration of gradation of aggregate to preclude rutting of the pavements under static loads. Small enough joint spacing for Portland Cement concrete pavements to minimize movements and to reduce potential for future maintenance interruptions of airline movements on ramp areas; affecting revenue. FOD control on both type surfaces by maintaining pavements in sound condition.

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   The overall quality of the pavements (selection of pavement type, gradation of aggregates, environmental conditions of placement and curing, equipment used for transport and placing of the materials, skills of the production team) is dependant upon good design by experienced airfield engineers. The need for compliance with all Standards and Recommended Practices is balanced by the cost effective use of local aggregates. That is the challenge to the aviation professional – to balance requirements against cost. All of these issues affect pavement quality and the overall pavement quality directly affects all the operational, safety and performance characteristics of aircraft on the runways, taxiways and aprons of each and every airport.

6. In your opinion, what is the average life of an asphalt surface or overlay for:

    a. Runways? 10
    b. Taxiways? 16
    c. Aprons? 20

7. What are the key **runway** pavement characteristics/distresses? Please list:

    a. Environmental – heat/cool (causing oxidation of surface, contraction and expansion of surface, melting of snow) ice (causing directional instability or ingestion of large particles of ice, differential thermal stresses on pavement surface), rain(getting into joints and cracks and reducing soil support of base courses or being retained on top of base courses and causing blow outs in hot weather).

    b. High gear loading and overlapping strains in subgrade by massive loads

    c. Keep subsurface water away from base courses – will reduce soil support and will lead to cracking of asphalt or faulting of concrete joints

    d. Unfocused pavement maintenance – seal cracks and reseal joints to minimize intrusion of water into pavement structure

    e. Mismatch of the PCN and ACN for aircraft – causing overstressing of the pavement matrix and reducing service life of the pavements; causing early cracking and increased potential for FOD

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

Environmental issues are very much a concern – icing, too much water standing on or not being drained from pavement surface. Rutting / shoving of pavements will cause errant movements of the aircraft. Base saturation will reduce soil support and could result in localized depressions affecting aircraft movement. Poor pavement maintenance can lead to pot holes or other localized failures causing or requiring abrupt avoidance maneuvers. Over stressing pavements can lead to localized failures and will result in additional FOD issues. The need for effective, uniform, dimensional constant and maintainable runway grooving to ensure efficient water runoff and dependable skid resistance if of utmost concern. Proper consideration of the transition from runway to high speed exit taxiways will also be required.

    b. Development of Foreign Object Damage potential?

Very high potential for all the factors shown above but with different failures modes and with varied requirements to limit or eliminate the potential for FOD.

c. Development of pavement maintenance needs?

Very high potential for distress for all the factors shown above but with different failures modes and with different maintenance issues. The critical nature of asphalt pavement maintenance beginning early and continuing for the life of the pavement WILL increase the operating cost of that pavement system.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

The use of carefully graded materials with a maximum particle size of 1/3 the proposed depth. The grading of the materials such that the plot on the 0.45 Power Curve of the FHWA does not cross the maximum density line twice. The bump grading of PG asphalts to address the mix of the loadings anticipated. The need to saw cut and seal periodic joints in the runway surface to reduce the potential for random cracking and increase the potential for FOD. It is critical to ensure the skid resistance on the runway and great care must be used to ensure

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. Same as 7 above

    b. Need for adequate under carriage clearance to the edge of the pavement section to not over stress the base courses near the edge and lead to premature pavement failures and maintenance issues.

    c. ______________________________

    d. ______________________________

    e. ______________________________

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

    Same as runway, except far less concern over pavement grooving.

    b. Development of Foreign Object Damage potential?

    Same as runway, but with more concern over joint maintenance as vacuum effect on taxiway pavement higher than on runway due to differing thrust settings in some areas and narrower pavement surfaces to be addressed regarding fugitive items affecting pavement surfaces.

c. Development of pavement maintenance needs?

Same as runway, but with more concern over joint maintenance as vacuum effect on taxiway pavement higher than on runway due to differing thrust settings in some areas.

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Same as runway but with

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. Localized subsidence at gate locations

    b. Numerous penetrations of the pavement surface which can lead to pavement distresses

    c. Fuel spillage impacts on pavement performance and durability

    d. Same as runway issues

    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

Same as taxiway

b. Development of Foreign Object Damage potential?

Same as taxiway

c. Development of pavement maintenance needs?

More critical than taxiway as more ground traffic can both cause and be affected by FOD. Pavement maintenance must be diligently addressed to reduce potential for joint failures or crack spalling. High levels of observation must be in place and prompt repairs / maintenance performed to maintain a safe environment for workers, ground traffic and aircraft traffic.

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Mix design for utmost stability using locally available materials with the consideration of future maintenance – will a seal coat be required in 8 – 10 years and what materials will be used? ? The maximum aggregate size should be carefully considered to place a very dense mix.

16. What HMA characteristic(s) do you believe are most important in affecting durability?

    Fractured faces in coarse materials. Non-rounded fine aggregates. Use of Performance Graded and bumped asphalts to provide for pavement loadings. Payments based on density, flow and air voids.

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Fractured faces in coarse materials. Gradation of the mixture to most closely align with Max. Density Line on 0.45 Power curve. Non-rounded fine aggregates. Use of Performance Graded and bumped asphalts to provide for pavement loadings. Base preparation prior to placement. Payments based on density, flow and air voids.

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

    GPS / Mapping to provide finished contour to a mean accuracy of 0.02 foot

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

    See 18

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

    No response

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

    No response

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

    No response

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

    I this application the journey is more important that the destination – how the mix is designed, the quality of the materials and the skill used to develop and then place the job mix is more important than simply evaluation what has been placed. This does not appear to be a valid way to spend money and then go through the iteriative measures necessary to correct poor performance. More importantly, the performance of a pavement over time is drastically influenced by other factors – weather, over stressing, etc. How do we ensure the contractor take the requisite care and skill in placement; if we based on performance, we MUST be able to find the contractor's liable for failure of maintenance over time. Not an enviable or logical task. We need to be involved in the formulation of the mix, the materials in the mix, how they are stuck together, how they are placed and how they are paid for. In simple terms, we must control the quality because the contractors prime directive is quantity, not quality.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Robert E. Boyer, PhD, PE

2. Agency: Boyer Consultant

3. Date of Interview: 11/20/2007

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

This Item presents a challenging question, and with the proper answers, the objective of Project 06-03 will be in focus. In view of this, some philosophical comments will be presented to stimulate interest for interactions that have impact on the question.

- **Performance Based Specifications [PBS] –** The development and implementation of PBS have received wide spread attention throughout the transportation industry. Historically, the PBS has been focused on correlation of material and construction parameters with long-term performance of a pavement section. The process depends on defined performance-prediction models to quantitatively correlate the material and construction parameters to distress types. As the process develops and the performance models are refined, then desirable characteristics of the materials and/or construction practice can be included in a PBS. The performance grade binder specification is a good example of a performance material parameter; wherein, the percent Gmm for in-place density may be considered an example of a performance construction parameter. For PBS, pavement performance is typically associated with distress types on the pavement surface. Mechanisms causing these distress types have been well documented in the literature. The dominant airport pavement distress types are load associated, including Rutting and Fatigue; and environment associated, including weathering and cracking.
- **Aircraft/Pavement Interaction –** This subject is not directly related to distress types [polished aggregate, but not the rubber build-up and characteristics of pavement texture] associated with load and/or environmental distress types, but the subject affects safety, comfort, and economics. The macro- and micro-texture of the runway pavement is an aircraft operational/performance characteristic influenced by the quality of the runway pavement. This is a consideration for the runway pavement PBS.
- **Commercial Services/General Aviation Interaction** - Asphalt pavement makes up more than 90+ percent of all airport pavements. The majority of asphalt airport pavement is general aviation pavement and is subject to different loads, traffic, etc. This situation is currently addressed by gross weight of aircraft in a general way for mix design and a bit more stringent for thickness design. This is a major consideration in development of a PBS because in using association to distress in a performance-prediction model will require a greater degree of unknown parameters because in the general aviation arena, the growth of GA aircraft in both load and traffic versus upgrade of pavement sections is not as well defined as in the commercial arena.

- **Thickness Design/Mix Design Interaction -** The current thickness design technology does not recognize quality of the newly constructed pavement, and compromises becomes reality.

a. Runways
Skid resistance [include hydroplane potential], directional control, FOD, minimum maintenance, roughness [or smoothness] - roughness [smoothness] considered to be long and/or short wavelength

b. Taxiways directional control, FOD, minimum maintenance, roughness [or smoothness]

c. Aprons Directional control, FOD, minimum maintenance

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   Quality impacts all aircraft operational/performance characteristics to some extent

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 15
   b. Taxiways? 15
   c. Aprons? 10

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. **Stability/**Alligator, Fatigue [Pre-Alligator], Rutting, Shoving

   b. **Durability/**raveling [Weathering]/Cracking

   c. **Grade/**Depression & longitudinal wavelength

   d. **Roughness [Smoothness]/**Distress [Undefined by D 5340]

   e. **Friction/**Distress [Undefined by D 5340]

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?

      7.a., 7..c, 7.d., 7.e.

   b. Development of Foreign Object Damage potential?

      7.b.

c. Development of pavement maintenance needs?

7.a., 7.b., 7.c, 7.d., 7.e.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Good mix design; Production of mix in accordance with mix design; and achieving 3.0 – 7.0 percent air voids for field placed materials.

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

a. **Stability/**Alligator, Fatigue {Pre-Alligator], Rutting, Shhoving

b. **Durability/**raveling [Weathering]/Cracking]

c. **Grade/**Depression

d. **Roughness [Smoothness]/**Distress [Undefined by D 5340]

e.

11. How do distresses from question 10 relate to the following:

a. Directional control of the aircraft?

10.a., 10.c.

b. Development of Foreign Object Damage potential?

10.b.

c. Development of pavement maintenance needs?

10.a., 10.b., 10.c. 10.d.

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Good mix design; Production of mix in accordance with mix design; and achieving 3.0 – 7.0 percent air voids for field placed materials.

13. What are the key **apron** pavement characteristics/distresses? Please list:

a. Stability/Alligator, Fatigue {Pre-Alligator], Rutting, Shhoving

b. Durability/raveling [Weathering]/Cracking

c. **Grade/**Depression

d.

e.

14. How do distresses from question 13 relate to the following:

a. Directional control of the aircraft?

13.a., 13.c.

b. Development of Foreign Object Damage potential?

13.b.

c. Development of pavement maintenance needs?

13.a., 13.b., 13.c.

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Good mix design; Production of mix in accordance with mix design; and achieving 3.0 – 7.0 percent air voids for field placed materials.

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Percent Asphalt Content/Air Voids/Voids Mineral Aggregate

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Stability may have an indirect effect, but should have no theoretical impact since structural performance is a function of thickness of pavement and not HMA characteristics

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Potential relationship between pavement surface elevation profile and aircraft ride quality criteria/present criteria appears sufficient for Taxiway and Apron pavements.

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Appratus and procedures to measure relationship between pavement surface elevation profile and aircraft ride quality criteria

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Require multiple layer placement lifts, where practical

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Safety, Stability, Durability, Smoothness, Grade

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Safety/Skid/Texture – RW only

Stability/Density

Durability/Percent Asphalt content & VMA

Smoothness/See Item 18

Grade/Survey

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

1) Two-sided field density control mandatory

2) Maximum & minimum lift thickness

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Ray Brown

2. Agency: Corps of Engineers, Engineer Research and Development Center

3. Date of Interview: November 5, 2007

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways Hydroplaning, friction, aircraft damage from roughness, FOD damage, tire damage from surface defects

   b. Taxiways FOD damage, adequate mobility, friction

   c. Aprons FOD damage, adequate mobility, friction

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   Need to build a smooth pavement with good friction and good drainage to prevent hydroplaning. The surface needs to stay intact so that FOD potential does not develop. The pavement needs to keep these properties throughout the life of the pavement.

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 12yrs
   b. Taxiways? 12yrs
   c. Aprons? 12yrs in areas of no fuel spills. In fuel spill areas-less than five years unless treated with fuel resistant sealer

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Loss of friction

   b. Roughness due to cracking, raveling, longitudinal joints, etc.

   c. Inadequate surface drainage

   d. FOD potential due to raveling etc.

   e. __________

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

The first 3 can cause problems with directional control.

    b. Development of Foreign Object Damage potential?

The 2 and 4 discuss FOD potential

    c. Development of pavement maintenance needs?

All can require maintenance be done.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

All are important---but aggregate quality (especially no polishing, limit on natural sand, and fractured faces on coarse gravel), asphalt cement grade, compaction in mat and joint, good bond, and control of volumetrics stand out. Also good control of grade is important to ensure smooth with no bird baths.

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. Rutting
    b. Raveling
    c. Cracking, primarily at longitudinal joints
    d.

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

Generally not a problem on taxiways but rutting can affect directional control

    b. Development of Foreign Object Damage potential?

Raveling and cracking can cause this.

    c. Development of pavement maintenance needs?

All three can result in maintenance needs

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

    Aggregate requirements (limit on natural sand and fractured faces of coarse aggregate), asphalt cement grade, good bond, compaction of mat and joint, and volumetrics

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. Problems from fuel spillage

    b. Rutting and shoving

    c. Longitudinal joints

    d. Segregation and raveling in hand work areas

    e. ____________________

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

    Generally not a problem on apron

    b. Development of Foreign Object Damage potential?

    Can be a problem in segregated and raveled areas or in areas of fuel spillage

    c. Development of pavement maintenance needs?

    All issues can cause maintenance problems.

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

    Same as for taxiways but more emphasis should be placed in handwork areas

16. What HMA characteristic(s) do you believe are most important in affecting durability?

    Good compaction, good volumetrics, and not overheating the asphalt during construction

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

    Good aggregate angularity, proper AC grade, good compaction, good volumetrics

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

    Straightedge should be used at joints etc. especially on aprons where difficult to use profilometer. In many cases profilometer should be used on taxiways but usually difficult due to cross taxiways, turns, etc. So may be better to use straightedge. On runway, profilometer should be used.

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

    No suggestions except profilometer may be better than present method where appropriate

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

    No

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

    Friction, Smoothness, Potential for hydroplaning, FOD potential

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

    Grade of pavement surface, potential for polishing of aggregate, test to evaluate rutting and cracking, compaction

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

    What ever methods are recommended should be applicable to use during the construction process. This should not be just a mix design or research method but one that is applicable to QC/QA during construction.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Samuel Hautequest Cardoso

2. Agency: ICAO

3. Date of Interview: 20 November 2007

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways Takeoff & landing: roughness
   Landing: skid resistance (aquaplaning) (eventually takeoff – overrun)
   Takeoff & landing: FOD ingestion

   b. Taxiways Runway to apron and vice-versa: FOD ingestion
   Maneuvering: rut depth

   c. Aprons Apron to taxiways and vice-versa: FOD ingestion

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

It was already answered in question 4

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 10-15 years
   b. Taxiways? 10-15
   c. Aprons? 20

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Cracks (block, alligator, longitudinal & transversal)
   b. Raveling
   c. Rut depth
   d. ________
   e. ________

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

    Rut depth is related to maneuvering and aquaplaning

    b. Development of Foreign Object Damage potential?

    Raveling and cracks, mainly alligator

    c. Development of pavement maintenance needs?

    All of them

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

    Stability (stiffness), air voids and asphalt content (Assuming that all the materials – coarse and fine aggregates, filler and asphalt cement – meet the requirements)

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. Rut depth
    b. Cracks
    c. Raveling
    d.
    e.

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

    Rut depth relates directly with maneuvering mainly for wet conditions

    Cracks, even if it is advanced, not much

    Raveling, even if it is advanced, not much

    b. Development of Foreign Object Damage potential?

    Raveling and cracks

    c. Development of pavement maintenance needs?

    All of them

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

The same as question 9 (for runways)

(Assuming that all the materials – coarse and fine aggregates, filler and asphalt cement – meet the requirements)

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. Longitudinal and transversal cracks

    b. Spalling

    c. Joint filling

    d. Corner breaks

    e. ______

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

Not really unless the slabs are shattered

    b. Development of Foreign Object Damage potential?

All of them

    c. Development of pavement maintenance needs?

All of them

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

HMA is not common for aprons. However, for some light aircraft it may occur and eventually large airports (aware of at least one with HMA for aprons)
Stability (stiffness), air voids and asphalt content
If possible, material resistant to fuel

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Selection of good aggregates

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Stability (stiffness), air voids and asphalt content

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

There is a tendency to only consider small wavelengths for airfield pavements. The long wavelengths are more important than the short ones for aircraft due to their small frequency of response (much smaller than ground vehicles in general)

Yes. Mainly for runways, the long wavelengths are more important. It should be different from the taxiways and aprons (if required)

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

The basic suggestion is to consider the aircraft response. Each aircraft needs to be checked for a particular runway (or taxiway) surface profile.
The evaluation of short wavelengths can give wrong answers.

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Again, the long wavelengths should be put in perspective.
If a good method is used for smoothness specifications, considering long deformations, the well known 3m or 4.8m straightedge could allow localized (one measurement) tolerance higher than 3 mm or 5 mm, according to ICAO or FAA. There is evidence in the literature

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Skid resistance

Roughness (smoothness)

Resistance to generate FOD

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Skid resistance: use of grooving and PFC (porous friction course). Always construct an experimental segment before the final decision on the asphalt mix

Roughness: Do not consider only the straightedges for controlling the surface. It can be done by using topographic leveling, which is based on methods that consider long wavelengths

Resistance to generate FOD: tight specification for controlling the loss of material (Maybe it will be necessary the development of additional method to control HMA durability)

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

To consider a rigorous control of the HMA characteristics that are related to the three suggestions of question 21 and 22.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Ron Corun*

2. Agency: *Citgo*

3. Date of Interview: *10/23/07*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?
   Consider separate requirements for runway ends and middle
   a. Runways
   Steerability on ends due to plastic deformation. Fatigue cracking on middle to
   Limit FOD. Braking action
   Steerability due to plastic deformation; Lack of FOD
   b. Taxiways
   Static indentation causing aircraft to become unable to power out
   c. Aprons
   Lack of FOD
   Friction and roughness not an issue

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?
   Density; volumetrics; durability (e.g., film thickness); smoothness

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *15-20* *Note: asphalt mastic has a significant impact on*
   b. Taxiways? *15-20* *on longevity, i.e., durability/ravelling*
   c. Aprons? *15-20*

7. What are the key **runway** pavement characteristics/distresses? Please list:
   Ends: Friction and rutting
   a.
   Middle: Raveling, FOD, fatigue, age related embrittlement, roughness
   b.
   c.

d. ____

e. ____

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      Roughness from rutting and poor placement procedures

   b. Development of Foreign Object Damage potential?
      Cracking; raveling; poor joints (consider cutting back long. Joints)

   c. Development of pavement maintenance needs?
      All

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

General feeling is current FAA P-401 specification has key elements covered, but specs must be enforced. Selection of proper binder and lift thickness can be tightened up.

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    Rutting; smoothness; durability/raveling and other FOD issues
    a. ____
    b. ____
    c. ____
    d. ____
    e. ____

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

Same as RW

   b. Development of Foreign Object Damage potential?

Same as RW

c. Development of pavement maintenance needs?

Same as RW

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Same as RW

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Static indentation*
    b. *Rutting*
    c. *Smoothness not as important*
    d.
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

Same as RW

b. Development of Foreign Object Damage potential?

Same as RW

c. Development of pavement maintenance needs?

Same as RW

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Same as RW

16. What HMA characteristic(s) do you believe are most important in affecting durability?

% AC and density. This was NCAT Test Track experience. Also, appropriate use of polymer modifiers

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Flow number and E from "Simple Performance Test" (SPT)

Aggregate type and structure

Binder grade

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

High speed, light weight profiler

For apron, need to consider structures (DI and MH)

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

High speed profilers

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Profilers and IRI

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Initial smoothness and density

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

IRI or other measure

Density

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Consider using different binder grades on RW ends and middle. Alsofor aprons and taxiways.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Gary Fuselier*

2. Agency: *Metropolitan Washington Airports Authority*

3. Date of Interview: *6 November 2007*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Braking (friction)*
   Ride quality
   Groove integrity

   b. Taxiways *Ride quality*
   Braking (less than runway)

   c. Aprons *Ability to withstand static loading (lack of static indentation)*
   Ability to make tight turns without deforming pavement

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?
   Friction influences braking
   Internal stability will influence ride quality

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *12*
   b. Taxiways? *10*
   c. Aprons? *15-20*

   However, pavement life at DCA approaches 20-years.

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. *Cracking*
   b. *Rutting / shoving*

Bleeding

c. ______________________________

d. ______________________________

e. ______________________________

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      Rutting / Shoving
      ____
      Bleeding
      ____

   b. Development of Foreign Object Damage potential?
      Cracking
      ____
      Extreme rutting / shoving
      ____

   c. Development of pavement maintenance needs?
      Cracking
      ____
      Rutting / shoving
      ____

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

% AC; Air voids; density (compaction); VMA; aggregate gradation
____

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    Same as Runway
    a. ______________________________
    b. ______________________________
    c. ______________________________
    d. ______________________________
    e. ______________________________

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?
    Same as Runway

    ___

    b. Development of Foreign Object Damage potential?
    Same as Runway

    ___

    c. Development of pavement maintenance needs?
    Same as Runway

    ___

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

    ___

    Same as Runway

    ___

13. What are the key **apron** pavement characteristics/distresses? Please list:
    Same as Runway
    a. ___
    Fuel resistance
    b. ___
    c. ___
    d. ___
    e. ___

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?
    Same as Runway

    ___

    b. Development of Foreign Object Damage potential?
    Same as Runway

    ___

    c. Development of pavement maintenance needs?
    Same as Runway

    ___

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Same as Runway; also binder grade will influence static indentation (stiffer on hot side)

16. What HMA characteristic(s) do you believe are most important in affecting durability?

% AC

Air voids (most important)

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

% AC; air voids and VMA; aggregate structure

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Straight edge good for all facilities, but it is a "localized" measurement

Profilograph & profilers will give long wave roughness

RWs & TWs: use profilers due to long pull lengths; Apron: use straight edge (short pulls)

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Smoother you start, smoother pavement will stay

Transverse & longitudinal joints are a problem, need to adhere to grade at joints

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

No

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Smoothness; lack of FOD; braking action

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Density

Smoothness

Quality construction joints

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Don't need to "invent" anything new.

Implement and enforce "tried and true practices

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Jeff Gagnon

2. Agency: William J. Hughes Technical Center

3. Date of Interview: October 23, 2007

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways stopping distance, roughness or profile as to ride of aircraft in landing and take-off in both the longitudinal and transverse directions

   b. Taxiways roughness issue – quality of ride in both the transverse and longitudinal directions

   c. Aprons same thing

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

For the aircraft it is a safety issue related to the wear and tear on the struts. Then there is the issue of how the user (both pilot and traveling public) feel about the ride.

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 5 yrs
   b. Taxiways? 5 – 7 yrs
   c. Aprons? 5-7 yrs

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Longitudinal cracking

   b. Transverse cracking

   c. alligator cracking

d. block cracking

e. rutting

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?

The cracking really doesn't affect the directional control of the aircraft. The only way it ever would is if the cracks ever got wide enough and that should never happen.

   b. Development of Foreign Object Damage potential?

Obviously – spalling of the cracking over time

   c. Development of pavement maintenance needs?

These distress are, or should be, on the critical path within the pavement management system used by an airport.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

For the longitudinal and transverse cracking, specifications for acceptance of the construction joints. All cracking types are affected by the mix design specification, the use of the SuperPave mix design system and the gyratory compaction equipment.

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. In addition to those listed for runways, this includes shoving as a result of the turning of aircraft

    b.

    c.

    d.

    e.

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

Obviously creates a roughness issue

    b. Development of Foreign Object Damage potential?

c. Development of pavement maintenance needs?

____

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Shoving is best controlled by the mix design and the asphalt binder selection. The use of modifers can help with the development of shoving.

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. Add fuel spillage to the list for taxiways
    b. ____
    c. ____
    d. ____
    e. ____

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

No response

    b. Development of Foreign Object Damage potential?

No response

    c. Development of pavement maintenance needs?

No response

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Same aspects as those that control shoving

16. What HMA characteristic(s) do you believe are most important in affecting durability?

materials mix design and the selection of the aggregates

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

same as durability, plus construction acceptance on compaction. Temperatures at time of placement and constructability issues will also have an impact.

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Good measurement of longitudinal profile issue using profilograph or line-in-grade

yes – runway – speed issue same for taxiway and apron (speed of aircraft is different on different areas

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

The evaluation should consider different areas differently because of the different speeds that are traveled on the runways, taxiways, and aprons. At those different speeds, the equipment will feel the impact differently. FAA is currently working on specs as related to the Boeing Bump index.

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

See answer above

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

life-cycle cost, maintenance and rehabilitation costs, constructability

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

smoothness or rideability, friction, compaction – quality control of materials and construction

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

specification need to incorporate PG-graded asphalts and the Superpave mix design criteria should be included in the P-401 specification.
Additionally, changing some of constructability issues which has already been done for concrete P-501 specification.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Tony Gerardi

2. Agency: APR Consultants

3. Date of Interview: 10/31/2007

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

a. Runways smoothness is important – roughness with rough pavement will increase required stopping distance. Can be a safety issue in an aborted take-off. If airplane is 100 knots and loose an engine, pilot has to hit brakes hard because of little runs, aircraft is heavy, pitch on nose-gear causing increased load on strut. Blow fuse plugs on tires. Drag brace on nose gear that holds vertical can break and then nose gear collapses.
Costs airlines more money to run on rough runways harder on equipment.
Shortens useful life of airplane.
From pavement perspective – reduces useful life of pavement

b. Taxiways primary concern is ride quality – passengers and pilots – at constant speed, no engine thrust or loud noises, so more likely to notice short wavelength roughness. Rough taxiways will impact operational cost of aircraft – because of wear and tear.

c. Aprons roughness not an issue on aprons, very slow, but still same as taxiways – primary concern on aprons is drainage.

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

See answers above

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? No clue – observation – hot day on asphalt and asphalt with insufficient structural integrity – aircraft could punch through – 315 psi F15 tire pressure, asphalt runways more likely to suffer damage from aircraft dynamic loads – more likely to be damaged by dynamic loading
   b. Taxiways?__________
   c. Aprons? ___________

7. What are the key **runway** pavement characteristics/distresses? Please list:

    a. Structural integrity of entire pavement as a system includes base and subbase – affects so many things. E.g., when subbase gives, asphalt follows, then get deflection, then get cracking and long wavelength roughness – stability of structure as a system

    b. ______

    c. ______

    d. ______

    e. ______

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

Accident investigation of surveillance airplane – nose gear hit arresting cable (severe bump). Airplane hit it, jarred stearing mechanism and lost directional control – only had rudder – airplane left runway at 100 knots. In an aborted take-off – may collapse a nose gear, don't know that has seen runway roughness caused any other directional problems

Bomber aircraft- series of long wavelength bumps – Pilots lost a little control because of bumps

    b. Development of Foreign Object Damage potential?

Structural integrity of runway and ability to settle – fatigue pavement, then develop pieces which cause FOD

    c. Development of pavement maintenance needs?

Extremely important to get baseline survey of pavement that is brand new, particularly one that has fill material where there is potential for settlement so that have continuous profile – MSL profile – can come back later and repeat survey and determine exactly how much has settled or swelled - more than just ride quality tool but also structural integrity tool

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

    see c above along with that – anything to enhance compaction – in order to track it must have baseline

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. Same as runways

    b. __________

    c. __________

    d. __________

    e. __________

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

directional control not an issue on taxiways and aprons

    b. Development of Foreign Object Damage potential?

same as runways

    c. Development of pavement maintenance needs?

same as runways

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

    same as runways – as a deliverable need baseline profile

FOR APRON QUESTIONS – See Taxiway answers

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. __________

    b. __________

    c. __________

    d. __________

    e. __________

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

____

____

____

    b. Development of Foreign Object Damage potential?

____

____

____

    c. Development of pavement maintenance needs?

____

____

____

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

____

____

____

____

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Insufficient experience in this area

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Insufficient experience in this area

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Complex issue – first, currently no specifications for when a runway has become too rough. Many airports still don't do anything about roughness until get pilot complaints. Needs to be criteria for runway roughness – life (taxiway and apron too). Mostly runway – because of speed related issues.

The current specification needs to be re-visited. There needs to be (currently based on straightedge technique) need to look at more than 16-ft straightedge. Use 25-ft straightedge, consistent with diamond grinder lengths, more practical – still only views short wavelengths. Need to look at long wavelengths. APR uses 100-ft straightedge. Aircraft have gear spacing up to 100 ft. Never find a runway meets criteria 100% of the time. Need to determine % per lot for exceeding criteria. Difficult for contractors to build PERFECT pavement. Will always find something that exceeds criteria. Need to relax some. Smoothness index which allows contractor to exceed some percent of the time.

From smoothness point of view, current specification states deviations no more than ½ from grade. Deviation from grade doesn't mean anything about smoothness. Grade control and roughness control are two different things.

On a taxiway and apron, particularly, more relaxing when it comes to outer lanes versus keel section. May want to use same criteria when build for penalty but no fixes. When out of compliance in outer lanes – who cares, never used. Runways most of the time will be in keel, but there are times when will be there. Can loosen on outer lanes but still important because will hit it sometime.

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

    some people use high speed and calculate IRI on runways. IRI on runways has limited value. IRI is ¼-car model. All it will say is what one strut might do. But has no relevance for long wavelength. Need to know what happens at main gear and how it impacts nose gear. Short wavelength may be informative.

    APR likes MSL for tracking settlement, can capture all wavelengths.

    True grade provides info related to high speed abort.

    Really short wavelengths not captured, and would be better to have more than every foot. Concrete joints – could miss taking every foot.

    Most aircraft tires – so big footprint will engulf more than every foot.

Fighter aircraft have fairly small nose gear. More frequent data doesn't hurt. How much is enough? Not known

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Need baseline survey, should be deliverable to customer.
Need to relax outer lane criteria and modernize 16-ft straightedge
Separate grade control from smoothness control

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

    haven't discussed friction, FOD damage, smoothness important, structural integrity

    PCI, structural, friction and smoothness

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Got to have periodic assessment, need to track,

Smoothness – measure profile, friction measurement, PCI on a new pavement shouldn't be an issue unless looking for faulty construction

Structural integrity – measure baseline profile

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

it's tought to come up with criteria that works for all stakeholders. Criteria needs to be field tested, or temp spec that is tested before becomes accepted by community. All stakeholders stand to loose – owner, operator, designer, regulatory agency, contractor. Contractor – really stand to lose – if criteria are too hard, then in a bind from the beginning. Criteria currently is very rigid.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Ed Gervais*

2. Agency: *Boeing*

3. Date of Interview: *10/22/07*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Surface texture and Friction – Braking action*

   Foreign Object Damage (FOD) to engine or air frame from poor longitudinal joints and oxidation

   Roughness is rare on new construction

   b. Taxiways *Roughness due to poor grade control*

   FOD – lower standard of maintenance on TW

   Taxiways with single slope (ie, no cross slope) will affect operation in freezing weather

   c. Aprons *Due to static indentation, asphalt surfacing not recommended for aprons for heavy, high tire pressure – only appropriate for GA*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   Poor grade control affects ride quality.

   Ride quality is primary aircraft performance and pavement quality requirement.

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 8-12 in torrid climate/ 16-18 years in temperate
   b. Taxiways? 8-12 in torrid climate/ 16-18 years in temperate
   c. Aprons? 8-12 in torrid climate/ 16-18 years in temperate

7. What are the key **runway** pavement characteristics/distresses? Please list:
   a. *Joint cracking*
   b. *Raveling*
   c. *Alligator cracking*
   d. *Bleeding*
   e. __________

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      Not at all
   b. Development of Foreign Object Damage potential?
      Raveling & alligator cracking
   c. Development of pavement maintenance needs?
      All

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?
   % AC (mainly too low) - %AC in mid 5% seem to hold up best
   Quality of asphalt cement (Saudi seems to be best)

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    Same as runway
    a. __________
    b. __________
    c. __________
    d. __________
    e. __________

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?
       Lack of crown, i.e., single slope with no crown, in freezing climates

    b. Development of Foreign Object Damage potential?
       Raveling and alligator cracking

    c. Development of pavement maintenance needs?
       Same as runway

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?
    Same as runway

13. What are the key **apron** pavement characteristics/distresses? Please list:
    No comment on apron, since asphalt pavement shouldn't be
    a. *Used except at GA airports*
    b. ______
    c. ______
    d. ______
    e. ______

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?
       NA

    b. Development of Foreign Object Damage potential?
       NA

    c. Development of pavement maintenance needs?
       NA

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

NA

16. What HMA characteristic(s) do you believe are most important in affecting durability?
% AC

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Fractured faces for aggregate

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Deviation from plan grade

Profilograph

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?
Use a device similar to the FAA's profiler with non-contact laser and is small and portable.

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

The current criteria is not significant with respect to aircraft operation

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Roughness; surface texture; no FOD

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Fractured faces with high percentage of crushed particles.

Non-polishing aggregates

% AC

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

No response__

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Gordon Hayhoe, PhD*
2. Agency: *FAA Tech Center*
3. Date of Interview: *6 November 2007*
4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Safety: braking (friction); groove integrity; ride quality; Lack of FOD*

   b. Taxiways *Safety: rutting, FOD, roughness*

   c. Aprons *Safety: FOD; roughness*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

Groove wear/closure due to rubber removal, high temps, poor mix design

Cracks cause FOD. Reflection cracks and general deterioration contribute to roughness

Transverse construction joints influence roughness.

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *10*
   b. Taxiways? *14*
   c. Aprons? *14*

7. What are the key **runway** pavement characteristics/distresses? Please list:

   No comment

   a. ______
   b. ______
   c. ______

d. ____

e. ____

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      No comment

____

   b. Development of Foreign Object Damage potential?
      No comment

____

   c. Development of pavement maintenance needs?
      No comment

____

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

____

No comment

____

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    No comment
    a. ____
    b. ____
    c. ____
    d. ____
    e. ____

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?
       No comment

____

    b. Development of Foreign Object Damage potential?
       No comment

____

c. Development of pavement maintenance needs?
No comment

---

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?
No comment

---

13. What are the key **apron** pavement characteristics/distresses? Please list:
No comment
a. ____________________
b. ____________________
c. ____________________
d. ____________________
e. ____________________

14. How do distresses from question 13 relate to the following:
a. Directional control of the aircraft?
No comment

---

b. Development of Foreign Object Damage potential?
No comment

---

c. Development of pavement maintenance needs?
No comment

---

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?
No comment

---

16. What HMA characteristic(s) do you believe are most important in affecting durability?
No comment

---

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

    No comment

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Any of the common roughness indexes will identify rough areas, except for features with long wavelength content, which is typically associated with construction problems or subsidence. Different limits should be used for runways, taxiways and aprons.

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Current methods (straight-edge, profilograph) are adequate and supported by experience for rigid pavements. Need standards and correlations for simulation of indexes from electronic profiles – particularly sample spacing for profilograph.

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Current methods appear to be adequate.

Need more experience with profilograph for runways.

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

    No comment

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

    No comment

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

No comment

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Frank B. Holt
2. Agency: Dynatest International A/S
3. Date of Interview: Nov 11,2007
4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways takeoff smoothness, braking performance, FOD ingestion

   b. Taxiways ride quality, FOD ingestion

   c. Aprons ride quality, FOD ingestion

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

Roughness has significant impact to the ride quality for the pilot station and for the passengers and to the maintenance of aircraft suspensions. The texture/mix design of the pavement will have enormous effect on the friciton characteristics of th epavement and thus the braking performance of the aircraft under both good conditions and especially under poor/contaminated conditions. Large cracks and ravelling will generate a fOD issue as well..

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 10 to20 years
   b. Taxiways? 10 to 20 years
   c. Aprons? 5 to 10 years

   * qualify this with the need to assume the subgrade is good and base materials are good and design is for the correct air craft and the contractor and QCQA are good.

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Cracking – including L&T, Jnt Ref cracks, and Gators

   b. rutting

   c. patching

   d. vertical distresses---faulting,swells, corrugation,blowups

   e. ravelling

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

With the exception of blowups... low severity has little effect. Above low severity all of the above may cause loss of directional control, may trap water and provide hydroplaning problems. Wide cracking may cause wheels to have reduced steering response in slow movement areas. Gators indicated a failure of the pavement structure.

    b. Development of Foreign Object Damage potential?

A, c, d, e above all have a high degree to provide FOD issues. When found in anything other than low severity.

    c. Development of pavement maintenance needs?

All of the distresses need monitoring as maintenance will be required. The technique for maintenance may actually cause more maintenance. Example patch failure due to poor removal of damaged/defective areas, poor placement procedure, conflicting materials due to need for speed.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Temperature of materials, rolling/ compaction techniques, QAQC of mix, smoothness

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. As for runways
    b. ______
    c. ______
    d. ______
    e. ______

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

______

    b. Development of Foreign Object Damage potential?

______

c. Development of pavement maintenance needs?

____

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Temperature of materials, rolling/ compaction techniques, QAQC of mix, smoothness

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. ravelling
    b. patching
    c. rutting
    d. ____
    e. ____

14. How do distresses from question 13 relate to the following:

    a. Directional control of the aircraft?

none

    b. Development of Foreign Object Damage potential?

ravelling

    c. Development of pavement maintenance needs?

Patching rutting

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Temperature of materials, rolling/ compaction techniques, QAQC of mix, smoothness

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Temperature at placement, AC quality

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

gradation

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Multiple runs over the length of the runway/taxiway/apron and run through proval or FAA smothness program (comfaa)

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Standardize data collection protocol and software data format for input

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

FAA needs to establish criteria for acceptance based on airport type and aircraft using airport

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Roughness, paving joint quality

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

roughness

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Need to have a specification that is calibrated, and standardized to allow inspectors to check repeatability, reliability and also ensure that equipment used to check is calibrated and functional.

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Bob Humer

2. Agency: The Asphalt Institute

3. Date of Interview: 10/23/07

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Roughness; Friction (Braking); FOD risk*

   b. Taxiways *Roughness; Friction (to lesser extent); FOD*

   c. Aprons *Fuel resistance*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?
   All are controlled by quality, but specifically density and volumetrics

   Need to differentiate between design and construction deficiencies

   Stripping (TSR)

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 15-20
   b. Taxiways? 15-20
   c. Aprons? 15-20

7. What are the key **runway** pavement characteristics/distresses? Please list:

    a. *Cracking and raveling (FOD risk)*

    b. *Deformation (rutting; blisters; dimples)*

    c. ______

    d. ______

    e. ______

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

Roughness (rutting)

    b. Development of Foreign Object Damage potential?

Cracks; raveling; poor paving joints

    c. Development of pavement maintenance needs?

All

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Materials: P-401 is adequate in ensuring material quality

Lift thickness important: 3-5 x nominal; 1.5-in minimum lift thickness

Can use diamond grinding to correct high spots

Emphasis on compaction and delamination

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. *Roughness, but less so*

    b. *Rutting*

    c. *FOD from poor or raveling joints*

    d. ______

    e. ______

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

All

    b. Development of Foreign Object Damage potential?

Same as RW

    c. Development of pavement maintenance needs?

Same as RW

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Same as RW

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Fuel resistance*
    b. *Static indentations*
    c.
    d.
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

NA

    b. Development of Foreign Object Damage potential?

Same as RW

    c. Development of pavement maintenance needs?

Same as RW

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Straight edge

Depressions & surface drainage

16. What HMA characteristic(s) do you believe are most important in affecting durability?

%AC

Compaction and in-place air voids

Marshall stability

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

E^* from TAI DAMA program documentation

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

High speed profiler

No difference between RW, TW and Apron

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

High speed profiler

Good construction practices – no start/stop

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Straight edge alone is not sufficient

Use of high speed profilers and diamond grinding for deficient areas (maybe followed by fog seal

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

FOD

Depressions/rutting affecting directional control

Good surface drainage

Fuel resistance on Aprons

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Need to include strength test, such as SPT

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Need a clear definition of performance based specification vs end result spec

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Ryan King
2. Agency: Federal Aviation Administration
3. Date of Interview: October 31, 2007
4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways Braking Performance based on tire interaction with macro and micro texture of the pavement.

   Steering/Directional control during landing and takeoff

   b. Taxiways Steering/Directional Control, braking

   c. Aprons Steering/Directional Control, braking

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   A good quality pavement will have adequate macro- and micro-texture to provide the tire interface with the necessary traction to brake effectively. Also macro texture. Micro-texture will provide pavement friction at low speeds, and macro texture will both reduce potential for hydroplaning, and provide friction (by hysteresis) at higher speeds.

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? N/A
   b. Taxiways? N/A
   c. Aprons? N/A

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Transverse Cracking
   b. Longitudinal Cracking in wheel path
   c. Rutting
   d. Rubber Accumulation
   e. ______

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

        Cracks can interrupt or reduce the contact area between the tire and pavement, and perhaps during landings in high cross wind and wet conditions, this could complicate a pilot maintaining directional control.

        Rubber accumulation in in the touchdown zone can significantly reduce available friction levels during wet conditions.

        Rutting can direct a wheel toward a direction that the pilot may not have intended it to go.

    b. Development of Foreign Object Damage potential?

        Cracking could potentially create FOD

    c. Development of pavement maintenance needs?

        Cracks, and ruts would need to be fixed. Rubber accumulation would need to be removed.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

    N/A – No expert opinion/Not area of expertise

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    N/A – No expert opinion/Not area of expertise

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

        N/A – No expert opinion/Not area of expertise

    b. Development of Foreign Object Damage potential?

        N/A – No expert opinion/Not area of expertise

    c. Development of pavement maintenance needs?

        N/A – No expert opinion/Not area of expertise

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

    N/A – No expert opinion/Not area of expertise

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. N/A – No expert opinion/Not area of expertise

14. How do distresses from question 13 relate to the following:

    a. Directional control of the aircraft?

       N/A – No expert opinion/Not area of expertise

    b. Development of Foreign Object Damage potential?

       N/A – No expert opinion/Not area of expertise

    c. Development of pavement maintenance needs?

       N/A – No expert opinion/Not area of expertise

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

    N/A – No expert opinion/Not area of expertise

16. What HMA characteristic(s) do you believe are most important in affecting durability?

    N/A – No expert opinion/Not area of expertise

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

    N/A – No expert opinion/Not area of expertise

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

    N/A – No expert opinion/Not area of expertise

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

    N/A – No expert opinion/Not area of expertise

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

    N/A – No expert opinion/Not area of expertise

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

    Friction and hydroplaning risk reduction

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

    Adequate friction, and water evacuation.

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

    N/A – No expert opinion/Not area of expertise

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Roy McQueen*

2. Agency: *Roy D. McQueen & Associates, Ltd.*

3. Date of Interview: *13 November 2007*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Braking action; "Steerability" / directional control; Lack of FOD; Rideability (smoothness)*

   b. Taxiways *Braking action; "Steerability" / directional control; Lack of FOD; Rideability (less so than runway)*

   c. Aprons *Braking action (less so than RW/TW); Lack of FOD; Lack of static indentation at parking positions*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

Surface friction; Smoothness; Mix stability; Durability (stripping, raveling, voids) Groove integrity

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *15-20*
   b. Taxiways? *15-20*
   c. Aprons? *15-20*

   No reason not to get 20 year life with proper mix design (optimization) and placement/ compaction techniques

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. *Durability related (e.g., raveling/stripping);*
   b. *Joint cracking;*
   c. *Groove closure; Smoothness;*
   d. *Segregation; Bleeding*

Mix related plastic deformation / rutting;

e. *Polished aggregate and loss of friction*

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      Mix related plastic deformation / rutting;

      Polished aggregate and loss of friction; bleeding

      Groove closure; Smoothness; Mix related plastic deformation / rutting
   b. Development of Foreign Object Damage potential?
      Segregation

      Durability related (e.g., raveling/stripping)

      Joint cracking
   c. Development of pavement maintenance needs?

      All, but FOD related most important

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Aggregate quality, fractured faces and gradation;

Binder grade, quality and percentage;

Volumetrics (voids, VMA) and film thickness

Compaction; longitudinal joint construction

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    Same as runway with less emphasis on smoothness & grooves
    a.
    Mix related stability more important due to operations
    b.
    c.
    d.
    e.

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

Same as runway except for grooves and less emphasis on smoothness

    b. Development of Foreign Object Damage potential?

Same as runway

    c. Development of pavement maintenance needs?

Same as runway

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Same as runway

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Static indentation and fuel spill damage*
    b. *Same as taxiway*
    c.
    d.
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

Not critically important

    b. Development of Foreign Object Damage potential?

Same as runway

    c. Development of pavement maintenance needs?

Same as runway

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Same as runway

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Asphalt content; film thickness; air voids; stripping potential; joint construction; density;

aggregate quality

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Asphalt content; binder grade; aggregate gradation and fractured faces;

amount of natural sand

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Profiler measurements and grade for acceptance; Straight-edge for quality control

Methods same for runway and taxiway with different limits due to operational issues

Need to correlate pavement measurement characteristic with aircraft performance to Develop specification limits for runways and taxiways

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Use of high speed profilers

Development of uniform standards and limits for measurement & acceptance

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Correlate measurement and limits with aircraft performance

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Smoothness; friction; lack of FOD

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Smoothness; voids, compaction/density; film thickness

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Need to correlate acceptance limits with aircraft/pilot requirements (e.g., smoothness vs. dynamic response of aircraft)

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Jeff Rapol & Rodney Joel (combined)*

2. Agency: *FAA AAS-100*

3. Date of Interview: *10/23/07*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Braking Action (speed related)*

   Friction

   Visibility of markings

   b. Taxiways *Pavement condition has minimal impact on aircraft performance*

   c. Aprons *Pavement condition has minimal impact on aircraft performance*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   Flushing leads to reduced friction

   Surface texture and "fineness" will affect friction

   Durability defined by thermal and block cracking and groove closure

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 15-17 yrs
   b. Taxiways? 15-17 yrs
   c. Aprons? 15-17 yrs

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. *Surface Texture*
   b. *Resistance to rutting and surface deformation*
   c. *Good durability – no raveling, cracking and "disintegration"*
   d. *Need to differentiate between RW ends and middle*

e. ______________________________

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
      Severe cracks filled with excess sealant
      ____
      Surface texture
      ____
      Rutting and surface deformation
      ____
   b. Development of Foreign Object Damage potential?
      Severe cracking
      ____
      Raveling
      ____
   c. Development of pavement maintenance needs?
      Severe cracking
      ____
      Raveling
      ____

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Density; Air Voids; % AC
____
Aggregate gradation, quality and optimum amount of "dust (p200): affects rut resistance & surface texture
Asphalt Quality
____
Asphalt film thickness
____

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    a. *Rut resistance*
    b. *Durability*
    c. ______________________________
    d. ______________________________
    e. ______________________________

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?
    Rutting, but to a lesser degree than RW due to operational speed

    b. Development of Foreign Object Damage potential?
    Durability

    c. Development of pavement maintenance needs?
    Durability

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?
    Same as Runway

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Static Indentation*
    b. *Scrubbing and shoving (from turning action)*
    c. *Durability*
    d. *Fuel and glycol resistance*
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?
    Little or none

    b. Development of Foreign Object Damage potential?
    Engine runup

    c. Development of pavement maintenance needs?
    Durability: keep FOD down

    Crack deterioration

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?
    Same as RW

16. What HMA characteristic(s) do you believe are most important in affecting durability?
    Current P-401 requirements are believed to be adequate

    % AC and quality of asphalt binder

    Density and air voids

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?
    Aggregate gradation

    Aggregate shape (coarse and fine)

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?
    Straight-edge and High speed profiler

    Adherence to design grade

    Don't need different methods, but do need different criteria

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?
    Multiple passes with inertial profiler for longitudinal and straight-edge for transverse

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?
    Relate the measurement to dynamic aircraft performance (response)

    (review status of simulator experiment planned by Dr Hayhoe of FAA NAPTF)

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?
    Friction

    Smoothness

    Lack of FOD

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?
    Durability - Lack of FOD

    Friction

    Structural performance, i.e., ability to withstand loads and tire pressures

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?
    Need a good definition of "performance based"

    Now, we are using indicators and NOT performance related tests

    Need also to look at sensitivity of tests in indicating or defining performance

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: Michael Roginski
2. Agency: Boeing
3. Date of Interview: 11-01-2007
4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways Landing and takeoff length requirements

   b. Taxiways Turning maneuvers

   c. Aprons Refueling of aircraft

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

____

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? 12 yrs
   b. Taxiways? 14 yrs
   c. Aprons? 14-20 yrs

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Lack of friction
   b. Excessive Roughness
   c. Ravelling-loose debris
   d. Badly sealed joints
   e. ______________________

8. How do distresses from question 7 relate to the following:
    a. Directional control of the aircraft?

Excessive roughness or lack of surface friction may lead to loss of pilot control of aircraft

    b. Development of Foreign Object Damage potential?

Ravelling and badly sealed joints leads to FOD and possible engine damage

    c. Development of pavement maintenance needs?

Rubber removal and timely seal coating typically help alleviate some of the more common performance issues.

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Proper compaction of HMA and joints.

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. Ravelling
    b. Joint cracks
    c. ______
    d. ______
    e. ______

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

NA

    b. Development of Foreign Object Damage potential?

Could lead to ingestion by engines

    c. Development of pavement maintenance needs?

Timely seal coating typically solves problem

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Same as for runways, however higher grade binder would be better for slower moving traffic.

13. What are the key **apron** pavement characteristics/distresses? Please list:

    a. Fuel spillage leading to breakdown of asphalt binder and FOD potential on apron

    b. ____

    c. ____

    d. ____

    e. ____

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

       NA

    b. Development of Foreign Object Damage potential?

       Definite FOD concern

    c. Development of pavement maintenance needs?

       Fuel resistant HMA should solve problem

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

    Use of fuel resistant HMA

16. What HMA characteristic(s) do you believe are most important in affecting durability?

    Controlling air voids- approx. 4-6% and using proper grade of asphalt

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

    Good aggregate angularity, no rounded stones
    Proper compaction and meet stability spec

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

We at Boeing are mainly concerned with the level of smoothness after initial construction. Runway roughness is a concern for aircraft landing gear and gets worse with pavement age.

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

No comments

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

No

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Jack Scott*

2. Agency: *FAA, Northwest Region*

3. Date of Interview: *8 Nov. 2008*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *Lack of FOD; smoothness (especially at joints); durability; integrity of grooves; friction and braking action (most important)*

   b. Taxiways *Lack of FOD; durability; groove integrity (esp. for high speed TW); braking action (high speed TW)*

   c. Aprons *Lack of FOD; durability; fuel spill resistance; Lack of static indentation*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

   ALL

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *12.5*
   b. Taxiways? *15*
   c. Aprons? *15*

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. *Long. Joint cracking; Joint raveling & deterioration;*
   b. *Groove closure; smoothness*
   c. *Stripping; segregation*
   d. *Oxidation (raveling); surface drainage*

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?
   Long joint cracks & deterioration; depressions/ponding
   b. Development of Foreign Object Damage potential?
   Cracks; raveling; oxidation; segregation
   c. Development of pavement maintenance needs?
   All, but poor joints mainly

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Fractured faces; gradations; limit on natural sand; binder characteristics; compaction;

Air voids & volumetrics; grade; film thickness & stripping potential

10. What are the key **taxiway** pavement characteristics/distresses? Please list:
    a. *Long. Joint cracking & raveling*
    b. *Stripping*
    c. *Oxidation*
    d. *Rutting*
    e. *Surface drainage; Smoothness (not as important as RW)*

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?
    Smoothness (not as important as RW)
    Cracking
    Rutting
    b. Development of Foreign Object Damage potential?
    Cracking; raveling; oxidation; stripping
    c. Development of pavement maintenance needs?

ALL

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Same as runway, but more so due to channelized traffic

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Same as runway*
    b. *Also, static indentation and fuel spill damage*
    c.
    d.
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?
       Not much
    b. Development of Foreign Object Damage potential?
       Same as runway
    c. Development of pavement maintenance needs?

ALL

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?
    Same as runway and taxiway

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Binder type; air voids; compaction; aggregate quality; fractured faces;

Film thickness; stripping potential

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Aggregate fractured faces; compaction; air voids; binder type

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Use combo of profilograph, grade and straight edge

Same methods but different limits for RW and TW

Different methods and criteria for aprons due to short pull lengths

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Need criteria for precision survey

More specific criteria for straight edge (where and how to measure

Need uniform standard for profilograph

Inertial profiler and lasers preferred

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

See answer to question 19

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Friction; smoothness; lack of FOD

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Smoothness; density; air voids; VMA and/or film thickness

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Water in pavement section is one of major factors causing deterioration

Performance based specification is way to go, and if done right it shouldn't

cost more

More reliance on NCAT oven

EXPERT AND AIRCRAFT MANUFACTURER INTERVIEW FORM

1. Interviewee Name: *Monte Symon*

2. Agency: *Auburn University*

3. Date of Interview: *24 October 2007*

4. What typical aircraft operational/performance characteristics do you believe are influenced by the quality of the runway, taxiway and/or apron pavements?

   a. Runways *1.Braking action; 2. rideability (smoothness); 3.lack of FOD that may injure engine or air frame*

   b. Taxiways *Same, but less so for 1 and 2*

   c. Aprons *Same, but less so for 1 and 2*

5. How does the quality of the pavement influence the aircraft operational/ performance characteristics from question 4?

Consider using "critical aircraft concept for measuring dynamic response

6. In your opinion, what is the average life of an asphalt surface or overlay for:

   a. Runways? *11-12 yrs*
   b. Taxiways? *Less due to higher strains from slow speed opera*tion
   c. Aprons? *Same as TW*

7. What are the key **runway** pavement characteristics/distresses? Please list:

   a. Friction

   b. Smoothness

   c. Grade

   d. Lack of FOD (durability)

   e. __________

8. How do distresses from question 7 relate to the following:
   a. Directional control of the aircraft?

Roghness (deviation from design profile);

Bumps, i.e., abrupt changes

   b. Development of Foreign Object Damage potential?

Ravelling

High dynamic response (aircraft/pavement interaction) causing dislodgements

   c. Development of pavement maintenance needs?

Grade adjustments (overlay/inlay) due to deviations

Seal Coat

9. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **runways**?

Stability

Smoothness

Durability

10. What are the key **taxiway** pavement characteristics/distresses? Please list:

    a. *Fatigue problems due to stop/start operation and "idling"*
    b. *Stability problems due to start/stop operation and "idling"*
    c. *Durability*
    d. *Generally ,slow speeds exacerbate prblems*
    e.

11. How do distresses from question 10 relate to the following:
    a. Directional control of the aircraft?

Not an issue

    b. Development of Foreign Object Damage potential?

Ravelling

c. Development of pavement maintenance needs?

12. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **taxiways**?

Stability and durability

13. What are the key **apron** pavement characteristics/distresses? Please list:
    a. *Fuel spill durability*
    b. *Static Indentation*
    c.
    d.
    e.

14. How do distresses from question 13 relate to the following:
    a. Directional control of the aircraft?

NA

b. Development of Foreign Object Damage potential?

c. Development of pavement maintenance needs?

Fuel resistant seal coat

15. What key aspects of a HMA construction specification do you believe are most important in controlling the development of the distresses identified for **aprons**?

Rut resistance

Fuel resistance

16. What HMA characteristic(s) do you believe are most important in affecting durability?

Type (grade) of asphalt

Maximum aggregate size

17. What HMA characteristic(s) do you believe are most important in affecting structural performance?

Aggregate structure

Aggregate strength

18. How should pavement smoothness be evaluated for compliance with specifications? Should different methods be used for runways, taxiways, and aprons?

Indexes, such as IRI, don't do well – bump criteria is better

Profile measurements

19. Do you have any suggestions for improvement in measurement methods for compliance with smoothness specifications?

Ability to acquire large amounts of data in a short time

Ability to rapidly measure transverse smoothness (can't link profiler measurements

20. Do you have any suggestions for improvement in acceptance criterion for smoothness specifications?

Ensure initial smoothness to increase longevity

21. What are the key operational pavement characteristics that should be considered in evaluating the performance of airport pavements?

Directional control

22. What are the key acceptance quality characteristics to include in a performance-based specification to control these operational characteristics?

Smoothness and bump (they are different)

23. Do you have any additional comments to make regarding pavement performance or performance-based specifications?

Dynamic aircraftresponse simulation

Deflection (e.g., FWD) measurements

APPENDIX D

RESEARCH NEEDS STATEMENTS

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Long-term performance evaluation of asphalt airfield pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

The commercial aviation industry has taken on increasing importance in our nation's economy serving to keep our nation connected with the rest of the world. The airports serving this industry represent a significant investment in our economy contributing an estimated $640 billion.(1) Keeping aircraft moving requires low maintenance, long lasting aviation pavements. Determining what makes an airfield pavement long-lasting and low-maintenance requires data on pavement performance, as-constructed materials, pavement designs, traffic, load response and climatic conditions.

Commercial airports are required by the Federal Aviation Administration to maintain a pavement management system to aid them in developing maintenance and rehabilitation decisions. These systems generally will identify the different construction events occurring on the pavement, the traffic on each feature, the pavement structure of each feature, and the pavement condition. Some pavement management systems contain additional information regarding cost of construction activities.

These systems rarely contain the detailed information necessary about the as-placed materials required to develop performance models. The pavement structure provides a significant contribution to the pavement performance, but an asphalt material that is constructed with an improper binder will be subject to either premature rutting or premature cracking. In other cases, the effect is more obvious when the as-constructed property is compared to the as-designed property. For instance, identification that the as-constructed asphalt content is 4 percent is of very little use unless it is also known that the design asphalt content is 6 percent.

Therefore a database is required that will house this research level information collected from airports across the nation which can yield the data required to develop a better understanding of aviation pavement performance. An important element of the database would be restrictive protocols designed to reduce variability in the data. Variability is a consequence of testing differences, uncontrolled data collection procedures and data handling and a variety of other sources.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of this project is to develop the procedures necessary to consistently collect the materials, performance, traffic, load response and climatic data required to improve our understanding of airfield pavement performance. A second objective is to develop a database to house the data collected using these protocols.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Experiment design and project selection

Task 2. Data collection protocols for monitoring data

Task 3. Data collection protocols for climatic data

Task 4. Data collection protocols for materials data

Task 5. Data collection protocols for traffic data

Task 6. Database design and development

Task 7. Data processing and storage

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is xx months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

Improved data collection protocols yield better understanding of the data being collected. In order to develop these protocols, it is necessary to identify the elements that contribute to the variability of the data being collected. Once these elements have been identified, it is much easier to develop methodologies that may be used to reduce the variability in the data collection. Ultimately, reduction in the variability of the collected data yields better data and improved decisions based upon that data.

A system is needed to house the kind of detailed information required to gain a better understanding of pavement performance. This type of system would provide the data required to develop performance models which can be used to develop performance-based specifications, improve pavement design procedures, and improve methods used in maintenance and rehabilitation decision-making processes.

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1. Budget in Brief: Fiscal Year 2009, Federal Aviation Administration, Washington, DC, February 2008.
2. *Data Collection Guide for Long-Term Pavement Performance Studies*, Federal Highway Administration, Pavement Performance Division, LTPP Division, McLean, Virginia, revised October 1993.
3. *Guidelines for the Collection of Long-Term Pavement Performance Data*, Federal Highway Administration, Pavement Performance Division, LTPP Division, McLean, Virginia, July 2005.
4. *Long-Term Pavement Performance Inventory Data Collection Guide*, Federal Highway Administration, Pavement Performance Division, LTPP Division, McLean, Virginia, July 2005.
5. *Long-Term Pavement Performance Project Laboratory Materials Testing and Handling Guide*, Federal Highway Administration, Pavement Performance Division, LTPP Division, McLean, Virginia, September 2007.

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Evaluation of pavement profile on airfield pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

Smoothness has been identified as one of the key factors in evaluating pavement for construction acceptance on roadways and airfield pavements. Research has been completed on evaluating roadway roughness to identify what wavelengths of roughness effect vehicle operations and driver comfort. This information has been useful in developing the equipment that may be used in collecting these data and how the data are analyzed to evaluate the roadway roughness.

Some work has been completed in airfield roughness to identify methods of evaluating pavement roughness. The Boeing Bump Index (BBI) was developed to evaluate the impact of pavement roughness on the aircraft frame. The aircraft landing gear do not respond in a manner similar to roadway vehicles. Generally, the landing gear struts are more rigid than automobile suspension systems so that they can absorb the load at landing.

Other research has been completed to develop a method to simulate the forces felt in the cockpit of the aircraft. The simulation allows airfield management personnel the opportunity to identify when pavement roughness has reached a level that interferes with pilot control of the aircraft. However, the characteristics of the pavement roughness interfering with pilot control may be different for different types of aircraft due to the differences in landing gear configuration and size of aircraft. The exact nature of the difference roughness characteristics effecting pilot control of aircraft are not known.

These methods for evaluating pavement roughness do not identify the wavelengths of pavement roughness that impact aircraft operations. Without understanding which wavelengths are important, it is difficult to specify what type of equipment are required for collecting roughness data or the limits that should be set on roughness for either construction acceptance or pavement management purposes.

Further, the factors affecting the development of the pavement characteristics resulting in these types of roughness (both the roughness affecting aircraft operations and pilot control) are not known. Models have been created to estimate roughness in highway pavements which are primarily related to other distresses. The model developed for highway pavements is related to the International Roughness Index (IRI). The IRI is intended to identify ride quality as it related to automobiles which have vastly different operational characteristics than aircraft. Therefore, this model will not be sufficient for estimating the development of roughness affecting aircraft operations or pilot control.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objectives of this research effort include:

(1) Identify the wavelengths of roughness that impact pilot control and aircraft dynamics
(2) Develop limiting criteria for use in evaluating pavement smoothness for construction acceptance
(3) Develop models to estimate the development of roughness as it relates to aircraft dynamics and pilot control

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review to identify prior work in this area and to identify potential model forms

Task 2. Develop database of characteristics of different types of aircraft

Task 3. Perform simulation to evaluate the wavelengths of roughness that impact the Boeing Bump Index

Task 4. Perform simulation to identify wavelengths of roughness impacting the forces observed in the cockpit using ProFAA. Simulation should be performed for a range of commercial aircraft.

Task 5. Interim Report - Draw some conclusions about wavelengths effecting aircraft based on differences and similarities observed between aircraft and between the two evaluation methods.

Task 6. Identify appropriate methods for measuring pavement roughness given wavelength study

Task 7. Set limitations on roughness to be used for construction acceptance.

Task 8. Identify data source for model development

Task 9. Develop models for estimating pavement roughness

Task 10. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $500,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 48 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The results from this research will provide improved understanding in the steps that need to be taken in measuring and evaluating roughness on airfield pavements. Identifying the specific wavelengths that need to be captured provides key information in identifying the characteristics of the equipment required to collect the roughness data and improve roughness data collection on airfield pavements.

The project is expected to provide key information in implementing improvements in roughness specifications that can lead to improved pavement performance. Specifically, the improvements will assist in identifying maximum levels of roughness that should be present on a newly constructed airfield pavement. These improvements are expected to leave in improvements in pavement performance with respect to roughness which will in turn yield improvements in aircraft performance requiring less maintenance over time, increased pilot satisfaction with airfield pavements, decreased maintenance requirements of the airfield pavements, and increases in overall pavement life.

The product from this research is expected to take the form of a report. The results will lead directly to improvements in the Federal Aviation Administration's P-401 specification for hot-mix asphalt. In order for the improvements to be fully implemented, it will be necessary for the FAA to adopt changes to the P-401 specification to incorporate the improvements developed as part of this project.

Finally, a model is needed to estimate the development of roughness for a variety of reasons. A model that can estimate the development of roughness based on pavement characteristics could improve the pavement design process. This type of model could result in a pavement section that is more resistant to roughness development.

This model will assist in the implementation of performance-based specifications allowing the agency to set limits based on factors that are known to impact the performance of the constructed pavement section. Completing construction acceptance evaluation based on the anticipated performance of the as-placed pavement structure has been identified as the best means for defining construction acceptance. A roughness model will identify quality characteristics that are directly related to roughness development. Further these models can be used to develop limits on the quality characteristics that are related to expected performance of the pavement.

A third improvement resulting specifically from the development of a roughness model is related to pavement management. In order to identify the appropriate timing of maintenance treatments on a pavement estimating the development of distress over time is key. A roughness model will improve the ability of pavement professionals to estimate future distress and, subsequently, better determine appropriate treatments to mitigate roughness development.

REFERENCES

DeBord, K.J., **Runway Roughness Measurement, Quanitification, and Application – The Boeing Method**, Boeing Document D6-81746, Boeing Commercial Airplane Group, 1990.

Hayhoe, G.F., M. Dong, and R.D. McQueen, "Airport Pavement Roughness with Nighttime Construction," **Proceedings of the Third ICPT Conference**, Beijing, China, April 1998.

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Development of cracking models for asphalt airfield pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

In order to complete development of a performance-based specification for HMA pavements on airfields, it will be necessary to establish how those pavements deteriorate in terms of cracking. The premise of a performance-based specification requires that the limits set on the various acceptance quality characteristics are based on their effect on the pavement performance. Cracking is one of the key performance characteristics that should be used in developing these limits.

Cracking occurs as the result of a variety of different mechanisms. The most obvious is related to the load applied to the pavement by the traffic traversing the pavement structure. A load-related cracking model is currently part of the FAA pavement design software FAARFIELD. The fatigue cracking model is currently an optional calculation within FAARFIELD because the permanent deformation model dominates in the pavement design calculations. Given this domination, it is fairly obvious that the cracking model in FAARFIELD should be reviewed and calibrated to improve its ability to estimate cracking on a pavement section. The calibration effort would include review of the cumulative damage factors associated with the climate to accumulate damage associated with seasonal variability in an appropriate manner, e.g., at high temperatures, a lower asphalt modulus results in lower cracking-related damage.

Another cracking mechanism is due to environmental stresses. In this case, the environmental stresses caused by temperature changes which result in expansion and contraction of the pavement materials. The Mechanistic-Empirical Pavement Design Guide (MEPDG) incorporates a model for estimating thermal cracking in the asphalt material. This model was developed for highway conditions; however, the basic mechanisms involved with cracking of asphalt materials due to environmental distresses should be the same. However, the calibration of the model as it exists for roadway pavements may not be directly applicable to airfields; therefore, the model should be reviewed and calibrated for airfield pavements.

A third cracking mechanism is related to reflection cracking. This type of cracking occurs primarily in overlays of existing pavements. The basic mechanism is strain concentration in the overlay due to movement in the existing pavement in the vicinity of either joints or cracks. The movement in the existing pavement may be the result of either vehicular loading or stresses caused by changes in temperature due to either daily or seasonal variations. NCHRP project 1-41 is in process of improving existing models for joint reflection cracking on roadways. However, similar to the thermal cracking model identified above, a model that is effective at estimating cracking on roadways is not necessarily directly applicable to airfield pavements.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of this project is to review and calibrate models to estimate the occurrence of cracking on asphalt pavements. The project is expected to result in improved models for estimating cracking.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review to identify prior work in cracking model development

Task 2. Identify potential models for fatigue cracking, thermal cracking, and reflection cracking.

Task 3. Identify data for use in calibration process with potential for full-scale testing at the National Airport Pavement Test Facility.

Task 4. Interim report and Phase II work plan.

Task 5. Perform revision and calibration of models.

Task 6. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $500,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 48 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The research will result in improved ability to estimate cracking on flexible pavements from the three primary mechanisms that cause this distress. These improved cracking models lead to a variety of improvements in pavement design and management. The first improvement is related to pavement design. At present, the pavement design is dominated by the permanent deformation model which is not necessarily reflective of how pavements actually perform in the field. Improvements in the cracking models could identify a need for a different pavement section or reduced base thickness to mitigate the occurrence of cracking in the pavement section.

A second improvement is related to construction acceptance evaluation of the as-placed asphalt concrete. Completing construction acceptance evaluation based on the anticipated performance of the as-placed pavement structure has been identified as the best means for defining construction acceptance. Improved cracking models provide a means for developing performance-related specifications. These cracking models identify quality characteristics that are directly related to crack development. Further, these models can be used to develop limits on the quality characteristics that are related to the expected performance of the pavement.

A third improvement is related to pavement management. In order to identify the appropriate timing of maintenance treatments on a pavement estimating the development of distress over time is key. Improved cracking models will improve the ability of pavement professionals to estimate future distress.

In summary, the calibrated cracking models will lead to improved pavement performance and life cycle which ultimately result in reduced budgetary requirements to maintain the same pavement network.

REFERENCES

1. "Airport Pavement Design and Evaluation," FAA 150/5320-6E, Federal Aviation Administration, Washington, D.C., November 20, 2007.

2. *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, National Cooperative Highway Research Program, Washington, D.C., March 2004.

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Permanent deformation model calibration for asphalt airfield pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

There are two primary mechanisms for the occurrence of permanent deformation in asphalt pavements. The first is the result of densification of the material within the pavement structure. This densification results in uniaxial movement of the pavement surface. Due to the limited amount of voids generally present in the pavement materials, the amount of permanent deformation due to densification is generally limited.

The second mechanism is the result of plastic flow of the material. The ruts that will occur as a result of plastic flow are generally accompanied by humps on the sides of the rut which are the result of movement of the material. This plastic flow may occur within any layer in the pavement structure. For instance, when the flow is primarily the result of deficiencies within the asphalt layer, the rutting may also be accompanied by bleeding or stripping of the asphalt concrete.

The model used by the FAA in performing mechanistic design of flexible pavements is related to the vertical strain at the top of the subgrade. In other words, this model only estimates the permanent deformation occurring at the top of the subgrade. Any permanent deformation occurring higher within the pavement structure, i.e. within one of the other layers, is ignored by this model. Ignoring the permanent deformation occurring in the other pavement layers can lead to an underestimation of the expected distress.

The Mechanistic-Empirical Pavement Design Guide (MEPDG) developed under the National Cooperative Highway Research Program project 1-37A for highways includes a model for estimating permanent deformation from each layer of the pavement structure. The MEPDG uses separate models for each type of material in the pavement structure to estimate the permanent deformation occurring within individual layers. These individual estimates are summed to provide the estimate of the total permanent deformation. The individual models for each material relate the permanent deformation to standard material properties. However, these models have been calibrated to estimate rutting on highway pavements.

The requirements of airfield pavements and highway pavements are very different and a model calibrated for a highway pavement may not be directly applicable for an airfield pavement. Highway pavements have to accommodate the geometric characteristics of personal and commercial vehicles and provide a safe and comfortable ride at the posted highway speed limits. In comparison, airfield pavements have to accommodate large and small aircraft; commercial, personal or military. Unlike vehicles, aircraft have more unique characteristics as far as geometry and loading. Airbus 380 for example has a wing span of over 260 feet, and a length slightly under 240 feet. Tire configurations (landing gear) vary from one aircraft to another and tire pressures can reach 300 psi for military aircraft. Total loads also vary greatly from one aircraft to another but are usually considerably higher than those seen on highway pavements. Therefore, the operational characteristics of airfield pavements and highway pavements are similar but with contrasting characteristics that have to be understood. In order to estimate the permanent deformation occurring within each layer of the pavement structure, the models associated with the highway pavements will need to be re-calibrated for airfield pavement conditions.

Work has been initiated by the Federal Aviation Administration (FAA) in cooperation with Boeing, Airbus, and ICAO to evaluate the impact of high tire pressures on asphalt airfield pavements. This work includes testing using the FAA's National Airport Pavement Test Facility to evaluate full-scale sections under accelerated loading conditions and laboratory testing of various asphalt mixtures. The full-scale sections have been equipped with heating coils to heat the pavement to simulate warm climatic conditions. Any research undertaken on this subject will need to identify the results of this work by the FAA

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of this project is to review and calibrate models to estimate permanent deformation in the various layers of a flexible pavement structure on airfield pavements. The project is expected to result in an improved model to estimate permanent deformation on airfield pavements.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review to identify potential models for each material type

Task 2. Identify data for use in calibration process.

Task 3. Interim report and Phase II work plan.

Task 4. Perform revision and calibration of models.

Task 5. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $450,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 36 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The research will result in an improved ability to estimate permanent deformation on flexible pavements from the various layers of the pavement structure and not just the top of the subgrade. These improved permanent deformation models lead to a variety of improvements in pavement design and management. The first improvement is related to pavement design. At present, the permanent deformation model used in designing airfield pavements estimates the vertical strain at the top of the subgrade. The amount of strain is not estimated for at any other location within the pavement structure. Improved estimates from other parts of the pavement structure will lead to improved pavement designs that are more resistant to rutting in each layer.

A second improvement is related to construction acceptance evaluation of the as-placed asphalt concrete. Completing construction acceptance evaluation based on the anticipated performance of the as-placed pavement structure has been identified as the best means for defining construction acceptance. An improved permanent deformation model will provide a means for developing performance-related specifications. These permanent deformation models identify quality characteristics that are directly related to the expected performance of the pavement.

A third improvement is related to pavement management. In order to identify the appropriate timing of maintenance treatments on a pavement estimating the development of distress over time is key. An improved permanent deformation model will improve the ability of pavement professionals to estimate future distress. Better estimates of future distress lead to better decisions about maintenance treatments to apply and subsequently improved life expectancy of the in-place pavement structure. Ultimately, an improved permanent deformation model can lead to more efficient use of State highway agency budgets.

REFERENCES

1. "Airport Pavement Design and Evaluation," FAA 150/5320-6E, Federal Aviation Administration, Washington, D.C., November 20, 2007.

2. *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, National Cooperative Highway Research Program, Washington, D.C., March 2004.

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Performance test for evaluation of as-constructed asphalt airfield pavement

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

Construction quality control testing requires that testing be simple to perform and provide rapid results. Testing must be sufficiently simple to allow it to be performed in the field. If a test cannot be used to provide results in a quick fashion, valuable time is lost by the contractor in determining if/where adjustments need to be made in the construction process to achieve a quality product. Additionally, the test performed must be sensitive to changes in mixture characteristics that can be controlled by changes in the construction process. These tests also need to be directly related to the performance of the pavement.

Test procedures commonly used include evaluating mix composition through density, gradations and asphalt content. These characteristics can influence mixture performance, but they do not provide a direct indication of performance. One vital element of a performance-based specification is a test procedure that may be used for construction acceptance that is directly related to the performance of the material being evaluated.

NCHRP 9-18 refined the field shear testing device to attempt to make this approach to performance testing for use with construction quality control more feasible for use in that sort of environment. However, this project also identified that the test procedure provided results that were too variable to provide meaningful results for use in construction quality control. NCHRP 9-18(01) was undertaken to develop improvements in the protocol used for completing testing with the FST. Both the results of complex shear modulus testing using the FST and the indirect diametral tensile strength were identified as being sensitive to changes in mixture composition.

NCHRP 9-18(01) identified the need for further study of these test methods and their applicability to construction acceptance testing. This further study will provide a means for any agency attempting to implement a performance-related or performance-based standard to incorporate a performance test procedure into that standard.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of the research will be to identify an appropriate performance test for construction acceptance testing of asphalt mixtures placed on airfield pavements and develop guidelines for their use.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review

Task 2. Identify existing tests with potential for field evaluation

Task 3. Design field experiment – field experiment should make use of construction projects at airfields

Task 4. Perform field experiment

Task 5. Recommendations for modification of test procedures

Task 6. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $400,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 48 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended *test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?*

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The true measure of the quality of an asphalt mix is the performance of that mix. Additionally, contractors and owner agencies agree that the best approach for defining construction acceptance is using characteristics that are directly related to mixture performance. In the past, these performance characteristics have been inadequate for use in construction acceptance testing because they do not lend themselves to field evaluation. The IDT and FST have been shown by NCHRP Projects 9-18 and 9-18(01) to yield a measure that may be sufficiently simple for field evaluation and are directly relatable to both performance and to changes in mixture composition.

The results of this research will provide a direct means for implementing these test procedures into routine construction acceptance testing. They will improve our ability to implement performance-related specifications into daily practice.

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Development of models for FOD potential on asphalt airfield pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

Foreign Object Damage (FOD) is estimated to cost the aerospace industry $4 billion each year.(1) FOD may develop from a number of sources including birds, tools or other debris left on the pavement surface, or deterioration of the pavement itself. As cracks develop on asphalt pavements, they increase in severity by becoming wider and by spalling such that chunks of the asphalt surface break off and become loose fragments that result in FOD potential. Raveling and weathering lead to loose aggregate on the pavement surface increasing the potential for this costly damage.

An approach has been developed to evaluate overall FOD potential of a pavement segment for the purposes of pavement management.(2) This approach incorporates the use of the distresses that provide moderate to high FOD potential and the procedure used to determine the Pavement Condition Index. This approach allows the airport operator to identify the relative potential for FOD on pavement segments across the airport. The primary contributor to this FOD index on asphalt pavements is moderate and high severity cracking.

Although an approach has been developed to evaluate existing FOD potential, there is no means for estimating the development of FOD potential over time. This evaluation will require the development of more than one model because it will need to consider the various distresses which result in FOD potential. One example would be in modeling the development of severity levels of cracking on these pavements. Cracking occurs as the result of a variety of mechanisms including load-related and climate-related. Another distress that would require modeling is raveling and weathering. The primary cause of raveling and weathering is believed to be segregation and other problems occurring during mix design/production and pavement construction. Because the mechanisms associated with the development and worsening of these two distresses is very different, different models will be required.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of this project is to develop models for forecasting FOD potential on asphalt airfield pavements.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review to identify prior work and potential model forms

Task 2. Identify potential model forms and inputs for forecasting distresses associated with FOD potential including development of cracking severity and raveling and weathering.

Task 3. Identify data for use in calibration process.

Task 4. Interim report and Phase II work plan.

Task 5. Perform revision and calibration of models.

Task 6. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $400,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 36 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product *should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?*

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The research will result in models that will allow for forecasting the development of FOD potential. This type of model leads to a variety of improvements in pavement construction and management. One improvement is related to construction acceptance evaluation of the as-placed asphalt concrete. Completing construction acceptance evaluation based on the anticipated performance of the as-placed pavement structure has been identified as the best means for defining construction acceptance. A model for FOD potential provides a means for developing performance-related specifications that mitigate the development of that distress. The model will identify quality characteristics that are directly related to FOD potential. Further, this model can be used to develop limits on the quality characteristics that are related to the expected performance of the pavement.

Another improvement is related to pavement management. In order to identify the appropriate timing of maintenance treatments on a pavement estimating the development of distress over time is key. A FOD potential model will improve the ability of pavement professionals to estimate future distress.

REFERENCES

1. FOD NEWS, FOD Defined, www.fodnews.com/fod-defined.html. Accessed May 19, 2009.

2. Keegan, K., S.D. Murrell, G. Zummo, and G.R.Rada, "Assessment and Rehabilitation of Foreign Object Damage Potential on Airfield Shoulder and Blast Pavements: Case of John F. Kennedy International Airport, New York," Transportation Research Record No. 1915, Transportation Research Board, National Academy of Sciences, Washington, D.C., 2005, pp 105-111.

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Development of friction deterioration model on asphalt airfield pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

Loss of friction on an airfield pavement is a safety issue. FAA AC 150/5320-12C "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces" is dedicated to maintaining minimal friction levels on airfield pavements through appropriate construction and maintenance practices. However, this advisory circular does not deal with forecasting the loss of friction over time.

Surface friction results from two primary sources: water on the pavement surface and changes in the pavement macro- and micro-texture. Water on the pavement surface is caused by rutting and other deformation of the pavement surface that prevents water from draining. This trapped water leads to hydroplaning of aircraft particularly at high speeds.

The other mechanism is associated with polish of the pavement surface. Wear in the pavement texture results in a slippery pavement surface and overall loss of friction. The wear is primarily due to loss of friction in the aggregate surface texture meaning that the aggregate characteristics are of primary concern when considering how to prevent loss of surface friction.

No method has ever been developed to estimate changes in surface friction over time. This effort would require the development of two models to cover both mechanisms associated with loss of friction. Development of each of these models could be quite complex. For instance, a model to forecast the hydroplaning mechanism involves the non-linear behavior of the pneumatic tire, the complex fluid flow and the non-homogeneous pavement surface characteristics. At present, the NASA hydroplaning equation seems like most widely used model for determining the speed at which hydroplaning occurs: $V = 6.36(p)^{0.5}$ where V is the hydroplaning speed in km/h and p is the tire inflation pressure in kPa.

Even though no model has been developed, such a model would provide a means for airport operators to make better maintenance decisions on their pavements and provide an opportunity to develop a performance-based specification that incorporates characteristics impacting loss of friction.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of this project is to develop a model for forecasting loss of friction on asphalt airfield pavements.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review to identify prior work and potential model forms

Task 2. Identify potential model forms and/or input variables for forecasting loss of friction and hydroplaning.

Task 3. Identify data for use in calibration process.

Task 4. Interim report and Phase II work plan.

Task 5. Perform revision and calibration of models.

Task 6. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $200,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 30 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The research will result in a model that will allow for forecasting loss of friction on asphalt pavement surfaces. This type of model leads to a variety of improvements in pavement design and management. The first improvement is related to mixture design. A model that forecasts loss of friction and hydroplaning could provide a means for screening material sources for use in asphalt surface mixtures.

A second improvement is related to construction acceptance evaluation of the as-placed asphalt concrete. Completing construction acceptance evaluation based on the anticipated performance of the as-placed pavement structure has been identified as the best means for defining construction acceptance. A model for loss of friction provides a means for developing performance-related specifications that mitigate the development of friction loss. The model will identify quality characteristics that are directly related to loss of surface friction. Further, this model can be used to develop limits on the quality characteristics that are related to the expected performance of the pavement.

A third improvement is related to pavement management. In order to identify the appropriate timing of maintenance treatments on a pavement estimating the development of distress over time is key. A model forecasting loss of friction will improve the ability of pavement professionals to estimate future distress.

REFERENCES

1. "Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces." *FAA Advisory Circular No. 150/5320-12C*, Federal Aviation Administration, U.S. Department of Transportation, Washington, DC (February 7, 2007)

FORMAT OF RESEARCH NEEDS STATEMENT FOR POSTING ON TRB WEBSITE

I. RESEARCH NEEDS TITLE

Development of model to forecast raveling and weathering on asphalt pavements

II. RESEARCH NEEDS STATEMENT

A statement of general problem or need -- one or more paragraphs explaining the reason for research Be explicit about how the intended research product will be used and by whom.

(Note: A TRIS Online literature search <http://ntl.bts.gov/tris> is encouraged to avoid duplication with existing or past research. If a literature search is performed, general comments on the results should be provided.)

Raveling and weathering is the wearing away of the pavement surface due to loss of binder resulting in dislodged aggregate particles. Any small particulate matter on the pavement surface results in the potential for foreign object damage (FOD) to aircraft. FOD is estimated to cost the aerospace industry $4 billion each year.(1) Developing an understanding of the causes of raveling and weathering and methods that can be used to prevent this distress could lead to savings of hundreds of thousands of dollars to the industry.

Pavement engineers believe that the primary causes of raveling and weathering are related to segregation and other problems occurring during mix design/production and pavement construction. However, the nature of the contributions of each item and the size of the contribution from each cause is not known. No work has been performed to attempt to forecast the occurrence of raveling and weathering on asphalt pavements.

Although a weathered pavement surface results in increased FOD potential, it also results in an increase in friction. A model that can be used to estimate the occurrence of raveling and weathering may be useful in assisting airport operators in balancing the resulting increase in friction and increase in FOD potential.

III. RESEARCH OBJECTIVE

A statement of the specific research objective, defined in terms of the expected final product, which relates to the general needs statement in III above. Define specific tasks necessary to achieve the objective.

The objective of this project is to develop a model for forecasting raveling and weathering on asphalt pavements.

The key tasks to accomplish the objective of this research are listed below. These tasks are intended to provide a framework for conducting the research. The objective is to develop a research plan that demonstrates consideration to the issues raised in the objective, an understanding of the problem, and a description of the research effort that can realistically be conducted within constrains of available funds and contract time.

Task 1. Perform literature review to identify prior work and potential model forms

Task 2. Identify potential model forms for forecasting raveling and weathering – an empirical model form may be necessary. In which case, this task should identify the potential variables to use in such a model.

Task 3. Identify data for use in calibration process.

Task 4. Interim report and Phase II work plan.

Task 5. Perform revision and calibration of models.

Task 6. Final Report

IV. ESTIMATE OF FUNDING AND RESEARCH PERIOD

Recommended Funding:

An estimate of the recommended funding levels to accomplish the objectives stated in item III is $200,000.

Research Period:

An estimate of the number of months to complete the research effort, including three months for preparation of a draft report to accomplish the research objectives identified in item III is 30 months.

(Note: These estimates may be changed by the AASHTO Standing Committee on Research to fit the problem into the broad program.)

V. URGENCY, PAYOFF POTENTIAL, AND IMPLEMENTATION

Statements concerning the urgency of this particular research in relation to highway transportation needs in general and the potential for payoff (couched in benefit/cost terms if at all possible) from achievement of project objectives should be given.

A statement should be included that further describes the anticipated product(s) from the research (e.g., recommended specification language, new instrumentation, or recommended test methods). The anticipated steps necessary for implementation of the research product should also be delineated (e.g., Will recommended specification language be considered for adoption by a committee within AASHTO?

Will an industry group have to adopt a new test method or revise their current practices or equipment?). This information should be as specific as possible, noting particular documents that may be affected, or techniques or equipment that may be made obsolete. Any institutional or political barriers to implementation of the anticipated research products should also be identified.

The research will result in a model that will allow for forecasting raveling and weathering on asphalt pavement surfaces. This type of model leads to a variety of improvements in pavement construction and management. This project would yield improvements in construction acceptance evaluation of the as-placed asphalt concrete. Completing construction acceptance evaluation based on the anticipated performance of the as-placed pavement structure has been identified as the best means for defining construction acceptance. A model for raveling and weathering provides a means for developing performance-related specifications that mitigate the development of raveling. The model will identify quality characteristics that are directly related to raveling. Further, this model can be used to develop limits on the quality characteristics that are related to the expected performance of the pavement.

A third improvement is related to pavement management. In order to identify the appropriate timing of maintenance treatments on a pavement estimating the development of distress over time is key. A model forecasting raveling will improve the ability of pavement professionals to estimate future distress.

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