SUPERPAVE FOR AIRFIELDS

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INTRODUCTION

Asphalt pavements have a long history of outstanding performance in airfield applications. One of the first modern airport projects in the country was Washington National Airport. Upon its completion in 1940, more than one million square yards hot-mix asphalt (HMA) pavements had been constructed to meet the bright future of commercial aviation. Much has changed in both the asphalt and airfield pavement industries over the last 63 years. Larger and more powerful aircraft have changed how we design pavement structures and mixes. Enhanced production, laydown, and quality control technology has led to increased quality and higher production capability on airfield paving projects. Finally, with the advent of Superpave, we now have a mix design system that is capable of developing improved HMA mixes for airfield projects.

During this long period of success with asphalt pavements, the Asphalt Institute has assisted the Federal Aviation Administration (FAA), Corps of Engineers, the US military departments and other agencies in developing best practices for the design and construction of HMA pavements. The Asphalt Institute continues to work in partnership with the airport community as it transitions to the Superpave system. This paper discusses the status of the transition and offers a description of the Superpave mix design system for airfields. Specifically, we address the differences between airport and highway pavements, current HMA specifications for airfields, and a strategy for implementing the new Superpave binder and mix design system, and finally, a brief look at some cases where Superpave has been successfully adopted.

DIFFERENCES BETWEEN AIRPORT AND HIGHWAY PAVEMENTS

When designing the mix properties for airport pavements, it is important to recognize that airport pavements are fundamentally different from highway pavements. It is typical for highway pavements to support a high volume of automobile and truck traffic that can amount to thousands of load repetitions per day. Conversely, only a handful of the busiest airport pavements will support a few hundred aircraft passes per day. The vast majority of airfield pavements see only a few dozen aircraft passes per day and some airport pavements, such as overruns and shoulders, may support only a few dozen loadings in an entire 20-year lifetime. In the absence of high volume loading, the overriding cause of distress in these pavements is the continual exposure to the damaging effects of the sun, air, rain, and other weather phenomena. Environmental exposure can lead to oxidation of the asphalt binder and eventual raveling and block cracking. Moreover, without a high volume of aircraft traffic, a pavement cannot take advantage of the healing effect of regular kneading by passing wheel loads.

Aircraft loads can range from very light general aviation (GA) aircraft that weigh as much as a small truck to enormous commercial passenger and cargo jets that dwarf even the heaviest truck traffic. While the federal legal load limit for highways is 80,000 lb, there are several models of aircraft that operate at loads greater than 500,000 lb and some can top 1,000,000 lb. Coupled to the significantly larger weight is the fact that aircraft loads are generally distributed to the pavement by a few wheels, concentrating the load in a smaller footprint. On a large portion of the typical airfield, aircraft operate at relatively slow speeds along designated taxiways and specific parking spots. The slow, channelized nature of the aircraft movements creates a further structural demand on the pavement system. As a result of the magnitude, speed, and channelized nature of aircraft loads, typical airport pavement sections tend to be much thicker than typical highway pavements.

Finally, foreign object damage (FOD) is of great concern to the safe operation of aircraft. Loose aggregate particles raveling from deteriorated pavements can be ingested into the high thrust jet engines. It is not simply a theoretical problem. Rather, FOD from loose aggregate particles from the pavement has been identified as the cause of at least one airplane crash that resulted in loss of life. Due to the life-safety implications of this problem, minimizing FOD must be considered one of the primary goals of the pavement design process.

Recognizing the specific challenges of airport pavements with regard to traffic volume, traffic loads, and FOD leads the HMA mix designer to ensure that the pavement is stable, durable, impermeable, and workable. Over its intended life, the pavement should adequately resist damaging environmental affects such as raveling, cracking, and stripping. Simultaneously, the HMA mix should be stable to resist enormous aircraft loads and impermeable to protect the pavement foundation. We cannot forget to make the mix workable so that it is capable of being placed in the field. The bottom line is that proper selection of the asphalt binder, adequate asphalt content, aggregate characteristics, and mix proportioning all greatly affect the ability of the pavement to perform over time.

CURRENT AIRFIELD SPECIFICATIONS

To discuss the status of Superpave technology for airfields, it is necessary to first discuss the various HMA airfield specifications used by the federal agencies. In 1998, an airfield user-producer group consisting of industry and agency experts developed a unified DoD/FAA guide specification UFGS-02749, *HMA for Airfields*. This specification is reviewed and updated each year by the same group and is available on the internet: www.hnd.usace.army.mil/techinfo/gspec. The Army, Air Force and Navy use it exclusively for airfield projects, while the FAA allows it to be used as a modification to standards, subject to approval by the Regional Office.

The FAA standard HMA airfield specification is Item P-401, well known for the Percent within Limits (PWL) pay criteria it contains. In December 2001, the FAA issued Engineering Brief 59 which provided guidance and an interim specification for using Superpave mixtures, titled P-401(SP). Like UFGS 02749, the P-401(SP) specification can be used in lieu of the standard P-401 by getting approval through the Regional Office. It can be used on any type of airport pavement (apron, taxiways, etc.) except runways that support aircraft heavier than 60,000 lb.

For projects designed for aircraft weighing less than 12,500 lb, state specifications and standards can be used without a FAA waiver. Projects designed for aircraft between 12,500 – 60,000 lb can also use state standards if approved by the FAA Regional office. State Superpave mixture specifications have been used in these cases, in addition to projects where federal money is not involved.

AN OVERVIEW OF THE SUPERPAVE SYSTEM

The Superpave strategy involves four important steps for successful implementation:

- Materials Characterization and Selection
- Design Aggregate Structure Selection
- Optimum Asphalt Content Determination
- Moisture Susceptibility Assessment

Mix designers who are accustomed to the Marshall system will find many familiar features in the Superpave system. The primary differences are the Superpave Performance Grade (PG) asphalt binder specification, aggregate selection criteria, gradation controls, and the Superpave Gyratory Compactor. Volumetric analysis and moisture susceptibility assessment of the compacted mixture is essentially the same as in the Marshall system. This section will discuss the status of Superpave in the U.S., highlight differences between Superpave and the Marshall system, and provide guidance for using Superpave on Airfields. It is not a complete guide to Superpave mix design, but rather a brief discussion of some key elements. The reader is referred to Asphalt Institute Superpave Series No. 2 (SP-2), *Superpave Mix Design*, for more information.

Status of Implementation

The Superpave Binder PG system has been adopted by almost all the State Highway Agencies as shown in Figure 1 [1]. Full implementation has been accomplished by 47 states. Two states, Nevada and Massachusetts, have started the implementation process by specifying PG grades in some new projects. Only California does not have plans to switch to PG specifications.

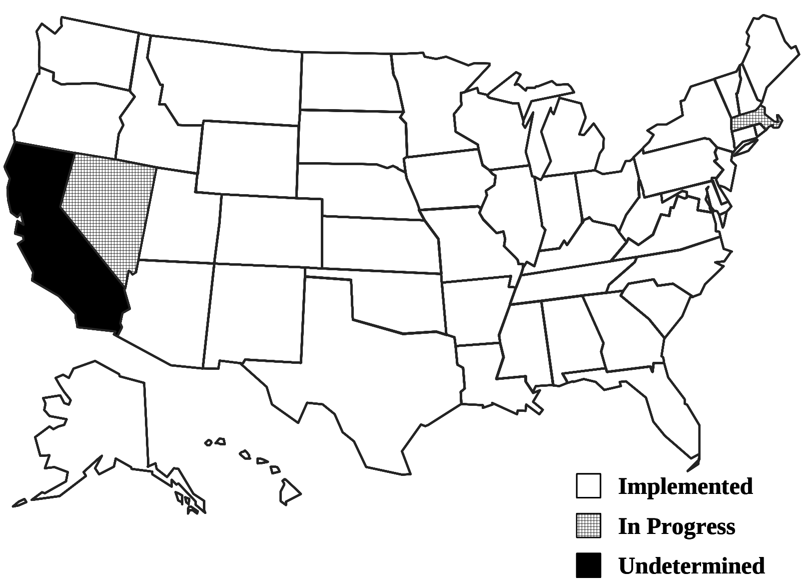

Figure 1—Superpave Asphalt Binder Implementation Status [1]

Use of the Superpave mix design system has grown steadily over the past decade for highway pavements. Figure 2 shows that 61% of the total mixture tonnage placed on U.S. highways in 2002 was designed with the Superpave system. This is up from 55% in 2001, 47% in 2000, 32% in 1999, and 20% in 1998 [1].

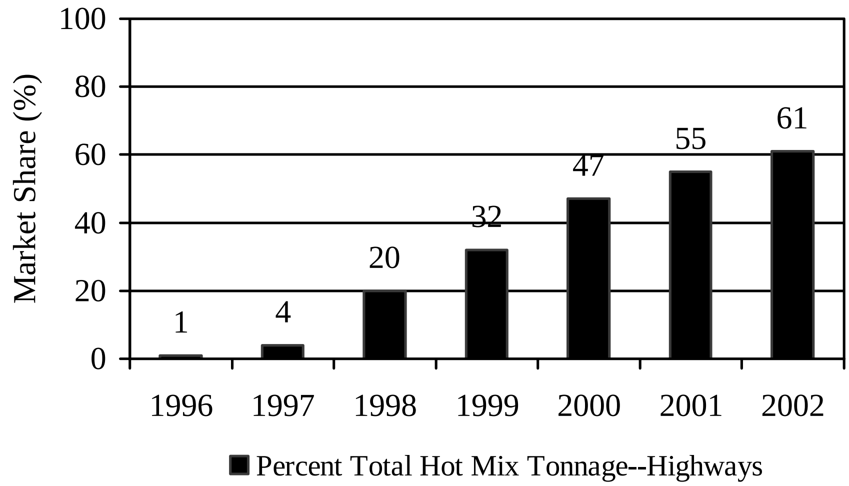

Figure 2—Superpave Tonnage on U.S. Highways [1]

The Superpave mix design system has been adopted by the majority of states, as shown in Figure 3 (FWHA, 2002). Thirty-three states have implemented Superpave, 13 states are moving towards implementation, and 4 states have no definitive plans to implement Superpave.

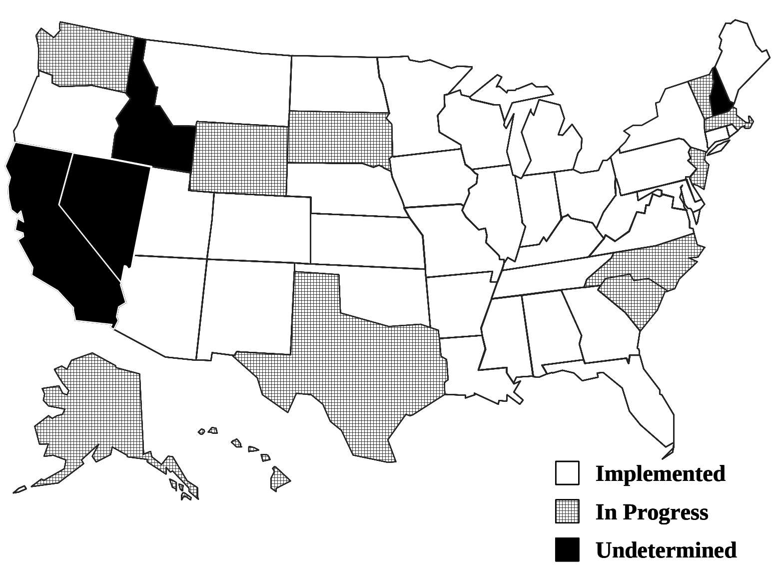

Figure 3—Superpave Mix Design Implementation Status [1]

Materials Characterization and Selection

As with any mix design process, materials selection with Superpave includes assessment of the asphalt binder and aggregates to be used in the mix.

Asphalt Binder Selection: All three federal airfield specifications mentioned above (UFGS 02749, P-401 and P-401SP) allow the use of PG binders. Since these guide specifications are used throughout the U.S. and abroad, they must provide general guidance notes to the designer (not part of the actual specification) on the binder grade to specify. While most states use the PG system, some still use viscosity grading. The designer should consult with the local highway department to determine which grades are typically being used and available in the project area. The challenge for the designer is to translate the PG selection guidance of highway agencies and apply it to airfields which have different methods of characterizing traffic and loads. Guidance suggests determining the "standard grade" used on highways designed for less than 10 million equivalent single axle loads over 20 years for the particular lift being placed. This "standard grade" should be sufficient on most General Aviation (GA) airports that see relatively light aircraft. For heavy-duty airfields, grade bumping from this "standard grade" should be considered for pavements that see high tire pressures, slow or standing traffic (stacking on taxiways), and channelized traffic. Grade bumping refers to increasing the high temperature grade by six-degree increments. For instance, if a PG 64-22 is the "standard grade", one grade bump would require a PG 70-22 and two grade bumps would call for a PG 76-22. Specific grade bumping guidance is shown in Table 1.

Table 1
Guidelines for "Bumping" PG Binder Grades

Aircraft Gross Weight (lb) [a]	**High Temperature Grade Bumps from "Standard Grade" for all Airfield Pavement Types (Runways, Taxiways, Aprons)**	Aircraft Tire Pressures (psi)[b]
Less than 12,500	**0**	Less than 100
12,500 – 100,000	**0 - 1**	100 – 200
Greater than 100,000	**1 - 2**	Greater than 200

[a] FAA Advisory Circular AC 150/6340-6D, Item P-401(SP) Specification
[b] Department of Defense, Unified Facility Guide Specification, UFGS 02749

Note tire pressure is the criteria used for military aircraft, while aircraft weight is used for civilian aircraft. Military fighters are relatively light, but operate on extremely high tire pressures that are most severe on a pavement in terms of rutting. The tire pressures of civilian aircraft, however, can be characterized fairly accurately by aircraft weight.

Aggregate Criteria: Extremely durable and angular aggregate are required for airfield projects, with only a minimal amount of rounded natural sand. Since the P-401 and UFGS 02749 specifications already have very high aggregate requirements, it is a minor adjustment to become familiar with Superpave criteria. Superpave aggregate requirements are generally equal to or slightly more stringent than the existing airfield specifications, as shown in Table 2. For example, in the P-401 and UFGS 02749 specifications, the toughness requirement is that aggregates must show wear of 40% or less as measured by the Los Angeles Abrasion test (ASTM C-131). This is the same requirement used by the P-401 (SP) specification. The P-401 specification allows a maximum of 20% natural sand in the mix, while the P-401 (SP) and UFGS 02749 specifications reduce the limit to 15%. The P-401 (SP) and UFGS 02749 specifications also incorporate a fine aggregate angularity requirement (ASTM C 1252, Method A), which is not part of the traditional P-401 specification. In the end, when compared to using existing airfield specifications, adopting the Superpave aggregate requirements is a small change for the mix designer.

Superpave Mixes: For airfield mixes, the goal is to develop a mix that optimizes several desirable qualities: stability, durability, impermeability, flexibility, and workability. Since we know that airfield pavements tend to fail due to the effects of aging rather than loads, we are more focused on designing mixes that are durable. Fatigue resistance, a key in designing mixes for highway use, is not a major consideration. Skid resistance is considered, but is often not the primary design goal for airfield mixes. By careful specification and proportioning of materials coupled with close attention to the control of the construction process, it is possible to build durable, long-lasting hot-mix asphalt (HMA) pavements using Superpave. The details of performing a Superpave Mix Design are discussed in the Asphalt Institute Superpave Series No. 2 (SP-2). The following paragraphs draw comparisons between the P-401 (SP) specification and current airfield HMA specifications.

Table 2
Comparison of Aggregate Requirements for Airfield Mixes

	P-401	UFGS 02749	P-401 (SP)
Coarse Aggregate			
Los Angeles Wear	<= 40 % Surface <= 50 % Base	<= 40 %	<= 40 %
Sodium Sulfate	<= 10 %	N/A	<= 10 %
Magnesium Sulfate	<= 13 %	<= 18 %	<= 13 %
Fractured Faces	85/1 and 70/2 >= 60 kips 65/1 and 50/2 < 60 kips	75/2	85/1 and 80/2
Flat & Elongated	<= 8 % @ 5:1	<= 20 % @ 3:1	<= 8 % @ 5:1
Fine Aggregate			
Plasticity Index	<= 6 %	N/A	<= 6 %
Liquid Limit	<= 25 %	N/A	<= 25 %
Natural Sand	<= 20 %	<= 15 %	<= 15 %
Sand Equivalent	>= 35 %	> 45 %	>= 40 %
Fine Aggregate Angularity	N/A	>= 45 %	>= 45 %

Gradation in the Superpave system is governed by improved definitions of aggregate sizes, use of the .45 power chart and control points (Figure 4). The restricted zone, once a key element to selecting a Superpave mix gradation, has been removed. Prior to Superpave, various terms and definitions were used to define aggregate size: maximum size, nominal maximum size, top size, etc. Superpave introduced a firm definition of nominal maximum size to classify mixes. The .45 power chart had been used in previous systems, but became mandatory with the Superpave system. Superpave control points offer wide room to design "coarse" mixes that were not typically specified in previous systems. At the same time, Superpave control points remain flexible enough to allow airfield mix designers the ability to design a "fine" dense mix, more typical for airfields. Fine-graded means that the gradation line falls above the maximum density line through the course and fine aggregate sizes.

Fine-graded dense mixes have been preferred for airfields because their tighter surface texture tends to be less permeable to water and air, leading to increased durability. Fine graded mixtures also offer improved workability versus coarse-graded mixes. Both the Department of Defense UFGS 02749 and the FAA P-401 specifications call for gradations that are dense and fine-graded. The Superpave system can be used to design these same fine-graded dense mixtures that have a history of good performance on airfields.

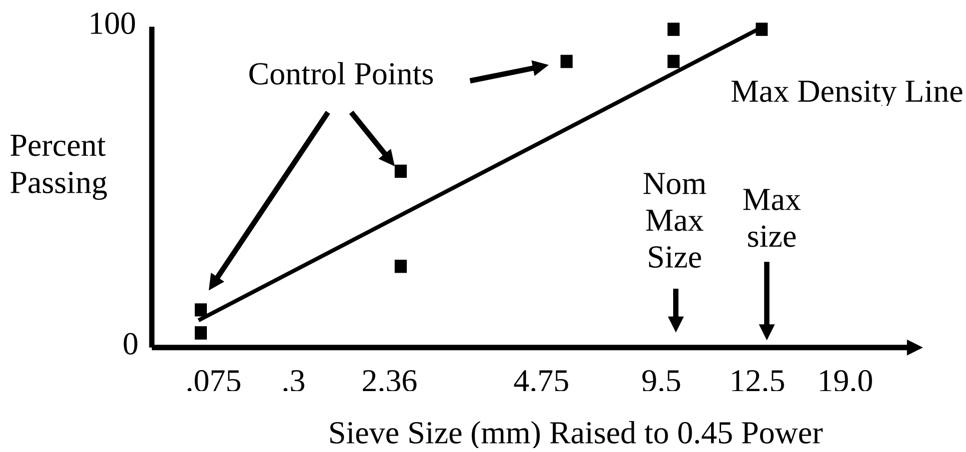

Figure 4—Superpave Gradation Control [2]

The UFGS 02749 and the P-401 standard specifications utilize the Marshall mix design system. In the Marshall system, the Marshall impact-hammer is used to compact laboratory specimens to select the optimum asphalt content by evaluating volumetric properties of the compacted mix. A shortcoming of the Marshall impact-hammer is that it offers a poor simulation to the compaction that actually occurs to HMA pavements during construction and trafficking. Instead of an impact force, the Superpave Gyratory Compactor imparts a constant rotational gyratory load to the specimen. This kneading action is widely accepted as a better simulation to the compaction that occurs under rollers and truck tires (Figure 5). The number of design gyrations, called N-design, varies depending on the design traffic level. Higher traffic levels call for a higher number of gyrations. While there were originally 28 different N-design levels for Superpave, there are now four: 50, 75, 100 and 125.

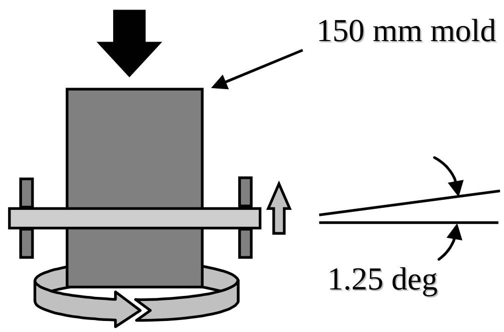

Figure 5—Superpave Gyratory Compactor [2]

CASE STUDIES

The first military airfield application was in 1997 on a runway restoration project at Little Rock Air Force Base in Arkansas [3]. The project called for milling the top 100 mm of asphalt to correct a delaminating problem occurring at a depth of 75 mm, and then placing two 50 mm lifts of a 12.5 mm Superpave mix. The high quality sandstone aggregate and coarse gradation selected provided a relatively high level of Voids in the Mineral Aggregate (VMA) at 15.0 %, even though the N-design was high at 138. The design asphalt content was 5.6 %, somewhat higher than the typical Marshall mixes used in past airfield projects at Little Rock AFB. A PG 70-22 binder was used, even though the base grade for the area was a PG 64-22, to provide greater resistance to permanent deformation. After more than five years of heavy use by C-130 aircraft, the Base Pavements Engineer recently reported that he is “very satisfied with the runway’s performance.” The only distress he mentioned was some “slight raveling at a few longitudinal joints.” This premature raveling may be the result of the mix being slightly permeable, which was detected the first year after construction when some water was noticed running out the sides of the day-lighted overlay. Achieving proper compaction, especially at the joints, was one of the early challenges for contractors when first learning how to place coarse-graded Superpave mixes.

Another military application of Superpave was a 7800-ft long runway reconstruction project in 1999 at Volk Field Air National Guard Base in Wisconsin. This runway supports heavy military cargo aircraft including the C-5, weighing over 600,000 lb, as well as fighters such as F-16s with tire pressures in excess of 280 psi. The reconstruction included placing a 75 mm base lift of 19 mm Superpave, followed by a 50 mm binder lift of 12.5 mm Superpave, followed by a 50 mm surface lift of 12.5 mm Superpave. The base and binder lifts utilized a PG 58-28 binder, while the surface mix used a modified PG 64-28 for additional durability and resistance to deformation. The gradations for all these mixes were on the fine side of the maximum density line. After four years of weathering and high volumes of severe traffic loadings, there is no rutting, cracking or raveling evident. The grooving that was cut in the surface for skid resistance at the completion of the project looks new (Figure 6). The integrity of these grooves with their sharp edges is significant, considering the large volume of high tire pressure aircraft that have used the runway.

Figure 6—Grooving on Superpave Runway at Volk Field after 4 Years (Courtesy Erv Dukatz)

The first FAA approved application of Superpave for an airport occurred in 1999 at Griffin-Spalding Airport in Georgia. For this 50 mm thick runway overlay, the Georgia DOT standard highway Superpave mix specification was used. The airport is for general aviation, supporting aircraft less than 12,500 lb. The Airport Manager recently stated that “performance has been outstanding, with the runway looking as new as the day it was placed.”

The North Carolina Division of Aviation has progressively transitioned toward using Superpave as their standard mix for light to moderate load airfields. A new connecting taxiway at Andrews-Murphy Airport utilized Superpave in 2001, followed in 2002 with two additional Superpave projects. Six North Carolina airfield projects are projected in 2003 to use Superpave. The Aviation Division has worked closely with the Division of Highways to select the standard 9.5 mm Superpave surface mix for these projects. The N-design level is 50 gyrations for pavements designed to support aircraft weighing less than 12, 500 lb, while the N-design is 75 for pavements designed for aircraft less than 60,000 lb. These mixes were selected for their ability to provide a tight smooth surface that will be impermeable and resist aging. In addition, these mixes provide excellent workability and are relatively easy to compact.

Also last year, two general aviation airports in Kentucky used state funds to overlay their runways with Superpave mixtures.

SUMMARY

While not the standard mix design system for airfields, Superpave use has gradually increased for airfield projects. While it may be fair to say the airfield pavement community has been slow to adopt Superpave mixes relative to the highway community, there is rationale in their caution. They have seen relatively good performance obtained from current airfield pavement specifications, especially in terms of rutting. Superpave was developed for highways, and was emphasized to be more resistant to rutting. The biggest general concern with airfields has not been rutting, but weathering and longitudinal joint deterioration. As the military and FAA continue to gain experience with Superpave mixes, they will move towards making it a standard on airfield projects.

REFERENCES

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3. Denny, John (1998), "Air Force Tests Superpave," *ASPHALT*, Fall 1998, Asphalt Institute, Lexington, Kentucky.