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From Research to Results

Innovative Projects from the FAA Airport Technology R&D Program

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In Perspective

This special issue of R&D Review focuses on the FAA's airport technology team of researchers and the work they are doing to ensure this nation's airports can accommodate projected air traffic growth safely and efficiently. Later in this issue you will "*Meet the Team.*"

"Aviation safety really does start - and end - at the airport," says Victoria Cox, FAA Air Traffic Organization Vice President for Operations Planning. Delivering one of the keynote addresses at the Airport Technology Transfer Conference held this past April 15-18 in Atlantic City, New Jersey, Cox added: "Our airports … both big and small … are going to be a central part of NextGen, the insider's shortened name for the Next Generation Air Transportation System. At the FAA, we are pleased that our Research and Development teams are hard at work to develop and refine the new technologies that will continue to enhance the safety and expand the capacity of our nation's airports."

Hosted jointly by the FAA and American Association of Airport Executives (AAAE), the recent symposium brought more than 150 government, academic, and industry attendees together from nearly a dozen countries to focus on airport safety and issues, challenges, and solutions involving airfield pavements. The Honorable Mark Rosenker, Chairman of the National Transportation Safety Board, also served as a Keynote Speaker.

Held once every three years, this respected technical conference provides a unique opportunity for the world's aviation industries and research community to exchange timely information that will help to ensure safe and efficient NextGen airport operations. The conference highlighted ongoing industry and academic research and development activities in its separate forums on airport safety and airport pavements issues.

The pavement technology presentations showcased the work being done at the FAA's National Airport Pavement Testing Facility. Researchers in the

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pavement technology track discussed pavement modeling and design; construction materials and methods; pavement evaluation, analysis, maintenance, and management; computer applications to airport pavements; and full-scale pavement testing.

In the airport safety technology discussions, panelists presented new concepts and ideas for aircraft rescue and firefighting, runway surface technology, runway incursion reduction, visual guidance, wildlife hazards, and airport planning and design.

This special issue of R&D Review focuses on the FAA's airport technology researchers and the work they are doing to ensure this nation's airports can accommodate projected air traffic growth safely and efficiently. As you will read here, we are working to meet tomorrow's challenges by continuously improving our airport system. Again to quote Cox in her keynote remarks, "without airports, airplanes would have no place to go; but without technology, our airports would not be able to keep up in the 21st century."

If you would like additional information on our program, I invite you to visit our website at http://www.airtech.tc.faa.gov/.

Satish Agrawal, Ph.D.
Program Manager
FAA Airport Technology R&D

in this issue

Conference Review

2007 Airport Technology Transfer Conference


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2·31 →
SPEAKER
←4
Road Materials and Pavement Design

Airport Technology Pavement Research

"The safe, efficient, and cost-effective movement of aircraft is critical to an airport's successful operation." Although airport pavements are obviously crucial to the takeoffs and landings of rapidly evolving modern aircraft, the operational surfaces at our nation's airports are not significantly different from those that used to carry only the volume of traffic, and the speed and weight of propeller-driven airliners.

In contrast, aircraft and other equipment design has made giant strides in the past 50 years. In a steady progression of improvements, aviation engineers have successfully adapted advanced technologies from many other applications into new aircraft and the ground-based electronics equipment that enhance the safety of flight. Examples of aircraft and navigational breakthroughs include the use of composite materials, high temperature alloys, inertial navigation, and fly-by-wire controls. Sometimes, even small improvements have returned large gains in performance and the economics of operation.

If left unchecked, the gap between advanced aircraft technologies and outmoded airport pavement technologies could jeopardize our transition to the Next Generation Air Transportation System (NextGen).

“Forecasters predict a three-fold increase in air traffic by 2025,” says Dr. Satish Agrawal, FAA Airport Technology R&D program manager. “To handle that kind of traffic, the national airport system will need to provide sufficient infrastructure to accommodate much higher user demand. To achieve the NextGen vision of sufficient numbers of airports, heliports, and other future landing and departure facilities to incorporate emerging NextGen benefits – and to ensure that these more numerous facilities draw upon fully adequate technologies – we must conduct the necessary research now.”

The nation’s public airports will be able to service the large subsonic and supersonic aircraft that are already going into service, expanding numbers of sophisticated regional jets, and many anticipated unmanned aircraft systems only with the benefit of significantly improved pavement design methodologies. Furthermore, durable, long-life pavements will be increasingly important in controlling system costs. Even now, besides annual expenditures of approximately two billion federal dollars for runway and taxiway upkeep, downtime for the maintenance and rehabilitation of failing pavements contributes alarmingly to the costs associated with aviation system delays. If pavement standards should fail to keep up with aircraft advances, national aerospace costs could increase exponentially.

“Aircraft movement areas – runways, taxiways, and aprons – take a large part of an airport’s budget,” states Dr. Agrawal. “The safe, efficient, and cost-effective movement of aircraft, now and in the future, is critical to a facility’s successful operation. Related costs include the construction of new pavements, the ongoing maintenance of existing pavements, and the refurbishment or upgrade of under-performing pavements.”

Today, of the more than 5,000 public use airports in the United States, almost 4,000 have paved runways. Furthermore, almost 5,000 of the approximately 14,500 private use airports have paved runways. These 9,000 or so paved airports maintain approximately 650 million square yards of runaway pavement surface. Every year, the Federal Government and the aviation community spend about $4 billion replacing, repaving, rehabilitating, repairing, and maintaining pavement surfaces worth an estimated $100 billion.

The FAA makes Airport Improvement Program funds available to public agencies – and in some cases, to private owners and entities – for airport pavement projects. The FAA also provides some grants for the planning and development of pavements at other public-use airports. Eligible projects must enhance airport safety, capacity, and security, and must mitigate environmental concerns. Many runway construction and rehabilitation projects qualify for these dollars. Supported by user fees, fuel taxes, and other similar revenue sources, the Airport and Airway Trust Fund is the original source of funding for these projects.

In Advisory Circular 150/5320-6D, the FAA requires airports to install pavements that can sustain their total anticipated load applications over a 20-year design life. The total number of anticipated load applications provides the defining parameters for pavement thickness (including components such as surface, base, and subbase layers) but do not specify the actual materials that comprise the total pavement (e.g., hot mix asphalt or Portland cement concrete mixes). Practical criteria establish years of effective service as the defining characteristics of required pavement life.

Airport pavements are of two types, rigid and flexible. Rigid surfaces consist of portland cement concrete laid over a subbase that covers a compacted subgrade. These pavements bend less than flexible surfaces built of bituminous or asphalt material. Rigid pavements distribute loads over a relatively wider area, while the many layers in flexible pavement individually give under the weight of aircraft to distribute the load over a smaller area. For flexible pavements, the intent of the FAA criteria is to protect the lower layers, particularly the subgrade, from shear failure. For rigid pavements, the specifications protect the Portland cement concrete top layer from fatigue cracking.

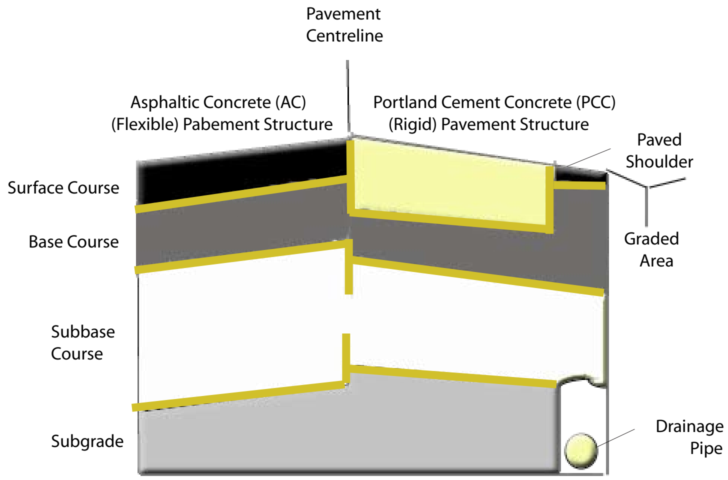
The quality and thickness of an acceptable airport pavement must be able to withstand, without damage, the abrasive action of traffic, adverse weather conditions, and other deteriorating influences when subjected to specified loads over a specified period of time. Operational pavements are most often constructed to provide adequate support for the attested loads imposed by the aircraft mix currently using an airport. Because the future is often hard to predict, construction plans do not always take into account potential traffic increases over, for example, the next 20 years.

Current pavement design methods have well-recognized shortcomings. The fundamental approach to asphalt pavement design is based on highway methodology developed in 1928 for single wheel loadings upon an unbound aggregate base and subbase layers. The concept that adapted this rigid design theory in 1945 to accommodate multi-wheel aviation landing gear assemblies was based on limited, and ultimately inadequate, test conditions.

The theoretical bases of airport pavement design methods differ fundamentally. Flexible design is empirically derived, while rigid design is rationally derived from an assumed theory. When combinations of the two pavement types are used (a common practice), engineers temper gross equivalency factors with human judgment to arrive at necessary proportions of materials and how they will be applied. The dissimilarities between the two methods point out an additional need for a design system that uses a common theory to treat all construction materials. A common system would follow from the results of studies using different combinations of materials, would base analyses of loading capacity on non-destructive testing (where appropriate), and would be particularly useful in the design of overlays and similar structures.

Like most structures subjected to repeated loading, pavements degrade incrementally with each load repetition, until accumulated fatigue causes failure. The design and construction of economical and durable pavement require an understanding of a variety of factors in determining the type and optimum thickness of pavement layers and understanding their failure modes.

Final pavement design is determined by working with models and adjusting the thickness of the various layers. The selection of materials and construction techniques is also affected by the local soil and climatic conditions and the availability of alternative materials. ▷



A critical element in pavement design is the selection of appropriate failure models and failure criteria. Every failure model is based on test data. The most important means of obtaining necessary data is through full-scale testing. Such testing involves the controlled application of simulated aircraft gears at realistic tire loads to a full-scale layered, structural pavement system. This test design determines pavement response and performance under a controlled, accelerated, accumulation of damage in a compressed time period.

Testing and analysis at the FAA National Airport Pavement Test Facility (NAPTF) is providing scientific knowledge about pavement properties. Located at the FAA William J. Hughes Technical Center in Atlantic City, New Jersey, researchers use NAPTF to generate full-scale pavement response and performance data for development and verification of airport pavement design criteria for all pavement types. The test track can be divided into as many as nine independent test items on three subgrade classifications – low, medium, and high strengths. Test items are trafficked to failure and then reconstructed for further study. Over 1,000 sensors are embedded in the test items to collect data. Static sensors monitor temperature, moisture, and crack status (resistance) on an hourly basis. Dynamic sensors measure quantities such as strain and pavement deflection in response to the load, and are triggered by the vehicle operations.

The facility, a cooperative venture of the FAA and the Boeing Company, allows researchers to collect years of testing data in the time span of weeks. A hydraulic vehicle, equipped with different configurations of landing gear, can speed up the effects of decades worth of wear and tear on different pavement surfaces by aircraft weighing as much as the new large aircraft – such as the Airbus A380.

“To date,” says Dr. Agrawal, “we have collected almost 100 gigabytes of data. These results are providing the knowledge base for the FAA to validate design standards and ensure compatibility between aircraft and airports. Without such data, we could not be certain we have the right pavement designs to meet 2025 traffic needs. To meet increased air traffic, the NextGen planners believe existing airports will need to be expanded and, in a few instances, new airports will need to be built to meet growth challenges. Many feeder airports, located outside metropolitan centers, may have to undergo substantial improvements as we move away from a hub and spoke system.”

Agrawal also notes that: “New pavement designs, based on thorough research, will provide manufacturers assurance of the compatibility of their aircraft on airports throughout the world. New software applications will provide airport operators precise cost estimates to permit new aircraft operations on their facilities and allow airlines to plan for new equipment and routes. And, most importantly, our data will ensure that federal funds for rebuilding or strengthening runways are being used prudently and the $100 billion investment in the infrastructure will be protected.”

Because of the critical need to understand better pavement properties, the FAA is making its test data , as well as descriptive information on the National Airport Pavement Test Facility, available on-line at http://www.airporttech.tc.faa.gov/naptf/. ■

FAArfield

Interest is growing, both within the United States and abroad, in the FAA's airport pavement design programs. In this country, Dr. Satish Agrawal and airport technology R&D staff are conducting a number of specialized technical workshops on "Airport Pavement Design and Evaluation." Domestic workshops have been held in Washington, DC, Atlanta, GA, Redmond, WA, and other locations. Internationally, the Airport Authority of India invited Dr. Agrawal, colleagues in the FAA Airport Technology Research Program, and researchers from the Boeing Company and Airbus to lead a pavement design workshop in New Delhi. The successful workshop was arranged with the help of ICAO. A second international workshop was recently held in Toronto, Canada, in cooperation with the Cement Association of Canada.

New Pavement Design Software for a New Era

After a decade of testing and development, the FAA has released a prototype innovative new software package that will change the way airport pavements are designed and evaluated. FAArfield 1.0, or FAA Rigid and Flexible Iterative Elastic Layer Design, has the potential to save the FAA and airport authorities tens of thousands of dollars in airport pavement redesign efforts.

"FAArfield will make the jobs easier for airport owners and operators, as well as pavement engineers," says Dr. David R. Brill, an engineer in the FAA Airport Technology R&D program. "The software provides a simpler way for airport planners to determine the needed thickness of runway and taxiway pavements. It will help civil engineers meet the standards for different airplanes, and model the thicknesses needed to handle them all." ▷

Background

FAA researchers knew they needed more advanced structural models capable of better predicting pavement response when new large aircraft with complex landing gear, such as the Boeing 777 and Airbus A380, began to emerge from the drawing boards. The FAA's standard pavement design methods, summarized in design charts contained in Advisory Circular (AC) 150/5320-6D, were the result of continuous development over a period of more than 30 years. The traditional models, however, could not accurately assess potential damage to airport pavement as a result of the complex gear loads of the Boeing 777.

"Complex wheel load interactions within pavement structures can contribute to premature failure of the pavement structures, and must therefore be considered in pavement design analyses," explains Gordon Hayhoe, airport technology R&D engineer. "When we used traditional pavement design methods to analyze loads from the new generation of landing gear, the results indicated a need for unrealistically thick pavements. The models indicated that billions of dollars would have to be spent over several years to strengthen the nation's runways to accommodate the new aircraft. This would have placed enormous financial strains on the aviation industry and U.S. economy. It fell on our research program to determine empirically if these new heavy aircraft would truly require airports to overlay, reinforce, or even rebuild runways to adapt to these new heavier aircraft."

Before the introduction of the Boeing 777, very closely spaced six-wheel landing gears had never been tested for their effect on pavement life. Lacking specifically relevant data, researchers at the FAA National Airport Pavement Test Facility set out to find at what point current runway pavement designs would fail under repeated loads from such heavy aircraft gears. To create more cost-effective, longer lasting airport pavement alternatives, the research team began developing criteria and methods for design, evaluation, performance, and serviceability of flexible as well as rigid airport pavements.

The surfaces of airport runways, taxiways, and aprons are categorized as either "flexible" or "rigid," depending on the type of materials and methods used to construct them. Flexible pavements are constructed of an asphalt surface on one or more subbase layers, while rigid pavements consist of concrete slabs on a prepared subbase. At larger airports, both types of pavements generally include a stiffened, or stabilized, base layer to provide additional support.

As aircraft get bigger and heavier, with new kinds of landing gears, they exert added stresses and strains on airport pavements. To predict new wheel load interactions and better provide the airport community with an evolving pavement design methodology suitable to the needs of heavier aircraft, FAA researchers have developed new, advanced computer-based design procedures that pick up where the older, design chart-based, methods leave off. In 1995, the FAA introduced LEDFAA, a computer program that implements the Layered Elastic Design (LED) method for airport pavements This program automates the LED procedures and provides design engineers with user-friendly graphical interfaces. The software minimizes user input variables and contains built-in error checking procedures on all the input values. Once all required input values are specified, the design thickness of the airport pavement is automatically computed. The current version of LEDFAA (LEDFAA 1.3) can be downloaded from the FAA's website at http://www.faa.gov/airports_airtraffic/airports/construction/design_software/.

FAArfield *continued from page 11*

In 2003, while the FAA continued to improve LEDFAA for the airport community, researchers completed development of a three-dimensional finite element (3D-FEM) structural model for rigid (concrete) pavements. The 3D-FEM model can handle greater detail and more complex characterizations of construction materials than can layered elastic analysis. It is particularly useful for application to rigid pavements, since the slab edges and joints that are often the critical components in rigid pavements can be modeled directly - something not possible using LED. In addition, 3D-FEM can incorporate nonlinear and non-elastic material models not available with LED. Like LEDFAA, the new program FAArfield consists of a traffic model, a failure model, and a structural response model. However, FAArfield incorporates both LED and 3D-FEM in its structural response model.

Next Generation Software

FAArfield is a significant advance in pavement design technology. FAArfield keeps the “look and feel” of LEDFAA 1.3 while incorporating the improved design models, an updated and expanded aircraft library, and run-time design guidance based on the AC. Like LEDFAA, FAArfield combines the FAA design standards for new rigid and flexible pavements, as well as overlays, in a single PC-based program. Dr. Brill says, “Special computer equipment isn’t required. The FAArfield software is contained in one easy-to-download package that can be installed and run on an ordinary WindowsTM PC.” The software allows the powerful and accurate 3D finite element method to be used in routine design procedures to compute the critical design stresses (stresses at the slab edges) for complex aircraft gears.

“Even as it makes use of some fairly sophisticated modeling methods, FAArfield has been designed with the requirements of the design engineer in mind,” explains Brill. “Previously, because of the excessive time needed to complete modeling, engineers had considered 3D finite element based procedures impractical for PC–based design applications. A combination of faster computer processors and innovative programming methods reduced run times to the point where FAArfield can be used for routine pavement design. Now, pavement designers can calculate thickness in minutes, compared to the ‘old days’ when it could literally take days to crunch the numbers.” FAArfield is programmed in the Microsoft Visual Studio.NETTM 2005 programming environment, which will allow it to be compatible with future advances in computer technology.

FAArfield 1.0 will be the basis for a major revision to AC 150/5320-6D, expected in early 2008. The revised advisory circular will retire the manual thickness design curves from previous versions and make FAArfield the standard FAA design procedure. In anticipation of this change, Brill and his colleagues are holding training sessions across the country, as well as in international locations, to familiarize potential users with the new software. “Airport pavement can only serve its purpose when it has good load-carrying capability, good rideability, and allows safe operations of aircraft,” explains Brill. “FAArfield is helping to achieve these goals.” ■

For more information on the Airport Technology R&D Branch’s advanced pavement design program, visit http://www.airporttech.tc.faa.gov/pavement/.

BAKFAA

FAA researchers recently made publicly available, at no cost, a new tool that measures the structural properties of airport runways and taxiways. The program, called BAKFAA (Backcalculation FAA), is the basis for a new FAA standard for nondestructive pavement testing.

BAKFAA provides uniform and accurate measurement of pavement properties, and when used with pavement design improvements outlined in a recent advisory circular update, it can save up to three percent in annual Airport Improvement Program expenditures for runway and taxiway maintenance. In fact, the Port Authority of New York and New Jersey recently accrued a cost savings of $15 million to accommodate the new Airbus A380 by using BAKFAA in a project to widen runways at New York's John F. Kennedy International Airport. The software allowed Memphis International Airport to achieve similar savings on its runway-widening project for new large aircraft.

"Airport authorities need fast, accurate methods of evaluating the strength and condition of existing airport pavements and subgrades," explains Dr. Gordon Hayhoe, FAA airport technology research program manager. "We can get good data from destructive testing, but that is not an efficient way to assess pavement. It takes specialized equipment, necessitates runway closures, and requires expensive repairs. For those reasons, airport authorities favor the commercial off-the-shelf nondestructive test equipment widely used in the highway community. But, for the test data to be relevant and useful, we need fast, accurate computer software to crunch that data into useful information about pavement integrity and strength. With such data, airports can increase the average life of pavements by optimizing maintenance schedules and reducing the average life-cycle costs."

A popular means of obtaining nondestructive pavement test data is to use a falling weight deflectometer (FWD). In the FWD test, a large weight is raised off the ground and dropped onto a rubber loading pad creating an impulse load (falling weight) representative of the real loading imposed by heavy traffic on the pavement. The excitation produced by the loading sets off waves in the pavement and underlying soil. Deflection time histories are gathered by an array of sensors placed at several nearby locations. The deflection data can provide both qualitative and quantitative information about the strength of a pavement at the time of testing.

Each of the several layers employed in airfield pavements exhibits different characteristics or properties. Each of the layers also tends to respond differently to variables such as moisture and temperature. That is why it is important to determine the integrity of sublayers. Dr. Hayhoe explains, "Nondestructive testing, using static or dynamic testing equipment, provides data on the structural properties of pavement and subgrade layers. The data are typically used to detect patterns of variability in pavement support conditions or to estimate the strength of pavement and subgrade layers. This information allows the engineer to design optimally effective structures, such as cross-sections and overlays, for use in new projects as well as restorations."

The traditional method for interpreting the FWD data is to extract the peak deflection from each displacement trace of the sensors (deflection basin) and match it through an iterative optimization method to the deflections predicted by a static model of the pavement. The process that is used to conduct this analysis is referred to as backcalculation because the engineer normally does the opposite of traditional pavement design. Rather than determining the thickness of each pavement layer based on assumed layer strengths, back-calculation typically involves determining pavement layer strengths based on assumed uniform layer thicknesses. This method is faster and cheaper than destructive testing or even nondestructive laboratory testing, and involves three basic steps: determining the properties of the pavement layers; calculating the critical stresses or strains under the design load(s); and comparing critical to permissible values (or use stresses or strains in a deterioration model).

Recent advances in hardware and software technology have significantly improved nondestructive testing data ▷

BAKFAA *continued from page 13*

collection and analysis software. To aid in back calculation, FAA researchers developed BAKFAA, a sophisticated computer analysis tool that helps pavement engineers:

- Estimate pavement structural life
- Investigate alternatives for pavement rehabilitation and design
- Evaluate the cost-effectiveness of design alternatives using life cycle cost analysis
- Prioritize needed improvements

BAKFAA is not limited to use with FWD data; it is designed to be used with any pavement nondestructive testing device that can measure the pavement deflection basin. The software can measure a maximum of 10 layers down, more than any other linear analysis backcalculation programs available in the public domain. With BAKFAA, pavement engineers can visualize the behavior of the layers. This ability provides engineers and airport managers with an objective reference to support decisions regarding pavement rehabilitation and funding.

BAKFAA also has the unique ability to measure pavement responses to aircraft gear loads. To compute airport pavement load strains, the development team combined the backcalculation program with another FAA-developed software tool, called Layered Elastic Analysis – FAA, or LEAF. The user may run LEAF independently to compute pavement response for arbitrary gear geometries. Collecting data on pavement responses to loading helps determine current pavement life and overlay requirements.

"With this new software, the FAA is providing a way to quickly and cost-effectively evaluate the present condition of airport surfaces," says Dr. Hayhoe. "BAKFAA measures pavement properties more precisely and more consistently than other similar program. And, when used with other design software improvements developed by the FAA, we know airports can reduce their runway maintenance expenditures."

BAKFAA is available online at http://www.airporttech.tc.faa.gov/naptf/download/index1.asp. ■

You can find other FAA airport pavement design software, including LEAF, at http://www.faa.gov/airports_airtraffic/airports/construction/design_software/.

U.S./France Sign Agreement for Airport Pavement Research and Development

An agreement signed June 19 between the top American and French aviation officials will formalize research and development efforts in the field of airport pavements. The FAA and the Direction Generale de l' Aviation Civile (DGAC) have agreed to cooperate in the coordination of research and development activities and the sharing of information resulting from related studies, tests, and analyses.

International aviation leaders witnessed the signing of the agreement by FAA Administrator Marion Blakey and DGAC Prefet Didier Lallement during the Paris Air Show.

The agreement will advance airport pavement research and development and improve coordination between the U.S. and French aviation agencies. This historic agreement will result in improved pavement design and analysis procedures that ensure continued safe airport operations and make best use of both countries engineering and management resources.

According to the FAA, U.S. enplanements will reach one billion passengers by 2015 up from 750 million today. Foreign countries expect similar increases and demands on existing aviation infrastructure. Recognizing this projected growth, the FAA and the DGAC will jointly investigate the comparison of methods to evaluate strain in airfield pavement, improve the compatibility of French and U.S. databases, and mutual exchange of information and data on state-of-the art airport pavement, design methods, and pavement materials. This research will address capacity concerns by investigating the possible effects of New Large Aircraft, such as the Boeing 777 and the Airbus A380, on existing airport pavements. This agreement is the sixteenth cooperative research Annex to the original Cooperation Agreement signed in 1980. ■

ProFAA

"We sometimes can avoid potholes when we're driving our cars," says Dr. Gordon Hayhoe, FAA pavement engineer, "but the pilot of a speeding airplane simply cannot slow down or steer around a rough section of pavement."

To aid in the safe maintenance of airport surfaces, the FAA is researching better ways to evaluate the surface qualities of pavement. "The objective of our research," explains Dr. Hayhoe, "is to develop practical procedures for measuring and characterizing the roughness of runways and taxiways." Key to this work is testing profiling equipment, conducting field measurements of runway profiles at airports, undertaking data reduction and profile identification, developing computer simulations, and developing indexes computed from measured surface profiles for characterizing the roughness of a pavement over specified lengths of the pavement.

Allowing "too many" irregularities to build up on an airport surface can subject aircraft to excessive bouncing motions that damage their components. Poor contact with the surface can also make airplanes difficult to control on the ground or cause them to become prematurely airborne. Vibration problems can even make it hard for pilots to read their on-board instruments. But when do surface imperfections move beyond acceptable and become excessive?

FAA specifications for runway, taxiway, and apron pavements smoothness are based on Agency research on runway pavement quality. Rather than measure surface smoothness (which is the quality a pavement has when it is brand new), pavement researchers and engineers normally measure the degree of roughness in the surface profile when the pavement is in service. Ideally, they can then compare the results against objective criteria stating when corrective action needs to be taken. However, measuring and evaluating surface roughness and its effect on aircraft operations is a complex problem, because each aircraft responds differently to the same pavement roughness.

Some minor roughness is built-into new pavements, although unintentionally, through imperfect construction techniques. Later, as the pavement ages, more bumps and dips start to form in the pavement. This roughness increases with time. Finally, as a pavement nears the end of its service life, irregularities can increase rapidly under traffic, and the need for maintenance patching and leveling can become much more extensive.

"Many factors related to both the pavement and aircraft form complicated interactions that govern how the aircraft will respond to runway imperfections," says Dr. Hayhoe. "Using just a single measure of roughness will give an incomplete description. Only by fully quantifying roughness and its effects can we determine meaningful criteria based on known aircraft operational response."

Roughness indexes are computed from longitudinal profiles which are generally measured with an inertial profiler. This device uses an accelerometer to form an inertial reference together with a height sensor that measures the pavement surface height relative to that reference and its longitudinal distance. Essentially, it compares the paved surface to the straightedge to identify areas in need of filling or smoothing. The result is a pavement profile, a series of numbers representing elevation.

Originally designed for highway use, profilers are typically made to travel at a constant speed – a much easier task to accomplish on a highway than on a closed-ended airport pavement. To use a profiler along the full length of a runway or taxiway, the test vehicle has to conduct some measurements while it is accelerating or braking. This can introduce large errors into the profile measurement.

To overcome such issues when characterizing roughness of airport pavements, FAA researchers designed and constructed a special portable profiler with three major components: a non-contact speed sensor, a non-contact displacement sensor, and an accelerometer. This design, with its small spot-size laser sensor, allows the instrument to measure the lateral grooving inherent in the distance to the pavement surface at a very high data rate.

Collecting the profile data is just the first step in determining roughness and defining scientifically-based smoothness criteria. It is also necessary to run the profile through a computer program to get a useful roughness index. There are many proven methods for analyzing and interpreting profiler data. It is possible for the set of numbers from a single profile to be processed several times, using different analyses to extract various kinds of information.

It is not enough just to measure and analyze the roughness of the pavement itself. A complete characterization also must take into account the dynamic response of representative aircraft to that roughness. By calculating roughness and also simulating aircraft response, FAA researchers can obtain a better understanding of overall pavement life and aircraft fatigue. Through this dual approach, researchers hope to develop a standard profile-based roughness statistic that can be used as the standard indicator of effective airport pavement roughness.

FAA airport technology researchers now have a publicly available runway profile data analysis software program, ProFAA, or FAA profile, that runs on a personal computer and evaluates a number of data sets. Data analysis and simulations performed by the software program have certain similarities to the calculation produced by a number of profiling devices or methods, such as Straight Edge, Boeing Bump, International Roughness Index, California Profilograph, and RMS Bandpass. The program also calculates the gear response of four representative aircraft: Boeing 727; Boeing 747; DC-9; and DC-10.

"Part of our work is evaluating the protocols for collecting and analyzing roughness data," says Dr. Hayhoe. "Airport pavement construction and reconstruction are funded, in part through Airport Improvement Program grants. That makes us stewards of public money, and we take that job very seriously. Our research team is providing the scientific information and test data necessary to develop tools, models, and assessment criteria for analyzing, testing, and sharing with the aviation community information on optimum airfield pavement construction and maintenance practices, all of which is critical to making ongoing decisions on pavement investments for this nation's airports." ■

For additional information on the FAA's pavement research activities or to download a free copy of ProFAA, please see http://www.airtech.tc.faa.gov/.

NAPTF

Durable, long-life pavements are important in controlling the costs of operating the National Aviation System. The United States maintains approximately six billion square feet of airport pavement surface, with an estimated replacement value over $100 billion. In addition to annual expenditures of approximately two billion dollars on pavements - a significant portion coming from the Airport Improvement Program funding - pavement outages and downtime for maintenance and rehabilitation contribute to the financial costs associated with aviation system delays.

FAA researchers at the National Airport Pavement Test Facility (NAPTF), located at the William J. Hughes Technical Center, are conducting studies to better understand why pavements behave as they do and what might be done to make them last longer. At the center of the Agency's pavement research program, this is the only facility in the world that allows researchers to replicate a wide range of aircraft traffic loads to simulate decades of wear on varied layers of pavements and bases in a matter of days and months. Now entering its ninth year in operation, the one-of-a-kind facility was constructed under a cooperative research and development agreement between the FAA and the Boeing Company.

FAA and industry researchers use the NAPTF to study pavement thickness requirements, rehabilitation and reconstruction methods, and pavement design standards. NAPTF testing supports the formulation of FAA runway and taxiway pavement requirements. With their unique test resources, these engineers can accelerate damage by increasing loads or repetitions.

The indoor full-scale pavement test track measures 900 feet long by 60 feet wide. This size permits simultaneous testing of nine different pavement cross-sections. Pavement test sections are constructed using conventional construction equipment and techniques, thus representing actual field construction. Wheel groups of four and six wheels can be moved laterally and longitudinally, thus simulating a variety of landing gear configurations.

A rail-based test vehicle with two hydraulic loading carriages runs the building's entire length. Researchers can configure the carriages for up to six wheels each with loads up to 75,000 pounds per wheel, settings that can simulate the landing gear of an aircraft weighing up to one million pounds.

Researchers have completed three construction cycles at the National Airport Pavement Test Facility since its opening. They have tested rigid (concrete), flexible (asphalt), and rubblized pavements. The latter is a rehabilitation technique in which deteriorated concrete is systematically broken and overlaid with hot mix asphalt. The current construction cycle—cycle 4—is concerned with testing concrete overlays on rigid pavements.

Each construction cycle involves:
- Including instrumentation in the construction of the pavements,
- Trafficking the pavements to their complete failure,
- Testing and documenting the results (including trenching), and
- Removing the pavements.

When the National Airport Pavement Test Facility began operation in 2000, researchers had installed 1,050 sensors and gages in the test track to let them measure variables that included deflection, strain, pressure, resistance, temperature, moisture, and humidity. Since 2004, researchers have used surface strain gages in addition to embedded ones to cost-effectively obtain critical measurements on top of the test slabs. Recently, they replaced the 900 gallons of hydraulic fluid and the filters in the test vehicle, and updated the wireless Ethernet connection and electronic control system.

Data from the facility are available to researchers worldwide on the Airport Technology R&D website. Because pavement longevity and replacement costs are global concerns, the database is receiving thousands of hits every month from airport engineers and researchers from around the world.

Researchers currently are preparing for Construction Cycle 5 to evaluate flexible pavements. Future plans call for studying the loads for aircraft with ten-wheeled main landing gears. ■

For additional information please visit the National Airport Pavement Test Facility online at http://www.airporttech.tc.faa.gov/NAPTF/,.

Atlanta’s Best

Atlanta Hartsfield Instrumentation

“Our experimental data are providing key input to new FAA pavement design procedures,” says Frank Pecht, an instrumentation specialist at the FAA’s National Airport Pavement Test Facility (NAPTF), “but it is always helpful to test our theories in real-world situations. So, when the Atlanta Department of Aviation invited us to install instrumentation on a taxiway they were reconstructing, we jumped at the chance.”

In recent experiments at the NAPTF, FAA researchers have observed that concrete pavement slabs are affected by more than heavy aircraft wheel loads. Temperature changes, moisture variations and shrinkage combine to cause slabs to curl – sometimes upwards, sometimes downwards. Curling can separate pavement slabs from the surfaces that support their edges or interior portions. Stresses caused by slab curling – the result of wheel loads, the slab’s own weight, or both, pushing down on the corners that are trying to curl up – can contribute to early pavement cracking and shortened pavement life.

“Until now,” says Pecht, “we have had limited field data to confirm test findings from our simulations at the National Airport Pavement Test Facility. The Atlanta project will provide long-term, in-situ data on vertical slab movements caused by aging and environmental loads. We hope these insights will help designers to develop longer-lasting and more cost-effective solutions for airport pavements.”

From 2004 through 2006, the FAA collected data from a pair of instrumented concrete slabs (the “twin slabs”) at the NAPTF. One slab was located inside the test facility and was subject to only seasonal temperature changes. The other was located outdoors and was exposed to weather as well as daily temperature cycles. The data from the twin slabs experiment confirmed the importance of the environment for slab curling, but several questions remained:

- Is slab curling a significant factor for the 20-inch thicknesses found at many major airports?
- Do slabs subjected to frequent aircraft traffic as well as environmental loads experience significantly different strain from slabs subjected to environmental loads only?
- Are strain responses at the joint of two slabs different from those at a free edge?

To help answer these and other questions, FAA researchers have now strategically placed instrumentation within Atlanta’s Taxiway E, near the east end of Runway 8R-26L. Researchers specifically instrumented three 25-foot square slabs of concrete near a threshold known to experience varying load conditions: ▷

Atlanta's Best *continued from page 18*

Slab 1: Subject to frequent heavy wheel traffic from taxiing aircraft coming from or heading to the holding area.

Slab 2: Adjacent to the first slab, receives some wheel load transferred through the longitudinal joint. Slab 2 also has a free edge bordering the shoulder.

Slab 3: Considered "unloaded," since it is out of the designated wheel path and experiences only environmental loads.

In October 2006, FAA researchers installed 64 sensors at the location of the three slabs at Atlanta just before workers placed the new concrete. They used 20 deflection (vertical displacement) transducers, of a more rugged type than those used at the NAPTF. These transducers detect slab movements as small as thousandths of an inch, as well as possible separation of the slab from the base layer. In addition, researchers installed 30 gages at various depths on the three slabs to measure strain variations related to slab movements. Two stacks of seven thermocouple sensors measure temperature changes in the entire 20-inch depth of slabs 2 and 3.

"The instrumentation is wired to a stand-alone remote data acquisition system just outside the taxiway object-free zone," explains Pecht. "The weatherproof enclosure is equipped with a self-contained power supply – consisting of an array of solar panels, a wind turbine generator, and a wireless Ethernet transmitter. The sensors embedded in the slabs let us retrieve data, once per hour, so we can monitor concrete behavior continually over the life of the taxiway. The results are being uploaded into a database, which also contains sensor coordinates and other details that help us to interpret the information precisely."

Already, FAA researchers are analyzing data collected while the concrete was curing during the first 48 hours, data from before and after the taxiway was opened to traffic two weeks later, and data from one month following the opening. The early data established a baseline for the later measurements. The preliminary data indicate some measurable vertical slab displacement at the free edge of slab 2 (next to the shoulder), as well as strain variations in response to daily temperature changes. ■

The FAA plans to make Atlanta pavement instrumentation database available to concrete engineers around the globe. For more facts about the installation, a paper presented at the 2007 FAA Worldwide Airport Technology Transfer Conference is available at http://www.airporttech.tc.faa.gov/naptf/att07/2007/Papers/P07079%20Brill%20et%20al.pdf.

Rubblization

The demand for more aircraft operations at the nation's airports could stress the concrete airport pavement infrastructure that has already served beyond its design and service limits. As a result, a major portion of these pavements will require rehabilitation in the near future. Traditionally, concrete pavement restoration procedures have been employed to maintain these pavements in a fair to good condition. However, with growing demand and rapidly aging pavements, these procedures are becoming more costly and less effective for rehabilitation efforts.

"Rehabilitation of pavements can be done by a variety of means, such as concrete pavement restoration, reconstruction, or resurfacing," explains Robert "Murphy" Flynn, a FAA pavement researcher. "Because of the expense, time, and traffic delay involved in rehabilitation and reconstruction, removing old concrete pavement and then resurfacing with a hot mix asphalt overlay is not the optimal option."

To save time and resources, airports are now borrowing a technique previously used only for highway restoration. Rubblization is quickly becoming the technique of choice for deteriorated concrete airfields. It is a unique means of rehabilitating concrete pavements that involves breaking existing pavement, rolling it, and leaving it in place to serve as a base course for the new pavement. Rubblization fractures the existing slab and breaks it into particles ranging from sand-sized to 3˝ at the surface and from 12˝–15˝ at the bottom of the rubblized layer. The rubblized layer behaves as a tightly interlocked, high-density unbound base. The end result is a material comparable to a high-quality aggregate base course.

Once the existing pavement is reduced, a new pavement surface course is constructed of either hot mix asphalt or Portland cement concrete. One of the advantages of this process is the elimination of reflective cracking in asphalt overlays. Asphalt

Rubblization *continued from page 19*

overlays placed directly onto existing Portland cement concrete pavements reflect the joints and cracks present in the underlying concrete pavement. Once reflected into the asphalt overlay, these cracks represent a major maintenance concern and are a known source of foreign object damage. Rubblization prevents the reflective cracks typically associated with hot mix asphalt overlays that are placed directly on existing concrete pavements. Reflective cracking is prevented by obliteration of the existing pavement distresses and the destruction of the existing slab action.

Rubblization requires the use of highly specialized equipment to break the concrete down to a specified maximum particle size. There are two basic types of self-contained, self-propelled devices for rubblizing pavements. The Multi-Head Breaker has sixteen 1,200- to 1,500-lb drop hammers mounted laterally in pairs with half the hammers in a forward row and the remainder diagonally offset in a rear row. Each pair of hammers is attached to a hydraulic lift cylinder that operates as an independent unit. The Resonant Frequency Breaker is a self-propelled device that uses high frequency, low amplitude impacts with a foot force of 2,000 pounds. The force applied to the pavement is achieved by vibrating the large steel beam connected to the foot.

“Airport authorities are finding that one of the biggest advantages to rubblization is monetary.” says Flynn. “Rubblization costs 66 percent less than removing the old concrete. Other benefits include time savings, reduced environmental impact, and a smoother ride.”

A number of airfield projects have used rubblization as a pavement rehabilitation technique. The projects range from heavy load military airfields to general aviation airfields. Although rubblization is becoming more popular, there is still no single standard design procedure or methodology for characterizing the rubblized layer. Without a standard, there is a risk of premature failure.

In 2004, the FAA published Engineering Brief 66, a directive providing specifications for rubblizing existing PCC pavement. This publication includes interim guidelines, based on available industrial experience, for the proper construction of rubblized Portland cement concrete base courses. A designer still must successfully submit a form called a “modification to standards” through proper approval channels before applying these interim guidelines on a FAA project.

Full-scale testing, however, is needed to develop design standards for the use of rubblization technology at airports under heavy aircraft loading. FAA researchers have yet to demonstrate conclusively whether rubblized concrete is as good as, better than, or worse than the crushed stone based material it replaces. The current working assumption is that rubblized and overlaid pavements behave like flexible pavements. Using this concept, the designer can assign an equivalent thickness value to the rubblized layer and then apply that value in a standard flexible pavement design procedure to determine the requisite overlay thickness. ▷

To test the validity of their current assumptions, researchers are now completing a study at the National Airport Pavement Test Facility in Atlantic City. They have constructed two parallel asphalt overlays for testing. One is placed over a rubblized section of concrete pavement and the other is not. While both test structures were constructed on the same medium-strength clay subgrade soil, they differ in their use of three base materials and/or construction techniques. This experimental design allows the scientists to conduct controlled, side-by-side tests on both structures.

The rubblized test items included 12-inch thick concrete slabs on different support systems (slab on crushed stone base, slab on grade, and slab on stabilized base) overlaid with five inches of hot mix asphalt. In this first study of rubblized pavement using full-scale accelerated pavement testing, the research team used the test facility load vehicle to traffic both the rubblized and unrubblized sections with simulated aircraft taxi loads. Traffic loads began at 55,000 pounds per wheel, but were later increased to 65,000 pounds to accelerate the failure.

Test results on the rubblized side indicated that the overlays performed significantly better than the design prediction based on current interim FAA guidance (Engineering Brief 66). The researchers expected this outcome, because the interim guidance is known to be conservative. When failure did occur, it generally resembled failures associated with flexible pavements. Researchers did not observe any reflection cracks on the unrubblized side. They also expected this result, since they had not exposed these sections to the daily temperature cycling that contributes to reflection crack failures. Researchers will use the data to determine the required thickness of asphalt overlays on rubblized pavements.

These test revealed some insight into the characteristics of the rubblized material. It indicated that rubblized concrete pavements with hot mix overlays overlay are a viable option on commercial airports. The presence of a stabilized base underneath the rubblized concrete layer limited the vertical deflection in the layer below the rubblized concrete layer and helped to keep the rubblized pieces tightly interlocked.

The researchers caution, however, that every rough, worn-out concrete pavement may not be a good candidate for rubblization with a hot mix asphalt overlay. A structural evaluation of the existing pavement, traffic, subgrade, and environmental conditions must be performed prior to rubblization to determine if the technique is well suited to the characteristics of the specific pavement. It is important to understand the soil and moisture conditions for the pavement system prior to making a decision on the rehabilitation type. They have found that most Portland concrete cement pavements are good candidates for rubblization. ■

Satish K. Agrawal, Ph.D - Dr. Agrawal is the manager of the FAA's Airport Technology Research and Development program. In this capacity he is responsible for formulating, directing, managing, and conducting research in the following areas: Airport Pavement Technology; Runway Surface Technology; Airport Visual Guidance; Runway Incursions; Wildlife Hazards at or near Airports; Airport Planning and Design Technology; and Post–Crash Aircraft Rescue and Firefighting. Dr. Agrawal has been with the FAA for 27 years. He earned his master's degree from the University of Iowa and his Doctorate from the Pennsylvania State University.

Barbara Davenport is the secretary responsible for providing administrative functions for 20 employees. Barbara started her career with the FAA as a cooperative education student in 1981 and worked as a secretary in the Aircraft Safety Branch. She has been with the FAA for 25 years. She earned her Associates Degree in Business Administration from Atlantic Cape Community College. She is also an active volunteer firefighter.

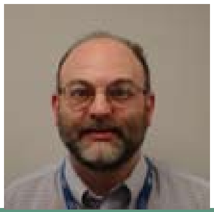
Donald Barbagallo is a civil engineer with 29 years of experience working for the U.S. Navy. He began his career as a naval architect at the Philadelphia Naval Shipyard working on the structural design modifications that formed the framework of the service life extension program for the Navy's conventional aircraft carriers. After the Shipyard, Don worked as a facility planner with the Naval Facilities Engineering Command where he developed facility requirements and cost estimates for new facilities under the DOD's Military Construction Program. Prior to FAA, Don was a structural engineer for the Navy Crane Center responsible for the design, modification, and procurement of cranes for the Navy's worldwide weight handling equipment program. Don uses his experience to assist in the planned upgrades to the test vehicle at the National Airport Pavement Test Facility as well as construction projects associated with ongoing pavement test experiments. Don earned his BSCE from the University of Delaware and is a registered professional engineer.

Gordon F. Hayhoe, Ph.D., is a general engineer and is manager of the National Airport Pavement Test Facility. He is also responsible for research and development in the area of airport pavement design and evaluation. Dr. Hayhoe has been with the FAA for ten years. He previously worked at Galaxy Scientific Corporation, Egg Harbor Township, New Jersey, and the Pennsylvania Transportation Institute, the Pennsylvania State University, in the areas of pavement design and evaluation, the measurement and analysis of pavement surface properties, and vehicle dynamics. He is a member of ASTM Committees E17 (Vehicle-Pavement Systems) and F09 (Tires). He earned his master's and doctoral degrees from the Cranfield Institute of Technology, Bedford, England, in 1969 and 1973 respectively.

Robert Flynn is the construction manager for the National Airport Pavement Test Facility. He has a Bachelor of Science in Ocean Engineering from Florida Institute of Technology, Melbourne Florida. From 1992 to 2000 he worked for the U.S. Army Corps of Engineers, Philadelphia District. From 1997 to 1999, the FAA contracted with the Army Corps of Engineers to build the NAPTF, during which time he served as the on site project engineer.

Al Larkin joined the Airport Pavement Technology R&D branch in October 2006 as a general engineer. He worked 16 years at Naval Weapons Station Earle as the Explosives Safety Officer (ESO). He also served as the ESO for all Navy Region Northeast activities from Maine to New Jersey. His experience in heavy construction – dredging, marine construction and municipal engineering contributes to his work at the National Airport Pavement Test Facility in Atlantic City, New Jersey., where he evaluates nondestructive (NDT) technologies for the structural or functional condition of airport pavement. Al earned his BSCE from the New Jersey Institute of Technology.

e Team



David R. Brill, Ph.D., is a general engineer responsible for research and development in advanced airport pavement design procedures. In addition, he is the FAA Program Manager for CEAT, the Airport Technology Center of Excellence. Dr. Brill has been with the FAA since 1999. He previously worked at Galaxy Scientific Corporation, Egg Harbor Township, New Jersey, in support of the FAA's airport technology program. He is a professional engineer licensed in New Jersey and Pennsylvania, and a member of the ASCE Airfield Pavement Committee. He earned his master's and doctoral degrees in civil engineering from Rutgers, the State University of New Jersey, in 1988 and 1996 respectively, and his Bachelor of Civil Engineering from the University of Pennsylvania in 1983.

Stephen Materio is an aerospace engineering technician responsible for operational planning and maintenance of the Pavement Test Vehicle. He is retired from the United States Air Force and has completed numerous technical and management courses in the field of aviation. He previously served as manager of the Mt. Washington Regional Airport located in Whitefield, New Hampshire. He holds a Commercial Pilot and Airframe/Powerplant License. While at the FAA he has performed many duties, such as test pilot and researcher examining Boeing 747-SP lateral gear loads and the impact loads of a King Air 90 striking taxi-way light markers.

Ryan Rutter is an electronics engineer responsible for maintaining and providing upgrades to the National Airport Pavement Test Vehicle. His main focus has been on the programming, hydraulic control systems and the electronics for the Vehicle. He has been with the FAA for three years. He previously worked at Galaxy Scientific Corporation, Egg Harbor Township, New Jersey. He earned his Bachelor's Degree from Capitol College, Laurel, Maryland in 1996.

Frank J. Pecht is a data acquisition specialist responsible for the design, installation, operation and maintenance of all pavement instrumentation at the National Airport Pavement Test Facility. He has been with the FAA for ten years. He previously worked at Galaxy Scientific Corporation, Egg Harbor Township, New Jersey, and the Princeton Plasma Physics Lab, Princeton University.

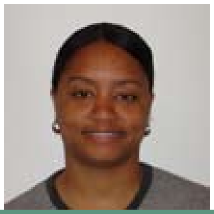
Navneet Garg, Ph.D., joined the FAA in May 2007, as a general engineer. He has 16 years of experience in various aspects of airport/highway pavement research. Prior to FAA, he worked at SRA/Galaxy since 1998. He has been actively involved in airport pavement research at the FAA National Airport Pavement Test Facility. A member of the Transportation Research Board Committee on Full-Scale and Accelerated Pavement Testing (AFD40), and American Society of Civil Engineers Airfield Pavement Committee, Garg earned his Doctoral degree in Civil Engineering from University of Illinois at Urbana-Champaign, Master's in Civil Engineering from Illinois Institute of Technology, Chicago, and Bachelor's in Civil Engineering from Karnataka Regional Engineering College, Suratkal, India.

continued on page 24 ▷

Meet the Team - continued

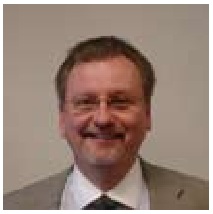
Paul H. Jones is the manager of the Airport Safety Technology R&D program. In this position, he has responsibility for development, modification, and evaluation of Airport Visual Guidance Systems, Wildlife Hazard Reduction, Airport Rescue and Firefighting, and Runway Surface Technology for the enhancement of safety on airfields. He has been with the FAA for over 34 years. Mr. Jones is a graduate of the New Jersey Institute of Technology with a Bachelor of Science in Mechanical Engineering. He is a pilot with multi-engine and instrument ratings

Nicholas M. Subbotin recently joined the FAA after three years with Hi-Tec Systems supporting various FAA programs such as the Aircraft Rescue & Fire Fighting (ARFF) and New Large Aircraft Research Programs. He also was a co-op student with FAA. Nick has worked as a key member testing and evaluating new airport firefighting technology, providing technical support changing ARFF standards, and researching the U.S. airports' accommodation of NLA, such as the Airbus A380. Nick will be working as a project manager supporting the ARFF, NLA, and Runway Surface Technology Research Programs. Nick earned his BS from Embry-Riddle Aeronautical University - Daytona Beach in 2003.



Renee N. Frierson recently joined the FAA after more than four years at Hi-Tec Systems supporting the Airport Safety Technology Visual Guidance Program. Renee has worked on various testing efforts involving new lighting technologies, paint markings, and signs within the Visual Guidance Program. In addition, she has worked with the Transportation Security Laboratory testing airport screeners on work-load fatigue studies. Before working at Hi-Tec Systems she also worked at Sikorsky Aircraft as a crew station designer, where she worked with the navigational system of the Comanche military helicopter. Renee earned her BS in Human Factors Psychology from Embry-Riddle Aeronautical University in 2001.

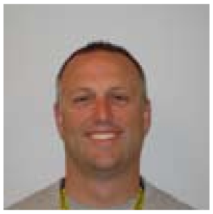
Holly Cyrus is currently a project manager performing research and development of Visual Guidance equipment and Pavement Marking Materials. She has been with the FAA for 19 years. Her experience includes two years with the Environmental Engineering Branch, Depot Engineering, where she found replacements for obsolete parts for lighted navaids and engine generators. She worked for eleven years with the Navigation and Landing Branch in Oklahoma City, Oklahoma, performing modifications and field support of lighted navaids. Holly is a graduate of the University of New Mexico, Albuquerque, New Mexico. She received her Bachelor's degree in Mechanical Engineering. She is a graduate of Capella University, Minneapolis, Minnesota. She received a Masters in Business Administration.



Donald W. Gallagher's initial assignment was with the FAA Helicopter Operations Program. He currently serves as the Visual Guidance program manager responsible for managing R&D flight test projects. During his almost 25 year FAA career, his duties varied from navigation systems (MLS, GPS) to Visual guidance systems testing (PAPI, MALSR, ALSF-2). He has coordinated R&D research of airport visual guidance systems (Signs, Lighting, and Markings) and supported various organizations within the FAA investigating new technology for use in Visual Guidance, while maintaining or improving the visual cues to pilots and ground vehicle operators. He is currently a Technical Advisor to the U.S. member of the ICAO Aerodrome Panel's Visual Aids Working Group and a current member of the Illuminating Engineering Society.

Ryan E. King is a general engineer responsible for the management, coordination, and conduct of research projects in the areas of Airport Surface Friction, Engineered Arresting Systems, and Wildlife Hazard Mitigation. He has been with the FAA for 11 years. He earned his Bachelor's degree in Civil Engineering from Virginia Polytechnic Institute and State University.

James Patterson is an airport safety specialist managing research projects in Visual Guidance, Aircraft Rescue and Firefighting, Airport Design Safety, and Operation of New Large Aircraft. Jim joined the FAA in 1999. He has a Bachelor of Science degree in Airport Management - Flight Technology from Florida Tech, Melbourne, Florida. He holds a Commercial Pilot Certificate with Instrument and Multi Engine ratings, a Certified Flight Instructor Certificate, and an Aircraft Dispatcher certificate. He is also an active volunteer firefighter.



Keith W. Bagot is an Airport Safety Specialist responsible for the management, coordination, and conduct of research projects in the areas of Aircraft Rescue and Fire Fighting (ARFF) and Airport Planning. He has been with the FAA for 18 years. Keith earned his Bachelor of Science degree in Aviation Management from Florida Institute of Technology, Malbourne, Florida.

Airport Technology Safety Research

Many, perhaps most, of us have waited at the gate for our flight and idly watched the finely tuned ballet of aircraft, people, and vehicles that moved about the airport's surface. But not all of us have realized that ensuring the amazing safety of this virtually non-stop performance is one role of the FAA Research and Development program. Think of it! Choreographed into this dance – this safety ballet – each year are 600,000 pilots making about 62 million takeoffs and landings. They, and many, many more passengers and crew – as well as thousands of individuals who operate fuel trucks, service vehicles, and luggage/cargo carriers – rely largely on the refinement of existing technologies and procedures, and the discovery of new ones, for their safety. ▷

"The sheer number of flights, people, and vehicles moving across airport runways and taxiways, means our research program needs to work proactively to ensure safety," says Paul Jones, airport technology safety R&D manager. "We have achieved significant advances in runway safety, including better airport layout, signage and lighting, implementation of technology designed to prevent accidents, and improved rescue and firefighting vehicles and techniques. But, with air travel increasing to all time levels, we must work hard – and we especially must work smart – to stay ahead of the rush."

The role of the airport technology safety research program is to help the FAA determine policy, guidelines, procedures, and technologies for take off and landing operations, airside and landside optimization, and airport surface operations.

FAA research is paying off. In the past decade, R&D findings have resulted in substantially revised airport standards, new standards, or changes in airport safety practices. Examples include:

- Enhanced centerline paint markings on taxiways at 72 airports now alert pilots that they are approaching "hold short" lines.
- Reflective glass beads added to the paint used in surface markings now make pavement markings and surface-painted signs easier to see under reduced lighting.
- Doubling the size of standard holding position markings, and – on light colored pavements – outlining the marking in black now makes them more readily seen. (The standard is now 12-inch wide lines and 12-inch spaces between the lines.)
- New stop bars are now being used at certain runway/taxiway intersections. (A stop bar is a series of in-pavement and elevated red lights that indicates to pilots that they may not cross.)
- Revised color coding of taxiway centerline lights are now being used at many taxiway/runway intersections. (Alternating green and yellow lights now inform pilots that their aircraft is within the runway safety area. The FAA expects these values to be incorporated into revised ICAO Standards and Recommended Practices.)
- Updated obstruction lighting standards now mandate the nighttime illumination of wind turbine farms with specific light fixtures, at particular spacings.

"Technology can and should play a pivotal role in meeting the demands for ensuring surface safety, maintaining infrastructure in good working condition, and keeping preservation and life-cycle costs as low as possible," says Jones. "Because airport safety is a critical priority of industry, we are teaming with the aviation community and academia to solve common concerns. This spirit of cooperation has led to the development of a number of unique products that are improving airport operations and saving lives. The engineered material arresting system, now being installed around the country to expand runway safety areas, is an excellent example of our partnering with industry. Also, a number of airports are installing an infrared deicing system created under a cooperative agreement with the Agency. And, our runway incursion research is resulting in fewer breaches of safety."

The FAA's airport safety research program runs the gamut from mitigating wildlife hazards, to improving runway lighting and marking, to working with industry to develop and set requirements for foreign object debris detection systems, to ensuring airports are ready to accept flights from the new generation of super jumbo jets. "We have a long legacy of success," states Jones. "In fact, our work is recognized worldwide as critical to improving operations on the airport surface."

FAA researchers are working with several new-technology companies to evaluate foreign object debris (FOD) systems that are capable of identifying small objects, such as bolts, screws, metal pieces, rocks, paper, plastic, plants and animals dropped on a ▷

runway surface. FOD costs the airlines an estimated $4 billion a year as a consequence of damage to aircraft engines, tires, landing gears, wings and aircraft bodies. These systems, which use radar, cameras, or a combination of both, provide real time detection information, as well as hazard identification, to airport operators so that they can swiftly act to remove the FOD from the runway before any harm is done to passing aircraft. FAA researchers are evaluating several such systems in an attempt to develop performance standards for FOD detection systems.

FAA researchers are also participating on a new subgroup of the International Civil Aviation Organization Aerodrome Panel, Visual Aids Working Group. Comprised of representatives from member states including the United States, Canada, Italy, France, and Germany, this panel is focused on the issue of using Light Emitting Diode (LED) technology for airport visual aids. The group will be providing guidance material on using LED technology in visual aids that will be included in the ICAO Aerodrome Design Manual, Part 4 – Visual Aids. Members are assigning research tasks to different government entities to avoid redundancy of work, accomplish necessary research faster, and facilitate closer cooperation among ICAO member states.

The airport technology R&D team is working to establish standards for airport and rescue and firefighting operations for new large aircraft, such as the Airbus A380 and the Boeing 747-8. FAA personnel have teamed with government researchers at Tyndall Air Force Base in Panama City, Florida, to construct a large aircraft full-scale live-fire mock-up. This working model will support the testing of fire-related new large aircraft programs, such as the development of a next generation high reach elevated turret, firefighting rescue strategies and tactics, and the interior intervention vehicle development.

With wildlife populations growing around airports, FAA researchers are investigating the feasibility of various mitigation techniques. Their current focus is on developing radar technologies to detect bird activity. In addition, they are studying wildlife habitats and examining possible ways to discourage wildlife from taking up residency at airports.

“Safety has always been and will always be a primary factor in the management of any airport,” says Jones. “With domestic and international travel increasing, it is critical we continue our pioneering efforts to ensure the highest level of safety. Technology advances and new systems are introduced almost daily, and it is up to the FAA to provide up-to-date guidelines and regulatory materials to maintain our excellent record of making this nation’s airports as safe as they possibly can be.” ■

Airport Design

A modern airport is actually a transportation hub, a complex intersection for air and ground modes of travel where, each day, thousands of air passengers depart and arrive from virtually every corner of the world. Most of us recognize the challenge that the designers of busy airports face in laying out runways and taxiways that can readily accommodate expanding numbers of large aircraft. The fact is, though, airport engineers must also ease the entrance and exit of many vehicles that are not aircraft – and of many aircraft that are not jumbo jets. On top of that, they must provide for the safe and efficient movement of fleets of vehicles involved in a wide range of airport and aircraft service operations. There is more to designing a modern airport than generally meets the public eye.

As complex as airport operations may be today, they will surely be more complex tomorrow. The FAA Aerospace Forecast Fiscal Years 2007-2020 predicts 768 million people will fly this year on U.S. commercial air carriers, more than one billion passengers by 2015, and 1.2 billion by 2020. In this rapidly changing transportation environment, the FAA determines airport design standards, updates them as needed, and advises airport operators on the safe operation, maintenance, and expansion of our airports.

With the number of commercial passenger boardings expected to nearly triple over the next two decades, airframe manufacturers have begun introducing new large aircraft to the national airspace system. Preliminary research shows that the introduction of new large aircraft will significantly affect nearly every U.S. airport that accepts them. The FAA has a comprehensive system to classify airport dimensional requirements by the size of the most demanding aircraft or group of aircraft intending to operate at the airport (see Table 1 below). New large aircraft, such as the Airbus A380 or the Boeing 747-8, will generally require the clearances and dimensional standards appropriate to design group VI. Airports that are expecting to serve these aircraft will have to expand and upgrade their facilities accordingly.

Table 1: FAA Airport Design Group Classification

Design Group	Wingspan (feet)	Example Aircraft
I	<40	Cessna 152-210
II	49-78	Saab 2000, EMB-120
III	79-117	Boeing 737, MD-80
IV	118-170	Boeing 757, Airbus A-300
V	171-213	Boeing 747 and 777, Airbus A-340
VI	214-262	Airbus A380, Boeing 747-8

For many years, FAA researchers have performed studies to ensure that the nation's airport guidance and standards remain up-to-date. Now, even as the era of super-jumbo aircraft approaches, these specialists are reconsidering airport requirements to accommodate the A380 and other new large aircraft. They are reviewing the current widths, clearances, and separations of airfield operational areas, and modeling how new air traffic control procedures – particularly queuing and spacing – may affect runway acceptance rates. Based on their preliminary findings, they recognize that existing airports may not meet all required new FAA design standards, such as runway safety area dimensions and separation between runways and taxiways.

The planning and design of any future airport must consider compatibility with all aircraft it serves. Accordingly, to provide the proper size, capacity, and operating characteristics, the envisioned aircraft mix will affect the layouts of both the airport's airside and its landside configurations. On the airside, all possible types of aircraft will dictate the length and width of runways, the minimum separation between runways and taxiways, the size of aprons and protection areas around the landing area, and the pavement strength.

Standard required dimensions will soon increase as new aircraft come into service. Yesterday's premier jumbo jet, the Boeing 747, held approximately 416 passengers, but various configurations of the Airbus A380 will hold between 500-800 passengers. The overall weight, wingspan, length, and performance characteristics of this and other new aircraft, combined with relevant ▷

site-specific conditions, will determine the length and configuration of the runways and taxiways of each airport that can accommodate them. The A380, for example, will need more than two miles of runway to take off and land.

Wingspan, in particular, has a profound effect on the planning of an airport's runway and taxiway dimensions and its required separation standards on the ground. The FAA recommends that, because the A380 has a 261-footwingspan, airports intending to serve this class of aircraft must provide taxiways that are at least 100 feet wide. Most existing taxiways, however, are built to accommodate smaller aircraft and have only a 75 feet wide taxiway straight section. The FAA has been conducting a multi-phased research program to determine if these new large aircraft could safely use these existing 75-foot wide taxiways.

The Boeing 747 is now the largest commercial aircraft in continual operation in the United States. Because of its availability and frequency of use, the FAA airport design research team has been studying this aircraft's dimensional requirements to prepare for the even-larger Airbus A380 and Boeing 747-8. In their initial research, the analysts placed laser rangefinders about 150 feet apart to measure how far the main and nose landing gears of 747's wandered or deviated from the middle of straight sections of taxiways. The analysis included more than 20,000 recorded instances at New York's John F. Kennedy International Airport, and nearly 30,000 observations at Ted Stevens Anchorage International Airport.

After researchers provided input from phase one of the study, the FAA released Engineering Brief No. 63, "Use of Non-Standard 75-Foot-Wide Straight Taxiway Sections for Airbus A380 Taxiing Operations," and made the report available online at http://www.faa.gov/arp/engineering/ briefs/eb63.doc. On the basis of these findings, the Agency has permitted its regional airport offices to approve modifications to standards for Airbus 380 taxi routes, allowing them to use 75-foot wide straight taxiway sections on existing taxiways, but only on an interim basis. New construction must adhere to the 100-foot standard. This should be recognized for what it is, a temporary and limited solution.

In the second phase of their research project, FAA engineers studied by how much 747s tend to deviate from taxiway centerlines at an additional large airport. Based on this information, engineers can extrapolate how likely the wing tips of A380s would be to interfere with aircraft operating on parallel taxiways. Phase II studies also involved other aspects of aircraft separations and obstacle clearance standards, such as the distances from an aircraft to other vehicles and buildings. The team installed three new pairs of laser rangefinders, including cameras to verify centerline deviations, at the San Francisco International Airport to collect additional data. Over 10,000 data points were collected during this installation. The next steps to be taken include deviation data collection at smaller design group airports to validate whether or not similar taxiing behavior exists with smaller aircraft, on the taxiway of smaller airports. Airport selection is currently underway.

The location of runways and taxiways relative to airport terminals is not the only design consideration of FAA researchers. They are also helping airports to identify funding strategies that will allow them to update their infrastructures to meet growing operational demands. One research project involves the development of a survey model, through which researchers hope to collect passenger input that will help to mold improved airport planning goals.

Research teams are not concerned only about the safety of large commercial airports. They are also helping to find new ways to improve the infrastructure designs of general aviation airports.

A large increase in volume as a result of new aircraft would affect both the busiest and the smallest general aviation airports. Neither facility type could necessarily handle a large increase in activity. Consequently, airports need to know what level of aircraft activity they can expect and what infrastructure, facilities, and services they would need to accommodate aircraft such as the new small jet aircraft currently being introduced, commonly called the Very Light Jet (VLJ). Engineers need to learn as much information as possible on the likelihood of general aviation aircraft activity increases at airports as influenced both by category of airport and by geographical location. ■

For more information, visit http://www.airporttech.tc.faa.gov/Design/

Runway Incursion

Making Runway Incursions a Thing of the Past

Introduction

The FAA predicts more than one billion passengers will be flying by 2015. With greater numbers of passengers flying on increasingly diverse types of aircraft all vying to use the nation's runway and taxiways, FAA researchers are working to mitigate the risks of runway incursions.

A runway incursion occurs when an aircraft in the process of landing or taking off passes dangerously close to another plane, vehicle, person, or object on the ground. When aircraft of different types and capabilities move closer together, when changing weather conceals normal visual cues, when airport signs and surface markings are unclear, when pilots must operate in unfamiliar airports, or when the layout of an airport seems unnecessarily complex and varied, the situation is ripe for a runway incursion.

Eliminating runway incursions is a top FAA priority and a prominent element on the National Transportation Safety Board's "most wanted" aviation safety improvements. This is not a priority that will be easily or quickly met, for it involves not only identifying the many factors that influence the risk of runway collisions but also developing new means to eliminate them.

The FAA's Airport Technology R&D program has taken on the challenge of finding technological and procedural solutions to help commercial and general aviation airports better accommodate traffic growth, while maintaining a safe operational environment. In the meantime, current awareness programs, training packages, procedures, and some effective new technologies are consistently helping to reduce incursion rates. The human diligence of FAA personnel, pilots, airport workers, and others who access active runways and taxiways will always be vital to keeping the flying public safe.

Complex fleets of aircraft and vehicles operate virtually non-stop on the paved areas of busy airports. Existing lighting, marking, and signage systems provide essential visual information to pilots and other vehicle operators to ensure their safety and ease their tasks of taxiing, taking off, landing, and just maneuvering on the airport surfaces. The introduction of available and envisioned technologies might significantly improve the design and performance of these crucial systems.

"The systems we study," explains Don Gallagher, FAA visual guidance research manager, "provide information that a pilot needs first of all to locate the airport itself, and then to identify the positioning of its runways and taxiways with their related parts and features – such as edges, thresholds, centerlines, and visual glide paths. Airport visual aids convey this information through varied lighting, marking, and signage."

Lighting

Of the nation's 480 airports with control towers, 310 have reported at least one runway incursion incident. Between 1999 and 2005, there were more than 2,450 incursions, seven of them resulting in collisions. Witnesses and participants report that inability to see the runway or its markings could have been a major factor.

Many airports have lighting that helps guide planes toward their runways and along their taxiways and runways at night or in bad weather. Green lights facing a landing aircraft, for example, indicate the beginning of the runway, while red lights indicate its end. White lights spaced out on both sides indicate the edges of the runway. Blue lights indicate the edge of taxiways, and some airports have embedded green lights in taxiways to indicate their centerline. Additional visual cues used for runway lighting may include other lights that indicate the approach. Pilots control the lighting to save electricity and staffing costs at some low-traffic airports.

One successful research project with commercial airports noted that pilots who are busy with taxi or takeoff checklists may miss the indications that they are nearing an intersecting runway. FAA researchers developed a new lighting configuration that alerts pilots of their proximity to a runway. Results indicated designers could enhance safety by changing the centerline taxiway lighting at a strategic "lead-on" point from all green to an alternating green and yellow pattern. Also, acting on suggestions from industry, researchers looked into the feasibility of reversing these yellow and green lighting configurations to warn the pilots of taxiing aircraft whether they are approaching or moving away from the intersecting runway environment. They tested whether it would be possible with the new reversible patterns to mark hold position areas more efficiently, potentially further reducing the risk of runway incursions. ▷

Runway Incursion *continued from page 31*

“The aviation industry can benefit significantly from solid-state lighting technologies, which hold promise for lower energy consumption and reduced maintenance.”

For testing purposes, researchers temporarily constructed a curved taxiway entrance lighting configuration, using standard FAA approved taxiway lighting fixtures, at the FAA William J. Hughes Technical Center. They found that illuminating the runway environment area with alternating yellow and green centerline fixtures was a cost-efficient, easy-to-deploy tool that could well have a positive impact on reducing runway incursions at airports that already have taxiway centerline lights. The new lighting scheme is particularly useful in distinguishing runways from taxiways in low light or foggy conditions, and the FAA now requires its use at commercial airports.

While the only runway incursions that usually make news headlines involve commercial passenger aircraft, the problem of close calls is proportionally greater at general aviation airports. As detailed in the 2005 FAA Runway Safety Report, general aviation planes make up 57 percent of operations in the national airspace system, yet account for 74 percent of incursions. Furthermore, three out of four of the most severe category incursions involve at least one general aviation aircraft.

A team of FAA researchers led by Jim Patterson recently completed a study at North Las Vegas Airport, a general aviation facility, to determine if changing the configuration of lights would help mitigate runway incursions. The airport had reported 40 runway incursions between 2001 and 2005, five of them categorized as serious, and one crash in 2003. For the study, researchers recruited 42 pilots who use the field regularly in the course of their work with flight schools and charter companies. The researchers conferred with the subjects to determine distances that mandatory hold signs (red and white), surface holding position painted markings (yellow), and three new configurations of the runway guard lights were acquired.

“When used together in a consistent application,” Patterson explains, “configurations with readily distinguishable meanings offer pilots enhanced visual cues that they are approaching the hold position marker, for example, and need further clearance to proceed. Even though runway guard lights are intended as a supplemental warning system for low-visibility conditions, pilots tell us the extra lights make runway hold positions much more conspicuous, and thus reduce the likelihood of causing a runway incursion.”

Patterson continues, “The standard signs performed best in the daylight, when compared to the in-pavement runway guard lights, while the elevated runway guard lights proved most effective during dusk, dawn, and nighttime conditions. Of the pilots polled, 60 percent ranked the elevated runway guard lights as the most effective identifier of the taxiway hold position. When approaching a hold position head-on under all test conditions, the subjects gave the highest effectiveness rating to the elevated and in-pavement runway guard lights, with the lighted sign alternative a close second. They considered the painted markings, especially when obscured by poor lighting or a partial covering of water, the least helpful.”

FAA researchers have also been actively trying to determine whether light emitting diodes (LED) might pose a viable replacement option for the technologies behind existing airport visual aids. LEDs are brighter than the bulk of today’s airport lights, and because they consume less power and last longer, they are cheaper to operate. The researchers have now evaluated the use of LEDs for varied airport lighting applications at, among others, New Jersey’s Atlantic City International and Hammonton Municipal airports, and at North Dakota’s Grand Forks International Airport.

“The aviation industry can benefit significantly from solid-state lighting technologies, which hold promise for lower energy consumption and reduced maintenance,” says Patterson. “We are collecting data at a number of diverse airports so we can recommend acceptable LED-based performance criteria to take the place of traditional lighting standards.”

“The introduction of the economical and efficient LED represents the greatest potential change in the lighting of airport visual aids in decades,” says Gallagher. “Our research, however, isn’t done yet. We need to further study how LED technology interacts when interspersed with standard incandescent lights on airport circuits; how LED intensity changes can be effected; and how LEDs can be seen on an enhanced vision display.” ▷

Other lighting solutions are showing potential for use in safety-critical areas of the nation's airports. The FAA lighting research team has also demonstrated the feasibility of using solar-powered lights at general aviation airports. This technology tested at Cross Keys Airport in Gloucester County, New Jersey, could eventually benefit thousands of similar small airports across the country. Many of these facilities provide little, if any, lighted guidance for pilots taxiing from runways to aircraft parking areas. The simplicity, economy, and reliability of high-quality solar-powered lights could safely serve remote sites that lack access to electricity, as well as airports with limited resources to pay for power.

Guidance Signs

Traffic signs on the surface areas of major airports help to direct the safe and expedient movement of taxiing aircraft and airport vehicles. Smaller airports, having fewer or no signs, may rely to a greater extent on generalized airport diagrams and charts. There are, however, two general classes of signage at airports, with several types within each:

Operational guidance signs

- Location signs (yellow on black) identify the runway or taxiway an aircraft is currently on or about to enter.
- Direction/Runway Exit signs (black on yellow) identify the intersecting taxiways an aircraft is approaching and indicate, by an arrow, required changes in direction.
- Other signs (throughout many airports) display conventional traffic messages such as "stop" and "yield."

Mandatory instruction signs (white on red) show entrances to runways or critical areas. Vehicles and aircraft are required to stop at these signs until the control tower gives clearance to proceed. Instructions include:

- Runway signs (white on red) identify a runway intersection ahead.
- Frequency change signs (usually a stop sign and an instruction to change to another frequency) are used at airports that separate ground control into multiple areas.
- Holding Position signs (single solid yellow bar across a taxiway) indicate a required stop; two solid yellow bars and two dashed yellow bars may indicate a holding position for an upcoming runway intersection. These standard instructions must never be violated without expressed permission.

New technologies – such as, photoluminecent painted signs, fiber optics for distance remaining signs, LED addressable signs – have been, and are being researched.

Pavement Marking

Airport pavement markings, a critical component of airfield visual aids, must be properly maintained. Airports dedicate considerable resources to this purpose, but ultraviolet radiation and other sources of environmental degradation start to break down traditional pavement marking products almost as soon as they are applied. Finding a viable maintenance solution is a high priority for FAA researchers.

Runway holding position markings, commonly referred to as "runway hold" lines or "hold short" lines, are among the important aids that help pilots and vehicle operators to navigate on the airport surface. Painted on taxiways, and sometimes on intersecting runways of controlled airports, these markings indicate areas that pilots must not cross until given specific permission to do so from air traffic control. "Increasing the conspicuity of these hold lines would provide safer control of aircraft on the ground and thus help to reduce runway incursions" explains FAA researcher Holly Cyrus.

In jointly-conducted experiments undertaken by the FAA and MITRE CAASD, researchers tested a new painting technique to see if it alerted pilots to the presence of the "hold short" line more effectively than the markings now in conventional use. When applied to surfaces at an airport in Frederick, Maryland, the experimental paint scheme made the "hold short" line appear three-dimensional. The tests at Ted Francis Green Airport in Providence, Rhode Island, proved so successful at reducing incursions that the FAA is taking the program nationwide. New enhanced centerline and hold short markings will be required by June 30, 2008 at the nation's 72 biggest airports (those airports with more than 1.5 million enplanements a year). The new markings will be optional at all other airports; but if they are used, they must be installed at every holding position on the airfield.

The FAA has published Advisory Circular 150/5340-1J, "Standards for Airport Markings," to mandate the following enhancements to current "hold short" centerline markings:

- Include a set of parallel dashes on either side of the existing taxiway centerline for the final 150 feet leading up to a runway hold line.
- Change the runway holding position markings on taxiways from four evenly spaced yellow lines and dashes to two solid yellow lines and two dashed white lines. These new lines must extend to within five feet of the edge of the pavement or twenty-five feet of the edge of taxiway, whichever is less.
- Place a second (painted) holding sign on the surface to the right of the taxiway centerline. ▷

"Airport pavement markings on runways, taxiways, and ramps play an important role in preventing runway incursions," states Ms. Cyrus. "They are important aids to help aircraft and vehicle operators navigate the airport surface and to communicate their location to air traffic controllers. Airport paint markings, however, become less conspicuous as they age and must be replaced over time. Our research program is working with the aviation community to find alternatives to traditional ways to mark airport pavement and to evaluate how visible the markings are."

Currently, the condition of pavement markings is determined by visual inspections, but the validity of these inspections cannot always be confirmed. To improve inspections, the FAA found a quick and objective way to automate the evaluation of paint markings applied to the vast surface areas of a large airport. The new method uses three measurement tools to eliminate subjectivity. A retro-reflectometer is used to rate the retro-reflectivity of the beads, a spectrophotometer to determine whether or not the paint marking had faded, and a transparent grid to quantify paint coverage. If any one of these three tests fails, the pavement marking is rejected. Additionally, the team has used a commercially available van-mounted mobile unit to increase the speed and sample size possible in the automated evaluation of markings at large airports with very long runway centerlines and thresholds.

In yet another application of available technology, FAA's airport safety researchers evaluated the effectiveness of a glass coating to prevent the deterioration of runway paint. This new marking material is called Adsil, a shortened name for anchored dendridic silicate interactive linkages. Adsil seals the surface to prevent damage from ultra violet light, fuel oil, and discoloration. Another product, which is a thermoplastic material and adheres to the airport pavement when applied with heat, shows promise as a longer lasting substitute for the standard water based paint used today. Researchers conducted a number of tests to see whether these new materials may be more practical for airport operations than conventional paints.

Another means of reducing the possibility of incursions is to minimize the total numbers of times vehicles and aircraft are permitted to cross the runway of the nation's airports. Currently, these frequencies are disturbingly high at airports with multiple parallel runways. Examples include: an estimated 1,100 crossings daily at Atlanta's Hartsfield International Airport, approximately 1,700 per day at Dallas/Ft. Worth International Airport, and nearly 2,000 per day at Chicago's O'Hare. As most of these crossings involve a taxiway at the end of a runway, they constitute a potential threat to any airplane that has been directed to taxi into position for take-off. Typically, departing aircraft are directed to use inboard runways while arriving aircraft use outboard runways. To increase operational capacity and to mitigate the risk of potential runway incursions, some airports are constructing taxiways, called end-around taxiways (EAT)that go around the runway ends. Other facilities are considering installing the EAT configurations. One problem has been noted with this configuration. An aircraft that is actually taxiing on the EAT may look like it is crossing the departure end of the runway. The pilot of an aircraft taking off on a runway that ends with an EAT may mistakenly perceive the risk of a possible accident or runway incursion and abort the takeoff or perform some other inappropriate maneuver.

To mitigate this situation, the FAA Airport Obstruction Standards Committee Executive Steering Group directed that a visual, screen-type device be designed and installed at airports with EAT facilities. The required design is based on simulator evaluations of a screen 13 feet high and 700 feet long. Pilots executing a takeoff roll, and having an unobstructed view of images on these screens, have demonstrated they can tell whether another aircraft was in fact crossing the active runway or it was simply operating on the EAT.

FAA airport safety researchers investigated the most conspicuous configuration and combination of color and materials for the EAT screen. The results of this evaluation validated that the pre-specified minimum screen height of 13 feet was satisfactory, that the color and size combination of 12 feet wide red and white engineering grade reflective material in a diagonal pattern proved most effective, and that no additional external lighting was needed to enhance screen visibility at night. No degradation of the screen's effectiveness resulted from tilting it at an angle of 14 degrees to avoid interference with radar systems or allow effective access for emergency equipment. On September 29, 2006, as a result of this research, the FAA issued Change 10 to Airport Design Advisory Circular 150/5300-13, adding design criteria for EAT Screens.

"We are steadily making progress in reducing runway incursions," concludes Don Gallagher. "For whatever reason, some pilots may not see the signage, painting, and lighting on the runways and taxiways. Our work is improving airport visual guidance tools and improved situational awareness equals improved safety." ■

For more information on the FAA's airport safety research program, please see http://www.airtech.tc.faa.gov/.

Runway Friction

Despite advances in aviation technology, operational procedures, and weather forecasting, safe winter runway operations remain a challenge that airport operators and air traffic controllers share with the international airlines and pilots they serve. These groups maintain a constant vigil to coordinate their efforts in a rapidly-changing weather environment – under conditions that are seldom the same at any two airports or countries.

Control of an aircraft during ground operations depends on adequate tire contact and friction between the tires and the pavement surface. This interaction is relied on for lateral control and to oppose side forces such as cross wind. Equally significant is the retarding force for braking. In situations where tire contact or friction is deficient, there is a loss of directional control and braking, generically known as slipperiness.

The presence of ice or snow diminishes a pilot's ability to control an aircraft moving on the surface of a runway, but the effects of another year-round problem are also intensified in the winter months. Investigators have shown that inaccurate, incomplete, or confusing surface information has played a role in a number of winter accidents in which airliners have slid off the end of a runway. In these cases, reduced traction owing to the effects of snow, ice, or rain has been involved – but so too has been the lack of information that would have helped the pilots of arriving aircraft to decrease their speed, or departing aircraft to reach the required liftoff speed, in the length of time and runway remaining to them.

As part of an international effort, FAA researchers are working with colleagues at NASA and Transport Canada to create a system that would allow airport operators to get a better handle on operative winter weather conditions and, on the basis of this knowledge, to reduce the numbers of accidents attributed to ice and snow on runways. The Joint Winter Runway Friction Test Program, begun in 1995, is the result. International interest has grown rapidly, and the project is now supported in a dozen countries by more than 30 organizations, including the European Joint Aviation Authorities.

"On an airport runway, friction is indispensable," explains Paul Jones, airport technology R&D safety program manager. "Airport operators monitor runway conditions for friction and contaminants. A runway that has a surface condition other than bare and dry is termed contaminated, and any amount of contaminant may reduce friction. To maintain acceptable operating conditions, airports use plows, brooms, and blowers to remove loose contaminants from pavement surfaces, and chemical agents to reduce the effects of runway ice and compacted snow."

As an aircraft approaches for landing, the control tower relays information to the pilot about these surface conditions as well ▷

as information about current wind, visibility, precipitation, and air traffic. In the final analysis, the responsibility for the decision to land or not to land (the “go/no-go” decision) ultimately rests with the pilot. External information sources – primarily supplied by the control tower – factor into this decision. In the moments just before taking action, however, the pilot relies on an intimate knowledge of the aircraft together with a trained perception of factors such as the available landing distance and the accessibility of alternate landing sites.

The joint research program is providing better tools for airport operators to use and more accurate and reliable runway friction data for pilots to make go/no go decisions for takeoff and landing during operations in winter weather. Research focuses on:

- Determining a relationship between readings from ground friction measuring instruments and aircraft braking performance,
- Correlating various ground friction measuring devices, and
- Establishing a methodology to create a common indication of runway conditions for use worldwide.

Researchers have structured the work of the program into five phases:

- Data collection from ground friction measuring vehicles,
- Data collection from instrumented aircraft,
- Data analysis, correlation, and interpretation,
- Development of a method of measuring and reporting conditions on contaminated runways, and
- Validation of the proposed methodology.

The research team has coordinated readings from a number of different ground vehicle friction measurements to develop a consistent friction scale for similar potentially hazardous runway conditions. The researchers tested a diagonal braked vehicle (DBV), a car with a specially modified braking system that allowed only two diagonally opposed tires to lock up when the brakes were applied sharply. The DBV measures the speed, acceleration, and stopping distance from the point of braked wheel lockup to determine the friction level of the runway. They also tested a device called a MuMeter, which consists of a 540 pound trailer towed behind a truck. This technology determines surface friction by measuring the side forces imposed on the trailer wheels. A third ground vehicle, called a BV11 Skiddometer, measures the speed of the vehicle, the torque applied during braking, and the slip ratio of an instrumented wheel to determine the runway friction level. Researchers have evaluated a number of different ground vehicles at different locations under varying winter conditions. To assess vehicle performance, the researchers had the particular test vehicle being studied make a pass down the runway. Two test airplanes followed. Researchers then compared the measurements made by the various ground devices and the airplanes. They measured braking performance over speeds,-ranging from 40 to over 100 miles per hour.

For the slower runs, the aircraft would accelerate to the required speed and then apply maximum braking. For the faster runs, the aircraft would take off, land, and then test the braking performance as it slowed down to a stop. The researchers also looked at the impact of engine reversers on aircraft braking performance in contaminated runway conditions and the effectiveness of different kinds of runway deicing substances. Initial tests at North Bay, Ontario, included braking tests with a variety of instrumented aircraft and various ground friction measuring devices. While work continued at the North Bay location, subsequent winters have seen the testing move to a series of international locations, including the NASA Wallops Flight Facility in Wallops, Virginia; Oslo, Norway; Gwinn Sawyer Airbase, Michigan; Munich, Germany; Erding Army Airbase, Germany; and Prague, Czech Republic. Tests have involved 10 aircraft, 49 ground vehicles, 10 test sites, and 450 individuals representing over 65 organizations from 16 countries. As a result, researchers have now created a database containing the test results from more than 275 aircraft runs and 10,000 ground friction measurements.

The runway friction tests demonstrated that it is feasible to correlate the ground vehicle friction measurements with aircraft braking performance. The goal is to one day be able to provide high fidelity runway condition information to pilots and airport operators that will translate directly into a reliable indicator of aircraft stopping ability during winter weather conditions. Data obtained from this research helped define the methodology for an International Runway Friction Index. Data analysis continues to improve the harmonization of ground vehicle friction measurements and determine a suitable Aircraft Friction Index based on calculated aircraft stopping distances using the International Runway Friction Index.

The tests also facilitated enhanced safety for all ground operations by providing information to help relieve airport congestion during bad weather. For example, the researchers confirmed that grooved runway surfaces proved an extremely effective ▷

method of maintaining safe friction levels in poor weather conditions. These results are also helping industry develop improved tire designs, better chemical treatments for snow and ice control, more reliable ground vehicle friction-measuring systems, and runway surfaces that minimize bad weather effects.

The ability of aircraft to safely transition to or from the runway surface is of critical importance to all airport operators, and especially so to those with large, transport-category aircraft operations. FAA Advisory Circular 150/5320-12B, Measurement, Construction, and Maintenance of Skid-Resistant Airport Pavement Surfaces, provides guidelines to airport operators on how to locate and restore areas on the pavement surface where friction has deteriorated below acceptable limits for aircraft braking performance. The material contained in this circular summarizes the findings of past research efforts.

Ongoing research will result in future updates to that circular. Currently, research efforts concentrate on two major areas: high skid-resistant pavement surface design and evaluation, and the application of proper maintenance techniques and procedures.

The importance of a friction management program is obvious during the winter season. Perhaps less obvious, but still critical for safe airport operations, is a year-round program that pays attention to removing warm-weather pavement contaminants, such as rubber deposits. Research is underway, therefore, to find more effective and efficient summer pavement assessment and cleansing techniques.

“When an aircraft takes off and lands, it produces high temperature on the surface between the tire and runway,” says Jones. “The melted rubber accumulates on the surface. This collection of material, however, is no longer like the rubber on the tires of the airplanes that put it there.”

The tire rubber is relatively soft and flexible so it can absorb some of the shock of the landing aircraft. The aircraft tires are stationary just before they touch the ground, but at the moment they touch, and for approximately 1,000 feet, the tires gain rotation speed, creating thousands of pounds of pressure between the tire and the surface. The heat created causes a chemical reaction in the rubber, turning it into a very hard material that is spread on the runway surface in a thin layer. In fact, about 1.4 pounds of this rubber are deposited per tire per landing of each large aircraft. With repeated landings of aircraft, this hardened rubber accumulates on the pavement giving it a smooth, almost glass like surface that can make landing the aircraft and stopping difficult, or even dangerous, particularly when the pavement is wet.

FAA researchers are working to gain a better understanding of the hydroplaning phenomena. Their work is determining a method for predicting aircraft tire performance on wet runways, examining ways to remove rubber deposits and restore runway traction to uncontaminated surface levels, and developing antihydroplaning runway surfaces, such as pavement grooving. In fact, future research is planned to evaluate improvements in the technologies that place grooves in runways to channel water off of their operational surfaces and thus enhance their skid resistance.

Because heavy jet aircraft are exposed to a greater risk of skidding on wet slippery runways, as a result of FAA surface research results, runway requirements are becoming more demanding. Research continues to assess and develop new ways to keep airplanes safely on runways and regulations will be adjusted as research finds new solutions to prevent runway slipperiness. ■

For additional information on FAA research, please see http://www.airtech.tc.faa.gov/.

EMAS

The Society of Automotive Engineers (SAE) International, American Institute of Aeronautics and Astronautics, Institute of Electrical and Electronics Engineers, American Society of Civil Engineers, and the Society of Naval Architects and Marine Engineers selected FAA researcher Jim White to receive the 2007 Elmer A. Sperry Award along with industry co-developers of the Engineered Materials Arresting System (EMAS), Bob Cook, Peter Mahal, and Pam Phillips.

The Elmer A. Sperry Award annually recognizes distinguished engineering contributions that, through application proved in actual service, have advanced the state of the art of transportation whether by land, sea, or air. It honors Elmer A. Sperry, who was renowned for his navigational gyroscope and who coined the word automotive, giving SAE its name. Past recipients have included Donald Douglas, Ferdinand Porsche, Sir Geoffrey De Havilland, Igor Sikorsky, and Charles Draper.

The award will be presented at the keynote session of the International Air Transport Conference in Irving, Texas, on August 20, 2007.

INTRODUCTION

The FAA is working with commercial airport authorities around the country to improve conditions affecting runway safety. New legislation introduced in 2005 mandates that by 2015 all major U.S. airports must construct their runways in line with federal safety standards that call for at least 1000 feet at the end of a runway as a safety buffer, or some alternative method. Approximately 350 of the nation's commercial airports lack the space to create a full runway safety area.

"Although no simple solution could ensure that no aircraft would ever overrun its runway," says Barry Scott, FAA Acting Director of Research and Technology Development, "the FAA and its industry partners have developed a technology that can stop an aircraft safely. Our research has found that soft ground arrestors – combinations of materials that deform readily and reliably under the weight of an aircraft to create drag and slow its movement – can dramatically increase safety at airports with limited overrun areas."

The first of such soft ground arresters, also now referred to as an engineered material arresting system, or EMAS, was developed under a cooperative research and development agreement by the FAA, the Port Authority of New York and New Jersey, and the Engineered Systems Company (ESCO) of Ashton, Pennsylvania. Made of water, foam, and cement, the system was engineered to address the potentially catastrophic consequences or aircraft overrunning the end of a runway.

As airports work to meet the 2015 requirement, the FAA has approved EMAS as a solution for airports lacking room for adequate safety areas. FAA Order 5200.9 states that, when combined with a safety area of just 600 feet, an EMAS installation is equivalent to an overrun safety area of 1,000 feet. EMAS, however, is one of several options under consideration by airport operators to improve runway safety areas. Among the other options are various combinations of the effects of relocating, shifting, or realigning runways or of reducing the lengths of some runways to create larger safety areas.

RESEARCH

The genesis for the development of an arrestor bed came in 1984 when a DC-10 aircraft could not stop within the confines of runway 4R at New York's John F. Kennedy International Airport. Fortunately, no serious personal injuries occurred, but the incident resulted in $30 million in damages and prompted the National Transportation Safety Board to recommend that the FAA should determine whether some type of arresting system was feasible. The pioneering EMAS system was installed by the Port Authority in 1996 at its JFK Airport, and another soon followed at LaGuardia Airport. Since then, EMAS has successfully kept three aircraft from going into the water at Kennedy and a saved a fourth last summer in South Carolina. ▷

While EMAS is a proven success, FAA researchers continue to work with their industry partners to improve the technology. Several years ago, FAA researchers tested a second-generation prototype designed to counteract the destructive effects of continual blasting from aircraft engines. The research team mapped the various components of jet blast forces on the severely affected overrun safety area of Runway 22 at LaGaurdia airport.

Using a powerful wind tunnel at the FAA William J. Hughes Technical Center, they tested the ability of a new protective coating applied to the cellular cement blocks to stand up against a full year of jet blasts. The experimental protective material is not only flame-retardant but also resists many chemical agents and ultraviolet rays. The underlying material and its new top surface performed very well under the harshest of simulated jet blast exposure. Researchers then installed a demonstration bed at LaGuardia 75 feet from the departure end of Runway 4. After 16 months of jet blast exposure the demo bed remained in excellent condition, and the top coating material has become a core EMAS component at all airports where arresting systems are subjected to continued jet blast. Other recent upgrades in the latest EMAS generation include use of a moisture-resistant bottom tray fitted with forklift slots for easier installation and the introduction of improved methods of sealing the sides of the arrestor beds and joints within them.

In 2005, the FAA research team constructed a large-scale test bed at the William J. Hughes Technical Center to assess the long-term environmental durability of EMAS installations. Over 100 sensors in the test bed continually measure temperature, humidity, and load data. Additional environmental data is collected from an adjacent weather station. In July 2006, the team completed the first full year of data collection. Project engineers hope that collected data will yield important insight into how EMAS material responds to a range of environmental condition changes. They also hope an understanding of these responses might help to predict how well arrestor beds installed in specific locations might hold up over their expected lifetimes.

Through an interagency agreement with the FAA, researchers at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire, plan to test EMAS under conditions of extreme and variable cold. Monitoring the material durability in an environmental chamber will allow the scientists to subject the materials to quicker, more frequent freeze-thaw cycles than they could readily observe during seasonal climate changes.

Three taxiing incidents causing damage to EMAS installations at two airports have alerted FAA researchers to the need to show more clearly where normal runway surfaces end and the surfaces of arrestor beds start. As required by FAA regulations, bright yellow chevrons now mark the end of runways; but these markings have not been spotted by some pilots. One incident led local authorities to install two-inch frangible plastic pipes, covered with reflector tape, between the EMAS and Runway 6 at Teterboro Airport. This same facility had also considered installing a special lighting system across the ends of the runway. Local solutions are to be commended, but a system-wide solution is needed. The FAA is considering requiring all EMAS-equipped airports to install a type of breakaway delineators at the junction of runway and arrestor surfaces.

While the FAA and others in the aviation industry accept the current EMAS product as the standard for runway safety areas, they are looking into possible alternatives. Emerging aircraft arresting system technologies are the focus of a recent FAA Airport Cooperative Research Program grant. The grant project will seek to identify options for alternative arresting systems. Anticipating results by 2009, this project will include a sensitivity analysis examining current FAA performance standards for arrester systems. Other FAA-funded researchers will compile and analyze historical data to help airport operators evaluate runway safety areas. ■

CURRENT NEWS

EMAS is now in place on 23 runway ends at 18 airports, and eight additional projects are under contract at six U.S. airports. Generally, the costs to install an EMAS at a U.S. facility range between $2 million and $4 million, exclusive of site preparation costs. Airports can apply to the FAA for Airport Improvement Program (AIP) grants to help defray the costs of the system. Arrestor beds are also being installed outside of the United States. EMAS is installed at Jiuzhai-Huanglong Airport, which is on a mountaintop in China, and projects are underway for two runways at Madrid-Barajas International Airport, Spain.

Information about the FAA's research of Engineered Material Arresting Systems is available online at http://www.airporttech.tc.faa.gov/safety/sgarrest.asp.

Open for Business

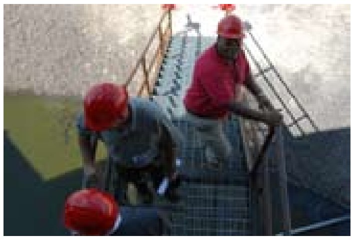
New Fire Test Facility Makes its Debute

On May 22, representatives from the FAA Office of Research and Technology Development and Air Force Research Laboratory dedicated the world's largest aircraft fire test facility at Tyndall Air Force Base, Florida. Constructed jointly by the FAA and Air Force, the New Large Aircraft Fire Test Facility is the focal point for live fire research for aircraft such as the Airbus A380 and the Boeing 747-8.

During the dedication ceremony, FAA airport technology researcher, Keith Bagot, explained that the mockup was constructed in-house by Air Force Research Lab engineers and researchers. The facility took 2,000 hours of design work (1.5 years) to construct and approximately six man years of labor to complete. Bagot said, "There's nothing like this anywhere else."

The facility measures 26 feet from the first deck floor to the ground level and is fully contained in a fire pit. It is 27 feet in diameter, all metal, with removable, authentic evacuation slides. To collect research data, the mockup is instrumented with 90 thermocouplers, two miles of thermocoupler wires, two miles of steel welding, and 250,000 lbs of steel.

The facility, built with input from the airport fire fighting community, will be used determine the best firefighting techniques and technologies for new large aircraft. ■



Fire & Rescue

The Emergence of Aircraft Rescue and Fire Fighting (ARFF) Technologies

Although infrequent, aircraft fires following crashes are typically far more severe – from their onset – than fires that develop in flight. Post-crash fires usually originate from the ignition of large quantities of spilled jet fuel rather than from the relatively small ignition sources that cause in-flight fires. Because post-crash fires can be catastrophic, reducing the risk they pose to passengers is a high priority of the Federal Aviation Administration.

Researchers in the FAA Aircraft Rescue and Fire Fighting (ARFF) R&D program are working with the aviation community to find better ways to halt the spread of fire into an aircraft and to ensure that passengers can safely escape the threats that burning interior materials pose to passenger evacuation.

During an aircraft crash, enormous impact energies combine with highly flammable aircraft fuel load to create a dangerous potential for fuel fires and resultant injuries. The survivability of crashes or other incidents occurring on the airport surface depend on the speed and effectiveness of airport rescue and firefighting actions.

Although fires outside an aircraft can be effectively extinguished, fires within the fuselage are much more difficult to control. They also entail greater risks to passengers. The presence of large amounts of smoke-laden toxic gases and high temperature levels in the passenger cabin can delay the evacuation of many passengers while threatening the safety and health of those passengers who are able to flee the stricken aircraft.

The FAA and its research partners have consistently recognized the need for new means to reduce the fire dangers threatening to trap the initial survivors of aircraft crashes. One such technology was the development of an elevated waterway system that could quickly penetrate an aircraft cabin fuselage so fire crews could pump water directly into the cabin area. ARFF vehicles equipped with this technology will be able to extend survivability time for trapped passengers while also providing a safer rescue environment.

“Firefighters know they have to apply an extinguishing agent as quickly as possible,” says Keith Bagot, the ARFF research and development project lead. “For an interior fire, a vehicle equipped with a high-reach extendible turret, or HRET, and a fuselage piercing nozzle can apply a water spray right into the cabin. The ARFF vehicle can pull directly up to the plane and deploy its turret immediately. HRET technology is now installed on over 650 ARFF vehicles around the world.”

In late 2005, the ARFF R&D program acquired a new Striker aircraft rescue and firefighting vehicle. This new vehicle offers a state-of-the-art test bed and expands the testing capabilities for FAA researchers. The vehicle has a large storage capacity for firefighting agents, and many specialized features. It holds 2,500 gallons of water, compared to the 800-gallon water capacity of the older research vehicle. The vehicle features an electronic proportioning system that takes foam concentrate from a separate tank and mixes it, at the proper ratio, into the water stream. This proportioning system continually monitors itself, providing better control of foam injection and better measurement of the amount of agent used. The vehicle also carries Halotron and dry chemicals that function as complementary extinguishing agents.

The new vehicle is already the most technologically advanced model available today, but it also provides the foundation for testing other technologies with promising future applications. Tests have been conducted on the rear-wheel steering system on the vehicle to evaluate its ability to improve vehicle handling and reduce tire wear.

FAA researchers are using the new firefighting vehicle to help establish performance criteria to meet the challenges posed by the Airbus A380, Boeing’s anticipated 747-8, and other future new large aircraft. To advance this effort, the research team has installed a next generation HRET on the new vehicle. The extendible boom reaches to a length of 65 feet, 15 feet farther than the previous model. With this additional range, an operator can now use the skin-penetrating nozzle to suppress a fire inside the second level of aircraft such as the Boeing 747 and Airbus A380.

With the arrival of new large aircraft, the FAA must determine the best methods to extinguish fires rapidly, evacuate passengers safely and efficiently, and minimize aircraft damage. Researchers are at work conducting the studies needed to ensure that future guidelines affecting ARFF technologies will be appropriate to the operational requirements of next generation of aircraft. Of particular concern are the implications of larger passenger capacities in new double-deck cabins, the increased footprint of evacuation slides, and the load and locations of fuel tanks. ▷

At nearly the height of a four-story building, “super jumbo” jets are taller than any aircraft that have previously used our nation’s civil airports. Because existing test-beds could not adequately model the fire-fighting requirements of these huge aircraft, FAA researchers joined with their Air Force Research Laboratory counterparts at Tyndall Air Force Base, Florida to design and build the world’s largest live-fire aircraft mock-up based on a section of the Airbus A380. Formally dedicated on May 22, the new facility is surrounded by an environmentally-contained 100-foot pit engineered for burning hydrocarbon fuel. The mock-up includes key features of the A380, such as:

- Cargo, main, and upper passenger decks,
- Three working passenger and cargo doors directly behind the cockpit,
- The first ten feet of the leading edge of the wing,
- 20-foot section of inboard engine nacelle suspended from the wing,
- Three detachable evacuation slides, and
- More than 75 thermocouples to monitor temperature and fire behavior.

The model A380 fuselage, which measures 60 feet long and 27 feet in diameter, serves as the cornerstone for FAA live-fire testing. The facility allows researchers to see how the fire attack is affected by the number of evacuation slides and the size of the engine nacelles. An actual A380 deploys 16 emergency exit slides in a complex arrangement, six of which extend from the upper deck, to speed the evacuation of nearly 900 passengers and crew. Its second level slides come out farther from the fuselage than do those on the Boeing 747. Researchers can alternately move the model’s three slides to the “dry” side to conduct ARFF vehicle maneuvers or to the “wet” side to deal with live-fire evaluations.

Research is not limited to the standard ARFF fire truck. The FAA is looking into alternative vehicles called Interior Intervention Vehicles (IIV). With these vehicles, airport firefighters could access the upper and lower deck exit doors. Some airports in the U.S. and other countries are using hydraulic scissor-lift platforms or air stair trucks to reach the doors sills of aircraft operating at their airports. Hartsfield-Jackson Atlanta International Airport, Los Angeles International Airport, and Chicago Midway Airport are among several U.S. airports to acquire the specialized vehicles for ARFF operations and emergency evacuations.

The FAA requires all ARFF vehicles to undergo a tilt table test to determine the static stability of the vehicle. A tilt table test had never been conducted on air stair vehicles. Recently, FAA researchers went to Port Washington, Wisconsin, to coordinate and set up a tilt table test for the air stair vehicle going into service at Atlanta Hartsfield-Jackson International Airport. Researchers selected JLG Industries, Inc., to conduct the test because its unique tilt table provides additional safety measures that would prevent any structural damage to the vehicle, its air stair structure, or the platform during the test. The data collected will be used to update FAA Advisory Circular 150/5220-10D, “Guide Specification for Aircraft Rescue and Fire Fighting Vehicles.”

Designers of new large aircraft have devised an extensive network of fuel tanks to carry the more than 80,000 gallons needed to give these giants their required range. They have located fuel tanks in center wing boxes and inside wings and vertical stabilizers. Studies are underway to determine the fire implications of greatly increased fuel load and multiple tank locations. The Agency may have to update its standards for agent quantities, application rates, flow rates, and numbers of ARFF vehicles needed at airports serving the new large aircraft. These studies extend to fuel load and location, fuselage geometry, improvements in application of agents, and aircraft material composition. In addition to the high-reach extendible turret with nozzle, scientists are looking at delivery systems with greater range and concentration. The advanced capabilities of the candidate systems include compressed air foam, foam/dry chemical applications, and water/foam under extremely high pressure.

Another emerging trend in the construction of aircraft has major implications for firefighters. Manufacturers are using far more composite materials than ever before to build new airplanes. Carbon fiber-reinforced polymers and fiberglass make up one-fourth the weight of the new Airbus A380. Researchers are concerned about the combustion characteristics of these materials and are examining what types of agents, application methods, and quantities work best to put out composite fires.

The FAA is also evaluating tests of a possible next generation firefighting system for small airports. They recently investigated whether a newly-developed quad-agent delivery system can extinguish fires faster, save more lives, and increase firefighter safety. In place of the dual-agent firefighting system now used in most small airports, a proposed quad-agent system would rely on a handheld hose or a bumper-mounted turret to let a firefighter choose among and discharge one or a combination of four agents:

- Water,
- Aqueous film forming foam (AFFF),
- Dry chemical (potassium bicarbonate or PK), and/or
- Clean agent (Halotron), which leaves no residue.

The quad-agent system’s ability to discharge alternative agents from the same nozzle will help a firefighter to adapt the attack on fires to unique circumstances.

FAA airport researchers are setting industry standards for firefighting equipment. Their work is saving lives. This past year, the 17th Annual ARFF Working Group International Conference recognized the FAA researchers for their ongoing contributions to protecting the public. More than 350 people from the international ARFF community watched as FAA personnel received the organization’s Outstanding Service Award. ■

For more information on the FAA ARFF research program, please visit http://www.airtech.tc.faa.gov/safety/largeaircraft.asp

Wildlife Mitigation

No airport or aircraft type is immune from the hazards of wildlife strikes. In addition to colliding with aircraft, wildlife that are roosting, nesting, or burrowing on airports can cause structural damage to pavement, equipment, and aircraft. As wildlife populations increase at and around airports, FAA researchers are working to mitigate risks to aircraft, people, and other vehicles.

“Wildlife at airports is a major concern because of the potential negative effect on human health and safety, as well as the costs in damages and delays for the aviation industry,” explains Ryan King, FAA wildlife mitigation R&D program lead. “Aircraft collisions with wildlife cost the U.S. civil aviation industry approximately $600 million annually in direct damage and associated costs and over 500,000 hours of aircraft down time. With the vast majority of wildlife strikes taking place in the airport environment, it its critical that we find new ways to control and even prevent wildlife hazards at airports.”

The FAA is currently undertaking a four-pronged research effort to find new ways to prevent wildlife strikes:

- Studying the habitat of problem species, such as black birds, birds of prey, rodents, and large mammals.
- Improving tools and methods that help the airport community detect wildlife at critical times of the year.
- Improving passive and active techniques that help the airport community manage wildlife at airports.
- Using regional and national data sets (such as migratory paths) to help predict wildlife strikes at specific airports.

“Effective mitigation techniques require an understanding of which species are causing problems,” explains King. “Different species require different management techniques. Researchers must improve their understanding of wildlife behavior patterns – particularly their daily and seasonal movements and the specific airport locations where their presence poses the most critical threat to aviation safety. We also need to learn how to discourage wildlife from congregating at airports. Some of the control strategies that we are examining are habitat modification, repellent and harassment techniques, and wildlife removal.”

Because maintaining a consistent record of wildlife strikes is essential to defining the hazard level and developing mitigation strategies, the FAA and its research partners created the National Wildlife Strike Database. This internet-based system allows analysts to view wildlife strike patterns of every species, for any season of the year, and to sort on records that range from national and state levels down to the patterns at individual airports. The data provides information about wildlife strike risk factors, possible risk reduction measures, and an evaluation of the effectiveness of these measures. Researchers now are working to enhance this proven tool with an additional graphical interface that shows all wildlife strikes, by state, across the nation.

Since the FAA began assembling the database in 1990, current totals (based on 82,385 reports at civil airports and 11,098 strikes at joint-use civil and military facilities) have grown to include more than 93,000 strikes involving 426 species of animals. In these 27 years, aircraft have struck birds in nearly 98 percent of the recorded incidents. Still, some interesting statistics on ground-based animals include: 776 deer, 285 coyotes, 137 foxes, 108 rabbits, 108 skunks, 70 turtles, 45 raccoons, 38 dogs, 15 cats, 15 armadillos, 14 alligators, 11 moose, 6 cattle, 3 bears, and 2 horses. There even are some records involving wildlife that would seem especially unlikely to collide with planes – such as 11 prairie dogs, 7 iguanas, and 2 river otters.

Lacking criteria to be placed in one of these strike types, many reported wildlife strikes are simply attributed to “unknown” species. Vague statistics are less helpful to officials, for knowing the size and behavior of the particular birds and mammals involved is key to prioritizing, planning, and implementing effective preventative measures. Identifications provide baseline data needed to implement habitat management plans on airfields and build avoidance programs. Also, the data helps engineers and aircraft developers to design windscreens and engines that are more resistant to damage from bird strikes.

The difficult job of finding out which animal species have struck aircraft goes to the Smithsonian Institution National Museum of Natural History Feather Identification Lab, with which the FAA has an interagency agreement. Identifying feathers or feather fragments is a tedious process for biologists. Feathers are cleaned and then compared with specimens in the museum collection to find a perfect match. When the feather sample is very small or contains few, if any, macroscopic diagnostic characters, the remains are examined using light microscopy. Biologists are also developing a DNA-based method for identifying bird strike remains.

Understanding the problem is just the first step in combating this growing safety hazard. Research and development efforts have not been effectively coordinated to create an integrated system for strike advisories throughout North America. Cooperation and integration of research, techniques, specifications, requirements, and procedures are needed to manage the problem. The North American Bird Strike Advisory System Strategic Plan, issued in 2005, outlined the architecture of a notional bird strike advisory system for North America. It identified the key agencies that must be involved in the development of the system. It established a top level schedule and identified six key goals in developing an integrated system. The plan described more detailed objectives and research activities required to accomplish these goals.

“The risk of wildlife strikes will only increase as the air traffic increases over the next decades,” explains King. “As air travel has increased, so have populations of animals hazardous to them.” The U.S. Air Force Research Laboratory’s Avian Hazard Advisory System uses database information to quantify strike risk associated with particular geographical regions or airport facilities. Having this precisely classified information helps pilots and controllers to rule out many factors involving wildlife strike risks as they decide upon prospective routings. ▷

Wildlife Mitigation *continued from page 43*

DID YOU KNOW . . .

- Over 195 people have been killed world-wide as a result of bird strikes since 1988.
- Over 7,100 bird and other wildlife strikes were reported for USA civil aircraft in 2005.
- An estimated 80% of bird strikes to civil aircraft in the U.S. go unreported.
- Waterfowl (32%), gulls (28%), and raptors (17%) represented 77% of the reported bird strikes causing damage to USA civil aircraft, 1990-2005.
- The North American non-migratory Canada goose population increased 3.6 fold from 1 million birds in 1990 to 3.5 million in 2005.
- A 12-lb Canada goose struck by a 150-mph aircraft at lift-off generates the force of a 1,000-lb weight dropped from a height of 10 feet.
- About 90% of all bird strikes in the U.S. are by species federally protected under the Migratory Bird Treaty Act.

Some troublesome species have also grown in number or better adjusted to their habitats due to strong environmental programs or laws protecting them. Natural habitats surround many airports and give animals a sanctuary with food and shelter they can't get in the cities. So, at the same time as many species have adapted to living around airports, their comfort ironically places them increasingly and often unavoidably in the path of faster, quieter turbofan and turbojet aircraft. To help airports prepare mitigation plans, in 2005, FAA researchers provided the scientific information for the guidelines published in Wildlife Hazard Management at Airports.

Because wildlife hazards are not a localized problem, the FAA, Department of Defense, Department of Agriculture, and aviation industry representatives created the Bird Strike Committee USA to facilitate the exchange of information and promote the collection and analysis of accurate wildlife strike data. Through this resource, representatives from government, industry, and the aviation community meet annually with their counterparts from similar organizations in other countries. Together, they exchange information, promote new technologies, encourage professional training, update standards for airport wildlife management programs, and generally share their knowledge and experiences.

FAA researchers have also joined with their partners to develop a real-time wildlife advisory system, one they hope can be accessed online and used by pilots and air traffic control alike. Before such a system becomes reality, however, researchers must first develop a reliable wildlife detection technique and algorithms for the computation of risk. Also integral to creating the wildlife advisory system is developing advanced detection methods to help the aviation community deal with wildlife.

A promising FAA-sponsored research project is integrating radar applications and geographic information systems into a unit that is now being tested remotely at an airport. Participating scientists hope that the use of improved geographic information system data, together with radar data, will allow them to replace human observers when modeling bird movement patterns, especially during nighttime or foggy conditions.

The FAA is also funding university research through its Airport Technology Center of Excellence program. Researchers at the University of Illinois are using advanced detection technologies to provide warnings (real-time or nearly) of wildlife movements. Recognizing that simple detection is inadequate, one of their research goals is to develop the capacity to convey hazard information quickly and effectively. The second goal is to develop protocols and standards for use of these avian detection systems on civil airports.

FAA-funded researchers at the Department of Agriculture are gathering information on wildlife habitats at airports. FAA research partner, Dr. Richard Dolbeer, a world-renowned expert in airport wildlife hazard mitigation, is pioneering applied research in wildlife mitigation. He created the U.S. Department of Agriculture's Wildlife Service Aviation Research Project to reduce wildlife hazards to aviation. This work has led to major advancements in managing airport environments to reduce wildlife use, produced a dramatic reduction in aircraft collisions with birds at New York's John F. Kennedy International Airport, and laid the foundation for subsequent work at more than 600 U.S. airports. For his efforts to improve airport safety, the FAA presented Dr. Dolbeer with its 2005 Excellence in Aviation Research Award.

Although airports have thus far achieved only partial success altering their surroundings to minimize the presence of animals, research continues into possible habitat changes. Planting the types of vegetation that certain animals find unpalatable might be one solution, and managing storm water runoff to keep wildlife from gathering at airports might be another. Work is underway to establish research parameters for experiments involving each of these possibilities.

"We are steadily making progress," states King. "Our research program is trying to stay one step ahead of growing wildlife populations. The only way to win this battle is to continue joint research with our national and international partners to understand the global challenge and determine cost-effective solutions." ■

To obtain additional information on the FAA Wildlife Mitigation R&D program, please visit http://wildlife-mitigation.tc.faa.gov.

Hot off the Press!

FAA's Latest Technical Reports

A STUDY OF NORMAL OPERATIONAL LANDING PERFORMANCE ON SUBSONIC, CIVIL, NARROW-BODY JET AIRCRAFT DURING INSTRUMENT LANDING SYSTEM APPROACHES (DOT/FAA/AR-07/7)

Because airports need improved capacity to accommodate the rapid growth of domestic air travel, researchers investigated Land and Hold Short Operations (LAHSO) as a feasible means to increase traffic flow without affecting safety. They analyzed aircraft landing performance data from in-flight recorders aboard two types of narrow-body passenger aircraft, the Boeing 737-400 and the Airbus A319, A320, and A321. Working with the National Aerospace Laboratory in the Netherlands, FAA researchers found no one single factor dominates how landing performance relates to LAHSO safety guidelines, which reduce the risks of incidents. The strongest variables include height above the threshold, speed loss from flare initiation to touchdown, and available runway length for landing. The researchers concluded that ground roll performance is strongly influenced by the available runway length, and only landings on shorter runways should be considered for evaluating LAHSO.

HIGH-OCTANE AND MID-OCTANE DETONATION PERFORMANCE OF LEADED AND UNLEADED FUELS IN NATURALLY ASPIRATED, PISTON, SPARK IGNITION AIRCRAFT ENGINES (DOT/FAA/AR-TN07/5)

FAA researchers compared the detonation performance differences of high- and mid-octane leaded and unleaded fuels at the onset of light detonation in spark ignition, piston aircraft engines. The research team tested a specially blended 100 low-lead (100 LL) aviation gasoline with the minimum allowable MON and supercharge rich rating of 130 against various unleaded fuels. The 100 LL significantly outperformed the unleaded fuels of equivalent MON, even one with a much higher supercharge rich rating, but did not perform as well as a 104 MON unleaded amine-laden fuel with a 161 supercharge rich rating. For mid-octane fuels, researchers determined an unleaded fuel would require 2 to 3 MON more than a leaded fuel of equivalent supercharge rich rating to provide the same full-scale engine detonation performance.

AVAILABILITY AND OPERATIONAL USE OF WEATHER INFORMATION BY EN ROUTE AND TERMINAL CONTROLLERS (FAA-TC-TN-07/01)

FAA researchers compare and contrast the procedures and phraseology en route and terminal controllers must follow when they gather and convey weather information. The study summarizes what weather data a controller has available at the workstation, and how the controller provides pilots with timely information about adverse weather conditions. Most basic functions are similar, but minor differences may apply to en route or terminal controllers. For example, both domains give pilots the same weather information and chaff areas, but en route controllers do not describe radar-derived weather for light precipitation. While ensuring controllers have direct access to pertinent information, the research could guide future concept changes to enhance awareness of weather challenges in the national airspace system.

COMMERCIAL OFF-THE-SHELF WIRING SYSTEM DIAGNOSTICS EVALUATIONS (DOT/FAA/AR-06/61)

A survey assessed available commercial off-the-shelf wiring diagnostics systems for their potential to help the FAA and aviation community diagnose wiring systems in aging aircraft. Researchers at Sandia National Laboratories evaluated whether each system could accurately detect a range of defects such as hard opens, hard shorts, chafed insulations, cracked insulations, and arc shorts, and identify the anomaly type, severity, and location on wire lengths of 50, 100, and 200 feet. They also investigated the diagnostics for soundness of the technical approach based on engineering principles, the manufacturer's qualifications and experience in wiring diagnostics, the degree of user training required, cost, and availability. Researchers blind tested selected systems on the Airworthiness Assurance Nondestructive Inspection Validation Center (AANC) wire test bed. They hope to find the best instruments to detect, and possibly predict, wire system anomalies.

END-AROUND TAXIWAY SCREEN EVALUATION (DOT/FAA/AR-TN06/59)

To increase operational capacity, airports construct dual and even triple parallel runways, many with taxiways coming off a runway, commonly called end-around taxiways. In some cases, a pilot taking off might perceive a taxiing aircraft as crossing the departure end of the runway. FAA ▷

researchers designed and evaluated a visual screen to mask aircraft using an end-around taxiway from those on a runway. They determined the most conspicuous material, configuration, pattern, color, and lighting methods. Tests showed the most effective screen was 13 feet tall, with 12-foot-wide red and white diagonal striping made from engineering-grade reflective material, which pilots could see both day and night. Researchers also discovered staggering sections of the screen would allow emergency vehicles through, and tilting the screen 14 degrees would avoid interference with radar systems. They found pilots on a takeoff roll could better discern the aircraft operating on an end-around taxiway from another aircraft crossing the active runway.

ANTI-ICING PAVEMENT COATING STUDY AT CHICAGO O'HARE INTERNATIONAL AIRPORT (DOT/FAA/AR-06/58)

Airports must minimize snow and ice buildup on aircraft movement areas during a winter storm. When a manufacturer claimed its new anti-icing pavement coating could reduce costs and environmental impact, researchers from the University of Illinois at Urbana-Champaign applied the permanent epoxy adhesive and porous aggregate chips to a 200-foot section of pavement on taxiway Kilo at Chicago O'Hare International Airport. They compared the coating to an untreated portion of pavement, and measured the durability and friction characteristics of the coating. Researchers found it took just as much chemical freezing-point depressant to clear the coated surface as the adjacent uncoated pavement. They also discovered signs of delamination and loose aggregate in some areas of the treated test section. The FAA will use the results of this study to determine the merits of the product for use on airport pavements.

EVALUATION OF THE REPRODUCIBILITY OF THE FAA OIL BURNER FIRE TEST FOR AIRCRAFT SEAT CUSHIONS (DOT/FAA/AR-TN06/55)

This report discusses the results of oil burner round-robin fire tests performed on aircraft seat cushions by nine FAA-approved facilities in the United States, as well as at the FAA Technical Center. Five laboratories conducted the seat cushion fire test in accordance with Title 14 Code of Federal Aviation Regulation (CFR) Part 25.853, and four labs ran the test according to FAA report DOT/FAA/CT-99/15, "Aircraft Materials Fire Test Handbook," a method equivalent to that specified in CFR 25.853. Researchers evaluated two sets of fire-hardened foam seat cushions and one set of fire-blocked foam test seat cushions, and found the weight loss and burn lengths generally consistent. Currently, the FAA is preparing for round robin testing in other countries, by working with governing bodies such as European Aviation Safety Agency.

IDENTIFICATION OF AIRCRAFT TOUCHDOWN POINT IN COMMERCIAL OPERATIONS (DOT/FAA/AR-06/52)

Safe airport terminal area operations depend on accurately determining aircraft landing distance, which consists of touchdown and rollout. Currently, analysts cannot readily measure and record operational touchdown performance based on landing parameters. Researchers traced aircraft movements in terminal areas to develop an algorithm that identifies touchdown and turnoff points. They verified with the data using Geographical Information System analysis of airport configurations. After refining the algorithm, researchers produced software that automates the data processing and facilitates the safety analysis. From a sample set of commercial flights, the application can correctly identify more than 90 percent of the touchdown points from operational landing traces.

LABORATORY-SCALE AND FULL-SCALE FIRE TESTING OF LIGHTWEIGHT AIRCRAFT SEAT CUSHION MATERIALS (DOT/FAA/AR-06/49)

New materials allow manufacturers to reduce the weight of aircraft seat cushions while retaining the comfort level. FAA researchers undertook a study to determine if lighter seat foam materials that do not meet the federal weight loss criteria for traditional seats are more or less hazardous under realistic cabin fire test conditions. They conducted laboratory-scale fire tests on different aircraft seat cushion materials, in accordance with the current standard specified in Title 14 Code of Federal Regulations Part 25.853(c), Appendix F, Part II. Researchers subjected samples that lost more than 10 percent of their weight to full-scale fire test conditions in a modified narrow-body aircraft fuselage. Results indicated several of the lightweight seat materials that failed the weight loss criterion did not result in greater fire hazards than the standard baseline foam seats. Researchers developed a conservative adjustment to allow their use.

DEVELOPMENT OF A COMPONENT HEAD INJURY CRITERIA (HIC) TESTER FOR AIRCRAFT SEAT CERTIFICATION – PHASE 2 (DOT/FAA/AR-06/47)

Engineers designing aircraft cabin interior furnishings must comply with Head Injury Criteria specified in Title 14 Code of Federal Regulations Parts 23.562 and 25.562. The current method of certification requires conducting a full-scale sled test that could destroy airline seats, and the aviation industry has been searching for a cheaper, faster, and more repeatable alternative process. Researchers at Wichita State University have modified and evaluated a device called the National Institute for Aviation Research Head Injury Component Tester. They tested its performance against that of the sled test, and determined that changing the rigid neck of the new tester to a flexible design improved its performance. The Head Injury Component Tester successfully reproduced the forces and accelerations generated in a full-scale test.

THE EVALUATION OF COLD DWELL FATIGUE IN TI-6242 (DOT/FAA/AR-06/24)

In this study, researchers examined a failure mode in titanium (Ti) alloys in aircraft engine rotors known as cold dwell fatigue, which is most prevalent at temperatures below 300˚C. Scientists at Ohio State University and Princeton University used sometimes novel experimental methods to investigate the mechanical and metallurgical factors that cause early crack initiation under dwell-fatigue conditions in Ti-6Al-2Sn-4Zr-2Mo (+Si). The researchers reported making significant progress in modeling time-dependent stress redistribution, as well as in understanding the fundamental aspects of dwell crack initiation.

EVALUATION OF RUNWAY GUARD LIGHT CONFIGURATIONS AT NORTH LAS VEGAS AIRPORT (DOT/FAA/AR-TN06/19)

Researchers conducted this study to determine if runway guard lights in the in-pavement, elevated, or T-configurations could offer the same ▷

safety enhancement to general aviation airports as they do at major commercial airports. They evaluated runway guard lights at eight different taxiway and runway intersections on North Las Vegas Airport. Researchers recruited 42 pilots, who helped determine acquisition distances for lighted red and white mandatory hold signs, yellow surface holding position painted markings, and three configurations of runway guard lights. The study showed elevated runway guard lights were most effective visual aid for identifying the taxiway hold position.

EVALUATION OF QUAD-AGENT SMALL FIREFIGHTING SYSTEM (DOT/FAA/AR-TN06/13)

Most small airports currently use a dual-agent firefighting system. Researchers tested a newly developed quad-agent firefighting system that can discharge four agents either individually or simultaneously. The one nozzle disperses four firefighting agents: dry chemical (potassium bicarbonate or PK), clean agent (Halotron), aqueous film forming foam concentrate, which mixes with the fourth agent, water, to create firefighting foam. Researchers tested how quickly different agent combinations extinguished engine nacelle flowing fuel fires and large-scale pool fires, and tested the system for flow duration and discharge distance. The project found the quad-agent system would allow a firefighter to adapt a fire attack by choosing which agent or agents to use.

DEVELOPMENT AND TESTING OF FLAME RETARDANT ADDITIVES AND POLYMERS

Novel flame-retardant chemical additives and polymers were synthesized and their flammability measured in the Underwriters Laboratory test for flammability of plastics (UL94). Self-extinguishing (V-0) compositions were obtained for poly (acrylonitrile-butadiene-styrene) and high-impact polystyrene by adding as little as 10 weight percent of boronic acid derivatives or halogen-containing bisphenylethenes (BPH). Self-extinguishing (V-2) compositions were obtained for polyethylene by adding as little as 10 weight percent BPH. The efficacy of BPH additives as flame-retardants suggested incorporating these moieties directly into the polymer to further reduce flammability. Polymers and copolymers were synthesized having BPH backbone and pendant groups, including backbone copolymers containing acetylene and phosphineoxide. The thermal combustion properties of polymers containing a BPH backbone or pendant groups were measured by microscale combustion calorimetry and found to be among the lowest values ever recorded, suggesting that aircraft cabin materials made from these polymers would be ultra-fire-resistant.

A STUDY OF NORMAL OPERATIONAL LANDING PERFORMANCE ON SUBSONIC, CIVIL, NARROW-BODY JET AIRCRAFT DURING INSTRUMENT LANDING SYSTEM APPROACHES

The need for improved capacity at airports to accommodate the rapid growth of domestic air traffic in the United States has led to the investigation of Land and Hold Short Operations (LAHSO) as a safe and feasible means to increase the traffic flow. While the capacity issue becomes increasingly more important, it is imperative that the increase in capacity does not lead to a safety decline. A key task was to investigate the aircraft landing performance pertaining to operational safety guidelines for reducing the risks of incidents and accidents associated with LAHSO. For this, a clear knowledge of the day-to-day landing operations is required.

Data from quick-access recorders can be used to analyze aircraft performance. Aircraft landing field performance is influenced by many variables. Some variables were found to have a more dominating influence than others. Variables found to have a strong influence are height above the threshold, speed loss from flare initiation to touchdown, and the available runway length for landing. However, there is not one single factor that dominates the landing field performance. This study used in-flight recorded data collected from day-to-day landing operations obtained from the quick-access recorders from two types of narrow-body jet aircraft.

BEST PRACTICE IN ADHESIVE-BONDED STRUCTURES AND REPAIRS

The opinions expressed in this technical note were presented at the Federal Aviation Administration (FAA) Bonded Structures workshop in 2004. Realizing the value of these observations and recommendations, the FAA commissioned a written record of them. The resulting document represents the experiences, some anecdotal, in the application and maintenance of bonded structures on one group. The record is not to be construed as a comprehensive survey and analysis of the failures or best corrective actions for bonded structures. Rather, it presents data that resulted from real-world applications and experience with disbands and other adhesive failures in structural applications.

SUMMARY OF SAFETY MANAGEMENT SYSTEM ACTIVITY STATUS

This technical note presents a review of the Safety Management System (SMS) Draft Standard, v.9, produced by the Joint Planning and Development Office (JPDO) working group. This review shows the concerns about how useful and effective the JPDO draft standard appears to be with respect to implementing SMS requirements by regulated entities such as airlines, repair stations, and manufacturers.

ENHANCED AIRCRAFT CONSPICUITY TO REDUCE RUNWAY INCURSIONS

A previous study of controller and pilot error in surface operations, conducted for the Runway Safety and Operational Services Office, recommended increasing aircraft conspicuity when the aircraft is on the runway. The suggested way to make aircraft more conspicuous – both to controllers and pilots, whether on the ground or on approach – was through the use of existing aircraft lights. The objectives of this research effort using standard aircraft lighting were to (1) determine the best aircraft lighting configuration for making an aircraft on the active runway more conspicuous to an aircraft on final approach and (2) determine from an air traffic control (ATC) tower which aircraft lighting configuration is better for making an aircraft on a runway more conspicuous to air traffic controllers. This research examined aircraft conspicuity from the two perspectives mentioned above, using a representative selection of aircraft types to the extent available as a target aircraft. Two aircraft were used for the approaches, one of which was equipped with an eye-tracker device that the subjects wore during the approaches.

Results of the flight test showed that, of the external aircraft lighting configurations studied (steady and pulsing landing lights), none provided enough of a visual cue for the needed conspicuity for an approaching aircraft. From the ATC tower, steady and pulsing landing lights were both effective in providing the needed conspicuity. ▷

CHARACTERISTICS OF RUNBACK ICE ACCRETIONS AND THEIR AERODYNAMIC EFFECTS

The results of a research program to investigate runback ice accretions due to hot-air ice protection systems, scaling of external flow parameters for testing thermal systems, and the resulting aerodynamic effects are presented. Ice accretion testing was conducted at the National Aeronautics and Space Administration Glenn Icing Research Tunnel to evaluate thermal scaling methods and produce representative runback ice accretions using a business jet wing section equipped with a hot-air, anti-icing system. Test conditions simulated an airplane holding in both at ambient static air temperatures near freezing (warm hold) and well below freezing (cold hold), as well as descending through (descent) Title 14 Code of Federal Regulations Part 25 Appendix C icing conditions. Warm-hold ice accretions were characterized on the suction surface by dense frozen rivulets that formed a ridge, while the pressure surface accretion was composed of nodules and chunks that formed a ridge. In all cases, a clean airfoil region of varying chordwise extent was located upstream of the runback ice accretions. The runback ridge formations were shown to be very sensitive to total air temperature in both height and chordwise location. Increased hot-air temperature and mass flow rate were found, in general, to correspond to shorter ridges located farther aft on the model. The cold-hold accretions had the character of rime ice and exhibited more spanwise variation due to the proximity of the ridge to the hot-air jet impingement zones. Descent accretions also exhibited spanwise variation in chordwise position, but were more uniform in height than the cold-hold accretion. Results of the scaling analysis showed that a useful and qualitatively accurate scaling method was developed for scaling thermal anti-icing systems for ground testing, but further development and investigation of the methods and governing equations are required.

SUBGRADE CBR VALUES FOR ALPHA FACTOR DETERMINATION USING DATA COLLECTED AT THE NATIONAL AIRPORT PAVEMENT TEST FACILITY

Full-scale traffic test results from tests run at the Federal Aviation Administration National Airport Pavement Test Facility (NAPTF) in 2000, 2001, and 2002 with four-wheel and six-wheel landing gears have previously been combined with results from tests run by the U.S. Army Corps of Engineers in the early 1970s. The combined results were analyzed in a recent report, and updated alpha factor values were determined for four- and six-wheel gears at 10,000 coverages. The strength of the subgrades in the NAPTF test pavements was characterized by averages of CBR (California Bearing Ratio) measurements made at the surface of the subgrade before and after testing and CBR measurements made after testing at depths of one foot and two feet (30.48 cm and 60.96 cm) below the surface of the subgrade. A number of minor transcription and rounding errors were made in the original calculations of the average CBR values and, since publication of the previous report, results have become available from an additional trench opened in one of the test items. The average CBR values for the NAPTF tests are updated in this report, resulting in an increase in the computed four-wheel alpha factor of approximately 0.6 percent and a decrease in the computed six-wheel alpha factor of approximately 1.3 percent.

THERMAL ANALYSIS OF POLYMER FLAMMABILITY

A thermal analysis method is presented that uses controlled heating of polymer samples and complete combustion of the evolved gases to separately reproduce the condensed and gas phase processes of flaming combustion in a single laboratory test. Oxygen consumption calorimetry applied to the combustion gas stream gives the heat release rate history of the sample as a function of its temperature. The maximum rate of heat release and the temperature at which it occurs are polymer characteristics related to fire performance and flame resistance. ■

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