CEAT: A 10-YEAR PARTNERSHIP WITH THE OMP

Research Highlights

The Center of Excellence for Airport Technology (CEAT), a partnership between the O’Hare Modernization Program (OMP) and the University of Illinois at Urbana-Champaign (UIUC), contributes to forward-thinking design and cost-effective construction.
INTRODUCTION

The OMP-UIUC partnership conducts multidisciplinary research in support of the O'Hare International Airport on a broad range of topics. The partnership has provided mutual benefits to Chicago and the University over a 10 year period. The original scope reflected priorities of the O'hare Modernization Program (OMP). Today, the research portfolio has branched out to address questions beyond the original OMP scope. Over the years, our university research team has worked closely with airport engineering staff to investigate technical issues and lead to improved and more cost-effective decisions. The CEAT vision for the future is to explore the most pressing technical topics encountered by the Chicago Department of Aviation (CDA).

This report recounts the key benefits that have been delivered by the research program. First, we recount the primary CEAT themes and summarize the value of projects conducted over the past 10 years. Second, we present 10 case studies that illustrate how the partnership has solved specific problems of high priority. in research, and inspires continuation of a strong partnership in years to come.

DELIVERING VALUE TO CHICAGO

The primary themes of the OMP-UIUC partnership align with important priorities of the City of Chicago.

- Quality. The UIUC research program has focused on improved materials, construction processes, and aspects of design.
- Safety. With outside funding from FAA, UIUC has helped develop new avian radar and FOD detection technologies that have been tested on-site at ORD. All research on pavement quality contributes to improved safety of operations at ORD.
- Public Health. Projects have addressed environmental engineering challenges such as quality of the water supply at ORD and treatment options for glycol runoff from deicing operations.
- Sustainability. OMP has been a leader in promoting sustainable practices at airports, and UIUC research has contributed through research on recycled concrete and asphalt materials, and a focus on reduction of cement content in concrete.
- Cost-savings. Many aspects of the UIUC research program address efficiency of design. The research has also led to cost-savings by helping OMP engineers minimize cost of procuring top soils from off-site.

The OMP-UIUC partnership has seen a wide array of accomplishments, including:

- The CEAT study on concrete materials led to “value engineering” ideas that were incorporated into the modified P-501 specifications used at OMP, thus improving quality and lowering costs.
- The CEAT study of subgrade stabilization and the “k-150” support issue contributed to decisions that avoided additional test sections, saving over $100,000.
- The CEAT study of subgrade stabilization provided specification language to define procedures for lime modification and lime stabilization, providing for improved construction quality and reduced potential for weather-related construction delays.
• The CEAT study of aggregate quality led to establishment of specification language to achieve longer pavement service life with 40-yr resistance to freeze-thaw and reduced potential for damaging alkali-silica reaction (ASR) in the concrete.

• The CEAT study on concrete mixtures led to specification language to reduce shrinkage cracking potential.

• The CEAT study of mixture proportioning identified strategies to reduce concrete cost compared to previous O’Hare mixtures, with potential to save over $100,000 on the 9L-27R new north runway.

• The CEAT concrete pavement testing program delivered new insight into temperature and moisture gradients and curling of slabs at O’Hare.

• The CEAT subgrade study of compaction of unsuitable fill soils provided guidance for construction planners at O’Hare.

• CEAT completed a study on removal of paint markings, providing recommendations related to equipment and technology that can be used at O’Hare.

• The CEAT study of recycled concrete provided guidance about using recycled aggregate in hot mix asphalt.

• The CEAT study of recycled concrete aggregate for use in Portland cement concrete has helped OMP refine mixture designs used in trial projects at O’Hare International Airport. The study demonstrated that concrete with recycled aggregate can perform at a high level, opening the door for this “green” construction practice.

• The CEAT study of excavation options related to railroad relocation (Stations 309+00 to 312+00) allowed OMP to consider column-supported embankments and geo-fabric embankment options.

• The CEAT study of soil and turfgrass contributed to a decision to avoid import of topsoil to O’Hare, saving millions of dollars.

• The CEAT study of turfgrass species contributed ideas about achieving reduction in wildlife at the airport through marginalization of plant life that serves as a food source for insects, small animals, and birds. Reduction of wildlife increases safety of operations at the airport.

• The CEAT study on water quality in retention basins provided technical concepts for solving long-term problems with discharge that impose high costs to CDA.

• A new mix design approach for Controlled Low Strength Material (CLSM) has been developed for ORD, using concrete removed from the airport during past phases of the OMP. CLSM utilizes fine particles from concrete crushing, and is an excellent and sustainable way to reuse a waste material.

• The CEAT study on concrete pavements has contributed a new method to measure the residual stress in concrete, giving OMP a new tool to assess the effect of restraint that might lead to cracking of pavement slabs.

• The CEAT hydrologic study is providing data to foster better understanding of stormwater flows and MWRD capacity via the Des Plaines TARP. This study provides new knowledge that can lead to a solution of a long-term stormwater problem at ORD that has significant annual cost.

• New strategies for using recycled shingles for asphalt materials at ORD have been developed. Recycling contributes to sustainable operations with cost and environmental benefits.
• The CEAT study on corrosion of light cans used in ORD runways has yielded a solution for how to resolve problems with polymeric light can liners.

• A total of 50 Tech Notes have been provided, covering a range of ideas that lead to cost savings, improved quality, and refined specification language.

TEN CASE STUDIES

1. Sustainable Concrete Pavement

Prof. Jeffery Roesler, UIUC and Prof. David Lange, UIUC

Sustainability is a major emphasis for CDA and the OMP. Over the past 10 years, research has advanced the use of sustainable materials and construction practices for the airport by increasing the amount of recycled materials utilized in the pavement structures, identifying alternative uses for recycled materials, quantifying the life cycle environmental impact of multiple pavement rehabilitation strategies, and improving construction efficiency on airfields. Initially, OMP was attracted to finding methods to reuse the construction and demolition waste generated onsite. A large research effort at University of Illinois explored the usage of crushed concrete as an aggregate (called recycled concrete aggregate - RCA) in new concrete pavement construction for airports. The high quality RCA sourced from O'Hare was shown to perform well as a coarse aggregate in new concrete construction, with research indicating that even up to 100% coarse RCA can be used in concrete without significantly reducing the desired hardened concrete properties and long-term performance. Concrete batched with 100% coarse RCA has been utilized on the O'Hare pavements, including reconstruction of Gate F7 and other concrete patch locations on the airfield.

When creating quality recycled coarse aggregates, approximately 50% of the material is considered waste fines. Recycled concrete aggregate fines (RFA) can adversely impact the concrete properties and pavement performance if not properly engineered. Recent research demonstrated that concrete mixtures containing coarse and fine recycled aggregates with higher supplementary cementitious materials can provide the properties required for long-life concrete airport pavements. Alternatively, RFA has been shown to be the main aggregate in controlled low strength materials (CLSM) especially for backfilling trenches and filling abandoned ducts and pipes on the airfield. CLSM is further made economical and sustainable by using high volumes of waste by-product cementitious materials such as fly ash as opposed to Portland cement. Finally, more fundamental research demonstrated that a weaker but useable cementitious binder material can be produced by first high temperature dehydration of RFA and subsequently rehydrating the RFA.

Current FAA regulations require the construction of a thickened-edge for all isolation joints, i.e., locations where taxiway, runways, and aprons intersect or connect, which requires significant time, energy, labor, and money to build. Several new details for constructing these isolation joints more efficiently were proposed by the University of Illinois and the FAA. In partnership with Chicago O'Hare, UIUC instrumented a field test section at O'Hare in 2013 that contained a constant thickness isolation joint cast with fiber-reinforced concrete and reinforced concrete slab. Both of these new isolation joints will significantly improve construction expediency without sacrificing any performance relative to the traditional thickened-edge joint.
The pavement structure of Taxiways A and B, which surround the main terminal and experiences over 400,000 aircraft operations per year, is reaching the end of its performance life and needs rehabilitation without impacting passenger travel. With the heavy, repeated loads, extreme weather patterns, and restricted access to the taxiway, the exact pavement condition in terms of distresses, existing layers (thickness, and stiffness), and surface/subsurface drainage is not well characterized. In order to provide realistic rehabilitation strategies, rapid assessment tools are required for nondestructive testing and evaluation of the current pavement structure. The University of Illinois researchers have demonstrated the potential of new technologies, such as ground-based LIDAR, 3D laser scanning, unmanned aerial systems (UAV), robotic imaging devices for drain inspection, and GPR, to provide more detailed and cost effective pavement, topographic, and drainage assessment tools. University of Illinois researchers have been evaluating rapid rehabilitation techniques, such precast concrete slabs or asphalt inlays with rubblization, for repairing the taxiway under short closure times between 8 to 48 hours. Finally, one of the first life cycle assessment tools for airport pavement structures, LCA-AIR 1.0, has been advanced to better quantify the sustainability of various rehabilitation strategies for airfield pavements by considering the material production, construction, maintenance and rehabilitation, and use phases of the pavement life cycle.

2. Repair Materials and Methods

Prof. David Lange, UIUC

Infrastructure built decades ago at O'Hare Airport is now entering into an era of continued maintenance and rehabilitation. This infrastructure ranges from those systems that are visible and exposed to the environment such as service roads, runways, taxiways, terminals, and railways. There is also a vast underground system of conduits, piping, tunnels, drainage, and utilities that remain unseen and can suffer extensive damage before visually manifesting themselves to airport personnel. An additional challenge arises as these vast systems are incrementally built over time leading to tightly configured zones of infrastructure. As such, the repair of any single utility may necessitate costly removal and relocation of nearby utilities or infrastructure. In order to mitigate these costs, it is of interest to O'Hare Airport personnel to identify new techniques and materials that can pinpoint damaged areas in order to perform minimally invasive yet succesful repairs.
Research on repair materials has addressed light can replacement, rapid repair materials, and CLSM using recycled fines from crushing concrete. In addition, UIUC has drafted a Repair Materials Guide for ORD with recommended test procedures for repair materials.

The majority of the infrastructure at O'Hare Airport includes the concrete pavement sections of the gate aprons, alleys, taxiways, runways, and service roads. The profile and joint configuration of jointed plain concrete pavements (JPCP) and jointed reinforced concrete pavements (JRCP) are designed to withstand the static and dynamic wheel loads of heavy aircraft. Recently, there has been greater design-consideration for fatigue loads induced by daily thermal cycling and seasonal moisture curling. However, it has been long observed that some pavements fail despite these design-considerations leading to premature conclusions that the quality of the material or construction was inferior.

Research by UIUC and the Federal Aviation Administration’s National Airport Pavement Test Facility has demonstrated, however, that there exists other stresses, dubbed residual stress, in concrete pavements that diminishes the loading capacity of the pavement and can lead to premature failure. Moreover, early research indicates that this material stress can be measured with a new field testing method allowing for airport personnel to make better-informed decisions regarding full- or partial-depth replacement, re-configuration of the joint spacing, or revised restrictions on ground traffic movement on particular pavement sections. This knowledge can provide CDA personnel insight into the cause of failure of pavement sections.

3. Asphalt Pavements

Prof. Bill Buttlar, UIUC

Topics related to asphalt paving materials have been included in the CEAT research portfolio every year. The CEAT study on warm-mix asphalt (WMA) helped the OMP lead the way in modifying P-401 standards to allow the use of temperature-reducing WMA additives, which moreover, promote sustainable practices and improve asphalt pavement performance and economy.

In another year, the CEAT focused on use of recycled asphalt shingles (RAS) in asphalt mixtures to promote mixture sustainability and economy while maintaining excellent material durability.

More recently, CEAT studied runway 9R-27L and developed an innovative, performance-based design method for a 2-layer overlay system specifically designed to resist cracking in the tough mid-continental climate at O'Hare. For the first time, both fracture (disk-shaped compact tension) and permanent deformation (Hamburg rut) performance tests were used in asphalt mixture design. One of the primary findings of this research was the need for laboratory performance criteria to supplement current FAA mixture design methods.

CEAT research helps O'Hare be more sustainable by improving asphalt paving practices to include warm-mix asphalt, recycled asphalt roofing shingles, and higher overall recycled binder content. The research provides theoretically-sound and practical results. The responsive relationship between UIUC and O'Hare helps the research bring immediate benefits through implementation of results.

Across the US, the O'Hare International Airport is a recognized leader in incorporating WMA, RAP, and RAS in asphalt mixtures located throughout the depth of their pavements. The OMP-UlUC collaborative approach provides confidence that green approaches can yield performance equal to or better than hot mix asphalt (HMA).
4. Subgrade

Emeritus Prof. Marshall Thompson, UIUC

From the first year of CEAT research with OMP, the research portfolio has contributed to our understanding of subgrade stability. The concerns have included compaction, suitability of subgrade soils, materials for base/sub-base use, soil stabilization, and characterization of soils-granular materials for pavement analysis. All of these issues were central to successful construction under highly visible schedule constraints in the early years of the OMP activities.

The CEAT research program provides a mechanism by which Prof. Thompson has responded “on call” to questions about subgrade condition and performance. During his long career at UIUC (since 1962), Prof. Thompson has focused his research/engineering efforts on the various issues referenced above and similar areas. He has provided state-of-the-art/practice inputs (primarily in the form of Technical Memoranda) to OMP and participated in subsequent discussions.

5. Horticulture

Prof. Bruce Branham, UIUC

OMP encountered a unique opportunity to address a critical airport safety problem by using construction techniques that made the airport less attractive to wildlife. While wildlife management at ORD is not new, the CEAT research program considered new questions about how horticulture-related decisions affected safety. The OMP recognized how modification of both open waters and landscapes on ORD can influence wildlife through past funding of CEAT research. For many years, the CDA has contracted with the U. S. Department of Agriculture Wildlife for services to manage and reduce wildlife hazards at ORD. CEAT provided design guidance for stream modifications and the grading and planting plans for new airport surfaces as a part of this program to build in wildlife deterrents at ORD. The design changes for topsoil types saved OMP significant costs with further research to validate this technique, particularly during periods of suboptimal planting conditions. Further research assessed wildlife use of different vegetation types and on areas with different treatments to manage vegetation. Moreover, the comparatively large plantings at O'Hare invite new, in situ, monitoring of wildlife use at appropriate spatial scales using new technologies, such as radar.

Previous research at the University of Illinois had included development of experimental plots where vegetation development featured species that are unpalatable to grazing wildlife. Complementing these experimental plots, studies have included observations that are quantifying the differential utilization of the experimental plots by birds and mammals. The objective of these studies was to establish how different types of turf affect the food base and local habitat quality for hawks and other bird species known to present hazards to aircraft movement at ORD.

In 2010, the research program completed vegetation studies and revegetation analysis for OMP. Continued research occurred at the UIUC experimental plots. The program also continued parallel studies ORD where UIUC established small field plots and on larger field plots developed through the cooperation of OMP
staff and USDA scientists. These efforts provided advice to the OMP about how airport surfaces can be designed to be unfriendly to wildlife based on guidelines for soil conditions, initial seeding, and vegetation maintenance.

6. Water Runoff

Prof. Art Schmidt, UIUC

Stormwater runoff from O'Hare impacts the capacity of the Des Plaines TARP system and therefore it has been of interest to optimize operational procedures for discharging runoff from the airfield. CEAT researchers have modeled different scenarios for discharging runoff from O'Hare to TARP and examined the impact of those scenarios on the TARP system.

Stormwater runoff from O'Hare airport is captured by an extensive collection network and routed to two detention storage ponds. These ponds have a combined capacity of $95.4 \times 10^6$ ft$^3$ (714 million gallons). This runoff often contains aircraft deicing fluids (ADF). Residual material from aircraft deicing operations can result in concentrations in runoff that exceed water-quality standards long (e.g., on the order of months) after application of ADF to aircraft and paved surfaces. Because of water-quality concerns related to ADF in runoff, the stormwater runoff needs to be treated prior to allowing it to be discharged to nearby waterways. An agreement between the City of Chicago (City) and MWRDGC allows stormwater runoff from O'Hare to be discharged to the Upper Des Plaines interceptor sewer (UDPI)—with some restrictions during wet weather—during the period November 1 through April 30. The UDPI carries combined sewer flows from Des Plaines and Park Ridge and conveys this runoff to the Stickney water reclamation plant (WRP) where it is treated before being discharged to the Chicago Sanitary and Ship Canal (CSSC). However, at present, no runoff from O'Hare can be discharged to the MWRDGC system between May 1 and October 31. Also, the present agreement limits flow from O'Hare to the sewer system to periods when the level in the UDPI is below the bypass weir that sends excess flow to the tunnel and reservoir plan (TARP) system. The present agreement also limits flow to a combined maximum of 35 cubic feet per second (CFS).

CEAT flow models were used to predict behavior of the interceptor system directed to the Des Plaines tunnel of the TARP system. The map shows the extent of the UDPI interceptor sewers and the Des Plaines tunnel of the TARP system. The study provided a technical basis for assessing the impact of O'Hare runoff on the UDPI, and suggested solutions in managing runoff in a manner that would serve both O'Hare and UDPI interests.
7. Water Supply

Prof. Wen-Tso Liu, UIUC

O’Hare infrastructure includes a water distribution system. A minimum residual chlorine concentration should be met in drinking water leaving the treatment plant in order to effectively kill microorganisms including pathogens, or suppress their growth or regrowth in the water.

In a typical distribution system, residual chlorine can be consumed through chemical or biological processes during water transport. The residual chlorine can be consumed or depleted by reacting with microorganisms on the inner surface of pipes in a form of biofilms. The depletion of residual chlorine can further encourage the development of more microbial biofilms by growing on the carbon and nutrient sources derived from the oxidized biomass after chlorination.

The amount and rate of residual chlorine consumed can also be influenced by other physical factors. For example, a long hydraulic retention time (from the point water leaves the treatment plant to the point where water is consumed) can lead to a high consumption of free residual chlorine. In addition, a longer hydraulic retention time can occur when water is kept stagnant overnight or is transported close to dead ends of a distribution system, where the water usage is low. Temperature can affect the growth rate of microbial biofilms usually with more growth observed in the summer time. The other factors that can affect water quality include the pipe materials, the age of the infrastructure, and the physical integrity of the distribution system (possible cross contamination or intrusion of contaminated water into a distribution system). As O’Hare International Airport (ORD) has a large drinking water distribution system, the aforementioned problems can occur.

The CEAT research program considered how these problems may arise at O’Hare, and how effective monitoring should be developed to maintain and ensure good quality water. The dialog between UIUC researchers and CDA built a better understanding of water quality throughout the entire water distribution system at the airport. The project supported experimental work at UIUC and meetings with engineers at OMP to understand the water quality parameters obtained from the ORD distribution system.

8. Non-Destructive Testing

Prof. John Popovics, UIUC

CEAT research has given visibility to new test methods that can be employed at O’Hare. The work included demonstration of air-coupled ultrasonic surface wave measurements to assess the depth of surface-breaking cracks in taxi-ways and access roads at O’Hare field (see photos). In a separate effort, UIUC researchers applied ultrasonic shear wave imaging to runway pavements at O’Hare field to help determine if internal dowel bars were properly placed around embedded runway light cans in the pavement (see photos). These modern NDT methods hold promise for improving accuracy and speed of assessing pavement condition.
9. Operations

Prof. Bo Zou, University of Illinois at Chicago

Airport pavement assets deteriorate over time due to operational and environmental factors such as aging, traffic loading, and weather conditions. Maintenance and Rehabilitation (M&R) plans are thus required to be carefully scheduled well in advance in order to satisfy pavement quality standards and to guarantee continuous operations at the airport. M&R actions have been estimated to be more than $332 million for the 10-year interval ending in 2021. This staggering need inspired a comprehensive and long-term M&R planning study undertaken by researchers at University of Illinois at Chicago.

Airport Pavement Management Systems (APMSs), as a systematic approach to airport asset management aiming at optimum returns to investment, is a process consisting of four essential steps: i) inventorying airport pavement assets; ii) inspecting and monitoring runway conditions; iii) predicting condition deterioration; and iv) supporting decision making on planning M&R activities. The CEAT study addresses the third module: it intends to provide a comprehensive review of modeling the future performance of runway pavements at O'Hare International Airport, which provides a crucial input for strategic management decisions such as optimal M&R decisions and budget optimization in the fourth step.

The study developed and applied a state-of-the-art infrastructure deterioration model, the stochastic duration model, for runway pavements at O'Hare International Airport. In this model, pavement deterioration was characterized by the probability of the time it takes for a pavement section to leave a specific condition state after it entered that state. Estimation of the proposed statistical model used historic data of O'Hare runway pavement conditions and maintenance activities. The models consider variables which explain the process of pavement deterioration, including flight traffic, pavement age, and pavement material type. The results offer several important insights. Among them, increased aircraft operations in keel sections of a runway raise the rate of pavement deterioration. Pavement sections surfaced with PCC have much lower deterioration rates than with APC. Also, the model shows that minor M&R activities were effective in slowing down pavement deterioration.

The model provided probabilities of runway pavements transitioning from one condition state to another as a function of the time. These transition probabilities serve as key inputs for the M&R planning model. The model can provide CDA with valuable information on future pavement conditions while CDA drafts its future Capital Improvement Plans and negotiates with airlines to secure funding for M&R activities on runways and taxiways.

10. Airport Safety

Prof. Edwin Herricks, UIUC

In 1998 the FAA approached CEAT to assist in implementing an array of airport safety technologies. The Airport Safety Management Program (ASMP) became a core area of CEAT research in foreign object debris
(FOD) detection systems and avian radar. ASMP research has also included the use of existing sensors for pavement condition assessment. All research conducted by the ASMP for the FAA benefited from cooperation with the Chicago Department of Aviation. The funding for this topic was provided through the FAA, and the OMP/CDA research budget was not used. The benefits of this work, however, are highlighted here because CEAT routinely brings value from research supported by federal funding sources.

Beginning in 2006 with initial planning, ORD was a site used for the performance assessments of foreign object debris (FOD) detection technologies. Two of the four primary technology types covered in Advisory Circular 150/5220-24 were tested at ORD. The stationary optical technology developed by Stratech Systems, Ltd. of Singapore was installed to scan a portion of Runway 27L and a portion of Taxiway MM. The installation was complete in 2007 and was functional until 2015. The second system was a mobile radar technology developed by Trex Enterprises, San Diego, CA. In this testing a radar unit was mounted on a Department of Aviation (DOA) vehicle and operated by DOA personnel around the airport. The mobile radar detection system was initially used in 2009 with testing continuing into 2012.

With completion of the performance assessments CEAT continued interacting with DOA personnel on FOD management at ORD. This cooperation resulted in a two year study to characterize FOD on runways at ORD. As part of the mandated runway inspection program one runway was closed during daylight every week for inspection. The DOA employed FOD collection devices during these runway closures and from July 2011 through May 2013 CEAT worked with DOA personnel to collect and analyze FOD. The result was publication of the first long-term characterization of FOD at a major international airport.

The stationary FOD detection sensors at ORD were also put to other uses. In 2011 a sensor from the runway location was removed and located on a platform installed at the end of E Concourse scanning the apron at the exit of C Southport. This sensor continues to support research on FOD and terminal surveillance. A second sensor at the Runway 27L location was maintained and continued functioning. In 2011 that sensor was used as a long term monitoring device in a pavement condition index (PCI) monitoring program. The second sensor was used by the manufacturer until its removal in 2015.

The avian radar deployment at ORD began in 2008 and radar operation continued until 2015. ORD is one of four airports in the United States for deployment of avian radar systems as part of the FAA’s avian radar performance assessment program. Avian radar deployment activities were initiated in 2008 with the installation of two radar systems, one with a single antenna, the second with dual antennas. The radars, mounted in two trailers, were located in the northwest corner of the airport near the end of Runway 14R. These radars were used in the FAA performance assessment from 2008 – 2011 that resulted in the publication of the FAA’s Advisory Circular 150/5220-25. Along with the DOA, the U. S. Department of Agriculture wildlife biologists contracted by ORD cooperated in several studies to assess radar detection during the assessment. Following use for performance assessments the radars at ORD were operated to address research questions and provide the radar vendor with access to the radars for their research. The avian radars were decommissioned in 2015.

CONTACT INFORMATION:

Prof. David A. Lange, Director  
Center of Excellence for Airport Technology (CEAT)  
Department of Civil and Environmental Engineering  
University of Illinois  
2129B NCEL, MC-250  
Urbana, IL 61801  
Phone: 217-333-4816  
Email: dlange@illinois.edu