The Alaska University Transportation Center (AUTC) theme, "Transportation Safety, Security, and Innovation in Cold Regions," was selected to complement the mission and direction of the University of Alaska—to inspire learning and to advance and disseminate knowledge through teaching, research, and public service, emphasizing the North and its diverse peoples.

This theme also takes into account the needs of such stakeholder groups as the Alaska Department of Transportation & Public Facilities, the Alaska Railroad Commission, the oil and gas industry, and the broader transportation community that extends across the nation. Research at the University of Alaska fills a national need; AUTC is the only center with a specific, primary focus on transportation in cold regions.

AUTC directs its efforts to all modes of transportation. Like many northern regions, Alaska depends on multimodal transportation for part of its economic growth. A mix of highway, air, marine, rail, and pipeline infrastructure make it possible to meet the need for goods and transportation for its people. Northern regions face special challenges, including a population density that varies across the region; long distances between communities (often with no interconnecting roads) and high dependence on aviation and marine transportation. Diverse geographic features, along with complicating factors such as unstable soils and extremely cold temperatures can lead to high transportation costs. Pipelines for oil and other fuels dramatically impact the economic well-being and security of the nation.

When such infrastructure traverses arctic and subarctic terrains, the challenges of planning, designing, constructing, and maintaining pipelines are unique.

According to Alaska Congressman Don Young, “Living in a climate where the weather has such a large impact on the condition of our roadways and infrastructure, it is especially important for us to study how we can improve on what is already being done. A focus of this should be better ways to pave our roadways and keep them intact.”

Improvements in cold regions transportation engineering and disseminating our innovative research to the national forum are AUTC’s primary goals.

The center addresses issues related to those identified in the Highway Research and Technology report (a joint publication released by the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the Transportation Research Board) as key research and technology themes, including but certainly not limited to the impact of climate change on permafrost, reducing construction and maintenance costs of transportation infrastructure, improving air quality during the winter months, and other measures that address multimodal issues facing Alaska and the nation’s transportation community.
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I’ve heard it said that time seems to pass 2.5 times as fast for a 50 year old as for a 10 year old. I think that factor is underestimated. AUTC’s five year existence seems more like five months. Yet during that time AUTC researchers have conducted 117 studies, awarded 22 graduate degrees, and forged numerous fruitful partnerships. During that time, one fundamental vision remained constant: produce research products that make a difference.

Over the last year, we have been working to tell our success stories. These include implementation of dust palliatives on ADOT&PF airports, changes to Alaska bridge codes to include the seismic impacts of frozen ground, implementation of permafrost research on DOT projects, and awarding degrees to the first three students to complete our new Construction Management graduate certificate program. Collaboration is no stranger to us. For example, we worked with the University of North Carolina, Oregon State University, University of Iowa and Washington State University to perform bridge research which has been implemented by ADOT&PF. We also partnered with the Western Transportation Institute, the University of Nevada Las Vegas, and the University of California, Davis to establish the Road Dust Institute. RDI is promoting research that will improve quality of life by reducing fugitive dust from transportation infrastructure.

We have been focused on producing reliable, accessible results. However, to be truly successful, the right people need this new, usable information in hand at the right time. Creating this convergence of opportunity, necessity, and know-how is surprisingly difficult. AUTC, like other agencies, can do a better job of getting the word out.

Others have recognized this. Two years ago, Clint Adler, Chief of Research and Technology Transfer, Alaska Department of Transportation and Public Facilities, came into my office and suggested we implement NCHRP 610, Communicating the Value of Research. I agreed. We also felt that one of NCHRP 610’s most important recommendations was to employ the services of a communication specialist. After attempting for 25 years to help researchers talk about their successes effectively, the wisdom of this suggestion struck a chord. Researchers are always excited about their work, but most find it difficult to talk about their research to anyone but their peers. Rarely are their peers in the position to integrate the research into practice, and rarely do they fund research.

As a result, AUTC and ADOT&PF have joined together to hire a communications specialist, Rob Harper. His background includes researching, planning, and coordinating outreach for public agencies and federally funded programs, most recently for several university research centers similar to AUTC. His unique background is a strong fit for our communication challenges. Rob will work with researchers to produce project summaries and other outreach materials, interact with the media, and work with our publications editor to produce newsletters and reports that go beyond mere information.

In coming months, we will work with researchers to produce materials for implementation of our work. You may also notice a shift in the tone and organization of this and other reports, as AUTC begins to communicate the value of its research to our most important stakeholders. Look for other changes and updates on our web pages and a stronger presence in other media. We hope to create excitement about what we do, and explain the wide benefits of our work to the public.

In short, AUTC is committed to making sure the results of our research are getting to the right people in a useful format and in a timely manner. If you have any feedback, please let us know.

[Signature]
Our board members represent both transportation technology users and those who must manage infrastructure at national, state, and local levels. All transportation modes are represented in this dynamic group. To learn more about our board members, visit ine.uaf.edu/autc.

**Amit Armstrong**  
Technology Deployment Engineer  
Western Federal Lands Highway Division  
Federal Highway Administration (FHWA), Washington, DC

**Bruce Carr**  
Director, Strategic Planning  
Executive Office  
Alaska Railroad

**Michael Downing**  
Senior Vice President  
HDR Oregon, Inc.

**Gary Gustafson**  
Manager, Environmental, Regulatory & Land, Alaska Gas Resources  
BP Exploration (Alaska), Inc.

**Rick Kessler**  
General Manager  
Chenega Logistics

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**Rick Kessler**  
General Manager  
Chenega Logistics

**Capitol Bob Pawlowski**  
Legislative Liaison  
Denali Commission

**Jeff Ottesen**  
Director, Statewide Planning  
Alaska Department of Transportation & Public Facilities

**Lance Wilber**  
Director  
Public Transportation  
City of Anchorage
AUTC faculty and staff perform research, offer training, disseminate results, and support a network of researchers all over the U.S.A.
Collaborative partnerships enhance AUTC’s work. The center maintains diverse and highly specialized academic, governmental, private industry, and international partnerships.

The center’s portfolio of new, ongoing, and recently completed projects includes 29 partnerships with principal investigators from 10 different academic and private sector organizations. Partnerships with the University of Alaska Anchorage facilitate the widest variety of research, entailing projects in each of the center’s four focus areas (see table on opposite page).

Of all its focus areas, AUTC’s work on structural integrity involves the highest number of collaborations, encompassing work with six different partners. Illustrating the collaborative nature of AUTC’s work, all four focus areas feature partnership projects with at least three or more different academic or private sector partners (see table). Beyond Co-PI partnerships, AUTC maintains collaborative relationships with 36 different organizations, including state/provincial governments, federal agencies, cities, counties, boroughs, private companies, academic institutions, and research centers.

Education and workforce development remain integral to these partnerships. Industry and academia are working together to provide opportunities to build the capacity of the transportation professions. As always, numerous faculty researchers maintaining active teaching schedules, incorporating state-of-the-art information into their classrooms. In addition, many undergraduate, graduate, and doctoral students across several fields are currently working on AUTC research projects. They receive unique hands-on professional exposure, networking opportunities, career building experience, field work, and the chance to learn about transportation research at America’s Arctic University. In addition, AUTC works with a variety of agencies to increase opportunities for workforce development as well as increasing dissemination of new data to a wider community of industry professionals and scientists.

International research and development opportunities have also emerged. Many projects feature international counterparts who share expertise and information, such as the center’s work with the Université de Montréal or China’s Harbin Institute of Technology; other studies support project-level information exchanges with cold weather transportation officials in Canada, China, Denmark, Iceland, Finland, and Norway.

Last, but hardly least important, are AUTC’s public-private collaborations. Industrial partners like TransCanada and the Alaska Railroad Corporation and innovative firms like TenCate Geosynthetics and GW Scientific are among numerous industry leaders who have joined with AUTC to increase the applicability of our research efforts and increase opportunities for professional enrichment across transportation-related fields.

The list on the opposite page recognizes our recent and current partners.
### AUTO Co-I Partnership Projects (Identified by Major Focus Area)

<table>
<thead>
<tr>
<th>Partner</th>
<th>Transportation Asset Management</th>
<th>Structural Integrity</th>
<th>Surface &amp; Subsurface Applications</th>
<th>Frozen Ground Studies &amp; Applications</th>
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<tr>
<td>Universite de Montreal</td>
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<tr>
<td>Oklahoma State University</td>
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<td>GW Scientific</td>
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<tr>
<td>University of Alaska Anchorage</td>
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<td>Iowa State University</td>
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**Private Sector Partners**
- Alaska Railroad Corporation
- Geo-Watersheds Scientific (GW Scientific)
- Kansas Structural Composites Inc. (KSCI)
- Midwest Industrial Supply Inc.
- Soilworks
- TenCate Geosynthetics
- TransCanada Corporation

**City/County/Borough Partners**
- Anchorage Metropolitan Area Transportation Solutions (AMATS)
- City of Fairbanks
- Fairbanks Metropolitan Area Transportation System (FMATS)
- Fairbanks North Star Borough
- Ted Stevens Anchorage International Airport

**State/Provincial Partners**
- Alaska Department of Environmental Conservation
- Alaska Marine Highway System
- Idaho Transportation Department
- Minnesota Department of Transportation
- Montana Department of Transportation
- Ohio Department of Transportation
- Oklahoma Transportation Center
- Oregon Department of Transportation
- Washington State Department of Transportation
- Yukon Highways Public Works

**Federal Partners**
- American Association of State Highway and Transportation Officials (AASHTO)
- Federal Highway Administration (FHWA)
- National Oceanic and Atmospheric Administration (NOAA)
- Transport Canada
- U.S. Department of Agriculture

**Other University Partners**
- Chico State University
Rodney Collins, graduate student in Civil Engineering is AUTC’s Student of the Year for 2011. Collins’ stellar academic performance, the quality of his research, and his leadership in student professional activities made him an obvious choice for this award.

Starting in 2008, Collins participated in various research projects, developing an interest in the use of geofibers and synthetic fluid for stabilizing marginal soils, which became the subject of his Master’s thesis. His research—part of a larger project jointly funded by the ADOT&PF and AUTC—involves lab testing of non-traditional soil stabilization technology. The project goal is to find new techniques to stabilize loose sandy and silty soils, improving their performance as foundations for such structures as buildings, airstrips, and roads.

Working in AUTC engineering research offers many opportunities in addition to a strong academic background. As part of his work on this project, Collins has traveled to communities like Barter Island, to study the effects of thawing permafrost; to Unalakleet, to test soil bearing capacity; Emmonak, to test dust-control measures; and Kwigillingok, to investigate the use of geofibers and synthetic fluid on clay subgrade. “Throughout my studies,” Collins noted, “the most important thing I have gained is the opportunity to interact with people from different cultures and understand engineering problems through the eyes of the people that live there.” Collins has coauthored two published papers on cutting-edge use of geofibers and synthetic fluid to stabilize Fairbanks silt. Two other papers are in progress: one involving large-scale direct shear tests of Ottawa sand mixed with geofibers; the other is a case study describing the use of geofibers and synthetic fluid to stabilize a road. After graduating from UAF with his Master’s degree, Collins plans to complete a Ph.D.

“I look forward to sharing my experiences...and also gaining a new perspective on engineering,” he said. After a PhD, and some time in the private sector—perhaps a consulting business—Collins hopes to return to UAF, where, as he described it, “I can continue conducting research and also educating new students.”
The UAF Graduate Certificate in Construction Management program saw its first three graduates in the spring of 2011. Jeff Russell and Andrew Schultz, of the Alaska Department of Transportation & Public Facilities, and Scott Shopa, of the US Army Medical Service Corps, will take a new level of expertise back to their professional communities. With dedication and hard work, all three completed 15 graduate-level credits in construction project management while performing at their existing jobs. All three will be better equipped to take on large projects and to mentor the new professional staff who join their organizations. With new skills and increasing confidence, these professionals will be better placed for promotion opportunities and more challenging projects. The Graduate Certificate Program in Construction Management was designed to make relevant, top quality education available to employees at a cost and time commitment attractive to their employers.

Michael Lund, another professional committed to continuing education, has completed his Masters of Science in Engineering Management.

Bob Perkins, professor of Engineering Management at UAF, notes that “about a third of our Civil Engineering graduates go into the field with very little management training. Our goal was to offer a program that would offer advanced training to practicing engineers. We found that there was also a group of technical professionals who could use the same training.”

Many professionals also saw a need for more training in communications—the “human side” of their construction. As the program has grown, UAF tapped Keith Whitaker, an engineer with expertise in design construction and litigation, to run the program.

“These are the best type of students,” said Whitaker, “hardworking, focused, enjoyable to have in class. I think they’re already seeing the benefits of this program.” Whitaker’s goal for the coming years is to attract more students from a wider range of employers, including the private sector.

“One great thing about this program is that the students come in with this large body of knowledge that they share with each other and with their instructors,” said Perkins. The new graduate program is supported by a group of organizations, including the ADOT&PF and the Alaska University Transportation Center.
Through a recently completed project funded jointly by AUTC and ADOT&PF, frozen ground experts Yuri Shur and Mikhail Kanevskiy conducted customized trainings in mitigating the impact of permafrost on road stability for geologists and engineers.

Shur and Kanevskiy took part in geotechnical investigations along a proposed re-alignment of the Dalton Highway between Mileposts 8 and 12, an area known as “Nine Mile Hill.” Field work in this area included drilling numerous boreholes in extremely ice-rich permafrost. While vexing for engineers, this section of highway—and the lessons Shur and Kanevskiy took from it—offered a teachable moment for Alaska’s road design professionals.

Using field and laboratory work, Shur and Kanevskiy taught ADOT&PF geologists how to describe extremely ice-rich frozen soils in terms useful to designers and scientists and how to evaluate permafrost properties.

Assisted by three UAF students (two Masters and one PhD student), the team gave instruction on dealing with diverse soil types, including hands-on field work on the Dalton Highway. They also held a workshop for 20 ADOT&PF engineers and geologists on methods of geotechnical investigations in areas with ice-rich frozen ground and how to evaluate frozen ground properties.

Shur and Kanevskiy continue their permafrost studies, involving two undergraduates and three graduate students in their ongoing work and taking every opportunity to share their expertise with everyone, from practicing engineers to students at all levels. A professor in UAF’s Department of Civil and Environmental Engineering, Shur teaches several specialty courses on frozen ground engineering that are foundational for students entering this profession.

Every day our climate brings professionals tough challenges—ones that require uniquely Alaskan solutions. To help overcome these obstacles, AUTC researchers have been turning their innovations into hands-on skill development for Alaska’s workforce.
Road dust management is another major area in AUTC’s public outreach and workforce development. Drawing on multiple new and ongoing research projects in this area, the center has worked to deliver new knowledge and training to rural and professional stakeholders in Alaska. AUTC is also a founding partner in a new national organization devoted to this issue.

For Alaska, road dust is a multi-pronged problem, with risks to public health, safety, infrastructure, quality of life, and fiscal spending. For example, ADOT&PF recently discovered that roughly one inch of road surface was lost each year on the Dalton Highway due to traffic dislodging dust. This figure translates to more than $24,000 per mile in maintenance costs and $6,000 per mile in mitigations costs—nearly $30,000 per mile. Public safety also suffers as vehicle dust reduces driver visibility, causing accidents. In another example, rural Alaskans, for whom salmon remains an important part of their diet, risk ingesting dust or calcium chloride by drying their fish near their homes. Instead, to avoid road dust, they must dry fish miles from their neighborhoods, incurring losses as wild animals take the fish.

Below left, (l to r) Mikhail Kanevskiy, graduate student James “Trip” Collier, and Yuri Shur travel to a field site for frozen ground studies.

Above, Salmon dries outdoors in a rural arctic community. In many of Alaska’s rural areas, the majority of the community depends on local food sources for subsistence. Road dust can degrade and contaminate such resources and hamper harvest activities.

Below right, a truck raises dust on the unpaved Dalton Highway during the summer season.
Researcher David Barnes leads seven new and ongoing projects dealing with road dust management, and these have evolved into a significant public outreach and education program.

Barnes teamed up with other AUTC and ADOT&PF counterparts to educate people in rural villages and state professionals on mitigation techniques.

Barnes and a team of presenters conducted two regional Road Dust Management workshops in Bethel and Fairbanks. These specialized sessions addressed the fundamentals of road design, and how good design helps control dust, as well as issues such as dust creation and dust-related health effects. Presentations discussed soil dynamics, road crowns, ditching and ditch clearing, speed control and other dust prevention issues.

Workshops offered hands-on exercises to illustrate the various topics, such as having attendants take handfuls of silt in their hands and begin adding water to the silt—slowly squishing—and adding more water until the silt turned into a mushy soup. The point: the same thing happens to road surfaces.

In addition to Barnes’ material, the workshops included presentations by Travis Eckhoff (UAF), Bob McHattie (ADOT&PF, retired), Billy Connor (Director, AUTC), Clark Milne (ADOT&PF), and Pug McLaughlin (UAF). Each event was attended by about 15 people from a variety of professional and research backgrounds, including DOT administrators and road engineers, tribal corporation officials and maintenance staff, and others involved with rural road work in Alaska. The courses were also made available at no cost through the Alaska Tribal Technical Assistance Program.

As Barnes and other AUTC stakeholders are aware, road dust is a problem across the nation. Recognizing this national interest in addressing dust-related transportation issues, AUTC partnered with the Western Transportation Institute, the University of California, Davis, the University of Nevada, Las Vegas, and the Federal Highway Administration to form the Road Dust Institute (RDI).

RDI’s mission is to provide “tools to manage dust on transportation facilities through research, education, and technology transfer” to improve “health, safety, mobility, environmental sustainability, and livability.” RDI’s goal is to reduce the impacts of dust by uniting a collective base of “knowledge, experience and capabilities” for “collaboration, partnering, and consolidation of resources to address the needs of industry, government, and other stakeholders.” To learn more, visit RDI's website at: roaddustinstitute.org.

The EPA estimated that 10.5 tons of fine particulates were produced from the nation’s 1.3 million roads (Federal Register, 2006). This translates to 7.9 tons of dust per mile of unpaved road per year. As base course materials cost roughly $25 a ton, the cost to federal, state, and local agencies is estimated at $260 million per year. On the public health front, a 1998 study found the unaccounted cost of mortality and morbidity due to road dust was somewhere between $3 billion and $153.5 billion.
Beyond frozen ground and road dust topics, AUTC’s recent workforce development efforts have focuses on another major area for its stakeholders: problems in maintaining safe and efficient gravel roads. In March, AUTC and ADOT&PF sponsored a specialized presentation and dissemination of a practitioner’s handbook for the Road Service Commission of the Fairbanks North Star Borough (FNSB).

Bob McHattie, a long-time road surface expert recently retired from ADOT&PF, developed a presentation and a handbook to equip FNSB road managers and service commissioners with the technical insight necessary to address a variety of gravel road issues.

*A Common Sense View of Fairbanks: Gravel Road Problems* outlines strategies for mitigating and preventing a variety of gravel road issues. Complete with background information, examples, and numerous “rules of thumb” and instructions, the custom-tailored publication helps FNSB professionals recognize both simple and complex road problems and their causes.

The book discusses problems that may be inherent—poor design, engineering, and construction issues—as well as those that accumulate over time, such as foundation failures, vehicle-caused wear and tear, drainage deficiencies, and poor preservation practices. It also gives guidelines to help practitioners make the often difficult decision between fixing a particular problem, or addressing its root cause through preservation strategies.

Of added importance to professionals, McHattie’s training and handbook address problems that are especially troublesome for northern regions. Seasonal soft areas, rutting, potholes, dust, corrugations, and foundation and permafrost problems are among the most persistent. This accessible and useful guide also discusses design features, including alignment, geometrics, obstructions, signage, lights, drainage, and materials issues. Similarly, ice-rich road foundation conditions, sub-standard and/or degraded construction materials can also complicate gravel road maintenance. The handbook provides detailed explanations and solutions for mitigating these varied issues, and also offers a chart that addresses unique “combination issues,” such as summertime dust occurring with springtime soft spots, or rutting that occurs along with overgrown ditches.

Giving practical, workable solutions to these problems helps practitioners get their jobs done more efficiently and effectively—an outcome that benefits everyone, from stakeholders to state decision-makers. From gravel road problems to permafrost to road dust, AUTC is working hard to translate its expertise and insight in cold region transportation issues into applied, specialized knowledge for today’s transportation workforce. The handbook is available on the Fairbanks North Star Borough web site (www.co.fairbanks.ak.us).

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Gravel road problems can be a costly maintenance effort. As an example, the Fairbanks North Star Borough, with roughly 97,000 residents in an area of more than 7,300 square miles, maintains roughly 400 miles of unpaved roads.
An important component of our work that is not fully captured in our expenditure statistics is the scope of our outreach activities. The majority of our public interface, workforce development, and specialized training is funded at the project level. Because of the value we place on implementation, most dissemination and outreach activities are linked to individual projects and funded through direct project and research funds rather than as a separate category of expenditure. Their beneficial results are not reflected within our budget statistics.

For example, David Barnes’ portfolio of work on dust reduction and palliatives (see pages 13-14) entailed significant public outreach through workshops with Native corporations, rural villages, and ADOT&PF personnel. Similarly, Yuri Shur and Mikhail Kanevskiy developed customized training for ADOT&PF engineers and geologists on geotechnical investigation methods, extremely ice-rich soil descriptions, and permafrost evaluation that does not appear within our financial statements either.

This outreach and education tangibly enhances AUTC’s work outcomes. By transferring knowledge from our researchers into the hands of community transportation managers, state road engineers, geologists and other specialists, these activities enhance the applied value of our work in ways that numbers do not reflect. These efforts also boost the return on investment for our federal, private, and state level funders.

Another important trend not highlighted in our expenditure figures is the leveraging of funds that has occurred with our work. In fact, AUTC projects and research have benefited greatly from a number of pooled-fund studies, private sector collaborations, university partnerships, and other activities.

In 2011, AUTC received a total of $3,243,400 million in RITA funding plus equivalent matching funds. Research and Administration costs, which encompass all project-level spending on research and supporting activities, is at 79%, a healthy level for a diverse program that serves a far-flung and varied professional community.

In an era when research institutions shoulder an increasing amount of project level administrative costs, and sometimes thereby diminish the end-product for their stakeholders, we are pleased to retain this level of project focus. Only 17% of the AUTC budget goes to General Administration costs. The remaining 4% contributes to Alaska Research and Technology Transfer and supports general outreach and education activities.

Private sector, industry partners and several collaborating universities have made substantial in-kind and operational donations to AUTC. Suppliers and producers of soil stabilization technology, for example, have freely donated their materials to our soil stabilization research. Similarly, local contractors have provided in-kind matches through the value of their property and equipment, supplementing the effectiveness of our work.
Our partnerships with a variety of research institutions enhance our projects by adding national and international expertise, tangible project matches, unique laboratory facilities, software and technology, and other research tools. Boosting the outcomes of our projects, these contributions add a comparative advantage to AUTC’s research.

Lastly, our close partnership with ADOT&PF benefits both state and national stakeholders well beyond what our funding figures illustrate. ADOT&PF is our major partner in research. Thirty-two percent of our funds are derived from this agency.

The USDOT RITA grant requires 1:1 matching of funds over the life of the grant, although individual projects and annual budgets may vary slightly in cost share level. AUTC is on track to meet this match commitment by program end. Additional research projects sponsored by both federal and other funding sources provide a multitude of benefits to the nation, as well as to the State of Alaska. The outputs of this research, outreach, training, and other project work continue to help transportation professionals on many fronts, as highlighted throughout this annual report.

AUTC’s innovative and flexible partnerships boost our project outcomes by making the best use of pooled resources, materials, and infrastructure.

<table>
<thead>
<tr>
<th>Funding Year</th>
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<th>Other Funds</th>
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<td>44%</td>
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A major portion of AUTC’s current project portfolio includes programs aimed at enhancing transportation asset management. As outlined by the Federal Highway Administration, Transportation Asset Management (TAM) is a strategy to reduce life-cycle costs involved in managing and maintaining transportation assets like bridges, rails, tunnels, roads, and roadside features. Defined by the American Association of State Highway and Transportation Officials’ (AASHTO) Subcommittee on Asset Management, TAM is “a strategic and systematic process for operating, maintaining, upgrading, and expanding physical assets effectively through their lifecycles.” Focused on “business and engineering practices for resource allocation and utilization,” TAM aims to bring “better decision making based upon quality information and well-defined objectives.” TAM is an increasingly broad topic including a range of issues from data systems integration and asset monitoring infrastructure to climate assessment and life cycle cost analysis. For example, Andrew Metzger's work on Geotechnical Asset Management and Jeffrey Miller's research on Intelligent Transportation are helping integrate information systems and monitoring into efforts to improve asset life cycles and management decision making. On the other hand, several projects discussed here address the connection that environmental factors like climate and precipitation have to asset performance and vulnerabilities, life cycle extensions, and cost reductions. Ming Lee's work with climate change assessment and Pacific Northwest surface transportation is helping better address environmental impacts upon transportation assets such as roads, railways, and bridges. Similarly, research by Douglas Kane, Svetlana Stuefer, and Amy Tidwell to update Alaska's precipitation frequency estimates will help engineers and designers lessen construction costs, reduce maintenance needs, and extend the service life cycles of bridge assets affected by flood flows. While these projects might reasonably fall within topical areas like Structural Integrity or Surface Applications, their grouping here represents AUTC's efforts to integrate our work into a topic of growing importance to our federal, state, local, industry and research partners.

However we categorize them, the value of these diverse projects lies in their ability to help maximize transportation system performance, minimize life-cycle costs, improve the use of existing transportation assets, and ultimately, improve customer satisfaction.

New TAM Projects

Geotechnical Asset Management (AUTC #510016)

Andrew Metzger, University of Alaska Fairbanks (UAF)

Geotechnical assets—things like rock and soil slopes, shore protection, embankments, retaining walls, material sites, bridge foundations, tieback anchors and more—literally touch or affect every other physical asset owned by the Alaska Department of Transportation and Public Facilities (ADOT&PF). Because of this acute interconnection, effective management of geotechnical assets is necessary to maintain the level of transportation safety and service required by ADOT&PF clients, aka people who utilize the transportation system in Alaska. In fact, ADOT&PF Commissioner Marc Luiken recently identified asset management as the second of six key initiatives the department will target in its new strategic plan.

Above, a roundabout, one of three, constructed in North Pole, Alaska. AUTC has supported ADOT&PF design and monitoring of roundabouts and traffic use of these structures in several Alaska locations.

Opposite page: UAA faculty member Jeff Miller works with FreeSim, a traffic simulator, to monitor traffic flow in Anchorage using data collected from tracking devices in vehicles. To learn more about this project, visit ine.uaf.edu/autc/projects/.
Supporting this initiative, new research led by Andrew Metzger at UAF seeks to develop a framework for addressing challenges related to geotechnical asset management (GAM) that can be implemented with other asset management systems.

Overcoming the several salient challenges GAM brings is integral to any comprehensive management approach. For instance, unpredictable service life, financial accounting complexities, and difficulties with maintenance performance are among the proven obstacles to managing geotechnical assets within most infrastructure organizations, including those in Alaska. Nonetheless, Metzger and his team expect the GAM project to produce a “road map” for transportation-related GAM in the state of Alaska. This draft program framework will include specific planning recommendations that address the most significant challenges for implementation of GAM across the broad range of geotechnical assets owned by ADOT&PF.

Information Gathering Infrastructure: Toward Intelligent Transportation (AUTC #510018)

Jeffrey Miller, University of Alaska Anchorage (UAA)

Much of the vital transportation-related research going on within ADOT&PF is affected by costly limitations to data collection and examination. On the one hand, such research is often constrained by a lack of real-time data analysis. On the other hand, this work typically relies upon privately owned cellular communication towers to relay necessary data, usually at great cost to researchers and to the state.

Addressing both these issues, a new project headed by researcher Jeffrey Miller is creating and using independent communication towers to transmit data through a Vehicle-to-Infrastructure (V2I) system, allowing for real-time, city-wide data analysis without costly monthly fees. Never before in ADOT&PF’s work has so much vehicle information been available in real time and exposed through a web interface with data transmitting live over a novel V2I architecture that may operate in perpetuity.

Cellular companies have not shown interest in partnering with a vehicle data gathering organization, so there will always be fees associated with each device communicating over the cellular network back to the central infrastructure. To minimize this cost, Miller’s team is installing independent communication towers that, instead of incurring external monthly fees, rely only upon internal support and maintenance. The project will use the On Board Diagnostics (OBD) port of a vehicle to allow data from the vehicle’s computer system to be gathered and transmitted over the V2I network. Hosted at UAA, the database server utilizes customized structural components designed with structural, modal, and dynamic finite element analysis techniques. Manufactured and fabricated in the UAA machine shop and design studio facilities, the system’s manufacturing and assembly drawings will be made available to ADOT.

While many of the costs are covered by ADOT&PF, this system’s benefits will serve a variety of other agencies. Miller is designing a protocol through which other agencies and public institutions may access the server; this protocol will have specific guidelines on data retrieval, requests for collecting specific information, and specifications on scalable interface design to support future applications and projects. Scaling and expanding this capacity for future projects remains a major priority for Miller’s team. Including such information as revolutions per minute (RPM),
fuel consumption, acceleration/deceleration rates, engine/cabin/outside temperature, tire pressure, and tire rotation, this data will be a gold mine for a variety of public entities, researchers, and planners.

**Knowledge Transfer Needs and Methods (AUTC #510009)**

**Robert Perkins (UAF)**

While many TAM resources are technical and physical, human resources are also a key component of asset management, and one that will soon become a major obstacle to ADOT&PF managers. Many organizations across the state, and ADOT&PF in particular, face a tremendous challenge as nearly one third of the current workforce soon becomes eligible to retire. This ballooning workforce loss makes timely knowledge transfer—the passing of knowledge from more experienced employees to newer employees—a looming and critical issue; ADOT&PF needs to prepare for and ensure efficient transfer of knowledge throughout its renewing workforce.

Research led by Robert Perkins at UAF will give ADOT&PF tangible implementation tools to enhance the knowledge-transfer process and mitigate this coming institutional knowledge crisis. Focused primarily on engineering and technical fields, the project examines the problem of knowledge transfer with respect to recruitment, retention, and succession planning with the aim of developing recommendations for the department. Perkins and his team are identifying barriers to knowledge transfer, such as managers’ reluctance, corporate culture, and history. They are also conducting focus groups with managers and professionals to determine the most effective available tools to improve the knowledge-transfer process within the department.

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**Ongoing TAM Projects**

**Updated Precipitation Frequency Estimation for the State of Alaska (AUTC #207119)**

**Douglas L. Kane, Svetlana Stuefer, and Amy Tidwell (UAF)**

Designing and building river and stream crossings like bridges, culverts, buried utilities, and pipelines is a costly exercise. The goal of a hydraulic engineer during design of such structures is to evaluate and accommodate the flood flows while minimizing both the cost of building the structure and maintaining it during the life of the structure.

To accomplish this task, good hydrological and meteorological estimates of streamflow and/or precipitation are needed. Such data is very sparse in Alaska. In the early 1960’s, distributed maps of rainfall intensity were developed for a range of durations (30 minutes to 10 days) and frequencies (1 year to 100 years) using historical precipitation data available at the time. It had been suggested frequently since the 1980’s that these maps be updated to make use of recently collected precipitation data.

In 2008, faculty in the Water and Environmental Research Center at UAF/INE teamed up with researchers at NOAA/NWS Hydrometeorological Design Studies Center in Washington, DC to refashion the intensity-duration-frequency (idf) analysis for the state of Alaska using the most recent data up to 2010. Tasks to date have included compiling data from over 1,000 stations from federal and state agencies and several university institutions, formatting, quality examination of precipitation and metadata, merging of neighboring stations, preliminary estimation of idf values, and external review of spatially distributed estimates over the whole of Alaska. The proposed task of bias correction for the gauge undercatch for various types of gauges was not completed because of the lack of comprehensive metadata on precipitation gauge installations.

The results of this study will be available online in electronic format in November, 2012 as Volume 7 of the NOAA Atlas 14, “Precipitation-frequency atlas of the United States“.
Assessing the Contribution of Traffic Emissions to the Mobile Vehicle Measured PM$_{2.5}$ Concentrations by Means of WRF-CMAQ Simulations (AUTC #410003)

Nicole Mölders (UAF)

Air quality is a growing public safety concern in Fairbanks, Alaska, where smog and other airborne matter form what locals describe as “ice fog,” which fills the valley in winter months. While many people think traffic may be the cause for the poor air quality, researchers remain unsure.

Nonetheless, the city’s air quality has fallen below the 24-hour National Ambient Air Quality standard (established by the Clean Air Act of 1990) for particle matter with diameters of 2.5μm or less (PM$_{2.5}$) every winter since the Environmental Protection Agency (EPA) set the new standard of 35 micrograms per cubic meter of air in 2006. These frequent exceedances of the standard are a concern.

The amount of fine particles in the air—that is, pollutants in the air we breathe—are measured in areas that are thought to suffer from poor air quality. In 1997, the EPA created a designation system to measure these particulates as “PM,” short for particulate matter. For example, when an area’s air exceeds the standard frequently, it is designated a PM$_{2.5}$ nonattainment area as these fine particulates in the air pose a great health risk because of their small size. When particles are tiny enough, they can be inhaled, where they become lodged in the lungs indefinitely and cause damage.

In the winters of 2008–09 and 2009–10, the Fairbanks North Star Borough started measuring PM$_{2.5}$ concentrations using vehicles equipped with measuring instruments. Although they represent a mixture of all potential PM$_{2.5}$ sources, the measurements are typically taken in places where traffic emissions could be higher than in adjacent neighborhoods, such as roadways. This research will assess the traffic-emission impact on observed concentrations under various traffic and cold-weather conditions using an Alaska-optimized version of EPA’s regulatory model package called WRF-CMAQ.

Using geographic information system (GIS) technology, researchers will use this project’s data and the ongoing Mobile Measurement Project to create maps that show PM$_{2.5}$ concentrations in Fairbanks neighborhoods under various weather conditions. The borough will then publish these maps on a public website, allowing residents and air quality specialists alike to see the various levels of air quality.

This project will help local and borough officials assess how traffic contributes to poor winter air quality. In an effort to enhance public health and safety, the maps will also help local and borough officials improve air-pollution mitigation strategies.

So far, the project has obtained emissions and meteorological data, performed first test simulations and evaluated them. Looking ahead, researchers will examine the impact of traffic emissions on PM$_{2.5}$ concentrations.

Gathering Vehicular Parameters through a Vehicle-to-Infrastructure Intelligent Transportation System (AUTC #410024)

Jeffrey Miller (UAA)

Intelligent Transportation Systems (ITS) combine communications technology, data, and transportation infrastructure to supply city planners and other decision makers with information on how and when traffic moves, particularly in an urban area. Potentially reducing highway accidents by 25% in rural areas and 30% in urban freeways, ITS technology can improve public safety considerably and offer millions in cost savings, according to Iowa State University research.

This project builds upon ongoing work at AUTC that is applying the latest ITS technology to the urban transportation system in Anchorage, Alaska. Recent work (“Assessment of Traffic Congestion in Anchorage Utilizing Vehicle-Tracking Devices and Intelligent Transportation System Technology,” see page 28) tracked the speed, location, and direction of vehicles in Anchorage. This new study will improve tracking by enhancing the data these systems use.

Miller’s work is improving public safety and contributing to major cost reductions from accident and maintenance prevention. Anchorage drivers will be able to use online traffic reporting to see live, real-time data and make more informed—and safer—travel decisions.
The current system only collects data on a vehicle’s speed, location, and a unique anonymous identifier. UAA researchers want to gather and transmit additional information to a central server through a vehicle-to-infrastructure (V2I) architecture. This system will transmit data as a text message from individual vehicles to a central server through existing cellular telephone networks.

The V2I network will collect data from a vehicle’s On Board Diagnostics port. This enhanced data will include engine revolutions per minute, fuel consumption, and acceleration/deceleration rates. In addition, many vehicles will give data about engine temperature, interior and exterior temperatures, tire pressure and rotation, and tire slippage—a key advancement.

Identifying tire-slippage areas will allow the system to alert drivers and maintenance response crews about dangerous locations through web interface, and potentially a text message in real time.

To date, the project has provided real-time traffic conditions to Anchorage travelers online at www.alaskatraffic.net.

This project’s advances in the V2I system are already showing promising benefits through significant improvements in public safety as well as major cost reductions from accident and maintenance prevention. Anchorage and Alaska travelers will be able to use the online traffic reporting to see real-time data and make more informed—and safer—travel decisions. Road maintenance teams will also have immediate knowledge of problem areas and can quickly arrive on the scene, preventing potential accidents and more costly maintenance issues.

**Fairbanks North Star Borough Road Upgrading Process**

(AUTC #309020)

**Billy Connor (UAF)**

This project helps transportation planners in Interior Alaska’s largest population center by developing a road-upgrade decision process. Using innovative technology and process design, the results will help maximize limited road budgets and increase the life cycles of priority roadways.

Roads in the city of Fairbanks, Alaska, and the greater Fairbanks North Star Borough (FNSB) serve a variety of important stakeholders under extreme climate and weather conditions. In addition to an international airport, two major U.S. military bases and numerous defense installations, the road system supports extensive commercial trucking and energy production as a conduit between southern Alaska and the North Slope oil fields. It also supports to the city of Fairbanks, with its flagship state university, numerous federal agencies, the seasonal tourism industry, and a growing population. Despite these varied needs, FNSB’s transportation planners are constrained by limited budgets, extreme climate, and unclear priorities.

Currently, FNSB planners lack adequate decision-making tools to prioritize road upgrades. This project will help FNSB develop a rational, effective, and efficient process to upgrade roads in a manner that allows it to either pave or continue with unbound surfaces without reconstruction. The resulting decision process will allow FNSB—or any county government nationwide—to maximize its road service area budgets.

The FNSB road system includes more than 470 miles of maintained roadways connecting 109 local service areas. Road conditions vary among the service areas and even among single roads. Unsurprisingly, drivability and maintenance costs are the most common challenges, leading to frequent budget requests from service areas to the FNSB for surface upgrades. Without a carefully designed process that considers the priorities, design options, and upgrade costs, FNSB cannot fully maximize its limited funding.

FNSB needs an effective systematic approach for selecting road upgrades. This project identifies and helps achieve long-lasting, cost-effective road improvement solutions. Its approach will include a scheme for examining and sampling potential road upgrades, a simplified flexible pavement design method, a model for estimating associated cost, and a Decision Support System (DSS) based on a GIS platform. The study will address issues intrinsic to the road-upgrading process such as dust reduction, emergency
service needs, evaluation of how inadequate gravel structures will affect future paving demands, and the economics of the upgrading investment. Harnessing the latest technology to improve this process, the results will be integrated in the GIS-based DSS to help FNSB decision makers and engineers develop projects for effective and economical road improvement.

Including Life Cycle Cost Analysis in Alaska Flexible Pavement Design Software (AUTC #309023)

Juanyu “Jenny” Liu (UAF)

When something you buy breaks down, it costs money to buy a new one. And when something you buy needs constant repair, it costs a lot to repair it. These simple concepts underlie life cycle cost analysis, which Alaska’s transportation engineers use to make decisions about the materials they purchase. It is also the focus of innovations this project is developing for Alaska’s Flexible Pavement Design software.

Life cycle cost analysis (LCCA) is a key consideration for selecting materials and techniques that optimize the service life of a pavement in terms of cost and performance. While the Alaska Flexible Pavement Design (AKFPD) software has been in use since 2004, no computerized analysis tool exists to help pavement engineers develop cost analyses for a given project. Including LCCA in the AKFPD software would benefit pavement designers substantially, allowing them to routinely improve infrastructure performance while making more cost-effective use of the design effort.

This study will update the current AKFPD program and create a single software package capable of executing economic cost analyses and structural analysis functions. Upon completion, the project will provide the updated software, a modified AKFPD manual, and case studies with complete analysis processes to help a new user navigate the software.

The project team has developed a new layout for the program. They have also added new modules, including “equivalent single axle loads calculation” and “LCCA analysis,” and designed more user-friendly interfaces for two other modules, “Mechanistic Pavement Design” and “Excess Fines Design.” These innovations will help engineers improve the cost effectiveness of their projects by enhancing the life cycles of materials they choose.

Model of Alaska Transportation Sector to Assess Energy Use and Impacts of Price Shocks and Climate Change Legislation (AUTC #309002)

Virginia Fay (UAA)

Alaska residents and business owners have a unique vulnerability to changes in energy prices and national regulations. This project is looking at how volatile energy costs and emerging national legislation initiatives impact Alaska’s economy.

Alaskans have a higher dependence on energy resources and are more vulnerable to energy price volatility than residents and businesses in most other states. Key industries like fishing, mining, tourism, and transportation, as well as subsistence activities, currently depend directly on liquid fossil fuels. At the same time, Alaska’s urban service economy relies heavily upon the relatively low cost of living and doing business (compared to costs in Alaska’s rural regions) made possible by cheaper fuels. According to the Energy Information Administration, for example, Alaska consumes 40% more fuel per capita than any other state—more than triple the national average.

National climate, fiscal, and energy policies can reshape energy costs. As congressional lawmakers reduce federal budgets, programs such as bypass mail and essential air service may be reduced or eliminated. It is unclear how such actions to address greenhouse gas (GHG) emissions will affect Alaska residents and businesses. This project is developing a model of Alaska’s transportation sector to see how changes in fuel prices or use may change activities in the state.

Part of a UAA Institute of Social and Economic Research program titled “Energy in the Alaska Economy,” this project will examine connections between energy use, energy prices, climate policy, and economic activity. Its results will inform public policy makers about how energy use and rising fuel costs impact Alaska transportation, tourism, and fisheries.

Fay's results will inform public policy makers about how energy use and rising fuel costs impact Alaska transportation, tourism, and fisheries.
**AUTC Participation in Climate Change Assessment for Surface Transportation in the Pacific Northwest and Alaska (AUTC #RR10.04)**  
**PI Ming Lee (UAF)**

As regional heat trends cause glaciers, ice, snow, and other frozen features to melt, the impact upon transportation systems such as roads, railways, and bridges may be severe.

A partnership between the Oregon Transportation Research and Education Consortium and AUTC, this project will assess the risks and vulnerabilities that regional warming may pose to surface transportation infrastructure in the Pacific Northwest and Alaska.

Researchers are synthesizing information needed to examine and describe the regions and identify critical infrastructure and transportation operations that would be vulnerable to climate change impacts. The project will provide recommendations on more detailed research and analysis. Topics in this area will include risk management and the adaptation of multimodal transportation infrastructure. UAF’s expertise in transportation analysis and GIS-based studies will help this project address challenges unique to Alaska’s extreme climate and weather patterns.

**Life Cycle Cost Analysis for Alaska Bridge Components (AUTC #207083)**  
**J. Leroy Hulsey (UAF)**

Decaying infrastructure and limited renewal funds are moving our national transportation system toward crisis. Which bridges are past their service life? Which could function safely for another decade? What will it cost to replace them? The U.S. Department of Transportation has asked every state to develop a long-range plan (through 2030) for bridge replacement.

To meet this goal, Alaska must create a priority list and a plan to replace its own aging infrastructure. The accepted design life for a bridge is 75 years, but this arbitrary number does not take into account new building techniques, seasonal stresses, or variations in frequency and size of vehicles supported, to say nothing of environmental stresses like scouring, ice damage, and earthquakes.

Bridges deteriorate in different ways, at different rates. A more accurate way to determine an existing bridge’s service life is essential to the state’s plan. The research team is collecting data on environmental conditions, material aging processes, repair records, and current costs. Results are contributing to a process for conducting life cycle cost analyses for highway bridges in Alaska. This project provides state planners and engineers with the tools to estimate an average cost per bridge, as well as the upper and lower bounds of maintenance and/or damage costs.

**Developing Guidelines for Pavement Preservation Treatments and for Building a Pavement Preservation Program for Alaska (AUTC #410038)**  
**Gary Hicks, California Pavement Preservation Center, Juanyu “Jenny” Liu (UAF), Hannele Zubeck (UAA)**

Alaska’s extreme climate takes a toll on pavement. Harsh cold, repeated freezing and thawing, moisture buildup, and other environmental factors, along with commercial wear and tear, reduce roadway service life. The resulting maintenance costs continue to strain state and federal budgets. In the past, the practice has often been “repair the worst first,” but this approach means that repairs are extensive and costly. Some decision-makers argue that more frequent and proactive maintenance can extend operational life and cost less over the longterm. The state of Alaska has committed to creating an active pavement preservation program, which requires development of program guidelines and solutions to road surface damage. The aim of this project, a joint venture between the California Department of Transportation (Caltrans), AUTC, and ADOT&P, was to provide a basis for these guidelines.

Using field site visits and internationally-distributed surveys, researchers identified road repair methods that are more cost-effective and environmentally sound. They helped ADOT&P and local agencies find pavement preservation techniques suitable to specific environmental regions in the state. Project findings will help the state realize considerable cost savings; some recent studies have found that active pavement preservation programs can save more than 50% in maintenance costs over a road’s 20-year life cycle. Proactive maintenance specifically tailored to Alaska’s various climate regions should improve the condition of Alaska’s roads and increase driver safety. To top it off, end-users will enjoy reduced roadway noise and reduced skid occurrences.
Researchers at the California Pavement Preservation Center are developing an online database of preservation methods based on results produced by UAA and UAF researchers, who have applied their specific expertise in Alaska’s cold regions to field monitoring test sites and synthesizing the vast amount of information available internationally.

In the next phase of the research, the team will determine which techniques will perform best in Alaska, and they will begin developing a process for selecting the appropriate preservation strategy for any given area and traffic scenario in Alaska.

To learn more about this project, visit the project wiki at https://sites.google.com/site/alaskap2/home.

Alaska Rural Airport Inspection Program (AUTC #309029)  
David L. Barnes (UAF)

Freezing temperatures and weathering invariably affect runway conditions and equipment, requiring high levels of maintenance and added expense. To compound this issue, many runways in rural Alaska are unpaved, which leads to erosion and subsequent undermining that eventually causes runway surface failure and serious safety risks.

As with any unpaved surface, routine inspection and maintenance are essential; however, the remoteness of many Alaska villages results in infrequent inspections. A comprehensive airport inspection program will improve transportation safety and reduce maintenance costs for Alaska’s transportation infrastructure, especially in rural areas where airports are the lifeline of the communities they serve.

This project is developing and implementing an inspection program for Alaska’s rural airports. Along with supporting long-term planning for airports and reducing maintenance costs, researchers are helping develop the state’s transportation workforce by involving students in a variety of field activities including lab tests, field inspections, and report drafting.

Completed TAM Projects

Serving Future Transportation Needs: Strategies to Improve Alaska ADOT&PF’s Professional and Support Staff Recruitment and Retention (AUTC #309038)  
PI Robert Perkins (UAF)

To maintain, design, and improve Alaska’s vast transportation infrastructure, ADOT&PF relies on one important component more than any other: people. As transportation agencies nationwide experience losses in professional and support staff as well as the vital institutional knowledge and expertise that goes with them, researchers at ADOT&PF are anticipating a future need for both seasoned and young employees. Before this problem arises, they want to know how to solve it.

This project identified management and organizational tools to improve recruitment and retention of the ADOT&PF workforce. With more than 90 years of combined management and professional experience in Alaska, the project team—Professor Perkins, Professor Emeritus Larry Bennett, and ADOT&PF engineer Bob McHattie—had crucial expertise and long-range vision. They surveyed all current and former employees in engineering job categories or other professional job types that directly support the engineering process. Using an innovative method to solicit survey feedback from current and former staff, they received a roughly 80% response rate. To achieve this high level of participation, they first asked the department’s commissioner to e-mail current employees and send a letter to former employees, seeking their feedback.

The team then met personally with individual employees and called former employees for interviews. After organizing survey responses anonymously, the team arranged the feedback according to region and job type, gleaning regionalized professional insight for future recruitment and retention efforts.

These results will help the department find ways to discover, hire, and retain the best employees possible to avoid a turnover trend that is all too common in other areas of the country. As public safety, budgetary savings, and end-user satisfaction all depend upon ADOT&PF’s smooth operations, the findings of this project will help ensure that Alaska’s key infrastructure—and the people who maintain it—serve it well in the future.
Bridge Deck Runoff: Water Quality Analysis and Best Management Practice Effectiveness (AUTC #RR08.13)

Robert Perkins (UAF)

The state of Alaska manages more than 700 bridges, and most of them span a body of water. Because rain, snowmelt, and stormwater runoff from bridge decking flow into these underlying water bodies, engineers must consider the related water quality and regulatory implications of runoff from bridge structures. UAF researchers sought to establish a useful set of Best Management Practices (BMPs) to address runoff issues on all of Alaska’s bridges.

Researchers looked at a variety of ambiguous, unclear, or overlapping best practices and safety regulations for dealing with bridge deck runoff to formulate a way of determining what best practices are needed for a specific bridge. For some bridges, state or federal statues outline BMPs to help guide engineers. With other bridges, existing guidelines were less clear.

Addressing this information gap, researchers conducted an inventory of Alaska’s bridges, raised questions with both economic and regulatory implications, and sought international expertise from countries and states familiar with the unique challenges of cold weather bridge design. This innovative synthesis yielded a study that will save time, money, and staff hours while alleviating environmental concerns surrounding bridge deck runoff.

Assessing Anchorage Traffic Congestion with Vehicle Tracking Devices and Intelligent Transportation System Technology (AUTC #309039)

Jeffrey Miller (UAA)

Anchorage’s population growth is increasing traffic congestion, but transportation planners are unsure how much. The city’s population grew 9%—roughly 8,000 people per year—since 2000, according to the U.S. Census Bureau. And while more people means more vehicles on the same roads, the exact impacts of this congestion remain unknown. Complicating matters, current congestion monitoring methods are inadequate. For that reason, this study sought to help move the city toward a real-time traffic monitoring capability to give transportation planners, local officials, and the public a clearer picture of the city’s congestion.

Anchorage’s current monitoring system has significant limitations. Vehicle counters and sparsely placed video cameras may or may not be monitored by a live person. Drivers only learn about current traffic conditions through radio and television broadcasts and other means which are not regularly updated or consistently accurate.

Motorists and transportation planners alike will benefit from better information through what is called a vehicle-to-infrastructure (V2I) system. V2I technology consists of an information architecture that combines vehicle tracking devices, cellular networks, and information monitoring activities to provide traffic congestion data and improve information availability.

This project installed tracking devices in 65 vehicles in Anchorage to analyze and display real-time traffic conditions based on the amount of time it takes to travel along main roads in Anchorage. Tracked vehicles travelled across the city from different locations during rush hour, while data was sent to estimate their travel time across the city’s main arterials.

The data was then uploaded for the public to access through a web interface called FreeSim (www.freewaysimulator.com) at the URL www.alaskatraffic.net. Color-coded road displays helped the user see whether traffic on a particular road was moving at less than 25% of the

Researchers conducted an inventory of Alaska’s bridges, raised questions with both economic and regulatory implications, and sought international expertise from countries and states familiar with the unique challenges of cold weather bridge design. This innovative synthesis yielded a study that will save time, money, and staff hours while alleviating environmental concerns surrounding bridge deck runoff.
A series of projects analyzing the Alaska Marine Highway System have yielded a detailed picture of the ferry system’s mission and performance, as well as its operating and financial scenarios for the next five to twenty years. This analysis includes both the transportation needs of coastline communities and the resources the state has available. Study results will benefit Alaska’s decision-makers as they plan for long-term operation of the state’s extensive ferry system.

For planners, this data is stored on a vehicle-by-vehicle basis in a database, where an application constructed by researchers allows the public, ADOT&PF, and Municipality of Anchorage to query the data to determine custom information. This accessible information improves transportation planning and decision making by giving officials accurate information about roadway use, congestion, and traffic flow that was previously unavailable. Researchers can also use this information to learn about traffic patterns, delays, seasonal traffic variations, how drivers circumvent traffic congestion, and whether route changes to avoid congestion actually save travel time.

Alaska Marine Highway System Analysis
(AUTC #RR07.04, #207105, #309018)
Paul Metz (UAF)

The Alaska Marine Highway System safely and reliably transports people, goods, and vehicles to Alaska communities, Canada, and the contiguous 48 states. AMHS has operated year-round since 1963, with regularly scheduled passenger and vehicle service to 30 communities in Alaska, plus Bellingham, Washington, and Prince Rupert, British Columbia.

During the past ten years, AMHS has carried an average of 400,000 passengers and 100,000 vehicles per year. Currently, AMHS generates almost $50 million in annual revenue. However, like much of the nation’s transportation infrastructure, AMHS facilities are aging, and the system will soon need new vessels and upgraded docking facilities. The state of Alaska already contributes to AMHS operating expenses, approaching $100 million a year. Its goal (and that of AMHS) is to keep the ferries running safely, reliably, and efficiently. This project developed a detailed picture of the Alaska Marine Highway’s mission and performance, as well as its operating and financial scenarios for the next five to twenty years. This analysis has taken into account the transportation needs of Alaska’s coastline communities and the resources the state is expected to have to meet those needs. Study results will benefit Alaska in planning for long-term operation of the state’s extensive ferry system. The final report for Phase 1 of this project is now available on the ADOT&PF web site.

LED Streetlight Performance in Interior Alaska (AUTC #RR10.01)
Richard Wies (UAF)

Successful transportation asset management includes improving the life cycle of facilities and reducing energy use, such as with efficient lighting systems. However, researchers must often assess the costs and potential safety issues that might arise in implementing a new technology, allowing decision makers to weigh these factors.

This project explored whether light-emitting diode (LED) streetlights could provide usable and safe illumination of Alaska roadways, and still meet standards set by the American Association of State Highway Transportation Officials (AASHTO). Researchers spent the past winter and spring lab-testing the illumination and color quality of LED lighting. Results showed that, though LED streetlights can provide usable light with much lower energy consumption than conventional streetlights (such as high-pressure sodium lights), they create a smaller “pool” or “cone” of light and would need to be spaced closer together to meet AASHTO illumination standards. It is likely that replacing Fairbanks’ existing streetlights with LED technology would require more lights for the same amount of roadway. In addition, researchers noticed that LED lights can cause reflections, which can make it difficult to see objects clearly, particularly for those who wear glasses with anti-UV coating. UAF suggested that improvements in both illumination and color quality would make LEDs a better replacement for HPS streetlights.
**Economical Analysis of Using Light-emitting Diode Technology for Alaska Streetlights (AUTC #207099)**  
**Hsueh-Ming Wang (UAA)**

Alaska’s winters provide few hours of sunlight during the day, driving up the costs to run municipal lighting systems. Around the nation, communities are exploring the use of LED technology for lighting streets to reduce energy use. For this reason, UAA researchers examined the costs and benefits of implementing LED streetlight technology in Anchorage.

Some researchers suggest that, under ideal conditions, an LED streetlight system might use 50% to 75% less energy than a traditional streetlight system, with a longer performance life. LED devices tend to be less fragile, switching on and off quickly without flickering. Additionally, while LED light systems normally overheat and burn out in temperate climates, companies suggest they can last five to ten times longer than fluorescents in colder climates. But, while LED technology could save millions, installing it may cost just as much. Converting an existing streetlight system to an LED system requires different circuitry and a different power supply, and installation costs alone could rise to several million dollars in a city like Anchorage.

UAA researchers wanted to determine the benefits versus the cost of using LED streetlights in some settings. They developed a hybrid self-sustainable LED lighting system with wind and solar energy and tested it on the Anchorage campus. Data collected from this new system indicated it has the potential to lead to energy independence from the energy grid system during summer months in Anchorage. Some of the research results may be patented in the near future. For some facilities, such as parking lots, this study’s results may save millions in annual maintenance costs while providing inexpensive energy to some facilities in Anchorage’s municipal system. In addition, providing safe lighting at a dramatically reduced cost could also provide lessons for other northern cities facing the same dilemma.

**Long-range Transportation Forecasting for Greenhouse Gas Emission Estimation (AUTC #309042)**  
**Ming Lee (UAF)**

As warming trends cause environmental changes along the Pacific Rim, transportation planners are weighing the long-term impacts that may threaten existing infrastructure. For example, studies have linked greenhouse gas (GHG) emissions to changes in the earth’s climate.

Increases in demand for freight transportation, personal vehicles, and changes in traffic operations all impact production of GHG. Urban planners need a reliable travel-demand forecasting model that help them predict and address how these components affect our ability to reduce or mitigate GHG emissions.

This project studied the Fairbanks Metropolitan Area Transportation System to determine if this modeling method could be used to estimate GHG emissions. Outputs from the FMATS model served as inputs for air quality models used by the EPA, which the agency uses to confirm air quality compliance. Some of these require traffic volume forecasts with spatial and temporal details that exceed what the current travel-demand models can produce.

This study examined inefficiencies of the models and developed effective methods of addressing them. Researchers validated, calibrated, and observed current data from the improved models, and applied forecasting scenarios to demonstrate the capability of the models and their ability to successfully predict the effectiveness of GHG emission reduction for a proposed transportation scenario.

**Developing Ambient PM2.5 Management Strategies (AUTC #107004)**  
**Ron Johnson and Tomas Marsik (UAF)**

Research on air quality problems in Fairbanks, Alaska is helping identify transportation management strategies that reduce air pollution and traffic while improving public safety.
ADOT&PF is looking for ways to “work smarter” with more efficient business practices and processes to increase its speed in delivering supplies to work sites, to optimize its workforce, and minimize major costs. UAA research into RFID technology can help.

To help Fairbanks meet EPA air quality standards, this project analyzed air quality and meteorological data to identify major contributors of fine particulate matter (PM$_{2.5}$), a pollutant.

Study findings showed that December and January traffic contributes to high PM$_{2.5}$ levels at a bus transfer point on Peger Road, and motor vehicles are responsible for about 30% of PM$_{2.5}$ downtown (near Cushman Street). Similar analysis of soot (black carbon) data indicated that wood smoke is a significant contributor to PM$_{2.5}$ during the heating season.

As a transportation management strategy, encouraging residents to work from home has some potential to improve ambient air quality, but perhaps not as much as borough managers might hope. For example, if 5% of current commuters worked from home, it would reduce downtown PM$_{2.5}$ levels by only about 0.4%. This assessment led the research team to conclude that Fairbanks needs major changes in its transportation management strategies to effect significant reductions in downtown PM$_{2.5}$ levels.

The final report for this project is available for download on the AUTC web site (ine.uaf.edu/autc/final-reports).

Feasibility Study of RFID Technology for Construction Load Tracking (AUTC #RR08.12)

Oliver Hedgepeth (UAA)

Many have heard the popular business mantra, “work smarter, not harder;” this advice may greatly improve ADOT&PF supply delivery activities. Results from this project will help the agency develop more efficient business processes to increase its speed in delivering supplies to work sites, optimizing its workforce and minimizing major costs.

The current ADOT&PF delivery tracking process requires staff effort at multiple points of the shipping process. It uses a computer-generated ticket carried by the truck driver to the dump point. The truck driver initially receives a cargo ticket while loading. A driver must maintain possession of the ticket at all times during cargo or load transportation, by state and federal regulations. Next, the load weight is recorded on the ticket at a plant weigh scale. At the dump point, the ticket is handed to a ticket taker, who records information on the ticket (such as the time and station of the dump point). A scale person updates this ticket. At the end delivery point, a ticket taker records the final data. Finally, an office person tallies the day’s tickets to create an account-payable item (payment) for the carrier or driver. At least four people handle this cargo tracking ticket: a truck driver, scale person, ticket taker, and an office person. These tickets must be physically stored for three years after project completion.

Technologies such as radio frequency identification (RFID) and GPS can be used to track the same data with far less human effort along the way. RFID utilizes technology to transfer data over radio waves sent from an electronic device, similar to the RFID dog collars that pet owners use to locate lost pets.

Below, field testing for RFID Technology in Construction project. A granite scale in Anchorage with stationary pole and RFID reader/antenna in the foreground (right). The PaveTag™ processing hardware is the gray box sitting on top of the concrete support, next to the antenna pole.
Collection of electronic data proved successful in this closed-loop road construction study. The tracked events were pickup and delivery of asphalt, with round-trip and time on station for loading; these key variables helped describe the initial intent of this study. RFID technology proved successful in tracking dump trucks from the loading plant to a paver location on a highway project. The average round-trip time was 1 hour and 4 minutes. The final report is under review by the funding agency.

**Feasibility of Electric Cars in Cold Regions (AUTC #RR08.05)**

**Jing Zhang (UAF)**

Electric vehicles—cars that run on electricity stored in batteries—have drawn increasing interest from federal agencies, the auto industry, and academia as a promising way to reduce fossil fuel reliance and eliminate pollutants. This project studied the feasibility of using electric vehicles as reliable transportation in cold regions.

Case studies were performed in several Alaska urban areas of different sizes, including Fairbanks and Barrow. Results suggested electric vehicles can be a viable option for certain users in subarctic and arctic communities. Researchers compiled energy use data on nine test vehicles both while driving and charging. Results were promising. For example, one test car, a Chevy Metro, used only 250 watt hours per mile.

The project found that many infrastructure factors can improve electric car efficiency. In colder areas such as Alaska and Canada, for example, existing public heater-block outlets in parking garages and at parking meters can also support electric car recharging, doubling their efficiency. These results offer DOTs and other transportation planners a “starting place” for estimating potential costs and necessary infrastructure adaptations, if electric vehicle use, on an agency level or a public level, increases in cold regions.

**Unstable Slope Management Program: Background Research and Program Inception (AUTC #RR08.10)**

**Margaret Darrow and Scott Huang (UAF)**

A growing factor in transportation asset management is foreseeing and addressing environmental threats to infrastructure, and one common threat to roadways in Alaska is slope instability.

This rapid response project gathered information on existing unstable slope management programs, with a focus on asset management practices in the U.S.A. and overseas. On the basis of this study, the research team summarized and recommended guidelines to develop an unstable slope management program for the ADOT&PF. This study gave transportation managers in Alaska tools to effectively mitigate a pervasive threat to the state’s roadways. The final report for this project is available on the AUTC web site (ine.uaf.edu/autc/final-reports, keyword “Darrow.”

Above, ADOT&PF staff work to protect a roadway in the aftermath of a rock slide. Margaret Darrow’s study on unstable slope management will give the agency the tools to identify and address such threats to our highways more proactively.
For transportation asset managers, it’s always good to anticipate a crisis long before it becomes one.

After the 2000 Census designated Fairbanks, Alaska, as an “urbanized area,” officials realized they would soon need to conform to the Federal Highway Administration’s (FHWA) requirement that such areas form a Metropolitan Planning Organization (MPO). MPOs manage travel planning and federal highway funding, and typically use a travel-demand model to assess current travel demands and to anticipate changes in an area’s transportation needs. Providing the new MPO with a suitable modeling system required assessing a variety of available information, such as air quality standards and traffic mapping, and integrating this information with new, more advanced software. This new system allows the MPO to forecast population, employment, travel, and environmental trends to anticipate problems and mitigate them before they become crises.

Performance Analysis of the Dowling Multi-Lane Roundabouts
(AUTC #RR08.08)
Ming Lee (UAF)

Although hardly new to the Lower-48 states, multi-lane roundabouts are relatively new to Alaska’s urban areas, but they are becoming an increasingly useful tool for shaping effective traffic operations.

Alaska’s first multi-lane roundabouts came to Anchorage’s Dowling Road/Seward Highway interchange in 2004. They serve as junctions for commuters accessing the Seward Highway, but as Anchorage’s traffic grows, the Dowling roundabouts are becoming more congested. To date, the roundabouts are operating at or near capacity, with longer lines at their entrances during peak traffic hours.

This research project examined the performance of multi-lane roundabouts and how drivers use them. Analysis showed that unbalanced flow patterns caused high circulating flow in front of one roundabout, leading to longer lines. This high circulating flow has resulted in lower capacity and longer delays. Researchers also found that accident rates and pedestrian dangers have increased in the past two years. Modeled traffic flow patterns for several possible alternatives suggested that reducing the eastbound flow rate (think of it as “upstream” of the roundabout) by 70% of the original flow could result in an acceptable level of delay and line length at the eastbound approach to the west roundabout.

A study like this not only helps planning engineering in Anchorage, but also gives agencies statewide better ideas about how to design future multi-lane roundabouts in ways that will provide safe and efficient travel. To learn more about this project, see the feature story in AUTC newsletter Volume 4, Number 1 on our web site.

NCHRP Report 572 noted that there was a lack of data from capacity-saturated multilane roundabouts in the US for performance analysis. Ming Lee’s study offers much-needed data for traffic engineers who study multi-lane roundabout performance in the US. Lee’s work provides an opportunity to actually see how performance measurements predicted by software applications compare to actual measurements in the field. Project results can also assist the Alaska Department of Transportation and Public Facilities in determining whether, where and how to construct additional multi-lane roundabouts.
Structural integrity remains a key area of AUTC’s current project portfolio.

With multiple ongoing programs in this area, AUTC’s research teams are partnering with other researchers—in North Carolina, Montana, and Washington—to address an array of structural integrity issues that impact infrastructure at the core of our nation’s transportation system. As a national leader in cold region transportation research, AUTC addresses this topic through a diverse project portfolio.

While some projects deal with seismic threats to bridges and others look at mitigating corrosion within reinforced concrete structures, all seek innovation and insight to address current challenges to transportation safety and security in the cold weather regions of the U.S.A. and beyond.

Many projects deal with emerging or unique structural integrity issues, as AUTC’s researchers have moved into project areas with international and maritime implications. For example, Robert Perkins’ work on wood preservatives used to protect harbor and docking facilities and Andrew Metzger’s research on pile-guided float structures yield important lessons for maritime transportation engineers. Similarly, Zhaohui Yang’s collaboration with Professor Yulin Yang, from China’s University of Science and Technology, Beijing, is helping both nations better understand how liquefaction instability impacts those vital bridge structures key to commercial transportation needs.

New Structural Integrity Projects

**Overheight Vehicle Collision Protection and Detection System for Cold Region Highway Bridges (AUTC #510024)**

Pizhong Qiao (WSU) and J. Leroy Hulsey (UAF)

Highway bridge safety is a concern nationwide, and of particular concern in northern states like Alaska and Washington, where overheight trucks damage the bottom corner or edges of girders. Researchers estimate that nearly one-third of the nation’s 600,000 highway bridges are currently in need of repair or replacements; applications for innovative bridge concepts and construction methods are vital to traffic safety and cost-effective maintenance. Because of this pressing issue, researchers are addressing a growing need for overheight impact protection and detection systems.

This collaborative research team, led by Dr. Pizhong Qiao of Washington State University and J. Leroy Hulsey of the University of Alaska Fairbanks, will examine novel use of high-energy-absorbing materials and smart sensors in cold regions to help protect against costly and unpredictable bridge damage.

Above: From the top, Huajie Wen, a Ph.D. student in the Department of Civil and Environmental Engineering at WSU, performs a Vickers Hardness test on an aged concrete sample, which appears in the next (counterclockwise) picture. To learn more about this project, read about the “Accelerated Degradation and Durability of Concrete in Cold Climates” project (AUTC #10029). Next, using his knowledge of ropes, structures, construction, electronics, instrumentation, and the marine environment, Andrew Metzger investigates a tricky strain gauge placement at the Seattle Ferry Terminal as part of the “Response of Pile-Guided Floats Subjected to Dynamic Loading” project.
Qiao and Hulsey are developing a system using lightweight and high-energy-absorbing honeycomb sandwich materials. The team will integrate the system with smart impact sensors for overheight impact detection and remote sensing to protect bridge girders from localized damage in cold regions.

The overheight project will address AUTC’s goals of transportation safety, security, and cold region innovation by exploring this novel use of advanced materials. Researchers are developing integrated remote detection and monitoring technology for use in difficult-to-access areas during cold weather. The team is also improving rapid construction and installation techniques by using lightweight honeycomb sandwich materials and modular units in cold climates. They are enhancing safety and security through early warning, online remote monitoring, load-rerouting, and impact damage prevention. The project is also integrating the collective knowledge of counterparts at UAF, WSU, Washington State Department of Transportation (WSDOT), ADOT&PF, the Ohio Department of Transportation, and the Federal Highway Administration (FHWA).

Structural Health Monitoring and Condition Assessment of the Klehini River Bridge (AUTC #510015)

Yongtao Dong, J. Leroy Hulsey (UAF), and He Liu (UAA)

Bridge safety and performance are national transportation priorities, and remain important challenges for ADOT&PF as well. New research on innovative structural health monitoring (SHM) technologies currently underway at UAF is helping address these challenges.

This research will focus on SHM protocol development for bridges in cold, remote regions. The project will improve the maintenance and repair of critical bridge structures, potentially extending their service life.

Through remote monitoring and on-site evaluations, Dong, Hulsey and their research team are examining the Klehini River Bridge, near Haines, Alaska, a damaged structure that the state wants to monitor closely. The team is developing SHM instrumentation and protocol for use on this bridge, with an eye toward extending this approach to bridges throughout Alaska. This SHM system will use a variety of sensors to measure and monitor structural and environmental conditions, providing the information necessary to continuously evaluate the safe performance of the Klehini River Bridge.

The system will monitor the behavior of defects or irregularities, collecting and relaying data on the bridge’s structural integrity and safety. The data will provide reliable information to improve decision-making about timely maintenance, repair, and closure needs.

Improving safety performance by providing more reliable information quickly on the structural health of any monitored bridge, the system will provide a new safety and management tool along with monitoring capabilities that complement traditional bridge inspection methods.

More effective bridge SHM systems can:
• Provide structural response data and enable the development of better decision-making tools; Conform and augment visual assessment, improve inspection credibility and subsequent rating;

Below: Full-scale testing of steel bridge pier, part of research performed by Mervyn Kowalsky (NCSU) and Andrew Metzger (UAF). Inset: close-up of instrumented bridge pier shows buckling of steel column wall within marker grid.
• Assist transportation asset management efforts in assessing long-term bridge performance;
• Optimize inspection schedules, maintenance schedules and dollars; and
• Increase structure reliability.

This structural health management system will help improve the structural conditions of certain Alaska bridges that are both regionally and nationally critical. For example, bridges such as those on the Dalton and Richardson highways support commercial traffic on the supply routes from North Slope oil and gas resources to Interior and Southcentral Alaska, and from there to continental markets.

Identification and Laboratory Assessment of Best Practices to Protect DOT Equipment from the Corrosive Effect of Chemical Deicers (AUTC #510000)
Xianming Shi, Montana State University-Bozeman (MSU) and Billy Connor (UAF)

Reinforced concrete is used in a wide spectrum of transportation infrastructure, but may suffer significantly from unrecognized corrosion in cold-weather regions. Addressing AUTC’s mission of maintaining cold-region transportation systems, AUTC Director Billy Connor is working with Xianming Shi, director of the TWI Corrosion and Sustainable Infrastructure Lab at MSU, on developing a reliable, cost-effective corrosion monitoring system for existing reinforced concrete (RC) transportation structures. The resulting technology will provide a lower cost system for existing DOT RC structures in aggressive service environments and offer higher-quality carriageway condition information. This technology will also detect corrosion initiation and propagation in RC structures at the earliest possible time, enabling condition-based maintenance strategies.

Connor and Shi hope to reach four specific objectives in their research of RC structures: (1) to improve and validate the corrosion sensor prototype for concrete corrosion monitoring systems; (2) develop algorithms for quality control and sensor data interpretation; (3) make viable implementation recommendations for corrosion monitoring systems and existing DOT inventory of RC bridges; and (4) deliver a deployable prototype corrosion sensing system for DOTs to continue field evaluations.

Minimizing premature rehabilitation or failure of highway bridges through appropriate maintenance and rehabilitation strategies can generate substantial cost savings for DOTs across the nation.

The project should increase reliability and remote-sensing capability for condition assessment and service life prognosis of RC structures, enabling assessment of life cycle performance for corrosion-affected RC structures. Given its potential to minimize the corrosion impact on the durability, serviceability, reliability, safety, and aesthetics of DOT RC structures, the payoff of this research is substantial.

Strain Limits for Concrete Filled Steel Tubes in AASHTO Seismic Provisions (AUTC # 510001)
Mervyn J. Kowalsky, North Carolina State University (NCSU) and Billy Connor (UAF)

Steel tubing is a key infrastructure component, and the integrity of concrete-filled steel tubing is a growing topic of concern for Alaska’s transportation engineers. The state’s transportation infrastructure uses concrete-filled steel tubing because of its strength and simple construction. However, because past research on concrete-filled tubes has dealt with tubes on a small scale and tubes without internal reinforcement, a number of important questions remain unanswered about how a particular application process will be used in Alaska.

Led by Mervyn J. Kowalsky and James Nau (NCSU) this project addresses several problems specific to Alaska’s climate: (1) the impact of reinforcing steel on the behavior of the pile column; (2) accuracy of analysis methods for predicting the force-deformation response of the pile column system; (3) impact of the ratio of tube diameter to tube thickness (D/t ratio) upon the performance of the pile column at multiple limit states; and (4) the plastic hinge length for the below-ground hinge developed in the pile column.

Researchers are using a series of 10 large-scale tests on concrete-filled pile columns to examine these problems, and a finite element model capable of capturing all of the anticipated modes of failure, including local buckling of the steel tube, throughout the testing process. The NSU team is conducting two tests in their environmental chamber to capture the effects of low
temperatures (-40°C) on structural behavior and performance. Results will provide construction guidance in Alaska by contributing to a concise design manual appropriate for ADOT&PF use.

**Ongoing Structural Integrity Projects**

**Ductility of Welded Steel Columns (AUTC #410001)**  
**Mervyn J. Kowalsky (NCSU) and Andrew Metzger (UAF)**

According to the Alaska Earthquake Information Center, seismic activity occurs frequently throughout the state, particularly in the interior, south central, and coastal regions, where population centers and commercial activity are most abundant. Many bridges and the welded steel columns that support them are strained by these recurring seismic forces.

This research project, a joint effort between AUTC and NCSU, seeks ways of strengthening bridges by improving their ability to absorb energy. Researchers are looking at ways to improve ductility, the ability of a structure to deform repeatedly into the inelastic range without significant loss of strength or stiffness. The project is a continuation of ongoing work to investigate how bridge and marine structures are designed and to identify improved connection design approaches to produce ductility and energy-absorbing capacities needed for Alaska’s bridges.

In previous testing, researchers were able to identify both insufficient and improved construction methods. They proved, for instance, that several existing methods were inadequate, such as the current practice of fillet-welding the cap beam to the pile. On the other hand, they confirmed that a new method of using a plastic hinge-relocating concept was more successful. This new approach reduced the inelastic demands of the cap beam weld, and forced the inelastic action to occur in the pile itself, displacing energy that might otherwise degrade the structure.

Current research will optimize this new design to improve energy displacement capacity and ductility in bridge and marine structure design, as well as investigate additional connection designs proposed by ADOT&PF engineers. Researchers have conducted three seismic tests, and plan to complete follow-up tests in coming months. The research will result in a series of design recommendations to ensure that bridges withstand Alaska’s seismic activity levels. The team’s research will help improve the design and performance of steel bridges and marine structures containing similar connections. It may extend bridge service life, reduce maintenance costs, and improve safety as a result.

To learn more about this research, see AUTC newsletter Volume 4, Number 2, at our web site.

**Effect of Load History on Performance Limit States of Bridge Columns (AUTC #410002)**  
**Mervyn J. Kowalsky (NCSU), Utpal Dutta (UAA), and Andrew Metzger (UAF)**

Transportation engineers and bridge designers are concerned about Alaska’s past history of earthquakes and other seismic activity, and the unseen effects it may have upon today’s bridges and other concrete structures. Addressing this issue, a collaborative team will examine how current studies evaluate the amount of strain that can be put upon a structure before it breaks.

This project investigates the impact of seismic loading history on the design of reinforced concrete bridge columns typically used in Alaska. Strain limit states are used by researchers when calculating the amount of stress that can be put upon a structure like a concrete bridge column, or a steel reinforcement beam. However, structural engineers currently use concrete and steel strain limit states in seismic design that only have minimal experimental or theoretical basis. This team hopes to propose strain limit states that account for seismic loading histories specific to Alaska, and to relate these proposed strain limits to displacement limits used in testing designs for the state’s bridges.

The team will conduct a combination of both analytical and experimental studies. These tests will include both frame-type and fiber-based analysis using ground motions, and the results will guide the initial selection of
specimen design variables. Conducting this research will involve nine tests on full-scale circular bridge columns, which will be subjected to load histories with varying characteristics, but typical of those experienced in Alaska.

The research team will provide ADOT&PF engineers with tools to refine bridge designs, optimizing for regional seismicity and ensuring that bridges in Alaska remain safe in major earthquakes and serviceable in smaller earthquakes. This advancement, in turn, may improve the reliability of bridges, decrease maintenance costs, and improve safety. To date, researchers have designed and constructed six additional test units, and have begun refining fiber-based models as they work to predict accurate strain distributions in the test columns. They will soon begin seismic testing on the six test units, parametric studies, and test-data analysis.

Selecting Preservatives for Marine Structural Timbers in Herring Spawning Areas (AUTC #410037)
Robert A. Perkins (UAF)

Marine harbors and docking facilities are a central piece of Alaska’s commerce, trade, and tourism industries, and key travel conduits in vast regions of the state that lack connected inland roads. Alaska marine harbors use wood for many structures that come in contact with salt water, including piles, floats, and docks, because it is economical to buy and maintain.

However, wood immersed in salt water is prone to attack by marine borers—various types of marine invertebrates that can destroy a wood structure in only a few years. Only two wood preservatives are currently recommended for use in Alaska’s waters—ACZA (ammoniacal copper zinc arsenate) and creosote, both of which have side-effects.

ACZA is a water-based preservative that leaches copper, which is toxic to both marine invertebrates and other species, into the marine environment. Creosote, an oil-based preservative made from coal tar, leaches hydrocarbon chemicals into the water. While some research has been conducted on these chemicals, we still have more to learn. For example, some research indicates that copper leaching from ACZA is slight after a year or so, while creosote leaches PAH at a declining rate over time, but is still measurable after many years. Previous researchers have had difficulty narrowing their search to just these two preservatives because harbors are frequently contaminated with many other chemicals, so determining how the wood preservatives alone impact marine life over time is difficult.

Perkins will test the toxicity of marine structural materials to herring eggs under a variety of conditions common in Alaska marine waters, focusing on Southeast Alaska. The study will also compare the durability of creosote-versus ACZA-treated marine timbers under comparable climatic and service conditions.

This project aims to provide relevant information to ADOT&PF to improve its selection of wood structural materials in the marine environment, especially the selection of wood-preserving methods. Its results may help structural engineers and other marine specialists make better-informed choices about wood preservatives that are both economical and environmentally sound. Perkins has performed toxicity tests on thousands of herring eggs and larvae using creosote marine timbers; over the next year, he will examine chemistry data and take samples near existing creosote structures.

Shake Table Experiments of Bridge Foundations in Liquefied Soils: An International Collaboration (AUTC #410015)
Zhaohui “Joey” Yang (UAA)

Chinese and American engineers are no strangers to the lingering destruction caused by earthquakes. This project brings together expertise from both nations to examine how earthquake-associated liquefaction threatens bridge foundations.

Soil liquefaction occurs when stress, usually caused by an earthquake or shaking, causes soil to act more like a liquid, losing stiffness and strength. An outgrowth of another AUTC project, this research will benefit from collaboration with Professor Yulin Yang, an engineer at China’s University of Science and Technology, Beijing. Yang is interested in liquefaction-induced geotechnical engineering problems in cold regions and is willing to share the cost of two large-scale shake table tests, which makes it feasible to integrate physical testing with AUTC’s ongoing simulation project.

Liquefaction and associated ground failures have been common in major earthquakes across Alaska, causing extensive infrastructure damage. Lateral
spreading—subsurface soil shifts that often rip apart fixed infrastructure above ground—is particularly damaging if a non-liquefiable crust rides on top of liquefied soil during an earthquake. This project aims to examine liquefaction-induced ground failures and their consequences for highway bridge substructures, and also to validate the results of computer modeling.

A key area of interest is how frozen ground layers behave. The physical properties of a crust of frozen ground change drastically in winter. Stiffness and strength increases, while permeability decreases. The impact on a bridge foundation by a frozen ground crust resting on a liquefied soil layer and the loads generated during a winter earthquake are unknown.

The knowledge gained from this project will lead to improvements in seismic design of highway bridge foundations in Alaska and in other northern regions with seismic activity. The research aims to eventually reduce the tremendous costs and safety risks created by large-scale destruction of key infrastructure during an earthquake. The project also represents a fruitful partnership between two nations that are increasingly dependent upon infrastructure innovations to further their commercial, transportation, and domestic energy needs.

**The Response of Pile-Guided Floats Subjected to Dynamic Loading (AUTC Affiliate Project)**

**Andrew Metzger (UAF)**

Pile-guided floats are structures, such as piers or docks, that boats and other sea vessels attach themselves to so that a ship can move up and down as water levels vary. Pile-guided floats provide an alternative to stationary dock structures.

ADOT&PF is considering using floating piers at certain stops along the Alaska Marine Highway System (AMHS). A potential design calls for the floats to be held in place by guide-piles that allow vertical rise and fall during tidal changes. The floats also undergo other varying forces, such as wind-generated waves and the weight of cargo and people as ships load and unload at the dock. There is little design information available concerning how this dynamic loading will affect the floats.

This project is developing a rational basis for estimating the dynamic response of floating pile-guided structures. Researchers will develop a model for two different systems. Both models will include functions that represent wave action and vessel loading over time. At the project’s end, AMHS and ADOT&PF will have a validated model and a ready-to-implement tool capable of providing any engineer with the necessary insight into good design criteria for both floats and guide-piles.

**Frozen Soil Lateral Resistance for the Seismic Design of Highway Bridge Foundations (AUTC #510021)**

**Zhaohui “Joey” Yang (UAA)**

With recent seismic activity and earthquakes in Alaska and throughout the Pacific Rim, seismic design is becoming an increasingly important public safety concern for highway bridge designers. Hoping to generate knowledge that can improve the seismic design of highway bridges in Alaska, UAA researchers tested a fixity-depth approach and a lateral-resistance (p-y) approach in seismic bridge design.

Currently, ADOT&PF utilizes a soil lateral-resistance approach in the seismic design of bridge pile foundations. Knowledge about lateral resistance of frozen soils, particularly seasonally frozen soils at shallow depths, can help improve pile foundation design in cold regions. Researchers Joey Yang and Anthony Paris are conducting laboratory experiments to examine key mechanical parameters for the frozen soils used to construct the p-y curve for modeling frozen soils.

Although studies have been conducted on the mechanical properties of frozen soils, many of these were based on remolded, artificially frozen soil samples, which do not necessarily behave the same as soils in the field. Similarly, few stress-strain behavior studies have focused on small strains (rather than catastrophic failures), and few have made use of naturally frozen samples (as opposed to samples frozen in the lab).

Yang and Paris hope to fill this knowledge gap by providing key frozen soil parameters for typical Alaska soils. According to Yang and Paris, these soil parameters are necessary for predicting the formation and location of plastic hinges and internal loads in bridge pilings embedded in frozen soils during seismic loading. As they develop more information, this team will hold a workshop for bridge design engineers to discuss their findings and how to apply them in the seismic design of bridges.
As Pacific commerce and travel grow, docking structures become more important from both an economic and public safety standpoint—especially as new shipping lanes are created by melting trends in northern waters. Anybody riding a ferry wants it to dock safely—and for port managers, having passengers and goods in the water is never a good thing. This project aims to mitigate uncertainty and assumptions about load demands on ferry terminal structures, specifically ferry landing structures. The project will provide information needed to safely and efficiently design ferry facilities while improving structural design criteria and procedures.

For Alaska Marine Highway System (AMHS) facilities, loads imposed on dolphin structures and mooring lines are of most concern. Marine facilities that rise above the water but are not connected to shore, Dolphin structures are used to extend piers, serve as ship cushions, or display information, such as directions or warning lights. Mooring lines are the (often large) rope ties that connect ships to docks. The loads placed upon these structures can determine if a ship docks successfully or not, and how well it will resist currents, waves, and other forces that might damage it or send it adrift.

Due to a lack of information about the magnitude of these loads or how they may be determined, AMHS engineers are forced to make design assumptions. The Washington State Ferry System (WSFS) also confronts these uncertainties, specifically in the design of wing wall structures that accept vessels during loading/unloading of passengers and vehicles. Wing walls are wall structures that are linked to larger-sized walls or structures next to them. While the structures used by AMHS and WSFS have fundamental differences, the metrics needed to determine appropriate design criteria are the same, and the instruments used to monitor these facilities are also similar.

These similarities present an opportunity for a cost-sharing project in which ADOT&PF and Washington State DOT are able to leverage research funding and benefit from a much more comprehensive project than either might be able to support individually. The partnership makes sense, as both states operate ferry systems linking traffic between Alaska, British Columbia, and Washington.

To achieve its goals, the project team will acquire a robust statistical sample of the metrics needed to define the design criteria. The data will be gathered by monitoring in-service facilities like the AMHS terminal at Auke Bay near Juneau, Alaska, and the WSF Seattle terminal in Washington. So far, the team has completed fieldwork in Auke Bay and Seattle, and has presented portions of its research at the 2011 Coastal Engineering Practice Conference.

For more information about this project, see the feature story in our newsletter (Volume 5, Number 1) posted on the AUTC website.
**Smart FRP Composite Sandwich Bridge Decks in Cold Regions**
(AUTC #107018)

**Pizhong Qiao, Washington State University (WSU)**

What if every time a bridge on a lonely road got icy, it automatically notified engineers or maintenance crews to begin ice-control safety measures? What if a bridge could tell someone every time an overloaded truck hit the decking, or when the trusses under it began to weaken? This kind of structural self-monitoring is closer to becoming a possibility at the completion of this research project.

A partnership between WSU, UAF, and Kansas Structural Composites, Inc., this project made the first steps to develop, manufacture, test, and implement Smart Honeycomb Fiber-Reinforced Polymer (S-FRP) sandwich materials.

This technology integrates advanced composite materials with sensors and actuators, allowing a bridge to alert engineers to surface and structural problems as they occur. Researchers expect that the system can quicken engineers’ reaction time, reduce excessive maintenance costs, and prevent significant safety risks before they occur.

Researchers tested an S-FRP sandwich deck panel, evaluated several S-FRP sandwich beams in cold temperatures, and developed effective structural-health monitoring strategies. They developed dynamic tests for the deck panel technology with and without damage, and created structural-health monitoring strategies for cold temperature exposures.

This combined experimental, theoretical, and numerical approach supplied new data on new techniques for structural-health monitoring and damage identification of thick sandwich deck panels. Results showed that wireless communication technologies may allow the developed structural-health monitoring strategies to remotely monitor and assess the structural integrity of sandwich bridge decks in cold regions. For Alaska bridges—many of which are located in isolated, remote areas with extreme weather—this innovation is a major step forward in terms of cost-effective maintenance and public safety preservation.

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**Seismic Performance of Bridge Foundations in Liquefiable Soils**
(AUTC #309010)

**Zhaohui “Joey” Yang (UAA)**

What physically happens to a bridge foundation during an earthquake? And what if the bridge foundation sits on a frozen crust of ground resting upon a layer of liquefiable soil, which behaves as a liquid during an earthquake? How can engineers make bridges strong enough to withstand these natural forces? Serious safety questions like these are unique to arctic areas such as Alaska, but no seismic analysis guidelines exist to explain how frozen-ground crust affects bridge foundations at a liquefiable site.

Addressing this knowledge gap, this project offered the first explanation of how bridge foundations withstand stress loads imposed on them by a frozen crust disturbed by liquefaction and lateral spreading. Study results are improving how engineers design arctic highway bridge foundations in areas threatened by seismic activity. Better seismic performance of Alaska’s bridges will increase transportation safety and reduce maintenance and reconstruction costs following a seismic event.

Researchers began this work by constructing a sophisticated model capable of simulating soil liquefaction and testing it. They used the model to simulate how a typical Alaska bridge pile foundation—one embedded in liquefiable soils under a frozen or unfrozen crust layer—would respond to seismic activity. Preliminary results showed that bridge pile was very sensitive to crust conditions. When the crust froze, for example the bridge pile’s internal forces changed by roughly 50%, demonstrating a greater need for further research into this phenomenon.

Because simply relying upon numerical simulations seemed insufficient for this work, researchers wanted to supplement it with an experimental component. Interestingly, this experimental component involved large-scale shake-table experiments conducted in collaboration with counterparts at China’s University of Science and Technology, Beijing. Test data, including soil responses and pile internal forces, were used to validate the computer simulation results.
The final outcome has given researchers a new understanding of how bridge foundations respond under such unusual stress, and how engineers can test future structures when they design future bridges.

**Bridge Structural Health Monitoring and Deterioration Detection: Synthesis of Knowledge and Technology (AUTC #309036)**

Yongtao Dong (UAF) and He Liu (UAA)

Many U.S. bridges were built during the 1960’s, so evaluating their structural conditions under today’s traffic loads and safety expectations is important, but difficult. This project is developing a practical program for structural health monitoring (SHM) of Alaska’s bridges. Researchers are conducting a literature review to summarize the current SHM knowledge and technology. They are also surveying ADOT&PF staff to determine which technologies are currently in use, to recommend techniques to implement in a successful SHM for Alaska.

**Completed Structural Integrity Projects**

**Alaska Bridge Bent Pushover Software, Including Concrete Confinement (AUTC #107013)**

Michael Scott (Oregon State University)

The American Association of State Highway and Transportation Officials is developing new recommendations for bridge designs that can better withstand earthquakes. These new guidelines use pushover analysis, a technique where a computer model of a structure is subjected to increasing lateral loading until its components fail. Pushover analysis is an effective way to highlight any weakness in a bridge’s performance under earthquake conditions. However no single, easy-to-use program has been available to design engineers. No programs have focused on the bridge bent design (sometimes called a pier design) most commonly used in Alaska, where steel shells encase reinforced concrete columns to improve seismic performance. This project developed software customized for pushover analysis of Alaska-style bridge bents.

**Creosote-Treated Timber in the Alaska Marine Environment (AUTC #RR08.14)**

Robert A. Perkins (UAF)

ADOT&PF is responsible for many structures that incorporate wood pilings and other timber in Alaska waters. Most are treated with preservatives to inhibit marine borers that will quickly destroy unprotected wood. While creosote is generally the most economical and frequently used preservative, it contains many toxic chemicals, and there are growing restrictions on its use.

To develop updated recommendations for preserving structures, this project reviewed current science and regulations on creosote use in marine waters.

Even with best management practices, hydrocarbons from new creosote timber leach into marine environments, but their effects can be mitigated. For example, creosote behavior tests verified that pollutants from marine piles in the water column became negligible after the first few weeks. Researchers found that with several factors—timber treated to best practices, non-anoxic sediments, non-stagnant waters, and no previous contamination—creosote marine timbers were unlikely to pose significant long-term environmental effects. Further testing indicated that effects were confined to a region close to the structures. These findings greatly helped transportation engineers and decision makers better understand the benefits and limitations of a key structural preservative. The project final report is available online at ine.uaf.edu/autc/files/2011/08/RR08_14_Creosote.pdf.
Evaluating the Overheight Detection System at the Eklutna River/Glenn Highway Bridge (AUTC #RR08.09)
Ming Lee (UAF)

One of Alaska’s most important transportation assets is its bridges. Unfortunately, overheight trucks frequently collide with bridge structures, causing damage and increasing maintenance costs.

The Eklutna River/Glenn Highway bridge has sustained repeated impacts from overheight trucks. ADOT&PF recently installed an overheight vehicle warning system, which uses laser detectors, alarms, and message boards to warn truckers that their rigs are too tall. Since its 2006 installation, the system has completely eliminated collisions from overheight trucks, but its alarms have also never been triggered. So researchers now wonder if the mere presence of the equipment is enough to deter drivers from gambling with a potentially overheight vehicle? Could it save costs at other bridges to only install early warning systems instead of the entire gamut of functional equipment?

Project researchers fitted the system with a camera and a datalogger to record any events that triggered the warning system. Project results will help ADOT&PF determine if and how well this system is functioning, and whether similar systems installed at other bridges would be cost-effective.

Seismic Design of Deep Bridge Pier Foundations in Frozen Ground (AUTC #107033)
Sri Sritharan (Iowa State University)

Structural integrity under extreme loads, particularly in bridges, often depends upon how foundations are constructed. This project developed design methods for drilled shaft foundations that are customized for bridges supported by Alaska soils and subjected to extreme seasonal temperatures.

Researchers tested how reinforcing steel, concrete, and soil all behave differently under warm and cold conditions. They demonstrated how cold temperatures impact the behavior of reinforced concrete and, most importantly, the behavior of the soil-foundation-structure interaction. The team established procedures to perform material tests at cold temperatures. They discovered that temperature effects on steel reinforcement caused different behaviors from what previous research described for comparable steel.

Researchers also discovered the inadequacy of the existing methods proposed for seismic design of drilled shafts. They developed a more rational design methodology for drilled shafts in cohesive soil. Project results included a review of the state-of-the-art on seismic design of drilled shafts. These findings were used to establish a new design methodology tailored to seismic regions subjected to seasonal freezing, especially relevant to Alaska bridge designers.

Iowa State University demonstrated how cold temperatures impact the behavior of reinforced concrete and—most importantly—how the soils, the foundation, and the structure interact. Their findings contributed to a new design methodology tailored to seismic regions where seasonal freezing is common.
From dust-control measures to pavement preservation, surface application research is widely applied across numerous transportation mediums.

For example, David Barnes’ diverse work on dust-reduction palliatives has entailed research on unpaved roads in both urban and rural settings, and also addresses rural runways. For local stakeholders, this work provides measures to improve air quality, enhance transportation services, and boost their quality of life.

Still central to all of AUTC’s work as a national leader in cold region transportation research, however, is the concern of preserving construction materials in some of the world’s most unforgiving climates. Jenny Liu’s numerous projects on pavement preservation, for instance, address a range of issues tied to more durable, long-lasting, and cost-efficient materials for cold-region transportation surfaces.

For road and repair managers as well as engineers, this area of research is helping create more durable, less expensive, and longer lasting roads, bridges, and runways.

**New Surface Applications Projects**

**Understanding and Mitigating Effects of Chloride Deicer Exposure on Concrete (AUTC #510003)**

Xianming Shi (Montana State University-Bozeman) and Billy Connor (UAF)

Relying on chloride deicers, The U.S.A. spends approximately $2.3 billion annually to keep highways free of snow and ice. Exacerbating these expenses, the associated corrosion and environmental impacts add at least $5 billion. Looking at the effects of chloride deicer exposure on concrete, UAF AUTC director Billy Connor teamed up with Xianming Shi, director of the WTI Corrosion & Sustainable Infrastructure Lab at Montana State University-Bozeman (MSU), to lead a project that will minimize the costs of concrete damage and repair caused by deicer exposure.

This work will link laboratory testing of deicer effects on concrete with actual field exposure and allow DOTs to predict and reduce levels of chloride-related infrastructure damage. Researchers will work with both ADOT&PF and the Oregon Department of Transportation (ODOT) to investigate how each entity uses chloride deicers, the effects of that use, and the best ways to mitigate those effects in Oregon and Alaska. Using

Above, Laboratory set-up for simple performance testing of warm mix asphalt samples, part of Juanyu Liu’s pavement preservation program. In the foreground is a pavement sample that has been subjected to dynamic modulus testing.

Opposite, graduate student Natalia Kulchitskaya reviews data collected as part of this series of tests.
surveys, laboratory research, and field investigations, researchers will advance the relevant knowledge base related to deicer/concrete interactions to improve long-range infrastructure repair and replacement planning and develop mitigation strategies.

The team will offer guidance on how to best mitigate negative impacts of chloride deicers on concrete and enhance concrete durability and sustainability, which will boost infrastructure service life. This guidance can translate into substantial cost savings and environmental benefits while enhancing the reliability of the transportation infrastructure in cold-climate states.

**Develop Locally Sourced Salt Brine Additive for Anti-icing (AUTC #510006)**

Xianming Shi (MSU) and Juanyu “Jenny” Liu (UAF)

A research partnership between Montana and Alaska may bring considerable cost savings and safety improvements to Alaska's roads. Xianming Shi from MSU’s Western Transportation Institute (WTI) and Jenny Liu (AUTC) partnered to investigate whether local agricultural or distillery by-products can replace high-cost proprietary products that enhance anti-icing operations on Alaska roads.

Using a literature review, agency surveys, laboratory investigation, and follow-up field tests, researchers will develop and test locally sourced salt brine additives to determine whether they are suitable for anti-icing during winter maintenance in Alaska. This determination will help improve traveler and commercial safety and mobility while reducing corrosion and environmental impacts. The project will also give ADOT&PF more options for their snow and ice control while promoting sustainable, cost-effective winter road service. Moreover, in a time of widespread fiscal belt-tightening, this work allows state winter road maintenance budgets to cover more roads or more frequent anti-icing activities.

Beyond reducing Alaska's winter road maintenance costs, this research may also boost local economic growth by helping build a new market for glycerol—the principal by-product of biodiesel production. The bio-based local materials may also be useful for dust suppression and soil stabilization, adding to the potential benefits of this research.

**Economic Impact of Fines in Unbound Pavement Layers (AUTC# 510012)**

Juanyu “Jenny” Liu (UAF)

In Alaska’s spring months, excess water thawing underneath road pavement weakens roads and other transportation infrastructure, causing great expense and inconvenience for private and commercial motorists. This project examines how the fines (P<sub>200</sub>) in base materials affect frost susceptibility and support for vehicular loads during the spring thaw. Realizing the variation in critical excess fines content, Liu's team is also evaluating the financial impact of using allowable fines in the unbound pavement layers and will identify critical excess fines contents (that is, threshold fines content) allowed in the typical Alaska unbound base courses.

Expanding upon a recent UAF study, Liu is investigating the impact of fines content on resilient modulus reduction of base courses during thawing when the base course material is frozen under different temperature gradients and with limited water access. To do this, Liu and her team will simulate a closed water system by collecting soil specimens with different initial moisture and fines contents and freezing them in the frost heave cell with no access to water. Her team will then test resilient moduli of soil specimens under different subfreezing temperatures and after a
freeze-thaw cycle under both undrained and drained conditions. The testing will provide recommendations to determine the situations when ADOT&PF can relax stabilized base policies and when builders might reduce costs by allowing excess fines in the base layers for highway construction.

**Impact of Embedded Carbon Fiber Heating Panel on the Structural/ Mechanical Performance of Roadway Pavement (AUTC #510022)**

*Zhaohui “Joey” Yang (UAA)*

Cold regions suffer serious transportation system safety problems in the winter months. Southcentral Alaska—Anchorage in particular—is susceptible to a large number of icing events due to frequent freeze/thaw cycles in the winter season. This creates ice on sidewalks, pavement, and bridge decks that poses a significant safety risk to travelers of all kinds. Black ice, a thin shiny layer of ice with a slick surface, is of particular concern because it is nearly invisible to drivers, pilots, and pedestrians.

This collaborative research project is finding more cost-effective and sustainable deicing solutions to benefit a wide variety of transportation infrastructure users. UAA is partnering with the University of Houston to test a technology based on carbon fiber tape (CFT) in hopes of offering an environmentally-friendly, anti-corrosive, cost-effective deicing strategy that can improve transportation safety. This new deicing technology is potentially applicable to bridge decks, ice-susceptible road sections, airport runways, street crossings, and high-use urban sidewalks in cold regions.

A series of deicing and anti-icing experiments showed considerable cost reduction compared to other electrical resistance heating type technologies. Researchers found that the new technology demonstrates excellent deicing capability and shows great potential for application in the transportation industry.

Continued lab and field work will address several other issues including: heating panel impact on pavement/bridge deck structural integrity, effects of coupled thermal and freeze-thaw cycling on pavement mechanical properties, and the impact of an electromagnetic field on steel reinforcement corrosion in bridge/pavement decks. Findings from the sidewalk test section and laboratory tests will be incorporated into a sidewalk constructed on the UAA campus to evaluate the field performance of this new technology.

**Field-Evaluating Crack Sealing of Asphalt Concrete Pavements in Alaska (AUTC #510005)**

*Juanyu “Jenny” Liu (UAF)*

For years, routine sealing of cracks in asphalt concrete (AC) has cost the state of Alaska millions of dollars annually. Without new technology to eliminate the cracking, sealing and minor patching will continue to be a major expense for ADOT&PF. This project aims to find possible cost-effective improvements to existing crack-sealing methods.

Some research suggests it may be possible to ignore cracks entirely, under certain circumstances, with no negative effects. Hoping to devise more economically sound approaches to road repair, Liu is working with field researchers to determine where sealing is necessary and where it is not. The team will also determine the effectiveness of several different repair treatments for major transverse cracks.

Ultimately, the team will provide recommendations for saving a significant portion of the maintenance and operations funds now spent on crack sealing and minor patching of major transverse cracks. The research will provide ADOT&PF with research findings that the agency can easily integrate into its Departmental Guidelines for Pavement Preservation Treatments in Alaska.

**Longevity Analysis of Dust Control Palliatives (AUTC #510019)**

*David L. Barnes (UAF)*

Rural Alaska’s residents and local stakeholders are looking for cost-effective methods to reduce road and airfield dust. However, they remain concerned about the longevity and performance of different types of dust-control products used in unpaved regional transportation systems.

Headed by researcher David Barnes of the Water & Environmental Research Center (WERC) at UAF, this project uses new instruments and methods to conduct field-based measurements of dust-control palliative
Barnes’ project is supported by Midwest Industrial Supply Inc., manufacturer of EK35—one of two palliatives tested in the study. The other palliative, Durosoil, is manufactured by Soilworks® LLC. ADOT&PF applied these products to several airfields and roads in Alaska, and researchers are monitoring their effectiveness over time.

This study will help community leaders as well as agencies like ADOT&PF and the Alaska Department of Environmental Conservation (ADEC) better understand the longevity, performance, and potential cost-effectiveness of these products. Barnes’ team will use laboratory-based testing to better understand why some applications of the same product do not perform as well as others. If this testing correlates with field-based measurements, researchers may be able to predict the possible performance of a palliative prior to its application, allowing for adjustments in application rates if necessary, as well as more cost-effective implementation. In addition, by enhancing knowledge about the performance of these two palliatives, this project may enable better-informed quality of life decisions in rural areas.

Rapid Determination of Unsaturated Moisture Diffusivity for Soils during Frost Heave (AUTC #510017)
Xiong Zhang, Gang Cheng (UAF), and Rifat Bulut, Oklahoma State University (OSU)

Frost heave and annual thaw cycles pose great risks to transportation infrastructure, raising maintenance costs and undermining transportation service and safety. Unsaturated soil mechanics and unsaturated water transmission are key factors in understanding frost heave and thaw weakening problems typical in northern regions. While significant progress has been made in unsaturated soil mechanics in the past two decades, the field has yet to apply practical solutions to these problems.

This new research partnership, funded in part by the ADOT&PF and by the Oklahoma Transportation Center (OkTC), is developing a unified, simple and practical testing method to measure unsaturated soil moisture diffusivity coefficients; both the drying and wetting diffusivity coefficients are key pieces of soil mechanics research. The new method significantly reduces the time and effort required to measure the drying and wetting unsaturated soil moisture parameters by exposing the cylindrical soil specimens to drying and wetting cycles.

The project aims to implement the most recent advances made in unsaturated soil mechanics to investigate the frost heave problem, utilizing equipment development, laboratory testing, model development, and numerical simulation. Greater understanding of unsaturated soil mechanics may greatly reduce the operations and maintenance budget for ADOT&PF by addressing frost heave and weakening problems and offering more efficient prevention and maintenance procedures.

Ongoing Surface Application Projects

Accelerated Degradation and Durability of Concrete in Cold Climates (AUTC #410029)
Pizhong Qiao (WSU) and Juanyu “Jenny” Liu (UAF)

Cold weather climates degrade concrete, causing fractures and erosion. For engineers, this means more costly maintenance and risks to public safety caused by hazardous roadways and other surfaces. In Alaska and other cold regions, concrete degradation, specifically the break down of aggregate materials within the concrete mix, is the central concern.

Aggregate materials are a major component of concrete. Typically, cement mix is blended with filler like rocks and stones of various sizes to make it more durable and cost-effective as a surface application. Cement mix is the most expensive component of concrete, so the optimal amount of aggregate makes a less expensive and more durable mix. For that reason, typical cement mixes contain as much as 60% to 80% aggregate to enhance longevity and cut costs. Extensive studies have been conducted on the design of concrete mix and the composition of cement materials to improve performance and durability.
A collaboration between UAF and WSU researchers, this project is looking for ways to improve how concrete aggregate is tested in cold environments. The team will apply a promising testing protocol for long term concrete performance. Using damage mechanics modeling, they will also evaluate how damage accumulates in concrete and how concrete remains durable at cold temperatures. Their central aim in this study is to develop specifications on performance criteria and service life predictions, and to provide guidelines for ADOT&PF engineers who evaluate concrete performance and safety. These outcomes will improve concrete construction and transportation infrastructure maintenance in cold climates.

**Testing and Screening Surfacing Materials for Alaska’s Yukon River Bridge (AUTC #410008)**

**J. Leroy Hulsey (UAF)**

The Yukon River Bridge is a formidable and somewhat iconic structure in Alaska. The story of its construction efforts in the 1970’s has become part of Alaska’s state heritage. Also known as the E.L. Patton Bridge, it carries the two-lane Dalton Highway and the trans-Alaska oil pipeline across the Yukon River at a 6% grade. It is 30 feet wide, more than 2200 feet long, and has 6 spans. It was designed to withstand -60°F temperatures, the force of huge ice loads on the river, heavy trucks hauling supplies to the oil fields, the oil pipeline, and, in the future, a gas line.

Over 30 years, the timber decking has been replaced several times—in 1981, 1992, 1999, and 2007. The trees that produced the original decking were massive old-growth firs, strong and close-grained. Subsequent decking has come from younger trees, which produce softer wood. As timber quality has decreased, time between replacements has also decreased, and material prices have increased.

To learn more about this project, see AUTC newsletter Number 1, Volume 1.

**Using the Micro-Deval Test to Assess Alaska Aggregates (AUTC #410009)**

**Juanyu “Jenny” Liu (UAF)**

Choosing the right material is half the battle in building Alaska’s roads. The extreme conditions typical to cold regions require a durable aggregate that is both abrasion-resistant and freeze-thaw resistant. ADOT&PF wanted to know if its engineers are using the most effective and accurate methods available to select the right aggregate to build the state’s highways.

To evaluate surface abrasion and degradation values, Alaska currently uses a testing method known as “Method 313,” or the Washington Degradation Test. This project is examining an alternate method that may prove safer and less costly, if its results are replicable and correlate with field performance. One method, the Micro-Deval test, involves putting aggregate materials in a tumbling steel drum with water and steel balls to measure how they degrade. The test is relatively easy, safe, and less costly to perform than traditional testing methods. It is also suitable for smaller equipment, requires smaller sample quantities, and uses a simple procedure.

Liu’s team has completed and summarized their aggregate testing results, and will soon focus on additional aggregate testing methods, which use sand equivalents and a hydrometer.

**Characterization of Alaska Hot Mix Asphalt Mixtures with a Simple Performance Tester (AUTC #410020)**

**Juanyu “Jenny” Liu (UAF)**

To make pavement more durable—thus safer and more cost effective—engineers are striving to better understand the properties of hot mix asphalt (HMA). Road builders are expressing a growing need for mechanistic flexible pavement design and for more reliable design procedures; both require a more accurate understanding of different HMA properties.

This study is aiding this process by giving engineers a better idea of which HMA mixtures are more durable and more suitable to Alaska’s demanding climate. The research team is developing a catalog of

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Research must identify a material suitable for bridge decking that will last more than 15 years in Alaska’s harsh climate. This will mean future savings to the ADOT&PF in the millions of dollars by reducing necessary maintenance and extending surface service life.
dynamic modulus values for mixtures typically used in Alaska. Dynamic modulus values measure the ratio of stress to strain that a material can withstand. Researchers are also investigating the correlations between simple performance test results and HMA lab performance, to gain a full understanding of specific HMA properties. The results will give ADOT&PF engineers practical information about how Alaska HMA mixtures respond to the new test procedures, and how using these mixtures will affect current flexible-pavement design methods.

So far, the project has manufactured mixture specimens and coordinated testing activities through counterparts at the University of Tennessee to begin analyzing data. In the coming months, the team will continue to fabricate specimens, verify mixture design, and conduct further tests to conclude the project.

**Construction Dust Amelioration (AUTC #RR10.03)**

Robert A. Perkins (UAF)

Dust produced on seasonal road construction sites in Alaska is both a traffic safety and public health concern. Dust emanating from unpaved road surfaces during construction severely reduces visibility, impacting stopping sight distance for drivers. When the dust is stirred by wind or traffic, it also contributes to the local burden of small particulates that pollute air quality (also known as PM 2.5). This study is examining a variety of factors dealing with the use of dust-control palliatives. Experts believe applying a dust-control palliative like calcium chloride, Enviroclean, Durasoil, or EK35 to unpaved surfaces during road construction will solve the dust problem. This research is determining the type of palliative to use, and when, how often, and in what concentration it should be applied. The project is looking specifically at several factors, including the amount and size of the dust particles, the time the surface is to remain unpaved, the makeup of the unpaved road surface, local environmental conditions, and the palliative's cost and availability.

The project is especially valuable because measurement systems used in other states involve special equipment and/or certification of observers, neither of which may be practical in Alaska with its remote locations and short construction season.

**Performance of Dust Palliatives on Unpaved Roads in Rural Alaska (AUTC #410036)**

David L. Barnes (UAF)

One of several dust-reduction projects underway at AUTC, this project is assessing the longevity of different palliatives applied to rural Alaska roads over two summer seasons.

Researchers are collecting data using the UAF’s dust monitoring system (DUSTM). Created and assembled by Project PI Barnes and fellow researchers at the UAF Civil and Environmental Engineering Department, DUSTM is a portable dust monitoring device that can be attached to the rear of an ATV, and is compact enough to be transported in a small airplane. It measures the amount of airborne or loftable dust that is spread on a village street or unpaved roadway, and can calculate reductions or increases in dust over time. The research team is applying and monitoring palliatives in five different sections of Alaska roads: three in rural villages and two in the towns of North Pole and Point McKenzie.

This project is co-funded by AUTC and the Alaska Department of Environmental Conservation; ADEC seeks to compare associated dust concentrations measurements from DUSTM with those collected by their own stationary monitors. Correlation between the two data sources will determine how much of the measured fugitive dust is from a controllable emission source, and how much is from uncontrollable sources. Both for public health and cost-effectiveness considerations, researchers want to know how much fugitive dust must be suppressed to meet regulatory standards. Researchers will use this information to help local communities plan the use of dust-control palliatives.
**Application of a Nontraditional Soil Stabilization Technology: Lab Testing of Geofibers and Synthetic Fluid (AUTC #207117)**

**Billy Connor (UAF)**

Gravel in essentially nonexistent in Western Alaska. Whenever gravel is needed for infrastructure such as a road or a runway, it is imported at a cost exceeding $200/ per cubic yard. These costs can be dramatically reduced if local soils can be made usable in place of imported gravel.

This project, funded by ADOT&PF and AUTC, is investigating a new technique for using geofibers and a synthetic fluid to stabilize loose, sandy, and silty soils typical of western Alaska. Lab tests measured how well these new materials might improve poor foundation soils. Results showed that fibers can double or triple the strength of the soil. While the addition of synthetic fluids adds some strength, their primary function is to reduce moisture sensitivity of the fine-grained material. However, a two-part chemical additive has proven to increase the strength of sands, silts and clays at a lower cost than imported gravel. This project is the basis for a field application of these new materials; see below to learn more.

**Application of a Nontraditional Soil Stabilization Technology: Use of Geofibers and Synthetic Fluid in the Field (AUTC affiliated project)**

**Billy Connor (UAF)**

In partnership with the Federal Highway Administration (FHA), this project taps into AUTC's ongoing work with soil stabilization to develop applications that can help a range of transportation projects from roads to runways.

Funded by FHWA, this project utilizes AUTC's expertise to test a new soil stabilization technique. Building upon AUTC's ongoing laboratory-focused studies in soil stabilization, researchers performed a practical field test using geofibers and a synthetic fluid to stabilize very loose, sandy, and silty soils. These kinds of soils are common to many parts of Alaska where transportation infrastructure faces excessive maintenance and safety challenges. Researchers wanted to base soil testing and applications at a site in the Matanuska-Susitna Borough near Horseshoe Lake, Alaska. Researchers then collaborated with FHWA to gather data from this test site as well as other active projects, and identified new test sites in the state of Washington. They aim to devise methods of strengthening soils in these regions to prevent erosion and other infrastructure damage.

Researchers hope to apply this work to a variety of transportation infrastructure needs. Presenting engineers with soil preparation strategies that make use of locally available materials, the project will significantly reduce overall construction costs. This approach can be used for roads, highway embankments, unstable slope management, and remote airports and landing strips. In addition to providing engineers with a variety of applied research results, this project has provided valuable hands-on experience for two UAF undergraduate students—another unique benefit to AUTC's partnerships with federal and state counterparts.

**Attenuation of Herbicides in Subarctic Environments Across Alaska (AUTC #207110, Seward test site; AUTC #309026, Fairbanks test site)**

**David L. Barnes (UAF)**

These two projects demonstrate how partnership between AUTC and the U.S. Department of Agriculture is helping to create more cost-effective infrastructure protection for Alaska's railways.

The Alaska Railroad Corporation (ARRC) needs effective, low-cost ways to manage vegetation growth along rail lines. Because manually removing railway brush and vegetation is costly and relatively ineffective, researchers want to know how herbicides might be best used in vegetation removal efforts.

AUTC researchers, together with USDA’s Agricultural Research Service, are investigating the environmental fate, attenuation, and effectiveness of several herbicides currently being evaluated for use along Alaska’s transportation corridors. Questions addressed include: Once these herbicides are applied, how long does it take for them to enter the soil? Where do they go? How long does it take for them to dissipate?

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In an affiliated partnership with the Federal Highway Administration, AUTC is leveraging ongoing work with soil stabilization to develop and test applications that can help a range of transportation projects, from roads to runways.
Herbicides have been applied at one field site near Seward, Alaska, at the southern end of the ARRC rail line. Researchers are tracking these applications over two years through a series of soil and groundwater samples to obtain site-specific attenuation data. In Fairbanks, they are performing mass balance studies on the same herbicides using lysimeters installed at the Experimental Farm on the UAF campus. Results will yield a better understanding of the environmental fate of these herbicides in Alaska's maritime subarctic zone. These tests will provide information on how long the herbicides last, and how effective they may be in treating railway side brush and vegetation in Alaska and other cold regions.

**Alaska Hot Mix Asphalt Job Mix Formula Verification (AUTC #309024)**  
**Juanyu “Jenny” Liu (UAF)**

Some asphalt pavement does not last as long as it should, which means that every year, the state spends significant sums on repair and maintenance of Alaska’s paved roads. Since hot mix asphalt (HMA) is the major paving material used in Alaska, assuring its quality is critical for contractors and ADOT&PF. Ensuring that contractors out in the field are operating with the appropriate HMA is crucial. This project is assessing HMA quality assurance specifications and evaluating how well contractors meet the requirements of job mix formulas (JMFs).

In recent work, researchers field-tested a HMA as part of a rehabilitation and resurfacing project on the Parks Highway, south of Nenana, and at an Anchorage International Airport (AIA) paving project. HMA mixtures applied under four different scenarios were sampled from nine sub-lots in Nenana and four sub-lots in AIA. The mixtures included specimens mixed and compacted using JMF in the laboratory; loose mixtures collected from windrow, and either compacted in the field using a portable gyratory compactor or compacted in the laboratory; and samples retrieved from the field. Researchers obtained data from ADOT&PF and contractors at each phase of lab/design, production, and new construction. Data included general project information, details of the materials and JMF used in the construction, and all construction test data.

Researchers will investigate HMA performance to further verify the JMF and evaluate any impact of the construction process. The project recently completed ignition tests for all its materials and performance tests for materials collected from the AIA paving project.

Project results will help improve current mix design protocols, benefit the asphalt-paving process, and ensure the quality of HMA. Verification will enhance the long-term performance of HMA pavements and significantly reduce the state’s pavement maintenance and repair budget.

**Measuring the Effectiveness of Rural Dust Control Strategies (AUTC #107019)**  
**David L. Barnes (UAF)**

Extending AUTC's expertise in road dust reduction, David Barnes of UAF is conducting one of several studies to improve rural dust control. Dusty, unpaved roads and airports affect the quality of life for many villages in cold regions; roughly 60% of Alaska’s roads are unpaved. Alaska isn’t alone. Of America’s 4.2 million miles of roads, 1.7 million are unpaved. Dust reduces road visibility, causes respiratory ailments, and affects fruit and plant harvesting activities. In addition, loss of fine material reduces road surface quality, increasing maintenance costs as well as wear and tear on vehicles.

Everybody acknowledges the problem, but finding a solution is a contentious matter. Simply paving is often unworkable; costs are high, local materials are often unsuitable, and long-term maintenance may be unavailable. Possibilities for dust control abound, but which will fit best with the subsistence lifestyle practiced in rural areas, and what can the state’s thinly stretched budget afford?

To help address these questions, this project is developing a dust control research map that prioritizes critical areas. It is designing instrumentation and methodology to accurately monitor road dust production. These tools will be used to support ADOT&PF in field-testing various dust control

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Liu’s team field-tested rehabilitation and resurfacing techniques on the Parks Highway, south of Nenana, and at Anchorage international Airport.
Dusty, unpaved roads and airports affect the quality of life for many villages in cold regions; roughly 60% of Alaska’s roads are unpaved. Alaska isn’t alone. Of America’s 4.2 million miles of roads, 1.7 million are unpaved. Dust reduces road visibility, causes respiratory ailments, and affects fruit and plant harvesting activities.

measures in several locations. So far, researchers have qualitatively assessed dust control performance on unpaved runways, tested new instrumentation, and measured palliative performance with this prototype instrument at one rural road site.

**Alaska Specification for Palliative Applications on Unpaved Roads and Runways (AUTC #309015)**

David L. Barnes (UAF)

AUTC’s work on dust reduction is not limited to roadway surfaces. For the past seven years, ADOT&PF Northern Region has been applying different dust-control palliatives to rural airport runways. The only guidance in applying these palliatives has come from the manufacturers; typically this material is too vague for much practical use. Engineers are unable to determine whether these products are meeting their own standards or not.

This project, using UAF’s dust-monitoring (DUSTM) instrumentation, is collecting data and comparing the effectiveness of newly laid palliative and older palliative, applied one to three years earlier. From these results, researchers will develop a reasonable performance-based set of specifications that cover the application of dust-control palliatives to unpaved transportation surfaces. These specifications will make it possible for ADOT&PF to choose the best palliative for a community’s needs, and hold vendors accountable for the quality of their products. This project will improve public safety and enhance the effectiveness of this technology.

**Dust Palliative Performance Measurements on Nine Rural Airports (AUTC #MISC4)**

David L. Barnes (UAF)

In the summer of 2009, ADOT&PF began applying dust-control palliatives to nine rural airport runways across Alaska. AUTC researchers are monitoring these runways to assess the quality and durability of several palliatives. Measurements are taken with the UAF dust-monitoring device (DUSTM), a portable instrument that measures lofted dust as it rises from the rear tires of an all-terrain vehicle. Palliative performance will be assessed by comparing the measured fraction of lofted dust produced by the ATV on the treated section of the runway to the fraction produced on the untreated control section.

Researchers have taken measurements within 30 days of the first treatment on each runway and have followed up with another measurement each following year. Recommendations will help ADOT&PF select the most effective out of several products and plan the most efficient application schedule for Alaska’s many unpaved runways.

**A Study of Unstable Soil Slopes in Permafrost Areas: Alaska case studies used as a training tool (AUTC #309032R)**

Margaret Darrow and Scott Huang (UAF)

The failure mechanisms of unstable soil slopes in permafrost areas are not well understood. Analysis of these slopes requires consideration of soil temperatures and ice content, and their effects on soil strength, which is not part of typical slope stability analysis. These unstable slopes may
vary in depth, affecting only the active layer or having a more deep-seated nature. Additionally, the subsurface conditions may be a complex mixture of frozen and unfrozen areas, which affects the groundwater flow and overall slope stability. Whatever their configuration, these unstable slopes possess characteristics that are unique to permafrost regions.

Several unstable soil slopes in frozen ground exist along highways in Alaska's northern region. These areas of instability require ongoing maintenance and monitoring until possible mitigation strategies are developed.

This study is summarizing three key historic and/or ongoing unstable soil slopes in Alaska. Researchers are conducting on-site visits for each site and reviewing previous design and mitigation strategies to determine possible solutions for stabilizing each slope.

This information and analysis will be summarized in a training program for ADOT&PF engineers that categorizes typical unstable soil slopes in permafrost areas and suggests appropriate mitigation strategies.

**Automatic Electrical Deicing System using Emerging Carbon Nanofiber Paper: A Pilot Field Testing (AUTC #410014)**

**Zhao Hui Yang, UAA**

Carbon Nanofiber paper is composed in extremely tiny layers, similar to the way ordinary paper is made. This material may help address a growing public safety risk in Alaska and other cold regions. Snow and ice on pavement and bridge decks are a persistent problem, where black ice—a thin, nearly invisible, and dangerously slick layer of ice—often covers sections of coastal highways and bridge surfaces. A common cause of winter accidents, black ice is difficult for motorists to spot and makes it even tougher for them to stop or slow down. Commuters, travelers, and commercial drivers alike are affected by this problem.

Several types of deicing strategies have been used over the years, but many have unintended consequences for the environment and nearby structures. Salt, for example, is one of the most commonly used deicers because it is cheap and effective. Yet, while sprinkling salt on roadways and bridges is simple, it pollutes the environment and corrodes reinforcing steel bars in concrete, damaging bridges and other structures as well as vehicles. Other chemicals, like calcium chloride, magnesium chloride, and potassium acetate have been used, but these remain fairly expensive for public agencies.

Similarly, thermal anti-icing approaches, such as electric self-regulating sidewalks and roads, are both difficult and expensive to install and maintain. Alaska, as well as other cold regions, needs a safe solution to black ice that is both cost-effective and environmentally friendly—and one that will not corrode other structures.

Electrically-activated carbon nanofiber paper may offer a solution. This project developed and tested an innovative deicing technology based on this emerging nanomaterial. It is simple to install, as engineers simply lay carbon nanofiber paper underneath regular pavement. This quick and simple application minimizes interference in pavement and bridge deck construction, and it does not require changes in how the pavement is mixed or applied. If successful, this technology could lower operational costs compared to other deicing methods, as well as lowering maintenance costs by reducing corrosion damage to bridge structures. Moreover, as this method avoids the use of chemical deicers it may also reduce runoff pollution to local water bodies.

A multi-disciplinary team made up of electrical, mechanical, and civil engineers along with five full- and part-time students designed a deicing system that utilizes carbon nanofiber paper. They participated in a test installation on the UAA campus.

Now that the installation project is complete, this test site will be monitored over the longterm to collect information on how the material performs under realistic conditions. Future outcomes will include assessment of the system's reliability and cost-effectiveness, with an eye toward providing recommendations on using such systems in Alaska.

To learn more about this study, see the project page at: ine.uaf.edu/autc/projects/automatic-electrical-de-icing-system-using-emerging-carbon-nanofiber-paper-a-pilot-field-testing
When shifting rivers threaten important infrastructure, engineers are left with the delicate task of re-directing a river to save structures that cost millions, and sometimes billions to build. Together AUTC and ADOT&PF engineers have developed several types of strategies to prevent stream bank erosion.

Completed Surface Application Projects

**Investigating Methods for Maturing Concrete in Very Cold Weather (AUTC #107052)**
**Yongtao Dong (UAF)**

Concrete curing is a process used to strengthen concrete, and transportation engineers in Alaska's arctic climates rely on this to create durable road surfaces—extending the service life of vital transportation infrastructure.

This project developed and tested protocols to determine concrete curing strength during the construction process, so that road crews can build safely and quickly in very cold conditions. But this is a delicate process, and construction teams rely upon tested strategies to make the most durable concrete. To this end, researchers determined the laboratory strength and maturity correlations for concrete mix designs that ADOT&PF teams commonly use. After conducting spring and summer field tests, the project team produced a guide with procedures and computations designed to help ADOT&PF personnel use developed methods on location to better estimate the strength of concrete they pour. The final report is available on the AUTC website ([ine.uaf.edu/autc/final-reports/](http://ine.uaf.edu/autc/final-reports/)).

**Field Study to Compare the Performance of Two Designs to Prevent River Bend Erosion in Arctic Environments (AUTC #309009)**
**Horacio Toniolo (UAF)**

Rivers often change their paths over time, and this can seriously threaten existing infrastructure. In Alaska, roadways and pipelines are vital conduits for people, goods, and resources. When shifting rivers threaten them, engineers are left with the delicate task of re-directing waterflow to save structures that cost millions, and sometimes billions, to build.

This study focused on two erosion-control projects built in Alaska using different design criteria. One was built by Alyeska Pipeline Service Company at Hess Creek to protect the trans-Alaska pipeline. The other was constructed by ADOT&PF to protect the Dalton Highway from the Sagavanirktok River.

Bank erosion along river bends results in lateral erosion, causing streams to shift laterally where they may pose risk to infrastructure. Engineers have developed several types of strategies to prevent stream bank erosion. These include watercourse realignment, a technique of moving water away from the bank that essentially imitates a natural process, to protect the transportation infrastructure from damage. Structures at the two study sites were composed of a series of stabilizing baffles, or barbs, one oriented downstream (Hess) and one oriented upstream (Sagavanirktok).

Lead by UAF’s Horacio Toniolo, researchers gathered hydraulic data, including continuous velocity measurements, at selected points on both waterways. Adding this data to a hydraulic numerical model, researchers simulated different hydraulic scenarios to demonstrate a river’s behavior under different flow conditions at different seasons. These models revealed that the first baffle or barb in a series is the most critical in the whole structure; if the first barb fails, chances that the others will also fail increases significantly. This new information is immediately valuable to current erosion control projects.

Armed with this new model, ADOT&PF personnel are now looking for opportunities to implement the model in different settings, particularly where the agency is planning river training structures. Helping designers plan appropriate structures for actual river conditions, this numerical model will improve the design process for future structures.
Characterization of Asphalt-treated Base Course Material (AUTC #107049)
Juanyu “Jenny” Liu (UAF)

Asphalt-treated bases (ATBs) are often used to increase the durability of new pavements. While ATBs are readily available and low-cost, little data exists on how they perform in cold regions. Hoping to apply their use in Alaska’s arctic climates, this study investigated four ATB types: hot asphalt, emulsion, foamed asphalt, and reclaimed asphalt pavement. These four types have been popular for treating base materials, so the research team collected data on material stiffness, fatigue, and permanent deformation characteristics under different temperatures. The team also compiled the latest research on ATBs to produce a detailed literature review.

Researchers tested ATB materials commonly used for Alaska’s three major regions, and went to ADOT&PF labs to fabricate foamed asphalt-treated base samples. Based on the results, Liu and her team developed comprehensive regression equations for all the studied ATB materials. Using these predicting equations allows pavement designers to make recommendations about resilient behavior of ATBs based on different treatment techniques, ambient temperatures, aggregate properties, and binder contents. The final report is available on the AUTC website (ine.uaf.edu/autc/final-reports/)

Warm Mix Asphalt: Experimental Features in Highway Construction (AUTC #MISC5)
Juanyu “Jenny” Liu (UAF)

One way to enhance the cost-effectiveness of durable surface applications is to find ways to reduce the amount of energy it takes to apply asphalt to a surface. Hot mix asphalt (HMA), used in many conventional paving projects, is typically spread at temperatures between 280° and 320°F. When road crews use warm mix asphalt (WMA), which can be applied at significantly lower temperatures (250° to around 270°F), they can reduce the energy requirements and costs of highway paving. This is why researchers wanted to see if WMA could be applied without adversely impacting pavement performance in Alaska.

One form of WMA involves adding small amounts of water (as steam) to the asphalt mixer system, and ADOT&PF used this approach on a paving project near Tok, Alaska. Liu’s research team collected samples on site and conducted a laboratory testing program to assess how this WMA technique works and to determine if there is any significant difference between how HMA and WMA pavements performed. Tests included material characterization, rutting potential, resistance to fatigue, moisture susceptibility, and performance under low temperatures.

Results show that the engineering properties of the asphalt mixture are not significantly affected by adding steam during production. Liu recommended that tests on field-collected field-compacted specimens for foaming WMA could provide more representative and definitive results.
As the nation’s premier facility for cold region transportation research housed at America’s Arctic University, AUTC puts a major emphasis on its permafrost and frozen ground studies.

While Alaska’s interior and northern regions demonstrate the most dramatic examples of the destructive effects thawing permafrost can have on transportation infrastructure, our location also affords ample opportunities for research. Our unique geography combined with AUTC’s partnership with ADOT&PF positions us as a leader in this field.

AUTC stakeholders—Alaska policy makers, our federal delegation, and engineers who deal with these issues everyday—benefit from AUTC’s innovative research. While diverse, all our projects in permafrost and frozen ground studies aim to help extend the service life of cold weather transportation infrastructure. For state decision makers, this means less expensive, longer lasting bridges, roads, and runways. For the federal delegation, it means maximized maintenance efforts and more cost-effective transportation budgeting—making the most of every dollar Alaska receives for transportation initiatives. AUTC also leads the way for other states wrestling with cold climate transportation issues. For engineers and project planners, our work means new ways of making their work more effective, efficient, and long-lasting.

**New Permafrost & Frozen Ground Projects**

**Impact of Groundwater Flow on Permafrost Degradation and Transportation Infrastructure Stability (AUTC #510011)**

*Margaret Darrow (UAF)*

Climate shifts in Alaska’s extreme environments cause extensive and costly damage to transportation infrastructure. Thawing permafrost, for example, causes significant structural challenges to roadway embankments, increasing life cycle costs and reducing transportation system effectiveness.

Extensive research has been conducted on how changing surface temperatures can affect permafrost and compromise embankment stability. However, we know much less about the impact of groundwater and advective heat transfer upon permafrost degradation below embankments. Studies indicate that groundwater flow along the permafrost table will increase permafrost degradation, accelerating damage considerably faster than atmospheric warming alone. Thus, to maintain long-term infrastructure stability in permafrost regions, we must gain a better understanding of the complex interactions between groundwater, permafrost and overlying embankments.

To this end, UAF researchers Margaret Darrow and Ronald Daanen have partnered with colleagues (lead by Daniel Fortier) at the Université de Montréal (UdeM) to investigate the relationship between groundwater flow, permafrost degradation, and embankment stability. Elements of the collaborative study include field work at a test section on the Alaska Highway near Beaver Creek, Yukon Territory, Canada; laboratory measurements of hydraulic conductivity and unfrozen water content; and modeling of the interaction among these complex phenomena, using coupled mathematical equations in COMSOL Multiphysics (a software package). Researchers will use this data in road embankment simulations
that determine how energy advection contributes to the frozen ground through groundwater flow. The results will improve our understanding of groundwater flow through taliks and within warm (near 0°C) permafrost soils with high unfrozen water content. Continued work and data modeling—incorporating both conductive and advective heat transfer processes—will help develop a powerful tool for roadway embankment designers.

Moreover, this work will help designers create robust embankments and more effectively mitigate groundwater flow, potentially resulting in cost savings for transportation infrastructure maintenance, increased life cycle, and improved system effectiveness.

**Experimental Study of Various Techniques to Protect Ice-Rich Cut Slopes (AUTC #510010)**

**Xiong Zhang (UAF)**

For more than 50 years, state construction officials have wrestled with the costly problem of uncontrolled erosion, runoff, and slope failures that result from permafrost. The permafrost that underlies most areas of Alaska potentially adds significant development costs in the form of environmental distress, project delays, change orders, and claims that often occur during building.

Researchers Xiong Zhang (AUTC) and Mingchu Zhang (UAF School of Natural Resources and Agricultural Sciences) hope to study potential thermal erosion mitigation techniques in order to find better methods for controlling erosion from cut faces in the first thaw season, effectively reducing many of these dangers and costs.

Cuts in permafrost surfaces are often required to achieve design grades in ice-rich permafrost areas, and excavation and exposure of a cut slope can destroy the existing thermal balance, resulting in degradation of the ice-rich permafrost. While research has been done to address the issue, environmentally acceptable, legal, and economically viable solutions remain rare. Further, new and strict environmental laws continue to increase the trend to make long-accepted ADOT&PF methods for dealing with ice-rich permafrost either undesirable or completely unacceptable.

Zhang and Zhang will study several potential thermal erosion mitigation techniques that address the regulatory concerns raised by current practices. Researchers will construct several test sections in the experimental study and monitor the sections to evaluate the effectiveness of different techniques. The team will offer recommendations and guidelines for design, construction, and for ensuring proper application of successfully tested mitigation approaches on future construction projects that require cuts in ice-rich permafrost.

**Supplemental Study to “Using Mirafi Nylon Wicking Fabric to Prevent Frost Boils in the Dalton Highway Beaver Slide Area, Alaska” (AUTC #510020)**

**Xiong Zhang (UAF) and Michael R. Lilly, Geo-Watersheds Scientific (GWS)**

Like the challenges posed by permafrost, frost boils also undermine highway infrastructure in a number of ways. Mirafi Nylon Wicking Fabric is becoming a prevention solution of interest for AUTC researchers, who are testing the new material’s ability to mitigate frost boils and subsequent road damage in the Beaver Slide area, near mile 110.5 of Alaska’s Dalton Highway. Jointly funded by ADOT&PF, Tencate Geosynthetics, and AUTC, this work began in August 2010 with construction of a test section in the area. While preliminary field results suggest that Mirafi Nylon Wicking Fabric did help prevent frost boils in the area, further research is necessary to provide conclusive data.

Researchers Xiong Zhang (UAF) and Michael R. Lilly (GWS) are extending studies to monitor the test section for another year, in addition to the original one and a half year study. The researchers are concerned that the original monitoring period is not long enough to provide sufficient data to help understand the frost boil problem. The research project will extend the monitoring period to December 2012.
**Ongoing Permafrost/Frozen Ground Projects**

**Stabilization of Erodible and Thawing Permafrost Slopes with Geofibers and Synthetic Fluid (AUTC #410028)**

**J. Leroy Hulsey and Xiong Zhang** (UAF)

Thawing, unstable, and eroding permafrost slopes pose serious challenges for road maintenance crews and transportation engineers. Changes in frozen soils impose safety risks such as sinking and cracks in northern roadways. However, recent research in the use of synthetic fluids and geofibers, which have proven to effectively reinforce subgrade soils in pavements, may mitigate these problems.

Traditional stabilization techniques are costly and require specialized skills and equipment to ensure adequate performance. They also are only marginally effective in the cold climates of Alaska and other northern regions. This project is conducting a large-scale field investigation to study the feasibility of stabilizing erodible and thawing permafrost slopes with geofibers and synthetic fluid. Recent research has shown that geofibers and synthetic fluids can improve very loose, sandy soils—the material often left behind after permafrost thaws. The outcomes of this research will help future engineering teams build safer, more reliable, cost-effective road embankments.

**Use of Mirafi Nylon Wicking Fabric to Help Prevent Frost Boils in the Dalton Highway Beaver Slide Area, Alaska (AUTC #RR10.02)**

**Xiong Zhang** (UAF) and **Michael Lilly** (GW Scientific)

Alaska’s famed Dalton Highway—paralleling the trans-Alaska oil pipeline from the north of Fairbanks to Prudhoe Bay—is perhaps the nation’s most remote road. Yet while few use it for regular travel, an estimated 250 commercial trucks rely on it daily during the winter months; another 160, during summer. As the recent popular television shows Ice Road Truckers and America’s Toughest Jobs have made clear, the extreme weather that abuses this highway causes many challenges for commercial drivers. In particular, the destructive effects of frost boils result in major safety risks and frequent accidents on the Dalton and other Alaska roads.

Frost boils are not a new problem. Summer weather brings snowmelt and thawing permafrost, and groundwater rushes downslope where it often pools near roadways, moves up during winter freezing, and accumulates in the pavement as an ice lens. Frost boils occur during the spring when these ice lenses thaw, disturbing roadbeds and the asphalt that rides on top of them, causing damage. A well-known example of this occurs repeatedly at a road section near mile 110.5 on the Dalton Highway called Beaver Slide, where conventional construction methods have done little to stop the damage.

Wicking fabric technology, like the kind used to make water-wicking athletic wear, may offer a solution to this safety problem. Preliminary lab tests of Mirafi Nylon Wicking Fabric (MNWF) indicate it has great promise as a cost-effective means of solving frost boil problems on road systems. Developed by Tencate Geosynthetics (North America), MNWF features high specific surface area and permeability; these properties may enhance pavement performance by better distributing pooling water and encouraging fast drainage. As opposed to the hundreds of labor hours and mechanical support needed currently to even attempt repairing frost boil damage, including this fabric in road systems may help mitigate, or even eliminate, this destructive phenomenon. This innovation could improve safety, increase a road’s service life, and reduce maintenance costs.

Researchers are evaluating an installation of MNWF at Beaver Slide, using moisture and temperature sensors to gather measurements on both frost boil formation and pavement performance. They are examining soil properties and thermal and moisture changes as well, to improve our understanding of how these soil mechanisms work. Data collected in the past year indicates that this new technique is a great success.

Research results could lead to incorporation of MNWF in the geotechnical engineering curriculum at UAF as well as informing recommendations to engineers for more reliable and economically cost-effective road design.

**Geophysical Applications for Arctic/Subarctic Transportation Planning (AUTC #410018)**

**William E. Schnabel**, UAF

Permafrost poses numerous challenges to cold region road and bridge designers. For example, roads and bridges constructed in permafrost areas are often damaged when the thermal state of the soil changes. Road and bridge designs that do not adequately account for these subsurface dynamics can result in flawed structures requiring excessive maintenance or replacement, increasing both safety risks and costs.
This project will help designers make better use of geophysical information when constructing bridges and roads in cold regions. Specifically, researchers will assess the use of geophysical methods such as electrical resistivity tomography (ERT) and ground-penetrating radar (GPR), technology currently under-utilized in arctic subsurface investigations. These methods could be powerful and relatively inexpensive tools for infrastructure planners. Current research indicates that using ERT and GPR together as part of a geophysical survey can effectively map the extent of subsurface ice formations that undermine structural stability, such as ice wedges, ice lenses, massive ice, and taliks (layers of year-round unfrozen ground within a permafrost area).

Scientists at UAF, UAA, and Laval University are finding ways to integrate ERT and GPR into current assessments of subarctic soils. The team will describe four case studies in which geophysical surveys using this technology are implemented into subsurface investigations along road and bridge alignments being conducted by ADOT&PF. Although results will be used to augment existing ADOT&PF projects, the team’s primary goal is to provide guidance on making ERT and GRP a routine component of characterizing arctic and subarctic soils.

In addition, this study will produce initial information for a database describing geophysical properties typical of Alaska’s permafrost and talik conditions. This database will allow engineers to better address the subsurface challenges that drive up maintenance costs and undermine safety. It will also facilitate protocols for carrying out and interpreting arctic/subarctic geophysical surveys, as well as guidance for selecting the appropriate methods and estimating survey costs. So far, the team has conducted surveys at various sites in the Anaktuvuk basin, at the 9-Mile Dalton Highway realignment, and at the UAF Agricultural and Experiment Farm. In future months they will complete fieldwork in the Goldstream Road region north of Fairbanks.

**Fast Determination of Soil Behavior in the Capillary Zone Using Simple Laboratory Tests (AUTC #410025)**

**Robert L. Lytton (TAMU) and Xiong Zhang (UAF)**

Freezing and thawing are major threats to infrastructure reliability and safety because they erode strong soils and the roads and structures built upon them. This study seeks to develop a new way to examine soil volume change and soil strength, allowing engineers to address the complex subsurface moisture issues unique to cold regions.

Frost heave and thaw weakening are typical problems for engineers building in northern regions. Thaw weakening makes pavement and other surface structures prone to damage when thawing water weakens the road. Frost heaving occurs when ice forms in the soil during freezing temperatures, then grows, often upward toward the freezing front. These behaviors are caused by water flowing through the capillary zone to a freezing front, where it forms ice lenses.

This project will develop a new way to examine soil strength that is cost-effective, more reliable, and less time-consuming than current methods. Researchers typically use suction-control testing to determine the strength of unsaturated soils. Although suction-controlled tests are the standard for characterizing unsaturated soils, such testing is too laborious, time-consuming, and costly for routine engineering projects. Learning about the stress/strain behavior for only one unsaturated soil can take up to three years, and moisture content measurements are unreliable.

This research team is developing a method for rapidly determining and analyzing unsaturated soil behavior through a new approach, the Modified State Surface Approach (MSSA). The MSSA can potentially reduce the time required to characterize unsaturated soils from several years to a few weeks or days, as well as provide more reliable measurements and representative soil behavior. If successful, this research will produce a useful tool for geotechnical engineers, allowing fast, practical, more comprehensive soil characterization for complicated soil behavior problems. It can drastically reduce research costs, improve reliability, and ultimately create stronger, safer infrastructure.

**Using Shallow Anchors and an Anchored Mesh System for Cut Slope Protection in Ice-Rich Soils (AUTC #207121)**

**Xiong Zhang (UAF)**

Permafrost soils present special problems to builders of roads and other transportation infrastructure in Alaska. When a sloped bank in a permafrost area is cut to make way for a road, the soil may thaw and slump or collapse, causing damage to infrastructure. In addition, as many as six years may pass
before new vegetation restabilizes a cut bank. While engineers can design embankments to compensate for these soil changes and protect roadways, there is growing concern that the eroding soils may impact water quality and fish habitat. Engineers are looking for new designs that better protect the immediate environment, meet federal guidelines, and remain economically viable.

Builders have tried many strategies for slope stabilization, some more effective (and more expensive) than others. One strategy is to use wire netting held in place by soil anchors, but little information exists on how this approach works in Alaska’s frozen, shallow, silty soils. This project, in partnership with ADOT&PF, is investigating how shallow anchors perform in frozen soils. Project outcomes include designing an anchored wire mesh system to protect and stabilize ice-rich cut slopes. Anchor creep tests have been completed in the laboratory, and ongoing anchor field tests and numerical simulation analyses continue. The findings will be useful for other types of mitigation strategies, including highway retaining walls, and for addressing rockslide areas.

These improved strategies will help control maintenance costs and water resource concerns often related to thawing permafrost.

**Evaluating In-Place Inclinometer Strings in Cold Regions (AUTC #309022)**

*Margaret Darrow (UAF)*

In cold regions, subsurface movement of frozen ground impacts transportation infrastructure, threatening roads, bridges, runways, railways, and other vital structures. Because knowledge about the subsurface is so important for transportation planners, researchers are striving to better understand how these forces work.

This study is an effort to improve how inclinometers—tools used to measure ground movement—perform in cold regions. Inclinometers measure vertical and horizontal ground movement on slopes, embankments, bridges, retaining walls, and other structures.

Current inclinometer technology presents some drawbacks. Since data acquisition requires manual measurements, for example, workers face expensive and potentially dangerous travel. Weeks or months often pass between manual readings due to budget considerations, causing workers to merely interpolate the recorded data. Accurate data collection varies, depending on the care and skill level of the person taking measurements. The inclinometer casing has limited flexibility and can shear when excessive ground movement occurs. In addition, the inclinometer probe length limits the amount of deformation a casing can experience before readings are no longer possible.

A new type of geotechnical instrumentation incorporates Micro-Electro-Mechanical Systems (MEMS) accelerometers, which were first used for automotive air bags. Automated in-place MEMS (AIMIS) technology allows them to be directly inserted in the ground, avoiding the setbacks of manual methods. These accelerometers are more flexible and can withstand greater ground movement. When the installation is accompanied by a remote power supply and a telemetry link, they can provide nearly continuous observation of ground movement without frequent field trips. Moreover they are potentially reusable; they can be removed from one installation and placed into another, resulting in further cost savings.

Since the AIMIS technology is new, its use has not been fully evaluated, especially in cold regions. Although AIMIS are designed to be reused, techniques for extracting installed strings are in their infancy and are problematic. New extraction techniques for use in frozen ground may need to be created and evaluated, and as with any equipment used in cold regions, the durability of AIMIS at subfreezing temperatures needs to be evaluated. Researchers will compare AIMIS against the existing methodology, evaluate its cold region versatility and accuracy, and test its ease of use and recoverability. The project will also evaluate AIMIS for applications in Interior Alaska that include monitoring creep in frozen ground and identifying and monitoring a slide shear zone. Researchers will also compare two different AIMIS products with the existing manual method and with each other to identify any benefits of one product over another. Fieldwork and data analysis will allow researchers to develop a set of Best Practice Guidelines for using AIMIS applications.

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**A new type of geotechnical instrumentation incorporates Micro-Electro-Mechanical Systems (MEMS) accelerometers, which were first used for automotive air bags.**
**Completed Permafrost/Frozen Ground Projects**

**Seasonally Frozen Ground Effects on the Seismic Response of Highway Bridges (AUTC #107014)**

J. Leroy Hulsey (UAF)

How does frozen ground affect bridge performance? Seasonally frozen ground is stiffer than unfrozen ground. Although we think of bridges as solid and unbending, every bridge will—and should—flex a little, under the right conditions, for example during an earthquake. Bridges built on deep pier foundations seem to become less flexible in winter. This project studied the influence of seasonal change on pier structures, measuring how structures responded to seasonal changes, and how bridge stiffness changed over time.

A joint effort between civil engineers at UAF, UAA, and Iowa State University, this project monitored a variety of bridges, including some with piers sunk in ice-rich soils. The team also analyzed models of bridge structures under seismic loading and monitored temperatures at test sites to determine the depth and seismic resistance of these structures.

Project results will contribute to new, guidelines to help ADOT&PF design for better bridge performance. This project's results have contributed to ADOT&PF efforts to plan for cost-effective monitoring and repair of Alaska's bridges.

**Preservation of the Alaska Highway, Phase 2 (AUTC #309035)**

Daniel Fortier (Laval University) and Yuri Shur (UAF)

Combining AUTC's permafrost expertise with applied fieldwork and the latest in 3D modeling technology, researchers on this collaborative project looked at ways to mitigate permafrost damage to the Alaska Highway, with the aim of curbing maintenance costs and reducing safety risks by extending the highway's service life.

The research team collected data along sections of the highway, using instrumentation installed as part of an earlier project. This included fine-scale thermal monitoring of permafrost mitigation techniques, surface drainage monitoring and snow dynamics monitoring. They lab-tested soil samples as well as performing extensive data analysis and modeling. Project fieldwork included constructing a snow shed along one section of the highway embankment. Similar to a tunnel, a snow shed is a wooden structure that provides a roof over a road embankment to block out precipitation, sunlight, and other hazardous weather. By keeping the insulating snow off the ground surface, the soil is exposed to cold air flowing over and under it. A snow shed helps cool the soil surface by deflecting heat from the ground and the air immediately above it, encouraging permafrost to stay frozen.

Researchers established a permafrost database and 3D cryostratigraphic model linked to a geographical information system (GIS). Along with thermal data, the database and cryostratigraphic model allows researchers to evaluate how well their techniques mitigate surface damage. Project results will help engineers in Alaska and western Canada prevent damage to the Alaska Highway and other infrastructure that crosses ice-rich soils. By working with the Yukon Highway Public Works Department on new design implementations, the project is already helping mitigate damage from thawing permafrost. This work will increase the Alaska highway's service life, prevent costly maintenance, and improve public safety.

**Evaluating Liquefaction Resistance in Degrading Permafrost and Seasonally Frozen Ground (AUTC 107041)**

Kenan Hazirbaba (UAF)

Permafrost degradation in regions of high seismic activity increases the potential for soil liquefaction, which threatens transportation and utility infrastructure. This became all too evident during the November 2002 Denali Earthquake (magnitude Mw 7.9).

Concerned by this seismic threat, researchers wanted to know more about how freeze-thaw cycles impact soil liquefaction and, by association, structural stability. This project conducted lab studies to investigate the liquefaction resistance of frozen and seasonally frozen ground. Researchers examined how soil liquefaction is influenced by freeze-thaw cycles throughout the year and how it is impacted by temperature distribution in degrading permafrost. The research showed that soils may undergo liquefaction at below freezing temperatures.

Results helped establish criteria for liquefaction susceptibility in thawing permafrost and soils that regularly undergo freeze-thaw cycles. This information will help engineers better design and test structures in arctic, seismic-prone environments.
**Geological Investigations for the Dalton Highway Innovation Project as a Case Study of Ice-rich Syngenetic Permafrost (AUTC #207122)**

Yuri Shur and Mikhail Kanevskiy (UAF)

What scientists call “syngenetic” permafrost actually grows upwards in size as sediments are deposited on the surface, causing major maintenance and safety problems for road designers hoping to cross such areas.

ADOT&PF plans to construct a new section of the James W. Dalton Highway in northern Alaska—a three-mile-long section that avoids a steep climb, making it safer to drive than the existing road. But this new section of highway will cross an area of extremely complex frozen ground, characterized by ice-rich, syngenetic permafrost that can be up to 100 feet thick and contain huge ice wedges.

Designing a road to cross such an area depends on having the best geotechnical information available, on continuous monitoring, and timely maintenance. AUTC permafrost experts Yuri Shur and Mikhail Kanevskiy helped prepare for this construction project by performing a geotechnical investigation of the area, training ADOT&PF engineers in permafrost behavior, and developing a methodology for describing, sampling, and testing the area's syngenetic permafrost. In addition to supporting the best design possible for the highway, project results will help future construction projects throughout the circumpolar North and contribute to the education of a new generation of engineers at the University of Alaska.

**Impact of Fines Content on Resilient Modulus Reduction of Base Courses During Thawing (AUTC #107045)**

Juanyu “Jenny” Liu (UAF)

Liu found that the $M_R$ of D-1 base course material is highly dependent on temperature. $M_R$ was significantly lower after only one freeze-thaw cycle, and specimens with low initial moisture contents demonstrated even lower $M_R$. Generally, after a freeze thaw cycle, base course with the highest fines content contributed to the lowest $M_R$. $M_R$ decreased as moisture content increased under different confining pressure and fines content levels.

Liu's team developed regression equations to correlate $M_R$ values with physical properties (moisture and fines contents), stress states, and temperature conditions for D-1 base course materials. For D-1 materials tested in this study, at room temperature, $M_R$ was found to be a function of stress state, moisture and fines contents. At subfreezing temperatures, $M_R$ was a function of deviator stress, temperature, and aggregate type.

These equations can be used to predict $M_R$ values of Alaskan D-1 materials for pavement design. These results will help efforts to extend road service life and reduce maintenance and safety risks.

**Effects of Permafrost and Seasonally Frozen Ground on the Seismic Responses of Transportation Infrastructure Sites (AUTC #107017)**

Zhaohui Yang, UAA

If you build a bridge in a permafrost area, is it more or is it less likely to survive an earthquake? Transportation engineers are eager to learn about how permafrost changes infrastructure's ability to withstand seismic force, like that generated during an earthquake.

This interdisciplinary project combined seismic data recorded at bridge sites with computer models to identify how highway bridges built on frozen ground behave during an earthquake. Two sites—one in Anchorage and another in Fairbanks—were selected for seismic testing. In assessing seismic motion in frozen soil, researchers considered the thickness of seasonally frozen soil, depth and thickness of permafrost, and depth of the bedrock. Results showed that the presence of frozen soil, particularly permafrost, significantly changes ground motion characteristics.

Study results will contribute to new guidelines that help engineers design better highway bridges and embankments in Alaska, ideally identifying how to account for permafrost effects in a simpler manner. These guidelines will help designers create more durable, long-lasting roads and reduce maintenance and safety risks.
Preservation of the Alaska Highway, Phase 1 (AUTC #107054)

Daniel Fortier (UAF)

Increasing the life span of the Alaska Highway depends upon understanding and mitigating the destructive effects of permafrost. The Alaska Highway, the only road connecting Alaska to the contiguous U.S., crosses large areas of permafrost-rich soils, which may thaw, shift, erode, or re-freeze seasonally—sometimes daily.

Highway reconstruction in the mid-1990's damaged the organic layer that insulated and protected the surrounding permafrost. Since then, heat has transferred through the road, melting the ground ice underneath. The thawing and settling ground has created dips, bumps, potholes, and cracks in the road. Throughout the past 10 years, the climate has been relatively stable, but if temperatures become warmer, permafrost degradation and the rate at which the road is damaged will increase. Working with the Yukon Highways and Public Works (YHPW), AUTC researchers explored ways to slow this permafrost degradation. They selected test sites, characterized surrounding soil conditions, and installed instruments for long-term data collection. Team members, working with engineers at YHPW and Laval University, finalized designs for mitigating permafrost degradation and highway embankment subsidence.

This research helped transportation engineers better understand the subsurface dynamics that impact road quality, and the associated maintenance and safety concerns. To learn more about this project, visit ine.uaf.edu/autc/.

Measuring Temperature and Soil Properties for Finite Element Model Verification (AUTC #RR08.11)

Margaret Darrow (UAF)

This study sought to develop ways of stabilizing embankments to reduce permafrost thawing, which severely damages roads and other structures. To do this, the project refined current analytical tools used to assess permafrost conditions.

ADOT&PF personnel frequently use a program called TEMP/W to conduct thermal modeling of various embankments to reduce the thawing of ice-rich permafrost through thermally stable embankment designs. The study’s goal was to verify the thermal modeling results produced by TEMP/W.

Temperatures and soil properties were measured at two different sites underlain by permafrost in Interior and Southcentral Alaska. While historic air temperature data provided an approximation of the regional climate, the data produced model results that were too cold by several degrees. Using air temperatures measured at each site resulted in models that closely matched the measured soil temperatures, and either matched or overestimated active layer depths. Using the overestimated active layer depth for design purposes would result in a more conservative embankment construction, which is a favorable approach if a warming climate is considered. This realization helped refine the current use of TEMP/W, giving engineers a clearer picture of the thermal interaction between permafrost and overlying embankments.

Nylon Wicking Fabrics (AUTC #RR10.02)

Xiong Zhang (UAF)

Innovative materials are helping preserve road surfaces and prevent erosion on Alaska’s highway system. Mirafi Nylon Wicking Fabrics (MNWF), for example, can be used underneath road surfaces to move water away from areas where it pools up and freezes—causing roadway damage and safety risks. Often, developing these materials requires a combination of field and laboratory testing.

This project applied lab testing to a privately developed geotextile—a fabric used to reinforce or drain soil—as part of a road repair project on Alaska’s Dalton Highway. To assist highway designers, researchers wanted to see whether MNWF would capture water welling up through foundation soils and route it to the side of a road, leaving the soil above drier and stronger. A collaboration between Tencate, which provided the geotextile, ADOT&PF, which installed the new material, and AUTC, which provided data collection monitoring, this project collected data over a two-year period to reveal how well the material performed.

Results are helping northern region road surface engineers design more resilient roads that require less maintenance.

Researchers worked with private industry to develop and install a new nylon wicking fabric under pavement to reduce or eliminate “soft spots”—areas where water pools underneath the pavement, causing rapid degradation and potholes.
Page 27: Photo of field testing for RFID Technology in Construction project by Oliver Hedgepeth, University of Alaska Anchorage.

Page 28: Photo of ADOT&PF staff clearing the results of a bank collapse from the highway by Margaret Darrow, College of Engineering and Mines at UAF.

Page 29: Illustration of roundabout system near Anchorage by graduate student Xuanwu Chen.

Page 30: Structural integrity design, from left and clockwise: Two photos show PhD student Huajie Wen performing tests on samples in a lab at Washington State University; photos by Dr. Fangliang Chen, WSU. Photo of Dr. Andrew Metzger, in the field as part of the “Response of Pile-Guided Floats Subjected to Dynamic Loading” project, by graduate student Jason Kwiatkowski.

Page 31: (lower right) Photos of “Full-Scale Testing of Steel Bridge Pier” courtesy of Steven Fulmer, North Carolina State University.

Page 40: Surface application design, photo by graduate student Peng Li.

Page 41: Photo of Natalia Kulchitskaya by P. Li.

Page 52: Permafrost and frozen ground design, from top and clockwise: Exposed bank showing ice wedges and areal photo of patterned ground by M. Kanevskiy. Photo of Margaret Darrow installing remote data collection system by student Travis Haller.