April 2011

RESEARCH
ENGINEERING THE FUTURE

Welcome to the Utah Department of Transportation (UDOT) Research Division Newsletter

A MESSAGE FROM THE DIRECTOR OF RESEARCH

By: Cameron Kergaye, PhD, PMP, PE

Research peer exchanges encourage state DOTs to learn best practices among transportation agencies. At a recent exchange hosted by Caltrans, UDOT Research interacted with research professionals from Connecticut, Ohio, Louisiana, Minnesota and Washington, in addition to FHWA and TRB. This collaborative meeting resulted in shared visions of innovation and technology implementation.

Recurring themes in implementation identified by Caltrans Division of Research and Innovation, through a preliminary investigation conducted by CTC & Associates, covered a broad spectrum:

- Encouraging management support
- Staffing for implementation
- Considering implementation throughout the research process
- Communicating research results
- Ongoing monitoring of implementation
- Encouraging innovation

Examples of supporting research from the participating states suggested common characteristics for accelerating the adoption of innovation. Successful organizations were those that support research, risk-taking and outreach, and involve internal stakeholders. Successful individuals were those with strong communication skills, who efficiently work across organizational lines and are motivated to solve problems. As UDOT prepares to host the UTRAC research workshop on April 7th, these themes will guide the delivery and implementation of our research program.

Participants of 2011 Caltrans Research Peer Exchange

In This Issue: (click on desired article on this page)

COUNTDOWN TO THE 2011 UDOT RESEARCH WORKSHOP. 2
EVALUATING HIGH SEISMIC PERFORMANCE SOLUTIONS FOR TYPICAL UTAH HIGHWAY BRIDGES. . . 3
FISH MOVEMENT THROUGH LINED CULVERTS. 5
BOND STRENGTH OF OVERLAYS FOR ABC BRIDGE DECKS. 7
CAN ROUGHNESS ELEMENTS HELP NATIVE UTAH FISH MOVE THROUGH CULVERTS? 9
A LOOK AT WHO WE ARE 11
TECHNOLOGY TRANSFER CORNER 12

2011 UTRAC RESEARCH WORKSHOP

COUNTDOWN TO THE 2011 UDOT RESEARCH WORKSHOP

The anticipation is mounting for our annual "UTRAC" Research Workshop scheduled for April 7, 2011 at the SLCC Larry Miller Campus in Sandy, Utah. At the workshop people from UDOT, FHWA, the Universities, consulting firms, and other research partners will gather to discuss the research needs of UDOT, and decide which ones are the highest priorities. The general session will feature a keynote address by James Christian, Administrator of the FHWA Utah Division. We will present the legendary Trailblazer Award to a worthy individual during the workshop lunch.

We have received several great problem statements for prioritizing at the workshop. Subject areas for the problem statements and workshop breakout sessions include Construction & Materials, Maintenance, Traffic Management & Safety, Geotechnical, and Structures. The highest priority problem statements selected by each of these groups will be considered for funding by the Research Division for the coming year.

Additional information on the April 7th workshop and past workshops can be accessed by going to our web site (www.udot.utah.gov/go/research) and clicking on "2011 UTRAC Workshop ". The deadline for submitting problem statements was March 21, and online registration closed on March 28. Submitted problem statements will be posted on our web site prior to the workshop date. If you have not registered and would like to attend the workshop, please contact David Stevens (801-965-4377, davidstevens@utah.gov). We look forward to your participation in this important part of UDOT's research project selection process.

By: Keri Ryan, Ph.D.
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Daniel Hsiao, P.E.,
UDOT Research Division

EVALUATING HIGH SEISMIC PERFORMANCE SOLUTIONS FOR TYPICAL UTAH HIGHWAY BRIDGES

The recent massive global earthquake devastation in places like Japan, New Zealand, Chile, and Haiti, underscores the importance of robust seismic protection for critical infrastructure and transportation networks. The seismic design guidelines published by AASHTO require as a minimum that life safety performance be provided in an earthquake with a 7% in 75 year probability of occurrence, or an earthquake with an expected return period of 1000 years. If such an earthquake occurs, however unlikely, Utahns must accept that achievement of minimum code standards means that critical bridges on the transportation network may be damaged beyond repair.

Bridges and highway overcrossings on the new Legacy Highway were designed for a higher performance standard; that is, they were designed to provide life safety in an even rarer (larger) earthquake with an expected return period of 2500 years. Consequently, the expected performance in a 1000 year return period earthquake is somewhat better than life safety, although not precisely quantified during the design process. Achievement of this design standard required high quantities of construction materials, and led to large columns and foundations.

An alternative approach to achieve high seismic performance is through the use of seismic isolation systems. With seismic isolation, the bridge superstructure is decoupled from the piers and abutments through use of a flexible isolation layer. Commercial isolation devices include elastomeric bearings, which are layers of rubber separated by steel shims (Figure 1), and friction pendulum bearings, or friction devices that slide within a curved dish (Figure 2).

Bridges designed with seismic isolation systems are conducive to accelerated construction techniques. Many large bridges in the U.S. and worldwide have been built with seismic isolation, and in some cases, the use of seismic isolation reportedly reduced the overall construction costs (e.g., the American River Bridge in Folsom, CA).

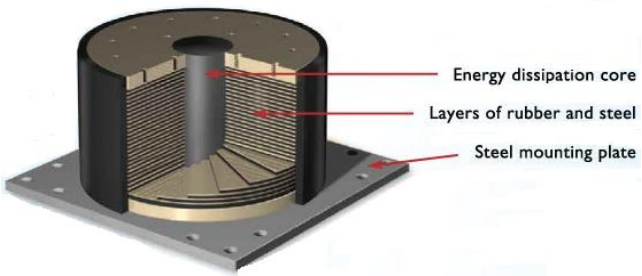

Figure 1: Cross-sectional view of an elastomeric bearing (Source: DIS, 2010)

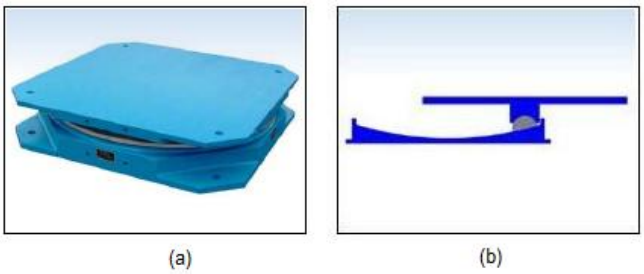

Figure 2: (a) Friction pendulum bearings and (b) Friction device on a curved dish (Source: DIS, 2010)

Researchers from Utah State University recently completed a project to evaluate the use of seismic isolation for typical highway bridges in the state of Utah. In this project, the design and projected seismic performance of a representative bridge on Legacy Highway, shown in Figure 3, was evaluated.

Figure 3: State Street Overpass on Legacy Highway

(Continued on page 4)

This bridge was then hypothetically re-designed to incorporate a seismic isolation system, and its seismic performance was compared to that of the original Legacy Highway Bridge. The isolated bridge was designed for a response modification factor (R) equal to 1, which means that damage free performance is expected in the design earthquake, which is above code standards even for seismically isolated bridges. With this design, the size of the pier columns was decreased by about a factor of two, and the overall size of the pier pile foundations was decreased by about a factor of six. The latter included a reduction in both the number and length of piles. The reduction in materials and cost is offset to some extent by the cost of isolation devices and added detailing at the abutments, as shown in Figure 4. A complete cost evaluation should be performed to determine conclusively if the seismic isolation approach can decrease construction costs.

The performance evaluation suggests that the performance of the seismic isolated bridge is far superior to that of the original bridge despite the sizeable decrease in material costs. All parts of the isolated bridge substructure respond well within the linear elastic range as expected. However, plastic hinges form in all columns of the original bridge, and although the peak ductility demand is only 1.5, the force demand has reached the capacity as determined by pushover analysis, which suggests that the acceptable performance relies on over strength that has not been accounted for in the analysis.

For ease of maintenance, an integral abutment design, which precludes the incorporation of a large seismic gap at the abutments, is often preferred. An alternative design strategy called partial isolation that accommodates this philosophy was also investigated. Partial isolation utilizes isolation devices at the piers only, while preserving the integral abutments. Partial isolation cannot achieve the same effect as full isolation on the overall dynamic properties of the structure; however, isolation devices at the piers can be designed as fuses to limit the lateral forces transferred to the columns.

In this case, the isolation devices should be force limiting friction devices with a capacity less than the column capacity. The strategy has been shown to be effective in limiting seismic forces transferred to the columns.

The final reports for this project are available for download at the Research Division website. For more information on this study, contact Dr. Keri Ryan, keri.ryan@unr.edu, of University of Nevada, Reno, or Daniel Hsiao, 801-965-4638, dhsiao@utah.gov, of Utah Department of Transportation.

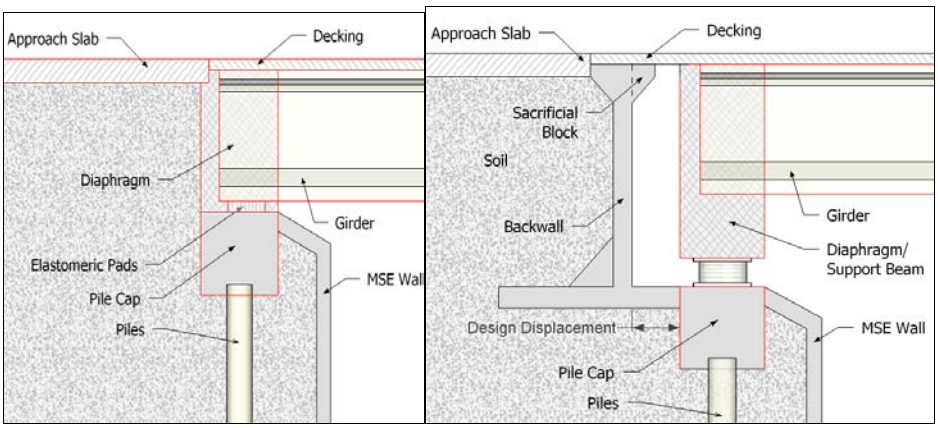

Figure 4: Modified bridge detailing at the abutments to accommodate seismic isolation

By: Amber Olsen
Graduate Student
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FISH MOVEMENT THROUGH LINED CULVERTS

The Utah Department of Transportation (UDOT) maintains more than 47,000 culverts, many of which are in need of repair. In many cases, the cost associated with culvert replacing can be cost prohibitive. An alternative to replacement is culvert rehabilitation. Culvert rehabilitation techniques typically consist of placing some type of liner inside the existing or host culvert [e.g., slip lining (solid-wall pipe), cured-in-place lining, and fold-and-form PVC lining]. Slip lining is commonly used because it requires the least amount of specialty training and equipment, making it relatively economical. The installation process also has a relatively low impact on the environment (i.e., no release of potentially toxic chemicals). Liners are commonly made out of solid-wall high-density polyethylene (HDPE) and are typically sized to be the largest liner diameter that will fit inside the host culvert; the liner size does, however, result in a reduction in flow area.

Despite the reduction in flow area, the discharge capacity of relined culverts can often be equal to or exceed that of the host culvert if the hydraulic roughness of the smooth-wall liner provides a significant reduction in the flow resistance relative to the host culvert (e.g., corrugated metal pipe, etc.). The increased pipe flow velocity associated with the smooth-wall pipe liner, however, can potentially create a hydraulic barrier to fish migration, producing a negative environmental impact and a restriction on where slip-lined culverts would be acceptable for use.

Figure 1. Baffled slip liner

UDOT has partnered with the Utah Water Research Laboratory (UWRL) at Utah State University to evaluate the ability of fish to successfully pass through a standard smooth-wall culvert liner and the same liner pipe with baffles added to the invert or bottom of the pipe. The successful passage of all fish is important, but of particular concern are those that are either threatened or endangered. Cutthroat trout are an important endangered species in Utah for whom culvert passage is of primary concern. Brown trout, which are not endangered in Utah, are being used in this study as a surrogate for cutthroat trout since swimming abilities are similar between the species. The Brown trout are slightly weaker swimmers, which make the test results conservative relative to the predicted Cutthroat trout performance.

Figure 2. Testing Brown trout

(Continued on page 6)

A 60-ft long, 2-ft diameter HDPE slip liner test facility was developed with the ability to flow test the culvert at slope ranging from 0 to 5%. Tests are ongoing to evaluate the ability of Brown trout to swim through the culvert as a function of culvert slope and discharge. Fish passage tests are being conducted in non-baffled and baffled culverts to evaluate the effectiveness of baffled liners as a potential solution to culvert rehabilitation in fish-sensitive environments.

Based on the literature review, we believe that this research is the first to test the swimming ability of wild fish in baffled culverts. The results will provide guidelines as to where baffled slip lined culverts can be installed and still allow for fish passage. Hopefully, the use of slip liners will expand so that more of Utah's culverts can be repaired without threatening fish passage or requiring culvert replacement.

For more information on this study, contact Amber Olsen at amber.olsen@aggiemail.usu.edu or Dr. Blake Tullis at blake.tullis@usu.edu of Utah State University, or Abdul Wakil at awakil@utah.gov of UDOT Research Division.

Figure 3. Experimental Setup

By: Erika D. Weber, P.E.
Graduate Student
Chris Pantelides, Ph.D., S.E.,
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BOND STRENGTH OF OVERLAYS FOR ABC BRIDGE DECKS

Steel reinforcement in concrete bridge decks is prone to corrosion caused by chloride ions from de-icing materials. Various overlays are used throughout the country to delay or prevent this corrosion. The Utah Department of Transportation (UDOT) has recently changed how it constructs bridges to implement the Accelerated Bridge Construction (ABC) method. This construction process includes half depth deck panels, full depth precast deck panels, self propelled modular transport (SPMT) deck and superstructure, and slide-in bridges. ABC bridge decks undergo additional load conditions which may cause deflections due to installation prior to standard traffic loading. The purpose of the research is to compare overlay systems for ABC bridge decks.

The primary focus of the research is to evaluate different bridge deck overlay systems under initial static deflection as well as cyclic loading and recommend acceptable overlay systems and procedures for ABC bridge decks. One of the criteria used to compare overlay systems is the bond strength between the overlay system and the bridge deck. The comparison in this study was made through field and laboratory tests.

Two bridges using different deck overlays were examined. The bridge deck overlay systems were applied the previous year. Four locations were selected for performing bond tests on each bridge. Bond tests were performed adjacent to a precast deck panel joint at each bridge site. The location of the pull-off tests was near the longitudinal midspan of the bridge and transversely between the first and second girders at approximately the center of the truck lane.

Two different laboratory testing procedures were designed for this research: (i) Test Type I, and (ii) Test Type II. Test Type I simulates the effects of the application of the bridge deck overlay *after* lifting and placement of the bridge deck. Test Type II simulates the effects of the application of the overlay *prior* to lifting and placement of the bridge deck.

During Test Type I, two 1'-6" x 8'-0"x 8 ¾ " concrete deck pieces were turned upside-down and deflected to induce initial cracking on the top face of the deck. This simulates initial cracking during lifting and placement in the negative moment regions. The two pieces were turned back over and joined through a grouted joint to construct a single 3'-0" x 8'-0"x 8 ¾ " specimen, as shown in Figure 1.

Figure 1: Type 1 specimen prior to grouting and placement of overlay

The deck overlay system was then applied per manufacturer's specifications on the top face of the single specimen where initial cracking had been imposed. Initial bond tests were performed on the combined specimen. The specimens underwent a five day cyclic test loaded on one side of the grouted connection, simulating load transfer through the grout as seen in the field. After each day of cyclic loading, two pull-off tests were performed next to the joint. During cyclic loading the specimen was post-tensioned with two 3/8 in. diameter carbon fiber rods.

(Continued on page 8)

During Test Type II, the deck overlay was first applied on the top of each of the two concrete deck pieces to simulate the application of the overlay system prior to the deck being moved and placed under ABC methods, as shown in Figure 2.

Figure 2: One 1'-6"x8'-0" specimen for Type II prior to grouting

Subsequently, each piece was turned upside-down and subjected to the same initial deflection as Test Type I specimens to induce initial cracking. The two pieces were then turned back over and joined through a grouted joint to construct a single 3'-0" x 8'-0"x 8 ¾ " specimen. A second application of the overlay system was then carried out as a splice over the grouted pocket and the specimens underwent the same cyclic testing (half-sine downward cycles) as Test Type I. During cyclic loading the specimen was post-tensioned with two 3/8 in. diameter carbon fiber rods.

Three different failure modes occurred during the pull-off tests: (i) epoxy failure, (ii) overlay failure, and (iii) concrete failure. Epoxy failure corresponds to failure of the glue used for the pull test and is not used as a comparison between bond strengths. Overlay failure corresponds to failure within the overlay or the bond between the overlay and the concrete. Concrete failure corresponds to tensile failure of the concrete and is considered preferable because this implies that the overlay has higher bond strength than concrete tensile capacity. Typical pull-off test results from the two bridges tested are shown in Figures 3 and 4. Figures 5 and 6 show pull-off results for non-epoxy failures for laboratory specimens.

Figure 3: Overlay and Concrete failure for bridge pull-off test

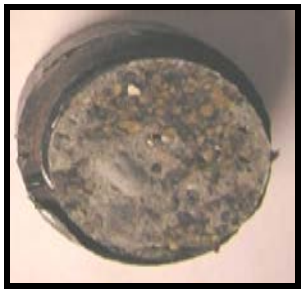

Figure 4: Overlay failure for bridge pull-off test

Figure 5: Test Type II concrete failure

Figure 6: Test Type II overlay failure

Table 1 shows the average recorded concrete and overlay pull-off stress values for two overlay systems. A total of five overlay systems will be evaluated. The results of these tests show significantly higher bond strength values in the laboratory than the actual bridges tested in the field. There were no significant differences between the bond test strengths recorded from Test Type I and Test Type II values.

Table 1: Average Non-epoxy pull-off stresses (psi)

Overlay System	Overlay 1	Overlay 2
Bridge	329	308
Type I	580	665
Type II	517	649

For more information regarding this research, please contact Erika Weber at erikadweber@hotmail.com.

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David Stevens, P.E.
UDOT Research Division

CAN ROUGHNESS ELEMENTS HELP NATIVE UTAH FISH MOVE THROUGH CULVERTS?

The laboratory answer is yes, and field verification is planned for this year. In recent years researchers at Brigham Young University (BYU) and Utah State University have been working with UDOT hydraulic engineers on different aspects of retrofitting culverts under highways that would otherwise not allow successful passage of native Utah fish. These studies have provided great insight into effective retrofitting methods and needed improvements in culvert design standards to improve fish passage. Much research has been done by others on passage of salmonid fish through culverts, the results of which have heavily influenced the current culvert design standards. Dr. Rollin Hotchkiss of BYU and his students recently completed Phase I of a study focused on culvert roughness elements for native Utah fish passage.

Background and Tasks

Culverts can increase stream velocities as a result of reduced waterway areas and prevent upstream passage of small non-salmonid fish. To mitigate this problem, current culvert design standards for fish passage match sustained fish swim speeds with average cross sectional velocity through the culvert. Such policies dictate relatively large barrels and do not recognize the role of reduced velocity zones near culvert boundaries. Obstacles and streambed substrate create lower velocity zones that could increase upstream fish passage in existing culverts.

Objectives and Tasks

The primary objective of this project was to experimentally determine the effect of artificial refuge placed in culvert barrels on upstream fish passage rates. The results of lab fish tests can be used to develop a culvert retrofit design to be field tested in Phase II.

A comparison of upstream passage success using native Utah fish in an experimental flume was conducted with three different conditions: (1) a smooth boundary, (2) a smooth boundary with strategically placed cylinders, and (3) a boundary consisting of natural substrate. Leatherside chub and Longnose dace, both of which are small non-salmonid fish, were used in the comparison. The refuge provided by the cylinders and substrate allowed fish to expend less energy as they swam upstream. Energy expenditure was compared between the conditions by mapping the velocity field near the boundary and approximating fish swim paths.

(Continued on page 10)

Results

The smooth boundary case required the highest energy expenditure as there was no refuge provided. Some of the benthic swimming fish were able to use the small boundary region above the Plexiglas flume bottom to hold position and avoid bursting for as long as possible. The midstream swimming fish could not use the boundary layer as efficiently.

Cylinders provided limited refuge that allowed fish to rest periodically as they navigated the flume. The cylinder setup was sufficient to provide holding for most fish, but not enough refuge to allow freedom of movement or other naturally observed behaviors such as foraging for food. Success in the substrate treatment was high with little or no motivation. Fish were observed swimming up and downstream several times during substrate treatment tests, and foraging for food in the crevasses between rocks. Substrate provided sufficient refuge for the fish to behave in a manner similar to their behavior in a natural environment and with significantly reduced energy expenditure.

Implementation

Several useful conclusions and recommendations resulted from the experiments in the laboratory flume. Substrate that scales with fish size can be used to backfill existing culverts and increase fish passage. Because the fish swim upstream very near the bed through amongst the rocks, comparing any culvert velocity to swimming ability is not necessary – you need only assure that the placed substrate will remain in the culvert barrel. Further field testing is necessary to fully substantiate the effectiveness of utilizing reduced velocity zones in culvert design for non-salmonid fish passage. If such a design approach can be used instead of the conservative average velocity method it will help minimize costs and result in fewer culvert replacements and smaller and simpler new designs. Other implications such as downstream effects on stream bed stability and scour remain an issue. This approach and related issues will be explored further when BYU performs the Phase II field verification effort this year using in-service culverts.

The input and feedback of Denis Stuhff and Jim Baird of UDOT Central Hydraulics and Michael Fazio, past Director of Research, was appreciated by the researchers during this study. The final report for Phase I is available on the Research Division website. For additional information, contact Dr. Hotchkiss at rhh@byu.edu or David Stevens of the Research Division at davidstevens@utah.gov.

A LOOK AT WHO WE ARE

The Utah Department of Transportation (UDOT) Division of Research is pleased to announce that Kevin Nichol, PE, MPA, has joined the research team as Research Project Manager.

Kevin has been with UDOT for twelve years, ten years in the Planning Division - first as Statewide Planning Engineer and then as Planning Manager - and two years in the Asset Management Division as Planning Statistics Engineer. He has overseen several programs, including rural long-range transportation plans development, bicycle and pedestrian planning, freight planning, scenic byways, functional classification, transportation enhancements, federal lands highways, HPMS, highway referencing, and data collection and analysis. Before coming to UDOT, Kevin worked for ten years in municipal engineering and public works for cities in Utah and northern California.

Kevin earned a Bachelor of Science degree in civil engineering and a Master of Public Administration degree, both from Brigham Young University. He and his wife live in West Jordan with their son and Kevin's mother. Kevin also has three daughters and four grandchildren, with a fifth on the way. He enjoys skiing, camping, gardening, and working with youth and is currently serving as a Scoutmaster.

The Research Division is enthused about benefitting from Kevin's diverse experience. Please join us in welcoming Kevin to UDOT Research.

You may contact Kevin at 801-965-4560 or knichol@utah.gov

We would also like to take this opportunity to extend our sincere gratitude to
Mr. Blaine Leonard who held the position of program manager in the Research Division for the past few years.

TECHNOLOGY TRANSFER CORNER

Upcoming Events

EVENT	DATE AND TIME	LOCATION & INFORMATION
2011 UTRAC Workshop	APRIL 7, 2011 7:30 AM -3:00 PM	Salt Lake Community College - Miller Campus, at 9750 South 300 West, in Sandy, Utah. http://www.udot.utah.gov/main//f?p=100:pg:0:::1:T,V:234,
WEBINAR: Field-Cast UHPC Connections for Prefabricated Bridge Elements and Systems	April 21, 2011 12:30 PM-2:00 PM	Library- Technology Transfer Room, UDOT http://www.udot.utah.gov/main//f?p=100:pg:0:::1:T,V:186,
Road School Conference	April 26-29, 2011 8:00 AM-5:00 PM	Dixie Center, St. George, Utah http://www.ulct.org/ulct/training/roadschool.html
TRB State Visit to UDOT	June 23, 2011 8:00 AM-5:00 PM	UDOT-Complex http://www.udot.utah.gov/
2011 National Research Advisory Committee (RAC) Meeting	July 25-28, 2011 7:30 AM-5:00 PM	Little America Hotel, Salt Lake City, Utah http://www.transportation.org/meetings/300.aspx

For additional UDOT training information, please check the UDOT Training Calendar at this link:
http://www.udot.utah.gov/main//f?p=100:cal:0:::P60_CAL_ID:1

Completed UDOT Research

Research publications are valuable resources, documenting the results of important research projects. For a list of recently completed Research Projects, please visit the Research Division website at:

www.udot.utah.gov/go/research

If you would like to obtain an electronic copy or a printed copy of our completed research reports, please contact awakil@utah.gov.

Need a Literature Search?

The UDOT Research Division and Lester Wire Library provide an important service through literature searches. These searches help identify published information about a topic of interest. To request a literature search, provide a brief description and some key words and submit it to Abdul Wakil at awakil@utah.gov. or Joni DeMille at jdemille@utah.gov.

This is a quarterly publication that provides highlights of the UDOT Research Division's activities. We hope you find our newsletter informative and we look forward to your input.

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