AASHTO

RESEARCH

Cost-Saving Techniques for Bridges and Structures

SCOR RAC

State departments of transportation are committed to using research and innovation to meet the challenge of delivering more efficient and safer transportation systems. The projects on these pages, funded primarily through national programs, are a few among many that exemplify the high return on transportation research investments. The State Planning and Research (SPR) Program, as the nation's cornerstone state transportation research program, provides federal aid funding to the states to address top concerns and identify solutions at the state level.

The bridge and structure projects highlighted here are examples of state DOTs providing "Transportation Excellence through Research." The projects were compiled from the 2014 High Value Research solicitation carried out by the Value of Research Task Force, part of the American Association of State Highway and Transportation Officials Research Advisory Committee.

Weblink: Research Impacts 2014

Integrating Aesthetics and Engineering

Texas

Pre-cast arches were lifted into place.

When it came time to replace the 100-year-old West Seventh Street Bridge linking Fort Worth's downtown and cultural district, results from a series of TXDOT research projects were put to work. The innovative bridge design incorporated several low-cost rapid-construction techniques. The beams and deck, plus all 12 of the identical 300-ton arches, were pre-cast on a nearby site and lifted into place over the Clear Fork Trinity River.

Opened to traffic in 2013, the architecturally stunning bridge features a network of stainless steel hangers tying the graceful arches to the deck and separating pedestrians and bicyclists from traffic on 10 1/2-foot travel ways along both sides of the bridge. Construction took only four months, compared to a typical 12-month bridge replacement using traditional methods.

https://www.youtube.com/watch?v=lZ-9ASlV5Rg&feature=youtu.be

Guidelines for Better Culvert Repair, Rehabilitation and Replacement

Minnesota

Culverts under our roadways are critical channels for water and wildlife. Over time, however, culvert deterioration due to erosion, corrosion, freeze-thaw cycles and loading can damage the roadway above, even to the point of collapse. Fortunately, a wide range of effective repair, rehabilitation and replacement techniques have been developed in recent years to cost-effectively address culvert deterioration.

Researchers worked with the Minnesota Department of Transportation to review published literature and existing techniques from other state transportation departments, Minnesota cities and counties, and contractors. The information was then organized into illustrated, easy-to-use *Best Practices Guidelines* for repair of centerline culverts ranging from 24 inches to 72 inches in diameter.

The *Guidelines* explain such techniques as cured-in-place pipe liner (CIPP), sliplining, centrifugally cast concrete lining, spall repair and joint repair. Model specifications, special provisions and standard detail drawings make the *Guidelines* immediately ready for practice. MnDOT implementation efforts include a webinar and training sessions to support district offices in use of the *Guidelines.*

http://www.dot.state.mn.us/research/TS/2014/201401.pdf

Spirally Wound Liner Installation (Caltrans, 2011)

Using Carbon Fiber Reinforcement (CFR) to Reduce Bridge Repair Costs

Louisiana

Pile cap repaired with high-strength composites.

Louisiana implemented existing technology using carbon fiber and inorganic polymer coating for repairing the pile cap of an end bent on the Morganza Floodway Bridge. The concrete tee beam had widespread spalling at the girder bearing extending to the bearing plates. This damaged concrete was removed and the cleaned surface was covered with epoxy concrete to patch the damaged areas. All bearing plate locations were strengthened to prevent delamination by confining it with high modulus carbon composite wrapping and then coating it with an inorganic polymer that provides UV protection and prevents mold and mildew growth. The carbon fiber composite has complete chemical adhesion with the pile cap and its high modulus fibers will not allow the material to separate from parent concrete.

The overall cost was 67% less than the cost of providing an external reinforcement retrofit, 83% less than the cost of replacing the pile cap, and 90% less than the cost of using vacuum assisted resin transfer molding cap repair. The project clearly demonstrates the significant cost savings that can be realized from effective implementation of existing composites technology for repairing and rehabilitating damaged components.

http://www.ltrc.lsu.edu/pdf/2012/capsule_12_3ST.pdf

Low-Cost Test Leads to Savings in Drilled Shaft Construction

Illinois

Drilled shaft depths will be reduced.

Over the last eight years, the Illinois Department of Transportation has spent about $13 million per year on foundation piling, while over the same time period, use of drilled shafts increased from less than $1 million per year to almost $14 million. This project studied drilled shafts founded in weak Illinois shale (<100 ksf) and developed a new in-situ testing procedure as well as a corresponding design theory to reduce testing costs and shaft length (and thus construction expense).

Eight bridge sites have been evaluated using the Modified Standard Penetration Test (MSPT) which was identified as the most consistent and low-cost way to characterize the in-situ strength. A correlation was developed to relate the MSPT to the unconfined compressive strength which allowed design methods to be evaluated and resistance factors developed. Drilled shafts at two sites were load tested with an Osterberg Cell (O-cell) to validate the proposed testing and design procedure.

The new testing and design method is expected to reduce shaft depth by about 20 percent. With about 40 percent of shafts being founded in shale and typically one-third of the shaft expense due to rock, the expected annual savings is at least $400,000 per year.

https://apps.ict.illinois.edu/projects/getfile.asp?id=3088

Infrared Testing Detects Drilled Shaft Defects

Washington

Supporting columns for highway structures are often constructed of concrete poured into drilled shafts. Assessing the final integrity and strength of these underground concrete columns is an important quality assurance step in bridge construction. Thirty years ago this assessment consisted primarily of monitoring the properties of the delivered concrete mix and testing the strength of hardened cylinders cast above ground from the same mix. Recent trends in quality assurance, however, also include post-construction, non-destructive testing of the underground concrete column made possible by steel access tubes attached to the rebar cage into which the wet concrete is poured. One group of such methods makes use of sonic sensors lowered into the access tubes at various depths to measure the structural soundness of the cured concrete.

Recognizing the limitations and relatively high costs of sonic and other state-of-the-art quality assurance methods to inspect subsurface concrete columns, the Washington State Department of Transportation explored a relatively new testing method called thermal integrity profiling (TIP). In this 18-month study WSDOT conducted TIP testing on eleven drilled shafts at eight sites throughout the state, with various shaft sizes and several concrete mix designs. Thermal sensors installed in the access tubes measured the temperatures generated by the curing concrete, providing an overall assessment of the concrete shaft based on the presence or absence of intact, heat-producing concrete. TIP testing provides details of shaft integrity, including effective shaft size (diameter and length), anomaly detection inside and outside the reinforcement cage, cage alignment and proper hydration of the concrete. The ability to detect concrete volumes outside the reinforcing cage is perhaps the strongest feature of the TIP method as compared with sonic testing.

WSDOT is implementing the TIP test method on select bridge projects with multiple drilled shafts and has submitted the TIP technology for consideration by the Federal Highway Administration for its Everyday Counts initiative that recognizes proven but underutilized innovations.

http://www.wsdot.wa.gov/research/reports/fullreports/770.1.pdf

Thermal sensors in underground tubes measure the strength of poured concrete columns.

Confirmation of New Bridge Connection Performance Means Future Savings
Montana

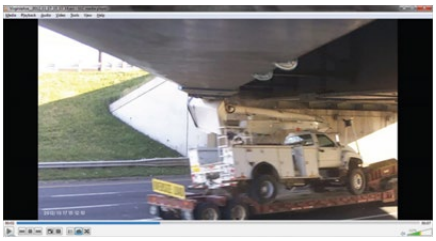
The Montana Department of Transportation (MDT) has completed a three-phase research project to verify the construction of Steel Pipe Pile/Concrete Pile Cap Bridge Support Systems as a viable option. In the most recent phase, confirmation of the connection method between the steel pipe and concrete cap was evaluated. It was found that concrete-filled steel tube (CFT) piles connected at the top by a concrete pile cap are a very cost effective support system for short and medium span bridges. The objective of the third project phase was to validate this new connection design methodology by physically testing connections designed according to the procedure used in the experimentation. In the experiment half-sized bridge caps were constructed and exposed to lateral forces while being subjected to a constant dead load. The specimens were tested to failure. The research confirmed that this methodology is a valid option.

A financial analysis component was included in the research. The potential cost-savings of this system were calculated by comparing the cost of this system to a drilled-shaft system commonly used by MDT. In particular, a single 6-foot diameter drilled concrete shaft and column system was compared to a driven CFT pile system with five 20-inch diameter piles. This analysis showed a potential cost-savings of $50,000 per bridge for the CFT pile system. It is anticipated that this system will now be used approximately two times per year in place of the drilled-shaft system, for a total savings of $100,000 per year. The useful life of this research product (new CFT connection design methodology) is anticipated to be 20 years. This results in a benefit/cost ratio of 6.78:1 and a return on investment of 5.78.

http://www.mdt.mt.gov/research/projects/structures/seismic.shtml

Lower-cost connections perform well.

Bridge Hits Captured on Pilot Web-Based Monitoring System
Indiana



Web video captures truck cargo hitting bridge.

Off-the-shelf data acquisition systems have advanced over recent years, becoming readily available, reasonably priced, and more user-friendly. High-speed wireless cellular networks have also been established, offering the potential for remote monitoring as never before. These monitoring systems, coupled with a web-based, real-time data display, can become very effective asset management tools for bridge owners.

The Virginia Avenue Bridge near Indianapolis, Indiana, has a superstructure that is often impacted by truck cargo because of its 14-ft. underclearance due to resurfacing below. Impacts with the bridge increased 11-fold, going from three reported impacts prior to resurfacing, to 33 reported impacts after; for a total of 36 known impacts as of July 2012. This bridge was selected as a case study to pilot and verify a prototype web-based bridge monitoring system. The monitoring system captured irrefutable data showing that the bridge was actually being impacted in a month more than twice as much as the reported incidents from an entire year. Thus, the bridge was being impact loaded more than 26 times as much as was being reported to INDOT.

The prototype system was targeted specifically to monitor and alert key personnel of any impacts. Additionally, the monitoring system automatically captured and delivered high definition video footage of the impact event.

http://docs.lib.purdue.edu/jtrp/1535/

Predicting Pile-Driving Vibrations to Prevent Damage
Michigan

Pile Driving at M-25 Site

Driving steel piles deep into the ground with impact hammers is often required to construct bridge foundations. However, the hammers induce vibrations in the pile that spread through the soil in waves, potentially causing soil settling and cracking of nearby structures, such as existing bridge components, buildings or underground utilities.

The Michigan Department of Transportation and the University of Michigan installed sophisticated vibration sensors (accelerometers and geophones) at various depths and distances from piles at five different construction sites. They used the collected data to develop attenuation rates for the vibrations propagating away from the driven pile and created a predictive spreadsheet tool for determining safe pile driving distances from existing structures.

Using information about soil characteristics, type of pile driving hammer and other factors surrounding a planned bridge project, MDOT engineers can apply this new tool in the design stage to minimize property damage during construction.

http://www.michigan.gov/documents/mdot/RC1600_451885_7.pdf

New Design Reduces Settlement of Bridge Approach Slabs

Louisiana

Placement of geogrid with strain gages.

The Louisiana Department of Transportation and Development has adopted a new design methodology for bridge approach slabs at locations where differential settlement is anticipated. The settlement problem is very common in southern Louisiana where bridge embankments are often constructed over deep, highly compressible organic soil. This causes a sudden change in slope or fault at the joint between the approach slab and the bridge deck and/or the roadway pavement and the approach slab respectively.

The new design involves increasing the flexural stiffness of the slab allowing contact loss and support from the embankment. The weight of the slab and the traffic load are carried by the two ends of the slab rather than distributed over its length. The joint between the roadway pavement and approach slab rests on geosynthetic-reinforced soil. Reinforcement increases the soil's bearing capacity and reduces the footing settlement by distributing the slab and traffic loads over a wider area.

To validate the new design, the Louisiana Transportation Research Center instrumented the traditional and reinforced approach slabs at the Bayou Courtableau Bridge and monitored settlement over a two-year period. The monitoring program showed that the new design performed as predicted with roughness profiles superior to those from the traditional design. Extra costs associated with the new design method are minimal when compared with the expenses for maintenance and repair at traditional installations.

https://www.ltrc.lsu.edu/pdf/2014/FR_520.pdf

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Calculating Appropriate Fees for Oversize/Overweight Vehicles

Texas

The research project evaluated the damage that Oversize/Overweight vehicles (including exempt vehicles) cause to the transportation infrastructure (including roads and bridges). The researchers performed a thorough cost analysis to quantify all direct and indirect costs associated with this damage. Once all cost elements were determined, the researchers provided recommendations for permit fees and fee structure adjustments including highway maintenance fees to properly compensate for the damages caused.

To address the damage determination, the researchers calculated the ratio of the overall impacts to the infrastructure between freight vehicles operating within defined, legal gross vehicle weight (GVW) and axle load limits and the state allows to operate beyond those limits. This was done by applying the concepts of Load Equivalency Factor (LEF) and Equivalent Damage Factor (EDF). A mechanistic approach calibrated to Texas conditions was applied that is consistent with the approach proposed by Federal Highway Administration in its Pavement Damage Analysis Tool (PaveDAT) and based on the Mechanistic-Empirical Pavement Design Guide (MEPDG). By selecting this approach, the research provided TxDOT a method that is also supported and promoted at the federal level.

After reviewing and summarizing existing databases, representative axle configurations and vehicles, routes and pavement structures were identified to calculate an average fee structure for the state; however, the developed methodology was implemented in a spreadsheet that enables the calculation of specific fees for a given vehicle configuration on a given route.

http://www.utexas.edu/research/ctr/pdf_reports/0_6736_2.pdf

Bridge damage from heavy load on overpass.