Wyoming Technology Transfer Center

WY T² LTAP

Local Technical Assistance Program

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Phone: 800-231-2815
Fax: 307-766-6784
wwweng.uwyo.edu/wyt2
wyt2c@uwyo.edu

T² Roads on the Range

The national Local Technical Assistance Program mission is to foster a safe, efficient, and environmentally sound surface transportation system by improving skills and increasing knowledge of the transportation workforce and decision makers.

County Culverts Inspection Program

Wes Werbelow and Khaled Ksaibati

Background

Ever since the introduction of the National Bridge Inspection Standards (NBIS) in 1971, there has been a tremendous amount of effort put into bridge rehabilitation programs and safety inspections. However, even though the NBIS has been shown to be a successful program and useful tool for bridge inspection, the procedure only applies to structures with spans over 20 feet. The Wyoming Department of Transportation (WYDOT) inspects these bridges in accordance with the NBIS on regular intervals, but there is currently no formal inspection procedure in place to assess the condition of short span structures, especially culverts. Culvert inspection and maintenance is the responsibility of the agency that owns them. Many counties in Wyoming do not have the funding, or the resources, to maintain detailed records on the condition of their culverts. The result is culverts can become neglected and fall into a state of disrepair and problems or deficiencies are not noticed until a much larger problem arises, such as roadway settlement or flooding. In order to aid county governments in Wyoming to assess the conditions of their culverts and to better allocate limited funding, a comprehensive inspection methodology was developed by the Wyoming T²/LTAP.

Methodology

The culvert methodology was developed in accordance with WYDOT's existing bridge inspection procedure, the NBIS Coding Guide, FHWA's Culvert Inspection Guide, the PONTIS CoRe Element Report, and several other inspection documents. One of the primary objectives of the culvert methodology was to

County Culverts, continued on p. 6

Inside this issue

Wyoming Technology Transfer Center

1000 E. University Ave., Dept. 3295
Laramie, WY 82071

wyt2c@uwyo.edu
wwweng.uwyo.edu/wyt2

PH: 307-766-6743
FAX: 307-766-6784

New Additions to DVD Library

The Wyoming Technology Transfer Center offers a comprehensive library of transportation literature. Below are the recent DVD additions to the library.

PA7323 – DVD – Critical Thinking and Analyzing Problems and Decisions (Insight Media): An introduction to critical thinking with an emphasis on solid knowledge base and good communication skills.

PA7324 – DVD – Social and Ethical Issues in Design and Technology (Insight Media): Explores the social, lifestyle, ethical and ecological considerations that designers must address while moving through the design cycle.

ST7394 – DVD - Solution to Cross-Median Crashes and Rumble Strips a Sound Investment (FHWA): A two part DVD first detailing different methods to help mitigate cross-median crashes and then how centerline and shoulder rumble strips are a cost effective road safety addition.

M7368 – DVD – Crack Filling/Sealing (Ohio DOT): Volume I of Ohio DOT'S series Best Practices, demonstrates proper procedures for crack filling and sealing

M7369 – DVD – Field Guid to Testing Deicing Chemicals (MLT Group): A walk through of the different types of field testing that can be done to evaluate deicing chemicals and guidance on what data should be collected.

M7370 – DVD – Culvert Replacement (Ohio DOT): Volume II of Ohio DOT's series Best Practices, gives common practices for successful culvert replacement.

M7371 – DVD – Successful Roadside Revegetation Using Native Plants (US DOT): This DVD documents the processes and techniques used in successful and innovative projects that used native plants for roadside revegetation.

M7372 – DVD - Snow and Ice Control, Winter Formula (Ohio DOT): Volume IV of Ohio DOT's series Best Practices, details the common practices for snow and ice control.

M7373 – DVD – Spray Injection Patching (Ohio DOT): Volume III of Ohio DOT's series Best Practices, concerning proper spray injection patching procedure.

M7374 – DVD – Berming (Ohio DOT): Volume IV of Ohio DOT's series Best Practices, details care and maintenance on road shoulders.

Upcoming Workshops

February 4-5, 2014; Casper
- -OSHA 10-Hour Safety Training
- -Preventing Runovers and Backovers

March 4, 2014; Rock Springs
- -Asphalt Paving

March 6, 2014; Gillette
- -Asphalt Paving

March 25-26, 2014; Laramie
- -Intelligent Compaction

April 1-2, 2014; Casper
- -Safety Congress

Signs and Pavement Markings for the MUTCD that Meet the Needs of the Driver

***Paul Carlson**, Ph.D., P.E.,*
Research Engineer, Texas A&M Transportation Institute, Texas A&M University, College Station, Texas;
***Cathy Satterfield**, P.E.,*
Safety Engineer, Office of Safety, Federal Highway Administration, Matteson, Illinois; presenters, 2013 APWA Congress

Nighttime driving is statistically more risky than daytime driving—the nighttime crash rate is about three times higher than the daytime crash rate. While many factors are at play during nighttime conditions, drivers generally acknowledge that their nighttime visibility of the roadway and roadside is significantly reduced compared to their daytime visibility. Traffic signs and pavement markings are made with retroreflective materials to help increase their visibility during nighttime conditions. Retroreflective materials are unique in that they shine headlamp light back toward the driver.

The Manual on Uniform Traffic Control Devices (MUTCD) requires most signs and pavement markings to be retroreflective but until recently, it did not provide guidance or define how retroreflective signs and pavement markings should appear to meet the needs of the nighttime driver. As a way to increase nighttime safety, the MUTCD was revised in January 2008 to include minimum retroreflectivity maintenance levels for traffic signs to help ensure that nighttime drivers can see and read the signs in time to react safely. Agencies had until June 13, 2014 to identify and use one of the sign retroreflectivity management methods listed in the MUTCD to maintain regulatory and warning sign retroreflectivity at or above the minimum retroreflectivity levels in Table 2A-3 of the MUTCD. Agencies are expected to add signs other than regulatory or warning to their method as resources allow.

The new MUTCD minimum sign retroreflectivity levels were based on the nighttime needs of older drivers to see and read traffic signs. As a result, the minimum criteria provide guidance for agencies to ensure that their signs are adequately bright enough for all drivers at night. In addition, Table 2A-3 restricts the use of some retroreflective

Signs and Pavement, continued on p. 3

Signs and Pavement, continued from p. 2

sheeting materials for signs because even when new and unweathered, those materials do not meet the nighttime needs of older drivers.

The Federal Highway Administration (FHWA) is now working on developing minimum retroreflectivity levels for pavement markings. As the FHWA moves forward on their pavement marking efforts, their supporting research has produced new safety-related findings regarding pavement markings.

In January 2013, research was presented at the Transportation Research Board's Annual Meeting that included statistical correlations between pavement marking retroreflectivity and safety. Previous research on this topic had provided mixed results and sometimes counterintuitive findings. Using data from Michigan, the researchers evaluated relationships between crashes and longitudinal pavement marking retroreflectivity. The retroreflectivity data consisted of pavement markings measurements representing white edge lines, white lane lines, yellow edge lines, and yellow centerlines.

The data included crashes and retroreflectivity measurements from 2002 to 2008. Only nighttime crashes that occurred at non-intersection and non-interchange segments during the non-winter months (between April and October) were considered (wet crashes were also excluded). While statistically significant findings were identified for both rural two-lane highways and freeways, a specific example of the findings for edge lines on rural two-lane highways demonstrates that nighttime and single vehicle nighttime crashes can be reduced by 9.5 percent when the edge line retroreflectivity is increased by 100 mcd/m2/lx. The findings for centerline pavement marking retroreflectivity showed that as the retroreflectivity decreases to 150 mcd/m2/lx and less, the effects in terms of nighttime crashes become statistically significant.

Not only does the retroreflectivity of the pavement markings appear to be linked to safety, but so does the width of the pavement markings. Recent research results from an FHWA-funded study performed by TTI show that wider edge lines on rural two-lane highways are a cost-effective, statistically-sound approach to reducing run-off-the-road crashes and fatalities. Overall, the findings demonstrated that wider edge lines on rural two-lane highways can reduce non-winter, non-intersection/non-interchange run-off-the-road crashes 15% to 30%. Interestingly, findings from these analyses do not support the use of wider edge line pavement markings for multilane highways.

In the past, many states adopted wider edge lines (six-inch instead of four-inch) for a variety of reasons but adoption has been slow and uncoordinated without sound empirical findings to support the policy change. The recent study sponsored by the FHWA included data from three states (Michigan, Kansas and Illinois) and provides information that agencies can use to make sound decisions about the use of wider edge lines. The study included rural two-lane highways as well as multilane highways. Although it is well known that causation is hard to establish based on observational studies, results from the statistical analyses consistently indicate that wider edge line pavement markings on two-lane rural highways lead to lower crash frequencies and reduced severity.

Wider edge lines are an effective countermeasure in their own right and can also be considered in combination with other countermeasures such as rumble strips. Ongoing research at TTI is starting to identify how wider edge lines and rumble strips mitigate different crash types. While rumble strips address crashes where the driver is distracted, drowsy, or otherwise inattentive and can be effective even when obscured by snow or rain, wider edge lines seem to be most effective where the driver is looking at the roadway/striping, or where the driver's peripheral vision is picking up the marking.

Traffic safety professionals continue to improve the signs and pavement markings on our nation's highway to provide a safer and more comfortable driving experience. As research findings continue to better define the relationships between nighttime visibility and roadway safety, agencies can develop specifications and practices to ensure adequate visibility for nighttime drivers.

Bringing Intelligent Compaction to Wyoming

Kam Ng, Assistant Professor
Khaled Ksaibati, Director
Wyoming T²/LTAP Center
University of Wyoming

Current Challenges of Road Compaction

When constructing roads, the performance of a road is highly dependent on the quality assurance and control (QA/QC) of field compaction. Compaction equipment is essential in ensuring that the field compaction attains the desired design requirements and specifications. Due to the heterogeneity of pavement materials, variability in compaction equipment and operators, and challenges in maintaining uniform lift thickness, achieving the required compaction requirement is a daunting task during road construction. Current compaction QC/QA programs are based on in-situ spot test techniques that cover less than 1% of the compacted area. State and local officials utilize these spot test techniques, using stiffness or density tests, to evaluate the compaction of a road. These tests reveal mechanistic properties of the soil or pavement that are measured at several points along a roadway as shown in Figure 1. These point measurements are used to represent the compaction quality of the entire paved area. However, sufficient compaction quality may not be achieved in several locations within the compaction area, which can lead to reduced long-term pavement quality and increased road maintenance costs.

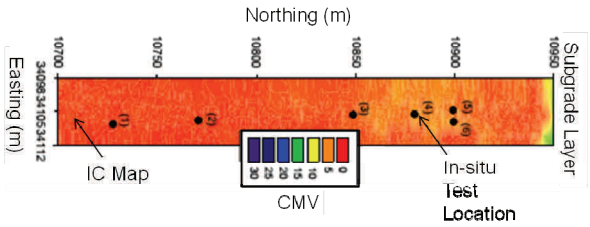

Figure 1. Spatial comparison of in-situ test locations and intelligent compaction map at a subgrade layer (adapted after White et al., 2010)

What is Intelligent Compaction?

To overcome the challenges listed above, a new compaction method known as intelligent compaction (IC) is being investigated throughout the United States. Intelligent compaction involves the use of compaction equipment that is equipped with a Global Positioning System (GPS), machine -integrated measuring sensors and control systems as shown in Figure 2. The integrated GPS provides a complete geographic information system-based record of the construction site.

IC technologies by different manufacturers yield different measurement values (MVs) of soil and/or asphalt stiffness from each compaction lift as summarized in Table 1. The CMV value is a ratio of vertical drum acceleration amplitudes at the operating vibration frequency. The CCV is an algebraic relationship of multiple vertical drum vibration amplitudes. The HMV indicates the stiffness of soil or asphalt pavement. The Kb or Evib is a stiffness value taking into consideration the vertical drum displacement and the drum-soil contact force. Collected MVs, in conjunction with GPS, allow for real-time compaction data to be gathered to spatially analyze the compaction levels of soils and pavements. These integrated sensor and control systems provide the capability of adjusting compaction effort (i.e., vibration amplitude and frequency) automatically based on the real-time and continuous feedback of variation in material properties during the compaction process.

Unlike the in-situ spot test techniques, IC provides 100% coverage for compacted earth materials and pavement conditions as represented by an IC map shown in Figure 1. By having immediate or real-time evaluation capability, weak-compacted areas during construction can be identified instantaneously and the required mitigation works to improve the compaction can be performed efficiently. In contrast, unnecessary over compaction can be avoided during construction.

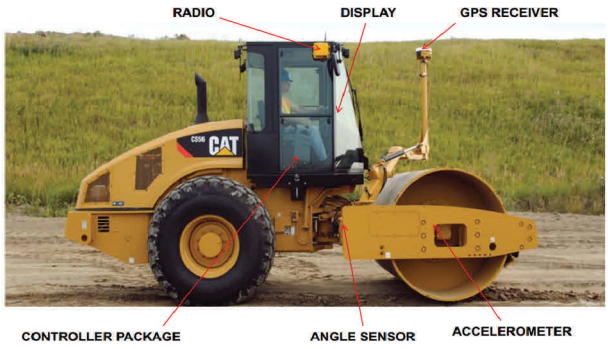

Figure 2. A typical vibratory single drum roller equipped with a GPS, sensors, and control systems

Benefits of Intelligent Compaction

Intelligent compaction has been evaluated by many state Departments of Transportation (DOTs) as the future technology to 1) improve road compaction efficiency and productivity; 2) lower construction cost and duration; 3) provide a better tool for QA/QC of field compaction; 4) improve road pavement uniformity, performance and service life; and 5) lower overall road maintenance cost. Furthermore, the benefits of intelligent compaction synergizes with the current momentum towards the Accelerated Bridge Construction (ABC) as well as the Every Day Counts (EDC) initiative of the Federal Highway Administration (FHWA). It is believed that the benefits experienced by other states will be similarly realized in the state of Wyoming.

Intelligent Compaction, continued on p. 5

Intelligent Compaction, continued from p. 4

Table 1. List of IC equipped roller models and measurement values for soil and asphalt pavement compactions (adapted after the Transtec Group, Inc., 2013)

Manufacturer	Model	Soil/Asphalt	MV
Ammann/Case	ACEplus	Soil	Soil Stiffness Value (K_b)
Bomag	VarioControl	Soil	Vibration Modulus (E_{vib})
	AsphaltManager	Asphalt	
Caterpillar	AccuGrade	Soil/Asphalt	Compaction Meter Value (CMV)
Dynapac	DCA-S	Soil	Compaction Meter Value (CMV)
HAMM(Wirtgen)	HCQ	Soil/Asphalt	Hamm Measurement Value (HMV)
Sakai	CIS	Soil/Asphalt	Compaction Control Value (CCV)
Volvo	Trimble retrofit	Soil	Compaction Meter Value (CMV)

Intelligent Compaction in the United States

Research project 21-09, initiated by the National Cooperative Highway Research Program (NCHRP), was completed by Mooney et al. (2010) to evaluate the reliability of IC and to develop specifications for the application of IC. As part of this research, five state DOTs constructed projects as indicated in Figure 3, with one each in Colorado, Florida, Maryland, Minnesota and North Carolina, which were identified for data collection and analyses. The research has led to the development of preliminary recommended construction specifications for the application of IC in soils and aggregate base materials. Six options for QA and guidelines for subgrade and base layers have been established as a result of this study. Other states shaded in green in Figure 3 (i.e., California, Georgia, Indiana, Iowa, Kansas, Louisiana, Maine, Mississippi, New York, North Dakota, Ohio, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Vermont, and Wisconsin) have piloted their research projects on the IC. For instance, the research project on IC conducted by White et al. (2010) with three demonstration projects in Iowa has led to the development of special provisions for using Roller Integrated Compaction Monitoring (RICM) technologies on three hot mix asphalt (HMA) overlay pilot projects in Iowa. The pilot research project in Texas has enabled the Texas DOT to draft a special specification titled "Quality Compaction Using Intelligent Compaction Rollers" (2012), which outlines the construction and quality assurance/control requirements. The recently completed demonstration project in Utah has enabled the establishment of scientific-sound procedures to use IC as a quality assurance tool for in-place HMA densities (George Chang et al., 2012). Three upcoming demonstration projects will be conducted in Washington, Idaho and Kentucky in 2014.

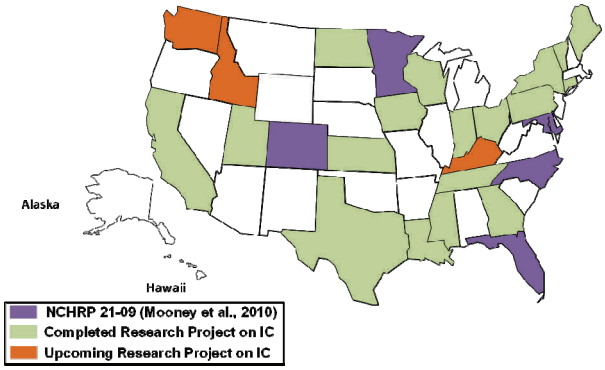

Figure 3. Status of intelligent compaction research projects in the United States

Intelligent Compaction in Wyoming

Research will be conducted at the University of Wyoming with the primary objective of studying the implementation of IC technologies for road constructions in Wyoming. Working closely with FHWA and WYDOT, a 1½-day workshop is scheduled on March 25 - 26, 2014 in Laramie, WY, to disseminate IC technologies to state engineers, county engineers, city officers, consultants, contractors, and pavement practitioners in Wyoming. The workshop agenda will be finalized and distributed to all relevant agencies. In conjunction with Wyoming Department of Transportation and Wyoming Contractor Association, a field demonstration of IC technologies will be arranged in summer 2014. Stay tuned on announcement of upcoming IC events.

County Culverts, continued from p. 1

apply an overall condition rating of "EXCELLENT", "GOOD", "FAIR", or "POOR" to the culvert, much like WYDOT currently does with larger bridges. Other objectives included being able to incorporate the level of debris in the pipe into the overall condition rating as well as have the ability to analyze specific elements of the culvert in order to recognize maintenance steps. This will allow counties to easily identify what is deficient in the culvert and rank structures based on maintenance needs.

The inspection procedure included any single barrel culvert pipe with a diameter of 36 inches or larger, as well as any multiple barrel culvert of 24 inches in diameter or large. Basic information was gathered for every structure, such as the county road name, structure type, barrel shape, top-to-bottom diameter, side-to-side diameter, length, type of usage (drainage, irrigation, or underpass), and the inlet/outlet type. On top of this, the procedure also gathered the percentage of the pipe that was filled with debris and element level inspections taken from the PONTIS CoRe Element Report. These element level inspections included examining cracking/corrosion, scour, and settlement/deformation. Each of these elements included 3 condition states on which to rate the culvert. Each condition state provided detailed information on what should be inspected in order to rate the culvert at that particular condition state. Each element level inspection included visual aids to help in the rating process.

Overall Condition

In order to determine the overall condition rating of the culvert, a decision tree was developed that used the element level inspections along with the level of debris as governing factors. This decision tree can be seen in Figure 1.

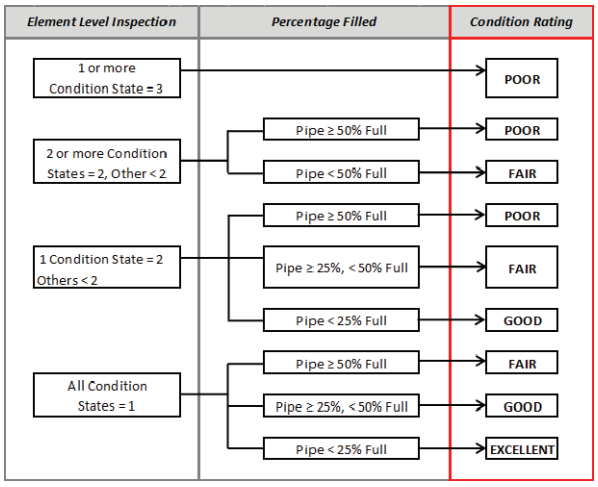

Figure 1: Culvert Condition Rating Decision Tree

The decision tree starts with consideration at the element level inspections. If one element received a condition state of 3, the structure automatically received a rating of "POOR" because a condition state of 3 represents that the structure has failed in some manner or another and needs replaced. The other categories involve structures which two or more of the elements received a 2, a structure which only one element receive a condition state of 2, and a structure which all elements received a condition state of 1. From here, the percentage of the pipe filled with debris was examined, where 25% was selected as a cut-off point due to low flows becoming hindered at this point, while 50% was selected because of the decreasing level of free surface above the midway of the pipe and the increased chance of further blockage. Using this criterion, the condition rating could then be generated.

Goshen County

In order to test the methodology, the inspection procedure was implemented in Goshen County in Wyoming. This county was selected based on its large ranching and farming communities which meant a higher likelihood of irrigation ditches and canals, resulting in a larger number of culverts. Every county road was driven and each qualifying structure was inspected using the methodology and the location was gathered using a laptop controlled GPS system.

After data collection was completed, a total of 235 qualifying structures were located in Goshen County. A breakdown showing the average and median values along with the standard deviations can be seen in Table 1.

Table 1: Average and Median Values for Culverts in Goshen County

Input	Avg	Median	Std. Dev
Top to Bottom Diameter (in.)	51.37	48.00	17.65
Side to Side Diameter (in.)	62.53	56.00	28.58
Length (ft.)	49.73	46.00	15.76
% Filled	11.13	0.00	19.83
Corrosion/ Cracking State	1.64	2.00	0.66
Scour State	1.34	1.00	0.52
Settlement/ Deformation State	1.29	1.00	0.50

It can be seen that for the level of debris the average was 11.13% while the median was 0%. This indicates that at least over half the pipes inspected did not have problems with debris blockage. Finally, the element level inspections of corrosion/cracking, scour, and settlement/deformation must be looked at. As can be seen, corrosion has the highest average and median values. With a median value of 2, this suggests that at least half of the pipes inspected have

County Culverts, continued on p. 7

County Culverts, continued from p. 6

moderate corrosion or cracking issues. Scour and settlement/deformation had very similar values compared to one another with scour having a slightly higher average value. Clearly, corrosion/cracking is of the largest concern in Goshen County based on these values.

After applying the condition rating decision tree, condition ratings for every inspected culvert were determined. A breakdown of the number of each structure for each condition rating can be seen in Figure 2. Over 40% of the structures in this county are in "POOR" or "FAIR" conditions, meaning these are the pipes that either need replaced or need to be heavily monitored.

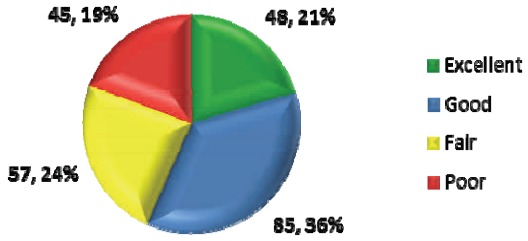

Figure 2: Goshen County Culvert Condition Ratings

One of the benefits of this study is providing counties the opportunity to determine the overall investment they have in culverts qualifying for this inspection procedure. Counties can also determine the investment needed to bring all culvert pipes to a "GOOD" rating. A "GOOD" rating should ultimately be the goal of each county as this ensures each pipe is in a completely functional and safe state. By using WYDOT's 2012 Weighted Average Bid Prices, the overall investment of culvert pipes in Goshen County was calculated and can be seen in Table 2.

Table 2: Goshen County Cost Summary

Structure Type	Current Investment	Cost to Achieve "FAIR"	Cost to Achieve "GOOD"
CMP	$ 1,642,290	$ 191,180	$ 354,893
RCP	$ 141,096	$ 9,623	$ 13,361
Steel	$ 114,645	$ 103,985	$ 117,717
Concrete Box	$ 252,063	$ -	$ -
Total	*$ 2,150,094*	*$ 304,788*	*$ 485,971*

At just over $2.1 million, Goshen County has a sizeable investment in culvert pipes. This is too sizeable investment to not have a methodology in place to monitor the conditions of these pipes. It can also be seen that an investment of just under $500,000 would bring deficient pipes up to an effective and safe level.

Statewide Implementation

By having this comprehensive methodology in place, counties now have the knowledge of the condition of their culverts and can more efficiently allocate their already limited funding. This knowledge also gives counties the tools to pursue additional funding. The methodology will be distributed to every county by early next spring in order to begin implementation. The LTAP center will also be providing workshops on the culvert inspection process to train county personnel and ensure uniformity in data collection.

Wyoming T2 Center
University of Wyoming
1000 E. University Ave., Dept. 3295
Laramie, WY 82071

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28th Annual Regional Local Road Conference

By Josh Jones

The regional local road conference is held once a year in Rapid City during the third week of October. The 2013 conference began with opening remarks from the program manager of the South Dakota LTAP, Ken Skorseth. Skorseth thanked everyone involved and mentioned that the conference continues to grow. This year there was a record 283 people attending. Some very innovative ideas were presented as part of the "You Show Us Awards." A county in North Dakota won for an invention that helps install signs. Pete Husman from Sheridan County presented on a new chloride application process. Bryan Keierleber, the NACE SC Region VP, talked about recent bridges his county constructed using the Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS). Old rail cars are being used for the spans, which greatly increased the cost savings.

Steve Monlux from LVR consultants gave a presentation on good gravel. Monlux talked about gravel specifications that the SDDOT developed and about the need for using specifications when putting the job out for bid. Monlux also presented some techniques for testing the gravel at the site to make sure the user is getting quality materials. Ken Skorseth presented on the SDDOT/SDLTAP gravel road experimental project. The project looked at using three types of gravel according to the SDDOT gravel specifications. The types included sub standard gravel, standard gravel, and modified gravel. Test sites in three counties have been monitored for the last three years. The modified gravel had less maintenance and the road conditions were remarkably better. Also the amount the gravel spread out was a lot less with more of the gravel staying on the road. The standard gravel performed better than the sub standard gravels, with reduced corrugations and pot holes.

The afternoon session started with a presentation about full depth reclamation with cement by Dave Rettner from American Engineering Testing Inc. Rettner talked about using recycled cement as a base for paved roads by getting the cement to act like soil. The final panel talked about the stabilization of subgrade and bases using chemical additives. The panel included speakers from four different county road and bridge departments in North and South Dakota. The use of Permizine and Base 1 were discussed with the pros and cons of each additive. Mostly the complaints were about using the chemicals on substandard bases for which the material created pot holes, but when used on the right soils, the chemicals created very good sub grades.

The second day began with a presentation from Dave Rettner about foamed asphalt and the cost savings that can be utilized. The costs have been around $120,000 to $150,000 per mile. The pictures from the presentation showed nice paved roads embedded with little pieces of RAP. Paul Cammack from Black Hills Energy spoke on natural gas vehicles. He highlighted some agencies that have switched their entire fleets into natural gas vehicles. Once the fleets have been transitioned to part time natural gas vehicles, the cost savings come from paying only $1.20 a gallon for natural gas. The concluding presentation was on communicating and dealing with elected officials by Jon Mill, a retired engineer from Burleigh County in North Dakota. He mentioned four main areas; listen to them, get facts about the issues, look at all the alternatives, and keep a daily diary of tasks. The conference is always very informative on the challenges facing local roads in the upper plains and Wyomingites are encouraged to attend!