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Workshop on the Use of Traffic Speed Deflection Device Data in Network- and Project-Level Pavement Decisions

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Workshop on the Use of Traffic Speed Deflection Device Data in Network- and Project-Level Pavement Decisions

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Preface

Traditionally, pavement management decision-making has relied on surface cracking as an indicator of structural condition. With early-intervention preservation activities to extend the life of pavements, however, surface cracks no longer are a reliable indicator of structural condition. In the past 15 years, traffic speed deflection devices (TSDDs) have been developed to measure structural condition at traffic speed. A 2018 Transportation Research Board (TRB) workshop examined TSDD technology, devices, data collection, and research. The 2019 TRB workshop, which is detailed in this circular, focused on the application and benefits of TSDD data in network- and project-level pavement decisions, based on experience from early adopters of the technology. This circular synthesizes the presentations and discussions from the 2019 workshop with a goal of producing a source of information on current uses and practices.

ACKNOWLEDGMENTS

The committee thanks the following standing committees that were cosponsors of the workshop: Pavement Condition Evaluation, General and Emerging Pavement Design, Structural Requirements of Asphalt Mixtures, and Geotechnical Instrumentation and Modeling.

The committee recognizes the following members who were contributors and editors of the e-Circular: James Bryce, Marshall University; Gonzalo Rada, Wood Environment and Infrastructure Solutions Inc.; and Nadarajah Sivaneswaran, Federal Highway Administration. They provided significant input in the preparation of this document as based on the discussions at the workshop.

Contents

Introduction

Traffic speed deflection devices (TSDDs) are devices designed to measure pavement deflections or deflection velocities in response to loads applied by trucks moving at or near prevailing traffic speeds. Deflections in response to a known load have been used for many decades to estimate the structural capacity of pavements, albeit primarily at the project-level due to the time-consuming nature of testing using devices such as the Benkelman Beam or the Falling Weight Deflectometer (FWD). The emergence of TSDDs has provided the opportunity to capture structural capacity measurements at the network-level, which have been demonstrated to be valuable in pavement management decision-making (*1*, *2*).

Many publications have demonstrated the types of TSDDs (*3*), the type and quality of data produced by TSDDs (*4*), the use of TSDD data for pavement modeling (*5*), comparisons of TSDD measurements with FWD measurements (*6*) and the integration of TSDDs with other equipment for pavement evaluation (*7*). Demonstrations of the use of TSDDs have also occurred as part of Transportation Pooled Fund (TPF) studies [e.g., the ongoing TPF-5(385)] and workshops at past Transportation Research Board (TRB) Annual Meetings, among other events. In other words, the research and literature regarding TSDDs has been built over the past several years, and TSDDs are beginning to be implemented in pavement management practice.

This E-Circular presents results from a 2019 TRB workshop regarding the use of TSDD data in network- and project-level decisions both domestically and internationally. The objective of this E-Circular is to broadly disseminate the materials presented in the workshop so the pavement engineering community is aware of the current state of practice. Six presentations were given and each are summarized as separate chapters:

- History of Deflection Testing Devices, Analysis, and Use, Peter Schmalzer, NCE;
- Virginia Traffic Speed Deflectometer Network Testing, Brian Diefenderfer, Virginia Transportation Research Council;
- Kansas Traffic Speed Deflectometer (and More) Experimental Findings, Richard Miller, Kansas Department of Transportation;
- Traffic Speed Deflectometer Testing in Germany: Lessons Learned and Findings, Dirk Jansen, Federal Highway Research Institute (BASt);
- Traffic Speed Deflectometer for Network-Wide Pavement Strength Monitoring: New South Wales, Australia, Experience, Hassan Mounzer, ARRB Systems; and
- Automated Collection of Continuous Integrated Pavement Condition Data: The South African Experience 2015–2018, Simon Tetley, ARRB Systems South Africa (Pty) Ltd.

The final chapter of this E-Circular documents questions and discussions that occurred during the workshop and references are presented after that.

History of Deflection Testing Devices, Analysis, and Use

PETER SCHMALZER
NCE

This presentation presented a retrospective of pavement deflection testing, beginning with Hveem using a linear variable differential transformer (LVDT) and covering up until modern times. Frank Hveem was an early pioneer in collecting pavement deflections using an LVDT and produced an allowable deflection table as a function of traffic and thickness. Following Hveem, deflection testing moved toward using the Benkelman beam, which was first tested on the Western Association of State Highway Officials road test around 1955 and is still in production. After the Benklemen beam was introduced people started developing ways to make it mobile—e.g., the California deflectograph. Then came the Dynaflect, which measured deflections in the time domain instead of relative to location reference points and used a 2,000-lb peak to peak oscillatory load. Because the Dynaflect did not produce enough load, the Road Rater introduced a variable frequency load. The FWD was produced after the Dynaflect and changed the sinusoidal loading to an impulse load. Following relatively little change in deflection testing technology for nearly 25 years, the Traffic Speed Deflectometer (TSD), developed in Denmark, was introduced outside of Denmark by being sold to Transport Research Laboratory (TRL) in England in 2005. Now, TSDDs represent the most current evolution in pavement deflection measurements. This process is shown in the slides presented as Figure 1 through Figure 3.

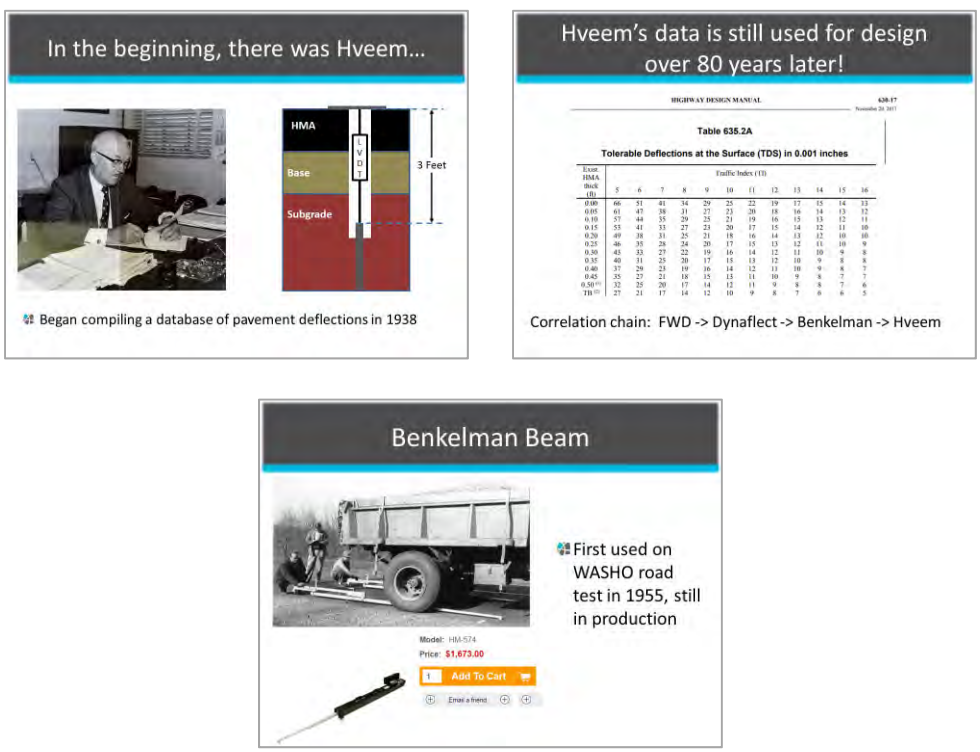


FIGURE 1 Slides describing the evolution of deflection testing over time.

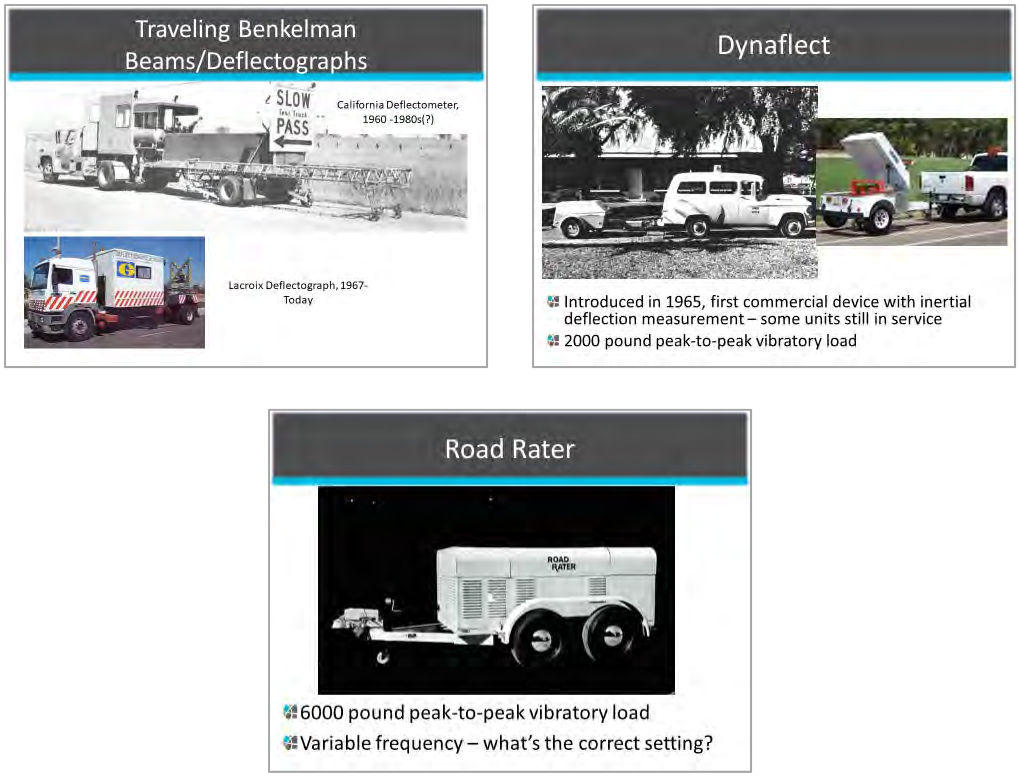


FIGURE 2 Additional slides describing the evolution of deflection testing over time.

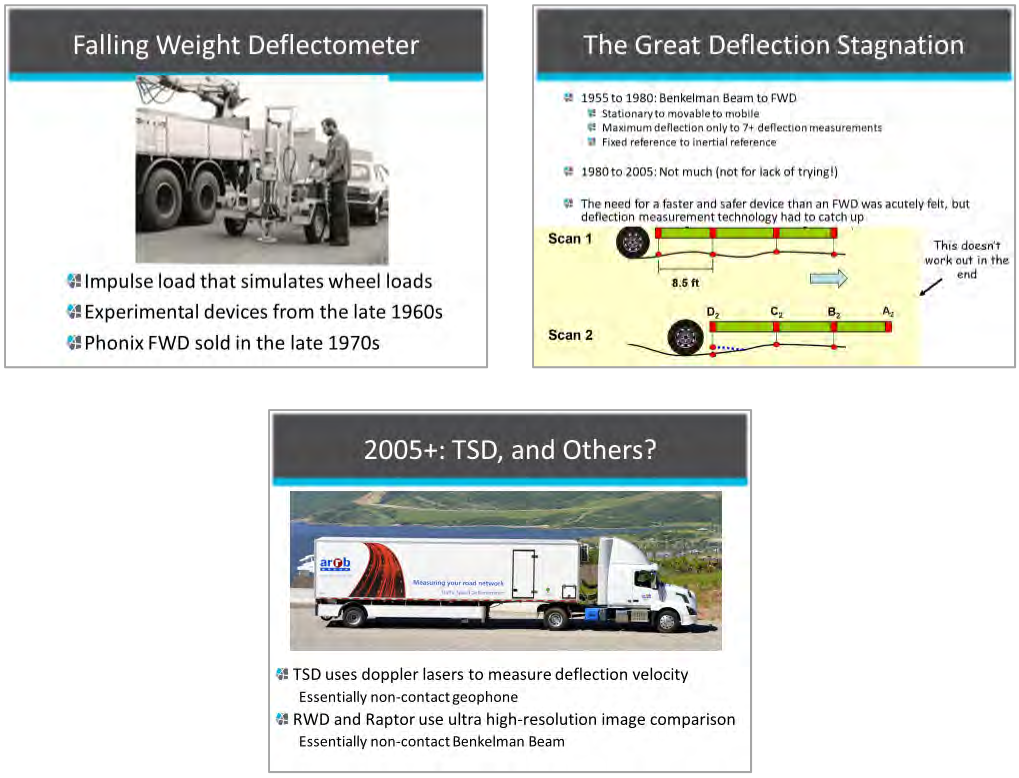


FIGURE 3 Additional slides describing the evolution of deflection testing over time.

The next part of the presentation discussed the reasons and need for deflection testing. Engineers use deflection testing to estimate model parameters that can in turn be used to predict other model responses (i.e., obtain structural model to predict distress and performance data). The deflections are often used in backcalculation, which uses the deflection data to estimate layer properties. Engineers use backcalculation in pavements because obtaining only the maximum deflection does not provide enough necessary information (e.g., strains, material properties, etc.). This explanation is given in the slides shown in Figure 4 through Figure 6.

The presentation was concluded by revisiting the evolution of deflection testing over time, which is shown in Figure 7.

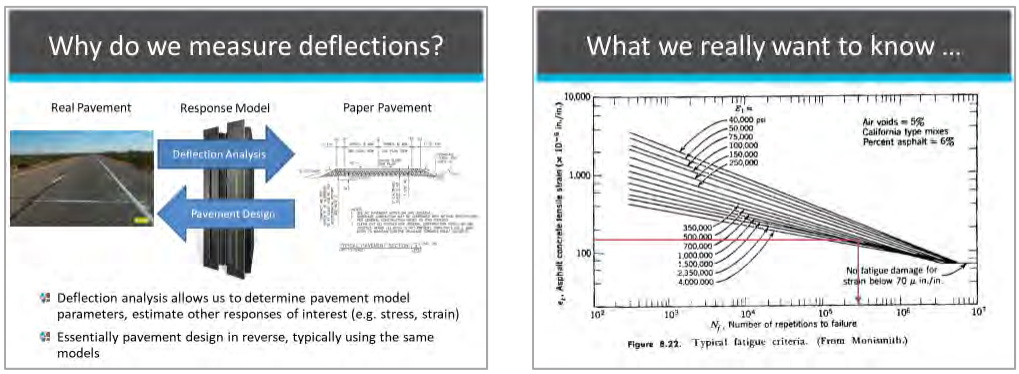


FIGURE 4 Information obtained from deflection measurements.

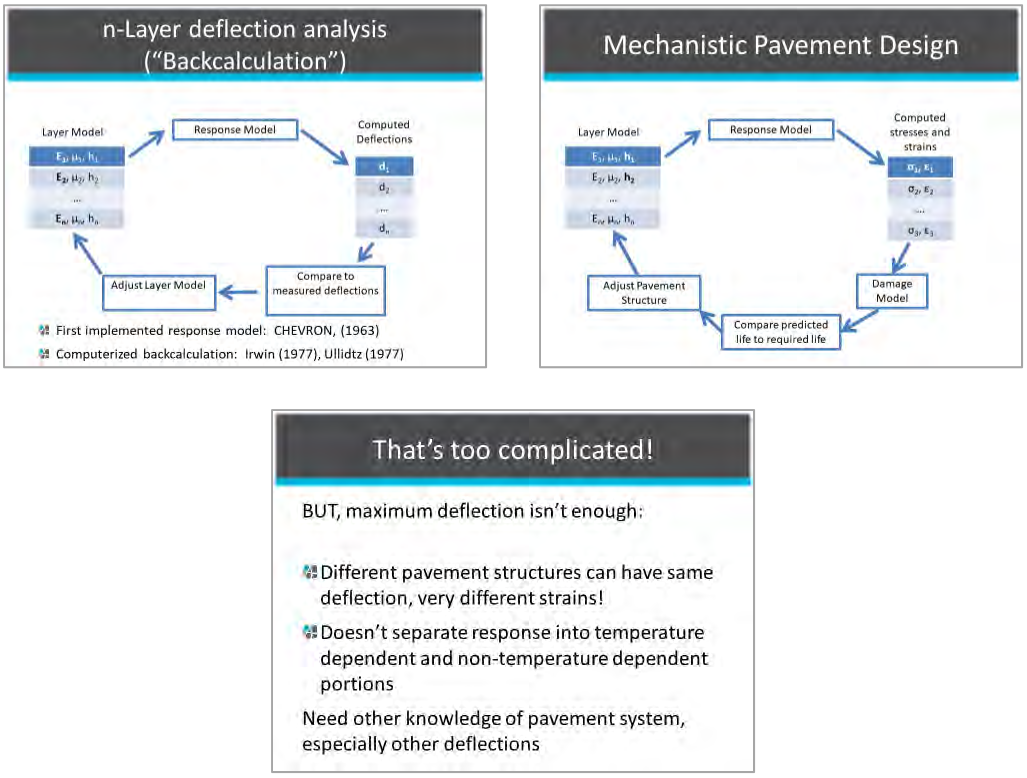


FIGURE 5 Description of how deflections are used.

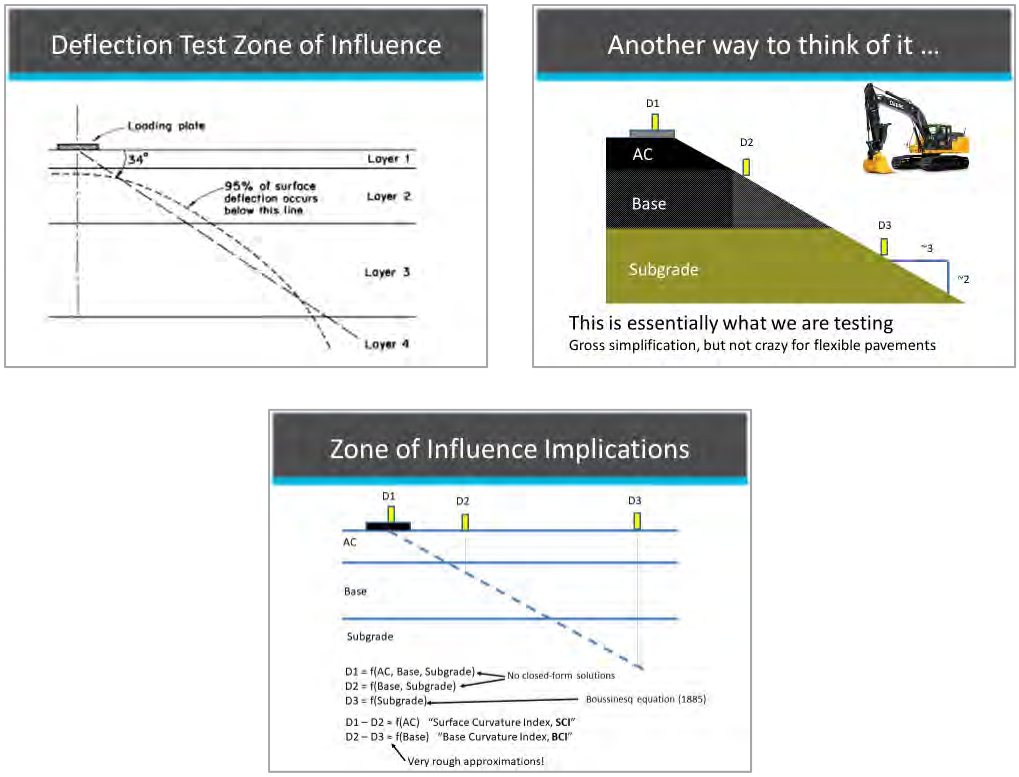


FIGURE 6 Description of deflection testing zone of influence.

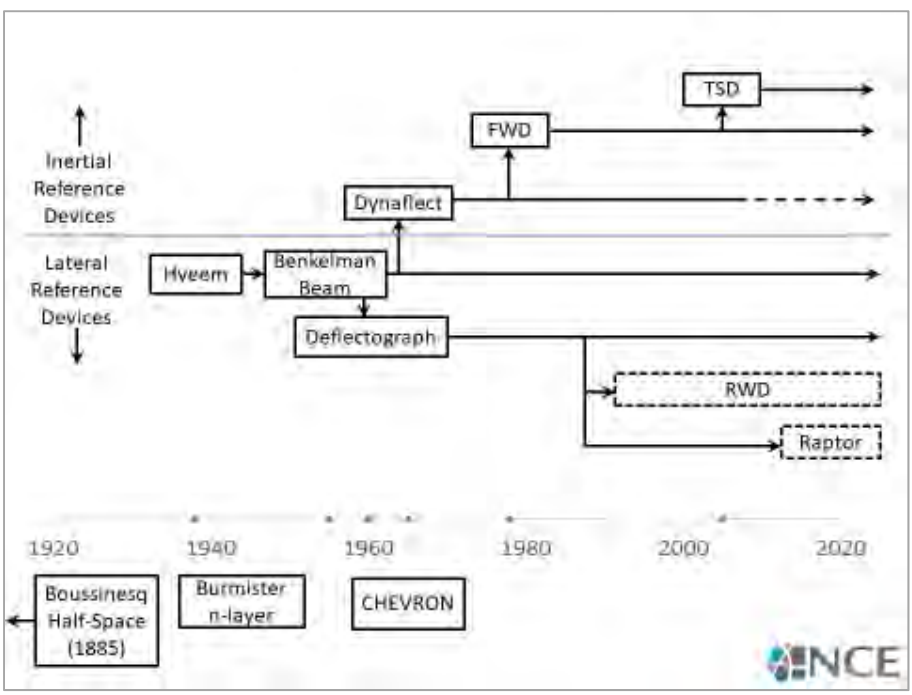


FIGURE 7 Evolution of deflection testing.

PRESENTER BIOGRAPHY

Pete Schmalzer is an Associate Engineer with NCE. He began his career as an FWD operator for the Cornell Local Roads Program while working on his undergraduate degree and has spent much of the 19 years since operating, maintaining, and calibrating FWDs as well as analyzing and using the data in various pavement research, evaluation, and design projects. He was fortunate to be involved in a TSD data analysis project for Idaho Transportation Department in 2015, and since then has worked on four follow-on projects

Virginia Traffic Speed Deflectometer Network Testing

BRIAN DIEFENDERFER
Virginia Transportation Research Council

The next presentation detailed the experience of the Virginia Department of Transportation (DOT) with TSDDs. In 2017, Virginia DOT contracted to have nearly 4,000 mi of its Interstate and primary network tested using iPAVe, which combines TSD and ARRB's pavement surface condition assessment equipment. This presentation highlighted the work conducted and preliminary results from the TSD testing. The Virginia DOT intends to implement the findings from this study into the pavement management system (PMS) so structural capacity measurements can be used along with pavement surface condition measurements to make more informed decisions regarding pavement rehabilitation.

The presentation began by providing background and description of previous TSDD testing, and noted that the Virginia DOTs main work has been performed using the TSD, although they are also interested in seeing the other devices. It was noted that the Virginia DOT performed a large-scale network-level FWD testing of the Interstate, and it took approximately 3 years to complete, thus the interest in TSDDs. The presentation outlined previous work, including the second Strategic Highway Research Program (SHRP 2) research (*3*), FHWA work (*4*) and the TPF study TPF-5(282) that ran from 2013–2017. The TPF-5(282) study covered 5,928 mi total over nine agencies, and the presentation described a comparison of multiple data collection cycles with FWD and TSD at the same location. The presentation noted that it was promising that the TSD identified a strong and consistent set of deflections at a location that was recently rehabilitated.

The presentation then showed the network-level decision process used by the Virginia DOT to include structural capacity measurements in the PMS. It was noted that the TSD is not currently implemented in PMS decision-making, but the Virginia DOT is working toward that goal. Additionally, the presentation described some of the results from Idaho's comparison of the TSD and FWD. The Idaho Transportation Department used homogenous pavement management sections for the comparison and compared the pavement structural number calculated using both devices and the results were significantly correlated. The slides describing this background information are shown in Figure 8 through Figure 10.

The presentation then presented several examples of data collected with the TSD and demonstrated that there is no correlation between pavement surface condition and the structural condition. It was noted that the Virginia DOT executed a contract for approximately 4,000 mi of pavement collection that was completed in 2017, and they are developing the mechanisms for integrating the data in the PMS. The TSD data collection also included the international roughness index (IRI), pavement surface distresses, cross-slope, and ground penetrating radar (GPR). The presentation then described the Virginia DOT's plans for the data and showed examples of the data that were collected, including where bridges were identified using deflection data. The slides on Virginia data collected are in Figure 11 and Figure 12.

Traffic Speed Deflectometer Devices

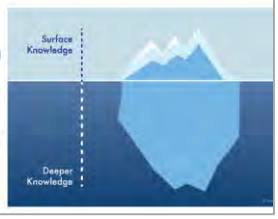
- What are they?
  - Can measure traditional surface-observable condition
  - Doppler lasers measure deflection slope (TSD)
  - Other technologies coming to market
- What can we do with them?
  - Assess the structural capacity of pavements at traffic speed (~50mph)
  - ...and measure rutting, ride quality, cracking, pavement and roadway images, cross slope

Benefits to Agencies

- Allow realistic production for network-level testing
  - Significant portions of a network can be covered daily
  - Include structural properties in PMS decision-making
- All this with...
  - Increased operator and public safety
  - Continuous (nearly) rather than discrete measurements

Background

- Pavement decision making
  - Based on surface observed distresses
  - Structural capacity data on a pavement network is rare
- Structural testing
  - Current state of the practice is FWD
    - Lane closures
    - Discrete data



Previous Research

- FHWA study, 2011 & SHRP2 study, 2013
  - Identified several traffic speed deflection devices
- Benefits included
  - Continuous collection
  - Collection at near highway speeds
- Future work should study accuracy and analysis methods

FIGURE 8 Background slides describing previous TSDD research.

Previous Research

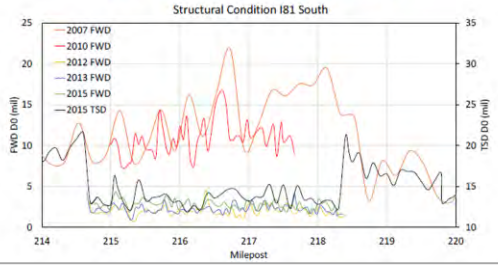
- FHWA study, 2012-2015 & TPF-5(282), 2013-2017
  - Focused on the devices identified previously
- Further studied TSDD data
  - Compared vehicle-measured pavement deflection with embedded sensors
  - Compared qualitative ranking of structural condition with FWD
  - Identified analysis parameters

TPF-5(282)

- Demonstrate network-level TSD testing
  - Two testing cycles
  - Two days per cycle
  - 9 agencies
- Agencies selected test routes

State	Miles
California	980
Georgia	646
Idaho	1,040
Illinois	400
Nevada	352
New York	595
Pennsylvania	567
South Carolina	726
Virginia	622
Total	5,928

TPF-5(282) Data Example



TPF-5(282) Data Example

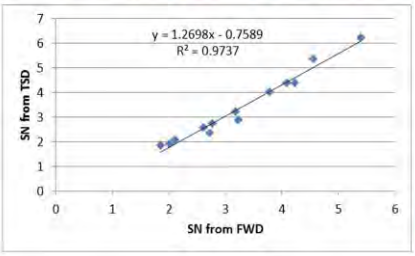


FIGURE 9 Additional background slides.

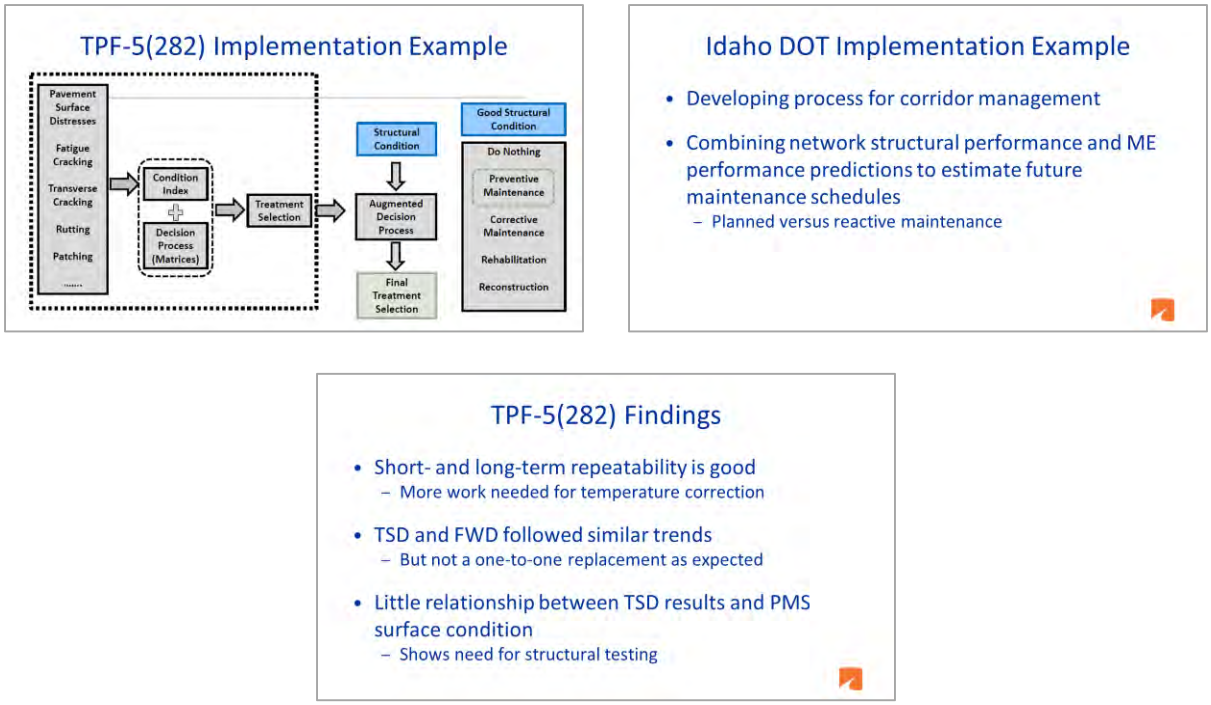


FIGURE 10 Additional background information for Virginia DOT TSDD testing.

FIGURE 11 Slides demonstrating data collected in Virginia.

FIGURE 12 Additional slides demonstrating data collected in Virginia.

The presentation then shifted to discuss the current TPF-5(385), and noted that it began in late 2018; there are openings for agencies to join. The TPF will collect data using the TSD owned by ARRB, and will attempt to use the Dynatest Raptor when it becomes available. The pooled fund is seeking to develop specifications for data collection and guidelines from PMS applications with the data.

PRESENTER BIOGRAPHY

Brian Diefenderfer is an Associate Principal Research Scientist at the Virginia Transportation Research Council (the research division of the Virginia DOT) in Charlottesville where he has worked for the past 15 years. His research focuses on providing better tools for Virginia DOT to use when designing and rehabilitating its pavement network, including pavement recycling techniques and pavement structural testing. Diefenderfer received his Bachelors, Masters, and Doctoral degrees in Civil Engineering from Virginia Tech and is a licensed Professional Engineer in the Commonwealth of Virginia.

Kansas Traffic Speed Deflectometer (and More) Experimental Findings

RICHARD MILLER
Kansas Department of Transportation

The Kansas DOT hired ARRB in July of 2018 to collect approximately 500 mi of pavement condition data using the TSD and laser crack measuring system. It was noted that the Kansas DOT has a reasonably robust collection programs already, but acknowledges that structural, surface, and texture data are collected independently. The site selected for the study described in this presentation is an Interstate route that is primarily full-depth asphalt with known areas of deep stripping. One question the Kansas DOT sought to answer is how extensive the stripping is at the location, how detrimental the stripping is to the functioning of the pavement, whether new areas are developing the same problem, and whether surface condition data can be used to infer structural condition. Also, the Kansas DOT is seeking to find what other information TSDDs can provide about their pavements and bridges that is currently missing. The presenter noted that very preliminary results were available at the time of abstract submission, but even some of the early results are proving insightful for the DOT. Kansas DOT had the TSD on their pavement network twice recently in June 2018 (approximately 500 mi on I-70) and November 2018 (approximately 312 mi on various routes). The slides discussing their research inquiries and the early testing are shown in Figure 13.

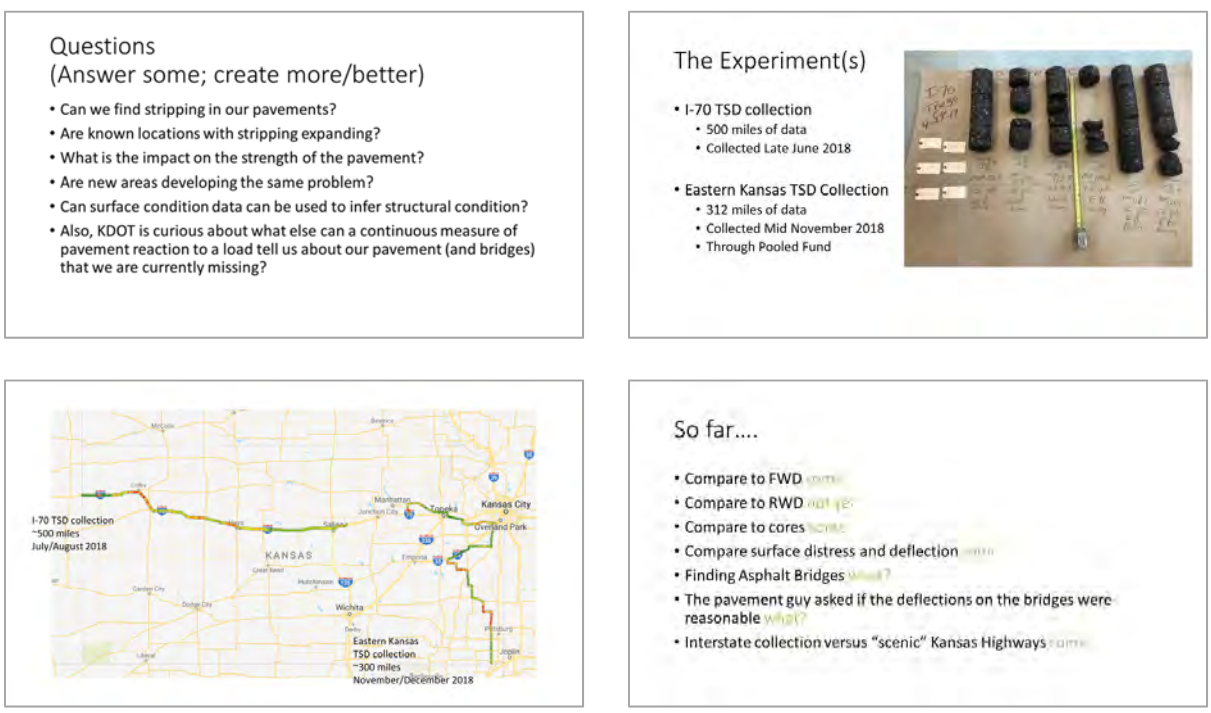
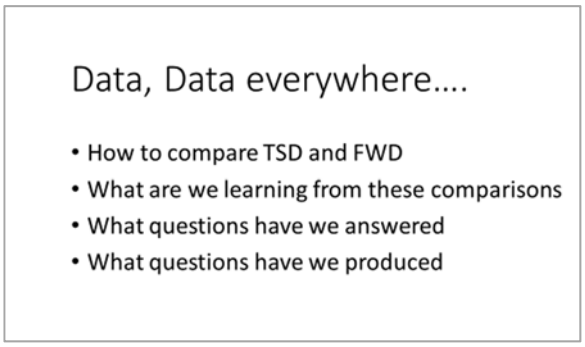


FIGURE 13 Questions and testing by the Kansas DOT.

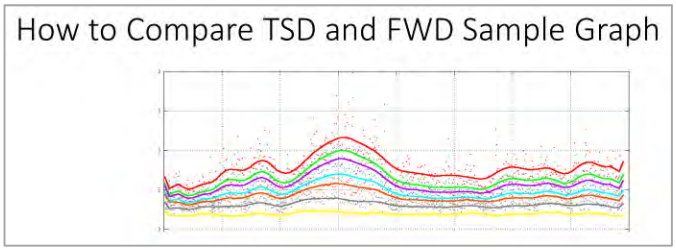
The Kansas DOT also had the rolling wheel deflectometer perform some testing in 2008, and it demonstrated variability in pavement deflections, which was much more than what was seen in the results of FWD testing. It was noted that the Kansas DOT performs approximately 1,300 mi of FWD testing at 0.1-mi increments annually. The presentation then discussed a comparison of TSD and FWD data, which had to be performed qualitatively. For the comparison in this presentation, the FWD deflections are shown as positive and TSD data are shown as negative—this convention was selected for convenience in showing the data. It was also noted that the TSD data has more resolution than the FWD, and this difference in resolution can be used to examine variability. The slides discussed during this part of the presentation are shown in Figure 14 through Figure 18. The presentation author also included notes with the slides, and those notes are presented with each slide.

The presentation then demonstrated cases where the TSD data showed a large discrepancy between the deflections close to the wheel and those further away; it was hypothesized this may be a case that reflects slippage cracking and delamination. It was noted that comparing the TSD and FWD has demonstrated interesting results, but also raised many questions. For example, some sites were identified that the data may indicate sinkholes below a strong pavement; it was posited that maybe the TSD data could help the DOT identify additional unknown sinkhole locations (though it was stressed that the results are preliminary and not conclusive). Finally, although the presentation did not cover concrete pavements, the Kansas DOT is investigating the use of the TSD for concrete pavements and it was noted that the preliminary results are promising. The slides for this section of the presentation (along with the speaker notes) are shown in Figure 14 through Figure 18.

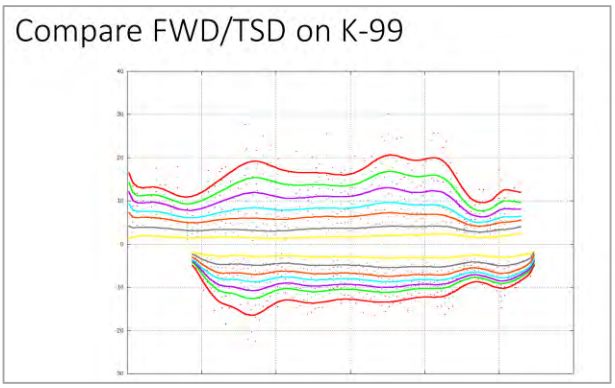


Honestly, I was not much interested in comparing FWD and TSD data until I started doing it. I expected the two to yield similar answers (and often they do), but sometimes they do not and that is interesting. Both TSD and FWD can produce a lot of data. So I was trying to find a good way (other than statistics) to make comparisons. The next slide will show you how I did it.

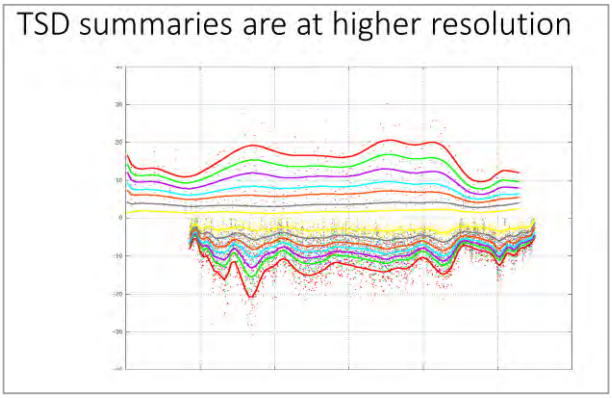
FIGURE 14 Comparing TSD and FWD in Kansas with author's notes.



The data is FWD data from I-70 in Thomas County from 2018. The points represent deflections. Colors show measurement location compared to the load (0, 8, 12, 18, 24, 36, and 60 in.). Lines are simply moving average representations of the dots. TSD data will be shown on the bottom half and FWD is on top. A mirror would say that the data was perfectly matched. So, we look to see how good is the mirror, plus where it is different, why?

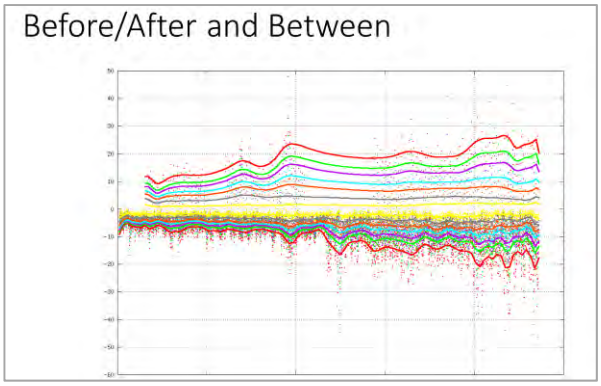


This is a State Route K-99 over about 10 mi. Again, the data above is from FWD with the yellow being the deflection farthest from the load and the top red being the deflection under the FWD load. The bottom red is the load at the TSD load. This is a decent reflection meaning the two means of collecting deflections are giving similar results. However….

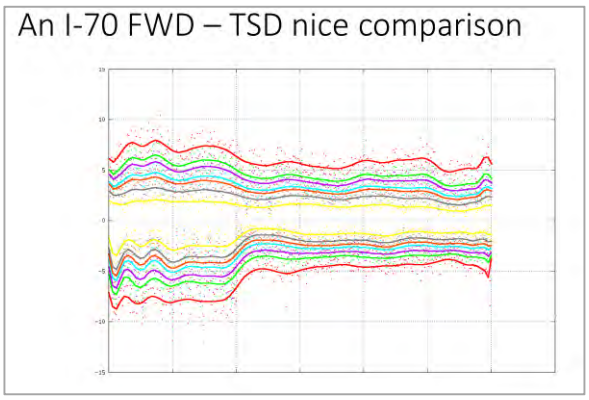


To create the previous slide, I summarized the TSD data to 0.1 mi to match the Kansas DOT FWD spacing. This is the same data, but the TSD is at 0.01-mi spacing now instead of summarized to 0.1 mi. It is a little more difficult to see the mirror. Therefore, do we need more resolution than 0.1 or not? That is a future question.

FIGURE 15 TSD and FWD data from Kansas with author's notes.



The FWD data here was collected in 2017 before a project; the 2018 TSD data was after a reconstruction project. So we would expect the TSD deflections to be smaller than the FWD deflections and they are. Also, note that the TSD collected right through the town of Girard. We can't or don't collect FWD through these areas because of traffic control issues.



On the Interstate, we do not have the cities and such, so the comparison are a little more direct (also the data were already in 0.1-mi resolution). This shows about 30 mi across a county of Interstate FWD and TSD comparison. Looks good to me.

At first glance, the comparison isn't terrible, but eventually the question becomes why is the TSD D0 so much different from the D8 and other locations? I will also note that we had major problems with this pavement AFTER both of these datasets were collected!

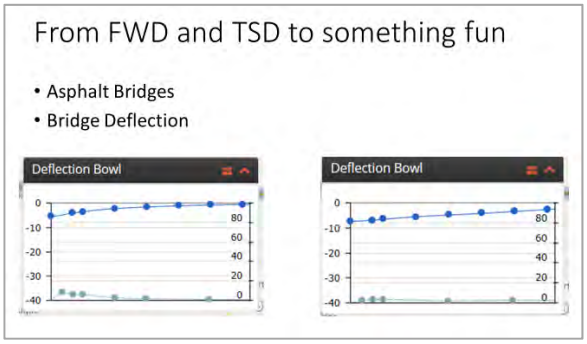
FIGURE 16 Additional TSD and FWD Data from Kansas with author's notes.

The pavement with the big (relative) separation between D0 and D8 is shown in the picture taken as the TSD ran in June 2018. The next picture was 3½ months later. Was the TSD telling us something the FWD was not? Measuring with a moving load versus a static position drop?

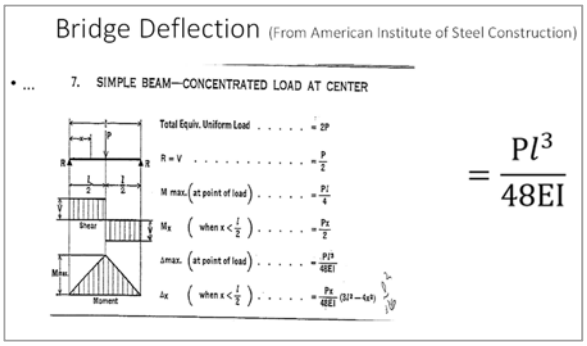
While I was patting myself on the back for figure out the previous slide, I got to thinking about the fact that we had the same problem in the other direction. So, again the forward picture taken during TSD collection on the left and during our mill and fill on the right. What did the TSD data look like here?

We do not see the same gap between the D0 and D8 despite that the pavement surface ended up falling apart here too. In fact, the prior slide picture comes from the right side of this graph where the TSD shows very little deflection for any of the sensors. Therefore, I understand there are over 11,000 researchers here. Maybe some of them can figure this out. I will note that other locations on I-70 also show that separation between D0 and D8 with the TSD but not for the FWD.

FIGURE 17 Slides and speaker notes for Kansas DOT testing.



Enough of the comparisons of FWD and TSD. There is obviously lots of work to do there still, but there are more fun questions elsewhere. Here are two deflection bowls. The load is applied at the left of each one and the blue dots at the top represent the deflections away from the load. The one on the left is typical (although these do not have much deflection). The one on the right looks like a straight line. Therefore, the load is pulling the pavement down in a linear fashion. Why would this be? The answer of course is a sinkhole is under this pavement, so the pavement (which is relatively strong) is bridging over a week earth. We knew these spots were here, but it made us start thinking that we could find other places that could literally swallow us up someday. If time permits, I can talk about some mine remediation that we are testing with the TSD based on this finding. **174.53 and 174.568 are the two bowls.**



So, since we were finding "Asphalt Bridges" where the pavement was acting like a bridge over sinkholes, I got to wondering what we might find on our "Non-Asphalt" Bridges." I thought back to my college days and remembered that we computed deflections based on the load on a bridge. I pulled out an old Steel Manual and found the formula for "Simple Beam—Concentrated Load at Center." What I was thinking was that where the TSD (a known ~Point Load) was moving across a bridge, we would get the deflection (actually an average over some length) that we could compare to the theoretical deflection based on the formula. Now, I am the pavement management person, so I found some bridge people and said why not? After a couple hours of excuses, they finally said something like; well it might tell us something? So, someone with some time to play…."

FIGURE 18 TSDD testing on bridges with author's notes.

PRESENTER BIOGRAPHY

Richard Miller earned a BS in Civil Engineering from the University of Kansas in 1988. After graduation, he was hired by the Bureau of Transportation Planning at the Kansas DOT. He held several positions in planning culminating as the Statewide Planning Engineer. Responsibilities in those positions included travel demand forecasting and modeling, statewide planning, corridor analysis, break-in-access requests, origin–destination studies, and long-range transportation plans for metropolitan planning organizations and the state. He served on several state and national committees related to transportation planning, freight, and planning data. In 1998, Miller moved to the Bureau of Materials and Research in Kansas DOT as an Assistant Geotechnical Engineer. His duties were primarily to oversee and run the optimization-based PMS. He also inherited pavement evaluation oversight at some point. Miller still has these duties, but organizational changes have him in the Bureau of Construction and Materials at Kansas DOT with a title of Pavement Management Engineer.

Traffic Speed Deflectometer Testing in Germany

Lessons Learned and Findings

DIRK JANSEN
Federal Highway Research Institute

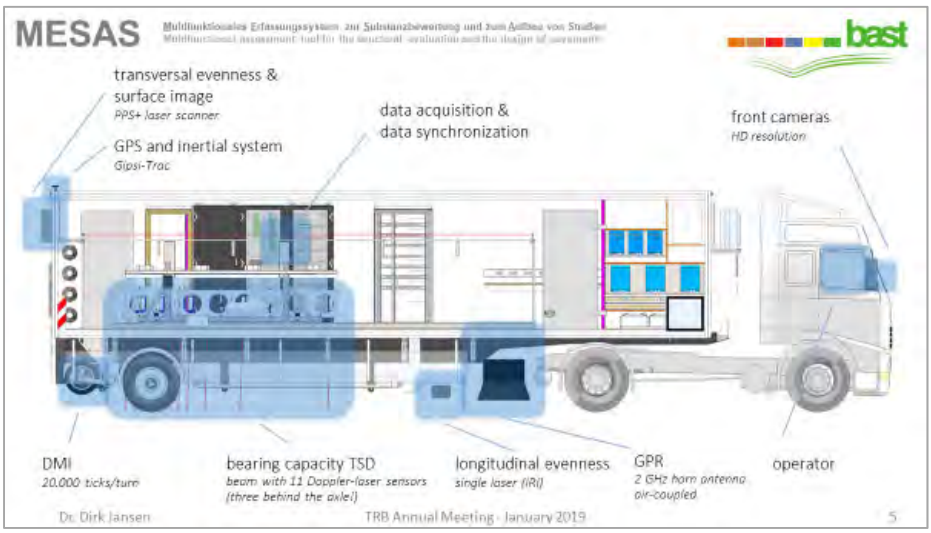
The presenter began by noting that Federal Highway Research Institute (BASt) has owned a TSD since the beginning of 2018 and has included additional equipment such as GPR and cameras (Figure 19). The combined equipment is referred to using the acronym MESAS, which, when translated to English, refers to Multifunctional Assessment Tool for the Structural Evaluation and the Design of Pavements. BASt uses a TSD with 11 Doppler sensors—eight in front of the loading axle and three behind the axle. The presenter also noted the benefit of having multiple cameras, specifically for the case of interpreting GPR data. The slides introducing the BASt equipment and testing are shown in Figure 19 and Figure 20.

The testing by BASt included basic analyses with the TSDs including the influence of loading levels and the influence of temperature on readings. BASt also conducts some quality management exercises, including conducting comparisons with other TSD devices. BASt is currently preparing for implementing the MESAS data in network-level pavement management. It was noted that BASt collected approximately 4,000 km of data in 2018 and have plans to collect approximately 10,000 km of road data in 2019. The size of the data is significant—approximately 3.5 terabytes of data per 1,000 km of roadway. The presentation slides describing the data collection are shown in Figure 21 and Figure 22.

The presentation then described some findings and questions that BASt will seek to answer. First, BASt is interested in understanding the best methods for performing the calibration of the TSD. To investigate the selection of calibration sites, BASt selected two pavements: a "soft" county road (i.e., low-bearing capacity) near BASt and a "stiff" road (i.e., high bearing capacity) on a major route. BASt then collected data along each pavement using the TSD and compared various areas of interest; they found that the choice of the calibration section and calibration procedure could influence the results. Based on the investigation, BASt decided to use "soft" sections of approximately 1 km in length to perform calibration. The slides describing the findings are shown in Figure 23 through Figure 26. The presentation also noted the value of collecting deflection basin information, as well as the importance of reporting not only the results, but also how they were collected and which technique was used to perform the calculations.

A question following the presentation sought clarity on the type of calibration performed, and the presenter noted that it is a system calibration. For example, they check the angles of the lasers—it was noted that the calculations of deflection slope are very sensitive to the angle of the sensors, but this is an issue of the operator and not a manufacturer issue.

Finally, the presentation described upcoming BASt projects using the TSD, including the testing of the pavement network, the development of quality assurance protocols and other tests to facilitate the use of the TSD. The slides discussing upcoming work are shown in Figure 27.



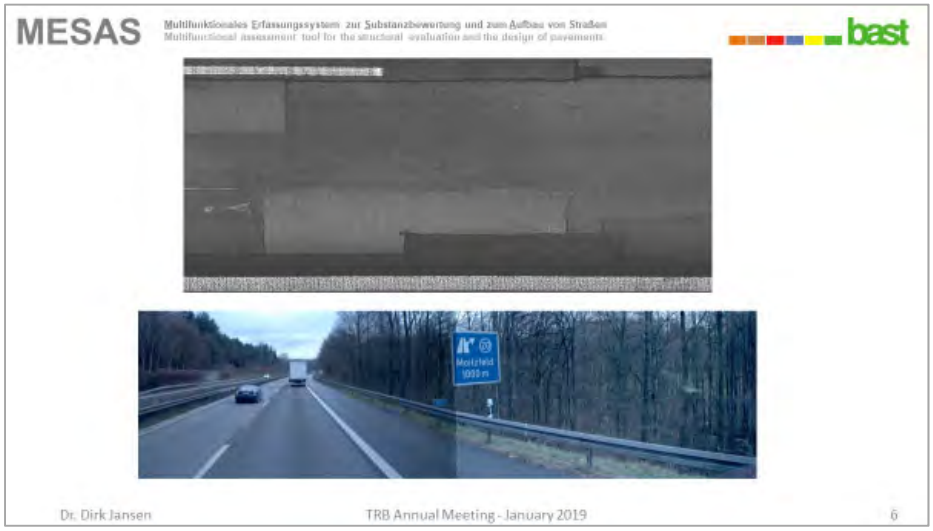


FIGURE 19 Introduction to BASt equipment and testing.

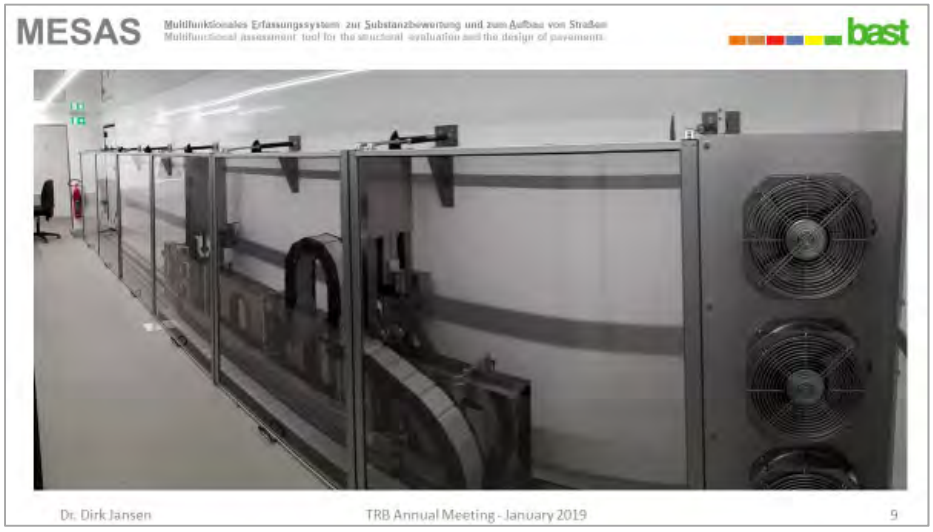


FIGURE 20 Introduction to BASt equipment and testing continued.

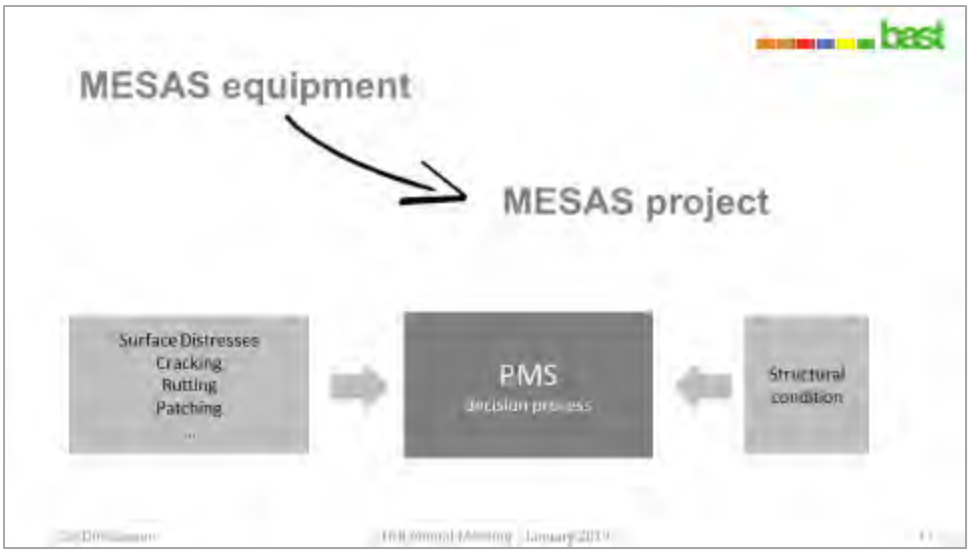
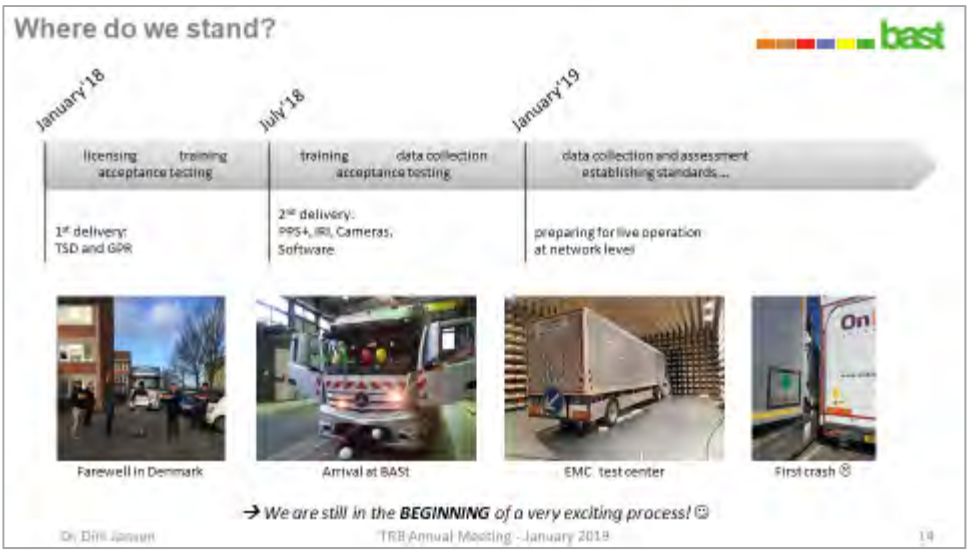


FIGURE 21 BASt TSD data collection.



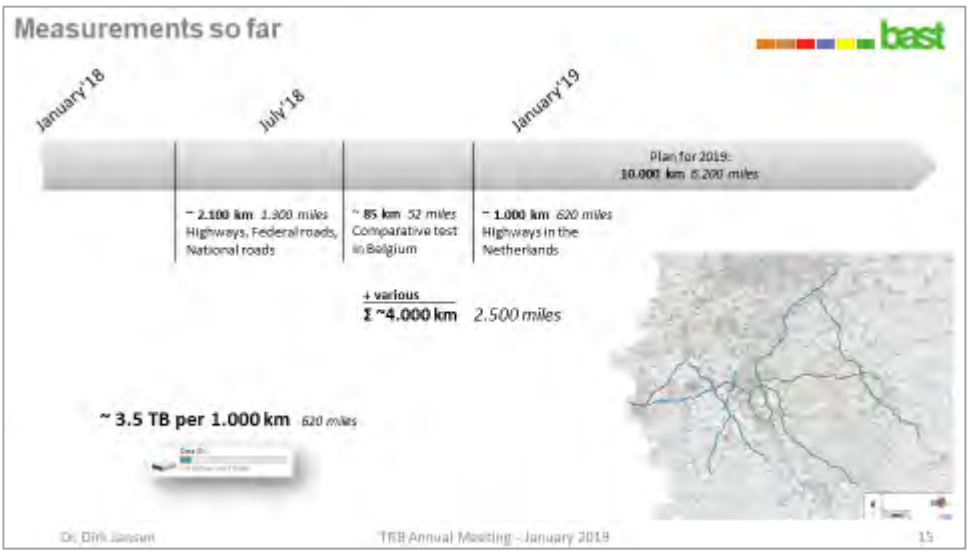


FIGURE 22 BASt TSD data collection continued.

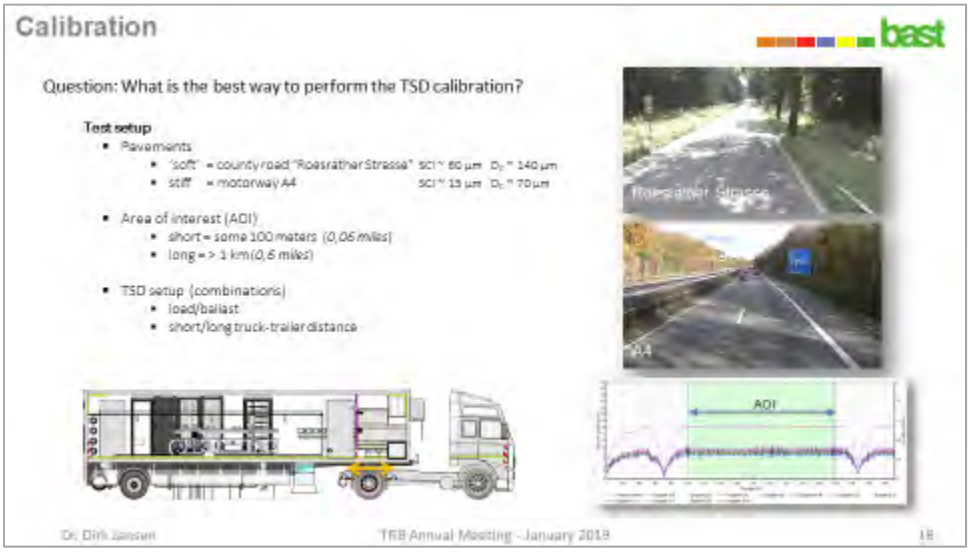
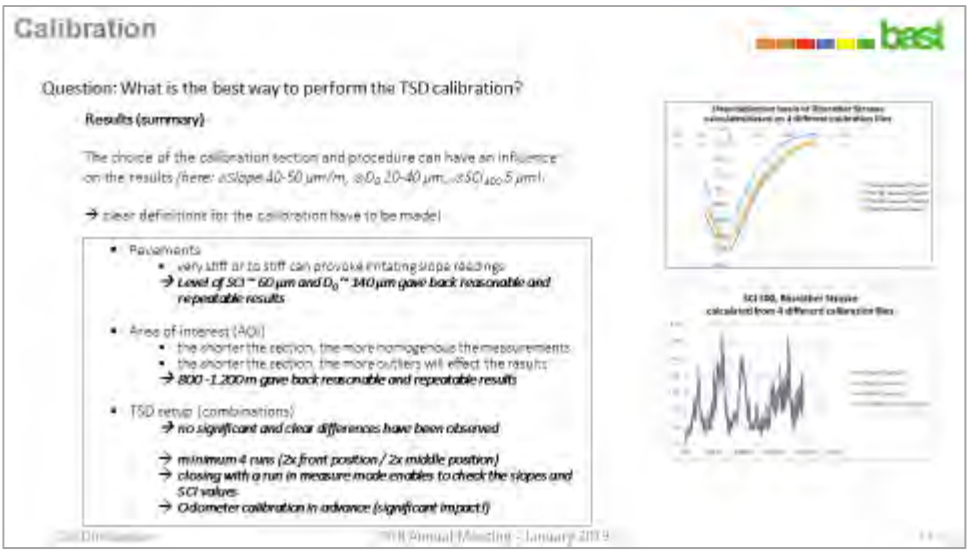


FIGURE 23 Findings from the MESAS study.



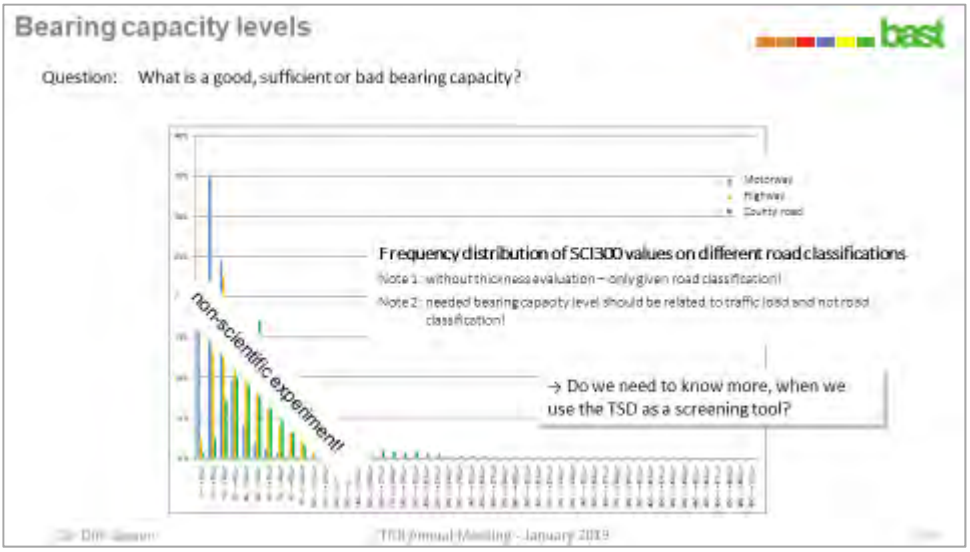
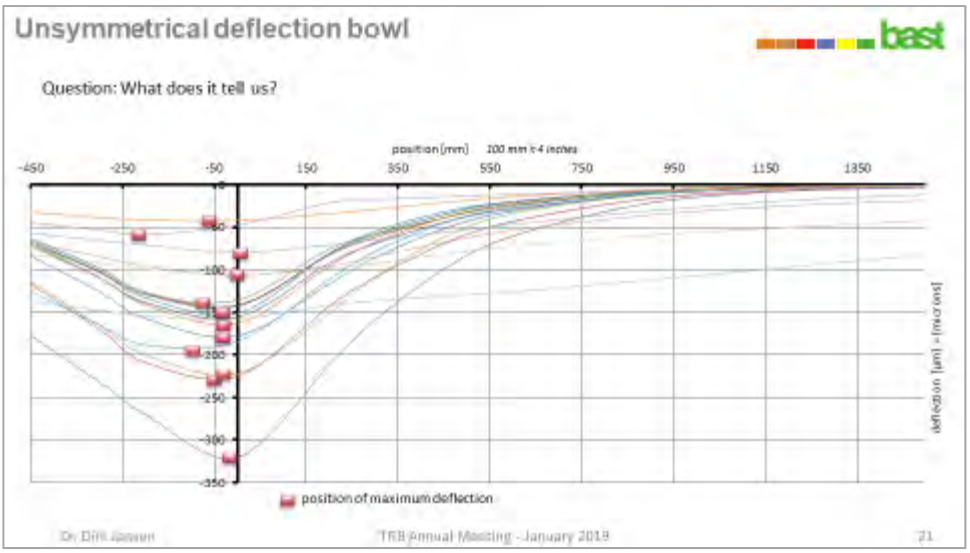


FIGURE 24 Findings from the MESAS study continued.



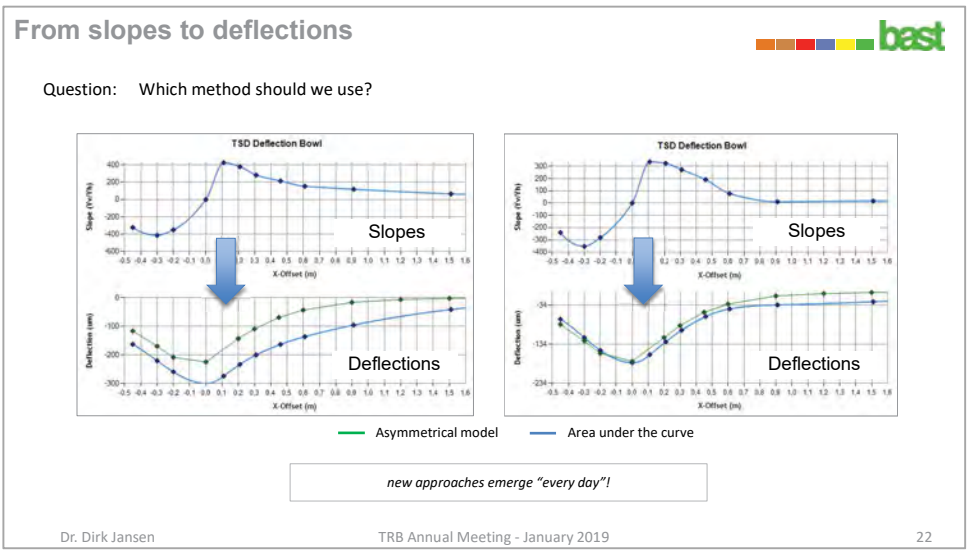


FIGURE 25 Findings from the MESAS study continued.

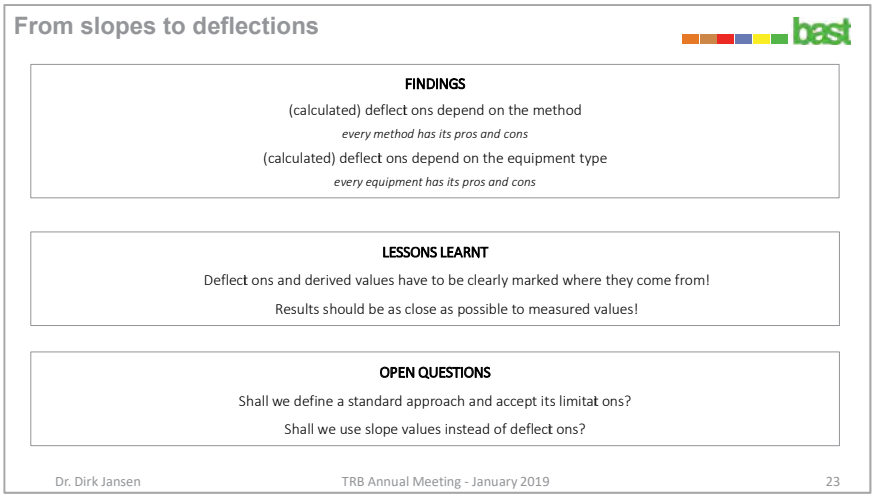


FIGURE 26 Findings from the MESAS study continued.

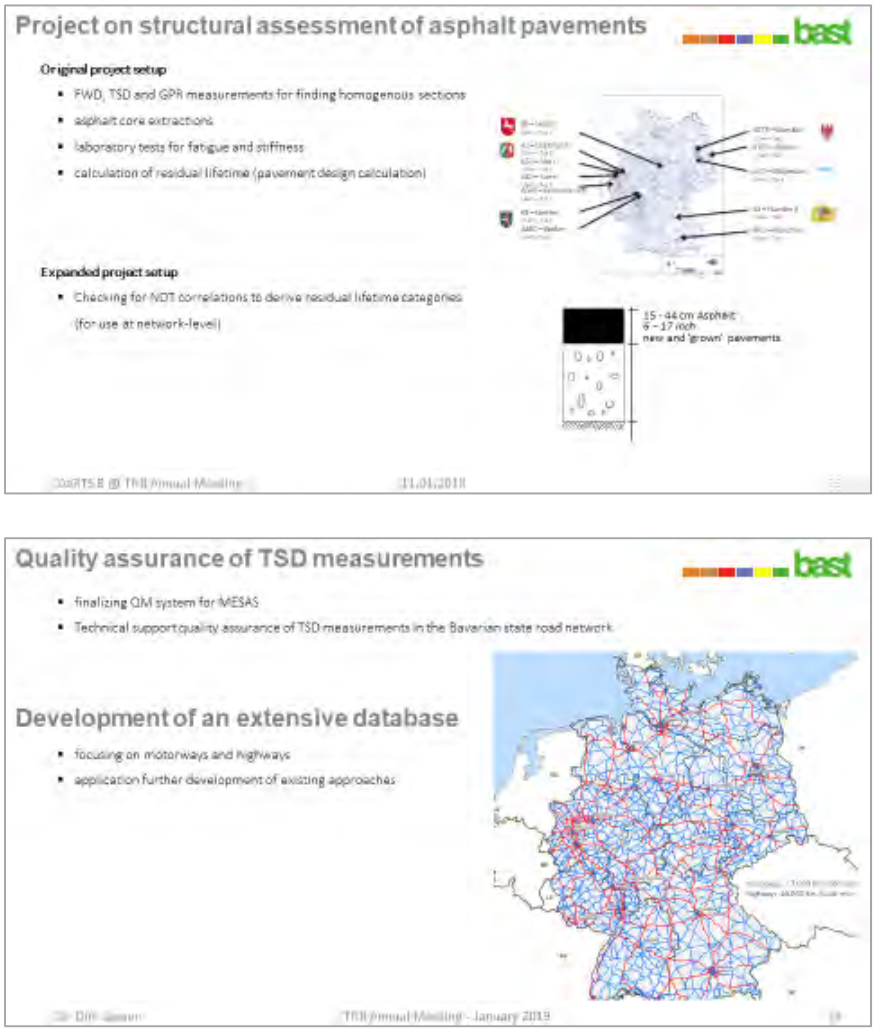


FIGURE 27 Upcoming BASt work with the TSD.

PRESENTER BIOGRAPHY

Dirk Jansen holds a doctorate in civil engineering and has been working as a scientist in the field of road construction and road maintenance for more than 14 years. He works as head of section Design and Structure of Pavements in the Department of Road Construction Technology of the German Federal Highway Research Institute (BASt).

After studying civil engineering at the University of Aachen and the University of Duisburg–Essen, he worked as a research assistant at the Institute for Road Construction and Transportation at the University of Duisburg–Essen. There he received his doctorate in 2009 with the topic "Temperature correction of deflections measured with the FWD on asphalt pavements." After a short employment in a special civil engineering company with focus on lifting and fixing of concrete roadway slabs, he changed to the section Earthworks and Minerals Aggregates of BASt. Since 2013, he has been in the BASt section Design and Structure of Pavements. His work focuses on the development and implementation of nondestructive testing (NDT) for the assessment of structural properties, the pavement design, and the performance of large-scale accelerated pavement tests.

Jansen is actively involved in the preparation of regulations and the implementation of research results in national committees of the German Research Association (FGSV) as well as in international committees dealing with road construction technology, structural assessment, and NDT methods. A focal point of his committee activities is the FGSV Working Committee Structural Assessment. Among others, he heads the FGSV working groups Bearing Capacity and Sensor Technology for Structural Assessment. He is co-author of the Handbook for Studies and Practice: *Road Construction and Maintenance*. Worldwide publications and lectures on the above-mentioned topics, as well as the implementation of relevant European and German research projects as project manager or project leader, complete his profile.

Traffic Speed Deflectometer for Network-Wide Pavement Strength Monitoring

New South Wales, Australia, Experience

Hassan Mounzer
ARRB Systems

The presentation detailed the network-level TSDD testing performed in New South Wales, Australia, by ARRB on behalf of the Roads and Maritime Services (RMS). It was noted that the TSD is the specific TSDD used by RMS, and the goal of the study is to develop a detailed understanding of the structural capacity of the road pavements. The presentation outlined details of the data that were collected, including the type and correlation s in the data, as well as applications in pavement design and planning. The presentation also detailed the reliability of estimates of pavement thickness and structural remaining life, as well as how these change over time. RMS employs a method to calculate the remaining life of pavements based on correlations developed by ARRB using cores and other information.

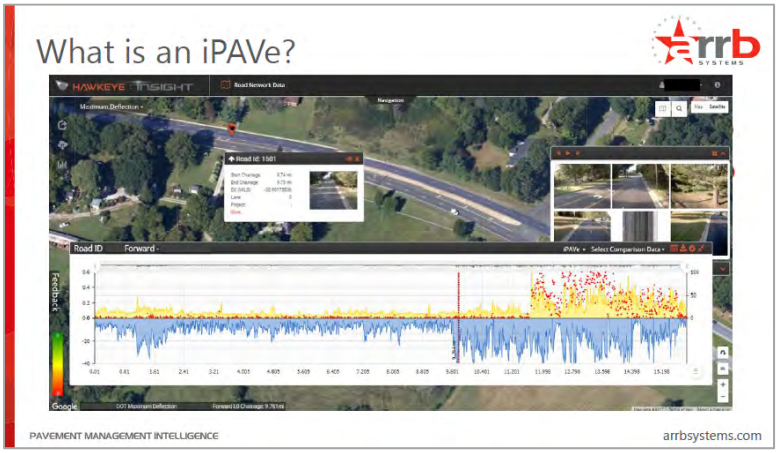
The presentation described iPAVe, which is a TSD that collects surface distress data along with deflection slopes. RMS used iPAVe to collect approximately 20,000 km of data in 2014, and has added to the data collection since that time. The presentation noted that RMS uses the area under the curve method (i.e., numerical integration) to calculate the deflections from deflection slopes. The network-level analysis with iPAVe is used to screen the pavements into risk levels based on remaining life (e.g., low-risk pavement has a predicted life of 10 years or greater). Validation was performed by comparing the FWD and TSD, and the two sets of deflection patterns in the data were very comparable. There was also a similar pattern between the Benkelman Beam and the TSD. Although the deflection values are fundamentally different because of the differences in the loading mechanisms and equipment, the same pattern being present over the pavement is promising. In terms of the functional condition data, it was found that iPAVe performed well compared to other measurement equipment, but there was a bias present in the rutting values. The slides describing the testing are shown in Figure 28 through Figure 30.

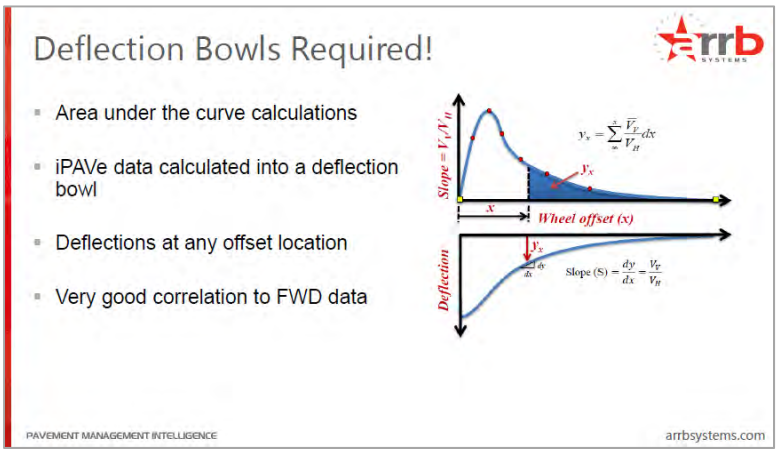
The next part of the presentation detailed results from the testing. First, approximately 384 km of roads had wide variations in deflections between the dry and wet seasons. By taking measurements in each season, a significant difference in the risk calculations between the two seasons was identified. It was noted that ARRB attempted to use the TSD for calculating an overlay design, but the design thickness varied by up to 30 mm depending on the equipment (i.e., whether it was calculated using the FWD, TSD, Benkelman beam). Finally, RMS concluded that network-level structural measurements are important for screening project types and provide valuable information regarding the risk calculations. The slides covering the latter part of the presentation are shown in Figure 31 through Figure 33.

A follow-up question requested clarity on the number of Doppler sensors on the iPAVe device. It was noted that multiple sensors exist and the number of sensors depends on the device.

A second follow-up question requested clarity on whether RMS has performed the verification–validation using outer sensors that are more affected by subgrade. They have not. They are more interested in deflection patterns than exact deflection values.

FIGURE 28 Description of iPAVe and data collection in New South Wales.





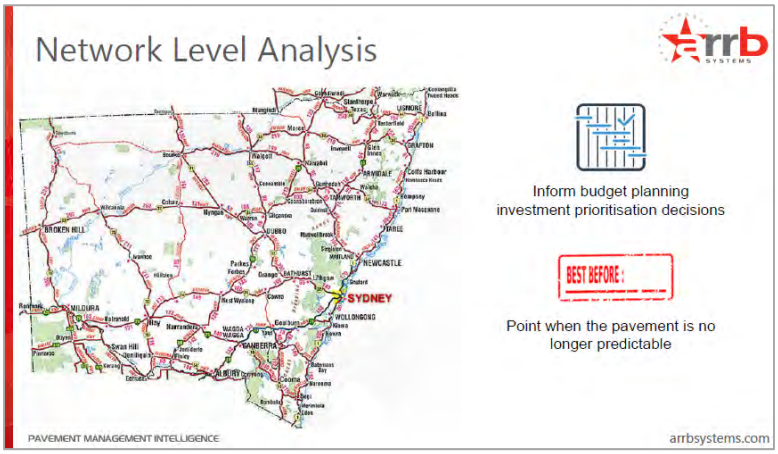
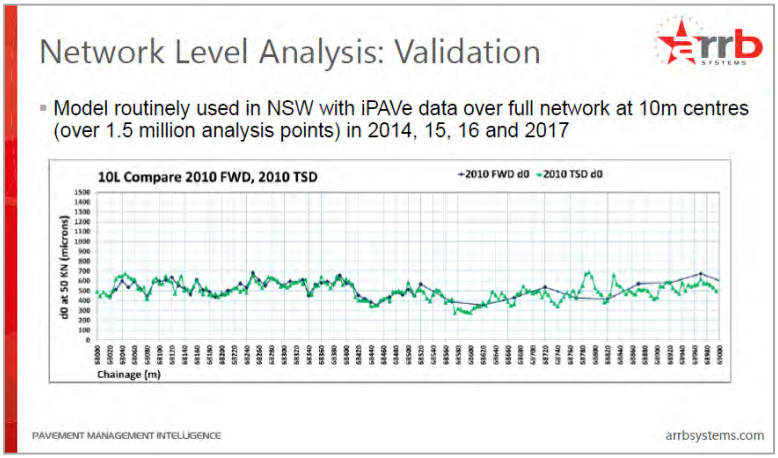
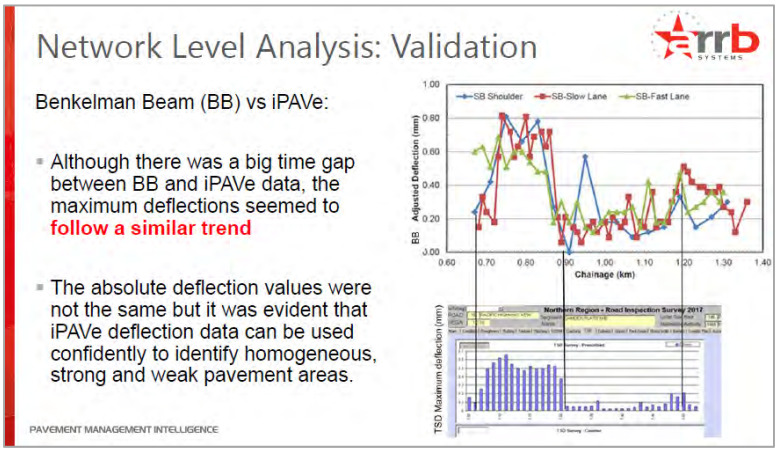


FIGURE 29 Description of iPAVe and data collection in New South Wales continued.





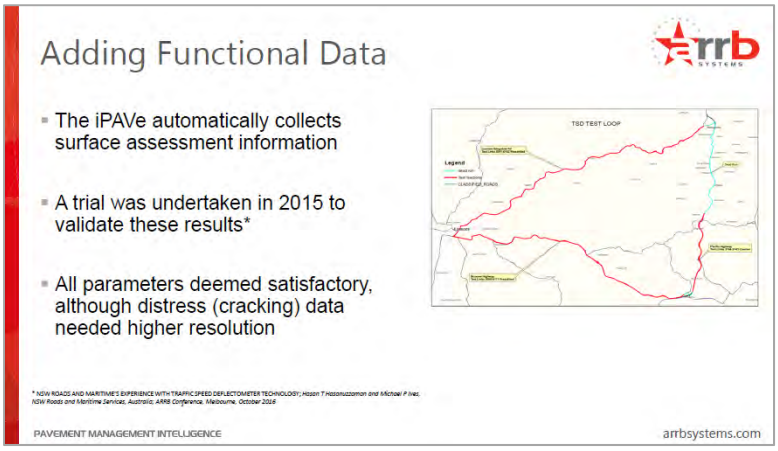


FIGURE 30 Network-level collection in New South Wales.

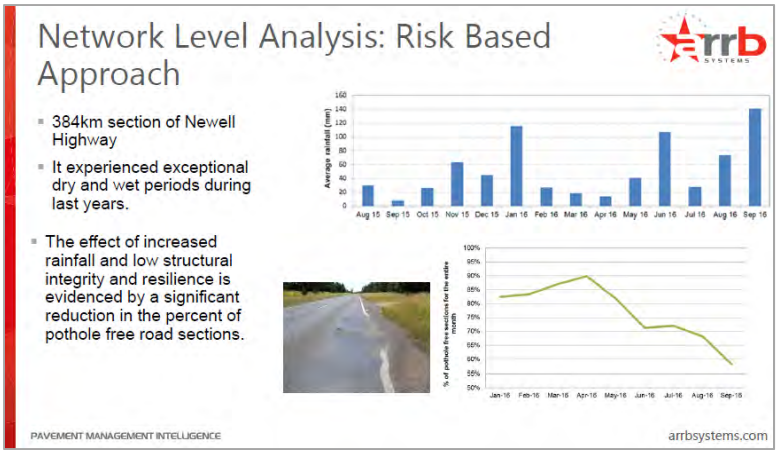
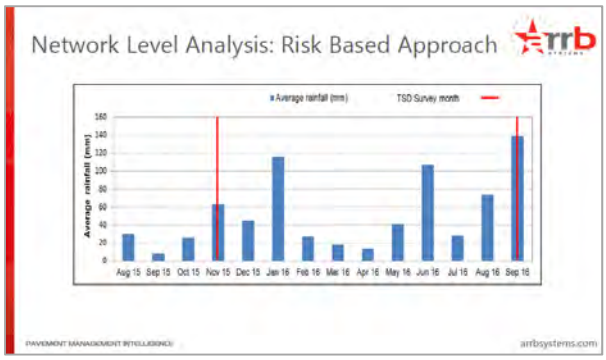
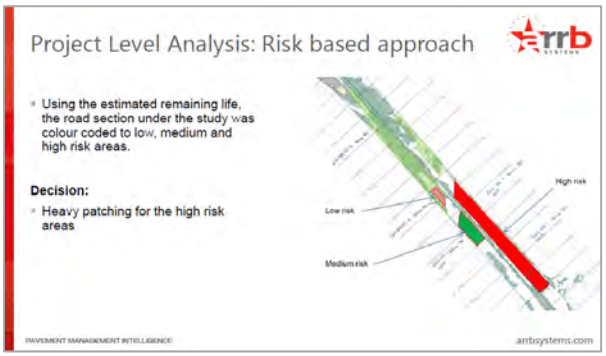
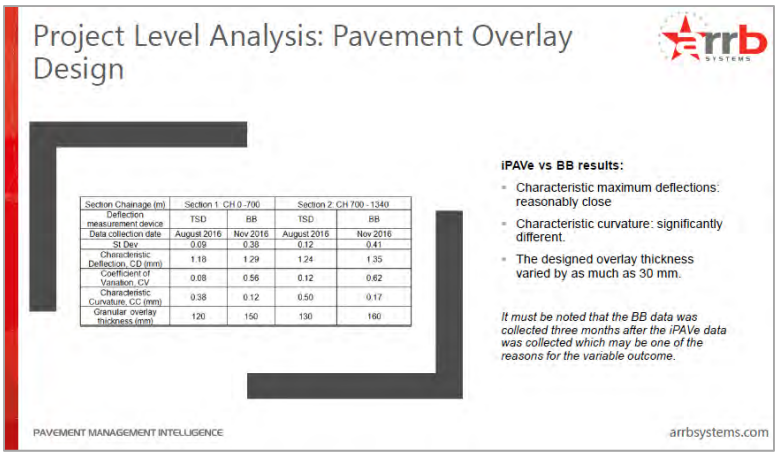


FIGURE 31 New South Wales testing.

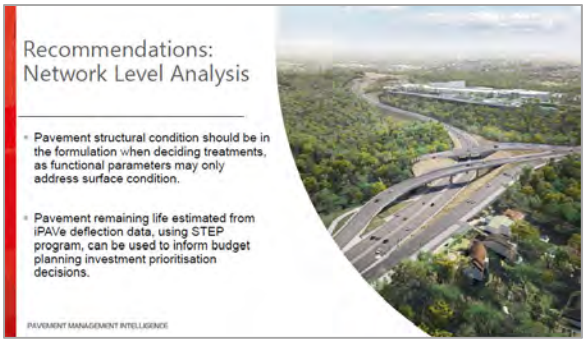


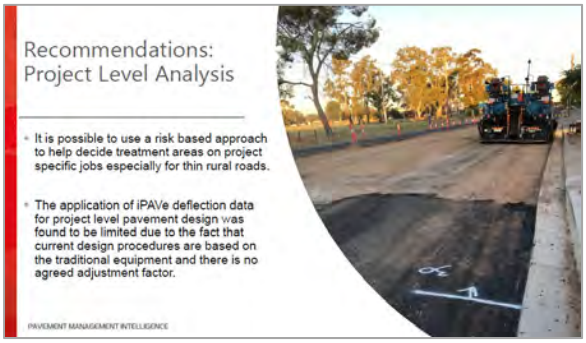




Section Chainage (m)	Section 1 CH 0 -700		Section 2 CH 700 - 1340	
Deflection measurement device	TSD	BB	TSD	BB
Data collection date	August 2016	Nov 2016	August 2016	Nov 2016
St Dev	0.09	0.38	0.12	0.41
Characteristic Deflection, CD (mm)	1.18	1.29	1.24	1.35
Coefficient of Variation, CV	0.08	0.56	0.12	0.62
Characteristic Curvature, CC (mm)	0.38	0.12	0.50	0.17
Granular overlay thickness (mm)	120	150	130	160

FIGURE 32 Results of New South Wales testing.





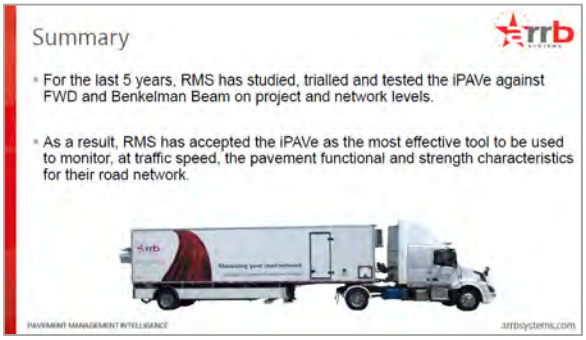


FIGURE 33 Results of New South Wales testing continued.

PRESENTER BIOGRAPHY

Hassan Mounzer began his career as a geotechnical engineer for the international offshore oil and gas sector (designing foundations and pipelines, and conducting lab studies). Following that, he worked in business development and marketing for several companies in the energy, engineering and software start-up sectors. In 2018, Hassan joined ARRB Group as the International Sales Manager to help grow the business. He holds a Master's degree in Geotechnical Engineering from the University of Grenoble (France) and an MBA from the University of Western Australia.

Automated Collection of Continuous Integrated Pavement Condition Data

The South African Experience 2015–2018

SIMON TETLEY
ARRB Systems South Africa (Pty) Ltd.

The final presentation described the testing performed in South Africa over the past several years using an iPAVe device. It was noted that the South African road network is the 10th largest in the world. The presentation began by discussing the status quo of road condition assessment, and noted the disconnect from using highly subjective manual data collection for trying to objectively develop budgets. South Africa performed testing at the network-level, and found that the deflection trends on the road classes followed an expect pattern—lower deflections for more important (and thus stronger) routes. The deflection trend also had a similar pattern to the IRI data, but not the rutting data. Then, an example of a surface treatment placed on a weaker pavement was shown—the surface condition was good, but the deflection values were high. The slides corresponding to the first part of the presentation are shown in Figure 34 and Figure 35.

Next, the presentation described multiple project-level activities being undertaken. For example, ARRB is currently evaluating the use of the iPAVe system for construction quality control. Another case was demonstrated where measurements were obtained at a location where a major rehabilitation had occurred, and the asphalt base was left open for approximately a year. The base mix began exhibiting block and fatigue cracking, leading to the concern that the base would need to be reconstructed. However, TSDD testing revealed no structural issues with the base section, and it was determined that no reconstruction was necessary.

Finally, the presentation showed a set of challenges with the iPAVe system (e.g., maneuverability concerns). The experience revealed many benefits and improvements that can be undertaken by combining functional and structural pavement evaluation. The integration of the data sets (i.e., functional and structural) provides a much clearer overall picture of the road condition, which leads to cost savings in the long-run due to the selection of proper maintenance and rehabilitation needs. Finally, it was noted that all of the presentations are saying something similar, which is an indication that this is going in the right direction. The last set of slides from the presentation are shown in Figure 36 through Figure 38.

FIGURE 34 Introductory slides for the South African testing.

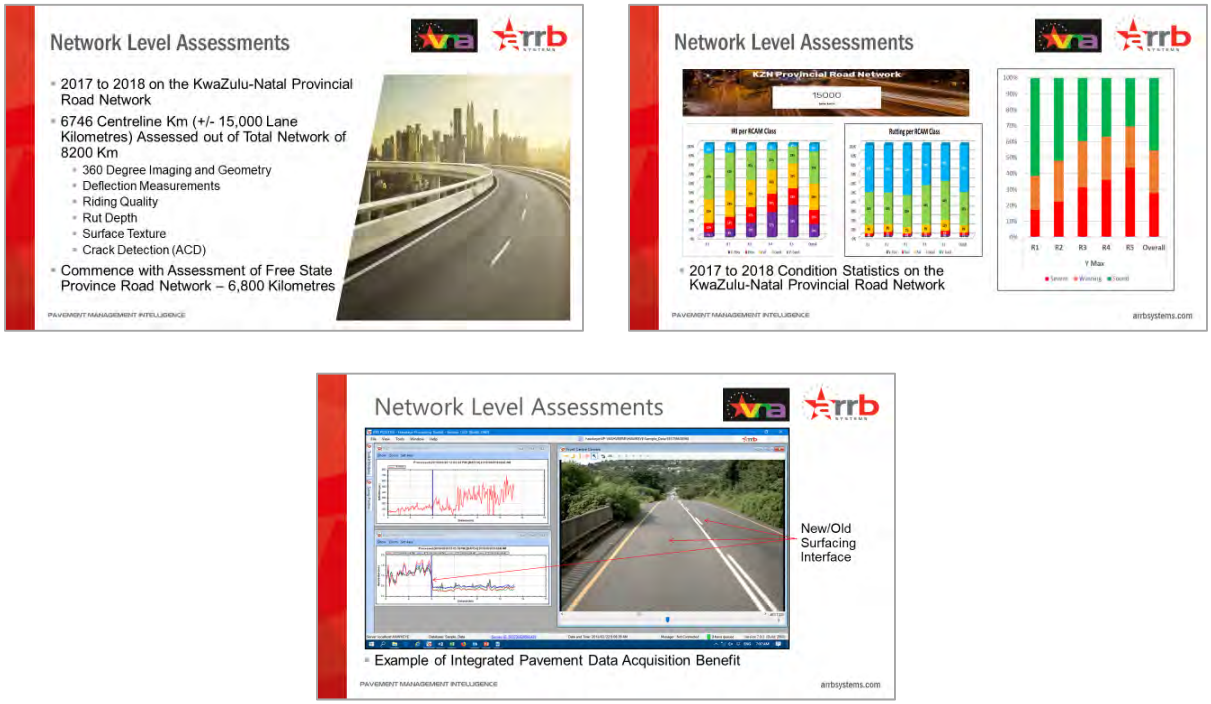


FIGURE 35 Network-level assessments.

FIGURE 36 Network and project-level assessments.

FIGURE 37 Project-level evaluations in South Africa.

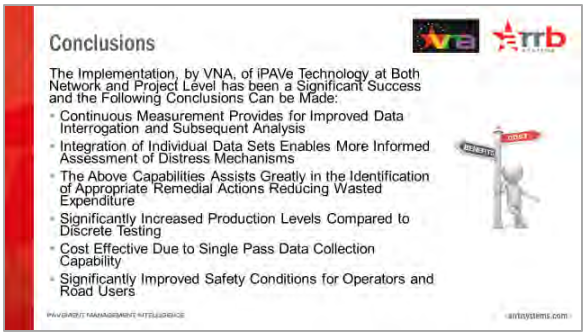


FIGURE 38 Benefits and conclusions.

PRESENTER BIOGRAPHY

Simon Tetley is a transportation engineer with 32 years of experience in the Consulting Engineering environment, and specializes in the fields of pavement/materials engineering, asset management, economic analysis, construction management and forensic investigation. Simon is a Fellow of the Institute of Highway Engineers and has authored or co-authored numerous conference papers both national and international.

Discussion and Conclusions

The workshop was concluded with questions and discussions from the audience and panel members, and those are summarized below.

- **How easy was it to get your organization to buy in?**
  - Rick Miller noted that Kansas takes the approach that, if there is a better, safer and faster method to collect data, then that is the standard used. It was not overly onerous to obtain buy-in by demonstrating the safety improvement.
  - Pete Schmalzer notes that Idaho requested NCE to perform approximately 500 mi of FWD testing at the same time as the original pooled fund study. Idaho seemed to like the results, which helped with organizational buy-in.

- **How many miles (or kilometers) have those that are using TSDDs collected?**
  - In Australia and New Zealand, they have 500,000 km of roadways they have (or plan to) collect.
  - South Africa, which has only done it for 2 years, has collected approximately 7,000 centerline km.

- **Tell us more about the data post-processing. With the data that is collected, how do you get it to the form where it can be analyzed?**
  - It depends on what post-processing you are referring. You can see the data almost immediately as it is being collected. It is also location referenced so you can see all of the rest of the data.
  - Jerry Daleiden of ARRB noted that the imagery and processing take about as long to complete as the data collection. For example, one week of collecting data and the data can be delivered after a week.
  - It was noted that, although the TSD data processing is fast, the additional data that is collected requires processing time.

- **Can you tell us about how your agency reports spatial averages?**
  - Australia reports data averaged every 10 m.
  - BASt reports data averaged every 10 m, but they are investigating different lengths for averaging.
  - Jerry Daleiden of ARRB noted that they can report data for as low as 1 m, and Jerry has done so for jointed concrete.

- **How is variability in speed reflected in the measurements?**
  - This is a topic that BASt is planning to investigate further this year, but they currently use the recommendations from TRL that, between 40 and 80 km speed, the influence is less.
  - Hassan Mounzer noted that the horizontal speed is accounted for in the deflection slope calculation.

- **How do you consider the effect of temperature?**
  - Although there are multiple approaches for older equipment (e.g., FWD), there is not yet one for TSDDs. This is a topic that BASt is planning to investigate further this year.
  - Pete Schmalzer notes that temperature corrections for FWD has its shortcomings, and a different methodology is needed for TSDDs.

- **How are the physics of the moving wheel load for back-calculation accounted for?**
  - It was noted that multiple moving load simulations have been and are being studied and will be presented elsewhere in TRB.
  - One speaker noted that, at the network-level and with significant variability in the data, the differences due to assuming a moving wheel versus a static loading may be insignificant to the results. However, research is ongoing to investigate this.

- **Do you have any advice on the device calibration?**
  - There are various sets of components that require calibration on different schedules, and there are specifications for different types of equipment. It was recommended to locate and test a suitable set of roads to use as calibration sites.

- **How do you know it is calibrated?**
  - Before calibration, we need to concern with stability of the measurements over time. There is a challenge with the manufacturer to provide the calibration process, but early experiences have shown the TSD devices to be stable.
  - It was also noted that it is very important to have a complete quality management plan behind the system.

- **South Africa used this for construction quality assurance – did you check for homogeneity (e.g., changes in surface curvature index over space)?**
  - Homogeneity is not one of the factors they evaluated, but it was noted that this is something they may investigate in the future.
  - Rick Miller noted that TSDDs may be used for contract specifications. Kansas currently specifies contracts based on thickness, but it is feasible to use TSDDs to specify contracts based on strength.

- **Did it turn out to be a good tool for investigating stripping?**
  - Rick Miller noted that preliminarily the results for stripping are not promising, but they are still investigating this.

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The **National Academy of Medicine** (formerly the Institute of Medicine) was established in 1970 under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health. Dr. Victor J. Dzau is president.

The three Academies work together as the **National Academies of Sciences, Engineering, and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The National Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Learn more about the National Academies of Sciences, Engineering, and Medicine at **www.national-academies.org**.

The **Transportation Research Board** is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to increase the benefits that transportation contributes to society by providing leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal. The Board's varied committees, task forces, and panels annually engage about 7,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

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500 Fifth Street, NW
Washington, DC 20001