CONSTRUCTION INNOVATION FORUM

INVESTIGATOR'S SUMMARY

Nomination 2003-02

Investigator: Charles R. Glagola
Associate Professor of Civil Engineering
University of Florida, Gainsville

PAVEMENT QUALITY INDICATOR

MANUFACTURED By

Trans Tech
TRANSTECH SYSTEMS, INC.

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PAVEMENT QUALITY INDICATOR

The Innovation

States' departments of transportation require that asphalt paving contractors achieve specified levels of density in their asphalt roadway mat. Density is the best measure of quality of the finished product that will assure an owner agency they will be getting a finished roadway that will last as long or longer than the design life. Most states tie contractor pay to achieving this required density and often provide bonus pay for exceeding the requirements. Contractors achieve density of their in-place asphalt material by applying heavy rolling equipment on the mat immediately after it has been placed by a spreader. Measuring density of the asphalt during compacting operations is critical to a contractor's success since determining when required compaction has been achieved provides a contractor with two valuable pieces of information. First, it tells the contractor where they are in relation to meeting the density requirement and can therefore be an indicator to the compaction crew if they may need to make adjustments in order to reach final density; and second, it tells the contractor when they may cease their compaction efforts and move on.

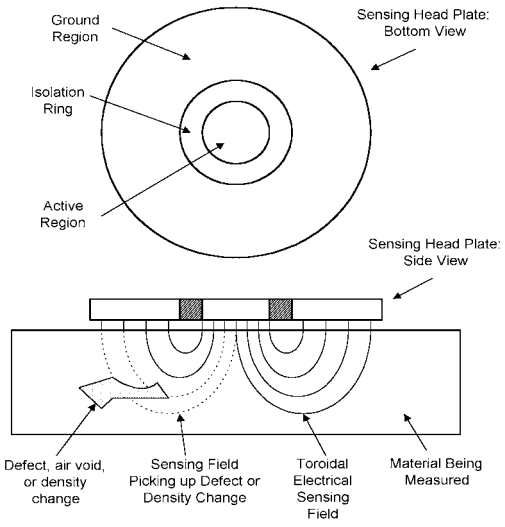
Historically, there have been only two ways to measure the density of a newly placed asphalt pavement; the first is by taking cores, a destructive method, and the second, by using a portable non-destructive nuclear density gauge. Although it is probably the most accurate way to measure density, the first means, coring the roadway, is so time consuming and costly that it is impractical for anything but a final determination of the density. The nuclear gauge is older technology but is much faster and cheaper than coring the pavement. However, it has many disadvantages. The first, and most glaring, disadvantage is that it utilizes a radioactive source and is thus heavily regulated and requires extensive training. Other disadvantages include the difficult licensing and renewal requirements, technician training and retraining, and inconvenient handling and storing requirements, to name but a few.

Until now, many paving contractors did not own or operate density testing equipment because of the liability, specialized training, and regulatory hassle of dealing with nuclear density gauges. These contractors still had the same requirements as all others, but they would have to subcontract density testing services at additional cost, as well as the inconvenience of not being able to get testing when and where they needed it. With the Pavement Quality Indicator™ (PQI) system, paving contractors will now be able to own and operate density testing equipment that is faster, safer, more versatile, and as, if not more, reliable than nuclear gauges. Another huge advantage is that contractors will be able to easily train virtually everyone on the job to operate

[1] January 15, 2003
[2] Associate Professor of Civil Engineering, University of Florida, Gainesville, Florida.

the PQI whereas in the past, because of training requirements, few contractors had more than one qualified density technician. This is a significant advancement for the industry.

A safer, faster, lighter, less expensive, and reliable alternative to the nuclear density gauge has been developed by TransTech Systems. This invention is the Pavement Quality Indicator™ (PQI), a "paving material density indicator". The PQI is in its fifth generation with the model 301 and has been improved, and become more successful, with each generation. The first generation machines were capacitance-based measuring systems (Patent No: US 5,900,736) while the 301 (Patent No: US 6,414,497) is impedance-based. The PQI provides a sensor with a multi-configuration geometry that provides an electrical field with a controllable depth of penetration. This attribute is an innovation not previously available from devices in current use.



The PQI system provides an electronic circuit that generates a radio frequency voltage that is applied to one sensing electrode to generate an electrical field in the paving material. A second sensing electrode measures the dielectric response of the paving material. A data processor determines the density of the paving material based on the measured complex impedance of the paving material. The data processor computes the accurate relative density corrected for moisture that may be present in or on the paving material. Corrections for influences outside of the desired measure, material density, are incorporated into the system. These automatic corrections account for: surface moisture, temperature variation, and sensor impedance. This automatic corrective action provides realistic density readings under varying conditions without having to make cumbersome manual adjustments to data.

The system has been designed to be adaptable to on-site conditions. Another innovation is the ability to change the sensor configuration, under computer control, to allow for selection of the depth to be tested. This is particularly important when testing at a joint in the pavement between two different applications of asphalt. Adjustability of the sensor configuration is also advantageous to the system because the sensor configuration dictates the depth of penetration and area of electrical field and, accordingly, the volume of the field of test. For instance, operation of a smaller sized sensor allows the depth of penetration to be reduced. Being able to accurately control the depth of penetration prevents imprecise determinations when the signal penetrates through a new lift coat into an underlying surface that may not have the same density, which is unique. The PQI system provides a constant voltage source circuit enabling the system to detect material density with more accuracy and reliability than other devices. A precision constant voltage source provides a stable system that is not alterable by environmental factors, e.g., electromagnetic interference.

Application of the Innovation

The PQI system was tested through the National Cooperative Highway Research Program (NCHRP) on IDEA Project 32 and IDEA Project 47. The equipment tested during these evaluations were earlier generations of the system and were tested to determine their usability as well as to evaluate modifications that would achieve a greater degree of accuracy and reliability. The NCHRP IDEA Program testing concluded that, "The ability of the PQI system to instantaneously read asphalt pavement density creates a cost-effective opportunity to significantly increase the number of density readings taken on the highway and provides real-time feedback to the paving crew for instantaneous corrective action. The PQI also might significantly reduce the current core sampling and laboratory analyses that are used to monitor asphalt pavement densities. Development and deployment of the PQI in the asphalt paving industry will yield more efficient paving operations, higher productivity, and better quality control, resulting in longer pavement lifetimes and lower overall life-cycle costs."

The current application of the PQI system is primarily by contractors to determine the attainment of density of asphalt paving, in a non-destructive way, during the laydown process. The speed and ease of use of the PQI system allows contractors to make adjustments to their compaction efforts "on the fly". The system can be used immediately behind the compaction rollers to ascertain whether or not compaction requirements are being met; however, application is not limited to contractors. An example of contractor use of the system can be seen in the February 2001 *Asphalt Contractor* magazine. In the article "Two Contractors in Two States Get Quality Control Bonuses", contractors in Florida (Orlando Paving) and Indiana (E&B Paving), put the PQI system to use after having previously used nuclear density equipment. E&B now has 19 paving crews all using the PQI system on the state, county and airport work that is done out of 14 plants across Indiana. In describing their use of the PQI system, E&B states, "…it's critical that we have the tools to get the job done fast and within specs." Milestone contractors, out of Indianapolis, also use the PQI system, employing 11 of the gauges throughout the company. They have evaluated the system side-by-side with their nuclear equipment and have found that the PQI system provides comparable results. Brad Cruea of Milestone likes the fact that the PQI system gives density without having to take cores from the pavement. He says that coring holes costs Milestone approximately 3 man-hours, as well as the costs for a vehicle and coring equipment. The PQI gauge can give the same information in 5 seconds. Brad says, "We are pleased that a company like TransTech Systems came up with such a unique, innovative device."

Engineering Testing Laboratories, such as Metro Quality Testing (MQT), out of Maplewood, MN are using the PQI system in their service both to contractors and to owner agencies such as departments of transportation. MQT is a consultant to small and medium size asphalt contractors in Minnesota. MQT was contracted by Bemidji Blacktop, Inc. to assist their paving team on two separate paving projects in northern Minnesota. The 313 Warroad project was a 2 lane state highway near the Canadian border, north of Warroad, Minnesota. The project was a 4-

lane highway, located in Fosston, Minnesota. Both projects were paved in the fall of the year (September and October).

On the 313 project, there was a smoothness specification. To be eligible for smoothness incentive, 25% or more of the densities on the project had to meet or exceed minimum density requirements, or the smoothness incentive would be disallowed. BBT realized successfully achieving density requirements would require a new and innovative approach for their paving team. After two days of paving, MQT was able to fine tune the calibration factor for the PQI, so that the PQI provided more accurate readings than the nuclear gauge when compared to the core densities.

For both of the projects, density incentives were achieved in the 102% to 104% pay factor. No penalties were realized on either project for density. In addition, for the TH 313 project with the ride smoothness specification, BBT realized additional incentive for the ride smoothness because they were able meet or exceed minimum density requirements on the project.

Eugene Teigland, Paving Foreman with BBT, commented that his person in the field, operating the PQI unit, was able to quickly identify when the volumetrics of the HMA changed, because the density readings from the PQI were indicating low density. This was confirmed minutes later when MQT called from the quality control lab to inform Teigland of mixture volumetric problems. His team was quickly able to adjust the roller pattern and still achieve minimum density requirements and avoid any penalties on compaction.

Background of the Innovation

Because density of hot mix asphalt is widely known to be the most important variable in the construction of durable, longer-lasting asphalt pavement surface, there was perceived an increasing need to develop a better and more reliable system compared to destructive core sampling and testing, as well as to the nuclear density gauges currently in use. Because of this increasing need in the industry for an alternative to the cumbersome and hazardous nuclear density gauge, development of a viable alternative was begun by a group of engineers in New York working through TransTech Systems. Work on this system was begun in the mid 1990s and has evolved into a state-of-the-art system, the PQI 301, now in use.

A number of prototypes were developed and tested through programs within state's departments of transportation such as North Carolina, Florida, New York, Pennsylvania, Delaware and others, as well as nationally recognized research programs such as the NCHRP IDEA Program and the National Center for Asphalt Technology (NCAT). TransTech also worked closely with contractor clients who evaluated the PQI system along with their conventional testing methods using nuclear gauges. Early models of the system showed great promise but, as would be expected, revealed opportunities for improvement. Two of these areas were in dealing with

temperature and moisture. The engineer-designers of the PQI used the evaluation data to continuously improve the product by redesign of critical components and adding instrumentation and new algorithms that would address noted areas of concern such as moisture interference. As the evolution progressed, the PQI system has become the preferred density system for contractors who have used it and, because it is naturally a slower transition, is being evaluated for acceptance by many departments of transportation as a device that can be used as an alternative to nuclear gauges. The Florida Department of Transportation District Three recently informed TransTech that they had reviewed the Florida test results for a project on US 90 (Mahan Drive) and, "…determined the PQI Density Gauge can accurately measure the relative level of density in the pavement consistently." The PQI system is approved for use of FDOT projects for Quality Control of In-Place Compaction (specification 334-5.4.1.3).

In Pennsylvania, the State's "Innovations Council" evaluated the PQI system against a nuclear gauge. Part of the results from this study revealed data related to the cost of training and operating which is provided in the following tabulation:

NUCLEAR GAUGE (initial cost)

Trainer (1-day)	$180	= $180
Salary of Personnel for 1 day training	$140 x 5 people	= $700
Two Week OJT W/licensed operator	$140 x 5 people x 5 trainers x 10 days	= $35000
Radiation Badges	$3.65 x 4/year x 5 people	= $73
Annual Gauge Re-calibration	$386 x 5 gauges	=$1930
Storage/Transportation		Non-reportable
Total		= $37883

TRANSTECH PQI SYSTEM (initial training)

Trainer (2 hours)	$45	= $45
Salary of Personnel for 2 hours training	$36 x 5 people	= $175
Total Training Cost PQI		= $220

TOTAL SAVINGS (initial training)	**$37883 - $220**	**= $37663**

USAGE COSTS (over 5 year period)

Final figures for operational cost savings use over a 5-year period:	**= $12655**
TOTAL 5-YEAR SAVINGS (using the PQI system)	**= $50318**

In order to facilitate universal acceptance of the PQI system, a request has been made to the standards agency that is used as the governing body for materials by almost all entities involved in use of asphalt products. A draft specification is currently under evaluation by the American Association of State Highway Transportation Officials (AASHTO).

Responsibility for the Innovation

The innovation, Pavement Quality Indicator, PQI, was developed at TransTech Systems, Inc., Schenectady NY. As far as who is responsible for the PQI, David Apkarian has indicated that TransTech would like to present a unified front because no one employee has been 100% responsible for the PQI stating, "All of us have played various roles in the 5 year development process. On behalf of TransTech, myself and Jaret Morse would be accepting this award for all the employees of TransTech if the PQI were to be selected." The names listed on the patents are: Robert A. Sovik, Richard N. Hosterman, and George G. Moross.

Opinions of Persons Contacted

The specific responses and opinions of persons contacted can be found in the "interview" section of this report. A succinct opinion of those involved in the process was that the current generation, the PQI 301, has many advantages over the conventional density measuring device, the nuclear density gauge. The PQI is as accurate, is more consistent, is much faster, is much easier to use, gives results much quicker and can therefore improve productivity, is much less expensive to operate (anyone on the job can be trained to use it in an hour or less), and its use involves no regulatory hassle or danger to the environment.

Investigator's Comments

Most of the previous information deals with user response to evaluation and testing of the PQI device in relationship to the conventional system in use, the nuclear density gauge. I would like to comment here that beyond the obvious pleasure expressed by end-users, the PQI is an engineering triumph. For many years, engineers and scientists have pondered alternatives to the use of the hazardous nuclear equipment. Testing has been done on everything from microwaves to x-rays. TransTech Systems addressed the engineering problem and developed a first-generation system that showed a great deal of promise using just the real part of the dielectric response as an indicator of density, but this proved to have limitations, such as sensitivity to surface water that may be present during the rolling process. Through hard work and diligence, TransTech engineers were able to develop an improved system that measured the complete complex impedance response of the asphalt. This innovation permitted the robust correction for the presence of surface water and asphalt temperature. They also established a comprehensive system for testing that was customer driven through departments of transportation, contractors, and prestigious national testing agencies. The valuable data that was developed allowed TransTech to determine which technologies to incorporate and which control systems would best meet the needs of the construction industry. Because of this technical triumph, I feel that the TransTech system is truly unique, innovative, and a major breakthrough in the construction industry.

SELECTED INTERVIEW SUMMARIES

Harlon Wiggins
Production Manager
APAC of Jacksonville
P.O. Box 2579
Sarasota, FL 34230
904-288-6300
Telephone interview by Charles R. Glagola, January 6, 2001

We are currently using three of these gauges and are planning on buying a fourth. The reason that we have gone to these gauges is that we find them more accurate and more reliable than the nuclear gauges. Even if this wasn't true, they have other distinct advantages. They can be used by anyone on the job with a minimal amount of training and don't require all of the regulatory qualifications, certifications, and renewals that you have with the nuclear equipment. In Florida, we pave on limerock base material. We have found that the PQI gauge is ideally suited for accuracy when paving over this type of base material.

Tom Micklewright
APAC - Pan American Division
Quality Control Manager
P.O. Box 2579
Sarasota, FL 34230
305-477-5058
Telephone interview by Charles R. Glagola, January 8, 2001

Since Florida is a state where pay is based on meeting the density requirements, nobody wants to take a chance on getting a pay deduction for not meeting density requirement; so let me first tell you that I wouldn't be using the PQI system, or any other system, unless I was sure that it was as accurate as the system we were using for QC.

Kimball Brock
Quality Control Manager
Better Roads Construction Company
Sarasota, FL 34230
863-465-5797
Telephone interview by Charles R. Glagola, January 6, 2001

We are very pleased with the PQI system. We have found that it compares better than the nuclear gauge when comparisons are made to the core samples. Our primary use is for on-the-job quality control where we need information fast and accurate in order to get the job done. The PQI system does this for us. If I had to describe one advantage of this system it would be that it gives us greater dependability and accuracy than previously attainable.

Barry McKeon
Quality Control Manager
Orlando Paving
Orlando, FL
407-293-4340
Telephone interview by Charles R. Glagola, January 7, 2001

We consistently get better readings than the nuclear gauge provided us. We are creating a database for different mix designs, which will help a great deal in the calibration in the future. We have found that we can instantly determine if we are realizing our density and adjust our roller patterns "on-the-fly". For us, it has done as well or better than the nuclear gauge without all of the regulatory hassles.

Lee Barwick
Quality Control Manager
Peavy & Son Paving
Tallahassee, FL
850-575-3606
Telephone interview by Charles R. Glagola, January 6, 2001

We are extremely pleased with our PQI system. We have only had it three months and find that it has saved us a great deal of time and effort. Once we get it calibrated for the mix, it's so consistent in it's performance it's almost scary. For us, the difference in using a nuclear gauge and using the PQI gauge is like night and day. I'll tell you, we can set the PQI down and take five or six successive readings on the same spot and they won't change at all. With the nuclear gauge we would be getting five or six completely different readings. We like it so much we've even recommended it to our competitors.

SUPPORTING EXHIBITS

1. **NCHRP –IDEA "Concept Digest"**

2. **Draft Specification submitted to AASHTO**

3. **Article – "Measuring Density Using an Electromagnetic Density Gauge As an Alternative to a Nuclear Density Gauge," by Alan B. Gilbert, November 11, 2002.**

4. **Article – "Two Contractors in Two States Get Quality Control Bonuses," Asphalt Contractor, Feb., 2001.**

5. **Article – "TransTech PQI Now Available In Language Versions," Grading and Excavation Contractor, 2000 – 2002 Forester Communications, Inc.**

6. **Article – "Pavement Quality Indicator is an Instant Success," Asphalt Contractor, July 1998.**

What is the NOVA Award?

The Construction Innovation Forum (CIF) is an international, non-profit organization formed in 1987 to recognize and encourage innovation that improves quality and reduces cost of construction.

Each year, the CIF presents the NOVA Award to honor innovations that have proven to improve construction quality and cost. The NOVA Award has a serious mission: to illuminate the innovations and innovators that have made important contributions to the construction industry. We encourage nominations from all parts of the construction industry from all parts of the world.

We invite you to browse our site for its valuable information on innovations that could help make your next project an even greater success. We welcome all inquiries, new members, and those who wish to enter our annual NOVA Award competition.

Our Goals

- Identify important innovations that have contributed to construction quality and cost effectiveness.
- Educate industry leaders on the importance of innovation in their companies and associations.
- Encourage contractors, engineers, buyers, associations, and vendors to develop, implement, and require innovative processes.
- Publicly recognize important construction innovations through awards, publications, etc.
- Develop financial support for further innovation within the construction industry and its varied services.

The NOVA Award statue is a construction worker prying a new star out of his common work, a star whose brightness throws new light on his work and changes it. The worker represents all construction people: labor, managers, engineers, suppliers, and owners, doing their daily work. The pry bar represents the common tools construction people use in their daily tasks. The soil represents the common materials and methods used in that work.

The star represents an uncommonly significant new idea, a method or tool or material that changes construction. It does not occur by itself. It is discovered and pried out by construction people who seek it and work to develop and use it. The star's illumination changes one's view of the work. The star's brightness disturbs more common work and illuminates its imperfections. Once the star is created and released, its brightness and its gravity cannot be ignored - it changes the work. However, a NOVA does not last forever, in time it will pale and become common, perhaps even disappear. Renewal requires us to continuously seek and develop innovations, or our work will become even more common or disappear.