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Promising Existing and Emerging Technologies & Techniques

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PRELIMINARY FINDINGS – SUBJECT TO UPDATES

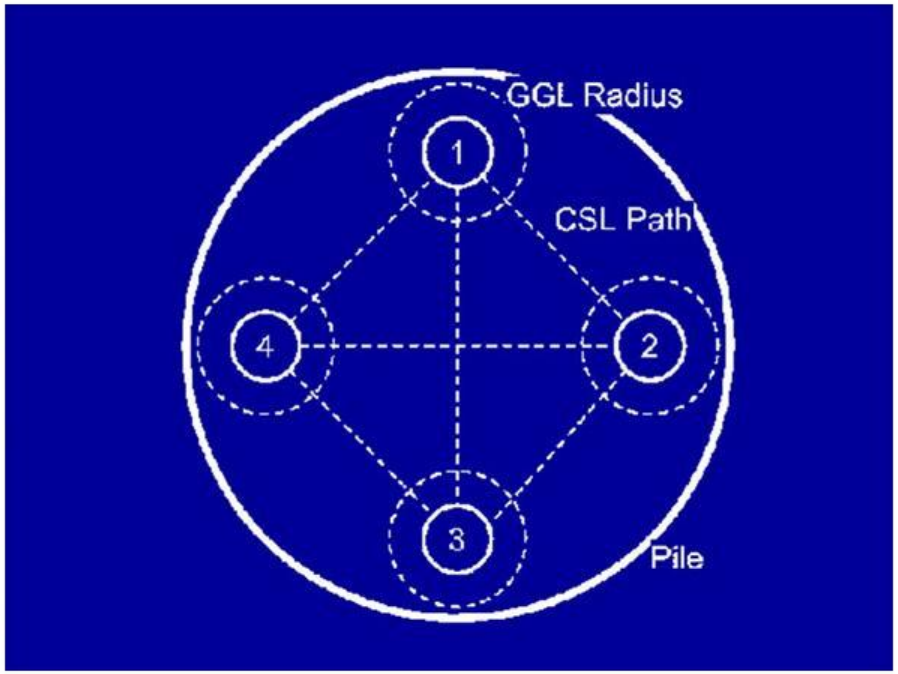
Content

- Surface Profile Measuring Systems
- MIT Scan
- Laser Scanning (LADAR or LIDAR)
- X-Ray Backscatter
- Sliding Profiler or Smooth Board
- Gamma-Gamma Logging and Cross hole Sonic Logging Integration
- Portable Seismic Pavement Analyzer and Free Free Resonant Column Test
- Vibration Based Bridge Monitoring
- Acoustic Emission
- Air Coupled Ultrasound

Content

- Magnetoresistive Sensor Technology
- Nonlinear Ultrasound
- Air Coupled Ground Penetrating Radar
- Ground Coupled Ground Penetrating Radar
- Real Time Automated Distress Data Collection
- Dynamic Cone Penetrometer
- Portable Light Weight FWD
- Hot Mix Asphalt Infrared Temperature Measurements
- Intelligent Compaction
- Rolling Dynamic Deflectometer
- Soil Resistivity Profiling
- Fourier Transform Infrared Spectroscopy

Gamma-Gamma Logging and Crosshole Sonic Logging Integration



Courtesy of Brian Liebich, P.E., California Department of Transportation.

Applications

- Assess the integrity of drill shafts or piles immediately after construction
- Gamma Gamma Logging can assess the exterior of the shaft, while Crosshole Sonic Logging can assess the shaft interior

Gamma-Gamma Logging and Crosshole Sonic Logging Integration

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Advantages

- Ability to assess drill shaft or pile integrity
- Ability to determine if and where repairs are needed

Limitations

- Gamma Gamma Logging is a nuclear technology
- Methods require the installation of access tubes
- Operator has to be licensed

Portable Seismic Pavement Analyzer and Free Free Resonant Column Test

Applications

- Directly measure the modulus of pavement layers
- Device has the potential to replace the nuclear density gauge
- Evaluation of ACP and granular base layers
- Device can be used for acceptance testing of concrete pavement
- Measurement of pavement thickness

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Portable Seismic Pavement Analyzer and Free Free Resonant Column Test

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Advantages

- Reduces number of destructive tests required for determining pavement layer properties
- Results can be obtained within two minutes for both tests, since the data is analyzed on site

Limitations

- The testing is discrete by nature (i.e. the testing measures properties at a single point per test, and it takes two minutes per test)
- Not suitable for rapid 100% coverage testing

Vibration Based Bridge Monitoring

Applications

- Damage detection due to structural degradation of bridges such as corrosion of rebars, ASR/DEF
- Determination of fatigue and fracture
- Damage detection due to earthquakes
- Identification of stiffness changes in bridge piers and girders

Vibration Based Bridge Monitoring

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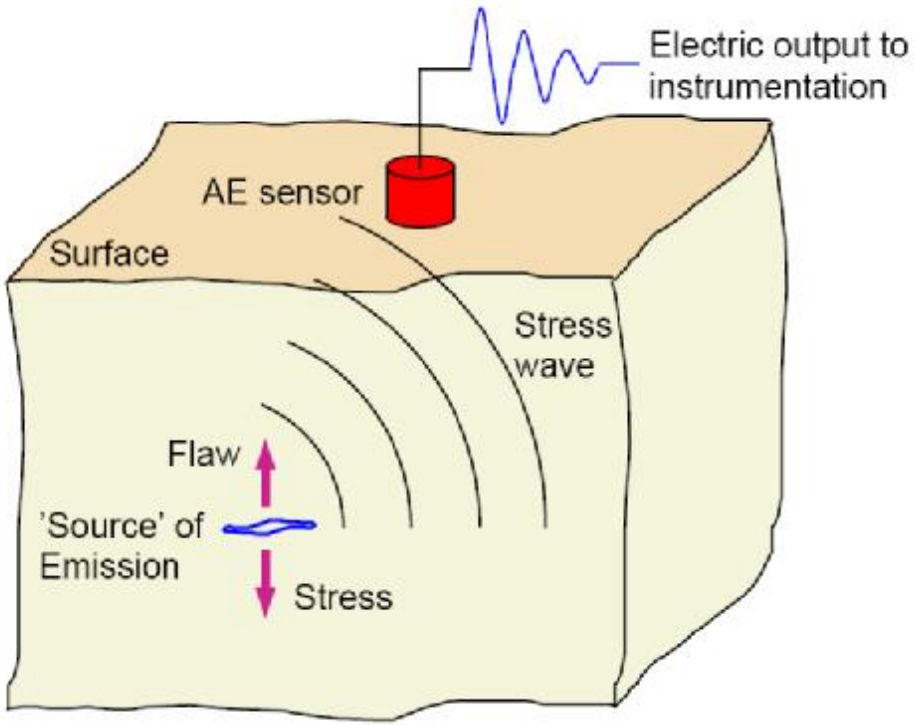
Advantages

- Global technique, so only a limited number of sensors is required to monitor a large bridge.

Limitations

- Method is limited because of the data interpretation.
- Difficult to relate changes in eigenfrequencies and modal shapes to damage detection since changes in environmental conditions such as temperature and humidity also cause changes in modal parameters
- Localization of defects are difficult since only a few sensors are used
- Low accuracy due to low frequency

Acoustic Emission



Applications

- Detecting the debonding of the deck from the girders
- Detection of delaminations
- Monitoring the tip velocity of a propagating crack

Acoustic Emission

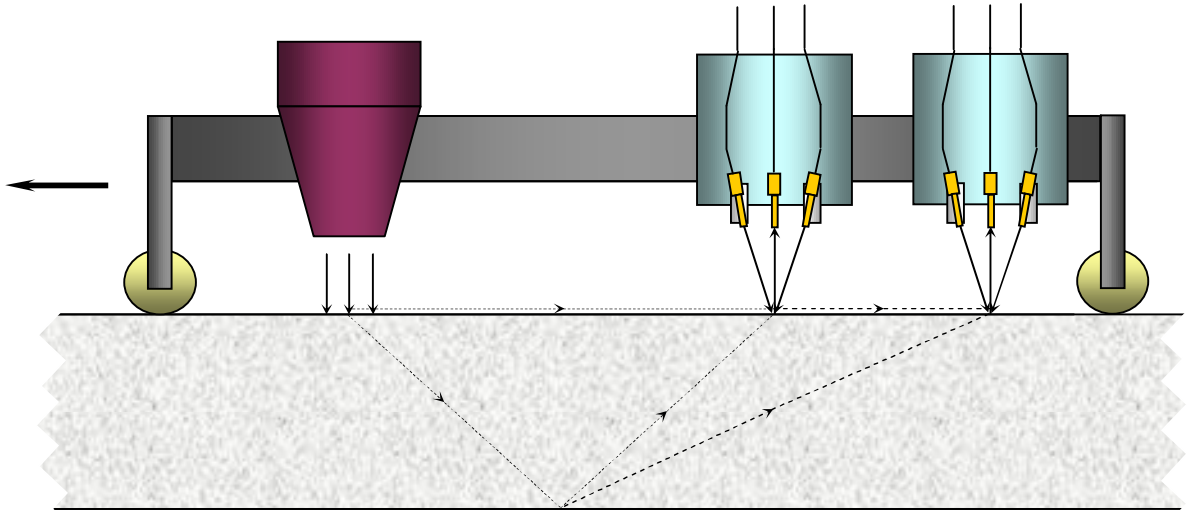
Advantages

- Passive technique
- No excitation of ultrasonic signals are required

Limitations

- History of acoustic emission signals cannot be caught on existing structures
- Estimation of the structural integrity of existing structures is difficult

Air-coupled Ultrasound



Applications

- Identification of thickness of pavement
- Identification of complex modulus of elasticity of pavements
- Nondestructive testing of bridge decks
- Nondestructive testing of tunnels

Air-coupled Ultrasound

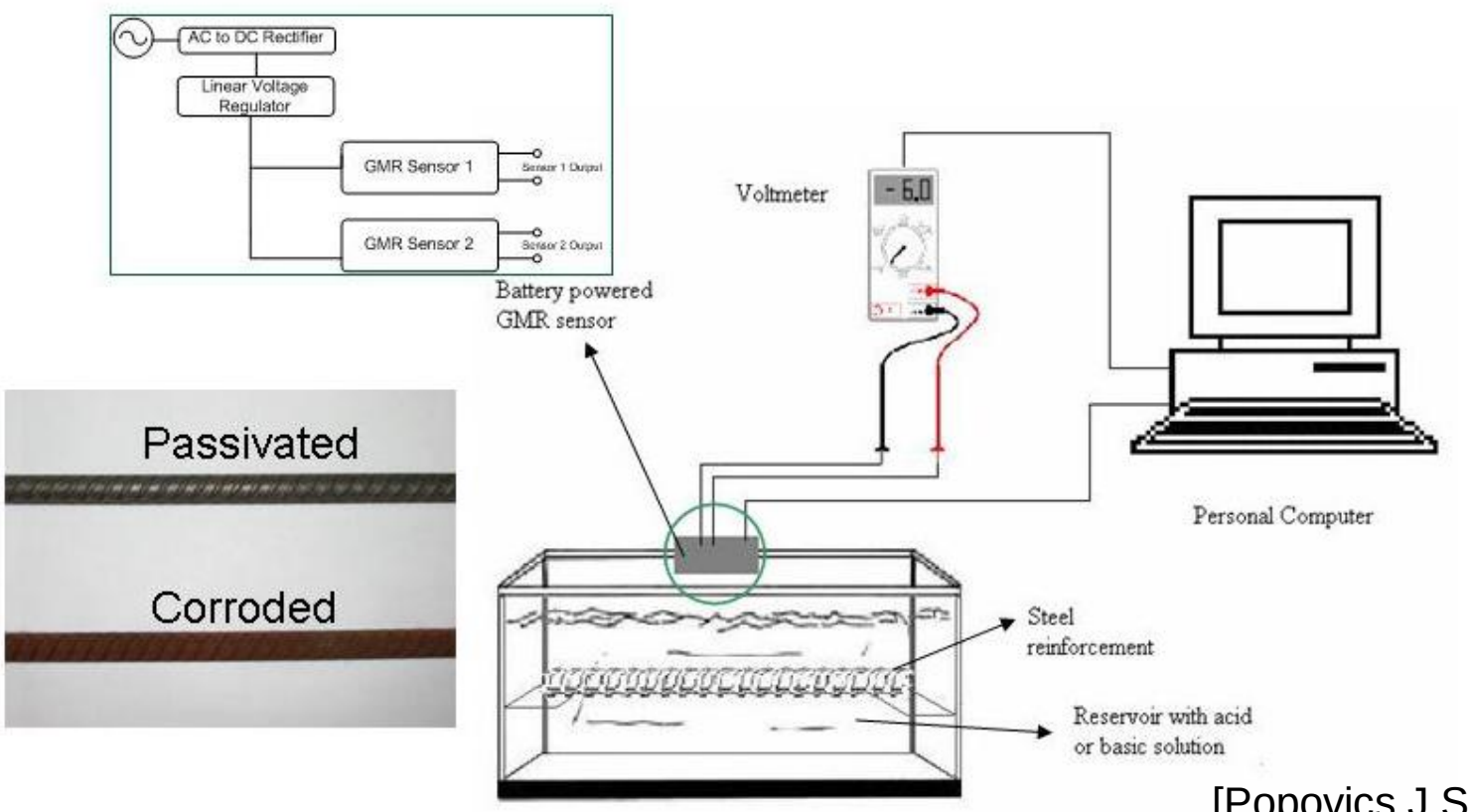
Advantages

- Non-contact technique,
- Potential for high speed measurement and evaluation.

Limitations

- There is a high impedance mismatch using air as couplant
- The generated and detected waves have a low signal amplitude relative to contact transducers

Magnetoresistive Sensor



[Popovics J.S., 2007]

Applications

- Identification of corrosion rate and extend in rigid pavements, bridge components, and tunnels.

Magnetoresistive Sensor

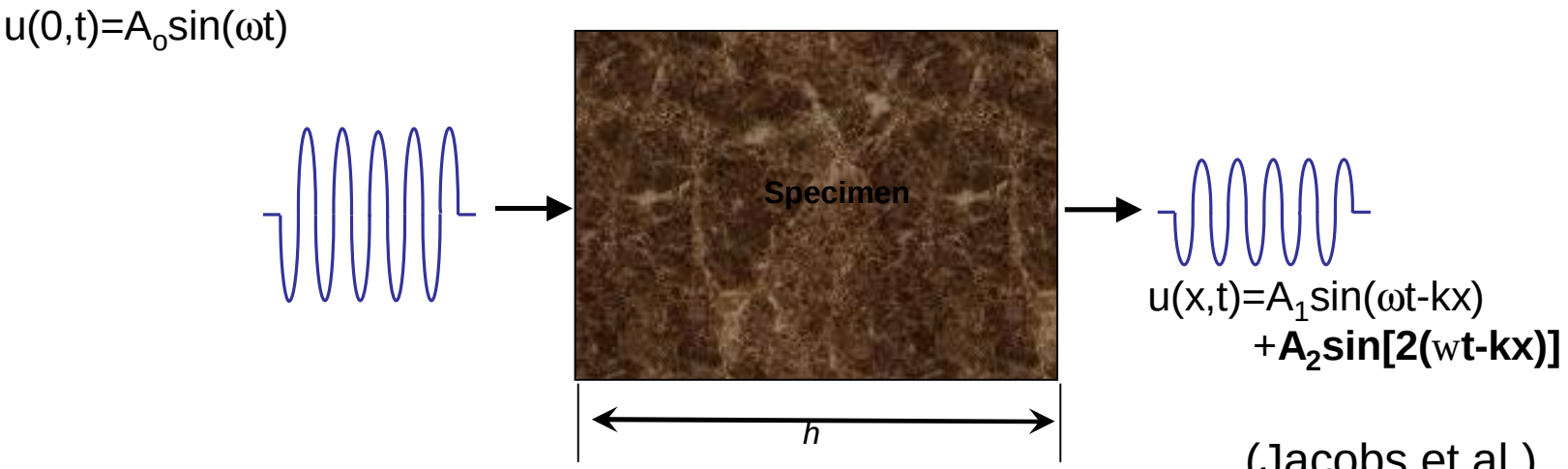
Advantages

- Giant Magnetoresistive (GMR) sensor offers promise for magnetic sensing of extend and rate of corrosion in concrete without having direct contact with the steel. The sensors have high sensitivity, are inexpensive and small

Limitations

- Not known yet

Nonlinear Ultrasound



(Jacobs et al.)

Applications

Identification of

- ASR/DEF deterioration in rigid pavements, bridges and tunnels
- fatigue life in steel members
- corrosion in steel reinforcement

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Nonlinear Ultrasound

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Advantages

- Acoustic nonlinearity parameter is an absolute material constant
- Acoustic nonlinearity parameter is directly measurable
- Nonlinear ultrasonics provides robust and quantitative characterization of fatigue damage, ASR/DEF deterioration or corrosion in in-service structural components

Limitations

- Acoustic nonlinearity is very small, and can be easily overwhelmed by a number of other factors
- A systematic experimental procedure that can identify and remove spurious sources of nonlinearity has to be developed

Air Coupled GPR

Interviews

In-house: Minnesota, Florida, Texas

Use Consultants: Other States

Widely used in Europe

Applications

- Thickness of pavement layers
- Moisture or density related defects in HMA and base layers
- Density of new Asphalt layers
- Delaminations in bridge decks (with HMA surfaces)
- Section uniformity (no surprises in construction)

Air Coupled GPR

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Advantages

- Only Highway speed subsurface pavement testing tool
- Excellent for Flexible pavement rehabilitation projects
- Can be merged with surface video and other NDT data

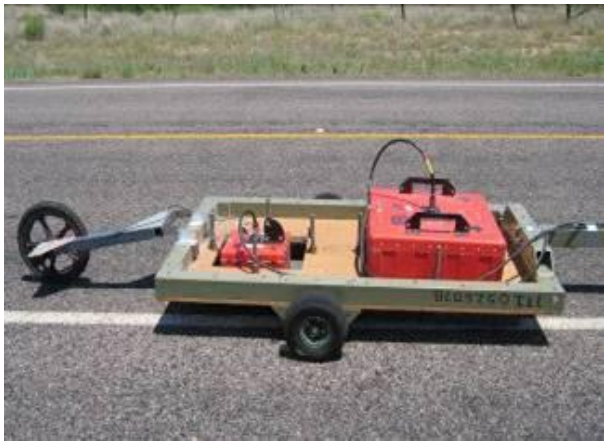
Limitations

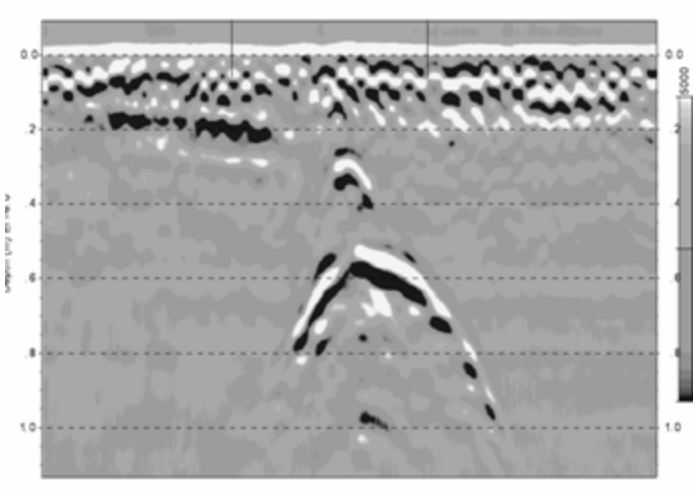
- Depth limited to top 20 – 24 inches
- Attenuation problems with concrete layers
- Initially limited software available for processing data
- Pavements and materials can be complex –
  training and structured implementation approach required
  must have dielectric contrast between layers

Barriers to Implementation

- In USA FCC restrictions on manufacturers
- Oversold - initial results disappointing-
- No Certification of equipment and vendors

Ground Coupled GPR





<u>In House</u> **Florida, Minnesota, Texas**

Used on an as needed basis in most DOT's

Europe (numerous)

<u>Applications</u>

- Detecting buried objects
- Voids under thick concrete slabs
- Detecting steel presence and depth
- Locations where deep investigations are required

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Ground Coupled GPR

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Advantages

- Fairly inexpensive
- Robust Equipment - technology and software widely available
- Deep investigations possible with low frequency equipment

Limitations

- Speed typically less than 10 mph
- Limited near surface information
- Penetration limited in clay material
- Qualitative info; usually need expert for interpretation

Barriers to Implementation

- Technology not well understood by DOT's
- No significant barriers

Real Time Automated Distress Data Collection

Technology under development for past 20 years

Manual interpretation systems widely used but $$

Automated systems (some real time) under development in various DOT's and in private Companies

Application

- Cracking estimates on flexible pavements

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Real Time Automated Distress Data Collection

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Advantages

- Speed
- Reduce cost if manual interpretation eliminated

Limitations

- Alligator cracking and sealed cracks more difficult to quantify
- Lighting conditions/trees/shadows cause problems
- Coarse textured surfaces.
- High equipment costs

Barriers to Progress

- Need for better lighting systems
- Better interpretation software

Dynamic Cone Penetrometer

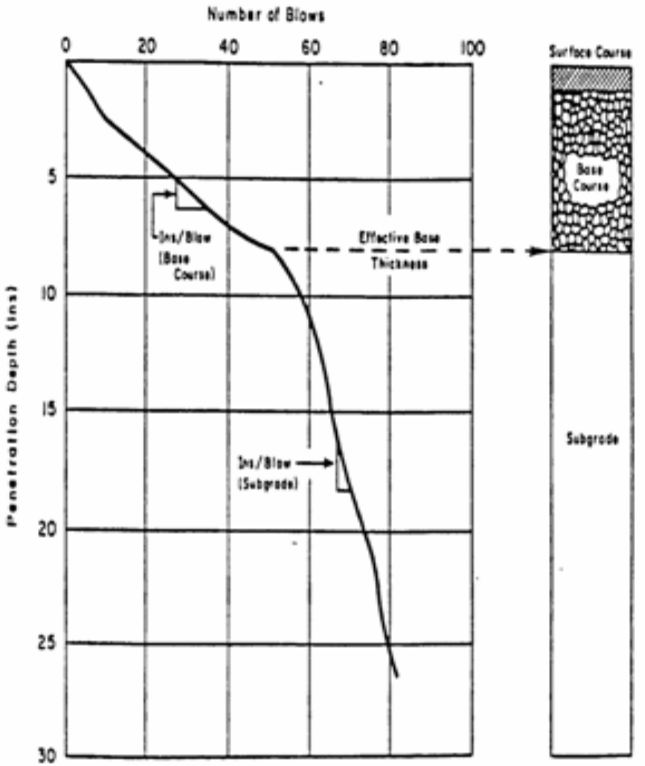
(for construction acceptance)

Most DOT's currently use for forensics and pavement evaluation

COE for pavement design

Minnesota taking lead in Construction acceptance

other DOT's active



Applications

- Quality assurance testing of subgrade and embankment materials
- Alternative to Nuclear density gauges

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Dynamic Cone Penetrometer

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Advantages

- Cheap/portable/simple
- Related to CBR and stiffness

Limitations

- Slow, labor intensive
- Point specific
- Problems with granular materials
- Rod friction should be accounted for in clays

Barriers to Implementation

- No specifications (trial specs in MnDOT)
- Influence of layer moisture content

Portable Light Weight FWD

Interest in many DOT's

Minnesota taking lead

Developed and used in Europe

Applications

- Rapid stiffness testing of bases and subgrades
- Alternative to Nuclear density gauges

Portable Lightweight FWD

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Advantages

- Deflections can be converted to stiffness (design parameter!)
- Low cost
- Portable

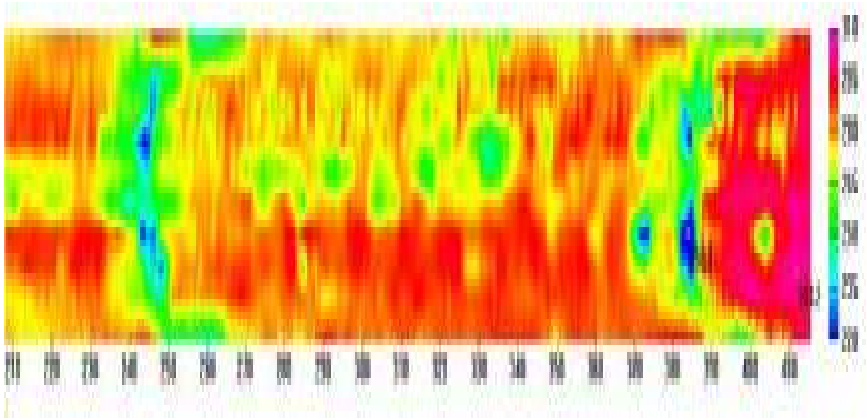
Limitations

- Depth of influence unknown
- Better software required for multilayer analysis

Barriers to Implementation

- No specifications
- Setting acceptance criteria
- Modulus is highly stress sensitive
- Influence of layer moisture content

HMA Infra-red Measurements



DOT's Washington, NCAT, Texas

Applications

- Temperature uniformity of new HMA layers
- Thermal Segregation detection
- Creating a permanent log of paving operations –
  - Location and duration of paver stops

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HMA Infra-red Measurements

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Advantages

- Segregation of hot mix a continuing problem
- Newer lower cost camera systems widely available
- Automated system with 100% coverage
- Cameras and guns available but difficult to obtained 100%

Limitations

- Equipment not widely available

Barriers to Implementation

- What should targets be -
  given the variability of PG gradations and mix types
- Not currently included in specifications

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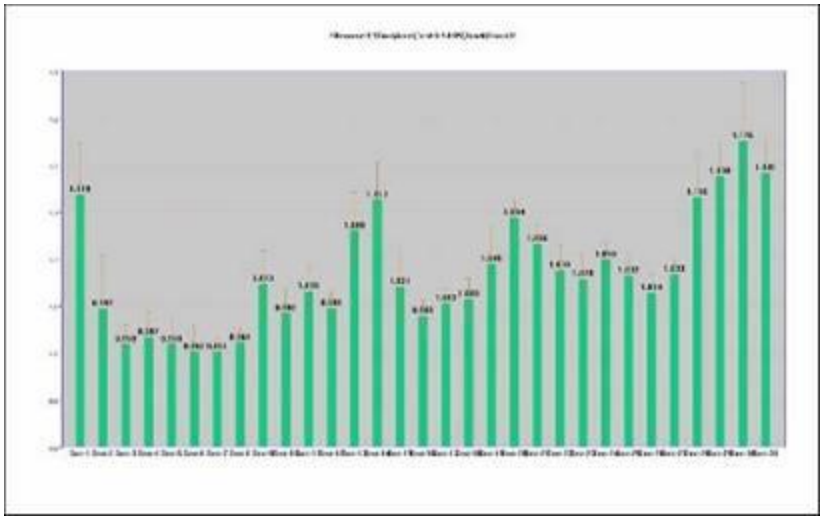
Intelligent Compaction



Developed in Europe, promoted by FHWA

Lots of interest in USA, pooled fund, Minnesota, Iowa

Applications

- Quality Control/Assurance testing of bases and subgrades
- When to stop rolling/Finding weak spots
- Hot Mix applications??

PRELIMINARY FINDINGS – SUBJECT TO UPDATES

Intelligent Compaction

Advantages

- 100% Coverage
- Related to sub structure support/stiffness

Limitations

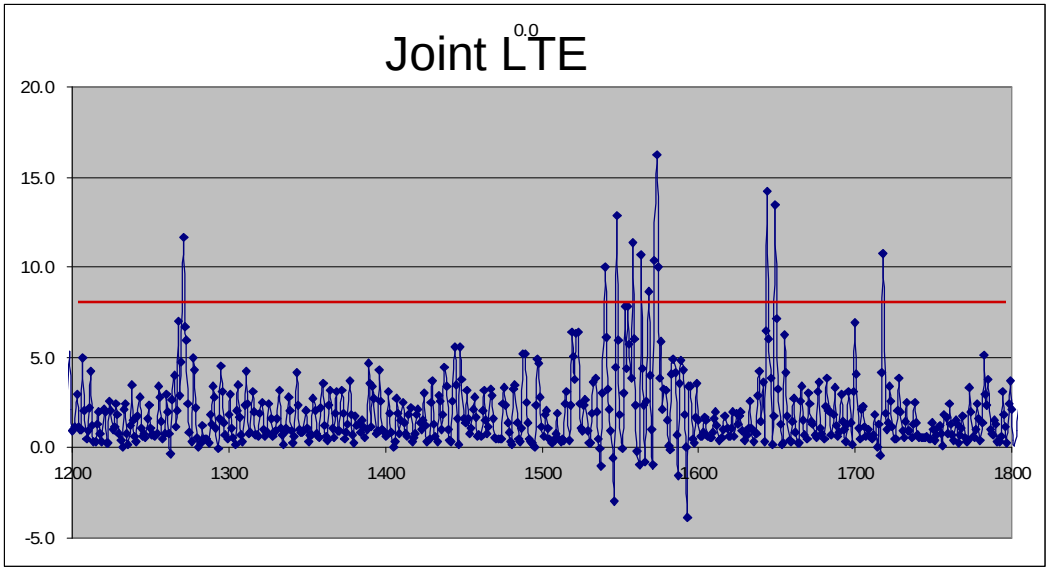
- What is being measured is not well understood
- Limited ability to check individual layers
- Equipment availability in USA
    - Typically option when purchasing new rollers

Barriers to Implementation

- Where should it be used?
- How can targets be selected
- How is moisture content accounted for
- Not currently included in design or specifications

Rolling Dynamic Deflectometer

(Project level only)



Texas and France ?? - Project Level
Numerous efforts at Network level laser based systems

Applications

- Rehabilitation planning on Jointed Concrete Pavements
- 100% coverage of Load transfer efficiency

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Rolling Dynamic Deflectometer

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Advantages

- Faster than other methods
- From interviews selecting Rehab for Jointed Concrete continues to be a major concern

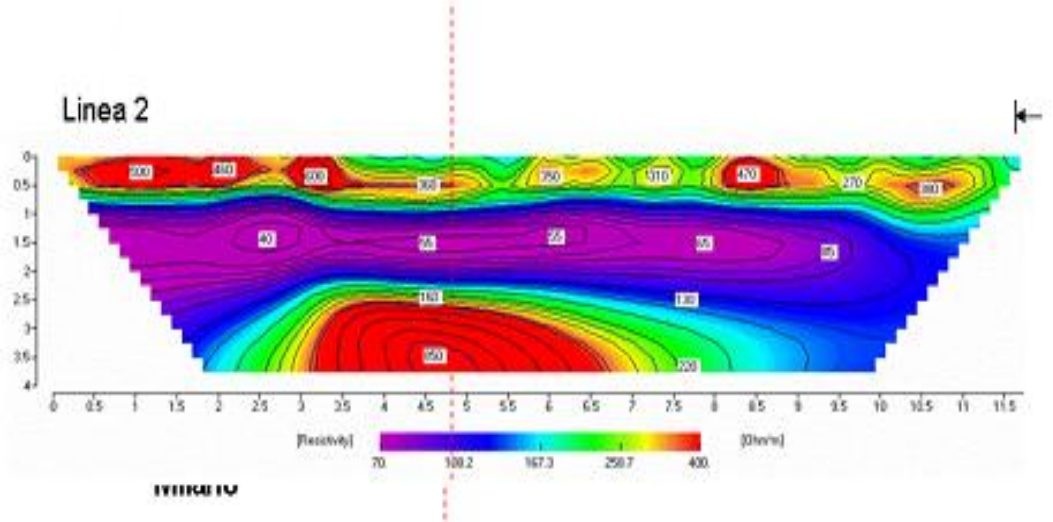
Limitations

- Slow speed (1.5 mph)
- Cost

Barriers to Implementation

- Need for a better rolling sensors system
- Need to increase speed
- Improved software required when existing slab has HMA overlay
- Influence of environmental conditions needs to be defined

Soil Resistivity Testing



Europe (Finland, Italy)

Minnesota

Applications

- Subsurface mapping during project design
  - Interpolating between bore holes
  - Locating problem soil deposits (organics)
- Sinkhole detection
- Aggregate exploration

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Soil Resistivity Testing

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Advantages

- Instrumentation is fairly inexpensive
- Works well in conductive (clay) soils
- Can look very deep (if needed)
- Mobile systems under development

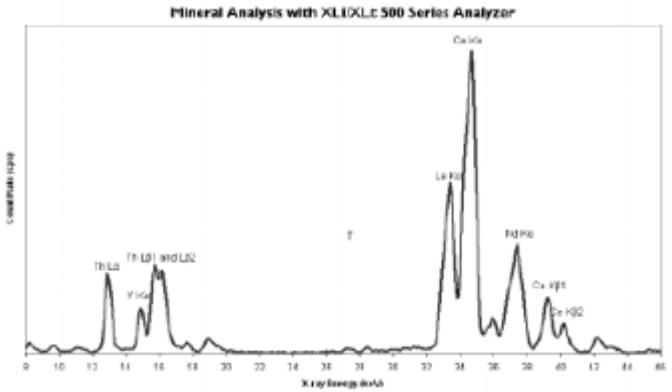
Limitations

- Slow
- Not widely used or understood by DOT's

Barriers to Implementation

- Clear guidelines needed on where when, how to use this technology

Field Spectroscopy Devices
XRF, FTIR, Raman



FHWA

(FTIR)

Applications

- Polymer content of Asphalt - Quality of lime
- Sulfate content of soils
- Uniformity of Emulsions
- Many, many potential applications

PRELIMINARY FINDINGS – SUBJECT TO UPDATES

Field Spectroscopy Devices
XRF, FTIR, Raman

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Advantages

- Works in field
- Rapid - fairly low cost $20-25K

Limitations

- New technology – Not sure what it can do
- FTIR limited by moisture content
- Needs to establish a reference library

Barriers to Implementation

- Clear guidelines needed on where, when, how to use this technology

Inertial Profilers

Applications

- High-speed inventory of pavement smoothness (most DOTs)
- Acceptance testing of as-built pavement smoothness
  - Majority of specifications on HMA testing
  - Used on PCC pavement construction in a few states
  - Initial interest on acceptance testing of base smoothness

PRELIMINARY FINDINGS – SUBJECT TO UPDATES

Inertial Profilers

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Advantages

- Provide objective measures of ride quality
- Profile data useful for various applications
- High-speed and 100% coverage of test wheel path
- Mature technology – used in-house by most DOTs

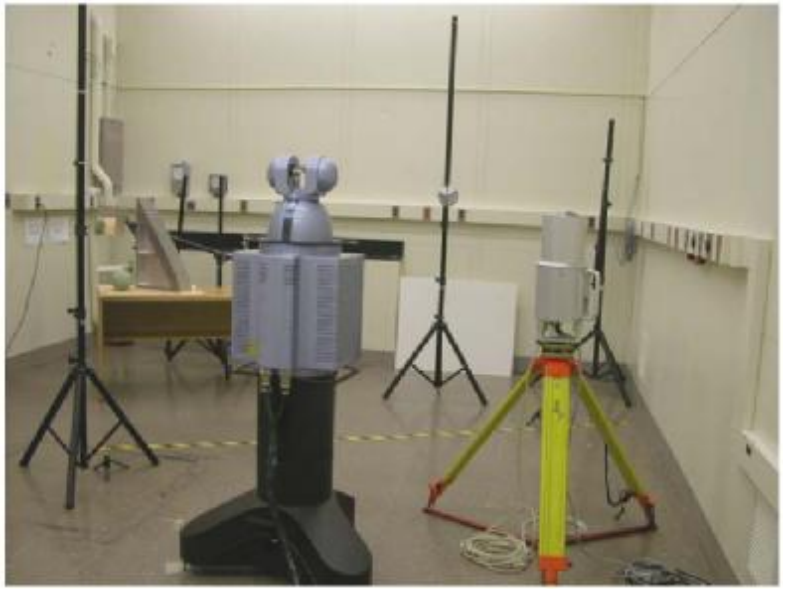
Limitations

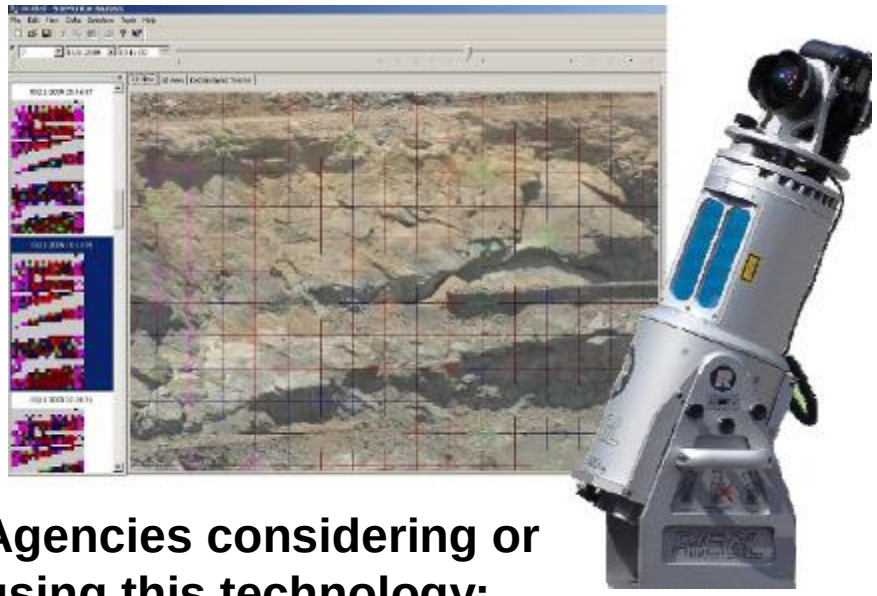
- Does not provide “true” profile

Barriers to Implementation

- Cost could be a factor
- Lack of training on proper operation and use
- Lack of understanding on what equipment can or cannot do

Laser Scanning





Agencies considering or using this technology:

- **California, Minnesota, Texas, Washington, FHWA; various consultants**

Applications

- Monitoring movements or deformations
- Mapping of highway assets
- Tunnel inspections
- Scour measurements

Laser Scanning

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Advantages

- Captures as-is conditions
- Provides 100% coverage
- Continuous monitoring for change detection
- Measurements of hazardous or inaccessible environments

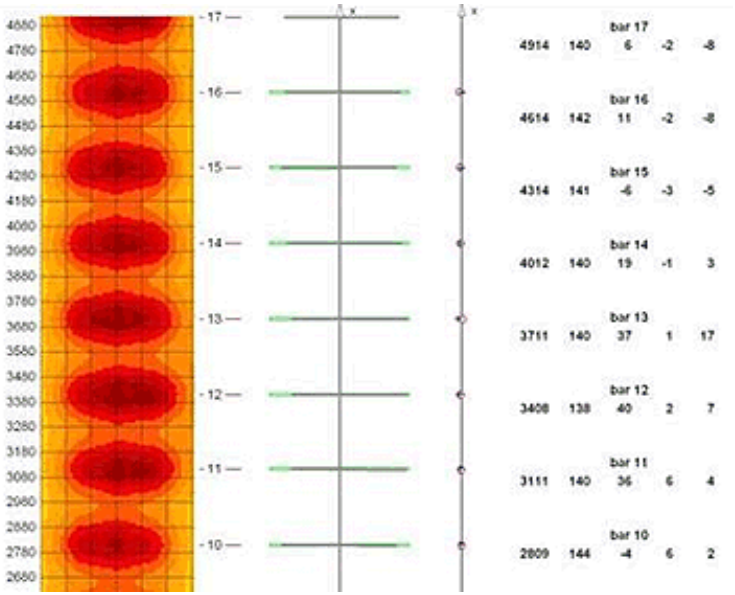
Limitations

- Targets must have clear line of sight
- Atmospheric effects

Barriers to Implementation

- High cost could be a factor
- Standards needed for comparing systems
- Automated processing of scan data

MIT Scan Device



Agencies considering or using this technology:

- **California, S. Carolina, Washington, FHWA; various consultants**

Application

- Locates position & depth of placement of dowel bars

MIT Scan Device

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Advantages

- Easy to use (Washington DOT and FHWA experience)
- Can be used to monitor dowel bars during construction
- Not affected by presence of water or change in moisture content

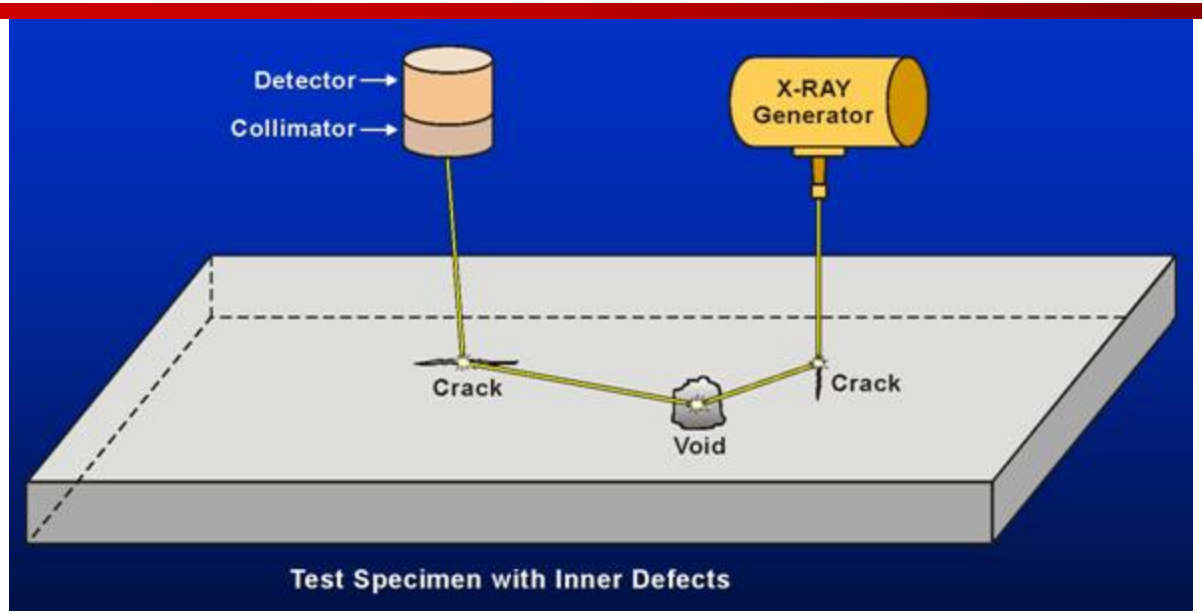
Limitations

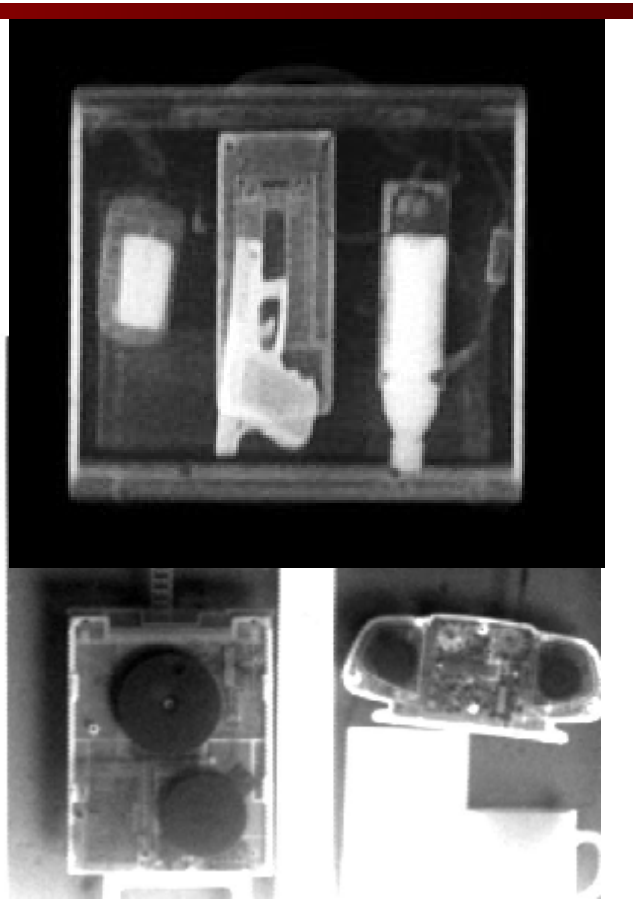
- Presence of near metal objects can introduce errors
- Upper limit of 190 mm for depth
- Evaluation limited to bar types included in parameter files

Barriers to Implementation

- Lack of specifications on use for construction
- Lack of understanding on what equipment can or cannot do

X-Ray Backscatter





Agencies considering or using this technology:

- **Florida DOT, Port and aviation authorities, NASA**

Applications

- Detection of defects in bridge decks
- Crack detection in pavements
- Corrosion of reinforcing steel in concrete
- Detect material flaws and defects

PRELIMINARY FINDINGS – SUBJECT TO UPDATES

X-Ray Backscatter

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Advantages

- Demonstrated ability to probe through several centimeters of concrete or steel
- Can provide images with high resolution and contrast
- Equipment can be installed in a van and operated at around 5 mph

Limitations

- Nuclear technology
- Limited experience with infrastructure applications

Barriers to Implementation

- Limitations noted may deter implementation

Sliding Profiler

- **Developed in Texas**
- **Initial implementation stage**

<u>Application</u>

- Quality control of concrete smoothness during placement

Sliding Profiler

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Advantages

- Relatively low cost
- Used on surface being placed
- Simple to operate
- Works at the speed of paving train

Limitations

- New equipment - limited field experience

Barriers to Implementation

- Lack of training on proper operation and use
- Lack of understanding on what equipment can or cannot do