RAW DATA. REFINED RESULTS.

INTRODUCTION TO HIGHWAY AND AIRFIELD PAVEMENT INSTRUMENTATION TECHNOLOGIES

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CONFIDENTIAL INFORMATION

BDI – NEW PAVEMENT DIVISION

WHAT WE DO ON PAVEMENTS

BDI provides instrumentation and services for pavement performance evaluation by providing sensors, monitoring systems and nondestructive evaluation services to help better understand pavement performance and underlying support conditions. This service is provided to Owners, Accelerated Pavement Test (APT) facilities, construction road and airport projects and in-service roads where existing conditions may need performance evaluation, repairs and/or rehabilitation.

WHY BDI IS UNIQUE

+ We are an engineering firm that provides instrumentation services.
+ We manufacture our own instruments based on **our field experience**.
+ We provide installation services, training and turn-key solutions.
+ We support our instruments through simple-to-use applications.

This rare combination makes BDI one of the most unique firms in the pavement instrumentation industry.

AGENDA

- PAVEMENT TESTING
- PAVEMENT INSTRUMENTATION
- DATA SYSTEMS AND SOFTWARE
- CASE STUDY APPLICATIONS
- NEW TECHNOLOGY
- QUESTIONS / DISCUSSION

NATIONAL AIRPORT TEST FACILITY

WHERE IT ALL STARTED –
FAA TEST FACILITY WITH 1000+ SENSORS!

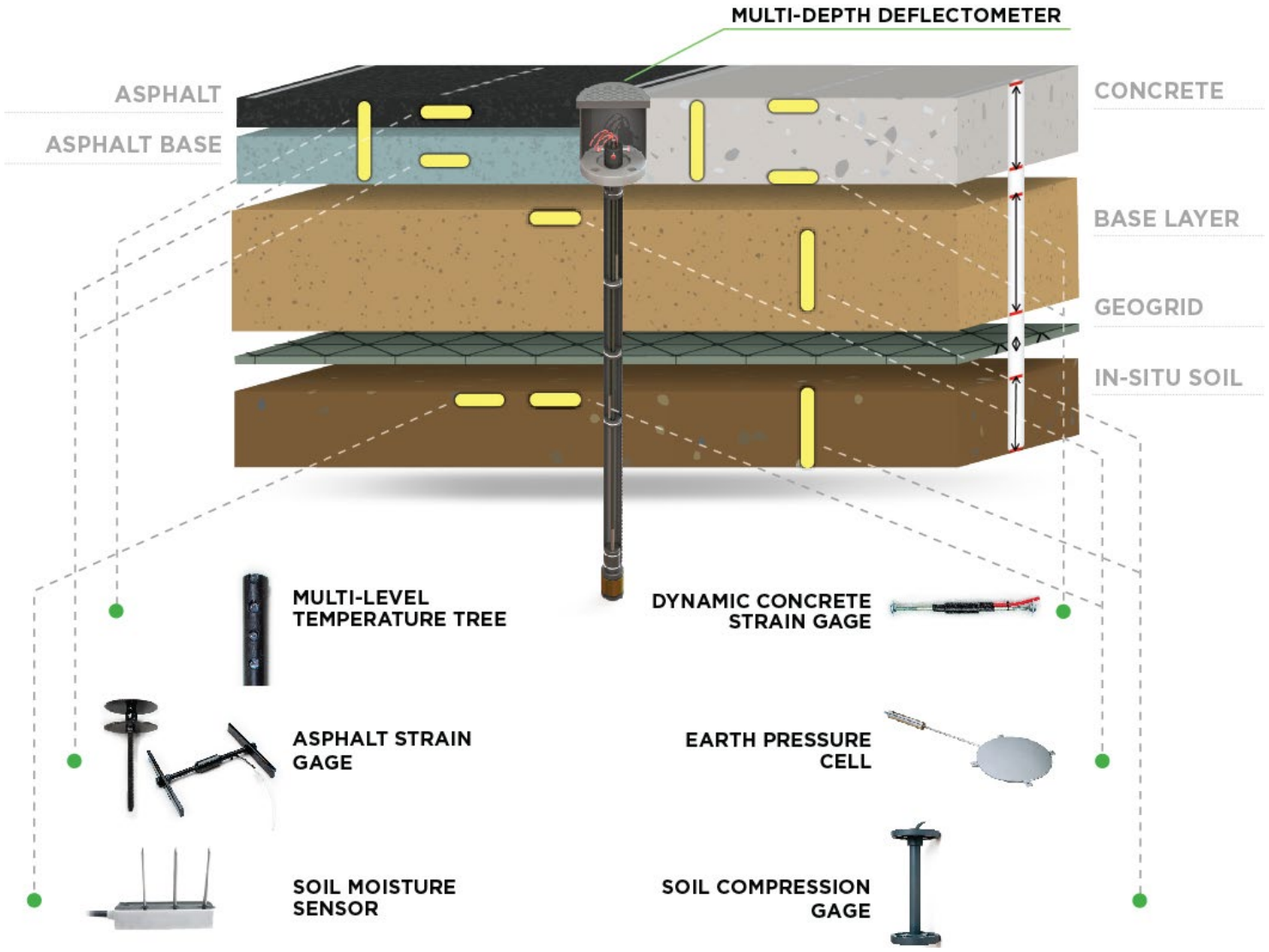
+ Concrete Strain Gages
+ Asphalt Strain Gages
+ Temperature Trees
+ Soil Compression Gages
+ Soil Pressure Cells
+ Soil Moisture Gages
+ Multi-Depth Deflectometer
+ Track-side ADAS
+ Control Room

PAVEMENT TESTING/MONITORING

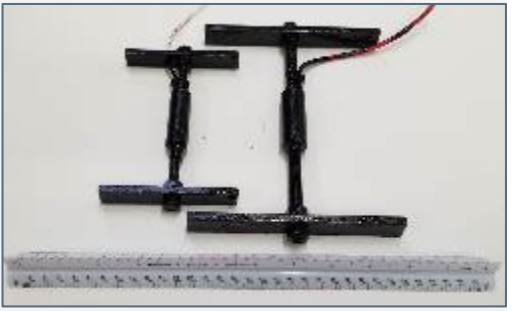
ACCELERATED PAVEMENT TEST FACILITIES AND VEHICLES

HOW DO YOU MEASURE PAVEMENT RESPONSES

1. **Pavements**
   - I. Asphalt Strain Gages
   - II. Concrete Strain Gages
   - III. Temperature Tree
   - IV. Multi-Depth Deflectometer
2. **Base Layers**
   - I. Pressure Cells
   - II. Multi-Depth Deflectometer
   - III. Vertical Strain
   - IV. Rotation
3. **Geogrid**
   - I. Geogrid Strain
4. **Sub-Base Layers**
   - I. Pressure Cells
   - II. Multi-Depth Deflectometer
   - III. Soil Compression
   - IV. Rotation
   - V. Soil Moisture



BDI SENSOR TECHNOLOGY



ASPHALT STRAIN

+ Two Sizes
+ Range: ±3000 με
+ 350Ω Fully Active Wheatstone bridge
+ Sensitivity: 1.3 mV_{out}/mV_{ext}
+ Temperature Range: -50 to +200 °C

VERTICAL STRAIN

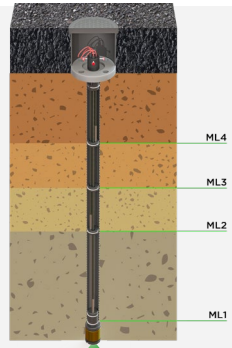
+ Range: ±3000 με
+ 350Ω Fully Active Wheatstone bridge
+ Sensitivity: 1.3 mV_{out}/mV_{ext}
+ Temperature Range: -50 to +200 °C

TEMPERATURE TREE

+ Temperature Range: -50 to +200 °C
+ Depth of Measurement: User defined
+ Sensor Type: Thermistor or Thermocouple

SOIL COMPRESSION SENSOR

+ Gage Length: Customer Specified
+ Measurement Rage: up to 2-in (50mm)
+ 3- to 4-wire potentiometer
+ Temperature Range: -*20* °C to +85 °C



MULTI DEPTH DEFLECTOMETER

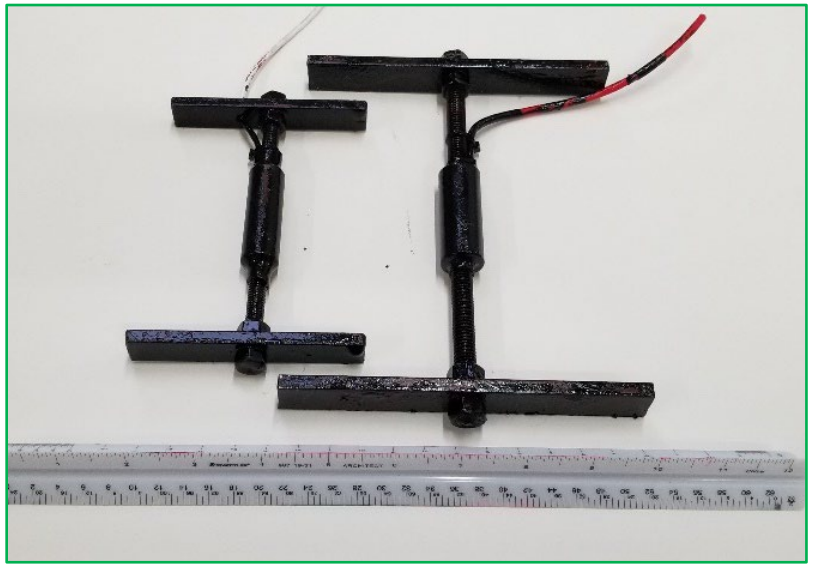
+ Range: ±0.5
+ Up to 6 positions (5 depths + anchor)
+ Depth up to 12-ft
+ Linearity: < ±0.5% F.S.
+ Resettable transducers for pavement rutting

ASPHALT STRAIN GAGE

SENSOR SUBJECTED TO WORST POSSIBLE CONDITIONS

INSTALL EXPERIENCE IS IMPORTANT TO PROTECT AGAINST

- Crushed/cut lead wires
- 350 deg HMA
- Paving train dragging/pulling on sensor/wire
- Rolling operation
- Vibratory rolling

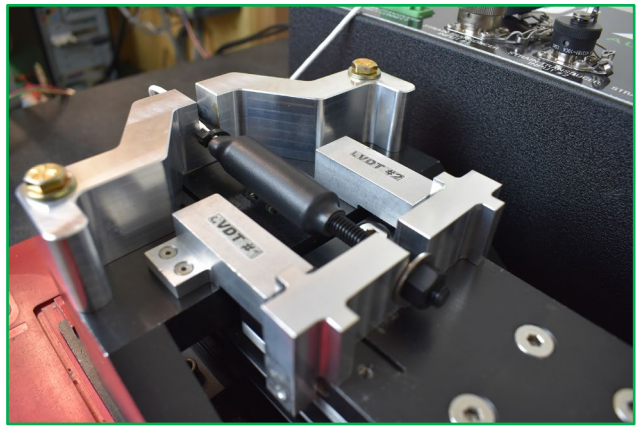


ASPHALT STRAIN GAGE

MAJOR IMPROVEMENTS FOR INCREASED SURVIVAL RATES (>90%)

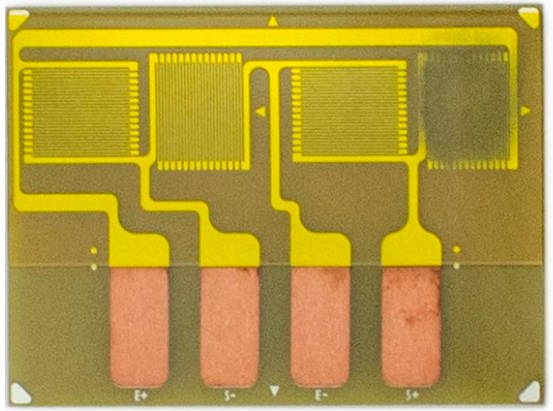
- Design by Civil Engineer with hands-on experience with more than 1000 sensor installations (only BDI)
- Final coating is bitumen- not driveway sealer
- Unbonded crush protection
- Dynamic calibration of sensor (only BDI).
- Fabrication by a 'true' sensor manufacturer (only BDI)
- **New** single matrix gage grid to eliminate delicate gage wiring (only BDI)

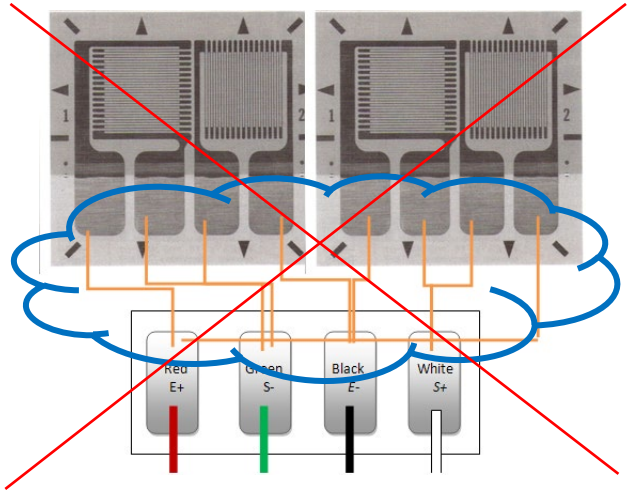
Above and continued improvements based on continuous interaction with the Test Pavement community (TRB AFD40 APT)



CONCRETE STRAIN GAGE (DYNAMIC)

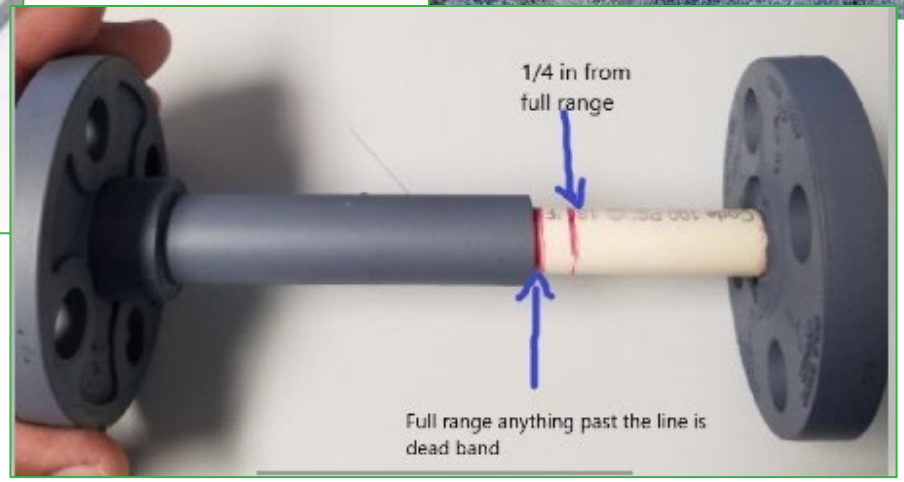
WOULD NOT RECOMMEND FOR CONCRETE STABILIZED BASE- CONCRETE ONLY





SOIL COMPRESSION SENSOR (DYNAMIC)

- RUGGEDIZED
- USED HORIZONTAL OR VERTICAL
- BEST ABOVE THE WATER TABLE, BUT PROTECTED FROM WATER INGRESS



QUALITY ASSURANCE / DOCUMENTATION

DOCUMENT, DOCUMENT, DOCUMENT

QUALITY CONTROL FABRICATION AND HOOK-UP SHEET

BDI RAW DATA. REFINED RESULTS. **DYNAMIC ASG** *ASPHALT STRAIN GAGE 6X8"* Gage ID:_____ Lead Length:_____

NOTE: MANUAL READINGS TAKEN USING VISHAY P-3500. GF = 2.00 BALANCE = 500

FABRICATION

GAGE RESISTANCE :_____

INITIAL READING AFTER WIRING GAGE :_____

SHORT TO SHIELD :_____

TENSION = _____ IN READING

READING AFTER J-COAT :_____

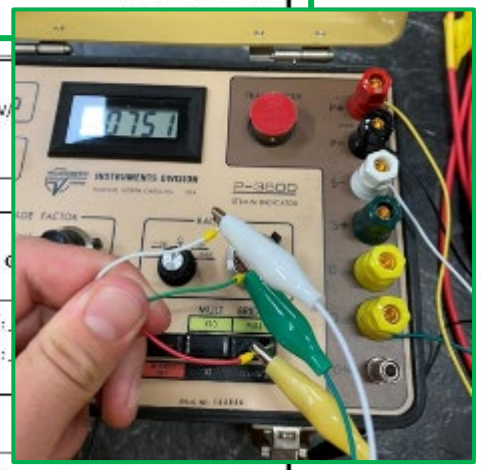
READING AFTER ALL PROTECTION :_____
(after butyl rubber and heat shrink)

DATE :_____ WHO :_____

SHORT TO SHIELD :_____

COMMENTS:_____

COLOR	BRIDGE	P-3500
Red	V_{EX}+	P+
Black	V_{EX}-	P-
White	V_{OP}	S-



CALIBRATION

EXCITATION :_____ CAL FACTOR :_____ ue/mV/

DATE :_____ WHO :_____

FINAL READING AFTER CALIBRATION AND DIPPING :_____

INSTALLATION

NOTE: MANUAL READINGS TAKEN USING VISHAY P-3500.

LOCATION :_____ X:_____

DATE :_____ READING :_____ EVENT :_____

DATE :_____ READING :_____ EVENT :_____

HOOKUP TO SYSTEM

SPU :_____ CHANNEL :_____

DATE :_____ READING :_____ EVENT :_____

QC/QA INSTALLATION AND HOOK-UP SHEET

BDI RAW DATA. REFINED RESULTS. **EARTH PRESSURE CELLS (EPC)** Gage ID:_____ Lead Length:_____

NOTE: MANUAL READINGS TAKEN USING HANDHELD READOUT

TYPE - 0-5 VOLT OUTPUT OVER 0.35MPA (50 PSI)

PRE-INSTALLATION

DATE :_____ WHO :_____ CAL FACTOR :_____

READING PRIOR TO INSTALLATION :_____

INSTALLATION

NOTE: MANUAL READINGS TAKEN USING MANUAL READOUT

LOCATION :_____ X:_____ Y:_____ Z:_____

DATE :_____ READING :_____

COMMENTS:_____

DATE :_____ READING :_____ EVENT :_____

COMMENTS:_____

DATE :_____ READING :_____ EVENT :_____

COMMENTS:_____

DATE :_____ READING :_____ EVENT :_____

HOOKUP TO SYSTEM

SPU :_____ CHANNEL :_____

DATE :_____ READING :_____ EVENT :_____

COMMENTS:_____

DATE :_____ READING :_____ EVENT :_____

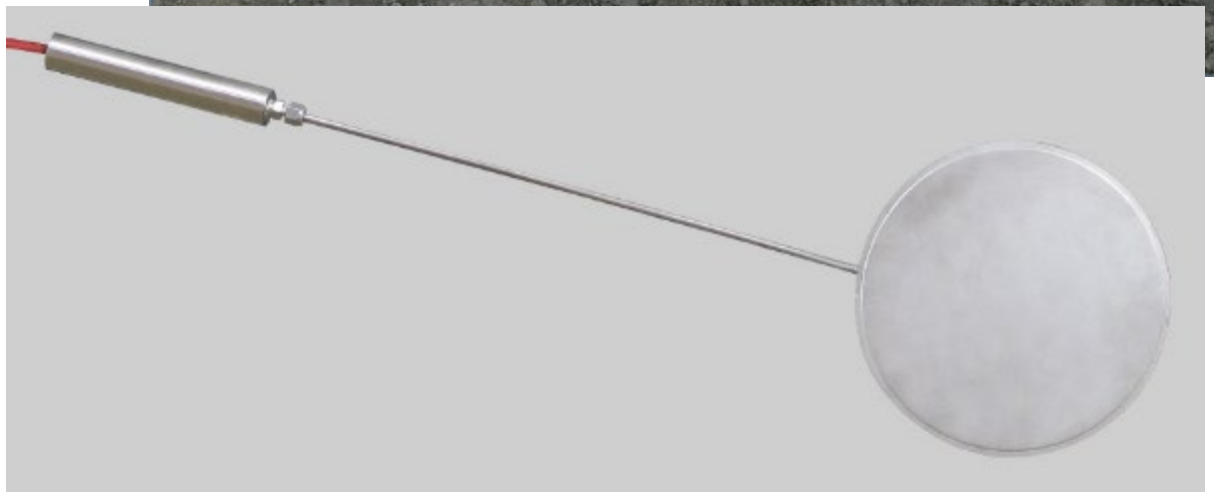
COMMENTS:_____

EARTH PRESSURE CELL (DYNAMIC)

BEDDING IS MOST IMPORTANT

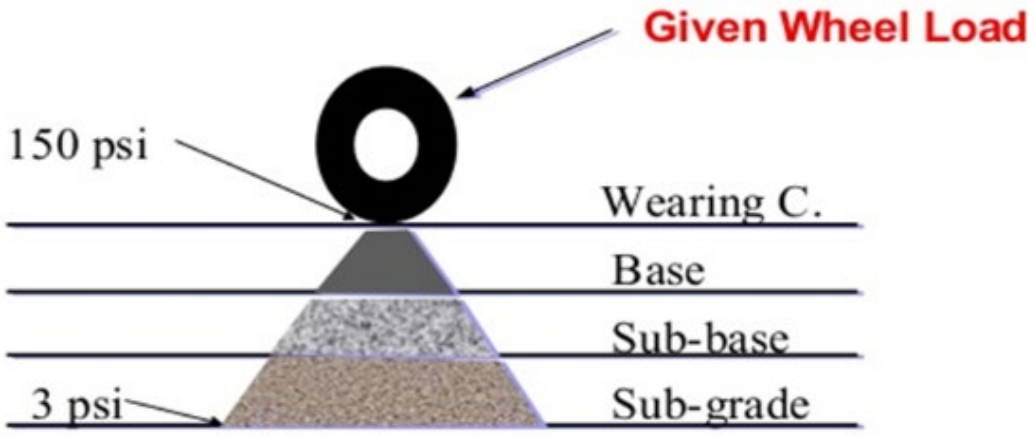
CAREFUL UNDER CONCRETE

VENDER MAY NOT HAVE ALL THE ANSWERS



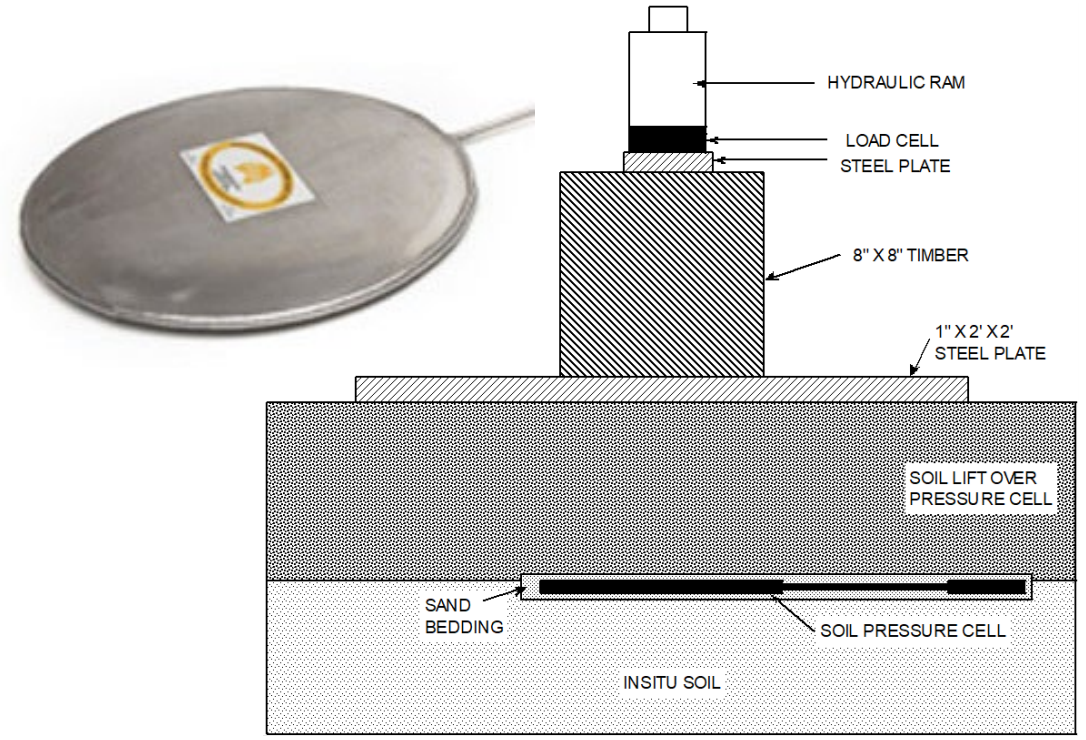
EARTH PRESSURE CELL (DYNAMIC)

CAREFUL WITH THE RANGE SELECTION



Load Distribution in Flexible Pavements

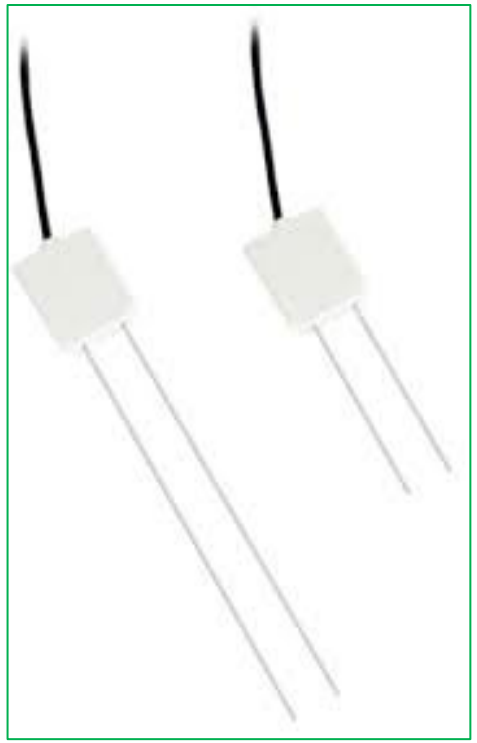
SHOULD YOU CALIBRATE?



SOIL MOISTURE (STATIC)

RESISTANCE TYPE NOT RESEARCH GRADE

TDR/CAPACITANCE SHOULD BE CALIBRATED FOR SOIL TYPE



TEMPERATURE GRADIENT (STATIC)

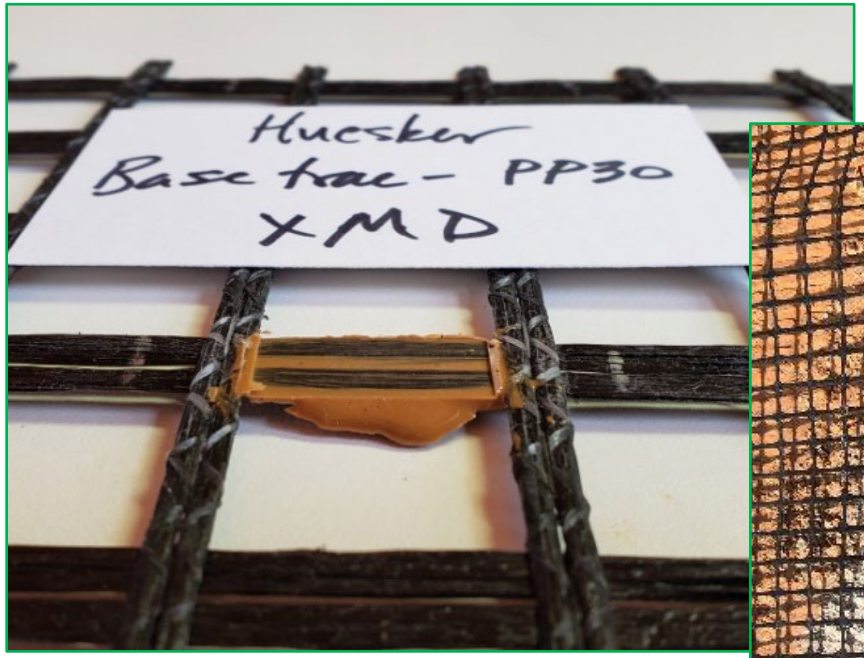
FOR ASPHALT OR CONCRETE

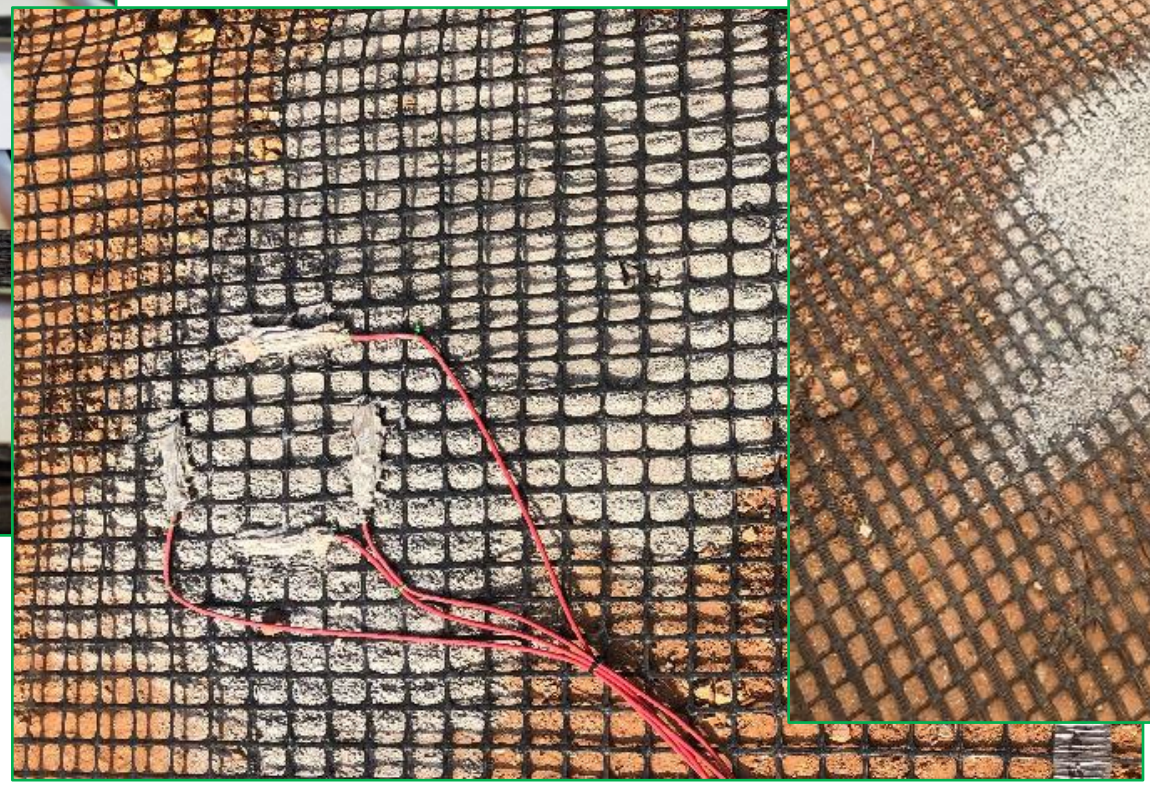
CAN BE TC, RTD OR THERMISTOR - WHAT IS EASIEST FOR SYSTEM

GEOGRID STRAIN (DYNAMIC)

TOUGH TO INSTRUMENT

WOULD FIBER OPTICS BE BETTER??

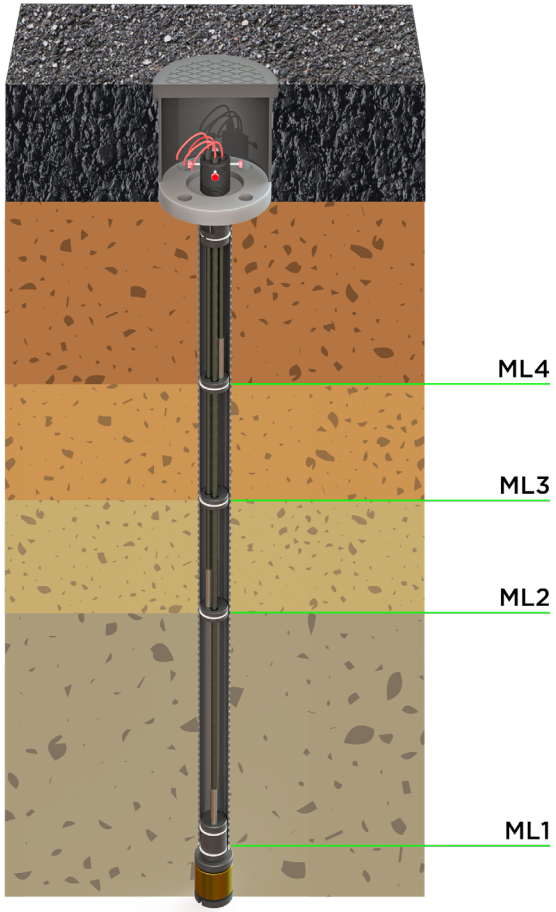




MULTI-DEPTH DEFLECTOMETER (DYNAMIC)

DYNATEST MDD

+ LINEAR ARRAY
+ SENSORS IN GROUND
+ SENSOR NOT REPLACEABLE
+ 2 DAY INSTALLATION
+ MDD COST - $$$$
+ INSTALLATION COST - $$$$



BDI MDD

+ PARALLEL ARRAY
+ SENSORS IN ROADBOX
+ SENSORS RE-STROKEABLE
+ PREFABRICATED
+ 2 PER DAY INSTALLATION
+ MDD COST - $$$
+ INSTALLATION COST - $$

MULTI-DEPTH DEFLECTOMETER (MDD)

Fig. 1

Fig. 2

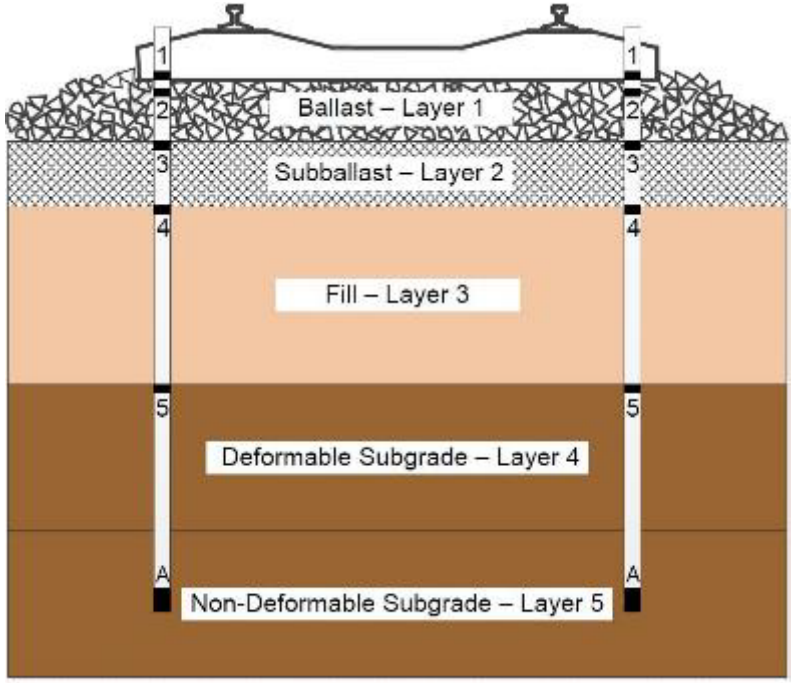
Fig. 3

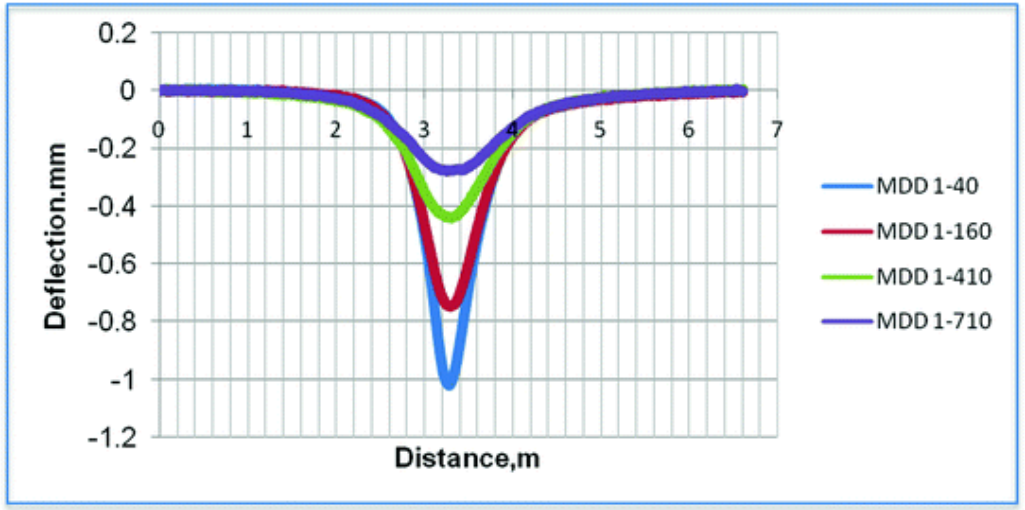
Fig. 4

1. Based off MPBX concept
2. Pre-fabricated with anchor and road box
3. Compressible tube with external ribbed surface
4. Resettable transducers inside road box at top surface

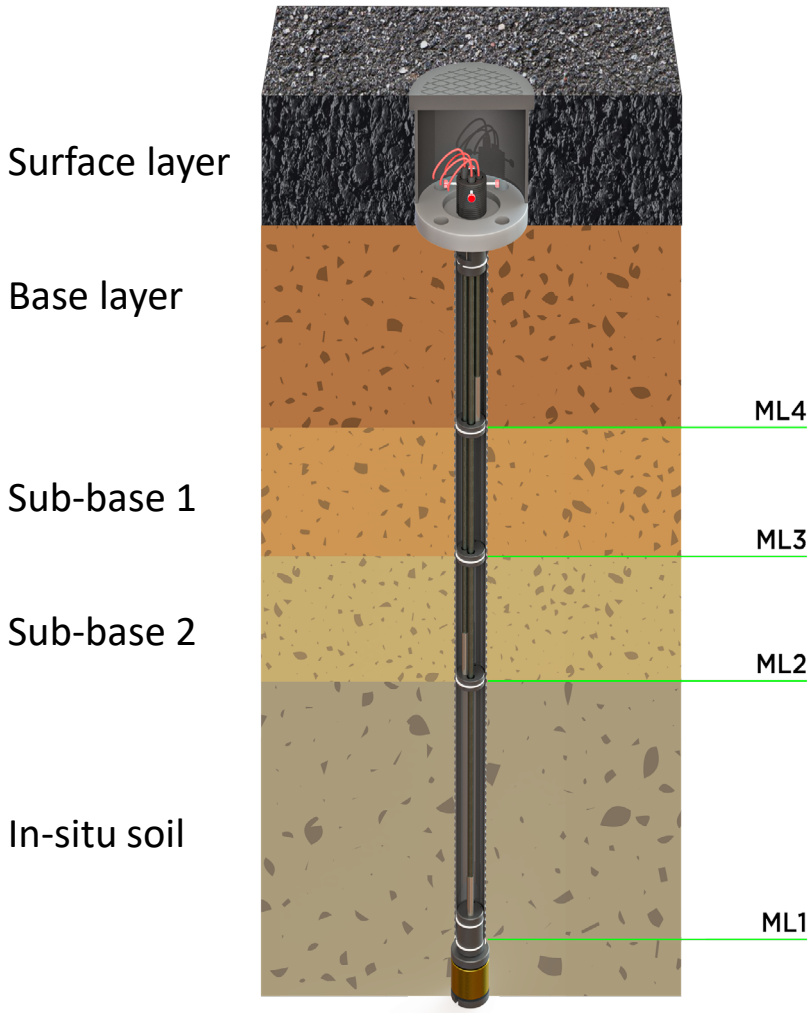
MULTI-DEPTH DEFLECTOMETER (DYNAMIC)

SLAB TRACK RAIL - TTCI
COAL MINING HAUL ROADS - CATERPILLAR
LOGGING ROADS – MINISTRY OF FORESTRY MANNITOBA
ACCELERATED PAVEMENT TESTING – NUMEROUS CLIENTS





MULTI-DEPTH DEFLECTOMETER (MDD)



WHAT DOES EACH MEASUREMENT LOCATION MEASURE?

- ML1 = Overall Pavement Deflection (Surface to Anchor)
- ML4 = Surface to Bottom of Base layer
- ML3 = Surface to Bottom of Sub-base 1
- ML2 = Surface to Bottom of Sub-base 2

- Base layer compression = ML4
- Sub-base 1 compression = ML3 – ML4
- Sub-base 2 compression = ML2 – ML3

- Surface compression is usually measured with VASG

MULTI-DEPTH DEFLECTOMETER (MDD)

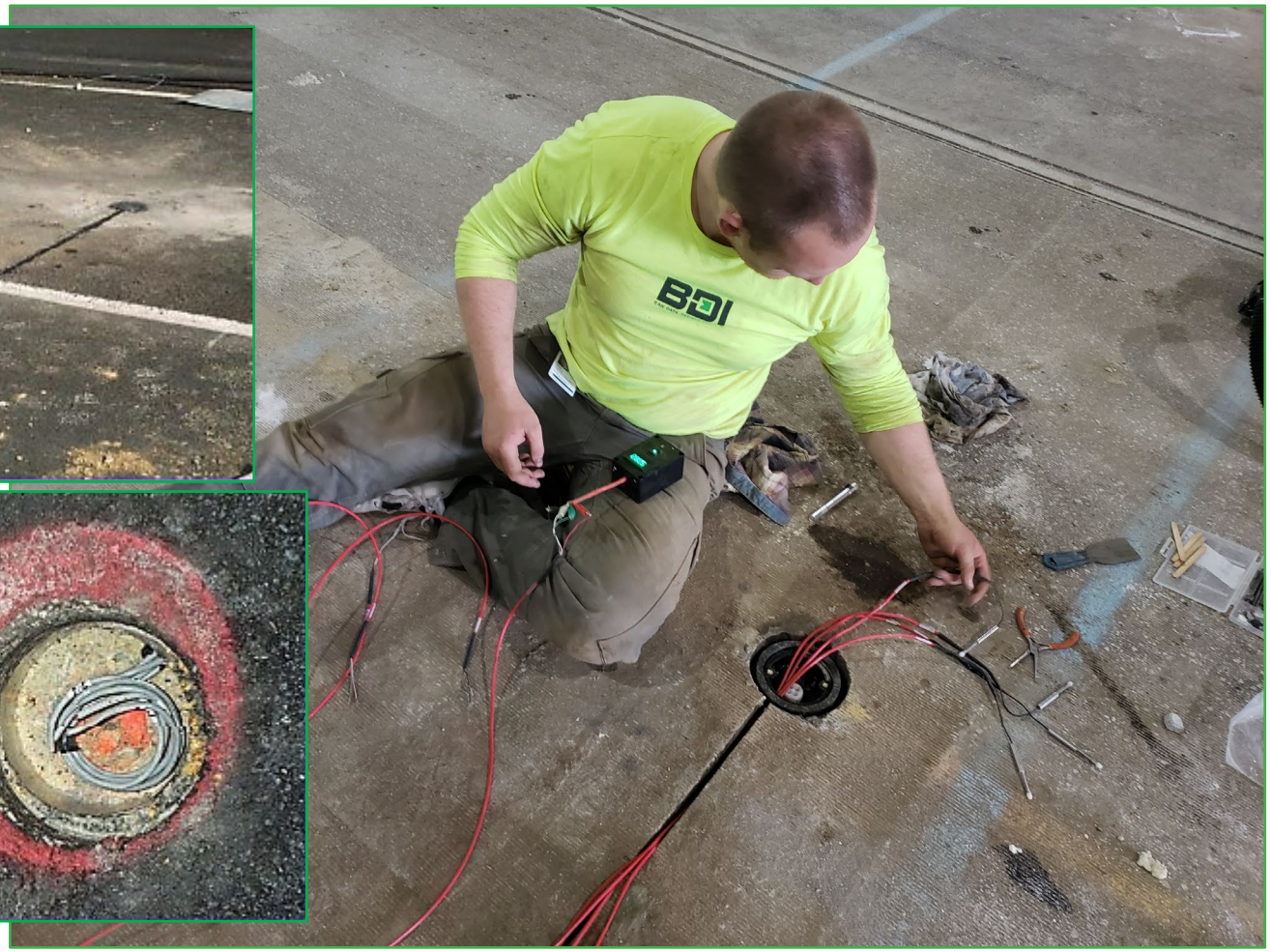
Installation Needs – tools, driller and split-spoon sampler

MULTI-DEPTH DEFLECTOMETER (MDD)

Installation Process – Drop in, set anchor, backfill

MULTI-DEPTH DEFLECTOMETER (MDD)

Get the Wires Out – Temporary, Pre-install/Post-install Road Box



WEIGH-IN-MOTION / CAMERA (DYNAMIC)

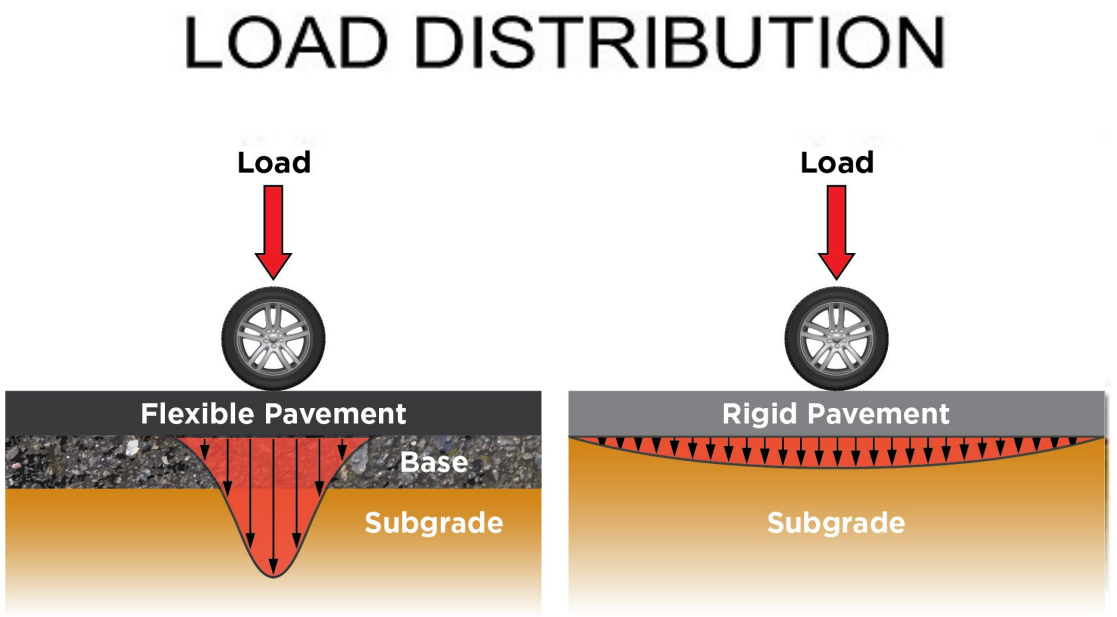
COULD BE SPEED

COULD BE AXLE COUNT

COULD BE VEHICLE CLASSIFICATION

DATA RATE "CHEAT SHEET"

	Data Points @ 250 Hz	Data Points @ 1000 Hz
50 kph = 14 m/s	53	210
+ $T_{flexible}$: 3 m in 0.21 s	143	570
+ T_{rigid}: 8 m in 0.57 s		
100 kph = 28 m/s	28	110
+ $T_{flexible}$: 3 m in 0.11 s	73	290
+ T_{rigid}: 8 m in 0.29 s		



50 points minimum to define a curve,
100 would be better

Wheel diameter (Wd) = 1 meter
Flexible influence zone (3Wd) = 3 meters
Rigid influence zone (8Wd)= 8 meters

BDI PAVEMENT (AND STRUCTURAL) MONITORING SYSTEM

4- OR 16-CHANNEL TERMINAL NODES

+ Voltage Input: +/- 10 volt (not constrained by Wheatstone bridge unbalance)
+ 0 to +5 Vdc and +15 Vdc excitation
+ +15 Vdc Power Supply
+ 24-bit ADC with up to 1 kHz sample rate
+ Configure Channels through STS-LIVE
+ Temperature Range: -40 to +85 °C

MONITORING ACCESSORIES

+ Intel® Atom™ processor E3800 family
+ DDR3L SDRAM up to 8GB
+ 128GB SATA II 2.5" SSD
+ Dual Gigabit LAN port
+ Programmable Watchdog Timer
+ One Selectable RS232/422/485 port (Optional)
+ Temperature Range: -40°C to +85°C

MONITORING ACCESSORIES

+ Solar/AC battery backed power
+ Complete Turnkey Systems
+ Environmental Enclosures
+ PoE Communication
+ Wireless communication
+ Third party sensors/systems integration
+ Cellular/Satellite/Hard Line communications
+ Many more, please inquire

DATA PROCESSING SOFTWARE

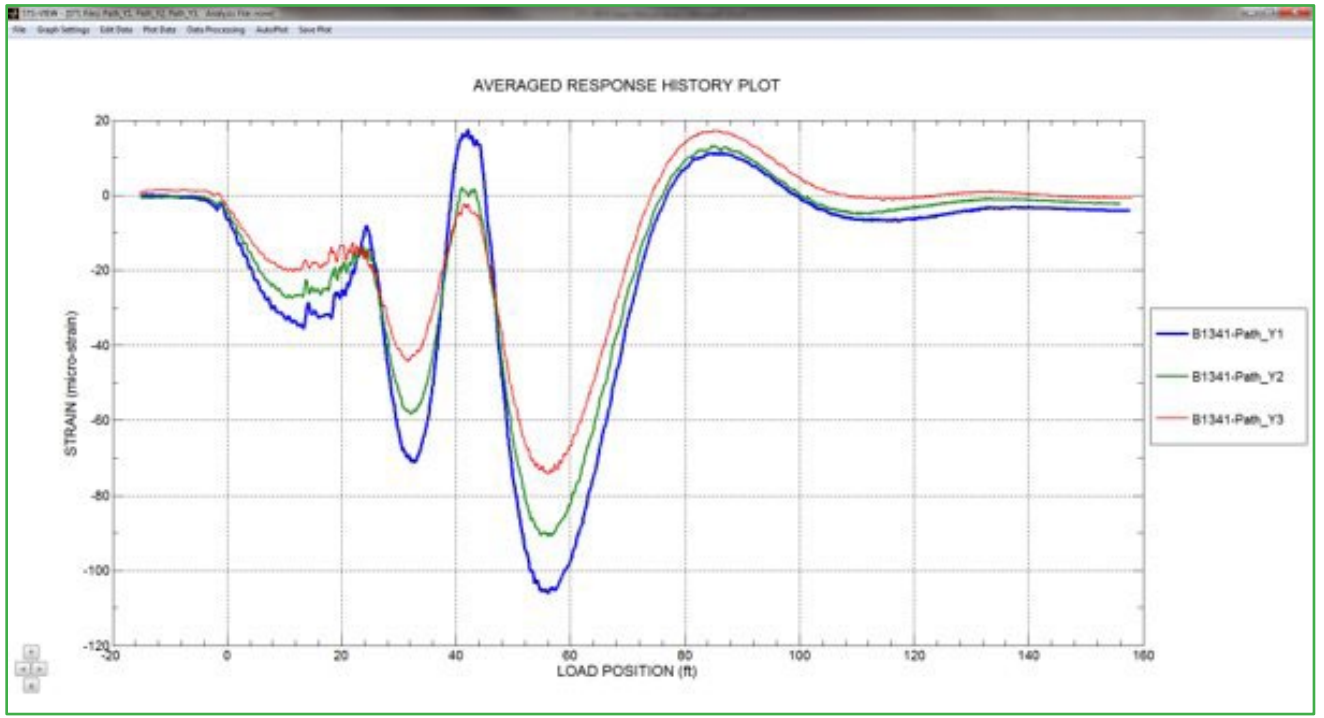
MENU DRIVEN!

STS-VIEW: DATA ACQUISITION SOFTWARE HAS BEEN DESIGNED WITH ALL THE FEATURES REQUIRED TO EVALUATE THE QUALITY OF THE DATA COLLECTED QUICKLY AND UNDER THE PRESSURE OF ON-SITE FIELD PROJECTS!

+ Compatible data files
  - Works with BDI *.tdms & *.dat data file structure
  - Compatible with Campbell Scientific data files

+ Data display options
  - Response, curvature, neutral axis plots
  - Range of filtering
  - Max/Min value extraction

+ Input Options
  - Load finite element analysis results for direct Graphical comparison with collected data



DATA COLLECTION ADAS

Manual (Bring laptop/logger)

+ Cheapest, must be there

Road/Trackside System

+ More expensive, need data management

Remote w/ AC Power

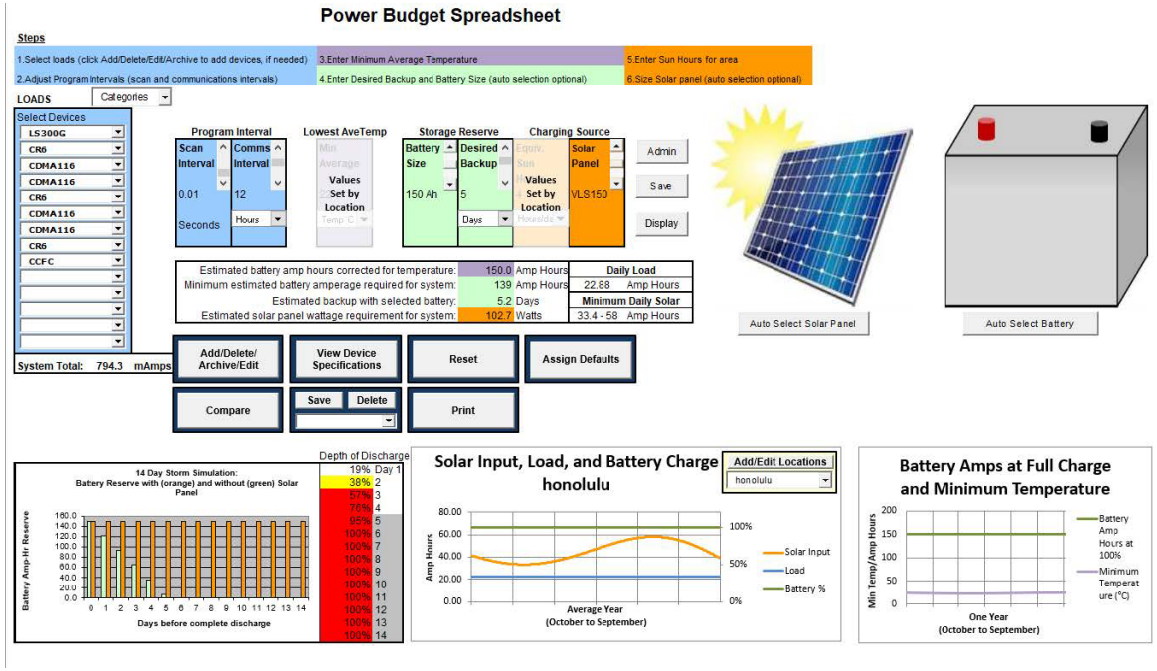
+ Communication/triggering/data download

Remote w/ Solar Power

+ Communication/triggering/data download

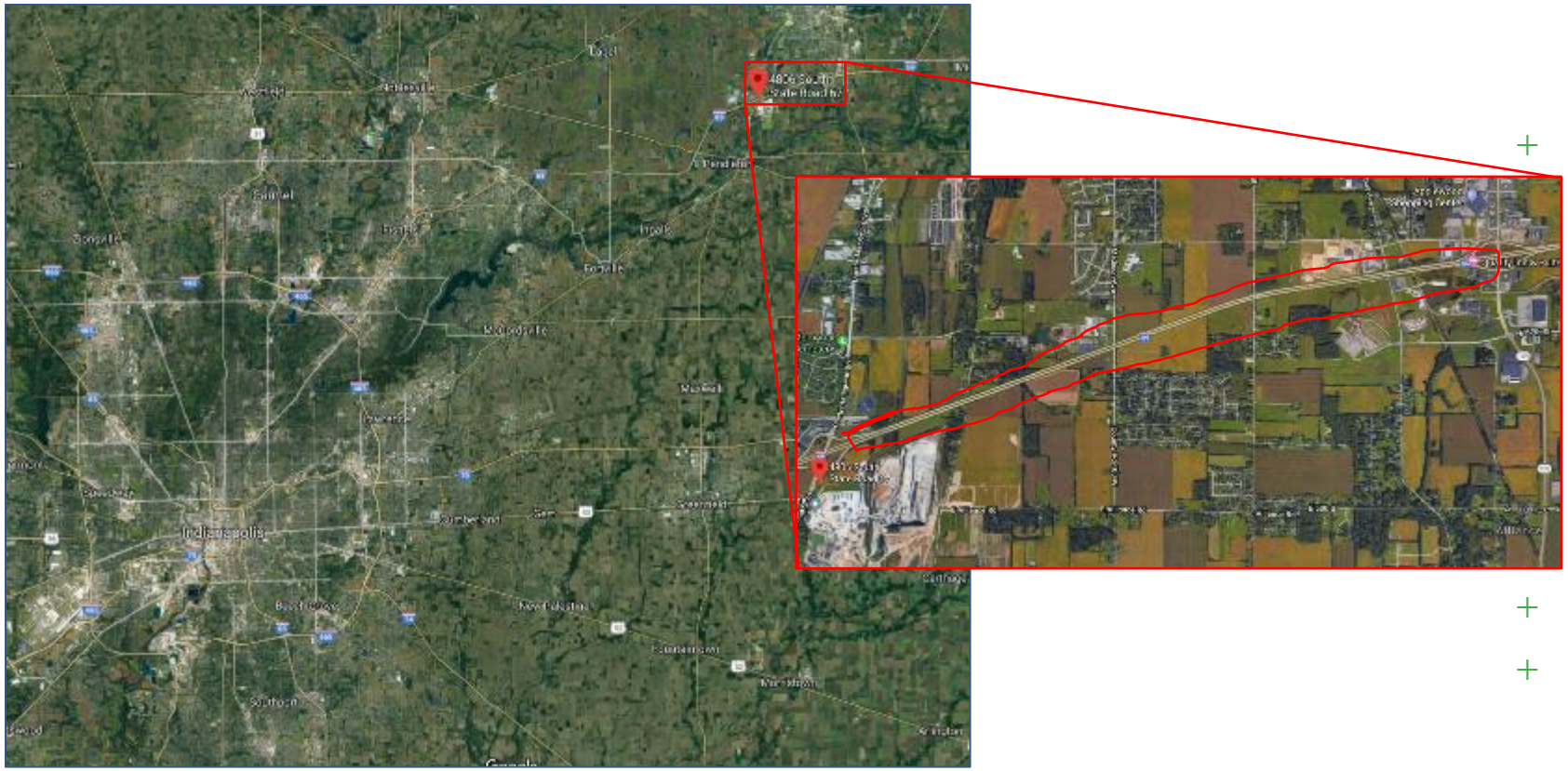
Remote w/ Solar Power / Camera

+ Communication/triggering/data download / vehicle identification



CASE STUDIES

I-69 PAVEMENT, INDOT 22 TEST SECTIONS



- Bid on Existing Specification
  - 22 Flexible Pavement Test Sections
  - 144 Asphalt Strain Gages **(+44)**
  - 48 Temperature Sensors
  - 78 Earth Pressure Cells
  - 10 Soil Strain Gages
  - 44 Moisture Gages
  - Portable ADAS
- Installation and Oversight
- Training, Load Testing and Support

PM for Geocomp on this project

CASE STUDIES

I-69 PAVEMENT, INDOT 22 TEST SECTIONS

- Penalty / Bonus System - $5,000/sensor type/test section$_{(*)}$ not meeting minimum success rates

Sensor	Total	Min	Plus 1	Plus 2	Plus 3
ASG	6	4	$1,000	$2,500	
TC	2	1	$2,500		
EPC base	2	1	$2,500		
EPC CSS	3	2	$2,500		
DSG $_{total}$	10	7	$1,000	$1,500	$2,500
MG	2	1	$2,500		
VSG	2	1	$2,500		

CASE STUDIES

HNL AIRPORT TAXIWAY

REMOTE STAND-ALONE SYSTEM

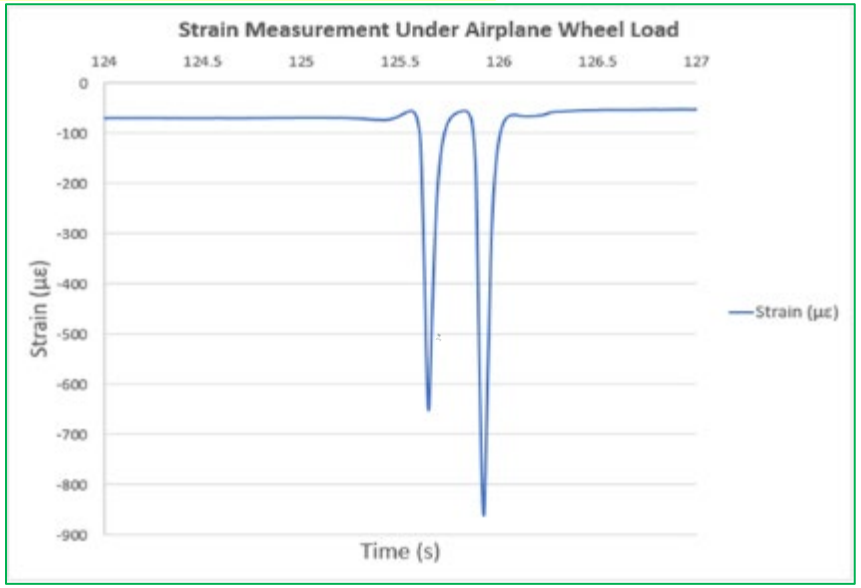
- Specification Development
  - One Cold Planed Flexible Test Section
  - 56 Asphalt Strain Gages
  - 2 Temperature Trees
  - Remote System Power
  - Remote System Communication
  - Operation and Maintenance Manual
- Installation and Commissioning
- Training and Support

PM for Geocomp on this project

CASE STUDIES

HNL AIRPORT TAXIWAY

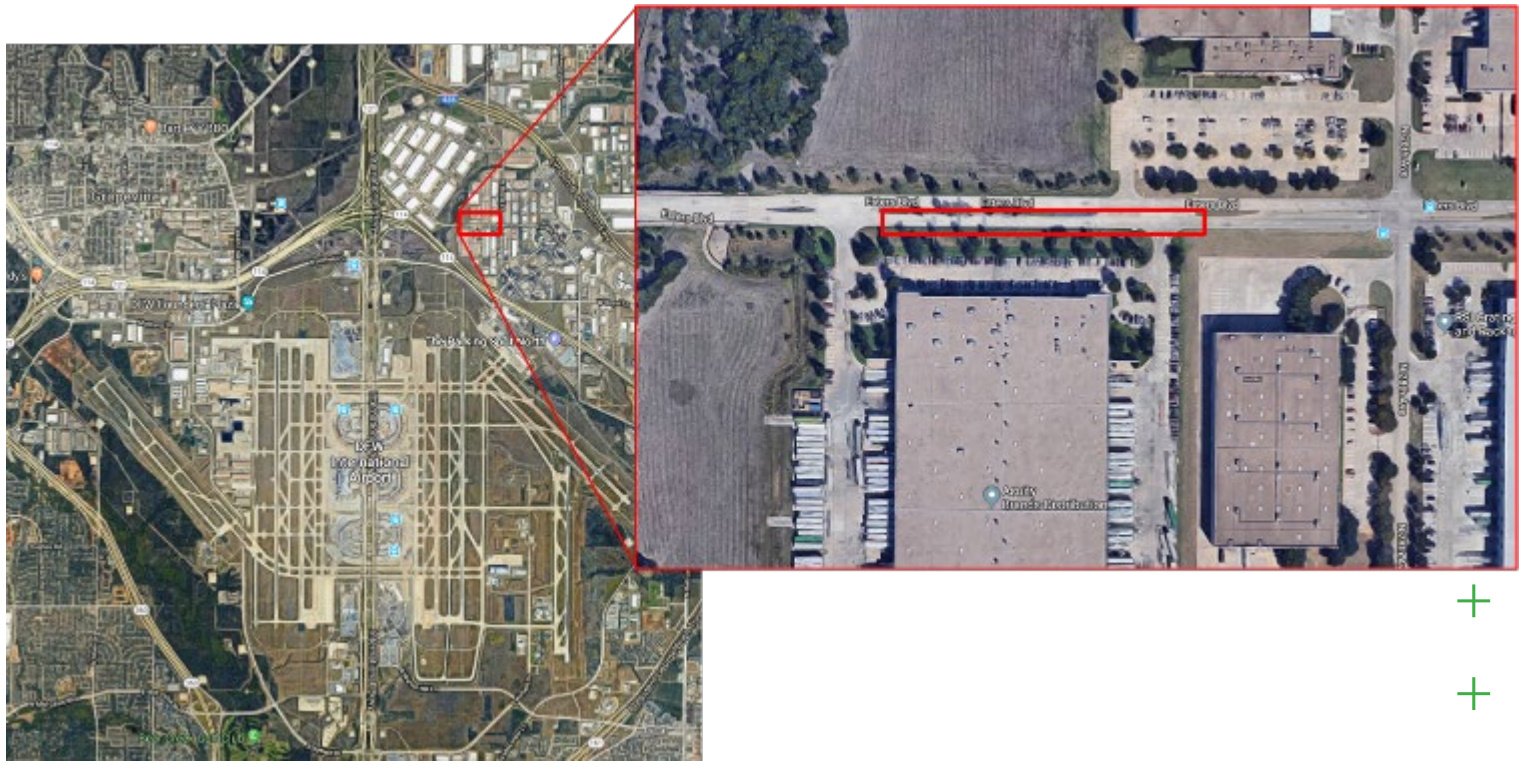
SENSOR TRIGGER DATA COLLECTION
SENSOR TRIGGER CAMERA IMAGE CAPTURE



CASE STUDIES

DFW SERVICE ROADS

REMOTE STAND-ALONE SYSTEM

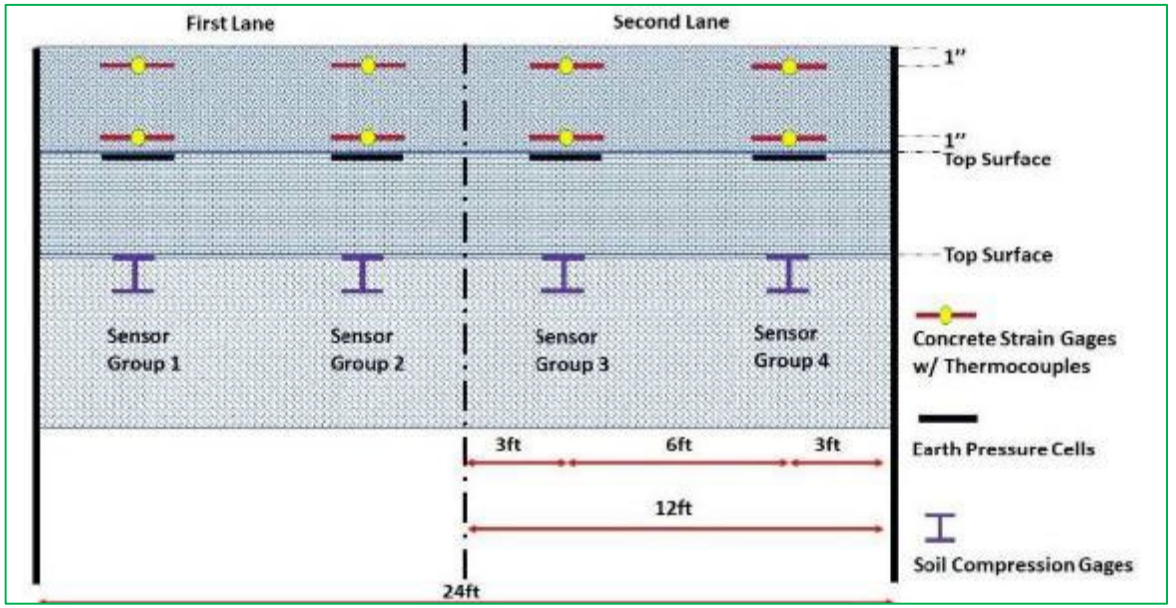


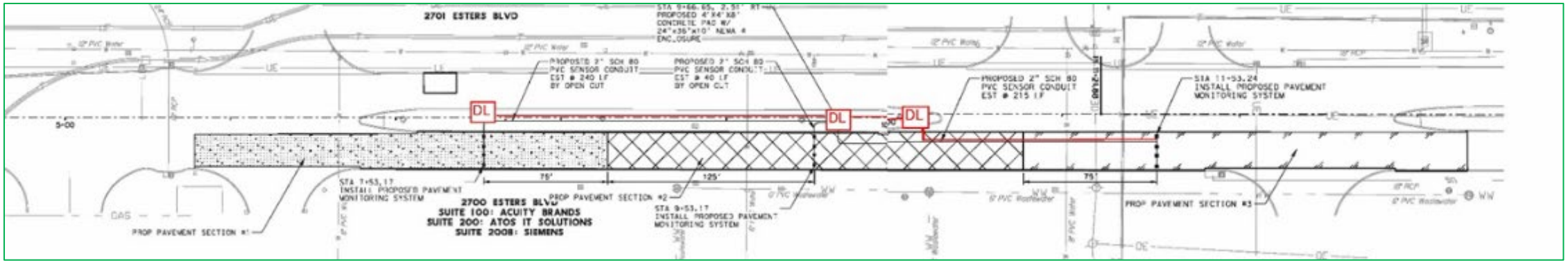
+ Specification Development
  - Three Rigid Pavement Test Sections
  - 46 Concrete Strain Gages
  - TC Temperature Tree Sensors
  - 12 Earth Pressure Cells
  - 12 Soil Compression Gages
  - Remote System Power/Communication
  - Operation and Maintenance Manual
+ Installation and Commissioning
+ Training, Load Testing, and Support

PM for Geocomp on this project

CASE STUDIES

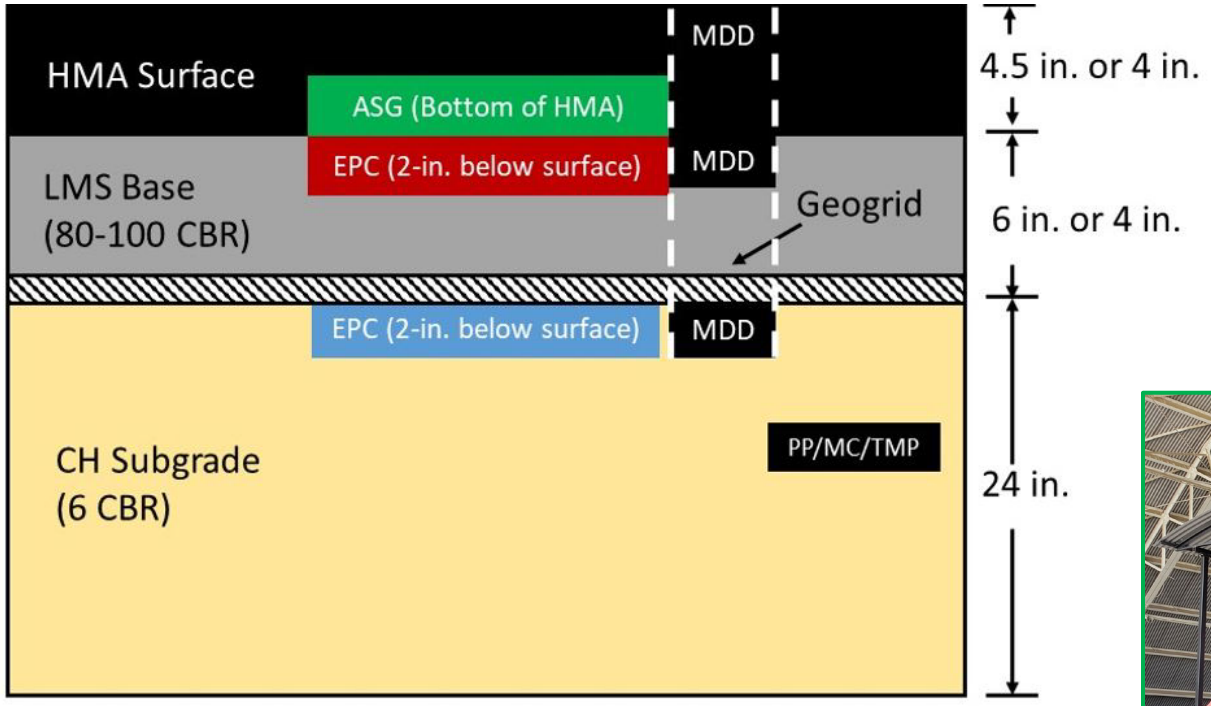
DFW SERVICE ROADS





CASE STUDIES

TENSAR PROJECT AT USACE-ERDC

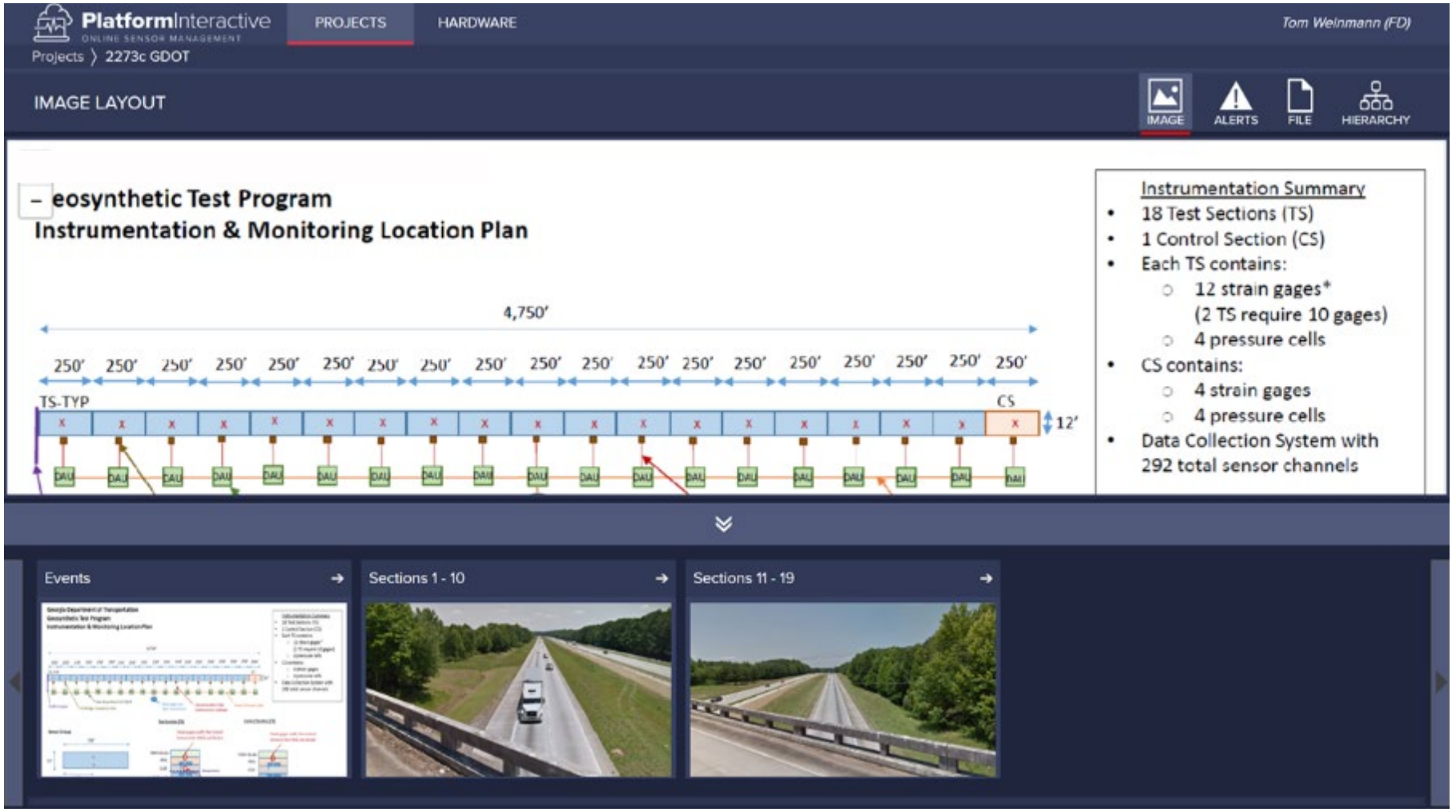


LMS = crushed limestone
CH = high-plasticity clay
HMA = hot-mix asphalt
NOT TO SCALE

EPC = earth pressure cell
MDD = multi-depth deflectometer
PP/MC/TMP = pore pressure/moisture content/temperature

CASE STUDIES

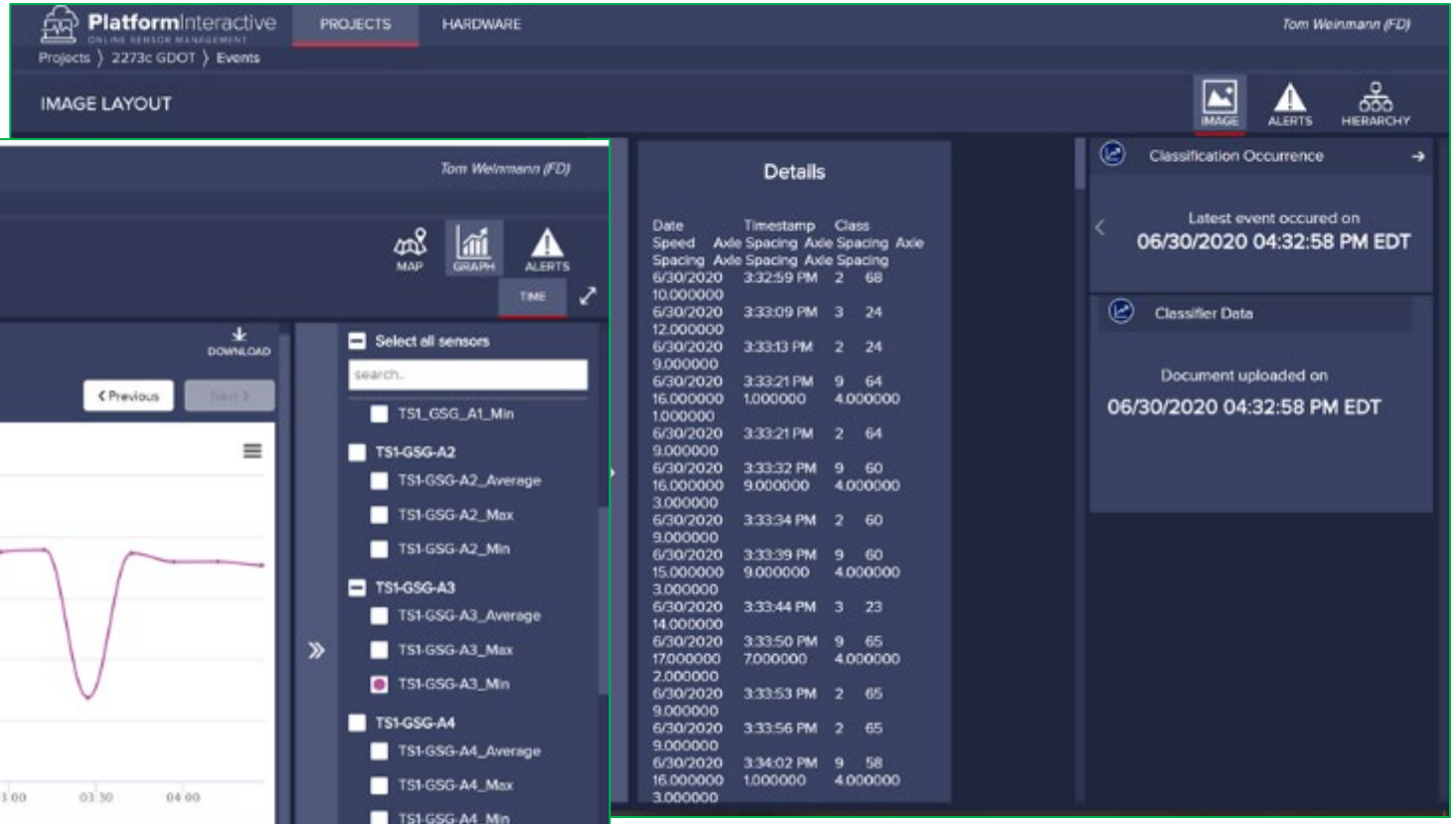
GEOSYNTHETIC TEST ROAD PROGRAM – 18 TEST SECTIONS



CASE STUDIES

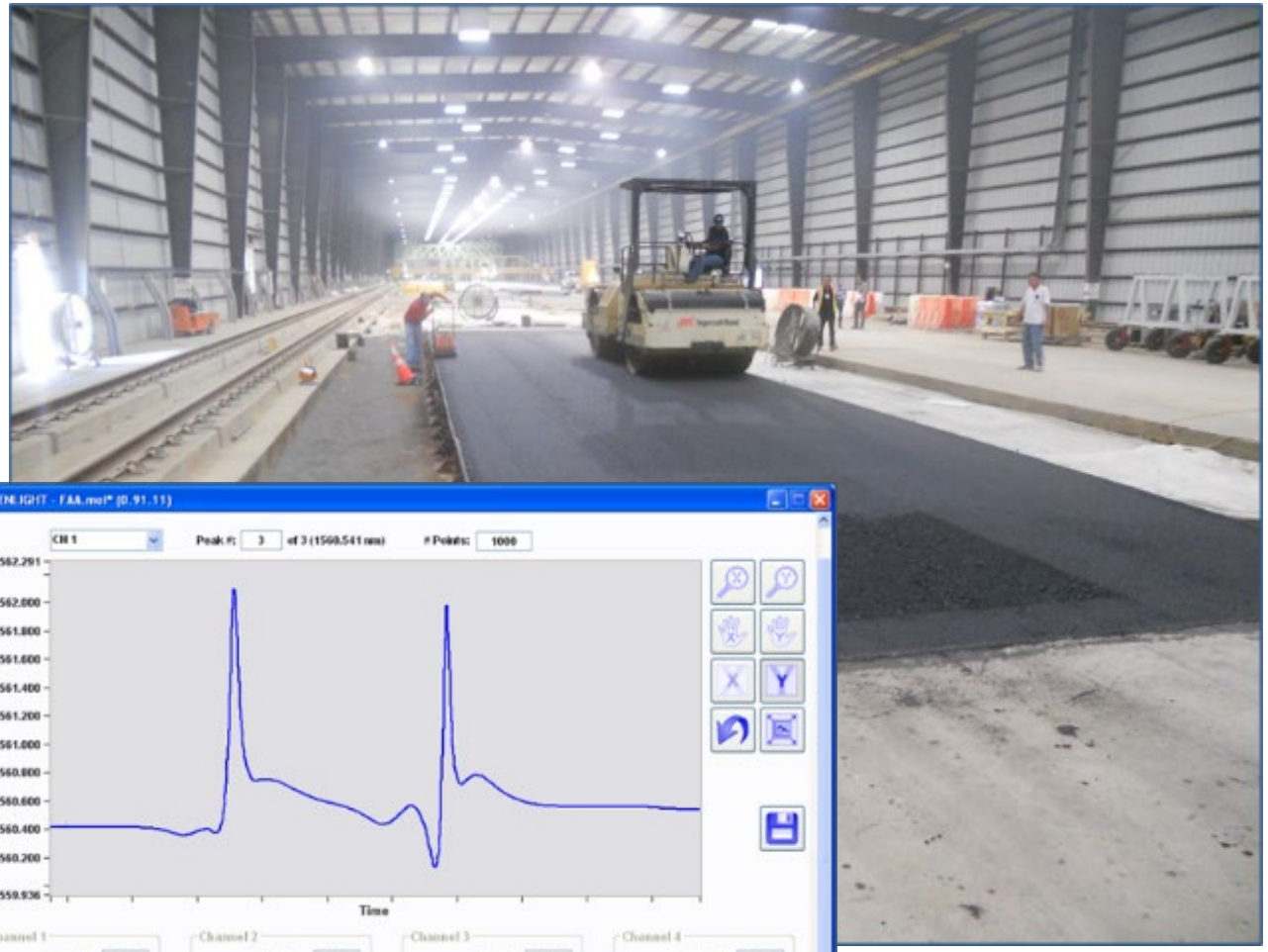
GEOSYNTHETIC TEST PROGRAM – 18 TEST SECTIONS

EVENT TRIGGERED
VEHICLE CLASSIFICATION



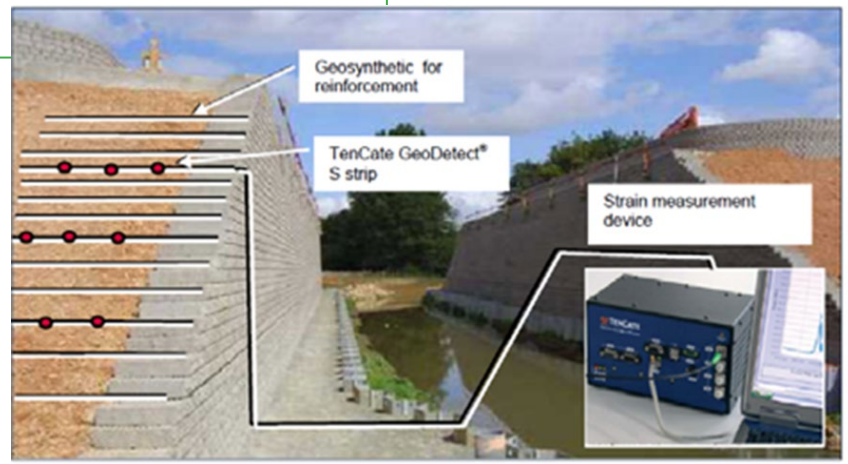
NEW TECHNOLOGIES

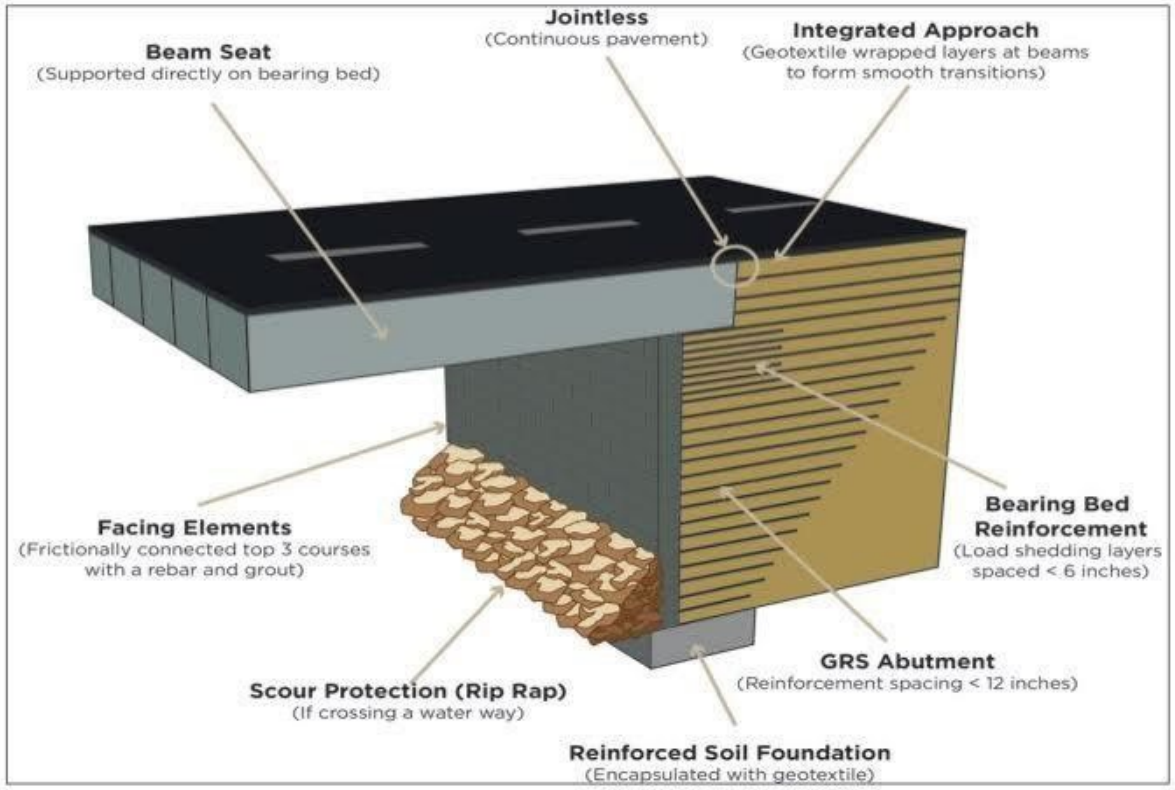
FBG STRAIN MEASUREMENTS



NEW TECHNOLOGIES

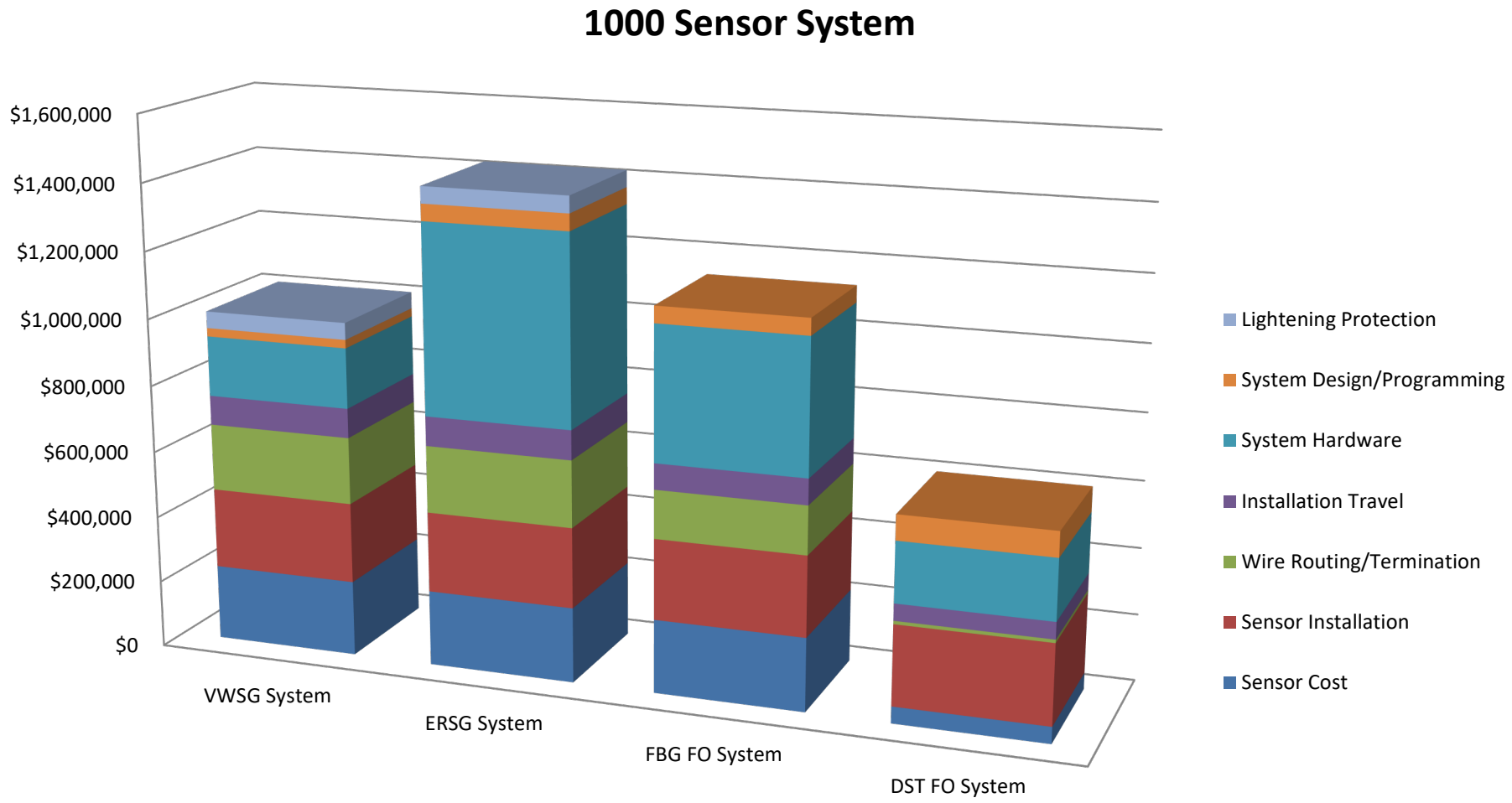
FIBER OPTICS FOR GRS-IBS





NEW TECHNOLOGIES

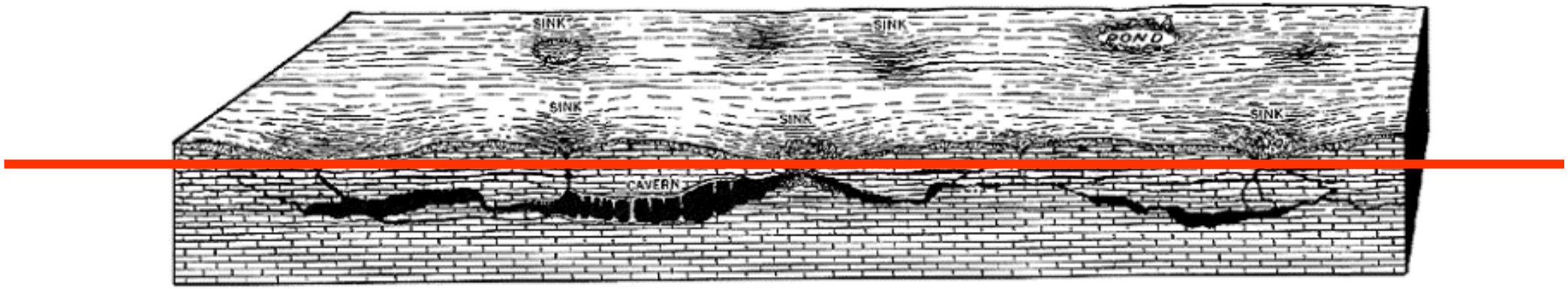
DISTRIBUTED STRAIN AND TEMPERATURE FIBER OPTICS



NEW TECHNOLOGIES (FOR PAVEMENT)

DISTRIBUTED STRAIN AND TEMPERATURE (DST FO)

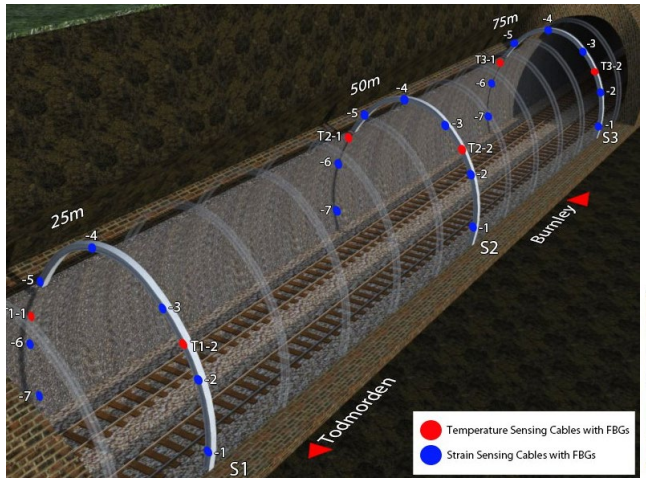
Sinks and their relation to solution cavities beneath the surface.

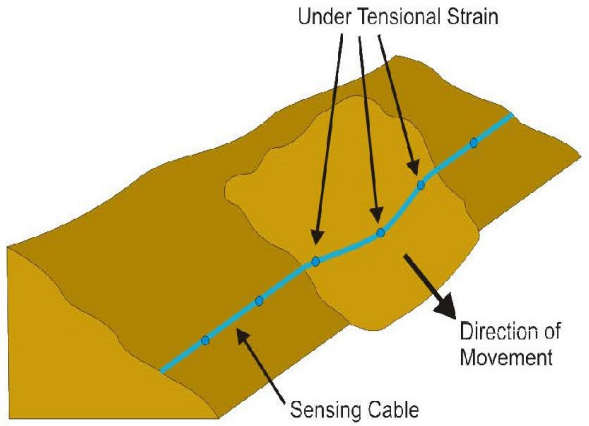


NOT NEW FOR OTHER APPLICATIONS

DISTRIBUTED STRAIN AND TEMPERATURE (DST FO)

- Embankment deformation
- Water seepage
- Cracking in continuous structures





Section of Earthwork

NEW TECHNOLOGIES (IN DEVELOPMENT)

ASPHALT SHEAR STRAIN GAGES

QUESTIONS?

PAVEMENT INSTRUMENTATION AND SYSTEMS

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