Use of the Traffic Speed Deflectometer (TSD) for Structural Evaluations of Pavements

Trusted advisor on roads and transport

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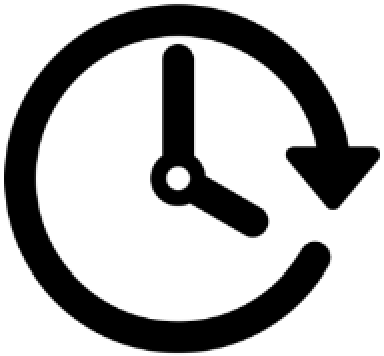
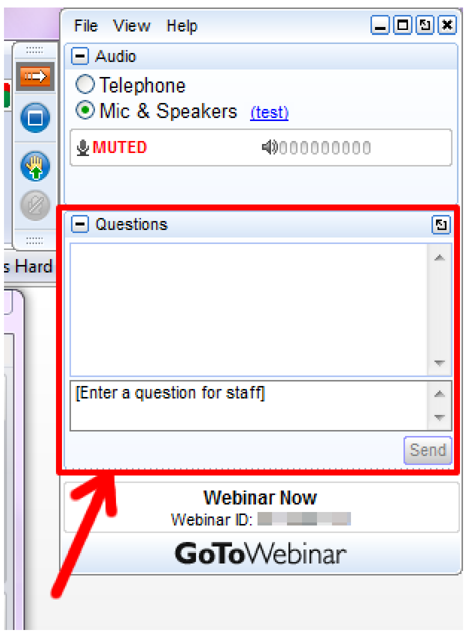
Housekeeping

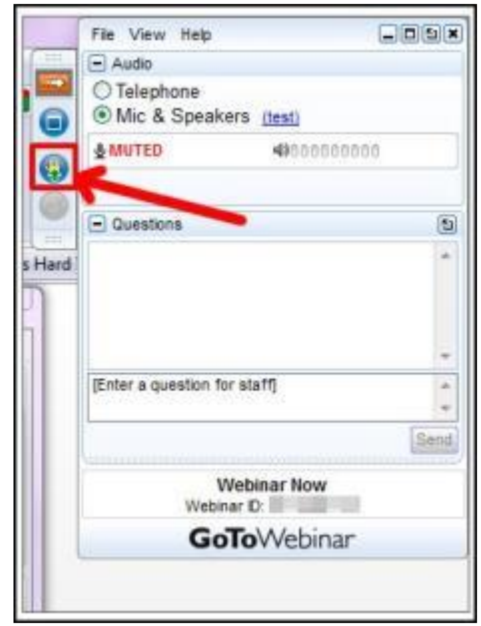


Webinar is = 45 mins

Question time = 15 mins

GoTo Webinar functions





Please type your questions here

Today's presenters

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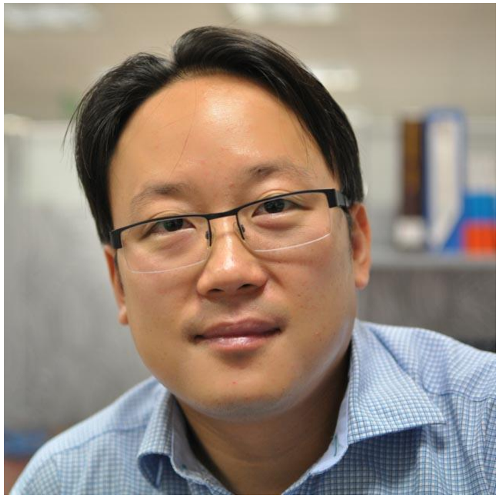

Today’s presenters

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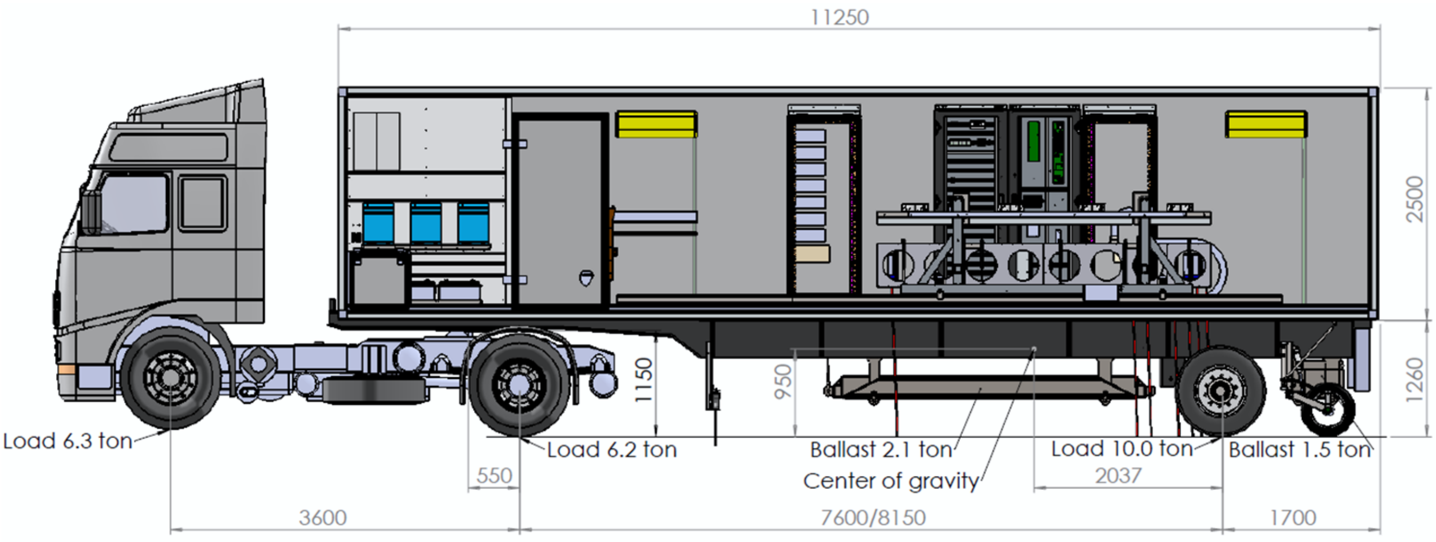
Outline of presentation

- Overview of Traffic Speed Deflectometer (TSD)
- National Asset Centre of Excellence (NACOE) P40 Research – Part 1 (FWD vs TSD correlation)
- NACOE P40 Research – Part 2 (Site instrumentation)
- Define homogenous sections & Advanced correlation techniques
- Summary and Conclusions

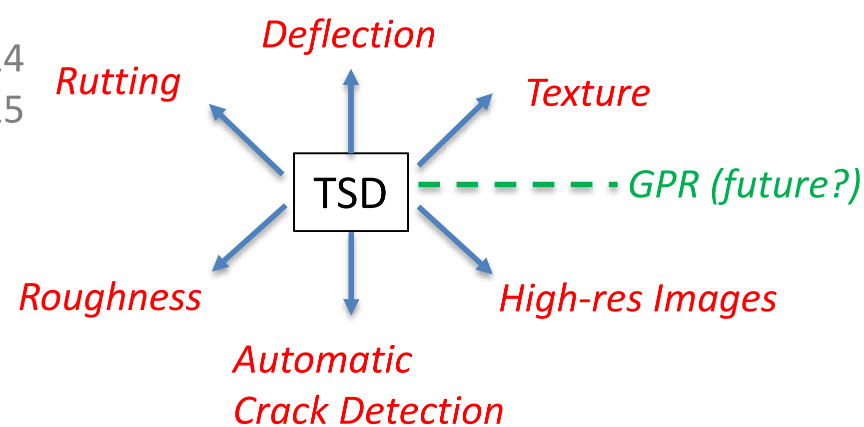
Overview of TSD

Overview of TSD



- Over 12,000 kms scanned across Queensland in 2014
- Over 20,000 kms scanned across Queensland in 2015
- Current conducting 2016 survey in Queensland
- (April – August)

Surveying at Traffic Speed
(typically 70 – 90 km/hr)



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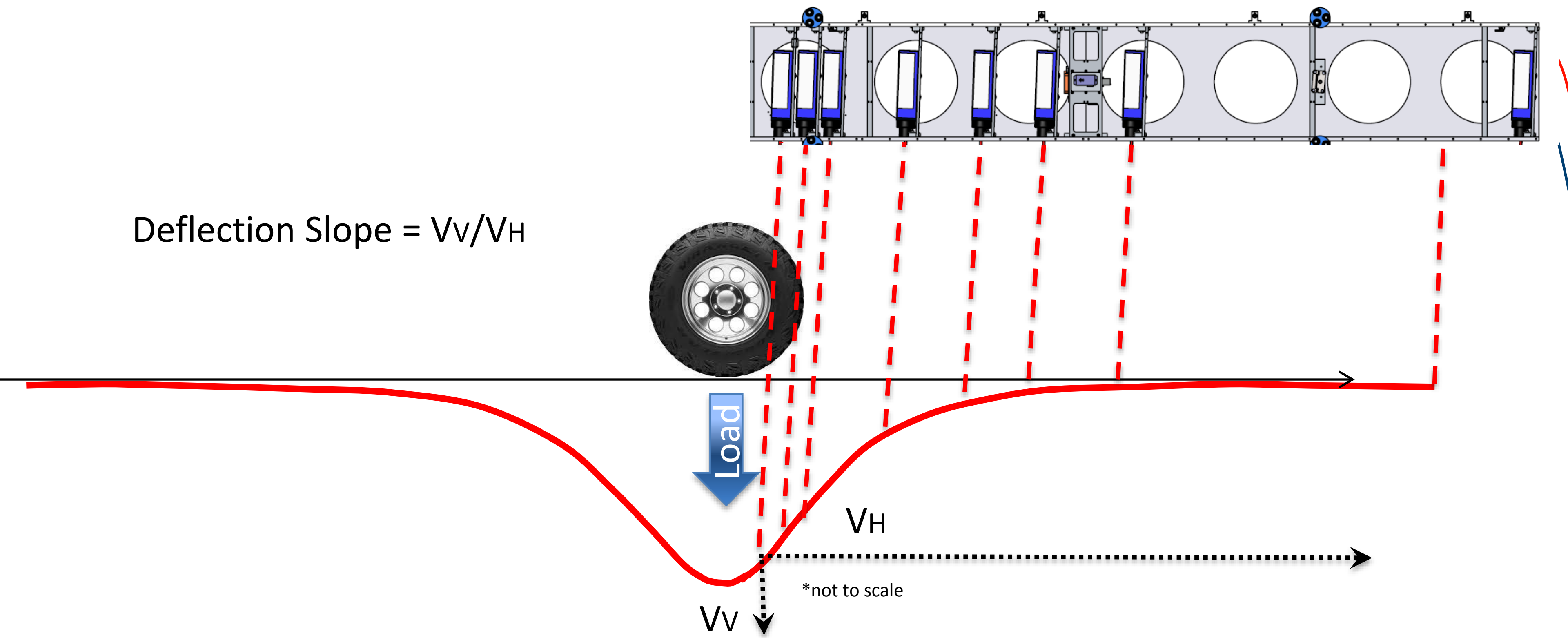
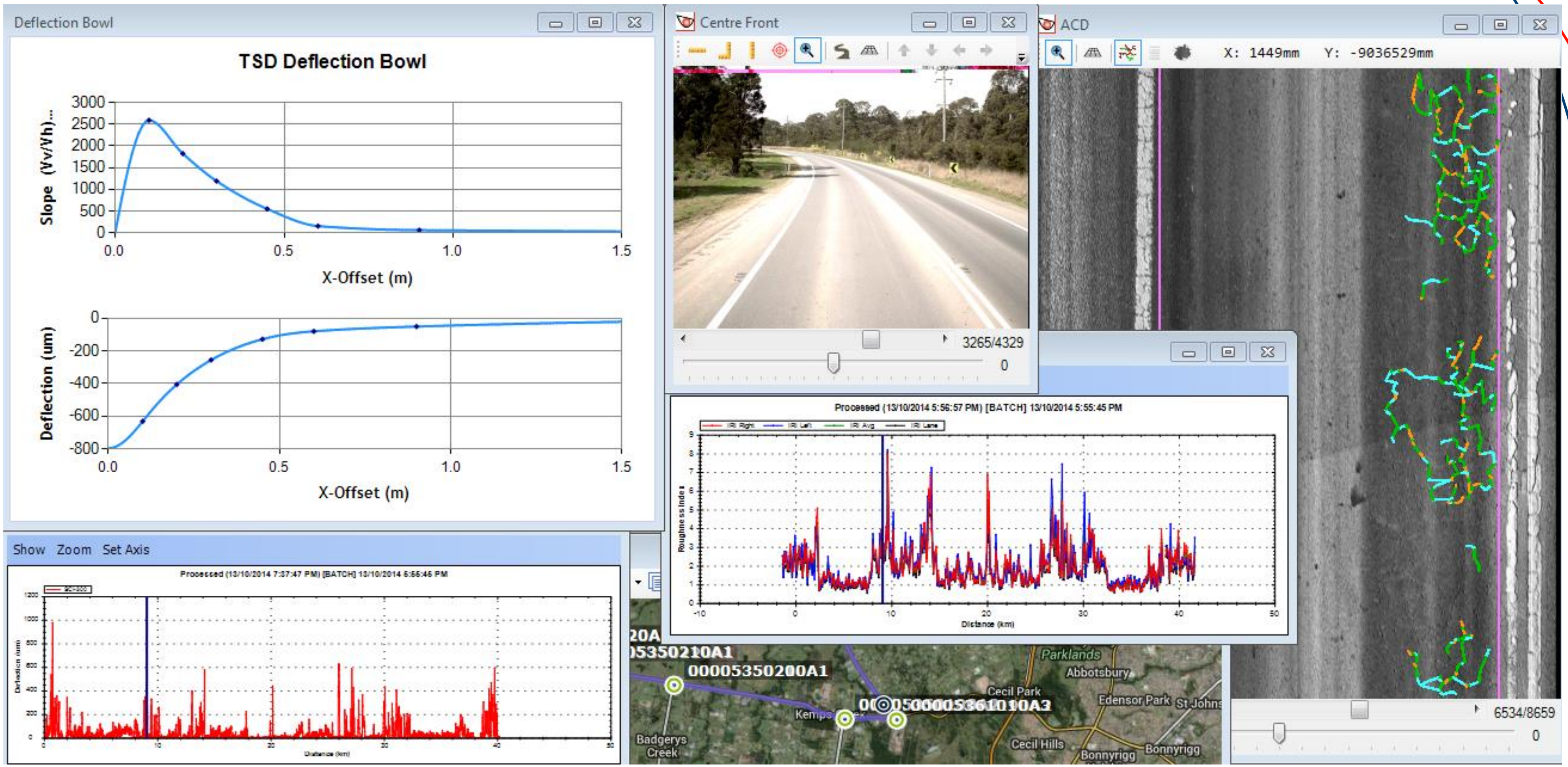
How a TSD works - theory

Deflection Slope = VV/VH



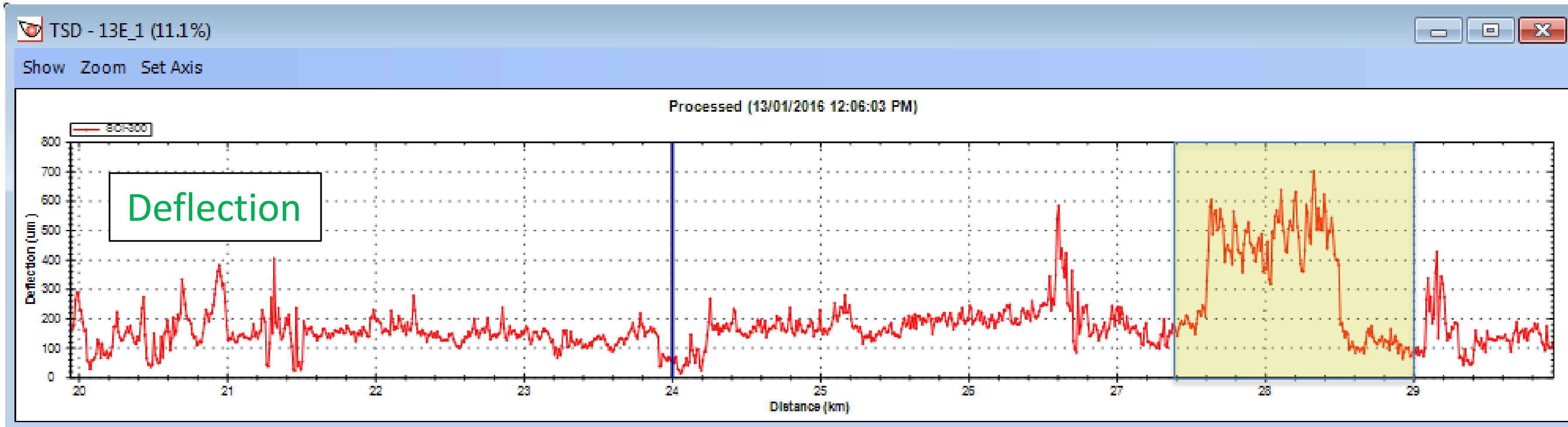
- Measures the velocity of deflection rather than displacement
- Vertical velocity (VV) and horizontal velocity (VH) data for each 20mm travelled
- Surface velocity is integrated with respect to time to yield deflection
- Deflection slope - the slope of the laser measured deflections

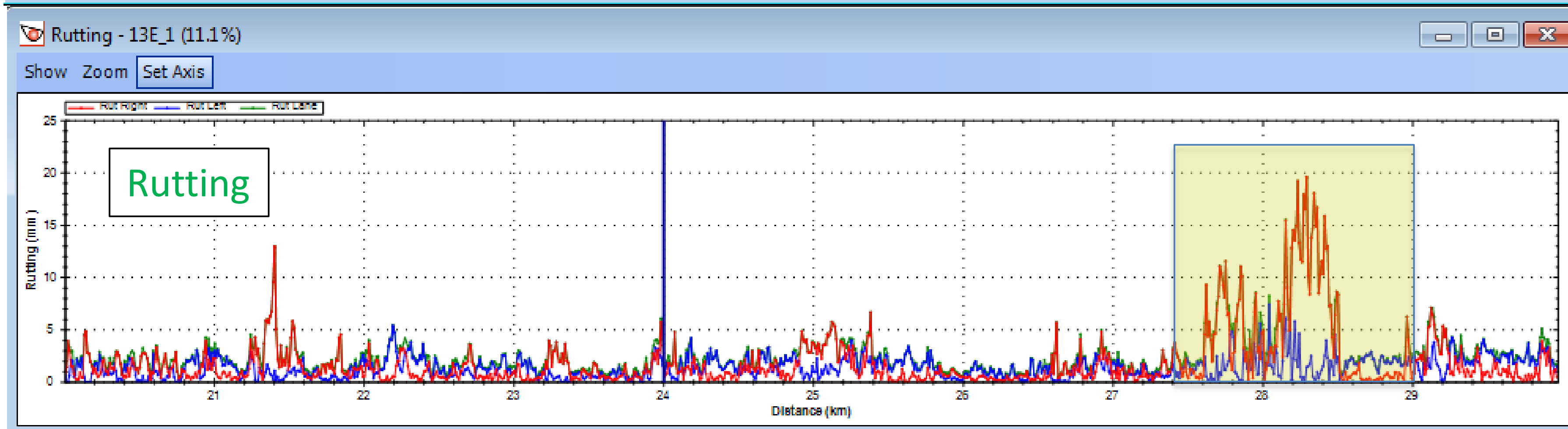
Comprehensive condition survey



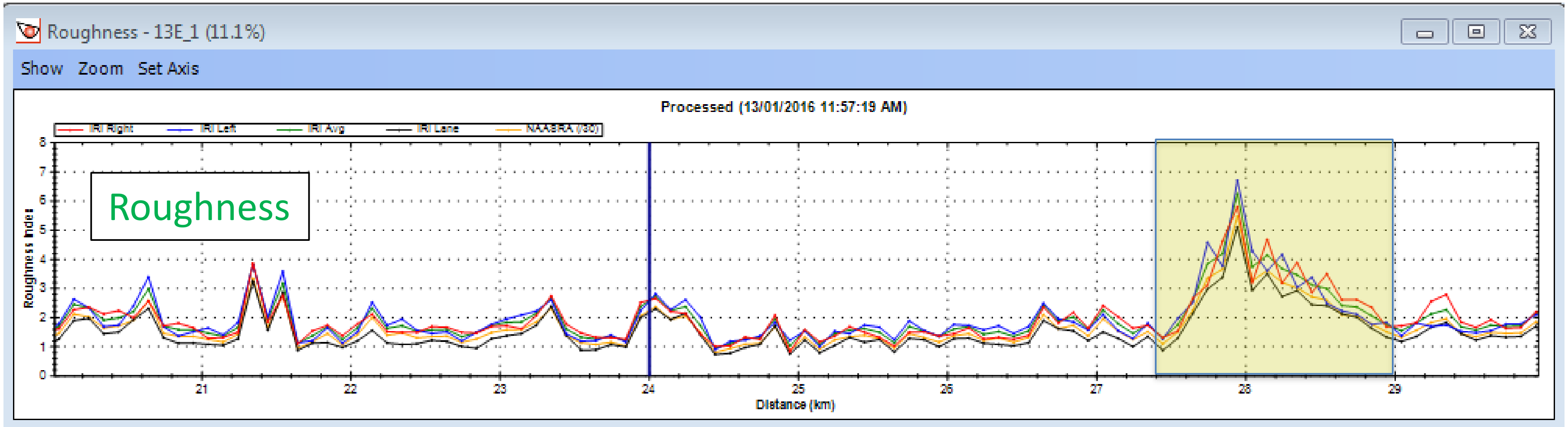
ARRB Hawkeye software

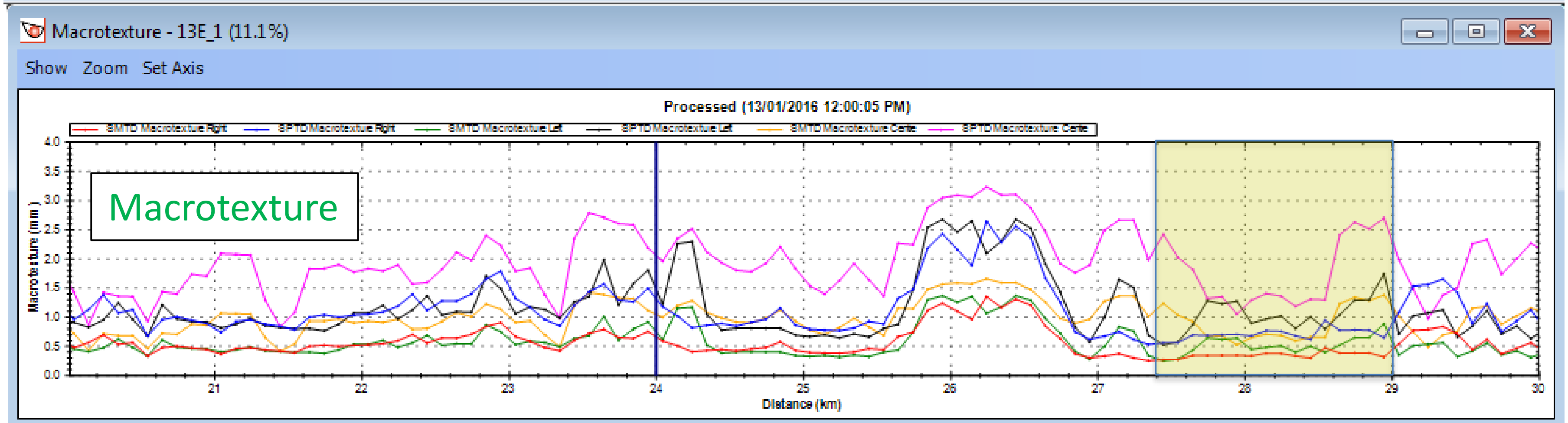
TSD – as a monitoring and forensic tool



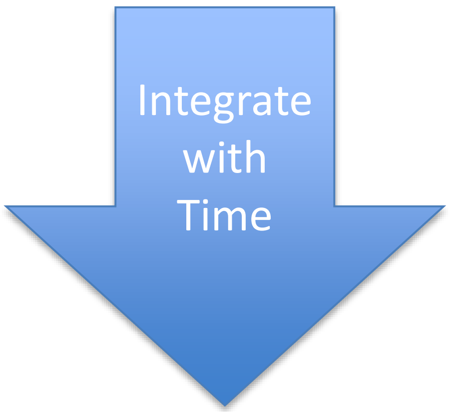


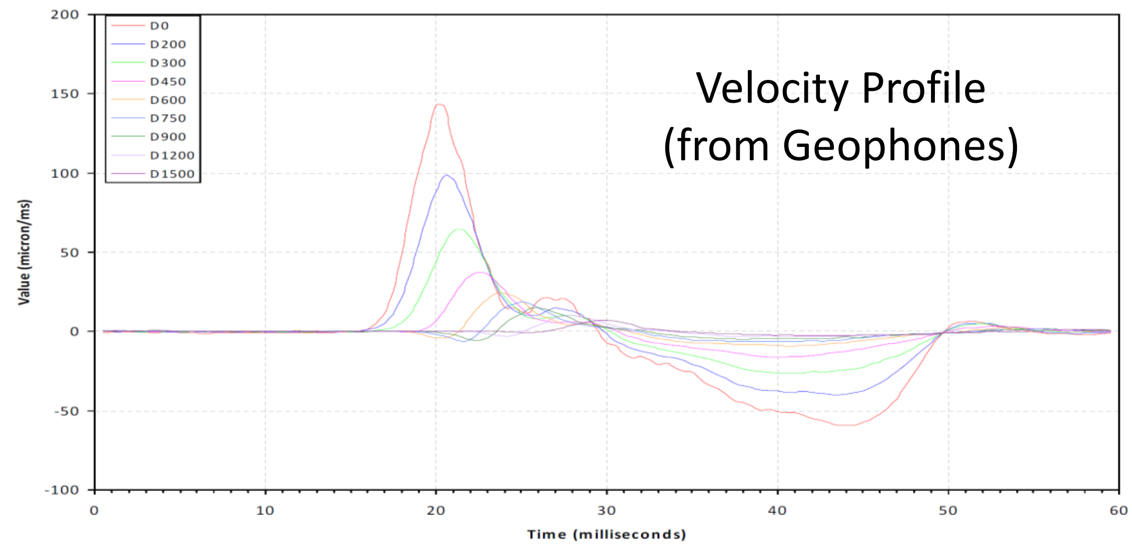
TSD – as a monitoring and forensic tool

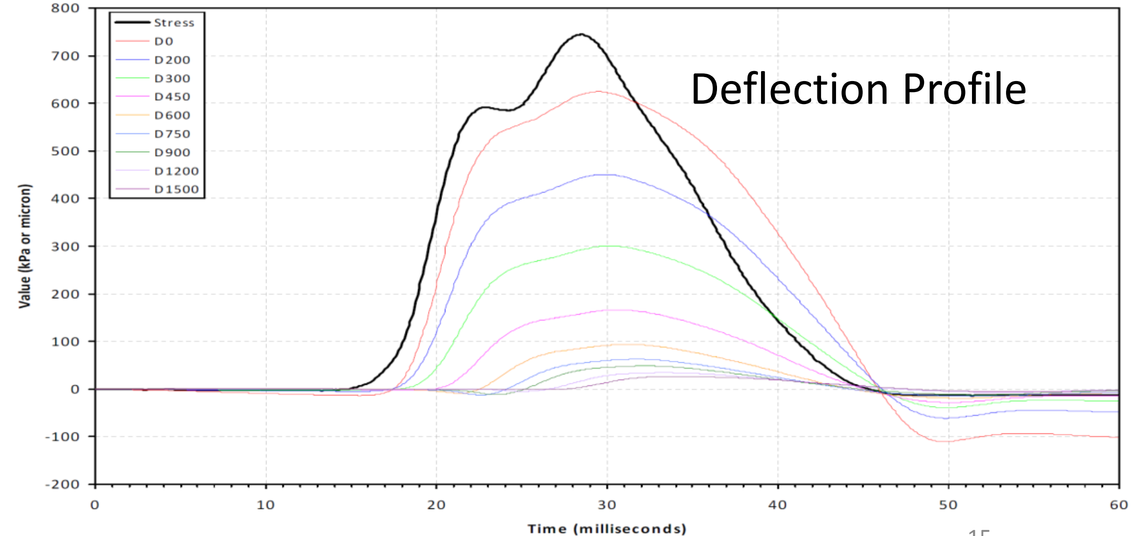




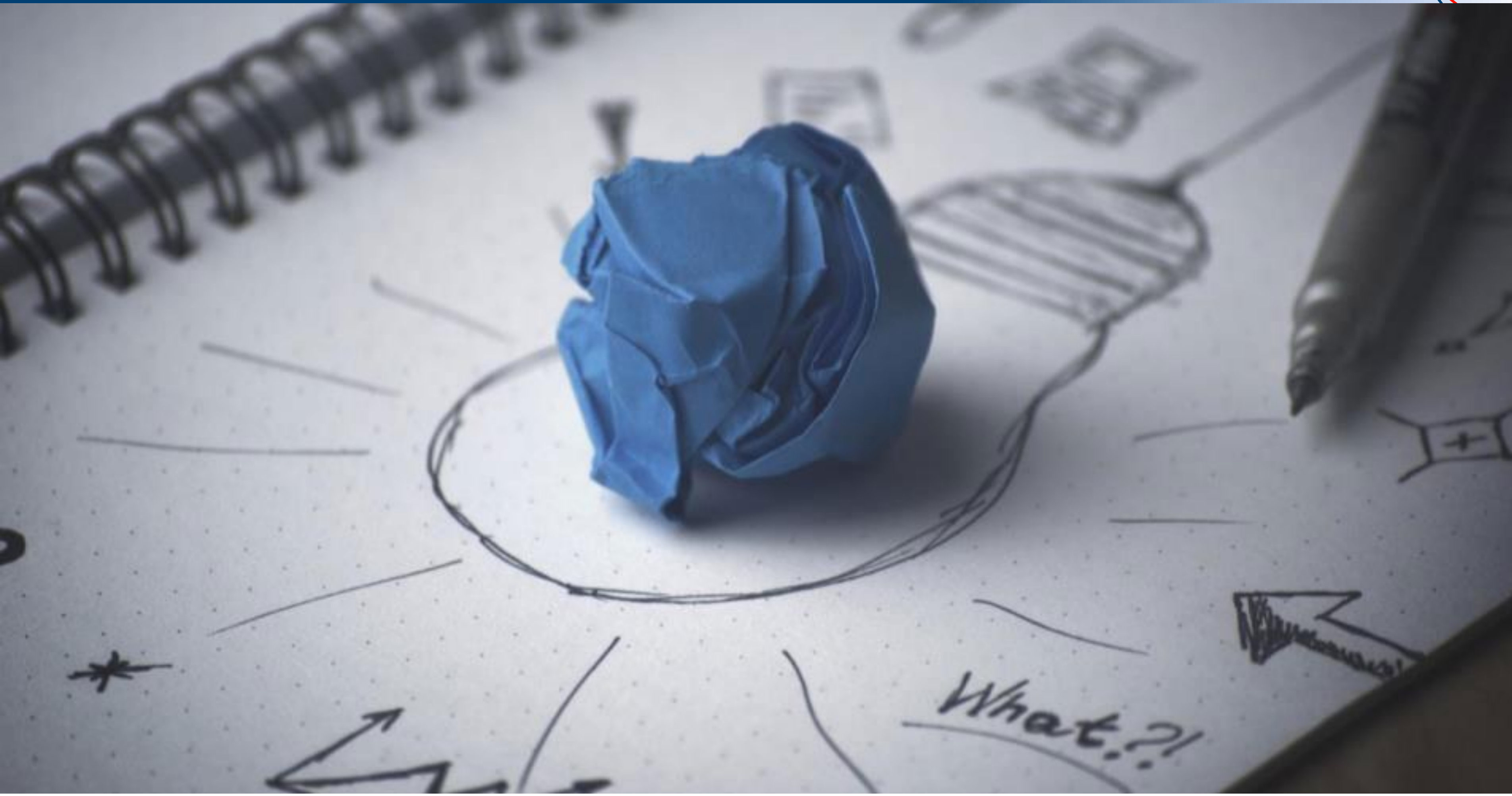
FWD time series







Poll Questions



POLL QUESTION

WHAT DOES THE TSD DEVICE MEASURE?

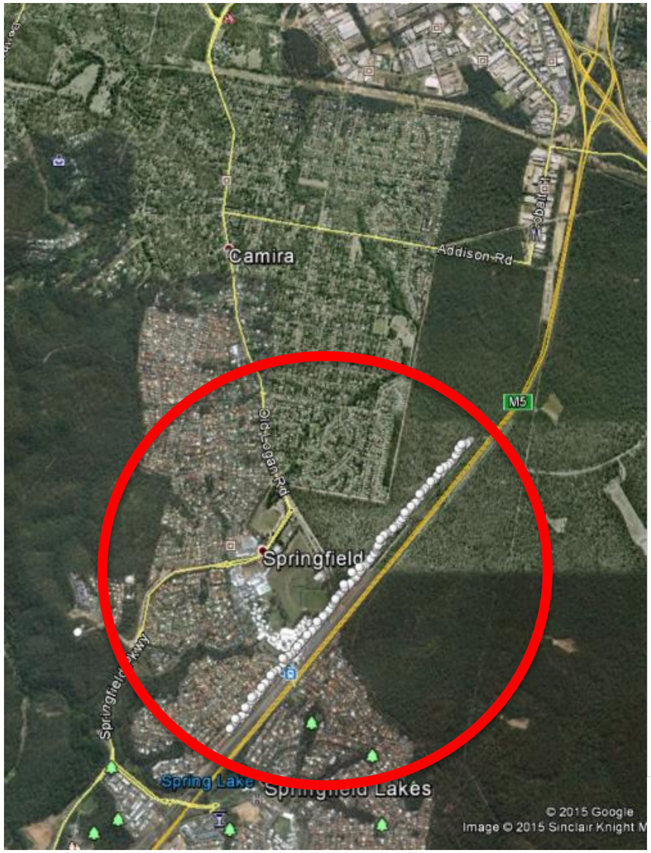
NACOE P40 Research
– Part 1 (FWD vs TSD correlation)

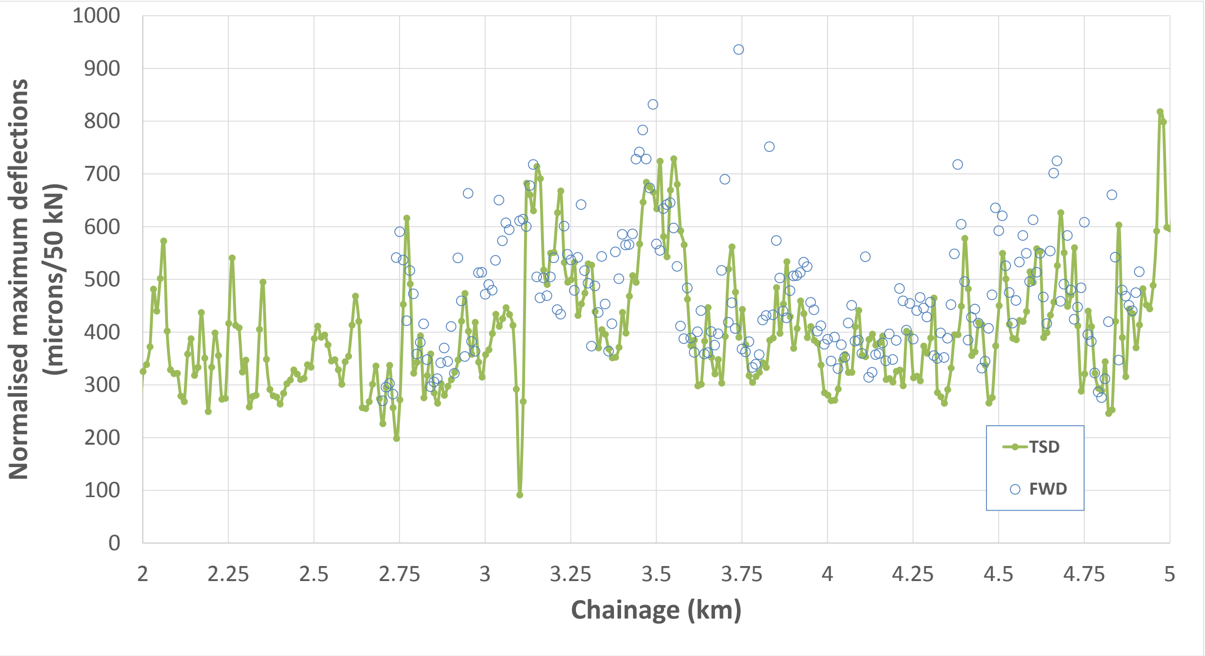
Side-by-side comparison (field measurements)

List of correlation sites FY15/16

Road	Pavement Structures
Ipswich – Boonah Rd (211)	Sprayed seal over foamed bitumen stabilised base
Centenary Highway (910)	Sprayed seal over granular pavement
Deception Bay Road (121)	Asphalt over granular pavement
D'Aguilar Highway (40A)	Sprayed Seal over CTB pavement
Bruce Highway (10A)	Asphalt over Lean Mix Concrete (anti-gazettal) Asphalt over granular pavement (gazettal)
Caboolture Connection Rd (9905)	Asphalt over granular pavement

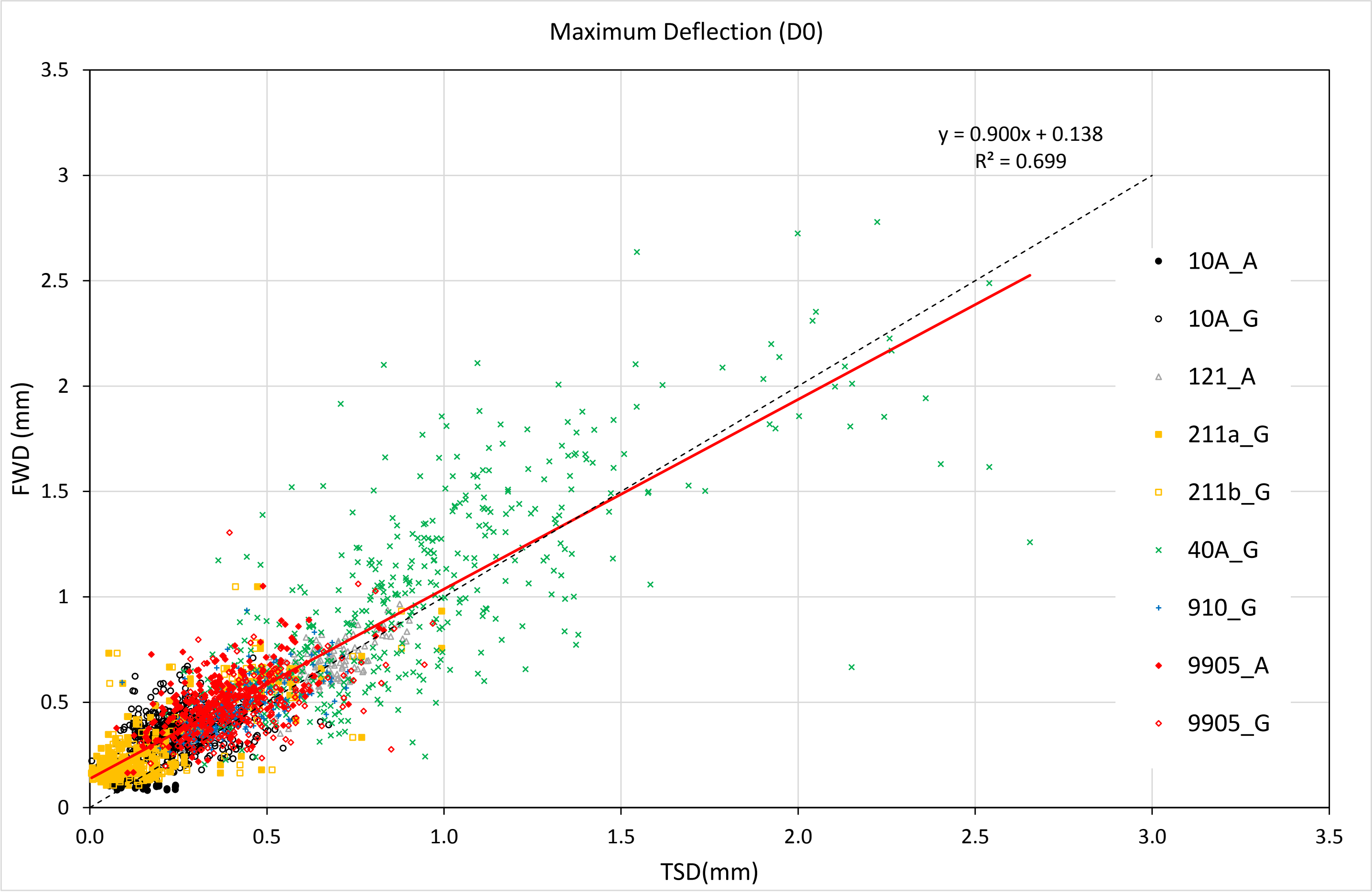
2015 TSD / FWD – Centenary Highway



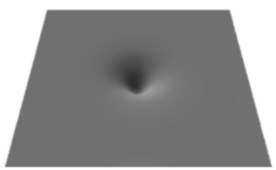
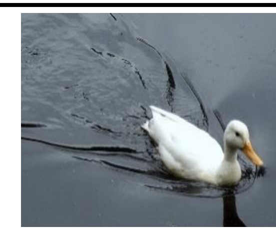


Centenary Highway
(high strength granular pavement)

FWD and TSD maximum deflection correlation



Comparing other deflection measuring devices

	Benkelman Beam	Deflectograph	Falling Weight Deflectometer (FWD)	Traffic Speed Deflectometer (TSD)
				
Analogy				
Speed of waveform while measuring	Stationary	1 m/s (3.5 km/h vehicle speed)	180 to 600 m/s (speed of Rayleigh waves*)	180 to 600 m/s ± 22 m/s (80 km/h vehicle speed)
Appropriate partial differential equations (PDE) for backcalculation	Static (x,y,z)	Static?	Dynamic (x,y,z,t)	Dynamic
PDEs currently used	Static	Static	Static	Static

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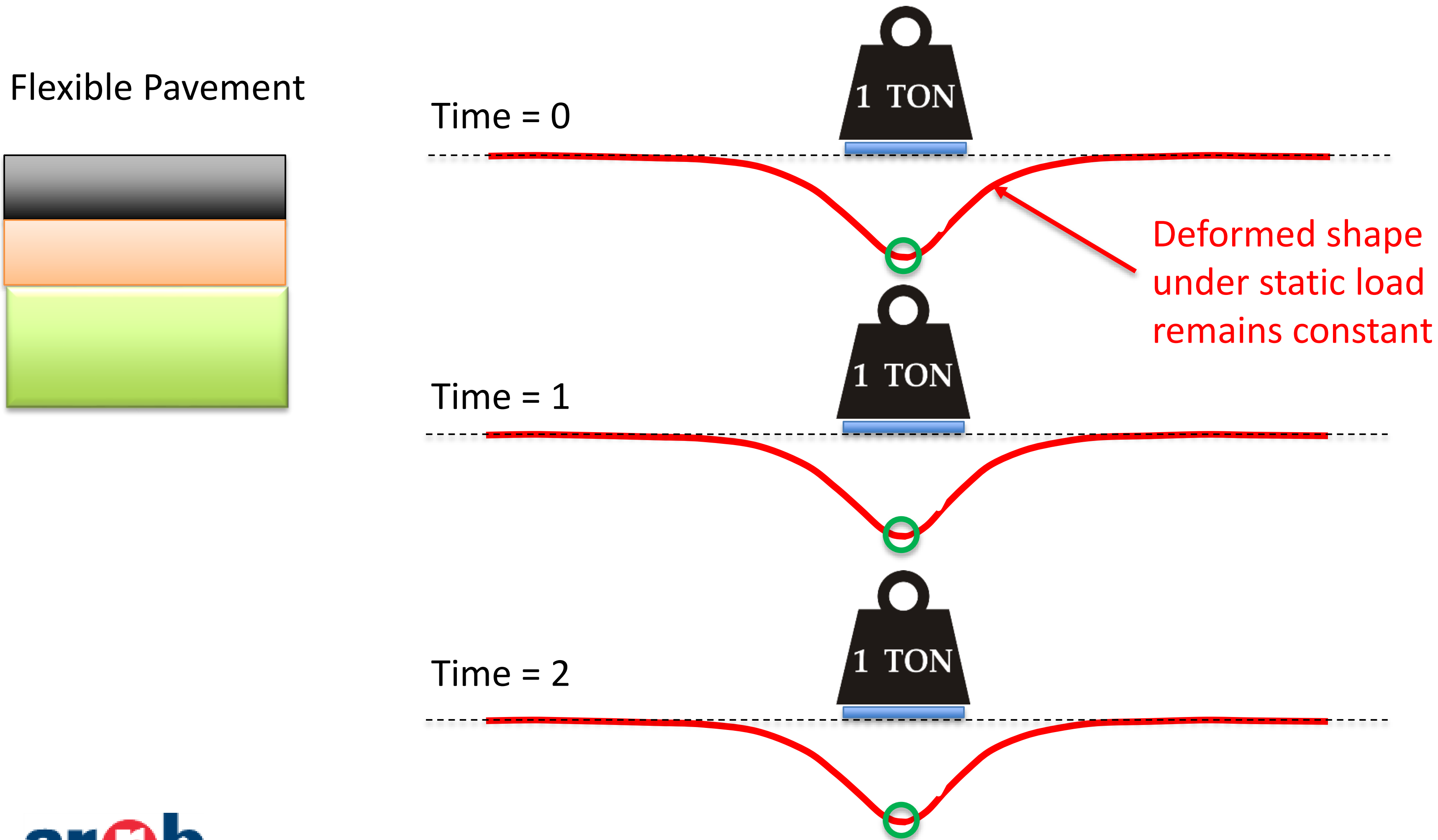
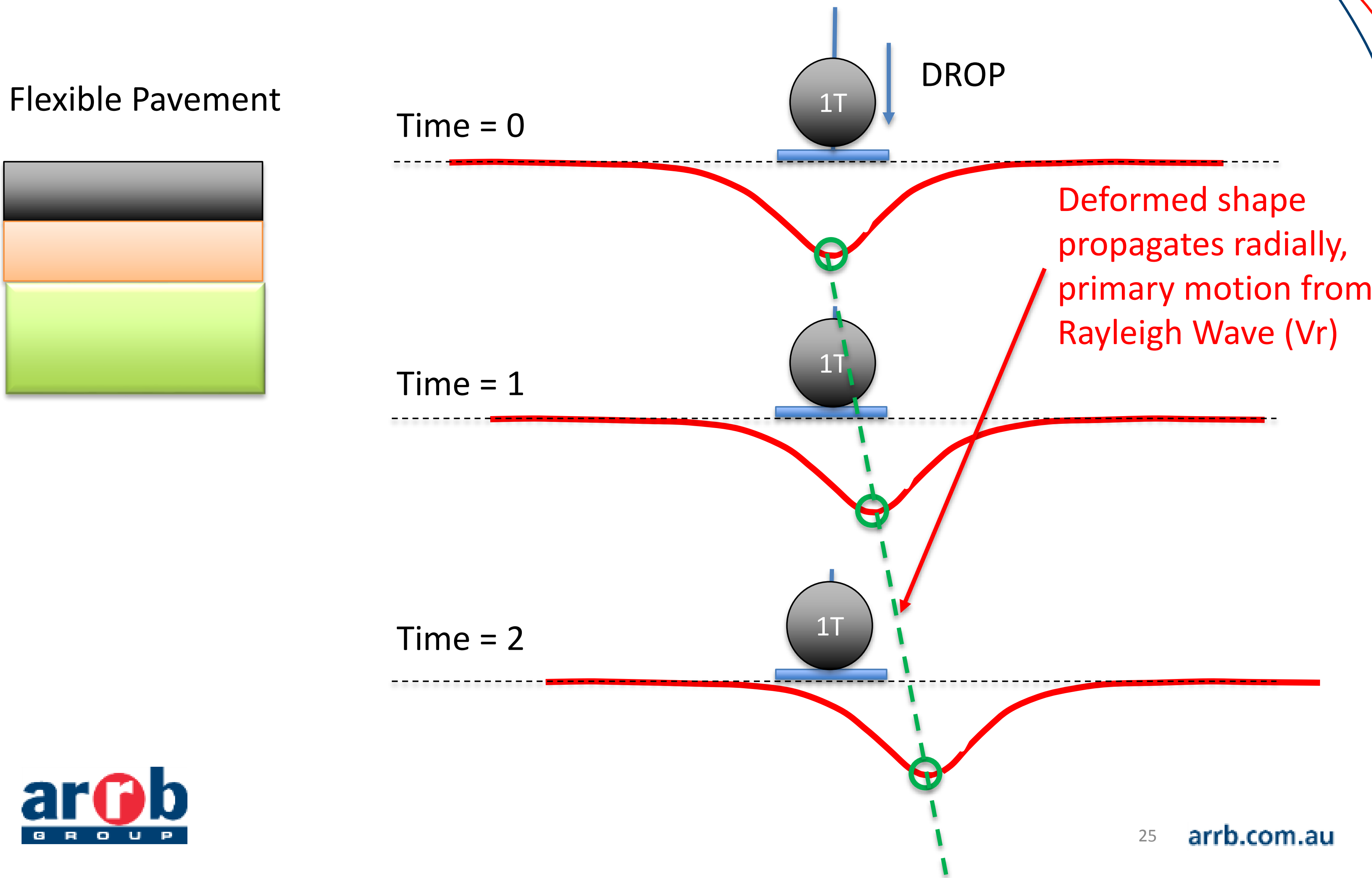
Static

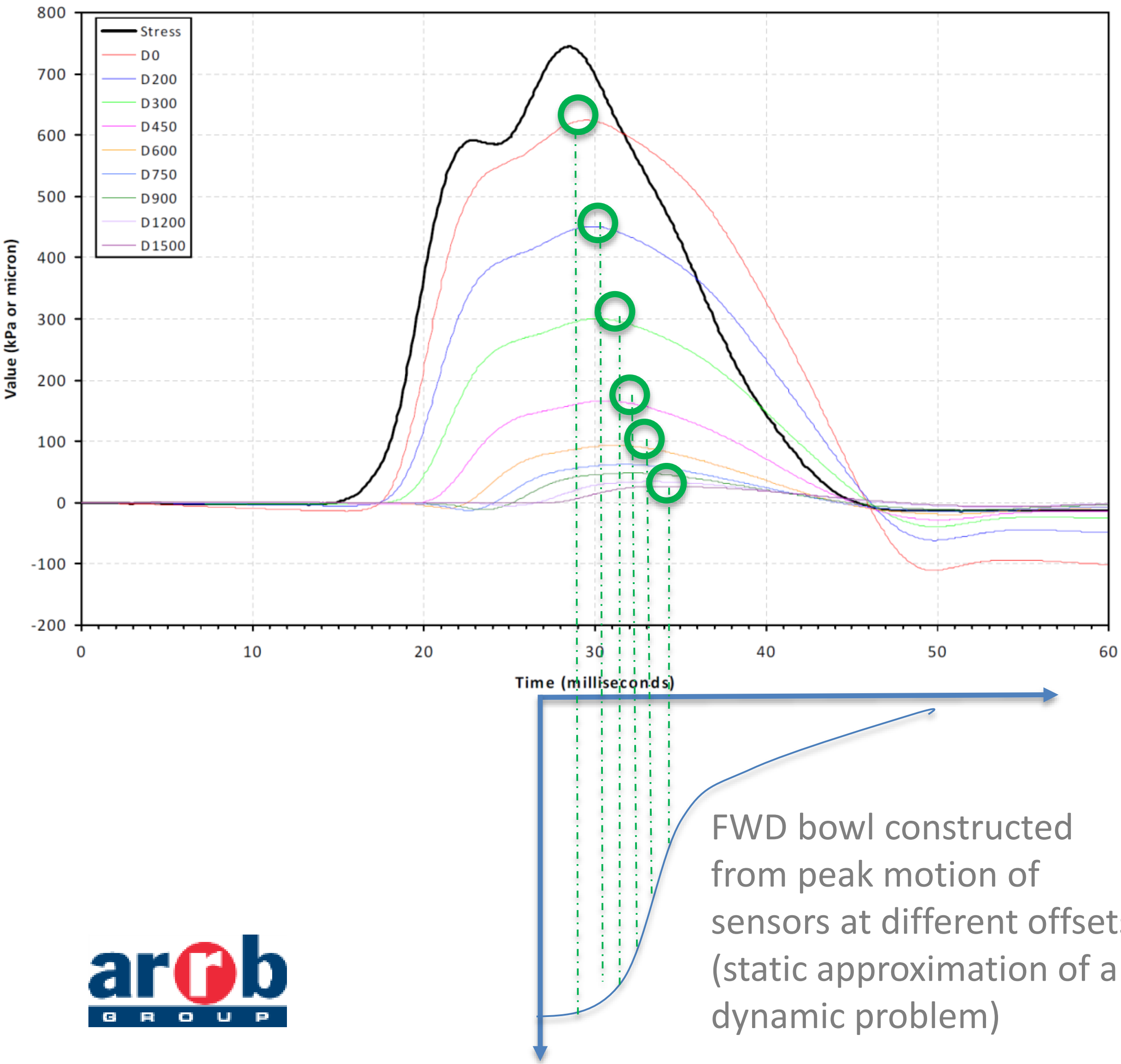
Flexible Pavement



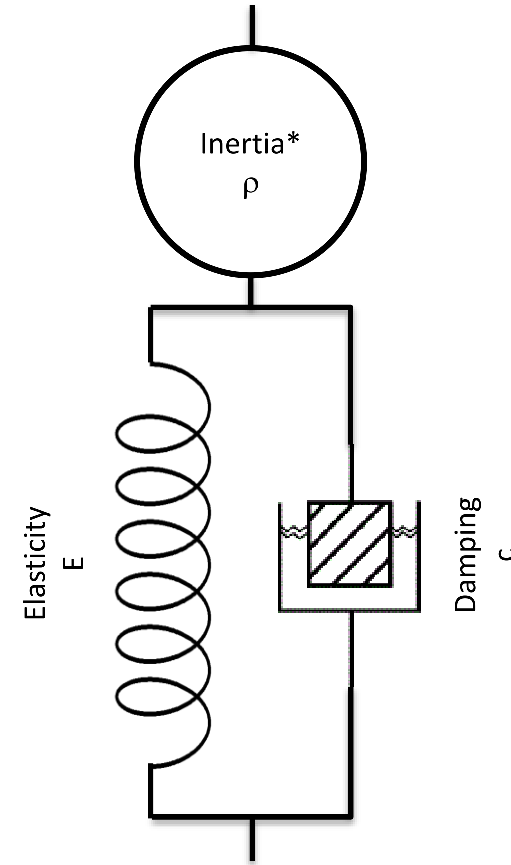
Dynamic – drop weight



FWD time histories



FWD bowl constructed from peak motion of sensors at different offsets (static approximation of a dynamic problem)



* Mass (density) of pavement material

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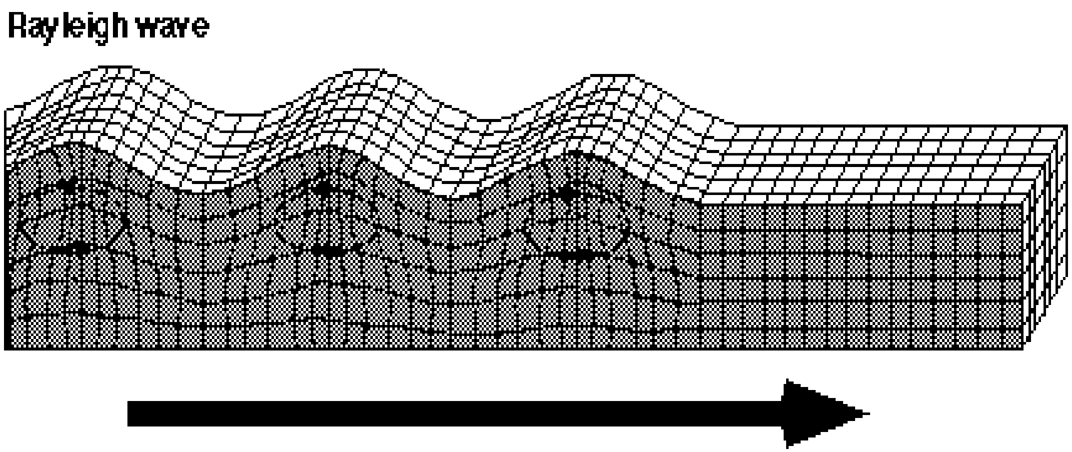
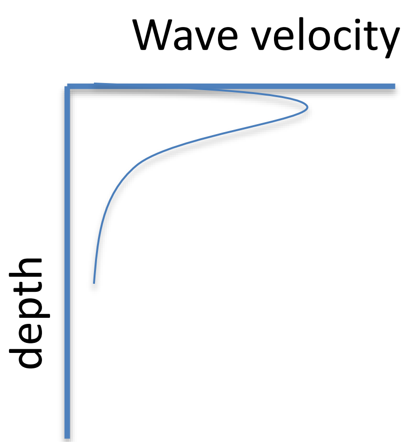
Dynamic – Rayleigh Wave



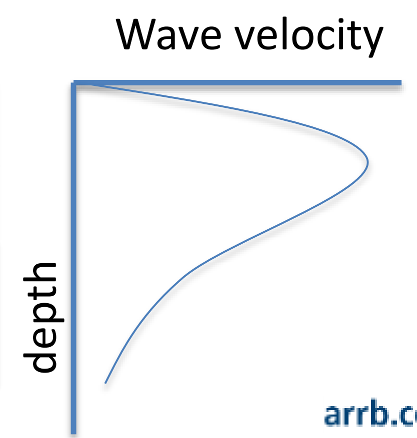
(Modified from Bruce A. Bolt, *Earthquakes: A Primer.* W.H. Freeman & Company. 1978)

Speed depends on frequency

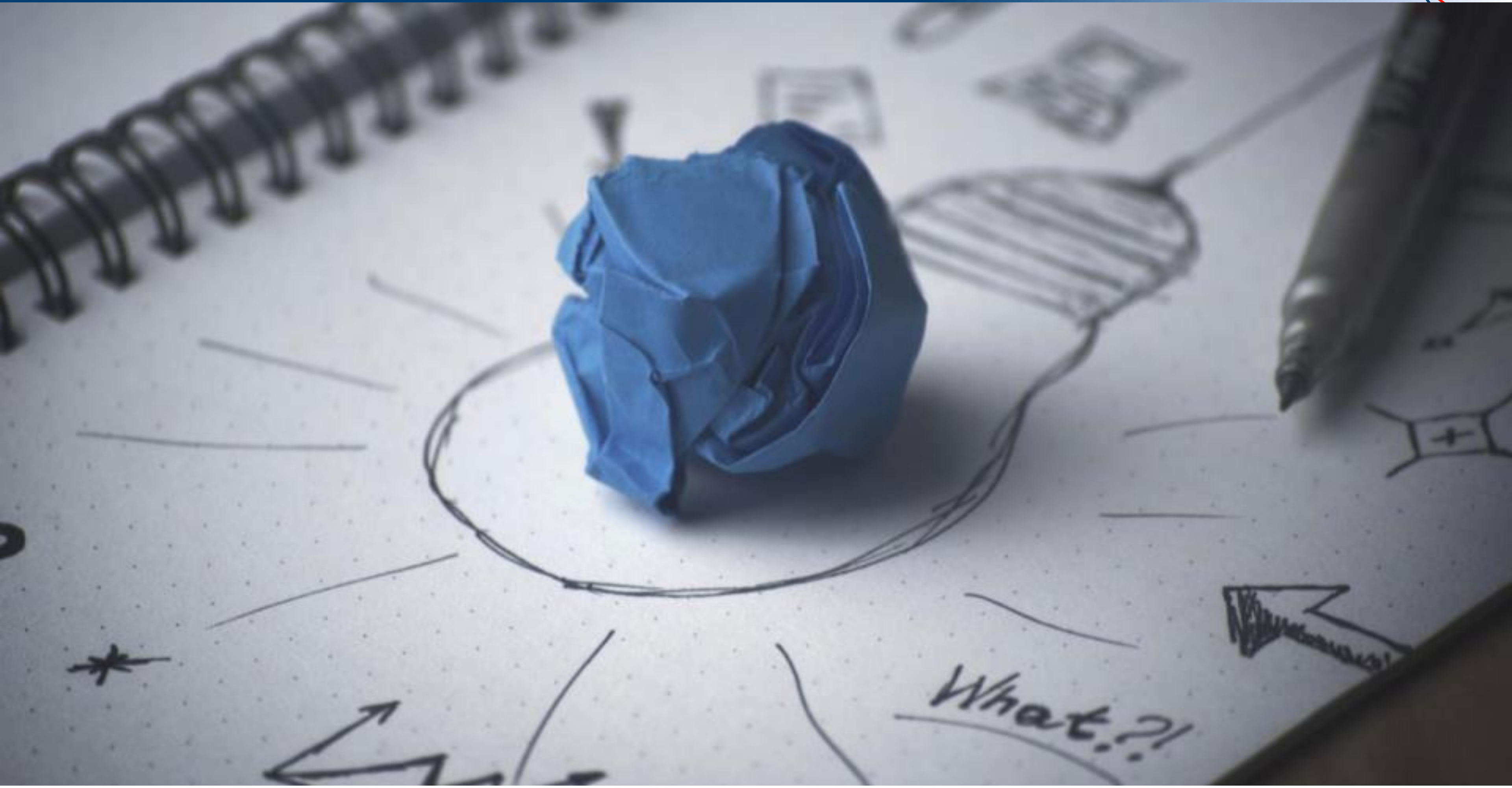
High Frequency Only Penetrates to **Shallow** Depth



Low Frequency Penetrates to **Greater** Depth



Poll Questions



POLL QUESTION

WILL DIFFERENT DEFLECTION MEASURING EQUIPMENT GIVE THE SAME VALUE OF DEFLECTION?

A) Yes

B) No

POLL QUESTION

WILL DIFFERENT DEFLECTION MEASURING EQUIPMENT GIVE THE SAME VALUE OF DEFLECTION?

A) Yes

B) No

If the answer is NO, why?

POLL QUESTION

WILL DIFFERENT DEFLECTION MEASURING EQUIPMENT GIVE THE SAME VALUE OF DEFLECTION?

MY ANSWER

NO.

WE EXPECT A LOT OF SCATTERING AS SHOWN IN THE DATA, BECAUSE EQUIPMENT CHARACTERISTICS AND DYNAMIC RESPONSE OF PAVEMENT MATERIALS VARY.

HOMOGENEITY OF PAVEMENT ALONG A SECTION OF ROAD FURTHER COMPLICATES THE ISSUE.

NACOE P40 Research
– Part 2 (Site Instrumentation)

TSD vs instrumented pavement section

Sensors selections

↓

Acquire DAQ system and sensors

↓

Geophone and accelerometer calibration (shake table)

↓

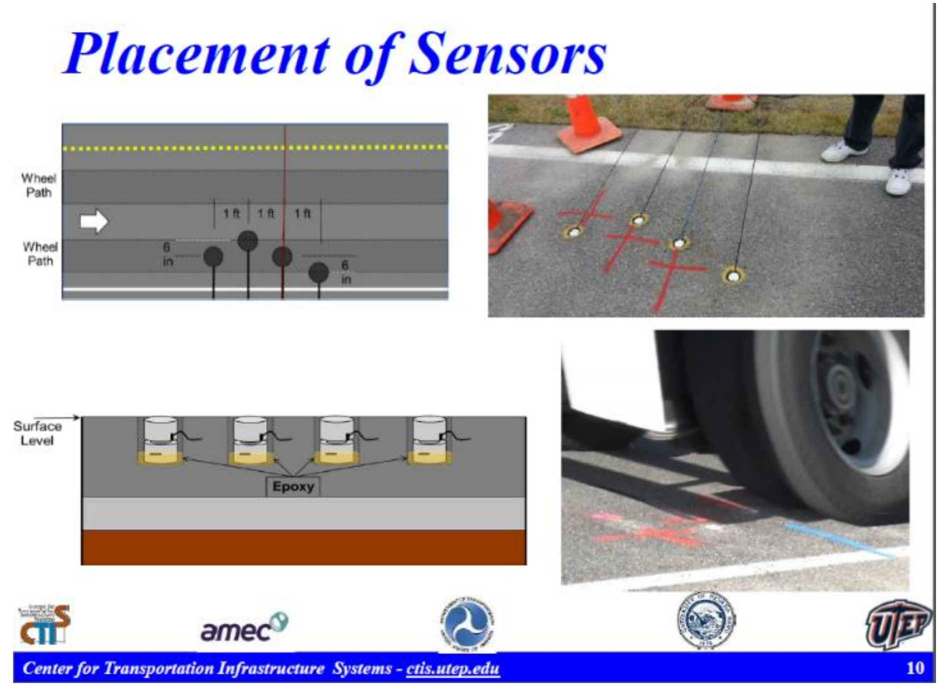
Install sensors at trial site

↓

Compare FWD testing with installed sensors

↓

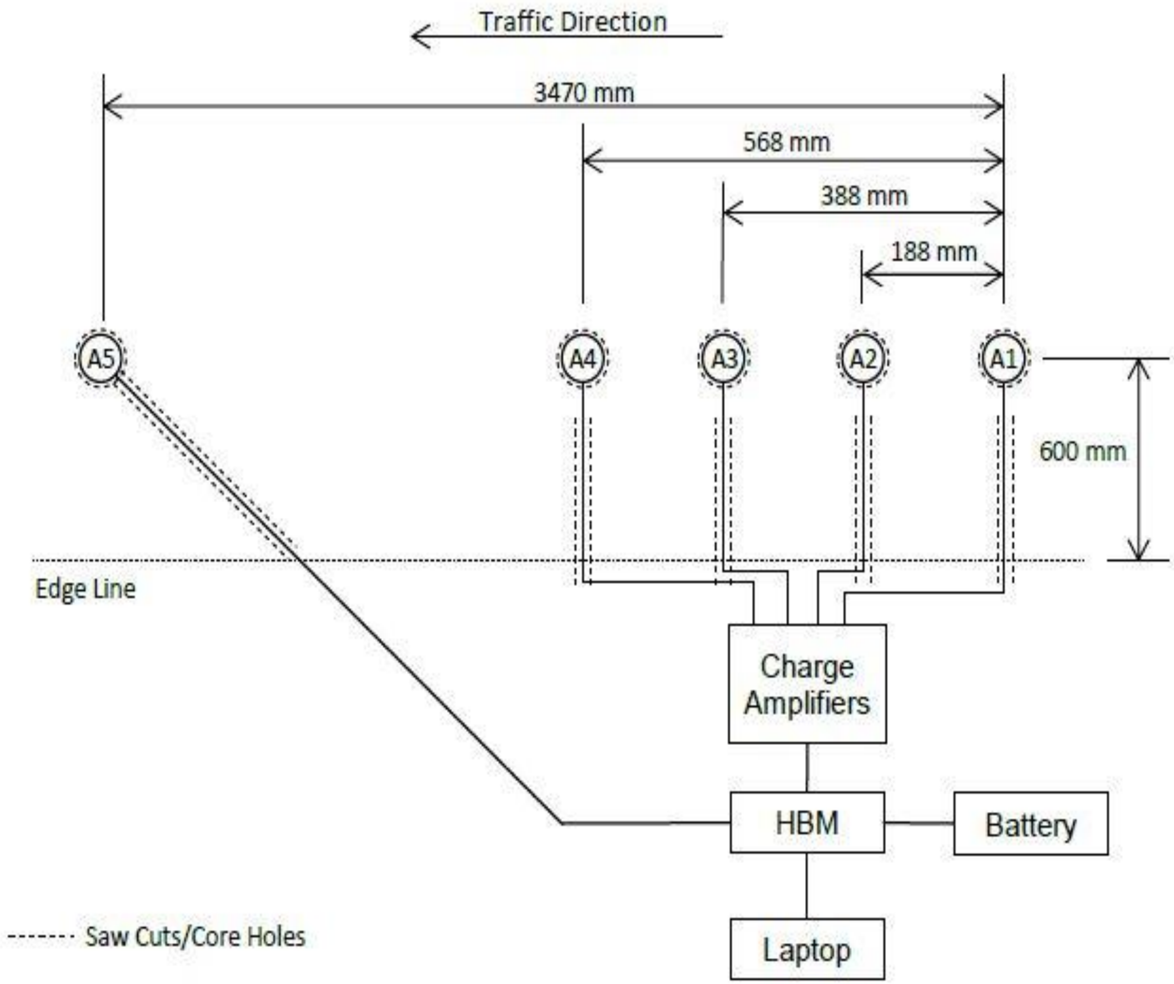
Conduct field trial with TSD

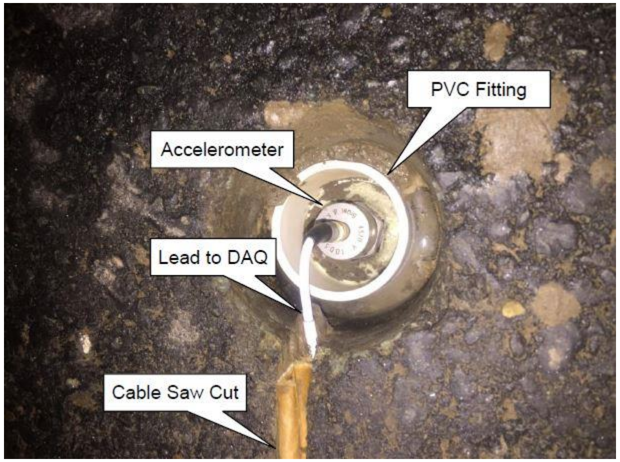


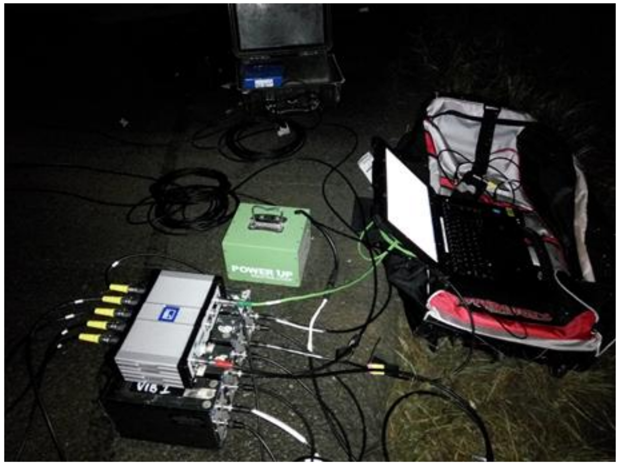
Nazarian, S 2014, ‘Evaluation of accuracy and precision of highway speed deflection devices’, *Pavement Evaluation 2014 conference, 2014*, *Blacksburg, Virginia, USA*.

Instrumented site can be used to calibrate TSD. It can be set up in calibration loop where TSD is routinely surveyed and measurement compared.

Site Instrumentation (Bruce Highway 10A)







Site instrumentation (Bruce Highway)

Coring

Saw Cut

Install Sensor

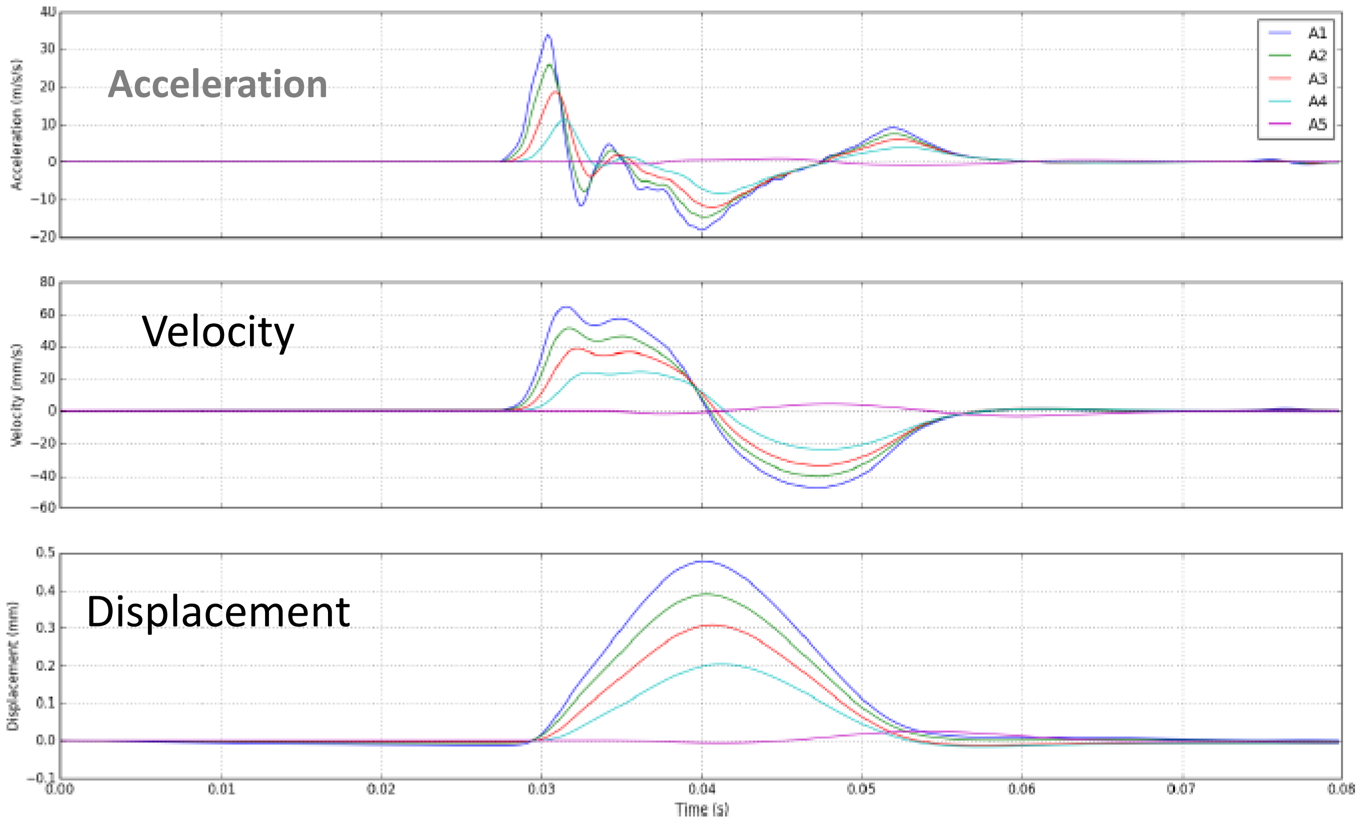
Site instrumentation (Bruce Highway)

Data Acquisition

FWD

Vehicle Pass-by

Converting acceleration to displacement



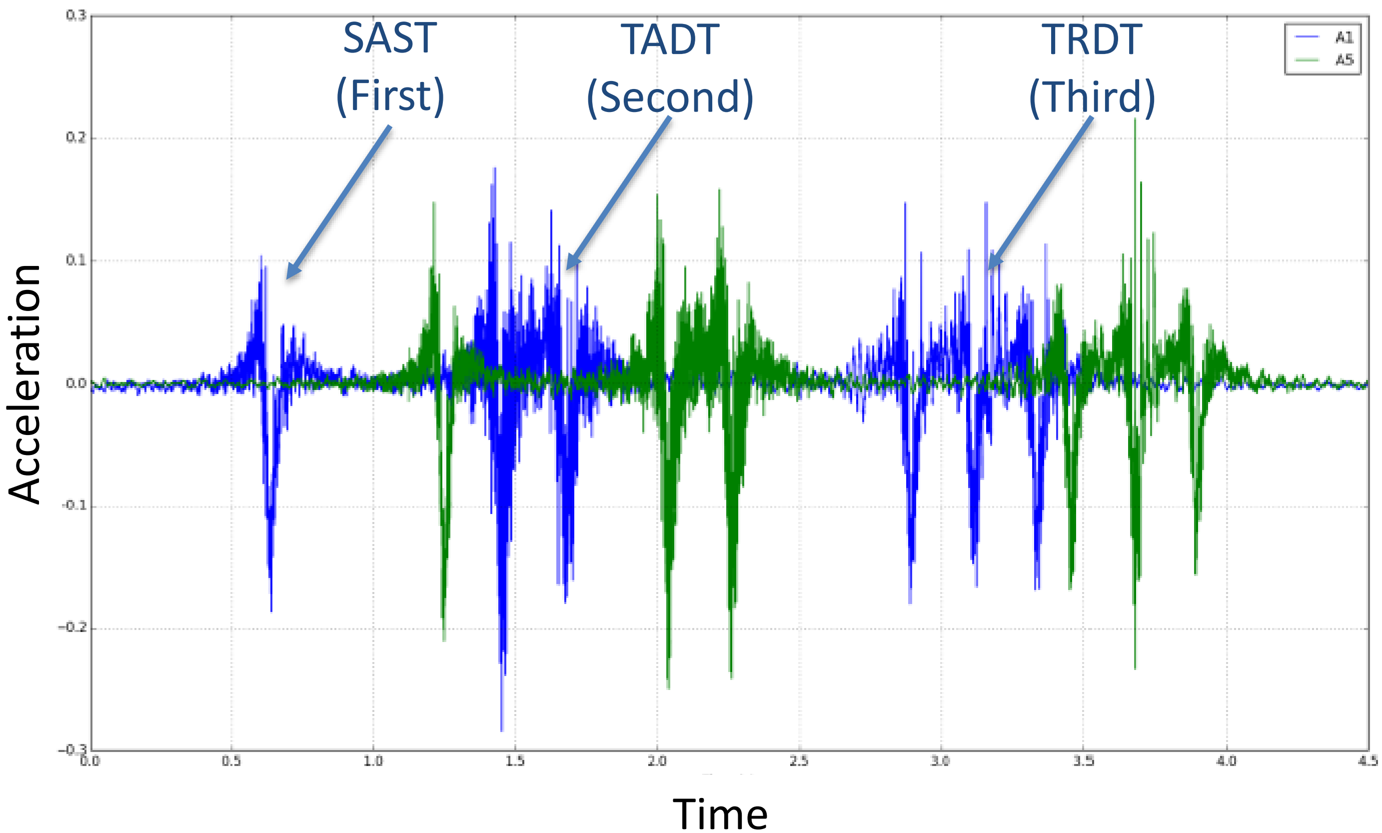
Comparing in-ground instrumentation with FWD measurements

Table 5 Comparison of Accelerometer and FWD Deflection Results

Test ID	Distance from Load (mm)	FWD Deflection (mm)	Accelerometer Based Deflection (mm)	Similarity (%)
1	182	0.256	0.282	9%
2	182	0.256	0.280	9%
3	182	0.420	0.477	12%
4	182	0.132	0.160	17%
5	200	0.247	0.255	3%
6	200	0.402	0.446	10%

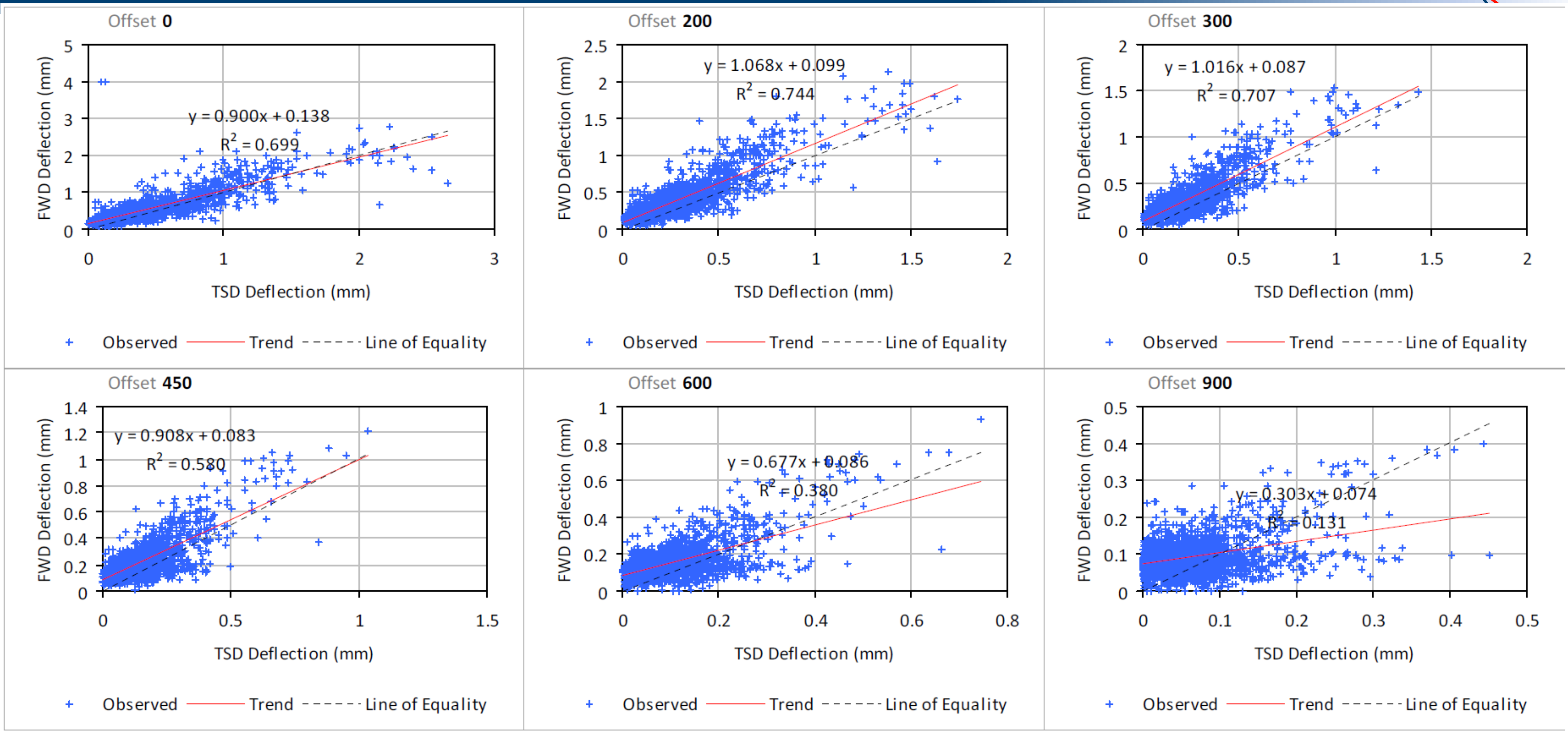
In-ground measurement of a semi-trailer

Figure 14 Acceleration Data for Last Semi-Trailer Pass-By (A1 and A5)



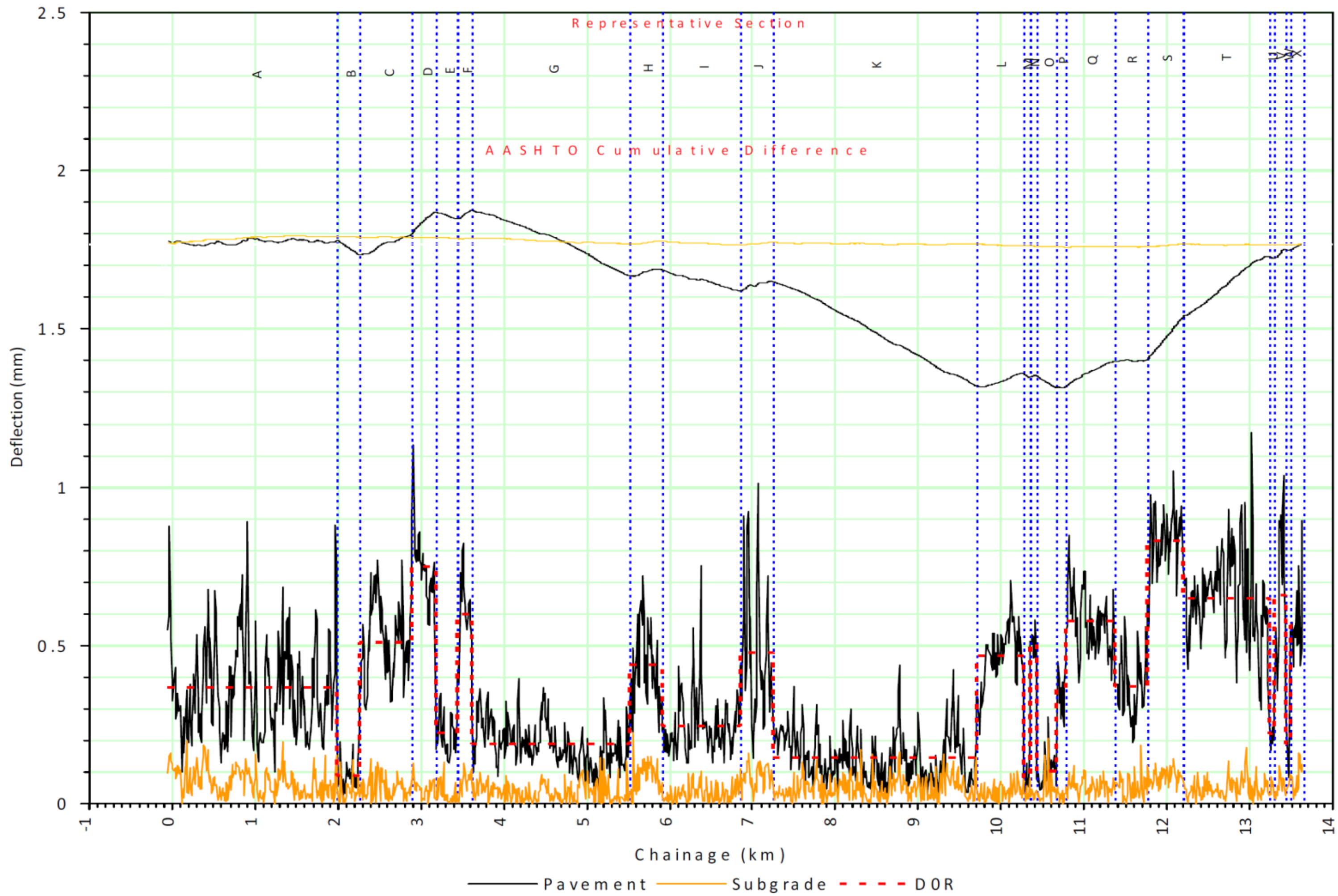
Define Homogenous Section & Advanced Correlation Techniques

Raw FWD v TSD



- **Approximately linear relationship**
- **Bias or Intercept ~ 100 μ**
- **Poor R^2, degrades with offset**
- **FWD generally larger deflection than TSD**

Representative section – AASHTO cumulative difference



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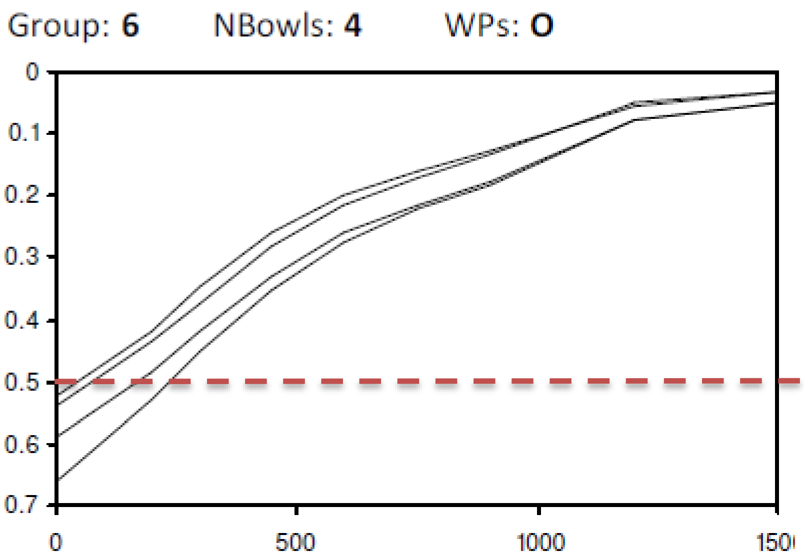
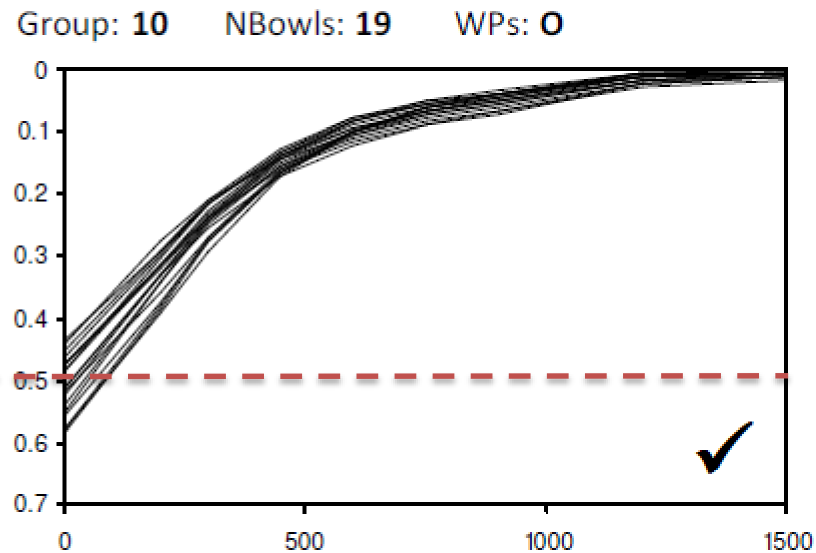
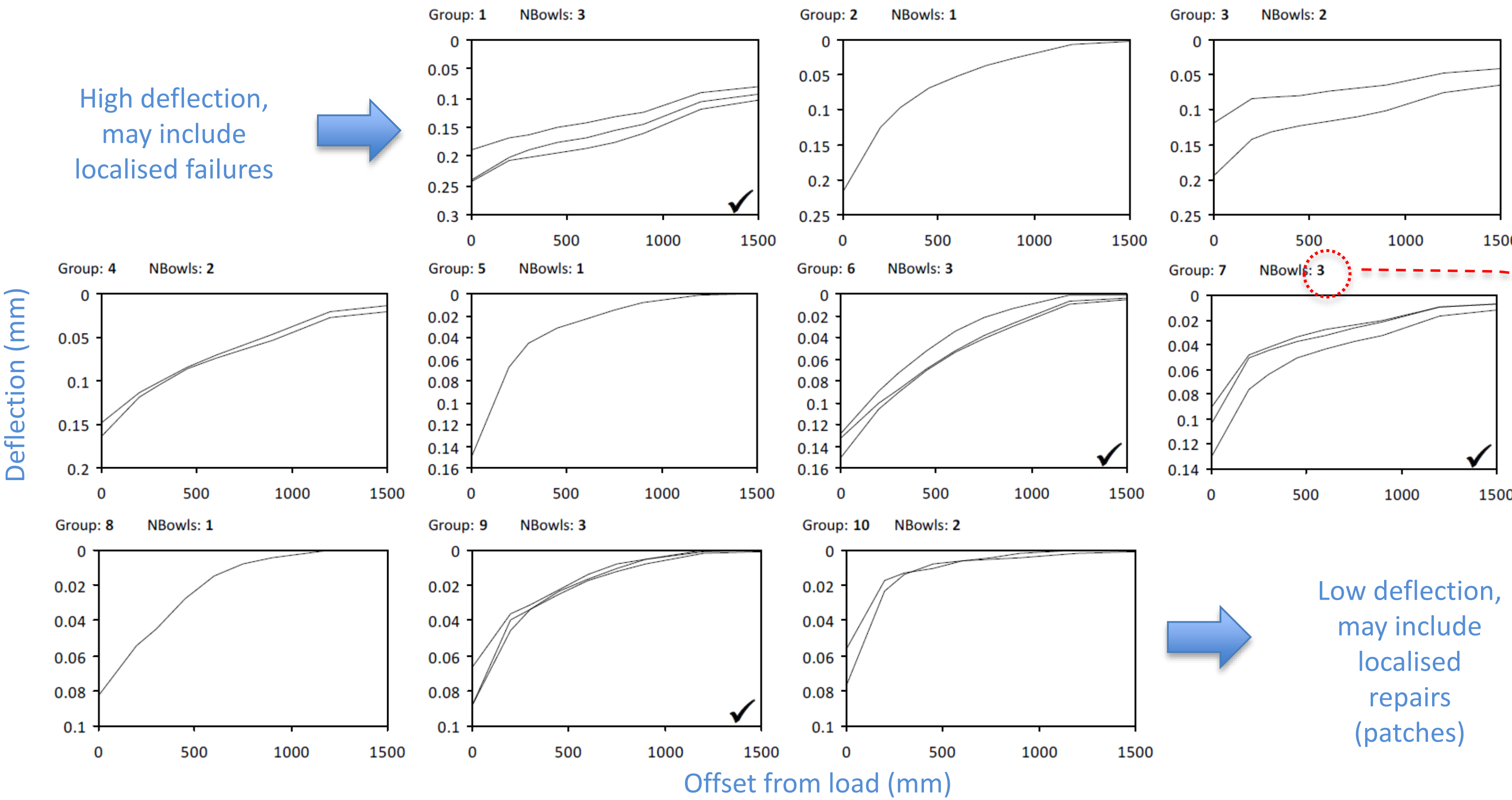
Distinguish between Bowls





Same maximum deflection, but shape is very different
It is more reasonable to analyse bowl groups that are similar in shape

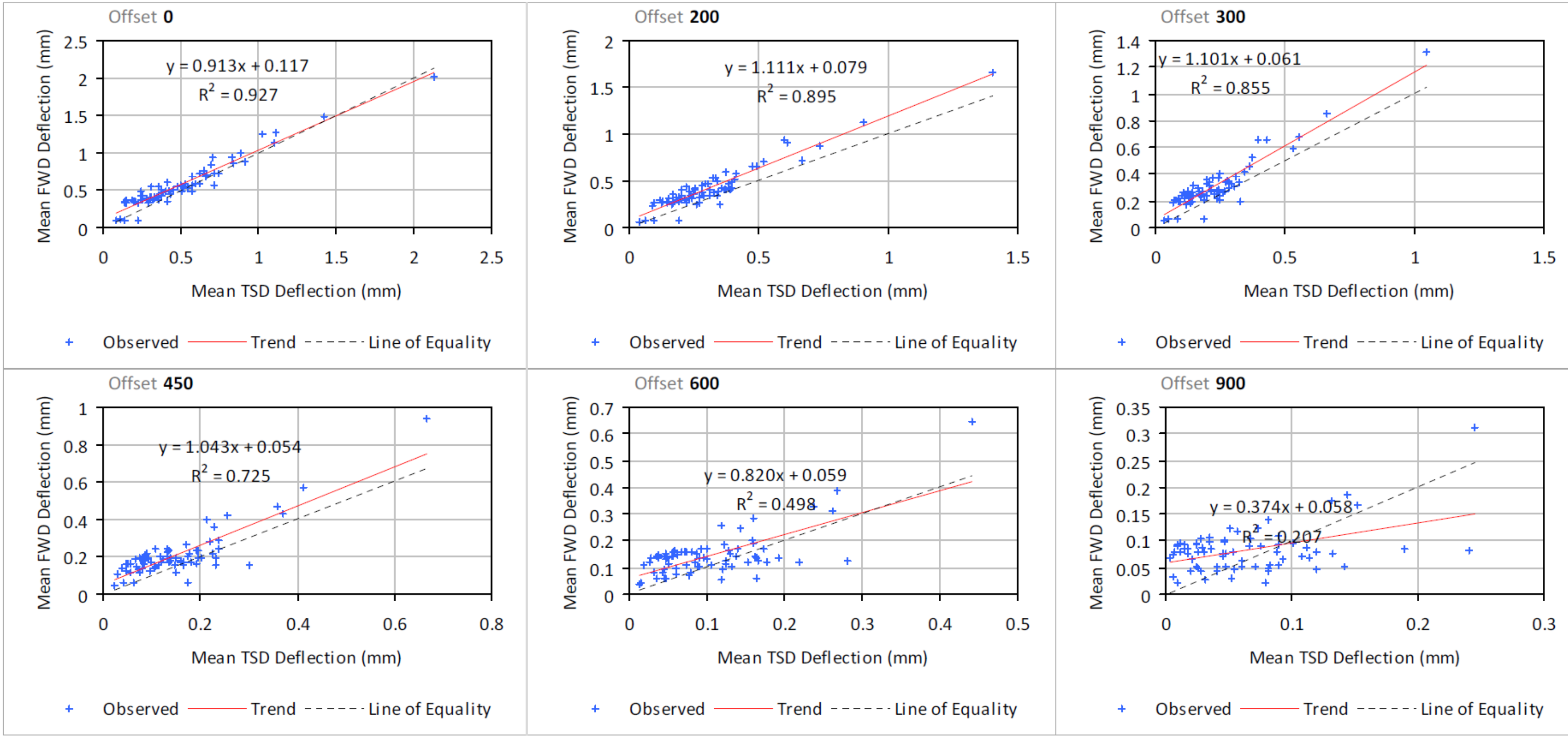
TSD Bowl Groups



- ✓ ⇒ selected for comparison with FWD
- Exclude smaller* groups as possible outliers
- Mean bowl ⇒ error reduced by $\sqrt{n}$

  ($\sqrt{3} \approx 1.73$)
- Agglomerative Hierarchical clustering (R Statistical Computing)

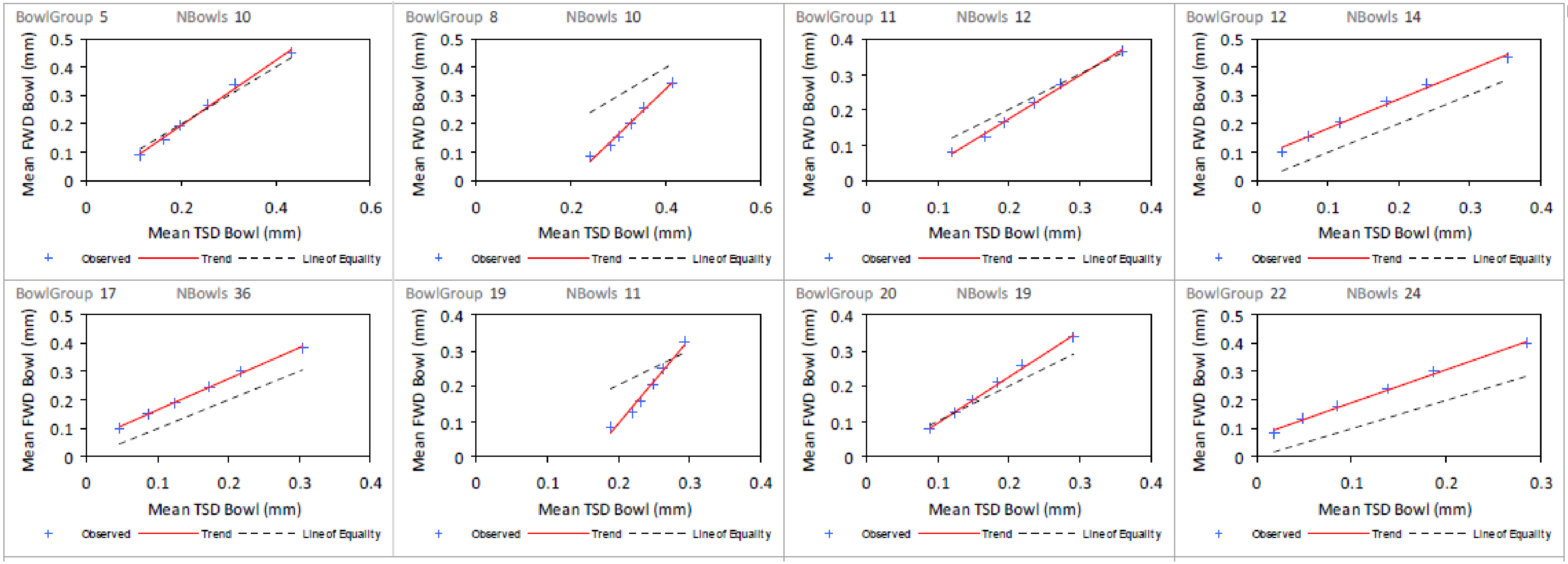
Bowl Group FWD v TSD



- **Approximately linear relationship**
- **Bias or Intercept ~ 60 µ**
- **Improved R^2, degrades with offset**
- **FWD generally larger deflection than TSD**

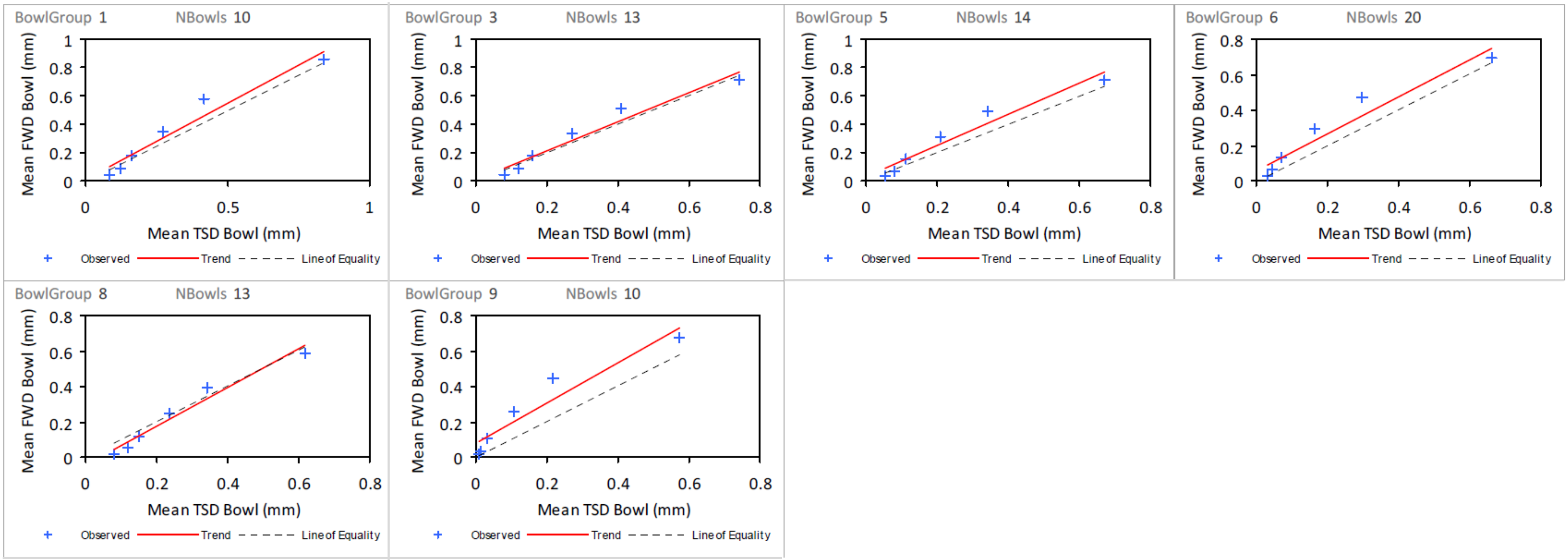
Linear Bowl group example

10A Bruce Highway, Brisbane - Gympie, North bound slow lane LWP



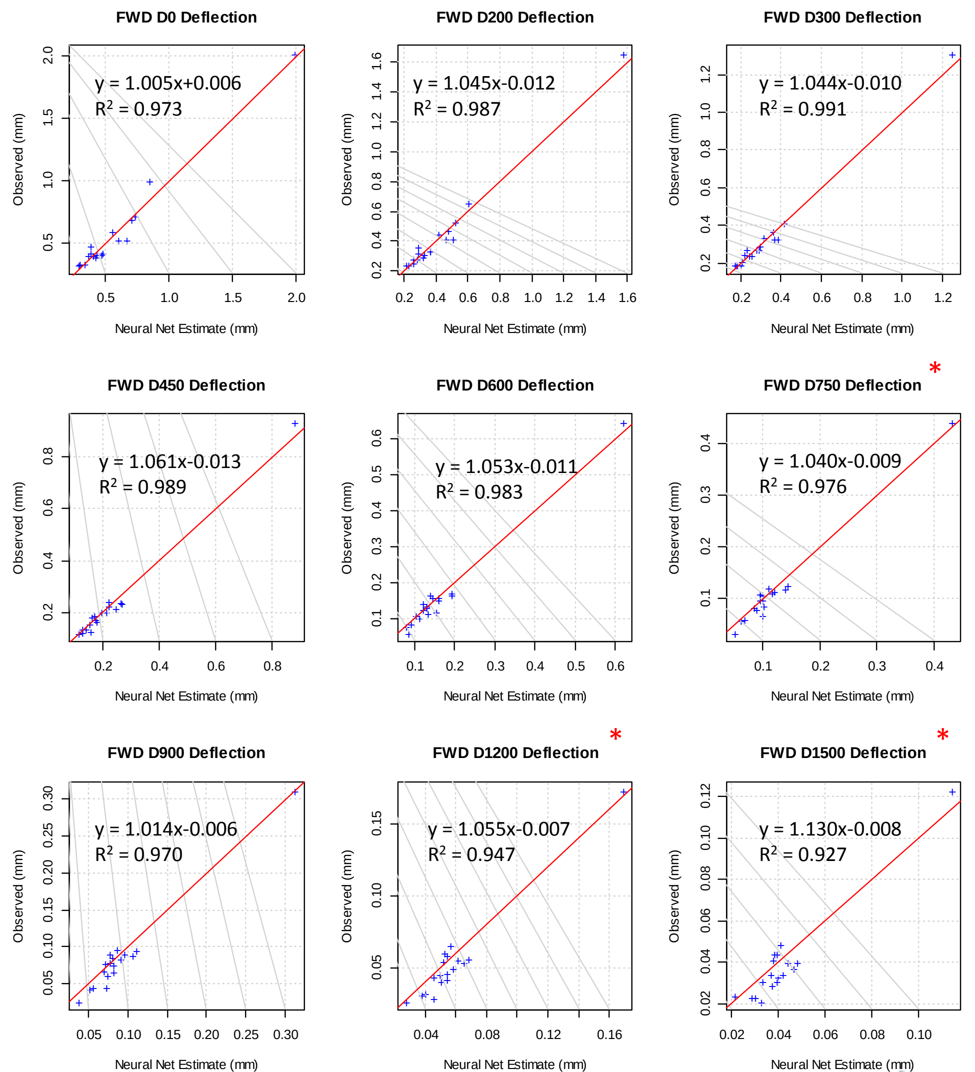
Non-linear Bowl Group example

121 Deception Bay Road, West bound slow lane LWP



Predict FWD from TSD using Neural Net

- Data: Mean bowl group deflections of chainage matched TSD and FWD
- $R^2 > 0.9$ for all offsets
- 6 TSD offsets → 9 FWD offsets
- 75% of data → training
- Remaining 25% → test predictive capability (refer charts)
- Can use existing backcalculation software developed for FWD



Summary and Conclusions

Advantages and disadvantages

Advantages

- Fast and high productivity
- Loading is the same as a real-life truck (compared to a drop load from FWD)
- Repeatable results
- Continuous measurement (deflection currently limited to 10m spacing)
- Collect different condition data in a single device (no sync issues)

Disadvantages

- Early in the product cycle (compared to FWD which is around for over four decades)
- Current configuration only measure deflections along the outer wheel path.
- Loading mechanism and dynamics are less well understood
- Limited readily available analysis software
- Only one to share across Australasia

Limitations

- Poor correlation with FWD for $D_0 < 0.2$mm
- A linear regression correlation developed is based on D_0 from limited number of sites.

Summary and conclusions

- TSD collects a range of condition data at traffic speed. It is a valuable tool for pavement structural assessment. Pavement engineers should not evaluate a pavement purely on the measured deflection values
- Similar to a FWD, TSD measures velocity and obtain deflection through a numerical integration process
- NACOE research provided additional data to correlate TSD with FWD
- Deflection from trafficking vehicle is a complex dynamic problem. Comparing with other established deflection equipment is only the first step to understand the TSD measurements
- NACOE research trialled in-ground instrumentation testing scheme to measure true ground motion and can be used for detailed study of the TSD
- Statistical clustering and advanced correlation techniques are presented. These techniques can be used to improve correlation results

Questions?

Thank you for your participation today

For further information, please contact:

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