EUROPEAN COMMISSION

SEVENTH FRAMEWORK PROGRAMME

Community research

Research DG

H2 Surface Transport

SMARTRAIL

SMARTRAIL – Work Package 1

Monitoring and Inspection

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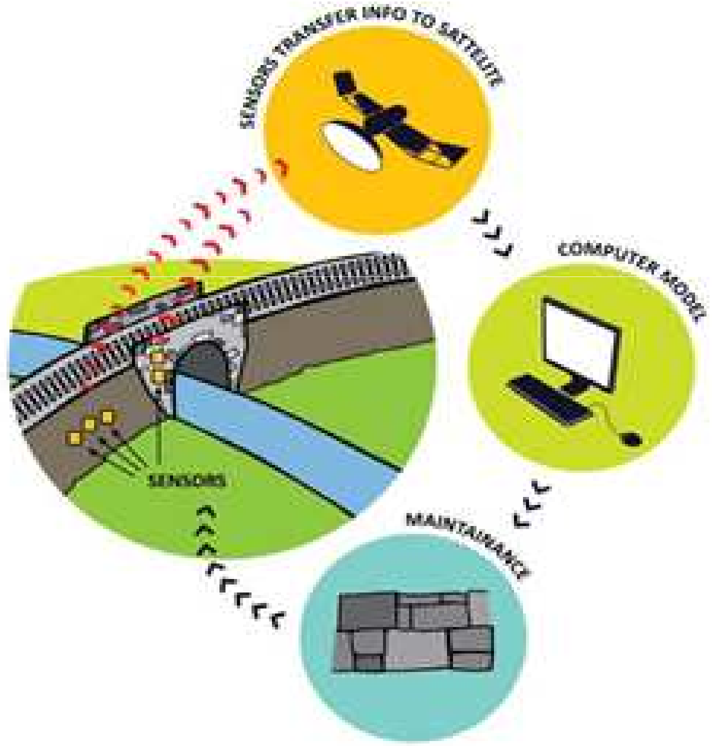
UCD DUBLIN

Objectives



WP1 aims to bring about a step change in the traditional methods of *visual inspection and ad-hoc monitoring* with integrated monitoring systems which utilize the *latest embedded sensor technology and optimized in-situ testing methods*.

Overview of Tasks

Task 1.1 Network of embedded sensor devices

Task 1.2: Instrumented Smart Slope

Task 1.3: Inspection of Slopes using NDT Techniques

Task 1.4: Development of a methodology for NDT assessment of bridges subjected to scour

Task 1.5: Use of instrumentation to monitor the condition of bridge structures

Task 1.1 Network of embedded sensor devices

Partners Irish Rail, Slovenian Railways, EURNEX (RTU), FERHL (VTI), ZAG and IK.

The participants will specify *embedded sensor systems* to monitor and control old railway networks:

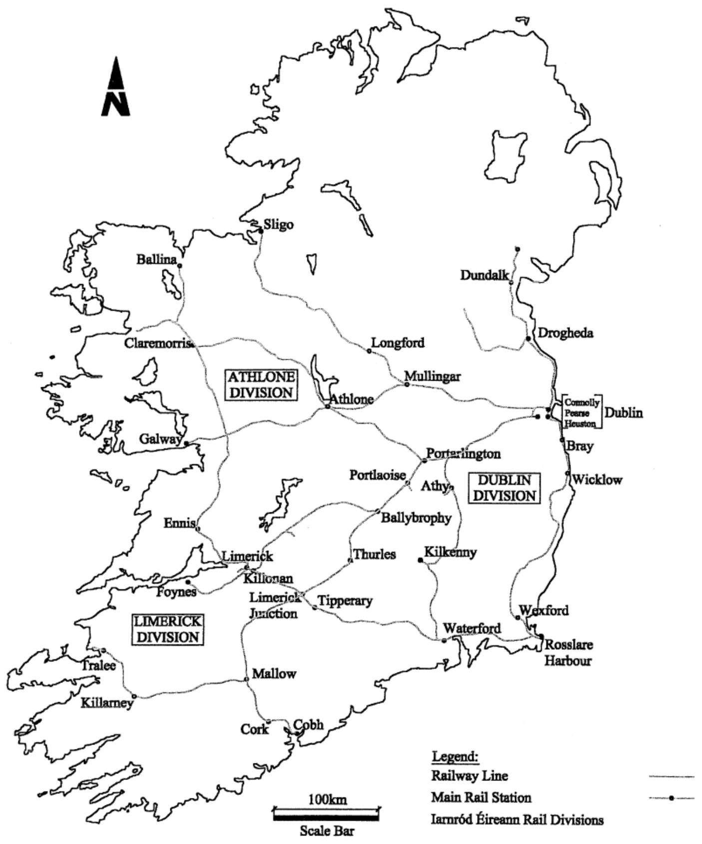
for SMARTRAIL emphasis is on soil slopes and bridges

Task 1.2: Instrumented Smart Slope

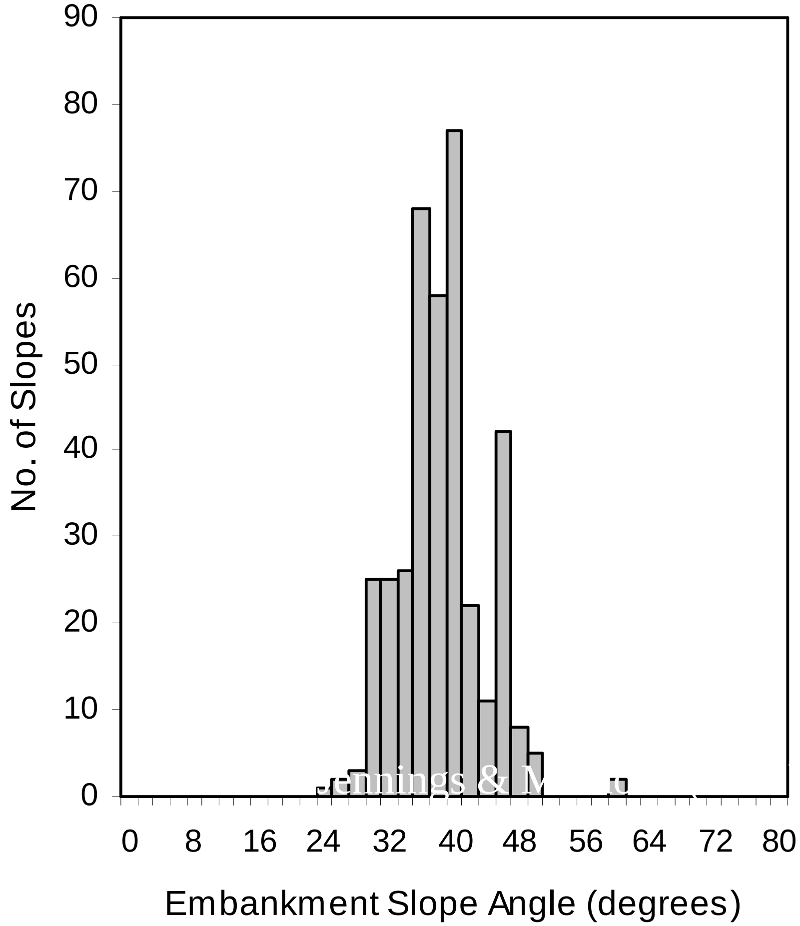
Partners: UCD and Irish Rail

- An exiting (disused) railway slope will be instrumented with pore pressure sensors, inclinometers, weather station etc.
- Controlled rainfall will be applied using a rainfall simulator
- Live slopes will be instrumented to provide real-time feedback

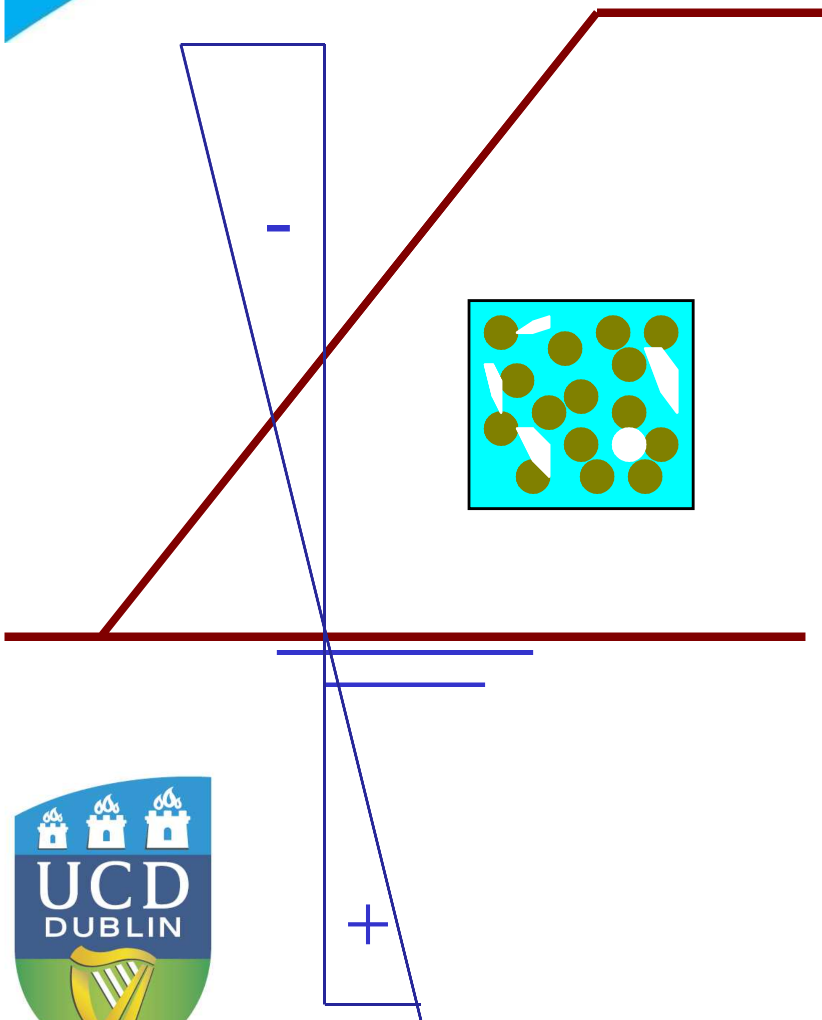
Survey of 150 year old railway embankments



Average slope angle = 38°

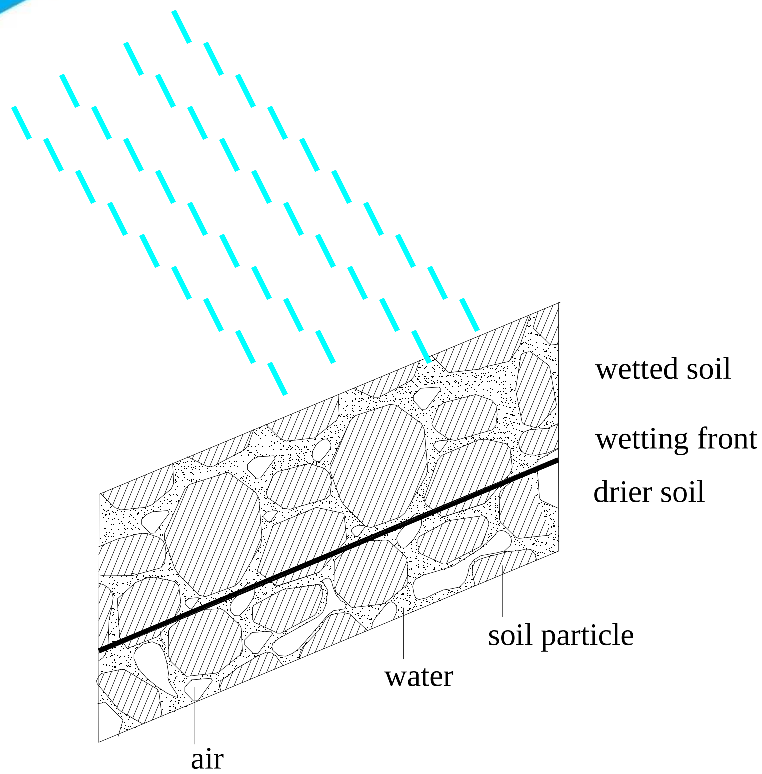


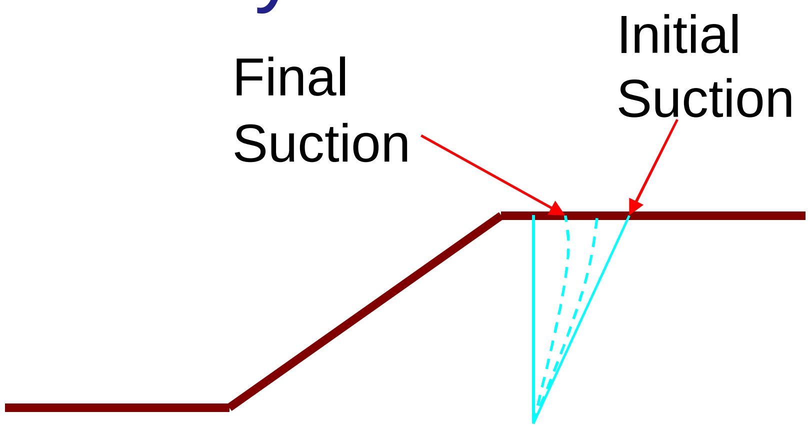
Slopes are Partially Saturated



- Air voids act like mini capiliary tubes, drawing water up from the saturated zone below the water table by suction
- This suction provides inherent stability

Stability is affected by rainfall

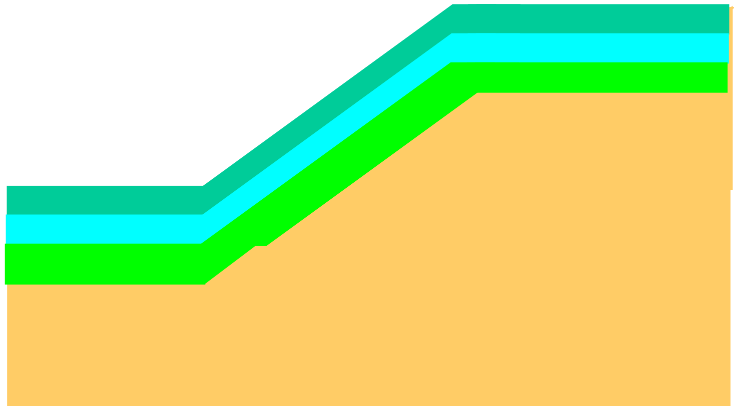




As rain falls, suctions reduce. A wetting front develops as the ground becomes *almost* saturated from the top down

Effect of suction on slope stability

$$\text{FOS} = \frac{\text{Capacity}}{\text{Demand}}$$



- Stability is provided by near surface suction (-pwp)
- Rainfall causes formation of wetting front (increased pwp) reduces suction and may cause failure – typically shallow slip

Instrumentation: Soil Suction

UMS T4eTensiometers:

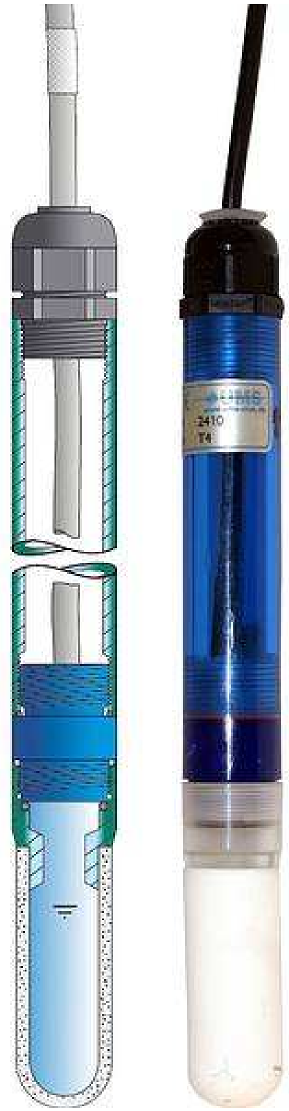
•Can measure soil pore pressure from -80kPa to 100kPa.

•External refilling.

•Accurate to .5kPa.

•Wide variety of lengths.

•Fast response.



Instrumentation: Soil Moisture Content

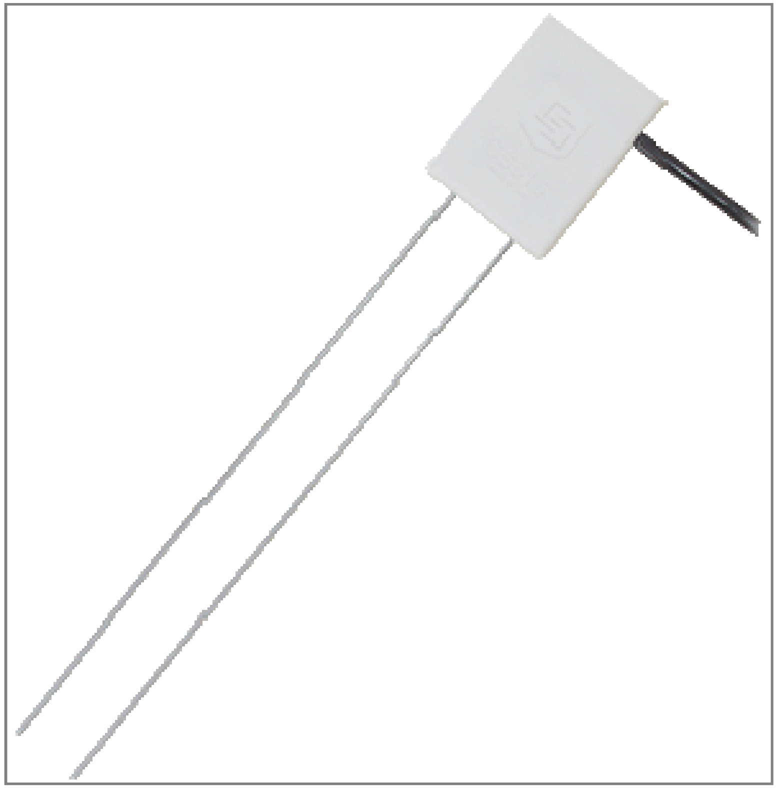
Campbell Scientific Soil moisture probes:

•The CS616 measures the volumetric water content from 0% to saturation.

•Can be buried or inserted from the surface.

•Fast response time.

•Very accurate



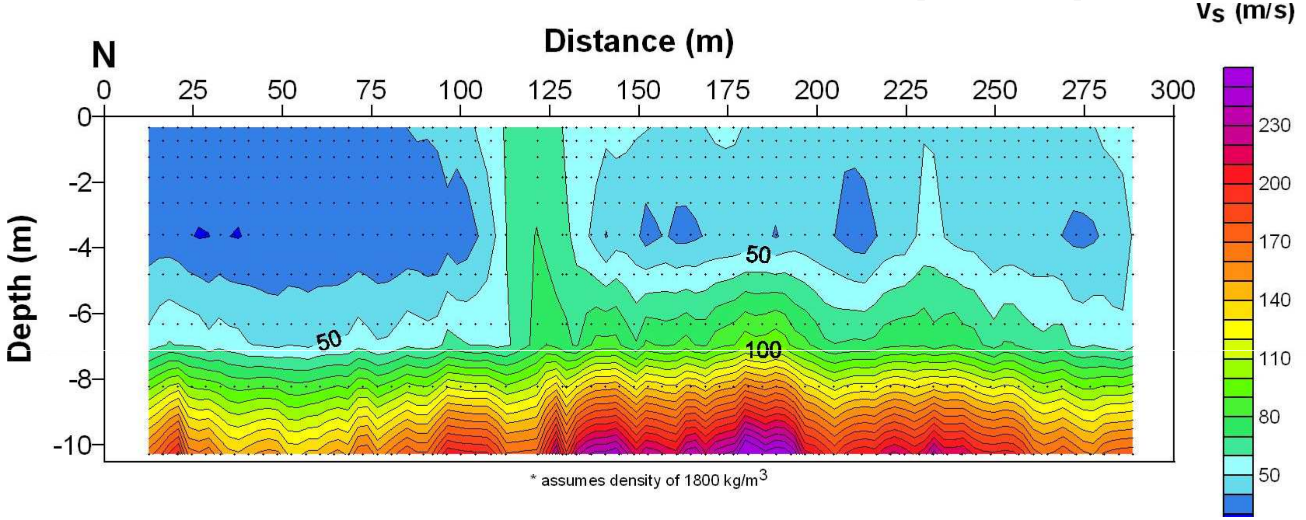
Instrumentation: Deformations

Trimble Mensei Laser Scanner

- Takes 3D laser scans.
- Accurate to 1.4mm in 50m.
- Volume change can be monitored over time by using a time sequence.

Task 1.3: Slope Inspection using NDT Techniques

Partners: UCD, FERHL (NTUA), IGH, Irish Rail



(i) Method to increase data acquisition from MASW

(ii) Develop improved models for interpreting the data e.g. GPR measurements to assess moisture content distributions in a soil mass

(iii) Investigate fundamental relationships between geophysical measurements and soil properties, e.g. Water content and stiffness

Recent Slope Failures

Rainfall Records

Extreme Rainfall Return Periods

Location: Gorey, Co. Wexford
Average Annual Rainfall: 982

Maximum rainfall (mm) of indicated duration expected in the indicated return period.

	Return Period (years)								
Duration	1/2	1	2	5	10	20	30	50	100
1 min				1.8	2.1	2.4	2.7	3.0	3.4
2 min				3.1	3.5	4.2	4.6	5.2	5.9
5 min				5.5	6.4	7.6	8.3	9.4	10.8
10 min				7.8	9.2	11.0	12.2	13.9	16.0
15 min	4.9	6.2	6.9	9.5	11.6	14.0	15.6	17.8	21
30 min	6.7	8.3	9.3	12.6	15.4	18.5	20.5	23	27
60 min	8.8	11.0	12.3	16.4	19.7	24	26	30	34
2 hour	11.8	14.3	16.0	21.1	25	30	33	37	43
4 hour	16.2	19.6	21.5	28	32	37	41	45	52
6 hour	19.7	23.6	26	33	38	44	48	53	61
12 hour	25.4	30	33	42	49	55	60	66	75
24 hour	32	38	41	51	59	67	73	80	90
48 hour	39	46	51	63	71	81	87	95	107
96 hour									

Notes: Larger margins of error for 1, 2 ,5 and 10 minute values and for 100 year return periods
M560: 16.4 M52d: 59 M560/m52d: 0.28

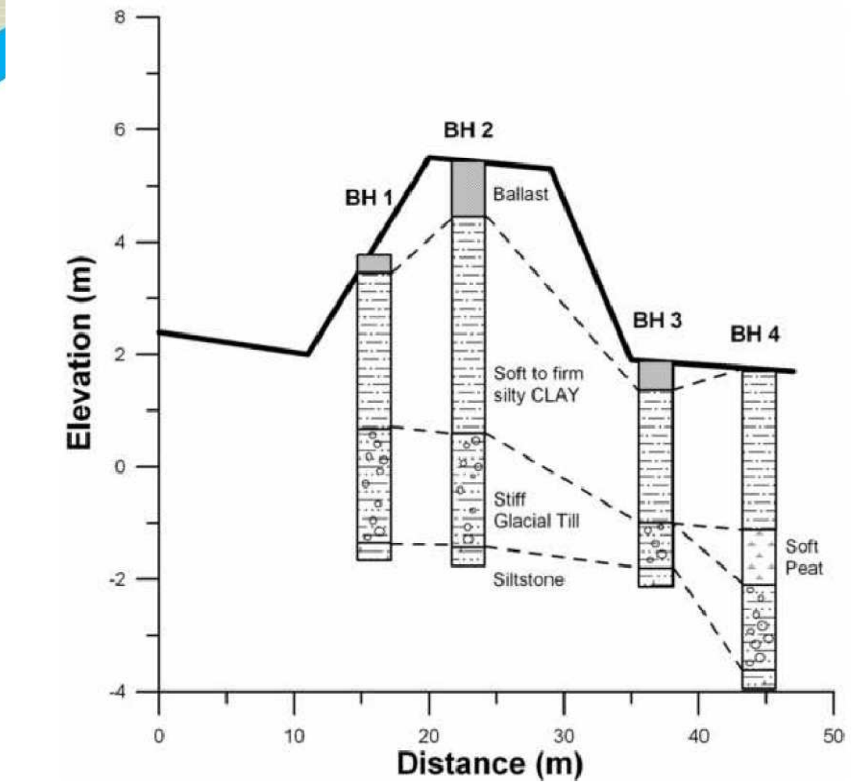
October

- no exceptional storms
- overall rainfall 50% above normal

November

- Rainfall 84% above normal
- Included storm on 25th with 58mm of rainfall over 6 hour

Cross-Section



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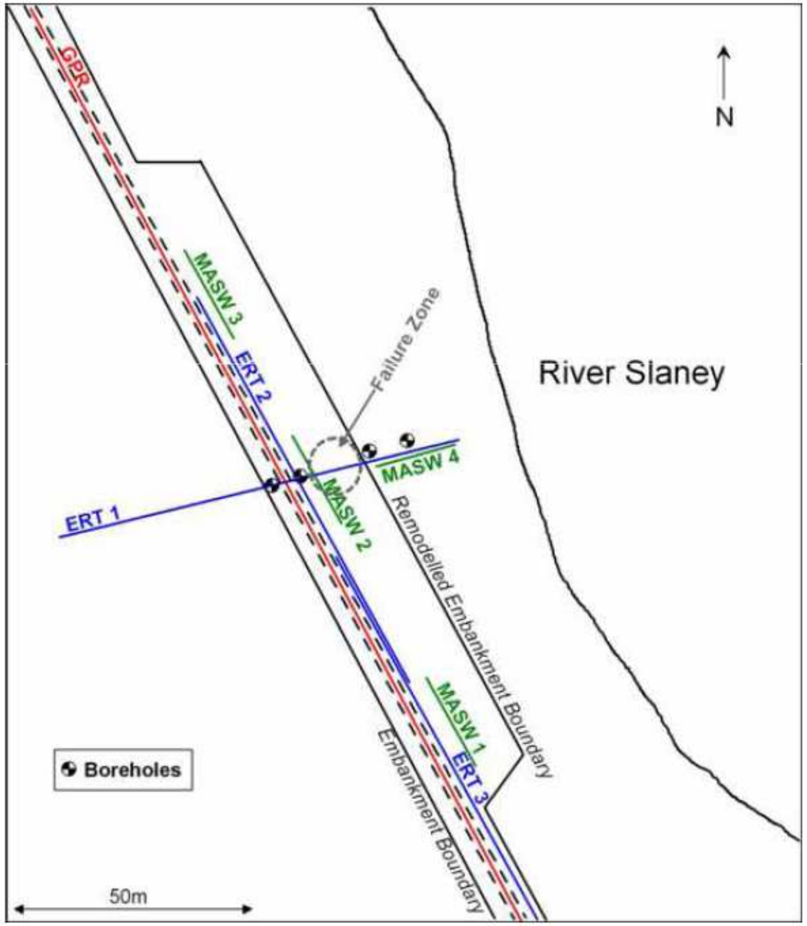
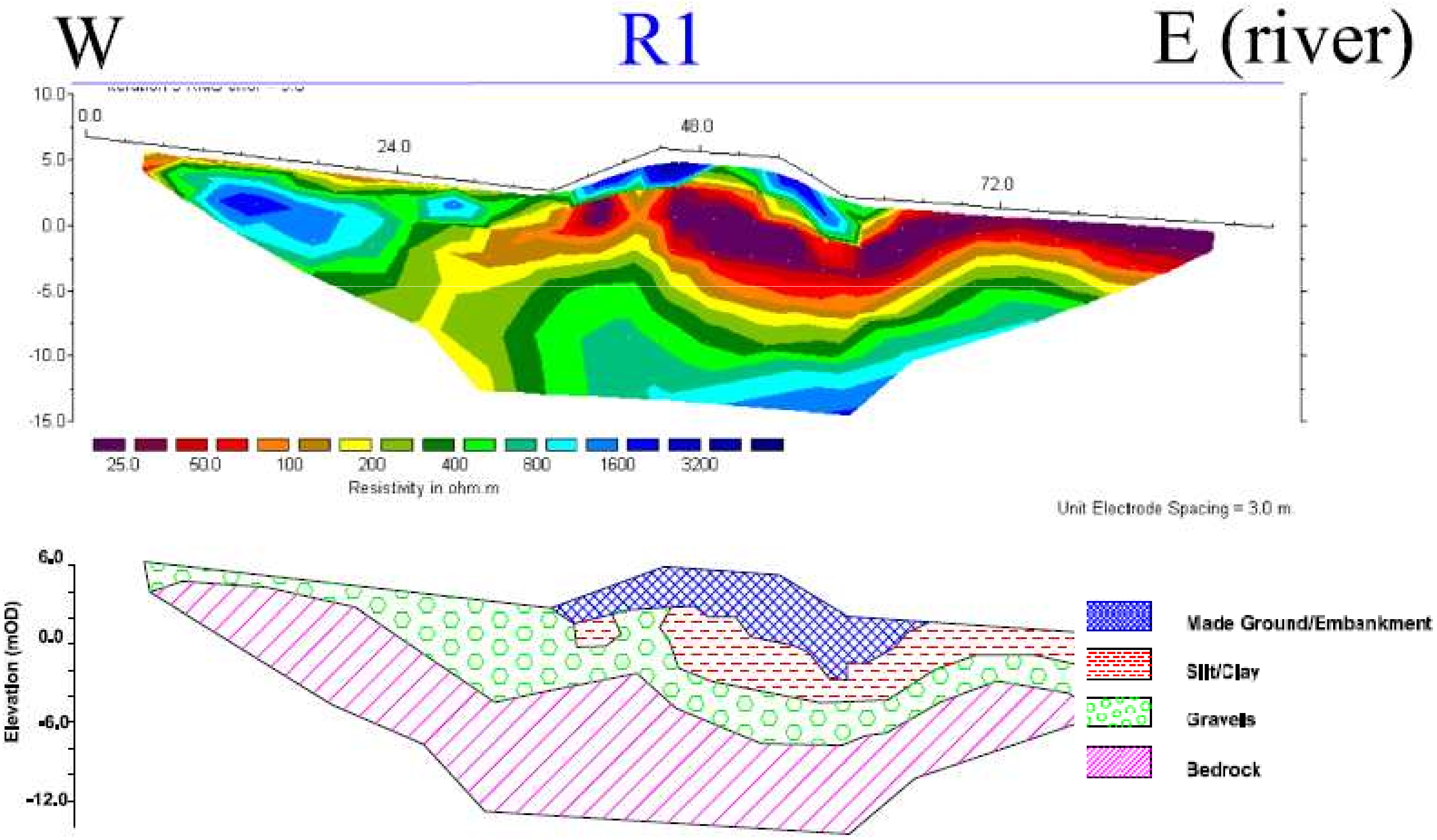
Geophysical Investigation



Resistivity investigation across failure plane and along track to confirm soil stratigraphy and investigate suspected lateral flow of water along embankment

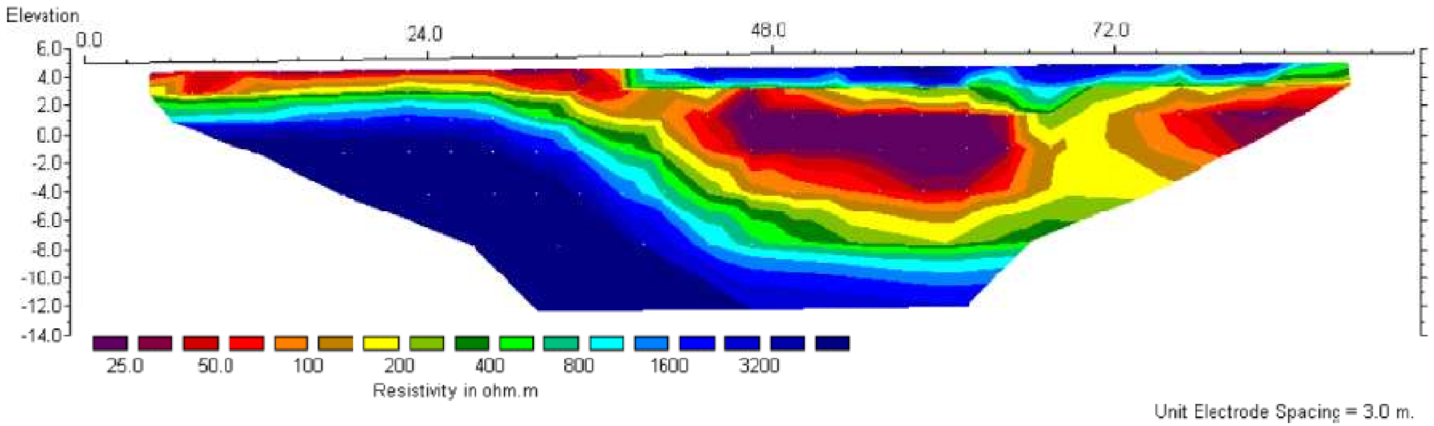
ERT profile across track through failure plane

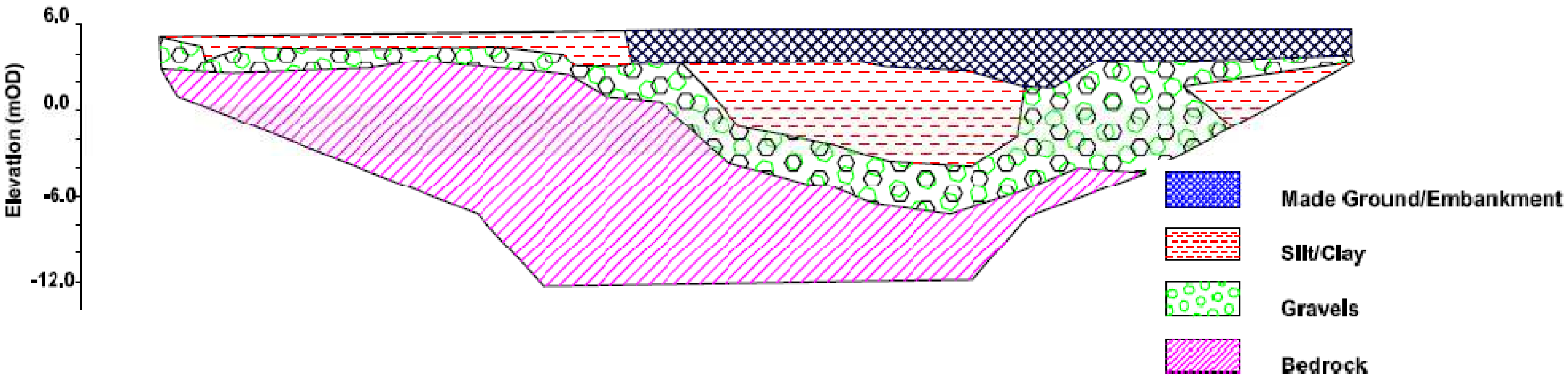


ERT Profile Along Track

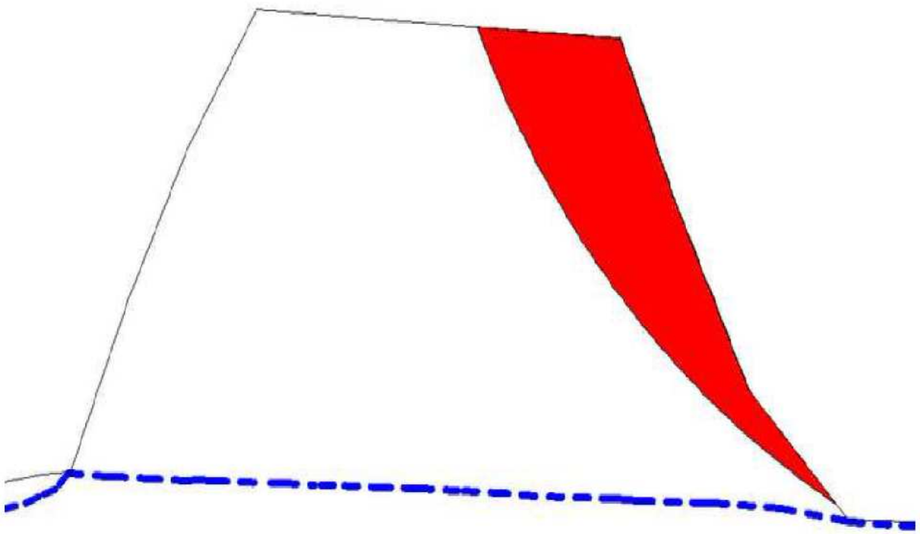
NW R2 SE

Overlap with R3





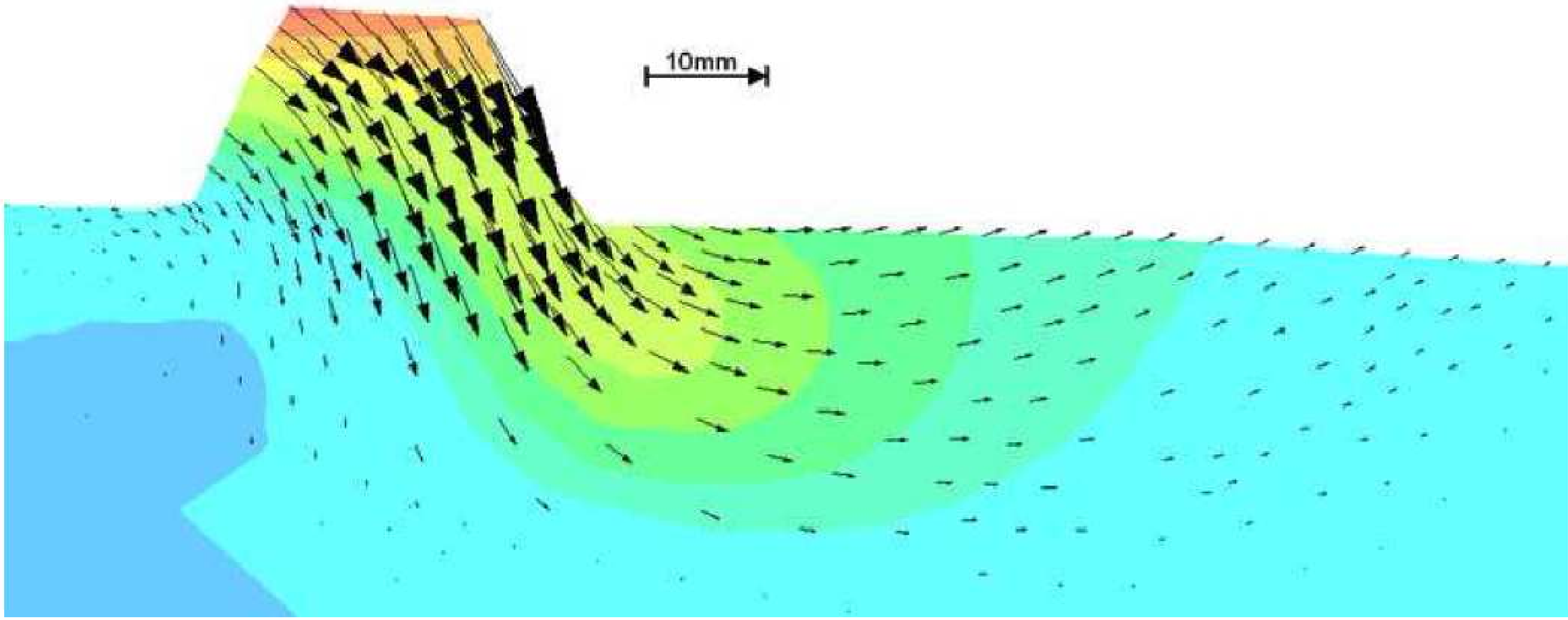
Seepage Analyses



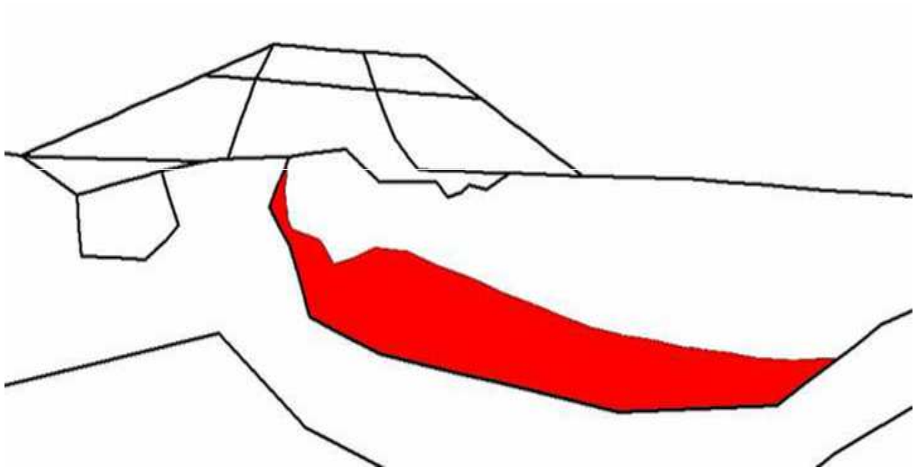
Rainfall data was used to model infiltration into embankment

- FOS reduced to ≈ 1.2
- Regrading of embankment caused increase in FOS to 1.3

Finite Element Analysis



Stress distribution beneath embankment



- Geophysical investigation highlighted extent of soft organic clay present beneath the slope
- Tube samples were obtained as part of a forensic investigation
- Samples exhibited significant creep at stress levels 80 – 100 kPa

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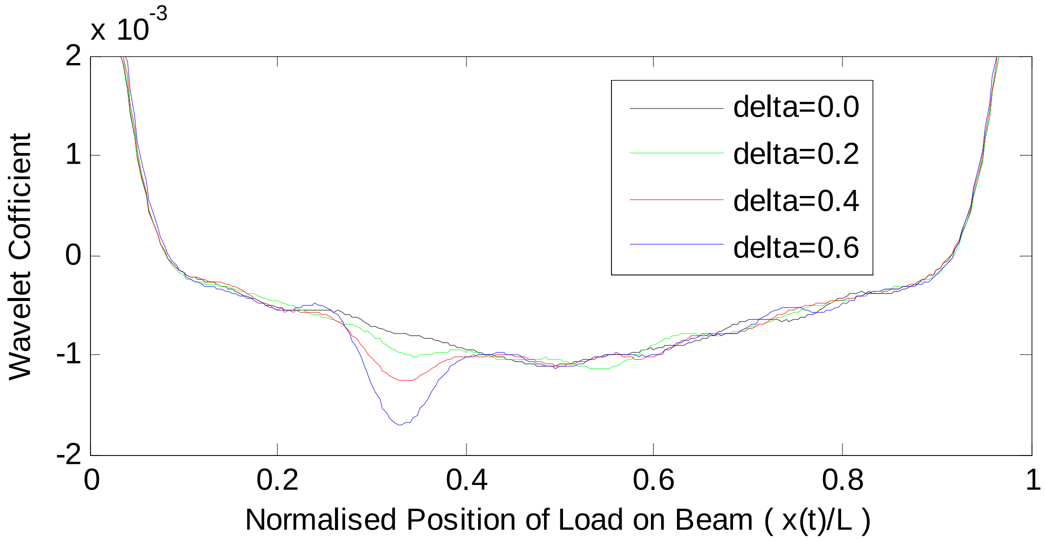
Task 1.4: NDT assessment of bridge foundations subjected to scour

Partners: UCD, NTUA, Irish Rail)



(i) Investigate geophysical techniques in field

(ii) Use of accelerometer data to measure changes in frequency response (lab – flume) and field.

Laboratory Investigation

Impulse Force Device

Accelerometer

Model Bridge Pier

Bed of Sand

By varying the bed level, we can model the scour process on the pier

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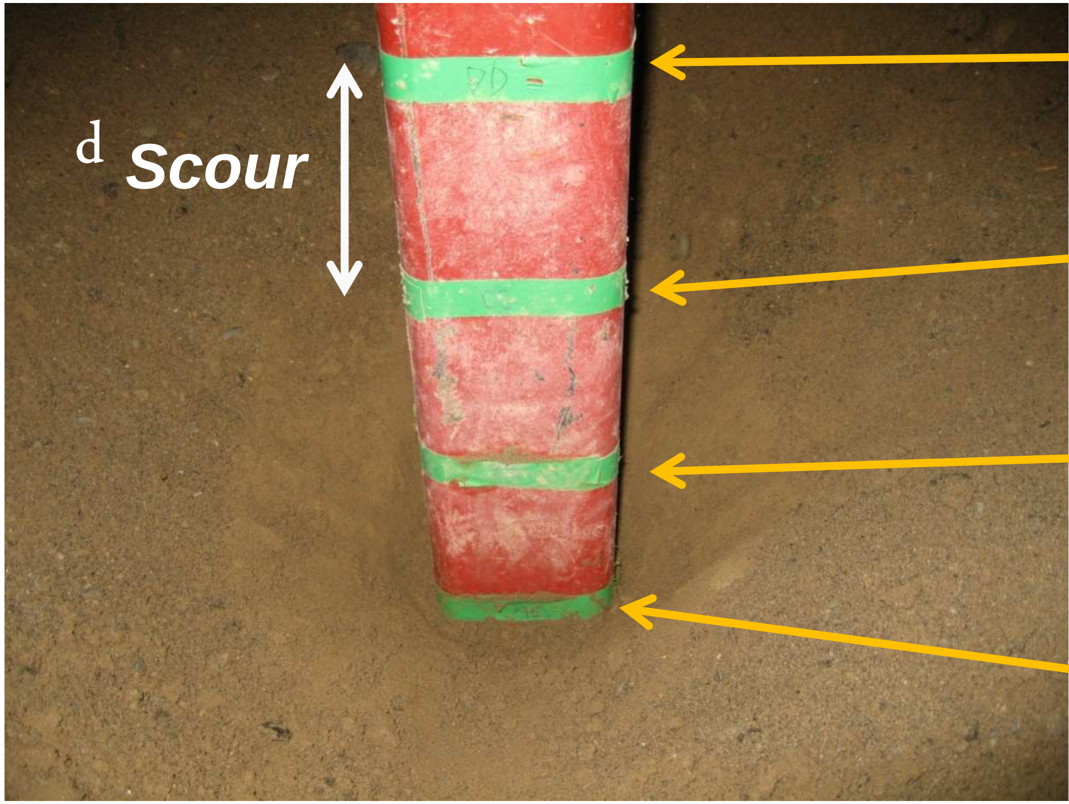
Laboratory Investigation



Level 3

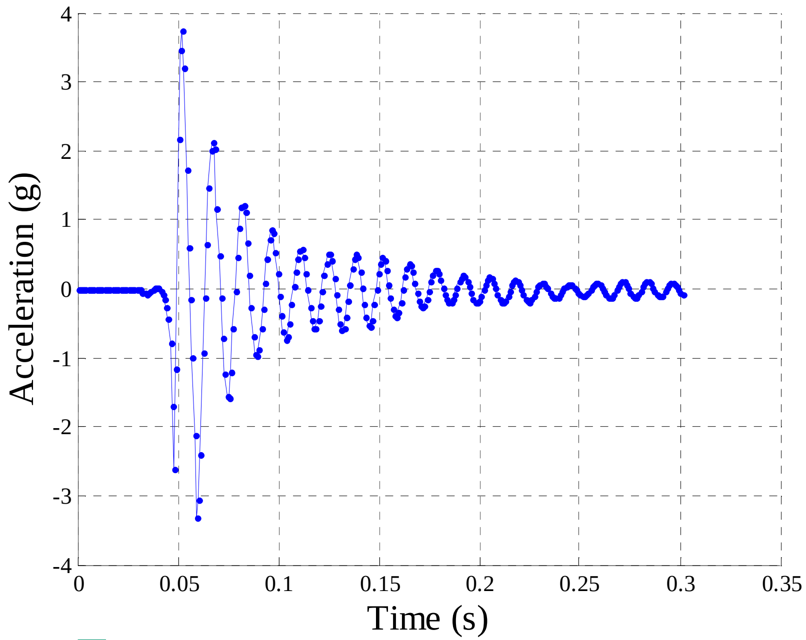
Level 2

Level 1

Level 0

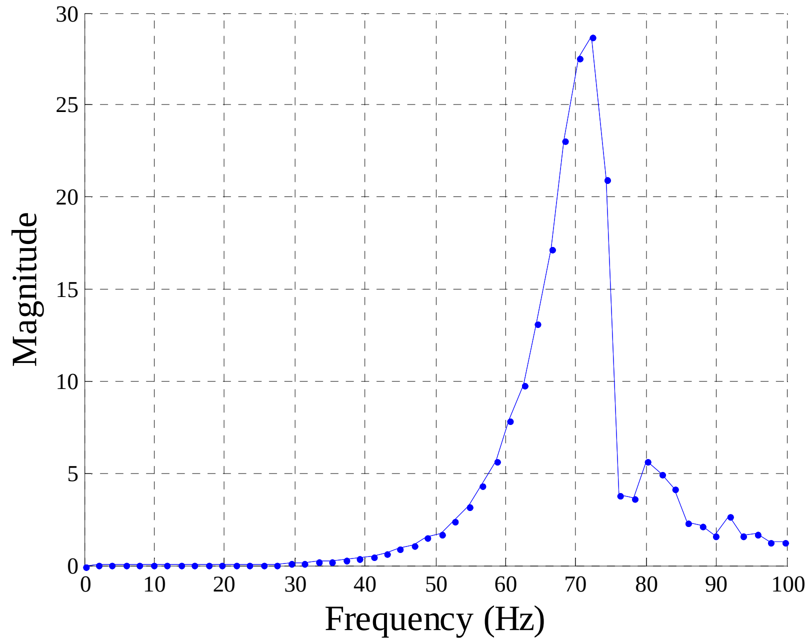
Natural Frequency Analysis

Acceleration Plot



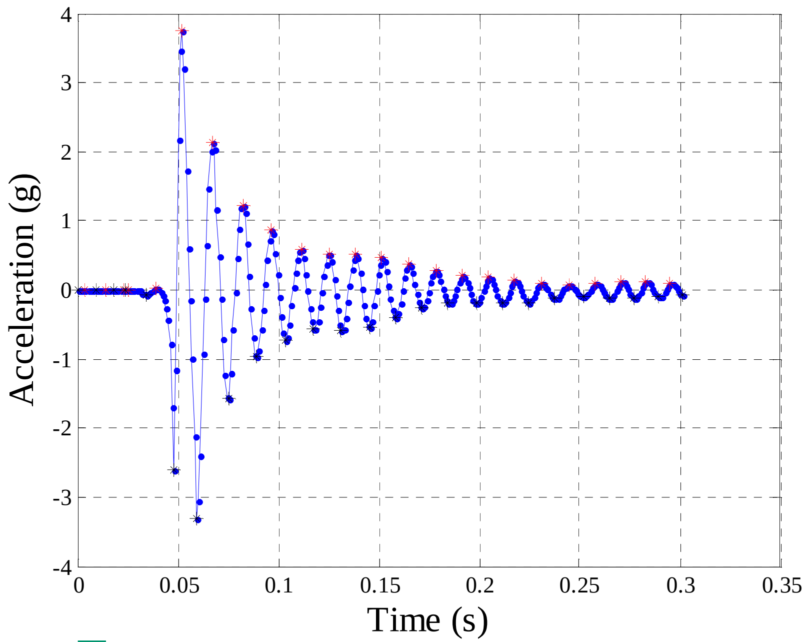
Fast Fourier Transform

Frequency Plot



Damping Analysis

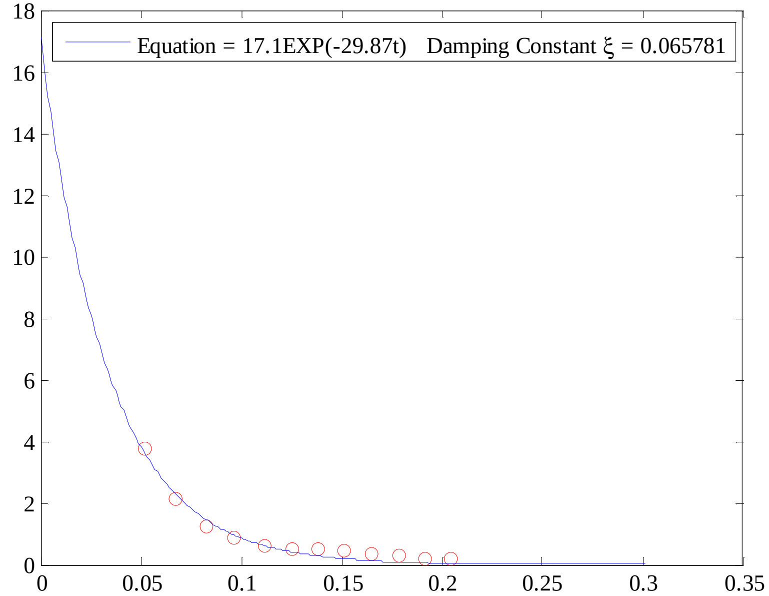
Acceleration Plot



$$Y = Ae^{Bt}$$

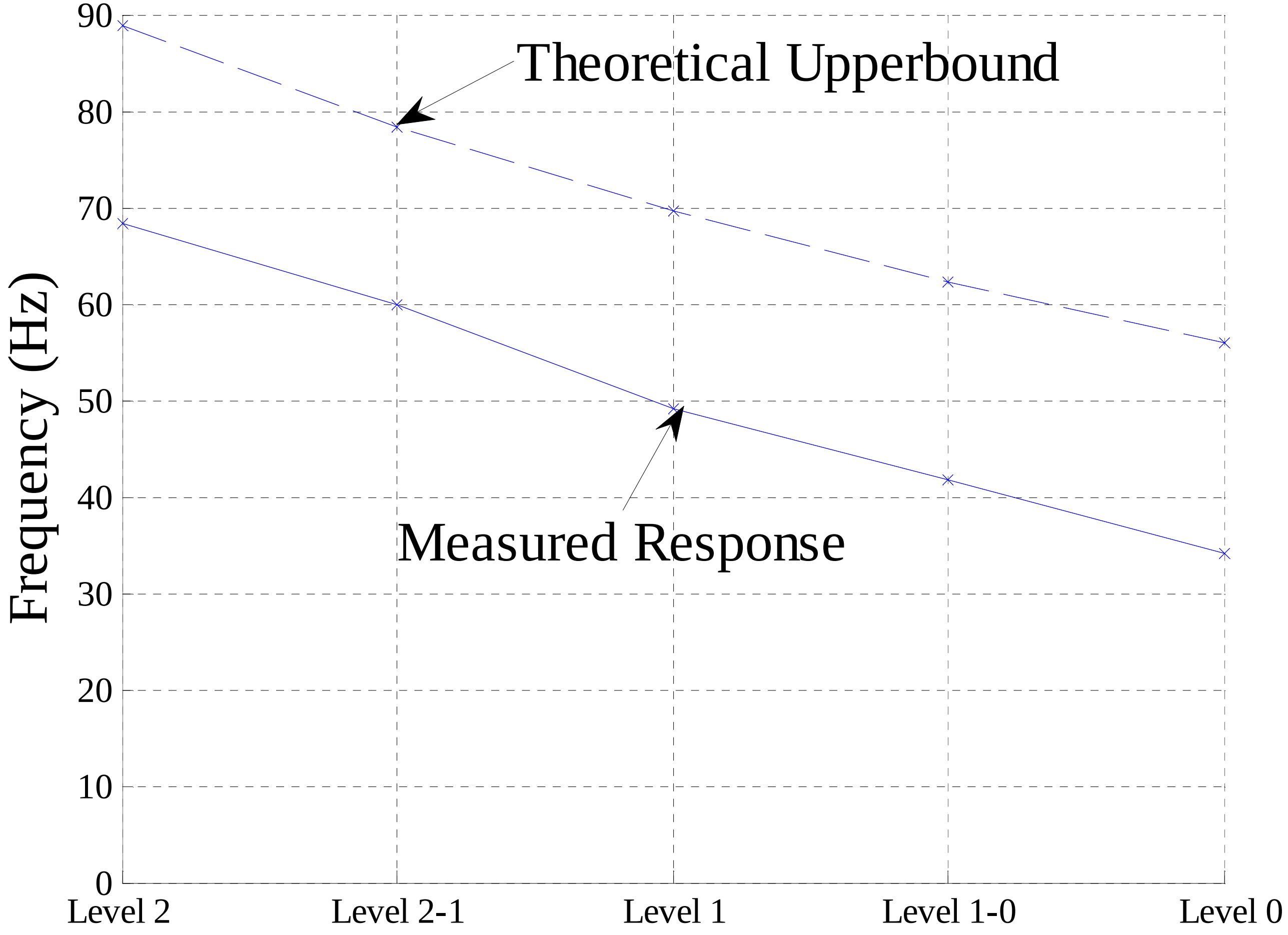
$$B = -\xi 2\pi f \rightarrow \xi = -\frac{B}{2\pi f}$$

Damping Plot

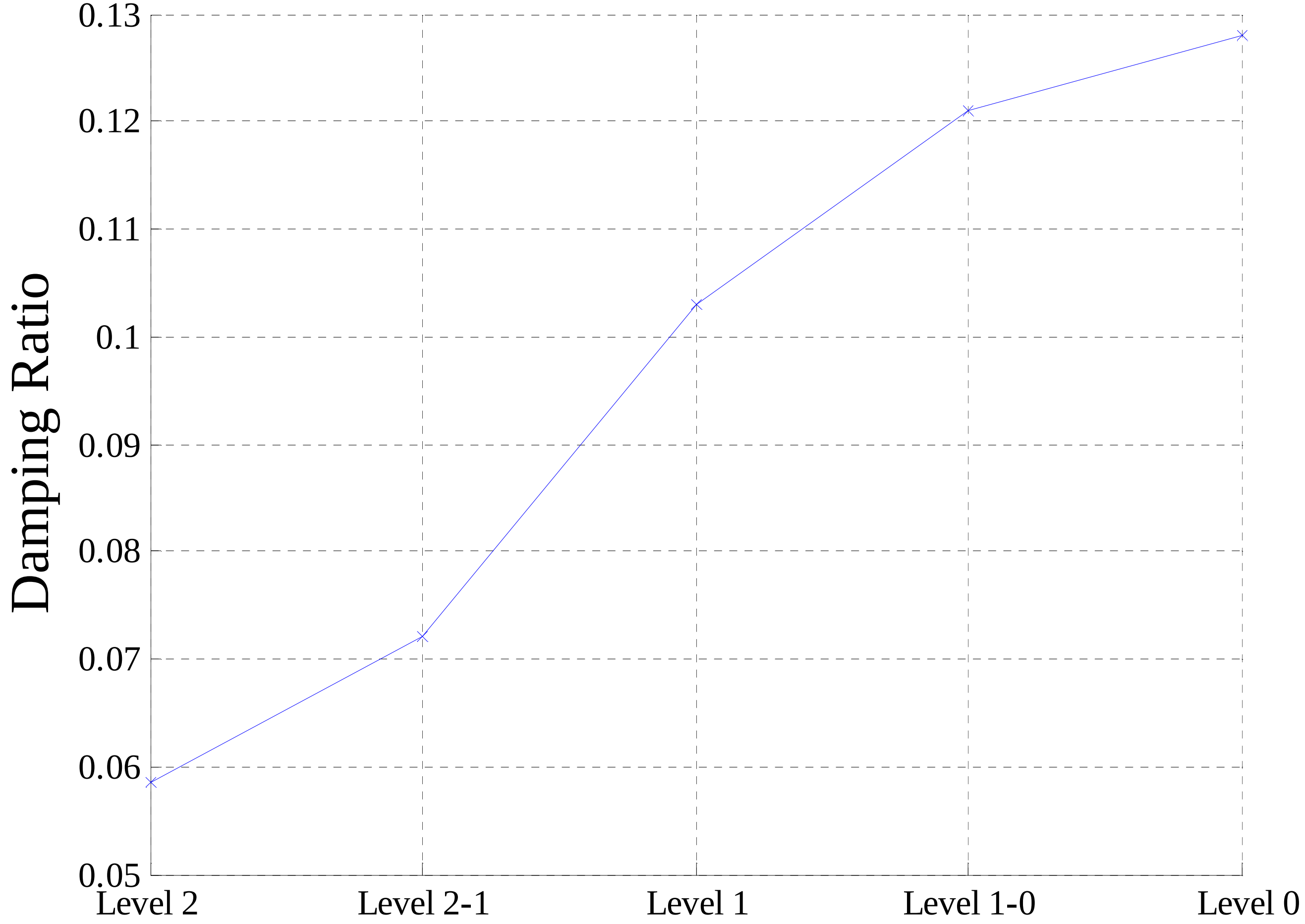


Exponential Curve Fitting

Results of Laboratory Investigation



Results of Laboratory Investigation



Present Works

- **Scale up laboratory investigation to pilot scale**
- **Instrument a free ended pier in "free field" condition**

Accelerometer(s)

Pilot Bridge Pier

Remove sand from base incrementally and measure accelerations

Irish Rail Bridge Instrumentation

- Hoped that train loading will adequately excite the bridge so that useful accelerometer data may be obtained
- Both the changes in frequency and damping can act as indicators of foundation stiffness change

Task 1.5 Use of instrumentation to monitor the condition of bridge structures

Partners: Adaptronica and Zag

- Instrumentation of the steel truss railways bridges with piezoelectric strain sensors with graphical interface
- A bridge weigh in motion system which is capable of separating the dynamic response will be developed
- A demonstration site in Poland underway

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Questions / Comments?