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The influence of ground damage on buried water mains failure

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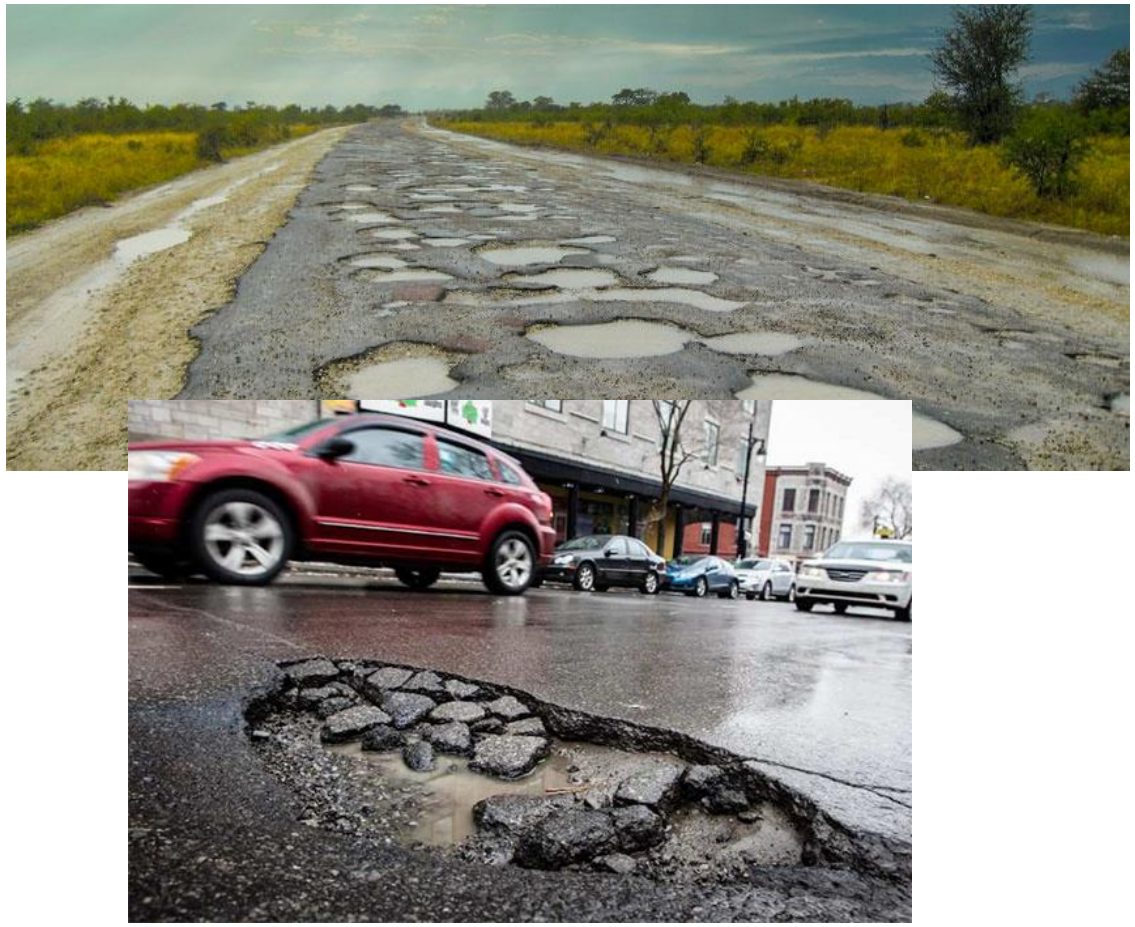
Ground damage

Voids → Internal damage

Potholes → Surface / external damage



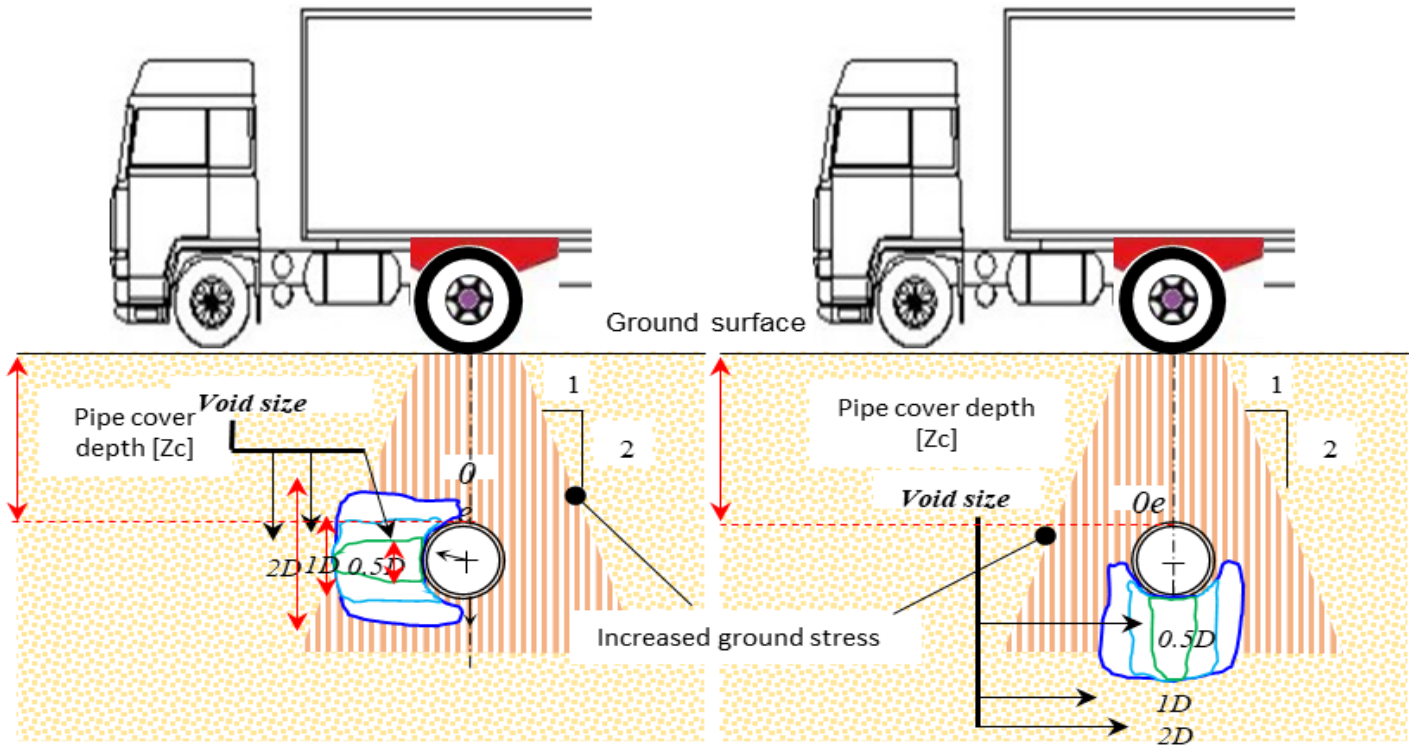
Part 1: Utility pipe infrastructure – impact of surface loading from large vehicles

PhD Research at the University of Sheffield by Dr Tawfeg Elmrom

PhD Research on – impact of voids and surface loading on water pipes

<u>Geotechnical centrifuge modelling</u>
of the impact of :-

- ➢ Heavy surface traffic loading
  - Magnitude, cycles
- ➢ Pipe location
  - Depth relative to size
- ➢ Void formation
  - Size, location



Why geotechnical centrifuge modelling?

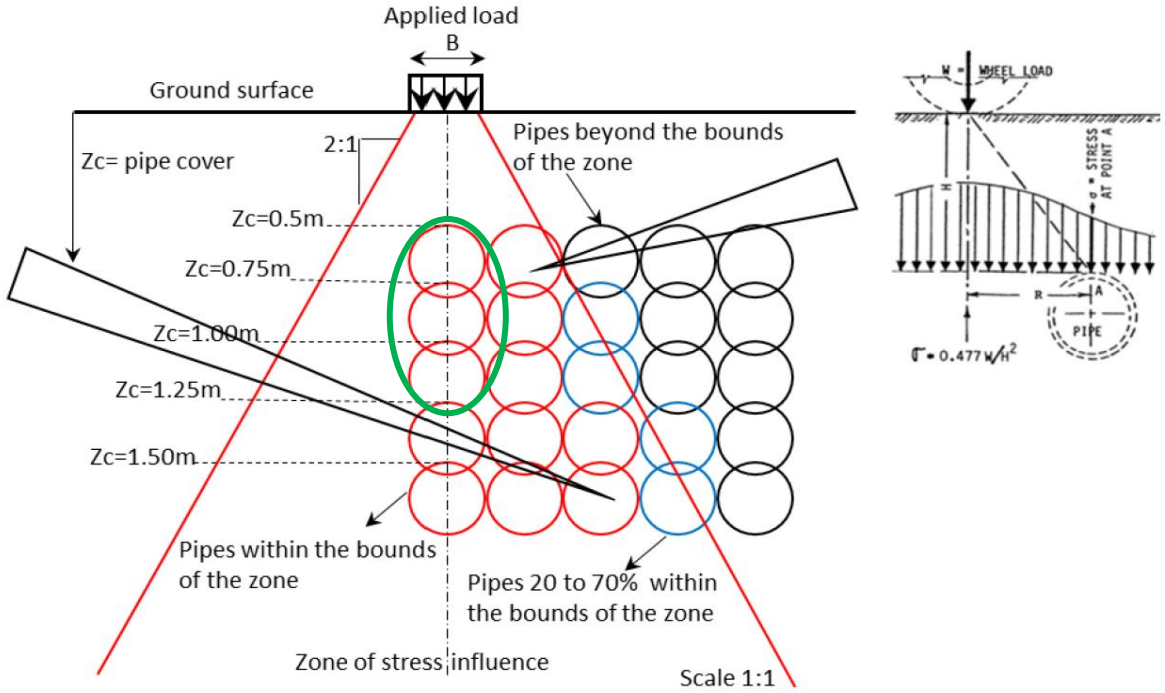
Small scale models of soil-structure-water systems

- Field : model scale → 10-100 : 1
- Strongbox: 600 mm x 200 mm x 450 mm
- Correct stresses in soil → correct soil behaviour
- Easily controlled boundary conditions
- Highly instrumented
- Can speed up ground-water-structure processes (e.g. movement of buried pipes under soil wetting / drying, weather & climate cycles)
- Economical compared with large scale testing

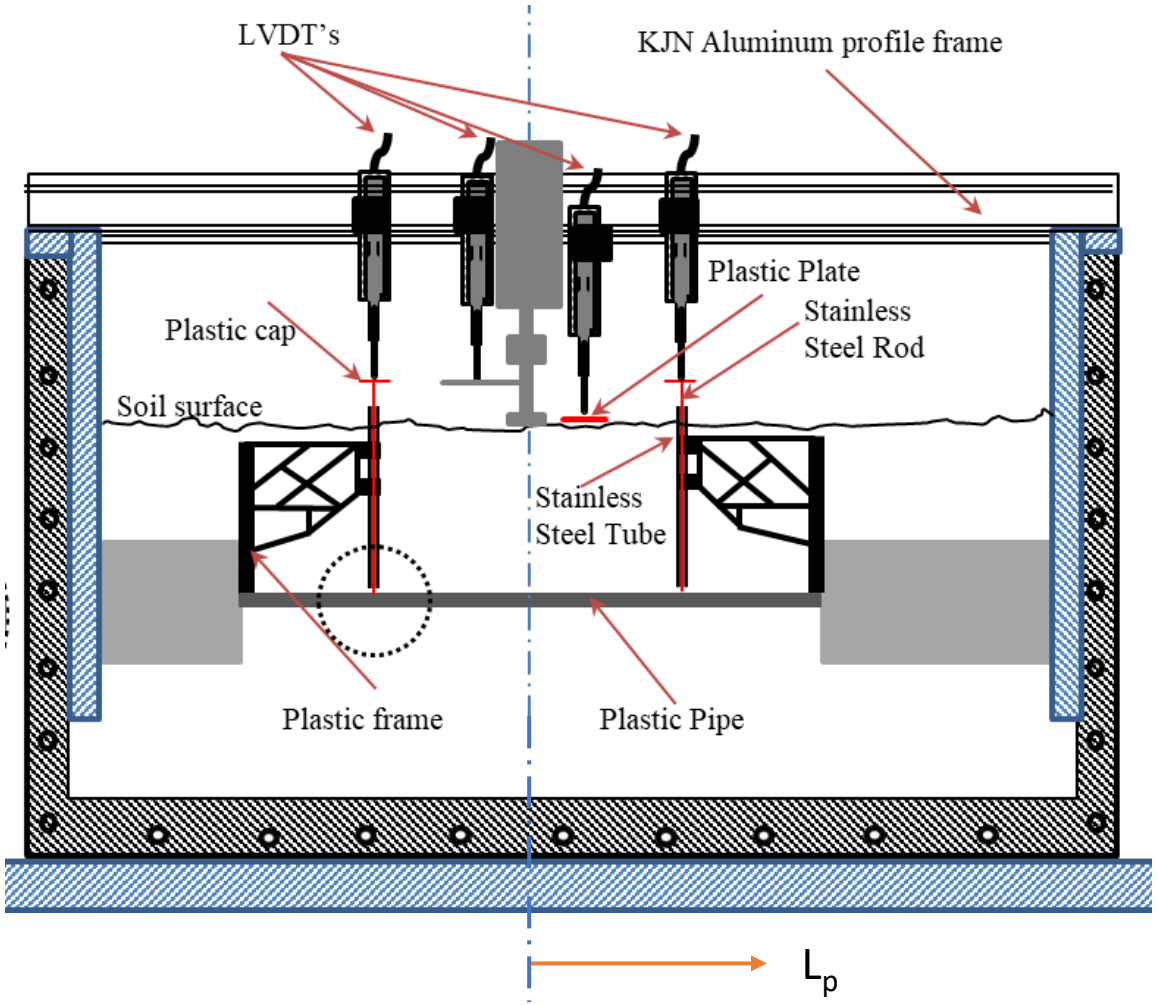
University of Sheffield's 50-gT 4m diameter geotechnical beam centrifuge

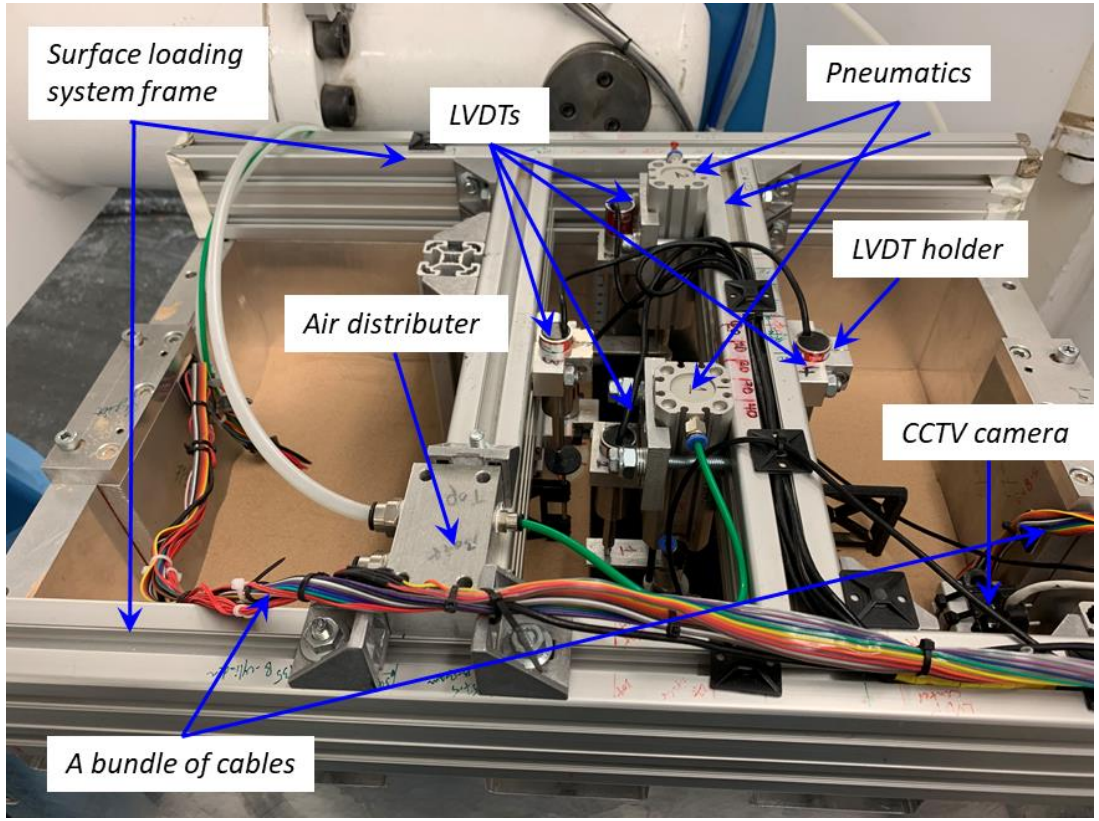
Wheel loading on pipes – centrifuge test arrangements

- Soil: dry fine sand, d = 0.5 mm
- Surface loading from dimensioned wheels at different positions
- Instrumented pipe of fixed geometry (model of 300mm HDPE empty main)
- Varied:
  - Depth of pipe
  - Static & cyclic loading
  - Magnitude of loading
  - Voids of differing size & position



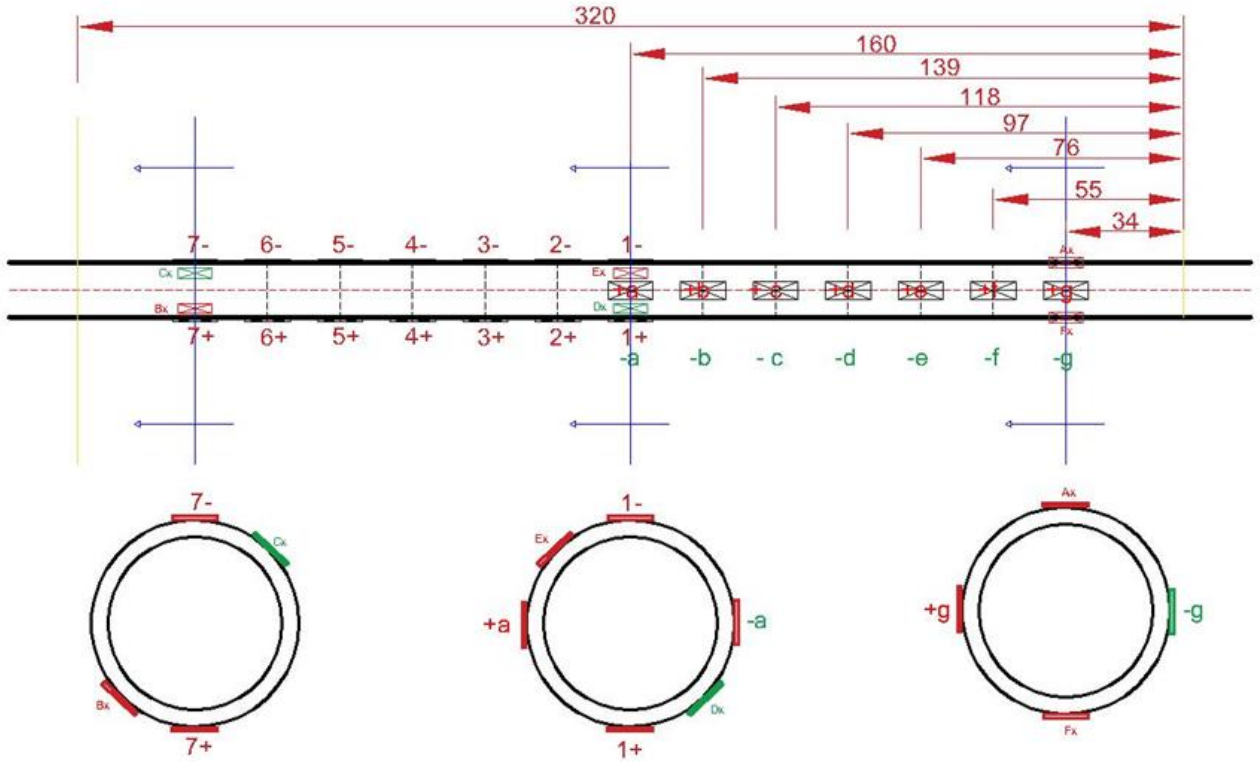
Centrifuge “package” – physical model



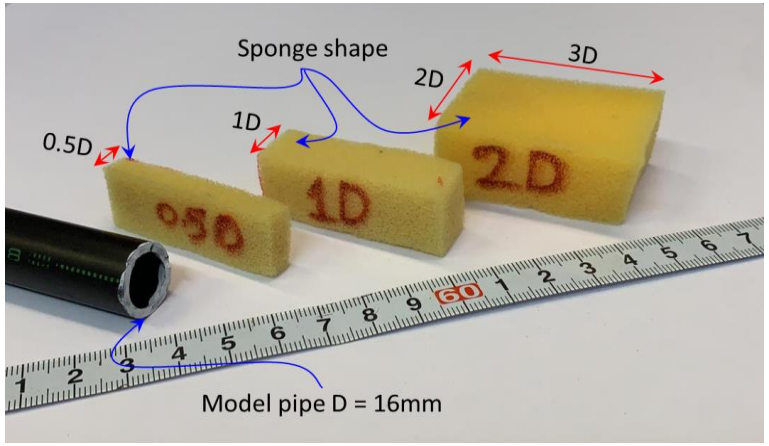


Model pipe instrumentation & void modelling

Pipe deformation, bending moment and shear stress:
Strain gauges along crown and spring line →
14 pair of strain gauges over model pipe length (315 mm = 6 m at field scale)

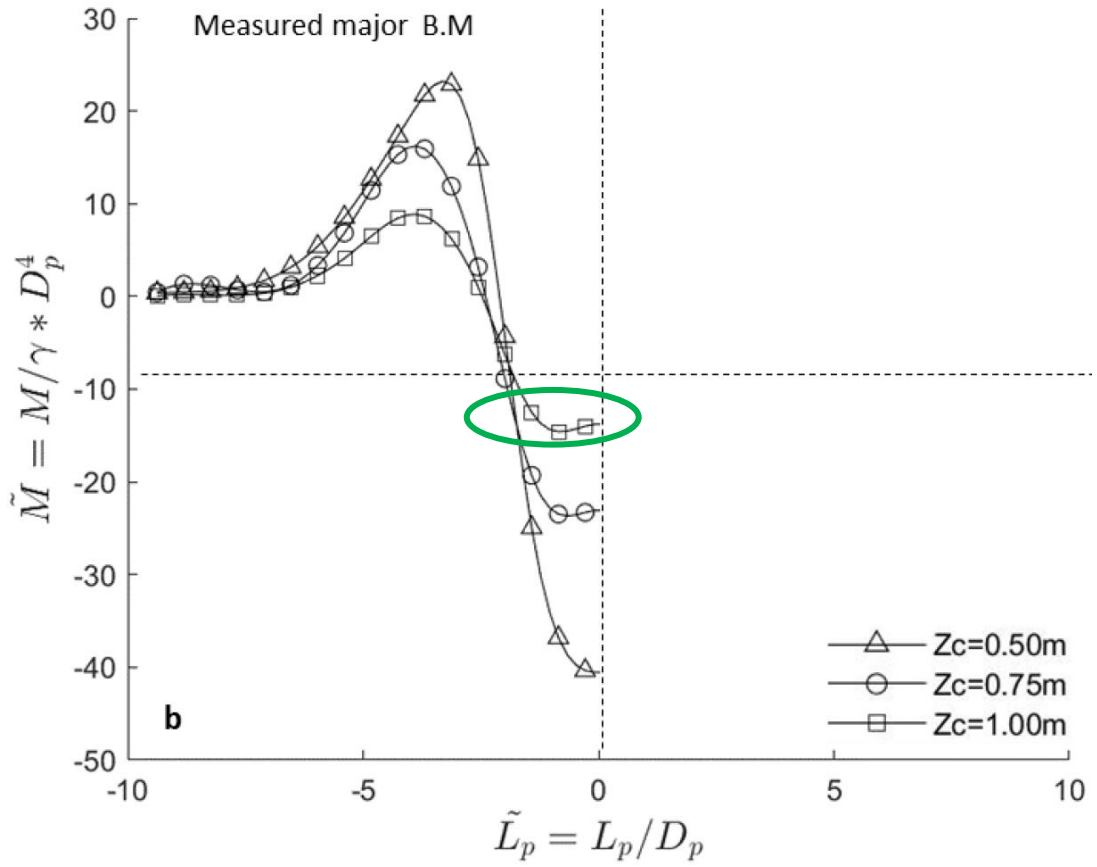


Model void →
Low stiffness sponge of 3 sizes

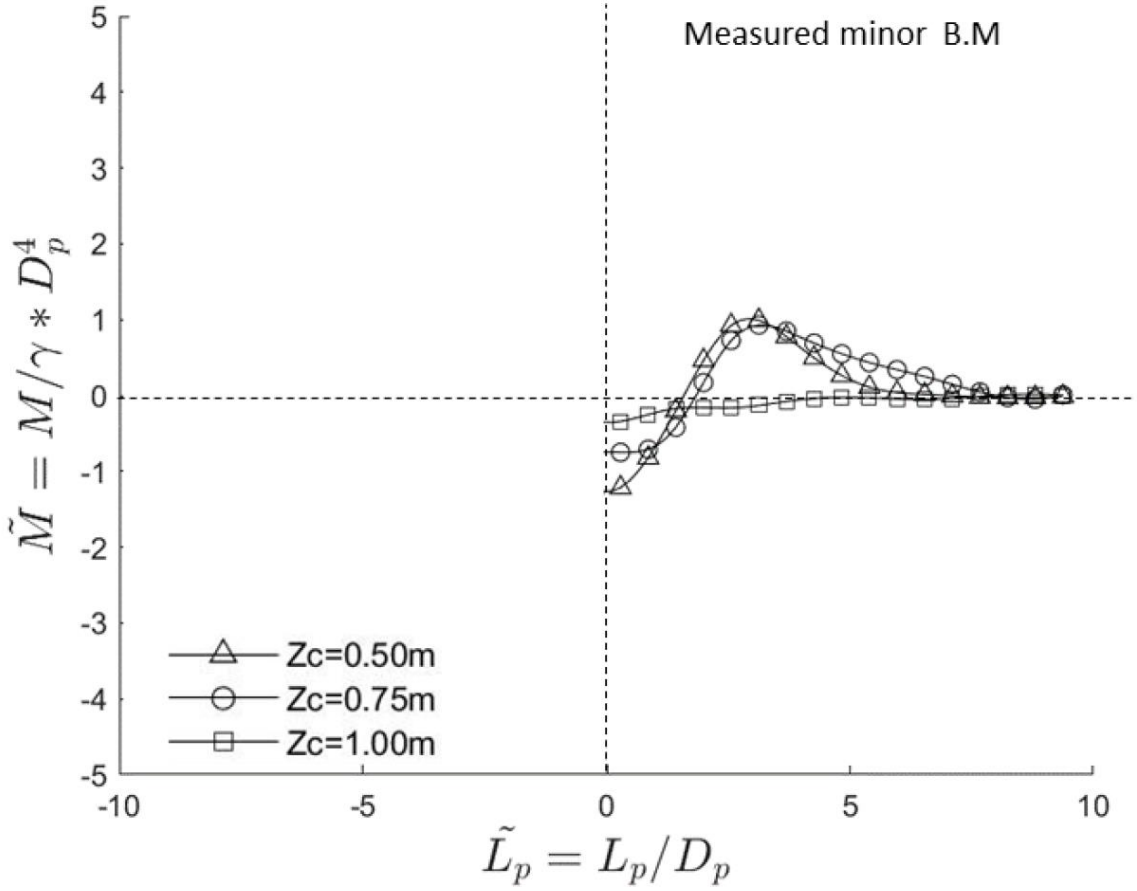


Results – influence of pipe burial – no voids

- **Bending moment – Major axis**

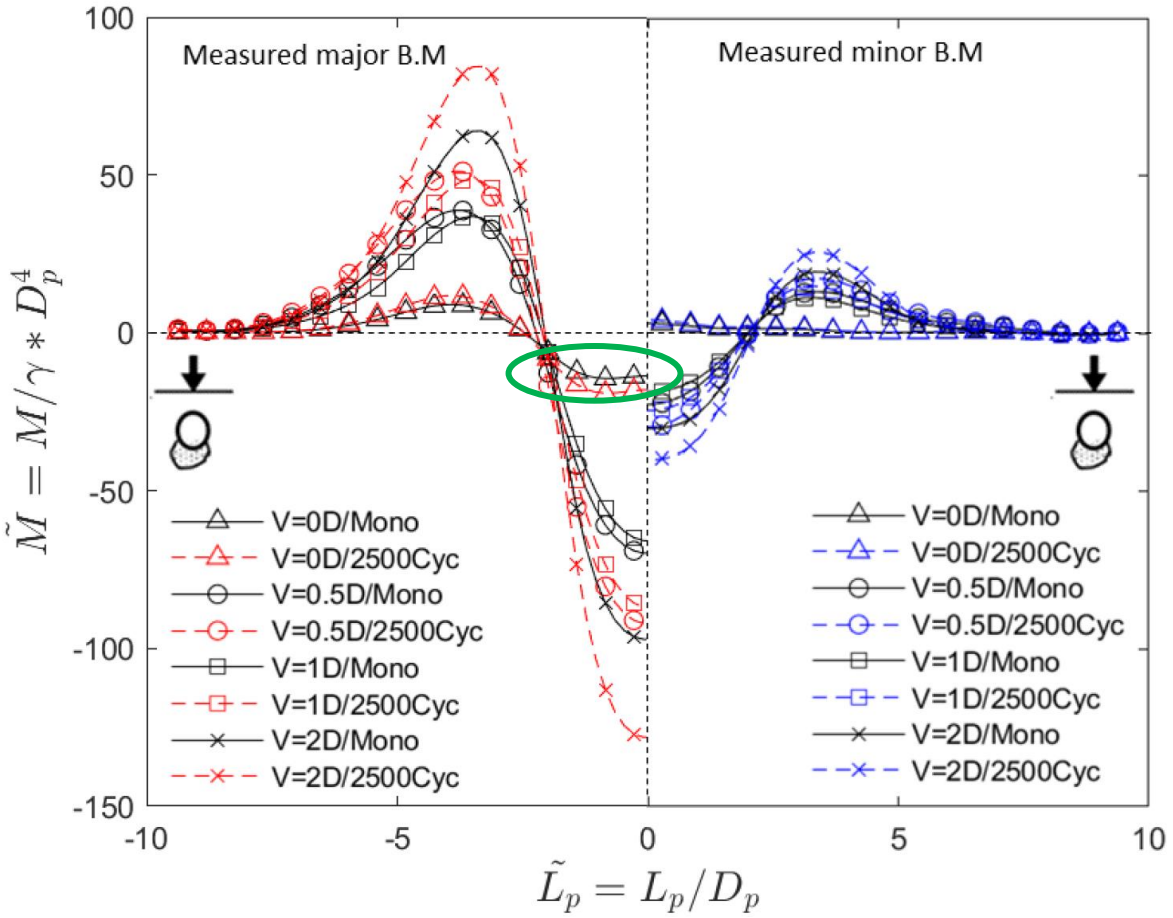


- **Bending moment – Minor axis**

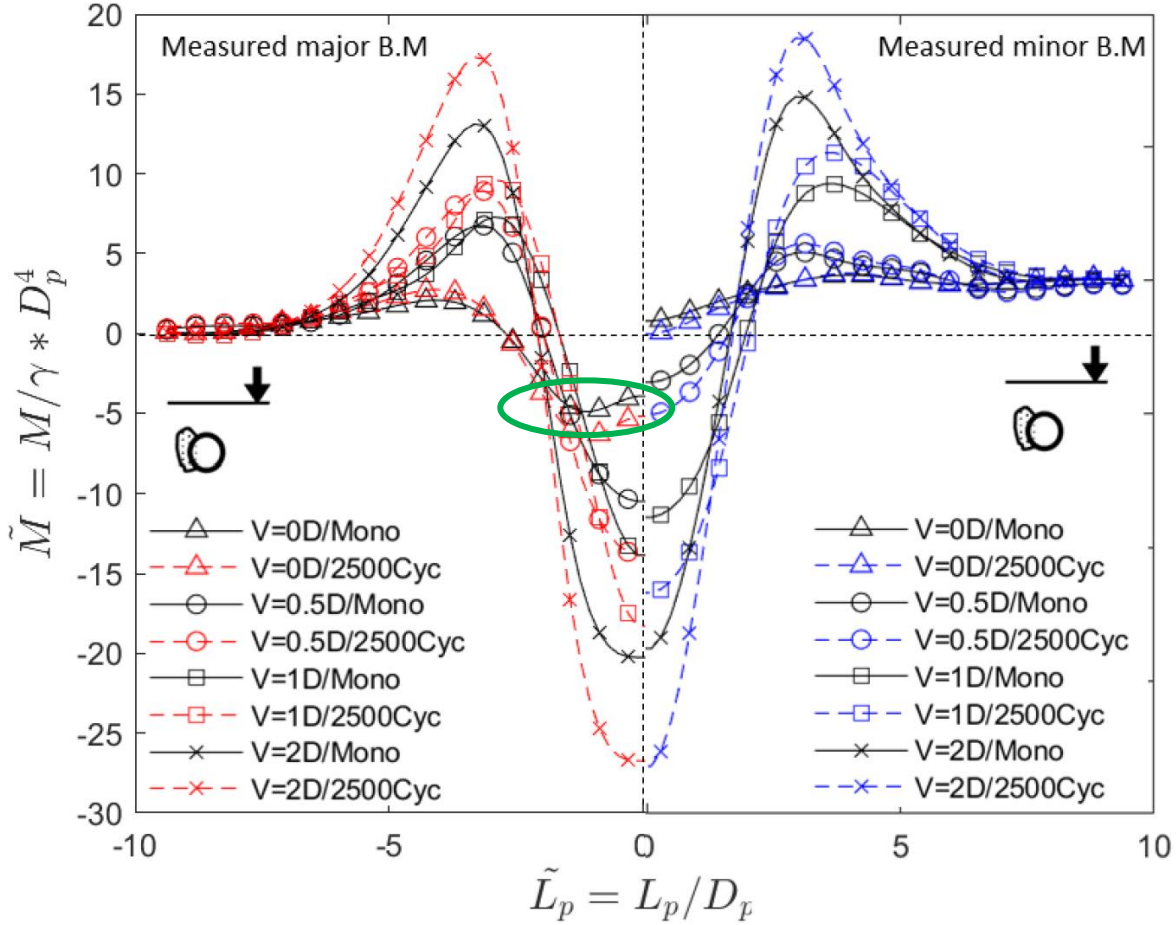


Influence of voids & repeated loading

➢ **Bending moment – Major axis**



➢ **Bending moment – Minor axis**



Conclusions

- PhD experimental research has quantified how voids near to pipes can significantly increase the load (bending moment and shear forces) and settlement of water utility pipes
- For voids adjacent (at springing) of pipes – bending moments up to 6 times were found for voids of 2 x pipe diameter at a normalised pipe depth of 3D
- For voids below pipes – bending moments increase up to 25 times for voids of 2D at a normalised pipe depth of 3D
- Results valid for dense dry sand and HDPE (flexible) pipes of 300 mm diameter (small dia main). What about clay? Water table? Layers? Joints? Other materials? Other sizes?
- Future work: WIRe CDT PhD proposal 2025/6

Part 2: “Understanding water infrastructure risks - major bursts, traffic volumes and the condition of road infrastructure”

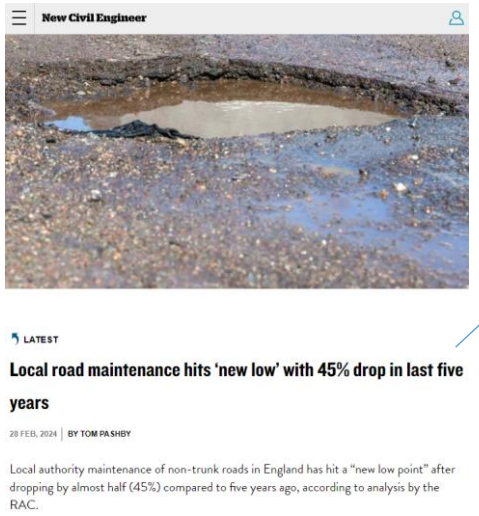
An ongoing **UKWIR sponsored project** undertaken by the University of Sheffield

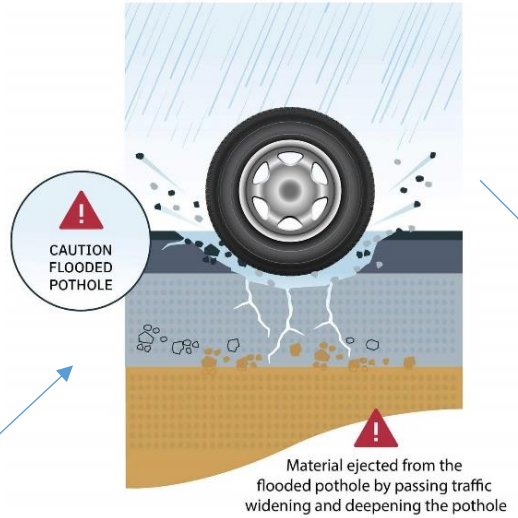
Project Aims / Outcomes

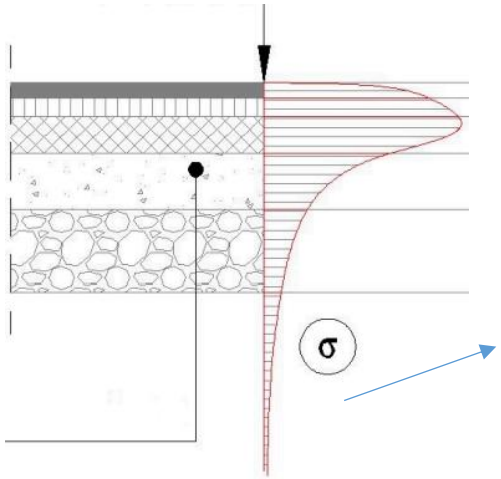
- To investigate:
  1. how many major bursts on mains pipes occur in close proximity to major roads, especially major road junctions
  2. if there is link between traffic volumes, road conditions and bursts.
- To produce a final report that:
  3. reviews the evidence
  4. makes recommendations on how to assess and monitor risk factors and mitigate against burst events
  5. identifies areas for further research, if necessary.

Large water main bursts at / near road junctions

- Water companies have noted increasing numbers of bursts in large mains proximate to major roads / road junctions in recent years
- What is the cause of this increase?
- Hypothesis is that poor road condition and traffic load have contributed through dynamic loading transferred through soil to pipe



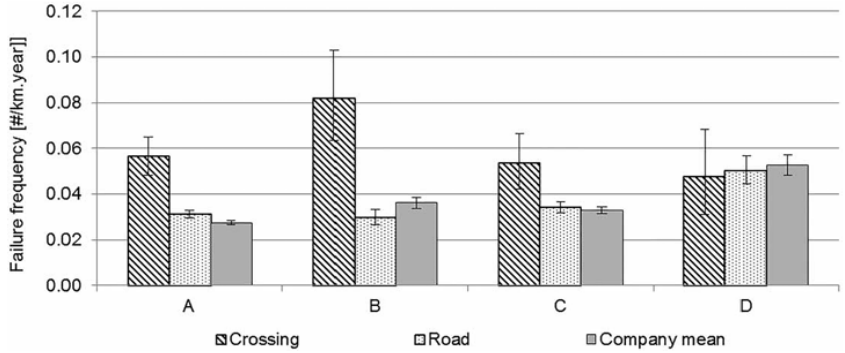


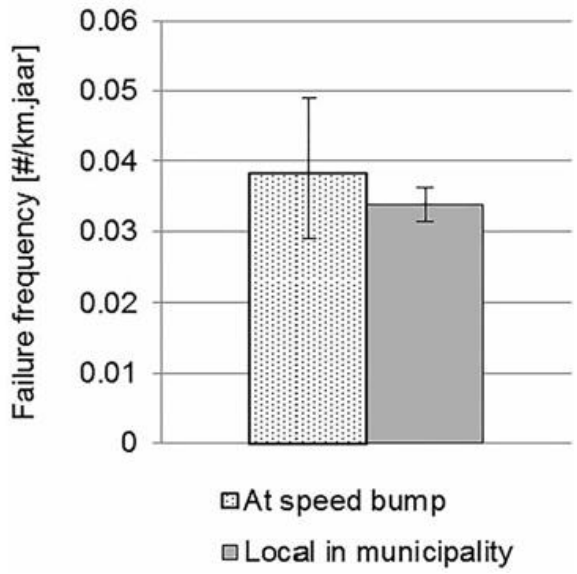


Factors influencing pipe failure: hypotheses

- Processes that may contribute to dynamic transfer of wheel load to subbase: breaking, wheel impact & traffic induced pumping action of water
- *Road deterioration*: Road surface cracks & water enters pavement, traffic, freeze-thaw cycles & standing water leading to loss of road subbase & potholes
- *Road layout*: Crossings may lead to braking; pipe layout under crossings more complex
- *Road bumpiness*: impact / braking with speed bumps & potholes may lead to dynamic loading

Research from UK, Romania, Netherlands, Canada (Barton et al. 2019; Aşchilean et al. 2018; Garmabaki et al. 2019; Moerman et al. 2016).





Workflow

09/2024 - 09/2025

Project Initiation

Kick off Steering Group meeting

Literature Review

Peer reviewed literature

Media reports

Unpublished data

Case Studies

Identify & engage with UK / Irish stakeholders

Data quality / quantity / granularity assessment

Research needs analysis

Data analysis

Engagement with international research organisations

Final Report

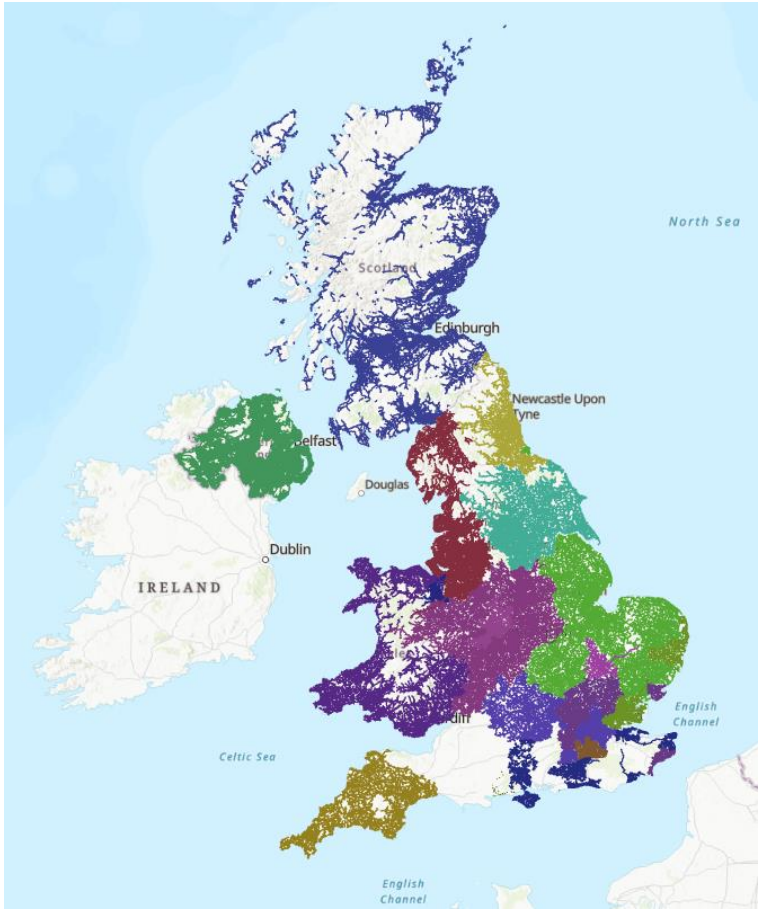
Dissemination workshop

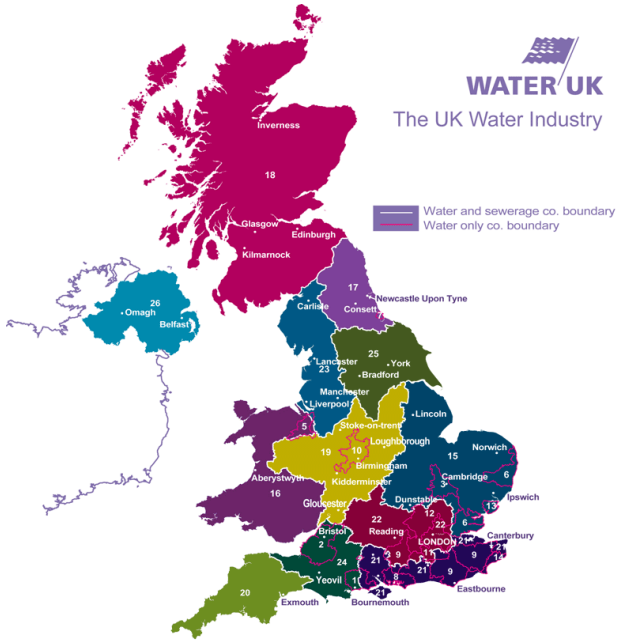
Project Questions & Challenges

- Does road deterioration contribute to the likelihood of failure of large (12'' and above) water mains near to heavily trafficked road junctions?
- What is role of:
  - Road geometry & condition?
  - Traffic volume, speed, acceleration / deceleration?
  - Pipe location (burial depth, soil type, soil moisture)?
  - Pipe geometry, age & condition (size, bends, junctions, damage)?
- Challenges:
  - 1 – Data for statistical / empirical analysis
  - 2 – Data on specific Case Studies

} *From Water Utility Companies*

A very preliminary result – NMD water pipe networks





Water Only Companies

1 - Sembcorp Bournemouth Water
2 - Bristol Water
3 - Cambridge Water
4 - Cholderton and District Water
5 - Dee Valley Water
6 - Essex and Suffolk Water
7 - Hartlepool Water (Anglian Water)
8 - Portsmouth Water
9 - South East Water
10 - South Staffs Water
11 - Sutton and East Surrey Water
12 - Affinity Water
13 - Affinity Water
14 - Affinity Water

Water and Sewerage Companies

15 - Anglian Water
16 - Dwr Cymru (Welsh Water)
17 - Northumbrian Water
18 - Scottish Water
19 - Severn Trent
20 - South West Water
21 - Southern Water
22 - Thames Water
23 - United Utilities
24 - Wessex Water
25 - Yorkshire Water
26 - Northern Ireland Water

Water UK, October 2012

Summary

- Project aims to determine if there a link between traffic loading & observed increased prevalence of mains pipe bursts
- Depending on outcome – mitigation / management strategies can be developed
  - Recognition of key pipe / road arrangements of concern
  - Road traffic / minimum condition requirements?
  - Pipe siting / geometry / depth / soil type / pipe age requirements may be recommended for pre-burst repair

- *But we Need You to help us by providing Your Data!*
- *Would you and/or your company like to be involved? Let's talk!*

Thank you for listening!

- Part 1: PhD Research Project “Impact of Voids on Buried Utility Pipes Subjected to Surface Traffic Loading” by Dr. Tawfeg A. Elmrom
  - Tawfeg Elmrom telemrom@sheffield.ac.uk
  - Lis Bowman e.bowman@sheffield.ac.uk

- Part 2: UKWIR Research Project WM/04/G/302 “Understanding water infrastructure risks - major bursts, traffic volumes and the condition of road infrastructure”
  - Edward John ed.john@sheffield.ac.uk
  - Lis Bowman e.bowman@sheffield.ac.uk