Polyethylene pipes: Network Performance

PIPA Seminar, Melbourne, 24th September, 2007

Introduction

- **CSIRO recently completed a American Water Works Association Research Foundation (AwwaRF) project to investigate the long-term performance of Polyethylene water pipelines**
- **In-kind support (data and pipe samples) was provided by a number of water authorities in Australia, UK and USA**
- **2 main goals of the project**
  - **Conduct an industry survey to assess the field performance of PE water pipelines**
  - **Develop a method to forecast the long term performance of a PE pipe in service**

Part 1:
Industry survey results: Field performance of PE water pipes

Industry Survey: Field performance of PE water pipe

- **Historical failure data requested from a total of 87 water utilities in Australia, UK and the USA**
- **Information requested:**
  - **Length of PE pipe in system**
  - **Age of PE pipes**
  - **Number of reported failures**
  - **Recording period of failures**
  - **Failure mode**
- **Level of detail and accuracy in information varied considerably:**
  - **Australia – 5 water authorities responded with historical failure data**
  - **UK – Access to the UKWIR national mains database with accurate records of number of failures and installation years for 17 water utilities**
  - **USA – No quantitative information, but anecdotal descriptions of experienced issues with PE pipes from 55 water utilities**

Reported average failure rates in PE pipes

	Av. Failure rate (per 100km/per year)	# of utilities	Earliest installation year of failed pipes	Recording period
AUS	**7.8**	**5**	**1982**	**1995-2004**
UK	**3.2**	**17**	**1975**	**1988-2003**

Comparison with other water pipe materials in use: UK data

Data source: UKWIR Nationally Agreed Failure Data (2003)

	Av. fail rate (per 100km/yr)
	UK water authorities
PE	3.2
Ductile Iron	5.3
PVC	7.3
Asbestos Cement	16.0
Cast Iron	20.1

Comparison with other water pipe materials in use: Australian data

Data sources: 1) CSIRO reports “Long Term performance of PE/PVC pipes” (2005/7)
2) CSIRO PARMS Asset management software (2007)

	Av. fail rate (per 100km/yr)	Data source
	Australian water authorities	
PVC	4.3	1
PE	7.8	1
Ductile Iron	9.5	2
Asbestos Cement	54.0	2
Cast Iron	59.7	2

Reported failure modes in PE pipes

- **Reported failure data from Australia and UK grouped into "Joints and Fittings" and "Pipe Fracture" and "Other"**

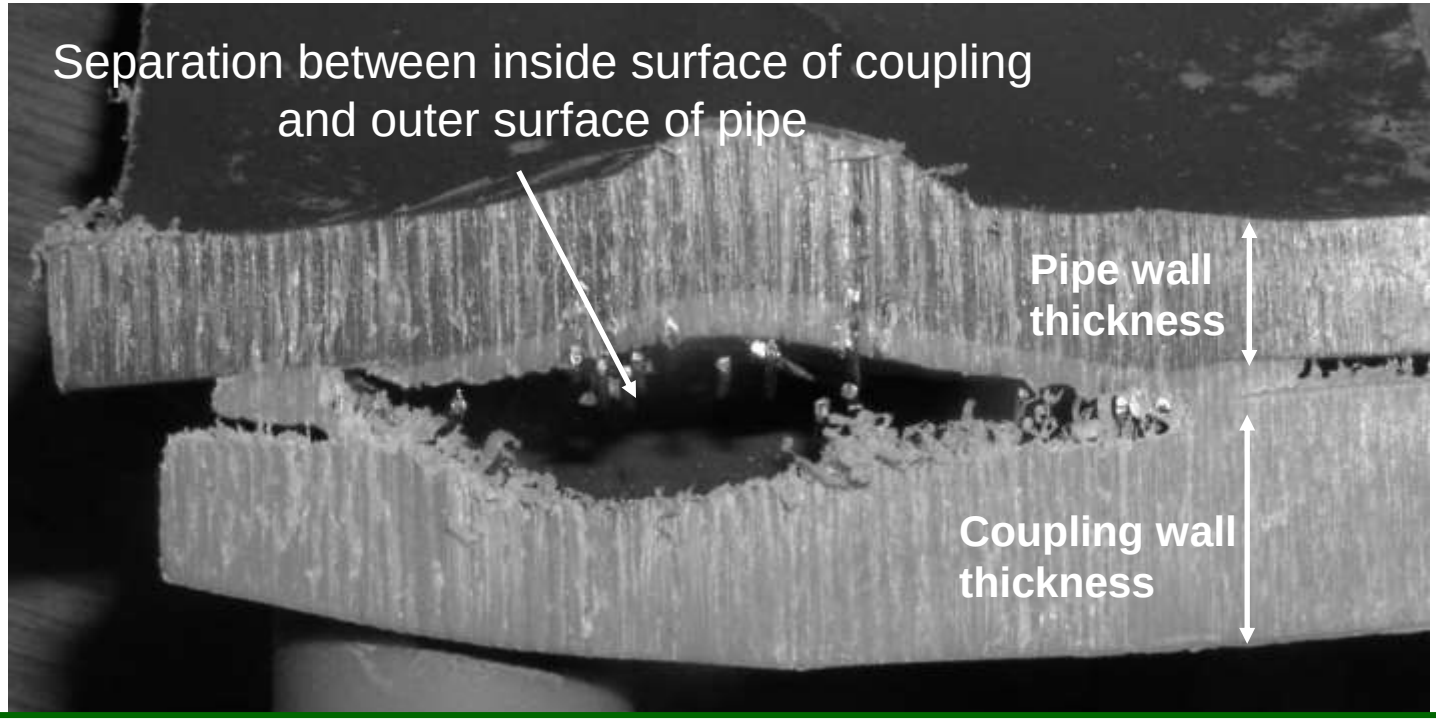
Data sources: 1) CSIRO reports "Long Term performance of PE/PVC pipes" (2005/7)
2) UKWIR Nationally Agreed Failure Data (2003)

	Fusion Joints/fittings (%)	Pipe fracture (%)	Other (%)	Source
AUS	41.0	36.0	23.0	1

Validation of these reported failure modes required sample examination

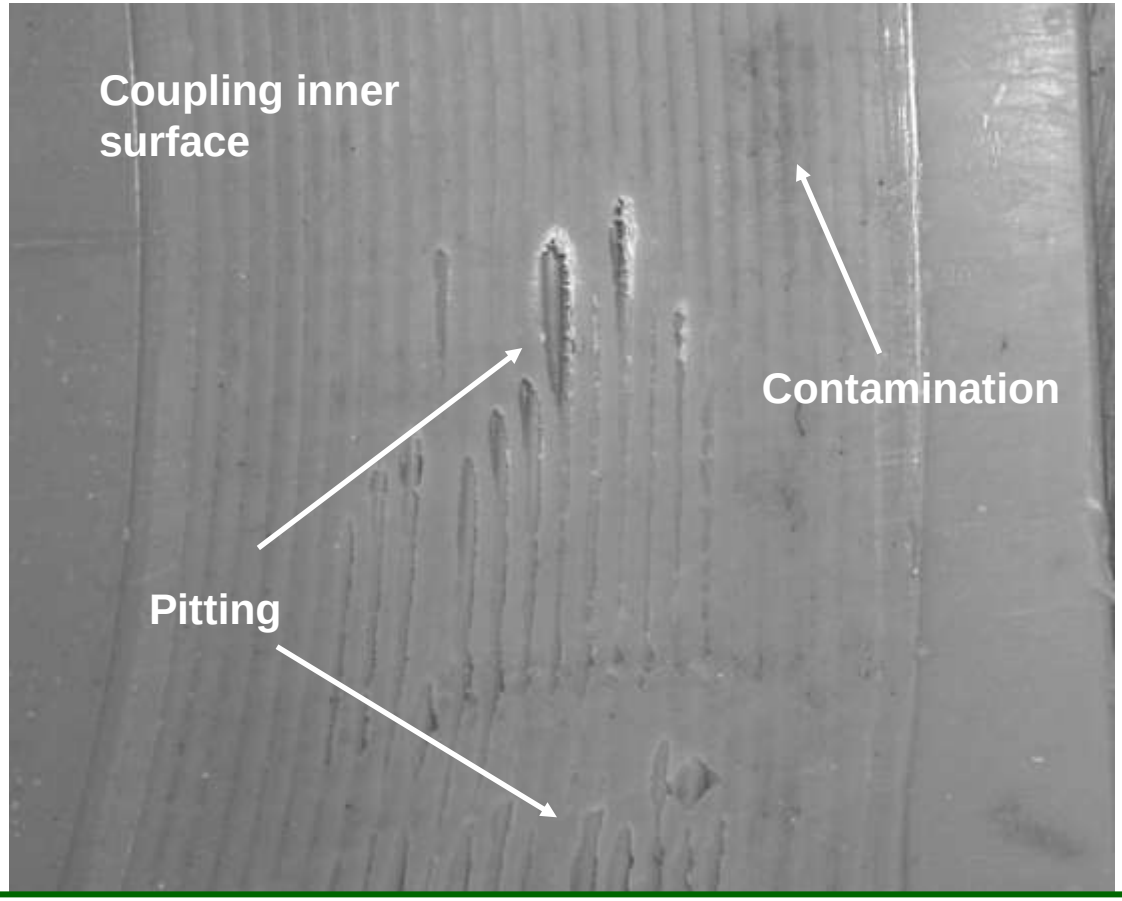
Electrofusion joint/fitting failures

- **Failed samples from WRc, UK**



Entrapped moisture boils and expands during fusion welding, causing separation – <u>Could be avoided by adequate surface preparation</u>

Electrofusion joint/fitting failures



Moisture and dirt lead to poor adhesion – Could be avoided with adequate surface preparation

Validation of reported joint/fitting failure modes

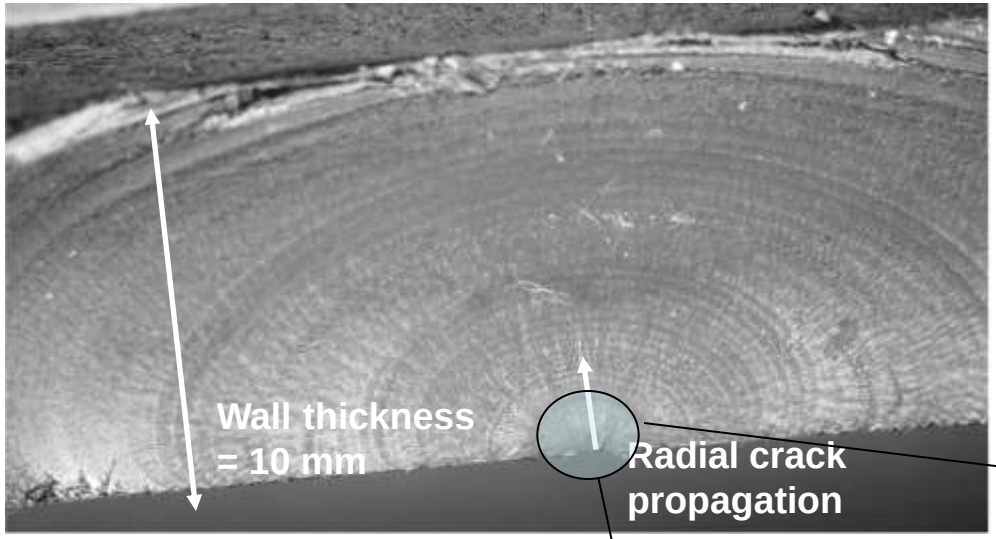
- **Of the recorded failure events, joints and fittings are reported more frequently than pipe fracture failures**
- **BUT: examination of failed samples indicates that reported failure modes are inaccurate**
- **Reported Joint/Fitting failures are due to the effects of improper surface preparation rather than failure under normal operating conditions**

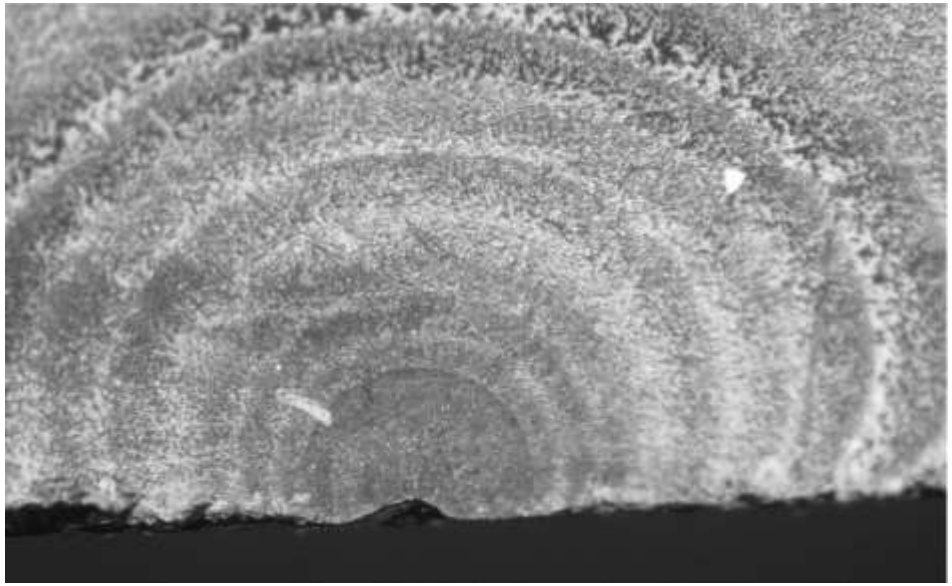
It was concluded that these reported failures do not give a fair representation of true system performance under normal conditions

Pipe slow crack growth failures

- **Failed samples from South Australia Water**

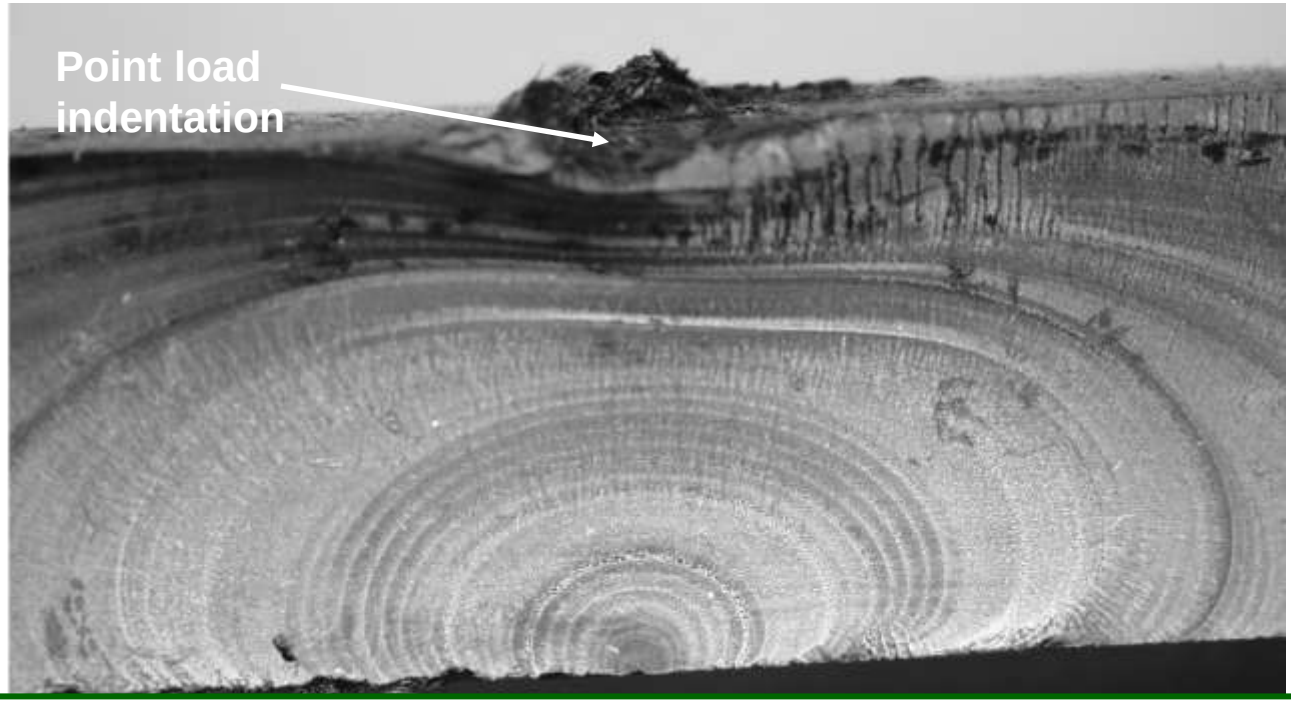
Pipe slow crack growth failures





Evidence of point loading at outer surface

- **Failed samples from South Australia Water, AUS (under repair clamp)**



Action of point load is to increase bending stress beyond the level expected and lead to crack opening at the inside surface – <u>Could be avoided</u>

Validation of reported pipe fracture modes

- While some slow crack growth failures appear to have occurred under normal operating conditions..
- Literature/expert opinion/sample examination indicate that many are actually due to point loading conditions or third party damage
- As such, they illustrate the effect of improper pipe installation rather than failure under normal operating conditions

These reported crack growth failures are <u>not</u> a true indication of PE performance under normal operating conditions

Part 2:
Methods for long-term performance prediction of PE water pipes in service

What measure of long term performance is required?

- **Question often asked: “How long will a PE pipe last?”**
- **Difficult to answer since service life depends on:**
  - **Pipe size**
  - **Operating conditions**
  - **Maximum size of defects and/or damage in the pipe wall**
  - **Resistance to crack growth**
- **Also, remaining service life of an individual pipe is not usually required by water authorities….**

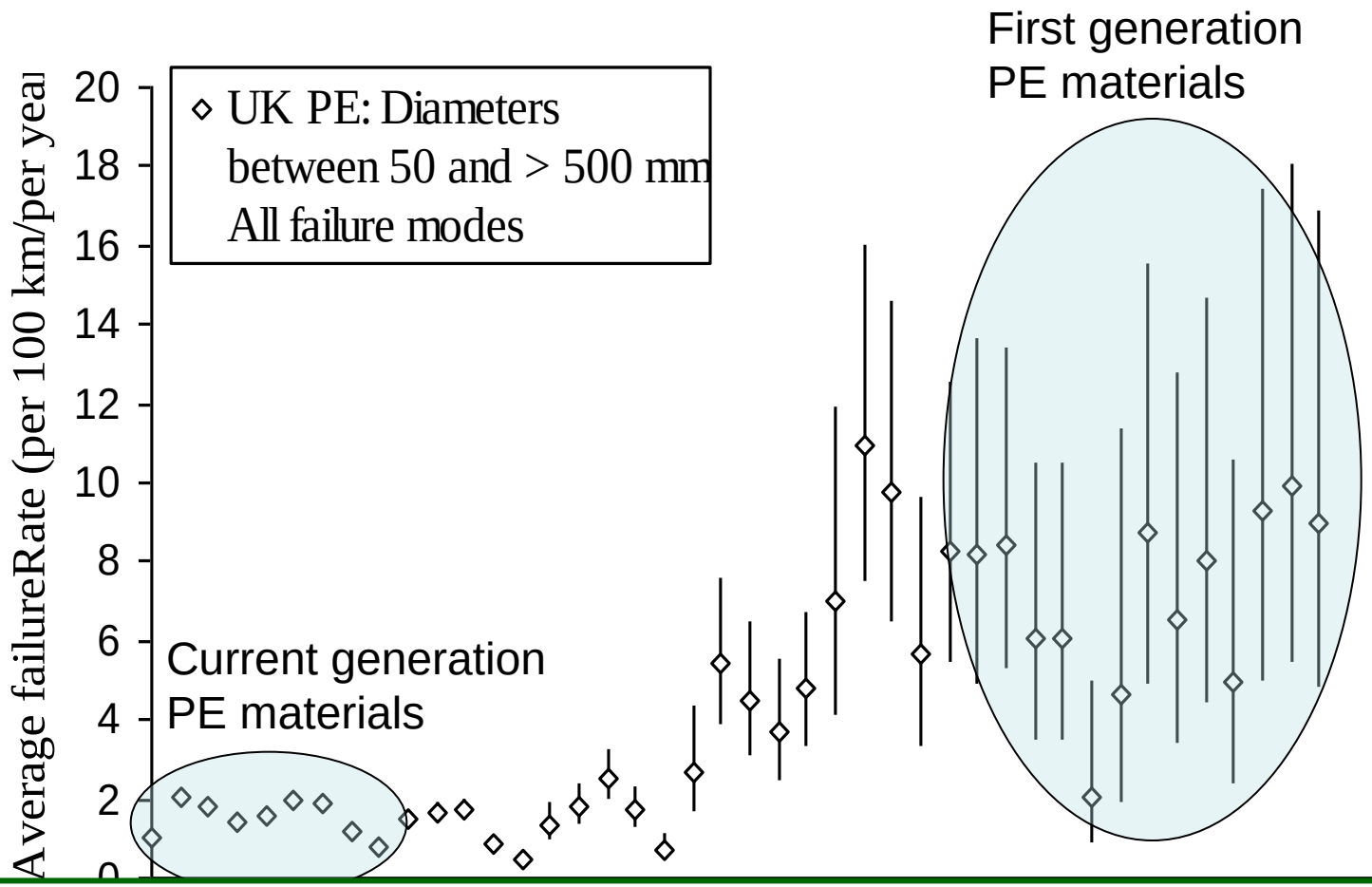
What measure of long term performance is required?

- **…of more use is the expected average failure rate (per pipe length/per year)**
- **This measure of network-wide performance lends itself to water authority asset management:**
  - **Can be used for maintenance and replacement budget planning**
  - **Can be benchmarked against actual data**

Long term performance prediction for PE pipes in service

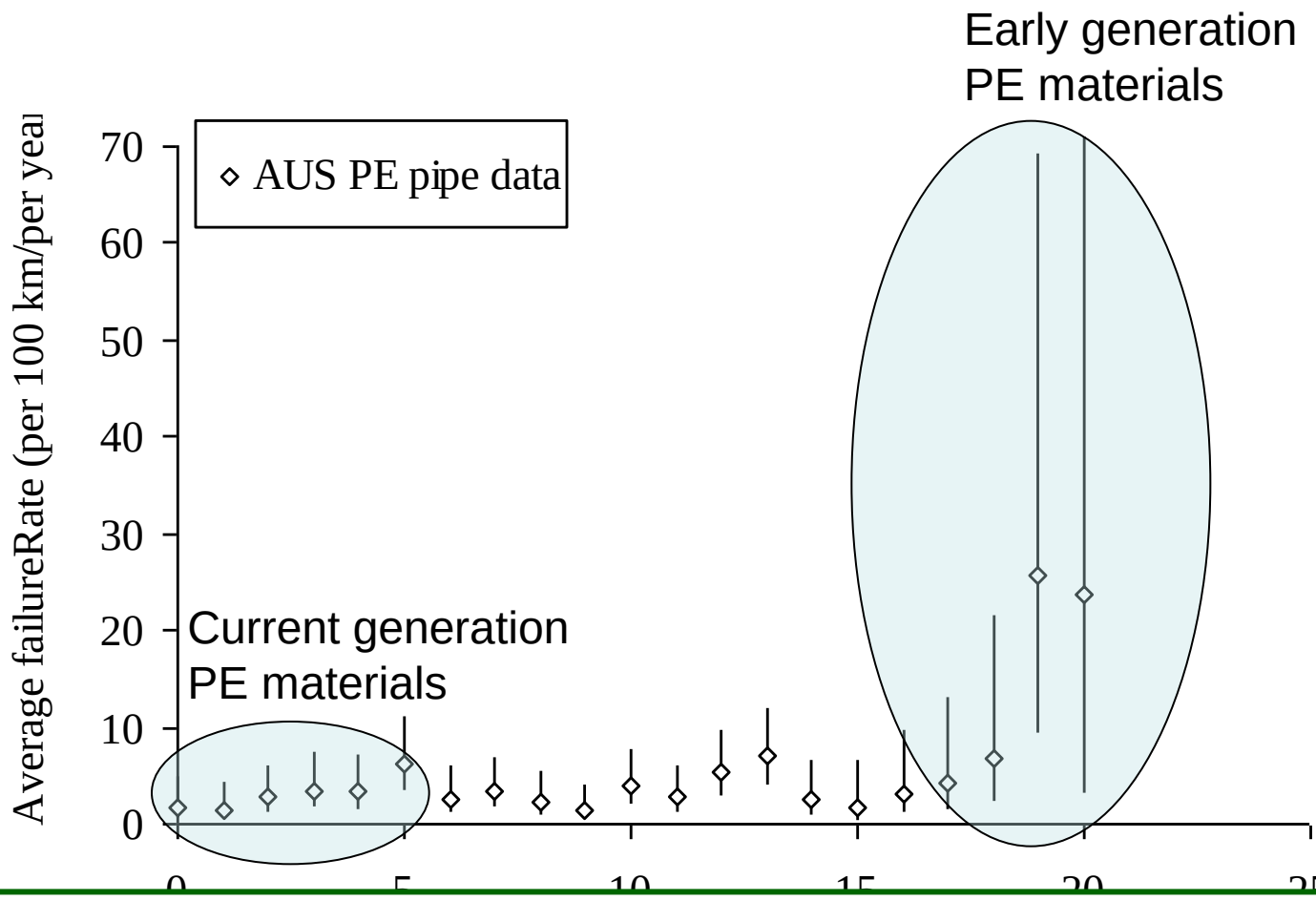
- **Traditionally, statistical approaches are used to forecast future failure rates in water pipelines**
- **Work well for older materials (Cast Iron, Asbestos Cement) which have a wealth of existing failure data**
- **PE materials present problems to this approach in that failure rates are low and there is rarely sufficient historical data for confident forecasts**
- **Different generations of PE materials displayed different slow crack growth resistances**
  - **These generational differences are not captured in water authority asset data (Pipes are simply designated as "PE")**

Effect of age on failure rate (UK data)



Current generation PE materials will behave differently to early generation materials as they age

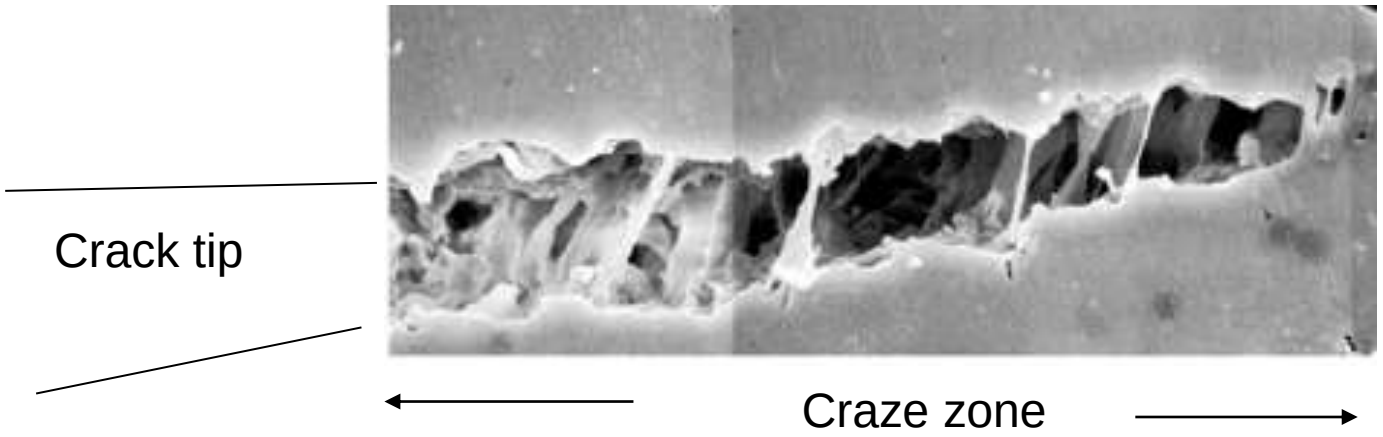
Effect of age on failure rate (AUS data)



Cannot use data for early generation materials to forecast the future failures in current PE materials

Crack growth prediction in PE pipes

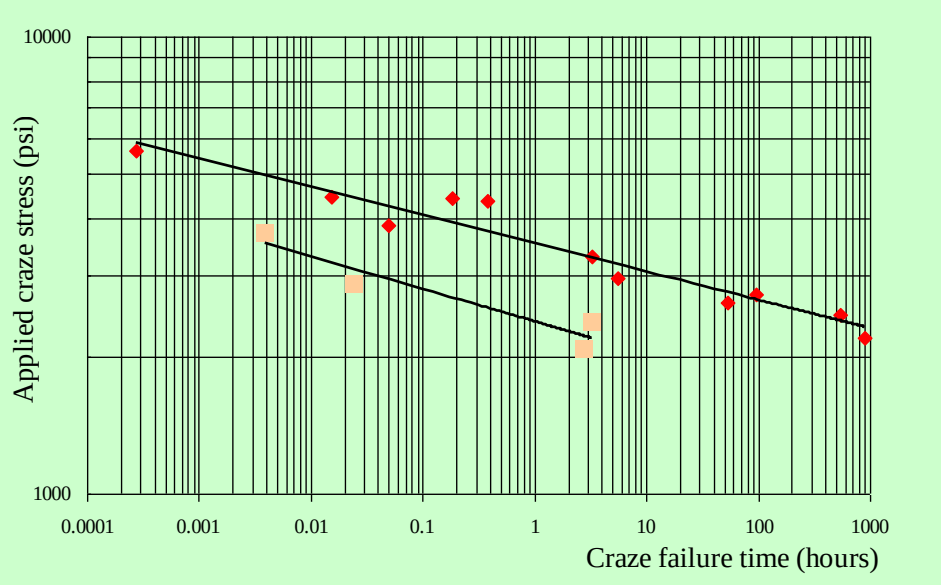
- **Alternative to statistical models is to use a physical model to predict crack growth**



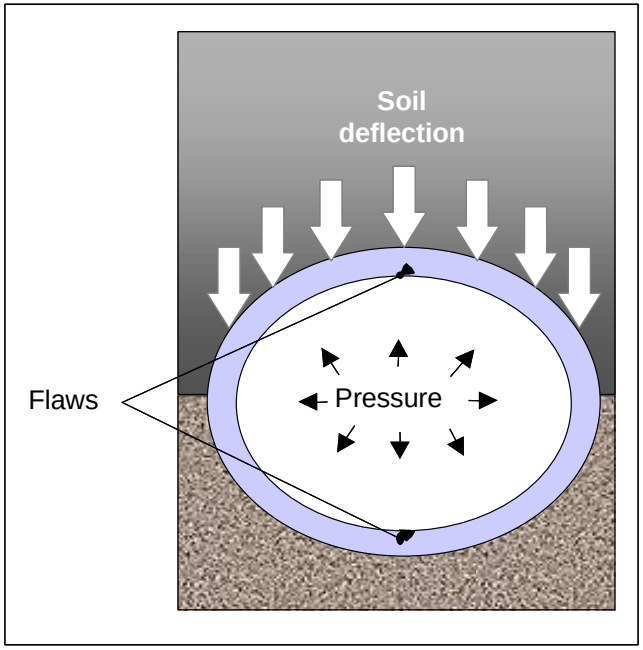
CSIRO developed a physically-based model to predict the behaviour of this craze zone……

Crack growth prediction in PE pipes

Experimental craze strength data

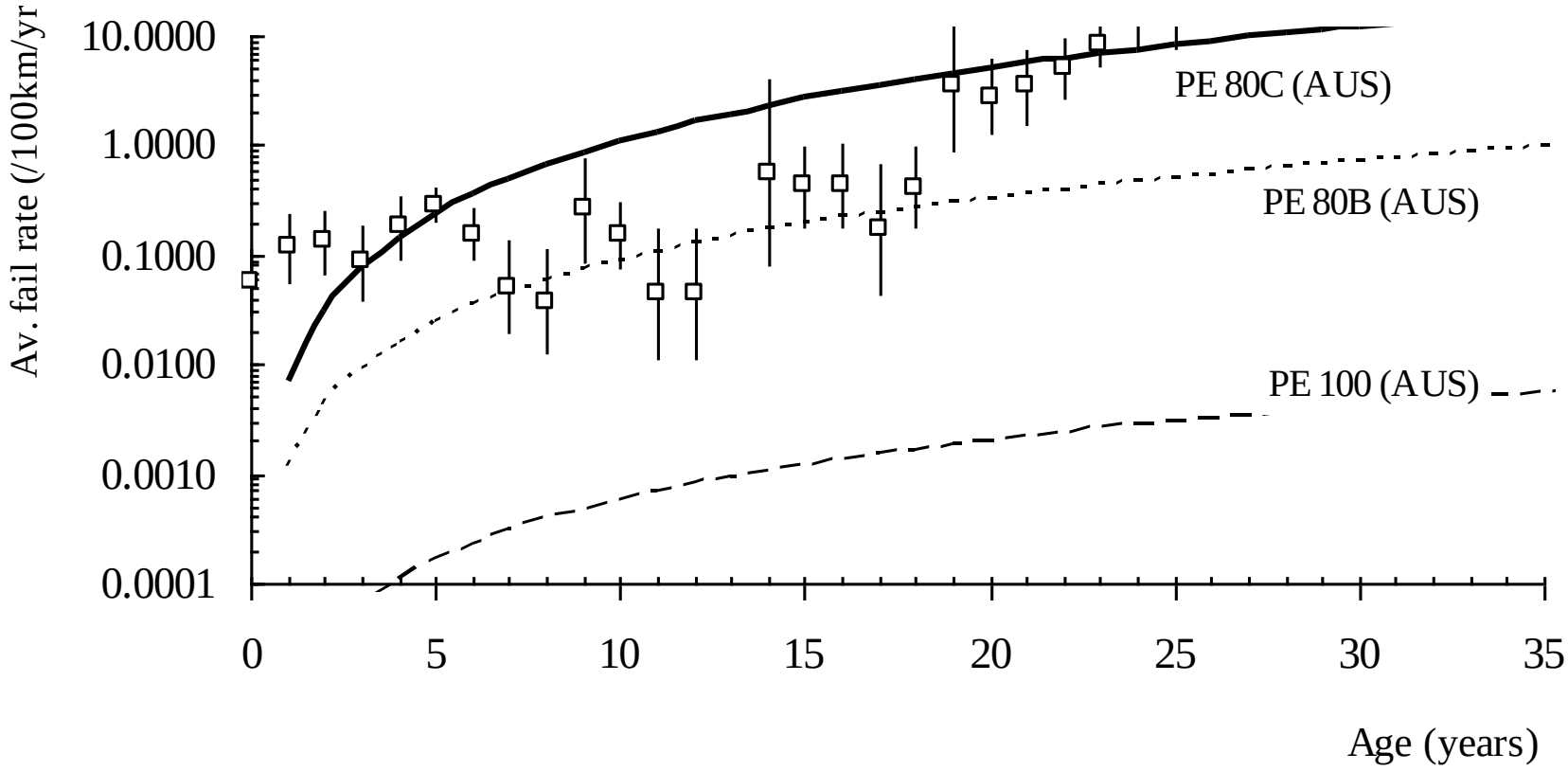


Provides crack growth model for service loading



Performance prediction for PE water pipes in service

….and then used statistical analysis to extrapolate this model and predict network-wide failure rates



Concluding remarks

INDUSTRY SURVEY OF FIELD PERFORMANCE

- PE has a low reported failure rate in comparison to other materials in use
- Reported failure modes in PE pipe systems are thought to be inaccurate
  - Failures in fusion joints and fittings are caused by surface preparation rather than failure under normal conditions
  - In many cases, pipe fracture failures are more likely to be caused by installation practice rather than failure under normal operating conditions
- In light of these inaccuracies, better reporting methodologies are required for PE
  - Retaining samples and examination?
  - New categories of failure mode?

Concluding remarks

LONG TERM PERFORMANCE PREDICTION

- Average failure rate is a more useful performance measure than pipe service life
- Traditional statistical methods cannot be applied
  - Insufficient historical data is available to forecast future failure rates confidently
  - Generational improvements in slow crack growth resistance also complicate the use of historical data for future prediction
- An alternative is to develop physical-based models to predict crack growth in different PE pipes
- CSIRO have developed such a model based on the crack-tip craze zone

Concluding remarks

LONG TERM PERFORMANCE PREDICTION cont'd

- **Comparisons between model and observed failure data are favourable**
- **Craze model highlights extremely low failure rates expected from current generation of PE materials under normal operating conditions**

THANK YOU