# Optical Fibre Instrumentation in Construction

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# Presentation Outline

**What are the optical fibres?**

↓

**How can they be used to measure strain?**

↓

**Case Studies/Current Activities**

↓

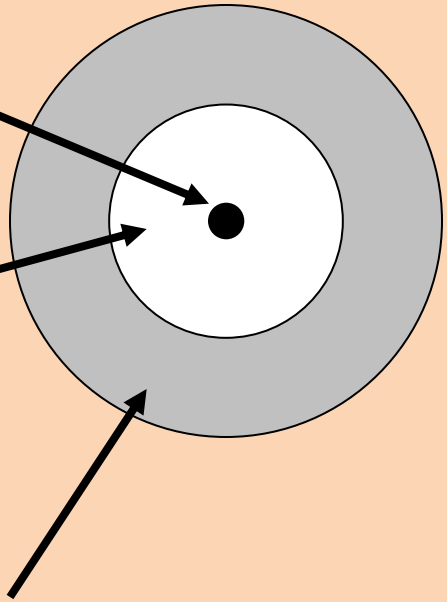
**Conclusions**

# What is an optical fibre?

Glass core (N1), ~8μm

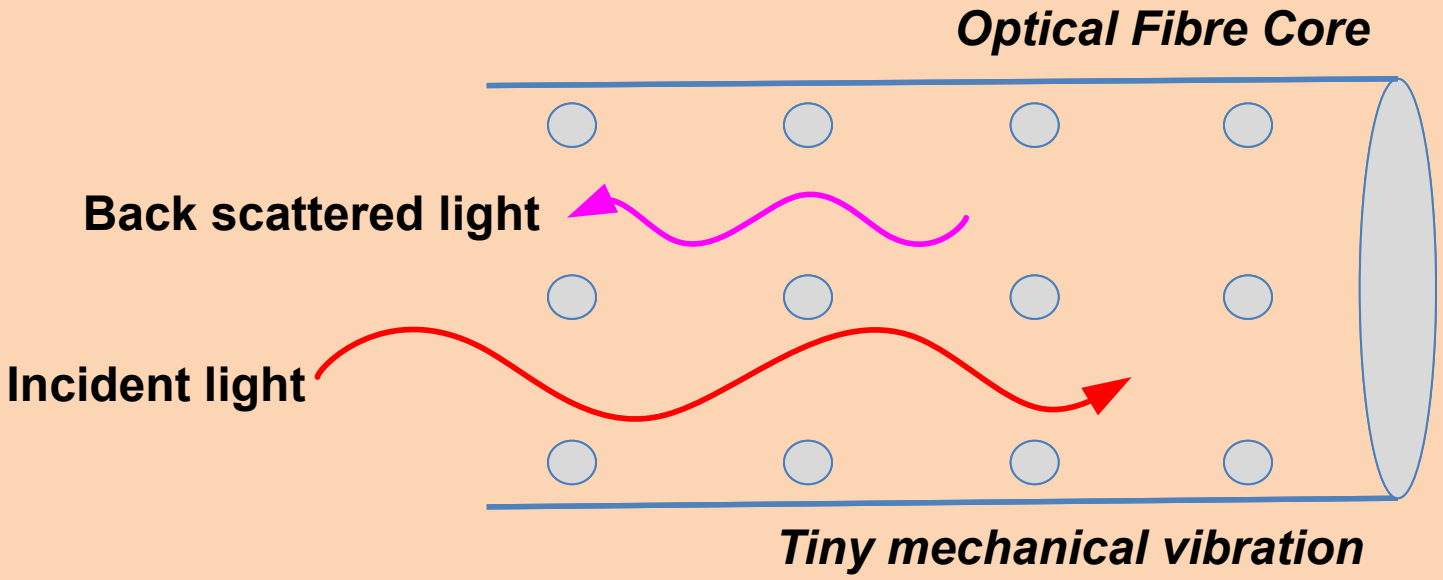
Glass Cladding (N2), 125μm

Plastic coating, 250μm / 900μm

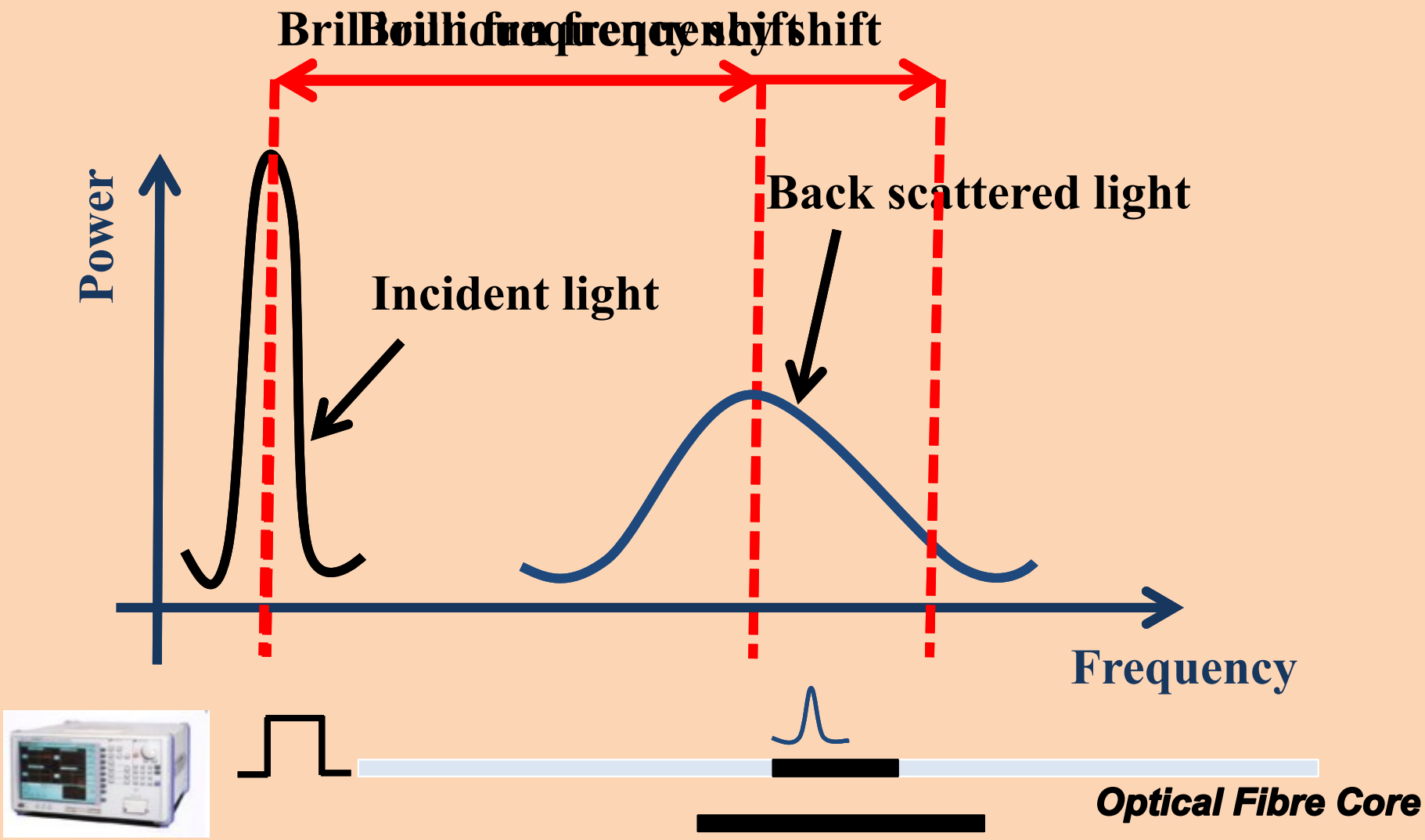


# How can optical fibres measure strain?

- Atoms vibrate with very small amplitudes
- Vibrations = fluctuation in the refractive index
- Fluctuation = scattering of the travelling light

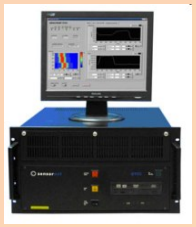


# How can optical fibre cores measure strain?



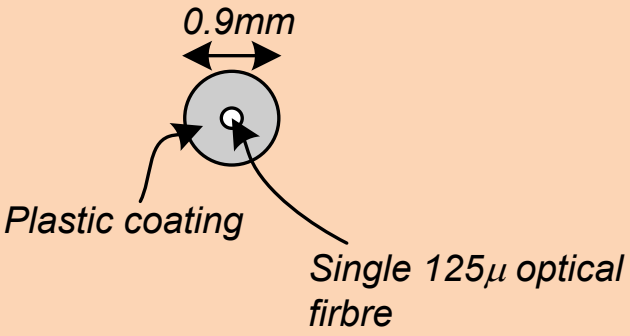

**Brillioun frequency shift is proportional to strain**

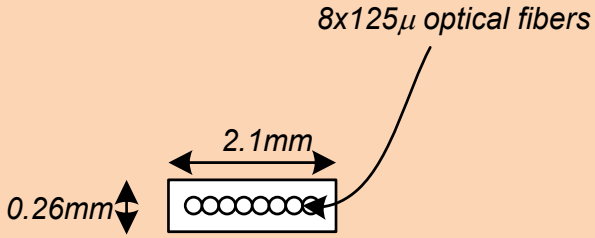
# Available BOTDR analysers

| Brand | Yokogawa | Omnisens | Sensornet | Adventest |
|---|---|---|---|---|
| Photo |  |  |  |  |
| Type | Single connection | Loop connection | Single Connection | Single Connection |
| Accuracy (2s) | 30me | 4me | 50me | 30me |
| Spatial resolution | 1m | 0.5m | 1m | 1m |
| Time for measurement | Static: ~40min | Static: ~20sec | Dynamic: 0.1sec (10Hz) | Static: ~40min |
| Length of measurement | 10km | 10km | 1km | 10km |
| Made in | Japan | Switzerland | UK | Japan |
| Cost | £80k-90k | | | |

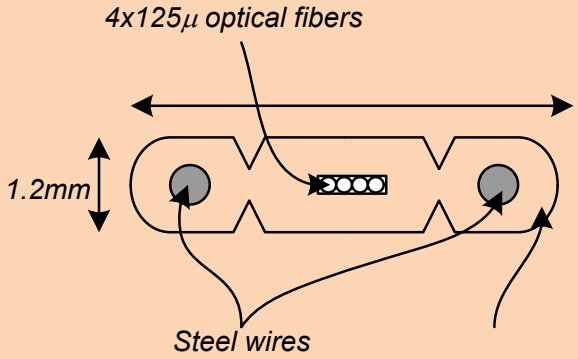
# Suitable fibres

## Fibres suitable for strain measurements:



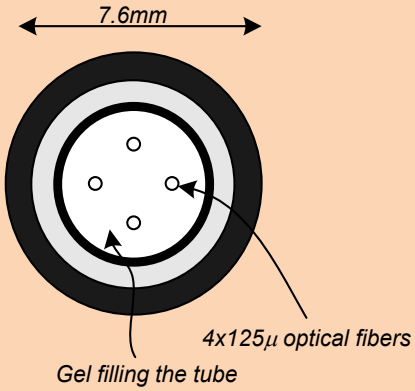



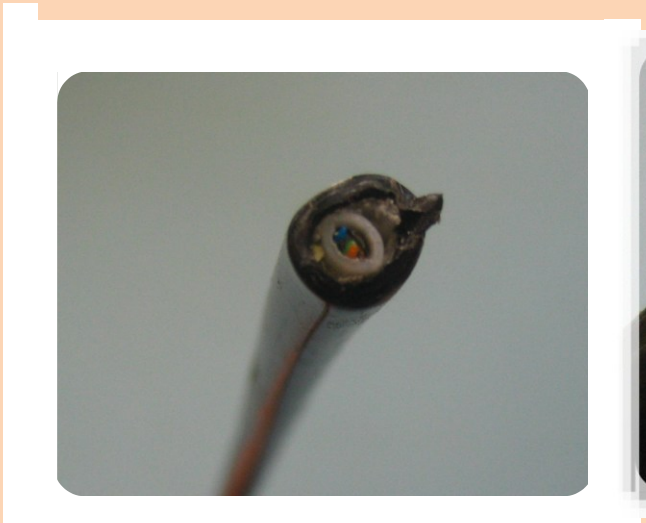

***FUJIKURA SM 8***
***Ribbon***

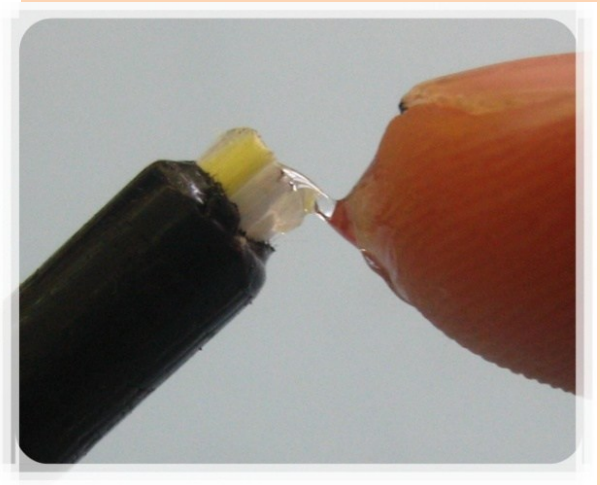



***FUJIKURA SM 4***
***Reinforced***

## Fibres for temperature compensation:



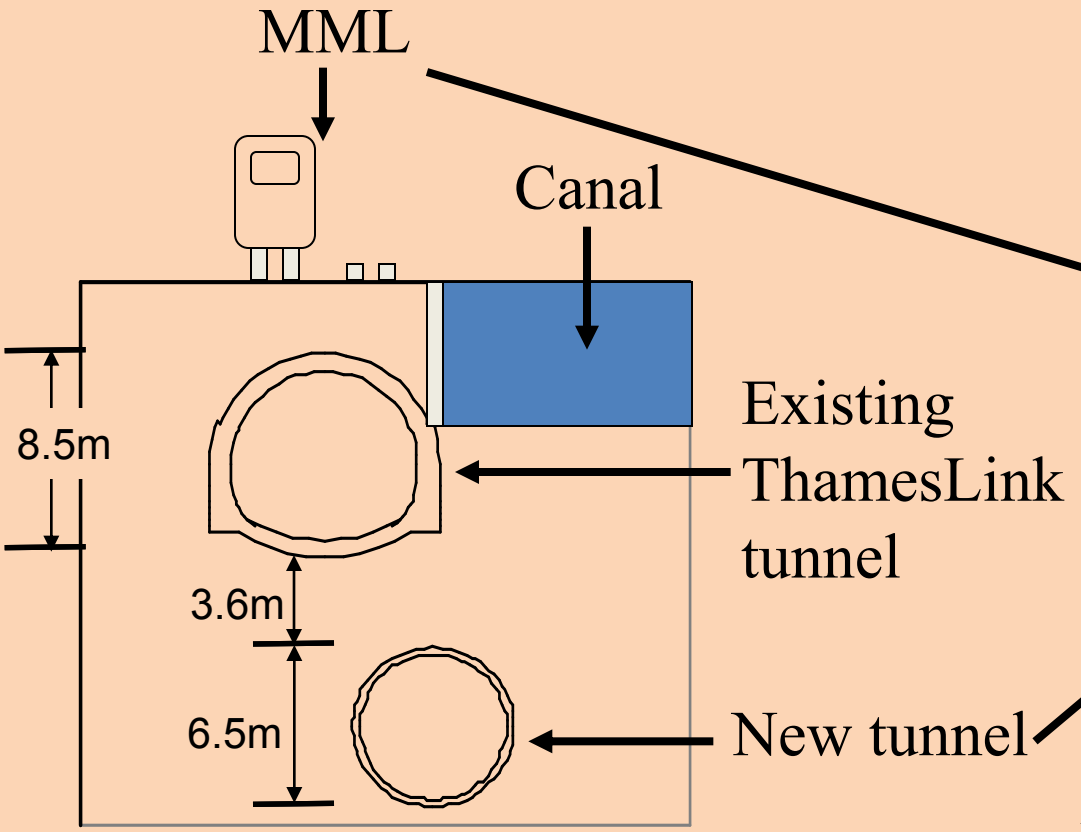



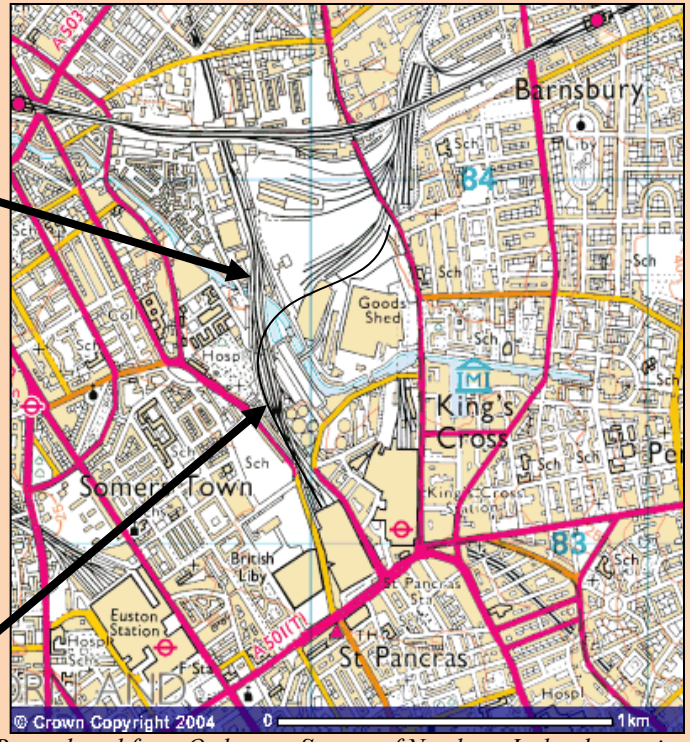


# CTRL Case Study

- New tunnel obliquely under existing Victorian masonry tunnel

- Integrity of the masonry lining was of concern

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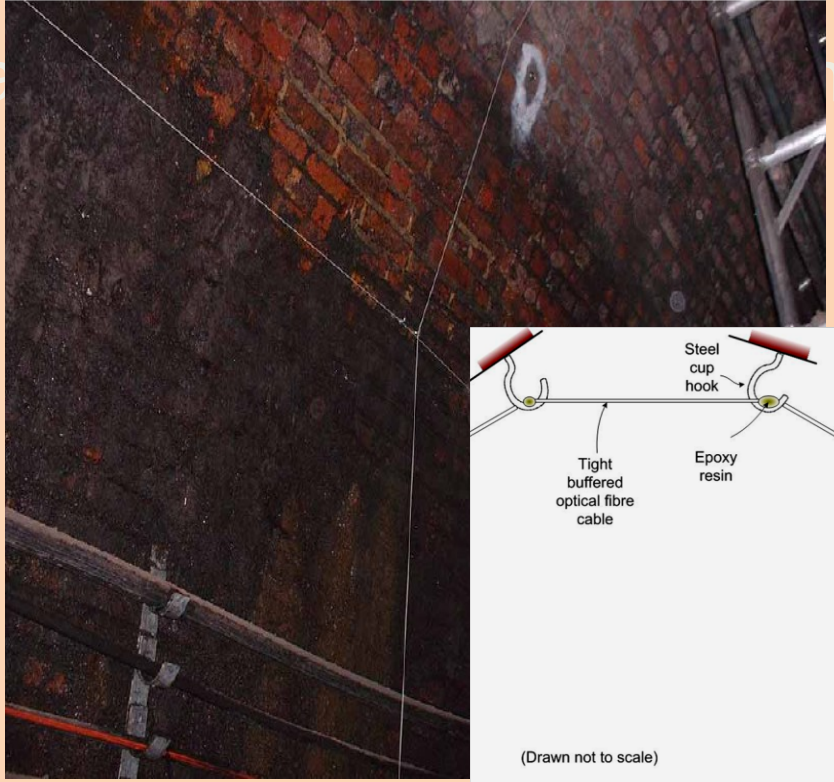
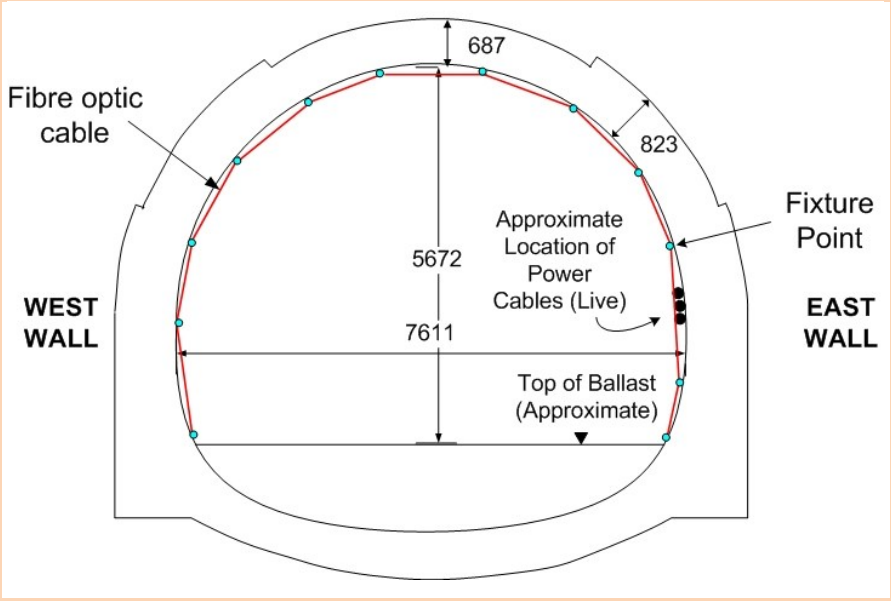
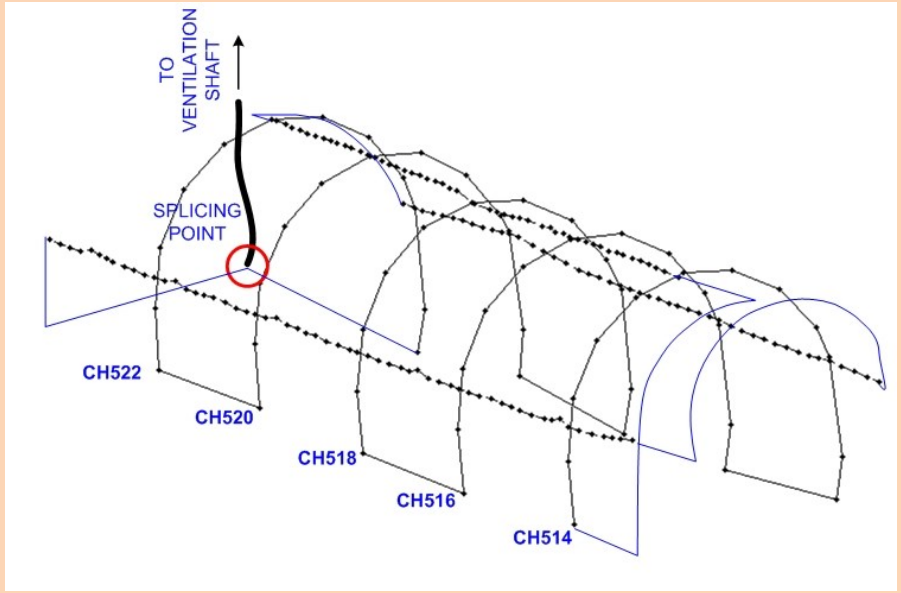
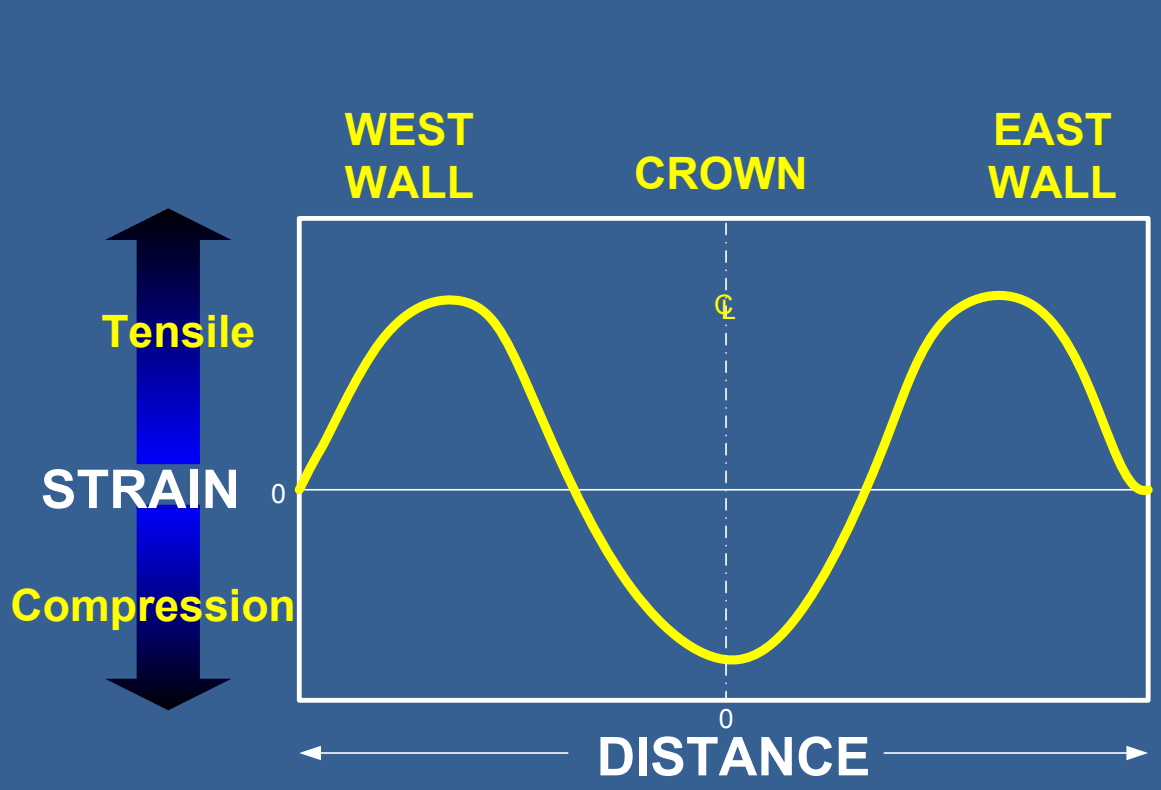
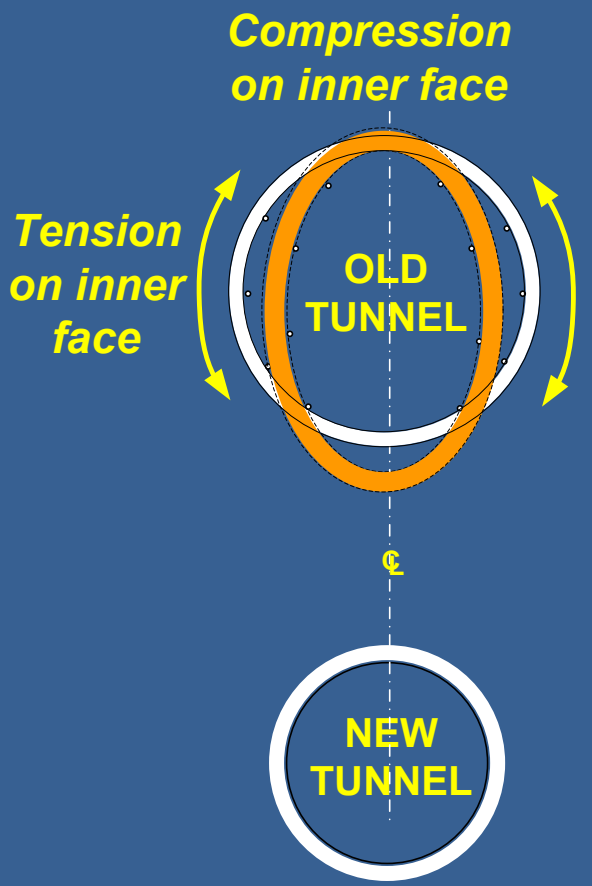

Steel cup hook
Brick surface
Tight buffered optical fibre cable
Epoxy resin
Pre-strain direction
Steel angle bracket
(Drawn not to scale)


687
Fibre optic cable
823
Fixture Point
Approximate Location of Power Cables (Live)
5672
WEST WALL
EAST WALL
7611
Top of Ballast (Approximate)

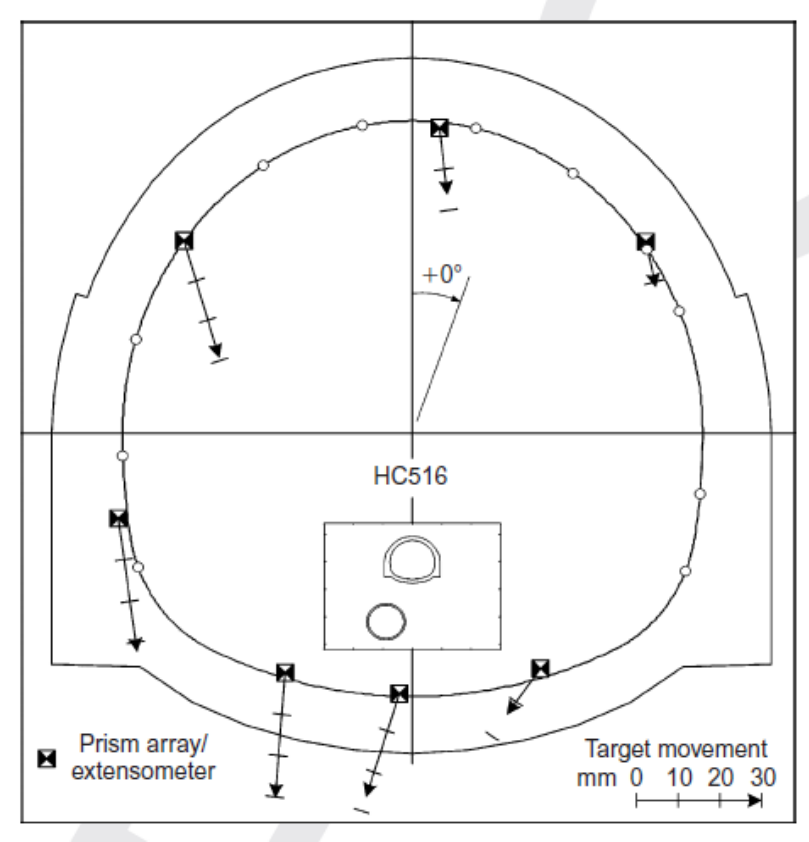

TO VENTILATION SHAFT
SPLICING POINT
CH522
CH520
CH518
CH516
CH514

# Monitoring Thameslink Tunnel

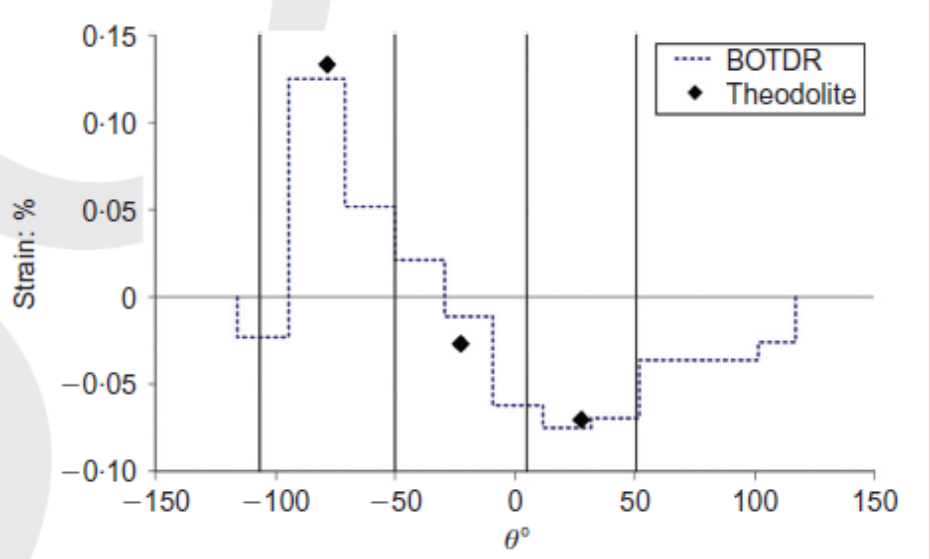


## Vector plots from total station measurements at CH516




## Comparison of BOTDR (optical fibre) strain measurements with strains from theodolite measurements (CH516)



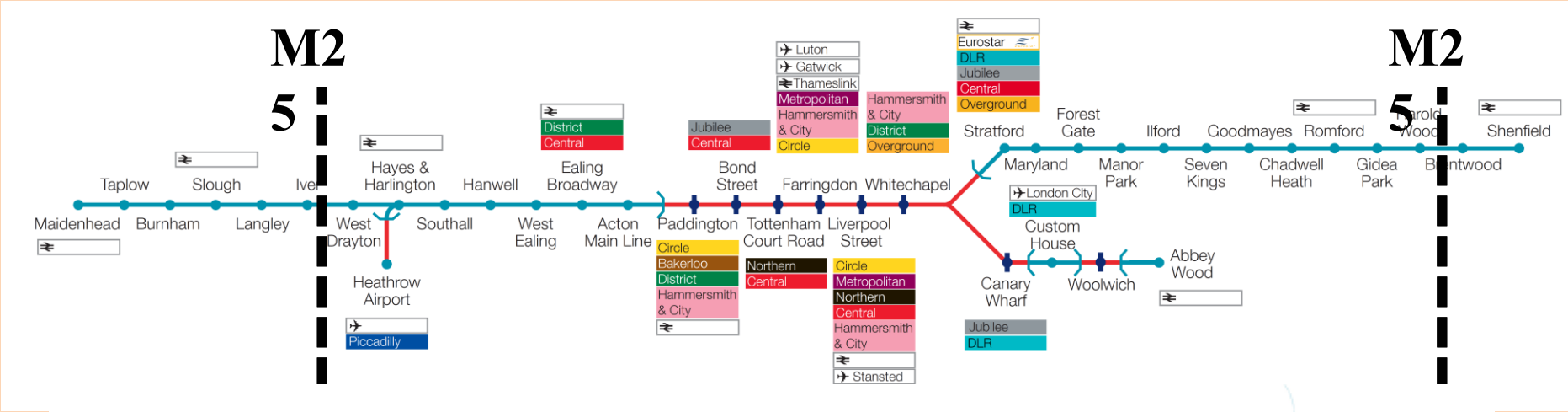

**Displacement measurements will not tell if there is a problem**

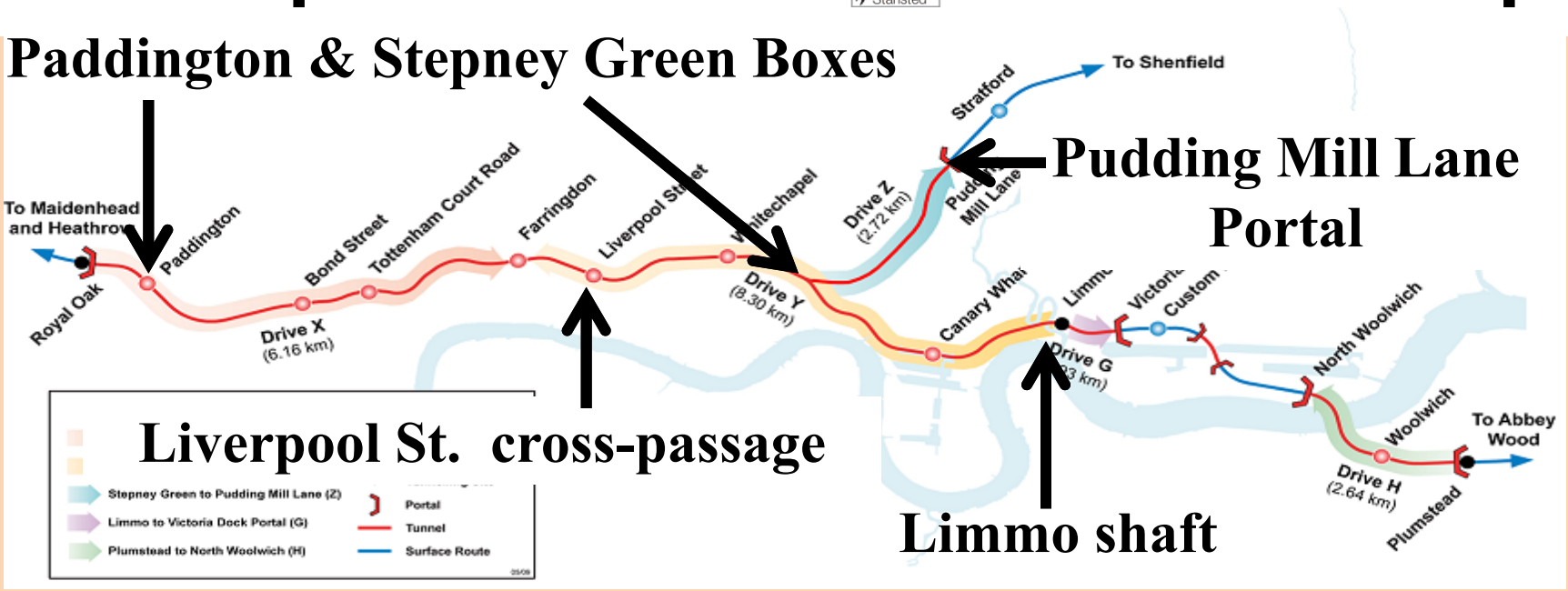
**Strain measurements will**

Mohamad, Bennett, Soga, Mair and Bowers (2010)

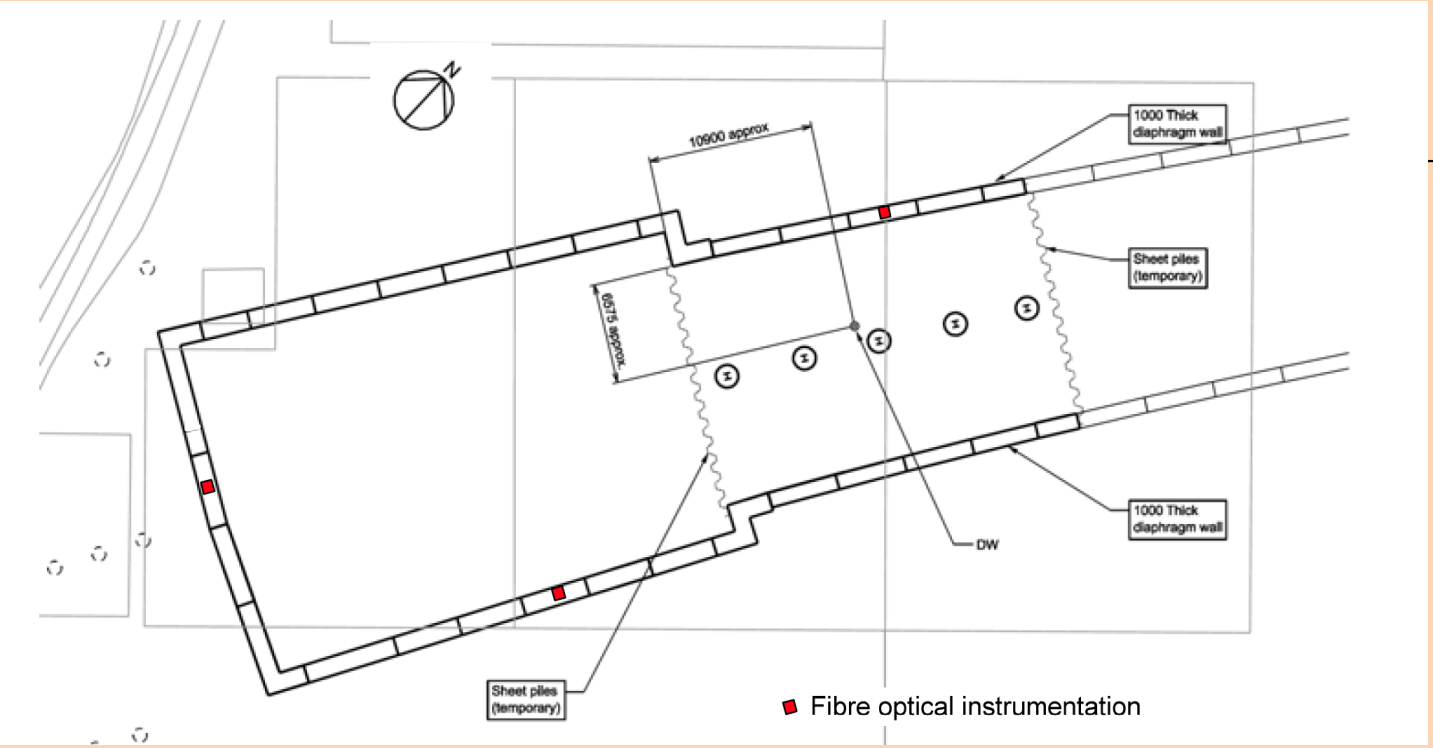
# Current Projects

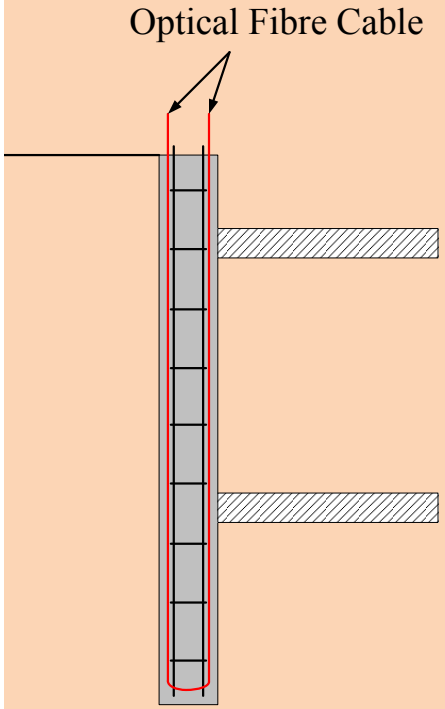
## Crossrail

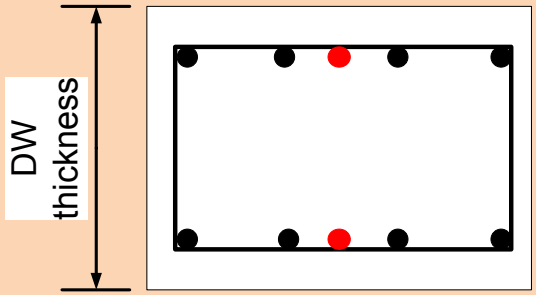


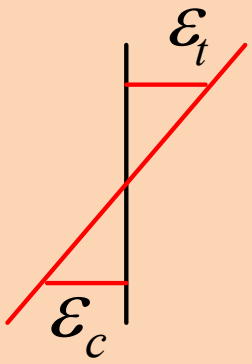



# Pudding Mill Lane Portal




**Stresses**

**Deflections**

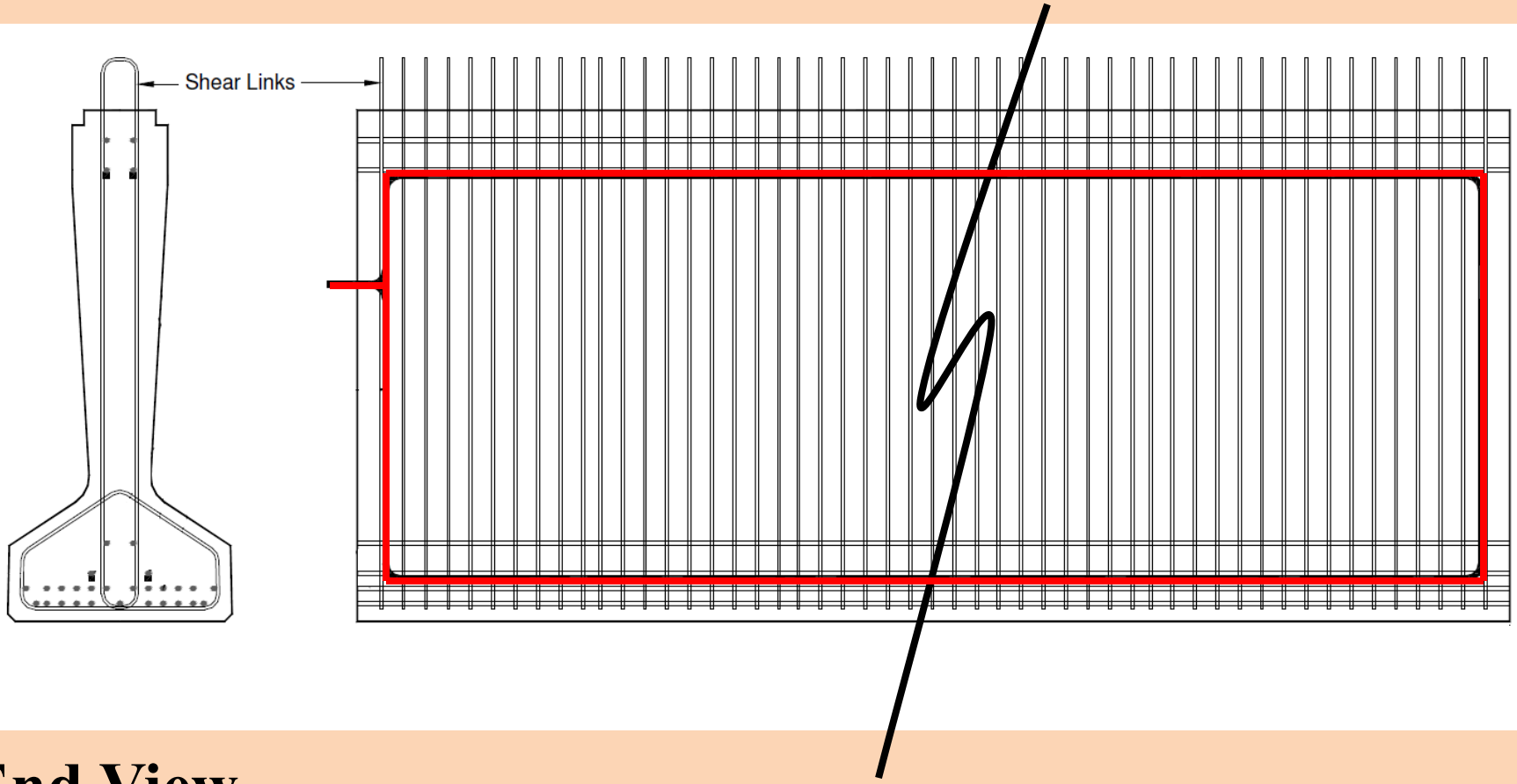

SWL 4.5TON
Yeoman
BANKSMAN
BANKSMAN
BANKSMAN

# Addenbrooke's Nine Wells Bridge

**Instrumented Beams**

**Graham Webb and Cam Middleton**

# Addenbrooke's Nine Wells Bridge

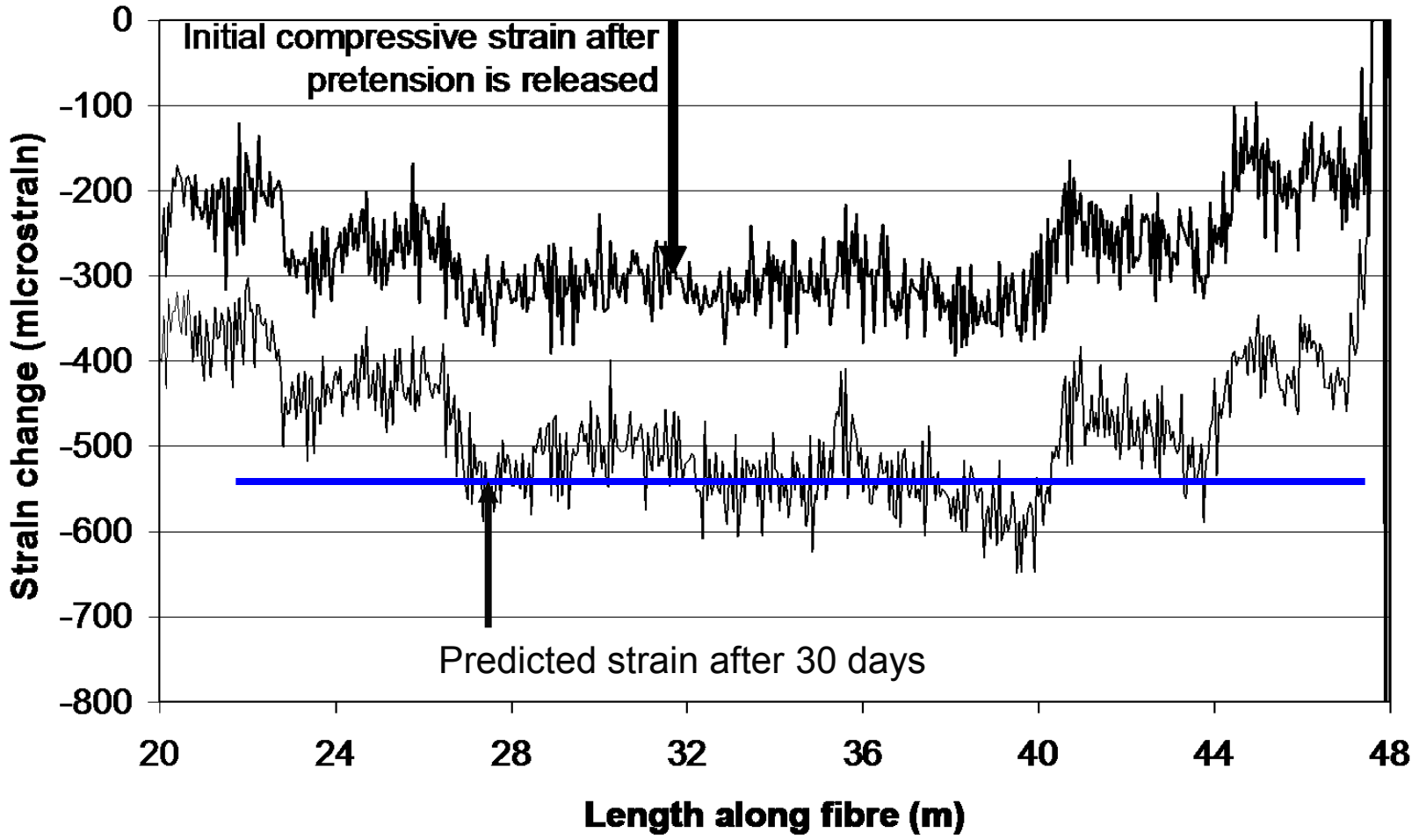



End View

Side View

# Strain Measurement

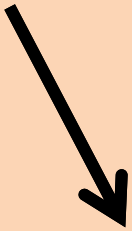
# Strain Change Along Bottom Strand



# Summary

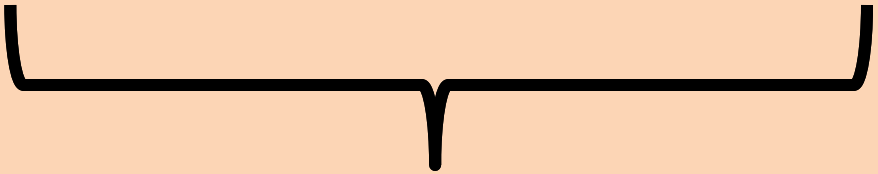
**Optical fibre strain sensing – very promising**

**Make step change in thinking**



**Strain is responsible for damage**

**Strain measurements show the overall behavior**



**Optical Fibre strain measurements could be very effective tool in decision making**

**Thank you.**