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Learning from Bridges

Bill Harvey

Bill Harvey Associates

Richard Feynman

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For successful technology
engineering must take precedence
over public relations
for nature cannot be fooled.

Born 100 years ago last week

Or the Royal Society

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Nullis in verba

By no man’s word.

That is

Question Everything

Or we are doomed to learn nothing

This little demo led to

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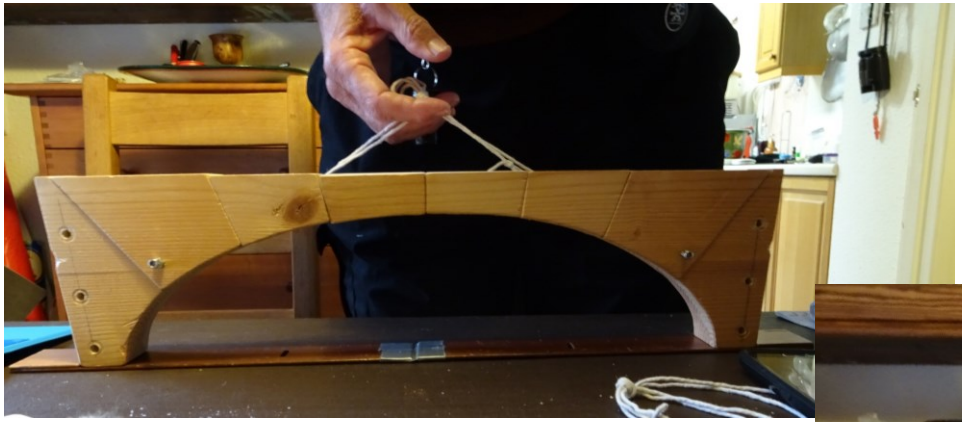

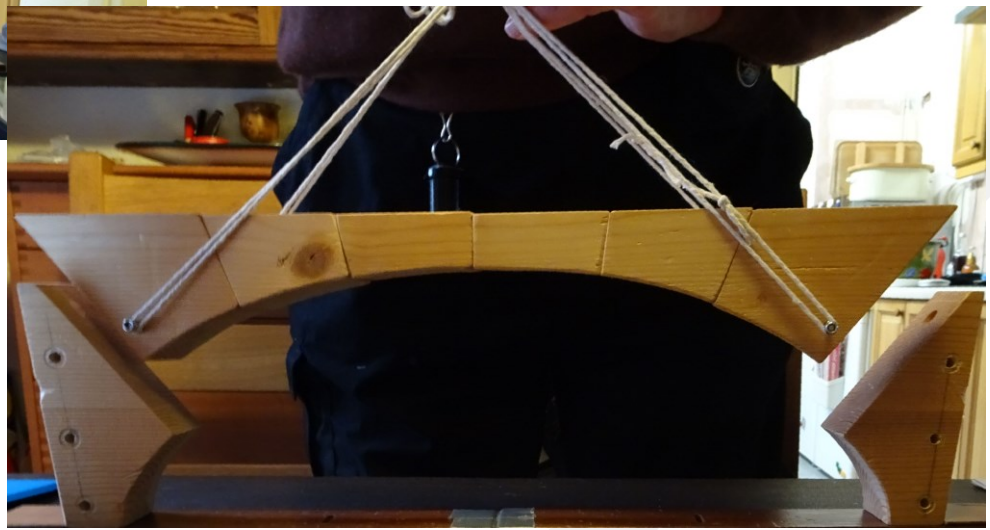

People still say it can’t be done

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Where to start?

DON’T IGNORE WHAT BRIDGES SAY

Stones dropping GSW 2002

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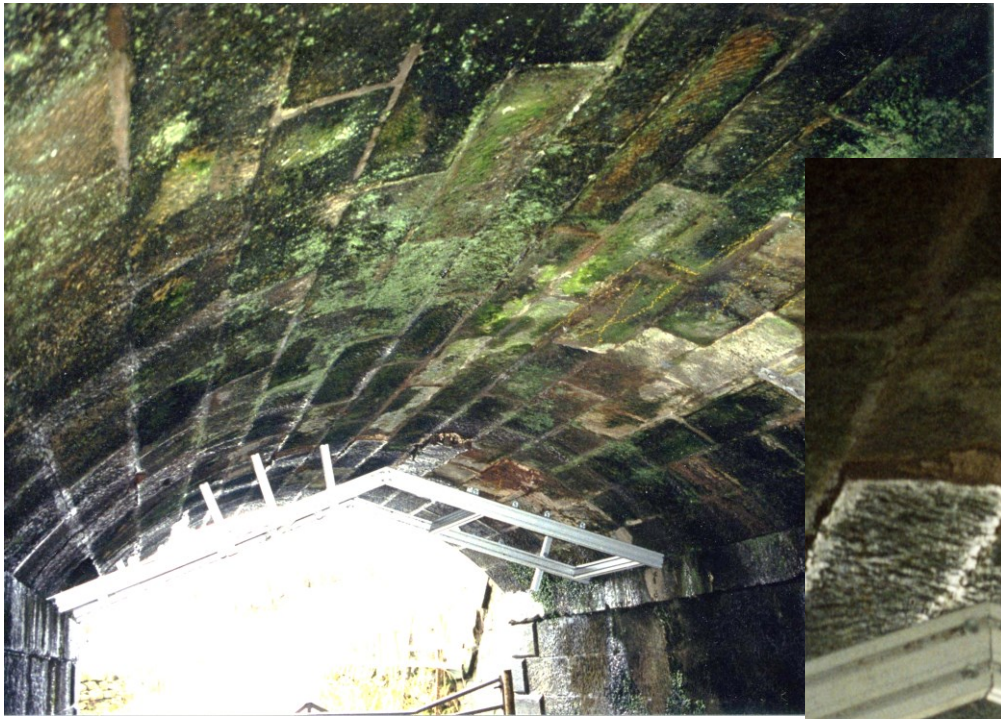
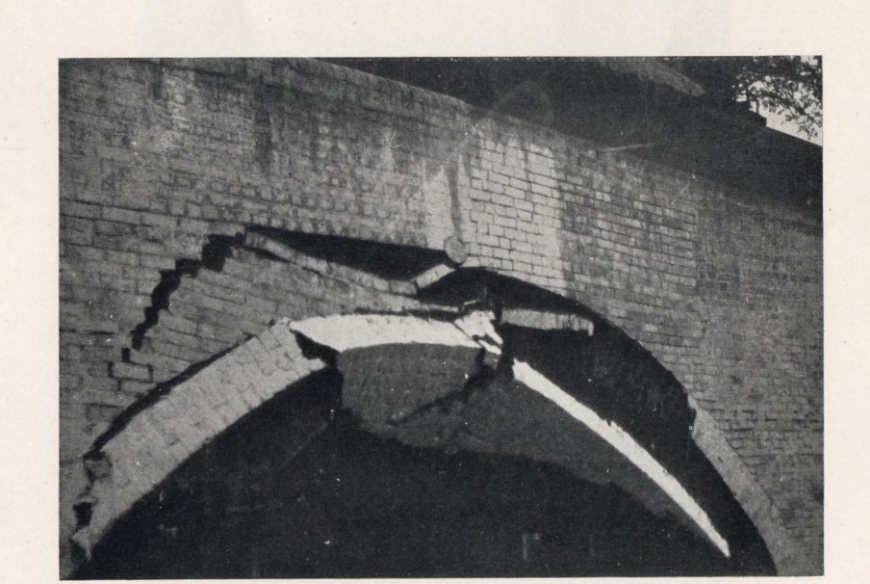


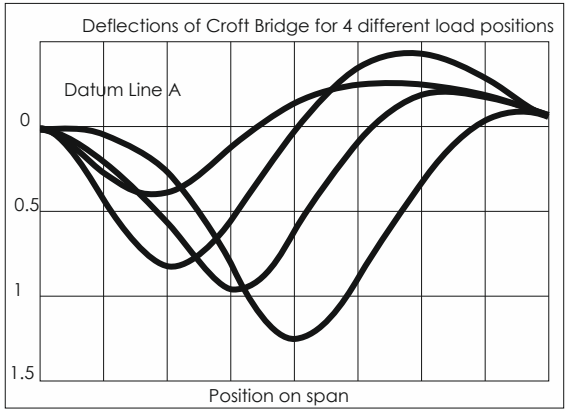
Diagonal cracking pattern

Davey, 1935



(B) *Yardley Wood Road Bridge at instant of collapse*

PLATE 7



Note how peak deflection moves away from load point as load moves towards abutment. Also reduces dramatically

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What Davey found but didn't see

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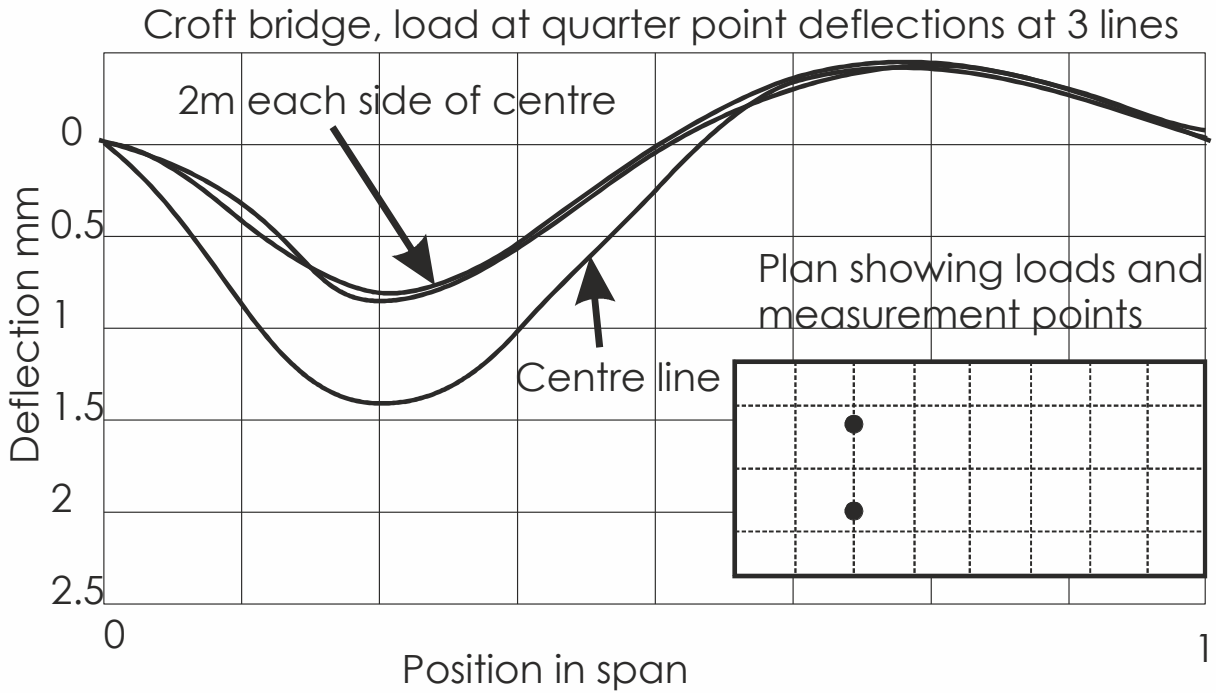

Deflection at far ¼ is uniform.
Despite added restraint from spandrels.
No "Effective strip"

Effective strip rule

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- Different for highways and railways
- NONSENSE. NIH!
- Both equally wrong
- Don’t tell us what we need to know.

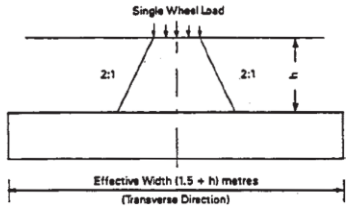
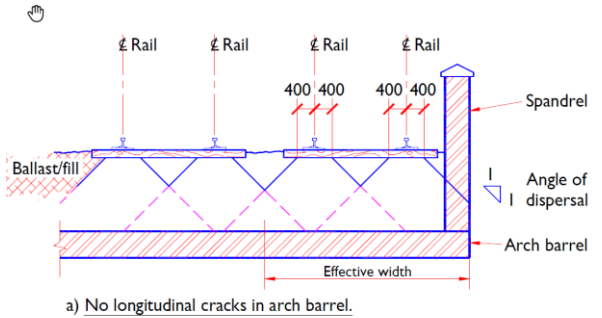


Figure 6.3 Effective Width Under a Wheel Load



a) No longitudinal cracks in arch barrel.

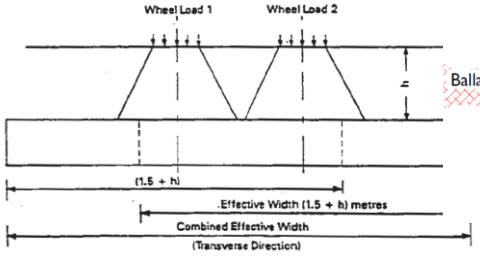
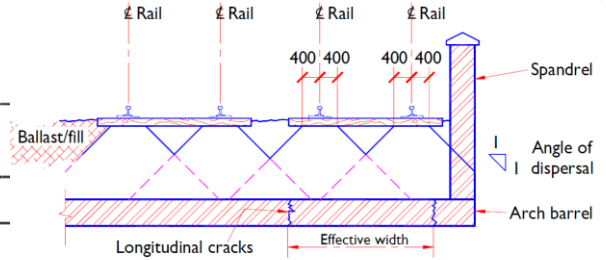


Figure 6.4 Combined Effective Width



b) Arch barrel cracked.

Membrane action

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- Not transverse bending
- VERY stiff
- Distribution varies with span not depth
- Simple model needs testing
- By analysis and in the field
- I don’t have the resources

Tunnel behaviour is a good test

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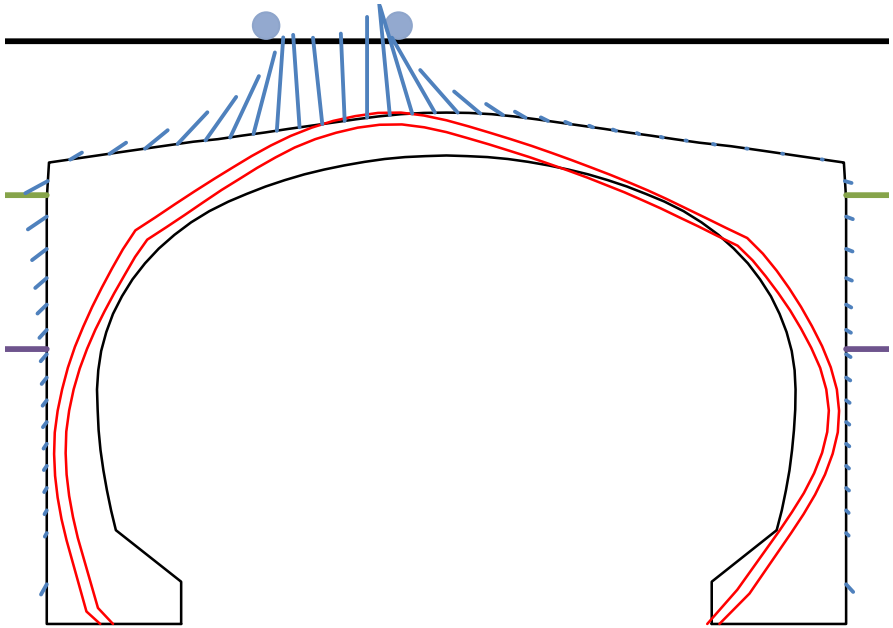

Metropolitan line
Big live loads
Distribution through width allows thrust to fit (though not exactly here.

Real Damage Local

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We can do better

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We MUST do better

It needs properly directed research

already enough evidence that

new model comes much closer to reality.

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If we cannot predict damage conservatively

WHY WASTE MONEY ON ASSESSMENTS

Many are not fit for submission anyway

Skew Bridges

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- They DO NOT SPAN SQUARE
- Mistake transferred from slab “knowledge”
- Serious damage to flattish arches with shallow cover.
- I know of 4 with more than 4 longitudinal cracks on the skew

Hidden by lining

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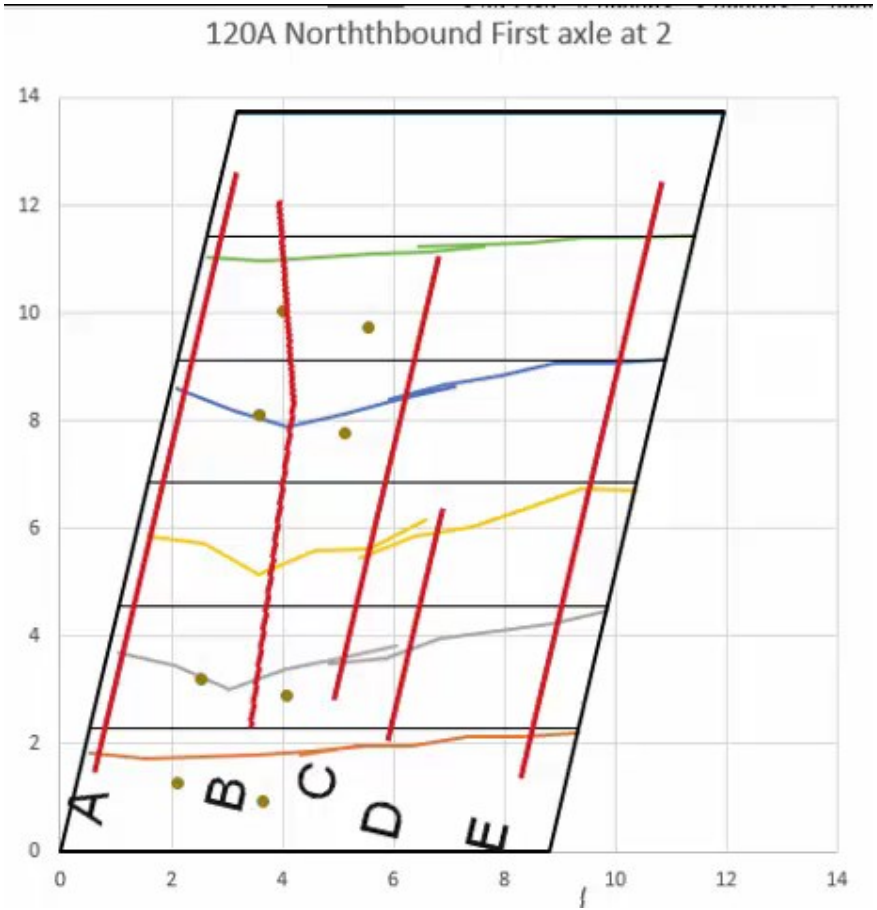
Deflection poles for dense measurement of vertical deflection



Concentrated deflections Note diff between long and short term measurement

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Width change (through lining)

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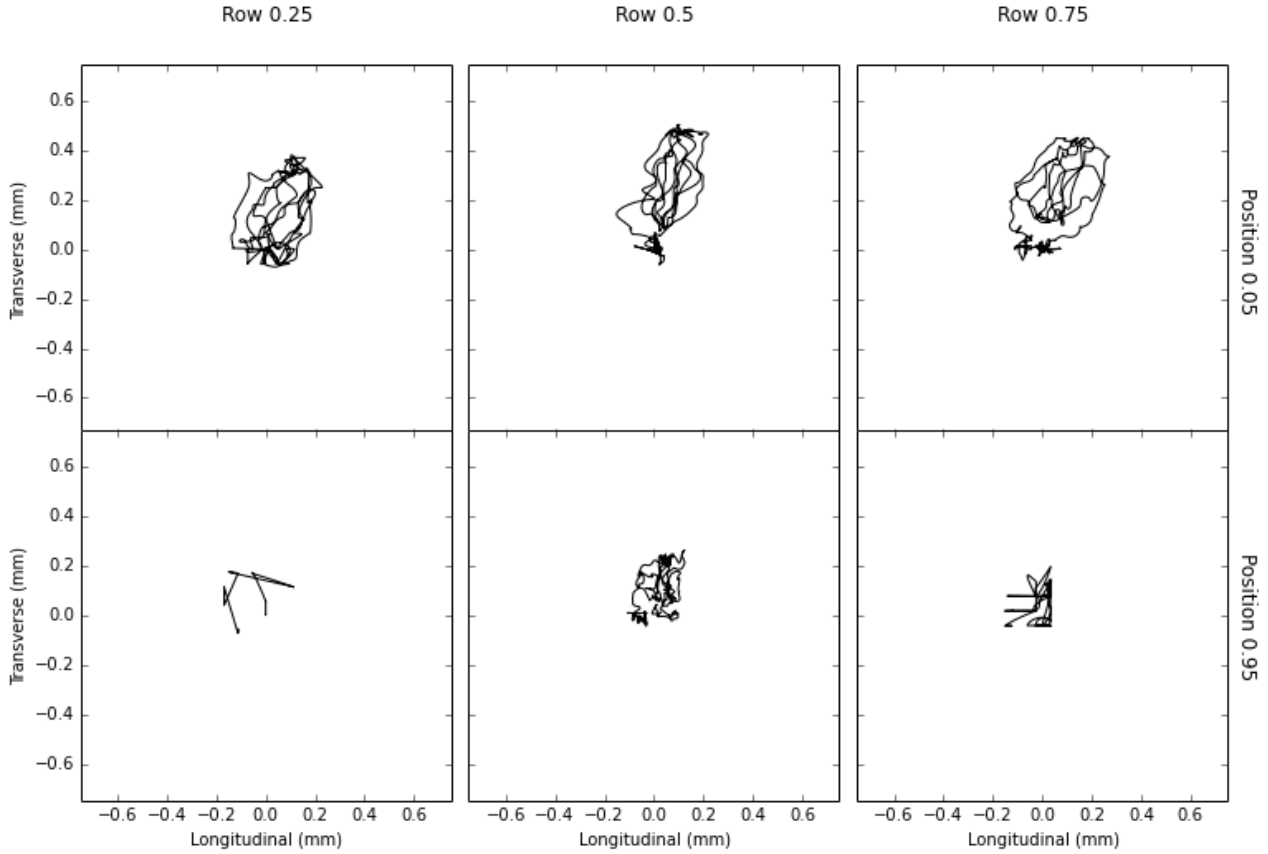

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Moiré Tell-Tale

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To understand why

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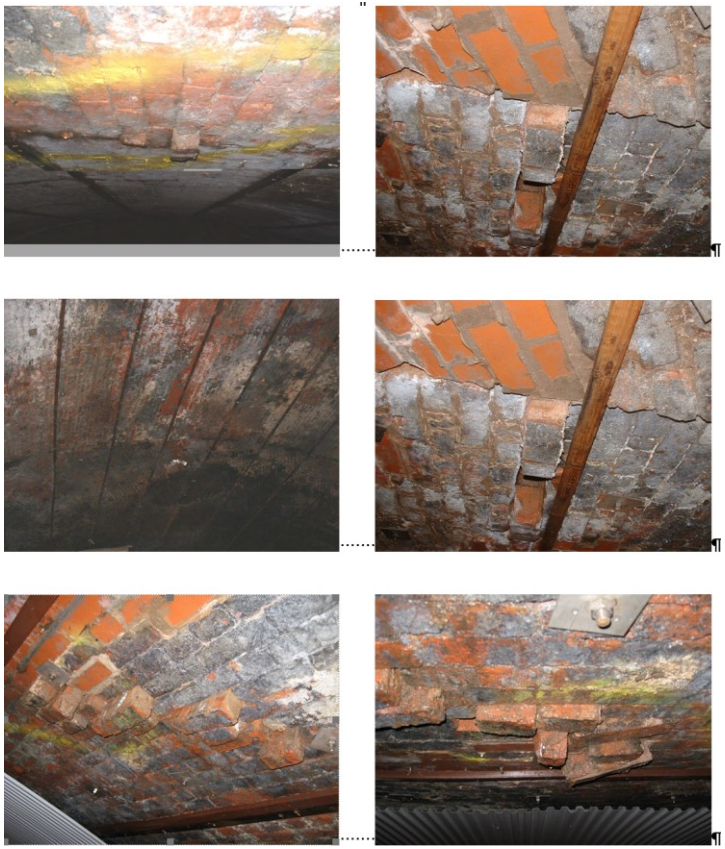
- We must first understand what
- Stop applying indefensible treatments
- ***It's a stiffness not a strength issue***
- Don't panic – measure and think.
- Sometimes you only find the problem by measurement

And incidentally



- Damage occurred shortly after lining.
- Sweating the mortar is seriously bad news.
- Lining arches is potentially dangerous

Viaducts

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- Two issues that compound
- Rocking pier top units
- Spreading divided piers
- The compound is more serious than it looks
- How do we teach owners to SEE

Rocking

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- Stiffness governs force flow
- Make the pier unit VERY stiff
- Can’t behave as an arch
- Becomes a seesaw
- Stands by gravity alone
- Like Forth Bridge

New(ish) problem

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- Has taken me 18 years to understand
- Only got there by measurement
- Expected the pier to rock but the mechanism was wrong.

Calculation is simple

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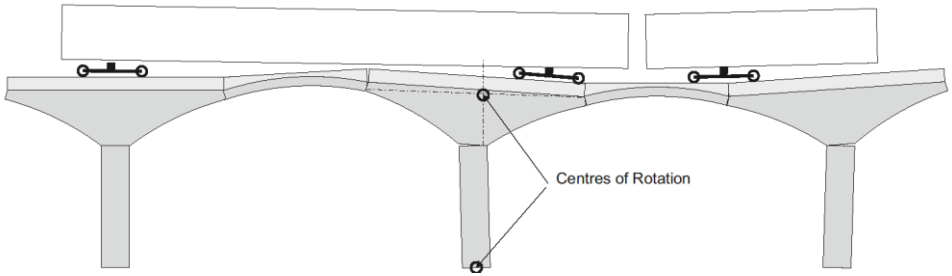
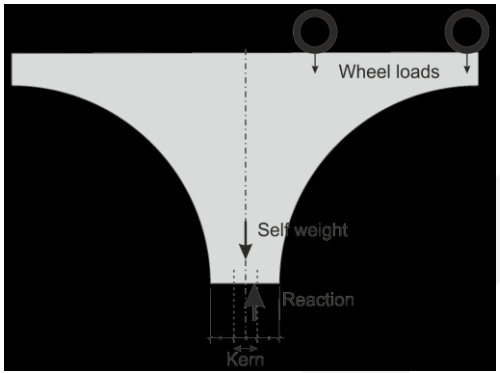
- Look at the weight on the pier
- Add an off centre load
- How far must the vertical reaction move





17m

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Movement (deflections) V small

But enough to cause damage to the bridge

And death to anyone below

Divided piers

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- OK, relieving arches, but what do they relieve?
- Main thing is the view

Drew this in 2002

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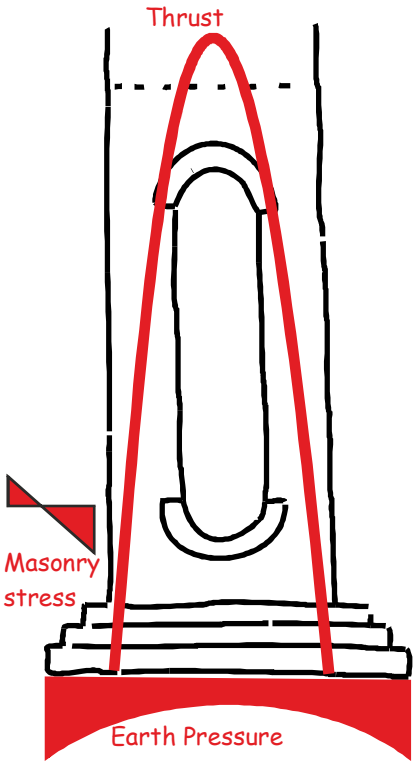
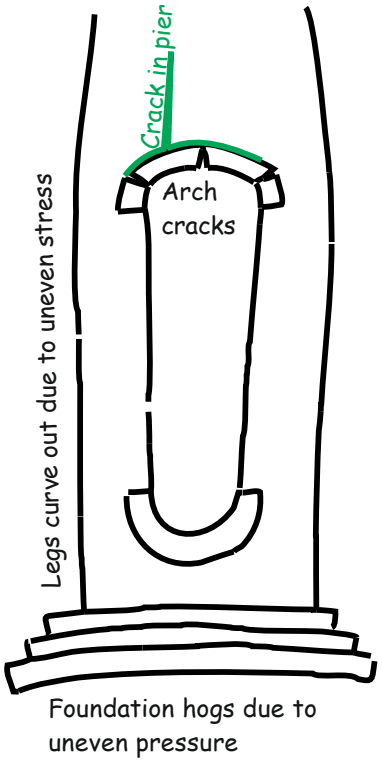
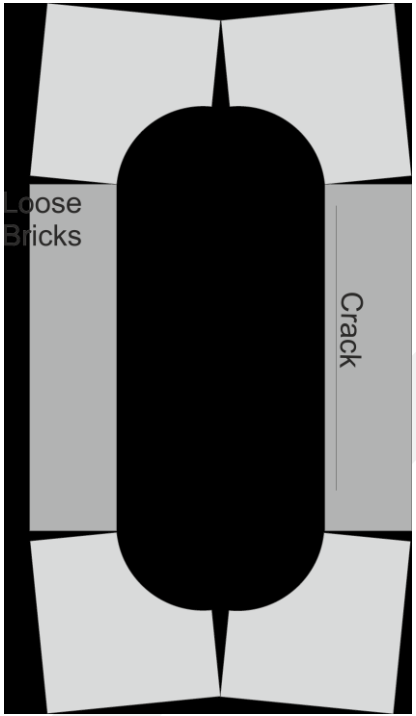




Missed implication

- Rotation means:
- All load moves to inside face
- Face splits off
- Arches sitting on points
- Bricks rattled loose



Balcombe Viaduct

Foundation has broken its back

Evidence found 2017

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Marsh Lane Leeds

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Dimensions, shape and records

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- Most site surveys not fit for purpose
- Not properly specified
- Laser scan, triumph of data over information
- Measurement needs understanding
- Sending girls and boys to do adults work
- WITHOUT EVEN TRAINING

Basic Spec

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- The bridge
- The whole bridge
- Nothing but the bridge.
- In bridge coordinates
- Properly registered

A medieval Bridge

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- New Bridge in Oxfordshire
- New in the sense that there were 2 older
- Now the oldest over the Thames

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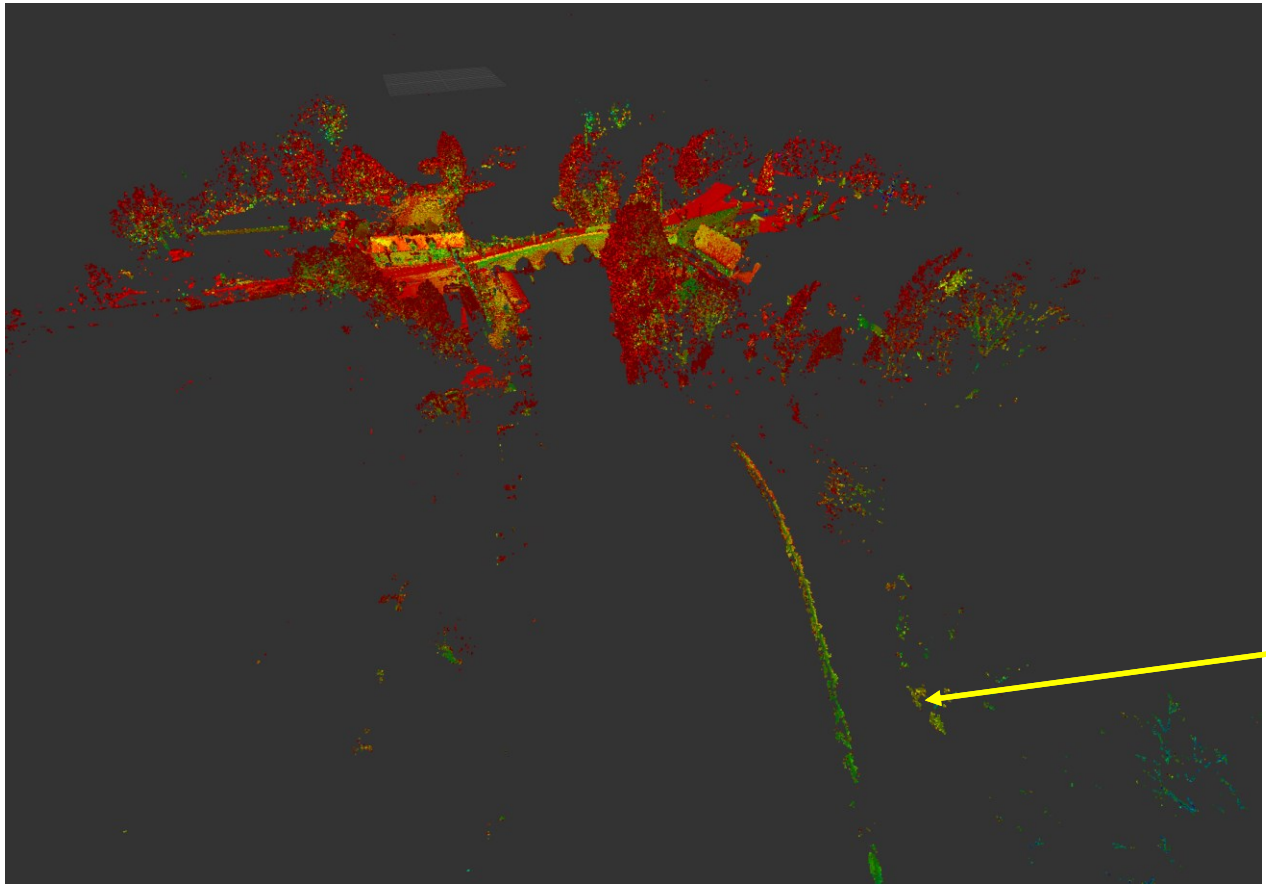
Point Cloud



Every leaf on this tree

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Big gaps in arches

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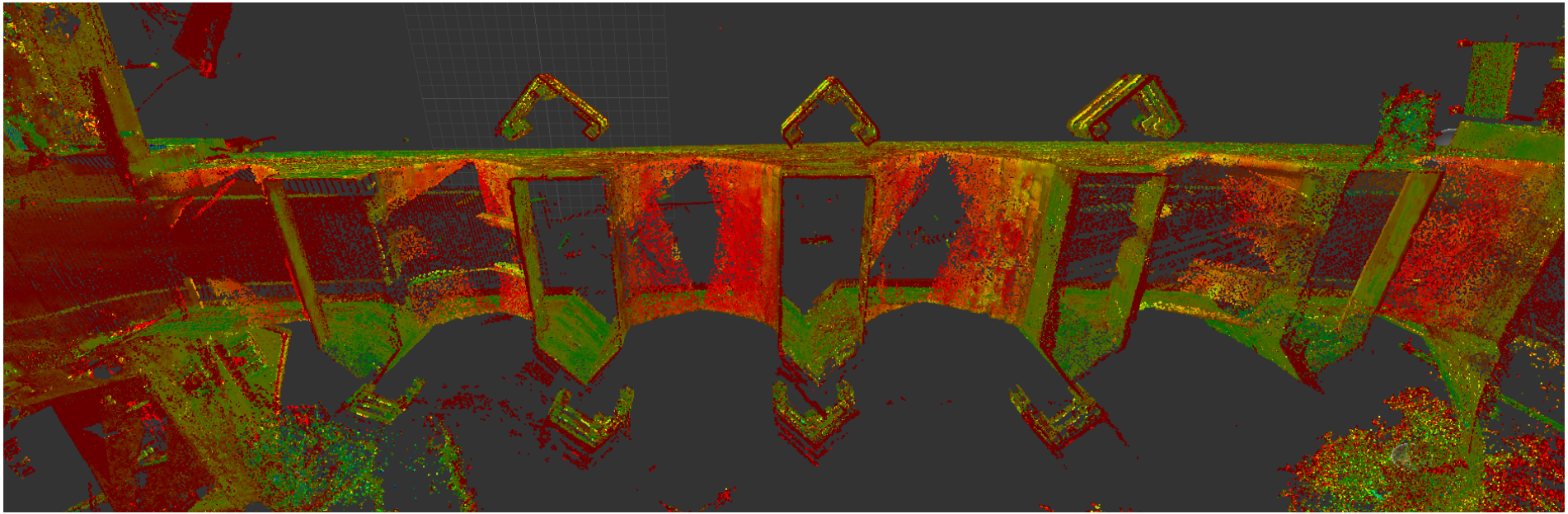

Common issues

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- Shadows, missing areas
- Substandard registration
- Huge volumes of data
- Information difficult to access

Can we do better than this?

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- More information
- Less data

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Photogrammetry

3D modelling of historic masonry structures

Six very different spans

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What do we do with the results?

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- Interrogate geometry
  - Extract planar sections
  - Fit curves and lines, determine current geometry
  - Explore possible original geometries
  - Explain deviations

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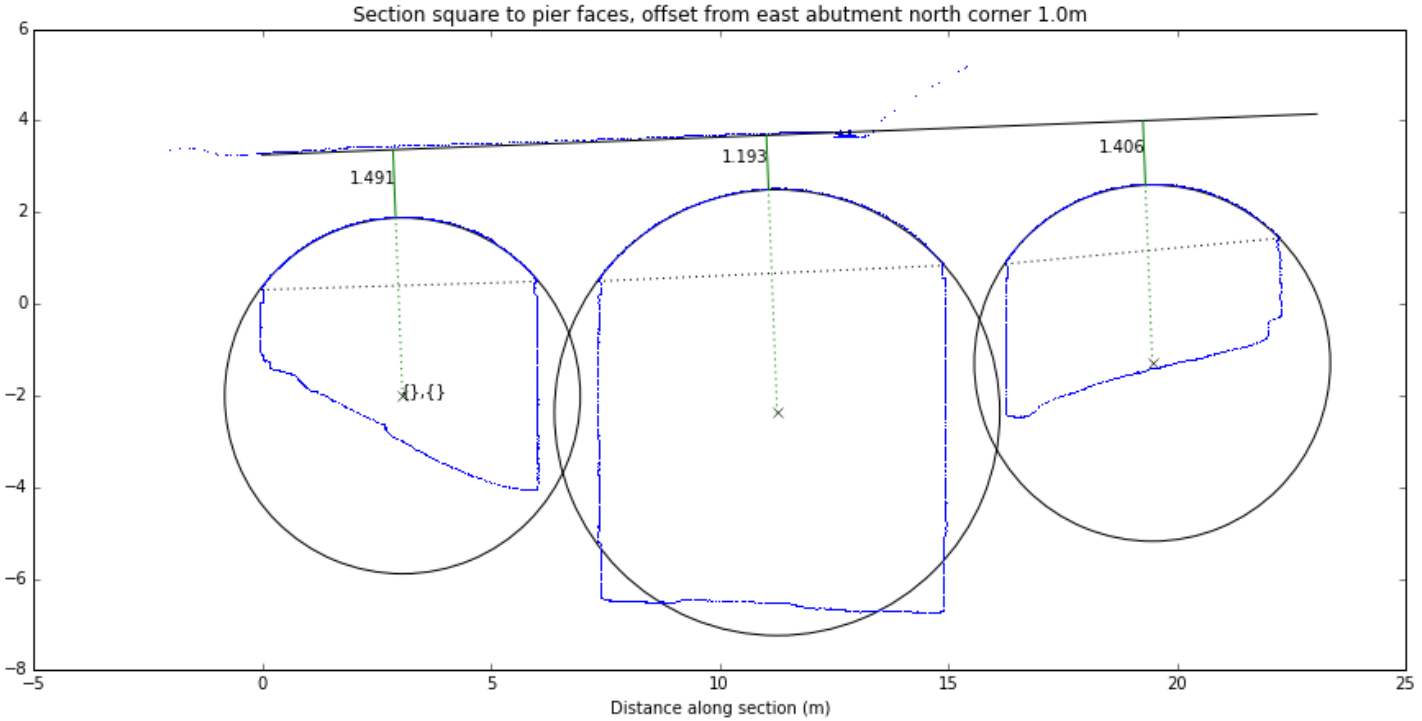

Geometry

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- Radii 3887mm, 4869mm, and 3892mm
- Or 12’9", 16’0", and 12’9”
  - Deviations 1mm, 8mm, 5mm

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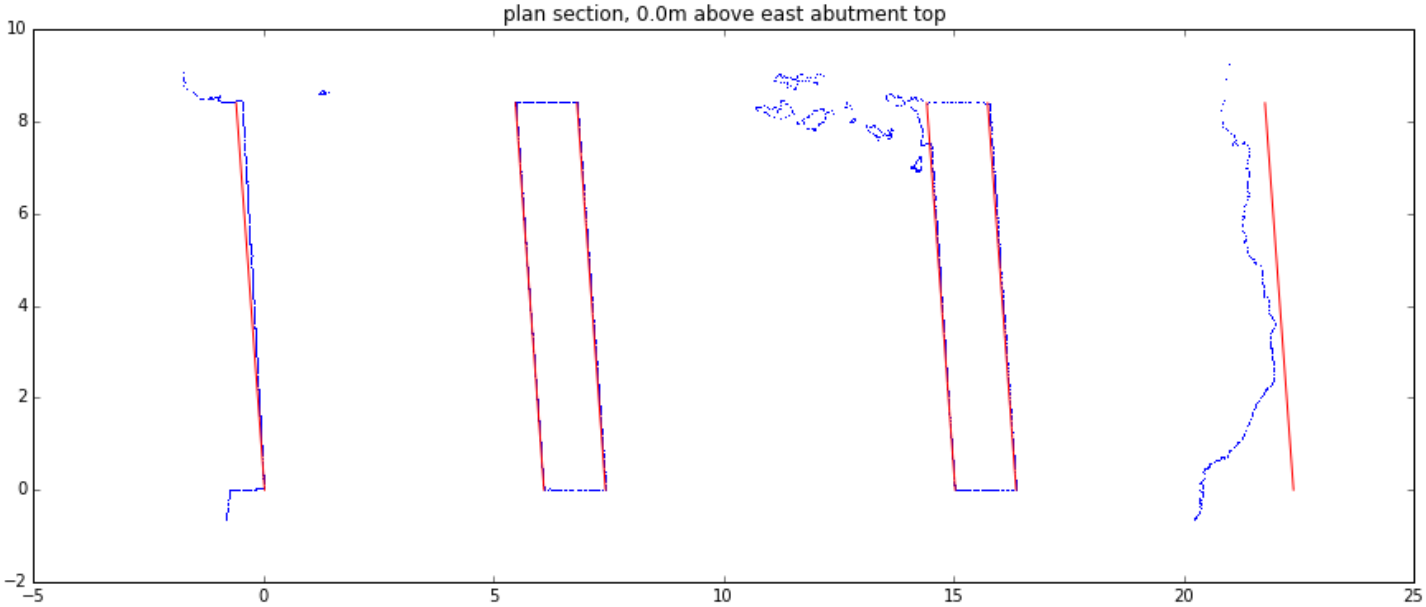

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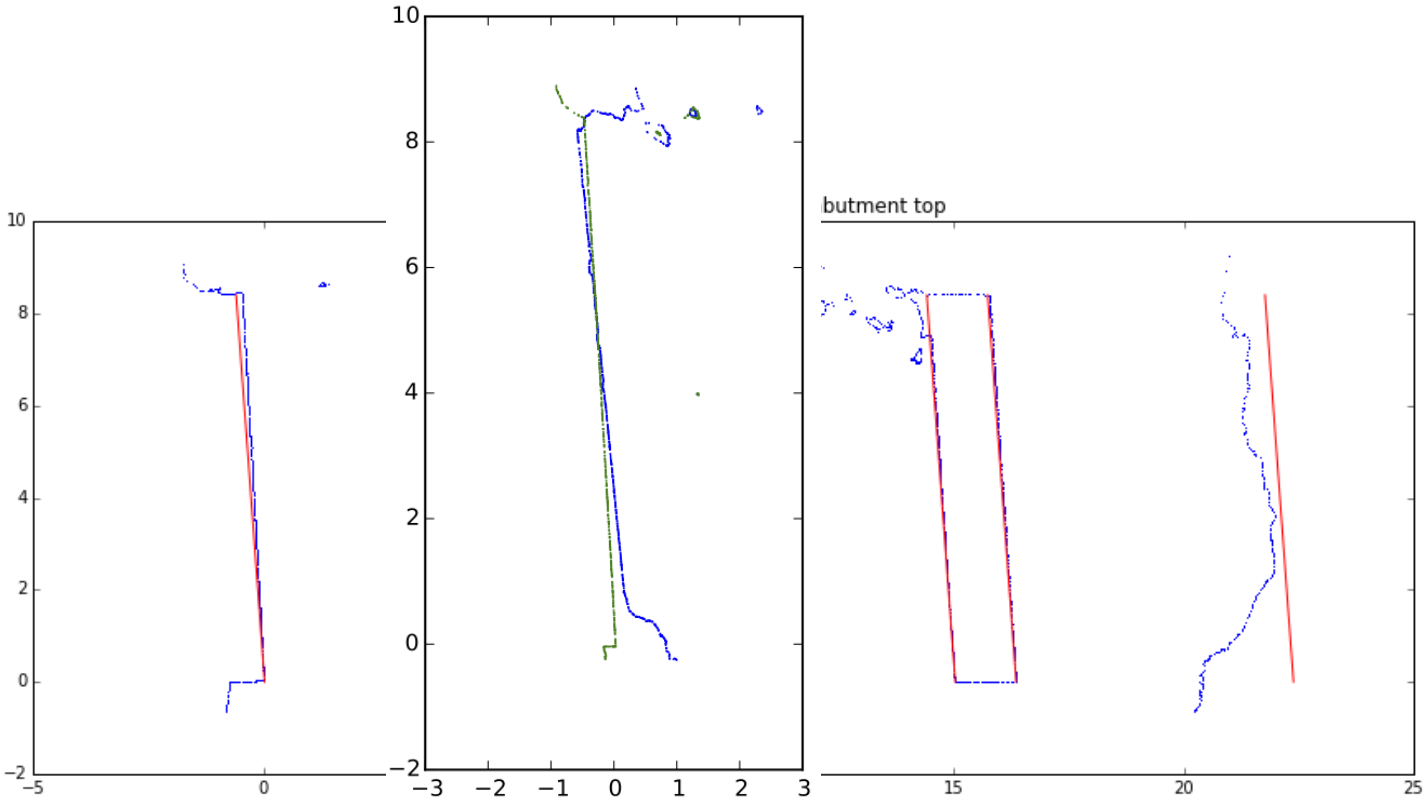

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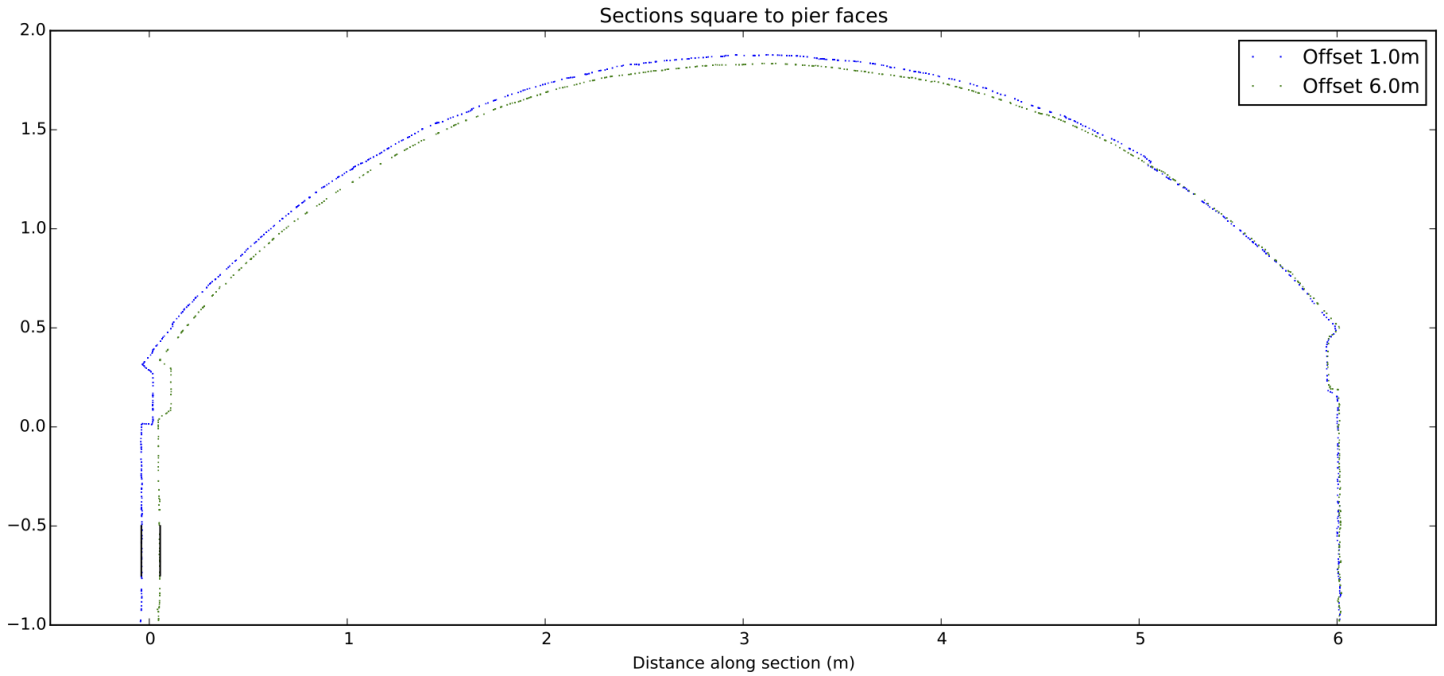

Need/want

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- Bigger models
- Better detail
- True orthographic projection
- Defined views
- Tools to aid interpretation
- Easy model comparison
- Annotations
- etc

And finally

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- The dire quality of inspection
- And inspection reports
- Just 3 examples of many

What's wrong with these dimensions

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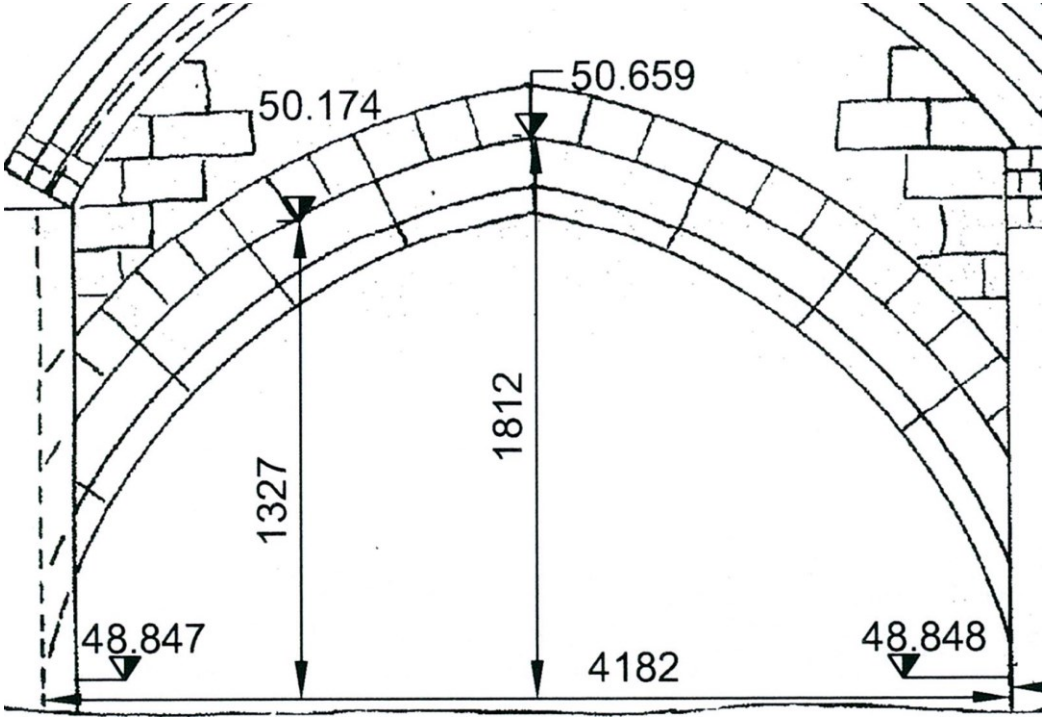

First arch job given to a grad with a simple analyse that message.

I regard that as abuse of grad and client.

And another

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Span	Rise	Pier	Batter
9227	3333		
9187	3379	3922	39
9221	3372	1151	43
9180	3339	1205	46
9202	3347	1208	45
9276	3367	1232	64

Span	Rise	Pier
30.27	10.94	
30.14	11.09	12.87
30.25	11.06	3.78
30.12	10.95	3.95
30.19	10.98	3.96
30.43	11.05	4.04

Measure to <9mm?

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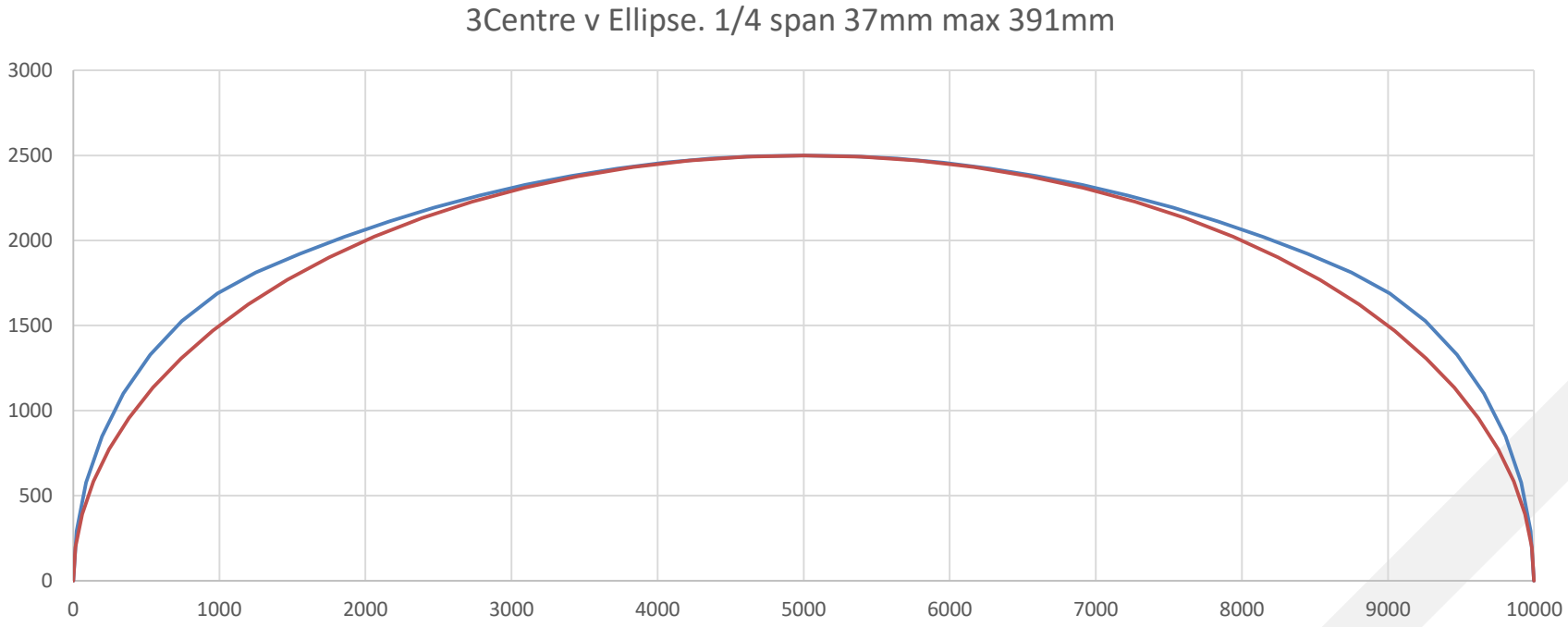

A photo of an arch

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Conclusions

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- Don’t believe what you are told
- Measure and analyse to TEST not confirm
- Keep your eyes and mind open
- Assume no one else does.
- AND I MEAN NO ONE

Links and more details

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- Email bill@billharveyassociates.com
- Marsh Lane compact model https://skfb.ly/PPQM
- Balcombe model https://skfb.ly/6o6oH
- Hidden defects note: goo.gl/twh7h8
- Twitter @billharvey2