The Institution of Structural Engineers
South – Eastern Counties Branch Meeting

DESIGN AGAINST ALL ODDS:

2 + 2 = ?

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DESIGN AGAINST ALL ODDS:

2 + 2 = ?

OR

Uncertainty in Design

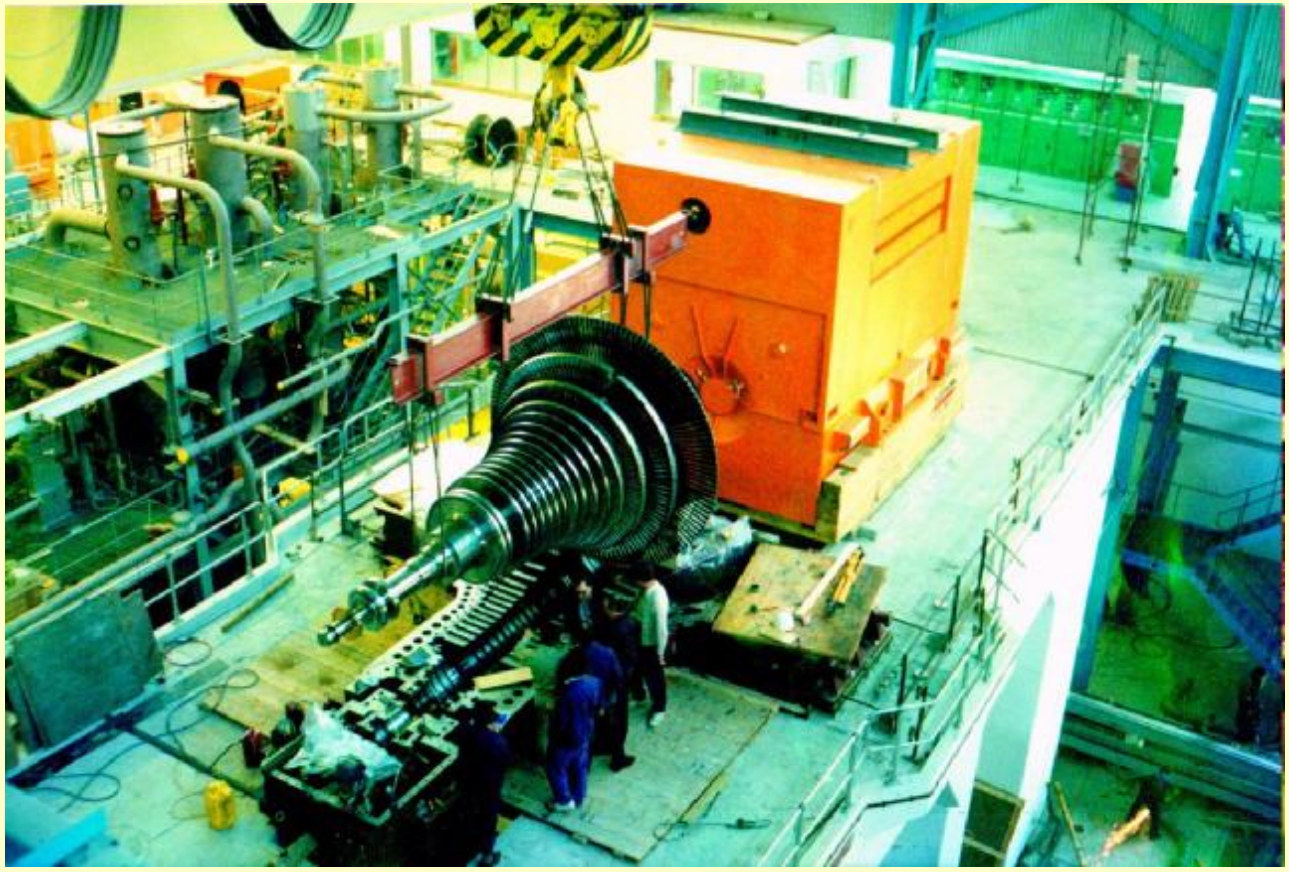
Introduction

Uncertainty in the design of structures

- **Accidental loading**
- **Dynamic Loading**
- **Earthquakes**

Introduction

Introduction



Introduction

Introduction

- **Early Prejudices**
- **What is the Common Denominator?**
- **What is the Link?**
- **What is the Difference?**
- **What are the Lessons?**
- **Uncertainty and Robustness**
- **Confirmed Prejudice**
- **Questions**

Early Prejudices

1

All Constants – aren't

All variables – don't

Early Prejudices

2

Where is the line of force?

What is the load path?

Early Prejudices

3

There is no more common error than to assume that, because prolonged and accurate mathematical calculations have been made, the application of the result to some fact of nature is absolutely certain.

A. N. Whitehead

Early Prejudices

4

An Engineer is a person to whom

2 + 2 = Nearly 4

What is the Common Denominator?

Morecambe Bay

Turbine Foundation

The London Eye

Design against all odds

Nuclear Storage Pond

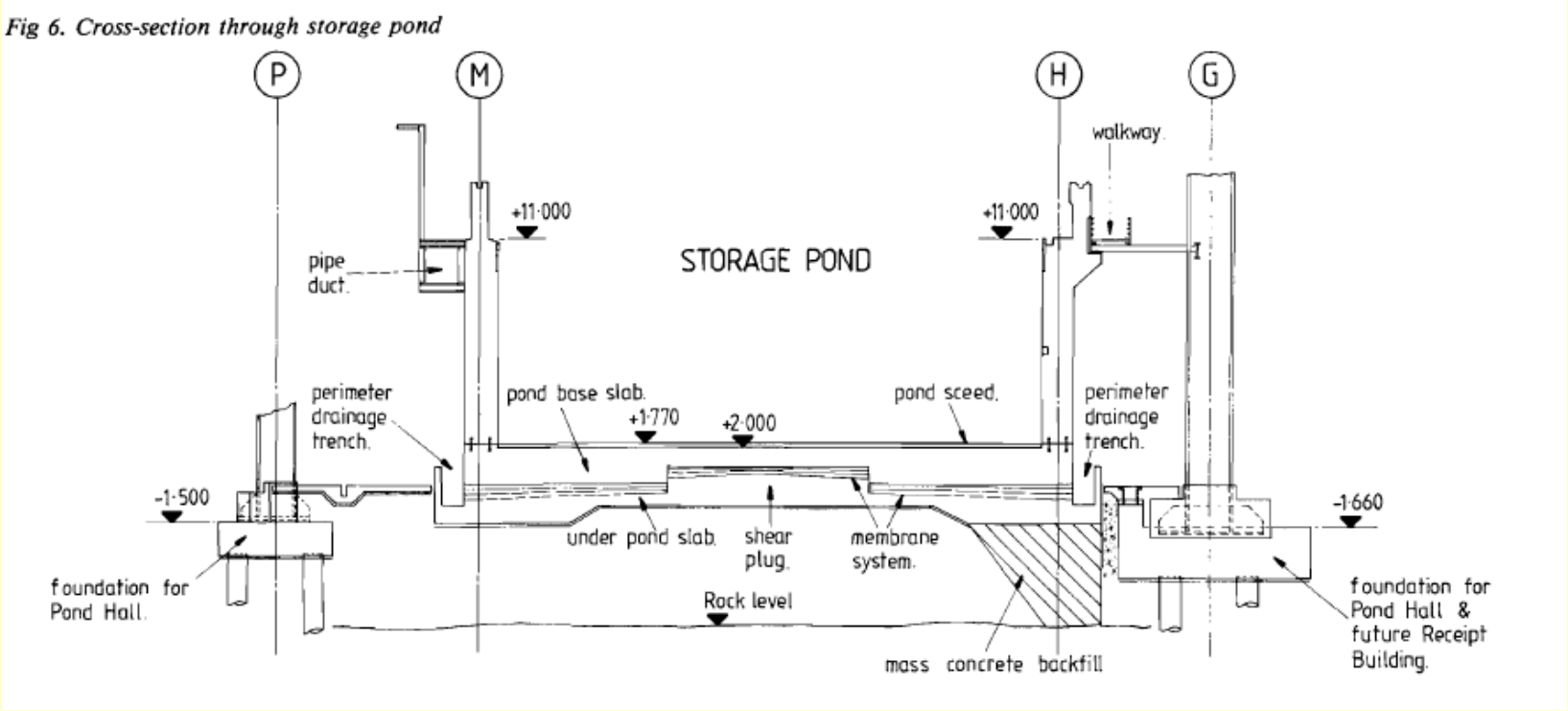
What is the Common Denominator?

The Common Denominator is

The Importance of the Basis of design

Design against all odds

Fig 6. Cross-section through storage pond



Design against all odds

Introduction

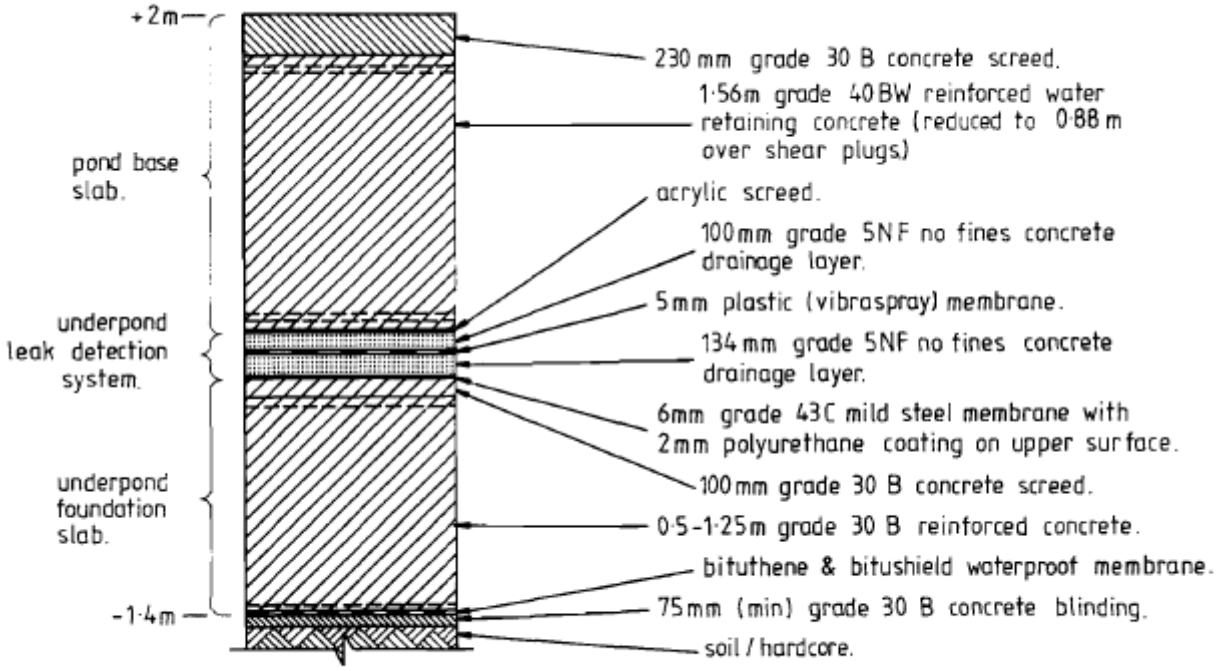


Fig 7. Pond base and membrane system

Design against all odds

Introduction

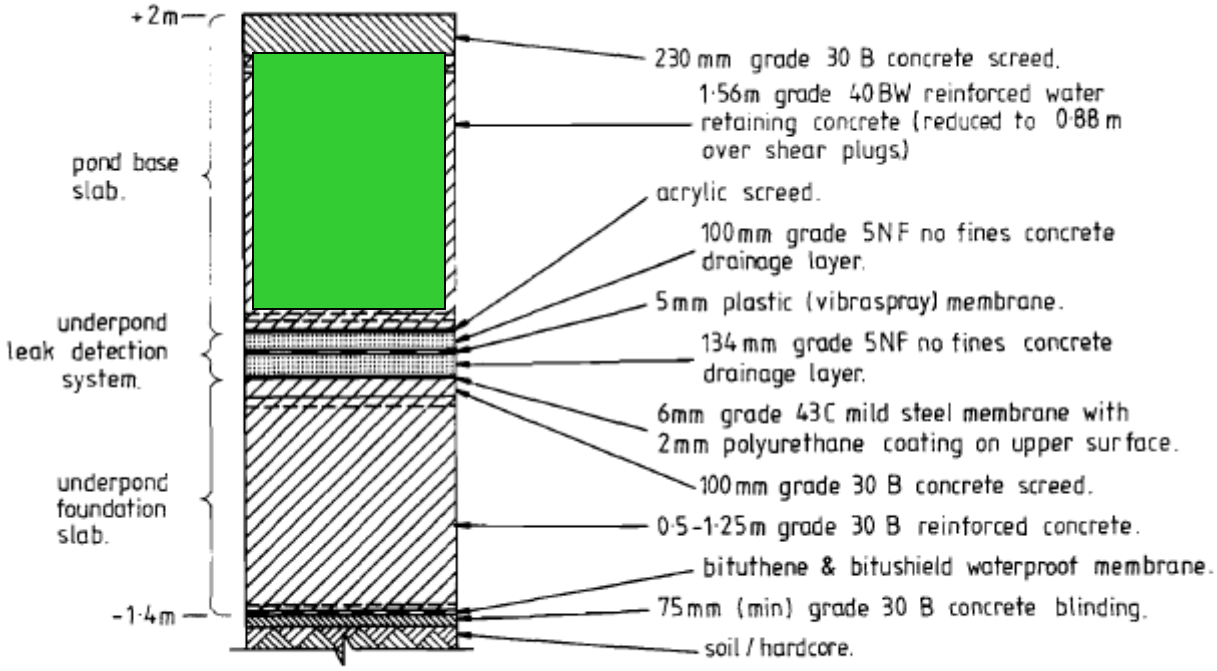


Fig 7. Pond base and membrane system

Introduction

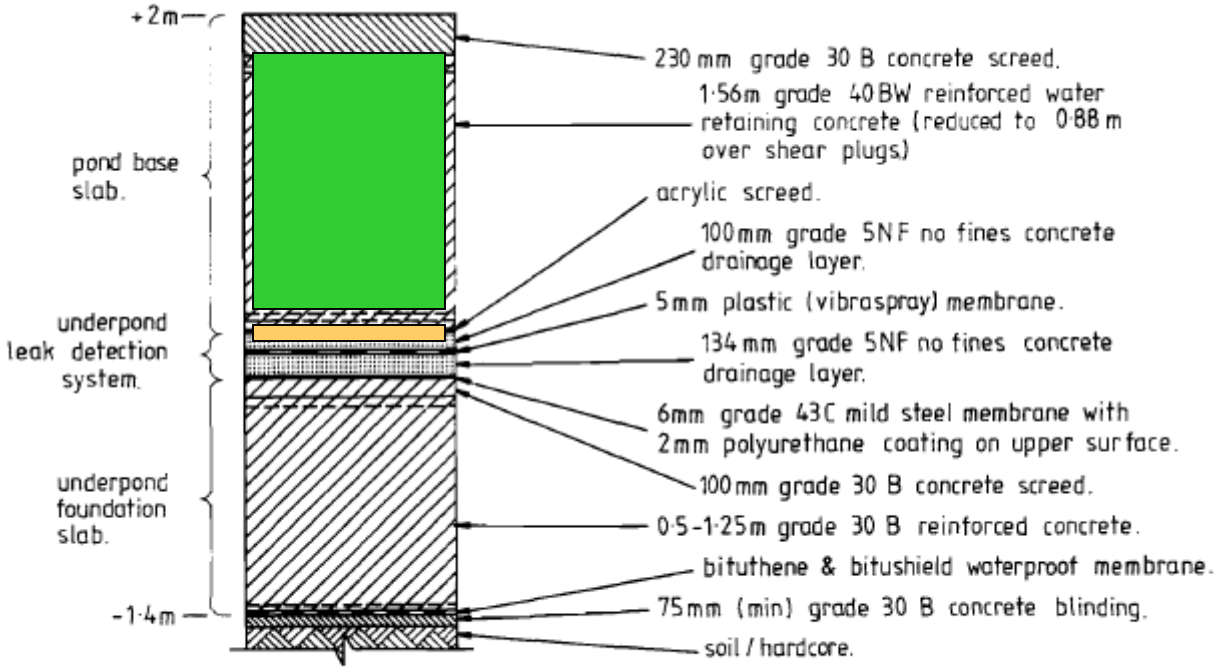


Fig 7. Pond base and membrane system

Introduction

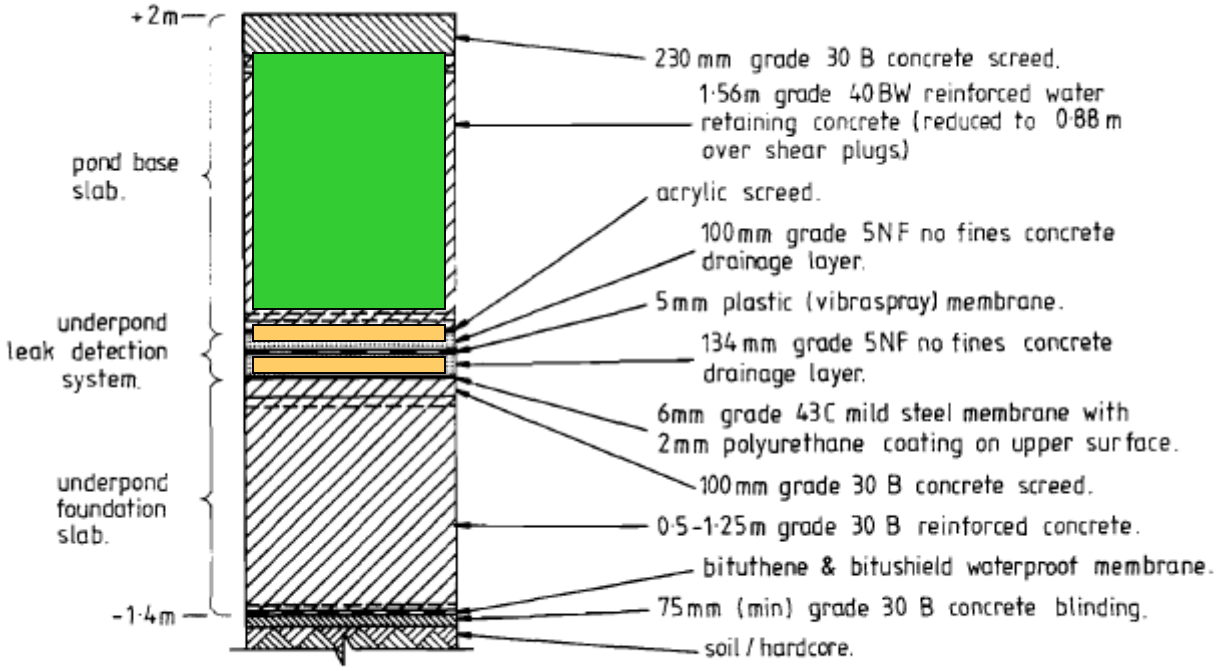


Fig 7. Pond base and membrane system

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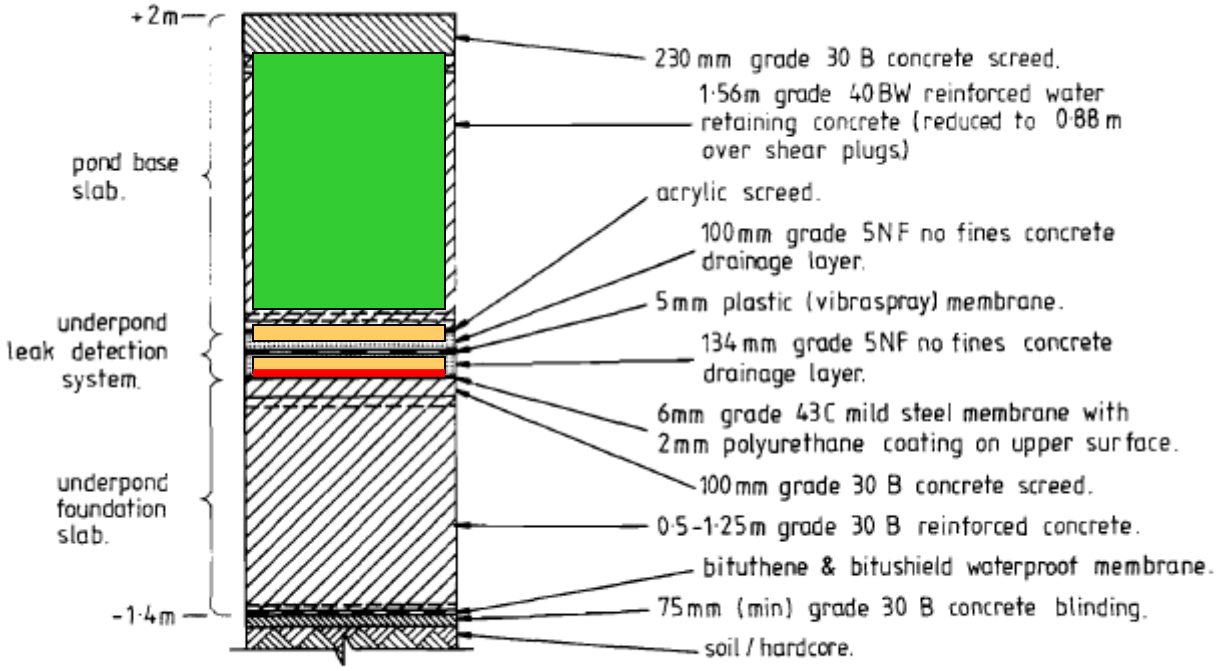

Fig 7. Pond base and membrane system

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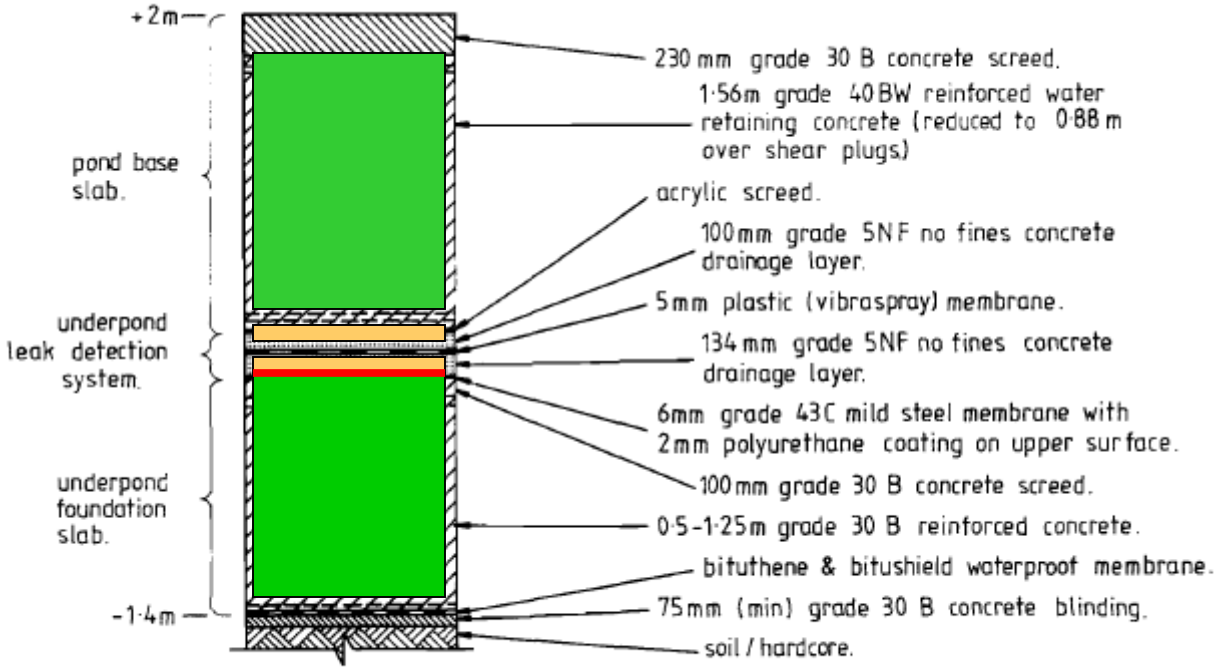


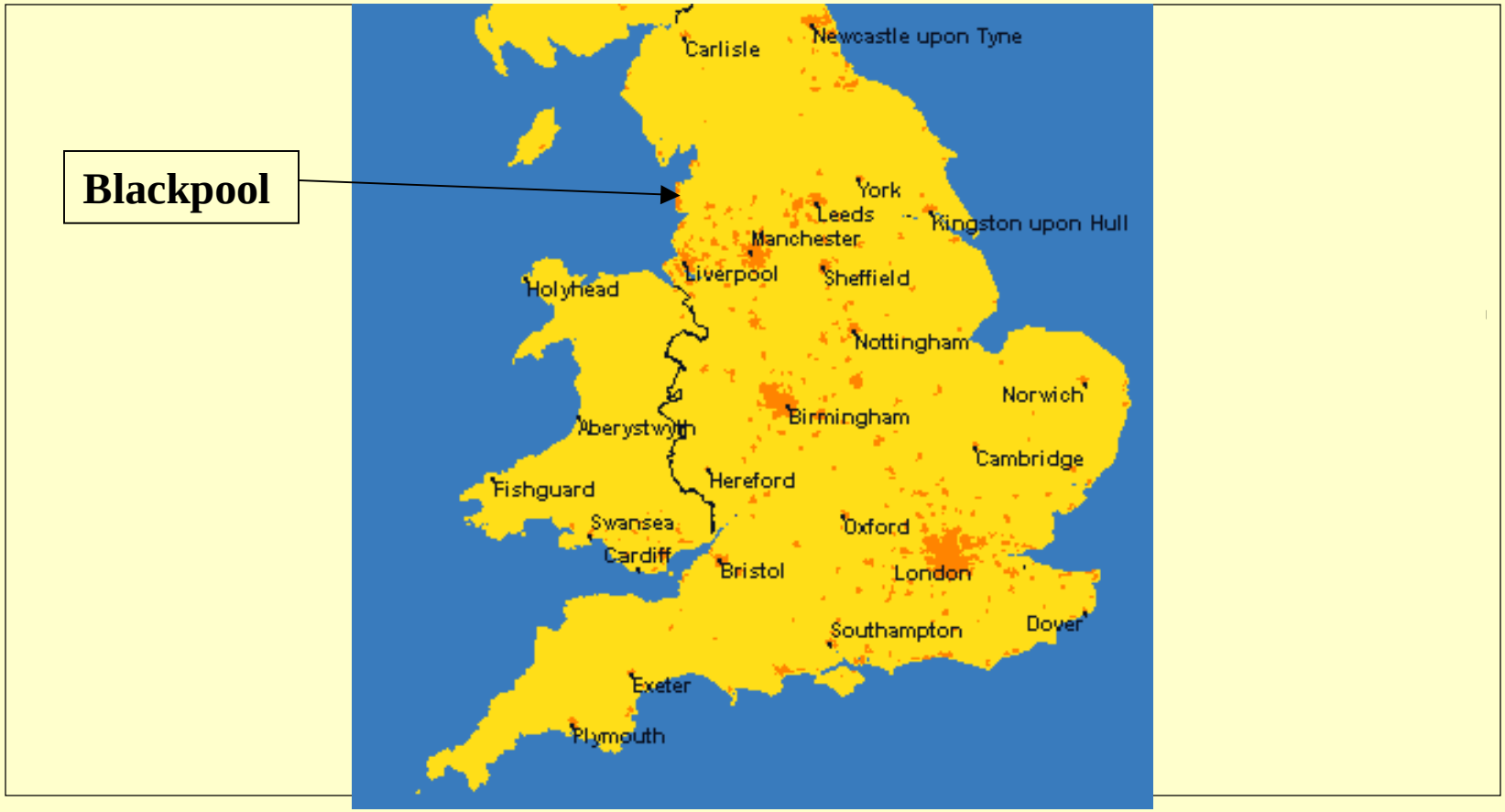
Fig 7. Pond base and membrane system

What is the Link?

Design against all odds

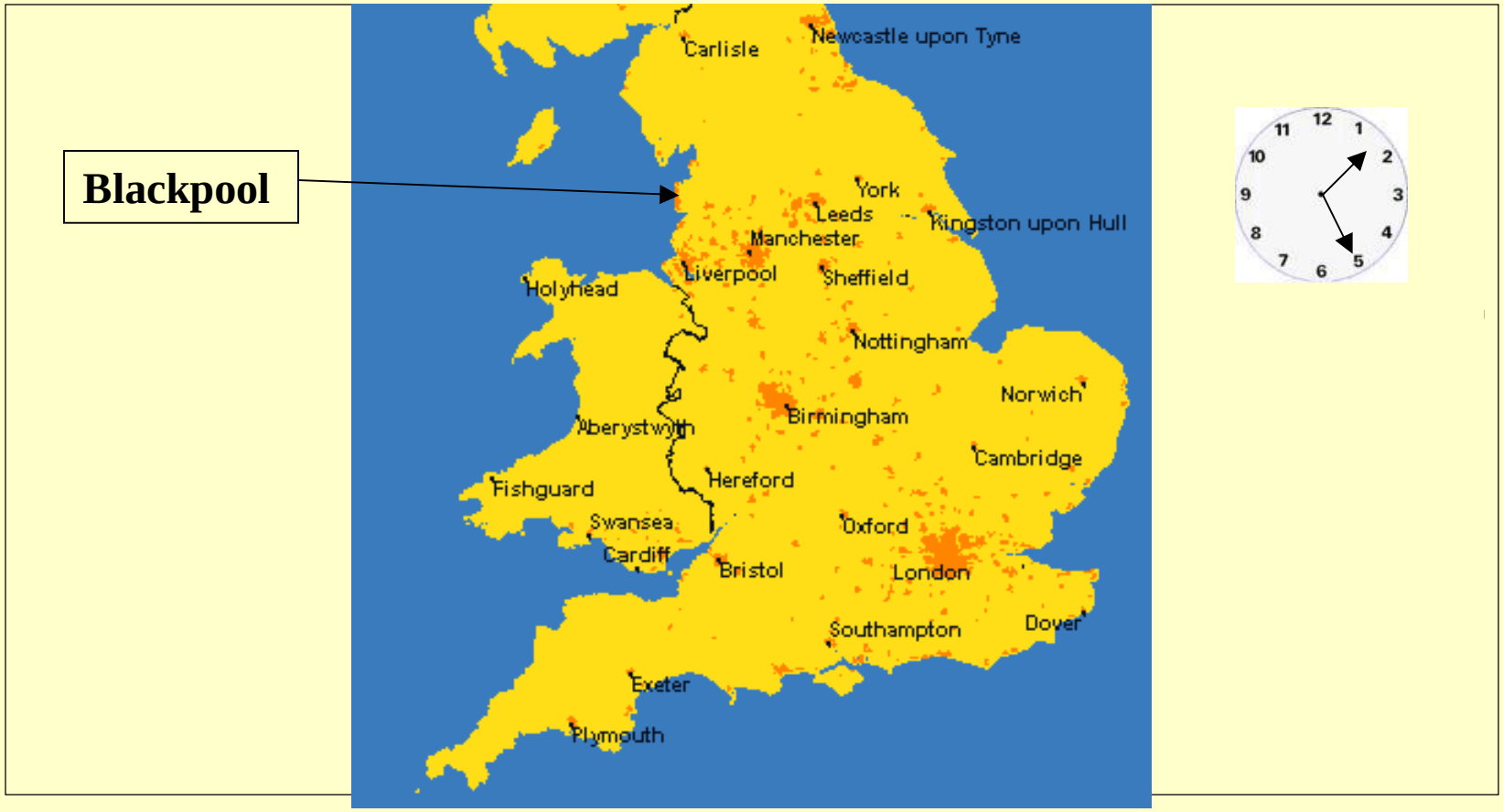
1930's Arcade

Design against all odds



Design against all odds

19th September 1992



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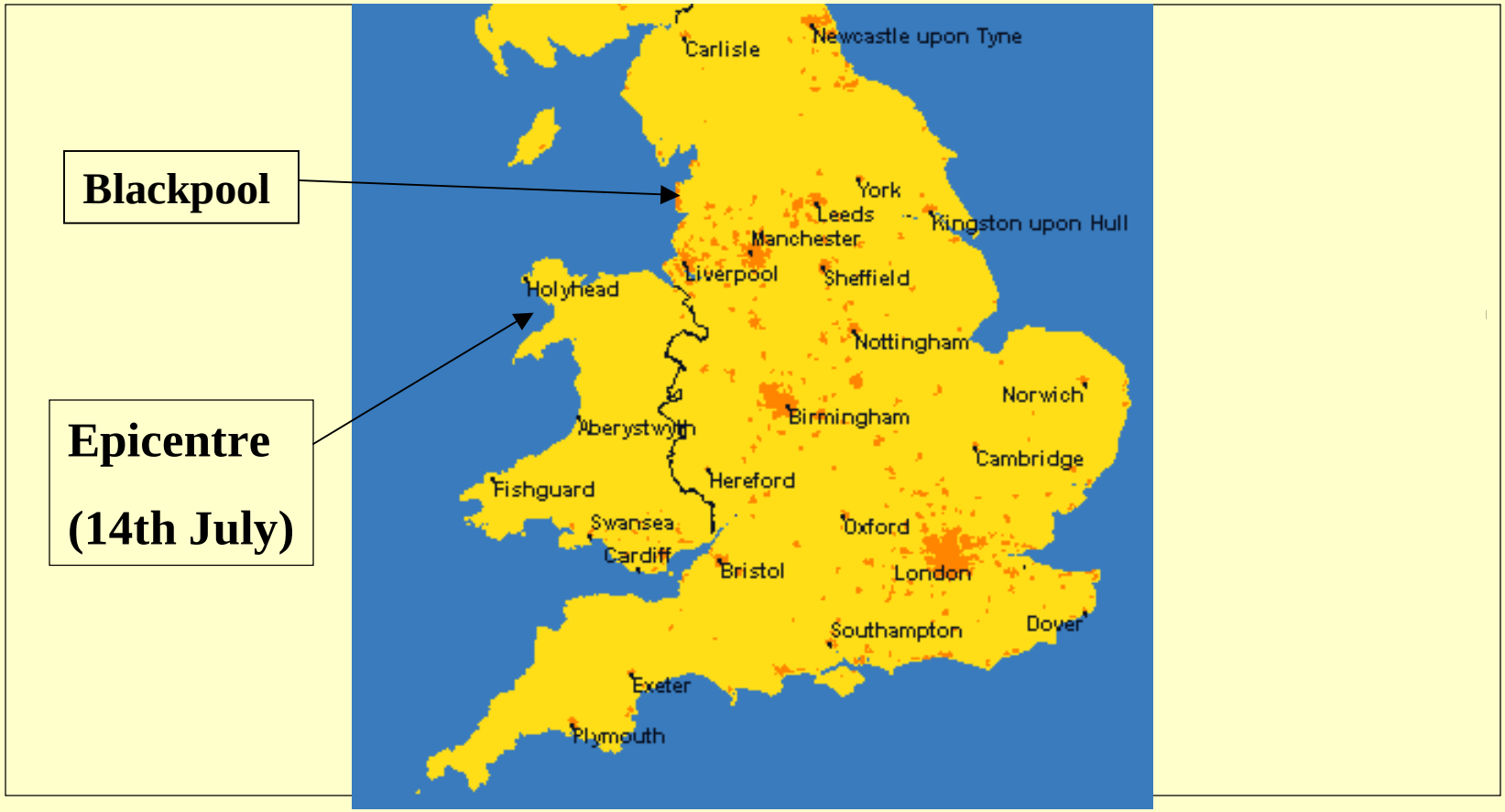

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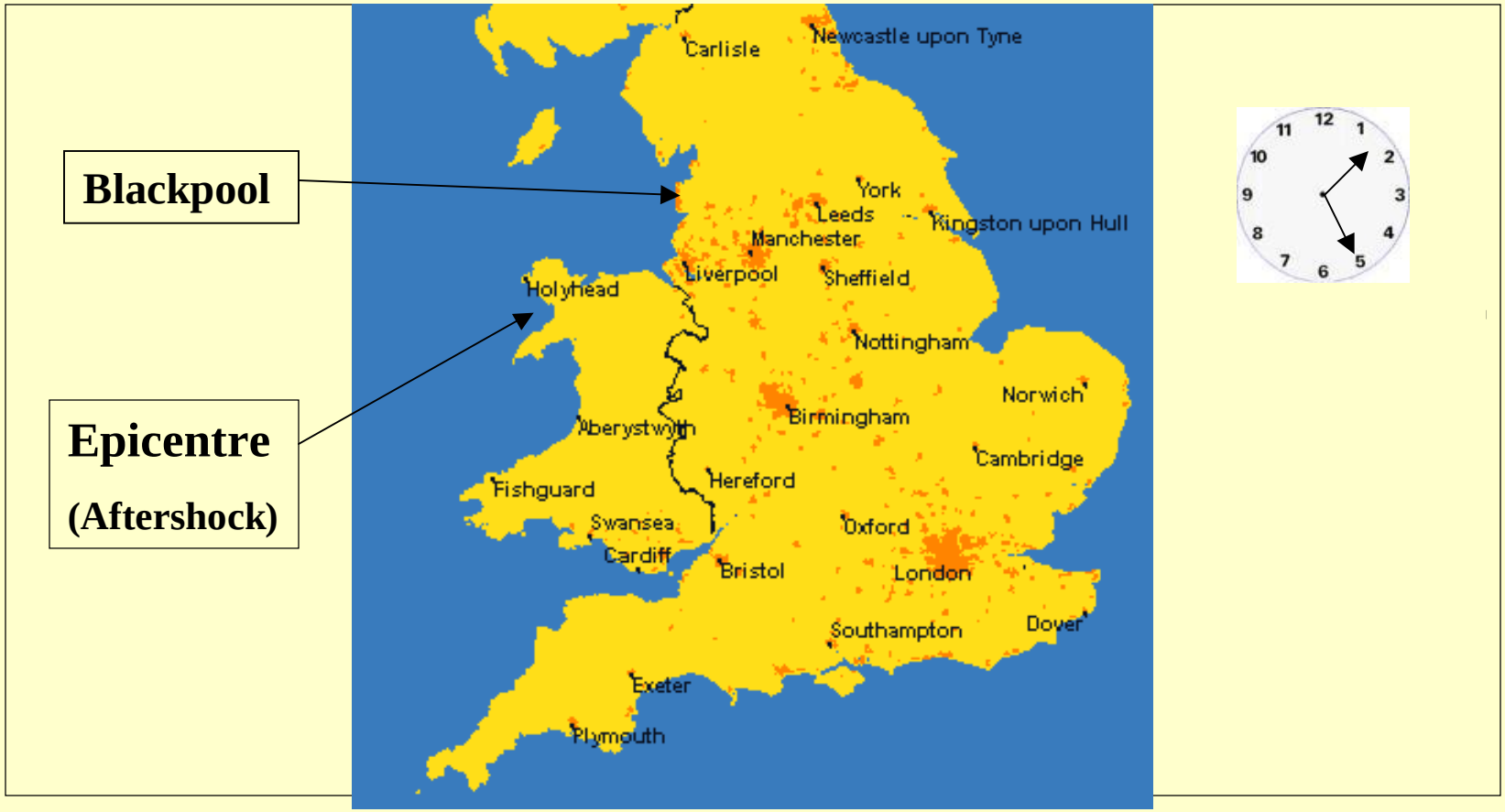

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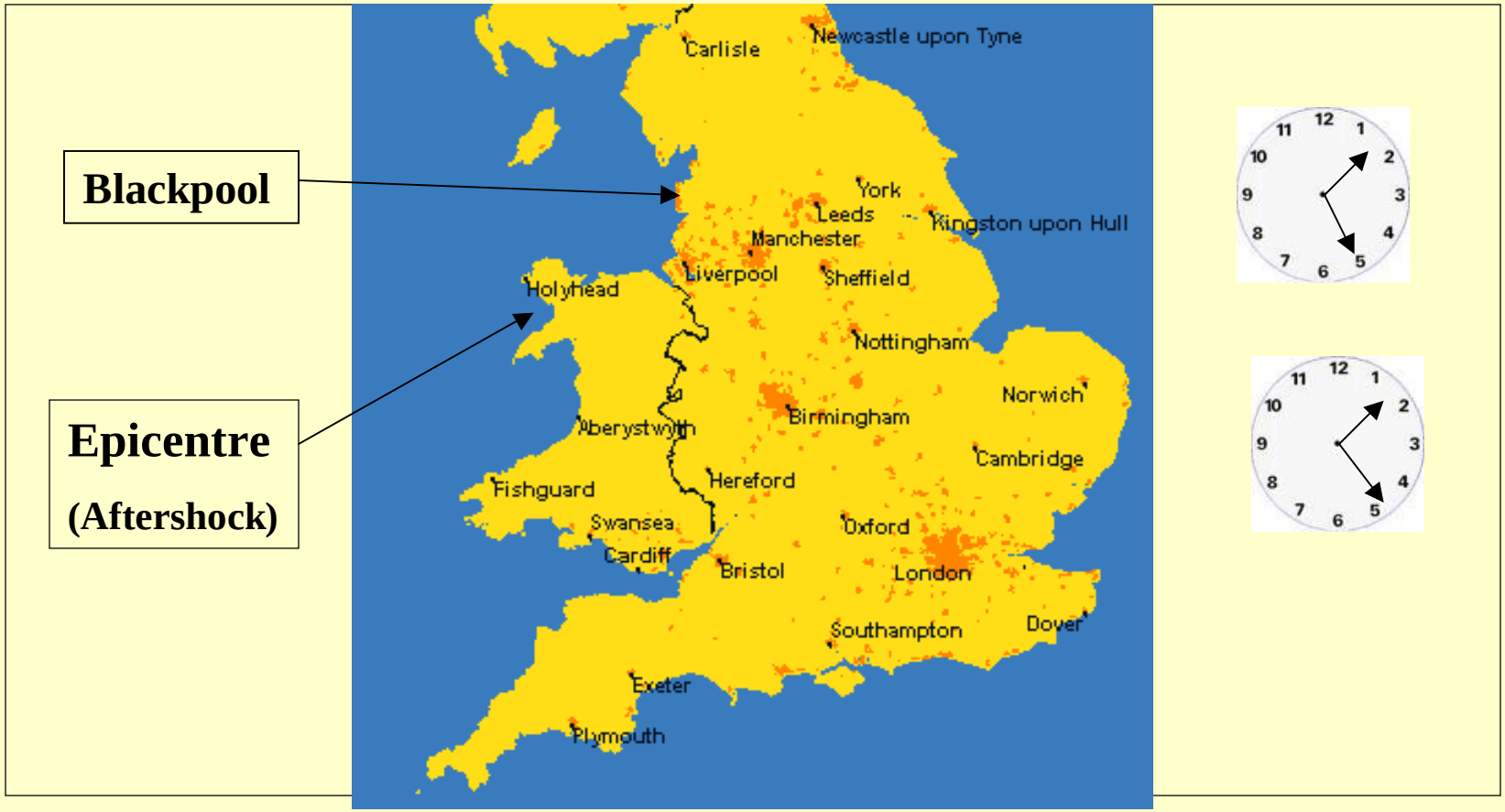

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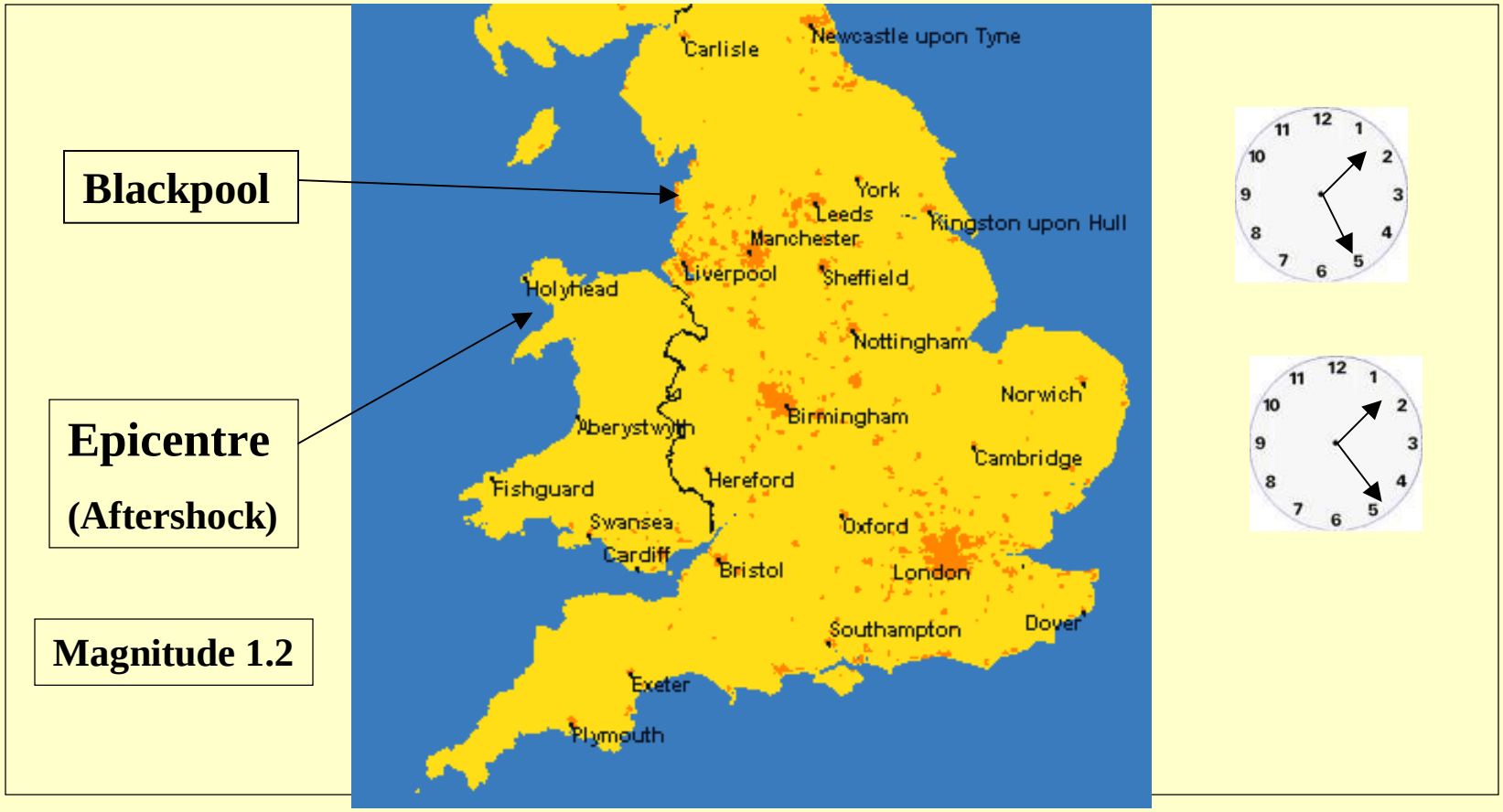

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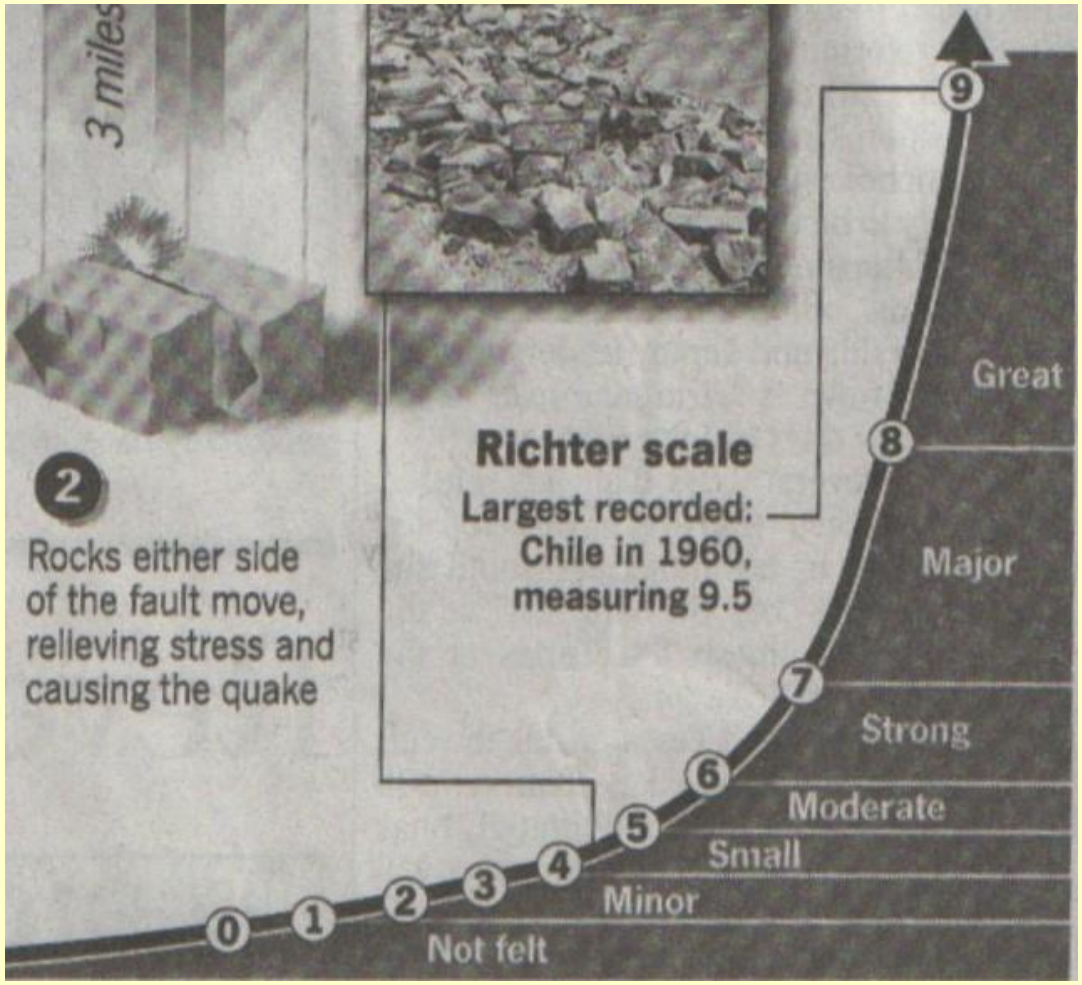

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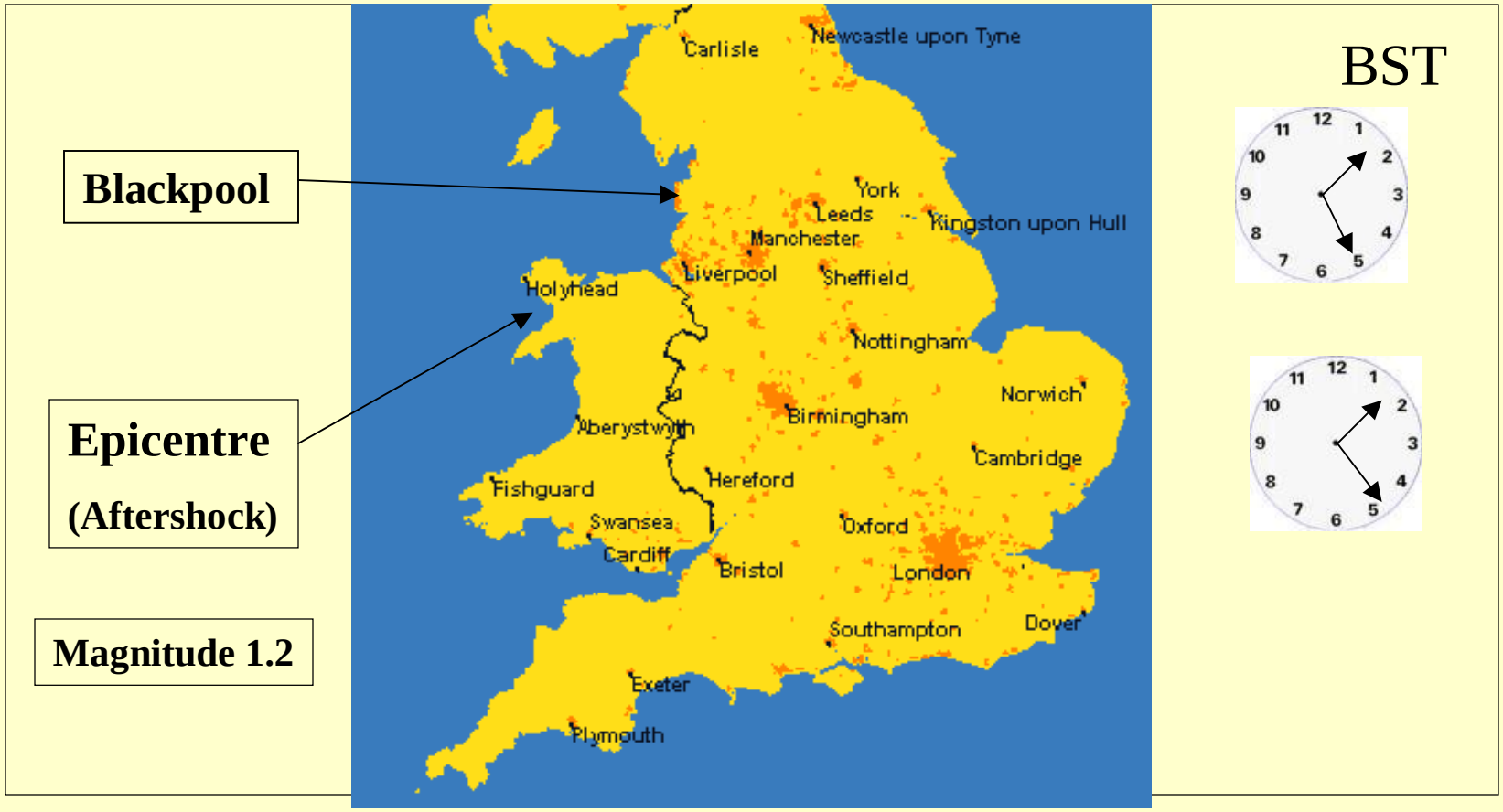

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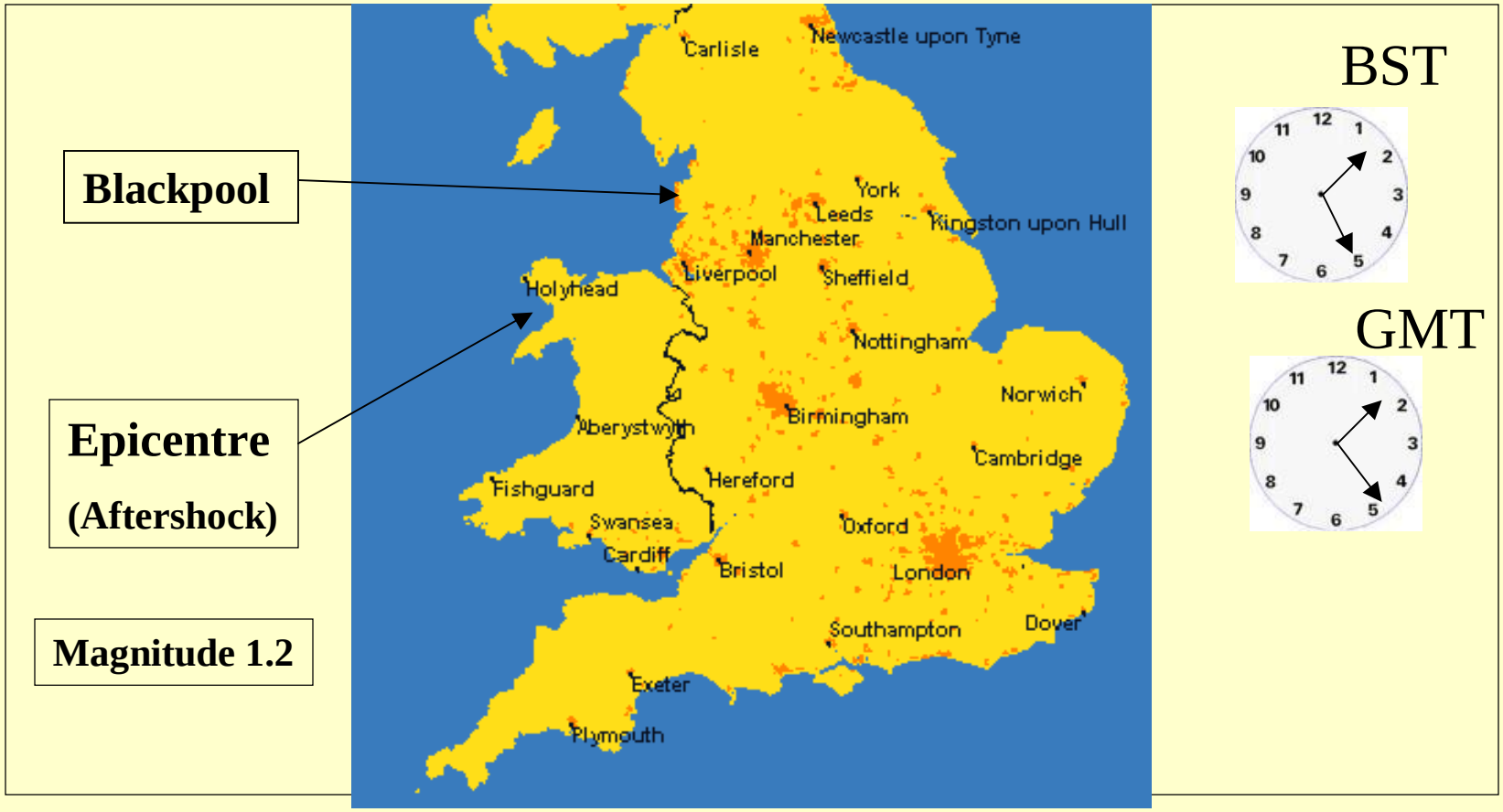

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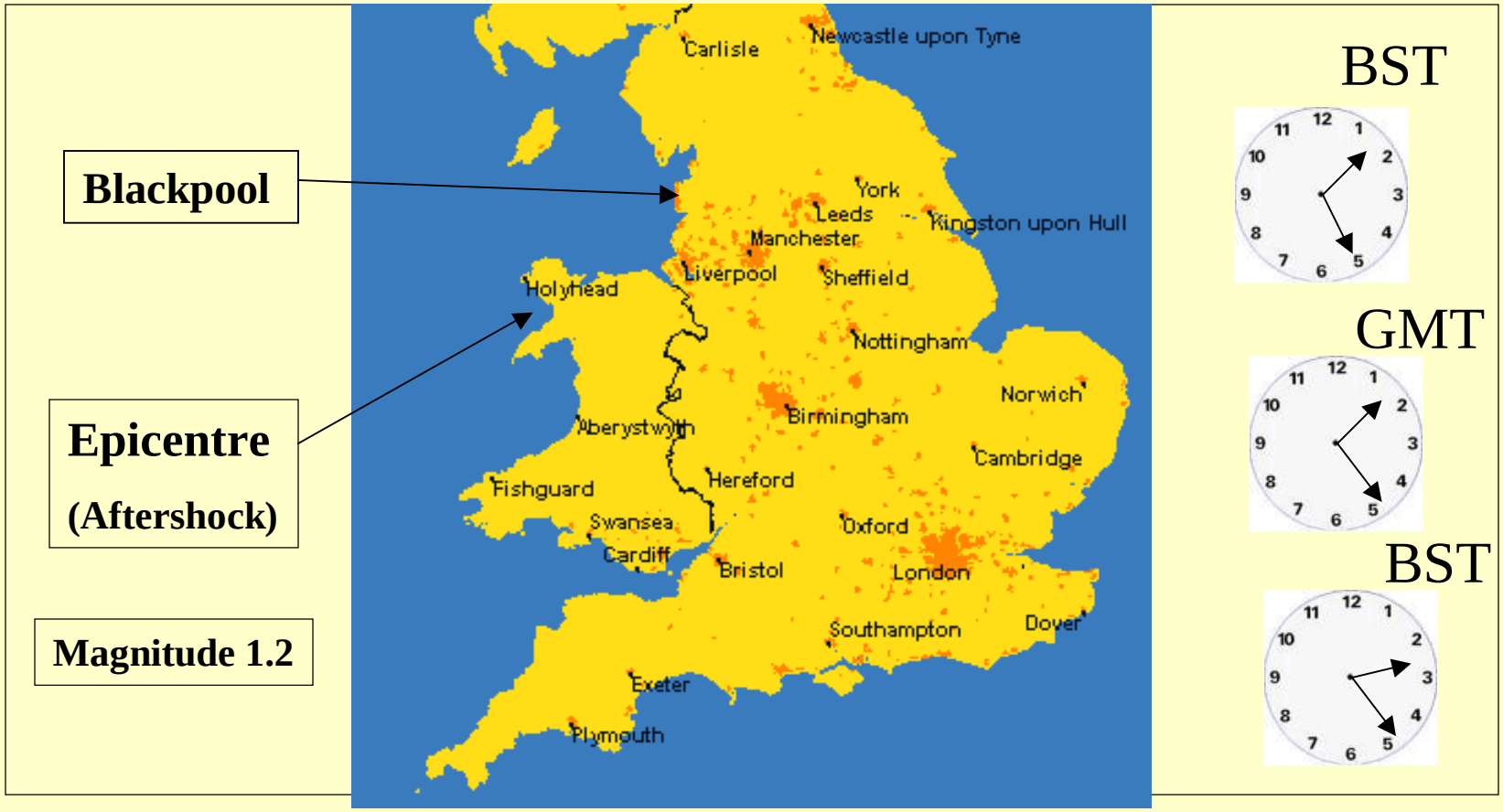


Early Prejudices

4

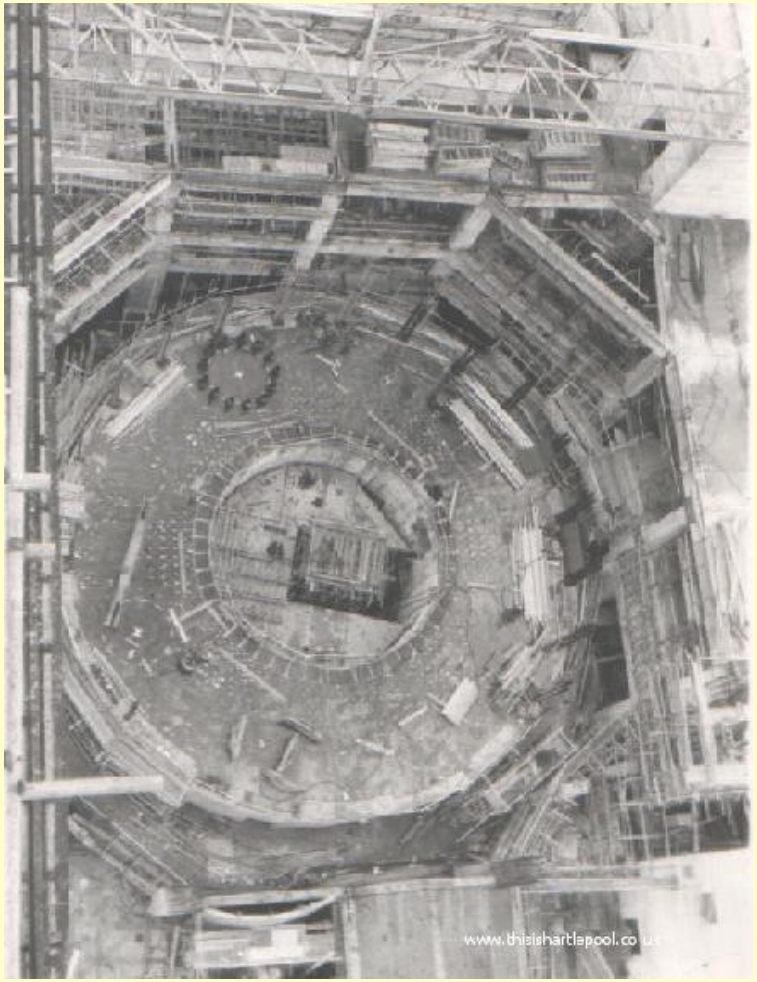
An Engineer is a person to whom

2 + 2 = Nearly 4

Or in this case about 10

What is the Link?

Concrete Pressure Vessel



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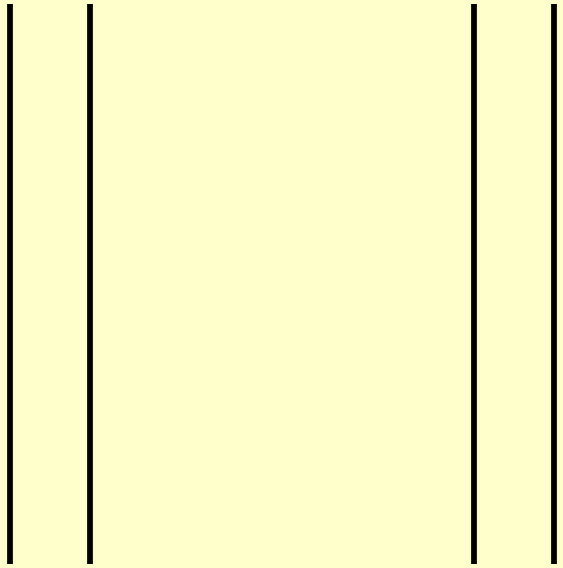

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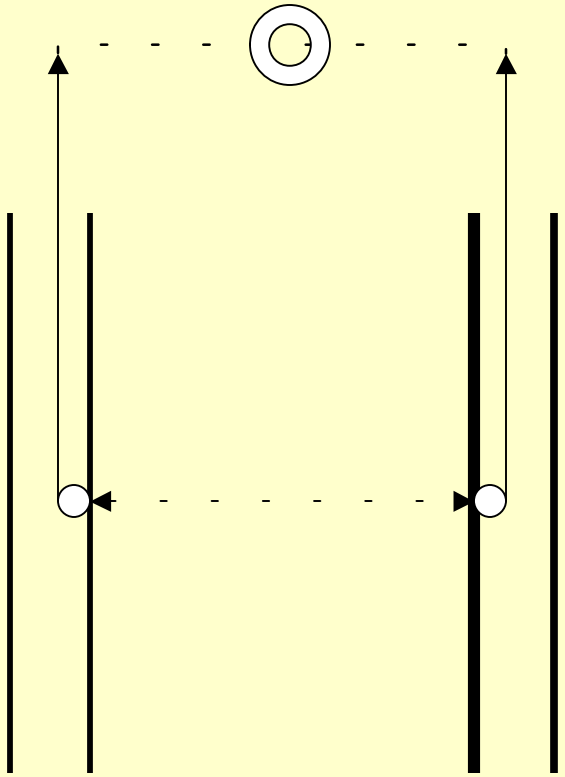
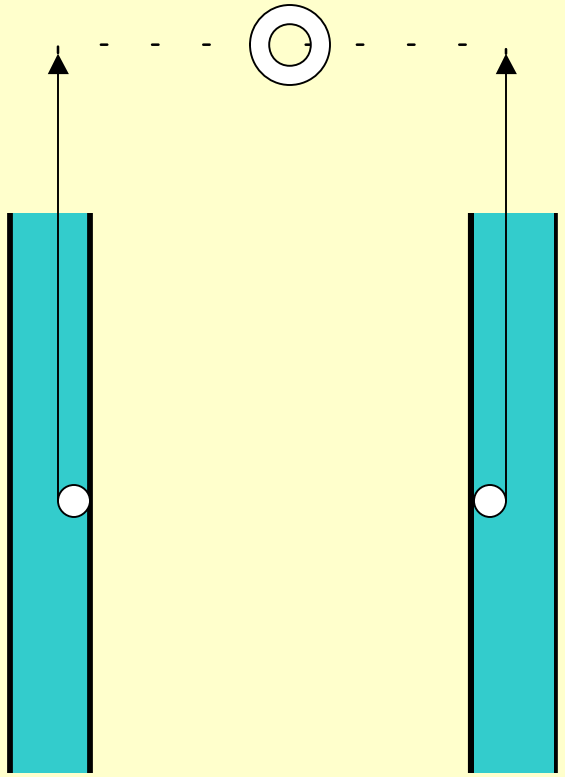


Ultrasonic probes

Design against all odds

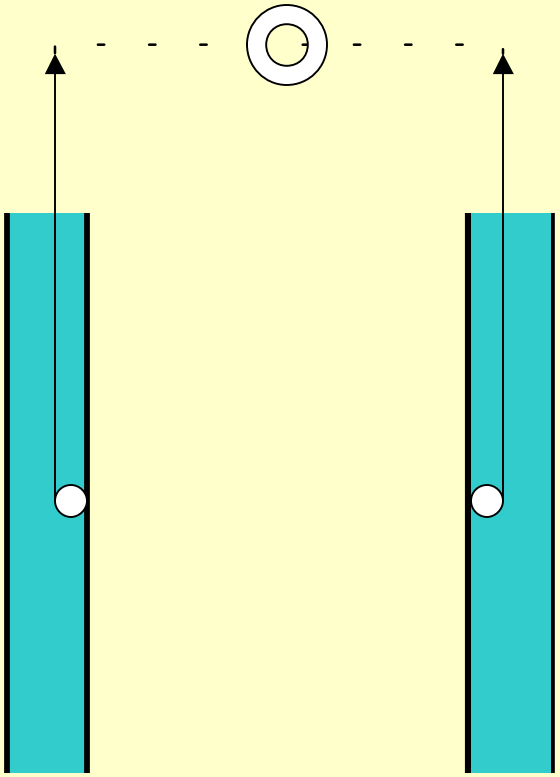


Ultrasonic probes

Filled with water

Reading for Good Concrete = 280

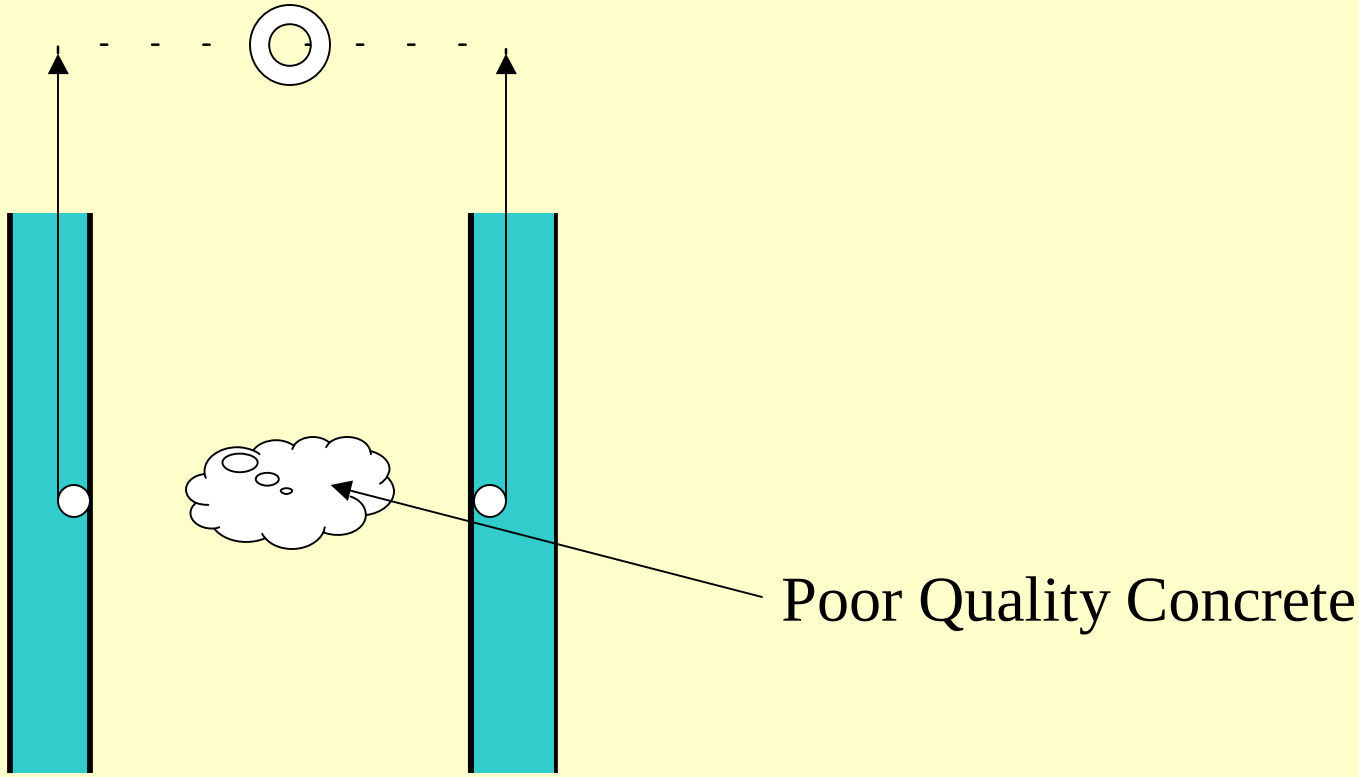
Design against all odds



Actual Range = 260 - 300

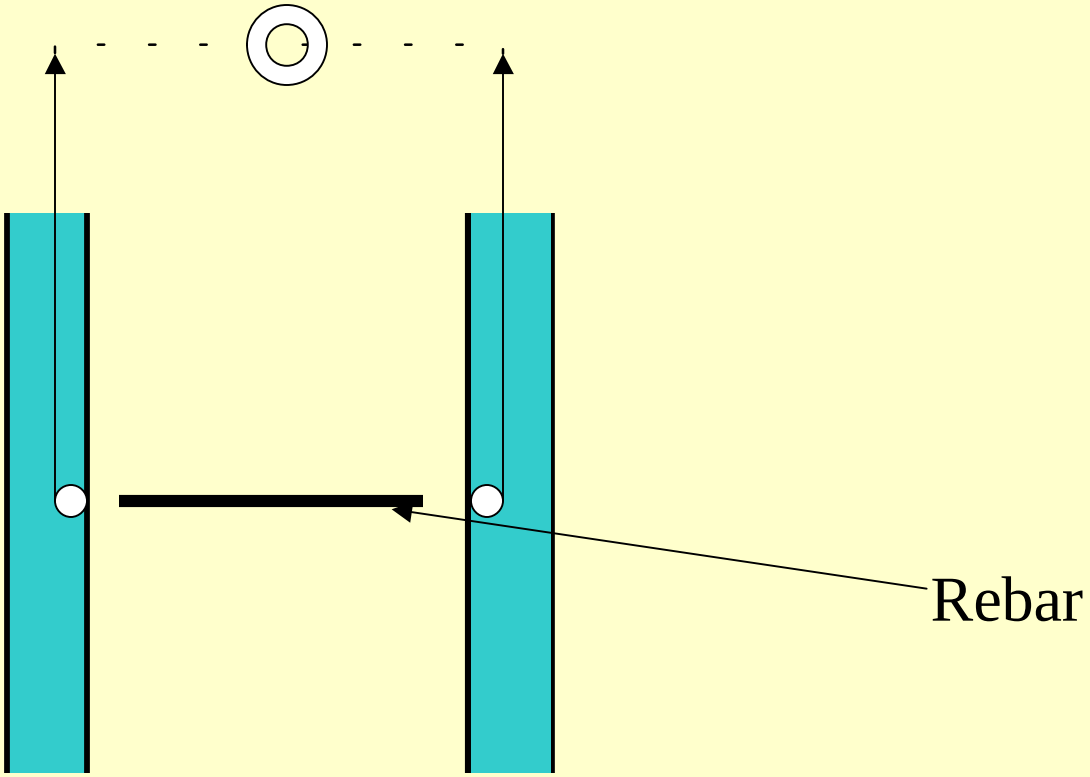
Reading for Good Concrete = 280

Design against all odds



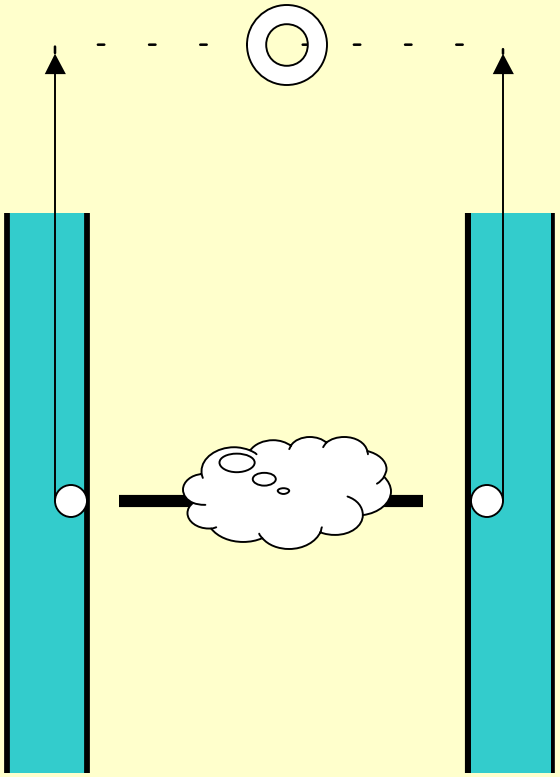
Reading for Poor Concrete = 280 - 340

Design against all odds



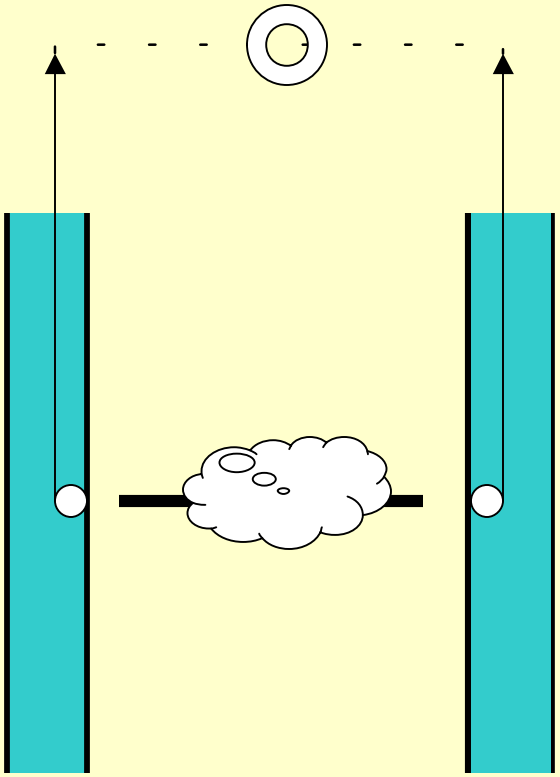
Reading for Steel = 170 - 280

Design against all odds



Reading Range = 170 - 340

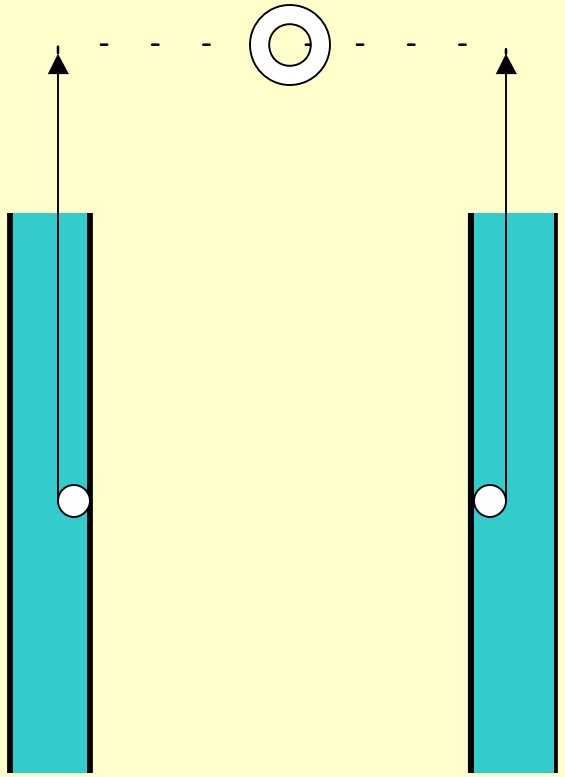
Design against all odds



Actual Range = 260 - 300

Reading Range = 170 - 340

Design against all odds



Ultrasonic probes

Filled with water

Reading for Good Concrete = 280

Early Prejudices

4

An Engineer is a person to whom

2 + 2 = Nearly 4

Or in this case whatever you want

Early Prejudices

1

All Constants – aren't

All variables – don't

What is the Link?

The London Eye

Design against all odds

London Eye

Partial Factor for Permanent Action γ_G

Permanent Action is accurately known

Can be assumed to follow the Normal Distribution

Has a small Coefficient of Variation

What is the appropriate Value of γ_G ?

London Eye - Required reliability

Capacity = 32x25 = 800 people say 1000 at risk

Using $P(f \mid year) < A\ N^{-\alpha}$

with A = 0.01, α = -2 and N = 1000

$P(f \mid year) < 10^{-8}$

Design life = 2 x working life = 2 x 5 = 10 years

$P(f) = 10^{-7}$ which is gives a Reliability Index β = 5.2

Design against all odds

London Eye

Using the Simple Probabilistic Model F = γ G

And First Order Reliability Methods (FORM)

$$\gamma_G = q_d G_d / q_k G_k$$

With G dominant and q non-dominant,

V_q = 0.1 and V_G = 0.05

And β = 5.2

$$\gamma_G = 1.35$$

Rational

Cost Effective

Safer

Early Prejudices

4

An Engineer is a person to whom

2 + 2 = Nearly 4

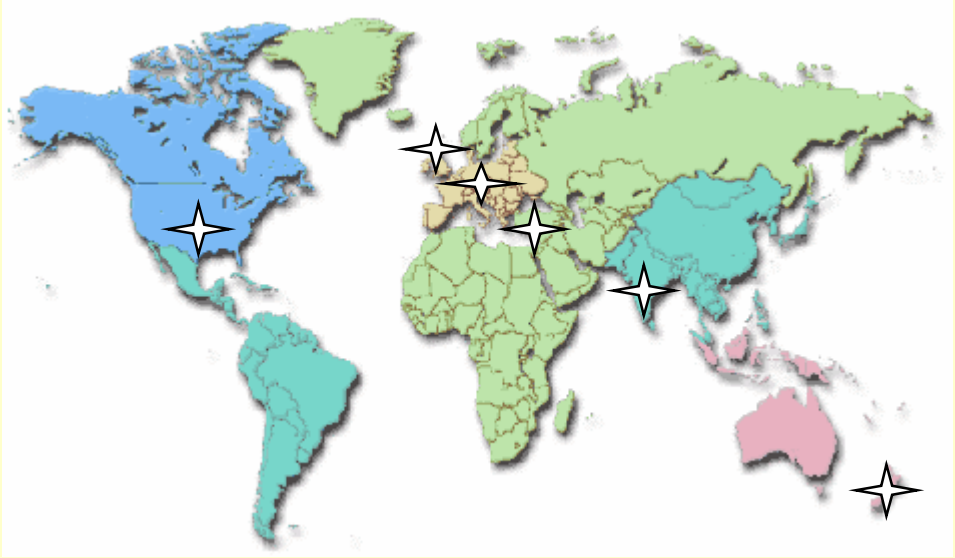
What is the Link?

The Link is

Engineering is the combination of applied science and applied common sense

What is the Difference?

- British Standards
- German Standards
- Indian Standards
- U S Standards
- Cypriot Standards
- New Zealand Standards



Design against all odds

"Standards were written because industry wanted them written and that continues to be the case".

"They are there to add value"

"They are there because they impact on the commercial health and profitability of the business".

Design against all odds

"…. any mention of Codes makes me wish to do something fairly unpleasant to the British Standards Institution.“

Correspondent, Verulam

Design against all odds

There are differences due to:

- Geography
- Varying local skills and materials
- Legislative procedures and customs

Differences are as much Ethnic as Technical

Design against all odds

If :

- Technical differences are small
- Cost impact is small
- Costs increase
- Same reliability and safety

Why bother to change to Eurocodes?

Design against all odds

Better Science

Better Background

More Complete

Challenge Prejudices

Rational Improvement

Reduce duplication of effort

Two way open market

World standard

What is the Difference?

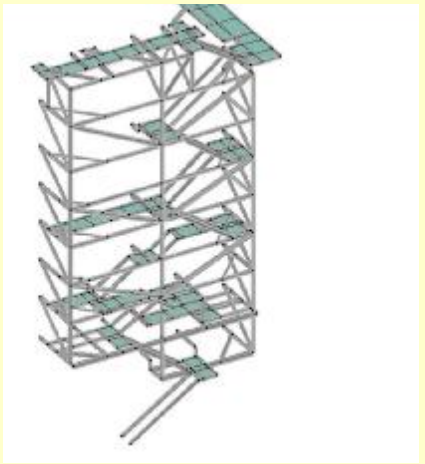
The Difference is

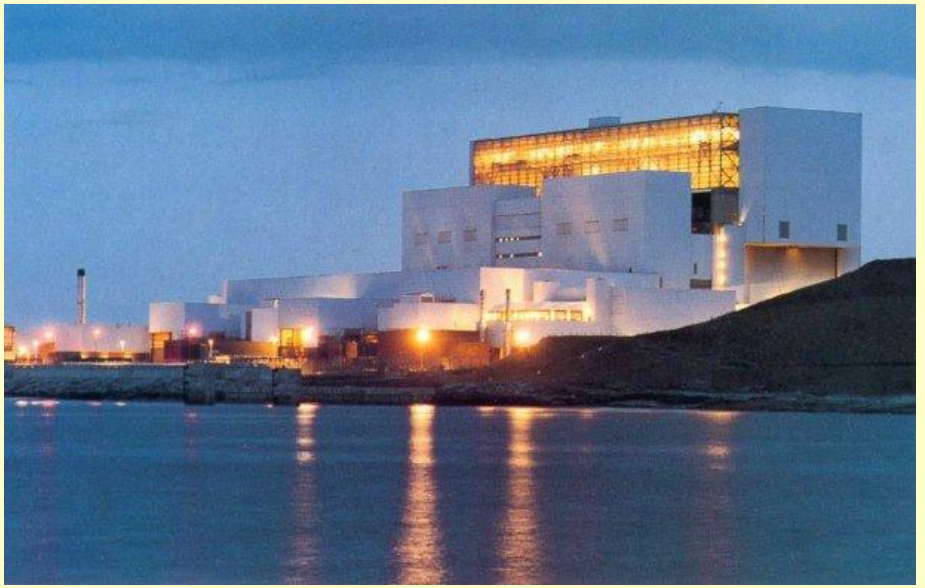
Very little

New Prejudice

Everyone should work on a code committee

What are the Lessons?



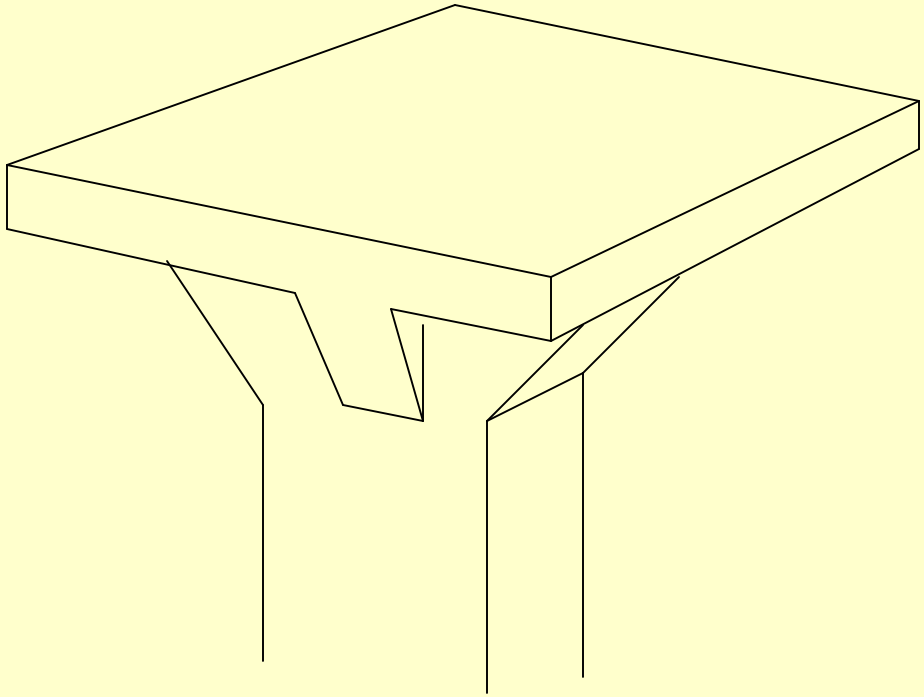


M6 Footbridge

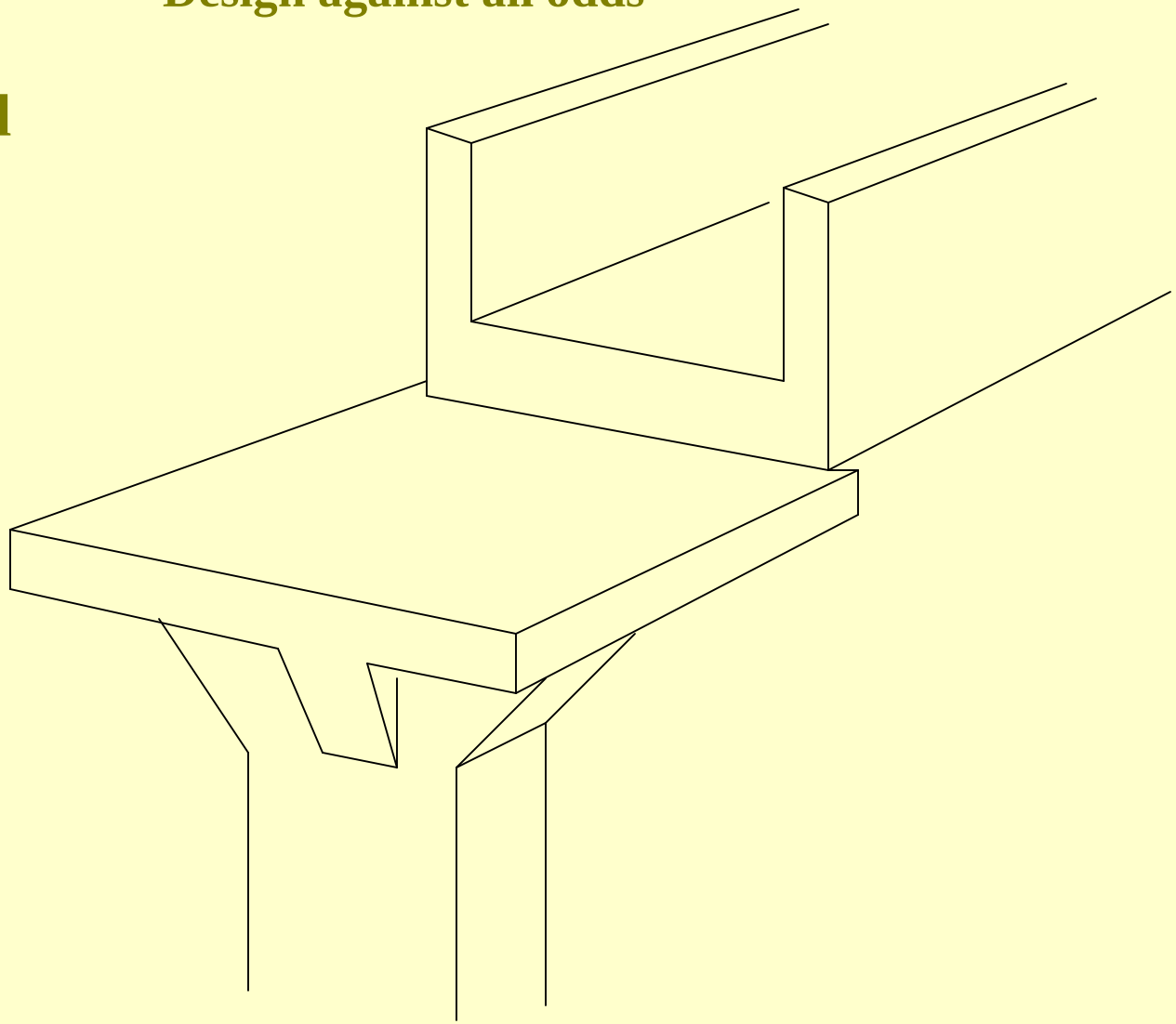
M6 Footbridge

M6 Footbridge

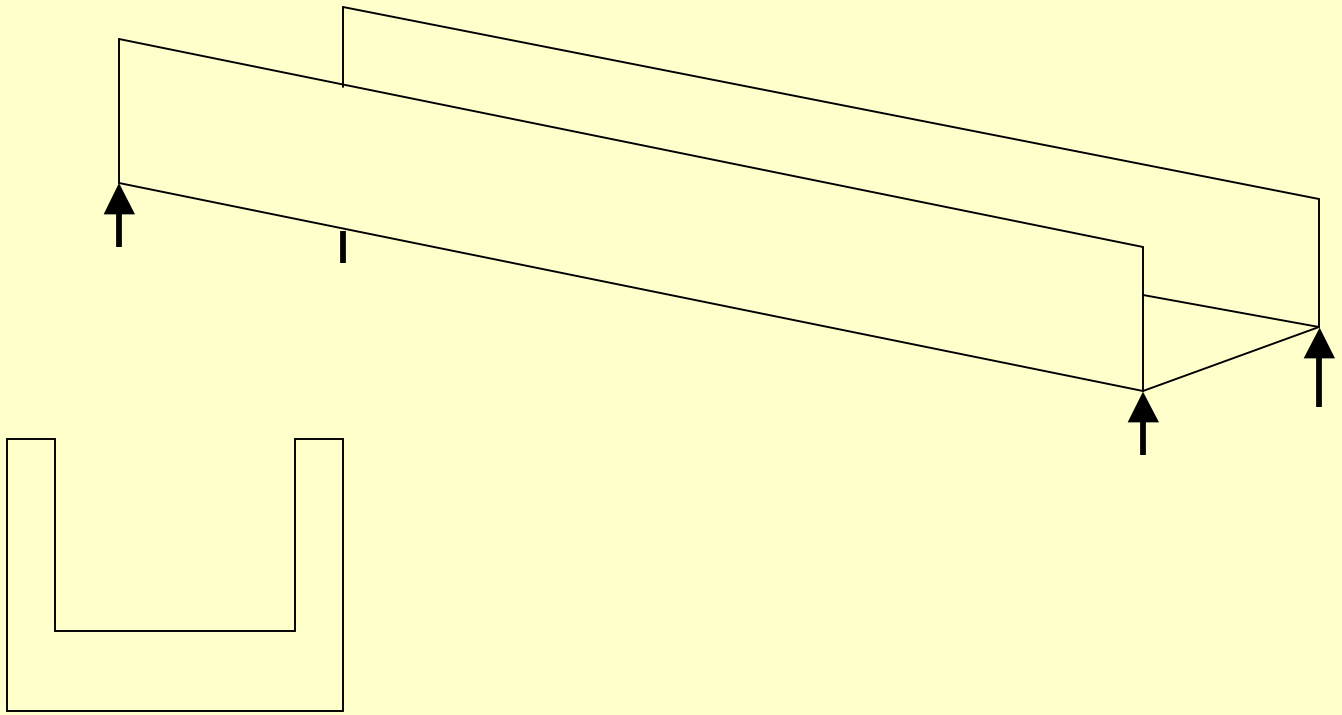
Column Head



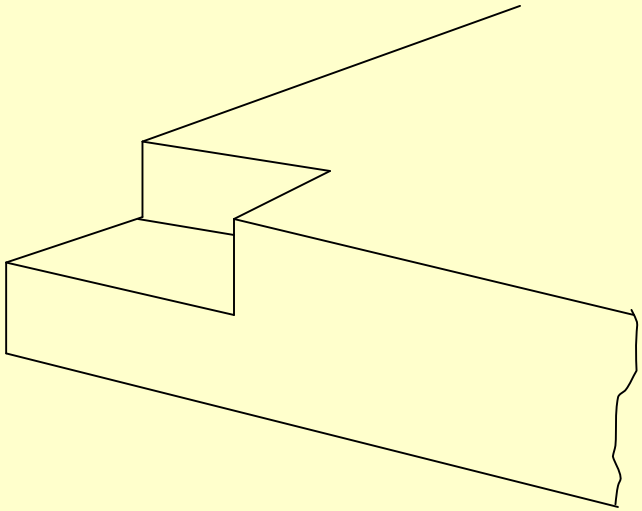
Column Head



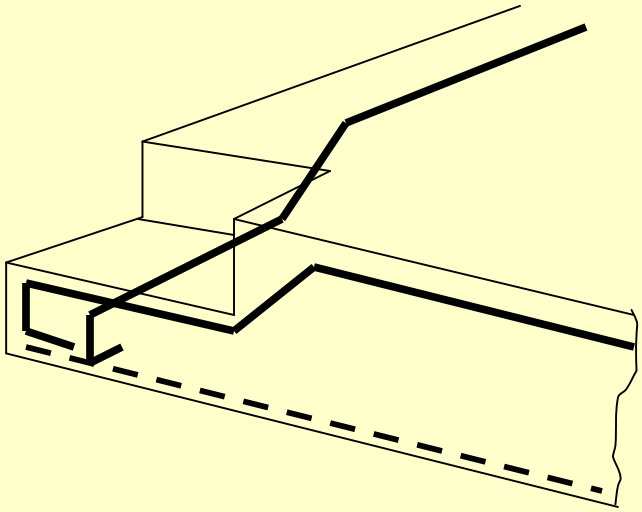
Beam



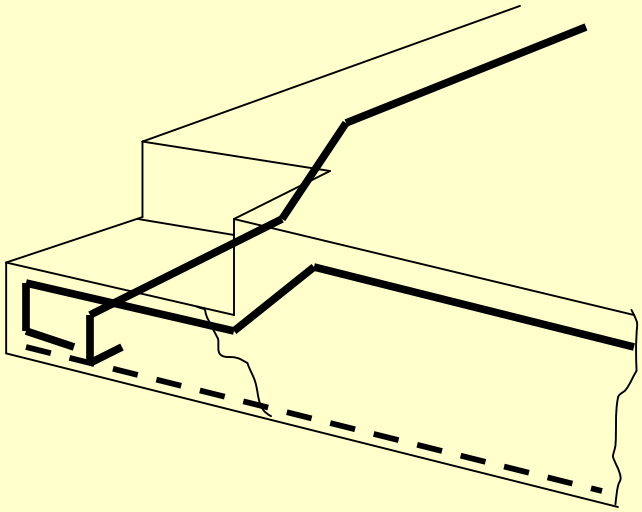
Corner Detail



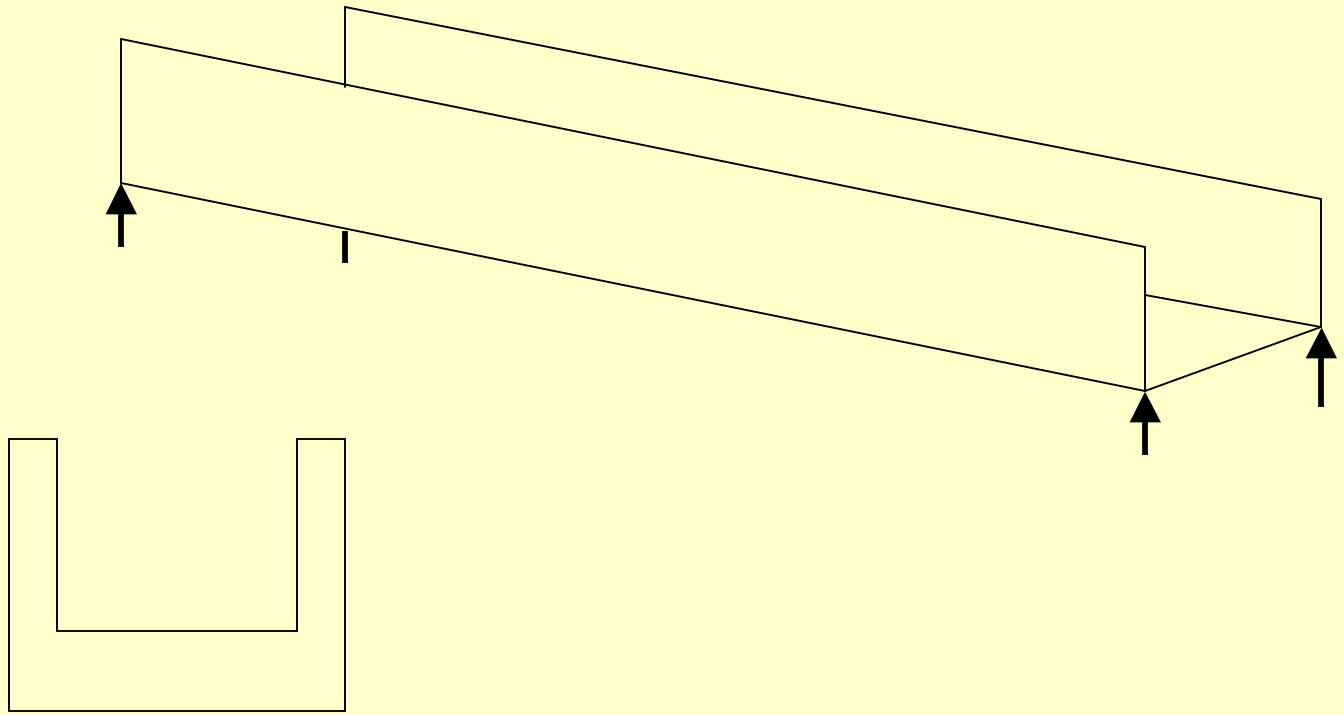
Reinforcement



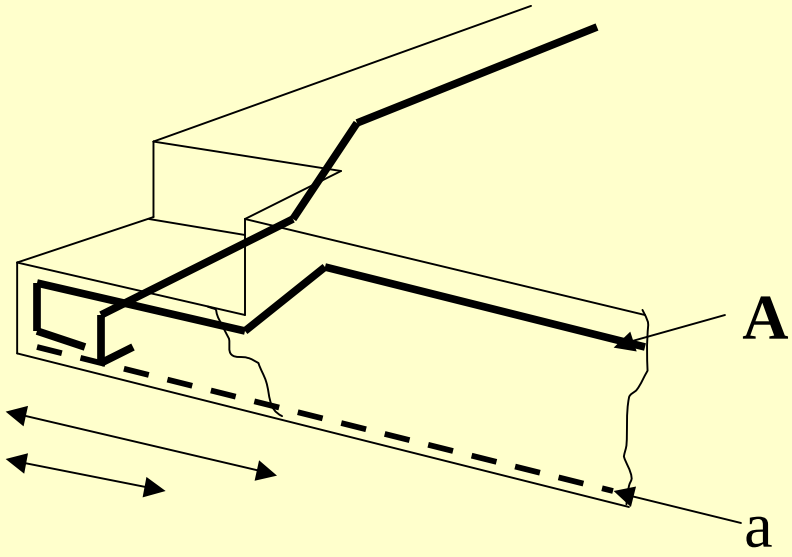
Failure



Hambly's Paradox



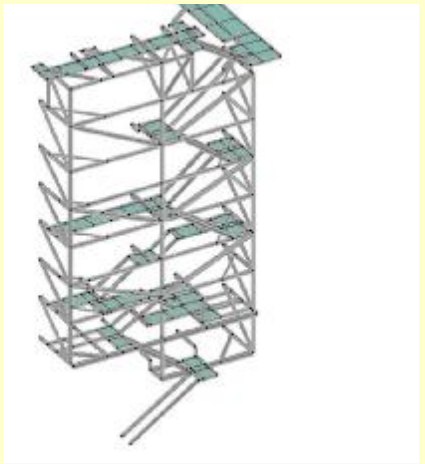
Basic Problems

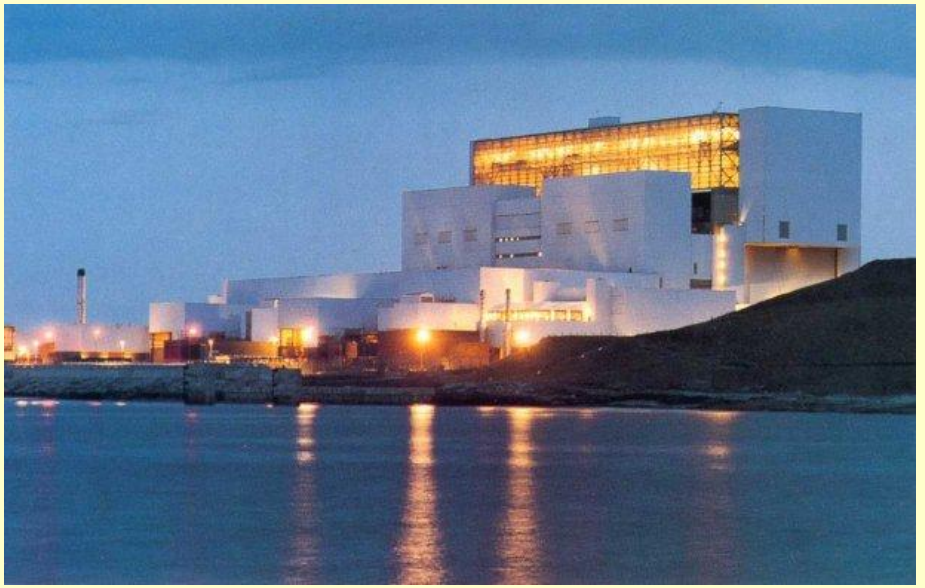


New Prejudice

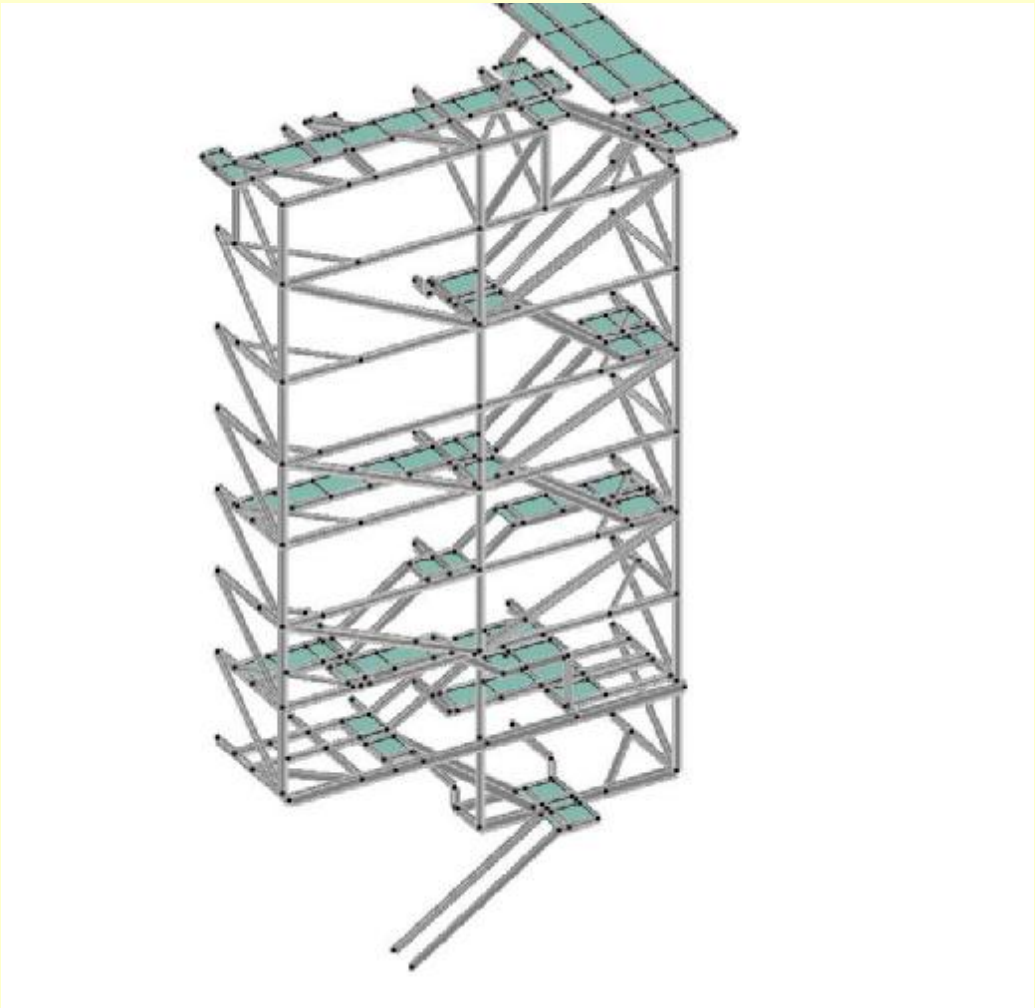
Everyone should work on a code committee

What are the Lessons?





External Stair



Early Prejudices

3

There is no more common error than to assume that, because prolonged and accurate mathematical calculations have been made, the application of the result to some fact of nature is absolutely certain.

A. N. Whitehead

Design against all odds

- **Computer analysis is a check and refinement of the engineer's understanding of the problem**

- **Inappropriate use of computers by some engineers does not compromise the good judgement exercised by others**

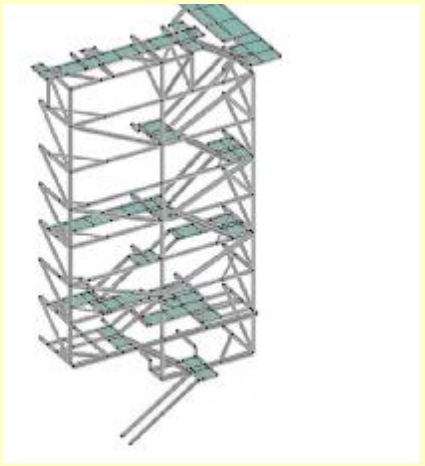
Dr Mark Raiss, Robert Benaim & Associates Ltd

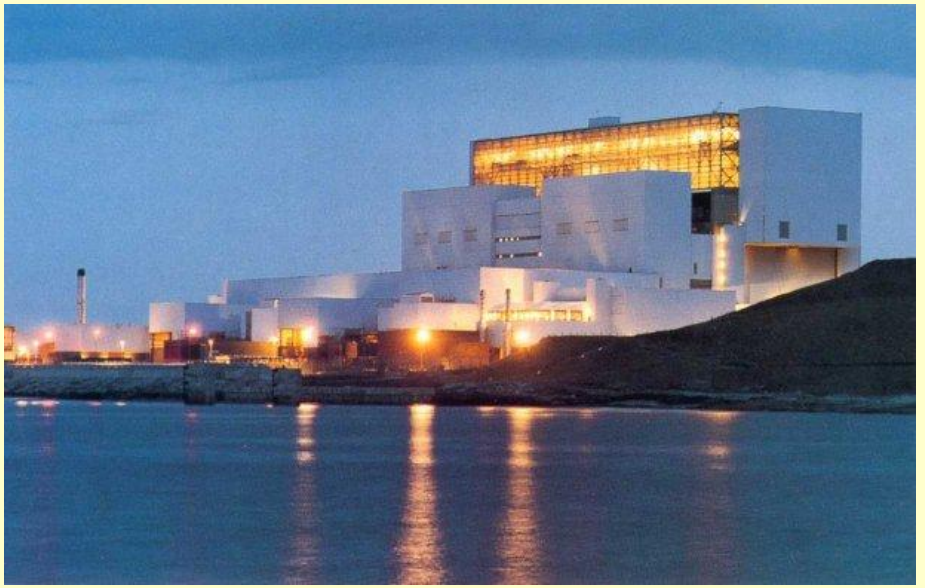
Gaining a clear understanding of mechanisms of behaviour prior to detailed analysis is vital.

New Prejudice

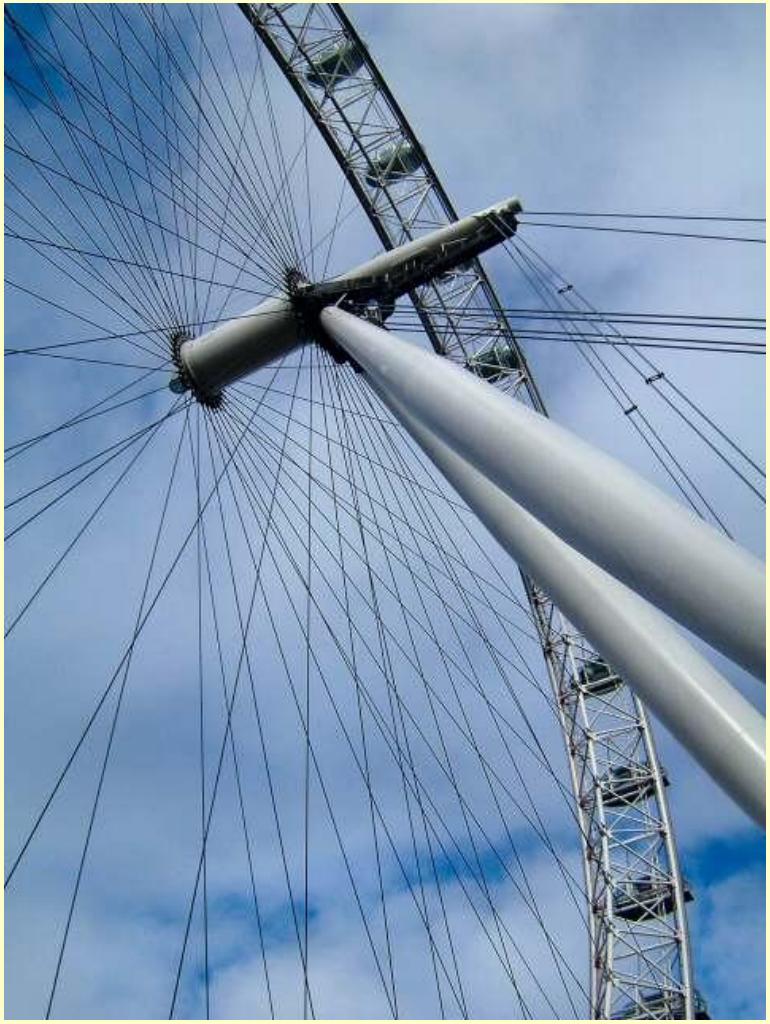
- **Understand and design structures that we could not analyse**
- **Analyse structures we cannot understand**

What are the Lessons?



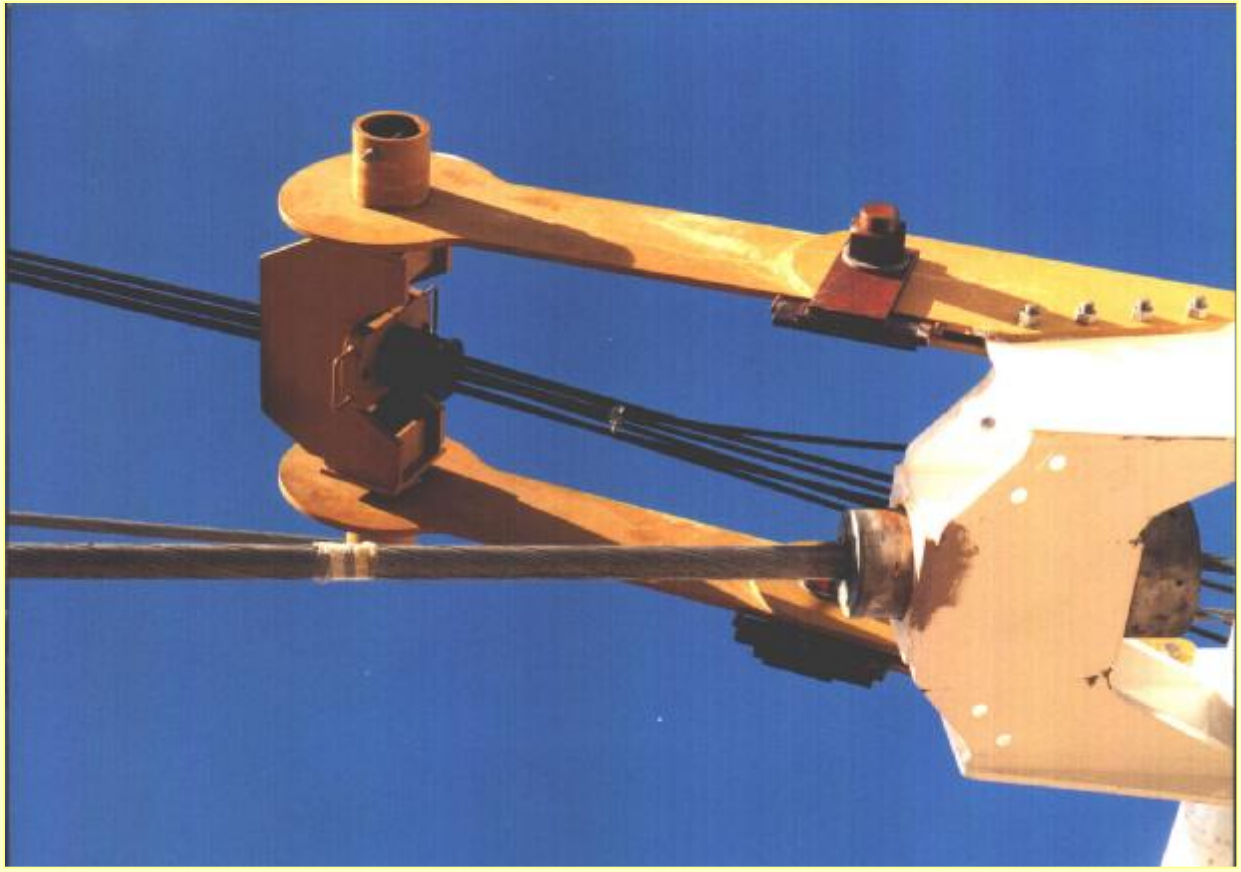


The London Eye



Design against all odds

Design against all odds



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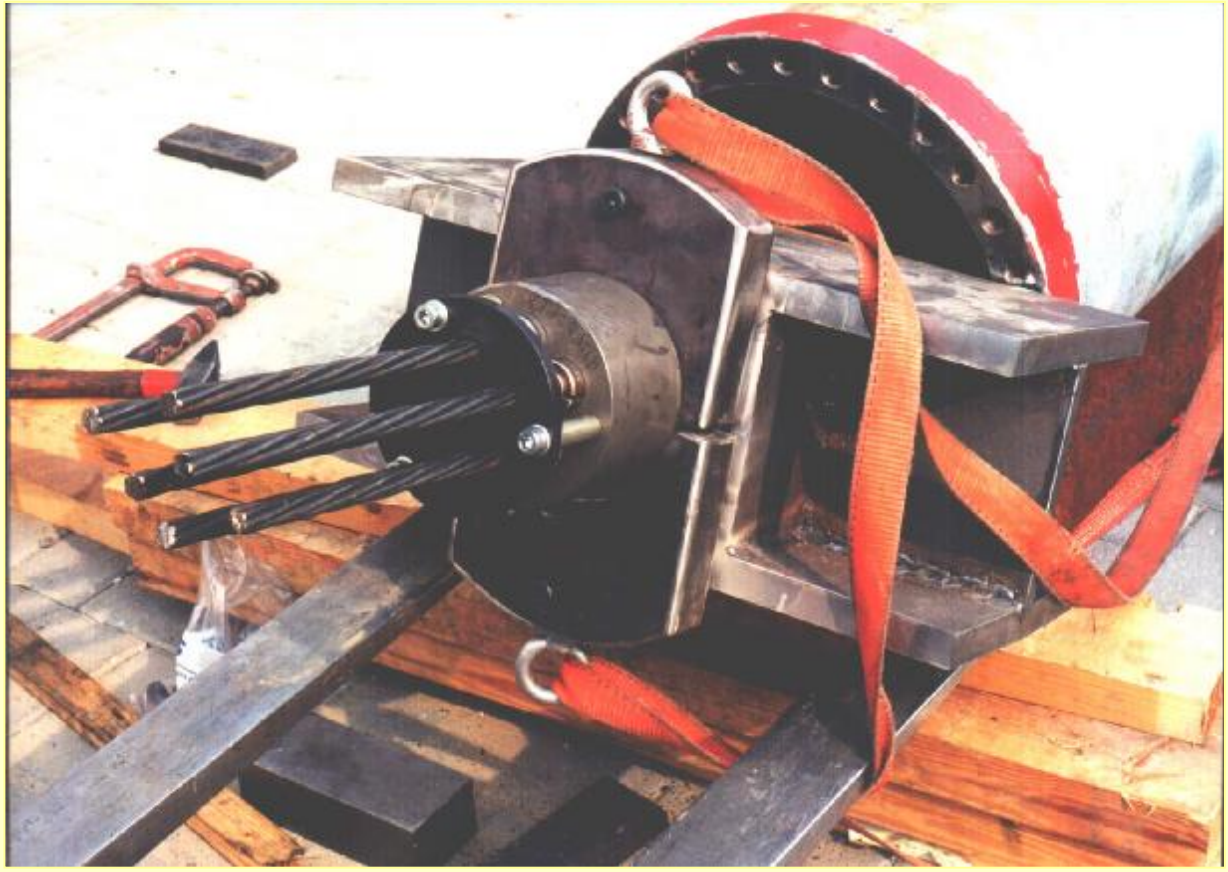
Design against all odds



Design against all odds

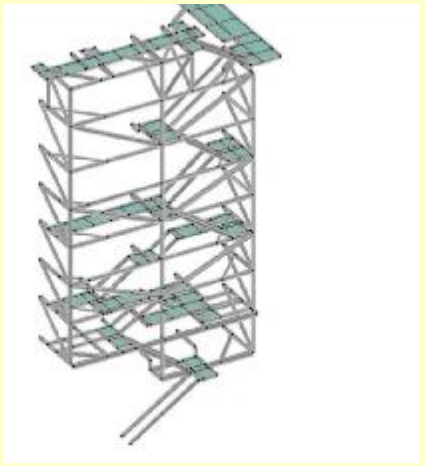
Early Prejudices

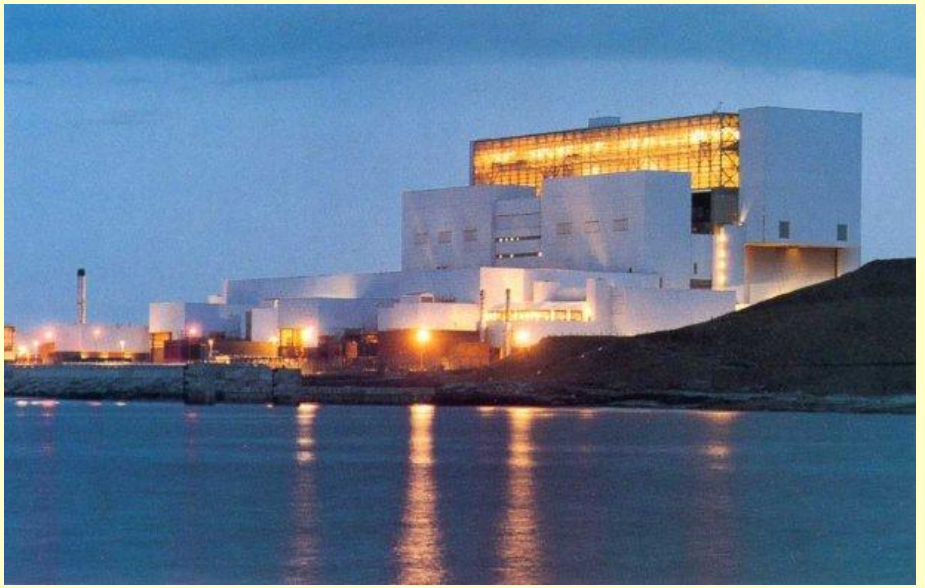
2

Where is the line of force?

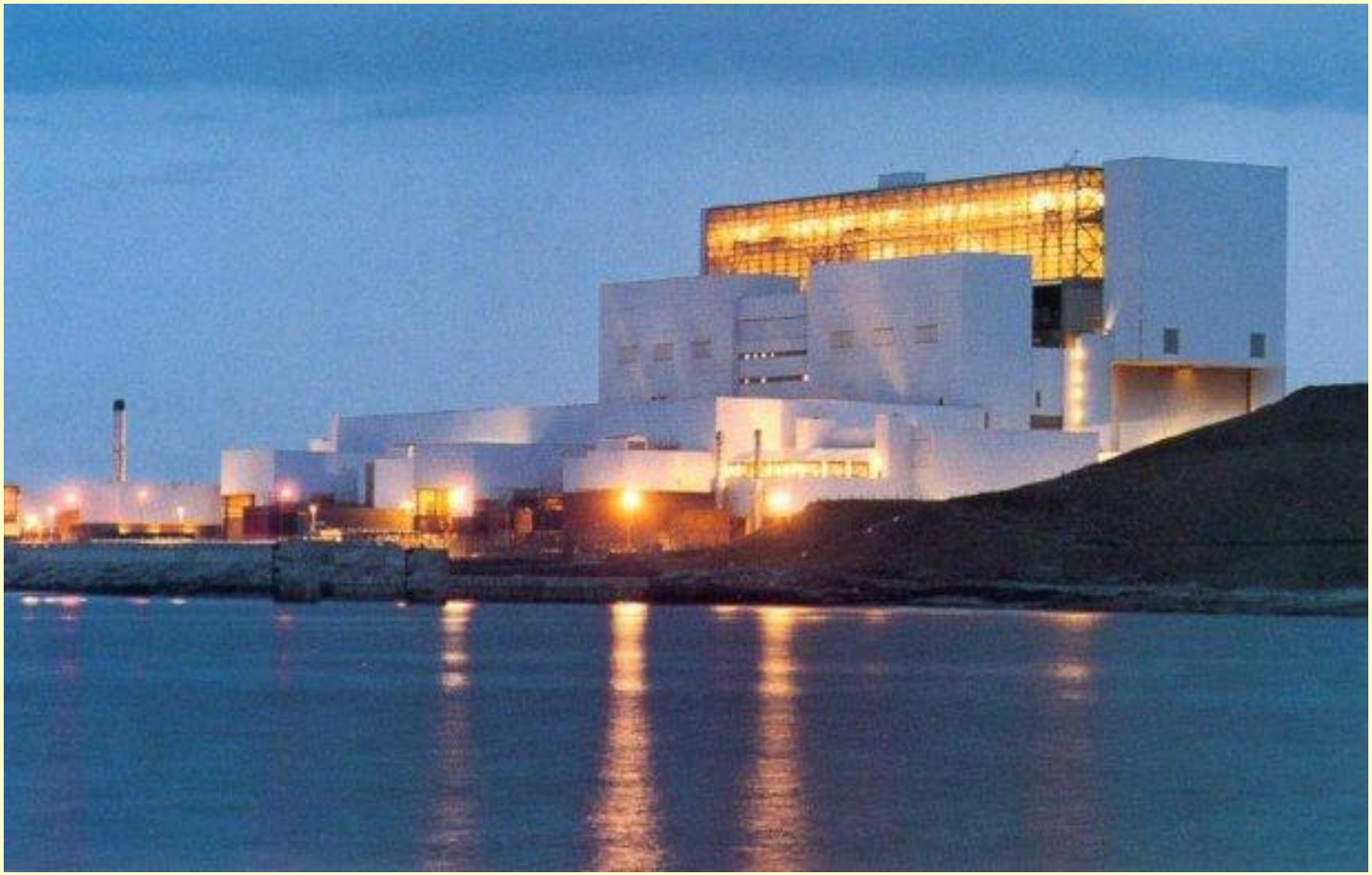
What is the load path?

What are the Lessons?





Extreme Wind Load on Nuclear Structures



Design against all odds

For structures with high consequence of failure

External hazards, such as extreme wind, use 10,000 recurrence period.

What partial factor should be used with such actions?

Using FORM we calculate

For 50 year recurrence with γ = 1.4 **$P(f \mid year) = 5.3 \times 10^{-6}$**

For 10,000 year recurrence with γ = 1.0 **$P(f \mid year) = 2.1 \times 10^{-7}$**

Rational **Cost Effective**

What are the Lessons?

The Lessons are

Good Design is All About

Understanding,and

Good Detailing

Concepts such as ductility and robustness underpin the success of structural design and more explicit recognition of these is needed.

Uncertainty and Robustness

Building Regulations

CIRIA 63

$$P_{ft} = 10^{-4} \frac{k_s \, n_d}{n_r} \qquad (39)$$

K_s = Social Criterion Factor

n_d = Design Life in years

n_r = Average number of people within or near the structure during the period of risk

Risk is represented by parameters

C Correlation with load
(0, 0.5, 1, 1.5, 2, 2.5)
D Structural type and nature of the material
(0, 0.3, 0.5, 1)

Consequences are represented by parameters

N Number of people at risk (0, 1, 2)
E The impact of the building in its environment
(0, 0.3, 0.5, 1)
S The societal criteria (1.6, 2, 3)

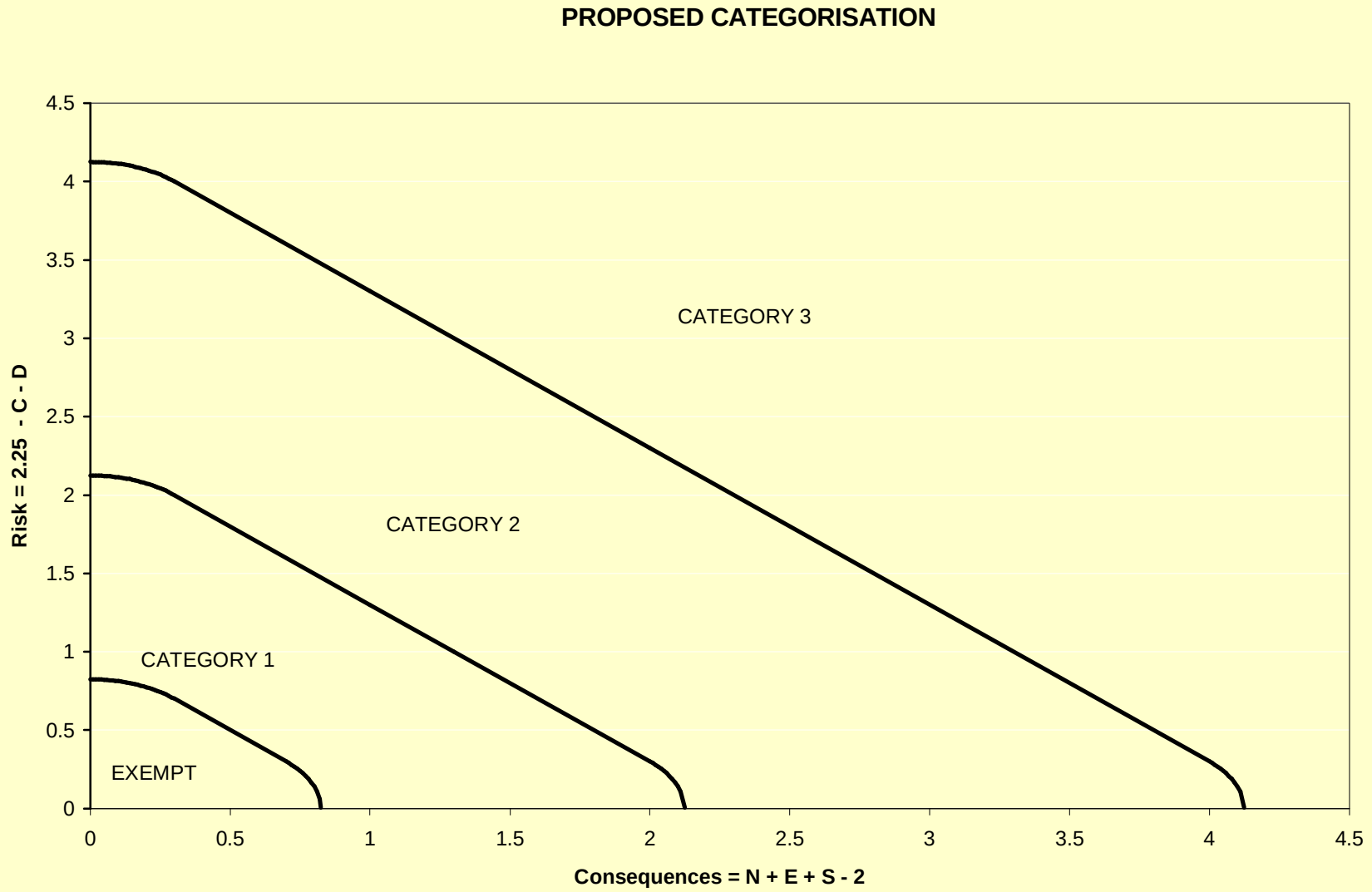
So the Risk Factor can be separated into two parts

Risk = C + D

Consequences = N + E + S

Consequences

Introduction



Confirmed Prejudice

Engineering is the art of modelling materials we do not wholly understand, into shapes we cannot precisely analyse so as to withstand forces we cannot properly assess, in such a way that the public has no reason to suspect the extent of our ignorance.

Dr AR Dykes

Institution of Structural Engineers, 1976.

Real Design

QUESTIONS