

Concrete Failure Analysis: What you don't know CAN hurt you.

Kevin MacDonald
Beton Consulting Engineers LLC



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Forensic engineering

Forensic engineering is the investigation of materials, products, structures or components that fail or do not operate or function as intended, causing personal injury or damage to property. The consequences of failure are dealt with by the law of product liability. The field also deals with retracing processes and procedures leading to accidents in operation of vehicles or machinery.

Failure Analysis

- Failure analysis is the process of collecting and analyzing data to determine the cause of a failure. It is an important discipline in many branches of manufacturing industry, where it is a vital tool used in the development of new products and for the improvement of existing products.

Origin of Failure

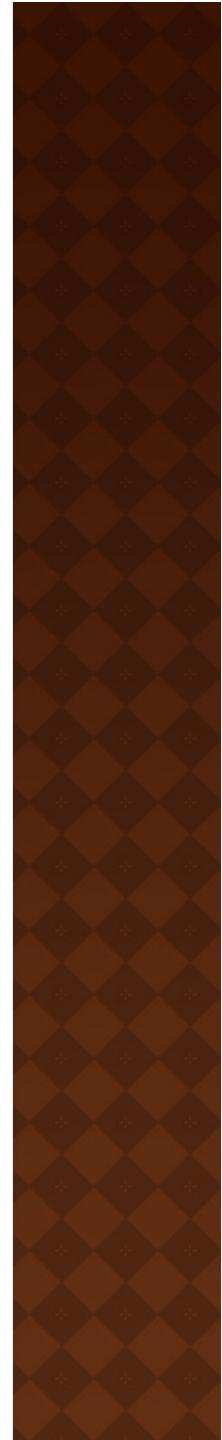
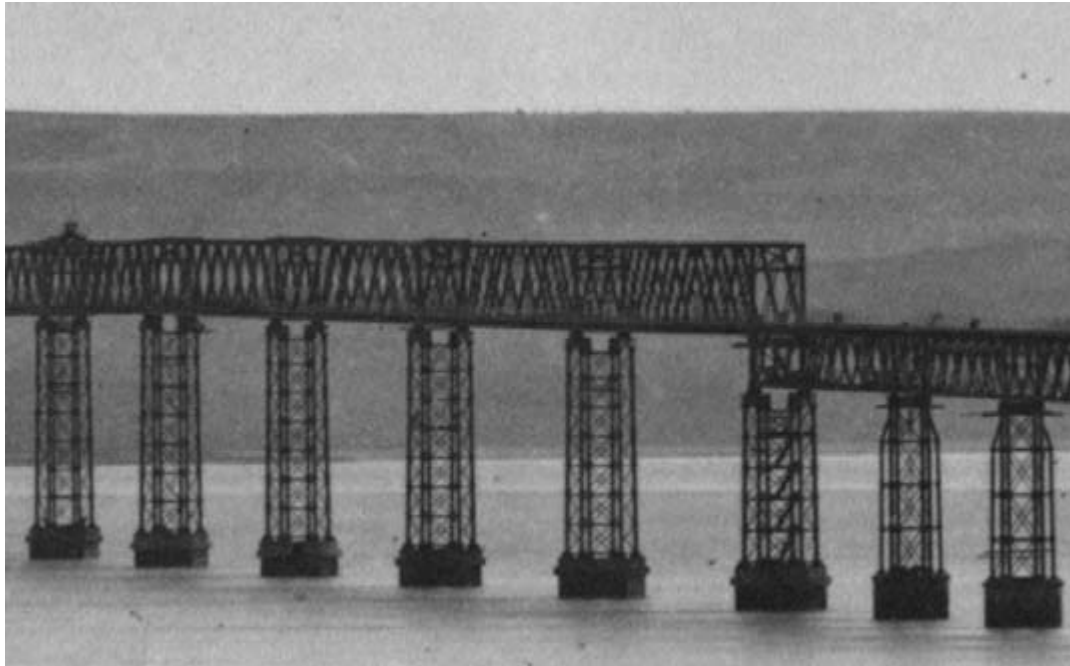
- ◉ Design
- ◉ Construction
- ◉ Materials
- ◉ Service
- ◉ Maintenance

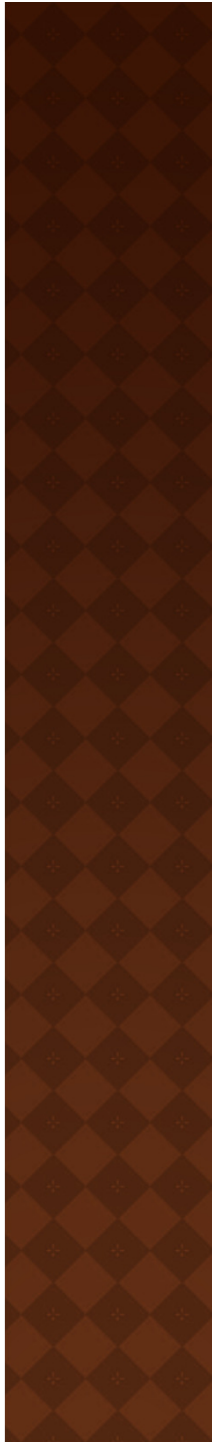
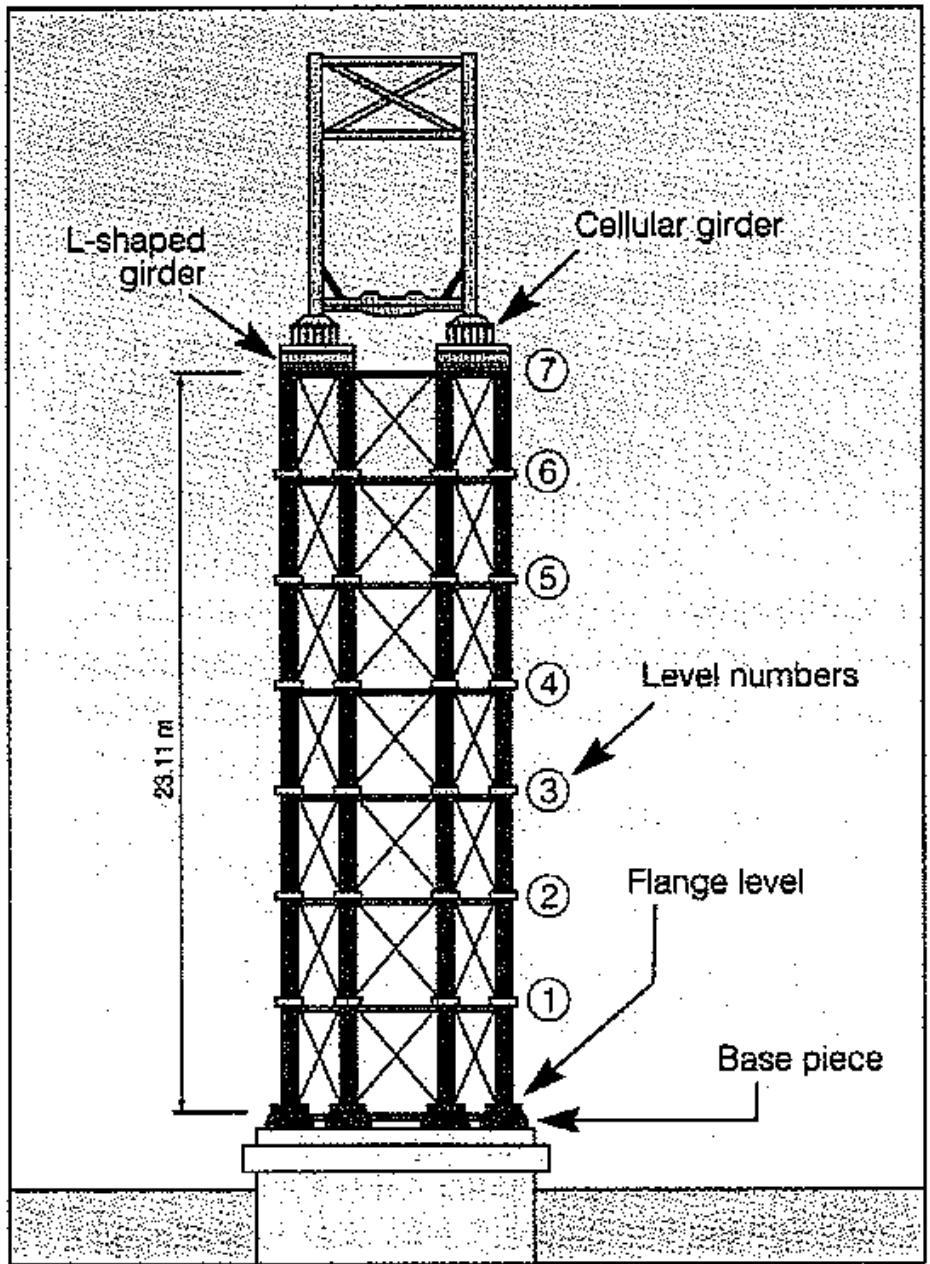
Tay Bridge

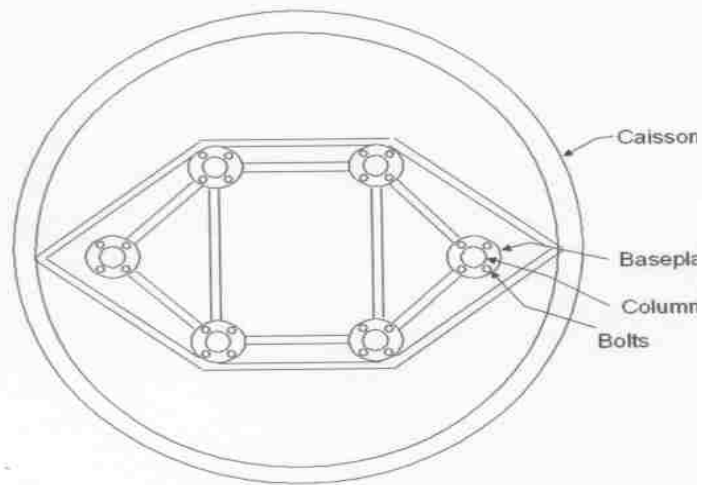
- The first Tay rail bridge was completed in February 1878 to the design of Thomas Bouch. Bouch was responsible for the design, construction and maintenance of the bridge. Most of his bridges were lattice girders supported on slender cast iron columns braced with wrought iron struts and ties, The building of the Tay bridge culminated in him being knighted.

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- The Tay bridge was nearly two miles long, consisting of 85 spans and at the time was the longest bridge in the world. The spans carried a single rail track; 72 of these were supported on spanning girders below the level of the track; the remaining 13 navigation spans were spanning girders above the level of the track (i.e. the train runs through a tunnel of girders).

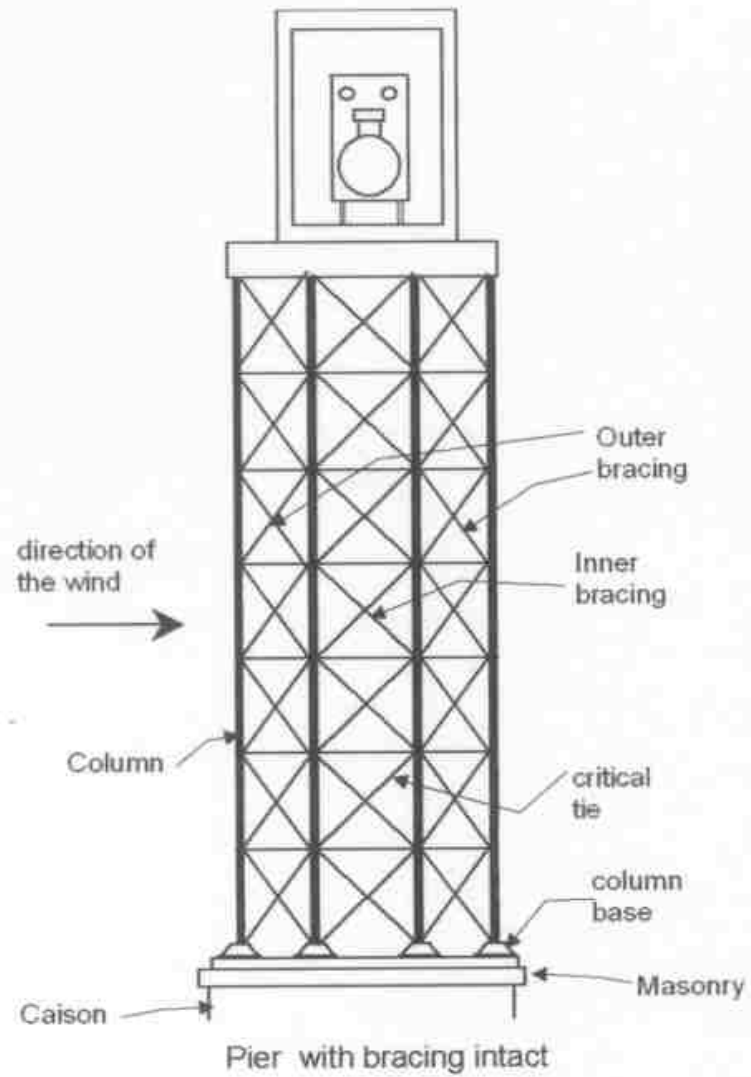








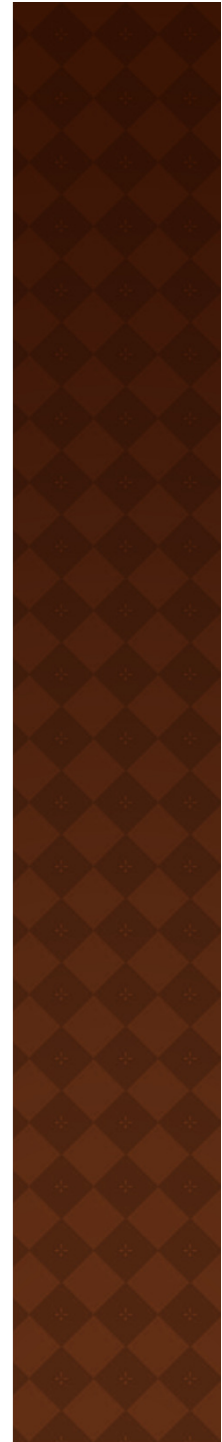
Plan of pier

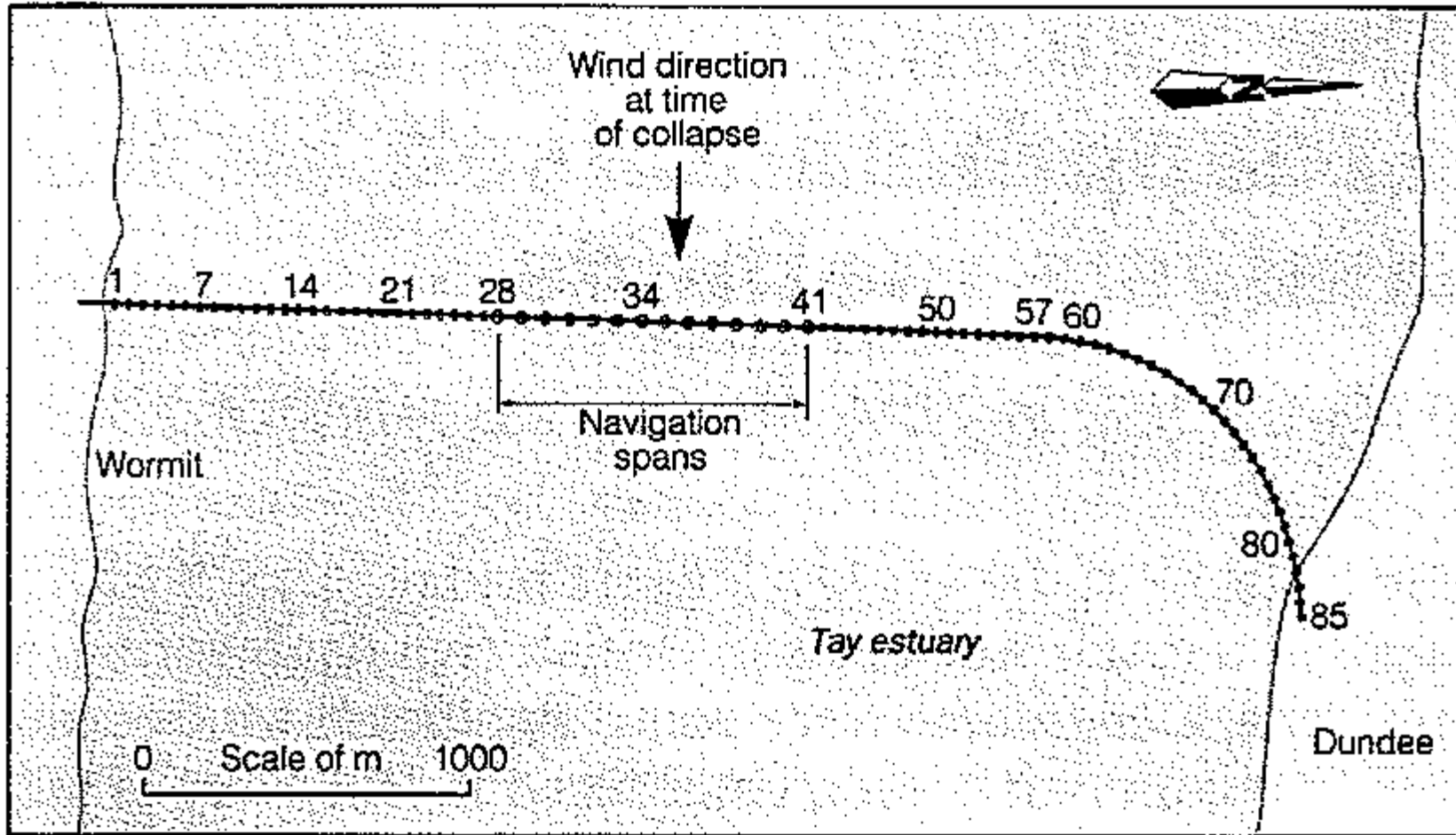


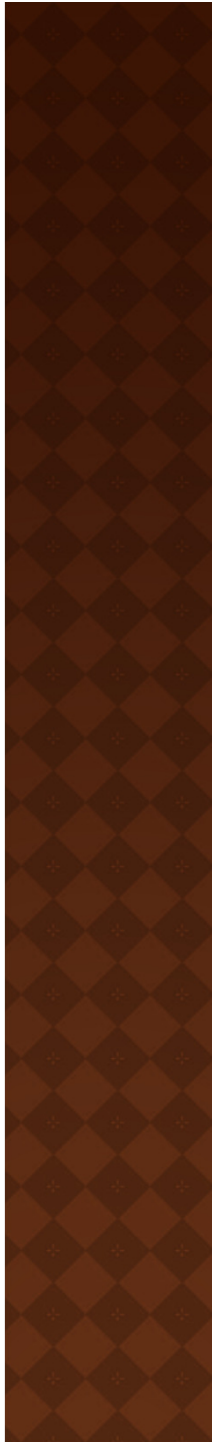
Pier with bracing intact

Tay Rail Bridge

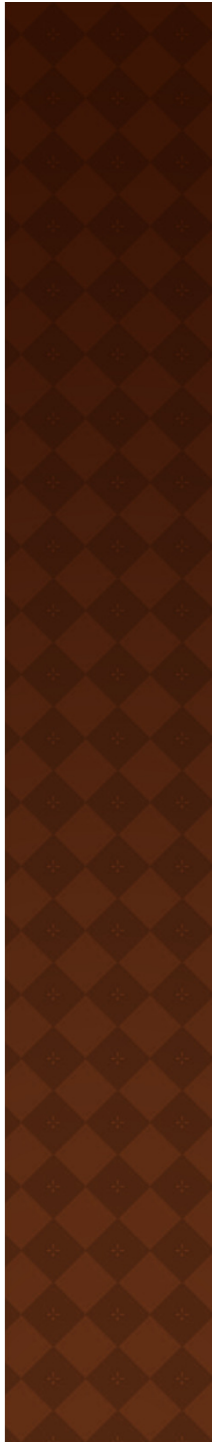
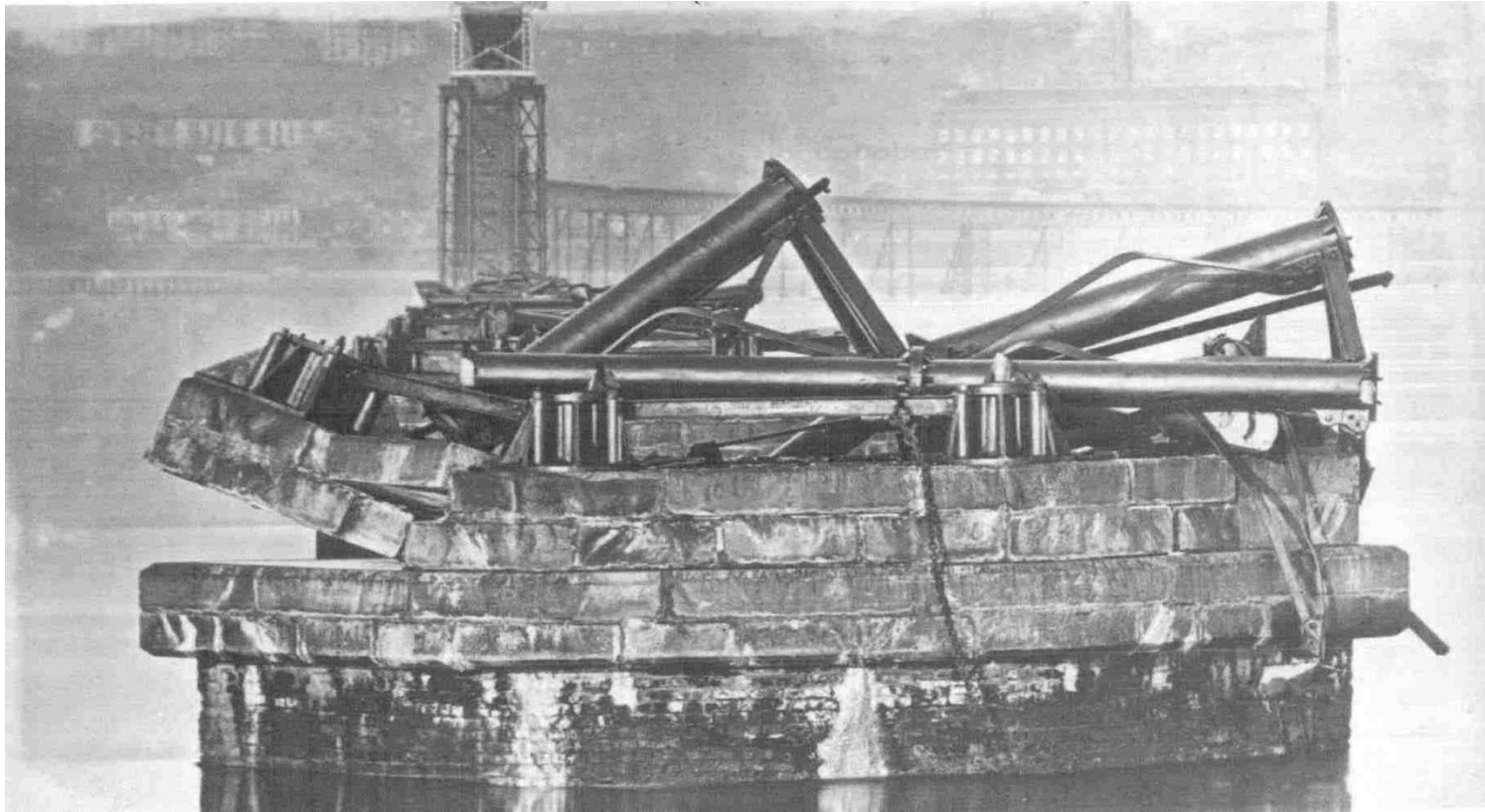
- It is just after 7.00 pm on 28th December 1879. The 4.15 train from Edinburgh leaves Wormit station on the south side of the Firth of Tay to cross the first Tay Rail Bridge heading for Dundee on the north side. It never arrives in Dundee. While the train was on the navigation spans of the bridge they collapsed into the Firth taking 75 people to their deaths. In terms of loss of life this was the worst disaster due to structural collapse recorded in the UK.



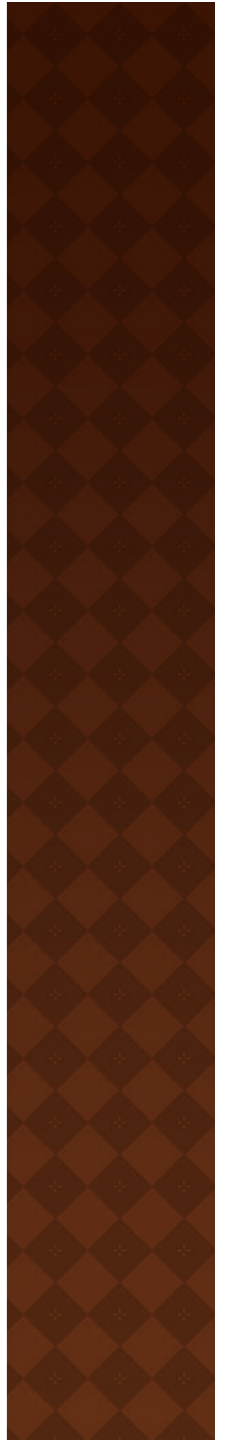
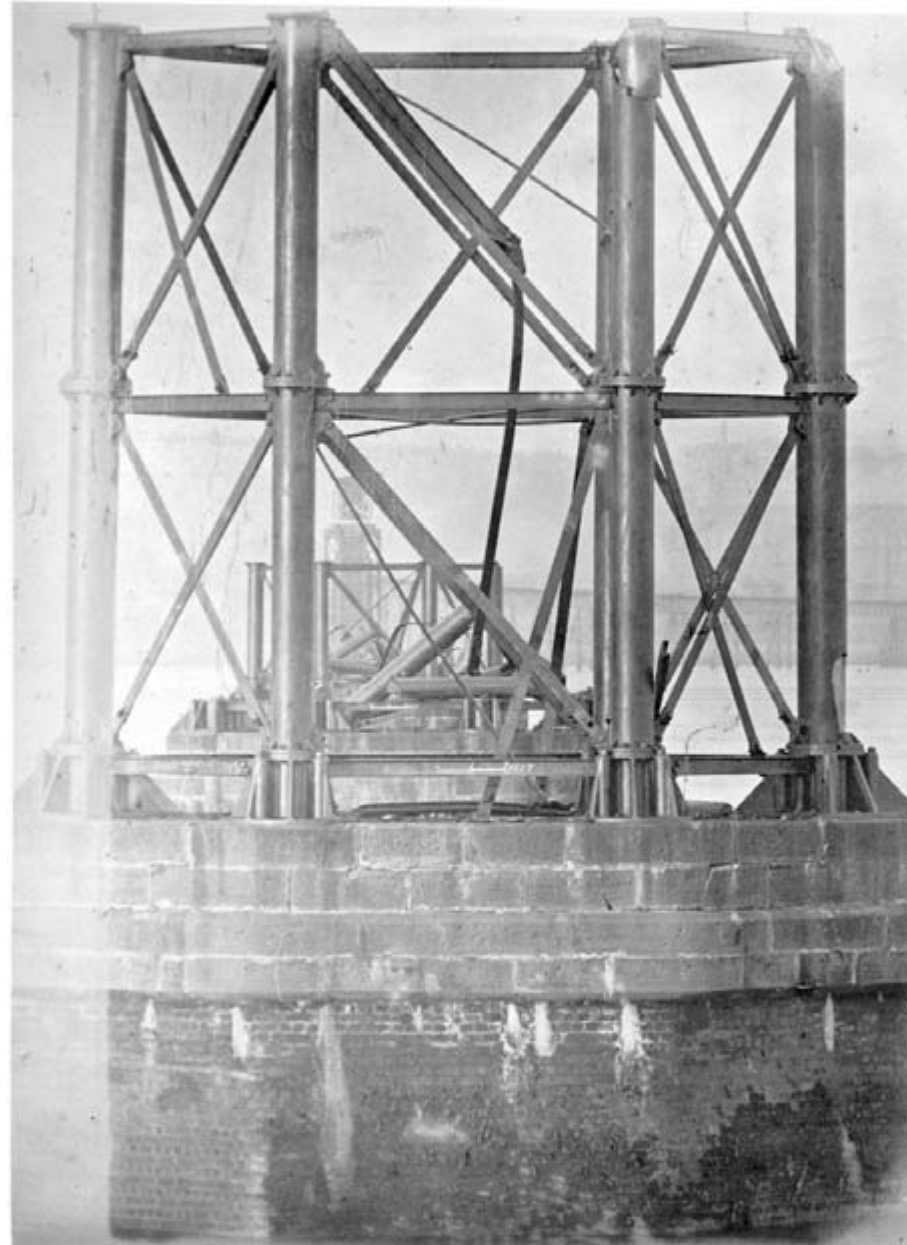




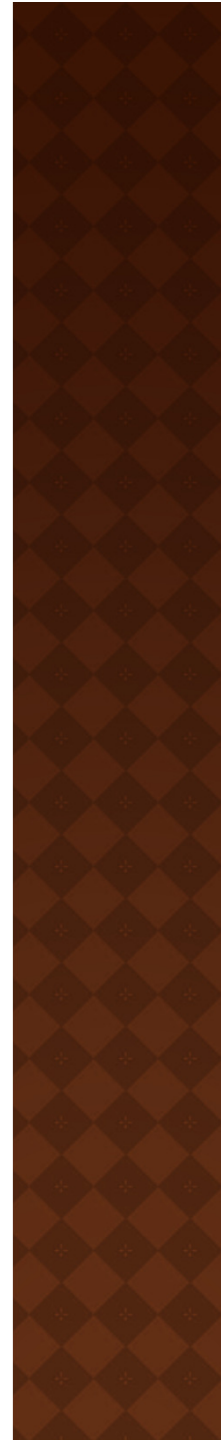
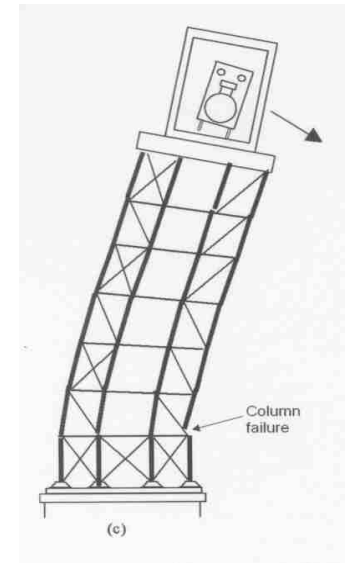
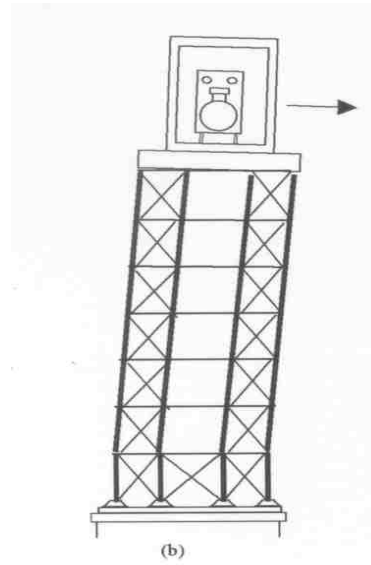
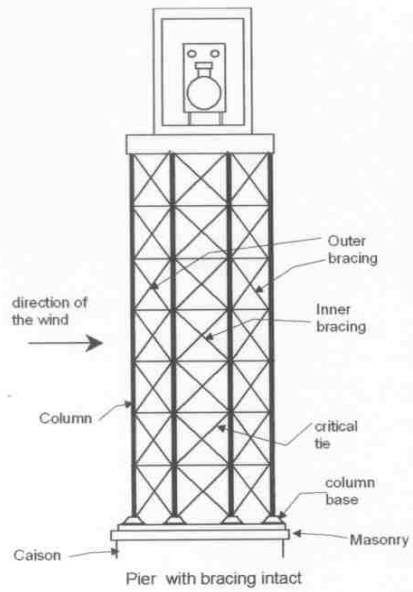
-
- These "high girders", as they were known, were 27 ft high with an 88 ft clearance above the high water mark. It was these spans which fell. Most of the girders below track level, all of which remained standing, were transferred to the present Tay rail bridge. At the time of the collapse Bouch was working on the design of the proposed Forth Bridge. In consequence, the design of the bridge was transferred to Benjamin Baker and Sir John Fowler



Pier No. 1







Court of Inquiry - Board of Trade

- The Court of Inquiry report concluded that, "The fall of the bridge was occasioned by the insufficiency of the cross bracing and its fastenings to sustain the force of the gale." The Court of Inquiry indicated that if the piers, and in particular the wind bracing, had been properly constructed and maintained, the bridge could have withstood the storm that night, albeit with a low factor of safety - 4 to 5 was the norm at the time.

Train derailment Theory

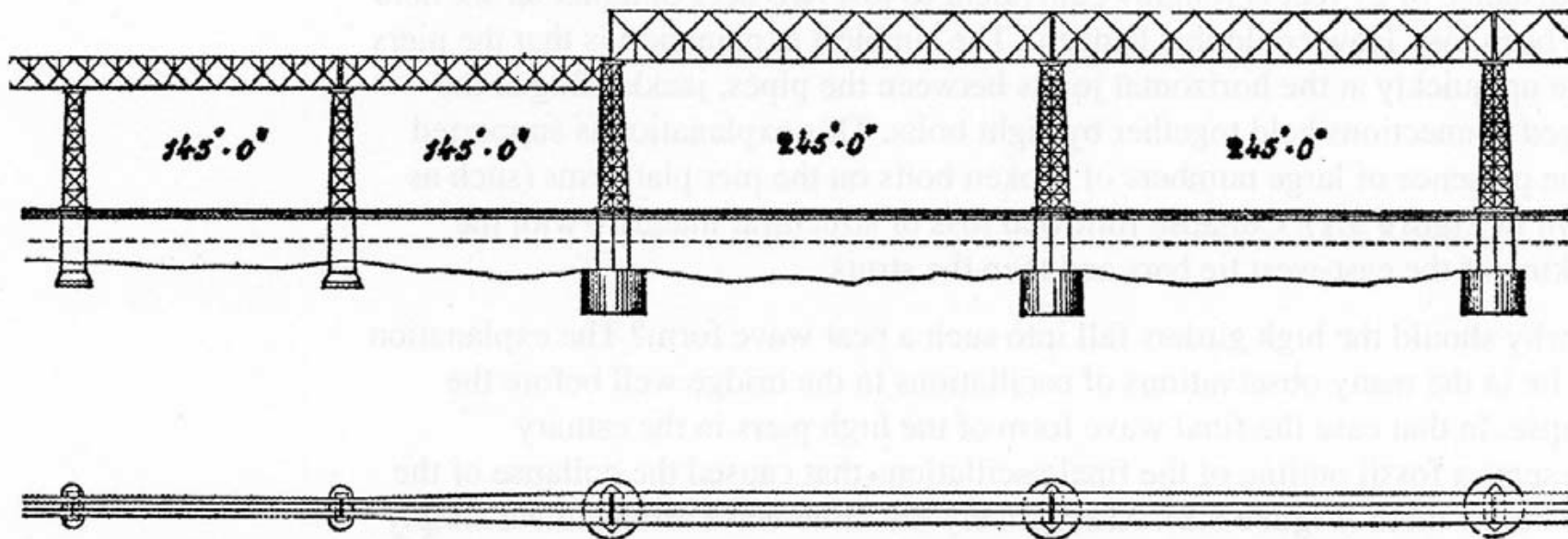
- This theory attributed to Bill Dow, a retired lecturer in Physics, postulates that the train came off the track due to a kink in the rails with uplift of the train attributed to aerodynamic forces. In consequence, one of the carriages hits the bridge and the shock experienced by the pier causes the cast iron lugs connecting the wind bracing members to the columns to fracture leading to the subsequent collapse of the pier structure. To add credibility for the theory, the fact is highlighted that all the deck spans remained standing while the high girders, which the train was passing through, all collapsed. In other words, the train was necessary for the collapse.

Train Operation

CLEVELAND INSTITUTION OF ENGINEERS

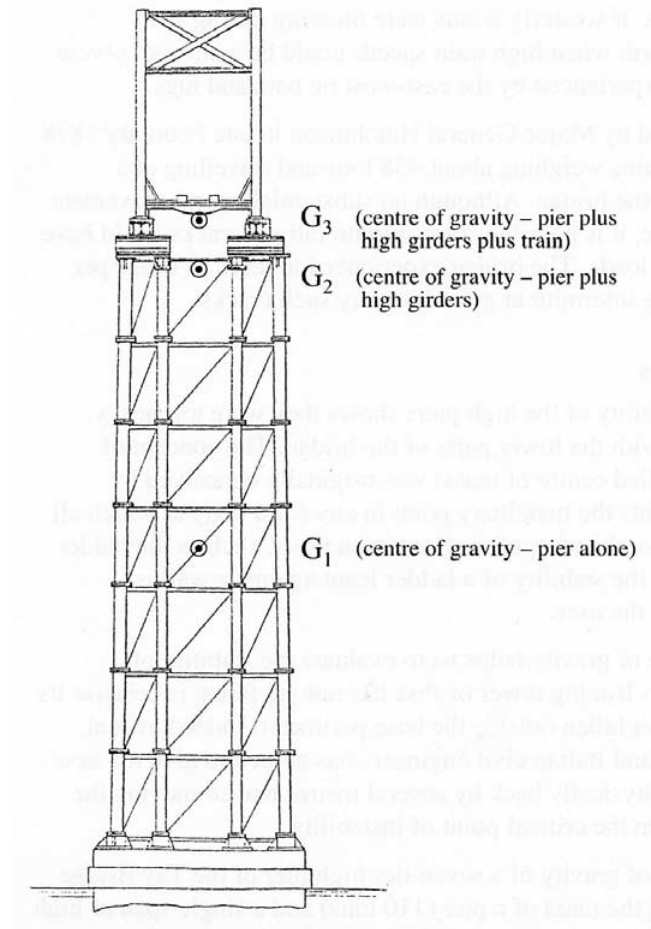
SESSION 1876-77.

ILLUSTRATING PROCEEDINGS DATED 6TH NOVEMBER 1876



TAY BRIDGE, ARRANGEMENT OF PIERS & GIRDERS.

Train Operation



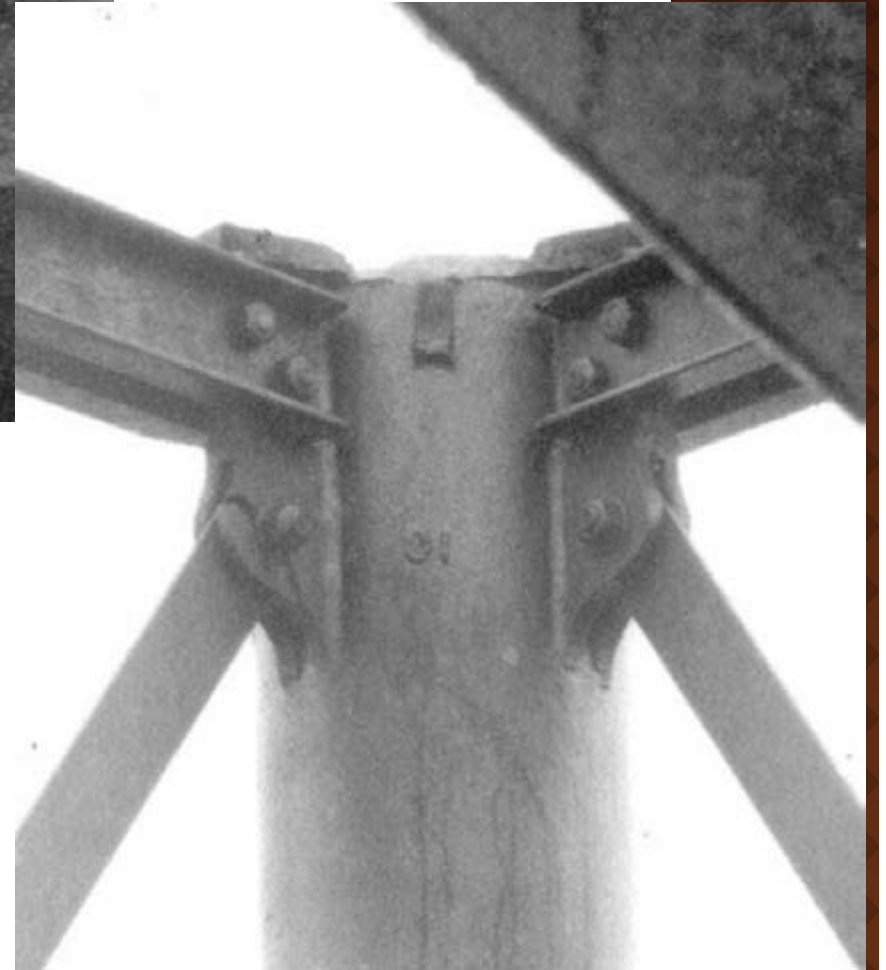
Maintenance and Inspection

- Reported that tie bars were “rattling”.
- Spacers were installed as needed to “tighten up” the connectors.

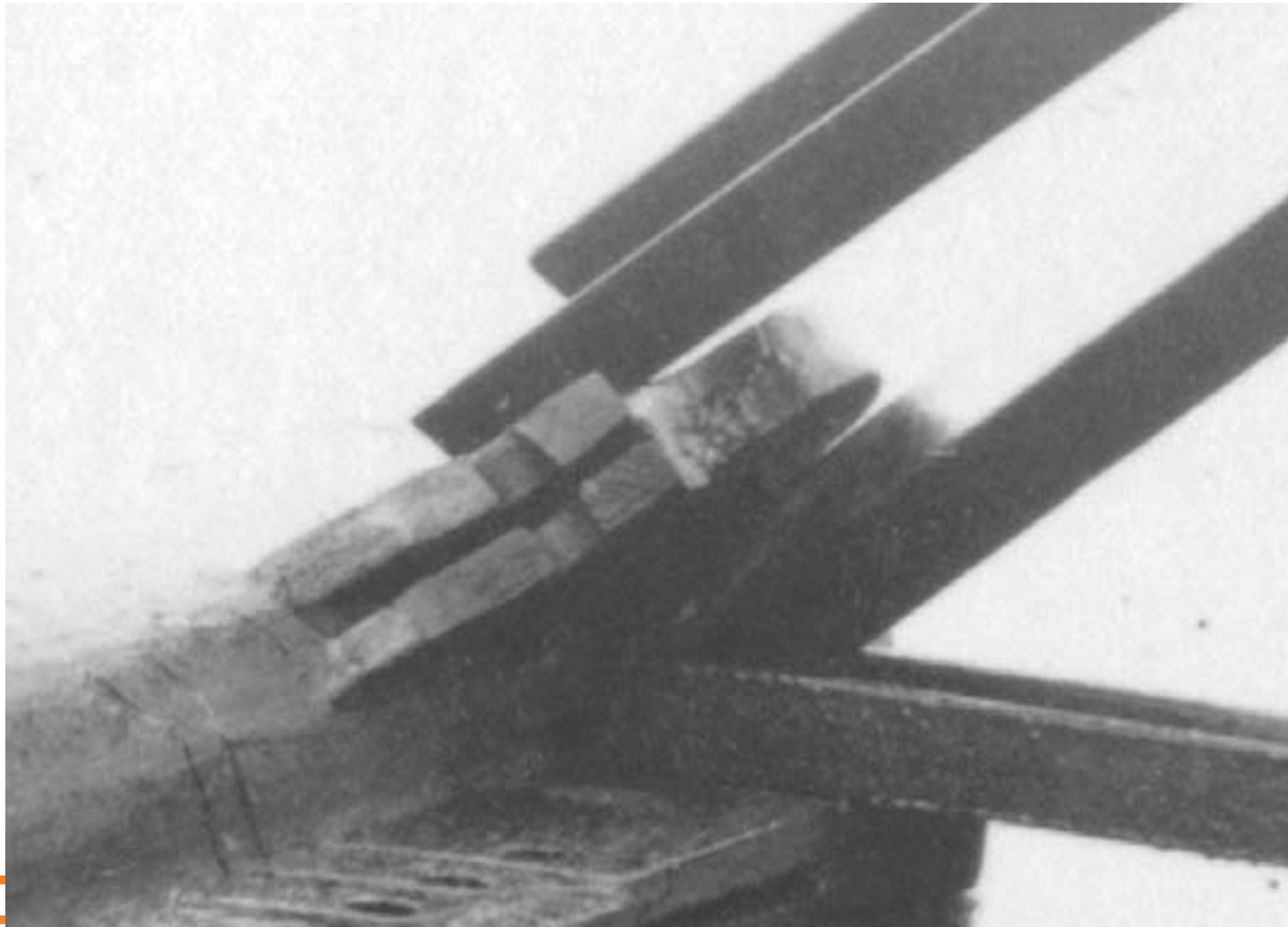
Fatigue Theory

- Dr. Peter Lewis, senior lecturer in the Department of Materials Engineering at the Open University, claims that dynamic effects are much more important than had been previously realised (11,12). It is claimed that dynamic effects caused the fatigue failure of the cast iron lugs. The evidence for the dynamic effects is based on the eye witness reports from painters and fitters that the high girders piers oscillated from side to side whenever a train crossed the bridge. On the basis of close inspection of high quality photographs (which show some limited evidence of crack arrest lines) of the failed parts it is claimed that the failure of the cast iron lugs was due to fatigue rather than overstressing..

Fabrication

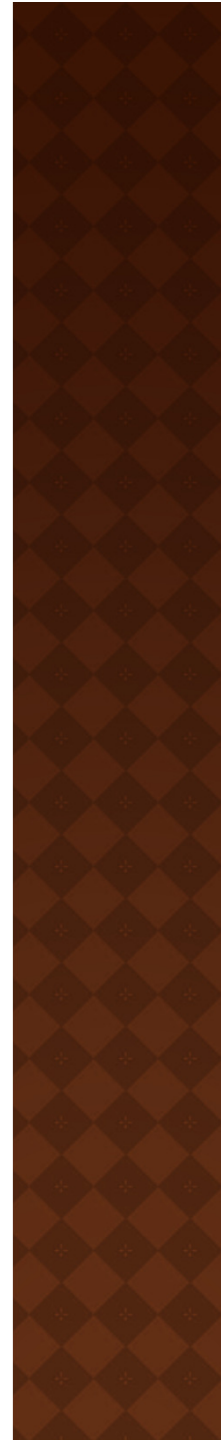


Fabrication



B

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When you hear hoofbeats.....

- William of Occam's abiding contribution to philosophy is a principle simplicity and economy, known as Occam's razor. It states that 'entities are not to be multiplied beyond necessity.' In modern language Occam's razor would translate something like: Given we have a potential set of solutions to a problem, which one is the most likely to be true: The one with the least amount of pre-suppositions and the theory which contains the simplest ideas.

RESPONSIBILITIES OF THE FORENSIC CONSULTANT

Independence

Act objectively and independently of the client to ensure that the data and/or report are not biased. Forensic consultants are not advocates and should endeavor to avoid conflict of interests as required by their profession.

Coordination

Coordinate and communicate closely with the client (or client's agent), maintaining confidentiality.

Expertise

Demonstrate specialized expertise and experience in the area of his/her assignment. This could include design, construction, and/or materials issues.

Reliability

Assure that the techniques used during an investigation are reliable and generally accepted by the relevant scientific, engineering, or construction community.

Consider all relevant standards and codes during the investigation. Collect all relevant information and data to minimize assumptions. Evaluate all plausible explanations of causes and effects. Develop objective and unbiased opinions based upon the available evidence.

Test Procedures

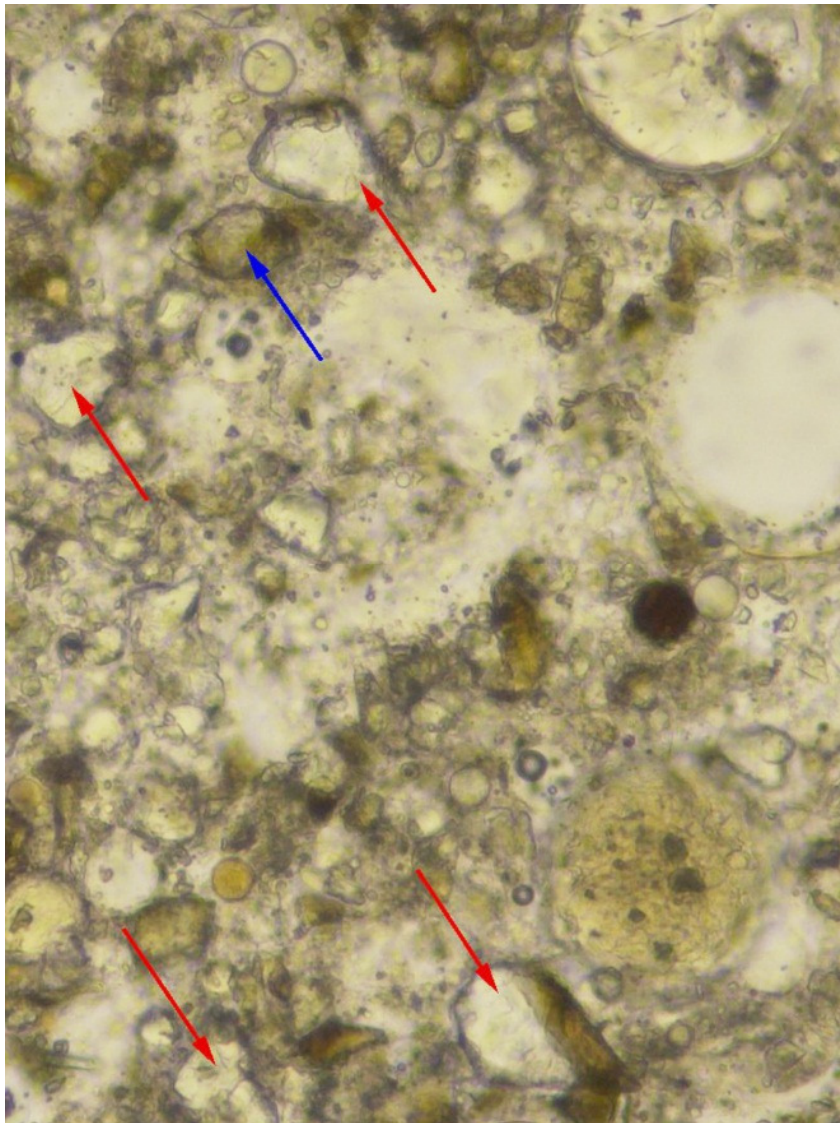
- Chemical Analysis
- Petrography
- Crystallography

Materials testing

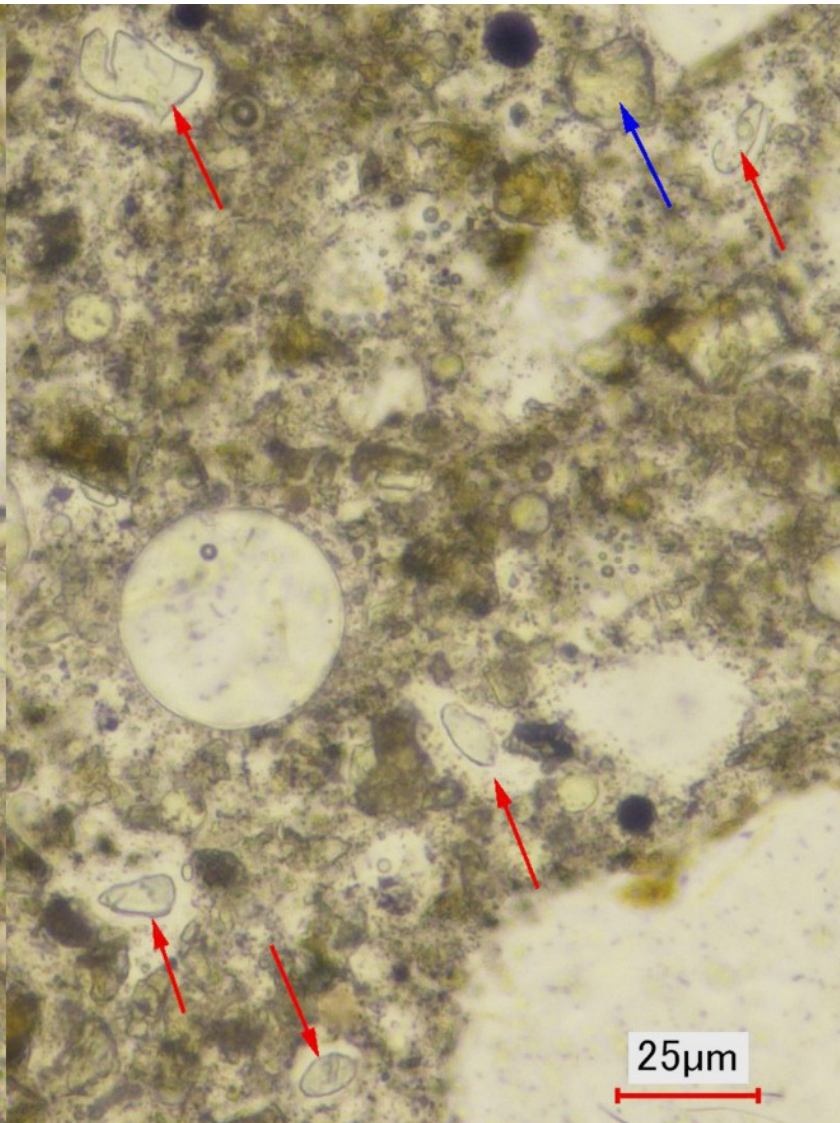
- Through materials testing, we can answer the following questions:
- Did the materials used match the concrete mix design?
- Were there any compatibility issues between the materials or environment?
- What was the water/cement ratio?
- Was the concrete placed properly?
- Was it finished properly?
- Did it cure properly?

Petrographic Examination



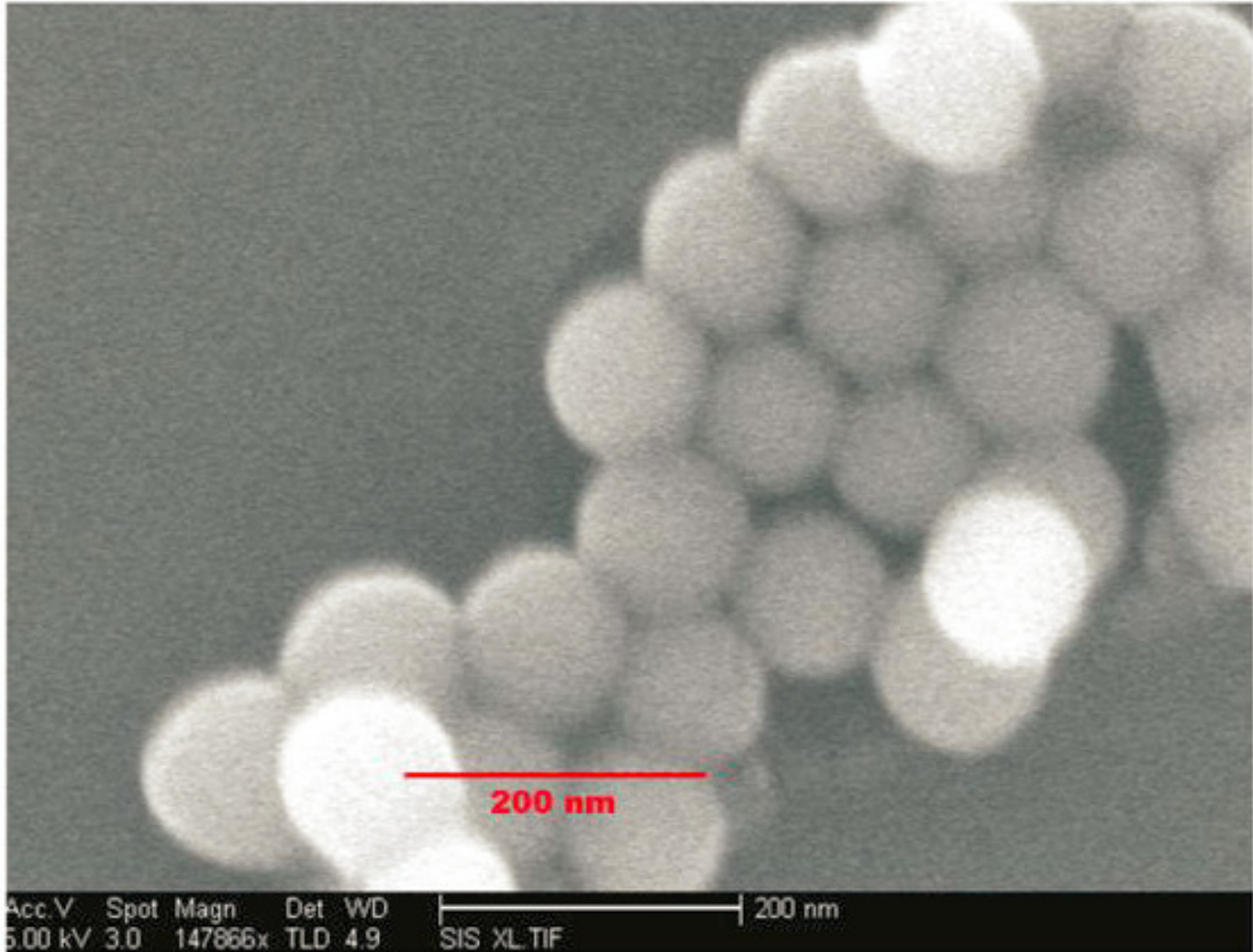


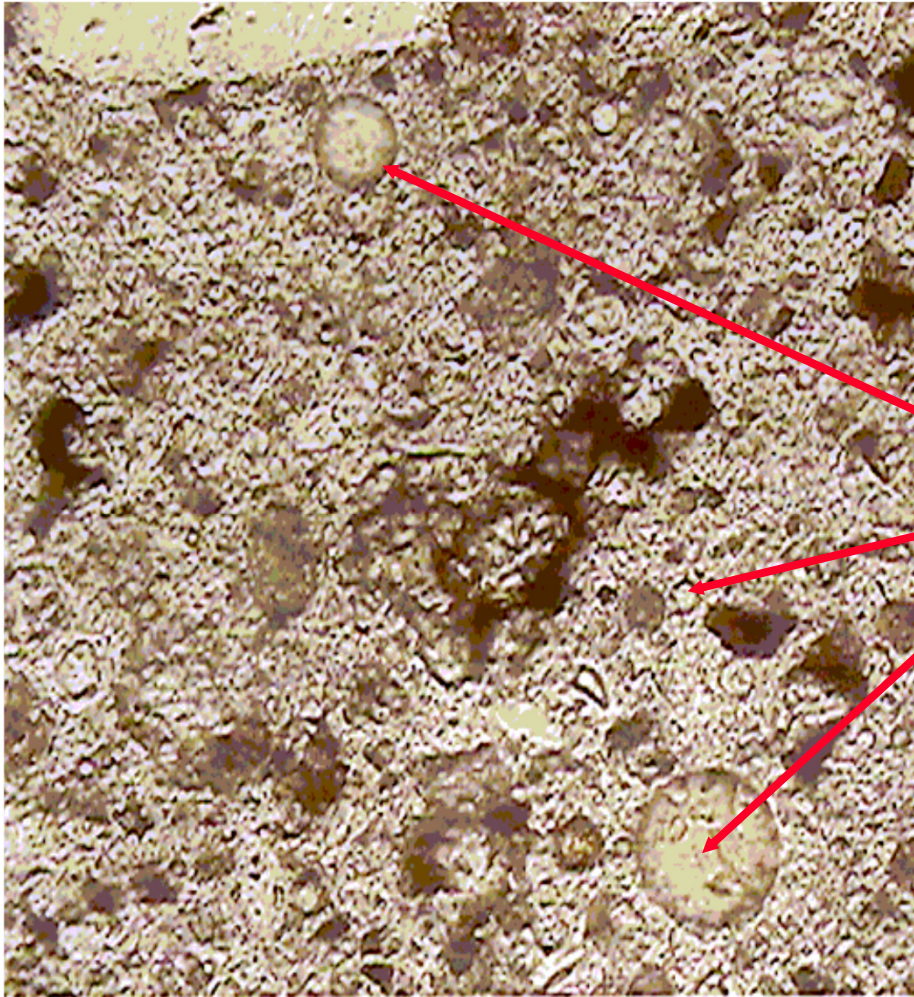
Low
Replacement



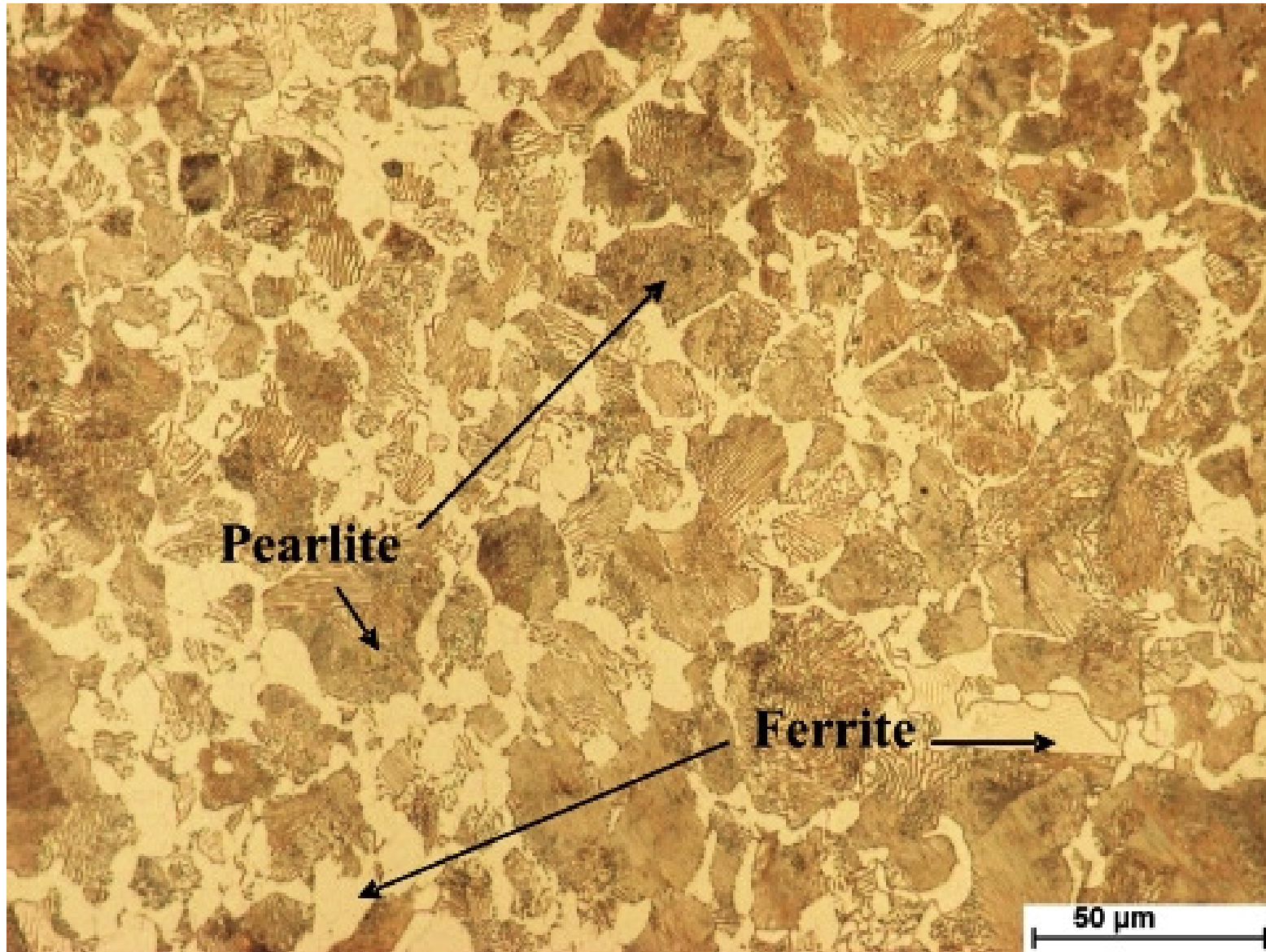
High
Replacement







Flyash
Particles



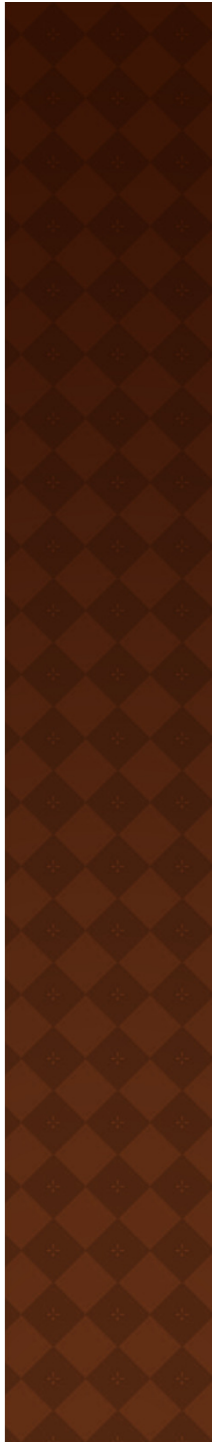
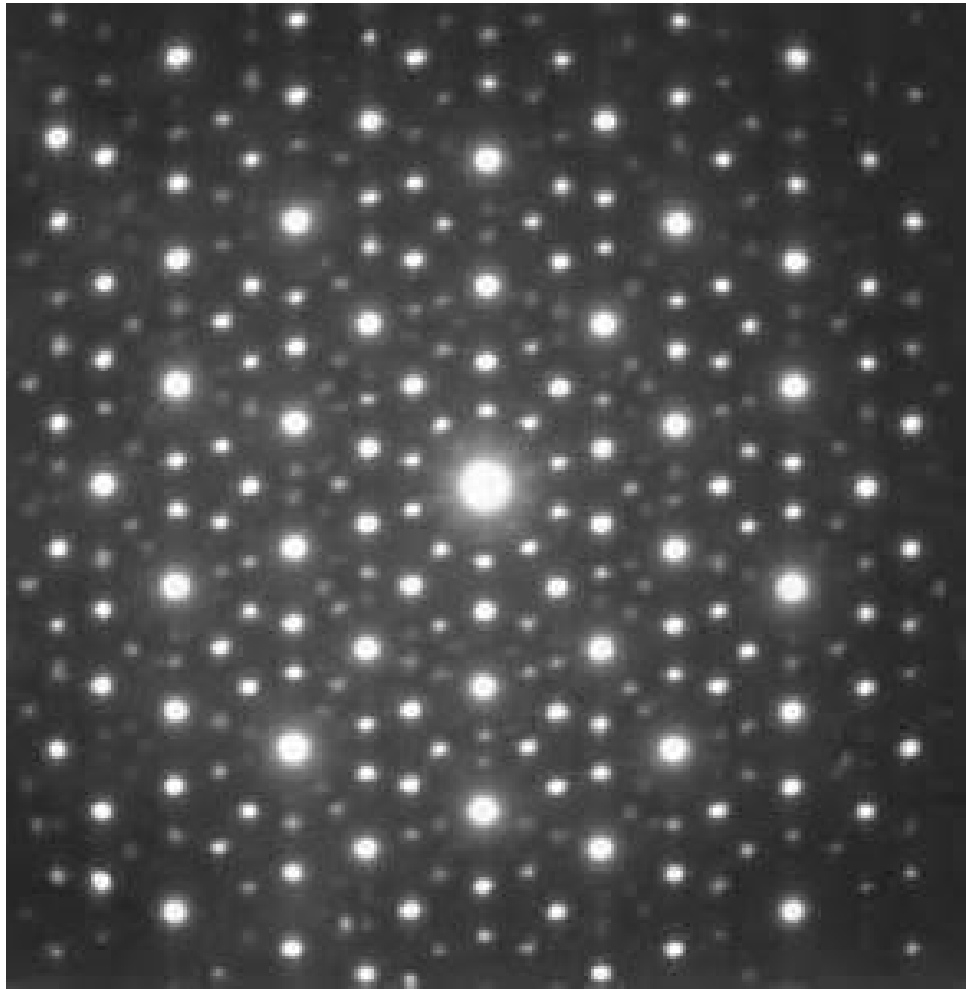


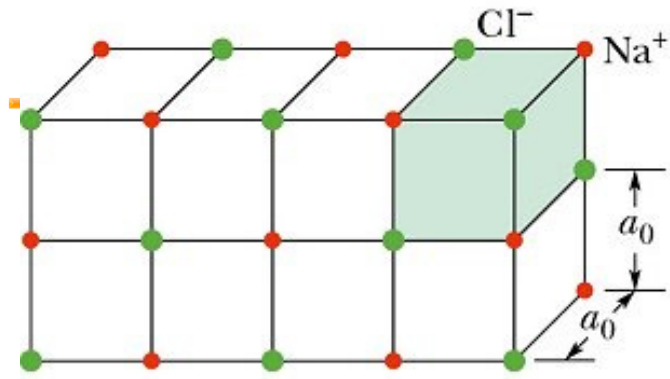
Sampling



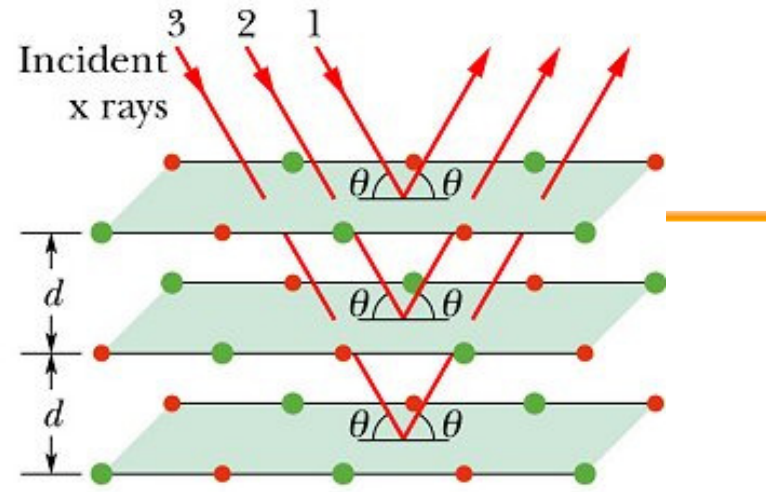
X rays and their Application



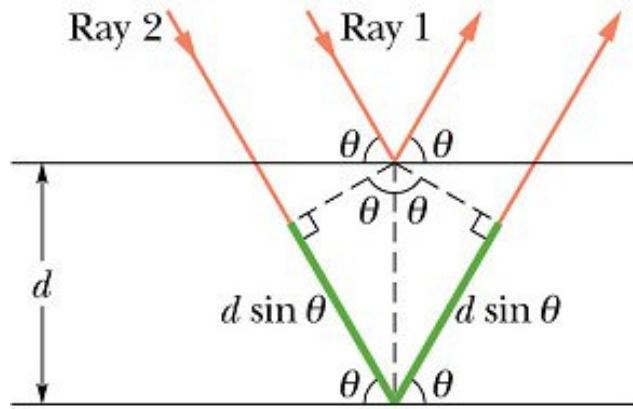




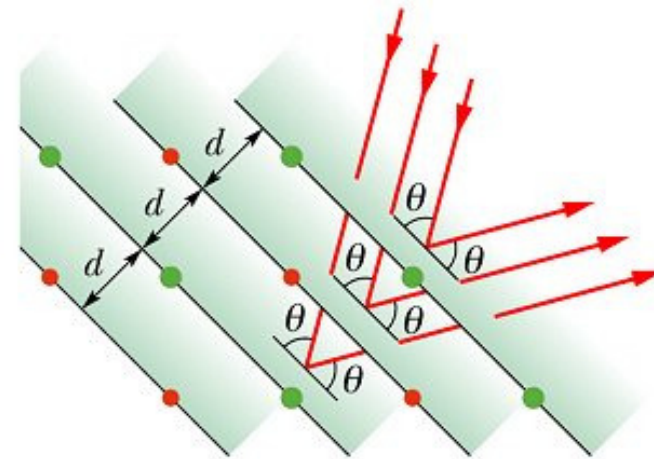
(a)



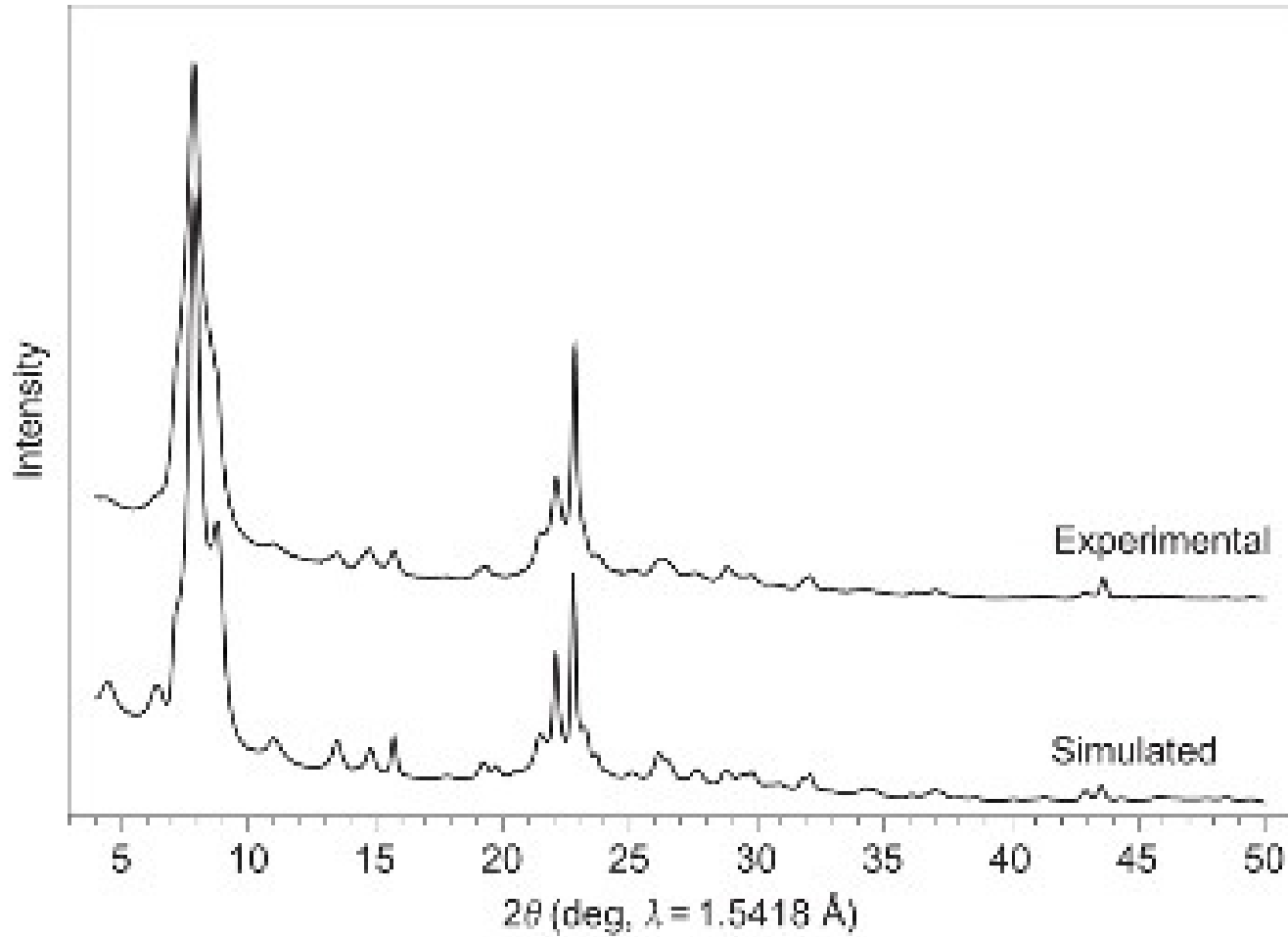
(b)



(c)



(d)



Counterfeit Johnnie Walker Black Label Scotch Whisky
found in North East London



Normal "UCP" logo

No "UCP" logo
on side of closure

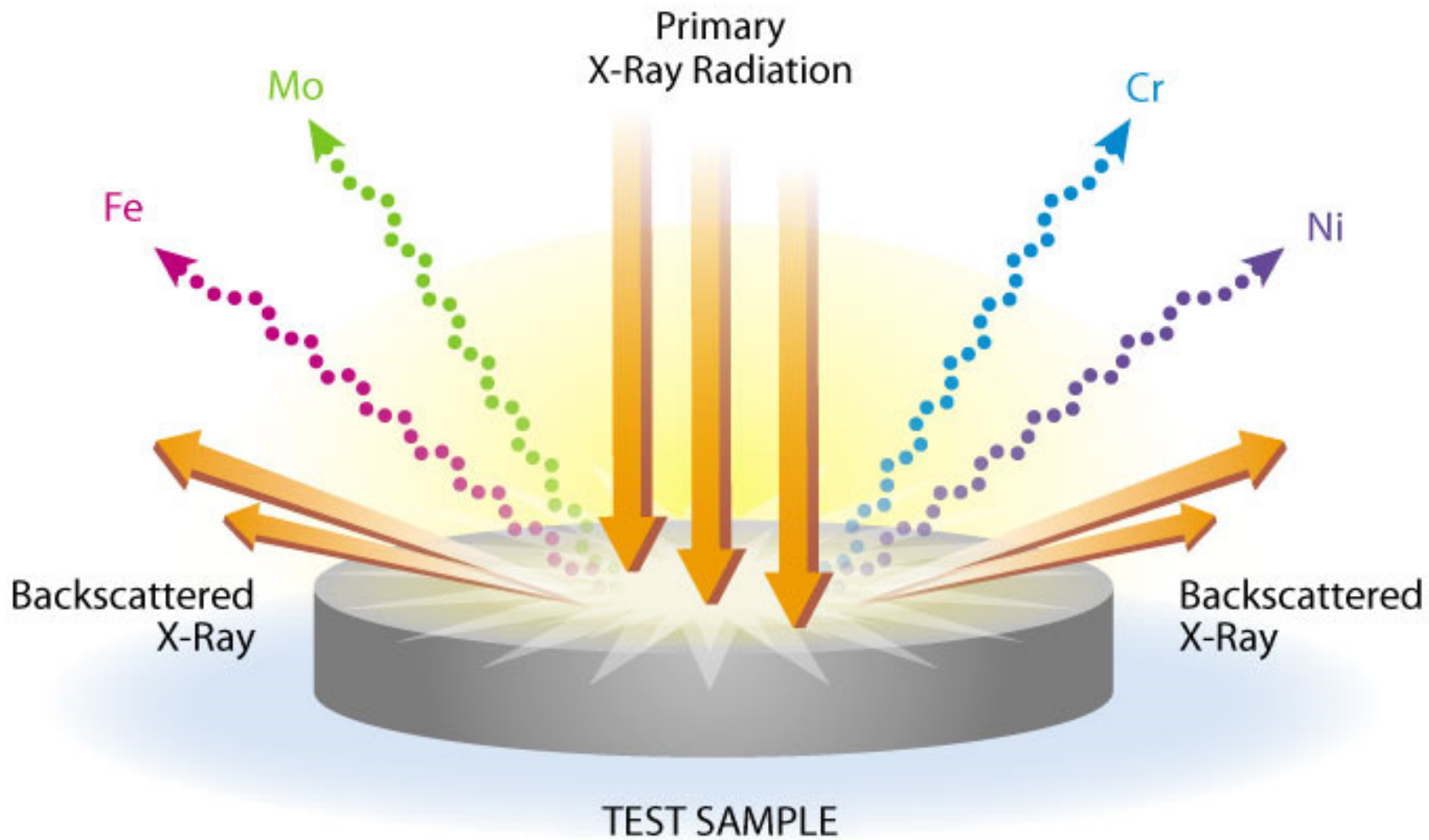
DISTILLERS incorrectly
spelled as DISTILLERIES"

Fake lot code L04P24878342
printed on rear of centre label

No E mark on base between
"700ml and 73mm"

Genuine

Counterfeit



Environment



Construction







Design





Includes updated diagrams of bridge hands

Bridge Building FOR DUMMIES[®]

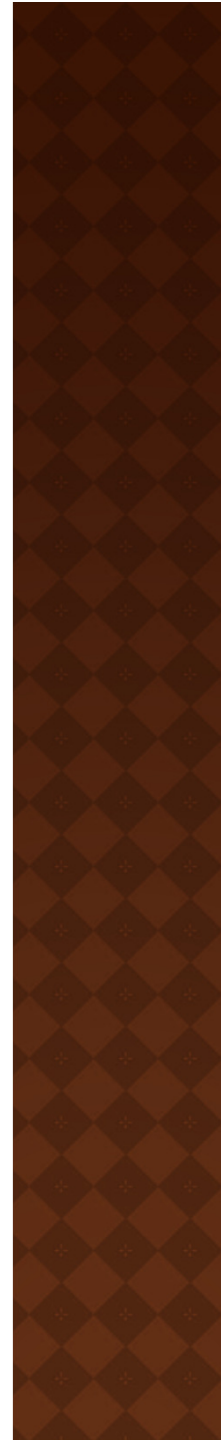
2nd Edition

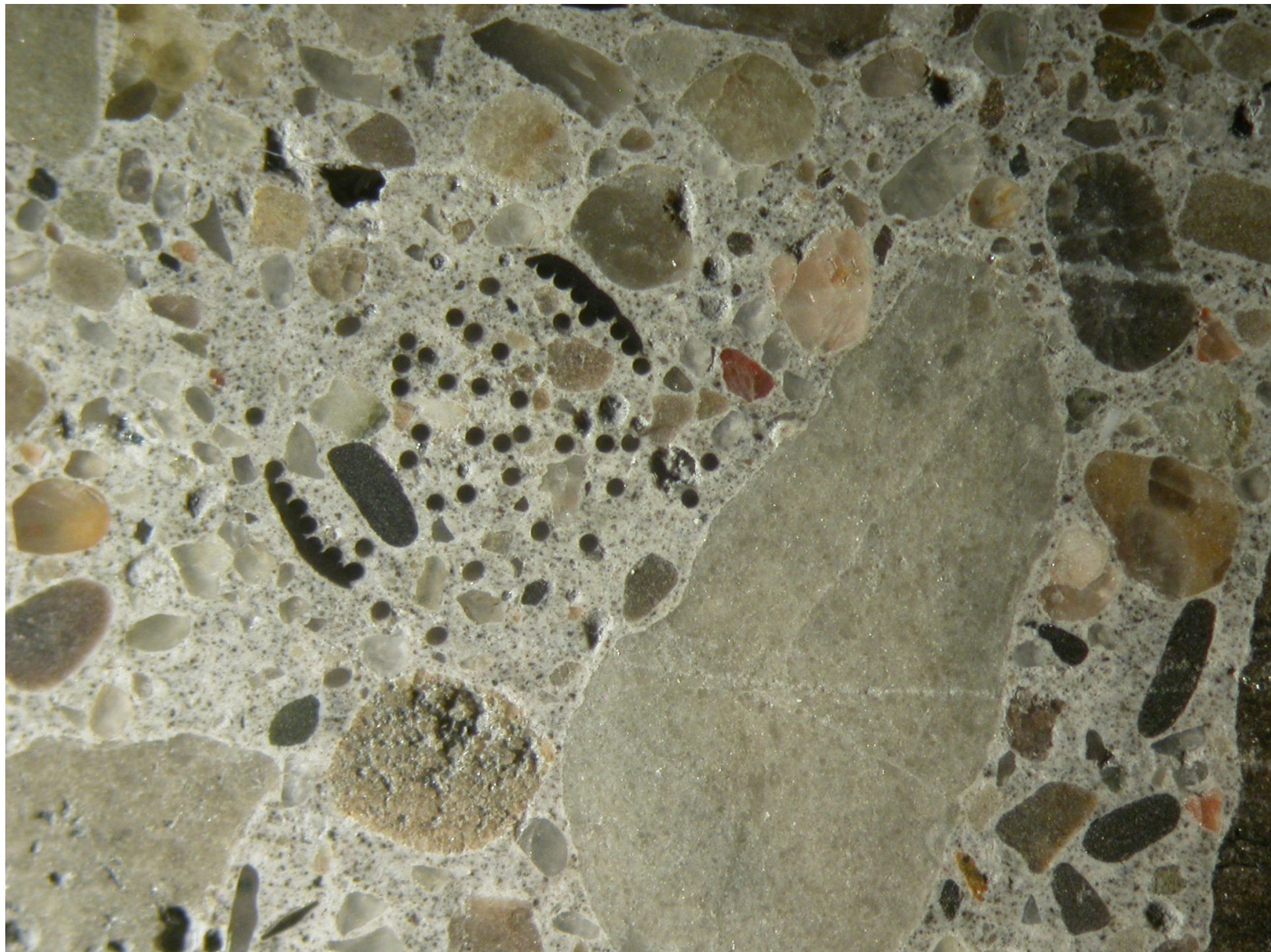


A Reference for the Rest of Us!



Barzin Mobasher ASU



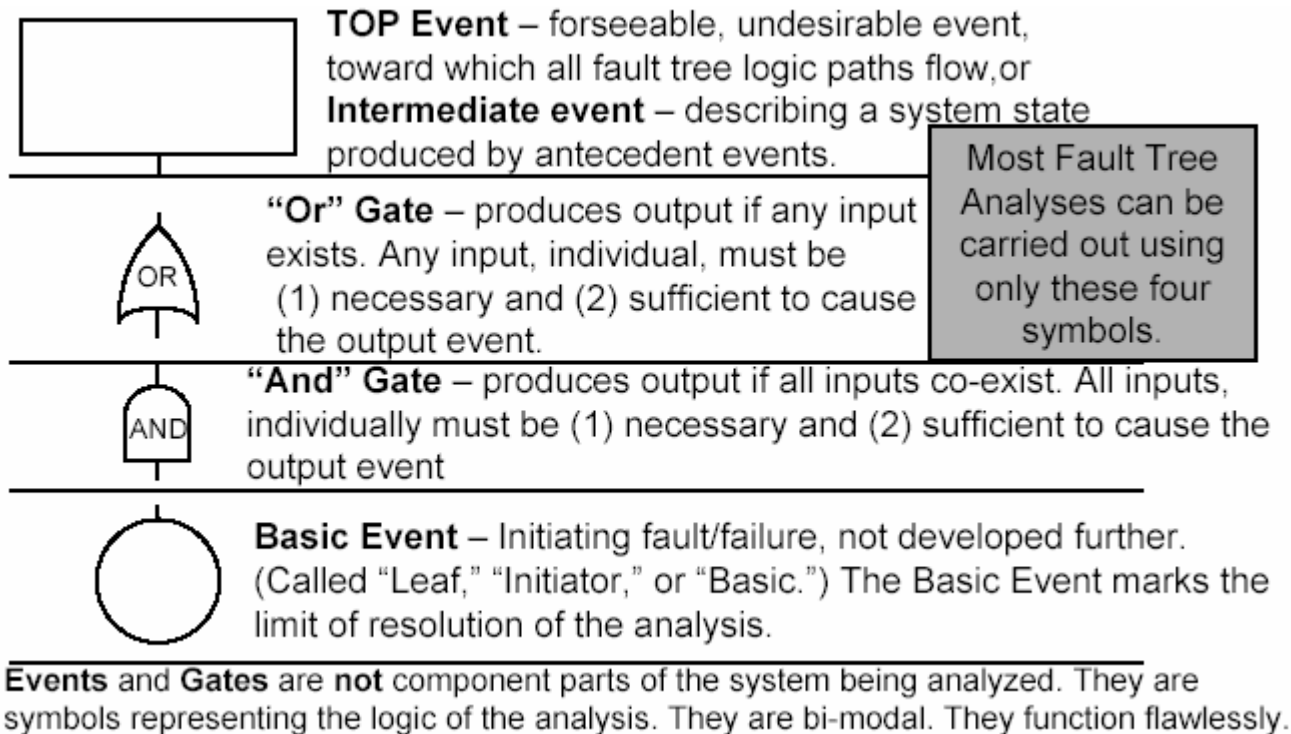




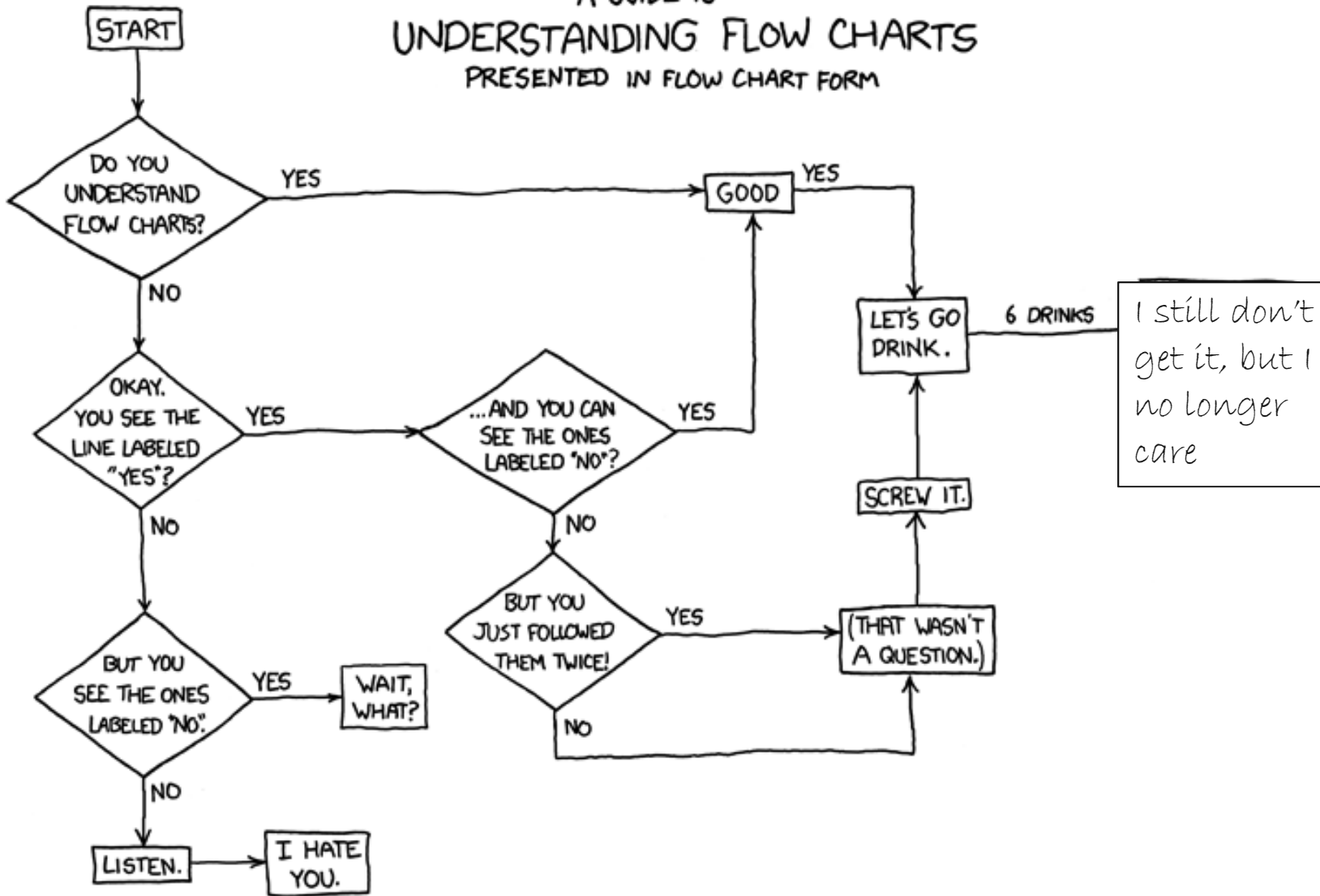
Many Techniques are Available

- Look at Fault Tree in detail

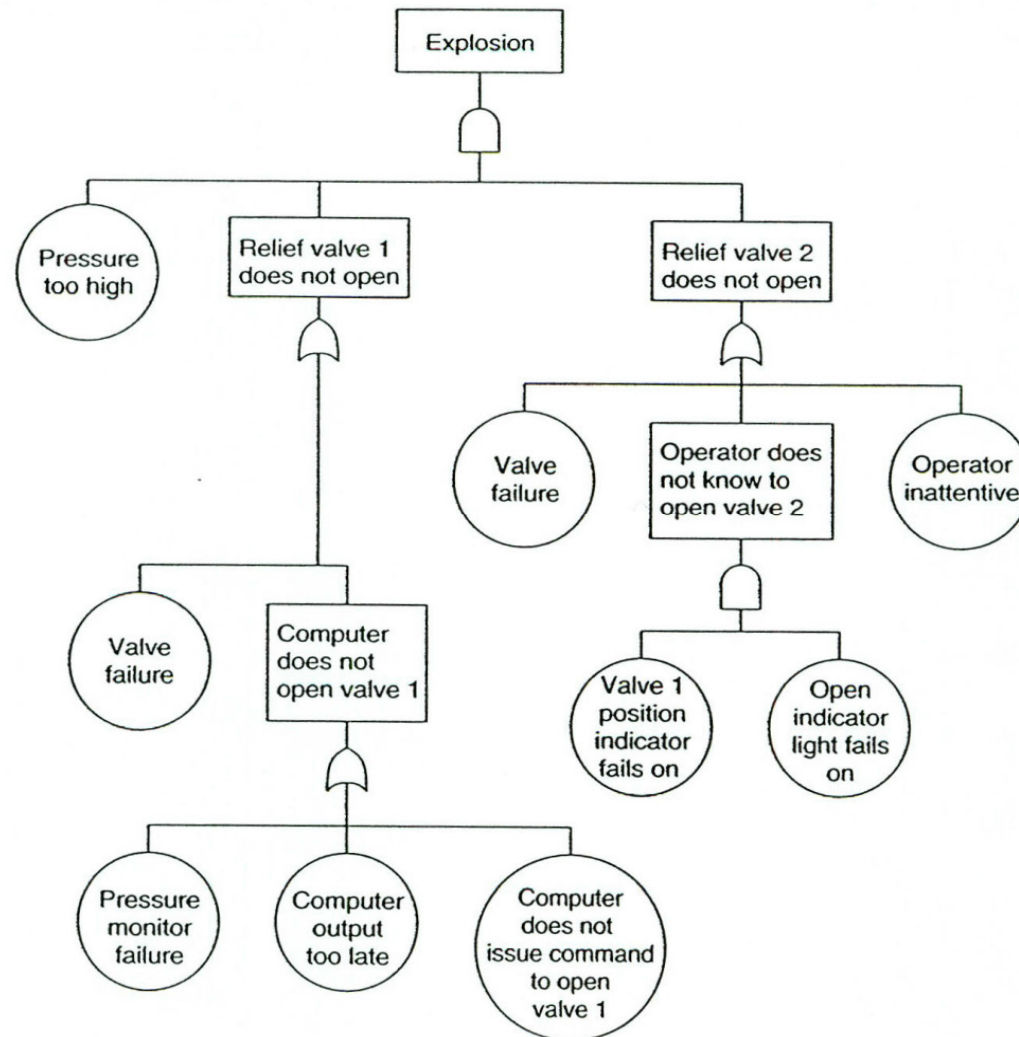
Fault Tree Analysis



A GUIDE TO UNDERSTANDING FLOW CHARTS PRESENTED IN FLOW CHART FORM

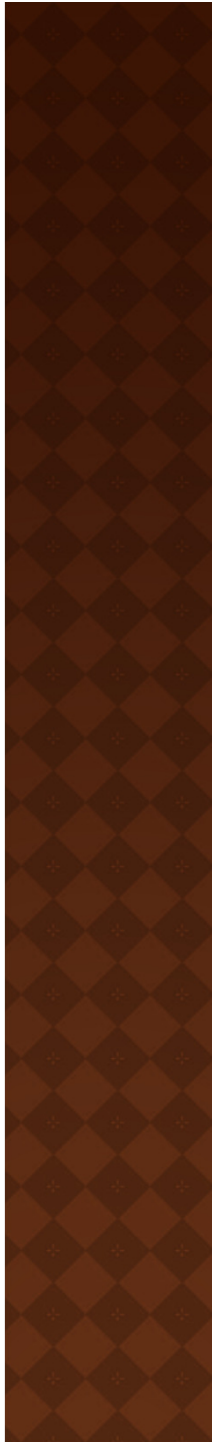
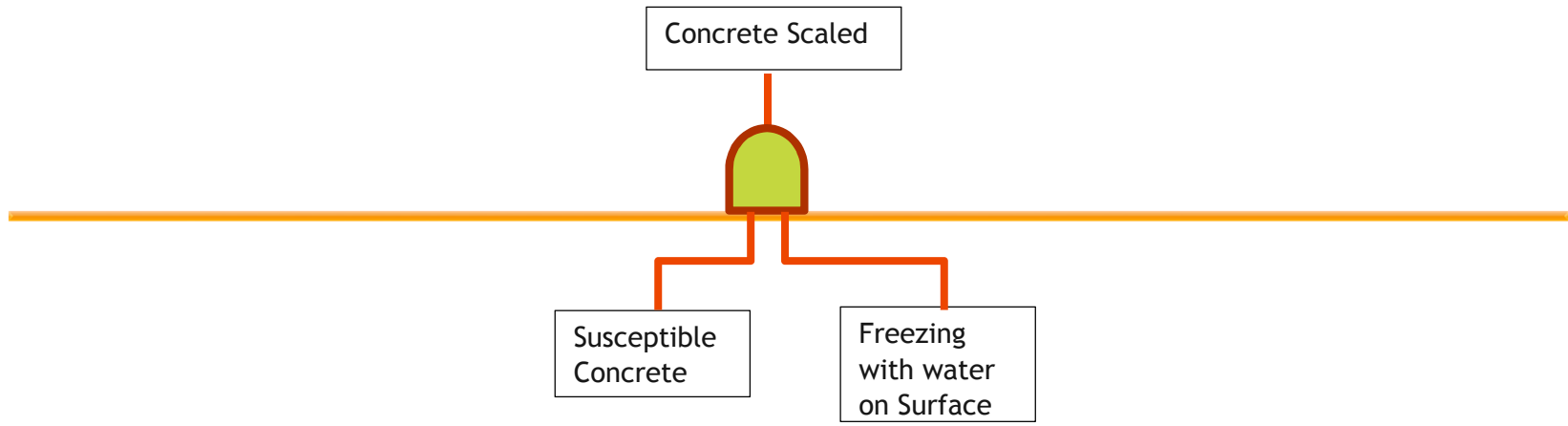


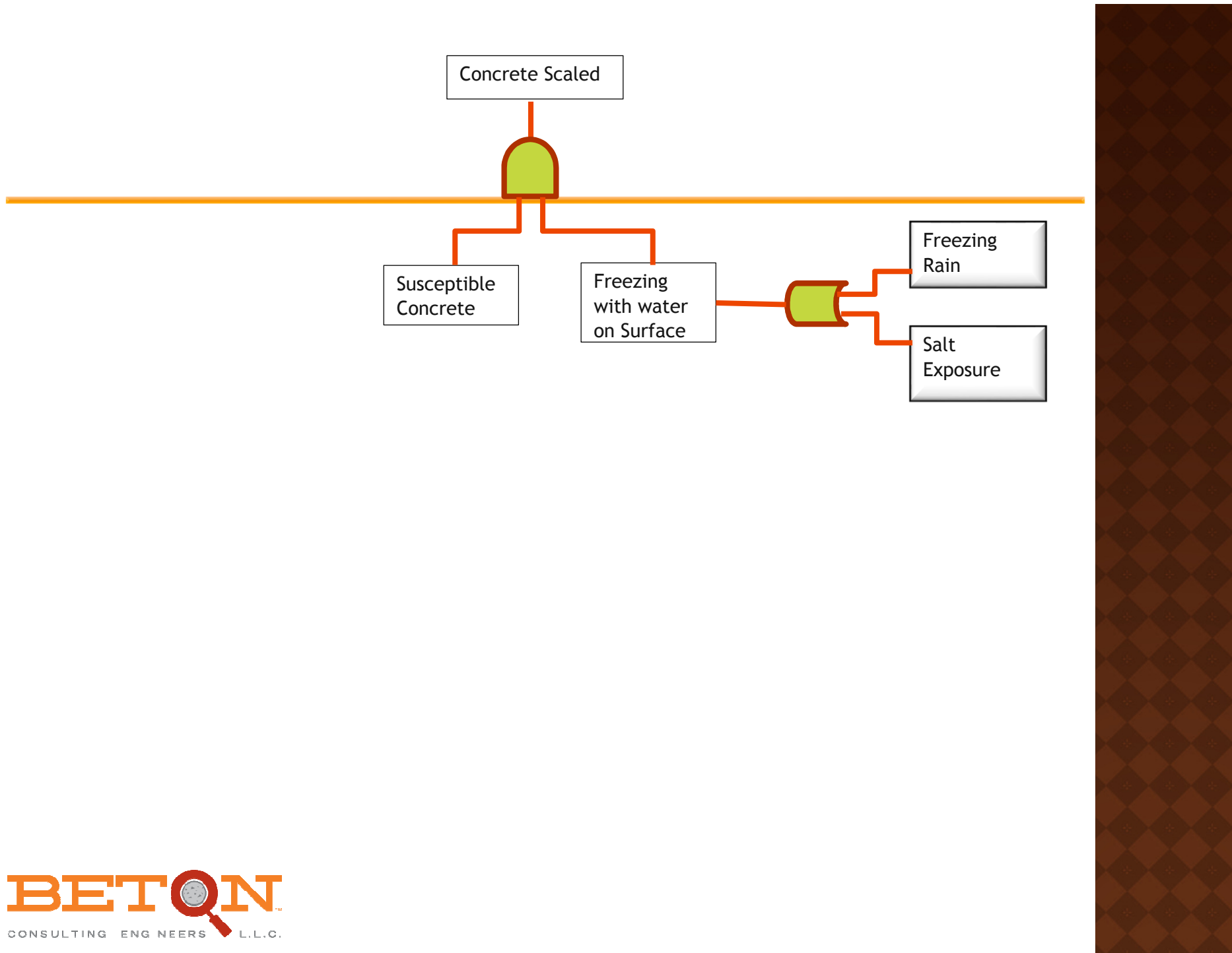
Fault Tree Analysis

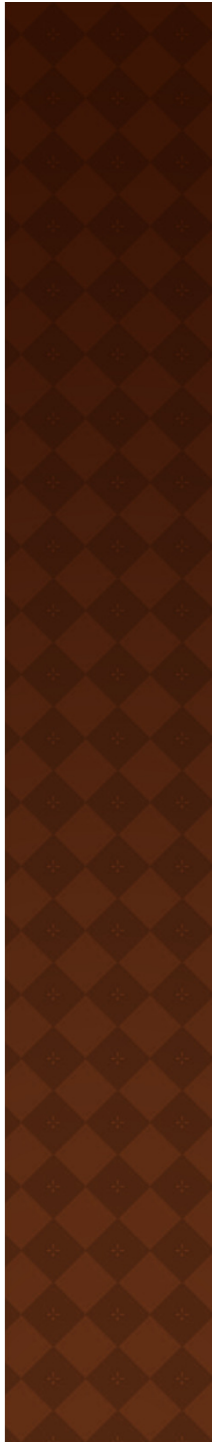
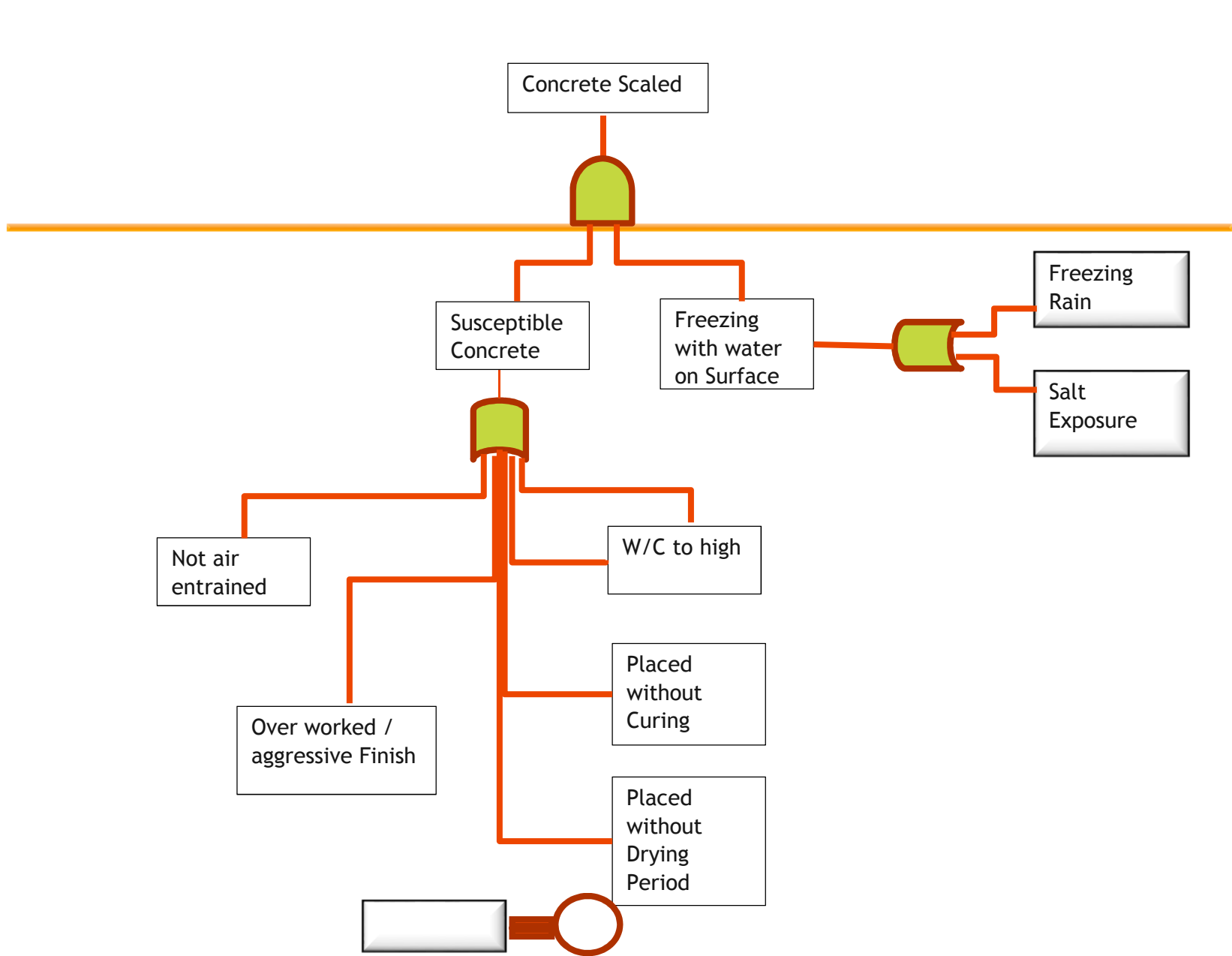


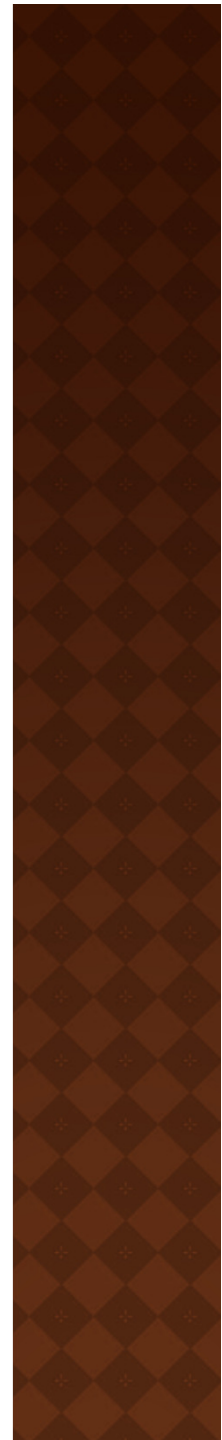
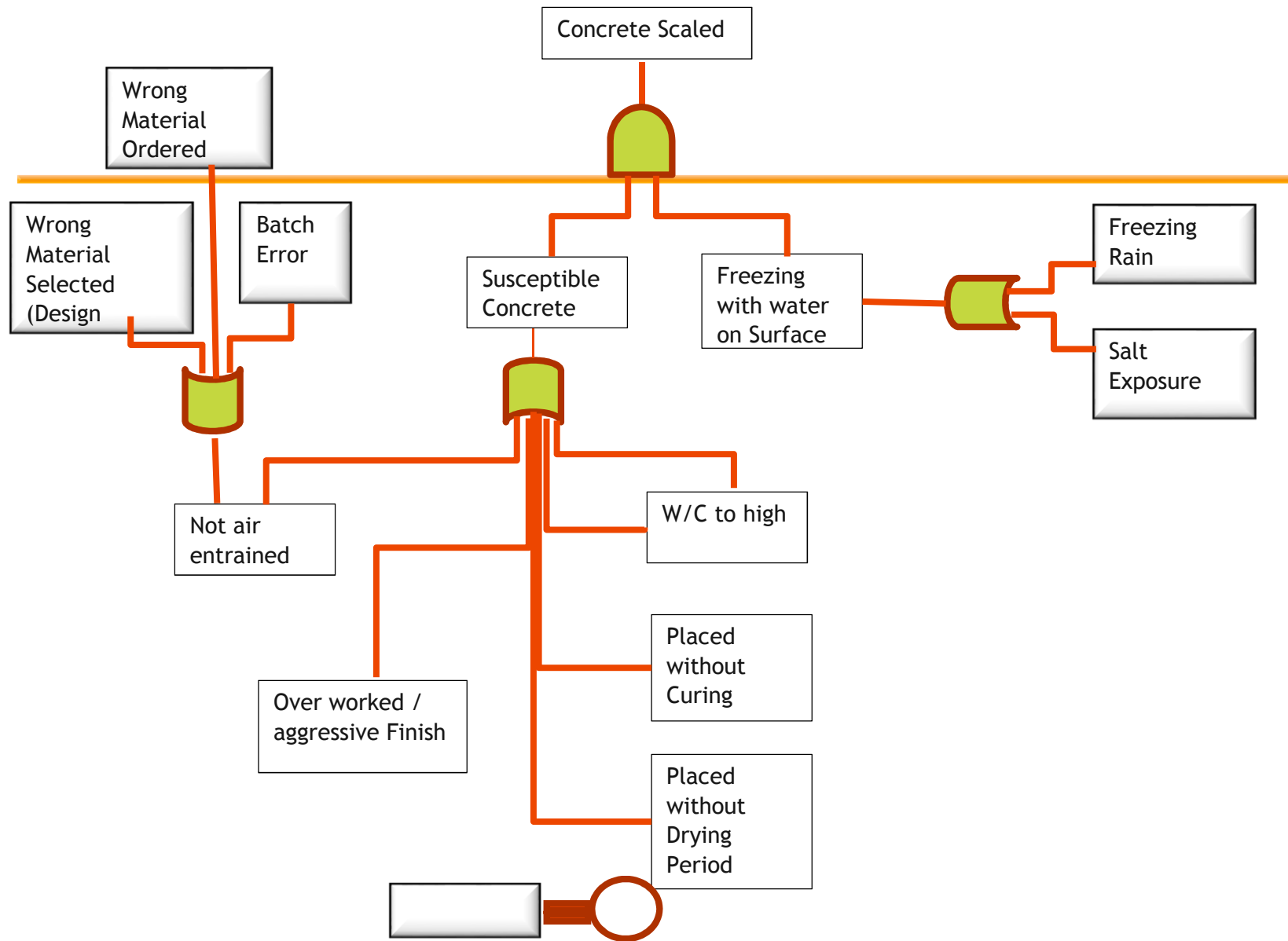
Concrete Scaled

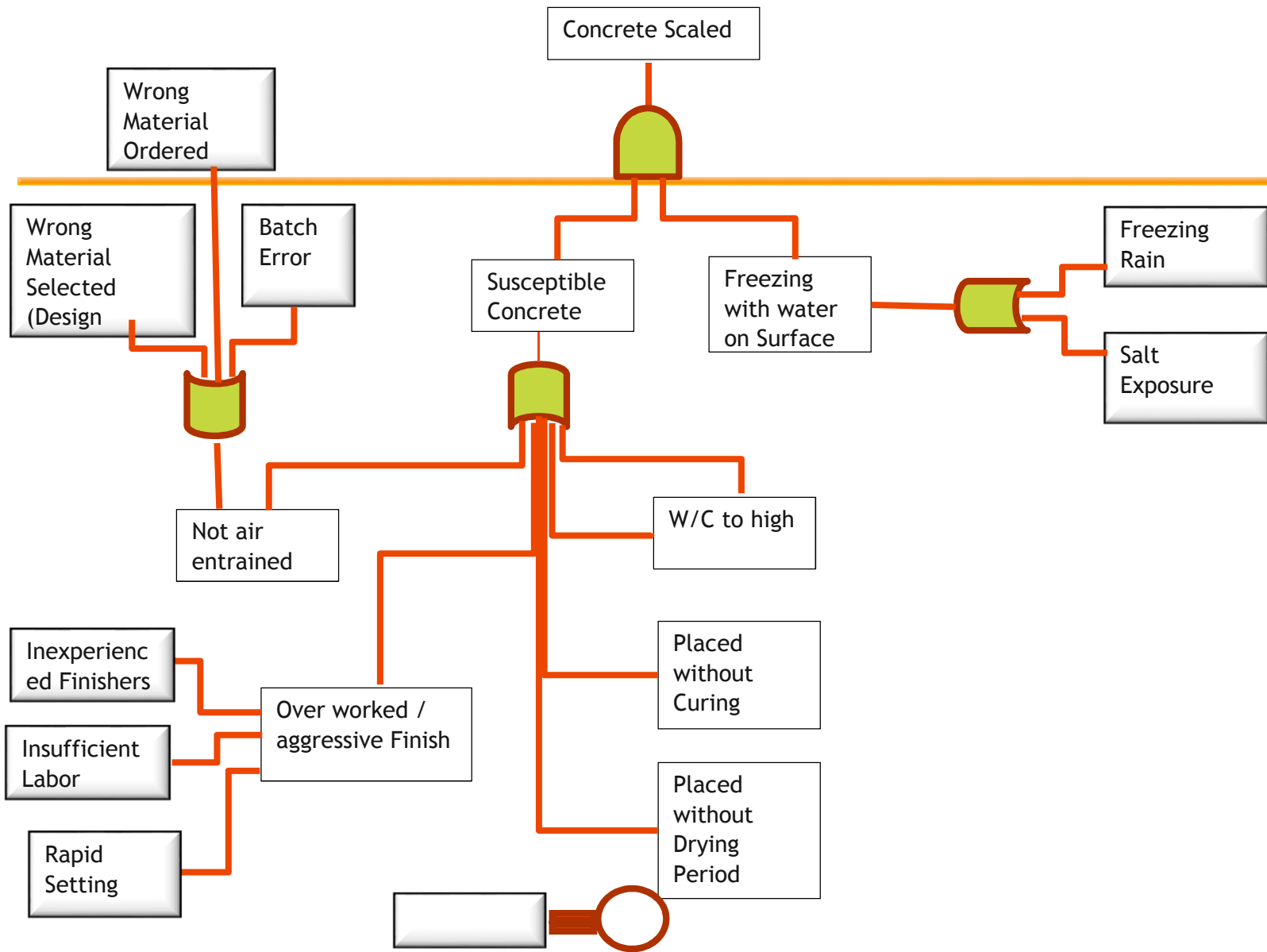


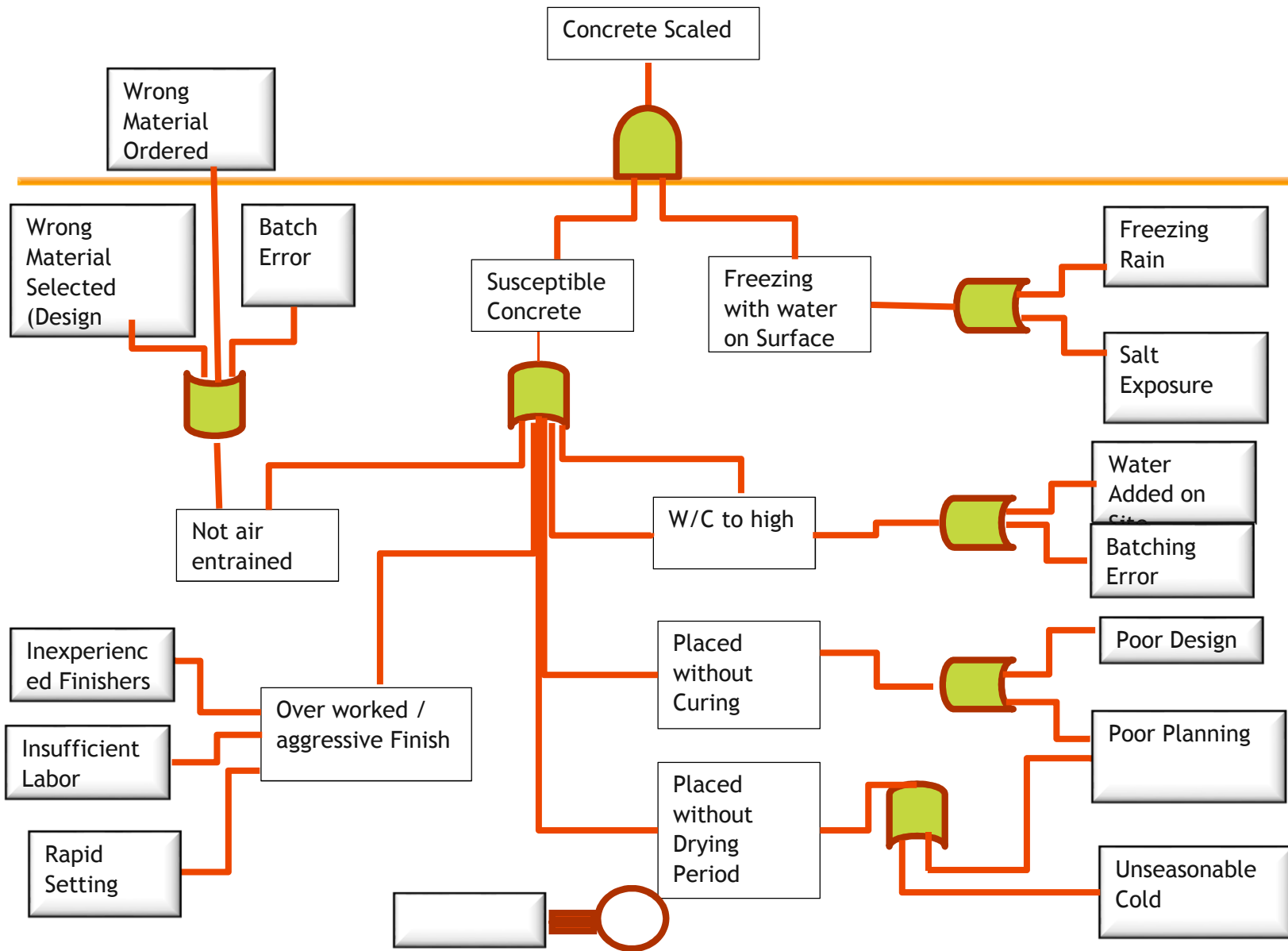


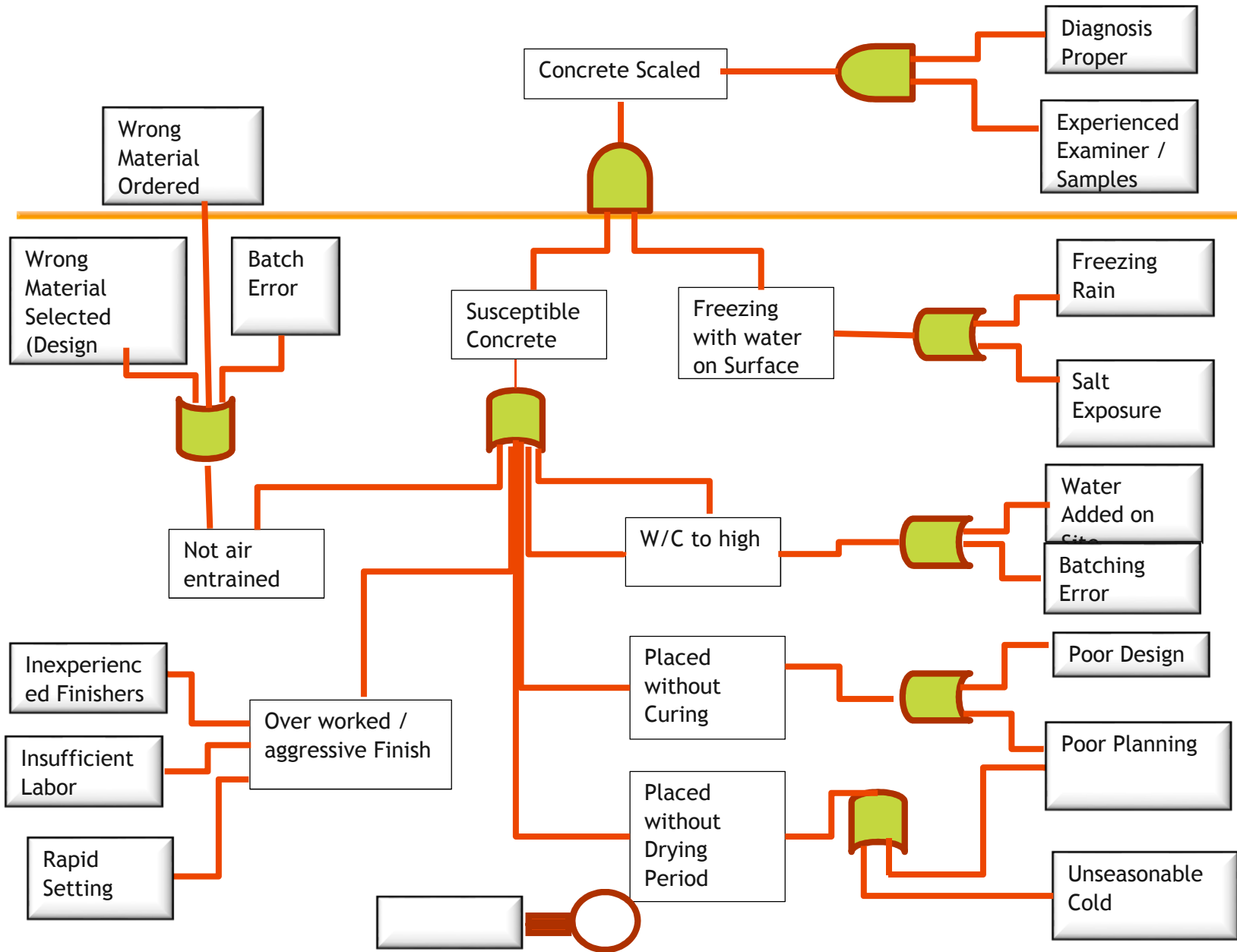








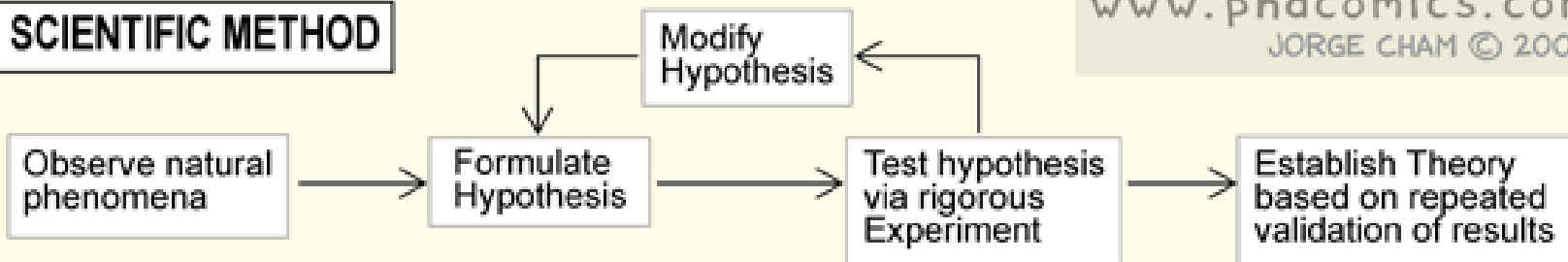




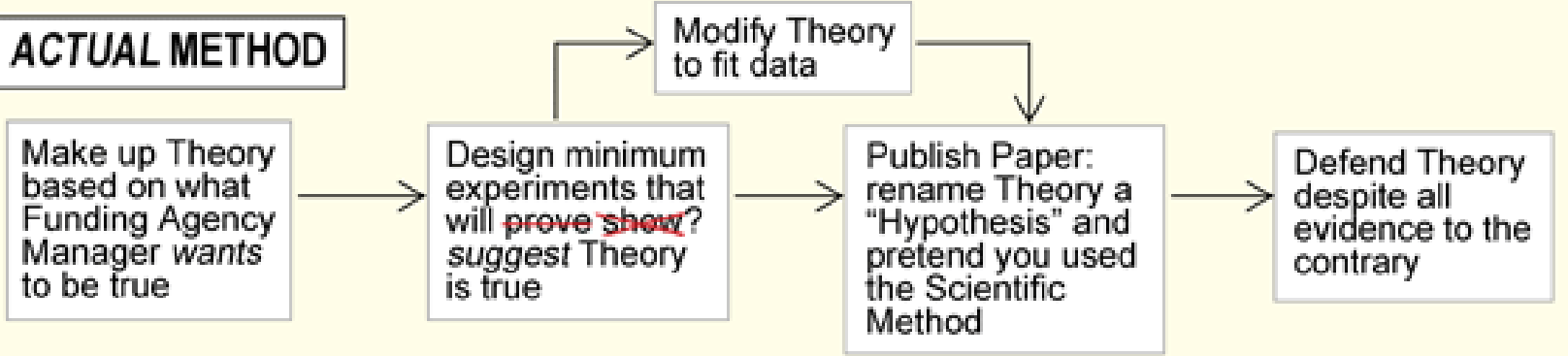
Which Analysis Method do you Prefer?

www.phdcomics.com
JORGE CHAM © 2006

THE SCIENTIFIC METHOD



THE ACTUAL METHOD



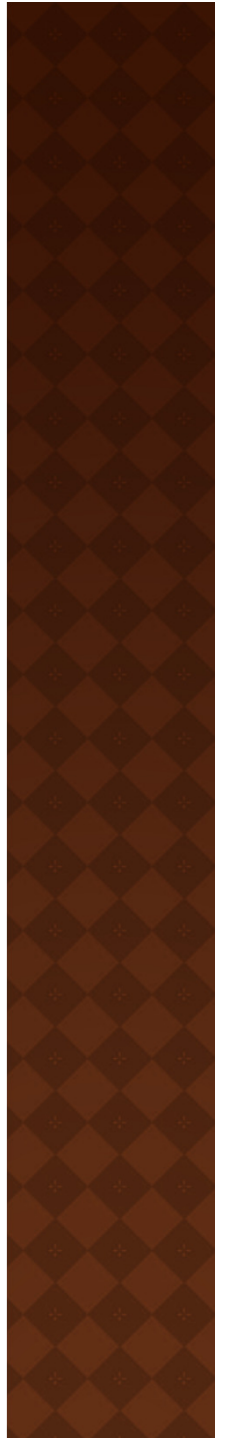
Scaling Case Study



Case Study - Low Strength I

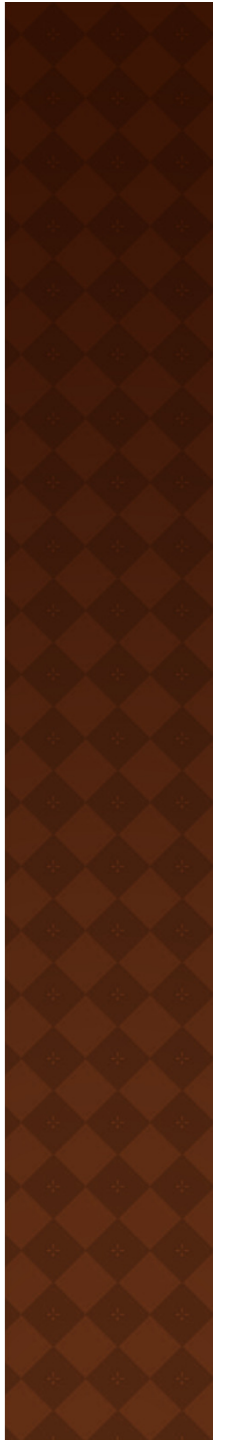
Case Study - Low Strength II

Case Study - Cracking



Case Study - Cracking II

Case Study - Environmental exposure



Conclusions

Failure is all around us



Questions?

- ◉ Thank you for the time and attention.