A common sense approach to building low-maintenance long-life concrete reservoirs for sustainability

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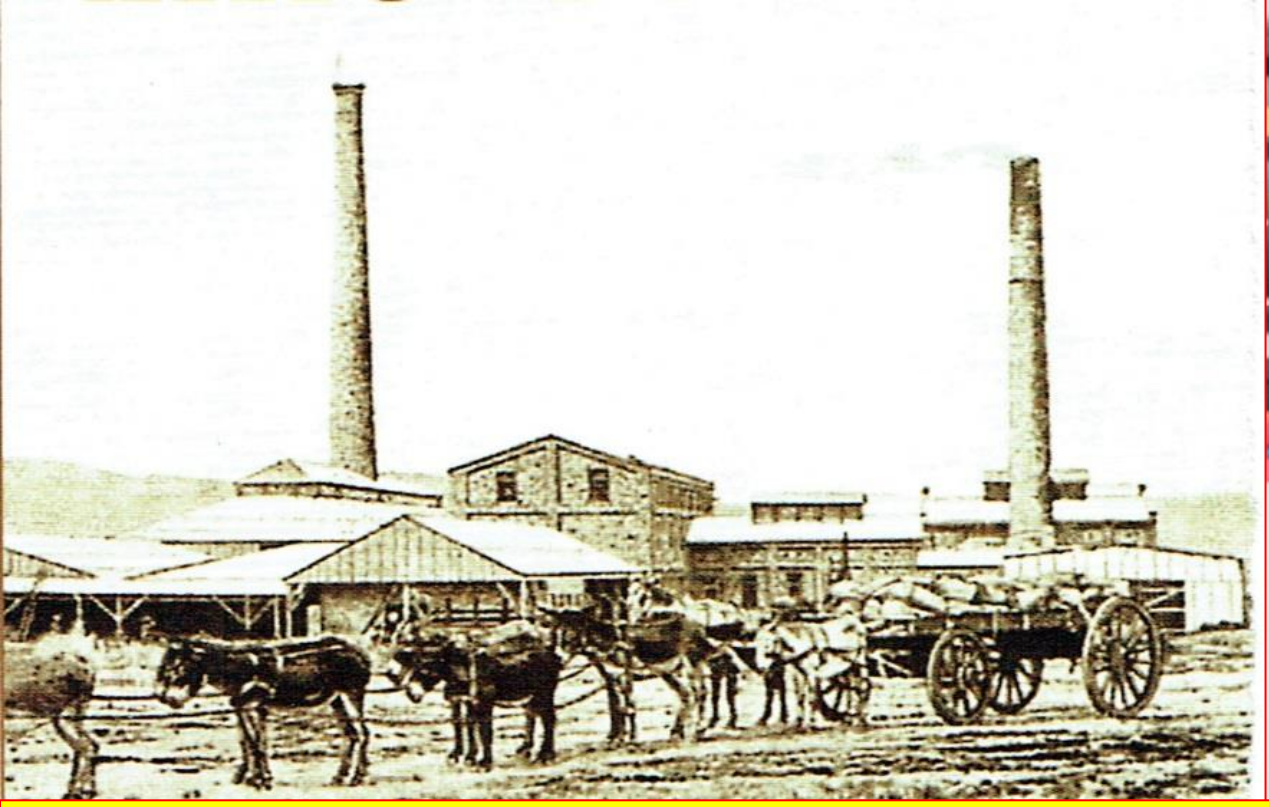
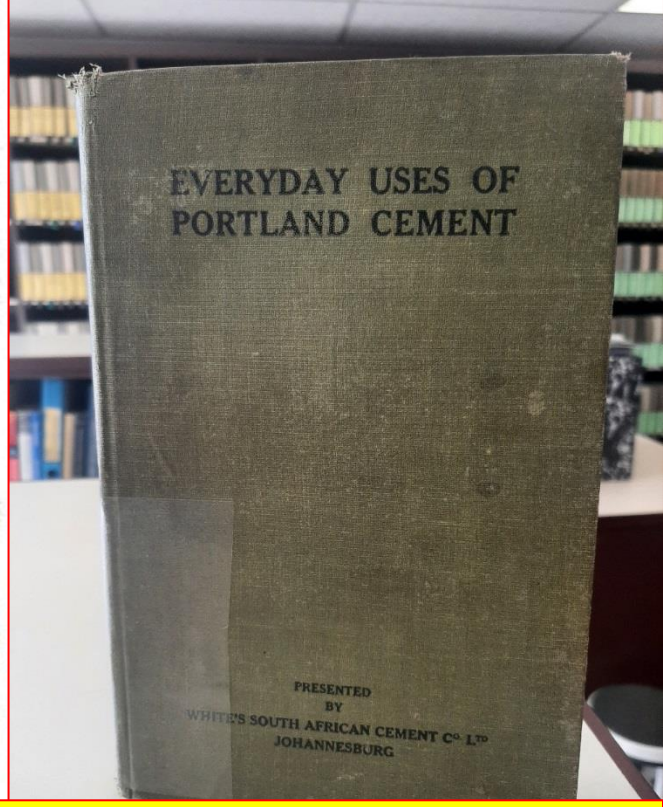
"*There are two things that know no bounds - the Universe and human stupidity. But I'm not so sure about the Universe.*"
Albert Einstein





In 1881, Mr. Edward Lippert obtained from the government of President Kruger an undertaking that, should he start a factory for the manufacture of cement, no similar factory would be permitted to operate within the Republic for a period of three years. Having secured his guarantee, Mr. Lippert wasted no time, and in early 1892, the first factory **Eerste Cement-Fabrieken, Beperkt** was producing portland cement at Daspoort, near Pretoria – not far from the present PPC Hercules Factory. Fulton's 5th Ed. 1976

"The Romans used lime concrete that has stood for centuries and is doubtless better today than when it was first made….But concrete made with hydraulic lime or Roman cement, was nothing like so strong and serviceable as Portland Cement concrete. We refer to it merely because it shows the remarkable resistance and life possessed by concrete. If lime concrete has stood unharmed throughout the ages, Portland Cement concrete, which is infinitely superior, must be imperishable." **Everyday uses of Portland Cement White's South African Cement Company 1914**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WORDSWORTH CLASSICS OF WORLD LITERATURE
THE DECLINE AND FALL OF THE ROMAN EMPIRE
EDWARD GIBBON
THE NO.1 INTERNATIONAL BESTSELLER
Jared Diamond
Collapse
HOW SOCIETIES CHOOSE TO FAIL OR SURVIVE
'A grand sweep from a master storyteller of the human race'
DAILY MAIL
NATIONAL GEOGRAPHIC
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SURVIVORS' TOOLKIT
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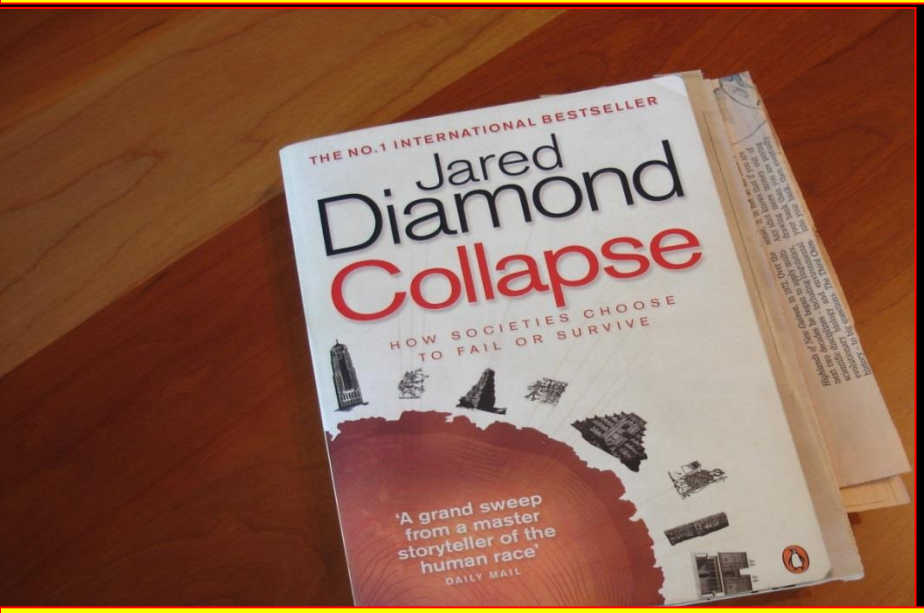
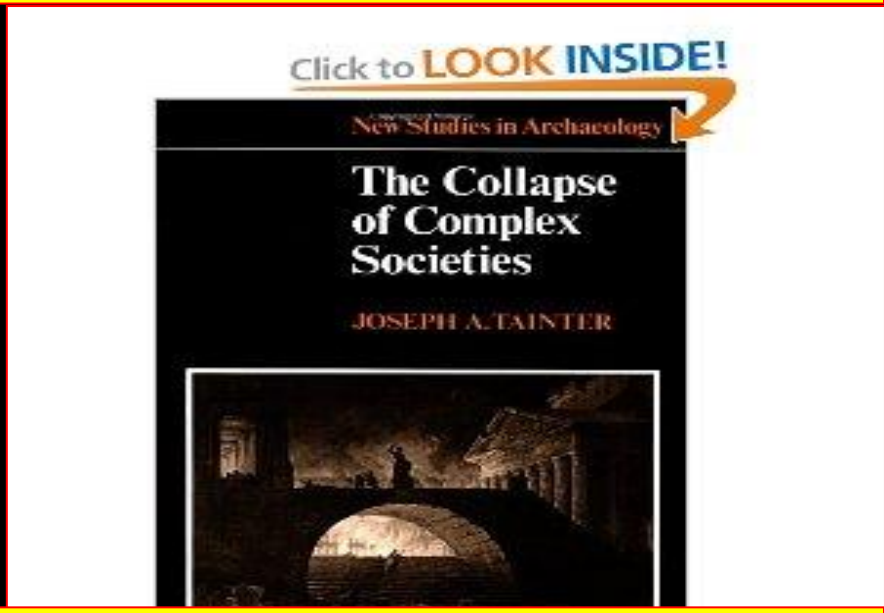
How Institutions Decay and Economies Die
Niall Ferguson
BASED ON THE BBC RADIO 4 REITH LECTURES 2012
'The most brilliant British historian of his generation'
THE TIMES

NO PREVIOUS CIVILISATION HAS ESCAPED COLLAPSE





Accounts of the collapse of 60 former societies including the Egyptians, Greeks, Romans, Aztecs, Incas, Mayans etc.

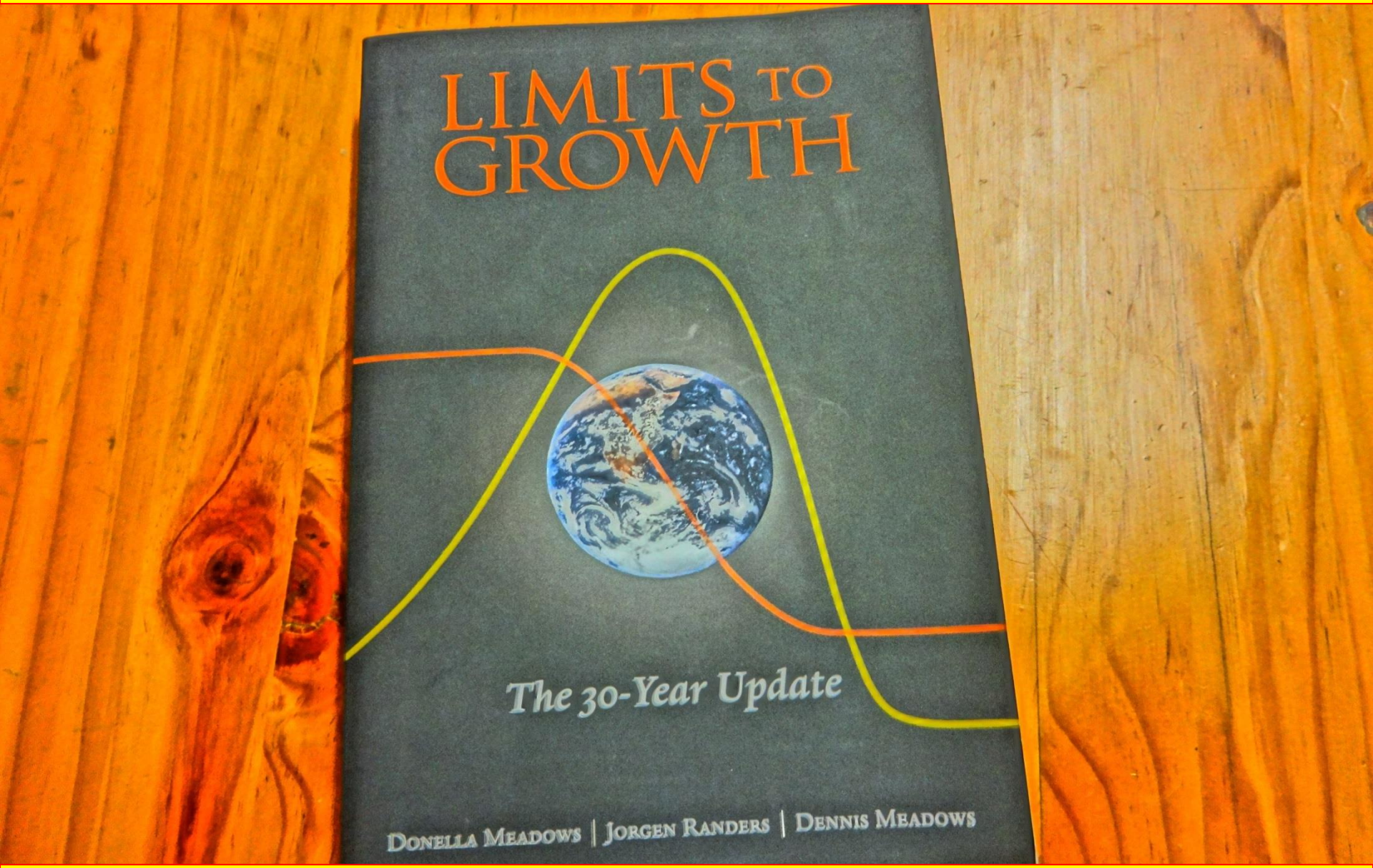
"Complex societies tend to collapse largely because their strategies for energy capture are subject to the laws of diminishing returns."

Why should ours be any different?

"*Intelligence is a lethal mutation. Successful species are able to mutate and adapt quickly.*" Ernst Myers

"*We are becoming increasingly specialized, and the paleaontological record warns us that specialization leads to vulnerability… our civilization sits on a knife edge.*" Prof. Terrence McCarthy

Club of Rome



"By the middle of this century, investment in industrial capital will no longer be able to keep up with depreciation."

"Delivery' needs to be understood as embracing not just the construction of infrastructure…, but the management of that infrastructure… throughout its intended life." Kevin Wall: *Managing municipal infrastructure assets*, Civil Engineering, October 2005 Vol 13 No 10, SAICE

Quote from: Kevin Wall: *Managing municipal infrastructure assets*, Civil Engineering, October 2005 Vol 13 No 10, SAICE.

"The evidence is overwhelming of the cost savings in the long term which result from the management of infrastructure. If . . . . infrastructure is maintained when it should be, then the long-term total cost of service delivery is significantly reduced. Thus, over a period of years, infrastructure management results directly in the 'freeing up' of funds for new infrastructure . . . . . "

A stitch in time saves nine

We assume we need new infrastructure. But is this assumption correct?

- World population cannot grow forever. 1 to 2 billion is deemed sustainable.
- We only need an annual 2% surplus of deaths over births to achieve this by the end of this century.
- Populations in the Global North have slowed. Many are in decline.
- Excess mortality since COVID has not reversed as expected in the US and UK.
- In 2023 US excess deaths were 40% higher than the historic mean – a 10 sigma event!
- Africa is the only continent where population is clearly still growing exponentially – predicted to reach 4 billion mid-century but this will not necessarily happen.
- We have biophysical limits – fresh water is not infinite. If we supply more, people will consume more.
- If we can't cope maintaining existing infrastructure, building more will only exacerbate the problem. (Rand Water Moratorium)

But if you are absolutely determined to build a new reservoir then for heaven's sake design it well and build it to last as long as possible! Min 100 years.

Cost of adequate prevention during design is minimal compared to cost of rehabilitation at a later date

De Sitter's "law of five"

One dollar (R19) during design and construction is as effective as spending $5 (R95) after the structure has been built, but corrosion is not yet evident, $25 (R475) when corrosion has started at some points, $125 (R2 375) when corrosion has become widespread and rehabilitation is required.

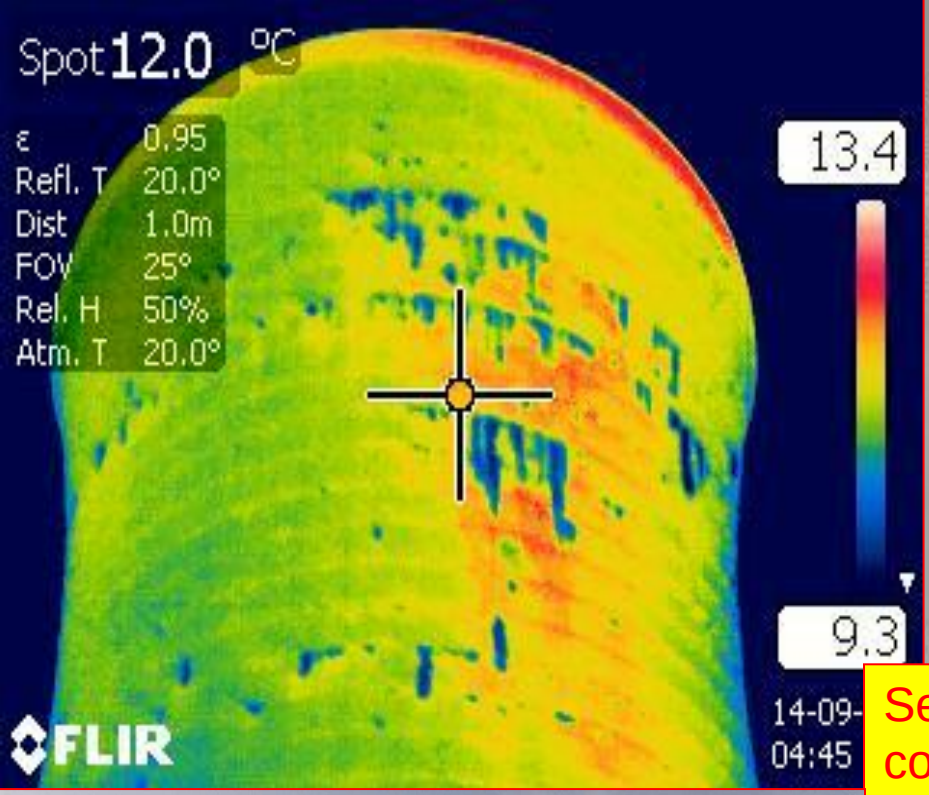
Apply common sense first!

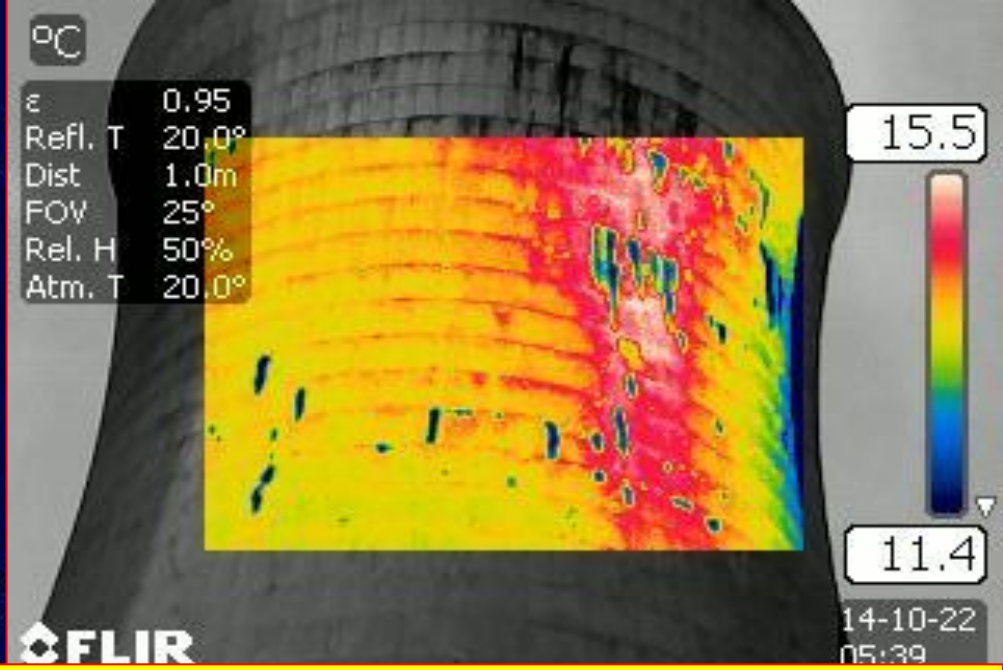
KISS! We don't need, and we don't want, unnecessary aesthetic features like this. At least not as long as our country is bankrupt and children are starving. Invest resources where it counts.

Where is the water leaking through?

The predominant leakage is through the cold-joint lifts. This is the weakest link in the chain.

And it is at these cold-joints where rebar starts to corrode first.





Seepage of moisture through the northern construction joints (from the throat upwards) at dawn. In the thermal images, wet areas beneath leaking construction joints appear as cold dark blue patches, due to the evaporative cooling effect of the moisture. Note that some of the smaller blue patches may be spalls – i.e. not due to moisture – particularly the isolated blue patches that are far away from construction joints. Top right thermal image was captured by a FLIR T335 Camera. Top left thermal image was captured by Matthew Scott with FLIR SC620.

The best way to ensure against corrosion of reinforcing is to hot dip galvanize the steel in accordance with **SANS 121 (ISO 1461)**

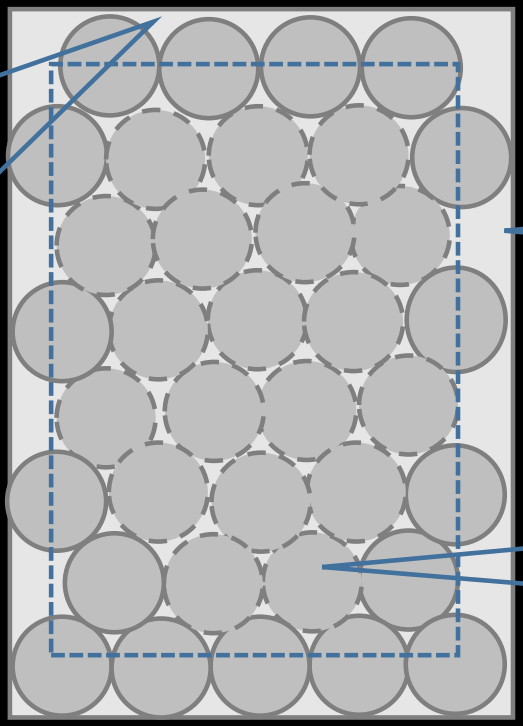
This will make the structure last at least three times as long as an equivalent structure built with black steel.

Inconvenient truths:

- There is no such thing as “self-levelling concrete”.
- Pumped concrete is not “self-compacting”.
- There are limits to how much concrete a single poker can vibrate in an hour.
- It takes 3 workmen to operate a poker vibrator!

Understanding honeycombing

Porosity near the top and bottom is about 0.30 where the natural packing density is interrupted by the flat floor and struck-off top (tetrahedral packing)



Porosity near the surface is ≥ 0.48 where the natural packing density is interrupted by the flat shutter (cubic packing)

Porosity in the centre is 0.26 where the natural packing density is optimal (orthorhombic twisted)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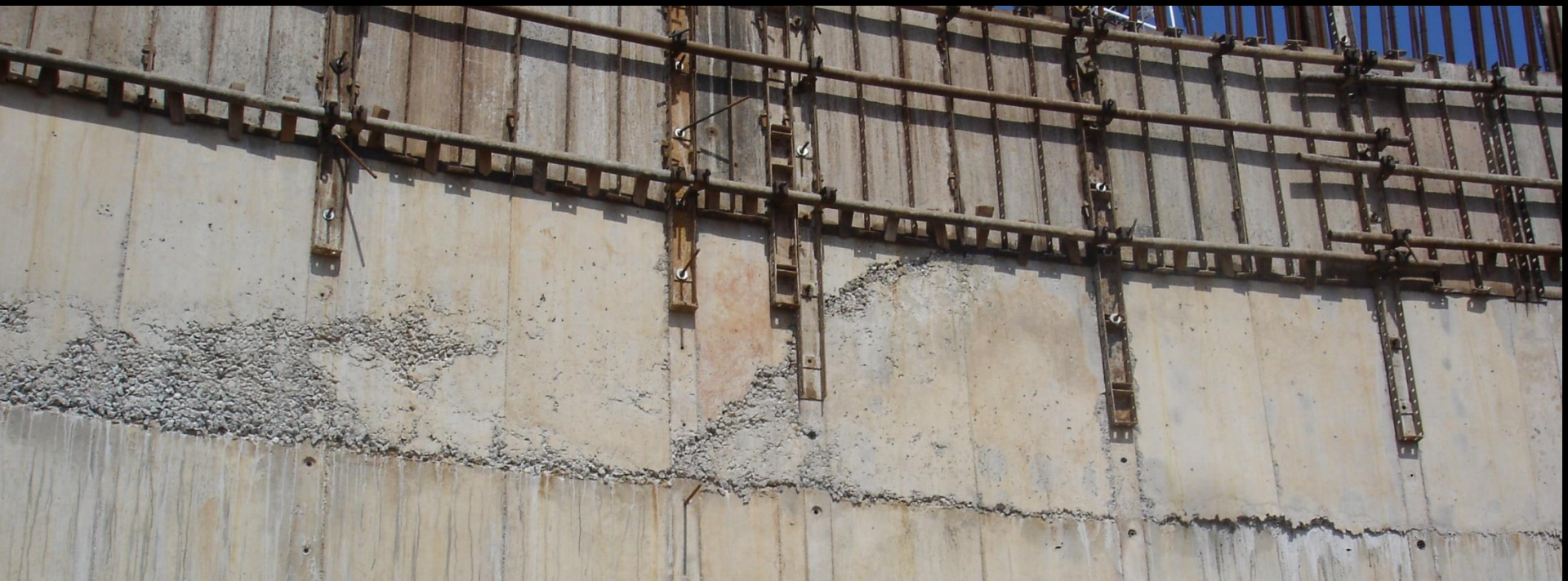
Always use an elephant trunk or hydro-valve when placing concrete into a deep form – even if it's pumped!

Good practice

On closed-circuit structures, work both ways simultaneously to avoid a cold joint at closure



Inadequate cover to reinforcing steel is the single biggest reason for poor durability. You have one chance to get it right so **please** get it right!

Corrosion of conventional reinforcing steel caused by **too little** cover.

Simple home-made go-no-go gauge – made from hardwood.

Be very careful of plastic wagon wheel spacers!

Grout loss at joints between adjacent shutters causes honeycombing. The more vibration the worse the grout loss. Ensure joints are grout-tight.

Self-adhesive compressible foam gaskets provide an excellent seal against grout loss.


2008 8 18


2008 3 17

For a hydrophilic waterstop to work it has to be coaxially confined! Don’t be coerced into using proprietary products just because they exist. An excellent watertight joint can be made without a hydrophilic strip.

Cylindrical wall founded on a Kilcher type rubber/PTFE bearing with bandage seal between wall and floor on inside.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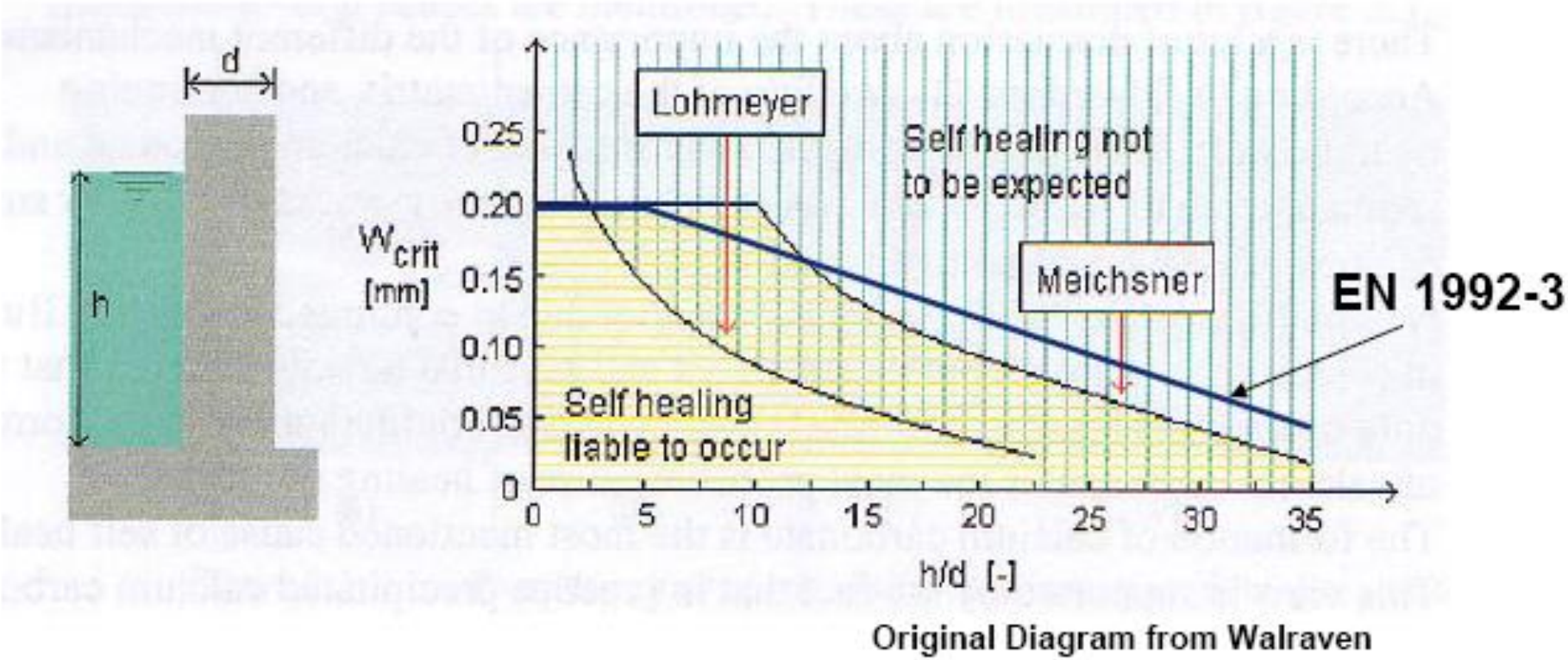

Original Diagram from Walraven

Leakage is proportional to the cube of crack width. There is a relationship between the hydraulic pressure of the contained fluid, the reservoir wall thickness and width of cracks that run continuous through the wall. **EN 1992-3-2006**, which is widely regarded to be a very conservative standard, allows for crack widths of up to 0.2 mm provided these cracks do not run continuous through the thickness of the wall. The standard also makes provision for autogenous healing by limiting the ratio of hydrostatic head (in meters) to wall thickness to a maximum allowable value of 35 for crack widths not exceeding 0.05 mm. Clearly, limiting crack widths to as little as 0.05 mm is not practical or realistic

Cracks not exceeding 0.3 mm in width will almost certainly seal themselves with time.


0.10 mm
0.20
0.30
0.40
0.50
0.75
1.00
1.25
1.50
1.75
2.00
3.00
4.00
5.00
6.00
8.00
Crack Comparator
"Reliable measurement is worth more than 1000 expert opinions"
The thickness of this gauge is 0.38mm
All dimensions are approximate
cm
1
2
3
4
5
6
7
8
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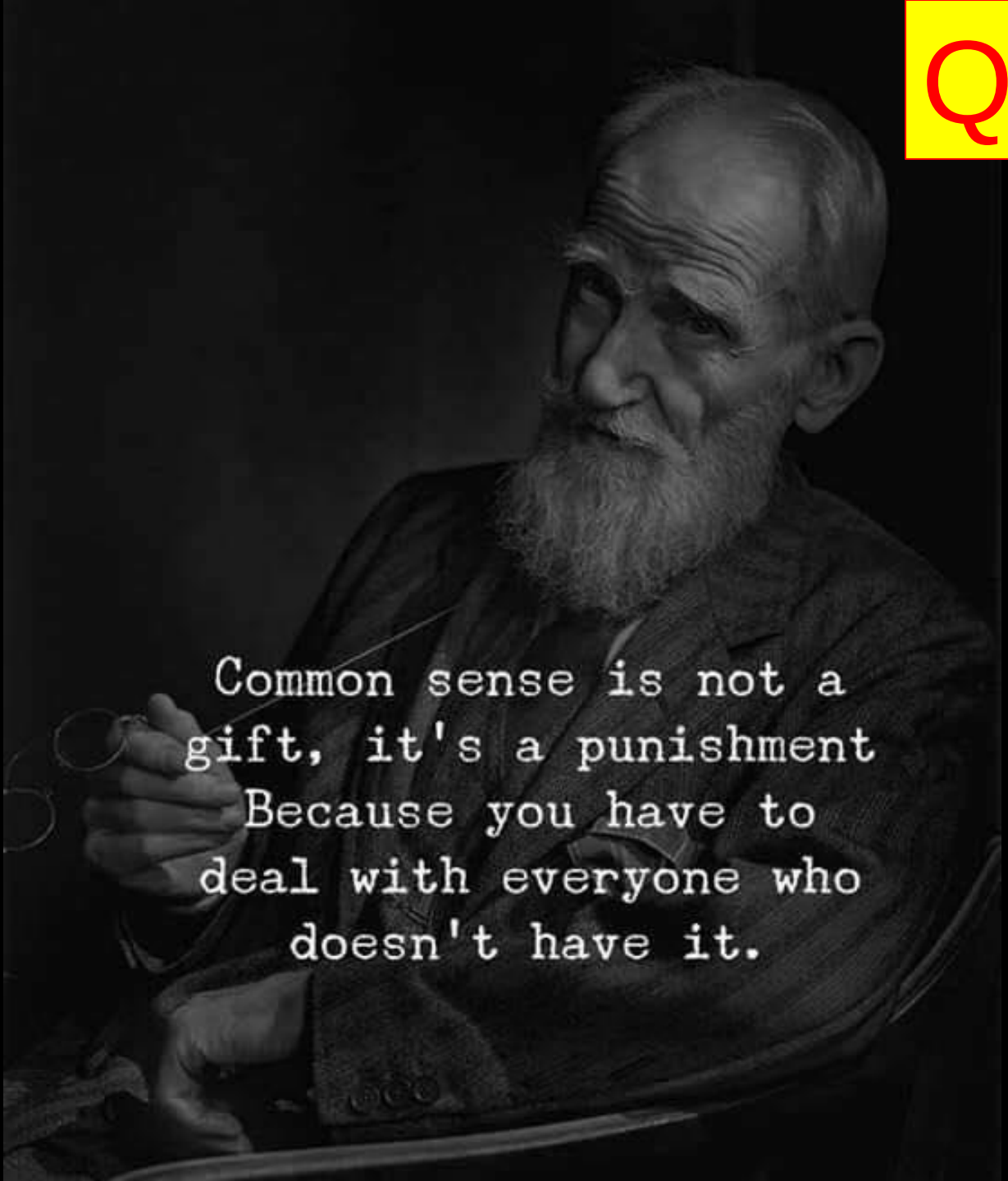
Leakage on first filling before autogenous healing.

After a few weeks of autogenous healing – no leakage.

Calcium hydroxide (a by-product of cement hydration) from within the concrete is transported by leaking water to the dry side. The water evaporates and the $Ca(OH)_2$ is deposited on the dry face as a precipitate. This then reacts with atmospheric CO_2 to form calcite ($CaCO_3$).

Questions?


Common sense is not a
gift, it's a punishment
Because you have to
deal with everyone who
doesn't have it.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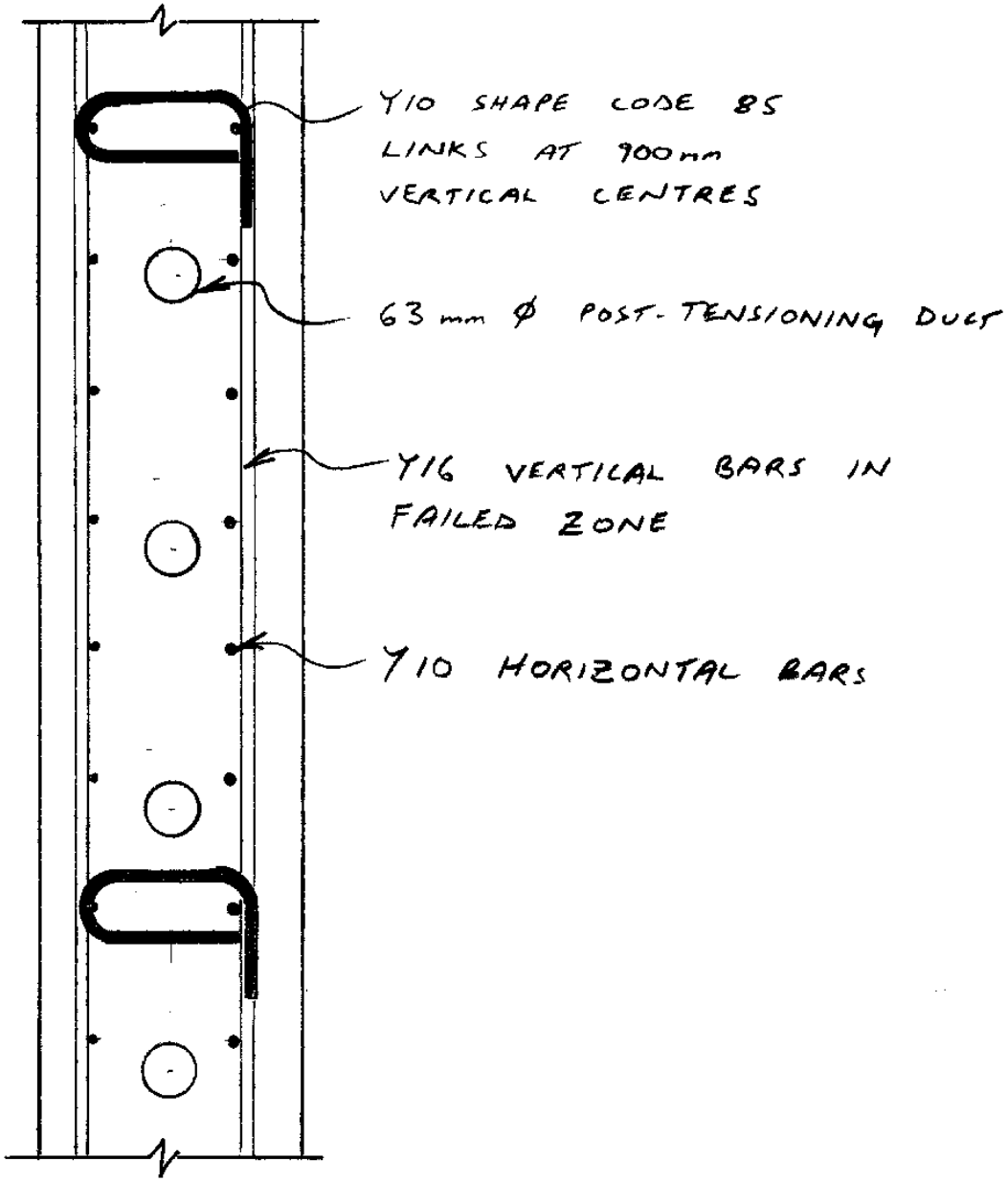
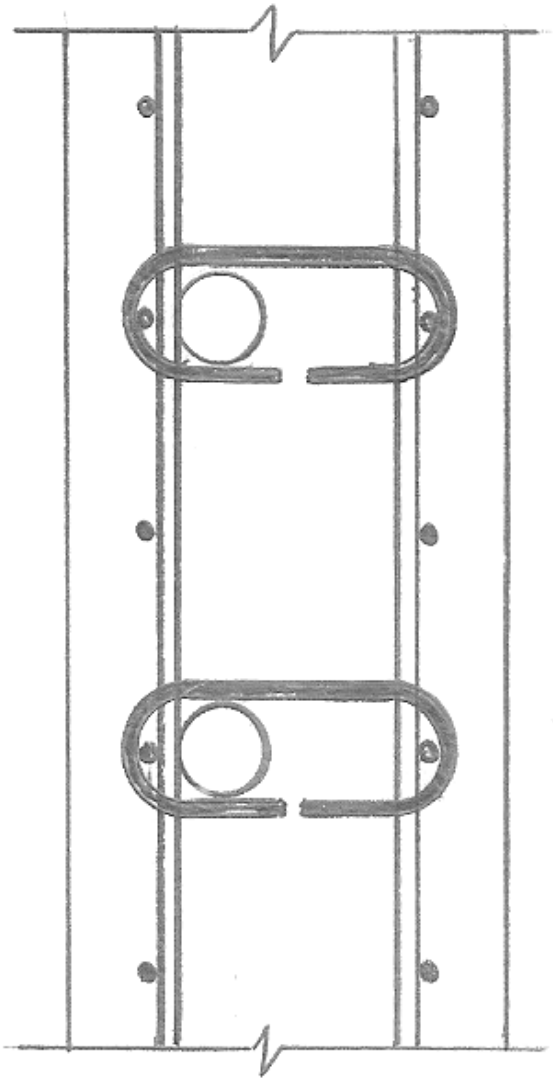
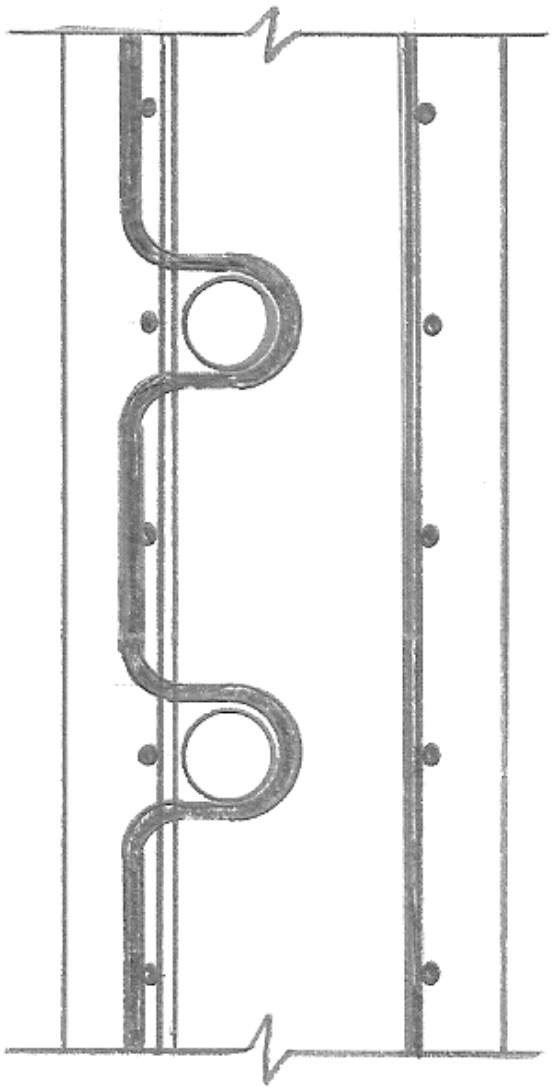

Y10 SHAPE CODE 85
LINKS AT 900mm
VERTICAL CENTRES
63 mm Ø POST-TENSIONING DUCT
Y16 VERTICAL BARS IN
FAILED ZONE
Y10 HORIZONTAL BARS





Effective confinement – Shape Code 33 clips

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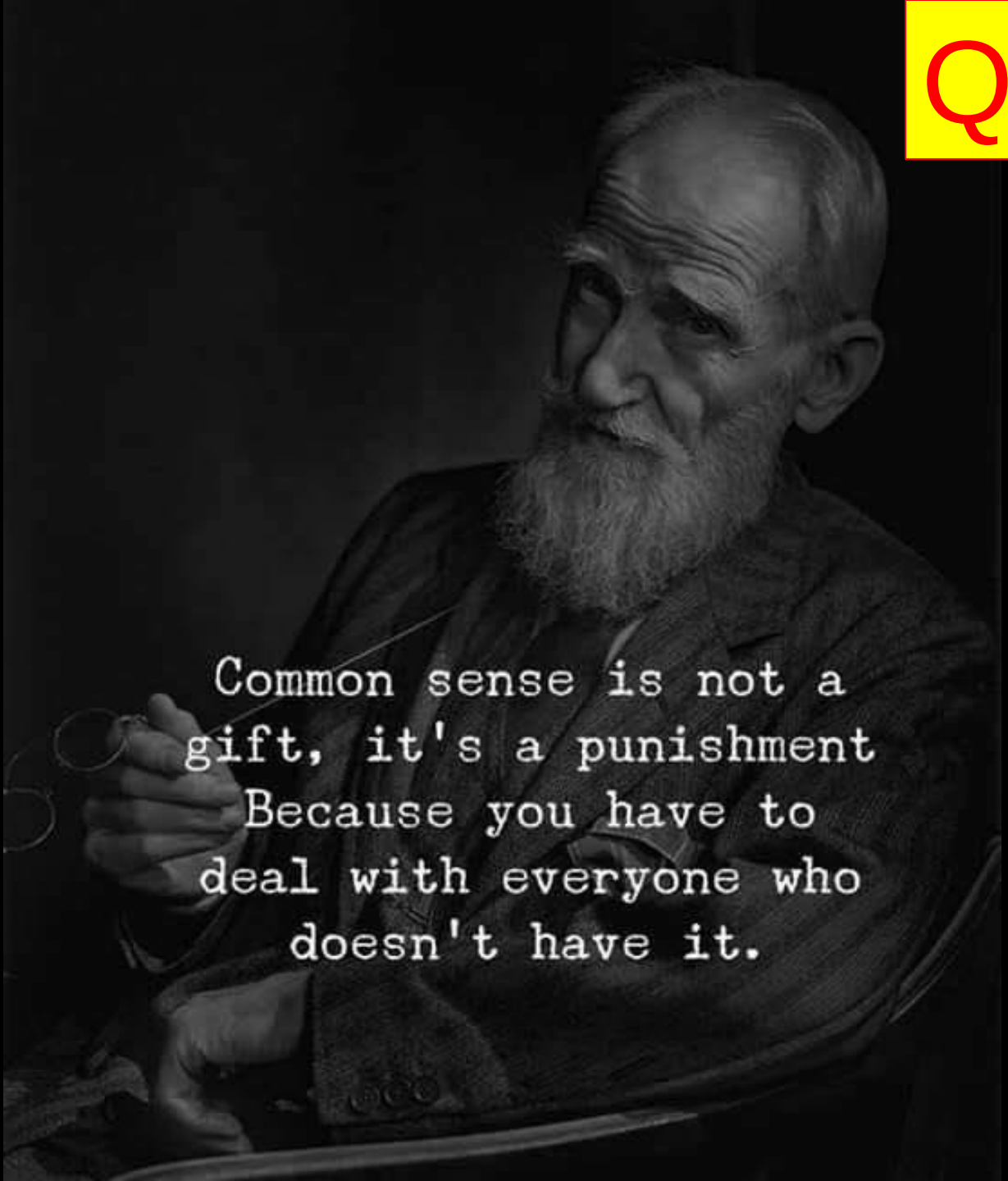
Questions?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