2021 Online Seminar

Progress of Recycling in the Built Environment

3 December 11:00 am (GMT)

RECYCLED AGGREGATES CONCRETE: LESSONS LEARNED

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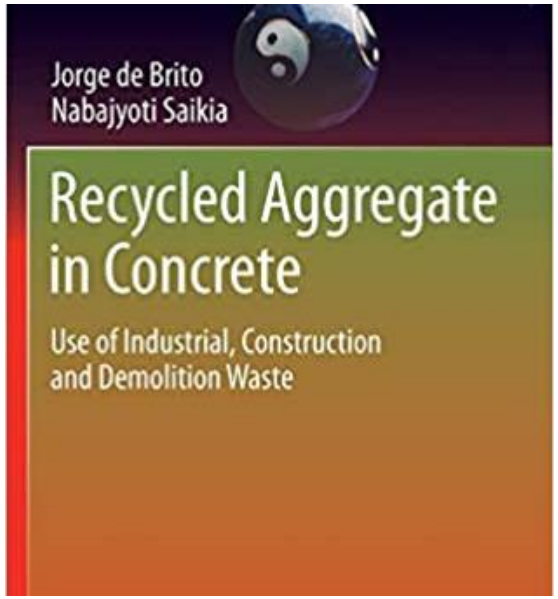
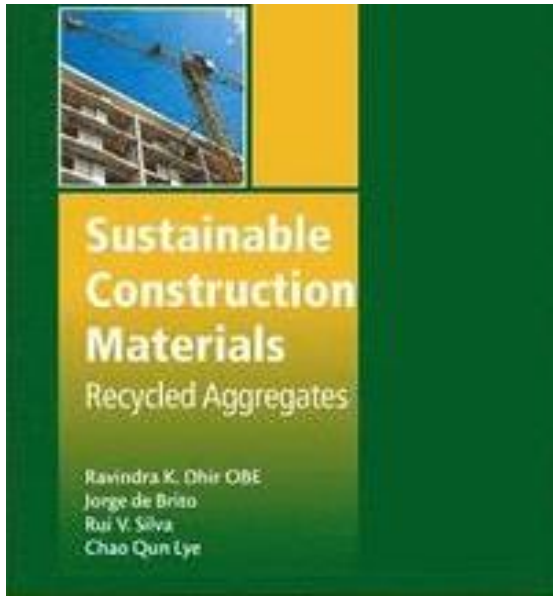




THE QUESTION

After:

- Dozens of books on Recycled Aggregates or Recycled Aggregate Concrete
- Hundreds of theses
- Thousands of papers
- Hundreds of thousands of hours of experimental work
- Hundreds of analytical models
- Many presentations such as this

What have we really learned about recycled aggregates and recycled aggregates concrete?

We learned A LOT!

Quite possibly enough to call it quits and move on in terms of research.

Yet, the industry still has not “bought” the concept.

So, maybe we should really understand the reasons for that.

But, first, the LESSONS WE LEARNED.

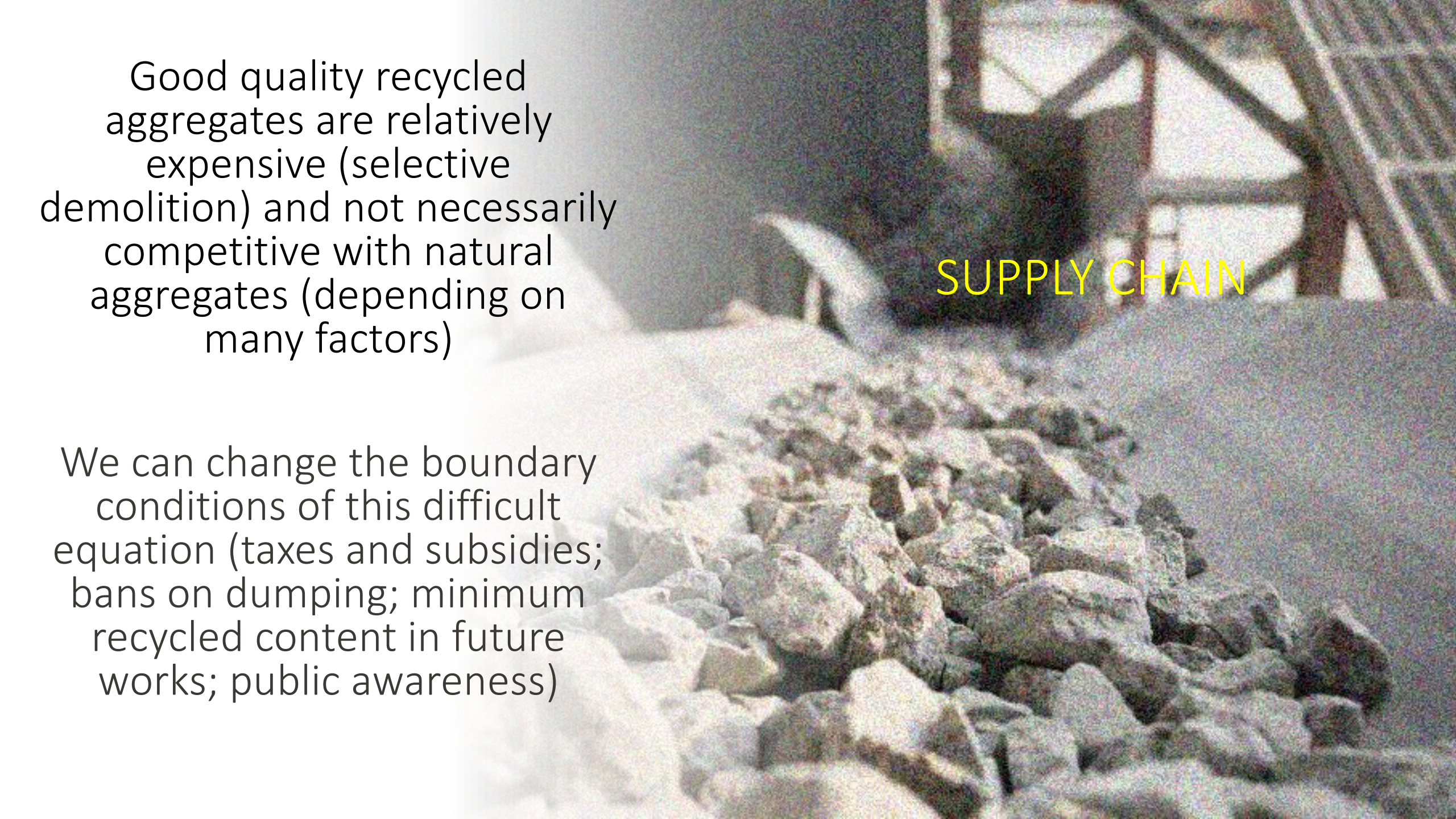
SUPPLY CHAIN

Recycled aggregates are easily available and abundant

Their quality depends very much on their segregation at the source and the way they are produced

Good quality recycled aggregates are relatively expensive (selective demolition) and not necessarily competitive with natural aggregates (depending on many factors)

We can change the boundary conditions of this difficult equation (taxes and subsidies; bans on dumping; minimum recycled content in future works; public awareness)



SUPPLY CHAIN

The needs of aggregates are much higher than the potential intake of recycled aggregates (by around 8 times)

With slight adaptations, the supply chain is already in place. It is called the natural aggregates industry!

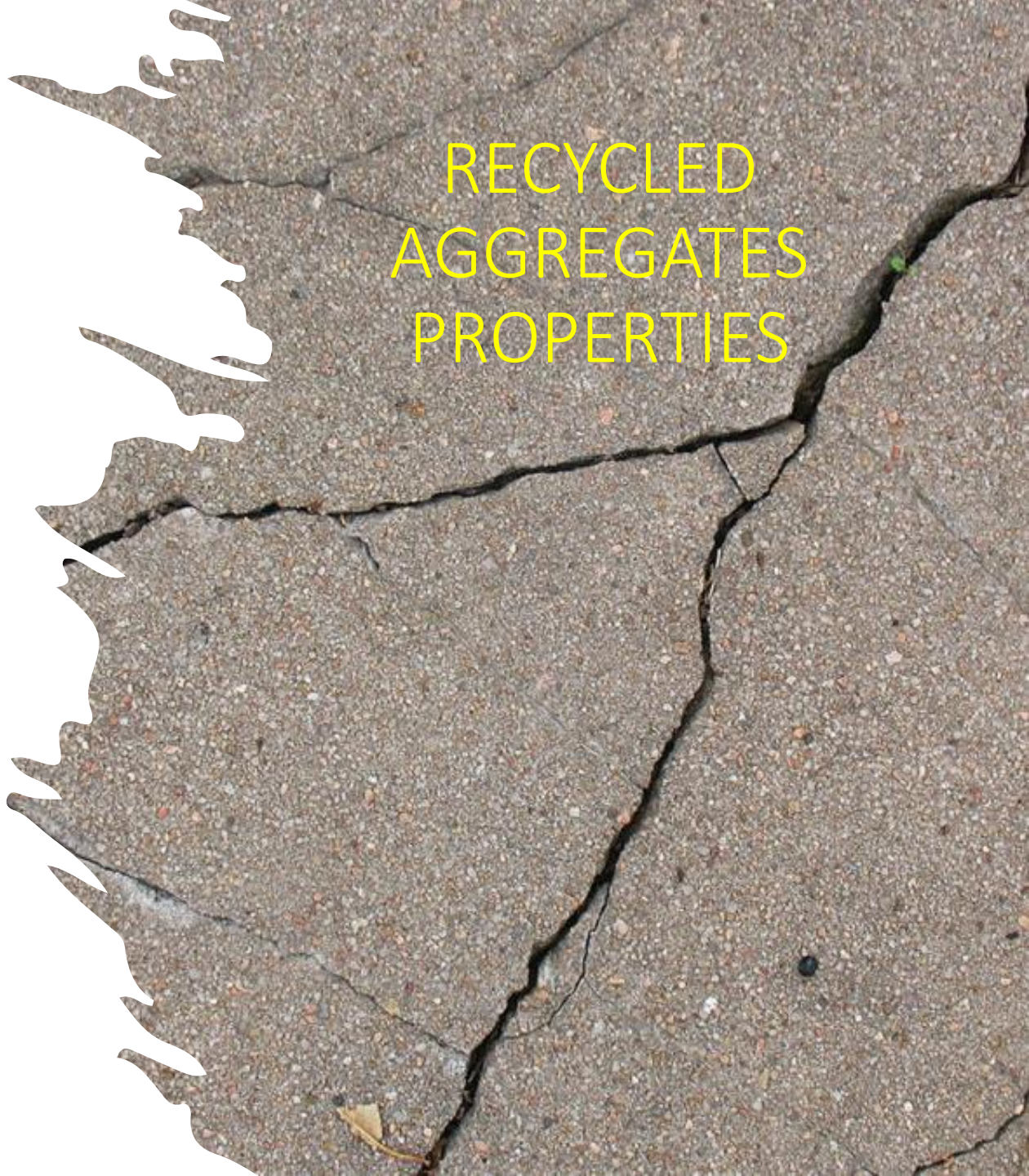
They already know the requirements of aggregates, and how to measure and guarantee them

Recycled aggregates quality is widely varying

Almost all of them can be used in concrete (even at 100% and for all sizes) but most of them shouldn’t

RECYCLED AGGREGATES PROPERTIES

The general performance of recycled aggregates is equal to or worse than that of natural aggregates, in most cases (this influences all concrete properties)

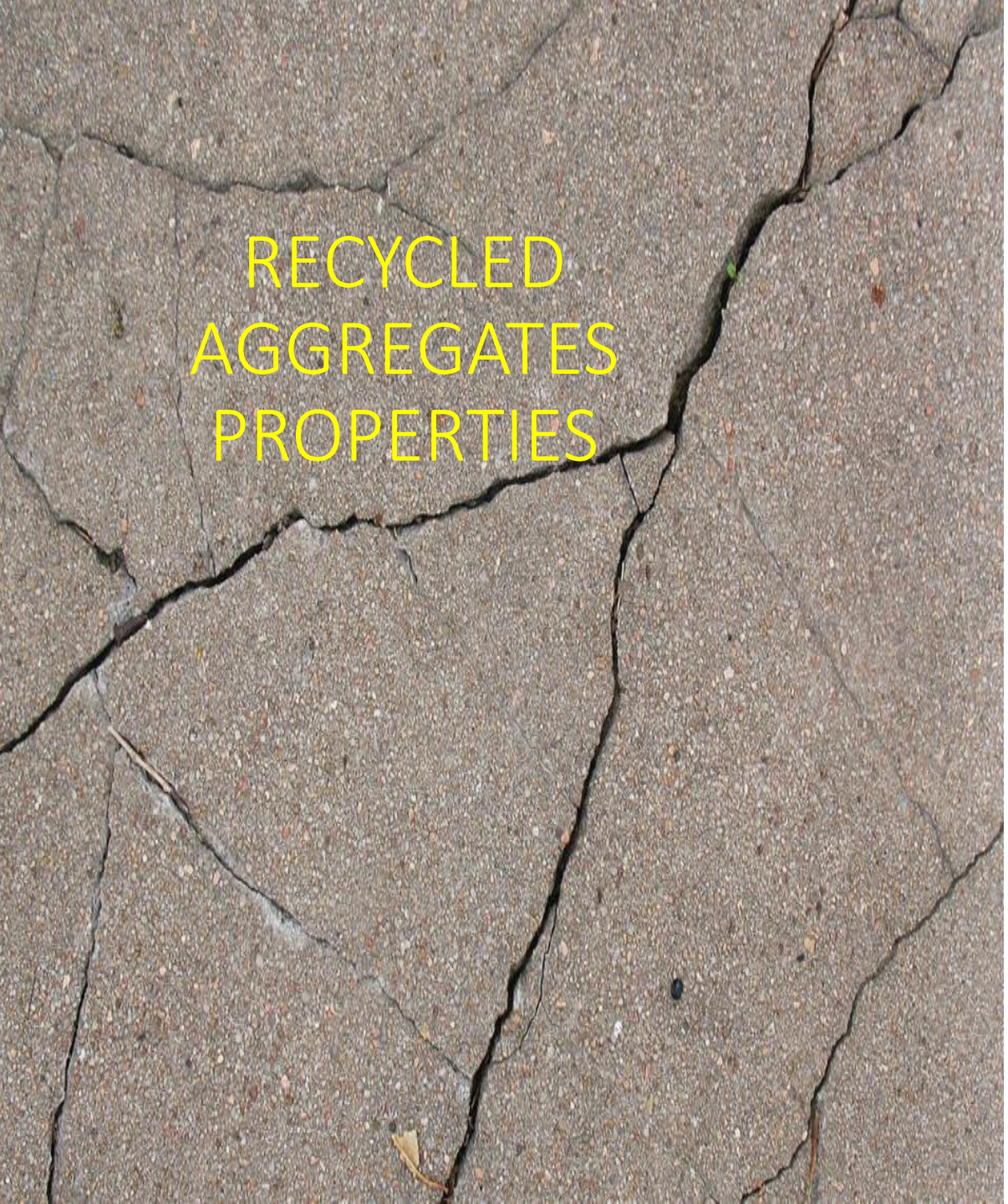


RECYCLED AGGREGATES PROPERTIES

But there is no need to replace 100% of the natural aggregates in concrete because:

a) There is no need (as established in the supply chain)
b) It is not smart in most circumstances (if there is an alternative)

The main differences between recycled and natural aggregates depend hugely on the source of both, but especially that of the former



RECYCLED AGGREGATES PROPERTIES

For the most adequate recycled aggregates for concrete (crushed concrete), we know that:

a. The coarse fraction is much more adequate than the fine fraction
b. The most defining factor is the amount and characteristics of the adhered mortar
c. These aggregates can have a performance quite near that of natural aggregates
d. Used at amounts less than 10-20% their influence is almost innocuous
e. Workability could be an issue for long fresh-state periods

RECYCLED AGGREGATES CONCRETE - MECHANICAL PROPERTIES

Besides the characteristics of the recycled aggregates, another important disadvantage results from the need of extra water for workability-related reasons (total water *versus* effective water)

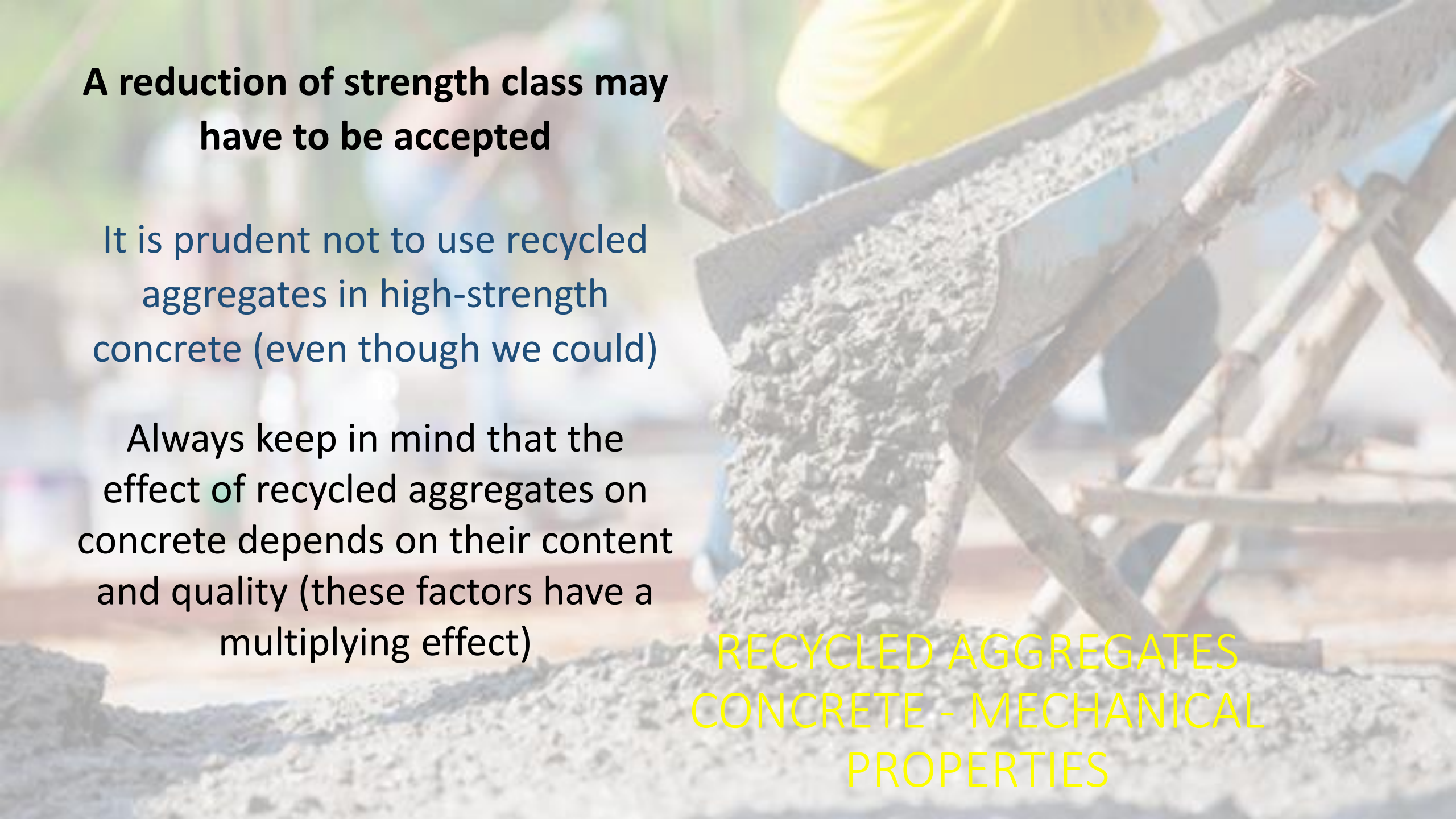
All the comparisons between recycled aggregates concrete and natural aggregates concrete are UNDER EQUAL CIRCUMSTANCES

- Compressive strength, tensile strength, abrasion resistance, among others are only moderately affected by the use of recycled aggregates
- Modulus of elasticity is much more affected (thus, recycled aggregates are harder to use in slabs than in other elements)
- It is possible to (partially) offset these trends (superplasticizers, water reducers) but increasing the cement content is not a good solution

A reduction of strength class may have to be accepted

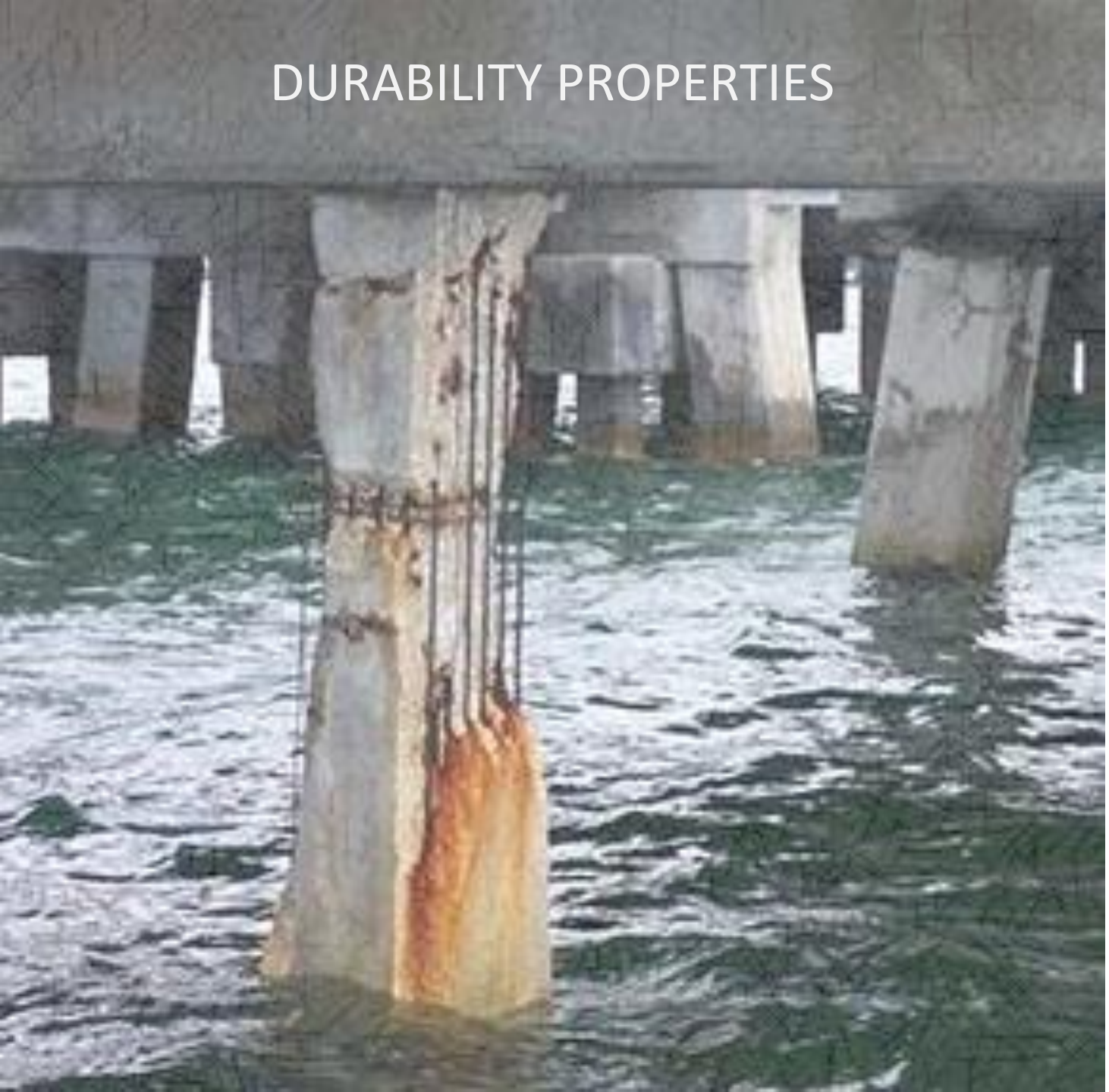
It is prudent not to use recycled aggregates in high-strength concrete (even though we could)

Always keep in mind that the effect of recycled aggregates on concrete depends on their content and quality (these factors have a multiplying effect)



RECYCLED AGGREGATES CONCRETE - MECHANICAL PROPERTIES

DURABILITY PROPERTIES



Everything about the influence of recycled aggregates on mechanical properties applies here

But the effects are clearly LARGER!

DURABILITY PROPERTIES

All durability properties are at least mildly affected by the use of recycled aggregates, even at relatively small contents

In particular, carbonation and chloride penetration are significantly increased

This poses problems in terms of reinforcement corrosion

DURABILITY PROPERTIES

Offsetting these problems by increasing the reinforcement cover can lead to increase of the concrete volume (counterproductive)

Clearly this is the major drawback of recycled aggregates concrete (and also of concrete with supplementary cementitious materials)

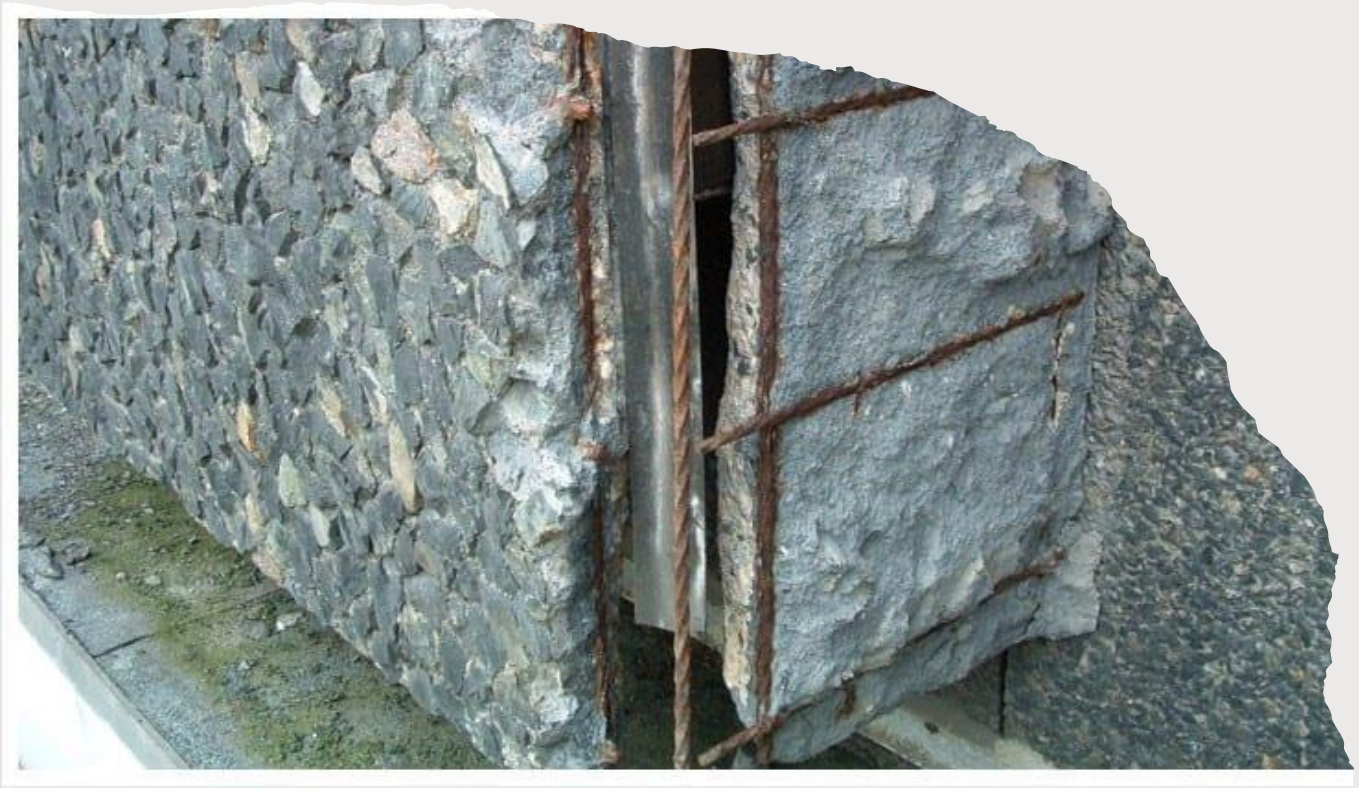
Solving this problem (i.e. guaranteeing durability but not by increasing strength) would totally change the way we look at concrete

LONG-TERM DEFORMATION BEHAVIOUR

Everything about the influence of recycled aggregates on the previous properties applies here

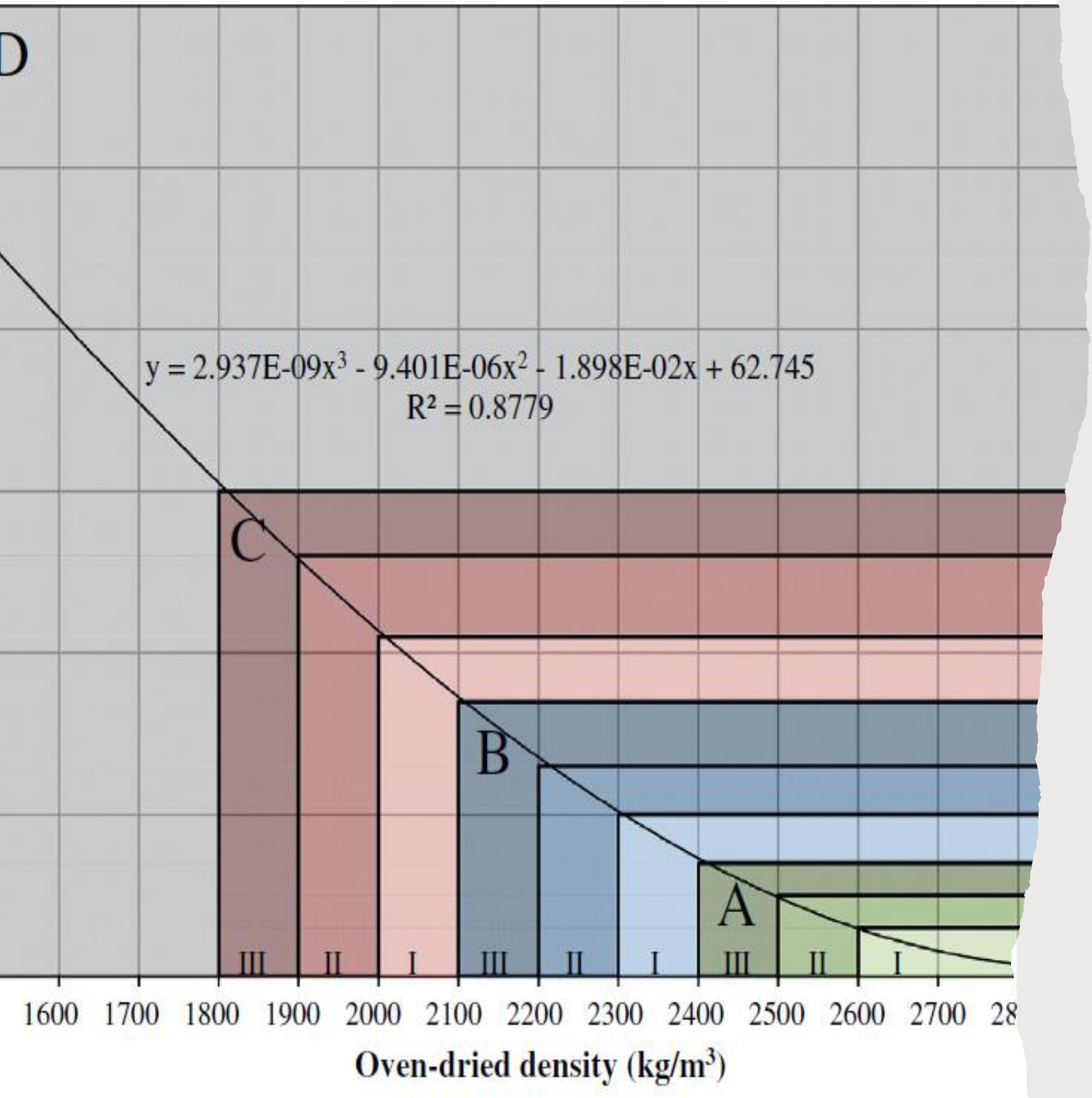
But again to a larger extent…

LONG-TERM DEFORMATION BEHAVIOUR



- Shrinkage and creep are expected to increase significantly with even moderate recycled aggregates content (not just because of the lower stiffness of the aggregates but also because of increased free water)

- This can easily affect cracking and deformation limit states to an extent that makes the use of large amounts of recycled aggregates unfeasible



STRUCTURAL DESIGN

The structural design of recycled aggregates concrete is not unlike that of natural aggregates concrete

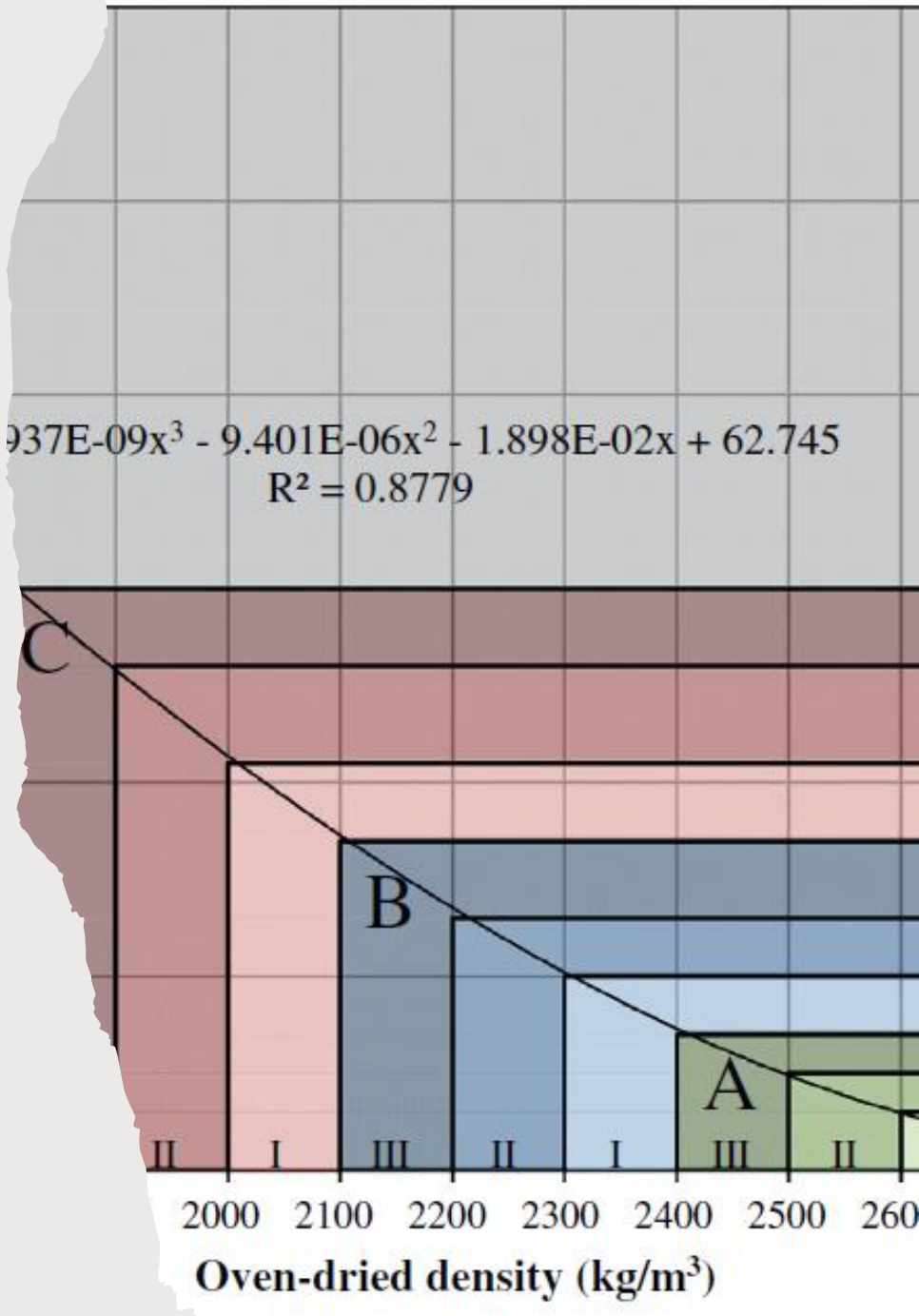
Only (some) structural engineers are convinced that natural aggregates do not influence the performance of concrete and therefore see recycled aggregates as a threat to safety

STRUCTURAL DESIGN

However, there is INDEED wider variability of the characteristics of recycled aggregates than of natural aggregates

The few existing studies on recycled aggregates concrete structural reliability indicate there is a need to increase some safety factors, but changes are not dramatic

A move towards performance-based design is required, not only for recycled aggregates concrete (codes are often over-simplistic and conservative)



COSTS AND ENVIRONMENTAL IMPACTS

Recycled aggregates (concrete) are not necessarily less costly and impacting than natural aggregates (concrete) but they tend to be so

A lot depends on transportation distances and therefore existing facilities availability

If recycled aggregates become widely used, and an efficient supply chain is put into place, their competitiveness will hugely increase

COSTS AND ENVIRONMENTAL IMPACTS

As stated before, general societal conditions can have a major effect on these comparisons (and Society should move in the direction of making recycled aggregates more competitive)

However, it is must be stressed that comparisons are only correct if equal circumstances (equivalent functional unit) are analysed

It is wrong to compare e.g.:

a. Equal volumes of concrete with different strength classes
b. Equal strength classes with different exposure classes
c. Solutions that comply with all codes requirements with others that do not

At this stage, valid conclusions can only be drawn on a case-to-case basis

UPSCALING

To me, this is the major challenge pending, because the technical feasibility of recycled aggregates concrete has been proved beyond reasonable doubts, notwithstanding the cautionary comments made in this presentation

UPSCALING

Who are the actors of this needed change?

a. SOCIETY - more public awareness

b. AUTHORITIES - without them it is not possible (taxes and subsidies; bans on dumping; minimum recycled content in future works)

c. DESIGNERS - reliable codes, simple design methods, specific training

d. OWNERS - selling a green image is perceived as a competitive advantage

e. CONTRACTORS - procedures need to be adapted (mistakes can be expensive, in terms of reputation)

f. US - research must be turned into practice; massive dissemination is required

FINAL REMARKS

- I have no doubt recycled aggregates concrete will be widespread in the decades to come
- It has even been proved that multiple recycling is technically viable, making recycling virtually eternal
- However, the potential repercussion in environmental terms (the main motor driving their use) is relatively small
- Recycled materials have other potential uses, namely when they have hydraulic or pozzolanic potential, and the impacts avoided by using large amounts of cement are one scale higher than those related to recycled aggregates

Moreover, in my opinion, we are presently designing concrete in such a way that we are not using the full potential of the materials used (e.g. durability through strength versus minimum strength with adequate durability)

But that would be the subject of another presentation…

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