Reducing $\text{CO}_2$ by Half, in Concrete!

An unavoidable opportunity for our profession; **Doing More with Less**

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NEXT GENERATION CONCRETE
Facts and Figures (per year)

• ± 9 Billion m³ concrete
• > 5 BT CO₂ by concrete (Prof. Sakai)
• ± 2.5 BT clinker produced (in China 1.28)
• ± 1 T Clinker = 1 T CO₂ = 1.6 T raw material (1.5 BT in ozon)
• Without changes, 260% increase by 2050
• When energy is renewable, 1/3 of CO₂ from concrete
• Water demand of OPC is increasing due to new grinding
• Water Cement Ratio is still common tool
• Non clinker binders on big scale operational ± 10 years?
• Carbon Capture Questionable and CO₂ absorption partial

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Double objectives

I. Reducing Carbon Footprint in concrete structures =

II. “Doing more with less” implies Transforming Concrete sector in the most popular High Tech building material technology, at ALL levels
Holistic Approach

◆ **PRODUCTION** Change to renewable Energy
  ✓ ± 70 BTPY aggregates and raw OPC meal (3 to 8 kWh/t)
  ✓ Concrete, precast and RMC (2 to 20 kWh/m3)
  ✓ At installation site
  ✓ Maintenance
  ✓ At demolition & recycling

◆ **TRANSPORT**; Change to renewable Energy

◆ **STRUCTURE**; **CLINKER CONTENT REDUCTION**
Doing More with less Clinker in concrete structures

- Even if heating of clinker is 100% renewable energy, **calcination** of limestone remains = loosing 1.5 BT!

Focus area’s of concrete profession;

✓ Optimize material use by engineering (Sakai, Lewis)
✓ Optimize installation with contractors
✓ Awareness creation at owners and legislators
✓ Reduce clinker content per m3 with producers

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London Olympics 2012 success story*

PARTICIPATION PYRAMID

(cost saving) SUSTAINABLE CONSTRUCTION PROCESS

CUSTOMER

LEGISLATION

Justification, Motivation, Coordination, Evaluation

CONTRACTORS

SPECIFIERS

Suppliers

ARCHITECT & ENGINEERS
Reduce Clinker Content per m³

1. Reduce **Paste content of Aggregate** > 125μ PSD
2. Reduce **clinker content of Paste**, by <125μ Particle Size Engineering, understanding that Strength is function of; **REACTIVITY**, **PACKING**, **ADHESION**
3. Use SCM pre-blended with OPC + in Concrete, on equal terms
4. Apply **Water POWDER Ratio** since DURABILITY is 90% corrosion and related to Permeability, not Strength
5. Design mix for tailor made strength demand at specific time
6. **CONSISTANCY**; Impose PSD control on incoming materials, Ken Day’s CUSUM on outgoing, and NDT on finished product
7. Involve RMC suppliers in installation, curing and monitoring
8. Train All people on All levels (U-tube RSA Animate/Education)

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Clinker Replacement Materials

- **SCM** = Supplementary CEMENTING Materials for lower Permeability (water demand) and Tailor made strength;

I. Recognized SCM by EN 197; Silica Fume, GGBS, PCFA, Natural Pozzolans, Ground Calcium Carbonate, Oil Shale Ash.

II. Scientific proven; Meta Kaolin, APReM (Activated Paper Recycled Minerals) RRiHSi (Reactive Rice Husk Silica), SuCaBM (Sugar Cane Bagasse Minerals),

- **NPC** (Non Portland) Alkali Activated, Magnesium Silicate, Calcium Magnesium, Sulpho Aluminate etc.
Case story sustainable precast (A)

Water Binder Ratio of Self Compacting Concrete using each 180 kg OPC, GGBS and Ground Calcium Carbonate (GCC)

<table>
<thead>
<tr>
<th>Country</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>0.40</td>
</tr>
<tr>
<td>NI</td>
<td>0.45</td>
</tr>
<tr>
<td>FR</td>
<td>0.66</td>
</tr>
<tr>
<td>DE, ES etc</td>
<td>0.92</td>
</tr>
</tbody>
</table>

0.36 acc. to EN 197 for “cement” recognized SCM mixed with CEM I = CEM II B LL + CEM III C equivalent binders made by concrete producer on an “equal rights” base

Lesson 1: Water Cement/Binder Ratio is market tool, penalizing the use of environmental friendly SCM’s by concrete producer
Case Story Sustainable precast (B)
Lesson 2; “non reactive” GCC stabilizer results in higher strength

Sustainable SCC
1. **190 kg CO₂/ m³**
2. Good demoulding strength
3. Noise, from music!
4. Skilled forces, Less errors
5. Homogeneous = durable
6. Smooth light surface
7. Same cost as vibrated c.
8. **Higher C 53/ 65 strength**
9. Highest grade OPC (> € !)

*CO₂ and cost can be reduced by less OPC use (= high Q.)*

Former vibration concrete
1. **360 kg CO₂/ m³**
2. Noise from vibrating
3. Dust from vibration tables
4. Unschooled workers
5. High maintenance
6. Non homogeneous
7. Rough surface
8. **C 35/ 45 strength**
## Mix design survey

C /35 for a watertight basement

<table>
<thead>
<tr>
<th>Country</th>
<th>Clinker</th>
<th>SCM kg</th>
<th>Water</th>
<th>WCR</th>
<th>W.Powder R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>250</td>
<td>+100 FA or GGBS</td>
<td>170</td>
<td>0.48</td>
<td>0.49</td>
</tr>
<tr>
<td>South Africa</td>
<td>260</td>
<td>+110 FA</td>
<td>195</td>
<td>0.75</td>
<td>0.38</td>
</tr>
<tr>
<td>Kenia</td>
<td>250</td>
<td>+160 natural pozzolan</td>
<td>195</td>
<td>0.45</td>
<td>0.38</td>
</tr>
<tr>
<td>Zambia</td>
<td>± 260</td>
<td>± 70 limestone (not GCC!)</td>
<td>190</td>
<td>0.57</td>
<td>0.35</td>
</tr>
<tr>
<td>India, USA, .</td>
<td>400</td>
<td>-</td>
<td>160?</td>
<td>0.40?</td>
<td>-</td>
</tr>
<tr>
<td>Netherland PILOT II</td>
<td>68</td>
<td>272 GGBS + GCC</td>
<td>165</td>
<td>2.43</td>
<td>0.48</td>
</tr>
</tbody>
</table>
Dialogue with cement producers

- What is “cement”? OPC or EN 197?
- Concrete is NOT anymore a packaging of “cement”
- **Is the steel content of a car important for its performance?**
- How much OPC is non hydrated filler?
- No barriers to use environmental friendly SCM by concrete producer
- Is “cement” content + strength or **Permeability** related to Durability?
- Does packing (matrix) and adhesion contribute to strength and durability?
- Future is “Tailor Made Concrete” = Tailor made binders
- Could we build the PANTHEON in Rome today using EN 197 & 206?

- CO2 reduction in clinker process is more or less engaged
- WBCSD engagement is sincere
- We can not expect cement industry to assist in less clinker/m3 concrete since
- Industry is bulk oriented
- Cement is distributed, not sold
- More financial contribution with high quality OPC for less volume
- Produce stable CEM I 62.5 R, CEM II C LL, CEM III C 22.5 etc. please
- Promotion of concrete common target; is there a 2000 year old Pantheon in metal or wood?
Better to change to a Win - Win game!

From Prescriptive to Sustainable Performance Verified Concrete

Healthier for our children

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6 pillars for concrete progress moving from prescription to Performance

1. EN 206 Art. 5.2.5.3 Equivalent Concrete Performance Concept testing protocol
2. Validation instead of Certification of innovations
3. L C S A; Sustainability Index - Concrete (CO₂ key)
4. Quality (FSC type) Label “Pantheon Performance”
5. STEBAS (Science, Technology, Ethical Board of Advisors and Supervisors)
6. Innovation Insurance more on “Real-Crete”
CONCLUSION

By EDUCATION on all levels,
Recognizing we are in a high tech profession,
Engaging all stakeholders, especially engineers,
Removing barriers to use sustainable concrete
Using new credible + dynamic tools for Performance

We prove that we can reduce
$\text{CO}_2 < 100/\text{m3}$ in $\frac{3}{4}$ of concrete

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Thank you for your attention + the EC for supporting the Sustainable Performance Concrete project www.sustcon.org