Reducing the Environmental Impact of Concrete Professor Peter Claisse. Coventry University.

The extent of the problem

•Current solutions (replacing some of the cement)

•Current research on new ideas (replacing all of the cement)

Unit-based CO₂ Emission in Cement Manufactures



Sakai, K., 2007. Contributions of the concrete industry toward sustainable development. In: Y.M. Chun, P. Claisse, T.R. Naik, E. Ganjian, ed. *Proc. Int. Conf: Sustainable construction materials and technologies*, 11-13 June 2007 Coventry. : Taylor and Francis, London, ISBN 13: 978-0-415-44689-1, p1-10

Estimated Cement Demand (by Humphreys et al.)



Sakai, K., 2007. Contributions of the concrete industry toward sustainable development. In: Y.M. Chun, P. Claisse, T.R. Naik, E. Ganjian, ed. *Proc. Int. Conf: Sustainable construction materials and technologies*, 11-13 June 2007 Coventry. : Taylor and Francis, London, ISBN 13: 978-0-415-44689-1, p1-10

Estimated World Cement Production (by Jahren)



Sakai, K., 2007. Contributions of the concrete industry toward sustainable development. In: Y.M. Chun, P. Claisse, T.R. Naik, E. Ganjian, ed. *Proc. Int. Conf: Sustainable construction materials and technologies*, 11-13 June 2007 Coventry. : Taylor and Francis, London, ISBN 13: 978-0-415-44689-1, p1-10

The Result

- The cement in each m³ of concrete produces about 300kg of CO₂
- About 1 tonne of concrete is produced per person per year in the UK
- That means that of our carbon footprint of 5-10 tonnes of CO₂ per year about 3% comes from concrete
- The world average is about 7% because the average total footprint is lower.

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Cement Replacements

- Pulverised Fuel Ash
- Ground Granulated Blastfurnace Slag
- Condensed Silica Fume

PFA (PULVERISED FUEL ASH)

- PFA is the ash from the burning of pulverized coal in power stations.
- About 20% of the PFA fused into large particles and drops out of the flue gases to form furnace bottom ash.
- The remaining 80% (fly ash) is extracted with electrostatic precipitators and the material for use with cement is obtained from this.

The Pantheon was built with fly ash ... but from a volcano





PFA Handling

Precipitator Hopper.





PFA Dumping

Existing Dump

Limestone quarry that will be filled



Applications for fly ash...

to Heathrow Terminal
5 to sewage treatment
plants...





Barriers to the use of PFA...

- The classification the PFA/fly ash that it is a waste!
 - A long and complex story
 - The Environment Agency and SEPA believe PFA is a waste
 - The UKQAA/Power Industry believe that fresh PFA is NOT a waste!
 - Discussions have been ongoing for years

Emissions to the environment:

- CIA/DETR project showed that using 30% PFA for equal 28 day strength in a concrete mix that:
 - Greenhouse gas emissions are reduced by 17%
 - Acidification reduced by 15%.
 - Winter smog reduced by 15%.
 - Eutrophication reduced by 13% .
 - Primary energy requirements reduced by 14%.

PFA/fly ash utilisation on increase despite EA and waste issue ...



Year

Cement Replacements

- Pulverised Fuel Ash
- Ground Granulated Blastfurnace Slag
- Condensed Silica Fume

GGBS (GROUND GRANULATED BLASTFURNACE

SLAG)

- Slag is derived from the production of iron in blastfurnaces.
- The slag contains all of the compounds which would affect the purity of the iron.
- The slag is a hot liquid and may be cooled in air, by mixing with water (foaming) or with high pressure water jets at high water/slag ratios (granulation).
- Only granulation produces non-crystalline slag and only this slag exhibits hydraulic properties and is therefore suitable for use with cement.
- The other types of slag are used as aggregate.

Blastfurnace Slag as a Cementitious Material

- 1862 Germans realise that slag is hydraulic
- 1892 Blastfurnace cement produced in USA
- 1957 Used in UK dam construction
- 1964 Wet Sleddale Dam, Cumbria (within mixer blending).



GGBS Project



GGBS Project



Limits to the use of GGBS

- All the GGBS produced in the UK is now used
- It costs almost as much as cement
- Some old steel works have insufficient space to install granulators.

Cement Replacements

- Pulverised Fuel Ash
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- Condensed Silica Fume

CSF (Condensed Silica Fume)

- This is a highly reactive pozzolan is also known as microsilica and is derived from the production of silicon steel.
- The production process is highly energy intensive and is carried out in countries like Sweden where hydropower is available.
- The high reactivity can be used to obtain very high strengths but means that great care must be taken with curing etc.
- Various problems have been reported with this material.

CSF Projects

Tsing Ma Bridge,Hong Kong. 200m high towers slipformed with microsilica concrete – specified for ease of placement and resistance to an aggressive marine environment.



Tried and Tested on the World's Most Demanding Projects

The benefits of microsilica were first recognised in the 1950s and for more than 20 years microsilica concrete has been specified around the world for the most demanding and prestigious structures.



La Grande Arche, Paris. Constructing a 100m cube, 40 storeys high would not have been possible without microsilica technology.



Canada, Denmark, Germany, Iceland, Norway, Sweden and the USA all have national specifications for the material.

Tarmac Topmix, the specialist ready-mixed concrete producer and Elkem, the giant of the silicon alloy industry, have pooled their resources to make Toproc available throughout the UK. Now a growing number of civil engineers are discovering the benefits of Toproc's unparalleled durability, high early build strength, speed, pumpability, long life and ease of used

There are no uncertainties. All applications have been thoroughly researched, tested and proven in the most demanding and aggressive of environments.



Gulfaks C Oil Platform: The innovative construction methods used to build North Sea oil platforms developed around the beneficial pumping properties of microsilica concrete.

Relative environmental impacts for 'C30' concrete [Concrete Industry Alliance Report Jan 2000]

Impact	PC- only	30% Fly ash	50% GGBS
Greenhouse gas (CO2)	100%	83%	60%
Primary Energy	100%	86%	71%
Mineral extraction	100%	96%	92%

Amount of Wastes Utilization for Cement Production in Japan



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The Six Trials

- Trials 1-3
 - concrete barriers for landfills.
 - 70 m³ of concrete.
- Trial 4
 - trench trial for mine or trench backfill.
 - 7 m³ of concrete.
- Trial 5
 - slab in a car park
 - 16 m³ of semi-dry concrete
- Trial 6
 - access road
 - stabilised 72 m³ of soil and placed 6m³ of a semi-dry paste (grout) as a road base

Some of the secondary materials used

- CKD Cement Kiln Dust from cement works
- BPD By-pass dust also from cement works
- Lagoon Ash from power station
- BOS Basic Oxygen Slag from steel manufacture
- Red Gypsum from titanium dioxide (white pigment) production
- PB Waste Plasterboard (gypsum)
- Sodium sulphate solution from lead-acid battery recycling
- Spent borax from silver refining

The mixture designs for the trials

Trial	Pour	Cementitious component	Strength MPa
1	Cell 1 top	Spent borax 100%	4.5
2	Cell 2 top	CKD 60%, Lagoon ash 40%	1.7
3	Cell 3 top	CKD 60%, Lagoon ash 40%	1.3
1	Cell 1 base	GGBS 90%,OPC 10%, Sodium sulphate	13
2	Cell 2 base	CKD 60%, PFA 40%, Sodium sulphate	6.9
3	Cell 3 base	OPC 5%, CKD, 70%, Lagoon ash 25%	6
4	Trench fill	BOS 60%, Red Gypsum 40%	1.8
5	Sub-base	BOS 80%, PB 15%, BPD 5%	10.8
6	Base course	BOS 80%, PB 15%, BPD 5%	30.55

Lab testing for Trials 1-3















Secondary materials in the mixes



Trial 4 – Gypsum/slagT rench Trial







Placing Trial 4.





Where we want to put the gypsum/slag blend (10 M m³)





The "Coventry Blend"

- Basic oxygen slag from steel manufacture (80%)
- Waste plasterboard (15%)
- Kiln by-pass dust from cement manufacture.(5%)

100 Tonnes of this blend were made for trials 5 and 6

This blend is not recommended for partial replacement of cement – it is for use without cement





Trial 5 Car Park

KROUSE



Trial 6 Semi-Dry Paste/grout





Concrete without Cement (Trials 5 and 6)



Concrete (trial 5)



Semi-dry paste/grout (trial 6)

CONCLUSIONS 1

- Viable mixtures which contain little or no Portland cement can be made for a wide variety of applications.
- Site trials represent the best route to develop these mixtures for commercial use.
- Pre-blended mixtures are the best way to use powder which contains several mineral wastes.

Conclusions 2

- While it is possible to demonstrate the viability of cementitious mixtures which are sustainable there are many difficulties which may prevent their industrial use. These include:
 - Insurance problems
 - Lack of capital investment
 - Environmental concerns which may or may not have any scientific basis

Thank you

For more information please visit www.claisse.info