TECECO CEMENTS – Abatement, Sequestration and Waste Utilization.

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Extended Abstract: Cement and Concrete Science, Warwick, 16th + 17th September 2004

Summary

Around 26 billion tonnes of CO_2 are released to the atmosphere annually, around 20 billion metric tonnes of which is from the burning of fossil fuels and close to a significant 2 billion tonnes from the production of Portland cement. The built environment is our footprint on the planet and huge in size. Tec-cements reduce emissions because the same strength concretes are achievable with around 25-30% less cement than if ordinary Portland cements are used whereas eco-cements gain strength by sequestering carbon from the atmosphere in porous materials.

Over two tonnes of concrete are produced per person on the planet per annum, representing an enormous opportunity to not only reduce net emissions but to utilize solid wastes including wastes for their physical property rather than chemical composition in cementitious composites with improved properties.

This paper discusses the potential impact on sustainability of the new tec and eco-cement technologies and goes into the as yet unclear chemistry of carbonation processes.

Introduction

Tec-cements contain around 5-15% added reactive magnesia and usually a pozzolan. Eco-cements contain more magnesia and rely on carbonation for strength in more porous materials.

Eco-cements became known to the world mainly through an article on them in New Scientist Magazine (Pearce 2002) and a program shown by Discovery Channel (Carbonating Eco-Cements 2003). There have been several reasons for the intense interest – the potential lower embodied energy, the ability of tec-cement and eco-cements to benignly encapsulate a wide range of wastes, the potential for reduced emissions using tec-cements and in combination with TecEco kiln technology, CO_2 sequestration by eco-cement concretes on a massive scale.

The built environment probably accounts for around 70% of all materials flows. Current cement production of around two billion tonnes per annum is enough to make over two tonnes of concrete per person on the planet per annum. (USGS 2004). The possibility of including carbon and other wastes, particularly those containing carbon such as plastics and sawdust that would otherwise be lost to the atmosphere must be considered seriously.

Global carbon dioxide flows in tonnes CO2 are (Haughton 2004 converted from tonnes C):

Atmospheric increase	=	Emissions from Fossil fuels	+	Net emissions from changes in land use	-	Oceanic uptake	-	Missing carbon sink
12.07 (±0.73)	=	20.152 (±0.1.83)	+	5.86 (±2.56)	-	7.32 (±2.93)	-	6.59 (±4.39)

Unless we want to face climate change on a massive and global scale we must sequester at least 6 billion tonnes of CO_2 per annum. As we are unlikely to give up the fossil fuel habit until we run out the need is urgent. Now Russia has joined the Kyoto treaty it has come into affect and countries that do not make an effort to sequester carbon will in due course face sanctions. Using TecEco technology emissions reduction is clear and definable and there are significant business opportunities particularly under the clean development mechanism of the treaty. What better way to sequester carbon and convert waste to resource than in our own built environment?

Abatement
Both tec and eco-cements potentially contain significantly less embodied energy. Tec cements reduce emissions by requiring less CO_2 emitting cement and utilizing a higher proportion of pozzolans for the same or more rapid strength development whilst eco-cements set by absorbing carbon dioxide from the air. This strength development has been demonstrated in several studies now including the manufacture of tec-cement blocks in Australia.
Combined with TecEco kiln technology which combines calcining and grinding in a closed system whereby CO2 can be captured there are very significant abatement opportunities

The rate of carbonation of both calcium and magnesium compounds depends on the dissolution rate of Ca^{2+} and Mg^{2+} and partial pressure and transport of CO_2. These in turn are influenced by the mix design, affect of aggregates on porosity and setting atmospheric conditions. Wet dry cycles appear to promote carbonation providing alternatively transport and reaction media. Well graded aggregates including a coarse fraction are essential as they are for lime mortars. Recent work by the author has demonstrated that most commercial sands specified by standards in Australia the US and Europe are unsuitable for the carbonation of mortars and that well graded sands including a coarser fraction up to 1/3 the thickness of a mortar joint are essential to allow the material to “breathe” thereby providing gas transport.

Ideal carbonation conditions are still being determined, currently coarse well graded aggregates including a coarse fraction, dry mixes and varying humidity with wet dry cycles is thought to work best. . The magnesia in eco-cements first hydrates forming brucite and then this carbonates forming hydrated carbonates the most important of which are an amorphous phase, nesquehonite and lansfordite. Properties are shown in Appendix 1 –Magnesium Carbonates in Eco-Cements on page 4.

XRD studies in Australia using blocks that have been allowed to carbonate both before and after HCL extraction prove complete carbonation occurs with under two years.

Converting Waste to Resource
Both tec and eco-cements provide a benign environment in which significant quantities of waste can be utilized. The shear thinning properties tend to prevent segregation of materials like plastics which is a problem with Portland cements and the lower long term pH prevents internal reactions from occurring.

The current technical paradigm for recycling generates separate outputs based on chemical composition rather than class of property. Costs are incurred and waste generated in separating what is required from the balance of materials and then transporting to factories that can only use specific waste inputs.

TecEco cements are benign low long term pH binders that can utilise wastes more on their class of property rather than chemical composition, and therefore reduce sorting problems and costs associated with recycling and provide an inherently more economic process.

In the above manner TecEco cements change the technology paradigm redefining wastes as resources (Pilzer 1990).

Durability and many other problems of including wastes are overcome. Reasons include:

- Lower reactivity (less water, lower pH)
- Reduced solubility of heavy metals (lower pH)
- Greater durability
- Greater density and impermeability and
- More homogenous.
- No bleed water
- Are not attacked by salts in ground or sea water
- Are dimensionally more stable with less cracking

Conclusion

Perhaps the most pre-eminent cement chemist ever, the late great H.F.W. Taylor, predicted a need to do something about global warming and wastes in regard to cement and concrete publicly at least as far back as 1990 in his address to a Conference on Advances in Cementitious Materials (Taylor 1990). Taylor forecast many changes not only in the way cements are made but in their composition, particularly in relation to the incorporation of wastes[1].

TecEco cements are a new innovation that offers sustainability in our own back yards. Tec-cements promise greater durability than ever achieved before and stronger materials with lower embodied energies and associated emissions whilst eco-cements are the first construction materials that successfully use carbon dioxide and wastes.

As stated by Fred Pearce in the article on eco-cements that was published in the New Scientist magazine (Pearce 2002) “There is a way to make our city streets as green as the Amazon Forest. Almost every aspect of the built environment from bridges to factories to tower blocks, and from roads to sea walls, could be turned into structures that soak up carbon dioxide – the main greenhouse gas behind global warming. All we need to do it change the way we make cement.”

References

1. Carbonating Eco-Cements (2003). The Daily Planet.
2. Haughton, R. (2004). Understanding the Global Carbon Cycle, Wood Hole Institute, www.whrc.org/science/carbon/carbon.htm.
3. Pearce, F. (2002). "Green Foundations." New Scientist **175**(2351): 39-40.
4. Pilzer, P. Z. (1990). Unlimited Wealth, The Theory and Practice of Economic Alchemy, Crown Publishers Inc.
5. USGS (2004). "Cement Year Book." http://minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmcs04.pdf.

[1] See TecEco Newsletter 36 at www.tececo.com for the full text.

Appendix 1 –Magnesium Carbonates in Eco-Cements

Numerous magnesium carbonates, hydrated magnesium carbonates and hydroxide carbonates exist. Mixed Mg-Ca, Mg-Fe Mg-Na etc. carbonates are not shown but numerous[2].

Basic Magnesium Carbonates

Numerous magnesium hydroxide carbonates exist.

Mineral	**Formula**	**XRD (By Intensity I/Io)**	**Molecular Weight**	**Hardness**	**Density**	**Solubility (Ml^{-1}, cold water)**	**ΔH^o reaction from hydroxide ($kJ.mol^{-1}$)**	**ΔG^o reaction from hydroxide ($kJ.mol^{-1}$)**	**Comment**
Nesquehonite	$Mg(HCO_3)(OH)\cdot 2(H_2O)$ or $MgCO_3\cdot 3(H_2O)$	6.5(1), 3.86(0.9), 2.61(0.7)	138.36	2.5	1.85	.012937	-175.59	-38.73	Commonly formed at room temperature and from Lansfordite

Hydrated Carbonates

Mineral	**Formula**	**XRD**	**Molecular Weight**	**Hardness**	**Density**	**Solubility (Ml^{-1}, cold water)**	**ΔH^o reaction from hydroxide ($kJ.mol^{-1}$)**	**ΔG^o reaction from hydroxide ($kJ.mol^{-1}$)**	**Comment**
Lansfordite	$MgCO_3\cdot 5(H_2O)$	3.85(1), 4.16(1), 5.8(0.8)	174.39	2.5	1.73	.01009			Commonly forms at room temperature

Source thermodynamic data for calculation ΔH^o and ΔG^o and reaction from hydroxide: Robie, Richard A., Hemingway, Bruce S., and Fisher, James R. *Thermodynamic Properties of Minerals & Related Substances at 298.15K and 1 Bar (105 Pascals) Pressure and at Higher Temperatures.* U.S. Geological Survey Bulletin 1452. Washington: United States Government Printing Office, 1978.

Source Solubility Data: Data extracted from CRC Handbook of Chemistry and Physics, 74th Edition, 1993-1994 and from Chemistry Web Server at California State University at http://155.135.31.26/oliver/chemdata/data-ksp.htm valid 01/11/2003

[2] For a list of carbonates see http://mineral.galleries.com/minerals/carbonat/class.htm. For detail as to each carbonate see http://webmineral.com.