

Tec, Eco and Enviro-Cements: New Markets for Reactive Magnesia

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Abstract

Production of magnesium compounds including reactive or caustic calcined grades of magnesia has not varied much since the 1960's. Instead of trying to invigorate current production and marketing paradigms, new production methods and markets are suggested in which the industry can create its own future.

Ratification of the Kyoto treaty has left many countries wondering how they will meet their commitments. New opportunities for the magnesium compounds industry will emerge because magnesium hydroxide is most suited for scrubbing CO₂ out of the air and magnesium carbonates are an ideal repository for mineral sequestration.

A total sequestration process has been developed by my company, this and how sequestration can occur in the built environment using the new tec, eco and enviro-cements and TecEco's new kiln technologies is described in detail. Properties of the new cements are also described in a non-technical way.

Keywords

Sustainability, calcination, sequestration, kiln, Kyoto, abatement, eco-cement, tec-cement, enviro-cement, caustic calcined magnesia (CCM), reactive magnesia (MgO), Brucite (Mg(OH)₂), Portland cement, hydration, silicification, pozzolan.

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John Harrison has degrees in science and economics, is the managing director and chairman of TecEco Pty. Ltd. and is known around the world for the invention of tec, eco and enviro-cements. He is an authority on sustainable materials for the built environment, has been a speaker at many conferences and is committed to finding ways of "materially" improving the sustainability of the built environment.

Global Environmental Problems

The two biggest problems facing the planet are climate change and what to do with our waste.

To solve the climate change problem there are really only two options - emissions reduction and sequestration on a massive scale. The best solution for waste is to find uses for it.

Throughout human history we have really only done something about problems at the last minute. The last minute to do something substantial about global warming is now and the Kyoto treaty has been signed by 132 nations to establish commitments in an agenda for action. Politically, the most acceptable option is sequestration as emissions reduction

implies rationing and the use of enforcement. Wastes are also becoming a big issue around the world.

The Kyoto Treaty

On the 16th February 2005 the 1997 Kyoto Protocol, drawn up in Kyoto, Japan in 1997 to implement the United Nations Framework Convention for Climate Change, finally became international law. Ratification of the agreement means Kyoto will receive support from participating countries that emit 61.6% of carbon dioxide emissions.

Signatory countries are legally bound to reduce worldwide emissions of six greenhouse gases (collectively) by an average of 5.2% below their 1990 levels by the period 2008-2012.

It will be a difficult task for most of the member countries to meet their Kyoto targets and already nations are falling behind. Spain and Portugal in the EU were 40.5% above 1990 levels in 2002. Canada, one of the first countries to sign, has increased emissions by 20% since 1990, and they have no clear plan to reach their target. The Japanese are also uncertain about how they will reach their 6% target by 2012.

Participating countries are establishing a legal value for carbon and until the element is more closely integrated with industrial ecologies and itself becomes a resource, doing so is an essential tool to make a start.

Sequestration

The only way of sequestering carbon permanently is as carbonates. The formation of carbonate sediments only occurs in geological time. Ways of accelerating carbonate sequestration include mineral carbonation. Another alternative is geological sequestration whereby CO₂ is pumped deep underground into suitable strata.

Oil has remained trapped in strata for millions of years and on this basis it is argued that carbon dioxide pumped down to push it up would also remain trapped. Given the fact that on average the pH of the earth is the same as that of seawater (8.2) then some neutralisation with the formation of immobile carbonates is also expected.

Although promoted by the petroleum industry as a means of extracting remaining reserves of oil "there are significant fundamental research needs that must be addressed before geologic formations can be widely used for carbon sequestration.(NETL, 2004)" Mineral carbonation, the reaction of CO₂ with magnesium silicates as inputs such as peridotites, forsterite or serpentine, to form magnesite has been identified as the safest, long-term option for storing carbon dioxide by many authors (NETL, 2004), (Seifritz, W., 1990), (Lackner, K., Wendt, C. et al., 1995), (Morgantown, W. V.), (Dahlin, D. C., O'Connor, W. K. et al., 2000), (O'Connor, W. K., Dahlin, D. C., Nilsen, D. N., Walters, R. P., and Turner, P. C, 2000) (Fauth, D. J., Baltrus, J. P. et al., 2001).

The idea of capturing CO₂ as carbonate in the built environment mimics what has in fact naturally been occurring for millions of years¹. Carbonates formed in seawater are the natural, large scale, long term sink for CO₂. Unfortunately geological processes take thousands of years to equilibrate. Good evidence of the enormous volumes of CO₂ that

¹ There have been at least seven (7) other epochs of global warming easily discernable from the geological evidence.

have been released from the interior of the earth during many volcanic episodes over the last few billion years is the high percentage (7%) of the earth's surface covered in rocks such as limestone, dolomite and magnesite.

The development of mineral sequestration is well under way with a number of universities and research organizations around the world involved. Although there still some kinetic issues the process is workable and potentially profitable under Kyoto.

Magnesium minerals are prime candidates for mineral sequestration and for scrubbing CO₂ out of the air.

Sequestration in the Built Environment with TecEco Technology

The problem of global warming is so big that the only way we are going to be able to beat it is if on average, everybody, everyday, in some way sequesters more carbon than they emit. Emissions reduction is essential; combined with sequestration on a massive scale the problem is solvable. Because of the sheer volume of materials flows, the obvious activity is construction and place to put carbon the built environment.

“In 1999, construction activities contributed over 35% of total global CO₂ emissions - more than any other industrial activity. Mitigating and reducing the impacts contributed by these activities is a significant challenge for urban planners, designers, architects, engineers and the construction industry, especially in the context of population and urban growth, and the associated requirement for houses, offices, shops, factories and roads (UNEP, 2001).”

According to the Human Settlements Theme Report, State of the Environment Australia 2001(CSIRO, 2001), “Carbon dioxide (CO₂) emissions are highly correlated with the energy consumed in manufacturing building materials.”

There is huge scope for emissions reduction and conversion of waste to resource given the massive size of the materials flows involved in the built environment of which concrete is around 30% at over 14 billion tonnes.

With the right materials and manufacturing technologies, because of its sheer size, the built environment and especially concrete could be a big part of the solution to global warming and other environmental problems rather than part of the cause.

Magnesium based eco-cement concretes and The TecEco kiln technology are the paradigms needed. With TecEco kiln technology magnesia can be made with no net emissions and eco-cements set by absorbing carbon dioxide out of the air. As Fred Pearce reported in New Scientist Magazine (Pearce, F., 2002), “There is a way to make our city streets as green as the Amazon rainforest”.

The Role of Magnesium Oxide (CCM) in Sequestration

The key to understanding the role of magnesium for sequestration is the magnesium thermodynamic cycle whereby magnesium acting as a carrier atom for water and carbon dioxide or both can be calcined, hydrated and then carbonated relatively easily.

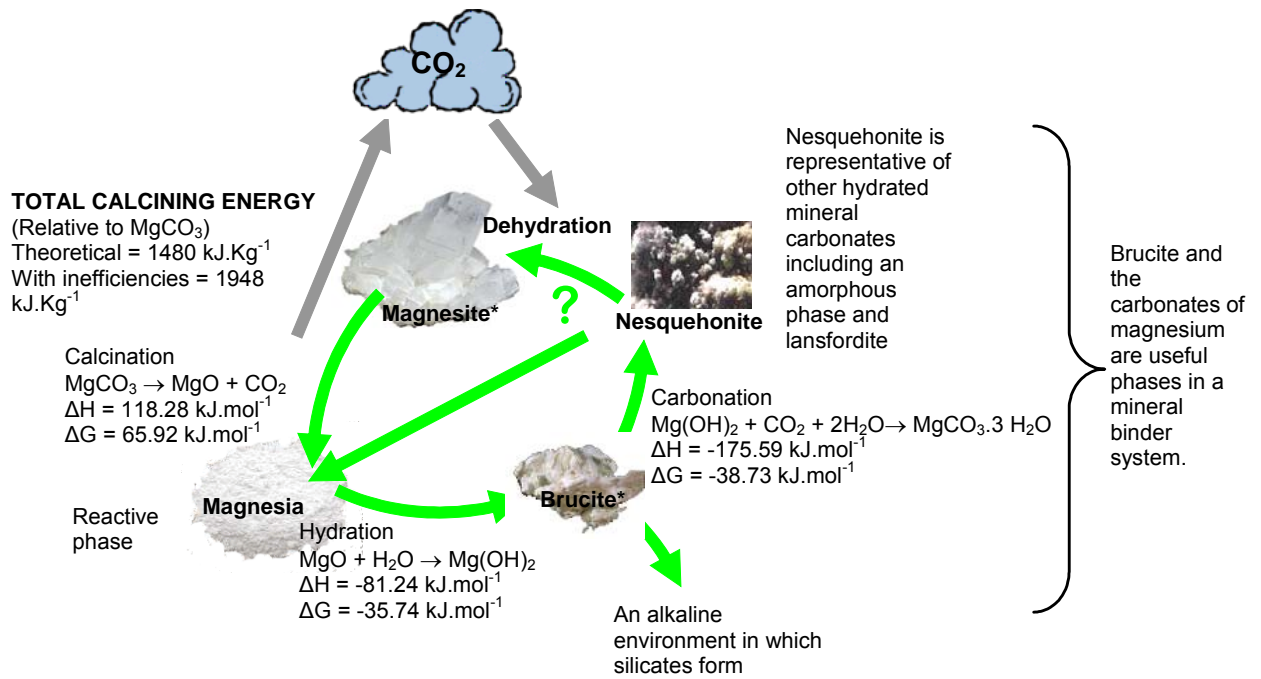
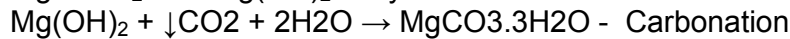
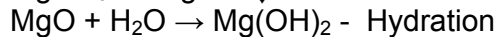


Figure 1 - The Magnesium Thermodynamic Cycle



The cycle:

- Does not take much energy to go from one state to another.
- Occurs at low temperatures.

Magnesium oxide (CCM) which hydrates to magnesium hydroxide and then carbonates is ideal for scrubbing CO_2 out of the air and sequestering the gas into the built environment:

- Because of the low molecular weight of magnesium

More CO_2 is captured than in calcium systems as the calculations below show.

$$\frac{CO_2}{MgCO_3} = \frac{44}{84} = 52\% \quad \frac{CO_2}{CaCO_3} = \frac{44}{101} = 43\%$$

- Magnesium minerals are relatively abundant.
- Potential low cost. New kiln technology from TecEco will enable low cost simple non fossil fuel calcination with CO_2 capture of magnesium carbonate.
- Because large quantities of carbonates (the binder in eco-cements) are produced from not much CCM. (The volumetric expansion from MgO to $MgCO_3.3H_2O$ is 568%).

Note that Brucite will only carbonate to magnesite in porous substrates such as bricks, blocks, pavers etc.

A Total Process for Sequestration using Magnesium Compounds

A total process has been developed by my company TecEco Pty. Ltd. whereby mineral sequestration occurs in CO₂ producing industries such as the power industry using mafic magnesium minerals the output from which is magnesite suitable for making caustic calcined magnesia (CCM). In the process envisaged by TecEco this is followed by calcination of the magnesite produced using non fossil fuel energy in a kiln designed by the company to produce reactive MgO (CCM). The CO₂ produced is geologically sequestered or sold replacing CO₂ made for industry. The reactive MgO (CCM) produced is used for sequestration in the built environment using eco-cements or in an oxide/hydroxide reactor process to directly sequester CO₂ out of the air.

The total process comprises a number of steps shown in Figure 2.

1. Mineral Sequestration in CO₂ producing industries such as the power industry using mafic magnesium minerals such as peridotite, forsterite or serpentine. Products include magnesite and silicic acid or silica.
2. Calcination of the magnesite produced from 1 using non fossil fuel energy to produce reactive MgO (CCM).
3. Geological sequestration of the CO₂ produced from 2 above.
4. Sequestration in the built environment of CO₂ using reactive MgO from 2 above.
5. An oxide/hydroxide reactor process using MgO/Mg(OH)₂ from 2 above to directly sequester CO₂ out of the air.

The Economics of a Massive Sequestration Process

The cost of mineral sequestration even without the advantages added by TecEco technology is predicted to be quite reasonable.

Assuming thermodynamically efficient processes a cost including rock mining, crushing and milling, of around \$ US 20/tonne of CO₂ are suggested (Yegulalp, T. M., Lackner, K. S. et al., 2001). For a 66% efficient power plant this would add less than 1 cent to the cost of a kilowatt hour of electricity (Yegulalp, T. M., Lackner, K. S. et al., 2001).

Should a price of carbon under the now legally binding Kyoto protocol be anything over \$ US 20/tonne of CO₂, the process would be economic once kinetic issues for chemically processing magnesium silicates are overcome.

A combined process involving TecEco tec-kiln technology would sequester several times more carbon and involve the eventual production of eco-cement concrete components that also sequester carbon to create the built environment and is therefore potentially very profitable even if an even lower price for carbon of say less than \$ 5.

The TecEco Total Sequestration Process

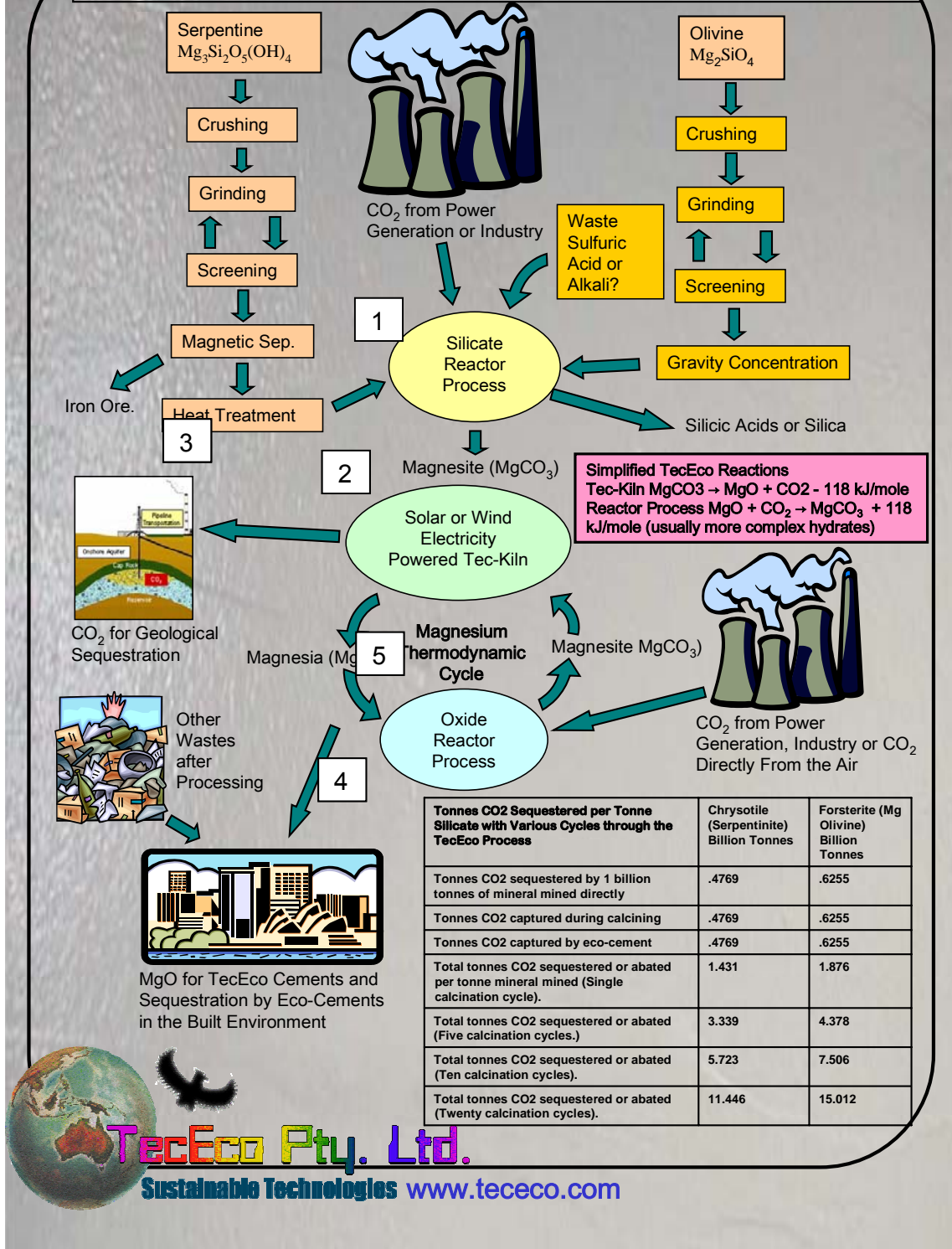


Figure 2 - The TecEco Process for Sequestration on a Massive Scale

Magnesium Cement Concretes.

My company have demonstrated that magnesium oxide can be combined with other hydraulic and cements and will be important in a sustainable world for sequestration in the built environment of CO₂ using reactive MgO from step 2 in the above total process because of it unique properties and potential low cost. Detailed information about the new cements is available on the company's web site.

Background

Ever since man began using hydraulic cementitious binders since way before Roman times they have essentially been based on calcium. Yet sediments contain both calcium and magnesium complementing each other in natural binders.

In 1917 the National Bureau of Standards (now the National Bureau of standards and Technology) and the American Society for Testing Materials established a standard formula for Portland cement which excluded MgO in any form. Other standards around the world followed. Even though we now know that it is lattice energy that causes the difference between amorphous magnesia and periclase and that amorphous magnesia, having no lattice energy to overcome, is safe to use in hydraulic binder cement systems, standards still ban any form of MgO in concretes to the detriment of the industry. This perception is something the magnesium compounds industry must overcome.

With the introduction of robotics (See Lemley, B., 2005) and sustainability as drivers for change the concrete industry can no longer sustain narrow perceptions about what their product of the future should be. A whole range of new composites that are more sustainable with new properties the boundaries of which are still being explored and expanded will be required.

Comparative Markets & Costs

The market for reactive or caustic calcined magnesia (CCM) is relatively small, according to Mike O'Driscoll (O'Driscoll, M., 2004) in the order of 1.7 million tonnes. Compared to the market for lime at 120 million tonnes or Portland cement at 2 billion tonnes; infinitesimal. Economies of scale do not apply.

Energy inputs are roughly the same as in the lime and Portland cement (PC) industries and given economies of scale energy dictates cost. This means that long run high volume costs should be similar for the production of magnesia, lime and Portland cement. At the present time, the lack of market volume is the main reason why CCM is roughly three times the price of lime or PC in many countries. Price and volume are inversely related to each other but not to profit.

Production

There has been little change in production of dead a caustic grades of magnesium oxide since the 1960's.

Production (Metric Tonnes)

World Production Magnesium Compounds

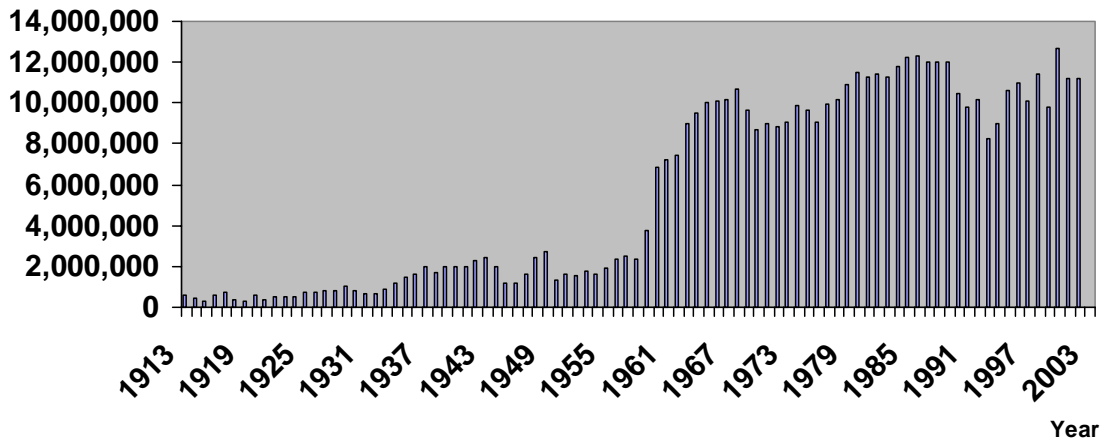


Figure 3 – Magnesia Production (DiFrancesco, C. A. and Kramer, D. A., 2004)²

World production of Portland cement has in contrast been continuously increasing.

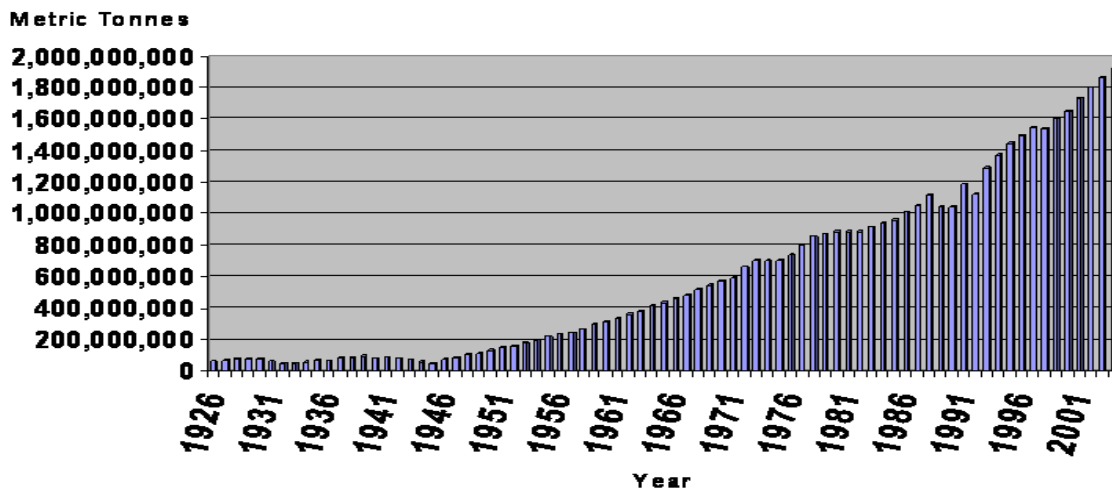


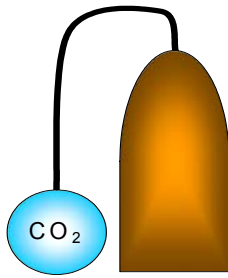
Figure 4 - Cement Production = Carbon Dioxide Emissions from Cement Production 1926-2002 (Van Oss, H., G., Hendriks, K. et al., 2003)

Reducing Costs of Production of Caustic Calcined Magnesia

Portland cement in many countries is less than a third the price of reactive magnesia. As the process and process energies are similar then the price should be similar. The only difference between the two industries is economies of scale.

Grinding uses around a third of the energy in magnesia, lime and Portland cement factories. Because reactive magnesia (CCM) is made at low temperatures it is easy to

² World production of dead a caustic grades of magnesium oxide are included in the one table as most companies produce both and can to some extent shift output from one grade to the other.



capture CO₂ during the process and combine grinding and calcining for improvements in efficiency. As most of the energy required for grinding is released as heat, combining grinding and calcining reduces energy consumption by 25% to 30%.

Although of secret design the kiln can be powered directly in a solar concentrator or utilise solar energy or waste heat.

Figure 5 - Schematic of the TecEco Kiln.

Although TecEco have yet to raise the money to build the kiln, we are confident it will be suitable for making reactive magnesia, lime, kandoxi (dehydrated clays) and one day maybe – Portland cement.

Role of the Magnesium Compounds Industry

The use of CCM for sequestration directly (as magnesium hydroxide used to scrub CO₂ out of the air) and as tec, eco and enviro cements in the built environment could potentially increase the market to in the order of billions rather than millions of tonnes.

Players in magnesium compound industry of the future will need to understand and get involved in sustainability issues and what TecEco are doing. Making sure:

- Mineral sequestration research, development and deployment remain on track as the physical outcome – the supply of large amounts of magnesium carbonate – will reduce mining costs considerably.
- The development of tec and eco-cements occurs as large quantities of reactive CCM will be required for this purpose.
- Enabling technologies such as the TecEco kiln are developed as they will allow production of the highly reactive magnesia required and reduce the cost base of manufacture.

There are significant outcomes requiring significant commitment and a vision for the future.

Advantages of TecEco Cement Concretes

Technical issues addressed by the new TecEco cement technology include:

- Strength
- Durability and Performance
 - Permeability and Density
 - Sulphate and chloride resistance
 - Carbonation
 - Corrosion of steel and other reinforcing
 - Delayed reactions (eg alkali aggregate and delayed ettringite)
- Rheology
 - Workability, time for and method of placing and finishing, stick and rebound with mortars.

- Shrinkage
 - Cracking, crack control
- Bonding to brick and tiles
- Efflorescence
- Sustainability

Concretes are already a relatively sustainable material. With low cost high thermal capacity they supply essential thermal mass to buildings. With the advent of TecEco technology, concretes will offer greater opportunities for sustainability with other improved properties such as:

- Greater insulation
- Lower binder aggregate ratios
- Greater durability
- Lower embodied and lifetime energies
- Waste utilisation and recycling
- Abatement and sequestration

And most importantly – the absorption of CO₂ in eco-cements

TecEco Binder System Summary

Formulations in the TecEco Cement system consist of a combination of a hydraulic cement, reactive magnesia and usually pozzolans as well as aggregates and fillers.

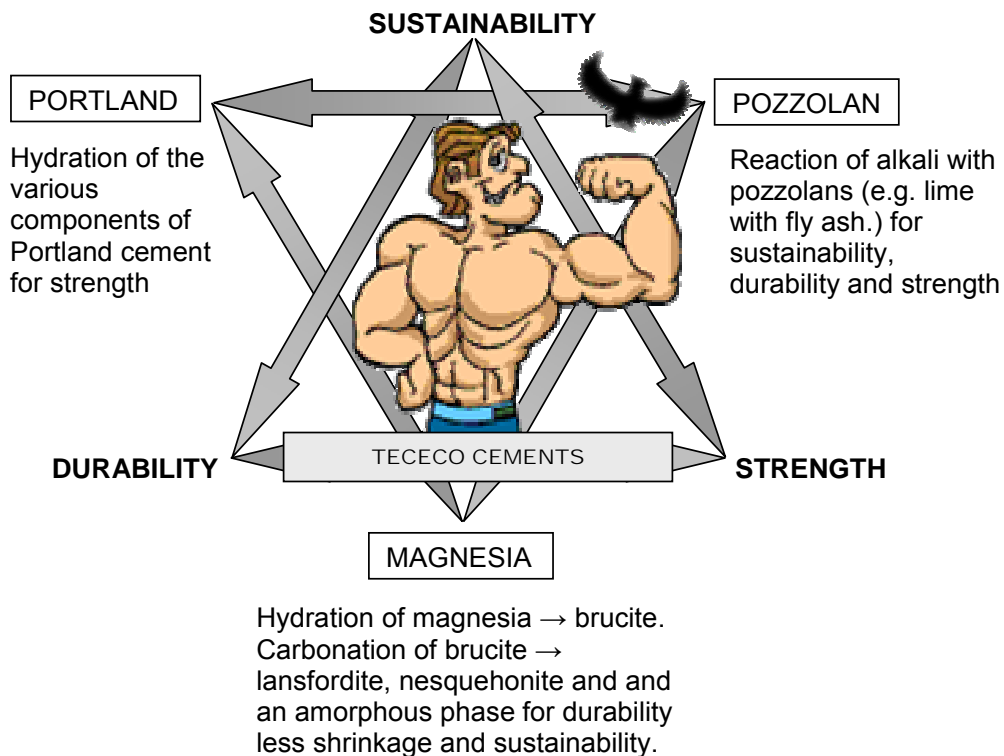


Figure 6 - TecEco-cements – Durability, Sustainability and Strength

Virtually all hydraulic cements can be blended with reactive magnesia and it appears not to interfere with their reactions. By far the most important is Portland cement.

The magnesia used should be as reactive as is commercially feasible to prevent risk of delayed hydration. Pozzolans include industrial wastes such as fly ash and ground granulated iron blast furnace slag.

Formulations Types

Compositions presently being developed in the context of early niche products are currently classified as tec-cements, enviro-cements or eco-cements depending on the proportion of magnesia to PC.

The affect of composition and porosity on strength in Figure 7.

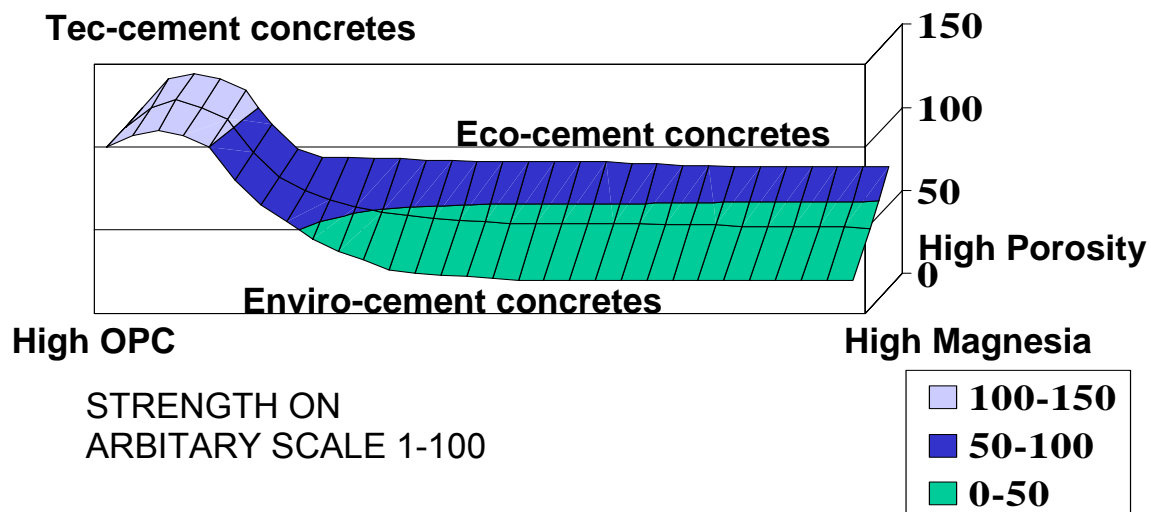


Figure 7 –TecEco Cement Concrete Types Relative to Porosity and Magnesia Content

The new materials technology is applicable to a wide range of uses depending on the sustainability, durability, rheology or strength required and three main formulation strategies have so far been defined:

- Tec- cements (e.g. 10% MgO, 90% OPC.)

Contain more Portland cement than reactive magnesia.

Reactive magnesia hydrates in the same rate order as Portland cement forming Brucite which uses up water reducing the water binder ratio, increasing density and possibly raising the short term pH increasing the effectiveness of reactions with pozzolans. After all the Portlandite has been consumed Brucite, which is less soluble, mobile or reactive controls the long term pH.

Other benefits include improvements in density, strength and rheology, reduced permeability and shrinkage and the use of a wider range of aggregates without reaction problems.

- Enviro-cements (e.g. 26-75% MgO, 25-75% OPC)

In non porous concretes Brucite does not carbonate readily.

High proportions of magnesia are most suited to toxic and hazardous waste immobilisation and when durability is required. Strength is not developed quickly.

- Eco-cements (eg 50-75% MgO, 50-25% OPC)

Contain more reactive magnesia than in tec-cements. Brucite in porous materials eventually carbonates forming stronger fibrous minerals adding strength and presenting huge opportunities for abatement.

Potential Uses

The new cements are suitable for a wide range of uses including

- As a stabilising binders in the production of earth buildings.
- Mortars, renders, grouts & drill hole cements.
- Controlled low strength materials
- Soil stabilisation/solidification.
- Agglomeration of furnace feeds and pellet manufacture.
- Waste and toxic waste immobilisation/fixation.
- For the production of porous pavement, bricks, blocks and pavers utilising coal combustion by-products including waste heat.
- To manufacture lightweight disposable high thermal capacity insulated packaging
- Blended with Portland cement to improve properties such as strength and durability.
- Where rheology is important such as with gunnite or shotcrete.
- Where fire retarding properties are essential.
- Use in areas of high chloride or sulphate contamination of sand and aggregates.
- Where there are critical resource shortages such as in China.
- Where cost or environmental considerations are important.
- Carbon sequestration

Lower usage costs for TecEco formulations will result from less cement being required in some formulations, easier placement and finishing, elimination of shrinkage and bleeding, faster strength gain (in some tec-cement formulations only), use of a wider range of aggregates reducing transport costs, less or no plasticisers, no bleeding and greater durability reducing replacement costs over time and potential carbon credits and should mean given adequate engineering back up widespread use.

No new plant and equipment is required to manufacture the new TecEco cements although the new TecEco kiln that captures CO₂ is preferred as with the resulting improvement in efficiency, the cost of magnesia is expected to fall below that of PC.

Given economies of scale and all of the above TecEco cement concretes should be cheaper.

It is common sense to distinguish reactive from dead burned materials. There are obvious advantages of including more stable alkalis or carbonates in cements so perhaps it is time to bury the hysteria regarding magnesia and rewrite all cement standards so that they only contain a performance based test such as in ASTM C 150 and ASTM C 595M where

autoclaving is required. No special comment should be necessary regarding dead burned lime or magnesia which would then be classed as a supplementary cementitious material.

Tec-Cements

Tec-cements concretes have a relatively low proportion (5-15%) of reactive magnesia added and this hydrates to form Brucite. They usually also contain a pozzolan which reacts with the Portlandite released as di and tri calcium silicate hydrate and forms more calcium silicate hydrates (CSH).

Noticeable from the moment water is added is the improved rheology (Workability is better than Portland cement concretes and this is due to the lubricating affect of the smaller magnesia particles and possibly some charge affects).

As a consequence of the removal of Portlandite and replacement by Brucite, tec-cement concretes have a different pH curve to Portland cement concretes with or without added pozzolan. As the hydration of magnesia takes up a lot of water (by Brucite in which 44.65 mass% is water, and Brucite hydrate gels containing even more water) and because tec-cement concretes do not bleed as much, it is thought that during the early plastic stage the pH may be higher. In the longer term however the pH is controlled by Brucite and is lower.



Figure 8 - Pouring the First Commercial Slab of 80 Cubic Metres



Figure 9 - Screeding off the First Commercial Slab of 80 Cubic Metres

The equilibrium pH of Brucite in water is 10.52 and it maintains the longer term pH of concretes in that range for much longer periods than Portlandite as it is far less mobile or reactive. For most kinetic pathways it carbonates much less readily (ΔG_r Portlandite \rightarrow calcite = - 64.62 kJ.mol⁻¹, ΔG_r Brucite \rightarrow nesquehonite = - 38.73 kJ.mol⁻¹). The equilibrium pH is still however at a sufficiently high level for steel to remain passive³ and for the stability of calcium silicate hydrates⁴. Dense concretes made using TecEco formulations should maintain reducing conditions and a pH over around 8.9 required for the long term survival of steel much longer than Portland cement concretes.

Tec-cement concretes exhibit high and faster development of strength and this is probably due the interaction of a number of factors. Most likely are:

- More silicification reactions including a more effective pozzalanic reaction during the early plastic stage whilst the pH is possibly elevated.
- A lower voids:paste ratio as a result of improved rheology due to better particle packing, some surface charge affects and high consumption of water by reactive magnesia as it hydrates.
- Slow release of water by hydrated Brucite gels ($\text{Mg}(\text{OH})_2 \cdot n\text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2$) resulting in more complete hydration reactions of PC.

The removal of excess water by magnesia as it hydrates has a number of consequences.

³ As Fe₃O₄ rather than oxides such as Fe₂O₃ or FeO₂ which tend to hydrate and are dimensionally unstable.

⁴ The neutralisation of Lime by pozzolans results in a drop in the Ca/Si ratio in CSH and potential brittleness

Bleeding and the introduction of associated problems such as efflorescence due to lime, freezing of bleed water and weaknesses such as interconnected pore structures and high permeability do not appear to occur.

Tec- cements concretes tend to dry out from the inside due to the water demand of magnesia as it hydrates and combined with a lower long term pH, density and the low solubility and reactivity of Brucite, improved durability results. Protection against sulfates, chlorides and other aggressive salts and delayed reactions do not occur.

The advantages of using Portland cement such as ambient temperature setting, easy placement and strength are not diminished however shrinkage is reduced if not eliminated due to low water loss and in appropriate proportions the expansion of magnesium minerals balancing the slight shrinkage of Portland cement concrete eliminating cracks and reducing porosity. Blended in the right proportions, concretes can be made that are dimensionally neutral over time.

As the propensity of Brucite to carbonate measured by the Gibbs free energy is also less and when it does carbonate it expands tending to block of the process, Brucite will remain as such under most conditions for much longer in a protective and pH regulatory role.

Brucite is a fire retardant and tec-cement concretes are drier because of the water consumption of magnesia meaning that fires tend to be cooled and heat induced spalling does not incur to the same extent.

More fly ash can be added to advantage and sustainability is improved by reduced binder:aggregate ratios, longer life and lower emissions ratios.

Enviro-Cements

Enviro-cements differ in that they contain higher ratios of magnesia to hydraulic cement. Chemically and physically they are more suited to toxic and hazardous waste immobilisation because they are more durable either lime, Portland cement or Portland cement lime mixes. They are also homogenous and do not bleed water, are not attacked by salts in ground or sea water and dimensionally more stable with less cracking.

In a Portland cement Brucite matrix⁵

OPC takes up lead, some zinc and germanium.

Brucite and hydrotalcite are both excellent hosts for toxic and hazardous wastes. Brucite has a layered structure and traps neutral compounds between the layers.

Heavy metals not taken up in the structure of Portland cement minerals or trapped within the Brucite layers end up as hydroxides.

The pH which is controlled in the long term by Brucite is around 10.4, and is an ideal long term value at which most heavy metal hydroxides are relatively insoluble.

⁵ Portland cement minerals and Brucite are the main binder minerals. A host of minor species also form and are also present.

Eco-Cements

Eco-cements require porous substrates to carbonate and differ in that they contain higher ratios of magnesia to hydraulic cement.

In porous or semi porous materials such as bricks, blocks, pavers, mortars and renders, as there are no kinetic barriers, the magnesia not only hydrates, but carbonates completing the thermodynamic cycle by reabsorbing the carbon dioxide produced during calcining.

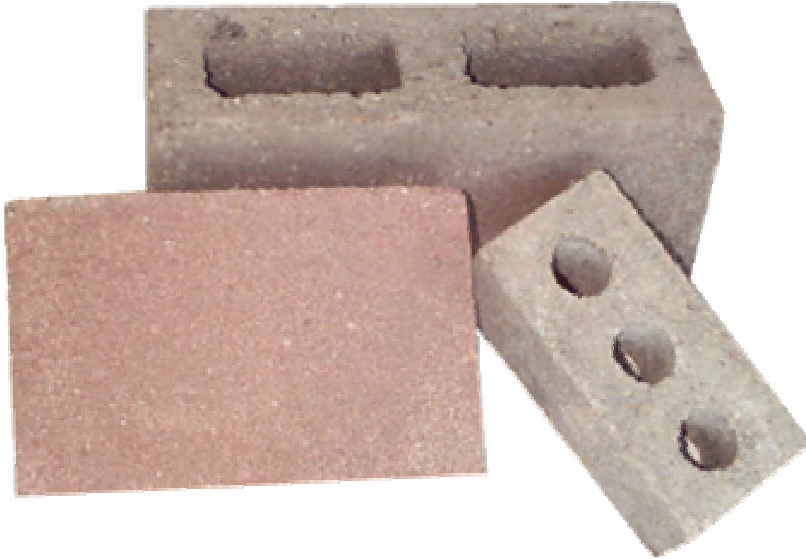


Figure 10 - Eco-Cement Bricks and Blocks

Eco-cement concretes are also to some extent recyclable and can have up to around 90% recycled industrial materials such as fly and bottom ash included in their formulation and are therefore likely to become the building material of future choice⁷⁸. Important uses will include providing a sustainable, low cost building material with high thermal capacity, low embodied energy and good insulating properties for construction in products such as bricks, blocks, stabilised earth blocks (mud bricks), pavers and mortars, porous pavements and in combination with wood waste for packaging. Carbonated eco-cement formulations for the built environment are also strong and resistant to the chemicals that attack Portland cement.

Brucite and magnesium carbonates bond well too many different materials including wood⁹ and will hold a large proportion of waste.

Eco-cement products will be favoured for energy conserving buildings because they can contain a wide range of materials, many of which are wastes that improve the insulation or thermal capacity.

Magnesium carbonates and hydrated magnesium carbonates are also fire retardants. Eco-cement concretes put fires out by releasing CO₂ or water vapour or both at relatively low temperatures.

⁷ 100% utilisation would reduce global CO₂ emissions in the order of 10% - 15%.

⁸ With either the collection of CO₂ at source or the inclusion of carbon based fibres or both eco-cements can be net carbon sinks

⁹ Hence the contemplated use for lightweight packaging.

Waste Utilization by TecEco Cement Concretes

Wastes, like weeds are only wastes because nobody wants them. The key is to find uses and convert them to resources.

Uses can be based on chemical composition or physical property. As many materials have common physical properties but are chemically very different utilization on the basis of physical property has huge potential, especially on a geographically distributed basis.

For robotic construction of the future (Lemley, B., 2005) a wide range of self setting solid composites will be required. Many materials currently considered as wastes can provide the properties necessary. For example plastics have in common low weight, low conductance and tensile strength. Why waste them? They can impart these properties to concretes.

One of the problems of using a wide range of wastes in concretes is that internal reactions can occur between them and concrete. TecEco magnesium cements are low alkali and relatively un-reactive and therefore have huge potential.

Deployment of TecEco Cements

Players in the magnesium compounds industry can play a role securing the development of the new TecEco technologies for their own benefit by:

1. Pressing to remove standards banning reactive magnesia (CCM) in mineral binder systems.
2. Advocating mineral sequestration.
3. Developing kiln technologies like TecEco's that can use non fossil fuels.
4. Taking a stand in the sequestration debate pointing out the advantages of magnesium compounds
5. Taking an interest in the development of TecEco magnesium cement and kiln technologies.

Conclusion

The quest for sustainability will involve the magnesia industry because magnesium oxide is the ideal mineral for sequestration on a massive scale.

There is a choice of futures – carry on a previously or embrace mineral sequestration and reap the profits.

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