

Sustainable Concrete Technologies for New Zealand – one company’s perspective.

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ABSTRACT:

Golden Bay Cement (GBC) runs a dry process kiln, fed by a pre-calciner that makes use of recovered waste heat, and utilizes local sources of limestone and cement rock in the production of Portland cement. The Company also burns wood-waste in its production process to further lower the carbon footprint of its cement. Pozzolanic fillers are used to decrease the “clinker factor” of the finished cement - in compliance with the current NZ Cement Standard. The company has also commissioned a state-of-the-art blending plant to produce special cement blends for those customers seeking more sustainable construction solutions; or special-purpose blends, beyond the requirements of current Standards.

New Zealand has plentiful supplies of silicon and aluminium-rich volcanic minerals, to act as pre-cursors to Inorganic Polymer Cements. Unreinforced test slabs incorporating these new binders have been exposed to regular use and weathering. Structural applications of this material have also been tested for use in earthquake-resistant construction and in drainage products.

Beyond the materials side of cement production, GBC has sponsored research into the use of thermal mass to lower the carbon footprint of residential buildings over their useful lives; the development of high durability self-compacting concrete mixes for long-life bridges; and the use of waste paint as an additive to improve the performance of concrete.

The ultimate in sustainable construction for a seismically active country like New Zealand, are structures designed for low seismic damage during large-magnitude earthquakes. GBC has helped to have PRESSS Technology (from the USA) included in our Concrete Design Standard. This has encouraged a broader understanding of displacement-based design of earthquake resistant structures, and ensured that the design methodology is taught at undergraduate level in our Schools of Engineering.

As the demands for even more sustainable construction ramp upwards, the New Zealand Cement and Concrete Industries will meet each new challenge with innovative, well researched solutions. The strategy has been to anticipate climate change legislation and knowledgeable market demands; without disrupting the traditional markets.

1 INTRODUCTION

Sustainable concrete technology can be compared to a long-distance race with no end: as global warming takes hold, those who can, will be asked to do more! Golden Bay Cement, a business unit within Fletcher Building Ltd (FBL), has prepared itself for this race by investing in initiatives that tackle sustainability and climate change (for both the cement and concrete industry's) on a number of different fronts.

The GBC strategy fits with Fletcher Building Ltd's environmental sustainability commitment, which is expressed in the Values:

- *FBL operations, products and services should have a positive impact on the environment*
- *The environment is a key consideration in everything that FBL does*

Increasing kiln fuel efficiency and lowering the embodied energy in each tonne of clinker was a decision that was financially attractive when it was made, but that decision makes even more sense now. Similarly, burning wood waste as a carbon-neutral bio-fuel (in terms of the Kyoto Protocol) has proven to be a wise decision, as ethical investment groups seek environmentally astute businesses in which to invest the funds under their control.

In terms of lowering the clinker factor in each tonne of cement, New Zealand's cement producers can only move as far or as fast as changes in the national Standards will allow, but GBC is actively participating in the Standards-change process. Current initiatives are aiming to allow the inclusion of up to 10% mineral filler, or pozzolan, in General Purpose cement. A key factor to ensure success with this change has been the conversion of the clinker-grinding plant to closed-circuit milling, to allow tighter control of the particle size distribution in the finished cement. An extensive testing programme is underway to prove similar performance to current General Purpose Cement, which can have up to 5% mineral addition (Freitag 2009). Regular testing and consistent cement quality enables concrete producers to minimize cement contents in their mixes – making customer communication another key sustainability strategy.

Even with the change to 10% mineral filler, some cement customers want other blends. GBC has commissioned a modern cement blending facility in Auckland, to service those special needs for Low-Heat binders; Green Star-rated concrete; concrete with high Marine Durability, or Chemical Resistance; Self-compacting Concretes; slow strength-gain Soil Stabilization blends; and other yet to be invented applications.

Helping cement customers to use the concrete wisely is a key part of any sustainability initiative. In New Zealand that has included improved thermal modelling of high-mass concrete buildings, to enable the reduction in heating and cooling costs over the life of the building to be accurately modelled in a rigorous Life Cycle Analysis (Munn 2004). Other research initiatives have included ensuring that the benefits of low seismic damage that accrue from smarter, displacement-based, building design (PRESSSS Technology, from the USA) can be easily used in New Zealand (Priestley, 2005).

Another technology that may deliver tangible benefits in the longer term is the use of inorganic polymer binders (McSaveney, 2003). Understanding the durability mechanisms of these materials is one current barrier, but an even more serious one is the fact that the better-performing inorganic polymers rely on the use of waste materials from energy intensive industries, as precursors, and those material are already coming under supply constraints (Harper 2002).

Adding waste, water-based paint into concrete, is another area where the Company is active. GBC is partnering with a paint company (Resene Paints Ltd) and a recycling business (3R Ltd) to find added value uses for the large volume of waste paint that is not suitable for normal "second use" application. Most of that left-over paint in New Zealand is recovered under a very effective "Product Stewardship" campaign, led by Resene and 3R.

Fletcher Building's progress towards meeting its energy use and CO₂ emissions targets can be found at:<http://www.fletcherbuilding.com/environment/environmental-sustainability/climate-change-and-energy>.

2 PRODUCTION CHANGES

2.1 Fuel Efficiency

The GBC kiln at Portland, near Whangarei, was converted from a slurry process to a dry process in 1983, when energy costs increased to the point that such a radical kiln conversion made economic sense. In 2005, fuel efficiency was further enhanced by capturing waste heat and feeding it back into the process for fuel drying; and to pre-calcine the raw feed going into the kiln. These recent modifications, undertaken at considerable expense to the shareholders of FBL, were to align GBC's production with the parent company's environmental values.

2.2 Alternative Fuels

Under the Kyoto Protocol, which New Zealand ratified in 2008, wood waste is considered to be a carbon-neutral bio-fuel. GBC's production plant was modified in 2003 to burn as much wood waste as possible with the current production configuration. The cement works is fortunate to be located very close to a major timber processing industry, and close to the "urban forest" of demolition timber from New Zealand's largest city. The high combustion temperature and the fact that solid residues are incorporated into the cement clinker, make combustion a very safe way to dispose of wood waste that could otherwise turn to methane, with 22 times the global warming potential of carbon dioxide, or is impregnated with toxic chemicals.

2.3 Improved Clinker Grinding

To take maximum advantages of the potential for mineral fillers to lower the clinker factor in their cement, GBC replaced its open-circuit mills with closed-circuit ball mills. This change allows better manufacturing control of the cement particle size distribution, leading to improved concrete rheology and lower cement contents. Closed-circuit milling, combined with more advanced chemical grinding aids, can ensure optimum performance from limestone or pumicite blends.

3 THE USE OF WASTE MATERIALS

Industrial waste products such as KOBM steel mill slag, and mill scale from a steel rolling mill, are incorporated in the raw feed to the cement kiln to ensure the right clinker chemistry and to lower the clinker-forming temperature. GBC is also able to use Class C fly ash from the nearby Huntly coal-fired power station, as a source of aluminates and calcium oxide, but supplies of that fly ash are limited so it has become more practical to save the fly ash for more appropriate uses, where it can have a greater impact on sustainability and job-site productivity.

However GBC has initiated research aimed at utilizing New Zealand's significant quantities of waste water-based paint, to modify the properties of concrete. With this end in mind, a variety of added-value applications are being explored by GBC customers, targeting niche markets where the surfactants, polymers and micro-fine fillers in paint can be used to enhance the fluid properties of concrete and reduce drying shrinkage.

Block-fill concrete, in reinforced masonry walls, is one area where the environment is better off through the use of waste paint as a flow-aid, a mix stabilizer, and for overall performance enhancement. Labour productivity is increased and filling quality is improved, while the paint is very effectively eliminated from the waste stream (Haig, 2008).

4 LOW SEISMIC-DAMAGE STRUCTURES

In a nation as seismically active as New Zealand, and where post-earthquake damage could have such a lasting economic impact, the ability of precast concrete buildings to survive major earthquakes with minimal damage can become an important sustainability consideration: both in terms of business continuation after the earthquake, and in terms of the impact on the Life Cycle Analysis of the need to demolish and re-build many buildings. The strategy to enable the US-initiated PRESSS Technology to be used in this country, has been to recruit people capable of teaching the new displacement-based design techniques, at the same time as the Concrete Design Standard (NZS 3101:2006) included the design method as an option. Study tours to building sites and precast factories that were applying the PRESSS Technology were undertaken and

progressive Structural Engineers were encouraged to apply the technique to appropriate buildings.

Now, with Engineering Graduates, who are familiar with the new PRESSS techniques coming out of both Schools of Engineering, the technology is starting to have an impact on construction in New Zealand.

5 ACCOUNTING FOR THERMAL MASS

Simplistic thermal modelling of buildings ignores the radiant heat effect on occupant comfort levels, of energy stored within the structural fabric of the building. We know that physiologically our body's heat-transfer response is affected 65% by radiant heat and only 35% by air temperature (conduction). This means that buildings with well-exposed thermal mass can operate comfortably at a lower air temperature than lightweight structures that can only rely on air temperature to regulate comfort levels – lower air temperature means lower operating energy costs that soon compensate for the marginally higher embodied energy in concrete structures, compared to timber ones.

Changing the New Zealand Building Code to enable the true comfort levels of concrete and masonry homes to be realistically assessed was a priority in a 2000 research programme, funded by the Foundation for Research Science and Technology. Uptake by the Concrete and Masonry Industries has not been as fast as it could have been, but such rigorous analytical techniques are now permitted.

6 ALTERNATIVE BINDER SYSTEMS

New Zealand has limited sources of industrial waste products that are suitable for use in Inorganic Polymer Concrete, and those natural minerals that could act as pre-cursors often require energy-intensive processing. Because of that production energy, the net embodied energy argument for a switch to Inorganic Polymer Binders is not yet a rational one. Attempts by the country's top inorganic chemists to understand the underlying science and to come up with a rigorous durability model that accounts for the water which is released as part of the polymerisation process, have not given a high level of confidence that Inorganic Polymer binders will quickly replace Portland cement as the preferred binder in reinforced concrete. A shortened life for Inorganic Polymer Concrete makes comparisons of the carbon footprint of such structures meaningless, at this point in time.

Given that Portland cement will be the binder of choice in the near future, there are a range of pozzolanic mineral fillers that can be used to lower the clinker factor in this cement. The pozzolanic filler of choice, around the world, is limestone: it is readily available at most cement plants, easily ground, and can enhance hydration and strength-gain at low doses. Beyond the level of clinker substitution that can be achieved with limestone, New Zealand has dispersed supplies of natural pozzolans – such as: Pumicite, Amorphous Microsilica and Diatomite, which are also being investigated (McSaveney, Shelford & South, 2008).

To enable the wider use of these materials, in such specialized applications as blends for: High Marine Durability, Green Star rated Cement, Low Heat, Chemical Resistance, Soil Stabilization and Improved Flow Characteristics, Golden Bay Cement has commissioned a state of the art blending facility in Auckland to produce a range of special purpose binders based on Portland cement:

6.1 High Durability Concrete

New Zealand has two principal corrosion mechanisms that designers of high-performance concrete structures are concerned about: Chloride penetration, in coastal structures; and Hydrogen Sulphide attack, in the active volcanic areas. Fortunately the Country has a deposit of naturally formed geothermal, amorphous microsilica, which is very effectively used to resist both of those forms of chemical attack. The product is mined, processed and distributed – as a dry powder, or in slurry form, under the brand name of **Microsilica 600**. In terms of strength enhancement of concrete; its ability to impart chemical resistance; and to improve durability; Microsilica 600 performs the same as silica fume, but without the handling difficulties (www.microsilica.co.nz).

In combination with the Class C fly ash from the Huntly Power Station, Microsilica 600 imparts exceptional marine durability to well-designed concrete mixes. The durability of these mixes can be further enhanced by taking advantage of the exceptionally low sorptivity that can be achieved with the dense surface structure inherent in self-compacting concrete. Much of New Zealand's modern infrastructure contains Microsilica 600.

The chemical resistance and anti-microbial properties imparted to concrete by the use of Microsilica 600 are taken advantage of in buildings for the processors of New Zealand primary industries – Dairy farms and milk processing, Wineries, Fruit and Vegetable processing, and Meat preparation.

7 FUTURE DIRECTIONS

Climate change is a global issue that transcends national boundaries; but as Governments change, the national perspective and priorities can also change. Already in New Zealand, we are seeing less evidence of our Government being intent on setting a low-carbon example to the rest of the world, at the expense of our national economy, and more emphasis on improving productivity in all sectors. Fortunately for concrete, these two strategies are mutually compatible: more sustainable concrete, with a high mineral filler content can be easily designed to be self-compacting, allowing Contractors and Precasters to take full advantage of the productivity gains of these modern concretes.

The easy availability of premium quality, off-the-form finishes, also enable Architects to expose the thermal mass of the structure with confidence; lowering the building's operating energy demands and greatly enhancing the life-cycle analysis and the economic payback. Many of the advantages that we used to take for granted have become more valued as building professionals rigorously strive for low-carbon buildings.

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