Utilization of Reclaimed Sands from Slag Waste

This report has been commissioned by EESTech Inc. Ltd, to assess market utilization of tailing sands reclaimed from the environmental remediation of waste slag dumps which originate from the production of metal alloys.

EESTech's reclamation process recovers up to 99% of any residual FeCr units from waste slag as a concentrate and approximately 600,000 tons per annum of post process tailings (PPT) being owned by EESTech. As a result of EESTech process all PPT will be categorised as an inert, high grade, synthetic sand with a unique chemistry suitable for range a of downstream applications.

This report seeks to highlight the applicability of the reclaimed sand produced by EESTech to be utilized as a feedstock for the provision of a low emissions, environmentally sustainable geopolymer cement products that will significantly reduce CO2 emissions as a replacement to Portland cement.

This report seeks to highlight the applicability of the reclaimed sand produced by EESTech to be utilized as a feedstock for the provision of a low emissions, environmentally sustainable geopolymer cement products that will significantly reduce CO2 emissions as a replacement to Portland cement.

Foresighting the Cement industry to 2030 and implications of Climate Change

It is not feasible to look at development in any productive sector today without performing a strategic foresighting analysis. Development in the sciences and engineering has now left the 'Moores law' era and has moved to the era of exponential development. Within the next 25 years the world economy must produce more iron ore, steel, energy, infrastructure, manufactured goods and food than that produced in the last 8000 years. It must achieve this massive productive demand sustainably with zero waste, reduced energy usage and zero carbon given that the exponential impact on climate change to 2050 is catastrophic.

Infrastructure

This paper looks at one single part of the productive sector, that of infrastructure and in particular concrete. The global cement industry is taking increasing climate action, encouraged by changes in policy, technology and new opportunities to raise profits and cut costs through reducing greenhouse gas emissions. The CO_2 emission from the concrete production is directly proportional to the cement content used in the concrete mix; 900 kg of CO_2 are emitted for the fabrication of every ton of cement, accounting for 88% of the emissions associated with the average concrete mix. The concrete sector accounts for at least 8% (2.2 Billion tonnes) of global CO_2 emissions and reducing this amount is critical in contributing to the goal of the 2015 Paris Climate Change Agreement to limit global warming to well below 2 degrees Celsius and as close as possible to 1.5. (Thinktank Chatham House 2018). Production of cement has increased more than thirtyfold since 1950 and almost fourfold since 1990. China used more cement between 2011 and 2013 than the US did in the entire 20th Century.

Cement and CO_2

The greatest proportion of concrete's CO_2 emanates from the production of cement using Portland limestone. The current cement manufacturing process is resource and energy intensive due to the extreme heat required for production. For example, large amounts of fossil fuel are used to heat a high temperature kiln to around 1400 degrees Celsius and decompose limestone and other raw materials to form clinker, which is then combined to form gypsum to make cement. Depending on the variety and process, cement plants today require 60 -130kg of fuel oil and 110kwh of electricity to produce each tonne of cement. For every tonne of cement made, the process releases approximately one tonne of carbon dioxide.

Clearly as countries act to implement the ambitious national climate action plans on which the Paris agreement's success ultimately rests, they will increasingly need to ensure that the concrete required for buildings and infrastructure is purchased from companies that have the lowest carbon footprint. (Bigger Climate action emerging in cement industry, 2018).

Scenarios

In applying strategic foresighting out until 2050 we can simply apply the plausible scenarios predicated by ARUP Consulting of UK. They have postulated that there are four main plausible scenarios for the future of the planet.

- **Post Anthropocene** shows how societal conditions and planetary health might exist in a harmonious relationship, fortifying each other for mutual progress and benefit.
- **Greenocracy** describes an improvement in planetary health which has been enabled by severe restrictions on human society : restrictive living conditions, conflict and authoritarian regimes prevail.
- **Extinction express** depicts both declining planetary health and societal conditions.
- **Human Inc**. represents our present trajectory; a world in which societal conditions advance at the cost of planetary health.

The Paris accord visualises the first plausible scenario and rejects the last scenario. Therefore it is very likely within the next 20 years or so any process that produces CO_2 emissions (not withstanding offsets) will be banned and that carbon offsets will be reduced and retired. This will include the production of Portland Cement. In visualising the future system state for cement it is easily seen that the traditional method of cement production will be phased out entirely. Within the next 30 years many industrial process will cease to be acceptable by the Paris accord and will be discontinued not withstanding offsets. Waves of change will occur through all industrial, agricultural and domestic sectors as we get closer to 2030.

Geopolymer cement

Portland cement is currently being replaced by Geopolymer cement in many circumstances. Geopolymer cement is still in its initial stages but is set to explode on the market within this current decade. Those that control the main raw material (slag) will rule the cement world. Production of geopolymer cement requires an aluminosilicate precursor material such as metakaolin or fly ash, a user-friendly alkaline reagent (for example, sodium or potassium soluble silicates with a molar ratio MR $SiO_2:M_2O \geq 1.65$, M being Na or K) and water. Room temperature hardening is more readily achieved with the addition of a source of calcium cations, often blast furnace slag.

EESTech's ThermaSand™ and Geopolymer cement

EESTech produces two unique products derived from the processing of ferrochrome slag that comes from the high temperature smelting of chromite ore in an electric arc furnace. The extreme temperature of smelting produces an amorphous glass phase slag that is water-granulated into aggregate and stockpiled by the millions of tons. The stockpiled slag is processed in EESTech's proprietary beneficiation plant that produces two product streams from the crushed slag. The first product is chrome concentrate that is smelted back into ferrochrome metal. The second product is a high-grade synthetic sand marketed by EESTech's as ThermaSand™, an inert sand product with the ideal chemistry for the production of geopolymer cement and concrete products.

EESTech's contracted right to millions of tons of ferrochrome slag guarantees supply chain certainty of ThermaSand to assure a market leading position as a provider of low emissions geopolymer products that will significantly reduce the carbon footprint of Portland Cement.

ThermaSand is an amorphous glass that is free of organic material, thermally stable, alkaline by nature, and consist mainly of silica (Si), aluminium (Al), and magnesium (Mg). It has the preferred silica to aluminium ratio that is required for making geopolymer cement and concrete. This specific ratio of Si, Al, and Mg is already thermally fused together as an amorphous glass and is chemically and physically perfect for high-grade geopolymer applications.

ThermaSand can be used seperately or mixed with fly-ash to form the sand component of geopolymer concrete or most importantly, as the raw material for making high-alkalinity activator that creates the geopolymerization of fly-ash, sand, and slag aggregate that makes up 95% of geopolymer concretes. High-alkalinity activator that polymerizes geo concrete materials is one of the most important components for making strong and consistent geopolymer cement and concrete. Most geopolymer cements and concretes are activated with sodium silicate which has a pH >13 depending on its molecular weight and chemistry.

However, sodium silicate on its own presents a long-term problem for cured geopolymer cement and concrete. Over time, the sodium in the sodium silicate leaches out of the geopolymer cement and concrete creating undesired salt deposits on the surface of the geopolymer material. The free sodium ions can also corrode the steel rebar used to reinforce concrete infrastructure causing premature failure. The solution to this problem was discovered through years of work conducted by the Geopolymer Institute. The addition of magnesium chemically binds the sodium into the geopolymer matrix preventing it from leaching and corroding the steel rebar inside the geopolymer concrete.

However, commercially pure magnesium oxide is not readily available at an acceptable commercial price limiting the commercial expansion of geopolymer worldwide. Whereas EESTech's ThermaSand has the correct chemistry ratio of Si, Al, and Mg required to eliminate any potential of corrosive causing leachates.

Geopolymer cements can be formulated to cure more rapidly than Portland-based cements; some mixes gain most of their ultimate strength within 24 hours. However, they must also set slowly enough that they can be mixed at a batch plant, either for precasting or delivery in a concrete mixer.

Geopolymer cement also has the ability to form a strong chemical bond with silicate rock-based aggregates. Geopolymer concretes are stronger and last longer than Portland cement based concrete.

In March 2010, the US Department of Transportation Federal Highway Administration released a TechBrief titled Geopolymer Concrete that states;

> *'The production of versatile, cost-effective geopolymer cements that can be mixed and hardened essentially like Portland cement would represent a game changing advancement, revolutionizing the construction of transportation infrastructure and the building industry.'*

EESTech is well positioned to facilitate what is being sought by the US Department of Transport.

Carbon Credits

The CO_2 emissions footprint of Portland Cement per tonne is 900Kg eCO_2. Geopolymer production has a CO_2 emissions footprint 80-90% less than that of Portland cement. The average carbon credit value throughout the world is approximately US$20 per tonne. This means for every tonne of geopolymer cement produced the possible carbon credit value is at least US$16. This can be greater in countries such as Canada which has set the carbon credit price at $30 per tonne rising to $50 by 2023.

By adding a waste stream such as incinerator fly-ash to the cement mix the landfill cost can also be offset. Depending on the scale of the geopolymer cement production, the Carbon credit and offset value may prove to be the bigger economic component. By 2030 if a producer is manufacturing one million tonnes of geopolymer cement the carbon credit revenue could be as high as US$50 million.

Conclusion

The expectation of rising carbon tax against CO_2 producers is becoming critical post the 2015 Paris Accord and the impact of Corporate Environmental & Social Governance accountability. Heading towards 2030 the opportunity in the cement industry for a significant paradigm shift employing geopolymer cement in anticipation of a 'ban' on Portland cement is the global impact that the Paris Accord was hoping for. By changing to geopolymer cement existing slag heaps become fully utilised and additionally incinerator fly-ash is acceptably assimilated into the geopolymer cement as it is deviated from landfill. From a global point of view this opportunity cannot be overlooked and those that get in the game first will benefit. It is my opinion that given the availability of multi-million tons of feedstock with the right chemistry, EESTech is in a position to capitalise on this market opportunity to become a world leading supplier of geopolymer cement products that will deliver the means to phase out Portland cement, significantly reduce the carbon footprint of the construction industry and to promote environmental sustainability.

Dr. Ir. Ron McDowall OBE
Hazardous and Toxic Substances Waste Scientist UNEP Geneva and UN FAO Rome.

Adjunct Senior Lecturer - Engineering School Waikato University, New Zealand
BBS/Sc (Physics), MPhil, PhD (The University of Waikato)

Distinguished Fellow Engineering NZ, Member Scientist Royal Society NZ
Chartered Engineer, Int PE. APEC Engineer, F.NZIM, M.InstD.
Scientific advisor EESTech Inc.

THE UNIVERSITY OF WAIKATO

EXPLORE | DISCOVER | SHARE ROYAL SOCIETY TE APĀRANGI