A Local Solution for a Local Problem

Cement Kiln Dust as a valued by-product

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Presentation overview

- Cement Manufacture, Cement Kiln Dust (CKD) generation and the generation journey
- Environmentally appropriate approach
- Waste hierarchy progression
- Void Stowing with Controlled Low Strength Fill (CLSF)
- CLSF mix design technology
- Acid Mine drainage reduction and management
- Industrial Ecology and Symbiosis
- Future Use
- Summary
Cement production

Temperature rise and fall inside the cement kiln

- Burning Zone
- Calcining Zone
- Drying Zone

Temperature (°C)
- 2000°
- 1500°
- 1000°
- 500°
- 0°

Distance in metres along kiln from kiln door
- 0m
- 10m
- 20m
- 30m
- 40m
- 50m
- 60m
- 70m
- 80m
- 90m
- 100m

Gas temperature
Average material temperature

CKD
Raw material slurry
CKD and the generation journey


Holcim
Environmental Appropriateness

Most Preferred

New Kiln Project 2014
CKD Void Stowing 2011
Insufflation 1993
Fertiliser 1988-1995
Landfilling 1974-1988

Least Preferred
Waste Hierarchy and Holcim’s Response

- The Holy Grail!
- Prevention
- Minimisation
- Reuse
- Recycling
- Material Recovery
- Disposal
- Land-filling
- Fertiliser
- Dust Insufflation
- Void Stowing
- Process Control
- The Holy Grail!

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Waste Hierarchy and Solid Energy’s Response with CLSF

- Resource Utilisation
- Overburden material use
- CLSF as Engineered Cap
- Fire mitigation
- Contaminated Coal (OB)
- Prevention
- Minimisation
- Reuse
- Recycling
- Material Recovery
- Disposal
Void stowing process with CLSF

CLSF

CKD

OPC

H₂O

Overburden (-35) + Sand(-7)
Controlled Low Strength Fill (CLSF) composition

- 52% Screened overburden waste nominal -35mm (onsite)
- 7% CKD (Holcim Westport Works)
- 3% OPC (Holcim Westport Works)
- Min 10% binder
- 18% Screened granite sand nominal -7mm (onsite)
- 20% Water (onsite)
- 52% Screened overburden waste nominal -35mm (onsite)
CLSF Processing Plant – Blair Athol, Clermont – QLD
(Holcim Australia – 1.8 million m³ voids stowed over 7 years)
Exposed opencast cut face – Blair Athol (Holcim Australia)

- Waste minimisation, reduced OB contamination
- Sets/structures locked into CLSF
- Reused as engineered OB cap (2nd life)
- Safe heavy machinery operation
- Extinguishes underground fires
Millerton Block mine workings - 1.25 million m$^3$ known voids
Solid Energy – Big Yellow CLSF processing plant
CLSF as an engineered cap

- Acid mine treatment (Pyrite, acid forming water run-off)
- Second life as an engineered cap
- Assists in pH management of water run-off
Industrial Ecology (Kalundborg Eco-park) – The Ideal…

- Sulphuric Acid
- Oil Refinery
- Pharmaceutical Manufacturer
- Agricultural Sludge Fish Farming
- Gypsum Plasterboard Plant
- Flyash, Clinker
- Gypsum
- Greenhouses
- District Heating
- Waste water
- Gas
- Steam
- Cooling water
- Extraction/discharge of water
- Materials Transfer
- Air Emissions
- Extraction/discharge of water
Holcim’s Industrial Ecology

- Aluminium Smelter
- Used Oil Recovery Programme
- Recycled Gypsum
- SOLID ENERGY Coals of New Zealand
Industrial Symbiosis

Cement Kiln Dust

Trials with Acid Rock for pH correction
Summary and acknowledgements

• Value and use of an industrial by-product in a 2 tier lifecycle
• Promotion through the waste hierarchy
• Evolution of CKD management utilising the most environmentally appropriate solution available
• Industrial symbiosis with complementary industry
• Future use;
  - Sewage sludge treatment
  - Contaminated ground remediation

Acknowledgements
Don’t be afraid to take a big step when one is indicated. You can’t cross a chasm in two small steps.  

*David Lloyd George*
A LOCAL SOLUTION TO A LOCAL PROBLEM: BENEFICIAL USE OF A CEMENTITIOUS BYPRODUCT

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ABSTRACT

Since the commencement of cement production in 1958 at Holcim (New Zealand) Ltd’s Westport cement works, both Holcim New Zealand and Solid Energy have been bound as supplier and customer. The energy intensive coal fired cement production process generates a by-product called cement kiln dust (CKD), an alkali dust-like product exhibiting minor cementitious properties. Historically this product was discharged to landfill. As technology has advanced, and environmental awareness and product stewardship has become foremost for Holcim’s operations, the waste process has traversed the waste hierarchy from 'disposal' to economic and viable 'reuse'. This has culminated in achieving an environmentally positive outcome with the use of CKD in a controlled low strength fill (CLSF) for void stowing at Stockton Mine, operated by Solid Energy.

The technique of void stowing involves the gravity fluming and injection of CLSF into boreholes filling the estimated 1.25 million m³ of voids in the historic Millerton Mine workings. Comprised of water, local overburden rock and sand processed on site, combined with general purpose cement and CKD, CLSF attains strength comparable to the surrounding coal and overburden after a four to six week curing period. The use of CLSF in void stowing achieves prime safety, environmental quality and waste minimisation objectives for both Holcim and Solid Energy. For Holcim, CKD is no longer discharged to landfill or converted to fertiliser. For Solid Energy, void stowing prevents heavy mobile plant falling through the overburden into the workings as well as assisting to extinguish underground fires. These factors lead to a vast improvement in the water quality of streams draining the historical workings, due largely to the neutralisation of mine water that previously generated acid run-off. Void stowing also results in improved opencast coal yields with waste minimisation of the overburden that doesn’t contaminate the coal resource. Void stowing has been a vital part in developing a workable and viable opencast mining plan for the area.

The utilisation of CKD in CLSF to stow voids and then to control acid mine drainage (AMD) and rehabilitation of the Stockton mine site meets the objective of the West Coast Regional Council (WCRC) Regional Policy Statement and contributes to the Solid Energy and Holcim materials life-cycle initiative of reusing waste streams for beneficial purposes.

With CKD use in CLSF for void stowing and subsequent reuse as an engineered cap for mine restoration and remediation we see a waste resource increasing in usefulness and value with decreasing environmental impact.

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INTRODUCTION

Since the Electrostatic precipitators (ESP’s) were installed at Westport, dust generated through the cement manufacturing process has been collected and either land filled, stockpiled or turned into fertiliser following a nodulising process. There is an estimated 600,000 tonnes of material which has been land filled on the site. Reports prepared by Norton (1991) indicate that historically the best use of the material was as a fertiliser for Pakahi type soils. Reference was made that CKD ‘for ameliorating acid coal mine overburden dumps also has some potential’.

Holcim New Zealand has worked closely with Solid Energy to achieve an economically viable and environmentally sensitive outcome for this byproduct. The production of Controlled Low Strength Fill (CLSF) enables the beneficial reuse of a byproduct whilst ensuring that the lowest cost solution is provided to Solid Energy. Additional benefits are achieved through the secondary reuse of the product where the CLSF, once open cast excavated with the coal reserves, is used as an engineered capping material thereby neutralising potentially acid forming run-off.

Improved environmental quality and resource consent compliance is achieved with the CKD remediation process. This uses engineered reworked overburden caps combined with CKD resulting in neutralised water runoff on the mining plateau, a key resource consent operational parameter.

CHARACTERISATION OF CKD

CKD is a solid, alkaline powder generated from the manufacture of cement. It is composed principally of 1 – 40 μm particles collected from electrostatic precipitators during the high temperature production of cement clinker. The chemical composition of CKD depends both on the raw materials used to produce the clinker, and on the type and source of carbon based fuel used to heat this material in the rotary kiln. The raw material used to produce the cement clinker at Holcim Cement Works is a combination of limestone and clay. Coal and used oil are used to heat the kilns to high temperatures to decarbonate the limestone and to produce the cement clinker. About 15% of all raw materials (approximately 80% limestone and 20% clay) are released as dust, much of which is recycled through the plant (Holcim, 2004). X-ray Diffraction Analysis suggests the mineralogy of CKD contains quartz, calcite, free lime, alunite, muscovite, gehlenite and syngenite (Solid Energy [2010], Mackenzie [2003]).
A CONTEMPORARY APPROACH

Generating a CLSF product with CKD provides an environmentally appropriate outcome. The preparation of CLSF ensures that any potentially leachable materials are bound within the fill material ensuring that they cannot be discharged inappropriately. Binding the leachable metals within the fill material ensures that any future leaching is eliminated.

The traverse through the waste hierarchy has been demonstrated as time has evolved. The following timeline gives an indication of the approach undertaken at the time.

![Timeline of CKD utilisation](image)

**Figure 1. Timeline of CKD utilisation**

Following the Westport Works opening in 1958, there has been the generation of Cement Kiln Dust as a by-product of the cement manufacturing process. While modern techniques are incorporated to minimise the dust escaping to the atmosphere, there has been varied responses to the disposal methods of CKD over time.

Following the installation of the ESP’s at Westport, the dust generated from the kilns was stockpiled on the site. This stockpile has grown in size. Consents were granted to allow the discharge of water from this catchment, and Holcim continues to investigate long term mitigation options for this historic pile.

In 1991, the use of CKD was adopted within a local fertiliser manufacturer. The CKD was ‘nodulised’ (formed into small balls with the incorporation of additional water) and sold to local farmers. Given the free lime content, and the high level of potassium, this was an effective low cost solution for local farmers (Norton, 1991). Alternative options were investigated and implemented where possible. Plant operations with strict monitoring protocols have ensured the trace metal contents are below the detailed and
specific consent limits. Historical trends of trace metals have been consistently well under the specified limits.

Dust insufflation equipment was installed in 1993 and allowed the return of dust to the cement kilns for reuse. Returning dust to the kilns is limited by the alkali factor which is permissible by the New Zealand Standard for cement. Approximately 2000-3000 tonnes per annum is returned to the kilns and reused for cement manufacture.

2005 saw the reuse of CKD as an ingredient in the engineered overburden caps at Solid Energy’s mines. The alkaline nature of the CKD aided Solid Energy in the mitigation of effects generated by Pyrite rock, which has the ability to form a low pH runoff when it is exposed to air and water.

The current use of CKD in CLSF is considered to be the most environmentally appropriate outcome due to the fact that any leachable metals are effectively bound within the concrete-like matrix. The ability for leachate generation is significantly reduced. Once the CLSF is in place, there are additional benefits for Solid Energy; these include waste minimisation and avoidance, and a second life for CLSF.

The use of a hard fill material within the voids enables Solid Energy to have a hard fill which can be broken up into chunks when required. This creates various benefits as previously discussed. Secondary use of the CLSF as a material within the engineered overburden cap is a beneficial reuse which aids in stability and the mitigation of low pH runoff from the site.

MINE VOID STOWING WITH CLSF AT THE MILLERTON BLOCK

In 2010 Solid Energy identified the Millerton Block, located in the northern part of the Stockton Coal Mining licence 30 km north east of Westport and approximately 3 km east of the coastline. Within the Millerton underground working are lithologies associated with the Brunner Coal Measures (BCM). BCM at the surface (20-70m thick) overlie basement granite. A basal sequence (2-30 m thick) of coarse quartz-feldpathic sandstone overlain by thin siltstone and mudstones is located above the basement granite. Localised areas of pebble to cobble conglomerate occur immediately overlying the granite. No geological formations younger than Brunner are preserved at the site. The coal measures include the Mangatini Seam (3 -14 m thick).

The CLSF used in stowing is an engineered fill comprised of overburden rock obtained from site, AP5 sand made from aggregate crushing, AP35 crushed overburden (BCM) on site, small proportions of general purpose cement (GPC) as required, and CKD from the Holcim Cement Plant.
CLSF is composed of:

- 1 - 3% general purpose cement
- 2 - 15 % (average 7%) CKD
- 20 - 40% AP5 quarry sand
- 40 - 60% AP35/40 overburden rock
- Water as required (average expected is 20%, that varies according to dry material moisture content)

The manner of CLSF disposal to ground as a coherent semi-cemented fill means that much of the material is unreactive and/or has minimal interaction with the underground drainage within the old Millerton underground workings. Underground assessment of the CLSF stowage has confirmed this, and no bleeding of leachate from the CLSF occurs.

CKD’s binding (pozzolanic) properties are essential to the stowage operation to retain flowability whilst also providing economically important cementing capacity to create a cohesive material. CKD also contributes to the acid neutralising ability of the material. The incorporation of CKD in CLSF creates a fill that is self supporting, has high flowability (able to tightly fill voids), is workable, produces a cohesive material (minimal amount to enable clean excavation and minimal dilution of coal) and can be dug out and easily removed by earthmoving equipment at the time of mining. Target strength is 0.5 to 1.0 MPa at about 70 – 90 days curing.

One key essential performance parameter that is maintained with the well balanced mix design is minimised segregation. When CLSF is gravity flumed through the 250 – 350mm diameter boreholes that are at depths of 5 to 30m, segregation can occur. This is reduced by maintaining a minimum binder content of ~10% cementitious materials, namely general purpose cement and CKD. Relatively tight control of the mix water also mitigates segregation (Holcim Australia, 2010).

CKD is stored in two 100 tonne silos that are accessible to road tankers. The CKD is pumped directly from the tankers or from a truck to the silos and the silos have dust filters to capture dust generated during filling. Once in the silos it is transferred to the blending plant where it is combined with other CLSF material to become a dry mix that is trucked to the mobile mixing plant. Water is added at the mobile mixing plant, and the CLSF is injected by gravity fluming to the underground voids.

Figure 2 shows a schematic material flow from blending the constituents, through the constant flow processing plant to gravity fluming to the voids. The processing plant, affectionately known as ‘Big Yellow’, being track mounted, is then relocated at the next borehole for further stowing. This sequence continues until the void is fully stowed to known stow points and is tight filled to the void ceiling. This process is similar to that undertaken at the Blair Athol Mine (Holcim Australia, 2010).
Figure 2: Mine void stowing with CLSF

Photo 1: Solid Energy mine void stowing constant flow CLSF processing plant (Big Yellow).
Photo 2 shows the CLSF plant, operated by Holcim Australia, at the Blair Athol mine (Clermont, Queensland). The material flow process can be seen from loader fed processed overburden for coarse and fine aggregate, cement from plant mounted ground silo (above axles) through the constant flow blending to the chute for gravity fluming to the borehole (partially obscured). Some 1.8 million cubic metres of fill has been stowed over a period of approximately six years.

Photo 2: Mine void stowing with CLSF at Blair Athol underground mine, Clermont, Queensland, Australia (Holcim Australia, 2005)
Photo 3 shows the open cast cut face at Blair Athol Mine. The key performance parameters of CLSF can be clearly seen where the voids have been tight filled to the void ceiling and required strength to support the surrounding coal whilst still be readily excavated in open cast operations.

Photo 3: Exposed open cast cut face at Blair Athol underground mine showing tight void stowing of the lighter coloured CLSF within the coal reserve. (Holcim Australia, 2005)
As alluded to in the previous section, many and varied options for CKD management have been contemplated and implemented over the past 30 years. These options have represented an evolution through the waste hierarchy for Holcim New Zealand. The end uses have represented what is considered environmentally appropriate at that point in time.

Historically, disposal was considered an environmentally appropriate outcome (as it was mitigating the discharge to the atmosphere). Time has moved on, and landfilling is no longer considered an appropriate response. The recycling of materials was introduced through the dust insufflation process, and this is still occurring today. This ensures a minimisation of waste being produced, so should therefore be continued.

Now, reuse of the waste material is considered to be the best practicable outcome as 100% of the material can be consumed, and it is utilised in an environmentally appropriate manner. The significant volume of voids at Stockton and Millerton ensures that, for Holcim, there is surety of demand for the CKD which is being generated. Options may also exist for historically dumped stockpiles to be consumed for mine restoration or remediation elsewhere.

Holcim’s technical team at the Westport Works are always working on technologies at the kilns to prevent the generation of CKD as a waste by-product. Optimistic targets
are set annually by the production team to minimise the volume of CKD generated, and different technologies are employed to achieve these targets. Unfortunately, with the wet process cement production technology available at the Westport cement works, the generation of CKD is unavoidable, and therefore it cannot be completely prevented. But it can be minimised.

Following through the waste hierarchy, the most preferred option is prevention – Holcim New Zealand seek to prevent the generation of CKD through the new kiln project which is proposed for Weston. The newer technology available and the dry process, ensures no CKD is generated.

INDUSTRIAL ECOLOGY

Enabling this flow between two industrial companies within the same geographic region ensures that the costs are kept to a minimum through the relatively short distance the material has to travel. Internationally, examples of industrial ecology incorporate more than one waste product (for example the Kalundborg Eco-industrial park). True industrial ecology involves both the flow of energy and materials through systems at different scales (Chertow, 2008).

INDUSTRIAL SYMBIOSIS

More accurately, Holcim’s involvement with Solid Energy can be defined as Industrial Symbiosis. Chertow (2000) indicates that industrial symbiosis engages typically separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products.

Holcim have a long track record for the utilisation of waste. Examples include waste oil for cement production, Spent Cell Liner (SCL) as a mineral replacement and fuel source, recycled gypsum from plasterboard and recycled glass as aggregate in concrete manufacture. These various waste streams enter as raw materials, and their reuse results in a second phase of life intended for no less than 50 years (roads, buildings, structures). This ensures that the wastes we receive are utilised (and bound) for a long time.

![Figure 4: Industrial Symbiosis in action at Holcim Cement](image)

Figure 4: Industrial Symbiosis in action at Holcim Cement
CONCLUSION

Holcim New Zealand has enabled a byproduct to become a particularly useful material for use within the burgeoning coal mining industry. Management of the by-product from the cement manufacturing process has evolved through the waste hierarchy in recent years. The current solution is considered to be the most environmentally appropriate outcome currently available.

The practice of CLSF whilst not new internationally, is new within New Zealand, and is considered to be beneficial for coalmines through the savings which can be made with the reduction in waste and ensuring the highest recovery rates of available coal within previously mined areas.

Improved environmental quality and resource consent compliance is achieved with the Millerton CKD remediation process. This uses engineered reworked overburden caps combined with CKD resulting in neutralised water runoff on the mining plateau, a key resource consent operational parameter.

Given environmental awareness and product stewardship is foremost with Holcim’s operations, the waste process has traversed the waste hierarchy from 'disposal' to economic and viable 'reuse'. This has culminated in achieving an environmentally positive outcome. A product stewardship philosophy has been adapted to the CKD by-product, extending producer responsibility as a result of the new void stowing initiative implemented by Solid Energy, in conjunction with Holcim, at the Millerton Mine near Stockton.

ACKNOWLEDGEMENTS

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