INSTITUTION OF MECHANICAL ENGINEERS HONG KONG BRANCH
TECHNICAL VISIT TO GREEN ISLAND CEMENT ON 3/5/2014

IMechE-HKB delegation to Green Island Cement [Benny C.Y. Sit]

Hong Kong, by its nature of extraordinary high population density, is a “concrete forest”. Residential flats, offices, shops and even industry workshops are within the high-rise concrete shells dotted across the narrow strips of land in the territory. The extensive use of cement is conceivable.

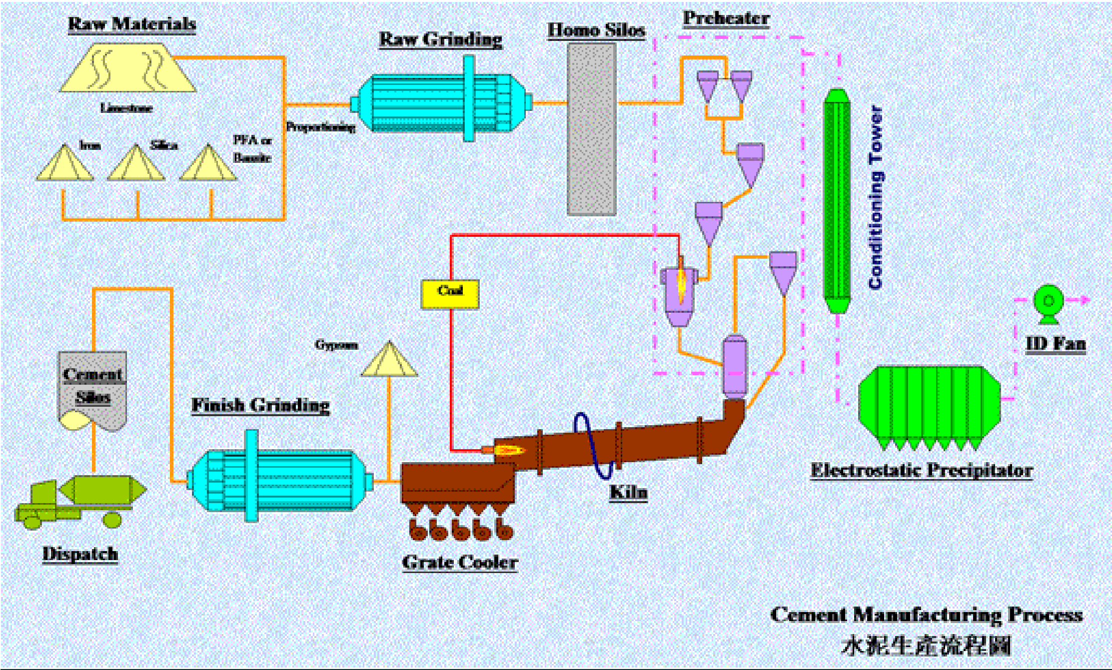
The “concrete forest” would not be built without the ingredient, cement. To support the usage of this essential construction material, Green Island Cement (GIC) supplies 60 % of the cement consumed in Hong Kong. GIC’s production facility in Hong Kong is the only integrated cement production plant in the territory and the largest of its kind in south China in terms of production capacity, processing raw materials to become high grade Portland cement. Its strategic importance to the construction industry and the development of Hong Kong attracted Institution of Mechanical Engineers Hong Kong Branch (IMechE-HKB) to visit it on 3rd May, 2014 to learn about the cement production process and the associated equipments and, more interestingly its upcoming major maintenance undertaking.

General

Green Island Cement (Holdings) Limited (GICH) is a wholly owned subsidiary of the largest publicly listed infrastructure company in Hong Kong, Cheung Kong Infrastructure Holdings Limited. Founded in 1887 at Tsing Chau (Green Island) in Macau, GIC is the first cement plant in China. The current production facility in west Tuen Mun of New Territories was built by the American company Kaiser Cement Corporation and was commissioned in 1982, under the name of China Cement Company (Hong Kong), Limited (China Cement) at the time. Subsequently the ownership of the plant was handed-over to the tycoon Li, Ka-Sing and the original GIC facility at the current Hutchison Park in Hung Hom moved into the current site. Absorbing the plant, GICH nowadays remains two (2) trading names, China Cement and GIC. Provision is in place for the expansion of production line from currently one (1) to ultimately two (2) in the existing site.

Cement Production

This section is written with reference to the GIC website http://www.gich.com.hk/Facilities/f_manflow.htm.



Cement manufacturing flow schematic
[extracted from GIC website http://www.gich.com.hk/Facilities/f_manflow.htm]

Raw materials and fuel

Typical raw materials and proportioning of cement is as tabled:-

Material	Component	Proportion
Limestone	Calcium ($CaCO_3$)	80 %
Sand or PFA	Silicon (SiO_2)	9 %
PFA or clay	Aluminium (Al_2O_3)	9 %
Iron ore or slag	Iron (Fe_2O_3)	2 %

The materials above are dosed precisely to a predefined chemical composition, and are then fed into the process.

Limestone is imported from China and Japan in rock form, which is pulverised for mixing with other materials. Not only for its own consumption, GIC supplies limestone powder to Lamma Power Station of HK Electric (LPS) for its flue gas de-sulphurisation (FGD) process.

GIC pioneered in the use of pulverised-fuel ash (PFA) in cement production, which has now become an industry practice. Originally a residue of coal-fired power generation to be disposed of, PFA finds its new value by becoming an ingredient of cement production. Nowadays almost all locally produced PFA is taken for cement production and GIC imports PFA from Japan to meet the cement production demand. Purpose-built piping is in place to transport PFA from the jetty to PFA silo.

Coal is the principle fuel for combustion and raising the temperature inside the Kiln. Unlike the coal-fired power stations which deploy open-air coal yard in most cases, GIC stores the coal inside the dedicated Coal Bin to keep from moisture. This is due to wet coal compromises combustion effectiveness and hampers the kiln temperature to reach the required level. Moreover, wet coal deviates the combustion profile from its optimum, which expedites wear and tear of the Kiln. As a result, the coal is bunkered to stay dry.

Raw Mill

The dosed raw materials are dried and finely ground in the Raw Mill to form an intermediate product, called "raw meal". The grinding provides an increased surface area to enhance the heat exchange in the downstream heating process.

Raw Mill crushes mixture of raw materials with Grinding Balls tumbling inside to become "raw meal"

The Raw Mill is a rotating horizontal steel tube, in which the raw materials in their original form are crushed into a uniform mixture by hundreds of Grinding Ball tumbling inside the Raw Mill as it rotate. Though lower efficiency, noisy and heat generating, the Grinding Ball method offers finer "raw meal" and better control of the process, delivering the process rate of 340 tonnes per hour.

Homo Silo

Preheater and cyclones housed inside the tower

The "raw meal" is then stored in Homogenising Silo in which the chemical variation is reduced. This homogenising process is important to stabilise the downstream sintering process as well as to provide a uniform quality product. The "raw meal" is then transferred to the Preheater Tower.

The Raw Mill is critical in terms of function reliability. Should it be out-of-service, the "raw meal" stored in the Homo Silo is good for staying production for six (6) days.

Preheater

In the Preheater, the “raw meal” undergoes a series of concurrent heat exchanges with the hot exhaust gas from the kiln system, driven by the Induced Draft Fan. The gas and material stream are separated by cyclones after each heat exchange process. The raw meal temperature increases from 80 ˚C to 1000 ˚C within 40 seconds. The first chemical reaction also takes place in the Precalciner of the Preheater, where limestone ($CaCO_3$) is decomposed into lime (CaO).

Kiln and Coal Mill

The calcinated material entering the Kiln, then undergoes a long heating process. The material temperature rises from 1000 ˚C to 1450 ˚C. Mineral matrixes of raw material are totally destroyed and cement minerals are formed at the sintering temperatures. A semi-product called “clinker” is formed. Coal and other alternative fuels are used as energy sources for the process. The ash from fuels is absorbed into the clinker matrix. The residual heat from the clinker leaving the Kiln is recovered by the Grate Cooler downstream to reduce the energy requirement.

The single Coal Mill provides full capacity of supplying coal dust for combustion inside the Kiln. Ten (10) mill ball grinds coal into fine dust form, and the pulverised coal is admitted into the Kiln at the discharge end and combusted in the counter-direction of the process flow for clinker formation.

Kiln under shelter running at above 1,000 ˚C 24-hours-a-day

The Kiln takes 30 hours to start-up from cold, burning ultra-low sulphur diesel (ULSD). The Kiln is duel fuel capable for consuming both coal and oil. Previously instead of ULSD, Grade 6 bunker oil was used. The Kiln shell thickness is measured once every five (5) years.

The “raw meal” is admitted into the Kiln at 312 t/h, while the discharge of clinker is at 200 t/h. The loss in weight goes to the formation of carbon dioxide in gaseous form. As a rule of thumb, the clinker is 0.612 times the “raw meal” by weight per time.

Technical details of Kiln refer to the “Kiln Shell Replacement” section below.

Conditioning Tower

The flue gas exiting the Preheater is directed to the Raw Mill for drying. Before it enters the Electrostatic Precipitator (EP) for its final dust removal process, its temperature and humidity is regulated in the Conditioning Tower. This process is essential as it affects the dust collecting efficiency of the EP.

Electrostatic Precipitator

EP is commonly used as the final dust removal device for flue gases. It consists of chambers each of which contains a series of collection plates and an overhead framework of suspended rigid high-voltage electrodes. Particles in the gas stream are charged by a high-voltage, direct current field which is generated from the discharge electrodes, suspended between the collector plates. Current applied directly to the discharge electrodes manifests a highly active and visible glow in the electrode known as the "corona". In the strong electrical field region near the electrode-emitting surface, large numbers of both positive and negative ions are formed. As the discharge electrodes have a negative polarity, the positive ions are attracted to them. Both negative and positive ions are formed in equal amounts directly in the corona region near the discharge electrodes and over 99 percent of the gas space between the discharge electrodes and the collector plates contain only negative ions. As the particles entrained in the gas stream pass through the corona field, they are bombarded by negative ions and become charged in a fraction of a second. They are then attracted to the grounded collector plates where they are collected.

Particulate matter on the collecting plates and high voltage electrodes is removed by the impact of "rapper" mechanisms. Dislodged particles from the high voltage electrodes and collector plates fall into a hopper directly below each precipitator chamber.

Grate Cooler

The residual heat from the clinker leaving the Kiln, is recovered by a Grate Cooler (consisting of rows of grates). Cooling air is injected from the bottom of the grate, and is forced into the clinker which is travelling slowly on the grate. The heated air is then recycled as secondary air for combustion in the Kiln, or in the Precalciner.

The clinker is stored in Clinker Silo, ready for the next processing stage.

Finish Mill

The final process of cement making is called finish grinding. Clinker dosed with controlled amount of gypsum is fed into a Finish Mill. Same as the Raw Mill, the Finish Mill is a horizontal steel tube filled with steel balls. As the tube rotates, the steel balls are lifted, tumble and crush the clinker into a super-fine powder. The particle size is controlled by a high efficiency air separator. Other additives may be added during the finish grinding process to produce specially formulated cement.

Synthetic gypsum in cement regulates the setting time, prevents flash setting, improves grindability, sensitivity to storage, volume stability and strength. Synthetic gypsum is a by-product of the FGD process in coal-fired power station, and the gypsum produced by LPS is recovered for cement production.

Packhouse

The output of the Finish Mill is cement and is stored in the Cement Silo, which beneath is the Packhouse for the packaging of cement. Cement is shipped in either bulk form by road tanker or barge, or palletised form. The bulk off-loading and strapping of the pallets are fully automatic.

Laboratory and quality control

The laboratory operates round-the-clock on three (3) shifts, fitted with fully automatic sample collection and analysis facilities to monitor the quality of feedstock, work-in-progress and final product. Samples obtained at sampling points are conveyed to the laboratory by a dedicated pneumatic conveying system, carrying the samples inside "bullet" sample containers. Once collected, the samples are made into 20 gram tablets for analysis inside a sophisticated analyser equipped with a robotic arm, the first of its kind in 1990s in Hong Kong. Should the conveying system fail, collection of samples is conducted manually.

The Homo Silo is the most critical stage in quality control. Sample is collected once every 15 minutes for laboratory testing for composition. The test results directly feedbacks to the dosing of the raw materials to ensure the predefined composition is always met.

Since the resources are in demand, GIC endeavours to diversify its sourcing of materials. The laboratory, as a result, is busy examining samples to warrant the consistency of the quality of materials procured, in spite of sourced differently from time to time.

Operation and maintenance

The Control Centre monitors and controls the entire production process and all production activities except packaging in the Packhouse. The Honeywell-supplied distributed control system provides real-time data and control of the process.

GIC has its own workshop for welding and maintenance, which is capable for handling components up to 20 inch in size. Pieces beyond which are sent to the workshop of either Hongkong United Dockyards or CLP Power.

The plant operates round-the-clock and scheduled outage for overhaul and maintenance (O&M) follows the cycle of the construction industry in a year. Usually the construction activities in Hong Kong stop in Chinese New Year, when the demand on cement is the lowest and hence the Raw Mill, Coal Mill and Kiln take outage for O&M.

To maintain delivery over the outage when the clinker production stops, clinker is imported to blend with the clinker in stock.

Kiln Shell Section Replacement 2014

Background

Rotary kiln is found in only two facilities in Hong Kong, namely Chemical Waste Treatment Facility on Tsing Yi Island and GIC, while the handling capacity of the former kiln is significantly smaller than the latter kiln. The laying of refractory inside a rotary kiln, though highly skilled, is an uncommon task. Each time prior to the laying works is performed, GIC has to train the workers using its in-house facility, a section of the Kiln taken from the kiln shell replacement in 2000, when 18 m of shell was replaced.

Kiln shell

New Kiln Shell Section awaited for assembly on the day of visit

GIC's rotary Kiln is made of ASTM A36 structure rolled steel plate, with internal diameter of 4,876.8 mm and in thickness and length of 25 mm and 76.2 m respectively. Carried on three (3) supports, the Kiln is driven by a helical ring and a dual drive, each powered by a direct connected 300 kW, 440 V "DC" motor at maximum 3.5 ramps per minute. It slopes at 2.0045º from the horizon and rotates counter-clockwise viewed from the discharge end.

Inner refractory and kiln operating conditions

Refractory lining in brick form is laid to cover the entire inner circumference of the Kiln. They serve for the resistance of abrasion, high temperature and chemical attack, and reduction of heat loss. The refractory must be able to withstand the stresses tabled as below:-

Stress	Cause
Mechanical	Resulting from the shell flexing due to ovality and kiln mis-alignment.
Thermal	Heat load and possible thermal shock.
Chemical	Reactions through heat and the chemical reactions of chlorine, sulphur in the raw material and fuel

From inlet and outlet, the refractory along the Kiln is subject to the following conditions:-

Zone	Temperature [˚C]	Operating condition(s)
Inlet	1,200 – 1,300	Abrasion
Upper transition	1,300 – 1,400	• Nil coating formation • Vapour phase attack • Ovality in tyre area • Thermal shock
Burning	1,300 – 1,600	o Stable coating formation o High temperature o Flame impingement o Liquid clinker o Thermal shocks o Reduction-oxidation reactions o Vapour phase attack
Lower transition	1,300 – 1,400	▪ Transient coating formation ▪ Thermal shock ▪ Ovality in tyre area ▪ High thermal load ▪ Hot abrasion ▪ Vapour phase attack
Cooling / Outlet	1,200	Abrasion

The Kiln operates in such critical and harsh conditions and its shell temperature is subject to scrutiny. Should hot spot(s) be identified, refractory failure and reduction of shell thickness is likely. Referencing Svedala (Allis-Chalmers) Engineering Study ES-005, upon 33 % of the original shell thickness of 25 mm is lost, replacement of that shell section would be necessary.

The section to be replaced is the Upper Transition zone from 41 m to 52 m of the Kiln discharge, which has been subject to serious corrosion caused by alternate oxidation at high temperature, acidic reaction at low temperatures when the kiln is stopped for repairs and of the reactions of oxides, chlorides and sulphide at high temperature.

Preparations

Upon the Upper Transition zone of the kiln shell was identified to be replaced, in 2013 invitation to tender was sent to Metso Minerals (Australia), UBE Industries of Japan and FLSmidth in Australia. The contract of about HK$8 million worth was awarded to Metso Minerals (Australia) covering the following work scope:-

- Supply of 11 m Kiln shell
- Installation of temporary supports and internal bracing
- Cutting and removal of the existing shell
- Alignment and welding of shell sections


Section of Kiln Shell for demonstration and training of refractory lining

Before commencing the replacement, GIC performed hot kiln alignment and grinding of carrying rollers and kiln tyres. The former works covered survey on the kiln rollers, tyres and shell as well as horizontal and vertical alignment of the kiln rollers. The latter works of re-conditioning the tyres was necessary because the severe wear caused by the metal-metal contact between the tyres and the heavy kiln and, consequently after long period of continuous loading the carrying rollers and tyres would be deformed to be convex/concave in profile or tapered.

Replacement works

The replacement section was mocked-up in Italy and fabricated in Turkey, adopting submerged arc welding (SAW). The kiln outage is scheduled is mid-May after the visit, when the Kiln is first cooled-down and then have reference lines marked, followed by the removal of refractory, erection of the kiln support stands and the installation of cradle and jacks.

Next the Kiln is stopped and locked in position with internal bracing, or “spiders”, installed to retain the kiln profile. The replaced section is then cut and jacked, with the replacement section installed and SAW-welded. Two (2) mobile cranes are deployed to lift the old and new Kiln section.

Remarks

Cement is an element of the construction industry, on which much of the prosperity of Hong Kong is built. GIC produces cement from raw materials in their original form in an efficient and environmentally-responsible manner. The Kiln, subject to continuous abrasion, corrosion and high temperature, is the heart of the GIC production. Its sectional replacement at height is a complex and dedicated mechanical engineering undertaking in order to keep it in its best condition. IMechE-HKB was privileged to glace the above and appreciate GIC's contribution in sustaining the continuous development of the territory.

Mr. Paul Kwong, Division Manager – Engineering (right) received souvenir after the visit

IMechE-HKB thanks the generous support and hospitality rendered by Mr. Paul Kwong, Division Manager – Engineering, Mr. Chi-Kwan Tam, Maintenance Manager, Mr. Kelvin Ho, Personal & Training Officer and their colleagues in GIC.

[*Post-visit note: the kiln shell section replacement works was successfully executed in June 2014*]

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Encl.
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IMechE Hong Kong Branch
Activity Sub-Committee
Local Technical Visit Group

TECHNICAL VISIT
GREEN ISLAND CEMENT

Institution of MECHANICAL ENGINEERS
Improving the world through engineering

Free of charge for IMechE members. Number of participants is limited to 20 with priority given to IMechE members.

Date: 3 May, 2014.
Time: 1000 hrs. to 1230 hrs.

Founded in 1887 at Tsing Chau (Green Island) in Macau, Green Island Cement (GIC) operates the only integrated cement plant in Hong Kong and has two cement and concrete operations in South China, supplying 60 % of Portland cement consumed in Hong Kong. The production of cement is fully automated, 24 hours a day. IMechE Hong Kong Branch is privileged to visit GIC to learn about its engineering and overhaul and maintenance of the production facilities which are unique in the territory.

Members who are interested in manufacturing, process and heavy machineries should not miss this opportunity.

Registration and Enquiries

For registration, please visit IMechE webpage:
http://nearyou.imeche.org/near-you/north-east-asia/hong-kong/events

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