

Constructing and commissioning Malaysia's most advanced ferromanganese smelter complex

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Abstract – Sakura Ferroalloys Sdn Bhd (Malaysia) is a global joint venture company with shareholding from Assore (Pty) Ltd (South Africa), African Rainbow Minerals (Pty) Ltd (South Africa), Assmang (Pty) Ltd (South Africa), Sumitomo Corporation (Japan), and China Steel Corporation (Taiwan). Sakura's latest project covered the greenfield construction of two 81 MVA ferromanganese / silicomanganese furnaces with associated raw material handling, gas cleaning, water treatment, product handling, services, and infrastructure on the remote island of Borneo. Metix (Pty) Ltd (South Africa) was chosen as the Engineering, Procurement and Construction (EPC) contractor, with assistance from its mother company, the SMS group, and locally established Metix Malaysia Sdn. Bhd., to execute this US \$328 million project.

The project brought with it a variety of firsts. It included the largest and most advanced submerged arc furnaces in Malaysia. It was Metix's first EPC project offshore, the SMS group's first EPC execution in Malaysia, and the first time SMS steel making scrubbers have been used in ferro-alloy production.

This global and world-leading smelter complex presented a variety of challenges during the project execution phase. Borneo's industrial presence is dominated by the petrochemical and palm oil industries, with few to no supporting industries. Large-scale fabrication and the availability of specialised equipment and materials are nonexistent on the island. The majority of inhabitants may speak English, but the contractors are more likely Mandarin or Hindi speaking. Added to the above, the project team had to deal with local issues such as extreme weather, legislation, taxes, construction regulations, safety and work permits.

One year after startup, the project yielded two furnaces running at more than 120% of design capacity, higher than 98% availability, lower than expected specific energy input, and production of on-grade product while generating industry-leading particulate emissions.

This paper provides an overview of the technologies and learnings in executing an EPC project in Borneo, Malaysia.

Keywords: greenfield, project, FeMn, SiMn, submerged arc furnaces, gas handling, drying, Metix, Malaysia, Borneo, Sarawak, Sakura, SMS Group

PROJECT OVERVIEW

History

South Africa's Assore (Pty) Ltd, African Rainbow Minerals (Pty) Ltd, and Assmang (Pty) Ltd, Sumitomo Corporation (Japan), and China Steel Corporation (Taiwan) formed the Malaysian company Sakura Sdn Bhd (Malaysia) in early 2013, with the goal of manufacturing high-carbon ferromanganese (HCFMn) and silicomanganese (SiMn) for the steel market. The majority of the ores would be sourced from South Africa and Australia, and the product exported mostly to markets in Asia. The construction of Sakura's US \$328m smelter complex in the Samalaju industrial park in East Malaysia was about to start after years of studies and engineering.

The site was selected at the end of 2011, and Metix was approached in 2012 to undertake a $\pm 30\%$ accurate Preliminary Feasibility Study (PFS), followed by a $\pm 10\%$ accurate Detailed Feasibility Study (DFS) and Front End Engineering Design (FEED). Up to the end of FEED, the intent was to execute the project on a combined Engineering, Procurement, and Supply (EPS) and Engineering, Procurement, and Construction Management (EPCM) basis. All technology equipment and imports would be done on an EPS basis, and construction in Malaysia would be done on an EPCM basis. After FEED, a conversion was done to an Engineering, Procurement, and Construction (EPC) project, and orders were placed on Metix South Africa and Metix Malaysia in late 2013.

Construction started at the end of 2013, with site establishment, palm tree removal, and bulk earthworks (early-works) before the official ground breaking in February 2014. Commissioning and training started at the end of 2015, where after Furnace 1 (F1) was hot commissioned in the first quarter of 2016, followed by F2 in the second quarter, and the drying plant in the third quarter.

Metix is a metallurgical engineering company with expertise in the design of processes and technology equipment for the pre-processing of ore, smelting, and final product handling, in both the ferro-alloy and non-ferrous industries. Their portfolio of projects ranges from consulting assignments and studies to various project execution formats of which the last decade included continuous, large EPC projects. Metix joined the global SMS group in 2011 and enjoys the financial and risk cover of the group as well as technical support of all its subsidiaries. Projects are executed on Project Management Body of Knowledge (PMBOK) practices, Design for Construction (D4C), and Building Information Modelling (BIM).

Location

The chosen site location was in Samalaju industrial park, Sarawak region of East Malaysia, which is on the Borneo Island in South East Asia, as depicted in Figure 1.

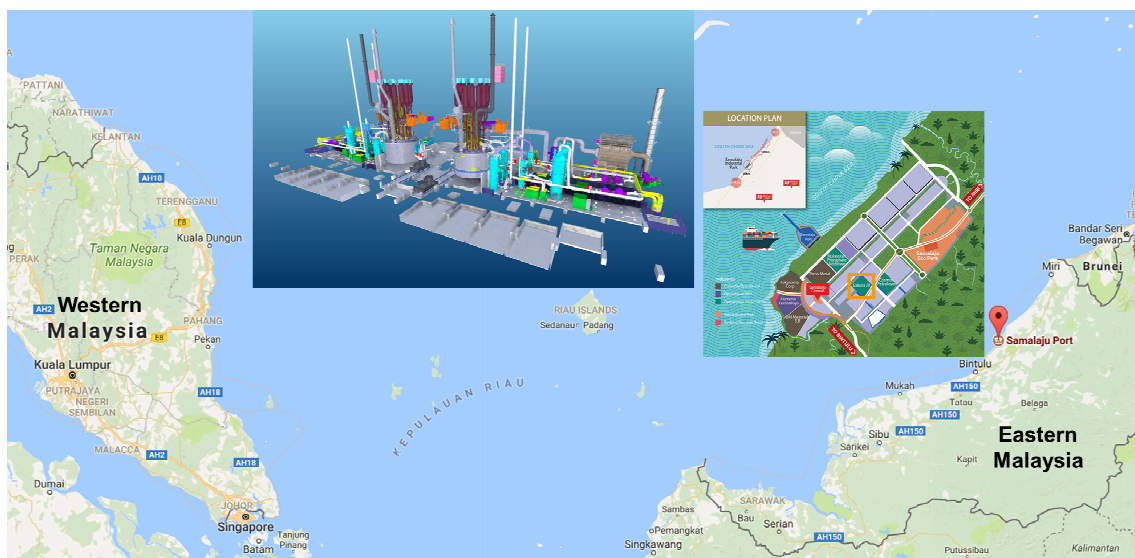


Figure 1: The Sakura site in Samalaju industrial park, close to Bintulu in Sarawak, East Malaysia

The industrial park forms part of the Sarawak Corridor of Renewable Energy (SCORE) that was set up in 2008 as one of Malaysia's five economic growth corridors aimed to transform Sarawak into a developed state by 2020 and to increase the region's GDP fivefold. The East Malaysian government's development strategy is based on the

supply of affordable and reliable hydroelectric power supplied by hydroelectric dams of which the Bakun hydroelectric project supplies Samalaju.

Smelter Complex

The smelter complex consists of 2 X 81 MVA furnaces with all ancillaries including raw material receiving and handling, gas cleaning, water treatment, and product handling, as well as all the required infrastructure. Each of the furnaces was designed to produce 105 kt/a HC FeMn with 76% Mn, or 70 kt/a SiMn with 65% Mn and 17% Si. The complete scope of this greenfield smelter complex was designed and erected by Metix, with gas cleaning technology supplied by the SMS group in Germany.

METALLURGICAL PROCESSES

Smelting of manganese ore and sinter to FeMn metal (refer to Figure 2) is done at high temperature (~1500°C) (Olsen, Tangstad, & Lindstad, 2007), with coke and char as reductants, and dolomite and limestone as fluxes. Quartzite is used as a fluxing agent to achieve the required slag composition and characteristics when SiMn is produced. Molten FeMn, or SiMn, and slag are tapped from the furnace via separate metal and slag tap-holes at different tap-hole heights (~1 m separation). In the duplex process, high-MnO slag produced in the HC FeMn reduction process are added together with sinter and lumpy ore as furnace feed. The MnO in the slag is reduced to Mn, thereby increasing the overall recovery in the plant.

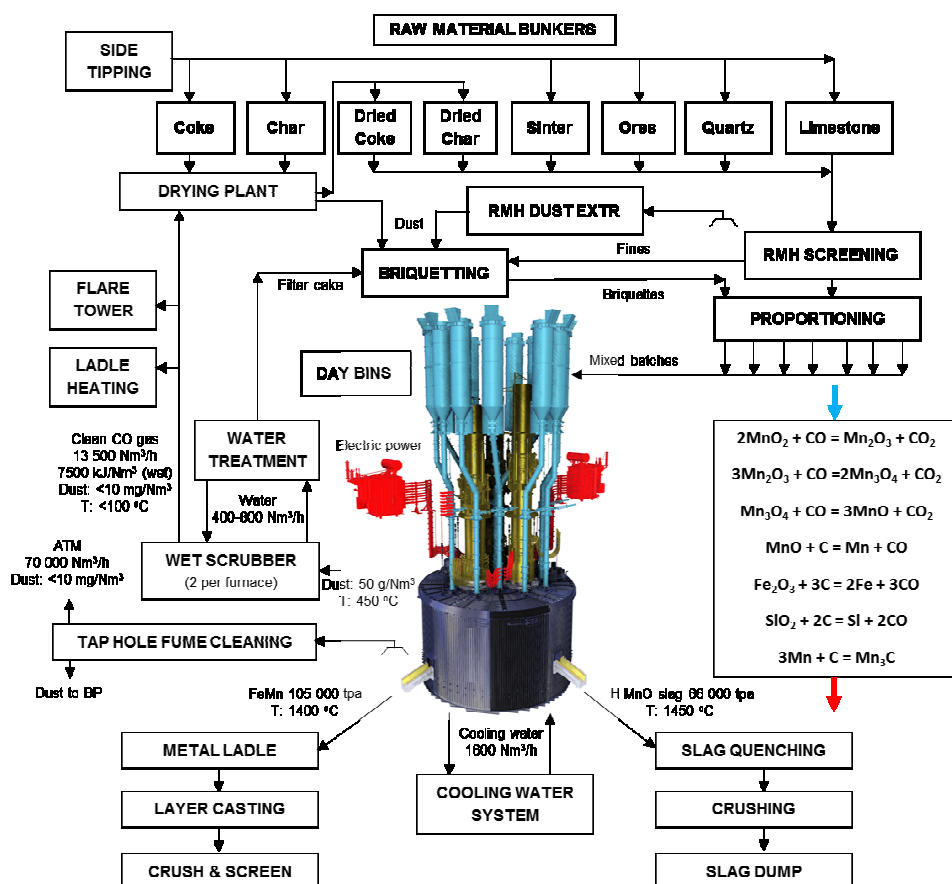


Figure 2: The FeMn process and high-order reactions

Due to a lack of test work, various metallurgical recipes were modelled and a keen understanding of the different process optimization options was maintained. The SMS Group's process optimization model for FeMn and SiMn production provided necessary guidance and insight (Jipnang, Monheim, & Oterdoom, 2013).

INNOVATIVE PLANT AND TECHNOLOGY

Infrastructure

Due to the remote and undeveloped location, the plant had to be designed as a standalone unit with sufficient storage and back-up of utilities. Utilities and services included potable, clean, plant, and fire water, sewerage, compressed air, oxygen, nitrogen, and propane. Environmental compliance and high rainfall (~5 m per year) necessitated a river diversion and a maze of collection channels, slag dump collection, dirty water, and clean water ponds. The system allows for plant water recovery and treatment in the case of torrential downpours. Facilities and buildings included security, admin and offices, canteen, training, clinic, change house, stores, workshops, laboratory, and control rooms.

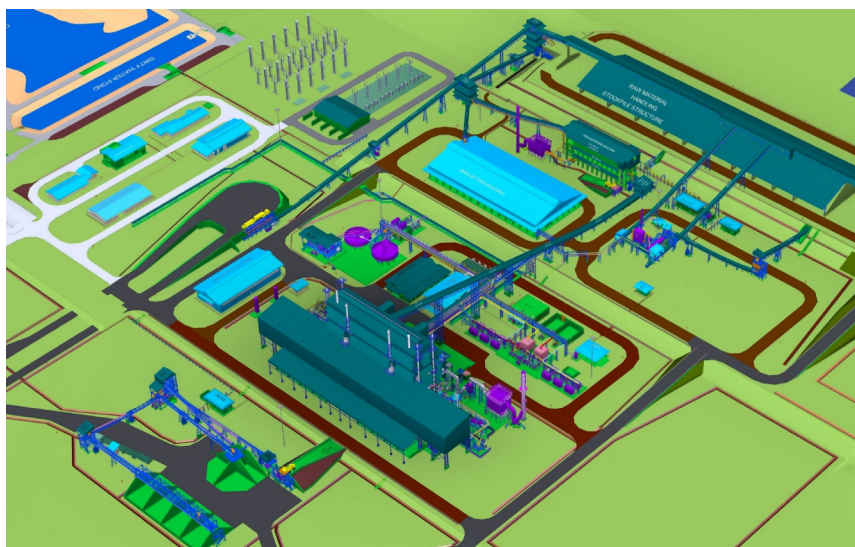


Figure 3: 3D development of the Sakura FeMn smelter complex in Borneo, Malaysia



Figure 4: Aerial photograph of the Sakura plant after successful commissioning of F1 in 2016

Electrical Distribution

Electricity is supplied by Sarawak Energy Berhad (SEB) from the Samalaju 132 kV substation. Transformers step the 132 kV down to 33 kV High Voltage (HV), 11 kV Medium Voltage (MV) and finally 400 V Low Voltage (LV). 33 kV Gas Insulated Switchgear (GIS) with double busbar switchgear is used to supply the furnace power, and 66 MVar Power Factor Correction (PFC). Air Insulated Switchgear (AIS) is used to supply the auxiliaries.

Reactive compensation mitigates and maintains a PFC of 0.95 at the Point of Common Coupling (PCC) in order to meet local grid requirements. Filter banks ensure that the Total Harmonic Distortion (THD) contribution from the plant to the grid substation is less than 0.23%.

Raw Material Handling, Drying, and Proportioning

All raw materials are weighed and delivered by road transport using side- or back-tipping trucks into an above ground, loading station. Data of incoming materials are captured and stocks managed with the Management Information System (MIS). Dry materials are stored in covered Raw Material Handling (RMH) bunkers, and wet materials in the open; using a tripper car with laser positioning and radar level sensors. Extensive covered storage is required to deal with large ship consignments that carry 1-2 months' raw materials. A self-draining, multi-directional tunnel extracts and feeds to a drying plant and the furnaces.

A kiln type drying plant that uses carbon monoxide (CO) rich gas from the furnaces' Gas Cleaning Plants (GCPs) is used to dry the sinter and reductants. Dried materials are stored under the roofed section and are fed to the furnaces with other materials. The furnace feed system consists of screening and proportioning where the mix is batched in accurate weigh flasks using Variable Speed Drives (VSDs). Separate dust extraction bag-house systems for the drying plant and furnace feed system ensure environmental compliance, and the dust, along with screened fines, is recycled as briquettes.

The RMH system offers full redundancy with back-up emergency feed and up-front design for four furnaces. Multi cross-over points allow batching and feeding from the two proportioning systems to any furnace. One proportioning system can also feed both furnaces using one of two incline conveyors.

Furnaces

The two 81 MVA submerged arc, alternating current (AC) furnaces, designed and supplied by Metix, are not only the biggest submerged arc furnaces in Malaysia but also the first to be closed. The application of AC technology for FeMn/SiMn production is preferred over Direct Current (DC) applications, due to lower vapour losses of Mn/Si. Closed furnace technology was used for environmental reasons because the off-gas volumes are tenfold less than for open furnaces, reducing the total solid contamination to the environment (Roberts *et al.*, 2013).

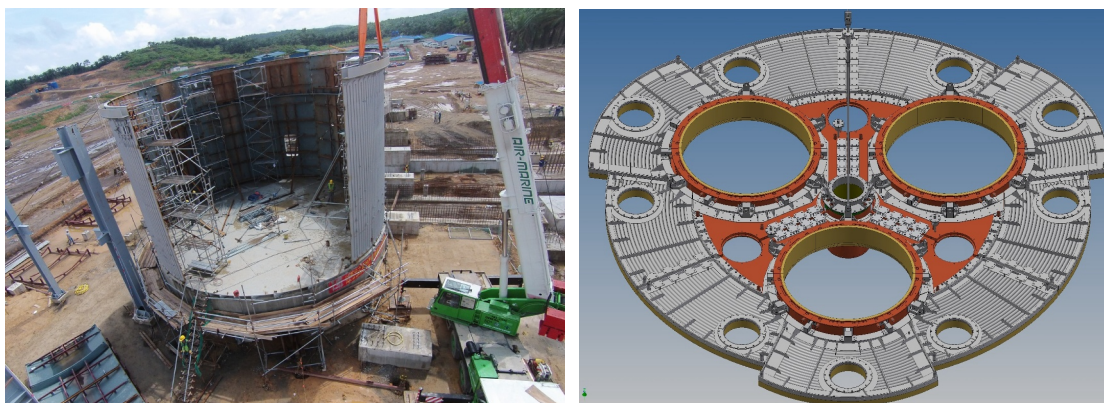


Figure 5: Furnace 1 shell erection (2015) and a 3D illustration of the roof, openings, and adjustable PCD

The shell is 14.3 m in diameter and 8.8 m deep, with a flat copper delta and tube-to-tube, water-cooled roof and 13 feed chutes (one central). In Malaysia, the utilisation of copper in the delta where the highest heating load is experienced is a first. Process and furnace dimension and parameters were calculated in-house using the combined Metix and SMS Group furnace models, with access to over 300 furnaces built over the past century. These models, along with the combined expertise, draw correlations between best performing furnaces, key parameters, and variables.

The copper feed chute tip arrangement ensures a constant bed profile that improves gas flow and furnace pressure control when combined with the higher volume cylindrical roof design. Computational Fluid Dynamics (CFD) analysis of the gas flow below the roof is used to optimise the positioning of the gas off-takes, raw gas stack, feed chute tips, and explosion hatches (Kadkhodabeigi, Ravary, & Hjertenes, 2015). An in-line Over Pressure Relieve Device (OPRD) allows the instantaneous release of over pressure conditions via the raw gas stack followed by the activation of alternative pressure relief equipment above.

The three 1700 mm Söderberg electrodes are regulated and slipped with the Metix failsafe slipping devices. The electrodes form part of a novel adjustable Pitch to Circle Diameter (PCD) system for added flexibility during FeMn and SiMn production designed specifically for this application. The furnace control is done through a “Mintek Minstral” system which is integrated with the main PLC.



Figure 6: Day bin rotating conveyor with cartridge filters and preassembled Metix slipping device

The furnace refractory is a freeze lining, with temperature measurement and energy flux determination, which is also a first for the Malaysian ferro-alloy industry. Excess energy is removed from the shell with serpentine cooling water channels on the side and forced air grillage cooling at the bottom. Various iterations of transient energy flux calculations and modelling were done to optimize the refractory quality concept, hearth thicknesses, and tap-hole positioning.

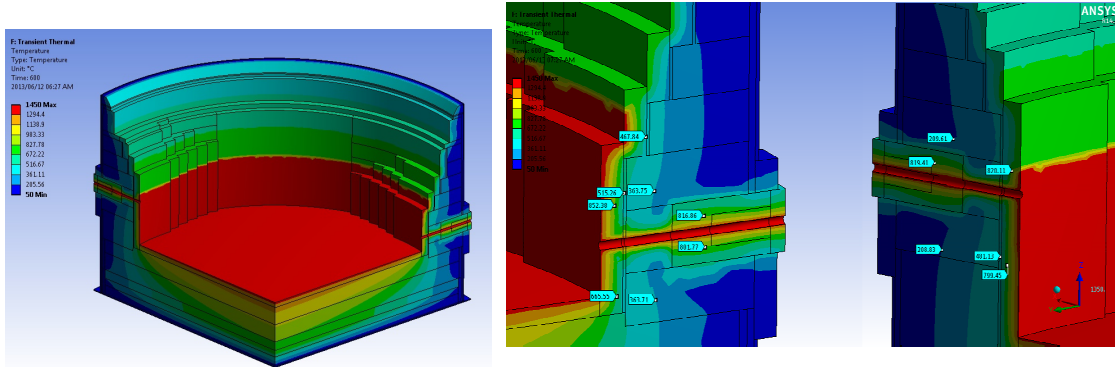


Figure 7: Transient energy flux analysis during tapping and between taps, using Ansys

Gas Cleaning Plant (GCP)

The gas cleaning plant is the SMS group's core technology installed in a variety of applications in the steel industry and tailored for the first-time use on a submerged arc furnace in the ferro-alloy industry. Under normal operating conditions, $\sim 13\,500\text{ Nm}^3/\text{h}$, the furnace pressure control and off-gas treatment is done in one venturi scrubber. The venturi scrubber consists of: a goose neck connected to the furnace; Stage 1 – Quencher vessel; Stage 2 – 1st venturi/saturator; Stage 3 – 2nd hydraulic, adjustable venturi; Stage 4 – Wet Electrostatic Precipitator (ESP); 2 Induced Draft (ID) fans; and a clean-gas flare stack.

To maximize availability and efficiency, each furnace has two independent GCPs that are permanently connected to the furnace. The use of innovative but robust sealing configurations and dual redundancy of the downstream water treatment plants allow for the dual streams to be on hot standby. The systems are monitored with continuous on-line gas analysis to facilitate explosion-free (Oterdoom, 2014) switch over with no flushing. Burnt-gas flushing or nitrogen flushing is available to use if purging is required. The two units can operate at the same time should there be adverse or severe metallurgical conditions. This full dual-redundancy gas cleaning system with a quick change over due to the hot standby is also a first for the industry.

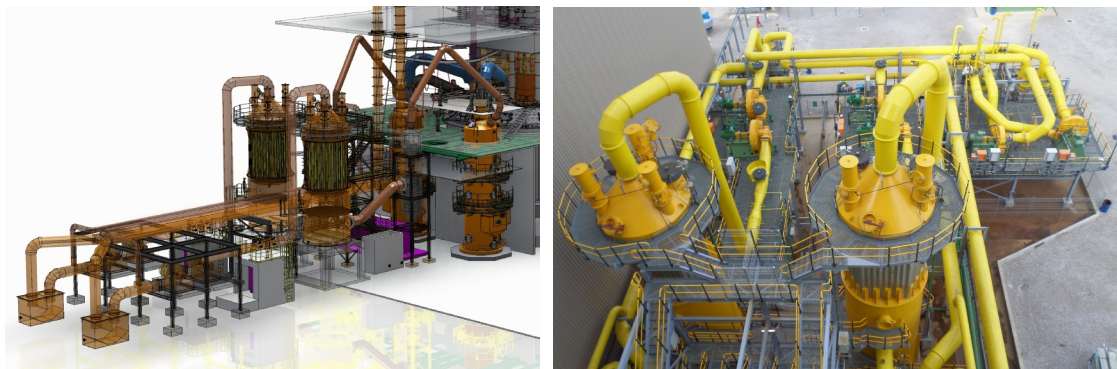


Figure 8: A 3D illustration of the SMS venturi configuration and the constructed duty/standby wet ESPs

On-line dust monitoring confirms a consistent solid content of less than 10 mg/Nm³ after the GCP, versus the 50 mg/Nm³ environmental requirement. Effective furnace pressure control and very high tolerances on machined equipment from the furnace core to gas distribution prevents air ingress, thus improving the CO content and gas calorific value for downstream utilisation of this energy-rich off-gas that includes drying and ladle heating, with the potential of co-generation as well.

The GCPs run on low-pressure water supply and are situated above ground which eliminates blockages or solid build-up in sumps. There are dedicated goose-neck removal systems that allow the swift replacement, cleaning, and storage of spare goose-necks. This novel system was engineered to effectively change goose-necks and remove the dirty one to a safe cleaning area with minimum time on the furnace operating floor which in turn minimizes compulsory downtime required when people access this floor. Metix has applied the use of a belt filter to remove the solids from the clarifier underflow in many sinter plants, but the use of them for solid removal from furnace scrubber slurries is new. The dry belt filter cake is stored and used in the production of briquettes, and the clean clarifier overflow is returned to the scrubber, thus allowing recycling (Gaal, Tangstad, & Ravary, 2010).

In addition to the environmental advantage of closed furnaces and the SMS group scrubbers, Sakura also boasts a first in Malaysia – dust extraction systems capturing fugitive dust throughout the raw material handling and proportioning systems as well as a tap-hole fume abatement system with dedicated bag-houses.

Product Handling

The alloy is cast into ladles on a ladle car, which moves into an isle where a 70 t overhead crane moves the ladle to casting beds for layer casting. The cooled product from the layer casting is transported to a wet crushing and screening plant, where primary and secondary crushing and screening steps produce a variety of size distributions for export.

EXECUTION AND LEARNINGS IN MALAYSIA

Entering Malaysia

Metix Malaysia SDN BHD was formed in 2013 as part of the Metix group to ensure that the execution in Malaysia was to take place in the most cost- and tax-effective format. Metix Malaysia then also employed a number of local and foreign individuals from South Africa, Germany, China, the Philippines, and elsewhere. To obtain a work permit in Sarawak, one needs to work for a Malaysian company. Foreign companies' professionals working for shorter times can get a professional pass with different conditions from those of the work permits. Approval or renewal of work permits in Sarawak can take up to three months.

From early on, and right through the project timeline, Metix and Sakura fostered good relationships with the regulatory bodies, thereby ensuring a successful implementation of the project. The following bodies supported the project through different phases:

MIDA – Malaysian Industry Development Authority. MIDA assists companies that intend to invest in the manufacturing and services sectors, by, amongst others, providing information on the opportunities for investments, as well as facilitating companies which are looking for joint venture partners. MIDA assisted the

Metix/Sakura team with the manufacturing licence, tax and duty exemptions, and employment passes for the allocated staff.

BDA – Bintulu Development Authority is a local council that governs local approvals for projects in Bintulu town and other areas of the Bintulu Division including trading licences and land registration.

SPA – SURUHANJAYA PERKHIDMATAN AWAM (Public services commission) regulates approvals for public services as required for new projects.

DID – Department of Irrigation and Drainage; **DOE** – Department of Environment; **NREB** – Natural Resources and Environment Board; all were involved with the approval and implementation of the Environmental Management Plan (EMP) and all the requirements related to it regarding the National Resources and Environment Ordinance (NREO). Due to high levels of erosion caused by very high rainfall and deforestation in Sarawak, high emphasis is placed on an Erosion and Sediment Control Plan (ESCP) as part of the EMP in Malaysia.

SEB – Sarawak Energy Berhad is the body serving as the Grid System Service Provider (GSSP) for the Sarawak region, and ensures that projects comply with the Electricity Rules 2003 (the Grid Code) before approving connection applications.

JKR – Jabatan Kerja Raya is the Malaysian Public Works Department, whose standards were implemented for the earth works, building, and civil works, as well as infrastructure and services for the Sakura project.

DOSH – Department of Occupational Safety and Health. According to the Malaysian Factory and Machinery Act 1967, it is mandatory for all construction sites to register with DOSH, irrespective of the project sum, and comply with all the relevant regulations as implemented by the department. During the design, erection, and commissioning phases of projects, there are a number of approvals that the designers and erectors need to obtain to ensure mitigation of risks, especially with respect to machinery, lifting equipment, and unfired pressure vessels.

BOMBA – The Fire and Rescue Department of Malaysia (Malay: Jabatan Bomba dan Penyelamat Malaysia), popularly known as Bomba, is the federal fire and rescue services agency in Malaysia. All companies, and specifically buildings/structures, need to comply with the requirements of the fire department, that include fire detection, suppression, and fire-fighting systems, based on the risks associated with the area's use and occupancy and governed by the Fire Safety Design Philosophy (FSDP) compiled by Metix and Sakura. The Metix representative, the professionally registered engineer from the project consultants, and the BOMBA representative, communicated throughout the project to ensure all applications, supporting documentation, site inspections, and emergency communication systems are fully operational and compliant.

CIDB – Construction Industry Development Board was established under the Construction Industry Development Board Act 1994 (Act 520) to establish, regulate, enforce, and carry out duties related to the construction industry. In 2012, the Act was amended to strengthen the role of the CIDB in the enforcement of regulations that can ensure quality and safe construction, as well as improve best practices in the construction industry. The board implements certain safety controls through their involvement, including a requirement that all contractors with a project value of more

than MYR 20 million have a full-time Malaysian Safety and Health Officer (SHO) on site. SHOs need to be suitably qualified, and in Sarawak they have to be local East Malaysian citizens, which makes them a scarce commodity in Borneo. All construction personnel need to undergo safety training and receive a green card allowing them to take part in construction projects. This is achievable only when employees have a valid work permit and medical fitness certificate.

The above list of regulatory bodies is not exhaustive, as there were many more that assisted in the safe execution of the Sakura project.

Early Works (Commenced 4th quarter 2013)

In November 2013, Metix commenced with early works, in preparation for construction. Palm trees and other vegetation over 45 ha were removed, construction roads built, and rivers diverted, all whilst negotiating more than 700 mm of rain in a month. Valuable lessons were learnt regarding the value of competent construction roads and temporary drainage facilities.



Figure 9: The construction site under water during the early works phase and terrace formation

Silt traps were designed and constructed to minimize silt overflowing into the main rivers and ultimately the ocean. The silt traps and wash bays had to be maintained and cleaned throughout the duration of construction. An environmental consultant regularly measured the water quality flowing from site into the river. Dengue fever (transmitted by mosquitoes) has reached pandemic proportions in Malaysia; therefore pools of standing water are illegal and punishable by fine or imprisonment and lashings.

Earthworks and Civils (Commenced 1st quarter 2014)

More than 1 000 000 m³ of earth was cut and removed or backfilled and compacted. The earthworks proved challenging, with exceptionally muddy conditions, unforeseen ground conditions, as well as unstable slopes. Earth drains, coffer dams, and sump pumps were used to minimize the effects of the up to 170 mm daily downpours experienced during the construction phase. In areas with similar rainfall and ground conditions, scheduling buried services, drains and access roads as a priority will enhance construction progress.

The fluctuating topographical area, with some areas below sea level, and geographical extremes, necessitated more than 6 300 piles of every type conceivable. Heavy foundations under the RMH bunkers and the heavy furnace units resulted in a total of more than 60 000 m³ of reinforced concrete.



Figure 10: A photo trail showing the development of construction to realise targeted design

Civil Work (Commenced 2nd quarter 2014)

60 000 m³ of reinforced concrete was cast. The RMH bunkers contained 2500 t of rebar, approximately the same as the structural steel of the furnace building. With large parts of the site only 5 m above sea level, the earth was saturated, and drainage was relatively slow after rain.

In Sarawak, cognisance needed to be taken of the requirement that key construction personnel, such as safety staff, riggers, electrical charge men, and crane drivers, need to be local Malaysian citizens.

Structural Erection (Commenced 2nd quarter 2014)

The contract for detailing, fabrication, and erection of 7000 t of structural steel was allocated to one major sub-contractor. Unfortunately, Samalaju doesn't have sufficient structural fabrication capabilities for a project the size of Sakura, and the bulk of the fabrication was done in West Malaysia and shipped piece by piece in containers to the island. This split-up of steel resulted in a vast amount of on-site assembly and the use of over 200 t of fasteners, with corresponding cost and time impacts. Designed sections or material grades were also not readily available in Malaysia, which often resulted in the redesign and detailing needing to accommodate the available structural members. S355JR structural steel was used for heavy load-bearing structures and had to be imported from Japan or Singapore.

The above resulted in numerous challenges and delays. To accelerate progress, Metix contracted directly with detailing companies and fabrication facilities to complete over 50% of the shop detailing drawings and fabrication of the structural steel. In addition to this, we directly employed a workforce of 150 artisans and supervisors to erect steel structures and complete the mechanical installation. One of the key learnings of executing projects in remote territories like on the Borneo Island is to always have a plan B ready – it will be required.

Cultural differences between South Africans, Malaysians, Chinese, Filipinos, Indians, and Europeans were challenging and resulted in a multitude of shrines, animal sacrifices, and fire crackers to celebrate major achievements and keep away evil spirits. The amount of effort exerted by Metix and Sakura to coach construction staff on first-world construction standards, safety, and health was immense.



Figure 11: Safety messages in different languages

Piping installation (Commenced 3rd quarter 2014)

Due to the oil and gas industry in Sarawak, the quality of the piping contractors was of an acceptable level, but, in spite of this, large quantities of pipe still had to be imported, causing some delays. Most of the 45 km of piping erected during the project was done at a reasonable tempo and quality. In Samalaju, however, you will not find many plastic piping installers, which posed a challenge. Hydraulic piping delivery was held up for months by customs while tests were conducted on the quality of the piping.

Electrical and Instrumentation (E&I) installation (Commenced 4th quarter 2014)

Almost 480 km of cabling was installed during the project. Similar to piping, the positive effects of the oil and gas industry on the E&I trade was evident, but sufficient materials were rarely available in Borneo, and at times not even in West Malaysia. Finding sufficient competent labour for the project was a constant challenge, due to the lack of industrialisation in Sarawak.

Safety

A proud safety achievement of 7.5 million fatality-free hours, with only 2 Lost Time Injuries (LTIs), was achieved over the duration of the project. The record achieved for LTI-free hours on the project was 3.89 million hours. Metix and Sakura are extremely proud of this record-setting achievement.

Start-up (Commenced 2nd quarter 2016)

A large contingent of Metix engineers and construction staff remained after cold commissioning to complete punch lists, debug, and optimize portions of the plant, and give start-up assistance and training to the Sakura operational team. With this being a greenfield project, the majority of staff had to be trained in the operation and maintenance of a smelter complex.

CONCLUSION

Although the project took longer than anticipated, it was done much faster than any other similar industrial plant development in the Samalaju region. Sakura and Metix managed to deliver on a first-world plant when it comes to quality, safety, and performance, and have invested interest and commitment to the empowerment of the local region and much-valued partners. These are the largest ferro-alloy furnaces in Malaysia, and the first closed furnaces, allowing the off-gas to be utilised for downstream processes. The utilisation of the latest monitored freeze-lining systems, together with environmentally friendly dust, water, and gas solutions, and the technologies to ensure high availabilities and dual redundancy, make this Malaysia's most advanced FeMn smelter complex to date. Both furnaces achieved their guaranteed performance with respect to power input, production, availability, and product quality in the 4th quarter of 2016 when the acceptance certificate for the project was signed.

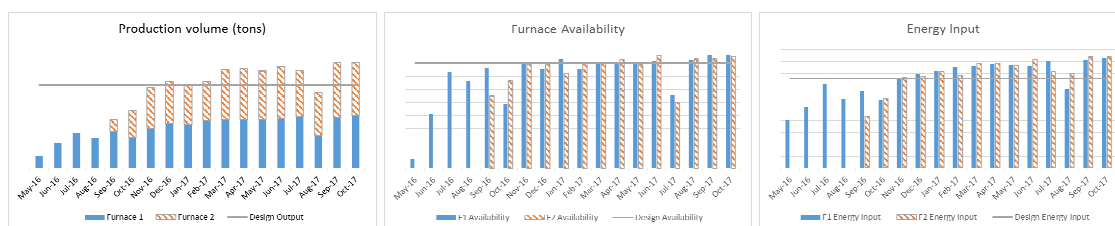


Figure 12: Record furnace performance on production, furnace availability, and energy input

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Wynand joined Metix in 2005. He is experienced in the management of metallurgical plants, execution of turn-key projects, and technology equipment development in the ferrous and non-ferrous industries. Wynand is passionate about executing projects innovatively for optimal results.



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Andrew is one of the original founders of Metix (Pty) Ltd, and director of various SMS group/Metix subsidiaries, including Metix Malaysia Sdn Bhd. He is experienced in the marketing and design of metallurgical plants, execution of turn-key projects and technology equipment development in the ferrous and non-ferrous industries.
