



# Sustainable

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## Architecture

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## Going more and green sustainable

When the inaugural edition of PREFAB Architecture was issued in 2003, its aim was to promote and upgrade the design and construction techniques of prefabricated architectures in Singapore. The intention was to feature outstanding prefabricated solutions used in various local and overseas buildings.

Over the years, the team has highlighted various prefabricated systems successfully adopted by local designers and builders. PREFAB Architecture has been well-received locally and overseas.

### Green Mark Scheme

In January 2005 BCA launched the Green Mark Scheme to promote environmental awareness and the development of green buildings in Singapore. Since then, close to 80 buildings have achieved Green Mark certification. Building designs are

increasingly focused on being **green** and **sustainable**. More developers and designers are incorporating best practices in environmental design and construction, and adopting green building technologies. These measures will reap many long term benefits for the building owners, such as reduced energy and utility bills, and improved indoor environmental quality for healthy living and reduced environmental impact.

It is therefore time for PREFAB architecture to be revamped and re-named Sustainable Architecture. Besides buildable buildings, Sustainable Architecture will showcase green buildings, green building technologies and products, and sustainable construction.

This inaugural issue of Sustainable Architecture features the Xilinx Asia Pacific headquarters, a BCA Green

Mark Platinum Award winner and the Parc Emily Condominium, one of the pioneer projects that was awarded the BCA Green Mark Gold Award in 2005. In addition, construction waste recycling technologies and the application of such recycled products are highlighted in another article.

I would like to thank SIA for its strong support and making this newsletter a successful private-public collaboration. I am confident that Sustainable Architecture will inspire designers to deliver more innovative, buildable and green designs in the future.

**Tan Tian Chong**  
Director

**Technology Development Division**  
Building and Construction Authority

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# ***Sustainable Industrial Building at every level***

By Joseph Goh, Project Engineer  
– M&E, Bovis Lend Lease





**Bovis Lend Lease was engaged to manage the design and construction of the Xilinx's new Asia Pacific headquarters in Singapore's Changi Business Park**

In 2002 Lend Lease conceived and developed the commercial building 30 The Bond, the first commercial building to be awarded a five-star greenhouse rating in Australia by the government-sponsored Australian Building Greenhouse Rating (ABGR) scheme. Since then Bovis Lend Lease, the project management and construction arm of Lend Lease Group, has been repeating its successes on environmentally sustainable buildings for its own facilities as well as for those of its clients. One such project in Asia is the Xilinx Asia Pacific Headquarters, which has been awarded Green Mark Platinum Award by BCA. This is a first for a privately developed industrial facility in Singapore.

Xilinx, a leader in the Programmable Logic Device (PLD) market which is one of the fastest growing segments of the semiconductor industry, has been listed as a Fortune 100 Best Companies to Work for since 2001 and it has not turned back since. It continues to strive for a working environment that is conducive for its employees and has achieved LEED (Leadership in Energy and Environmental Design) accreditation in its San Jose facility in the US. The same drive has motivated Xilinx to do the same wherever it operates, including its new Asia Pacific headquarters in Singapore.

As part of Xilinx's expansion plans, Bovis Lend Lease has been engaged to manage the design and construction of its new Asia Pacific headquarters in Singapore at Changi Business Park.

One key design theme of the building is sustainability and the aim is to create a 'green' space that provides the most conducive work environment via practical means. Passive and active design features were explored.

It is also Xilinx's intention to create space where creativity can be induced and interaction among employees encouraged at the workplace. The internal courtyards at Level 3 and 4 were hence introduced in the design to address these needs and also to allow diffused natural lighting into the workspace. Natural lighting helps to increase productivity of employees and having work stations with a view helps to reduce eye fatigue at work.

**To ensure that the courtyards' outdoor environment is comfortable for staff congregation and brainstorming sessions, Computational Fluid Dynamics (CFD) studies are conducted to ensure sufficient wind and acceptable temperature can be achieved**



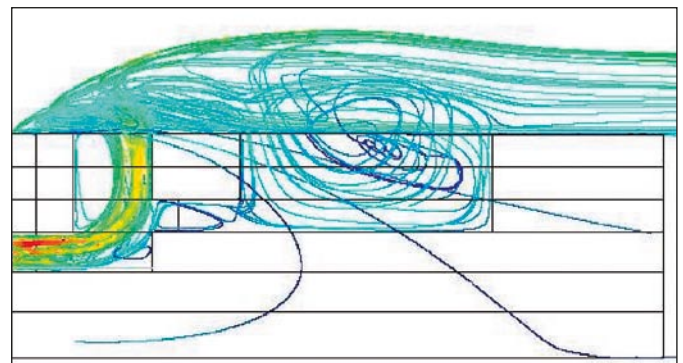




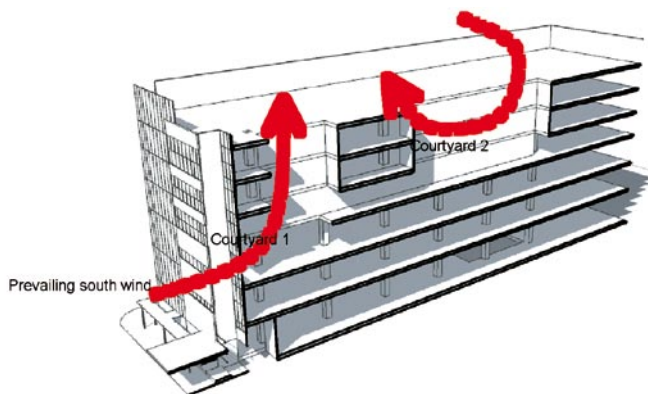
Courtyard at Level 4

Another unique feature of the building is its double-skinned façade. The envelope thermal transfer value (ETTV), a mandatory calculation indicating the performance of the building envelope in heat transfer from outside, has achieved a low of  $38.53 \text{ W/m}^2$  (Singapore code requirement calls for a maximum of  $50 \text{ W/m}^2$ ). Aesthetically, Xilinx Asia Pacific headquarters also appears outstanding at Changi Business Park where most buildings are clad in green or blue façades.

Tasked to ensure the incorporation of sustainable technology at Xilinx's new headquarters, Bovis Lend Lease, with its consultants, proposed green features that enabled a mere 1.1% increase in construction investment to reap an estimated savings of S\$500,000 each year.



Computational Fluid Dynamics Studies



The dark grey façade comprises high performance double-glazed units with low-emissive coating in its curtain wall



**In Xilinx's facility, condensate water is collected, filtered and recycled for landscape irrigation**

## Lighting Management

The arrangement of sectionalised energy-saving lightings is computerised to enable alternating lighting depending on the light flow in the building. Depending on the brightness of the environment, the computerised pre-programmed lighting management system will manage the number of lights used and hence can eliminate the use of lights in less required sections. The system is also able to inform the building management when it is time to do re-lamping so as to enable the building owner to capitalise on economies of scale and minimise disruption due to individual lamps failing.



**Lighting and Air Conditioning operating hours, and computerised functions were all controlled through the system**

## Ductless Fan System for Basement Car Park System

Most car park systems in Singapore use the conventional ducted system, which requires a lot of galvanised steel material for the ventilation ductwork. The 'ductless fan' concept removes all duct work by using localised fans to circulate the air with the

Key features include:-

### Pre-Cooled AHUs

The test floor within the building requires environmental control of the temperature and humidity. As Singapore's climate is warm and humid, it requires a lot of energy to achieve environmental control. The main factor causing humidity to rise is the outdoor air supply serving the various air-handling units on the various floors. Creative design to maintain the humidity is introduced by installing pre-cooled AHUs with heat pipes to bring in the outdoor air. This design reduces the size of the desiccant dehumidifier used for humidity control and decreases the operating period resulting in significant energy savings.

help of a computational fluid dynamic study to prove that smoke purging is not compromised during fire incidents. This not only saves on installation time/material but also on the structural costs from the reduced height of the basement.

## Recycling Condensate Water for Landscape Irrigation

With the use of pre-cooled air-conditioners, condensation from the outdoor air takes place at the centralised location and condensate water can be easily collected. This is normally channelled out of the building as wastewater. In Xilinx's facility, however, condensate water is collected, filtered and recycled for landscape irrigation.

## Recycled Chips for Signage

Xilinx recycles its unwanted chips to turn them into usable signage in the building, thereby cutting down on waste generation. Signages are found on every level of the new Asia Pacific headquarters building, and they are all made of discarded chips from the production line. This reflects the essence of sustainability in Xilinx's operation.

## Building Management and IP Camera System Integration

Conventionally, all CCTV system and monitoring devices require dedicated home run to the central system, which is located at the Fire Fighting Command Centre. However, the design has made it possible to run all the control cables to the nearest network switches in the communication rooms instead and feedback will be given to the central system via the IT network. This results in an estimated savings in embodied carbon from the supply reduction of up to 40% copper cables and steel support system used.



## Project Details

<b>Owner</b>	Xilinx Asia Pacific Pte Ltd
<b>Management Contractor</b>	Bovis Lend Lease Pte Ltd
<b>Architect</b>	RSP Architects Planners & Engineers Pte Ltd
<b>Structural Engineer</b>	RSP Architects Planners & Engineers Pte Ltd
<b>M&amp;E Engineer</b>	Squire Mech Pte Ltd
<b>Interior Designer</b>	Design Worldwide Partnership Pte Ltd
<b>Landscape Designer</b>	Envirospec Pte Ltd



*Influenced by  
climate,  
inspired by site*

Parc Emily Condominium



**P**arc Emily Condominium is a project whose success hinges on the synergy between the developer, consultants and contractor, who are all ISO 14000 and/or ISO 18000 certified and committed to socially and environmentally responsible developments throughout Singapore.

The development, with a site area of 11,978 sq m, is located in the city and next to Mount Emily Park. It consists of five blocks of 8-storey apartment blocks with a total of 295 units comprising studio, two-bedroom, three-bedroom, four-bedroom and duplex units.

The architecture, influenced by local climate and inspired by the site, harnesses the natural elements of the sun, wind, rain and natural landscape. The architects gave due consideration to environmental and health performance by maximising natural daylight and ventilation with big panel windows, and orientation of the apartment blocks away from the western sun achieving 94.6 percent of units facing North-South-East. The tall and lush mature trees at the adjacent Mount Emily Park offers natural landscape shading against the western sun to mitigate thermal heat gain at the gable end wall facing the park. The orientation of the apartment blocks captures the prevailing winds from the North-East and South-West throughout the year providing effective natural ventilation.

The generous amount of natural lighting, ventilation and reduced thermal heat gain has resulted in lower demand for energy to light up and cool the units. These were further enhanced by using energy efficient light system and air-conditioning system for optimum energy efficiency.

## Green Roof at Clubhouse



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The project adopted many environment-friendly and sustainable features during construction and in the building design to embrace the 'green' philosophy.

## Structural and Building Systems

The residential tower block adopted a buildable precast flat plate structural system. The vertical elements such as the shear wall were all precast to ensure speedy erection. The flat plate was formed using the reusable 'Skydeck' aluminum platform formwork to minimise wastage, which resulted in a cleaner and safer working environment. A raft foundation was adopted in lieu of piling, which eradicated the vibration and noise that piling works can cause to neighbouring buildings and the public.

There is also an eco-friendly subsoil drainage hatch box system below the raft foundation basement slab that relieves water pressure acting on the raft to achieve a thinner foundation slab and lesser reinforcement steel, saving resources and energy. The permanent retaining wall along boundaries of neighbouring sloping sites adopted innovative secant pile retaining wall system which is more environment-friendly and buildable. It prevents drawdown of the water table at the adjacent landscape of the public park as well as reduce wastages, energy, resulting in lesser output of smoke and dust to the environment compared to the conventional braced excavation method. The project has also used an eco-friendly modular perimeter drain system made from corrosion resistant polymer concrete. This drain system is lightweight and has interconnecting profiles for easy installation. One of its features is that it accommodates shallow gradient but achieves high flow capacity. This greatly increases the efficiency of the system.

## Layered facade treatment with large overhang







**Reusing of Existing Rocks in Landscape**



**Solar Powered Self Emitting Landscape Lighting**

The project is the first private residential condominium development in Singapore that used prefabricated bathroom units (PBUs) for all its units to minimise wastage. These PBUs were prefabricated off-site in quality-controlled factories to ensure that the bathrooms meet the necessary standards. Another buildable feature is the lightweight drywall system that was used as internal wall partitions, which helped to reduce structural loading and eliminate wet work and wastages at the site.

## Construction Waste Recycling

Construction waste was recycled as much as possible to minimise wastage and disposal at the landfill. Construction wastes like concrete, metal, wood, paper and plastic were sorted and recycled whenever possible. Concrete wastes like concrete cubes and hardened spillage from trucks were crushed and used for backfilling works. The stone boulders from the excavated materials were salvaged and used as landscape features.

## During Construction

The builder adopted many green practices during construction to ensure a truly 'green' site. The water at the site was recycled using an innovative water recycling filtration system that saved an amount of water equal to that of 14 Olympic size swimming pools. To minimise pollution to the environment, locally produced or fabricated materials such as concrete, steel, glazing, ceiling and wood were procured within a transportation radius of 500 miles.

The site carried out monthly monitoring of water, electricity, waste, dust and noise levels and a KPI was set for each item. Noise level was mitigated by constantly measuring the machines and boundary noise to ensure they were within the stipulated limits.

The developer engaged an independent and professional Environment, Health and Safety (EHS) auditor under the CDL 5-star EHS Field Audit rating system to audit the site quarterly.

The site personnel were also well taken care of. Site administration office and meeting rooms were located away from the construction site and adjacent to the park for a clean, green and healthy working environment. This people-friendly practice helped to improve productivity and reduce absenteeism at work.

## Building Design

The development adopted many green building technologies and environment-friendly features.

### Energy Efficiency

- Solar powered lightings at BBQ pits and self emitting lighted tiles at landscape area
- Sun pipe to light up dark corners of basement car park during the day
- Solar powered water heater system for clubhouse showers
- Energy efficient motor room-less lift system that consume lesser energy
- Energy efficient air-conditioning system with green label inverter system and R410A refrigerant for zero ODP



**Loading of prefab bathroom units into each apartment**



**Installed prefab bathroom units**



**Coordinated services within drywall construction**





## Recyclable Metal Base Outdoor Exercise Equipment

- Electrical equipment that comply with energy efficient index (EEI) for energy consumption in building
- Energy saving lamps with alternate circuit and timer at common areas
- Electrical sub-meters to monitor energy usage in common areas
- White coloured external wall to mitigate heat gain for units
- Generously sized window panels to allow ample natural lighting into units to reduce electricity usage for artificial lighting during the day

## Water Efficiency

- Automatic flushing system for W.C. and urinals at clubhouse
- Dual flush system for W.C. at all units
- Self closing delay action water taps at clubhouse
- Flow regulator for hot/cold water mixer for water efficiency
- Shower jet set in units that comply with water saving flow rate stipulated by PUB
- Rainwater harvesting and recycling system for landscape irrigation
- Water sub-meters to monitor water usage at common areas

## Environmental Protection

- Twin chute pneumatic waste disposal system for recycling and organic waste
- Green recycle corners at all blocks to encourage recycling
- Organic waste compost for landscaping
- Recyclable metal doors at all M&E risers at common areas
- Recyclable metal base bathroom sanitary accessories
- Recyclable plastic/rubber for children play equipment
- Recyclable metal base outdoor exercise equipment and furniture
- Conservation of existing trees on site
- Sustainable site with access to public transport network within 200 m radius

## Indoor Environment Quality

- Ductless MV system with CO sensor at basement car park
- Low VOC paint for internal walls at units/lobbies
- Low emission formaldehyde in wood product

## Other Green Features

- Generous planters and balconies for high-rise greenery and sunshading
- Extensive landscape roof system at clubhouse and bin centre

With its extensive green, environment-friendly and safety features, the project has won numerous 'Green' and 'Safe' awards in Singapore.

It was among the pioneers to be awarded the inaugural Green Mark Gold Award (equivalent of LEED) in 2005 and the C21 Best Practice Award for its Mobile Water Recycling plant by the Building and Construction Authority (BCA) in 2005. In 2006, it received the Public Utilities Board's (PUB) Friends of Water, Ministry of Manpower (MOM) ASHPA Gold Award for overall safety and MOM OSHBP Outstanding & Innovation Award for safe and green secant bore pile wall. In 2007, it was granted the MOM WSHBPA Outstanding & Innovation Award for noise pollution control.

Besides the awards from Singapore authorities, City Developments Ltd (CDL), the developer for Parc Emily, also awarded the project team the CDL Environment, Health & Safety (EHS) Excellence Award 2005/2006.



## Large Panel Windows Maximising Natural Daylight and Ventilation

## Project Details

<b>Client</b>	TC Development Pte Ltd (Joint venture between City Developments Ltd and TID Pte Ltd)
<b>Architect</b>	ADDP Architects
<b>C&amp;S Engineer</b>	LSW Consulting Engineers
<b>M&amp;E Engineer</b>	United Project Consultants Pte Ltd
<b>Project Manager</b>	City Developments Ltd
<b>Quantity Surveyor</b>	KPK Quantity Surveyors (Singapore) Pte Ltd
<b>Landscape Designer</b>	Site Concepts Internationals Pte Ltd
<b>Interior Designer</b>	Index Design Pte Ltd
<b>Main Contractor</b>	Tiong Seng Contractors (Pte) Ltd
<b>Precaster</b>	SW Metal & Construction Pte Ltd
<b>Precaster for Prefab Bathrooms</b>	Eastern Pretech Pte Ltd



# Constructive application of waste materials in construction

By Dr. Ho Nyok Yong & Dr. Kelvin Lee Yang Pin,  
Samwoh Corporation Pte Ltd

**S**ingapore is a highly urbanised country with a small land area of about 700 sq km. The amount of solid waste generated has increased six times over the past 30 years. At this rate, the National Environment Agency (NEA) has estimated that a new incineration plant has to be built every 5-7 years and a landfill every 25-30 years. The recycling of the waste materials for construction applications has become one of the key interests of the Singapore government. Not only does it help to reduce the amount of waste disposed in landfill, it also provides a substitute for natural aggregate which is largely imported from overseas. The recent incidents of sand ban and disruption of granite aggregate supply have further reinforced the importance of recycling waste materials.

There are three major types of waste materials that can be or has been used for construction applications in Singapore in recent years, namely, construction and demolition waste, asphalt pavement waste and incinerator bottom ash generated from the incineration of refuse waste.

## Construction and Demolition Waste

Construction and demolition (C&D) waste is generated from construction activities such as demolition works, concreting, renovation and road works. The waste contains mainly crushed concrete, metals, bricks, ceramic tiles, wood, plastics etc. A significant amount of C&D waste is generated every year. In 2007 Singapore's property market rocketed, generating a high number of property and commercial developments. The buoyant property sector has led to many collective sales of old condominiums and other properties, whose rebuilding activities have created substantial C&D waste.

Over the years, C&D waste has been used mainly for temporary access roads at construction sites and in the subbase course (see Figure 1) for road construction. With the increasing demand and cost of natural aggregate, there is a need to recycle the C&D waste for more beneficial applications.

In 2005, BCA awarded Samwoh Corporation Pte Ltd (Samwoh) a research grant to conduct a study on the effective use of C&D waste for construction applications. The C&D waste can be processed into recycled concrete aggregate (RCA) which contains mainly aggregate and cementitious material. The recycling processes include removal of ferrous metals, removal of foreign materials, crushing and screening of RCA into various sizes as shown in Figure 2.

The findings of the study showed that RCA can be used as an alternative to natural granite in the base course for road construction and non-structural precast concrete components such as road kerbs and drains. The RCA also provides cost savings of about 30 percent compared to natural granite, depending on the quantity and cost of natural aggregate. Further tests are being carried out on the use of RCA in semi-structural and even structural concrete. It is envisaged that the RCA can be incorporated in the specifications for various construction applications.

## Asphalt Pavement Waste

Asphalt pavement waste is generated mainly from the milling of asphalt pavement and full-depth removal of asphalt pavement during pavement maintenance and rehabilitation. The waste can be processed into reclaimed asphalt pavement (RAP) which is the removed and/or reprocessed pavement materials comprising mainly aggregate and asphalt (a by-product of petroleum-refineries). At present, the waste is largely used in subbase course for road construction and temporary access roads in construction sites. However, these applications are of low economical value as the asphalt in the RAP can be more beneficially used in the production of asphalt mixtures for the wearing and binder courses (see Figure 1), thereby reducing the demand for new asphalt (which cost about 20 times more than aggregate). The use of RAP in asphalt mixture has been practiced worldwide for many years.

Currently, a study is being carried out by Samwoh to evaluate the use of RAP in the asphalt mixture for the wearing and binder courses under a research grant from NEA. The study involves laboratory evaluation, processing of the asphalt pavement waste and setting up an asphalt batching plant with recycling facilities as shown in Figure 3. The project is scheduled to be completed by early 2008.

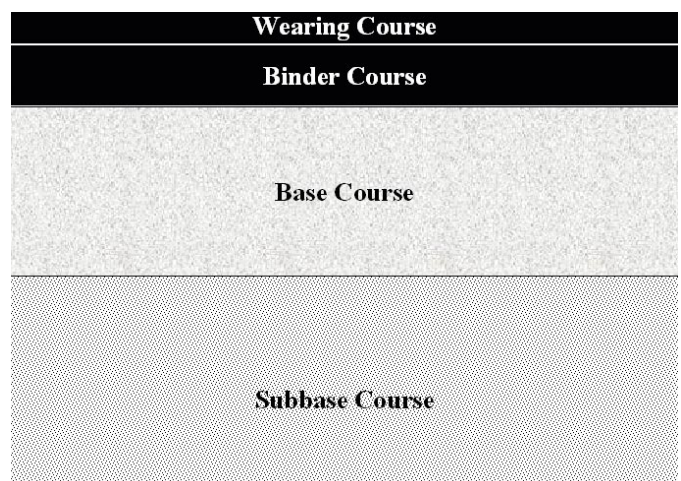


Fig 1 - Pavement section





**C & D waste**



**Preliminary crushing and removal of ferrous metals**



**Removal of foreign materials such as bricks, plastics and asphalt**



**Further crushing and screening of RCA into various sizes**



**Stockpile of RCA for usage**



**Applications of RCA**

**Fig 2 - C&D processing**





**Loading of asphalt pavement waste for crushing**



**Crushing and screening of asphalt pavement waste**



**RAP is ready to be used**



**An asphalt batching plant with recycling facilities**

**Fig 3 - Asphalt processing**

## Incinerator Bottom Ash

Incinerator bottom ash (IBA) is derived from the incineration of refuse waste. Presently, IBA is disposed in Pulau Semakau, which is an offshore landfill in Singapore. Studies have been carried out worldwide on recycling IBA to see if it is possible to extend existing landfill capacity and to create a value-added product that conforms to regulatory requirements for management and to use IBA as a substitute for natural aggregate. A major concern is the possible leaching of heavy metals such as cadmium and lead. Most regulatory agencies require the ash to be assessed for composition and potential leaching of hazardous compounds before it can be used.

Recently, Samwoh is carrying out a project on the use of IBA for construction applications. The project involves setting up a proper commercial facility to process IBA into an engineered aggregate. The proper processes include weathering (or ageing) for stabilisation reactions to occur, removal of ferrous and non-ferrous metals, crushing, separation of over-sized particles, screening, and chemical treatment using a patented system which is well-proven for treating incinerator ash as shown in Figure 4. The treatment allows the treated IBA to meet regulatory leaching limits and be safely used for construction applications such as

base and subbase courses, asphalt mixture, concrete, land reclamation and backfill for trenching works.

## Conclusion

The recycling of waste materials for construction applications has offered a means to alleviate waste disposal problem in land scarce Singapore and to provide a substitute for natural aggregate. There are three types of waste materials that can be beneficially used for various construction applications:

- 1) RCA, which can be used in base course for road construction and partial replacement of natural aggregate for producing concrete;
- 2) RAP, which can be used in asphalt pavement mixtures for the wearing and binder courses; and
- 3) Treated IBA, which can be used for road construction including base and subbase courses, sea shore protection and other applications such as land reclamation.

Such applications have been practiced worldwide for many years. The recycling of these waste materials will provide economical and environmental benefits as well as contribute towards Singapore's goal to achieve environmental sustainability.

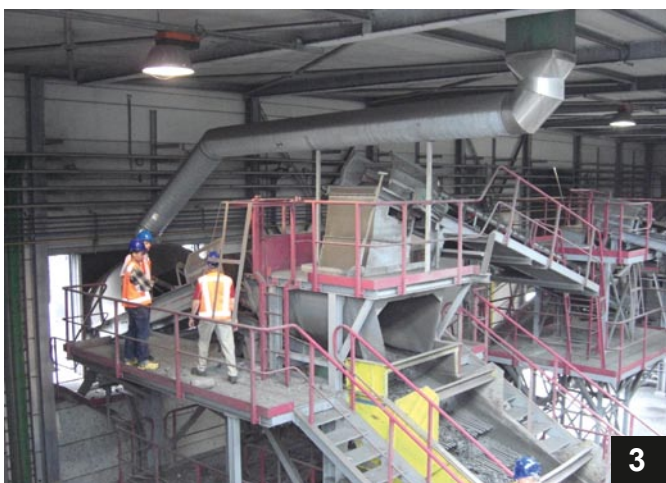




**IBA is produced after the incineration process**



**Aging of IBA**



**Crushing and screening of IBA**



**Removal of ferrous and non-ferrous metals from IBA**



**Chemical treatment of IBA using a patented system**



**Applications of treated IBA**

**Fig 4 - IBA processing**





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