THE HONG KONG INSTITUTION OF ENGINEERS
香港工程師學會
Environmental Division
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ANNUAL SEMINAR

March 2013

Green Building and Construction Materials- Challenges for Innovation and Excellence

TECHNICAL REPORT

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Acknowledgements

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Executive Summary

The Annual Seminar of the HKIE Environmental Division was held on 22 March 2013 at Hong Kong Convention and Exhibition Center with the leadership of the Organizing Committee Chairlady Ir Irene M C Lo and the Chairman of HKIE Environmental Division, Ir Kenny Wong. Regarding the critical impact of construction material on building environmental performance over its life cycle (including raw material extraction, manufacturing, transportation, disposal), the Annual Seminar provided opportunity to distinguished guests, practicing engineers, academics, contractors and other professionals to share valuable experiences and views on the theme: *"Green Building and Construction Materials-Challenges for Innovation and Excellence"*. The keynotes, presentations and discussions on this topic highlighted not only significant achievement in building and construction material greening process in Hong Kong, but also existing obstacles and difficulties which have to be overcome. Participants also noticed existing favorable conditions susceptible to drive innovation and excellence in building construction materials greening over near future. The rapid development of testing, certification and labeling of local construction materials and the promotion of recycling industry in Hong Kong will undoubtedly lead to embed greening throughout the entire building construction process from design to demolition.

1Introduction

Global warming, stratospheric ozone depletion, resource depletion, energy scarcity, drastic environmental degradation and human toxicity triggered by increasing emissions of greenhouse gas (GHG) and various toxic substances; and industrial mal practices, have been identified as the greatest challenges nations, governments, business and citizens are facing over upcoming decades. In response, international, national, regional and local initiatives are being developed and implemented to limit environmental nuisances. The Government of the Hong Kong Special Administrative Region is committed to closely collaborating with the international community in formulating measures to clean the environment. As a member of the Asia-Pacific Economic Co-operation (APEC), Hong Kong is working towards achieving significant reduction in ozone depletion substances and other toxic substances, and more importantly, a reduction in energy intensity of at least 25% by 2030 (with 2005 as the base year), as set out in the APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development issued in September 2007. Within this process, building sector, considered as one of major sources of GHG emissions in Hong Kong, should play an essential role in reducing environmental burden. Because of its products' longevity, the construction industry is therefore in a preponderant position to support environmental benefits both through green building jobsite practices and lasting structural improvements. Ultimately, promotion of green building standards leads to a shift in the construction industry, with greening thoroughly embedded in its practice, materials, standards, codes, and regulations.

Going beyond building energy efficiency, the Annual Seminar, by providing a platform of discussion and sharing of valuable experiences and views for practicing engineers, academics, contractors and other professionals, aimed to focus on an integrated multidisciplinary approach of green building which considers green construction materials and environmental performance from materials extraction, manufacture and transportation to building construction site. This technical report summarizes discussed salient aspects including green building standards, life cycle carbon emission and toxic substances of construction materials, construction materials testing and certification schemes, measurement of embodied carbon for classifying and labeling building and construction materials, green procurement for construction, and cost-effectiveness of green construction materials. The report also provides with perspectives and challenges of promoting green building and construction materials in Hong Kong.

2 Concept of Green Building

The concept of green building was considered as full life cycle of a building's environmental impact and performance (Colin C L Chung and Ernest K W Tsang). This concept incorporates environmental performance not only into the building construction, but also building operations, maintenance and demolition. In other words, a green building is designed to minimize the total environmental impact of its materials, construction, operation and demolition while maximizing opportunities for indoor environmental quality and performance (W K Lo; KS Wong). It should also be emphasized that green buildings not only contribute to a green construction and environment but also to lower development costs, lower operating costs, increased comforts and enhanced durability and less maintenance costs (W K Lo; John Ng; KS Wong).

3 Green Building Standards

3.1 Hong Kong BEAM and BEAM Plus

As introduced by speakers (Colin C L Chung; John Ng; CS Poon), Hong Kong Building Environmental Assessment Method (HK-BEAM) was established in 1996 with the issue of two assessment methods, one for 'new' and one for 'existing' office buildings largely based on the UK Building Research Establishment's BREEAM. Environmental issues were categorized under 'global', 'local' and 'indoor' impacts, respectively. In 1999 the 'office' versions were re-issued with minor revisions and updated references, together with an entirely new assessment method for high-rise residential buildings.

BEAM is owned and operated by BEAM Society Limited, an independent not-for-profit organization whose membership is drawn from many professional and interest groups in Hong Kong's building construction and real estate sectors (Colin C L Chung and Ernest K W Tsang; John Ng). Following initial funding from The Real Estate Developers Association of Hong Kong (REDA), BEAM development is funded from assessment fees with voluntary support from the efforts of BEAM Society's members and associates, and the professional supporting team. BEAM provides a label for building quality (John Ng). The label signifies levels of quality in respect of safety, health and comfort, which are important considerations for building users and levels of performance in respect of environmental and social dimensions, which are of importance to society as a whole.

BEAM essentially seeks to enhance the quality of buildings in Hong Kong, provide a comprehensive set of performance standards that can be pursued by developers and owners, reduce the environmental impacts of buildings throughout their lifecycle, and ensure that environmental considerations are integrated right from the onset rather than retrospectively.

The climate change and global warming have become international issues for several years. Various countries including developed and developing areas cooperated to help improving the existing situations. In response to the critical global environmental issues, BEAM Plus has been evolved to meet the higher expectation from the public and communities. BEAM Plus conserves the environmental aspects of BEAM as showed in Fig.1, but enhances the performance criteria. Six factors, including site aspects, materials aspects, energy, water use, indoor environmental quality, innovation and additions are considered in BEAM Plus assessment scheme (Colin C L Chung and Ernest K W Tsang). Table.1 presents the grade types for classification of building performance under the BEAM Plus scheme (Colin C L Chung and Ernest K W Tsang; John Ng; CS Poon).

Figure 1 Environmental Aspects in BEAM Plus Schemes (John NG; CS Poon)

Table 1: Award Classification for BEAM Plus for new buildings (Colin C L Chung and John NG**)**

	Overall	**SA**	**EU**	**IEQ**	**IA**
Platinum	75%	70%	70%	70%	3 credits
Gold	65%	60%	60%	60%	2 credits
Silver	55%	50%	50%	50%	1 credit
Bronze	40%	40%	40%	40%	N/A

Under the BEAM Plus scheme, twenty seven building construction projects in Hong Kong have been assessed from 2010 to 2012 of which twelve obtained the highest performance of platinum grade as summarized in Fig. 2 (John NG).

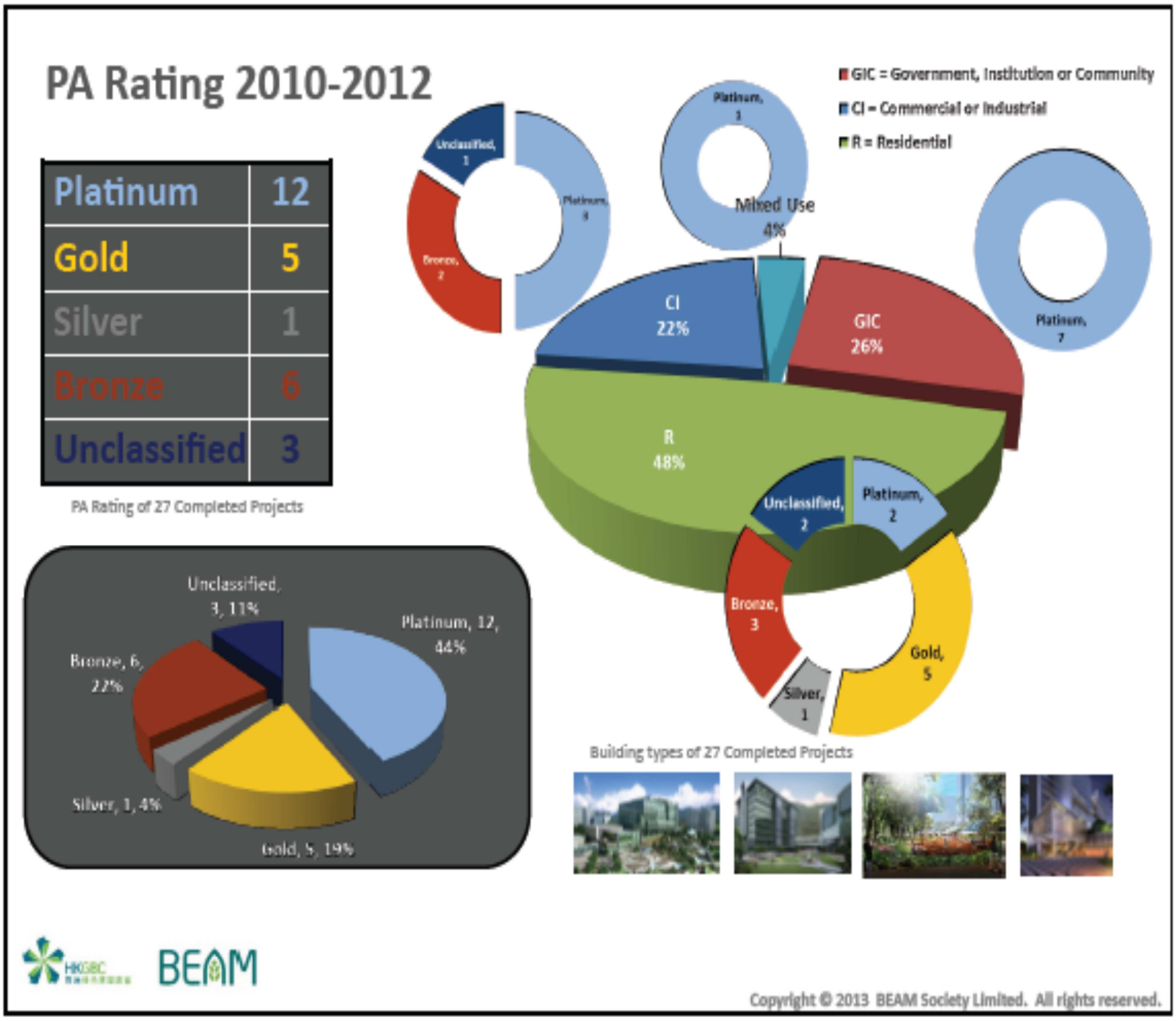

Figure 2 Performance Assessment of Building Construction Projects under BEAM Plus in 2010-2012 (John Ng)

In raising awareness about the environmental impact of buildings, BEAM Plus has contributed to the development of green and sustainable buildings in the HKSAR. BEAM Plus has assessed more buildings and more square meters of space than any other similar scheme in use worldwide on a per capita basis.

The scheme provided recognition for improved building performance to lots of landmark properties in Hong Kong, Beijing, Shanghai and Shenzhen, comprising over 9.5 million m^2 of spaces and 50,000 residential units. Most of the assessed buildings were air-conditioned commercial buildings and high-rise residential buildings, which are the leading users of energy and other natural resources in Hong Kong.

Integrated into construction materials assessment, BEAM Plus essentially aims at promoting sustainable use of natural resources, minimizing waste generation, encouraging waste recycling, conserving landfilling resources, protecting ozone layer and minimizing greenhouse gas emission (CS Poon). The main aspects of construction materials assessment are: timber used for temporary works (well-managed use of timber from sustainable forest products), use of non-CFC based refrigerants (reduction of the release of chlorofluorocarbon into the atmosphere), construction and demolition waste management plan (best practices in the management of construction and demolition wastes, including sorting, recycling and disposal of construction waste), waste recycle facilities (reduction of pressure on landfill sites and help to preserve non-renewable resources by promoting recycling of waste materials), building reuse (reuse of major elements of existing buildings, to reduce demolition waste, conserve resources and reduce environmental impacts during construction), modular and standardized design (enhanced use of modular and standardized components in building design in order to enhance buildability and reduce waste), prefabrication (use of prefabrication building elements to reduce wastage of materials and quantities of on-site waste), adaptability and deconstruction (design of building interior elements and building services components that allow modifications to space layout, and to reduce waste during churning, refurbishment and deconstruction), rapidly renewable materials (wider use of rapidly renewable materials in appropriate applications), recycled materials (use of recycled materials in order to reduce the consumption of virgin resources), ozone depleting substances (reduction of chlorofluorocarbons and hydrochloro-fluorocarbons into the atmosphere), regionally manufactured materials (use of materials manufactured locally so as to reduce the environmental impacts arising from transportation), demolition waste reduction (best practices in the management of waste, including sorting, recycling and disposal of demolition waste), construction waste reduction (best practices in the management of waste, including sorting, recycling and disposal of construction waste). BEAM Plus will continue contributing to this development process by widening its coverage and setting higher performance levels (CS Poon; John Ng; Colin C L Chung).

3.2 Comparative Analysis of Green Building Standards in China, USA, Singapore and HK

Rapid urbanization and economic growth in China increased the pressure on limited natural resources and policy options to deal with sustainability problems. Within this context, several policy instruments have been implemented to encourage the development of green building under various schemes such as design standards, testing standards, management standards, and building energy consumption standards of which the Evaluation Standard for Green Buildings GB/T 50378-2006 issued in June 2006 is one of the most popular (Colin C L Chung). GB/T 50378-2006 aims to encourage buildings to go beyond the minimum energy efficiency requirements. This scheme processes an analysis of building energy consumption data, assesses energy performance based on standards, and issues the three-star building certification to qualifying buildings. GB/T 50378-2006 provides guidelines requirement for different phases of construction including planning, design construction and operation and arrangement. The main aspects of assessment include land saving, outdoor environment, energy saving and energy utilization, water saving and water resource utilization, material saving, resource utilization, indoor environment quality and operation management (Colin C L Chung and Ernest K W Tsang). There are three types of credit in the scheme namely, pre-requisite, preference and general items. The rating includes "★", "★★" and "★★★" and tabulated in Table 2.

Table 2: Rating System for GB/T 50378-2006 (Colin C L and Ernest K W Tsang)

Grade	★	★★	★★★
Land Saving and Outdoor Environment	3	4	5
Energy Saving and Energy Utilization	4	6	8
Water Saving and Water Resource Utilization	3	4	5
Material Saving and Material Resource Utilization	5	6	7
Indoor Environment Quality	3	4	5
Operation Management	4	5	6
Preference Items	0	6	10

In Singapore, the Green Mark Scheme was launched by the Building and Construction Authority (BCA) in January 2005 as an initiative to drive Singapore's construction industry towards more environment-friendly buildings.

It is intended to promote sustainability in the built environment and raise environmental awareness among developers, designers and builders when they start project conceptualization and design, as well as during construction (Colin C L Chung and Ernest K W Tsang). The BCA Green Mark provides a meaningful differentiation of buildings in the real estate market. It is a benchmarking scheme which incorporates internationally recognized best practices in environmental design and performance. The main assessed aspects include the design of building and its major coverage includes energy, water, environmental protection, indoor environmental quality and other green feature. our different ratings namely, Certified, Gold, Gold^{plus} and Platinum are available in Green Mark (Table 3).

Table 3: Score for Green Mark (Colin C L Chung and Ernest K W Tsang)

Green Mark Score	Green Mark Rating
90 and above	Green Mark Platinum
85 to < 90	Green Mark Gold^{Plus}
75 to < 85	Green Mark Gold
50 to < 75	Green Mark Certified

Leadership in Energy and Environmental Design (LEED) is the green building and construction materials assessment scheme in USA. LEED comprises of location and transportation, sustainable site, water efficiency, energy and atmosphere, material and resources, indoor environment quality and innovation. There are four grades in LEED assessment scheme, which include Certified, Silver, Gold and Platinum as showed in Table 4.

Table 4: Credit Point for LEED 2012 Draft Version 4 (Colin C L Chung and Ernest K W Tsang)

LEED Rating	LEED Credit Point
Certified	40-49
Silver	50-59
Gold	60-79
Platinum	80-110

In sight of obvious similitude among above schemes (GB/T 50378-2006, BCA Green Mark and LEED), significant discrepancies subsist in assessing specific aspects such as site, water use, material, energy, indoor environmental quality, as highlighted by the speakers (Colin C L Chung and Ernest K W Tsang). It is also noticed that except the LEED, these assessment schemes are conceived for a specific region and align with the development policy of the local government or reflect the history or background of a city or country. GB/T 50378 and BEAM Plus encourage the building complying with the requirements of site planning and construction design (ecological impact of land use, use of green field and brownfield, natural daylight to neighborhood, quality public transportation, control of heat island effect) in order to provide basic living standard for the citizen in the view of economic, utilization of resources and the standard of urban design, while the Green Mark do not have any specific requirement. However, all four assessment schemes encourage having larger landscape. For water assessment, GB/T 50378 and Green Mark state on control of water consumption whereas LEED and BEAM Plus assess the percentage of water being saved. Major discrepancies in energy assessment are related to embodied energy in BEAM Plus and LEED, use of solar thermal in GB/T 50378, and assessment of energy use in carpark in BEAM Plus and Green Mark. Control of use of raw materials, location of manufacturing, use of renewal materials, waste minimization, design flexibility, adaptability and deconstruction are the main aspects of discrepancy among LEED, BEAM, Green Mark and GB/T 50378 in construction materials assessment. Regarding the indoor air quality assessment, fresh air, performance of ventilation system and construction materials, are covered in LEED, BEAM and GB/T 50378 while in Green Mark, there is a credit for the use of high frequency ballast in fluorescent luminaires (Colin C L Chung and Ernest K W Tsang).

4 Assessment of Green Construction Materials

4.1 Determination of Carbon Footprint of Construction Materials

Estimating the carbon footprint of a construction material helps to determine the environmental quality of the material for classification and labeling. This also contributes to reduce the embodied carbon of the material and provide a basis for prediction of carbon emissions in construction (Jack C.P. Cheng; Nick Lewis). The carbon footprint includes all greenhouse gas identified in Kyoto Protocol (1997) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

(1) Methodology

Estimation of the carbon footprint of a construction material is to investigate its embodied carbon (Jack C.P. Cheng et al.). As shown in Fig.3, the embodied carbon of a building material can be defined as the total carbon released over its life cycle (from material extraction, manufacturing, and transportation to construction site). The embodied carbon data is region-specific since the manufacturing processes of a product in different areas vary largely and the fuel and electricity emission factors are widely different. Thus, an embodied carbon database for local construction materials is needed, which can provide a benchmark for green material selection and green label development as well as a basis for prediction and estimation of carbon footprint (Jack C.P. Cheng et al.). In order to create a Hong Kong embodied carbon database for construction materials, commonly used construction materials, such as aluminum, brick, cement, ceramics, concrete, glass, gypsum board, steel and wood, have been selected for embodied carbon investigation.

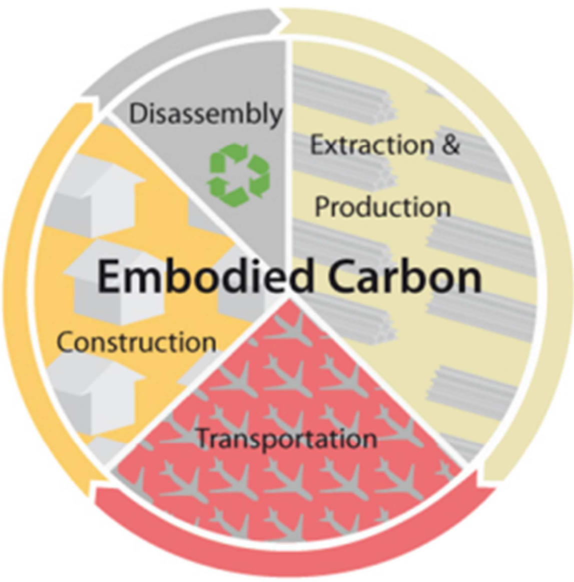

Figure 3 Carbon Embodied (Jack C.P. Cheng et al.**)**

In view of life cycle, the system boundary for the investigation of embodied carbon of building material can be set as "cradle-to-site", which covers the raw material extraction, manufacturing and transport until the material has reached the construction site (Fig. 4).

For the carbon estimation of each material, it is necessary to firstly conduct the background study of the material, and then define the system boundary of each material, followed by the questionnaire design and data collection (Jack C.P. Cheng et al.).

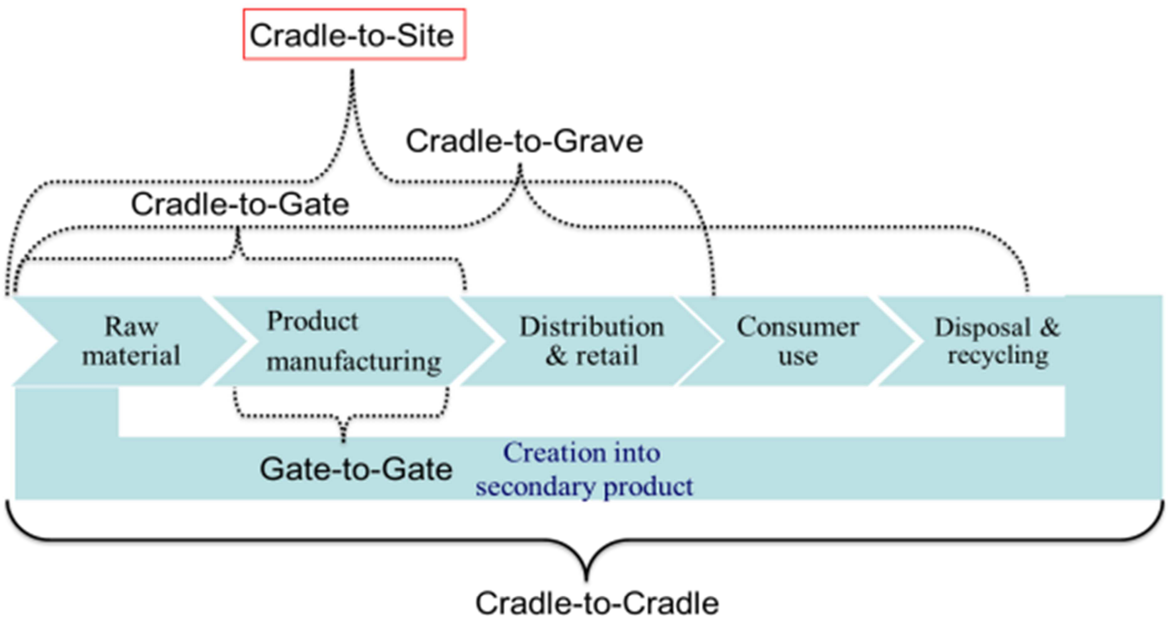

Figure 4 System Boundary of Life Cycle (Jack C.P. Cheng et al.**)**

Based on the data and information obtained from the previous study and data collection, the next step is to set the carbon footprint calculation method. Within this process the speaker (Jack C.P. Cheng) developed two methods as summarized below:

-The first method localization is to convert existing embodied carbon databases to the HK case by referring to the life cycle carbon inventories in other countries. The *Cradle-to-Gate* data are obtained from existing embodied carbon databases in other countries (e.g. the Inventory of Carbon & Energy by University of Bath in the UK) assuming the same manufacturing processes, and then adjusted with the fuel and electricity emission factors based on the suppliers and locations. The calculation of *Cradle-to-Site* considers the *Cradle-to-Gate* data plus the carbon emissions of product transportation, considering fuel and vehicle types, distance, and weight of freight, etc.

-The second method estimates the carbon footprint of the construction material based on the *life cycle assessment (LCA)* which is considered as a technique evaluating the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (Fig.5).

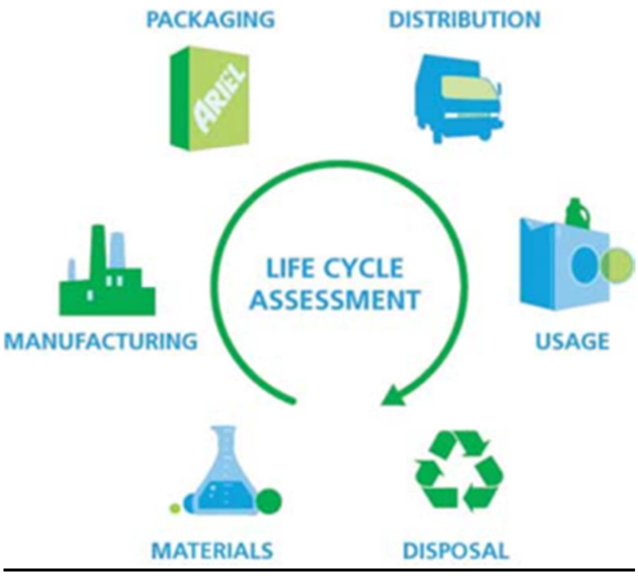

Figure 5 Life Cycle of a Product (Jack C.P. Cheng et al.**)**

2) Application to Portland Cement

This case study applies the second method (LCA method) to estimate the carbon footprint of Portland cement. The scope of the measurement for cement (from raw material extraction and manufacture to the cement transportation to site for construction) is shown in Fig.6. Background information on the greenhouse gas emission sources at each stage of the *Cradle-to-Site* life cycle was reviewed and data collection was conducted. The main aspects taken into account in the greenhouse gas calculation are company information, energy use (electricity consumption, fuel combustion), transportation (raw material and product transport, distance, weight of freight), calcination CO_2 (raw material, raw meal, clinker, cement kiln dust, bypass dust) and other useful information (Table 5).

Figure 6 Scope of Carbon Footprint for Cement (Jack C.P. Cheng et al.**)**

Table 5 Identification of Greenhouse Gas Emission Sources for Cement Life Cycle (Jack C.P. Cheng)

Stages	Input	Process	Equipment	GH G
(1)Raw material extract (2)Raw meal preparation	Fuel	Extraction	Truck / Shit	Transport
	Electricity	Crushing	Crusher	Electricity Consumption
		Proportioning	Weight feeder	
		Grinding	Raw Grinding mill	
		Homogenizing	Homo Silo	
(3) Clinker production	Fuel	Preheating	Preheating	Fuel Combustion
	Fuel	Calcination	Rotary Kiln	
	Electricity	Rapid Cooling	Grate Cooler	Chemical reaction
		Conditioning	Conditioning Tower	Electricity consumption
		Dust Collecting	Electrostatic Precipitator	
		Gas Driving	Induced Draft Fan (ID Fan)	
		Finish Grinding	Finishing Grinding Mill	
	Imported Clinker	Clinker Production	N/A	Clinker Promotion from other factory
(4) Cement Production (5) Production packing and transportation	Electricity	Finish Grinding	Finish Grinding Mill	Electricity consumption
		Storage	Cement Silo	
	Fuel	Packaging Dispatching	Packaging Machine Truck/Barge	Transport

The cement life cycle greenhouse gas (GHG) emission calculation is performed based on existing standard guidelines such as IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), GHG Protocol Corporate Accounting and Reporting Standard (WBCSD/WRI, 2004), and CSI-CO_2 Accounting and Reporting Standard for Cement Industry (WBCSD/CSI, 2011). The result of each GHG source is summarized and shown in Table 6.

Table 6 Greenhouse Gas Estimation Emissions for Cement Life Cycle (Jack C.P. Cheng et al.**)**

	GHG Source	kg CO_2 / kg clinker	kg CO_2–e / kg clinker	kg CO_2 / kg cement	kg CO_2–e / kg cement
A	Raw materials	8.385×10^{-3}	2.295×10^{-2}	7.267×10^{-3}	1.989×10^{-2}
B	Calcination	0.551	0.551	0.478	0.478
C	Energy use	0.397	0.399	0.379	0.381
D	Imported clinker	/	/	0.058	0.058
E	Transportation	0.063	0.085	0.055	0.074
Cradle-to-site total (A+B+C+D+E)		1.019	1.058	**0.977**	**1.011**
Gate-to-gate total (B+C+D)		0.948	0.950	**0.915**	**0.917**

(3) Other Case Studies

Estimation of construction materials greenhouse gas and other pollutants (ozone depletion and various toxic substances) are crucial in testing, inspection and certification of green construction materials. The carbon footprint for construction materials may also vary from country to country or region to region depending on the variability of the conditions and locations of the materials extraction, manufacture and transportation to the construction sites as evoked above by the speakers (Jack C.P. Cheng; Nick Lewis). For example, an assessment of the carbon footprint of nine key construction materials in Mainland China (Nanjing) based on the *Cradle-to-gate* approach (Nick Lewis), shows the results presented in Fig.7.

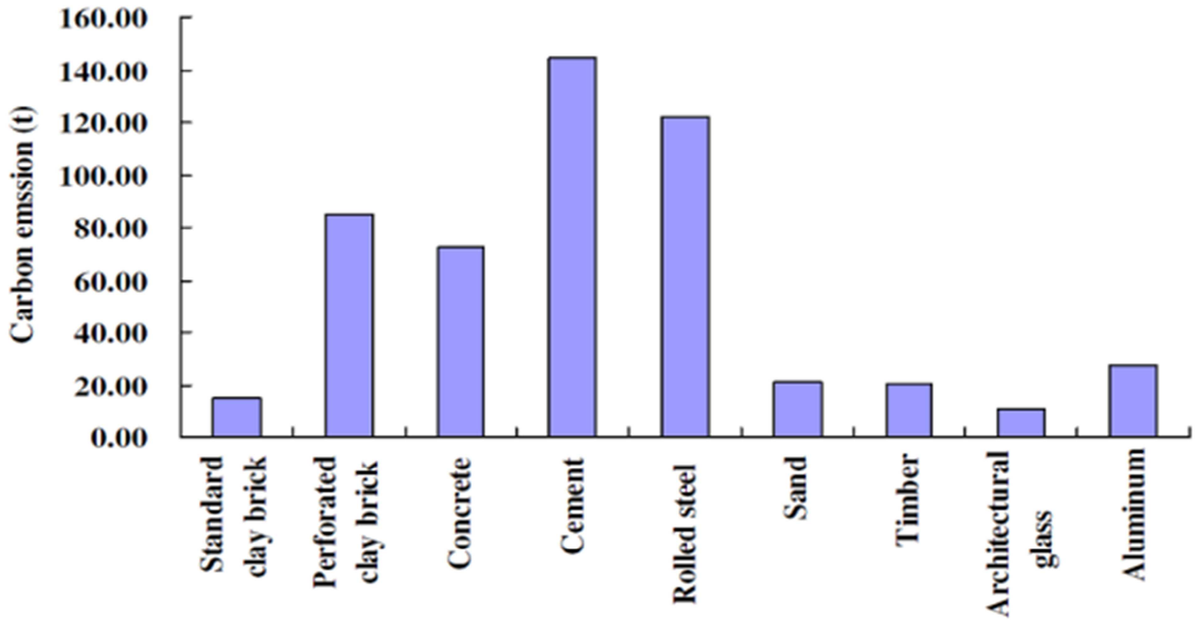

Figure 7 The Carbon Emission of Main Construction Materials in Nanjing, China (Nick Lewis)

The result on Fig.7 illustrates that steel, concrete, aluminum and glass represent almost 90 percent of the building's embodied carbon (Nick Lewis). The findings from these carbon footprinting studies therefore support the overall recommendation to focus on identifying low-carbon alternatives to these key construction materials when establishing carbon reduction strategies (Nick Lewis, Gary S K Chou). Another illustration of carbon footprint of construction materials was performed on construction formworks during the construction of Expansion of Tseung Kwan O Hospital by Chun Wo Development Holdings Ltd (Gary S K Chou). The study was conducted comparing 6 different options (semi-precast slabs + timber forms in option 1; semi-precast slabs + aluminum forms in option 2; semi-precast slabs + steel forms in option 3; aluminum forms only in option 4; steel forms only in option 5; timber forms only in option 6) for construction of the concrete structures. It is perhaps not immediately obvious that using timber formwork is an environmentally friendly solution; however, the findings showed timber forms entailing the lowest CO_2 emission (Fig.8). This raises the challenge of forest preservation and construction formworks greening.

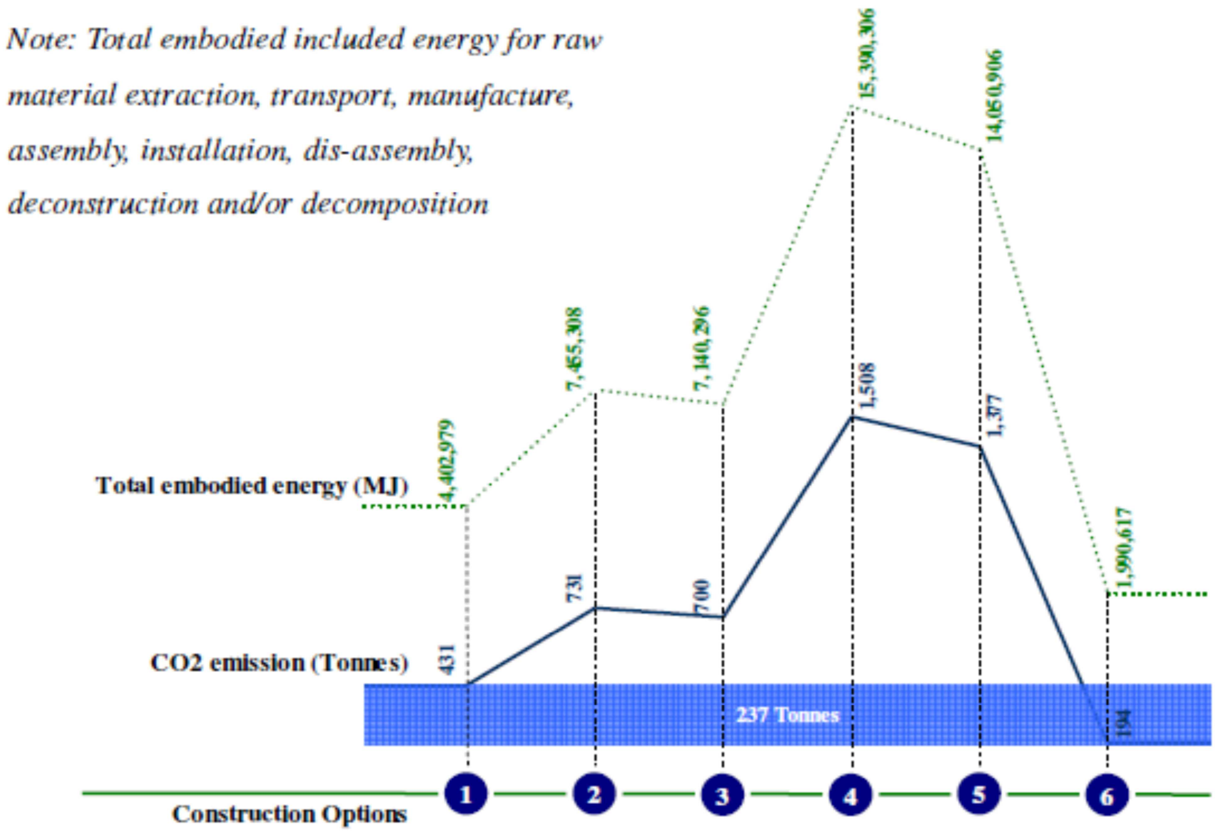

Figure 8 Resulting embodied energy and possible CO_2 emission (kg CO_2 ≈10.204 MJ) for different construction options (Gary S K Chou)

4.2 Testing, Inspection and Certification of Green Construction Materials

Established in 2009, Hong Kong Council for Testing and Certification (HKCTC) is a Government advisory body to promote the development of testing and certification industry. It is helping the industry to develop services in both areas of construction materials and environmental protection (John Hung). Generally speaking, "green materials" refer to materials that cause minimal adverse environmental and human health impacts. Some of their characteristics include high recyclability, containing less or no irritating/toxic substances and adoption of resource-efficient manufacturing processes (e.g. reduced energy consumption, waste and greenhouse gas (GHG) emissions). Testing, inspection and certification can assist users of these materials to ascertain their "green" performance.

Examples of green related testing for construction materials in Hong Kong include testing of the performance of concrete with recycled content (e.g. pulverized fuel ash), testing for the presence of harmful substances like volatile organic compounds and asbestos. Green buildings will find the indoor air quality certification scheme launched by the Environmental Protection Department useful in demonstrating their air quality to occupants. In addition, buildings can seek certification on energy management system to the international standard ISO 50001for improved energy performance, reduced operation costs and enhanced reputation. Buildings can also quantify and reduce their GHG emissions based on the ISO 14064 series standards, and seek third-party validation and verification of their GHG reports for enhanced credibility.

Testing, inspection and certification are also strongly helpful in mineral products industry which has a key role to play in promoting and developing green construction materials, techniques and technology. The mineral products sector covers a broad span of industrial activities which range from energy-intensive processes like the manufacture of cement, lime and slag to the production of aggregates, ready-mixed concrete, asphalt, and blocks and pavers involving relatively low carbon dioxide equivalent (CO_2-e) emissions per unit of production (Nick Lewis). Given the historic lack of client appetite in Hong Kong for innovation in construction and adoption of new materials standards, there is a real or perceived culture of risk aversion, with no coherent industry-wide strategy or leadership for research and development. Consequently, companies working in the sector (designers, contractors and suppliers) typically develop competitive advantage via cost efficiency rather than investment in cutting edge innovation; and this applies equally to steps that might be taken towards the provision of low carbon construction material solutions (Nick Lewis). On the other hand, although green schemes have been implemented for buildings assessment, there is a lack of a comprehensive green labelling scheme specifically designed for building materials / products to support the local building and construction industry (Professor Thomas NG). Thus, enhanced development and performance of construction materials testing, inspection, certification and labeling, are imperative and will obviously help reducing the environmental impacts associated with the extraction, processing, fabrication, transportation, installation, operation and disposal of building materials / products, leading to the promotion of green construction industry in Hong Kong (John Hung; Nick Lewis; Thomas Ng).

In clear, with a practical and credible green labelling scheme for the building and construction sector, industry stakeholders can make more informed choices when procuring building materials / products by considering their environmental performance (Thomas Ng).

4.3 Towards Local Green Construction Materials Labeling

In order to set up a green building product labelling scheme for Hong Kong, the Hong Kong Green Building Council has commissioned the University of Hong Kong (HKU) to conduct a study to develop a local based green building product labelling framework (Thomas Ng). The speaker (Professor Thomas NG) thus shared with Annual Seminar participants, the preliminary finding of this study and discussed the way forward of the Hong Kong based green building product labelling scheme.

The first step consisted of developing a product categorisation regime (raw materials, processed materials, semi-finished products, finished products, components, etc.) for the proposed green building products labelling scheme. For this purpose, research team of HKU reviewed relevant classification methods (International Classification for Standards issued by ISO; the Central Product Classification adopted by the United Nations; the United Nations Standard Products and Services Code adopted by the Institute for Environmental Research and Education; and the Global Product Classification employed by the Sustainability Consortium. In addition, the MasterFormat, Hong Kong Standard Method of Measurement of Building Works, 4th Edition (HKSMM4) and Inventory of Carbon and Energy); determined the characteristics and environmental impacts of various construction materials (e.g. reinforced concrete, brick, wood products and plastics), construction products (e.g. temporary work, structural work and finishing work), and building services components (e.g. pump, fans and electronic ballast); and also consulted industry stakeholders as well. Based on this information, the building products are classified according to their functions and environment impacts as detailed in Table 7 (Thomas Ng).

Table 7 The Product Classification Regime (Thomas Ng)

ID	Category	Product
I	Concrete and Structures	Cement products; ready-mixed concrete; reinforcing and structural steel; precast concrete units
II	Facade and Roof System	Metal cladding; coatings (including paint); waterproofing (asphalt, liquid / sheet membrane, etc.); windows; window film and coatings; curtain walling; glazing; tiles
III	Interior Systems	Flooring (tiles, wood-based products, stone / marble, raised access floors, etc.); ceilings (mineral fibreboard, gypsum plasterboard, calcium silicate and metal); internal walls (drywalls – gypsum plasterboard, partitions, bricks / blocks, etc.); thermal and acoustic insulating products (rockwool, cork, fibreglass, polystyrene, etc.); furniture (only those included in the building specifications, e.g. classroom desks and seating, shelves, institutional seating, etc.)
IV	Finishes	Adhesives and sealants; wall coverings; carpeting; paints and coatings.
V	Materials for Electrical and Mechanical	Copper products (ducts / pipes, cables and wiring, etc.); cast iron ducts / pipes; PVC ducts / pipes; valves; air grilles (e.g. damper and diffuser); cooling tower; tank connectors; meters and detectors; sprinkler heads; break-glass type call point; trunking; fused spur unit points / switched socket points; air break switchgear / breakers
VI	Electrical and Mechanical	Electronic ballast; transformers; switchboards / distribution boards; electric lamps (compact fluorescent lamps, LED lamps, etc.); chillers; water pumps; electric motors; fans; fan coil units / air handling units; auto tube cleaning systems
VII	Miscellaneous	Doors; moulding and millwork; ironmongery; mirrors; temporary works; formwork; scaffolding; ceramic sanitary products; galvanised mild steel products; stainless steel products

In order to perform a selection of building materials / products which covers a wide variety of product categories and help to ensure that the proposed green labelling scheme is representative and thus encourage a more environmental friendly design and construction, an extensive study of the bills of quantities (BQ) of seven representative local building projects was conducted to determine the key building materials in respect to their environmental impacts. Based on the findings of the BQ analysis, along with the results of SimaPro 7.0 and eQUEST (commonly used software for analysing the energy performance of buildings), twenty building materials / products as shown below were selected in the proposed labelling schemes (Thomas Ng**)**:

- i) Reinforcing bars and structural steel
- ii) Composite wood
- iii) Aluminium window frame
- iv) Stone
- v) Tiles (ceramic)
- vi) Wall covering
- vii) Ready-mixed concrete
- viii) Furniture
- ix) Paint and coatings
- x) Chiller
- xi) Cement products
- xii) Electric motor
- xiii) Adhesives and sealants
- xiv) Transformer
- xv) Cables and wires
- xvi) LED lamps
- xvii) Gypsum plasterboard
- xviii) Compact florescent lamp
- xix) Windows
- xx) Electronic ballast

The next key step consisted of developing the specific environmental assessment standards (development of assessment guidelines) based on (i) desktop study; (ii) evaluation criteria development; and (iii) verification. Such analysis resulted in representative assessment guidelines (assessment variables) such as general requirements, resource consumption, human toxicity, and ecosystem impacts. More stringent substantiations are required for core criteria such as laboratory reports, safety data sheet and detailed production documentation (Thomas Ng**)**. In addition, the tests should be conducted by a third party or the manufacturer should have received ISO 17025 certification or the national accreditation systems. Any products which meet all the minimum requirements under the "core criteria" of the product specific standards will be awarded a green label with a "pass" grade. Higher eco-points are needed to gain the "good" and "excellent" grades (Thomas Ng**)**. However, the validation (through a series of focus group meetings and / or document based consultation exercise with experts including but not limited to manufacturers, contractors, consultants, academics, etc. to determine whether the data required for the assessment and initial benchmarks are realistic under the Hong Kong scenario) of the assessment guidelines is necessary before proper implementation of the labelling system. Once the system validated, a pragmatic implementation plan will be proposed for the launching of the green building product labelling scheme in Hong Kong (Thomas Ng).

5 Green Construction Materials Procurement: Case Studies

Regarding the GHG and other toxic substances emissions from construction materials / products, application of green materials procurement in construction is imperative in Hong Kong to improve environmental performance of the industry (Nick Lewis; Shirlee Algire; Gary S K Chou). A green procurement framework involves people; policy, strategy & communication; the procurement process; engaging the supply chain; and measuring and reporting. Moreover, this process considers number of factors in the supply chain such as the environment, social and economic consequences of design; non-renewable material use; manufacture and production methods; logistics; service delivery; use; operation and maintenance; reuse; recycling and disposal options; suppliers and subcontractors capabilities (Shirlee Algire). Based on such analysis framework, green procurement of number of construction materials is being applied in the industry. Speakers (Shirlee Algire; Nick Lewis; Gary S K Chou) focused on some of key materials such as steel, concrete, asphalt, and granulated slag.

5.1 Green Steel

Construction is the largest market for steel consuming up to 50% of the world steel production (Shirlee Algire). Steel is essential to all transport infrastructures and the equipment used to construct infrastructures (including plant, scaffold, moulds, safety belts, anchors, and lifting gear). Mills are located all over the world and utilize two processes; Blast Furnace with Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF). Life Cycle Inventories are carried out by the World Steel Association to quantify resources use, energy and environmental emissions associated with the processing of a variety of steel industry products from the extraction of raw materials in the ground through to the steel factory gate (Shirlee Algire). Accordingly, steel produced from EAF has a much lower footprint and more attractive lifecycle (Table 8). Nevertheless, risk of price volatility and surety of delivery are important factors which drive contractor's decision in procuring EAF or BOF sources. The most common mill sources for rebar, H-pile, column, beam, plate and sheet pile are in Turkey, Russia, Korea, Taiwan, Guangdong China, Japan, Europe. Materials are imported by 'stockers' who are continually tracking and buying from best price source for the required quality. In practice, great effort is required in verifying and managing individual chain of custody records (Shirlee Algire).

Assessment of green steel in Hong Kong is performed by BEAM Plus and USGBC LEED green building standards which drive regional and recycled sourced steel (EAF source). Basically, BEAM Plus gives credit for materials manufactured within 800km and for recycled content. LEED gives credit for recycled content and raw material source, depending on transport mode, of up to 1500km. The economic and recycle quality considerations hence become balanced with the lower lifecycle impact material and drive the procurement decisions (Shirlee Algire). However, the speaker (Shirlee Algire) reported that the most recent updated version of BEAM Plus (BEAM Plus 2.1) restricts the supply of the raw materials (iron ore and recycle scrap billet), and it may even be impossible to get declaration letters from mills on the source of scrap billet (Shirlee Algire). In clear, no regional source of H-pile meets the requirements. Regarding rebar, Taiwan mills become the only one regional green source. Such situation offers the supply monopole to only one regional source, limits contractors' choices for optimal combination of green construction materials, and raises the challenge of construction greening and cost-effectiveness.

Table 8 Comparison of Electric Arc Furnace and Integrated Steelworks (Shirlee Algire)

Inputs	Units	BOF route	EAF Route
Coal/Coke	g	686	78
Flux	g	60	70
Iron Ore	g	1725	
Iron and Steel Scrap	g	148	1065
Water	litre	11.5	1
Air	m^3	0.0012	
Total Primary Energy	MJ	21.71	7.43
Outputs	**Units**	**BOF route**	**EAF Route**
Steel Product	g	1000	1000
To Air			
CO_2	g	1987	365
CO	g	25.9	3
SO_2	g	2.1	1
NO_x	g	2.4	0.8
Methane	g	0.2	0.7
Other hydrocarbons	g	14	0.1
H_2S	g	0.1	0
VOCs	g	0.1	0.1
Particulates	g	1.8	0.3
Water vapour	g	7.5	0
To Water			
Chloride	g	0.3	1
Suspended solids	g	0.1	0.1
NH_3	g	0.1	0
Waste water	litre	0.28	0.21
To Earth			
Mining Tailings	g	2394	
Recovered Materials			
Slags	g	25	11
Dust and Sludge	g	10	
Tailings and fines	g	17	
Other recovered materials	g	13	12.5
Total Waste	**g**	**1520**	**122**

5.2 Green Concrete

Concrete is one of the most widely used construction materials in Hong Kong. The production of concrete, which requires the addition of cement, generates carbon dioxide, a greenhouse gas that contributes to global warming. A reduction in the use of cement can make a significant difference in protecting the environment. Numerous researches have been performed on this issue. The use of filler technology has been demonstrated to contribute to improve environmental performance of concrete, by improving the cohesiveness and dimensional stability, and reducing its cement consumption (Gary S K Chou). Use of recycled aggregates also significantly improves the environmental performance of concrete (Gary S K Chou). Within this process, development of green concrete paver is also being carrying out by K.Wah Construction Materials (Nick Lewis). As a leading company in paver production technology and application in Hong Kong, K.Wah Construction Materials uses natural aggregates, construction & demolition waste, recycled glass and coloured pigments to create aesthetically pleasing, practical, and hard wearing paving solutions (Nick Lewis). 'Life pave' program of K.Wah Construction Materials demonstrates a "cradle to grave and back to cradle" approach to sustainability, by reducing impacts on virgin resources through producing concrete pavers containing up to 65% recycled element (Nick Lewis). Compared with clay pavers, concrete pavers use less energy to produce and can use locally recycled wastes such as C&D and glass bottles (Nick Lewis). K.Wah Construction Materials is also promoting permeable paving system in Hong Kong. Permeable paving is suitable for both pedestrian and vehicular traffic and can be used for tree surrounds, driveways, pathways, car parks, pool surrounds and decorative areas (Nick Lewis). In application, permeable paving is more 'flexible' than concrete, strong, permeable, UV stable, 'bound' so there's no loose gravel, and can filter contaminates from surface water run-off. Many pollutants are substantially removed and treated within the permeable system (Nick Lewis).

5.3 Green Reclaimed Asphalt Pavement

According to the speaker (Nick Lewis), K. Wah Construction Materials suppliers the green reclaimed asphalt pavement which is one of most recycled materials, with millions of tons of asphalt pavements being removed, recycled and re-laid every year. With recent changes to specifications allowing green claimed asphalt pavement to be used, Hong Kong has now joined a long list of participating countries and regions.

Basically, contractors and suppliers of asphalt are able to procure from K.Wah Construction Materials, the more carbon friendly reclaimed asphalt pavement in-situ replacement, whereby the material is removed, re-worked and replaced in one continuous operation; or the off-site reclaimed asphalt pavement whereby the material is removed back to the asphalt plant, processed, and then a percentage of it is used in the production of new material. Reclaimed asphalt pavement presents GHG benefits such as reduction of the use of ‘virgin’ materials (i.e., aggregates, sand and bitumen), reduction of the need to dump milled and excavated asphalt pavement in public tips as a waste product, re-use of up to 30% of reclaimed asphalt pavement per ton in production of new material, significant reduction of embedded carbon (Nick Lewis).

5.4 Ground Granulated Blast Furnace Slag (GGBFS)

GGBFS is a cement substitute, manufactured from a by-product of the iron-making industry (Nick Lewis). Within the current European cement standard EN 197-1, seven cements are listed which may contain GGBFS contents of up to 95% (Nick Lewis). Calculations made by the German Institute for Building Materials Research have shown that CO_2-emissions were reduced by about 22 million ton in the cement industry (hence in the industry as a whole) in Europe in 2011, because of the use of 24 million tons of GGBFS (Nick Lewis). The reduction is equivalent to the Kyoto objective of countries like Belgium and the Netherlands together. Thus, GGBFS contributes positively to the sustainability of the whole European cement industry and in the fight against climate change. GGBFS is more sustainable than other cement substitutes such as pulverized fuel ash (Nick Lewis). Compared to the ordinary Portland cement (OPC), GGBFS is a lower-carbon construction material, and as a partial OPC replacement, one ton of GGBFS will save almost one ton of CO_2 (Fig.9).

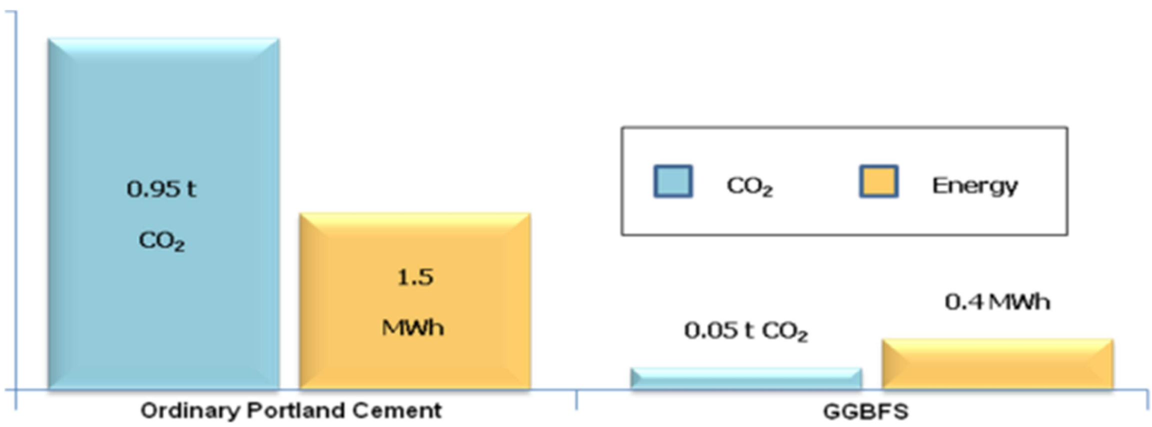

Figure 9 Comparison of energy and embedded CO_2 per ton of OPC & GGBFS (Nick Lewis)

As concrete structures are getting larger, GGBFS has been used in many cases to eliminate thermal cracking. It also has excellent workability, density, durability and chemical resistance (Nick Lewis). The GGBFS is considered as an excellent substitute of ordinary cement and can significantly contributes to reduce emission in construction industry in Hong Kong.

5.5 Challenge of Construction Greening and Cost-effectiveness

Facing increasing demand of construction materials, the challenge for wider construction sector is to meet this demand while reducing the environmental footprint over a construction's entire life cycle, and across the entire building materials value chain. The main concern is how to deal with green design and procurement to reach the optimum construction combination, since a green material is not necessary cost-effective. The situation in Hong Kong remains complex with regard to the requirements for number of construction materials. For example, the change in BEAM Plus to require regionally sourced raw components of steel drives Taiwan to be the only eligible (Shirlee Algire). According to this change, the net impact is in an order for 1000 MT of steel purchased, the total quantity of scrap contained falls from 180 MT to 100 MT (decrease of 44%), which compromises the supply of recycled scrap billet. The reality is that contractors need to balance price and surety of delivery which is at risk by specifying only one or two suppliers. Contractors' scope of using green construction materials / products is largely prescribed by clients through their specifications, and in the competitive world of construction, numerous clients are not currently prepared to pay the cost premiums (Shirlee Algire; Gary S K Chou). Similarly, many contractors and suppliers are not eager to adopt green construction while compromising their profit. However, as long as practicable, some of contractors, in particular Gammon Construction Ltd and Chun Wo Development Holdings Ltd, are still committed by their sustainable procurement policy to choose the material with the lowest lifecycle impact (Shirlee Algire, Gary S K Chou). They are also committed to working with the supply chain to make green procurement more practicable. Another challenge is the insufficient knowledge of the capital costs and the benefits of green building and construction material solutions. Investors are not willing to pay higher initial costs, even though it would result in lower resource expenditures over the long-term. Furthermore, while green building schemes have been implemented in Hong Kong, there is a lack of a comprehensive green labelling scheme specifically designed for building materials / products to support the local building and industry. Such situation also curbs the promotion of green building and construction materials.

6 Conclusions and Perspectives

Moving towards green building and construction materials is a global environmental and economic imperative and represents a huge economic opportunity for construction industry in Hong Kong. The holistic approach must be to embed greening throughout the entire construction process from design to demolition, and with all leading clients, contractors, and material suppliers. Appreciable innovative actions have been taken in this field. Rapid development of BEAM provided recognition for improved building performance to lot of landmark properties in Hong Kong, Beijing, Shanghai and Shenzhen, comprising over 9.5 million m^2 of spaces and 50,000 residential units. Integrated into construction materials assessment, BEAM Plus contributes to promote sustainable use of natural resources, minimize waste generation, encourage waste recycling, conserve landfilling resources, protect ozone layer and minimize greenhouse gas emission. Moreover, development of construction material life cycle carbon emission assessment, testing, certification and green procurement strongly support construction greening in Hong Kong.

In sight of existing related obstacles and difficulties, Hong Kong must continue to develop strategies for green building and construction materials and make green more practicable and accessible to all construction stakeholders. Within this process, favorable conditions exist and will undoubtedly drive innovation and excellence in local construction greening trend in near future. It is expected in long term that China will become a large producer of key construction materials in the world and will change technology to take advantage over many other producers. Given the 800km range of the BEAM Plus requirement, this will enable more materials to qualify for the regional credits. There is also a move to encourage a recycling factory in Hong Kong to supply local demand of construction aggregates. On the other hand, the development and implementation of local construction materials label will enhance construction greening in Hong Kong with the development of recycling industry. This will add value and benefit Hong Kong in long-term waste management, infrastructure maintenance and green construction needs.

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7 LEWIS Nick, Director, Business Development, Engineering, HSE& Sustainability, K.Wah Construction

8 LO W K, Member (Engineering Functional Constituency), Legislative Council, HKSAR

9 NG John, Director, Hong Kong Green Building Council and Director and Vice-Chairman, BEAM Society Ltd

10 NG Thomas, Professor, Department of Civil Engineering, The University of Hong Kong

11 POON C S, Professor, Materials Aspects Panel Chair & Green Building Faculty, Hong Kong Green Building Council

12 WONG K S, JP, Secretary for the Environment, Environment Bureau, The Government of the HKSAR