Low Carbon Construction Implementation in a Public Housing Development and the Implication to the Life Cycle Decision Making Tool

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ABSTRACT

A combined Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) Study was undertaken to quantitatively measure the environmental impacts and cost implication of (1) an existing public housing block (50-year life); (2) an existing private sector residential block (50-year life) and (3) Integer Concept Tower (50-year and 75-year life) in 2003. The study measured the environmental impacts generated from the whole building life cycle stages including, raw material extraction, building material manufacturing, transportation, building operation, repair and maintenance, and disposal. However, the study did not quantitatively measure the environmental impact of on-site activities, except construction wastage. In 2013, Low Carbon Construction Plan was conducted for a new local public housing development in Hong Kong. The project develops the first low-carbon construction implementation plan for new housing development. The analysis included the entire 2.5-year construction period including (1) supply-chain; and (2) on-site construction. The project accounted and reported of the potential greenhouse gas emissions, possible offsets and removals for construction contract stage at the new public housing development in Hong Kong. This paper will report the findings and carbon reduction of the low-carbon construction measures and the implication of the life cycle carbon footprint of recent housing development in Hong Kong.

Keywords: *climate change, green construction technology, life cycle assessment*

1. INTRODUCTION

1.1. Life cycle assessment study in 2000s and the limitation on addressing public housing development in Hong Kong in 2010s

A combined Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) Study quantitatively measured the life-cycle energy consumption, greenhouse gas emission, waste generation and cost implication of three 40-storey residential towers in Hong Kong - (1) an existing public housing block (50-year life); (2) an existing private sector residential block (50-year life) and (3) the Integer Concept Tower (50-year and 75-year life) in 2003 (Figure 1) (Amato, et al., 2003). One of the environmental indicators the study measured was the greenhouse gas emission generated from the whole building life-cycle including, raw material extraction, building material manufacturing, transportation, building operation, repair and maintenance, and disposal stage. Figure 2 shows the life-cycle greenhouse gas emission per construction floor area of the three 40-storey residential tower types. The building operation stage and repair and maintenance stage of the existing public housing block (50-year life) emitted 56% and 25% of the life-cycle greenhouse gas emissions, respectively. On the other hand, the building operation stage and the repair and maintenance stage of the existing private-sector residential block (50-year life) emitted 38% and 36% of the life-cycle greenhouse gas emissions, respectively. The result shows that the 50-year operational stage of existing public housing block emitted higher proportion of greenhouse gas emission (56%) than the existing private sector residential block (38%). It is because existing public housing block had a higher population density than private sector block in 2000s. The study concluded that energy efficiency, renewable energy generation, varying and improving how the housing to be run and maintained could greatly reduce the overall life-cycle environmental impacts and life cycle cost of the existing public housing block (Amato, et al., 2003).

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Figure 1: (1) Existing public housing block; (2) Existing private sector residential block and (3) The Integer Concept Tower (left to right) developed in 2000s in Hong Kong

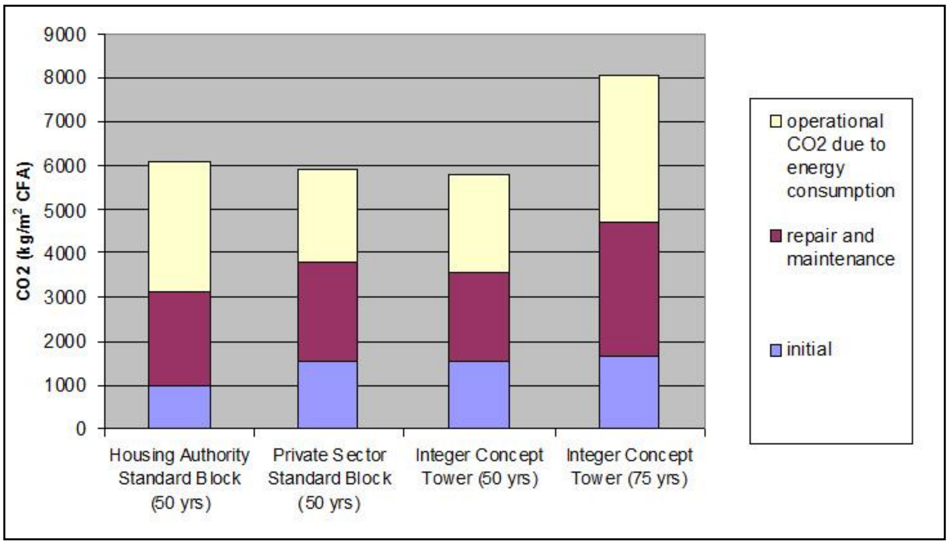

Figure 2: Life-cycle greenhouse gas emission per construction floor area of three residential tower types (Amato, et al., 2003)

In view of the conclusion of the above study, the newly-designed public housing blocks developed in 2010s incorporated numerous energy-efficient features and renewable energy system to reduce greenhouse gas emissions from the building operational stage. For instance, new public housing development completed in 2013 applied electronic ballast, T-5 fluorescent tubes and LED lighting on the lighting of the communal area. A two-level lighting control system was deployed in the lighting in the lift lobbies and corridors. The system could sustain a lower but acceptable level of lighting under normal conditions and could switch on the extra lighting when required. Those lighting control had reduced the energy consumption of lighting in communal area by 30% (Hong Kong Housing Authority, 2015). Renewable energy system in form of a photovoltaic system and lift with regenerative power generated 2% of energy consumption of the communal building services installation of the public housing block. Those energy efficiency measures reduce the carbon footprint of the building operation of newly-designed public housing developed in 2010s.

Figure 2: Two-level lighting control system (normal mode: 50 lux; triggered mode: 85 lux) (left); Roof photovoltaic system in a public housing development in 2010s (right)

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In view of the construction stage, the previous life cycle study did not measure the greenhouse gas emission of on-site activities, except construction wastage. The construction contract period, including supply chain and site operation, can contribute a lot of the life-cycle greenhouse gas emissions of a public housing development.

1.2. Low carbon construction plan of public housing development

In 2013, Low Carbon Construction Plan was completed in a new local public housing development. The construction was commenced from 2010 and completed at 2013. The new public housing estate is comprised of 6 housing blocks of 35-40 storey residential buildings accommodating 5,204 units, car park, commercial centre, community youth service centre and elderly day centre.

This paper will report the findings and carbon reduction of the low-carbon construction measures and the implication of the life cycle carbon footprint of the new housing development in Hong Kong. Accounting covers the whole construction contract period, including:

- Supply Chain
    - Raw-material extraction,
    - Transportation from the extraction site to factory,
    - Building-material manufacturing in factory
    - Transportation from factory gate to the construction site; and
- Site Operation – construction activities in the local housing development

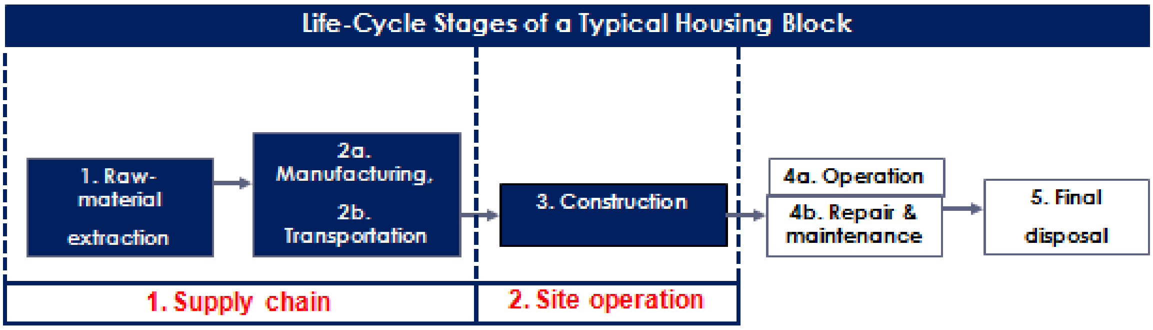

Figure 3: Life cycle stages in the construction contract period

2. ACCOUNTING METHODOLOGY AND RESULT OF CARBON REDUCTION

The accounting of greenhouse gas emission for the Low Carbon Construction Plan began in March 2011. The study took the below accounting methodology for the reduction of the low-carbon measures of the new local public housing development. Table 1 includes the low-carbon construction measures of the Low Carbon Construction Plan, their accounting methodology and their carbon reduction.

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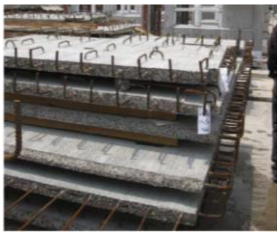
	Low Carbon Construction Measures	Accounting Methodology	Carbon Reduction
	• Volumetric Precast Bathroom (VPB) • Volumetric Precast Kitchen (VPK)	Life Cycle Assessment (Cradle to Site Stage) a. Raw-material extraction b. Transportation from extraction site to prefabrication factory c. Manufacturing of VPB/ VPK and precast elements at prefabrication factory d. Transportation of VPB/ VPK and precast elements from prefabrication factory to construction site	2854 tonne CO_2-e
	• Precast façade • Precast wall • Precast stair • Precast tie beam • Precast landing • Precast refuse chute • Precast beam and column for carpark		4329 tonne CO_2-e
 ; 	• Semi-precast slab with fabric reinforcement	Life Cycle Assessment (Cradle to Site Stage) a. Raw-material extraction b. Transportation from extraction site to prefabrication factory c. Transportation of fabric reinforcement from Hong Kong to prefabrication factory d. Manufacturing of prefabrication elements at prefabrication factory e. Transportation from prefabrication factory to construction site	1400 tonne CO_2-e
	• Marine mud material into useful building element	The accounting measured the reduction of carbon footprint for transportation of the paving materials made in factory to site and the transportation of waste marine mud to public fill and the electricity consumption of convey belt and mixer.	487 tonne CO_2-e
	• Early electricity supply from grid	The accounting measured the reduction of carbon footprint between electricity from grid and from diesel generator during construction period.	1866 tonne CO_2-e

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	• Recycling and waste sorting facilities on each block	The accounting measures the reduction of carbon footprint from recovery of materials from waste recycling and sorting. The waste recovered includes steel bar, concrete, plastic bottles, paper and aluminium cans.	2394 tonne CO_2-e
Reuse of concrete to produce temporary site drain  Waste sorting facilities	• Volume of reused water and water saving	The accounting measures the reduction of carbon footprint from water reuse for vehicle washing facilities and dust control during construction period and water saving	3.8 tonne CO_2-e
	• Diesel bobcat\ forklift/ truck with biodiesel fuel (B5)	The accounting reports the carbon emission reduction due to the use of biodiesel B5 for replacement of normal diesel. Biodiesel was blended in the diesel. In Hong Kong, most of the biodiesel is sourced from the collected cooked oil from restaurant. In Hong Kong situation, biodiesel is more environmental friendly as it reuses waste cooked oil from restaurants.	0.5 tonne CO_2-e
	• Solar hot water system for staff showering	The accounting reports the reduction in carbon emission when using solar hot water system in addition to electrical water heater.	4.8 tonne CO_2-e
	• Food waste decomposer for staffs	The accounting reports the carbon reduction from food waste decomposer in compare to landfill decomposition. Food-waste-decomposer was adopted to convert the food waste into fertilizer which can be used in tree planting or donated to nearby school or communities.	0.4 tonne CO_2-e
	• Tree planting for hoarding greening	The accounting reports the carbon absorption from trees pre-planting on construction site.	2.2 tonne CO_2-e
	• Electric site car	The accounting reports the carbon reduction in carbon emissions when using electric car to replace petroleum site car as contract car.	2.2 tonne CO_2-e
	• Computer Document	The accounting reports the carbon reduction in carbon emissions in paper	0.9 tonne CO_2-e

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	Management System	saving.	

Table 1: Low carbon construction measures of the low carbon construction plan and accounting methodology

3. CARBON REDUCTION FROM THE LOW CARBON CONSTRUCTION PLAN

Low Carbon Construction Plan reduces a total of 13,345 tonne CO_2-e for the construction contract period of the new public housing development which accommodates over 5,000 residential units. The total carbon reduction from Volumetric Precast Bathrooms, Volumetric Precast Kitchens, prefabrication elements and semi-precast slabs are 8,583 tonnes CO_2-e. Most of the carbon emission reduction result in carbon emission in raw-material extraction stage. It is because far less formwork and better quantity and quality control occur in prefabrication manufacturing in a factory environment. For instance, 12 sets of steel formwork were used during the whole production period to produce 4,910 numbers of Volumetric Precast Bathrooms, which is far less than the quantity of formwork required in in-situ construction. (Wong & Tang, 2012) Some low-carbon construction measures are implemented in small scale. Examples are diesel bobcat\forklift\truck with biodiesel fuel (B5), electric site car, tree planting for hoarding greening and food waste decomposer for staffs. The carbon reduction can potentially be increased if all diesel fuels would be replaced with biodiesel (B5) and all site cars would be replaced by electric cars in the future project.

4. IMPLICATION TO THE LIFE CYCLE CARBON FOOTPRINTS GREENHOUSE GAS EMISSION OF HOUSING DEVELOPMENT

The new local public housing development adopts both low-carbon construction measures and energy-efficient features. The pioneer low-carbon construction approaches include Volumetric Precast Bathroom, Volumetric Precast Kitchen, various precast construction elements; semi-precast slab; marine mud building elements; early grid connection; recycling and waste sorting facilities; reused water and water saving; use of biodiesel; solar hot water for staff showering; food waste decomposer; hoarding greening and electric site car. The energy-efficient features include electronic ballast; T-5 fluorescent tubes; LED lighting; two-level lighting control system for lift lobbies and corridors; renewable energy system in form of a photovoltaic system and lift with regenerative power. Both low-carbon construction measures and energy-efficient features reduce the carbon footprint of both construction and building operation stages.

In consideration of the carbon emission from both supply chain, site operation and building operation, Figure 4 shows the comparison of the life cycle greenhouse gas emission per construction floor area of the public housing block of 2003 study and the new local housing development with Low Carbon Construction Plan completed in 2013.

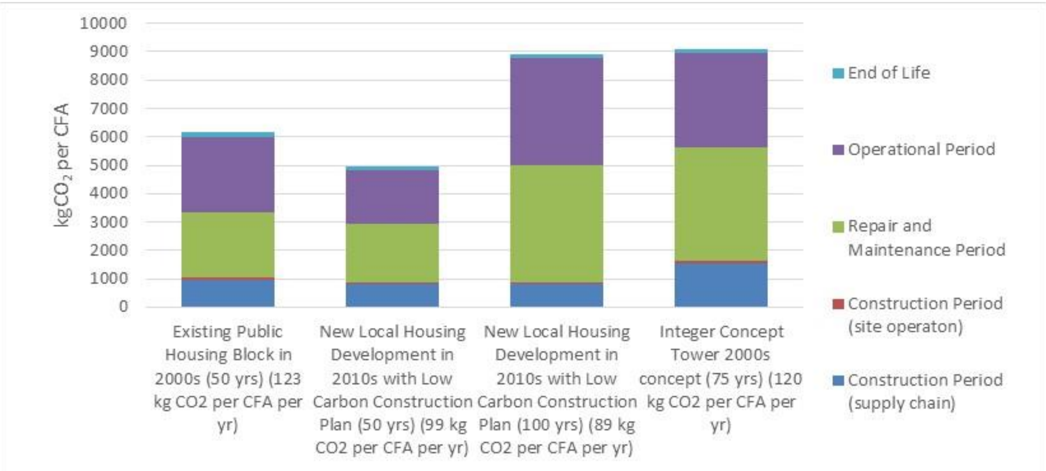

Figure 4: Life cycle greenhouse gas emission of the new local housing development with low-carbon construction plan and energy-efficient measures compared to existing public housing block and integer concept tower developed in 2000s

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The life-cycle greenhouse gas emission of the new local housing development accounts both carbon reduction of Low Carbon Construction Plan, energy efficiency and renewable energy systems. The life-cycle greenhouse gas emission can be reduced by 19.4% under 50 years of operational life with Low Carbon Construction Plan, various energy efficiency and renewable energy systems. Low Carbon Construction Plan reduces 15.9% of the greenhouse gas emissions of construction contract stage while energy efficiency and renewable energy system reduce 29% of the greenhouse gas emissions of building operational stage. The operational life of new housing buildings could be at least 100 years according to recent research and development work (Mak, 2010). In consideration of the extended 100-year life, the indicator in form of life-cycle greenhouse gas emissions per construction floor area per year can be adopted to compare building with different operational life. The local housing development in 2010s with Low Carbon Construction Plan and energy efficiency measures with extended 100-year life can reduce life-cycle greenhouse gas emission to 89 kg per construction floor area per year while the life-cycle greenhouse gas emission of public housing block (50-year life) and Integer Concept Tower (75-year life) in 2003 study emitted 123 kg and 120kg per construction floor area per year. 28% and 26% greenhouse gas emission can be reduced from the Low Carbon Construction Plan and energy efficiency measures.

5. CONCLUSIONS

This paper takes into account the carbon reduction from the Low Carbon Construction Plan and the implication of the life-cycle carbon footprint of housing development in Hong Kong. Most of the carbon reduction come from prefabrication plan for the local public housing development. The carbon reduction can potentially be increased if the small-scale measures can apply in project-scale. Low Carbon Construction Plan reduces 15.9% of greenhouse gas emission of construction contract period. The study does not take into consideration the implication from varying and improving how the housing is run and maintained. The study does not take into consideration the life-cycle cost implication of the Low Carbon Construction Plan. Analysis can be made on the cost-effectiveness of various low-carbon construction measures. Guidelines can then be set up to direct the whole construction industry towards sustainable and low carbon construction in a cost-effective manner.

6. ACKNOWLEDGMENT

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