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Carbon-emission Considerations in Built Heritage Conservation to Address the Climate Change

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Abstract

A great deal of manpower and material resources has been devoted to protect the historical and cultural city by the government. As early as 1987, the "Washington Charter" proposed that "the protection of historic urban areas should become an integral part of the overall effect of social and economic development, and also should be taken into account at all levels of urban planning and management plans." In the process of modernization, only if the development will be integrated into the entire city and its operating mechanism, it is possible to pursue the more efficient and slow-release cultural values by a spirit with more rationality and responsibility in a wider geographical area. Therefore, the establishment of a new type of heritage conservation model not only has a very broad prospect, but also has a profound and lasting significance.
In Hong Kong as a fast-moving economy and dense city, up to now, a total of 1444 heritage sites on the key protection list have been publicized by The Antiquities Advisory Board in Hong Kong. Compared to new construction works socially, conservation projects help to retain the sense of place and cultural heritage of a community, and can conserve buildings that might otherwise be obsolete or prematurely demolished. Environmentally, these projects lessen the demand for new resources through reusing part or all of a building's fabric, reducing construction debris and minimizing ecological footprint through the reclamation of carbon embodied in existing materials. However, economically the cost of these projects may be more or less than that of the new-build, depending on the extent of conservation works, latent conditions of the project and complexities involved in construction. New build projects, of course, have fewer constraints and can offer higher levels of utility through new design and increased development intensity. This study aim to take into consideration of carbon emission to quantified the merits of reusing heritage buildings over new construction from an environmental perspective with due consideration of construction cost to support decision-making for sustainable heritage conservation.

Keywords: Carbon-emission, Built Heritage, Conservation, Environmental, Climate Change

1. Introduction

Since the industrial revolution, a lot of current crisis come into being naturally, such as the massive energy consumption, ecological deterioration, disappeared culture and indifferent human feelings — currently, one of the most severe problems the human society facing is global warming. This is believed to be caused by the emission of greenhouse gases, especially carbon dioxide. Increasingly amount of CO2 has been released due to the human economic activities like the combustion of fossil fuel, change of the land use method, etc. (IPCC, 2007). The human society attempt to find a balance in the game of protection and development, which not only protects the unique patterns and traditional way of life but also allows the residents living here to enjoy the convenience that modern life has brought. Establishing a sustainable environment is conducive to improve the urban vitality and eliminate social problems produced in the process of urban development.

Compared to new constructions, conservation projects can reuse the existing constructions' fabric, which can reduce construction debris through the reclamation of carbon embodied in the existing materials. The problem of comparing carbon emissions between new buildings and the refurbished buildings have aroused the society's concern. On the aspect of sociology, refurbishment projects help preserve the local and cultural heritage of the community for the benefit of future generations and protect buildings that may be outdated, disrepair or prematurely demolished (Yung et al., 2014). On the aspect of ecology, these projects reduce the need for new resources by reusing some or all of the structure of the buildings, reducing debris sent to the landfills and minimizing debris by recycling the carbon contained in existing materials — the ecological footprint of buildings.

This study selected a series of new projects and renovation projects completed in Hong Kong in the past five years as the research object, using the method of building material embodied energy used in Australian to calculate the average carbon contents per square meter of different types of projects. This study not only use this model outside Australia but also provides methods and ideas for the calculation of carbon emissions in Hong Kong's context. The data confirmed that the carbon emissions in the building renovation process are much lower than that of new buildings, and can effectively reduce the impact of building embodied carbon on the climate.

2. Methodology

This study uses the case analysis method. The bills of quantities (BQ) for new-built and refurbished buildings is collected from two quantity surveying consulting companies in Hong Kong, including a list of building materials and their corresponding quantities. These projects are all independent and have no connection with each other.

By comparing the international methods of calculating embodied carbon, an appropriate method- the hybrid input-output model is found which can apply equally to both new-built and historic buildings (Lenzen and Murray, 2001; Treloar, 1994).

Under the framework of the calculation of embodied carbon for new buildings and historic buildings, the following approach is used to calculate the specific embodied carbon from the BQs.

In the calculation process, the amount of material is converted into mass and multiplied by the Embodied carbon emission factor (ECEF) to obtain the sum of all materials EC. ECEF are largely fixed in the same countries or regions (Yeo, 2016).

Material quantity × Embodied carbon emission factor (ECEF) = Embodied carbon (EC)

An example of the carbon calculation for a specific building component involves breaking down the component into its critical carbon elements:

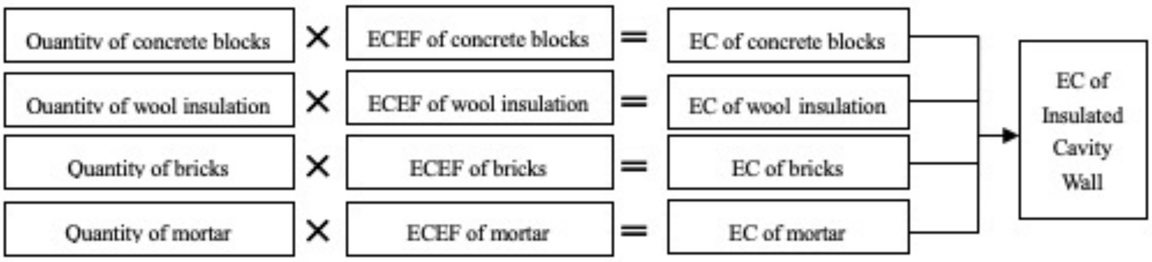

Figure 1: Carbon Calculation for a Specific Building Component

3. Case study

The 26 projects' BQs are collected from two quantity surveying consulting companies in Hong Kong. These projects included 14 new buildings and 12 refurbished buildings. The new buildings are all residential, and the refurbished ones involve structural reinforcement and decorative renovation. **Table 1** and **Table 2** show the results of embodied carbon (EC) and the corresponding costs per construction floor area (CFA) of each of the new construction and renovation of the sample buildings (Longston, 2018).

Table 1: New-build projects *(Source: Langston et al. 2018)*

ID	CFA	Cost	EE	EE/CFA	EC/CFA	Cost/CFA	Comment
1	25,477	588	362,195	14.22	836	23,093	
2	107,663	3750	1,181,816	10.98	645	34,835	
3	19,735	748	222,860	11.29	664	37,880	
4	17,901	1097	257,327	14.38	845	61,271	low-rise
5	164,533	4827	1,910,130	11.61	682	29,339	
6	384,137	14,165	4,430,499	11.53	678	36,875	
7	53,969	2000	723,626	13.41	788	37,067	
8	240,846	6963	2,929,006	12.16	715	28,912	
9	146,775	6689	2,644,634	18.02	1059	45,574	
10	15,785	1236	235,325	14.91	876	78,277	low-rise
11	48,496	2113	533,310	11.00	646	43,570	
12	74,292	2532	968,524	13.04	766	34,086	
13	192,047	6749	2,439,680	12.70	747	35,145	
14	179,725	6365	2,170,321	12.08	710	35,415	
			Mean:	12.95	761	40,096	

Notes: CFA = construction floor area (m^2); Cost = HKD (millions); EE = embodied energy (GJ); EC = embodied carbon ($kgCO_2e$); EE>EC conversion = 58.78 $kgCO_2e/GJ$.

By double checking the data, Project 4 and Project 10 are low-rise residential projects. As the CFAs of both projects are relatively low compared with the relatively high EC value of some elements, such as foundation, the two projects are removed from the sample. The CFA data of Project 23 data is missing and therefore not used. Project 21, 24, 25 and 26 are all decorative works without structural reinforcement works. These projects are not comparable to the new-build buildings so the data is not used. Data for Project 4, 10, 21, 23, 24, 25, and 26 are removed.

Table 2: Refurbish projects *(Source: Langston et al. 2018)*

ID	CFA	Cost	EE	EE/CFA	EC/CFA	Cost/CFA	Comment
15	23,161	253	115,684	4.99	294	10,905	
16	28,150	992	257,119	9.13	537	35,236	
17	2900	158	26,009	8.97	527	54,410	
18	4712	107	38,376	8.14	479	22,784	
19	4800	64	46,299	9.65	567	13,300	
20	24,490	571	183,204	7.48	440	23,316	
21	275	3	2095	7.62	448	11,891	decorative
22	18,294	577	203,727	11.14	655	31,557	
23	n/a	71	4199	n/a	n/a	n/a	façade
24	610	3	3485	5.71	336	5082	decorative
25	10,155	13	70,617	6.95	409	1325	decorative
26	4010	35	29,741	7.42	436	8728	decorative
			Mean:	7.93	466	19,867	

Notes: CFA = construction floor area (m^2); Cost = HKD (millions); EE = embodied energy (GJ); EC = embodied carbon ($kgCO_2e$); EE>EC conversion = 58.78 $kgCO2_e$/GJ.

In refurbishment projects, building materials such as steel and wood can be reused on site. This effectively reduced energy emissions during the production and transportation of new building materials. **Figure 2** combines new and refurbished buildings. The research results show that the carbon emissions of refurbished buildings that reuse building materials are much lower than those of new buildings.

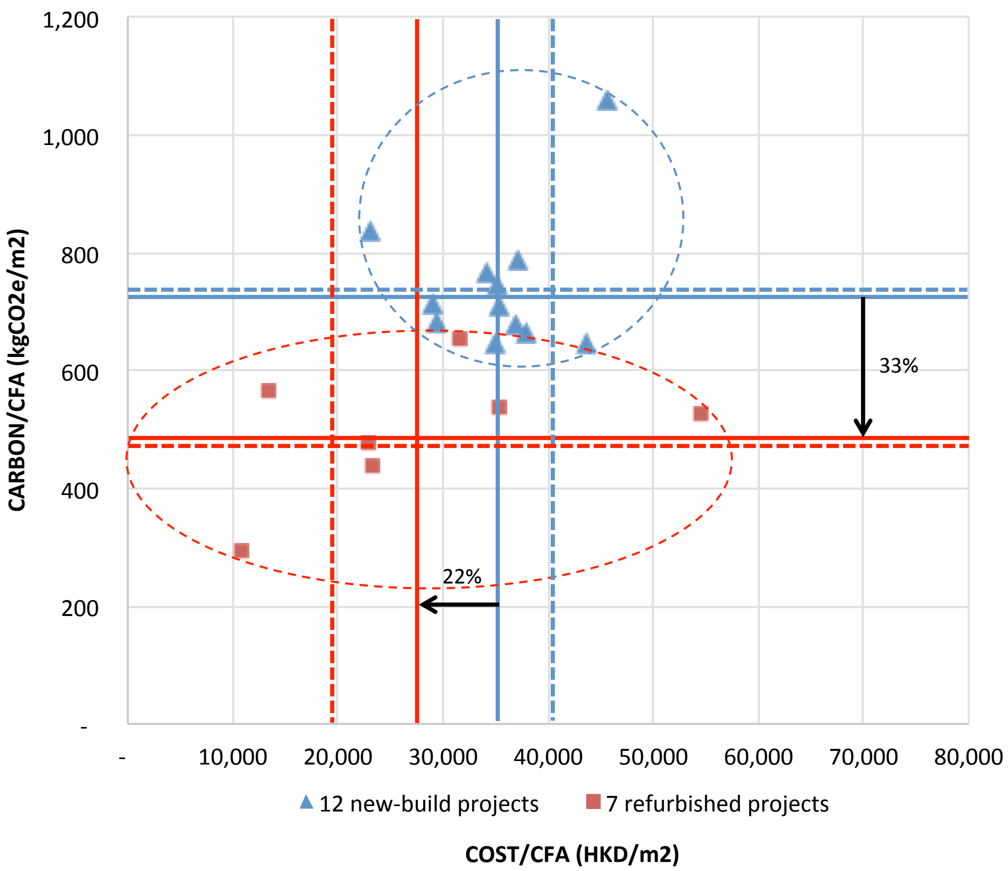

Figure 2: New-build versus Refurbishment EC and Cost Comparison *(Source: Langston et al. 2018)*

Although the construction technologies of each project are not necessarily the same, compared with different sub-divisional works, it can be found that the embodied energy of new and old buildings are different in foundation and substructure works. Refurbish projects can reuse existing foundations. There is no carbon emission from the foundation and substructure works in the refurbishment project. Similarly, refurbished projects can reuse reinforced concrete sections, so the carbon emissions caused by this section are significantly different between new and refurbish projects. **Table 3** shows that the rational use of existing buildings can effectively reduce carbon emissions.

Table 3: The EE Proportion of Foundation Works and Reinforced Concrete Works

ID	EE of Foundation and Substructure Works / Total EE	EE of Reinforced Concrete Works / Total EE
1	2.91%	8.91%
2	4.21%	2.53%%
3	-	2.82%
5	2.48%	17.51%
6	5.40%	13.50%
7	6.17%	10.40%
8	4.82%	15.68%
9	27.92%	22.43%
11	4.60%	7.18%
12	2.83%	11.80%
13	5.78%	13.98%
14	-	18.54%
15	0.00%	0.28%
16	0.00%	1.00%
17	0.00%	2.06%
18	0.00%	2.36%
19	0.00%	1.97%
20	0.00%	0.00%
22	0.00%	2.94%

4. Conclusion

The research result indicates that the EC of renovation projects is reduced by 33% compared with that of new buildings. It shows that the carbon emissions of refurbished buildings are generally lower than the new-built ones in these cases. Under the premise of ensuring safety, renovation of old buildings can not only reduce carbon emissions but preserve traditional urban features, which has significant economic, social and technology innovative benefits. The research provides a feasible scheme for reducing the carbon implications of construction practices in Hong Kong.

This study is a beneficial trial of general application for the expected saving or justified expenditure on construction costs while achieving low embodied carbon through innovative reuse strategies. The results serve as a useful reference for other countries to develop their own specific frameworks to evaluate embodied carbon vs. construction costs. The findings in this study enable recommendations to be made about industry practice and policy on heritage conservation contributing towards mitigating climate change.

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