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Sustainable Design and Operation of Construction Site Offices

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ABSTRACT

Site offices are essential provisions for all construction works including building and civil engineering projects. Their design and operation are different from normal buildings since they are temporary structures and need to cater for the particular site conditions. If sustainability and environmental performance are not considered adequately in their design and operation, then significant amount of energy and resources will be wasted and the productivity of the workers will also be affected.

This paper reports a research study to assess and investigate sustainable design and operation of construction site offices in Hong Kong. Four existing site offices have been studied and evaluated. Useful information was obtained to assist the planning and design of another new site office which is a pilot project aiming at promoting green and sustainable design. Analysis of thermal performance of the existing site offices indicates that there is lost of saving opportunities in the current practices. Evaluation of the lighting systems also shows that a green site office can operate with lower costs and increased worker satisfaction. As construction site offices have short life spans, usually 2 to 4 years, their design and operation will present a challenge to resource efficiency and life cycle analysis.

Keywords: Construction site offices, sustainable design and operation, Hong Kong.

1. INTRODUCTION

The building and construction sector plays a major role in the sustainability of a society and the world (Halls and Rovers, 2003). To reduce the negative environmental impact of construction activities and improve the operation of construction sites, it is essential to review and assess the primary issues and elements of the construction process. One of the important factors is the construction site offices which are often treated as temporary facilities and are overlooked during the building process (Hui and Law, 2003).

In the past decade, safety, health and environmental issues on construction sites have attracted more and more attention. To promote environmental good practice on site, relevant guidebooks have been developed, such as Building Employers Confederation (1994), Coventry and Woolveridge (2002), HKCA (2002) and Venables, R., et al. (2000). The main areas of concern include good site management, environmental nuisance abatement, and environmentally friendly construction practices. However, relatively little information is provided on the design and operation of construction site offices which are indispensable facilities for almost every building and construction project.

This paper reports a research study to assess and investigate sustainable design and operation of construction site offices in Hong Kong. Four existing site offices have been studied and evaluated from building design and environmental points of view. Useful information was obtained to assist the planning and design of another new site office which is a pilot project aiming at promoting green and sustainable design. It is hoped that better information can be established to help people understand the building performance, identify the key life-cycle parameters and promote environmentally responsible practice for the site facilities.

2. CONSTRUCTION SITE OFFICES

Site offices are essential provisions for all construction projects including building and civil engineering projects. They are usually erected or put on the site at the beginning of the project and will be dismantled and removed when the project is completed. Figure 1 shows some typical examples which include a pre-fabricated structure and a container-based structure. Nowadays, these two types of site offices are commonly found in Hong Kong because they are quicker and easier to erect than permanent buildings and the manufacturing and construction methods are less expensive.

Pre-fabricated Container-based

Figure 1. Examples of construction site offices

The strategy to design and operate site offices are different from normal permanent buildings since they are "temporary" structures and need to cater for the particular conditions on the site. In Hong Kong the construction methods and materials used for site offices are evolving in the past few decades. In the 1980s, site offices are usually constructed using timber or wooden materials. Starting from the 1990s, it becomes very common to employ a combination of cargo or shipping containers with connecting structural members and interior finishes. In recent years, prefabricated structure made of metal panels came into the market and they can be found in many construction projects.

Hong Kong has a world-renown container port and new or second-hand container units are not difficult to find. Therefore, cargo containers are often used as the building material or modified to form container buildings or storage units. Usually, second-hand or recycled containers are adopted for constructing the site offices. Even though some second-hand units are slightly salt-stained, they are still incredibly durable and waterproof. As a basic unit the container can be stockpiled for use as required and is easily transported by road and rail.

Prefabricated buildings have a substantial market potential and are characterised by increasing levels of specification. With modular construction and demountable light-weight components, these buildings are manufactured off-site and will be assembled or put into place for the site office. This can provide better quality control and greater design flexibility. But the price is often higher than container-based one.

From both environmental and economic points of view, procurement and usage of the site office for such a short period (2 to 4 years) will present a challenge to resource efficiency. To extend the lifetime of the structure and reduce disposal costs, it is not uncommon for construction companies to reuse or resell building components from previous site offices.

3. CASE STUDIES IN HONG KONG

To investigate the influencing factors and current conditions, four existing site offices were selected as the target. The general information of these site offices is summarised in Table 1. The gross floor areas range from 282 m^2 to 547 m^2 and all of them are of two storeys high. Two of them were made of pre-fabricated metal panels while the other two were constructed using containers as the base structure. These site offices are put into use for 2-4 years depending on the nature of the project. The design of functional rooms inside them (like private offices, open-plan office, conference rooms and store rooms) are similar because they are serving as the office space for the project team(s) and related site personnel from the same company.

Table 1 General information of the site offices

	Office A	Office B	Office C	Office D
Gross floor area (m^2)	547	480	529	282
Number of storeys	2	2	2	2
Construction type	Pre-fabricated	Container	Container	Pre-fabricated
Net envelope area (m^2)	347	320	395	251
Window area (m^2)	30.0	28.0	28.0	18.8
Roof surface area (m^2)	279	245	270	144
Year built	1999	1999	2000	1998
No. of occupants (persons)	30	25	40	20

Generally speaking, the construction industry in Hong Kong is still relying heavily on traditional building technology employed by small and medium construction companies. Site offices and other related buildings are usually constructed by builders or their sub-contractors using simple, conventional methods and without paying much attention to architectural and engineering designs, not to say green building practices (Hui and Law, 2003). People often are not paying enough attention to ensure good environmental performance of these buildings and their building systems. Therefore, the durability and efficiency of the site office buildings will be affected. As Riley, Pexton and Drilling (2003) pointed out, the contractor's role in green buildings shall not be underestimated. Construction organisations certainly have both the potential and the responsibility to enhance green building project.

To evaluate the site office buildings, research investigations and measurements were carried out in 2002 to 2003. Two important aspects of the research are described in this paper:

- Analysis of thermal performance
- Evaluation of lighting systems

4. ANALYSIS OF THERMAL PERFORMANCE

The thermal performance of building envelope of the four site offices was studied by assessing the areas and thermal properties of its components (opaque walls, windows and roof) and by calculating the likely heat gains through these components. To reflect the local conditions in Hong Kong, the heat gain calculation is worked out based on the Code of Practice for Overall Thermal Transfer Value in Buildings (Building Authority Hong Kong, 1995). Overall thermal transfer value (OTTV) is an index for comparing the thermal performance of buildings. It is a measure of the average heat gain into a building through the building envelope and consists of three major components: (a) conduction through opaque walls, (b) conduction through window glass, and (c) solar radiation through window glass.

Figure 1 shows the heat gains calculated for the walls, roofs and windows. Tables 2 and 3 give the detailed figures of OTTV calculations. The roof and window heat gains play an important role. If we consider the component areas, we can see that the windows is the weakest link that allows significant heat gain to pass through and adding burden to the cooling requirements. The roof also tends to admit much heat and since its relative area is large in these buildings, control of roof heat gain is a critical issue for thermal performance.

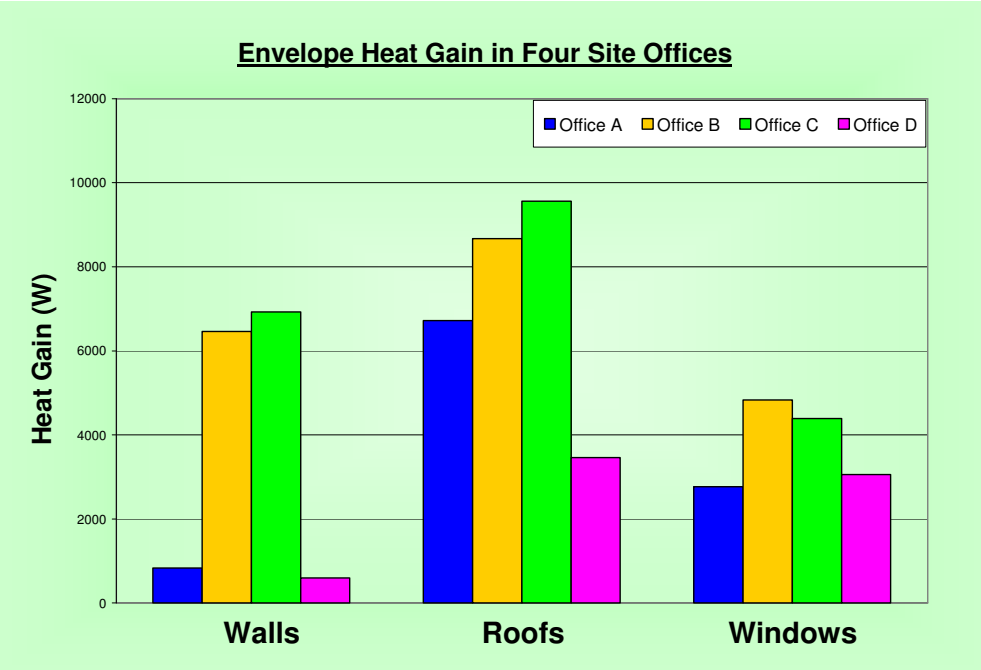

Figure 1. Envelope heat gain (roof, walls, and windows) of the site offices

Table 2 OTTV calculation for roof in the site offices

	Office A	Office B	Office C	Office D
Roof area (m^2)	279	245	270	144
Roof heat gain (W)	4332	5589	6162	2234
OTTV for roof (W/m^2)	15.5	22.8	22.8	15.5

Table 3 OTTV calculation for walls in the site offices

	Orient-ation	Wall Area (m^2)	Door Area (m^2)	Window area (m^2)	Wall+door heat gain (W)	Window heat gain (W)	$OTTV_w$ (W/m^2)
Office A	N	107	---	11.4	154	1184	11.3
	E	65	---	5.2	183	869	15.1
	S	107	3.2	8.3	236	1582	15.3
	W	63	1.6	5.2	159	906	15.3
Office B	N	96	---	8.2	936	1126	19.8
	E	65	---	4.3	751	851	23.0
	S	87	5.9	11.2	1020	2254	31.4
	W	65	---	4.3	580	596	16.9
Office C	N	145	10.2	9.0	951	936	11.5
	E	43	---	4.3	561	726	27.2
	S	154	---	10.3	1525	1971	21.3
	W	43	---	4.3	486	756	26.3
Office D	N	81	1.6	5.3	118	546	7.6
	E	45	1.6	0.8	132	126	5.5
	S	78	---	9.8	166	1862	23.2
	W	44	---	3.0	109	525	13.4

When assessing the thermal properties of building envelope, other aspects of the envelope performance should be considered too. For example, noise control, dust control and architectural layout shall be satisfied in order to provide and ensure a reasonable and comfortable environment for the occupants. The window design also has implications to the use of natural daylight and creation of healthy indoor environment.

5. EVALUATION OF LIGHTING SYSTEMS

Lighting design relies on a combination of specific scientific principles, established standards and conventions, and a number of aesthetic, cultural and human factors applied in an artful manner (Benya, 2001). Good lighting results in productivity benefits for the organisation, and economic analysis shows that just a tiny improvement in worker productivity far outweighs the cost of an enhanced lighting system.

Table 4 Lighting systems in existing site offices

	Office A	Office B	Office C	Office D
No. of fluorescent lamp	242	214	355	123
Total lamp wattage (W)	10672	9437	15656	5424
Total floor area (m^2)	547.2	480.0	529.2	282.2
Light power density (W/m^2)	19.5	19.7	29.6	19.2

Table 4 gives a summary of the lighting installations in the four site offices. Simple fluorescent battens are used in Offices A, B and D because of easy installation and low first cost (Office C is using recessed light fittings). These lighting battens are in two lamps

controlled by simple on/off switches. Number of lighting circuits are usually minimal and individual zone control of the lighting is difficult or impossible. The fluorescent lamps are switched on early in the morning and off until 7 to 8 p.m. (by the security guard). There are no task lighting applied in the site office to supplement the general lighting.

Some site measurements have been carried out at Office A to assess the actual conditions and develop better understanding of the visual environment. It is found that the general lighting environment in the site offices is not very good because there is limited control capability in the space and there are some areas where uneven lighting distribution and glare might cause discomfort to the occupants. Figure 2 shows the visual environment and lighting systems in Office A and Office B.

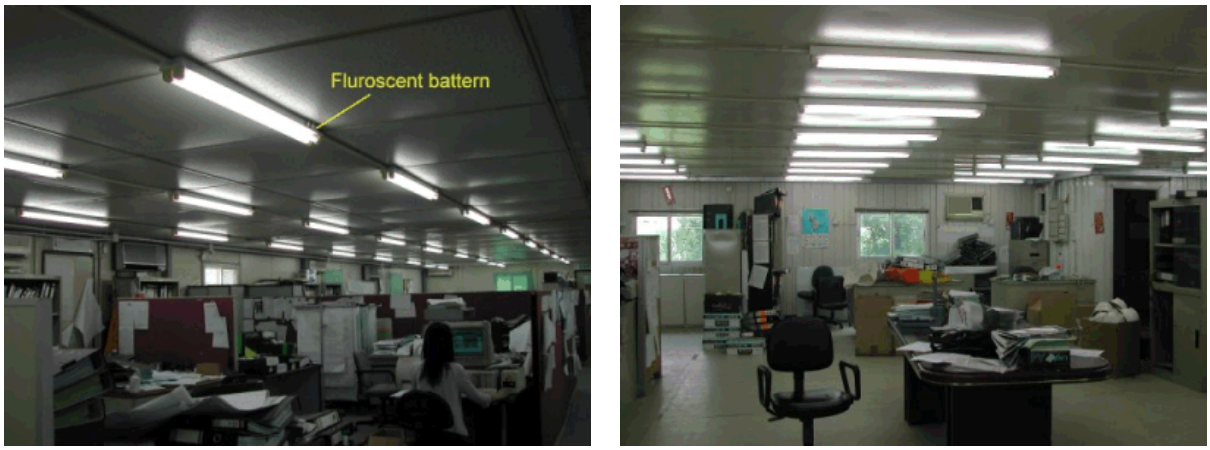

Figure 2. Visual environment and lighting systems in the site offices (Office A & Office B)

Lighting has considerable impact on the environment. The production of electricity needed for lighting consumes fossil fuels, which contribute to air and water pollution. Furthermore, some lighting equipment is fairly short lived and lighting equipment and components create a continuous waste stream, as raw materials are extracted from the earth, delivered to factories, made into lighting equipment, installed in buildings, and finally removed and disposed of.

All of the electricity used for lighting eventually turns into heat and this excess heat must be removed from buildings via air conditioning. The additional air-conditioning load created by electric lighting can add another 20% to the electricity use attributable to electric lighting. Therefore, it is recommended that the lighting system of site offices should be carefully designed so as to ensure energy efficiency and lighting quality.

6. DEVELOPMENT OF GREEN SITE OFFICE

After evaluating the four existing site offices, useful information was obtained to assist the planning and design of another new site office which is a pilot project aiming at promoting green and sustainable design. The objective of the pilot project is to assess the key factors for designing green site offices and formulate a strategy for their planning and design. Figure 3 gives the main features of the new green site office developed in the project and Figure 4 shows its outlook after completion. This site office has received an award on Environmental Innovative Solution from Skanska headquarters in Sweden (http://www.skanska.com/). The approach for developing the green site office is explained in the following paragraphs.

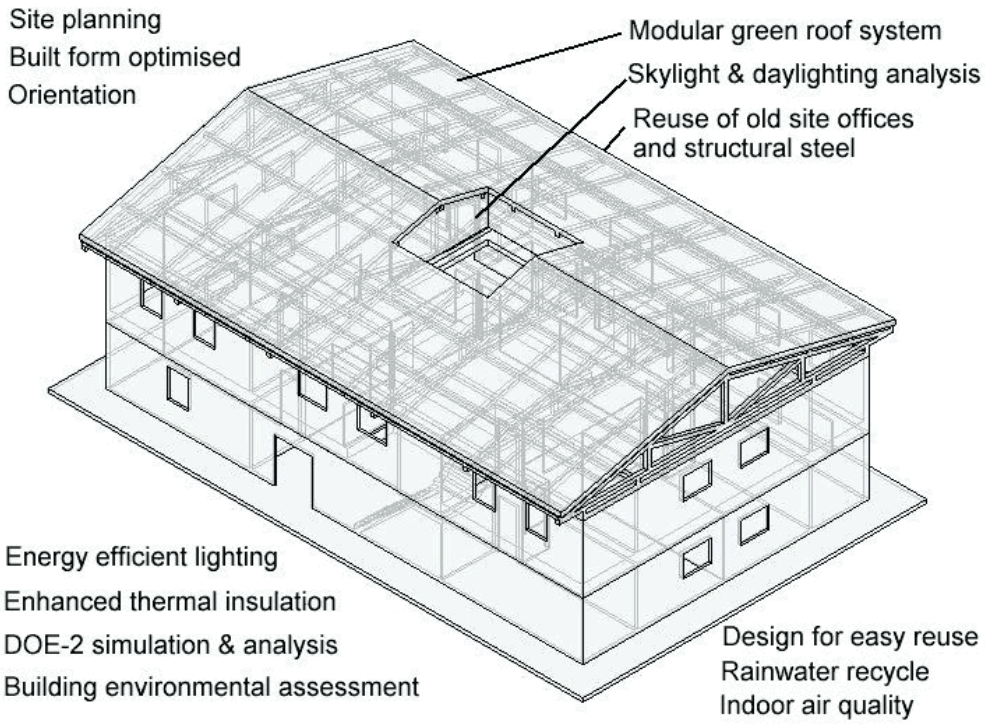

Figure 3. Main features of the green site office
(* Further info can be found at: http://www.hku.hk/bse/greensiteoffice/index.html)

Figure 4. Actual outlook of the green site office

Basically, the goal of green design is to reduce material use during construction, save energy during building operation, and ensure a healthier working environment. To formulate the strategy for the green site office, three key areas have been identified.

(a) Planning and Design

The most important opportunity to shape a green and energy efficient building is during the early design phase. Planning a green building often involves additional modelling and design costs. Although these early additional costs are small compared with the overall building costs, they often still form a major impediment to better building designs. Our research

indicates that time and first cost are the most important factor in Hong Kong for selection of construction methods and materials; environmental performance and reduction of waste are of less important in the contractors' minds. To plan and design a green site office, it is important to build a "green team" and set up the project's environmental goals at the very beginning. All members of the project team must be educated and oriented to the goals, costs and benefits of green design.

At the start of the pilot project, we have discussed with the local site staff to develop a set of planning and design strategy with them. Although not every items have been implemented or adopted at the end, it is believed that a clear picture of the influencing issues and design options have been generated at the outset for guiding the design process. Today, there are many literature and references that examine the major aspects of sustainable design, such as AIA (1999), BSRIA (1999), Mendler and Odell (2000) and RAIA (2002). Many of the design principles and considerations are applicable to site offices as well. The key recommendations applicable to green site office include:

- Locate the building near public transportation to minimise pollution from vehicle use.
- Plan, design, and lay out spaces and components with flexibility and reuse in mind.
- Landscape facility grounds with native plants and vegetation.
- Limit disruption to the site's native plant and animal species.
- Take advantage of daylighting, natural ventilation, passive solar design by optimised built form and orientation.
- Purchase furniture and interior finishes that are durable and easy to maintain, so as to limit replacement costs, and cut down on waste.

(b) Construction Methods and Materials

The project team could improve the building's environmental performance and minimise the production of waste through innovative and sustainable technologies such as modular building and recycled building components (like cargo containers and structure steel). Development of modular unit for site office can increase flexibility and the chance of reusing the materials or components. There are lots of recyclable materials in Hong Kong suitable for the construction of site office. By selecting and designing the building components to be durable and with good insulation properties, the energy and environmental performance of the site office can be enhanced.

Other green techniques which result from the ingenuity and creativity of the people working on-site are also helpful. These techniques range from improvements in equipment and processes to the use of simple new ways to control and reuse waste materials. For example, the site staff in the pilot project has suggested and designed a modular green roof system (see Figure 4) that allows sectioning of the green roof, flexible system design and easy reuse/relocation.

(c) Environmental Policy and Management

While good design and information can influence the way that a building is used, it is equally important to involve all the stakeholders in the process through environmental policy and management in the organisation. For example, a large company could implement waste reduction scheme and central management of obsolete equipment/materials for its many site offices so that total waste generation can be controlled and the sharing/reuse of equipment/materials can be made possible. Green site office could have recognisable benefits to employees and the environment. It's not just the right thing to do; it's the responsible thing

to do. By ensuring good quality indoor space, efficient operation and reduced environmental impact, the work productivity can also be ensured.

To promote the culture of green design and construction, it is crucial to have clear guidelines, education and training, leadership and information. Some companies have implemented an environmental management system and made effort to adopt green practices in construction sites because promotion of green design can help them build up the corporate image and staff morale. It is believed that further efforts are needed to strengthen the knowledge and the people's participation in implementing green procurement, sustainable design principles and environmental management standard such as ISO14000.

7. CONCLUSIONS

The quest for sustainable construction is growing rapidly in the world. To promote sustainable building, one shall not overlook the construction site offices. Analysis of thermal performance of the existing site offices in Hong Kong indicates that there is lost of saving opportunities in the current practices. Evaluation of the lighting systems also shows that a green site office can operate with lower costs and increased worker satisfaction. As construction site offices have short life spans, usually 2 to 4 years, from both environmental and economic points of view, their design and operation will present a challenge to resource efficiency and life cycle analysis.

Green design is a holistic process that will lead us to a new way of thinking on a sustainable world. Experience from the pilot project on green site office indicates that the development process requires early planning, critical assessment, innovative solutions and effective management within the green project team.

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建造工地辦公室之可持續設計及運作

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摘要： 本論文就研究在香港如何評核和探討建造工地辦公室之可持續設計及運作作出報告。 該研究考察和評核了四所現有建造工地辦公室，從而獲得有用資料來幫助規劃和設計另一所新的工地辦公室，目的是以此指導項目來推廣綠色及可持續設計。 通過分析現有工地辦公室的熱工特性，指出現行設計常規會錯過很多節約機會。 同時，評估照明系統之結果亦指出，綠色工地辦公室能有更低運作成本，以及能夠提高員工之滿意程度。 因爲建造工地辦公室通常只有二至四年的使用期，所以它們之設計及運作會成爲節約資源和生命週期分析的一項挑戰。

關鍵詞：建造工地辦公室，可持續設計及運作，香港。