<u>**Research Report**</u>

Green Design and Construction of Site Offices

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This research report is prepared for Gammon Skanska Limited as a form of collaborative research study for promoting green building design and construction methods.

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Executive Summary

This study and report was commissioned by the Gammon Skanska Limited to provide an assessment of their construction site offices to help formulate the strategy for planning and design of green site offices. This work reflects a collaborative development process between the company and the University of Hong Kong, with the aim to promote green building design and construction. The study has set out a theme to address and investigate green design and construction of site offices. It attempts to gather the key information and evaluate practical solutions to improve the building's performance.

Analysis of thermal and energy performance of the sites offices indicates that there is lost of opportunities in the current practices. It is recommended to consider and adopt energy conservation measures to improve the building's environmental performance. Possible measures include thermal insulation, external shading, green roof and efficient lighting.

Evaluation of lighting system shows that green building can operate with lower costs and increased worker satisfaction. Design and calculation have been made for the new site office. It is found that with similar wattage and power consumption, the efficient lighting can provide a better lighting level and quality. It is also recommended to investigate further on task-ambient lighting and daylighting control.

A brief review has been conducted to assess the environmental performance of the site office and evaluate green design potential of future site offices. Important issues for promoting green design have been identified for consideration, implementation or further investigation. These issues include planning and design strategy, construction method and materials, as well as environmental policy and management.

Acknowlegements

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1. Introduction

This study was initiated by the Gammon Skanska Limited and conducted by the researchers from The University of Hong Kong on a voluntary basis. This work reflects a collaborative development process between the company and the University, with the aim to promote green building design and construction, as well as to improve information and knowledge about the subject matter.

The study was conducted in the period from 2 July 2002 to 31 August 2002 (two months) and the work was carried out by Dr. Sam C. M. Hui with the support from a Research Assistant, Ms. Allison Y. M. Law. Because this pilot study was for two months of work only, some analyses are developed based on the best available information and described in general terms. It is hoped that the research results and findings could provide the key information for the assessment of the site offices and for designing a strategy for planning and development of "green" site offices in the future. It is believed that this is a meaningful research that can help improve sustainable design skills and environmental awareness of the construction industry in Hong Kong.

1.1 Background

Green buildings are designed to provide a high level of comfort and service while using less energy and having a substantially lower environmental impact. The benefits of green building design include lower operating costs, reduced construction costs and increased occupants' productivity. Promotion of green building design and construction can also help to build up the corporate image and staff morale of companies. Therefore, more and more construction companies are interested in establishing an environmental profile by promoting green building practices. For example, in *Skanska Code of Conduct*, "environment" is put forward as a key requirement as described below:

"Caring about the environment permeates all of our work. Compliance with relevant legal and other environmental requirements, especially from our clients, provides the foundation for our environmental ambition. We are committed to preventing and continually minimizing adverse environmental impact and to conserving resources.

- We think ahead to determine how our work will affect the environment and base our decisions on available relevant facts.
- We avoid materials and methods with environmental risks when there are suitable alternatives available. We strive to recommend that clients use environmentally better alternatives whenever the circumstances permit.
- We do not engage in activities that have unacceptable environmental and social risks. We aim to identify such risks as early as possible to facilitate timely and adequate actions and decisions."

Site offices are essential provisions for all construction projects including building and civil engineering projects. Their design and operation are different from normal buildings since they are "temporary" structure and they need to cater for the particular conditions on the site. Site offices are often overlooked when considering green building practices. Past experience shows that environmental performance is not considered adequately in the design and operation of the site offices. Significant amount of energy and resources would be wasted during the lifetime of the site offices.

1.2 Objectives

The objectives of this pilot study are:

- To collect and evaluate key information for designing green site offices
- To assess and design the major building systems and components for a new site office
- To formulate the strategy for planning and design of green site offices

The environmental conditions in some existing site offices are investigated and possible measures are developed and evaluated for promoting green design in a new site office to be erected in Tsing Yi.

1.3 Report organisation

This report is divided into seven chapters along with the Appendices. Chapter 1 is the introduction which describes the background and objectives of the study. Chapter 2 reports the results of technical evaluation on existing site offices. Chapter 3 explains the study on thermal performance of building envelope. Chapter 4 describes the investigation into energy performance of site offices using building energy simulation and modelling techniques. Chapter 5 explains the evaluation on lighting system and dayligting design. Chapter 6 provides an assessment of environmental performance of the site office and evaluate green design potential of future site offices. Finally, Chapter 7 gives conclusion to the study.

2. Evaluation of Existing Site Offices

Four existing site offices operated by Gammon Skanska were selected as the target for the study so as to collect key information and study the design and operation of the buildings. These site offices are located in the following areas in Hong Kong:

- Tsing Yi
- Tuen Mun
- Wu Tip Kuk
- Eastern Corridor

The background information of the site offices, including location, outlook and floor plans, is given in Appendix I.

2.1 General information

The general information of the existing site offices is summarised in Table 2.1. The gross floor areas range from 282 m^2 to 547 m^2 and all of them are of two storeys high. The site offices at Tsing Yi and Wu Tip Kuk were made of pre-fabricated metal panels while the ones at Tuen Mun and Eastern Corridor were constructed using containers as the base structure. The site offices are usually put into use for 2-4 years depending on the nature of the project. The functional rooms (like private offices, open-plan office, conference rooms and store rooms) inside the four site offices are similar since they are serving as the office space for the project team(s) and related personnel working on the sites. The normal working hours are 8:00 a.m. to 6:00 p.m. for 6 days per week (some staff may have shorter working hours on Saturdays).

Table 2.1 General information of the existing site offices

	Tsing Yi	Tuen Mun	Eastern Corridor	Wu Tip Kuk
Gross floor area (m^2)	547.2	480.0	529.2	282.2
Number of storeys	2	2	2	2
Construction method	Pre-fabricated	Container	Container	Pre-fabricated
Net envelope area (m^2)	347.00	319.88	394.85	250.89
Window area (m^2)	30.02	27.96	27.96	18.75
Roof surface area (m^2)	279.02	244.75	269.84	143.87
Year built	1999	1999	2000	1998
Current status	In use	In use	In use	Not in use

From both environmental and economic points of view, constructing and using the site office for such a short lifetime (2-4 years) will present a challenge to resource efficiency. It is not uncommon to reuse or resell building components from previous site offices for constructing new ones. However, people are often not paying enough attention to ensure good performance for the design and operation of the site offices. Therefore, the durability and efficiency of the site office buildings will be affected.

2.2 Technical assessment

Investigations have been carried out to compare and evaluate the design and requirements in the existing site offices. Efforts have also been made to study the planning process and constraints of the site offices. Information is collected from site surveys, interviews with local staff and reference to related documents. Appendix II provides the checklists designed for the interview and site survey in this study. Table 2.2 shows a summary of the internal loads for these site offices including occupancy, lighting and equipment. The occupancy is estimated based on the office layout and the information provided by local site staff. It can vary from one stage of the construction process to another stage.

Table 2.2 Internal loads of the existing site offices

	Tsing Yi	Tuen Mun	Eastern Corridor	Wu Tip Kuk
Occupancy (design)				
- Number of people	30	25	40	20
Lighting				
- No. of fluorescent lamps	242	214	355	123
- Lighting power density (W/m^2)	19.5	19.7	29.6	19.2
Equipment (nos.)				
- Computer	25	5	37	10
- Printer	9	4	15	5
- Fax machine	5	1	5	1
- Scanner	3	0	3	0
- Photocopier	3	1	4	1

The general indoor environment of the site offices can be seen in Figures 2.1 to 2.4. Simple fluorescent battens are used in three site offices because of easy installation and low price (Eastern Corridor site office is using recessed light fittings). Usually these battens are in two lamps and are 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.

Figure 2.1 Indoor environment of Tsing Yi site office

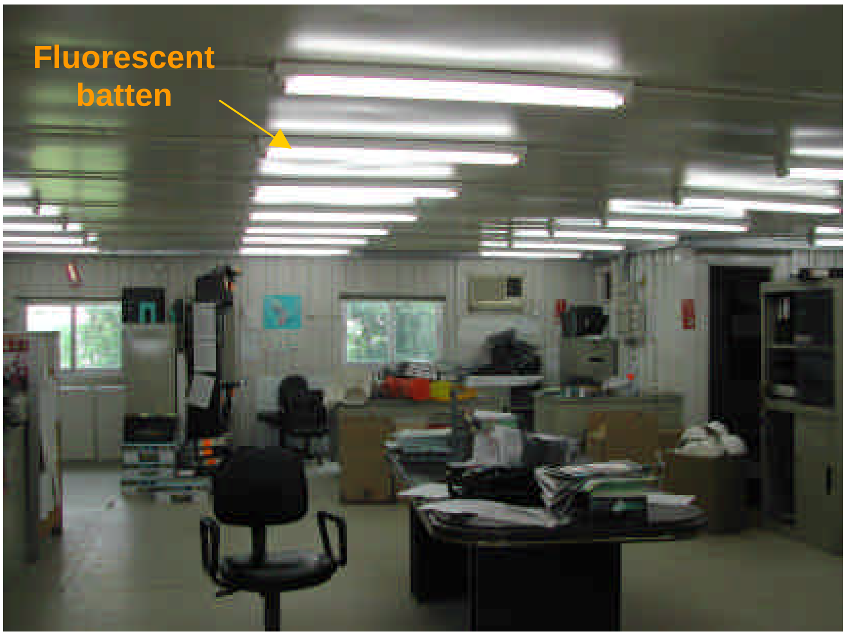


Figure 2.2 Indoor environment of Tuen Mun site office

Figure 2.3 Indoor environment of Eastern Corridor site office

Figure 2.4 Indoor environment of Wu Tip Kuk site office

The air conditioning systems being used in the site offices are of simple unitary type including split type and window type air conditioners because of their low first cost and easy of control. The air conditioners consume a significant amount of electricity and their service life tends to be short because of the operating conditions on site.

Assessment has been made on the building fabric, thermal performance and visual quality inside these site offices, so as to evaluate the environmental performance of the existing buildings. Appendix III give a summary of the site measurements in the existing site offices. Information is also collected to prepare for the detailed analysis which will be described in the proceeding chapters of the report.

2.3 Site survey and measurements

To investigate further the quality of the built environment, the Tsing Yi site office has been chosen to be the candidate for more detailed measurements on environmental conditions including indoor temperature, relative humidity and lighting level. The measurements were carried out using miniature data loggers (HOBO loggers). These loggers were put in three different functional areas, including Project Manager's office, Engineers' office and Secretary office. Data on indoor temperature, relative humidity and lighting level were recorded every five minutes for a one-week period from 5 July 2002 to 12 July 2002. A summary of the results is shown in the following three graphs (Figures 2.5 to 2.7).

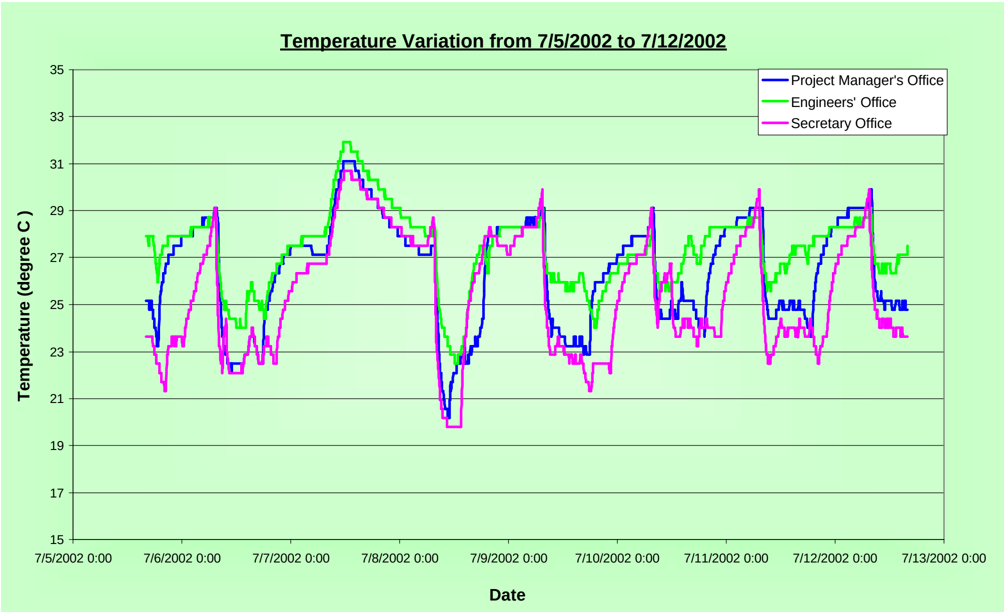


Figure 2.5 Temperatures in Tsing Yi site office (5-12 July 2002)

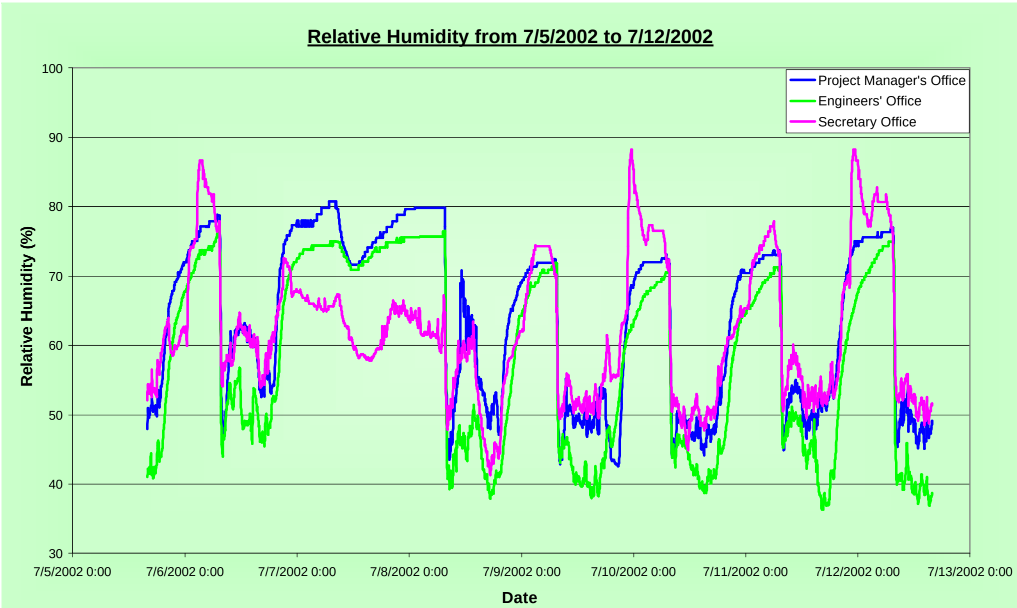


Figure 2.6 Relative humidity in Tsing Yi site office (5-12 July 2002)

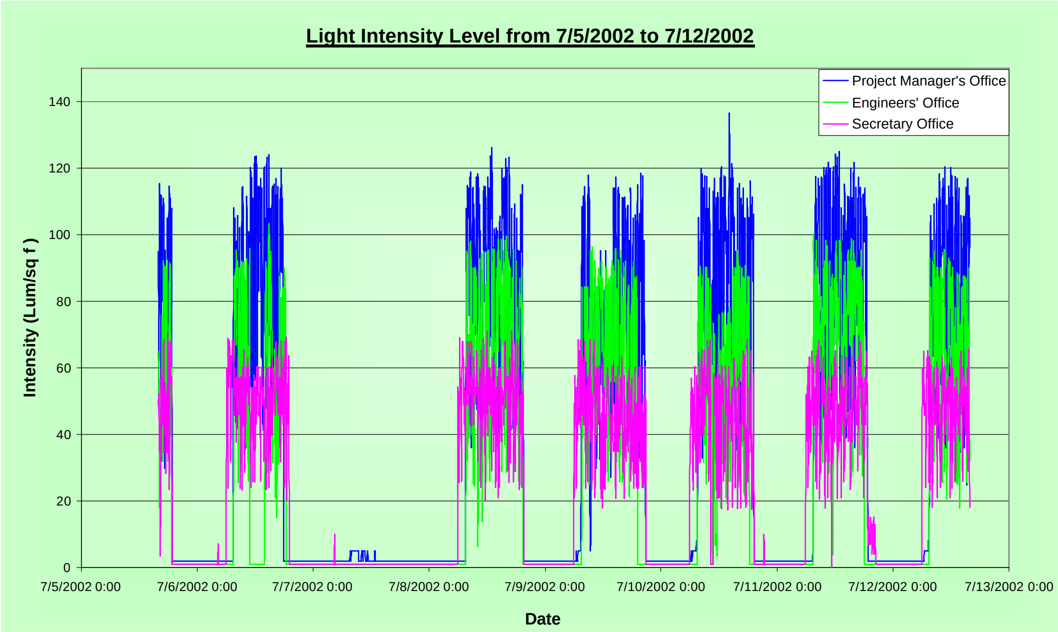


Figure 2.7 Lighting levels in Tsing Yi site office (5-12 July 2002)

The patterns of the building operation can be observed from the variation of the environmental paremeters. For example, the temperature, humidity and lighting level were maintained within comfortable range during the office hours. During the off hours (night time) and holidays, temperature and humidity fluctuated according to ambient weather and lighting were mostly switched off.

From the temperature and humidity graphs (Figures 2.5 and 2.6), it can be seen that during the measurement period (which is a hot summer week in Hong Kong), the comfortable condition was maintained during the daytime office hours (by air-conditioners), but the indoor conditions tend to vary over a wide range in a day. This suggests that the thermal mass of the building is low and the effect of thermal inertia is not obvious for the site offices. The Project Manager's Office (a private office) seems to have slightly smaller variations and better lighting level than the Engineer's and Secretary's Offices.

The 24-hour profiles of the environmental conditions for a typical working day can be studied from Figures 2.8 to 2.10. If we compare the results with the usual comfort requirements for indoor conditions (such as temperature 24 ^{o}C ± 2 ^{o}C and relative humidity 50% ± 10%), we can see that optimisation is possible to improve the comfort conditions and reduce energy use for the environmental control systems. Further analyses are carried out and the major findings will be reported in the proceeding Chapters of the report.

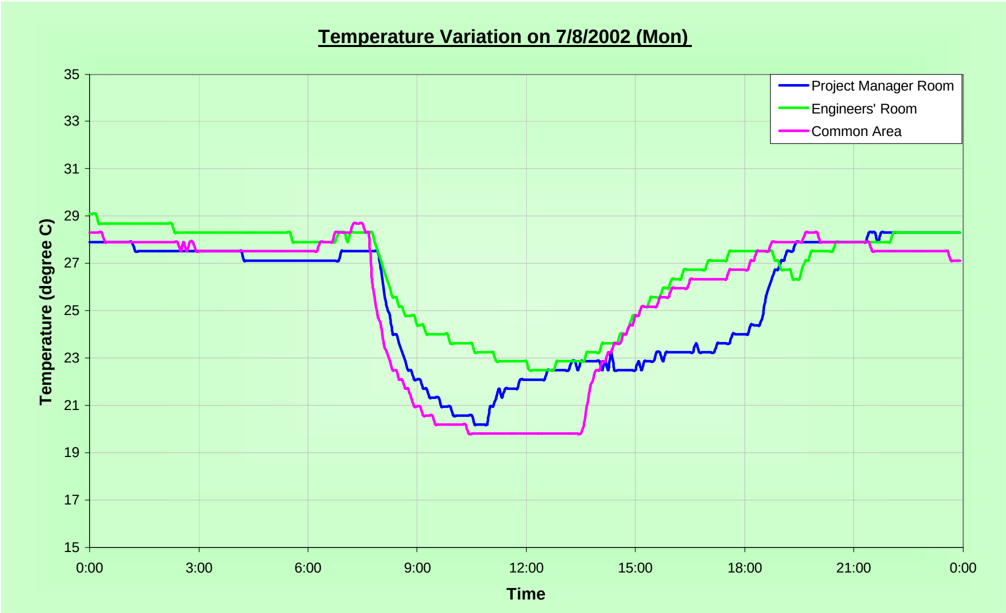


Figure 2.8 24-hour temperature profile in Tsing Yi site office (Monday, 8 July 2002)

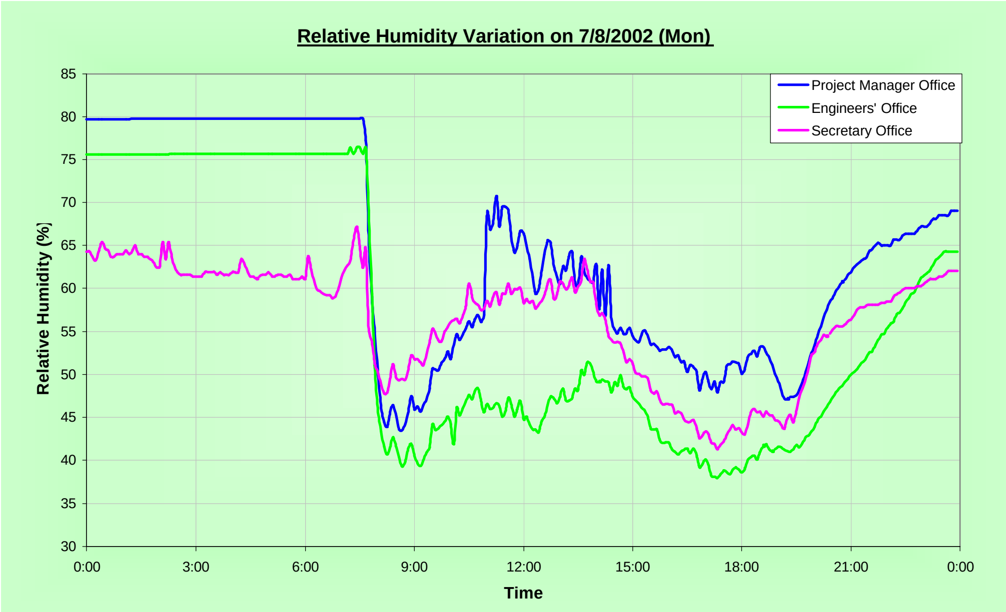


Figure 2.9 24-hour relative humidity in Tsing Yi site office (Monday, 8 July 2002)

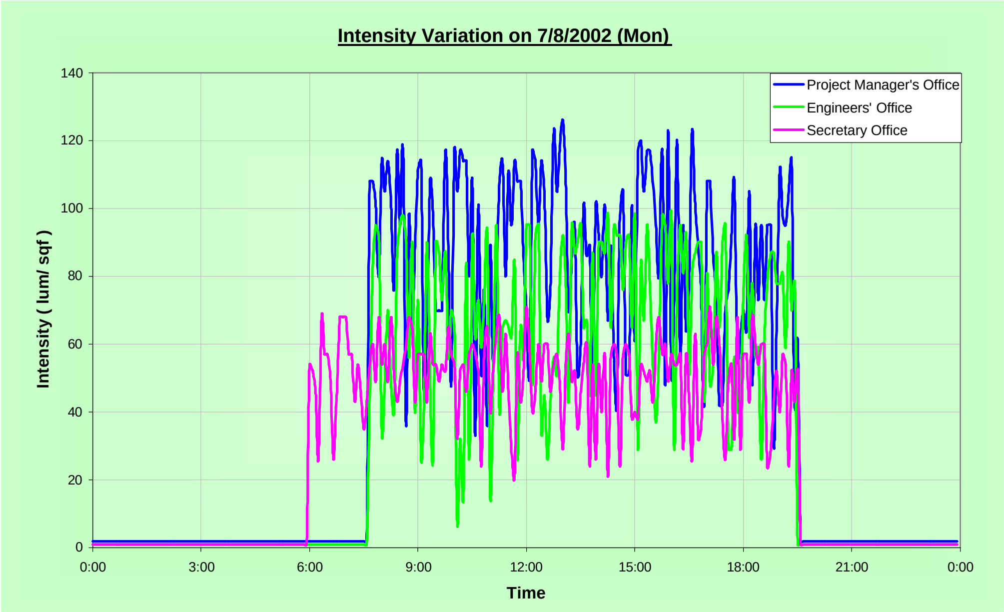


Figure 2.10 24-hour lighting level in Tsing Yi site office (Monday, 8 July 2002)

To develop a better idea about the quality of the indoor environment, a brief assessment on indoor air quality has also been conducted in the Tsing Yi site office. Appendix IV gives a summary of the assessment results. It has also been found from the interview that tobacco smoking is sometimes happening inside the office and may introduce air pollutants to the indoor space.

2.4 Establishment of performance baseline

The information collected from the existing site offices will serve as the performance baseline for evaluation and comparison with the new site office to be erected in Tsing Yi. Based on the data and conditions collected from the existing site offices, design parameters for average performance of the site offices have been determined. The information will be used for setting up analytical models for analysis of energy and environmental performance of the site offices (for details of the models, see Chapter 4).

Unfortunately, we are only able to collect energy (electricity) and water consumption data for two of the existing site offices (Tsing Yi and Tuen Mun). For the other two site offices, the data are either incomplete or not available at the time of the investigation. It is recommended that proper procedure and policy should be set up in the future to collect and maintain the essential information for energy and water consumption so that the environmental performance of the buildings can be studied in details.

The available data from the two site offices is difficult to analyse because the actual consumption might include usage in other parts of the site (connected to the same meter) and the number of users or occupants in the building might change over the construction process (no record can be found to indicate the patterns of the change). Table 2.3 shows the electricity consumption and the estimated energy intensity. For the Tsing Yi site office, the data include the Gammon's (contractor's) office and site engineer's office. For the Tuen Mun site office, the data include both offices and some container cargos offices designed for the subcontractors. We have tried to break down the energy consumption data according to the gross floor areas of each part of the site. Figures 2.11 and 2.12 show the electricity consumption of the Tsing Yi and Tuen Mun site offices respectively.

Table 2.3 Electricity consumption of two site offices

	Record period	Total floor area (m^2)	Electricity consumption (kWh)	Energy intensity (kWh/ m^2/yr)
Tsing Yi	1-Sept-1999 to 3-Jun-2002	1,367	1,269,280	336.8
Tuen Mun	17-Aug-1999 21-Feb-02	840	377,096	178.3

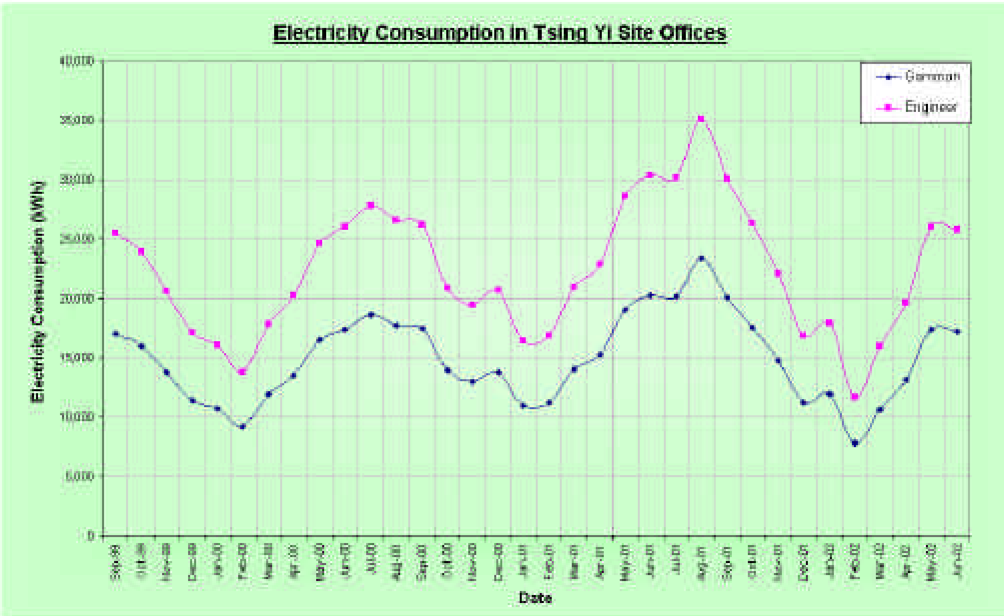


Figure 2.11 Electricity consumption profile of Tsing Yi site office

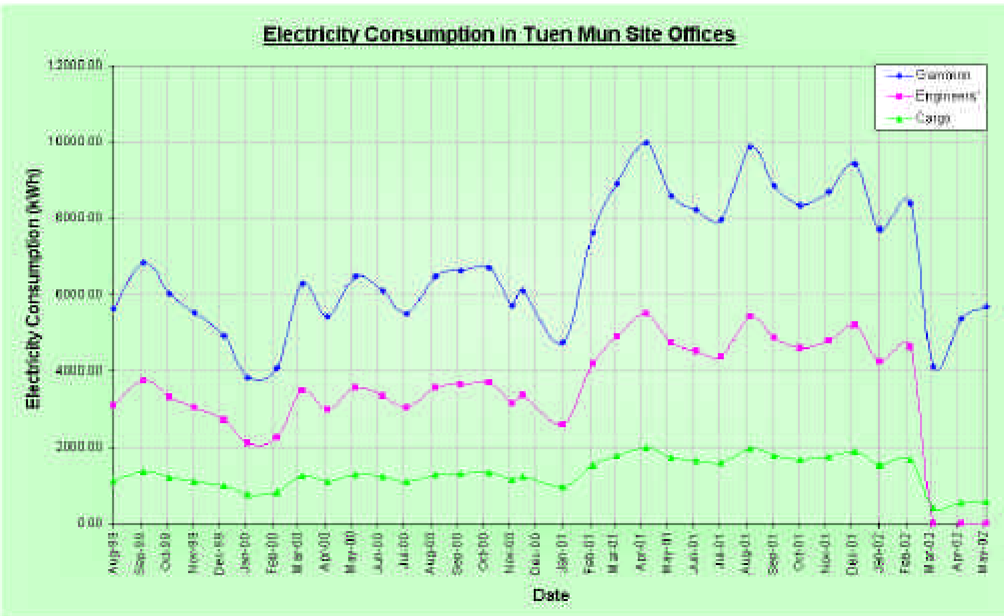


Figure 2.12 Electricity consumption profile of Tuen Mun site office

3. Thermal Performance of Building Envelope

The building envelope of the site offices has significant impact on their environmental performance since it is the shell to create the indoor space and is constructed using much building materials. Investigations have been carried out to assess the thermal performance of the building envelope for the four existing site offices and evaluate the factors affecting the design of the building envelope.

3.1 Study methodology

The thermal performance of building envelope 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. The usual practice is to have two sets of OTTV, one for the exterior walls and the other for the roof (Hui, 1997).

Figure 3.1 shows the areas of the building envelope components (opaque walls, windows and roof) for the four existing site offices. The walls and roofs are most important because the buildings only have two storeys and the window areas are relatively less in these site offices.

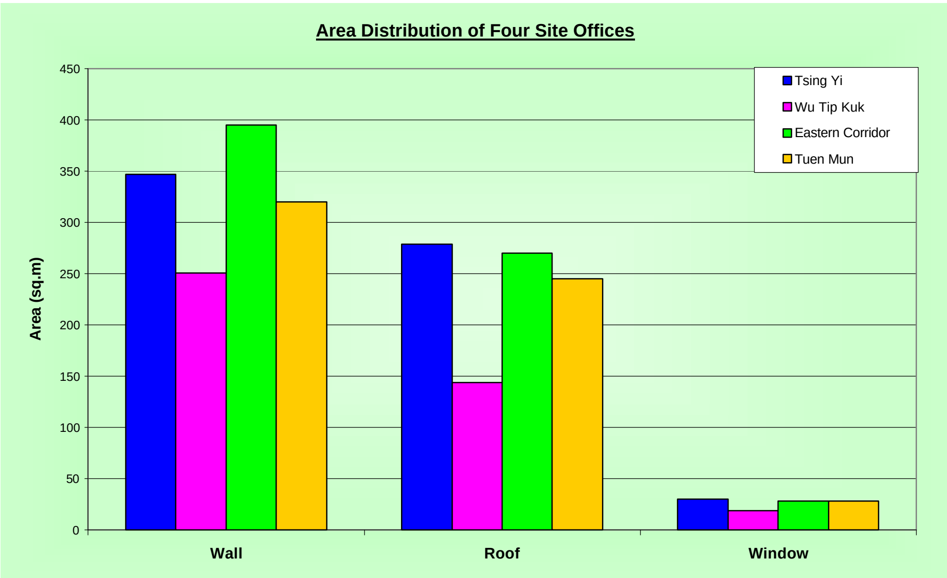


Figure 3.1 Envelope areas (roof, walls, and windows) of existing site offices

Table 3.1 gives a summary of the thermal properties (U-values) estimated for the building envelope components. For Tuen Mun and Eastern Corridor site offices (container-based structure), the properties of walls are calculated based on metal sheet on the outside and plywood board on the inside with an air gap in between them. For Tsing Yi and Wu Tip Kuk site offices (prefabricated structure), the properties of walls are calculated based on metal sheets on the outside and inside with polystyrene foam board in between. In general, the prefabricated structure has a better thermal insulation property. For the roofs, a simple construction consisting of galvanized steel plate on the outside and plywood on the inside with air gap between them is taken.

Table 3.1 U-values estimated for the building envelope components

	Tsing Yi	Tuen Mun	Eastern Corridor	Wu Tip Kuk
U-value of walls ($W/m^2.K$)	0.74	2.99	2.99	0.74
U-value of doors ($W/m^2.K$)	0.78	1.96	1.96	0.78
U-value of roofs ($W/m^2.K$)	1.64	1.64	1.64	1.64

3.2 Analysis of thermal performance

Figure 3.2 shows the heat gains calculated for the walls, roofs and windows. It can be seen that the roof and window heat gains play an important role in all four cases. If we consider the component areas in Figure 3.1 with the heat gains, 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 low-rise site offices, the control of the roof heat gain becomes a critical issue for thermal performance.

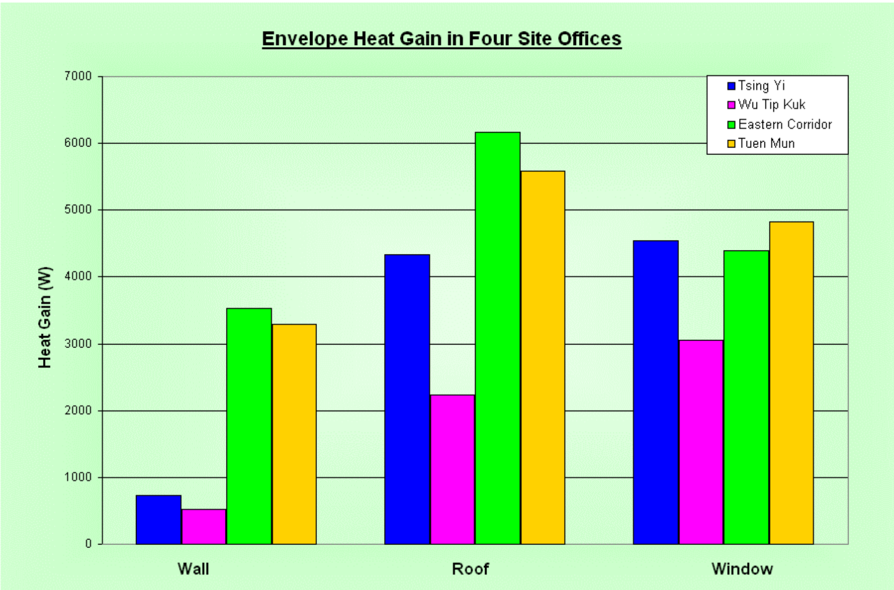


Figure 3.2 Envelope heat gain (roof, walls, and windows) of existing site offices

The OTTV of the walls and roofs in the site offices has been determined to assess the heat transfer intensity through the building envelope. Figure 3.3 shows the estimated OTTV for the walls and roofs. Tables 3.2 and 3.3 provide the numerical figures for the calculations.

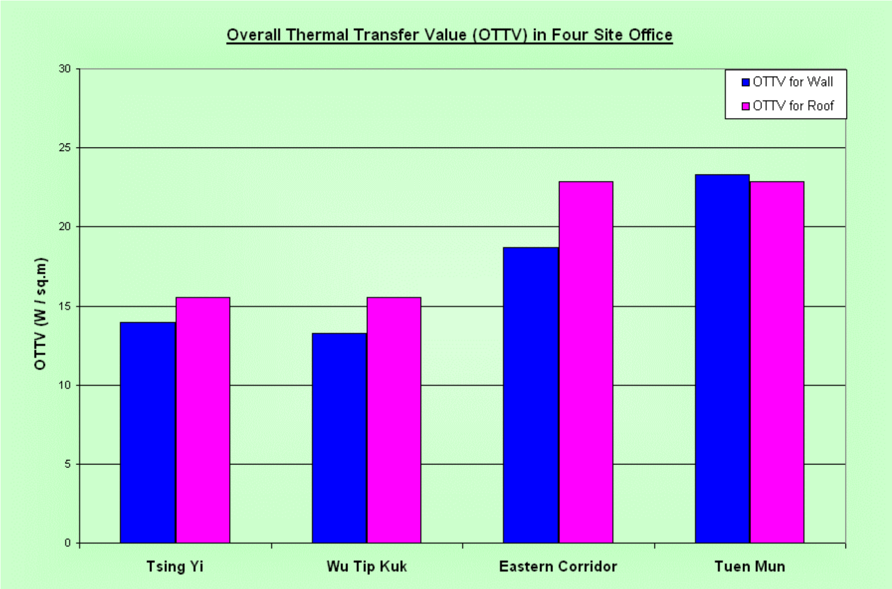


Figure 3.3 OTTV figures of existing site offices

Table 3.2 OTTV calculation for walls in existing 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)
Tsing Yi	N	107.4	---	11.4	154.4	1184.0	11.3
	E	64.6	---	5.2	183.3	869.4	15.1
	S	107.3	3.2	8.3	235.7	1581.5	15.3
	W	63.0	1.6	5.2	159.1	905.6	15.3
Tuen Mun	N	96.0	---	8.2	935.8	1126.1	19.8
	E	65.4	---	4.3	751.0	851.0	23.0
	S	87.2	5.9	11.2	1020.1	2254.3	31.4
	W	65.4	---	4.3	580.3	596.2	16.9
Eastern Corridor	N	144.9	10.2	9.0	951.2	936.0	11.5
	E	43.0	---	4.3	560.7	725.8	27.2
	S	153.8	---	10.3	1525.2	1971.1	21.3
	W	43.0	---	4.3	486.0	756.0	26.3
Wu Tip Kuk	N	80.7	1.6	5.3	118.4	546.0	7.6
	E	45.0	1.6	0.8	132.4	126.0	5.5
	S	77.8	---	9.8	165.7	1862.3	23.2
	W	44.3	---	3.0	109.0	525	13.4

Table 3.3 OTTV calculation for roof in existing site offices

	Tsing Yi	Tuen Mun	Eastern Corridor	Wu Tip Kuk
Roof area (m^2)	279.0	244.8	269.8	143.9
Roof heat gain (W)	4332.5	5588.8	6161.7	2233.9
OTTV for roof (W/m^2)	15.5	22.8	22.8	15.5

At present, the OTTV method in Hong Kong is used as a control measure for building envelope design in commercial buildings and hotels. The controls on OTTV aim at reducing external heat gains through the building envelope and hence the electricity required for air-conditioning. It is understood that the criteria of the OTTV method may not be applicable directly to site offices, but we can still compare the current OTTV limit which is set at 30 W/m^2 to that figures presented in Figure 3.3. All the existing site offices can meet the current OTTV requirement.

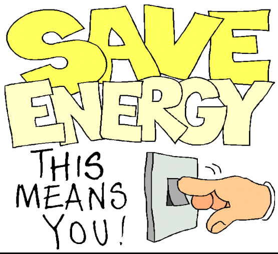
The thermal performance of the exterior walls at different orientations can be studied from the data presented in Table 3.1. If better performance is to be achieved, then more efforts should be put on the critical portions of the walls, like the window areas. However, it should also be noted that the window design has implications to the use of natural daylight and creation of healthy indoor environment. Analysis will be needed to evaluate the interaction of heat gain and daylight at the windows in order to determine the most appropriate solution.

3.3 Recommendations

It is recommended to investigate measures and new techniques for improving the thermal performance of the building envelope of the site offices so that the heat gain, and hence the cooling energy requirements, can be reduced. For example, adding insulation and external shading to the building envelope components can improve the thermal performance.

It is proposed that emphasis can be put on the roof to improve its thermal performance so that significant saving can be achieved. Analysis should also be conducted to study the design of windows and opaque walls in the site office so that optimal performance can be obtained in terms of thermal insulation and daylight penetration.

When assessing the thermal properties of the building envelope, other aspects of the envelope performance should be considered too. For example, noise control, dust control and architectural layout will need to be satisfied and ensured in order to provide a reasonable and comfortable environment for the occupants.



4. Energy Performance of Site Offices

Detailed building energy simulation models have been developed for the new site office and used for studying the energy performance of the buildings. The models were generated based on information collected from site survey and some assumptions have been made to reflect the conventional design and building practices. Major findings and results from the computer simulation analysis are reported in this Chapter.

4.1 Building energy simulation tool

The DOE-2 detailed building energy simulation program is used for the building energy analysis exercise in this study (LANL, 1980). The program is developed by the simulation Research Group of Lawrence Berkeley National Laboratory and is funded by U.S. Department of Energy (DOE). The version of DOE-2 being used is version 2.1E based on the VisualDOE 3.0 package in the *Green Design Tool* developed by Eley Associates (see http://www.eley.com for more information). Figure 4.1 shows the interface of VisulDOE 3.0.

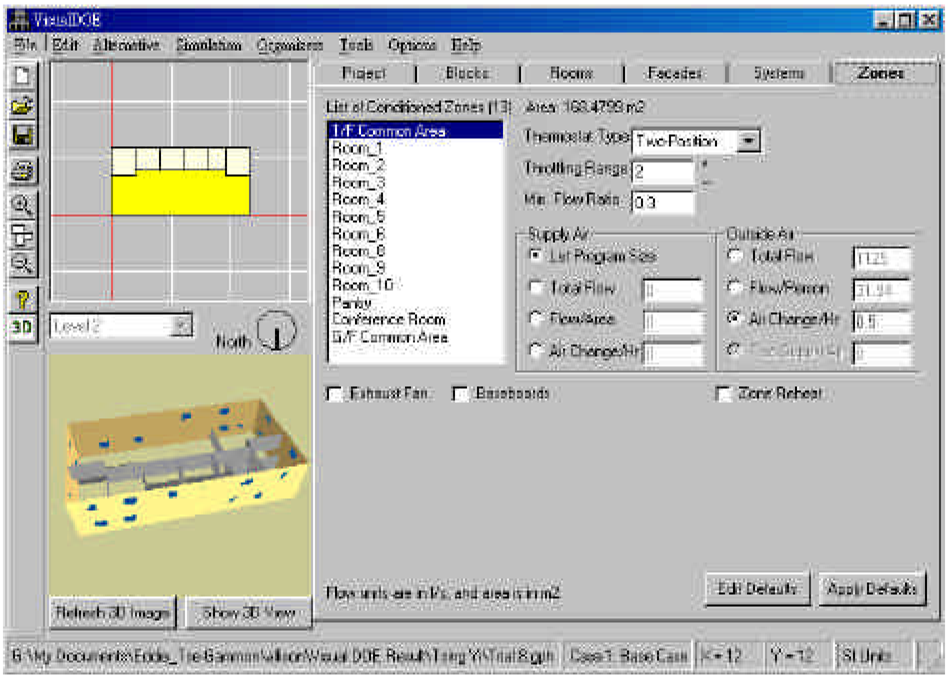


Figure 4.1 Interface of VisulDOE 3.0 from the Green Design Tool

DOE-2 calculates the hourly energy use and energy cost of a building given information about the building's climate, construction, operation and heating, ventilating, and air-conditioning (HVAC) equipment. Through the building energy simulation, a user can obtain an accurate estimate of the building's energy consumption, interior environmental conditions and energy operation cost. The program has been used widely in the world for building design and energy conservation studies.

To carry out the building energy analysis for Hong Kong, local weather data is required. The weather file used in this study contains full hourly data of Hong Kong for the year 1989. The year 1989 has been selected as the Test Reference Year (TRY) for Hong Kong from a previous research study (Hui and Lam, 1992) and is suitable for comparative energy studies.

4.2 Modelling assumptions

A base case model building has been established to serve as a reference point for evaluation. The model is set up based on the proposed design of the new site office in Tsing Yi, and with suitable modifications to reflect typical building design and operation as found out in the previous studies on the existing site offices. Appendix V shows the floor plans and design drawings of the new site office. Table 4.1 gives a summary of the major modelling assumptions for the based case building.

Table 4.1 Major modelling assumptions for the base case building

Items	Assumptions		
Building envelope	Container-based		
Construction materials	Wall	Aluminum and steel siding sheet + Air layer + Plywood	
	Roof	Aluminum and steel siding sheet + Air layer + Plywood	
	Floor	Roof wood framing + Plywood **+ c**arpet with fibrous pad	
	Partition	Gypsum board + Wall metal framing + Gypsum board	
	Window	On container walls:	Single-glazed PVC box window Size: 0.8 m x 1.2 m
		On other walls:	Single-glazed PVC box window Size: 1.2 m x 0.8 m
Lighting system	Fluorescent battens and magnetic ballast		
Scheduling	Lighting system	7am-8pm: 95% (no lunch break)	
	Occupancy	Weekday	8am-6pm: 95% (Lunch: 40%)
		Saturday	8am-12noon: 90% (Lunch: 40%) 1pm-6pm: 80%
	Equipment	Same as Occupancy	
	Air-conditioning	7am-8pm: 95% (no lunch break)	
Air-conditioning system	Packaged terminal air conditioner (split type or window type)		
Other systems	No water heating system; exterior lighting system excluded		
Utility rates	Electricity	HK$1/kWh	
	Fuel	No energy from fuel	
Daylighting	No skylight; no daylighting control		

After studying the operation of the existing site offices, we have determined sets of schedules for the internal loads appropriate to the practical situations in the site offices. Figures 4.2 to 4.4 show the schedule profiles assumed for lighting, occupancy and air conditioning equipment, respectively.

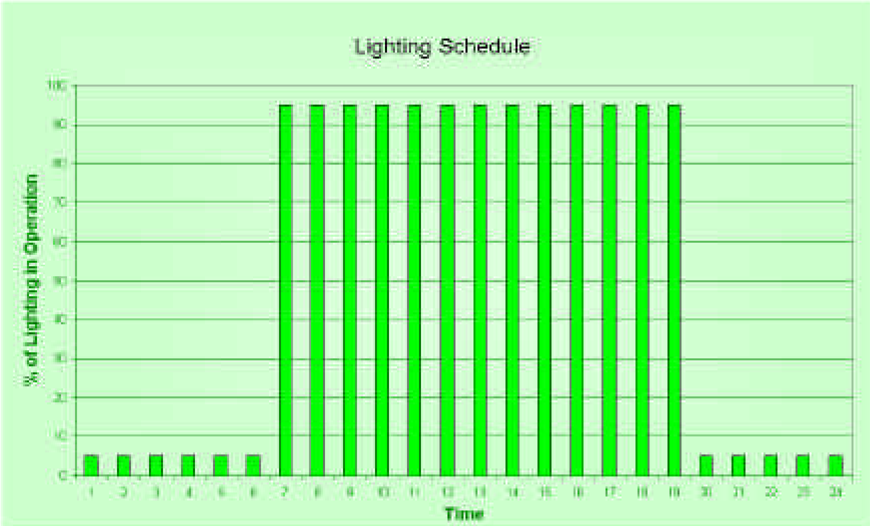


Figure 4.2 Lighting schedule in base case

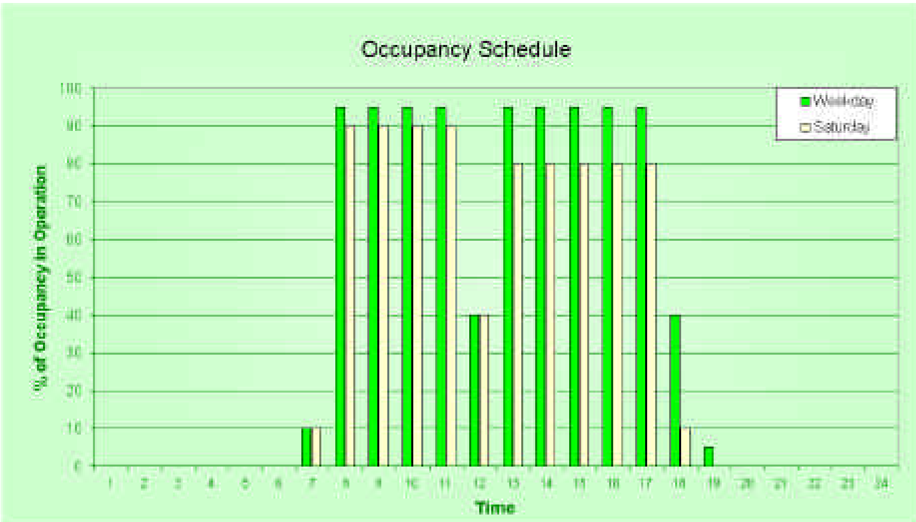


Figure 4.3 Occupancy/equipment schedule in base case

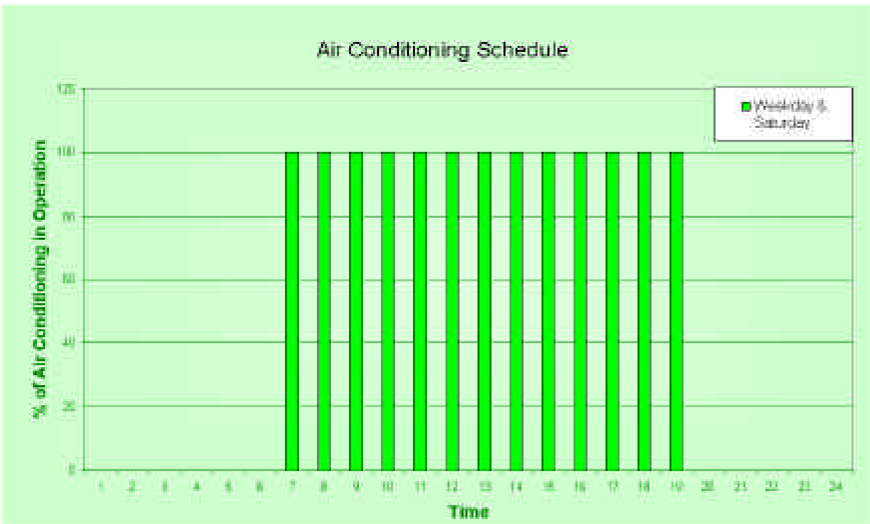


Figure 4.4 Air-conditioning schedule in base case

4.3 Major findings and results

In order to study and assess the impact of energy saving measures and green design features for the new site office in Tsing Yi, a number of DOE-2 simulations ("alternatives") have been performed by changing the design parameters in the based case model building. The alternatives being studied were identified from the previous studies on existing site offices and determined from discussion with the local site staff. Our analysis focuses on the following areas for environmental improvement and aims at providing better understanding of the effect of the measures on the building's energy performance:

- Wall insulation
- Roof insulation and green roof
- Sun control and protection
- Scheduling
- Lighting system
- Skylight and daylighting

Different combinations of the alternatives have also been studied to evaluate the optimal solutions for the different measures. Major findings and results of the analysis are described in the following sub-sections.

4.3.1 Wall insulation

To study the effect of wall insulation, we have carried out analysis for the following design options:

- Change the container-based structure to prefabricated wall
- Add one inch preformed mineral insulation board
- Add one inch polystyrene expanded insulation board
- Add one inch polyurethane expanded insulation board

Figure 4.5 shows the effects on the wall's U-value and on the building load component of wall in the energy requirements. It can be seen that improving the wall insulation will reduce the load component to about half of that of the base case.

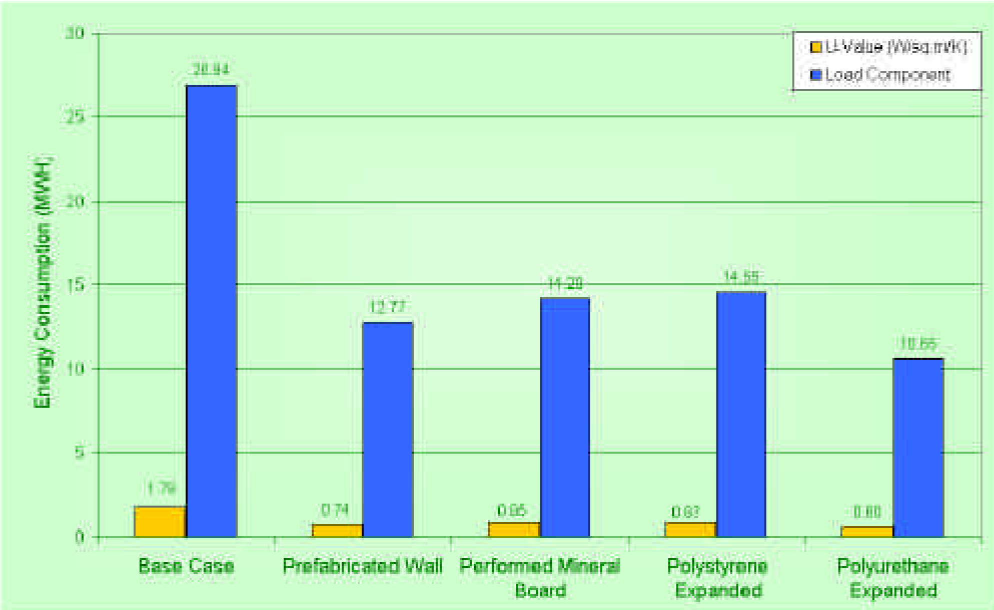


Figure 4.5 Effect of wall insulation

4.3.2 Roof insulation and green roof

The following design options have been considered for the roof and the results of the analysis are shown in Figure 4.6.

- Add one inch preformed roof insulation
- Add one inch polystyrene expanded insulation board
- Add one inch polyurethane expanded insulation board
- Add “green roof” to the top (represented thermally by a 160mm gravel)

It can be seen that the load component of roof can be greatly reduced by adding insulation to the roof layer. It is recommended to introduce roof insulation together with the use of green roof to get maximum benefits for environmental improvement.

A green roof usually consists of a plant level, a vegetation layer, a filter sheet, a drainage layer and a protection layer (see Figure 4.7). However, in our analysis the effect of the green roof is represented by using a 160 gravel layer. It is believed that the actual thermal insulating effect can be larger because of the presence of moisture in the soil and the evaporation effect of the plants. However, these effects may vary from time to time, and for design purpose, they are not taken into account in our analysis.

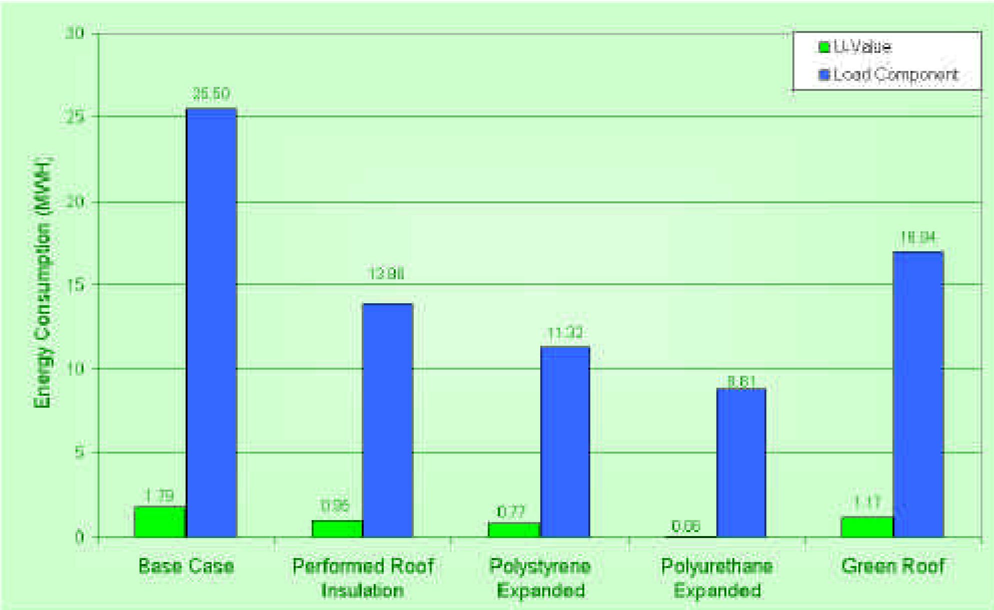


Figure 4.6 Effect of roof insulation

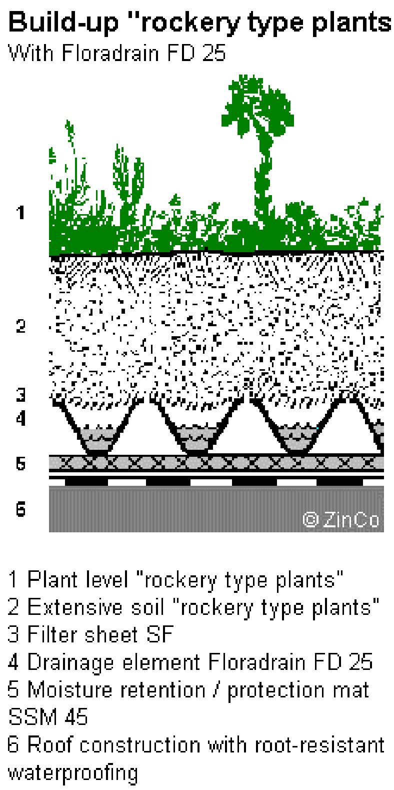


Figure 4.7 Section of green roof design

The green roof design is proposed as an alternative not only to enhance thermal insulation but also to introduce greenery and healthy environment to the site office. There are lots of environmental advantages by applying green roof. Their shallow soil can reduce rainwater run off to less than 50% of normal, reducing the pressure on the ground level drainage system. The rainwater retained in the soil supports the plants, reduces the temperature, humidifies the air and reduces the dust levels, through evaporation. However, care must be taken to ensure waterproofing of the roof structure. The local site staff has discussed with the green roof supplier and proposed a basin-type arrangement for the soil of the green roof so as to promote reuse of the green roof components and ensure waterproofing.

4.3.3 Sun control and protection

To study the effect of sun control and protection measures, we have introduced external shading device to the windows of the building. The external shading includes overhangs of 400 mm deep and side fins of 400 mm deep. Figure 4.8 shows the effect of external shading on the total annual building energy consumption (site energy). The building energy consumption is reduced from 271.3 kWh/m^2/yr to 261.7 kWh/m^2/yr when both overhangs and side fins are added to the windows. It is believed that by careful design of window orientation and configuration, the shading against direct sunlight can help to reduce solar heat gain and hence decrease the energy consumption for air conditioning.

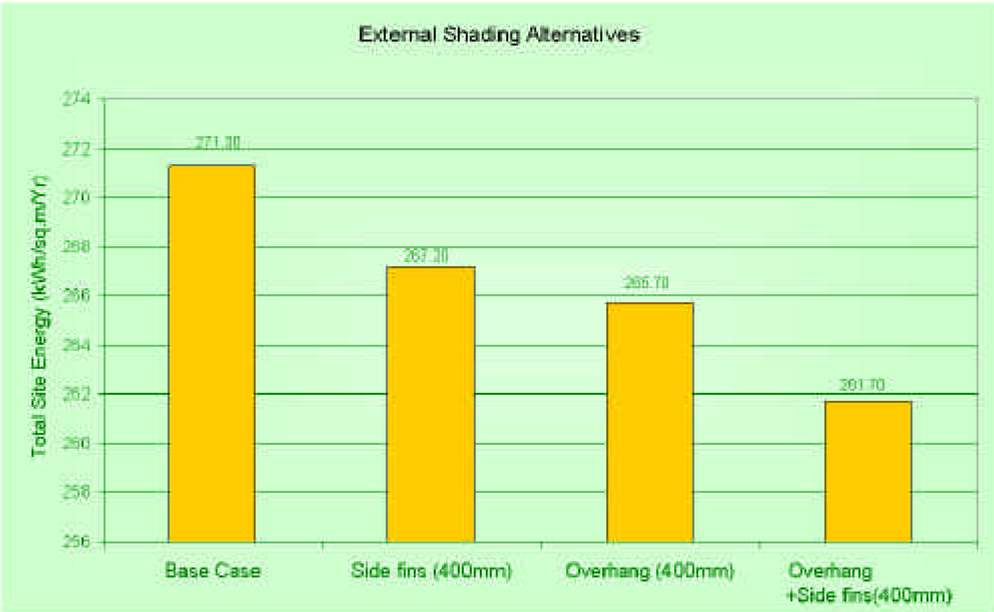


Figure 4.8 Effect of external shading

Initially, a new technique using window film or protective coating has been considered for improving the window performance. But after obtaining the price information and discussing with the local site staff, this option is not adopted because of the high first cost.

4.3.4 Scheduling

The scheduling and operation of the building' s internal loads can have a significant impact on the building energy consumption. In order to evaluate the effect of scheduling, we have designed and studied two options for the site office. The first option is to adjust the lighting and air conditioning equipment schedule on Saturdays to reflect the situation when some people will be off in the Saturday. The percentage of lighting load has been decreased by 5 to 15 percents depending on the time of the day and the shut-off of the air conditioning has been changed to one hour earlier than the base case. Figures 4.9 and 4.10 shows the profiles of the lighting and air conditioning schedules.

The second option is about optimum start/stop of the lighting and air conditioning equipment. From the studies on the existing site offices, it is found that the lighting and air conditioning equipment are not optimally controlled and operated. There is a potential for adapting the operation to the actual requirements of the occupants. To model and study the effect, we have adjusted the morning start up time to one hour later and the afternoon shut off time to one hour earlier. The actual control will of course depend on the building's operation and it can be implemented through automatic or manual switches.

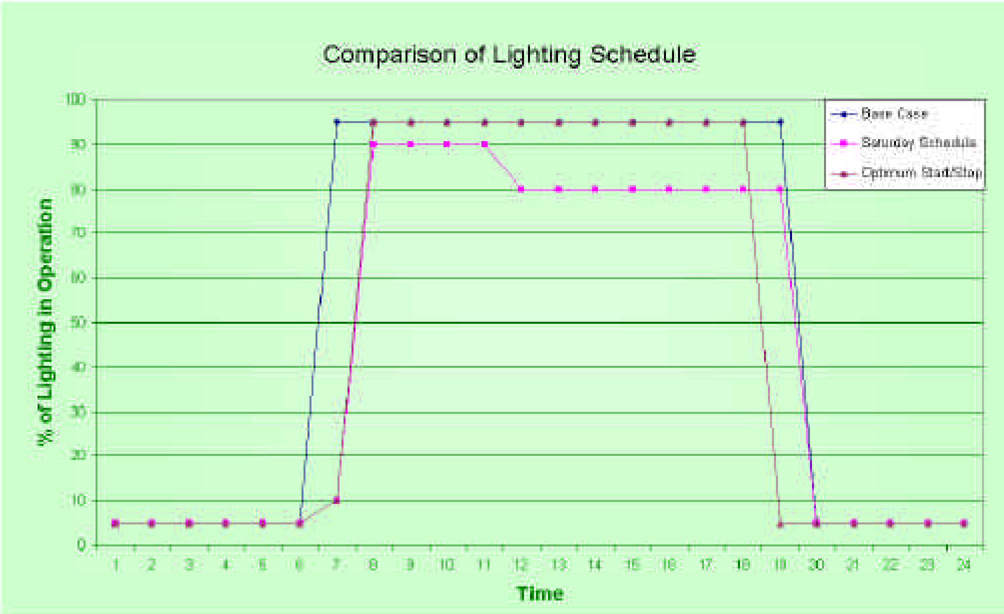


Figure 4.9 Lighting profile for the study of schedule and operation

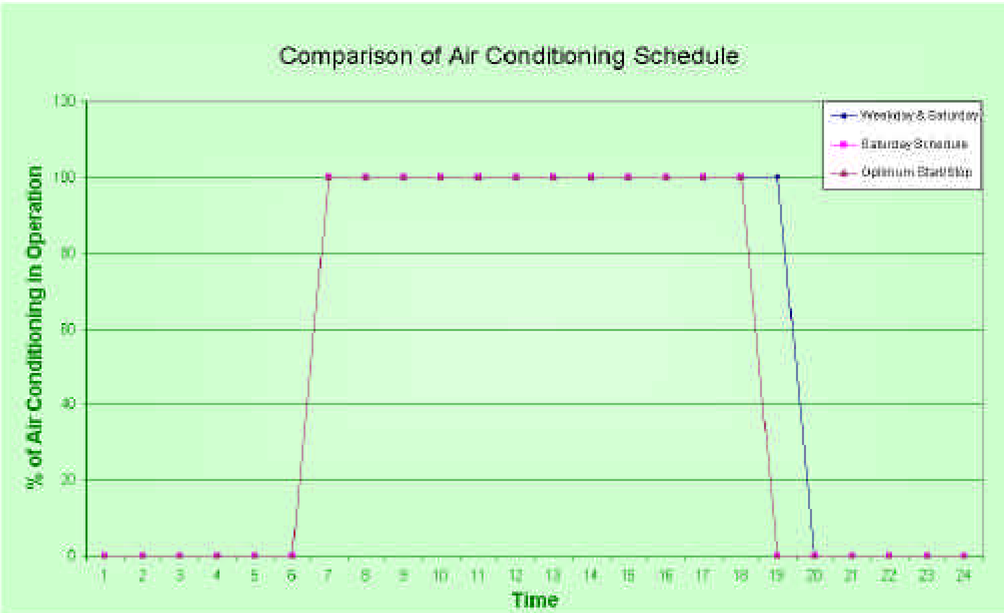


Figure 4.10 Air-conditioning profile for the study of schedule and operation

Figure 4.11 shows the effect of scheduling on the building's annual energy consumption. The energy consumption is reduced by 1.5% and 6.8% respectively for the two options. It can be seen that the saving is significant and the measures should be investigated further.

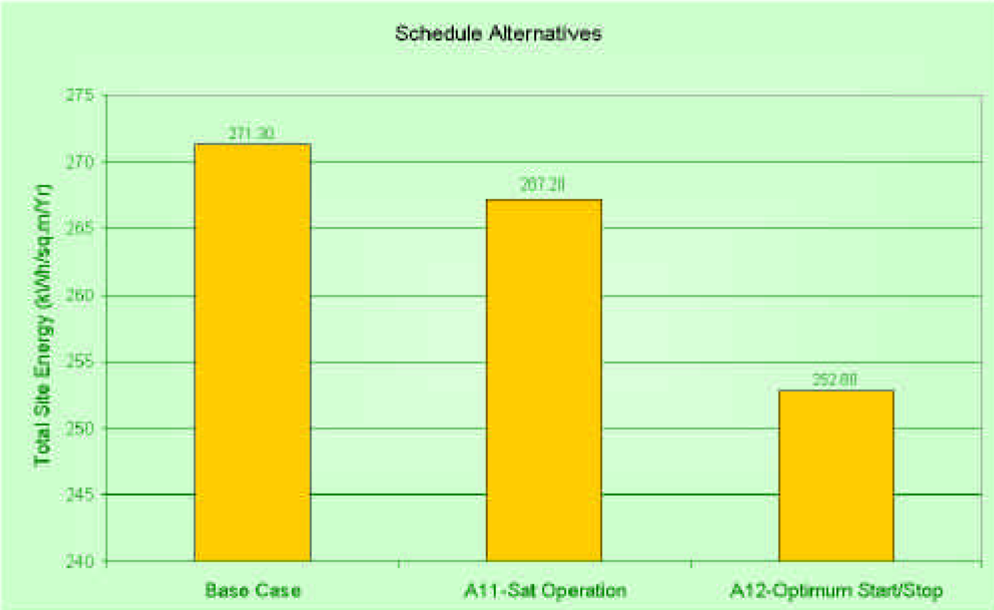


Figure 4.11 Effect of scheduling

4.3.5 Lighting system

To improve the lighting system, we have proposed to change the fluorescent battens lighting installation to a recessed fluorescent system based on luminaries with two energy saving TL-D lamps. Because the luminaries have been changed, complete lighting design calculation need to be performed to determine the optimal lighting configuration to meet the same illumination criteria. Please refer to Chapter 5 for details about the lighting design and calculation.

Building energy simulation has been performed for the new lighting system and the result is shown in Figure 4.12. It can be seen that the annual building energy consumption has been reduced by 12% as compared to the base case. The saving comes from the reduction in lighting energy and the decrease of lighting heat gain extracted by the air conditioning system.

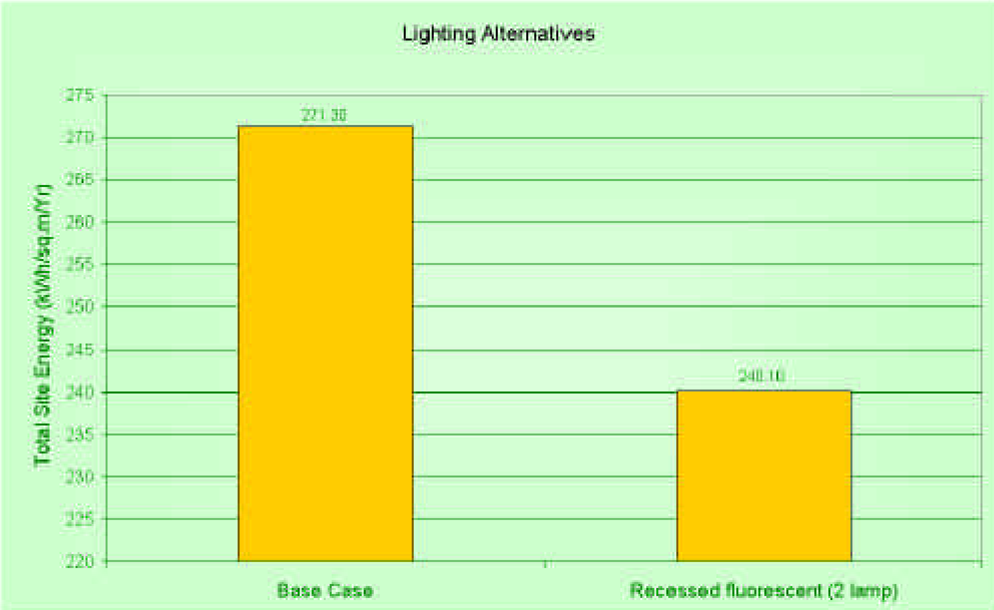


Figure 4.12 Effect of changing fluorescent battens to recessed fluorescent

4.3.6 Skylight and daylighting

After discussion with the local site staff, it is proposed that a skylight could be introduced to the new site office in order to improve the architectural quality and improve occupant's contact with natural daylight in the interior space. The design of the skylight will be presented in Chapter 5.

Simulations have been carried out to study the effect of the skylight on the building's energy consumption. It is believed that the skylight will allow more heat to enter the building and will increase the cooling energy requirements. But at the same time, the penetration of natural daylight can help reduce the lighting energy use if proper daylighting control is being used in the building. The complicated interaction between heat and light, together with psychological effect with the quality of the indoor environment, should be considered.

Two types of glass have been studied for the skylight (one is single clear glass and the other is single bronze glass) and the effect of daylighting control using dimming device has also been evaluated. Figure 4.13 shows a summary of the simulation results. It can be seen that on the whole the building's energy consumption is increased by introducing the skylight. But if proper strategies can be taken to select higher performance glass and adopt daylighting control, the net increase of energy use can be reduced. The occupants can then enjoy the benefits of skylight without having to pay much penalties on energy consumption.

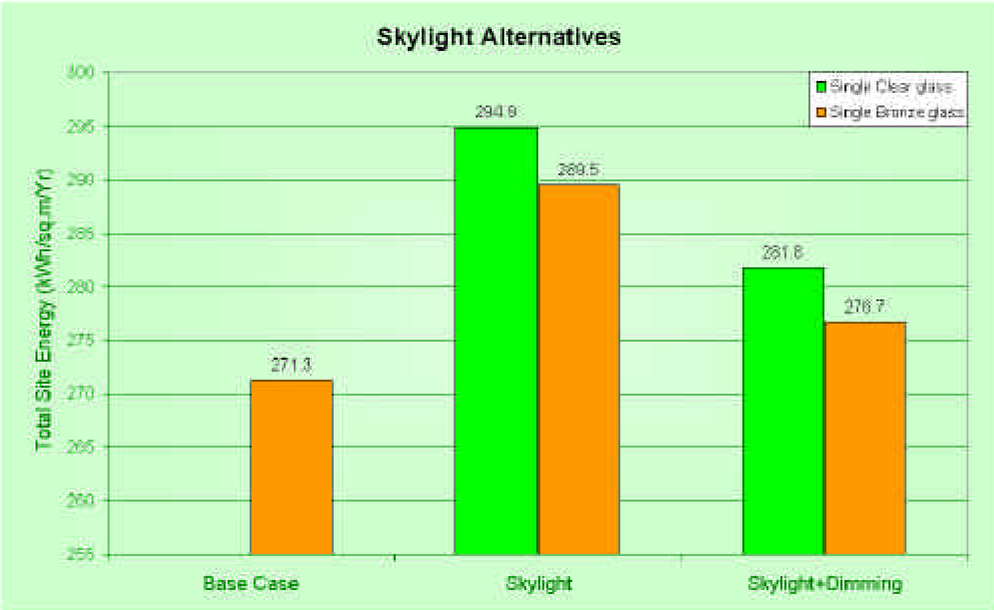


Figure 4.13 Effect of skylight and daylight dimming control

4.3.7 Combination of alternatives

Simulations were carried out to study the effect of combining the different alternatives which have good saving potential. Figure 4.14 shows the results of the combination studies. The alternatives relating to roof insulation, external shading and lighting system are evaluated. It can be seen that the annual building energy consumption is reduced by 26.5% when all three sets of measures are used in the building.

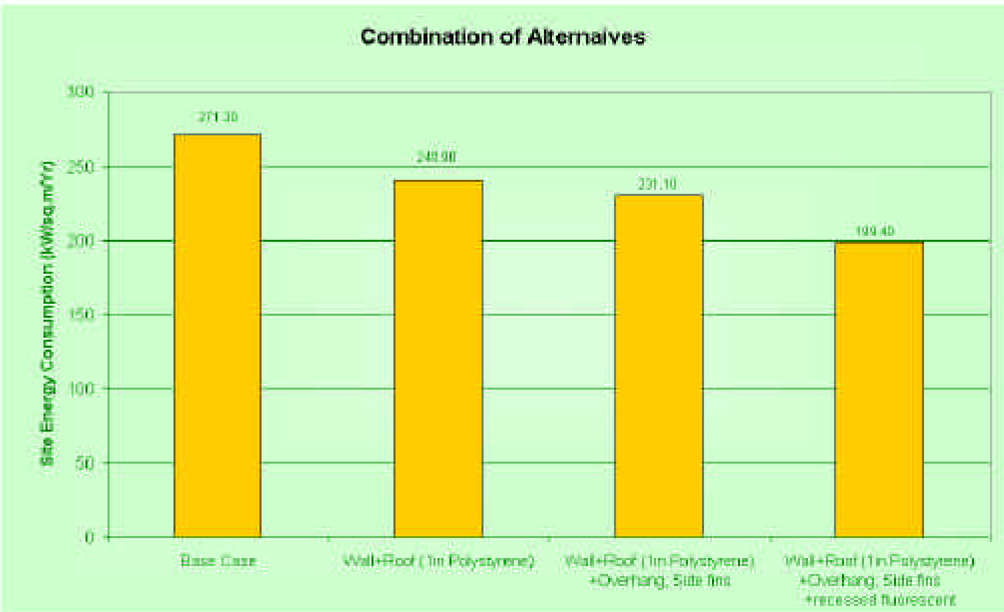


Figure 4.14 Combination of alternatives

5. Lighting System and Daylighting Design

Lighting enables humans to go about their lives, including work and play, as effectively as possible. It provides for our visual needs, and also safety and security. It is fairly obvious that lighting is crucial to human performance and proper design is needed to ensure satisfactory effects. Good lighting results in productivity benefits for the company, and economic analysis shows that just a tiny improvement in worker productivity far outweighs the cost of an enhanced lighting system.

In our analysis on energy performance, it is found that the lighting system has good saving potential. It is also important for green building design to achieve good visual environment and quality to enhance human performance. Therefore, design and analysis have been carried out to evaluate the lighting system for the site offices and recommend good practices for the new site office in Tsing Yi.

5.1 Design and evaluation of lighting system

First of all, we have collected information and studied the lighting systems of the four existing site offices. Table 5.1 gives a summary of the lighting installations in these site offices. Some site measurements have also been carried out at the Tsing Yi office to assess the actual conditions and develop better understanding about the visual environment. Appendix VI gives the results of the lighting measurements in Tsing Yi site office. It is found that the general lighting environment in the existing 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.

Table 5.1 Lighting systems in existing site offices

	Tsing Yi	Tuen Mun	Eastern Corridor	Wu Tip Kuk
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
Lighting consumption (kWh)	10672.2	9437.4	15655.5	5424.3

To design and evaluate the lighting system for the new site office in Tsing Yi, we have calculated the lighting levels and visual quality for two cases, one representing the conventional design and the other representing a green, energy efficient design.

- *Base case*: Fluorescent battens (TMS012/236-2xTL-D36W/25)
- *Alternative case*: Recessed fluorescent with parabolic louvers and reflectors to enhance distribution and minimise glare (TBS300/236-2xTL-D36W/25)

Appendix VII provides details of the lighting design calculations. The lighting design and evaluation is carried out using a spreadsheet method we developed from the formulae and data in lighting design handbooks as well as a computer program called “Calculux Indoor” obtained from Philips Lighting. The performance and quality of the current lighting installations have been assessed with the aim to identify areas for energy saving and visual quality improvement.

The recessed fluorescent lighting system is recommended because it has better visual quality and lower power consumption. Recessed fluorescent with louvers and reflectors can improve lighting distribution and reduce the glare which is uncomfortable to the occupants. The reflectors can concentrate the light down to occupied zone, which can help reduce the lighting power density and electricity consumption. As shown in Table 5.2, the total number of luminaries, total wattage and lighting power density are reduced in the alternative case.

Table 5.2 Summary of characteristics of lighting system

	Base case	**Alternative case**
Total number of luminaries	93	74
Total number of lamps	154	116
Total system wattage (W)	6791	5116
Total lamp wattage (W)	5544	4176
Light power density (for system) (W/m^2)	15.98	12.03
Light power density (for lamp only) (W/m^2)	13.04	9.82

To study the visual quality of the lighting system, detailed lighting calculations have been performed for a selected area of the site office, which is the HS&E and Engineer area. Figures 5.1 and 5.2 show the filled ISO contour of the area for the base case (fluorescent batten) and the alternative case (recessed fluorescent). It can be seen that with similar wattage and power consumption, the alternative case can provide a better lighting level and quality.

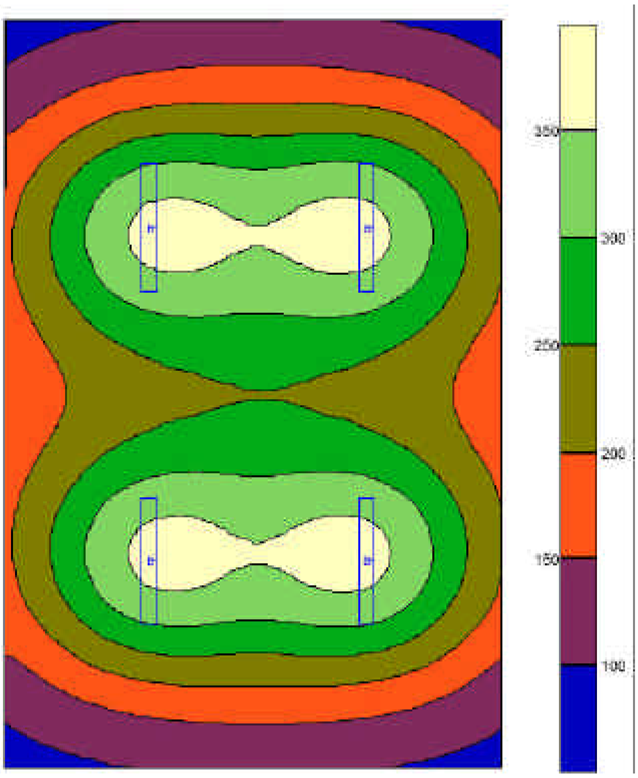


Figure 5.1 Filled ISO Contour for HS&E and Engineers’ area (fluorescent batten)

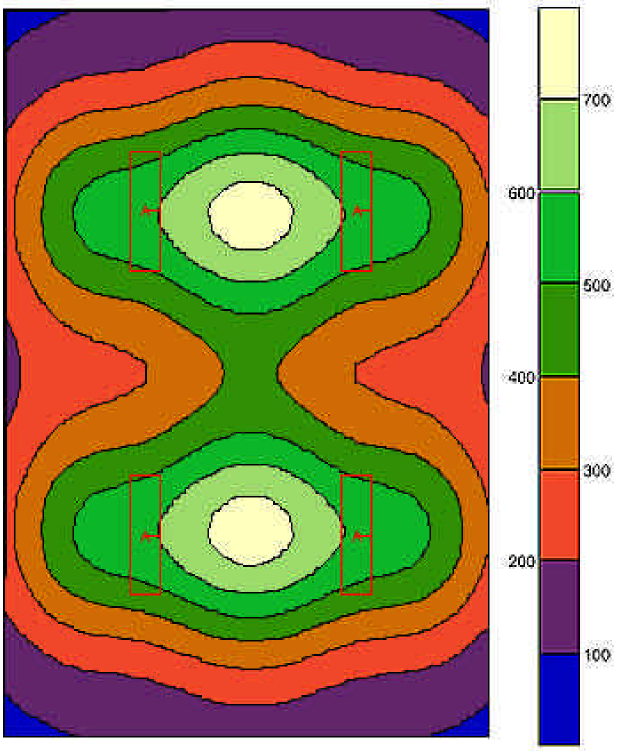


Figure 5.2 Filled ISO Contour for HS&E and Engineers’ area (recessed fluorescent)

5.2 Assessment of dayligting potential

Many research studies have confirmed that people consistently prefer having natural light and windows in their workspace, and that they also believe that the presence of windows or natural light contributes to enhanced productivity. To achieve better lighting design for the new site office, studies have been carried out to assess how daylighting can be better utilised in the office space.

First of all, the architectural planning and building orientation must consider this so as to provide the best opportunity for admitting natural daylight. Figure 5.3 shows the location of the new site office in Tsing Yi and the area designed for the building is about 23 m x 15 m. It is found that although the current location is constraint by the available land area, the basic architectural layout of the site office would encourage daylighting from the south and other directions. However, as the minimum dimension of the site office exceeds 10 metres, it may not be easy for the interior space to have window openings and receive natural daylight. To resolve the problem, and after discussion with the local site staff, it is proposed to add skylights on the roof and a small atrium in the middle of the building. The small atrium can let in light and air, as well as encourage circulation of groups and individuals working in the site office.

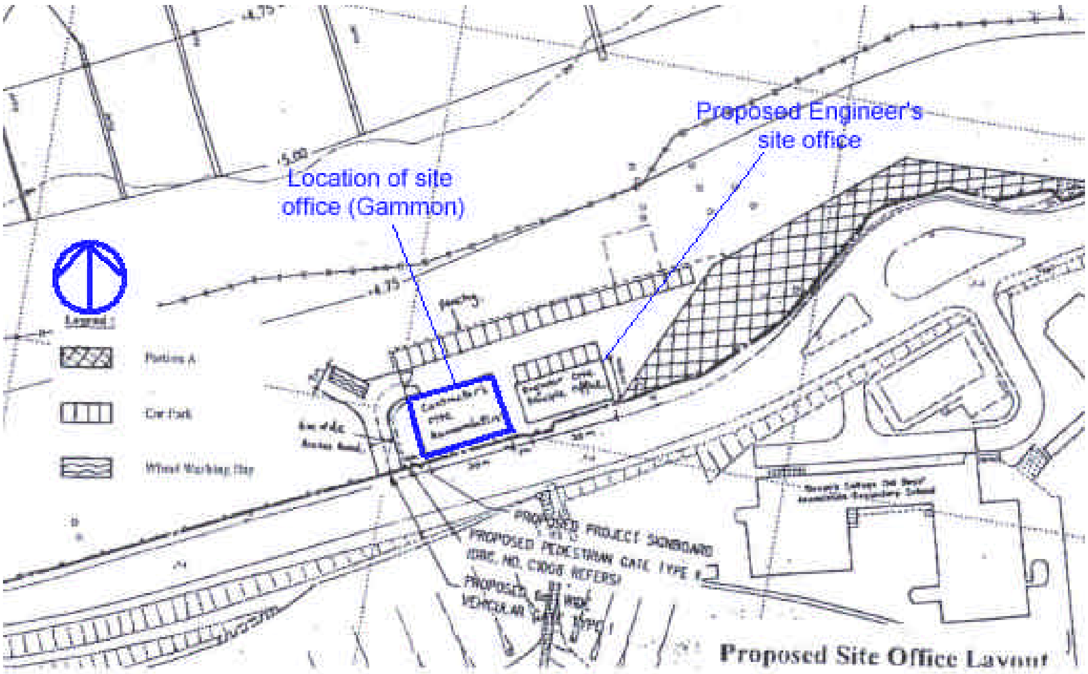


Figure 5.3 Location of the new site office in Tsing Yi

Figures 5.4 to 5.6 shows three options for external design of the sklight that have been considered for the new site office in order to avoid excessive glare and sunlight falling into the interior space. However, they are not adopted in the final building design because the local site staff has suggested to reuse an existing roof frame structure from another site office and it will be difficult to create the skylight like this without causing problems to water proofing. The final building design has adopted a simple flat surface for the skylight (see Figure 5.7).

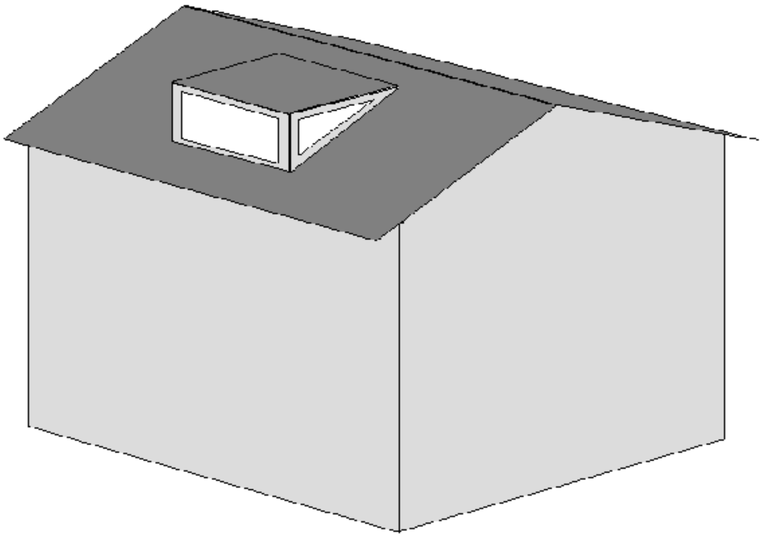


Figure 5.4 External design of the skylight, option 1

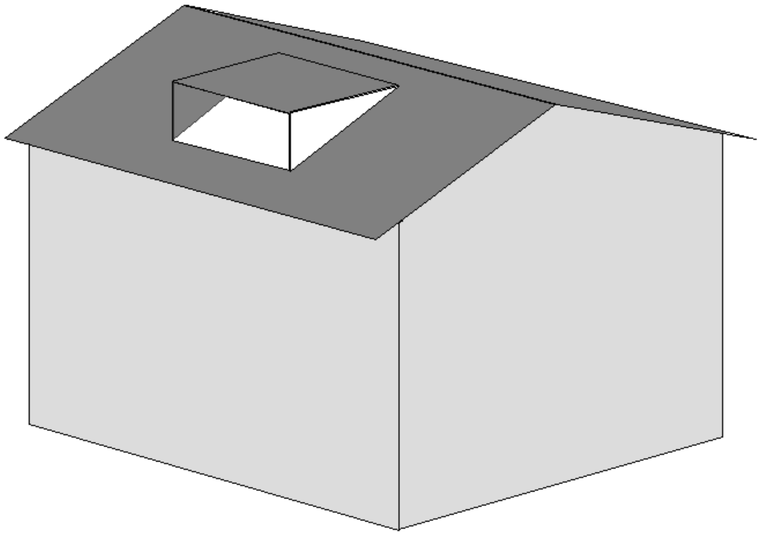


Figure 5.5 External design of the skylight, option 2

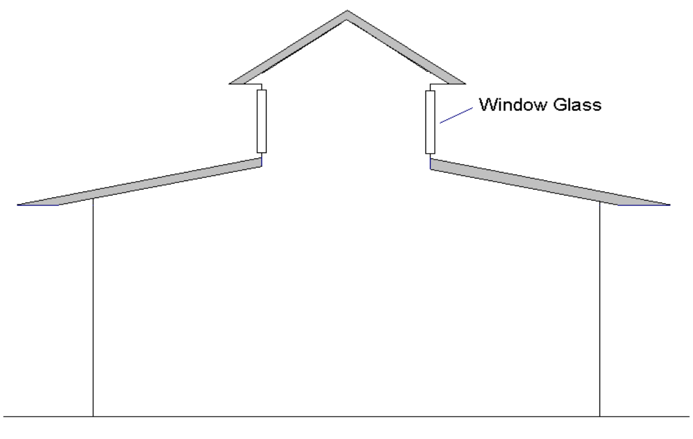


Figure 5.6 External design of atrium skylight, option 3

When the skylight is put on the top of the two-storey atrium of the site office, the people standing right below may feel uncomfortable under the direct sunlight. In order to avoid or minimise this discomfort, internal shading has been suggested and two design options as shown in Figures 5.7 and 5.8 have been studied. The purpose is to protect the occupants from glare and direct sunlight. It is recommended also that the internal shading should be of material that can convert direct sunlight into diffuse light so that the interior space can have sufficient daylight for illumination and the environment can be more healthy.

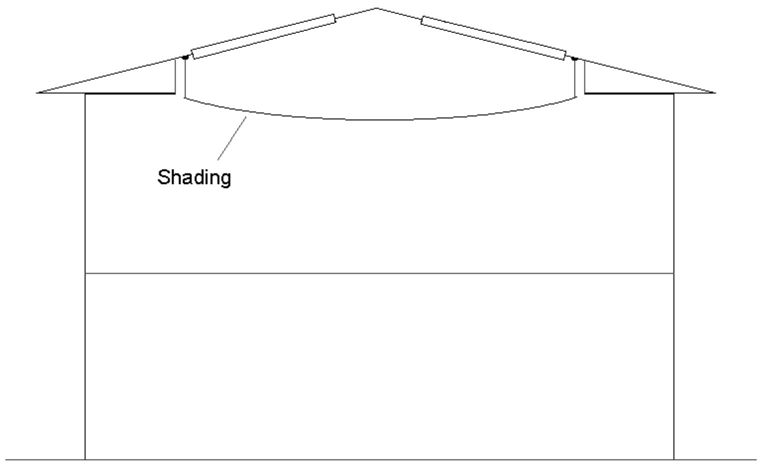


Figure 5.7 Internal shading of skylight, option 1

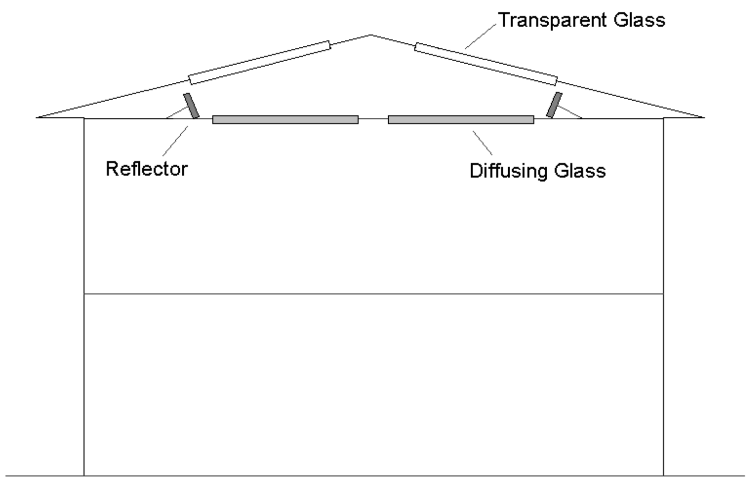


Figure 5.8 Internal shading of skylight, option 2

5.3 Recommended practices

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. It is believed that lighting has considerable impact on the environment and it is one of the major energy end uses in buildings. 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.

One effective way to reduce lighting equipment and energy consumption is the use of *task-ambient lighting*. Task-ambient lighting strategies produce energy savings in three ways. First, locating the light source close to the task most efficiently produces the illumination levels needed for the task. Secondly, task illumination levels don't have to be maintained uniformly throughout the space, so ambient levels can be lower. And finally, some occupants won't use their task lights, and empty offices or workstations with absent occupants don't have to be fully illuminated, saving even more energy. Usually an ambient light level of around 200 lux is provided to permit casual task work in most environments, and this also relates well to most task types requiring 500 lux of task illumination. It is recommended to investigate the possibility of task-ambient lighting for the site office. It is also advisable to provide individual control of the workplace, including lighting and cooling.

It is clear that *natural daylight* can save energy, money, and positively impact building occupants. Coupled with exterior and interior shading devices, high-performance windows and photosensors, daylighting can be integrated and used effectively in the site office so that higher percent of employees have access to daylight and outdoor views. There are two types of automatic daylighting control systems: dimming and switching. Dimming control varies the light output over a wide range to provide the desired light level. Switching controls turn individual lamps off or on as required. In a conventional two-lamp fixture, there are three settings: both lamps off, one lamp on, both lamps on. The same strategy can be used with three- and four-lamp fixtures. Dimming systems require electronic dimmable ballasts and are more expensive than switching systems, however, they achieve the largest savings and do not have the abrupt changes in light level characteristic of switching systems. It is recommended to investigate further what type of daylighting control is suitable for the site office.

6. Assessment of Green Design Potential

The term "*green*" can have many meanings in different situations. In the present context, green design and construction involves a holistic approach to the planning, design, construction and operation of the site offices. All the resources that go into the building, be they materials, fuels or the contribution of the users need to be considered if a green site office is to be produced.

A brief review has been conducted at the end of this study to assess the environmental performance of the site office and evaluate green design potential of future site offices. Important issues for promoting green design have been identified for consideration, implementation or further investigation. It is believed that green design requires an integrated approach that considers the whole life cycle process of building development from planning, to site selection, to system design, to materials specification, to operation and to disposal/demolition of the building.

6.1 Building environmental assessment

It is found out from our literature review that there is no building environment assessment method specifically designed for the situation of construction site offices. In order to carry out the assessment, we need to rely on the methods available and keep this in mind when interpreting the assessment results. Two assessment methods have been chosen and used to assess the new site office in Tsing Yi. These methods include the Hong Kong Building Environmental Assessment Method (HK-BEAM) (CET, 1999) and the Leadership in Energy & Environmental Design (LEED) in USA (USGBC, 2001).

HK-BEAM is a voluntary scheme initiated by the Real Estate Developers Association of Hong Kong. It tries to define good practice criteria for a range of environmental issues relating to the design, operation, maintenance and management of buildings. Credits are awarded where standards or defined performance criteria are satisfied. Where these are not satisfied, guidance is given on how performance can be improved. The outcome of the assessment is shown on a certificate as a rating of "Fair", "Good", "Very Good", or "Excellent". Further information about the assessment procedure can be found in the HK-BEAM document (CET, 1999). Table 6.1 shows a summary of the assessment results for the site office. A total credit points of 29 is obtained and this indicates that there is still much room for improvement.

Table 6.1 Summary of HK-BEAM assessment results

Credit Requirement	Credits Obtained
Electrical energy consumption	11
Facility for recycling materials	1
Electricity maximum demand	3
Water conservation	2
Recycled materials	1
Transport and pedestrian access	2
Vehicular access for servicing and for waste disposal	2
Operations and maintenance	2
Indoor air quality	3
Interior lighting	2
TOTAL =	29

LEED is the most widely recognised and used green building design and certification program in the USA. It provides a framework covering six broad areas:

- Sustainable site planning
- Improving energy efficiency
- Conserving materials & resources
- Enhancing indoor environmental quality
- Safeguarding water
- Integrated design process

LEED is a point-based system that applies a set of requirements in each of the six key areas and then offers a menu of credits. Buildings can be LEED certified, silver level, gold level or platinum level, based on ascending level of points achieved by the building design. Table 6.2 shows a summary of the LEED assessment results for the site office. Appendix VIII gives the details of the LEED assessment criteria. The new site office in Tsing Yi can only get 24 points out of 69 points and fails marginally in this assessment. However, as a pilot design for green site offices, it is understandable that the performance could be improved and better understanding of the relating issues could be developed in the future.

Table 6.2 Summary of LEED assessment results

Credit Requirement	Credits Obtained
Site selection	1
Brownfield redevelopment	1
Reduced site disturbance	2
Landscape & exterior design to reduce heat islands	1
Light pollution reduction	1
Optimize energy performance	2
Renewable energy	1
Additional commissioning	1
Building reuse	1
Resource reuse	2
Recycled content	1
Local/Regional materials	2
Controllability of systems	2
Thermal comfort	1
Daylighting & views	1
Innovation in design - Green roof - Skylight - Atrium - Daylighting control system	4
TOTAL =	24

6.2 Important issues for promoting green design

The goal of green design is to reduce material use during construction, save energy during building operation, and result in a healthier working environment. To formulate the strategy for achieving green site offices, three key areas have been identified and described below.

- Planning and design strategy
- Construction method and materials
- Environmental policy and management

6.2.1 Planning and design strategy

The most important opportunity to shape a green and energy efficient building design is during the early design process. Designing a green building often involves additional modelling and design costs. Although these early additional costs are very small relative to overall cost of buildings, they are a major impediment to better building designs, especially during the period of economic downturn.

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. In order to benefit from the new opportunities that green building design offers, all members of the project team must be educated and oriented to the goals, costs and benefits of green design. Today, there is sufficient literature and references that examine all aspects of green or sustainable design and development. Examples of good design guidebooks include AIA (1994), BSRIA (1999), Commonwealth of Pennsylvania (1999), Hermannsson (1997), Mendler and Odell (2000), Ove Arup & Partners (1993), RAIA (1995), USGBC (1996) and Venables, et al. (2000). Many of the design principles and considerations are applicable to site offices. For instance, the following guidelines are useful for ensuring good and green design:

- Locate a building near public transportation to minimise pollution from vehicle use.
- Plan, design, and lay out spaces with flexibility in mind. The ability to adapt areas to meet unforeseen future needs will limit demolition, renovation, and, moreover, disposal of building materials in area landfills.
- Landscape facility grounds with native plants and vegetation; during new construction projects, limit disruption to the site' s native plant and animal species.
- When possible, avoid developing new facilities on greenfield sites. Effectively locate on brownfield sites and in existing buildings when possible.
- Take advantage of daylighting, natural ventilation, passive solar heating and water systems by orienting buildings on an east-west axis. Likewise, consider area wind patterns to promote cross ventilation.
- Purchase furniture and interior finishes that have "classic" design elements. Durable products with timeless design will keep facilities from looking dated, limit replacement costs, and cut down on waste.
- Implement a plan to control erosion and sedimentation during construction.

At the beginning of this pilot study, we have discussed with the local site staff and developed a set of planning and design strategy for their consideration. Table 6.3 shows the major items of the planning and design strategy. Although not very items have been implemented or adopted, 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.

Table 6.3 Planning and design strategy for green buildings

Site Planning • Site selection and analysis • Transportation strategy • Built forms and orientation
Energy Efficiency • Building envelope (window/opening design, thermal insulation, air tightness) • Passive cooling and heating (natural ventilation, thermal storage) • Shading and sun control (against overheating) • Daylighting (natural lighting) • Cooling strategy (heating, ventilating & air conditioning) • Lighting systems • Other building services systems (e.g. plumbing) • Appliance energy efficiency (e.g. energy labels) • Heat/energy recovery (waste heat recovery) • Building management and controls
Renewable Energy • Passive solar (low energy architecture) • Active solar (e.g. solar hot water) • Photovoltaics (solar electricity) • Wind power • Other renewables (e.g. biomass, biogas)
Water Conservation • Reduction of water consumption • Rainwater collection & recycling • Greywater recycling • No-/Low-water composting toilets
Building Materials • Green specifications • Prefabrication • Life cycle analysis
Indoor Environment • Indoor air quality • Visual quality • Acoustic quality

6.2.2 Construction methods and materials

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. In the 1990s, it becomes very common to employ a combination of cargo containers with connecting structural members and interior finishes. Nowadays, pre-fabricated structure made of metal panels can be found in many construction projects.

However, the construction industry in Hong Kong is still relying heavily on traditional building technology. Site offices and other related buildings are usually constructed by the conventional method. Not surprisingly, our research study indicates that time and cost are the most important factor in selection of construction methods and materials for building projects. Environmental performance and reduction of waste are the least important factors in the minds of the contractors.

In fact, there is a potential for the project team to improve the building's environmental performance and minimise the production of waste in site offices by using innovative and sustainable technologies such as modular building and recycled building components. 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 that are suitable for the construction of low rise building like 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.

6.2.3 Environmental policy and management

While good design and information can to some extent influence the way that a building is used, it is also critical to involve other stakeholders in the process, for example, the local site staff, occupants, facility managers, operators and subcontractors. True green building will require the cooperation & participation of PEOPLE. It is important to increase people's awareness through environmental policy and management in the organisation. Greening the site office can 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 improved.

To create and promote the *culture* of green design and construction, it is crucial to have clear guidelines, education and training, leadership and information. Currently, Gammon Skanska has implemented an environmental management system and has also made effort to adopt green practices in construction sites, such as waste reduction scheme (WasteWise) and central management of equipment/materials for site offices (sharing/reuse is possible). 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

What makes a “green” site office or building? How shall we integrate green design in the construction activities?

This study has set out a theme to address and investigate green design and construction of site offices. It attempts to gather the key information and evaluate practical solutions to the above questions. In fact, producing green buildings involves resolving many conflicting issues and requirements. Each design decision in the construction process has environmental implications. To minimise the environmental impact, we must understand the various performances of the building and its related design factors.

7.1 Green design and construction

Site offices usually have short life span (2 to 4 years) and will require a different equation to their life cycle analysis. An advantage of “greening” the design and engineering process is the savings typically identified in the building systems that can be used later in the project. The task usually focuses on the minimisation of environmental impacts on our site neighbours, continuing improvements in reducing noise emission, air pollution and waste water discharge, as well as the recycling and disposal of construction and demolition materials.

Analysis of thermal and energy performance of the sites offices indicates that there is lost of opportunities in the current practices. It is recommended to consider and adopt energy conservation measures to improve the building’s environmental performance. Evaluation of lighting system also shows that green building can operate with lower costs and increased worker satisfaction. If the offices are “thinking spaces”, then their design should allow people to envision the living world around us. Green design is a process that will lead us to a new way of thinking on a sustainable world.

7.2 Suggested further studies

A number of possible further studies have been identified and they include:

- Monitoring & analysis of the new site office in Tsing Yi (a follow-up to what is estimated here).
- Development of a set of standard guidelines for green site offices that can be disseminated to others.
- Investigation of construction methods and buildability of innovative techniques.

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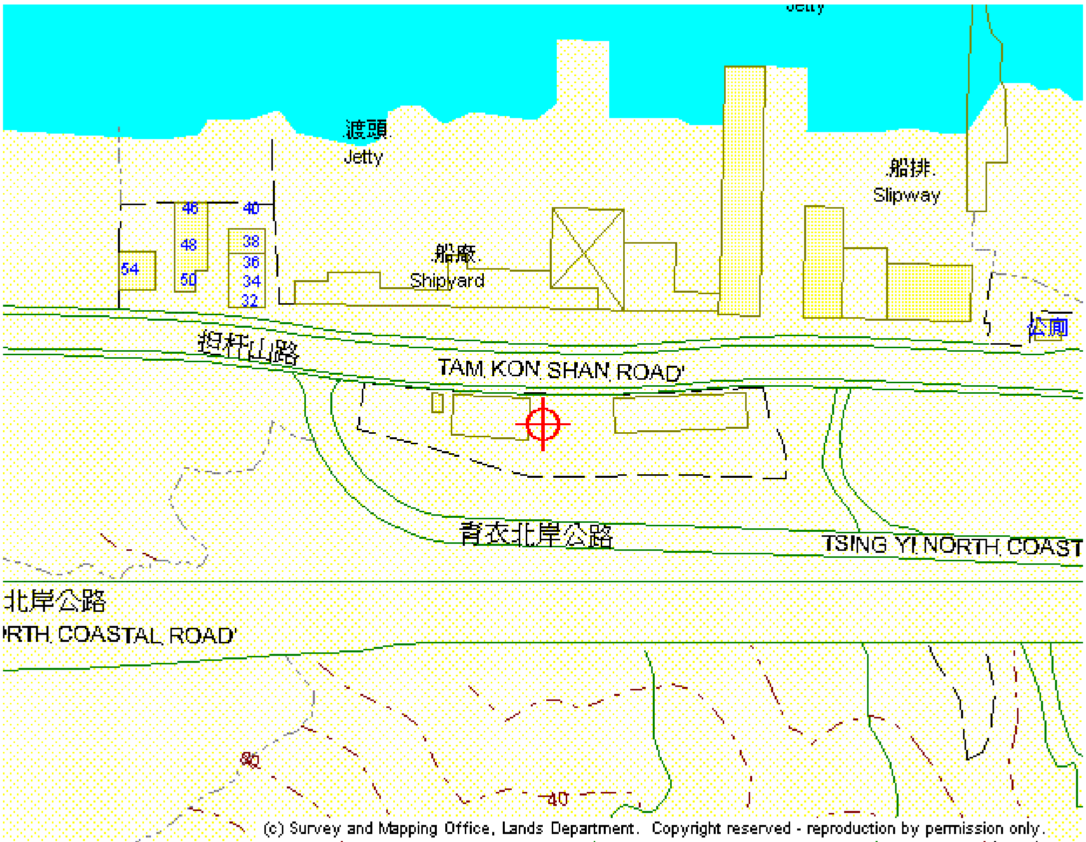
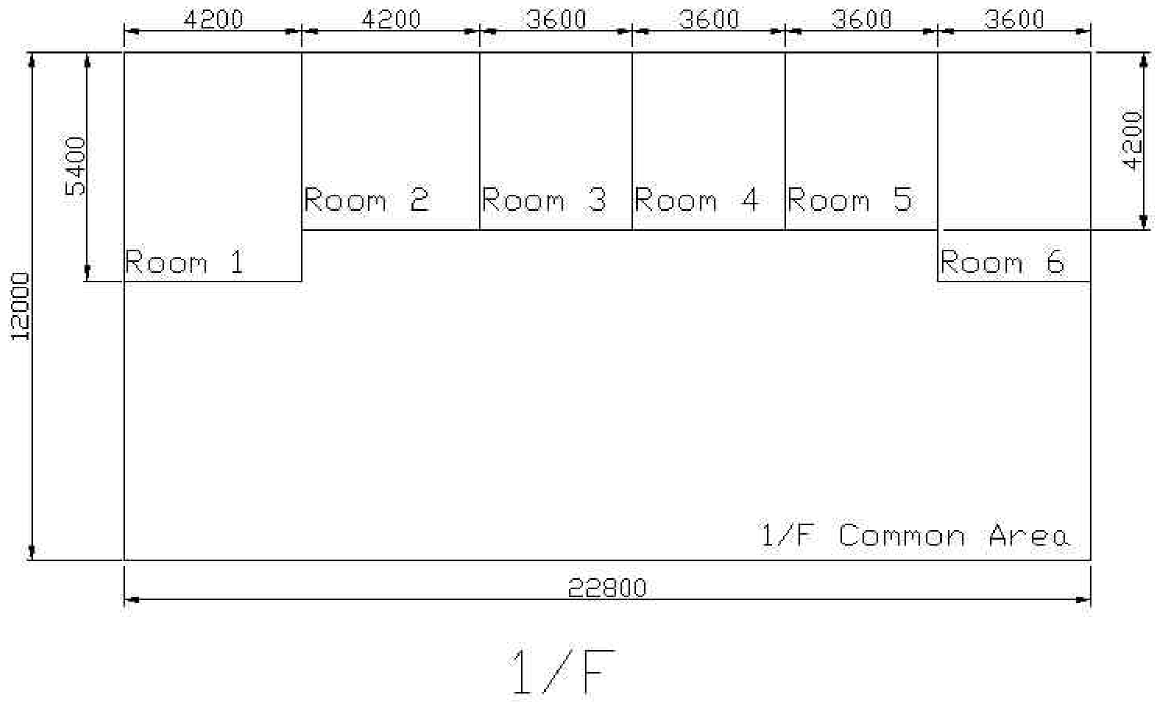
Appendix I – Background information of existing site offices

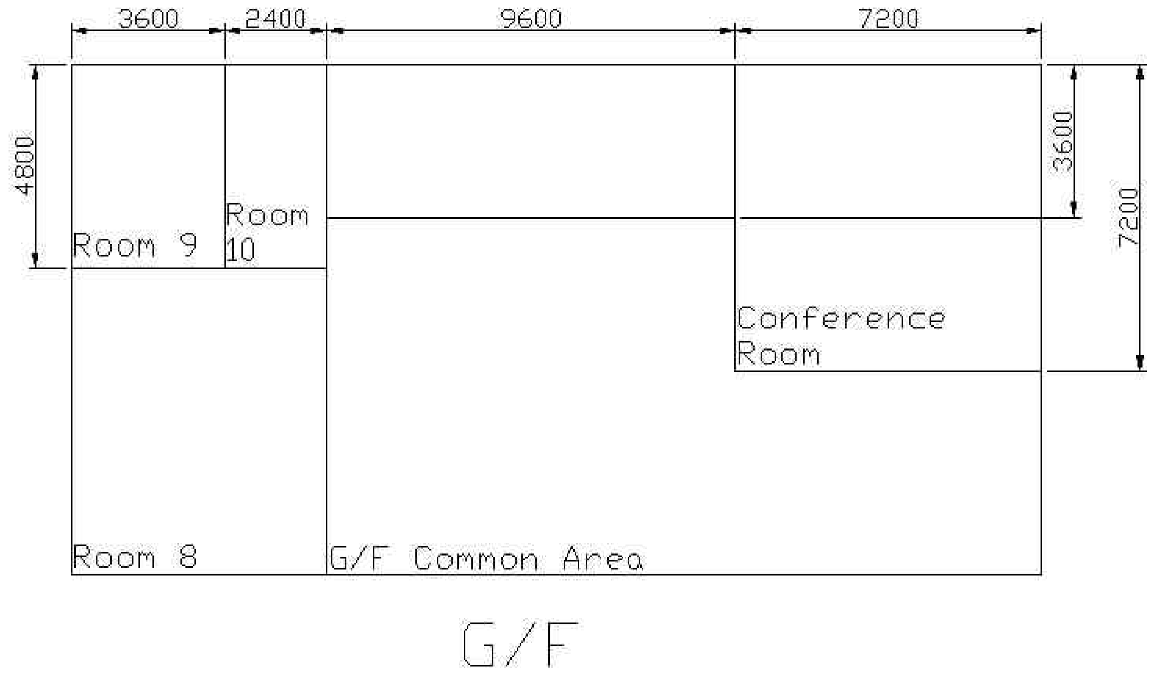
1. Tsing Yi site office



Location map of the site office at Tsing Yi

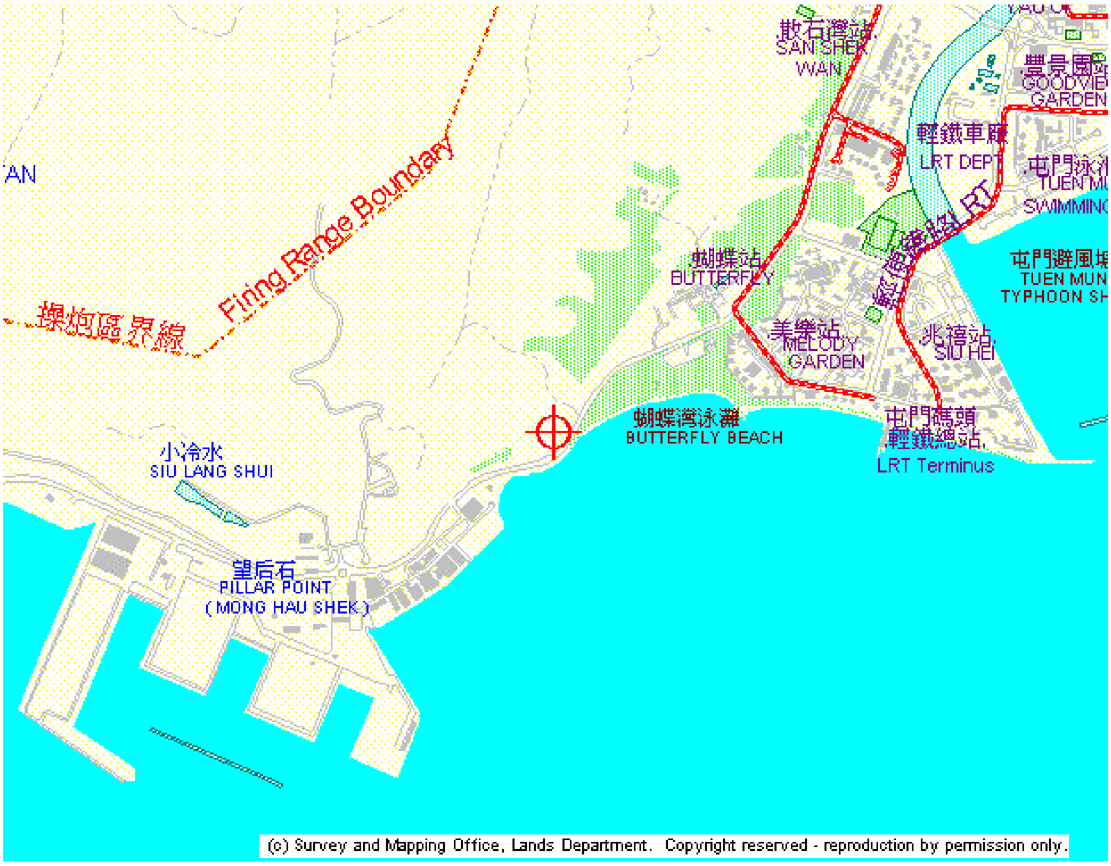
Picture of the site office at Tsing Yi





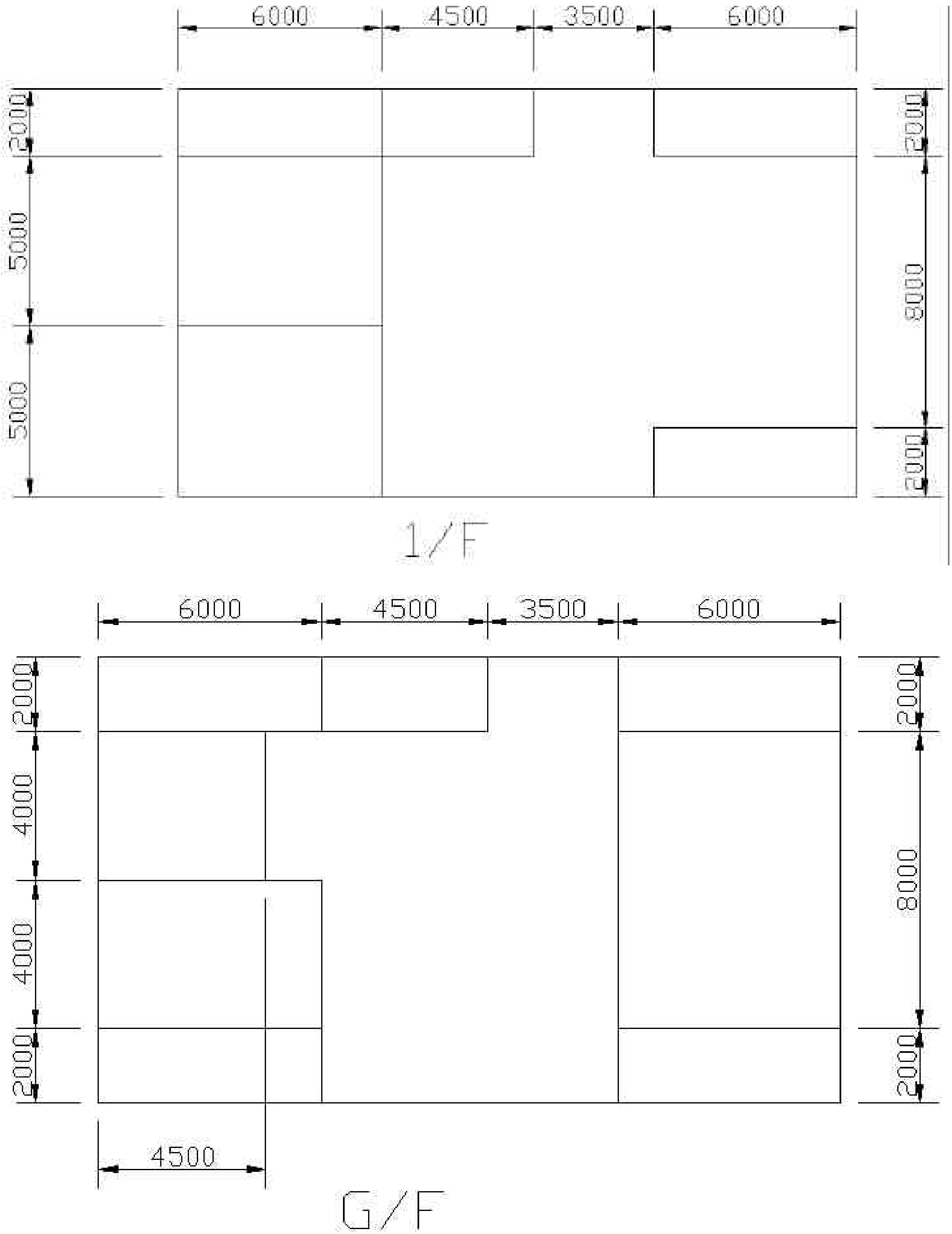
Floor plans of the site office at Tsing Yi

2. Tuen Mun site office



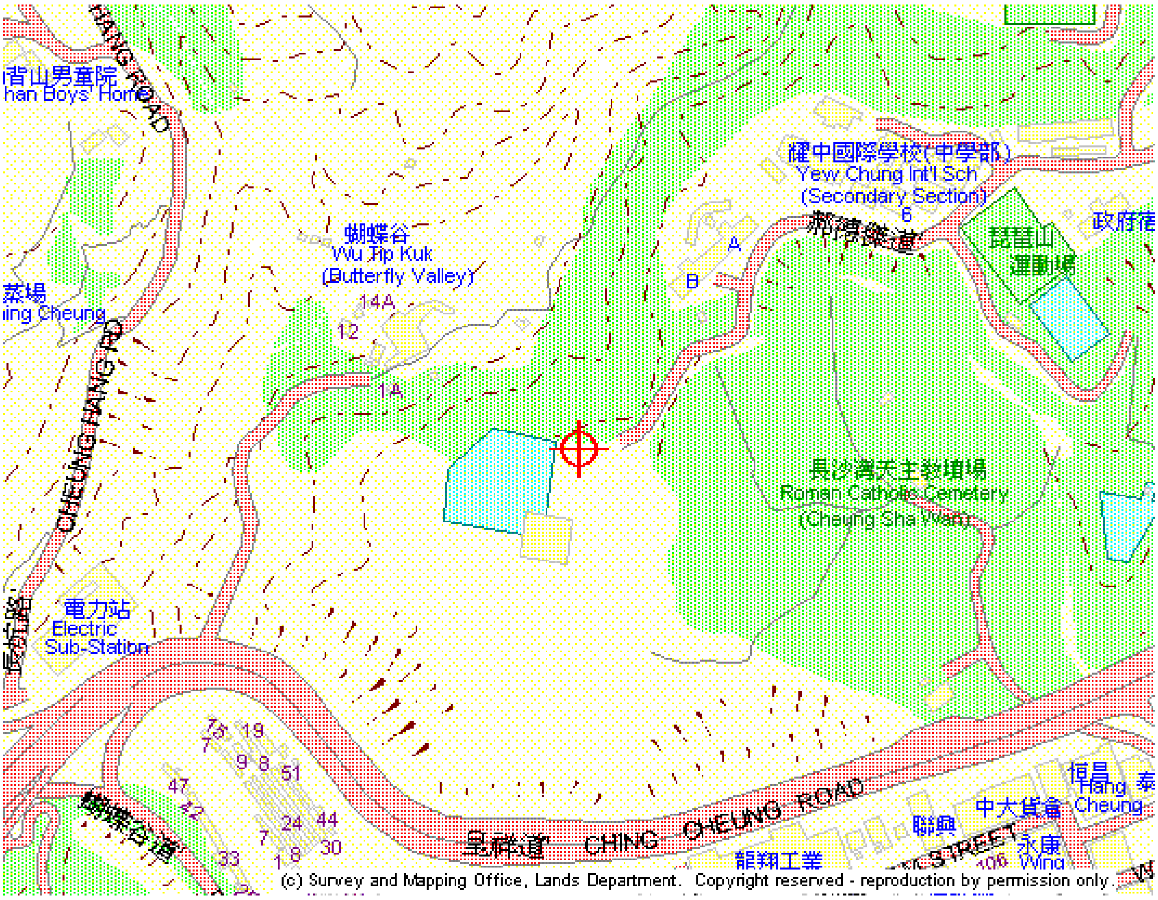
Location map of the site office at Tuen Mun

Picture of the site office at Tuen Mun



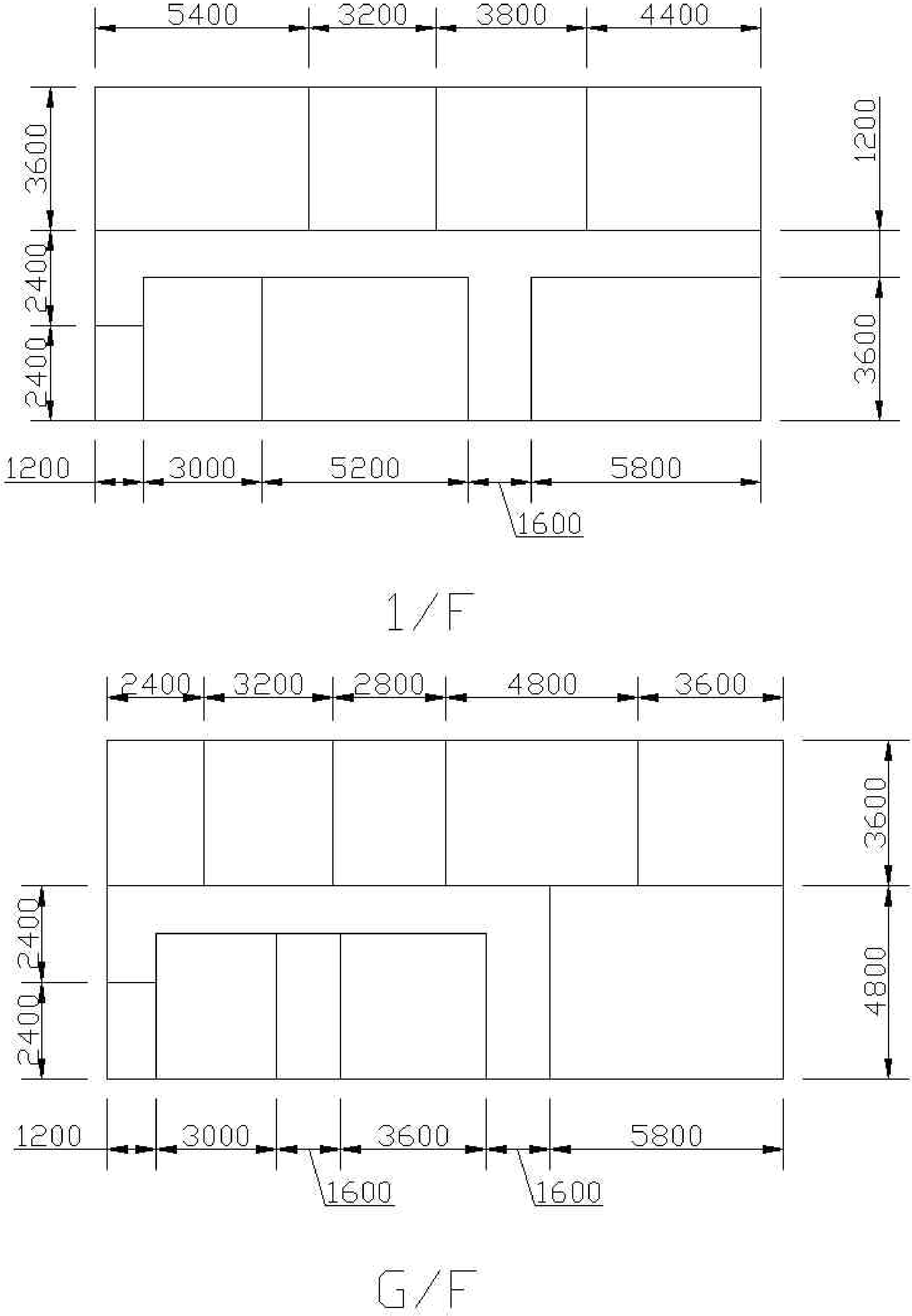
Floor plans of the site office at Tuen Mun

3. Wu Tip Kuk site office



Location map of the site office at Wu Tip Kuk

Picture of the site office at Wu Tip Kuk



Floor plans of the site office at Wu Tip Kuk

4. Eastern Corridor site office

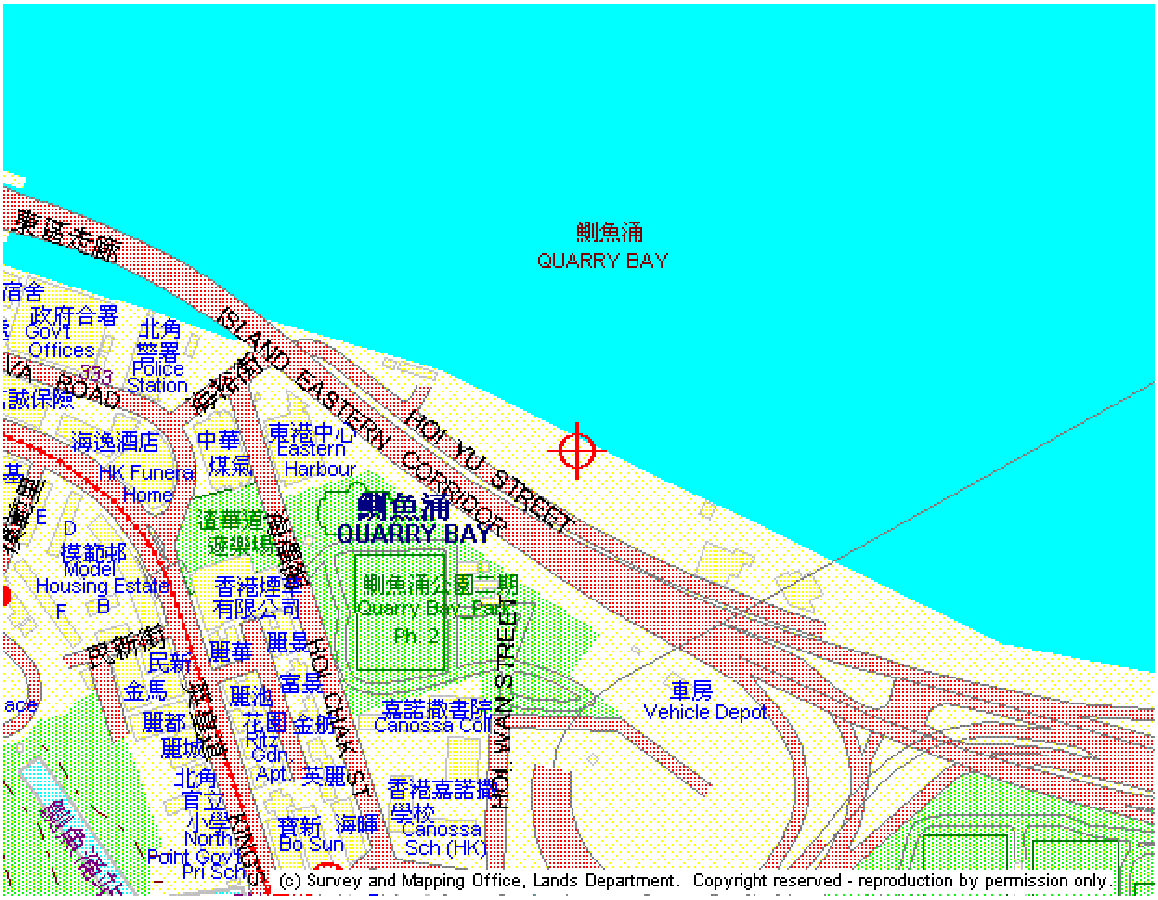
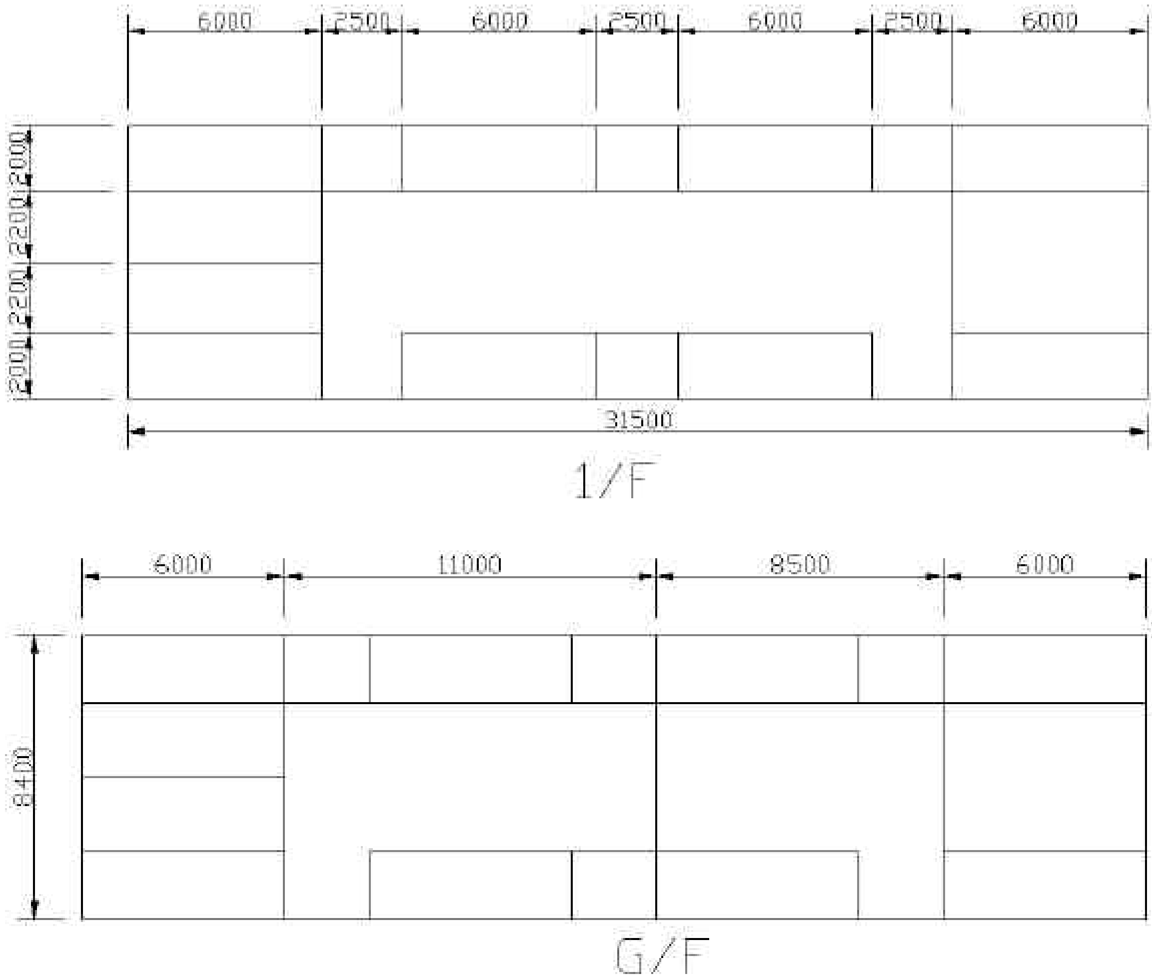


Figure 2.10 Location map of the site office at Eastern Corridor

Picture of the site office at Eastern Corridor



Floor plans of the site office at Eastern Corridor

Appendix II – Checklists for interview and site survey

Interview -- Technical assessment on planning, design and construction
To collect key information for designing green site offices

1. Planning

Consideration of selecting the location of the site office		
Orientation of the site office		
Budget		
Building lifetime		
Building system used	Rain water collection	
	Air conditioning	
	Fire system	
	Electric system	
	Network	

2. Design

Drawings of site office

Floor

No. of floor	
Area of each floor	

Material used in construction

External wall	
Inner wall	
Roof	
Floor	
Door	

Window

No. of windows	
Size of window	
Direction of window	
Any shading applied	

Construction

Construction time		
Who construct the site office		
How to construct the site office		
Disposal of the site office	Equipment	
	Furniture	
	Envelope	

Building operation - Time schedule

Operation hour	Engineers	
	Officers	
	Others	
Lighting and air conditioning service hour		
Lunch hour		
Total no. of occupants in the site office		
Environmental policy (staff training?)		

3. Operation cost

Type of operation cost in the site office

Items	% of total operation cost
Water	
Electricity	
Office machinery	
Stationary	
Security guard	
Pantry	

Equipment	No.	Model	Location
Lighting (fluorescent lamp)			
Air conditioner			
Computer			
Hot water pot			
Exhaust fan			
Printer			
Fax machine			
Photocopier			

Site office checklist										
Location										
Lighting										
	Model									
	No.									
	Lux									
	Morning	with shading								
		without shading								
		usual practice								
	Afternoon	with shading								

		without shading								
		usual practice								
Air-conditioning										
	Model									
	No.									
Window										
	Orientation									
	No.									
	Size									
	Occupancy									
External Wall										
	Orientation									
	No.									
	Size									
	Equipment									
	Surface temp.	Morning								
		Afternoon								
Function										

Appendix III – Summary of site measurements in existing site offices

1. Tsing Yi

1/F	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Common Area
Lighting level							
Morning/Afternoon (lux)	350/420	400/410	400/500	380/390	650/560	420/530	320/370
External wall							
Wall-1: Orient., area (m^2)	W, 13.0	N, 10.1	N, 8.6	N, 8.6	N, 8.6	N, 8.6	W, 15.8
Wall-2: Orient., area (m^2)	N, 10.1	---	---	---	---	E, 13.0	S, 54.7
Wall-3: Orient., area (m^2)	---	---	---	---	---	---	E, 15.8
External wall temp (^oC)							
Wall-1: Morning/Afternoon	24/31.3	29/32.8	28/32.2	24.2/26.3	22/25	24.5/28.3	24/32.8
Wall-2: Morning/Afternoon	21.5/25.4	---	---	---	---	25/26.8	24.5/28.9
Wall-3: Morning/Afternoon	---	---	---	---	---	---	25.5/28.1

G/F	Conference Room	Room 8	Room 9	Room 10	Common Area
Lighting level					
Morning/Afternoon (lux)	450/450	300/310	250/220	340/360	300/310
External wall					
Wall-1: Orient., area (m^2)	N, 17.3	S, 14.4	W, 11.5	N, 5.8	E, 8.6
Wall-2: Orient., area (m^2)	E, 17.3	W, 17.3	N, 8.6	---	S, 40.3
External wall temp					
Wall-1: Morning/Afternoon	26.7/26.7	25.1/24.3	24.3/28.4	26.1/27.8	25/26.9
Wall-2: Morning/Afternoon	26.5/26.2	24.8/26.8	24/26.2	---	26.8/25.8

2. Wu Tip Kuk

1/F	Room 1	Room 2	Room 3	Room 4	Conference Room	Room 6	Room 7
Lighting level							
Morning/Afternoon (lux)	450/500	570/80	300/320	390/470	400/460	250/370	180/190
External wall							
Wall-1: Orient., area (m^2)	W, 8.6	W, 8.6	S, 9.1	S, 7.7	S, 13.0	N, 7.2	N, 12.5
Wall-2: Orient., area (m^2)	N, 13.9	S, 10.6	---	---	E, 8.6	---	---
External wall temp (^oC)							
Wall-1: Morning/Afternoon	29.7/32.7	26.8/25.6	35.1/35.7	31.8/32.3	31/32.3	35.6/33.4	35.7/33.8
Wall-2: Morning/Afternoon	30.8/32.2	30.2/30.7	---	---	28.3/26.7	---	---

G/F	Room 8	Room 9	Room 10	Room 11	Room 12	Room 13
Lighting level						
Morning/Afternoon (lux)	310/390	540/540	320/380	150/250	250/300	310/350
External wall						
Wall-1: Orient., area (m^2)	N, 13.9	W, 8.64	S, 11.5	S, 6.7	S, 7.7	S, 5.76
Wall-2: Orient., area (m^2)	W, 11.5	S, 8.6	---	---	---	---
External wall temp						
Wall-1: Morning/Afternoon	30.2/31.7	28.9/32.4	32.2/33.1	32.2/33.3	32.8/33.7	33.8/33.7
Wall-2: Morning/Afternoon	30.6/33.4	28.5/31.4	---	---	---	---

3. Eastern Corridor

1/F	Room 1	Room 2	Room 4	Room 6	Room 10	Room 12	Common Area	Conference Room
Lighting level								
Morning/Afternoon (lux)	900/430	850/---	210/220	280/290	220/200	500/330	110/100	500/330
External wall								
Wall-1: Orient., area (m^2)	E, 4.8	E, 5.3	S, 14.4	S, 14.4	N, 14.4	N, 14.4	---	W, 10.6
Wall-2: Orient., area (m^2)	N, 14.4	---	---	---	---	---	---	---
External wall temp (^oC)								
Wall-1: Morning/Afternoon	33.9/26.2	34.3/---	28.1/28.8	28.6/32.1	29.8/26.7	29.4/28.9	---	29.6/30.9
Wall-2: Morning/Afternoon	28.8/24.5	---	---	---	---	---	---	---

G/F	Room 14	Room 17	Room 22	Room 24	Room 26	Room 27	Common Area
Lighting level							
Morning/Afternoon (lux)	150/150	150/160	160/170	160/150	130/130	150/150	130/130
External wall							
Wall-1: Orient., area (m^2)	E, 5.3	S, 14.4	W, 10.6	N, 14.4	N, 14.4	---	---
External wall temp							
Wall-1: Morning/Afternoon	29.8/27.3	27.2/28.4	28.8/30.3	26.6/23.7	26.5/26.4	---	---

4. Tuen Mun

1/F	Room 5	Room 4	Room 2	Room 1	Common Area	Room 3
Lighting level						
Morning/Afternoon (lux)	400/490	320/290	330/360	900/750	650/580	320/340
External wall						
Wall-1: Orient., area (m^2)	SE, 4.8	NE, 14.4	NW, 12	NW, 12	SW, 11.3	SW,19.2
Wall-2: Orient., area (m^2)	---	SE, 4.8	---	---	SE, 19.2	NE, 14.4
Wall-3: Orient., area (m^2)	---	---	---	---	NE, 19.2	NW, 4.8
External wall temp (^oC)						
Wall-1: Morning/Afternoon	30.3/32.4	32.1/32.6	30.9/34.4	33.4/38.8	34.2/37	32.4/34.2
Wall-2: Morning/Afternoon	---	---	---	---	34.5/33.9	33.2/35.1
Wall-3: Morning/Afternoon	---	---	---	---	32.2/33.6	29.7/37.1

G/F	Room 9	Room 8	Room 6	Common Area
Lighting level				
Morning/Afternoon (lux)	410/450	210/280	240/200	380/370
External wall				
Wall-1: Orient., area (m^2)	NE, 14.4	NW, 9.6	NW, 9.6	NE, 8.4
Wall-2: Orient., area (m^2)	NW, 4.8	---	---	SW, 19.2
External wall temp				
Wall-1: Morning/Afternoon	32.5/34.5	29.4/34.1	27.3/31.5	29.2/30.3
Wall-2: Morning/Afternoon	32.6/36	---	---	29.7/29.4

Appendix IV – Summary of the brief assessment on indoor air quality

Date: 26th August 2002
Instrument: Indoor Air Quality Meters IAQ-CALC™ Model 8760/8762

1. Engineers' Room

CO_2 level: 937ppm
Indoor Temperature: 26.6 °C
Size: 23 sq.m

Description: There are consistently 2-3 people stays in this room. One external wall of this room is facing south and the other is due west.

2. Manager's Room

CO_2 level: 570ppm
Indoor Temperature: 23.4°C
Size: 15 sq.m

Description: There are generally two people stay in this room, sometimes may be more due to some small meetings being held here. The only external wall of this room is facing south.

3. 1/F Common Area

CO_2 level: 666ppm
Indoor Temperature: 25.3^{o}C
Size: 168 sq.m

Description: Usually there are 7-8 people stay in here, which include 2 secretaries, also 5-6 people from another project team. There are also many people circulate around this area as many office equipments are here such as the graphic porters, photocopiers, fax machines etc.

4. G/F Common Area

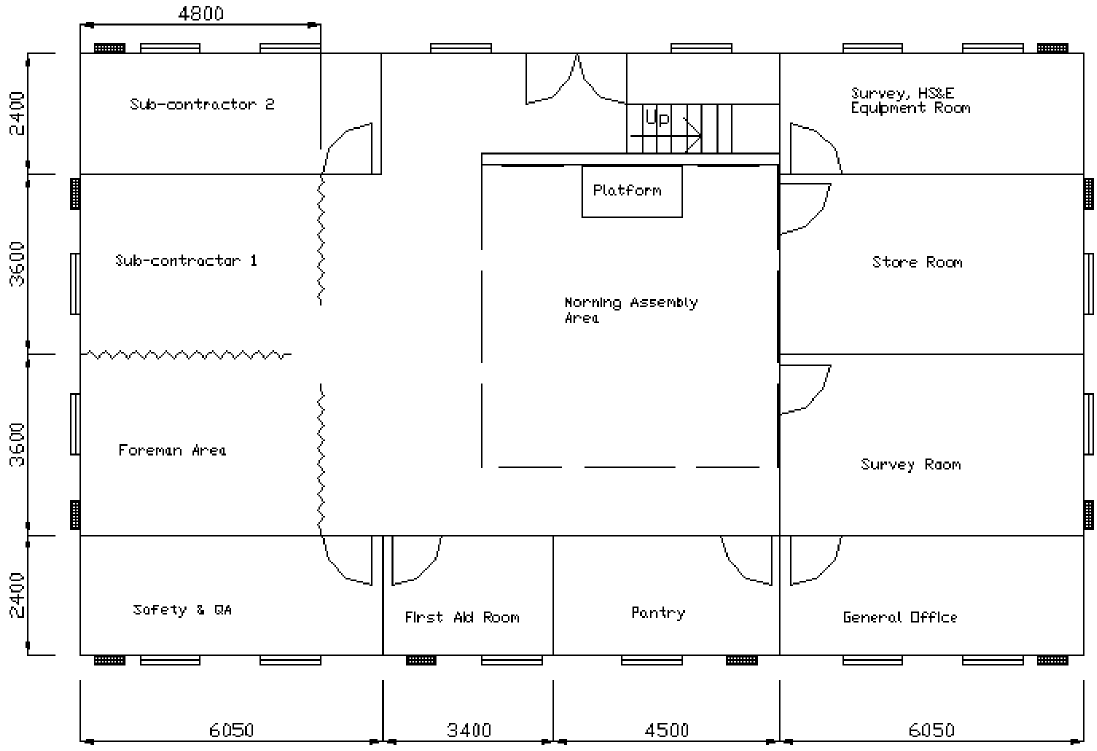
CO_2 level: 650ppm
Indoor Temperature: 24°C
Size: 107 sq.m

Description: 1-2 people from the general office and 2 people from sub-contractor stay in the G/F common area with low partition for separation.

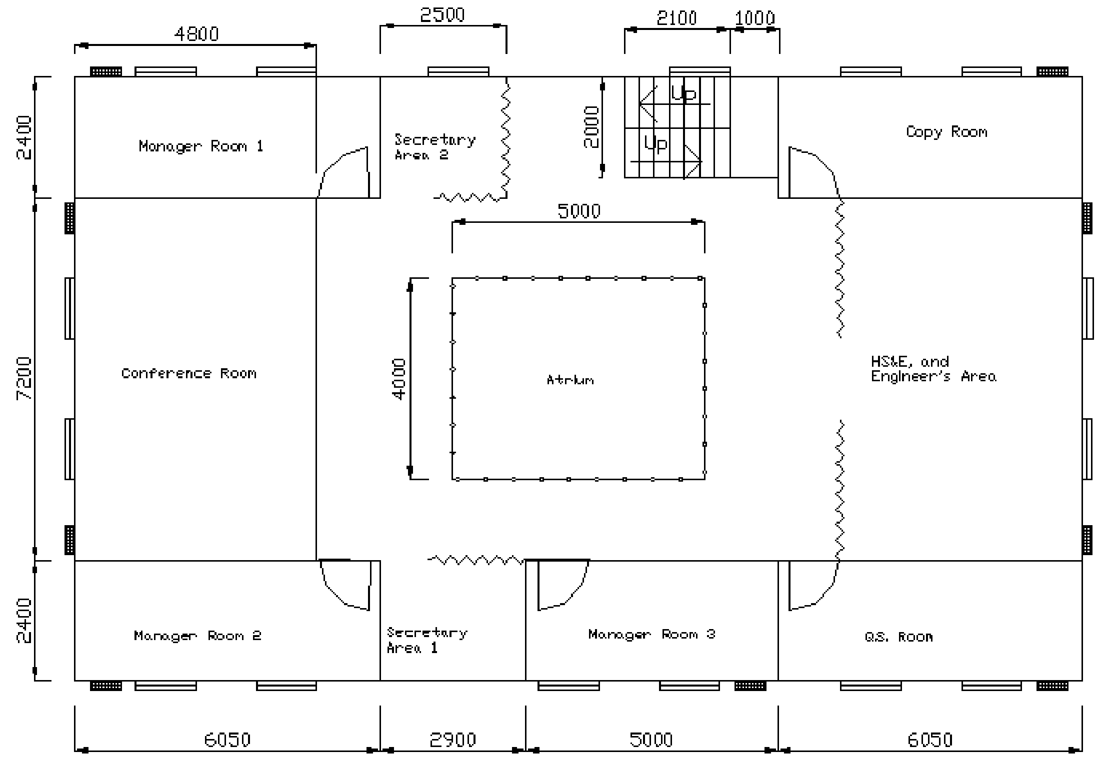
5. External Environment

CO_2 level: 365ppm
Indoor Temperature: 33.5^oC

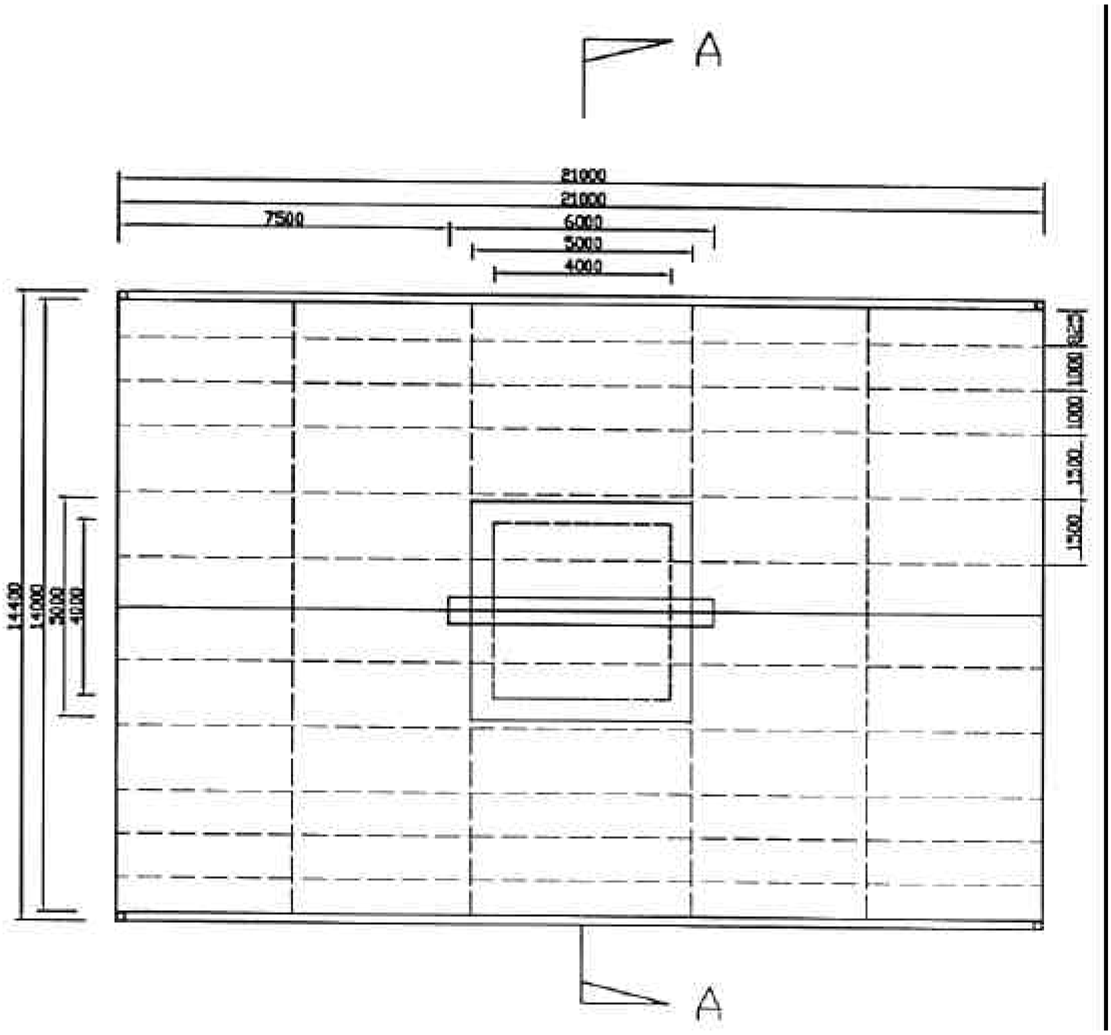
Appendix V – Floor plans and design drawings of the new site office



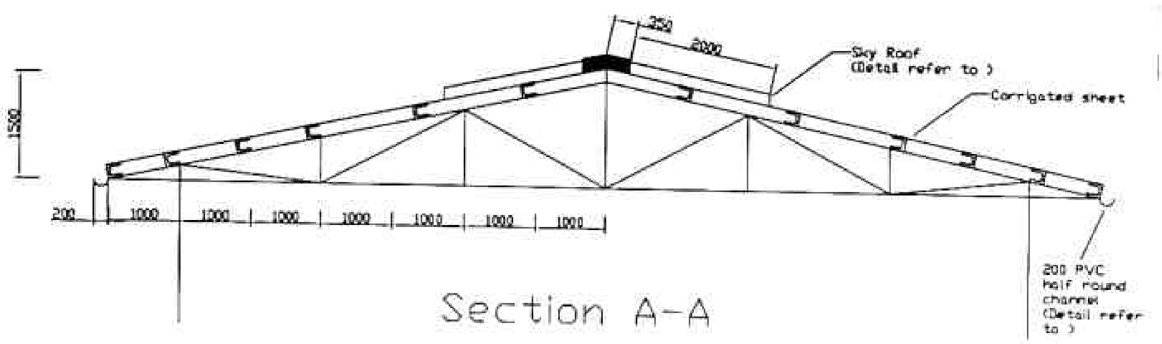
Ground Floor Plan



First Floor Plan

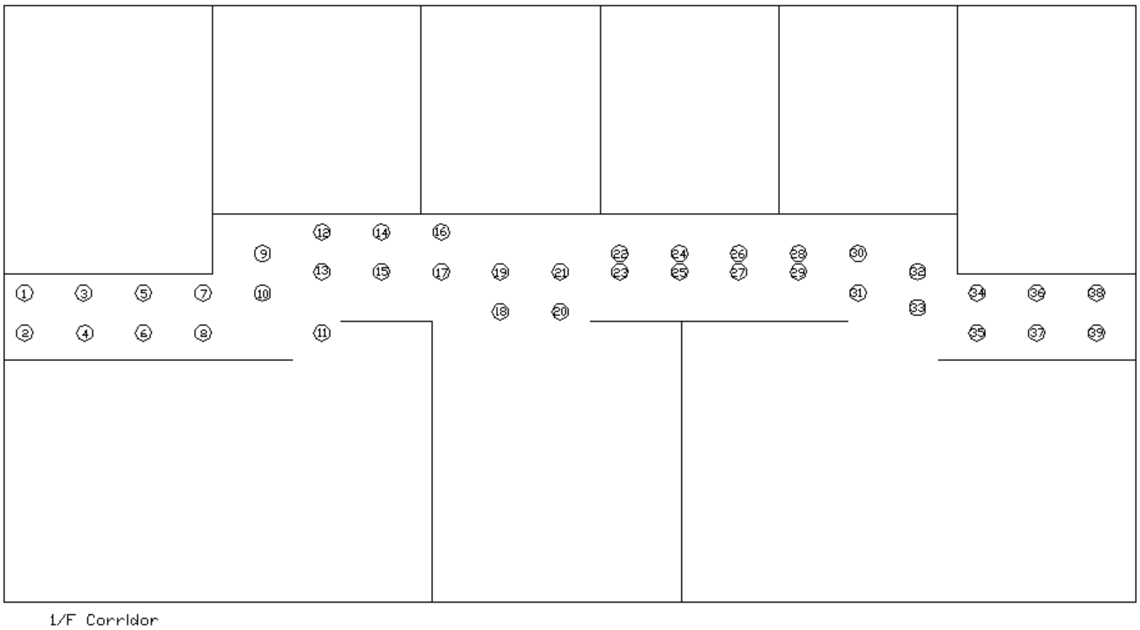


Roof Plan

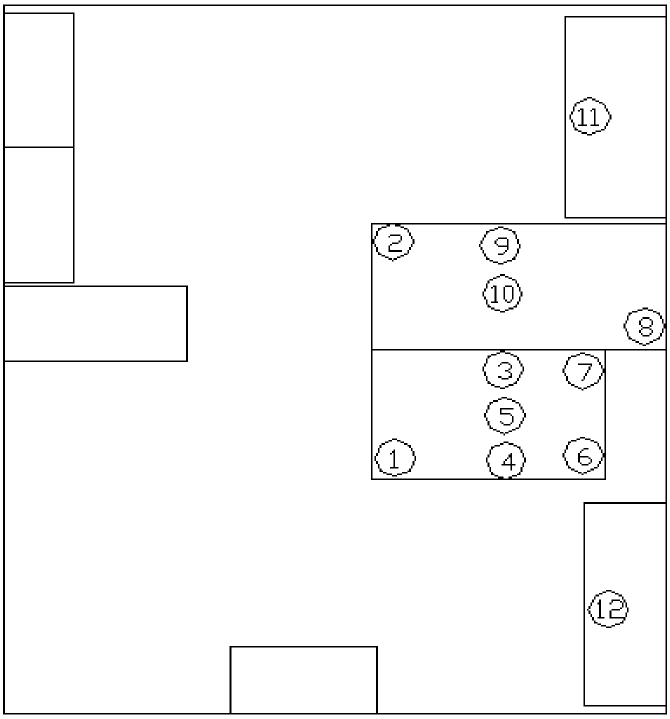


Section of the roof structure

Appendix VI – Lighting measurements in Tsing Yi site office

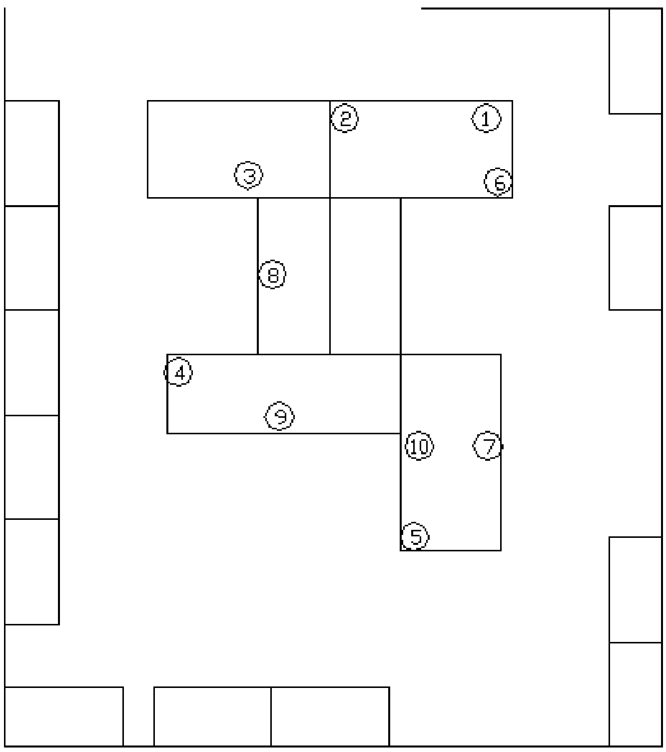


Point	Lux level	Point	Lux level
1	136	21	344
2	73	22	276
3	186	23	282
4	129	24	232
5	251	25	223
6	213	26	270
7	350	27	259
8	318	28	319
9	333	29	282
10	337	30	324
11	345	31	308
12	285	32	338
13	286	33	375
14	280	34	341
15	250	35	328
16	299	36	378
17	312	37	337
18	335	38	240
19	373	39	287
20	318		



Point	Lux level
1	730
2	655
3	650
4	690
5	687
6	600
7	540
8	497
9	623
10	653
11	511
12	510

Room 5



Point	Lux level
1	423
2	400
3	511
4	475
5	435
6	476
7	472
8	555
9	511
10	392

Secretary Area

Appendix VII – Lighting design for the new site office

1/F		Manager Room 1	Manager Room 2	Manager Room 3	HS&E & Engineers' Area
	Length (m)	6.05	6.05	5	7.2
	Width (m)	2.4	2.4	2.4	4.8
	Floor area (m^2)	14.5	14.5	12.0	34.6
Base Case	No. of luminaries	4	4	2	4
	No. of lamp per luminaries	1	1	2	2
	Total no. of lamps	4	4	4	8
	Total lamp wattage (W)	144	144	144	288
	System wattage (W)	176.4	176.4	176.4	352.8
	Average luminance (lux)	217	217	234	235
	- Min/Ave	0.54	0.54	0.47	0.31
	- Min/Max	0.41	0.41	0.33	0.20
	Light power density (W/m^2)	12.15	12.15	14.70	10.21
Recessed fluorescent	No. of luminaries	4	4	1	4
	No. of lamp per luminaries	1	1	2	2
	Total no. of lamp	4	4	2	8
	Total lamp wattage (W)	144	144	72	288
	System wattage (W)	176.4	176.4	88.2	352.8
	Average luminance (lux)	217	217	221	368
	- Min/Ave	0.54	0.54	0.19	0.19
	- Min/Max	0.41	0.41	0.08	0.1
	Light power density (W/m^2)	12.15	12.15	7.35	10.21

1/F		Quality Survey	Copy Room	Conference Room	1/F Common Area
	Length (m)	6.05	6.05	7.2	---
	Width (m)	2.4	2.4	4.8	---
	Floor area (m^2)	14.52	14.52	34.56	93.36
Base Case	No. of luminaries	4	4	4	20
	No. of lamp per luminaries	1	1	2	2
	Total no. of lamps	4	4	8	40
	Total lamp wattage (W)	144	144	288	1440
	System wattage (W)	176.4	176.4	352.8	1764
	Average luminance (lux)	217.00	217.00	235.00	---
	- Min/Ave	0.54	0.54	0.31	---
	- Min/Max	0.41	0.41	0.20	---
	Light power density (W/m^2)	12.15	12.15	10.21	18.89
Recessed fluorescent	No. of luminaries	4	4	4	11
	No. of lamp per luminaries	1	1	2	2
	Total no. of lamp	4	4	8	22
	Total lamp wattage (W)	144	144	288	792
	System wattage (W)	176.4	176.4	352.8	485.1
	Average luminance (lux)	217	217	368	---
	- Min/Ave	0.54	0.54	0.19	---
	- Min/Max	0.41	0.41	0.1	---
	Light power density (W/m^2)	12.15	12.15	10.21	5.20

G/F		Sub-contractor Room 1	Sub-contractor Room 2	Foreman Area	Safety & QA
	Length (m)	3.6	6.05	3.6	6.05
	Width (m)	4.8	2.4	4.8	2.4
	Floor area (m^2)	17.28	14.52	17.28	14.52
Base Case	No. of luminaries	2	4	2	4
	No. of lamp per luminaries	2	1	2	1
	Total no. of lamps	4	4	4	4
	Total lamp wattage (W)	144	144	144	144
	System wattage (W)	176.4	176.4	176.4	176.4
	Average luminance (lux)	203.00	217.00	203.00	217.00
	- Min/Ave	0.40	0.54	0.40	0.54
	- Min/Max	0.24	0.41	0.24	0.41
	Light power density (W/m^2)	10.21	12.15	10.21	12.15
Recessed fluorescent	No. of luminaries	2	4	2	4
	No. of lamp per luminaries	2	1	2	1
	Total no. of lamp	4	4	4	4
	Total lamp wattage (W)	144	144	144	144
	System wattage (W)	176.4	176.4	176.4	176.4
	Average luminance (lux)	329	217	329	217
	- Min/Ave	0.3	0.54	0.3	0.54
	- Min/Max	0.16	0.41	0.16	0.41
	Light power density (W/m^2)	10.21	12.15	10.21	12.15

G/F		First Aid Room	Pantry	General Office	Store Room
	Length (m)	3.4	4.5	6.05	3.6
	Width (m)	2.4	2.4	2.4	6.05
	Floor area (m^2)	8.16	10.8	14.52	21.78
Base Case	No. of luminaries	2	2	4	3
	No. of lamp per luminaries	2	2	1	2
	Total no. of lamps	4	4	4	6
	Total lamp wattage (W)	144	144	144	216
	System wattage (W)	176.4	176.4	176.4	264.6
	Average luminance (lux)	304.00	264.00	217.00	240.00
	- Min/Ave	0.54	0.52	0.54	0.25
	- Min/Max	0.40	0.39	0.41	0.16
	Light power density (W/m^2)	21.62	16.33	12.15	12.15
Recessed fluorescent	No. of luminaries	1	1	4	3
	No. of lamp per luminaries	2	2	1	2
	Total no. of lamp	2	2	4	6
	Total lamp wattage (W)	72	72	144	216
	System wattage (W)	88.2	88.2	176.4	264.6
	Average luminance (lux)	297	245	217	388
	- Min/Ave	0.35	0.15	0.54	0.12
	- Min/Max	0.2	0.07	0.41	0.06
	Light power density (W/m^2)	10.81	8.17	12.15	12.15

G/F		Survey Room	Equipment Room	G/F assembly area	
	Length (m)	3.6	6.05	---	
	Width (m)	6.05	2.4	---	
	Floor area (m^2)	21.78	14.52	77.4	
Base Case	No. of luminaries	3	4	17	
	No. of lamp per luminaries	2	1	2	
	Total no. of lamps	6	4	34	
	Total lamp wattage (W)	216	144	1224	
	System wattage (W)	264.6	176.4	1499.4	
	Average luminance (lux)	240.00	217.00	---	
	- Min/Ave	0.25	0.54	---	
	- Min/Max	0.16	0.41	---	
	Light power density (W/m^2)	12.15	12.15	19.37	
Recessed fluorescent	No. of luminaries	3	4	10	
	No. of lamp per luminaries	2	1	2	
	Total no. of lamp	6	4	20	
	Total lamp wattage (W)	216	144	720	
	System wattage (W)	264.6	176.4	441	
	Average luminance (lux)	388	217	---	
	- Min/Ave	0.12	0.54	---	
	- Min/Max	0.06	0.41	---	
	Light power density (W/m^2)	12.15	12.15	5.70	

Appendix VIII – Summary of LEED assessment results

Green building assessment using Leadership in Energy & Environmental Design (LEED) Rating System Version 2.1

Project Checklist

1. Sustainable Site (14 Possible Points)

No.	Description	Max. Point	Point Obtained
Prereq 1	Erosion & Sedimentation Control	Required	
Credit 1	Site Selection Brownfield, near a moderate density industrial district	1	1
Credit 2	Urban Redevelopment	1	
Credit 3	Brownfield Redevelopment	1	1
Credit 4.1	Alternative Transportation, Public Transportation Access Near mini bus stop	1	1
Credit 4.2	Alternative Transportation, Bicycle Storage & Changing Rooms	1	
Credit 4.3	Alternative Transportation, Alternative Fuel Refueling Stations	1	
Credit 4.4	Alternative Transportation, Parking Capacity Car park is provided	1	1
Credit 5.1	Reduced Site Disturbance, Protect or Restore Open Space Use public field to replace contaminated soil	1	1
Credit 5.2	Reduced Site Disturbance, Development Footprint (?)	1	
Credit 6.1	Stormwater Management, Rate or Quantity (?)	1	
Credit 6.2	Stormwater Management, Treatment	1	
Credit 7.1	Landscape & Exterior Design to Reduce Heat Islands, NonRoof	1	
Credit 7.2	Landscape & Exterior Design to Reduce Heat Islands, Roof Implement of green roof	1	1
Credit 8	Light Pollution Reduction Use of recessed fluorescent and dimming control system	1	1
		Total Points	7

2. Water Efficiency (5 Possible Points)

No.	Description	Max. Point	Point Obtained
Credit 1.1	Water Efficient Landscaping, Reduce by 50% (Irrigate the green roof?)	1	
Credit 2	Water Efficient Landscaping, No Potable Use or No Irrigation	1	
Credit 3	Innovative Wastewater Technologies	1	
Credit 4.1	Water Use Reduction, 20% Reduction	1	
Credit 4.2	Water Use Reduction, 30% Reduction	1	
		Total Points	0

3. Energy & Atmosphere (17 Possible Points)

No.	Description	Max. Point	Point Obtained
Prereq 1	Fundamental Building Systems Commissioning	Required	
Prereq 2	Minimum Energy Performance	Required	
Prereq 3	CFC Reduction in HVAC&R Equipment	Required	
Credit 1.1	Optimize Energy Performance, 20% New / 10% Existing	2	2
Credit 1.2	Optimize Energy Performance, 30% New / 20% Existing	2	
Credit 1.3	Optimize Energy Performance, 40% New / 30% Existing	2	
Credit 1.4	Optimize Energy Performance, 50% New / 40% Existing	2	
Credit 1.5	Optimize Energy Performance, 60% New / 50% Existing	2	
Credit 2.1	Renewable Energy, 5% Solar external lighting	1	1
Credit 2.2	Renewable Energy, 10%	1	
Credit 2.3	Renewable Energy, 20%	1	
Credit 3	Additional Commissioning Design team for the site office	1	1
Credit 4	Ozone Depletion	1	
Credit 5	Measurement & Verification	1	
Credit 6	Green Power	1	
		Total Points	4

4. Materials & Resources (13 Possible Points)

No.	Description	Max. Point	Point Obtained
Prereq 1	Storage & Collection of recyclables	Required	
Credit 1.1	Building Reuse, Maintain 75% of Existing Shell Reuse existing building structure and shell	1	1
Credit 1.2	Building Reuse, Maintain 100% of Shell	1	
Credit 1.3	Building Reuse, Maintain 100% of Shell & 50% Non-Shell	1	
Credit 2.1	Construction Waste Management, Divert 50%	1	
Credit 2.2	Construction Waste Management, Divert 75%	1	
Credit 3.1	Resource Reuse, Specify 5% Reuse container	1	1
Credit 3.2	Resource Reuse, Specify 10% Reuse containers, frame structure	1	1
Credit 4.1	Recycled Content, Specify 25%	1	1
Credit 4.2	Recycled Content, Specify 50%	1	
Credit 5.1	Local/Regional Materials, 20% Manufactured Locally Use building materials that are manufactured regionally	1	1
Credit 5.2	Local/Regional Materials, of 20% Above, 50% Harvested Locally Use building materials and product that extracted within 50miles	1	1
Credit 6	Rapidly Renewable Materials	1	
Credit 7	Certified Wood	1	
		Total Points	6

5. Indoor Environmental Quality (15 Possible Points)

No.	Description	Max. Point	Point Obtained
Prereq 1	Minimum IAQ Performance	Required	
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Required	
Credit 1	Carbon Dioxide (CO2) Monitoring	1	
Credit 2	Increase Ventilation Effectiveness	1	
Credit 3.1	Construction IAQ Management Plan, During Construction	1	
Credit 3.2	Construction IAQ Management Plan, Before Occupancy	1	
Credit 4.1	Low-Emitting Materials, Adhesives & Sealants	1	
Credit 4.2	Low-Emitting Materials, Paints	1	
Credit 4.3	Low-Emitting Materials, Carpet	1	
Credit 4.4	Low-Emitting Materials, Composite Wood	1	
Credit 5	Indoor Chemical & Pollutant Source Control	1	
Credit 6.1	Controllability of Systems, Perimeter Provide operable window and lighting control zone	1	1
Credit 6.2	Controllability of Systems, Non-Perimeter Provide controls for individual lighting (task lighting)	1	1
Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992	1	
Credit 7.2	Thermal Comfort, Permanent Monitoring System Air conditioning with temperature and humidity monitoring system, humidification and dehumidification system	1	1
Credit 8.1	Daylight & Views, Daylight 75% of Spaces Use of daylighting	1	1
Credit 8.2	Daylight & Views, Daylight 90% of Spaces	1	
		Total Points	4

6. Water Efficiency (5 Possible Points)

No.	Description	Max. Point	Point Obtained
Credit 1.1	Innovation in Design: Specific Title Green Roof	1	1
Credit 1.2	Innovation in Design: Specific Title Skylight	1	1
Credit 1.3	Innovation in Design: Specific Title Atrium in site office	1	1
Credit 1.4	Innovation in Design: Specific Title Daylighting control system	1	1
Credit 2	LEED™ Accredited Professional	1	
		Total Point	4

Project Totals **69 Possible Points**

Project Totals Points Obtained **24 (Fail)**