Sustainable Building Services Systems for Historic Buildings

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ABSTRACT

Conservation of historic buildings is significant to a society for protecting its cultural resources and preserving important heritage. To promote the active use and care of historic buildings, attention must be paid to the design and management of building services systems. Upgrading of the building services systems requires creativity to respect the original design and materials while meeting applicable codes and occupant needs. Management of historic buildings and their systems often has to strike a balance between retaining original building features and accommodating new technologies and equipment. This paper reports a research study on the assessment of building services systems for an historic building in the campus of The University of Hong Kong. The requirements of architectural conservation have been studied. Major limitations of the existing building services systems were evaluated through analysis of building performance, safety aspects and technical facilities.

Keywords: Sustainable building services systems, historic buildings, The University of Hong Kong.

1. INTRODUCTION

An historic building is one that gives us a sense of wonder and makes us appreciate its culture and our heritage (Feilden, 2003). It has architectural, aesthetic, historic, social, economic, spiritual and symbolic values that are enjoyed in the society and shall be preserved. As the building must continue to stand up, economic factors often demand that it should remain in use. There is a need to harmonise the conservation of historic buildings with the requirements of building systems.

To promote active use and care of historic buildings, attention must be paid to the design and management of building services systems (CIBSE, 2002). When installed in an appropriate manner, building services can assist the preventive conservation of historic buildings, prolong their lives in beneficial use and improve the internal environment. By nature, building conservation is a sustainable form of property development. Improving existing buildings and sustaining the historic environment has become a critical policy for many cities and countries in the world (Insall, 1972; Meckler, 1994; Mills, 1994).

This paper reports a research study on the assessment of building services systems for an historic building in the campus of The University of Hong Kong (HKU). The meaning and requirements of the architectural conservation have been studied. Major limitations of the existing building services systems were evaluated through analysis of building performance, safety aspects and technical facilities. The strategy to plan and design building services in historic buildings is examined and discussed.

2. CONSERVATION OF HISTORIC BUILDINGS

Conservation of historic buildings is significant to a society for protecting its cultural resources and preserving important heritage (Insall, 1972). The process is multi-disciplinary and will involve a team of professionals including architects, archaeologists, economist, engineers, historians, building contractors, surveyors, town planners, and some specialist consultants (Swanke Hayden Connell Architects, 2000). The objective of architectural conservation usually focuses on the following three main aspects (Feilden, 2003):

- Prevention of decay caused by climate and human
- Management of change dynamically
- Documentation and presentation of the building

When considering conservation, first of all, it is important to identify and analyse the values (including emotional, cultural and use) and place them in order of priority so that suitable judgements and decisions can be made when determining the design strategy and options. Table 1 shows the typical values of historic buildings or monuments.

Table 1: Typical values of historic buildings or monuments (adapted from (Feilden, 2003))

Emotional values	**Cultural values**	**Use values**
• Wonder • Identity • Continuity • Respect and veneration • Symbolic and spiritual	• Documentary • Historic • Archaeological and age • Aesthetic and architectural values • Townscape • Landscape and ecological • Technological and scientific	• Functional • Economic (e.g. tourism) • Social • Educational • Political

The most important thing is to ‘respect’ the building (architecture and history) and ‘preserve’ the quality of its special characteristics. In most cases, intervention must be minimum necessary and any changes must be harmonious with the original setting. CIBSE (2002) has highlighted the fundamental principles for repair of historic buildings:

- Understand the reason and purpose of the repair or alternation
- Minimise intervention and avoid impact of the appearance
- Prevent unnecessary damage
- Seek reversibility and minimise irreversible changes

Basically, conservation is a process that leads to the prolonged life of cultural property for its utilization now and in the future. It is consistent with the goal of sustainability and can also bring social and economic benefits to the society. In order to maintain the usefulness of historic buildings to meet present-day needs, it is necessary to adapt the building for new uses

and rehabilitate or upgrade the building to satisfy new occupants or users (Wagner, 1996). This, however, will introduce competing logics and conflicting criteria to the work.

Modern materials and techniques are often incompatible with traditional construction. As the old building fabric was not designed to take modern plant, the installation of new building services can raise acute technical and aesthetic problems. When adapting existing products to older buildings, it is important to consult conservation architects or historians on the selection of appropriate equipment. To ensure acceptable design solution and performance, a holistic and interdisciplinary approach is required. Special design skills and judgement are needed to understand and assess the different needs of occupants, building fabric, and sometimes even the contents kept inside the building. Inevitably, this process will involve compromises and a balance of different requirements.

3. UPGRADING OF BUILDING SERVICES SYSTEMS

Modern building services present a great challenge to architectural conservation. It is often difficult to reconcile the technical requirements with the principles of conservation. If insufficient care is paid to the building services design and installations, the result and damage can be disastrous for the building. On the other hand, if the rehabilitation or upgrading is done in a sympathetic and appropriate manner, the renewing of building services can give new life to an old building.

There are three principal strategies for handling building services in historic buildings:

- Re-use existing building services systems
- Install new building services systems
- Upgrade existing ones

3.1 Inspection and Appraisal

It is always helpful and essential to carry out inspection of existing building services at the very beginning of the conservation project. The aim is to see if the systems do not present a hazard to the fabric of the historic building and to check if they are functioning adequately. Since the documentation and information of the building systems in old buildings are often incomplete or missing, full investigation through site survey and user consultation is needed. The condition of existing systems can be tested by the services engineer and the strategy on refurbishment or renewal will be discussed with the related professionals such as architect, structural engineer, historian and contractor.

The services and structural elements are often critical in the refurbishment of old concrete buildings (Gold and Martin, 1999). The level of refurbishment scheme required will depend on the existing condition, client's requirements and capital allowance. From past experience, the cost and time of refurbishment projects tend to involve more uncertainty and risk than new-build projects. Therefore, good planning and contingencies are needed.

Moreover, appraisal and study of the measured drawings and architectural design could enable a better understanding of the building and its passive design concepts. This will allow creative ideas for planning changes to the interior environment and for designing the

ventilation and air-conditioning system (Park, 1999). A thorough understanding of the building in its historical context is very important for appropriate selection and design of building services systems. The key areas to look at include:

- Understand older building technologies (e.g. to find interstitial space suitable for running services) and the properties of old materials
- Understand the effect of local climate on the building, and its physical and thermal characteristics as a spatial structural and environmental system
- Understand the history of electrical and mechanical installations to determine the need for renewal and preservation

3.2 Planning and Design

The building services elements in a building typically last 15 to 30 years (Moss, 2001). During the lifetime of an historic building that stands 100 years or more, the building services components would have been replaced or renewed several times. Therefore, the management of building services maintenance and continuous upgrading is a critical policy for the building owner and manager. Guidebooks such as CIBSE (2000) and CIBSE (1994) indicate the general principles for effective operation and maintenance of building services systems. When applied to historic buildings, it appears that the general approach is still valid but particular attention must be put onto the requirements of architectural conservation. For example, in order to respect the building's character, we may need to use components which would normally be considered inefficient or uneconomical, such as air ducts of odd cross-sectional dimensions.

In most situations, hiding the systems from sight using concealed pipework and services space is preferable than exposed services and services runs, unless when the value of the historic building services is one of the conservation objects. The distribution routes and techniques is often a concern to aesthetics. To improve appearance and ensure accessibility for inspection and maintenance, detailed design of the building services distribution must be carefully done and verified on site. New installations should be skillfully concealed to avoid inappropriate intrusions. In some cases, decorative features associated with building services systems such as grilles, lighting fixtures, ornamental switchplates, and cast iron radiators are retained and preserved so as to present the visible character of the historic systems and create an atmosphere of retrospection.

Needless to say, new regulations and building codes may present a danger to historic buildings as they may find it difficult to comply, such as on structural, fire, security and hygiene issues. Building owners and officials must dual with them in a flexible way. The reasoning behind the regulations must be understood and trade-offs made in order to find reasonable compromises. A holistic approach is needed to diagnose the problems and find the right solution in consultation with other professionals. To avoid inappropriate design and materials, building services engineers shall cooperate closely with adjacent trades and recognise the unique characteristics of existing systems. On fire protection aspects, for instance, Bukowski, Nuzzolese, and Bindo (2001) pointed out that performance-based regulatory systems are well suited to the special needs of historical structures. Watts (2001) identified many disparate approaches to regulating fire safety in historic buildings in U.S.A. and commented that performance codes may contribute flexible solutions to the problems.

3.3 Occupant Needs and Sustainability

People's expectation of the service standards in buildings are much higher now than in the past. Modern building services such as air-conditioning, lighting, fire protection, cabling and telecommunication is an essential element of every building nowadays. To maintain usefulness of historic buildings, it is necessary to accommodate these services and consider the needs of the occupants. Moreover, with growing global concern for environmental sustainability, it is imperative to promote sustainable design, enhance building's performance and reduce environmental impact.

It is really a challenge to deal with all these requirements on building services systems without causing irreversible damage to architectural integrity. There is a need to design building services installations that are compatible with the spatial, thermal and physical characteristics of the historic building. Sometimes, a good solution is to harness the potential advantages of historic buildings to meet modern standards, for example using the effects of thermal mass and the advantages of natural ventilation combined with shutters and blinds. To enhance sustainability, CIBSE (2002) has suggested the following key points:

- Reduce energy consumption and carbon dioxide emissions
- Reduce pollution of all types to the external environment
- Improve health and indoor environment
- Use more sustainable materials (manage waste and exploitation of natural resources)
- Adopt efficient plant and system
- Reduce water use
- Reuse existing services and components

After refurbishing the building services systems, people must also be aware of the importance of proper commissioning and testing. Like any new-build projects, it is advisable to document as-built installations carefully for future reference and to provide maintenance manuals and schedules for building owners. This would ensure the design intent has been implemented correctly and the ongoing building maintenance and operation can be carried out in an effective manner.

4. CASE STUDY

The HKU Main Building (see Figure 1), completed in 1912, was assessed in our research study in order to find out and evaluate the important factors for designing and arranging building services systems in historical environment.

4.1 Building Information

The exterior of HKU Main Building is a declared monument in Hong Kong since June 1984. It is an important representative figure of the University and has become a key image of higher education in Hong Kong. The building was first used by the engineering and medical faculties, and has undergone a number of changes in the past decades. At present, it serves mainly the Faculty of Arts and has a number of lecture rooms, staff offices, function rooms and court yards. The centre of the building is the Luke Yew Hall where important ceremonies and functions of the University would take place.

The Main Building has great historical significance and architectural value since HKU is one of the oldest universities of western tradition in the Far East. According to the declaration of historical buildings, the facade, roof, main ceremonial grand staircase, external corridors and courtyards of the building should be preserved.

Key Information of the Building:

Gross floor area = 14,000 m^2
Number of storeys = 4
Construction style: Renaissance
Construction materials: Red brick and white stone
Electrical load (estimated) = 1561 kVA
Cooling load (estimated) = 124 TR
Total energy consumption (Yr 2002-03) = 1,270 MWh
Energy utilization index = 90.7 kWh/m^2/year

Figure 1. HKU Main Building

In order to assess the condition of the building, walk-through survey, interviews with the occupants and facility management staff, opinion questionnaire and detailed environmental measurements were conducted. In general, it is found that the Main Building can provide a comfortable environment for the users, but analysis of thermal performance, safety aspects and technical facilities of the building shows that there are some limitations of the existing building services systems to satisfy present-day needs of the occupants. For example, the security, fire protection and air-conditioning systems could be enhanced.

4.2 Design Considerations for Building Services

The electrical power supply is another area that this old building was not designed for at the outset. The building does not have its own electrical transformer and emergency power supply system. The routings of electrical power cables and trunkings, the locations of distribution boards and the backbone for information technology were not planned and integrated efficiently. However, it is understood that adding new electrical plantrooms and arranging electrical distribution are difficult jobs when architectural integrity and conservation is to be maintained.

Luckily, fire outbreaks are not common at all during the lifetime of the Main Building. But prevention of fire and protection of life and property are always critical issues that must not be overlooked. The local fire safety regulations are framed mainly with the design of new buildings in mind and their primary concern is the safeguarding of life rather than the building's values. It is advisable to examine the potential hazard and causes of fire and then investigate the means of lessening its extent and effect. Within most of the internal spaces of the building, the fire risk can be reduced by considering and implementing appropriate passive and active fire protection measures such as compartmentation, building materials selection, and fire detection and alarm. In addition, management precautions such as fire drills and user education are also important to ensure safety of the occupants and to solicit their cooperation in the prevention of fire.

Fire and security precautions must be taken together to resolve possible contradictions in their requirements – one interest requiring door to be open and the other shut and securely locked. Generally speaking, security design involves a wide range of imponderables and it is all a matter of judgement for the building owner and designers (Mills, 1994: Chapter 7). Usually only the owner or full time occupant of the historic building can make a realistic assessment of the risks. Common security measures include physical protection, detection systems and security personnel. To prevent and minimise crime, it is necessary to identify all possible risks and review the influencing factors relating to site, construction and equipment.

Nonetheless, there are many practical problems relating to security in historic buildings. The findings at the Main Building can help illustrate the situation and major considerations. First of all, the floor layout of the building is quite open with colonnade balconies, external and internal corridors which are easily accessible by visitors (see Figure 2). Control of the people entering the building and going to different parts is complicated. Secondly, the old door construction and locks are deteriorating, and because of large number of doors and windows it is not easy to maintain integrity. There is no definite answer to overcome the weakness. Alertness and careful attention to detail is the key to success.

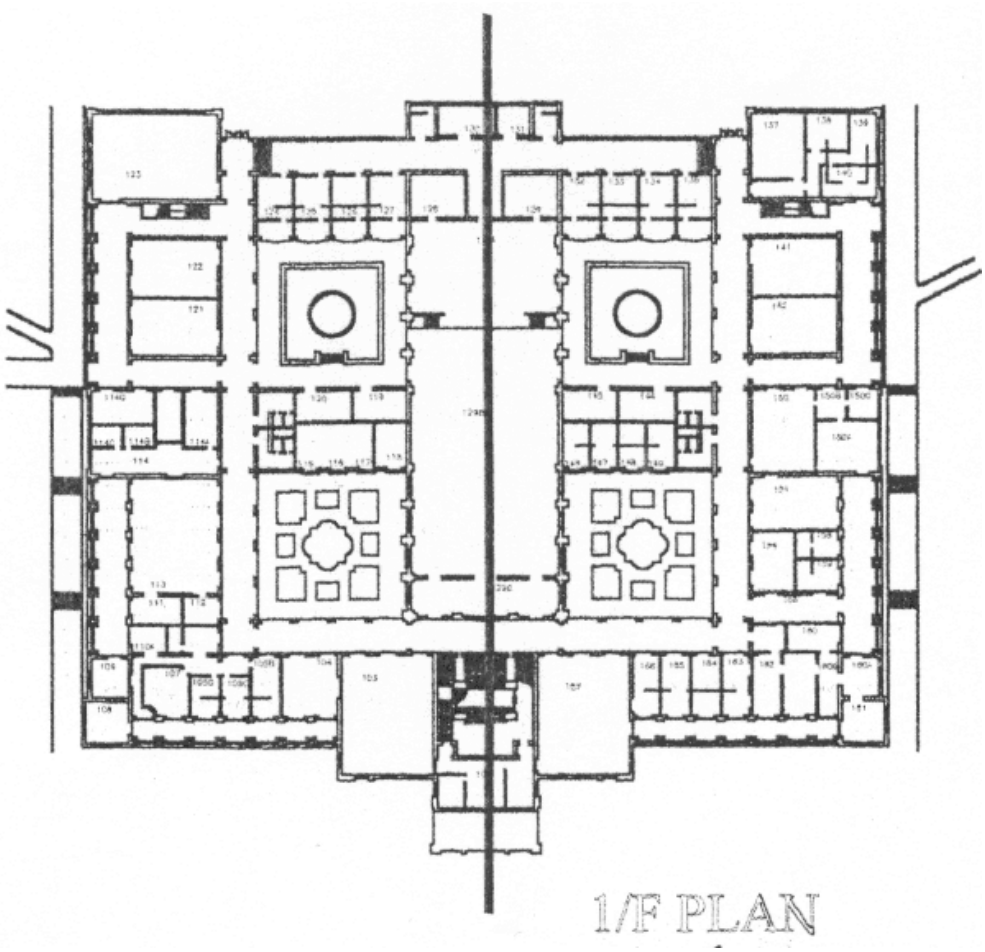

Figure 2. First floor plan of HKU Main Building

Throughout the past 90-years history of the Main Building, its surrounding environment has changed a lot because of growing building density in the urban area of west Hong Kong Island. This does not only affect the architectural background but also the macroclimate in which the building fabric stands. Ryhl-Svendsen, et al. (2003) have carried out continuous

measurements of indoor environmental conditions to analyse the microclimate in some historic buildings in Europe. They found out that the structure of the room, the nature of the stored materials and the custodian decisions combine to influence the indoor climate. It is believed the Main Building is facing many external and internal stresses which combine to affect the durability and performance of the building.

To maintain comfortable internal environment for temperature and humidity, different types of air-conditioning systems have been installed in the Main Building, including window-type air-conditioners and split-type units. These systems are now scattering on the façade, corridors and the roof, and they will affect aesthetics of the building as well as create noise and hot air problems. The maintenance of these systems is more demanding than central plant and the energy efficiency level is also limited. Nevertheless and fortunately, the reversibility of these systems is believed to be high. If other better alternative solution is available, the units can be removed easily with relatively less irreversible damage to the building.

5. DISCUSSIONS

Historic buildings often pose unique problems to building services design because they do not conform to the generic types of new construction. Standard design solutions are usually inappropriate. Designer must understand the historic building well and use critical thinking and strategy to develop custom building services systems.

Elefante (2003) pointed out that historic buildings can teach us about sustainable design because they were built with nature in mind using traditional building systems such as natural ventilation and daylighting. Their architectural design was developed at the time period before the emerging of mechanical systems. Thus, historic buildings have the qualities of low energy consumption, loose fit and long life, so the lessons learned from their study are relevant to modern building design (Feilden, 2003; Park, 1999).

The HKU Main Building is a good example of traditional architecture that is adaptable and responsive to local climate. Its colonnade balconies can act as a barrier to direct sunlight and promote diffuse daylight into the interior. The four courtyards inside the building complex can provide breathing into the building as well as a place for relaxation. Usually interesting historic buildings have structural integrity, high ceiling, simple spaces and organisation to suit different changes of uses. Although they might not be as effective as a building without systems, they can still offer good thermal performance and energy efficiency to help building owner save on running costs and maintain comfort throughout the building life cycle.

There are many factors affecting the longevity of building services systems and plant, including functional, technological and economic aspects (Moss, 2001). In order to achieve sustainable design for historic buildings, professionals knowledgeable in multiple disciplines are required and their collaborative efforts to consider conservation, safety, security, health, maintenance and life-cycle costs will determine the outcome of the project. To manage the change dynamically, holistic and sympathetic thinking will enable the generation of acceptable, cost-effective design approaches and appropriate treatments for rehabilitating and upgrading of historic buildings.

6. CONCLUSIONS

An historic building represents an artifact of architectural or historical significance. The conservation of historic buildings requires wise management of resources, sound judgement and aesthetic sensitivity. It also demands a dedication to preserve our cultural heritage. Upgrading of building services systems in historic structures requires creativity to respect the original design and materials while meeting applicable codes and occupant needs. Management of historic buildings and their systems often has to strike a balance between retaining original building features and accommodating new technologies and equipment. There is a need to find better ways to service historic buildings that are compatible with conservation and aesthetic, as well as meeting occupants' expectation and sustainability.

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However, these buildings are largely concentrated to a limited number of countries and there are several EU MS where voluntary certification schemes have not been developed yet, and which rely primarily on the mandatory EPC system implemented under the EPBD. In particular, environmental certification of residential buildings is still lagging behind in most countries as it presents extra costs and complexity where specific efforts to meet the needs of the residential market have not been made.Â Â· Transforming the Economy; Â· Addressing natural capital and ecosystems services; Â· Tackling key sectors (food, buildings, mobility).Â Resource efficiency in the context of moving towards more sustainable buildings is Making heritage buildings sustainable is just as important as preserving their history â€“ and they can offer energy-efficiency lessons of their own.Â Across Australia, historical buildings are being adapted for reuse. While preserving heritage is key, construction methods have changed dramatically while energy efficiency is often paramount, so architects are looking at ways to make these buildings more sustainable. Facebook. Twitter.Â One of the challenges in historic buildings is light. Many require extra artificial lighting or skylights. That didnâ€™t put off the restoration of the heritage-listed Mayfair building in Melbourne. Specialist building services might also include systems for bacteria and humidity control, specialist lighting and security, emergency power, specialist gas distribution, fume cupboards, operating theatres, and so on.Â Increasingly, building services engineers are central to the design and assessment of sustainable systems, assessing the life cycle of buildings and their component services to minimise the resources consumed and the impact on the environment during fabrication, construction, operation and dismantling. According to The Chartered Institute of Building Services Engineers (CIBSE): 'In any new construction project, building services typically account for 30-40% of the total cost.' (Ref. CIBSE fact sheet) and buildings account for almost 50% of carbon emissions (Ref.