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DESIGN AND MATERIAL IN MUSEUM: DOES IT AFFECT THE VENTILATION IN INDOOR AIR QUALITY?

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ABSTRACT

Problem related with indoor air is rapidly becoming a major health issue worldwide. It is because people spend almost 90% of their time indoors. Nowadays, people are being exposed to a variety of health risks from the surrounding indoor pollution, which can affect one's health. Some of the risks are unavoidable. In Malaysia, museum is one of niche products of Malaysia cultural heritage tourism attraction that could affect the growth of the tourism industry in this country. A balanced of indoor environment conditions in museum buildings refer to the preservation of cultural objects and the human comfort both the visitors and the staffs. It is because most of the historic building which has been convert into museum are building were built about 100 years ago. Rely entirely on the mechanical systems without paying attention to the building's original design and its features as ideal climate tools, for both human comfort and the conservation of museum collections. The application of mechanical ventilation system supposedly provides a healthy and better indoor environment inside the museum building. There a need for careful planning to be conducted during the early stages of designing new mechanical systems so that only suitable and appropriate systems are installed.

Keywords: indoor air quality (IAQ), ventilation, museum environment.

1. INTRODUCTION

Problem related with indoor air is rapidly becoming a major health issue worldwide. It is because, people spend almost 90% of their time indoors, which is they might be exposed to hazardous and unhealthy concentrations of pollutants [1]. Usually, people who are easily exposed to the risks of hazardous pollution are the aged people, the ill and the very young, because they will spend nearly all of their time indoors.

Indoor air quality (IAQ) of building occupant is a basis determinant of healthy life and people's well being, comfort and productivity of respondents. According to Environmental Protection Agency, the quality of indoor air can be affected from several factors such as the interactions between the site, climate, building system, construction techniques, contaminant source and respondents itself [2]. The good IAQ can be provided based on these characteristics which is include introduction and distribution of adequate ventilation air, control of airborne contaminants, maintenance of acceptable temperature and relative humidity.

The indoor environments are include places as homes, offices, stores, restaurants, warehouses, factories, public buildings and even vehicles. Building such as museum, archive and library are building that can be categorized as public buildings and they are unique because most of these building are historical or heritage building. According to Papadopoulos and colleagues, historical building can be high energy consumers if they not necessarily provide satisfactory comfort and health conditions [3].

IAQ issues are not new in Malaysia. However, lack of study, data and local regulation become one of the major contributions towards this problem especially with the non-industrial sector [4]. Nowadays, people are being exposed to a variety of health risks from the surrounding indoor pollution which can affect one's health. Some of the risks are unavoidable. In Malaysia, museum is one of niche products of Malaysia cultural heritage tourism attraction that could affect the growth of the tourism industry in this country [5]. So, museum needs to focus on visitor satisfaction that able to create returning visitors in order to compete in highly competitive world of leisure and tourist attraction. Basically, there are several issues that affected by the poor indoor environment quality such as health problem, country reputation and productivity of workers in the heritage museum [6].

2. INDOOR AIR QUALITY

The indoor environment represents an important microenvironment in which people spend a large part of their time each day. As a result, indoor air pollution, originating from both outdoor and indoor source, is likely to contribute more to population exposure than the outdoor environment. IAQ is a part of indoor environmental quality (IEQ) which is also consists of thermal, acoustic, visual or lighting, aesthetic, spatial and ergonomically quality. Each factor has its own parameters based on either quantitative or qualitative indicators according to acceptable numbers, ranges or characteristics [7]. IAQ is a challenge to environmental health issues as the pollutant that causes it are not only physical attributes and chemicals but also microbiological agents. The major sources of indoor air pollution worldwide include combustion of solid fuel indoors, tobacco smoking, outdoor air pollutants, emissions from construction materials, furnishings, and improper maintenance of ventilation and air conditioning system. However, when discuss about building related to IAQ problems, generally, Heating, Ventilation and Air conditioning (HVAC)

systems and water damage to the building envelope are the most common sources of building related IAQ problems [8]. Other causes of IAQ problems can be attributed to various phases of the building process including poor site selection, choice of materials, roof design, poor construction quality, improper installation or any number or combination of other factors.

Air quality is an important factor in the preservation of cultural heritage, especially in museum environment. Systematic air quality assessment is a requirement in most heritage conservation plans. Temperature and humidity are identified as one of important factors that contribute either the air quality inside the building is good or poor. In museum, imbalance of temperature and humidity could bring potential risk towards people and collection materials because it could produce indoor gaseous pollution inside the museum building [9]. However, apart from temperature and humidity, air pollution, which is another air quality parameter, is less often monitored [10]. It is true that most pollutants are dangerous to human health, such as particulate matter, gaseous pollutant and traffic-generated pollutants, but they are also harmful to heritage materials. The World Health Organization has long identified particulates matter as one of the pollutants most dangerous to human health. For this reason, particulates matter is the most widely monitored pollutant worldwide [11]. Other outdoor pollutants such as nitrogen dioxide and sulphur dioxide are also commonly monitored by local air quality monitoring networks.

Air pollution is a particular problem in historical buildings such as museums, because they were not originally built to exhibit and protect art objects in a sustainable way [12]. According to Ambrose, he noted that museum should have a constant humidity all year round and that humidity should not rise above 60% or fall below 40% while temperature of 18°C is an acceptable for the museum [13]. He also pointed out that for museum in older building, 45% to 50% of relative humidity is an effective compromise with the temperature between 15°C to 25°C. In tropical climate like Malaysia, they experiences high relative humidity, varying from 67% to 96 % with an average value of around 80% [14]. The outdoor air temperature varies from 24°C to a maximum of 33°C.

3. MUSEUM

Generally, museum is an institution that cares and conserves a collection of artifacts and other objects of scientific, artistic, cultural or historical importance and makes them available for public viewing through exhibits that may be permanent or temporary. Besides that, human comfort also has been considered as important element to produce a healthy environment in the museum building. Recently, museums throughout the world realized that entertainment, leisure and education are the legitimate parts of their repertoire [15]. Public museums and galleries are under pressured to act more like business [16]. In a highly competitive world of leisure and tourist attractions, museums need to focus sharply on visitor satisfaction, in which might be able to create returning visitors [17]. There is pressure on attraction operators to seize new opportunities and to focus greater attention on engaging visitors with new needs and demands [18].

Many scientists and researchers in museum environment agree to have a compromised indoor climate and environment [19-22]. However, Conrad pointed out that it was not a compromise where two extremes values are averaged into one but rather, a balance in which the different needs of the building, the occupant, and the collection can all be satisfied through a realistic analysis [23]. So, a proper measurement and study must be done to identified suitable needed of each elements required in museum environment. According to Iwata and colleagues, it was found that the passive sampling method was more suitable for museums to determine the indoor climate and environment, especially for air quality [24]. However, museum's air quality includes many kinds of pollutants, so it is necessary to reduce the number of measured pollutants for efficiency of analysis.

Since the last decade, research on environment conditions in historic buildings, mainly in museum and archival buildings, is in great demand [25]. Although many museums have been widely investigated in Europe, the effects of pollutants inside the museums under tropical and subtropical climates and with different economic realities are still unclear [26]. Different climate especially in hot and humid environment may causes deterioration due to differences of air quality and microclimatic condition.

In Malaysia, museum is one of the popular destinations among the tourists. Museum is one of the niche products of Malaysia cultural heritage tourism attraction that could affect the growth of the tourism industry in this country [27]. Museums were established in Malaysia more than hundred years ago. After the founding of the first museum, the Perak Museum, in Taiping in 1883, more than 100 museums have been set up in this country [15]. They were run by various government agencies from federal to the states levels. Museums in Malaysia are being challenged with poor general perception from the public as dull repository as well as being queried from financial providers based on museum's performance in giving back profit to the nation [28].

According to Sulaiman and her colleagues, in Malaysia, there has about 56 historical museum buildings which is originally not a purpose built museum buildings, where few studies has been done so far on the quality of their indoor environment [7]. Since the year 2005, Malaysia has been moving away from constructing new buildings in favor of refurbishing historic and old ones. This is due to a number of reasons, including economic crisis, land limitation and sustainable issues, while for occupant's well-being and performance are affected by various aspects of the building, included but not limited to, exposure to daylight and access to views, air quality, temperature, odors, noise, ergonomics, the design of the built environment and opportunities for social gatherings

and relaxation [29]. As to demolish the historical buildings are not very good decisions therefore, often the case they will be refurbished, restored, adaptive re-used, conserved and preserved into other type of buildings including museum. In historical buildings, balancing the needs of the building fabric, the occupants and the contents, while meeting desired environmental criteria can be difficult and it is even more crucial in museum building where it needs a strict building control system [30, 31].

In 2012, there has a research focus on the airborne particulates at the indoor of heritage building, to determine type of airborne particulate in heritage building, identify type of damage to historical materials and reduce the harmful effect towards human health [32]. During this time, this study or knowledge seems to be new in Malaysia because the lack of information from government compared to Singapore, which are focusing deeper on fine particles effects and its contribution but Malaysia still focusing on total suspended particulates.

a) Purpose of museum

According to Czop, museum's main aim is to collect, preserve, interpret, and display items of cultural, artistic, or scientific significance for the education of the public [33]. For historical museum buildings and the artifacts inside them, the ultimate aim is to making things last longer or sustainable as those are the natural assets not only for today but also for the use of future generations [34], while provide the service and comfort for people was its second aim of the museum's purpose. A balanced of indoor environment conditions in museum buildings refer to the preservation of cultural objects and the human comfort both the visitors and the staffs [7]. The current situations of researches on indoor environment control especially in museum environment are mainly focused in largely isolated ways which try to separate solution for each factor.

Every single artifact either exhibited in a museum or as an integral part of a historical building, needs a controlled microclimate in order to be preserved [35]. The needs to observe the environmental parameter status and variations over time are one of the primary environment factors in museums, beside temperature, humidity, lighting pollution and human factor [33]. These environment factors can possibly deteriorate or even destroy the material cultural goods that are kept, protected and displayed in museum collections. Museum exhibition facilities and storage areas have been shown to be the most crucial factor of the environmental conditions, concerning the preservation of collections and artifacts to minimize environmental influences within the museum building [25, 36]. Modern approaches to the conservation of objects within museum collections seek to minimize the need for cleaning and interventive restoration [37]. Although important, restoration always creates a potential risk of damage to sensitive items. The best conditions for conservation avoid dangerous microclimatic fluctuations as much as possible.

Besides protecting the artifact collections, provide a safety and comfortable environment for human also has been identified as one of museum primary purpose. To attracts more tourist to visit museum, a healthy environment inside the museum building has been identified as one of the important element that must been considered and also to provide a good working environment among museum staffs. Here, IAQ has become an important factor to provide a healthy environment in the museum building, but it is not sure either IAQ in the museum building provide a good air quality or not. Human can experience discomfort and health symptoms when they are exposed to the indoor contaminants due to indoor environmental factors [8]. Indoor contaminants are including formaldehyde, volatile organic compounds, particles, pesticides, radon, fungi, bacteria, and nitrogen oxides.

In Malaysia, there were limited researches done on the effect of the pollutant on people in museum environment scientifically. The analyses were mostly relying on their perception and feedback where almost in all literatures said that museum fatigue is known as the effect of poor indoor environment to the visitors regardless due to these agents or others and only based on psychological or behavioral point of view [7]. In 2014, a researches has been conducted by Shuang and colleagues on sick building syndrome and indoor environment quality towards human. They mention that the most crucial factors of the indoor environment performances in the museum are the staffs and visitors perception towards sick building syndrome and indoor environment quality [6]. The museums need to focus on visitor satisfaction so that able to create returning visitors in order to compete in highly competitive world of leisure and tourist attraction.

b) Design element

Heritage buildings are known to be climate responsive, and its building materials were properly selected to attenuate exterior conditions. Many of these buildings such as Stadthuys, Bastion House and British Colonial buildings in Malacca, while in Kuala Lumpur, Istana Negara and Sultan Abdul Samad building were converted into museums, which need to have a stable indoor climate in order to safeguard valuable collections they housed. Many cultural objects are sensitive to environmental conditions with temperature and humidity being the key agents of deterioration in museum collections. Many argued the practicality of housing a museum in the heritage building. The issue highlighted is that museum needs specific requirements, layouts and other considerations which are vital to the stability and safety of the collections it trying to kept and protect [38].

In Malaysia, most of the historic building which has been convert into museum are building were built about 100 years ago during the Dutch colonization and British colonization. Historic building material of Dutch colonization can be described by the size of bricks as wide but thin, different with the size of bricks nowadays [39]. This material is processed from clay which is then dried at

high temperatures to make it stronger and more durable. This material was used to build Stadthuys building, which has been identified as the first building built by the Dutch system in Malaysia. The wall mostly constructed thicker in order to ensure the strength and resilience in terms of weather, enemy attacks and natural disasters. The usage of thick and durable wooden doors and thick brick walls with wrought-iron hinge handmade, shown the characteristics of the historical building during the Dutch colonization that still can be found in Malacca nowadays. The usage of iron, bricks, roof tiles, floor tiles, plaster of cement and lime show that the material which been used to construct the building during the British colonization about over 100 years ago.

c) Material element

The indoor climate is one of the most important factors contributing to climate-induced damage to the building materials and cultural collections of a monumental building [40]. The traditional materials in old buildings are now less capable of adapting to their change of usage to outdoor condition. In the short term, the risks due to active ventilation alteration are the risks of changing the indoor cooled environment [14]. In the long term, problems will occur due to the frequencies of interaction between the buildings fabric and both outdoor and indoor condition. The issues here are of condensation, which relates to dampness, humidity, moisture movements and temperature.

In addition, there has a study focused on the problems caused by the HVAC system and the effects due to the presence of carpets conducted by Camuffo and colleagues. The carpet has a negative influence as it retains particles and bacteria which are re-suspended each time people walk on it [41].

4. VENTILATION

In the outdoors, pollution is a function of climate, geography, the number and type of industries and vehicles, the fuel used and others. Outdoor pollutants can enter a building, especially a naturally ventilated building and pose a risk to collections. Natural ventilated buildings have indoor concentrations of pollutants that are nearly equal to the outdoor levels. However, building with HVAC systems that have gas-phase filtration minimize the infiltration of pollutants, reducing the indoor level to as low as 5% of the outdoor concentration [42]. Ventilation systems mainly fall into 3 main categories, either the space is fully natural ventilation, combination of natural and mechanical ventilation which is mixed mode or fully mechanical ventilation [14].

Previous research conduct by Kim and colleagues has shown that the prevalence of health symptoms and indoor environment quality complaints was higher in air-conditioned buildings than in naturally ventilated buildings [43]. Many argued the practicality of housing a museum in the heritage building. The issue highlighted is that museum needs specific requirements, layouts and other considerations which are vital to the stability and safety of the collections it trying to kept and protect [39]. Rely entirely on the mechanical HVAC systems without paying attention to the building's original design and its features as ideal climate tools, for both human comfort and the conservation of museum collections [44]. HVAC systems, when chiefly designed for human welfare, are not suitable for conservation and can cause dangerous temperature and humidity fluctuations [42]. It shown that it was difficult to achieve balanced of indoor environment conditions in museum buildings refer to the preservation of cultural objects and the human comfort.

a) Natural ventilation

Natural ventilation is a vital and extensively used alternative to mechanical ventilation in terms of cost and operational simplicity. People can open or close the windows thus allowing the outdoor air to flow through the space and create a positive thermal sensation. For passively cooled buildings, natural ventilation is the main technique for achieving indoor thermal comfort and the only means for satisfying IAQ requirements [45]. Moreover, provided that the outdoor-air quality is acceptable, natural ventilation, unlike mechanical ventilation, is not a pollution source. A major problem, however, with controlling natural ventilation is the continuously varying environmental condition. In particular, variations of wind velocity might cause continuous changes of the controlled parameter, for example the window opening area. It was found that, the size of windows, the number of windows and the positioning of windows have major impact on IAQ [46]. In the naturally ventilated buildings IAQ can be manipulated by using the open able area and locations of windows.

As heritage buildings are often not equipped with HVAC systems, it is necessary to provide proper interventions and measures with the aim of monitoring and controlling indoor physical parameters [47]. There has a study focused on the concept of passive design in climate control conduct by Tharazi. The concept of passive design is basically to provide a comfortable and healthy environment for the human [39]. Besides that, it is an economical, environmental friendly and aesthetic. For economic aspect, it reduce the needs of heavy mechanical systems, while for aesthetic aspect, the design of the building is more likely to be based on local climate. Lastly for environmental aspect, less energy consumed translates to less amount of waste.

The concept of passive design in climate control is always associated with traditional and vernacular architecture. Due to this, Toledo noted that buildings in warm and humid regions always have physical similarities which contribute to the climate control such as ventilated pitched roofs, openings on all facades, long eaves, above-grade basements and stilts that separate the building from humid ground [45]. In Malaysia, those features can be found in its traditional built forms, especially the traditional house. Therefore, climate control can be achieved by simply enhancing the original architectural

features without having to rely heavily on the controlled mechanical systems. According to Henry, key element in conditioning the indoor climate of heritage buildings was the active participation of its inhabitants, which operate the building features such as doors, windows, shutters or shading devices to capitalize on favorable external aspects, such as breezes, for ventilation and comfort [48].

b) Mechanical ventilation

Generally, many of heritage buildings lost its passive climate features due to the installing of new air conditioning systems, mean that they will be tightly sealed and heavily modified [39]. Adapting new mechanical systems to heritage buildings are not an easy task as there is a need for careful planning to be conducted during the early stages of designing new mechanical systems so that only suitable and appropriate systems are installed [49]. However, some evidence is offered through a dilapidation survey on several historical buildings in the Historical City of Malacca which was carried out in 2007 by Zawawi. Here it was found that the retrofitted air conditioning systems in the building had damaged the existing internal building elements [50].

In Malaysia, tropical develop country, Mechanical, Ventilation and Air conditioning (MVAC) systems are commonly used to control the temperature, humidity, circulation, ventilation as well as purification of the air in a building. Major challenge for mechanical and electrical design engineers is to achieve minimum comfort level in tropical buildings due to unique hot & humid climates in tropical country [51]. According to Balocco and Grazzini, suitable conditioning plant design is only one aspect of a wide problem that concerns thermo-physical building performance and then building envelope characteristics quality [22]. It is important when the building is a museum and it preserves the work of art at the same time.

There has a study on energy saving strategy in air-conditioning conduct by Ascione and colleagues, to reduce energy requirements for HVAC systems in an exhibition room of a modern museum [52]. Considering that the air-conditioning system has to operate constantly, suitable techniques permit to obtain useful energy savings. However, the main causes of the dangerous variations of the microclimatic conditions in the exhibition rooms are the thermal loads due, respectively, to the outdoor air and to the visitors. For museum which is mechanical ventilated air-conditioning, the recommended thermal-hygrometric parameters for the conservation of the various materials have placed priority on human comfort and are stricter as regards both humidity and temperature. Due to the necessity of guaranteeing artwork conservation and, if possible, thermal comfort for visitors too, moderate indoor conditions are preferable in exhibition areas. HVAC systems for museum can create problems for the time stability of the thermal-hygrometric conditions due to the high occupancy variation and discontinuous flow of people can cause significant sudden changes of the microclimatic parameters in the museum environment.

Besides that, there has another study which is about the performance of retrofitting climate control systems focusing on air conditioning systems in refurbished old buildings in tropical climates, conduct by Sulaiman and her colleagues [14]. This study raises several important issues relating to indoor environmental quality. Based on the studies conducted, there is clear evidence that the overall refurbishment works of installing air conditioning system in an old building presents risks to the existing building elements. However, only in hot and humid climate conditions do the problems with the installation of cooling system appear prevalent. Beyond the obvious aesthetical issues, the installation of air conditioning systems tends to create thermal instabilities and indoor environment imbalances in refurbished buildings. Furthermore, there is also a gap between the necessities of conserving the precious features of old buildings and the demand for better thermal comfort by the occupants.

5. CONCLUSIONS

Heritage buildings are known to be climate responsive, and its building materials were properly selected to attenuate exterior conditions. Many of these buildings were converted into museums, which need to have a stable indoor climate. Museum building, either it is historic museum building or modern museum building, must achieve balanced of indoor environment conditions inside the building to provide a better indoor air quality for collection care and for human comfort. A healthy environment inside the museum building could attract more tourists to visit museum and also to provide a good working environment among museum staffs. The application of mechanical ventilation system supposedly provides a healthy and better indoor environment for both collection care and human comfort without affect one of them. There a need for careful planning to be conducted during the early stages of designing new mechanical systems so that only suitable and appropriate systems are installed.

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