



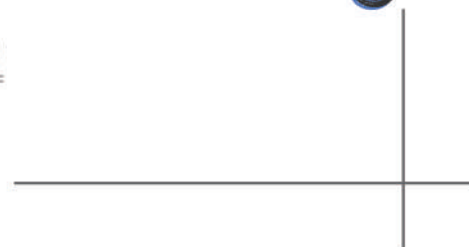
Frontiers Research of 2019 • April

Architecture and Engineering

Volume 2 Issue 2 • April 2019 • ISSN 2591-7587 (print) 2591-7595 (online)



**BILINGUAL
PUBLISHING CO.**
Pioneer of Global Academics Since 1984



Editorial Board

Editor-in-Chief	Bin Xu	Huaqiao University, China
Associate Editor	Kiruthiga Kandasamy Jianhui Hu Zhenyu Zhao	National Institute of Technology, India Shanghai Jiaotong University, China North China Electric Power University, China
Editorial Board Members	Peijun Wang Dongsheng Li Gokce Onal Peter Hasdell Noguchi Masa Aniza Abdul Aziz Mario D'Aniello Yong Zeng Zhao Xianbo (Bill) Hai Ye Rui Duarte Neves Yuanxin Zhang Oguzhan Kelestemur Solomon Olusola Babatunde Song Lih-Yau Kim Jee-Sang Xiaomeng Hou Lin Weiwei Suman Saha Najib Mohammed Al-Fadhali Quantao Liu Chunxu Xia Kunamineni Vijay Afonso Rangel Garcez Azevedo Behnoush Golchinfar Amos Darko Jianhui Zhan Wandong Zheng Garfield Guan Xianzhang Soliman Amr Abu-Samra Chen Yujiao Dayi Ou Mattheos Santamouris Tan Chun Liang Ma Xiaoli Yuna Zhang Rima Fayaz Ece Kalaycioglu Pedro Fernandes Pereira Junye Hua Zongbing Lu Sungjin Kim Marta Maria Sesana Aliaa Hussein Alsadaty Mitra Kanaani Emilio J. Mascort-Albea	Shandong University, China Dalian University of Technology, China Eskisehir Osmangazi University, Turkey Hong Kong Polytechnic University, Hong Kong University of Melbourne, Australia University of Malaya, Malaysia University of Naples Federico II, Italy Chongqing Jiaotong University, China Central Queensland University, Australia Tongji University, China Polytechnic Institute of Setubal, Portugal Guangzhou University, China Firat University, Turkey Obafemi Awolowo University, Nigeria National Taipei University of Technology, Taiwan Seokyeong University, Korea Harbin Institute of Technology, China Waseda University, Japan National Institute of Technology, India Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia Wuhan University of Technology, China Dalian University of Technology, China National Institute of Technology, India Federal Fluminense Institute, Brazil Stevens Institute of Technology, USA The Hong Kong Polytechnic University, Hong Kong Hubei Provincial Communications Planning and Design Institute Co. Ltd, China Tianjin University, China G & K Consultancy Ltd, Hong Kong Concordia University, Canada Harvard University, USA Huaqiao University, China University of New South Wales, Australia National University of Singapore, Singapore University of Hull, United Kingdom Baumann Consulting Inc., United States University of Art, Iran Ozyegin University, Turkey University of Porto, Portugal Nanjing Normal University, China Nantong Xinhua Construction Group, China University of Alabama, United States Politecnico di Milano, Italy Cairo University, Egypt New School of Architecture & Design, USA University of Seville, Spain

Aim and Scope

Frontiers Research of Architecture and Engineering is an international, scholarly and peer-reviewed journal (print and online) with open access published quarterly in Singapore by Bilingual Publishing Co., an international publisher with a long history and high prestige, founded in 1984. It reports the latest and most innovative research results in all fields of engineering and architecture. It aims to promote the theory and practice of engineering science and architectural management. The Journal welcomes contributions which drive the exchange of ideas and rational discourse between educators and engineering researchers all over the world. A broad outline of the journal covers original research articles, case and technical reports, reviews and papers.

The scope of the papers in this journal includes, but is not limited to:

- Architectural design
- Municipal public facilities construction
- House and civil engineering building
- Green building
- Industrial and mining engineering building
- Municipal engineering
- Railway/road/tunnel/bridge engineering
- Construction and building materials
- Building operations
- Running water conveyance project
- Central heating and central gas supply for building
- Municipal road construction

Volume 02 Issue 02 • April 2019
ISSN 2591-7587 (Print) 2591-7595 (Online)

Frontiers Research of Architecture and Engineering

Editor-in-Chief
Bin Xu
Huaqiao University, China

Contents

Article

- 1 Dynamic Performance Analysis of Steel Frame Structure under Seismic Action**
Xiaojun Yuan Jinlong Liu Yanmu Qu Kailin Wei Haifeng Zong
- 5 An Assessment of Indoor Environmental Quality in School Buildings in the State of Kuwait**
Jamal Al-Hubail Abdul-Salam Al-Temeemi

Review

- 20 Discussion on the Intelligent Design of Ultra-Low Energy Consumption Passive Buildings**
Xin Tong Xiaolin Yang Xiao Ma
- 25 Research on the Application and Public Experience of Green Landscape Color Art in Fuzhou**
Ying Ouyang

Copyright

Frontiers Research of Architecture and Engineering is licensed under a Creative Commons-Non-Commercial 4.0 International Copyright (CC BY-NC4.0). Readers shall have the right to copy and distribute articles in this journal in any form in any medium, and may also modify, convert or create on the basis of articles. In sharing and using articles in this journal, the user must indicate the author and source, and mark the changes made in articles. Copyright © BILINGUAL PUBLISHING CO. All Rights Reserved.

**ARTICLE**

Dynamic Performance Analysis of Steel Frame Structure under Seismic Action

Xiaojun Yuan* Jinlong Liu Yanmu Qu Kailin Wei Haifeng Zong

Jiangsu Testing Center for Quality of Construction Engineering Co., Ltd., Nanjing, Jiangsu, 210028, China

ARTICLE INFO*Article history*

Received: 19 March 2019

Revised: 1 April 2019

Accepted: 23 April 2019

Published Online: 30 April 2019

Keywords:

Steel frame structure

Dynamic time-history analysis

Dynamic performance

ABSTRACT

In order to find out the dynamic characteristics of a steel frame structure project in the 8 degree (0.3g) area, the artificial wave, Taft wave and El Centro wave were input by using the finite element analysis software ANSYS. The dynamic time-history analysis of the structure shows the dynamic performance of the structure under the frequent earthquakes and rare earthquakes.

1. Introduction

The Earth is currently in an active period of geological structure, and earthquakes occur more frequently, research on earthquakes has once again become a major research issue. The assessment of the seismic performance of existing buildings is also of great practical significance. Taking the 8 degrees (0.3g) six-layer three-span steel frame structure in high-intensity area as an example, the finite element software ANSYS is used to analyze the dynamic time-history under earthquake action. The seismic resistance of the structure is obtained to verify whether it can meet the deformation requirements under strong earthquake conditions.

2. Engineering Overview and Finite Element Model**2.1 Engineering Overview**

There is a six-layer three-span steel frame structure with a height of 3.6 m and a longitudinal span of 6 m. The structural arrangement is shown in Figure 1 and Figure 2. The dead load on the roof is 4.65kN/m², and the load on the beam partition is equivalent to 6kN/m for line load, 2kN/m² for live load, 2kN/m² for roof load, the basic wind pressure is 0.4kN/m², and the snow load is 0.4kN/m². The seismic fortification intensity is 8 degrees (0.3g), the ground roughness is Class B, the site category is Class II, and the design earthquake group is the first group. The cross-sectional dimensions of the structure are shown in

**Corresponding Author:*

Xiaojun Yuan,

Jiangsu Testing Center for Quality of Construction Engineering Co., Ltd., No. 107 Hongshan Road, Nanjing, Jiangsu, 210028, China;

E-mail: 1476892342@qq.com

Table 1. The above parameters are input into PKPM to obtain the periodic seismic forces of the structure as shown in Table 1.

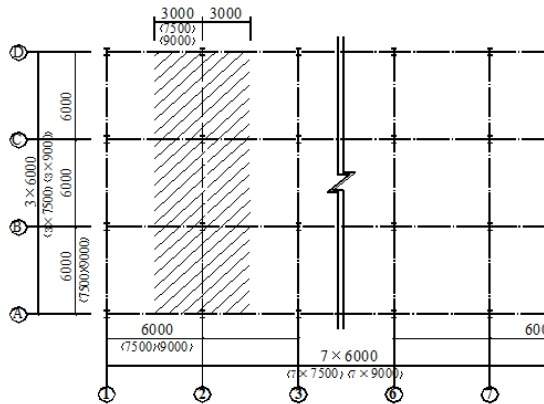


Figure 1. Plane layout diagram of steel frame structure

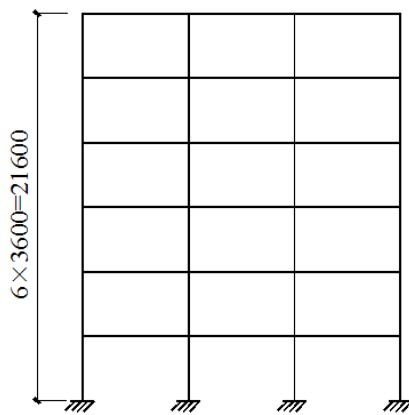


Figure 2. Facade layout diagram of steel frame structure

2.2 Finite Element Model

Plan the frame unit when ANSYS builds the model. The unit selects the international standard unit system (SI system). Beam and column adopt beam188 unit; material adopts steel with yield strength of 235N/mm², elastic modulus is $E=2.06 \times 10^5$ N/mm², material density $\rho=7.85 \times 10^3$ kg/m³, Poisson's ratio $\nu=0.03$; the resilience model adopts the bilinear follow-up strengthening model, and the late stiffness of the beam and column is taken as 0.02 times of the initial stiffness.^[1]

The load that the structure bears, the dead load is calculated by actual calculation, and the live load is reduced by 0.5, which can be expressed as $q=q_{\text{constant}}+0.5q$. The input of the load is equivalent, and the load of the structure is converted into the density of the structure. Taking Model 1 as an example, it is known that $h=0.25$, $b=0.25$, $t_w=0.008$, $t_r=0.014$. $A=(h-2t_r) \cdot t_w+2 \cdot b \cdot t_r$, $\rho=7849+q \cdot k_w/(A b_1 \cdot 9.8)$; The gravitational acceleration g is 9.8 m/s^2 . Since the stability outside the plane of the structure is not considered, the z -direction constraint is applied to the beam, and the connection between the beam and the column and the connection between the column and the ground are both rigidly connected. The structural damping model uses Rayleigh damping.^[4] The Rayleigh damping is assuming that the damping matrix is proportional to the mass matrix and the stiffness matrix:

$$C = \beta M + \alpha K \quad (1)$$

α, β In general, the scale factors can be expressed as:

$$\alpha = \omega_1 \omega_2 \beta = 4\pi^2 f_1 f_2 \beta \quad (2)$$

$$\beta = \frac{2\zeta}{\omega_1 + \omega_2} = \frac{2\zeta}{2\pi(f_1 + f_2)} \quad (3)$$

Where ω_1, ω_2 is the circular frequency; f_1, f_2 is the frequency and ζ is the structural damping ratio.

3. The Selection of Seismic Records

It is well known that the determinants affecting seismic response are mainly:^[2] the spectrum, amplitude and duration of ground motion. Below we will analyze the common seismic records in these aspects to select the appropriate ground motion record.

Through seismic record spectrum analysis, three seismic records suitable for the first group of earthquakes in China II site design are selected in the common seismic records: artificial wave, Taft wave and El Centro wave.

How to make the seismic record meet the seismic intensity of 8 degrees (0.3g), it is necessary to adjust the ground motion intensity, mainly to adjust the ground motion amplitude. This method only changes the amplitude

Table 1. The calculation results of structure size and partial PKPM

Layers	Beam Size / mm	Side Column / mm	Center Column / mm	Cycle / s	Earthquake force / kN
1-3 Layers	350X250X8X16	380X300X12X20	450X350X12X20	1.467	277.7
4-6 Layers	350X250X8X14	380X250X12X20	400X300X12X16		

of the ground motion response spectrum without changing the spectral characteristics. The specific adjustment formula is:

$$a'(t) = \frac{A'_{\max}}{A_{\max}} \cdot a(t) \quad (5)$$

Where $a(t)$, $A_{\max}$ represents the seismic acceleration curve and peak value of the original record; $a'(t)$, $A'_{\max}$ represents the adjusted seismic acceleration curve and peak value. According to “Code for Seismic Design of Building Structures”,^[3] For the Class II sites and the fortification intensity of 8 degrees (0.3g), under the conditions of frequent and rare earthquakes, the dynamic time-history analysis should adjust the peak acceleration of ground motion to 1.1m/s² and 5.1m/s² respectively.

The determination of the duration can be based on the relevant provisions of the seismic code to select 3-4 times the basic period of the structure, and not less than 10s and ensure that the strongest part of the seismic wave is included in the determined duration. For the above seismic records, the time interval of the record near the peak is selected, and the time interval is 0.02s.

4. Seismic Response Analysis

4.1 Reaction Characteristics under Multiple Earthquakes

The displacement response of the structure under multiple earthquakes can be adjusted to 1.1m/s² by the Formula (3), and then ANSYS dynamic time-history analysis. The structural displacement values and the inter-layer displacement angles are shown in Figure 3 and Figure 4. It can be seen from the figure that the inter-layer displacement values of the structures under different seismic records are different from the displacement values obtained by the PKPM software designed according to the specifications. The artificial wave and El Centro wave ratios are smaller according to the specifications; while the results calculated by Taft wave are larger than those calculated by the norm, and the difference between the average value of the three seismic records and the calculated value is within 20%, which is statistically consistent. The maximum base shear forces of the three seismic records, namely artificial wave, Taft wave and El Centro wave, are 275.3kN, 419.6kN and 271.0kN, respectively. Compared with the value 277.7kN obtained from the mode decomposition reaction spectrum, the ratios are 99%, 151%, and 98% respectively meeting the specification requirements ($\geq 65\%$), and the average value of the three seismic records is 116% to meet the specification requirements ($\geq 85\%$), which shows that the above three seismic records meet the requirements.

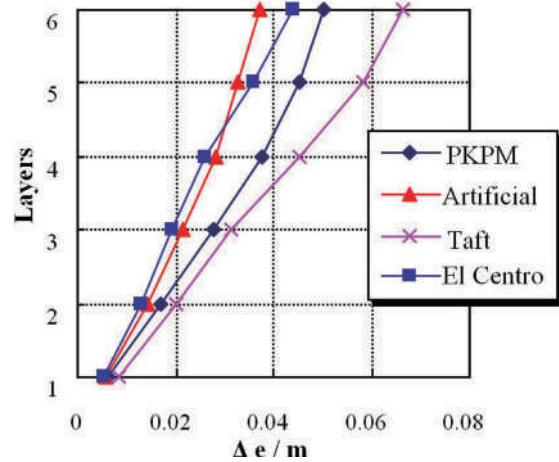


Figure 3. The displacement of the structure under multiple earthquakes

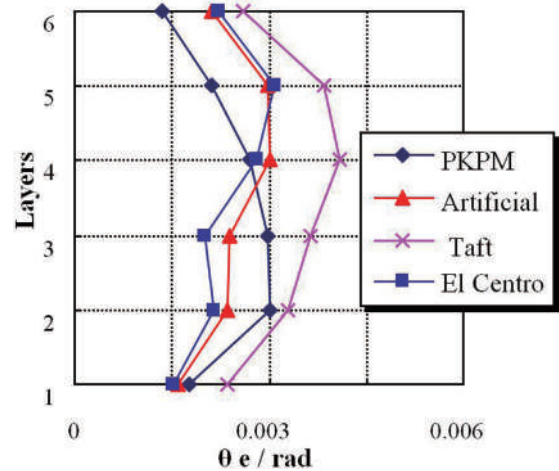


Figure 4. The displacement angle of the structure under multiple earthquakes

4.2 Reaction Characteristics under Rare Earthquakes

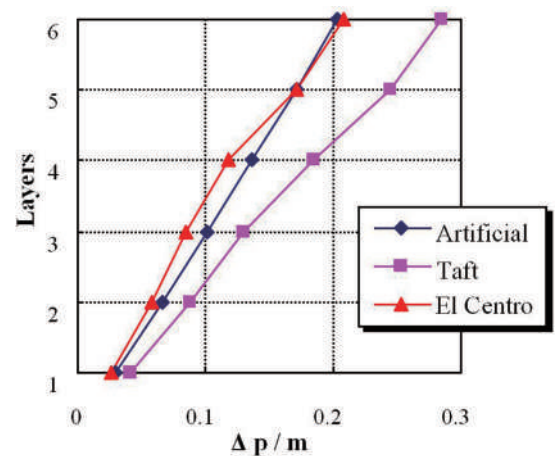


Figure 5. The displacement of the structure under rare earthquakes

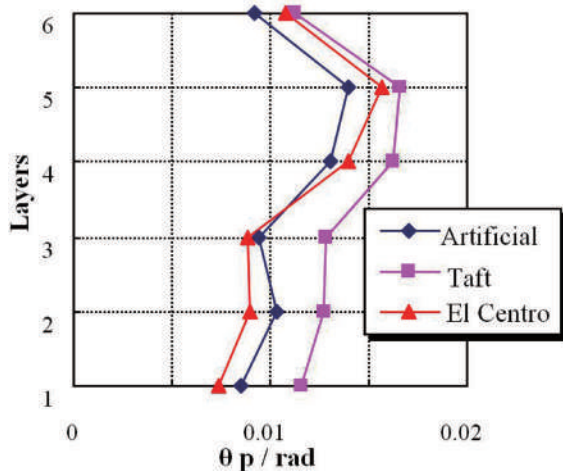


Figure 6. The displacement angle of the structure under rare earthquakes

The displacement response of the structure under rare earthquakes can be adjusted to 5.1m/s^2 by the Formula (3), and the ANSYS dynamic analysis is performed. It is shown that the displacement of the structure and the displacement angle between the layers under rare earthquake conditions are shown in Figure 5 and Figure 6. It can be seen from the figure that the interlayer displacement value of the structure under different seismic records is smaller than the standard steel frame structure displacement angle limit of 0.02, and the larger displacement of the structure appears in the fifth layer, which shows that the weak layer of the structure appears on the fifth layer, where a large plastic deformation occurs; at the same time, the vertex displacement response curves of the structure under different seismic records are also shown in Figure 7.

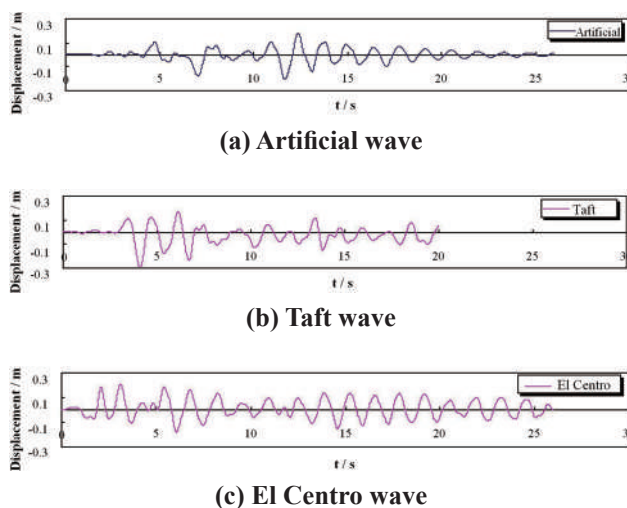


Figure 7. Structural vertex displacement response curves

5. Conclusion

Through the dynamic time-history analysis of the three-span six-layer steel frame structure under multiple encounters and rare earthquake conditions, the following conclusions can be drawn:

(1) There are some differences between the inter-layer displacement values of the structures under multiple earthquakes and the results of PKPM. It can be seen that the structural displacements obtained by the specific seismic records and the base shear forces of the structures are different, which also reached a statistically consistent within 20%.^[2]

(2) When the floor yield strength coefficient of the frame structure is uniform, the structural weak layer always appears on the bottom layer.^[4] The dynamic time history analysis of the above-mentioned structures under different earthquakes and rare earthquakes shows that the maximum plastic deformation of the structure always appears in the fifth layer of the structure, indicating that the weak layer of the design appears in the fifth layer;

(3) The maximum interlayer displacement angle of the structure under rare earthquake intensity is smaller than the elastoplastic displacement angle limit of the seismic code. The design meets the fortification requirements of large earthquakes mentioned in the specification.

Based on the above analysis, it can be considered that the structure can meet the fortification conditions of China's "no damage in small earthquakes, no collapse under strong earthquakes", if the stiffness of the 4-6 layer structure can be properly adjusted, the energy consumption of the structure can be better utilized and the seismic level of the structure can be improved.

References

- [1] Guoqiang Li. Steel structure design of multi-tall buildings[M]. Beijing: China Building Industry Press, 2004. (in Chinese)
- [2] Standards of the People's Republic of China. Code for seismic design of buildings (GB50011-2010)[S]. Beijing: China Building Industry Press, 2010. (in Chinese)
- [3] Bo Zhang, Hetai Sheng. ANSYS finite element numerical analysis principle and engineering application[M]. Beijing: Tsinghua University Press, 2005. (in Chinese)
- [4] Guoqiang Li, Jie Li, Xiaozu Su. Seismic design of building structures[M]. Beijing: China Building Industry Press, 2002. (in Chinese)



ARTICLE

An Assessment of Indoor Environmental Quality in School Buildings in the State of Kuwait

Jamal Al-Hubail* **Abdul-Salam Al-Temeemi**

College of Technology, 367173, Kuwait

ARTICLE INFO

Article history

Received: 11 March 2019

Revised: 1 April 2019

Accepted: 23 April 2019

Published Online: 30 April 2019

Keywords:

Building environment

sick building syndrome

Classroom environment

Indoor physical parameters

Temperature

Relative humidity

Illumination

Noise

Space density

ABSTRACT

In this study, indoor quality and environmental comfort were investigated in secondary school buildings located in the State of Kuwait. Comfort variables such as temperature and relative humidity (thermal comfort), noise (acoustic comfort), illumination (visual comfort), as well as allocated classroom floor area per student (spatial comfort) were measured. Data was collected over a 7-month period on a spot basis during school hours in student-occupied classrooms at 46 selected schools. The measured data was then compared to international guidelines and standards related to indoor environment quality. The data for noise and allocated space were shown to be in the comfort ranges in all the schools. However, 11% of the schools are not adequately illuminated, 33% had temperatures not within the recommended limits, and 22% of the schools had humidity levels either higher or lower than the recommended levels. Also, 9% of the schools had low illumination readings.

In addition, during the data monitoring, a survey was conducted by which the student occupants completed a questionnaire so that subjective and objective evaluations could be compared. The findings of the questionnaire displayed significant correlations between the measured data and some ailments and other complaints experienced by the students.

Ultimately, the results found in this research will provide a baseline for comparison with future indoor environment quality assessments in buildings. Furthermore, recommendations are suggested in order to improve the environmental quality problems encountered in some of the schools, which may be beneficial for policymakers, facilities managers, and design engineers.

1. Introduction

Indoor environmental quality (IEQ) is a term used to depict the characteristics of indoor built space, including indoor air quality (IAQ), the acoustic, thermal,

and visual environment. Both quantifiable physical and precept human comfort variables assume a vital part in characterizing IEQ. Clean and healthy Indoor air quality, acoustical comfort, visual comfort (lighting), thermal comfort as well as physiological comfort are the main fac-

**Corresponding Author:*

Jamal Al-Hubail,

College of Technology, Kuwait;

E-mail: ja.alhubail@paaet.edu.kw.

About another author: Abdul-Salam Al-Temeemi, College of Technology, Kuwait;

E-mail: temeemi@hotmail.com.

Fund Project:

The research reported here was supported by a grant (Project No.: #TS-07-13) from the Public Authority for Applied Education and Training in the State of Kuwait.

tors which can bring about a good or bad level of a particular indoor environment. With a building's IEQ having an effect on the comfort and health of building inhabitants, naturally, productivity at work will be impacted^[1].

Sick Building Syndrome (SBS) is another term employed to portray symptoms involving illnesses and discomfort linked to the time building occupants spend in poor indoor environments. Colds, dry throat, skin rash, muscle aches, headaches, nausea, itchy skin, fever, asthma are just some of the SBS symptoms that have been credited to uncomfortable temperatures or humidity, poor air quality, inadequate lighting, poor acoustics, and crowded workspaces^[2-5]. The SBS symptoms are likely to rise in significance with the time that individuals occupy the building and vanish when individuals exit the building^[6].

The problem of SBS in offices and homes is causing lower levels of productivity and many other health complications. According to the Health and Safety Executive Report in the UK, approximately 30 to 50% of buildings suffer from poor IEQ, with up to 85% of its occupants suffering from SBS symptoms. SBS is an indoor environmental concern that has been studied and confirmed by various kinds of disciplines such as environmental agencies, contractors, policy makers; medicine as well as many other industries^[7]. Due to poor indoor environments, the rates of absenteeism at offices, schools as well as other organizational environments have increased and been associated with physiological and psychological discomfort faced by various individuals^[8].

IEQ in school environments is essential since growing youth are especially susceptible to poor indoor conditions. Students at this age are still physically growing, and in contrast with grown-ups, will endure the outcome of a poor indoor condition sooner^[9]. Furthermore, except for being at home, students will occupy most of their time at school. Therefore, the acoustical, visual, thermal, and space conditions in classrooms have a noteworthy part with respect to students' comfort and health.

A review of previous studies on the classroom environment reveals research mainly centered on the effect of the indoor environment on student learning and achievement^[10]. However, a variety of conditions related to IEQ can exist in classrooms that can be detrimental to their health resulting in absenteeism and associated long-term health ailments, but the data is limited. The poor environment of schools can cause difficulty in concentrating, fatigue, lethargy, and illness, consequently affecting the health and performance of student^[11]. The National Center for Educational Statistics^[12] reported that 43% of the schools in the United States were rated as unsatisfactory in either ventilation, lighting, temperature, indoor air qual-

ity, or noise control.

1.1 Space Density

The issue of occupant space density in a building can be assessed by the psychological effects of territoriality. The average space area allocated to building occupants impacts freedom of movement in a room, social distance, and personal space^[27]. People who function in congested spaces may carry out their work badly, attain stress, and have a greater chance of catching contagious diseases^[28, 29].

Classroom density (that is, the amount of space available to each pupil in a class) has received early attention in the literature. The implications of high-density spaces that comprise of too many students in a classroom or too little space are increased transmission of airborne diseases causing an infection risk, such as tuberculosis and influenza that can spread through coughing or sneezing^[30]. In addition, as the density increases in a classroom, there will tend to be dissatisfaction, nervousness, and stress^[31]. People naturally feel uncomfortable when others encroach upon their personal space and become defensive, aggressive or recluse. Therefore, over-crowded classrooms can cause discipline difficulties and behavioral disturbance that can produce noise and alter the clearness of verbal interaction^[32]. In addition, crowding can cause personal loss of privacy, distraction, and excessive stimulation. These surroundings can cause mental fatigue, which can weaken a students' concentration^[33, 34].

Space standards pertaining to educational classroom occupancy define requirements for student capacity, area allocations, and utilization. These standards take into account comfort, overall efficiency, and safety to the classroom occupants^[35]. Based on these standards, the space requirement per student is to be a minimum of 1.39 sq. m² per student to avoid the feeling of crowding in schools^[36].

1.2 Noise

Acoustic comfort in an indoor environment is an equally important factor for comfortable indoor environments. Any excess sound or voices, normally of high intensities which are undesirable and cause irritation or discomfort by occupants, is considered noise pollution. Indoor environments having poor acoustics will create difficult environments for humans to live and work in, as a result of which lower rates of productivity and health are formed^[54]. Excessive noise can produce many health problems such as hearing loss, fatigue, and high blood pressure. Also, long-term exposure to such noise can harmfully alter psychosocial relationships and working performance, interfere with communication, provoke annoyance, and change

the social behavior^[55]. Not only has noise been demonstrated to have harmful consequences after lengthy exposure, but it also can distress people in times of intermittent exposure and occurrences, depending on a person's sensitivity levels^[56]. With abrupt elevated sound levels, there is a possibility of mechanical damage to the outer and the inner ear. Accordingly, acoustical evaluation studies that consider healthy noise exposure limits are critical.

In a classroom environment, noise disrupts communication and is unsettling and unfavorable to student learning^[57]. Noise can be generated by many sources, including other students (both inside and outside the classroom), noise from sources in adjacent rooms and hallways, HVAC systems, and external noise, which is transmitted through a building's exterior walls, such as nearby industry, traffic, construction, and vehicular traffic. Road traffic is in most cases the chief external noise source, especially in urban areas^[58].

Avoiding exposure to noise in classrooms is necessary and researchers are conscious of the complications produced by noise in school buildings. Studies regarding excessive noise in classrooms have shown that symptoms such as headaches, fatigue, difficulty concentrating, low performance, stress, and irritability exist for both teachers and students^[59]. Studies also indicate that the heart rates of teachers are associated with the stress reaction to noise levels. Many teachers complain of vocal strain due to the need to speak at high vocal levels in order to prevail over the background noise^[60]. Students show the same reaction with evidence of hearing loss^[59]. Other studies showed that students at a school near an airport had reduced long-term memory^[61], which improved after the closing of the airport. The most prevalent and documented reaction to noise is annoyance^[62].

To deal with these noise problems, some countries have adopted legislation and standards concerning the acoustics of industries, including schools. The purpose of these guidelines is to make explicit proposals for the implementation of a practical hearing protection program. One such standard is recommended by the US Occupational Safety and Health Administration (OSHA), which is a regulatory agency, and therefore, the standard is binding by law in the U.S.A. The OSHA acoustics standard recommends maximum noise levels should not exceed 105 dBA^[63].

Many studies, however, have still shown elevated levels of noise in school surroundings. Classrooms in urban area schools, in particular, didn't have acceptable acoustic conditions due to the effect of outdoor noise^[64-67]. There is evidence of impaired performance in noise-exposed students especially around airports and the excessive exposure to noise was related to reduced reading compre-

hension, long-term memory, and motivation^[68,69].

1.3 Lighting

People spend a large amount of their time indoors and lighting has a substantial bearing on IEQ. Without proper light, people may have physiological and psychological problems, which in some cases can cause sickness^[13,14]. There is evidence of visual injury, allergic reaction, dry eyes, burning eyes, exhaustion, and headaches because of poor lighting in the workplaces^[15]. Optimal lighting may enhance overall health and comfort. Lengthy spells of low light intensities can trigger depression and diminished functioning for some^[16]. It has been shown that adequate lighting conditions decrease unfavorable health symptoms^[17]. Lighting can also affect occupants' productivity, comfort, and overall wellbeing, amount of fatigue, in addition to safety^[18,19]. Therefore, the lighting of any given room should accomplish its illumination design objectives.

According to Saade and Ramadan^[20], the illuminance level of light, measured in lux, is the main parameter in order to achieve visual comfort. Several standards^[21] prescribe that the illumination of school classrooms must be 300 lux or more at any point on a work surface. Analysis of research showed that overall, a lux illumination intensity of above 300 made people were more satisfied with the visual comfort of their indoor environment^[22]. Research has also shown that adverse effects of poor lighting are commonly found when illuminance was below the recommended level. A study conducted by Juslén^[23] showed that lower levels of illumination made it harder for the occupants to read, write, or work and concentration levels dropped. However, there is evidence in the literature that discomfort will be incurred such as glare, stress on vision, and the inability to concentrate when illuminance at pupils' desks is above 1000 lux^[24-26].

1.4 Indoor Temperature

As stated by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Standard 55^[37], thermal comfort is defined as "a state of mind which expresses satisfaction with the thermal environment". Essentially, thermal comfort in a space is attained by sustaining temperature, humidity, and air movement within a specified range. Indoor air temperature is one of the most significant factors controlling thermal comfort, which subsequently affects health. Of all the IEQ factors, Clements-Croome^[38] report that building users are most dissatisfied with temperature and ventilation. Results from the evaluation and analysis of 95 buildings have shown sig-

nificant effects of temperature on the prevalence of SBS^[39]. When it gets too warm, people tend to feel stuffy and congested in a particular space. It can also lead to a feeling of nausea and suffocation. Therefore, it is very crucial to maintain a stable and comfortable thermal setting in a given environment, or else it may create tense and pressured conditions which negatively influences the performance and productivity of an individual^[40,41]. Cold air temperatures alternatively can too add immense discomfort and ill-health. Optimum indoor temperature varies between 19° to 23°C for IAQ and can be valid for assessments in classrooms^[37]. One study proved that a thermally comfortable indoor environment can majorly help in the reduction of absenteeism by almost 35%^[42].

Past research has evaluated the thermal environment in classrooms assessed by thermal comfort criteria. These studies mainly infer that the thermal preferences of the students were not in the comfort range specified by international standards^[43]. Too high or low indoor air temperatures are commonly found to be outside the recommended ranges in school buildings^[44,45].

Suitable IAQ and thermal comfort are vital for any space, but especially so for classrooms in order to assure health and comfort for its occupants. Thermal discomfort, whether it is excessively hot or cold classrooms, has been linked to physical stress, and hence, can cause health ailments and deficient pupil performance. Satisfactory IAQ and thermal comfort in an indoor environment will produce a feeling of general wellbeing resulting in improved student attention and productivity^[38]. In an educational setting, researchers have presented data that thermal conditions can stimulate students' behavior^[46], attitudes^[47], comfort and preferences^[48], personality development^[49], learning^[50] and performance such as understanding, reading, and calculating^[51].

1.5 Humidity

Humidity is another factor affecting thermal comfort. Maintaining appropriate humidity indoors is essential for the comfort and health and of building inhabitants. The allowable range of relative humidity (RH) set by ASHRAE is between 30-60%^[37]. Too high RH has been associated with SBS, which may be related to the progression of bacteria, mold, allergens, viruses, and fungi in spaces with poor ventilation^[52]. On the other hand, overly dry air can raise the risk of upper respiratory infections^[53].

1.6 Current study

Evidently, from previous research, the indoor environment in classrooms will have a great influence on students'

health and comfort. It has been found that the improvement of the indoor environment factors such as air quality, temperature, and humidity, light, acoustic and space density need to be considered to provide healthy and comfortable surroundings. According to research, these factors can be evaluated readily by field measurements.

Many studies have evaluated the indoor conditions in educational buildings. Most, however, focused on one or two indoor environmental aspects only^[70-75]. With little data obtainable in the literature regarding IEQ in schools in some developing countries, including Kuwait, there is a need for valid, current, and reliable data for this inquiry. IEQ issues not being fully investigated have resulted in occupants possibly being sick or uncomfortable.

As part of an ongoing research project, the goal of the current study is to examine the effectiveness of school facilities in the State of Kuwait regarding IEQ compared to international standards and the impacts of this on the students. A previously published study by the authors focused on the air quality aspect of IEQ in schools^[76]. As such, this study was performed by measuring the remaining IEQ factors (temperature, humidity, light, acoustic and space density) and the data were compared with relevant standards and schools with substandard IEQ were identified. In addition, the association between these IEQ factors and the occurrence of SBS and perception of comfort in their respective indoor environments was evaluated through a subjective post-occupancy survey of the students. The combination of measured data and survey offers a more comprehensive indication of environmental quality and occupants' well-being. Several studies^[74,77,78] implemented this way of investigation in order to look for a relationship between physical measurements and subjective responses.

The results of this study can be used to provide recommendations to school administration, architects, and engineers and as a guide for other researchers to obtain information about the efficiency of the current indoor environments in schools. Appropriate remedial measures can then be applied, if needed, to provide a satisfactory learning environment.

2. Materials and Methods

2.1 Overview of Target Buildings

Forty-six secondary schools were chosen as a sampling size for this research out of a total of 136 gender-segregated secondary schools that exist in Kuwait at the time of this study. The quantity of schools chosen represents a suitable statistical number (or more than 30% of the total number of schools in Kuwait). Roughly half of the selected schools, 24, were schools for girls. The schools were

chosen arbitrarily and were situated geographically in all the urban areas of Kuwait (Figure 1). The selected schools varied in the age of construction with the most dated school being built in 1959 and the most contemporary school was erected in 2010.

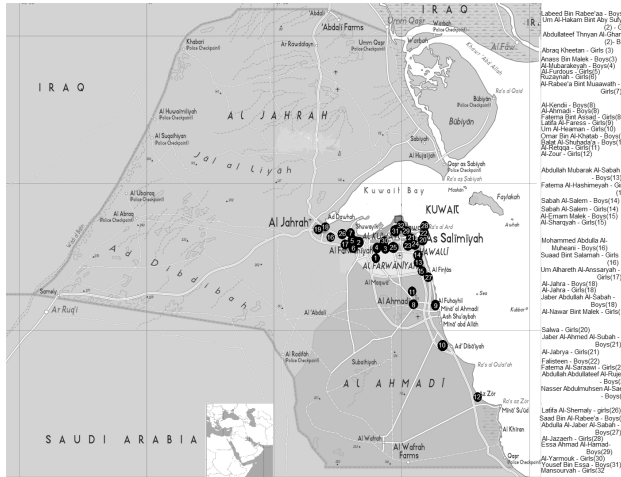


Figure 1. The locations of the 46 schools in Kuwait selected in this study

Before commencing of the testing, each selected school was inspected by the researchers to both familiarize the school administration with the current study and to expedite the research task. Previously, an official memorandum from the Ministry of Education had been conveyed to the administration of all the chosen schools for the study with a request of cooperation with the research team.

2.2 Indoor Environment Testing

A number of indoor environmental parameters for public schools were tested over a 7-month period from October 2017 to May 2018. The test measured five parameters, namely ambient air temperature (T), relative humidity (RH), illumination (ILL), noise (N), and available space per pupil (Sp). The daily testing for a chosen school took between 3.5 to 4 hours during regular school hours (7:30 AM to 1:45 PM). The data collection was done using three different devices or instruments and a measuring tape. All the devices utilized in the testing have previously been used in several published studies [79-82].

One device utilized in the research was the EVM-7 (S/N EML040010), produced by the Quest Technologies, as an environmental monitor that was factory calibrated. The EVM-7, which includes an automatic sensor recognition, is a compact device that is able to concurrently monitor temperature and relative humidity, as well as other parameters not within the scope of this research.

Simultaneously, the SoundPro SE/DL Series Sound Level Meter SP-DL-2-1/3, manufactured by M3, was used

for sound level monitoring and comprehensive data analysis. The meter provides Class/Type 2 unit with 1/1 and 1/3 Octave RTA with real-time frequency analysis displayed and data storing capabilities. The SoundPro SE/DL Series features user-friendly calibration.

For the illumination measurements, the Advanced Light Meter (Model 840022C), manufactured by Sper Scientific Ltd., was used every day during the experimental period. This device provides multi-detection ranges (40/400/4000/40000 and 400000 Lux) with a resolution of 0.01 to 100 Lux. The meter was calibrated in accordance with the National Institute of Standards and Technology (N.I.S.T.). The device's sensor uses an exclusive photodiode while the color and cosine corrected sensor meets the C.I.E. photopic spectrum. It offers measuring a variety of lighting such as tungsten, fluorescent, mercury, and sodium lights. The data measurements are registered within the device's LED screen.

Measuring space allocated to pupils was a direct process; the classroom area was calculated by measuring length and width using a measuring tape. This calculated area was divided by the total number of pupils in the classroom resulting in student density.

Data gathering in the occupied classrooms usually commenced at 8:30 A.M. Five classrooms were chosen in each selected school. The chosen classrooms were located on both school floor levels.

The data gathering process was performed in two phases. In the first phase, sound level and light meter devices were deployed and disseminated over the classrooms space (e.g., front right and left, rear right and left, and center of the classroom). The devices were fixed on a tripod at a height between 1.00 to 1.20 meter and 30 cm away from the pupils' facial position. This positioning of the device was to make certain that the relevant parameters being examined were in close proximity to the pupils, and in particular, the face. The testing was performed during the course of a teaching session which lasted 45 minutes. The devices logged the results at intervals according to their manufactured technology.

In the second phase, while the devices were still in operation, the researcher concisely clarified the research aims and framework of the questionnaire to the students. The researcher then asked interested pupils to answer the questionnaire. Usually, 10 to 12 students in each classroom agreed to participate. Consequently, the students' commitment was established to ascertain their reflection of the classroom environment. The participating students answered 23 questions which covered the parameters being studied. In other words, the researcher, through implementing the questionnaire, was trying to cross-check

the devices' readings with the current feeling of the pupils or of any physical complaint when readings exceeded the recommended limits. During the questionnaire partaking, the classroom area was measured and the total number of students occupying the classroom was noted.

This data gathering operation was repeated in the other selected classrooms. After the daily operation ended, data collected from the devices and instruments were recorded, evaluated, and compared to the allowable threshold levels. The questionnaire data was input into a statistical package, SPSS, for subsequent analyses.

3. Results and Discussion

3.1 Space Density

After counting the number of pupils and measuring the areas of the selected 230 classrooms, it was found that the number of pupils occupying each classroom varied from 9 to 33. The average number of pupils in each classroom equaled 23, with a standard deviation of 4.18, and standard of error of 0.276, with the lone exception being the Al-Zoor Girls School. By dividing the classroom areas by the total number of pupils occupying those classrooms, an area allocated for every pupil was generated, which amounted to a range of 28 to 85.5 m². The calculated average area per student amounted to 50.65 m², with a standard deviation of 8.71 and a standard error of 0.57. The results confirm that all the schools provided adequate spatial density for students and complied with the recommended standard given by Spreiregen and De Paz^[36]. Table 1 illustrates the minimum, maximum, and average values for the available area per pupil in the 230 classrooms located in the 46 schools under study.

Table 1. Allocated area per pupil data for all schools

No. of schools	Allocation of area per pupil (m ²)				
	Min.	Max.	Average	S.D.	S.E.
46	1.38	5.75	2.50	0.227	0.0335

3.2 Noise

The acoustical noise was measured for 230 classrooms in the selected 46 schools using the SoundPro device, which recorded the noise continuously over the testing period. Five random readings were taken for every classroom in locations described previously. Consequently, one average reading was calculated for those measurements. This calculated average was then compared to the permissible OSHA acoustics standard, which states that maximum noise levels should not exceed 105 dBA^[63]. Table 2 illustrates the results of the noise readings in the 230 class-

rooms, which indicates all readings were below the permissible limit, and hence, conforms with the OSHA noise standard.

Table 2. Noise measurements showing conformance of with the OSHA standard

No. of measurements	Noise measurement (db)				
	Minimum reading	Maximum reading	Average	Standard deviation	Standard error
230	60	89.5	74.9	4.302	0.284

3.3 Illumination

In an endeavor to test the adequacy of illumination in the schools being studied, the Advanced Light Meter was used to record data in 230 classrooms. A one-side T-test was implemented for the illumination data to ascertain whether the readings were within the recommended minimum (300 lux) and maximum (1000 lux) levels according to the previously cited references^[21,24,25,26]. The results showed that classrooms in four schools (about 9% of the total schools under study) were found to be suffering from low illumination levels. The results from those four schools are shown in Table 3 with a significant correlation at the 0.05 level. It was noted by the researchers during the testing that these schools with low illumination suffered from poor maintenance, such as broken and missing light fixtures in some classrooms.

Table 3. Data for schools with low illumination levels ($H_0: \mu = 300$ versus $H_1: \mu < 300$) with significant correlation at 0.05 level

Variables	N	Mean	StDev	SE Mean	95% upper bound	T	P
Al-Mansouriyah - Girls	5	192.4	60.111	26.883	249.71	-4.00	0.008
Al-Mubarakayah -Boys	5	222.5	70.964	31.736	290.16	-2.44	0.036
Al-Jazae'r - Girls	5	192.4	60.111	26.883	249.71	-4.00	0.008
Al-Emam Malek - Boys	5	222.5	70.964	31.736	290.16	-2.44	0.036

The SPSS software was used to analyze the illumination data corresponding with the hypotheses (H_0 and H_1) of whether or not the measurement exceeded the recommended illumination level. In other words, H_0 denoted the data is within the recommended level whereas H_1 indicated the data exceeded the level. The data analysis revealed that there was only one school which exceeded the higher recommended value for illumination. Table 4 depicts that Al-Ahmadi Boys School was the lone school which exceeded the recommended higher limit with a significant

correlation at the 0.05 level. The researchers noted that the possible reason for the elevated illumination at this school might be due to the windows having no curtains or blinds and being located in direct sunlight.

Table 4. Data for schools with elevated illumination levels ($H_0: \mu=1000$ versus $H_1: \mu > 1000$) with significant correlation at 0.05 level

Variable	N	Mean	StDev	SE Mean	95% lower bound	T	P
Al-Ahmadi - Boys	5	1072.80	115.670	51.730	962.520	3.34	0.014

3.4 Indoor Temperature

Kuwait's climate is typically hot and arid and is characterized by its long summers where temperatures can reach more than 50°C^[82]. Air conditioning systems in buildings are normally in constant use from the beginning of April until the end of October. Winters are mild and short, lasting only two months with average daily temperatures of about 14°C. The relatively mild temperatures do not impose a great demand on the use of heaters.

Air temperature data was measured in the 230 classrooms in the schools being investigated. The data was analyzed using the statistical software, SPSS, in accordance with the recommended temperatures range by ASHRAE^[37]. In other words, below 19°C and above 23°C were selected as the norm limits. The software analysis established a null hypothesis (H_0) which indicated that the reading does not satisfy the recommended ASHRAE standard, while the hypotheses (H_1) indicated that the registered temperature data at the school meet the recommended standard. The hypotheses were repeated for both limits (below 19°C and above 23°C) alternatively. Descriptive statistics for the schools' temperature data are summarized in Table 5, which includes the school names, number of classrooms per school, temperature means, standard deviation, and standard error.

Table 5. School temperature data with their descriptive statistical analysis

Variables	N	Mean	StDev	SE Mean
Al-Ahmadi - Boys	5	26.44	0.7162	0.3203
Balat Al-Shuhada'a - Boys	5	25.46	0.6269	0.2804
Fatema Bent Asad - Girls	5	25.24	0.4930	0.2205
Al-Zoor - Girls	5	24.02	0.2950	0.1319
Anas Ibn Malek - Boys	5	24.94	0.5983	0.2676
Al-Retqqa - Girls	5	24.84	0.6656	0.2977
Um Al-Haiman - Girls	5	24.00	0.3606	0.1612
Um Al-Hareth Al-Anssaryah - Girls	5	28.76	2.4583	1.0994

Sabah Al-Salem - Boys	5	24.98	0.9910	0.4432
Omar Ben Al-Khatib - Boys	5	23.96	0.5941	0.2657
Al-Emam Malek - Boys	5	24.74	1.2700	0.5680
Jaber Abdullah Al-Sabah - Boys	5	24.70	1.2510	0.5595
Labeed Ibn Rabea'a - Boys	5	23.96	0.9072	0.4057
Al-Jahra - Girls	5	24.18	1.2194	0.5453
Fatema Al-Hashemyah - Girls	5	23.40	0.4583	0.2049
Abdullah Mubarak Al-Sabah - Boys	5	23.62	0.7950	0.3555
Mohammed Al-Mehaini - Boys	5	23.84	1.5010	0.6713
Al-Kindy - Boys	5	23.38	0.7259	0.3247
Al-Jahra - Boys	5	24.06	5.2305	2.3391
Suaad Bent Salamah - Girls	5	23.02	0.6535	0.2922
Sabah Al-Salem - Girls	5	22.88	0.3962	0.1772
Fatema Al-Sara'awy - Girls	5	22.68	0.5891	0.2634
Al-Shargeyah - Girls	5	22.66	0.4393	0.1965
Lateefa Al-Fares - Girls	5	21.72	1.3554	0.6061
Al-Furdous - Girls	5	22.26	0.7570	0.3385
Nasser Abdulmuhsen Al-Saeed - Boys	5	22.54	0.3847	0.1720
Falasteen - Boys	5	21.90	0.9000	0.4025
Abdulateef Thnyan Al-Ghanim - Boys	5	22.18	0.6058	0.2709
Al-Mansouryah - Girls	5	21.56	0.9397	0.4202
Al-Mubarakeyah - Boys	5	21.06	1.0286	0.4600
Al-Rabee'a bent Mua'awath - Girls	5	21.32	0.8614	0.3852
Al-Nawar Bent Malek - Girls	5	22.02	0.4147	0.1855
Ruzainah - Girls	5	22.64	0.1517	0.0678
Abdullah Abdulateef Al-Rejaib - Boys	5	20.72	0.6611	0.2956
Abdullah Al-Jaber Al-Sabah - Boys	5	20.42	0.8643	0.3865
Jaber Al-Ahmad Al-Sabah - Boys	5	20.72	0.6611	0.2956
Yousef Ben Essa - Boys	5	21.84	0.3362	0.1503
Abraq Khaitan - Girls	5	21.06	0.4506	0.2015
Al-Jaberiah - Girls	5	21.10	0.4000	0.1789
Al-Jazae'r - Girls	5	18.62	0.2387	0.1068
Al-Yarmouk - Girls	5	20.92	0.3962	0.1772
Essa Ahmed Al-Hama - Boys	5	20.74	0.4980	0.2227
Lateefa Al-Shemali - Girls	5	20.26	0.4393	0.1965
Saad Ben Rabea'a - Boys	5	20.68	0.5357	0.2396
Salwa - Girls	5	21.76	0.2702	0.1208
Um Al-Hakam Bent Abi Sufyan - Girls	5	19.28	0.4207	0.1881

In order to verify whether or not the classroom temperatures readings have complied with the ASHRAE standard, a one-side T-test was applied. The results revealed that classrooms in fifteen schools failed in terms of the minimum and maximum temperature limits. In more detail, Table 6 shows only one school, Al-Jazaer Girls, registered a marginally lower temperature reading in com-

parison with the recommended requirement, with an average temperature of 18.62°C and with a standard deviation of 0.2387. It is worth noting that Al-Jazaer Girls School was visited on the 27th of December when the registered temperature seemed to match the average seasonal weather temperature in Kuwait. On the other hand, fourteen schools which represent 30% of the total schools, registered temperatures exceeding the maximum recommended limit of 23°C as illustrated in Table 7.

Table 6. Lone school with marginally low temperature with a significant correlation at 0.05 level

Variable	N	Mean	StDev	SE Mean	95% upper bound	T	P
Al-Jazae'r - Girls	5	18.6200	0.2387	0.1068	18.8476	-3.56	0.012

Table 7. Temperature in schools with temperatures exceeding ASHRAE recommended limits with significant correlation at 0.05 level

Variables	N	Mean	StDev	SE Mean	95% lower bound	T	P
Al-Ahmadi - Boys	5	26.44	0.7162	0.3203	25.7571	10.74	0.000
Balat Al-Shuhada'a - Boys	5	25.46	0.6269	0.2804	24.8623	8.77	0.000
Fatema Bent Asad - Girls	5	25.24	0.4930	0.2205	24.7700	10.16	0.000
Al-Zoor - Girls	5	24.02	0.2950	0.1319	23.7388	7.73	0.001
Anas Iben Malek - Boys	5	24.94	0.5983	0.2676	24.3696	7.25	0.001
Al-Retqqa - Girls	5	24.84	0.6656	0.2977	24.2054	6.18	0.002
Um Al-Heaman - Girls	5	24.00	0.3606	0.1612	23.6563	6.20	0.002
Um Al-Hareth Al-Anssaryah - Girls	5	28.76	2.4583	1.0994	26.4163	5.24	0.003
Sabah Al-Salem - Boys	5	24.98	0.9910	0.4432	24.0352	4.47	0.006
Omar Ben Al-Khatib - Boys	5	23.96	0.5941	0.2657	23.3936	3.61	0.011
Al-Emam Malek - Boys	5	24.74	1.2700	0.5680	23.5292	3.06	0.019
Jaber Abdullah Al-Sabah - Boys	5	24.70	1.2510	0.5595	23.5073	3.04	0.019
Labeed Iben Rabeea'a - Boys	5	23.96	0.9072	0.4057	23.0951	2.37	0.039
Al-Jahra - Girls	5	24.18	1.2194	0.5453	23.0174	2.16	0.048

It should be noted that the higher temperature occurrences were observed during the end of March and April consecutively, where outside temperatures start to rise significantly in Kuwait. Thus, although air conditioning was in use at the schools, they were not satisfactorily efficient. In a number of those schools, particularly Um Al-Hareth Al-Anssaryah Girls School, the researchers observed

irregular sounds when operating the AC unit, some damaged AC parts, inadequate airflow, and the temperature set by the remote control did not match the air temperature emitted by the AC unit. Therefore, although the classrooms had adequate unit sizes and number of units, they seemed to lack proper maintenance.

Since the results showed that 30% of the tested schools suffered from elevated indoor air temperatures, it was deemed worthy to ascertain if this statistic could be valid for all the schools in Kuwait. Consequently, a further ANOVA test was employed to compare the schools' data results and determine whether they were similar or had a significant difference. Table 8 illustrates the ANOVA test results, which compared the temperature variable at the different schools at a significance level of 0.05. In respect to temperature, the data results revealed that there were significant differences among the classrooms in the schools under study.

Table 8. ANOVA test for school temperatures with significant correlation at 0.05 level.

Temperature	Sum of Squares	df	Mean Square	F	Sig.
Between groups	875.942	45	19.465	15.698	0.000
Within groups	228.156	184	1.240		
Total	1104.098	229			

3.5 Humidity

Relative humidity testing was carried out in 230 classrooms in the 46 schools. Table 9 summarizes the schools' indoor humidity data in a descriptive statistic. Again, using the statistical software, SPSS, the humidity data was analyzed in accordance with the relative humidity range suggested by ASHRAE^[37]. Specifically, below 30% and above 60% humidity were designated as the standard limits. The software analysis instituted a null hypothesis (H0) which indicated that the reading does not conform with the recommended ASHRAE standard, while the hypotheses (H1) specified that the registered temperature data at the school meet the recommended standard. The hypotheses were repeated for both limits (below 30% and above 60%), alternatively.

Table 9. Schools' indoor humidity statistics for all schools

Variables	N	Mean	StDev	SE Mean
Al-Jazae'r - Girls	5	66.2600	0.6804	0.3043
Al-Mansouryah - Girls	5	66.2600	1.2857	0.5750
Al-Furdous - Girls	5	64.1000	1.6416	0.7342
Um Al-Hareth Al-Anssaryah - Girls	5	66.9000	5.6859	2.5428

Yousef Ben Essa - Boys	5	63.9400	3.3050	1.4780
Sabah Al-Salem - Boys	5	59.0000	1.0198	0.4561
Omar Ben Al-Khatib - Boys	5	54.8400	3.7407	1.6729
Al-Shargeyah - Girls	5	56.6400	2.0057	0.8970
Al-Yarmouk - Girls	5	58.2400	1.0502	0.4697
Abdullah Al-Jaber Al-Sabah - Boys	5	51.7400	2.6463	1.1835
Al-Jahra - Girls	5	54.2400	1.7170	0.7679
Al-Nawar Bent Malek - Girls	5	58.8400	0.3782	0.1691
Al-Zoor - Girls	5	50.5333	3.5161	1.4354
Essa Ahmed Al-Hamad - Boys	5	51.1000	2.9942	1.3390
Nasser Abdulmuhsen Al-Saeed - Boys	5	49.3400	2.8219	1.2620
Ruzainah - Girls	5	56.5400	0.9154	0.4094
Abdulateef Thnyan Al-Ghanim - Boys	5	52.1600	0.7092	0.3172
Abdullah Abdulateef Al-Rejeeb - Boys	5	43.6400	1.4775	0.6608
Abdullah Mubarak Al-Sabah - Boys	5	33.0600	2.8413	1.2707
Abraq Kheetan - Girls	5	43.2800	0.9257	0.4140
Al-Ahmadi - Boys	5	28.3600	1.1459	0.5124
Al-Emam Malek - Boys	5	36.0400	2.7107	1.2123
Al-Jabryah - Girls	5	47.7400	0.7232	0.3234
Al-Jahra - Boys	5	27.3800	3.2244	1.4420
Al-Kendy - Boys	5	33.4600	4.9873	2.2304
Al-Mubarakayah - Boys	5	48.7000	2.0125	0.9000
Al-Rabee'a bent Mua'aawath - Girls	5	45.0600	0.7765	0.3473
Al-Retqqa - Girls	5	25.0000	0.7314	0.3271
Anas Iben Malek - Boys	5	55.1200	0.7530	0.3367
Balat Al-Shuhada'a - Boys	5	45.2400	1.9152	0.8565
Falasteen - Boys	5	52.7000	1.8207	0.8142
Fatema Al-Hashemyah - Girls	5	32.6000	3.2504	1.4536
Fatema Al-Sara'awy - Girls	5	48.5200	1.3971	0.6248
Fatema Bent Asad - Girls	5	26.1400	1.4153	0.6329
Jaber Abdullah Al-Sabah - Boys	5	42.3400	1.5947	0.7132
Jaber Al-Ahmad Al-Sabah - Boys	5	43.6400	1.4775	0.6608
Labeed Iben Rabee'a - Boys	5	52.7667	0.8981	0.3667
Lateefa Al-Fares - Girls	5	27.2400	2.0562	0.9196
Lateefa Al-Shemali - Girls	5	50.7800	0.8927	0.3992
Mohammed AL-Meheani - Boys	5	21.2600	2.2579	1.0098
Saad Ben Rabee'a - Boys	5	48.2200	1.0964	0.4903
Sabah Al-Salem - Girls	5	49.5800	1.6438	0.7351
Salwa - Girls	5	45.7800	0.4494	0.2010
Suaad Bent Salamh - Girls	5	31.7200	2.7179	1.2155
Um Al-Hakam Bent Aby Sufyan - Girls	5	44.9000	1.6355	0.7314
Um Al-Heaman - Girls	5	42.1400	1.8407	0.8232

In an endeavor to ascertain the level of indoor humidity at the schools within the recommended range of the ASHRAE standard, a one-side T-test was applied. In gen-

eral, ten schools, or 21% of the total schools, had either higher or lower humidity than the recommended ASHRAE standard. The results showed that there were five schools that exceeded the higher limit, although marginally, while five other schools were below the recommended level. Tables 10 and 11 depict the results, consecutively.

Table 10. Schools with low humidity level with significant correlation at 0.05 level

	Variables	N	Mean	StDev	SE Mean	95% upper bound	T	P
1	Al-Retqqa-Girls	5	25.0000	0.7314	0.3271	25.6973	-15.29	0.000
2	Mohammed AL-Meheani-Boys	5	21.2600	2.2579	1.0098	23.4126	-8.66	0.000
3	Fatema Bent Asad-Girls	5	26.1400	1.4153	0.6329	27.4893	-6.10	0.002
4	Al-Ahmadi-Boys	5	28.3600	1.1459	0.5124	29.4525	-3.20	0.016
5	Lateefa Al-Fares-Girls	5	27.2400	2.0562	0.9196	29.2004	-3.00	0.020

Table 11. Schools with elevated humidity levels with significant correlation at 0.05 level

	Variables	N	Mean	StDev	SE Mean	95% lower bound	T	P
1	Al-Jazae'r-Girls	5	66.2600	0.6804	0.3043	65.6113	20.57	0.000
2	Al-Mansouriyah-Girls	5	66.2600	1.2857	0.5750	65.0342	10.89	0.000
3	Al-Furdous-Girls	5	64.1000	1.6416	0.7342	62.5349	5.58	0.003
4	Um Al-Hareth Al-Ansaryah-Girls	5	66.9000	5.6859	2.5428	61.4791	2.71	0.027
5	Yousef Ben Essa-Boys	5	63.9400	3.3050	1.4780	60.7890	2.67	0.028

Given that 21% of the tested schools suffered from unsatisfactory humidity levels, a further ANOVA test was applied to establish if this statistic was similar or had a significant difference with the other schools in Kuwait. Table 12 illustrates the ANOVA Test results, which compared the humidity variable at the different schools at a significance level of 0.05. In respect to indoor humidity level, the results disclosed significant differences among the schools in regard to humidity.

Table 12. ANOVA test for school humidity levels with significant correlation at 0.05 level

Humidity	Sum of Squares	df	Mean Square	F	Sig.
Between groups	32065.133	45	712.559	145.896	0.000
Within groups	898.656	184	4.884		
Total	32963.789	229			

3.6 Ambient Environment Comfort Questionnaire

In an attempt to verify any correlation between health symptoms the students were experiencing and with the measured data, a questionnaire was disseminated among the pupils in all the schools. An average of eleven students in each classroom agreed to participate. Only interested students were chosen to partake in the questionnaire in order to make sure of the pupils' commitment and to increase the actual reflection of the classroom environment.

The questionnaire contained 23 questions comprising a wide range of concerns relevant to ambient environment comfort with a focus on temperature, humidity, noise, and illumination, which were the parameters of interest in the current research. Subsequently, each question was verified with the parameter(s) that might be instigating any aggravation. Table 13 shows the relationship between the questionnaire questions and the pertinent parameters. The correlations were examined and revised by the Department of Occupational Health at the Ministry of Health in the State of Kuwait.

Table 13. Questionnaire answers with cross checking of parameters with health symptoms

Sr.	Question	Temperature	Relative Humidity	Noise	illumination
1	I feel uncomfortably hot in the classroom	S	S		
2	I perspire during my stay in the classroom	S	S		
3	My mouth and/or throat feels dry during class	S	S		
4	I feel that the classroom temperature is uncomfortable.	S	S		
5	I have trouble concentrating during lessons in the classroom.	A	A	S	S
6	I feel joint pain during lessons in the classroom.		S		
7	feel some dizziness in the classroom	A			
8	I get headaches in the classroom.	S			D
9	feel skin dryness in the classroom.		S		
10	I feel exhausted in the classroom.	S		D	D
11	I have trouble thinking during lessons in the classroom.	A	A	S	
12	I feel irregular heartbeats while in the classroom.	S		S	
13	I sometimes feel sudden cramping in my fingers or toes while in the classroom.		A		
14	I suffer from nasal congestion while in the classroom.	A	A		
15	I have difficulty breathing in the classroom.		S		
16	I feel chest tightness while in the classroom.		S		

17	I hear noise during the lecture			S	
18	I hear my teacher during the lecturing with difficulty			S	
19	I feel ear tinnitus during lecturing			S	
20	I feel irritation in the eye in the classroom.				
21	I feel exhausting when I look around in the classroom.	S		S	S
22	I feel cold in the classroom.	S	S		
23	I feel sleepy in the classroom.				A

Notes:

S: Chosen by the researcher based on information from theoretical framework and literature review

A: Was added to the table on recommendation of the Department of Occupational Health - Kuwait Ministry of Health

D: Was deleted from the table on recommendation of the Department of Occupational Health - Kuwait Ministry of Health

3.7 Pilot Test Analysis

In order to check the reliability of the questionnaire, which was given to students of both genders and as explained in the operation methodology, a Cronbach's Alpha test was performed. The outcome of this test indicated that the questionnaire's reliability was 0.847, which shows that the questions were neither vague nor missing data.

3.8 Statistical Validation

A Rotated Component Matrix was employed to decrease the breadth of the questionnaire to a rational number of independent, uncorrelated factors. Consequently, the questionnaire questions were condensed and grouped into seven main factors. The extraction method utilized was a Principal Component Analysis. The rotation method applied was a Varimax with a Kaiser Normalization and the rotation converged in nine iterations. Table 14 shows the classifications of the seven factors with the pertinent correlations. For clarification, the correlation between question #2 and Factor V is approximately 71%. Specifically, question #2 is accountable for 71% of the discrepancies in the pupils' answers in regard to Factor V. In another example, question #18 is correlated to Factor IV with a discrepancy of about 65%. Since each Factor comprised of several related questions, the authors devised a table representing the seven factors and proposed titles for the newly composed factors as shown in Table 15.

Table 14. Rotated Component Matrix classifications of the seven factors with the relevant correlations

	Factors						
Questions	1	2	3	4	5	6	7
Q1					0.788		

Q2					0.710		
Q3							0.520
Q4					0.576		
Q5	0.534						
Q6	0.553						
Q7	0.682						
Q8	0.622						
Q9							0.539
Q10	0.623						
Q11							
Q12							
Q13						0.649	
Q14		0.617					
Q15		0.696					
Q16		0.538					
Q17				0.686			
Q18				0.651			
Q19							
Q20			0.675				
Q21							
Q22					0.701		
Q23	0.574						

Table 15. Newly proposed composed factors

Factors	Questionnaire question #	Suggested title
Factor I	5, 6, 7, 8, 10 and 23	Pain, Tiredness & Faint
Factor II	14, 15 and 16	Allergy
Factor III	20	Eye Itching
Factor IV	17 and 18	Noise
Factor V	1, 2, 4 and 22	Heat
Factor VI	13	Sudden Cramping
Factor VII	3 and 9	Draught

An ANOVA Test was then employed to ascertain if the schools had any effect on each of these seven factors. The outcome, as shown in Table 16, reveals that the schools under study had significant differences to all factors.

Table 16. The schools under study showed significant differences to all factors

		Sum of Squares	df	Mean Square	F	Sig.
Factor I	Between Groups	139.590	45	3.102	3.340	0.000
	Within Groups	1232.410	1327	0.929		
	Total	1372.000	1372			
Factor II	Between Groups	71.102	45	1.580	1.612	0.007
	Within Groups	1300.898	1327	0.980		
	Total	1372.000	1372			

Factor III	Between Groups	65.049	45	1.446	1.468	0.025
	Within Groups	1306.951	1327	0.985		
	Total	1372.000	1372			
Factor IV	Between Groups	157.286	45	3.495	3.818	0.000
	Within Groups	1214.714	1327	0.915		
	Total	1372.000	1372			
Factor V	Between Groups	163.545	45	3.634	3.991	0.000
	Within Groups	1208.455	1327	0.911		
	Total	1372.000	1372			
Factor VI	Between Groups	70.855	45	1.575	1.606	0.007
	Within Groups	1301.145	1327	0.981		
	Total	1372.000	1372			
Factor VII	Between Groups	88.192	45	1.960	2.026	0.000
	Within Groups	1283.808	1327	0.967		
	Total	1372.000	1372			

Lastly, a correlation matrix was executed to discover the correlation between the newly composed factors and the significant parameter variables, such as noise, illumination, temperature, and humidity. The results in Table 17 reveals that noise measured in Factor IV (Noise) with significant correlation of 0.035 at a 95% significance level. Furthermore, the analysis revealed that illumination measured in Factor III (Eye Itching) and indicated a significant correlation of 0.004 at a 95% significance level. Temperature was shown to measure in both Factor III (Eye Itching) and Factor V (Heat) with a significant correlation of 0.001 and 0.01 at a 95% significance level, respectively. Humidity was represented in both Factor VI (Sudden Cramping) and Factor VII (Draught) with significant correlation of 0.012 at a 95% significance level and 0.005 at a 95% significance level, respectively.

Table 17. Correlation Matrix showing the correlation between the newly composed factors and the parameter variables

Parameters	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII
Noise	-0.029	0.050	-0.003	0.057	-0.039	0.021	-0.009
	0.283	0.062	0.915	0.035**	0.148	0.432	0.735
Illumination	-0.021	-0.003	0.078	-0.032	0.072	-0.030	-0.038
	0.441	0.904	0.004**	0.231	0.007	0.267	0.161
Temp	-0.004	-0.007	0.091	-0.047	0.070	-0.039	-0.019
	0.897	0.800	0.001**	0.079	0.010**	0.151	0.477
Humidity	0.037	-0.034	-0.052	0.021	0.040	0.068	-0.076
	0.170	0.202	0.056	0.435	0.137	0.012**	0.005**

Notes: (**) : Significant correlation at 0.05 level

4. Conclusion

4.1 Summary

The current research tested the IEQ in 46 public schools in the State of Kuwait. Testing involved spot-check monitoring of area allocated for each student, noise, illumination, temperature, and humidity. The measured area allocated per student and noise were deemed satisfactory when compared with international standards. However, in a number of classrooms, measured temperature, humidity, and illumination were not considered acceptable.

The data showed that in 30% of the tested schools, the temperature exceeded the upper recommended limits of ASHRAE during the end of March and April. This period of time coincides with outdoor temperatures beginning to rise significantly in Kuwait. It is believed that the inadequacy and inefficiency of the air-cooling systems in the suspect schools was the main culprit.

The data also revealed that about 21% of the schools considered in this study had humidity levels either higher or lower than recommended by ASHRAE. Results of the T-test disclosed that 8% of the schools exceeded the higher limit, while another 8% were below the recommended level.

Less of a concern was the illumination readings. Employing a T-test with a 95% confidence level revealed that 9% of the schools had low illumination. On the other hand, only one school had a value exceeding the recommended level of over 1000 lux. It is believed that improper lighting maintenance (e.g. missing and burnt bulbs) and suspect illumination design were the problems in these few cases.

The evaluation of the obtained data for noise and allocated student space was in the comfort ranges in all the schools when compared with international standards.

Suitable statistical procedures were used to analyze the questionnaire data output. The outcome of the analysis disclosed that the schools under study had significant differences in all comfort and health factors. Furthermore, it was determined from the applied statistical outputs that Illumination and “itchy eyes” indicated a significant correlation of 0.004, giving a 95% significance level. Furthermore, measured noise levels and “loudness discomfort” are correlated with a significant correlation of 0.035, giving a 95% significance level. Moreover, the measured temperature is correlated with both “itchy eyes” and “thermal discomfort” with significant correlation of 0.001 and 0.01, respectively, giving a 95% significance level. Finally, measured humidity levels depicted a correlation

with “sudden cramping” and “draught discomfort” with a significant correlation of 0.012 and 0.005, respectively, for which the significance level was 95%.

4.2 Recommendations

Some environmental parameters researched in this study were unsatisfactory in some schools and could cause discomfort or impact the health of students. This reality offers prospects for improving the IEQ and as guidance for the supervision of future and existing educational buildings. Design for future school classrooms can be enhanced if indoor environment matters can be addressed earlier in the design and planning stage. In existing buildings, improvements should be carried out to ensure that the occupants of the building are comfortable with their working environment and to decrease the prevalence of SBS occurrence among occupants in school buildings. For example, monthly maintenance should be done to make sure that the air conditioners are functioning well. Proper functioning HVAC systems are important in a hot climate like in Kuwait to ensure a comfortable and healthy educational environment.

Policy implications need to be studied in order to understand why the design and build have failed to provide adequate IEQ in certain schools. In schools found to be adequate, it may help education policy makers to formulate and regulate schools to maintain these IEQ standards. Consequently, a healthy and comfortable environment will be sustained in these schools.

Long-term monitoring during school hours was not feasible in this research owing to the disturbance it would have produced in the classes. However, when the inhabitants are a sensitive group such as young aged students, then there is a certain need to measure continuously. The several schools measured to have unsatisfactory IEQ parameters would be candidates for long-term monitoring.

References

- [1] P. Paevere, S. Brown, A. Leaman, M. Luther, R. Adams, Indoor environment quality and occupant productivity in the CH2 building, in: SB08: Proceedings of the 2008 International Scientific Committee World Sustainable Building Conference, 2008, pp. 222-229.
- [2] O. Seppanen, W.J. Fisk, D. Faulkner, Cost benefit analysis of the night-time ventilative cooling in office building, in: Proceedings of the Healthy Buildings 2003 Conference, 2003, pp. 394-399.
- [3] A.P. Jones, Indoor air quality and health, *Atmos. Environ.* 33 (28) (1999) 4535-4564.
- [4] Y.H. Mi, D. Norbäck, J. Tao, Y.L. Mi, M. Ferm, Cur-

- rent asthma and respiratory symptoms among pupils in Shanghai, China: influence of building ventilation, nitrogen dioxide, ozone, and formaldehyde in classrooms, *Indoor Air* 16 (6) (2006) 454-464.
- [5] P. Sarafis, K. Sotiriadou, D. Dallas, P. Stavrakakis, M. Chalaris, Sick-building syndrome, *J. Environ. Prot. Ecol.* 11 (2) (2010) 515-522.
 - [6] D.J. Van der Voordt, H.B. van Wegen, *Architecture in Use*. Routledge, 2007.
 - [7] T. Redman, P. Hamilton, H. Malloch, B. Kleymann, Working here makes me sick! The consequences of sick building syndrome, *Hum. Resour. Manage. J.* 21 (1) (2011) 14-27.
 - [8] D. Mudarri, Public health consequences and cost of climate change impacts on indoor environments. U.S. Environmental Protection Agency, 2010.
 - [9] D.J. Satterlee, J.M. Molavi, M.E. Williams, An evaluation of early education based on physical environmental guidelines, *SAGE Open* 5 (2) (2015) 1-11.
 - [10] K.D. Fisher, Building better outcomes: the impact of school infrastructure on student outcomes and behavior, Department of Education, Training and Youth Affairs, 2000.
 - [11] B.T. Doane, The relationship between school facilities and academic achievement, Master's Thesis, Ohio University, 2008.
 - [12] National Center for Education Statistics. Condition of America's public school facilities: 1999 (NCES 2000-032). U.S. Department of Education, 2000.
 - [13] P.R. Boyce, Why daylight? In: *Proceedings of Daylighting '98*, 1998, pp. 359-366.
 - [14] R. Küller, The influence of light on circarhythms in humans, *J. Physiol. Anthropol. Appl. Hum. Sci.* 21 (2) (2002) 87-91.
 - [15] SteelCase, Seeing the Difference: The Importance of Quality Lighting in the Workplace. SteelCase Inc., 1999.
 - [16] B. Erwine, *Lighting*, in: *Safe and Healthy School Environments*, Oxford University Press, New York, 2006, pp. 20-33.
 - [17] R. Küller, The effects of indoor lighting on well-being and the annual rhythm of hormones, in: *CIE 21st Session*, 1987, pp. 342-345.
 - [18] T. Hwang, J.T. Kim, Effects of indoor lighting on occupants' visual comfort and eye health in a green building, *Indoor Built Environ.* 20 (1) (2011) 75-90.
 - [19] Heschong-Mahone Group, *Skylighting and Retail Sales: An Investigation into the Relationship between Daylighting and Human Performance*, Sacramento, CA: Pacific Gas and Electric Company, 1999.
 - [20] J.J. Saade, A.H. Ramadan, Control of thermal-visual comfort and air quality in indoor environments through a fuzzy inference-based approach, *Int. J. Math. Models Methods Appl. Sci.* 2 (2008) 213-221.
 - [21] X. Yu, Y. Su, Daylight availability assessment and its potential energy saving estimation—A literature review, *Renewable Sustainable Energy Rev.* 52 (2015) 494-503.
 - [22] L. Huang, Y. Zhu, Q. Ouyang, B. Cao, A study on the effects of thermal, luminous, and acoustic environments on indoor environmental comfort in offices, *Build. Environ.* 49 (2012) 304-309.
 - [23] H. Juslén, Lighting and Productivity in The Industrial Working Place, in: *Lighting Engineering*, 2006, pp. 53-62.
 - [24] M. Winterbottom, A. Wilkins, Lighting and discomfort in the classroom, *J. Environ. Psychol.* 29 (1) (2009) 63-75.
 - [25] A. Nabil, J. Mardaljevic, Useful daylight illuminances: A replacement for daylight factors, *Energy Build.* 38 (7) (2006) 905-913.
 - [26] J. Wienold, *Daylight glare in offices*. Fraunhofer-Verlag, 2010.
 - [27] F.W. Banghart, A. Trull, Jr., *Educational Planning*, New York: The Macmillan Company, 1973.
 - [28] D.F. Cotts, M. Lee, *The Facility Maintenance Handbook*. Washington, DC: American Management Association, 1992.
 - [29] D.G. Carnevale, Physical settings of work: A theory of the effects of environmental form, *Pub. Prod. Manage. Rev.* July 1 (1992) 423-436.
 - [30] J. Wakefield, Learning the hard way: the poor environment of America's schools, *Environ. Health Perspect.* 110 (6) (2002) A298.
 - [31] Y.M. Epstein, Crowding stress and human behavior, *J. Social Issues*, 37 (1) (1981) 126-144.
 - [32] D.C.C.K. Kowaltowski, M.S. Deliberador, P.R.P. Perreira, Designing the positive public school environment: a Brazilian perspective, in: *Noise and ergonomics in the workplace*, Nova Publishers, NY, USA, 2013, pp. 1-33.
 - [33] G.W. Evans, *Learning and the Physical Environment*, In: *Public Institutions for Personal Learning: Establishing a Research Agenda*, American Association of Museums, Washington, DC, 1994, pp. 119-26.
 - [34] J.F. Wohlwill, W. Van Vliet, *Habitats for Children: the Impact of Density*, Psychology Press, 2013.
 - [35] ICC, International Building Code. International Code Council Inc., Country Club Hills, IL., USA, 2014.
 - [36] P.D. Spreiregen, B. De Paz, *Pre-design*, Kaplan AEC Architecture, 2005.
 - [37] ASHRAE, Thermal Environmental Conditions for Human Occupancy, ASHRAE Standard 55, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 2010.

- tioning Engineers, Atlanta, Georgia, 2013.
- [38] D.J. Clements-Croome, Indoor environment and productivity, in: *Creating the productive workplace*, Taylor & Francis, 2006, pp. 53-82.
- [39] M.J. Mendell, A.G. Mirer, Indoor thermal factors and symptoms in office workers: findings from the US EPA BASE study, *Indoor Air*, 19 (4) (2009) 365-368.
- [40] K. Heidorn, "A simple guide to personal thermal comfort", (1997) [online]. Available: <http://www.islandnet.com/~see/living/winter/personalcomfort.htm>, Accessed date 24 March 2017.
- [41] Canadian Centre for Occupational Health and Safety, "Thermal comfort for office work", (2011) [online]. Available: http://www.ccohs.ca/oshanswers/phys_agents/thermal_comfort.html, Accessed date 7 April 2017.
- [42] D.K. Milton, P.M. Glencross, M.D. Walters, Risk of sick leave associated with outdoor air supply rate, humidification, and occupant complaints, *Indoor air* 10 (4) (2000) 212-221.
- [43] Z.S. Zomorodian, M. Tahsildoost, M. Hafezi, Thermal comfort in educational buildings: A review article, *Renewable Sustainable Energy Rev.* 59 (2016) 895-906.
- [44] R. Schulte, B. Bridges, D. Grimsrud, Continuous IAQ monitoring, *ASHRAE J.* 47 (5) (2005) 38.
- [45] R. Walden, School Environments, in: *Encyclopedia of Applied Psychology*, Elsevier, New York, 2004, pp. 327-338.
- [46] C.S. Cash, Building condition and student achievement and behavior, PhD Thesis, Virginia Tech, 1993.
- [47] C.S. Weinstein, The physical environment of the school: A review of the research, *Rev. Educ. Res.* 49 (4) (1979) 577-610.
- [48] S.P. Corgnati, M. Filippi, S. Viazzo, Perception of the thermal environment in high school and university classrooms: Subjective preferences and thermal comfort, *Build. Environ.* 42 (2) (2007) 951-959.
- [49] B.W. Roberts, R.W. Robins, Person-Environment fit and its implications for personality development: A longitudinal study, *J. Pers.* 72 (1) (2004) 89-110.
- [50] T.A. Lashari, M. Alias, M.J. Kesot, Z.A. Akasah, The Effect of an Integrated Affective-Cognitive Teaching and Learning Approach on Academic Achievement, Self-Efficacy, Locus of Control and Attitude Towards Engineering, *J. Tech. Educ. Train.* 6 (1) (2014).
- [51] M.C. Lee, K.W. Mui, L.T. Wong, W.Y. Chan, E.W.M. Lee, C.T. Cheung, Student learning performance and indoor environmental quality (IEQ) in air-conditioned university teaching rooms, *Build. Environ.* 49 (1) (2012) 238-244.
- [52] K. Engvall, C. Norrby, D. Norbäck, Sick building syndrome in relation to building dampness in multi-family residential buildings in Stockholm, *Int. Arch. Occup. Environ. Health* 74, (4) (2001) 270-278.
- [53] J.J.K. Jaakkola, Temperature and Humidity, in: *Safe and Healthy School Environments*, Oxford University Press, New York, 2006, pp. 46-57.
- [54] G.W. Evans, R. Stecker, Motivational consequences of environmental stress, *J. Environ. Psychol.* 24 (2) (2004) 143-165.
- [55] O.S. Oyedepo, A.A. Saadu, Evaluation and analysis of noise levels in Ilorin metropolis, Nigeria. *Environ. Monit. Assess.* 160 (1) (2010) 563-577.
- [56] R.A. Dobie, W.W. Clark, Exchange rates for intermittent and fluctuating occupational noise: A systematic review of studies of human permanent threshold shift. *Ear Hear.* 35 (1) (2014) 86-96.
- [57] L.E. Maxwell, Noise, in: *Safe and Healthy School Environments*, University Press, Oxford, 2006, pp. 34-45.
- [58] B.M. Shield, J.E. Dockrell, The effects of environmental noise on child academic attainments. In *Proceedings of the Institute of Acoustics*, 24 (6) (2002).
- [59] A.B.M. Lacerda, C.G.O. Gonçalves, G. Lacerda, D.C.B. Lobato, L. Santos, A.C. Moreira, A. Ribas. Childhood hearing health: educating for prevention of hearing loss, *Int. Arch. Otorhinolaryngol.* 19 (1) (2015): 16-21.
- [60] S.G. Kujawa, M.C. Liberman, Acceleration of age-related hearing loss by early noise exposure: evidence of a misspent youth. *J. Neurosci.* 26 (7) (2006) 2115-2123.
- [61] M.M. Haines, S.A. Stansfeld, R.F.S. Job, B. Berglund, Chronic aircraft noise exposure and child cognitive performance and stress, in: *Proceedings of the 7th International Conference on Noise as a Public Health Problem*, 1998, vol. 1, pp. 329-335.
- [62] P. Lundquist, A. Kjellberg, K. Holmberg, Evaluating effects of the classroom environment: development of an instrument for the measurement of self-reported mood among school children, *J. Environ. Psychol.* 22 (3) (2002) 289-293.
- [63] U.S. Department of Labor, Occupational Safety and Health Administration, "OSHA Technical Manual – Noise", (2013) [Online]. Available: https://www.osha.gov/dts/osta/otm/new_noise/index.pdf, Accessed date: 22 May 2016.
- [64] M. Aliabadi, N. Mahdavi, M. Farhadian, M.S. Motlagh, Evaluation of noise pollution and acoustic comfort in the classrooms of Hamadan University of medical sciences in 2012, *J. Ergon.* 1 (2) (2013) 19-27.

- [65] V. Duran-Narucki, School building condition, school attendance, and academic achievement in New York City public schools: A mediation model, *J. Environ. Psychol.* 28 (3) (2008) 278–286.
- [66] E. Boman, I. Enmarker, Factors affecting pupils' noise annoyance in schools: The building and testing of models, *Environ. Behav.* 36 (2) (2004) 207–228.
- [67] C.C. Crandell, J.J. Smaldino, C. Flexer, *Sound field amplification: Applications to speech perception and classroom acoustics*. Clifton Park, NY: Thomson Delmar Learning, 2005.
- [68] M.A. Crook, F.J. Langdon, The effects of aircraft noise in schools around London airport, *J. Sound Vib.* 34 (2) (1974) 221–232.
- [69] S. Hygge, G.W. Evans, M. Bullinger, The Munich airport noise study: Cognitive effects on children from before to after the changeover of airports. In *International congress on noise control engineering*, pp. 2189–2194, 1996.
- [70] M. Mendell, G. Heath, Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature, *Indoor Air.* 15 (1) (2005) 27–52.
- [71] D.J. Clements-Croome, H.B. Awbi, Z. Bako-Biro, N. Kochhar, M. Williams, Ventilation rates in schools, *Build. Environ.* 43 (2008) 362–367.
- [72] S.P. Corgnati, M. Filippi, S. Viazzi, Perception of the thermal environment in high school and university classrooms: subjective preferences and thermal comfort, *Build. Environ.* 42 (2) (2007) 951–959.
- [73] M.A. Humphreys, A study of the thermal comfort of primary school children in summer, *Build. Environ.* 4 (12) (1977) 231–9.
- [74] P.H. Zannin, C.R. Marcon, Objective and subjective evaluation of the acoustic comfort in classrooms, *Appl. Ergon.* 38 (5) (2007) 675–680.
- [75] K.E. Al-Rashidi, D.L. Loveday, N.K. Al-Mutawa, Investigating the applicability of different thermal comfort models in Kuwait classrooms in hybrid air-conditioning mode, in: *1st International Conference on Sustainability in Energy and Buildings*, Brighton, UK, 2009.
- [76] “Authors” (2015)
- [77] P. Ricciardi, C. Buratti, Thermal comfort in the Franchini theatre (Pavia, Italy): Correlation between data from questionnaires, measurements, and mathematical model, *Energy Build.* 99 (2015) 243–252.
- [78] S.M. Kennedy, M. Hodgson, Subjective assessment of listening environments in university classrooms: perceptions of students, *J. Acoust. Soc. Am.* 119 (1) (2006) 299–309.
- [79] B. Risavi, R. Wadas, C. Thomas, D. Kupas, A novel method for continuous environmental surveillance for carbon monoxide exposure to protect emergency medical service providers and patients, *J. Emerg. Med.* 44 (3) (2013) 637–640.
- [80] E. Chatzidiakou, D. Mumovic, A. Summerfield, H. Altamirano, Indoor air quality in London schools. Part 1: ‘performance in use’, *Intell. Build. Int.* 7 (2e3) (2014) 101–129.
- [81] L. Shou, J. Hayes, W. Cheng, C. Wu, T. Townsend, T. Vinson, et al., Characterization of ammonia gas release from concrete added with ammoniated fly ash, *Air quality, Atmos. Health* 7 (4) (2014) 505–513.
- [82] A. Macedo, O. Magalhaes, A. Brito, O. Mayan, Characterization of indoor ~ environmental quality in primary schools in Maia: a Portuguese case study, Human and ecological risk assessment, *Int. J.* 19 (1) (2013) 126–136.



REVIEW

Discussion on the Intelligent Design of Ultra-Low Energy Consumption Passive Buildings

Xin Tong^{1*} Xiaolin Yang¹ Xiao Ma²

1. Graduate Students Brigade, Logistics University of People's Armed Police Force, Tianjin, 300309, China

2. Logistics support Department of the Armed Police Logistics College, Tianjin, 300309, China

ARTICLE INFO

Article history

Received: 26 March 2019

Revised: 1 April 2019

Accepted: 23 April 2019

Published Online: 30 April 2019

Keywords:

Ultra-low energy consumption

Passive buildings

Intelligent design

ABSTRACT

With the continuous development of science and technology and the gradual improvement of modern building technology, people pay more and more attention to the introduction of advanced technology in architectural design, such as the application of intelligent technology. With the increasingly severe environmental situation, people are increasingly demanding the environmental performance and green performance of buildings. The establishment of ultra-low energy consumption passive buildings has become one of the key construction contents of construction projects. This paper mainly analyzes the design points and architectural forms of related buildings from the perspective of intelligent control.

1. Introduction

With the continuous development of economic construction and the continuous improvement of people's living standards, people's requirements for the built environment are getting higher and higher. The current environmental damage and energy shortages are becoming more and more prominent. The total energy consumption and energy consumption intensity of buildings are significantly improved due to the increasing volume of buildings. The concept of energy conservation and emission reduction is deeply rooted in the hearts of the people. It is important to pay attention to the green design of the building and to promote the transformation of the building towards a green and low carbon type. Establish passive buildings, use advanced scientific

and systematic architectural concepts to improve and transform related buildings, give full play to the advantages of energy-efficient buildings, and provide people with high-quality architectural design.

2. The Overview of Ultra-Low Energy Consumption Passive Buildings and Related Design Points

2.1 The Definition of Ultra-Low Energy Consumption Passive Buildings

The ultra-low energy consumption passive buildings differ from ordinary buildings mainly in that they can adapt to natural conditions and climatic characteristics, and can maintain a structure with better thermal insulation

**Corresponding Author:*

Xin Tong,

Graduate Students Brigade, Logistics University of People's Armed Police Force, No. 1 Huizhi Ring Road, Dongli District, Tianjin, 300309, China;

E-mail: 578036446@qq.com.

performance and airtight performance. The use of high-efficiency fresh air heat recovery technology to minimize the energy consumption of buildings during use and make full use of renewable energy, which can provide residents with a comfortable indoor environment and a new type of building that can meet the energy saving and emission reduction effects. The construction concept of passive building has a wide range of applications in the current construction field. It is the most advanced low-carbon energy-saving building in the world. It has the advantages of scientific principles, advanced concepts, complete research and testing, and mature technology models. Energy-efficient buildings have high cost advantages and technological advantages. Passive buildings maximize the use of renewable energy and the natural environment, greatly improving the air tightness and thermal insulation of buildings, which allows buildings to reduce energy consumption for heating and cooling, and to reduce the energy use of buildings during use, which allows natural resources such as natural ventilation, day lighting and solar radiation to be fully utilized during the operation of the building to minimize the need for energy consumption, to save energy and reduce emissions and protect the environment.^[1]

2.2 The Design Points of Passive Buildings

2.2.1 Set the Air Barrier and Insulation Layer

In the design work of ultra-low energy consumption passive buildings, the first thing to complete is the design of the building's airtightness and insulation layer, the air barrier and the insulation layer of the building can be separated from each other or overlap each other. In the design of the passive building space, the space including the air barrier and the insulation layer is required. The air barrier can be installed inside the insulation layer, but the air barrier cannot pass through the insulation layer. Both designs should be as simple as possible to avoid complex changes. Buildings can be wrapped in the bedroom, dining room, living room, bathroom, study, kitchen, stairwell and other areas to fully play the role of the insulation layer. However, in order to further control and reduce the cost, the air barrier can be installed in some areas with good air permeability, such as stairwells, unit halls and outdoor corridors. These places can also be tested without air tightness to reduce the cost of production and construction.^[2]

In the process of placing the insulation layer and the air barrier, it is also necessary to separately and centrally arrange the relevant equipment space and living space according to the current building layout and related spatial characteristics, so as to better complete the installa-

tion and processing of the equipment, the length of the relevant pipeline is reduced as much as possible. For ultra-low energy consumption passive buildings, it is generally necessary to install integrated ventilation equipment that uses pipes to transfer wind resources to various areas of the building. Ventilation equipment is typically placed between equipment or bathroom ceilings to minimize heat loss during transport. In the spatial layout of the equipment, the centralized equipment space layout should be selected first, and the laying length of the pipeline should be reduced as much as possible to improve the air supply efficiency of the ventilation system and reduce the heat and loss during the air supply.^[3]

2.2.2 Carry out the Design and Calculation Work of the Thermal Bridge

Ultra-low energy consumption passive building design requires the use of a heat-free bridge design. The thermal bridge coefficient needs to be reduced to a sufficient extent within the building envelope, paying attention to the heat dissipation and the amount of infection in different areas. For example, for the position of the reinforced concrete ring beam in the outer wall, the heat transfer amount of these places is much larger than the main part, and the temperature of the main body is also much lower than the temperature of the inner surface. Therefore, in the process of designing the boom node, it is necessary to fully understand and analyze the relevant structure and related equipment of the building, then mark all possible thermal bridges in the building, and use professional software to calculate the parts where heat bridges may exist to determine the relevant thermal bridge coefficients. When the calculation result indicates that the thermal bridge coefficient is high, the relevant designer needs to re-design the thermal bridge construction node and recalculate the relevant thermal bridge coefficient until the standard requirement is reached.^[4]

2.2.3 Carry out the Design Work of the Kitchen Ventilator

The setting of the kitchen ventilator is also a key project for the ultra-low energy consumption passive building. During the setting process of the kitchen ventilator, it is necessary to complete the setting work of the self-contained fume purification device and part of the system. In the case that the kitchen usage rate is relatively low and the soot is relatively small, the fresh air ventilator and the kitchen ventilator unit can be combined to use the fresh air ventilator unit air duct to complete the fume removal work. With the kitchen ventilator's own fume purification

device, for some kitchens with low usage rate, the purification efficiency should be higher than 98%. For the daily cooking situation where the kitchen application is frequent and the soot is relatively large, an independent air supply system needs to be established, and the supplemental air is directly introduced from the outdoor, and the related insulation measures and sealing measures need to be taken into consideration.^[5]

3. The Intelligent Design Work of Ultra-Low Energy Consumption Passive Buildings

3.1 The Integrated Design Work

With the continuous development of science and technology and the arrival of the information age, the application of intelligent technology in various industries has deepened. Applying intelligent technology to the control and management of buildings during the construction and use of buildings can effectively reduce the energy consumption of buildings, achieve good resource and energy distribution, and achieve better energy saving and emission reduction effects. In the design process of ultra-low energy consumption passive buildings, it is necessary to design according to the passive priority and active optimization design principles. The performance-oriented design principles that aim at energy consumption are designed throughout the design. First of all, the overall design work needs to be completed. After fully understanding the passive building-related functions and the local climatic environment, local natural light, natural ventilation, and building heat storage and shading measures can be used to better meet the spatial functional requirements and design aesthetic requirements of the building. Control the construction cost of the building, and at the same time reduce the cost, apply various intelligent means to better control the building system. The application of intelligent technology can provide better energy optimization solutions for the system to more effectively utilize various natural resources such as geothermal energy and solar energy, and reduce the consumption of fossil energy, which ensures that in the design process, every design step can reflect the details of energy saving and emission reduction, and create intelligent buildings.

3.2 Reasonable Space Design and Layout

The rationality of the space design of the building is directly related to the energy consumption of the building during operation. In the design process of ultra-low energy consumption passive buildings, under the premise of satisfying the function of building use, the layout of the

building plane and space should be reasonably carried out, and the intelligent design of the building orientation, window opening form, body shape coefficient, lighting and sunshade area should be reasonably set according to the characteristics of different areas. The shape of the relevant building needs to be regular and compact, avoiding irregular changes and excessive decorative components, and controlling the building shape coefficient to a lower range. To reduce the area of the building's outer protective structure, the flat design of the building should be more conducive to natural ventilation and winter sunshine. The arrangement of the building door and window openings and the organization of the relevant space should be conducive to the passage of the wind, so as to achieve natural ventilation in summer, reduce the need for air conditioning use and the time of air conditioning use, and reduce energy consumption. The orientation of the intelligent building needs to adopt a north-south or near-north-north direction. According to the sunshine situation in China and the corresponding seasonal changes, the room should avoid the dominant wind direction in winter.

According to the lighting conditions and related ventilation conditions, the regional planning is reasonable, and the relevant designers can reasonably arrange the gaps and spacing between the buildings according to the local climate characteristics, so as to avoid the hindrance of the building sunshine in the back row. At the same time, it is also possible to prevent the rear buildings from being attacked by the cold wind in winter, and to set the high-rise buildings to the position facing the winter wind direction, thereby contributing to the reduction of winter heating needs. The area ratio between the relevant building windows and the wall is optimized and calculated through the performance design method. From the perspective of climate change and temperature throughout the year, the area ratio between the window walls is reasonably set to meet the heating function demand of the building. Under normal circumstances, in order to better achieve the insulation effect of the building, the outer window generally adopts three-layer glass, and the outer door and the household door are insulated and sealed. In addition, the design of the pipe arrangement of the building should be carried out, according to the layout of the building and the layout of the space. It is necessary to be able to design an optimal pipeline line to facilitate the installation of equipment, promote cost reduction, reduce resource consumption during installation, and save energy and reduce emissions.

3.3 The Energy Consumption Monitoring of BAS System

The BAS system can effectively manage and control the

whole process and full parameters of the building energy consumption system, and realize the optimization and monitoring of the energy-saving operation system. The system can monitor the temperature changes in various areas of the building in real time, especially for the related lighting energy consumption, socket energy consumption, heating energy consumption, etc., thereby the relevant energy consumption data can be collected in real time and transmitted to the management center. The management center uses intelligent technology to conduct comprehensive analysis and statistical work on relevant energy consumption data, upload it to the energy consumption monitoring center, monitor abnormal energy consumption power in time, find out the cause of the abnormality, and solve it in time. In the real-time monitoring and network management of indoor temperature, pay attention to the selection and application of temperature sensors, finely manage the use of central air conditioners, and control the time and temperature control of central air conditioners. Carry out real-time monitoring of related door and window status, avoiding the use of heating equipment and air-conditioning equipment when opening windows and opening doors, reducing unnecessary loss of energy. The application of intelligent technology in buildings can also be embodied in the intelligent lighting control system. The intelligent lighting control system can monitor the brightness of the room in real time, adjust the brightness of the light according to the law of the human body, and control the opening and closing of the light, which avoids the situation that the light is still on after the person walks, reduces the waste of electric energy, and the intelligent home control system in the ultra-low energy consumption passive building can control the opening and closing work of the curtain in real time. It is also possible to remotely control related electrical equipment, thereby minimizing the consumption and waste of energy resources, and reflecting the effect of energy saving and emission reduction.

3.4 Intelligent Monitoring and Control of Fresh Air System

With the continuous development and intelligence of science and technology, technology has been deepened in furniture applications, and high-efficiency fresh air systems have been widely used in new buildings. The system is capable of building control with intelligent technology to provide a comfortable and comfortable indoor environment for the building. Efficient heat recovery fresh air delivers fresh air to the room, while also providing heating, cooling, dehumidification and humidification. The intelligent control system can control the air outlet

speed and the outlet air temperature of the heat recovery fresh air. The heat recovery of the fresh air equipment filter can reach 90%, providing a comfortable and healthy indoor environment for the occupants. Compared with the traditional air supply system, efficient heat recovery fresh air system can increase heat recovery efficiency by 75%, which greatly reduces the energy consumption of heating and cooling, and effectively improves the indoor health and comfort. The control system is implemented in accordance with relevant national standards and building requirements, and can ensure that the indoor environment can effectively meet the residential needs and health needs of the residents.

3.5 Intelligent Technology Construction Points

Applying the skills technology to the building field has become one of the important goals of the current building development. With the continuous development of China's construction industry and the increasing number of construction companies, relatively speaking, the development of the construction industry has reached a bottleneck, and the competition between construction companies is also increasing. In order to ensure the vitality and vitality of construction enterprises, it is necessary to reform the traditional construction plans and construction methods of construction enterprises, and arm construction techniques with the latest technology, so that construction projects can better meet the needs of current society and people's development. First of all, we must improve the construction and quality control of the ultra-low energy consumption passive building field. We will focus on solving the problem of no-heat bridge construction, air tightness system and equipment installation. According to the actual situation and the requirements of the residents, the design drawings should be properly adjusted. In the construction plan, it is necessary to pay special attention to ensure the integrity of the building airtightness. The cross-section and plan view of the relevant design plan should be able to clearly mark the position and orientation of the air barrier, and write a patented construction plan according to the relevant construction requirements.

4. Conclusion

The construction of ultra-low energy consumption passive buildings in the current construction field can effectively reduce the energy consumption of buildings during operation, promote the ecological civilization construction of the city, and have a good environmental protection effect. This paper mainly studies the intelligent design of ultra-low energy consumption passive buildings, and points

out the specific application of intelligent technology in the passive building design process, hoping to provide some reference for related industries.

References

- [1] Xiaoxia Han, Tiangang Fan, Guqiang Wei, Congc-huan Hu. Analysis of renewable energy application scheme for ultra-low energy consumption passive buildings[J]. *Building Energy & Environment*, 2016(35):12-13. (in Chinese)
- [2] Kan Zhu, Xiaojing Liu, Chao Xu. Application analysis of ultra-low energy consumption passive building technology in Jiangsu province[J]. *Building Energy Efficiency*, 2016(44):10-11. (in Chinese)
- [3] Lei Liu, Zhigang Zhang. Waterproof construction technology in building construction engineering[J]. *Social Sciences (Digest)*, 2016(10):182. (in Chinese)
- [4] Haiyin Cheng, Guodong Lou, Zhongmin Fang. Semi-reverse construction technology of a basement of a engineering podium in Wuhan[J]. *Construction Technology*, 2014, 43(7):22-25. (in Chinese)
- [5] Gang Li. Underground railway concrete waterproof engineering construction technology[J]. *Architecture Technology*, 2015, 46(8):707-709. (in Chinese)

**REVIEW****Research on the Application and Public Experience of Green Landscape Color Art in Fuzhou****Ying Ouyang***

Fuzhou University of International Studies and Trade, Fuzhou, Fujian, 350202, China

ARTICLE INFO*Article history*

Received: 1 April 2019

Revised: 6 April 2019

Accepted: 23 April 2019

Published Online: 30 April 2019

Keywords:

Color art

Green landscape

Public experience

ABSTRACT

In the landscape design, the green landscape is an indispensable landscape element, and the plant color is an important factor affecting the green landscape. The color matching and layout are inseparable from the research on color art. Color art not only affects our vision, but also influences people's psychology and behavior through vision. In the following, Fuzhou will be used as an example to analyze the application of color art in the green landscape and the public experience.

1. The Current Situation of the Application of Color Art in Urban Green Landscape**1.1 The Research Situation of Overseas Urban Color Art**

Overseas research on urban color issues began in the 1970s, and the purpose of the research was to protect and restore old cities. Due to the consideration of the coordination between the old city and the new district, the research on the exterior color of the building is not related to the research on color art of the entire city. However, with the development of science and technology and the trend of global integration, the traditional culture of the region is seriously deficient, and people have begun to pay attention to the research on urban characteristics in

various aspects, also includes the research on urban color art, but still focuses on buildings and public facilities, and there is little color art research on urban green landscape^[1]

1.2 The Current Situation of Color Art in China

Color art can play a leading role. With the development of Chinese society, culture and economy, people's perception and demand for color have also undergone unprecedented changes. Especially in the fields of decoration, clothing, construction, etc., it has been widely used. In recent years, some large cities in China have gradually begun to pay attention to color issues in planning and construction, and have carried out different levels of color planning. The color industry is also developing in the direction of industrialization, diversification and innovation. However, these applications and research on color are limited to designers

*Corresponding Author:

Ying Ouyang,

Fuzhou University of International Studies and Trade, No. 28 Yuhuan Road, Shouzhuan New District, Changle, Fuzhou, Fujian, 350202, China;

E-mail: 56474415@qq.com.

and researchers. The lack of public participation and lack of knowledge about color art have affected their ability to appreciate color landscapes.

1.3 The Main Existing Problems in the Application of Color Art in Green Landscape

In the landscape architecture, the green landscape is the most popular, and color is more important as a feature of the plant's most ornamental value. How to give full play to the charm of the color of the plant itself and how to coordinate the color of the plant with the surrounding environment and urban color is something we need to pay special attention to now. At present, the description of plant color is mostly focused on qualitative language description, and because each person's understanding of color is different, the description of the same color will produce a big difference. The difference in color in brightness and saturation is easily overlooked by people, so that the color cannot be accurately expressed, so that the plant color of the design and the actual color effect of the plant are greatly deviated. Plant color lacks specific color language and special color scheme, which greatly affects the development of plant landscape color art. Therefore, it is necessary to carry out quantitative research plant color.

Fuzhou is located on the southeastern edge of Eurasia, southeast of China and east of the Pacific Ocean. It is a typical subtropical monsoon climate. The temperature is appropriate, warm and humid, the rainfall is abundant, little frost and snowless, and most plants are evergreen. Therefore, Fuzhou's green landscape is more than green and lacks color, and the plant landscape also lacks seasonal changes. In the "Fuzhou City Master Plan (1995-2010)", the implementation of the "Showing Landscape" project has significantly improved the indicators of urban green in Fuzhou. However, it ignores the importance of colorization, resulting in a monotonous green landscape. On April 23, 2018, the first Digital China Construction Summit New Smart City Forum, co-sponsored by the National Development and Reform Commission and the National Internet Information Office, was held in Fuzhou. whereby the forum, Fuzhou vigorously carried out the greening and upgrading work of Huahua Caihua, such as Cangshan District, focusing on the improvement of green landscape in the following areas: Exhibition Island, Nanjiang Binxi Avenue, Cangqian Road, Third Ring Road, Yongnan Road, Jiefang Bridge and Linpu Road—"One Point and Six Line" green landscapes, which made the original dull and monotonous street and node green space fresh and pleasant, and won the praise of the public. The green landscape occupies an important position in the urban color, and the main body of the city is the people living in it. The public experience is the most intuitive. Therefore, the application and research of color art in green landscape is insepa-

table from the research and analysis of public experience^[2]

2. The Significance of Color Art in Urban Green Landscape Design

2.1 Carry out the Research on Color Art as an Important Part in Green Landscape Design

75% of a person's initial impression comes from color, and then other elements such as form. Color not only affects our vision, but also changes people's experience through people's visual experience, affecting people's psychology and behavior. However, in today's park planning and construction, often only emphasize the landscape space, physical features, etc., while ignoring the importance of landscape color. In the color of the landscape, the color of the green landscape occupies a large part. The color matching is unreasonable. As a whole, there is no good plant color environment, and it is impossible to play an excellent color landscape to stabilize the nervous system and mental state of people, improve people's sense of safety and comfort, and reduce accidents. Therefore, putting color art as an important part in the design of green landscape, analyzing people's understanding of plant color landscape, and people's tendency to plant color landscape, is of great significance in theory and practice^[3].

2.2 Carry out the Quantitative Analysis of Plant and Leaf Color in Fuzhou to Provide a Basis for Green Landscape Color Scheme

The quantitative analysis of plant color and leaf color in Fuzhou is aimed at accurately expressing plant color by quantifying plant color, which provides the designer with effective plant color information, allowing the plant's color to be accurately and efficiently applied and maximized in the plant landscape.

At present, the plant landscape in Fuzhou is monotonous, and the color is monotonous and has no features and highlights. Through the quantitative analysis of the plant colors of several important green land types in Fuzhou, combined with the theory of color matching, the effect of the greening configuration is analyzed. At the same time, based on the existing color and leaf color resources, some suggestions for plant color combination can be proposed, so that more plant color types can be fully utilized^[4].

2.3 Make the Research More Practical through an In-Depth Investigation of the Public Experience

Through the investigation and analysis of the public experience, the influence of color art on people's psychology and behavior is studied. Different types of green spaces, people

feel different in them, which also includes color feelings, which requires that our survey not only needs to target different age groups, but also conduct separate surveys and statistical analysis for different types of green spaces, making this study more operative in practical applications.

3. The Application of Color Art in Green Landscape of Fuzhou City

Based on the theory of color science and landscape design, this project is based on the basic theory of chromatistics. It mainly studies the application of color art in Fuzhou green landscape with the experience of people in the landscape environment as the starting point. The aim is to improve the influence of color art application in landscaping landscape and enhance the practical applicability of color art in urban green landscape design^[5].

3.1 Analysis of the Relationship between Color Planning and Green Landscape Color Research in Downtown Area of Fuzhou City

The scope of color planning in the downtown area of Fuzhou city mainly includes 5 Districts (except Mount Shou, Rixi Village and Huanxi Town in Jin'an District), and Jingxi Town, Nanyu Town, Nantong Town, Shanggan Town, Xiangqian Town, Qingkou Town, Shangjie Town in Minhou County and Guantou Town in Lianjiang County, which are consistent with the downtown area planned in the overall planning of Fuzhou City, with a construction land of 378 km². The color planning goal of Fuzhou City is based on the new ecological landscape pattern of "Building a Scenic City" in accordance with the overall planning pattern of Fuzhou City. Create a city color landscape of "Warm Two rivers with Colors, Make Rongcheng (the elegant name of Fuzhou) Charming", the main color of the future is warm white, warm gray tone (concentrate on the color range of different brightness and saturation of the hue 5YR~10YR). The color research of the green landscape should be based on the overall color planning of Fuzhou, and targeted research should be conducted according to different types of green space^[6].

3.2 Investigation and Research on the Flower and Leaf Color in Fuzhou City

3.2.1 Quantitative Analysis Research on Plant and Leaf Color in Fuzhou City

The research mainly investigates the current situation of the color art of Chinese plants in green areas such as park green space, road greening and residential area greening, and some functionally prominent land use such as hospitals, nursing homes, and children's parks. Using NCS color card to take

color, according to the collected plant color and leaf color information, using the principle of chromatistics, from the color distribution of flower color, leaf color, flower color, leaf color brightness and saturation status and plant species distribution, etc., the plant color and leaf color used in the above types of land use were statistically and quantitatively analyzed, and the current status of flower color and leaf color resources in the land was grasped, so as to facilitate targeted plant color application in such green areas in the future^[7].

3.2.2 Research on the Use Frequency and Application Distribution of Plant Flower and Leaf Color in Fuzhou City

Count the actual use frequency of each plant, select the plants with higher application frequency, and match the color and leaf color information of the collected plants with the specific plant color and leaf color. The color distribution of flower color and leaf color commonly used in several types of land in Fuzhou City was obtained. According to the statistical results, the current situation of flower color and leaf color was analyzed, and corresponding suggestions were given^[8].

3.2.3 The Configuration Application and Discussion of Plant Flower and Leaf Color in Fuzhou City

According to the quantitative analysis results of the plant color and leaf color of the above-mentioned types of land use, and the use of color and leaf color, the relevant application of color and leaf color is discussed by using the color matching principle, and corresponding suggestions are put forward.

3.3 Research on Public Experience

Questionnaires were conducted on different groups of people, such as the elderly, children, and young people, mainly from the perspective of people's psychological feelings, analyze the color propensity of the color art of the plant in the green space of the park, the greening of the road and the greening of the residential area, and some functionally prominent land, such as hospitals, nursing homes, children's parks, etc, mainly from the following aspects^[9]

3.3.1 Public Understanding of the Color in the Green Landscape

It is not difficult to find that most of the public lacks a basic understanding of the basic knowledge of color landscapes and color and color. Therefore, neither the landscape designer nor the ordinary tourists and users have given the attention to the landscape color, which is also one of the purposes of studying the garden color landscape, because only by letting the public know what color landscape is, and they

can better appreciate and identify the color landscape.

3.3.2 The Public's Satisfaction with the Color of the Green Landscape

Through the satisfaction survey of the green landscape color of several different land types, we can find out which plant colors are more likely to attract the attention of the public. People pay more attention to the richness of color and the coordination of colors. According to the investigation and analysis of different types of land use, the targeted color selection requirements are proposed to guide the green landscape design work of this type of land in the future, and to make features to avoid monotony and similarity^[10]

3.3.3 The Evaluation of the Influence of Green Landscape Color on Public Mood and Behavior

Investigate the extent to which the public believes that the color of the green landscape in the park influences their mood and behavior during the tour, whether it is very influential or has some influence, and compare the effects of other landscape elements, such as buildings, landscape amenities, garden paving materials, on public psychology, it is concluded that the degree of psychological impact of the green landscape on people in the landscape is large, and the importance of it in the landscape design is understood^[11].

3.3.4 The Comparison of Factors Affecting the Color of Green Landscape

The seven factors of geographical conditions, seasonal transformation, traditional aesthetic habits, weather and light and shadow effects, plant selection, color psychological influence and economic and technological conditions were selected. It is concluded that the public believes that the color of the green landscape is the most important, and the problems in the application of green landscape color are solved in many aspects.

3.3.5 Create an Intention of the Color of Green Landscape

Mainly for different types of land use for separate statistics, study the requirements and expectations of the public in the various colors of the green landscape. Through this survey, specific analysis of specific issues in each survey site can be carried out in a more targeted manner, making survey statistics more practical^[12]

4. Conclusion

In the color application of landscape design, the color of the green landscape is the most abundant. The color matching and layout of plants profoundly affect the overall effect of

garden landscape design. Whether the color matching of plants is perfect or not is the key to determining whether the landscape design is vivid. Therefore, we should scientifically use color psychology and related research activities to create a green landscape color image with Fuzhou characteristics, which is not only the responsibility of the landscape architect, but also should be upgraded to the government level, such as the formulation of the overall color planning of Fuzhou City and the sub-planning according to different types of green space, clear theme color; detailed regulations on plant color orientation; conduct regular surveys of plant color public experiences, etc. in order to make the color art fully integrated into the green landscape design, people can enjoy the visual enjoyment better, and make the green landscape present a more unique beauty^[13].

References

- [1] Jieming Cheng, Xiajie Chen, Kai Gu. Color Science[M]. Beijing: Science Press, 2006:1-9. (in Chinese)
- [2] Lianfu Guo, Jihua Zhang. Color Aesthetics[M]. Xi'an: Shaanxi People's Fine Arts Publishing House, 1992. (in Chinese)
- [3] Yuhong Guo, Yunnan Cai. Planning strategies and approaches for urban color[M]. Beijing: China Building Industry Press, 2010. (in Chinese)
- [4] Wei Cui. Urban Environment Color Planning and Design[M]. Beijing: China Building Industry Press, 2006:2-5, 4-18. (in Chinese)
- [5] Can Liu, Qixiang Zhang. Color Harmonic Theory and Plant Landscape Design[J]. Landscape Architecture, 2005(02):29-30. (in Chinese)
- [6] Lvtai Gao. Improvement of Urban Color[J]. Huazhong Architecture, 2002, 31-32. (in Chinese)
- [7] Li Ni. Research on color application of urban garden plant landscape design[D]. Central South University of Forestry and Technology, 2007. (in Chinese)
- [8] Dequan Kong. The application of plant color in urban gardens[D]. Northwest A&F University, 2011. (in Chinese)
- [9] Baining Sun. Applied research on numerical methods based on landscape garden color[D]. Northeast Forestry University, 2010. (in Chinese)
- [10] Gruffydd B. Tree Form, Size and Colour[M]. Spon Press, 1944, 4.
- [11] Wang Siqi. Study on the color and application of garden plants in Taiziwan Park, Hangzhou[D]. Zhejiang Agriculture and Forestry University, 2013. (in Chinese)
- [12] Birren, Fader. History of Colour in Painting[M]. New York: Van No strand Reinhold, 1965.
- [13] Jun Wang, Yingqi Li. Application of Color in Landscape Design[J]. Development Guide to Building Materials: Volume 2, 2015(09). (in Chinese)

About the Publisher

Bilingual Publishing Co. (BPC) is an international publisher of online, open access and scholarly peer-reviewed journals covering a wide range of academic disciplines including science, technology, medicine, engineering, education and social science. Reflecting the latest research from a broad sweep of subjects, our content is accessible worldwide – both in print and online.

BPC aims to provide an academic platform for academic exchange and cultural communication that help organizations and professionals in advancing society for the betterment of mankind. BPC hopes to be indexed by well-known databases in order to expand its scope to the science community, and eventually grow to be a reputable publisher recognized by scholars and researchers around the world.

BPC adopts the Open Journal Systems, see on ojs.bilpublishing.com

About the Open Journal Systems

Open Journal Systems (OJS) is sponsored by the Public Knowledge Project Organization from Columbia University in Canada, jointly developed by PKP, the Canadian Academic Publishing Center and Canada Simon Fraser University Library. OJS can realize the office automation of periodical editing process, station build and full-text journals by network publishing. The system design is in line with international standards, and supports peer review. It is very helpful to improve the citation rate, academic level and publication quality of periodicals.





Frontiers Research of Architecture and Engineering

Bilingual Publishing Co. is a company registered in Singapore in 1984, whose office is at 12 Eu Tong Sen Street, #08-169, Singapore 059819, enjoying a high reputation in Southeast Asian countries, even around the world.

Frontiers Research of Architecture and Engineering is an independent open access journal published by Bilingual Publishing Co., who publishes without boundaries, ensuring its resources are accessible across the globe, in print, digital and online formats.

Tel: +65 65881289

E-mail: contact@bilpublishing.com

Website: www.bilpublishing.com



**BILINGUAL
PUBLISHING CO.**

Pioneer of Global Academics Since 1984

ISSN 2591-7587



9 772591 758196