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EFFECTS OF DIFFERENT TYPES OF HOUSING ENVIRONMENTS ON THE PHYSICAL INDEX AND PHYSIOLOGICAL INDEX

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ABSTRACT

The aim of this present study was to promote the quality of living environment, and create a healthy living environment through advocating for low carbon and green buildings. An additional aim is gaining recognition for wood structured housing, thus gaining recognition in customers and consumption to further promote the green ecological and sustainable development of wood structured houses. This work examined the physical environment indexes and physiological indexes of the participants in three different structure types of housing environment with

behavioral analysis (CAPTIV) and environmental data (BAPPU) synchronous test system. The results of the MANOVA revealed a significant main effect for the housing environment indexes with temperature, moisture content, noise, illumination, air flow rate and skin temperature, ECG, and respiration of three different structure types (log, glulam, reinforced concrete). In comparison, the influence of the physical environment factors in both the log structure and the glulam structure housing were better than the reinforced concrete structure housing. It indicated that woody housing environment was benefit to the health of habitants. Participants were interested in the log structure and glulam structure housing environment with joy and comfortable feelings. Different proportion of building environment and interior wooden decoration proportion can influence different cognitive and feelings of habitants. Therefore, wooden housing environment is helpful to adjust emotion, relieve work pressure and improve tasty, which would provide people with both physical and mental benefits.

KEYWORDS: Wood structure, healthy, comfortable, livable environment, physical index, physiological index

INTRODUCTION

The health and comfort of building environment, as well as caring for the needs of high work efficiency is increasing with the rapid development of economy and living level day by day. Simultaneously, the rapid development of the construction industry puts forward increased demands on the building environment. The building environment should not only meet the life and work demands for healthy, comfortable, livable and efficient, but also reduce building energy consumption and environmental pollution. Additionally, it is important to leave our carbon footprint low by constructing green eco-buildings.

Recent scientific evidence indicates an important connection between housing and health (Krieger and Higgins 2002). Housing is a very basic human needs for life and work. It requires the consideration of the environment, which is sometimes ignored by architectural design and developers for the effects of building properties (Gerilla et al. 2007). The living environment we live day to day has a tremendous impact on our lives. It affects us both physically, as well as psychologically. Recently, there has been a growing recognition of the importance of healthful living (Rice et al. 2006). The building environment has a tremendous impact on human's physical and mental health. Interiors of our home can have a great impact on our daily activities, such as residential developments to promote an older adults' sedentary behavior and active living (Ahrentzen and Tural 2015). To an occupant or user, a house is more than just a building. It should be an interdependent small ecosystem made up of many parts, including its structure, environment quality, and environment performance. Bayne and Taylor (2006) examined and suggested that aesthetical properties, such as fire and energy related properties were perceived as the advantages of using wood. It was indicated that wood was suitable for smaller buildings, such as housing for the elderly, schools, public buildings, smaller office buildings, and clinics (Bysheim and Nyrud 2008). Therefore, by increasing wood use in interior design, one can bring the positive health benefits of nature into the built environment (Burnard and Kutnar 2015). It is generally known that the wood give a person the feeling of warmth, simplicity, comfortability, cleanliness, softness and uniqueness. In the smooth wood grain with similar skin tactility have the basic function of reassure mood and regulate emotions. The characteristics of wood properties cannot be replaced with other materials: moisture absorption, heat preservation, fire resistant,

elastic tension, release the elegant aroma at the same time. Previous studies have also suggested that the use of wood products in indoor environment have a positive impact on people's emotional states and psychological health (Tsunetsugu et al. 2007). The use of wood and dimension stock to construction energy-saving houses, make its affinity nature, low-carbon footprint, while providing heat preservation and sound insulation, staying warm in winter and cool in summer. Simply put, wood structured buildings can achieve "Healthy Housing" goals by improving the indoor environmental quality, expanding the living space, and enhancing energy saving and comfortability.

Many studies have been conducted on the physical health and psychological effects of different aspects of our homes (Rice et al. 2006, Godish 2001, Shaw et al. 2001, Yoshino et al. 1990), but little has been done to investigate their physiological impacts. In this study, the people's physiological index and physical environment index can be synchronous monitoring in three types of building construction; it is a new and relatively unexplored method. To elucidate if the different structure housing environment in the interior had an influence on physiological and physical responses.

MATERIAL AND METHODS

Participants

Twenty volunteers aged 25–35 years old participated in the experiment as subjects from different trade backgrounds. There were 10 male and 10 female, with a mean age of 27.15 years. Education was as follows: graduate degrees accounted for 35%, bachelor degree 15%, specialist qualifications 25%, specialized subject the flowing 25%. Informed consent was obtained from all participating volunteers. They were all native speakers of Chinese and had normal or corrected-to-normal vision, normal hearing, and were without other nerve psychiatric diseases.

Experimental environment and apparatus

The experimental environments of physical and physiological tests were conducted in three types of building construction: log structure made by Metasequoia (*Taxodium Rich*), glulam structure made by *Pseudotsuga menziesii* Carr, and the reinforced concrete structure (Figs. 1-3). The test time was chosen from October to December during a day in autumn and winter, three different building types for the subjects were chosen for the procedure of the experiment. The three types of building areas were basically the same, log structure housing within the wooden decoration is approximately 95%, glulam structure housing within the wooden decoration is approximately 70%, and the reinforced concrete structure housing within the wooden decoration is approximately 20%.

Fig. 1: Log structure.

Fig. 2: Glulam structure.

Fig. 3: Reinforced concrete structure.

This experiment took place at the exemplary low-carbon area in Suzhou Crownhomes CO., LTD in China. The experimental apparatus used CAPTIV (Fig. 4) and BAPPU (Fig.5). The physiological measurement was conducted with the CAPTIV, and the physical environmental data measurement using the BAPPU.

Fig. 4: CAPTIV behavior synchronous analysis.

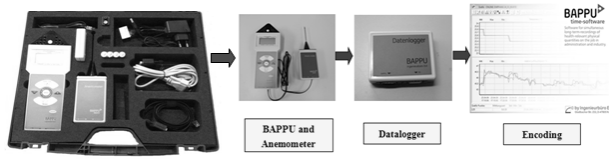

Fig. 5: BAPPU synchronous analysis.

Experimental procedures

A randomized complete experiment test group design: three types of houses (log, glulam, and reinforced concrete)* three kinds of weather conditions (sunny, cloudy and rainy) * six types of physiological indexes (Temperature, GSR, EMG, ECG, Respiration, CFM) * five types of physical environment indexes (temperature, moisture content, noise, illumination, air velocity) *four tasks (sit, walk, climb stairs and looking).

The purpose and the procedure of the experiment were given to the subjects in advance in order to guide the participants familiar with the experimental task, which may stable carry out all required tests. This experiment recorded and tested the physiological indexes of subjects by CAPTIV behavior analysis system synchronous, the 6 wireless sensors (Temperature - skin temperature), GSR (galvanic skin response), EMG (electromyography), ECG (electrocardiogram), Respiration, CFM (heart rate)) were located at the trunk and arm parts of the subjects respectively (Fig. 6). They used the BAPPU portable tester in order to monitor the environmental data in synchronicity (temperature, moisture content, noise, illumination, air velocity).

The house orders of trials were randomized for each participant. All the subjects were allowed to come into the three types of homes in turn, each participant stayed 8-10 min in each house to complete the test.

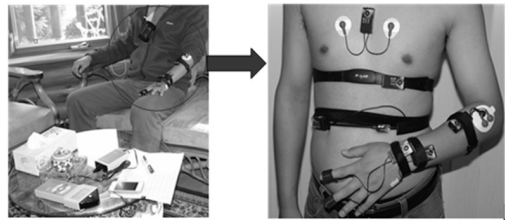

Fig. 6: The schematic of CAPTIV and BAPPU synchronous test.

Data Analysis

Each physiology data was synchronous measured by CAPTIV L7000 Analysis Software. Each physiology data was synchronous measured by BAPPU Time Analysis Software. The data analysis used multivariate analysis of variance (MANOVA). Statistical significance was set at a probability level of 0.05.

RESULTS AND DISCUSSION

Effects from the physical environment index can be seen from the results of the analysis, and there is a clear difference for log, glulam, reinforced concrete three different structures types of housing environment in temperature, moisture content, noise, illumination and air velocity. The results of the MANOVA revealed a significant main effect on the environmental temperature for different structure types of housing ($F=27.154$, $p<0.05$). For the temperature factor, temperature value in glulam structure housing environment > temperature value in log structure > temperature value in reinforced concrete structure (Fig. 7). It had a significant main effect on the environmental moisture content ($F=5.928$, $p<0.05$). For the moisture content factor, moisture content value in reinforced concrete structure housing environment > moisture content value in glulam structure > moisture content value in log structure (Fig. 8). As wood can exchange water from the air and adjust air moisture content, the moisture content in the log structure housing which have the most proportion of wood is more close to the humidity moisture content outside the house. The average person feel most comfortable under the 45-55% relative humidity in the glulam structure housing because of it's use of the wall thermal insulation system. In addition, houses with ventilated wooden facades can decrease the thermal load on facades (Mlakar and Strancar 2013). Other studies have also shown superior thermal performance of wood frame wall has perfect heat performance, and effectively reduce the relative humidity in the thermal insulation layer, which improves indoor environment comfort level (Wang 2011). Among factors that influence the living environment, humidity and temperature are the most important (Mlakar and Strancar 2013). Thus, the glulam structure housing use of wooden frame wall thermal insulation system have good function of heat preservation, moisture protection and ventilation. It had a significant main effect on the environmental noise ($F=15.652$, $p<0.05$). For the noise factor, the level of noise in reinforced concrete structure housing environment >glulam structure > log structure (Fig. 9). It had a significant main effect on the environmental illumination ($F=21.262$, $p<0.05$) and also a significant main effect on the air flow rate ($F=37.443$, $p<0.05$). For the illumination factor, illumination value in log structure housing environment > illumination value in reinforced concrete > illumination value in glulam structure (Fig. 10). It had a significant main effect on the air flow rate ($F=37.443$, $p<0.05$).

For the air velocity factor, the air velocity value in reinforced concrete structure housing environment > air velocity value in glulam structure > air velocity value in log structure (The air velocity factor in glulam structure housing is also roughly the same as the log structure) (Fig. 11). As a result of the wooden material own attribute act in the environmental conditions or status, such as ambient light, sound, color, air quality, temperature and moisture content control, etc. It is because the existence of the feeling feature for automatic adjustment to the environment state, which makes the wooden material to create a stable and comfortable interior bedroom environment have a long-term effect and positive effect on human body health (Rice et al. 2006, Sakuragawa et al. 2005). Above all, this study proves that log structure and glulam structure housing environment are superior in term of heat preservation, moisture content, noise, illumination and indoor ventilation. This is beneficial to the health of residents.

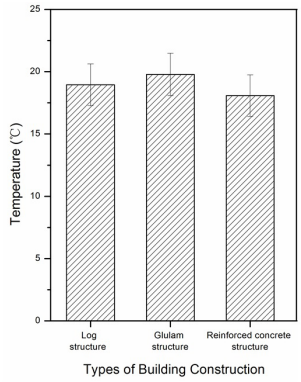

Fig .7: Comparison of different structure housing environment on temperature.

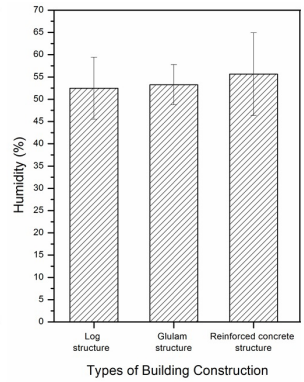

Fig. 8: Comparison of different structure housing environment on moisture content.

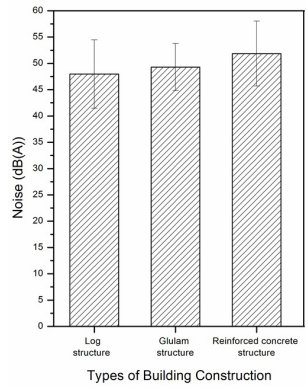

Fig. 9: Comparison of different structure housing environment on noise.

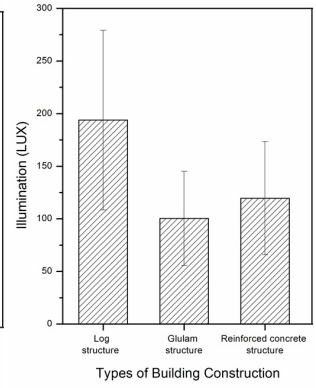

Fig. 10: Comparison of different structure housing environment on illumination.

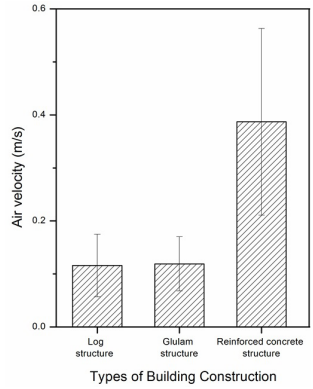

Fig. 11: Comparison of different structure housing environment on air velocity

For the effect of physiological index, as can be seen from the results of the analysis, there are clear differences for log, glulam, reinforced concrete within the three different structures types of housing environment in temperature, ECG, and respiration. Housing structure types have a significant main effect on temperature ($F=5.532$, $p<0.05$). Participants skin temperature indicators were various in different structure buildings environment, the results were as follows: skin temperature indicator in glulam structure > skin temperature indicator in log structure> skin temperature indicator in reinforced concrete structure (Fig. 12). The body is in a state of relative comfort because the wall thermal insulation system structure of the glulam housing to keep the subjects' skin temperature good. The main effect was not significant difference in GSR ($F=0.143$, $p>0.05$) and the main effect was not significant difference in EMG ($F=0.003$, $p>0.05$). It has significant differences in ECG ($F=5.617$, $p<0.05$).For participants' ECG indicator within different structure buildings environment, they were as follows: ECG indicator in reinforced concrete structure > ECG indicator in glulam structure> ECG indicator in log structure (Fig. 15). It has significant differences in Respiration ($F=13.971$, $p<0.05$). The main effect was not significant difference in CFM ($F=1.732$, $p>0.05$). For people's respiration indicator in different structure buildings' environment, they were as follows: respiration indicator in log structure > respiration indicator in glulam structure> respiration indicator in reinforced concrete structure (Fig. 17). Heart rate and ECG index in reinforced concrete structure are higher than the wooden structure, this shows that the participants may be a bit nervous in the reinforced concrete structure housing environment due to long work hours and pressure and are not as relaxed as in other housing structures, such as wooden structure housing. The index of skin temperature, respiration and skin conductance and electromyography of subjects are mostly in the wooden structure housing environment is higher than reinforced concrete structure housing, this is because skin conductance tend to rise, heart rate increased, the heart speeds up, cardiac interval decreased of electrocardio when excited (Alfons et al. 2002, Willem et al. 2011). This shows that the participants are in a state of excitement in the wooden structure housing environment with happier and more comfortable feeling. This is because the wood has unique features such as color, aroma, qualitative, grain, and its surface has a natural visual aesthetic feeling, as well as the most excellent and strong material quality (Tsunetsugu et al. 2007). At the same time, this research has proven that woodiness material consisting of indoor environment significantly better than that of metal, stone, plastic and other materials composition of the environment for the psychological,

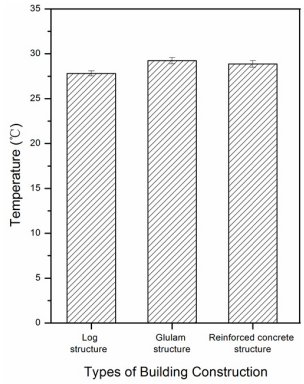

Fig. 12: Comparison of different structure housing environment on temperature.

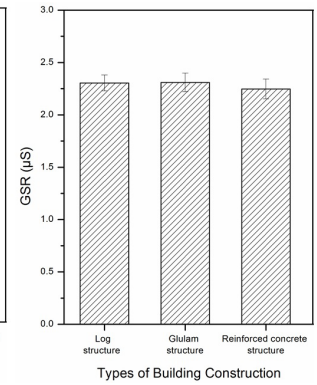

Fig. 13: Comparison of different structure housing environment on GSR

physiological, development and growth, immunity and reproduction of human body and so on (Liu 2008). There also appears to be a strong belief that the use of wood can help to create healthy environments, and commonly evoked descriptors for wood rooms include “warm”, “comfortable”, “relaxing”, “natural”, and “inviting” (Rice et al. 2006).

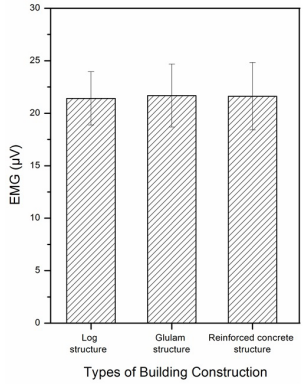

Fig. 14: Comparison of different structure housing environment on EMG.

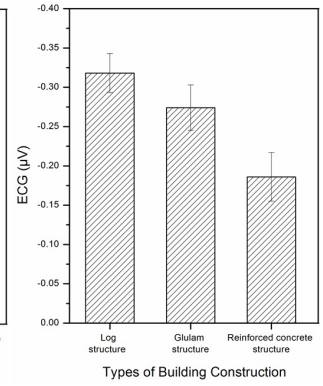

Fig. 15: Comparison of different structure housing environment on EMG.

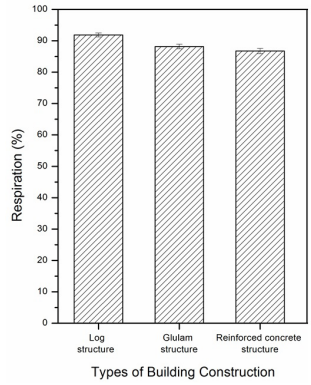

Fig. 16: Comparison of different structure housing environment on respiration.

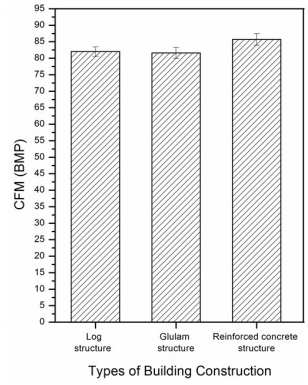

Fig. 17: Comparison of different structure housing environment on CFM.

In summary, timber construction create wooden environment space not only creates a good physical environment for human life, but also makes people have good psychological and physiological feelings. People learning and living in such wooden environment space will feel comfortable, which can improve the efficiency of work, interest in learning, relieve pressure and improve the quality of life at the same time.

Wood is one of the four major building materials in the world, which are the most main raw materials on construction, decoration and furniture and so on. It is closely related to people's living environment, the indoor physical environment quality and the user's psychological physiology reaction. Moreover, it undoubtedly has a significant impact on the user's physical and mental health. From the perspective of sustainable development and livability, make a better development

of wood construction, as well as a better application of wooden environmental material to create a good indoor environment is a subject worth exploring. Therefore, the studies from the human side as the main research object above give us much useful information to consider the "health and livability" of wooden houses. Through CAPTIV and BAPPU synchronous test and analysis of environment index and physiological index of the participants in different building, it can be revealed that the influence of wood structure housing living environment performance would have profound influence for human health and protect the ecological environment, and play an important role for promoting the development of green building. The development of wood construction has a certain theoretical significance and practical value, at the same time to meet people's growing environmental protection requirements, and creates a more comfortable and healthy living environment.

CONCLUSIONS

This study investigated the physiological and physical environment indexs in order to draw conclusion on the effects on humans in three different structure housing with different interior designs environment. The findings of the study can be summarized as follows:

1. The log, glulam, and reinforced concrete are three different structures housing environment that have significant effect on temperature, moisture content, noise, illumination, air velocity. By contrast, the influence of physical environment factors on inhabitants in log and glulam structure housing was better comparing with that in the reinforced concrete structure housing. Therefore, log and glulam structures housing environment is benefit to physical health of inhabitants.
2. The log, glulam, and reinforced concrete are three different structures housing environment have significant effect on physiological index temperature, ECG, and respiration. Participants in glulam structure building environment index of skin temperature is higher than the log and reinforced concrete structure, reinforced concrete structure ECG index is higher than log and glulam structure, log and glulam structure respiration index is higher than the reinforced concrete structure. This suggests that the participants are not only interested in the log and glulam structure housing environment, but also have cheerful mood and comfortable feeling.
3. Compared with reinforced concrete structure housing, two kinds of wooden structure houses give a person with comfortable state, of which glulam structure housing was slightly better than log structure housing. Quantitative physiological indexes monitoring can well reveal people within different structure housing environments that could not be detected by some sensory effects.

The present study clarified that architectural environment has very important effect on human health, and different structure housing environment cause different physical environment index and physiological responses. Different construction environment and interior decoration materials can cause significant cognitive differences and sensory evaluation. Further study is necessary to consider consumer perceptions and reflect those individual differences of physical, psychological, physiological indexes in the designing of artificial environments.

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