New Climate-Oriented Designing and Controlling Strategy for Sustainable Building in Subtropical Region

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1. INTRODUCTION
Since the year 1998 the first Green Building Challenge was held in Vancouver, the trend of sustainable or green building issues became the future step for the architects and the building developers to follow up. Literature review shows that many indicators have been used in sustainable building assessment system, including assessment of environmental impacts, surface environment of building, energy-efficient and reuse, water recycle, materials selection, efficient use of nature resources, indoor environmental health indicators, and etc.

Taiwan, the Formosa, located in subtropical area in East Asia, also developed the new concept of the future building. Year 2001 was an important turning point for Taiwan because the new government declared and proposed a “Green silicon island” blueprint for future development. The “Green silicon island” is a strategic plan to redevelop Taiwan into a country with unique green life, rich eco-diversity, and sustainable economic development. The development of sustainable building to change fundamentally living environments in Taiwan is therefore crucial to implement this blueprint.

Our study is therefore aimed to develop an assessment system by integrating subtropical climatic factors, geographic characteristics, ecological consideration, energy-efficiency and healthy living consideration to design a sustainable building reflecting the unique concerns of subtropical region.

2. NEW CONCEPTS OF SUSTAINABLE BUILDING IN TAIWAN
Since 1994, the Archilife Research Foundation began the research stage of symbiosis buildings. The research group includes Physical-Environment, Planning and Construction, Biological-Environment, Agriculture and Fishery, Health and Hygiene, and Literature and History. The long-term research developed the new concepts of sustainable building in Taiwan.

2.1 Climate and geography dependent design
From a geographic perspective, Taiwan presents a great level of variation. For example, the
highest mountain is 3,998 meter high from the sea level, and plain stands for 20% area of the entire island. The central mountain chain strings up from the north to the south of Taiwan.

In terms of climatic variation, the direction of monsoon is North East direction in winter and South-West in summer. The average temperature in summer is 28.5 degree in Celsius with frequent typhoons, and 14.8 degree in Celsius with Mainland frigid air mass. The average relative humidity level is 83%. The climate is very different between the north and south, the east and west parts. The geographic difference results in the great diversity of microclimate in this small island. Figure 1 is the yearly variation of climate observed by the weather station we set up in Fulong of northern Taiwan that is quite different from the other parts of Taiwan. The yearly variation is approximately following to the 24 solar terms in old Chinese calendar.

![Figure 1 Yearly variation of climate observed by weather station in Fulong.](image)

The geographic and climatic variation in Taiwan has inspired our research group to develop a building design that is microclimatic and geographic dependent while it can be a sustainable and healthy one. In addition, we also attempt to setup an evaluation system for the sustainable and healthy building.

### 2.2 Healthy living of sustainable building in subtropical region

Healthy living is the basic demand for human living. People spend most of their time indoors, whether it is at home, at work, at recreational facilities or other places. Therefore, the quality of indoor environment becomes one significant factor affecting human health. We propose the ultimate goal of a step-by-step development from healthy building to sustainable building.

Construct a healthy building environment with good indoor environmental quality (IEQ) to meet the human health requirement should comprise of many indicators. An integrated IEQ control program also should consider all stage of building lifecycle: design, construction, operation, and maintenance. The subtropical climatic characteristics have some potential risks such as heat stress, microbial contaminations, and higher emission rate of organic compounds in our building environments. Therefore, these IEQ indicators and our susceptible characteristics should be taken into account when constructing a healthy and sustainable building in subtropical region.
2.3 Comprehensive Approach Proposed for Designing the Sustainable Building

The comprehensive approach proposed for designing the sustainable building in Taiwan is composed of the following. First of all, the design must reflect the microclimatic and geographic variation. Secondly, it should also provide a healthy environment with proper control of physical, chemical and biological factors affecting human health. Finally, the consideration of meeting the criteria for green building, such as the energy and resource management, ecological planning and the amenity of the building should be included. We suggest such an operation process be a comprehensive approach for designing the sustainable buildings. How to control the living environment with the variation of natural frequency to locate in the health zone of the wave is the ultimate goal of the research with the new building concepts.

3. METHODS - THE CFD AND FULL-SCALED CLIMATE CHAMBER APPROACH

3.1 Evaluation method in design procedure—CFD simulation

Computer software is used in design process to further evaluate the effects of different physical environments. By input of different boundary conditions, the results can easily reflect the variation of different microclimate and geography.

![Figure 2. CFD solution for an experimental sustainable building](image1)
![Figure 3. CFD simulation on the new living model room in Taiwan](image2)

Figure 2 shows the profile from an experimental case where 2 different design strategies are used to achieve a level of satisfactory natural ventilation. CFD is applied to compare whether there is still any pitfalls between these 2 approaches. Figure 3 shows the flow pattern of the model room, the results supply the comparison data for the experiment studies. The ventilation for the model room is the experimental concept of the new ventilation and the thermal control strategy. A CFD profile is to assist, after taking into account the thermal and ventilation effects in the regions, the actual design for the renovation.

3.2 New Controlling Strategy Approach —Full-Scaled Climate Chamber Test

The climate chamber can provide different climatic status by controlling factors. Therefore, the full-scaled climate chamber can provide the environment simulation with the controls of outdoor temperature, humidity, velocity, pressure, sunlight, outdoor soundscape and the building envelope heat loading. To realize the performance of the new model, the chamber also can monitor the indoor flow pattern, temperature, humidity patterns, air cleanliness capability, ventilation efficiency, sound frequency, pressure distribution, illumination distribution and building materials.

The design of the system last for two years to collaborate and set-up the framework. Begin to construction in August, 2000 and finished in May 2001. The experimental items include:
24 solar terms corresponding, plants and sun light, performance of indoor environmental quality, performance of construction and indoor health in biological factors. The chamber is located in Archilife Environ-Control Research Center of National Cheng-Kung University. The research projects all to look for the sustainable living system in Taiwan.

3.2.1 Ten Controlling Factors in the Model Room. The climate chamber in the research center is setup for the new controlling strategy of sustainable building. Thus, the more flexibility and control-ability is the characteristic of this chamber. The factors includes, (1) Green Tower (Symbiosis Living ENV), (2) window shutters, (3) floor openings shutters, (4) vent-floor, (5) the wall-modular of acoustics control, (6) furniture, (7) stack ventilation and VENT tower, (8) Indoor vent-shutters, (9) passive vent-shutters, and (10) the clothing control. Therefore, the control variables are from outdoor green tower to the indoor environment control, in the topics of ventilation, thermal comfort, healthy acoustics, different illumination and the new living types for sustainable living. By different controlling factors and the results of the climate simulation in the place of Taiwan, we can improve the controlling strategy for better indoor living environment.

3.2.2 Climate Simulation with the Variation of 24 Solar Terms in Climate Chamber. In order to find out the new model of sustainable building in Taiwan, the microclimate and the geographic situation are both two major topics in the researches. As the figure 1 shows the year variation of the climate conforms to the 24 solar terms in old Chinese calendar. Therefore, to compress the yearly climate-variation in the research into one month is the proof of the chamber capability. The simulation is set to look for the solutions of the new concepts of buildings in Taiwan’s climate. The whole period, we called it “long modular”, takes one month with the climate control, real time monitoring, the control of the window, one person living in it and the questionnaire. Thus, the information can provide the research group to analyze the adjustments of controlling factors made the building more healthy and sustainable.

4. RESULTS
Through 3 months to modify the stabilities of the climate chamber, and 6 months of the first model to modify, the results can be conducted into three parts, the tree effect for controlling the thermal exposure, the effectiveness of marble humidity control system and the all new living system in Taiwan.

4.1 The Tree Effect for Controlling the Thermal Exposure in Subtropical Region
Hot and high humidity climate is the most important problem need to be solved in Taiwan. Therefore, with the data of rain forest in tropical region, the temperature stably maintains in 28 degree in Celsius. The same situation appears under the big covers of banyan. The former researches proved the effect of cooling effect with the mechanism of transpiration effect of plants. The effect, we call “Tree Effect” utilized in the building facade, could maintain outdoor thermal environment from the range of 14.1°C ~ 31.8°C to the range of 17.6°C ~ 29°C. Table 1 shows the results of the full-scaled climate chamber experiments with the weather simulation in 24 solar terms. The bold curve shows the outdoor temperature. If we delimit 24°C is the neutral line of the temperature, the tree effect can effectively control hot temperature below 29°C, located in the thermal comfort area with the wind correction by ASHRAE Psychrometric Chart.
Table 1  Comparison of the temperature results of 24 solar-terms experiments in the controlling model room.

Table 2  Comparison of the relative humidity results of 24 solar-terms experiments in the controlling model room.
4.2 The Marble Humidity Control System for Stable and Suitable Indoor Environment

According to the fundamental research of Archilife Research Foundation in 1996 to 1998, The solutions of humidity problem in Taiwan are the strategy combined the effectively natural ventilation design and the material humidity control. The solution is to adopt marble material to reduce the relative humidity of indoor environment by the characteristic of absorbing moisture. We design a new ventilation system with the elevated and vent floor with the marble of high porous ratio. Table 2 shows the humidity results of the experiments in 24 solar terms.

In summer time, the ventilation and material system can reduce the RH from 95% to 83% and 80% to 60%. In winter, the system also can provide the healthy and comfort effects of the 80% relative humidity level. That’s the critical control strategy for the human health with low risks of biological and physiological factors.

5. DISCUSSIONS

Over the last 8 years, our research group has come to believe that building, a fine partition between human beings and the outer natural environment, should be able to respond to climatic variation and to reflect the local individuality. A comfortable and healthy indoor environment can be achieved through proper construction and equipment designs. The present data of the research still have some barriers to conquer, such as how to increase the effect of the tree, and the situations of long-term climate with high humidity level. The accumulation results need to be proved in the real experimental building. Therefore, the future scope of promoting sustainable building in Taiwan is engage in the local implementation with the perspective application of the subtropical region. We are confident in our own uniqueness in terms of climatic variation and comprehensive designs. At the mean time, we appreciate and look forward to the opportunity of exchanging our data and experiences in further collaboration with colleagues around the world.

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7. REFERENCES

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