劉志鵬建築師綠能建築構造相關研究論文摘要

※綠能建築構造研發及實測分析（臺北科技大學設計學院設計博士班博士論文）

關鍵詞：綠能建築構造、低耗能建築、健康建築、減法綠建築

臺灣地處海島型亞熱帶氣候區，常年溫、濕度變化小但濕度高，臺灣混凝土相關構造物，占新建物 84.1 %，然一般鋼筋混凝土牆板及窗戶平板玻璃 U 值偏高，因此居室環境易受外部氣候變化而影響，夏天悶熱、冬天濕冷，空調能耗高。構材則因結露、反潮現象而受潮質變，未妥適處理換氣及過度不良裝修則形成病態建築環境，就發展因地制宜適切的低耗能、健康建築，是一重要的課題；AG 建築構造係以減、隔震基礎系統，上置 SN 鋼構骨架及輕質壁、板體的創新建築構造工法，摩擦椿上置隔震墊架高一樓樓板，下面舖設砂石及木炭的基礎構造方式，在樓板與地表間產生氣室，周邊外氣經由進氣口進入氣室後，透過地溫及木炭來調節溫濕度，外牆則為外側高斷熱、內側高蓄熱之 3D 斷熱牆所構成，構造特性異於一般混凝土構造。

本技術研發動機，AG 建築構造雖具外牆高斷熱特性，但居室溫度相較於混凝土牆或磚牆並未呈現良好的情形，因而產生探究提高窗戶開口斷熱及室內壁體蓄熱方式是否有助於室溫調節的想法！此外，在室內空氣品質及濕冷氣候時之居室濕度，能否經由地溫換氣與建築構造體的構材組合方式來調節？本技術研發希望透過標的物所在的氣候環境作用，實測分析以釐清問題並提出良好的解決技術。

本研發成果提出「綠能建築構造」發明，相較於鋼筋混凝土構造，量測期間研發標的在經斷熱窗簾及地溫換氣調控時，居室冬季室溫高 3.5℃、壁溫高 3℃以上，夏季室溫低 3.5℃、壁溫低 3℃以上，有空調冷暖房時，室溫調節更為明顯，經地溫換氣 CO_2 濃度從 3,600 ppm 降為 750 ppm，冬季濕冷時無須除濕機運作相對濕度少 10％以上。經實測分析建立觀點：(１) 居室溫、濕度環境具差異性，(２) 運用外部環境氣候能量變化影響居室環境，(３) 運用構材質性差異可調節居室環境品質，(４) 運用外牆外側高斷熱、內側高蓄熱方式應為良好的外殼構造方式，(５) 運用地溫綠能於換氣具改善居室溫度及 CO_2 濃度調節功能。

本研發成果具體呈現出，在居室環境熱得的處理上，不同於以往僅關注在牆體高斷熱及節能窗來減少夏天熱得的單一觀點，而是視氣候變化及居室環境的需要，以外殼斷熱及室內蓄熱搭配斷熱窗簾及平板玻璃的調控，來減少冷暖房空調的需求並提高居室溫濕度的品質，而地溫換氣部分具體減少空調設備使用，有效降低 CO_2 濃度提高居室空氣品質，均符合「減法綠建築」的理念並達成低耗能、健康建築的研發目的。就綠能建築構造的發明及 AGS1 的實際開發，有利於臺灣低耗能、健康建築發展方向之運用。

ABSTRACT

Research, Development and Measurement Analysis of Green Energy Building Structures
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Keywords: green energy building structure, low-energy building, healthy building, simplified green buildings

Taiwan is located in a subtropical island climate zone of year-long, steady high humidity. Concrete structural objects account for 84.1 % of new building constructions in Taiwan. However, the U values of typical reinforced concrete wall panels and window plate glass are relatively high. Therefore, indoor home environments are prone to be affected by external climate change and are thus hot and stuffy in the summer and moist and cold in the winter. Air conditioners consume excess energy, while structural materials degrade due to dampness from condensation. Improper ventilation and excessively poor renovation contribute to sick environments in buildings. Therefore, developing low-consumption, healthy buildings based on local conditions is a matter of importance. AG building structures adopt a vibration reduction and insulation foundation system and an innovative new building construction method consisting of an SN steel skeleton and lightweight wall and panel installation, with a foundation structure of first-floor floor plates elevated through vibration isolation pads above friction piles with sand and charcoal paved underneath to form an air chamber between floor plates and the ground surface.

Outside air enters the air chamber through the vent and regulates the temperature and humidity through ground temperature and charcoal; the external walls are constructed of a 3D insulation wall composed of highly insulated external materials and high heat storage internal materials that differ from typical concrete structures.

The motive behind this technological research and development project is to investigate, based on the highly insulative external walls of AG building structures and the lack of improved indoor temperature compared to those of structures with concrete or brick walls, whether increasing insulation in window openings or improving heat storage methods of indoor walls help to regulate room temperature. Additionally, this study also analyzes whether the indoor air quality, such as indoor humidity in wet and cold climates, can be regulated via building structural materials and combinations thereof. This technological

research and development project expects to measure and analyze the effects of the climate and environment on the target structure to clarify the problem and propose relevant technical solutions.
The invention of the Green Energy Building Structure was proposed in this study.

Compared to reinforced concrete structures, the target research structure during the measurement period recorded a 3.5 °C higher indoor temperature and 3 °C higher wall temperature in the winter, and a 3.5 °C lower indoor temperature and 3 °C lower wall temperature in the summer by the use of insulation curtains and ground temperature ventilation regulation. The differences in regulated temperatures were more pronounce in cooled or heated air-conditioned rooms. By use of ground temperature ventilation, CO_2 concentrations were reduced from 3,600 ppm to 750 ppm. Without necessary dehumidifier operations, relative humidities during the wet and cold winter season were reduced by at least 10 %. The following were concluded through actual measurement and analysis: (1)Indoor temperature and humidity environments varied, (2) Using external environmental climate energy change affected the indoor environment,(3) Using structural material variations can regulate indoor environmental quality,(4) Using a highly insulative external wall structure and high heat storage internal wall structure is an adequate shell structure, (5) Using ground temperature green energy in ventilation to improve indoor temperature and regulate CO_2 concentrations.

The results of this research and development specifically show that in the treatment of the heat of the living room environment, it is different from the single view that only focusing on the high wall insulation and energy-saving window to reduce the summer heat, but depending on the climate change and the needs of the living environment, the heat insulation of the shell structure and the regulation of the heat storage curtains and plate glasses are used to reduce the demand for air conditioning in the air conditioning room and improve the quality of the room temperature and humidity. The ground-temperature ventilation section specifically reduce the use of air-conditioning equipment, effectively reduced the CO_2 concentration and improved the air quality of the living room. Both are in line with the concept of "simplified green buildings" and achieve the goal of research and development for low energy consumption and healthy buildings. The invention of the green energy building structure and the actual development of the AGS1 are beneficial to the application of low energy consumption and healthy building development in Taiwan.

※綠能建築構造之溫度調節效益研究——以 AGS1 住宅為例

關鍵字：綠能建築構造、低耗能建築、隔熱、複合式通風、地溫綠能

摘要：
在全球氣候變遷及能源短缺下，發展因地制宜適切的低耗能綠建築，是一重要的課題。臺灣地處亞熱帶季候區、海島型氣候，95%為鋼筋混凝土構造建築，隔熱差、熱質量大，加上窗戶開口欠缺隔熱處理，居住環境夏天悶熱、冬天濕冷，空調耗能密度高。臺灣桃園市龍潭區渴望園區內一棟三層樓建築「AGS1 住宅」，係以整合外殼及窗戶隔熱處理，地溫綠能運用及複合式通風設計之創新綠能建築構造，此研究動機在於確切掌握其實際的溫度調節效益。

本研究首先以文獻分析法，探討臺灣氣候特性、建築牆體與開口之隔熱、蓄熱、地溫運用、通風換氣等影響居室溫度變化因素，繼之以個案研究方法，就「AGS1 住宅」進行單一空間之實測分析及電腦模擬；本研究獲得成果為「AGS1 住宅」之地溫綠能氣室相較於室外氣溫，夏至高溫時低約 6℃，冬至低溫時高約 5℃，具運用潛力，單一空間在適度配套使用空調換氣機制時，相較於鋼筋混凝土構造，夏冬時室溫可減增 3.5℃，壁溫則減增約 3℃，冷暖房變化速率較快；AGS1 夏冬季期間溫度調節負擔為 RC 的 39.36%，顯示「AGS1 住宅」綠能建築構造溫度調節效益良好，相較於 RC 構造呈冬暖夏涼之狀態，有助益於臺灣低耗能透天住宅發展之運用。

The Study of Effect of the Green Building Construction on the Temperature Adjustment – an Example of AGS1 House

KEYWORDS: Green Building Structure, Low Energy Consumption, Insulation, Hybrid Ventilation, Geothermal Green Energy

ABSTRACT
In the global climate change and energy shortages, it is a significant issue for development of a suitable low-energy green building to apply to local condition. Taiwan is located in the subtropical seasonal area of the island-type climate, 95% of the building made by the reinforced concrete structure, the wall insulation is poor, thermal mass, coupled with the general window openings of the lack of heat insulation treatment, muggy in summer, wet cold in winter, high air conditioning energy consumption. An innovative green construction (named AGS1 House, the 3-story house) located in Aspire Science Park, Lung Tan District, Taoyuan City, which is integrated with house shell and window heat insulation, high heat opening treatment, geothermal green energy and composite ventilation design. The motivation of this study is to accurately control its actual temperature adjustment efficiency.

In this study, first of all, the literature analysis of Taiwan's climate characteristics, building walls and window openings of the heat insulation, heat storage, ground temperature, ventilation and other factors affect the building temperature changes. Followed by a case study method, we implement the "AGS1 House" for a single space of the measured analysis and computer simulation. The results of this study, "AGS1 House", the geothermal green energy air chamber compared to the outdoor temperature, about 6℃ lower in summer solstice, about 5℃ higher in winter solstice. It is appropriate and potential to use for the air conditioning ventilation mechanism in a single space. Compared with the reinforced concrete structure, the room temperature in summer and winter can adjust by 3.5℃, the wall temperature also can adjust by about 3℃, the change rate of cold and warm room is faster. The study results of indicates that the temperature adjustment burden of AGS1 in summer and winter is 39.36%, the AGS1 House is warm in winter and cool in summer. It shows this green building construction temperature adjustment efficiency is good and construction method can be used on development of Taiwan's low energy consumption and residential.

※臺灣夏季高溫窗戶隔熱對居室壁面溫度的影響——以 AG 綠能構造為例

Influence of Window heat insulation on House Wall in High Temperature of Taiwan Summer - The Case of AG Green Energy Structure

摘要：

本研究為掌握在臺灣夏季高溫氣候時窗戶斷熱對居室壁面溫度影響，於 2017 年 8 月 4 日至 9 日期間，進行了二棟相同 AG 綠能建築構造，在有無窗戶斷熱處理的差異上，控制三樓窗戶及一樓地溫氣孔的開關，來記錄室內各處壁體表面溫度的實測數據，量測期間室外溫度 26℃-33.5℃，地溫 26.5℃-27℃，分別以測點及測次方式整理後進行分析。

在牆體具高斷熱的綠能建築構造中，窗戶經斷熱處理不一定有助益於夏季高溫時降低室內壁體溫度；從標的物四個面向的外牆面溫與戶外溫度比較，可以看出西北側及西南側溫度，明顯高於東北側及東南側。標的物在 15:00 時，窗戶經斷熱處理，有助益於減少一樓壁體溫度上升，但在三樓則反而不利，在 23:00 及 07:00，窗戶經斷熱處理反而不利於一樓壁體溫度降低，在三樓亦同。

三樓開窗時，外溫會明顯影響三樓壁溫，白天使壁溫上升，夜間則降低，二樓不影響，一樓壁體溫度降低則較明顯，且窗戶未處理斷熱反而利於壁溫減少升溫。另一樓地溫氣孔打開時則有助益於壁體溫度降低，尤其一樓較為明顯。

※透射型製冷膜玻璃窗運用在室內溫濕度調節效益研究

關鍵字：透射型製冷膜、熱得、濕度

摘要：

「牆壁隔熱好，不代表夏天室內不會熱」，因為一般雙層玻璃中隔熱膜方式，雖然能將大部分的輻射熱阻擋，卻也造成熱吸收量大停留狀態溫度高，而對室內從輻射熱轉為傳導熱與對流熱，尤其臺灣室內溼度偏高，熱傳導速率高加速了對室內構材的蓄熱作用，因此節能效益不高，相對的由美國美國馬里蘭大學及科羅拉多大學團隊所研發出的透射型輻射製冷膜，其相對熱吸收量 20W/m^2（SAV），冷卻能力為 100-150 W/m^2，大氣窗口輻射率大於 90%，顯示了直接在窗玻璃外側直接排除日照輻射熱並且對室內冷卻，這樣的方式有其實質的效益。

本研究以運用「近似實證研究法」發現及解決課題，標的物於實測期間，就透射型輻射製冷膜之安裝前後玻璃、室內及受照體溫度變化紀錄，分析得到，透射型輻射製冷膜較一般雙層玻璃中隔熱膜，熱吸收表溫度低約 15℃，而受照木板表溫則相近，均較清玻璃受照木板表溫少約 12℃，運用透射型輻射製冷膜可以大量減少室內熱得。

針對臺灣潮濕氣候居室，夏天時減少熱得晚上需要散熱，冬天時獲得熱得並曬到陽光，晚上則需要減少熱損，遮陽板或是窗戶外遮陽裝置外，玻璃型態的選用是關鍵，一般多層內置節能膜的產品多半效能有限，且影響冬天室內日曬，有景觀考量時可選擇透射型輻射製冷膜(冬天時相對需要保溫，透射型輻射製冷膜則應該要貼在內側，如果有窗戶型態能夠將玻璃內外翻轉，又能有好的氣密性是最為理想的方式。)，若沒有景觀方面的考量時，則可考慮斷熱窗簾的運用，如此可以減少約 60% 的室內熱得或熱損；倘若進一步考量冬天室內濕度的調節，運用冬天外氣溫較室內低的特性，在適當位置的玻璃產生室內冷凝方式來調降濕度的方式，北側及東側窗戶不貼透射型輻射製冷膜或是使用多層玻璃，負責夏天室內散熱及冬天冷凝調濕，西側南側玻璃則貼透射型輻射製冷膜，只要有窗戶就選用適當的斷熱窗簾。

※透射型製冷膜玻璃窗運用在室內溫濕度調節效益研究之冬天量測

桃園市龍潭區渴望社區海拔 300m，冬天時氣溫低且濕度高，一般鋼筋混凝土構造建築，室內壁體及室溫偏低，濕氣高所以成濕冷狀態，家具及物品容易受潮，AGS1 係針對臺灣潮濕氣候所開發的綠能防潮建築，具高斷熱內蓄熱 3D 牆體且整合斷熱窗簾及地溫換氣運用機制，相較於 RC 建築，明顯具有冬暖及濕度調節的特性，為進一步掌握其冬天氣候作用時的室內溼度情形，且運用窗戶玻璃在使用透射型製冷膜時，對室內溼度調節及窗戶結露位置情況，進行實測並加以分析。

視 2020 年 0129 - 0131 日期間，其外氣溫濕度呈冬天外氣候特性進行相關實測作業，於 AGS1 二樓日式房間南側窗戶內側扇玻璃外面貼一層透射型製冷膜，送風 18.9℃地溫也同時有排風，500W 電熱扇增溫，測試時斷熱窗簾關閉且門扇關閉，日式房有二位成人使用之狀態，相對同時量測二樓美式房，其狀態為斷熱窗簾未關但門扇關閉，無人使用之狀態，無任何送排風及電熱增溫。(本量測之二間房間其方位不同，但量測之時段以夜間為主，較不受日照調間差異影響，風向則具有影響性但不納入分析。)

實測結果，冬天有調控的日式房間相較於美式房間，壁溫差約 6℃，室溫差約 5-6℃，明顯的日式房間相較於美式房間室內外溫差要大，所以日式房間窗戶有結露情形，而美式房窗戶則不產生結露，日式房的溼度較美式房則低約 8-10%，顯示出日式房調控環境時的效益佳，此外日式房窗戶外貼一層透射型製冷膜時相較於未貼部分，其結露情形相較少量，其內側溫度則相對較高 1-2℃。

實測顯示冬天運用 AGS1 綠能建築構造斷熱窗簾及地溫換氣，確實能調控具舒適溫濕度環境，另運用透射型製冷膜確實可以助益於冬天窗戶結露位置之調控，並利於室內溫溼度之調節。