Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Analysis of Substitutive Design Technique with Integration of Offshore Residential Buildings and Thermal Energy Utilization of Solar Energy

Ruozhu Wang, Ruting Ma, Yongmei Qian*, Yujie Jin, Chunfeng Zhu
Jilin Jianzhu University, Changchun, Jilin, China
*Corresponding Author.

Abstract:

This study mainly investigated the integrated application of solar energy, as green renewable energy, in offshore buildings. With the gradual increase of offshore residential buildings, the use of solar thermal energy has become the main popularization and application mode for the integration of offshore residential buildings and solar energy. In relation to the prominent problems that exist in the integrated design application of solar heat collection equipment and offshore residential buildings, this study investigated the potential impact of heat collection equipment on the design of offshore residential buildings and adopted a substitutive design technique to expand its functions through the integrated design of buildings and heat collection equipment, thus laying a theoretical foundation for the popularization of the integrated design of solar energy utilization and offshore residential buildings.

***Keywords**: Offshore residential building, Solar energy, Thermal energy utilization, Heat collection equipment, Integrated design, Substitutive design technique.*

I. INTRODUCTION

With the gradual growth of green buildings, the application of renewable energy sources, such as solar energy in buildings, has become an important indicator for the implementation of policies related to the development of green buildings, energy conservation and environmental protection [1]. In addition, it brought many new challenges to architectural design. Since the beginning of the new century, the real estate industry in China has developed rapidly and various residential buildings have appeared [2]. In the past two decades, a relatively mature modulus mechanism for residential buildings in China has been formed. From macro planning to detailed house and residential layout designs, architects have also begun to look for new detailed changes to the overall framework [3].

A brief analysis of residential architectural styles that gave emerged in recent years, such as English style, French style, Spanish style, Art Deco, Brownstone, metropolis, Chinese classical, Western classical, neo-modern, ultra-modern, etc., was conducted.[4]. However, an in-depth study of the differences in various residential architectural styles involves nothing more than the color and texture of materials, the

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

scale and orientation of the architraves, and the differences in sections and rhythms. The most basic techniques are still based on contrast and unity, strengthening and weakening, rhythm and order, repetition and reproduction, etc. [5]. In this case, however, solar heat collection equipment, as a new building component, has become an initial consideration in architectural design such as windows and architraves [6]. What impact will its integration have on the appearance of the buildings in addition to the economic and environmental benefits? How to realize integrated building design? This is a key problem to be solved in terms of the utilization of solar thermal energy in architectural design.

There are three ways to add new elements: i) added element can become an extension of the original element; ii) combining the original element to create a transformative effect; and iii) imitation of the original element and its complete replacement [7]. The “element” mentioned here can refer to physical components such as windows, railings and sun louvers, as well as to virtual objects such as rhythms, lines and directions [8]. Adding any new element will affect the original whole. The purpose of the analysis in this study is to reduce the dissonance of solar heat collection equipment integrated with offshore residential building design, and even to beautify the offshore residential buildings, making solar heat collection equipment a language of architectural design, which is an indispensable part in architectural design.

II. METHODS

2.1 Substitutive Design Technique

Substitution describes the way things are exchanged, which, however, have the same essence [9]. New things replace original things, but they do not change either in function or in nature. In architectural design, the substitution technique often indicates a result that is determined by the designers after a series of scrutiny [10]. This technique differs from extension and transformation, which are characterized by performing design and reconstruction based on original components or order, while substitution indicates complete replacement of original components or order, thus presenting a new form to the outside world. It is not the change represented by the techniques of extension and transformation, which are a process, and substitution is a result without comparative objects.

The substitution technique is widely used in architectural design [11]. Any component can be replaced by other components of different forms with different materials, textures, stair forms, spaces, architectural styles, etc. [12]. Substituted things can be those that exist objectively, such as the color of the material and the type of architrave from a microscopic perspective, and the architectural style and art form from a macroscopic perspective; there can be the order and rhythm of intention, etc.

2.1.1 Integrated-window-type heat collection equipment substitutes French windows railings

In the design of modern offshore residential buildings, designers began to consider more humanistic care for users striving to obtain more sunshine by increasing the area of windows. Especially for residential buildings in offshore areas, where there is a lot of sunshine, it is more common to transit to the living room

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

through the south-facing balcony. The design of the balcony window is to set a 300-high windowsill under the window, with the upper part of the window directly topped on the ring beam or lintel in an attempt to obtain more sunlight (Fig 1). However, when the height of the windowsill is reduced, security problems come with it. In view of this case, the Design Code for Residential Buildings explicitly states that when the windowsill of an external window is less than 0.9 meters from the floor and the ground, protective facilities should be installed. Therefore, it is necessary to strengthen security by designing railings inside the window. This study conducted a discussion on the substitution of the protective railings of French windows with integrated window-type solar heat collection equipment.

Fig 1. Stiff French window railings affect the beauty

Integrated window-type solar heat collection equipment, as its name suggests, is a heat collector integrated with windows (Fig 2). It first appeared at the 13th International Green Building Energy Conservation Conference and New Technology and Product Expo in Beijing. In essence, it is an advanced type of the heat collection equipment. The working principle is the conversion of solar radiation into thermal energy to meet the needs of users for water heating through heat collection equipment, and a household (gas or electric) water heater is used as a component of the solar water heating system. This solves the problem of the weather influence on solar water heater [13].

Fig 2. The case of the built integrated-window-type residence

Compared to planar and evacuated solar heat collection equipment, the advantage of integrated window-type heat collection equipment is that no storage water tank is required, and hot water is stored directly in the collector tube, which saves indoor space and improves customer satisfaction with the solar water heater. The indoor installation directly eliminates the danger of falling from high altitude and

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

injuring people, as well as avoiding problems such as pipeline cracking in summer and freezing cracks in winter in order to extend the service life.

The most important advantage of the window-type solar water heater integrated with the French window (Fig 3) is that the integrated window-type heat collection equipment is very strong. Unless seriously hit, it can completely have the role of protective railings. After meeting the safety performance, the scale of the window can be further expanded, which affects the overall appearance of offshore residential buildings. In addition, the windowsill can be designed above the heat collection equipment, with materials such as marble slab or wood plywood, and the shadow caused by it will not affect the collector tube. Assuming to satisfy its own function, the integrated window-type solar heat collection equipment also gives priority to the functions of beautifying architectural modeling, saving space, etc., which shows a very high degree of integration with the offshore residential buildings.

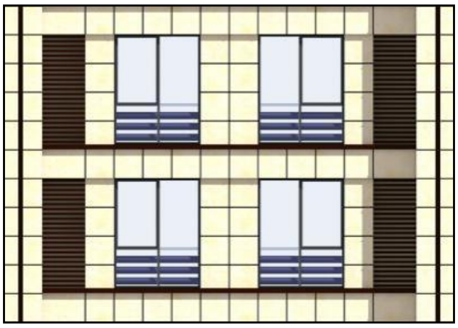

Fig 3. External details of integrated window-type

A specific method is to install the integrated window-type heat collection equipment under the French window or on the balcony or in a bedroom and fix both ends through components pre-installed in the wall. The pipeline can be designed in three ways. However, since the heat collection equipment is close to the ground, and too long pipeline will affect the beauty, it is not advisable to hide the pipeline in the ceiling architrave. Two other methods can be used. Windowsills can also be installed on top of the heat collection equipment, with two sides mounted on frames at both ends of the heat collection equipment and fixed with marble glue. For further aesthetics, the grille can also be placed to protect the interior of the heat collection equipment. If the grille is made of metal, it can also reflect a certain amount of solar thermal radiation. Such integrated window-type heat collection equipment is suitable for any form of residential buildings, with an extremely high degree of integration, so that the heat collection equipment really become part of many building components and a kind of architectural design language.

2.1.2 Integrated-window-type heat collection equipment substitutes French windows railings

As for the form and evolution process of external air conditioning stands, very detailed studies have been conducted. Based on similar characteristics between its grille texture and solar evacuated heat collection equipment, the design of the extension can be performed so that the solar heat collection equipment can be perfectly integrated with the external air conditioning stands, thus becoming a derivative

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

of the original component (Fig 4).

Fig 4. Substituting grilles for air-conditioning stands

What is being studied is that the equipment for collecting solar energy completely substitutes the grilles, thus forming a unique new situation. The specific approach is shown in Fig 5. At the beginning of the architectural design, the scale of the necessary heat collection equipment is negotiated with the solar water heater manufacturer in order to avoid errors in size for the integration. Using evacuated heat collection equipment to substitute the grilles of external air conditioning stands does not mean a complete substitution. The metal grilles facing the external machine were retained, and only the grille at the junction of the two metal grilles was substituted. In this way, the overall grille texture is the same, but detailed changes still exist, with different densities. Through the members pre-installed in the wall, the equipment for collecting solar heat is fixed, and the water tank can be placed in the bedroom or on the balcony. There are three ways to arrange the pipeline layout, and a proper choice can be made according to the location of the water tank.

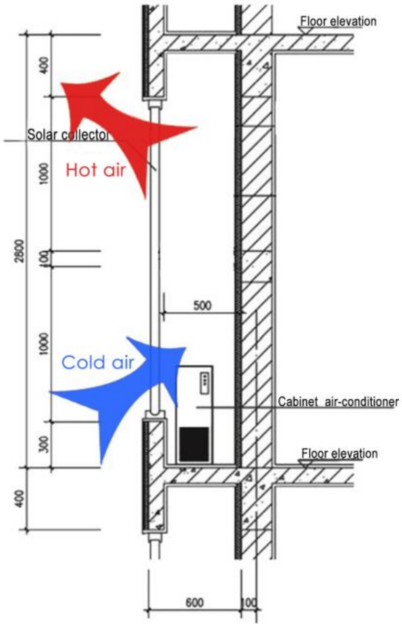

Fig 5. Schematic diagram of the microclimate in air conditioning stands

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

The advantage of substituting the heat collection equipment with the grilles of external air-conditioning stands is that it completely substitutes the original components, as well as has the function of heat collection equipment as the enclosure and protective component. The entire space of the air conditioner stands, evacuated heat collection equipment and metal grilles constitute a microclimate. Cold air enters from the lower metal grilles and is discharged from the upper grilles, thus accelerating the air flow. It is suitable for any residence with external air-conditioning stands.

2.1.3 Heat collection equipment substitutes the floating slabs at the top of the building

The emergence of floating slabs at the building top mainly benefits from the increase in residence with a modern minimalist style. After European-style and classic-style residencies gained popularity in the domestic market in China, designers began to look for new styles to increase the purchasing power of the public. The minimalist style characterized by having no stitch, and a variety of colors quickly became a new favorite of designers, and a large number of minimalist-style residences began to emerge in every metropolis.

Floating slabs have a decorative role in the architectural modeling. The emergence of new materials has also solved a number of structural problems, making floating slabs lighter. However, simple decorative components could be abandoned in future architecture. Therefore, the integrated design of the floating slabs and heat collection equipment gives full advantage to the new functions, while retaining the texture of the floating slabs.

Different types of floating slabs can be integrated in different ways. For example, as for integral floating slabs (Fig 6), the heat collection equipment can be built into the floating slabs, and the two ends of the frame of the heat collection equipment can be fixed with pre-installed members. The heat collection equipment with dark color is regularly interspersed in the floating slabs, making them lighter.

Fig 6. Integration of the integral floating slab

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

Fig 7. Integration of the distributed floating slab

For the distributed floating slabs (Fig 7), the sizes of the floating slabs and the evacuated heat collection equipment can first be matched to achieve their integration. The color of the floating slabs can be adjusted to achieve a contrast between them, which emphasizes the heat collection equipment. To adjust pipeline and water tank, pipeline can be placed directly inside the floating slabs, entering the bathroom or kitchen of each household along the pipe to reduce heat loss.

The integrated design of the heat collection equipment and floating slabs at the building top has the advantage that it does not occupy the south wall of the residence. As the decorative effect of the architrave is abandoned, designers prefer the protuberant block decorations to enrich the modeling, and there may not be enough space on the southern wall of the residence to install heat collection equipment. Therefore, the heat collection equipment will be arranged on the building roof, and the existence of floating slabs will make the residence modern in style. The addition of heat collection equipment can not only maintain the original form of the floating slabs, but can also have new functions. It completes the organic integration of solar heat collection equipment, thus becoming a part of the building.

2.1.4 Evacuated heat collection equipment substitutes parapet railings

The parapet is part of the components of a flat roof building, which refers to the low wall around the building roof. In addition to the two basic functions of maintaining safety and preventing rainwater overflow, it also has certain decorative functions. According to the different service properties of the roofing, the parapet has different height requirements. The height of the parapet for inaccessible roofs should not be less than 600mm, and for accessible roofs it should reach 1100mm. However, an unjustified increase in the height of parapet will not only increase costs, but will also increase the load on the building, thus the height of the parapet should not exceed 1500mm.

As for other suggestions regarding height, e.g., no less than 1200mm, the parapet is regarded as a safety protective equipment, which deviates from the real intention. For safety considerations, it is absolutely advisable to place 600mm high railings on the 600mm high parapet for protection. This approach not only satisfies the function of the parapet itself, but also makes it lighter. The “half-solid and half-empty” railings or glass panels become a transition between the physical parapet and the sky, softening the skyline of the building. Evacuated heat collection equipment can substitute railings as a new

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

form of parapet due to its similar texture as railings (Fig 8).

Fig 8. Design sketch for substituting the parapet with heat collection equipment

A specific method is to design the parapet of the residence in the form of 600mm +600mm as mentioned above. Transverse railings were arranged on the 600mm high solid base, and all southward railings were substituted with evacuated heat collection equipment (Fig 9). The spacing and color of the railings can be matched with the heat collection equipment to achieve a uniform visual effect. In terms of structure, the two ends of the heat collection equipment are directly fixed to a structural column that rises from the parapet base through pre-installed elements in order to ensure that it can withstand wind and snow loads.

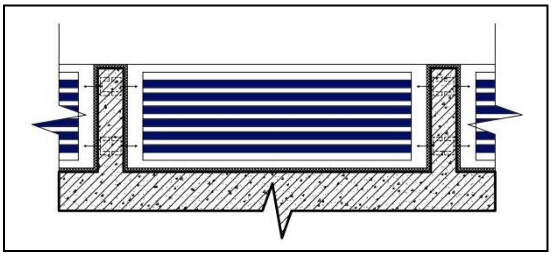

Fig 9. Structure for substituting the parapet with heat collection equipment

This method has the advantage of optimizing the original parapet. As mentioned above, the parapet is not a structural part, and walls that are too high only increase the load on the buildings and become a burden. Therefore, the practice of “base + railing” is adopted to satisfy its functions and reduce the load. On the basis of this case in relation to the property that evacuated heat collection equipment have a similar texture to railings, using the evacuated heat collecting equipment to substitute the parapet railings can not only result in the solar heat collection equipment being organically integrated into buildings and being a part of the building, but also fulfill their original usage functions. As this is a supplementary approach to the heat collection equipment area, it is suitable for any building with a flat roof.

III. CONCLUSION

There are enough solar energy resources in the offshore areas that should be fully utilized. The substitutive design technique was proposed according to the characteristics, texture, material and element properties of the solar heat collection equipment combined with the exterior architectural characteristics of the offshore residential buildings. Due to the previous construction practices, it has high feasibility. The solar water heater and the offshore residential buildings are designed and constructed synchronously, with the two coordinating with each other. According to the combined parts, the type, texture, and dimensions of the heat collection equipment are adjusted, which makes the heating collection equipment not only serve as an objective component after being integrated into the building, but also beautifies the architectural modeling in terms of virtual elements such as rhythm and order. Finally, the solar water heater becomes part of the building components and the architectural design language.

The Central Committee of the Communist Party of China (CPC) and the State Council of China give great importance to problems such as air and marine pollution, haze weather, degradation of ecological functions, and damages caused by coal and other traditional energy sources. Chinese President Xi Jinping has repeatedly stressed that "green hills and clean waters indicate the wealth of gold and silver mountains", "we must adhere to the basic state policy of conserving resources and protecting the environment", and "we should protect the ecological environment like we protect our eyes and treat it like we treat our lives". Chinese Premier Li Keqiang has repeatedly pointed out that we must strengthen comprehensive environmental governance, raise the level of ecological civilization and promote green development, in order to be determined in the search for a win-win path between economic development and environmental improvement. Since the 18th National Congress of the CPC, the General Plan for Institutional Reform of Ecological Civilization has been issued and progress has been made in environmental protection, such as improving ecological and environmental quality, over-meeting the pollution control targets and reducing emissions, achieving good results in ecological protection and construction, making continuous improvement in environmental risk prevention and control, and continuous improvement of the legal construction of ecological and environmental protection. Environmental protection and species protection have become a top priority in the society. First of all, we must realize the implementation of environmental protection by everyone and raise people's awareness of environmental protection. Secondly, we should clarify the division of labor, increase investment intensity, improve legal provisions, etc. The most important thing is to strengthen the development and utilization of new energy and popularize the benefits of clean energy. The results of this study will provide the most effective support for the utilization of solar thermal energy and the integrated design of the residential buildings in offshore areas.

ACKNOWLEDGEMENTS

We acknowledge the support provided by the National Natural Science Foundation of China (NSFC), 52078239, 51478205.

REFERENCES

[1] Karagiorgas, M., Tsoutsos, T., Drosou, V., Pouffary, S., Pagano, T., Lara, G.L., Mendes, J.M.M. (2006). renewable energies in the hotels. An extensive technical tool for the hotel industry. Renewable and Sustainable Energy Reviews, 10(3): 198-224. https://doi.org/10.1016/j.rser.2004.09.012

Forest Chemicals Review
www.forestchemicalsreview.com
ISSN: 1520-0191
July-August 2022 Page No. 1357-1366
Article History: Received: 30 March 2022, Revised: 8 April 2022, Accepted: 15 April 2022, Publication: 30 April 2022

[2] Chaithanakulwat, A. (2019). Design of solar-powered aeration system for shrimp ponds of farmers in Thailand. European Journal of Electrical Engineering, 21(6): 539-546. https://doi.org/10.18280/ejee.210608
[3] Benramdane, M., Abboudi, S., Ghernaout, M. (2019). Contribution to the simulation and parametric analysis of the operation of a solar concentration thermal installation. International Journal of Heat and Technology, 37(2): 446-456. https://doi.org/10.18280/ijht.370210
[4] Guellai, F., Labed, A., Moummi, N., Mahboub, C. (2019). Measurement and Analysis of Thermal-Hydraulic Performance of Curved and Plate Flat Solar Air Heaters; A Comparative Study. Instrumentation Mesure Métrologie, 18(6): 553-558. https://doi.org/10.18280/i2m.180606
[5] R. ZH. WANG, Y. M. QIAN, W. TIAN, X. JIANG, Integrated Design Between Energy-saving Solar Water Heaters in High-rise Residential Building: A Case Study on Changchun, Northeast China. No.4, 1265–1279 (2020).
[6] R. ZH. WANG, Y. M. QIAN, W. TIAN, X. JIANG, A Practical Scheme for Integrated Utilization of Passive Solar Heating in Coastal High-rise Residential Buildings, Journal of Coastal Research, 115, 438-442(2020).
[7] X. X. DING: Research on the Integration of Solar Hot Water System and Building in Changsha. Hunan University, (2), 20 (2013).
[8] Xue, Y.B., Yang, Q.M., Wang, C.J. (2014). Building Solar Energy Utilization Technology for Series Teaching Materials of Building Environment and Energy Application Engineering in General Colleges and Universities. China Building Materials Press.
[9] C. ZHANG, W. HUANG, X. F. ZHENG: The Integrated Design of Solar Water Heating System for High-rise Housing: Taking the “Yuqin Wan of Jing Cheng” Residence as an Example. Huazhong Architecture, 28 (4), 75 (2010).
[10] Wang, R., Qian, Y., Tian, W., Jiang, X. (2020). Integration between energy-saving solar heating equipment and high-rise residential buildings. Journal of Environmental Protection and Ecology, 21(5): 1697-1707.
[11] Xue, H.S. (2016). Experimental investigation of a domestic solar water heater with solar collector coupled phase-change energy storage. Renewable Energy, 86: 257-261. https://doi.org/10.1016/j.renene.2015.08.017
[12] J. H. WANG, Z. R. GONG: Optimal Selection of Solar Energy and Heat Pump for Hot Water, Water & Waste Water Information, (2), 8 (2011).
[13] O. D. DINTCHEV: Solar Water Heater Heating as an Instrument for Global Action of Climate Change. Mitigation and Adaptation Strategies for Global Change, 7, 140 (2002).