Study on Thermal Insulation Structure of Assembled Residential Graphene EPS Module Based on Energy efficiency 65% in Severe Cold Area

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Abstract. Based on the climatic and actual conditions in the severe cold region represented by Changchun, Jilin Province, this paper analyzes the problems in the exterior insulation materials currently used in the market. By studying the basic characteristics of graphene EPS module, we put forward the construction method applied to the external wall thermal insulation of the assembled residential building in severe cold area where the energy efficiency rate is 65%.

1. Introduction
In severe cold area, the difference in temperature indoors and outdoors can reach to 30°C - 60°C in winter. The largest percentage of the building envelope is the wall, so the heat loss caused by heat transfer is more than that of other structures. In the development of assembled buildings, the insulation of prefabricated wall panels can meet or exceed current standards place, so it is an important aspect of promoting the development to the assembled buildings in severe cold area.

2. Overview
The external thermal insulation system mainly includes EPS board thin plastering, which come into use in 2000, and EPS board cast-in-place concrete external wall thermal insulation system in severe cold areas. But EPS board has many disadvantages. For example, the unstable production process, the poor material properties, and the poor product quality, the imperfect node structure, and the construction method to be improved, resulting in the indoor wall appeared cold, moldy condensation and outer wall insulation occurred hollow drum, cracking, shedding and other energy-saving construction quality problems, which seriously reduce the durability of energy-efficient buildings. In order to respond to the call of China to popularize the assembled buildings, Jilin Province, as a place where buildings with high energy consumption in severe cold areas, urgently needs to develop new insulation materials and energy-saving building systems to solve these engineering quality problems and achieve the same life span of the outer insulation layer and the structural wall.

With the climate characteristics of severe cold region in Jilin Province and the current 65% energy-saving standards, due to the lack of products, the traditional EPS board wall insulation system cannot meet the sustainable development of assembled energy-saving building requirements, so we try the new type of wall insulation module of graphene EPS module. Compared with the traditional EPS material, the EPS of the modified graphene material has the characteristics of high strength, very low thermal conductivity and antistatic properties. Its breaking strength is 100 times higher than that of the
best steel in the world. Under the same thermal insulation effect, the thickness of the thermal insulation board is thinner, which saves a lot of transportation costs. Such a material which is light high in strength, reliability, economy, good stability, is the ideal building insulation materials. The combination of graphene EPS module and fabricated structure system and BIM technology will certainly become the future trend of the development of Chinese building.

3. Basic Features of Graphene EPS Module

Graphene, also known as single-layer graphite, is a new discovered two-dimensional nanomaterial which is the highest hardness, highest toughness and the best conductivity of the nanomaterials. Most of the light can go through the graphene, which is therefore essentially completely transparent and absorbs only 2.3% of the light. Graphene is a kind of special band structure of zero-gap semiconductor materials, and the electron mobility of it can reach to 100000cm2.V-1.S-1.

3.1. Low thermal conductivity of modified graphene

Traditional graphene materials have good thermal conductivity. When the filling amount of EPS insulation material is small, the graphene is modified to form modified graphene to reduce the thermal conductivity. A closed cavity with modified graphene dispersed in the cell wall has multiple planar reflections in the graphene confined cavity in the EPS cell. The mutual reflection formed by the heat in the cavity cannot be transmitted outward, which makes the thermal insulation performance of the graphene EPS module better than other materials, making the wall cross-sectional dimension being more accurate and less error. In the EPS insulation materials filled with less when the modified graphene can be its thermal conductivity decreased. When the amount of graphene filled is relatively small, the graphene can be uniformly dispersed without contacting with each other so that the thermal conductivity network cannot be formed, resulting in a decrease of thermal conductivity. Conversely, when the filled graphene reaches a certain level, they are closely connected with each other, and the thermal conductive network dominates the thermal conductivity of the thermal conductive network.

3.2. Graphene EPS module characteristics

Graphene EPS module is a new type of wall insulation module, with the new performance of high strength, low thermal conductivity, anti-static, sound insulation. Graphene is by far the highest intensity of the material found, and the addition of graphene EPS strength can up to 0.30 MPa. The new performance of high strength graphene is an important breakthrough in the development of building exterior insulation, which reduces the weight of the wall and ensures the safety of the external wall insulation system. At the same time, the original graphene material is a relatively high thermal conductivity of the material, when graphene is polymerized with EPS, graphene is evenly distributed in the EPS, which can generate random light reflection in the EPS channels, so that the heat is not easily transmitted and plays a role of reducing the thermal conductivity. Due to its low thermal conductivity, when the insulation effect is same, it requires greatly less, insulation materials than that of the traditional EPS module, saving a lot of raw materials. At present, most urban building energy efficiency standards have also been increased from the previous 50% to 65%, so the thickness of ordinary white EPS would not meet the safety performance requirements.

The conductivity of graphene materials being particularly good, graphene EPS can achieve an unprecedented antistatic ability when graphene is polymerized with EPS. With this property, graphene applied in the solar photo voltaic utilization value needs to be studying. In addition, the use of graphene EPS material in the building floor insulation system can fully meet people's demand for residential comfort enhancement. The noise level of impact sound insulation can reach to 60 decibels or lower, far below the design specifications.

3.3. Applicability of graphene EPS modules

The Code for Fire Protection of Building Design (GB / T 50016) implemented since May 2015 stipulates the use of Class B1 insulation materials with a height of 27-100 meters for civil buildings.
and the use of Class B2 with a height of 27 meters. At present, China's newly built civilian buildings are generally higher than 27 meters in height, therefore, B1 grade insulation materials will become the mainstream of the construction market in the future. At the same time, the implementation of the national standard "Molded Polystyrene Board Plaster Exterior Insulation System Materials" (GB/T 29906-2013) clearly provides B1 grade EPS on the wall except to meet the combustion performance requirements, and its thermal conductivity also less than or equal to 0.033, while the Class B1 EPS on the market that can meet both of these conditions is only graphene EPS, see Table 1.

| Table 1. Physical indicators of insulation materials(1) |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Material name                   | Thermal insulation board heat transfer coefficient W/(m²·K) | Apparent density (Kg/m³) | Compressive strength MPa | Water absorption% | Fire-proof level |
| White EPS polystyrene board    | 0.039           | 18              | 0.1             | 0.4             | B1              |
| Gray EPS polystyrene board     | 0.037           | 18.6            | 0.1             | -               | B1              |
| Graphene EPS module            | 0.028           | -               | 0.3             | 0.2             | B1              |

In addition to the better fire resistance, the graphene polymerization is stable. The stability of the production process is much higher than the traditional EPS insulation module. In addition, graphene with very small additions can exceed the performance of traditional graphite EPS, so the production cost can be relatively reduced. Compared with ordinary graphite, modified graphene has shorter reaction period and stable reaction in EPS polymerization. Under the same conditions, the yield of the heat-preservation module is increased and the la

Bor cost is reduced.

4. Graphene EPS module insulation structure form

4.1. Prefabricated graphene EPS module exterior insulation structure forms
As shown in Table 2. (a), the graphene thermal insulation module is placed on the outside of the external wall of the building, and the building area is larger than that of the internal insulation, which can well solve the influence of the cold and thermal bridges in all parts of the building. Due to indoor and outdoor temperature difference occurs in the outer insulation layer, the inner wall of the main subject to minor effects and small temperature changes, so the main wall can greatly reduce the risk of cracks, deformation, and damage when using the external insulation and the life of the wall can be extended. However, the external wall insulation material of prefabricated panels is easy to destroy in the transport process, which is gradually unsuitable for cold areas.

4.2. Prefabricated external wall insulation structure forms within the graphene EPS module
As shown in Table 2. (b), the amount of insulation material placed inside the outer wall of building is much smaller than that of the external insulation wall, the cost is relatively low, and the heating and cooling speed is fast. However, its durability is poor, the insulation layer is easy to crack, and it occupies the indoor use area. If you want to retrofit buildings in the late energy-saving, it will seriously affect the daily life of nearby residents, and ring beams, floors, structural columns will result in greater heat loss, and the appearance of the thermal bridge will lead to condensation on the inner surface of the inner wall and the thermal insulation effect will reduce greatly, which is not suitable for cold areas.
4.3. Prefabricated external wall module graphene EPS insulation sandwich form of construction

As shown in Table 2. (c), the insulation material is placed in the middle of the building wall. This kind of sandwich insulation precast concrete has many advantages. The outer wall of the prefabricated panel can effectively maintain the inner wall and the insulating material so as to protect it from the external environment, so it plays a protective role in the whole building, prolonging the service life of the building, improving the durability and reducing the fire and freeze-thaw cycles and others as a hazard or natural disasters on the wall hazards. And the use of sandwich insulation can reduce the thermal insulation effect of wall insulation, which greatly improved wall insulation effect.

The advantages of prefabricated sandwich insulation wall panels are also reflected in the surface smoothness of the factory production, which is better than the cast-in-place construction in the field, and can even eliminate the part of plastering, thus reducing the cost of construction. And constructing prefabricated sandwich concrete wallboard required less workers than that of cast-in-place wall panels, which also reduced the construction cost. The prefabricated sandwich insulation wallboard has low requirements on the construction environment, and the environment and the climate will not affect the construction operation, which solves the construction delay problem and shortens the construction period.

Table 2. Graphene EPS module insulation structure form

| Prefabricated graphene EPS module exterior insulation structure forms | Prefabricated external wall insulation structure forms within the graphene EPS module | Prefabricated external wall module graphene EPS insulation sandwich form of construction |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| ![Structure form](image1) | ![Structure form](image2) | ![Structure form](image3) |

5. Simulation calculation

By this above analysis, prefabricated graphene EPS insulation module sandwich wall panels are most suitable for use in severe cold areas. According to the Design standard for energy efficiency of residential buildings (energy efficiency 65%) in Jilin Province Table 4.2.2-2 Standard for Thermal Performance of Enclosure Structure in Severe Cold Area (3800≤HDD18 <5000), see Table 3. In residential buildings, as long as the outer wall heat transfer coefficient of less than three buildings is less than 0.35W/ (m²·K), all floors of residential buildings can be satisfied. Through the following two kinds of software simulation, we calculated the most suitable for 65% energy saving in winter cold wall construction method.

Table 3. Limitation Standard of Heat Transfer Coefficient of Exterior Wall for Design for Energy Efficiency of Residential Building in Jilin Province

| Envelope parts       | ≤ 3-storey building heat transfer coefficient K [W / (m²·k)] | 4 to 8 floors of the building heat transfer coefficient K [W / (m²·k)] | ≥ 9-storey building heat transfer coefficient K [W / (m²·k)] |
|----------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Exterior wall        | 0.35                                            | 0.45                                            | 0.50                                            |

5.1. Green built Si Weier energy efficiency design software BECS

BECs is one of Greensville's computational analysis of building energy efficiency software, using three-dimensional modelling on AutoCAD platform, which make the building and energy efficiency
design together. The software follows the national standard, landmark and the implementation details, applicable to building energy efficiency design, energy analysis, and energy efficiency review and so on.

By heat 2 software simulation analyses, we got the most suitable method for the outer wall of the cold region construction, then by the Swell software BECS calculation and analysis as shown in Table 4, the heat transfer coefficient was 0.34 W/(m²·K). And after the energy efficiency inspection in Table 5, it is more confirmed that the structure and the design of the structure meet the standard of energy efficiency 65% in severe cold areas.

### Table 4. Energy efficiency calculation

| Material name                | δ (mm) | λ (W / (m·K)) | W / (m²·K) | α | R (m²·K) / W | D = R * S |
|-----------------------------|--------|---------------|-------------|---|-------------|-----------|
| Fibreboard (ρ = 600)        | 20     | 0.340         | 5.280       | 1.00 | 0.059       | 0.311     |
| Graphene EPS module         | 60     | 0.028         | 0.036       | 1.00 | 2.143       | 0.077     |
| Reinforced concrete         | 200    | 1.740         | 17.200      | 1.00 | 0.115       | 1.977     |
| Fibreboard (ρ = 600)        | 150    | 0.340         | 5.280       | 1.00 | 0.441       | 2.329     |
| Sum of layers Σ             | 430    | -             | -           | -     | 2.758       | 4.694     |
| ρ                           |        |               |             |      | 0.75(default)|           |
| K = 1 / (0.15 + ΣR)         |        |               |             |      | 0.34        |           |

### Table 5. Energy efficiency inspection conclusion

| Serial number | Check items in conclusion | Whether the performance of trade-offs |
|---------------|---------------------------|--------------------------------------|
| 1             | Exterior wall construction| meet                                 |

5.2. Conclusion

After the calculation and analysis of the two kinds of software, it is concluded that the most suitable pre-graded graphene EPS module sandwich concrete wallboard with 65% energy-saving standard in severe cold areas constructed as follows. The thickness of the prefabricated core-sandwich concrete wallboard is designed to be 430mm thick, and the outer wall is made of 20mm thick cement fiberboard with the function of protecting the wall. Then a 60mm-thick graphene insulation module is connected as an insulation layer through an electric welding mesh sheet, and then through a number of connections to connect the 200-thick steel truss, late-site concrete pouring as the main load-bearing wall, the inner wall of the wall with 150mm thick fibreboard, making the wall insulation better.

References

[1] Code for thermal design of civil building, (GB 50176-2016): 39.
[2] Design standard for energy efficiency of residential buildings (energy efficiency 65%) in Jilin Province, (DB22/T450-2007): 18.
[3] Huang Pei-ying. Prefabricated concrete sandwich wall insulation characteristics and design analysis [J] Chinese and Foreign Architecture, 2017 (07): 261 - 263.
[4] Panzhi Ying, Yu shui, Feng Guohui, Zheng Shu, Dinghong Yu. Heat insulation materials ability to affect Prefabricated analytical EEB [J] energy, 2015, 34 (04): 51 - 55.