CHEMICAL ENGINEERING TRANSACTIONS
VOL. 66, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Songying Zhao, Yougang Sun, Ye Zhou

ISBN 978-88-95608-63-1; **ISSN** 2283-9216
DOI: 10.3303/CET1866059

Application of Thin Polyurethane Plastering Thermal Insulation System in Building Energy Conservation

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In this paper, through the study of the principle and method of the preparation of rigid foam polyurethane foam, the foaming process was optimized and the best formula was obtained. The effect of thin plastering on the thermal stability of the composites was analyzed, and the mechanism of the action of coupling agent and straw fiber was discussed. Physical adding method was used to introduce thin plaster for rigid polyurethane thermal insulation material. Synergistic insulation system is formed in polyurethane system to improve its thermal insulation performance. At the same time, the failure mechanism of the straw fiber polyurethane foam was also discussed. It is concluded that the compressive strength of the straw wall reinforced foam plastics is enhanced due to the addition of thin plastering, which improves the compressive strength of the thin plastering polyurethane foam.

1. Introduction

The plastering is the layer coated with polymer adhesive glue on the external surface of the insulating layer. The layer directly coated on the insulation layer is the bottom coating and is relatively thin (generally 2~3 mm), with reinforcing materials included interiorly. The reinforcing materials are usually alkali-resistant glass fiber mesh cloth contained in and integrating with the plastering to improve the mechanical strength of the plastering layer, ensure its continuity, disperse the shrinkage stress and temperature stress, avoid stress concentration, and prevent cracks on the surface. Mesh cloth must be completely buried in the bottom coating, invisible from the outside, so as to separate it from the outside water (because the damp net mesh will significantly reduce its ultimate strength) (Tahsildoost and Zomorodian, 2015). For different external thermal insulation systems, the thickness of the plastering varies to a certain extent. However, as a whole, the thickness of the plastering must be appropriate, with that of thin layer ranging between 2~3mm. If the layer is too thin, it will be not firm enough to resist the possible external forces. On the other hand, if it is too thick, the reinforcing materials are too far away from the outer surface to prevent cracking (Colinart et al., 2013).

Polyurethane and polystyrene particle thermal-insulation slurry composite external wall thermal insulation system is a new type of thermal insulation system for external walls with excellent cost performance that is co-developed by relevant scientific research departments and experts under the guidance of the national building energy conservation policies and relevant provincial and municipal construction departments, to tackle existing bottlenecks in the external wall thermal-insulation technology to achieve the energy saving by 65%. The technical architecture of this system solves several problems such as cracking, low surface strength, and failure to add heavy-load ornaments on the surface like tiles (Amponsah et al., 2012).

Please refer to figure 1 for the structure of the composite external wall thermal insulation system with polyurethane and polystyrene particle thermal-insulation slurry.

Please cite this article as: Zhi J., 2018, Application of thin polyurethane plastering thermal insulation system in building energy conservation, Chemical Engineering Transactions, 66, 349-354 DOI:10.3303/CET1866059

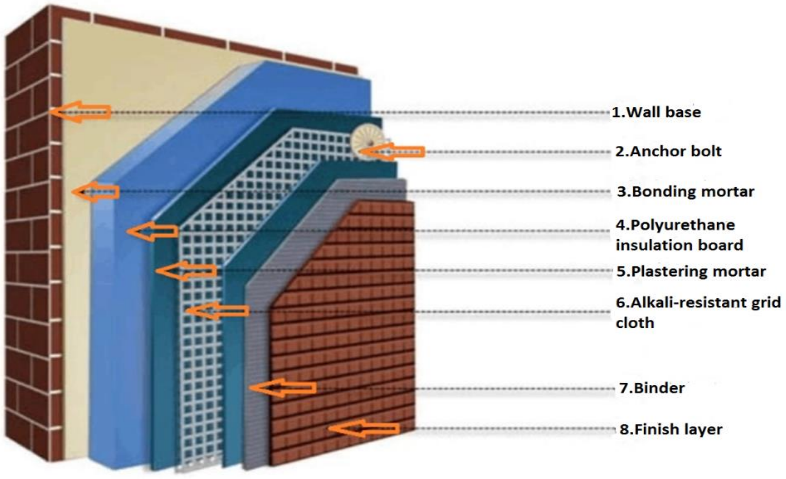

Figure 1: Schematic diagram of the structure of polyurethane thermal insulation composite exterior wall insulation system

2. The Selection of the Raw Materials and Production Process for the Composite External Wall Insulation System with Polyurethane Thin Plastering Insulation Slurry

The Production Process as shown in figure 2

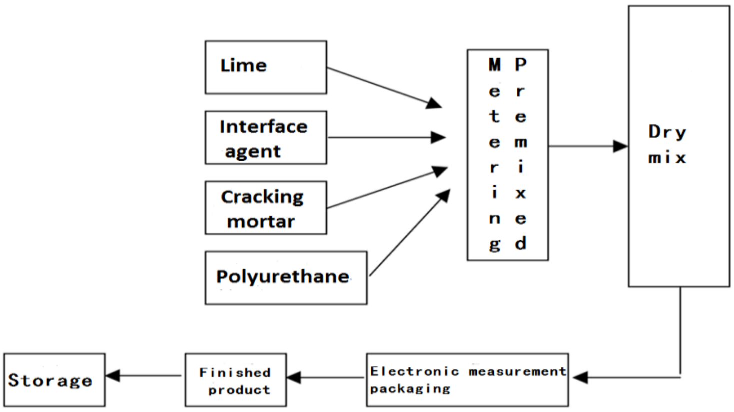

Figure 2: Process flow chart for the production of polymer dry powder mortar

Polymer dry mortar is used in the building exterior wall thermal insulation system for the thermal-insulation material paste, layer treatment, interface agent, exterior tile paste, and tile hook treatment. And polystyrene particles thermal-insulation slurry is used in the thermal-insulation layer of the building external wall thermal-insulation system.

3. Performance Test and System Test Result of Composite External Wall Insulation System with Polyurethane Thin Plastering Insulation Slurry

3.1 Analysis of Thermal Conductivity

The thermal conductivity is one of the critical indexes to evaluate the rigid polyurethane foam as an insulating material, so it is very important to obtain the low and steady thermal conductivity. The thermal conductivity of rigid polyurethane foam is determined by several factors.

$$\lambda_F = \lambda_G + \lambda_S + \lambda_R + \lambda_C \qquad (1)$$

In the formula, λF refers to the thermal conductivity of the rigid foam, with λG as the thermal conductivity of the gas phase, λS as the thermal conductivity of the solid phase, λR as the thermal conductivity of the radiation, and λC as the thermal conductivity of the convection (Kusnerova et al., 2014). The results show that the pore diameter of the rigid foam is very small, and the gas convection heat transfer in the hole can be neglected. During the heat transfer of foam, mainly heat conduction, heat transfer through radiation is relatively low. The thermal conductivity of the rigid foam depends mainly on the thermal conductivity coefficient value of the gas in the hole. The lower the heat conductivity coefficient, the lower the thermal conductivity coefficient value of the foam.

3.1.1 Influence of Gas Composition in Foam Holes

The gas composition in the holes has an obvious influence on the thermal conductivity of the rigid foam. Different foaming agents in the same formula will lead to various thermal conductivity, with details seen in Table 1.

Table 1: The influence of different gases on the thermal conductivity

Gas composition	Thermal Conductivity(W/(m·K))
CO_2	0.03
HCFC—141b	0.018
CO_2、HCFC—141b	0.021

It can be seen from the above table that if CO_2 is adopted as the foaming agent, the thermal conductivity of the rigid foam will be higher, and the proper mix of CO_2 and hcpc-141b can adjust the thermal conductivity.

3.1.2 The Influence of Aging Time

In the foaming process of polyurethane, with the increase of material viscosity, the pore structure will be strengthened until the holes are completely closed. Mix the A and B materials of rigid polyurethane foam, with the general cream time of 2-5 seconds and the non-stick time of 10-20 seconds. And after 10-15 minutes, the mix starts hardening. Different aging time leads to different thermal conductivity, with the results shown in Table 2.

Table 2: The effect of aging time on thermal conductivity

Recipe number	Density(Kg/m3)	Aging time(h)	Thermal Conductivity(W/(m·K))
PU-012	39.5	2	0.0215
PU-012	39.5	8	0.0218
PU-012	39.5	24	0.023
PU-012	39.5	156	0.0221

From Table 2, the thermal conductivity is relatively low at the initial shaping stage of rigid polyurethane foam, and tends to be steady after 24 hours with longer aging time and the gradually stabilized pore structure. The reason is that in the initial shaping stage, the foaming agent gas in the holes is high in the pressure and content, and then diffuse along with the aging time to enable a steady pore structure of the polyurethane foam.

3.1.3 The Influence of Density

The thermal conductivity of rigid polyurethane foam is closely related to and varies with density. In general, its thermal conductivity and density are positively related, with details in Table 3.

Table 3: The influence of density on the thermal conductivity

Recipe number	Density(Kg/m3)	Aging time(h)	Thermal Conductivity(W/(m·K))
1	31	48	0.0223
2	36.5	48	0.0201
3	45.2	48	0.0194
4	50.3	48	0.0193
5	53.9	48	0.0192

It is shown from Table 3 that when the density value is 35 kg/m3, the thermal conductivity of the rigid polyurethane foam is lower. The ideal density range for rigid polyurethane foam is 35—65 kg/m3, when the thermal conductivity can be maintained between 0.18—0.25W/ (m·K). When the density is low, such as less than 30 kg/m3, the thermal conductivity increases, which is mainly because the extremely low density of foamed plastics with higher opening hole structure ratio will result in increased thermal conductivity.

3.2 Bond Strength

Rigid polyurethane foam plastic, a polyurethane material same as polyurethane adhesives, because of its structure containing polar groups -NCO-, can improve adhesion to various materials. In particular, rigid polyurethane foam adopts on-site spray molding process which reacts on concrete or clay bricks to shape, providing excellent bonding effects with both physical and chemical bonding forces (Dong et al., 2014). Table 4 reflects the bond strengths of different primary wall materials and polyurethane.

Table 4: Cohesive strength of different base walls and polyurethane

Wall	Bond strength(MPa)
Concrete	0.32
Cement mortar	0.35
Solid clay brick	0.3
Asbestos board	0.28
Steel	0.33
Aluminum	0.32

3.3 The Influence of Density on Polyurethane Performance

Density as an important index of rigid polyurethane foam plastics has a significant effect on other properties of rigid foams. The rigid polyurethane foam for external wall thermal insulation, especially the on-site spraying type, if no strengthening measures, can bear the weight ≤60 kg/m2, with the density no less than 35 kg/m3. And taking into account the thermal insulation performance and cost factors, the density should not exceed 60 kg/m3. For the performance of rigid polyurethane foam with different densities, please see Table 5.

Table 5: The effect of density on the properties of polyurethane

Density (kg/m3)	Compressive strength (kPa)	Tensile (kPa)	strength	Thermal Conductivity W/(m·K)	Density Compressive strength tensile strength Thermal Conductivity Dimensional stability 48 h later(%)
35	325	265		0.0202	-0.5
45	432	310		0.0197	-0.3
55	460	362		0.0192	-0.3
65	510	412		0.0205	-0.2

As for the contact surface among solids, the heat convection in the heat transfer process is negligible, so the main influencing factors of temperature rise of the sample surface are thermal radiation and heat conduction (Forni et al., 2011). Generally speaking, the thermal conductivity of RPUF materials is in the range of 0.018-0.024 W/ (m·K). Assuming that the thermal conductivity of the sample is 0.018 W/ (m·K), the heat flux of heat conduction and thermal radiation in each temperature range can be calculated by formula, producing the curve of the influence of thermal radiation and heat conduction on the specimen in the sand bath process.

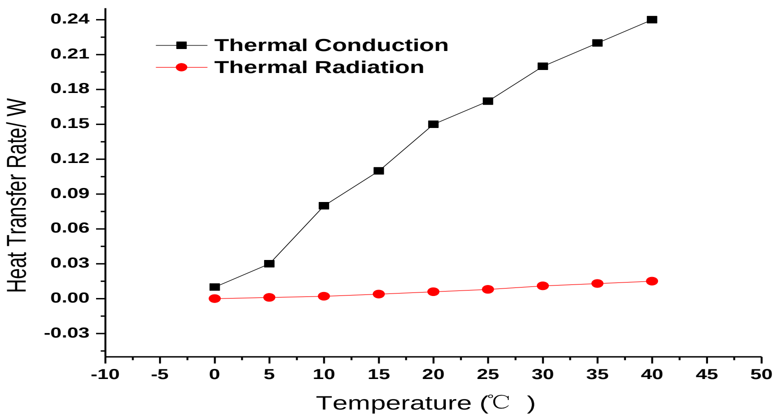

Figure 3: Curves of heat radiation and heat conduction on the thermal flow of a building sample

The influence of thermal radiation and heat conduction on the building specimen is shown in Figure 3. It can be seen from the figure that the thermal radiation has little influence on the temperature rise rate of the sample, while the heat conduction has the greatest influence on the temperature rise rate. Thus, in the test, the temperature rise rate curve of the sample mainly reflects the change of heat flux in the heat conduction process. In the structure, the polyurethane is sprayed on the external wall under high pressure, which is easy to bond with other substrates due to its own characteristics as a natural adhesive material with strong adhesion. It is fully attached to the external wall with no cavity (Hassan and Jonsson, 2014), which is especially advantageous to resistance to negative wind pressure for high-rise buildings. After the polyurethane foams, a thin film (crust) formed on the outer surface, which also serves as a waterproof layer with sound thermal insulation performance. Then, the layer of interface agent is sprayed with polystyrene particle thermal-insulation slurry combined (plastered) for better bonding. Polystyrene particle thermal-insulation slurry can not only serve as a supplemental thermal-insulation layer, but also a polyurethane anti-aging protective coating. And because of the thickness of 25 mm with a certain degree of cement strength, the thermal-insulation layer has enhanced resistance to external forces, which is an exclusive attribute compared with other external wall thermal-insulation systems.

4. Technical Advantage of Polyurethane Thin Plastering Insulation Slurry Compound External Wall Insulation System

4.1 Strong Stability

Polyurethane and polystyrene particle thermal-insulation slurry is a new technology for building energy-saving in the external wall thermal insulation. Through the application in engineering practices, it has obvious advantages despite some drawbacks to be improved (Gutiérrez-González et al., 2012). Rigid polyurethane foam shall be sprayed in solid bonding with the base wall, which is a premise to ensure the stability of the external thermal-insulation layer. The wall shall undergo interface treatment, such as loose or empty layers, to ensure that the rigid polyurethane foam thermal insulation layer is closely bound to the wall.

4.2 Sound Fireproofing Performance

Although the rigid polyurethane foam thermal-insulation layer is on the exterior wall, the fire prevention still cannot be neglected. After adding flame retardant, polyurethane becomes self-distinguishing material which is hard to light, and then form a fire prevention system combined with polystyrene granule slurry, effectively preventing the fire from spreading. Buildings' exterior walls, doors and windows are all tightly covered with fire-resistant polystyrene granular materials, with no disclosing parts. Thick polystyrene particles fire-proof plastering is conducive to improving the fire resistance of the thermal-insulation layer.

5. Conclusion

A variety of external wall insulation technology has achieved considerable development. Our country's exterior insulation technology played a certain role in the promotion and application of this technology. It not only improves the comfort living environment, and has a good energy saving effect and economic benefits. With the continuous improvement of building energy efficiency requirements and comfort requirements in China, the demand for external thermal insulation is becoming increasingly urgent, and the external thermal insulation market will expand rapidly. In recent years the domestic external thermal insulation technology has evolved rapidly, and it makes a useful contribution to building energy conservation state, also lays the foundation for China's actual technological transformation of energy-saving building and technology innovation. These practice projects has proved that as long as follow the regular exterior insulation requirements, and design and construct in accordance with the relevant requirements, the exterior insulation engineering quality is fully guaranteed.

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