Comparison of Building Energy Efficiency and Life Span for Different Envelopes

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Abstract: Unsuitable building energy saving technology will result in plenty building trash and waste buildings. In China, the life of many buildings is less than 50 years because of improper building heat preservation envelopes. It is found that irrational heat insulation measurement and heat preservation material position brings wall flaws and building life reduction. Comparisons of two building envelope heat insulation features are carried out by physical parameter measurements and calculation. The first is the internal heat preservation wall mode, which is mainly affected by indoor climate, and the temperature difference is generally less than 10^0C in a year. Second, in the external heat preservation wall mode, the temperature difference varies from 50^0C to 80^0C annually in cold and humid climates. The investigation results indicates that the external heat preservation wall mode is better compared with the internal heat preservation wall mode, and the former can effectively extend building life and provide occupants a more comfortable indoor climate. At the same time, this heat preservation technology can ensure building energy efficiency and economy. It is reasonable to adopt the external heat preservation wall mode to make the building safer and have a longer life compared with internal heat preservation. Assuming a 65% imperative national building energy saving standard calculation, the net cost is only RMB 10 Yuan increment with a 1% cost elevation due to the cost of envelope construction and heating system for the external heat preservation method.

Key words: building envelope, internal insulation, external insulation, building life, energy efficiency

1. INTRODUCTION

China is currently suffering from increasing pressure of energy shortage and environmental depravation with rapid population inflation. Building industry is becoming biggest energy consumption terminal with the rapid economic development and lagging energy saving technology generalization, the rate of which in total national energy utilization increases from 10% in 1970's to 27.6% in recent years [1], and among the building energy consumption, about 60% is utilization by heating, ventilation and air-conditioning (HVAC). Energy saving design standards of civil architecture (heating and residential section, JG26-86) was published in 1985 with a goal of 30% energy saving compared the common local standards prevailing in 1980. The China Ministry of Construction (MOC) developed revisions to this standard in July 1996 with a targeted energy saving rate of 50%[2]. Although China has implemented 50% imperative energy saving national standard from 1997 in building industry, and up to now more than 170 cities are enforcement the national standard, the effect of building energy saving and technological level are still dissatisfaction. China is seen to the medium-term and post-term flourish of building industry in 2000-2005. 14.906 billions m^2 building area and 9.616 billions residential building area are respectively existence in China up to the end of 2004[3]. And the new built area in 2000 was two times that of 1980s, and will be estimated to achieve 20 billion m^2 in 2020. It is well known that

reduction in heat penetration through building envelope is important and climatic design for energy efficiency in buildings as well [4]. The heat preservation methods of external wall adopted by architect and developer in recent years in China are multiples. Among these heat preservation methods, general adoption is internal heat preservation method, core heat preservation or even no heat preservation for the envelope for the sake of reduction fabrication cost. It is well known that unreasonable envelope heat preservation methods will badly decrease the life and comfort of buildings, and increase building energy consumption in the process of buildings operation. Assumption of average 20 years buildings life decrease is true, which is caused by unreasonable envelope heat preservation methods, and then tens billions of squares trash buildings will produce in 40-50 years in China. Buildings life reduction caused by unreasonable envelope heat insulation methods will not only result in low building energy efficiency but also building wastes in the process of operation and maintenance during the building life cycle (BLC). China has broad lands and multiple climates, which involves rigid cold, cold, summer hot and winter cold, warm climate and summer hot and winter warm climates, so the demand of envelope heat preservation is also great diversity. At present China is boosting building energy saving application from north (chilled and cold climate zone) to south (summer hot and winter warm zone), and manifold kinds of envelope heat preservation techniques are presented. Although these heat preservation applications can basically meet the requirement of building energy saving, the quality problems of envelope are still plenty of existence. Furthermore, the 95% of existed buildings and 20% of new built buildings can't achieve the national energy saving standard, which are hardly application of envelope heat preservation engineering. So it is extremely essential for buildings envelope to be application of appropriate and right heat preservation methods for the sake of energy efficiency and environmental affect.

The paper firstly surveys the heat preservation of buildings and building life reduction caused by unreasonable heat preservation methods, and then analyzes the reason of buildings destroy and the effect of heat preservation layer crack. Finally, two different heat preservation methods of building envelope are compared under the condition of cold climate and the economic analysis about external heat preservation is presented as well. In the paper, many parameters are analyzed mainly based cold climate conditions (such as extreme temperature difference), but the results are adaptive in other climate in China. In addition, envelope here mainly refers external as well.

2. HEAT PRESERVATION SURVEY OF OLD AND RETROFIT BUILDINGS

2.1 Building Envelope Quality, Maintenance And Building Life

The life or lifetime about building life assessment (LCA) involves the energy and material used and waste produced during the construction, operation, maintenance and demolition of buildings [5]. Building life in the paper refers the whole process from creating, operation and demolishment, which are not different of the general conception of LCA. The study in Japan indicated that the building construction aging accounts for 47%, equipment retrofit 7% among the short life buildings, and the rest belongs to social factors (such as the alteration of building utilization, cities reconstruction, elevation land benefit, and so on)[6]. These illuminate that more than half (54%) of buildings demolishment are the demotion of construction and equipment, which is forced to stop operation in advance. Of course, the rest (46%) is the result of shift of consumption concept and social demand). The case of short life building in Japan possesses considerable representative in other countries. In East Asia, short life residential buildings (30-40 years) phenomenon is the results of rapid economic development, city expanding, and population transfer. The National Standard of China stipulates that the building life is 100 years and 50-100 years for the main construction of important or high-rise buildings and common buildings respectively [7]. Detail reports and study are not available in China

up to now, but in fact with our simple survey, the building life, especial for residential buildings, is often seen less than 30 years in cities. For example, recent survey indicated that the average building life in Beijing is only 30 years, while that of America is 80 years, Switzerland with 70-90 years and Britain even to 132 years [8]. In China, many buildings even have to be retrofitted and maintained only several years after completion. Besides inferior construction quality, groundsill sinkage, layout regulation and traffic pressure, the survey also shows that the reason of quite a few buildings life reductions is unreasonable heat preservation configuration, which renders the walls crack. Most developers of residential buildings only cater to market demand without or with little research of building fashion, building energy efficiency, building flexibility. The most important reason is that in China, the residential building maintenance fund is provided by buildings owners but not by developers, and loose quality and layout supervision by government before the houses deliver to owners. Although the quality of residential buildings is gradual improvement, the problems of leakage and cavitation are conquered in certain extent. However, new quality problems such as wall crack are becoming general with the population of envelope heat preservation engineering. At present, quite a few wall quality bugs rises in completed residences involving crack, dew condensation, mildew and fall-off, and among of which, the problem of wall crack is most severely. Unfortunately, no government department or developers in China will concern the applicability and adaptability as well as flexibility of residential building after the house is delivered to owners in 10 years or even 5 years.

2.2 Methods Of Envelope Heat Preservation

There are two methods of envelope heat preservation in the application in China. One is external heat preservation method, and another is internal heat preservation method (Fig.1, (a) and (b)). External heat preservation method refers the construction of heat insulation layer out of envelope (bearing wall). This heat preservation configuration can meet the requirement of waterproof, wind pressure and exquisite temperature variety because of implementation external side heat preservation of the bearing wall. Moreover, it can withstand the outside attack not easy to crack and attain favorable protection and decoration between border upon place (door, window, pipeline) and corner of wall, thus the application is more and more exclusive. The application of external heat preservation can make the residential buildings keep original state during several decades operation.

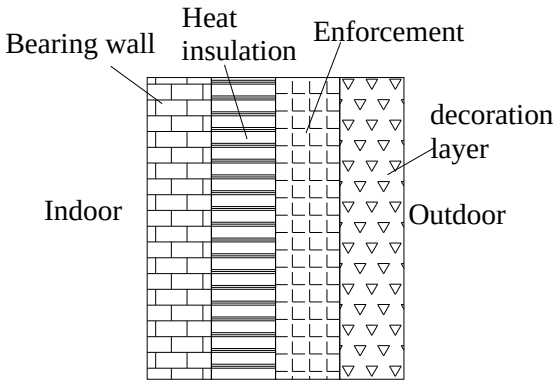

Fig.1 (a) External heat preservation structure

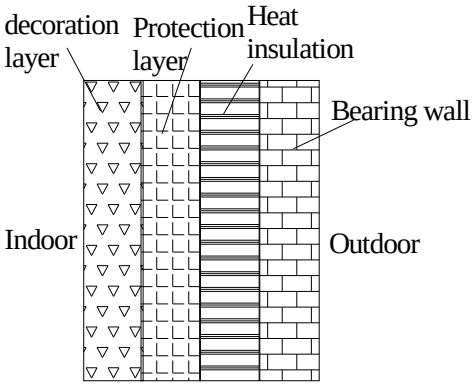

Fig.1(b) Internal heat preservation structure

At present in China, common envelope heat preservation is adoption of internal heat preservation, because the risk of this method is smaller compared with external heat preservation. Internal heat preservation method is that the heat insulation plank attaches on indoor bearing walls. Prefabricated insulation plank is applied for the sake of decrease damp operation in engineering practice, which is machined and processed in factory and is sticked in field in order to be convenient. In our survey, the internal heat

preservation wall will produce some extent split after construction 3 months to one year, and it is especially obvious at the connection slot of heat insulation planks. This construction envelope crack caused by internal heat preservation is called "internal heat preservation technology syndrome"

2.3 Effect Of Envelope Heat Preservation Crack

The crack of envelope caused by heat preservation layer will great harm, so it is one of the key techniques that should be settled in wall heat preservation engineering. Theoretically, wall body including bearing wall, heat preservation, protection layer and decoration layer all will produce crack, which also accords with our survey. Here we discuss the crack caused by heat preservation problems, although the crack may be location not only at heat preservation layer. As above-mentioned, envelope heat preservation method can divide internal and external heat preservation, and accordingly, the wall crack can also divide internal and external heat preservation respectively. Internal heat preservation wall crack mainly locates in the interconnection of heat preservation planks, surrounding of windows, transition of heat preservation wall and the corner of windows. While external heat preservation wall crack mainly locates in the daughter walls, interconnection of heat preservation planks, surrounding of windows and the middle of large area walls. It is general seen the internal heat preservation wall crack more than external heat preservation wall crack.

Two disadvantages will be produced if wall crack occurs. One is degradation of wall quality such as integrity, outlook, enduring and resistance-shake performance, and it is even hazard to construction safety for collapse, which is sharp reduction the building life and increase the cost of operation or maintenance. Another is decrease the building energy efficiency, which can't meet the energy saving requirements due to the awfully variety of the wall heat preservation performance. In cold and damp climate, the decrease of envelope heat preservation performance also renders the internal wall dew condensation, which brings indoor environment mildew with adverse comfort.

3. METHODS

The most basic method in the study is field investigation and physical heat transfer model analysis. It is investigated by engineering practice and statistical data that the crack by distortion, especially by temperature rapid alteration or temperature and outside force together action, accounts for more than 80%, while the rate of crack of envelope merely by the outside force demolition is little in terms of collision, wind pressure and earthquake. The crack of wall is mainly caused by different distortion rate and stress at the interface of two materials and two layers in the wall. The main elements of wall distortion are constitution of temperature, humidity and gravity that cause different layers of the wall shrinkage and expand rate or asymmetry settlement. Different building materials under the same temperature and same materials under different temperature presents different distortion rate of hot expand and cool shrinkage, which will produce thermal stress in the interface of different building materials. Frame construction and light filled wall, its conductivity coefficient is 1.74 w/(m•k), and gas-filled concrete brick is 0.2 w/(m•k), which is discrepancy about 8 times. The conductivity coefficient of concrete sand mixture is 0.93 w/(m•k) with discrepancy 4-5 times compared with gas-filled concrete brick. Thus different distortion rate will produce with the temperature variety. This distortion causes crack and destroy between steel concrete frame and light gas-charged wall, between bearing wall and heat insulation layers after several months or years. Different season and climate, even different time in a day, whole building is a unsteady body, the temperature difference of wall makes location distortion production in the place of interface of doors, windows, walls and rooftops.

At present, the application of high-efficiency heat preservation material in China, its conductivity coefficient is all below 0.06 w/(m•k). These heat preservation materials present strong thermal fluxes obstruct performance, which makes the two side of the construction, even on the two sides of same layers large temperature difference. As example of

internal heat preservation, the annual average temperature difference variety of the internal side of heat preservation wall and floor is comparatively small (less than 10^0C), since it is affected by indoor temperature. While which of external side of heat preservation is considerable large (50^0C~80^0C), since it is decided by outdoor climate. For example, the surface temperature of decoration layer and protection layer can attain to 80^0C under the violent solar radiation in summer, but the temperature may decrease to 30^0C if encountered heavy rainfall, and the temperature of outdoor can obtain -50^0C but indoor temperature is above 20^0C in cold climate in winter. The linear expand coefficient of concrete is 1×10^{-5}m/^{0}C , and that of concrete sand mixture is slightly larger than concrete, about 1.5×10^{-5}m/ , but the linear expand coefficient of heat insulation materials is greater 6-8 times. Thus stress and distortion are formed if these materials are constituted together at their interfaces. At the calculation of linear expand coefficient difference 1×10^{-5}m/ of each materials, a building of 50m high which is adoption of internal heat preservation techniques will render 25-40 mm distort difference. This distort difference enough makes wall body to crack at the different locations and demolish the construction of the buildings.

In addition, besides the distortion caused by temperature, the distortion caused by humidity variety is also not neglected. For example, distortion and crack of the wall by unqualified waterproof and configuration, and absorption moisture or froze ice melt by the envelope will cause wall body destroy. In cold and damp climate, heat preservation layer of the wall is often in the humidity if the dew condensation of the wall can't be effectively controlled. In cold climate, dew condensation will often occurs in winter at the temperature difference between indoors and outdoors. Assumption the indoor temperature 20^0C and 70% related humidity, the dew point temperature is 14^0C, and then the wall surface will be appearance of dew once below 14^0C. If the heat preservation layer locates in the internal side of the envelope in the heat preservation engineering, the temperature of wall body will almost below 14^0C in winter in cold climate, that means dew condensation occurrence in the interface of heat preservation layer and bearing wall. If the heat insulation materials possess no favorable resistance of vapor penetrability, the absorption of heat preservation will envoy its conductivity coefficient increment more, which promotes the dew condensation phenomenon. At present the most applied heat insulation materials in China belong slurry style materials, which are easy soft encounter water and lose strength. Of course, bearing wall will also lose intension if moisture absorption. These all result in crack and demolish the construction of buildings.

4. COMPARISON OF ENVELOPE HEAT INSULATION MEASURE

As above-mentioned, two kinds of heat preservation techniques are existence in China, which is internal heat preservation and external heat preservation. Present general adoption in China is internal heat preservation method or even no heat preservation for the envelope for the sake of reduction fabrication cost. Internal heat preservation method (Fige.1 (b)) makes the bearing wall exposure in the unfavorable outdoor climate conditions. Although this kind of heat preservation also can keep the enclosure construction some extent heat insulation performance, this unreasonable heat preservation techniques no doubt will bring plenty of waste building due to the illogical heat preservation layer place, and this also makes the building life decrease 20 years, while the life of heat preservation itself will reduce as well. That is equivalent decrease of building energy efficiency.

External heat preservation technique (Fig.1 (a)) is the main application of building energy saving technology, but it is seen comparative little in China. Present main external heat preservation for the outdoor wall involves polypropylene, polymer plank and expand polymer compound plank. External heat preservation method can eliminate the thermal bridge of the envelope, especially in the sensitive places such as in steel concrete poles, floors and girders, which will decrease the heating and refrigeration load during building operation,

thus reduce the total cost of energy to benefit environment protection. Furthermore, it can protect bearing wall dry and make the envelope of the buildings favorable climate adaptability and resistance of aging, which can extend about 20 years life for buildings. In addition, external heat preservation techniques can effectively reduce the thermal stress received in building construction, which is avoidance of crack production due to the temperature variety under the climate shift. It is also estimated that external heat preservation method make envelope favorable resistance of crack safety and collision performance, which is about 4 times and 10 times more than traditional concrete heat preservation system respectively. Table 1 illuminates the comparison of main features both internal and external heat preservation.

Even for the external heat preservation method, the design and application of different wall heat preservation engineering practice is different because of different building materials, building shape, building construction and climates. Because in heat preservation engineering practice, the crack problems caused by construction operation are comparative excessive, it is important to regulate the construction operation and supervise the quality. Effective measurement should be carried out during the construction of heat preservation engineering, and professional direction by the building material supplier is the significant means of quality guarantee based their production features.

5.ECONOMIC ANALYSIS OF EXTERNAL HEAT PRESERVATION

The study by Kenneth D. Walsh et. al. indicated cost of 1% benefit from upgrading the wall system $443.12[9]. External heat preservation of envelope configuration is cost-efficient and affordable for the residents in China. As the demand of 50% building energy saving standard, which is also the imperative national standard, present applied heat insulation products can meet the requirement of building energy saving. The original investment of per square external wall area cost increases RMB 40 Yuan if adoption of polymer benzene plank as heat insulation material, and the cost of per square of buildings area increases RMB 20 Yuan accordingly. According to the average price RMB1400 Yuan calculation, which is the direct construction cost of common multilayer steel concrete brick framework residential buildings in China, the construction cost of external heat preservation is only 1.5% increment. For the external windows, present products.

If calculation as 65% imperative national building energy saving standard, the average original investment per square with envelope cost is RMB 50 Yuan, which is only 2.5% construction cost increment. But this will make the original investment of heating system cost decrease RMB 40 Yuan, which accounts for 18% total heating system cost. So the net cost is only RMB 10 Yuan increment with the 1% cost elevation integration the cost of envelope construction and heating system.

For the windows, the average cost of increment is RMB 50 Yuan, and the total cost building increment about 0.8% if as the 65% energy saving standard design. Therefore, Chinese residents can accept the cost increment caused by envelope heat preservation. Furthermore, as the increase of cost in building envelope heat preservation, the expense in heating system will also decrease simultaneously. Once the favorable heat preservation application is successfully carried out, the design capacity of heat source, pipeline, pumps and heat exchangers is accordingly reduction

Tab 1. Comparison of internal and external heat preservation

Item	internal heat preservation	external heat preservation
principle	heat preservation layer location the internal side of bearing wall	heat preservation layer location the external side of bearing wall
cost	relative low	relative high
construction	easy	difficult
application	extensive	limitative
protection for building	poor	good
building energy efficiency	common	excellent
building life	reduction 20 years	postpone 20 years

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6. RESULTS AND DISCUSSION

Two heat preservation methods in envelope heat insulation engineering are investigated and compared in the paper. Unsuitable envelope heat preservation methods will produce different temperature environment between external and internal wall, which causes different stress and distortion in the different place of the envelope, thus crack and tiny split will occur. If reiteration of stress and distortion is made in a period, then crack and tiny split will grow, and the buildings will be destroyed.

In our survey, the buildings life less than 50 years are often seen, many of which is caused by wall crack due to unreasonable heat preservation techniques. Because of temperature difference and humidity action, the linear expand coefficient between heat insulation layer and bearing wall materials is greater 6-8 times. Thus stress and distortion are formed if these materials are constituted together at their interfaces. A building of 50m high which is adoption of internal heat preservation techniques will render 25-40 mm distort difference. This distort difference enough makes wall to crack at the different locations and demolish the construction of the buildings. Internal heat preservation method reduces buildings 20 years life, but external heat preservation method increases 20 years life. External heat preservation of envelope configuration is cost-efficient and affordable for the residents in China. If calculation as 65% imperative national building energy saving standard, the net cost is only RMB 10 Yuan increment with the 1% cost elevation integration the cost of envelope construction and heating system.

The envelope heat preservation engineering is affected by clime and height of building. China has broad lands and multiple climates, which involves chilled, cold, summer hot and winter cold, summer hot and winter warm and transition zone climates, so the demand of envelope heat preservation is also great diversity. In the heat preservation engineering practice, the design, materials selection and construction all should be considered according to the height of buildings, orientation, ventilation, temperature and humidity.

A principle should comply for windows in building energy saving, and it is must be avoidance production of heat bridge through the connection between heat preservation layer and windows as to a same system. Generally speaking, external heat preservation method is protection of bearing wall from outdoor climate and avoidance of the environmental influence for building construction, it also can assure the favorable indoor environment.

7. CONCLUSIONS

It is reasonable for adoption of external heat preservation in China, and the ability of resistance water and collision is better for building envelope compared with internal heat preservation techniques. It can effectively extend the building life through protection of envelope. Moreover, higher building energy efficiency and lower building cost during in operation can be obtained utilization of external heat preservation. The original investment

increment of external heat preservation is affordable for Chinese residents. So it deserves generalization and application for this reasonable heat insulation. Of course, more regulation and policy should be established in China to encourage and pilot favorable application of external heat preservation consideration the short-term behavior adoption by the developer at the present.

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