Research on Construction Technology of Ultra-Low Energy Reconstruction of Existing Buildings

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Abstract. Taking the renovation project of the family building of the Hebei Academy of Building Research as an example. This paper studies the construction process and construction points of the ultra-low energy transformation process, and forms a complete and refined ultra-low energy consumption of existing buildings. Reconstruction of construction technology provides a reference for the promotion and application of ultra-low energy consumption technology in the energy-saving renovation of existing buildings.

1. Introduction
Building energy saving should not only do well in new building projects, but also pay attention to the effect of energy saving transformation projects. Ultra-low energy buildings with its unique advantages has become the focus of building energy conservation.

The renovation project of the building of the Hebei Academy of Building Research put the ultra-low energy consumption technology applied to the existing building energy saving transformation. In this paper, the construction technology of ultra-low energy consumption transformation of existing buildings will be studied to form a complete and refined set of ultra-low energy consumption transformation construction technology.

2. Existing building external wall reconstruction construction technology
The ultra-low energy consumption renovation construction of existing buildings mostly adopts the external wall insulation system and general uses of double-layer seam paste method for construction. Heat transfer coefficient of exterior wall of ultra-low-energy buildings is 0.15W/(m²•K).The thickness of insulation layer in cold areas is 200mm~300mm, it's necessary to paste the layered staggered seam. In the process of ultra-low energy consumption transformation of existing buildings, graphite polystyrene board should be used as the external wall insulation material.
2.1. **Metope basic level treatment**

When the external walls of existing residential buildings are reconstructed, the base should be treated effectively first, so as to ensure the effective bonding between the base and insulation materials. In the grass-roots processing, should pay attention to the following points: a. The old coating should be completely removed, the face brick that is opposite loose, empty drum and Mosaic should knock off and use high pressure faucet to float and sink wall surface clean; b. The base shall be smooth, strong, dry, free of pollution or other harmful materials; c. Fire ladders, water pipes, burglar-proof windows embedded parts, or other embedded parts, inlet pipelines or other reserved holes outside the walls shall be constructed in advance according to the requirements of the design drawings or construction acceptance codes; d. Door and window hole should pass acceptance, dimensions and positions meet the design quality requirements, and door and window frame already installed; e. The holes of the bolts on the outer wall should be sealed with polyurethane foam.

2.2. **Insulation layer paste**

In view of the uniqueness of ultra-low energy consumption buildings, in the process of external wall construction and renovation, it is necessary to strictly control the insulation board paste process, which usually adopts the layered and staggered paste method. The size of the external insulation polystyrene board is 600mm×1200mm, actual construction according to the size of the need to cut with a tool, the cut must be perpendicular to the plate and the minimum size of the graphite polystyrene board at the corner of the whole wall shall be greater than 300mm. Row plate according to the horizontal order, up and down staggered seam paste, the Angle of Yin and Yang do staggered raft processing.

2.2.1. *The first layer of graphite polystyrene board is pasted with dot-frame method.* Using notched sickle to stick mortar vertically and evenly on the graphite polystyrene board. Around the board daub a ring of mixed bond mortar, and the width is generally 50mm. Evenly daub 3 points in the center of the board, the paste area is not less than 40%. Paste it on the wall as soon as you finish, after sticking it on the wall, press it flat with a 2m ruler to ensure the flatness and firmness of sticking, as shown in the figure 1.

Graphite polystyrene board should be jointed tightly, plate surface vertical, flat, allowable deviation not more than 3mm, or using the appropriate thickness of graphite polystyrene batting plug seam. The height difference of the board surface shall not be greater than 1.5mm, and if it exceeds the height, sandpaper or special grinding machine shall be used for polishing and leveling. When grinding, do not polish along the direction parallel to the graphite polystyrene plate seam, should do gentle circular motion, with the brush cleaning debris and floating and sinking.

![Figure 1. Dot-frame paste](image1.png)

![Figure 2. Full-sticky paste](image2.png)

2.2.2. *The second layer of graphite polystyrene board adopts full sticky method.* The first layer of graphite polystyrene board paste 24h, can be used to paste the second layer of graphite polystyrene board full stick, as shown in the figure 2. Immediately after coating the graphite polystyrene board paste on the wall, with 2m against the ruler to flatten, ensure flatness and paste firmness. When pasting, please pay
attention to remove the overflow of glue paste between the board and the board. The split seam treatment method of the second layer is the same as that of the first layer.

2.3. **Drill hole and install insulation nail**

The construction of insulation nail shall be completed after the second layer of graphite polystyrene board is pasted for 24h and the bonding mortar reaches the specified strength. The insulation nail shall be drilled in the corresponding position of the insulation board according to the construction layout drawing. The insulation nails should be installed at the four corners of the insulation board to prevent the feet from rising. When installing insulation nails, the diameter of the hole should be 2mm larger than that of the insulation nails, the depth of the hole should be 5cm deeper than the base wall, and the number of insulation nails should be no less than 4 per square meter, as figure 3 shows.

![Figure 3. Insulation nail typography](image)

2.4. **Paste alkali-resistant glass fiber mesh cloth**

Inspection and acceptance with anti-crack mortar plastering, the bottom anti-cracking mortar is evenly coated on the surface of graphite polystyrene plate with a thickness of 2~3mm, the special high strength alkali resistant mesh cloth is tensioned on the bottom anti-crack mortar, the curved surface of the mesh cloth is towards the wall, and the mortar is pressed into the surface layer of the mortar from the middle to the four sides with the plastering knife, so that the mesh cloth is embedded in the mortar without wrinkles. After the surface is dry, the anti-crack mortar of precauser layer shall be of a thickness of 1.0mm to ensure that the mesh cloth is not exposed.

In case of overlapping, the overlapping requirements of 100mm horizontally and 100mm longitudinally must be met. The part to be cut off shall be overlapped with supplementary mesh, and the length of overlapped connection shall not be less than 100mm.

2.5. **Paste alkali-resistant glass fiber mesh cloth**

When the plastering base surface meets the construction requirements, the surface construction can be carried out, the same as the ordinary surface finishing process, generally use matching special materials or other paint compatible with the insulation system.

3. **Existing building outside doors and Windows renovation construction technology**

Doors and windows of ultra-low energy consumption should check whether the size and flatness of the Windows conform to the actual requirements before construction. Avoid the size deviation and distortion of window frame caused by unqualified production and processing, improper transportation or improper stacking on site.
The ultra-low energy window adopts the energy saving window with the whole window heat transfer coefficient $K_w \leq 1.0$ W/(m$^2$·K). The window glass adopts three glasses and two hollow glass (6mm+Trisilve low-E glass+12A(95%Argon gas)+6mm Toughened glass+12A(95%Argon gas)+6mm Mono-silver Low-E All-toughened glass), The outer door adopts energy-saving door with heat transfer coefficient $K_w \leq 0.8$ W/(m$^2$·K). External Windows of existing buildings should be installed in an embedded way, the outer door adopts the installation method of hanging type, as figure 4-5 show.

3.1. The details of the window opening
The window hole must be refined before installation to ensure that the flatness, perpendicularity and the dimension of Yin and Yang Angle of the hole meet the design requirements. Doors and Windows of the same type and their adjacent upper, lower, left, right openings should be horizontal and vertical, maintain the same vertical and horizontal line.

3.2. Outside window positioning, window frame fixed
First determine the position of fixings on both sides of the bottom of the window frame and drill holes to install expansion bolts. When finished, place the window frame on both sides of the bottom of the hole as the supporting point, after adjusting the position of the window frame, mark the fixed points of the remaining positions. Insert the window frame inside the hole, make the outside of the window frame flush with the outside of the hole, fix the window frame inside the hole with expansion bolt. During the fixing process, the deviation should be adjusted timely to ensure that there is no visible gap between the window frame and the wall contact surface.

3.3. Paste waterproof poncho
Pasting outside waterproof rain cloth above all, waterproof rain cloth sticks the side upside down on window frame oneself, hit next on wall body sealant, make sure sealant covers the aperture between window frame and aperture completely, stick the waterproof rain cloth on the sealant to ensure that the waterproof rain cloth and the wall stick tightly, without bubbles or wrinkles. The procedure of pasting water proof rain cloth on indoor side is the same as that on outdoor side.

3.4. Installation of window sills
Make outer windows waterproof and sealed, after the wall insulation is done around the outer window, the installation of window sill board is needed. The material is generally stainless steel or aluminum window sill board made of finished products.

Figure 4. External window installation schematic
Figure 5. External door installation schematic
4. Existing building roofing reconstruction construction technology

Ultra-low energy roof insulation materials should have low water absorption, small thermal conductivity, and a certain compressive strength characteristics. Therefore, roof insulation materials usually use extruded polystyrene board. The construction technology of ultra-low energy consumption roof reconstruction is basically the same as that of ordinary reconstruction.

4.1. Basic level processing

When ultra-low energy consumption reconstruction is carried out on the roof, the original roof structure should be removed, debris removed and cleaned with water. Protruding base concrete knot, steel bar head, mortar, floating concrete and so on chisel away. There is at least 3cm gap between the outer wall of all kinds of air outlet pipelines with reserved holes, and the gap is filled with polyurethane foam to cut off the heat conduction between the roof board and the pipeline.

4.2. Insulation layer construction

Due to the thickness limitation, the ultra-low energy insulation board needs to adopt three layers of staggered seam dry laying. Laying the first layer of XPS board should be carried out after the construction of the first waterproof layer. According to the shape and size of the base, reasonable blanking to insure the patchwork. Flat roof insulation adopts dry laying form, board and board between vertical staggered seam, staggered, close and reliable. If the seam is larger than 2mm, the corresponding width of extruded polystyrene sheet shall be used for filling, or polyurethane foaming agent shall be used for filling. The second layer and the third layer are laid with staggered seams. After the laying is completed, it is guaranteed that the three-layer extruded polystyrene board should be smooth and neat, with tight seam stitching and no obvious gaps. The seam stitching over 2mm meets the requirements after treatment, and there is no empty drum feeling under foot.

4.3. Construction of waterproof layer

The first waterproof coil, in cement mortar leveling layer to reach the specified strength, first uniform brush a basic treatment agent (more for adhesive bitumen primer). After the coating of waterproofing base treatment agent is finished, lay a self-adhesive waterproof rolling material and meet the requirements of lap connection. After the laying, the waterproofing layer shall be well protected to avoid damage.

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**Figure 6.** Roof node schematic

**Figure 7.** Roof insulation board laying
The second layer of waterproof coil shall be constructed after passing the acceptance of insulation layer. Cement perlite for slope searching and cement mortar leveling layer.

5. Existing buildings without thermal bridge reconstruction construction technology

The following principles should be taken into consideration in the construction of ultra-low energy consumption buildings:

a. The protruding member and the insulation main structure are insulated to prevent the heat transfer;
   b. Plan and reserve the position of metal components in advance, and conduct heat insulation treatment between the main structure;
   c. Insulation layer should be continuous no gap, uniform thickness, uniform quality.

In the reconstruction of existing buildings with ultra-low energy consumption and heat-free bridge, the most common parts that need to be treated without heat-free bridge are pipe crossing node and air-conditioner rack installation node.

5.1. No thermal bridge construction technology for pipeline crossing wall joints

Holes should be reserved when the pipe goes through the outer wall. The size of the casing is two sizes larger than that of the pipe, and the size of the hole is about 100mm larger than that of the pipe. The gap between the inner wall of the pipe and the casing should be filled with polyurethane foaming agent, which is required to be dense. Polyurethane foaming agent can effectively block the thermal bridge between the outer wall and the pipe. After the polyurethane foaming agent is dried, remove the excess foam, paste the waterproof vapor barrier film and waterproof vapor permeable film on the root of the pipe, paste them on the base hole with a good performance binder, and lap the wall with 150mm size and the pipe with 100mm size. The outer insulation is consistent with that of the main wall.

5.2. No thermal bridge construction technology for installation node of air conditioner frame

The installation position of air conditioner rack is a common hot bridge position. The air conditioner rack is directly connected with the main body wall, which will destroy the continuity of the insulation layer. In the process of ultra-low energy consumption transformation, high strength foam glass is added to the contact part between the fixed steel plate of the air conditioner frame and the wall as the pad of the broken heat bridge. The fixed steel plate, foam glass and main wall of the air conditioner frame are fixed with expansion bolts and covered with thermal insulation materials. The junction between the air conditioner frame and thermal insulation is sealed with waterproof tape and sealed with waterproof sealant to ensure the continuity of thermal insulation.

Figure 8. Pipe through wall node schematic

Figure 9. Air conditioning rack installation node schematic
6. Conclusion
Ultra-low energy consumption renovation projects of no.2 and no.3 buildings of the Hebei Academy of Building Research provide a new template for the ultra-low energy consumption transformation of existing buildings and becomes the first project of ultra-low energy consumption and energy saving transformation of existing residential buildings in China. This paper studies the construction technology and key points in the process of ultra-low energy consumption transformation, and forms a set of refined ultra-low energy consumption transformation construction technology, which provides technical support for the complete construction of ultra-low energy consumption transformation of existing buildings and provides reference for the popularization and application of ultra-low energy consumption buildings.

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References
[1] DAI Zhanbiao, ZHAO Shiyong, SU Mubiao. Study on Construction Process of Exterior Insulation of Passive House [J]. Construction technique, 2017.11 (22): 93-96.
[2] Cui Shaohua, Fu Sujuan. Application of passive low energy building energy saving technology in existing residential buildings [J]. The construction of science and technology, 2017.06: 29-31.
[3] Hao Yuhang, Shi Yuanyuan, Fu Sujuan. Study on Graphite Polystyrene Board Applicated in the Energy-saving Reconstruction of Exterior Walls in Existing Building [J]. The construction of science and technology, 2018.11: 18-21.
[4] GUO Xianfa, ZHAO Shiyong, SU Mubiao. Research on Selection and Installation of Passive Window [J]. Construction technique, 2017.11 (22): 97-100.