

# RESEARCH AND APPLICATION OF THE DRY-HUNG AND WET-LYING CONSTRUCTION TECHNOLOGY OF TILED-ROOF WITH STEEP SLOPE IN SEVERE COLD REGION

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## ABSTRACT

Based on the project of Hengda Oasis in Shenyang, this paper fully studies the construction technology of the tiled roof with steep slope in severe cold region, and proposes that the new technology of dry-hung and wet-lying is a good way to solve the common faults existing in the construction of roof with steep slope in severe cold region, which offers a good example to similar projects. It has a promising prospect and popularizing significance in severe cold region.

**Keywords:** *Severe Cold Region, Tiled Roof, Steep Slope, Construction Technology.*

## 1. INTRODUCTION

With the development of use function of residential architecture in our country and the variety of architectural styles, more and more residential roofings are designed into reinforced concrete slab paving decorative tile in the tile roof. To some extent, this changes the monotonous, dull style of city roofing and adds a lot of bright spots for urban construction. But there are also many construction problems and quality defects of slope roofing. The greater the slope is, the more problems there will be, in particular, especially when the slope is greater than 60°, the tile roof slope engineering is significantly affected by weather factors. Because the cold architectural seasonal characteristics is obvious in the climate region, temperature difference is great in four seasons, cold in winter, hot in summer, and windy and dry in spring and autumn, these regional climate characteristics bring a lot of impact on the pouring of large slope tile roof and the construction of waterproof layer. In this study, a large number of instances of construction are collected.<sup>[1]</sup> The new construction technology of large slope of hanging wet lying tile roof in cold regions is put forward by analyzing and summarizing. The technology not only solves the above-mentioned problems in the construction of large slope tile roof in the cold regions with advanced technology and safe, reliable molding quality, and reasonable economy. The technology has passed the technical appraisal of the Committee of Experts of Bureau Four of China

State Construction. Its integrated construction technology has reached the domestic leading level. In summary, the new technology has good prospects for the development and promotion significance in cold regions.<sup>[2]</sup>

## 2. PROJECT PROFILE

The first-phase project of Hengda Oasis in Anshan is located in Lishan District of Anshan, to the east of Shengli Road, to the west of Jiancai Street, to the north of Binhe Road, having the convenient transportation, complete public facilities and flat terrain. The first-phase project consists of six 33-floor high-rise residential buildings, i.e. Building No. 5, Building No.6, Building No.7, Building No.8, Building No.9, Building No.10, and all high-rise buildings are shear wall structure, with a total construction area of about 180,000 square meters. In the project, there are total of 24 tiled roof towers with steep slope in the residential buildings, adopting the method of dry-hung and wet-lying in the engineering construction of roof with steep slope in severe cold region.

The rework does not occur in the construction of Hengda Oasis project. The degree of horizontal control for roof panel is within allowed limits, and there is no honeycomb, holes, pitted surface and fracture in the panel. The effect of waterproof, thermal insulation and energy-saving of roof as well as hanging tile shaping quality can meet the requirements for design and specification. The primary acceptance rate can reach 100%.<sup>[3]</sup>

### 3. KEY CONSTRUCTION TECHNOLOGY

#### 3.1 Process Flow

The construction process of “Dry-hung in the engineering construction of roof with steep slope in severe cold region” is shown as below:

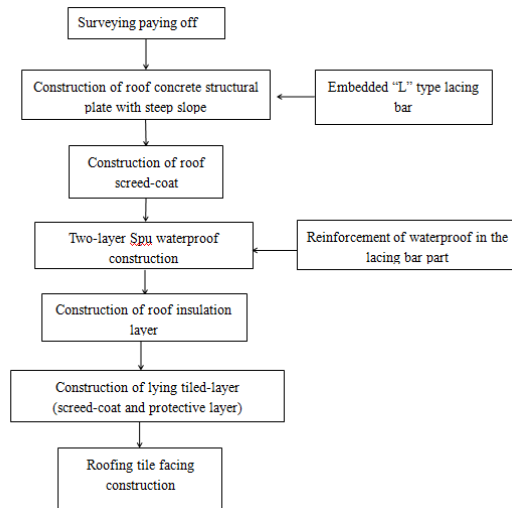


Fig. 2.1 Process

#### 3.2 Key Construction Technology

##### 3.2.1 Construction of Concrete Structural Slab of Roof with Steep Slope

(1) Full fastener-type steel pipe scaffold erection;

(2) After the completion of construction of roof slab bottom steel bars, put “几” shape reinforced stirrups, and then install top bars on the roof boarding;

(3) Lay upper formwork of sloping roof plate, in the construction of roof concrete structural slab, along the direction of roof slope and within 3/4 bottom-up range, adopt “the construction methods similar to shear wall double-sided formwork supporting in the construction process of main structure”. Within 1/4 range above the roof structural slab, adopt unilateral formwork.

(4) For the roof floor is higher and its slope is steeper, the commercial concrete is adopted and concrete slump is controlled. The concrete is poured into the sloping-roof concrete face in the form of pouring wall concrete. Within the scope of non-double-sided formwork, the artificial heaped-up concrete is adopted. In the range of double-sided formwork, the small plug-in vibrating rod is used for vibration. Within 1/4 range above non-double-sided formwork, the concrete pouring adopts the

artificial paving and vibrating compaction, striking and trowelling.

(5) The concrete need to be watered for maintenance in 7 days after completion of pouring.

##### 3.2.2 Embedded “L” Shape Lacing Bar

Before pouring the roof slab concrete, “L” shape lacing bar needs to be embedded, with 900 vertical and horizontal spacing, enters into the protective cover (screed-coat), and ties with reinforcing mesh in the protective cover (screed-coat), to ensure the firm tie.

##### 3.2.3 Construction of Roofing Waterproof Layer

###### (1) Roof waterproofing method

The roof waterproofing method is shown in the Fig. 2.2

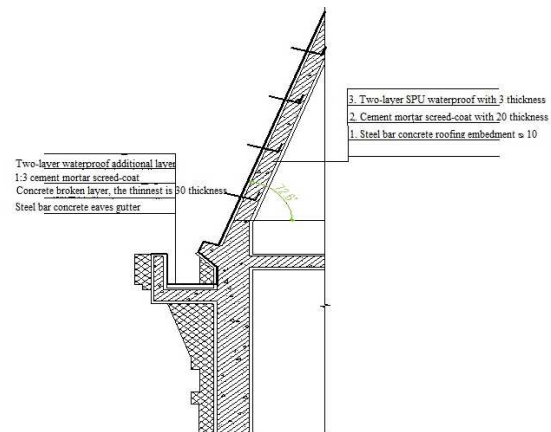


Fig. 2.2 Node Diagram Of Roofing Waterproof

###### (2) Working Environment

Painting the waterproof layer is not allowed in the rain, the environmental temperature of construction should not be less than 5 °C. In the construction, the environment should keep ventilated, and no smoking.

###### (3) Basic Treatment

Before painting the waterproof layer, at first clean up sundries, mortar hard lump, etc. on the surface of base course, and wipe off for one time with wet cloth. After checking, the base course is clean and strong, has no water, no emptying swell, cracks and other defects, and then proceeds to the next working procedure.

(4) Construction of additional enhancement-type coating layer

The vulnerable positions such as ridge, drainage port, corner and lacing bar and so on should complete the construction of additional enhancement-type coating layer before large-scale construction of coating layer.

“L” shape lacing bar penetrates through waterproof layer, so it needs enhancement processing. Before waterproof engineering construction, lacing bar should be painted with antirust paint, and the construction of additional enhancement-type waterproof coating layer should extend to lacing bar, stretching out insulation board.<sup>[6]</sup> The details see the Fig. 2.3

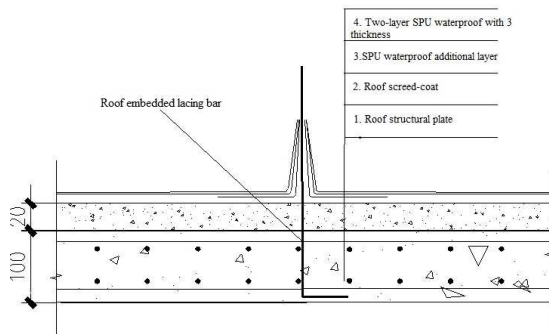


Fig. 2.3 Reinforcement Of Waterproof In The Lacing Bar On The Roof

#### (5) Paint the first coating film

After curing and drying the materials of previous additional enhancement-type coating layer, at first, it should be checked whether there is residual air pore or bubble in the additional layer position, if not, the first coating film can be painted. If there is a hole or bubble, the rubber scraper is used to press mixture into air hole, and the local part is coated, and then the construction of the first coating film proceeds.

#### (6) Paint the second coating film

When the first coating film cures and is not tacky, the second coating film is evenly coated on it. The amount and thickness of coating material are same as those of the first coating film. The direction of coating should be vertical with that of the first coating<sup>[4]</sup>.

### 3.2.4 Construction of roof insulation layer

#### (1) Lay benzene slab

When laying benzene slab, slab joint should be clamped, and the adjacent slabs should be flush. In the construction, the gap between control boards should not be more than 2 mm, and the height difference between boards shall not be more than

1.5 mm. When the gap between boards is more than 2 mm, benzene batten must be used to choke it up.

#### (2) Apply polymer anti-crack mortar and embed fiberglass mesh

The trowel is used to evenly apply polymer mortar on the benzene slab, the thickness is controlled in 1-2 mm, and it is ensured to have no missing place.

#### (3) Apply polymer anti-crack mortar on the surface course

After applying polymer mortar and press the fiberglass mesh into it, the mortar cures and its surface is basically dry and not tacky, and then began to apply polymer mortar on the surface course. The total thickness of polymer anti-crack mortar on the surface course should be controlled in 3- 5 mm.

### 3.2.5 Construction of lying-tile layer

#### (1) Method of lying-tile layer

The roof fixed-tiled base course with 35 thickness of C20 fine stone concrete is internally allocated 6@300 x300 reinforcing mesh. To ensure insulation layer, lying-tiled base and structural slab are firmly pulled together, “L” shape lacing bar, which completes the waterproof enhancement-type processing and stretches out the thermal insulating layer, is artificially bent upwards into a hook, to pull together 6@ 300 x300 reinforcing mesh in the lying-tiled layer. Later, C20 fine stone concrete is poured, striking and artificially trowelling. The waterproof of lacing bar position enters into 10 mm of roof lying-tiled layer, and the expansion O-ring seal is set in the end. The schematic diagram for pulling “L” shape lacing bar and reinforcing mesh together on the lying-tiled layer is shown in the Fig.<sup>[7]</sup> 5.2.8-1.

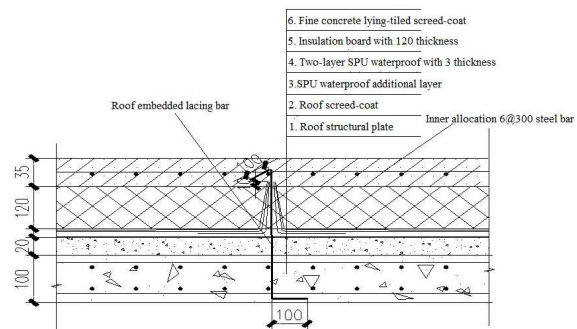


Fig. 2.4 Node Diagram Of Roof Waterproof And Insulation And Horizontal Tile Leveling Layer

#### (2) Cleaning the base course

Clean up loosening sundries on the thermal insulating layer or thermal-protective layer, remove hard lump stretching out from the surface of base course, and water it for wetting.

### (3) Laying reinforcing steel bar

The reinforcing steel bar is laid out by 300x300 spacing in the bi-direction. "L" shape lacing bar, which completes the waterproof enhancement-type processing and stretches out the thermal insulating layer, is artificially bent upwards into a hook, to pull together 6@ 300 x300 reinforcing mesh.

### (4) Rib punching and plastering

According to the slope requirements, pull the wire, cut the slope stick and plaster. Punch the rib from top to bottom of roof, and the spacing of rib punching is 1.0 m.

### (5) Pouring fine stone concrete

The large-area of fine stone concrete is laid out (the mix proportion shall meet the design requirements), the trowel is used for spreading, and then short wooden pole is used to slick according to both sides of rid punching elevation. Next, the wooden float is used for leveling, and then the wooden rod is use to check its evenness. When the concrete begin to condense and people step on it, having footprints but no caving, the iron float is used to press it for the second time. Attention should be paid to prevent the lack of compaction, and the dead pit, blind angle and sand hole are trowelled. When the trowelled cannot be pressed into the smear lines, and then level out and compact it.

## 3.2.5 Construction of Tiled Finish Coat

### (1) Roof paying off

After roof structural layer, waterproof layer, thermal insulating layer and protective layer, etc. are strictly accepted according to the design and the Code for Acceptance of Construction Quality of Roof. The roofing counter batten and batten are paid off on the completed roofing tiled base course. The paying-off must be positioned accurately.

### (2) Arrangement of counter batten and batten

The counter batten and batten should adopt coniferous species of 25×25 (mm) and 30×25 (mm), with about 6.2 m per square meter. Before using, the diesel asphalt mixture is used for the anti-corrosion treatment. The tile is fixed with 50-60 (mm) steel nail. The center spacing for counter batten is 350-500 mm perpendicular to the roof

eaves with uniform arrangement. The counter batten is fixed on the concrete base surface with cement steel nail according to the position of chalk line. The spacing of nail @ is 450 mm or less, and the counter batten should be parallel with the cornice. The top is cut into a bevel angle parallel with the ridge (30 mm away from the ridge). The bottom is in the convex angle (ridge and eaves) 20mm away from the eaves edge, and its ends should be parallel with other counter battens. A piece of counter batten is nailed on both sides of slopping ridge, and cement paste is used on both sides for enhancement. The uneven place of lower sub-base of counter batten can be slanted and padded with anticorrosive wood wedge. And The flux line is pulled for leveling.

The center spacing of western-style batten is 285 mm, the batten is fixed in the counter batten with L=60mm nail, and the joint between each batten and each counter batten should be nailed. The batten should be nailed neatly and firmly, the top edge should be in a straight line, which all should be parallel with the batten on the cornice and roof eaves. Meanwhile, the joints should be staggered on the counter batten. Two battens are set on the eaves, and its height should be 50-60 (mm) upwards from the counter batten. The flux line is pulled for leveling.

(3) The dry-hung method (nail-hanging method) is adopted for laying large-scale plain roofing tile.

After the counter batten is leveled, the roofing batten can be laid with the tiles. The first tile is laid from the left bottom of eave (skew plate), from left to right and bottom to top. The tile is fixed on the batten with steel nail, and the overlap joint of tiles should be fully used, to ensure the evenness of tiles and waterproof performance. The tiles are overlapped each other, and the left lower gap and the upper right gap must be aligned in place, which are nailed down with steel nails. The upper tile presses the nail cap of the lower tile, to save waterproof rubber mat. So, it can prevent the leakage of water, but need not use the rubber strip for filling the gap. If the number of entire tile cannot reach, the portable cutting machine will be applied for cutting. The length for tile stretching into roof gutter and eave gutter is 50-70 mm, and the length for tile cap picking out the verge board is 50-70 mm.

The distance between the tile interior surface and the lying tile base course is usually kept in 50-70 mm (i.e. overhead), so as to have adiabatic ventilation effect.



(4) The cement paste wet-lying method is adopted for laying ridge tile on the roofing inclined ridge.

After the plain roofing tile is laid in order, in the roofing inclined ridge, from top to bottom two "Flat" and "Straight" flux lines should be pulled for auxiliary construction according to the specifications of ridge tile. Starting from the bottom of inclined roofing ridge, the inclined ridge tiles are installed to the top of inclined roofing ridge from bottom to top according to the provisions of lap length. Each edge for imbrication width of ridge tile on both slopes should not be less than 40mm.

The shield-shaped tile is divided into straight ridge shield-shaped tile and inclined shield-shaped tile, respectively used in both sides of straight ridge tile and inclined ridge tile. The top of joint of three-way sloping roof, namely, the joint of two inclined ridges and main ridge, adopts three-way ridge of fittings tile.

Considering the straightness of ridge tile at the joint of inclined ridges, it is appropriate that the ridge tile needing to be cut uses two-time cutting method.

1) Before formal paving, the first incision is required. In this incision, a little more remaining part should be kept.

2) After paving, the cutting auxiliary line is straightened from the roofing upper to the lower. The original remaining part is cut evenly for the second time, so the cutting joint of two inclined ridges can be cut in order.

In the roofing inclined ridge, cement mortar in the proportion of 1:2 is coated. In order to avoid the influence of lower-temperature frost heave in the winter on lying tile mortar, it is advisable that the plumpness of mortar ridge of t tile and lying tile is controlled at 80%. The gap is reserved between base course and ridge tile, and the ridge tile is installed on the cement mortar and fixed with reinforcing steel nail. The mortar is brushed with the coating, of which the color is same as that of the tile. The above measures are taken to prevent ridge tile falling off because of the low-temperature frost heave.

#### (5) Processing for tile edging and cornices

The convergence of tile edging is coated, pressed and compacted tightly with cement mortar in the proportion of 1:2, and it is done in the prismatic same as the shape of tile edge. After seven days after roof construction, the special coating of

cement tile, which has the same color of roof, is used to coat the gray part naked externally for two times. The special coatings belong to water-based paint. If the paint seems to be thick, fresh water not more than 10% can be added for dilution. Please note that oil items cannot be used for dilution such as gasoline, xylene and so on. The storage temperature of paint is from +4°C to +30°C.

Attention should be paid to protect the neatness of tile, and the surface of tile should not be contaminated, and be cleaned promptly. In the cornice, cement mortar is used to seal the first double-layer batten, and the reinforcing steel bar with the diameter of 20mm is used to poke a hole between two counter battens, for easy drainage and ventilation.

#### (6) Node processing

In the roof, there are parts in which tiles are combined with wall or other structures, the processing for these parts is the key to roof waterproof. In the processing, the combining method and materials must be seriously considered, and the construction should strictly comply with the design requirements or the corresponding standard atlas.

1) The method to pave the sewer tile: pop the center line of sewer and then pop two parallel paving lines about 60 mm apart from the left or right of the center line. The effective width of sewer tile is about 215 mm, among them, the width of open trench is 120 mm, and the rest is cement mortar-bottom (the pulp is 50 cm or so). When paving, the center of ditch tile should be lowered as far as possible, and the pulp given priority to on both sides of every piece of ditch tile, creating the convenience for laying the following main tiles. The linkage line at about 60 mm on both sides of the center line between the first and the last sewer tile is regarded as the cutting line of main tile. The cement mortar in the proportion of 1:3 is used for actual cutting part (400 mm on both sides), in case of leakage of water in the rain.

2) The flashing width of side tile sticking into the roofing wall should not be less than 50 mm.

3) The procedure for cutting the main tile: according to the requirements of roof cutting angle, at first, the cutting line need to be marked out on the tile surface with slate pencil and strip line, the electric circular saw is used to cut the main tile along the cutting line, cement mortar in the proportion of 1:3 is used as the main tile incised.

#### 4. CONCLUSIONS

The Hengda Oasis project adopts the new technology of dry-hung and wet-lying in the construction of roof with steep slope in severe cold region. In comparison of the method of traditional sloping roof single-layer framework bracing cast concrete, it greatly shortens the construction period, and saves labor cost. Combined with actual conditions in the severe cold region, “L” shape lacing bar is set in each structural layer of the roof, to connect each structural layer of the roof, so the latter maintenance cost is greatly reduced. Taking the above aspects into consideration, the Hengda Oasis engineering adopts the system of dry-hung and wet-lying in the construction of roof with steep slope, to save the construction period of about 24 days (40%), seven-time manual work, wages for workers of RMB 240 yuan/person/day, rental expense for tower crane of RMB 800 yuan/day, and to achieve the good effect of economic benefits of about RMB16 yuan/m<sup>2</sup>. Therefore, this new construction technology is worthy of popularization and application.

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