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# Research on the Construction Technology of Ancient Building Monolithic Movement

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***ABSTRACT :*** *In order to solve the problems in the movement of ancient buildings, this construction method combines specific engineering application cases to carry out monolithic innovation on the movement of ancient buildings, and develops a construction method of monolithic movement of ancient soil, wood and stone buildings, which comprehensively adopts protective demolition, foundation separation and underpinning, monolithic rotation of buildings, monolithic translation of buildings, and integral jacking of buildings, The existing ancient buildings with soil, wood and stone structures will be relocated. The results show that with this construction method, the ancient buildings can be accurately moved to the new design coordinate point, and the original architectural style of the ancient buildings is retained at the maximum level during the construction process, without damage to the main structure. Compared with the traditional construction, this process has little damage to the upper structure, and has obvious social and economic benefits.*

***Keywords****-Ancient building; Monolithic movement; Monolithic rotation; Underpinning technology; reinforce*

## I. INTRODUCTION

In recent years, with the rapid development of China's economy, the old architectural planning and layout no longer meet the requirements of the new urban monolithic planning and design. Therefore, in addition to the demolition of the old buildings, it is also necessary to carry out protective some special significant ancient architectures by monolithic moving technology to meet the requirements of the new urban monolithic planning and design[1-2].

The ancient buildings with special significance, such as ancestral temples, historic buildings, etc., mostly adopt the soil, wood and stone buildings. The integrity of this structure is poor, and the service life of the buildings is relatively long. Therefore, when the monolithic movement construction is carried out, it is easy to cause damage to the main structure of the building, with potential safety hazards, or damage the existing decoration and auxiliary structures of the building, and damage the architectural style[3]. On the other hand, most of the existing building translation construction technologies only involve the single direction parallel movement of the building, but cannot rotate the whole building around the axis, which greatly limits the application of the movement technology in the building movement project[4].

In order to solve the problems existing in the movement construction of ancient buildings, this paper combines specific engineering application cases to carry out technical innovation on the movement construction of ancient buildings, and develops a construction method for the monolithic displacement of ancient soil, wood and stone buildings. The construction methods of protective demolition, foundation separation and underpinning, monolithic rotation of the building, monolithic translation of the building, and monolithic jacking of the building are comprehensively adopted to carry out the movement construction of existing ancient soil, wood and stone structures. With this construction method, the ancient building can be accurately moved to the new design coordinate point, and the original architectural style of the ancient building is retained at the maximum level during the construction process, without damage to the main structure and causing potential safety hazards.

## II. PROCESS PRINCIPLE

On the premise of high construction speed, high construction quality and little damage to the existing ancient buildings, the underpinning technology is used to separate the superstructure from the foundation, install

the walking mechanism and apply power to achieve horizontal displacement. The lifting mechanism is installed to achieve vertical displacement and adjust the tilt. By using the hydraulic propulsion system, the horizontal displacement speed is increased and the work efficiency is improved, which provides conditions for the popularization and application of the monolithic displacement technology of buildings.

The underpinning beam constructed first is used as a bracket, and the traveling mechanism arranged between the underpinning beam and the foundation or translation track is used to move horizontally under the external power; Or that is used to the jacking mechanism arranged between the bracket and the foundation to carry out vertical displacement. The underpinning beam cuts the building along a certain horizontal plane to form a plane bracket, transfers the load of the upper structure to the bracket, separates the upper structure from the foundation, and forms a movable whole. The underpinning beam is generally a reinforced concrete structure, which is composed of section construction. The roller is placed between the underpinning beam and the foundation or translation track, and the horizontal displacement can be implemented. Temporary translation track shall be set between the building and the place in place, and permanent foundation shall be built at the place in place to make the building move horizontally to the place in place. After the jack is placed between the underpinning beam and the foundation, the vertical straight displacement can be implemented. After the building is in place, it shall be reliably connected when the jacking force is greater than the total load of the building.

## III. CONSTRUCTION PROCESS FLOW AND KEY OPERATION POINTS

### 3.1CONSTRUCTION PROCESS FLOW

The construction process flow chart is as follows：

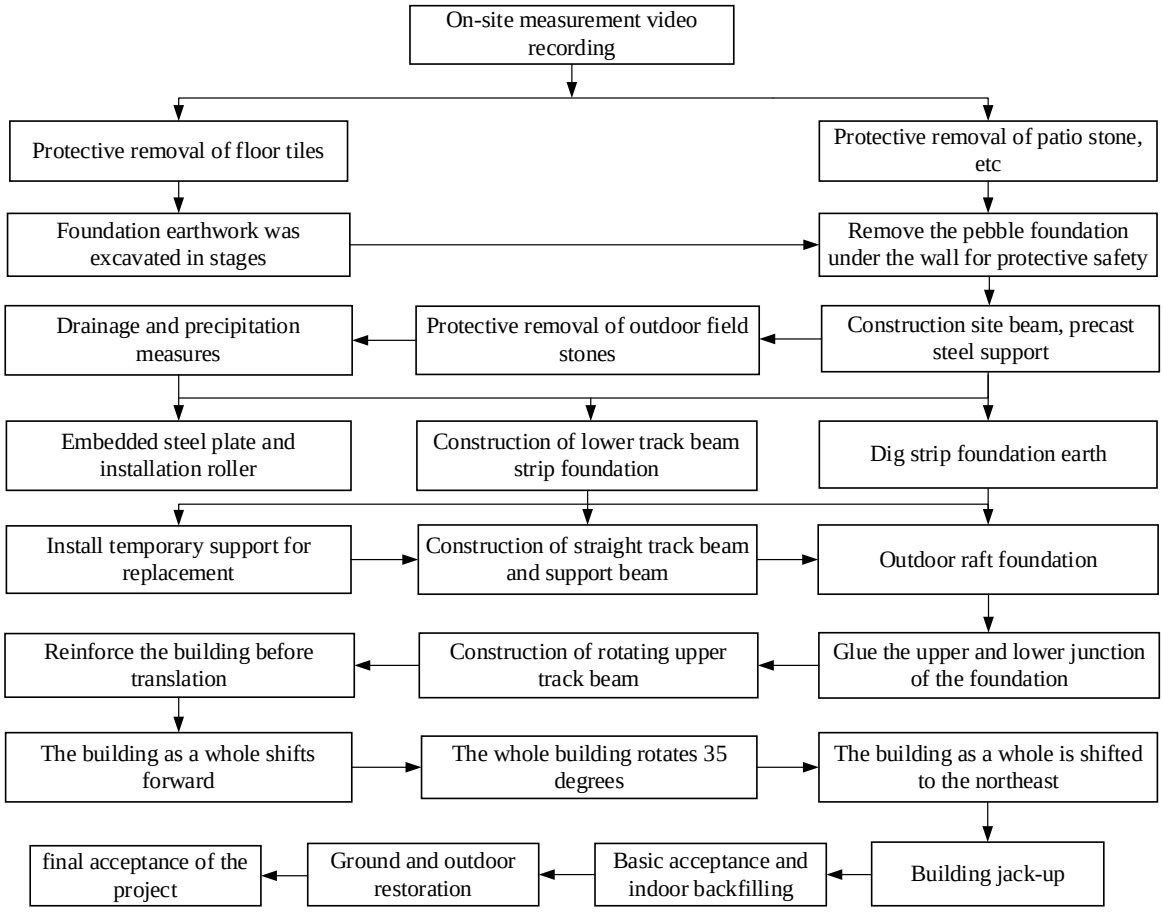


**Figure 1 Construction process flow chart of monolithic displacement construction method for ancient buildings**

### 3.2KEY POINTS OF OPERATION

#### 3.2.1 CONSTRUCTION PREPARATION

Constructors are organized into the construction site, construction preparation is made in advance, temporary facilities are erected, the working surface is cleaned, the construction site is leased and arranged, and

construction machines and tools are mobilized to enter the construction site. The timely delivery of construction equipment, materials and manpower are implemented. We shall collect the technical data required by the project, review the construction drawings and specify the construction design of the project, and prepare specific supply plan and stacking site for main materials and equipment.

**3.2.2 CONSTRUCTION MEASUREMENT AND MONITORING**

1) First of all, the original measurement and exterior measurement of the existing ancient buildings are recorded to understand the building's foundation settlement, wall verticality, and wall cracks.

2) Benchmark elevation setting and elevation resurvey: the owner, the supervisor and the designer determine the red line and benchmark within the scope of construction. According to the elevation control points in the design drawings, and in combination with the site conditions, set the point nail pile for survey. After the survey, the elevation of the original water point shall be rechecked and the elevation of the newly established ground pile shall be closed. The closing error must meet the requirements of the measurement specification before use.

3) Construction setting out and measurement: due to the particularity of the monolithic translation project, the requirements for horizontal and axis accuracy and component surface flatness are high. According to the design requirements, special control point monitoring scheme shall be prepared, leveling shall be strengthened, and multi-point calibration shall be checked repeatedly to ensure the axis setting out accuracy and component construction accuracy.

**3.2.3 CONSTRUCTION PREPARATION**

1）Protective removal of original floor tiles

The removal of floor tiles is a protective removal. When cutting, the slices should be cut along the junction of tiles and pointing (about 3mm wide from the tiles). The tiles must be protected from damage or nicks. After cutting on both sides of the back joint, we shall use manual chiseling to remove the cement mortar of the mortar joint with a steel drill, and then knock the floor tiles open. We do not use too much force when chiseling to avoid cracking the floor tiles as much as possible. After the floor tiles are opened, the mortar around the floor tiles shall be cleaned immediately, and the garbage stuck on the floor tiles shall be cleaned up with tools such as brick knives. The cleaned floor tiles shall be stacked 5~10 pieces, and bound firmly with plastic tape. The manual bucket truck shall be used for transportation. During transportation and use, the bricks shall be handled with care, and the overlap shall not be too high at a time, so as to avoid crushing or falling of the floor tiles. The removed floor tiles shall be stored in the place designated by the production director of the Project Department. When storing, we shall pay attention to the packaged floor tiles, which are stacked in two to three layers neatly.

2）Protective removal of original patio slats

In order to repair the patio and the edge of the outdoor stone lath in an orderly manner in the future, the stone lath of the indoor patio shall be coded with red paint before removal, so as to facilitate the restoration and installation in the future. In order to protect the integrity of the strip stone, the jack shall be used to jack off the upper strip stone, the galvanized steel pipe shall be installed at the bottom, and then the steel chisel shall be used to pry off the strip stone to prevent it from being damaged by prying. Since the strip stone weighs about 1.2~1.6 tons, it is hoisted with a hoist and placed on a galvanized steel pipe as a roller for easy transportation. We shall use galvanized steel pipes as rollers to move the heavy stones to the outside and store them away. The small forklift shall be used to transport to the designated place for storage, and shall be covered for protection after storage.

**3.2.4 FOUNDATION EARTHWORK CONSTRUCTION**

Before excavation, the location and elevation must be measured and determined before excavation. The excavation shall be carried out by sections and the excavation length shall be limited in strict accordance with the design requirements. If any underground cultural relics are found during the construction, they shall be properly protected and reported to the project department for treatment immediately before continuing the construction. If any underground pipeline or pipeline section is found during construction, it shall be reported to the Project Department in advance, and protective measures shall be taken during construction to prevent damage to the pipeline. When excavating the foundation pit below the groundwater level, the excavation size shall be controlled according to the geological data, and the foundation soil structure shall be prevented from being damaged. The sump or well point dewatering measures shall be taken. As the building foundation of this project is dry laid river pebble foundation, the excavation tools shall not collide with the river pebble foundation to avoid the collapse of the dry laid river pebble foundation, causing adverse consequences. The earth excavation shall be carried out from top to bottom, in sections and layers, and from Axis A to Axis F for drainage. For the excavation width of the bottom of foundation pit (trench), in addition to the width of foundation bottom, the width of working face, drainage facilities and supporting structure shall be increased according to the construction needs. The excavation of foundation pit (trench) shall not exceed the elevation of

the foundation base. In case of over excavation in some places, the same soil as the foundation soil shall be used for filling and tamping to the required compactness.

**3.2.5 BEAM CONSTRUCTION OF UNDERPINNING STRUCTURE SYSTEM**

1）Cutting wall foundation

The construction shall be carried out in sections in strict accordance with the design requirements, and the excavation of foundation earthwork shall be controlled within 1.6m for each construction section to avoid collapse of dry laid shallow foundation during excavation. Before excavation, all materials required for temporary support and ground beam pouring and tamping shall be prepared. The excavation shall be carried out carefully and slowly, and the upper river pebble foundation shall not be damaged by pounding. Observe any abnormal phenomenon during construction at any time. If there is any problem, we must stop the operation immediately and take temporary support measures. The excavated stone and earthwork shall be transported immediately to avoid affecting the construction of concrete ground beam.

2）Foundation beam construction

The ground beam reinforcement shall be fabricated on the ground, and then installed after the foundation is leveled, compacted and positioned. 18mm thick plywood is used as the formwork material, and the aggregate for formwork shall be pine wood with the size of 80 × 80 × 2000mm, reinforced with diameter φ 10 screw with diameter in the middle φ 15 Plastic pipe is sheathed. The concrete must be mixed mechanically, and the concrete ground beam must be poured and tamped after the acceptance of the formwork. The pouring and tamping process must be carried out according to the safety operation procedures, and attention must be paid to the concrete watering and curing and the production of concrete test blocks for inspection.

3）Lower track construction

4 dewatering wells around the existing buildings are dug for drainage and dewatering. When the groundwater level drops below the excavation elevation, use temporary support or sloping to conduct deep earthwork excavation. Each construction section of earthwork excavation shall be controlled within 1.6m. When the earthwork excavation reaches the design elevation, we shall conduct trench inspection. After the trench inspection is qualified, we shall carry out the construction of the lower rail beam foundation. We shall construct the lower rail beam foundation in strict accordance with the design requirements, After the foundation plain soil is compacted, leveling and measurement shall be carried out, and then the formwork shall be installed and the C15 plain concrete cushion shall be poured. After the initial setting of the concrete, surveying, setting out and snapping shall be carried out again. The installation of the lower rail beam reinforcement shall be in accordance with the design requirements, and the embedded steel reinforcement for the raft partition construction must be considered in the installation project. After the reinforcement passes the acceptance, the C30 concrete strip foundation shall be poured and tamped. Before the initial setting (wet) of the strip foundation concrete, the level on the surface shall be checked. After leveling, the 20mm thick steel plate of the walking track shall be installed. The level shall be checked again. The height difference of adjacent steel plates shall not be greater than 2mm.

For the construction of the upper track beam, it must be considered whether the concrete strength of the lower track reaches 80% of the design requirements. Before the construction of the upper track beam, the walking steel roller and the bottom steel plate of the upper track must be placed in advance, and the temporary support (constructed according to the design drawings, the support is pushed to the bottom of the ground beam) must be made in advance. After the installation of the temporary support, several supports are welded with steel bars to ensure the stability of the support.

The upper and lower track steel plates shall be installed at the same position and level. After installation, the monitoring shall be carried out. After confirmation, the upper track beam and the supporting beam reinforcement shall be installed. After installation, the supporting beam reinforcement shall be accepted. The next process (formwork installation) can only be carried out after the acceptance is qualified. In order to pour and tamp concrete, the surface shall be 10cm wider than the bottom (5cm on one side for pouring concrete and vibrating). After the installation of formwork, strict measurement and recheck must be carried out to ensure the accuracy of the ground beam axis and level. Pour and tamp C30 concrete for straight track and underpinning beam. Before pouring and tamping concrete, the formwork axis, elevation, size and installation firmness must be strictly reviewed. The pouring and tamping process must be carried out in accordance with the safety operation procedures. Pay attention to the concrete watering and curing work and the production of concrete test blocks for inspection.

4）Construction of upper track and underpinning beam

The underpinning construction is carried out in the dry masonry shallow foundation. Before the construction, the shallow foundation within a certain range above the surface elevation of the underpinning beam or upper track beam shall be grouted and reinforced; During the construction of lower track foundation, upper track beam and longitudinal underpinning beam, the length of one underpinning construction section shall be ≤ 1.2m, and the support shall be provided and the concrete shall be poured in time. As the underpinning beam

is constructed in sections, the concrete coordination of each section beam shall be considered, the reinforcement connection shall be reserved, and the reinforcement arrangement, reinforcement anchorage or welding length shall be strengthened; The traveling mechanism is 700mm in length and diameter φ 60 solid steel rollers can be placed (front mounted) or jacked in place (rear mounted) during the construction of prefabricated upper track beam, with the spacing of steel rollers not greater than 200mm; The bottom elevation of the upper rail beam shall be strictly controlled at the same level. After the traveling mechanism is installed in place, the allowable deviation of the bottom elevation of the pressure bearing steel plate at the bottom of the beam is ± 3mm.

**3.2.6 RAFT REINFORCED CONCRETE CONSTRUCTION**

The elevation of the raft foundation surface must be consistent with that of the indoor straight lower track surface. The raft foundation construction must be carried out after the construction of the lowest part of the indoor straight track is completed. An angle steel is set every 2m on the raft surface Control points to control the level of raft concrete surface. The pressure bearing steel plate of the lower track shall be laid in place at one time before the translation construction. The overlapping areas shall be spot welded and spliced, and the welding points shall be ground smooth. The raft concrete shall be pumped commercial concrete. The embedded parts shall not be impacted during the concrete pouring and tamping. The concrete surface must be dense and flat. After it is slightly dry, it shall be leveled with a 3m long aluminum alloy ruler.

**3.2.7 REINFORCEMENT BEFORE MONOLITHIC DISPLACEMENT OF BUILDINGS**

1）1st floor structure reinforcement

The openings of doors and windows on the first floor are temporarily reinforced with wooden window sleeves, and the wall sections with large transverse wall spacing are provided with horizontal braces at the window sill elevation of door and window openings. The corner of the building adopts φ 30 The hemp rope is tied and tensioned around the window opening, and one is set at the top surface of the window opening and the elevation of the window sill. For stone wall members, round logs or steel pipes shall be used for temporary reinforcement. The gap between the old and new joints of the foundation shall be treated, and grouting construction shall be carried out after the completion of the ground beam construction.

2）Foundation sealing and painting outside the dado

Grouting holes shall be opened every 30cm above the foundation to install grouting pipes, and the gaps outside the wainscot shall be sealed and painted with strong grade cement mortar. After the cement mortar applied to the outer wall skirt is cured, it is necessary to check the tightness of the sealing belt. Apply soapy water on the sealing belt and around the grouting nozzle. The inspection method is to squeeze the air through the grouting nozzle with the air pressure controlled at 0.15 ~ 0.3MPa. If foam is found on the sealing belt after ventilation, it indicates that there is air leakage at this part. The air leakage part needs to be sealed again and explosion-proof measures.

3）Grouting

We shall pour the prepared grouting liquid into the grouting tank, cover and tighten it, and pressurize it with an air compressor. When the pressure gauge of the air compressor shows 0.15~0.2MPa, turn on the slurry outlet switch, and observe the slurry flow in the transparent grouting pipe. If the slurry inlet is not smooth, increase the pump pressure appropriately. The pressure grouting is gradually pressed from the low end to the high end, and poured from top to bottom. We must pay attention to observation during grouting. After grouting is started from one end, when the grouting nozzle at the other end sprays slurry with the same concentration as the injected slurry after discharging the gas in the crack, grouting can be stopped, and the grouting nozzle can be blocked while maintaining the pressure.

**3.2.8 CONSTRUCTION OF MONOLITHIC MOVEMENT OF BUILDINGS**

For long-distance horizontal displacement, if conditions permit, the rear traveling mechanism is preferred, and its horizontal error can be adjusted by cushion when the traveling mechanism is placed. We can monitor the displacement, correct the deviation in time, and prevent excessive deviation. In case of monolithic horizontal displacement, the actual applied force at each application point of the applied force shall be observed and recorded, and the abnormality during displacement shall be judged according to the change of the applied force. At the same time, the ruler and theodolite are used to monitor the building deviation during the displacement process, and the leveling observation is used to monitor the foundation settlement of the translation track. At the same time, it is necessary to strengthen the observation of the upper structure to find out the potential safety hazards in time.

**3.2.9 BUILDING MONOLITHIC JACKING CONSTRUCTION**

The overall jacking construction can be carried out after the overall translation in place, with each jacking of 0.8m. The location of the site lofting jack should be paid attention to to avoid the location of doors, Windows and weak load-bearing components. The maximum stroke of the manual mechanical jack is 120 ㎜, a stroke in place, the need to replace the stroke, the jack to replace the stroke, should be used in the jack beside the jack support can be unloaded back. Put the composite steel plate concrete pad prepared in advance under the

jack, and the standby jack can be removed after the top of the jack is good. After the rise of the building, the brick wall will be built in the void after the rise of the building using fast hard mortar. Thick steel pads with stress diffusion should be set up and down the jacking jack to prevent local damage of structural components during jacking. When the pad is placed under the jack, it should be ensured that the top surface of the pad is level and the jack is vertical. Block produced by construction units themselves, should adopt composite reinforced concrete block or GangDian block (figure 10), it is forbidden to use wood, stone, concrete used as a block, block composite surface should be smooth, its plane size in addition to meet the requirements of bureau of pressure bearing capacity is still should satisfy the stability requirement, and should have the lateral limit device. Jacking ruler should be set in the position of the monitoring point, the maximum jacking amount of 10mm should be suspended, and check the jacking amount of each monitoring point, the deviation of the jacking amount of each point should be less than the allowable deformation of the structure.

The monolithic lifting construction can be carried out after the monolithic translation is in place. The lifting is 0.8m in each time. The location of the site setting out jack should avoid the door and window openings and weak load-bearing components. The maximum stroke of the manual mechanical jack is 120mm. After one stroke is in place, the stroke needs to be changed. When the stroke of the jack is changed, the jack shall be firmly supported by the jack before unloading the return stroke. The prepared composite steel plate concrete cushion block shall be placed under the jack, and the standby jack can be removed after the jack is jacked. After the building rises, we shall use quick hardening mortar to build the brick wall in the space after the building rises. A thick steel pad with stress diffusion shall be set up above and below the jack to prevent local damage to the structural members during jacking. When placing the pad under the jack, we must ensure that the top surface of the pad is horizontal and the jack is vertical. The cushion block shall be made by the construction unit itself, and shall be composed of reinforced concrete cushion blocks or steel cushion blocks. It is strictly prohibited to use wood blocks, stones and plain concrete as cushion blocks. The upper and lower overlapping surfaces of the cushion blocks shall be horizontal and flat, and their plane dimensions shall meet the stability requirements in addition to the local pressure bearing capacity requirements, and shall be equipped with lateral limiting devices. The jacking scale shall be set at the monitoring point. When the maximum jacking amount reaches 10mm, the jacking shall be suspended, and the jacking amount at each monitoring point shall be checked. The deviation of the jacking amount at each point shall be less than the allowable deformation of the structure.

#### 3.2.10 GROUND AND OUTDOOR REPAIR

The floor tiles and patio stone bars pulled down from the protective demolition before will be restored in situ relative to the ancient buildings.

## IV. CONCLUSION

### 4.1 ECONOMIC RESULT

Compared with the traditional construction method of monolithic displacement, this construction technology can be flexibly disassembled and reused by using the combined lower walkway plate and movable reaction bearing in the monolithic horizontal displacement; The hydraulic propulsion system and combined lower walkway plate can effectively improve the work efficiency, shorten the construction period and reduce the project cost. It has good economic benefits.

### 4.2 SOCIAL RESULTS

When this construction technology is used for construction, the monolithic construction efficiency is high. The ancient building does not need to be demolished, its upper structure is kept in its original state, and its use function is retained or restored. This construction technology has promoted the progress of the construction technology of building monolithic displacement, and has obvious social benefits. It has good promotion and application value and broad market application prospects. Compared with the traditional construction, this construction technology has little damage to the upper building, and has obvious social benefits.

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