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Research on the application of airbag support system for double shear wall formwork at deformation joints

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Abstract The narrow width of building expansion joints presents significant challenges in constructing shear walls on both sides of the joint. The limited working surface prevents entry into the expansion joint, making template support and removal difficult, often resulting in templates being left within the joint. This paper examines construction methods for double-shear wall formwork at deformation joints to address these concerns. Inspired by the bridge inflatable core mold, the research creatively incorporates the rubber airbag used in bridge construction into the project. A special rubber airbag is developed to support the double-shear wall formwork at the deformation joint. When inflated, the airbag forms a compressive elastic body to support the side formwork pressure of the shear wall. The shear wall formwork on both sides of the deformation joint is then reinforced with tension bolts at intervals between the airbags. This combination creates a complete and stable system. Experimental studies on the airbag's deformation characteristics under external force and calculations of the overall support system's stability demonstrate that the deformation value meets the requirements for stable support of the formwork side pressure, confirming the system's stability and reliability. This technology is highly innovative, scientifically sound, simple to operate, and provides reliable quality assurance, offering guidance for constructing similar projects with the same structure.

Index Terms expansion joint, shear wall, airbag, formwork

I. Introduction

In recent decades, China's urbanization has progressed rapidly, resulting in dramatic changes in the urban and rural landscape. The construction industry, housing system, and urban and rural construction planning and management systems have undergone rapid and profound reforms. Consequently, the housing and urban and rural construction industries have continuously advanced, significantly improving residents' housing conditions and achieving remarkable progress in urban and rural construction [1], [2]. The construction industry has experienced rapid development, with large-scale buildings being continuously developed and constructed, and the safety of building structures has been consistently enhanced. The growth rate of China's construction industry has surpassed that of any other country during any period. The application of scientific and technological advancements, new materials, and intelligent systems in the construction industry has provided the technical and material conditions necessary for the rapid development of modern architecture [3]–[6]. With the continuous advancement of construction technology, shear walls and frame structures have been widely utilized in housing construction projects. Research on related formwork support systems plays a crucial role in ensuring the safety of construction projects [7], [8].

Buildings are typically equipped with expansion joints to meet structural design requirements. Shear wall structures on both sides of these expansion joints are common in buildings [9]. However, due to the narrow width of the expansion joints, supporting and removing the shear wall formwork on both sides often presents construction challenges. The traditional method involves constructing the shear wall on one side first, followed by the other side. During this process, fillers such as benzene boards are often used in the expansion joints. However, these fillers are prone to deformation, making it difficult to control construction quality. Additionally, benzene boards pose a significant fire hazard during construction [10]–[12]. Furthermore, these fillers cannot be removed or are not removed cleanly, resulting in staged construction of shear walls on both sides of the expansion joints, which hinders optimization of the construction period [13]. Even when constructing shear walls on both sides of individual expansion joints simultaneously, the fillers or formwork used for support cannot be removed cleanly, directly affecting the structural function of the expansion joints [14], [15].

I. A. Application of airbags in construction

The airbag is filled with pressurized air within a soft, closed air chamber, utilizing the compressible nature of air to achieve elasticity [16]. The airbag operates reliably, has a simple structure, is easy to maintain, has a long service life, and offers significant economic benefits. Currently, the application of airbags has yielded positive results in bridge construction [17]. The bridge airbag inner mold is a cylindrical bag that can shrink and expand freely. When manufacturing hollow components, the rubber airbag inner mold is placed in the middle of the concrete component, and high-pressure air is then filled into the airbag [18]. Once the concrete component is formed, the air in the airbag is released, causing the bridge airbag inner mold to shrink immediately, allowing it to be easily removed from the cavity. The rubber airbag inner mold is economical and easy to operate. It can shrink flexibly without inflation, can be curled arbitrarily, and can also be folded [19], [20]. When filled with air, the airbag inner mold can withstand various pressures of concrete, which is challenging to achieve with traditional rigid templates. Construction practice has demonstrated that the use of the bridge airbag inner mold hole-forming method is fast, widely applicable, and reusable up to 80-100 times [21]. It is the preferred tool for accelerating construction progress and reducing costs. This method not only conserves materials but also allows for the realization of various shapes, such as elliptical and circular pipes [22]. It enables the construction of lighter, thin-walled, and hollow structures, altering the traditional reliance on rigid formwork. In summary, the application of airbag materials is flexible, simple, and economical. It performs well in bridge construction, lifting, and transportation, and holds significant potential for broader application in the construction industry [23], [24].

Recent experimental studies on unreinforced masonry (URM) walls have explored methods for enhancing the out-of-plane performance of cavity walls subjected to seismic loading, utilizing pressure-controlled quasi-static airbag tests. Specifically, configurations that incorporate near-surface-mounted (NSM) fiber-reinforced polymers (FRP) and improved cavity connections have shown strength increases of up to 282% compared to traditional construction methods [25]. Additionally, innovative testing approaches for slender concrete wall systems have addressed shortcomings in earlier research, which often overlooked axial loads and real-world constraints. These systems enable safe and effective evaluations by integrating axial and lateral uniform loading, yielding comprehensive insights into wall behavior under actual conditions [26]. Research focused on the in-situ boundary conditions of URM walls underscores the significance of construction details such as openings and wall ties on out-of-plane strength. This research compares energy-based methods to equilibrium methods for predicting strength, aiming to enhance assessment techniques for wall performance under dynamic circumstances [27]. Furthermore, an innovative energy-dissipating infill system, utilizing slotted concrete blocks and energy-dissipating link elements, has been tested against conventional brick infills. Results demonstrate superior lateral strength and energy dissipation capabilities, particularly during out-of-plane tests after in-plane damage, thereby boosting structural resilience during seismic events [28]. The impact of boundary elements on the out-of-plane performance of reinforced concrete block walls has been investigated in the context of blast loading, revealing that enhanced wall stiffness significantly improves resistance. This highlights inadequacies in existing standards and the need for new design guidelines [29]. Current research indicates that externally bonded composites, including environmentally friendly materials, can significantly improve the out-of-plane behavior of masonry walls, with all tested materials exhibiting considerable increases in load capacity and ductility [30]. Advancements in layered shell finite element modeling have further developed the understanding of masonry wall systems under out-of-plane loads, analyzing various reinforcement strategies and their influence on structural integrity during loading. This knowledge aids in refining retrofitting strategies [31]. A systematic review of testing methodologies for URM walls has identified inconsistencies and a lack of standardization, emphasizing the necessity for uniform procedures to enhance the reliability and consistency of masonry assessments [32]. Research into tire walls, made from earth-filled tires, has confirmed their out-of-plane load-bearing capabilities during seismic events. Recommendations for analytical approaches to calculate resistance and validate empirical data in structural design practices have emerged from this work [33]. Confined masonry has shown promise as a cost-effective solution for earthquake resistance; however, existing reviews indicate a pressing need for appropriate design guidelines in Europe to adequately assess its application in seismic-prone areas [34]. New hypotheses regarding shear strength in confined masonry suggest that tension-induced lateral deformation can reduce shear strength, with tests showing diminished capacities under combined shear and moment forces, particularly affecting slender walls [35]. Additionally, a macroblock modeling approach has been successfully employed to analyze the nonlinear load-displacement behavior of two-way spanning URM walls, enhancing predictions of collapse mechanisms and offering potential integration into displacement-based seismic design techniques [36]. The innovative application of in-plane isolation techniques for masonry infills, paired with measures for out-of-plane restraint, has been thoroughly investigated, demonstrating significant enhancements in the performance of reinforced concrete frames during seismic activity [37].

This work studies and analyzes construction methods for double shear wall formwork at deformation joints both domestically and internationally. Addressing the problems and construction difficulties associated with double shear wall formwork at deformation joints, this paper conducts an in-depth study of the shear wall formwork support system on both sides of the deformation joint. Inspired by the bridge inflatable core formwork, the research creatively incorporates the rubber airbag used in bridge inflatable core formwork into the project. A special rubber airbag is developed to support the double shear wall formwork at the deformation joint, forming a compressive elastic body when inflated to support the side formwork pressure of the shear wall. The shear wall formwork on both sides of the deformation joint is then reinforced with tension bolts at intervals between the airbags. The combination of the expanding rubber airbag and the tension bolts creates a complete and stable system. Experimental studies on the airbag's deformation characteristics under external force and calculations of the overall support system's stability demonstrate that the deformation value meets the requirements for shear wall concrete side pressure support stability, confirming the support system's stability and reliability.

II. Deformation characteristics of airbags under external pressure

II. A. Principle of airbag support structure

During the construction of shear walls in buildings with shear wall structures on both sides of an expansion joint, the side templates of the shear wall near the expansion joint are assembled and directly hoisted into place. The side templates of the shear walls on both sides of the expansion joint, away from the expansion joint, are supported synchronously according to conventional practice. Subsequently, the shear wall templates on both sides of the expansion joint are reinforced with tension bolts. A high-pressure airbag support is placed in the expansion joint. When inflated, the airbag forms a compressive elastic body with the tension bolts, shear wall templates on both sides, and steel pipe supports outside the expansion joint, creating a stable double-sided shear wall template support system. This allows for the synchronous construction of shear wall templates on both sides of the expansion joint and the simultaneous pouring of concrete.

Once the airbag is inflated to the design pressure, it possesses sufficient strength to withstand the side template pressure during the pouring of shear wall concrete and to resist deformation caused by uneven side pressure during shear wall construction. When the conditions for template removal are met, the airbag and the side shear wall template of the expansion joint can be easily removed by deflation and decompression, leaving no construction waste in the expansion joint. The schematic diagram of the airbag support system is shown in Figure 1.

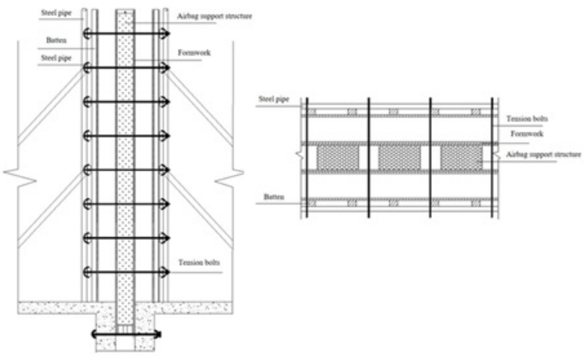

Figure 1: Schematic diagram of the airbag support system

II. B. Construction features of airbag support structure

The application of airbags as the supporting structure for double shear wall formwork at expansion joints enables the synchronous support of shear wall formwork on both sides of the expansion joint and the simultaneous pouring of concrete. This approach contrasts with the traditional phased construction of shear walls on both sides of the expansion joint. The construction operation is simple and convenient, significantly shortening the construction period. Airbags can be manufactured in different specifications and models, with varying working pressures, to meet diverse application needs. The airbag structure is stable and has a long service life. The pressure-resistant body formed after inflation maintains stable air pressure. The formwork support system at the expansion joint is safe and reliable, ensuring the construction quality of the shear wall. The overall improvement of the inner formwork of the shear wall can greatly save labor, and the airbag support at the formwork and the expansion joint can be reused, reducing one-time material investment and significantly lowering material costs. When the formwork is removed, the high-pressure airbag is depressurized by deflation, allowing the airbag and the inner formwork of the expansion joint to be easily removed, saving demolition labor and preventing residual construction waste in the expansion joint.

II. C. Introduction, performance characteristics, and parameters of airbags

The rubber airbag is a type of airbag that can expand and contract by vulcanizing the polymer characteristics of rubber and high-strength fiber cloth. It is used in conjunction with the formwork to serve as the supporting member of the concrete component. During construction, the airbag is placed in the middle of the cavity and filled with compressed air. The airbag expands to meet its pressure and size design requirements. The inflation pressure is determined based on the load to be carried. After use, the airbag can be pulled out of the cavity. The rubber airbag inner mold is economical and durable, easy to operate, soft and shrinkable when not inflated, can be curled and folded at will, and can withstand various pressures of concrete after inflation. Figure 2 shows the actual rubber airbag used in this experiment.

Figure 2: Rubber airbag

Performance characteristics of rubber airbags:

(1) The use of rubber airbags is convenient, time-saving, labor-saving, and material-saving. It particularly addresses the problem of demolding components when the cavity is small and personnel cannot enter.

(2) The inner mold of the airbag has good anti-aging performance and is durable.

(3) This product is made of natural and chloroprene rubber combined with nylon cloth and then vulcanized. It has good anti-expansion strength, can adapt to high temperatures, has elasticity and flexibility, and can fully adapt to various construction environments.

(4) The applicable temperature range is large, and the material changes little within this range.

The specifications and dimensions of the airbag are determined based on the height and width of the deformation joint of the application project. For example, in the first phase ward building project of the new campus of Weifang Yidu Central Hospital, the designed airbag length is 4000mm, the width is 400mm, the height is 200mm, the airbag wall thickness is 4±0.5mm, the height tolerance is ±0.2%, the length tolerance is ±20mm, the width tolerance is ±5mm, the factory inspection pressure is 0.08MPa, the allowable pressure is 0.06-0.075MPa, the airbag is flat with no exposed cloth, and the pressure drop after 8 hours of inflation to the use pressure is not allowed to exceed 10%.

II. D. Airbag load test verification

II. D. 1) Purpose and significance of the test

(1) To measure the deformation value of the airbag after loading different loads within the design air pressure range and verify whether the deformation of the airbag after applying the same load on the shear wall concrete pouring side meets the requirements of the shear wall formwork.

(2) To test whether the theoretical design air pressure value of the airbag can meet the requirements of resisting deformation.

II. D. 2) Basic principles of the test

The flat plate load test involves inflating the airbag to the design pressure value and then placing two airbags on a flat ground with 200mm between them. The template used in the project is laid on the airbags, and a uniformly distributed load is gradually increased. The change in value between the template and the ground is measured, representing the corresponding deformation value of the airbag. This process yields the Load value (F)-deformation (ε) curve of the pressure plate (i.e., F-ε curve). To ensure rigor, the test also measures the corresponding airbag deformation value during unloading and plots the load removal pressure (F)-deformation (ε) curve for comparison. By analyzing the F-ε curve, the change in the airbag under different load pressures can be determined. If the F-ε curve indicates that the theoretical design pressure value of the airbag cannot resist deformation, the airbag pressure must be increased and retested until the airbag deformation is within the allowable range.

II. D. 3) Specific test steps

Step 1) Inflate and Place the Airbags and Bearing Plate. Choose a wide and flat site. If there are potholes on the ground, lay a layer of plywood on the site. Use an air pump and air compressor to inflate the test group (two) airbags to the theoretical design value (0.06-0.075Mpa). In this test, the airbag inflation pressure is 0.06Mpa. Place the airbags straight and evenly with an interval of 200mm, then place the bearing plate flat on the positioned airbags.

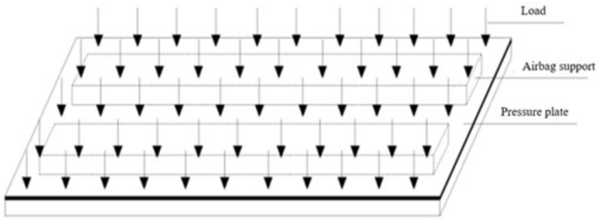

Figure 3: Schematic diagram of pressure application by heavy object loading method

Step 2) Loading, Unloading Operation, and Test Record. Before loading, use a caliper to measure the initial deformation value of the airbag. The loading level is generally divided into 10 to 12 levels, not less than 8 levels; in this test, we use 10 levels. Based on the calculated side pressure of 34.56KN/m² and the pressure plate area of 4.8m², the maximum load is determined to be 166kN, so each level is approximately 16.6kN. After each level of load is applied, measure the value between the templates. Record each reading accurately to ensure data reliability. To enhance test rigor, measure the corresponding airbag deformation value during unloading as well.

II. D. 4) Test data statistics

(1) The raw data collected from the test are presented in Table 1. These data were processed using standard analysis techniques to extract meaningful values, resulting in the refined dataset shown in Table 2. Utilizing the processed data, the force–strain (F–ε) curve was generated to visually represent the mechanical behavior of the material during the test, as illustrated in Figure 4.

No.	Load value (KN)	Internal caliper reading (mm)
1	0	199.985
2	16.52	198.945
3	33.31	198.072
4	50.24	197.236
5	66.12	196.798
6	83.11	196.380
7	100.08	196.088
8	116.53	195.984
9	133.07	195.888
10	149.52	195.828
11	166.12	195.792

Table 1: Test raw data record

No.	Load value (KN)	Deformation value (mm)
1	0	0
2	16.52	1.040
3	33.31	1.913
4	50.24	2.749
5	66.12	3.187
6	83.11	3.605
7	100.08	3.897
8	116.53	4.001
9	133.07	4.097
10	149.52	4.157
11	166.12	4.193

Table 2: Test calculation data

(2) The raw data obtained from the pressure test during the unloading phase are presented in Table 3. After applying appropriate data processing techniques, the refined and structured results are shown in Table 4. Based on the processed data in Table 4, the force–strain (F–ε) relationship is graphically illustrated in Figure 5, which provides a clear visual representation of the material's response during unloading.

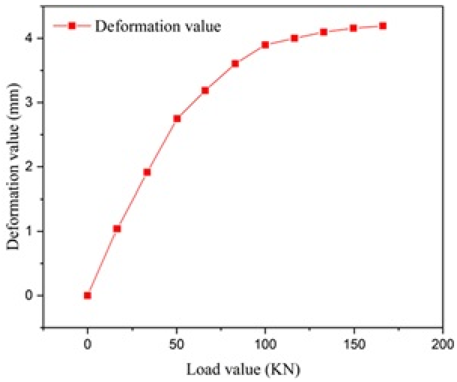

Figure 4: F-ε curve of airbag loading

No.	Unload value (KN)	Internal caliper reading (mm)
1	0	195.792
2	16.53	195.817
3	33.27	195.877
4	50.11	195.973
5	66.10	196.088
6	83.14	196.369
7	100.11	196.788
8	116.46	197.236
9	133.16	198.072
10	149.48	198.934
11	166.12	199.985

Table 3: Test raw data record

No.	Unload value(KN)	Deformation value(mm)
1	0	4.193
2	16.53	4.168
3	33.27	4.108
4	50.11	4.012
5	66.10	3.897
6	83.14	3.616
7	100.11	3.197
8	116.46	2.749
9	133.16	1.953
10	149.48	1.051
11	166.12	0

Table 4: Test calculation data

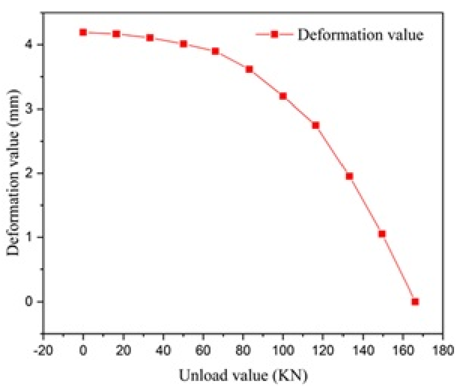

Figure 5: F-ε curve of airbag with load removed

II. D. 5) Test results analysis and test conclusions

The load test provides the original record of the load-deformation relationship, along with other relevant information such as the size of the load plate, measuring instrument and model, weather, and temperature. The test results indicate that after inflating the airbag to the designed air pressure, the deformation under maximum load meets the engineering requirements for the supporting structure. Additionally, based on the airbag characteristics and theoretical derivation, the following formula is obtained for reference in calculating the airbag deformation under different parameters in actual applications:

$$y = f(x) = 4.25k^2 sinh(0.0151x)/a^2 cosh(0.0151x) + 0.00491ln(0.0606x + 1), \quad (1)$$

where *k* is airbag inflation pressure value (Mpa), *a* is actual pressure of airbag inflation (Mpa), *x* is the applied load is the lateral pressure (KN) and y is airbag deformation (mm).

III. Construction method of double shear wall formwork airbag support system at deformation joint

III. A. Overall process flow

Construction preparation → Production and installation of deformation joint formwork and airbag bracket platform → Production and installation of steel bars → Installation of formwork → Placement of high-pressure airbags → Installation of shear wall head formwork and formwork cover → Concrete pouring and maintenance → Formwork removal.

III. B. Construction operation steps

III. B. 1) Construction preparation

(1) Familiarization with Construction Drawings and Design Documents. Before starting construction, thoroughly review the construction drawings and design documents. Prepare for construction by conducting technical and safety briefings according to relevant standards and specifications.

(2) Technical Parameters and Airbag Testing. Study the technical parameters of the airbag based on the project's actual situation and prepare high-pressure airbags. Before using the airbags, test them on the ground to check for damage or leaks, ensuring they are intact to avoid quality and safety hazards during concrete pouring.

(3) Line Layout. Perform line layout before construction. According to the construction drawings, mark the shear wall edge lines and construction control lines on the lower floor slab work surface that has been poured, ensuring the layout error is within construction requirements.

III. B. 2) Formwork and airbag bracket platform production and installation at the deformation joint

(1) PVC Pipe Embedding. To support the shear wall formwork and high-pressure airbags on both sides of the deformation joint, embed ¢20 PVC pipes at a horizontal spacing of 500mm, 200mm below the bottom of the floor slab during the construction of the lower layer's shear wall. The PVC pipe should run through the shear walls on both sides of the deformation joint, with the horizontal height of both ends consistent and perpendicular to the shear wall.

(2) Insertion of Tension Bolts. Insert ¢16 tension bolts into the embedded PVC pipe. Tighten the tension bolts to prevent them from falling off or bending during concrete pouring and vibration, ensuring the bearing capacity meets the requirements.

(3) Platform Plate Production and Installation. Use 50mm×80mm wooden squares and 12mm thick templates to create the deformation joint formwork and airbag bracket platform plate, which is 190mm wide. A U-shaped slot is set at the bottom of the wooden square. During installation, the slot is placed on the tension bolt and centered to ensure uniform gaps between the platform plate ends and the double-layer mold positions on both sides of the deformation joint. Leave two circular holes with a diameter of 15mm at both ends of the platform plate, and insert 10mm diameter nylon ropes into the holes. During subsequent construction, lift the nylon rope to the upper end of the formwork to facilitate lifting the platform plate out from above the cast shear wall after formwork removal.

III. B. 3) Rebar production and installation

(1) Rebar Tying. Tie the shear wall reinforcement after the lower floor slab and wall are poured with concrete and accessible for construction. Before tying, perform positioning and adjust and reinforce embedded dowel bars with significant displacement. Set ladder bars (main bars, transverse bars $\Phi 12$) at both ends and in the middle of the shear wall as needed, tying them to the shear wall vertical bars. Then, tie the shear wall transverse bars according to their positions. Set horizontal ladder bars at the top. Use circular control positioning hoops at the shear wall ends to ensure the vertical reinforcement's position. Paint both ends of the ladder bars with anti-rust paint. Tie the shear wall reinforcement point by point, ensuring the position and lap length of the reinforcement meet relevant regulations. Tie the upper, lower, and both sides of the reinforcement symmetrically, and secure the lap joint ends and center firmly with iron wire.

(2) Concrete Limit Strips and Pads. Tie concrete limit strips with the same width as the shear wall to the transverse reinforcement perpendicular to the formwork, or tie concrete pads with the designed thickness of the concrete protective layer on the outside of the reinforcement to support the deformation joint side formwork and prevent tilting toward the reinforcement side. If there is an opening in the wall, draw the elevation line on the vertical reinforcement of the opening and tie additional

reinforcement at the opening according to design requirements. Ensure the anchorage length of each node and wall corner and the seismic structural reinforcement meet corresponding requirements. Arrange pre-buried and reserved openings, pipes, and iron parts designed in the wall according to design requirements. If steel bars are cut, tie additional reinforcement steel bars.

(3) Surface Preparation. Remove floating slurry, debris, and other materials from the shear wall base to prevent quality issues in the concrete at the wall root. Install the template only after the concealed works, such as steel bars, are accepted.

III. B. 4) Installation of formwork

(1) Installation of Inner Side Formwork (Near the Deformation Joint Side). The inner side formwork, near the deformation joint, is assembled using 18mm thick and 12mm thick wood glue formwork. A U-shaped slot is reserved at the bottom of the formwork for insertion into the tension bolts in the formwork at the deformation joint and the airbag bracket platform, preventing horizontal movement. The slot position is determined based on the tension bolt position. After assembling the double-layer formwork on both sides, reserve two lifting hooks on the outer side of the upper part of the formwork for lifting it into place. Ensure the formwork stacking site is within the working radius and maximum load range of the tower crane, and as close to the use site as possible to shorten the lifting distance. Apply release agent before lifting the double-layer formwork, ensuring it is applied evenly without flowing to prevent contamination of the steel bars. Paste a self-adhesive sponge strip on the lower edge of the formwork to prevent leakage during concrete pouring. Use a tower crane to hang a steel wire rope to tie the two hooks on the assembled template and hoist it into place, inserting the template into the gap between the deformation joint template, the airbag bracket platform, and the shear wall steel bars to prevent bulging at the wall root during concrete pouring. Ensure the U-shaped slot at the bottom of the template is secured on the tension bolt in the bracket platform. Nail 100mm wide template strips at the top of the template joints to prevent shifting and dislocation. Weld angle steel at the template top to temporarily fix the inner template, preventing tilting of the shear wall templates on both sides of the deformation joint before subsequent work is completed.

(2) Installation of Outer Side Formwork (Away from the Deformation Joint). The outer side formwork of the shear wall, away from the deformation joint, uses 18mm thick wood glue formwork. The inner keel on the back uses 50×80mm wood squares with a 400mm vertical spacing, and the outer keel uses 48×3.6mm double steel pipes. The vertical spacing of ¢16 tension bolts is 400mm, and the horizontal spacing is 600mm. Pull and fix the two outer side formworks of the shear wall, then use 48×3.6mm steel pipes as diagonal braces to fix them to the lower floor. Before installing the formwork, pop out the formwork positioning line and apply the release agent evenly without flowing to prevent contamination of the steel bars. Paste a self-adhesive sponge strip on the lower edge of the formwork to prevent leakage during concrete pouring.

III. B. 5) Placement of high-pressure airbags

(1) Placement of Airbags. Place the airbag vertically and slowly into the deformation joint, with the inflation nozzle facing up, ensuring the airbags are arranged at a uniform specified height. Place the airbags on the bracket platform to prevent sinking before reaching the designed inflation pressure. Temporarily fix the top of the airbags with a rope. Calculate and design the spacing between the airbags before construction, with a center spacing of 600mm, evenly arranged between the tension bolts.

(2) Installation and Pressurization of High-Pressure Airbags. After placing the airbags, open the air inlet valve and inflate them with an air compressor. Inflate symmetrically along the two ends of the deformation joint. Observe the airbags during inflation, stopping if any distortion or beating occurs. Adjust the airbags' position to ensure vertical alignment and consistent height before inflating to the required pressure. Close the air valve and stop inflation, controlling the airbag pressure within 0.06-0.075Mpa. Assign someone to observe and maintain stable airbag pressure, avoiding over-pressurization.

III. B. 6) Installation of shear wall end formwork and formwork cover

(1) Installation of Shear Wall End Formwork. Attach the end formworks of the shear walls on both sides of the deformation joint to the formworks on both sides of the shear wall, reinforcing with square wood to meet the quality indicators of the formwork project as per acceptance requirements.

(2) Production and Installation of Formwork Cover at the Deformation Joint. Once the shear wall formwork support system is stable, remove the temporary fixing bracket on the top of the outer formwork. Manufacture the deformation joint cover plate and place it at the deformation joint after supporting the formwork to prevent concrete from entering the deformation joint during pouring. The cover plate also helps fix the two outer formworks. The cover plate length is 1m and can be opened during construction to check the air pressure stability of the airbag.

III. B. 7) Concrete pouring and maintenance

(1) Simultaneous Concrete Pouring. Pour concrete simultaneously on the shear walls on both sides of the deformation joint, ensuring full vibration during the pouring process.

(2) Observation During Pouring. Assign a special person to observe the formwork and airbag pressure during concrete pouring. Address any abnormalities promptly, stopping work for rectification if necessary to ensure the appearance and size of the concrete components.

(3) Post-Pouring Maintenance. Assign a special person to maintain the concrete promptly after pouring is completed.

III. B. 8) Removal of the formwork

(1) Deflation and Removal of High-Pressure Airbags. Deflate and decompress the airbag only after the shear wall concrete reaches the designed demolding strength. First, remove the deformation joint cover plate, then open the airbag valve to deflate it. Pull out the deflated airbag slowly from the upper mouth of the deformation joint, avoiding quick withdrawal to prevent scratches.

(2) Removal of the Assembly Formwork of the Shear Wall on the Deformation Joint Side. After deflating the airbags and removing the tension bolts of the shear wall formwork, remove the assembly formwork of the shear wall on the deformation joint side. Use a tower crane to hang a steel wire rope to tie the hook of the assembly formwork and lift it out carefully to avoid damaging the concrete structure.

(3) Removal of the Formwork and Airbag Bracket Platform at the Deformation Joint. Lift the nylon rope tied to the platform plate along the deformation joint, move the platform plate out of the deformation joint, then loosen the tension bolts through the lower shear wall, and pull out the tension bolts for reuse.

IV. Conclusions

This paper investigates the domestic deformation joint shear wall formwork support system and analyzes the traditional double shear wall construction method at the deformation joint. To develop a system that meets structural safety and reliability requirements, ensures the construction quality of the shear wall, and addresses the technical challenge of simultaneous construction of double shear wall concrete wall slab formwork at the deformation joint, we innovatively proposed the theory of a double shear wall formwork airbag support system at the deformation joint. This theory is based on the characteristics of rubber airbags and their application in engineering construction. Experimental research on the deformation characteristics of the airbags under external pressure and calculations of the supporting structure system have demonstrated that the system is stable and reliable.

The double shear wall formwork airbag support system technology at the deformation joint has been successfully applied in several projects, including the first phase ward building of the new campus of Shandong Weifang Yidu Central Hospital, Shandong Qingzhou Rongjun Hospital Comprehensive Ward Building, and Shandong Qingzhou Enterprise Headquarters Center Building, all undertaken by Shandong Huabang Construction Group Co., Ltd. These applications have yielded significant economic and social benefits. The implementation of the double shear wall formwork airbag support system at the deformation joint has achieved the following effects:

(1) Simultaneous Construction. The shear wall formwork on both sides of the deformation joint can be supported and concrete poured simultaneously, changing the traditional phased construction practice. This approach simplifies and expedites the construction process, significantly shortening the construction period.

(2) Stable and Reliable Support. The pressure-resistant body formed by the inflation of the high-pressure airbag maintains stable air pressure, ensuring the safety and reliability of the formwork support system at the deformation joint and the construction quality of the shear wall.

(3) Cost and Labor Efficiency. The inner side formwork of the shear wall (close to the deformation joint side) uses double-layer formwork staggered splicing to form a whole, allowing for the formwork to be lifted as a whole. This method greatly reduces labor costs. Additionally, the formwork and airbag support at the deformation joint can be reused, reducing one-time material investment and significantly lowering material costs.

(4) Easy Removal and Clean Construction. When the formwork is removed, the high-pressure airbag is deflated to reduce pressure, allowing the airbag and the deformation joint side formwork to be easily removed. This process avoids the generation of residual construction waste in the deformation joint.

The double shear wall formwork airbag support system at the deformation joint developed in this paper can be promoted and used in construction projects with similar structures.

Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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