

Voice of America Mall Target Project: A Steel Push Pier Underpinning Case Study

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Abstract

Hydraulically driven steel push piers were used for the lifting and stabilization of two walls of a partially constructed Target department store located in the Voice of America Mall in West Chester, OH. Both the north and south walls experienced similar settlement and outward rotation problems, and significant failures occurred in the concrete floor slabs near the base of each wall. The soil conditions on the site predominantly consist of glacial till overlying shale with very shallow ground water. Due to limitations of lot lines, the original foundation design for the new structure consisted of eccentrically loaded spread footings. Hydraulically driven steel push piers were installed at the outside edge of the spread footings along the masonry walls. The piers were driven to refusal at an average depth of 13.5 feet. Once all piers were in place, the installation contractor systematically manipulated the hydraulic driving rams to achieve the necessary degree of lift at specific locations along each wall. As a result of vertical lifting, the tops of both walls were successfully rotated to near plumb while, at the same time, the vertical deflections were significantly reduced and brought to well within tolerances defined for the project. Contained herein is a chronology of events, push pier installation data, a detailed description of the repair, and information pertaining to building loads and soil conditions.

Introduction

Dave Jacob, Dwyer Concrete Lifting's Ohio Regional Manager, received a phone call from Elford Construction Project Manager, Dave Jones on the afternoon of October 14th. Mr. Jones asked Dave if he would come to the construction site at the new Voice of America Mall to look at settlement problems with two masonry block walls that were part of a new Target Department Store currently under construction. Dave met with both Dave Jones of Elford and John Wise – the construction manager for Target's mid-

eastern district, and the two men explained to Dave that there was a serious foundation failure on the north and south walls of this 120,000 sq. foot store. The problem was described to Dave as critical because all steel roofing and steel structural work had been shut down. After this brief introductory meeting, the three men went to view the problems with the walls. Photographs of the site before repair are shown in Figs. 1 and 2. As can be seen in the figures, the store was in the early stages of construction. Concrete masonry unit (CMU) block walls had been constructed and were temporarily braced for wind

loads. The roof trusses were not completely in place at the time of the failure.

The first wall that the owner, the construction manager, and Dwyer's Dave Jacob visited was the north wall – the wall with the most severe problem. A considerable crack in the interior concrete slab was immediately apparent, and it measured approximately 1/2" to 5/8" wide at its worst point. The crack ran adjacent to the wall for approximately 200 feet and ranged in distance from 3 to 4 feet from the wall's base. The two men quickly pointed to some hand written measurements marked at eye level on the wall about every 20 feet. As they explained to Dave, these markings represented the distance the north wall had rolled outward (to the north) at the top of its 27 foot height as measured by the steel contractor on October 10th. The measurements ranged from a minimum of 1/8", close to both the west and east corners of the wall, to a maximum of 2-3/4", near the center of the wall's 310-foot total length.

The extreme amount of lateral wall movement had created two serious situations for the contractor and owner.

1. The roof truss supports could not be welded to the wall, and
2. The wall had actually "moved" across the property line into the adjacent tenant's property

Dave Jacob immediately queried both men about the foundation design that was selected to support the wall. Elford's Dave Jones explained that there was intended to be an 18" to 36" wide spread footing under the entire wall.

Due to the close proximity of the adjacent property line, the design was changed and instead the first approximately 250 feet of the wall's footing was shifted inward and constructed flush with the exterior alignment of the CMU block wall. This change in the foundation design, in conjunction with heavy amounts of rain at the site for several days, were deemed, by Elford's structural engineers and the contracted geotechnical firm for the project, to be the sources of the failure.



Fig. 1 North Wall of Target Store Under Construction



Fig. 2 North Wall of Target Store Showing Lateral Bracing

When the three men finished discussing the conditions at the north wall, they quickly went to examine the similar conditions at the structure's south wall. Although the settlement and subsequent outward roll of the south wall was not as severe as with the north wall, the top of the south wall had rolled outward (south) 1-7/8" inches near the center of the wall's 260 foot total length, as recorded by the steel contractor. The concrete slab also had a crack similar to the crack at the base of the north wall. The slab crack is shown in Figs. 3 and 4. A similar foundation design change had been made on this side of the building due to the close proximity of the property boundary. The foundation failure of the south wall was again attributed to the eccentric loading on the spread footing for the first approximately 200 feet of the wall measuring west to east. A photograph of one of the cracks in the CMU block wall is shown in Fig. 5.



Fig. 4 Close-up View of Example Floor Slab Crack



Fig. 3 Example Floor Slab Crack Adjacent to South Wall



Fig. 5 Example Vertical Crack in South Wall of Target Store

Once the south wall examination was complete, the three men returned to the construction office to discuss a potential remedy. The ensuing discussions focused on the amount each wall would have to be rotated inward in order to achieve a near plumb condition and satisfy both the roof construction requirements and the adjacent property line restrictions. Dave Jacob was informed that each wall could not be more than $\frac{3}{4}$ of an inch out of plumb in order to complete the welding of the steel roofing trusses, and this amount would more than satisfy the property line requirements. Additionally, Jacob was informed the remediation project had to be started immediately – preferably on Monday, October 21 at the latest (only 6 days after the initial telephone call). Dave was provided with a set of prints for the project as well as the geotechnical engineer’s soils report for the site. He informed the two men that he would be in touch later that day with a proposal to return both walls to within the required specifications.

Upon reviewing the job with Dwyer engineers and piering specialists, it was determined that piers would need to be installed every five feet along the walls. This meant that a total of 50 piers would be required for the south wall and 60 piers for the north wall. It was also decided that all piers for each wall would have to have hydraulic rams mounted on them simultaneously for lifting, which would require Dwyer to mobilize 60 hydraulic rams to the site to complete the lift. It also necessitated careful review and some rescheduling of the piering projects already planned in Dwyer branch offices located in Cincinnati, Columbus, Lexington and Louisville.

After making the decision to proceed, Dave Jacob called Elford’s Dave Jones and provided him with a verbal price estimate and a brief description of the proposed solution. He also informed Mr. Jones that Dwyer would commit to starting the project on the following Monday, October 21st. The proposed piering method, the price and the start date were all deemed to be tentatively acceptable, and Jacob formalized the quotation, terms and conditions in writing in preparation for a meeting the next morning - Wednesday.

Dave Jacob presented the proposal as planned on Wednesday, and the project was formally approved to start on the following Monday.

Building and Site Description

The Voice of America Mall project site is located on Tylersville Road in West Chester, OH. The ground surface is comparatively flat across the site. Subsequently, minimal site grading was performed in preparation of Target Store construction.

A view of the Target Store from a distance is shown in Fig. 6. A view of the inside of the store at the time of repair is shown in Fig. 7. This figure reveals that the store consists of a combination of masonry and steel construction. The rectangular store footprint encompassed approximately 120,000 sq. feet, and measured roughly 310 ft x 400 ft.

Adjacent property lines to the south and north walls were extremely close. In fact, the store width was only 8 inches smaller than the lot width. This condition necessitated that the foundation had to be virtually flush with the block wall as shown in Fig. 8.



Fig. 6 Distant View of Target Store Site



Fig. 7 View from Inside Target Store



Fig. 8 As-Built Spread Footing Shown Nearly Flush with Exterior Wall

The north and south exterior walls were to consist of 8" CMU block with a brick veneer and foam insulation. Both walls were grouted on 32" spacing. The final height of the walls was 27 feet from interior slab finished floor to the top of the parapet. The foundation extended approximately 30 inches below the top of the slab. The original foundation design for these walls can be summarized as follows:

North Wall

The foundation for the north wall was designed as follows:

0 to 250 feet – 26" wide, 12" thick spread footing eccentrically offset and vertically flush with exterior wall

250 to 310 feet – 18" wide, 12" thick spread footing centrally located under exterior wall

South Wall

The foundation for the south wall was designed as follows:

0 to 200 feet – 26" wide, 12" thick spread footing eccentrically offset and vertically flush with exterior wall

200 to 260 feet – 18" wide, 12" thick spread footing centrally located under exterior wall

Subsurface Conditions

The soil conditions on the site predominantly consist of soft, wet silty clays to lean clays with sand partings, gravel, and rock fragments (glacial till) that gradually stiffened with depth

underlain by stiff layered shale and interbedded hard limestone at a depth of 7.5 to greater than 15.4 feet. Ground water was typically encountered at depths of 1 to 3 feet below the ground surface at the time of drilling.

Foundation Loads

The building was designed with an internal steel frame and external masonry walls. The structure's roof system consisted of steel bar joists with corrugated metal deck and standard built-up roof materials. The masonry walls were load bearing and spaced approximately 22 feet from the closest set of interior steel columns. Thus, the walls supported approximately 11 ft of tributary roof loads and their own weight.

The estimated dead load of the walls and foundation prior to attachment of the roof joists and installation of the brick veneer is 2.5 kips/lf. After construction is completed, the total live and dead load on the walls is on the order of 4.5 kips/lf. This assumes a 20 psf snow load for the Ohio area.

The required total dead and live design load capacity of the piers spaced 5 feet on-center is 23 kips. Applying a factor of safety of 1.5, indicates that each pier must be installed and load tested to a minimum of 35 kips.

Since the weight of the structure itself is used as resistance for the installation of this type of hydraulically driven steel push pier, pier spacing is typically governed by the weight of the structure that can be utilized safely without risk of overstressing and cracking the foundation and wall. It could be assumed that the store wall was, at a minimum, designed to span an

unsupported distance of eight feet. Hence, the available load for pier installation without risk of damage is the weight of 16 feet of wall or about 40 kips. Pier installation to 35 kips could be accomplished by installing the piers individually thereby utilizing slightly less than the available weight of the wall at each pier location.

Lifting and rotation of the wall is performed using all Magnum Piering hydraulic rams simultaneously. It follows that the dead load on each pier due to the partially constructed wall, which was 12.5 kips per pier, should correspond roughly to the lifting forces that would be necessary. The true force required for lifting may be higher than this due to soil mobilization along the interior of the foundation wall and cohesion under the footing.

Alternative Repair Solutions

Target and the general contractor considered tearing down and replacing both walls and their respective foundations, but the added construction costs and lost time made this extremely expensive option a last resort. Using the Magnum Piering remedial steel push pier underpinning system was considered to be the most economical solution with the least amount of impact on the overall construction schedule.

Other systems that may have been considered are helix remedial piers or concrete piers. Each of these systems has drawbacks. Helix piers generally introduce more disruptive loads to the structure due to the larger eccentricity of helix pier brackets. It is also more difficult to use helix piers to achieve the precise, uniform, and controlled lift that was required by project tolerances.

Concrete underpinning piers are generally cost prohibitive and could not be installed within the property line restrictions. Concrete piers would require much more time to install, and they would not transfer loads below the soft soils with the building loads available due to increased installation pressures of the larger diameter concrete cylinders.

Considering time, cost, practicality, and sound engineering, hydraulically driven steel push piers were found to be the best solution for this project. Dwyer Concrete Lifting has been using the Magnum Piering Steel Push Piering System for over 10 years, and the firm has successfully stabilized thousands of commercial and residential foundations in the region.

Installation Data

The process of pier installation began by excavating along the exterior of the foundation as shown in Fig. 8. A site safety meeting was held whereby crews were briefed on construction hazards, and a wall monitoring program was set in place.

Next, bracket positions were marked along the wall, as shown in Fig. 9. Each Magnum Piering bracket was secured using $\frac{1}{2}$ inch diameter by $5\frac{1}{2}$ inch long, wedge anchors extending into the side of the footing. Normally, the footing is chipped flush with the foundation wall prior to bracket installation in order to minimize

rotational eccentricities. This step could be skipped, since the footing was already flush with the wall above. Bracket installation is shown in Fig. 10.

Next, the ram assembly is attached to the bracket and the installation of 30 inch sections of 3 inch O.D. high strength steel pier shaft is conducted, as shown in Fig. 11.



Fig. 9 Marking Bracket Positions Along Foundation Walls



Fig. 10 Bracket Installation

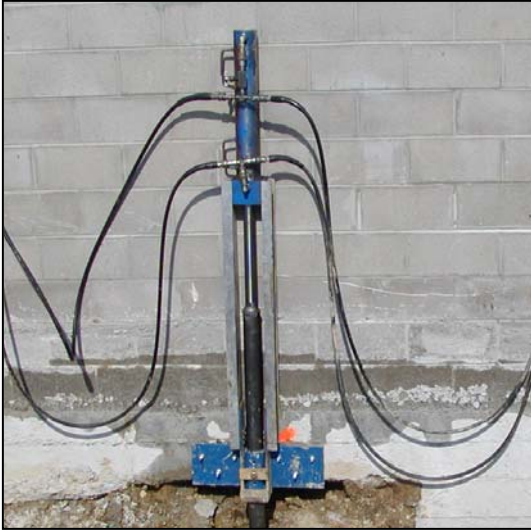


Fig. 11 Pier Installation

Hydraulic pressure during pier installation is recorded at various depths, as shown in Fig. 12. A log of these readings is prepared for each pier location. Pier installation is halted once the hydraulic pressure corresponding to the design ultimate capacity of the pier is reached. At that point, the load is maintained on the pier and movement is monitored over a period of time until the pier movement decreases to less than 1/16th inch per ½ hour. This process constitutes a full-scale load test at each pier location.



Fig. 12 Logging Pier Depth and Hydraulic Pressure

At the Target Store, the design ultimate capacity of each pier was 35 kips. In order to add to the factor of safety and ensure proper pier installation, Dwyer personnel installed each pier to the maximum load that could safely be applied to the structure (40 kips), which corresponds to a hydraulic ram pressure of approximately 5,000 psi. The final depth of the piers along the North and South walls of the building are shown in Figs. 14 and 15.

As can be seen in the figures, the final depth of the piers along the North wall varied from 10 to 20 feet below the top of slab and along the South wall from 15 to 19 feet. In either case, a discernable profile is evident. The reason for larger variation in pier depth on the North side of the site is unknown. However, the depth of the piers was generally consistent with the depth and variability of bedrock described in the geotechnical engineer's report for the project site. It was concluded that all piers are likely supported on or within the bedrock.



Fig. 13 Monitoring Wall Movement During Lifting Phase

After all piers were individually installed, it was time to lift and rotate the building walls back to within tolerances for plumbness. All rams were utilized simultaneously in the lifting process.

Survey stations were established inside and outside the building in order to monitor movement, as shown in Fig. 13.

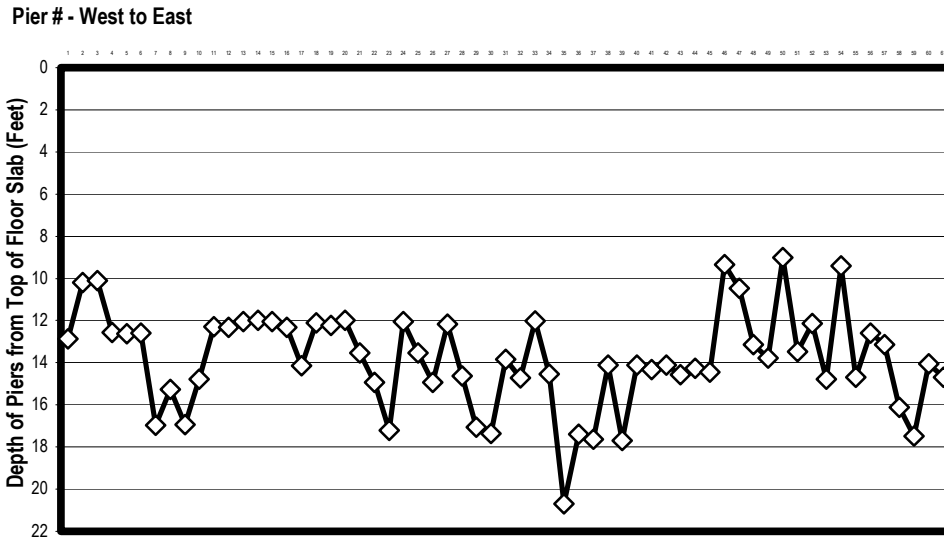


Fig. 14 Final Pier Depths Along North Wall

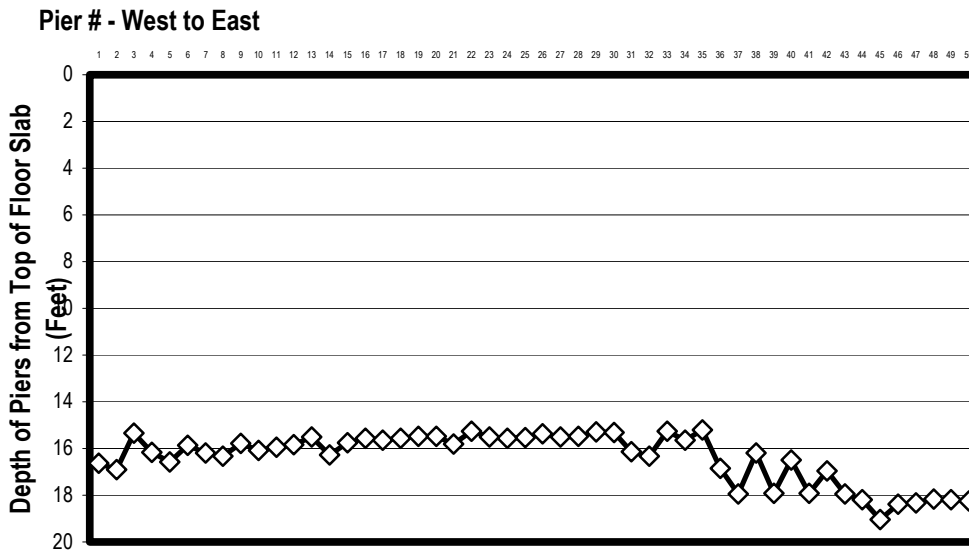


Fig. 15 Final Pier Depths Along South Wall

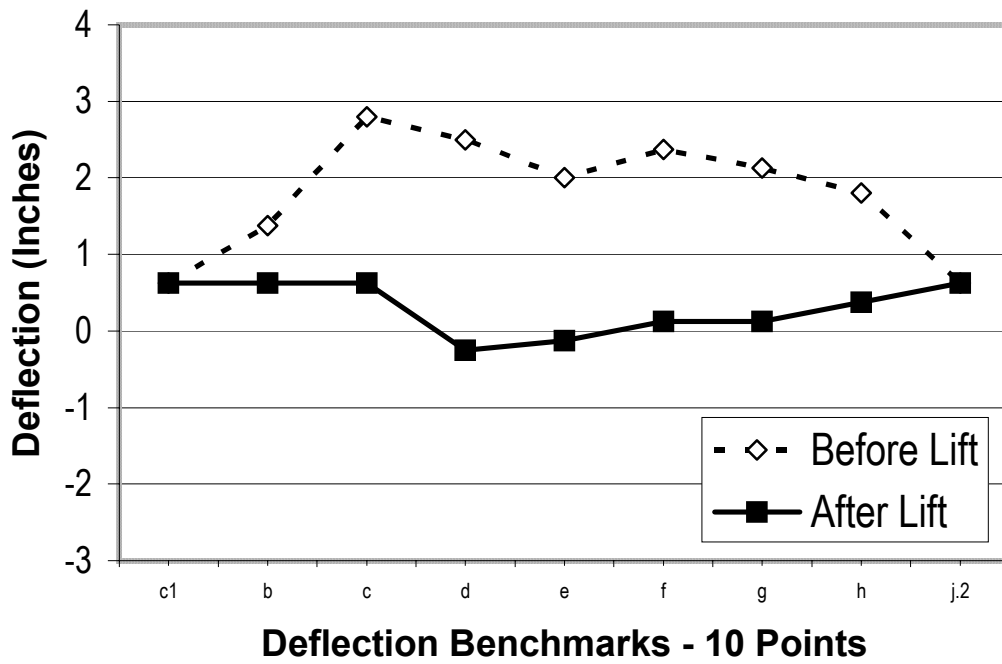


Fig. 16 Initial and Final North Wall Top Location

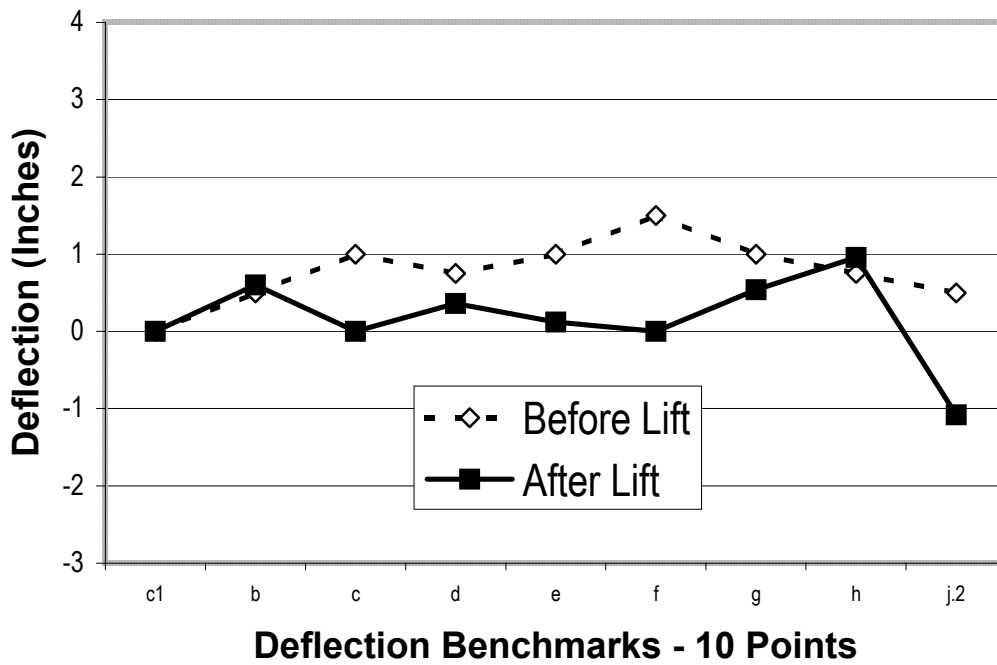


Fig. 17 Initial and Final South Wall Top Location

Both walls were successfully relocated. Initial and final top of wall locations with respect to plumb are shown in Figs. 16 and 17. The North and South walls were restored to within ½ inch of plumb, except for the Eastern portion of the South wall. The reason for this discrepancy is that the wall was not constructed perfectly straight. It was identified during this phase that the South wall had started to settle during masonry construction, and the block mason had to adjust the course of the wall. Afterward, the wall continued to move and eventually ended in the position where Dwyer was called to the site. The wall could not be improved beyond that shown unless it was reconstructed. It was deemed that the lift was acceptable and the underpinning project was completed.

Lifting was achieved at ram pressures of approximately 2,000 psi, which corresponds to a load of 16 kips. As expected, lifting forces were slightly higher than the dead load of the wall, 12.5 kips, due to soil mobilization along

the inside of the wall and cohesion below the footing.

After lifting, each bracket was rigidly fixed to the piers using two ¾ inch diameter grade 8 bolts. The hydraulic ram assemblies were removed, and the tops of the piers were cut flush with the tops of the brackets. Backfilling of the trench commenced and the piers were concealed.

Conclusions

The Target Store walls were successfully repaired using hydraulically driven steel push piers. The piers caused no discernable damage to the structure during installation. Each pier was installed and load tested to a factor of safety of 1.7 times the design total live and dead load of the completed structure. The entire 110 pier underpinning project was completed within 8 days from the start date and at a cost significantly less than the cost to reconstruct both walls.