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Micropile Underpinning of the Mandalay Bay Hotel & Casino

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ABSTRACT: Micropiles are small diameter high capacity drilled and grouted piles that are ideal for building foundations on sites with poor ground conditions, sensitive surroundings, restricted vertical clearance, or difficult access. They are also well suited for foundation underpinning, arresting ground movements, and increasing the capacity of existing foundations. This paper provides a case history of the emergency installation of over 500 micropiles to underpin the 43 story Mandalay Bay Resort and Casino in Las Vegas, NV prior to completion of final construction.

1 PROJECT BACKGROUND

On July 1, 1998, Nicholson Construction Company was asked to consult with the owner and developer of a large hotel development in Las Vegas, NV called the Mandalay Bay Hotel. Circus Circus Enterprises, now named Mandalay Resort Group were building a 3,700 room hotel complex consisting of 43 stories, and three radial wings that emanated from the central elevator core at 120-degree intervals (Figure 1). The central elevator core accommodated 28 vertical cars to be constructed inside four large shear wall enclosures. The total dead and live loading on the center core was estimated at 250,000 kips.

The center core was built on a 10-foot thick mat foundation at about 20 feet below grade. In early July of 1998, after the reinforced concrete structure was topped out, it was recognized that the vertical movements, and particularly differential movements between the tower core and the wings, were unacceptable. The structure, consisted of heavy reinforced concrete columns, that supported relatively flexible post-tensioned concrete floor slabs. If the movements were not stopped structural damage would occur. The center core at this point was sinking at a rate of about ½ to ¾ inches per week and the wings were sinking at a slower rate thereby increasing the differential distortion between column bays. It was imperative to quickly develop and implement a plan for supporting the structure. Micropiles (previously marketed by Nicholson as Pin Piles), installed with small equipment, inside the structure and adjacent to the large concrete shear walls that surrounded the elevator shafts were proposed and accepted by the owner and his engineers.

Figure 1. Overall elevation view of Mandalay Bay in 1998.

2 GEOTECHNICAL CONDITIONS

The valley of Las Vegas consists of very deep interbedded layers of alluvial sands, silts and clay (Vanderpool, 1998). Some layers of caliche and cemented sands and gravels exist at various elevations. Most large structures are built on mats foundations that gain support from the caliche layers. At the Mandalay Bay site, caliche layers several feet in thickness were identified at 20, 25, 65 and 85 feet below the surface. Harder layers of partially to fully cemented materials were also identified at depths of 185 to 200 feet below the mat and another at 300 feet below the mat. To obtain a sunken resort feel at the Mandalay Bay the shallow caliche layers were at least partially removed.

3 FOUNDATION SYSTEM

The approach was to drill and install micropiles through holes cored into the mat and not bonded in the mat, so that the piles could be jacked into the ground and maintain the building at a desired level. Then structural beam supports would be installed to act as permanent attachments and jacking frames. The entire system had the capacity to lift the center of the tower if that proved to be necessary. In order to support the center core, a layout consisting of 536 micropiles (Pin Piles) was developed by the structural engineer, Lochsa Engineering. Due to the limited plan area and the fact that it would be impractical to delay elevator construction to drill inside the shafts, all piles were located outside of the shafts. The resulting system was designed to support the core as if it was one very large pile cap. All the micropiles used to support the hotel core were 200 feet deep, were fully bonded with grout to the various soil and caliche layers and were isolated from the mat. The decision to drill 200 feet was based on a fairly substantial caliche layer being encounter at the depth in a preliminary methods hole and subsequent boring also often encountering a similar layer.

4 CONSTRUCTION

Each micropile consisted of 7-inch OD 80 ksi pipe sections drilled down with threaded flush jointed 10-foot long pieces. The lead piece had an 8-1/2 inch diameter roller bit attached to it so that an oversized hole was drilled. External flushing with water and polymer additives assured that the heavier soil particles were lifted around the annulus of the pile and ejected. The external flush drilling also provided very rapid advancement of the casing. In other cases, duplex drilling may have been selected as a lower risk option; however, the increased production obtained with external flushing far outweighed any ground loss risk, particularly given the predominantly clayey sands and sandy clays underlying the mat. A preliminary methods test hole was drilled outside the work area and cutting captured to prove this method would not cause major loss of ground.

Once the casing reached the desired bottom elevation, a flexible tremie pipe was lowered inside the pipe casing to the bottom of the hole. Neat cement grout, mixed in high shear colloidal mixers, with water to cement ratio of 0.45 and a super-plasticizing admixture was then pumped through the tremie pipe. This very fluid grout would often travel a significant distance up the annulus just under the head of the tremie. Finally, full external grouting was completed by attaching the drill head back on the casing, and pumping additional grout through the head of the drill until it was observed to be flowing up from around the outside of the pile (Figure 2). This technique of fully grouting around the pile annulus was developed in order to assure that the potential ground loss that may have been created with the external flush drilling was immediately restored in each case with the grout filling. Additionally, the fully bonded piles proved to act as reinforcement against ground movement, and improved the situation as the installation progressed.

Figure 2. Externally flushing with grout.

A 10-foot long PVC pipe was inserted over the top of the pile into the mat to act as a bond breaker. To connect the micropiles to the mat foundation each pile was constructed with its own reaction frame/transfer beam assembly and its own 350-ton jack (Figure 3). Four steel reaction bars were grouted into the mat around each pile. A small beam was placed on top of the pile, followed by the hydraulic jack and then another beam. The four reaction bars were attached to the top beam with large nuts. When the jack was extended, the force pushed down against the pile and up against the mat. When the desired load was reached, nuts were tightened down on the bottom beam to lock in the load on the pile. The forest of loading frames was accomplished by isolating a sub-basement below a new steel framed deck and floor at the lower entrance/baggage level of the hotel. All the utilities were restored and snaked through the new sub-basement.

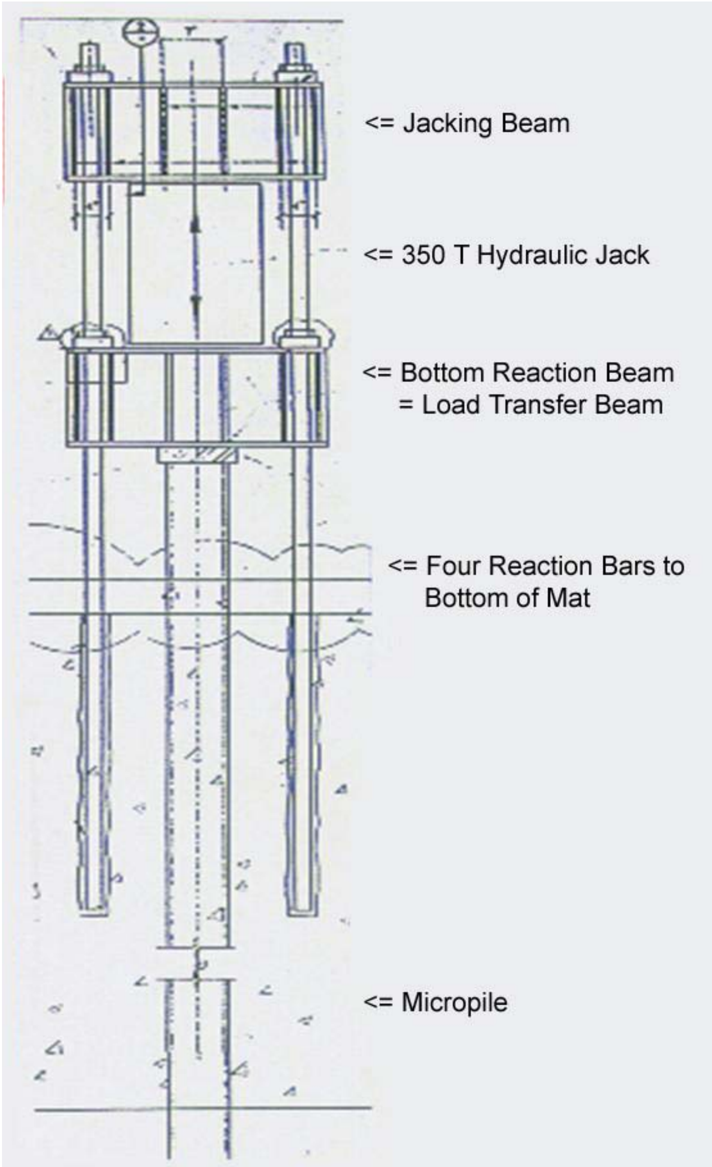

Figure 3. Load transfer and jacking frame.

5 QUALITY CONTROL

Each pile was cyclically load tested (Figure 4) with its own jack to 600 kips and finally locked off at a nominal load of 50 kips. This testing also tested the grouting of the reaction bars into the mat. This unprecedented level and magnitude of pile testing was a major selling point to the Engineers and Inspectors.

Grout samples were obtained at least once per shift and tested. Under full application of the observational approach, the building was also continuously monitored during micropile construction using level survey and tiltmeters to verify that methods were improving the settlement rate.

Figure 4. Overhead view of pile attachment frames.

6 RESULTS

From July 4th to the start of drilling, 9 feet of fill overlying the mat hat to be excavated around numerous utilities, and the utilities had to be relocated. Drilling work began on July 15, 1998 and was completed on October 9, 1998, working around the clock. Prior to full attachment, vertical building movements were reduced. After full attachment and jacking, the movement rate was further reduced. This is by far, a record for the largest number of full-scale pile load tests ever done on one site. No lifting of the core was attempted since the differential settlement between the core and wings was continually improving and since the floors were being leveled continuously during construction and attachment of the adjacent structures.

7 SUMMARY

In all, 536 7-inch diameter micropiles, were drilled and grouted over their full 200 foot length both outside and inside of the pipe Due to the full bonding, the piles acted as both ground reinforcement and structural supports to significantly reduce the rate of settlement of this major structure. Each pile was tested to 600kips = 1.5 times design load.

The major construction feat was the installation of about 110,000 lineal feet of high capacity piles in a very small plan area, with only about 20 feet of overhead clearance, all in about 2-1/2 months. All of the 536 load tests and attachment frames were completed only about 4 weeks after the last pile was drilled, at which time the nominal load of 50 kips was applied to all the piles. This entire time, crews worked together in one space performing

concrete coring, micropile drilling, frame installation, pile testing/jacking, installation and monitoring of instrumentation, installation of steel decking to form the floor above, and replacement of utilities that were diverted to accommodate the underpinning work.

A major reason this feat could be accomplished in the time frame was the willingness to use external flush drilling with the application of the observational method and full length grouting.

Because of Nicholson's prompt and efficient response, underpinning of the resort prevented any significant structural damage. The building is performing very much to the satisfaction of the owner, and in fact, even with the all of the additional foundation underpinning work that had to be performed, the hotel opened on schedule in early March of 1999.

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