

DOYLE DRIVE – EXTREME PILE INSTALLATION

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The foundations for the new South Viaduct Bridge in San Francisco were extremely challenging due to the requirement for very large and deep piles installed adjacent to historic structures. Drilled shafts up to 12' foot in diameter were constructed to a maximum depth of 200' feet in alluvial soils and Franciscan Bedrock using an oscillator system for the installation of the permanent steel casing. This paper provides an overview of the construction techniques, the equipment, and the challenges associated with constructing 12' foot diameter shafts on this very complex project in one of the nation's nicest landscape setting.

INTRODUCTION

The existing south access road to San Francisco's Golden Gate Bridge, known as Doyle Drive or Presidio Parkway requires replacement. Built in 1936 it is the primary highway and transit linkage through San Francisco between counties to the north and south and requires extensive seismic, structural and traffic safety upgrades.

The access road was named after Frank P. Doyle who was a roadway advocate and civic leader as well as the first private citizen to cross the Golden Gate Bridge.



Figure 1: Historic Bridge Rendering

The roadway is tucked into the natural contours of the Presidio and the Golden Gate National Recreation Area, one of the nation's largest urban parks. The High Viaduct is the result of the Golden Gate Bridge engineering team headed by Joseph B. Strauss of Chicago and principal engineer Charles Alton Ellis who was chiefly responsible for the design of the suspension bridge.

The old steel truss structure will be replaced by concrete cast-in-place bridge. The foundation

design of the new bridge is based on single drilled shafts below each bridge column. Most shafts required large diameter permanent steel casing to be installed under strict vibration limitations since several historic landmarks are in the direct vicinity of the project alignment.

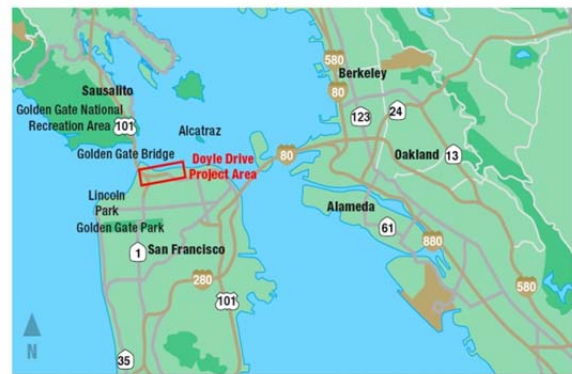


Figure 2: Project Plan

SUBSURFACE CONDITIONS

The area occupied by the Presidio is generally hilly, sloping down northwards to the Bay. In the western half of the project route, two bluffs rise steeply to about 80' feet. The two bluffs are separated by a valley 60 feet deep and 1,500 feet wide, which is spanned by the old and new High-Viaduct Bridge.

Overburden soils in this valley are made up of artificial fill, slope debris, ravine fill and Colma Formation, an unconsolidated to weakly consolidated fine to medium-grained sand unit with clay beds.

The Bay Muds encountered in the project area are typically clayey silts, greenish gray to dark

gray, and generally soft, becoming medium stiff with depth.

The basement rocks underlying the overburden belong to the Franciscan Formation.

The Franciscan Formation, described as Shale, Sandstone, Serpentine and Greywacke is extremely variable in hardness, fracturing and weathering. The material can vary from very hard to very soft, can be slightly to very intensely fractured and almost not weathered to totally decomposed within relatively short distances both laterally and vertically.



Figure 3: Franciscan Formation

Rock strength can vary from too weak to be tested to Serpentine layers with UCS of 15,000 psi or higher.

Groundwater levels in the area are typically no more than 10 to 20 feet below the ground surface.

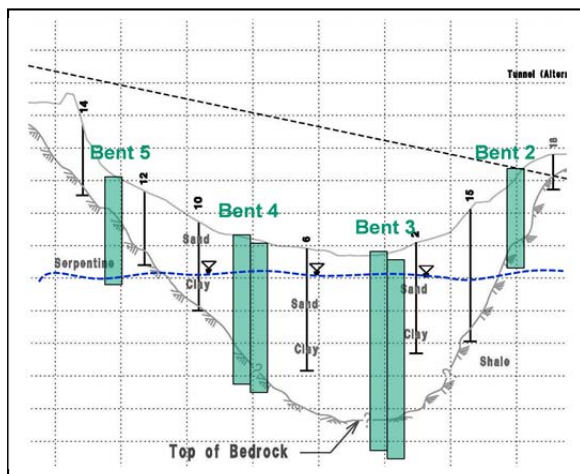


Figure 4: Viaduct Cross Section

CONSTRUCTION

The main viaduct bridge is supported on 6 bents with one 12 foot shaft underneath each bent. Abutments and one on-ramp are supported by smaller diameter shafts not discussed in this paper.

The Doyle Drive Viaduct is the first highway bridge structure in California supported by 12 foot diameter drilled shafts.

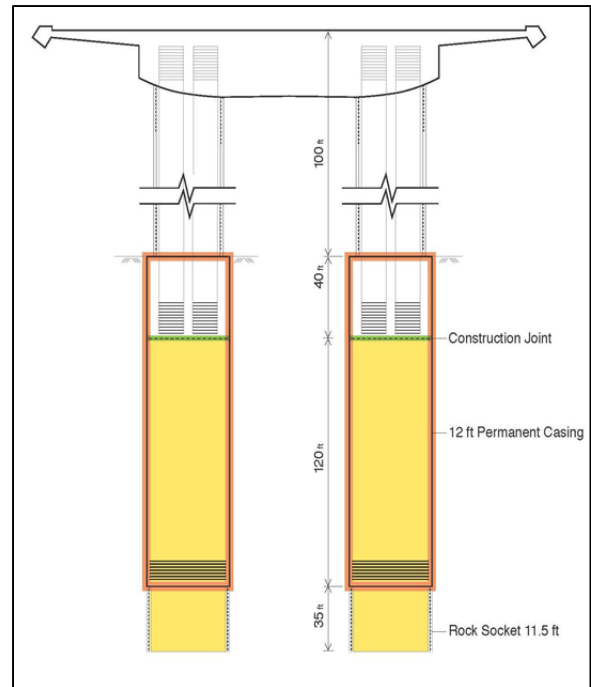


Figure 5: Bent Cross Section

Casing Installation

All 6 Viaduct shafts have been designed with permanent 1.5 inch wall thickness steel casing. The total weight of the longest 170 foot casing was in excess of 400,000 lbs and required multiple splices to facilitate handling. Full penetration welding for such large casings takes time even while utilizing multiple welding crews. The risk of pile freeze during such extended welding time increases the risk of not advancing the casing to depth... The ground conditions on site included massive layers of non-cohesive materials which increases this risk.

The installation of such long 12 foot diameter steel casings by vibratory methods was ruled out due to noise and vibration issues. Moreover, even without these restrictions utilizing the

largest Vibro hammer would have been a major challenge.



Figure 6: 12 foot Diameter Permanent Casing Section

Impact driving was considered very risky since the vibrations limits which the adjacent historic brick structures could withstand may be exceeded by the required powerful pile driving hammers.



Figure 7: 12 foot Oscillator Machine

To eliminate the risk of vibration entirely, it was decided to utilize the largest available oscillator to advance the casings without inducing any ground vibration and to help eliminate potential “freeze-up”. This was the first time such a large oscillator was used throughout the world. Therefore no comparable performance data was available. To complicate matters, schedule and site lay-out restrictions required the deepest shaft to be constructed first. One can imagine that almost everybody involved in the project anxiously awaiting the results for the casing installation.

Overburden excavation within the casing was performed with a spherical grab operated by another brand new 210 ton duty cycle crawler crane, equipped with 2 synchronized 30 ton winches for the extraction of this 40 ton tool.

The casing was designed to prevent caving in the upper very loose Dune sands and soft clay layers and to provide the best possible means for a defect-free construction of such large mono-shafts. The advantage which the oscillator

installation method offers by using temporary instead of permanent casing was not incorporated into the design or installation procedures by the client.

Rock Socket Drilling

The clients design required all casings to be installed 5 to 10 foot into the underlying Franciscan formation. Through the casing, Malcolm Drilling would then drill an “open hole” rock socket an additional 35 to 45 feet into the bedrock.



Figure 8: Oscillator with Spherical Grab

Specifications required the mandatory use of Polymer drilling fluid for all cased shafts as well as the uncased rock socket. Since material strength in the Franciscan formation can vary widely, the casing tip is the most vulnerable section when penetrating the rock. Carbide reinforced teeth were attached to the casing tip to aid the installation and to provide sufficient cutting clearance.

One of the largest rotary drilling rigs, a Bauer BG 40 S was employed to drill the 11.5 foot in diameter rock sockets up to a maximum depth of 200 feet below grade. Several tools had to be

custom build or shipped from overseas for these “extreme” shaft dimensions.



Figure 9: Rock Drilling Operation

Reinforcement Installation

Extreme seismic loads and very tall bridge columns resulted in a very dense reinforcement configuration with individual shaft cages weighing up to 150 tons. A custom designed tipping frame and unique suspension system was required to handle and splice these exceptionally long and heavy rebar cages.



Figure 10: Rebar Cage Tipping Frame

Additional stiffener rings were attached to each cage section to safely support and transfer the load of up to 150 ton.



Figure 11: Rebar Stiffener Rings

The Pile rebar cages were suspended over the casing using a custom built suspension frame and hydraulic jacks. Loads added to the suspension system by the fresh concrete were factored into the capacity of the system.



Figure 12: Rebar Suspension Frame



Figure 13: Rebar Cage Suspension

Concrete Mix and Performance

The concrete mix design was developed with special emphasis on maintaining workability for the extended duration of the tremie concrete placement operation.

Total placement duration was not controlled by the extraction of casing (since permanent) but by the successful supply of concrete which was transported across the city of San Francisco. Traffic restrictions, as well as unforeseen road blockades due to accidents, rallies, or simple day-by-day rush hour traffic were the challenges.



Figure 14: Concrete Consistency

This 'high-performing' concrete mix had the characteristics of a self-consolidating concrete (SCC). About 50% of the Portland cement was replaced by a blend of ground granulated blast furnace slag and fly-ash which improved the workability and remarkably reduced the bleeding and segregation tendency. The ½ inch crushed stone represented about 50% of the total aggregate in the mix. A variety of chemical admixtures was used to control and maintain the workability for the extended placement duration.

Concrete trial test month ahead of the first pour were required to develop the mixture and fine-tune the dosage of all 4 different admixtures.

The mix proved to be one of the most successful 'high-performance' concrete mixes used by Malcolm Drilling and is now a standard mix throughout the company.

QUALITY CONTROL

Standard specification for any transportation project in California require the integrity testing of every shaft constructed with the Slurry

Displacement Method using Gamma-Gamma NDT testing.

This test uses a radioactive probe which is lowered into a single (PVC) access tube and measures the amount of reflected photons. These are related to the energy level of the surrounding material and can be calibrated to the relative concrete density in a 2"-4" inch radius around the probe. Since access tubes are placed at the shafts perimeter, any sudden change in density might reveal a potential anomaly on the outside of the shafts, affecting the structural integrity of the entire shaft.

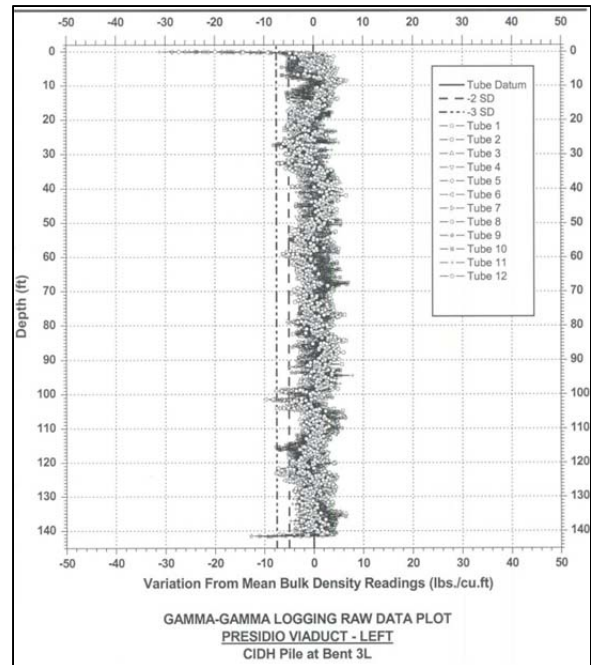


Figure 15: Gamma-Gamma Test Result

Additional CSL testing might then complement the Gamma-Gamma testing to determine the extent of the potential shaft anomaly through the core of the shaft.

All shafts on this project were tested with both methods and revealed only very little potential for anomalies. One minor near-surface concrete repair had to be performed and some so called "administrative deductions" were imposed by the client. The deductions for potential minor anomalies which do not impose any structural risk are a standard condition within Caltrans Specifications.

Since the shaft design was based entirely on load transfer in the rock socket section, one of the main focuses during construction was

directed towards the cleanliness of the shaft socket.

Visual inspection by a Mini SID camera was employed for every shaft. The acceptance criteria was very strict with less than ¼ inch of sediment over a maximum of 50% shaft base.



Figure 16: Shaft inspection Device (SID)

This criteria required the use of specially fabricated cleaning buckets, polymer sedimentation aids and air lifting to ensure contract compliance.

Given the nature of the 'soil-type' material rather than a classic hard-rock socket at the shaft base, there is definitely the need for material specific criteria to avoid unnecessary and potentially harmful shaft base cleaning procedures in the future.



Figure 17: Slurry Tank Battery

CHALLENGES

The Franciscan formation is locally known to be very variable and sometimes results in local block failures due to the large borehole radius.

Local instabilities can easily create unstable excavation conditions which cannot be stabilized with drilling slurry and could jeopardize the entire shaft construction.

This condition occurred in one shaft which required partial backfilling of the rock socket with lean concrete and the re-drilling of the rock socket to the specified depth and diameter.

Predictable drilling conditions and procedures as well as efficient cleaning of the shaft tip are keys to successful completion and compliance with the specification in such ground conditions

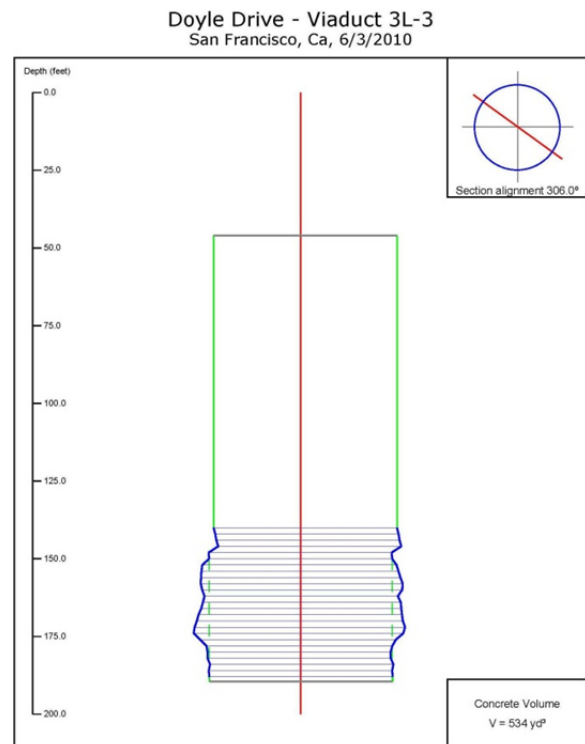


Figure 18: Sonic Caliper Test Result

Such large shafts with single concrete volume of up to 600 cubic yards require detailed planning for every construction step. Equipment is getting so big and requires not only sufficient footprint for set-up, but also stable working platforms.

At times support piles are required to transfer the installation forces. Oscillators able to install 12 foot casings can induce up to 900 tons of downward pressure into surrounding soil immediately adjacent to the pile being drilled.

Support equipment like service cranes and slurry holding tanks soon exceed "normal" dimensions and numbers which our industry is

familiar with when constructing “extreme” shafts. Lay-down areas have to be planned and constructed with extreme care and foresight.

CONCLUSIONS

Drilled shafts of this diameter and depth require a different perspective and approach than the “normal” foundation pile due to size and weight of all materials as well as required installation equipment.

They also require special considerations of the borehole wall stability, both in caving soils and potentially caving rock.



Figure 19: Site Set-Up

The new 12 foot in diameter oscillator has proven that it can effectively advance steel casings to such extreme depth of 170 feet using a vibration free method.

This construction method does not only allow construction in environmental sensitive areas but further enables the replacement of commonly used permanent steel casings with reusable temporary segmental drill casing.

Temporary drill casings could also be further advanced into unstable or soft rock conditions, as previously demonstrated on the 7 foot in diameter shafts for the Benicia Martinez Bridge in California.

With the new generation of powerful hydraulic rotary drill rigs, pile socket can be drilled in fractured rock formations to extended depths even deeper than 200 feet

Temporary and permanent casing methods provide a superior installation method in regards to pile integrity. This method has the best track record in anomaly-free pile installation as compared to other slurry displacement methods.

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