A Case Study: Farrell Drilled Displacement Column Ground Improvement

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The objective of this study is to document the ground improvement techniques employed by Farrell Design-Build Inc. to allow for the construction of the Emeryville Public Market. The market is a Mixed use building, housing tenants, a ground floor grocery, and parking structure. By showing the effectiveness of this system, it is the hope that other industry professionals will be more capable to undertake and solve complex soil issues. Ground improvement is a technical, and necessary part of construction, allowing for vertical construction to begin. Farrell's technology has the ability to transform industry standards, and create new methods of dealing with poor soils. In this instance, on the Public Market, the land designated for construction had a history of being a dumping ground in the early 1900's. Close to the San Francisco bay, all types of contaminants contributed to the degradation of the soil, from oil, to benzene, to asbestos. This created marsh-like, toxic soils, in which footings could not be easily excavated and poured. Farrell's patented Drilled Displacement Column™ technique was of great use in this situation, and has the potential to be of equal use in other similar projects. Documenting this process is vital to the constant improvement of the construction industry, and the never ending push towards quality construction practice.

Keywords: Soil, Ground Improvement, Documentation, Farrell, Drilled Displacement

Introduction

April of 2016, General Contractor (Plant Construction) broke ground on the Emeryville Public Market, in Emeryville, California utilizing a specific type of ground improvement to rectify the poor soil conditions. Post geotechnical results, it became clear that the location of the project had in the past been a dumping ground for much of Emeryville's shipping waste. A toxic cornucopia of objects and contaminates were found, including: Benzine, Asbestos, Tar, and all manners of trash waste. The combination of these materials and significant time (approx. 70 years) created a swamp-like soil that was hazardous and unacceptable for construction. Plant Construction hired Farrell Design-Build Inc., who used their patented ground improvement technique, Drilled Displacement Column™ (DDC). This was selected to provide improved settlement performance and increased bearing capacity for the Public Market Structure. Without their technique, construction would have been difficult to move forward on, making foundation excavation and pouring impossible. Farrell's DDC ground improvement technique allows for a unique solution to the problem of construction on less than ideal soils.

General Background

Farrell Design-Build Inc.'s company mission statement is, "Go Vertical with Confidence" and that stands true. (Farrell website) Dedicated to the improvement of existing ground systems, they strive to achieve the best possible results. From their conception in the 1980's as a general contractor, Farrell has found its niche as a leading specialty geocontractor in the industry. With their core values based in safety, both of the structure, and those who work/occupy it, they were the perfect fit for such a project.

Plant Construction, the general contractor hired for the construction of the Emeryville Public market, has shares a similar mission with Farrell. The website states, "If it's worth building, its worth building well" Their constant commitment to not only on budget and on time construction, but excellent building practices, allowed them to search for, and find Farrell Design-Build Inc. and hire them as subcontractors for the ground improvement work.

Farrell had their work cut out for them, the highly contaminated and unsustainable soil posed a great challenge for any company wishing to move vertical. But through their confidence in their new Drilled Displacement Column, Farrell was able to move forward with the project.

Research Objectives

The objective of this case study is to analyze and report on the effectiveness and functionality of Farrell's Drilled Displacement Column™ technique. Based on both qualitative and quantitative data and research, the now completed Public Market will be evaluated. Now that the building is complete, the structural questions can be answered. Did Farrell's DDC technique allow the contaminated soil to be transformed into one capable of sustaining the stress and strain of a building? Is this a system that can be utilized on any number of future sites with similar issues? The results of this study will allow Farrell and the industry to maximize the effectiveness of their system and pave way for a new ground improvement solution.

General contractors and project managers can use these finding to further their understanding of soils industry. Knowledge is the best ally to any contactor, and understanding as many possible solutions make a manager far more effective in his or her role. Is this system a potential solution for certain contractors? What other situations and projects can this technique be used for? Contractors and their managers will be able to make informed decisions about using this system in their future projects.

The benefit of this case study reaches past Farrell, affecting the industry as a whole. In a world where land is a limited resource, the ability to use contaminated soils for construction becomes increasingly important. Farrell's DDC system can be a driving force for change, allowing new methods for repairing all types of undesirable soil. Construction strives when there is a desire and need for constant improvement, and change is always a positive aspect when it comes to improving current means and methods.

Methodology

The methodology for this case study includes quantitative and qualitative research and data. By taking the quantitative data gathered and applying it qualitatively to construction as a whole, there will be a greater understanding of the use of Farrell's DDC system and how its application can transform ground improvement practices. By referencing the specific implementation of the technique, a greater understanding as to its effectiveness will be achieved.

The quantitative research was gathered from industry professionals at both Farrell Design-Build Inc., and Plant Construction Company. Documentation on the technical systems and their function were acquired and allowed for use in this case study. Details regarding the specific use of the DDC system was provided by:

- Sam Warren, Project Engineer at Farrell Design-Build Inc.
- John Ho, PhD Principle Engineer at Farrell Design-Build Inc.

Information pertaining to the ground improvement portion of the Public Market Project was provided by:

- David Smith, Senior Project Manager at Plant Construction Company LLC

Case Study

The following are the steps taken by Farrell Design-Build Inc. and Plant Construction Company to ensure the system was a fit for this project, as well as detailing Farrell's implementation of the DDC system on the Public Market Project.

Farrell's Drilled Displacement Column™ are deep, partial, and full displacement, well-defined, pressure grout, ground improvement methods. DDC are used to improve any soft/loose soil or contaminated soil. The DDC process constructs strong engineered composite ground for the support of foundations and slabs. DDC uses a displacement drill to compact soil in the ground, resulting in higher capacity and lower spoils. For DDC, large cavity expansion in the displace soil produces the increased strength and ground improvement. DDC strengths are enhanced by the pressure grout effect during construction. DDC increases bearing capacity, increases soil stiffness, reduces soil compressibility, increases soil resistance to liquefaction, and increases composite soil shear strength. Construction of said DDC columns produces low noise and no vibration in the ground. The composite ground supports heavy loads on conventional foundations, slabs, and mats with uniform and reduced settlement.

The application of this system is mainly used in:

- Support foundations
- Structural mats
- Slabs
- Embankments
- Mechanically stabilized earth walls
- Industrial Foundations

The use of DDC's in this case study were the support foundations for the Public Market building

Ideal site types for this system include:

- Deep, Soft and loose soil sites and bay mud/sensitive soil sites
- Compressible soil sites
- Contaminated soil and undocumented debris fill sites
- Groundwater protection Regions
- Sensitive sites with vibration concerns near critical structures
- Sites near occupied buildings and in dense urban areas.

The Geotechnical report for the subsurface conditions of Emeryville Public Market reported:

- Fill and marsh deposits extend down 5-12 feet below ground surface
- Fill underlain by alluvial deposits consisting primarily of stiff to hard clay with occasional layers of medium dense to very dense sand
- Groundwater generally at depths between 3 and 8.5 feet below the ground surface

The Emeryville Public Market is located less than half a mile from the San Francisco Bay, fitting the criteria for bay mud/sensitive soil sites. This close proximity, and subsequent shallow groundwater depths, caused significant liquefaction in the soil, contributing to the poor condition. As previously mentioned, Benzine, Asbestos, Tar, and all manners of trash waste were discovered throughout the site, and as excavation continued, considerable amounts of undocumented debris were discovered. This area was also considered to be a groundwater protected region, with SWPPS (Storm Water Pollution Prevention Plan) being mandatory on the site. The Public market site co-inhabits the adjoining space with residential tenants, packed into the heart of Emeryville. Because of this, noise and vibration were precautions that were necessary.

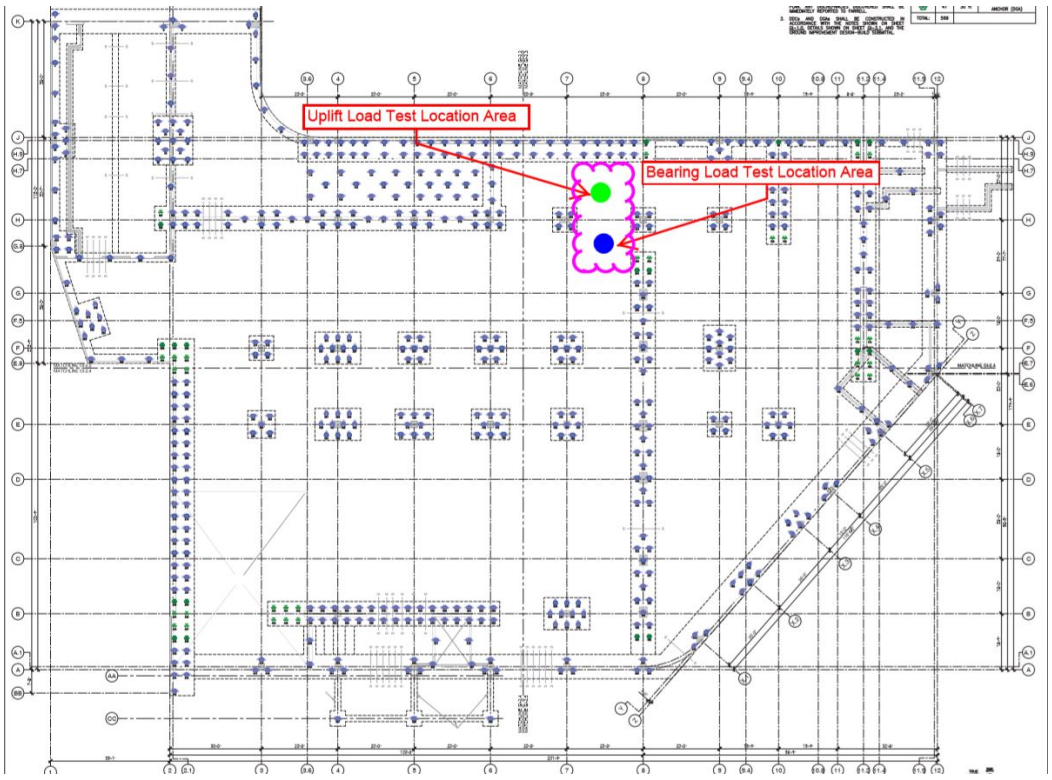

Figure 1: DDC/DGA Locations

The above Figure 1 depicts the DDC locations based on their calculation and load testing also shown.

Farrell determined this site to be suitable for installation of 367 DDC's, as well as 39 DGA (Drilled Ground Anchors) in key locations to include additional uplift resistance. These DGA columns act similarly to the DDC's but has an added single steel reinforcement bar installed in the center of the pier, which is later embedded into the foundation, for uplift resistance. Both column types to be installed at 45' below grade. These were proposed to increase the strength and stiffness of the native soils, and limit static total and differential settlement.

Load testing included two different types of tests to assure the correct number of columns were installed, in the appropriate locations.

- Load Bearing test: The maximum load of 90 kips at 100% load and up to 192 kips at 200% load was applied to confirm design assumption by a full-scale load test in general accordance with the project plans and specifications.
- Uplift Load test: The maximum load of 52.5 kips at 100% and up to 105 kips at 200% was applied to an installed DGA to confirm design assumptions by a full scale load test in general accordance with the project plans and specifications.

Passing these tests, the installation of the Drilled Columns came next. Farrell has a four step construction process for the column placement.

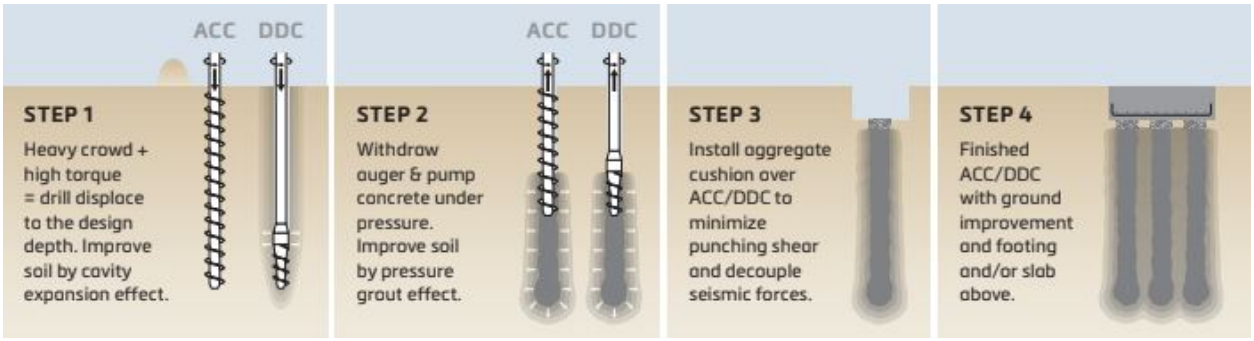

Figure 2: 4-Step Construction Process

As seen above, the DDC system of installation consisted of this 4 step process, repeated a total of 367 times. The ACC process was not used in the Emeryville Public Market Project.

The DDC rig uses a full displacement tool that is shaped to laterally displace and compact the adjacent soil into the ground, forming strong composite ground. The tool and the pressure grout effect result in a coarse sided sand-cement column. The displaced soil causes cavity expansion, increasing shear strength, increases density, increases over-consolidation, reduces the void ratio, and increases stiffness of the composite ground. This creates deep ground improvement columns.

After the drilling and installation of the DDC system, Plant Construction is able to pour concrete footings without worry of inadequate soils.

Discussion

Farrell's relatively recent approach to ground improvement is monumental to the construction industry. This system fills a niche that has been vacant until now. This is not to say that there are no similar systems, but to say that none solve the issue presented in the Emeryville Public Market. Hayward Baker Inc. has a ground improvement technique that appears to be similar in nature. In their brochure on their Rigid Inclusion system, it states, "*Rigid Inclusions (RIs) are high modulus/controlled stiffness grout columns typically installed through weak, highly compressible soils to reduce settlement and increase bearing capacity."* This system offers a ground improvement solution with similar method to Farrell, using grout method. However, it fails to meet some of the criteria required for the Public Market's soil. Previously it was mentioned that the public market site did indeed have highly compressible soil, but it was also found to be a high water content, bay mud soil, with contaminants, and SWPPP requirements. Other ground improvement techniques, like Hayward Bakers, do not satisfy these requirements for a solution. The Farrell Drilled Displacement Column™ is an, "*Innovative upgrade to rigid inclusion ground improvement for foundation support. With an expanded base, DDC achieve higher bearing capacity than other rigid inclusions."*(Farrell Website)

Conclusion/Results

Farrell Design-Build Inc. used their Drilled Displacement Column™ Technology to transform the Emeryville Public Market contaminated, unusable soil into a structurally sound and supported site. After the final columns went in, Plant Construction was able to pour the footings and continue with the Market, as though working on perfect condition soil. There were no issues with the foundations, and as of 2018, the market is officially open and conducting business.

The benefit of the DDC system is its use in loose, liquefied, contaminated soils. With the proximity of the San Francisco Bay, and its history of dumping, the public market made an ideal candidate for Farrell. Through testing and implementation, the soil post DDC installation passed all necessary inspection and compaction requirements.

This system was the perfect fit for the Emeryville Public market, and shows great promise for similar situations, especially in the immediate area. On top of this, Farrell has other breakthrough technologies, with slightly different variations, allowing this system to be applied to a multitude of other scenarios. They build this ground improvement system to allow for a wide variety of soil types, and contamination levels.

The ability to understand limitations and surpass them is what allows for forward progress. With Farrell's DDC system, they are taking the necessary steps to improve the industry for the better. Their work, bettering previously existing ground improvement technology, is innovation at its finest. The use of this for projects similar to Emeryville Public Market is not only possible, but necessary.

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