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Ground Improvement

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PROJECT CASE STUDY

Soil-reinforcement challenges in California

New wastewater treatment plant meets demands of a growing community and earthquake procedures.

By Robert Kahl P.E., G.E.; Jennifer Skrel, P.E.; and Tom Farrell M.S., P.E., G.E

Project

Wastewater treatment plant, Oakley, Calif.

Participants

Ironhouse Sanitary District

GeoEngineers

Western Water Constructors

Farrell Design-Build | Geopier California

Project application

The Impact System, a soil-displacement Rammed Aggregate Pier method developed by Geopier Foundation Company, Inc., was used to reinforce and control static and seismic settlements.

The Ironhouse Sanitary District's wastewater treatment plant project site is located in Oakley, Calif., less than 1,000 feet from the south shoreline of the Big Break Slough in the low-lying San Joaquin/Sacramento River Delta.

California has long been aware of earthquakes and their potentially damaging effects. Twenty years ago, public agencies were often concerned with significant earthquakes located in seismic zone 4 or those areas closer to the San Andreas Fault. Today, civil engineers and owners face new challenges with updated building codes and revised procedures for determining earthquake ground motions, often in areas that were previously overlooked or not considered a significant hazard. The Ironhouse Sanitary District (ISD) in Oakley, Calif., was not immune to these new and revised earthquake evaluation procedures and the earthquake hazards identified by them.

ISD provides wastewater collection, treatment, and disposal services for the city of Oakley, Bethel Island, and some unincorporated areas of Contra Costa County in Northern California. The existing wastewater treatment plant consists of aerated ponds, storage ponds, and disinfection by means of sodium hypochlorite. Currently all treated effluent is land-applied to 425 acres on Jersey Island and 166 acres of "mainland" property. The wastewater treatment plant (WWTP) has a permitted capacity of 3 million gallons per day.

Substantial growth during the last several years has resulted in flows to the WWTP that are approaching capacity. To meet the demands for the growing community, ISD developed and evaluated several effluent disposal and treatment alternatives. The land selected for construction of the new WWTP presented additional challenges that included location within the 100-year floodplain, high groundwater, compressible soils, and liquefaction potential.

ISD chose to implement continued land disposal in conjunction with construction of a new outfall into the San Joaquin River. The original treatment alternative selected was extended aeration (oxidation ditch) treatment with ultraviolet (UV) disinfection constructed on lands owned by ISD; however, during the design phase, construction cost increases required

re-evaluation of the project components. Ultimately, ISD chose to change the treatment process from oxidation ditch to membrane bioreactor (MBR) because construction costs for MBR treatment were identified to be less than an oxidation ditch. This is because of substantially smaller treatment tanks and the 20-year present worth (PW) of the secondary and filtration portions of the MBR. Oxidation ditch processes were identified to be essentially equal even though the MBR treatment process is more costly to operate and maintain on an annual basis. Additionally, construction of the MBR facilities would have the following cost reductions and advantages compared with those reflected in the PW analysis:

- smaller footprint, resulting in savings for foundation construction, site work requirements to construct above the 100-year floodplain elevation, and less yard/process piping networks;
- higher clarity effluent, allowing downsizing of UV disinfection facilities;
- "state-of-the-art" technology, resulting in advantages to the NPDES permitting process;
- less costly to add future capacity; and
- more suitable to add reverse osmosis, if required in the future.

Facilities to be constructed as part of the overall project include: new influent trunk sewer, influent pump station, two-stage screening, grit removal, anoxic/aeration basins, MBR basins, UV disinfection, solids handling, chemical/electrical/blower building, and effluent pipeline and outfall.

GeoEngineers' Walnut Creek, Calif., office provided geotechnical engineering services during design and construction of the WWTP expansion project. The project site is located less than 1,000 feet from the south shoreline of the Big Break Slough in the low-lying San Joaquin/Sacramento River Delta.

Subsurface investigation revealed that the upper, approximately 14 to 18 feet of soil underlying the WWTP expansion site consisted of medium-stiff to soft clay with localized weak compressible soils and loose to medium-dense sands. Below 14 to 18 feet, medium-dense to very dense sands and stiff to hard clay were encountered to the full depth explored of 71 feet. Groundwater was present at depths of 2 to 4 feet below the existing ground surface.

The project area is subject to ground shaking during future displacement of the nearby Greenville fault and other seismogenic sources in Northern

Workers installed more than 2,400 Rammed Aggregate Pier elements in six weeks with two crews working five days a week.

California. The estimated peak ground acceleration at the project site during maximum magnitude (characteristic) earthquakes having a 10 percent probability of exceedance in 50 years is on the order of 0.37g. Analysis showed that the sands in the upper 2 to 18 feet would be susceptible to liquefaction at the estimated peak ground accelerations, resulting in post seismic settlement potential of 1 to 3 inches at the site.

The weak, compressible, and liquefiable soils underlying the WWTP expansion site were not suitable for supporting heavy hydraulic reinforced concrete treatment plant structures, which have a relatively low tolerance for total and differential settlement. To mitigate the total and differential settlement associated with problematic soils, GeoEngineers considered:

1) over-excavation of problematic soils and replacement with engineered fill;
2) support of structures on deep foundations; and
3) in-situ ground improvement.

The most cost-effective solution was identified to be ground improvement for control of total and differential foundations settlement associated with the design sustained and seismic loading conditions. Deep dynamic compaction (DDC) was considered because of its use for a nearby project to densify clean sands. The need to improve the compressible clay layers and the potentially liquefiable sands resulted in DDC not being considered as an attractive option for this site. The most attractive ground improvement methods for the WWTP expansion site were Rammed Aggregate Pier (RAP) elements or stone columns.

Western Water Constructors (WWC) of Santa Rosa, Calif., was the successful low bidding general contractor. "It's a 30-month project," said Vice President and Chief Estimator Josh McGarva. "We're literally going out on what used to be a green site and building a new sewer plant. When finished, the membrane bioreactor plant will sit on six and a half acres of land and produce 4.3 million gallons a day of tertiary treated effluent for irrigation and discharge into the San Joaquin River."

Farrell Design-Build | Geopier California presented the successful ground improvement bid utilizing the RAP elements. The preferred method of installation by Farrell was a displacement method known as the Impact System, a soil-displacement RAP method developed by Geopier Foundation Company, Inc., of Mooresville, N.C. The Impact System uses a hollow mandrel that is driven into the ground using hydraulic crowd pressure augmented with a high-frequency vertical vibratory driving energy. Aggregate is bottom-fed through the mandrel and compacted using a unique tamper foot that forces the aggregate vertically and laterally into the surrounding matrix soil.

The Impact process is a common ground improvement application for loose saturated sands and in compressible soils that require reinforcement and control of static and seismic settlements. The Impact System provides a clean, dry installation resulting in little to no spoil generation. The RAP elements are designed to provide increased composite stiffness of the soil for static loads and control seismic settlements by:

- installation of dense, non-liquefiable RAP elements;
- densification of liquefiable sands;
- increased lateral stress and reinforcement within the matrix soil; and
- drainage for excess pore water pressure during seismic loading.

The Impact System was designed for sustained bearing pressures of 450 to 1,000 psf for static loads with a total and differential settlement performance specification of 1 inch total and 0.5 inch or less over 50 feet for lighter structures. Heavier structures, such as the Anoxic Aeration Basins, had design bearing pressures as great as 3,600 psf with a post-construction total and differential settlement of 2 inches and 0.75 inch or less over 50 feet, respectively. For liquefaction and post-seismic settlement control, GeoEngineers specified that post-liquefaction improvement cone penetration tip resistances were to achieve a minimum qc_{1Ncs} = 140 tsf.

RAP spacing of up to 8 feet on-center was used to control heavy column, wall, and slab loads, and liquefaction. The RAP drive depths extended to 22 feet below the ground surface. The RAP ground improvement design was verified by full-scale modulus load testing demonstrating performance that would meet or exceed the settlement criteria for sustained loading conditions. Seismic settlement control was verified by post-installation CPT testing within the matrix soil. Results of the CPT testing demonstrated that the resistance to liquefaction triggering was increased substantially through pre-installation normalized cone tip resistance values ranging from 80 to 150 tsf to post-installation values of 150 to 300 tsf, exceeding the minimum requirements for the project. Farrell Design-Build | Geopier California installed more than 2,400 RAP elements in six weeks with two crews working five days a week.

The Impact System demonstrated that the composite soil system would provide the required static and seismic performance, as specified in the contract documents. Through the combined efforts of the design team, contractors, and owner, the project resulted in a cost-effective solution for ISD that met or exceeded the project requirements. ■

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December 1, 2011

Tom Farrell
Farrell Design-Build Companies, Inc.
3025 Venture Road
Placerville CA 95667

RE: Ironhouse Sanitary District
ISD Waste Water Treatment Plant Expansion
Oakley, CA

Dear Tom,

Western Water is a general engineering contractor in the states of California and Oregon. We primarily construct water and waste water treatment facilities for both public works and private development projects. We had the opportunity to work with Farrell Design-Build Inc. on the $54,000,000 Ironhouse Sanitary District Waste Water Treatment Plant.

We worked hand in hand with Farrell Design-Build during pre-construction shop drawing and construction phases. This project was particularly challenging before vertical construction could begin with the loose sand conditions to depths of 30 feet. Farrell installed an innovative vibratory, displacement, ground improvement method to improve the density of the sand and increase the bearing capacity of the soil. Farrell used the displacement Rammed Aggregate Pier system known as Impact pier. It worked great.

During the time Farrell worked with Western Water on the project, they were professional, willing to put out the extra effort to keep us on schedule, and their crew on the ground was very efficient and performed a safe job. The Farrell team matches Western Water's value of a strong safety program and fair and ethical service for its customers.

I can confidently recommend Farrell Design-Build, Inc. as a solid and reliable ground improvement designer and installer. We look forward to working with the Farrell team on future projects!

Best Regards,

Micah Addison
Project Manager
Western Water Constructors
707-477-0683