**PROJECT MEMORANDUM**

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Company: City of Moorpark

Subject: Moorpark Library Project Site, Conceptual Ground Improvement Plan Cost Estimate

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This memorandum outlines a conceptual ground improvement plan cost estimate for the proposed Moorpark Library project site adjacent to High Street in Moorpark, California. The subsurface site conditions at the proposed library site are described in OGIs report dated June 17, 2017, and consist of an upper zone of very loose to loose granular soil from the ground surface to a depth of about 40 feet underlain by interbedded medium dense granular soils and medium stiff fine-grained soils from a depth of about 40 to 75 feet below the ground surface. Groundwater was encountered at a depth of about 37 feet during the site explorations in late April 2017. The results of the analyses indicate the granular soils in the upper 60 feet are susceptible to liquefaction-related settlement, dry seismic settlement, and lateral spreading. Based on the findings and analyses, ground improvement is required by the current building codes to densify or strengthen the onsite prior to construction of the proposed library building.

The preliminary geotechnical report identified two possible ground improvement methods; vibro-replacement (VR - stone columns) or deep soil mixing (DSM). Other ground improvement options could potentially be utilized pending evaluation by a qualified ground improvement contractor. The current building codes generally require seismic-related settlement be limited to two inches of total settlement and one inch of differential settlement. The estimated seismic settlements at proposed library site range from about 12 to 38 inches with an average of about 19 inches.

The suggested potential ground improvement techniques may be able to limit the seismic settlement to two inches or less; however, a more likely scenario would be that the selected ground improvement method could reduce the seismic settlement to about four inches and the proposed building foundation would need to be strengthened using a grade beam/waffle system or possibly a mat-type foundation.

Estimated fees are provided below for the two potential ground improvement options and for a grade beam-type foundation support system that appears to be generally suitable for a one-story wood frame building. We note both ground improvement methods have been used successfully at several sites in the Tri-county area: VR at Las Virgenes Municipal Water District's Tapia Wastewater Treatment Plant and the City of Santa Barbara's El Estero Wastewater Treatment Plant and DSM at the Ventura County Medical Center Replacement Clinic Building in Ventura, California.

**Conceptual Ground Improvement Elements:**

1) **Vibro Replacement (VR - stone columns).** As described in OGI's preliminary geotechnical report, the VR procedure consists of advancing a 30-inch diameter steel mandrel to the selected depth (approximately 40 feet at the library site) using a combination of the weight of mandrel and vibration. Once the mandrel reaches the selected depth, ¾-inch crushed rock is used to backfill the hole. The gravel is vibrated and "rammed" into the soft, loose granular soils. The stone columns are placed on a grid pattern with a spacing typically in the range of six to nine feet on-center. The soil displaced by the mandrel is "pushed" laterally into the adjacent soil, densifying the soil mass at the site to the point where it will resist liquefying and settlement in response to earthquake ground shaking. CPTs are advanced between columns after the VR is performed to evaluate the increase in soil strength/resistance to liquefaction. VR is an effective method of densifying granular soils to a depth of about 50 feet, but the process does not significantly improve the density of fine-grained silt and clay soils or highly interbedded fine-grained and granular soils (such as present below a depth of about 40 feet at the library site). In our opinion, VR will be most effective in the upper 40 feet at the proposed library site.

   VR typically extends about one column spacing outside of the proposed building foundation to provide improved/densified soil outside of the building footprint and reduce the potential for lateral spreading to impact the structure. For the proposed library site, the conceptual VR plan consists of:

   - 30-inch diameter columns at 8-foot on-center (replacement area of about 7.8%),
   - 24 rows of 15 columns/row with a total of 360 columns x 40 feet deep,
   - Estimated cost of VR columns is $30/foot,
   - Mobilization/Demobilization of $60,000,
   - Estimated column installation cost of $430,000, and
   - Estimated cost of VR is approximately $500,000.

2) **Deep Soil Mixing (DSM).** DSM uses a large-diameter auger (three- to eight-feet in diameter) mounted to a large drill rig or crane to advance the auger to the target depth (approximately 50 feet for the library project). Cement is mixed into the soil at a regulated rate of around 10 percent and mixed by the auger using several up and down passes of the auger. The amount of cement added to the soil is determined by laboratory testing to optimize the soil strength versus amount of cement utilized. Once the cement and soil are uniformly mixed, the auger is withdrawn and moved to the next location. The DSM columns can be placed in a variety of patterns (grid, tangent, overlapping) depending on the project requirements. For the proposed library project, one option is to place the DSM columns on a grid pattern with a center to center spacing of two to three diameters with a grade-beam type foundation system supported on the columns. The column configuration will depend on the column diameter selected (typically three to eight feet), cement percentage, soil type, and amount of soil improvement

required. Once the columns are completed, a grade-beam type foundation can be installed on top of the DSM columns to support the structure. Other column configurations such as tangent columns, overlapping columns, etc. can be utilized depending on project requirements. The advantages of the DSM method are that it can installed to depths of greater than 50 feet and it can improve the strength of fine-grained soils. Disadvantages are that the DSM method does not improve the soil density between the columns and about 20 percent waste material is generated during the installation process that must be disposed of. A conceptual DSM ground improvement plan for the proposed library building consists of:

- Four-foot diameter columns at 10-foot on center (replacement area of about 12%),
- 11 rows of 19 columns/row with a total of 209 columns x 50 feet deep,
- Estimated cost of DSM columns is $50/foot,
- Mobilization/Demobilization of $150,000,
- Estimated DSM column installation cost of $525,000, and
- Estimated cost of DSM is approximately $675,000.

3) **Grade Beam/Waffle Foundation System.** As described above, at this point in the project planning effort, a supplemental support system such as a grade beam-type foundation likely will be required in addition to one of the ground improvement options discussed above. If future analyses and evaluation indicate the seismic settlement at the site can be reduced to two inches or less, a supplemental grade beam system may not be required. A grade beam foundation system consists of a grid of deepened steel-reinforced concrete beams typically on a spacing of 8 to 10 feet. The grade beam lengths and depths vary depending on the foundation support and structural engineering design. For a one-story, wood frame building as proposed for the Moorpark library, the grade beam system might consist of grade beams 12-inches deep, 18- to 24-inches wide, at a grid spacing of 10-foot on-center. The grade beam system ties into the overlying concrete building slab that would be approximately 6-inches thick. The conceptual grade beam system could consist of:

- 10-foot center to center grid spacing,
- 24-inches wide and 18-inches deep,
- Ties into 6-inch-thick concrete slab above the grade beam system (note that the grade beam system does not include the cost for the concrete slab which would be part of standard construction),
- Grade beam length equals about 4,000 feet,
- Estimated cost of $400/cubic yard for concrete ($15 cubic foot),
- Estimated volume of grade beam system 8,000 cubic feet, and
- Estimated cost of grade beam system $120,000.

## SUMMARY

The preliminary cost estimates for the ground improvements (VR or DSM) and supplemental grade beam system are summarized below. The estimates have been provided at the request of the City of Moorpark staff to assist with the project planning efforts, however, we note they do not include permitting costs.

To the best of our knowledge, the estimated costs summarized below represent reasonable planning-level estimates; however, we strongly advise the City of Moorpark have a civil/structural engineering firm familiar with project estimating and experience with ground improvement and grade beam foundation systems provide updated cost estimates for the project elements at the earliest possible time.

| Project Element | Vibro-Replacement (VR) | Deep Soil Mixing (DSM) |
|---|---|---|
| Ground Improvement Option | $ 500,000 | $ 675,000 |
| Grade Beam System | $ 120,000 | $ 120,000 |
| **Estimated Subtotal:** | **$ 620,000** | **$ 795,000** |
| Contingency (20%) | $ 125,000 | $ 160,000 |
| Design (15%) | $ 90,000 | $ 120,000 |
| Construction Management (10%) | $ 60,000 | $ 80,000 |
| **Planning-Level Cost Estimate:** | **$ 895,000** | **$ 1,155,000** |