24 January 2020

DRAFT

Mr. Steve Minden
Mission Rock Partners, LLC
c/o Tishman Speyer
One Bush Street, Suite 450
San Francisco, California 94104

SUBJECT: Lightweight Cellular Concrete Geotechnical Design Criteria
Mission Rock – Phase 1 Horizontal Development
San Francisco, California
Langan Project No.: 750604203

Dear Mr. Minden:

This letter presents our recommended geotechnical design criteria for raising street grades with compensating lightweight cellular concrete for the Mission Rock Phase 1 Horizontal Development project in San Francisco, California. The results of our geotechnical investigation for the horizontal components of the Mission Rock Phase 1 project were presented in a report dated 31 October 2019. Information provided herein are based the subsurface conditions documented in the 31 October 2019 report as well as the conclusions and recommendations provided therein. Anyone relying on the recommendations herein should be familiar the subsurface conditions, assumptions, and conclusions provided in the 31 October 2019 report.

Background

Existing site grades within the Phase 1 Development area range from about Elevation 97 feet to about 101.5 feet[1]. Site grades for the future streets and sidewalks will be raised to accommodate future sea level rise, with planned street grades up to about Elevation 104 to 104.5 feet and sloping down to meet the existing street grades at 3rd Street. If conventional soil fill is placed to raise grades, the load from this new fill would result in consolidation settlement in the underlying soft clay (known locally as Bay Mud), which is unacceptable for the project requirements. Therefore, the project has elected to raise grades using permeable lightweight cellular concrete (LLC). However, because the LCC has some weight and will be covered with street improvements, some existing soil at the site will need to be overexcavated and replaced with LCC to compensate or offset all new loads.

[1] Elevations based on topographic survey by Martin Ron, dated 2 July 2019, Mission Bay Datum (Old San Francisco City Datum plus 100 feet).

Design Criteria

The design criteria for the LCC at Mission Rock includes the following geotechnical elements:

- To provide a factor of safety against additional consolidation settlement by offsetting the new improvement loads by excavation existing fill with a target of reducing the effective stress at the top of the Bay Mud by at least 10 percent.
- The design of the new LCC and overlying street sections to resist hydrostatic uplift during future groundwater rise up to the potential future (year 2100) high-range groundwater level is 99.5 feet.
- LCC should be sufficiently strong to resist crushing under anticipated loading; including weight of overlying improvements and temporary loads, such as heavy wheel loading
- LCC should be sufficiently resilient to provide an adequate substrate for the San Francisco Standard pavement design
- LCC should be sufficiently permeable to allow for groundwater to move through the material
- LCC should be excavatable to allow for underground utility repair or other maintenance
- LCC should perform adequately to provide vertical support following a major earthquake.

Details regarding each of these criteria and the engineering background for each criteria are provided in the sections below.

Load Compensation Evaluation

To offset the additional weight caused by raising the site as much as 5½ feet for the new street improvements, existing fill will be removed to a specified depth and then backfilled using permeable LCC. Within the new 60- to 70-foot-wide Right of Way, there will be new utilities, streets, sidewalks, light poles, and tree planting areas between the building parcels.

The evaluation includes the weight of new improvements, including the loads from new utilities, utility bedding and shading, the street and sidewalk structural sections, trees, light poles, tree-planting structural soil, and the increased density of improved fill (that remains below the LCC). The following are some of the assumptions included in calculating the required depth of the compensating open cell (porous) LCC:

- existing observed average high groundwater level is at Elevation 93 feet
- unit weight of brackish groundwater is 63 pounds per cubic foot (pcf)
- target cast unit weight of the open cell (porous) LCC is 26+/- 2 pounds per cubic foot (pcf) with a minimum as-cast compressive strength of 50 pounds per square inch (psi)
- target cast unit weight of the upper two feet of LCC is 30+/- 2 pcf with a minimum as-cast compressive strength of 50 psi

- long-term (potentially fully saturated) unit weight of porous LCC below groundwater is 68 pcf, resulting in a new buoyant (effective) unit weight of 5 pcf (68 pcf minus 63 pcf). This number is based on vacuum-pressure laboratory saturation testing, which indicates a potentially fully saturated unit weight of 63 pcf and adding 5 pcf to account for potential variability.
- unit weight of the existing fill varies from 110 (very loose sand) to 140 pcf (concrete and brick debris), with an average of approximately 125 to 130 pcf; a unit weight of 125 pcf is used for load offset calculations. Improved fill (beneath the new LCC section), will have a unit weight of 131 pcf, an increase of 6 pcf above the existing conditions.
- pavement section is comprised of 8 inches of Portland cement concrete overlain by 4 inches of asphalt concrete, both with a unit weight of approximately 150 pcf, underlain by 4 inches of gravel material such as aggregate base as a buffer before encountering LCC, with a unit weight of approximately 130 pcf.
- structural soil (for tree planting) has a unit weight of 110 pcf will be placed in the planter strips. The widths of the planting strips is different for each street section

The bottom elevation of the lightweight fill section should be determined such that the effective stress on the top of the Bay Mud following placement of the improvements will be at least 10 percent less than the existing effective stresses at that same level; this results in a "factor of safety" for net unloading (removed load/new load) of at least 1.1. We judge that, in utilizing this approach, there would be a net unloading of the Bay Mud across the site, and the potential for inducing an additional cycle of primary consolidation will be low. In addition, the net unloading will likely significantly slow any ongoing secondary compression settlement of the Bay Mud under existing loading within the street sections.

Mitigation of Hydrostatic Uplift of LCC section

To prevent significant hydrostatic uplift, open cell (porous) LCC will should be designed and used at Mission Rock. The open cell LCC will allow water to flow through the material, preventing significant hydrostatic pressure from building up at the bottom of the LCC section. The critical condition for hydrostatic uplift is where the LCC is only partially saturated, therefore this density is used for uplift calculations. The assumptions used as the design criteria for the hydrostatic uplift check include:

- existing observed average high groundwater level is at Elevation 93 feet
- unit weight of brackish groundwater is 63 pounds per cubic foot (pcf)
- future (year 2100) mid-range groundwater level of Elevation 97 feet and high-range groundwater level is 99.5 feet[2]
- target cast unit weight of the open cell (porous) LCC is 26+/- 2 pounds per cubic foot (pcf) with a minimum as-cast compressive strength of 50 pounds per square inch (psi)

[2] Groundwater levels have been taken from potential sea level rise levels provided in FEMA Guidelines.

- target cast unit weight of the upper two feet of LCC is 30+/- 2 pcf with a minimum as-cast compressive strength of 50 psi
- short-term (partially saturated) unit weight of porous LCC below groundwater of 50 pcf, resulting in a net buoyant unit weight of -13 pcf (50 pcf minus 63 pcf). This value will be used to check for hydrostatic uplift calculations.

The check for hydrostatic uplift compares the total stress at the base of the LCC against the theoretical hydrostatic pressure based on the figure high groundwater levels. Each section of LCC should be considered safe provided the factor of safety against hydrostatic uplift is at least 1.1 when checking the high range groundwater level of Elevation 99.5 feet and a factor of safety of 1.2 when checking the mid-range groundwater level of Elevation 97 feet.

LCC Crushing

LCC is adequate for support of the improvements listed above in the new ROW provided the LCC has the appropriate compressive strength. LCC should be sufficiently strong to resist crushing under anticipated loading; including weights of overlying improvements and temporary loads. These loads should include checks against the likely pressures beneath San Francisco's heaviest fire trucks, which represents the critical case for LCC crushing.

For design, the LCC should have sufficient strength to resist crushing with a factor of safety of about 2. We conclude LCC with a minimum submerged strength of 40 psi has a factor of safety of 2 for crushing under fire truck loads. Based on test results, LCC with an as cast minimum compressive strength of 50 psi has a saturated (in brackish groundwater) minimum compressive strength of at least 40 psi (which includes up to a 20 percent reduction due to saturation).

Pavement Design

As described in the geotechnical report for the project, the City and County of San Francisco have specified a pavement type for this project. This pavement section consists of 4 inches of Asphalt Concrete over 8 inches of Portland Cement Concrete (PCC) with an unconfined compressive strength of 4,500 psi. In addition, a 4-inch layer of aggregate base is provided beneath the PCC layer. This composite section is not consistent with either rigid or flexible pavement design methodologies. However, the design calculation, consistent with AASHTO 1993, indicates the concrete section over a substrate with the strength and modulus of LCC is capable of supporting more than 11 million equivalent 18 kips axle loads (ESAL's). This ESAL value suggest that for a typical 20-year pavement design life the pavement could support either 395 trucks per day (three axles, max legal weight at rear, with a combined weight of 54,000 pounds, examples include dump, trash, fire, or full concrete trucks) or 500,000 light trucks per day (two axles with a combined weight of 8,500 pounds, examples include Box Vans, Utility Trucks, or a Pick-up with a Trailer).

This number of ESAL's appear to meet or exceed the expected performance for San Francisco City Streets, but should be confirmed by City and Port personnel. We therefore conclude that the LCC should provide an acceptable substrate for the San Francisco City Street pavement section.

LCC Permeability

For design, LCC should be sufficiently permeable to allow for groundwater to move through the material, which will mitigate significant hydrostatic uplift forces during fluctuations in the groundwater table. For design, the material should have a minimum permeability of 0.005 cm/sec.

LCC Excavatability

LCC can be excavated using standard equipment for future improvements or necessary repairs, provided the cellular concrete is not too strong, and can be excavated in vertical cuts. Therefore, using LCC is beneficial for future work in the streets.

LCC with a cast density of 24 to 28 pcf and compressive strength of 200 psi has a removability modulus (RM) of 0.2, which is well below the RM value of 1.5 for material that is not easily excavatable based on department of transportation guidelines. Therefore, a maximum compressive strength of 200 psi should be used as a design criteria for all LCC material placed at the project.

Seismic Design and Performance

Project will be permitted under the 2016 San Francisco Building Code and will be used as a basis for the seismic design. SF Public Works, Public Utilities, and Transportation codes and standards are also being used as applicable for different features of the horizontal infrastructure.

To evaluate the potential for breakage of the LCC under the stresses of vertically propagating shear waves from earthquakes, we first evaluated the magnitude of the shear stress ratio (shear stress/effective stress) from our linear and non-linear evaluation of the site response analyses under MCEr loading at the site. The maximum shear stress ratio in the fill at the site is about 0.6 to 0.66. Therefore, the maximum anticipated shear stresses imposed on the LCC from an MCEr earthquake are on the order of 200 to 265 psf, which is 10 percent of the target minimum LCC strength (2,880 psf). If there is an existing crack or cold-joint in the LCC and the residual strength at this interface is equivalent to a friction ratio of 35 degrees, the LCC still has sufficient strength to resist further degradation.

In addition, considering these are linear elements, we evaluated the potential for LCC breakage from a horizontally propagation Rayleigh wave. Our analyses indicates the unit shear stress in the LCC is about 1/4 to 1/2 of the minimum submerged LCC strength (correlating to a minimum compressive strength of 40 psi). Therefore, using the 2016 Building Code as a design criteria for performance of the LCC, it appears that the LCC should perform adequately under a seismic event. In addition, even if the LCC cracks it will still provide vertical support for the streets and improvements.

Dewatering

A dewatering contractor should design a limited and controlled dewatering system to limit drawdown beyond the planned excavations to no more than two feet below the excavation depth. Within the limits of Mission Rock, but beyond the LCC excavation limits, groundwater should not be lowered below Elevation 90 feet unless remediation measures are taken to mitigate the stress increase in the underlying Bay Mud in areas of the site that will be drawn down below Elevation 90 feet, grades should be lowered within the lowered groundwater area to offset the additional effective stress increase due to the dewatering. For planning purposes, approximately one foot of soil can be removed to offset a dewatering drawdown equal to two feet of water head.

Groundwater levels beyond the excavation should be monitored while dewatering is in progress. Should groundwater drawdown be measured greater than anticipated, the contractor should recharge the groundwater outside the excavation limits through recharge wells.

Groundwater should not be lowered outside the limits of Mission Rock. Cutoff walls may be needed at the site boundary to prevent dewatering drawdown.

Other Design Considerations

To prevent fines migration into the LCC section, filter fabric will be placed at all interfaces where LCC touches soil.

In the event an excavation needs to be made into the LCC, the excavation can be temporarily backfilled with soil for a duration no longer than 3 months provided the excavation has a volume less than 10 cubic yards. After that, the soil should be removed and replaced with the approved LCC.

We appreciate the opportunity to assist you with this project, please call with any questions.

Sincerely,
Langan Engineering and Environmental Services, Inc.

Peter Brady, PE
Project Engineer

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Senior Associate

750604203.21_PDB_LCC Design Criteria

Attachments: