301 Mission St Perimeter Pile Upgrade

Calculations

Vol 1 – Design Overview

301 Mission Street
San Francisco, CA

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SGH Project 147041.10

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1. PROJECT DESCRIPTION

Voluntary seismic upgrade and foundation stabilization. Addition of new piles, extending to rock and transfer of approximately 20% of the building weight to the new piles with the intent of arresting building settlement, and improving the foundation lateral capacity.

Figure 1-1 shows an isometric overview of the proposed improvements.

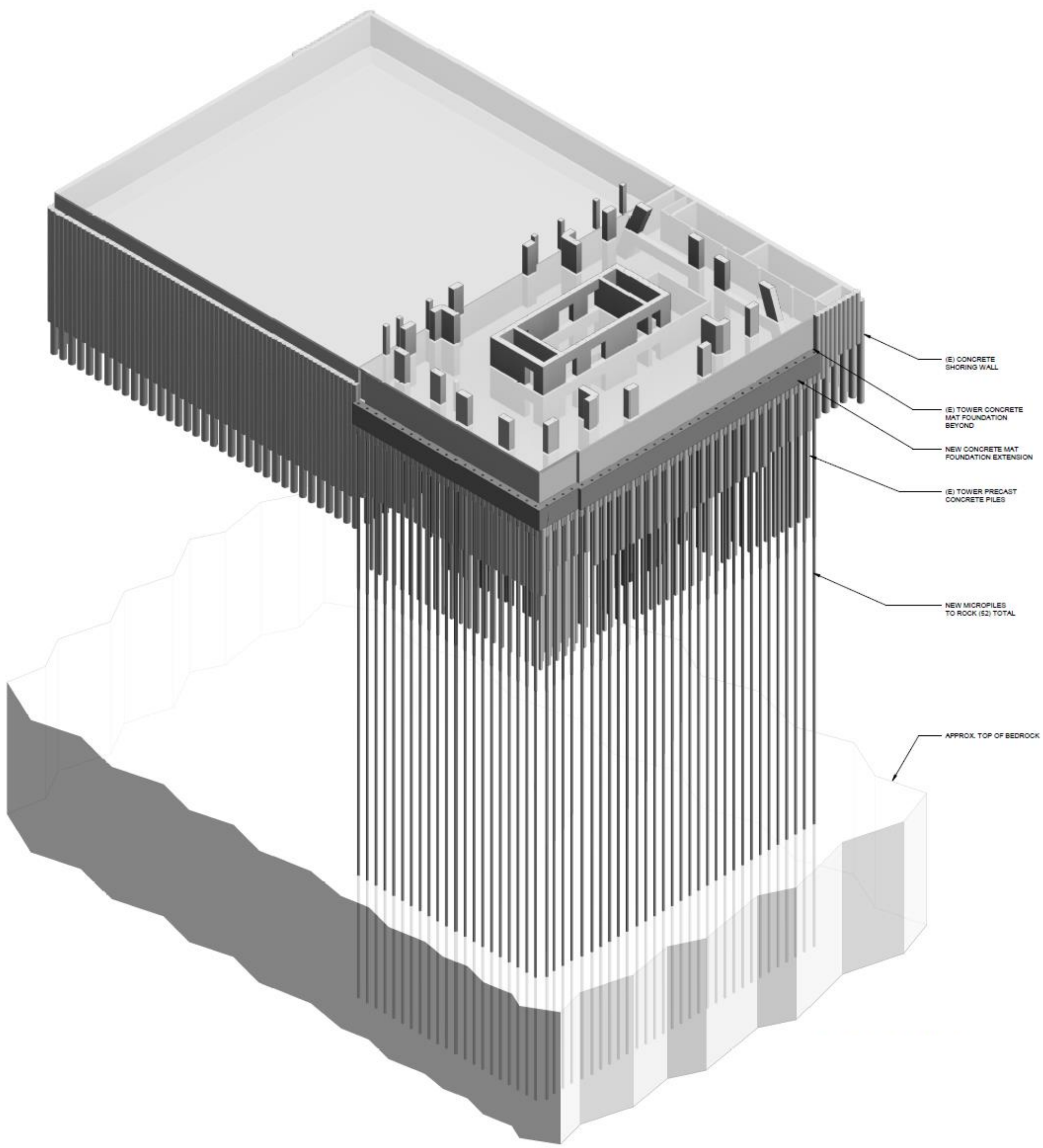

Figure 1-1 – Isometric View of New Piles Along North and West Sides of Mat

2. PROJECT OBJECTIVES

This project comprises a voluntary structural upgrade to accomplish the following:

- Install new foundation elements extending to bedrock to remove sufficient stress from Old Bay Clay materials underlying the 301 Mission Street building to arrest settlement and tilt due to primary compression (consolidation); reduce future settlement associated with secondary compression to predictable levels that will have negligible impact on future building performance; and, assure long term building stability.

- Assure that the building can provide the seismic performance intended of new structures designed to the San Francisco Building Code.

- Improve the seismic performance of the foundation.

3. DESIGN CRITERIA

3.1 Codes and Standards and Guidelines

Design is conducted in accordance with the following codes and standards:

1. 2016 San Francisco Existing Buildings Code
2. ASCE 7-16
3. ACI 318-14
4. Pacific Earthquake Engineering Research Center, Guidelines for Performance-based Seismic Design of Tall Buildings, V. 2.03, May 2017 (PEER TBI).

3.2 Code Exceptions

ASCE 7-16 Minimum Design Loads and Associated Criteria for Structures is used to determine loading in lieu of the 2010 edition of this standard. This is because the nonlinear response history analysis procedures contained in Chapter 16 of ASCE 7-16 is more compatible with the procedures recommended by PEER TBI.

3.3 Design Approach

Design is conducted under the code criteria for voluntary seismic upgrade of existing buildings. Specifically, design is conducted under the criteria of Section 403.9 of the International Code for Existing Buildings:

> **403.9 Voluntary Seismic Improvements**. Alterations to existing structural elements or addition of new structural elements that are not otherwise required this chapter and initiated for the purpose of improving the performance of the seismic-force resisting system of an existing structure or the performance of seismic bracing or anchorage of existing nonstructural elements shall be permitted, provided that an engineering analysis is submitted demonstrating the following:
>
> 1. The altered structure and the altered nonstructural elements are no less conforming to the provisions of the California Building Code with respect to earthquake design than they were prior to the alteration.
> 2. New structural elements are detailed as required for new construction.
> 3. New or relocated structural elements are detailed and connected to existing or new structural elements as required for new construction.

4. The alterations do not create a structural irregularity as defined in ASCE 7 or make an existing structural irregularity more severe.

Seismic performance of the building is evaluated using the PEER TBI guidelines.

3.4 Analysis Software

- Nonlinear Structural Analysis – CSI Perform, v6.0.0
  ABAQUS, v6.14
- Linear Analysis of Structure – CSI ETABS, v16.2.1 Nonlinear
  CSI SAP2000, v19.2.2 Advanced
- Linear Analysis of Foundations – CSI SAFE, v16.0.0 Post-tensioning
- Lateral response of piles – LPile, v2016-09.008
- Concrete section analysis – Xtract, v3.0.7
- Nonlinear soil analysis – FLAC3D, v6.00.59

3.5 Loading

- **Dead Load** – Self weight of structural elements.
- **Superimposed Dead Load** – Estimate of weight of cladding, ceilings, finishes and MEP.
- **Live Load** – Per San Francisco Building Code with permitted reductions.
- **Wind Load** – Per original Wind Tunnel Report by Rowan Williams Davies & Irwin Inc. (RWDI), dated 9 August 2005, scaled to the basic wind speed specified in ASCE 7-16..
- **Seismic** – Site-specific MCE_R and DE per San Francisco Building Code and SLE per PEER TBI, developed by the Egan Team.
- **Settlement** – Per Arup Measurements dated June 2017 supplemented by measurements obtained by Langan through August 2018.

3.6 Analysis Approach

3.6.1 Existing Structure

The condition of the existing structure, and its ability to resist dead, live, seismic loading, and settlement-induced stresses prior to retrofit has been demonstrated by nonlinear analysis as documented in the following SGH Reports:

- Foundation Settlement Investigation, dated 8 September 2016.

- Foundation Settlement Investigation, dated 3 October 2016.
- Supplemental Report for Foundation Settlement Investigation, dated 21 July 2017 and revised 26 July 2017.
- Letter to Ms. Naomi Kelly Re: As-Built Pile Doweling, Supplemental Analyses, dated 7 May 2018.

3.6.2 Retrofitted Structure

The condition and future performance of the structure with retrofit modifications is demonstrated as follows:

3.6.2.1 Geotechnical

The Egan Team conducted a detailed three-dimensional finite difference analysis of the site and structure to estimate the long-term settlement characteristics following installation of the retrofit. The model includes representation of:

- Soil layering at and around the site extending from the surface to and including the underlying Franciscan formation rock. Layering will include surficial artificial fills, Young Bay Mud marine deposits, the Colma formation, Old Bay Clays and Alameda formation. Properties for these various layers will be based on available geotechnical reports for the 301 Mission Building and surrounding projects, as well as updated data obtained from supplemental exploration programs conducted at the site since construction completion.
- Time-dependent loading effects on the soils including; excavation for adjacent structures, construction and habitation of the adjacent structures, and recorded and estimated water table fluctuation.
- Installation of the retrofit construction.

Bounded properties for soils are used to produce most-likely, i.e. “best” estimates of the Tower behavior as well as likely upper and lower bounds on settlement, resulting from uncertainty in soil properties and loading.

The analyses are used to validate that the retrofit is effective in arresting primary consolidation; to obtain long term estimates of future settlement due to secondary soil compression effects; and to confirm the total demands on the new foundation piles installed in the retrofit project.

3.6.2.2 Structural

- Dead, Live and Wind Loading – ETABS analysis and SAFE analysis

- Dead, Live and Seismic Loading (SLE, DE) – ETABS analysis and SAFE analysis
- Dead, Live, Settlement and Seismic (MCE_R) – PERFORM-3D analysis

3.6.3 Element Action Designation

In nonlinear seismic analysis, elements are assigned the ductility/criticality designations indicated in Table 3-1.

Table 3-1. Element Criticality and Ductility Class

Element/Action	Ductility Class	Criticality
Shear Walls		
Flexure	Deformation-controlled	n/a
Shear	Force-controlled	Critical
Outrigger Columns		
Axial, Shear	Force-controlled	Critical
Flexure	Deformation-controlled	
Outrigger Coupling Beams	Deformation-controlled	Non-critical
Coupling Beams	Deformation-controlled	
Foundation Piles		
Axial	Deformation-controlled	
Lateral	Deformation-controlled	
Foundation Mat		
Flexure	Deformation-controlled	
Shear	Force-controlled	Ordinary

3.7 Material Properties

Table 3-2 below presents the material properties used in analysis and design verification:

Table 3-2. Material Properties

Element	**Nominal**	**Expected**
Existing Mat Foundation		
Concrete f'_c	7,000 psi[1]	9,100 psi
Reinforcing f_y	75 ksi	82 ksi
Shear Walls, Outriggers		
Concrete f'_c	7,000 psi – 10,000 psi	9,100 psi – 13,000 psi
Reinforcing f_y	60 ksi / 75 ksi	69 ksi / 82 ksi
Moment Frame Beams and Columns		
Concrete f'_c	7,000 psi – 10,000 psi	9,100 psi – 13,000 psi
Reinforcing f_y	60 ksi / 75 ksi	69 ksi / 82 ksi
Existing Piles		
Concrete f'_c	7,000 psi	9,100 psi
Reinforcing f_y	60 ksi	70 ksi
New Piles		
Casing F_y	35 ksi	
Core, f_y	120 ksi	TBD[2]
Grout	5,500 psi	7,100 psi

[1]Calculated based on results from concrete breaks and the provisions of ACI 301-16.
[2]To be determined based on testing of individual low aspect ratio bars in compression.

3.8 Nonlinear Acceptance Criteria

Table 3-3 summarizes the deformation quantities used to verify the adequacy of deformation-controlled behaviors. Global criteria conform to the PEER TBI Guidelines limitations on transient drift, residual drift and unacceptable response.

Table 3-3. Deformation-controlled Acceptance Criteria

Element Type	Deformation Quantity	Limit
Core Walls	Confined compressive strain	0.011
	Steel tensile strain	0.05
Outrigger Coupling Beams	Shear strain	0.025
Reinforced Concrete Frame Beams	Plastic hinge rotation, θ_p	varies 0.036-0.05 radian[1]
Steel Composite Coupling Beams	Plastic hinge rotation, θ_p	0.03 radian[1]
Reinforced Concrete Columns	Plastic hinge rotation, θ_p	varies 0.008-0.009 radian[1]
Foundation Mat	Plastic hinge rotation, θ_p	0.01 radian

[1]Based on ASCE-41 CP values, with the appropriate tie spacing and axial loads