City and County of San Francisco
Department of Building Inspection

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INFORMATION SHEET

NO. S-20

DATE : June 5, 2019

CATEGORY : Geotechnical

SUBJECT : **Preliminary Guidelines for Review of Geotechnical Reports prepared for Design and Construction of Tall Buildings**

PURPOSE : To establish preliminary guidelines for reviewing of geotechnical reports prepared for design and construction of tall buildings, 240 feet or taller, as to ensure the completeness and appropriateness of the reports in regarding of existing field condition investigations, in situ and laboratory tests, geotechnical engineering studies, foundation support design, shoring and excavation design, and field monitoring of the construction; thereby strengthening tall building safety in San Francisco.

REFERENCE : 2016 & 2017 San Francisco Building Code (SFBC)

- AB-082 Guidelines and Procedures for Structural Design Review
- AB-083 Requirements and Guidelines for the Seismic Design of New Tall Buildings using Non-Prescriptive Seismic-Design Procedures
- Information Sheet S-18: Interim Guidelines and Procedures for Structural, Geotechnical and Seismic Hazard Engineering Design Review for New Tall Buildings

ASCE 7-10 & ASCE 7-16 Minimum Design Loads for Buildings and Other Structures

ATC-119-1 San Francisco Tall Buildings Study prepared by Applied Technology Council dated December 2018

PEER 2017, Guidelines for Performance-based Seismic Design of Tall Buildings, PEER Report 2017/06, Pacific Earthquake Engineering Research Center, University of California, Berkeley, California

State of California Department of Conservation Division of Mines and Geology (CDMG) Seismic Hazard Zones Map for San Francisco, released November 17, 2000.

BACKGROUND : The City's Office of Resilience and Capital Planning selected Applied Technology Council (ATC) to prepare a Tall Building Safety Strategy Report to identify risks from future earthquakes and to develop recommendations to reduce the most significant earthquake impacts for all tall buildings 240 feet or taller throughout the city. San Francisco Department of Building Inspection (SFDBI) will develop an Administrative Bulletin to address the recommendations for foundation and geotechnical issues. Meanwhile, this information sheet provides preliminary guidelines to ensure that essential building safety information is included in the completed and submitted geotechnical reports for improvements of tall building safety.

For the purpose of this information sheet, tall buildings are defined as buildings 240 feet or taller.

DISCUSSION :

In accordance with AB-082, DBI requires all tall buildings be reviewed by an Engineering Design Review Team (EDRT), consisting members with expertise in Structural Engineering, Geotechnical Engineering, or Site-specific Hazards Analysis when Site-specific earthquake response is used. The preliminary guidelines below will thereby be used by SFDBI and an EDRT as well for reviewing the geotechnical reports. These preliminary guidelines may be modified as appropriate based on the judgement and experience of the geotechnical engineer of record (GEOR) with approval from both the EDRT and SFDBI. These preliminary guidelines are intended to be used in combination with Part 2, Chapters 1-9 of the ATC-119-1 report.

1. **Project Definition & Design Criteria**

   In coordination with the project architect and structural engineer, the following information - as much as is available at the time of the geotechnical study - shall be provided: project team and project description including a map showing the site location; number of stories; number of basement levels; structural framing system including lateral load resistance system; anticipated building gravity loads; applicable codes / design guidelines for performance-based design of tall buildings (e.g. PEER TBI 2017 performance-based design of tall buildings); and code exceptions (if any) related to approach for development of design ground motions. Information provided in this section shall be consistent with the project Basis of Design (BOD) document.

2. **Site Surface Conditions**

   Description of existing structure on site with information specific to its foundation (if any) and information regarding the site's historical and current use; site surface elevation including the reference Datum; and description of adjacent facilities and structures with specific details of their foundation system within a horizontal distance of (a) twice the depth of excavation or (b) 150 feet, whichever is greater.

3. **Regional & Local Geology**

   This section shall include a description of regional geology including regional seismic setting. A fault map shall show the location of Holocene active faults within a 100 km radius of the site, with epicenter and magnitude of historical earthquake events shown on the map. A table shall be provided containing the following information based on applicable code: fault name, fault mechanism, site-to-source distance, fault activity (slip rate), maximum magnitude based on UCERF2 fault data file (2016 CBC / ASCE7-10) or mean / mode magnitude obtained from de-aggregation of results of probabilistic seismic hazard analysis (PSHA) performed for a return period of 2,475 years at the key periods of interest to the building design using UCERF3 fault data file (2019 CBC / ASCE7-16).

Description of local site geology shall provide information regarding anticipated engineering soil / rock properties likely to be encountered at the site. This section should include hazard maps / information from USGS and State including flood potential with consideration of sea level rise (e.g. FEMA 2018), soil liquefaction / lateral spreading, landslides, and tsunami/seiche (for sites near the shoreline).

4. Field Investigation & Laboratory Testing

The subsurface conditions shall be explored by drilling borings and conducting Cone Penetration Test (CPT) soundings as described below:

A. Borings without CPT soundings – A minimum of four (4) borings for a site with plan dimensions of 100 feet by 100 feet and eight (8) borings for a site with plan dimensions of 200 feet by 200 feet shall be drilled. For depth-to-bedrock of more than 100 feet, one boring shall extend at least 30 feet below the surface of bedrock; other borings shall be at least 100 feet in length. For depth-to-bedrock of less than 100 feet, all borings shall extend to bedrock with one boring extending at least 30 feet below the surface of bedrock.

B. Combination of borings & CPT soundings – Up to two borings may be substituted by 2 to 3 CPT soundings each as determined by the GEOR (i.e. 4 to 6 CPT soundings if two borings are eliminated). CPTs shall be pushed to refusal using a 20-ton CPT rig. One CPT sounding shall be near a boring for calibration purposes.

Shear wave velocity shall be measured at least at one location using downhole and suspension logging technique or surface wave method as appropriate. The shear wave velocity measurement shall be conducted in such a manner to allow for accurate determination of $V_{s(30)}$. The shear wave velocity of bedrock shall be measured.

At least one boring shall be converted to piezometer and piezometric levels shall be observed over a cycle of dry and wet season.

Existing geotechnical borings also could be used to substitute for new borings provided that they are located reasonably close to the project site and drilled in accordance with currently acceptable methods and standards.

Soil borings shall be drilled using rotary wash drilling method (unless the groundwater table is below the bottom of the boring). Drilling fluid or casing shall be used to prevent collapse of borings or bottom instability. If borings are drilled in clayey soils in close proximity (as determined by the GEOR) to the foundation of an existing structure, casing shall be used to prevent settlement of adjacent building. This is especially important when drilling in clayey soils below the tip of a deep foundation supporting an adjacent building.

In soft clayey soils (e.g. Young Bay mud -YBM), samples shall be obtained using thin-wall

Shelby tubes or Dames & Moore piston sampler. In stiff clays (e.g. Old Bay clay - OBC) where strength or consolidation testing is planned, Pitcher Barrel sampler or approved equivalent shall be used. Standard Penetration Test (SPT) should be performed in cohesionless soils. California modified sampler or S&H sampler may be used in alluvium often found between the bottom of OBC and bedrock. Hammer energy measurements shall be performed for drive sample system (e.g. SPT and California Modified sampler).

Rock coring shall be used to obtain rock cores within Franciscan Formation. Rock cores shall be reviewed and classified by a registered engineering geologist. Parameters defining rock mass rating (uniaxial compressive strength, RQD, spacing of discontinuities, conditions of discontinuities, groundwater conditions, and orientation of discontinuities) shall be recorded as directed by the GEOR.

If numerical modeling using finite element or finite difference method is planned for site response analysis or kinematic soil structure interaction analysis, appropriate in-situ and laboratory testing (e.g. field vane test, pressure-meter test, cyclic simpler shear test, cyclic triaxial test, resonant column test, etc.) shall be performed within representative soil layers as directed by the GEOR. These tests shall collectively support calibration of the constitutive model(s) at the element level.

For all soil types, sample intervals shall be 5 feet unless based on depth and thickness / uniformity of soil layer, data from field vane tests or CPT soundings, a larger interval is deemed appropriate by the GEOR.

For sandy soils, the following laboratory tests shall be conducted: moisture-density, fines content (minus sieve No. 200), sieve analysis, and PI (if silty or clayey sand).

For cohesive soils, one or more of the following tests shall be conducted as deemed appropriate by the GEOR: unconsolidated or consolidated undrained triaxial tests and direct simple shear test. Unconfined compressive strength test shall not be used. If OBC exists at a boring location, but is less than 10 feet thick, one undrained shear strength and one consolidation test shall be performed on an OBC sample. If OBC exists at a boring location and its thickness exceed 10 feet, one undrained shear strength and one consolidation test shall be performed for every 10 feet of OBC. The total number of tests (pairs of strength and consolidation tests) need not exceed 15 for sites with plan dimensions of 100 feet by 100 feet. The total number of tests (pairs of strength and consolidation tests) need not exceed 25 for sites with plan dimensions of 200 feet by 200 feet. If OBC is expected to be subjected to vertical effective stresses higher than pre-consolidation pressure, additional tests are required to measure the secondary consolidation characteristics of OBC.

Pocket penetrometer or Torvane tests may be used on clayey soil samples, but shall not be considered as a substitute for any laboratory tests described above.

5. Subsurface Conditions

For sites with plan dimensions of 100 feet by 100 feet, at least two cross sections shall be provided. For a site with plan dimensions of 200 feet by 200 feet, at least 4 cross sections shall be provided. Full description of all soil layers / geologic units with engineering properties (consistency and consolidation characteristic for clayey soils and density / potential for soil liquefaction and settlement for sand layers) shall be provided.

Design ground water elevation with consideration of sea level rise and seasonal fluctuation of groundwater table (if known) shall be specified. Groundwater table anticipated to be encountered during construction also shall be identified.

6. Geotechnical Engineering Studies

6.1 Site Class Identification – Based on site-specific shear wave velocity measurement, potential for soil liquefaction below the foundation level, and consistency of clayey soils, Site Class designation shall be identified following the applicable code (ASCE7-10 / ASCE 7-16) as presented in the BOD document.

6.2 Ground Motion Studies – For Site Class A through E (and for Site Class F sites where liquefiable soils and soft soils are removed as part of excavation for construction of basement and a revised Site Class designation is assigned based on $V_{s(30)}$ of soils below the basement), site-specific ground motion study shall be performed following the applicable code (ASCE7-10 / ASCE 7-16) requirements and using $V_{s(30)}$ below the bottom of foundation.

For Site Class F sites without planned ground improvement or excavation of soft / liquefiable soils as part of basement construction, bedrock motion shall be developed and site response analysis shall be performed using nonlinear models implemented in computer programs DEEPSOIL, FLAC, or others as approved by the EDRT. Free field motion at the ground surface shall be compared with 80% of Site Class E spectrum and higher of the two motions shall be used in seismic analysis and design of the structure, as required by the governing code.

Kinematic soil structure interaction analysis may be performed using (a) simplified methods accounting for base averaging and embedment effects following NIST / NEHRP 2012 report or (b) finite element / finite difference kinematic SSI analysis. It should be noted that ASCE7-16 provides a cap of 70% on reduction of ground motion due to combined (base averaging and embedment) kinematic SSI effects. When using simplified method for evaluation of embedment effects, the $V_{s(30)}$ at the ground surface (as opposed to bottom of basement) shall be used.

If finite element / finite difference kinematic SSI analysis is performed: (a) the ground motion near the boundary of the model shall be similar to those obtained from 1D site response analysis and (b) kinematic ground motion shall meet ASCE7-16 requirements.

If ground acceleration time series are used (i.e. performance-based design approach), seed motions shall be selected based on characteristic of controlling earthquake scenario (magnitude, site-to-source distance, D_5-D_{95} duration, Arias intensity, etc.) and the $V_{s\ (30)}$ at the recording station. From de-aggregation of seismic hazards with respect to directivity at 2,475 return period, percentage of seed motions with near source / directivity effects (ground motions with velocity pulse) shall be identified and used in selection of seed motions.

If spectral matching of seed motions is performed, care shall be exercised not to eliminate or unreasonably elongate the pulse period. Pulse identification method developed by Professor Baker and /or others shall be used for this check.

Ground motions with velocity pulse shall be rotated and oriented along fault normal (Fn) and fault parallel (Fp) directions. Furthermore, the spectrally matched motions in Fn and Fp directions shall be rotated again based on orientation of the building axis. Other seed motions w/o velocity pulse may be used in a random orientation.

6.3 Soil Liquefaction Studies – Soil liquefaction study shall be based on methods developed by Idriss & Boulanger (2014) or other methods as approved by geotechnical member(s) of EDRT. If potentially liquefiable soils are present below the foundation level, the potential for lateral spreading also shall be evaluated. For sites within 300 feet of the shoreline where there are no structures or other means of ground improvements between the site and the shoreline, potential for shoreline seismic instability shall be evaluated and addressed.

Effects of soil liquefaction (settlement and down drag loads) on deep foundation shall be addressed. Effects of lateral spreading on foundation shall be evaluated and an appropriate mitigation measure identified. It is noted that due to kinematic SSI effects (pile pinning effects), pile-supported foundation system could mitigate up to 6 inches of lateral spreading computed based on free field (w/o presence of structure) conditions.

6.4 Settlement Analysis

6.4.1 Shallow Foundation – Short term and long term (consolidation) settlement calculations may be performed using nonlinear models implemented in 3D SETTLE or 3D PLAXIS computer program.

6.4.2 Deep Foundation – Short term and long term (consolidation) settlement analysis shall be based on 3D PLAXIS computer program.

The settlement calculation shall account for various stages of construction including placement of shoring, dewatering, excavation for construction of basement / foundation, termination of dewatering, and long-term recharge of ground water table. However, in some cases and depending on soil permeability, recharging of the groundwater table may not occur until some time after completion of construction. This delay in ground water recharge shall be accounted for when evaluating the hydrostatic uplift pressure during / after termination of dewatering (i.e. accounting for full and immediate groundwater recharge after termination of dewatering may be un-conservative).

6.5 Sea Level Rise – Effects of sea level rise during the design life of the structure shall be evaluated based on 2018 FEMA study.

7. Foundation Support

If either (a) total settlement of foundation exceeds 4 inches or (b) differential settlement exceed angular distortion of 1/500 (flexible structures) or 1/750 (rigid structures), deep foundation shall be used. Alternatively, ground improvement may be used to bypass compressible / liquefiable soils. GEOR shall work closely with the structural engineer to determine whether the structure is classified as rigid or flexible. It is noted that non-structural components such as cladding or partition walls may control the acceptable differential settlement.

For shallow foundations, the factor of safety against bearing failure (both global failure mechanism and punching shear failure mechanism) shall be evaluated. A minimum safety factor of 3 shall be maintained under gravity loads considering the above bearing failure mechanisms.
If ground improvement (e.g. Deep Soil Mixing – DSM) is used, the ground improvement

elements shall be in a grid pattern. i.e. individual columns of improved ground are not acceptable. The replacement ratio and geometry of grid pattern shall be such that the ground improvement system maintains its integrity under structural gravity loads, seismic loads (base shear and overturning moment applied by the structure), as well as seismic loads due to vertical propagation of seismic waves. The geotechnical engineer of record (GEOR) shall develop recommendations for minimum replacement ratio, minimum unconfined compressive strength, and acceptance criteria and provide the information to Design Build (DB) ground improvement contractors. The GEOR shall review design calculations by DB contractor to check that the integrity of ground improvement elements is maintained during both static and seismic loading conditions. The GEOR shall also review quality measures by DB contractor that will demonstrate that the ground improvement element installation meets the design intent.

If deep foundation is used to bypass compressible / liquefiable soils, the following construction design issues shall be addressed:

7.1 Driven Concrete & Steel H piles – Axial and lateral pile capacity, driving criteria, acceptable tolerance in positioning and verticality of piles, noise and vibration effects, corrosion protection (steel H piles), and indicator pile driving program.

7.2 Auger Cast Piles - Axial and lateral pile capacity, integrity testing requirements (especially in case of loose to medium dense saturated sandy soils and soft clayey soils) using cross hole sonic logging, cross hole Gamma-Gamma logging, or thermal testing, acceptable tolerance in positioning and verticality of piles, and requirements for automated data acquisition system.

7.3 Drilled Shafts – Axial and lateral pile capacity, axial pile load test for drilled shafts with diameter less than 3 feet, pile load test using O-Cell testing for drilled shafts with diameter larger than 4 feet, integrity testing using cross hole sonic logging, cross hole Gamma-Gamma logging, or thermal testing, and acceptable tolerance in positioning and verticality of piles.

End bearing for shafts with diameter less than 4 feet shall be ignored. If end bearing for shafts with diameter larger than 4 feet is accounted for, the bottom of shafts shall be cleaned thoroughly and tested using MiniSID (Shaft Identification Device) or equivalent.

8. Shoring, Dewatering, Excavation & Underpinning

Design of shoring, dewatering, and underpinning system is typically handled by specialty contractors with design parameters (soil and ground water pressure) provided by the GEOR. However, GEOR shall provide acceptable limits of lateral and vertical movement of shoring and underpinning system and shall review contractor's analysis / design to ensure the design meets the criteria. The GEOR also shall request and approve an action plan from contractor should the lateral and vertical movement of the shoring / underpinning system approach acceptable limits.

The GEOR shall specify the allowable drop in groundwater table outside of the excavation and request and approve from dewatering contractor an acceptable action plan should groundwater table drops below the specified limit. Because of presence of sandy soils layers within YBM and OBC, nested piezometers shall be installed outside the excavation for monitoring any drop in ground water table and water head within various sand layers.

If cohesionless soils are exposed at the bottom of the excavation, factor of safety against bottom instability shall be calculated to ensure that bottom heave (quick sand condition) is prevented. If cohesive soils are exposed at bottom of excavation, factor of safety against basal heave shall be calculated. Finally, if a cohesionless soil layer is overlain by a layer of cohesive soil at the bottom of excavation, the blow out condition shall be carefully analyzed and, if necessary, the cohesionless soil layer shall be depressurized to prevent bottom blow out condition.

6/5/19

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