

FOUNDATION REPORTS
For
BUILDINGS and MISCELLANEOUS STRUCTURES

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DIVISION OF ENGINEERING SERVICES
GEOTECHNICAL SERVICES



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1. INTRODUCTION

1.1 Intent of this Document

The intent of this document is to define the Department's standard of practice for preparation of the Foundation Report (FR) for structures requiring foundations at maintenance stations, safety roadside rest areas, CHP truck inspection facilities, toll bridge plazas, and toll operations buildings. The plans package for these facilities including the specifications is prepared by the Office of Transportation Architecture (OTA). Structures that may require design support from Geotechnical Services include buildings, retaining walls, canopies, material storage bunkers, tanks, power generation equipment, light towers and sound walls. Standardized and consistent report presentations benefit the Department's staff, engineering consultants, bidders, and contractors. Geotechnical Services staff as well as any other organization preparing these reports must comply with the requirements presented herein.

This document addresses report content and foundation engineering practice (investigations, design procedures, etc.) that is specific to OTA designed buildings and miscellaneous structures. The structures and facilities addressed by this document are design in accordance with the *California Building Code* (CBC). At the time of the preparation of this document, a digital copy of the 2016 CBC was available at the following website:

[https://archive.org/details/publicsafetycode?and\[\]=title:\(2016%20California\)](https://archive.org/details/publicsafetycode?and[]=title:(2016%20California))

1.2 Reporting for Caltrans Project Delivery

Buildings and miscellaneous structures are most often funded from the Minor A or B Program. As a result, foundation investigations and reporting generally occurs only at the design or I phase of a project (WBS 240.80). Planning and preliminary design reports are infrequently requested for building facilities. If a Structure Preliminary Geotechnical Report or a Preliminary Foundation Report is requested for a building facility, adhere as closely as possible to the format presented in this document.

1.3 Report Format

A foundation report can present foundation recommendations for all structures located at a facility such as a maintenance station, CHP inspection facility, or toll plaza.

1.3.1 Reports Prepared by Caltrans Staff

Foundation Reports are written to the OTA Designer and Structure Construction. They are also provided to bidders via the Information Handout. Specifications are prepared by the OTA designer.

For reports prepared by Geotechnical Services staff, Foundation Reports must be prepared using the current departmental memorandum format with the subject line of "Foundation Report for *Facility Name*" or "Preliminary Foundation Report for *Facility Name*". Do not use the section numbers in the report. Section titles must be used.



The Log of Test Borings (LOTB) and/or As-built LOTB are not to be submitted as part of the FR. Microstation LOTB files and scanned copies of the As-built LOTB sheets will be sent to the Office of Transportation Architecture for inclusion within the Contract Plans.

Signing and sealing requirements are presented in the *Communications and Reporting* section of the *Offices of Geotechnical Design – Quality Management Plan*.

1.3.2 Reports Prepared by Consultants

Foundation Reports must consist of the following: cover sheet, table of contents, main contents per this document, and appendices. The cover of the report and any addenda/amendments to the report must include the following information: Caltrans District, County, Route (if applicable), Post Mile (if applicable), and Expenditure Authorization (EA) number.

The LOTB and/or As-built LOTB must be submitted as part of the FR. Refer to the *Caltrans Soil and Rock Logging, Classification, and Presentation Manual* for direction on the preparation of the LOTB and As-built LOTB.

2. FOUNDATION REPORT (FR)

The following topics, if applicable, must be addressed in the Foundation Report.

2.1. Scope of Work

Summarize the scope and types of work performed to obtain the information supporting the foundation recommendations. Include a statement that the current report supersedes all previous reports (referenced by title and date).

Example: Foundation Report

Per the request dated January 10, 2016, this Foundation Report has been prepared for the proposed Little City Maintenance Station. The purpose of this report is to summarize the investigations performed and to provide foundation recommendations for the crew building and the vehicle maintenance building at the Little City Maintenance Station. The recommendations presented in this report are based on the site plans dated December 10, 2015, a subsurface investigation, proposed foundation configurations and load demand information provided by the Office of Transportation Architecture.

2.2. Project Description

Describe the proposed buildings and miscellaneous structures. Discuss the previous land use. Discuss if the site has been graded and/or disturbed. Discuss the approximate depth of fill at the location(s) of the proposed structure(s). Provide pertinent project information relating to the planned foundation improvements. The datum used to reference the elevations in the report is also included.

Example

The maintenance station site is located in Little City on State Route 21 at PM R3.8. A new crew building and vehicle maintenance building are necessary. All elevations referenced within this report



are based on the North American Vertical Datum of 1988 (NAVD 88), unless otherwise noted. To convert an elevation at this site from National Geodetic Vertical Datum of 1929 (NGVD 29) to NAVD 88, add 2.3 feet to the NGVD 29 elevation.

Based on the Site Plan (dated December 10, 2015) and Foundation Report request, the proposed buildings will be supported by continuous footings founded below the exterior perimeter walls. The superstructure will be masonry and timber. The preferred foundation type is shallow footing.

2.3. Exceptions to Policies and Procedures

Discuss exceptions to Departmental policies and procedures relating to the FR. Approved *Request for Exception* forms must be included in the Appendix.

2.4. Field Investigation and Field Testing Program

Provide a very brief overview of the field investigation performed to support the foundation recommendations, including the number of boreholes, the number of CPT soundings, and a brief description of geophysical testing. The borehole and CPT logs will be provided on a LOTB.

Example

In May 2016, a subsurface investigation was performed consisting of two hollow stem auger borings drilled to a maximum depth of 40.0 feet. Additionally, the As-built LOTB indicates that three borings were drilled to a maximum depth of 45 feet in April 1968.

A rule of thumb for determining the number of boreholes is to drill one borehole per 10,000 square feet of building footprint. Where footings are selected, borehole depths should be a minimum of 25 feet below the bottom of the footing, and extend to a sufficient depth to evaluate settlement and liquefaction. Consider employing SPT sampling at 2.5 foot intervals to a depth of 15 feet below the bottom of the footings. Also consider advancing the boreholes using hollow stem augers so that groundwater observations can be made during and shortly after the drilling of the borehole. Review the *Shallow Foundations for Bridges* section of the Geotechnical Manual for further guidance.

2.5. Laboratory Testing Program

Provide an overview of the laboratory testing program, if performed, to support the foundation recommendations. Briefly explain how the tests contributed to report findings (e.g. soil classification, settlement, strength parameters).

Example

During the most recent field investigation, soil samples for particle analysis and Atterberg limits were collected from borings RC-16-001 and RC-16-002 for soil classification and liquefaction evaluation. The summary of the results will be provided in the Information Handout (referenced in the Special Provisions, Supplemental Project Information section), and the test sample locations will be shown on the Log of Test Borings.



2.6. Site Geology and Subsurface Conditions

Based on the field investigation, provide an updated generalized description of the project site geology and known subsurface conditions.

Do not re-create the As-built LOTB in detail in this section. A generalized discussion is sufficient.

Present only factual information in this section, not how it relates to design and construction. Discussion of the site geology, geological features, and subsurface conditions as they relate to the foundation design and construction must be placed in the *Foundation Recommendations* and *Construction Considerations* sections, respectively.

Example

The maintenance station site is located within the Mojave Desert Geomorphic Province of California. The “Geologic Map of the San Bernardino Quadrangle” (Bortugno and Spittler, 1998) shows that the maintenance station site is underlain by Quaternary alluvium.

During the 2016 investigation, boring RC-16-001 was drilled near the northeast corner of the proposed crew building. Boring RC-16-002 was drilled near the southwest corner of the proposed vehicle maintenance building.

The soil borings revealed that the site is underlain by interbedded layers of predominantly dense to very dense poorly-graded sand with silt and well-graded sand with gravel, cobbles, and boulders, to the maximum depth drilled at the site of 40.0 feet (elev. 2377.9 feet). Soil descriptions from the 2016 subsurface investigation are presented on the Log of Test Borings.

At the northeast corner of the maintenance building (Boring A-16-001), very hard boulders up to 4 feet in size were identified. However, larger boulders up to 8 feet were exposed in the adjacent natural slope.

2.7. Groundwater

Report observed groundwater elevation(s) and date(s) of measurements. Use of a table is recommended if there are numerous borings and/or measurements. Include discussions relating to the presence of wet or saturated soil when groundwater measurements were not made. Discuss surface water conditions that might influence the design or construction of the foundations. The presence of shallow groundwater is of importance for determining the need for a vapor barrier below the slab of occupied space.

State the groundwater elevation(s) used for foundation analyses and design.

Example

As-built LOTB’s from the April 1968 subsurface investigation indicate that groundwater was encountered in several borings at that time, and ranged from elevation 2381.9 feet to elevation 2382.2 feet (NAVD88 datum). During the 2016 subsurface investigation groundwater was measured in Boring A-16-001 at elevation 2381.3 feet and in Boring A-16-002 at elevation 2383.9 feet. The groundwater elevation used for design was 2385.0 feet.



2.8. As-built Foundation Data

If not addressed elsewhere in the FR, include discussion of relevant As-built data, such as the type of foundation systems used for pre-existing structures at the site. Include as much specific data as possible: foundation types, elevations, widths and loading. Discuss the potential of encountering buried obstructions such as abandoned foundations and utilities.

2.9. Corrosion Evaluation

Report and discuss pertinent site corrosion data. Corrosion test only soils and groundwater that will be in contact with foundation elements.

Example: No information available

Historical corrosion data is not available. The site should be considered non-corrosive based on the presence of predominantly cohesionless material.

Example: Non-Corrosive

Two soil samples were collected for corrosion testing during the 2016 subsurface investigation. Corrosion test results for those samples are shown below in Table 1. Based on current Caltrans' standards, the site is considered to be non-corrosive.

Table 1: Soil Corrosion Test Summary

<i>Boring ID</i>	<i>Elevation (ft)</i>	<i>Minimum Resistivity (Ohm-Cm)</i>	<i>pH</i>	<i>Chloride Content (ppm)</i>	<i>Sulfate Content (ppm)</i>
<i>A-16-001</i>	<i>2409.2 to 2410.7</i>	<i>1544</i>	<i>7.24</i>	<i>N/A</i>	<i>N/A</i>
<i>A-16-002</i>	<i>2415.3 to 2416.8</i>	<i>683</i>	<i>7.94</i>	<i>384</i>	<i>432</i>

Caltrans currently defines a corrosive environment as an area where the soil has either a chloride concentration of 500 ppm or greater, a sulfate concentration of 1500 ppm or greater, or has a pH of 5.5 or less. Soil and water are not tested for chlorides and sulfates if the minimum resistivity is greater than 1,000 ohm-cm.

Example: Corrosive

During the 2016 subsurface investigation four soil samples were collected for corrosion testing. Corrosion test results for the samples collected from borings A-16-001 and A-16-002 are shown below in Table 1. Due to chloride content being greater than 500 ppm in two of the samples tested, the site is considered to be corrosive based on current Caltrans' standards, and corrosion mitigation is required.

2.10. Seismic Design Information and Recommendations

Seismic design and site seismicity are determined per California Building Code (CBC) Section 1613. This section utilizes ASCE 7, *Minimum Design Loads for Buildings and Other Structures*. Geotechnical Services provides OTA the soil profile Site Classification, and the spectral accelerations for the short or 0.2 second period (S_S) and 1 second period (S₁). The Foundation Report should also provide the seismic parameters that are derived from the short period and 1 second period spectral accelerations per the CBC, S_{MS}, S_{M1}, S_{DS} and S_{D1}. These parameters are determined per the formula



provided in CBC Sections 1613.3.3 and 1613.3.4, and as shown later in this section. The developed data should be provided in the Foundation Report as shown below, in Table 2.

Table 2: Maximum Considered Earthquake Response Spectral Parameters

S_S	S_I	S_{MS}	S_{M1}	S_{DS}	S_{D1}
1.580	0.562	1.580	0.977	1.053	0.651

Step 1: The calculations require the soil profile at a project location be assigned a Site Classification. Per Section 1613.3.2 of the CBC, Site Classifications are determined in accordance with ASCE chapter 20. The following Table provides the Site Classifications from ASCE 7. Provide the Site Classification in the Foundation Report.

Table 3: Site Classification

Site Class	Weighted Average of V_S	Weighted Average of N or N_s	Weighted Average of S_u
A. Hard rock	>5,000 ft/sec	NA	NA
B. Rock	2,500 to 5,000 ft/sec	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/sec	>50	>2,000 psf
D. Stiff soil	600 to 1,200 ft/sec	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/sec	<15	<1,000 psf
	Any profile with more than 10 feet of soil having the following characteristics: <ul style="list-style-type: none"> • Plasticity index greater than 20 • Moisture content greater than or equal to 40%, and • Undrained shear strength less than 500 psf 		
F. Soils requiring site response analysis in accordance with Section 21.1 of ASCE7	Liquefiable soils, peat, high plasticity clay		

The weighted average values used in Table 3 are for the 100 feet of the soil or rock immediately below the footings. If subsurface data is not available to this depth, use judgement to extrapolate or infer appropriate values. The site class can be determined by one of three methods: 1) using the shear wave velocity, 2) SPT blow count corrected to 60% hammer energy, or 3) a combination of the undrained shear wave velocity for cohesive soils and the SPT blow count for cohesionless soils.

The equation for calculating the weighted average of V_S for the upper 100 feet is:

$$V_S = \frac{100 \text{ feet}}{\frac{D_1}{V_1} + \frac{D_2}{V_2} + \frac{D_3}{V_3} + \dots + \frac{D_n}{V_n}} ; \text{ Where } D \text{ is the layer thickness (feet) and } V \text{ is the shear wave velocity (feet/sec) for that layer.}$$

The equation for calculating the weighted average of N for the upper 100 feet is:

$$N = \frac{100 \text{ feet}}{\frac{D_1}{N_1} + \frac{D_2}{N_2} + \frac{D_3}{N_3} + \dots + \frac{D_n}{N_n}} ; \text{ Where } D \text{ is the layer thickness (feet) and } N \text{ is the SPT blow count corrected for hammer energy for that layer.}$$

When using the undrained shear strengths of cohesive soil to determine the site classification, use the following equation for calculating the weighted average of S_u for the portion of the upper 100 feet of the soil column that is cohesive soil:

$$S_u = \frac{d_c \text{ feet}}{\frac{D_1}{S_{u1}} + \frac{D_2}{S_{u2}} + \frac{D_3}{S_{u3}} + \dots + \frac{D_n}{S_{un}}} ; \text{ Where } d_c \text{ is the total thickness of cohesive soil layers, } D \text{ is the layer thickness (feet) and } S_u \text{ is the undrained shear strength (psf) for that layer (not to exceed 5,000 psf).}$$

Use the following equation for calculating the weighted average of N for the portion of the upper 100 feet of the soil column that is cohesionless soil:

$$N_s = \frac{d_s \text{ feet}}{\frac{D_1}{N_{s1}} + \frac{D_2}{N_{s2}} + \frac{D_3}{N_{s3}} + \dots + \frac{D_n}{N_{sn}}} ; \text{ Where } d_s \text{ is the total thickness of cohesionless soil layers, } D \text{ is the layer thickness (feet) and } N_s \text{ is the SPT blow count corrected for hammer energy for that layer.}$$

Step 2: Spectral accelerations for the 0.2 second or short period (S_s), and 1 second period (S_1) are determined from CBC Section 1613.3.1 (Figures 1613.3.1(1) and 1613.3.1(2)). For most locations in California, these figures are not of sufficient clarity to determine the S_s and S_1 coefficients. It is recommended that the URL below be used to access the OSHPD website to determine S_s and S_1 . While this website does calculate all of the parameters shown in Table 2, the seismic parameters generated on the website should be checked against hand calculations following the methods provided in CBC Sections 1613.3.3 and 1613.3.4, as shown below.

<https://seismicmaps.org/>

The calculator on the website requires that the project location be entered either by coordinates or by locating the project location on a map. Enter the appropriate design code reference document. This is tied to the version of the CBC that OTA is using for design of the structure. For the 2016 edition of the CBC the reference document is ASCE 7-10. The Risk Category for occupied maintenance structures is considered to be Risk Category II. This is the category that applies to residential, commercial, and industrial buildings.



Step 3: Calculate the maximum considered earthquake response acceleration for short periods (S_{MS}) and at 1-second periods (S_{M1}) per the following equations and Tables.

$$S_{MS} = F_a * S_s$$

$$S_{M1} = F_v * S_1$$

Where:

F_a = Site coefficient defined in Table 4

F_v = Site coefficient defined in Table 5

S_s = The mapped spectral acceleration for short periods.

S_1 = The mapped spectral acceleration for a 1-second period.

Table 4: Values of Site Coefficient F_a

Site Class	Mapped Spectral Accelerations at Short Period				
	$S_s \leq 0.25$	$S_s = 0.50$	$S_s = 0.75$	$S_s = 1.00$	$S_s \geq 1.25$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.2	1.2	1.1	1.0	1.0
D	1.6	1.4	1.2	1.1	1.0
E	2.5	1.7	1.2	0.9	0.9
F	Note b	Note b	Note b	Note b	Note b

- a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at short period S_s
- b. Values shall be determined in accordance with Section 11.4.7 of ASCE 7.

Table 5: Values of Site Coefficient F_v

Site Class	Mapped Spectral Accelerations at 1-Second Period				
	$S_s \leq 0.1$	$S_s = 0.2$	$S_s = 0.3$	$S_s = 0.4$	$S_s \geq 0.5$
A	0.8	0.8	0.8	0.8	0.8
B	1.0	1.0	1.0	1.0	1.0
C	1.7	1.6	1.5	1.4	1.3
D	2.4	2.0	1.8	1.6	1.5
E	3.5	3.2	2.8	2.4	2.4
F	Note b	Note b	Note b	Note b	Note b

- a. Use straight-line interpolation for intermediate values of mapped spectral response acceleration at 1-second period S_1
- b. Values must be determined in accordance with Section 11.4.7 of ASCE 7.



Step 4: Calculate the 5 percent damped design spectral response acceleration at short periods (S_{DS}) and at 1-second period (S_{D1}) per the following equations.

$$S_{DS} = 2/3 * S_{Ms}$$

$$S_{D1} = 2/3 * S_{M1}$$

Where:

S_{Ms} = The maximum considered earthquake spectral response accelerations for short period.

S_{M1} = The maximum considered earthquake spectral response accelerations for 1-second period.

In the Foundation Report, provide seismic hazards for the proposed foundations (e.g., fault rupture evaluation, liquefaction and seismic settlement evaluation). Provide mitigation measures for seismic hazards. For deep foundations and upon request, provide p-y and t-z curves.

Example: Liquefaction

Due to the presence of loose to medium dense alluvial material and high ground water beneath the site, the potential for soil liquefaction under strong ground shaking is present. The liquefiable zone elevations at locations within the project limits are provided below in Table 6.

Table 6: Liquefaction Potential at Little City Maintenance Station

<i>Location</i>	<i>Liquefaction Elevation (ft)</i>	<i>Estimated Seismic-induced Settlement (in)</i>
<i>NE corner of crew building</i>	<i>Elev. 20 to 15 and Elev. 0 to -5</i>	<i>3</i>
<i>Center of crew building</i>	<i>Elev. 10 to -5</i>	<i>4</i>
<i>SW corner of crew building</i>	<i>Elev. 20 to 10</i>	<i>3</i>

Example: Lateral Spreading Potential

It is anticipated that lateral spreading may occur at the proposed location of the crew building. Mitigation of this settlement may include a deep foundation consisting of piles or ground improvement.

Example: Seismic Settlement

Liquefaction-induced settlement of the ground surface is estimated to range from 3 to 5 inches. Mitigation of this settlement may include a deep foundation consisting of piles or ground improvement.



2.11. Foundation Recommendations

Building and miscellaneous structure foundations are designed per the California Building Code Chapter 18. Calculations are performed using Allowable Stress Design Methodology. Provide complete and concise foundation recommendations by addressing the topics in the applicable portions of this section. Discuss the recommended foundations and any special considerations which influence their design and selection (ground improvement, liquefaction, etc.).

Example: Shallow Foundations

The following recommendations are for the proposed Little City Maintenance Station, as shown on the Site Plan dated March 14, 2016. At the Crew Building and the Vehicle Maintenance Building, continuous footings are recommended. The subsurface information gathered for the site indicates that the footings will be founded in alluvial soil. The following foundation recommendations were designed in accordance with the 2016 California Building Code.

Example: Deep Foundations

The following recommendations are for the proposed Little City Maintenance Station, as shown on the Site Plan dated March 14, 2016. Based on the subsurface information gathered at the site, driven precast concrete piles (Alt. "X") are recommended at both the Crew Building and Vehicle Maintenance Building. The following foundation recommendations were designed in accordance with the 2016 California Building Code.

2.11.1 Spread Footings and Continuous Footings

While the CBC provides *Presumptive Load Bearing Values* in Table 1806.2, it is Caltrans practice that a site investigation be conducted and that the gross nominal bearing resistance be computed in accordance with the analytical methods provided in the Geotechnical Manual Section *Shallow Foundations for Bridges*. The allowable soil pressure is computed by applying a Factor of Safety of 3 to the gross nominal bearing resistance. For shallow foundations, spread footings and continuous (strip) footings, OTA requires allowable soil pressures in units of psf.

Present and/or discuss the following:

1. A description of the material on which the footing is to be placed.
2. The soil or rock strength parameters and unit weight used for the bearing resistance calculations.
3. The minimum footing embedment required for the recommendations to be valid. The CBC Section 1809.4 specifies the minimum embedment into undisturbed material must be 12 inches. Bearing resistance, frost penetration and erosion considerations influence this recommendation.
4. Summary of foundation elevations or range of elevations, allowable soil pressures and footing sizes. The CBC Section 1809.4 specifies the minimum footing width must be 12 inches.
5. The influence of new footing construction on the adjacent structures and/or utilities, if applicable.



Report the footing allowable soil pressure recommendations in the following table:

Table 7: Footing Design Recommendations for Crew Building

<i>Footing Type</i>	<i>Footing Width (feet)</i>	<i>Minimum footing embedment below grade (feet)</i>	<i>Approximate Footing Elevation (feet)</i>	<i>Ultimate Soil Pressure (psf)</i>	<i>Allowable Soil Pressure (psf)</i>
<i>Continuous</i>	<i>2.0</i>	<i>1.5</i>	<i>7.24</i>	<i>3300</i>	<i>1100</i>
<i>Continuous</i>	<i>3.0</i>	<i>2.0</i>	<i>6.74</i>	<i>4200</i>	<i>1400</i>
<i>Square</i>	<i>6.0</i>	<i>2.0</i>	<i>6.74</i>	<i>5100</i>	<i>1700</i>
<i>Square</i>	<i>8.0</i>	<i>2.0</i>	<i>6.74</i>	<i>6600</i>	<i>2200</i>

Section 1806.1 of the CBC states that the presumptive *vertical foundation pressure* provided in Table 1806.2 may be increased for load combinations that include short term or transient loads used in the alternative basic load combinations of Section 1605.3.2. The permitted increase is 33%. It is interpreted that the same provision applies to allowable soil pressure values calculated from site specific foundation data. Reiterate this allowance in the Foundation Report.

Perform total and differential settlement calculations for building structures in conformance with the methods outlined in the Geotechnical Manual Section *Shallow Foundations for Bridges*. Settlement calculations should be performed using the Service Loads. Present the immediate settlement and long term settlement values.

Lateral load demands on footings are resisted by a combination of friction along the bottom of the footings and lateral passive bearing pressure along footing vertical surfaces. Report the coefficient of friction for sliding of the foundation along subgrade soils per Section 1806.3. The coefficient of friction values provided in Table 1806.2 are presumptive, and may be exceeded if data from a field investigation supports doing so. Also consult Section 3.10.1 of FHWA NHI-01-023, *Shallow Foundations* for guidance to determine the lateral sliding resistance.

Presumptive values of lateral bearing pressure are provided in Table 1806.2 of the CBC. The presumptive lateral bearing pressure values provided in Table 1806.2 are conservative. Passive lateral earth pressures can be computed using Rankine earth pressure theory, however the results may yield unconservative designs and should be used with caution because the displacement required to achieve these pressures is excessive. In order to limit the lateral movement of shallow foundations to tolerable values, the recommended lateral passive bearing pressure values are less than passive lateral earth pressures. It is recommended that a 50% reduction be considered. If the possibility exists that the soil adjacent to the foundation will be excavated in the future, no lateral bearing pressure should be used to resist lateral loads.



Section 1806.1 of the CBC states that the presumptive *lateral bearing pressure* provided in Table 1806.2 may be increased for load combinations that include short term or transient loads used in the alternative basic load combinations of Section 1605.3.2. The permitted increase is 33%. It is interpreted that the same provision applies to lateral passive bearing pressure values calculated from site specific foundation data. Reiterate this allowance in the Foundation Report.

Per CBC Section 1809.5, unless founded on rock, footings are either founded at depths below frost penetration or are constructed in compliance with ASCE 32. Frost depth is determined by consulting the local building codes. Observations and knowledge of frost depth from local practice at the project site, are the best sources of information. In general, penetration of frost into the ground is a potential design factor in Northern California, the Sierra Nevada Mountains and east of the Sierra Nevada Mountains (FHWA NHI-01-023, *Shallow Foundations*, Section 2.5.1). Conditions for the exception to this specification are found in CBC Section 1809.5.

The presence of expansive soil beneath footings should be investigated and analyzed. Building footings are relatively lightly loaded and may be susceptible to damage caused by expanding and contracting foundation soils. If evaluation of the uplift pressure indicates that it exceeds the contact stress resulting from the service loads on the footings, mitigation should be considered. The first strategy that should be considered is taking measures to maintain constant moisture content in the soils beneath the footings. Other typical mitigation measures include remove-and-replace the expansive soil, and treatment-in-place to eliminate the expansion potential.

Notes to the Structure Designer (Shallow Foundations)

Provide the following (applicable) information to aid in preparation of the contract plans.

1. Footings below groundwater level.

Example

Groundwater will be encountered during construction of the continuous footings at the location of the proposed Crew Building. Dewatering is anticipated for construction.

2. Footings with sub-excavation and replacement with structure backfill.

Example

At the Vehicle Maintenance Building, unsuitable native soils were identified in the subsurface investigation and possibly underlie the proposed continuous footing. Therefore, it is recommended that the native materials be removed to a depth of 2.0 feet below the bottom of footing, and be replaced with structure backfill compacted to 95% relative compaction, or concrete to the bottom of footing elevation. The bottom of sub-excavation elevations are listed in Table 1. The limits of the sub-excavation and replacement must conform to the limits specified in Standard Specification 19-5.03B for compaction of embankments under retaining wall footings without pile foundations.



Table 8: Little City Maintenance Station – Bottom of Sub-Excavation Elevation

Support Location	Bottom of Sub-Excavation Elevation (ft)
Vehicle Maintenance Building	4334.4

3. Location of footings adjacent to existing footing or utilities

Example

Avoid transferring load from proposed foundations to existing foundations by configuring their bearing surfaces below an imaginary 1.5 horizontal to 1 vertical plane that is projected upward from the bearing surface of the existing footing.

Construction Considerations (Shallow Foundations)

Provide the following (applicable) information in this section for use by the OTA Design Engineer, Structure Construction Representative, Contractor, and others.

1. Include the following instructions to address potential construction disturbance of native material below the specified bottom of footing elevation(s).

Example

At the Crew Building, the continuous footings are to be constructed on native alluvium at the bottom of the excavation. The structural concrete is to be placed neat against the undisturbed native alluvium at the bottom of the footing excavation. Should the bottom of the footing excavation be disturbed, then the disturbed material must be removed to a depth of 1.0 feet below the disturbance, and recompacted to 95% relative compaction.

Example

At the Crew Building, the continuous footings are to be constructed on the weathered rock at the bottom of the excavation. The structural concrete is to be placed neat against the trimmed walls and undisturbed rock at the bottom of the footing excavation. Should the bottom of the footing excavation be disturbed, then the disturbed material must be removed and replaced to the bottom of footing elevation with concrete.

Example

Gravel, cobbles and boulders were observed in the foundation soils. Excavations for the continuous footings may encounter gravel, cobbles and boulders that extend beyond the planned limits of the footings. All soils disturbed during excavations are to be removed and replaced with structure backfill compacted to 95% relative compaction.

2. Include instructions for the removal of obstructions, and their replacement with lean concrete or structure backfill compacted to 95% relative compaction.



2.11.2 Deep Foundations

Deep foundations consisting of driven piles are rarely warranted for building foundation use. The use of CIDH piles is extremely rare. Building and canopy load demands are low when compared to bridge structures, therefore adequate bearing resistance can at most locations be provided with continuous (strip) and spread footings. Settlement behavior may warrant deep foundations, particularly when differential settlement with relationship to adjoining or connecting features that have minimal foundation loads and therefore settle very little. This includes utilities, walkways and driveways.

If the design team determines that the expense of deep foundations is warranted for performance and maintenance reasons, the Geotechnical Designer should compute deep foundation recommendations with the methods outlined in the Geotechnical Manual Sections *Driven Pile Foundations and CIDH Pile Foundations*. However, deep foundations for buildings are designed utilizing the CBC which specifies that Allowable Stress Design methodology is used. Therefore, the allowable bearing load or pile design load is determined by applying an appropriate Factor of Safety to the calculated pile ultimate or nominal bearing resistance. A Factor of Safety value of 2 is typically utilized. CBC Section 1810.3.3.1.7 specifies that a minimum value of 2 is used for the Factor of Safety.

Pile design tip elevations for settlement are calculated per the Geotechnical Manual Sections *Foundation Reports for Bridges, Driven Pile Foundations and CIDH Pile Foundations*. If site conditions will result in more than 0.25 inch differential settlement for the specified tip elevations report this value to the OTA designer.

Piles may be subject to lateral loads, particularly if they are not fully embedded. If the upper portions of piles are unbraced in air or water, or the upper portions of the piles are embedded in weak soils, the OTA designer may request assistance with a lateral pile analysis. Often the OTA engineer will determine the design tip for lateral load, and include it in the plans. Consult the CBC for lateral load and resistance requirements.

Also consider foundation conditions that may impact pile design and performance such as downdrag and liquefaction.

The following Foundation Recommendations Table and Pile Data Table are included in the Foundation Report. These tables have been modified from those found in Memos to Designers 3-1 to reflect Allowable Stress Design practice, not LRFD.



Table 9: Little City Maintenance Station – Foundation Design Recommendations

Foundations Design Recommendations									
Location	Pile Type	Cut-off Elevation (ft)	Service Load per Pile (kips)	Total Permissible Pile Settlement (inches)	Nominal Resistance (kips)		Design Tip Elevations (ft)	Specified Tip Elevation (ft)	Nominal Driving Resistance Required (kips)
					Compression (FS = 2.0)	Tension (FS = 2.0)			
Crew Building	Class 90 Alt. "X"	4.8	60	1	120	20	-30 (a) -15(b) -20(c)	-30	120

Notes:

- 1) *Design tip elevations are controlled by: (a) Compression, (b) Tension, (c) Settlement, and (d) Lateral Load, respectively.*
- 2) *The specified tip elevation must not be raised above the design tip elevations for Tension, Settlement, and Lateral Load.*
- 3) *The nominal driving resistance required is equal to the nominal resistance needed to support the factored load plus driving resistance from the unsuitable penetrated soil layers (very soft, liquefiable, scourable, etc.), if any, which do not contribute to the design resistance. Unsuitable soil layers extend to elevation -10 ft.*
- 4) *Design tip elevation for Lateral Load is typically provided by OTA*

Table 10: Little City Maintenance Station – Pile Data Table

Pile Data Table						
Location	Pile Type	Nominal Resistance (kips)		Design Tip Elevation (ft)	Specified Tip Elevation (ft)	Nominal Driving Resistance (kips)
		Compression	Tension			
Crew Building	Class 90 Alt. "X"	120	20	-30(a) -15(b) -20(c)	-30	120

Notes:

- 1) *Design tip elevations for are controlled by: (a) Compression, (c) Settlement, (d) Lateral Load*
- 2) *The specified tip elevation must not be raised above the design tip elevations for Tension, Settlement, and Lateral Load.*
- 3) *Unsuitable soil layers (very soft, liquefiable, scourable, etc.) that do not contribute to the design nominal resistance exist to elevation -10 ft.*

Incorporate appropriate report content that follows the guidance in the *Notes to the Designer* and *Construction Considerations* Sections of the Geotechnical Manual document *Foundations Reports for Bridges*. This includes considerations for pile modification from the standard plan details, pile acceptance criteria, and predrilling limits.

2.11.3 Concrete Slabs on Grade

Building floor slabs are lightly loaded and rarely warrant sub-excavation and material replacement beneath the floor slab. Sub-excavation beneath slabs should rarely be recommended. If recommended, provide detailed justification.

State the proposed bottom of slab elevation, and provide the modulus of subgrade reaction for slab foundation soils. The first step to determining the modulus of subgrade reaction is to determine the representative subgrade modulus (k) for a 12 inch plate load test using the following table (Lindeburg, Civil Engineering Reference manual, 15th Edition). Select a k value from the table, where higher values within each range are appropriate for stiffer soils.

Table 11: 12 inch plate subgrade modulus

Group symbol	Range of subgrade modulus, k (psi/in)
GW	300-500
GP	250-400
GM	100-400
GC	100-300
SW	200-300
SP	200-300
SM	100-300
SM-SC	100-300
SC	100-300
ML	100-200
CL	50-200
OL	50-100
MH	50-100
CH	50-150
OH	25-100

Modify the k value to reflect the dimensions of the foundation. Using the following formulae, determine and provide in the Foundation Report the appropriate subgrade modulus: k_s , $k_{s,rect}$ or $k_{s,cont}$.

- Square footings or floor slabs $k_s = k * ((B+1)/(2*B))^2$
- Rectangular footings or floor slabs $k_{s,rect} = k_s * ((1+(B/L))/1.5)$
- Continuous footings $k_{s,cont} = 0.67 * k_s$



Where:

B = the foundation width

L = the length of a rectangular foundation

The recommendation for a vapor barrier beneath occupied buildings is provided by Geotechnical Services (GS) in the Foundation Report. This will be based on the predicted height of ground water and the height of capillary rise beneath the slabs of occupied buildings. If it's anticipated that moisture can reach the bottom of the floor slab, then a vapor barrier should be recommended. OTA will specify the vapor barrier configuration and material that is in conventional use at that time. OTA also has a standard practice and detail for base courses that are placed beneath concrete slabs.

The presence of expansive soil beneath slabs should be investigated and analyzed. Expansive soils meet the characteristics set forth in CBC Section 1803.5.3. Soils having an expansion index greater than 20 as determined by ASTM D4829 are considered expansive. Also consult Section 6.2 of FHWA NHI-01-023, *Shallow Foundations*. Floor slabs are lightly loaded and susceptible to damage caused by expanding and contracting foundation soils. If evaluation of the uplift pressure indicates that it exceeds the contact stress resulting from the dead weight of the slab, mitigation should be considered. The first strategy that should be considered is taking measures to maintain constant moisture content in the soils beneath the slab. Other typical mitigation measures include pre-saturation, remove-and-replace the expansive soil and chemical treatment to eliminate the expansion potential.

2.11.4 Retaining Walls and Earth Retaining Structures (ERS)

Retaining walls employed in non-roadway settings do not typically utilize the Standard Plan concrete cantilever retaining wall design details. The Office of Transportation Architecture (OTA) designer will most often start with the standard plan wall concrete cantilever design as a template, and modify the design with the intent of economizing. This is achieved by not designing the retaining wall for loads that are not applicable, such as traffic surcharges. The OTA designer requests that the Geotechnical Designer provide *lateral soil loads*. Table 1610.1 of Section 1610 of the CBC is used to determine the *lateral soil load*, at-rest or active, whichever is applicable. The results of the geotechnical investigation can be also used to determine the *lateral soil load*. The values provided in Table 1610.1 apply to moist drained soils. If retaining wall backfill is undrained, then the retaining wall is designed for hydrostatic pressure in addition to the buoyant soil being retained. Lateral pressures resulting from expansive soils must also be identified. Retaining wall and ERS foundation calculations and recommendations follow the guidelines provided in the Geotechnical Manual sections for the specific wall type and *Foundations Reports for ERS*.



2.11.5 Site Grading

If requested, the Foundation Report provides recommendations for cut slope and fill slope inclinations. If the site requires the placement of more than 3 feet of fill at locations of proposed occupied structures, embankment caused settlement should be analyzed. Recommendations for settlement periods will be the most common mitigation measure to address predicted unacceptable settlement and differential settlement. Fill surcharge may be considered in rare cases.

Provide recommendations as to the suitability of on-site materials for use as structure backfill.

2.11.6 Radio Communications Towers and Infrastructure

The equipment for radio communications are purchased as a package from the manufacturer. A prescriptive foundation design is included with the equipment. OTA will check the design of the foundation elements. In order to check the communications tower foundation and lateral load design, OTA may request that GS provide bearing resistances and lateral soil resistances. Compute passive lateral earth pressure distributions using Rankine Earth Pressure theory. Guidance can be found in the Geotechnical Manual Section for Non-gravity Cantilever Retaining Walls. Presumptive *lateral bearing pressure* values are provided in CBC Section 1806, Table 1806.2. Per Section 1806.3.4, the table values can be doubled for short-term loads if 0.5 inch displacements do not adversely affect performance or maintenance.

2.12. Additional Considerations

Provide any recommendations that have not already been addressed in any of the preceding sections.

2.13. Supplemental Project Information

Standard Special Provision 2-1.06B, "Supplemental Project Information", discloses to bidders and contractors a list and location of pertinent information available for their inspection prior to bid opening. Documents and information are presented in the following table:



Table 12: Supplemental Project Information

<i>Means</i>	<i>Description</i>
<i>Included in the Information Handout</i>	<i>Foundation Report for Little City Maintenance Station Lab Test Results for Little City Maintenance Station Cone Penetration Test Results for Little City Maintenance Station</i>
<i>Available for inspection at the District Office</i>	
<i>Available for inspection at the Transportation Laboratory</i>	

The Geoprofessional must identify and forward all pertinent geotechnical information (in PDF) to the OTA Designer so that it can be properly included in the construction contract via SSP 2-1.06B. Include all relevant geotechnical reports and laboratory test results. Items available for inspection at the Transportation Laboratory or District Office are typically core samples.

2.14. Report Copy List

The FR must be addressed to the OTA Designer and copies provided to those listed under Report Distribution in the *Communications and Reporting* section of the Geotechnical Design Quality Management Plan, with the exception that the report is not distributed to the Structures Office Engineer.

2.15. Appendices

The Foundation Report appendices provide detailed information supporting foundation type selection, analyses, recommendations, and construction considerations.

Reports prepared by Geotechnical Services staff must include:

Appendix I: Exceptions to Policy

- Attach all approved "Request for Exception" forms.

Reports prepared by consultants must include:

Appendix I: Site Map showing project location

Appendix II: Log of Test Borings (including as-built LOTB)

Appendix III: Field Exploration and Testing

- Data acquired from field exploration and testing such as surface geologic mapping and surface geophysical surveys, logs from the Cone Penetration Test, Pressuremeter, Dilatometer, and in-situ Vane Shear Tests, Borehole Geophysical logging, Piezometer Readings, etc.

Appendix IV: Laboratory Test Results

- Soil and rock laboratory test results.



- Corrosion test results.

Appendix V: Analyses and Calculations.

- Engineering analyses and calculations supporting the foundation recommendations including all QC/QA signature sheets.

Appendix VI: Exceptions to Policy

- Attach all approved "Request for Exception" forms.