6. SEISMICITY AND FOUNDATION PERFORMANCE

6.1 Site Assessment

6.1.1 Seismicity and Foundation Data

The geotechnical engineer shall provide the following geotechnical data. See MTD 1-35 for information on requesting foundation data.

- Seismicity
  - Fault distance
  - Earthquake magnitude
  - Peak rock acceleration
  - Soil profile type
- Liquefaction potential
- Foundation stiffness or the soil parameters necessary for determining the force deformation characteristics of the foundation (when required)

6.1.2 ARS Curves

The geotechnical engineer will assess each bridge site and will recommend one of the following, a standard 5% damped SDC ARS curve, a modified SDC ARS curve, or a site-specific ARS curve. The final seismic design recommendations shall be included in the Final Foundation Report.

6.1.2.1 Standard ARS Curves

For preliminary design, prior to receiving the geotechnical engineer's recommendation, a standard SDC ARS curve may be used in conjunction with the peak rock acceleration from the 1996 Caltrans Seismic Hazard Map. The standard SDC ARS curves are contained in Appendix B. If standard SDC ARS curves are used during preliminary design, they should be adjusted for long period bridges and bridges in close proximity to a fault as described below.

For preliminary design of structures within 10 miles (15 km) of an active fault, the spectral acceleration on the SDC ARS curves shall be magnified as follows:

- Spectral acceleration magnification is not required for $T \leq 0.5$ seconds
- Increase the spectral accelerations for $T \geq 1.0$ seconds by 20%
- Spectral accelerations for $0.5 \leq T \leq 1.0$ shall be determined by linear interpolation

For preliminary design of structures with a fundamental period of vibration $T \geq 1.5$ seconds on deep soil sites (depth of alluvium ≥ 250 feet {75 m}) the spectral ordinates of the standard ARS curve should be magnified as follows:

- Spectral acceleration magnification is not required for $T \leq 0.5$ seconds
- Increase the spectral accelerations for $T \geq 1.5$ seconds by 20%
- Spectral accelerations for $0.5 \leq T \leq 1.5$ shall be determined by linear interpolation

6.1.2.2 Site Specific ARS Curves

Geotechnical Services (GS) will determine if a site-specific ARS curve is required. A site specific response spectrum is typically required when a bridge is located in the vicinity of a major fault or located on soft or liquefiable soil and the estimated earthquake moment magnitude $M_m > 6.5$.

The rock motion and soil profile can vary significantly along the length of long bridges. Consult with GS on bridges exceeding 1000 feet (300 m) in length to assess the probability of non-synchronous ground motion and the impact of different subsurface profiles along the length of the bridge.

The use of free field ground surface response spectra may not be appropriate for structures with stiff pile foundations in soft soil or deep pileshafts in soft soil extending into bedrock. Special analysis is required because of soil-pile kinematic interaction and shall be addressed by the geotechnical engineer on a job specific basis.

6.2 Foundation Design

6.2.1 Foundation Performance

- Bridge foundations shall be designed to respond to seismic loading in accordance with the seismic performance objectives outlined in MTD 20-1
- The capacity of the foundations and their individual components to resist MCE seismic demands shall be based on ultimate structural and soil capacities

6.2.2 Soil Classification[6]

The soil surrounding and supporting a foundation combined with the structural components (i.e. piles, footings, pile caps & drilled shafts) and the seismic input loading determines the dynamic response of the foundation subsystem. Typically, the soil response has a significant effect on the overall foundation response. Therefore, we can characterize

[6] Section 6.2 contains interim recommendations. The Caltrans' foundation design policy is currently under review. Previous practice essentially divided soil into two classifications based on standard penetration. Lateral foundation design was required in soft soil defined by $N \leq 10$. The SDC includes three soil classifications: competent, marginal, and poor. The marginal classification recognizes that it is more difficult to assess intermediate soils, and their impact on dynamic response, compared to the soils on the extreme ends of the soil spectrum (i.e. very soft or very firm).

The SDC development team recognizes that predicting the soil and foundation response with a few selected geotechnical parameters is simplistic and may not adequately capture soil-structure interaction (SSI) in all situations. The designer must exercise engineering judgement when assessing the impact of marginal soils on the overall dynamic response of a bridge, and should consult with Geotechnical Services and Structure Design senior staff if they do not have the experience and/or the information required to make the determination themselves.

the foundation subsystem response based on the quality of the surrounding soil. Soil can be classified as competent, poor, or marginal as described in Section 6.2.3 (A), (B), & (C). Contact the Project Geologist/Geotechnical Engineer if it is uncertain which soil classification pertains to a particular bridge site.

6.2.2(A) Competent Soil

Foundations surrounded by competent soil are capable of resisting MCE level forces while experiencing small deformations. This type of performance characterizes a stiff foundation subsystem that usually has an insignificant impact on the overall dynamic response of the bridge and is typically ignored in the demand and capacity assessment. Foundations in competent soil can be analyzed and designed using a simple model that is based on assumptions consistent with observed response of similar foundations during past earthquakes. Good indicators that a soil is capable of producing competent foundation performance include the following:

- Standard penetration, upper layer (0-10 ft, 0-3 m) $N = 20$ (Granular soils)
- Standard penetration, lower layer (10-30 ft, 3-9 m) $N = 30$ (Granular soils)
- Undrained shear strength, $s_u > 1500$ psf (72 KPa) (Cohesive soils)
- Shear wave velocity, $v_s > 600$ ft/sec (180 m/sec)
- Low potential for liquefaction, lateral spreading, or scour

N = The uncorrected blow count from the Standard Test Method for Penetration Test and Split- Barrel Sampling of Soil

6.2.2(B) Poor Soil

Poor soil has traditionally been characterized as having a standard penetration, N<10. The presence of poor soil classifies a bridge as non-standard, thereby requiring project-specific design criteria that address soil structure interaction (SSI) related phenomena. SSI mechanisms that should be addressed in the project criteria include earth pressure generated by lateral ground displacement, dynamic settlement, and the effect of foundation flexibility on the response of the entire bridge. The assumptions that simplify the assessment of foundation performance in competent soil cannot be applied to poor soil because the lateral and vertical force-deformation response of the soil has a significant effect on the foundation response and subsequently on the overall response of the bridge.

6.2.2(C) Marginal Soil

Marginal defines the range on soil that cannot readily be classified as either competent or poor. The course of action for bridges in marginal soil will be determined on a project-by-project basis. If a soil is classified as marginal, the bridge engineer and foundation designer shall jointly select the appropriate foundation type, determine the impact of SSI, and determine the analytical sophistication required to reasonably capture the dynamic response of the foundation as well as the overall dynamic response of the bridge.

6.2.3 Foundation Design Criteria

6.2.3.1 Foundation Strength

All foundations shall be designed to resist the plastic hinging overstrength capacity of the column or pier wall, M_o defined in Section 4.3.1 and the associated plastic shear V_o.[7] See Section 7.7 for additional foundation design guidelines.

6.2.3.2 Foundation Flexibility

The demand and capacity analyses shall incorporate the expected foundation stiffness if the bridge is sensitive to variations in rotational, vertical, or lateral stiffness.

[7] An exception is permitted for pile cap and spread footing foundations in competent soil, where the foundation may be designed for M_p in lieu of M_o. Designing for a smaller column capacity is justified because of additional capacity inherent to these types of foundation systems that is not typically included in the foundation capacity assessment.