analysis are obtained from generic modulus reduction and hysteretic damping curves recommended by EPRI TR-102293 (Reference 11) based on site response analysis of soil columns for the standard plant profiles considering shear strains compatibility.

3.7.1.3 Supporting Media for Seismic Category I Structures

Seismic Category I structures are founded directly on rock or competent soil. The nuclear island and emergency diesel generator building correspond to the seismic Category I structures of the APR1400 standard plant design. The nuclear island consists of the following seismic Category I structures, the reactor containment building and the auxiliary building, which are founded on a common basemat. The emergency diesel generator building and a diesel fuel oil storage tank room are also seismic Category I structures. The foundation embedment depth, foundation size, and total height of the seismic Category I structures are presented in Table 3.7-8.

For the design of seismic Category I structures, nine soil profiles and one fixed-base condition are established with various shear wave velocities compared with soil depth.

The supporting media for the generic site are described in Appendix 3.7A about soil properties, layering characteristics, shear wave velocity, shear modulus, and density. Basically, soil-structure interaction analyses on soil sites for the APR1400 use the soil degradation curves recommended by EPRI TR-102293. The curves are used to generate the strain-compatible soil properties.

These nine profiles are considered representative to envelop sites where competent soil is defined by the shear wave velocity of the supporting medium at the foundation level exceeding 304.8 m/sec (1,000 ft/sec). The shear wave velocity profiles of the nine sites considered are shown in Figure 3.7-23. The nine soil profiles, S1 through S9, are developed as combinations of six soil layering categories, which are designated as 55, 100, 200, 500, 1,000 ft, and half-space, and five average-shear-wave-velocity categories, namely, 1,200, 2,000, 4,000, 6,000, and 9,200 ft/sec. The generic site soil profiles are described further in Technical Report, APR1400-E-S-NR-14001-P (Reference 9).

To generate more conservative seismic responses, the extreme groundwater level (El. 98 ft 8 in.) in Subsection 3.8A.1.4.2.3.2 is considered in the seismic analyses of the seismic Category I structures, rather than the design groundwater level (El. 96 ft 8 in.) in Subsection 3.8.4.3.1.

Evaluation of the capability of a structure for a given load combination is based on providing a factor of safety appropriate to the probability of occurrence. The appropriate factor of safety is reflected in the load factors and allowable stresses for the various load combinations.

The COL applicant is to identify any applicable site-specific loads such as site proximity explosions and missiles, potential aircraft crashes, and the effects of seiches, surges, waves, and tsunamis (COL 3.8(2)).

3.8.4.3.1 <u>Normal Loads</u>

a. Dead loads – (D)

Dead load refers to loads that are constant in magnitude and point of application. The types and definitions of dead loads and their combination requirements are given in Table 3.8-8.

b. Live loads – (L)

Live load refers to any normal loads that may vary with intensity and location of occurrence. The types and definitions of live loads and their combination requirements are given in Table 3.8-8. The specified design values for live loads are summarized in Table 3.8-7.

1) Soil and surcharge load (L_g)

Soil and surcharge load refers to load due to weight and pressure of soil, water in soil, or other material such as soil surcharge. ~~Maximum flood~~ Design groundwater level is specified to be ~~0.30 m (1 ft)~~ 0.61 m (2 ft) below plant grade for safety-related structures. For the construction loading condition, the minimum surcharge load is 48.0 kN/m^2 (1,000 psf) over any unoccupied area plus the actual construction loading surcharge from any known structures or load sources. For the normal loading condition, the minimum surcharge load is 24.0 kN/m^2 (500 psf). For the design of underground utilities, the minimum surcharge load for the construction loading condition is 24.0 kN/m^2 (500 psf) and for the

3.8A.1.4.2.3.2 Stability Check

The NI common basemat structure is evaluated for stability against overturning, sliding, and flotation. The calculated factors of safety against overturning, sliding, and flotation for the load combinations meet the criteria of Section II of SRP 3.8.5 as shown in Table 3.8A-14.

The sliding and overturning factors of safety are determined using load combination containing dead load (D), SSE (E_s), and buoyant load at normal (H_e). The floatation factor of safety is determined based on dead load (D) and buoyant force at flood (H_s).

The ~~normal~~ design groundwater ~~elevation~~ is El. 96 ft 8 in. The extreme groundwater ~~elevation~~ is the same as plant grade level (El. 98 ft 8 in.) considering probable maximum flood.

level

In the earthquake load, axial force, shear force, and moment due to horizontal and vertical excitation of the structure are obtained from seismic analysis. Since seismic load governs over wind load, stability checks are not considered under wind load. A summary of overturning, sliding, and flotation check is provided in Table 3.8A-15.

3.8A.1.4.2.3.3 Basemat Uplift Check

The ground contact uplift ratio between the basemat and soils is carried out to provide reasonable assurance that the linear soil-structure interaction (SSI) analysis remains valid. The ground contact ratio is defined as the minimum ratio of the area of the foundation in contact with the soil to the total area of the foundation. Among the results from the NI common basemat analysis, the load combination cases, which are shown, the uplift phenomena are considered for uplift check. Table 3.8A-16 shows the uplift area ratios of NI common basemat. The APR1400 NI common basemat has an 80 percent or more contact area during basemat uplift, and it can be concluded that the contact area would be acceptable.

3.8A.1.4.2.3.4 Settlement Check

Differential settlements are divided by the differential settlement within the NI common basemat and the differential settlement between the NI basemat and the turbine generator

, and the buoyant force in stability check of the seismic Category I structures for the overturning and the sliding

$$V_p = \sqrt{\frac{2(1-\nu)}{1-2\nu}}\; V_s$$

Where

Vs = Shear wave velocity,

Vp = Compression wave velocity

v = Poisson's Ratio.

level

The design groundwater ~~table~~ is used for calculating the hydrostatic load, the hydrodynamic load, ~~and the buoyancy load~~ in the structural analyses. In the seismic analyses of seismic Category I structures, the groundwater ~~table elevation~~ is considered at the ground surface at El. 98'-8" to induce more conservative analysis results.

level

and

extreme

The representative generic site profiles, S1 through S9, for the shear wave velocities and compression wave velocities used in the site response analysis for the APR1400 are shown in Tables 5-3 to 5-11 and Figures 5-2 to 5-10.

The shear-strain-dependent, soil/rock modulus degradation and damping value variation curves for the soil/rock materials (sand, soft rock, and rock) considered for the nine generic site profiles are shown in Figure 5-11 for sand, Figure 5-12 for soft rock, and Figure 5-13 for rock. The curves for sand considered, as shown in Figure 5-11, adopt the sand curves published in the Electric Power Research Institute (EPRI) TR-102293 (Reference 15). The curves for soft rock, as shown in Figure 5-12, adopt the curves for soft rock published in Silva's report (Reference 16). The curves for rock considered, as shown in Figure 5-13, adopt the curves for rock used in the SHAKE computer program (Reference 17, 18).

level

For the APR1400 standard plant design, the design groundwater ~~table elevation~~ is 2 ft below the ground surface at El. 96'-8"~~, and the extreme groundwater table elevation considered in the design is at the ground surface at El. 98'-8" (Reference 3)~~. If the compression wave velocity (V_p) of subgrade soil below the groundwater table computed from the low-strain shear wave velocity and Poisson's ratio has a value less than the V_p of water (4,800 ft/sec), the V_p value of the soil is taken to be not less than 4,800 ft/sec.

The extreme groundwater level is also used for calculating the buoyancy load in the structural analyses and the buoyant force in stability check of the seismic Category I structures for the flotation.

5.2 Strain-Compatible Soil Properties

Horizontal free-field site response analyses subjected to the free-field seismic ground motion input at the ground surface at El. 98'-8". The free-field seismic ground motion input is the CSDRS-compatible acceleration time histories H1 and H2 applied in the plant E-W and N-S directions, respectively. For each generic site profile, the horizontal free-field site response analyses are performed separately for H1 (E-W) and H2 (N-S) time-history inputs using the SHAKE computer program (Reference 17, 18). The shear-strain-compatible shear wave velocity profiles obtained from the analyses using H1 and H2 inputs are then averaged to produce the averaged shear-strain-compatible shear wave velocity profile for each generic site profile considered. The averaged shear-strain-compatible shear wave velocity profiles so obtained for S1 through S9 are the free-field site profiles used in development of the seismic SSI analysis models.

For the free-field site response analysis for each generic site profile, a low-strain soil column model to be used in the SHAKE analysis is developed. The SHAKE soil column models are developed to pass vertically propagating plane seismic shear waves up to a cut-off frequency of at least 50 Hz. The SHAKE soil column models so developed for all nine generic site profiles considered are tabulated in Tables 5-3 through 5-11.

In the horizontal site response analyses, the strain-compatible soil/rock properties resulting from the E-W and N-S components of the seismic input motions differ slightly from each other because of the different time-history input motions. To obtain a common set of strain-compatible soil properties for the SSI analysis, the strain-compatible soil properties resulting from the E-W and N-S input motions for each case are averaged. The average sets of strain-compatible properties for nine soil profiles are shown in Tables 5-12 through 5-20. The strain-compatible soil properties shown in Tables 5-12 through 5-20 and Figures

Where

V_s = Shear wave velocity,

V_p = Compression wave velocity

ν = Poisson's ratio.

In the seismic analyses of seismic Category I structures, the extreme groundwater level is considered at the ground surface at El. 98'-8" to induce more conservative analysis results.

The shear-strain-dependent, soil/rock-modulus-degradation and damping-value variation curves for the soil/rock materials considered for the nine generic site profiles are shown in Figure 4-2 (sand), Figure 4-3 (soft rock), and Figure 4-4 (rock). The curves for sand, as shown in Figure 4-2, adopt the sand curves in an EPRI report (Reference 12). The curves for soft rock, as shown in Figure 4-3, adopt the curves for soft rock in Silva's report (Reference 13). The curves for rock considered, as shown in Figure 4-4, adopt the curves for rock used in the SHAKE computer program (References 14, 15).

4.2 Backfill Material

For the APR1400 standard plant, backfill material used for backfill adjacent to the Seismic Category I structures is SFG. In accordance with the APR1400 Design Criteria Manual (Reference 16), the reference low-strain dynamic shear modulus (G_{max}) of SFG in units of kg/cm² (1 kg/cm² = 2.0439 kip/ft² or ksf) is derived as follows:

$$G_{max} = 2{,}000 \times \sqrt{\sigma_m} \tag{4-2}$$

Where

σ_m = Mean confining pressure in kg/cm².

The total and saturated weight densities (unit weights) of SFG are 137 and 140 pcf, respectively, and the dynamic Poison's ratio is 0.33.

For the standard design, the reference shear-strain-dependent modulus-degradation and damping-value-variation curves for the SFG considered are shown in Figure 4-5.

4.3 Groundwater Table Elevation

For the APR1400 standard plant design, the design groundwater ~~table elevation~~ level is 2 ft below the ground surface at El. 96'-8". ~~The extreme groundwater table elevation considered in the design is at a ground surface of El. 98'-8".~~ If the compression wave velocity (V_p) of subgrade soil computed from the low-strain shear wave velocity and Poisson's ratio using Eq. (4-1) has a value less than the V_p of water (4,800 ft/sec), the V_p value of the soil is considered to be not less than 4,800 ft/sec.

4.4 Free-field Site Response Analysis

Horizontal free-field site response analyses are conducted for the nine (9) generic site profiles S1 through S9 and subjected to the free-field seismic ground motion input at the ground surface at El. 98'-8". The free-field seismic ground motion input are the CSDRS-compatible acceleration time histories H1 and H2 applied in the plant E-W and N-S directions, respectively.

For each generic site profile, a horizontal free-field site response analysis is performed for H1 (E-W) and H2 (N-S) time history inputs using the SHAKE computer program (References 14, 15). The shear-strain-

3.2 Generic Site Profiles

The APR1400 standard plant design considers the plant is supported in various generic site profiles. A total of nine generic site profiles plus a 10th fixed-base support condition. The nine generic site conditions considered are all horizontally layered sites with site shear wave velocities varying from soft to medium to firm soil sites and soft to medium to hard rock sites.

The nine generic site profiles considered for design of the APR1400 standard plant consist of six site-layering categories, labeled as Site-Layering Category A through F with their site-layer thickness and depths from the ground surface as follows:

Site-Layering Category	Layer Thickness (ft)	Layer Depth Range (ft)
A	55	0 ~ 55
B	45	55 ~ 100
C	100	100 ~ 200
D	300	200 ~ 500
E	500	500 ~ 1000
F	Infinite	Half space > 1000

In addition to six site-layering categories, five average-shear-wave-velocity categories, labelled as P1 through P5, with their average shear-wave-velocity values as shown below are considered:

Average-Shear-Wave-Velocity Category	Average Shear Wave Velocity (ft/sec)
P1	1,200
P2	2,000
P3	4,000
P4	6,000
P5	9,200

The site soil/rock material unit weight (weight density), Poisson's ratio, and types of shear-strain-dependent modulus-degradation and damping-value-variation curves for the soil/rock material (sand, soft rock, and rock) considered for each of the categories P1 through P5 are shown in Table 3-2.

The nine generic site profiles considered for design of APR1400 standard plant, designated as S1 through S9, are developed with combinations of the site-layering categories A through F and the average-shear-wave-velocity categories P1 through P5, as shown in Table 3-3. Figure 3-6 shows the low-strain shear wave velocity profiles vs. depth for the nine generic site profiles considered.

The shear-strain-dependent, soil/rock-modulus-degradation and damping-value variation curves for the soil/rock materials (sand, soft rock, and rock) considered for the nine generic site profiles are shown in Figures 3-7 for sand, Figure 3-8 for soft rock, and Figure 3-9 for rock. The curves for sand considered, as shown in Figure 3-7, adopt the sand curves published in the EPRI report (Ref. 10). The curves for soft rock, as shown in Figure 3-8, adopt the curves for soft rock published in Silva's report (Ref. 12). While the curves for rock considered, as shown in Figure 3-9, adopt the curves for rock used in the SHAKE computer program (Refs. 13, 14).

3.3 Groundwater Table Elevation

groundwater level

For the APR1400 standard plant design, the design ~~ground water table elevation~~ is 2 ft below the ground surface at El. 96'-8" (Ref. 1). ~~The extreme ground water table elevation considered in the design is at the ground surface at El. 98'-8".~~ If the compression wave velocity of subgrade soil has a value less than the compression wave velocity of water (4,800 ft/sec), the compression wave velocity value of the soil is taken to be not less than 4,800 ft/sec.

In the seismic analyses of seismic Category I structures, the extreme groundwater level is considered at the ground surface at El. 98'-8" to induce more conservative analysis results.