SOIL BACKFILL CONDITIONS

SAN ONOFRE NUCLEAR GENERATING STATION

UNIT 1

AUGUST 12, 1982

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1.0 INTRODUCTION

1.1 Background

The overall site soil conditions present at the San Onofre site are reported in Reference 1. The results and the soil parameters described therein are applicable to the native San Mateo formation.

At the beginning of the Systematic Evaluation Program (SEP) Seismic Reevaluation, the backfill at the San Onofre Unit 1 site was assessed to be San Mateo sand having a minimum relative compaction of 95 percent. Therefore, the soil parameters developed for the backfill and used in the SEP analyses were based on this assessment (References 2 and 3).

In a letter to the USNRC dated April 30, 1982, SCE indicated that as a result of soil testing conducted during the construction of the seismic upgrade modifications for the turbine building during the current outage, it was discovered that fill soil with relative compaction less than 95 percent was present. In the local areas where this was encountered, remedies were implemented. In addition, SCE committed to investigate the potential for similar conditions in other areas of the site and to resolve the potential impact of such conditions on the seismic analyses.

1.2 Purpose and Organization

The purpose of this report is to provide a characterization of the fill soils at San Onofre Unit 1. Additionally, where differences are identified between this characterization and the corresponding basis for the seismic reevaluation of the various structures, systems and components, the effects of the differences are assessed and resolved.

This report is comprised of seven sections including this introduction. Specifically, in Section 2, the site backfill conditions are characterized based on a thorough review of site grading drawings, construction photographs, the documentation of San Onofre Unit 1 compaction testing during the original construction, and more recent observations and testing performed in conjunction with various plant modifications including the foundation modifications of the north extension and the west heater platform of the turbine building. The turbine building modifications were performed during the period March-June 1982.

Section 3 provides a detailed description of the backfill behavior during a 0.67g Housner Design Basis Earthquake (DBE) event. The methodology which is used to determine the effect of the backfill on the SEP seismic reevaluation analysis parameters is also discussed.

Section 4 addresses the specific analysis effects of the soil fills for each of the structures. The significance of the soil fill analysis effects on the previously completed seismic analysis of the structures is evaluated and described.

Similiary, Section 5 addresses the specific backfill soil behavioral effects which are pertinent to the affected safety related systems and components. These effects and results are then evaluated for each individual component. If further resolution is necessary, conceptual modifications are identified which, when implemented, will either preclude the cause of the effects, or adequately mitigate the effects on the component.

A summary of the report conclusions is provided in Section 6, and the report references are listed in Section 7.

2.0 SOIL BACKFILL CHARACTERIZATIONS

This section describes the characterization of the backfill areas at the site. The development of the characterization involved: defining the backfill areas; evaluating the available information on the relative compaction of the fill in the various areas to identify the amount of compaction; indexing the fills in accordance with the degree of compaction; and assigning an appropriate category to the backfill in each area. The sections that follow describe these steps.

2.1 Areal Extent of Backfill

The first step in defining the backfill areas was the examination of the original site grading plan and the available construction photographs. The plan dimensions and locations of structures, as shown on the original excavation plan, were determined to be correct. However, the excavation slopes (shown as 1:1 on the plan) were not in agreement with the construction photographs. Based on an interpretation of numerous construction photographs, discussions with construction personnel, and field observations made during subsequent plant excavation (See Section 2.2), it was determined that the actual slope of the construction cuts were 1/2:1. In addition, a working space of about two to three feet between a structure and the base of the excavation slope was considered to be consistent with the apparent construction procedures used and with photographic evidence. An excavation plan was drawn depicting the tops and bottoms of the excavations using two to three feet of working space around structures and 1/2:1 cut slopes except where photographic evidence indicated otherwise. Areas between the excavation slopes and structural walls were designated as backfill areas. In addition, areas above the anchor blocks where the finished grade was higher than the elevation at the top of the anchor blocks, were designated as backfill areas. Based on these considerations a site plan showing the areal extent of the backfill was prepared and is presented in Figure 2-1. A water table elevation of +5 feet is used to distinguish between fills which are above and below the water table.

2.2 Characterization of Backfill Compaction

After defining the backfill areas at the site, as discussed in Section 2.1, the compaction of backfill was characterized based on all available information. This information consisted of: results of field tests made during the original construction; observations and tests made in utility trench excavations constructed subsequent to initial construction; observations made during the construction of the sphere enclosure building and the diesel generator building; and observations and tests made during the recent turbine building north extension and west heater platform foundation modifications.

During the initial construction of the plant, field density tests were made by Twining Laboratories. Tests made in the power block area are summarized in Table 2-1. It is noted that the degree of compaction, as reported by Twining Laboratories, was based on a laboratory maximum dry density of 121 pcf. More recent tests made over the past 8 years with the San Mateo sand from San Onofre Units 1, 2 & 3 following the ASTM D 1557-A procedure indicate that a more representative laboratory maximum dry density is 120 pcf. Therefore, the percent relative compactions shown in Table 2-1 are based on a maximum dry density of 120 pcf. The use of a maximum dry density of 120 pcf for San Mateo sand provides a consistent basis for comparisons of relative compaction in the backfills evaluated here and at other locations at the site. Figure 2-2 is a location map for Figures 2-3 to 2-6 which summarize, in plan view, the approximate locations of these tests and their results.

In addition to the above, and subsequent to the original construction, backfill observations were made for plant modifications including utility excavations, construction of foundations for the sphere enclosure building, the diesel generator building, and the recent turbine building footing modifications. These backfill observations consist of field tests and/or probing (with a 3/8-inch diameter, 3-ft long steel probe) as excavations progressed. The location of the tests, results and observations were carefully documented. The approximate locations and results of these tests are summarized in Figures 2-3 to 2-7. Summaries of the observations made in utility trench excavations are presented in Table 2-2. At the time these observations were made, it was concluded that they were the result of placement of uncontrolled utility trench backfills. Therefore, these observations were concluded to be localized conditions and not representative of the generic condition of backfills. Field density tests and observations made on soil exposed in excavations for foundations for the sphere enclosure building are summarized in Table 2-3. Woodward-Clyde Consultants 1982 report summarizing the results of field tests and observations made during the turbine building footing modifications, is included in Appendix A. The observed conditions at the bases of various excavations made for the turbine building footing modifications are shown in Figure 2-8. The legend notes in Figure 2-8 describe the observations made during the excavations. The "daylight" lines between backfill and native soil which were observed during the footing excavations were checked against the areal distribution of fill as delineated in Figure 2-1 and were determined to be in good agreement.

In addition to the plan views showing the locations of the observations described above, the test results were also plotted on cross sections to aid in characterizing the backfill in the various locations. Ten cross sections showing the configuration of the backfill at various locations and the results of these field tests are presented in Figures 2-9 through 2-12.

2.3 Characterization of Backfills

To characterize backfills at various locations, the configuration of the backfill in the excavations was also considered with regard to the amount of working space and the type of compaction equipment observed in construction photographs. Based on this information and the information presented in Sections 2.1 and 2.2, the backfills delineated in Figure 2-1 were characterized into four general categories as described below and as shown in Figure 2-13. Figure 2-14 reflects the characterization of Figure 2-13 as well as the remedial measures which were undertaken during the construction of the sphere enclosure building and the recent turbine building footing modifications.

Category A - This characterization represents well compacted backfill, with a minimum relative compaction of 95 percent. As shown in Figure 2-14, the area with this type backfill is located mainly over the discharge culvert. Cross-sections presented in Figures 2-9 to 2-12 show that the backfill in this area is wide and placed over a relatively flat base. In addition, construction photographs show the presence of compaction equipment in this area. Further, tests made in the area of the turbine building southwest footing modification which are summarized in Figure 2-4 (see Appendix A), indicated high levels of relative compaction.

Category B - This characterization represents moderate to well compacted backfills, with relative compaction of 90 to 95 percent. Backfills of this category are located adjacent to the intake structure, between the intake-culverts and in the narrow sloping surfaces shown in Figure 2-14. This is based on the available information which includes: the Twining test data summarized in Tables 2-1 and 2-3 and Figures 2-3 to 2-7; the utility trench observations summarized in Table 2-2; tests and observations made along the southern portion of the west footing and outrigger footing, summarized in Figures 2-4 and 2-6 and cross sections presented in Figures 2-9 to 2-12. In addition, deep narrow fills in these areas, with widths of less than 6 to 10 ft, are assumed to have a lower degree of compaction, which is estimated to be about 85 percent, because of the difficulty of access and maneuvering of compaction equipment.

Category C - This characterization represents near surface moderate to well compacted backfills, with relative compactions of 90 to 95 percent, extending to depths of 2 to 6 feet. At greater depths, the backfill may have a lower degree of compaction, estimated to be about 85 percent. Based on the limited available data (specifically the utility trench observations summarized in Table 2-2), these fills are in areas around the screen well and tsunami gates and other narrow fills shown in Figure 2-14.

Category D - This characterization represents backfills with an estimated 85 percent relative compaction. This is based on observations made during construction of a portion of the north extension footing during the recent turbine building footing modifications (Appendix A), as shown in Figures 2-3, 2-8 and 2-9, and on observations made for miscellaneous pipe support foundations, which are summarized in Table 2-2. These fills have been defined to include narrow, long areas around structures, where it was difficult to maneuver compaction equipment and where a high degree of compaction may not have been considered essential at the time of construction. As shown in Figure 2-14, the fills in this category include the areas around the reactor auxiliary building, the fuel storage building, narrow fills around the turbine mat, between the west anchor block and the discharge culvert, and shallow, narrow fills around the control building.

It should be noted that the degree of compaction which is shown to be 85 percent relative compaction for categories B, C, and D fills represents an average value based on the results of probings and field density tests discussed in Section 2.2.

The backfill conditions summarized on Figure 2-14 are considered conservative since in those areas where limited or no data were available, the worst conditions were assigned from areas with available data.

2.4 Remedial Measures Implemented During Footing Construction

Some of the new footings for the sphere enclosure building and for the recent turbine building modifications are located within the backfills placed during the original plant construction.

A summary of the specific remedial measures which were implemented to accommodate backfill conditions which were encountered during the construction of the turbine building foundation modifications is presented in Table 2-4. In general, if the fill exhibited a density beneath a new footing of less than 95 percent relative compaction, the soil was overexcavated and the footing base extended to native soil. The overexcavated area was backfilled with lean concrete or the soil was compacted to 95 percent relative compaction. When backfill adjacent to a foundation was found to exhibit a density below 95 percent relative compaction the backfill was generally left in place and the foundation stiffness parameters were modified to reflect this condition as discussed in Section 3. Further detail is provided in Table 4-1. The resulting structural evaluations using the revised design parameters for the footings are discussed in Section 4.0. The final footing configurations reflected by these changes are shown on the cross sections shown in Figures 2-15 through 2-18.

Table 2-4 also includes a description of the overexcavation remedial measure which was undertaken during the construction of the sphere enclosure building foundation. As shown in Figure 2-7 only a very minor portion of the foundation was affected.

TABLE 2-1
SUMMARY OF FIELD TEST RESULTS BY TWINING LABORATORIES IN POWER BLOCK AREA

Test No.	Date	Location	Approximate Elevation of Test (ft)	γ_d Field (pcf)	Moisture Content Field (%)	Relative Compaction* (%)	Comments (from Twining Reports)
27	16 Dec 64	Pump Well Area East of Intake Structure	-10	114.8	8.7	95.7	
28	16 Dec 64	Pump Well Area East of Intake Structure	-10	107.4	6.4	89.5	Retested, new designation as test No. 33
29	16 Dec 64	North of Intake Structure	-10	115.1	8.7	95.9	
30	12 Dec 64	North of Intake Structure	-10	111.6	7.5	93.0	Does not meet the required 95% compaction
31	12 Dec 64	South Side of Field Storage Building	+12	108.6	3.6	90.5	To be retested
32	12 Dec 64	South Side Field Storage Building	+12	106.4	3.6	88.7	To be retested
33	18 Dec 64	Pump Well Area East of Intake Structure	-10	115.1	8.1	95.9	
34	18 Dec 64	North Side of Field Storage Building	+13	115.1	5.3	95.9	
35	18 Dec 64	North Side of Field Storage Building	+13	109.2	8.1	91.0	
36	12 Jan 65	South of Turb-Ped Mat.	+14	115.2	4.7	96.0	
37	12 Jan 65	South of Turb-Ped Mat.	+14	115.4	5.8	96.2	
38	12 Feb 65	Between Intake Culverts	2.0	119.9	9.9	99.9	
39	12 Feb 65	Between Intake Culverts	2.0	119.2	8.3	99.3	
40	12 Feb 65	Top of Discharge Culvert - East End	8.0	119.0	7.5	99.2	
41	12 Feb 65	Top of Discharge Culvert - East End	8.0	119.8	8.3	99.8	
42	24 Feb 65	South of Screen Well	-1	103.6	5.3	86.3	
43	24 Feb 65	South of Pump Well	+4	112.1	7.5	93.4	
44	24 Feb 65	South of Pump Well	+4	113.5	8.1	94.6	
45	24 Feb 65	North of Intake Culverts	-6	113.8	6.4	94.8	
46	24 Feb 65	West Side Screen Well	-1	114.5	8.7	95.4	
47	24 Feb 65	North of Screen Well	-1	117.2	9.9	97.7	
48	24 Feb 65	North Side Pump Well	-1	117.1	9.9	97.6	
55	23 Mar 65	South of Screen Well	8.0	119.5	8.1	99.6	
56	23 Mar 65	South of Screen Well	8.0	118.8	12.4	99.0	
57	23 Mar 65	South of Pump Well	13.0	117.8	7.5	98.2	
58	23 Mar 65	Area 12 Over Discharge Culvert	13.0	111.4	5.6	92.8	
59	23 Mar 65	Area 13	13.0	120.5	8.1	100.4	
60	23 Mar 65	Area 11 Over Discharge Culvert	18.0	118.0	7.0	98.3	
61	23 Mar 65	South of Intake Structure	13.0	107.4	3.6	89.5	

* Relative compaction based on a laboratory maximum dry density of 120 pcf.

TABLE 2-2

SUMMARY OF OBSERVATIONS MADE IN VARIOUS EXCAVATIONS

Date	Excavation Description	Approximate Depth (ft)	Location	Observation*
Mar 76	Manhole Excavation	10-20	Electrical manhole structure 710A and 711A	Backfill with relative compaction of 87 percent to an unknown depth.
Apr 76	Sphere Enclosure Foundation	7	Southwest of column no. C-2 near the Fuel Storage Building	Backfill with estimated relative compaction of less than 95 percent to about el. +7 was removed and replaced with 95 percent compacted backfill.
Oct 76	UPS Trench Backfill	8	West and south side of trench next to manhole nos. 743 & 744	Backfill with relative compaction of about 85 percent to a depth of at least 8 ft (el. +6).
Sep 77	Catch Basin #5	12	South of screen well	Backfill with relative compaction of about 85 percent from surface (el. +14) to at least el. +2.
Oct 77	Utility Trench	6	South of pump well between column lines K & L and west of column line 13	Backfill with relative compaction of about 85 percent from surface (el. +14) to at least el. +8.
Oct-Nov 77	Trenches for Misc. Piping	11	West of pump well near screen well	Backfill with relative compaction of about 85 percent from surface (el. +14) to at least el. +3.
Feb 78	Chlorination Tank Pad and Yard Sump	3	South of intake structure near west wall of pump well	Backfill with relative compaction of about 85 percent from surface (el. +14) to at least el. +11.
Jun 78	Cathodic Protection Boring	9-10	Between pump well and screen well	Backfill with relative compaction of 90 to 95 percent from surface (el. +14) to a depth of 4 to 6 ft and with relative compaction of about 85 percent below el. +15.
May 80	Miscellaneous Footings	5	East of anchor block, north of column line 1	Backfill with relative compaction of about 85 percent from surface (el. +14) to at least el. +9.
Dec 80 - Jan 81	Miscellaneous Pipe Support Footings	4	Against north and west walls of Fuel Storage Building	Backfill with relative compaction of about 85 percent from surface to bottom of excavation. Probing indicated loose soil to additional depth of at least 3 ft (el. +7).
Jan 82	Miscellaneous Footings	5	Against north wall of Fuel Pool near northeast corner of Fuel Storage Building	Backfill with relative compaction of about 85 percent from surface (el. +19) to at least el. +14.

* Observation interpreted from field notes and on discussions with field personnel. Approximate relative compaction estimated by using a 3/8-inch diameter, 3-ft long steel probe.

TABLE 2-3 Summary of Field Density Tests in Foundation Excavations, Sphere Enclosure Building

Field Data Sheet

Sheet No: 1

Job Name: SONGS Unit 1 Sphere Enclosure Building

Job Number: B675F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
Apr 07	1			S9+57 W5+49	Blow Down Header	15	124	6	SC	120	103	95	SEP-211 Sec CS-1 1.11.7	SR *
Apr 08	2			S9+58 W5+50	" " "	17	118	9	"	"	99	"	"	" *
Apr 13	3			S9+43 W5+17	Column C-7	13	123	10	"	"	102	"	"	" *
"	4			S9+31 W4+87	Column C-8	13	121	7	"	"	100	"	"	" *
Apr 14	5			S9+30 W4+64	Column C-9	13	121	8	"	"	101	"	"	" *
"	6			S9+57 W5+50	Blow Down Header	19	120	8	"	"	100	"	"	" *
Apr 19	7			S9+40 W5+10	Column C-7	15	119	6	"	"	100	"	"	" *
"	8			S9+32 W4+90	Column C-8	15	120	6	"	"	100	"	"	" *
"	9			S9+31 W4+59	Column C-9	15	121	6	"	"	100	"	"	" *
"	10			S9+40 W4+38	Column C-10	13	121	5	"	"	101	"	"	" *
Apr 20	11			S9+43 W4+32	Column C-10	15	122	8	"	"	102	"	"	" *
Apr 22	12			S9+62 W5+33	Column C-6	13	118	9	"	"	98	"	"	" *
Apr 26	13			S9+59 W5+30	Column C-6	15	114	5	"	"	95	"	"	" *
Apr 29	14			S9+68 W4+17	Column C-11	13	118	7	"	"	98	"	"	" *
"	15			S9+90 W4+06	Column C-12	13	121	7	"	"	101	"	"	" *
Apr 30	16			S9+60 W4+15	Column C-11	15	118	7	"	"	98	"	"	" *
"	17			S9+95 W4+05	Column C-12	15	122	8	"	"	102	"	"	" *
May 10	18			S10+55 W5+18	Column C-2	9	118	10	"	"	98	"	"	" *
May 11	19			S10+59 W5+20	Column C-2	11	121	9	"	"	100	"	"	" *
May 12	20			S10+40 W5+27	Stack footing	9	121	8	"	"	101	"	"	" *
"	21			S10+58 W5+30	" "	11	122	9	"	"	101	"	"	" *

Remarks: SC = Sand Cone Density Test (ASTM D1556-64)

* = Test requested by Bechtel

SR = Safety Related

Class 1 & 2 Reviewed By: A.M. Worsnicke

Class 3 & 4 Reviewed By:

TABLE 2-3 (continued)

Field Data Sheet

Sheet No: 2

Job Name: SONGS Unit 1 Sphere Enclosure Building

Job Number: B675F

1976 Date	Test Number	Retest by	Retest of	Grid Number	Location of Test	Elev.	Field Dry Density (pcf)	Moist. %	Method	Max. Lab. (pcf)	Rel. Comp. %	Spec. Reg. %	Drawing No., Spec.	Quality Class.
May 12	22			S10+40 W5+41	Stack footing	9	116	9	SC	120	96	95	SEP-211 Sec CS-1 1 11 7	SR *
May 13	23			S10+38 W5+39	" "	11	121	9	"	"	101	"	"	" *
"	24			S10+18 W4+05	Column C-13	12	118	8	"	"	98	"	"	" *
May 14	25			S10+44 W5+30	Stack footing	10	123	7	"	"	102	"	"	" *
Sep 24	41			S9+60 W5+55	Seal Water Filter Enclosure Structure	15	123	8	"	"	103	"	"	" *
"	42			S9+61 W5+52		17	122	7	"	"	102	"	"	" *

Remarks: SC = Sand Cone Density Test (ASTM D1556-64)

* = Test requested by Bechtel

SR = Safety Related

Class 1 & 2 Reviewed By: [signature]

Class 3 & 4 Reviewed By:

TABLE 2-4

SUMMARY OF REMEDIAL MEASURES
FOR SOIL BACKFILL CONDITIONS ENCOUNTERED
(sheet 1 of 2)

Foundation	Soil Condition Encountered	Remedial Measures Implemented
A. Turbine Building		
1. North Turbine Footing	Most of the footing is founded on native soil or 95% compacted backfill. During the excavation of the western portion of the footing 80-93% compacted backfill was encountered.	Backfill on western end of excavation was removed and replaced with concrete to el. +1 ft. Backfill below el. +1 ft. was compacted in place by vibration.
2. Northwest Turbine Footings		
• Footing E-11	Most of the footing is founded on native soil except for a small portion along the east wall. Backfill against the side of the footing is dense except for small portions of the east and south walls where it is 80-82% relative compaction.	The stiffness parameters were modified.
• Footing C-9	Most of the footing except a small width near the north side is founded on native soils. Backfill against the side of the footing is 85-87% relative compaction.	The stiffness parameters were modified.

TABLE 2-4 (continued)

SUMMARY OF REMEDIAL MEASURES
FOR SOIL CONDITIONS ENCOUNTERED
(Sheet 2 of 2)

Foundation	Soil Condition Encountered	Remedial Measures Implemented
3. West Turbine Footing	The footing is founded on native soil or backfill with 90-95% relative compaction. Backfill against the side of the footing has 90% relative compaction.	The stiffness parameters were modified.
4. Southwest Turbine Footing	The northern and western portions of the footing are founded on backfill with relative compaction of 95-100%. The remaining footing had backfill with 83-85% relative compaction at elevation +7 ft. Backfill against the side of the footing varied between 90 and 95% relative compaction.	The excavation was deepened to about elevation +3 ft., and the overexcavated area was filled with concrete.
5. Outrigger Turbine Footing	Tests in the excavation showed backfill at a relative compaction of 87 to 93% to elevation +3 ft.	The footing was modified to be supported by the intake culverts, and the overexcavation below the footing base at elevation +5 ft. was backfilled with concrete.
B. Sphere Enclosure Building	During the construction of the sphere enclosure building, the footing excavation at the southwest end of the building indicated some backfill at a relative compaction of less than 95%.	The excavation for the sphere enclosure building's foundation at this location was extended to elevation +7 ft. and replaced with fill compacted to 95% relative compaction.