Investigation of Soils Placed Behind Caltrans' Abutments

Caltrans-PEER Seismic Seminar
June 8, 2009

Po Lam
Earth Mechanics, Inc.

Topics:

- How many bridges were investigated?
- How were the bridges selected?
- What type of soil is placed behind the back wall of Caltrans' bridges?
- What were the significant parameters in the study?
- What were the results of the study?
- What is the confidence level in generalizing your results?
- How did the study influence Caltrans' practice?
- What is the expected performance of abutment backfill?

How Many Bridges were Investigated:

Project from 2002-2006, through an UCSD Contract.

- Two Phase Approach:
- Phase I- Screening for Candidate Sites for Borings.
- Phase II- Conduct Site Investigation.
- During Phase I:

  Reviewed 90 grew to 115 Bridge Plans and Boring Logs Statewide for Screening for about 20 sites for more In-depth Investigation, including Site Reconnaissance. Reconnaissance Sites grew to 35 sites.

- During Phase II Data led to Scope of Site Investigation for 10 Sites.
- Actual Phase II Scope:
  Boring at 11 Sites including 26 Soil Borings, 22 CPTs and 14 PMT
  Plus Bulk Sample Testing at 4 Other Sites

Caltrans Abutment Backfill Requirements

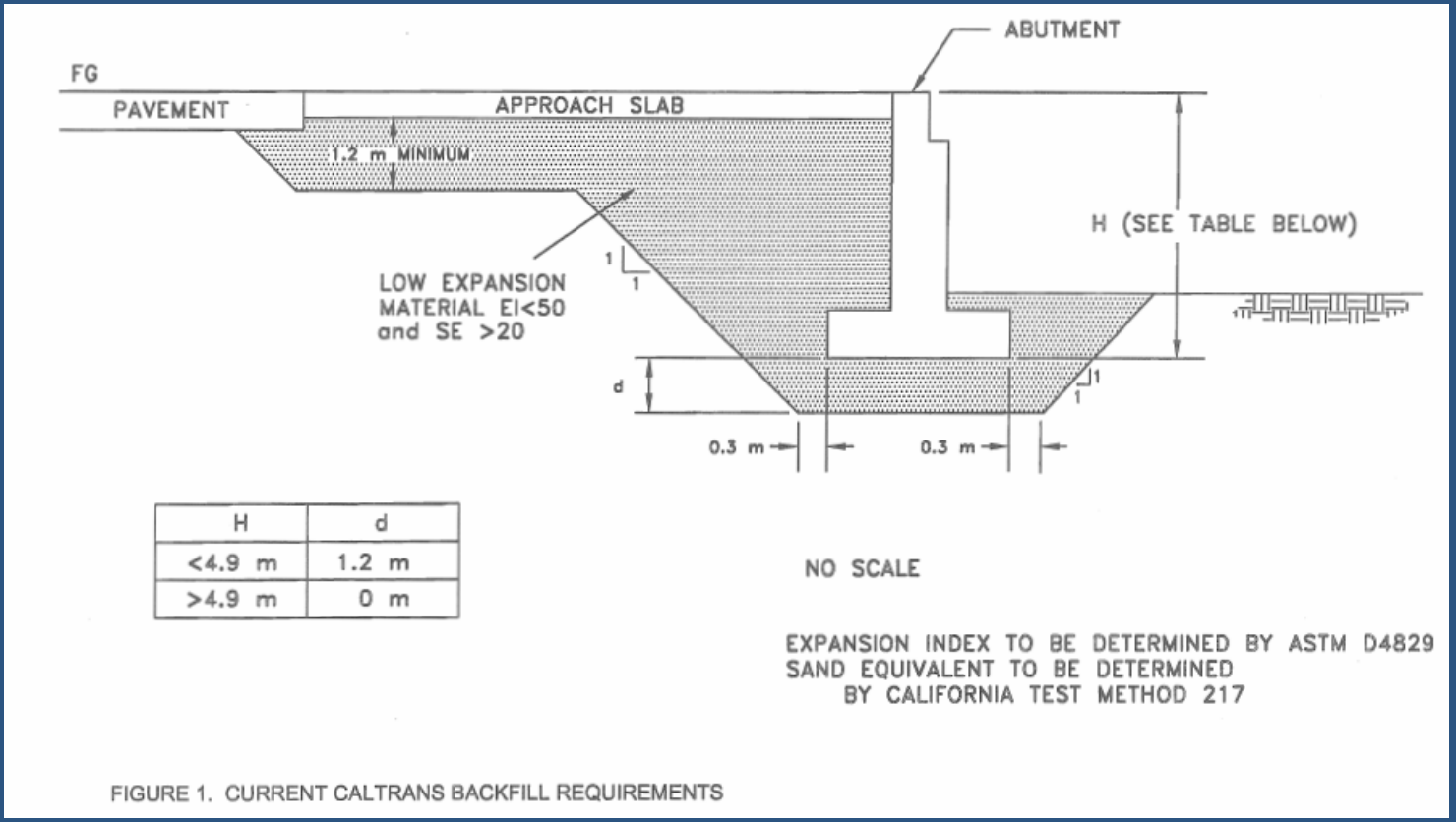


FIGURE 1. CURRENT CALTRANS BACKFILL REQUIREMENTS

- Prior to 1995-96, there is no backfill requirements regarding soil type.
- Caltrans Standard Specifications, 1999a, Sections 19.306 and 19-3.065 contain gradation requirements and a compaction requirement of 95% relative compaction.

Database Compiled in Phase I

Table 1. Bridge Database

Date: 1/19/2005 3:58:15 P MK/EMI

ID#	Bridge No.	Bridge Name	County	Route	Date Built	Have Plans?	Visited	Candidate for Drilling?	Comments	# of Lanes	Rdwy Width	Latitude	Longitude	Location Description
86	57-0791 S	"E" Street On-Ramp	San Diego	I-5	1992	Y	N	N?	drill thru conc. appr. Slabs	2	11, 13.7	32.6396	-117.0998	Chula Vista, I-5/route 54 intersection
17	23-0213	Allison Drive OC	Solano	I-80	1997	Y	N			4	28	38.3615	-121.9693	Vacaville, just south of Nut Tree Factory
87	57-0935	Ammo Rd OC	San Diego	I-15	1982	Y	N	N		2	8.5	32.8751	-117.1070	Miramar Marine Corps Airstation--Difficult to pinpoint
29	39-0154	Arburua Rd OC	Merced	I-5	1971	Y	N			2	24.1	36.9643	-120.8824	~7 mi SW of Los Banos
72	54-1107	Archibald Ave Offramp SEP	San Bernardino	I-10	1996	Y	Y	N		2	11.2	34.0676	-117.5933	North of Ontario Airport
51	53-1204	Atlantic Ave OC	Los Angeles	I-405	1963	Y	Y	Y*		4	28	33.8153	-118.1851	Long Beach
54	53-1986	Balboa Boulevard OC	Los Angeles	I-5	1971	Y	N	N	no struct. Plans, T/C diff. @ north abut	2	12.2	34.3209	-118.4964	LA, near I-5/I-210
33	44-0124	Bardin Rd OC	Monterey	US-101	1955	Y	N			2	8.5	36.6610	-121.6230	Near Salinas Municipal Airport--CAN'T FIND SPECIFIC ON MAP
21	28-0083 S	Barrett Ave UC	Contra Costa	I-80	1997	Y	Y	Y	busy, may require TC	1	7.3	37.9355	-122.3268	Richmond over Barrett Ave
53	53-1605	Barrington Ave	Los Angeles	I-10	1963	Y	Y	N		10	42.7	34.0296	-118.4441	LA, just west of I-10, I-405 intersection
23	34-0047 S	Bay Shore Ave UC	San Francisco	US-101	1950	Y	Y	N	No LOTB avail, busy loc, TC req'd, permit	2	7.9	37.71592	-122.3985	San Francisco, US-101 south of 280
114	51-0234	Beckstead OC	Santa Barbara			N	Y	Y	Collected bulk sample			34.4738	-120.2090	Santa Barbara
43	52-0247	Borchard Rd OC	Ventura	US-101	1962, 1992	Y	N	N	T/C not feas.	2	11.3	34.1844	-118.9256	7.1 mi west of LA County line in Ventura County
34	44-0131 L	Boronda Rd OC	Monterey	US-101	1965	Y	N	N	has MSE walls	2	12.3	36.7220	-121.6599	Salinas
65	54-0415	Bridge Across Colorado River at	San Bernardino	I-40	1966	Y	N	Y?	req. T/C	4	18.3	34.71696	-114.48657	Colorado River Crossing on I-40 at CA/AZ border
50	53-1203	California Ave OC	Los Angeles	I-405	1964	Y	Y	Y		2	17.1	33.8143	-118.1806	Signal Hill
92	57-1083 R/L	Camino Ruiz UC	San Diego	SR-56	2002	Y	Y	Y				32.9580	-117.1553	San Diego, on SR-56 between I-5 and I-15
100	57-1077 L	Carmel Valley Rd UC	San Diego	SR-56	2004	N	Y	Y	Drilled 2/7/04. Collected bulk sample			32.9487	-117.2031	San Diego, on new SR-56 between I-5 and I-15
89	57-0991 S	Carmel Valley UC	San Diego	I-5	1996	Y	Y	Y		2	11.9	32.9326	-117.2410	Del Mar, north of I-5/I-805 merge
48	53-1200	Cherry Ave OC	Los Angeles	I-405	1964	Y	Y	Y*		4	25.6	33.8135	-118.1676	Long Beach
108	53-1353	Coldwater Canyon	Los Angeles	SR-101	1971	Y	Y	Y	Drilled 4/19/04			34.1569	-118.4137	101 over Coldwater Canyon
56	53-2264	Colorado Boulevard SEP	Los Angeles	SR-134	1975	Y	N	N		5	26.5	34.1457	-118.1549	Pasadena

Page 1 of 6

Selected Drilling Sites for Phase II

Site Explored Bridges in Phase II

Table 2. Bridge Sites Investigated Date: 1/19/2005 3:59:06 PM MK/EMI

ID#	Bridge No.	Bridge Name, County	Drilled	Abut Wall Height	Borings/SPT No.	Borings/SPT Depth (ft)	Borings/SPT Setback (ft)	CPT No.	CPT Depth (ft)	CPT Setback (ft)	PMT No.	PMT Depth (ft)	PMT Setback (ft)
27	37-0609	Rte 87/880 SEP	Drilled 1/30/04	13.6	B-1	31.5	42.5	CPT-1	30.0	44.5			
		Santa Clara		12.2	B-2	31.5	45.0	CPT-2	30.0	47.0			
101	57-1078 S	Gonzalez Creek Off-Ramp	Drilled 2/7/04	8.0	04-1	25.5	2.0	04-1C	17.4	7.0			
		San Diego											
100	57-1077 L	Carmel Valley Rd UC	Drilled 2/7/04. Collected bulk sample	8.0	04-2	22.8	8.0	04-2C	25.0	8.0			
		San Diego											
106	55-0257	Harbor Blvd UC (Widen)	Drilled 2/28/04	27.3	04-3	21.5	13.0	04-3C	15.0	13.0			
		Orange		10.0	04-4	21.5	2.0	04-4C	20.0	3.7			
				27.3				04-5C	20.0	5.0			
107	55-0414	Tustin Ave OC (Widen)	Drilled 3/6/04	20.3	04-6	21.5	5.5	04-6C	20.0	16.0			
		Orange		25.4	04-7	21.5	6.5	04-7C	20.0	16.0			
				25.4	04-8	11.5	18.0						
108	53-1353	Coldwater Canyon	Drilled 4/19/04		04-9	16.5	5.0	04-9C	14.3	5.0	04-9P	7.5	5.0
		Los Angeles									04-9P	12.5	5.0
					04-10	16.5	5.0	04-10C	14.9	5.0	04-10P	10.0	5.0
109	33-0250	Patterson Slough	Drilled 6/17/04	5.5	04-11A	21.5	3.0	04-11C	20.0	3.0	04-11P	5.0	3.0
		Fremont		5.5	04-12A	21.5	3.0	04-11C	20.0	3.0	04-12P	5.0	3.0
110	35-0083	Route 101/84 SEP	Drilled 6/13/04		04-14A	21.5	6.0	04-14C	28.0		04-14P	7.5	6.0
		San Mateo			04-13A	21.5	9.0	04-13C	20.0		04-13P	7.5	9.0

ID#	Bridge No.	Bridge Name, County	Drilled	Abut Wall Height	Borings/SPT No.	Borings/SPT Depth (ft)	Borings/SPT Setback (ft)	CPT No.	CPT Depth (ft)	CPT Setback (ft)	PMT No.	PMT Depth (ft)	PMT Setback (ft)
112	04-0236	Painter St	Drilled 7/1/04	12.3	04-15A	15.5	5.0	04-15C	14.0	4.0	04-15P	8.0	5.0
		Humboldt		11.5	04-16A	14.0	4.0	04-15D	9.5	5.0	04-16P	12.5	2.0
				12.3				04-16C	12.5	5.0			
111	58-0215	Meloland Rd OC	Drilled 8/20/04	13.0	04-17A	21.5	3.0	04-17C	30.0	3.0	04-17P	11.0	3.0
		Imperial		13.0	04-18A	21.5	2.5	04-18C	4.0	3.0	04-18P	7.5	2.5
											04-18P	11.5	2.5
114	51-0234	Beckstead OC	Collected bulk sample		04-19	3.0							
		Santa Barbara											
84	56-0318	Spruce Street OC (Replace)	Collected bulk sample		04-20	3.0							
		Riverside											
81	56-0390	Jackson St OC (Replace)	Bulk sample collected		04-21	3.0							
		Riverside											
113	53-0687	Santa Clara River (Replace)	Collected bulk sample. Drilled 6/5-6/04		04-22	3.0							
		Los Angeles			04-23	25.0	3.0	04-23C	25.0	5.0	04-23P	5.5	4.0
					04-24	25.0	5.0	04-24C	25.0	7.0	04-24P	7.5	4.0
116	42-0398	Maple Ave UC	Collected bulk sample		04-25	10.0							
		Fresno											

Total Count of Bridges Selected: 15 **Total Counts:** **26 Boreholes** **22 CPT's** **14 PMT's**

*) Depth is in ft below existig grade. Setback is distance in ft behind back face of abutment wall.

ID#	Bridge No.	Bridge Name, County	Drilled	Abut Wall Height	Borings/SPT No.	Borings/SPT Depth (ft)	Borings/SPT Setback (ft)	CPT No.	CPT Depth (ft)	CPT Setback (ft)	PMT No.	PMT Depth (ft)	PMT Setback (ft)
112	04-0236	Painter St	Drilled 7/1/04	12.3	04-15A	15.5	5.0	04-15C	14.0	4.0	04-15P	8.0	5.0
		Humboldt		11.5	04-16A	14.0	4.0	04-15D	9.5	5.0	04-16P	12.5	2.0
				12.3				04-16C	12.5	5.0			
111	58-0215	Meloland Rd OC	Drilled 8/20/04	13.0	04-17A	21.5	3.0	04-17C	30.0	3.0	04-17P	11.0	3.0
		Imperial		13.0	04-18A	21.5	2.5	04-18C	4.0	3.0	04-18P	7.5	2.5
											04-18P	11.5	2.5

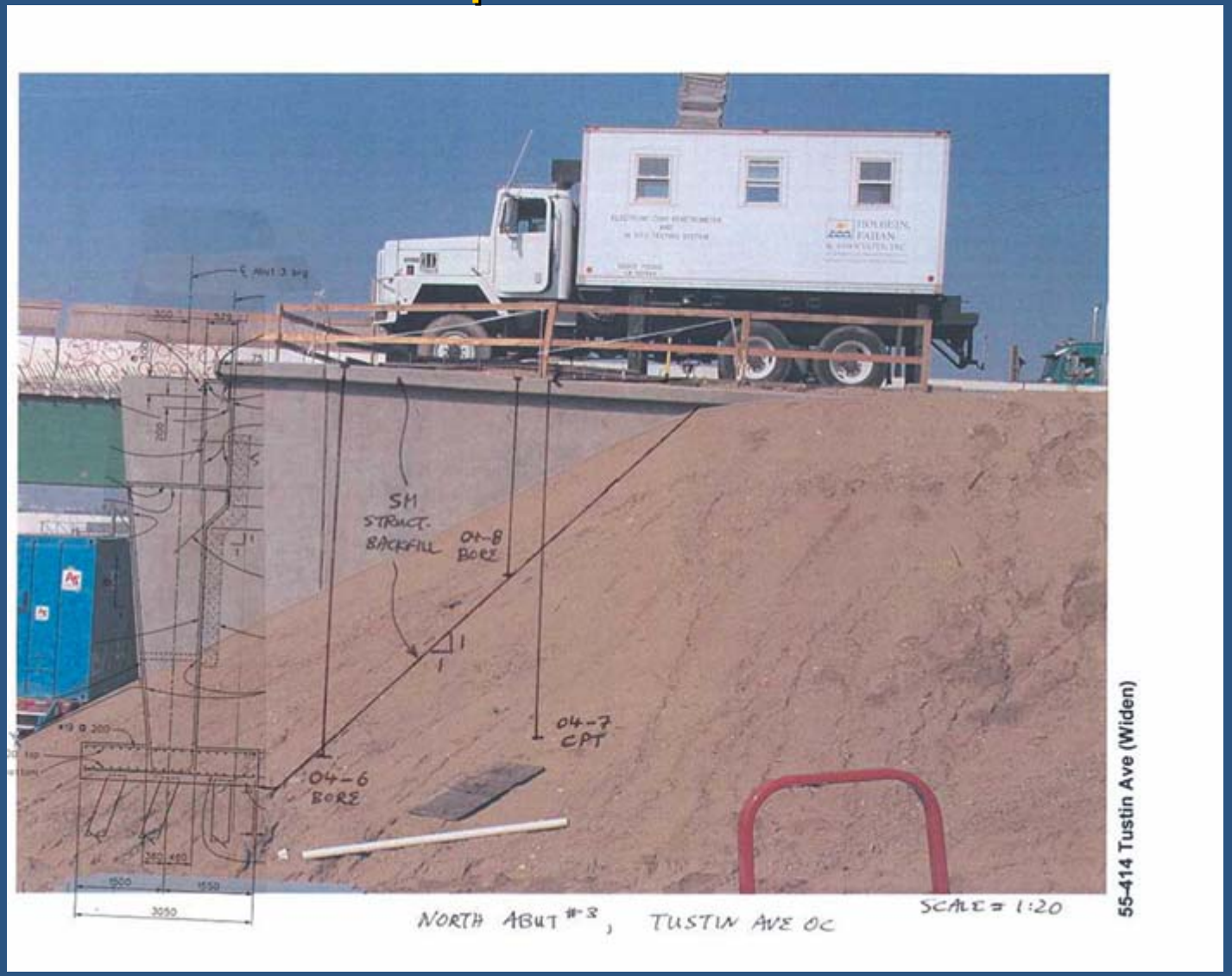
Final Documentation Report

Research Documentation to Caltrans/UCSD 2005

Field Boring Program Documentation

Soil Borings with Sampling

Verification of Compliance for New Constructions

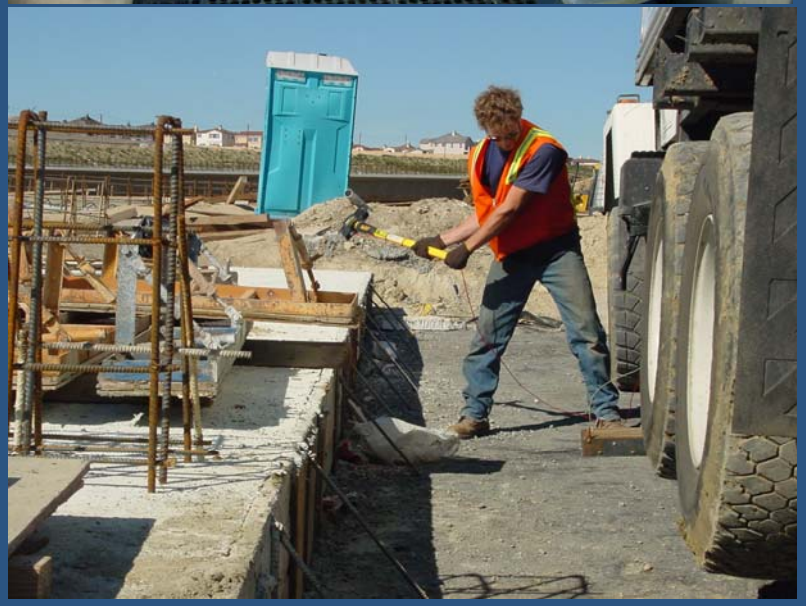


Backfill Testing behind Bridge Abutment

Seismic Cone Penetrometer Tests

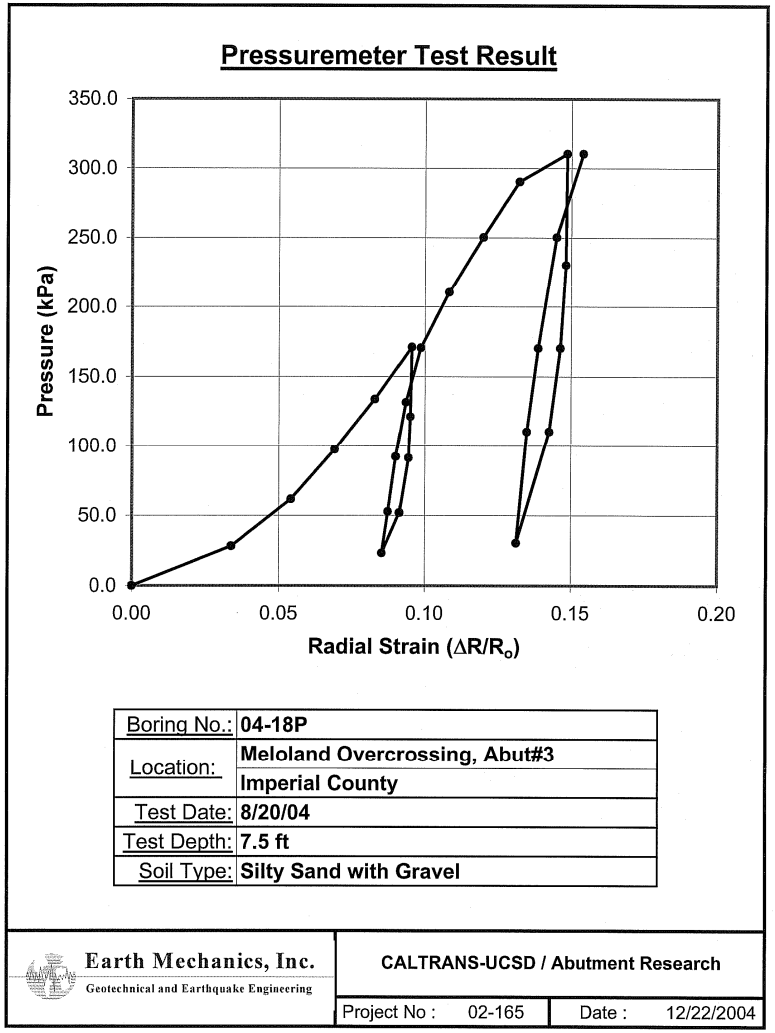
6-30-04, Painter St Bridge, West Abutment.
First CPT attempt, 04-15, refusal at 9.5' depth.

6-30-04, Painter St Bridge,
Gregg Drilling CPT truck



Cone Penetrometer Testing with Seismic Wave Velocity Measurement

Pressuremeter Tests



In-hole Pressuremeter Testing

Soil Boring Logs

Bridge	County	Boring No.	Sample No.	Depth	Soil Type	SPT Blow-count	Moist. Content	Dry Density	Void Ratio	Poro-sity	Grain Size Distribution				Atterberg Limits				Sand Equi-valent	Expan-sion Index	Com-paction		Unconsolidated Undrained Triaxial				Direct Shear				PMT
						N_{SPT}	w	ρ_d	e	n	Gravel	Sand	Fines	sand size	LL	PL	PI	plast.	SE	EI	$\rho_{d,max}$	w_{opt}	ρ_d	σ_c	ϕ	c	ϕ_{peak}	c_{peak}	ϕ_{res}	c_{res}	Depth
				(ft)	(USCS)	(bpf)	(%)	(pcf)	(-)	(%)	(%)	(%)	(%)	(-)	(%)	(%)	(%)	(-)	(-)	(-)	(pcf)	(%)	(pcf)	(ksf)	(deg)	(ksf)	(deg)	(ksf)	(deg)	(ksf)	(ft)
Patterson Slough	Alameda		B-0	0-5	ML/CL																										
			D-1	8.00	ML/CL	18																	120.7	1.08/2.15/4.32	6.9	0.92					
		04-11A	S-2	10.00	Sa. CL	12	15.5				0	30	70	fine	28	16	12	med.													
			D-3	12.50	ML/CL	23								fine									121.8	1.73/3.46/6.91	15.2	4.34					
			S-4	15.00	Sa. CL	32	15.7				0	15	85	fine	37	17	20	med.													
			D-5	20.00	Sa. CL	19	18.7	107.7	0.56	36.08	0	35	65	fine				l-m													
			B-0	0-5																											
			D-1	2.50	SM w/ Gr	26	5.1	125.9	0.34	25.27	20	50	25	coarse				none													
			D-2	5.00	Sa. CL w/ Gr	30	10.7	120.8	0.39	28.30	10	30	60	coarse				low													5.0
		04-12A	S-3	7.50	Sa. CL	15	15.4				0	25	75	fine				med.													
			D 4	10.00	Sa. CL	32	19.2	115.8	0.45	31.27	0	30	70	fine				l m													11.0
			S-5	12.50	SM w/ SP	32	18.3				0	25	75	fine	38	26	12	med.													
			D-6	15.00	Sa. CL	45	15.7	107.6	0.57	36.13	0	30	70	fine				med.													
			S-7	20.00	Sa. CL	19	21.0				0	30	70	fine				med.													
Route 10/84 SEP	San Mateo		B-0	0-	Sa. CL w/ Gr		11.8							coarse				med.	9												
			D-1	2.50	SP	19	21.0	95.7	0.76	43.20	0	95	5	medium				none													
			S-2	5.00	SM w/ Gr						10	70	20	coarse				none													
			D-3	7.50	SP	10	5.8	89.8	0.88	46.70	0	95	5	medium				none													7.5
			S-4	10.00	SP	2	7.3				0	95	5	medium				none													
		04-13A	D-5	12.50	SP-SM	10	7.2	95.2	0.77	43.49	0	90	10	medium				none													
			D-6	15.00	SP-SM	11	7.9				0	90	10	medium				none													
			S-7	18.50	CL		8.1																								
			D-8	20.00	Sa. CL w/ Gr	27	7.6	125.9	0.34	25.27	10	25	65	coarse				med.													
			S-9	25.00	SC w/ Gr	37	11.0							coarse				l-m													
			D-10	30.00	CL-CH	39	28.2	94.6	0.78	43.85				fine				m-h													
			D-1	2.50	SC w/ Gr	45	6.7	124.1	0.36	26.34	20	55	25	coarse				low													
			D-2	7.50	SC-SM	22	10.0	114.4	0.47	32.10	10	60	30	coarse				low													7.5
		04-14A	D-3	10.00	SC w/ Gr		7.3				5	60	35	coarse	29	15	14	low					125.1	1.37/2.73/5.47	22.8	1.28					
			S-4	12.50	Sa. CL	26	8.6				0	35	65	coarse				l-m													
			D-5	15.00	Sa. CL/SC w/ Gr	36	10.0	115.0	0.47	31.74	20	40	40	coarse				low													
			S-6	20.00	SM w/ Gr	24	16.4				0	65	35	fine				low													
Painter St	Humboldt		B-0	0.00	GW-GM		2.2				59	35	6	coarse				none	43												
			S-1	2.50	SP w/ Gr	59	3.1				25	70	5	coarse				none													
			S-2B	5.00	SP w/ Gr	47	3.9				25	70	5	coarse				none					129.5	0.87/1.01/1.3	43.3	0.13					
			B-3A	7.00	SP w/ CL		4.5							coarse				none													
		04-15A	Comp.	2.5-7	SP																		129.5	1.00	NA	NA					
			D-3B	7.50	Sa. CL	32	19.9				3	35	62	coarse	34	19	15	low					115.7	1.0/2.01/4.02	11.5	3.90					8.0
			S-4	10.00	CL w/ Sa.	16	16.4							medium				med.													
			D-5	12.50	CL w/ Sa.	18	21.0	116.2	0.45	31.03				coarse				med.					116.2	1.07	0.0	7.75					
			S-6	14.00	ML	20								medium				med.													
			B-0	0.00	SP		2.2				35	60	5	coarse				none													
			S-1	2..5	SP	63	4.2				25	70	5	coarse				none													
			D-2	5.00	SP	90	4.1	124.5	0.35	26.10	20	75	5	coarse				none													
		04-16A	S-3A	7.50	CL		19.6				0	20	80	fine				med.													
			S-3B	7.50	SP	11	5.8				10	85	5	coarse				none													
			D-4	10.00	CL w/ ML	19	28.9	90.2	0.87	46.46	0	25	75	fine	42	27	15	med.					115.2	1.3/2.59/5.46	7.1	3.30					
			S-5	12.50	CL	19	21.2				0	25	75	fine				med.													12.5

Laboratory Testing of Samples

Laboratory Triaxial Tests

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST
ASTM D2850

Project Name:	UCSD \ Abutment Research\Carmel Valley Rd UC\San Diego Co.		**Project No:**	02-165	
Boring No.:	04-1	**Tested by:**	J.R	**Date:**	07/21/04
Depth (ft):	8.5	**Checked by:**		**Date:**	
Sample No.	4A	**Sample Type:**	Remolded		
Soil Description:	Brown, SM/ML	**Comments:**			

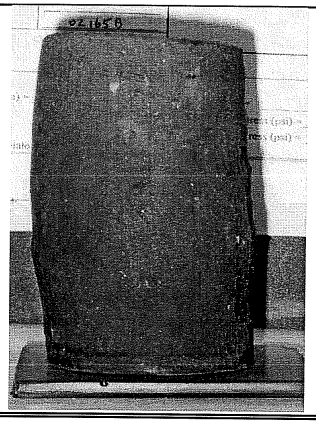
	1	2	3		
Diameter (in.):	2.429	2.432	2.43	Average:	2.430
Height (in.):	4.930	4.875	5.000	Average:	4.935

Moisture Content Calculation	
Wt. Wet Sample + Container (g) :	173.95
Wt. Dry Sample + Container (g) :	161.7
Container (g) : No.	8.48
Moisture Content (%) :	**8.0**

Density and Saturation	
Wt. Wet Sample + Container (g) :	
Container (g) :	
Wet Density (pcf) :	**125.0**
Dry Density (pcf) :	**115.7**
Void Ratio :	**0.456**
% Saturation :	**47.4**

Gs=2.70 (assumed)

SKETCH / PHOTO AFTER TEST:



Shear Cycle	1, 2, 3
Confining Stress (ksf) :	**1.14, 2.3, 4.6**
Deformation Rate (% / min) :	**4**
Failure Criterion: the maximum deviator stress	

At Failure Cycle	1, 2, 3
Deviator Stress (ksf) :	**12.29, 13.64, 17.12**
Eff. Minor Principal Stress (ksf) :	**1.14, 2.3, 4.6**
Eff. Major Principal Stress (ksf) :	**13.43, 15.93, 21.72**
Axial Strain (%) :	**4.1, 5.6, 15.1**

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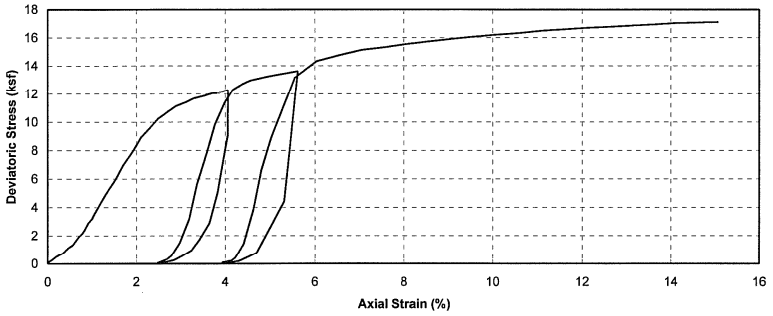
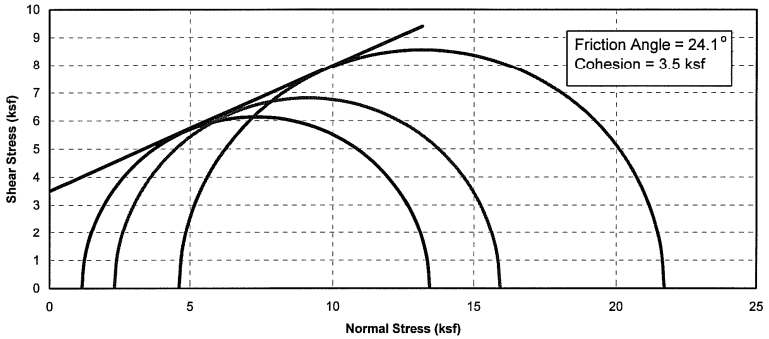
Geotechnical and Earthquake Engineering





Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf) Cycle 1, 2, 3	Max. Dev. Stress (ksf) Cycle 1, 2, 3	Initial Saturation (%)
04-1	4A	8.50	Brown, SM/ML	115.7	8.0	1.14, 2.3, 4.6	12.29, 13.64, 17.12	47.4

Earth Mechanics, Inc.
Geotechnical and Earthquake Engineering

Caltrans\UCSD \ Abutment Research

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST (ASTM D2850)

Project No. : 02-165 Date : 07/21/04

Determination of Cohesive Strengths - Silty Sand

Determination of Cohesive Strengths – Sand with Gravel

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST
ASTM D2850

Project Name:	UCSD \ Abutment Research\Painter Street, Humboldt Co			**Project No:**	02-165
Boring No.:	04-15A	**Tested by:**	J.R.	**Date:**	11/03/04
Depth (ft):	2.5-7	**Checked by:**		**Date:**	11/03/04
Sample No.	B-0, S-1, S-2B, S-3A	**Sample Type:**	composite		
Soil Description:	**Dense coarse sand w/ gravel**	**Comments:**			

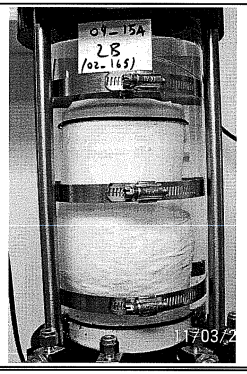
	1	2	3		
Diameter (in.):	2.862	2.862	2.862	Average:	2.862
Height (in.):	5.750	5.750	5.750	Average:	5.750

Moisture Content Calculation	
Wt. Wet Sample + Container (g) :	
Wt. Dry Sample + Container (g) :	
Container (g) : No.	
Moisture Content (%) :	**4.0**

Density and Saturation	
Wt. Wet Sample + Container (g) :	
Container (g) :	
Wet Density (pcf) :	**134.7**
Dry Density (pcf) :	**129.5**
Void Ratio :	**0.301**
% Saturation :	**35.9**

Gs=2.70 (assumed)

SKETCH / PHOTO AFTER TEST:



Shear Cycle	1, 2, 3	**At Failure** Cycle	1, 2, 3
Confining Stress (ksf) :	**0.87, 1.01, 1.3**	Deviator Stress (ksf) :	**4.33, 5.04, 6.18**
Deformation Rate (% / min) :	**4**	Eff. Minor Principal Stress (ksf) :	**0.87, 1.01, 1.3**
Failure Criterion:		Eff. Major Principal Stress (ksf) :	**5.2, 6.04, 7.47**
the maximum deviator stress		Axial Strain (%) :	**3.1, 4.9, 7.1**

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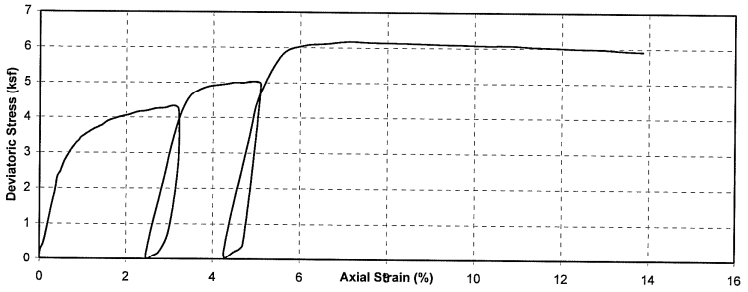

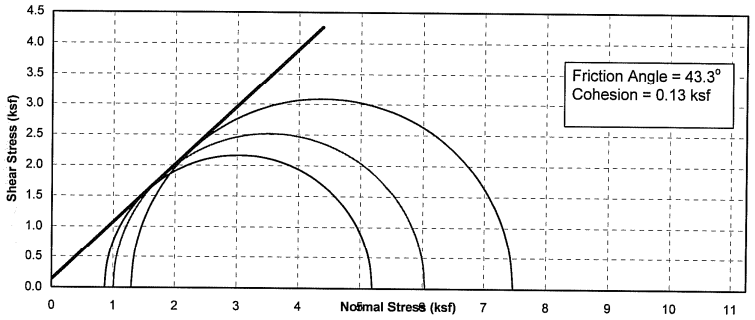

Boring No.	Sample No.	Depth (ft)	Soil Type	Dry Density (pcf)	Moisture Content (%)	Conf. Stress (ksf) Cycle 1, 2, 3	Max. Dev. Stress (ksf) Cycle 1, 2, 3	Initial Saturation (%)
04-15A	Composite	2.5-7	Dense coarse sand w/ gravel	129.5	4.0	0.87 1.01 1.3	4.33 5.04 6.18	35.9

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Caltrans\UCSD \ Abutment Research

Project No. : 02-165 | Date : 11/03/04

UNCONSOLIDATED UNDRAINED TRIAXIAL TEST (ASTM D2850)

Determination of Cohesive Strengths – Sand with Gravel

Table 4 SOIL TYPE CATEGORIES
CT-UCSD/ABUTMENT RESEARCH PROGRAM

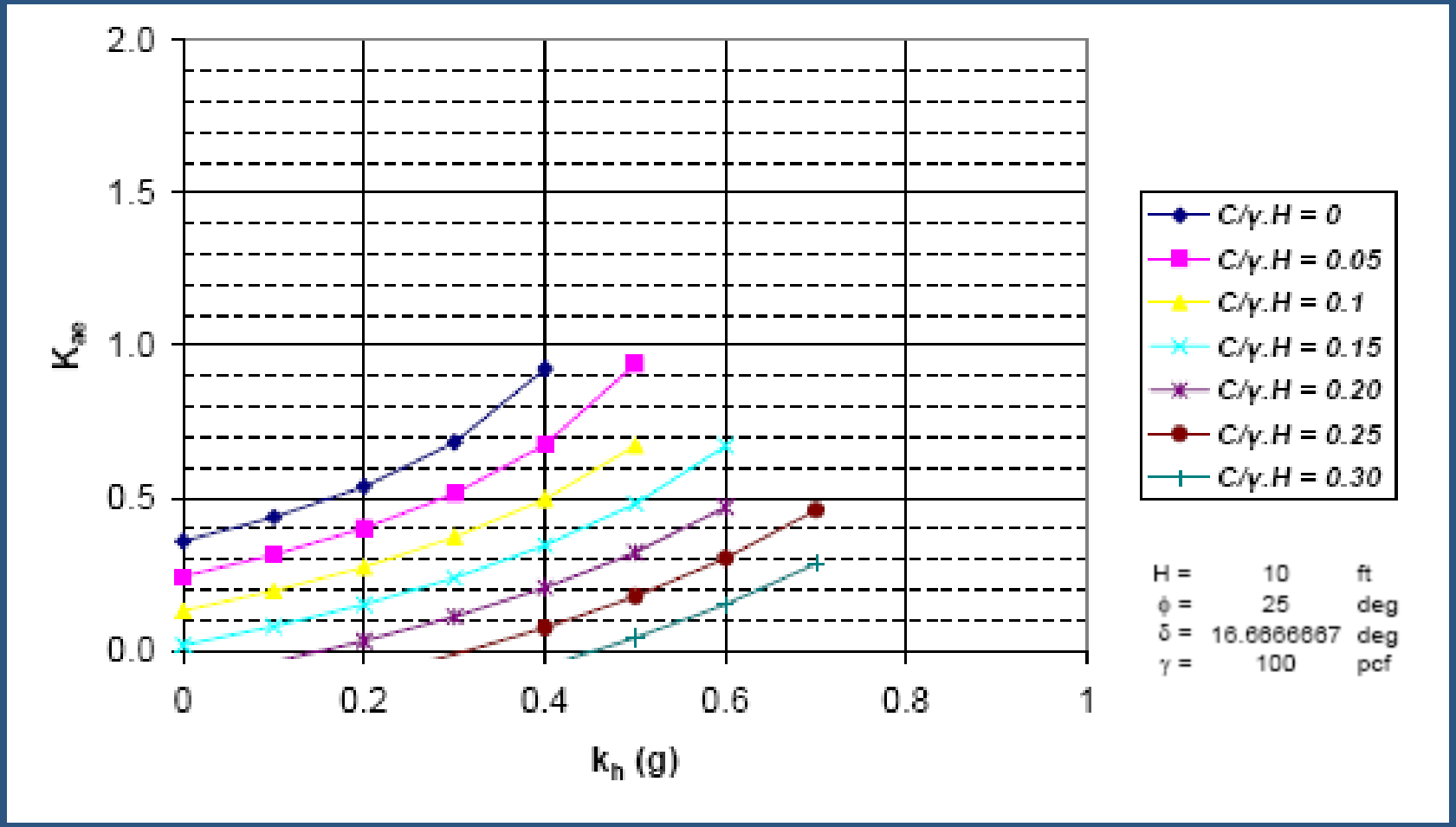
Soil Type Categories		Number of bridges	Number of samples tested	Depth (ft)	Sand grain size	Plasticity	SPT Blow-count	Field Moisture Content	Field Dry Density	Grain Size Distribution			Plas-ticity	Sand Equi-valent	Expan-sion Index	Compaction		Shear strengths of compacted soil (95% R.C.)			Shear wave velocity	Secant Modulus	Secant Modulus
							N_{SPT}	w	ρ_d	Gravel	Sand	Fines	PI	SE	EI	$\gamma_{d,max}$	w_{opt}	ρ_d	ϕ	c	v_S	initial E_S	reload E_R
							(bpf)	(%)	(pcf)	(%)	(%)	(%)	(%)	(-)	(-)	(pcf)	(%)	(pcf)	(deg)	(ksf)	(fps)	(MPa)	(MPa)
I	DENSE TO VERY DENSE SANDS WITH GRAVEL	2	2	2.5-7.5	coarse	none-low	52-59	3-6	120	8-25	70-79	5-13	<5 (0)	37-43 (40)	0-7	NM	NM	125-130 (125)	35-43 (38)	0.13-0.3 (0)			
II	MEDIUM DENSE SILTY SANDS, SOME WITH GRAVEL	9	10	0-9.5 (0-5)	fine-coarse	none-low	9-15	5-14	105-120	1-28	60-87	12-35	5-10 (8)	21-52 (34)	0-2	109-127	8-12	116-127 (120)	24-35 (33)	0.25-1.5 (0.5)	700-1,000 (800)	2-4	10-15
III	MEDIUM DENSE CLAYEY SANDS, SOME WITH GRAVEL	4	4	5-10	medium coarse	low	20-44	7-15	113-114	0-8	50-60	35-50	6-14 (10)	11	0	NM	NM	116-125 (120)	22.5-24 (23)	1.3-6 (2)			
IV	STIFF-HARD CLAYS WITH FINE TO COARSE-GRAINED SANDS, SOME WITH SILTS	5	10	5-12.5	fine-coarse	medium-high	18-35	14-29	90-116	0-3	25-35	62-75	12-41 (22)	0-3 (0)	20-77	114-122	17-22	106-122 (110)	0-17 (6)	1-8 (3.5)	550-800	1.5-3	6-10

Typical parameters are in ()
NM=Not measured

Interpreted Backfill Properties

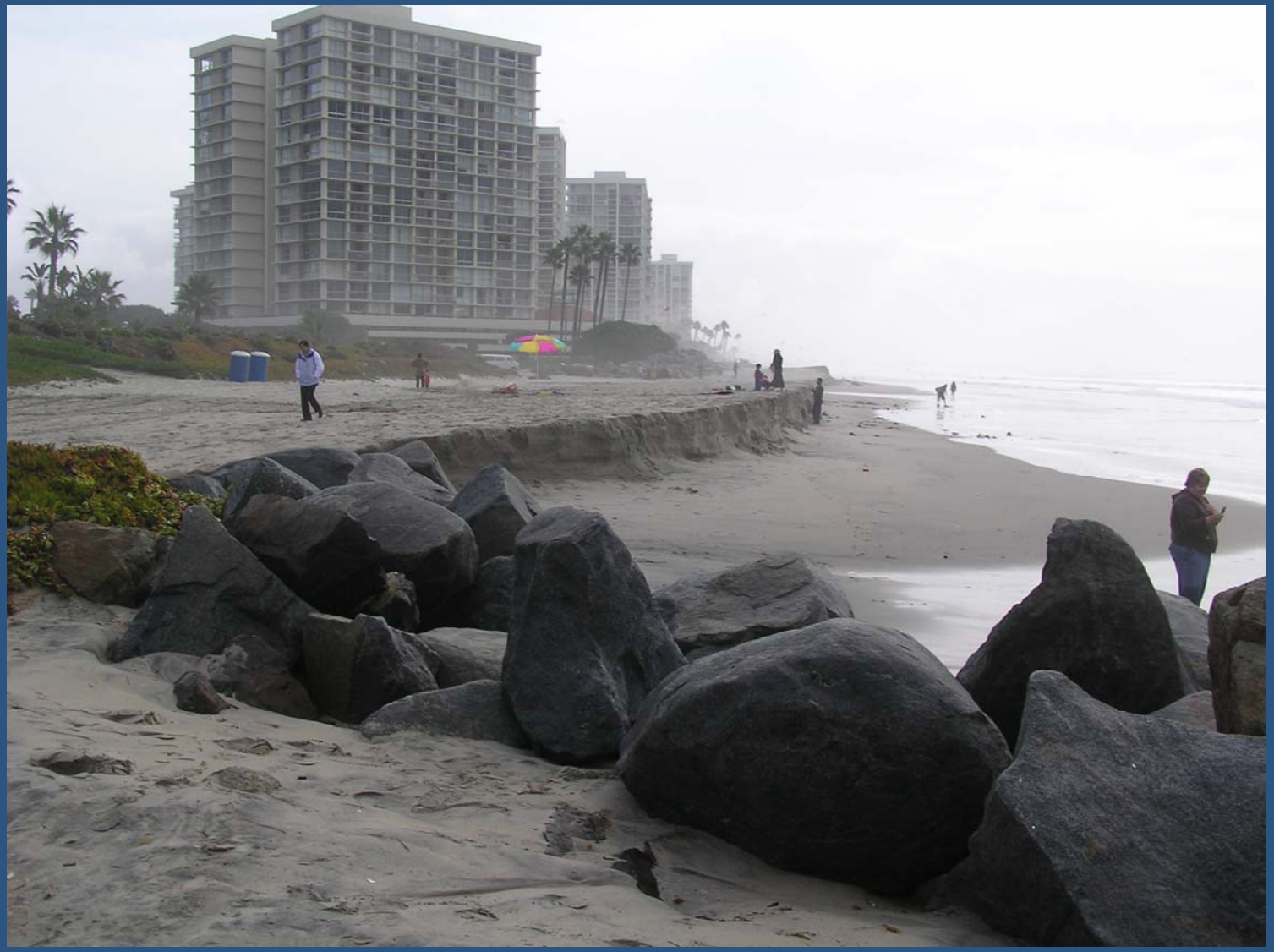
Most Significant Aspects of Backfill Property for Design

- Cohesive Strength Parameter for Design, Especially for Sandy and Gravely Soils for the Seismic Load Case



Influence of c on Earth Pressure Coefficient for Cohesionless Soils

How Reasonable is a zero c Assumption?



THANK YOU!