STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

▲ 5010.64 (FRONT)

CLIENT & PROJECT	PAGE 1 OF 21
PRIVATE FUEL STORAGE, LLC - PRIVATE FUEL STORAGE FACILITY	

CALCULATION TITLE (Indicative of the Objective):

SUPPLEMENT TO ESTIMATED STATIC SETTLEMENT OF CASK STORAGE PADS (SEE CALC 05996.02-G(B)-03, REV. 3)

QA CATEGORY (✓)

☑ I – NUCLEAR SAFETY RELATED

☐ II ☐ III ☐ _____ OTHER

CALCULATION IDENTIFICATION NUMBER

J. O. OR W. O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
05996.02	G(B)	21		

* APPROVALS – SIGNATURE & DATE			REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION * REQUIRED (✓)	
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)			YES	NO
Thomas Y. Chang Thomas Y. Chang 5-17-01	Lee Liu Lee Liu 5/21/01	Lee Liu Lee Liu 5/21/01	0			✓

DISTRIBUTION*

GROUP	NAME & LOCATION	COPY SENT (✓)	GROUP	NAME & LOCATION	COPY SENT (✓)
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GEOTECHNICAL	S&W STOUGHTON	✓			

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	PAGE 2 of 21
0599602	G(B)	21		

Objective of Calculation:

To update and refine the Static Settlement estimate of the Storage pads to account for (1) incorporation of additional consolidation test results from the Canister Transfer Building borings for Recompression Ratio (RR) determination (2) incorporation of the time of the end of primary consolidation in the Secondary Settlement estimate (3) Incorporation of the Storage pad length change from 64 ft to 67 ft (SAR Figure 4.2-7 Cask Storage Pads).

To estimate the magnitude of differential Settlement between the crushed rock surface and the top of the Storage pads

Assumptions / Data:

See Calculation 05996.02-G(B)-03-Rev. 3 Estimate Static Settlement of Storage Pads

Source of Data / Equations:

See Calculation 05996.02-G(B)-03-Rev. 3 Estimate Static Settlement of Storage Pads

Conclusions:

The total Settlement of Storage pads after 40 years approximately equal to 1 3/4".

The maximum differential Settlement between the edge of Storage pads and the center of crushed rock aisle is 3/4".

The primary consolidation settlements of shallow foundations on overconsolidated clay loaded to less than its preconsolidation pressure are generally computed from

$$\rho_{PRI} = H \times RR \log \frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{vo}}$$ (See calc 05996.02-GCB)-03-3) P. 6

where H = thickness of layer

RR = Recompression ratio

$\bar{\sigma}_{vf}$ = Final effective vertical stress at center of layer = $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo} < \bar{\sigma}_{vm}$

$\bar{\sigma}_{vo}$ = Initial effective vertical stress at center of layer

Ideally, the recompression ratio should be evaluated over the range $\bar{\sigma}_{vo}$ to $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo}$ from the rebound-reloading cycle from consolidation tests. However, due to the limited number of rebound-reloaded consolidation tests available when previous versions of settlement calculations, the RR value was conservatively determined using average of RR and SR values from recompression, rebound-reloading and rebounding loading sequence from load level exceeding $\bar{\sigma}_{vm}$ (See page 13 and calc 05996.02-GCB)-05). This approach is conservative, since the RR determined is generally higher than RR determined over the range of $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_v$, which

results in higher estimate of settlement.

The laboratory testing program conducted for the Canister Transfer Building area included additional consolidation tests with rebounding - reloading cycles over the range $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo}$. These consolidation tests from the Canister Transfer Building area along with the consolidation tests performed from the Pad emplacement area were evaluated to determine the RR value over the range $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo}$ as shown in attachment A. The RR values determined are listed as follows:

Boring	Sample	Sample Depth (ft)	RR	
C-1	U-3B	10.8	0.008	Pad emplacement area
C-1	U-3C	11.2	0.008	
C-1	U-3D	11.4	N/A	
C-2	U-2C	10.9	0.008	
C-2	U-2E	11.7	0.007	
CTB-4	U-2E	9.8	0.008	Canister Transfer Building Area
CTB-5	U-12C	23.5	0.008	
CTB-5	U-14E	27.3	0.008	
CTB-N	U-2D	8.6	0.007	
CTB-5	U-3C	10.0	0.005	
		Average	0.007	

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The average RR value determined from the range $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo}$ is only about 50% of the value used in previous settlement calculations (See calc. 05996.02-GCB)-03-3 P. 13). Therefore the primary consolidation settlement in layer 1 presented in Page 21 of calculation 05996.02-GCB)-03-Rev.3 should be adjusted accordingly as

$$\rho_{PRI} = \frac{0.007}{0.014} \times 1.67'' = 0.835'' \text{ say } 0.84''$$

The secondary consolidation settlement of the shallow foundations are computed from

$$\rho_{sec} = H \times C_\alpha \, \Delta \log t$$

(See Pi.7 Calc. 05996.02-GCB1-3 Rev 3)

$$= H \times C_\alpha \, (\log t_c - \log t_p)$$

$$= H \times C_\alpha \log \frac{t_c}{t_p}$$

Where H = thickness of layer

C_α = Coefficient of Secondary Compression

$\Delta \log t = (\log t_c - \log t_p) = \log \frac{t_c}{t_p}$

t_c = time since middle of loading period

t_p = time required for primary consolidation

The previous secondary settlement estimate presented in pages 14 to 20 of Calc. 05996.02-GCB)-03-Rev.3 Conservatively assumed t_p = 1 min for the entire 27 feet of layer 1. The consolidation test results indicated that the maximum C_v in the range $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo}$ is 3.5×10^{-2} cm^2/sec (See Calc. 05996.02-GCB)-05-1). Conservatively assume a double drainage for the 27 feet of the layer 1, then the time to reach the end of primary consolidation is calculated as

$$t_p = \frac{T \cdot H^2}{C_v}$$

Conservatively using 90% Consolidation $T = 0.848$ for the time of the end of primary consolidation t_p calculation

$$t_p = \frac{0.848\left(\frac{27}{2} \times 30.48\right)^2}{3.5 \times 10^{-2}} = 4,102,278 \text{ Sec} = 68,371 \text{ min}$$

$$= 47.5 \text{ days} = 1.58 \text{ month}$$

To be conservative, assume $t_p = 1$ month to estimate the secondary settlement. Therefore the secondary consolidation settlement in layer presented in Page 21 of the calculation 05996.02-GCB)-03-Rev 3 should be adjusted accordingly as

$$\rho_{Sec} = \rho_{Sec_{40yrs}} - \rho_{Sec\,1\,month}$$

$$= 1.16'' - 0.74'' = 0.42''$$

$\rho_{Sec_{40yr}} = 1.16''$
$\rho_{Sec\,1\,month} = 0.74''$

} from Table 3, Page 29 of Calc. 05996.02-GCB)-3-Rev 3 for secondary settlement values

The Settlement estimates previously calculated were based on the Storage pad dimensions of 30'x64'. The length of the Storage pad was increased from 64 feet to 67 feet (See SAR Figure 9.2-7 Cask Storage Pads). This will result in the decrease of bearing pressure on the layer 1 by approximately 5%. The reduction of the soil bearing pressure 5% will reduce the immediate settlement in layer 1 of approximately 5%. No reduction of the immediate settlement in layer 2-4 is anticipated since they are deep located and total load of the casks remain the same.

The primary consolidation settlement in layer 1 will decrease by about 2% ($\log \frac{64}{67} = -0.02$) because the primary consolidation settlement is proportional to the logarithm of the pressure ratio.

The secondary compression in layer 1 will not decrease because of the small decrease in stress ratio is not expected to reduce the coefficient of the secondary compression. Therefore total estimated settlement of the Storage pad is estimated as following page:

Immediate Settlement in layer 1

$$\%\ \text{reduction} = \frac{0.25''}{1.05} = 0.24''$$ (See Calc. 05996.02-G(B)-3-Rev.3 p. 21)

Immediate Settlement in layer 2-4

$$\text{No reduction} = \frac{0.25''}{1.00} = 0.25''$$ (See Calc 05996.02-G(B)-3-Rev. 3 p. 21)

Primary Consolidation in layer 1

$$2\%\ \text{reduction} = \frac{0.84''}{1.02} = 0.83''$$ (See p.5 of this calc.

Secondary Compression in layer 1

$$\text{No reduction} = \frac{0.42''}{1.00} = 0.42''$$ (See p7 of this calc.)

Total $= 1.74''$

Say $1\ 3/4''$ total settlement after 40 yrs

Therefore negligible change in settlement for storage pad length change from 64' to 67'.

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The maximum differential settlement between the crushed rock surface and the top of the storage pads should exclude the 0.25 inches of immediate settlement in layer 2-4 since they are deep seated settlement which cover the entire pad emplacement area. Therefore, the maximum differential settlement between the center of the crushed rock aisle and the center of storage pad is 1½ inches. The settlement at the edge of the storage pads should be about half of the settlement at the center of the storage pads surface, or about ¾". The settlement will gradually decrease from this value to 0 moving from edge of pads to center of crushed rock aisle. The maximum differential settlement between the edge of storage pads and the center of crushed rock aisle is therefore ≤ ¾".

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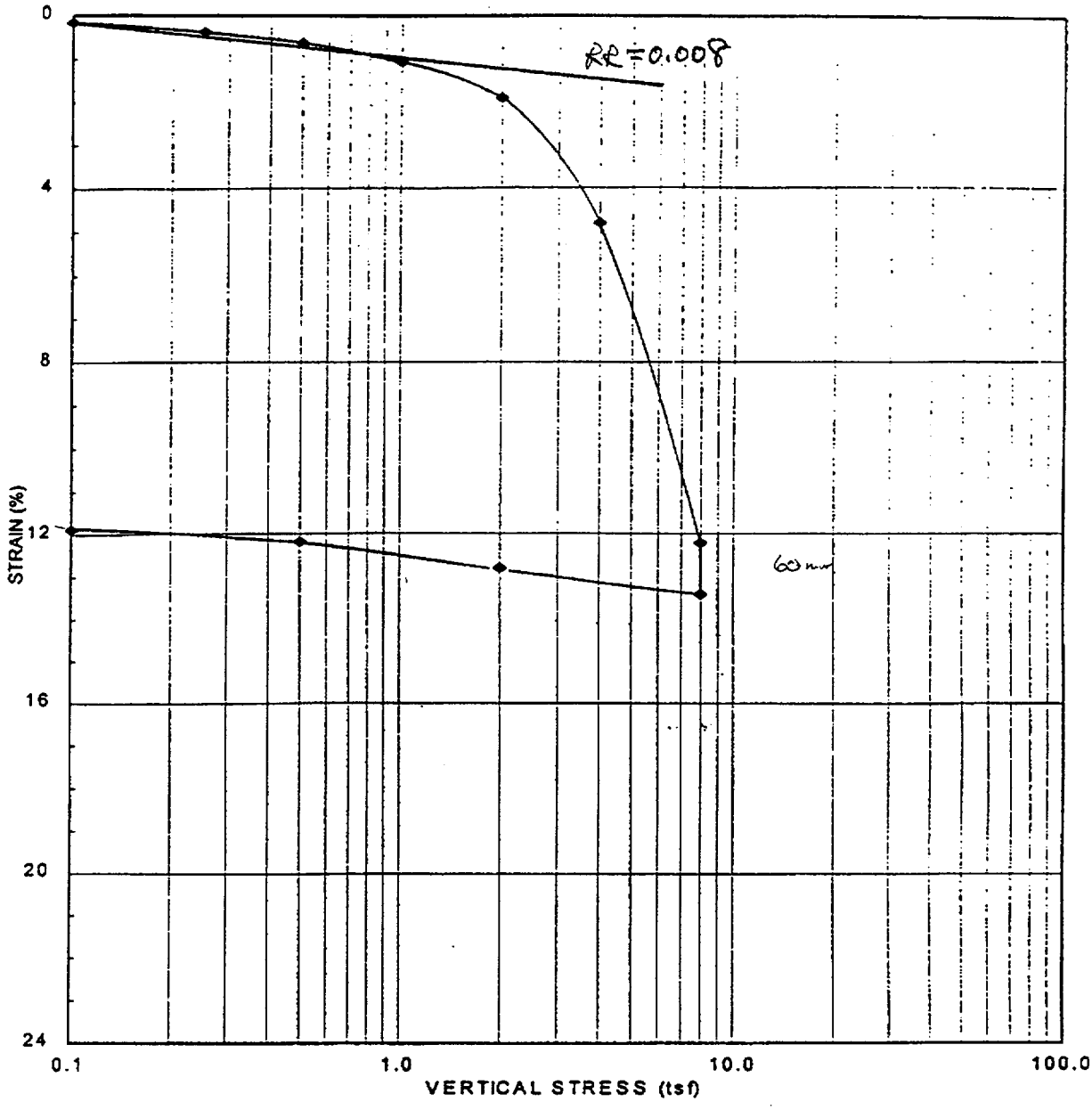
Attachment A – 10 pages

Determination of RR value over range $\bar{\sigma}_{vo} + \Delta\bar{\sigma}_{vo}$

Boring	Sample	Depth	
C-1	U-3B	10.8	Pad emplacement area
C-1	U-3C	11.2	
C-1	U-3D	11.4	
C-2	U-2C	10.9	
C-2	U-2E	11.7	
CTB-4	U-2E	9.8	Canister Transfer Building area
CTB-5	U-12C	23.5	
CTB-5	U-14E	27.3	
CTB-N	U-2D	8.6	
CTB-S	U-3C	10.0	



SAMPLE INFORMATION:

BORING:	C-1	DATE:	1/9/97
SAMPLE:	U-3B	TESTED BY:	ACS
DEPTH:	10.8 ft	CHECKED:	PJT
DESCRIPTION:	Clayey SILT		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	30.3 %	28.7 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	64.7 pcf	73.4 pcf	2.72 (est)
VOID RATIO:	1.625	1.315	
SATURATION:	50.7 %	59.3 %	

NOTE: Sample was not inundated and porous stones were dry

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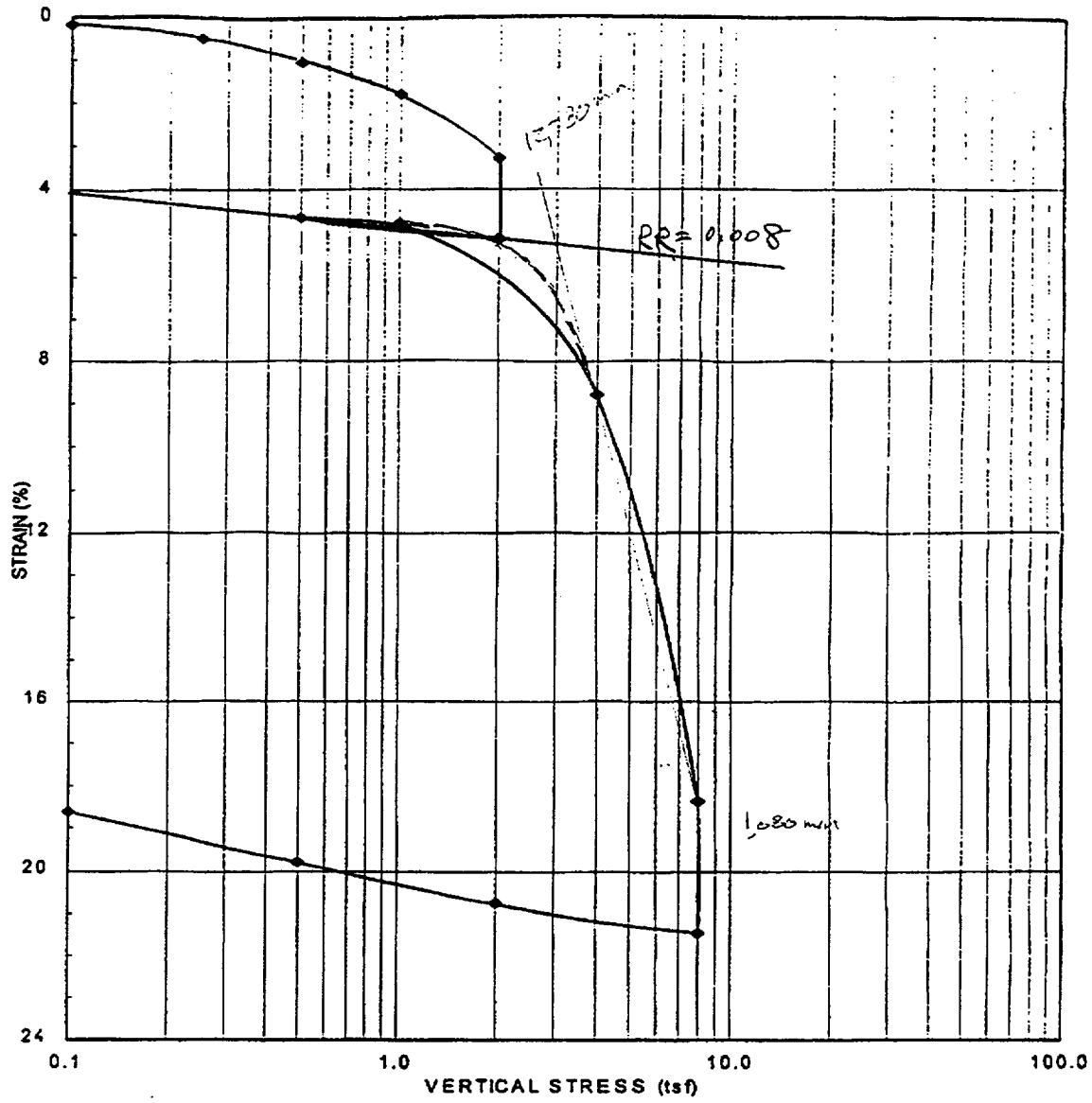
STONE & WEBSTER ENGINEERING CORP. BOSTON, MASSACHUSETTS	CONSOLIDATION TEST RESULTS BORING C-1, SAMPLE U-3B	JO 05996.01 January 1997



SAMPLE INFORMATION:

BORING:	C-1	DATE:	12/20/96
SAMPLE:	U-3C	TESTED BY:	ACS
DEPTH:	11.2 ft	CHECKED:	PJT
DESCRIPTION:	Clayey SILT		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	38.9 %	51.9 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	55.8 pcf	68.4 pcf	2.72
VOID RATIO:	2.041	1.484	
SATURATION:	51.8 %	95.2 %	

NOTE: Sample was not inundated and porous stones were moist

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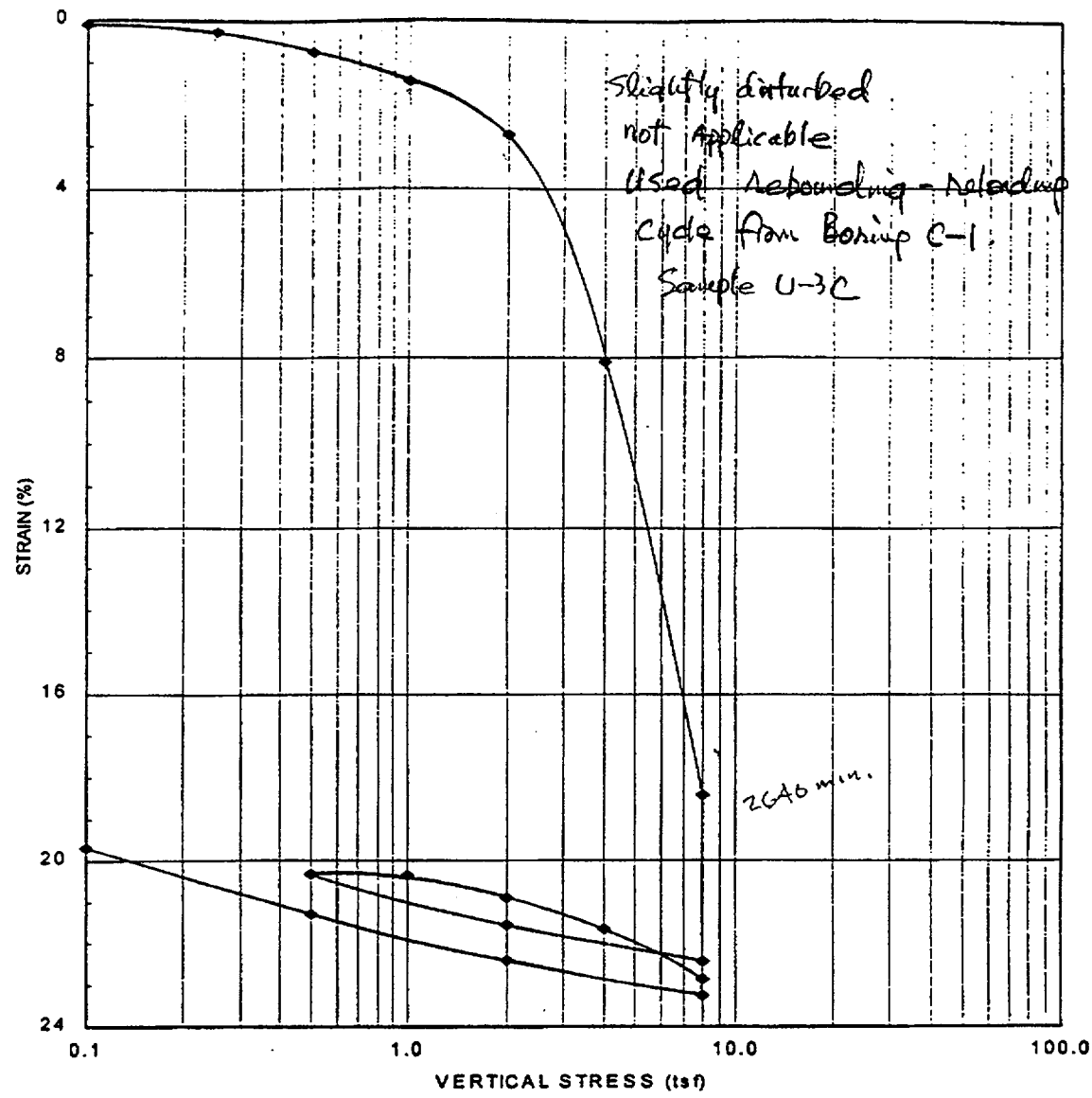

SAMPLE INFORMATION:

BORING:	C-1	DATE:	12/12/96
SAMPLE:	U-3D	TESTED BY:	ACS
DEPTH:	11.4 ft	CHECKED:	PJT
DESCRIPTION:	Clayey SILT		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	46.7 %	62.4 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	51.7 pcf	64.1 pcf	2.72
VOID RATIO:	2.285	1.649	
SATURATION:	55.6 %	103.0 %	

NOTE: Sample was inundated when the applied pressure was 0.5 tsf.

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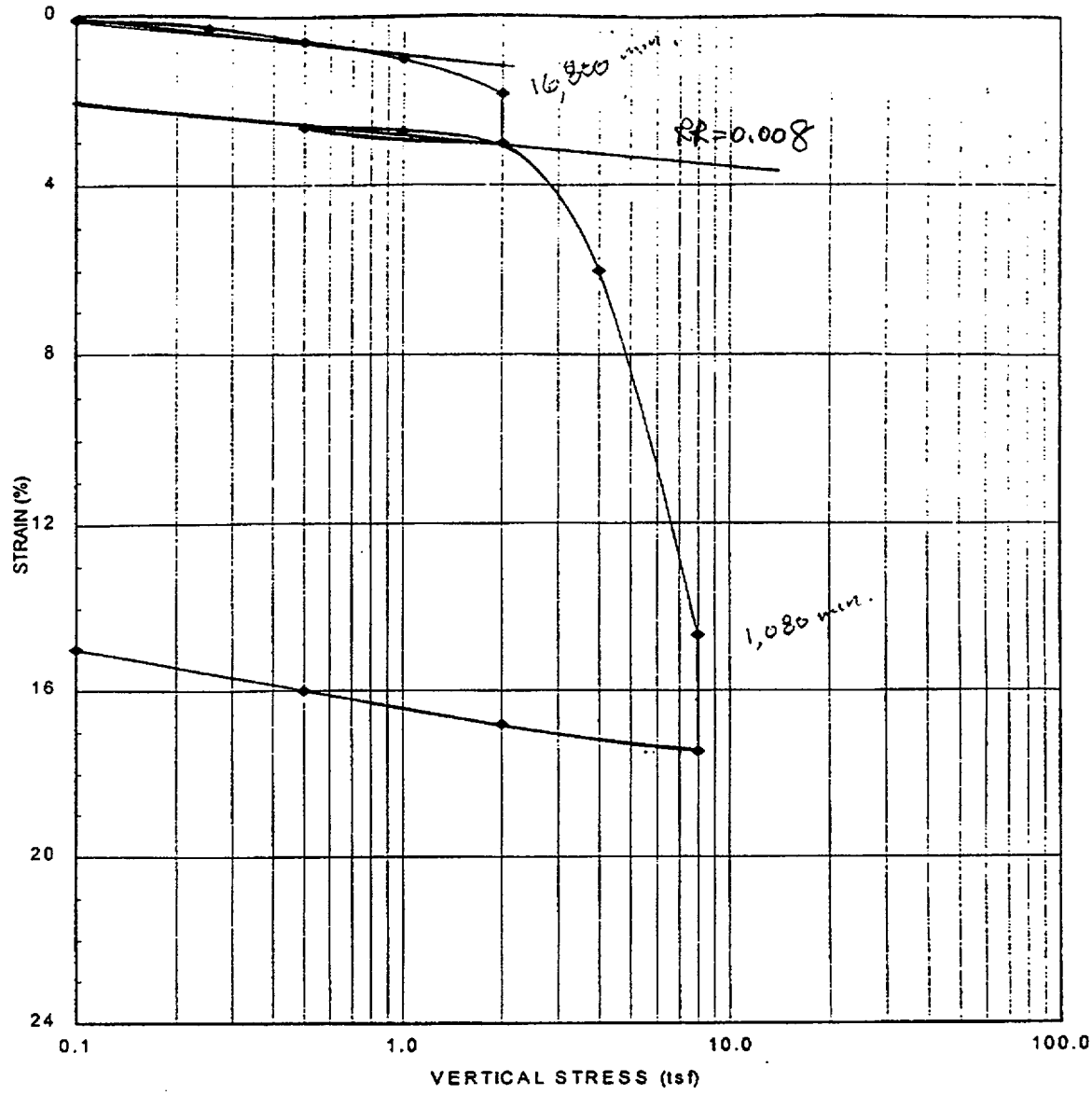

SAMPLE INFORMATION:

BORING:	C-2	DATE:	12/17/96
SAMPLE:	U-2C	TESTED BY:	ACS
DEPTH:	10.9 ft	CHECKED:	PJT
DESCRIPTION:	Clayey SILT		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	27.6 %	44.2 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	64.9 pcf	76.2 pcf	2.72 (est)
VOID RATIO:	1.615	1.230	
SATURATION:	46.4 %	97.7 %	

NOTE: Sample was inundated when the applied pressure was 0.5 tsf.

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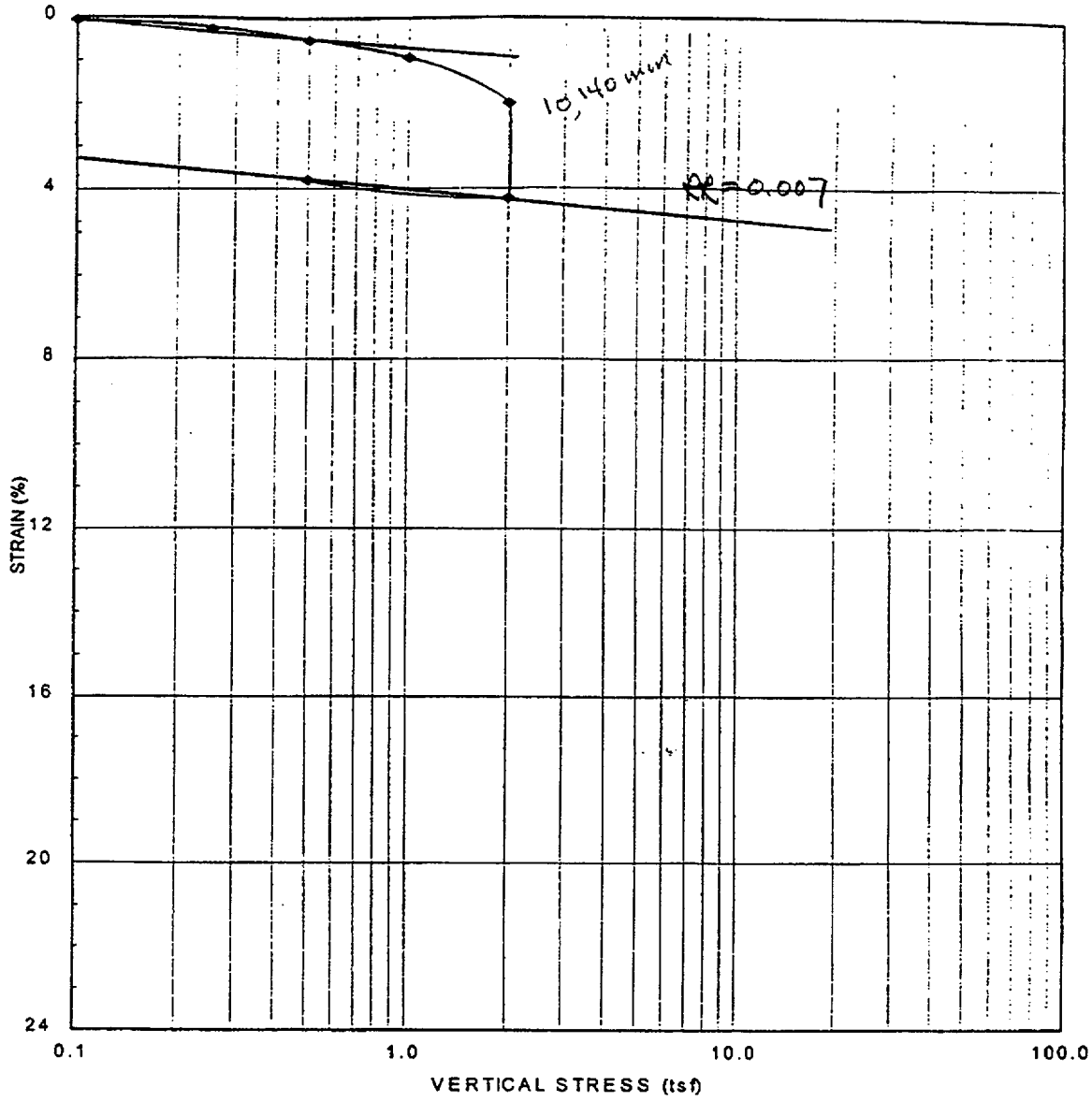

SAMPLE INFORMATION:

BORING:	C-2	DATE:	12/10/96
SAMPLE:	U-2E	TESTED BY:	ACS
DEPTH:	11.7 ft	CHECKED:	PJT
DESCRIPTION:	Clayey SILT		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	39.7 %	65.0 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	57.5 pcf	59.8 pcf	2.72 (est)
VOID RATIO:	1.952	1.840	
SATURATION:	55.3 %	96.0 %	

NOTE: Sample was inundated when the applied pressure was 0.5 tsf.

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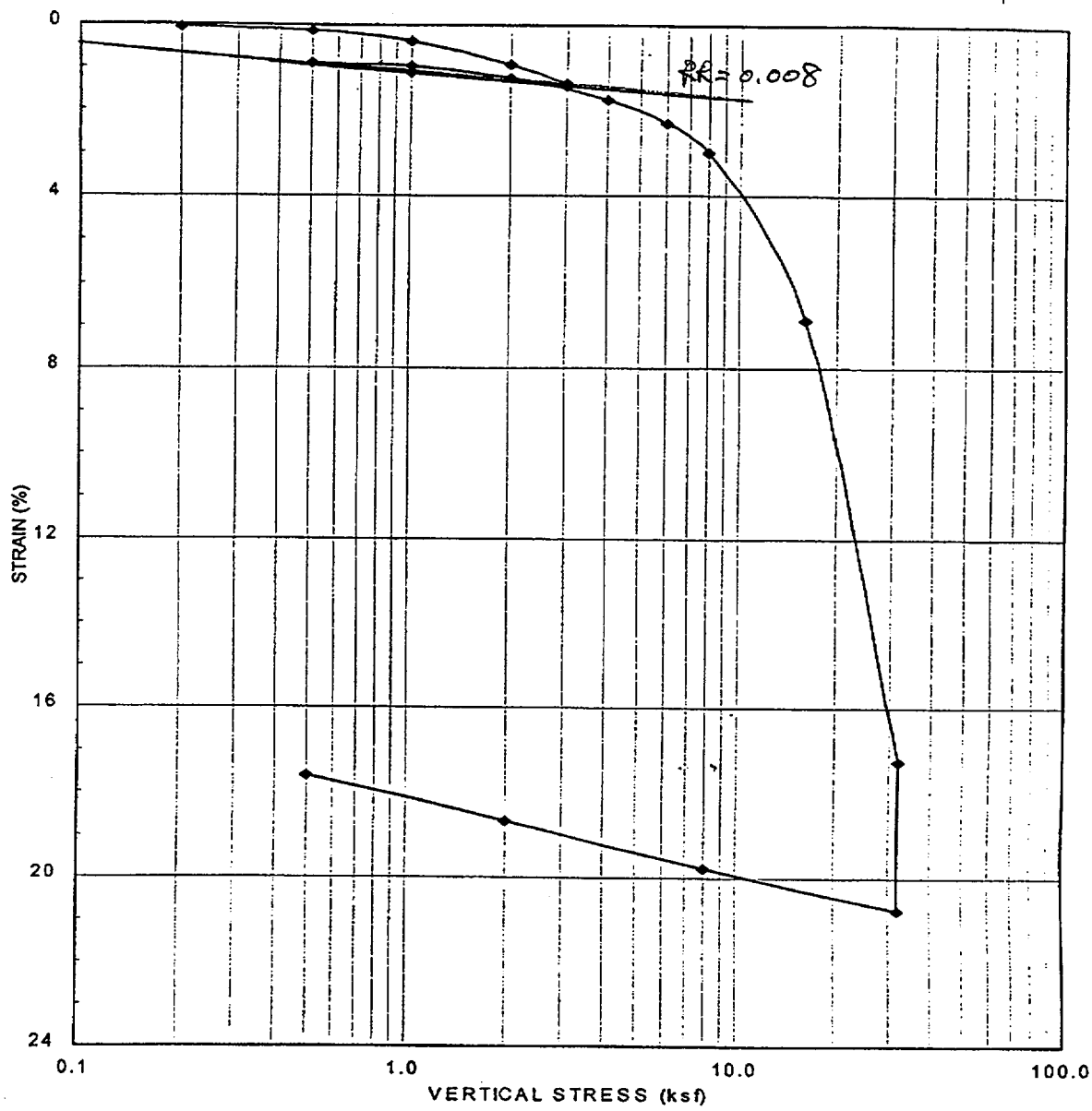
STONE & WEBSTER ENGINEERING CORP. BOSTON, MASSACHUSETTS	CONSOLIDATION TEST RESULTS BORING C-2, SAMPLE U-2E	JO 05996.01 January 1997



SAMPLE INFORMATION:

BORING:	CTB-4	DATE:	4/21/99
SAMPLE:	U-2E	TESTED BY:	ACS
DEPTH:	9.8 ft	CHECKED:	TYC
DESCRIPTION:	CLAY (CH)		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	48.9 %	42.1 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	63.2 pcf	75.8 pcf	2.72 (est)
VOID RATIO:	1.687	1.240	
SATURATION:	78.8 %	92.3 %	

NOTE: Sample was not inundated

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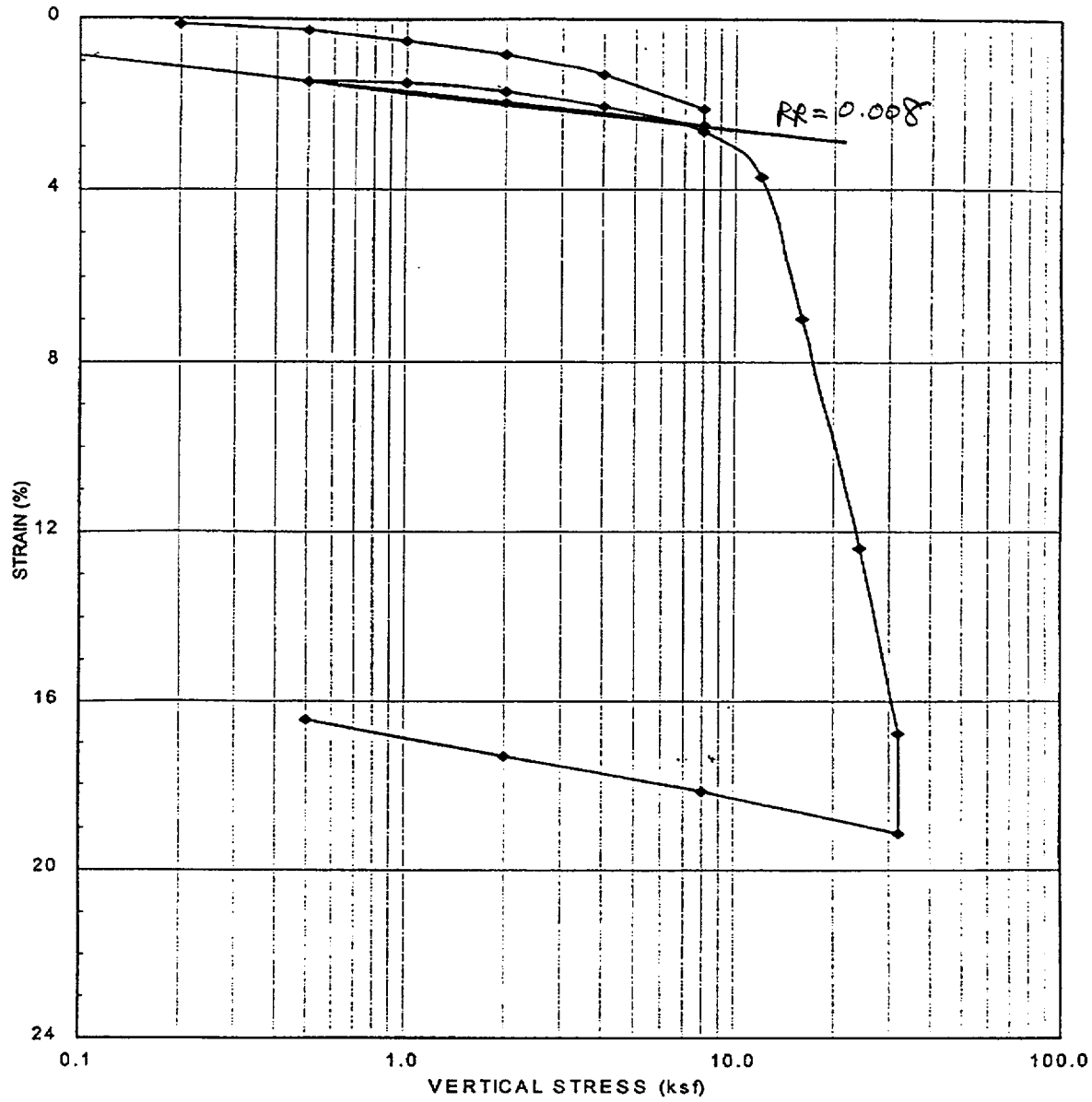

SAMPLE INFORMATION:

BORING:	CTB-5	DATE:	4/14/99
SAMPLE:	U-12C	TESTED BY:	ACS
DEPTH:	23.5 ft	CHECKED:	TYC
DESCRIPTION:	SILT (MH)		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	52.4 %	43.6 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	63.3 pcf	75.0 pcf	2.72 (est)
VOID RATIO:	1.683	1.265	
SATURATION:	84.6 %	93.8 %	

NOTE: Sample was not inundated

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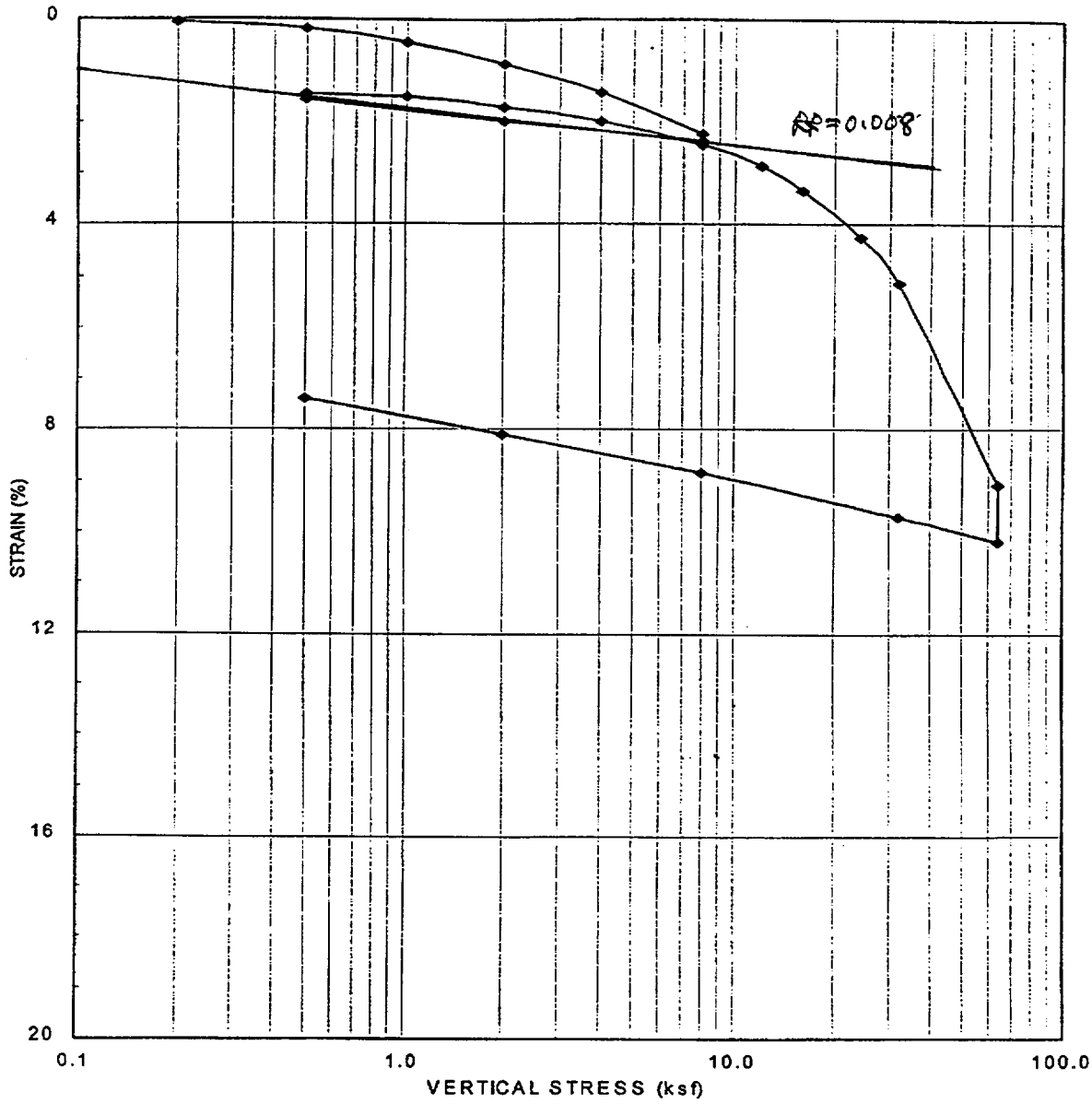
STONE & WEBSTER ENGINEERING CORP. BOSTON, MASSACHUSETTS	CONSOLIDATION TEST RESULTS BORING CTB-5, SAMPLE U-12C	JO 05996.02 April 1999



SAMPLE INFORMATION:

BORING:	CTB-5	DATE:	4/14/99
SAMPLE:	U-14E	TESTED BY:	ACS
DEPTH:	27.3 ft	CHECKED:	TYC
DESCRIPTION:	CLAY (CL)		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	26.2 %	24.9 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	90.9 pcf	97.9 pcf	2.72 (est)
VOID RATIO:	0.868	0.735	
SATURATION:	82.1 %	92.2 %	

NOTE: Sample was not inundated

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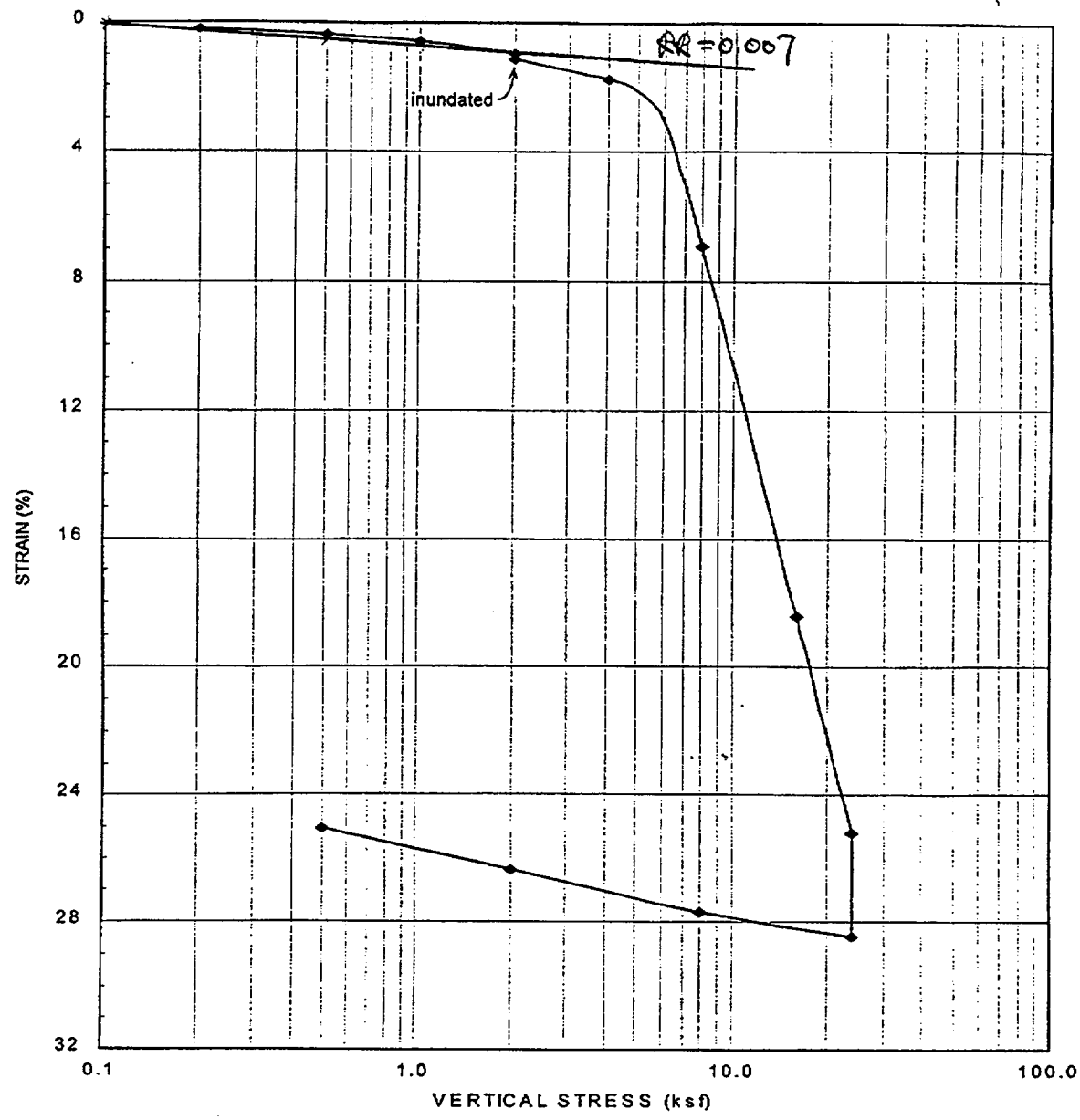
STONE & WEBSTER ENGINEERING CORP. BOSTON, MASSACHUSETTS	CONSOLIDATION TEST RESULTS BORING CTB-5, SAMPLE U-14E	JO 05996.02 April 1999



SAMPLE INFORMATION:

BORING:	CTB-N	DATE:	4/12/99
SAMPLE:	U-2D	TESTED BY:	ACS
DEPTH:	8.6 ft	CHECKED:	TYC
DESCRIPTION:	SILT (MH)		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	63.0 %	60.6 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	48.4 pcf	64.0 pcf	2.72 (est)
VOID RATIO:	2.511	1.655	
SATURATION:	68.2 %	99.5 %	

NOTE: Sample was inundated 41 minutes after applying a vertical stress of 2 ksf

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STONE & WEBSTER ENGINEERING CORP. BOSTON, MASSACHUSETTS	CONSOLIDATION TEST RESULTS BORING CTB-N, SAMPLE U-2D	JO 05996.02 April 1999

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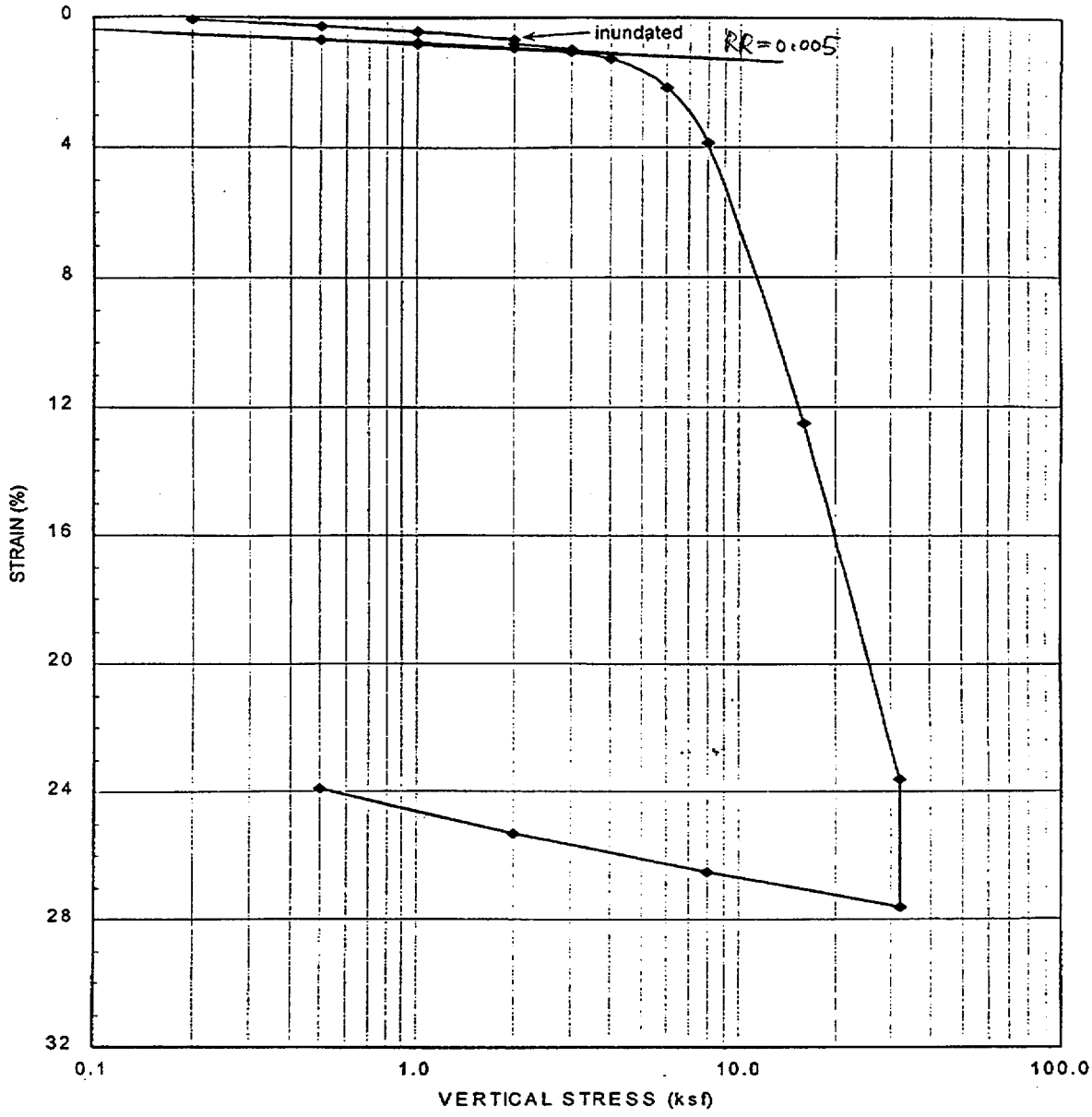

SAMPLE INFORMATION:

BORING:	CTB-S	DATE:	4/21/99
SAMPLE:	U-3C	TESTED BY:	ACS
DEPTH:	10 ft	CHECKED:	TYC
DESCRIPTION:	SILT (MH)		

SPECIMEN INFORMATION:	INITIAL	FINAL	
WATER CONTENT:	72.2 %	54.4 %	SPECIFIC GRAVITY:
DRY UNIT WEIGHT:	51.9 pcf	67.4 pcf	2.72 (est)
VOID RATIO:	2.269	1.519	
SATURATION:	86.6 %	97.4 %	

NOTE: Sample was inundated 34 minutes after applying a vertical stress of 2 ksf

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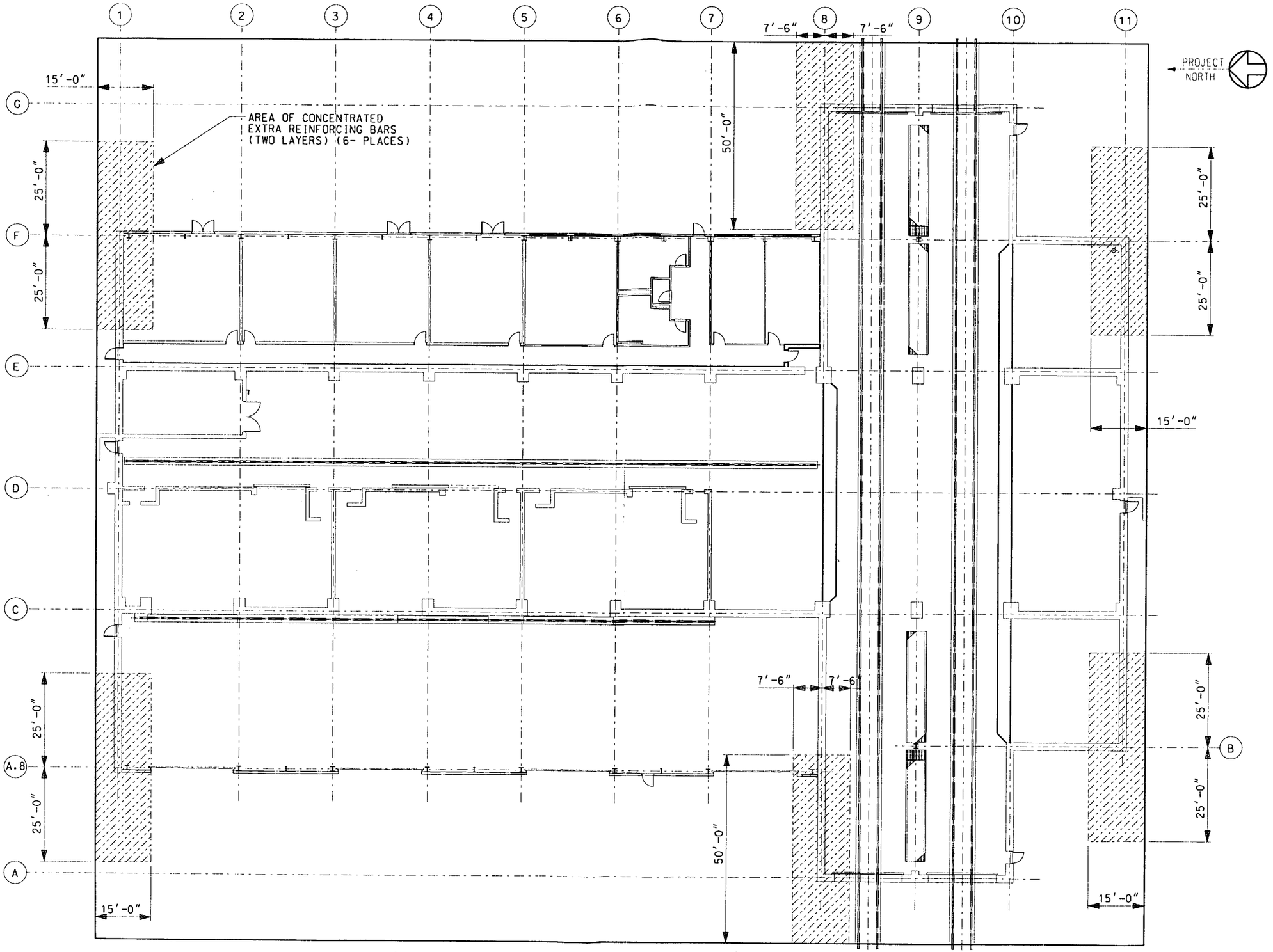
STONE & WEBSTER ENGINEERING CORP. BOSTON, MASSACHUSETTS	CONSOLIDATION TEST RESULTS BORING CTB-S, SAMPLE U-3C	JO 05996.02 April 1999



CANISTER TRANSFER BUILDING FLOOR PLAN 5/23/01 0599602-SKA-401A

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