

**CALCULATION TITLE PAGE**

\*SEE INSTRUCTIONS ON REVERSE SIDE

▲ 5010.64 (FRONT)

CLIENT & PROJECT PRIVATE FUEL STORAGE, LLC - PRIVATE FUEL STORAGE FACILITY				PAGE 1 OF 2		
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 (✓) <input checked="" type="checkbox"/> I - NUCLEAR SAFETY RELATED <input type="checkbox"/> II <input type="checkbox"/> III <input type="checkbox"/> 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 LIO Lee Lin 5/16/01	Lee LIO Lee Lin 5/16/01	0			✓
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GEO TECHNICAL	S&W SToughton	✓				

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 2 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
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(A) - 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  $1 \frac{3}{4}$ ".

The maximum differential settlement between the edge of storage pads and the center of crushed rock aisle is  $\frac{3}{4}$ ".

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 3 of 4
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	G(B)	26		

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

$$P_{PRI} = H \times RR \log \frac{\bar{\sigma}_{vf}}{\bar{\sigma}_{v0}} \quad \left( \begin{array}{l} \text{See calc 05996.02-G(B)-03-3)} \\ \text{P. 6} \end{array} \right)$$

where  $H$  = thickness of layer

$RR$  = Recompression ratio

$\bar{\sigma}_{vf}$  = Final effective vertical stress at center of layer  
 $= \bar{\sigma}_{v0} + \Delta \bar{\sigma}_{v0} < \bar{\sigma}_{vm}$

$\bar{\sigma}_{v0}$  = Initial effective vertical stress at center of layer

Ideally, the recompression ratio should be evaluated over the range  $\bar{\sigma}_{v0}$  to  $\bar{\sigma}_{v0} + \Delta \bar{\sigma}_{v0}$  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-G(B)-05). This approach is conservative, since the  $RR$  determined is generally higher than  $RR$  determined over the range of  $\bar{\sigma}_{v0} + \Delta \bar{\sigma}_{v0}$ , which

STONE & WEBSTER ENGINEERING CORPORATION  
CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 4 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	GCB)	21		

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	}
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	
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-S	U-3C	10.0	0.005	

Average 0.007

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE <u>5 of 21</u>
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	GCB)	21		

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The average RR value determined from the range  $\bar{T}_{10} + \Delta T_{10}$  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

$$P_{PR1} = \frac{0.007}{0.014} \times 1.67'' = 0.835'' \text{ say } 0.84''$$

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE <u>6 of 21</u>
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	G(B)	21		

The secondary consolidation settlement of the shallow foundations are computed from

$$\begin{aligned}
 P_{sec} &= H \times C_{\alpha} \Delta \log t && \left( \begin{array}{l} \text{See P.7 Calc. 05996.02-G(B)-3} \\ \text{Rev 3} \end{array} \right) \\
 &= H \times C_{\alpha} (\log t_c - \log t_p) \\
 &= H \times C_{\alpha} \log \frac{t_c}{t_p}
 \end{aligned}$$

Where  $H$  = thickness of layer

$C_{\alpha}$  = 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-G(B)-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  $C_{\alpha}$  in the range  $\bar{T}_{v0} + \Delta \bar{T}_{v0}$  is  $3.5 \times 10^{-2} \text{ cm}^2/\text{sec}$ . (See Calc. 05996.02-G(B)-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

$$t_p = \frac{T_v \cdot H^2}{C_{\alpha}}$$

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 7 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	GCB)	21		

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

$$P_{sec} = P_{sec_{40yrs}} - P_{sec_{1month}}$$

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

$P_{sec_{40yrs}} = 1.16''$   
 $P_{sec_{1month}} = 0.74''$

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

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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 8 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	GC(B)	21		

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The Settlement estimates previously calculated were based on the Storage pad dimensions of 30' x 64'. The length of the Storage pad was increased from 64 feet to 67 feet (See SAR Figure 4.2-7 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 seated 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:



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CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 9 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
05996.02	G(B)	21		

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3 Immediate Settlement in layer 1

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$$s_{\%} \text{ reduction} = \frac{0.25''}{1.05} = 0.24'' \quad \left( \begin{array}{l} \text{See} \\ \text{Calc. 05996.02 -} \\ \text{G(B) - 3 - Rev. 3} \\ \text{p. 21} \end{array} \right)$$

8 Immediate Settlement in layer 2-4

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11  
12

$$\text{No reduction} = \frac{0.25''}{1.00} = 0.25'' \quad \left( \begin{array}{l} \text{See Calc 05996.02 -} \\ \text{G(B) - 3 - Rev. 3} \\ \text{p. 21} \end{array} \right)$$

13 Primary Consolidation in layer 1

14  
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16  
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$$2\% \text{ reduction} = \frac{0.84''}{1.02} = 0.83'' \quad \left( \begin{array}{l} \text{See p. 5 of this} \\ \text{calc.} \end{array} \right)$$

18 Secondary Compression in layer 1

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$$\text{No reduction} = \frac{0.42''}{1.00} = 0.42'' \quad \left( \begin{array}{l} \text{See p 7 of this} \\ \text{calc.} \end{array} \right)$$

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$$\text{Total} = 1.74''$$

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Say  $1 \frac{3}{4}''$  total settlement  
after 40 yrs

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

## CALCULATION SHEET

▲ 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 10 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
0599602	GLB)	21		

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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  $1\frac{1}{2}$  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  $\frac{3}{4}$ ". 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  $\leq \frac{3}{4}$ ".

CALCULATION SHEET

▲ 5010.65

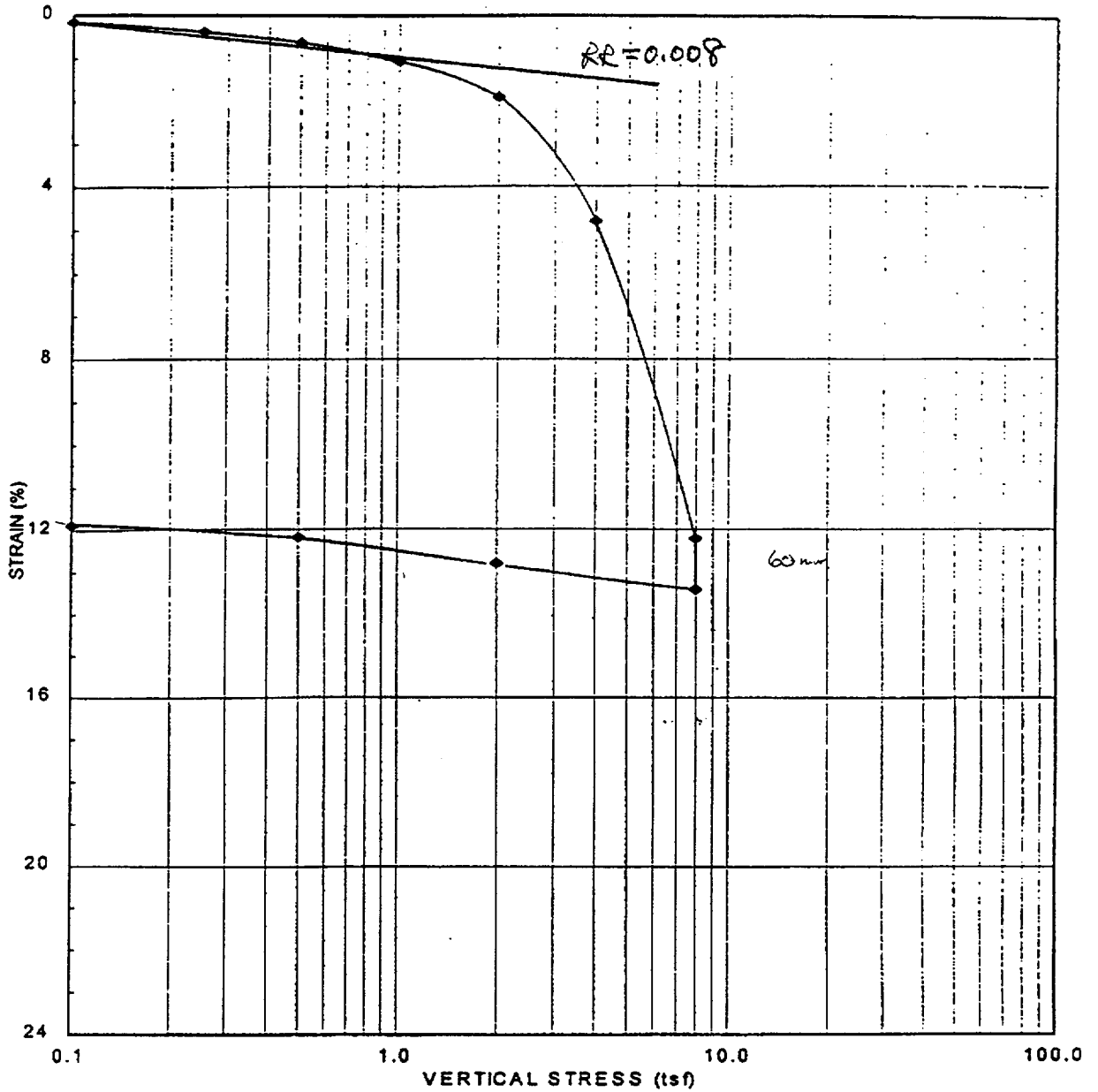
CALCULATION IDENTIFICATION NUMBER				PAGE 11 of 21
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
0599602	GCB)	21		

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Attachment A - 10 pages

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

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	} Carrier 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  
 SAMPLE: U-3B  
 DEPTH: 10.8 ft  
 DESCRIPTION: Clayey SILT

DATE: 1/9/97  
 TESTED BY: ACS  
 CHECKED: PJT

**SPECIMEN INFORMATION:**

	INITIAL	FINAL
WATER CONTENT:	30.3 %	28.7 %
DRY UNIT WEIGHT:	64.7 pcf	73.4 pcf
VOID RATIO:	1.625	1.315
SATURATION:	50.7 %	59.3 %

SPECIFIC GRAVITY: 2.72 (est)

**NOTE:** Sample was not inundated and porous stones were dry

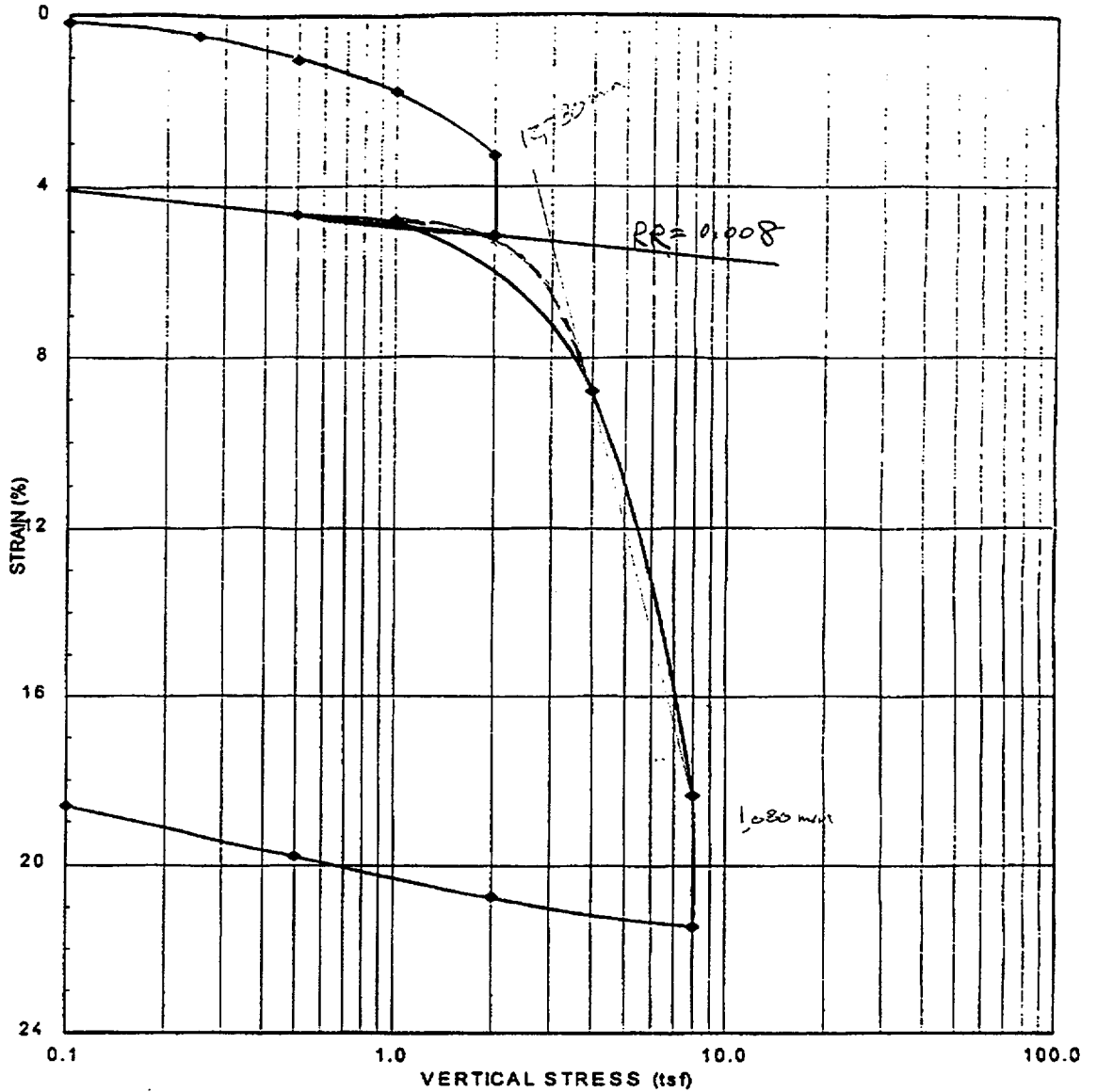
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 BOSTON, MASSACHUSETTS

CONSOLIDATION TEST RESULTS  
 BORING C-1, SAMPLE U-3B

JO 05996.01  
 January 1997



**SAMPLE INFORMATION:**

BORING: C-1  
 SAMPLE: U-3C  
 DEPTH: 11.2 ft  
 DESCRIPTION: Clayey SILT

DATE: 12/20/96  
 TESTED BY: ACS  
 CHECKED: PJT

**SPECIMEN INFORMATION:**

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

**NOTE:** Sample was not inundated and porous stones were moist

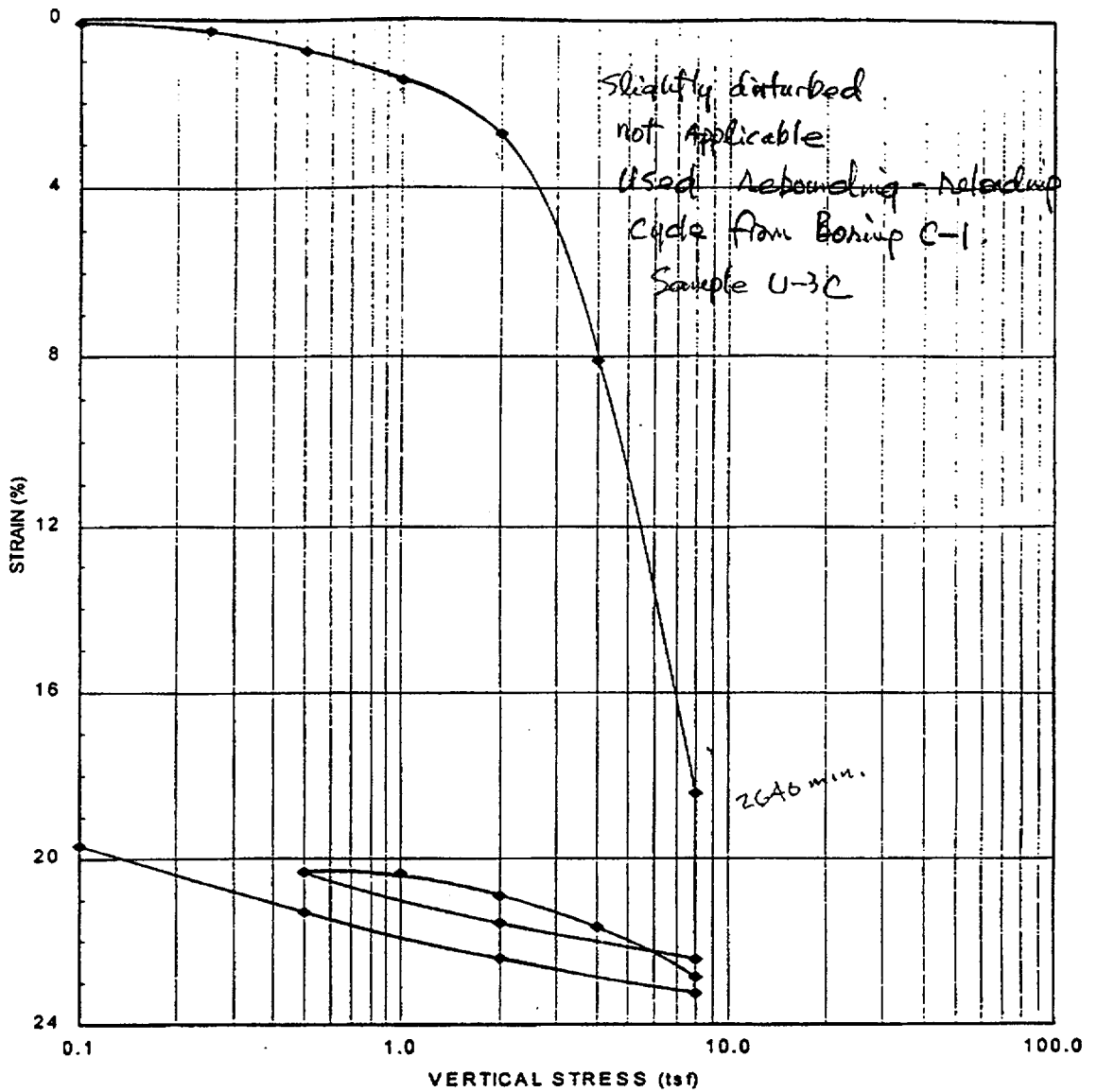
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CONSOLIDATION TEST RESULTS  
 BORING C-1, SAMPLE U-3C

JO 05996.01  
 January 1997



**SAMPLE INFORMATION:**

BORING: C-1  
 SAMPLE: U-3D  
 DEPTH: 11.4 ft  
 DESCRIPTION: Clayey SILT

DATE: 12/12/96  
 TESTED BY: ACS  
 CHECKED: PJT

**SPECIMEN INFORMATION:**

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

SPECIFIC GRAVITY: 2.72

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

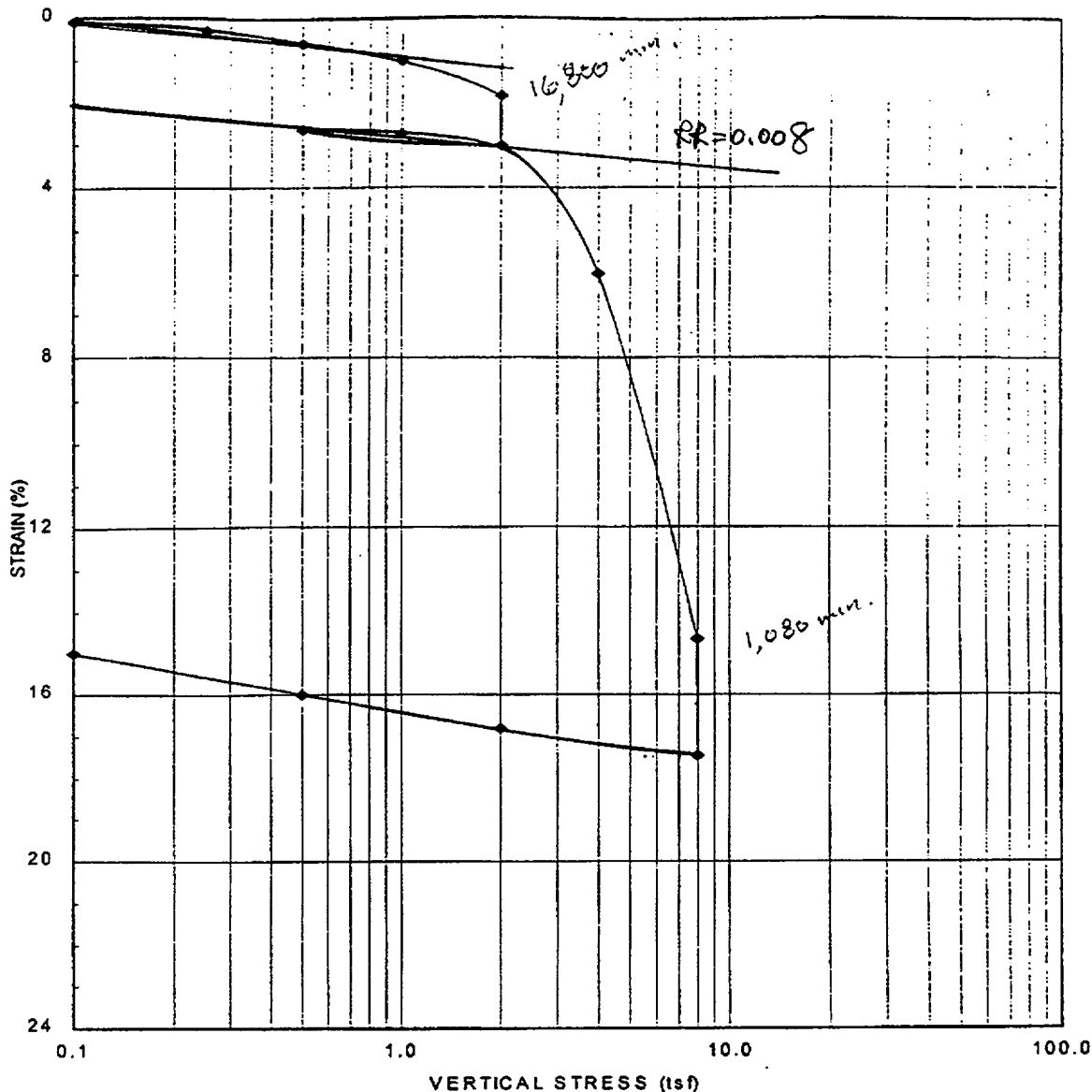
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CONSOLIDATION TEST RESULTS  
 BORING C-1, SAMPLE U-3D

JO 05996.01  
 January 1997



**SAMPLE INFORMATION:**

BORING: C-2  
 SAMPLE: U-2C  
 DEPTH: 10.9 ft  
 DESCRIPTION: Clayey SILT

DATE: 12/17/96  
 TESTED BY: ACS  
 CHECKED: PJT

**SPECIMEN INFORMATION:**

	INITIAL	FINAL
WATER CONTENT:	27.6 %	44.2 %
DRY UNIT WEIGHT:	64.9 pcf	76.2 pcf
VOID RATIO:	1.615	1.230
SATURATION:	46.4 %	97.7 %

SPECIFIC GRAVITY: 2.72 (est)

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

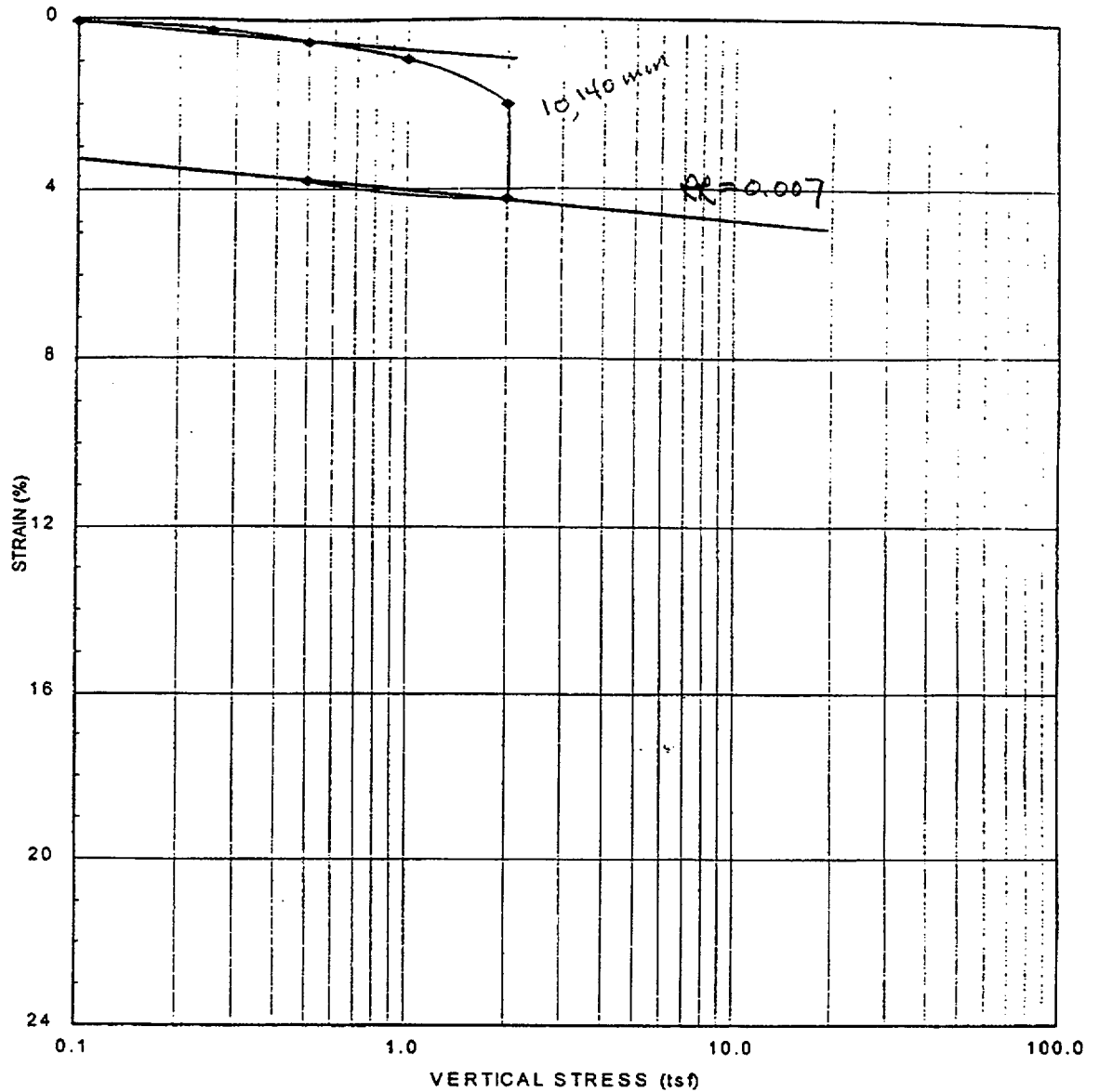
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CONSOLIDATION TEST RESULTS  
 BORING C-2, SAMPLE U-2C

JO 05996.01  
 January 1997



**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	SPECIFIC GRAVITY:
WATER CONTENT:	39.7 %	65.0 %	2.72 (est)
DRY UNIT WEIGHT:	57.5 pcf	59.8 pcf	
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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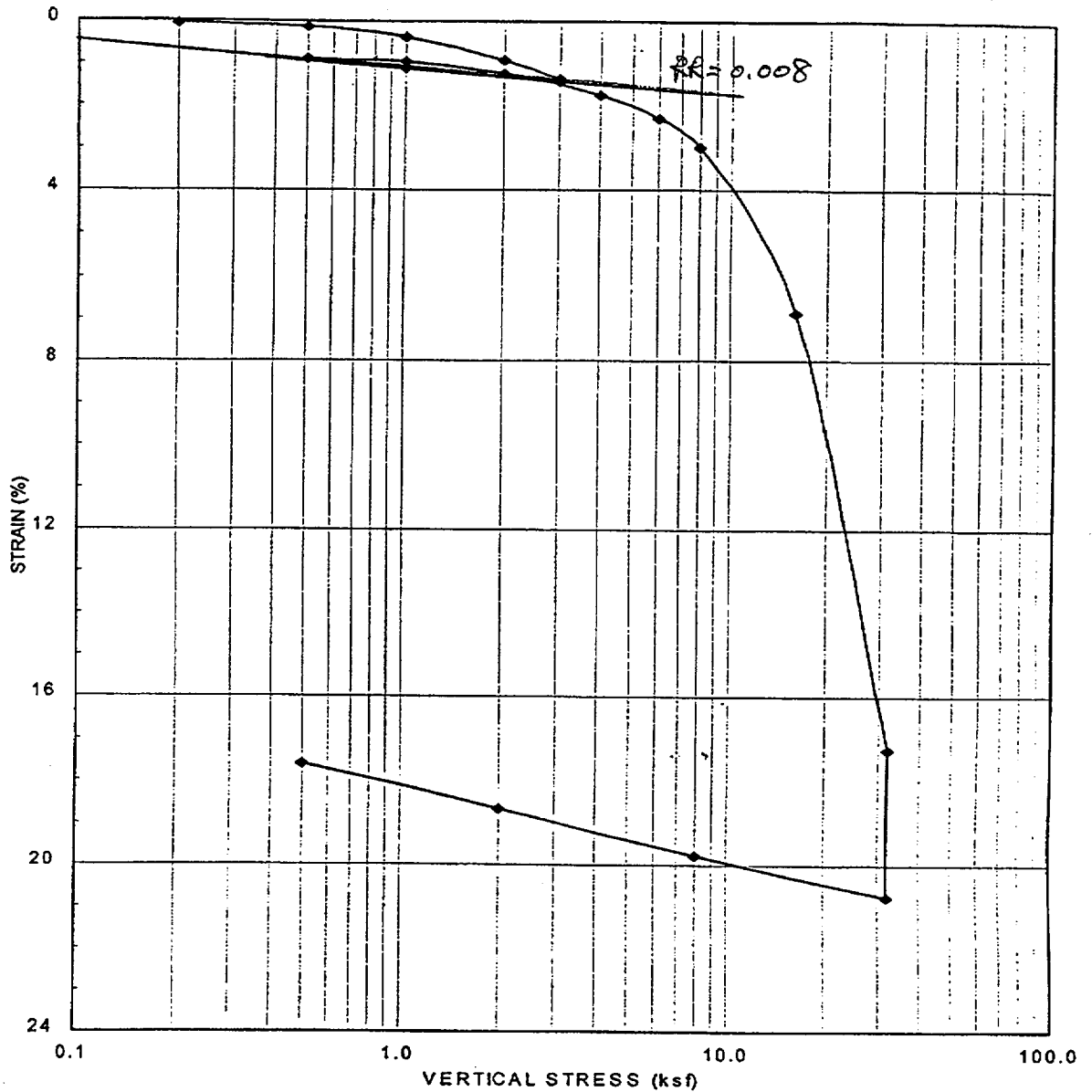


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BOSTON, MASSACHUSETTS

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

**NOTE:** Sample was not inundated

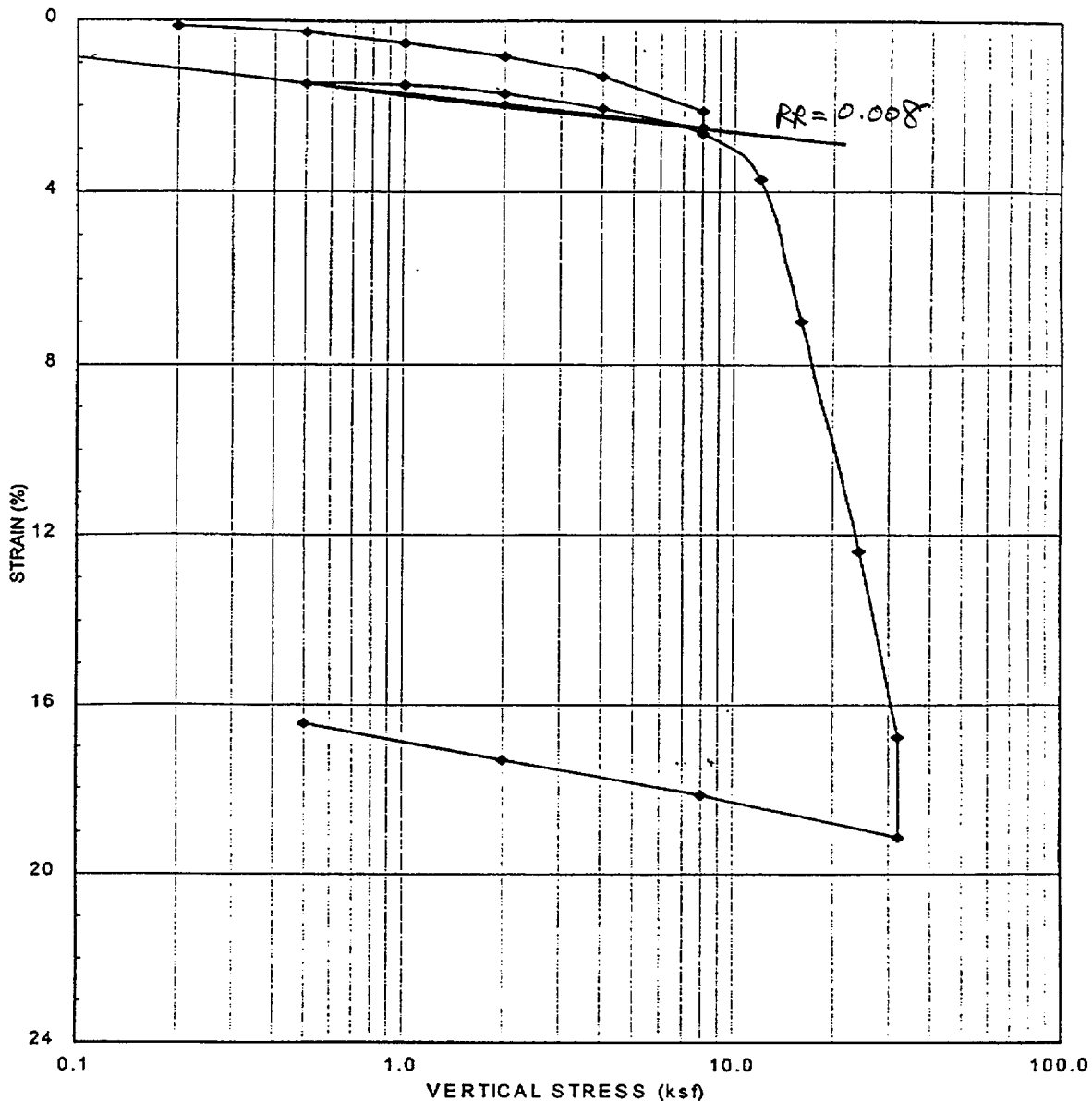
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BOSTON, MASSACHUSETTS

CONSOLIDATION TEST RESULTS  
BORING CTB-4, SAMPLE U-2E

JO 05996.02  
April 1999



**SAMPLE INFORMATION:**

BORING: CTB-5  
 SAMPLE: U-12C  
 DEPTH: 23.5 ft  
 DESCRIPTION: SILT (MH)

DATE: 4/14/99  
 TESTED BY: ACS  
 CHECKED: TYC

**SPECIMEN INFORMATION:**

	INITIAL	FINAL
WATER CONTENT:	52.4 %	43.6 %
DRY UNIT WEIGHT:	63.3 pcf	75.0 pcf
VOID RATIO:	1.683	1.265
SATURATION:	84.6 %	93.8 %

SPECIFIC GRAVITY:  
 2.72 (est)

**NOTE:** Sample was not inundated

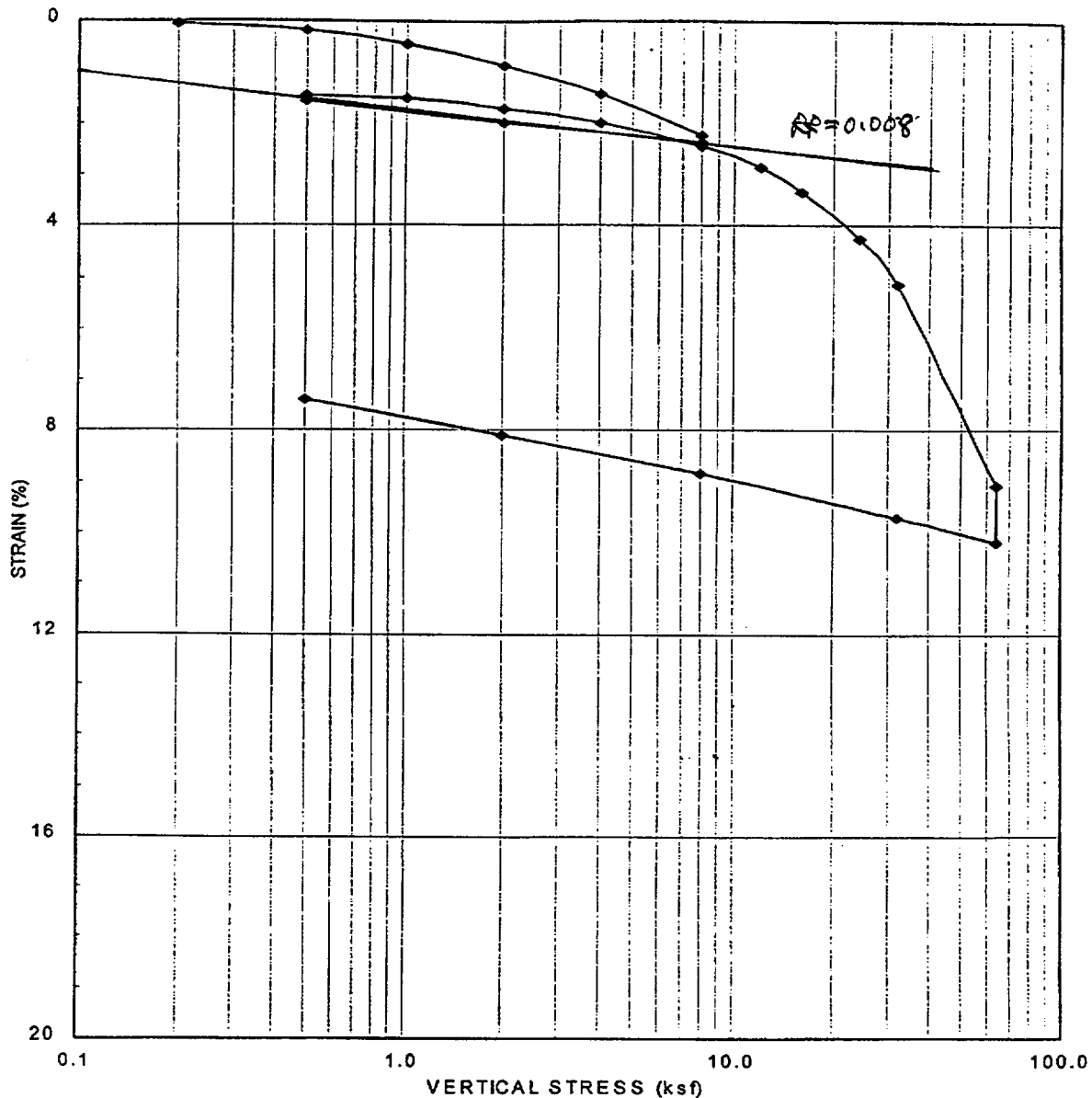
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CONSOLIDATION TEST RESULTS  
 BORING CTB-5, SAMPLE U-12C

JO 05996.02  
 April 1999



**SAMPLE INFORMATION:**

BORING: CTB-5  
 SAMPLE: U-14E  
 DEPTH: 27.3 ft  
 DESCRIPTION: CLAY (CL)

DATE: 4/14/99  
 TESTED BY: ACS  
 CHECKED: TYC

**SPECIMEN INFORMATION:**

	INITIAL	FINAL	
WATER CONTENT:	26.2 %	24.9 %	
DRY UNIT WEIGHT:	90.9 pcf	97.9 pcf	
VOID RATIO:	0.868	0.735	
SATURATION:	82.1 %	92.2 %	

SPECIFIC GRAVITY:  
 2.72 (est)

NOTE: Sample was not inundated

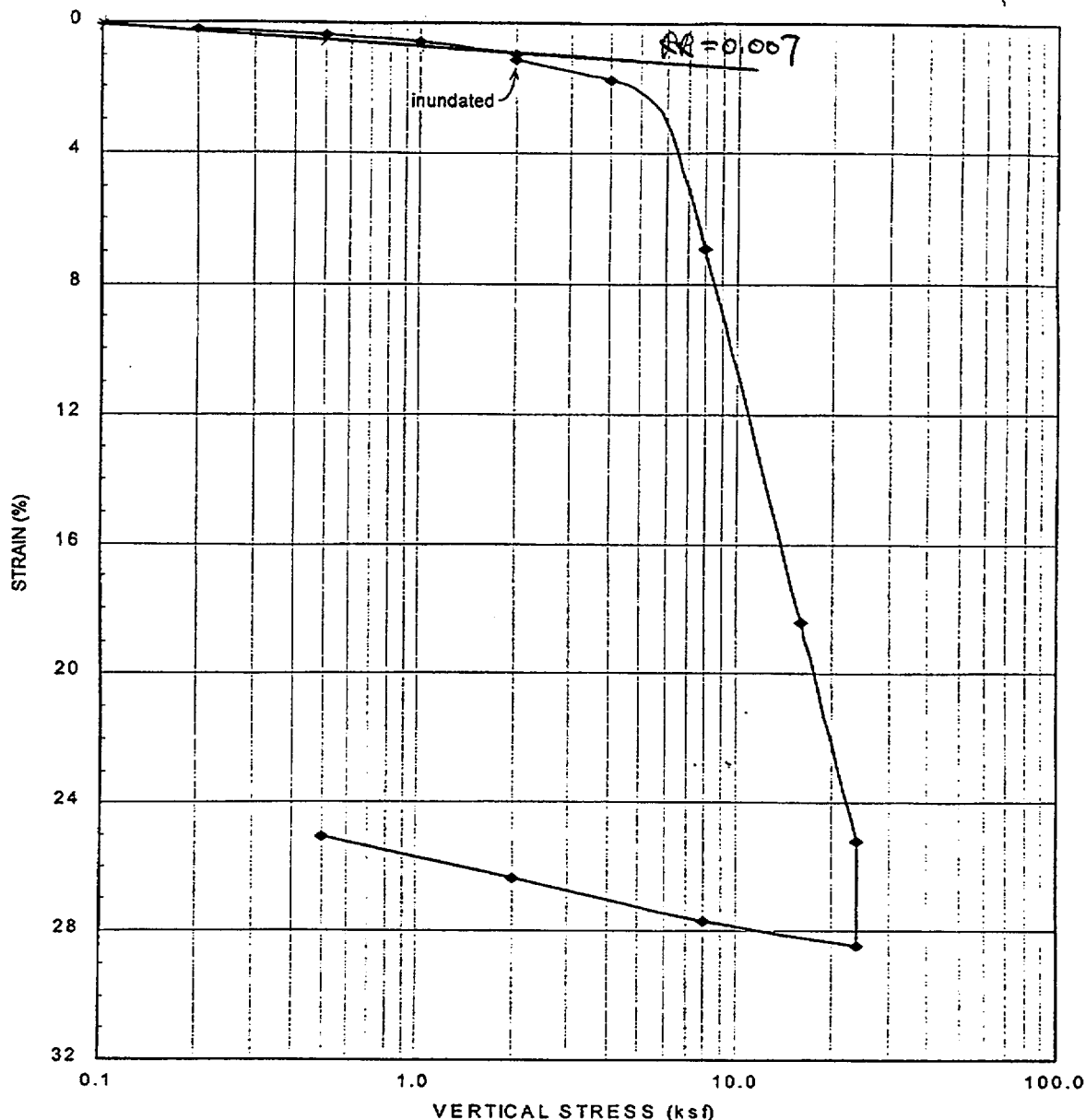
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 SKULL VALLEY  
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STONE & WEBSTER ENGINEERING CORP.  
 BOSTON, MASSACHUSETTS

CONSOLIDATION TEST RESULTS  
 BORING CTB-5, SAMPLE U-14E

JO 05996.02  
 April 1999



**SAMPLE INFORMATION:**

BORING: CTB-N  
 SAMPLE: U-2D  
 DEPTH: 8.6 ft  
 DESCRIPTION: SILT (MH)

DATE: 4/12/99  
 TESTED BY: ACS  
 CHECKED: TYC

**SPECIMEN INFORMATION:**

	INITIAL	FINAL
WATER CONTENT:	63.0 %	60.6 %
DRY UNIT WEIGHT:	48.4 pcf	64.0 pcf
VOID RATIO:	2.511	1.655
SATURATION:	68.2 %	99.5 %

SPECIFIC GRAVITY: 2.72 (est)

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

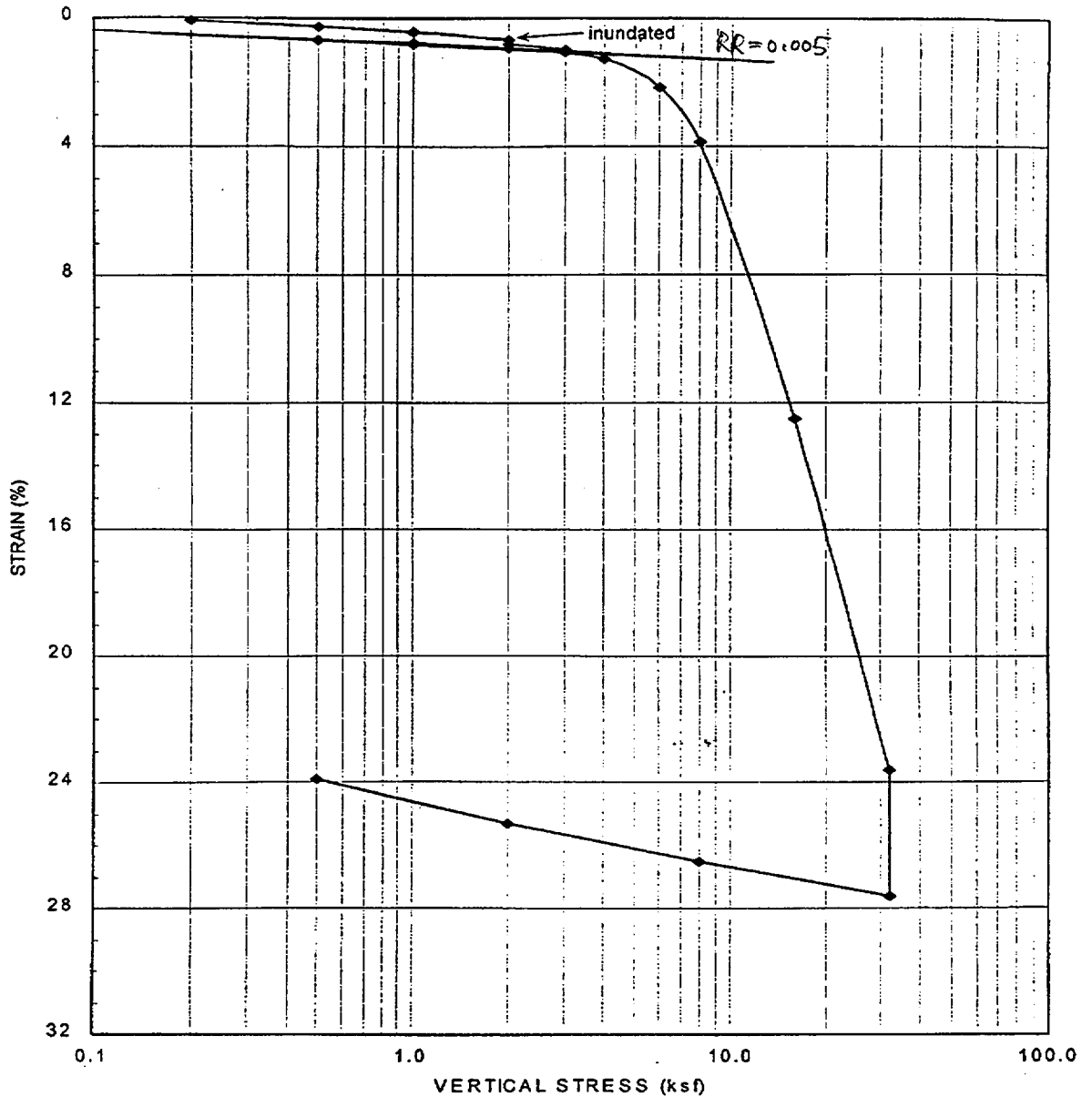
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CONSOLIDATION TEST RESULTS  
 BORING CTB-N, SAMPLE U-2D

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**SAMPLE INFORMATION:**

BORING: CTB-S  
 SAMPLE: U-3C  
 DEPTH: 10 ft  
 DESCRIPTION: SILT (MH)

DATE: 4/21/99  
 TESTED BY: ACS  
 CHECKED: TYC


**SPECIMEN INFORMATION:**

	INITIAL	FINAL
WATER CONTENT:	72.2 %	54.4 %
DRY UNIT WEIGHT:	51.9 pcf	67.4 pcf
VOID RATIO:	2.269	1.519
SATURATION:	86.6 %	97.4 %

SPECIFIC GRAVITY: 2.72 (est)

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

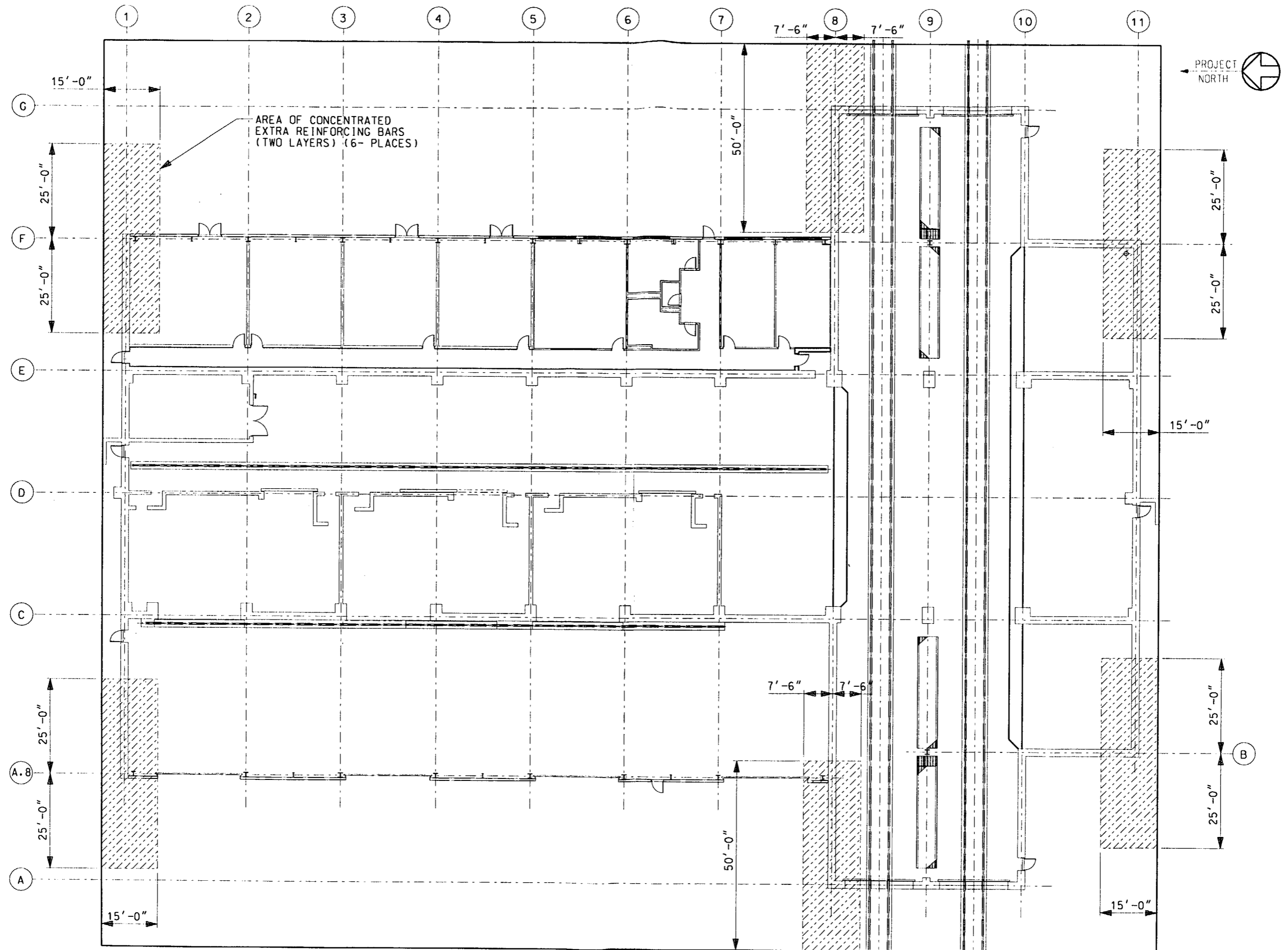
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CONSOLIDATION TEST RESULTS  
 BORING CTB-S, SAMPLE U-3C

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 April 1999



CANISTER TRANSFER BUILDING FLOOR PLAN

5/23/01

0599602-SKA-401A