UNIVERSITETET I TRONDHEIM
NORGES TEKNISKE HØGSKOLE
INSTITUTT FOR GEOTEKNIKK

CONOCO TENSION PILE

Triaxial and oedometer tests
on Cyl. No. 71 and 119 from
McClelland's Boring 5.

O.82.02-1 NTH, May 1982

EXTRACT: A total of 5 multistage triaxial tests, 5 continuous oedometer tests and one incremental oedometer test are run on cyl. No. 71 and 119 from McClelland's Boring 5. The results are interpreted according to NTH practice to obtain a better base for our predictions and recommandations.	
AUTHOR: G. Svanø	PROJECT MANAGER: L. Grande
PROJECT CLIENT: Det Norske Veritas	CLIENT's REF.: T. Kvalstad

POSTADRESSE:
INSTITUTT FOR GEOTEKNIKK
HØGSKOLERINGEN 7
N-7034 TRONDHEIM - NTH

TELEFON:
INSTITUTTET (075) 94 590
LABORATORIET (075) 94 620

TELEX
55186 NTH HB N
ATTN.: GEOTEKNIKK

GEOTECHNICAL DIVISION
THE UNIVERSITY OF TRONDHEIM
THE NORWEGIAN INSTITUTE OF TECHNOLOGY

CONTENTS

1. INTRODUCTION

In connection with the CONOCO tension pile load test project, NTH, the Geotechnical Division, received two 3" sample cylinders from McClelland Engineers' borings at CONOCO's test site in Block 58 of West Delta Area in the Gulf of Mexico. The cylinders were No.71 from 115 to 117 feet depth, and No. 119 from 205 to 207 feet depth.

The intention was to obtain a first hand knowledge of the material properties, so that our predictions might have a better base.

This report concentrates on triaxial and oedometer tests, and all relevant results from these tests are given in plots and tables. The classification test results are shown in Plates 1 and 2, and will not be commented upon, except to mention that they compare well with those given in McClelland's report No.0181-0217. Eq. the fall cone shear strengths fall well in line with McClelland's remote vane measured in situ shear strengths.

2. TRIAXIAL TESTS

The following five multistage triaxial tests are run:

Cyl. 71:	CON1	z = 35.27 m
	CN102	z = 35.40 m
	CN103	z = 35.50 m
Cyl.119	CON10	z = 62.68 m
	CON11	z = 62.77 m

Test CON1 is logged partly manually, partly on a five channel pen recorder. The others are logged automatically on a HP1000 computer.

TEST PROGRAM

The test program is given in detail in Plate 3. All the tests are oedopath consolidated, meaning that σ'_a (axial) and σ'_r (radial) are increased simultaneously with open drains, such that the cross sectional area A_0 of the specimen is maintained constant. The oedopath is run up to a vertical effective stress σ'_a equal to or just below the assumed effective overburden in situ.

The oedopath is followed by two or three sequences of cyclic, undrained loading. Before the first undrained cyclic sequence, however, 10 (in CN102 only 5) drained cycles are run, to "repair" for possible sample disturbances.

Finally, the last cyclic sequence is followed by static, undrained loading to failure ($\dot{\varepsilon}$ = 3% per hour).

All the tests are run with a backpressure of 300 kPa which was introduced before the start of the respective oedopaths.

Two exceptions from this program are made. Test CON1 is taken from the disturbed part of cyl.71. Before start of the oedopath, this specimen is loaded and unloaded drained, isotropically up to σ'_r = 165 kPa in steps 0-10-17-33-83-165 -83-33-17-10 kPa, hoping to repair for sample disturbances. Each step was maintained for 100 minutes. 12 cm^3 water (ε_v = 15%) was pressed out at 165 kPa. The unloading caused suction, so net volume reduction at the start of the oedopath was 8.9 cm^3 (ε_v = 11.1%). The corresponding compression and swelling bulk modulus $M_v = \Delta\sigma'_m/\Delta\varepsilon_v$ is plotted in Plate 4. Curve fitting $M_v = m_v\sigma'_m$ yields a modulus number m_v = 16 compression, and m_{sv} = 55 to 65 for swelling.

In test CON10, the backpressure was lost by accident immediately after start of the oedopath run. This caused a 6 minutes isotropical consolidation at σ'_r = 310 kPa. 5 cm^3 porewater was pressed out (ε_v = 6.3%). Unloading to σ'_r = 8.2 kPa caused suction of water, so the net volume reduction at the start of the successful oedopath run was 1.9 cm^3 (ε_v = 2.4%).

OEDOPATH RESULTS

The oedopaths are started at an isotropical stress σ'_r between 8.2 and 30 kPa. The vertical strain $\Delta\varepsilon_1$ (and hence the volumetric strain $\Delta\varepsilon_v$) at the end of the oedopath was 6.8% to 10.6% for cyl.71, and ~12.2% for cyl.119. (Plate 3).

The earth pressure coefficient at rest is here defined as

$$K'_0 = \frac{\sigma'_r + a}{\sigma'_a + a}$$

where a is attraction according to Plate 10. K'_0 varies from 0.52 to 0.65 for cyl.71, and from 0.55 to 0.60 for cyl.119, Plate 11. (K'_0 is measured at the end of the oedopath).

CYCLIC TEST SEQUENCES

Accumulated porepressures during cycling.

For the undrained test sequences the observed porepressures vs. number of cycles are given in Plates 12 through 22. The porepressure set-up is interpreted in terms of resistance R_u in Plates 23 and 24.

Definition:

$$R_u = \Delta\sigma_d \frac{dN}{du}$$

where

$$\Delta\sigma_d = (\sigma_a - \sigma_r)_{max} - (\sigma_a - \sigma_r)_{min}$$

σ_a, σ_r is axial, radial stress respectively

N is number of cycles
u is porepressure.

High pore-pressure resistance R_u means little tendency to accumulate pore-pressure during cyclic loading.

For the first undrained cyclic sequence c2, the tests CN102, CN103 and CON11 behave significantly different from the tests CON1 and CON10. (Plates 23 and 24). CN102c2, CN103c2 and CON11c2 start with a very small resistance R_u, which increases rather linearly with N, the number of cycles. This is the "normal" behaviour for normally- (or under-) consolidated clays.

CON1c2 and CON10c2, on the other hand, start with a rather high R_u, and set up small excess porepressures. The latter group of tests has been consolidated isotropically up to an effective stress near to or perhaps above the in situ mean stress $\sigma'_{m0} = \frac{1}{3}(\sigma_{v0}' + 2\sigma_{h0}')$ before the oedopath consolidation, while the first group has not. This is probably the explanation for the pronounced difference in the porepressure resistance R_u.

In CON1 and CON10, the high R_u at sequence c2 is broken down at the beginning of sequence c3, due to increased amplitude of cycling, and/or to introduction of two-way cycling. This reduction of R_u with increased cycling intensity (increased amplitude, increased degree of mobilization, and/or introduction of two-way cycling) seems to be a general trend for all the tests.

For the tests were R_u starts at a low value at the beginning of cycling, the behaviour is characterized by the "resistance number" $r_u = dR_u/dN$. r_u is in the range 6 to 12 for cyl.71, and 6 to 11 for cyl.119. This is fairly low, i.e. the soil relatively easy accumulates pore pressure during cycling.

Observe test CON1, Plate 9. After the severe cycling of sequence c3, the specimen is reconsolidated. The following sequence c4 is a repetition of the modest cycling in sequence c2. Now, the resistance is extremely high. ($R_u > 2500$), and the soil hardly sets up additional excess porepressures at all.

CON10c4 (Plate 8) is also reconsolidated, and the amplitude is reduced from sequence c3 to c4. In this case, however, the degree of mobilization is increased, leading to a reduction of the resistance R_u. *I.e. introduction of a high bias load during cycling may therefore cause high accumulated excess porepressures even for moderate cyclic amplitudes.*

The current test results are not extensive enough for quantitative calculations of accumulated excess porepressures, but they can act as a basis for judgement, bearing in mind that:

- Increased intensity of cycling is likely to break down the resistance R_u from previous cycling. The resistance number r_u will then vary between 6 and 11.
- Reduced intensity of cycling gives higher R_u than in the previous cycling. Reconsolidation seems to have the same effect.
- Isotropical "overconsolidation" tends to give high resistance against excess porepressures (CONc2 and CON10c2)

Cycling intensity is increased if:

- The amplitude $\Delta\sigma_d = (\sigma_a - \sigma_r)_{max} - (\sigma_a - \sigma_r)_{min}$ increases
- The degree of mobilization increases
- Two-way cycling is introduced.

Accumulated strains during cycling.

The observed strains versus number of cycles (N) are plotted in Plates 25 through 34. The accumulated strains are interpreted in terms of resistance $R_\varepsilon = dN/d\varepsilon_1$ in Plate 35. (ε is relative strain, not in %). High R_ε means small accumulated strains during cycling. The results may seem a bit confusing, but to some extent there is consistency:

- The isotropical consolidation before oedopath in test CON1 and CON10 results into practically no accumulated strains in the first undrained sequence c2. ($R_\varepsilon < -40000$, i.e. in fact a very small swelling).
- High degree of mobilization f gives small R_ε (CN013c2 and CON10c4).
- Greater amplitude $\Delta\sigma_d$ gives smaller R_ε for the same f, even after reconsolidation. (CN103c3 vs. CN103c2).
- Repetition of "mild" cycling after "intensive" cycling gives negligible accumulated strains, or almost elastic behaviour. (CON11c4).
- Two-way cycling seems to give small accumulated strains ($R_\varepsilon \approx 60000$ for CON1c3 and $R_\varepsilon > 100000$ for CN103c4), which is hardly surprising, since the sample is alternately compressed and stretched.

As for accumulated porepressures, the test results can mainly act as a basis for judgement. The main impression is that the accumulated strains from cyclic action are small.

Dynamic G-modulus.

The undrained cyclic shear strains $\Delta\gamma = \frac{3}{2}\Delta\varepsilon_a$ vary from test to test, but $\Delta\gamma$ ranges between 0.3% and 2%. ($\Delta\varepsilon_a$ is difference in axial strain between top axial load and minimum axial load). The computed dynamic shear moduli $G_{dyn} = \Delta\sigma_d/\Delta\gamma$ are plotted in Plates 36 and 37. The results show that:

- Increased amplitude $\Delta\sigma_d$ gives reduced G_{dyn}, even if the sample is reconsolidated. (CN103, CON10, CON11).
- "Mild" cycling after "intensive" cycling gives high G_{dyn}, at least when the sample is reconsolidated (CON11c4 after CON11c3).
- Degree of mobilization seems not to be as influencive for G_{dyn} as it was for R_ε and R_u. Observe that CON10c4 has almost twice as high G_{dyn} as CON10c3 despite increased degree of mobilization.
- Two-way cycling gives low G_{dyn}. (CN103c4 has lower G_{dyn} than CN103c2, although $\Delta\sigma_d$ is about the same, and although the sample has been reconsolidated twice).
- Consolidation gives higher G_{dyn}. The high G_{dyn} of CON1c2 and CON10c2 is probably a result of the isotropical preconsolidation of the samples.

As a whole, G_{dyn} varies between 3 and 11 MPa for cyl.71, and between 7 and 19 for cyl.119.

STATIC CU-TEST

Since the main interest is assumed to be cyclic behaviour, and since the amount of available material was limited, all the static tests were run after multistage cyclic tests. Hence, for some of the tests considerable amount of pore-water had been pressed out. For cyl.71, ε_v was 7.3 to 17%, and for cyl.119, ε_v was 20.2% at the start of the static test.

The resulting stress paths are plotted in Plates 5 to 9, and the shear strength data are listed in Plate 11. The attraction a is about 20 kPa for both cylinders, and friction $\tan\phi$ is about 0.53 for cyl.71, and 0.50 for cyl.119. The material of cyl.71 tends to dilate during static shearing, while the material of cyl.119 tends to contract. If the material had not been previously exposed to cyclic loading, the contractancy/dilatancy would probably have been different. Most likely more contractancy would appear.

3. OEDOMETER TESTS

The following oedometer tests (consolidation tests) are run:

Cyl. 71:	1 incremental	INOD1	z = 35.20 m
	3 continuous	COOD1	z = 35.34 m
		COOD2	z = 35.57 m
		COOD3	z = 35.60 m
Cyl.119:	2 continuous	COOD4	z = 62.63 m
		COOD5	z = 62.83 m

The deformation characteristics are interpreted in terms of the constrained modulus $M = d\sigma'/d\varepsilon$. Observed strain and computed M, c_v and k are plotted against effective vertical stress σ' (or p') in Plates 38 through 42.

Cylinder 71, depth 115 to 117 feet.

Test COOD1 is from the disturbed, upper part of cyl.71. The disturbance is evidenced in the soil behaviour, as M increases linearly with p'. For undisturbed samples, M increases linearly with p' mainly above p'_c. Expressing $M = mp'$, the modulus number ("slope") is equal to 15. c_v is constant, and equal to 0.8 m^2/year.

Tests COOD2 and COOD3 seem less disturbed. COOD3 has a fairly constant $M \approx 2000$ kPa up to $p' = 140$ kPa, and above this level M increases with a slope $m \approx 15$. This might suggest a preconsolidation pressure p_c' at 140 kPa.

In COOD2, M is high (3000 to 6000 kPa) up to $p' = 280$ kPa, where M starts to drop. This gives a vague indication of p_c' at or above 280 kPa. I.e. the preconsolidation pressure can not be determined exactly, but is located between 140 and 280 kPa. c_v-interpretation gives the same range for p_c'.

If the effective overburden p'_0 equals 230 kPa, M is between 3200 and 6300 kPa at p'_0. COOD1 and COOD3 show a linear increase in M with p', with the modulus number m = 15.

c_v is fairly constant in COOD1 and COOD3 (c_v = 0.8 m^2/year). In COOD2, c_v starts at about 8 m^2/year, and decreases with p' to 0.8 m^2/year at p' = 450 kPa.

The incrementally loaded test INOD1 (Plate 38) shows the same trend as COOD1 both in M and c_v, only here m = 17.

Cylinder 119, depth 205 to 207 feet.

The soil in tests COOD4 and COOD5 seems to be in good condition. Both give constant M, COOD5 gives M ≈ 3500 kPa, and COOD4 gives M ≈ 2500 kPa. COOD5 gives c_v = 0.5 m^2/year at p'_0, if $p'_0 \approx$ 400 kPa. None of these tests lead to preconsolidation pressures. The constant M throughout the applied stress range suggests, though , that p'_c is above 440 kPa. (The sudden drop in M at p' = 380 kPa for test COOD5 is probably due to some test error).

4. SUMMARY

NTH, The Geotechnical Division, received two sample cylinders from CONOCO's test site in Block 58 of West Delta Area in the Gulf of Mexico. Cyl.No.71 contained plastic clay from 115 to 117 feet depth, and Cyl. No. 119 high-plastic clay from 205 to 207 feet depth.

In addition to standard classification tests, a total of 5 triaxial multistage tests, 5 continuous oedometer tests and one incremental oedometer test were run.

The test results are summarized as follows:

TRIAXIAL TESTS:

Oedopath : K'_0 = 0.52 to 0.65 for cyl.71
K'_0 = 0.55 to 0.60 for cyl.119

Cyclic : To begin with the soil sets up excess porepressures relatively easy. Reduced cycling intensity and/or reconsolidation gives large resistance against excess porepressures. (Both cylinders).

The accumulated strain from cyclic loading are small, except if the degree of mobilization is high, and/or the cyclic amplitude is high.
G_{dyn} is 3 to 11 MPa for cyl.71, and 7 to 19 MPa for cyl.119.

Static CU : The static CU-tests are run after 2 or 3 sequences of cycling. Attraction (Plate 10) and friction is a ≅ 20 kPa and $\tan\phi \approx 0.53$ for cyl.71, and a = 20 kPa and $\tan\phi = 0.50$ for cyl.119. The clay in cyl.71 is dilatant, and the clay in cyl.119 is contractant.

OEDOMETER TESTS:

Cyl.71 : Vague indications of p_c' between 140 and 280 kPa.
Compression modulus at $p_0' \approx 230$ kPa (in situ effective overburden) is
M = 3200 to 6300 kPa
$c_v \cong 0.8\ m^2/year$

Cyl.119 : Indications that p_c' might be above 440 kpa, which is close to the effective overburden p_0'
M = 2500 to 3500 kPa
$c_v = 0.5\ m^2/year$ at p_0'

The results of laboratory tests will be viewed in the light of the in situ test results to obtain design parameters.

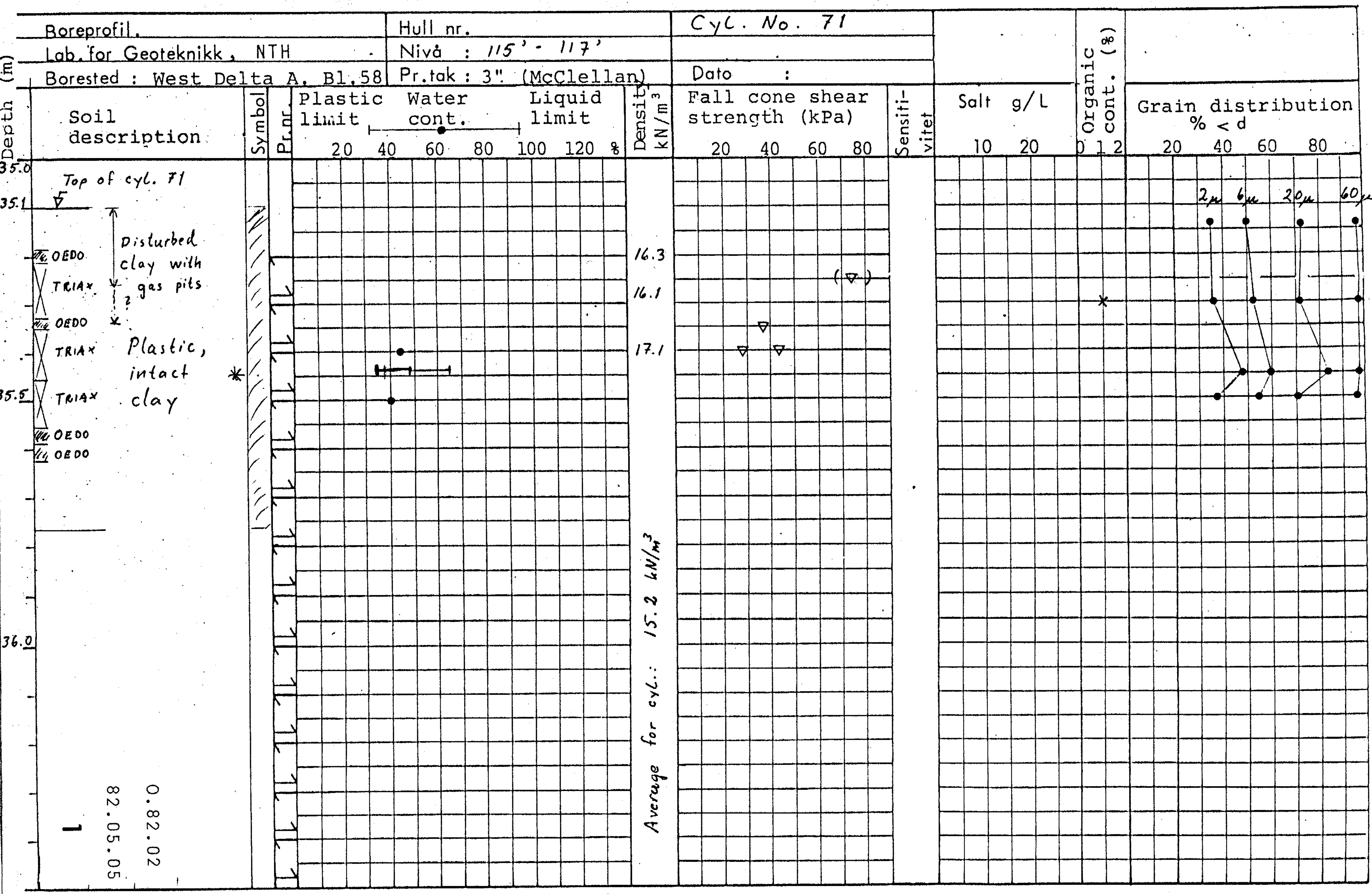
5. LITERATURE

Janbu,N., O.Tokheim and K.Senneset (1981):
"Consolidation Tests with Continuous Loading".
X ICSMFE, Stockholm 1981. Vol.I pp.645-654

Janbu,N. (1973): "Shear strength and stability of soils".
NGF-lecture 1973. Printed by NGI, Oslo 48 p.

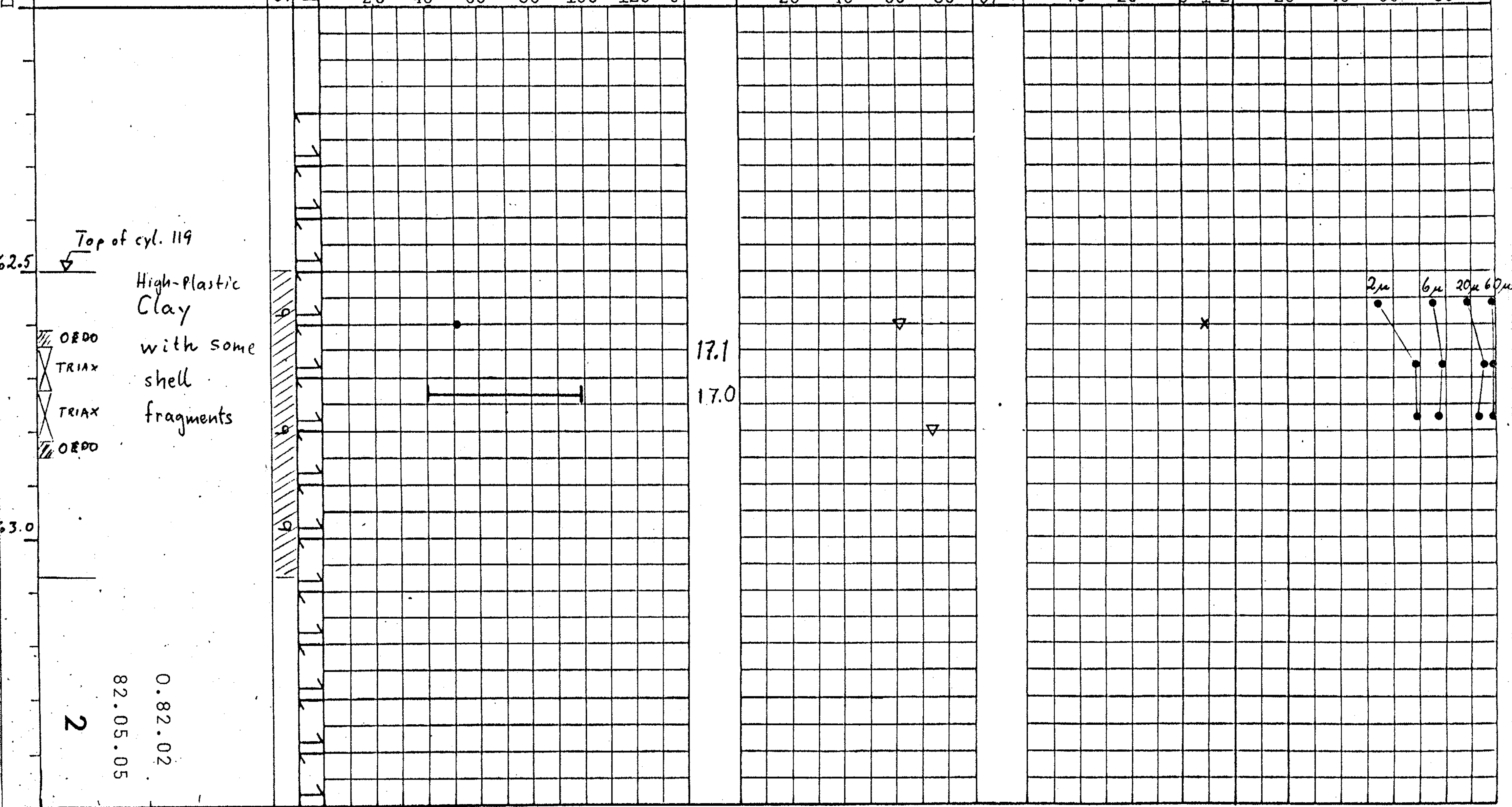
Janbu,N. (1976): "Soils under cyclic loading".
Specialty Session No.1 on Soils, Chairman report,
Behaviour of Offshore structures (BOSS) 1976,
NTH, Norway.

FIGURES AND TABLES


Boreprofil.
Lab. for Geoteknikk, NTH
Borested : West Delta A. Bl.58
Hull nr.
Nivå : 115' - 117'
Pr.tak : 3" (McClellan)
Cyl. No. 71
Dato :
Depth (m)
Soil description
Symbol
Pr.nr.
Plastic limit
Water cont.
Liquid limit
20 40 60 80 100 120 %
Density kN/m³
Fall cone shear strength (kPa)
20 40 60 80
Sensitivitet
Salt g/L
10 20
Organic cont. (%)
0 1 2
Grain distribution % < d
20 40 60 80
2μ 6μ 20μ 60μ
35.0
35.1
35.5
36.0
Top of cyl. 71
Disturbed clay with gas pits
Plastic, intact clay
OEDO
TRIAX
OEDO
TRIAX
TRIAX
OEDO
OEDO
16.3
16.1
17.1
Average for cyl.: 15.2 kN/m³
0.82.02
82.05.05
1

Boreprofil.	Hull nr.	Cyl. No. 119		
Lab. for Geoteknikk, NTH	Nivå : 205' - 207'			
Borested : West Delta A, Bl. 58	Pr.tak : 3" (McClellan)	Dato :		

Depth (m)	Soil description	Symbol	Pr.nr.	Plastic limit — Water cont. — Liquid limit (20 40 60 80 100 120 %)	Densit. kN/m³	Fall cone shear strength (kPa) (20 40 60 80)	Sensitivitet	Salt g/L (10 20)	Organic cont. (%) (0 1 2)	Grain distribution % < d (20 40 60 80)



TRIAXIAL TEST SUMMARY

TEST IDENT.	CON1	CN102	CN103	CON10	CON11
Cyl. No.	71	71	71	119	119
Depth cyl.	115-117'	115-117'	115-117'	205-207'	205-207'
Depth center specim.	35.27m	35.40 m	35.5 m	62.68	62.77
BACKPRESSURE	300	300	300	300	300
Introd. at σ_r'=	10.5	33	10	8.2	9.7
water suction due to bacpressure (cm³)	3.6	≈10 (?)	4	-	3
OEDOPATH CONSOLID.					
End: $\Delta\varepsilon_1$	7.8	6.8	10.6	12.3	12.2
" σ_r'	136	125	98	199	224
" $\frac{1}{2}(\sigma_a' - \sigma_r')$	45	47	57	86	80
DRAINED CYCLES (c1)					
Start: $\Sigma\varepsilon_v$	10.5	7.3	11.9	19.5	14.2
" $\Sigma\varepsilon_1$	9.5	7.0	12.2	16.8	13.8
Cycl.: No. of cyc.	10	5	10	10	10
" σ_r'	135.3	127	97	202	227
" $\frac{1}{2}(\sigma_a - \sigma_r)$max/min	45/3	47.2/24.2	60/32	103/53	91/45
End: $\Delta\varepsilon_v$	0	0	0	0	0
" $\Delta\varepsilon_1$	-0.2	*	.06	-.04	-0.04
UNDRAINED CYCLES (c2)					
Start: $\Sigma\varepsilon_v$	10.5	7.3	12.3	19.5	14.2
" $\Sigma\varepsilon_1$	9.3	*	12.2	16.7	13.8
" $\sigma_r - u$	135-0	127-2	97.3-15.1	203-4	227-2
" $\frac{1}{2}(\sigma_a - \sigma_r)$	53.7	47.2	63.5	102	92
Cycl: No. of cyc.	100	95	100	90	100
" $\frac{1}{2}(\sigma_a - \sigma_r)$max/min	53.7/2.6	47/24	63/31.5	103/52.5	91/44
End: $\frac{1}{2}(\sigma_a - \sigma_r)$	53.7	47	62.8	102.6	90.8
" Δu	14	31	19.9	2.8	56
" $\Delta\varepsilon_1$	.28	*	.8	-.03	.28
UNDRAINED CYCLES (c3)					
Start: $\Sigma\varepsilon_v$	10.5	7.3	12.4	19.7	15.9
" $\Sigma\varepsilon_1$	9.5	*	13.3	16.8	15.2
" $\sigma_r - u$	135-20	127-36	97-11.7	202-6	227-5
" $\frac{1}{2}(\sigma_a - \sigma_r)$	53.7	47.5	64	102	92
Cycl.: No. of cycles	100	100	30	200	210
" $\frac{1}{2}(\sigma_a - \sigma_r)$max/min	53.7/-23.3	47/2	63/1	102/11	92/11
End: $\frac{1}{2}(\sigma_a - \sigma_r)$	53.6	46	62.9	101.3	91.3
" Δu	24	28	28.1	27	60.7
" $\Delta\varepsilon_1$	.2	*	2.2	.04	.13
UNDRAINED CYCLES (c4)					
Start: $\Sigma\varepsilon_v$			13.1	20.2	20.2
" $\Sigma\varepsilon_1$			7.8	17.2	16.7
" $\sigma_r - u$			97-24.1	201-5	227-4
" $\frac{1}{2}(\sigma_a - \sigma_r)$			27	103	93
Cycl.: No. of cycles	None	None	100	270	300
" $\frac{1}{2}(\sigma_a - \sigma_r)$max/min			26/-4	134/82	95/47
End: $\frac{1}{2}(\sigma_a - \sigma_r)$			25.1	132.2	94.0
" Δu			33.2	40	2
" $\Delta\varepsilon_1$			.22	2.0	-0.04
STATIC CU-TEST					
Start: $\Sigma\varepsilon_v$	10.5	7.3	17	20.2	20.2
" $\Sigma\varepsilon_1$	9.9	7.1	10.8	18.8	16.6
" σ_r'	77	52.2	35.8	158	212
" $\frac{1}{2}(\sigma_a - \sigma_r)$	58.1	20.2	22.2	103	86
Shear: ε_1 (%/hour)	3	3	3	3	3
End: $\Delta\varepsilon_1$	8.8	4.4	11.4	10.8	11.5
a	20	15	25	20	20
tan φ	0.52	0.55	0.54	0.50	0.49
REMARKS:	Isotr. consol. at 155 kPa to "repair" for sample disturbances. Ca. 8.9 cm³ porewater pressed out.	*System for logging of cyclic deformations failed.		Accidental loss of backpressure at start of oedopath lead to isotr. cons. at 310 kPa for 6 min. Anisotr. cons. 14 hrs. after oedopath	Anisotr. cons. for 17 hrs. between c3 and c4, with σ_r' = 227 kPa and σ_a' = 433 kPa

ALL STRESSES IN kPa. ALL STRAINS IN % (PERCENT)

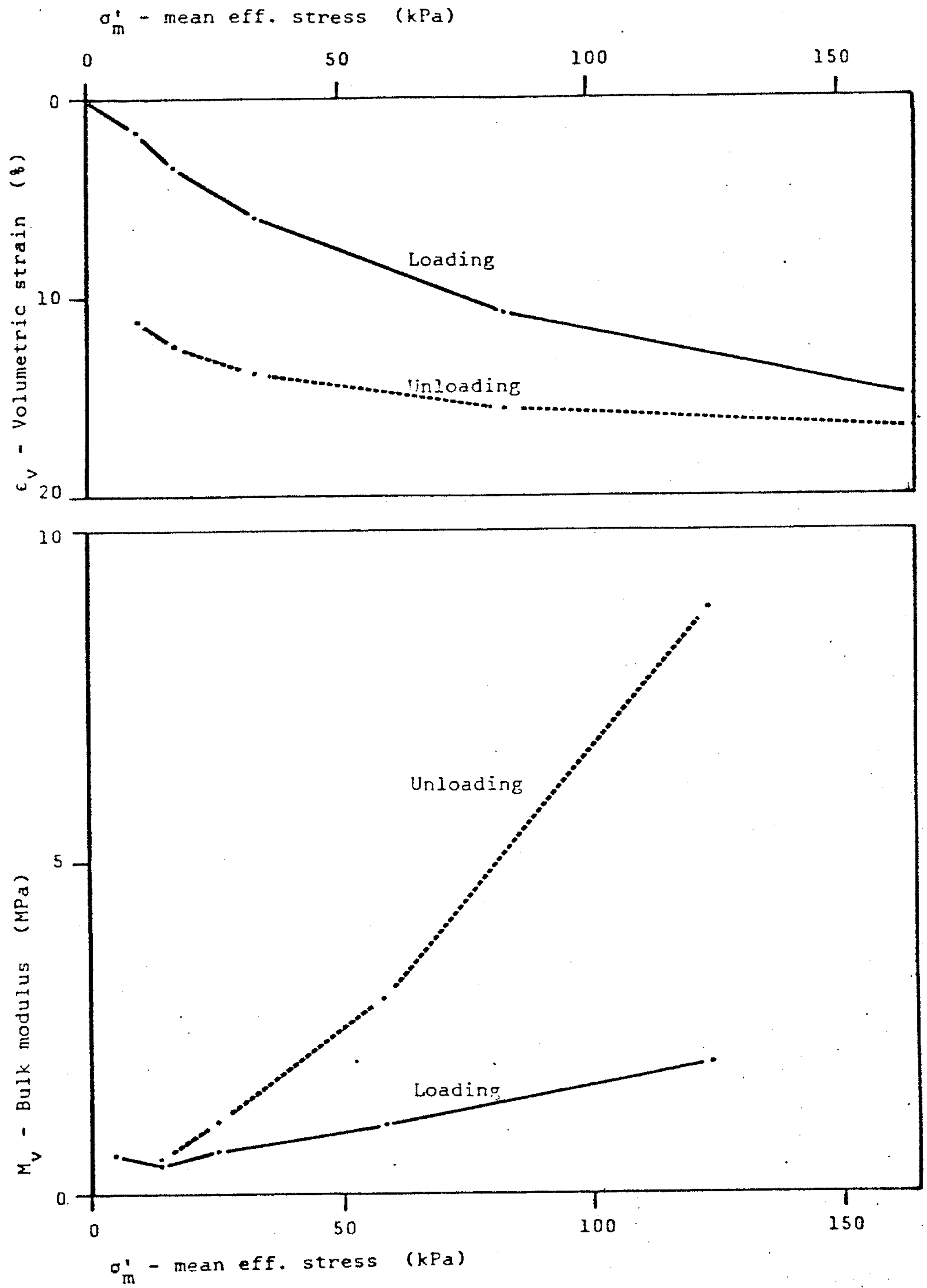
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

TRIAXIAL TEST SUMMARY

PROJECT 0.82.02

DATE 82.05.05

FIG. 3



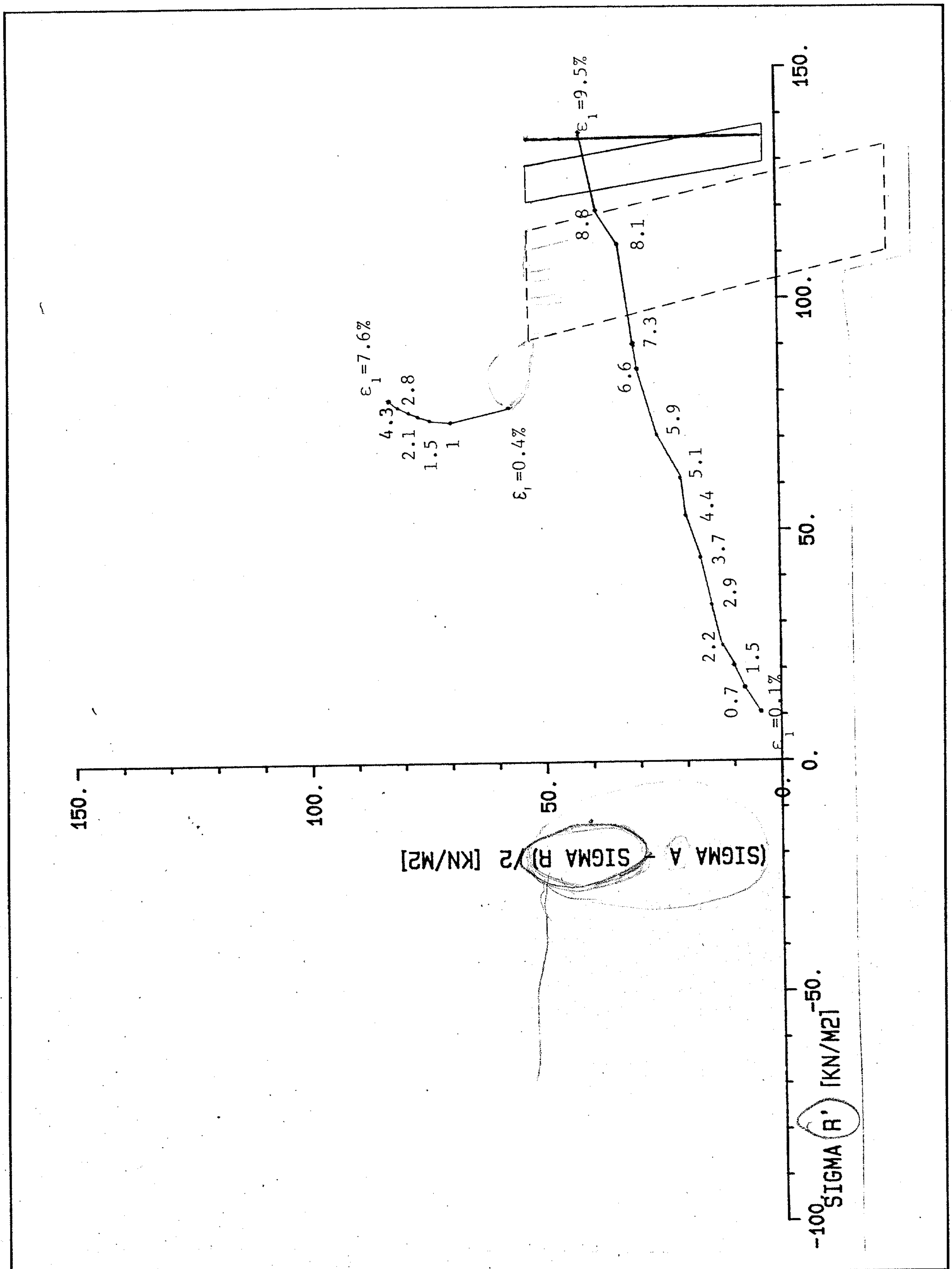
CON1 - Cyl. 71

ISOTROPICAL LOADING AND UNLOADING (DRAINED)

BEFORE OEDOPATH

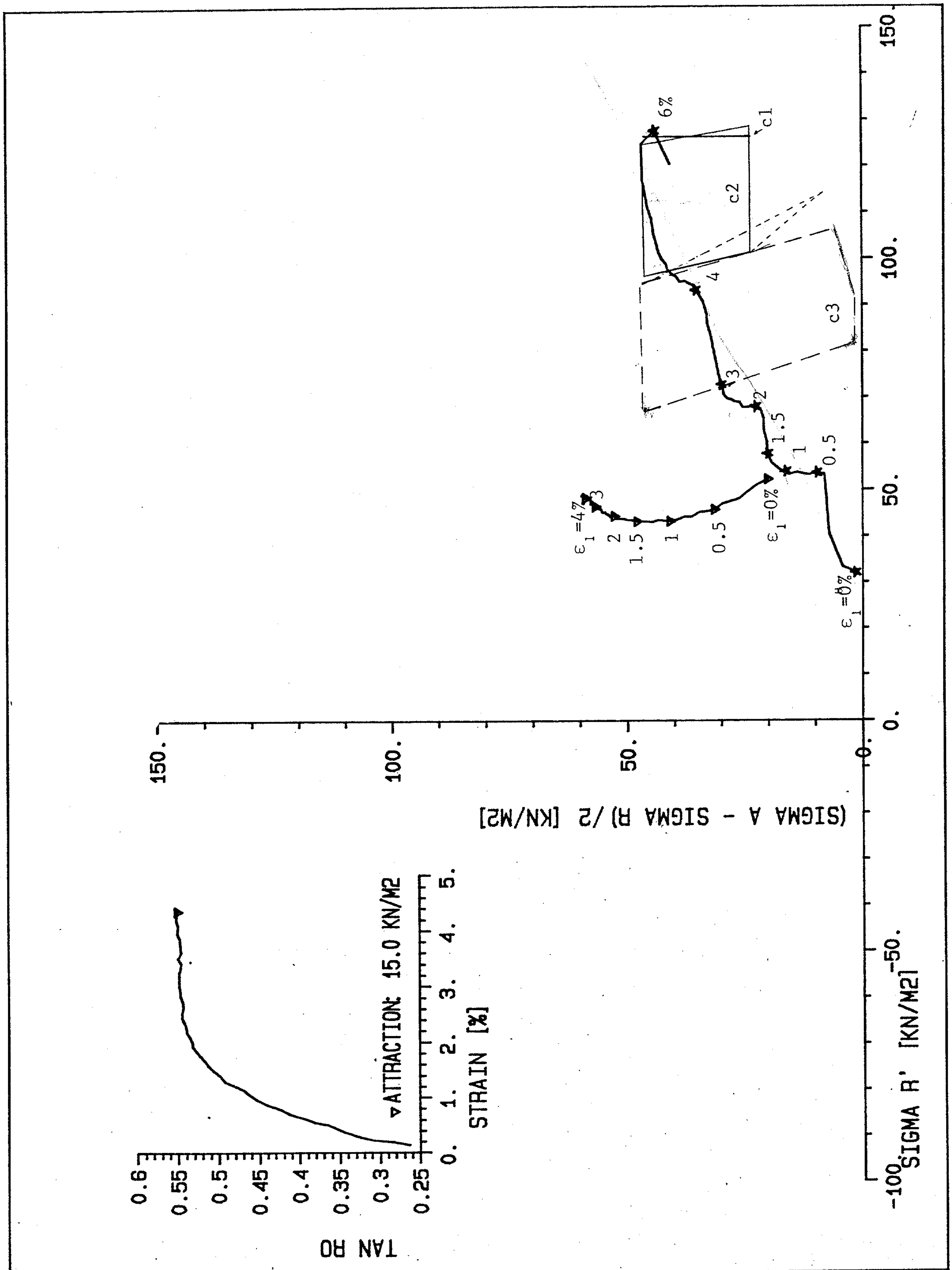
PROJECT	0.82.02
DATE	82.05.05
FIG.	4

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH



CON1 - Cyl. 71 TRIAXIAL TEST. STRESS PATHS AND CYCLE BLOCKS	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 5

BJÆRUM grafiske as

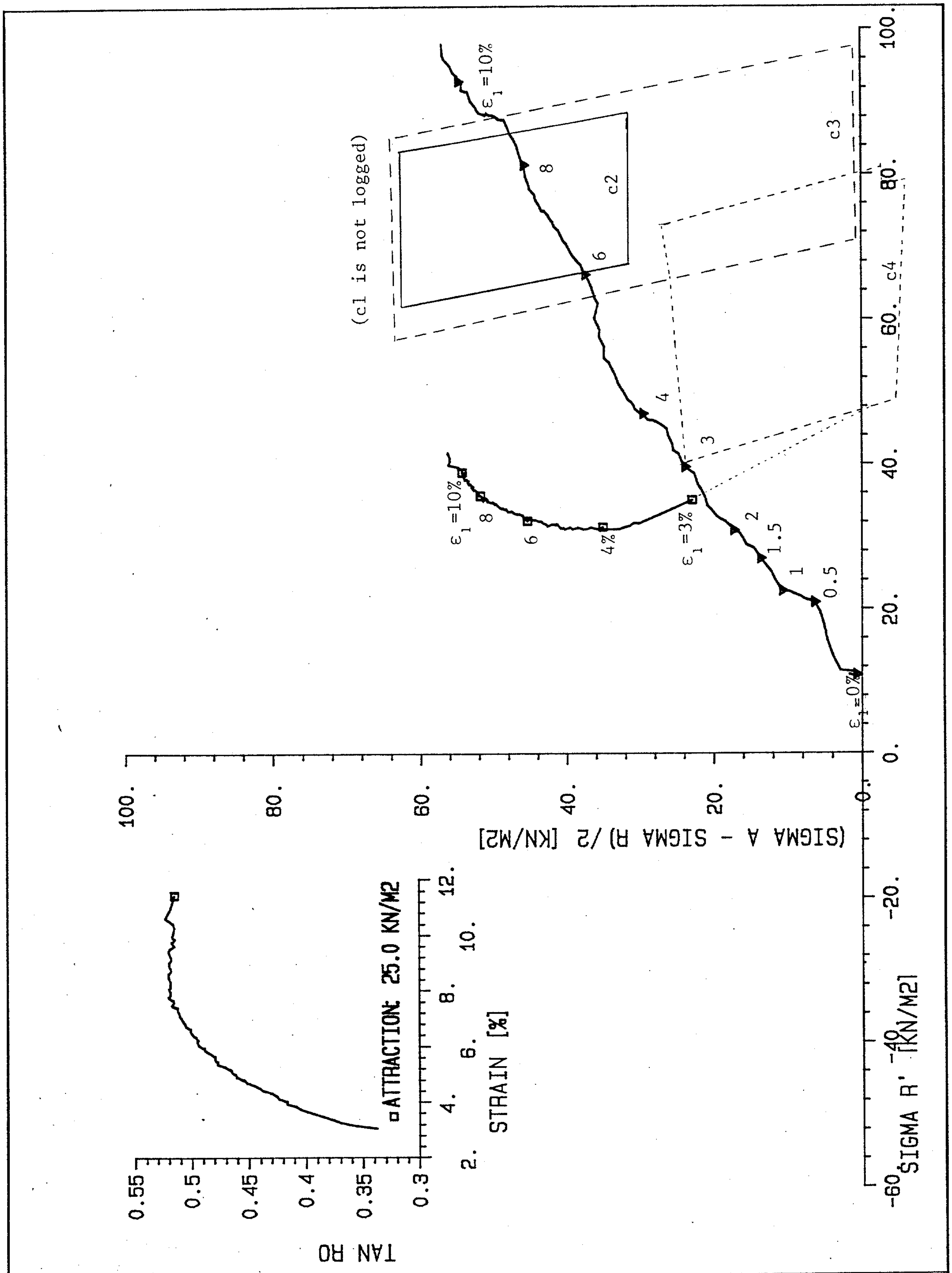


CN102 - Cyl. 71

TRIAXIAL TEST. STRESS PATHS AND CYCLE BLOCKS

PROJECT	0.82.02
DATE	82.05.05
FIG.	6

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH



CN103 - Cyl. 71

TRIAXIAL TEST. STRESS PATHS AND CYCLE BLOCKS

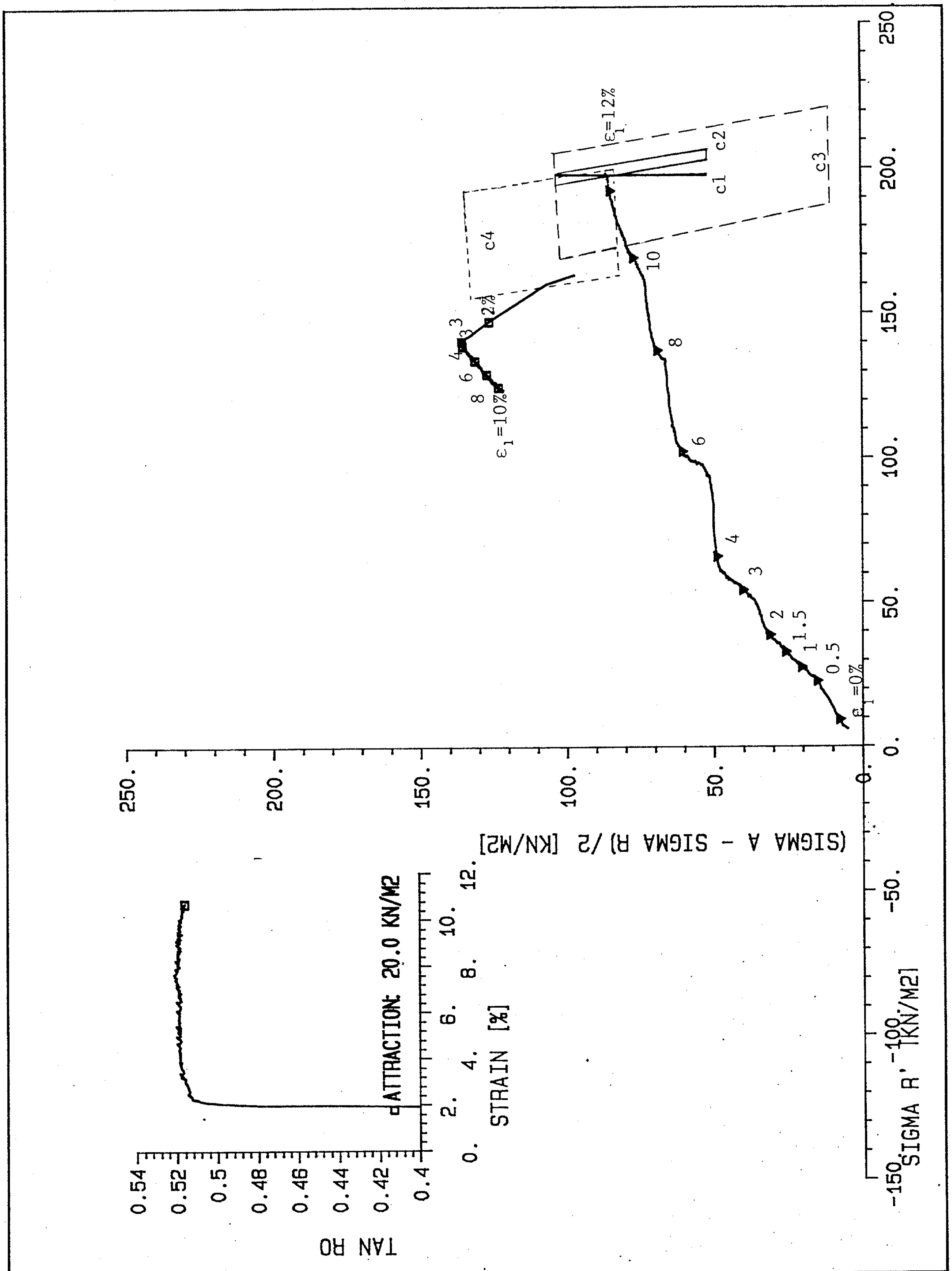
PROJECT 0.82.02

DATE 82.05.05

FIG. 7

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as



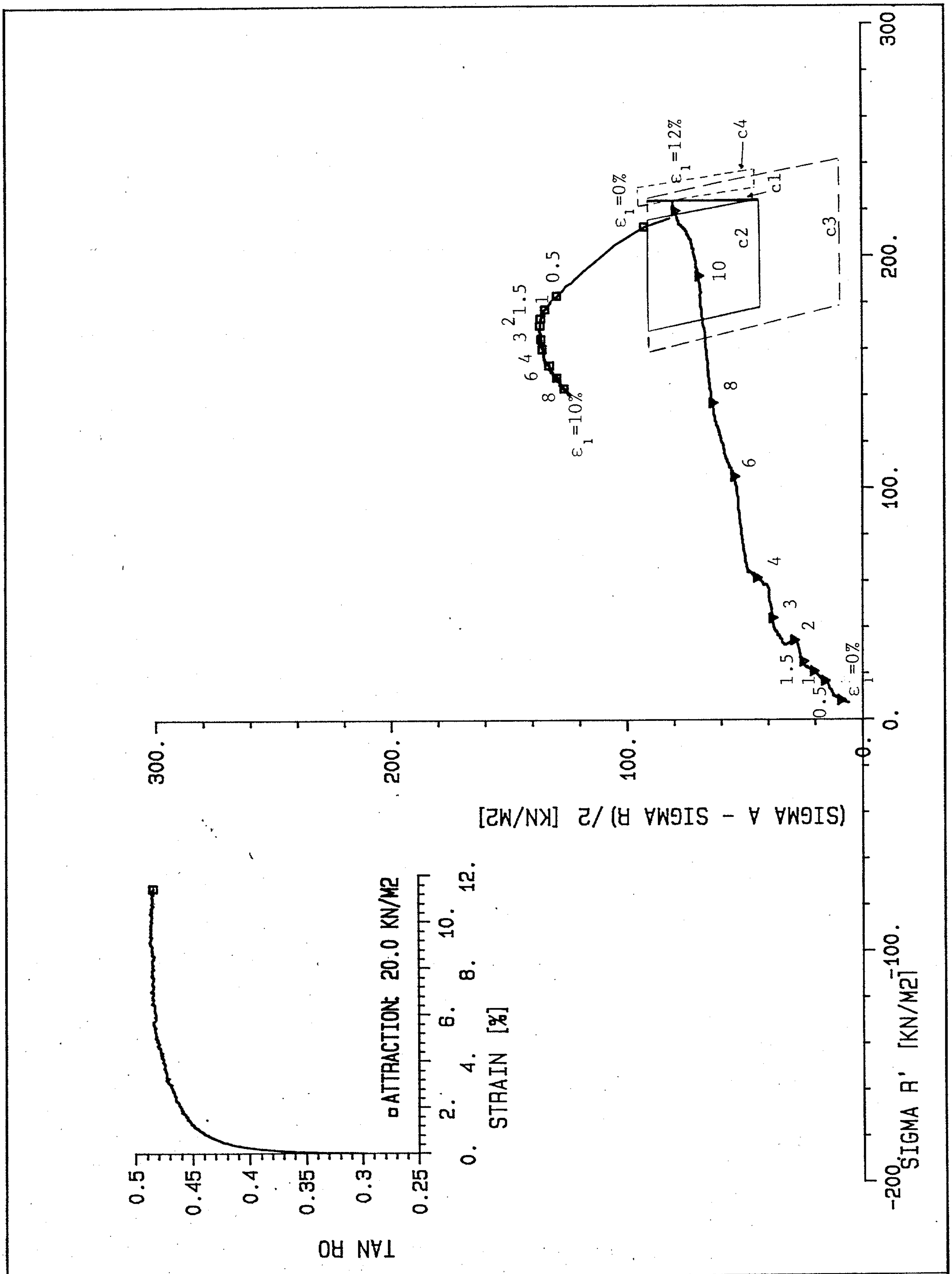
CON10 - Cyl. 119

TRIAXIAL TEST. STRESS PATHS AND CYCLE BLOCKS

PROJECT	0.82.02
DATE	82.05.05
FIG.	8

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

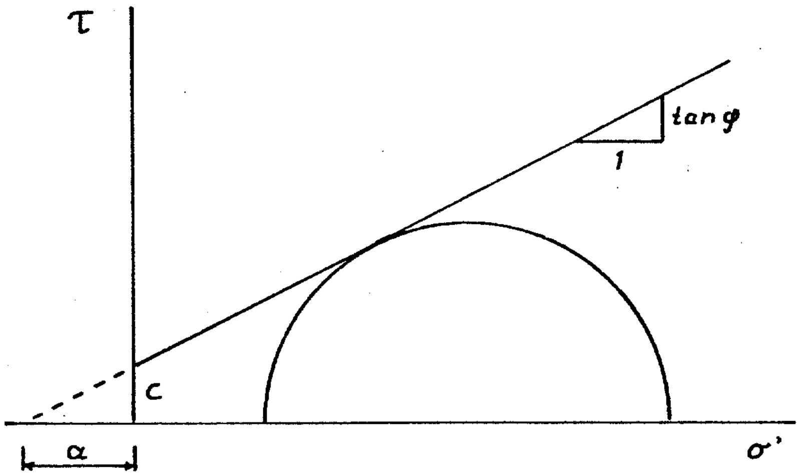
BJÆRUM grafiske as



CON11 - Cyl. 119 TRIAXIAL TEST. STRESS PATHS AND CYCLE BLOCKS	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 9

BJÆRUM grafiske as

DEFINITION: The attraction a is the negative intercept of the σ' - axis by the extention of the Coulomb failure line



a = attraction

c = cohesion

$\tan\phi$ = friction

$$\tau_f = c + \sigma' \tan\phi$$

$$\tau_f = (a + \sigma') \tan\phi$$

$$c = a \tan\phi$$

DEFINITION: The undrained excess porepressures from static loading can be computed by the equation

$$\Delta u = \Delta\sigma_{oct} - D\,(\Delta\sigma_1 - \Delta\sigma_3)$$

where

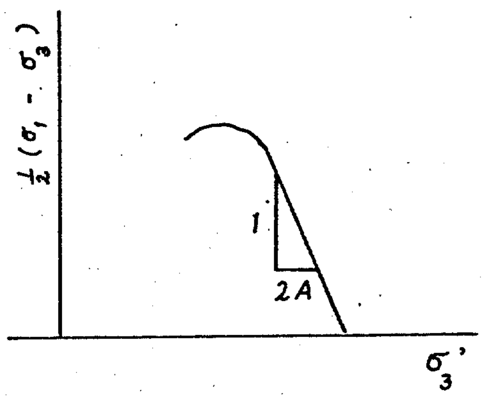
$$\sigma_{oct} = \frac{1}{3}\,(\sigma_1 + \sigma_2 + \sigma_3)$$

D = dilatancy parameter

($D<0$ - contractant behaviour

$D=0$ - neutral behaviour

$D>0$ - dilatant behaviour)



D is related with Skempton's parameter A in his equation

$$\Delta u = \Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)$$

through:

$D = \frac{1}{3} - A$ for triaxial compr. tests

$D = \frac{2}{3} - A$ for triaxial extention tests

DEFINITION OF ATTRACTION AND DILATANCY PARAMETER	PROJECT 0.82.02
	DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 10

STATIC TRIAXIAL TEST RESULTS

TEST 10	CON1	CN102	CN103	CON10	CON11
Cyl.No.	71	71	71	119	119
z(m)	35.27	35.40	35.50	62.68	62.77
OEDOPATH					
K_0'	0.65	0.59	0.52	0.55	0.60
SHEAR					
D	~0.25	~0.16	~0.25	0	-0.1
a	20	15	25	20	20
$\tan\phi$	0.52	0.55	0.52	0.50	0.49

K_0' is measured at the end of the oedopath.

Def.: $K_0' = \dfrac{\sigma'_r + a}{\sigma'_a + a}$

D is the dilatancy parameter for the equation

$$\Delta u = \frac{1}{3}(\Delta\sigma_1 + \Delta\sigma_2 + \Delta\sigma_3) - D(\Delta\sigma_1 - \Delta\sigma_3)$$

for undrained excess porepressures due to static loading.

D is here computed as a secant value up to a degreee of mobilization f equal to 0.95
(f = mobilized friction/friction at failure = $\tan\rho/\tan\phi$)

TRIAXIAL TEST RESULTS FROM STATIC TESTS

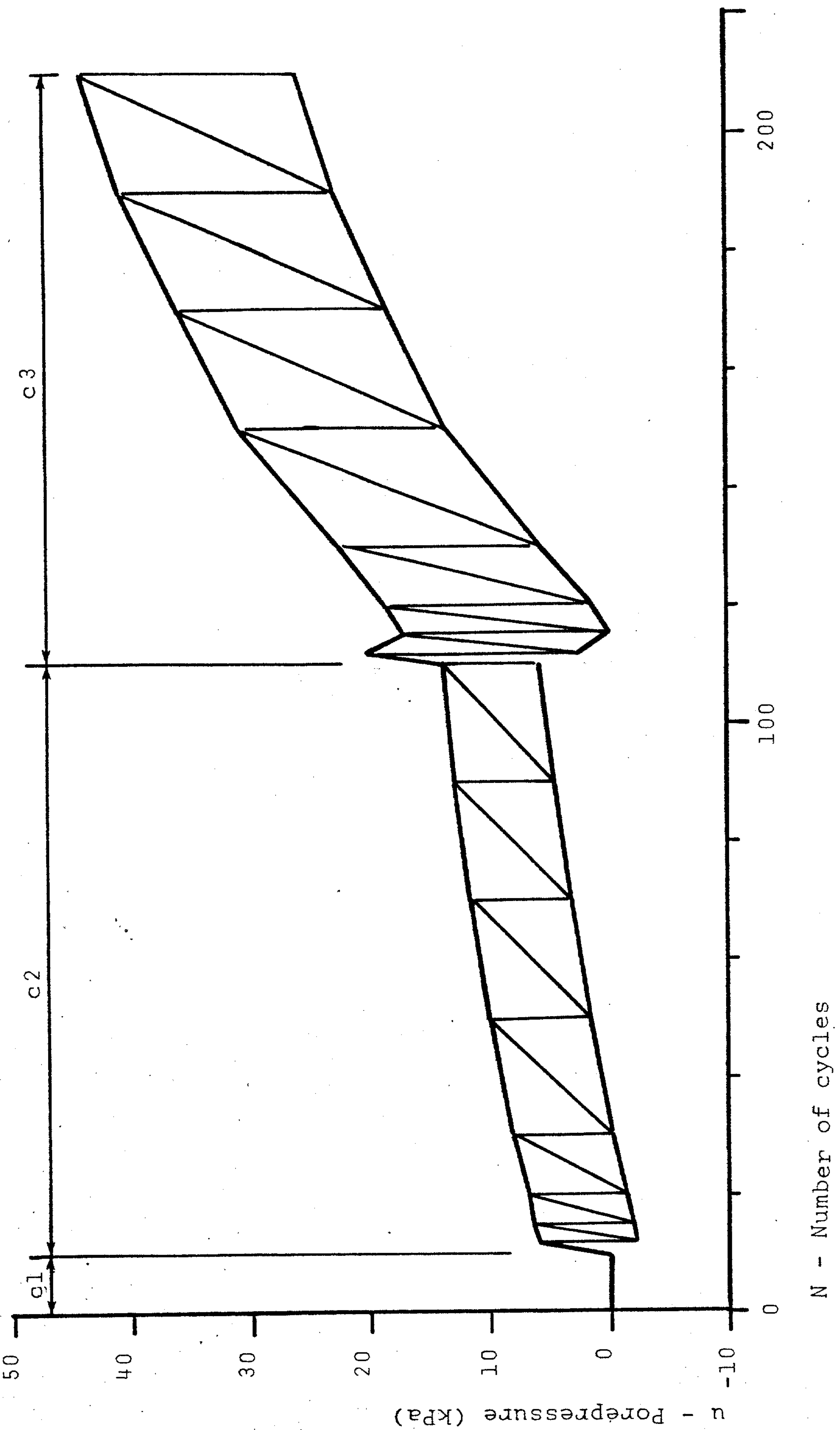
PROJECT 8.82.02

DATE 82.05.05

FIG. 11

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as

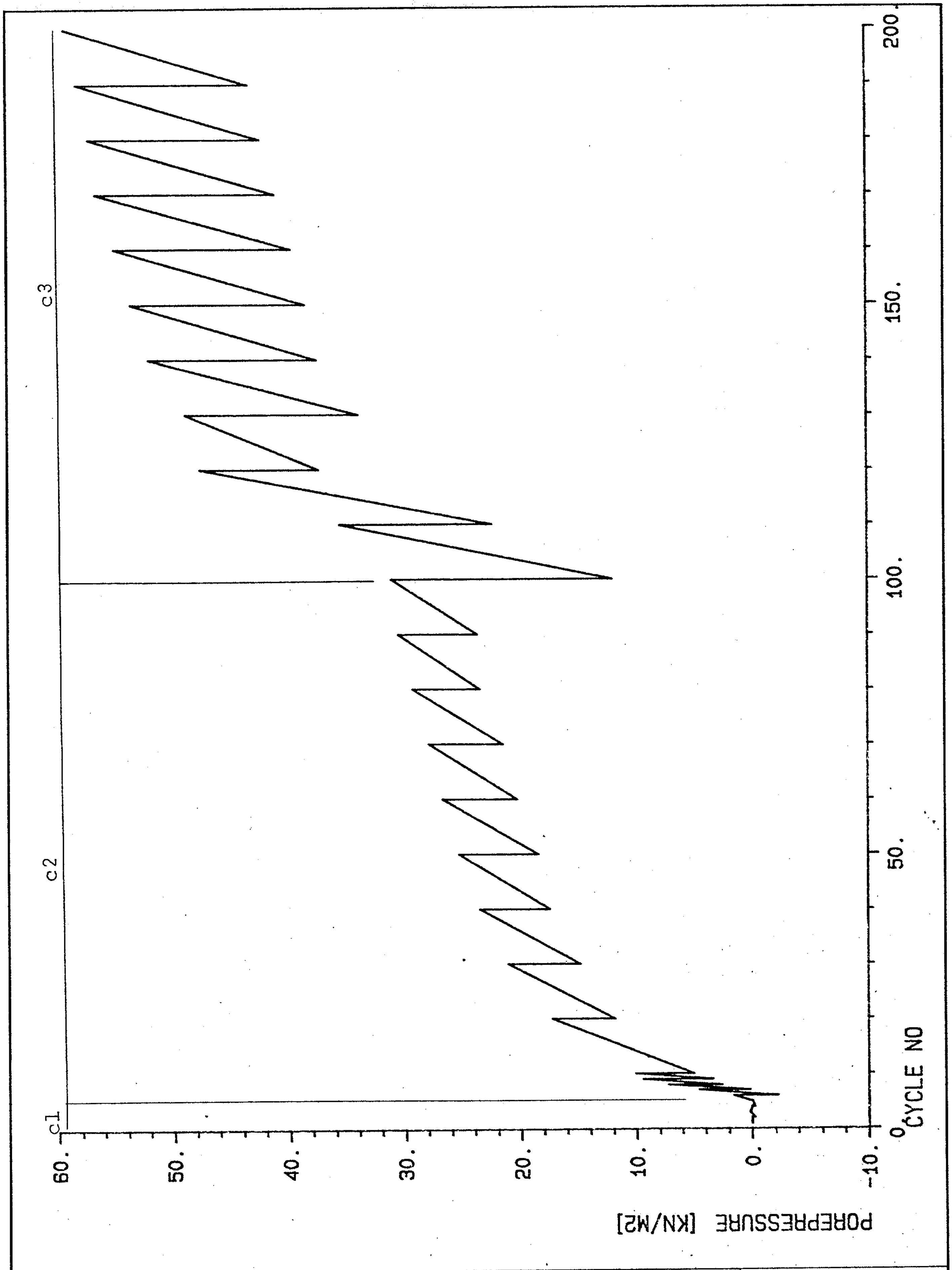


CON1 - Cyl. 71

TRIAXIAL TEST. POREPRESSURES DURING CYCLING

PROJECT	0.82.02
DATE	82.05.05
FIG.	12

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH



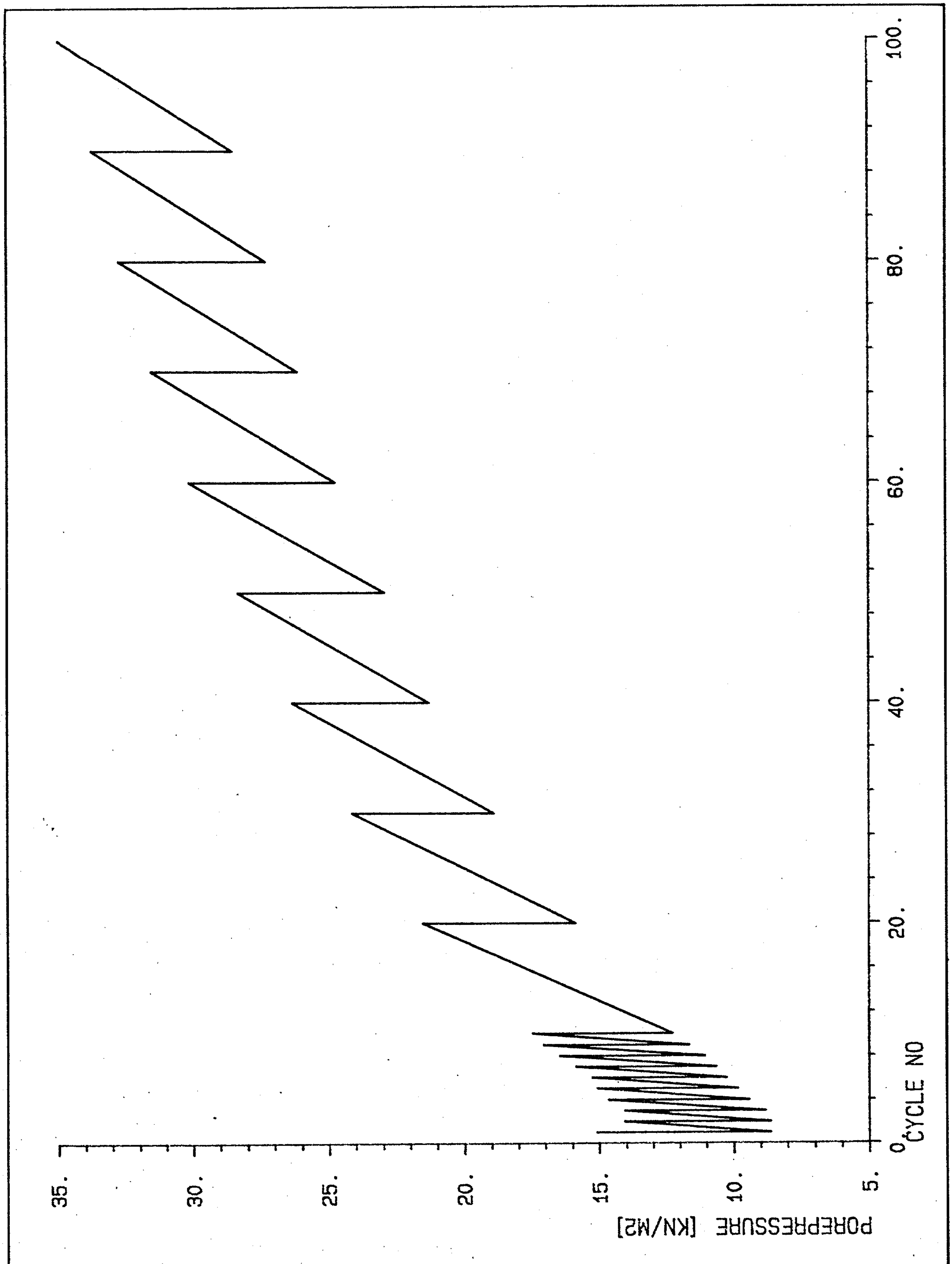
CN102 - Cyl. 71

TRIAXIAL TEST. POREPRESSURES DURING CYCLING

PROJECT	0.82.02
DATE	82.05.05
FIG.	13

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as

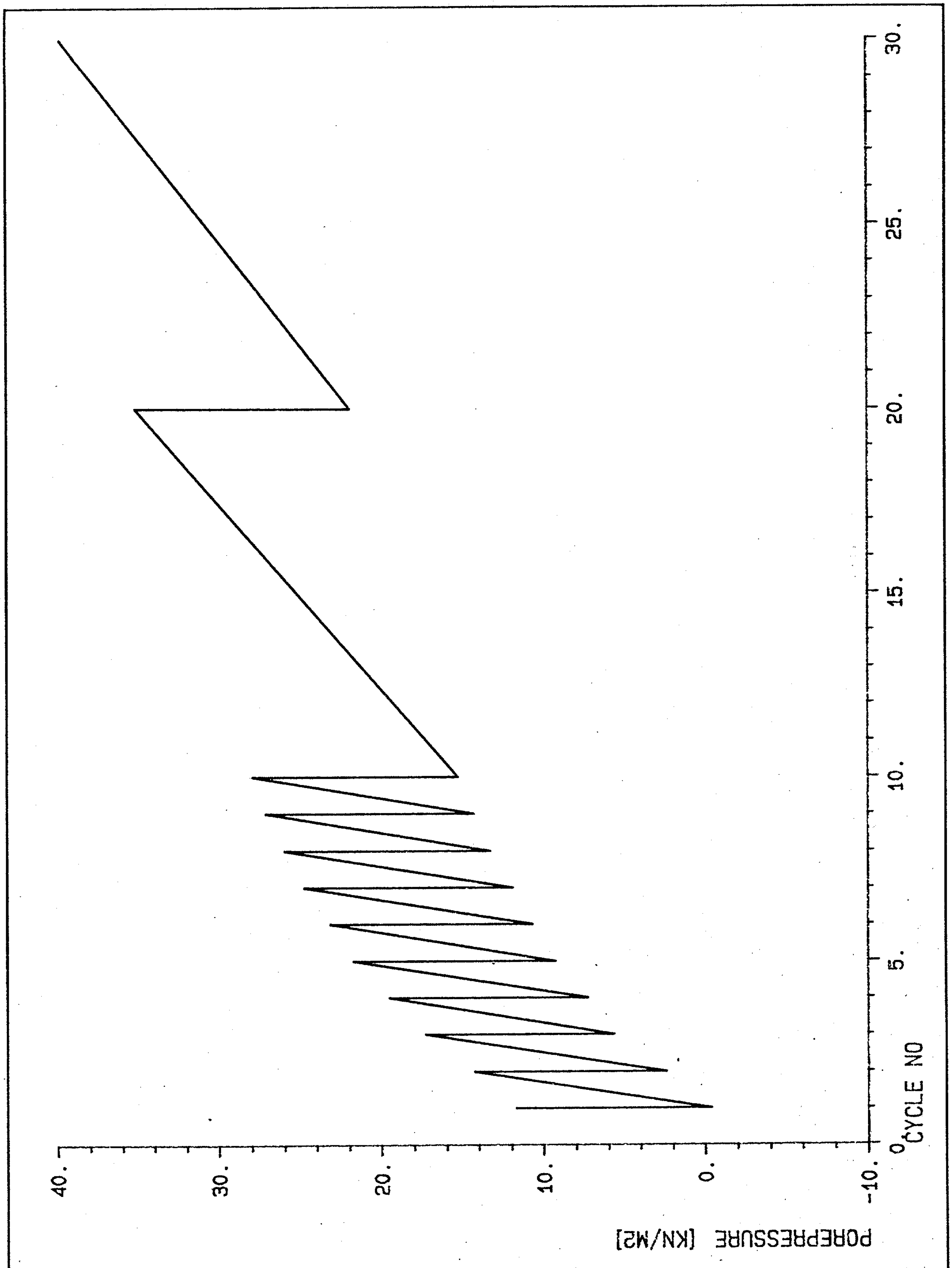


CN103 c2 - Cyl. 71

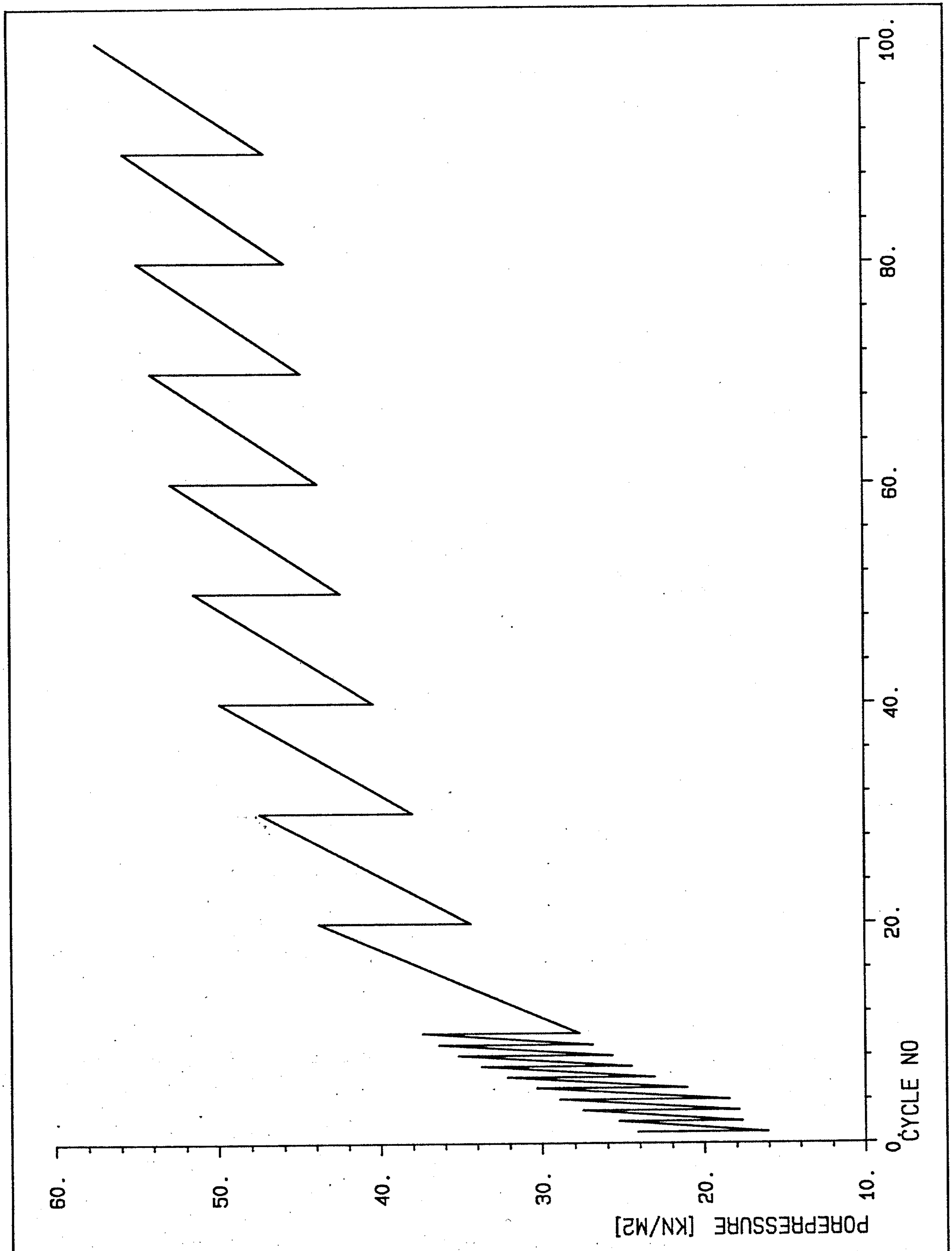
TRIAXIAL TEST. POREPRESSURES DUDRING CYCLING

PROJECT	0.82.02
DATE	82.05.05
FIG.	14

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH



CN103 c3 - Cyl. 71 TRIAXIAL TEST. POREPRESSURES DURING CYCLING	PROJECT 0.82.02
	DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 15

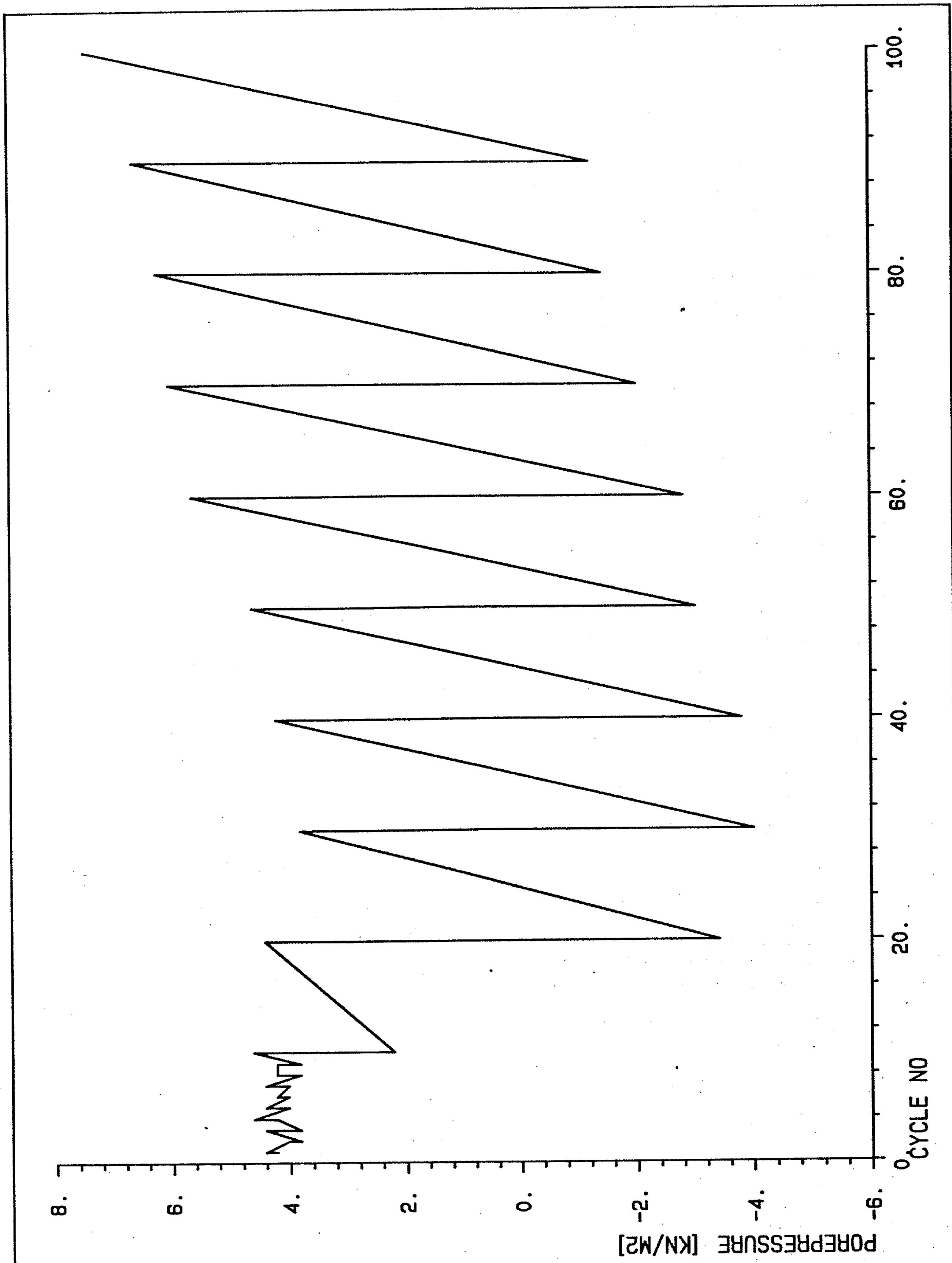


CN103 c4 - Cyl. 71

TRIAXIAL TEST. POREPRESSURES DURING CYCLING

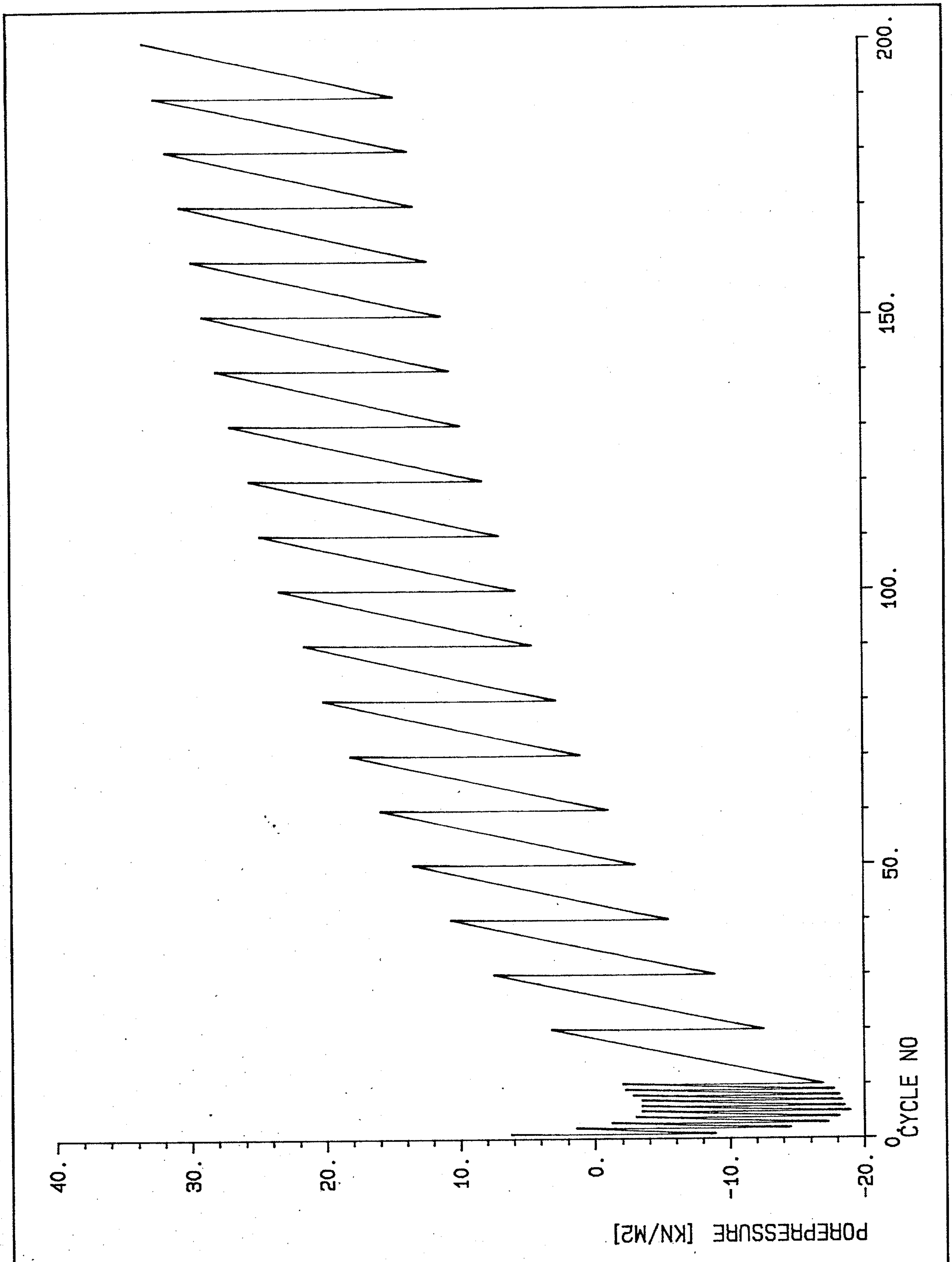
PROJECT	0.82.02
DATE	82.05.05
FIG.	16

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

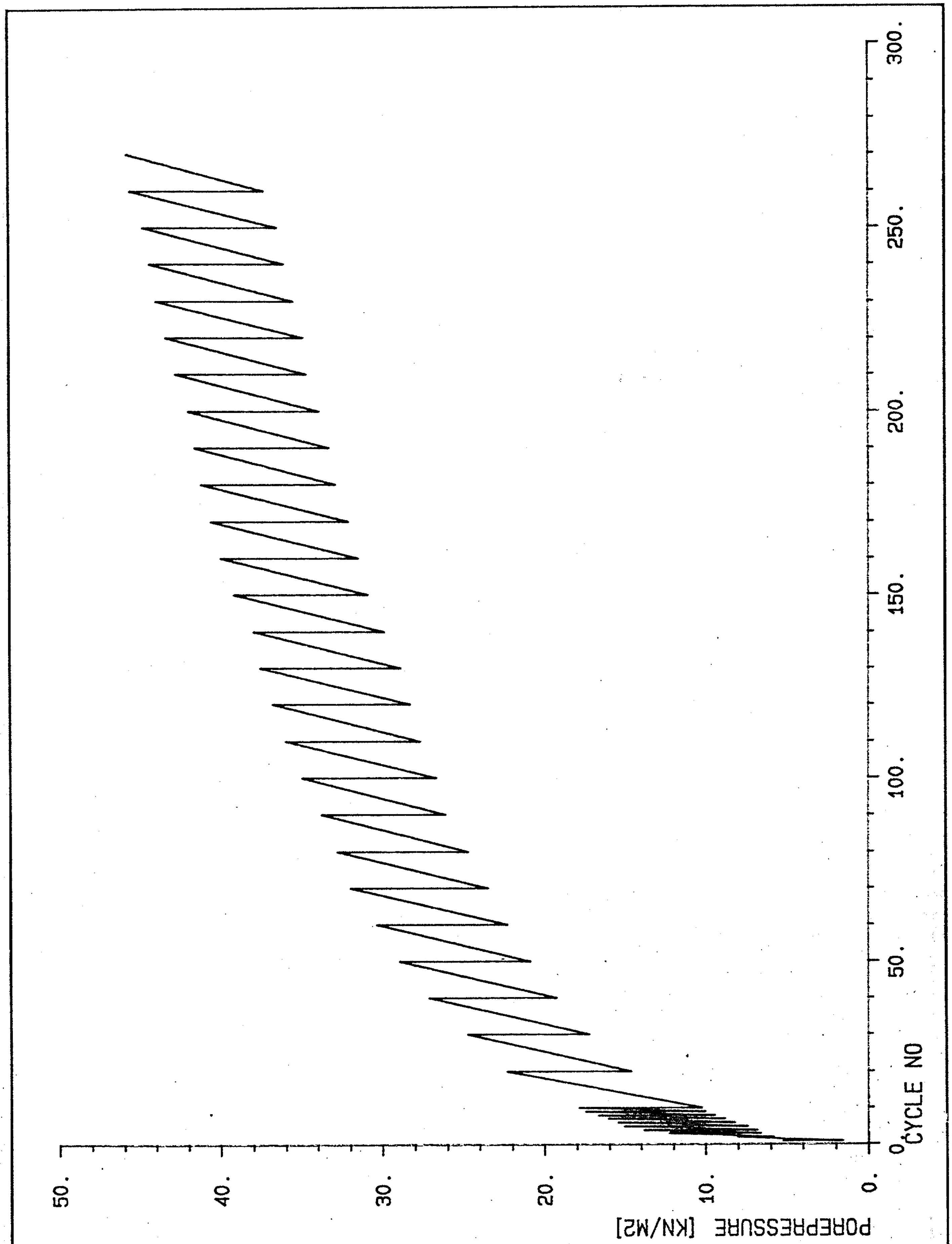


CON10 cl and c2 - Cyl. 119 TRIAXIAL TEST. POREPRESSURES DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 17

BJÆRUM grafiske as



CON10 c3 - Cyl. 119 TRIAXIAL TEST. POREPRESSURES DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 18



CON10 c4 - Cyl. 119

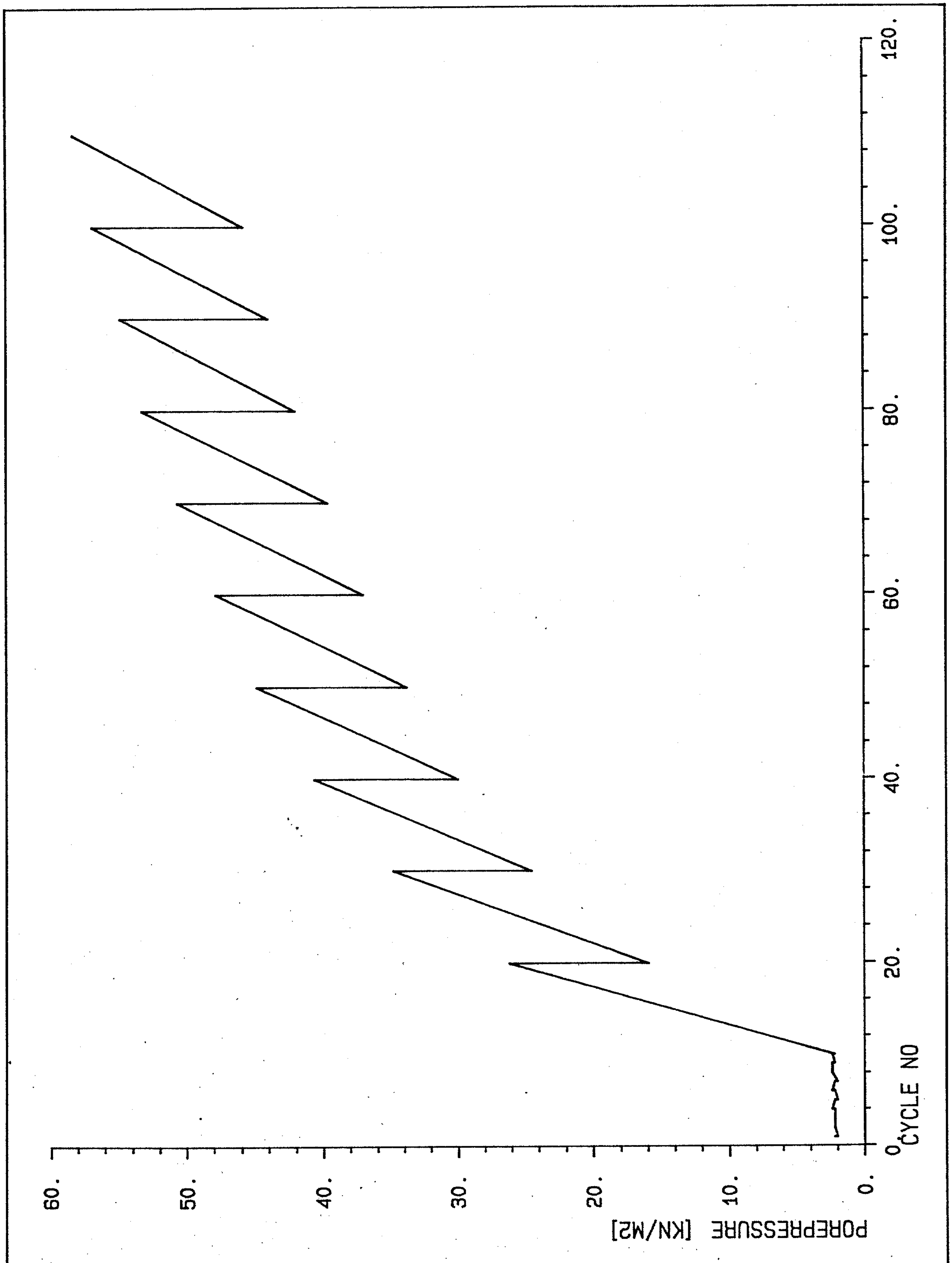
TRIAXIAL TEST. POREPRESSURES DURING CYCLING

PROJECT 0.82.02

DATE 82.05.05

FIG. 19

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH



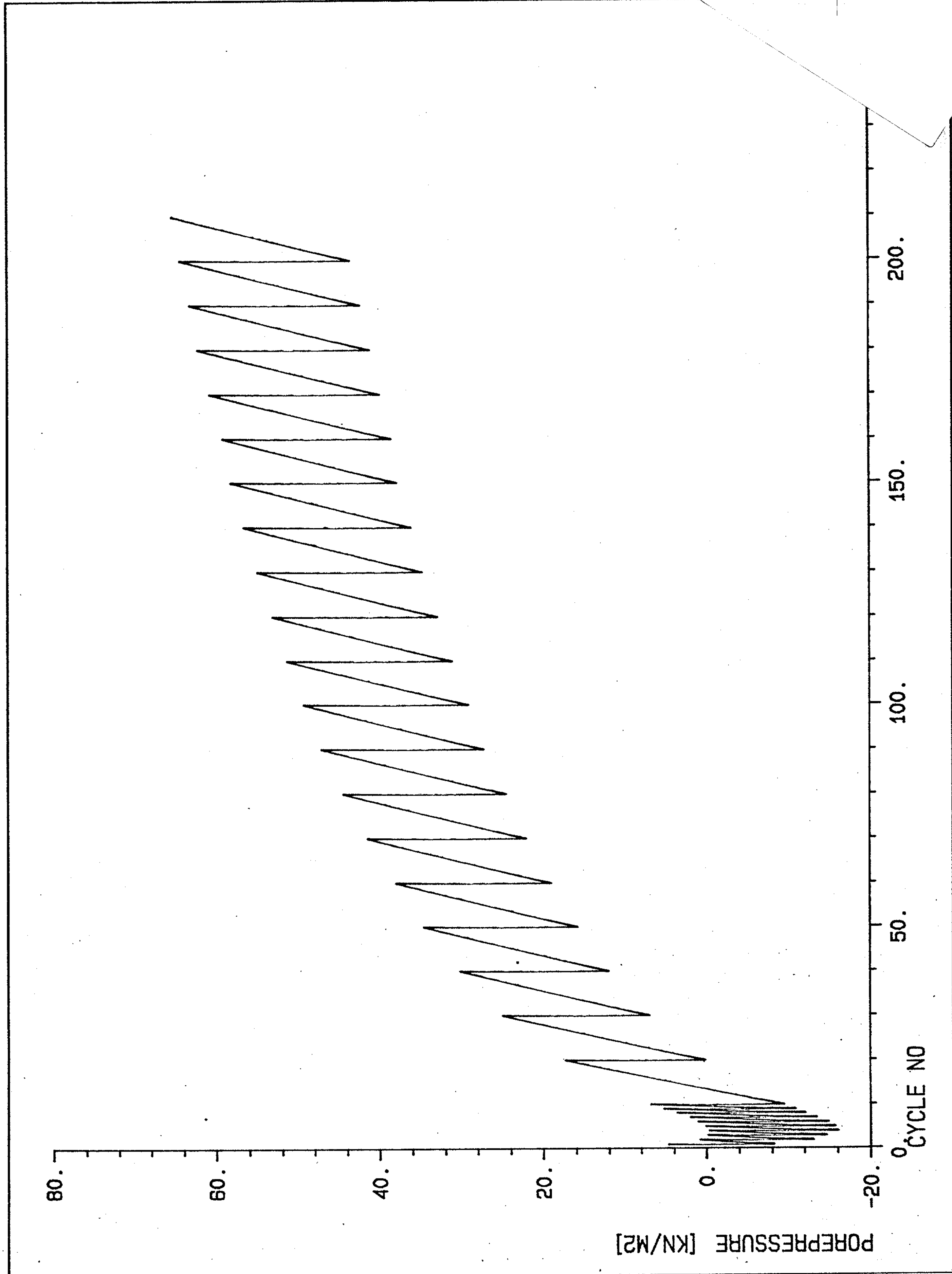
CON11 c1 and c2 - Cyl. 119

TRIAXIAL TEST. POREPRESSURES DURING CYCLING

PROJECT	0.82.02
DATE	82.05.05
FIG.	20

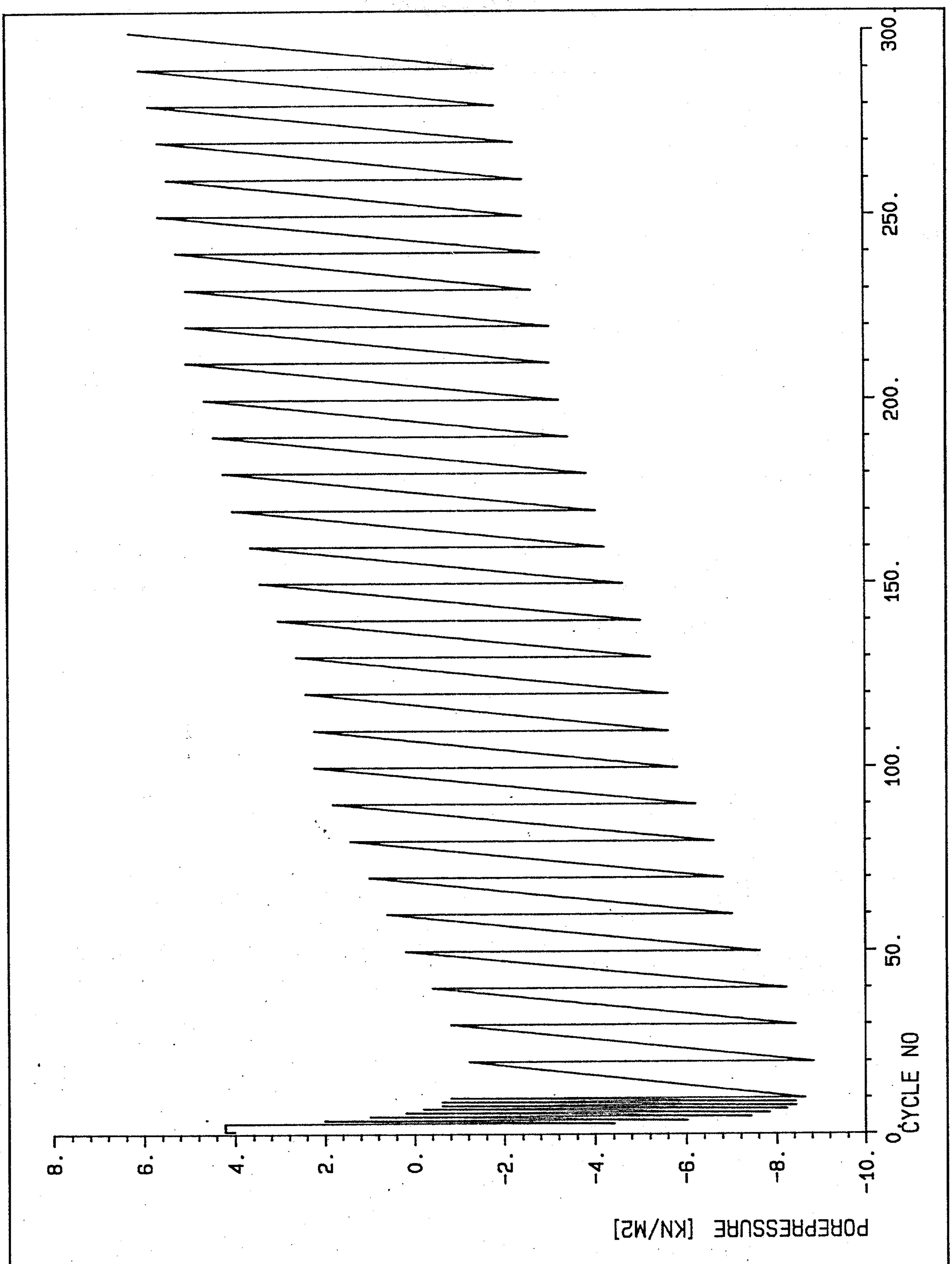
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as



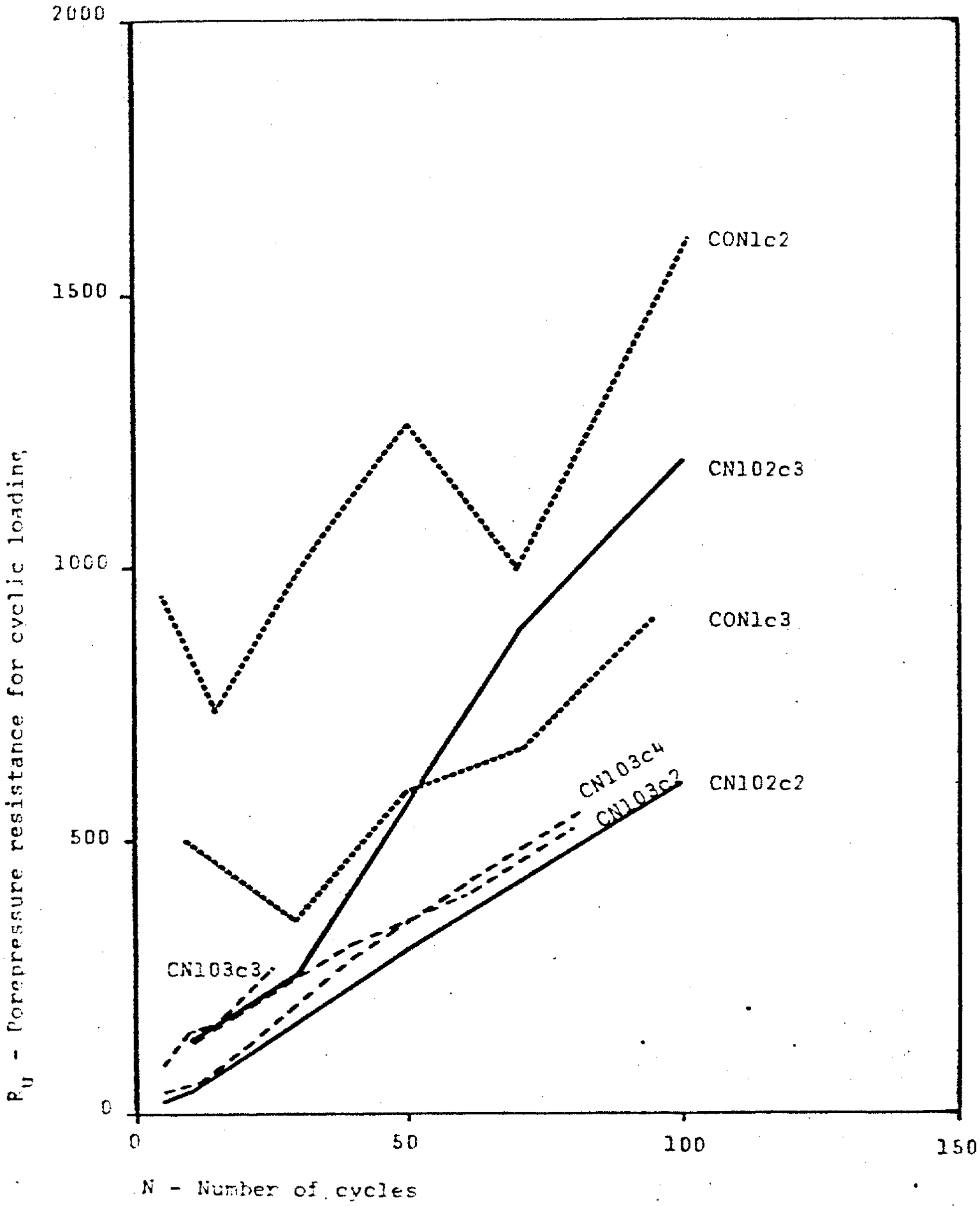
CON11 c3 - Cyl. 119 TRIAXIAL TEST. POREPRESSURES DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 21

BJÆRUM grafiske as



CON11 c4 - Cyl. 119 TRIAXIAL TEST. POREPRESSURES DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 22

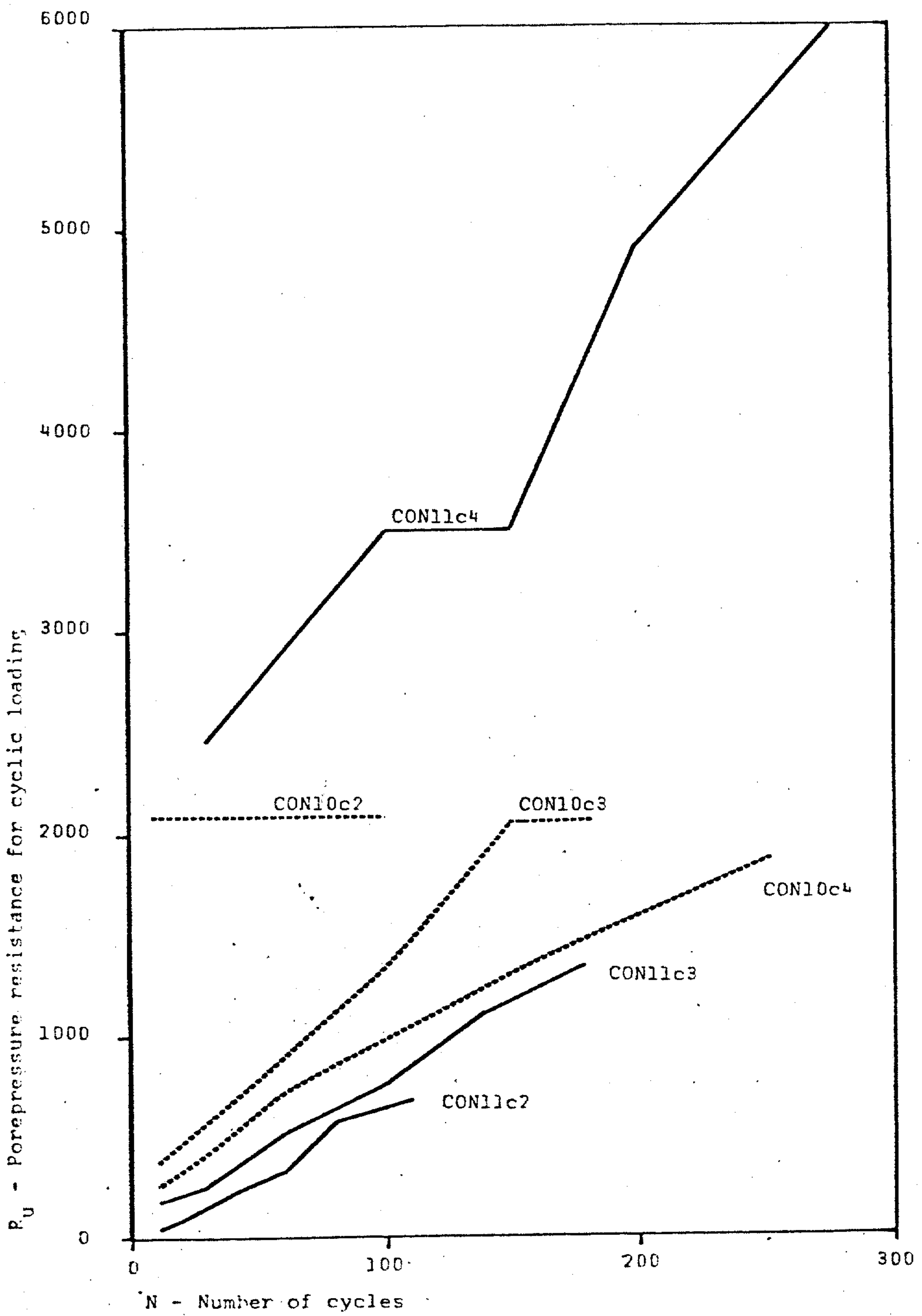
BJÆRUM grafiske as



DEF.: $R_u = \Delta\sigma_d$ (dN/du)

Cyl. 71 - POREPRESSURE RESISTANCE FOR CYCLIC LOADING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 23

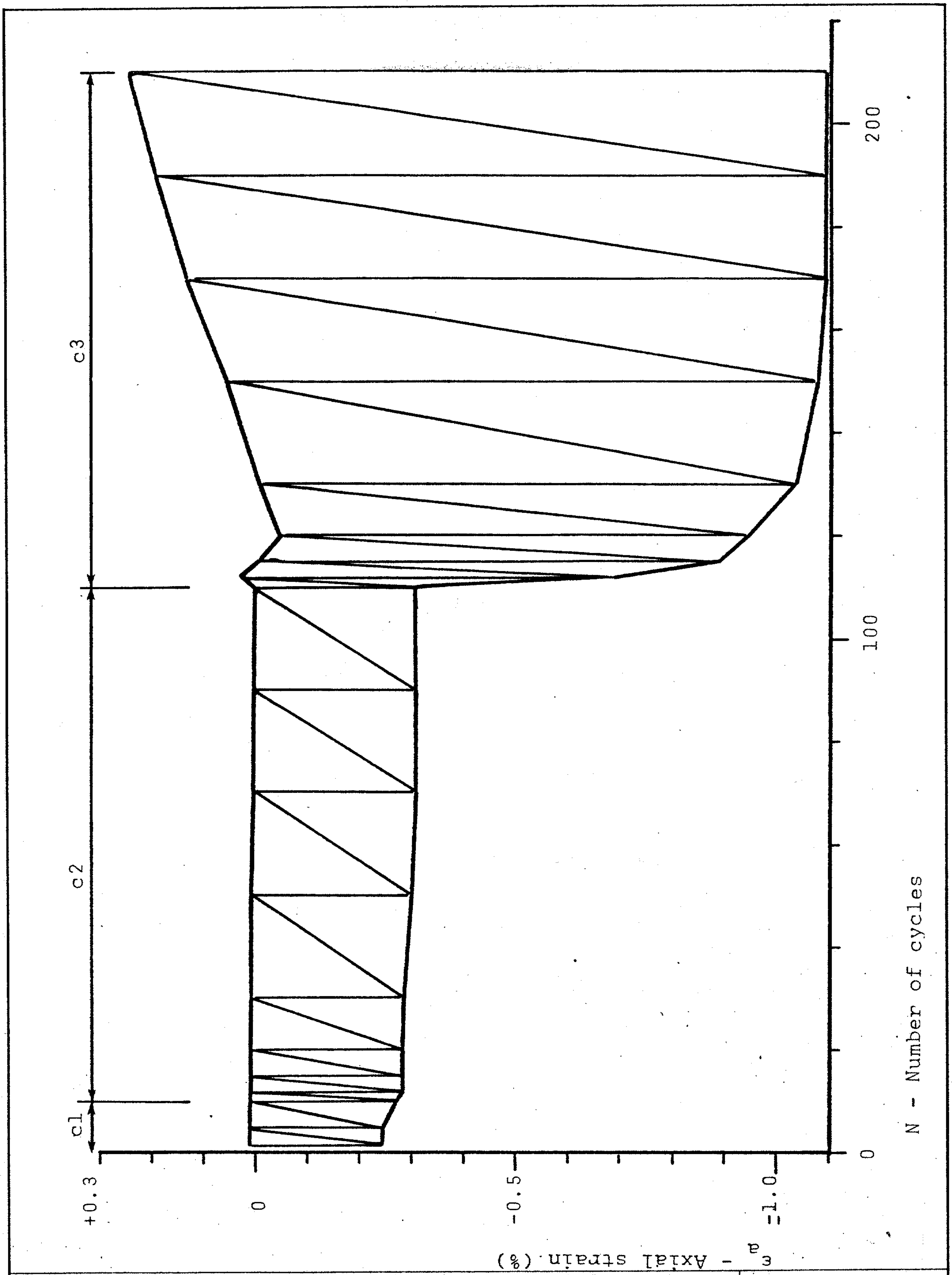
BJÆRUM grafiske as



DEF.: $R_u = \Delta\sigma_d$ (dN/du)

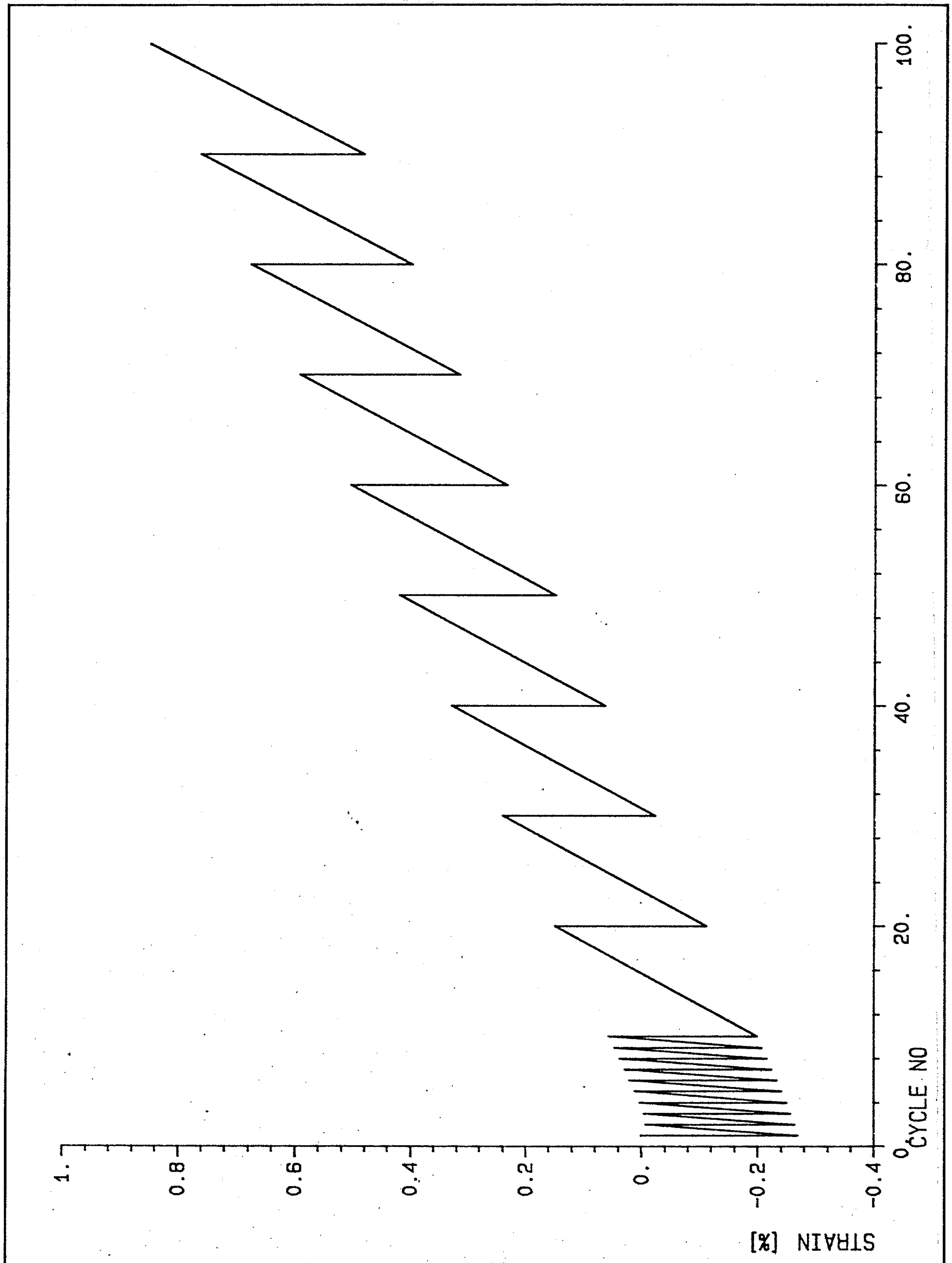
Cyl. 119 - POREPRESSURE RESISTANCE FOR CYCLIC LOADING	PROJECT 0.82.02
	DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 24

BJÆRUM grafiske as



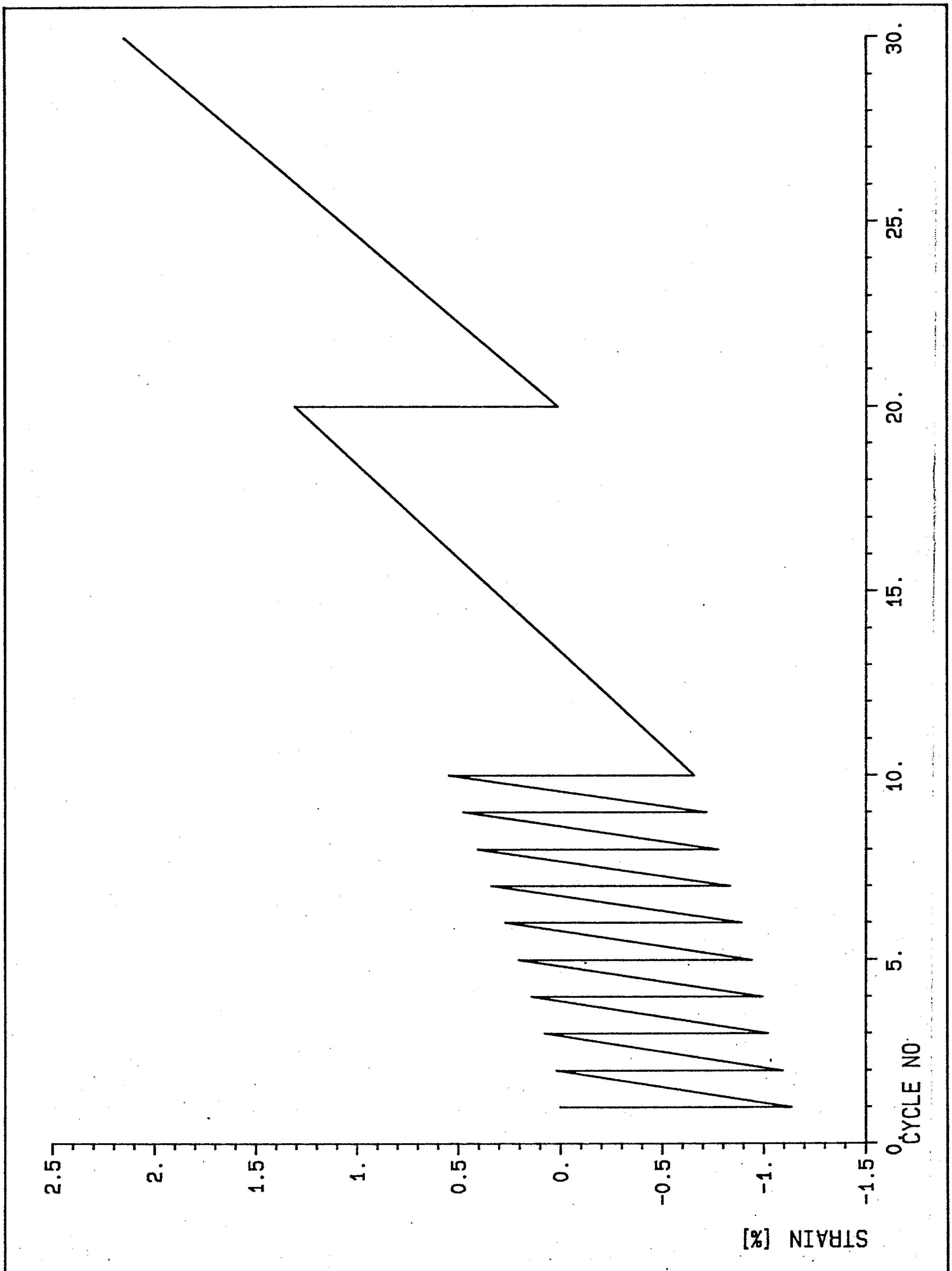
CON1 - Cyl. 71 TRIAXIAL TEST. STRAINS DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 25

BJÆRUM grafiske as



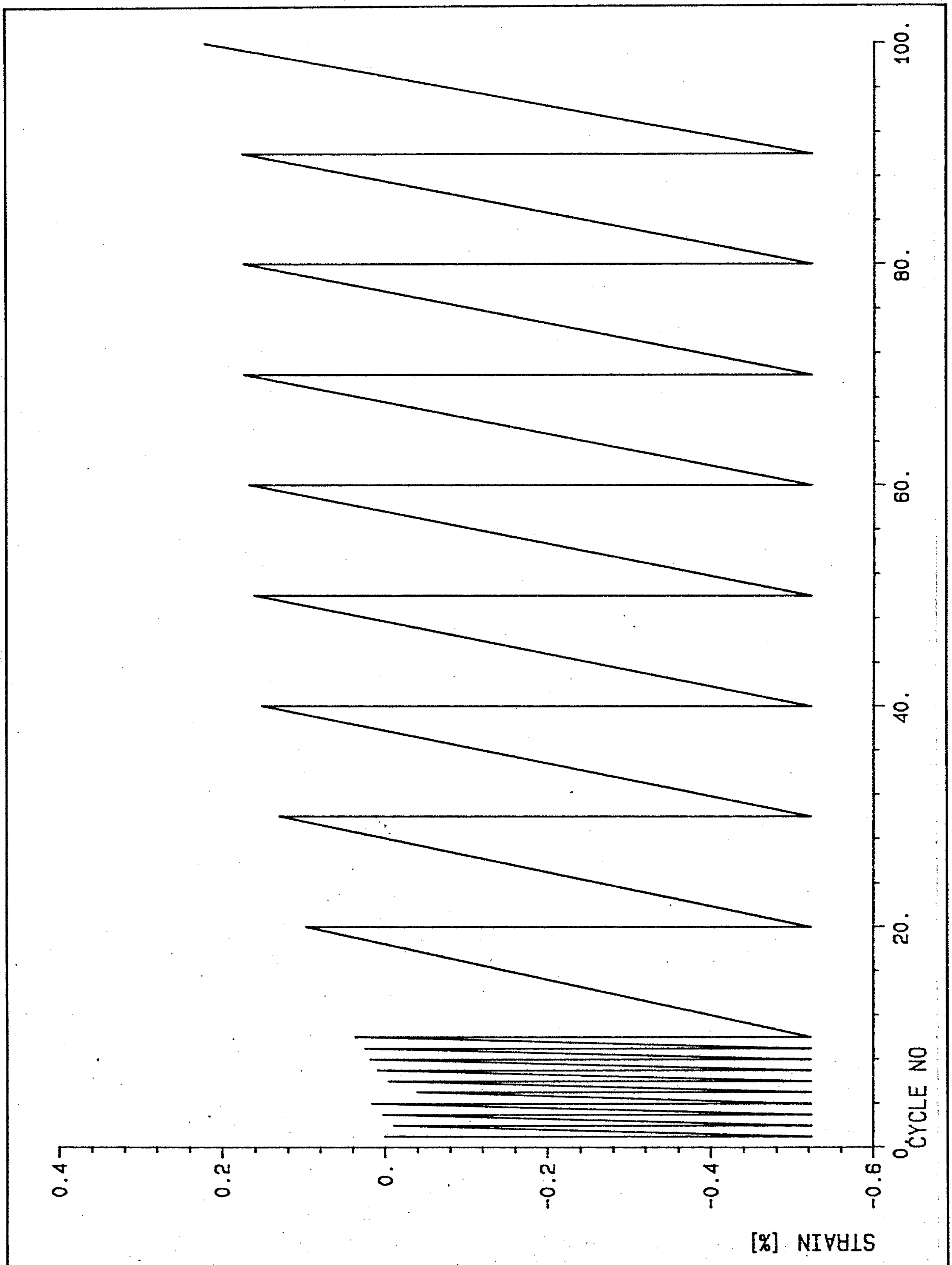
CN103 c2 - Cyl. 71 TRIAXIAL TEST. STRAINS DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 26

BJÆRUM grafiske as

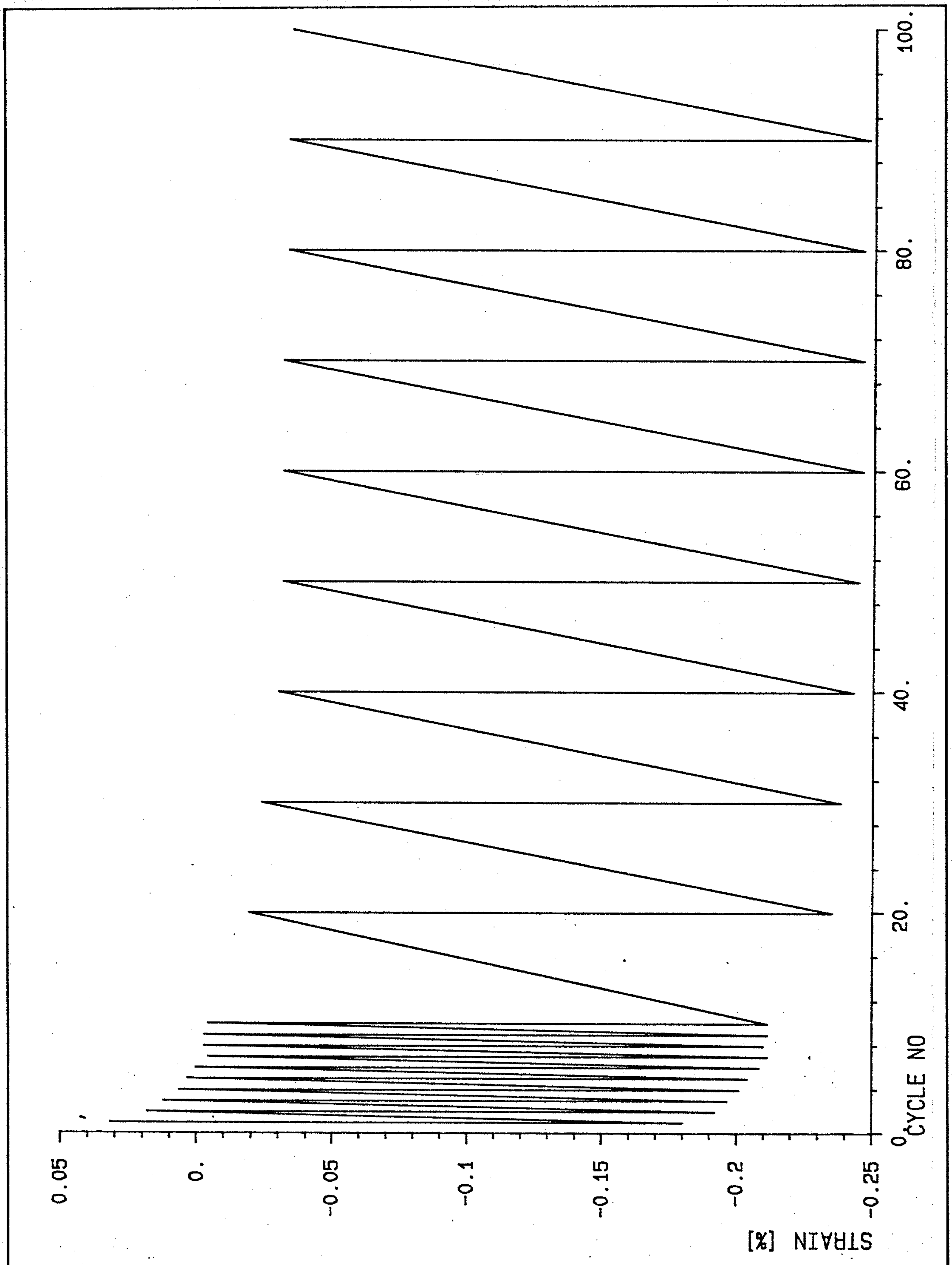


CN103 c3 - Cyl. 71 TRIAXIAL TEST. STRAINS DURING CYCLING	PROJECT 0:82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 27

BJÆRUM grafiske as



CN103 c4 - Cyl. 71 TRIAXIAL TEST. STRAINS DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 28



CON10 c1 and c2 - Cyl. 119

TRIAXIAL TEST. STRAINS DURING CYCLING

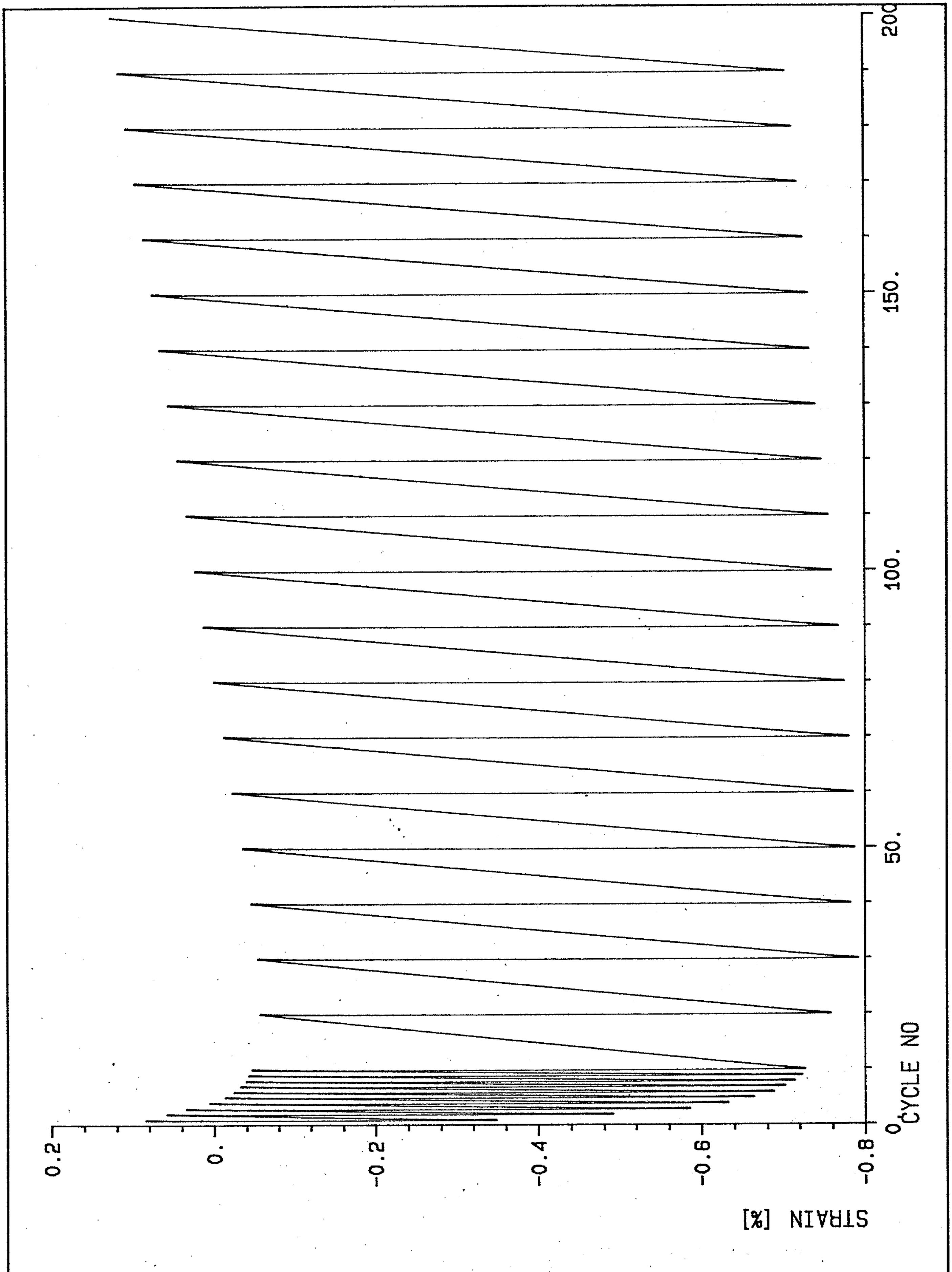
PROJECT 0.82.02

DATE 82.05.05

FIG. 29

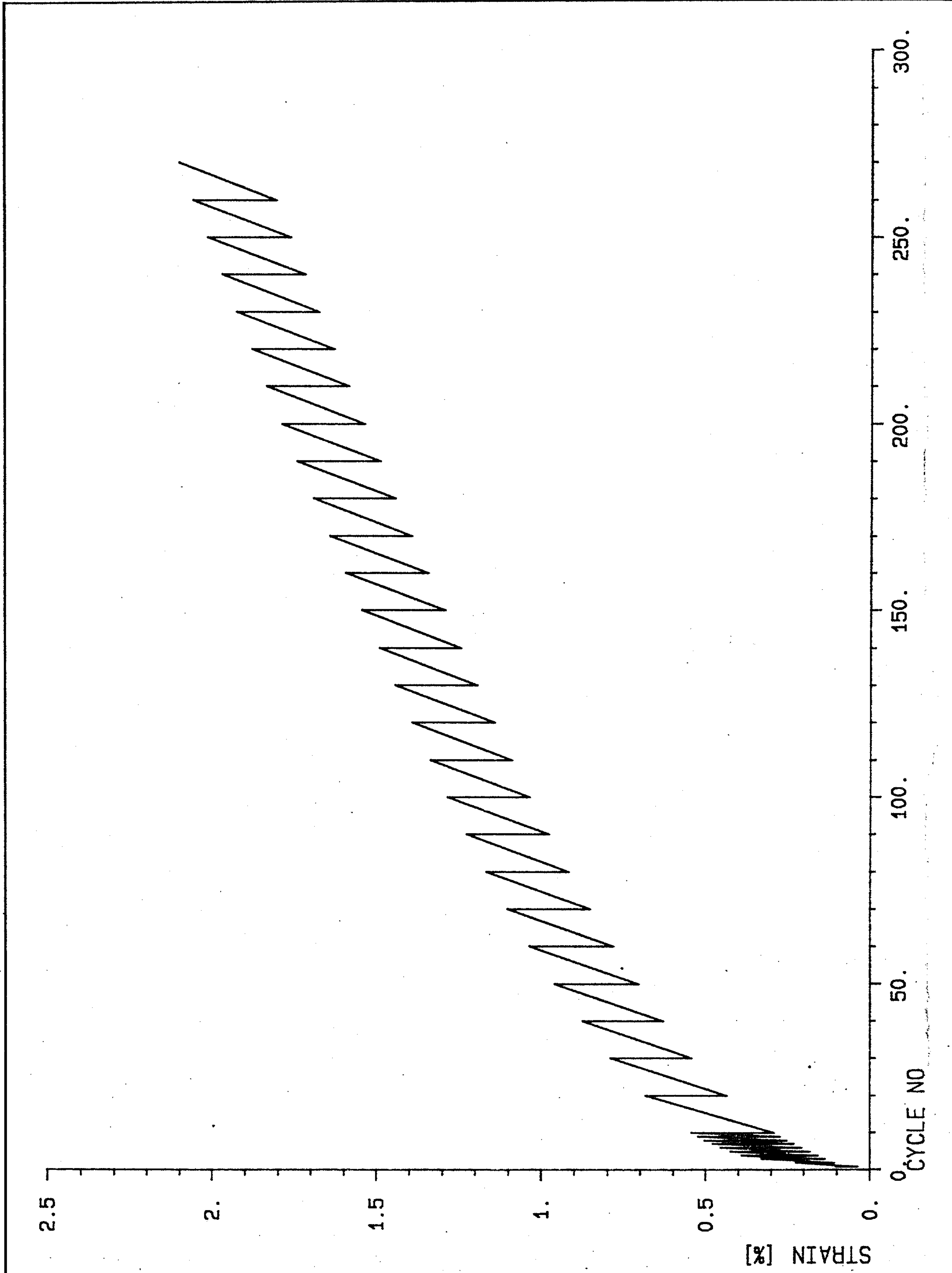
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as



CON10 c3 - Cyl. 119 TRIAXIAL TEST. STRAINS DURING CYCLING	PROJECT 0.82.02
	DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 30

BJÆRUM grafiske as



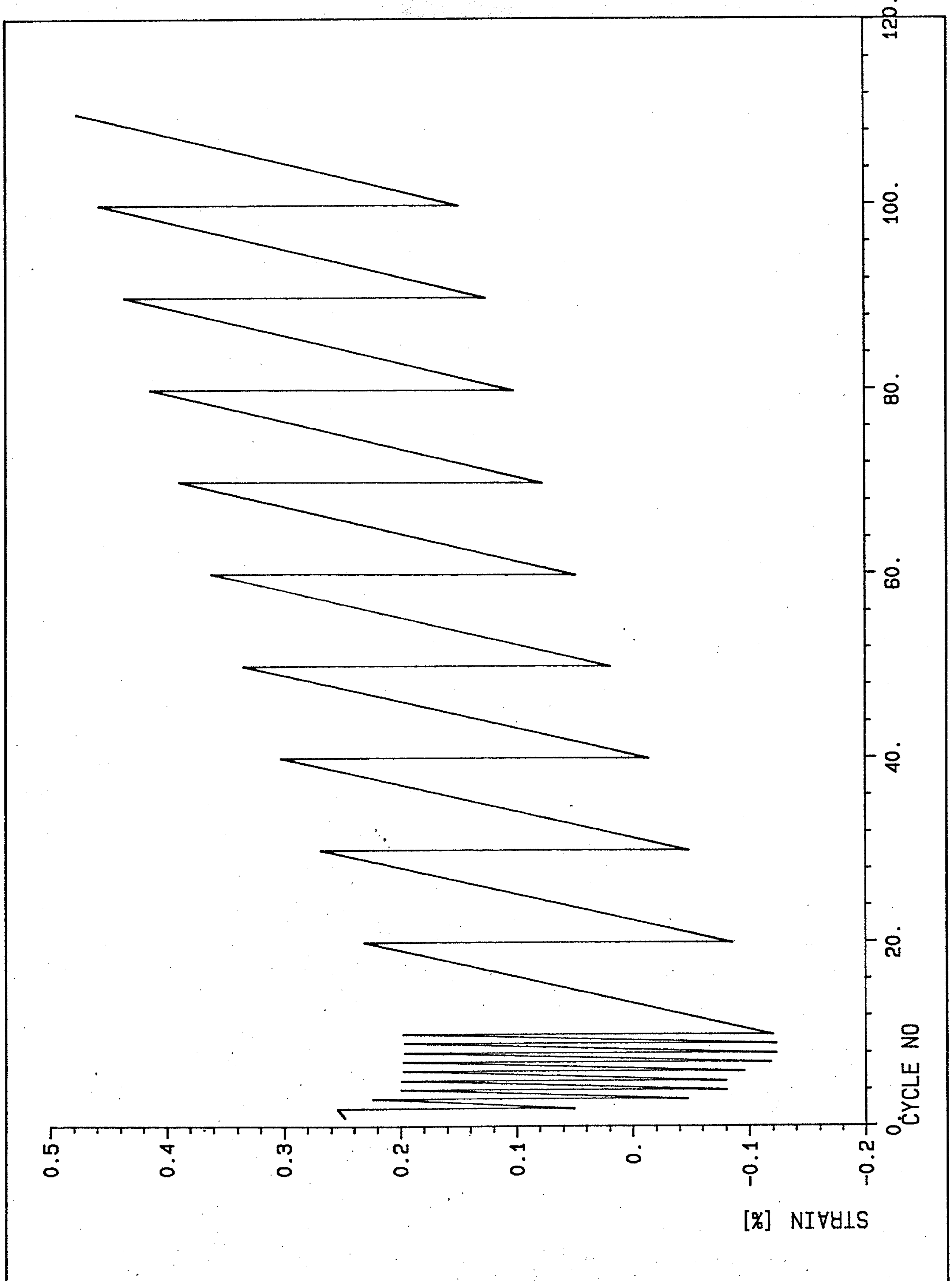
CON10 c4 - Cyl. 119

TRIAXIAL TEST. STRAINS DURING CYCLING

PROJECT	0.82.02
DATE	82.05.05
FIG.	31

GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as



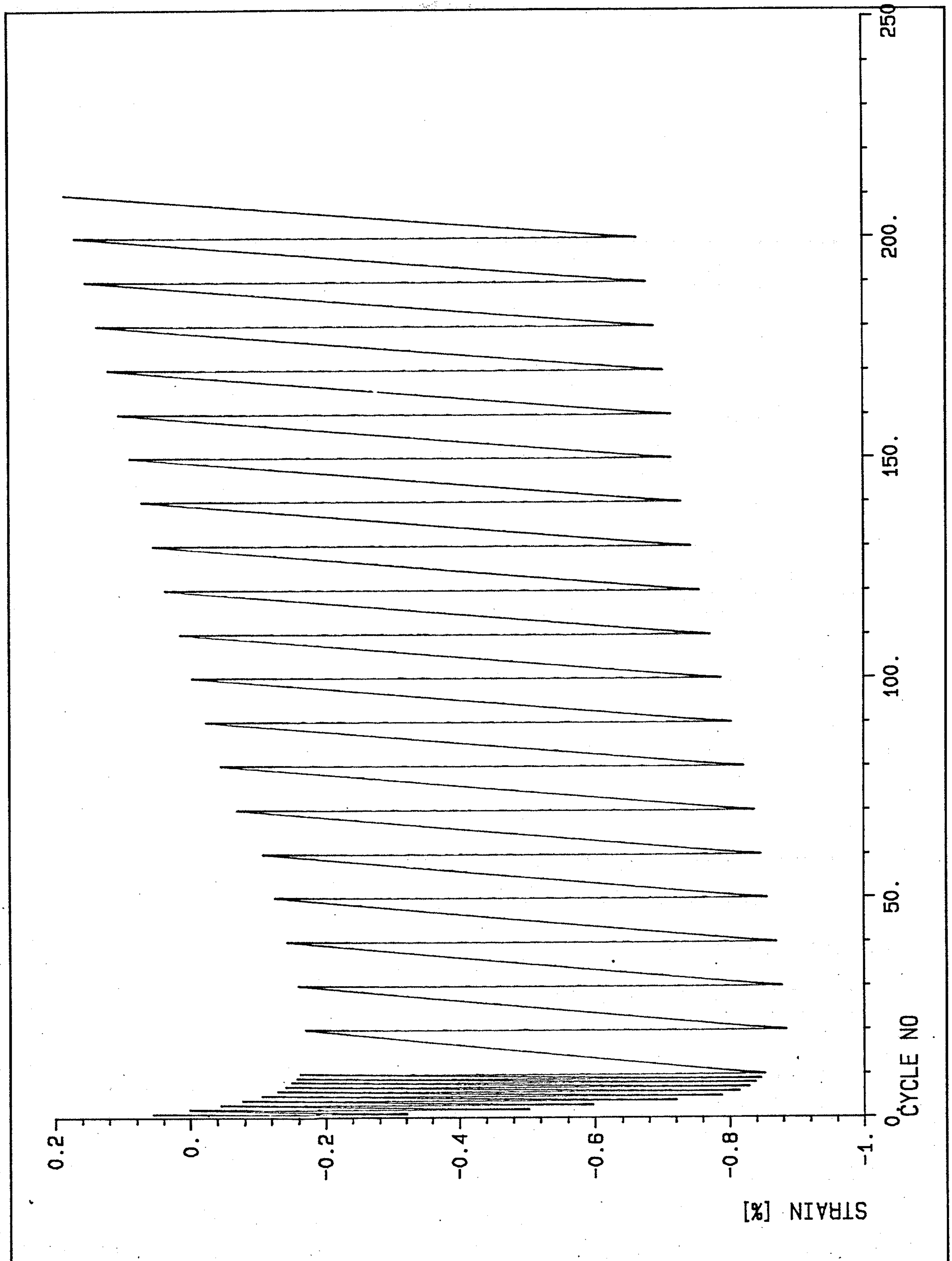
CON11 c1 and c2 - Cyl. 119

TRIAXIAL TEST. STRAINS DURING CYCLING

PROJECT	0.82.02
DATE	82.05.05
FIG.	32

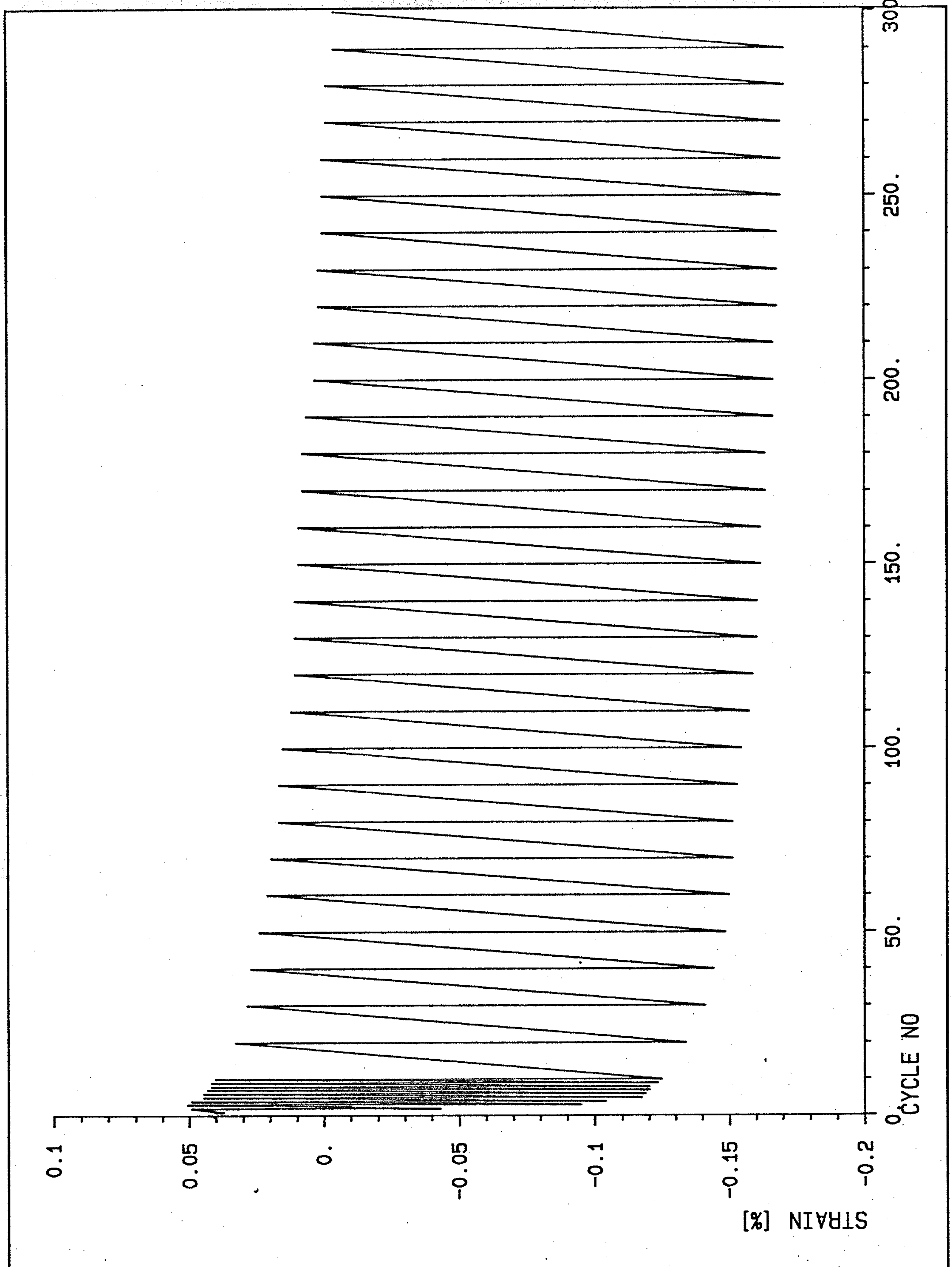
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

BJÆRUM grafiske as



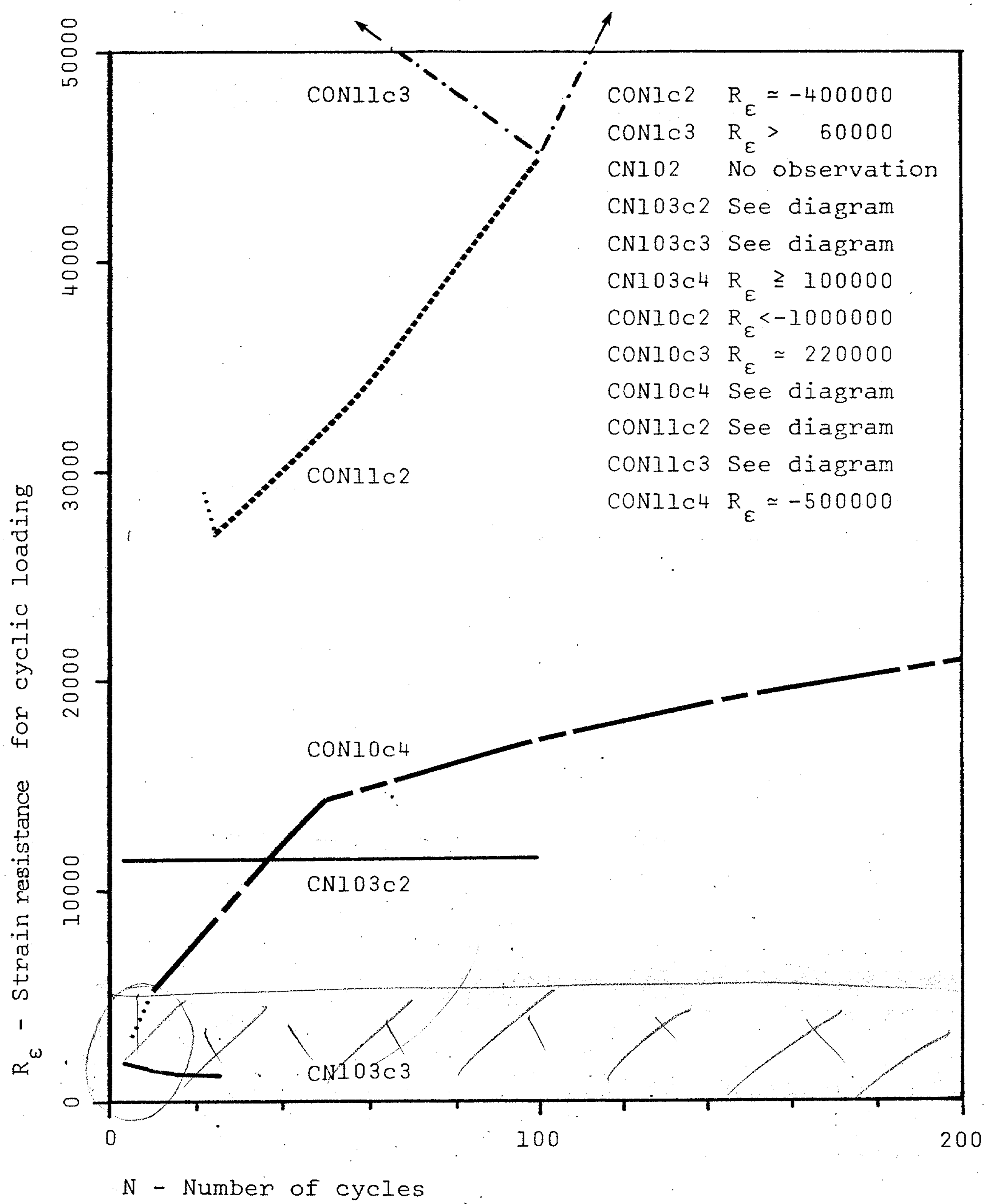
	PROJECT 0.82.02
CON11 c3 - Cyl. 119 TRIAXIAL TEST. STRAINS DURING CYCLING	DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 33

BJÆRUM grafiske as



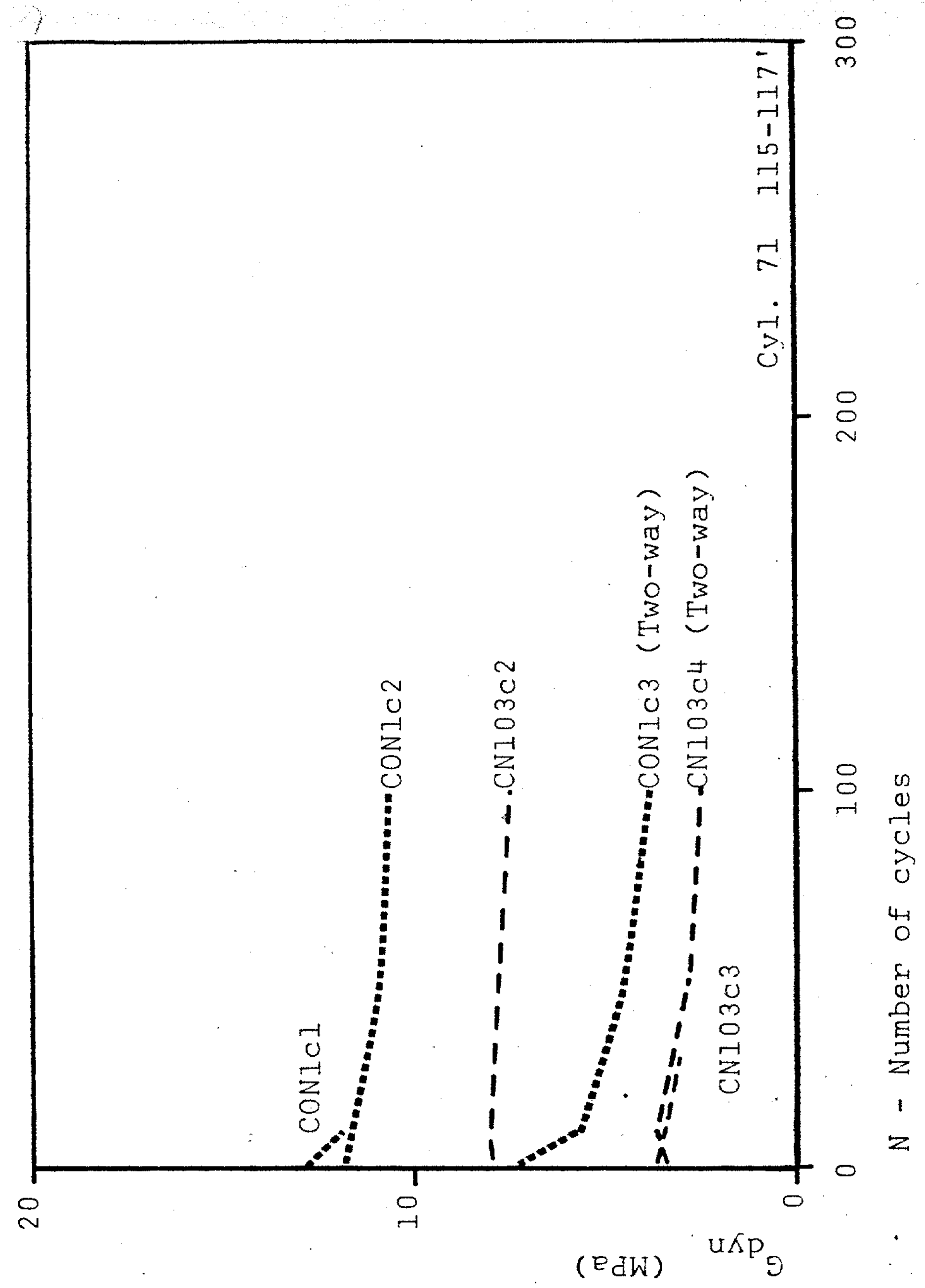
CON11 c4 - Cyl. 119 TRIAXIAL TEST. STRAINS DURING CYCLING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 34

BJÆRUM grafiske as



DEF. $R_\varepsilon = dN/d\varepsilon$

Cyl. 71 and 119: STRAIN RESISTANCE DURING CYCLIC LOADING (TRIAXIAL TESTS)	PROJECT 0.82.02
	DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 35



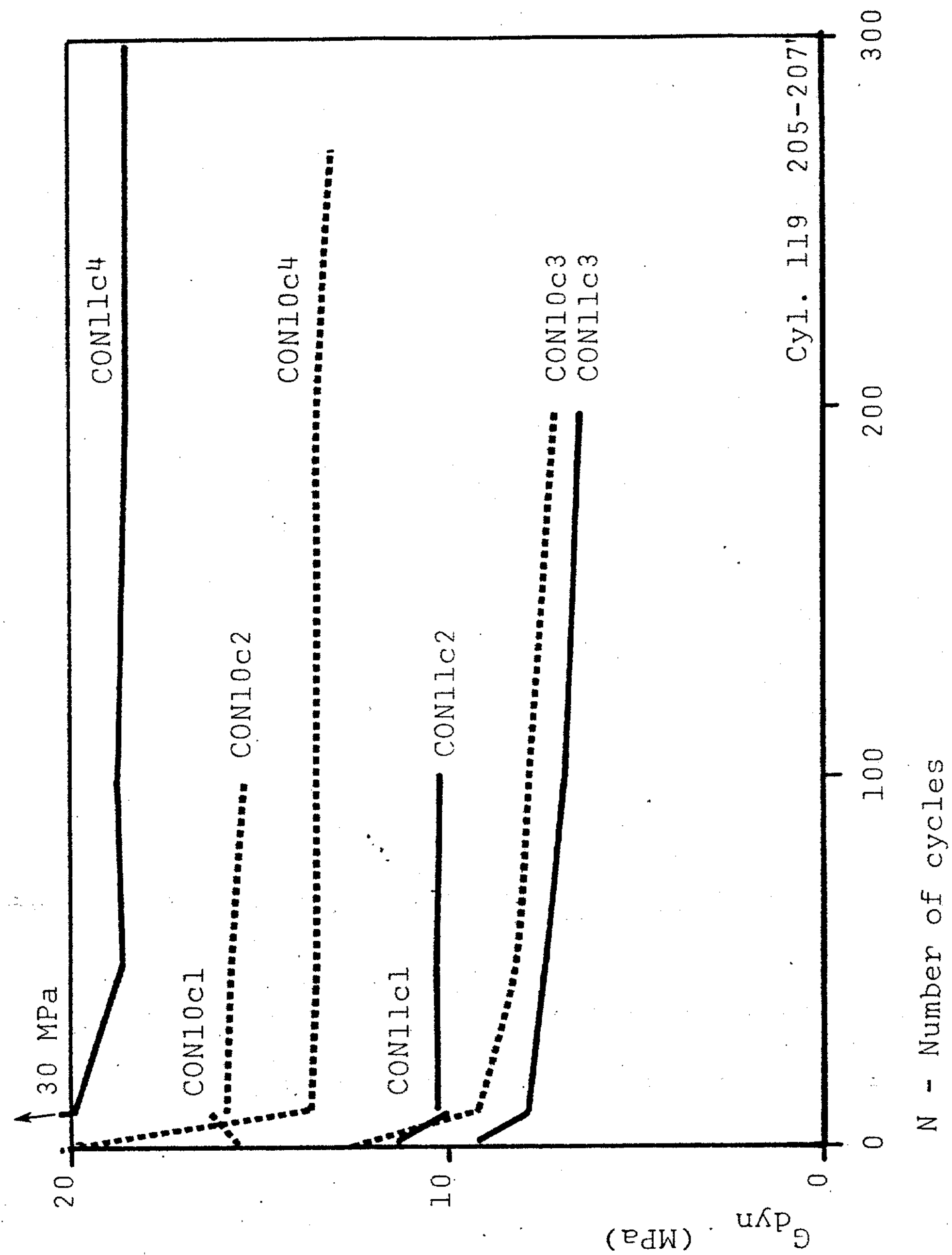
CYL. 71: TRIAXIAL TESTS

DYNAMIC SHEAR MODUDLUS G_{dyn}

PROJECT	0.82.02
DATE	82.05.05
FIG.	36

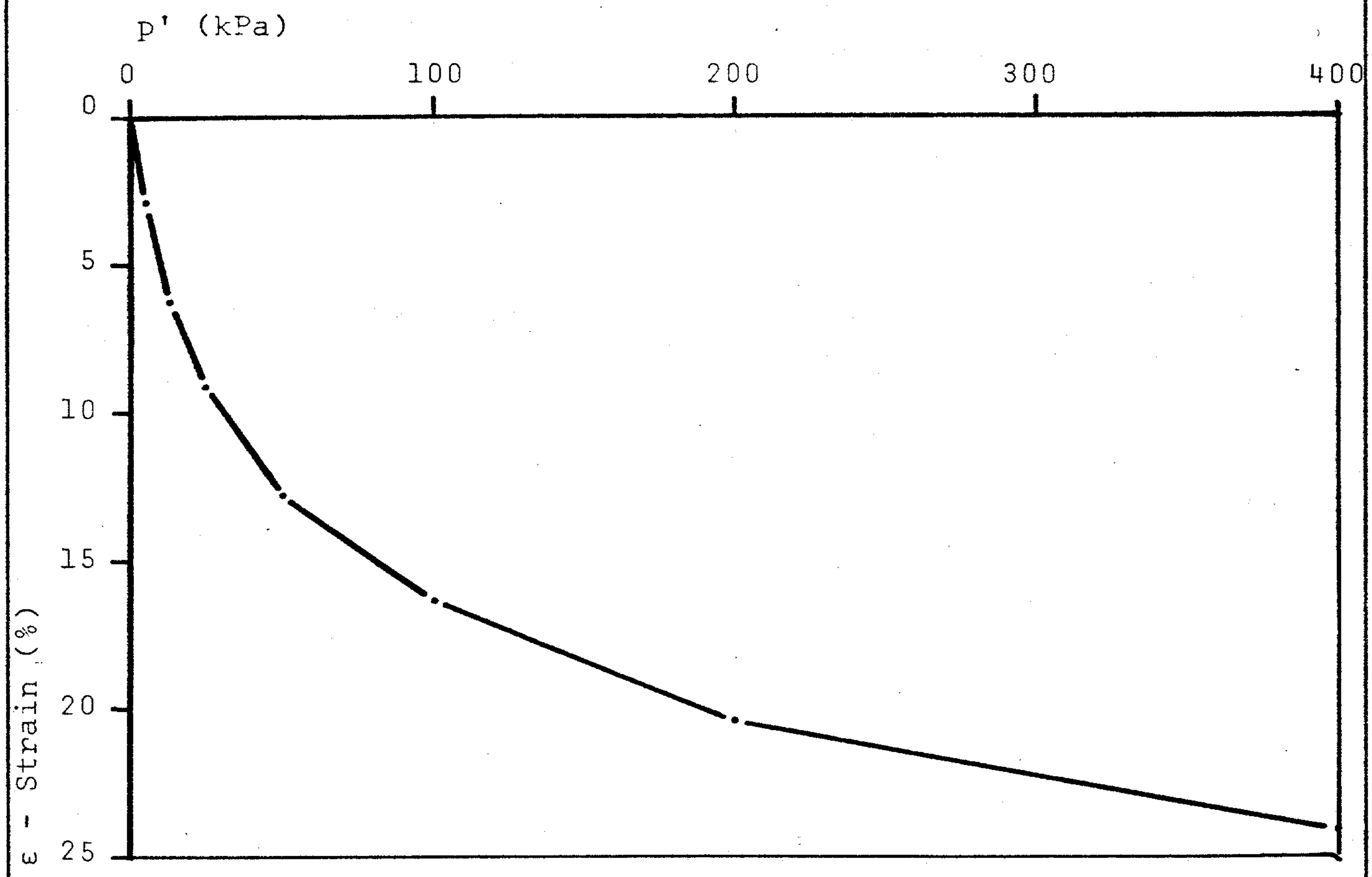
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH

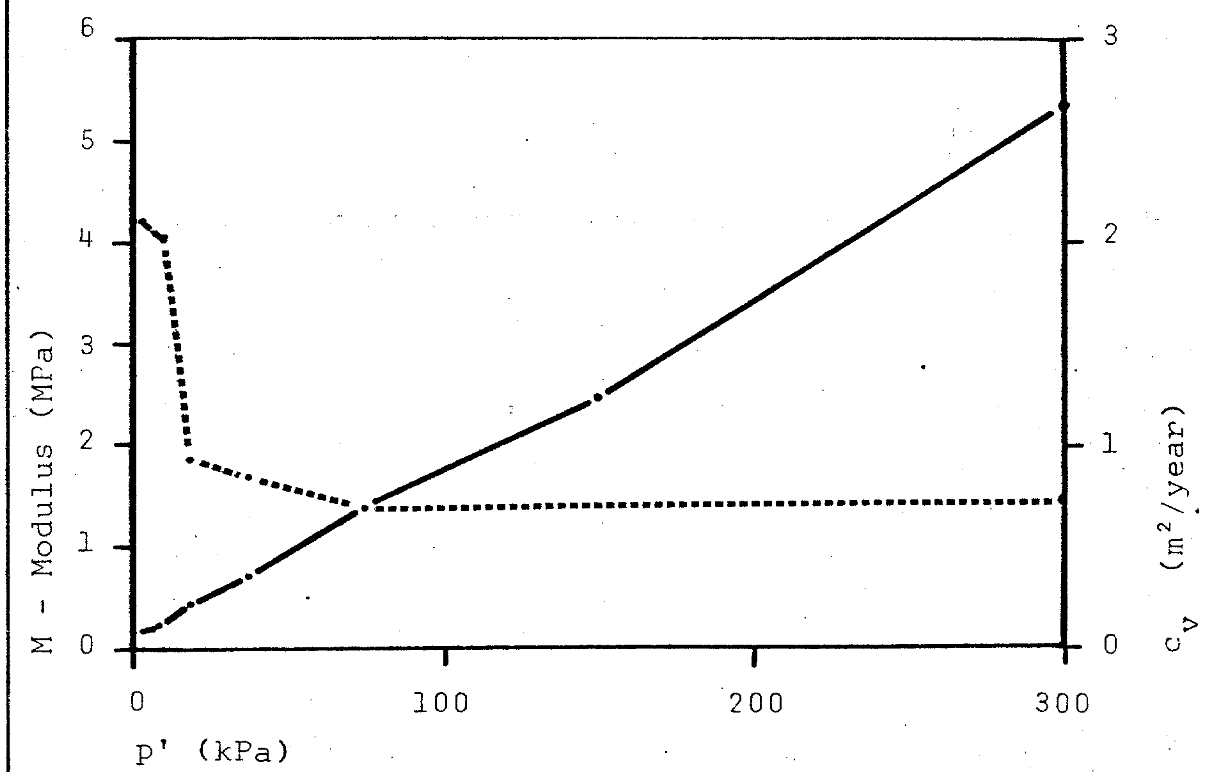
BJÆRUM grafiske as



Cyl. 119: TRIAXIAL TESTS DYNAMIC SHEAR MODULUS G_{dyn}	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 37

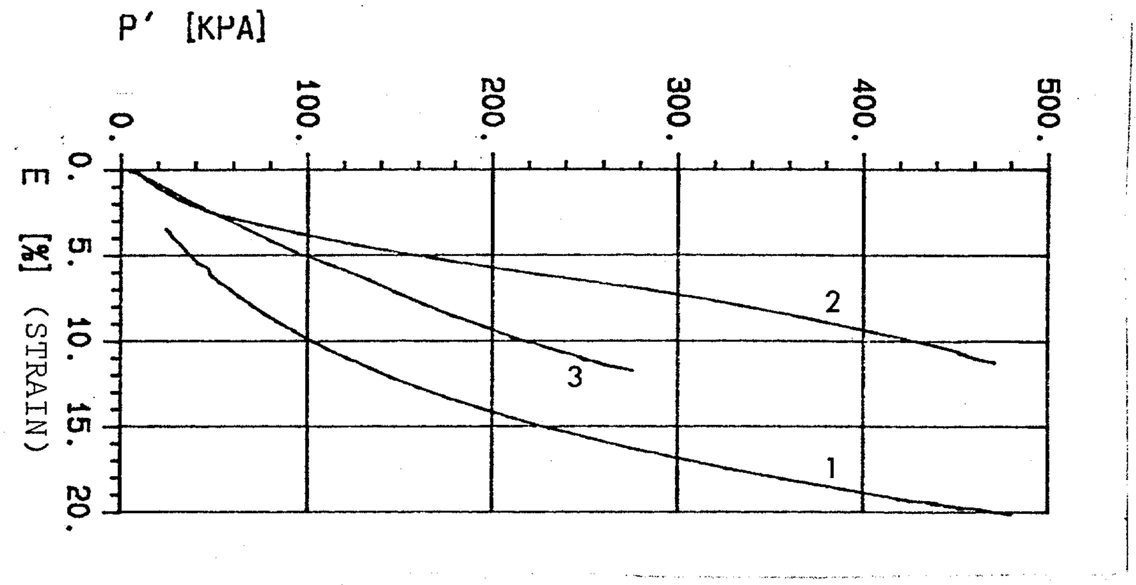
BJÆRUM grafiske as

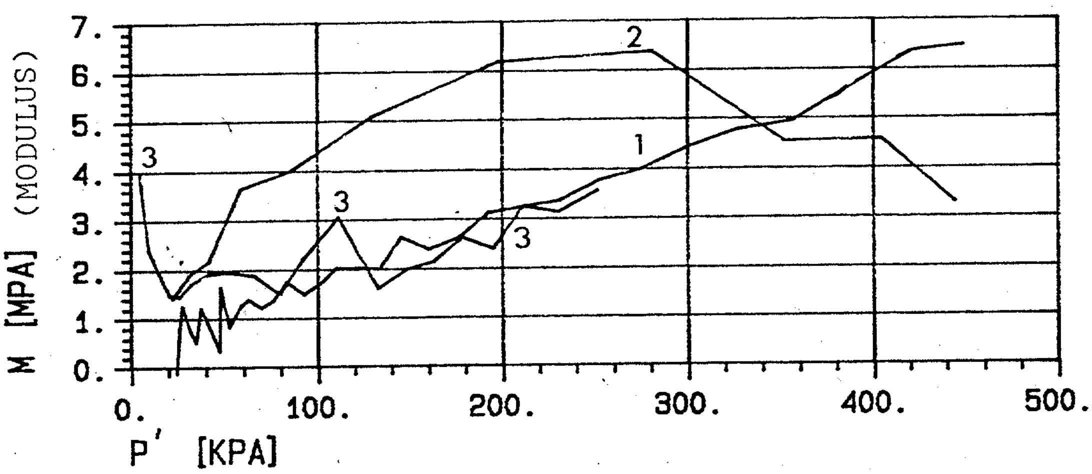




INOD1 - Cyl. 71 OEDOMETER TEST, INCREMENTAL LOADING	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 38

BJÆRUM grafiske as





DEF.: $M = d\sigma'/d\varepsilon$

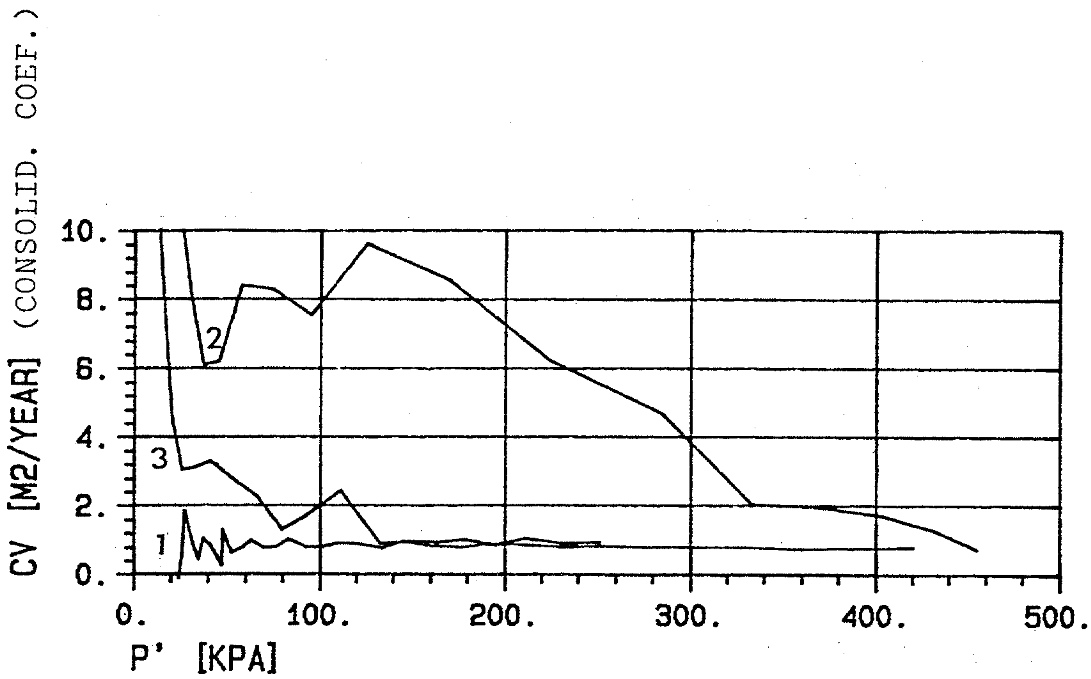
1: COOD1 - z = 35.34 m (Some disturbed)

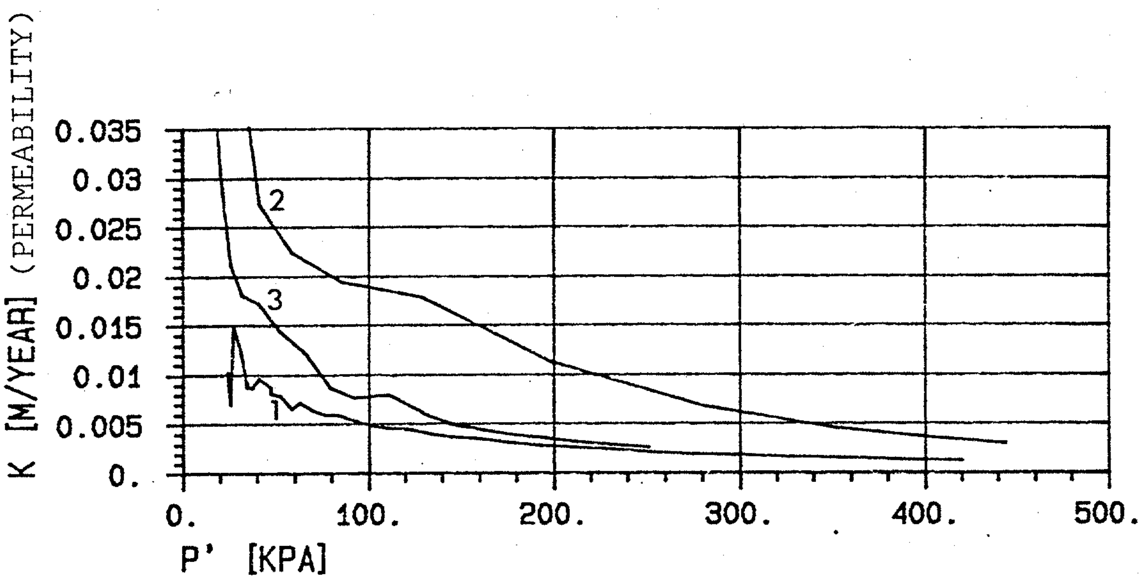
2: COOD2 - z = 35.57 m

3: COOD3 - z = 35.60 m

Cyl. 71 CONTINUOUS OEDOMETER TESTS	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 39

BJÆRUM grafiske as

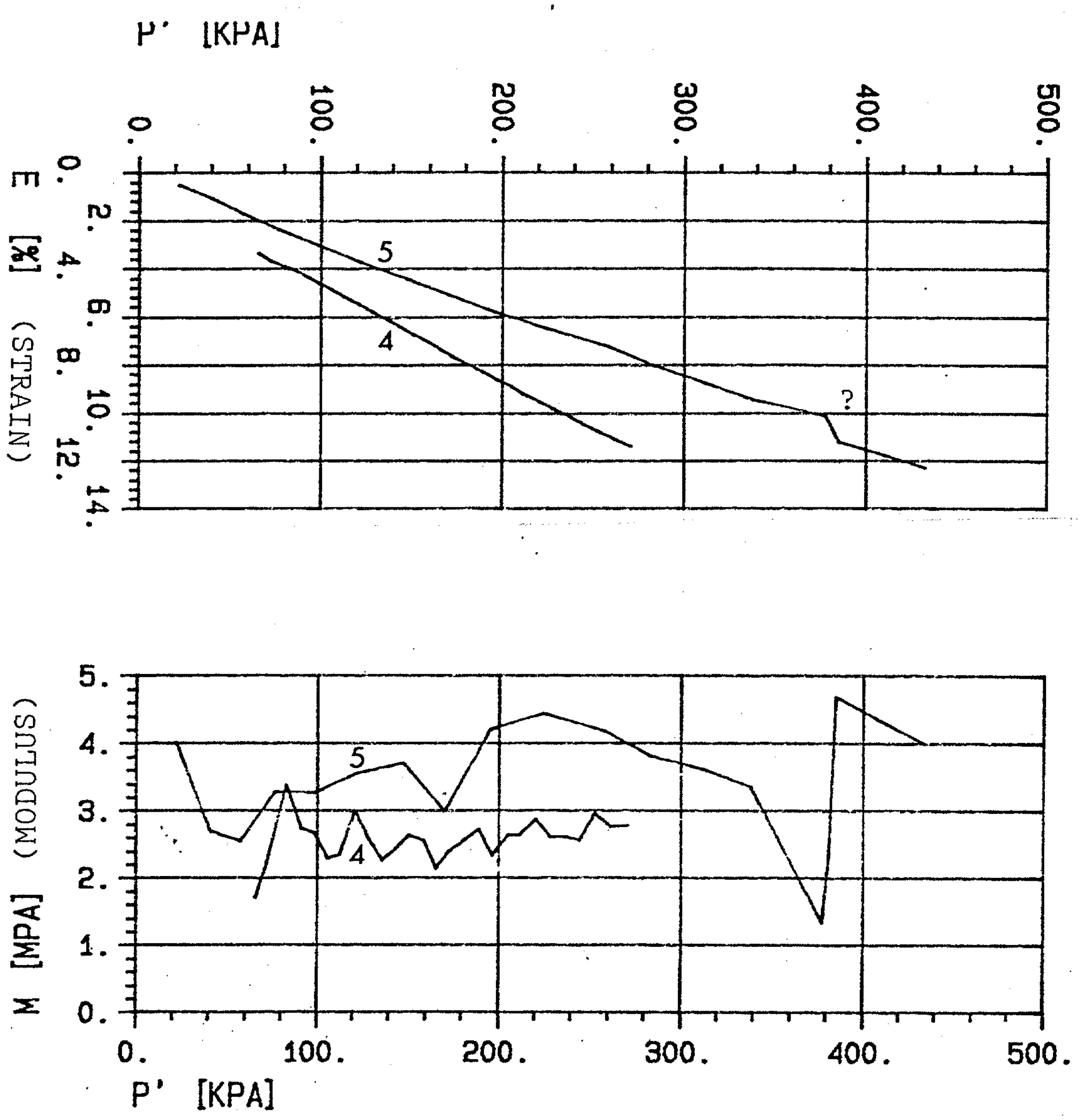




1: COOD1 - z = 35.34 m (Some disturbed)
2: COOD2 - z = 35.57 m
3: COOD3 - z = 35.60 m

Cyl. 71 CONTINUOUS OEDOMETER TESTS	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 40

BJÆRUM grafiske as



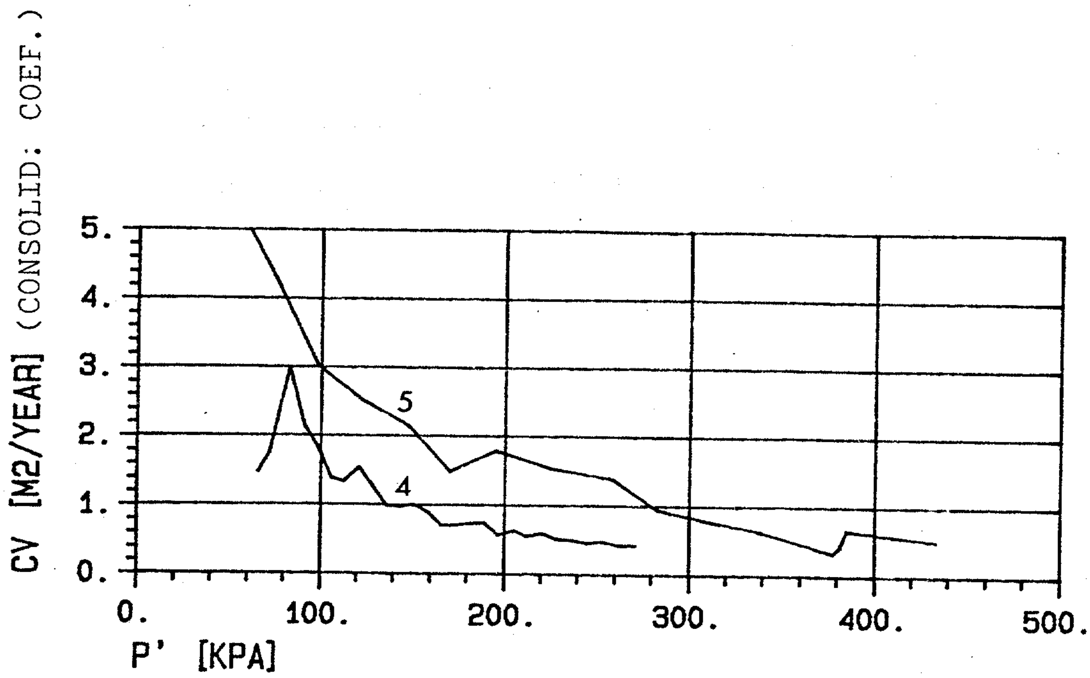
DEF.: M = dσ'/dε

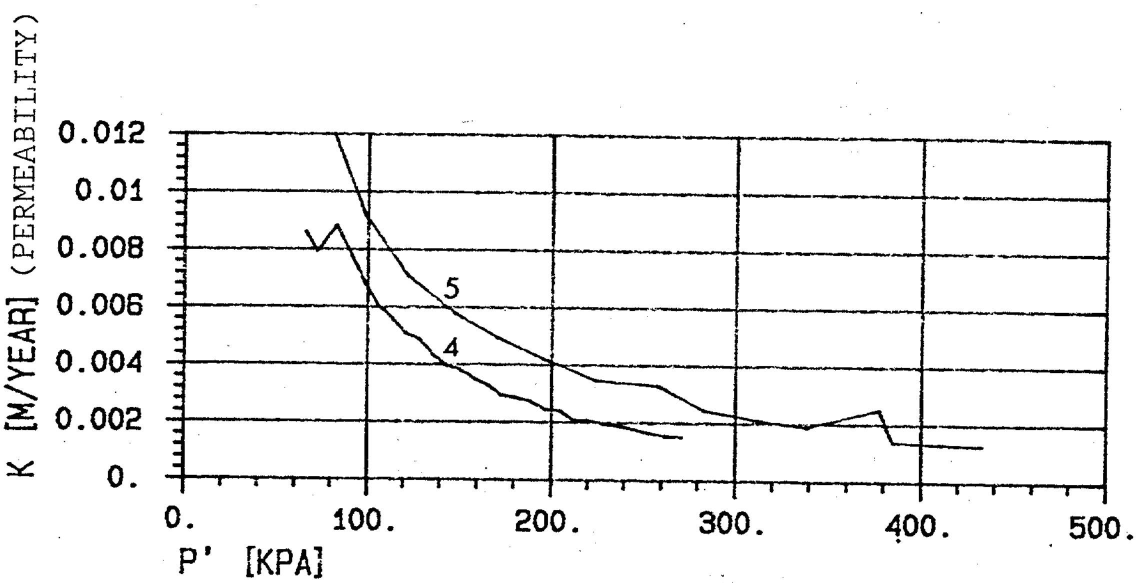
4: COOD4 - z = 62.63 m

5: COOD5 - z = 62.83 m

Cyl. 119 CONTINUOUS OEDOMETER TESTS	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 41

BJÆRUM grafiske as





4: COOD4 - z = 62.63 m
5: COOD5 - z = 62.83 m

Cyl. 119 CONTINUOUS OEDOMETER TESTS	PROJECT 0.82.02 DATE 82.05.05
GEOTECHNICAL DIVISION, N-7034 TRONDHEIM - NTH	FIG. 42

BJÆRUM grafiske as