THE CHARACTERIZATION OF UNSATURATED SOIL BEHAVIOUR FROM PENETROMETER PERFORMANCE AND THE CRITICAL STATE CONCEPT

Volume 2 of 2

BY

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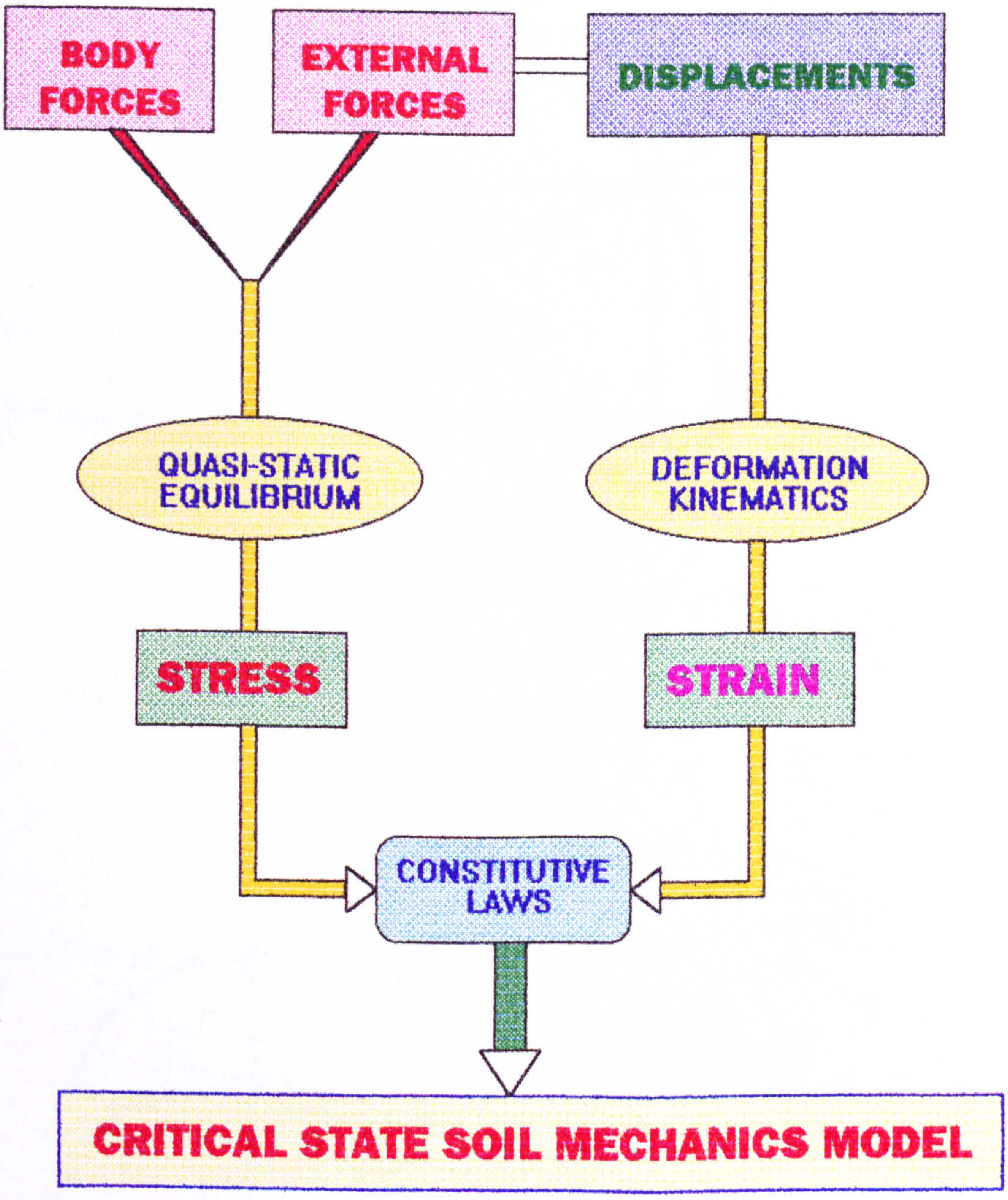

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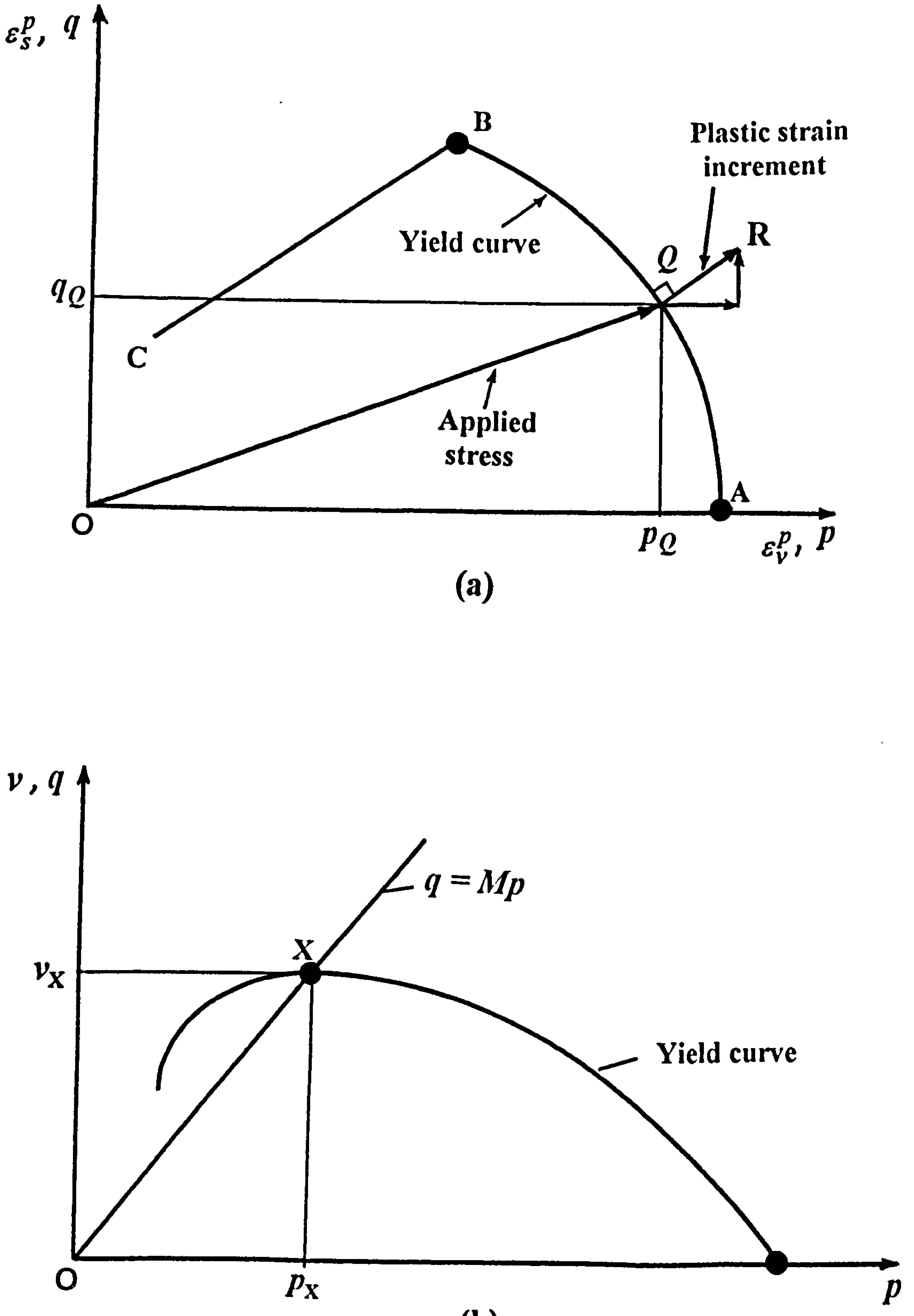

(a)

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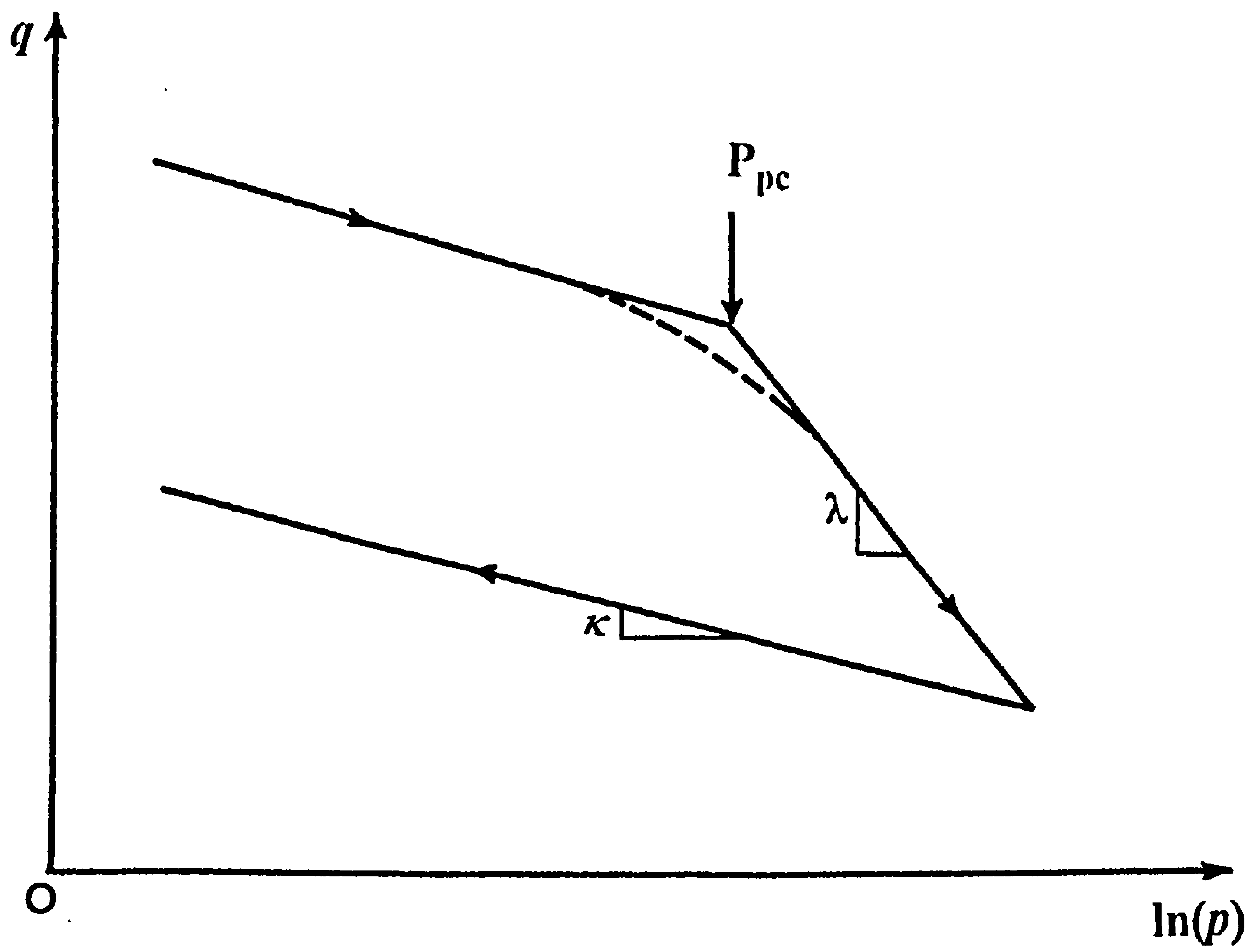

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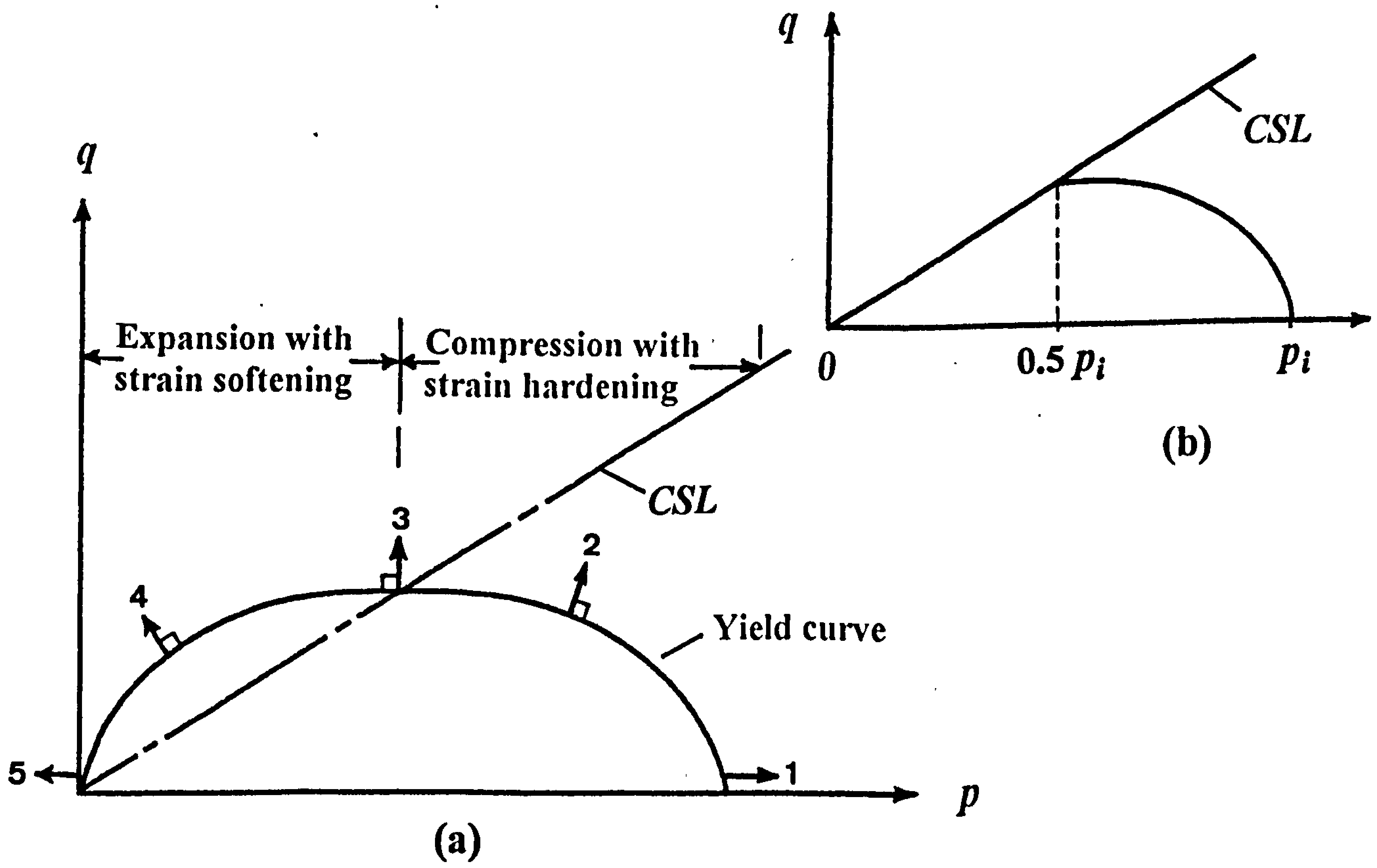

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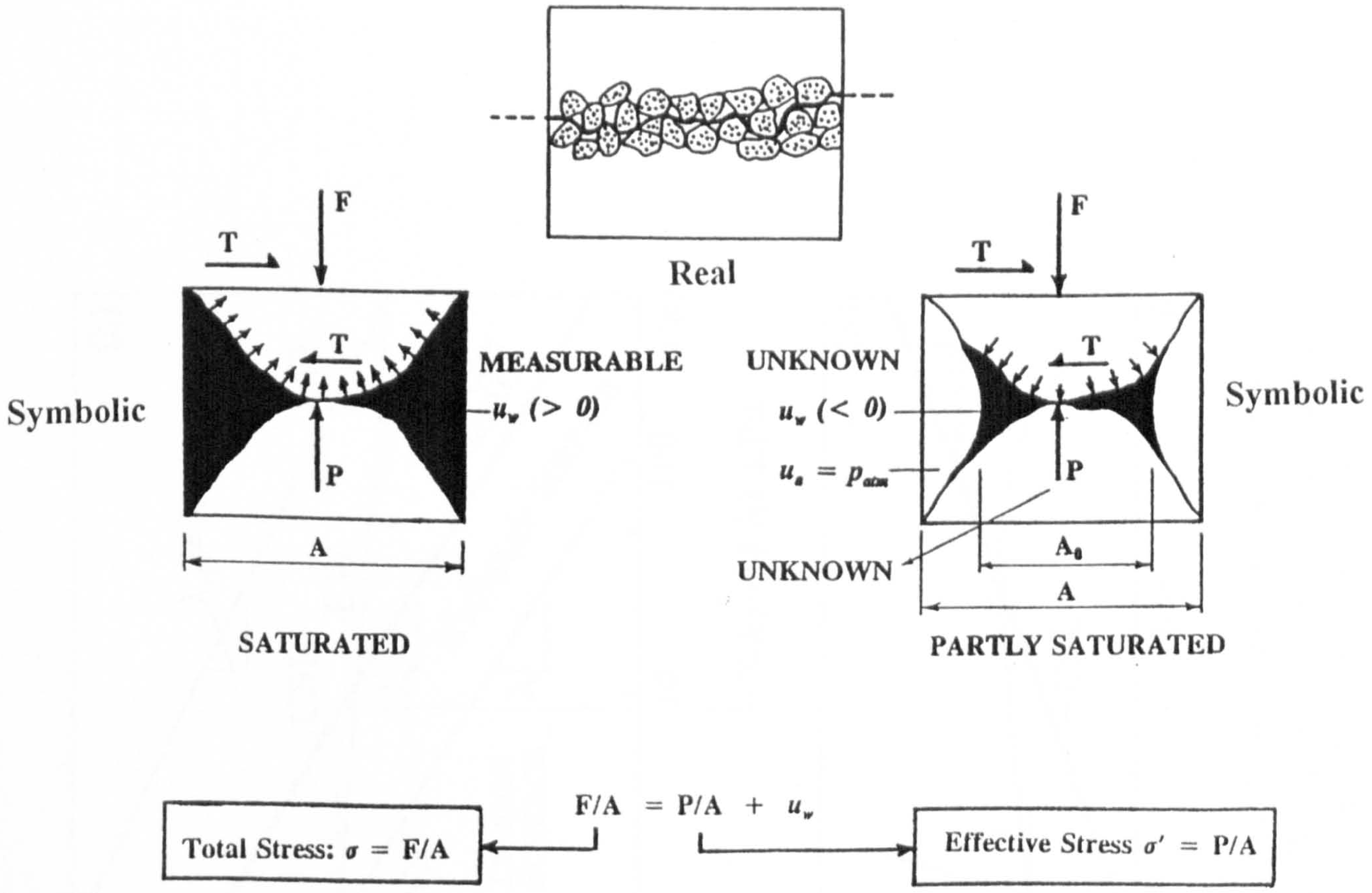

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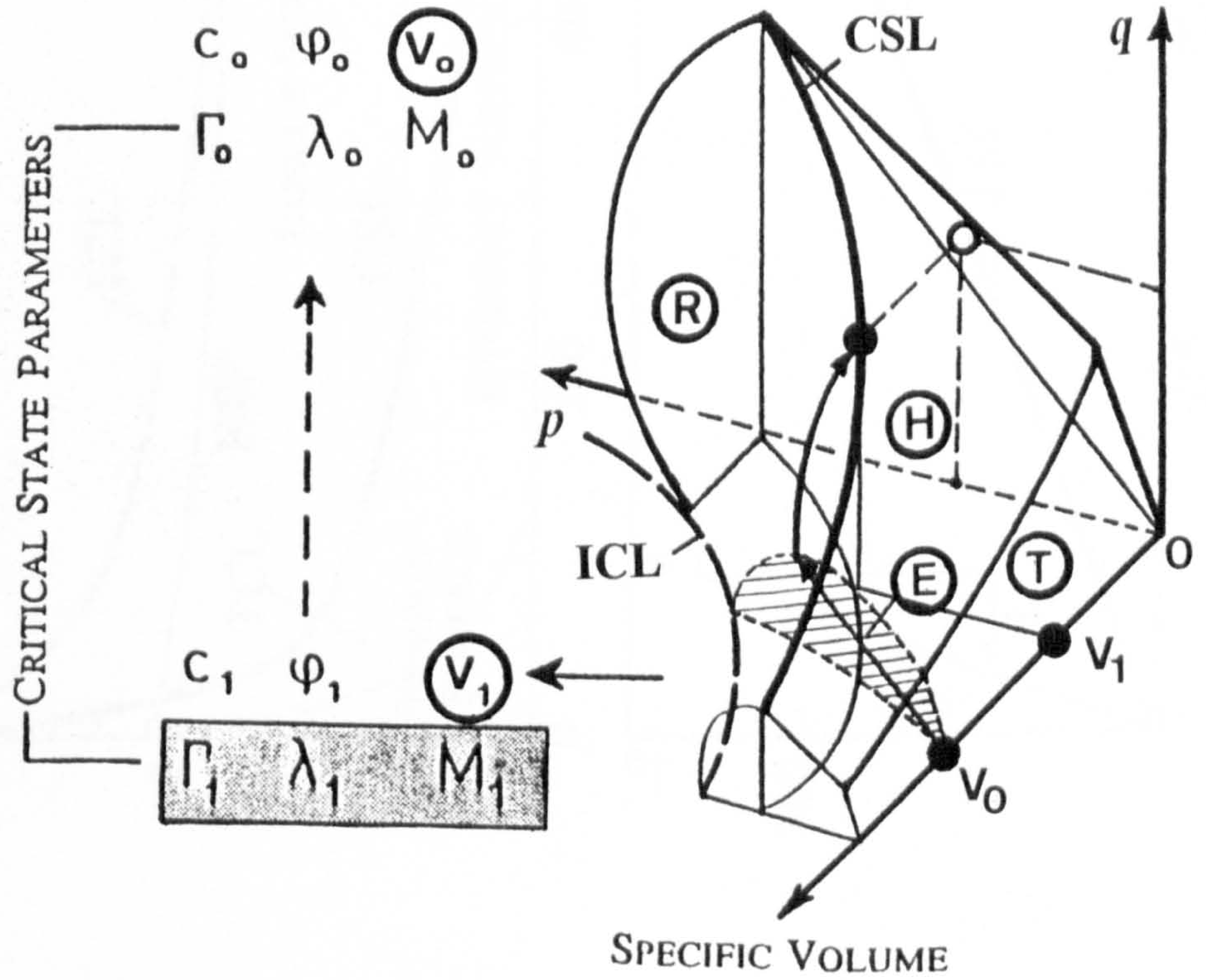

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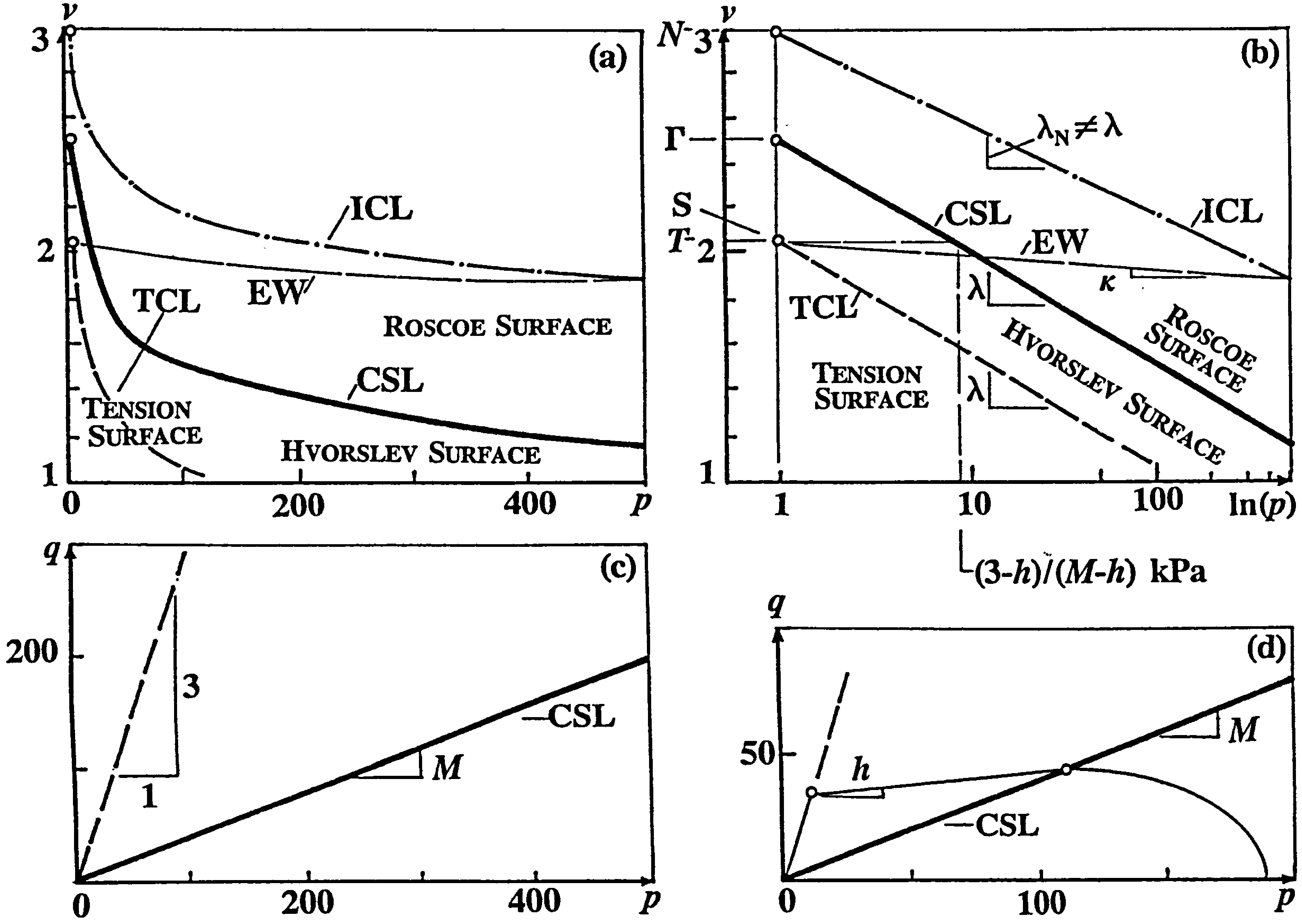

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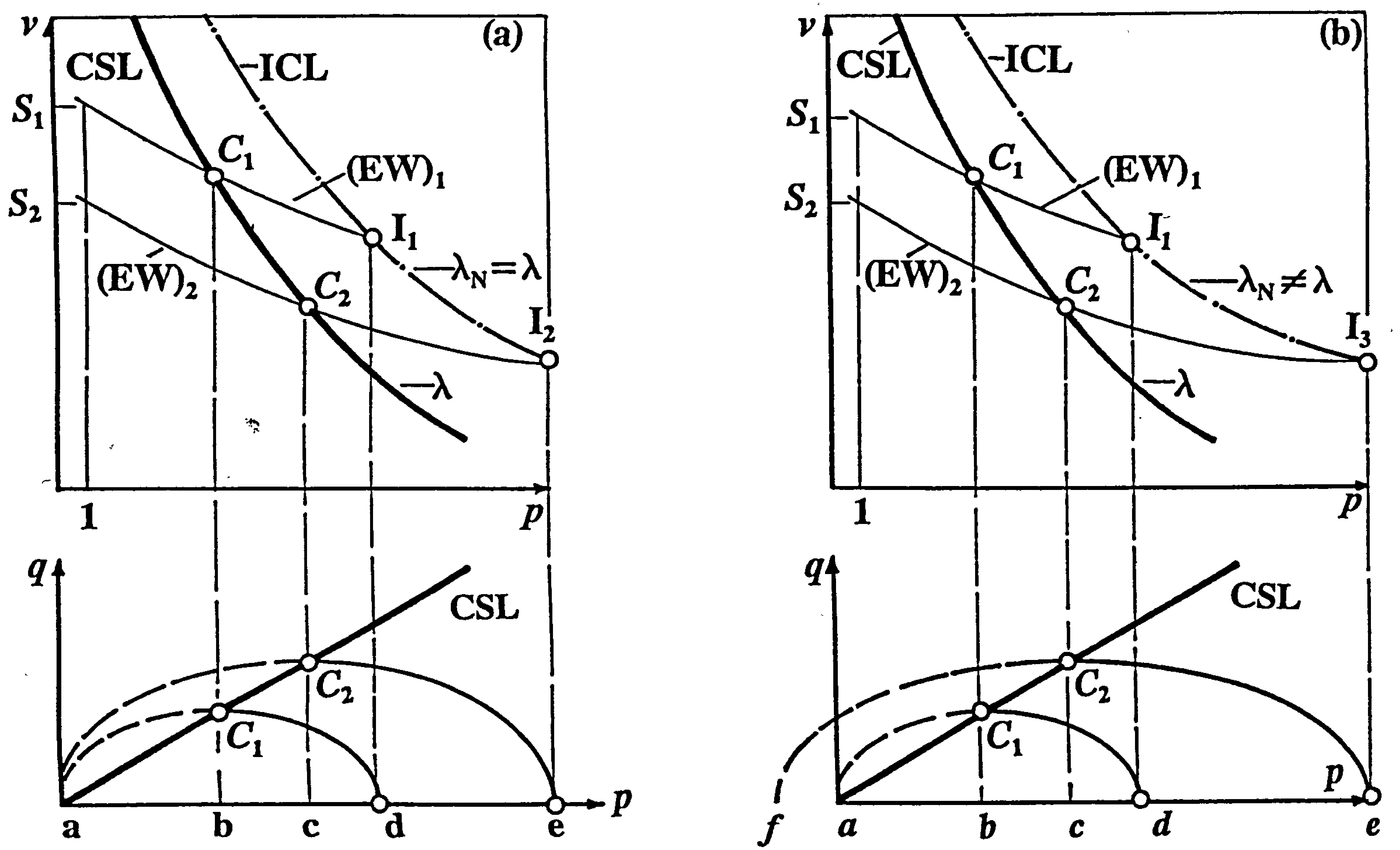

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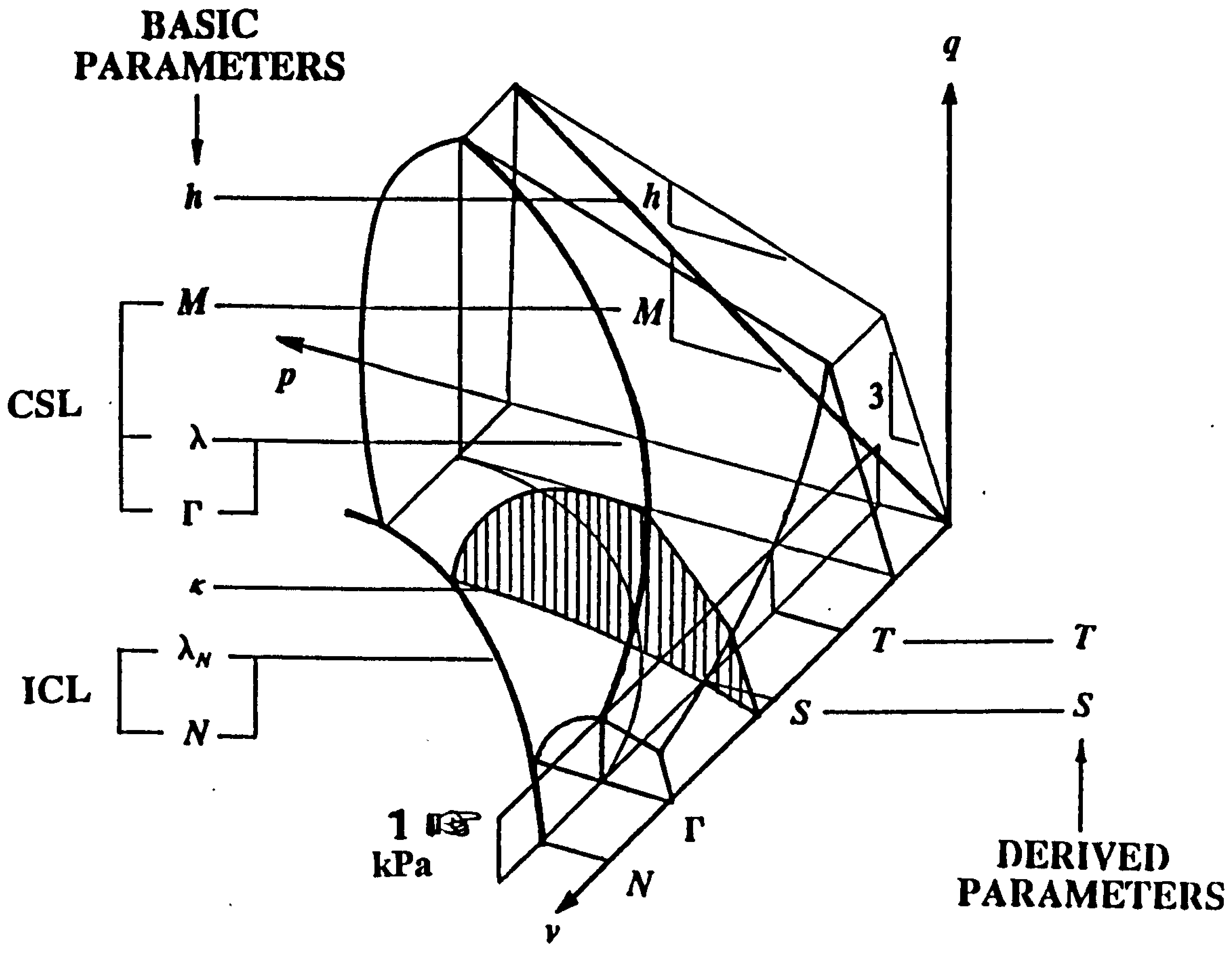

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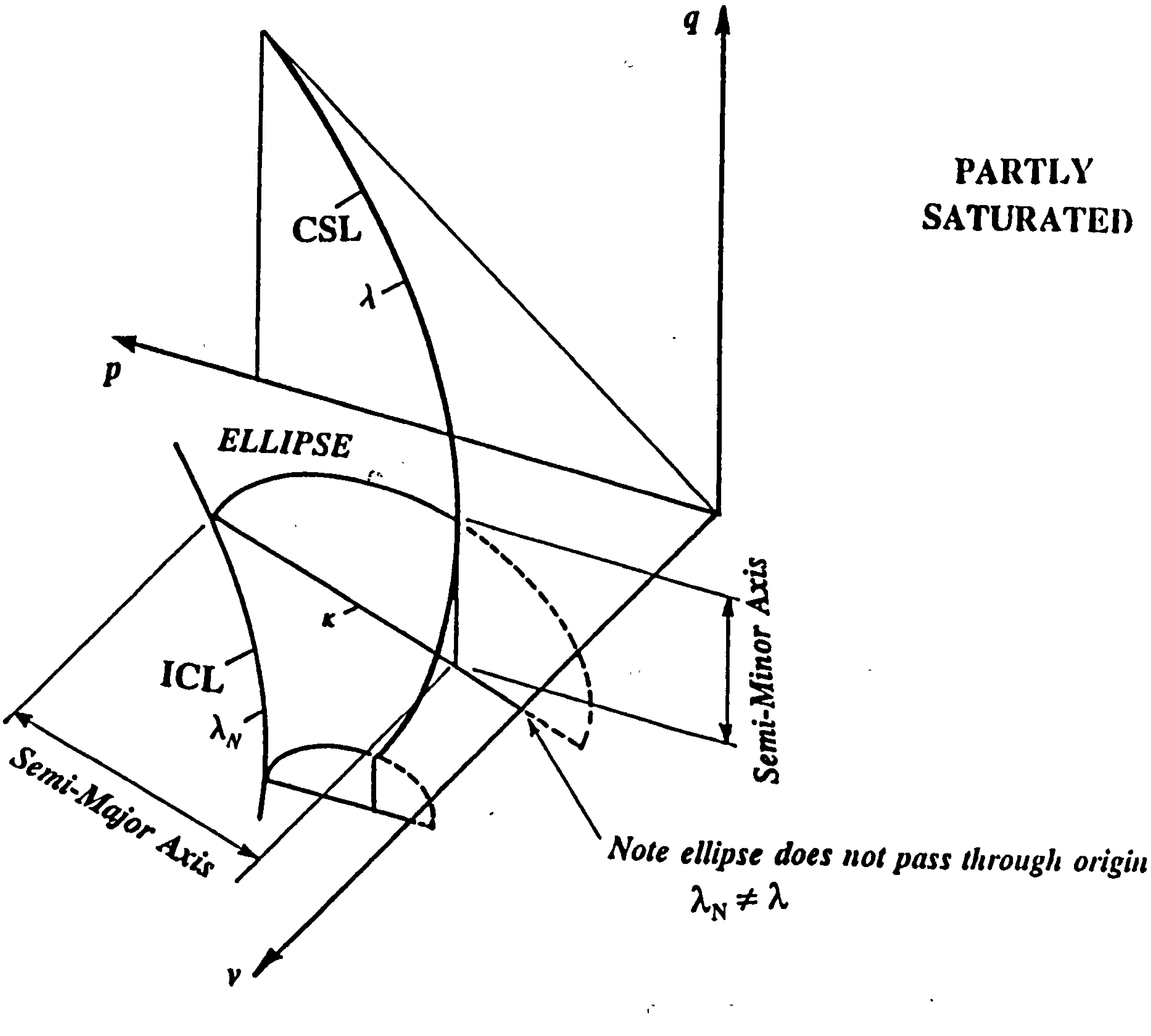

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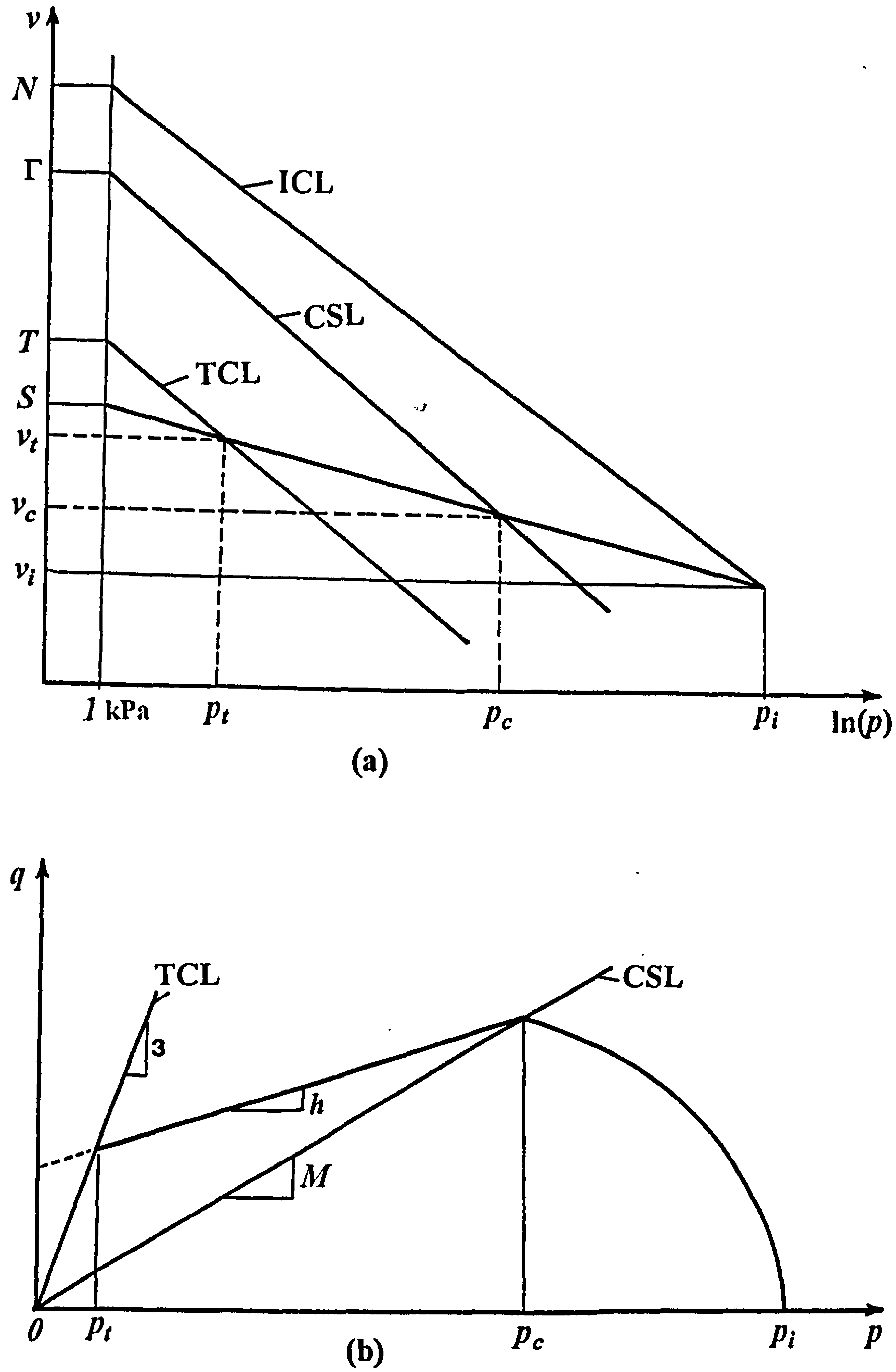

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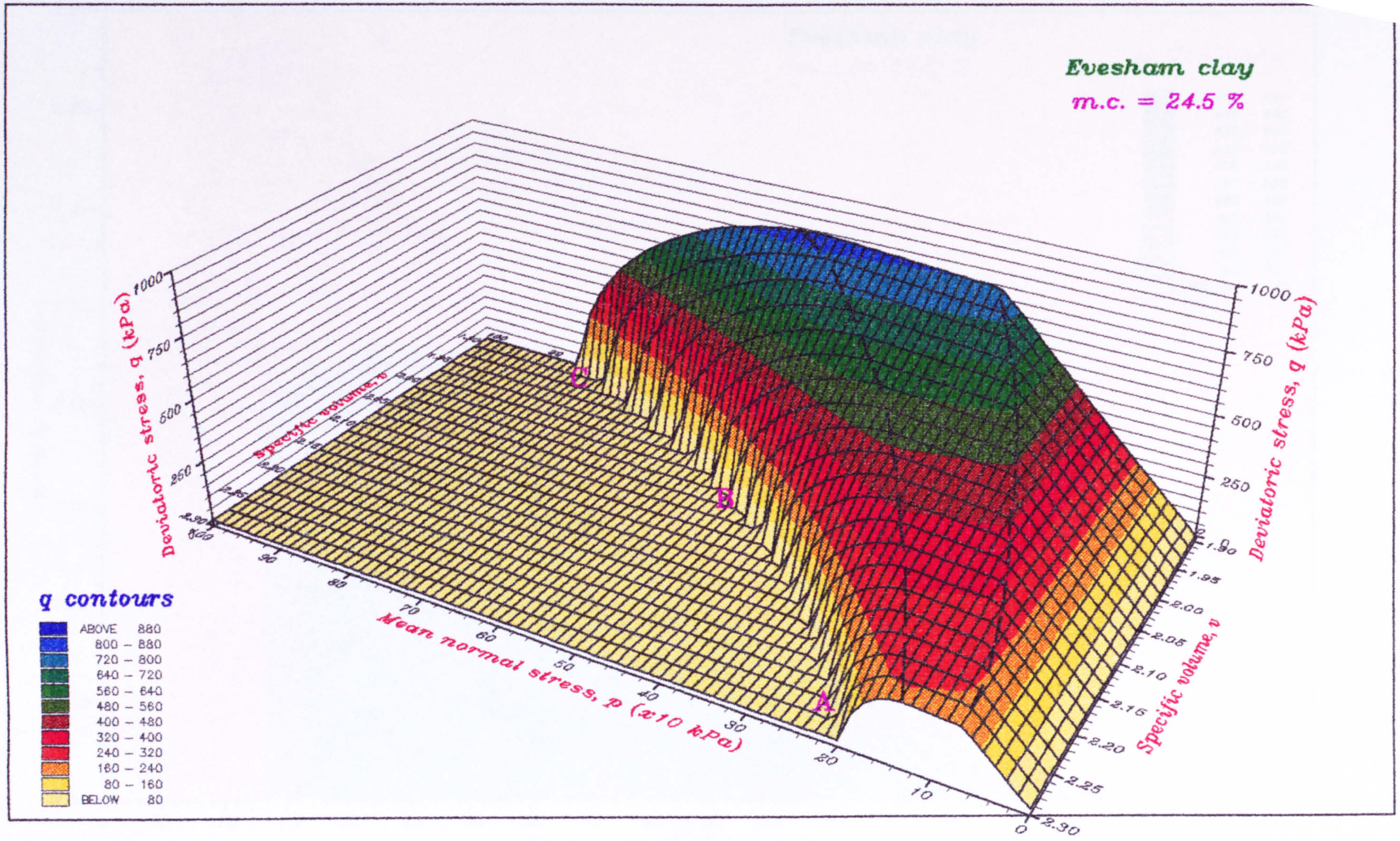

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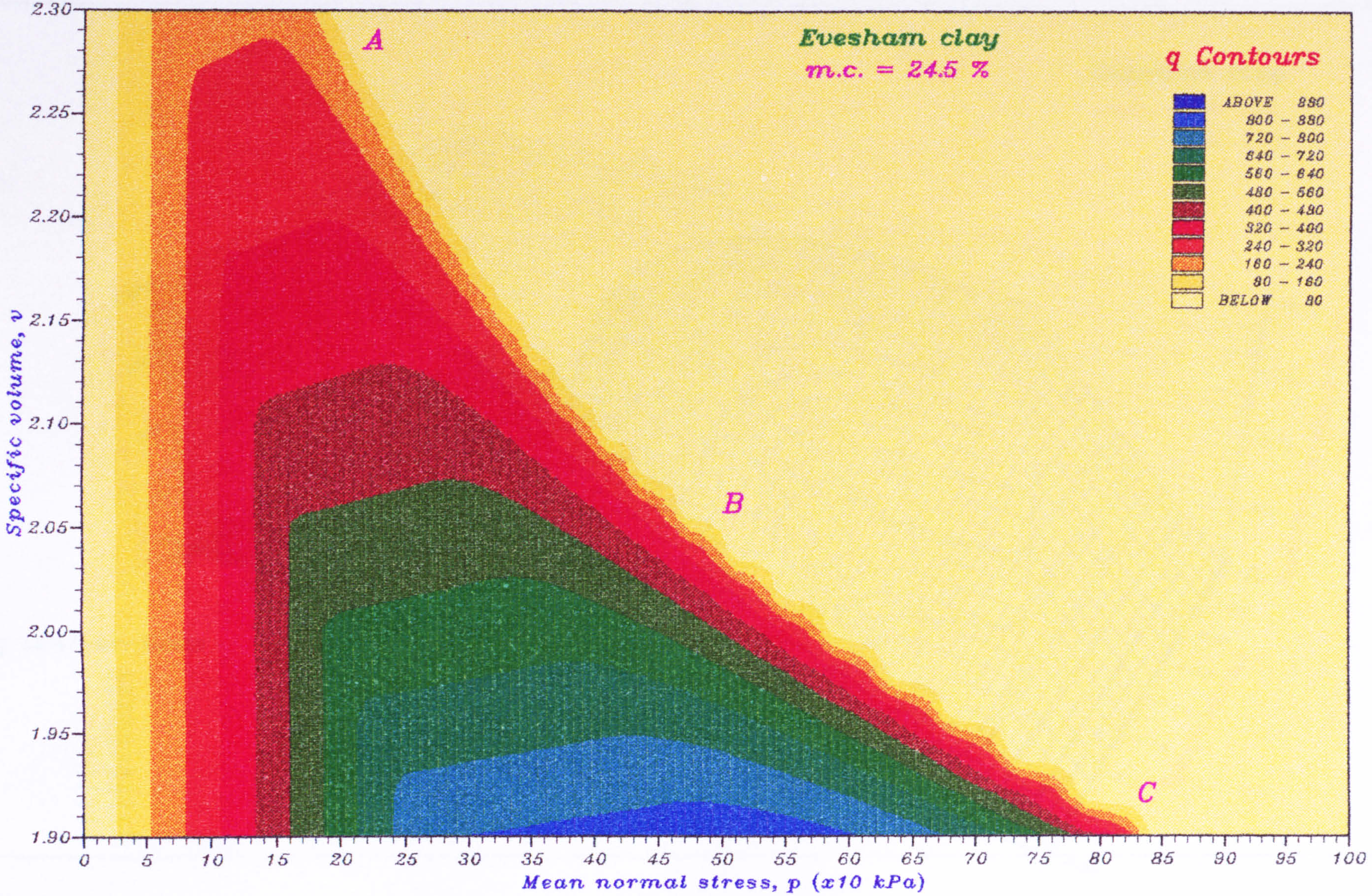

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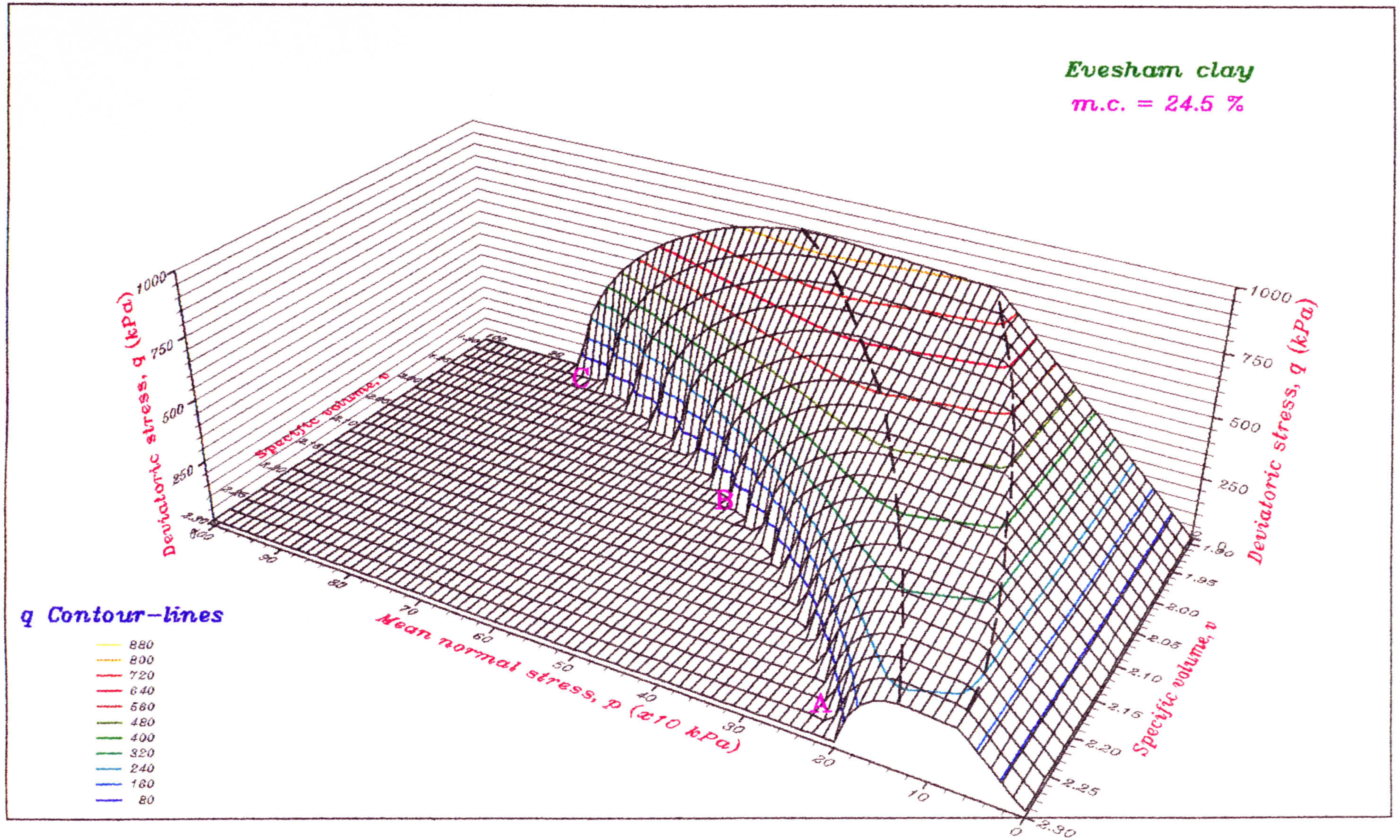

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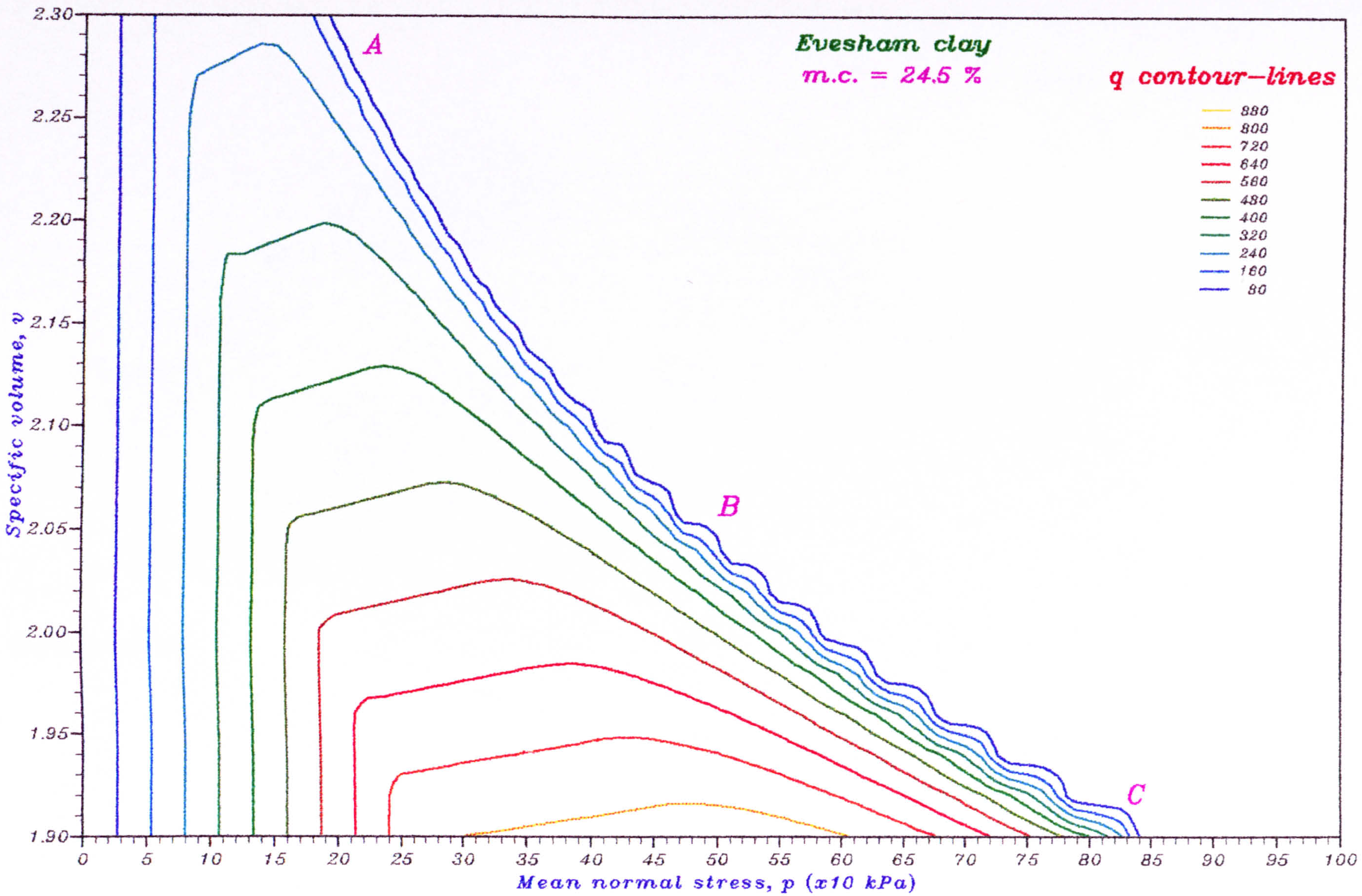

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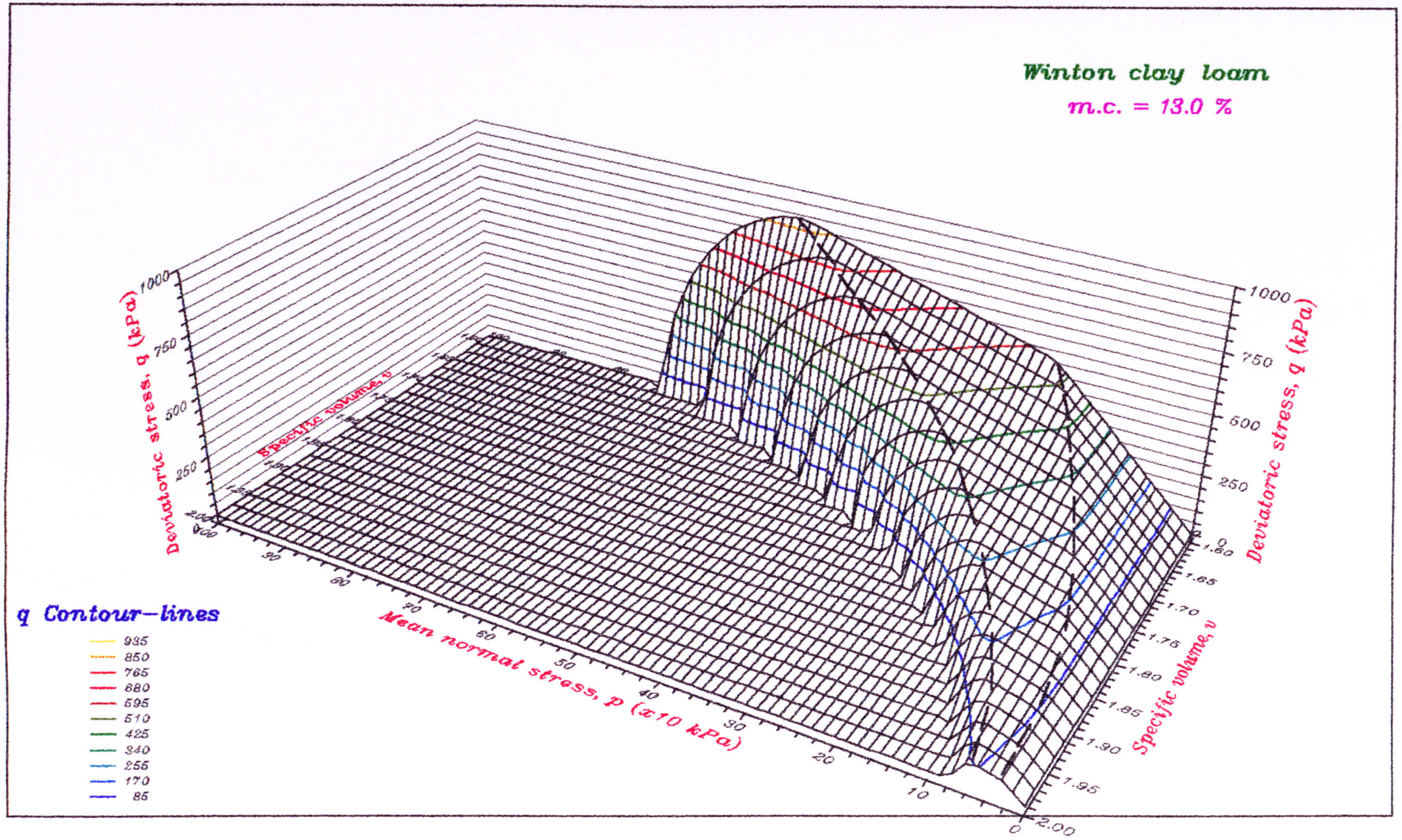

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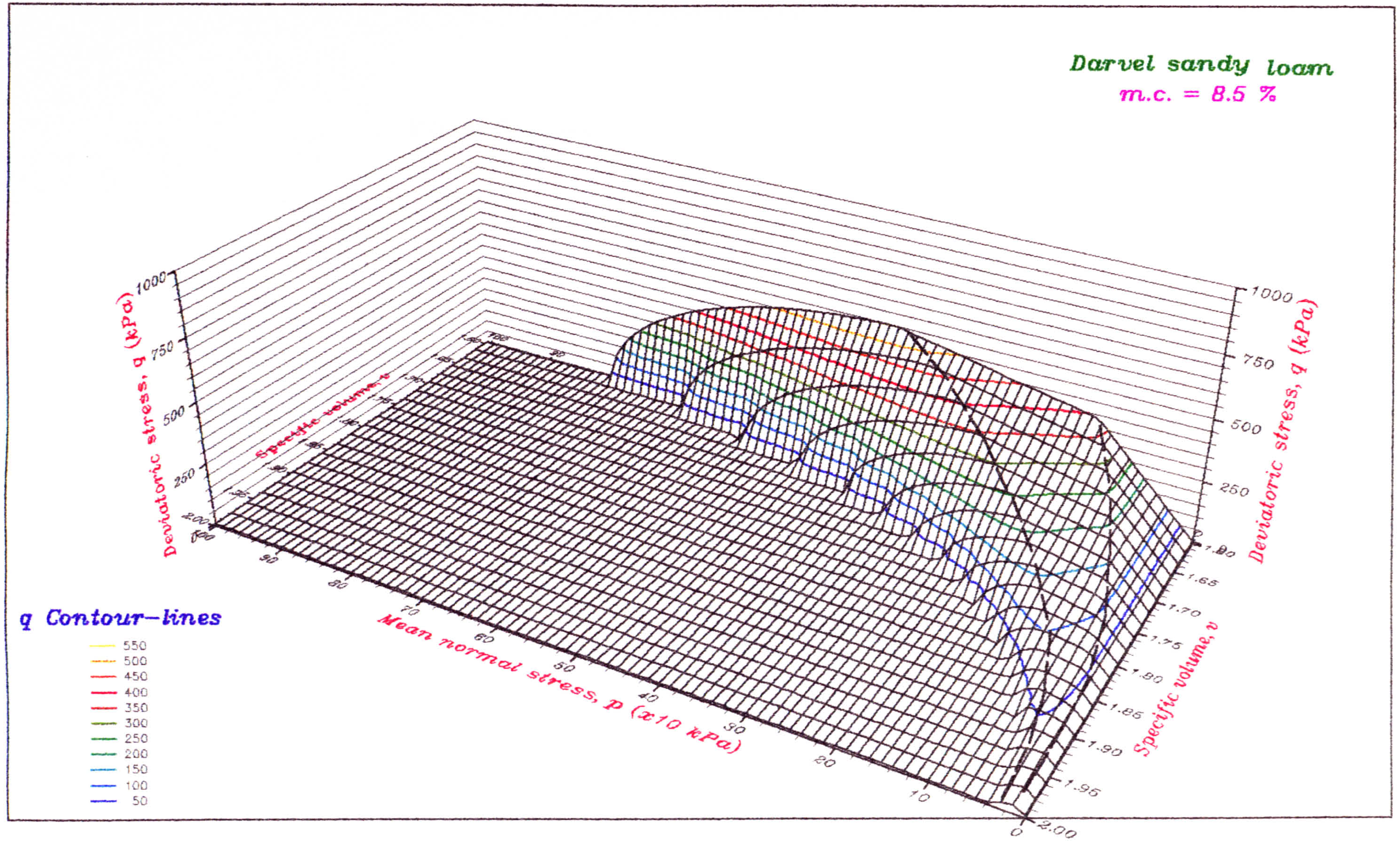

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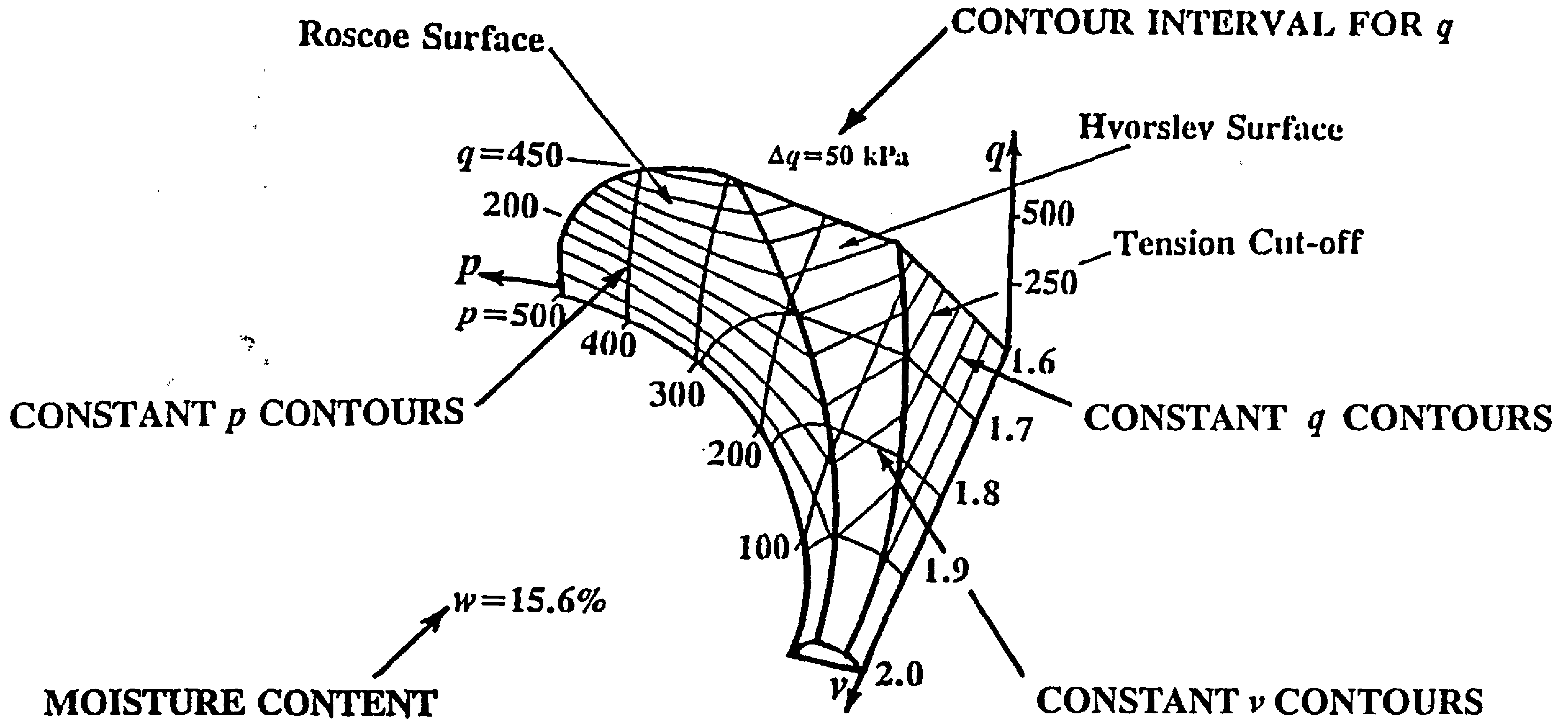

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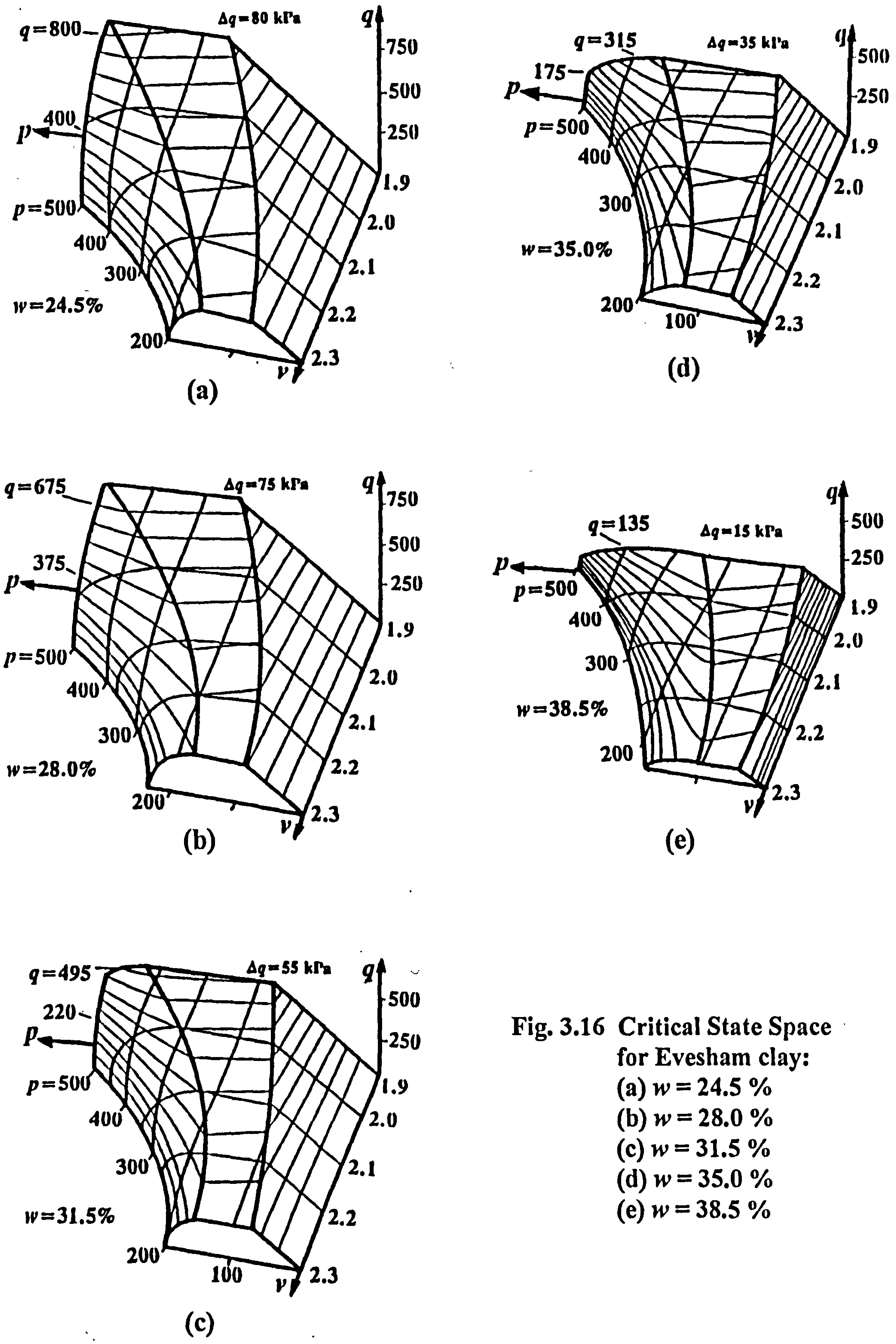


Fig. 3.16 Critical State Space for Evesham clay:
(a) $w = 24.5$ %
(b) $w = 28.0$ %
(c) $w = 31.5$ %
(d) $w = 35.0$ %
(e) $w = 38.5$ %

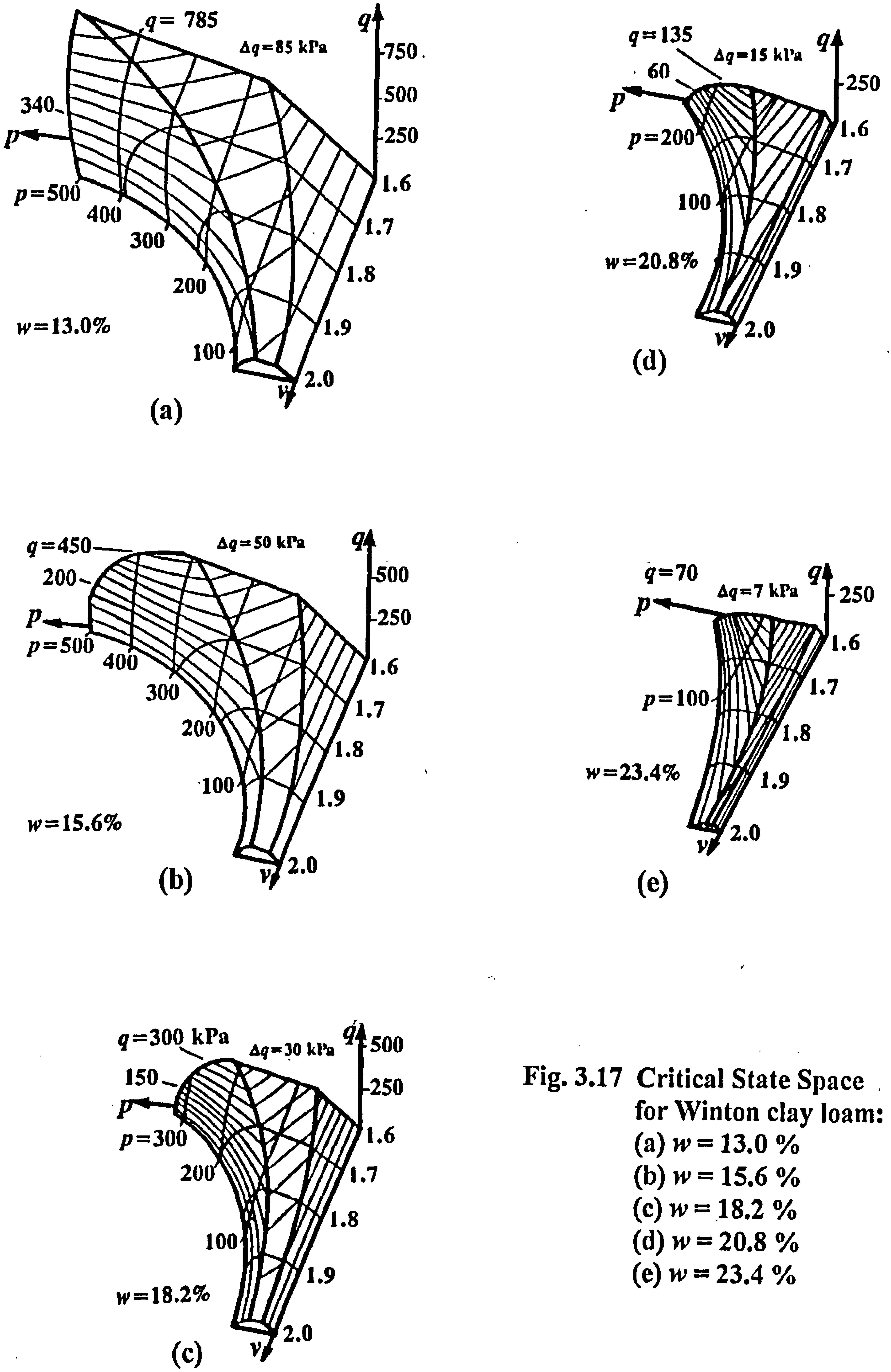
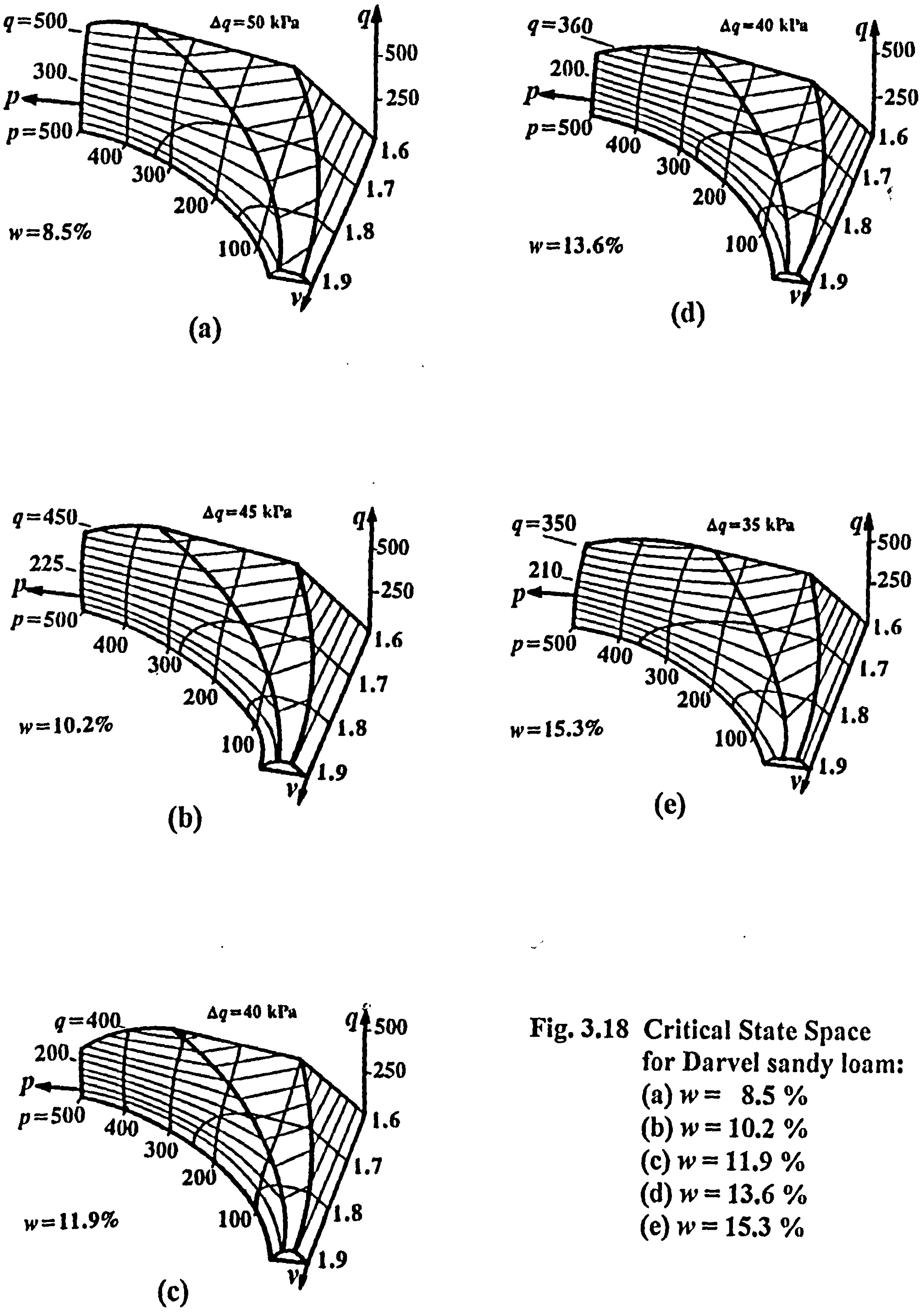


Fig. 3.17 Critical State Space for Winton clay loam:
(a) $w = 13.0$ %
(b) $w = 15.6$ %
(c) $w = 18.2$ %
(d) $w = 20.8$ %
(e) $w = 23.4$ %



(a)

(d)

(b)

(e)

(c)

Fig. 3.18 Critical State Space for Darvel sandy loam:

(a) w = 8.5 %
(b) w = 10.2 %
(c) w = 11.9 %
(d) w = 13.6 %
(e) w = 15.3 %

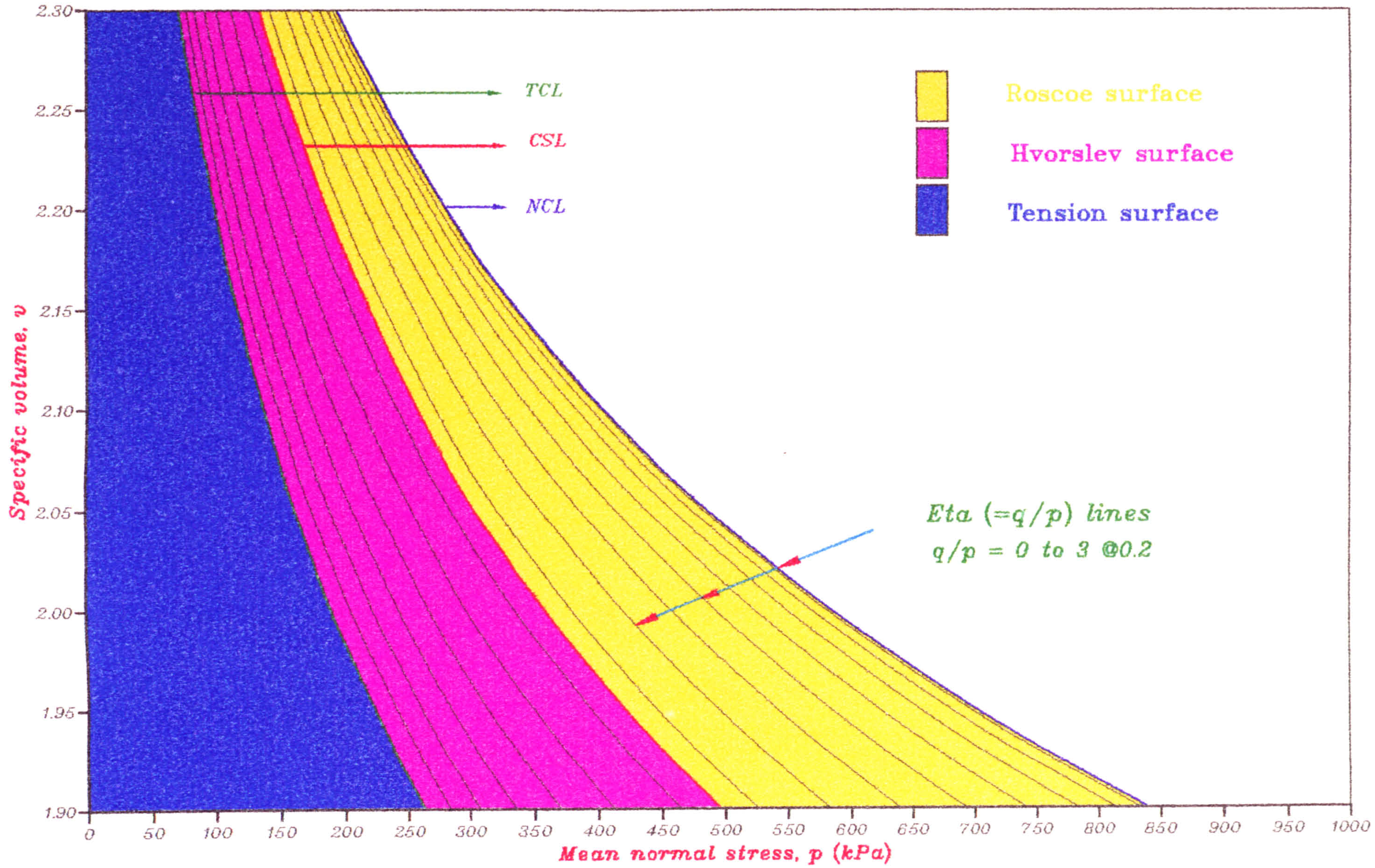
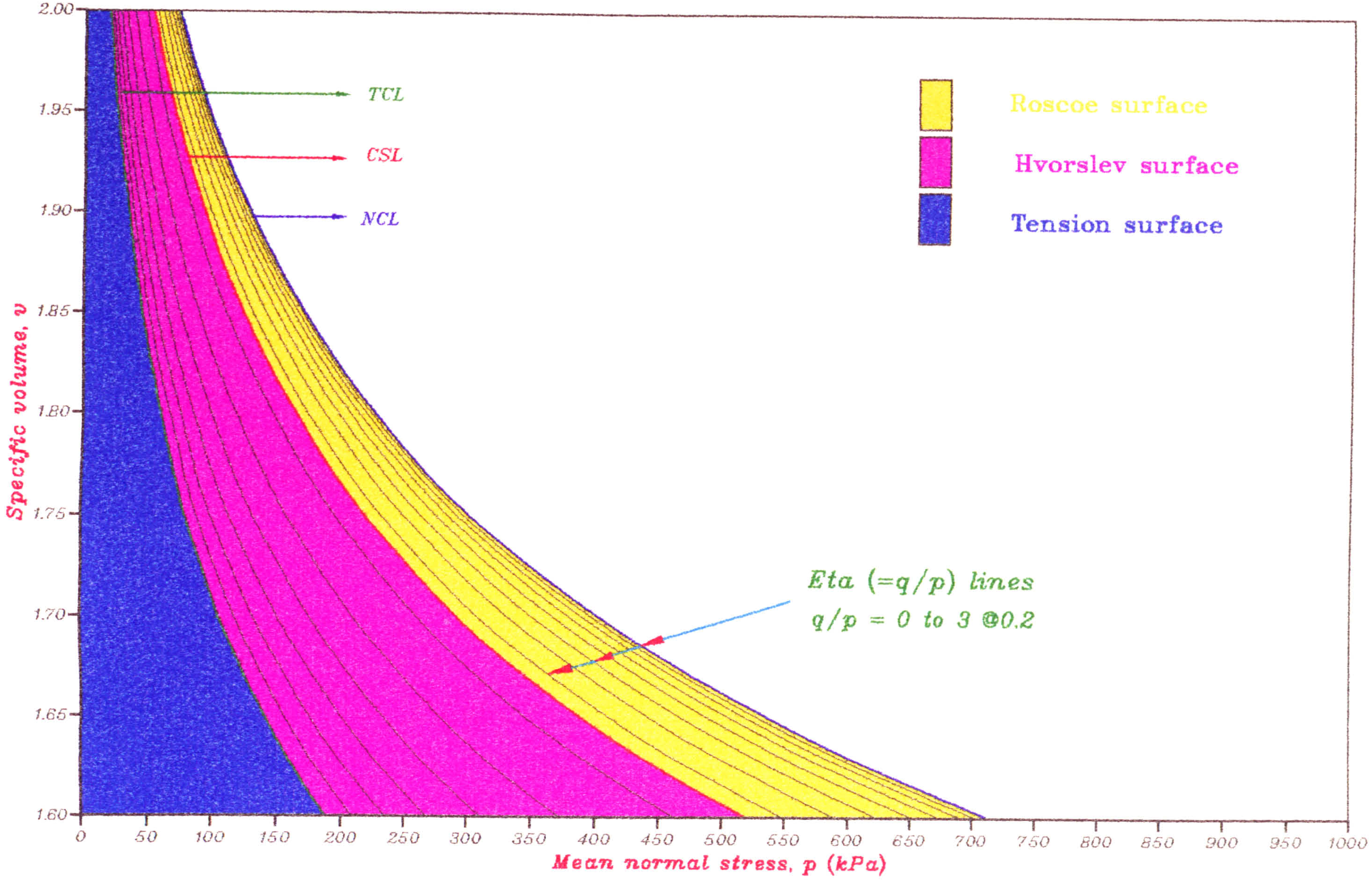


Fig. 3.19 Typical output of State boundaries and Eta lines in p–v plane (Evesham clay, m.c.= 24.5%)



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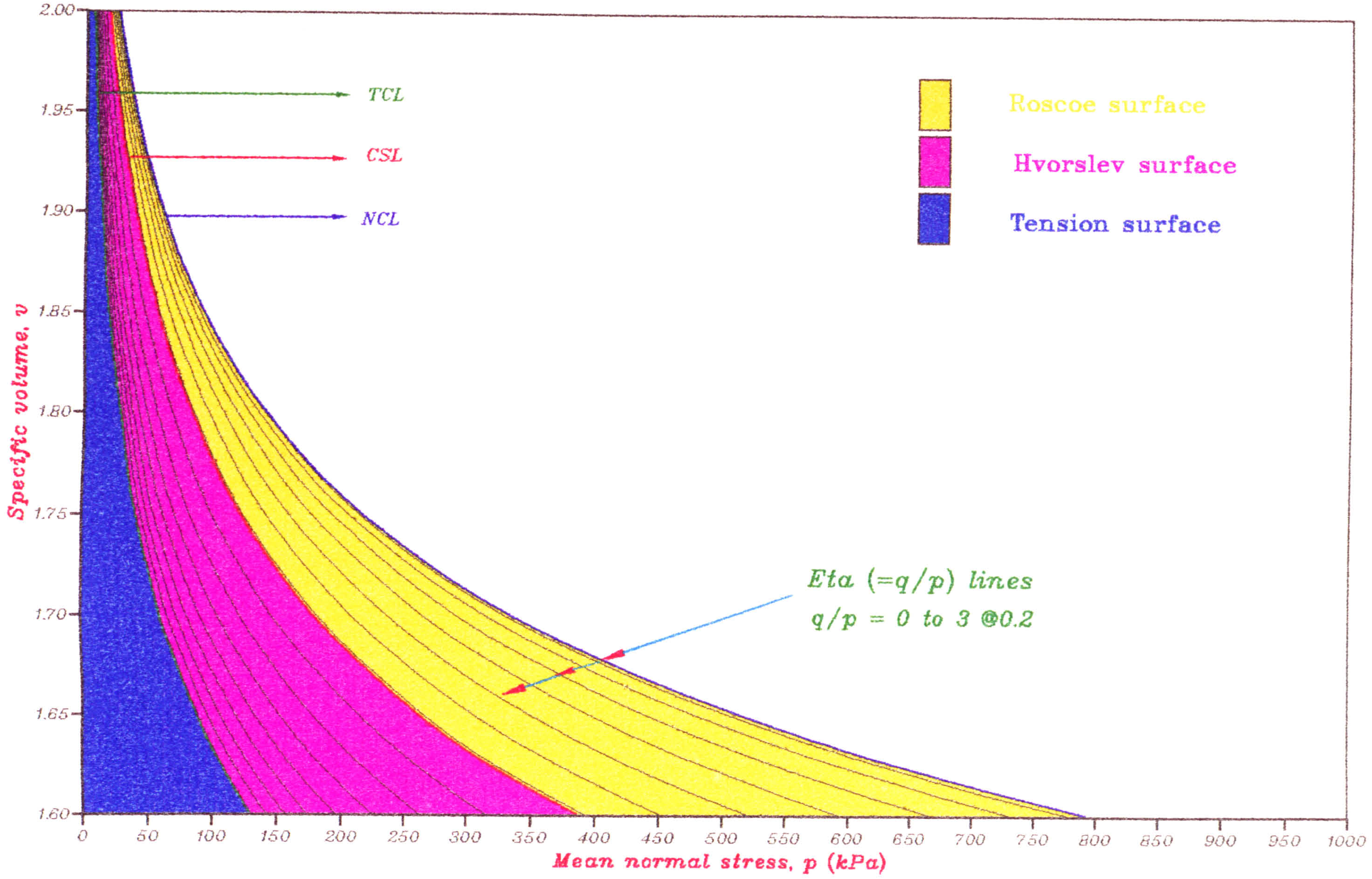

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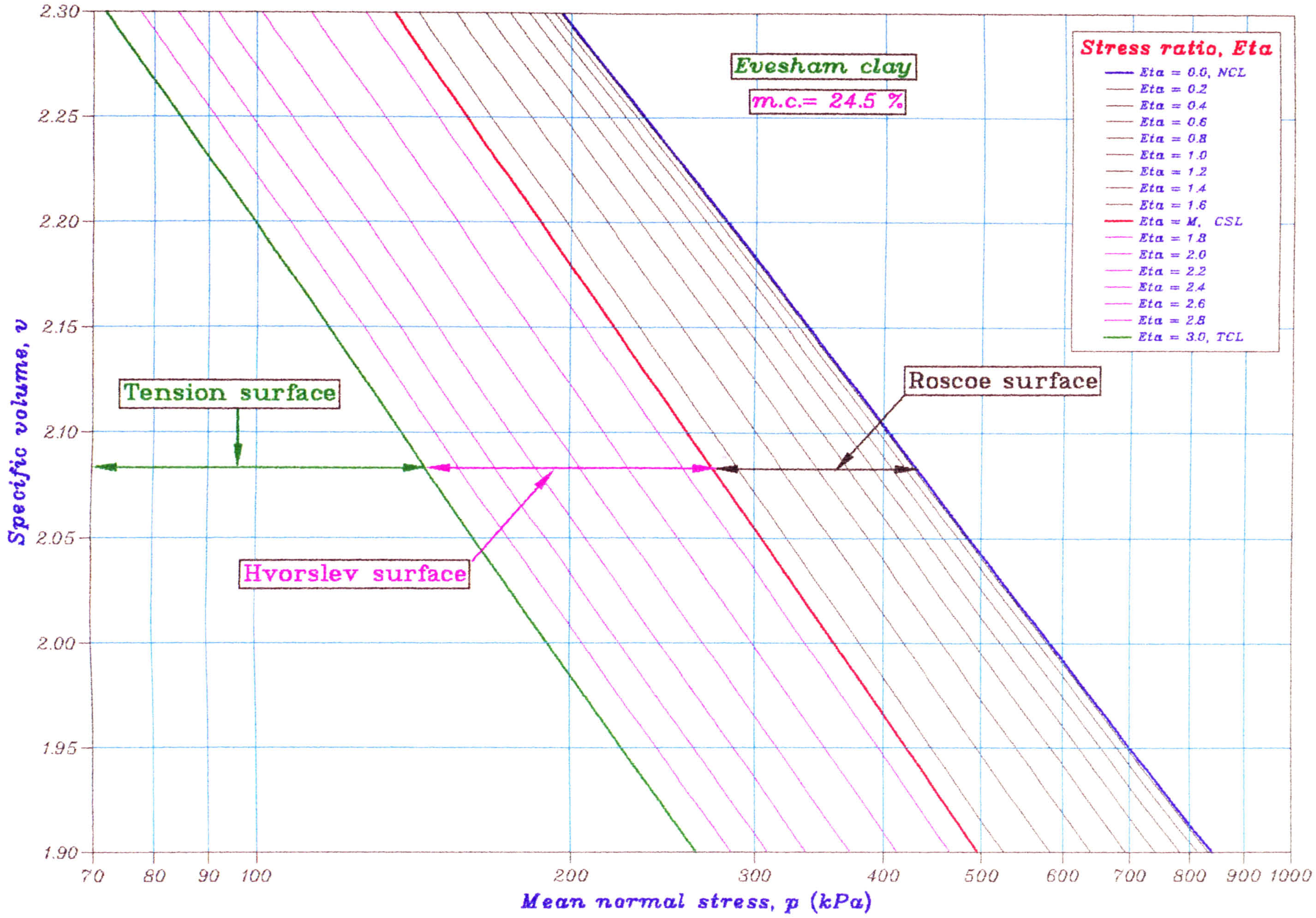

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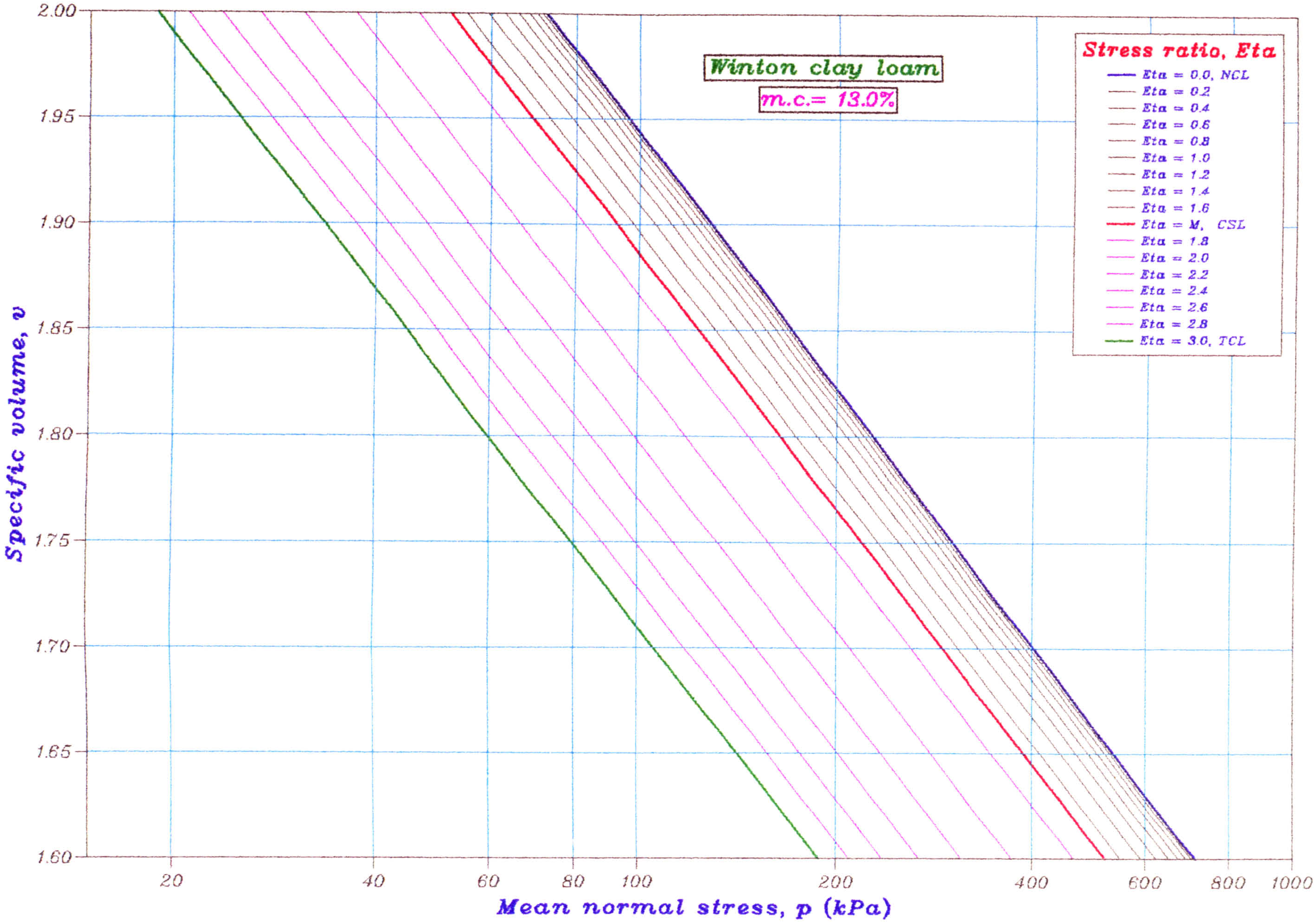
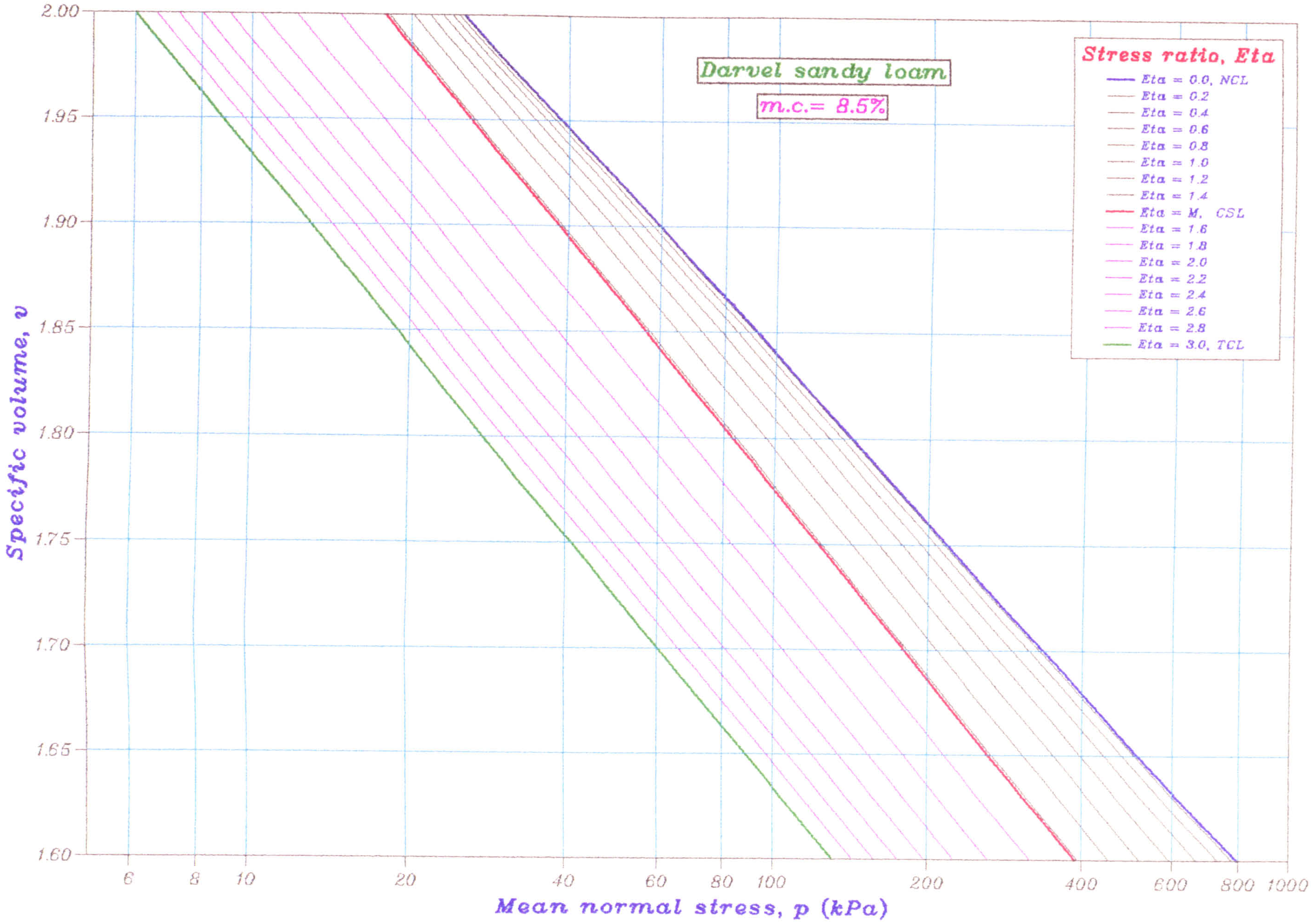


Fig. 3.23 Typical output for state boundaries and Eta-lines in v-ln(p) plane



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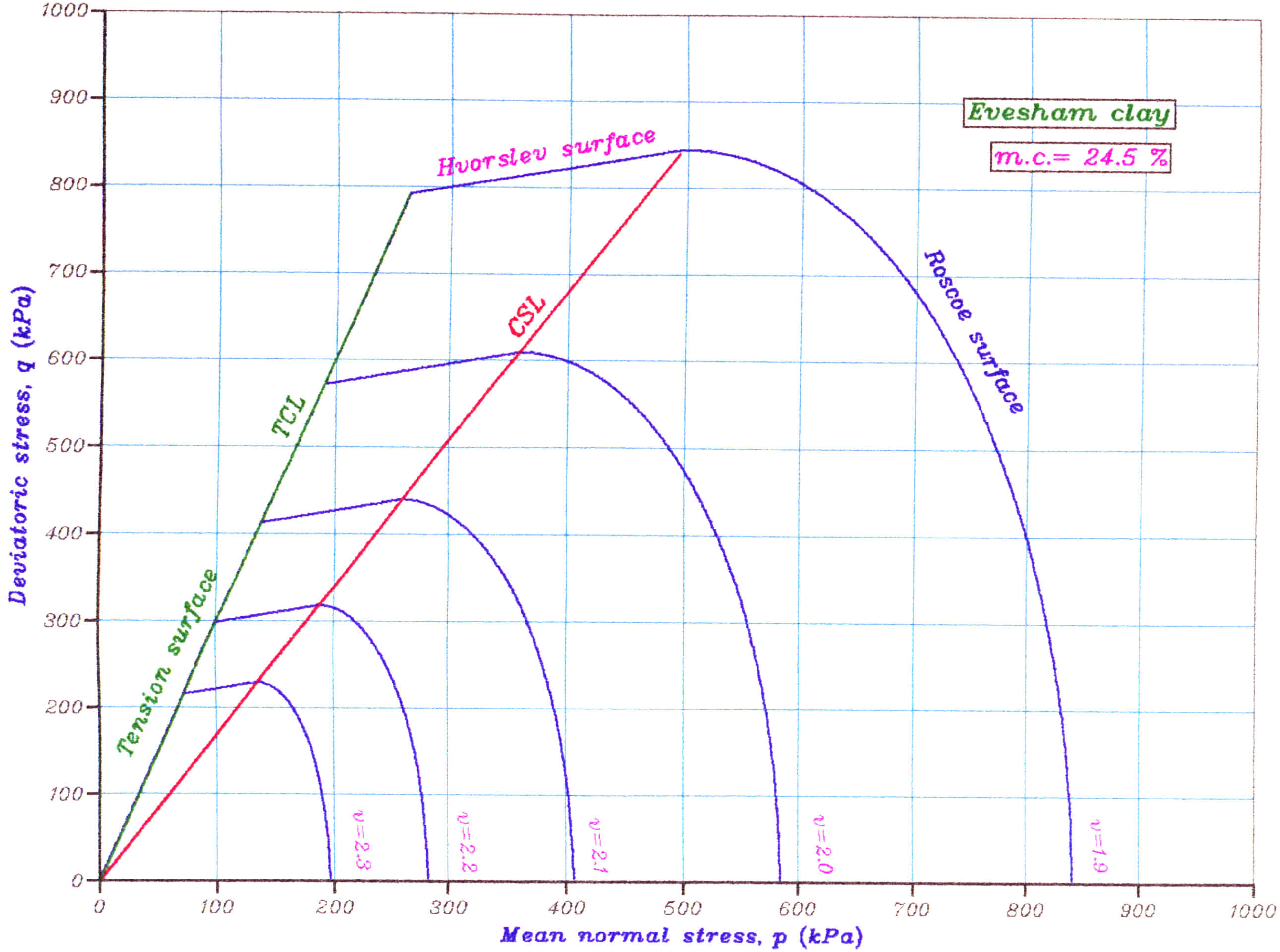

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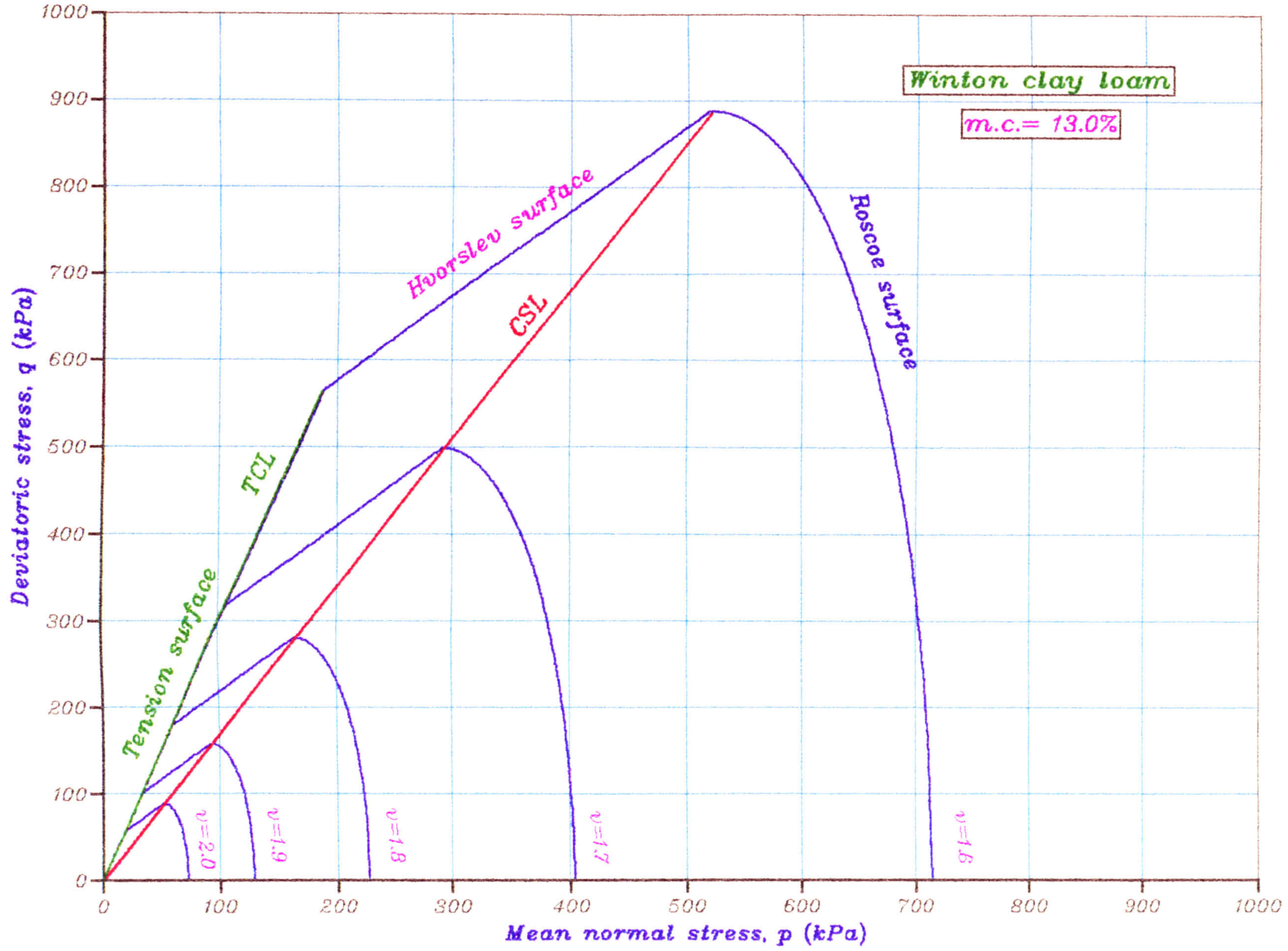


Fig. 3.26 Typical plot for constant v-lines in q-p plane

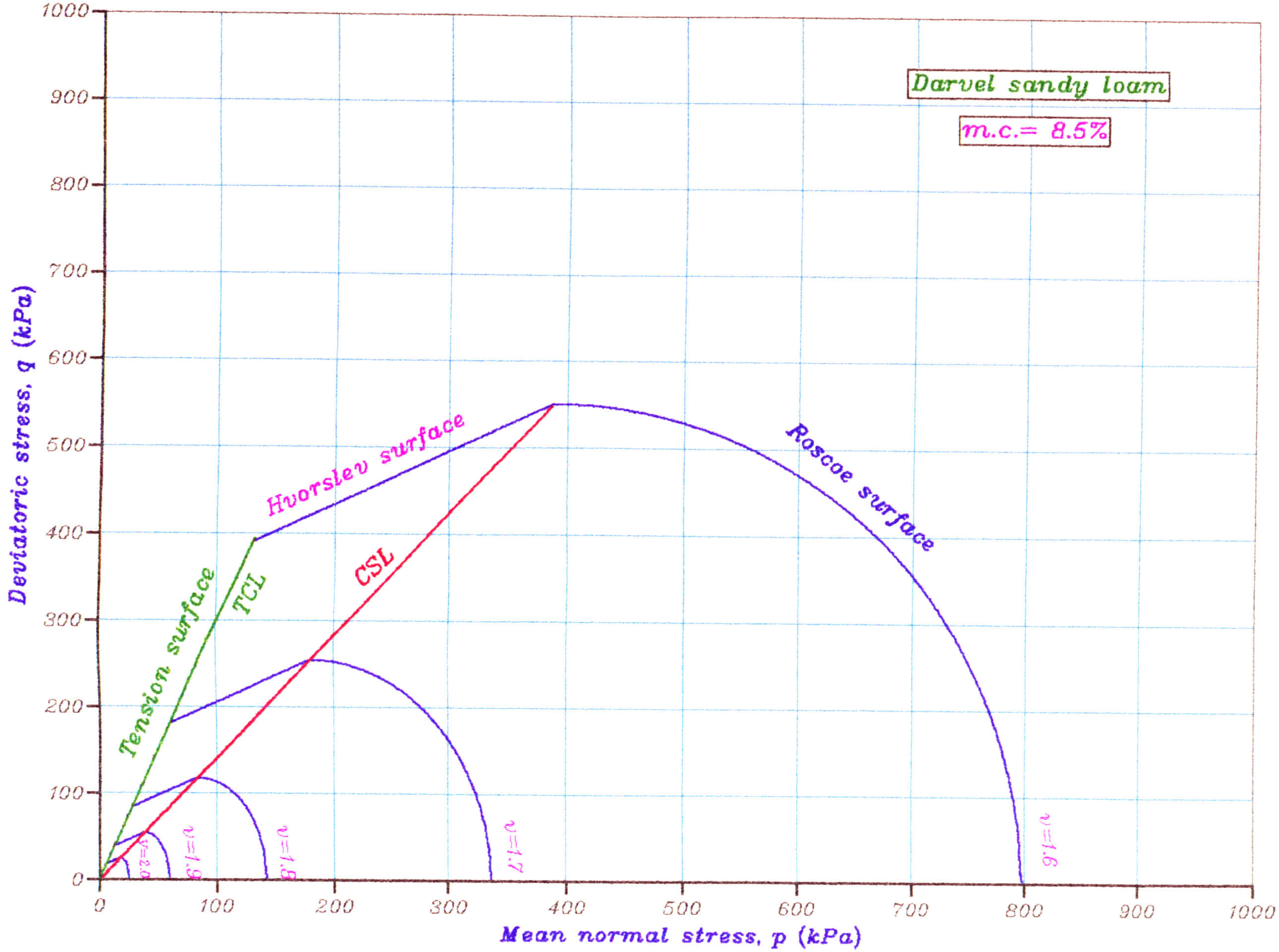


Fig. 3.27 Typical output for constant v–lines in q–p plane

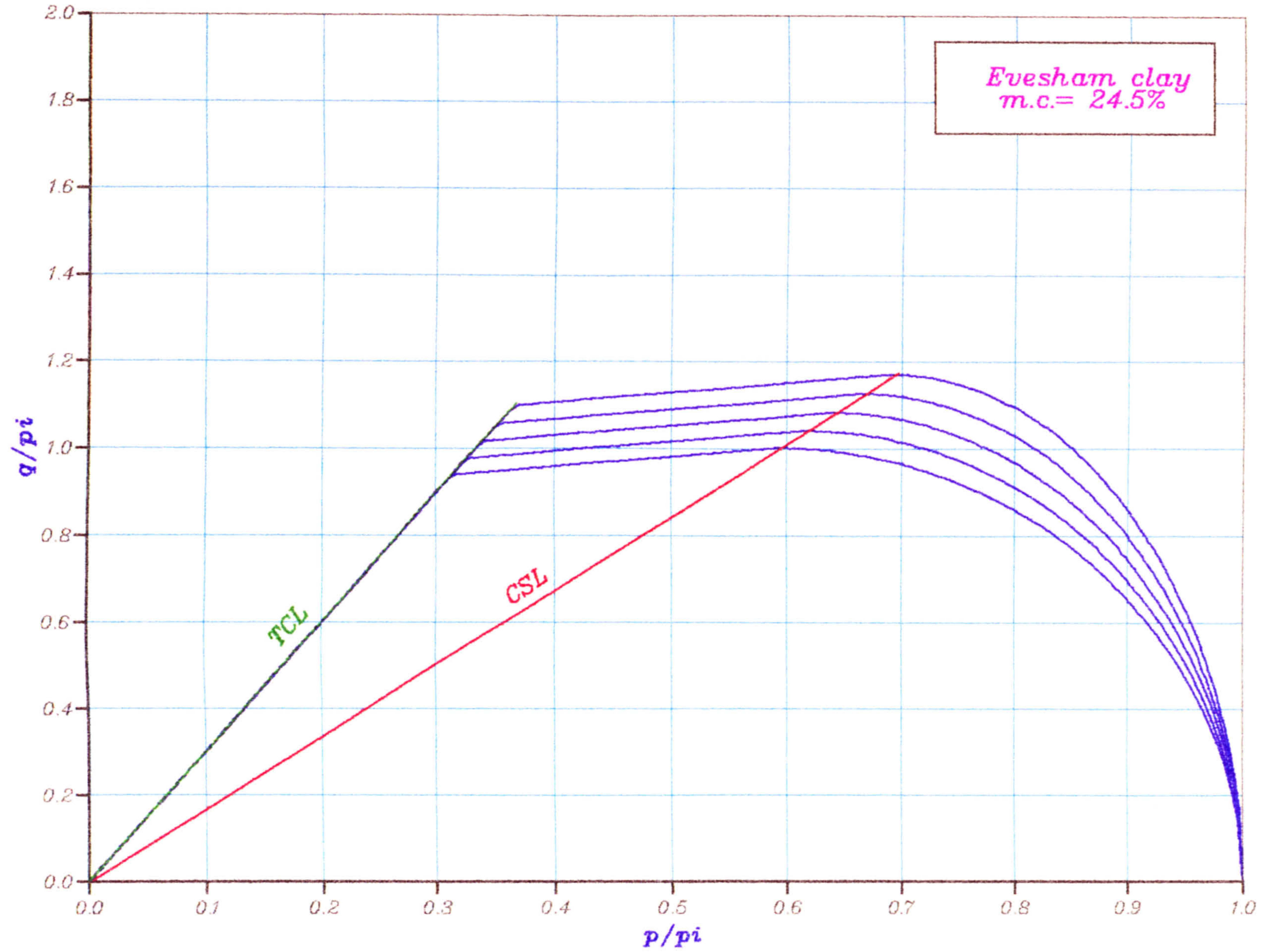
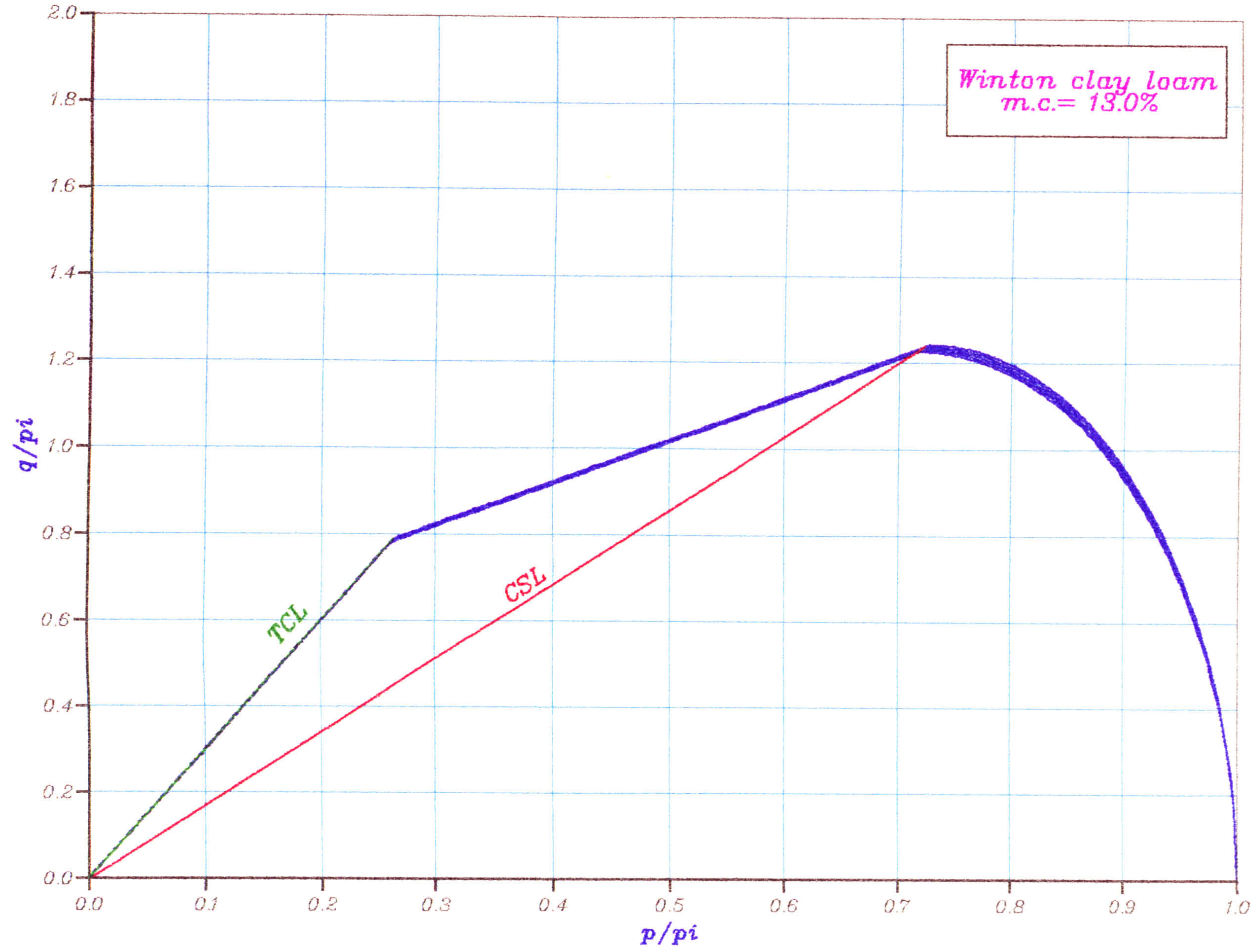


Fig. 3.28 Typical normalized plot on q/pi – p/pi plane for Evesham clay



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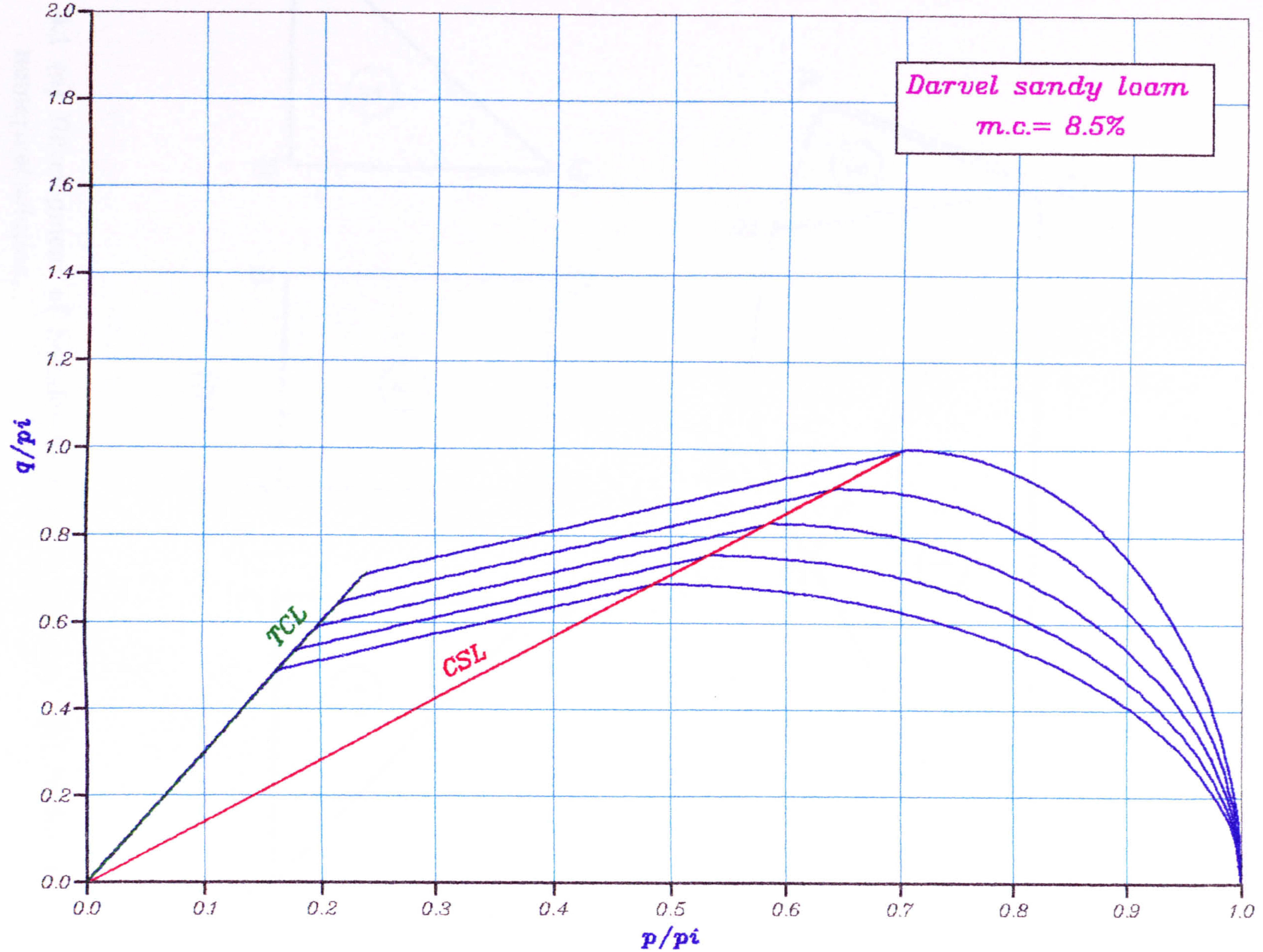


Fig. 3.30 Typical normalized plot on q/pi – p/pi plane for Darvel sandy loam

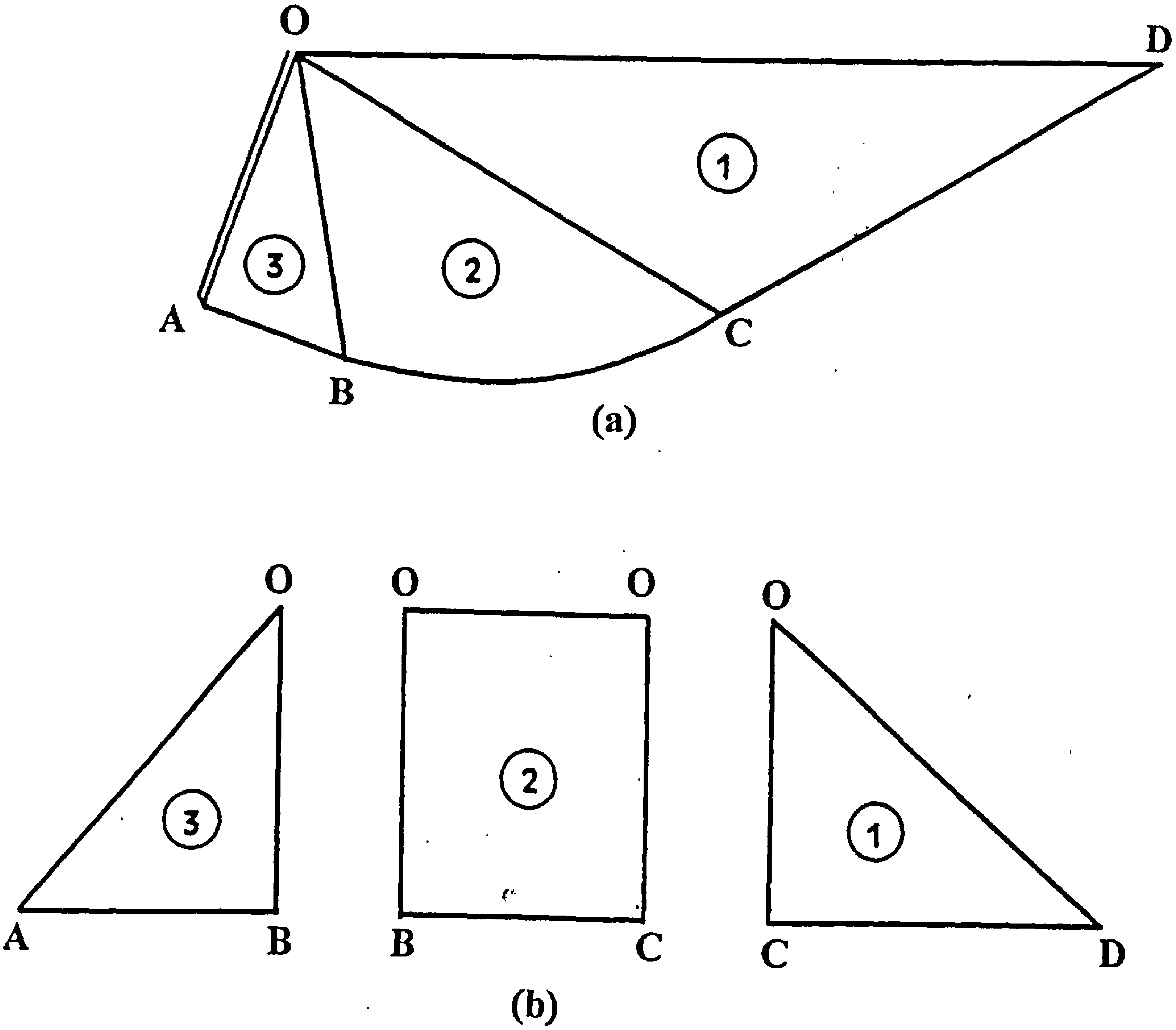
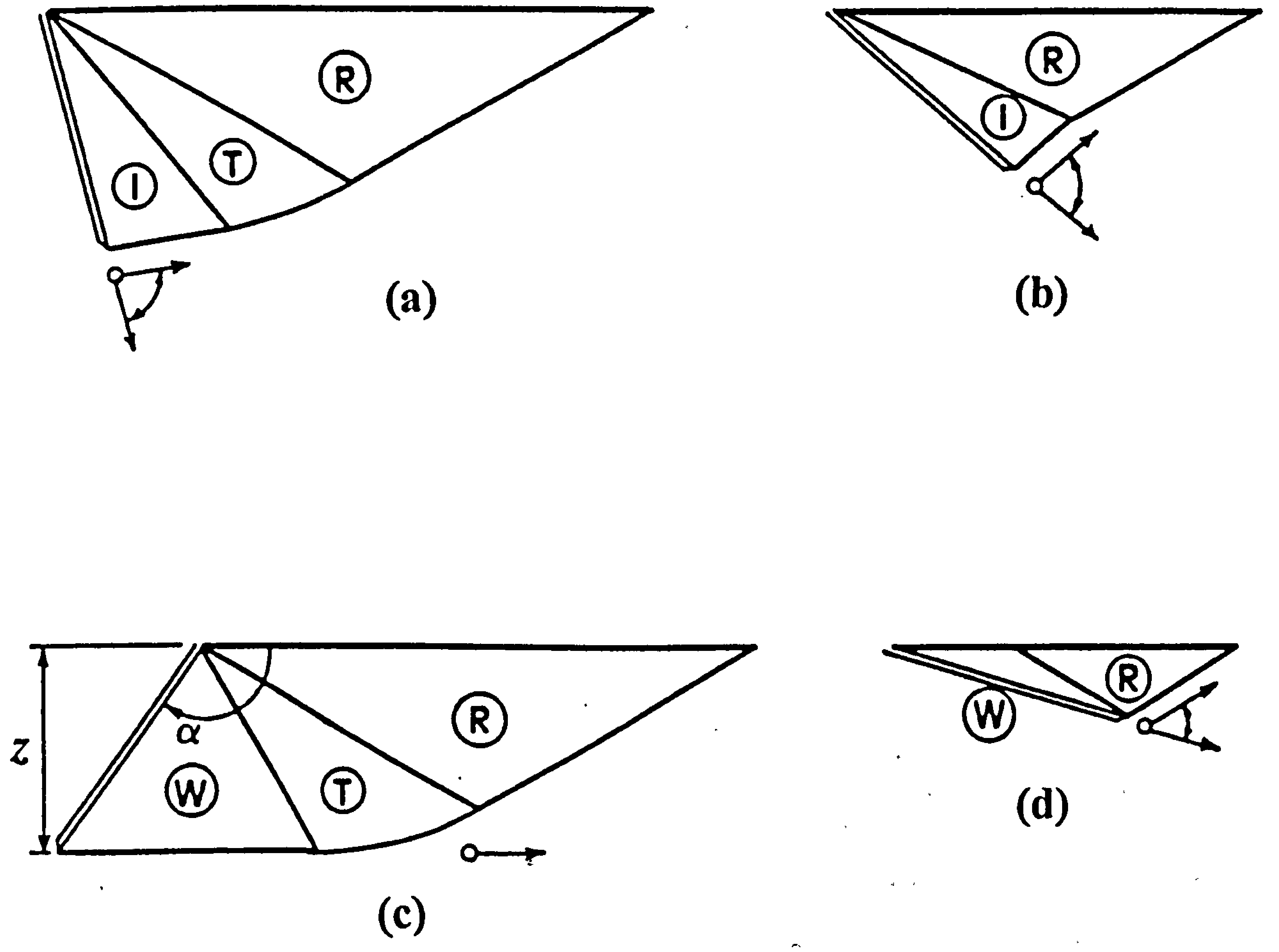
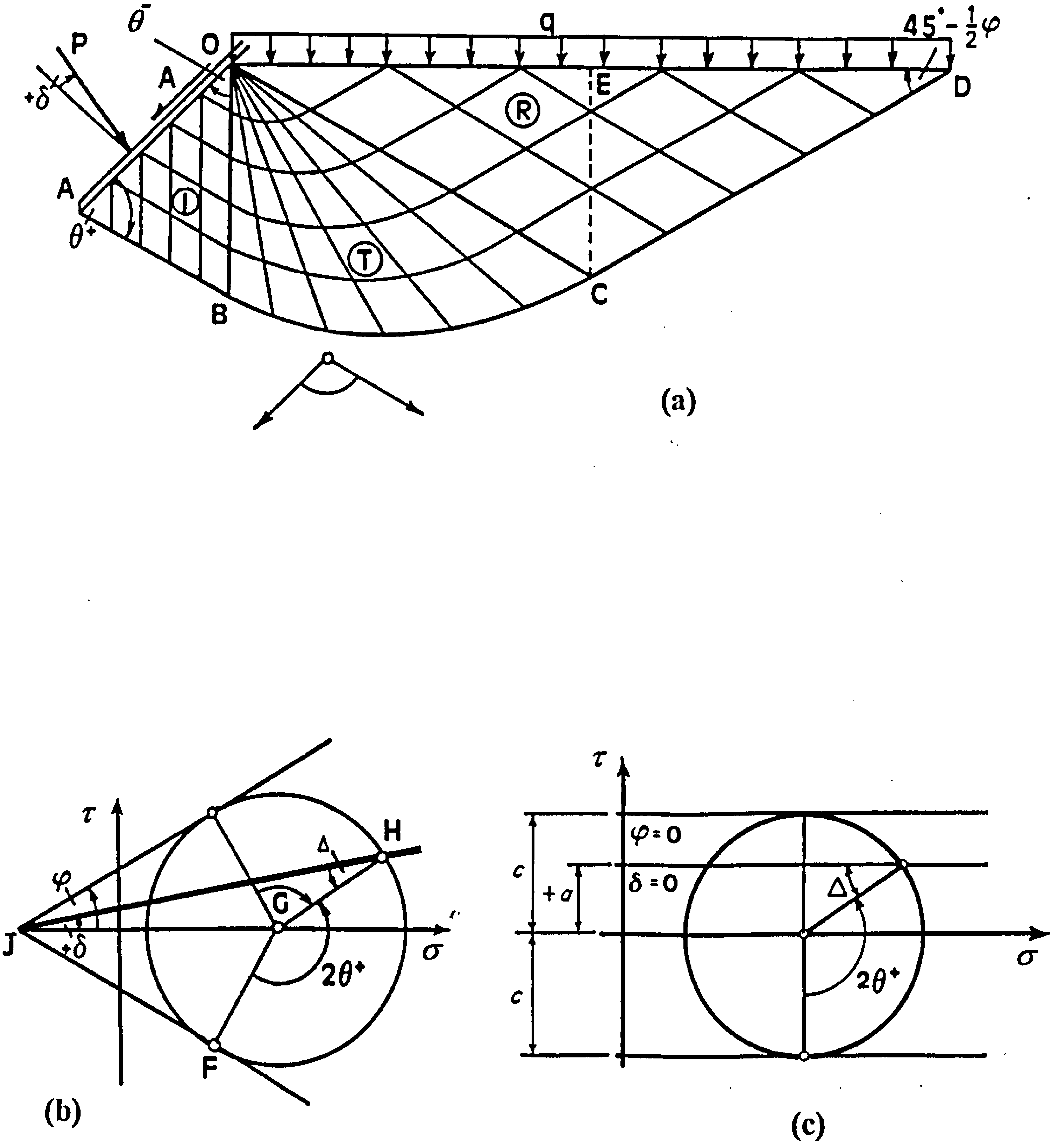


Fig. 4.1 (a) Development of Sokolovski rupture surface. (b) Nodes in numerical solution.



(a) (b) (c) (d)

Fig. 4.2 Main types of slip-line fields; (a) Basic field comprising the Interface (I), Transition (T) and Rankine (R) zones. (b) Small rake angles inducing a stress discontinuity between (I) and (R). (c) Large rake angles with soil boundary wedge (W) fixed to interface. (d) Small rake angles with wedge or discontinuity for a fully rough interface.



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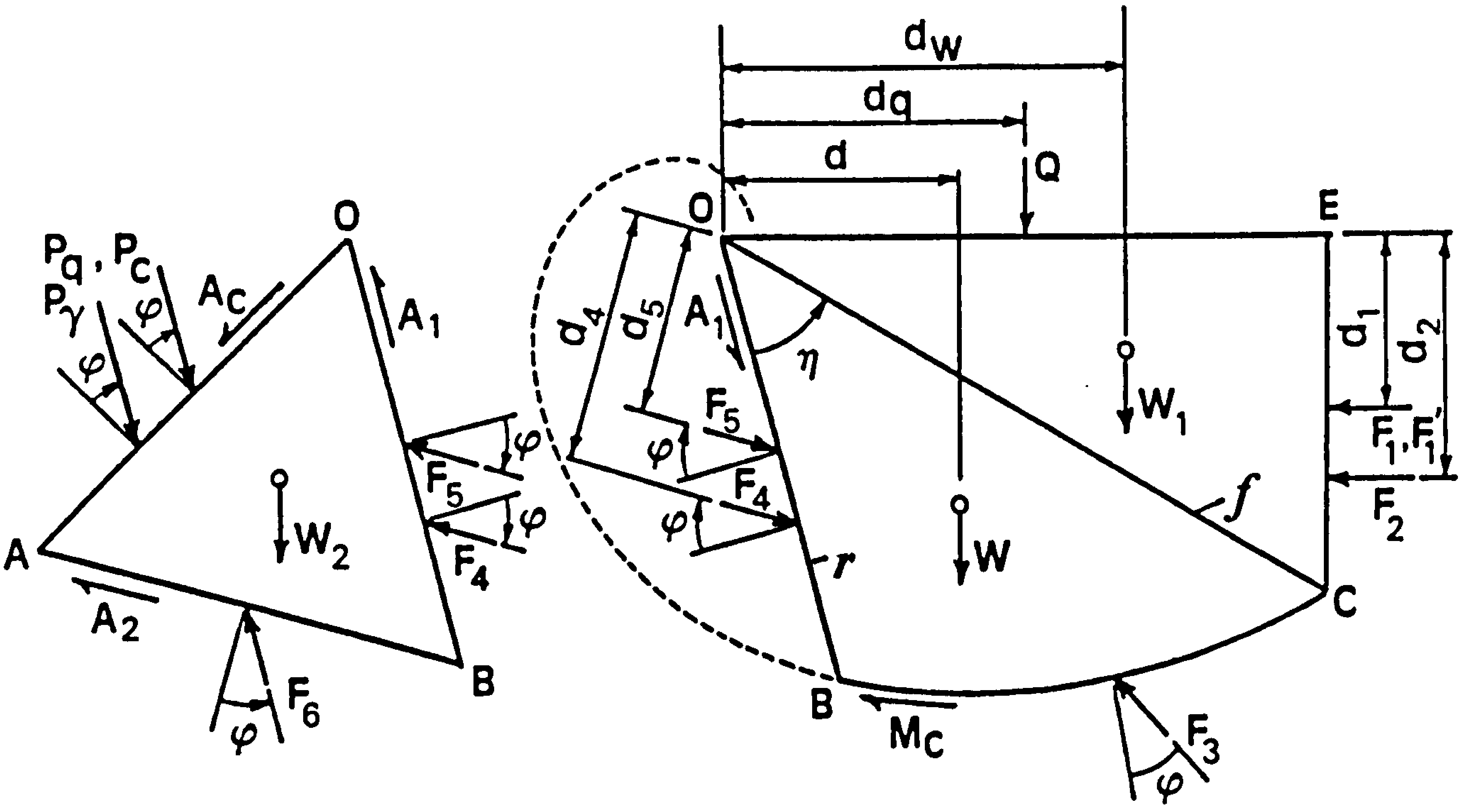


(a) (b)

Fig. 4.4 Forces on the soil rupture block in basic passive failure; (a) Interface zone (b) Transition zone and half the passive Rankine zone.

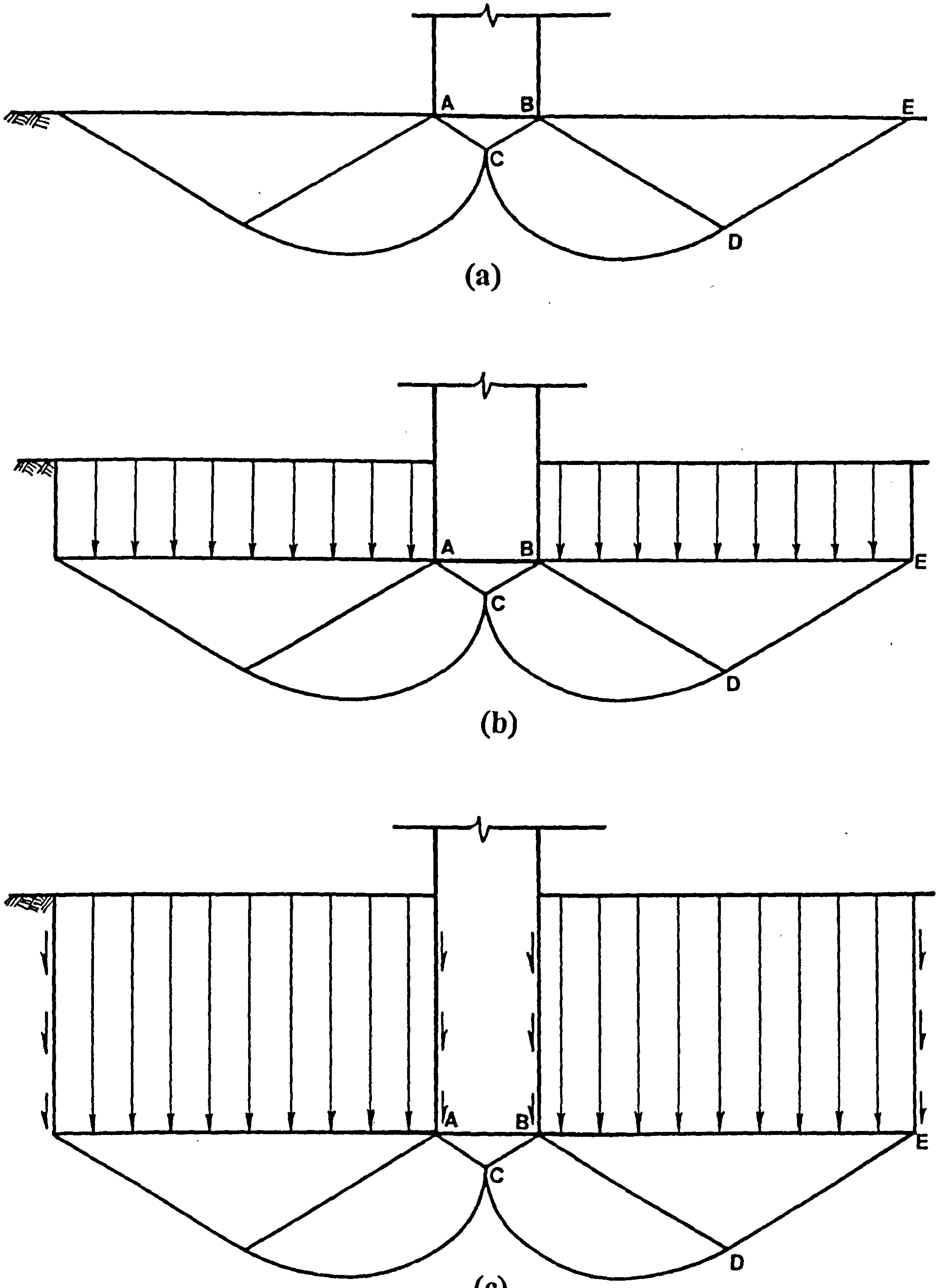
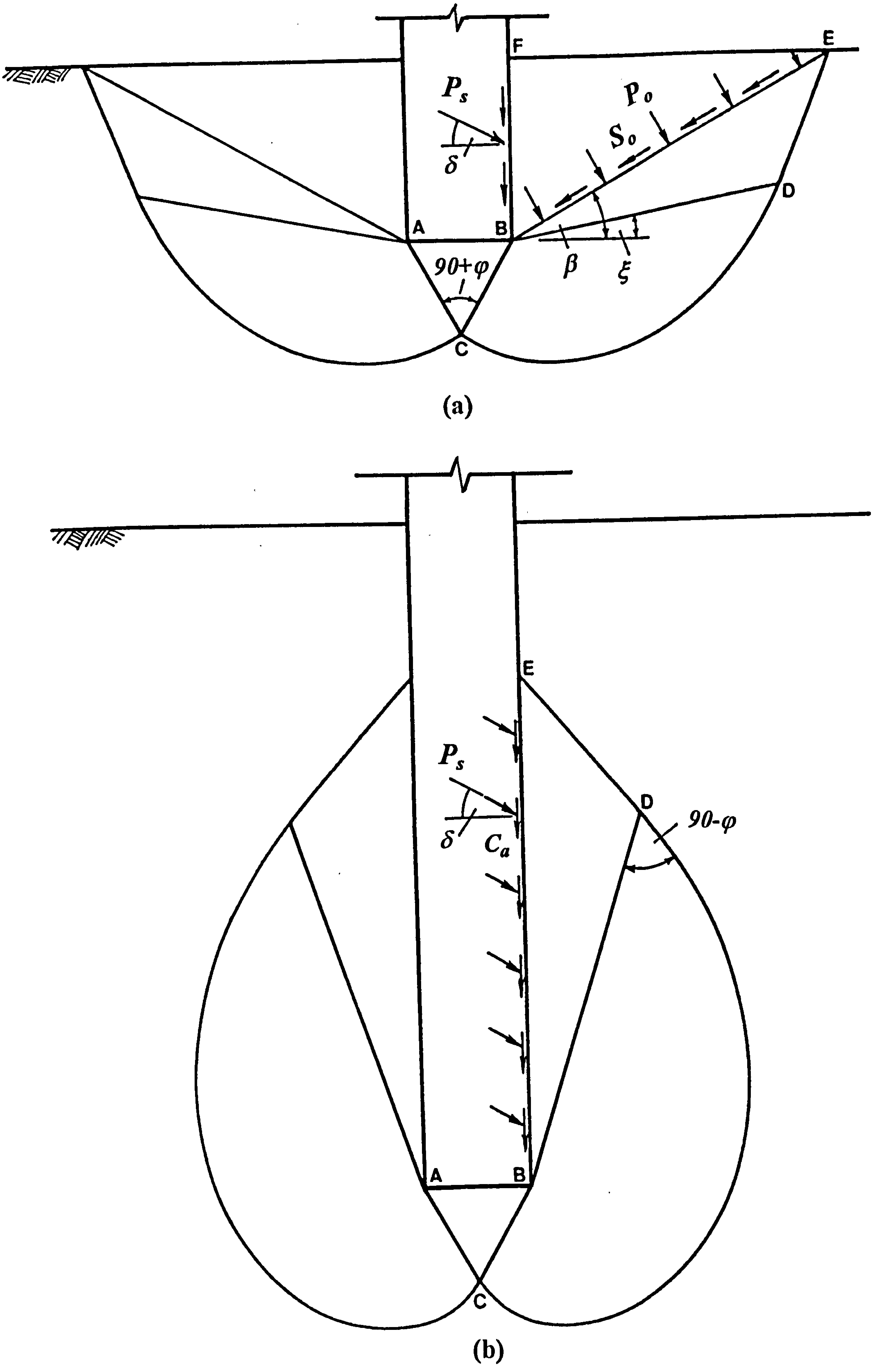


Fig. 4.5 Terzaghi's foundation failure; (a) Surface foundation (b) Shallow foundation (c) Deep foundation.



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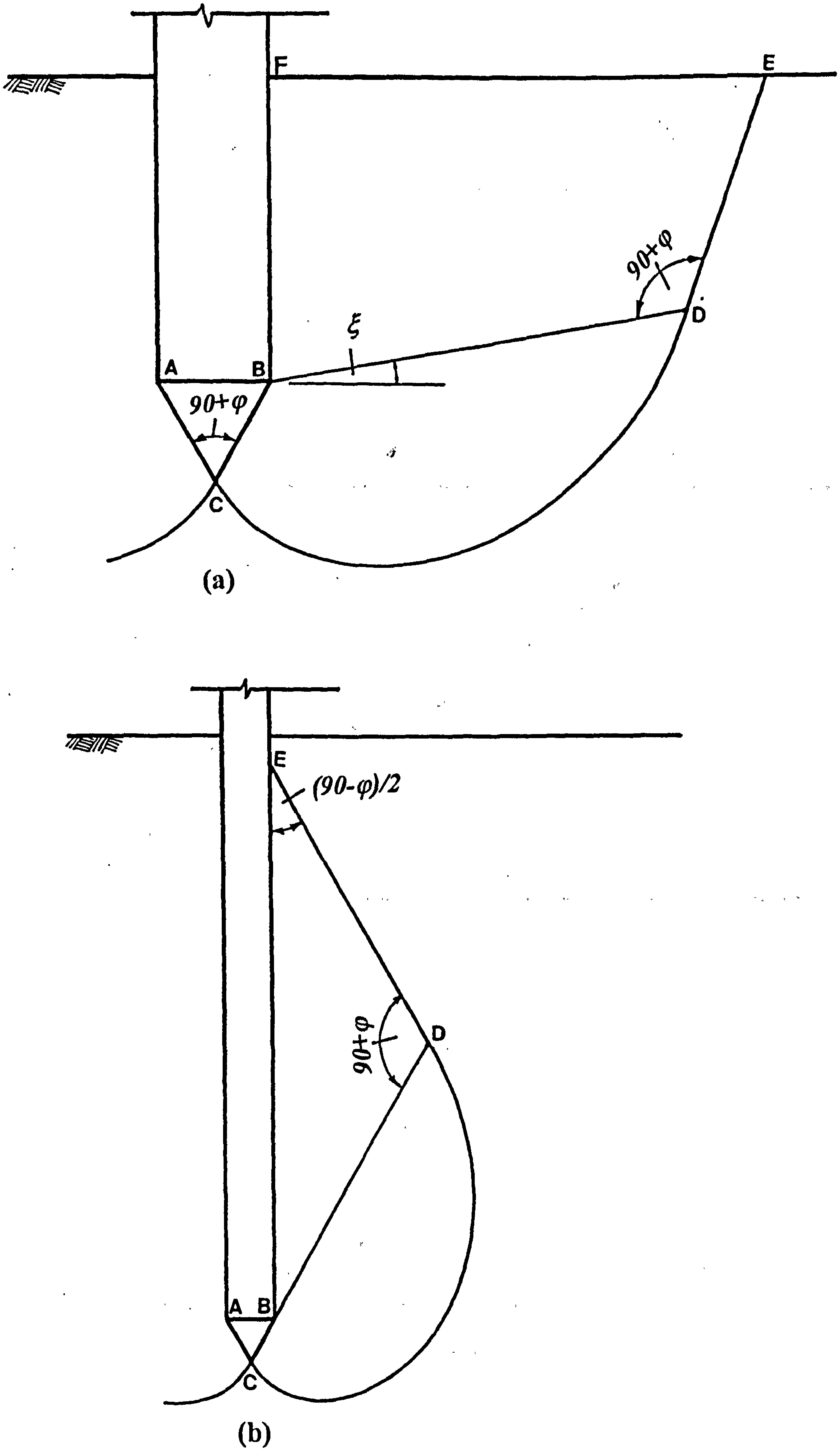
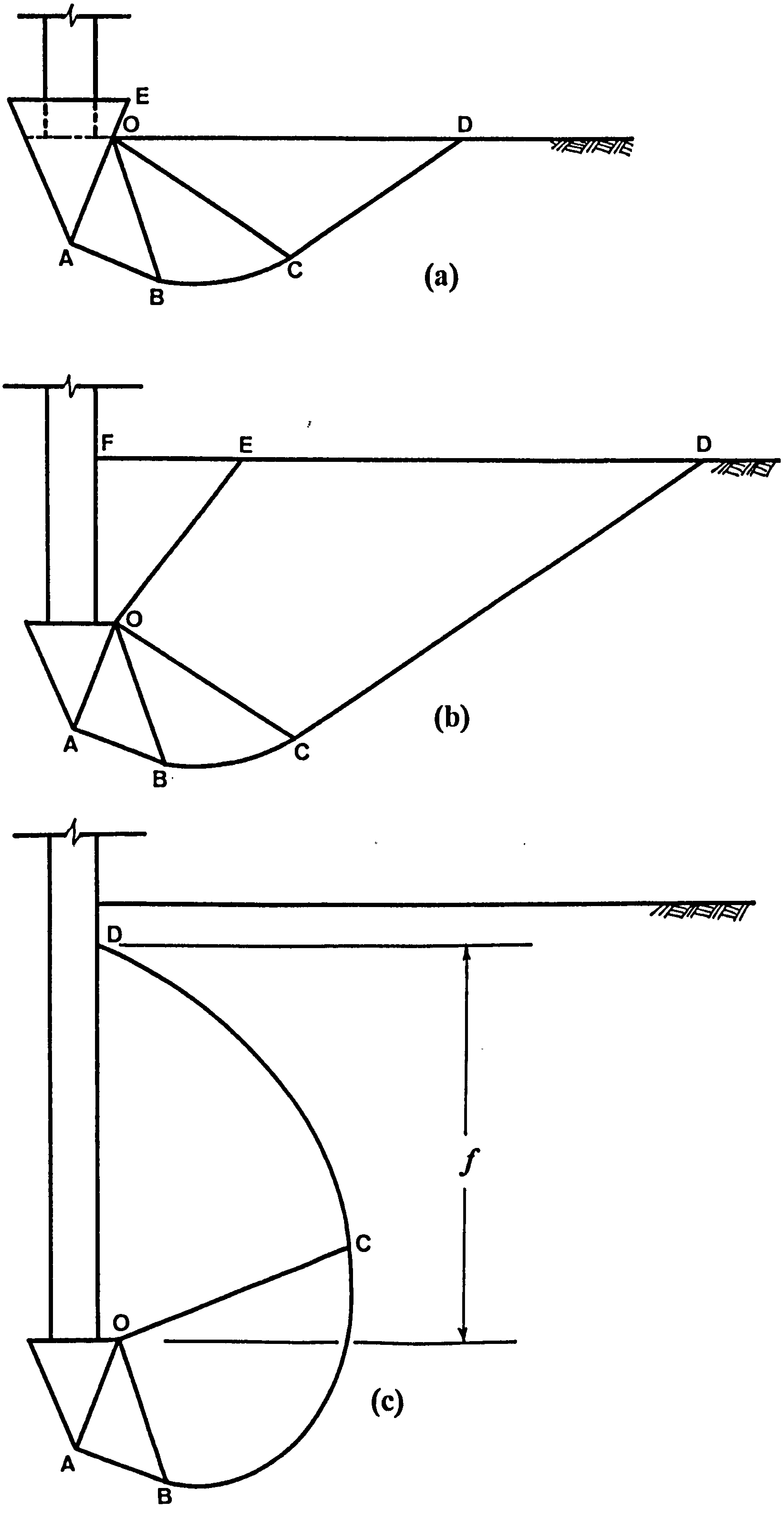


Fig. 4.7 Witney's foundation failure geometry; (a) Shallow Sinkage (b) Deep sinkage.



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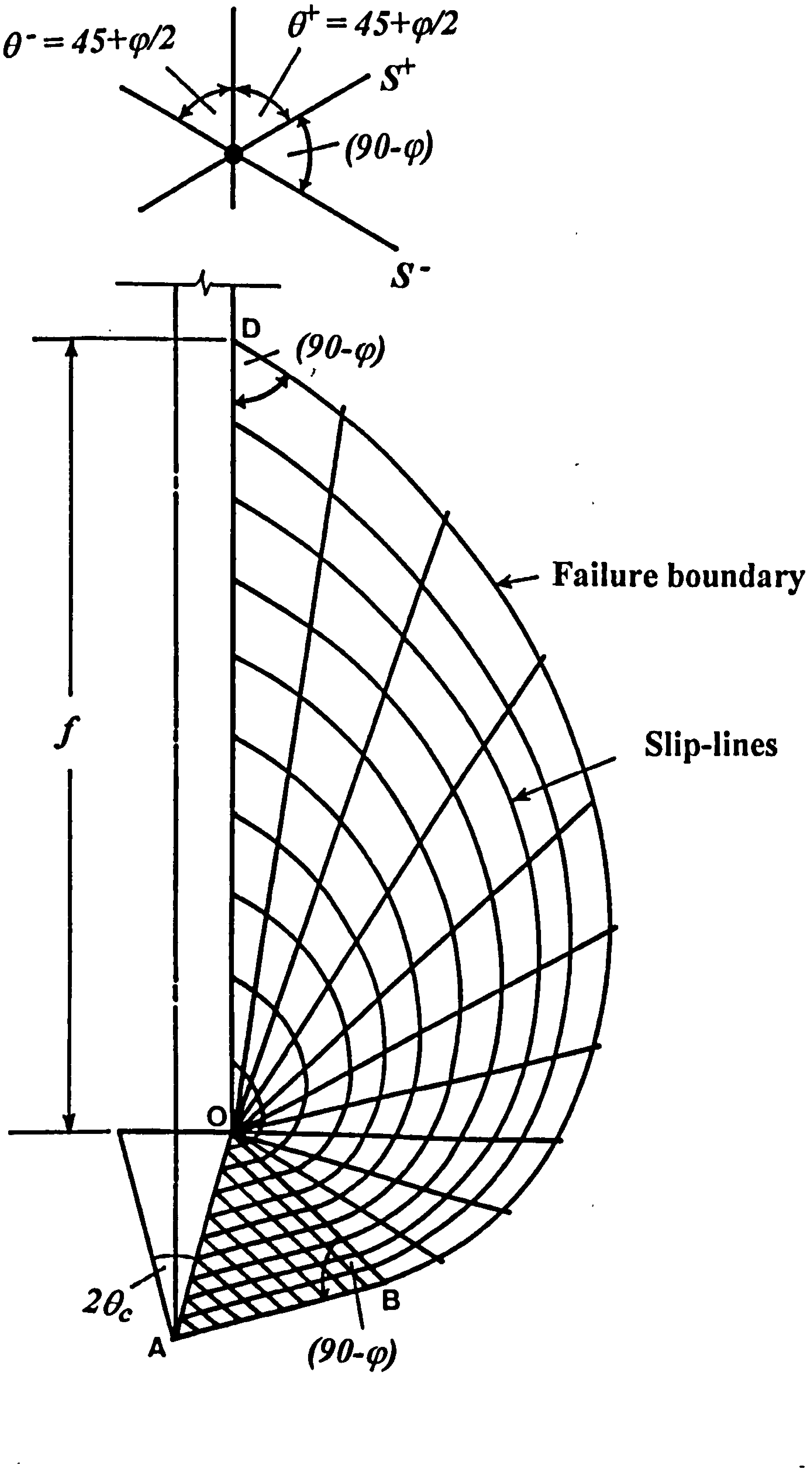


Fig. 4.9 (a) Development of Slip-line field for cone penetrometer analysis ($\varphi = 30^0$ and $\delta = 0^0$).

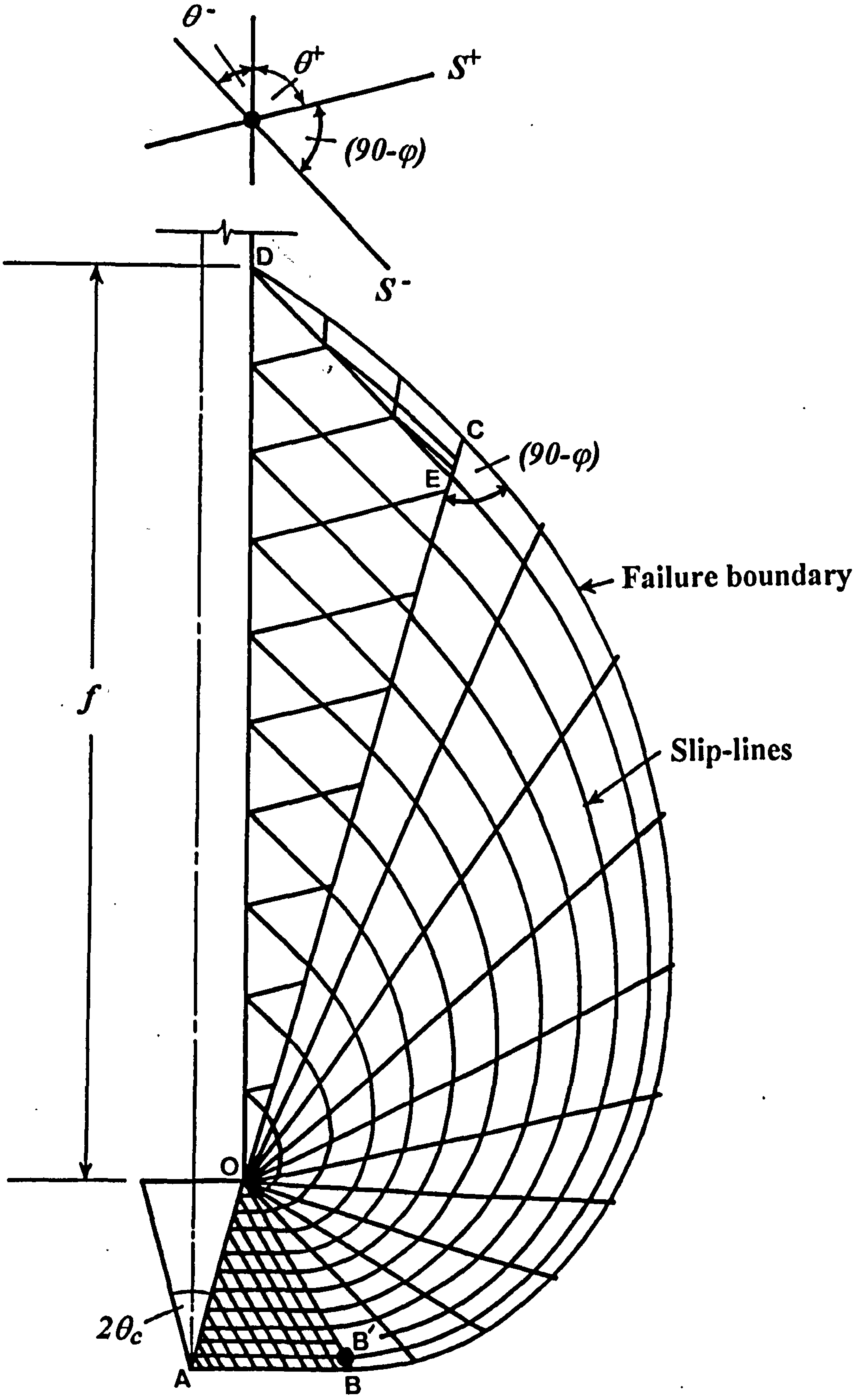


Fig. 4.9 (b) Development of Slip-line field for cone penetrometer analysis ($\varphi = 30^0$ and $\delta = 10^0$).

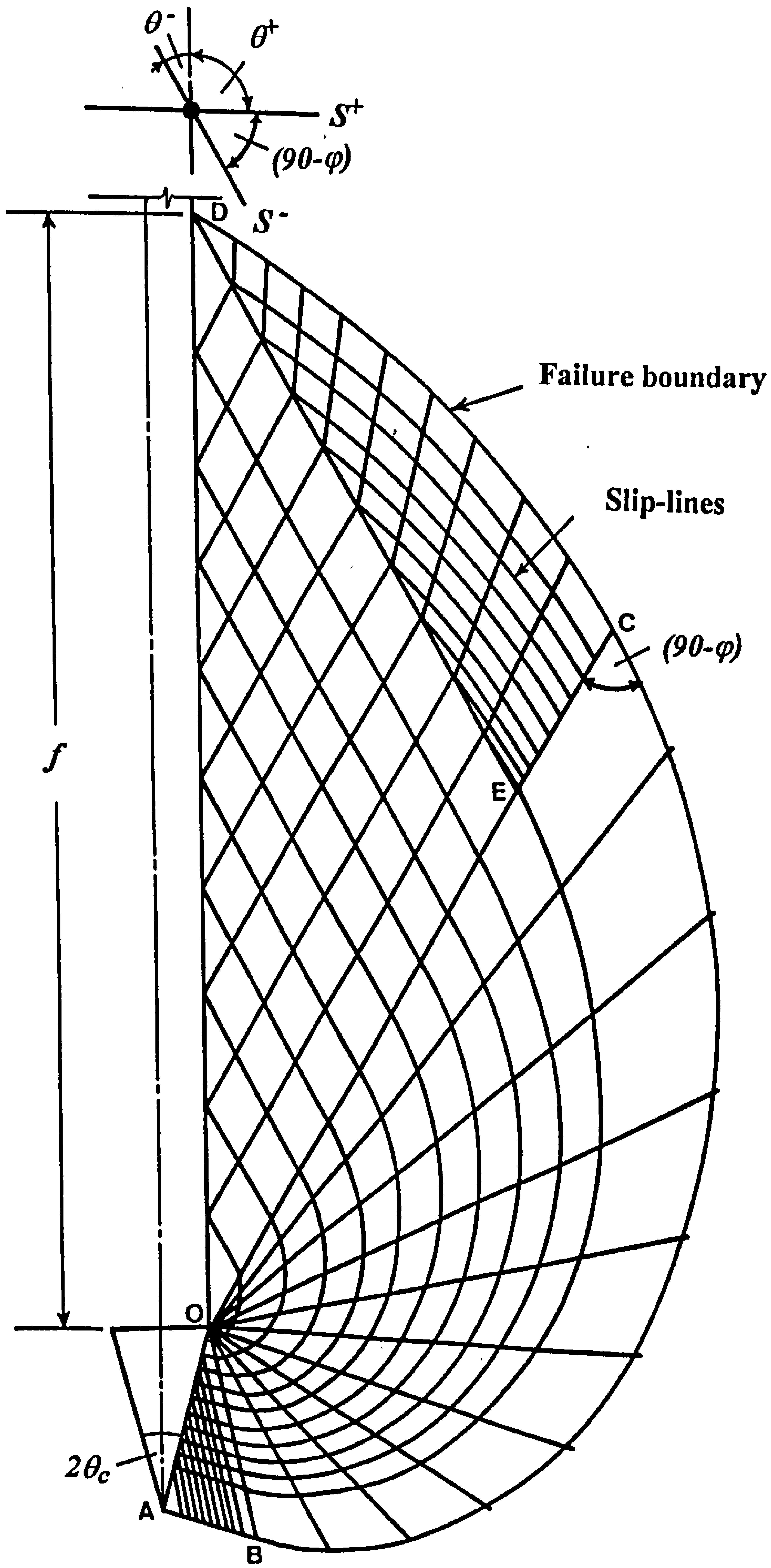


Fig. 4.9 (c) Development of Slip-line field for cone penetrometer analysis ($\varphi = 30^0$ and $\delta = 20^0$).

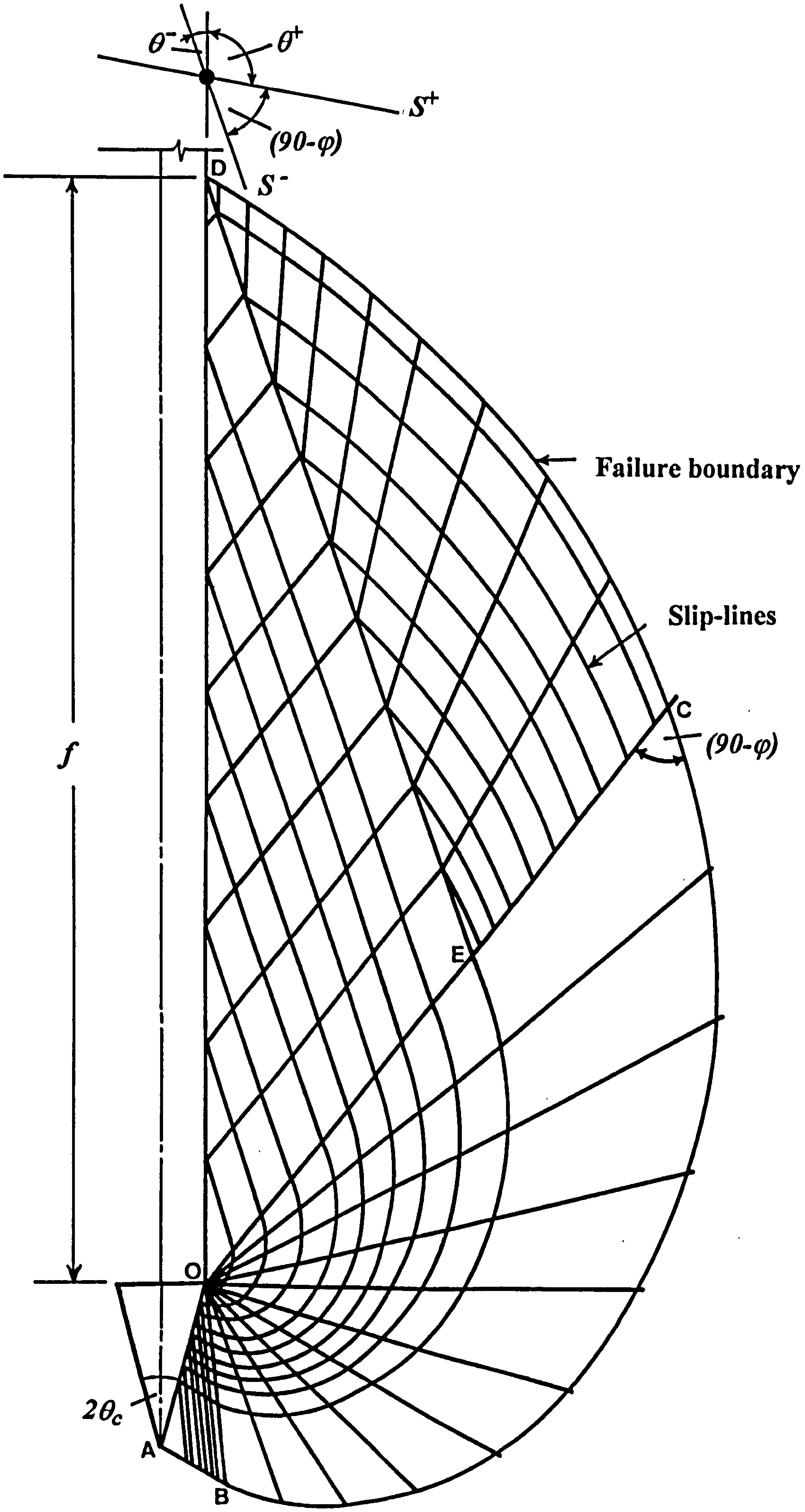


Fig. 4.9 (d) Development of Slip-line field for cone penetrometer analysis ($\varphi = 30^0$ and $\delta = 25^0$).

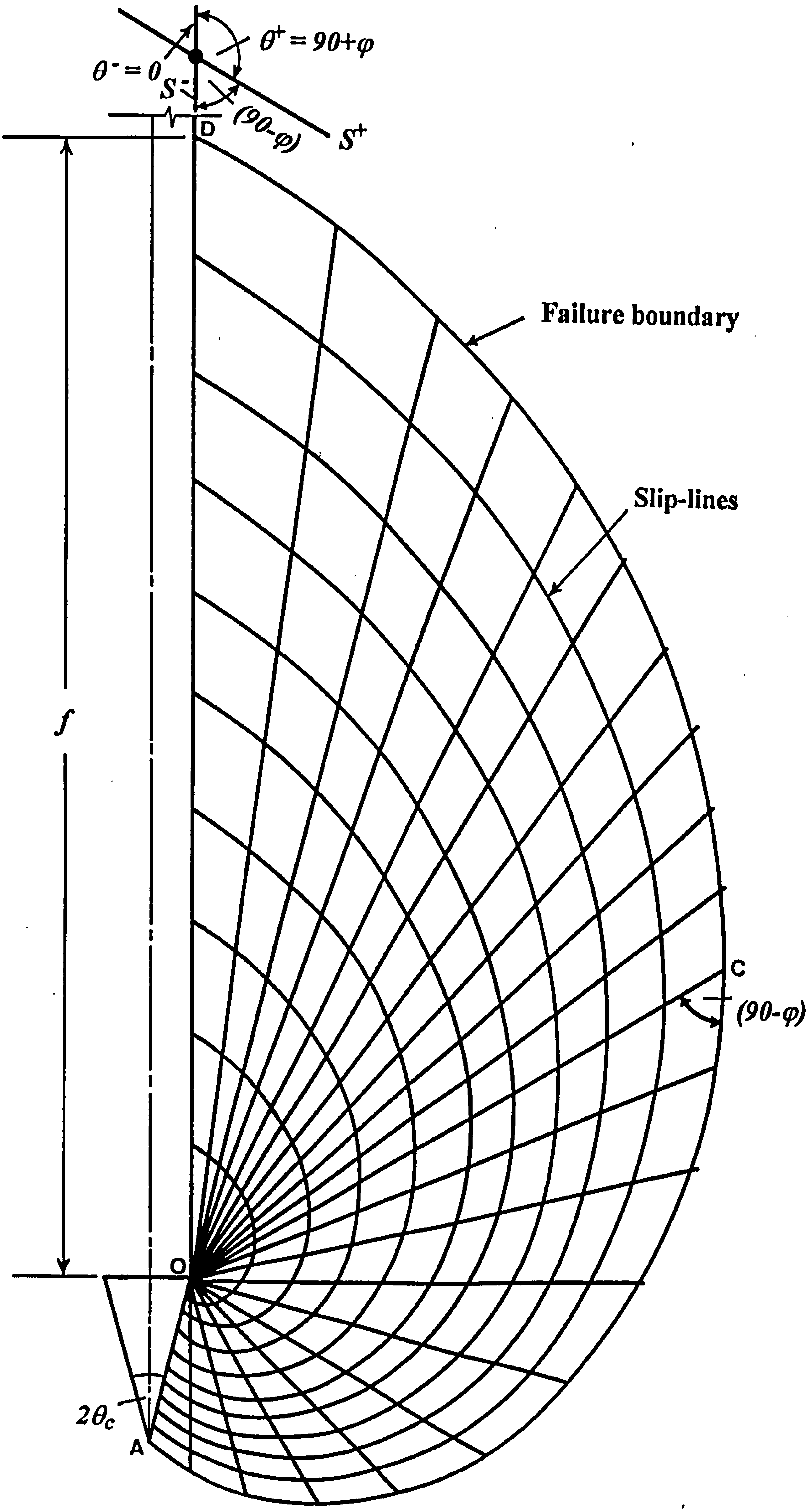


Fig. 4.9 (e) Development of Slip-line field for cone penetrometer analysis ($\varphi = \delta = 30^0$).

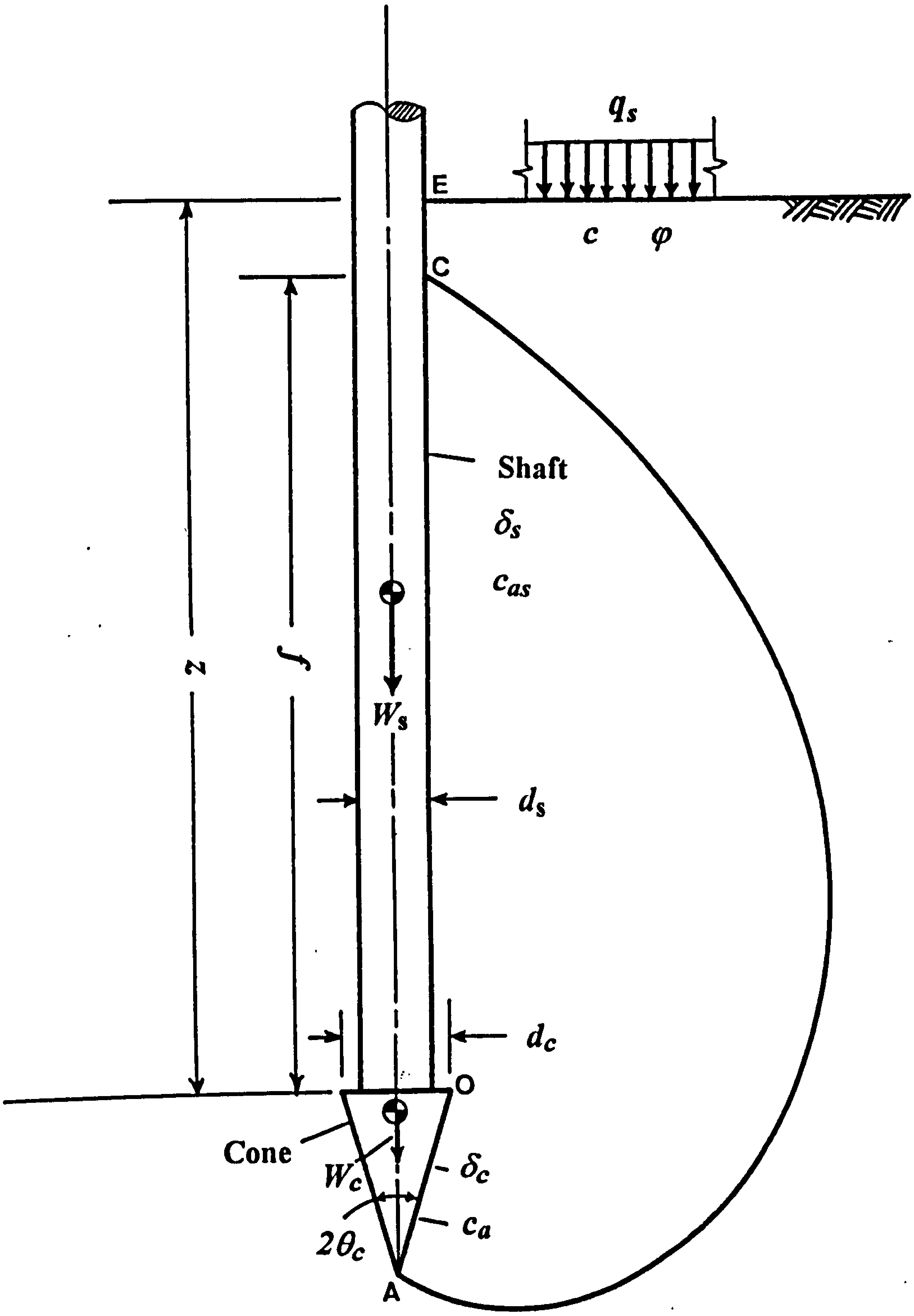


Fig. 4.10 Basic parameters for cone penetrometer model.

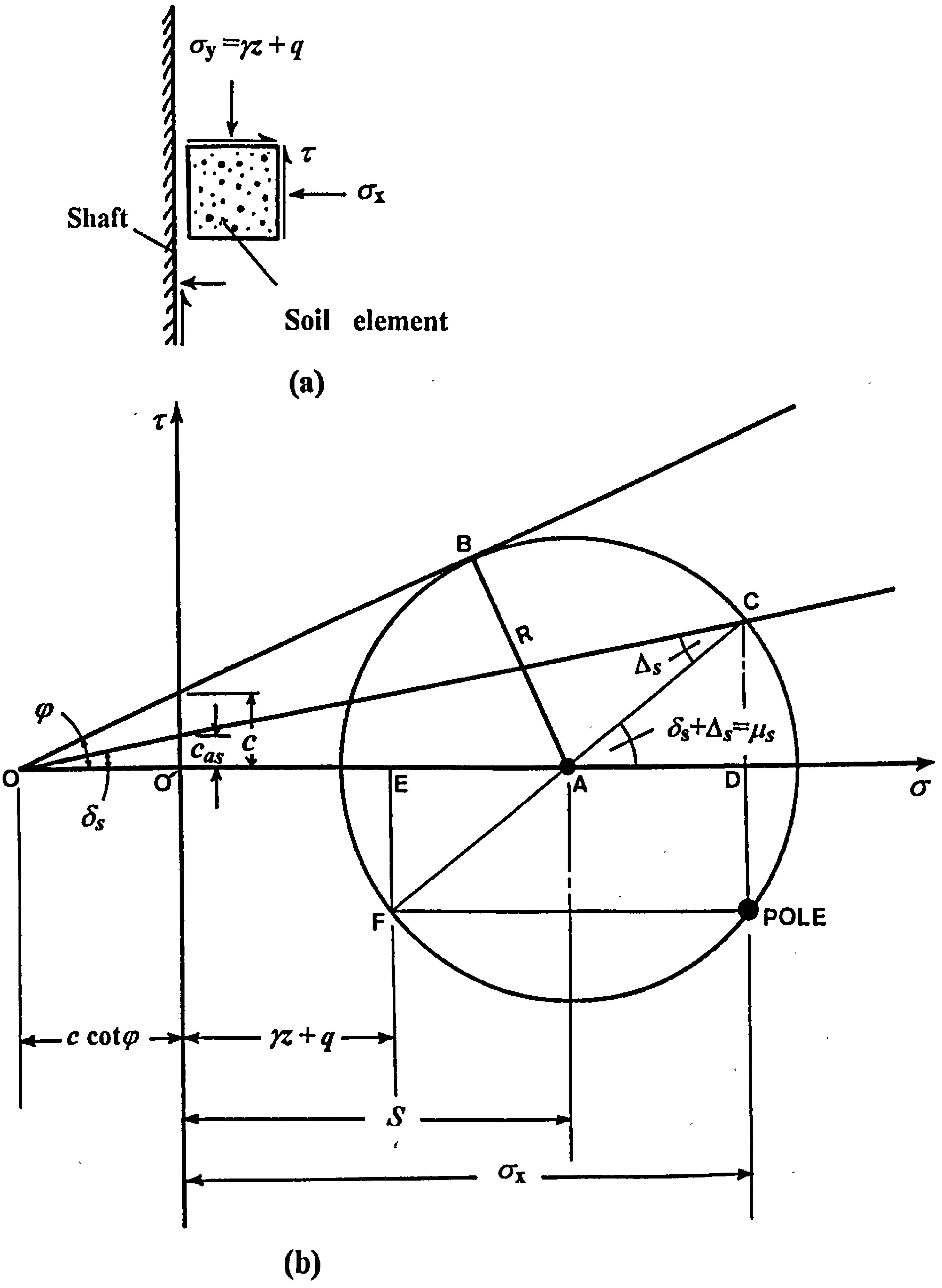


Fig. 4.11 (a) Equilibrium of soil element. (b) Mohr's diagram for shaft boundary.

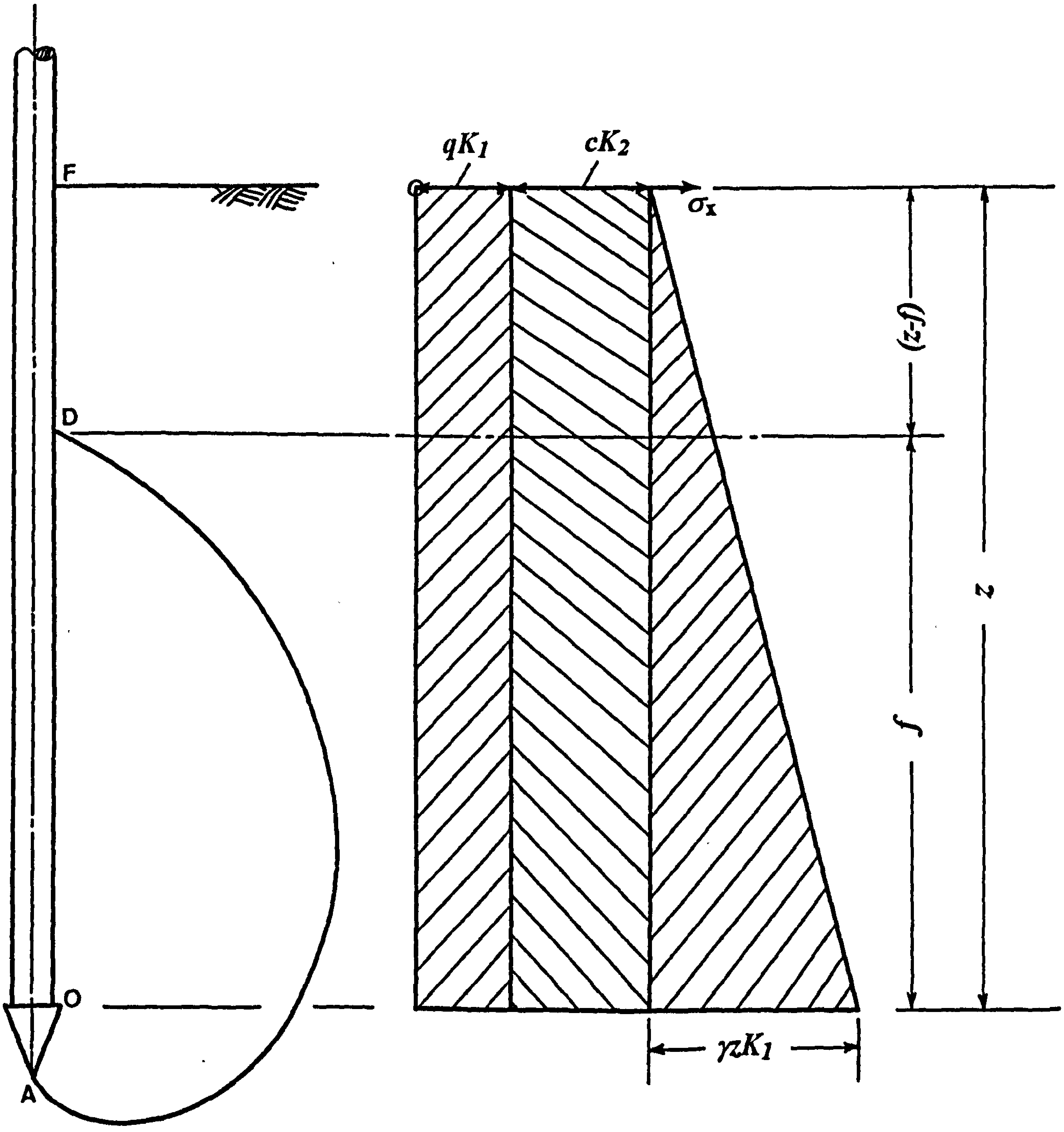


Fig. 4.12 Variation of three stress components with depth of penetration.

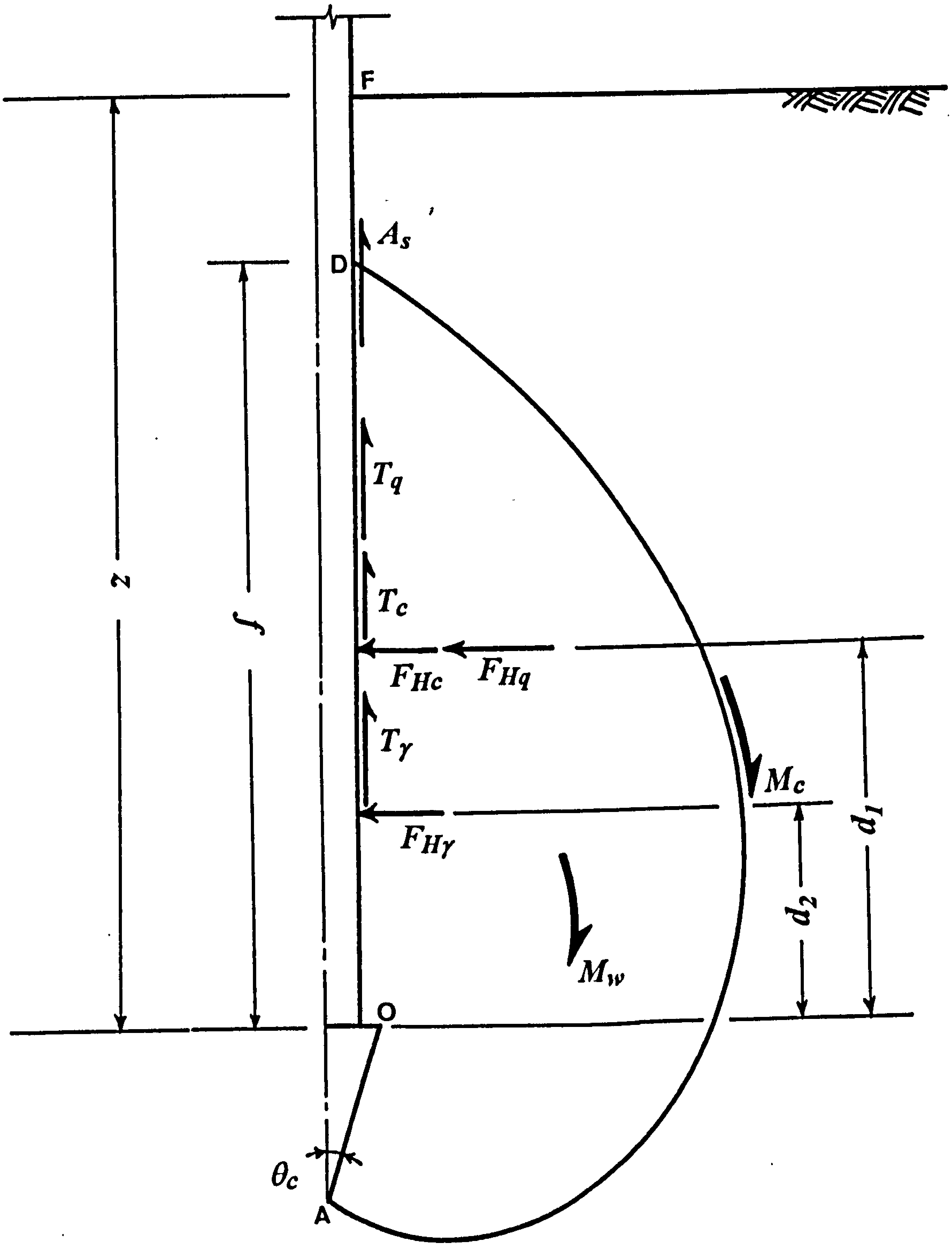


Fig. 4.13 Forces acting on shaft surface.

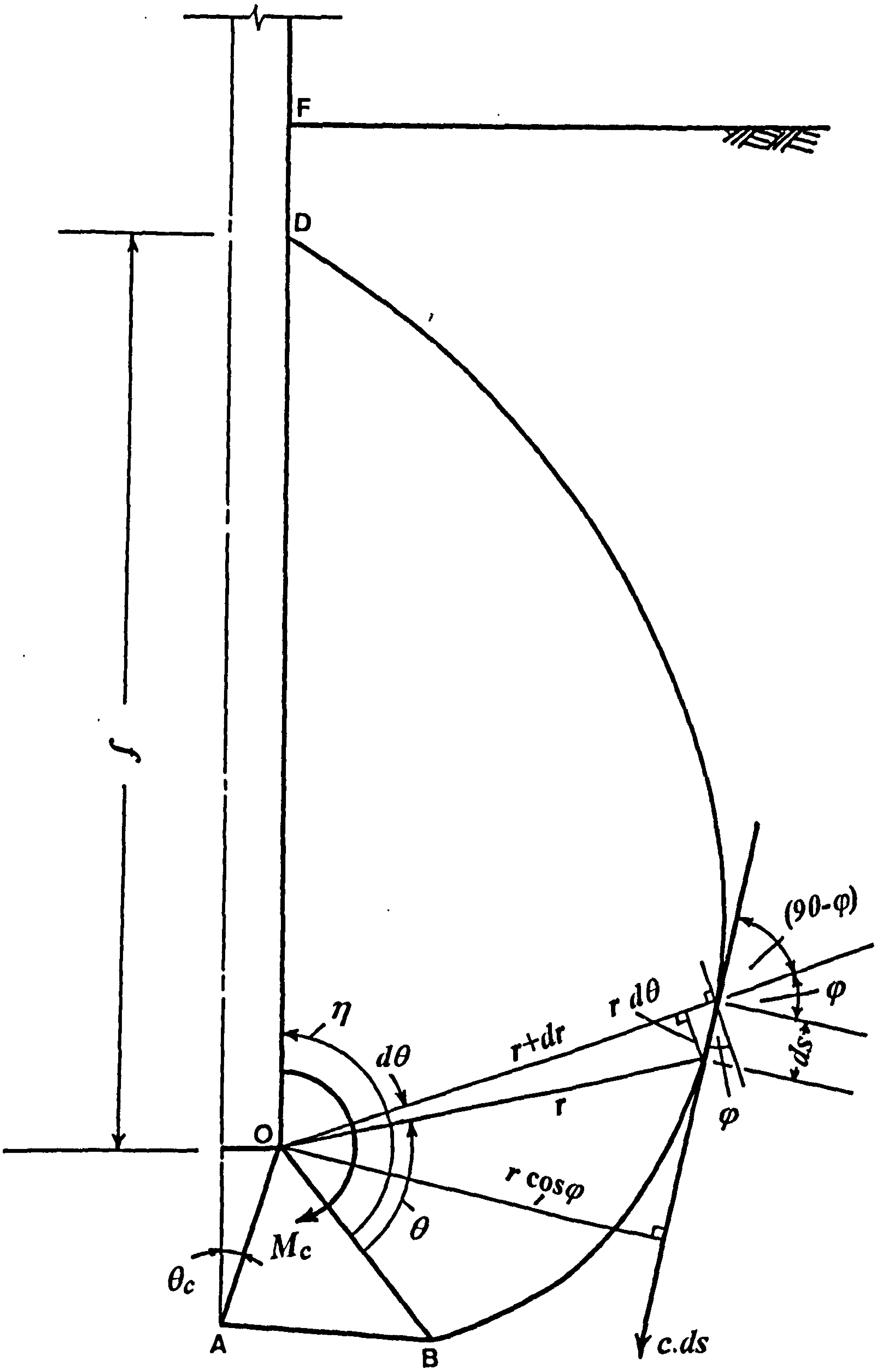


Fig. 4.14 Determination of Cohesive moment (M_c) along failure boundary.

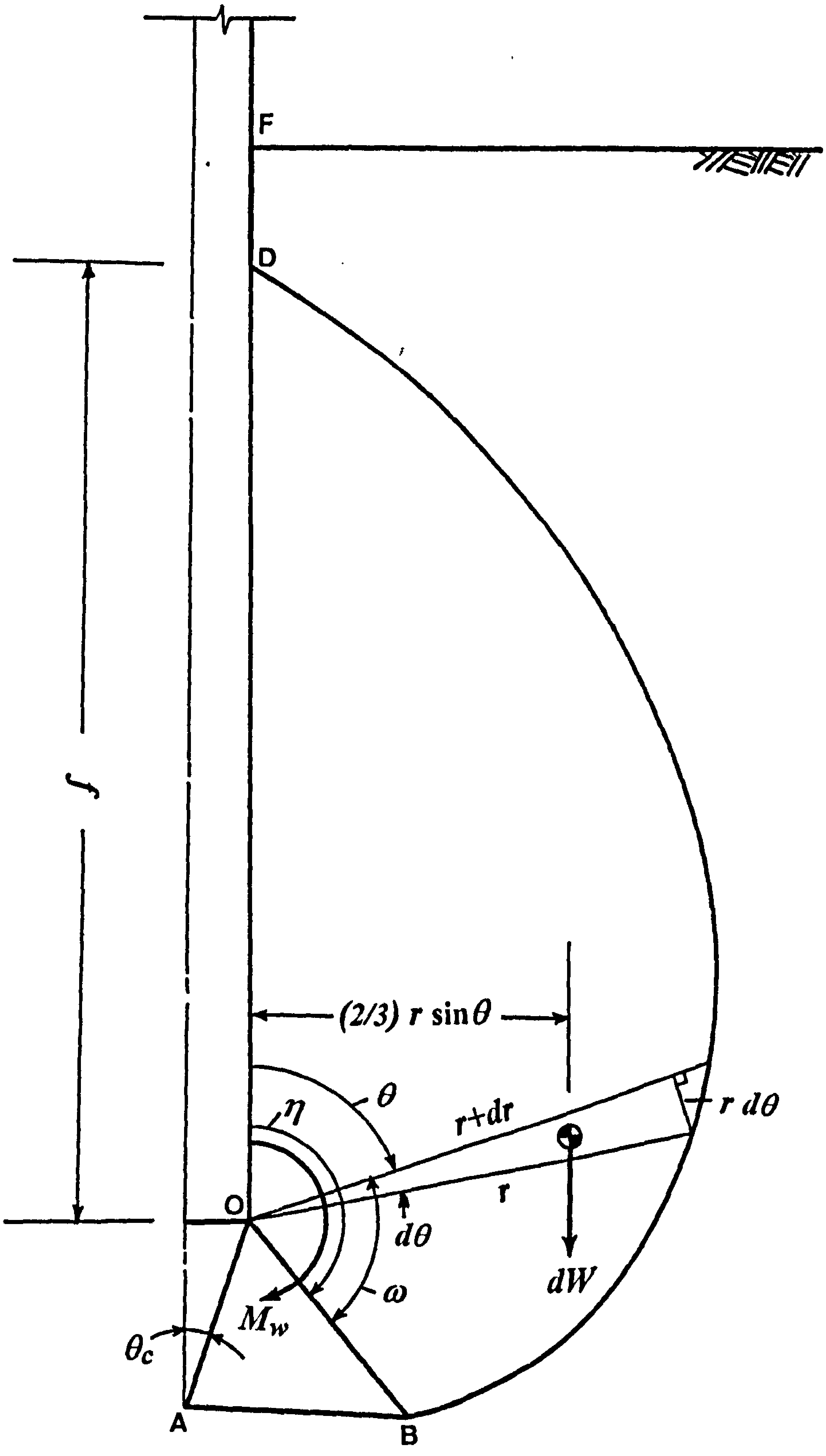
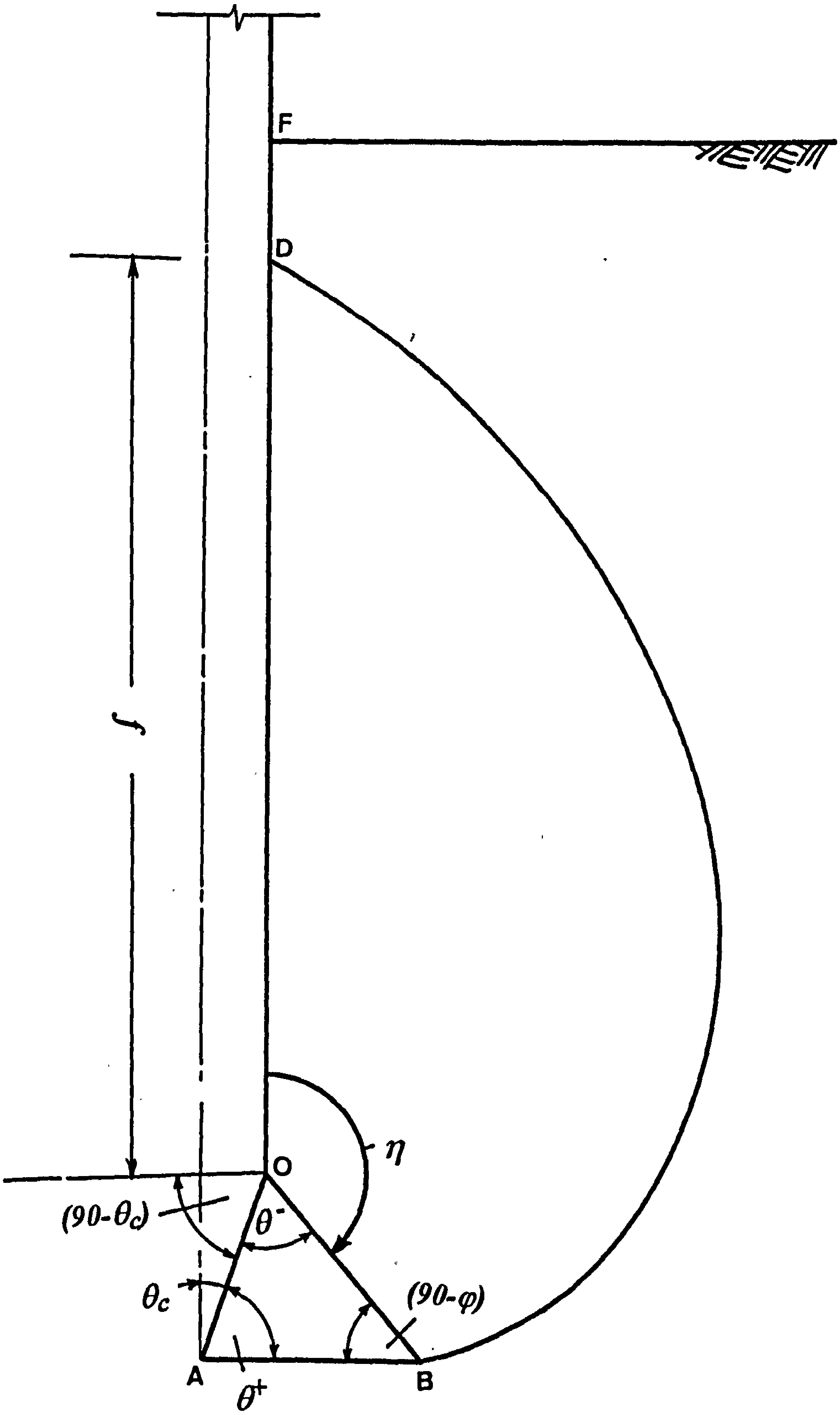


Fig. 4.15 Determination of Gravitational moment (M_w) for rupture surface.



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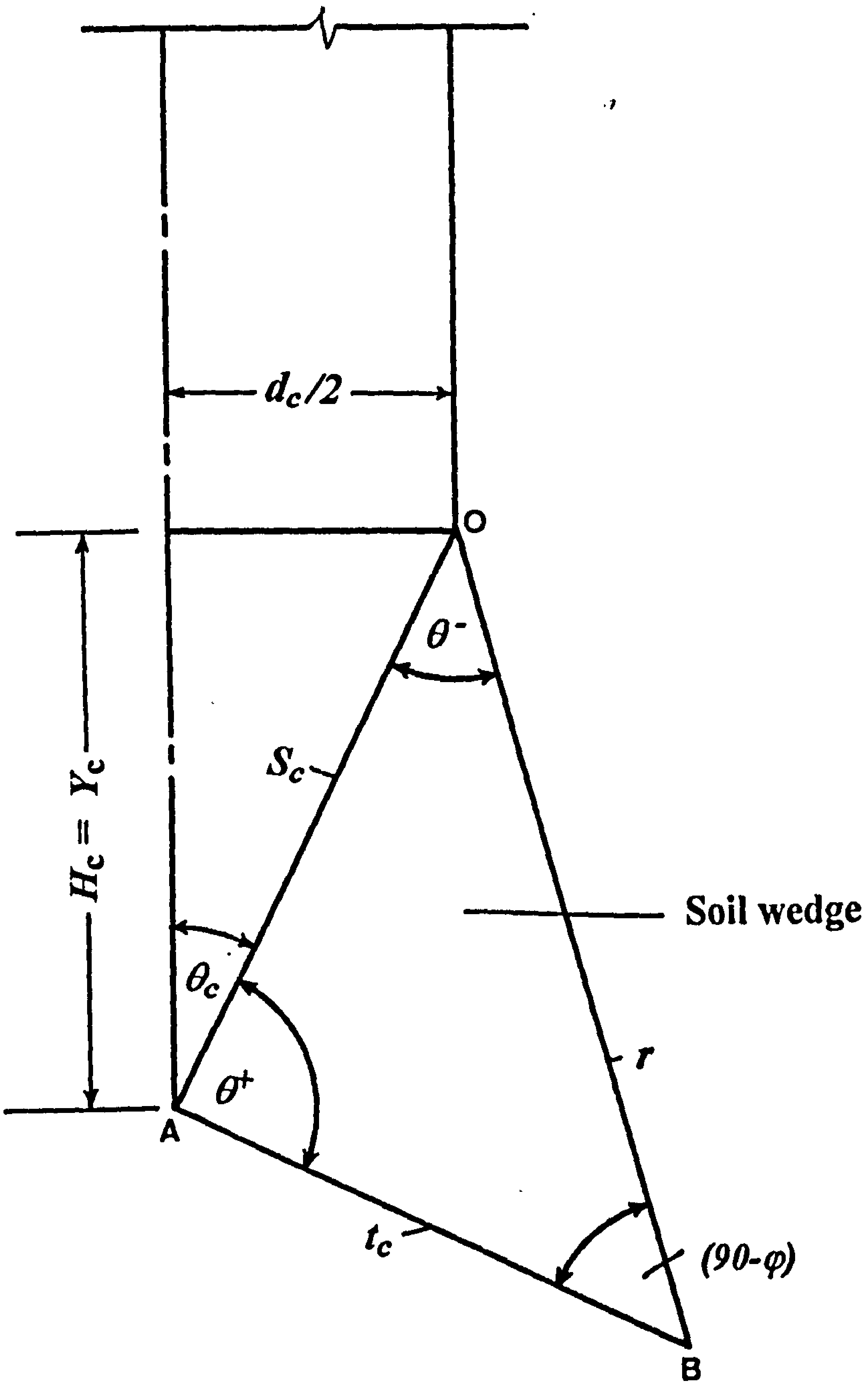

Fig. 4.17 Calculation of interface length (r), S_c and t_c.

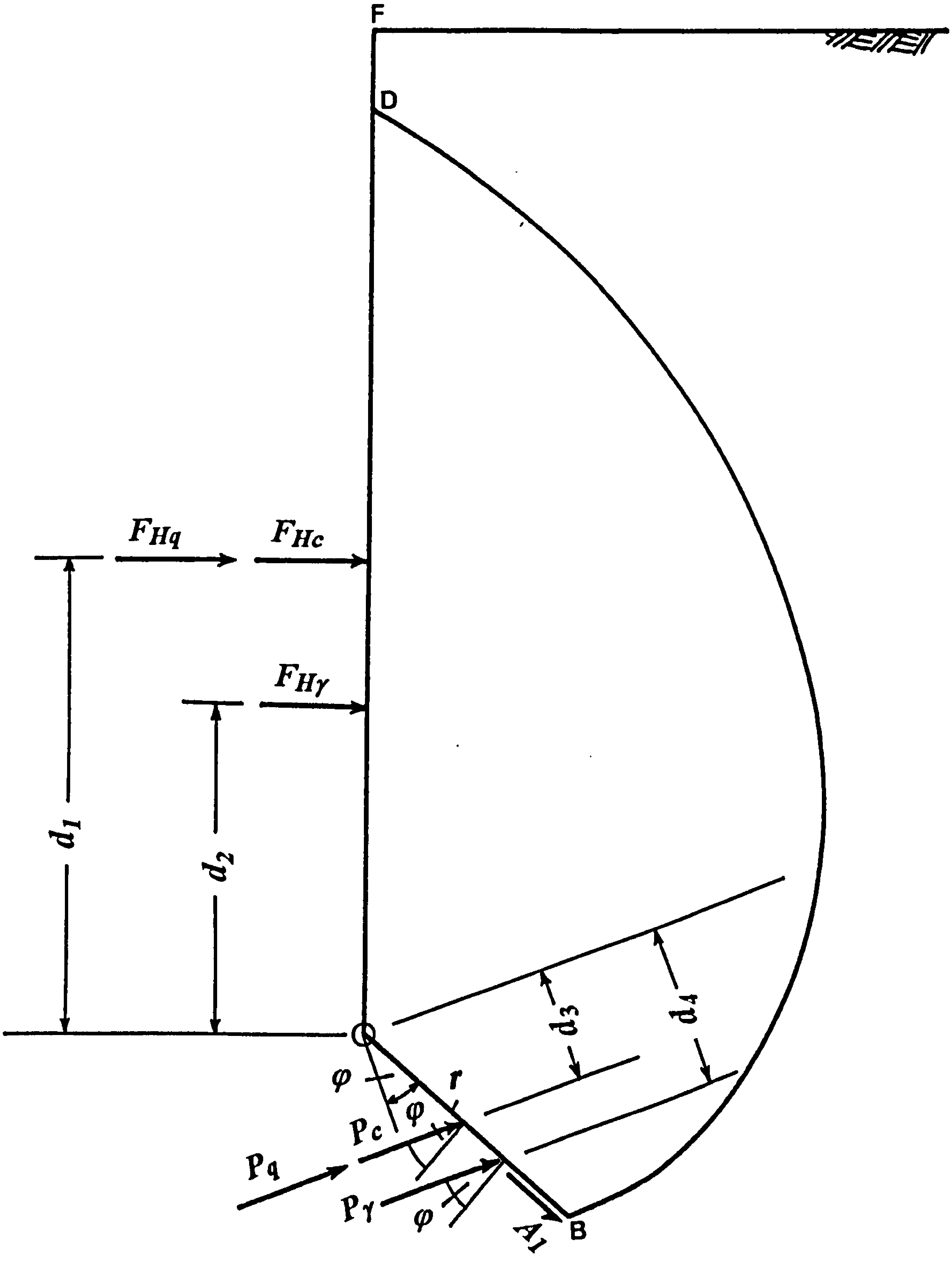

Fig. 4.18 Determination of moment arms.

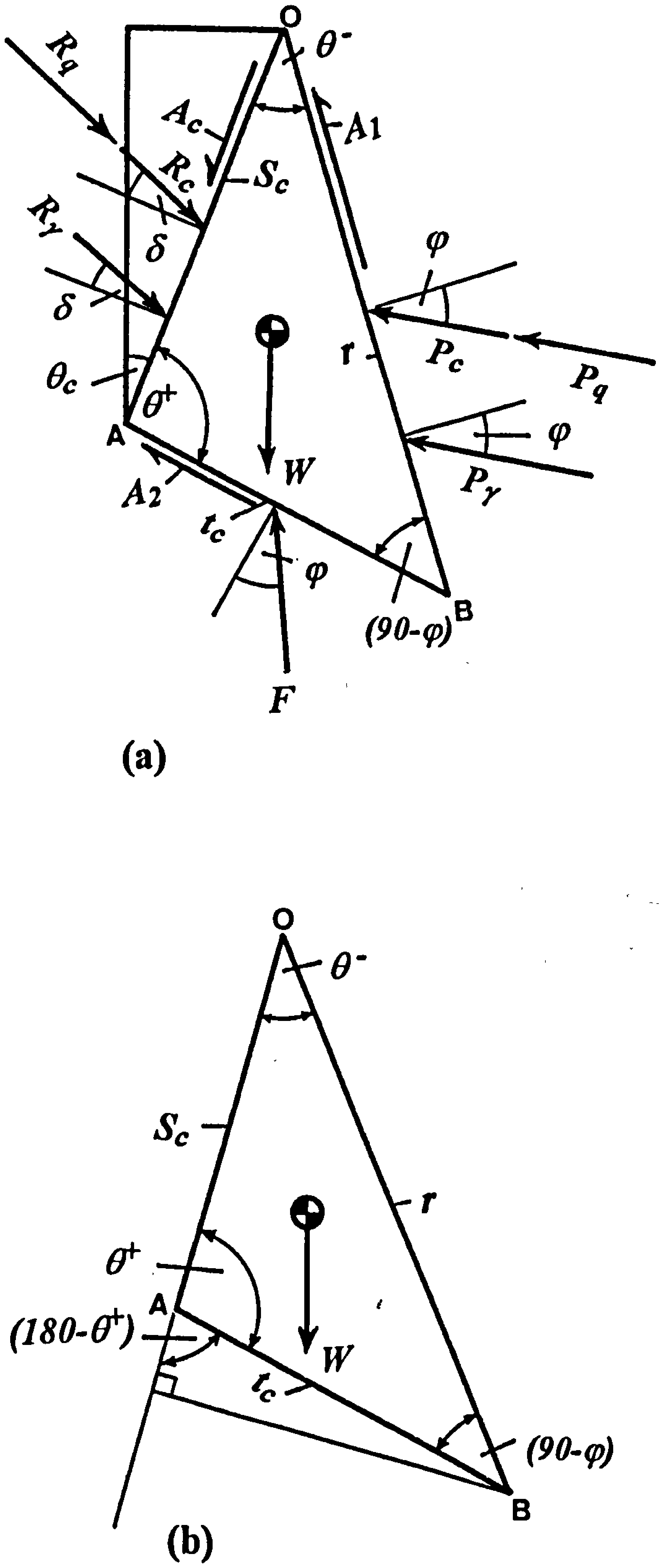

Fig. 4.19 (a) Forces acting on the soil wedge. (b) Determination of the weight (W) of soil wedge.

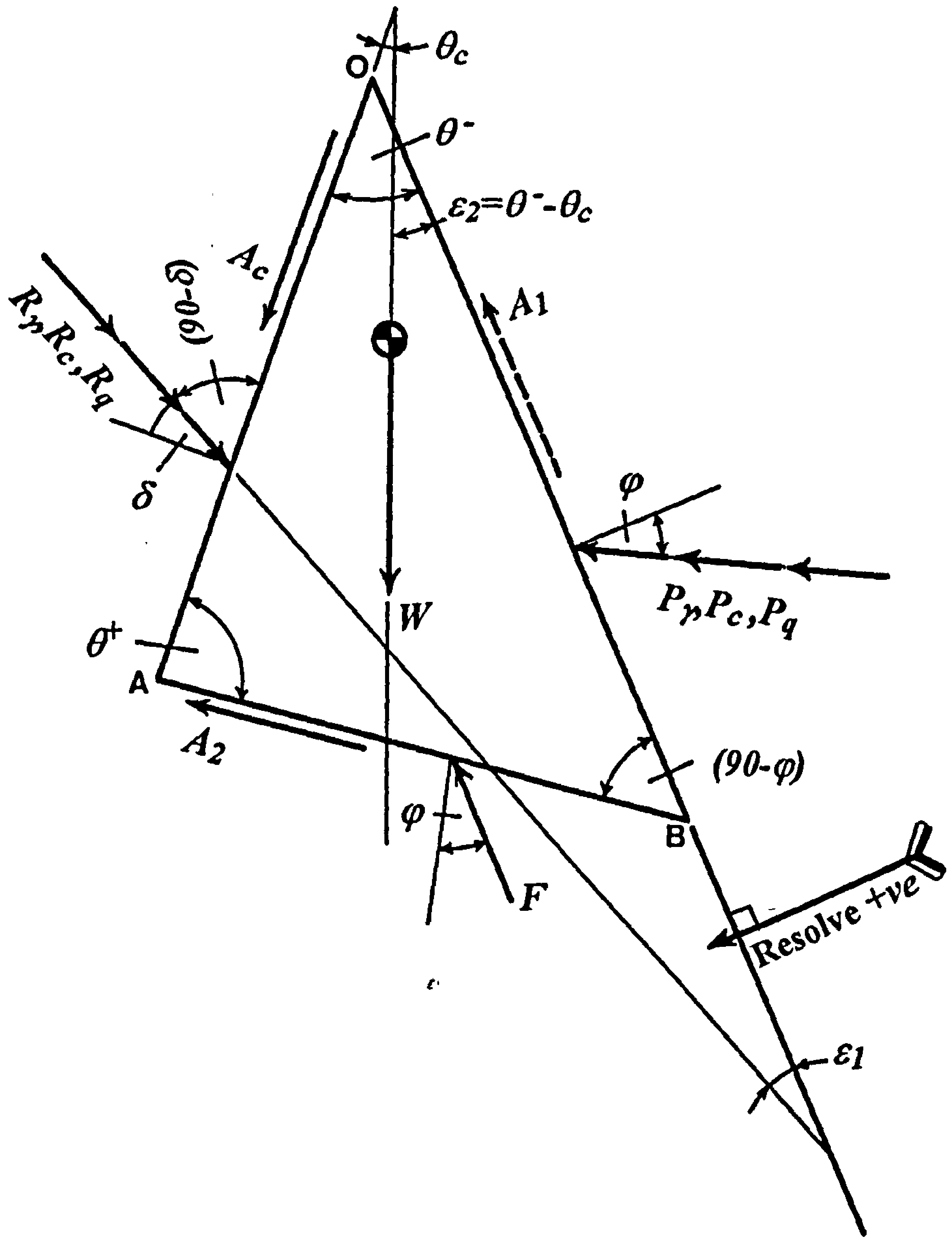

Fig. 4.20 Equilibrium of forces acting on the soil wedge.

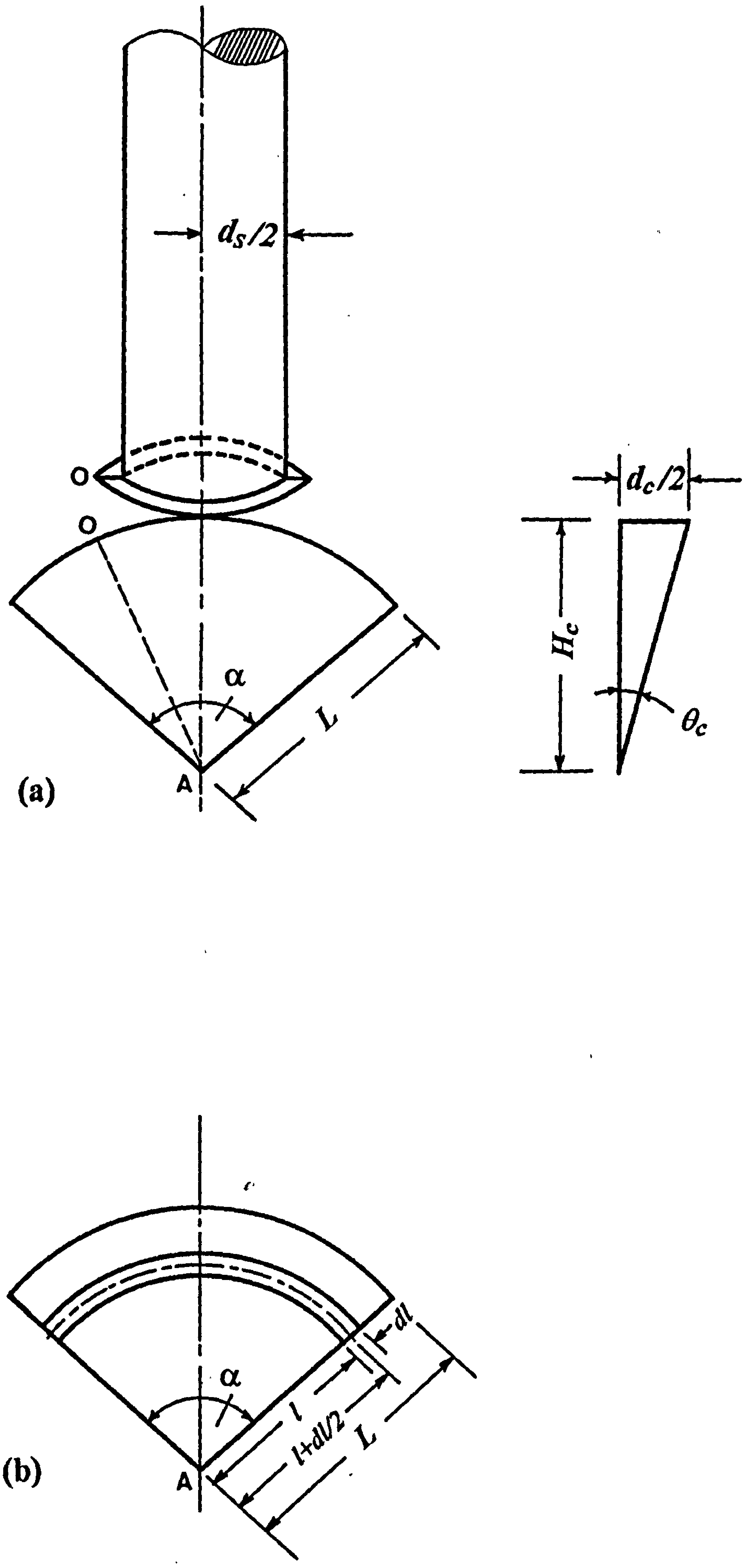

Fig. 4.21 Angle (α) of the opened-up cone.

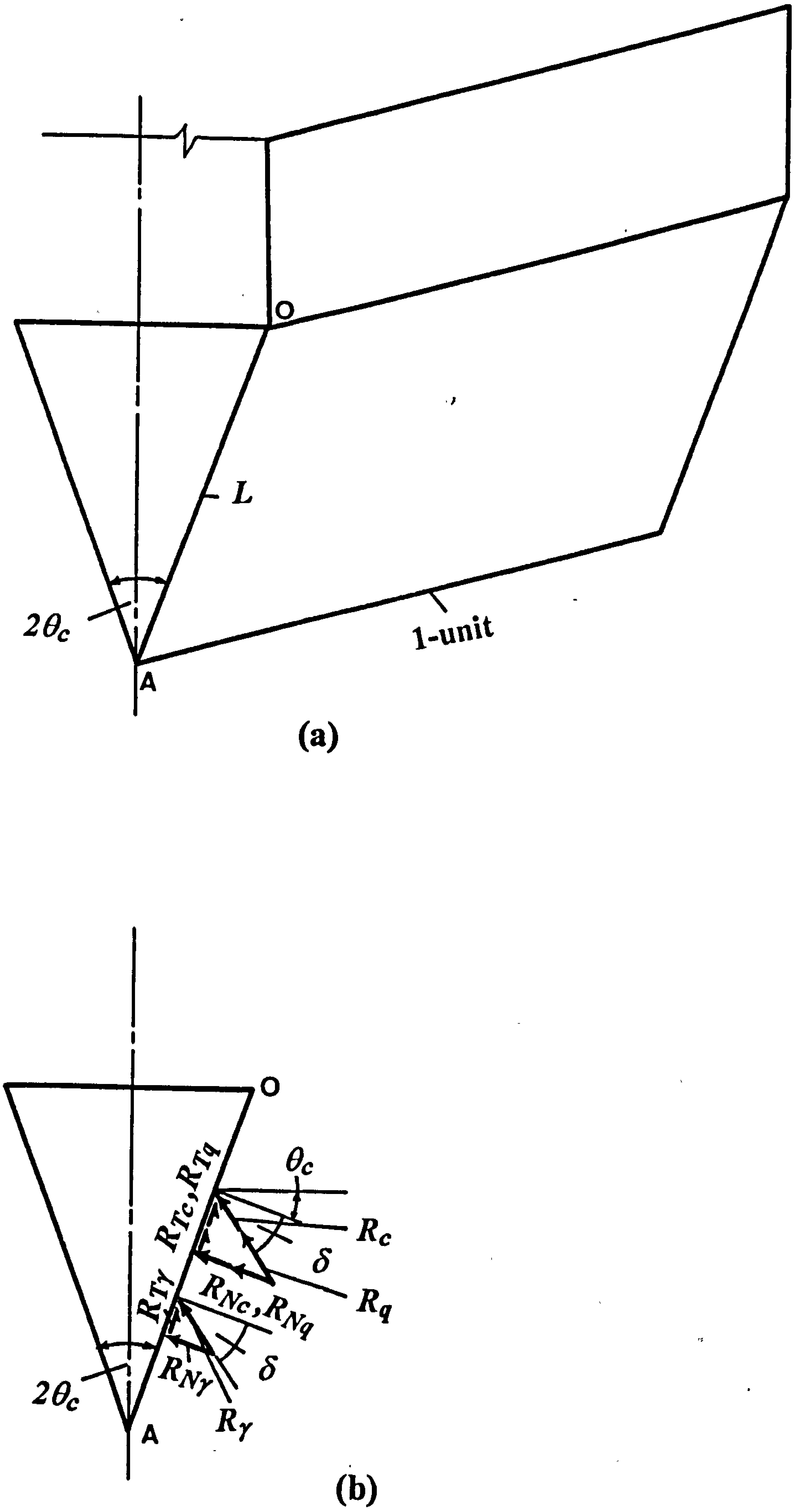

Fig. 4.22 The force components acting on the cone surface.

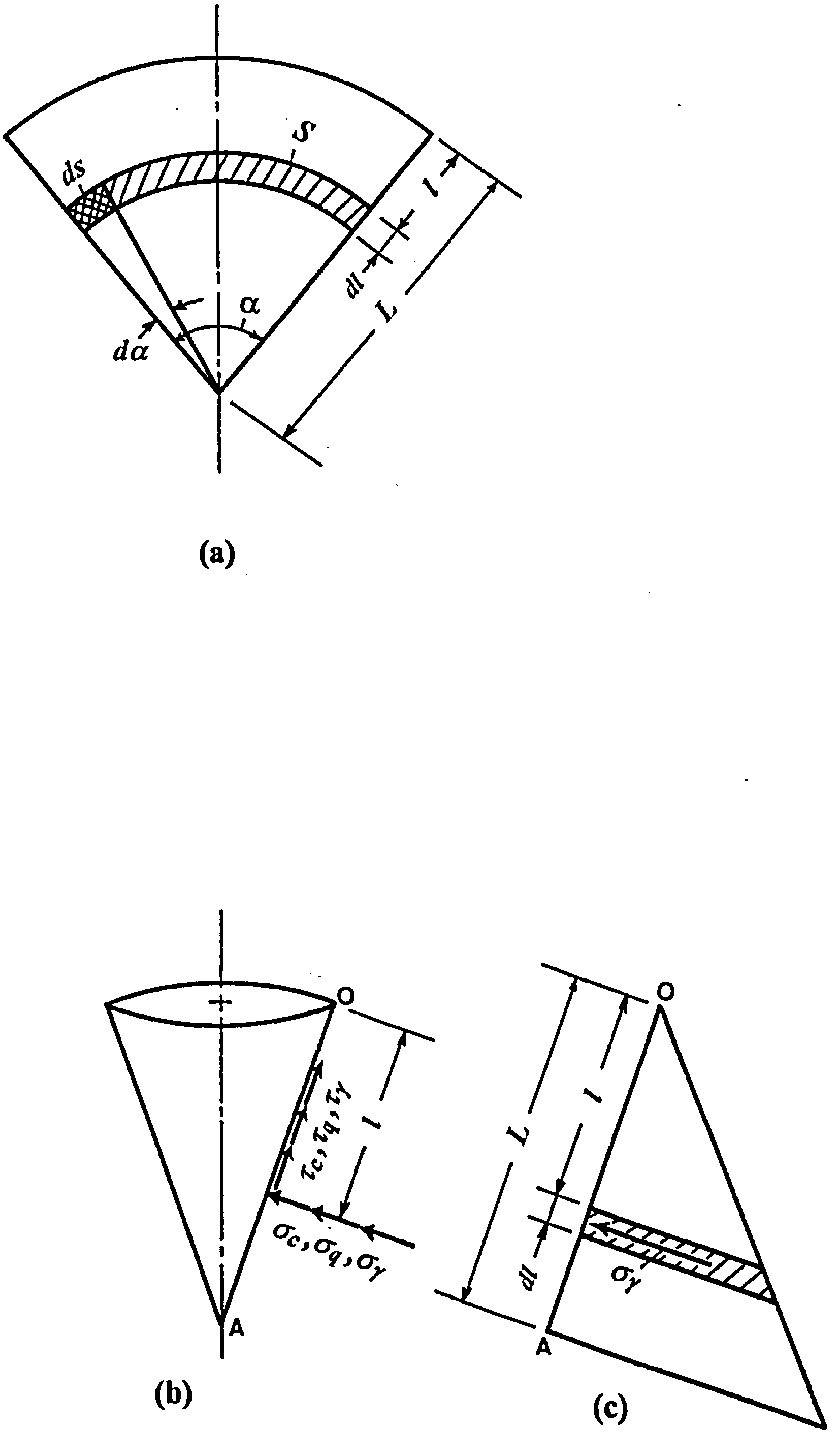

Fig. 4.23 (a) and (b) The elemental stress on cone. (c) Calculation for gravitational stress.

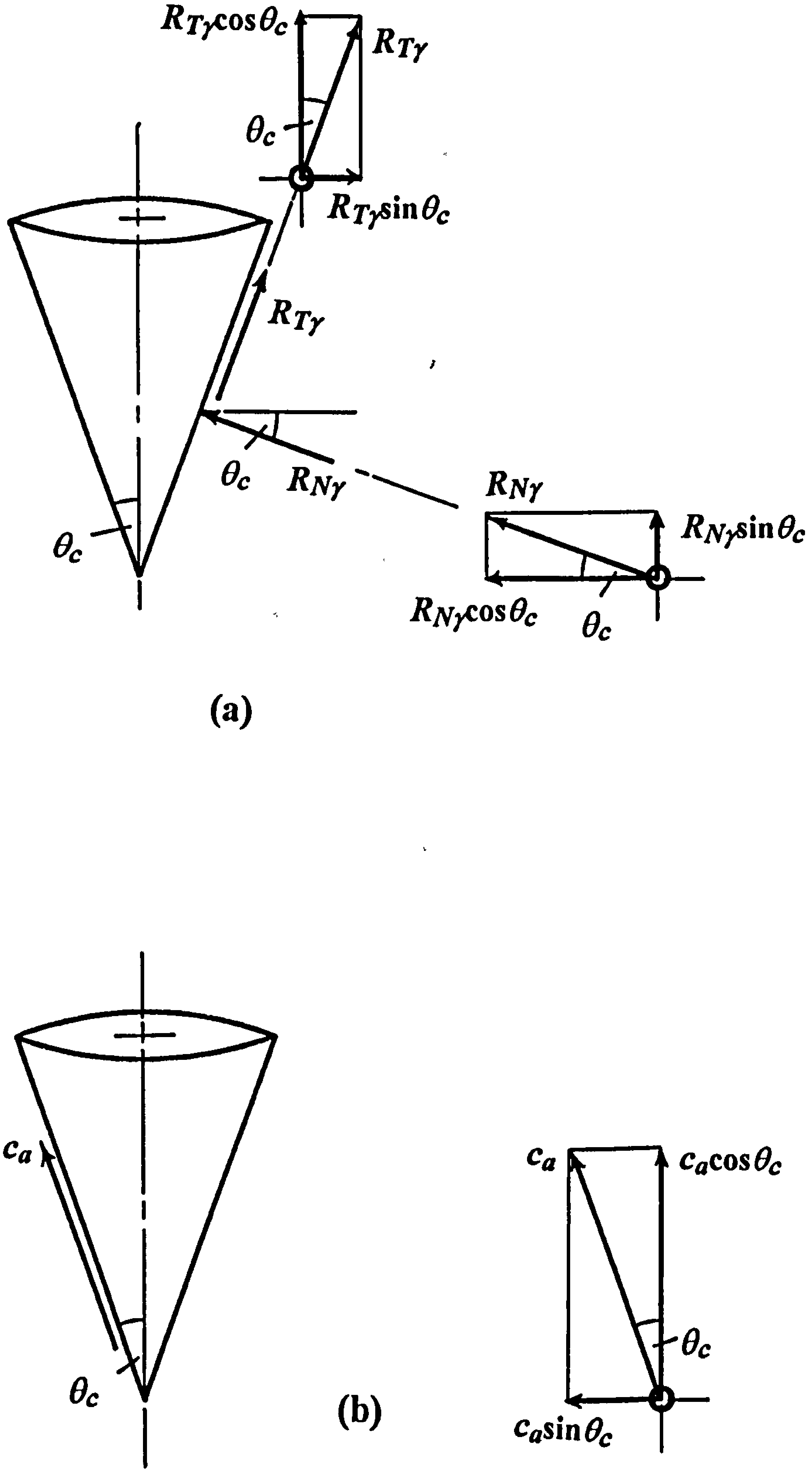

Fig. 4.24 (a) Determination of the vertical component of force. (b) Determination of the vertical component of adhesion.

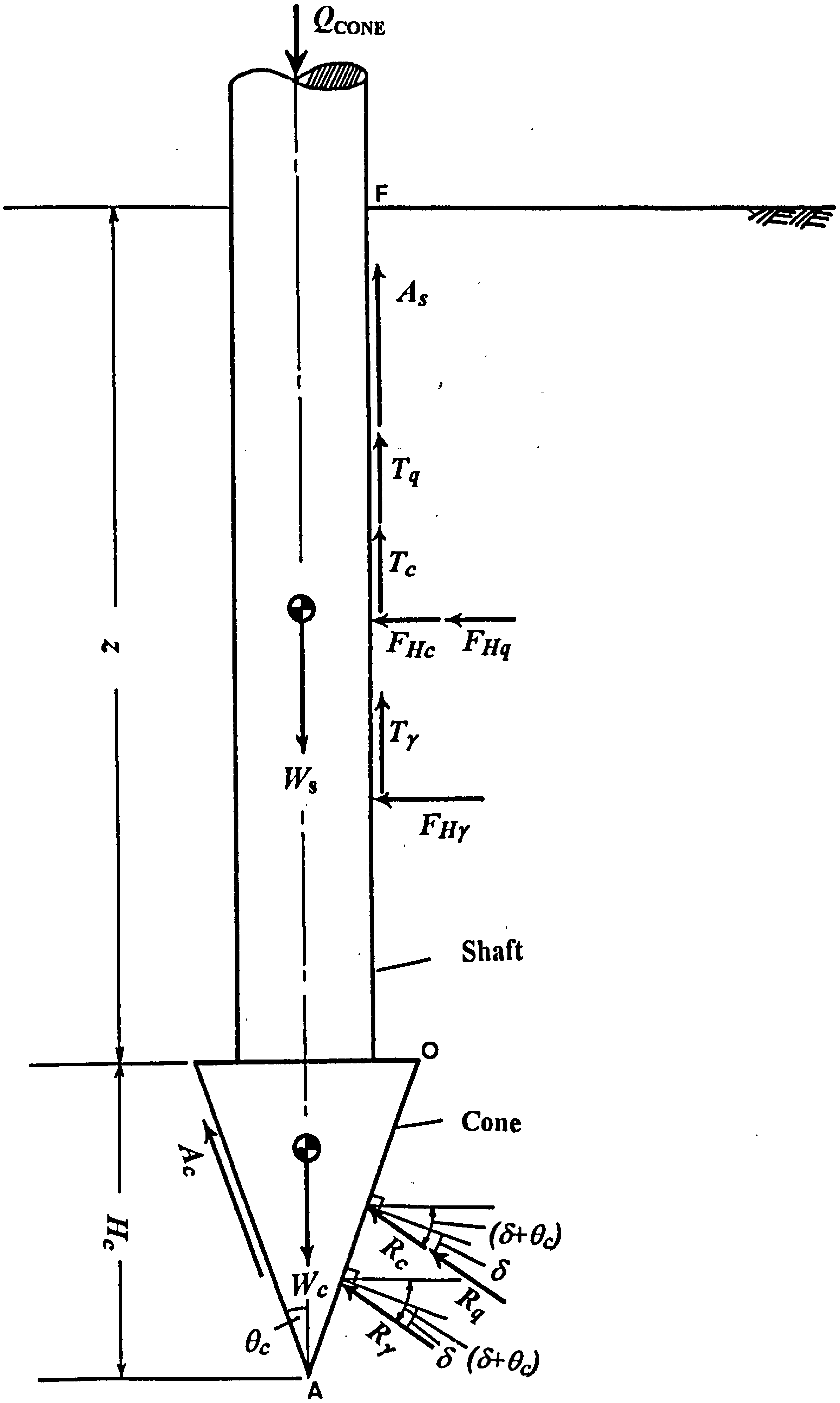

Fig. 4.25 Equilibrium of Cone and Shaft.

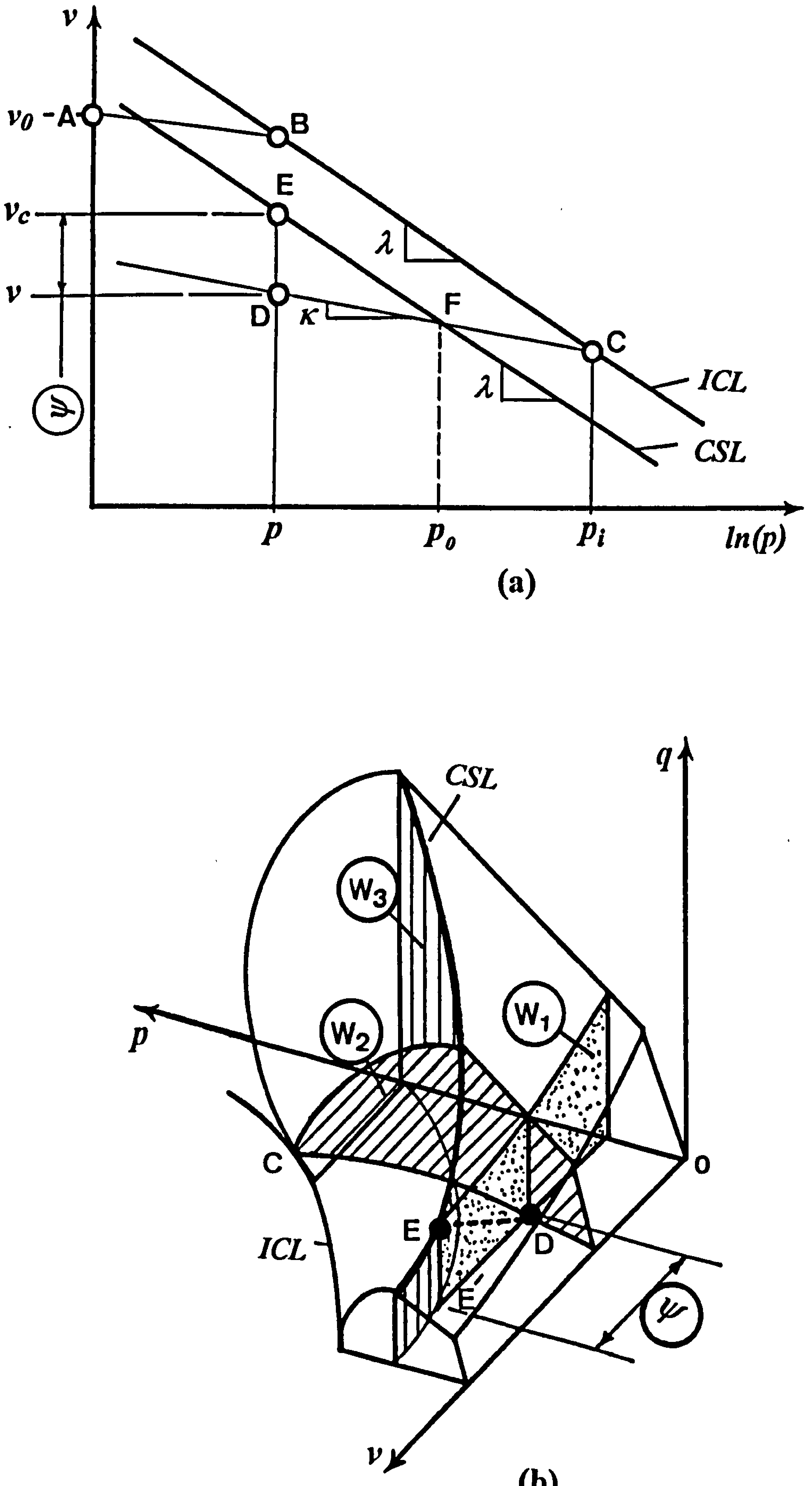

Fig. 5.1 (a) Definition of State parameter, ψ in v-$ln(p)$ plane. (b) Elastic walls associated with State parameter in Critical state space.

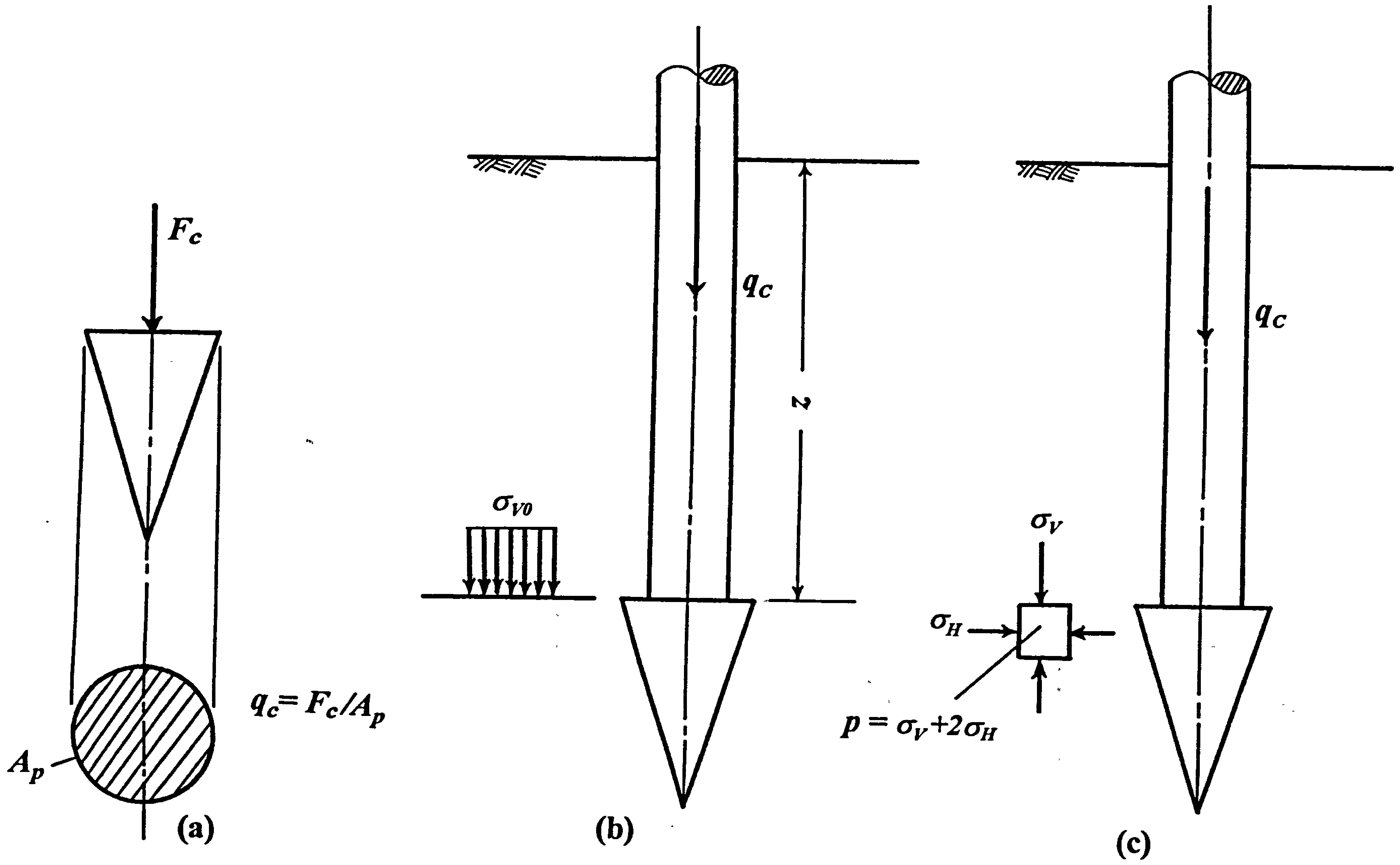

Fig. 5.2 (a) Cone index. (b) Geostatic stress on horizontal planes at cone level. (c) Mean normal stress at cone level.

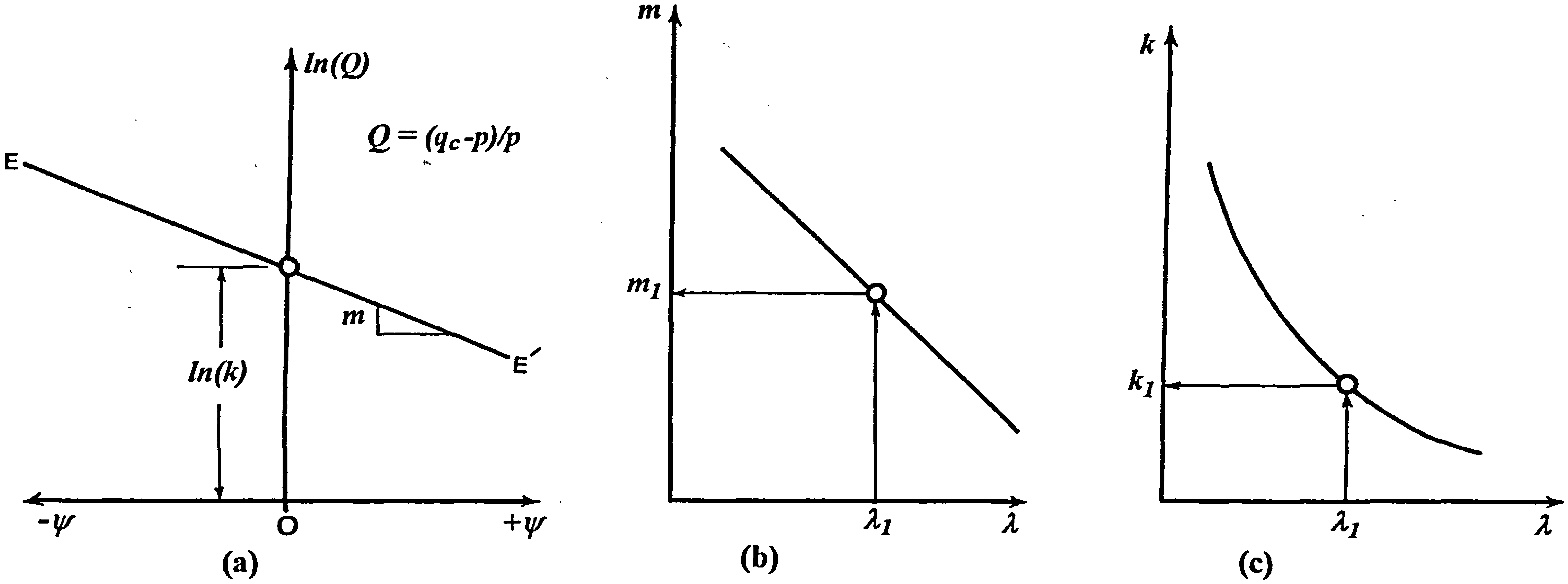

Fig. 5.3 (a) Relationship between State parameter, ψ and normalized Cone index, Q. (b) Variation of gradient m with critical state parameter λ. (c) Variation of intercept k with critical state parameter λ.

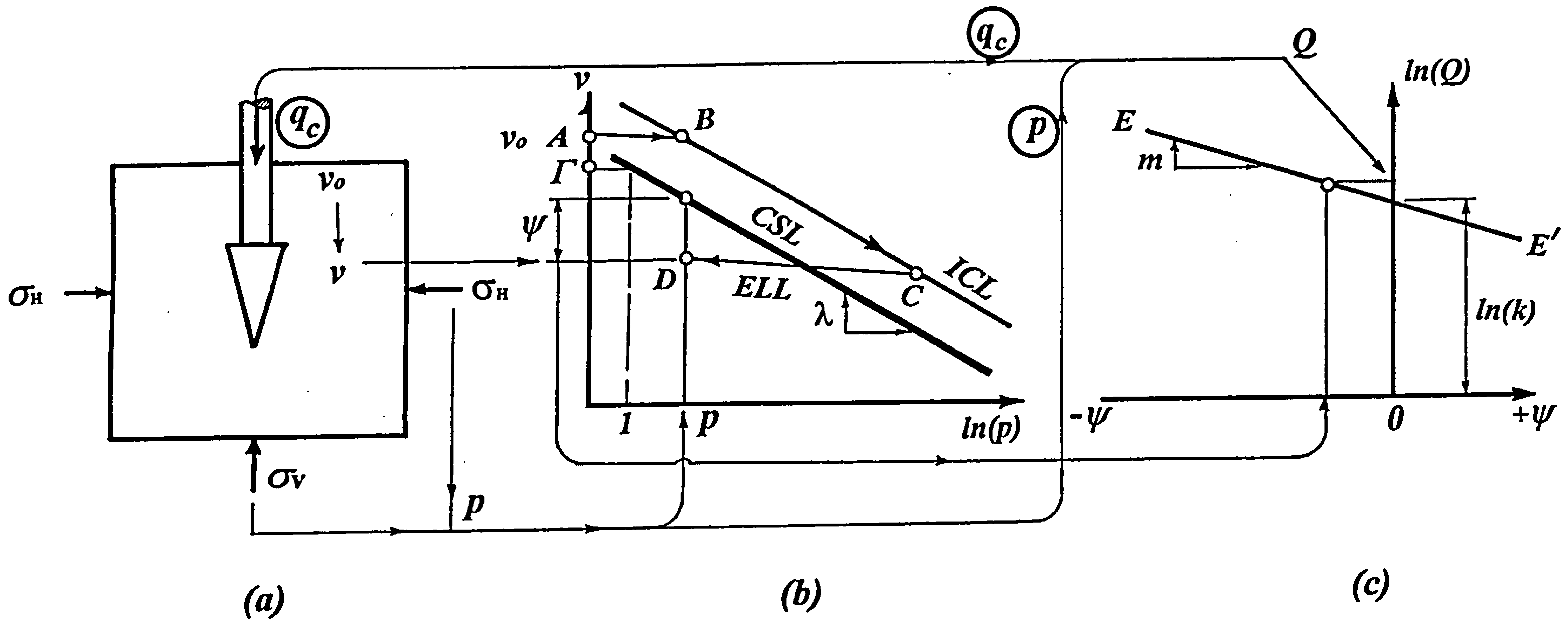

Fig. 6.1 (a) to (c) Steps in the calibration process.

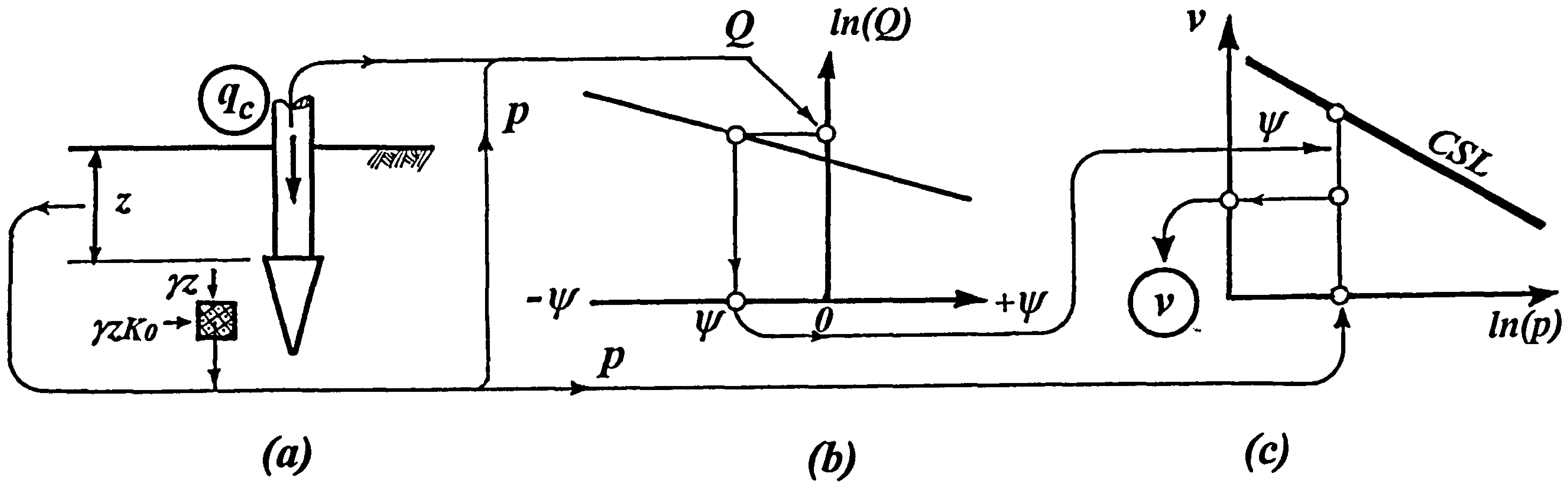

Fig. 6.2 (a) to (c) Conversion of Cone index to soil specific volume.

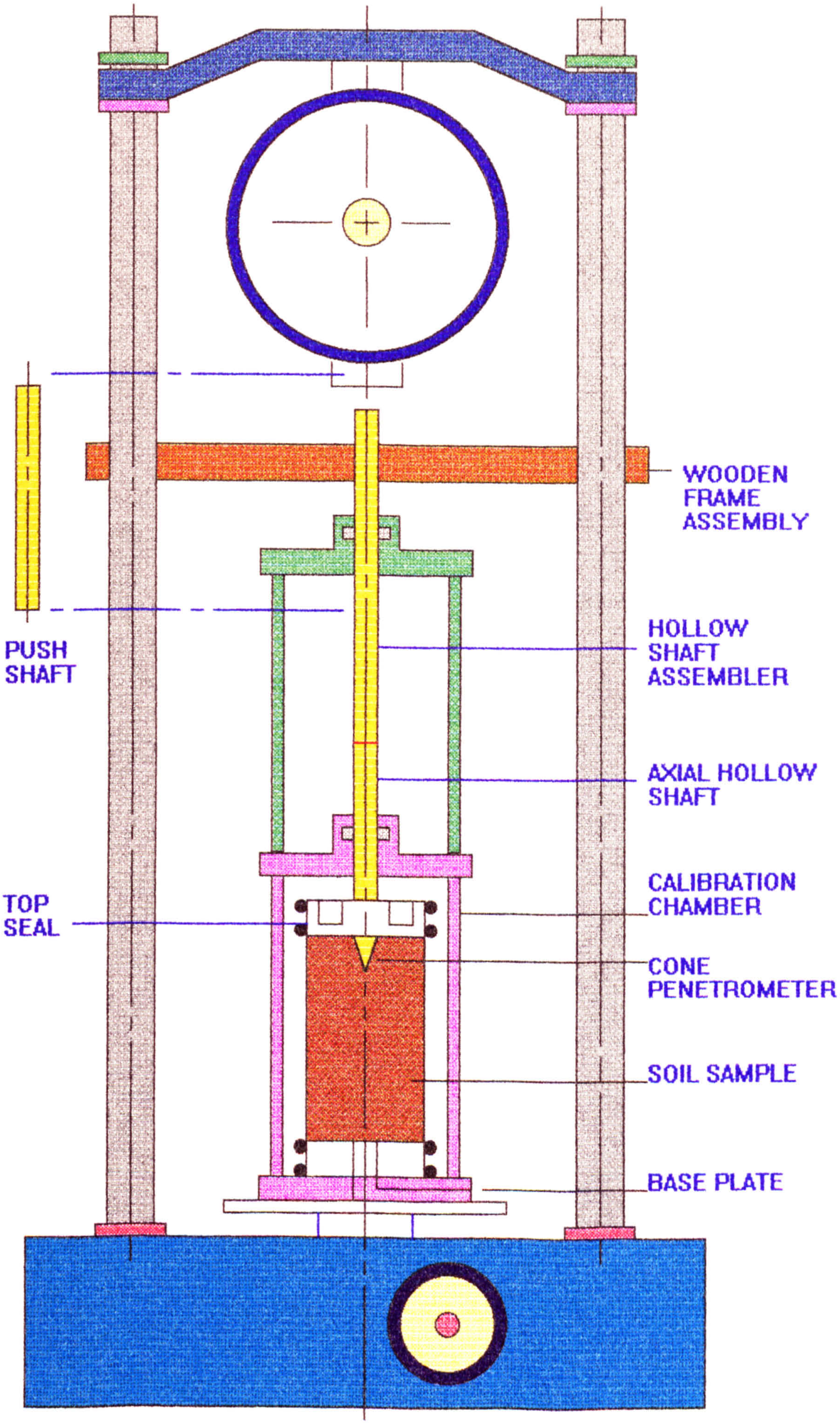

Fig. 6.3 Schematic arrangement for triaxial calibration chamber test.

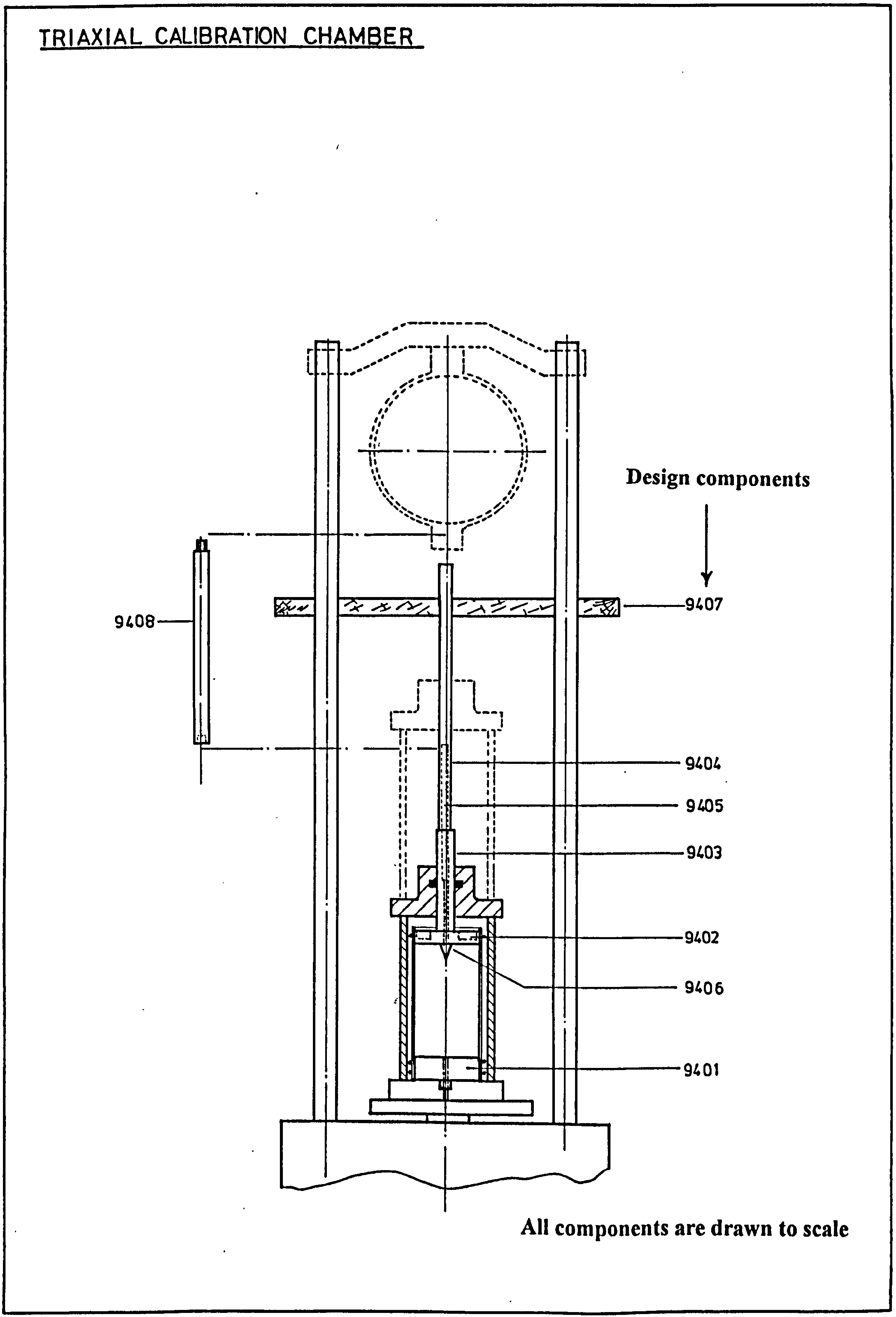

Fig. 6.4 The revised design components for the triaxial Calibration chamber.

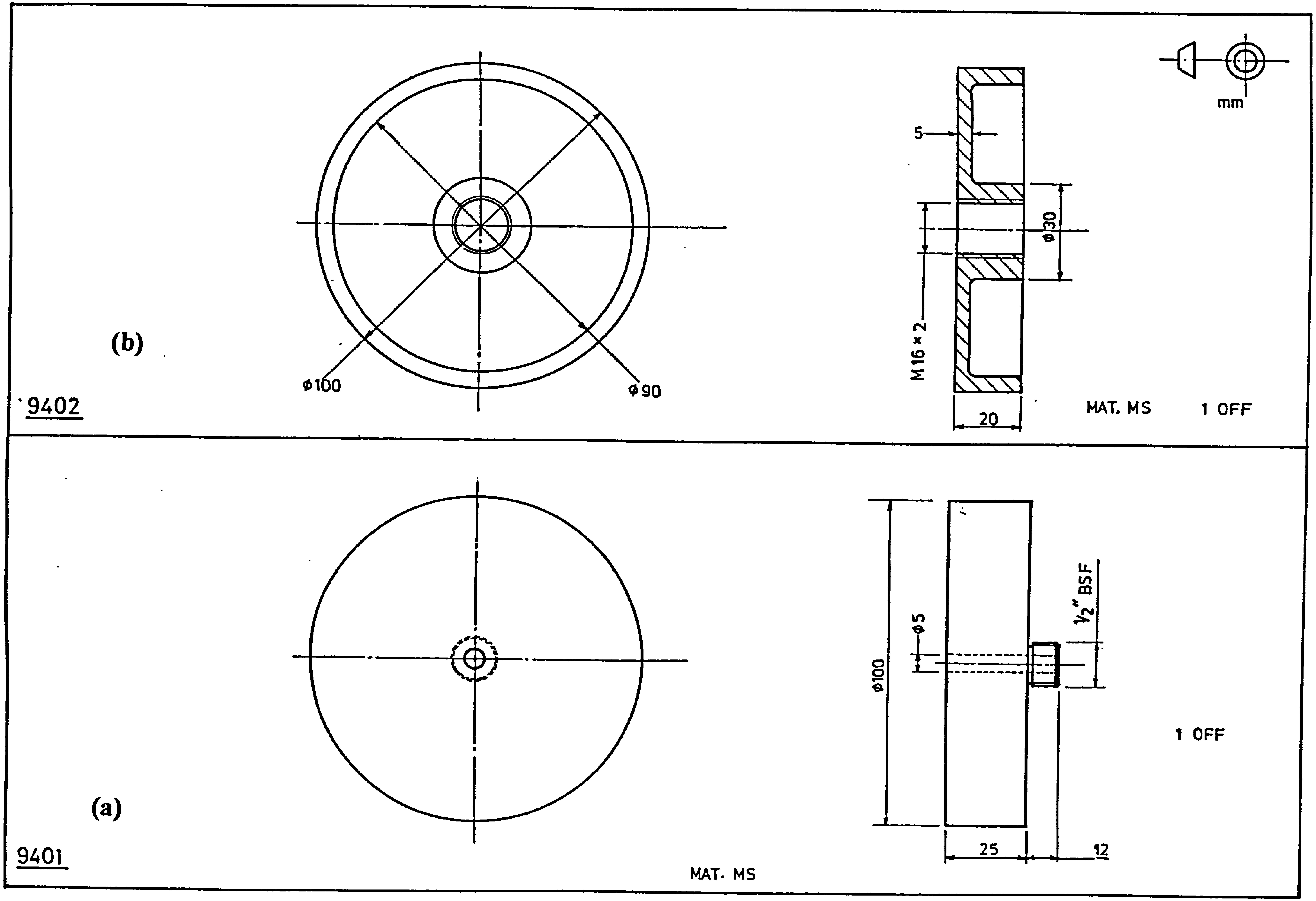

Fig. 6.5 (a) The design details for modified Base plate. (b) The design details for Top seal.

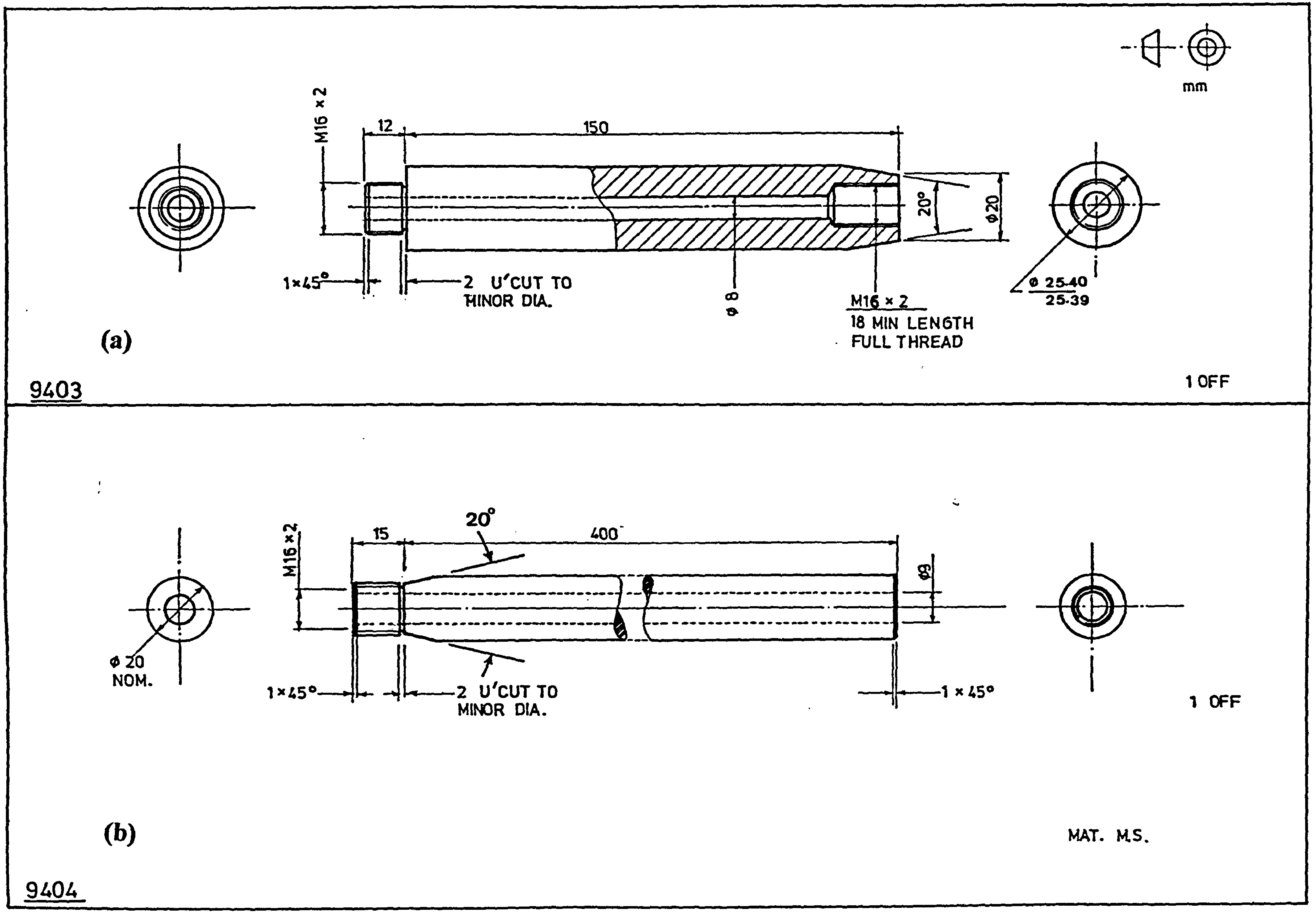

Fig. 6.6 (a) The design details for Axial hollow shaft. (b) The design details for Hollow shaft assembler.

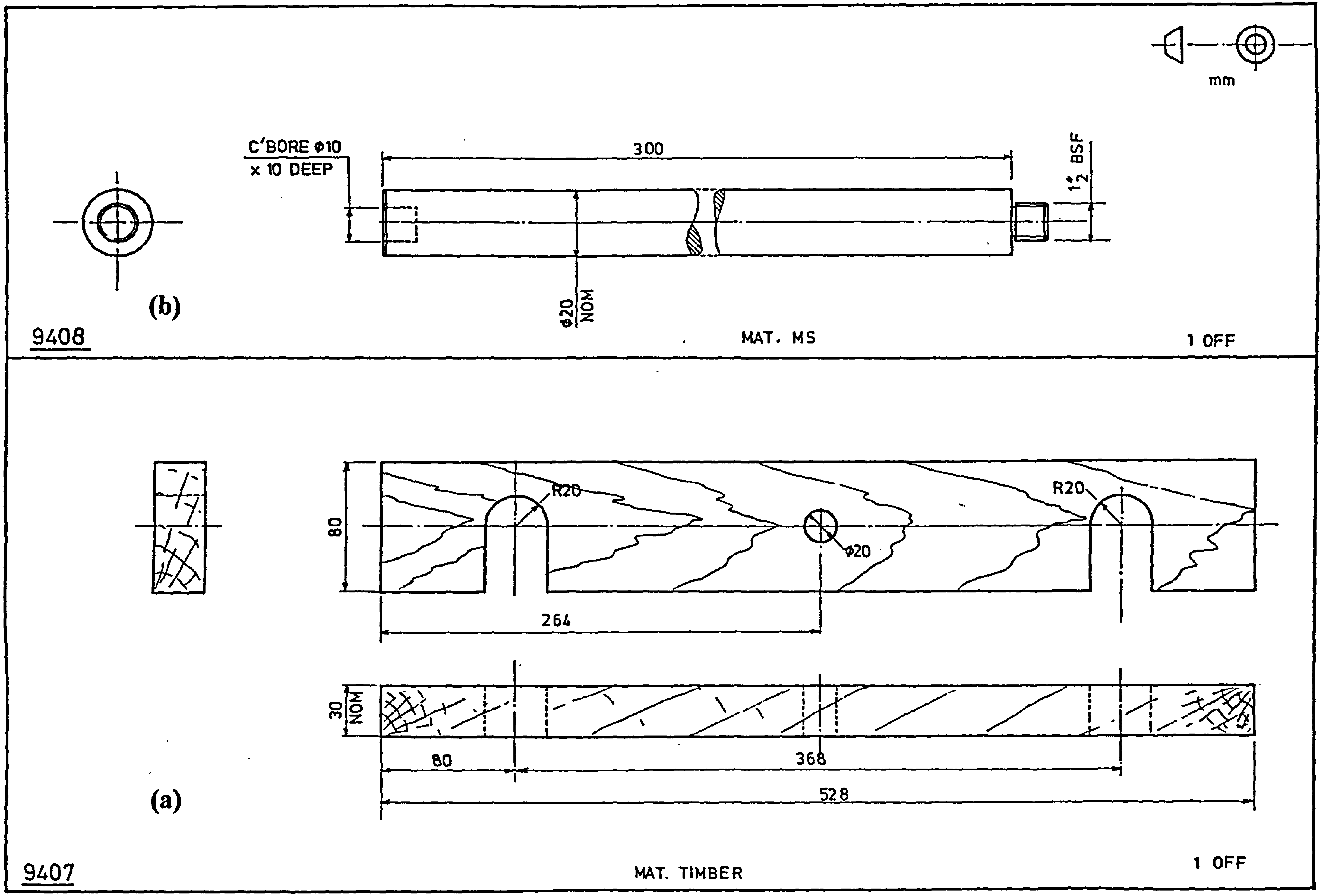

Fig. 6.7 (a) The design details for Wooden frame assembly. (b) The design details for Penetrometer aligner (Push-shaft).

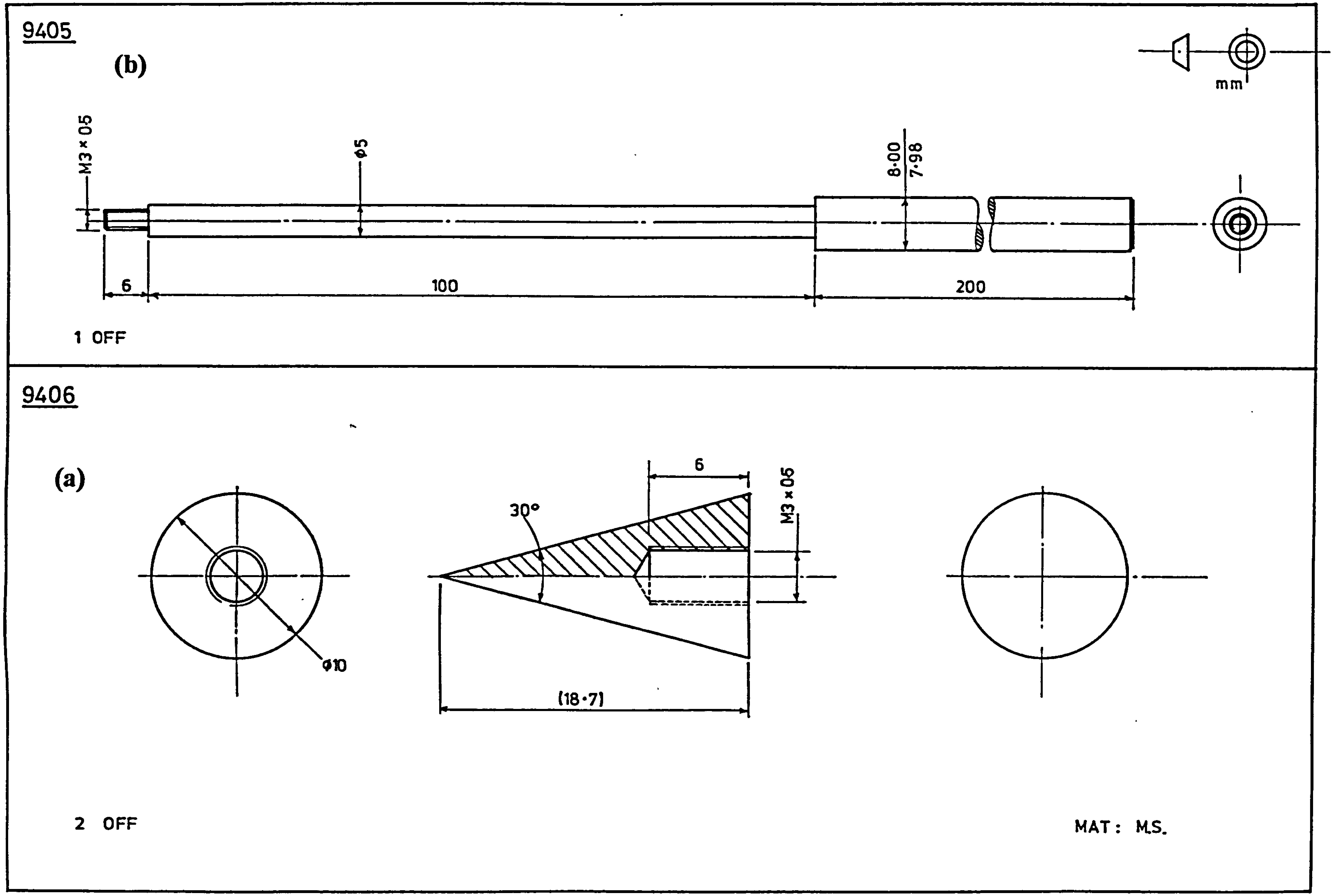

Fig. 6.8 (a) The design details for miniature Cone. (b) The design details for Penetrometer shaft.

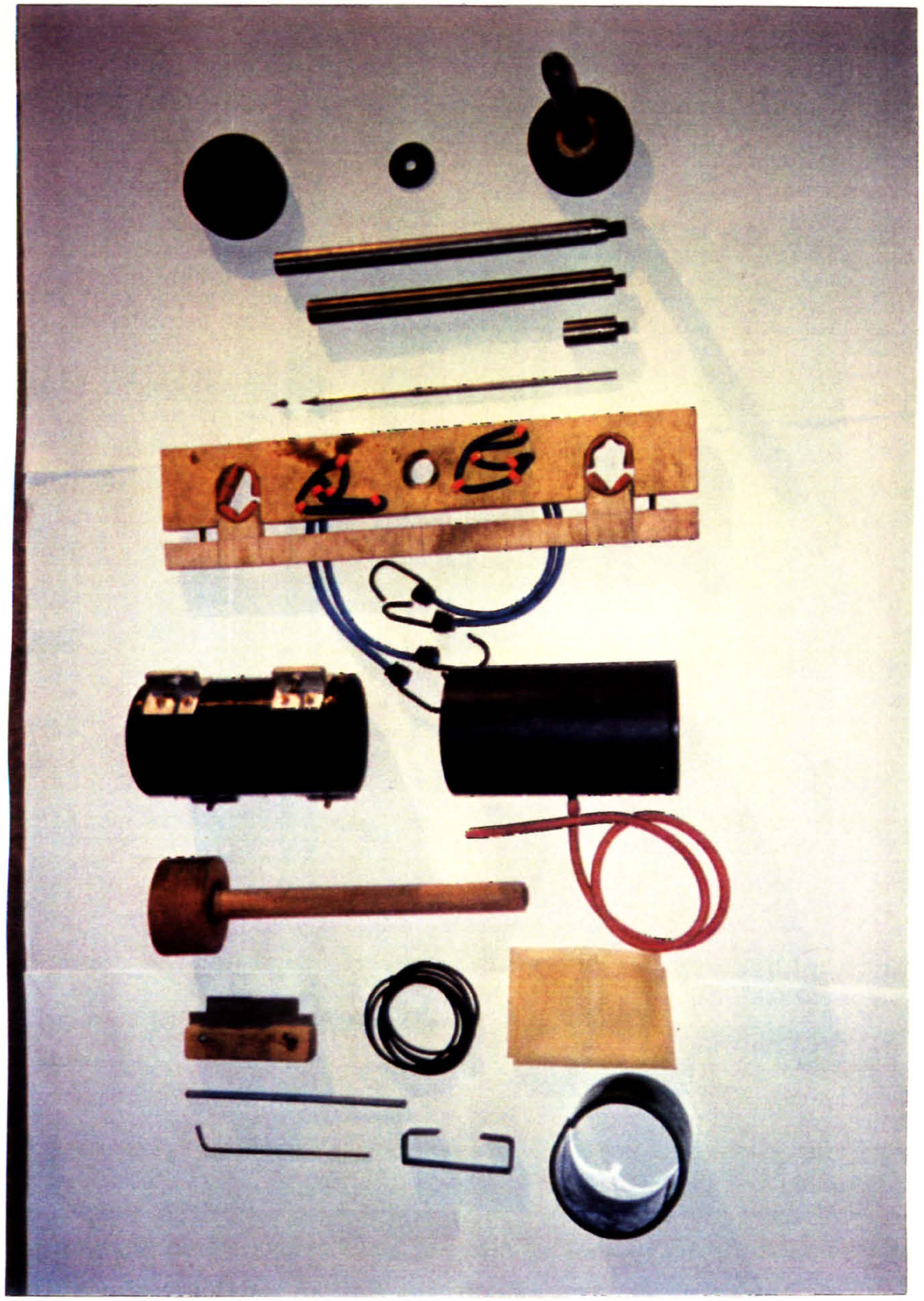

Fig. 6.9 (a) The revised design components and the sample preparation accessories for the triaxial calibration chamber test.

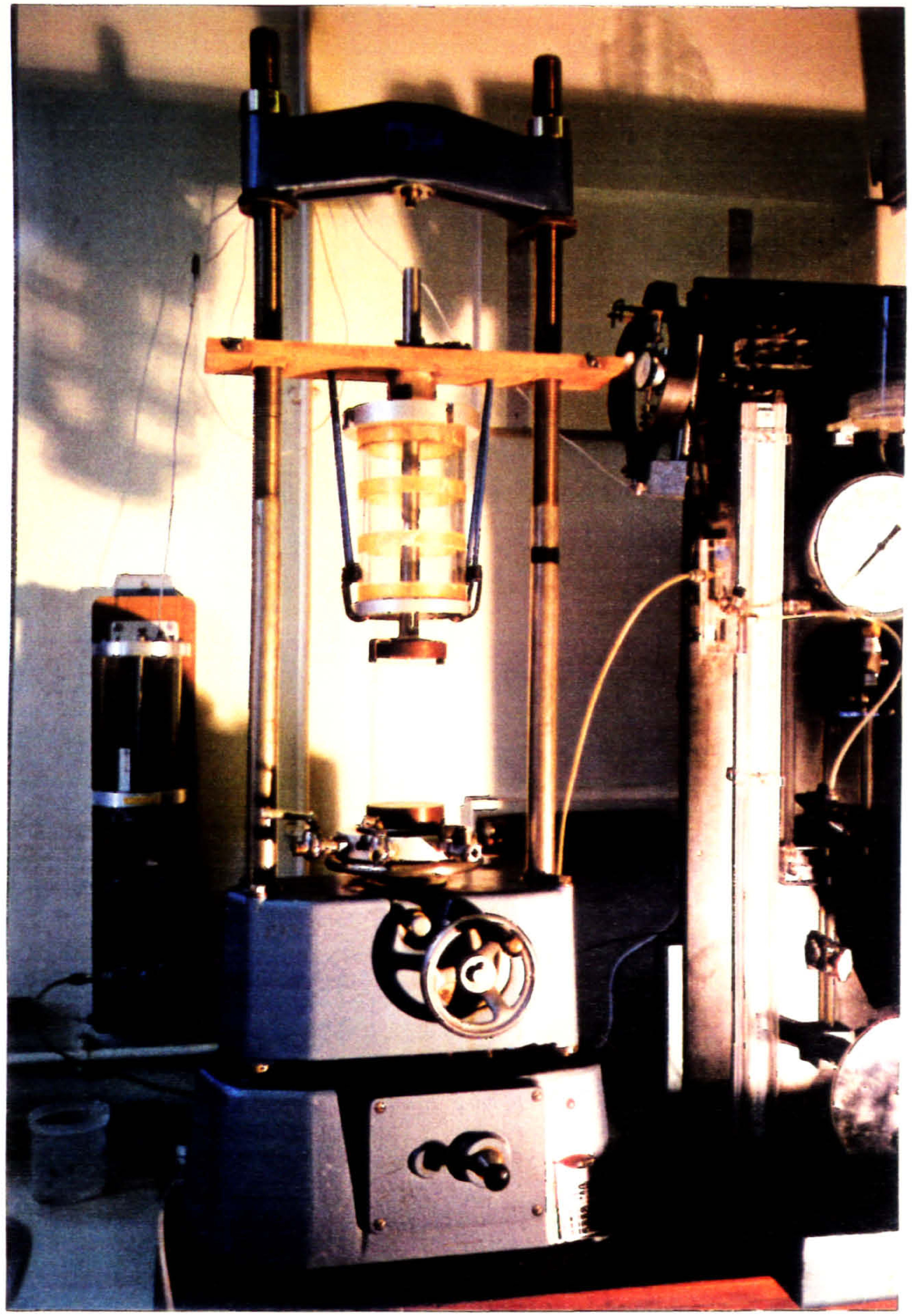

Fig. 6.9 (b) Steps in the working principle; Procedure for holding the triaxial calibration chamber with the Wooden frame assembly.

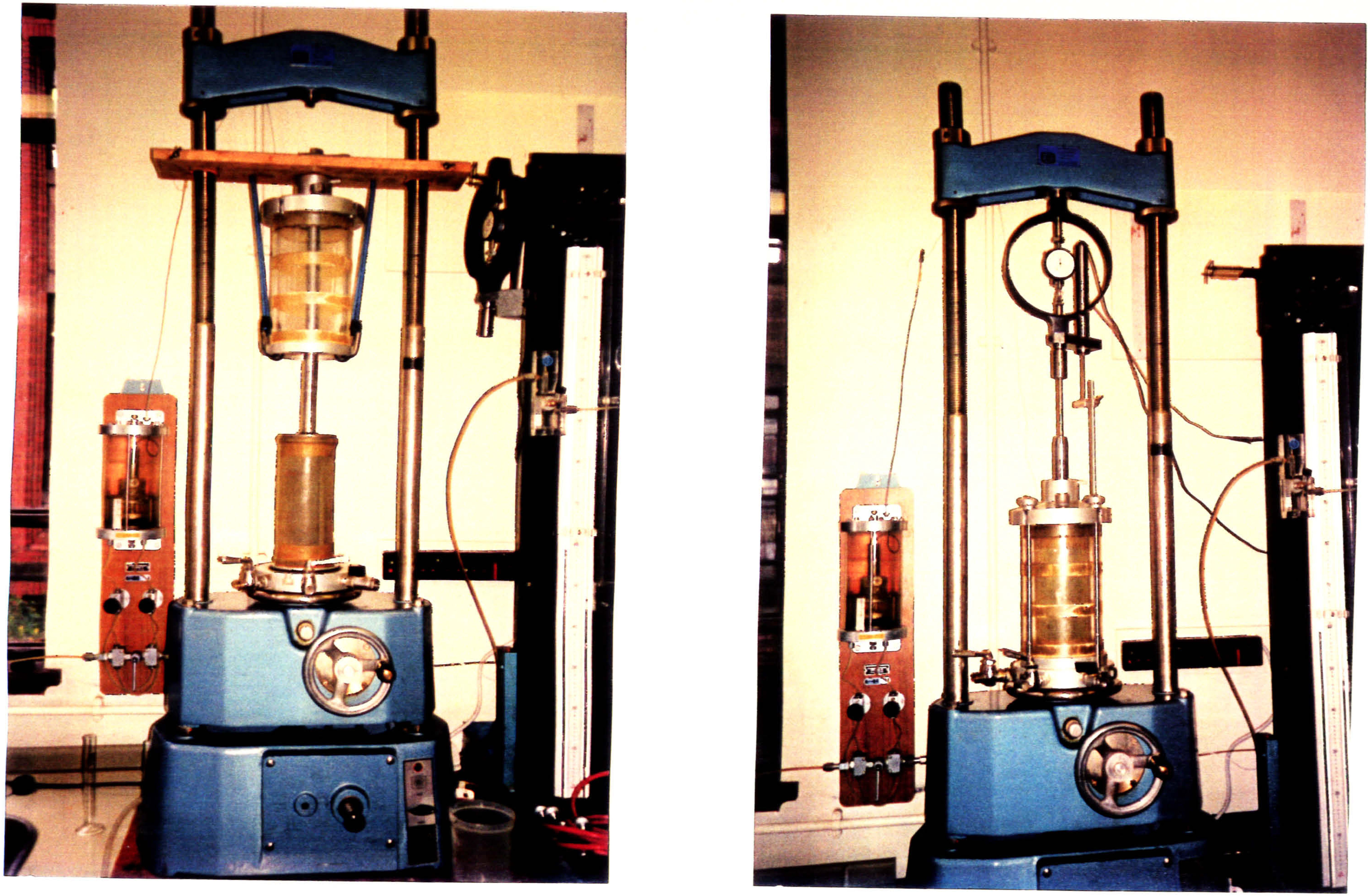

Fig. 6.9 (c) and (d) Procedure for placing the sample in the triaxial calibration chamber.

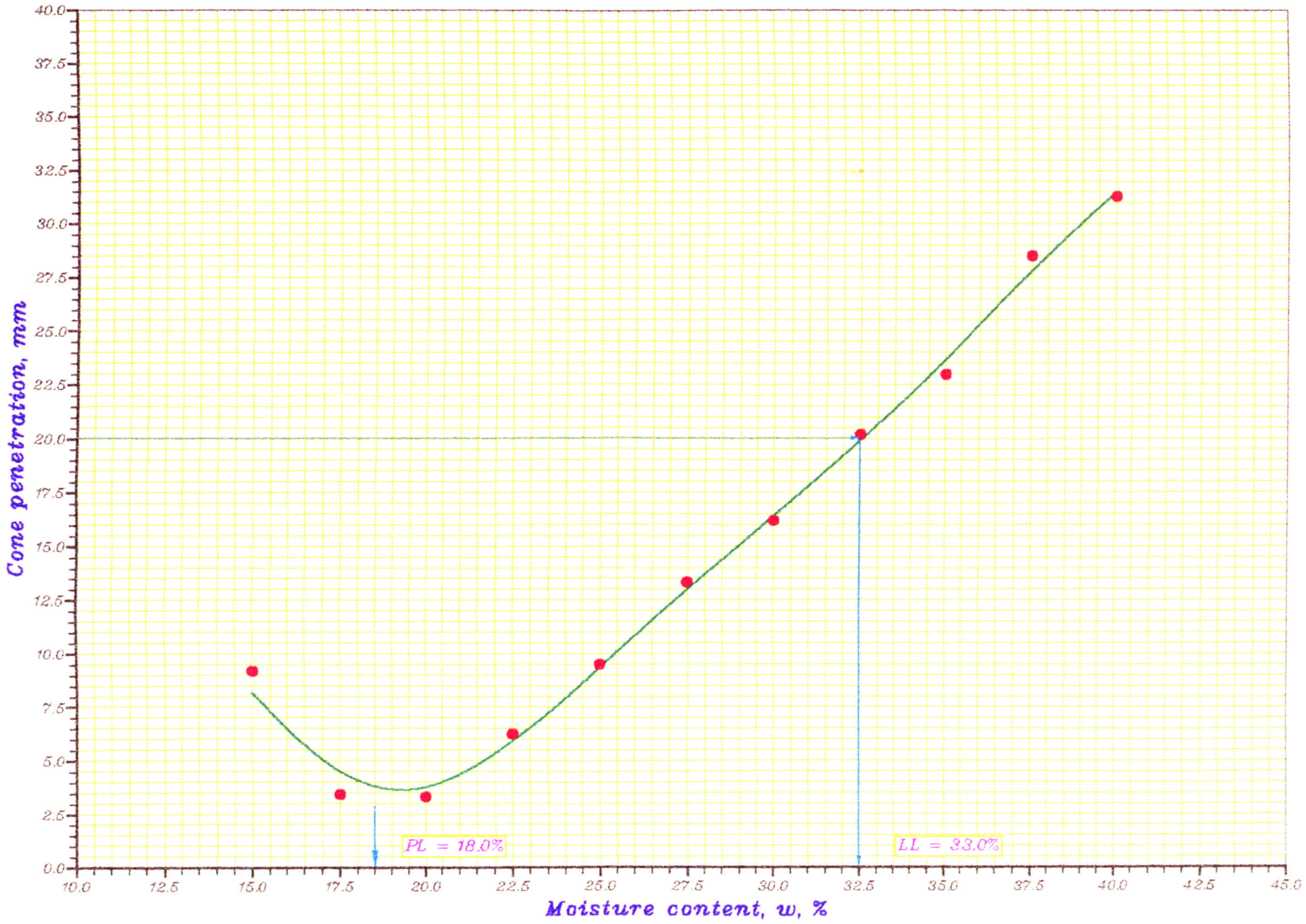

Fig. 7.1 Determination of Liquid limit and Plastic limit for the experimental soil

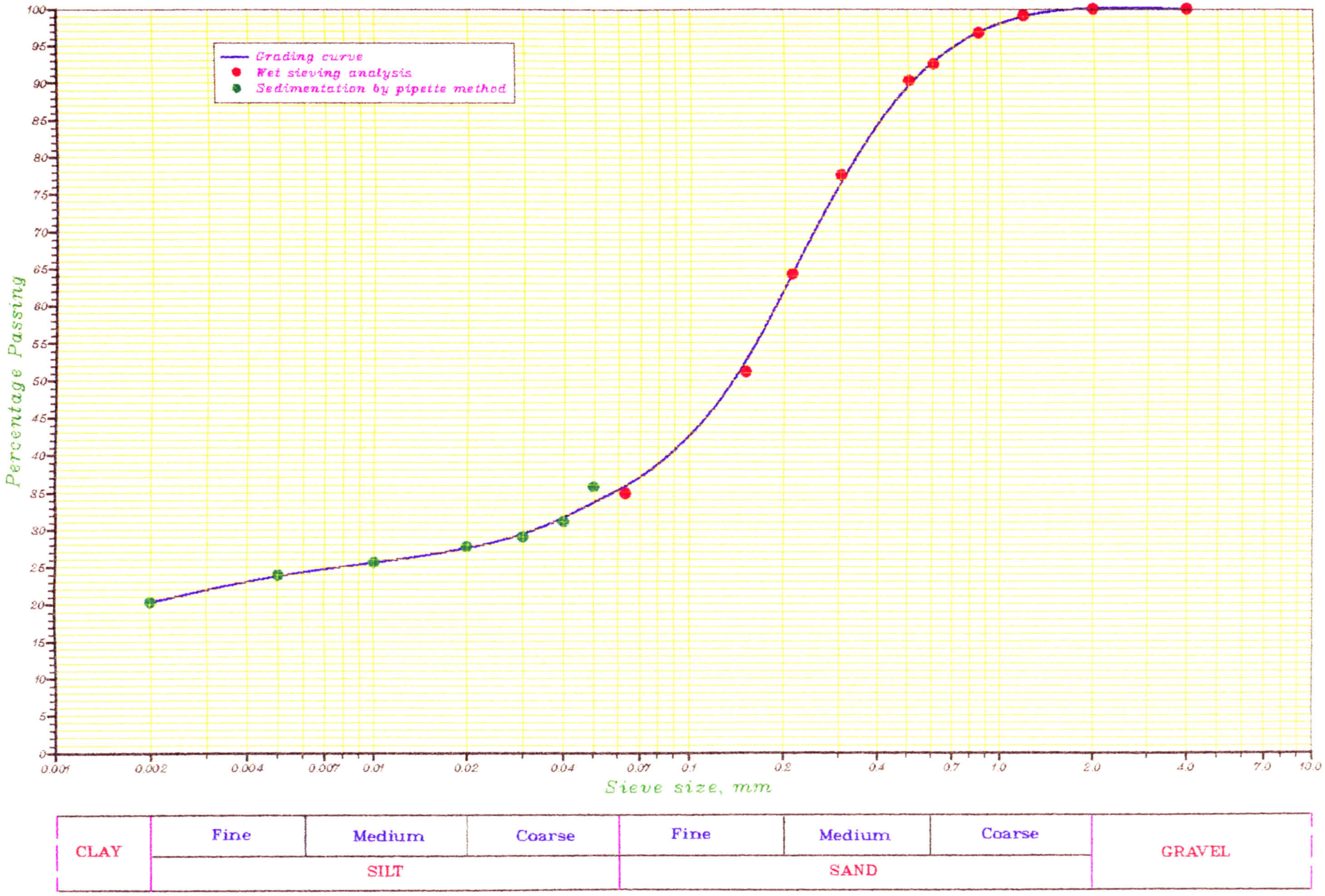

Fig. 7.2 Grading curve of the experimental soil

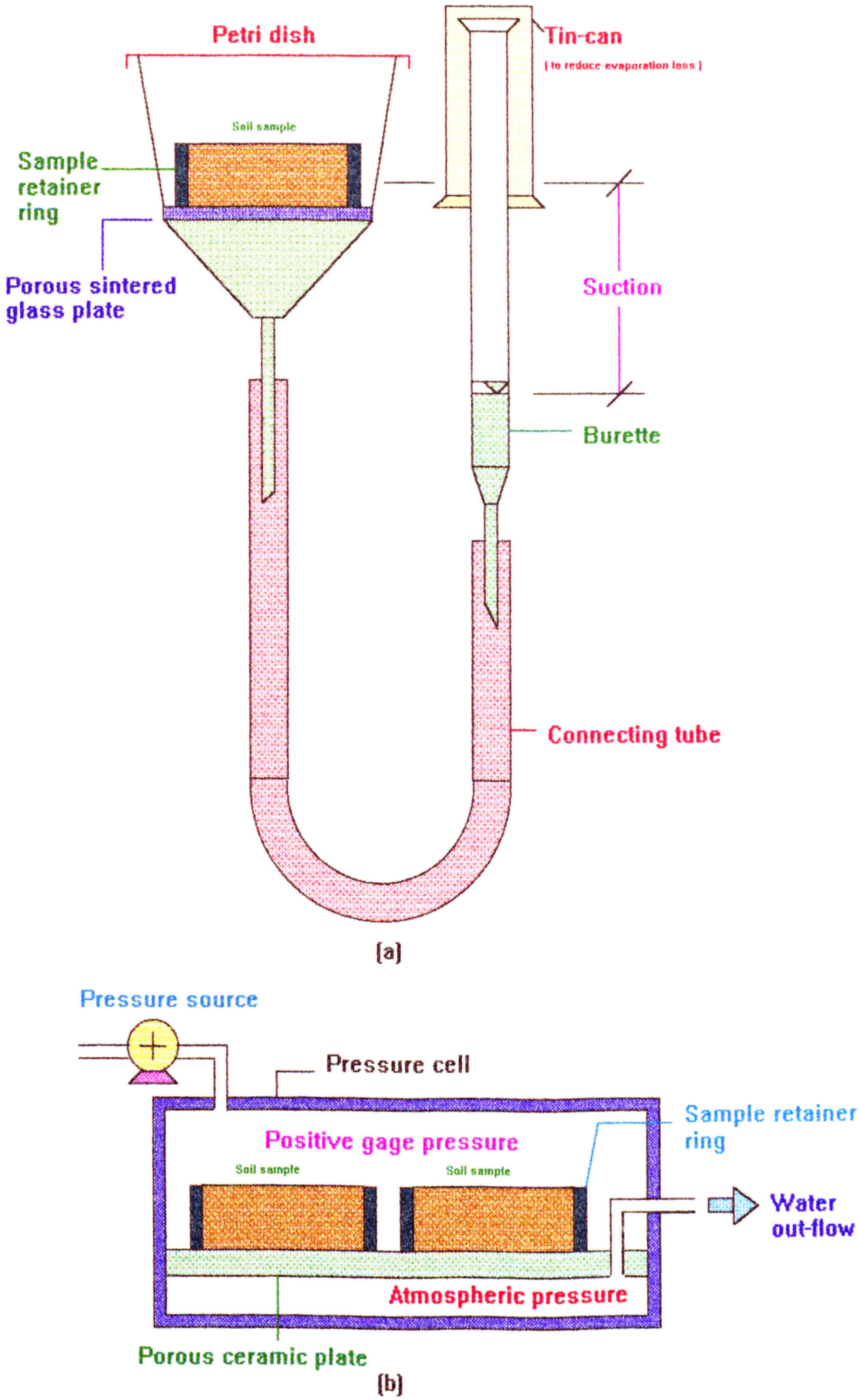

Fig. 7.3 (a) Schematic arrangement for Haine's Apparatus.
(b) Schematic arrangement for Pressure Plate Extractor.

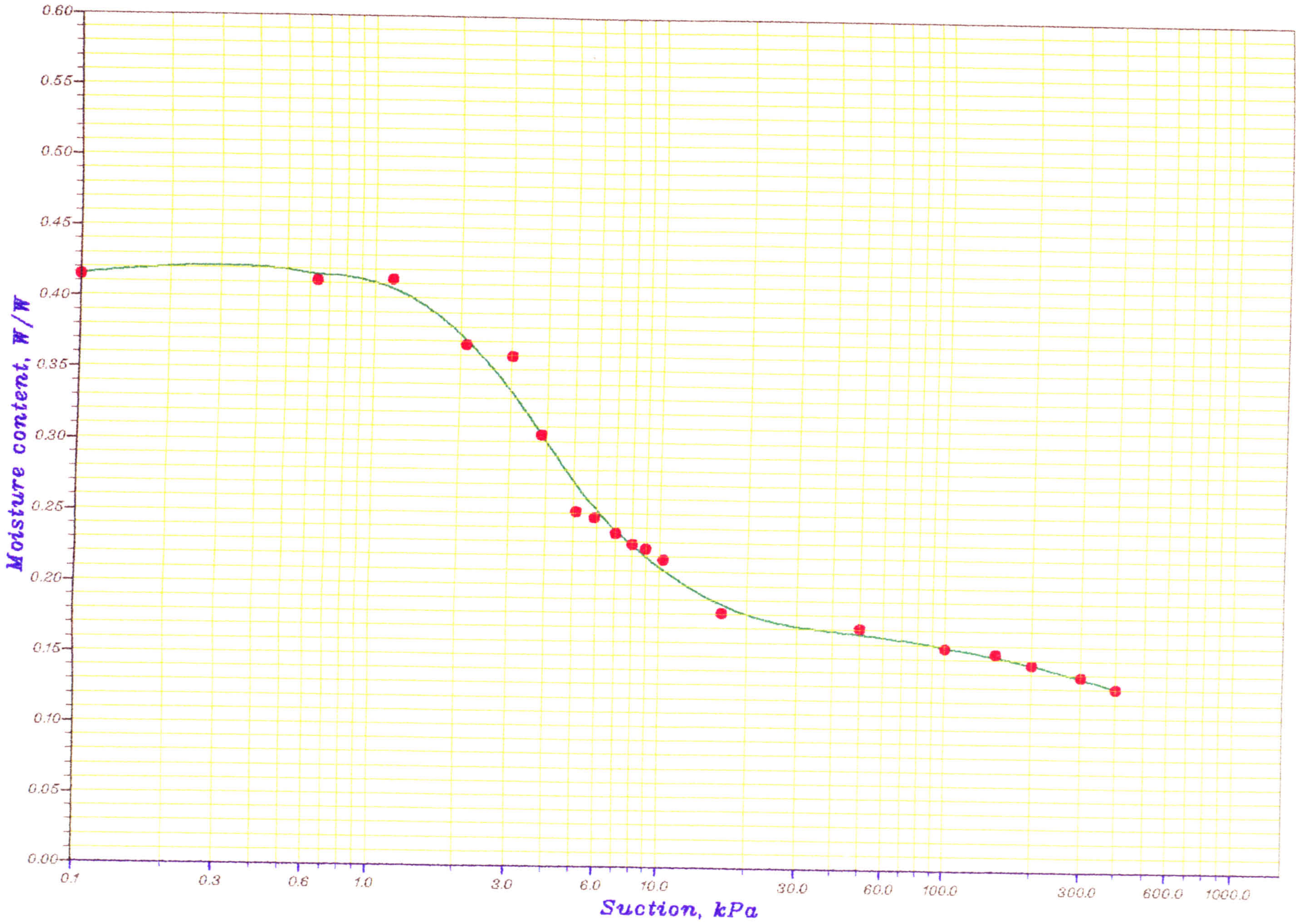

Fig. 7.4 Moisture release characteristics of the experimental soil

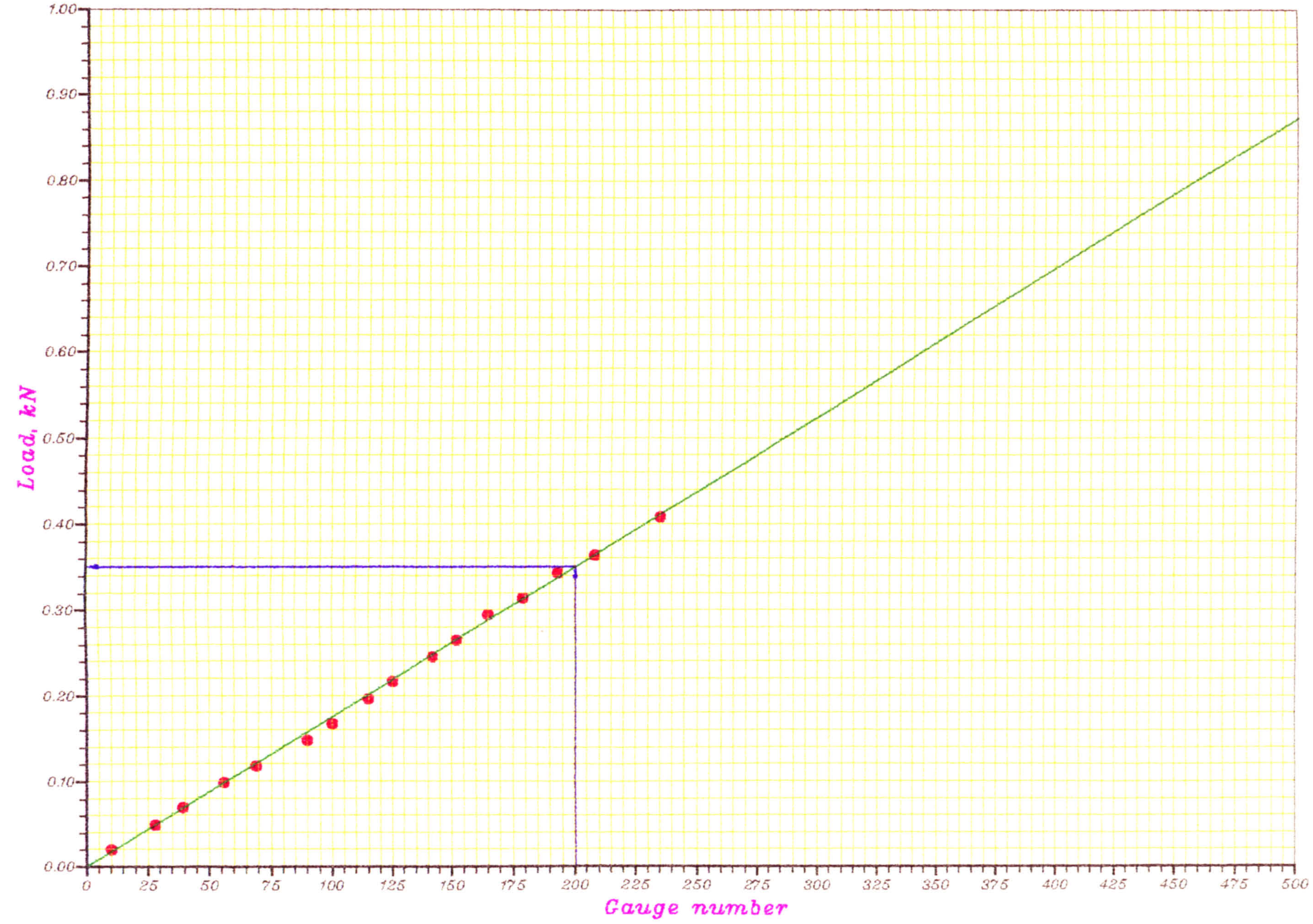

Fig. 7.5 Calibration (compression) for proving ring in the triaxial apparatus

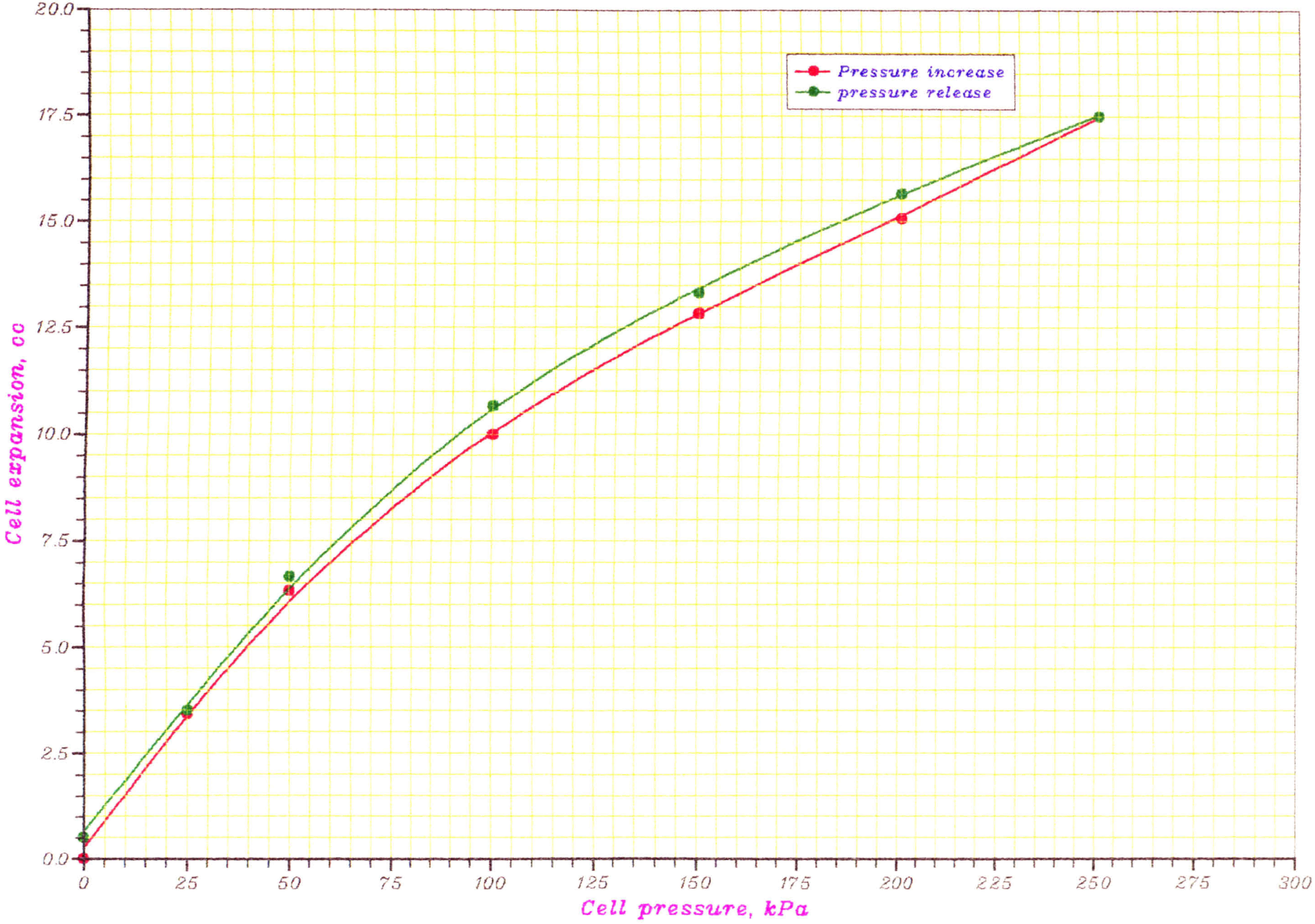

Fig. 7.6 Calibration for triaxial cell expansion due to hydrostatic pressure

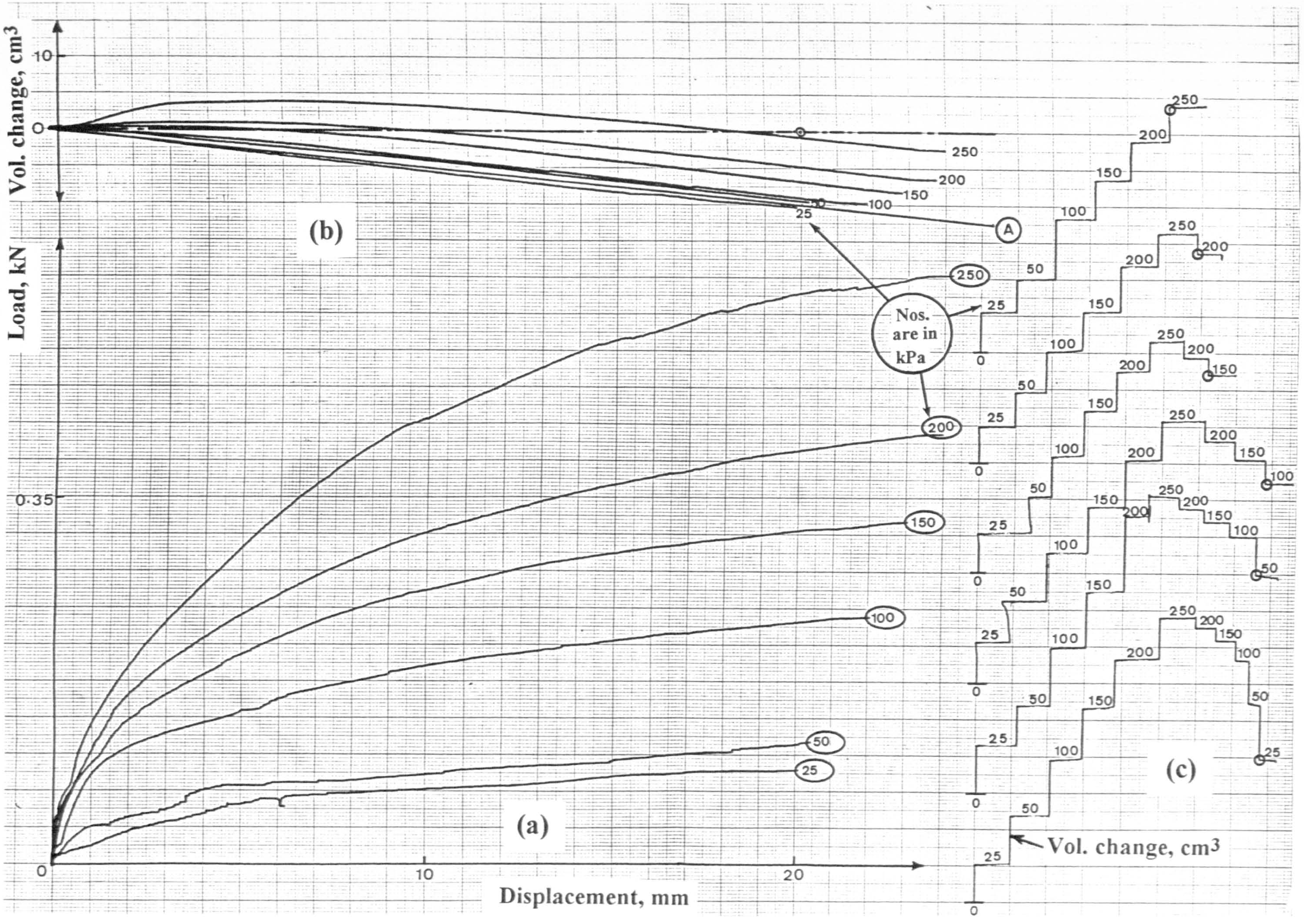

Fig. 7.7 A typical output on the X-Y-Y plotter from triaxial test; (a) Load versus displacement. (b) Volume-change versus displacement. (c) Recording for the volume-change of the specimen during isotropic compression and subsequently allowed it for swelling.

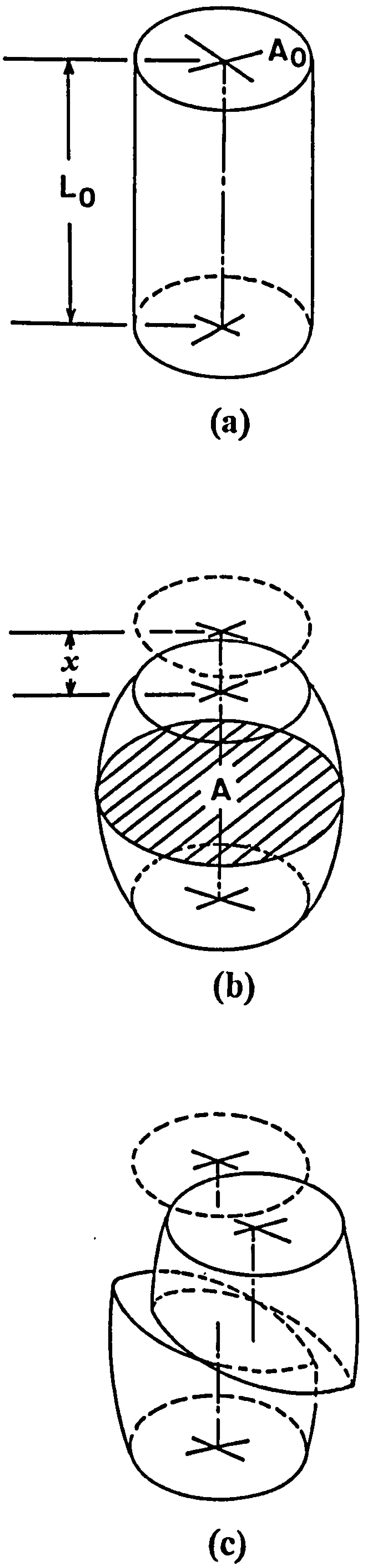

Fig. 7.8 Change in area in mid-section in the triaxial test sample during failure; (a) Original sample. (b) Plastic failure. (c) Brittle failure.

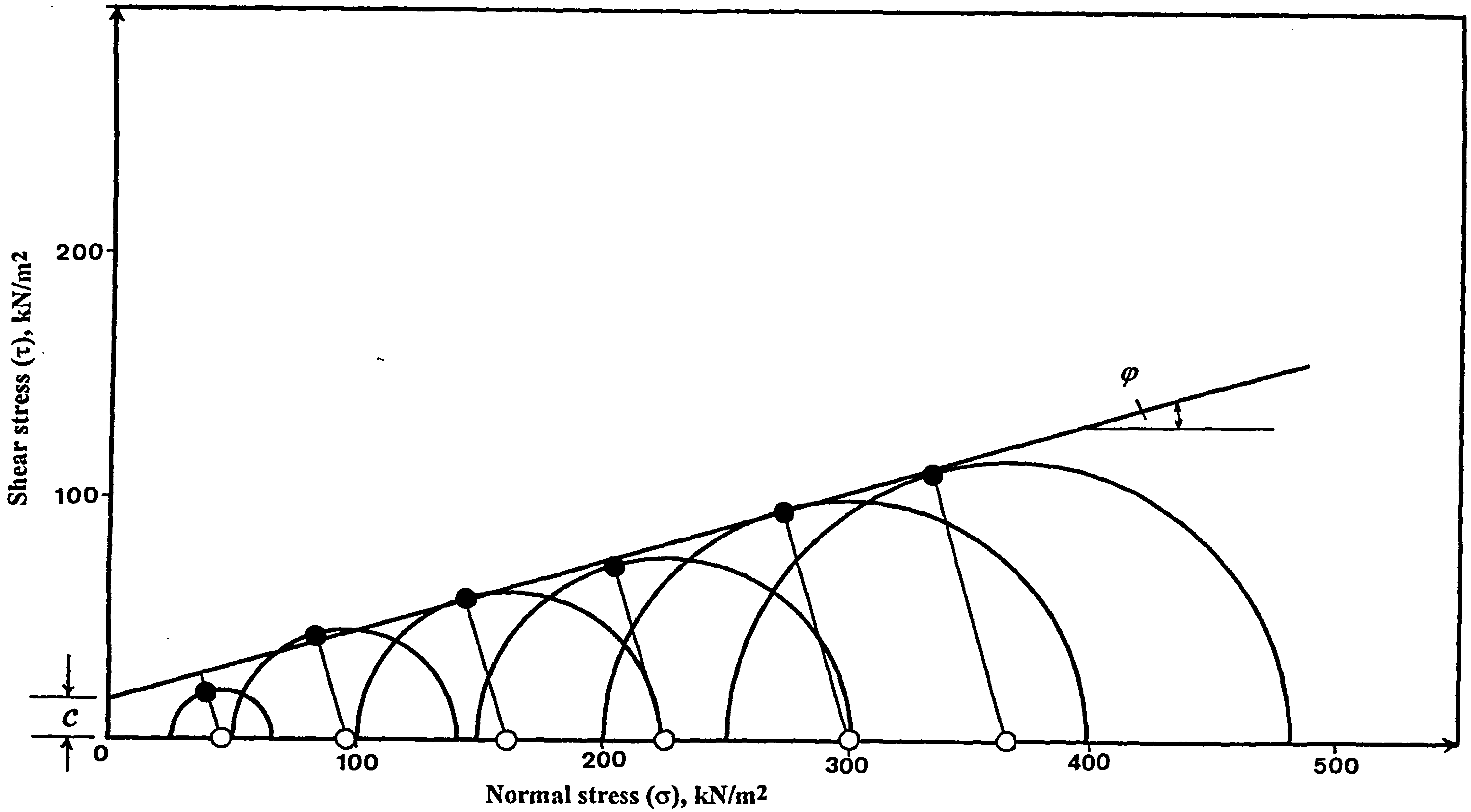

Fig. 7.9 Mohr's diagram (top part) for the experimental soil at 15.0% m.c.

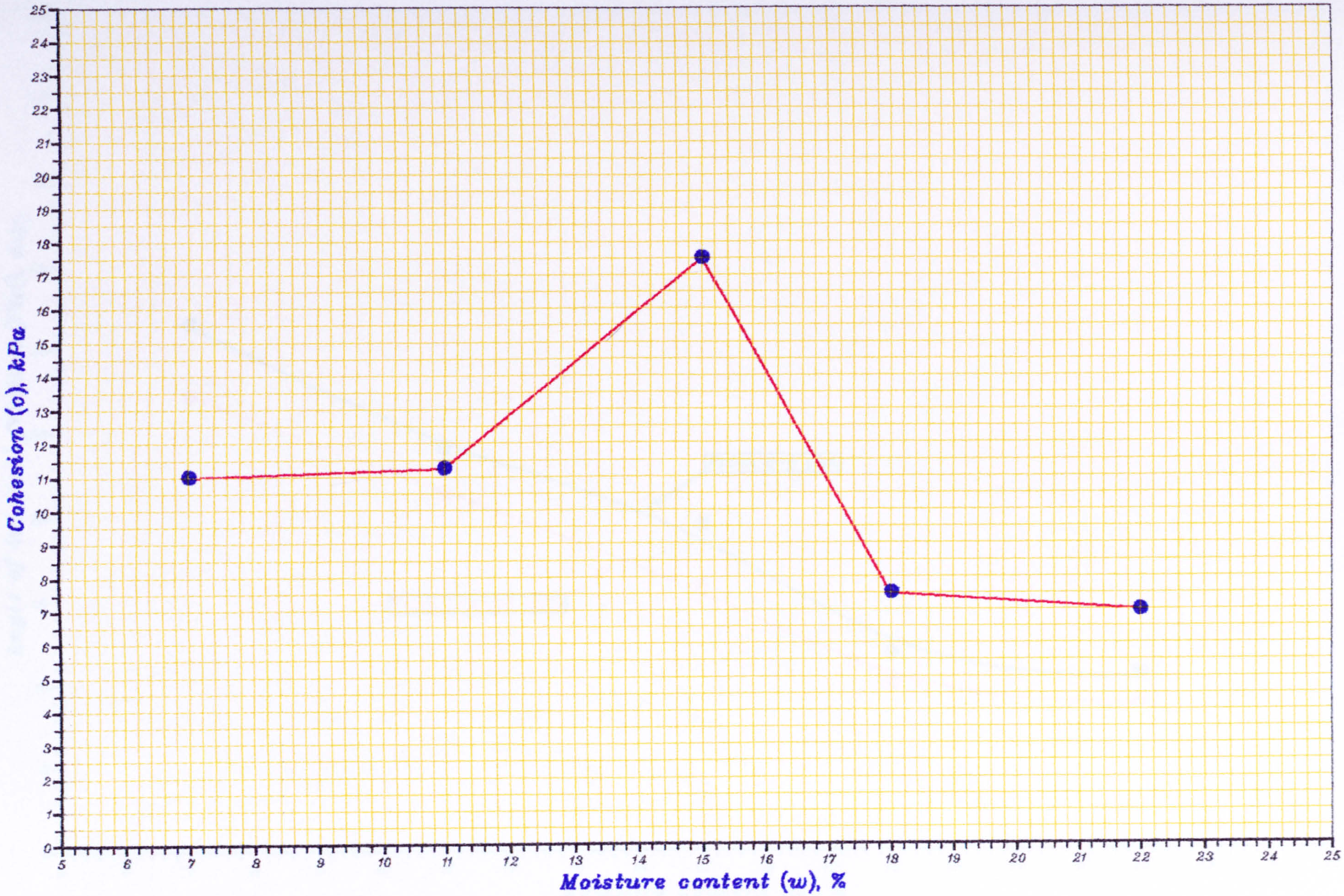

Fig. 7.10 Variation of cohesion, c with m.c.

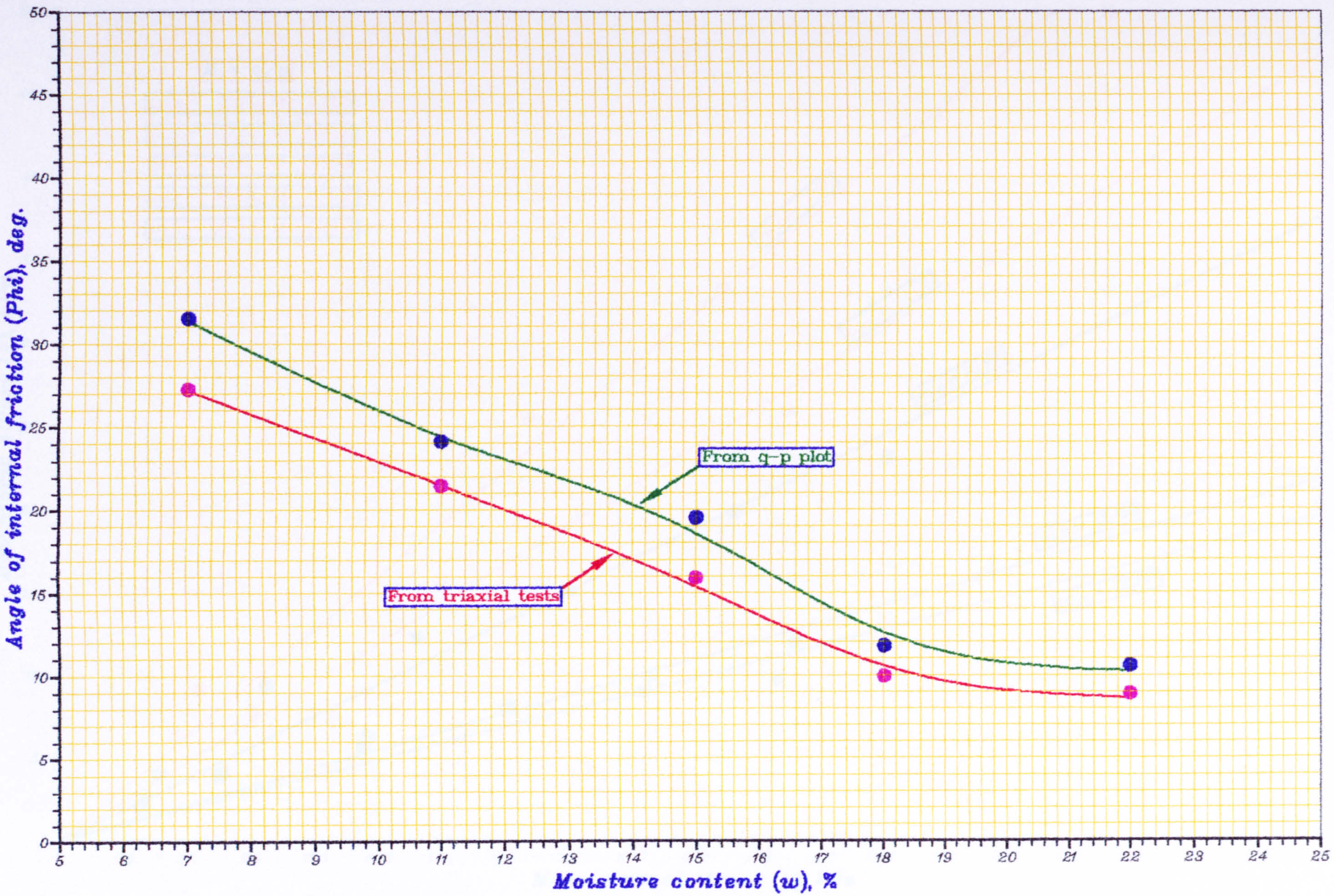

Fig. 7.11 Variation of the Angle of internal friction, Phi with m.c.

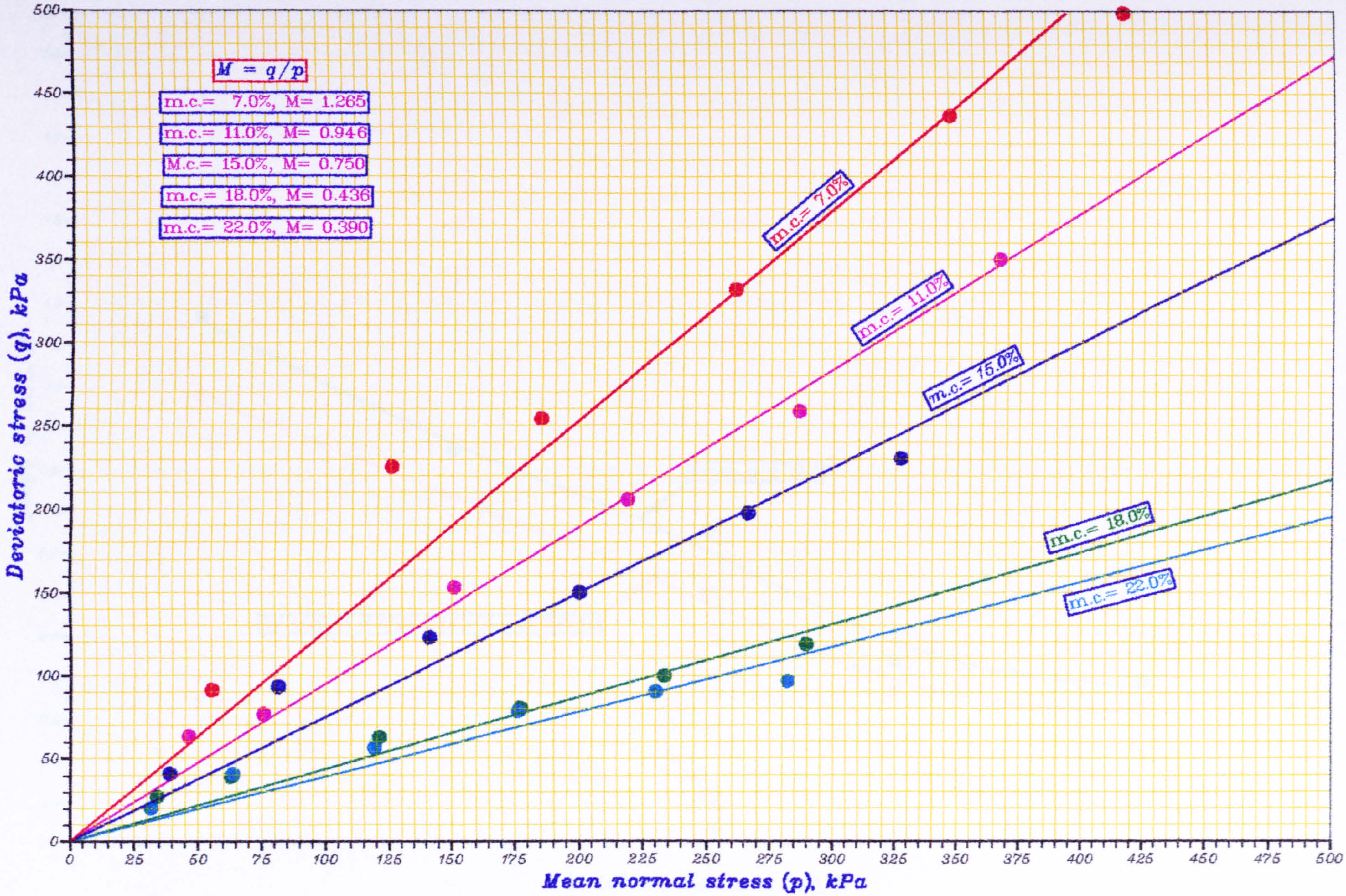

Fig. 7.12 The CSL at different m.c. in q–p plane

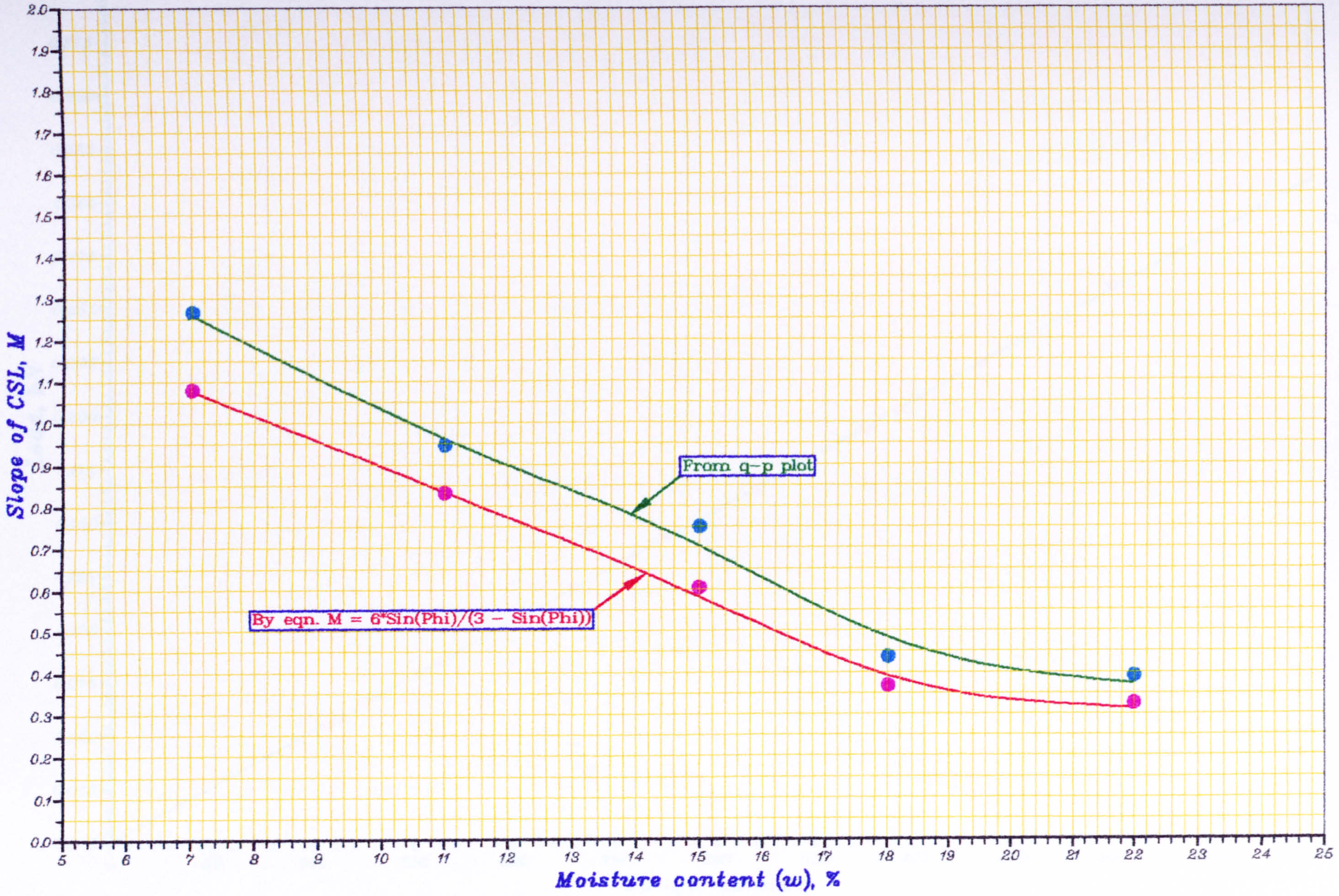

Fig. 7.13 Variation of the Slope of CSL, M with m.c.

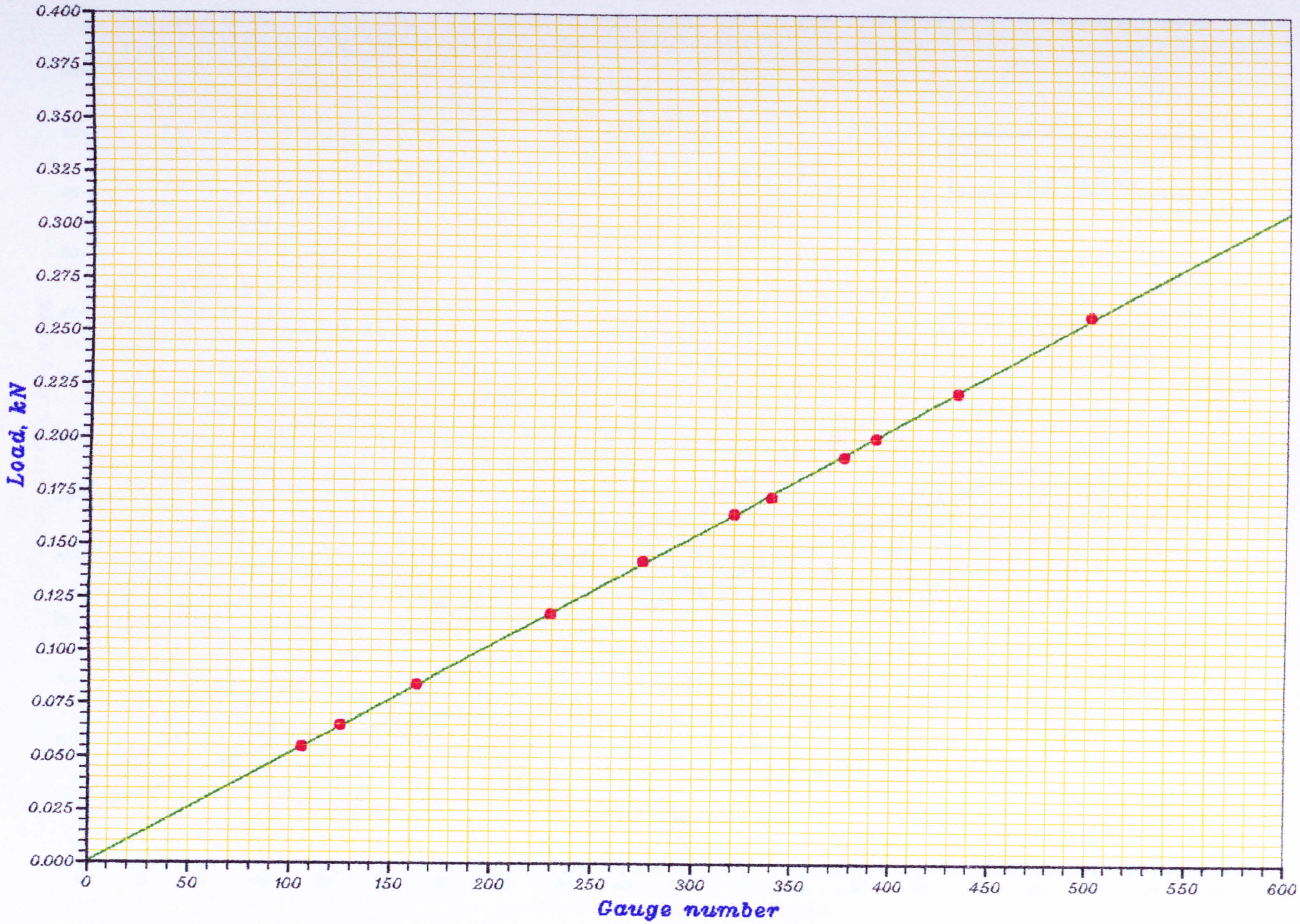

Fig. 7.14 The calibration (compression) of proving ring in the Shear box apparatus

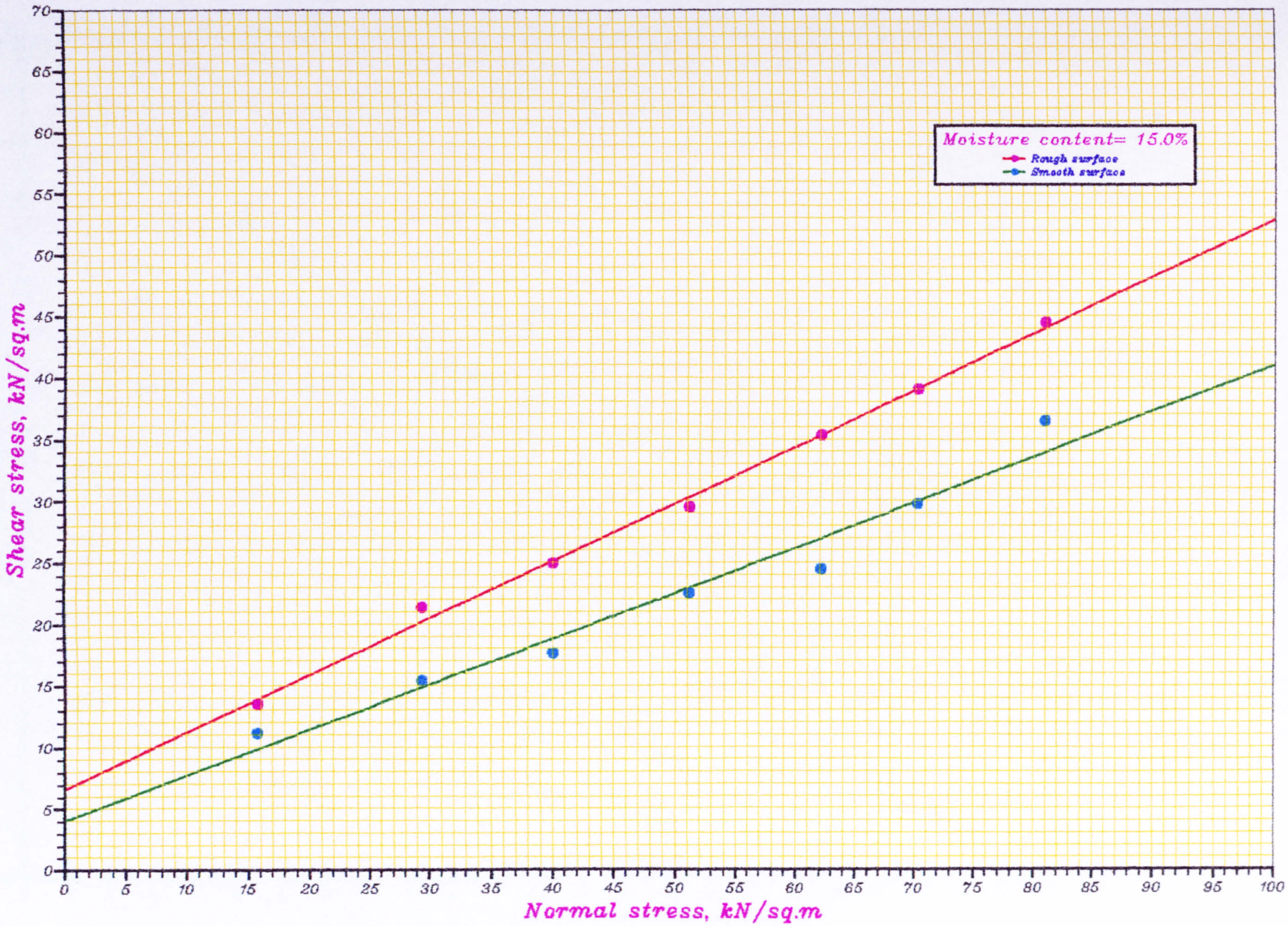

Fig. 7.15 A typical Normal stress vs Shear stress plot from Shear–box test at 15.0% m.c.

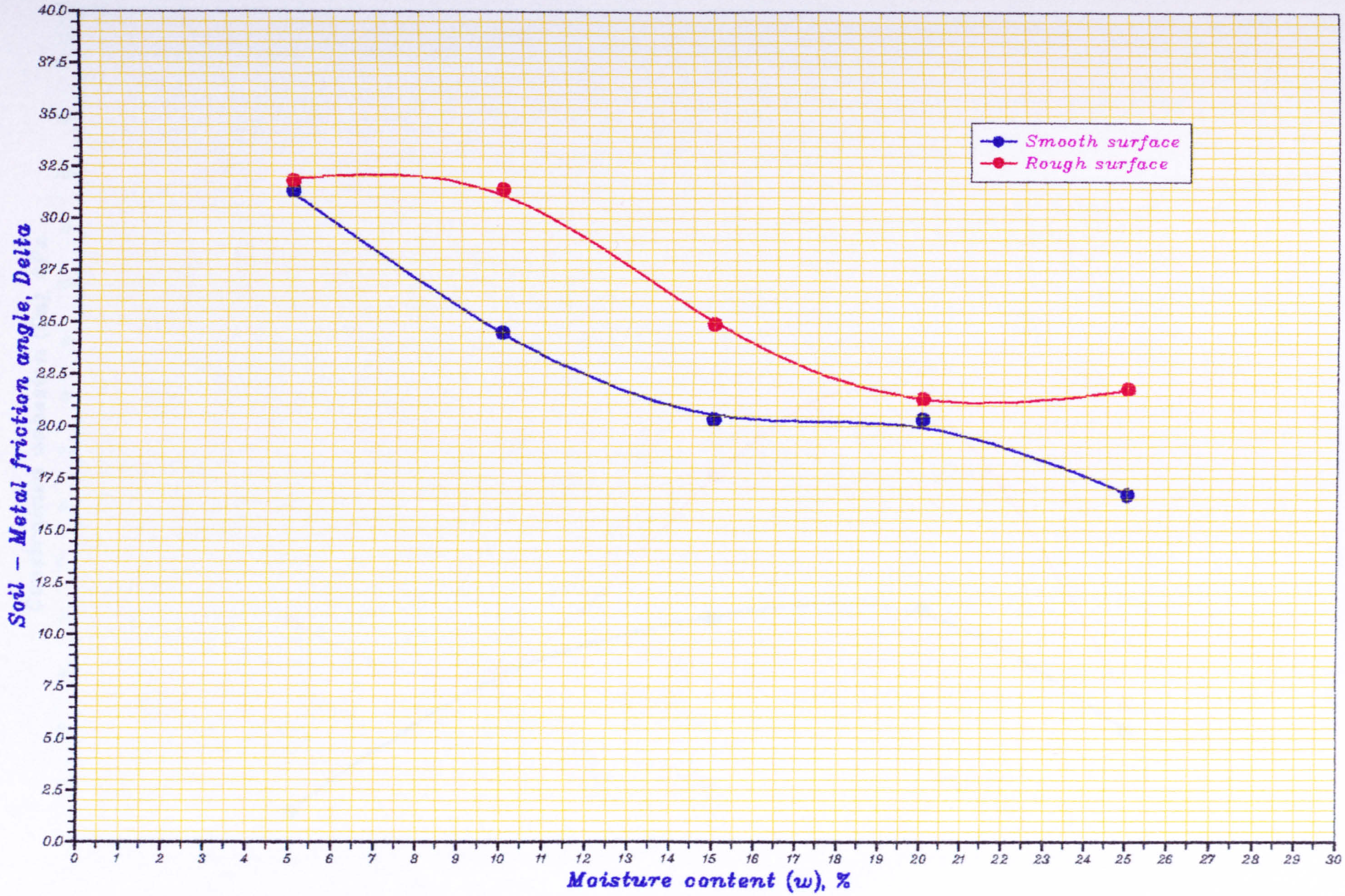

Fig. 7.16 The variation of Delta with m.c.

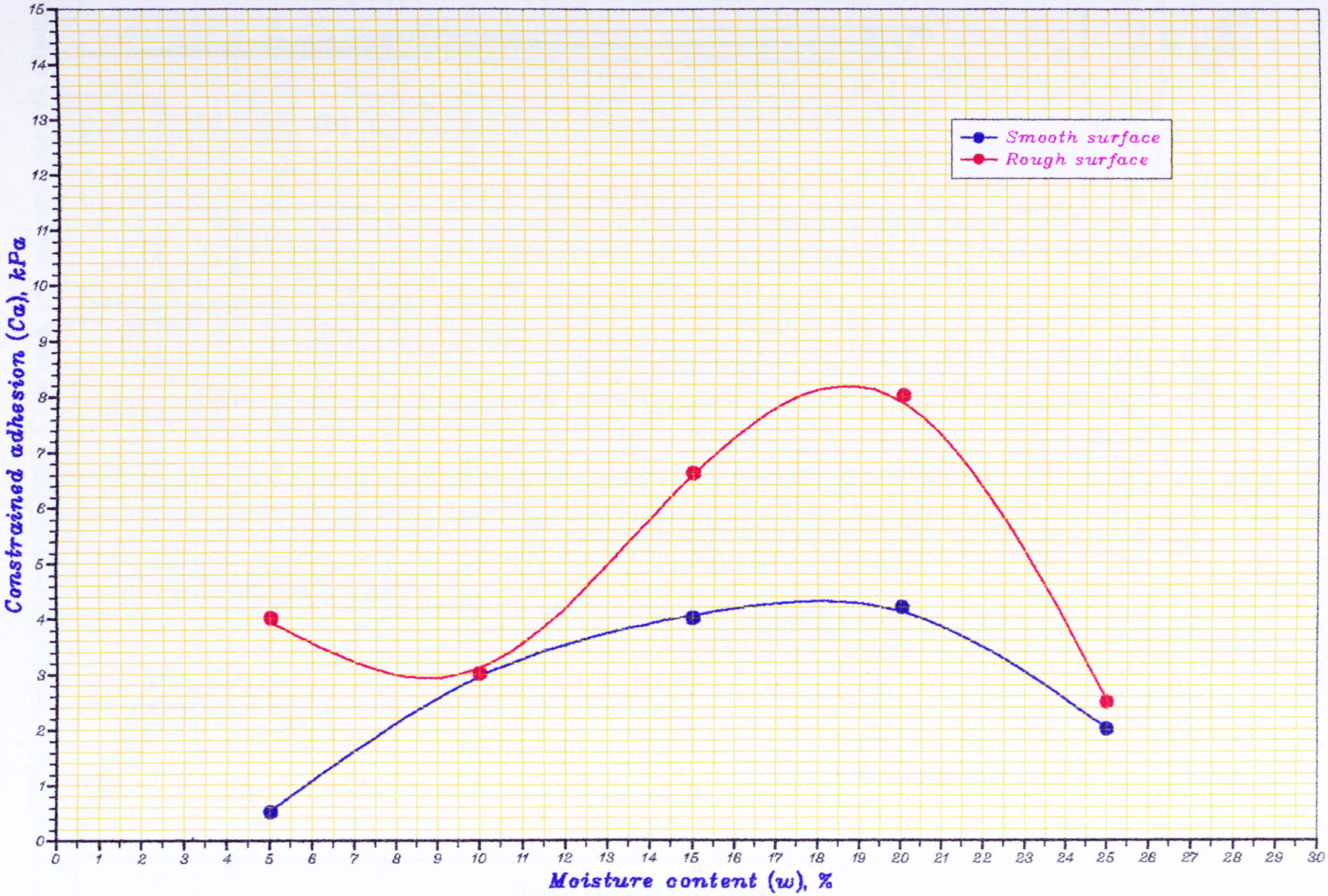

Fig. 7.17 *The variation of constrained adhesion, Ca with m.c.*

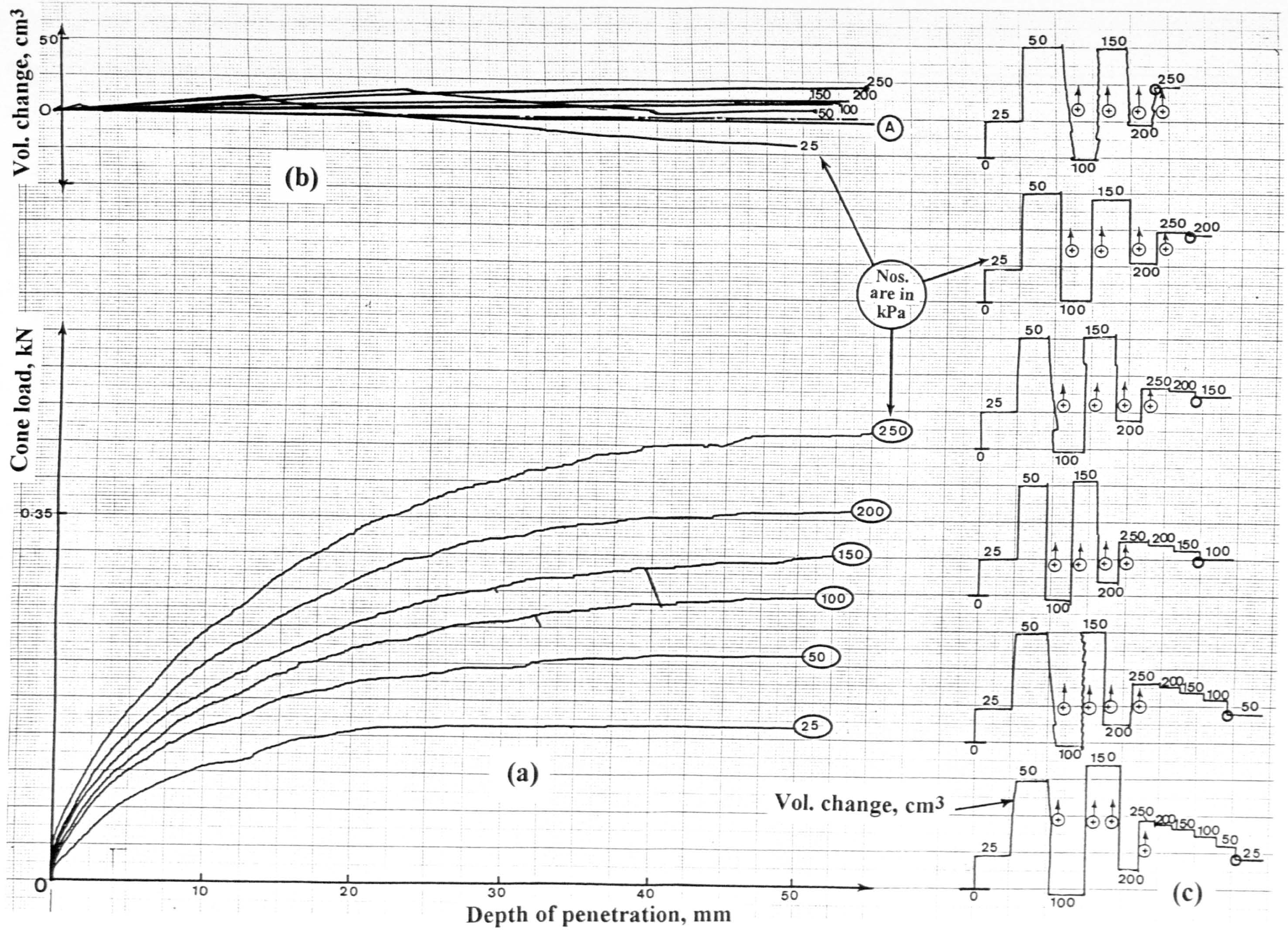

Fig. 7.18 A typical output on the X-Y-Y plotter from triaxial calibration chamber test; (a) Cone load versus displacement. (b) Volume-change versus displacement. (c) Recording for the volume-change of the specimen during isotropic compression and subsequently allowed it for swelling.

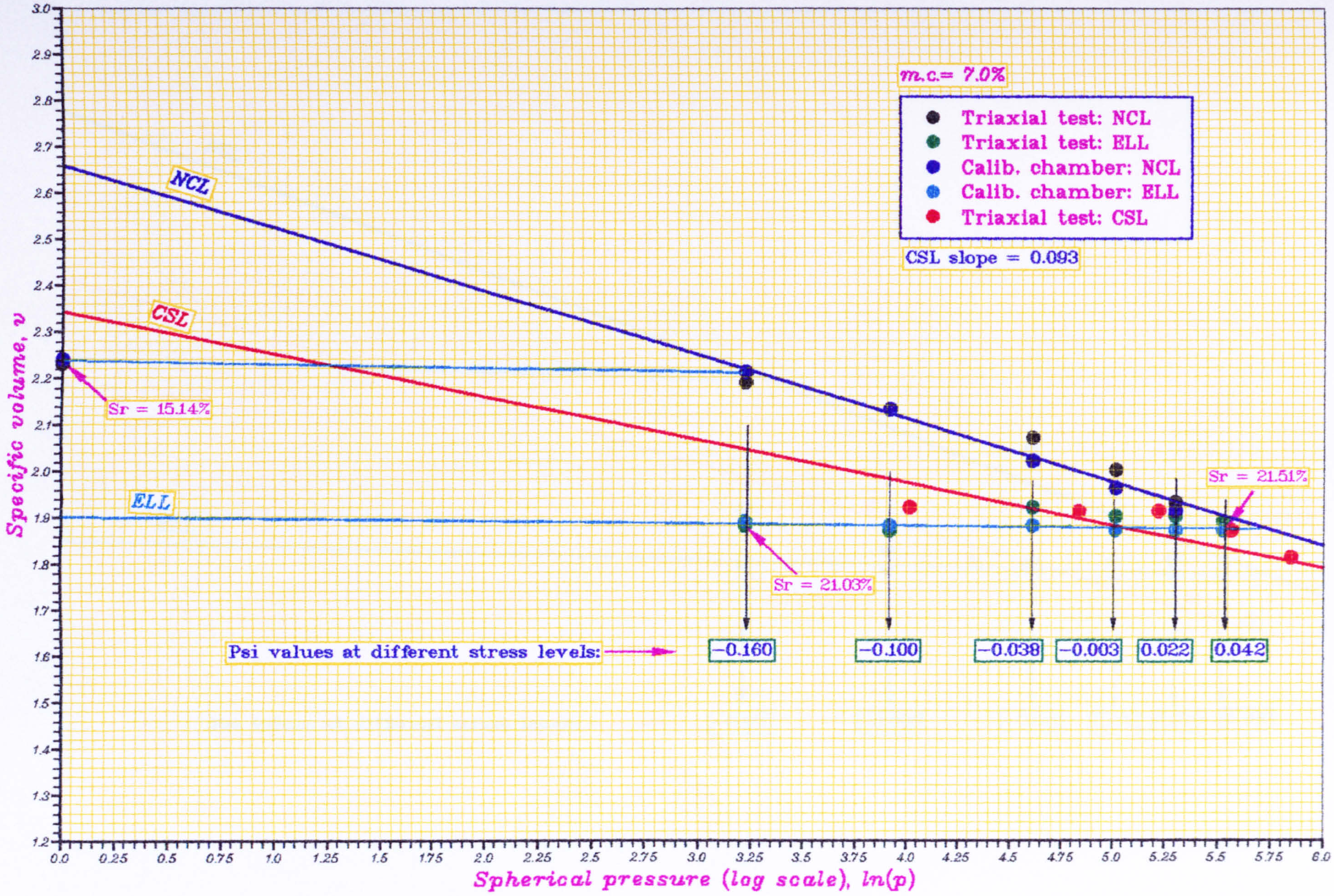

Fig. 7.19 A v–ln(p) plot from Triaxial and Calibration chamber tests at 7.0% m.c.

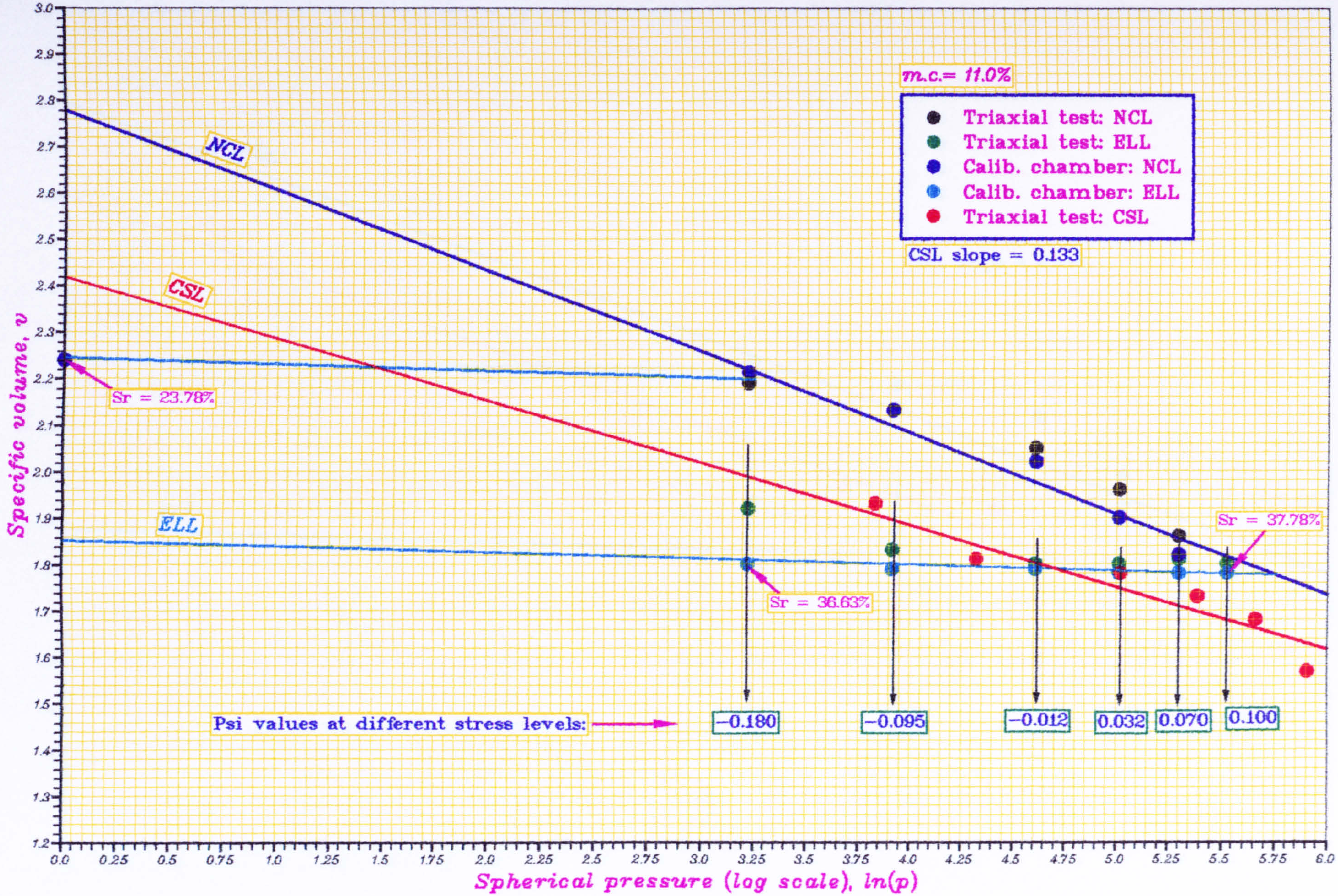

Fig. 7.20 A v−ln(p) plot from Triaxial and Calibtation chamber tests at 11.0% m.c.

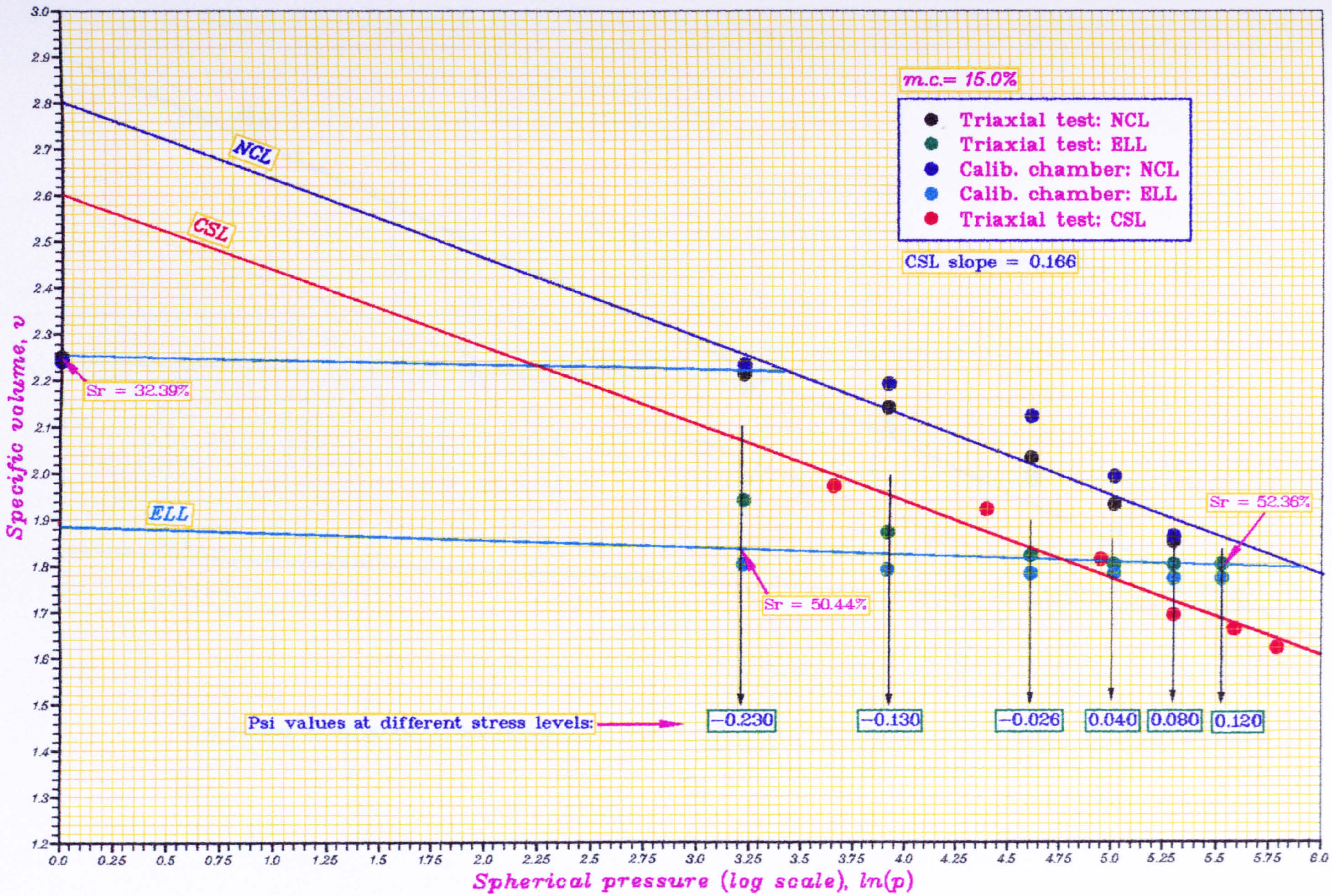

Fig. 7.21 A v−ln(p) plot from Triaxial and Calibration chamber tests at 15.0% m.c.

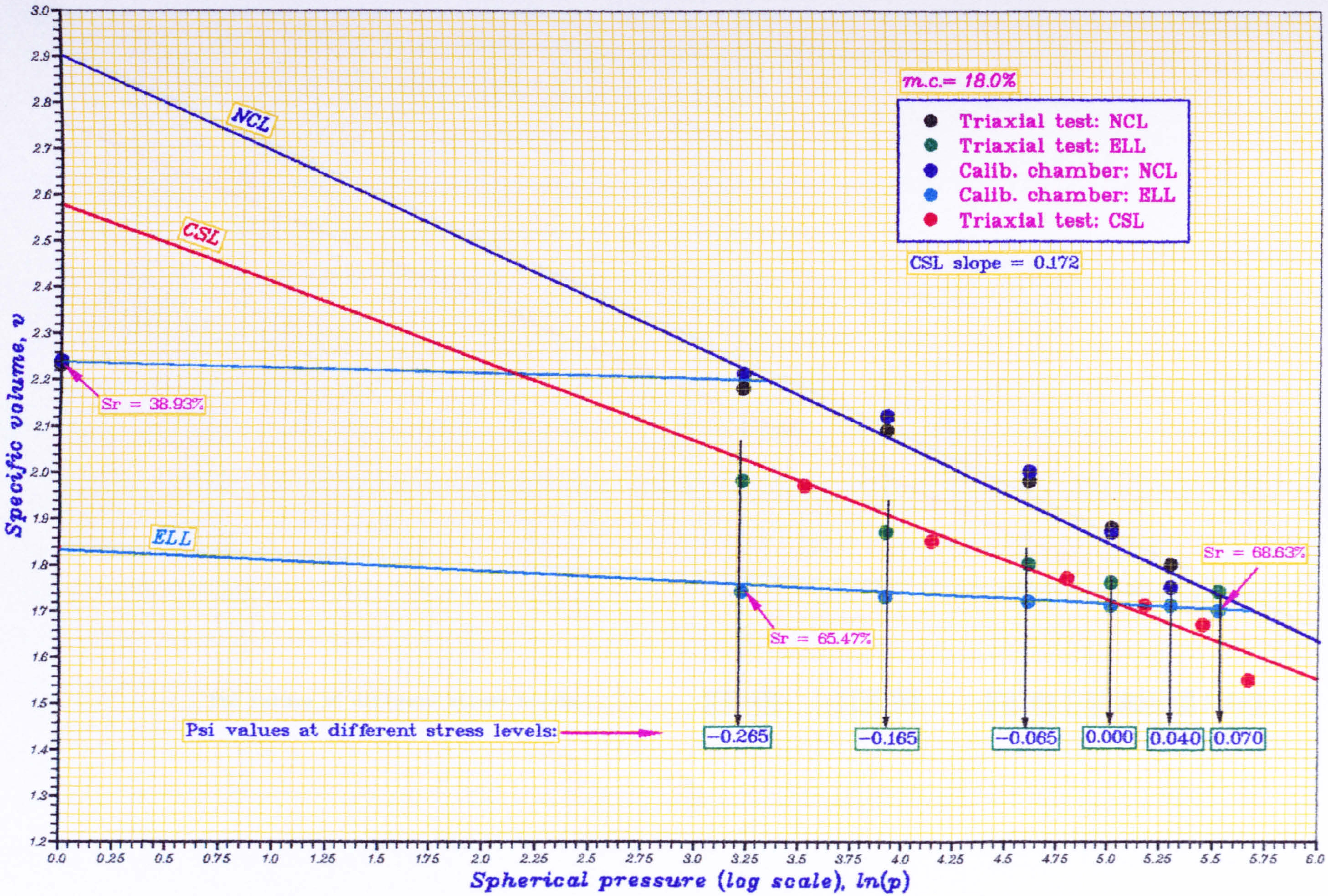

Fig. 7.22 A v–ln(p) plot from Triaxial and Calibration chamber tests at 18.0% m.c.

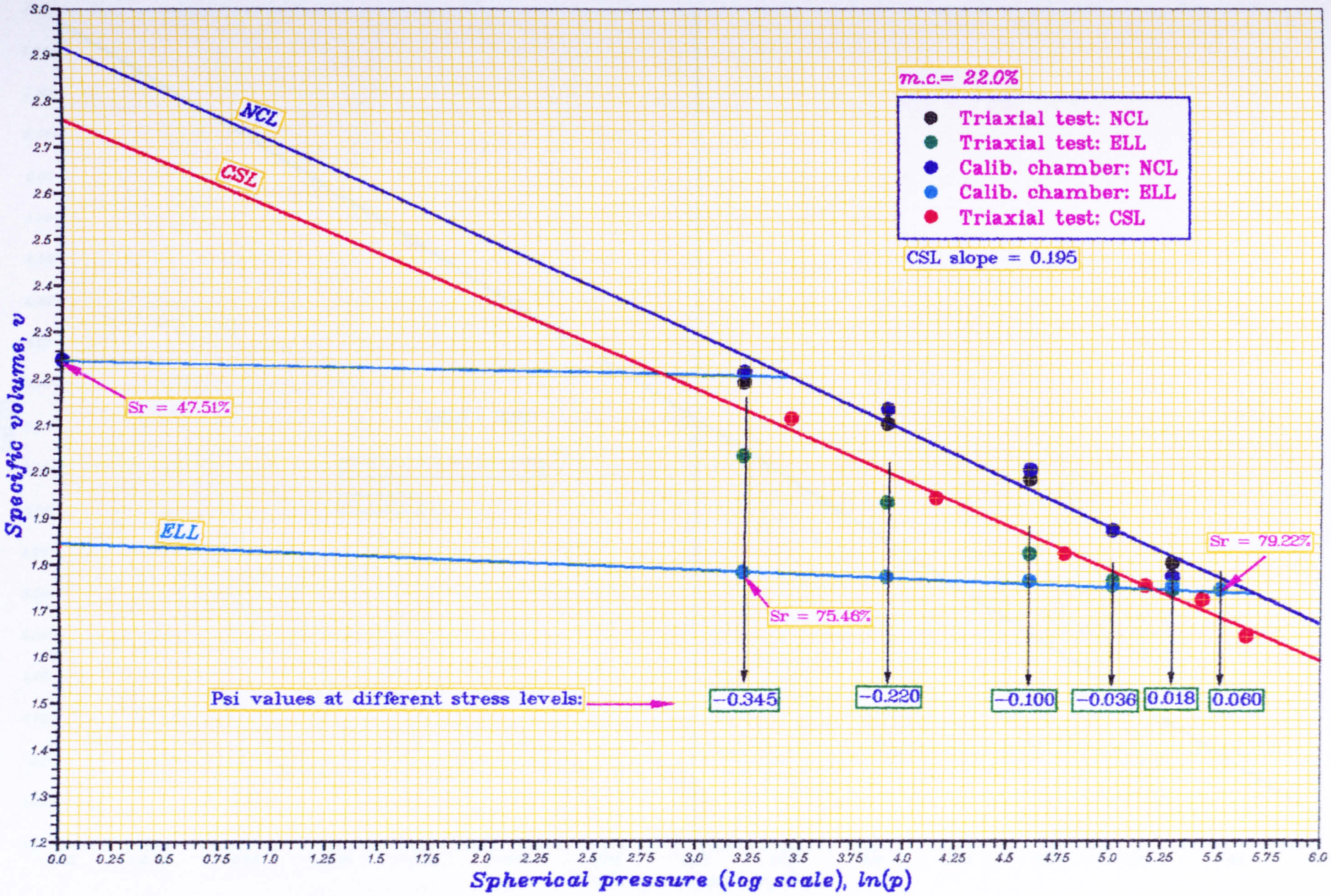

Fig. 7.23 A v–ln(p) plot from Triaxial and Calibration chamber tests at 22.0% m.c.

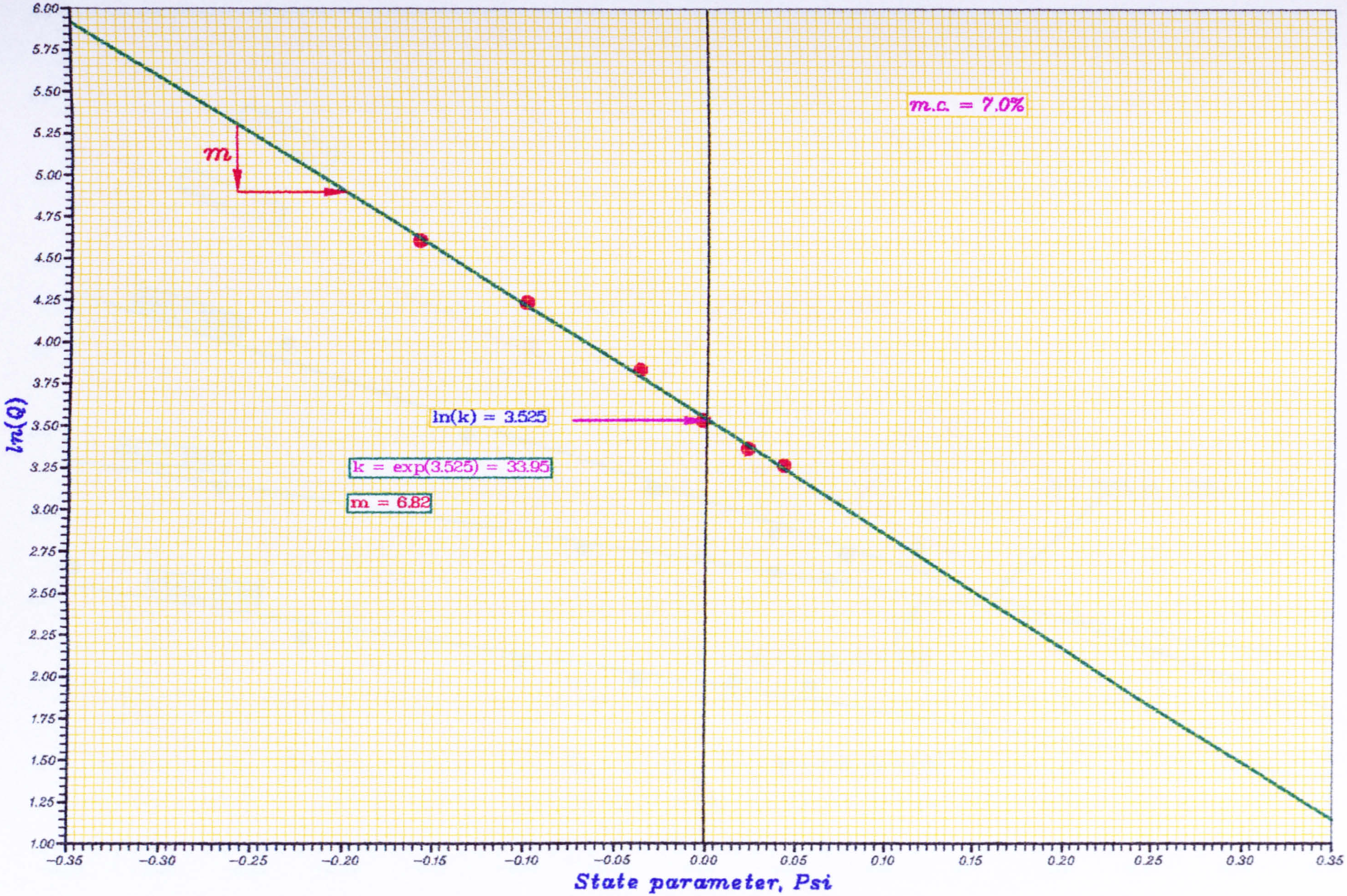

Fig. 7.24 A typical ln(Q) − Psi plot for 7.0% m.c.

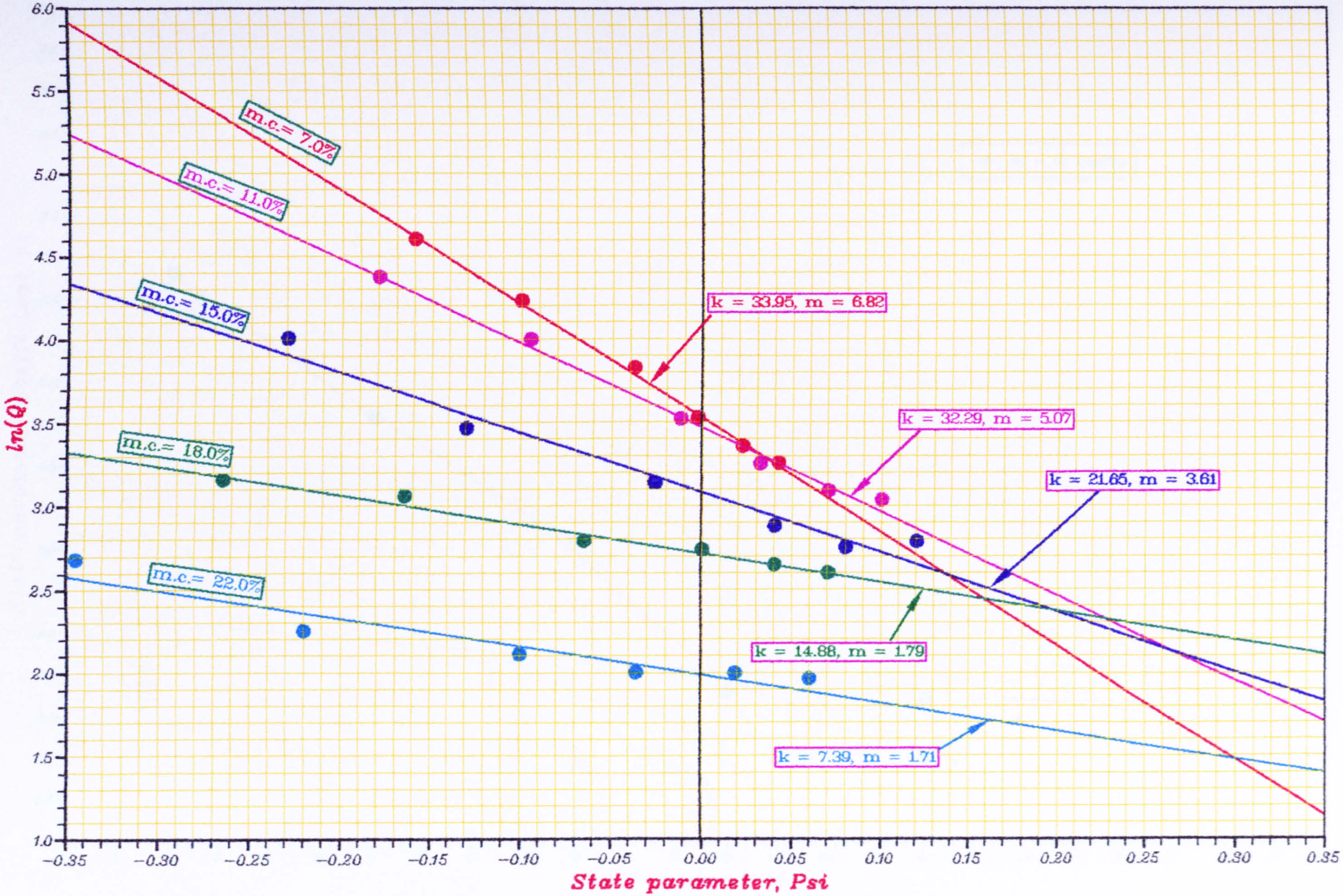

Fig. 7.25 The summarised ln(Q) – Psi plot for different m.c.

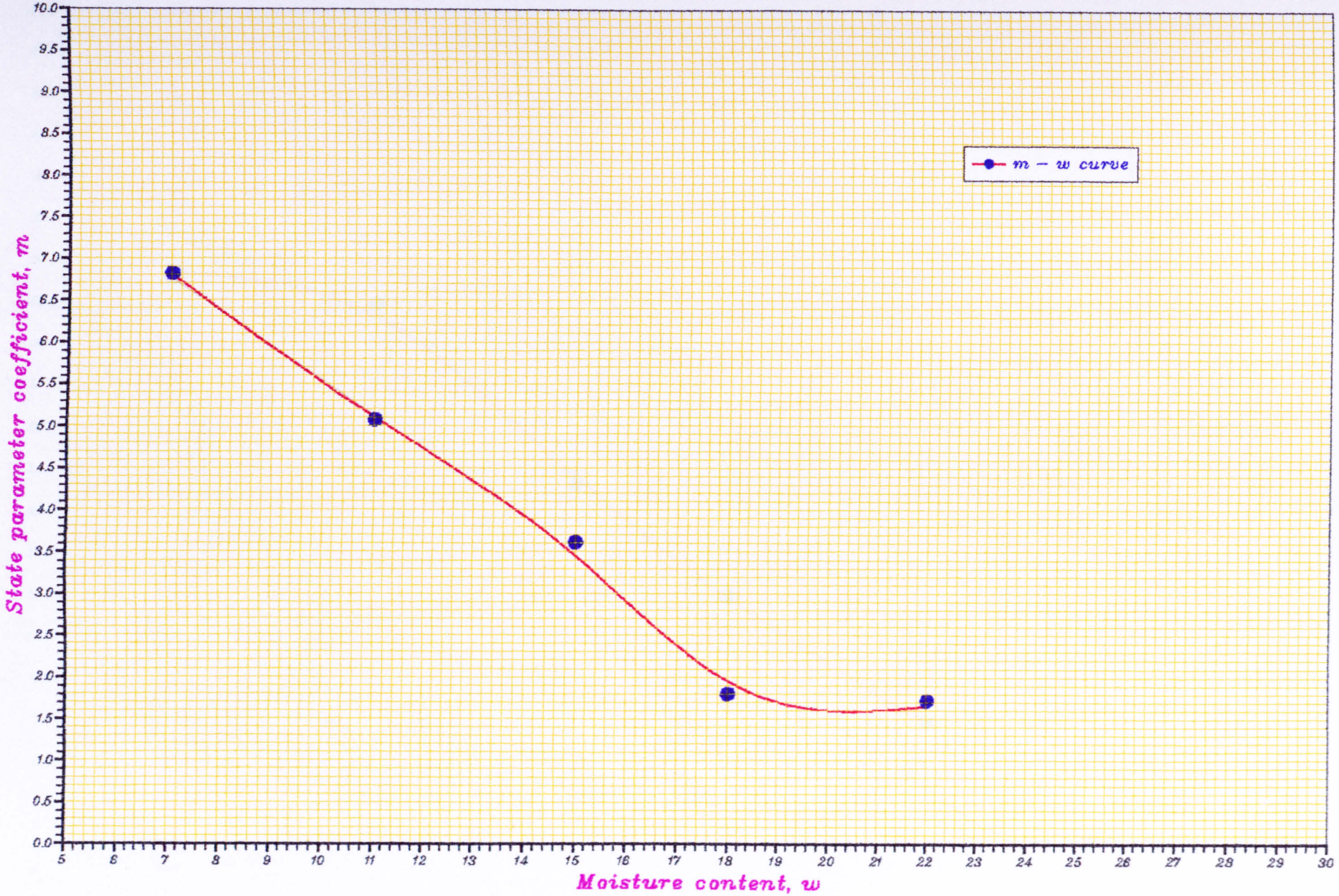

Fig. 7.26 The variation of State parameter coefficient, m with m.c.

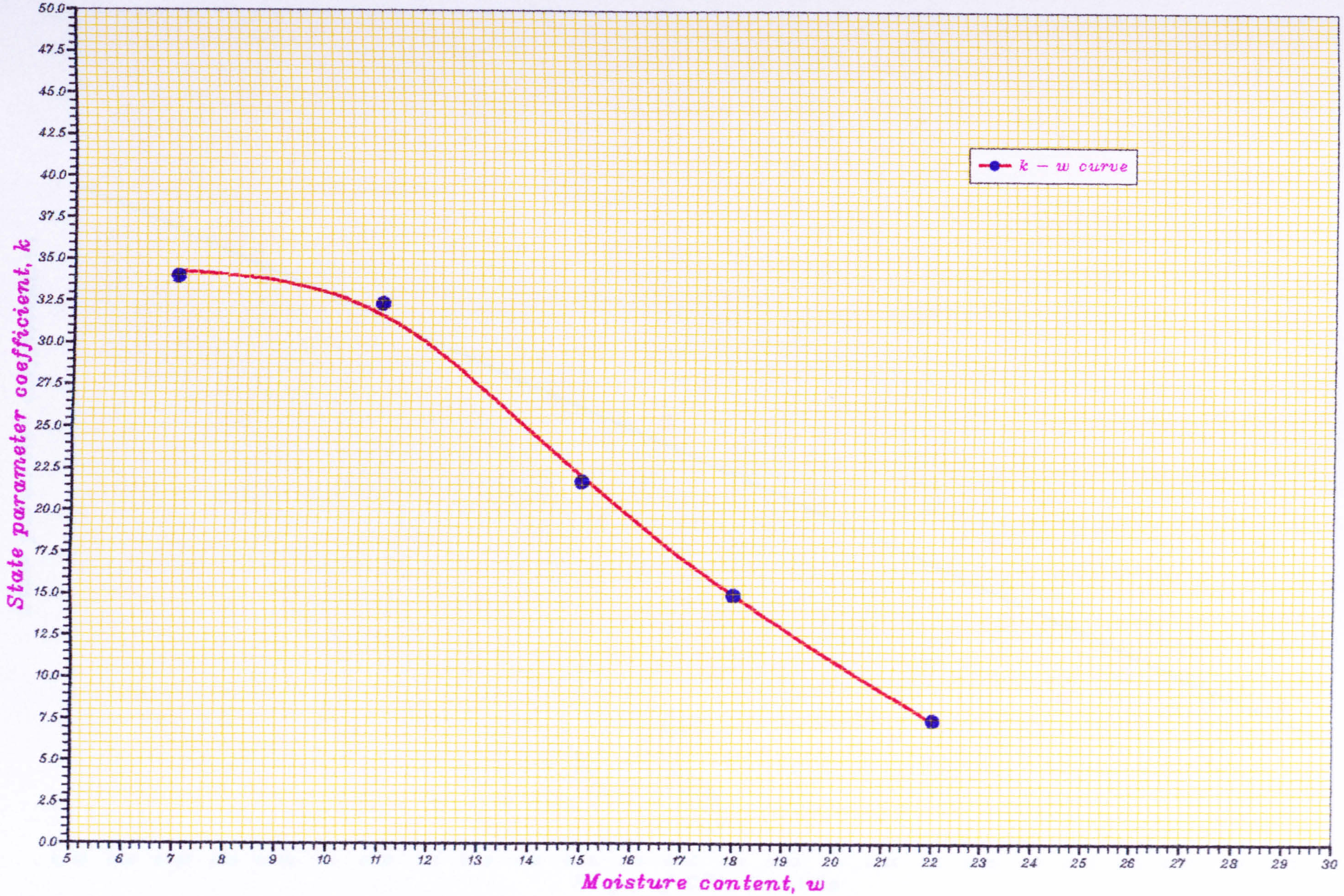

Fig. 7.27 The variation of State parameter coefficient, k with m.c.

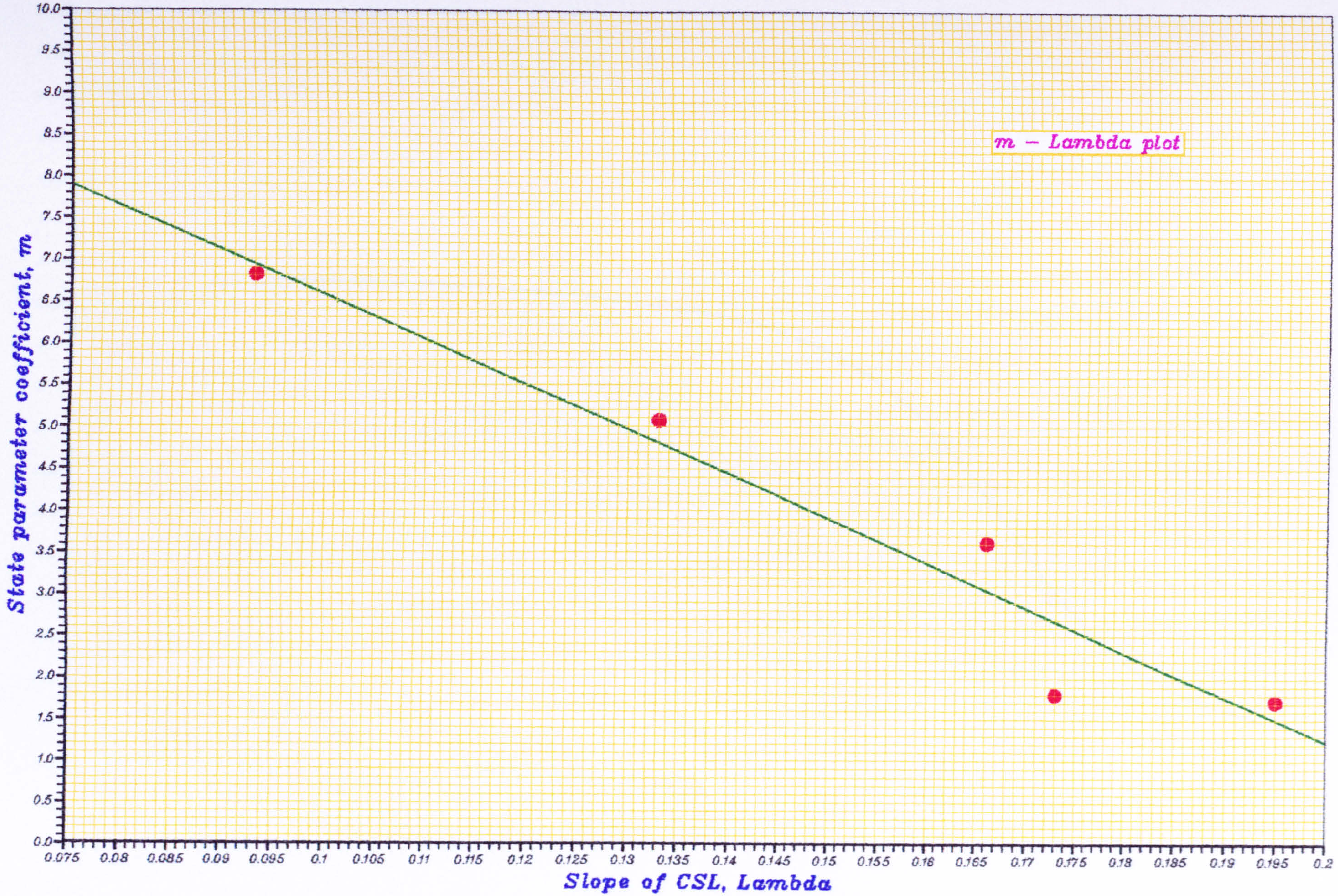

Fig. 7.28 The variation of State parameter coefficient, m with the slope of CSL

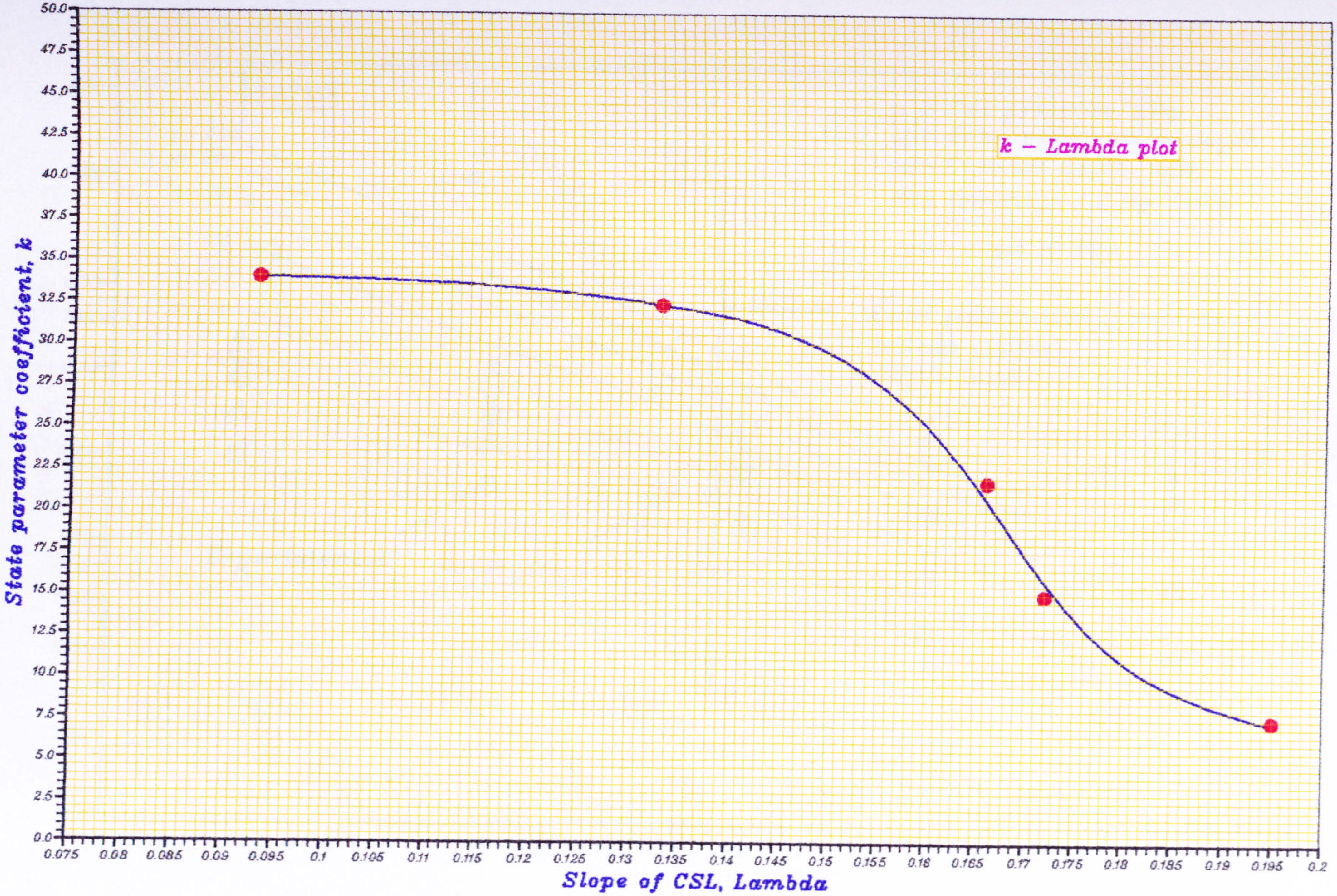

Fig. 7.29 The variation of State parameter coefficient, k with the slope of CSL

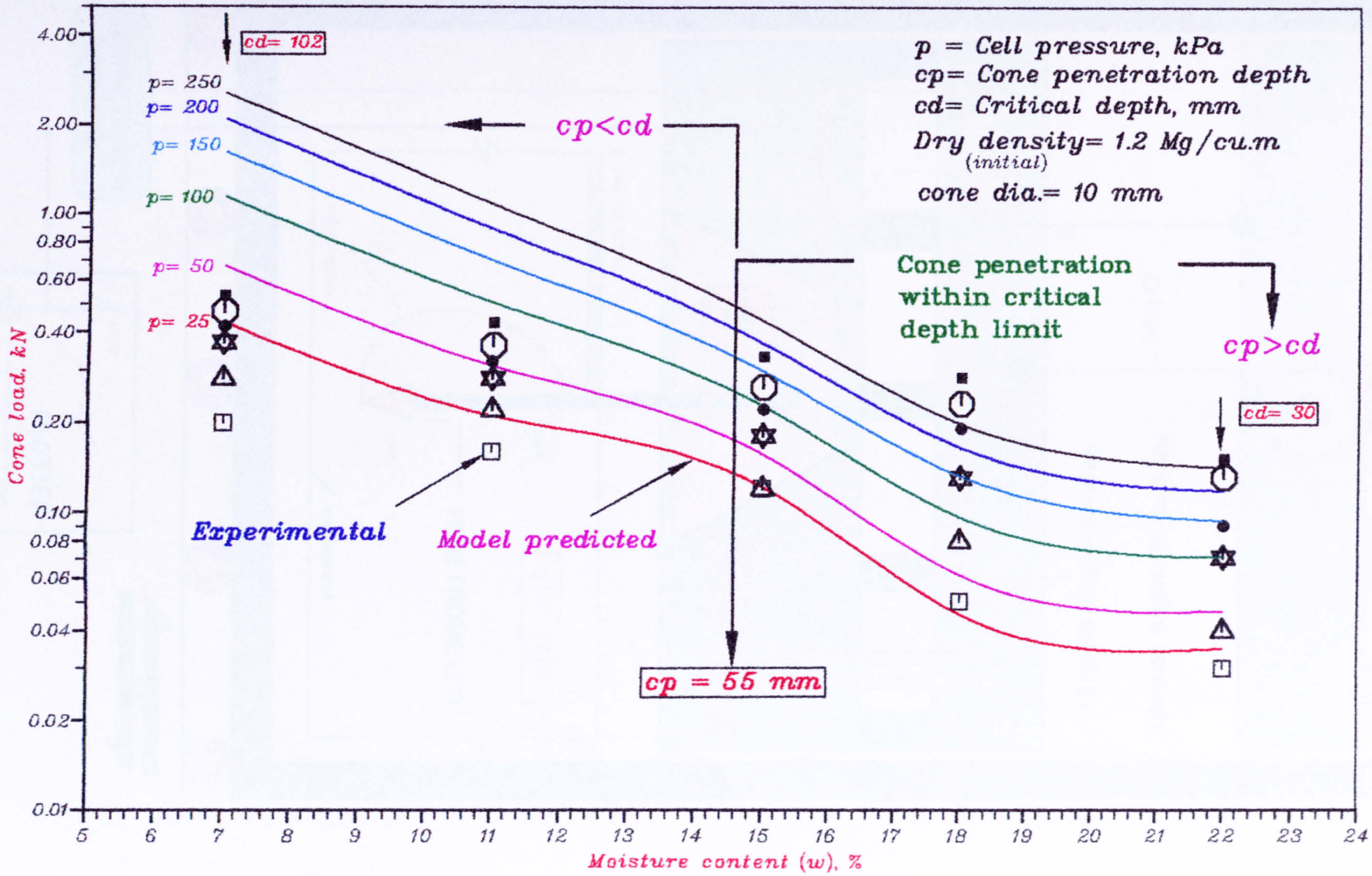

Fig. 7.30 A typical validation results of the cone penetrometer test in the Calib. chamber

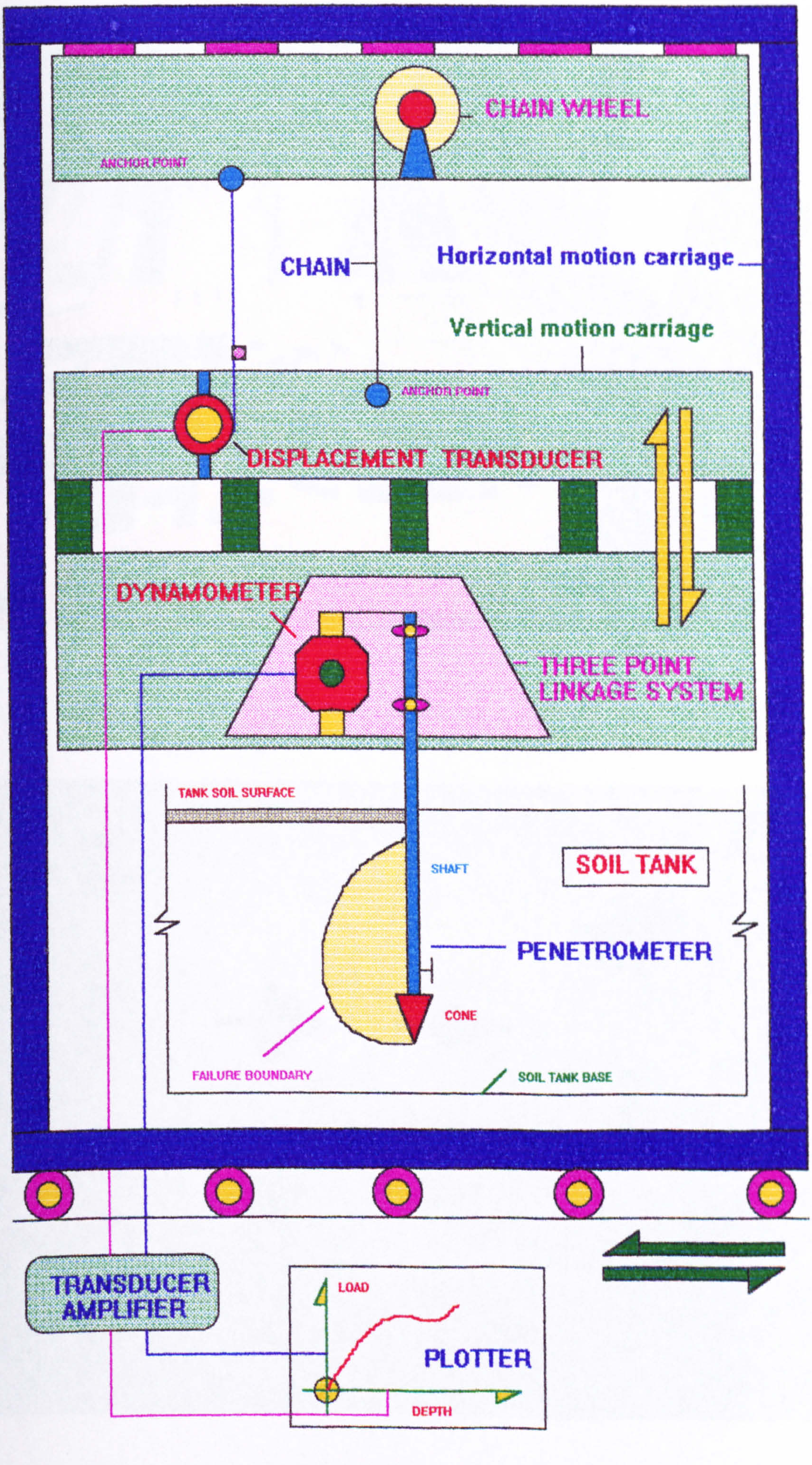

Fig. 7.31 The schematic arrangement of the experimental set-up for cone penetrometer test in the soil tank.

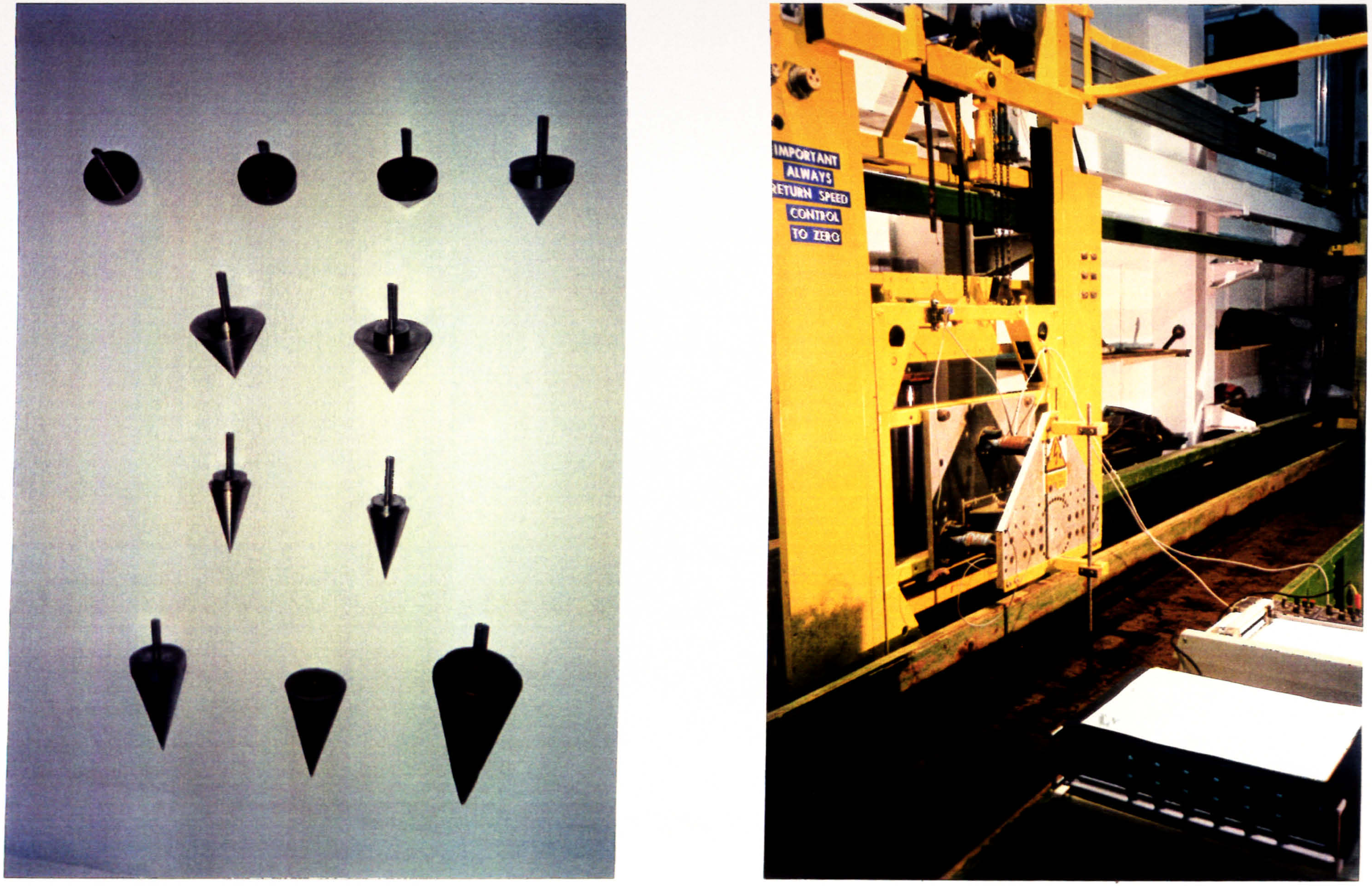

Fig. 7.32 (a) Cones with different geometry and surface roughness used in the Soil-tank experiment. (b) The complete experimental set-up of the cone penetrometer test in the Soil-tank.

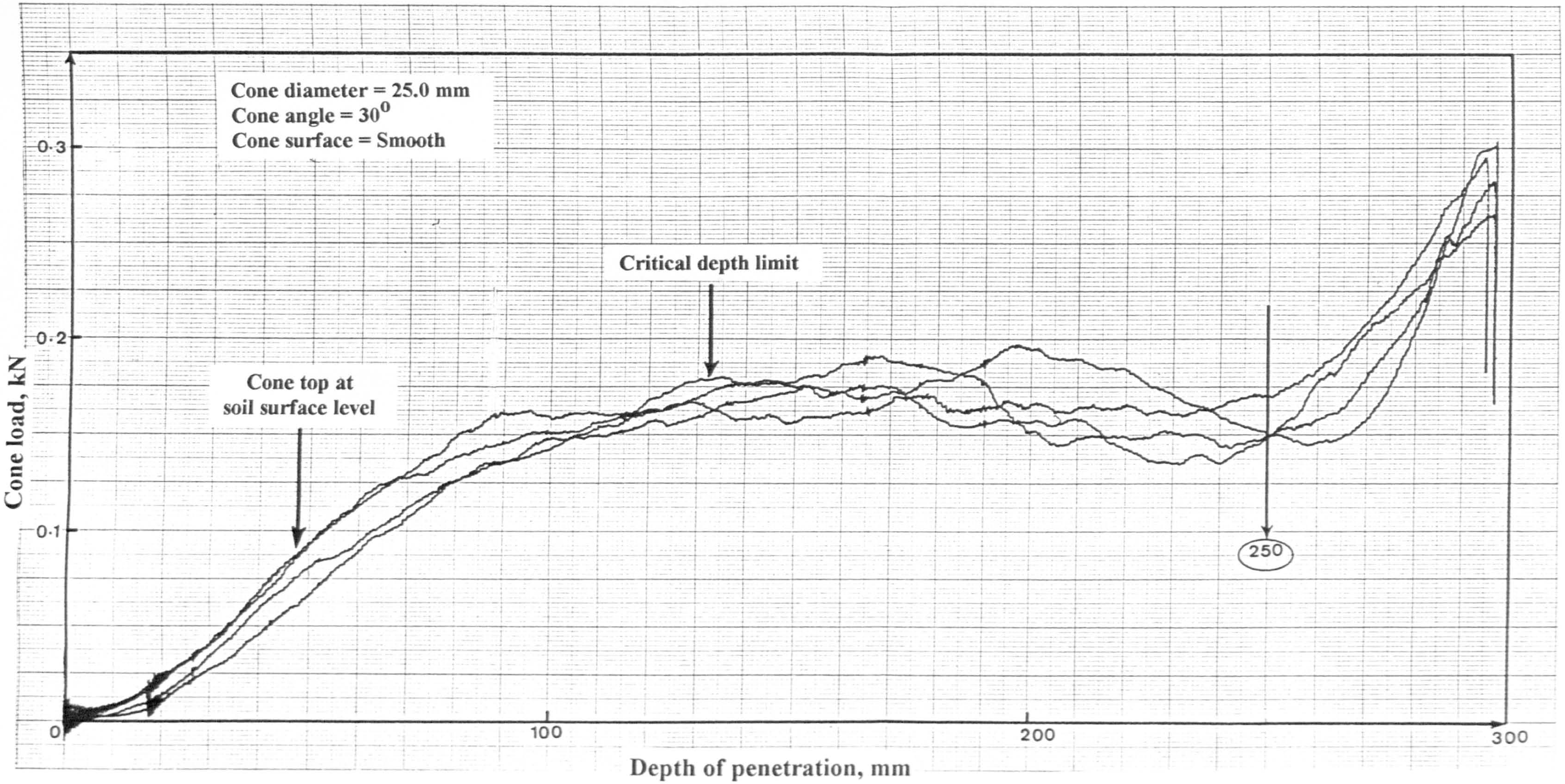

Fig. 7.33 A typical output on the X-Y plotter from the Soil-tank experiment.

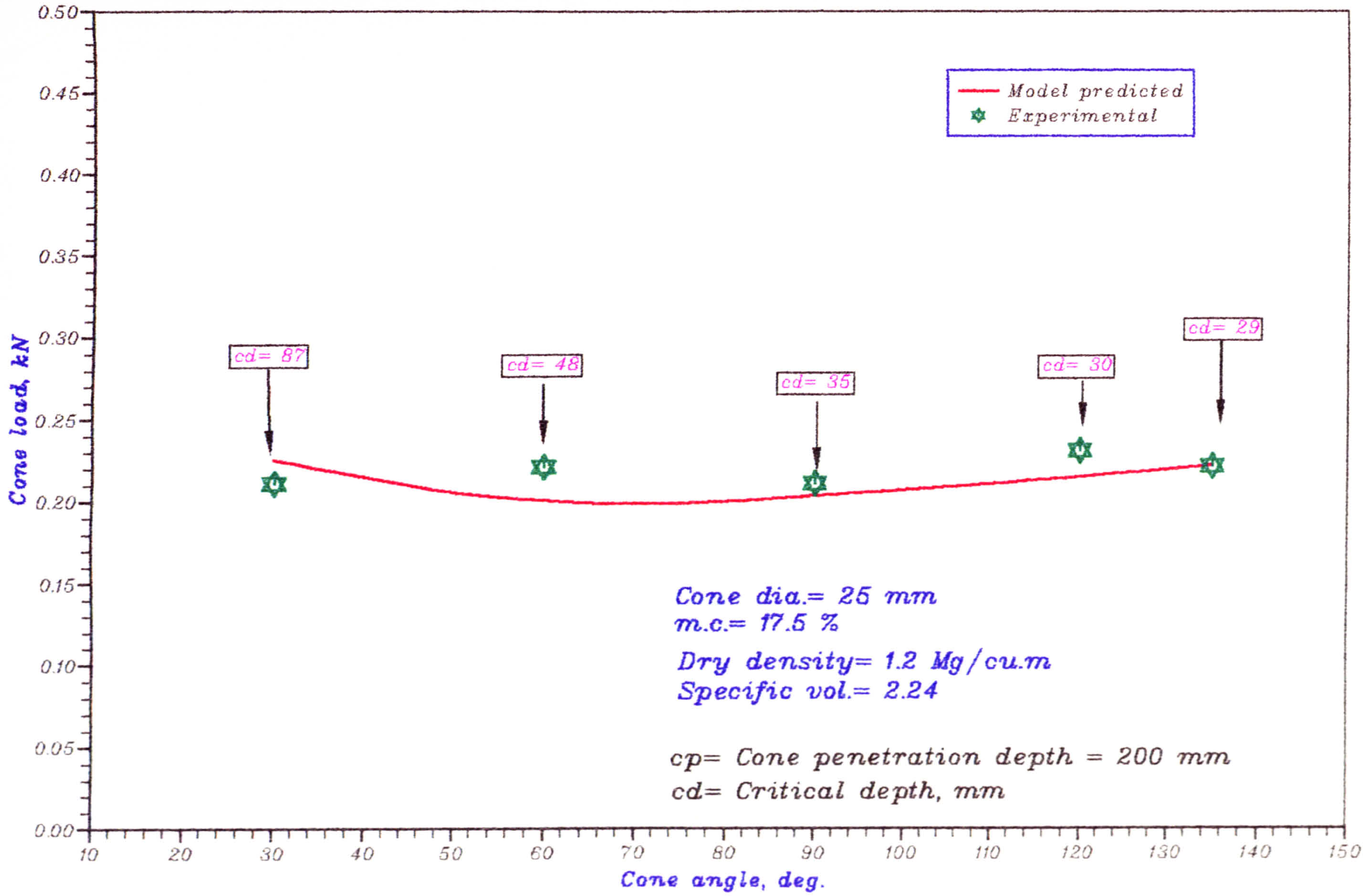

Fig. 7.34 A typical validation results of the cone penetrometer test in the Soil tank

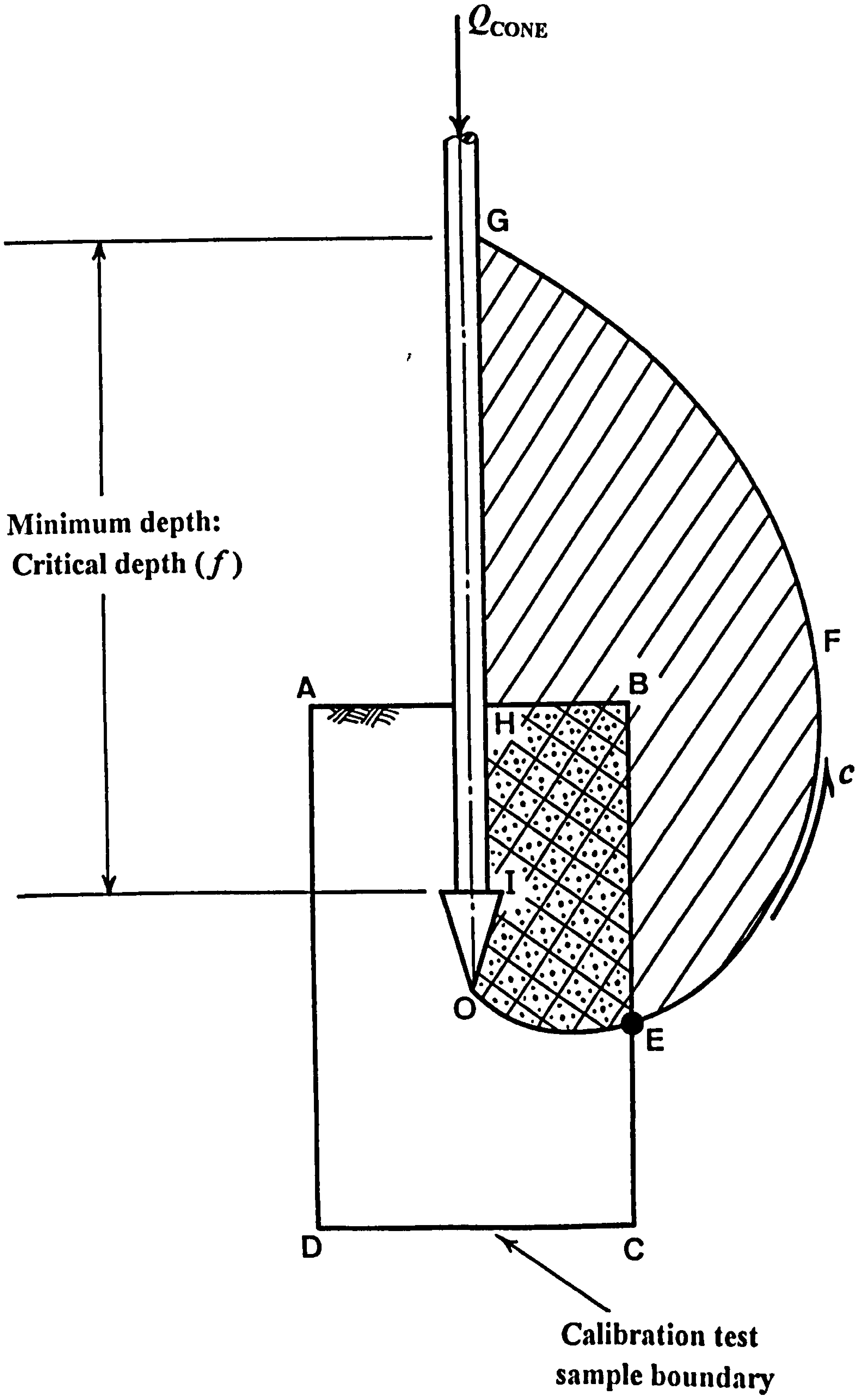

Fig. 8.1 An example of critical depth limit (f) in validation of the model for triaxial calibration chamber.

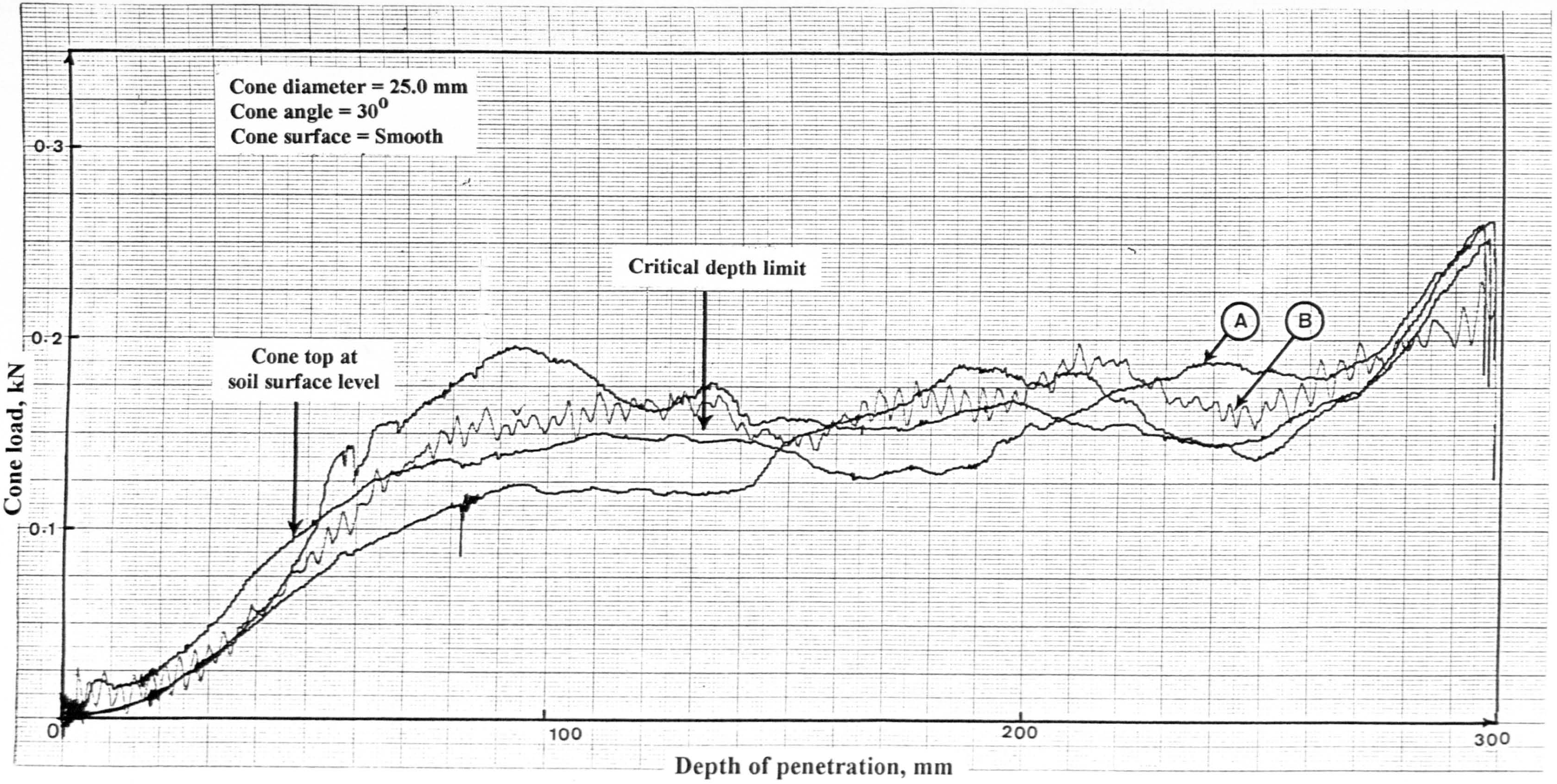

Fig. 8.2 A typical output on the X-Y plotter from the Soil-tank experiment showing the effect of penetration rate on penetration load.

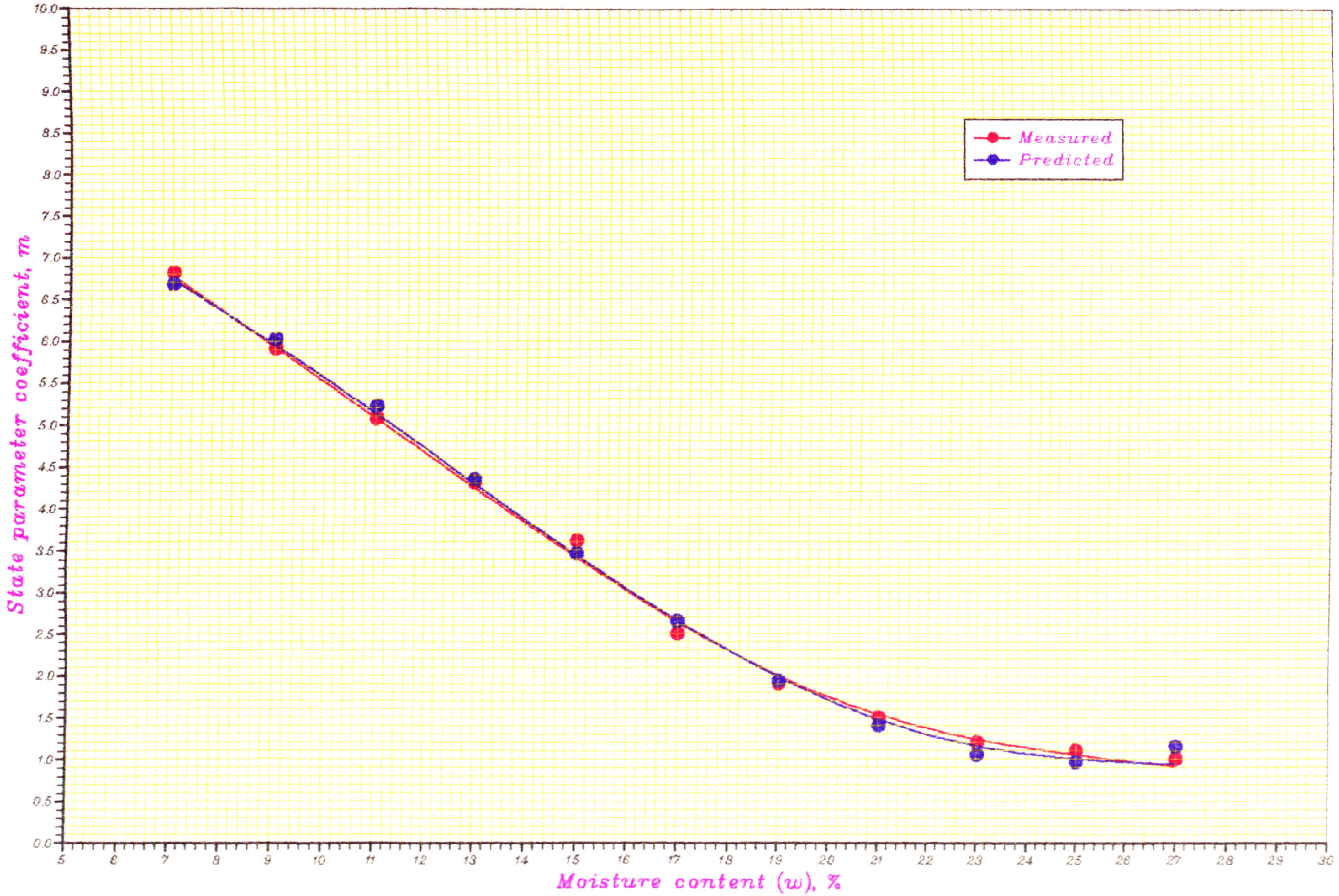

Fig. 9.1 Characterization of State parameter coefficient, m as a function of m.c.

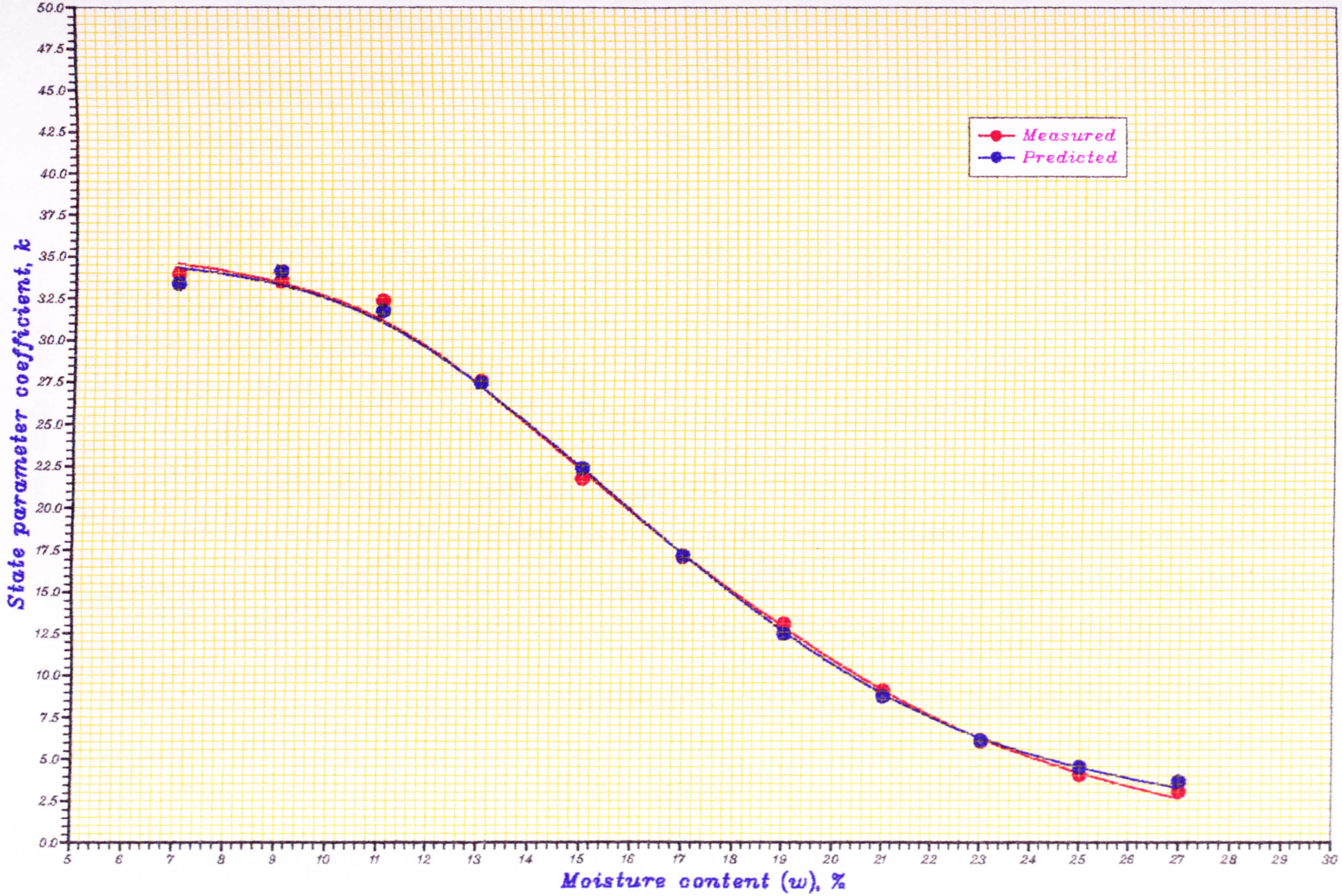

Fig. 9.2 Characterization of State parameter coefficient, k as a function of m.c.

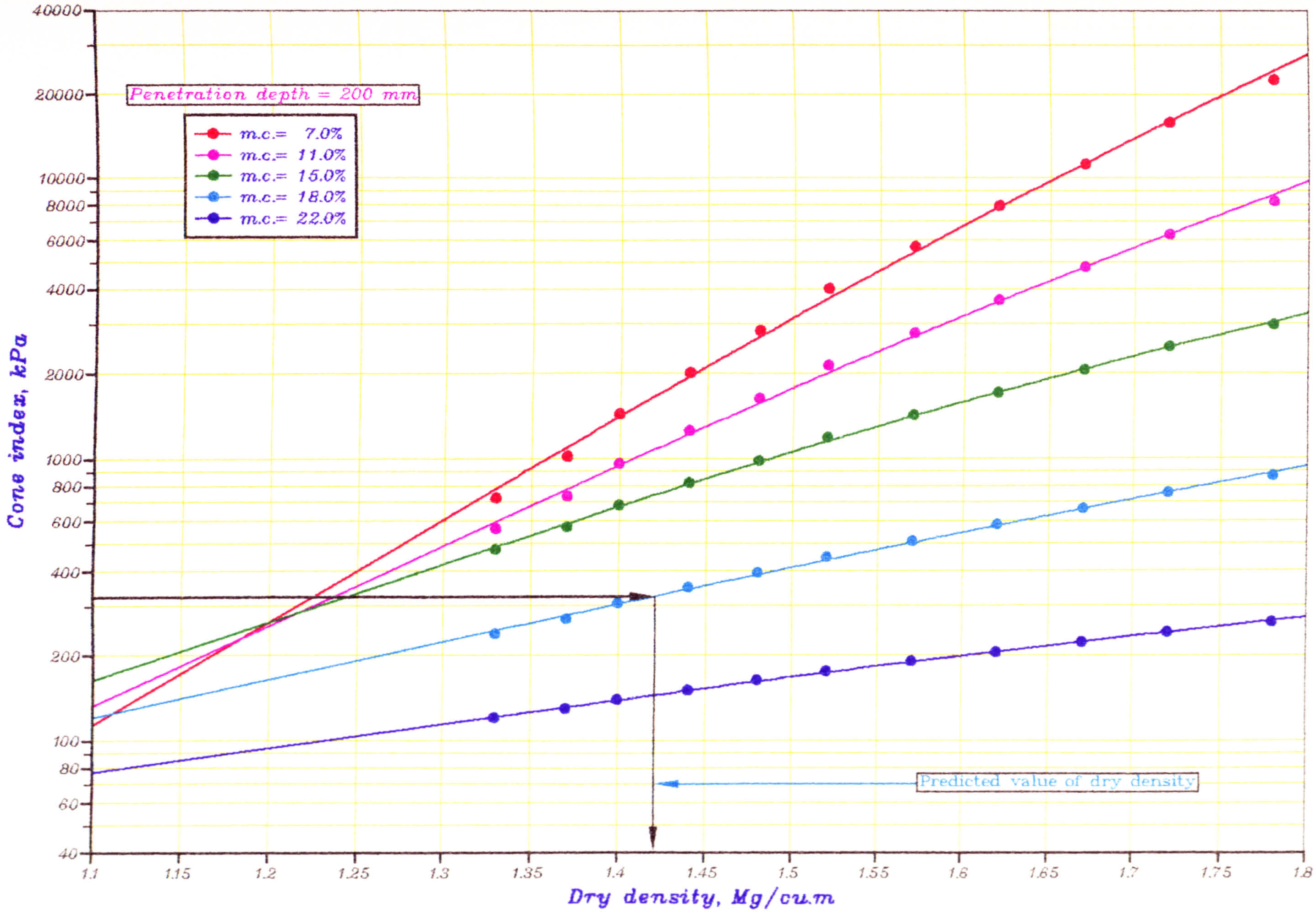

Fig. 9.3 Prediction of Cone index against Dry density at different m.c.

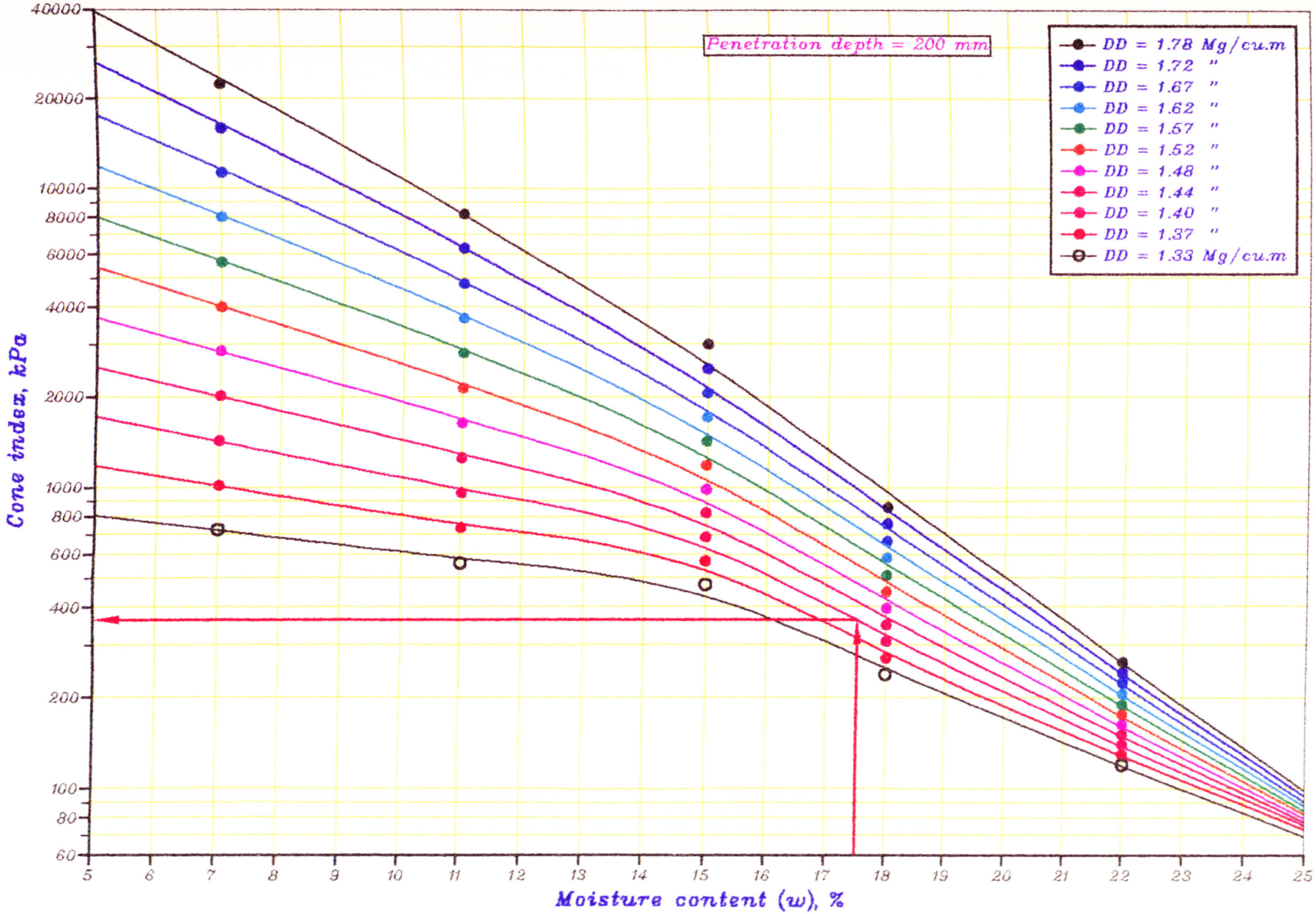

Fig. 9.4 Prediction of Cone index against Moisture content at different dry densities

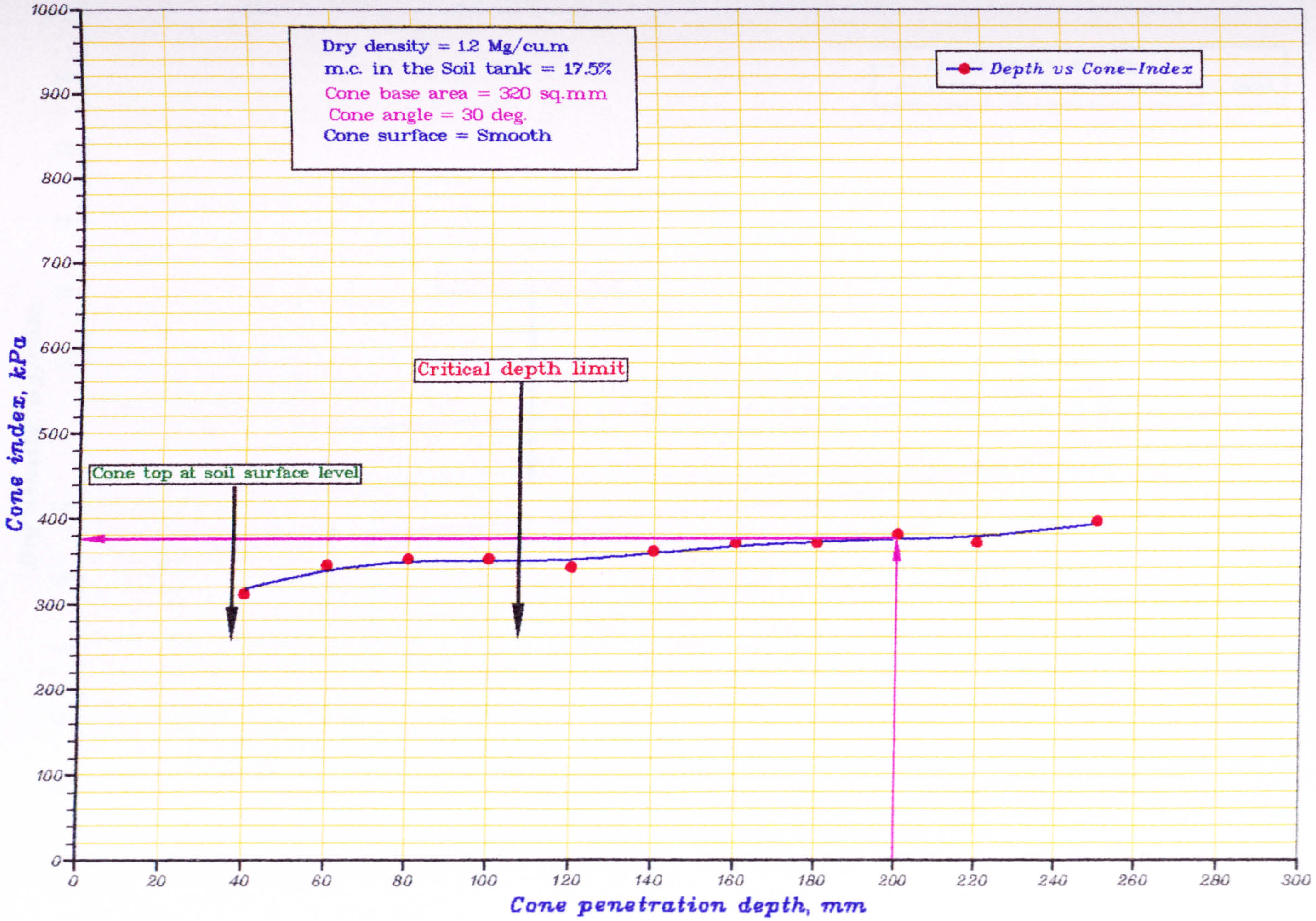

Fig. 9.5 Conversion of cone load to cone index at different depths for a 30 deg. cone

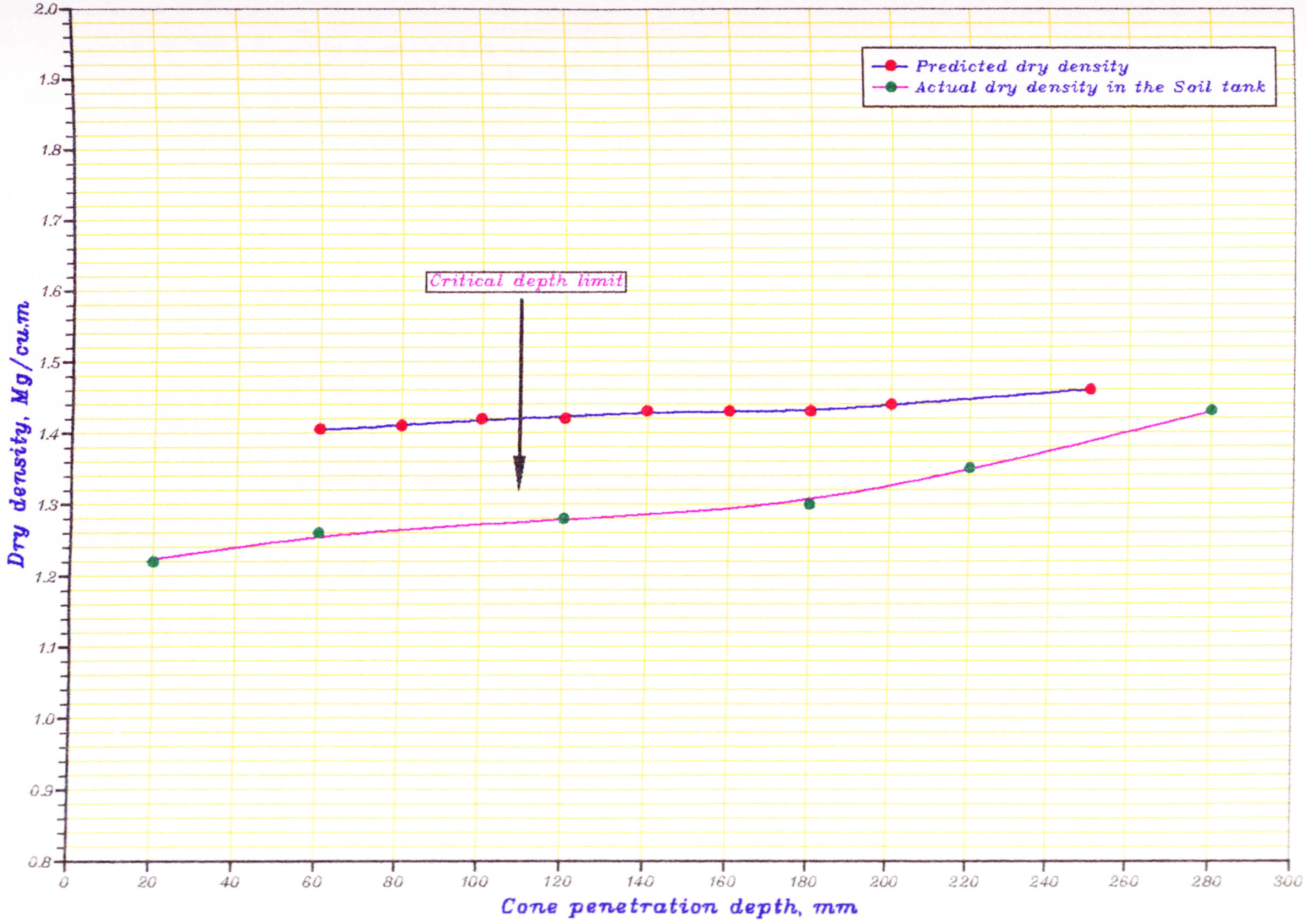

Fig. 9.6 Predicted values of dry density at different depths (using 30 deg. cone)

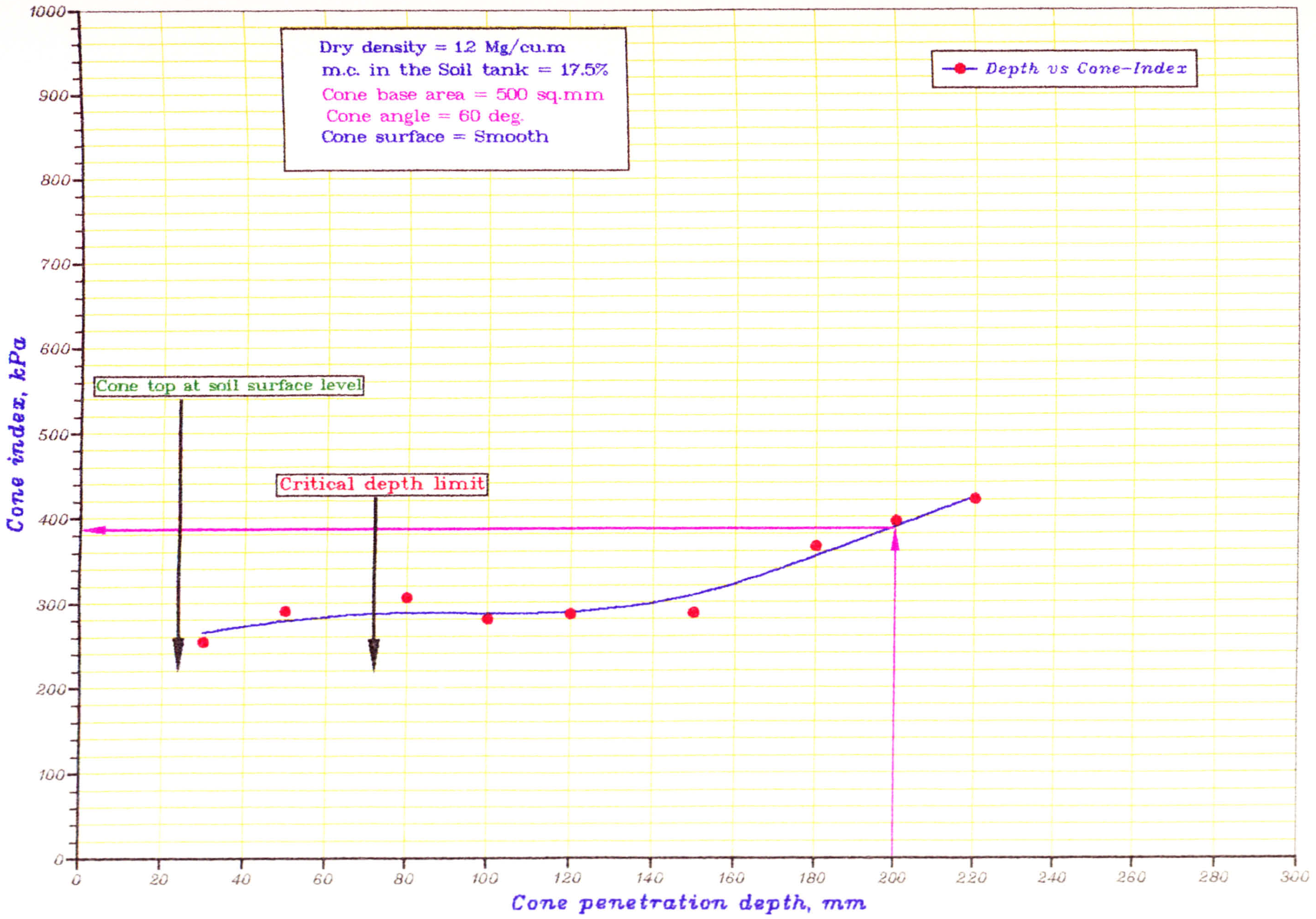

Fig. 9.7 Conversion of cone load to cone index at different depths for a 60 deg. cone

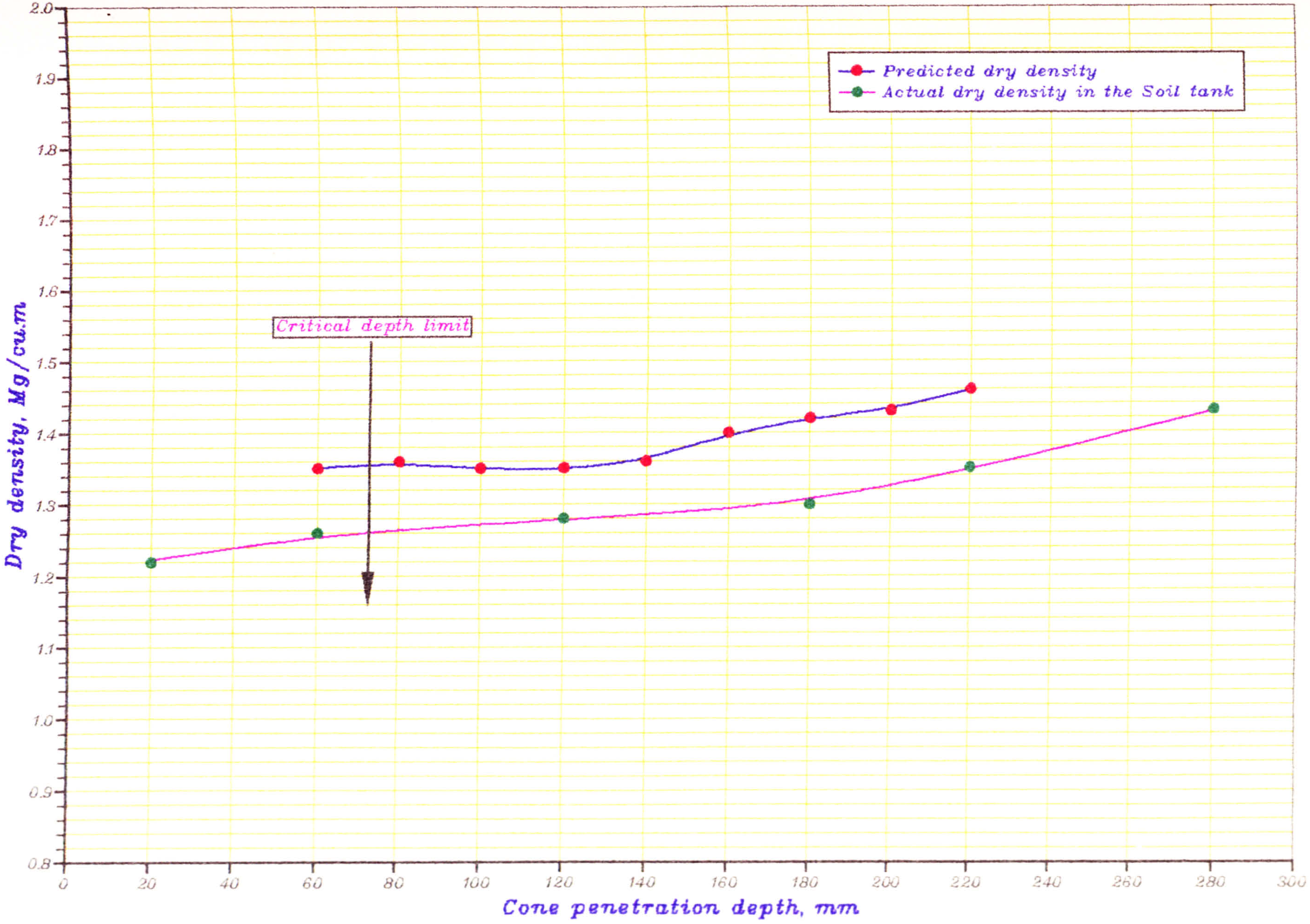

Fig. 9.8 Predicted values of dry density at different depths (using 60 deg. cone)

Table -3.1 Soil properties

Soil type	Sandy loam	Clay loam	clay
Soil series	Darvel[a]	Winton[a]	Evesham[b]
Sample depth, mm	0 -150	0 -200	0 -200
Liquid limit, g/kg	290	400	600
Plastic limit, g/kg	240	300	390
Cone penetrometer plastic limit[c], g/kg	170	260	350
Organic matter (H_2O_2), g/kg	30	31	41
Sand (2.0 - 0.06 mm), g/kg	645	375	184
Silt (0.06 - 0.002 mm), g/kg	259	382	212
Clay (<0.002 mm), g/kg	96	243	604

[a]Ragg & Futty (1967), [b]Palmer (1982). [c]Campbell (1976).

Table -3.2 Soil parameters

Soil series	w, %	N	λ_N	Γ	λ	M	κ	h^e
Evesham clay	24.5	3.752	0.275	3.812	0.308	1.700	0.000	0.225
	28.0	4.063	0.325	3.973	0.333	1.710	0.000	0.182
	31.5	4.200	0.360	4.063	0.363	1.500	0.000	0.150
	35.0	4.250	0.375	4.125	0.387	1.180	0.000	0.120
	38.5	4.250	0.375	4.162	0.416	0.790	0.000	0.100
Winton clay loam	13.0	2.750	0.175	2.688	0.174	1.710	0.000	0.975
	15.6	2.750	0.184	2.690	0.189	1.680	0.000	0.925
	18.2	2.750	0.199	2.750	0.214	1.550	0.000	0.880
	20.8	2.760	0.210	2.760	0.234	1.150	0.000	0.820
	23.4	2.760	0.225	2.770	0.260	0.780	0.000	0.700
Darvel sandy loam	8.5	2.375	0.116	2.375	0.130	1.420	0.000	0.620
	10.2	2.376	0.120	2.375	0.132	1.420	0.000	0.600
	11.9	2.382	0.124	2.380	0.136	1.401	0.000	0.600
	13.6	2.392	0.124	2.390	0.138	1.362	0.000	0.600
	15.3	2.382	0.116	2.380	0.136	1.291	0.000	0.580

(after O'sullivan *et al.*, 1994), [e]Hatibu (1987)

Table- 7.1 Typical output of PROGRAMME-4

```
SAMPLE INFORMATION:

    sample height    sample dia    sample mass     water content
         mm          mm                gms                %
        81.0          38.0            118.0               7.0


ISOTROPIC   COMPRESSION:

    ------------------------------------------------------------------
    sph.press          sp.vol          VCC            VCX        Net vol.ch.
    ------------------------------------------------------------------
        0.00            2.23           0.00           0.00           0.00
       25.00            2.19          -5.00           3.42          -1.58
       50.00            2.13         -10.50           6.33          -4.17
      100.00            2.07         -16.75          10.00          -6.75
      150.00            2.00         -22.25          12.83          -9.42
      200.00            1.93         -27.33          15.08         -12.25
      250.00            1.89         -31.74          17.50         -14.24
      200.00            1.90         -29.44          15.66         -13.78
      150.00            1.90         -26.94          13.33         -13.61
      100.00            1.92         -23.61          10.66         -12.95
       50.00            1.88         -21.36           6.66         -14.70
       25.00            1.87         -18.36           3.50         -14.86
    ------------------------------------------------------------------


  TRIAXIAL   COMPRESSION:

  --------------------------------------------------------------------
  sigma3    sigma1    C.cir.      VCS     sp.vol    sph.press    dev.str.
  --------------------------------------------------------------------
   25.00    115.64     70.32     2.00      1.92       55.21       90.64
   50.00    275.40    162.70     1.50      1.91      125.13      225.40
  100.00    353.75    226.87      .50      1.93      184.58      253.75
  150.00    481.47    315.74    -1.50      1.87      260.49      331.47
  200.00    636.63    418.31    -3.50      1.81      345.54      436.63
  250.00    748.35    499.17    -7.00      1.72      416.12      498.35
  --------------------------------------------------------------------
```

Note: Details of the abbreviated headings are given in the Programme

Table- 7.2 Typical output of PROGRAMME-5

```
SAMPLE INFORMATION:

   sample height     sample dia     sample mass      water content
        mm               mm             gms                %
      185.0            100.0          2120.0              22.0


ISOTROPIC COMPRESSION:

   --------------------------------------------------------------
   sph.press        sp.vol       VCC            VCX       Net vol.ch.
   --------------------------------------------------------------
      0.00           2.24          0.00          0.00          0.00
     25.00           2.21        -25.00          3.42        -21.58
     50.00           2.13        -78.75          6.33        -72.42
    100.00           2.00       -163.75         10.00       -153.75
    150.00           1.87       -252.50         12.83       -239.67
    200.00           1.77       -320.75         15.08       -305.67
    250.00           1.74       -340.00         17.50       -322.50
    200.00           1.75       -335.00         15.66       -319.34
    150.00           1.75       -330.87         13.33       -317.54
    100.00           1.76       -321.62         10.66       -310.96
     50.00           1.77       -310.50          6.66       -303.84
     25.00           1.78       -302.00          3.50       -298.50
   --------------------------------------------------------------
```

Note: Details of the abbreviated headings are given in the Programme

Table- 7.3 Typical output of the PROGRAMME-6

```
     DIAC = 10.0 mm, ACONE ANGLE = 30.0 deg., DIAS = 5.0 mm

 Cell pressure =    25.00 kPa
-------------------------------------------------------------------
  m.c      Phi       C       Gamma    F, mm    Ng      Nca      Nq        Qcone
-------------------------------------------------------------------
  7.0    27.22    11.00    14.87   101.04    .506 31.586 17.173     .43518
 11.0    21.43    11.25    16.18    67.37   1.717 16.696  6.859     .20182
 15.0    15.86    17.50    16.82    46.92   1.131  9.799  2.849     .13552
 18.0     9.93     7.50    17.86    32.57    .548  6.084  1.074     .04074
 22.0     8.88     7.00    18.01    30.57    .472  5.650   .895     .03481
-------------------------------------------------------------------

 Cell pressure =    50.00 kPa
-------------------------------------------------------------------
  m.c      Phi       C       Gamma    F, mm    Ng      Nca      Nq        Qcone
-------------------------------------------------------------------
  7.0    27.22    11.00    14.93   101.04    .506 31.586 17.173     .67134
 11.0    21.43    11.25    16.27    67.37   1.717 16.696  6.859     .29615
 15.0    15.86    17.50    16.89    46.92   1.131  9.799  2.849     .17470
 18.0     9.93     7.50    17.97    32.57    .548  6.084  1.074     .05551
 22.0     8.88     7.00    18.09    30.57    .472  5.650   .895     .04712
-------------------------------------------------------------------
 Cell pressure =   100.00 kPa
-------------------------------------------------------------------
  m.c      Phi       C       Gamma    F, mm    Ng      Nca      Nq        Qcone
-------------------------------------------------------------------
  7.0    27.22    11.00    14.97   101.04    .506 31.586 17.173    1.14362
 11.0    21.43    11.25    16.33    67.37   1.717 16.696  6.859     .48479
 15.0    15.86    17.50    16.95    46.92   1.131  9.799  2.849     .25305
 18.0     9.93     7.50    18.05    32.57    .548  6.084  1.074     .08505
 22.0     8.88     7.00    18.21    30.57    .472  5.650   .895     .07174
-------------------------------------------------------------------
 Cell pressure =   150.00 kPa
-------------------------------------------------------------------
  m.c      Phi       C       Gamma    F, mm    Ng      Nca      Nq        Qcone
-------------------------------------------------------------------
  7.0    27.22    11.00    15.00   101.04    .506 31.586 17.173    1.61589
 11.0    21.43    11.25    16.36    67.37   1.717 16.696  6.859     .67342
 15.0    15.86    17.50    17.01    46.92   1.131  9.799  2.849     .33141
 18.0     9.93     7.50    18.13    32.57    .548  6.084  1.074     .11459
 22.0     8.88     7.00    18.32    30.57    .472  5.650   .895     .09636
-------------------------------------------------------------------
 Cell pressure =   200.00 kPa
-------------------------------------------------------------------
  m.c      Phi       C       Gamma    F, mm    Ng      Nca      Nq        Qcone
-------------------------------------------------------------------
  7.0    27.22    11.00    15.04   101.04    .506 31.586 17.173    2.08817
 11.0    21.43    11.25    16.40    67.37   1.717 16.696  6.859     .86205
 15.0    15.86    17.50    17.05    46.92   1.131  9.799  2.849     .40976
 18.0     9.93     7.50    18.17    32.57    .548  6.084  1.074     .14412
 22.0     8.88     7.00    18.35    30.57    .472  5.650   .895     .12098
-------------------------------------------------------------------
 Cell pressure =   250.00 kPa
-------------------------------------------------------------------
  m.c      Phi       C       Gamma    F, mm    Ng      Nca      Nq        Qcone
-------------------------------------------------------------------
  7.0    27.22    11.00    15.05   101.04    .506 31.586 17.173    2.56043
 11.0    21.43    11.25    16.41    67.37   1.717 16.696  6.859    1.05068
 15.0    15.86    17.50    17.11    46.92   1.131  9.799  2.849     .48812
 18.0     9.93     7.50    18.22    32.57    .548  6.084  1.074     .17366
 22.0     8.88     7.00    18.40    30.57    .472  5.650   .895     .14560
-------------------------------------------------------------------
```

Table- 7.4 Typical output of PROGRAMME-7

```
      DIAS  =  16.00 mm

   WC,%= 17.50  PHI,deg.= 11.00  C,kN/sq.m= 11.00  GAMMA,kN/cu.m= 16.28
   ---------------------------------------------------------------------
   Acone,deg. Dcone,mm  Coeff.  F, mm      Ng      Nca       Nq    Qcone,kN
   ---------------------------------------------------------------------
     30.00      20.00    .75    66.02     .368    3.789     .836      .127
     30.00      20.00   1.00    71.13     .412    4.368     .949      .146
     30.00      25.00    .75    86.86     .464    4.986    1.100      .220
     30.00      27.00    .75    93.81     .493    5.385    1.188      .257
     30.00      38.00   1.00   142.25     .700    8.736    1.897      .584
     60.00      25.00    .75    47.31     .451    4.413     .989      .195
     60.00      33.00    .75    62.45     .577    5.825    1.305      .340
     60.00      33.00   1.00    67.29     .617    6.380    1.413      .372
     90.00      25.00    .75    35.20     .467    4.480    1.002      .198
    120.00      25.00    .75    30.24     .493    4.727    1.050      .209
    135.00      25.00    .75    29.08     .509    4.885    1.080      .216
   ---------------------------------------------------------------------
```

Table - 9.1 Typical output of the PROGRAMME-8

```
1. Analysis for polynomial coefficients (for k):

 --------------------------------------------------
   X       Y(actual)   Y(theo.)  deviation  % deviation
 --------------------------------------------------
  7.0       33.95      33.3538     .5962     1.7560
  9.0       33.50      34.0962    -.5962    -1.7796
 11.0       32.29      31.6938     .5962     1.8463
 13.0       27.50      27.3993     .1007      .3661
 15.0       21.65      22.2462    -.5962    -2.7536
 17.0       17.00      17.0491    -.0491     -.2887
 19.0       13.00      12.4038     .5962     4.5859
 21.0        9.00       8.6874     .3126     3.4738
 23.0        6.00       6.0576    -.0576     -.9608
 25.0        4.00       4.4538    -.4538   -11.3459
 27.0        3.00       3.5962    -.5962   -19.8721
 --------------------------------------------------

          Polynomial coefficients for k
          ------------------------------
          A0 =  -17.226213
          A1 =   15.062773
          A2 =   -1.433905
          A3 =    0.048894
          A4 =   -0.000570
          ----------------
```

```
2. Analysis for polynomial coefficients (for m):

 --------------------------------------------------
   X       Y(actual)   Y(theo.)  deviation  % deviation
 --------------------------------------------------
  7.0        6.82       6.6749     .1451     2.1269
  9.0        5.90       6.0170    -.1170    -1.9823
 11.0        5.07       5.2151    -.1451    -2.8610
 13.0        4.30       4.3420    -.0420     -.9776
 15.0        3.61       3.4649     .1451     4.0181
 17.0        2.50       2.6451    -.1451    -5.8022
 19.0        1.90       1.9379    -.0379    -1.9937
 21.0        1.50       1.3932     .1068     7.1214
 23.0        1.20       1.0549     .1451    12.0879
 25.0        1.10        .9614     .1386    12.5988
 27.0        1.00       1.1451    -.1451   -14.5054
 --------------------------------------------------

          Polynomial coefficients for m
          ------------------------------
          B0 =   6.658403
          B1 =   0.378318
          B2 =  -0.067790
          B3 =   0.002117
          B4 =  -0.000015
          ---------------
```

```
*    PROGRAMME - 1
*    *****************
*    krrr.f
*
*    This  programme is used to  calculate the  value of
*    p, q and v at every point on the state surface for any
*    given set of  value of  soil parameters.
*
     SUBROUTINE PCORD (V,S,T,PT,PC,PN,QT,QC)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     T   = GAMMA - ALAM * ALOG((3.0 - H)/(AMU - H))
     PN = EXP((ANU - V)/ALAMN)
     S   = V + AKAPPA * ALOG(PN)
     PT  = EXP((T - S)/(ALAM - AKAPPA))
     PC = EXP((GAMMA - S)/(ALAM - AKAPPA))
     QT = 3.0*PT
     QC = AMU*PC
     RETURN
     END
*
     SUBROUTINE TCOS (V,S,P,Q)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     PT = EXP((T - S)/(ALAM - AKAPPA))
     Q  = 3.0*P
     RETURN
     END
*
     SUBROUTINE HVORS (V,S,P,Q)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     PC = EXP((GAMMA - S)/(ALAM - AKAPPA))
     Q   = (AMU-H)*PC + H*P
     RETURN
     END
*
     SUBROUTINE ROSCOE (V,S,P,Q)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     PC = EXP((GAMMA - S)/(ALAM - AKAPPA))
     PN = EXP((ANU - V)/ALAMN)
     Q   = SQRT((AMU*AMU*PC*PC)
    + *(1.0-((P-PC)*(P-PC)/((PN-PC)*(PN-PC)))))
     RETURN
     END
*
*     MAIN PROGRAMME
     PARAMETER (RADN = 3.14159265/180.0,  NY=50, NX=5000)
     REAL P(NY,NX), V(NY), Q(NY,NX)
*
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
```

```
*
*    Read : Soil parameters
*
 102 READ(5,'(3F10.2)') ALAM, GAMMA, AMU
 103 READ(5,'(2F10.2)') ALAMN, ANU
 104 READ(5,'(F10.2)')  AKAPPA
 105 READ(5,'(F10.2)')  H
*
    IF (H .LT. 0.0) THEN
    NROUTE = IFIX(ABS(H)+0.01)
    GO TO (102,103,104,120), NROUTE
    END IF
*
*    Write : Soil parameters
*
    WRITE(6,500)
    WRITE(6,504) ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
*
*    Format Statements
* -------------------------------------------------------------
 500 FORMAT(/' '/,9X,'Lambda',4X,'Gamma',7X,'M',
   +6X,'Lambda*n',5X,'N',9X,'k',9X,'h'/)
 502 FORMAT(/' '/,11X,'V',9X,'Pt',7X,'Pc',
   +6X,'Pn',9X,'Qt',7X,'Qc'/)
 503 FORMAT(/' '/,8X,'P',8X,'V',9X,'Q'/)
 504 FORMAT(' ',3X,7F10.3/)
 507 FORMAT(3F10.2)
* -------------------------------------------------------------
*
    DO 200 J=1,21
*
*    V(J) = REAL(J-1)*0.02 + 1.60
     V(J) = REAL(J-1)*0.02 + 1.90
     VY  = V(J)
*
    CALL PCORD (VY,SY,TY,PT,PC,PN,QT,QC)
*
    DO 201 K=1,101
    P(J,K)  = REAL(K-1)*10.0
    IF (P(J,K) .LE. PT) THEN
    PTCO  = P(J,K)
*
    CALL TCOS (VY,SY,PTCO,QTCO)
    Q(J,K)  = QTCO
    ELSE IF (P(J,K) .GT. PT.AND. P(J,K) .LE. PC) THEN
    PH      = P(J,K)
*
    CALL HVORS (VY,SY,PH,QH)
    Q(J,K)  = QH
```

```
    ELSE IF (P(J,K) .GT. PC.AND. P(J,K) .LE. PN) THEN
    PR     = P(J,K)
*
    CALL ROSCOE (VY,SY,PR,QR)
    Q(J,K) = QR
    END IF
*
 201 CONTINUE
 200 CONTINUE
*
*    Write : output values
*
    WRITE(6,503)
*
    DO 205 L  =1,21
    DO 204 M =1,101
    WRITE(6,507) P(L,M)/10.0, V(L), Q(L,M)
 204 CONTINUE
 205 CONTINUE
*
 120 STOP
     END
```

```
*    PROGRAMME - 2
*    *****************
*    kqqq.f
*
*    This programme is used to calculate the value of p against v
*    (ranging from  1.90 to 2.30  for Evesham clay and 1.60 to 2.00
*    for both  Winton clay loam  and Darvel sandy loam) firstly for
*    a set  of  value of  Eta   (0< η <M)  for  Roscoe  surface,
*    secondly Eta  (M< η <3)  for  Hvorslev surface, thirdly Eta
*    (η =3) for Tension Cut-off  surface.
*
*    Parameters for:
*              NCL =>  λN (ALAMN), N (ANU)
*              CSL =>  λ (ALAM), Γ (GAMMA), M (AMU)
*              ELL =>  κ (AKAPPA)
*
     REAL V(200), P(200,200), ALP(200,200), ETA(200)
*
*    Data for specific volume:
     DATA (V(NA), NA = 1,41)
*
* For Evesham clay
    +/2.30,
    + 2.29, 2.28, 2.27, 2.26, 2.25, 2.24, 2.23, 2.22, 2.21, 2.20,
    + 2.19, 2.18, 2.17, 2.16, 2.15, 2.14, 2.13, 2.12, 2.11, 2.10,
    + 2.09, 2.08, 2.07, 2.06, 2.05, 2.04, 2.03, 2.02, 2.01, 2.00,
    + 1.99, 1.98, 1.97, 1.96, 1.95, 1.94, 1.93, 1.92, 1.91, 1.90/
*
* For Winton clay loam and Darvel sandy loam
    +/2.00,
    + 1.99, 1.98, 1.97, 1.96, 1.95, 1.94, 1.93, 1.92, 1.91, 1.90,
    + 1.89, 1.88, 1.87, 1.86, 1.85, 1.84, 1.83, 1.82, 1.81, 1.80,
    + 1.79, 1.78, 1.77, 1.76, 1.75, 1.74, 1.73, 1.72, 1.71, 1.70,
    + 1.69, 1.68, 1.67, 1.66, 1.65, 1.64, 1.63, 1.62, 1.61, 1.60/
*
*     Data for Eta (= q/p) values:
     DATA (ETA(NB), NB = 1,17)
    +/0.000,
    + 0.200, 0.400, 0.600, 0.800, 1.000,
    + 1.200, 1.400, 1.600, 1.700, 1.800, 2.000,
    + 2.200, 2.400, 2.600, 2.800,
    + 3.000/
*
*  Read : Soil parameters:
  101 READ(5,'(3F10.2)') ALAM,GAMMA,AMU
  102 READ(5,'(2F10.2)') ALAMN,ANU
  103 READ(5,'(F10.2)')   AKAPPA
  104 READ(5,'(F10.2)')   H
```

```
*
      IF (H. LT. 0.0) THEN
      NROUTE = IFIX(ABS(H)+0.01)
      GO TO (101,102,103,120), NROUTE
      END IF
*
*     Format Statements
* ---------------------------------------------------------------------
  502 FORMAT(' ',7F10.3)
  503 FORMAT(' ',F10.3)
  505 FORMAT(' ',3F10.2)
  506 FORMAT(/' '/,9X,'Va',7X,'Pa',6X,'Log(Pa)'/)
  507 FORMAT(/' '/,6X,'Eta=')
  508 FORMAT(/' '/,7X,'Lambda',3X,'Gamma',
     +8X,'M',5X,'Lambda*n',5X,'N',9X,'k',9X,'h'/)
  509 FORMAT(/' '/,3X,'Roscoe surface')
  510 FORMAT(/' '/,3X,'Hvorslev surface')
  511 FORMAT(/' '/,3X,'Normal Consolidation Line')
  512 FORMAT(/' '/,3X,'Critical State Line')
  513 FORMAT(/' '/,3X,'Tension Cut-off')
  514 FORMAT(' '/,9X,17F7.1,/)
  515 FORMAT(' ',F6.2,2X,17F7.1)
  516 FORMAT(' '/,4X,'v',6X,'c1',5X,'c2',5X,'c3',5X,'c4',5X,'c5',
     +5X,'c6',5X,'c7',5X,'c8',5X,'c9',4X,'c10',4X,'c11',4X,'c12',
     +4X,'c13',4X,'c14',4X,'c15',4X,'c16',4X,'c17')
* ---------------------------------------------------------------------
*
*     WRITE(6,508)
*     WRITE(6,502) ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
      WRITE(6,516)
*
      DO 602 NA = 1,41
      VA = V(NA)
      DO 601 NB = 1,17
*
      PN = EXP((ANU - VA)/ALAMN)
      S   = VA + AKAPPA*ALOG(PN)
*
      IF (ETA(NB) .LT. AMU) THEN
      GO TO 301
      ELSE IF (ETA(NB) .GT. AMU .AND. ETA(NB) .LE. 3.0) THEN
      GO TO 302
      END IF
* ------------------------------- : Calculations for Roscoe surface
*     Roscoe surface
*     (0.0 <= η <= M)
*
  301 PC = EXP((GAMMA - S)/(ALAM - AKAPPA))
      IF (ETA(NB) .LT. 1.0E-06) THEN
```

```
      PA = PN
      GO TO 105
      END IF
*
      F   = AMU*PC/ETA(NB)
      A   = (PN - PC)
      GG = F*F/(A*A)
      C1  = 1.0 + GG
      C2  = 2.0*PC*GG
      C3  = F*F - GG*PC*PC
      C4  = SQRT(C2*C2 + 4.0*C1*C3)
      PA  = (C2 + C4)/(2.0*C1)
  105 P(NA,NB)  = PA
      ALP(NA,NB)= LOG(PA)
      GO TO 601
*
* ----------------------------------- : Calculations for Hvorslev surface
*   Hvorslev surface
*   (M <= η <= 3.0)
*
  302 PCH = EXP((GAMMA - S)/(ALAM - AKAPPA))
      QCH = AMU*PCH
      Q1H  = H*PCH
      PAH  = (QCH-Q1H)/(ETA(NB)-H)
      P(NA,NB)      = PAH
      ALP(NA,NB) = LOG(PAH)
*
  601 CONTINUE
  602 CONTINUE
*
*    Write: output values
*
  107 WRITE(6,514) (ETA(NB), NB=1,17)
      DO 10 NA=1,41
      WRITE(6,515) V(NA), (P(NA,NB), NB=1,17)
   10 CONTINUE
*
  108 WRITE(6,514) (ETA(NB), NB=1,17)
      DO 20 NA=1,41
      WRITE(6,515) V(NA), (ALP(NA,NB), NB=1,17)
   20 CONTINUE
*
  120 STOP
        END
```

```
*    PROGRAMME - 3
*    ****************
*    krr.f
*
*    This  programme  is used to  calculate the  value of
*    p/pn and   q/pn (with v ranging from 1.9 to 2.3 for
*    Evesham clay and 1.6 to 2.0 for both Winton clay
*    loam and Darvel sandy loam) for any  given set of
*    value of soil parameter.
*
     SUBROUTINE PCORD (V,S,T,PT,PC,PN,QT,QC)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     T    =  GAMMA - ALAM * ALOG((3.0 - H)/(AMU - H))
     PN  = EXP((ANU - V)/ALAMN)
     S    = V + AKAPPA * ALOG(PN)
     PT   = EXP((T - S)/(ALAM - AKAPPA))
     PC  = EXP((GAMMA - S)/(ALAM - AKAPPA))
     QT  = 3.0*PT
     QC  = AMU*PC
     END
*
     SUBROUTINE TCOS (V,S,P,Q)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     PT = EXP((T - S)/(ALAM - AKAPPA))
     Q  = 3.0*P
     END
*
     SUBROUTINE HVORS (V,S,P,Q)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     PC = EXP((GAMMA - S)/(ALAM - AKAPPA))
     Q  = (AMU-H)*PC + H*P
     END
*
     SUBROUTINE ROSCOE (V,S,P,Q)
     COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
     PC  = EXP((GAMMA - S)/(ALAM - AKAPPA))
     PN  = EXP((ANU - V)/ALAMN)
     CONST = AMU*AMU*PC*PC
     Q  = SQRT(CONST*(1.0 - ((P-PC)*(P-PC)/((PN-PC)*(PN-PC)))))
     END
*
*     MAIN PROGRAMME
*
     PARAMETER (RADN = 3.14159265/180.0,  NY=50, NX=5000)
     REAL P(NY,NX), V(NY), Q(NY,NX)
     REAL PE(NY)
*
```

```
      COMMON ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
*
*     Read : Soil parameters
*
  102 READ(5,'(3F10.2)') ALAM, GAMMA, AMU
  103 READ(5,'(2F10.2)') ALAMN, ANU
  104 READ(5,'(F10.2)')  AKAPPA
  105 READ(5,'(F10.2)')  H
*
      IF (H .LT. 0.0) THEN
      NROUTE = IFIX(ABS(H)+0.01)
      GO TO (102,103,104,120), NROUTE
      END IF
*
*     Write : Supplied soil parameters
      WRITE(6,500)
      WRITE(6,504) ALAM,GAMMA,AMU,ALAMN,ANU,AKAPPA,H
*
*     Format Statements
* ------------------------------------------------------------
  500 FORMAT(/' '/,9X,'Lambda',4X,'Gamma',7X,'M',
     +6X,'Lambda*n',6X,'N',9X,'h'/)
  502 FORMAT(/' '/,11X,'V',9X,'Pt',7X,'Pc',
     +6X,'Pn',9X,'Qt',7X,'Qc'/)
  503 FORMAT(/' '/,8X,'P',8X,'V',9X,'Q'/)
  504 FORMAT(' ',2X,6F10.2)
  507 FORMAT(3F10.3)
* ------------------------------------------------------------
*
      DO 200 J=1,5
      V(J) = REAL(J-1)*0.10 + 1.9
      VY  = V(J)
      CALL PCORD (VY,SY,TY,PT,PC,PN,QT,QC)
      PE(J) = PN
*
      DO 201 K=1,101
      P(J,K)  = REAL(K-1)*PT/100.0
      PTCO  = P(J,K)
      CALL TCOS (VY,SY,PTCO,QTCO)
      Q(J,K)  = QTCO
  201 CONTINUE
*
      DO 202 K=101,200
      P(J,K) = REAL(K-100)*(PC-PT)/100.0 + PT
      PH     = P(J,K)
      CALL HVORS (VY,SY,PH,QH)
      Q(J,K) = QH
  202 CONTINUE
```

```
*
      DO 203 K=201,300
      P(J,K) = REAL(K-200)*(PN-PC)/100.0 + PC
      PR     = P(J,K)
      CALL ROSCOE (VY,SY,PR,QR)
      Q(J,K) = QR
  203 CONTINUE
*
  200 CONTINUE
*
*      Write : output values
      WRITE(6,503)
*
      DO 205 L =1,5
      DO 204 M=1,300
      WRITE(6,507) P(L,M)/PE(L), V(L), Q(L,M)/PE(L)
  204 CONTINUE
  205 CONTINUE
*
  120 STOP
      END
```

```
*    PROGRAMME - 4
*    *****************
*    ttest.f
*
*    This programme is used to calculate the value of bulk density,
*    void ratio and specific volume from triaxial test for a given
*    cell pressure. And finally arrange the values  in v-p and q-p
*    plane to find out the soil parameters
*
*  Notations:
*
*    DEVIST = Deviatoric stress due to shear, kPa
*             = SIGMA1 - SIGMA3
*    GS       = Specific gravity of soil particle
*
*    SAAREA  = Sample area, sq.mm
*    SAHT      = Sample height, mm
*    SADIA    = Sample diameter, mm
*    SAMASS = Sample mass, gms
*    WC        = Water content, gms/100gms
*
*    SAVOL   = Sample volume, cu.mm
*    BULKD   = Bulk density, kg/cm.m
*    VOIDR    = Void ratio
*    SPVOL    = Specific volume
*    VOL1       = Volume after consolidation, cc
*    VOL2       = VOL1 renamed to use when shearing, cc
*    VOLS2    = Volume after shear, cc
*    WATERD  = Density of water
*                 = 1000.0 kg/cu.m
*    SIGMA1 = Major principal stress, kPa
*    SIGMA2 = Intermediate principal stress, kPa
*               = SIGMA3 for triaxial test condition
*    SIGMA3 = Minor principal stress, kPa
*    SPHERP = Spherical pressure, kPa
*               = (1/3)*(SIGMA1 + 2.0*SIGMA3)
*    Y          = Displacement at failure of specimen, mm
*    VCX      = Volume change due to expansion of triaxial cell,cc
*    VCC      = Volume change due to consolidation of soil sample,cc
*    VCCN   = Net volume change due to consolidation of sample,cc
*              = VCC +  VCX
*    VCS      = Volume change due to shear, cc
*
*    Note: -ve sign indicates compacting
*             +ve sign indicates dilating
*
     REAL VOL2(15)
```

```
      OPEN (UNIT=5, FILE='dttest')
      OPEN (UNIT=6, FILE='rttest')
*
*     NSLU = Nos.of steps in loading and then unloading the
*          soil specimen
*
      NSLU = 12
*
      WATERD = 1000.0
      GS    = 2.68
*
*       Read: Sample information
 101 READ(5,'(2F10.2)') SAHT, SADIA
 102 READ(5,'(F10.2)')  SAMASS
 103 READ(5,'(F10.4)')  WC
*
      PI    = 3.14159265
      SAAREA = (PI/4.0)*(SADIA/1000.0)*(SADIA/1000.0)
      SAVOL  = SAAREA*(SAHT/1000.0)
*
      WRITE(6,508)
*
      WRITE(6,505) SAHT, SADIA, SAMASS, WC
*
* ======== Step 1: Soil sample normally consolidated ========
*    Spherical pressure, p= SIGMA3 with no deviatoric stress
*
      WRITE(6,509)
*
      DO 601 JJ = 1,NSLU
*
 105 READ(5,'(3F10.2)') SIGMA3,VCC,VCX
*
      VCCN    = VCC+VCX
      VOL1    = SAVOL+(VCCN/1000000.0)
      BULKD1 = (SAMASS/1000.0)/VOL1
      VOIDR1  = GS*(1.0 + WC)*(WATERD/BULKD1) - 1.0
      SPVOL1  = 1.0 + VOIDR1
*
      VOL2(JJ) = VOL1
      WRITE(6,507) SIGMA3, SPVOL1, VCC, VCX, VCCN
*
 601 CONTINUE
*
* ======== Step 2: Same soil sample subjected to shear =========
*      Spherical pressure, p= (1/3)*(SIGMA1 + 2*SIGMA3)
*
```

```
      WRITE(6,510)
*
      DO 602 KK = NSLU, (NSLU/2+1), -1
*
  110 READ(5,'(2F10.2,F10.4,F10.2)') SIGMA3,VCS,ALOAD,Y
*
      VOLS2   = VOL2(KK) + (VCS/1000000.0)
      BULKD2 = (SAMASS/1000.0)/VOLS2
      VOIDR2  = GS*(1.0 + WC)*(WATERD/BULKD2) - 1.0
      SPVOL2  = 1.0 + VOIDR2
*
      DEVIST  = ALOAD*((SAHT - Y)/1000.0)/SAVOL
      SIGMA1 = DEVIST + SIGMA3
      SPHERP = (1/3.0)*(SIGMA1 + 2.0*SIGMA3)
      CCIRCL = SIGMA3 + (DEVIST/2.0)
*
      WRITE(6,506) SIGMA3,SIGMA1,CCIRCL,VCS,SPVOL2,SPHERP,DEVIST
*
  602 CONTINUE
*
*     Format Statements
* ------------------------------------------------------------------
  502 FORMAT(' ',2F10.3)
  503 FORMAT(' ',3F14.4)
  504 FORMAT(' ',4F14.4)
  505 FORMAT(' ',4F15.4/)
  506 FORMAT(' ',5F9.2,F10.2,F10.2)
  507 FORMAT(' ',5F13.2)
  508 FORMAT(/' '/,6X,'sample height',4X,'sample dia',
     +4X,'sample mass',5X,'water content'/)
  509 FORMAT(/' '/,6X,'sph.press',7X,'sp.vol',
     +7X,'VCC',10X,'VCX',7X,'Net vol.ch.'/)
  510 FORMAT(/' '/,4X,'sigma3',3X,'sigma1',3X,'C.cir.',5X,
     +'VCS',4X,'sp.vol',3X,'sph.press',3X,'dev.str.'/)
  514 FORMAT(/' '/,6X,17F10.3,/)
  515 FORMAT(' ',F6.2,17F10.2)
* ------------------------------------------------------------------
*
  120 STOP
      END
```

```
*   PROGRAMME - 5
*   *****************
*   tt.f
*
*   This programme is used to calculate the value of bulk density,
*   void ratio and specific volume from  calibration  chamber test
*   for a given cell pressure.  And finally arrange the values  in
*   in v-p space to find out the soil parameters.
*
* Notations:
*
*   DEVIST = Deviatoric stress due to shear, kPa
*              = SIGMA1 - SIGMA3
*   GS        = Specific gravity of soil particle
*
*   SAAREA  = Sample area, sq.mm
*   SAHT      = Sample height, mm
*   SADIA    = Sample diameter, mm
*   SAMASS = Sample mass, gms
*   WC         = Water content, gms/100gms
*
*   SAVOL  = Sample volume, cu.mm
*   BULKD  = Bulk density, kg/cm.m
*   VOIDR  = Void ratio
*   SPVOL  = Specific volume
*   VOL1    = Volume after consolidation, cc
*   VOL2    = VOL1 renamed to use when shearing, cc
*   VOLS2  = Volume after shear, cc
*   WATERD = Density of water
*                 = 1000.0 kg/cu.m
*   SIGMA1  = Major principal stress, kPa
*   SIGMA2  = Intermediate principal stress, kPa
*                = SIGMA3 for triaxial test condition
*   SIGMA3  = Minor principal stress, kPa
*   SPHERP  = Spherical pressure, kPa
*                = (1/3)*(SIGMA1 + 2.0*SIGMA3)
*   Y            = Displacement at failure of specimen, mm
*   VCX       = Volume change due to expansion of triaxial cell,cc
*   VCC       = Volume change due to consolidation of soil sample,cc
*   VCCN    = Net volume change due to consolidation of sample,cc
*                = VCC +  VCX
*   VCS       = Volume change due to shear, cc
*
*   Note: -ve sign indicates compacting
*            +ve sign indicates dilating

    REAL VOL2(15)
*
```

```
      OPEN (UNIT=5, FILE='dtt')
      OPEN (UNIT=6, FILE='rtt')
*
*     NSLU = Nos.of steps in loading and then unloading the
*            soil specimen
*
      NSLU = 12
*
      WATERD = 1000.0
      GS     = 2.68
*
  101 READ(5,'(2F10.2)') SAHT, SADIA
  102 READ(5,'(F10.2)')  SAMASS
  103 READ(5,'(F10.4)')  WC
*
      PI     = 3.14159265
      SAAREA = (PI/4.0)*(SADIA/1000.0)*(SADIA/1000.0)
      SAVOL  = SAAREA*(SAHT/1000.0)
*
      WRITE(6,508)
      WRITE(6,505) SAHT, SADIA, SAMASS, WC
*
* ==========  Soil sample normally consolidated  ==========
*     Spherical pressure, p = SIGMA3 with no deviatoric stress
*
*
      WRITE(6,509)
*
      DO 601 JJ = 1,NSLU
*
  105 READ(5,'(3F10.2)') SIGMA3,VCC,VCX
*
      VCCN    = VCC+VCX
      VOL1    = SAVOL+(VCCN/1000000.0)
      BULKD1  = (SAMASS/1000.0)/VOL1
      VOIDR1  = GS*(1.0 + WC)*(WATERD/BULKD1) - 1.0
      SPVOL1  = 1.0 + VOIDR1
*
      VOL2(JJ) = VOL1
      WRITE(6,507) SIGMA3, SPVOL1, VCC, VCX, VCCN
*
  601 CONTINUE
*
*     Format Statements
* ------------------------------------------------------------
  502 FORMAT(' ',2F10.3)
  503 FORMAT(' ',3F14.4)
  504 FORMAT(' ',4F14.4)
```

```
 505 FORMAT(' ',4F15.4/)
 506 FORMAT(' ',4F10.2,2X,F10.2,2X,F10.2)
 507 FORMAT(' ',5F13.2)
*
 508 FORMAT(/' ',6X,'sample height',4X,'sample dia',
   +4X,'sample mass',5X,'water content'/)
 509 FORMAT(/' ',6X,'sph.press',7X,'sp.vol',
   +7X,'VCC',10X,'VCX',7X,'Net vol.ch.'/)
 510 FORMAT(/' ',5X,'sigma3',4X,'sigma1',6X,'VCS',
   +5X,'sp.vol',4X,'sph.press',3X,'dev.stress'/)
 514 FORMAT(/' ',6X,17F10.3,/)
 515 FORMAT(' ',F6.2,17F10.2)
* ----------------------------------------------------------------
*
 120 STOP
     END
```

```
*    PROGRAMME - 5A
*    ******************
*     ttl.f
*
*    Programme for calculating the degree of  saturation
*    initially and at different confining pressure along
*    rebound line (i.e. ELL = Elastic Loading Line)
*
*    GS     = Specific gravity of soil particle
*    SAAREA = Sample area, sq.mm
*    SAHT     = Sample height, mm
*    SADIA    = Sample diameter, mm
*    SAMASS = Sample mass, gms
*    WC         = Water content, gms/100gms
*
*    SAVOL  = Sample volume, cu.mm
*    BULKD  = Bulk density, kg/cm.m
*    VOIDR  = Void ratio
*    SPVOL  = Specific volume
*    VOL      = Volume after consolidation, cc
*    WATERD = Density of water
*                = 1000.0 kg/cu.m
*    SPP      = Confining pressure, kPa
*    VCX    = Volume change due to expansion of triaxial cell,cc
*    VCC    = Volume change due to consolidation of soil sample,cc
*    NVC    = Net volume change due to consolidation of sample,cc
*             = VCC +  VCX
*    SR       = Degree of saturation
*
*    Note: -ve sign indicates compacting
*            +ve sign indicates dilating
*
     OPEN (UNIT=5, FILE='dttl')
     OPEN (UNIT=6, FILE='rttl')
*
     WATERD = 1000.0
     GS     = 2.68
*
*      Read: Sample information
  101 READ(5,'(2F10.2)') SAHT, SADIA
  102 READ(5,'(F10.2)')  SAMASS
  103 READ(5,'(F10.4)')  WC
*
     PI     = 3.14159265
     SAAREA = (PI/4.0)*(SADIA/1000.0)*(SADIA/1000.0)
     SAVOL  = SAAREA*(SAHT/1000.0)
*
     WRITE(6,508)
```

```
*
   WRITE(6,505) SAHT, SADIA, SAMASS, WC
*
* ==========  Soil sample normally consolidated  ==========
*  Spherical pressure, p= SIGMA3 with no deviatoric stress
*
   WRITE(6,509)
*
   DO 601 KK = 1,7
 105 READ(5,'(2F10.2)') SPP, NVC
*
   VOL     = SAVOL+(NVC/1000000.0)
   BULKD  = (SAMASS/1000.0)/VOL
   VOIDR  = GS*(1.0 + WC)*(WATERD/BULKD) - 1.0
*
   SR1   = WC*GS/VOIDR
   SR     = 100.0*SR1
   WRITE(6,502) SPP, SR
*
 601 CONTINUE
*
*    Format Statements
* ------------------------------------------------------------
 502 FORMAT(' ',2F14.2)
 505 FORMAT(' ',4F15.4/)
 507 FORMAT(' ',5F13.2)
 508 FORMAT(/' '/,6X,'sample height',4X,'sample dia',
   +4X,'sample mass',5X,'water content'/)
 509 FORMAT(/' '/,7X,'Conf.press.',8X,'Sr'/)
 510 FORMAT(/' '/,5X,'sigma3',4X,'sigma1',6X,'VCS',
   +5X,'sp.vol',4X,'sph.press',3X,'dev.stress'/)
* ------------------------------------------------------------
*
 120 STOP
     END
```

```
*    PROGRAMME - 5B
*    ******************
*     tts.f
*
*    This  programme is used  to calculate the  value  ln(Q) from
*    calibration chamber test data and finally arrange the values
*    in ln(Q) - Psi space to find out the parameters m and k.
*
*  Notations:
*
*    CDIA     = Cone diameter, mm
*    CAMM   = Cone area, sq.mm
*    CAREA  = Cone area, sq.m
*    FC         = Force at cone base lavel, kN
*
     REAL P(10)
     REAL Q(10)
     REAL QL(10)
*
     OPEN (UNIT=5, FILE='dtts')
     OPEN (UNIT=6, FILE='rtts')
*
*     NSL  = Nos. of stress levels at which the specimen is
*                 subjected to cone penetration
      NSL  = 6
*
  100 READ(5,'(F10.2)') WC
        WRITE(6,506) WC
  101 READ(5,'(F10.2)') CDIA
*
     PI    = 3.14159265
     CAMM   = (PI/4.0)*(CDIA*CDIA)
     CAREA   = (PI/4.0)*(CDIA/1000.0)*(CDIA/1000.0)
*
     WRITE(6,508)
     WRITE(6,505) CDIA, CAMM
     WRITE(6,509)
*
     DO 601 JJ = 1,NSL
  105 READ(5,'(F10.2,F10.4)') CP,FC
*
     P(JJ)    = CP
     QC       = FC/CAREA
     Q(JJ)   = (QC - CP)/CP
     QL(JJ) = ALOG(Q(JJ))
  601 CONTINUE
*
*    Write: output values
```

```
      DO 602 KK = 1,NSL
      WRITE(6,507) P(KK), QL(KK)
*
  602 CONTINUE
*
*    Format Statements
* -----------------------------------------------------------------
  505 FORMAT(' ',F15.2,2X,F15.4/)
  506 FORMAT(/' ',5X,'Moisture content,% =',2X,F5.2)
  507 FORMAT(' ',F15.2,2X,F15.4)
*
  508 FORMAT(/' '/,6X,'cone dia,mm',4X,'cone area,sq.mm')
  509 FORMAT(/' '/,6X,'conf.press.,kPa',4X,'ln(Q), kPa')
* -----------------------------------------------------------------
*
  120 STOP
      END
```

```
*    PROGRAMME - 6
*    *****************
*    ccam.f
*
*    Analysis of forces on CONE  PENETROMETER
*    C            = Cohesion, kN/sq.m
*    APHI         = Angle of internal friction, deg.
*    GAMMA  = Soil unit weight, kN/cu.m
*    ATHEC     = Half of cone angle, deg.
*    ACONE    = Cone angle, deg.
*    DIAC       = Cone diameter, m
*    DIAS       = Shaft diameter, m
*    WTC        = Weight of cone, kN
*    WTS        = Weight of shaft, kN
*    CA           = Soil-Cone constrained adhesion, kN/sq.m
*    CAS         = Soil-Shaft constrained adhesion, kN/sq.m
*    ADELTA  = Angle of  Soil-Cone friction, deg.
*    ADELTS   = Angle of  Soil-Shaft friction, deg.
*    Q              = Surcharge, kN/sq.m (optional)
*    Z               = Depth of penetration, m
*    Qcone       = Total force on cone penetrometer, kN
*    HC            = Cone height, m
*    SC             = Cone face length, m
*    R               = Interface length, m
*    F                = Rupture distance (i.e. Critical depth), m
*
* ---------------------------------------------------------------------------
     SUBROUTINE ZLIM (PHI, C, CA, THEC, DIAC, DELTAC, F)
*
     RADN   = 3.14159265/180.0
     DELC    = ASIN(SIN(DELTAC)/SIN(PHI))
     AMUC  = 0.5*(DELC + DELTAC)
     PSI       = 45.0*RADN + 0.5*PHI
     THETAP  = PSI + AMUC
     THETAM = PSI - AMUC
     SC      = DIAC/(2.0*SIN(THEC))
     ETA    = 270.0*RADN - (90.0*RADN-THEC) - THETAM
     R      = SC*SIN(THETAP)/COS(PHI)
     F      = R*EXP(ETA*TAN(PHI))
     RETURN
     END
* -----------------------------------------------------------------------------------------
     SUBROUTINE CONE (C, PHI, GAMMA, THEC, DIAC, WTC, DIAS, WTS,
    + DELTAC, DELTAS, CA, CAS, Q, Z, TFG, TFCA, TFQ, QCONE)
*
     RADN  = 3.14159265/180.0
     PI         = 3.14159265
     DELC   = ASIN(SIN(DELTAC)/SIN(PHI))
```

```
      AMUC   = 0.5*(DELC + DELTAC)
      PSI     = 45.0*RADN + 0.5*PHI
      THETAP  = PSI + AMUC
      THETAM = PSI - AMUC
      DELS   = ASIN(SIN(DELTAS)/SIN(PHI))
      AMUS   = DELS + DELTAS
      AK11   = (1.0+SIN(PHI)*COS(AMUS))
      AK12   = (1.0-SIN(PHI)*COS(AMUS))
      AK1    = AK11/AK12
      AK2    = COS(PHI)*COS(AMUS)*(AK1+1.0)
      SC     = DIAC/(2.0*SIN(THEC))
      ANGLE  = 2.0*PI*SIN(THEC)
      HC      = DIAC/(2.0*TAN(THEC))
      TC     = SC*SIN(THETAM)/COS(PHI)
      ETA    = 270.0*RADN - (90.0*RADN-THEC) - THETAM
      R    = SC*SIN(THETAP)/COS(PHI)
      F    = R*EXP(ETA*TAN(PHI))
      D1   = (1.0/2.0)*F
      D3   = (1.0/2.0)*R*COS(PHI)
      D4   = (2.0/3.0)*R*COS(PHI)
      D2   = F * ((3.0*Z -2.0*F)/(3.0*(2.0*Z - F)))
*
*     Equations for gravitational moment, AMW
      AA      = -3.0*TAN(PHI)
      AMW1 = GAMMA*F*F*F/(3.0*(AA*AA+1.0))
      AMW2 = EXP(AA*ETA)*(AA*SIN(ETA)-COS(ETA)) + 1.0
      AMW   = AMW1*AMW2

*     Equation for cohesive moment, AMC
      IF (PHI .EQ. 0.0) THEN
      AMC  = C*R*R*ETA
      ELSE
      AMC  = C*(F*F-R*R)/(2.0*TAN(PHI))
      END IF

*     Normal force (per unit length) to the shaft surface, kN/m
      FHG   = 0.5*GAMMA*AK1*F*(2.0*Z - F)
      FHC   = C*F*AK2
      FHQ   = Q*F*AK1
*
*     Total shear force to the shaft surface, kN
      WIDTHS = PI*DIAS
      AREAS   = PI*DIAS*Z
      STG   = FHG * TAN(DELTAS) * WIDTHS
      STC   = FHC * TAN(DELTAS) * WIDTHS
      STQ   = FHQ * TAN(DELTAS) * WIDTHS
*
      AS    = CAS*AREAS
*
```

```
*   Forces on soil block: kN/m width
    PG   = (AMW + FHG*D2)/D4
    PC   = (AMC + FHC*D1)/D3
    PQ   = FHQ*D1/D3
*
    A1    = R*C
    A2    = TC*C
    AC    = SC*CA
*
*   Weight of wedge, WW, kN/m width
    HW    = TC*SIN(THETAP)
    WW    = 0.5*GAMMA*SC*HW
    E1      = 90.0*RADN - DELTAC - THETAM
    E2      = THETAM - THEC
*
*   Forces on cone face: kN/m width
    RG   = (PG*COS(PHI) + WW*SIN(E2))/SIN(E1)
    RC   = (PC*COS(PHI) + AC*SIN(THETAM) + A2*COS(PHI))/SIN(E1)
    RQ   = (PQ*COS(PHI))/SIN(E1)
*
*  Total vertical component of RG,RC,RQ
    FVG   = (ANGLE*SC*RG/3.0) * SIN(DELTAC+THEC)
    FVC   = (ANGLE*SC*RC/2.0) * SIN(DELTAC+THEC)
    FVQ   = (ANGLE*SC*RQ/2.0) * SIN(DELTAC+THEC)
*
*   Vertical component of AC
    VAC   = CA*PI*HC*HC*TAN(THEC)
*
*   Equilibrium of cone+shaft
    TFG     = FVG + STG - (WTC + WTS)
    TFCA  = FVC + STC + AS + VAC
    TFQ     = FVQ + STQ
*
    QCONE = TFG + TFCA + TFQ
    RETURN
    END

*           MAIN
*        PROGRAM
*    ****************
*
    REAL SIG3(10)
    REAL WC(10)
*
    OPEN (UNIT=5, FILE='dccam')
    OPEN (UNIT=6, FILE='rccam')
*
    RADN   = 3.14159265/180.0
    PI          = 3.14159265
```

```
*
*    Cone:
     DIAC   = 0.010
*    WTC    = 0.000038
     WTC    = 0.0
     ATHEC = 15.00
*
*    Shaft:
     DIAS   = 0.008
*    WTS    = 0.000965
     WTS    = 0.0
*
*      Format statements
* ---------------------------------------------------------------------------
  501 FORMAT(' ',4X,'m.c',4X,'Phi',5X,'C ',5X,'Gamma',3X,'F, mm',
     +3X,'Ng',5X,'Nca',5X,'Nq',6X,'Qcone')
  502 FORMAT(' ',3X,67(1H-))
  503 FORMAT(' ',3X,67(1H_))
  504 FORMAT(/)
  505 FORMAT(' ',3X,20(1H*))
  507 FORMAT(' ',3X,'DIAC  = ',F5.3)
  508 FORMAT(' ',3X,'ATHEC = ',F6.2)
  509 FORMAT(' ',3X,'ACONE = ',F6.2)
  510 FORMAT(' ',3X,14(1H*))
  512 FORMAT(' ',3X,'CA  = ',F5.2,3X,'CAS  = ',F5.2/)
  515 FORMAT(' ',3X,'DIAC = ',F4.3,3X,
     +'ACONE = ',F5.2)
  517 FORMAT(' ',3X,'DIAS = ',F4.3)
  518 FORMAT(/' ',3X,'Cell pressure = ',F7.2)
  520 FORMAT(' ',3X,'APHI = ',F5.2,3X,'C = ',F5.2,3X,
    +'GAMMA = ',F5.2/)
  525 FORMAT(F8.1,4F8.2,3F7.3,F10.5)
  530 FORMAT(F10.2,3F10.5,F10.5)
* ---------------------------------------------------------------------------
*
     THEC     = ATHEC*RADN
     ACONE  = 2.0*ATHEC
*
     WRITE(6,504)
     WRITE(6,515) DIAC, ACONE
     WRITE(6,517) DIAS
     WRITE(6,504)
*
     DATA (SIG3(NA), NA = 1, 6)
    +/25.0, 50.0, 100.0, 150.0, 200.0, 250.0/
*
     DATA (WC(NC), NC = 1, 5)
    +/7.0, 11.0, 15.0, 18.0, 22.0/
*
```

```
   DO 601 NA = 1,6
   Q1    = SIG3(NA)
*
   WRITE(6,504)
   WRITE(6,518) Q1
*
   WRITE(6,502)
   WRITE(6,501)
   WRITE(6,502)
*
   DO 701 NC = 1,5
 102 READ(5,'(3F10.2)') APHI, C, GAMMA
*
   WATERC = WC(NC)
   PHI        = APHI*RADN
*
   ADELTC  = (3.0/4.0)*APHI
   DELTAC  = ADELTC*RADN
   CA          = C*TAN(DELTAC)/TAN(PHI)
*
   ADELTS  = (3.0/4.0)*APHI
   DELTAS  = ADELTS*RADN
   CAS       = C*TAN(DELTAS)/TAN(PHI)
*
   CALL ZLIM (PHI, C, CA, THEC, DIAC, DELTAC, F)
   Z    = 0.055
   Q    = Q1 + GAMMA*Z
*
   CALL CONE (C, PHI, GAMMA, THEC, DIAC, WTC, DIAS, WTS,
  + DELTAC, DELTAS, CA, CAS, Q, Z, TFG, TFCA, TFQ, QCONE)
*
   ANG    = TFG/(GAMMA*Z*Z*DIAC)
   ANCA  = TFCA/(C*Z*DIAC)
   ANQ    = TFQ/(Q*Z*DIAC)
*
   WRITE(6,525) WATERC,APHI,C,GAMMA,F*1000.0, ANG,ANCA,ANQ,
                      QCONE
*
 701 CONTINUE
     WRITE(6,502)
*
 601 CONTINUE
*
 150 STOP
     END
```

```
*   PROGRAMME - 7
*   *****************
*   denm.f
*
* ------------------------------------------------------------------------------
    SUBROUTINE ZLIM (PHI, C, CA, THEC, DIAC, DELTAC, F)
*
    RADN   = 3.14159265/180.0
    DELC   = ASIN(SIN(DELTAC)/SIN(PHI))
    AMUC   = 0.5*(DELC + DELTAC)
    PSI    = 45.0*RADN + 0.5*PHI
    THETAP = PSI + AMUC
    THETAM = PSI - AMUC
    SC     = DIAC/(2.0*SIN(THEC))
    ETA    = 270.0*RADN - (90.0*RADN-THEC) - THETAM
    R      = SC*SIN(THETAP)/COS(PHI)
    F      = R*EXP(ETA*TAN(PHI))
    RETURN
    END
* ------------------------------------------------------------------------------------------------
    SUBROUTINE CONE (C, PHI, GAMMA, THEC, DIAC, WTC, DIAS, WTS,
   + DELTAC, DELTAS, CA, CAS, Q, Z, TFG, TFCA, TFQ, QCONE)
*
    RADN   = 3.14159265/180.0
    PI     = 3.14159265
    DELC   = ASIN(SIN(DELTAC)/SIN(PHI))
    AMUC   = 0.5*(DELC + DELTAC)
    PSI    = 45.0*RADN + 0.5*PHI
    THETAP = PSI + AMUC
    THETAM = PSI - AMUC
    DELS   = ASIN(SIN(DELTAS)/SIN(PHI))
    AMUS   = DELS + DELTAS
    AK11   = (1.0+SIN(PHI)*COS(AMUS))
    AK12   = (1.0-SIN(PHI)*COS(AMUS))
    AK1    = AK11/AK12
    AK2    = COS(PHI)*COS(AMUS)*(AK1+1.0)
    SC     = DIAC/(2.0*SIN(THEC))
    ANGLE  = 2.0*PI*SIN(THEC)
    HC     = DIAC/(2.0*TAN(THEC))
    TC     = SC*SIN(THETAM)/COS(PHI)
    ETA    = 270.0*RADN - (90.0*RADN-THEC) - THETAM
    R      = SC*SIN(THETAP)/COS(PHI)
    F      = R*EXP(ETA*TAN(PHI))
    D1     = (1.0/2.0)*F
    D3     = (1.0/2.0)*R*COS(PHI)
    D4     = (2.0/3.0)*R*COS(PHI)
*
    D2     = F * ((3.0*Z -2.0*F)/(3.0*(2.0*Z - F)))
```

```
*
* Equations for gravitational moment, AMW
    AA     = -3.0*TAN(PHI)
    AMW1 = GAMMA*F*F*F/(3.0*(AA*AA+1.0))
    AMW2 = EXP(AA*ETA)*(AA*SIN(ETA)-COS(ETA)) + 1.0
    AMW   = AMW1*AMW2
*
* Equation for cohesive moment, AMC
    IF (PHI .EQ. 0.0) THEN
    AMC  = C*R*R*ETA
    ELSE
    AMC  = C*(F*F-R*R)/(2.0*TAN(PHI))
    END IF

*    Normal force (per unit length) to the shaft surface, kN/m
    FHG    = 0.5*GAMMA*AK1*F*(2.0*Z - F)
    FHC    = C*F*AK2
    FHQ    = Q*F*AK1

*    Total shear force to the shaft surface, kN
    WIDTHS = PI*DIAS
    AREAS   = PI*DIAS*Z
    STG    = FHG * TAN(DELTAS) * WIDTHS
    STC    = FHC * TAN(DELTAS) * WIDTHS
    STQ    = FHQ * TAN(DELTAS) * WIDTHS
    AS      = CAS*AREAS

*   Forces on soil block: kN/m width
    PG    = (AMW + FHG*D2)/D4
    PC    = (AMC + FHC*D1)/D3
    PQ    = FHQ*D1/D3
*
    A1    = R*C
    A2    = TC*C
    AC    = SC*CA

*   Weight of wedge, WW, kN/m width
    HW    = TC*SIN(THETAP)
    WW    = 0.5*GAMMA*SC*HW
    E1     = 90.0*RADN - DELTAC - THETAM
    E2     = THETAM - THEC
*
*   Forces on cone face: kN/m width
    RG    = (PG*COS(PHI) + WW*SIN(E2))/SIN(E1)
    RC    = (PC*COS(PHI) + AC*SIN(THETAM) + A2*COS(PHI))/SIN(E1)
    RQ    = (PQ*COS(PHI))/SIN(E1)
*
*   Total vertical component of RG,RC,RQ
    FVG    = (ANGLE*SC*RG/3.0) * SIN(DELTAC+THEC)
```

```
      FVC   = (ANGLE*SC*RC/2.0) * SIN(DELTAC+THEC)
      FVQ   = (ANGLE*SC*RQ/2.0) * SIN(DELTAC+THEC)
*
*      Vertical component of AC
      VAC   = CA*PI*HC*HC*TAN(THEC)

*  Equilibrium of cone+shaft
      TFG    = FVG + STG - (WTC + WTS)
      TFCA  = FVC + STC + AS + VAC
      TFQ    = FVQ + STQ
*
      QCONE  = TFG + TFCA + TFQ
      RETURN
      END
*
*            MAIN
*          PROGRAM
*
      OPEN (UNIT=5, FILE='ddenm')
      OPEN (UNIT=6, FILE='rdenm')
      RADN   = 3.14159265/180.0
      PI        = 3.14159265
*
      WTC   =  0.0
      DIAS  =  0.016
      WTS   =  0.0
*
* Format statements
* ----------------------------------------------------------------------
  501 FORMAT(' ',2X,'Acone,deg.',1X,'Dcone,mm',2X,'Coeff.',2X,
     +'F, mm',5X,'Ng',5X,'Nca',6X,'Nq',4X,'Qcone,kN')
  502 FORMAT(' ',2X,69(1H-))
  503 FORMAT(' ',2X,69(1H_))
  504 FORMAT(/)
  505 FORMAT(' ',3X,20(1H*))
  507 FORMAT(' ',3X,'DIAC  = ',F5.3)
  508 FORMAT(' ',3X,'ATHEC = ',F6.2)
  509 FORMAT(' ',3X,'ACONE = ',F6.2)
  510 FORMAT(' ',3X,14(1H*))
  512 FORMAT(' ',3X,'CA  = ',F5.2,3X,'CAS  = ',F5.2/)
  515 FORMAT(' ',2X,'WC,%= ',F5.2,2X,'PHI,deg.= ',F5.2,2X,
     +'C,kN/sq.m= ',F5.2,2X,'GAMMA,kN/cu.m= ',F5.2)
  517 FORMAT(' ',2X,'DIAS, mm = ',F5.2)
  518 FORMAT(/' ',3X,'Cell pressure = ',F7.2)
  520 FORMAT(' ',3X,'APHI = ',F5.2,3X,'C = ',F5.2,3X,
     +'GAMMA = ',F5.2/)
  525 FORMAT(1X,F9.2,2X,F9.2,F7.2,F9.2,3F8.3,F9.3)
  530 FORMAT(F10.2,3F10.5,F10.5)
* ----------------------------------------------------------------------
```

```
*
   WRITE(6,504)
   WRITE(6,517) DIAS*1000.0
   WRITE(6,504)
*
 101 READ(5,'(F10.2)') WC
 102 READ(5,'(3F10.2)') APHI, C, GAMMA
*
   WRITE(6,515) WC, APHI, C, GAMMA
   PHI   = APHI*RADN
   WRITE(6,502)
   WRITE(6,501)
   WRITE(6,502)
*
 103 READ(5,'(3F10.2)') ATHEC, DCONE, COEFF
*
   IF (ATHEC .LT. 0.0) THEN
   GO TO 140
   END IF
*
   DIAC     = DCONE/1000.0
   THEC     = ATHEC*RADN
   ACONE  = 2.0*ATHEC
*
   ADELTC = COEFF*APHI
   DELTAC = ADELTC*RADN
   CA        = C*TAN(DELTAC)/TAN(PHI)
   ADELTS = 0.0
   DELTAS = ADELTS*RADN
   CAS      = C*TAN(DELTAS)/TAN(PHI)
*
   CALL ZLIM (PHI, C, CA, THEC, DIAC, DELTAC, F)
   Z    = 0.200
   Q    = GAMMA*Z
*
   CALL CONE (C, PHI, GAMMA, THEC, DIAC, WTC, DIAS, WTS,
   + DELTAC, DELTAS, CA, CAS, Q, Z, TFG, TFCA, TFQ, QCONE)
*
   ANG    = TFG/(GAMMA*Z*Z*DIAC)
   ANCA  = TFCA/(C*Z*DIAC)
   ANQ    = TFQ/(Q*Z*DIAC)
*
   WRITE(6,525) ACONE,DCONE,COEFF,F*1000.0,ANG,ANCA,ANQ,QCONE
   GO TO 103
 140 WRITE(6,502)
*
 150 STOP
     END
```

```
* PROGRAMME - 8
* *****************
*    pna.f
*
     INTEGER      N, M1
     PARAMETER    (N=11,M1=5)
*
     DOUBLE PRECISION  YY(N), DEV(N), PDEV(N)
     DOUBLE PRECISION  REF
     DOUBLE PRECISION  A(M1), X(N), Y(N)
*
     DO 101 J  = 1,11
     READ(5,'(2F10.0)') X(J),Y(J)
 101 CONTINUE
*
     CALL E02ACF(X,Y,N,A,M1,REF)
*
     WRITE(6,515)
     WRITE(6,500)
     WRITE(6,503)
     WRITE(6,502) (A(I),I=1,M1)
     WRITE(6,503)
     WRITE(6,515)
* Format:
* ------------------------------------------------------------
 500 FORMAT (4X,'Polynomial coefficients')
 502 FORMAT (6X,F10.6)
 503 FORMAT (' ',3X,23(1H-))
 504 FORMAT (' ',9X,53(1H-))
 505 FORMAT (13X,'X',5X,'Y(actual)',3X,'Y(theo.)',
    +2X,'deviation',2X,'% deviation')
 510 FORMAT (6X,5F11.4)
 515 FORMAT (///)
* ------------------------------------------------------------
*
     WRITE(6,505)
     WRITE(6,504)
     DO 102 K  = 1,11
     YY(K)    = A(1)+A(2)*X(K)+A(3)*X(K)**2+A(4)*X(K)**3+A(5)*X(K)**4
     DEV(K)   = Y(K) - YY(K)
     PDEV(K) = (DEV(K)/Y(K))*100.0
     WRITE(6,510) X(K),Y(K),YY(K),DEV(K),PDEV(K)
 102 CONTINUE
     WRITE(6,504)
*
     STOP
     END
```

```
* PROGRAMME - 9
* *****************
*    final3.f
*
      REAL SPV(500), UWT(500), QINDEX(500,500)
*
      GS     = 2.68
      WATERD = 0.997
      PI         = 3.14159
      RADN     = 3.14159/180.0
*
      CONED  = 0.027
      CONEA  = (PI/4.0)*(CONED**2)
      Z          = 0.300
*
      A0  = -17.226213
      A1  =  15.062773
      A2  =  -1.433905
      A3  =   0.048894
      A4  =  -0.000570
*
*
      B0  =   6.658403
      B1  =   0.378318
      B2  =  -0.067790
      B3  =   0.002117
      B4  =  -0.000015
*
*
      DO 601 KK = 1,5
*
      READ(5,'(4F10.0)') WC, GAMAI, ALAMDA, APHI
*
      AK0   = 1.0 - SIN(APHI*RADN)
*
      AK  = A0 + A1*WC + A2*WC**2 + A3*WC**3 + A4*WC**4
      AM  = B0 + B1*WC + B2*WC**2 + B3*WC**3 + B4*WC**4
*
      DO 602 JJ = 11,1,-1
*
      SPVOL    = FLOAT(JJ - 1)*0.05 + 1.5
      DRYD      = GS*WATERD/SPVOL
      BULKD    = DRYD*(1.0 + (WC/100.0))
      UNITWT  = 9.80665*DRYD
      SPV(JJ)   = SPVOL
      UWT(JJ)  = UNITWT
*
      P      = UNITWT*Z*(1.0 + 2.0*AK0)
```

```
*
   SPVOLC = GAMAI - ALAMDA*ALOG(P)
*
   PSI   = SPVOL - SPVOLC
*
   Q    = AK*EXP((-AM)*PSI)
   QC  = Q*P + P
   QFORCE = QC*CONEA
*
   QINDEX(JJ,KK)= QC
*
 602 CONTINUE
*
   AK0 = 0.0
   AK   = 0.0
   AM   = 0.0
 601 CONTINUE
*
* ------------------------------------------------------------------------
 501 FORMAT (26X,'CONE INDEX, kN/sq.m at different m.c')
 502 FORMAT (6X,F10.6)
 503 FORMAT (' ',3X,67(1H-))
 504 FORMAT (' ',23(1H-))
 505 FORMAT (5X,'SPVOL',4X,'UNITWT',6X,'7.0%',5X,'11.0%',
   +5X,'15.0%',5X,'18.0%',5X,'22.0%')
 510 FORMAT (4X,3F11.2,F11.5)
 515 FORMAT (///)
 516 FORMAT (/)
 518 FORMAT (7F10.2)
* ------------------------------------------------------------------------
*
   WRITE(6,515)
   WRITE(6,503)
   WRITE(6,501)
   WRITE(6,505)
   WRITE(6,503)
*
*   Write: output values
*
   DO 701 NA= 11,1,-1
   WRITE(6,518) SPV(NA), UWT(NA), (QINDEX(NA,NB), NB=1,5)
 701 CONTINUE
   WRITE(6,503)
*
 300 STOP
     END
```

```
* PROGRAMME - 10
* *****************
*   final4.f
*
      REAL WCT(50), QINDEX(500,500)
*
      GS     = 2.68
      WATERD = 0.997
      PI     = 3.14159
      RADN   = 3.14159/180.0
*
      CONED  = 0.027
      CONEA  = (PI/4.0)*(CONED**2)
      Z      = 0.300
*
      A0 = -17.226213
      A1 =  15.062773
      A2 =  -1.433905
      A3 =   0.048894
      A4 =  -0.000570
*
*
      B0 =   6.658403
      B1 =   0.378318
      B2 =  -0.067790
      B3 =   0.002117
      B4 =  -0.000015
*
*
      DO 601 KK = 1,5
*
      READ(5,'(4F10.0)') WC, GAMAI, ALAMDA, APHI
*
      WCT(KK) = WC
*
      AK0  = 1.0 - SIN(APHI*RADN)
*
      AK  = A0 + A1*WC + A2*WC**2 + A3*WC**3 + A4*WC**4
      AM  = B0 + B1*WC + B2*WC**2 + B3*WC**3 + B4*WC**4
*
      DO 602 JJ = 1,11
*
      SPVOL   = FLOAT(JJ - 1)*0.05 + 1.5
      DRYD    = GS*WATERD/SPVOL
      BULKD   = DRYD*(1.0 + (WC/100.0))
      UNITWT = 9.80665*DRYD
*
      P     = UNITWT*Z*(1.0 + 2.0*AK0)
```

```
   SPVOLC = GAMAI - ALAMDA*ALOG(P)
*
   PSI   = SPVOL - SPVOLC
   Q   = AK*EXP((-AM)*PSI)
   QC  = Q*P + P
   QFORCE = QC*CONEA
*
   QINDEX(JJ,KK)= QC
*
 602 CONTINUE
*
   AK0 = 0.0
   AK   = 0.0
   AM   = 0.0
 601 CONTINUE
*
*     Format statements
* ------------------------------------------------------------------------------
 501 FORMAT (26X,'CONE INDEX, kN/sq.m at different Dry density,
   +kN/cu.m')
 502 FORMAT (6X,F10.6)
 503 FORMAT (' ',94(1H-))
 504 FORMAT (' ',23(1H-))
 505 FORMAT (2X,'m.c',3X,'d17.5',4X,'d16.9',3X,'d16.4',
   +3X,'d15.9',3X,'d15.4',3X,'d15.0',3X,'d14.6',3X,'d14.2',
   +3X,'d13.8',3X,'d13.4',3X,'d13.1')
 510 FORMAT (4X,3F11.2,F11.5)
 515 FORMAT (///)
 516 FORMAT (/)
 518 FORMAT (F5.1,2F9.2,9F8.2)
* ------------------------------------------------------------------------------
   WRITE(6,515)
   WRITE(6,503)
   WRITE(6,501)
   WRITE(6,505)
   WRITE(6,503)
*
*    Write: output values
*
   DO 701 NA= 1,5
   WRITE(6,518) WCT(NA), (QINDEX(NB,NA), NB=1,11)
 701 CONTINUE
   WRITE(6,503)
*
 300 STOP
     END
```