TOMO III. ANEXOS EXPERIMENTALES

" MEJORA DE LA TIERRA ESTABILIZADA EN EL DESARROLLO DE UNA ARQUITECTURA SOSTENIBLE HACIA EL SIGLO XXI "

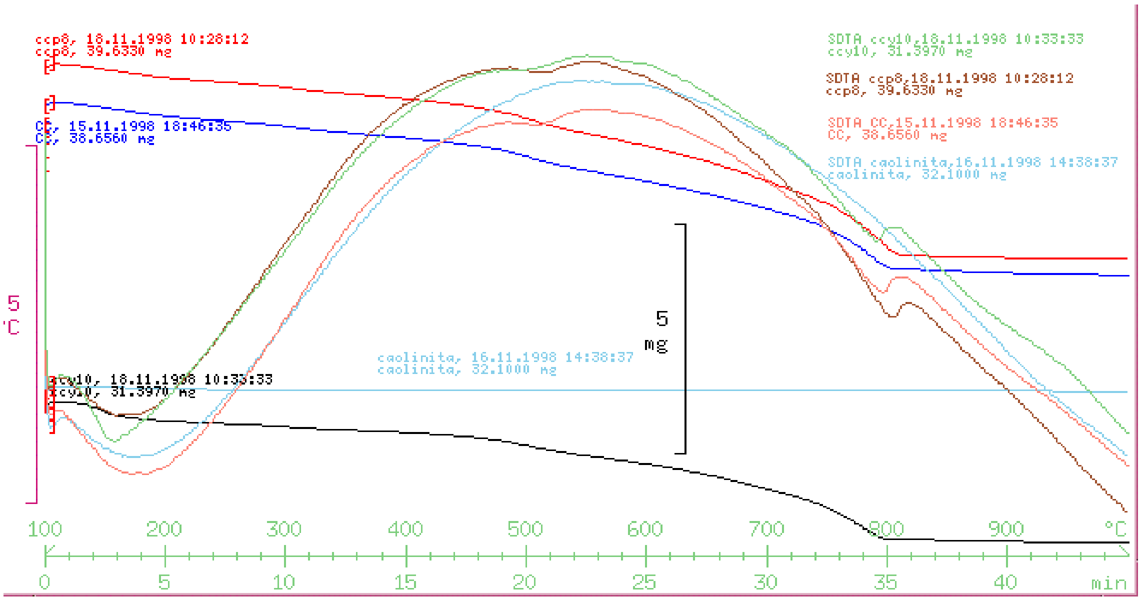
TESIS DOCTORAL

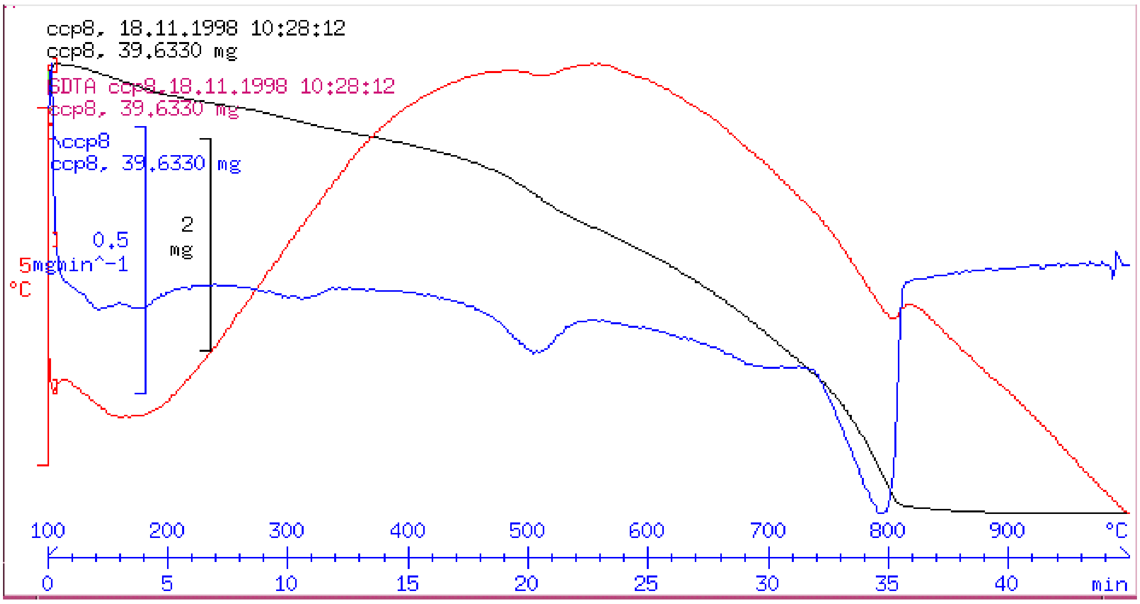
ETSAB. ESCOLA TÉCNICA SUPERIOR D'ARQUITECTURA DE BARCELONA. UPC. POR EL ARQUITECTO GABRIEL BARBETA I SOLÀ
AÑO 2002
Tutor. Ferran Gomà i Ginestà.

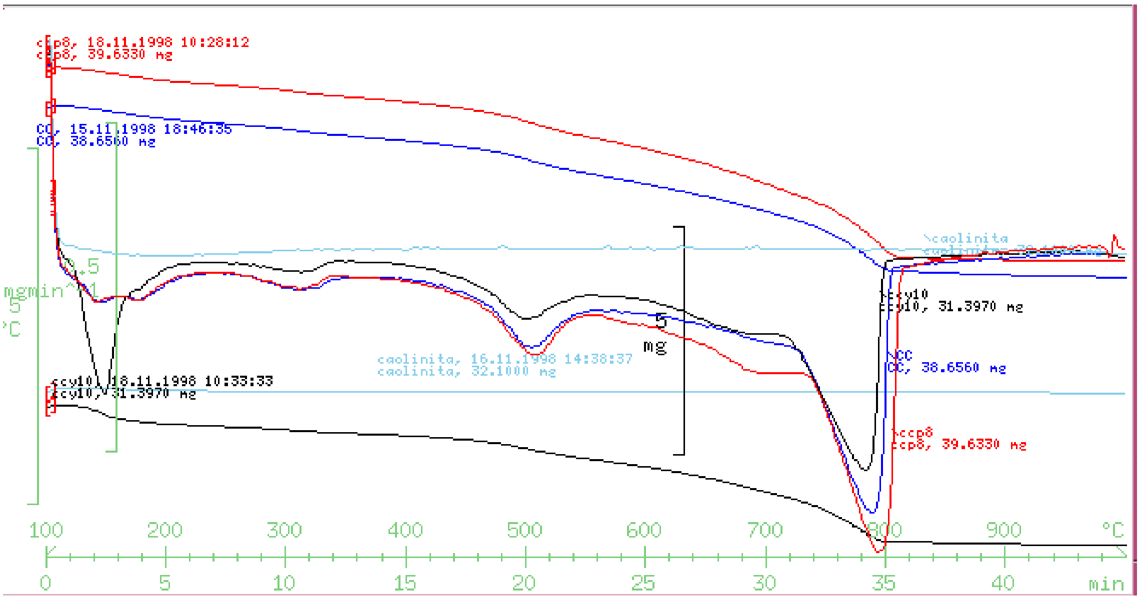
Anexos

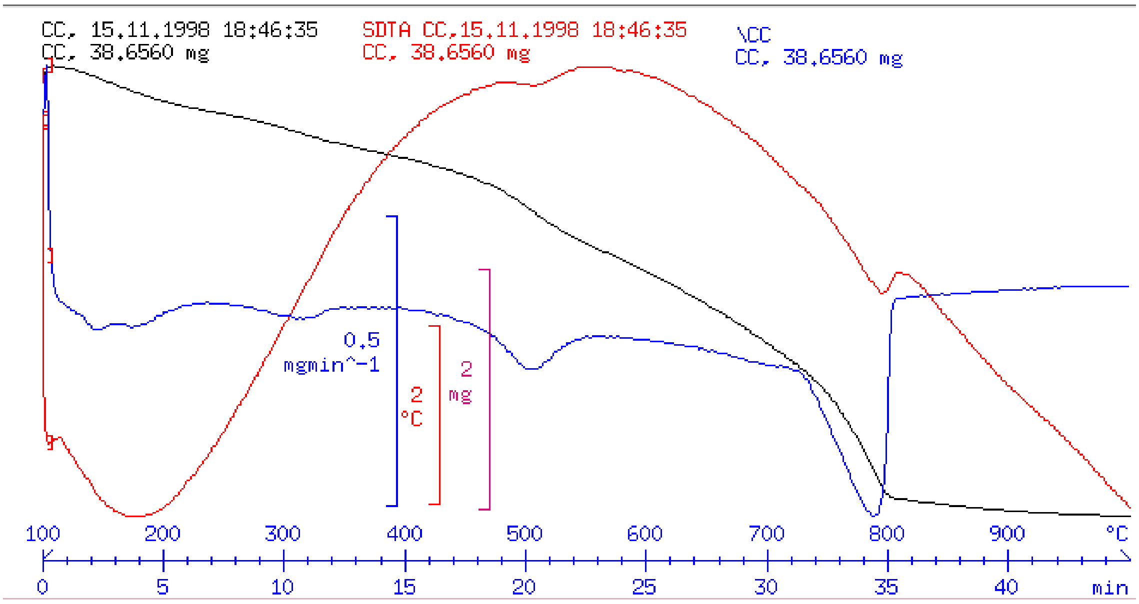
Análisis experimentales Tierras Grupo II

Análisis ATD

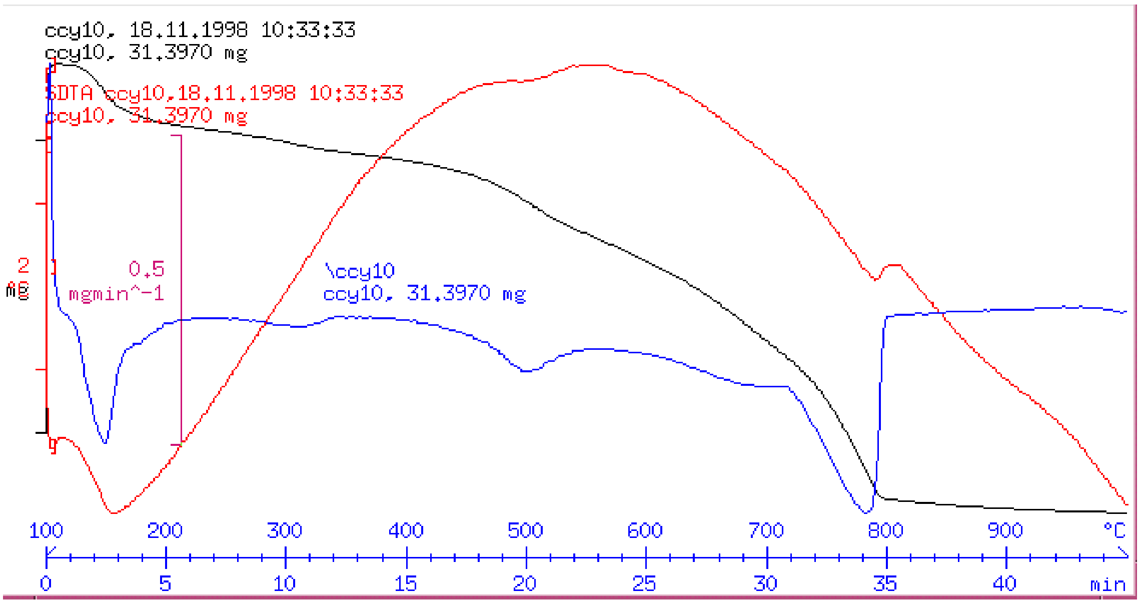



ccp8, 18.11.1998 10:28:12
ccp8, 39.6330 mg
DTA ccp8 18.11.1998 10:28:12
ccp8, 39.6330 mg
\ccp8
ccp8, 39.6330 mg
0.5
2
mg
5mgmin^-1
°C
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

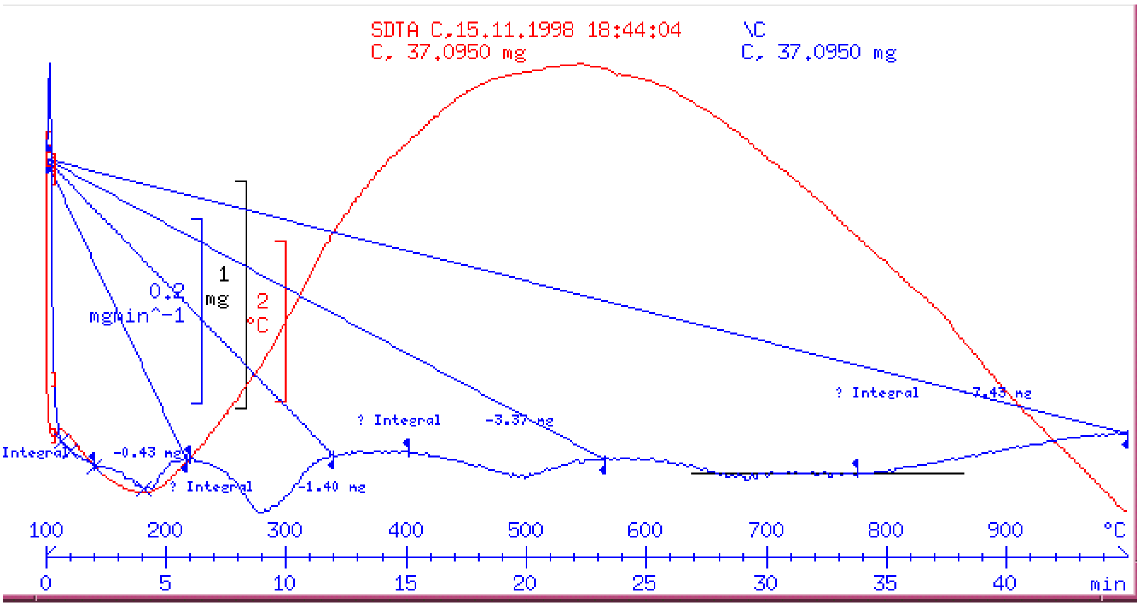

ccp8, 18.11.1998 10:28:12
ccp8, 39.6330 mg
CC, 15.11.1998 18:46:35
CC, 38.6560 mg
0.5
mgmin^-1
5
°C
ccy10, 18.11.1998 10:33:33
ccy10, 31.3970 mg
caolinita, 16.11.1998 14:38:37
caolinita, 32.1000 mg
5
mg
\caolinita
\ccy10
ccy10, 31.3970 mg
\CC
CC, 38.6560 mg
\ccp8
ccp8, 39.6330 mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

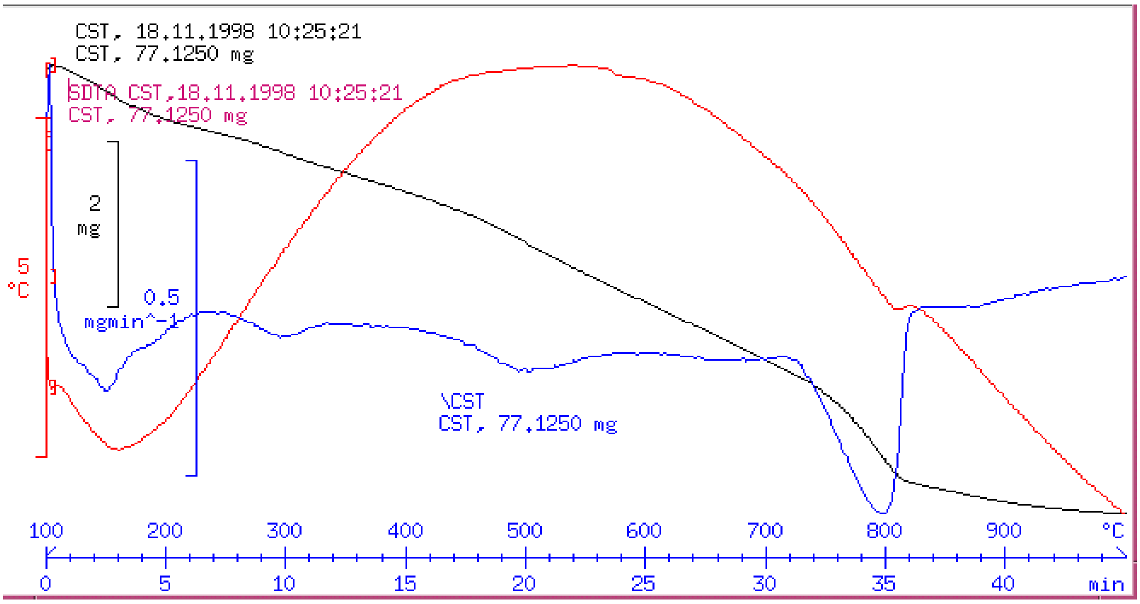


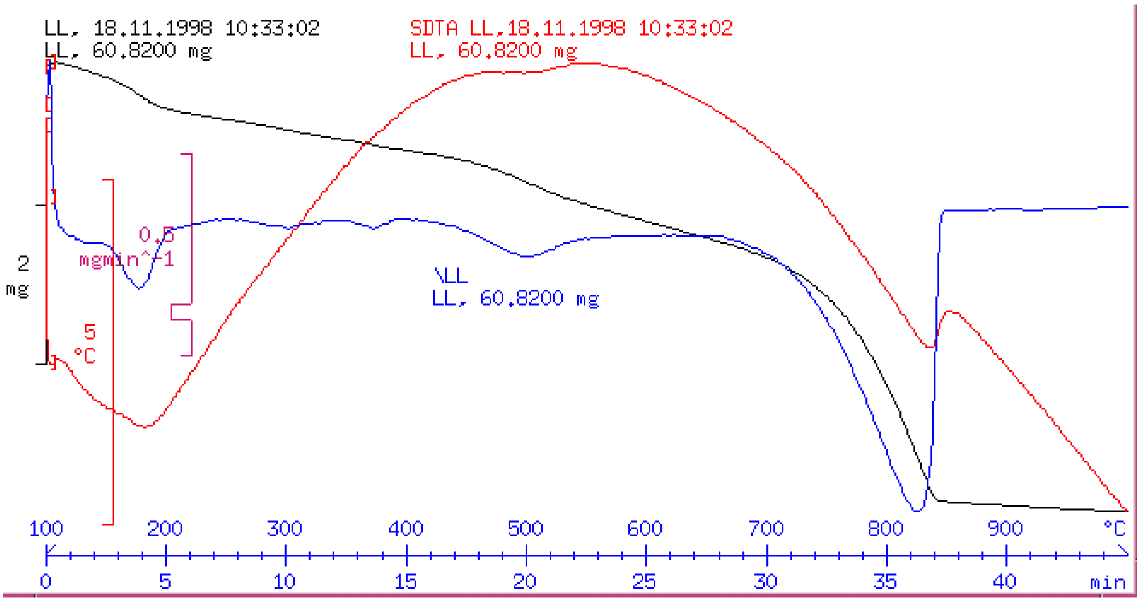
Muestra CCy10. Can Cerdà estabilizada al 10% con yeso

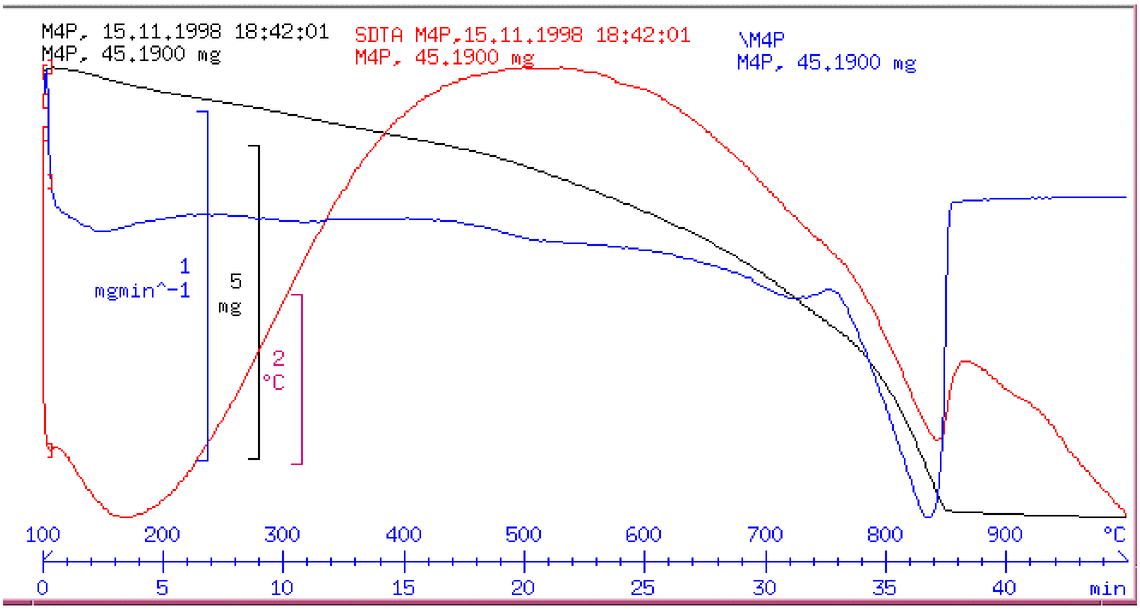


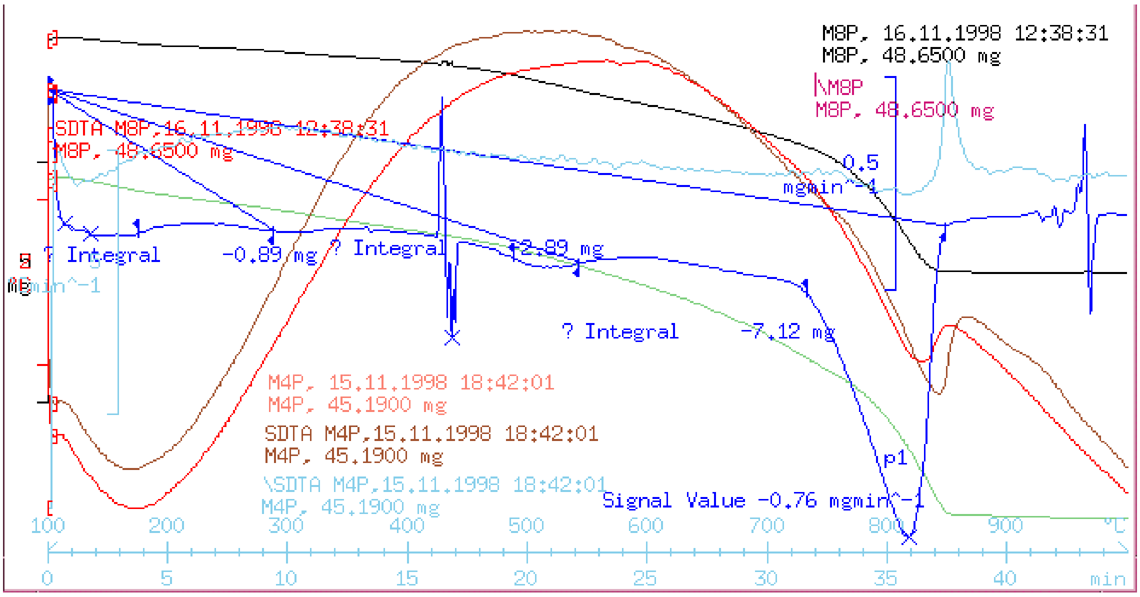
Muestra tierra C.Corbera

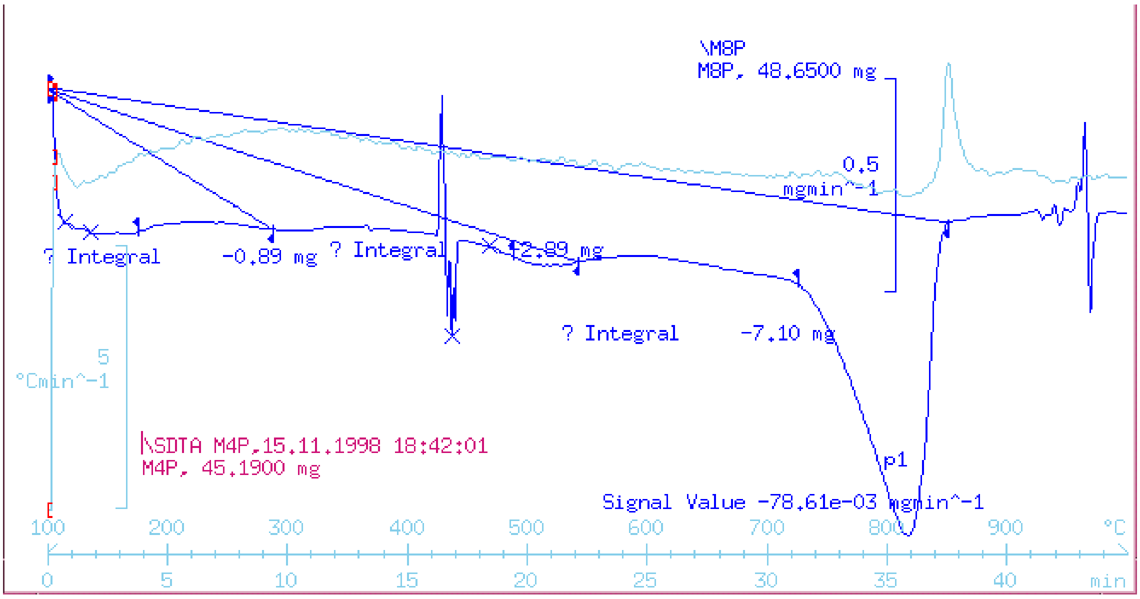

SDTA C,15.11.1998 18:44:04
C, 37.0950 mg
\C
C, 37.0950 mg
0.2
mgmin^-1
1
mg
2
°C
Integral
-0.43 mg
? Integral
-1.40 mg
? Integral
-3.37 mg
? Integral
-7.43 mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

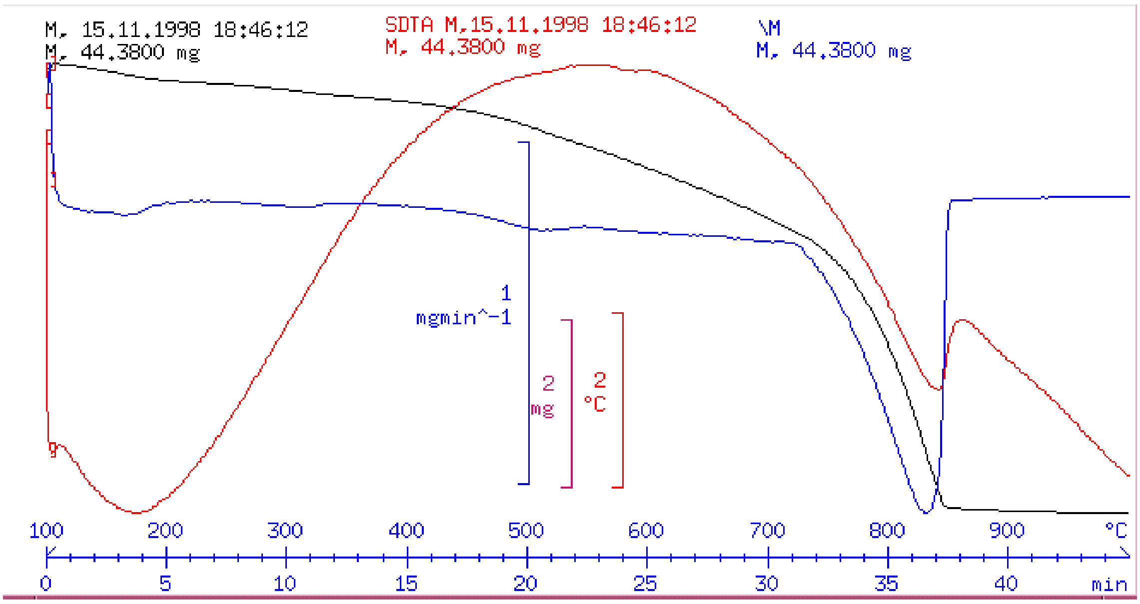

CST, 18.11.1998 10:25:21
CST, 77.1250 mg
SDTA CST,18.11.1998 10:25:21
CST, 77.1250 mg
2
mg
5
°C
0.5
mgmin^-1
\CST
CST, 77.1250 mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

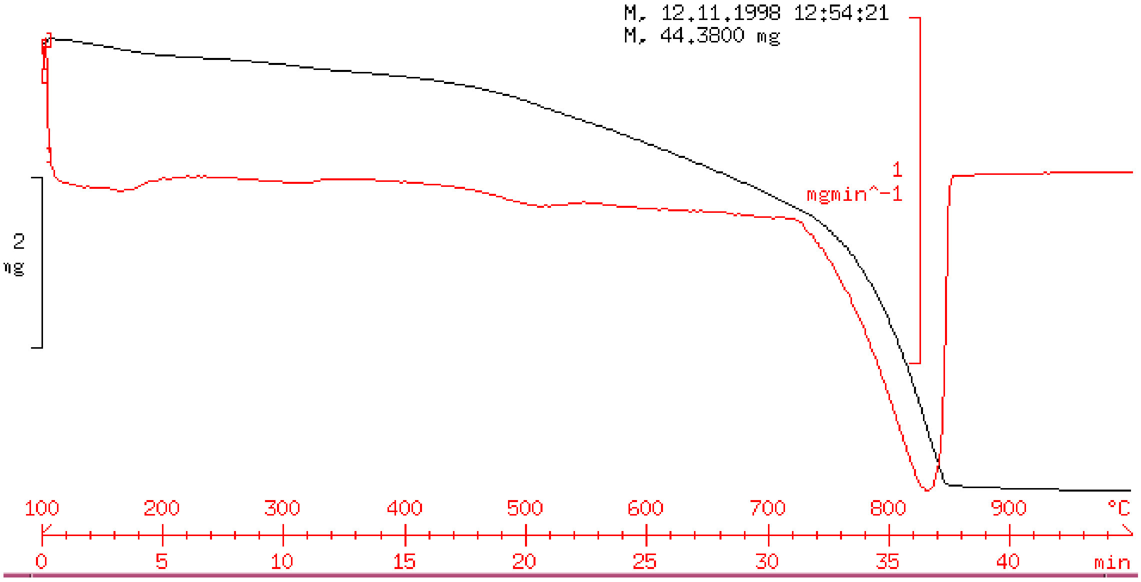

LL, 18.11.1998 10:33:02
LL, 60.8200 mg
SDTA LL,18.11.1998 10:33:02
LL, 60.8200 mg
2
mg
0.5
mgmin^-1
5
°C
\LL
LL, 60.8200 mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

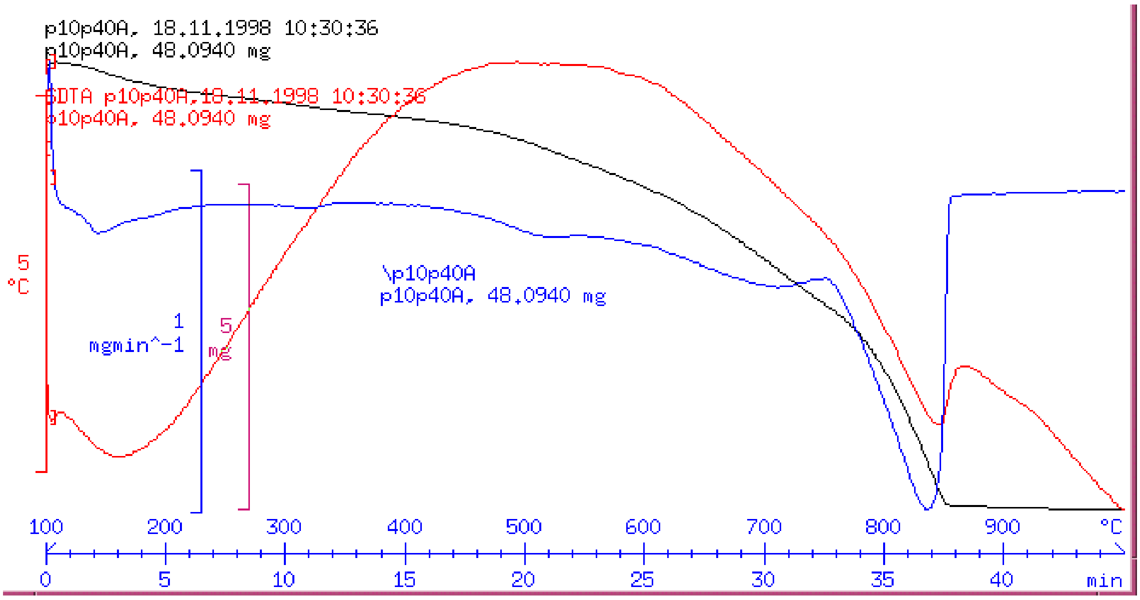

M4P, 15.11.1998 18:42:01
M4P, 45.1900 mg
SDTA M4P,15.11.1998 18:42:01
M4P, 45.1900 mg
\M4P
M4P, 45.1900 mg
1
mgmin^-1
5
mg
2
°C
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

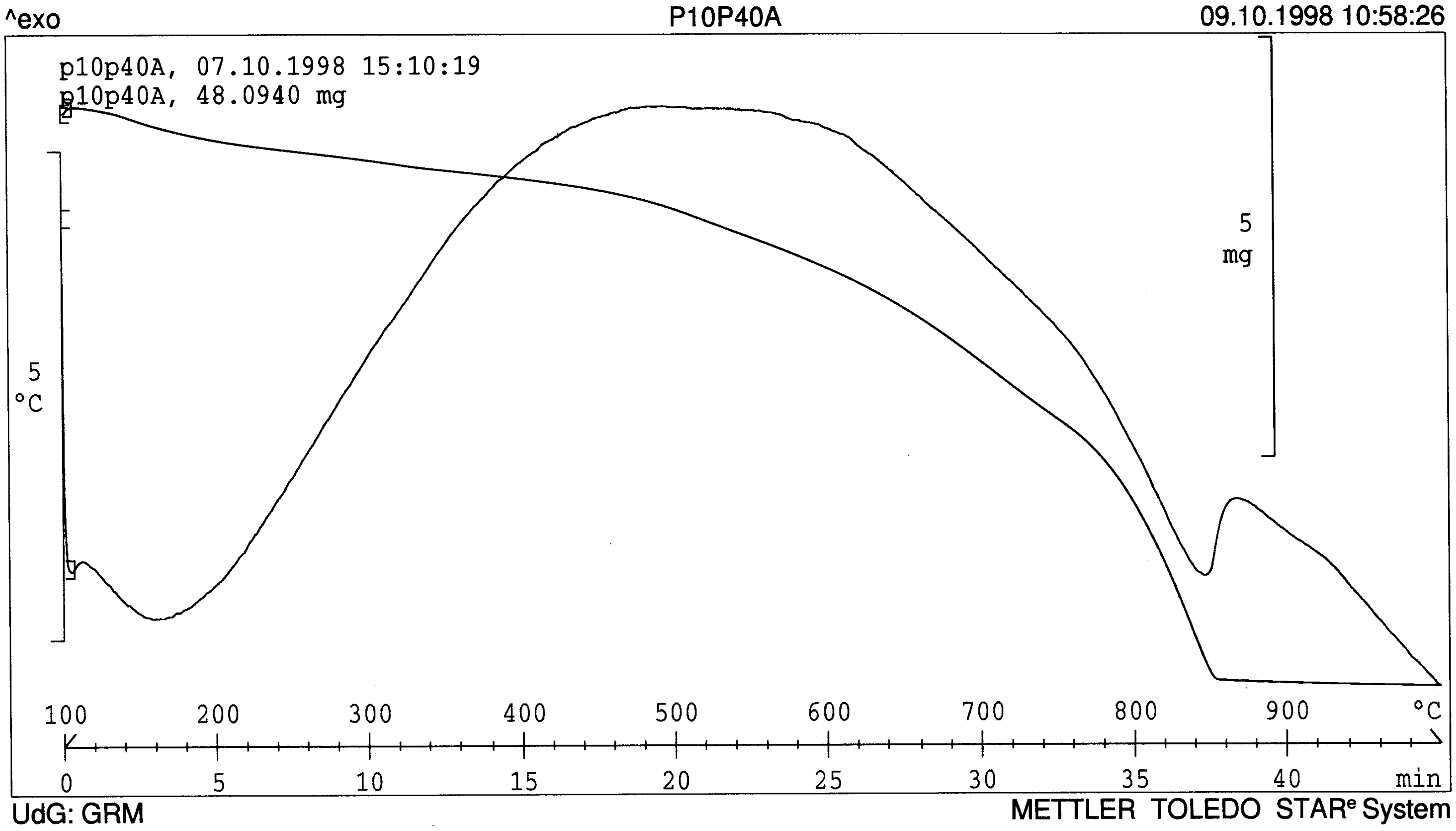

M8P, 16.11.1998 12:38:31
M8P, 48.6500 mg
\M8P
M8P, 48.6500 mg
SDTA M8P,16.11.1998 12:38:31
M8P, 48.6500 mg
0.5
mgmin^-1
5
mg
mgmin^-1
? Integral
-0.89 mg
? Integral
-2.89 mg
? Integral
-7.12 mg
M4P, 15.11.1998 18:42:01
M4P, 45.1900 mg
SDTA M4P,15.11.1998 18:42:01
M4P, 45.1900 mg
\SDTA M4P,15.11.1998 18:42:01
M4P, 45.1900 mg
p1
Signal Value -0.76 mgmin^-1
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

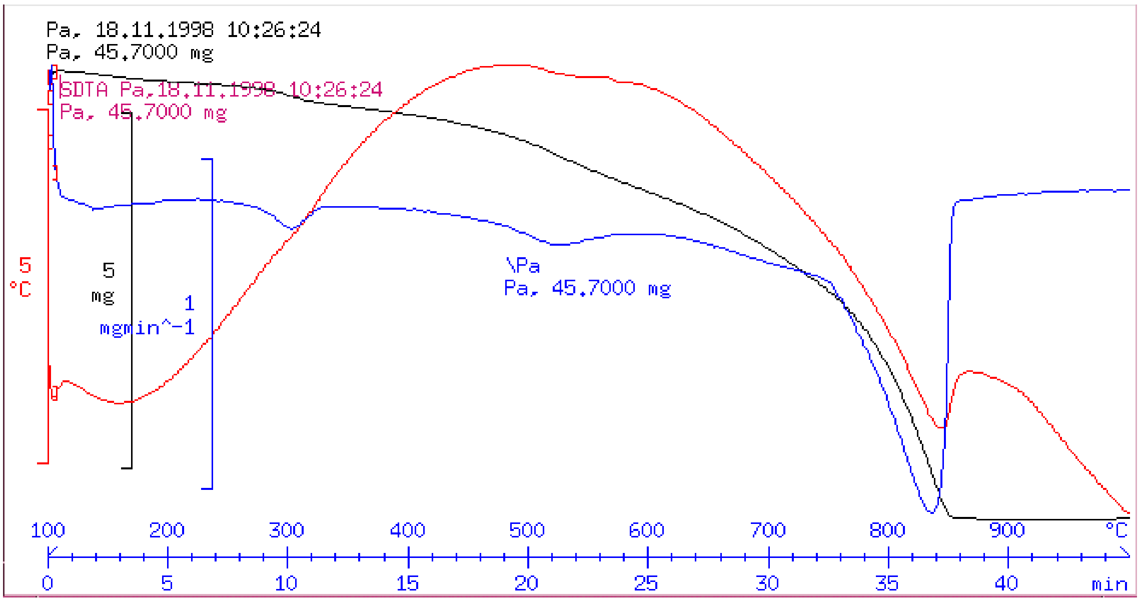

\M8P
M8P, 48.6500 mg
0.5
mgmin^-1
? Integral
-0.89 mg
? Integral
-2.89 mg
? Integral
-7.10 mg
5
°Cmin^-1
\SDTA M4P,15.11.1998 18:42:01
M4P, 45.1900 mg
p1
Signal Value -78.61e-03 mgmin^-1
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

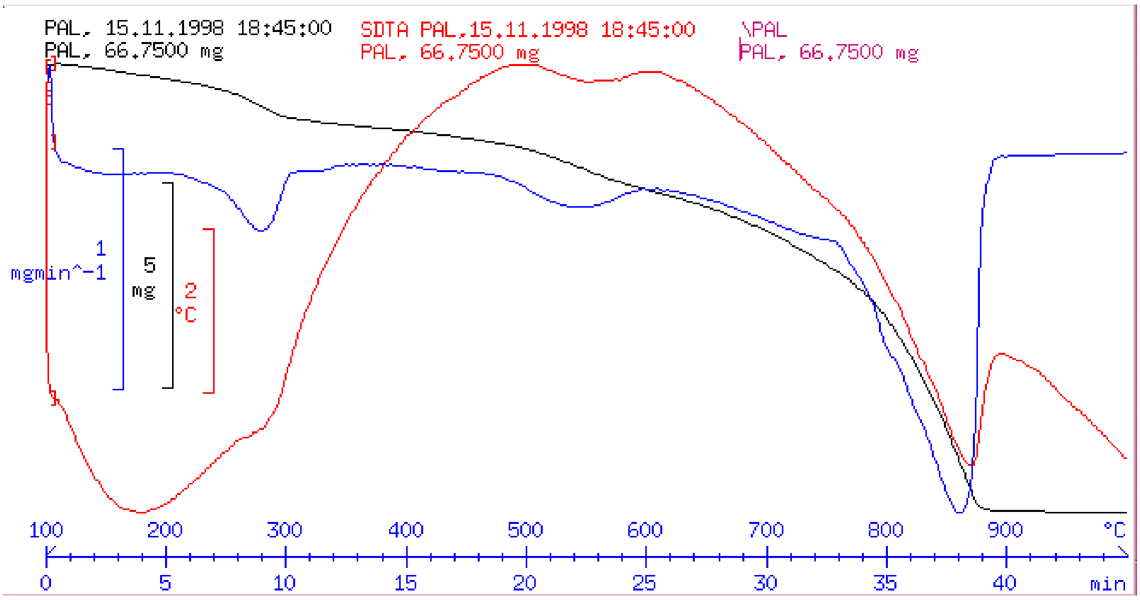

M, 15.11.1998 18:46:12
M, 44.3800 mg
SDTA M,15.11.1998 18:46:12
M, 44.3800 mg
\M
M, 44.3800 mg
1
mgmin^-1
2
mg
2
°C
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

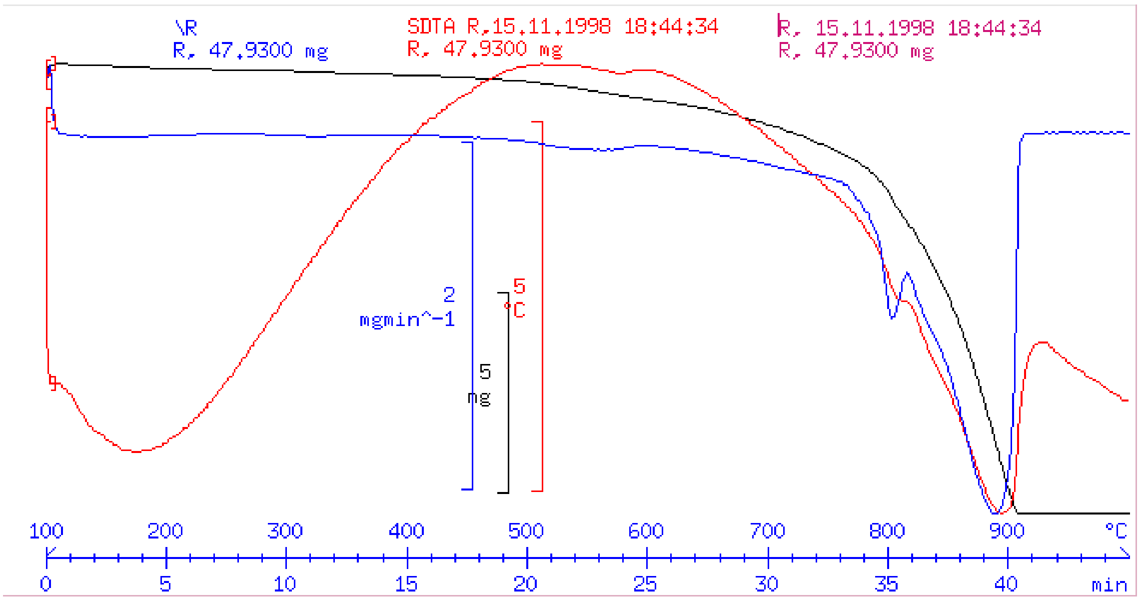

M, 12.11.1998 12:54:21
M, 44.3800 mg
1
mgmin^-1
2
mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

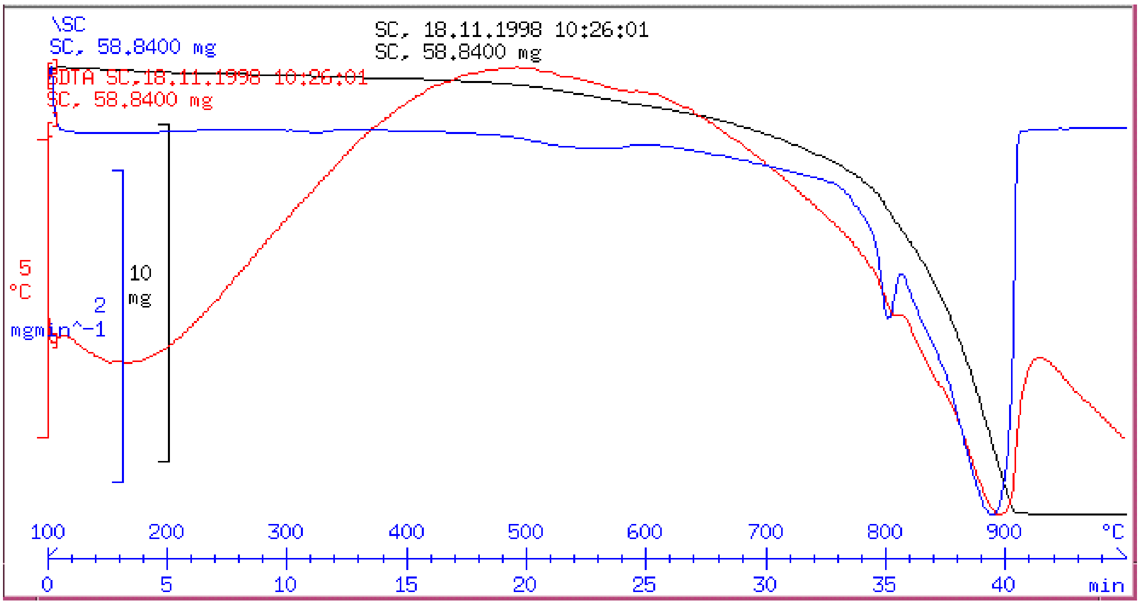

p10p40A, 18.11.1998 10:30:36
p10p40A, 48.0940 mg
SDTA p10p40A,18.11.1998 10:30:36
p10p40A, 48.0940 mg
5
°C
1
mgmin^-1
5
mg
\p10p40A
p10p40A, 48.0940 mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

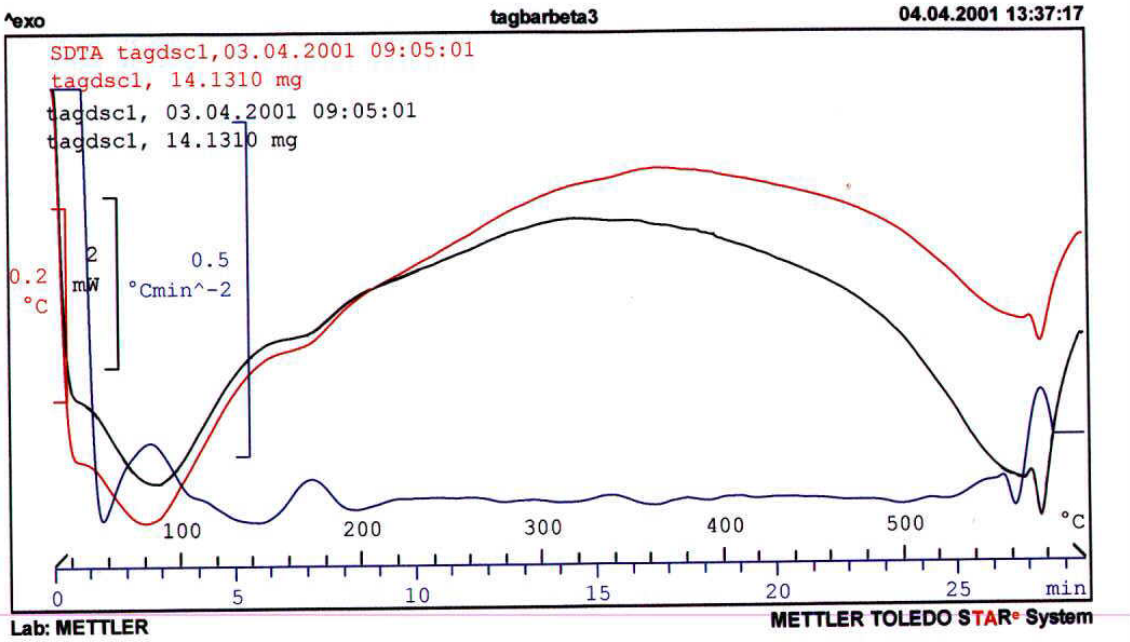

^exo
P10P40A
09.10.1998 10:58:26
p10p40A, 07.10.1998 15:10:19
p10p40A, 48.0940 mg
5
°C
5
mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min
UdG: GRM
METTLER TOLEDO STARᵉ System

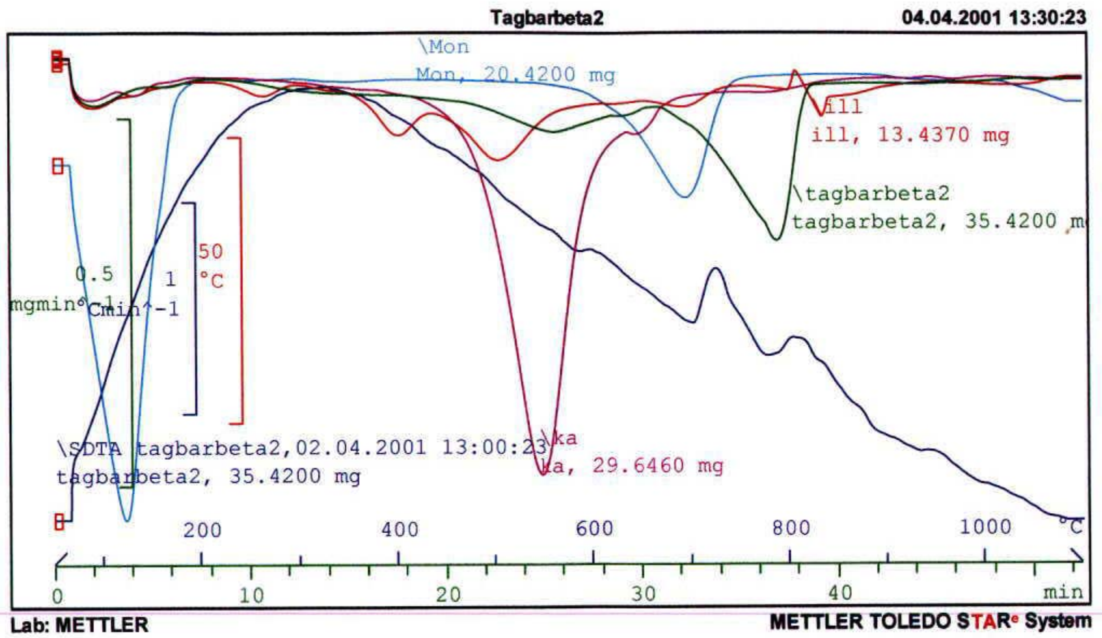

Pa, 18.11.1998 10:26:24
Pa, 45.7000 mg
SDTA Pa,18.11.1998 10:26:24
Pa, 45.7000 mg
5
°C
5
mg
1
mgmin^-1
\Pa
Pa, 45.7000 mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

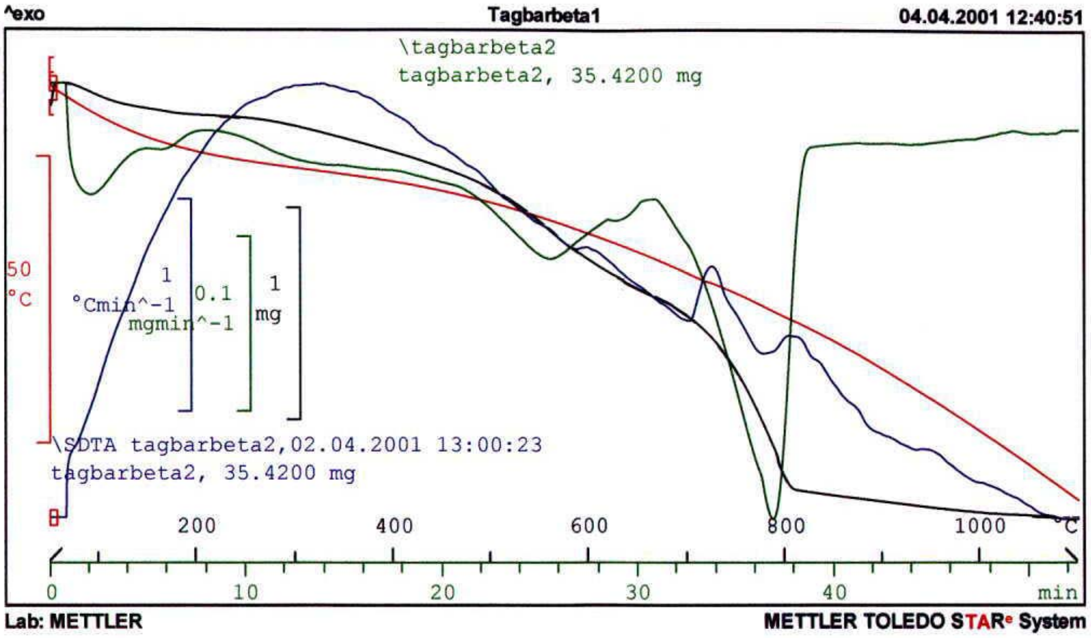

PAL, 15.11.1998 18:45:00
PAL, 66.7500 mg
SDTA PAL,15.11.1998 18:45:00
PAL, 66.7500 mg
\PAL
PAL, 66.7500 mg
1
mgmin^-1
5
mg
2
°C
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

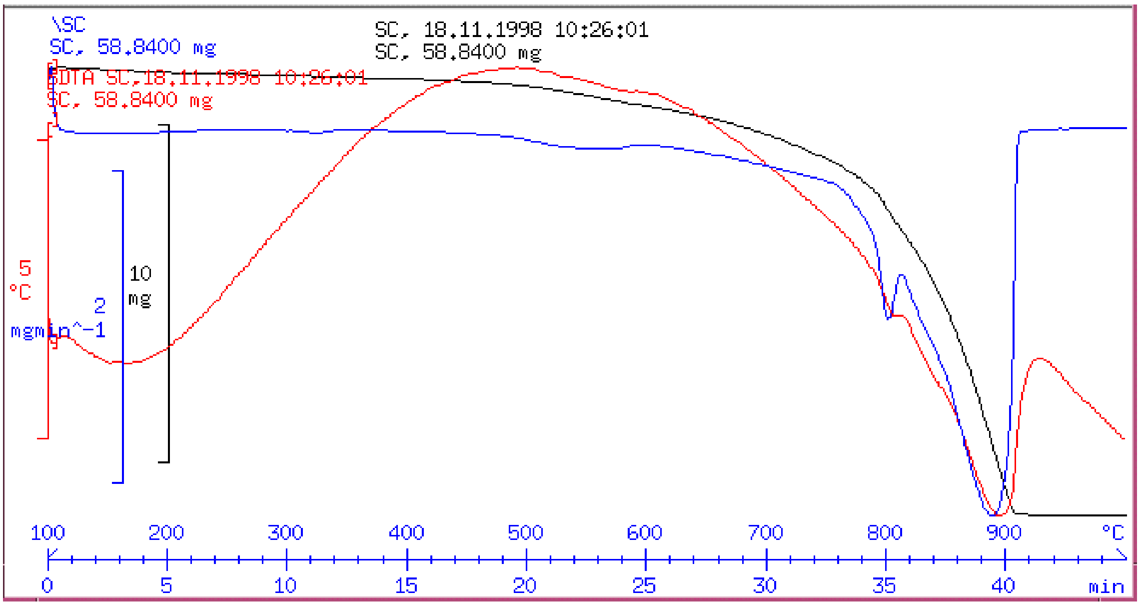

\R
R, 47.9300 mg
SDTA R,15.11.1998 18:44:34
R, 47.9300 mg
R, 15.11.1998 18:44:34
R, 47.9300 mg
2
mgmin^-1
5
°C
5
mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

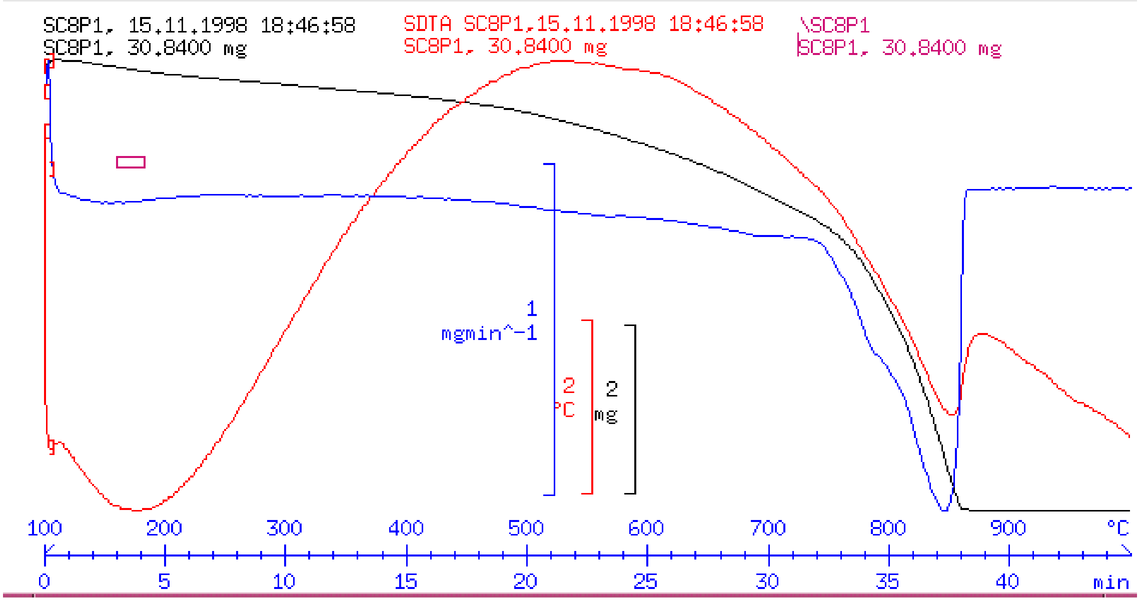

\SC
SC, 58.8400 mg
SC, 18.11.1998 10:26:01
SC, 58.8400 mg
SDTA SC,18.11.1998 10:26:01
SC, 58.8400 mg
5
°C
2
mgmin^-1
10
mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

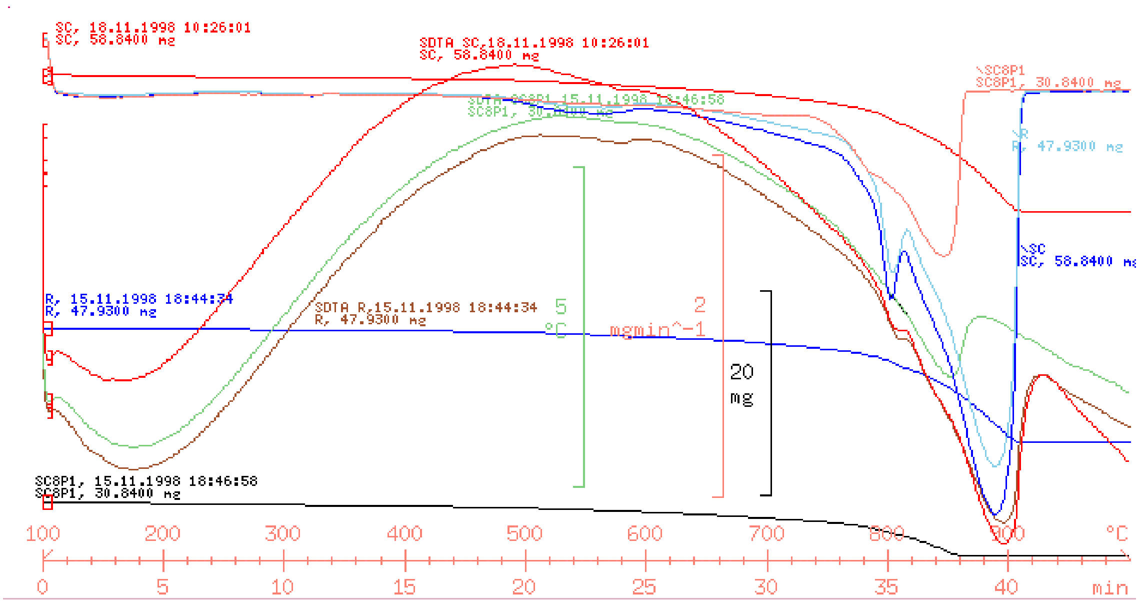

^exo
tagbarbeta3
04.04.2001 13:37:17
SDTA tagdsc1,03.04.2001 09:05:01
tagdsc1, 14.1310 mg
tagdsc1, 03.04.2001 09:05:01
tagdsc1, 14.1310 mg
0.2
°C
2
mW
0.5
°Cmin^-2
100
200
300
400
500
°C
0
5
10
15
20
25
min
Lab: METTLER
METTLER TOLEDO STARe System

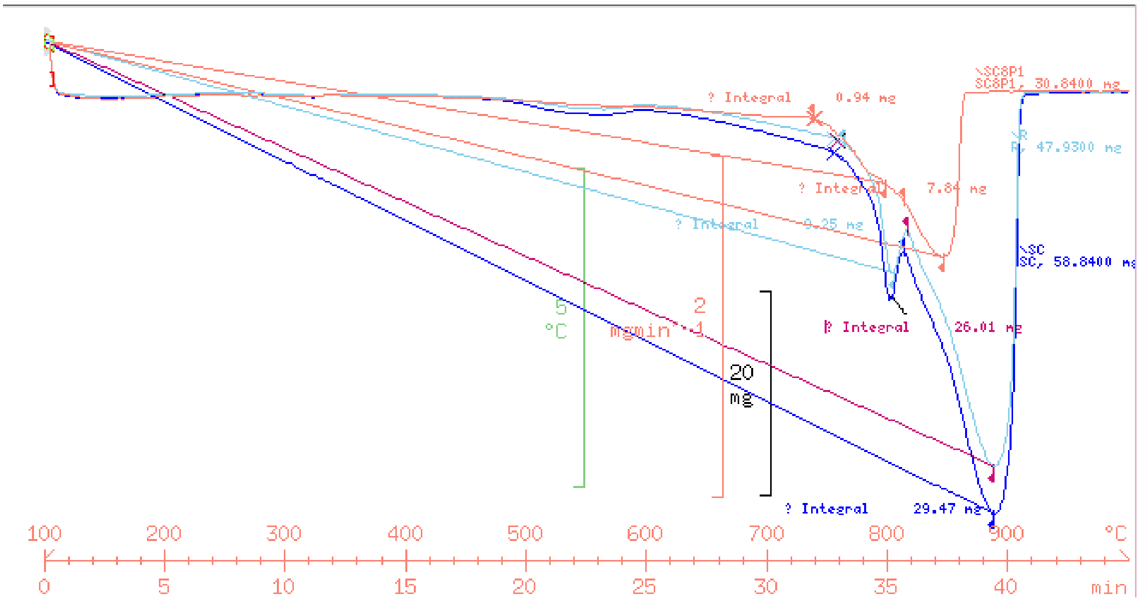

Tagbarbeta2
04.04.2001 13:30:23
\Mon
Mon, 20.4200 mg
\ill
ill, 13.4370 mg
\tagbarbeta2
tagbarbeta2, 35.4200 m
0.5
mgmin^-1
1
°Cmin^-1
50
°C
\SDTA tagbarbeta2,02.04.2001 13:00:23
tagbarbeta2, 35.4200 mg
\ka
ka, 29.6460 mg
200
400
600
800
1000
°C
0
10
20
30
40
min
Lab: METTLER
METTLER TOLEDO STARe System


^exo
Tagbarbeta1
04.04.2001 12:40:51
\tagbarbeta2
tagbarbeta2, 35.4200 mg
50
°C
1
°Cmin^-1
0.1
mgmin^-1
1
mg
\SDTA tagbarbeta2,02.04.2001 13:00:23
tagbarbeta2, 35.4200 mg
200
400
600
800
1000
°C
0
10
20
30
40
min
Lab: METTLER
METTLER TOLEDO STARe System


\SC
SC, 58.8400 mg
SC, 18.11.1998 10:26:01
SC, 58.8400 mg
SDTA SC,18.11.1998 10:26:01
SC, 58.8400 mg
5
°C
2
mgmin^-1
10
mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min

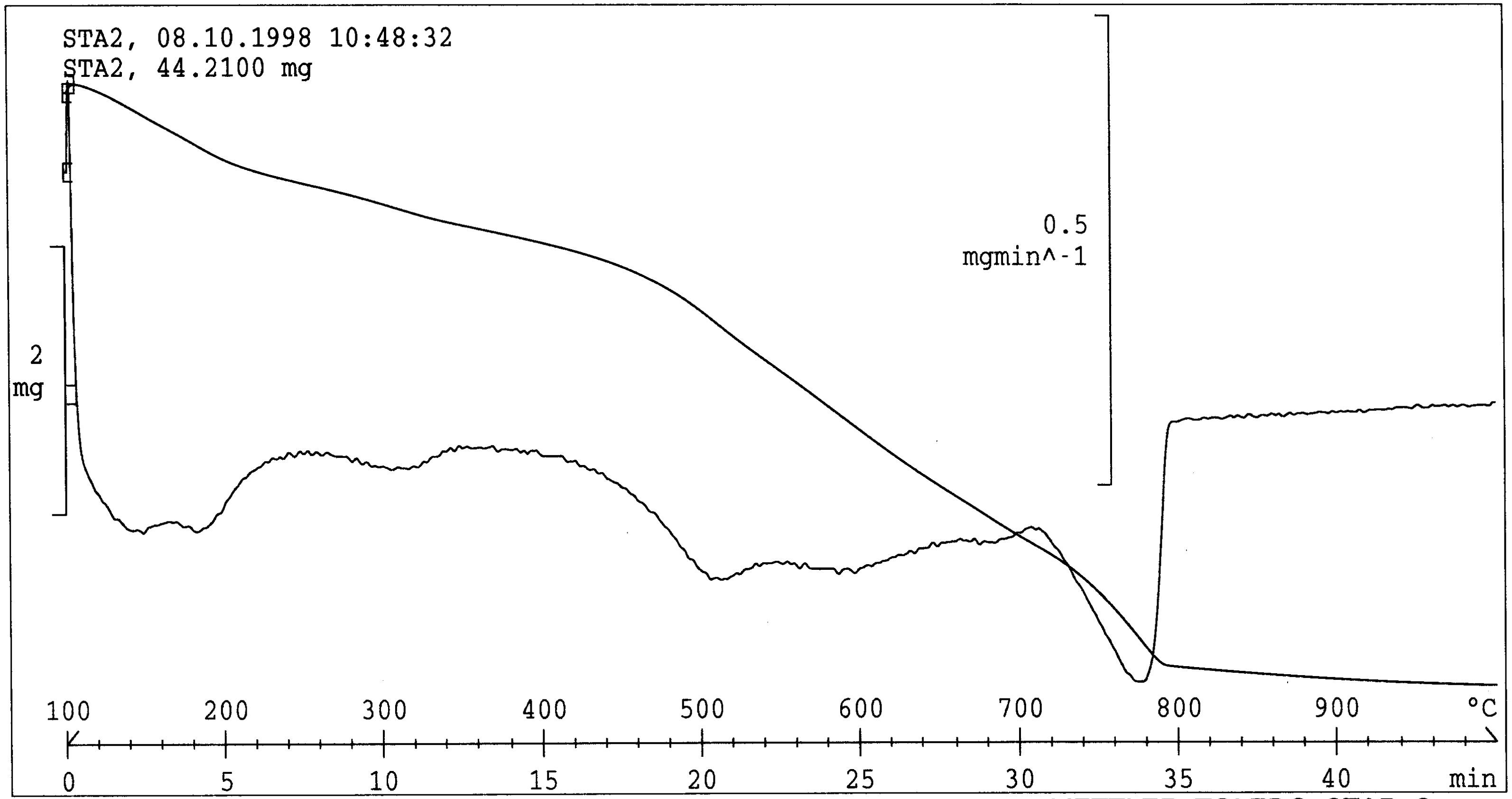

SC8P1, 15.11.1998 18:46:58
SC8P1, 30.8400 mg
SDTA SC8P1,15.11.1998 18:46:58
SC8P1, 30.8400 mg
\SC8P1
SC8P1, 30.8400 mg
1
mgmin^-1
2
°C
2
mg
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min


SC, 18.11.1998 10:26:01
SC, 58.8400 mg
SDTA SC,18.11.1998 10:26:01
SC, 58.8400 mg
SDTA SC8P1,15.11.1998 18:46:58
SC8P1, 30.8400 mg
\SC8P1
SC8P1, 30.8400 mg
\R
R, 47.9300 mg
\SC
SC, 58.8400 mg
R, 15.11.1998 18:44:34
R, 47.9300 mg
SDTA R,15.11.1998 18:44:34
R, 47.9300 mg
5
°C
2
mgmin^-1
20
mg
SC8P1, 15.11.1998 18:46:58
SC8P1, 30.8400 mg
100 200 300 400 500 600 700 800 900 °C
0 5 10 15 20 25 30 35 40 min


\SC8P1
SC8P1, 30.8400 mg
? Integral 0.94 mg
\R
R, 47.9300 mg
? Integral 7.84 mg
? Integral 0.25 mg
\SC
SC, 58.8400 mg
5
°C
2
mgmin^-1
20
mg
? Integral 26.01 mg
? Integral 29.47 mg
100 200 300 400 500 600 700 800 900 °C
0 5 10 15 20 25 30 35 40 min

STA2d

09.10.1998 11:01:05



UdG: GRM

METTLER TOLEDO STAR^e System

Tablas con resultados físico-químicos de todo el Grupo III según métodos utilizados en muestras AU y COV.

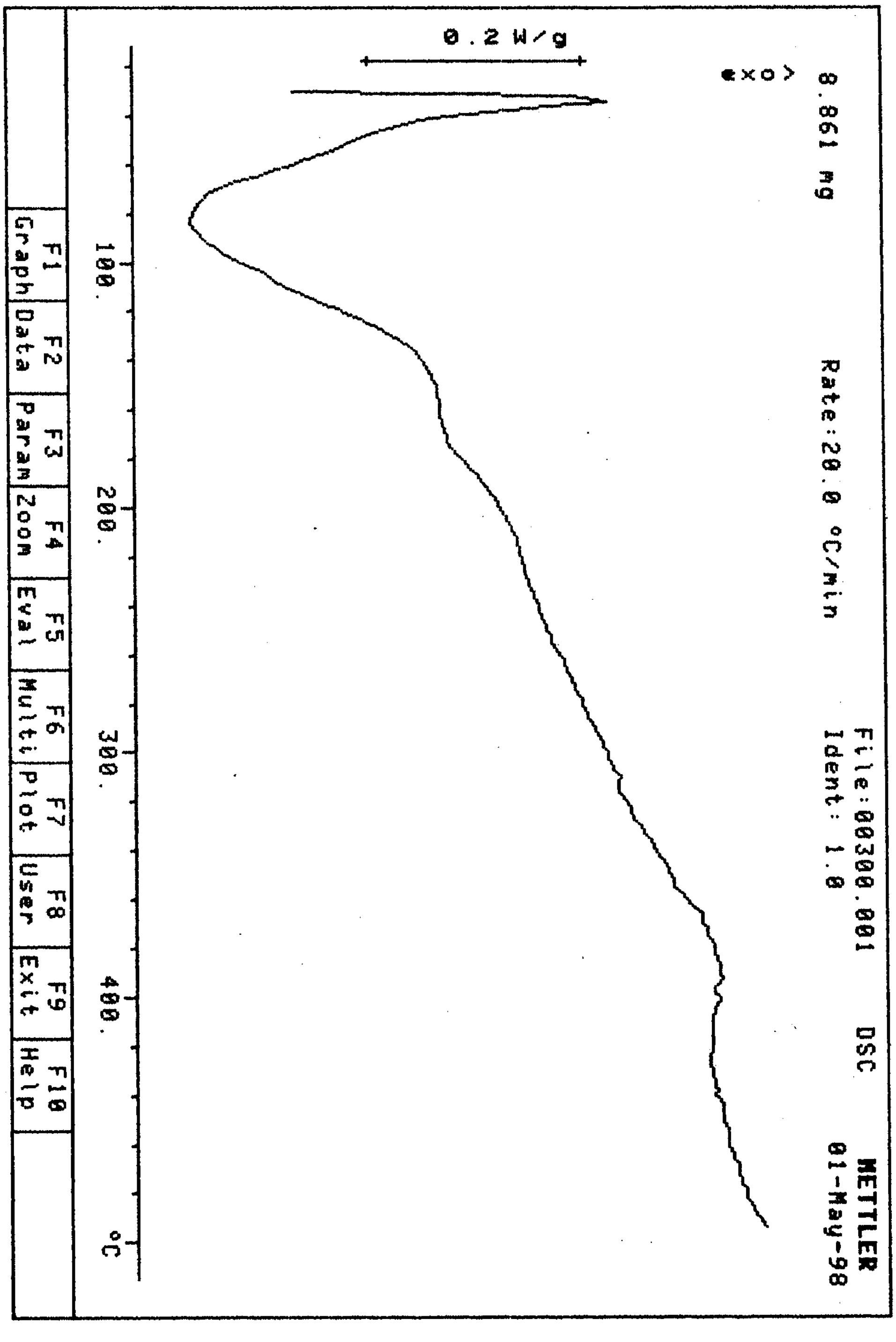
Terres2 granulometria.pdf

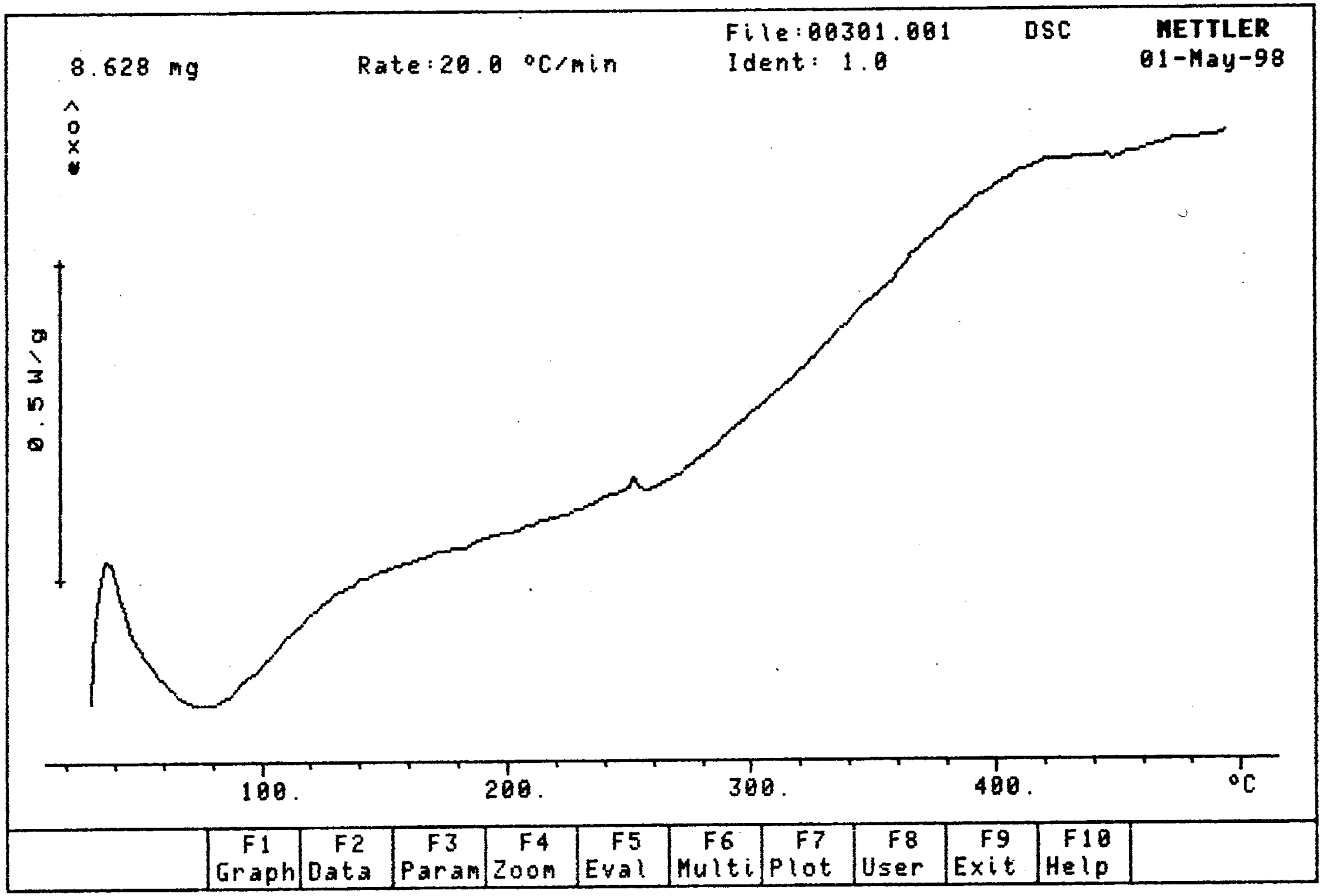
Terres2.pdf

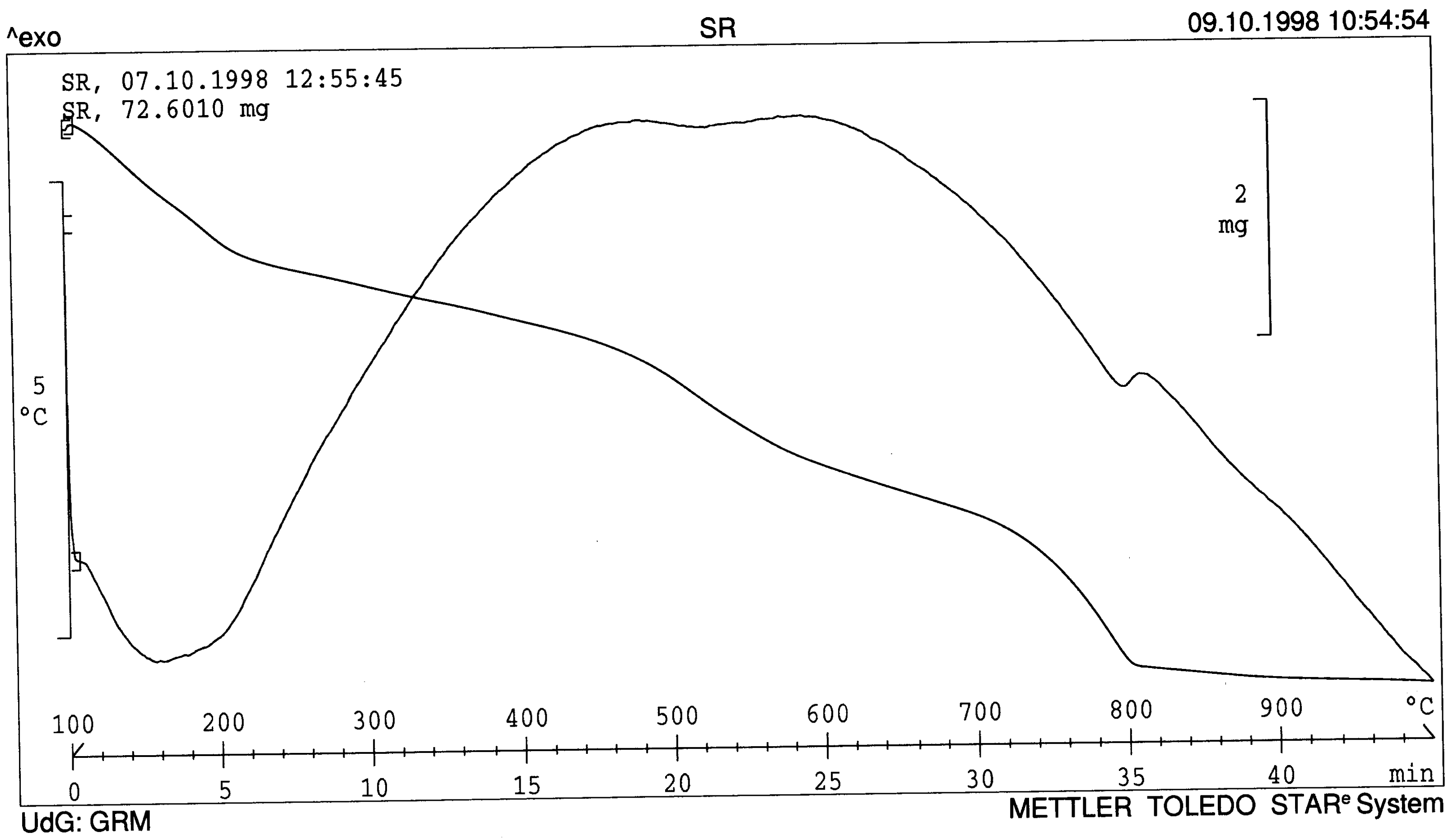
1.1.1. Análisis experimentales Tierras Grupo III

Análisis ATD

Grupo tierras Cubanas




8.628 mg
Rate:20.0 °C/min
File:00301.001
Ident: 1.0
DSC
METTLER
01-May-98
exo >
0.5 W/g
100.
200.
300.
400.
°C
F1 Graph
F2 Data
F3 Param
F4 Zoom
F5 Eval
F6 Multi
F7 Plot
F8 User
F9 Exit
F10 Help

^exo
SR
09.10.1998 10:54:54
SR, 07.10.1998 12:55:45
SR, 72.6010 mg
2
mg
5
°C
100
200
300
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min
UdG: GRM
METTLER TOLEDO STARᵉ System

ACIONAL
E LAVIVIENDA

DE BAJO CONSUMO

IMPERMEABILIZACION

SISTEMA DE IMPERMEABILIZACION DE CUBIERTAS
MEDIANTE MORTERO CENICONS

CODIGO:
I-02

FECHA:
JUNIO/92

DESCRIPCION TECNICA

onsiste en la conformación de una capa impermeabilizante en base a un mortero alierado, hidrófugo, de cemento PP-250, zeolita, cieno, arena y ceniza orgánica exraida de los hornos de ingenios azucareros mezclados con agua.

icho mortero se coloca sobre el enrajonado en la cubierta.

CAMPO DE APLICACION

ara impermeabilizar cubiertas planas e nclinadas en edificaciones.

ESPECIFICACIONES

- La capa de enrajonado tendrá una dosificación de una parte de cemento, una de cal apagada y veinticinco de material calizo.
- Se adicionará agua hasta obtener una consistencia pastosa-seca susceptible de ser compactada por medio de pisón; una vez creada.
- La dosificación del mortero aligerado es la siguiente:

cemento	zeolita	cieno	arena	ceniza	agua
1	3	1	3	3	3

- Ceniza orgánica: residuos de la combustión en calderas de los ingenios azucareros provenientes del bagazo de caña, limpio de impurezas y pasado por una zaranda no menor de 5 mm.
- Arena: arena sílice o arena de mina lavada, libre de partículas de arcilla u otras impurezas, granulometría uniforme, libre de piedras.

Cieno: (cal de carburo) desecho industrial de la planta de acetileno.

Zeolita: material procedente de yacimientos del territorio.

- Resistencia del mortero a los 28 días
  Flexión: 0,64 MPa
  Compresión: 3,3 MPa
- Los paños del mortero tendrán un ancho variable en dependencia a la tecnología constructiva donde se aplique. El espesor del mortero será de 0.04 m.
- Las juntas entre los paños serán solapadas, dicho solape será de 0,05 m donde se aplicará masilla asfáltica.

MATERIALES COMPONENTES

- Cemento PP-250
- Arena lavada
- Hidrato de cal (cal apagada)
- Recebo (material calizo)
- Zeolita peso específico 1,87 T/M3
- Cieno
- Ceniza orgánica

INDICES DE CONSUMO

- Para 1 m2;	
- Enrajonado	
cemento	4.0000 Kg
hidrato de cal	0.0030 Ton
recebo	0.0618 M3
- Mortero Cenicons	
cemento	8.3290 Kg
zeolita	28.9700 Kg
cieno	0.0052 m3
arena	0.01550 m3
ceniza orgánica	0.01550 m3
- Total de materiales por m2	
cemento	12.3290 Kg
hidrato de cal	0.0030 T
recebo	0.0618 m3
zeolita	28.9700 Kg
cieno	0.0052 m3
arena	0.0155 m3
ceniza	0.0155 m3

INSTITUTO NACIONAL DE LA VIVIENDA

CATALOGO DE SOLUCIONES ALTERNATIVAS DE BAJO CONSUMO

ELEMENTO: Cimiento corrido

CODIGO: C-07

FECHA: Mayo/92

CIMIENTO CORRIDO DE HORMIGON CICLOPEO UTILIZANDO COCOA.

DESCRIPCION TECNICA

Esta solución consiste en un cimiento corrido de hormigón ciclópeo donde se utiliza cocoa, material extraido en la zona de Puerto Padre. Sobre dicho cimiento se levantarán los muros de la edificación.

CAMPO DE APLICACION

- Este cimiento corrido se utilizara en viviendas de una sola planta con cubierta ligera.
- El cimiento servirá para distribuir los esfuerzos hacia el estrato resistente.

ESPECIFICACIONES

- Se utilizarán preferiblemente en suelos cuya capacidad admisible sea 100 Kpa (1kg/cm2) o más y donde las pendientes del terreno natural sean menores del 15%.
- La sección transversal de la cimentación para la que se calcularon los índices de consumo tiene las siguientes dimensiones:

  Ancho = 0,35 m
  Profundidad = variable, promedio 0,50 m.
- Dosificación del hormigón ciclópeo (1:24)
  (1 cemento, 15 arena, 9 cocoa) 60% rajón.
- Antes de levantar los muros se colocará sobre el cimiento ciclópeo un sello de mortero con dosificación cemento, arena, cocoa (1:4:2) de 0.02m de espesor como impermeabilizante para evitar que ascienda la humedad por el muro.

VENTAJAS

- El material(cocoa) que se extrae de la excavacion se utiliza para construir el hormigón ciclópeo.
- No se utiliza madera para encofrado.

MATERIALES COMPONENTES

- Cemento PP-250
- Arena de minas y ríos cernida
- Cocoa (material de mejoramiento)
- Rajón : cumplirá con la Norma Cubana NC-054-001-1978.

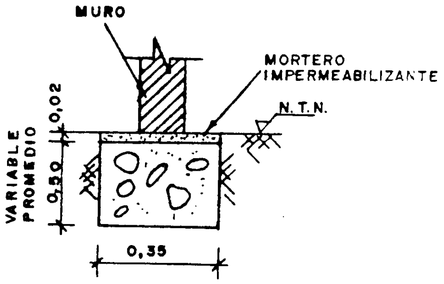
INDICES DE CONSUMO

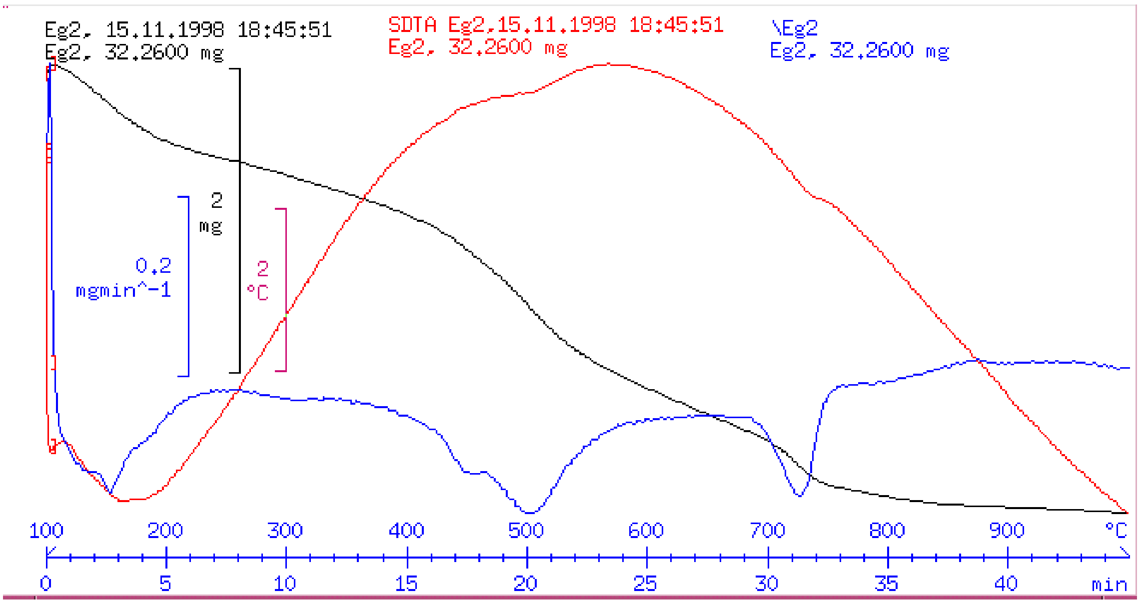
(Por metro lineal)

(Incluye el mortero de impermeabilización)

Cemento	:	9,03 Kg
Arena	:	0,0708 M3
Cocoa	:	0,0420 M3
Rajón	:	0,1628 M3

GRAFICOS




Eg2, 15.11.1998 18:45:51
Eg2, 32.2600 mg
SDTA Eg2,15.11.1998 18:45:51
Eg2, 32.2600 mg
\Eg2
Eg2, 32.2600 mg
2
mg
0.2
mgmin^-1
2
°C
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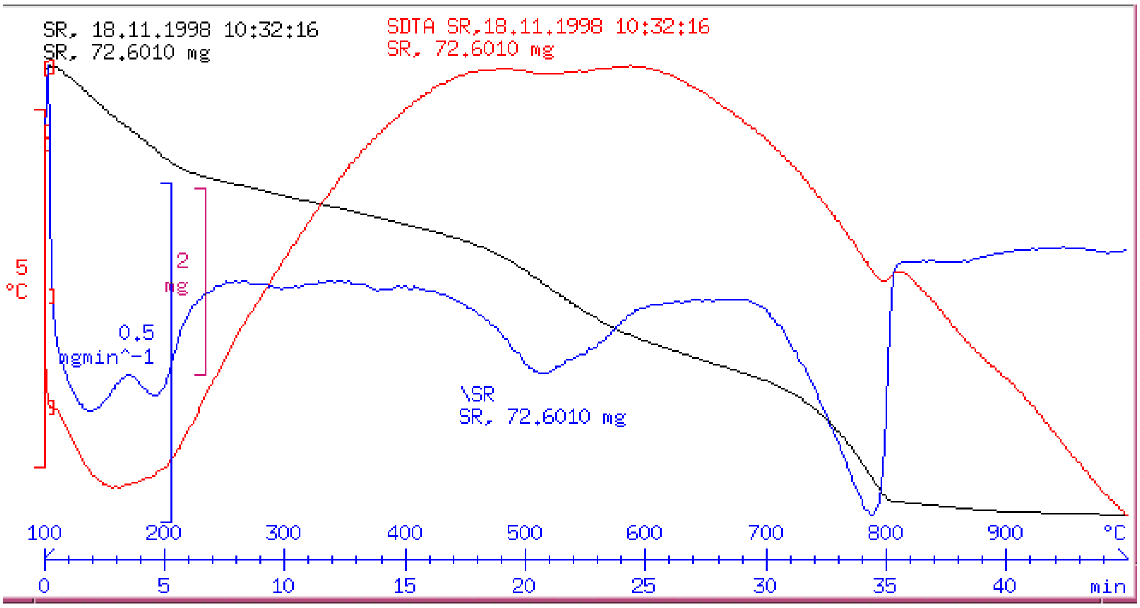
400
500
600
700
800
900
°C
0
5
10
15
20
25
30
35
40
min


SR, 18.11.1998 10:32:16
SR, 72.6010 mg
SDTA SR,18.11.1998 10:32:16
SR, 72.6010 mg
5
°C
2
mg
0.5
mgmin^-1
\SR
SR, 72.6010 mg
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400
500
600
700
800
900
°C
0
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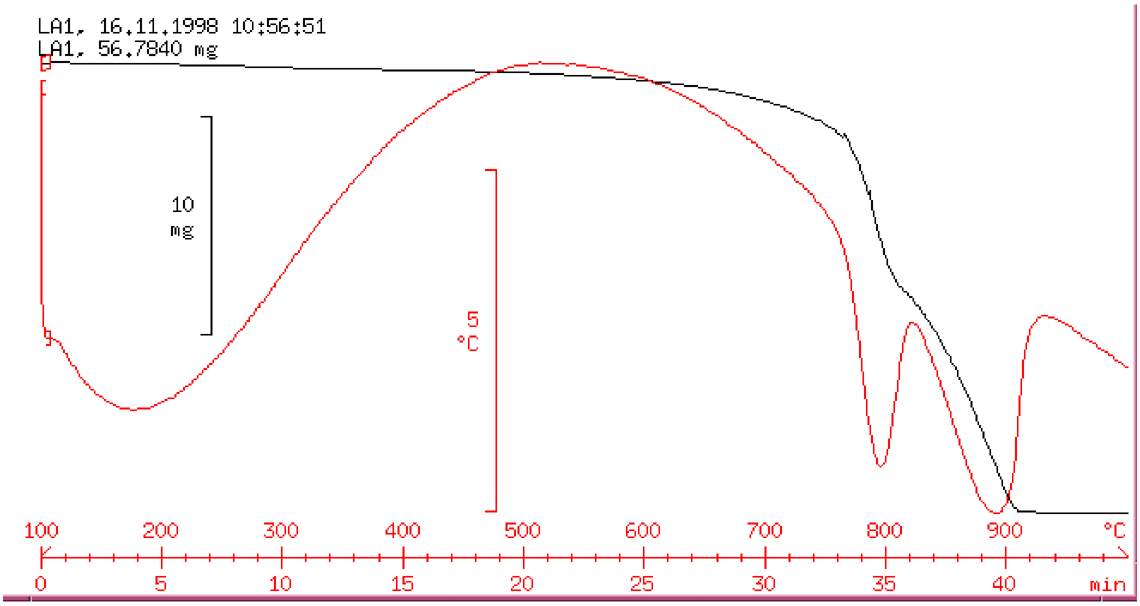
LA1, 16.11.1998 10:56:51
LA1, 56.7840 mg
10
mg
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°C
100
200
300
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500
600
700
800
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°C
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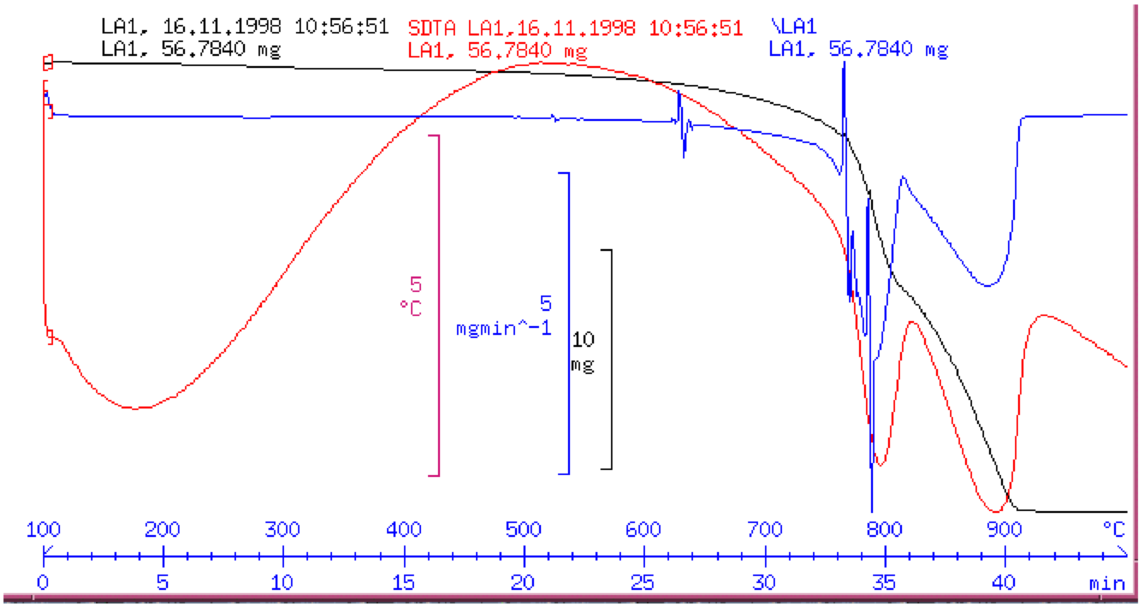
LA1, 16.11.1998 10:56:51
LA1, 56.7840 mg
SDTA LA1,16.11.1998 10:56:51
LA1, 56.7840 mg
\LA1
LA1, 56.7840 mg
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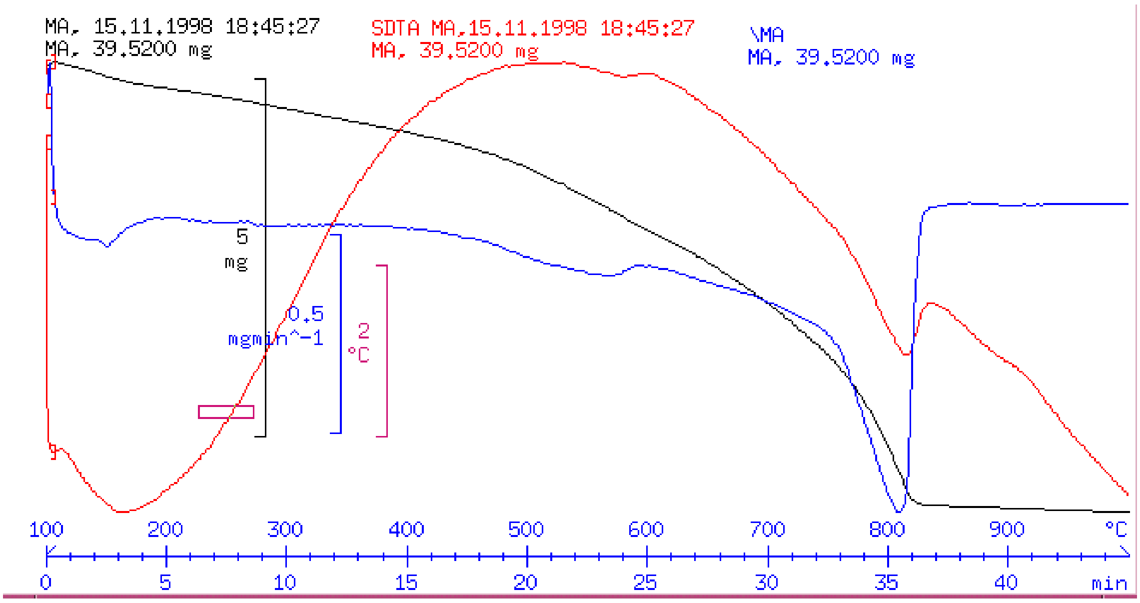
MA, 15.11.1998 18:45:27
MA, 39.5200 mg
SDTA MA,15.11.1998 18:45:27
MA, 39.5200 mg
\MA
MA, 39.5200 mg
5
mg
0.5
mgmin^-1
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min

Tablas con resultados físico-químicos de todo el Grupo II según métodos utilizados en muestras AU y COV.

1.1.2. Webs sobre soil-cement

The Earth Building Foundation, Inc.

P.G. McHenry
5928 Guadalupe Trail Northwest
Albuquerque, NM 87107
Phone: (505) 345-2613
email to: mchenry@unm.edu
Website: www.unm.edu/~mchenry

School of Architecture and Planning
University of New Mexico
Albuquerque, NM 87131
Phone: (505) 277-2903
Fax: (505) 277-7600

Effective August 1, 1998, the Earth Architecture Center, International, Ltd. has evolved into The Earth Building Foundation, Inc. a non-profit corporation, currently applying for tax-exempt status.

Our mission is simple:
Help people learn how to utilize earth building for better, safer, shelter.
Our new organization will allow a greater level of public service.

Accurate technical information on earthen building (adobe and rammed earth) is needed to show how this material really works. It is not now readily available to the people who need it, but The Earth Building Foundation can fill that need. Architects, engineers, planners, building officials, and owner builders need to have knowledge of this of this forgotten building art to meet the future.
The advantages of Earth Building are:

Available on-site, worldwide

Processed by the sun

Semi-skilled labor

Low energy cost

Ecologically best

A viable solution to low cost housing!

Earth Building Foundation News

Adobe Mini-FAQ

Come visit and sign our Guestbook

Significant Publications for Sale by EBF

Adobe, Rammed Earth, and Straw-Bale Building-Codes

SearchEBF - Our Bibliographic Database

Education, Workshops, Seminars, and Coming Events

EBF Purpose and Organization

EBF Services

EscAberta - Open School for Alternative Technologies. Escola Aberta de Tecnologias Alternativas. See a picture of a soil-cement brick class or a community garden...
--http://webwrite.com/partners.bsb-dc/escabert.htm

Frederick Derr & Company - Frederick Derr & Company. ROAD BUILDING AND SITE PREPARATION IN SARASOTA AND MANATEE COUNTIES. Whether you're out for a drive, or ready to hit your first..
--http://flying.fish.com/~lizd/fderr%26co/

Structural Mechanics - Civil Engineering - Structural Mechanics. General information, Strength of Materials. The Structural Mechanics group is also active in the assessment of stiffness and...
--http://www.bwk.kuleuven.ac.be/mechanics/research/stm.html

Special topic: Aggregates - AGGREGATES. Technical literature compilations. ITI topical bibliography for aggregates. None available at this time. TRB TRIS research abstracts: highways.
--http://iti.acns.nwu.edu/clear/high/hi_agg.html

LAUNCH CONTROL CENTER - LAUNCH CONTROL CENTER. If the Vehicle Assembly Building is the heart of Launch Complex 39, theLaunch Control Center is its brain. The LCC is a four-story..
--http://shuttle.nasa.gov/sts-74/shutref/sts-lcc.html

Open House - making bricks - During a class of the Open School for Alternative Technologies, these kids are learning how to make bricks using just soil, water and some cement, that...
--http://webwrite.com/partners.bsb-dc/openbrik.htm

CHL - State DOT Lettings - Delaware - Delaware Department of Transportation Advertisement for Bids. Checks should be made payable to the Department of Transportation. Additional copies of...
--http://www.contractorshotline.com/statedot/lettings/delaware.html

The use of recycled materials in highway construction - The Use of Recycled Materials in Highway Construction. by Robin L. Schroeder. Reproduced from Public roads v. 58, no. 2 (Autumn 1994), p. 32-41. Published.
--http://iti.acns.nwu.edu/clear/infr/pr_au94.html

Special topic: Pavement base courses - PAVEMENT BASE COURSES. Technical literature compilations. ITI topical bibliography for pavement base courses. None available at this time. TRB TRIS...
--http://iti.acns.nwu.edu/clear/high/hi_pbc.html

LTAP Video Alphabetical Index - Alphabetical Index of LTAP Videos. A D/C-129 Aesthetic Bridge Rails and Guardrails. 10 D/C-207 Aggregate Blends. 14 P/A-106 Agri Access Network. 30...
--http://www.dot.state.ga.us/homeoffs/training/techtran/t2_video/alphavid.htm

Lake Fork Project - Lake Fork Project. [Table of Contents | Index | Search this Site | About this Site | Comments] This project is located on Lake Fork Creek, a major...
--http://www.sra.dst.tx.us/projects/lfp.htm

Toledo Bend Project - Toledo Bend Project. [Table of Contents | Index | Search this Site | About this Site | Comments] This project is located in Louisiana and Texas on the...
--http://www.sra.dst.tx.us/projects/tbp.htm

CONSTRUCTION ENGINEERING TECHNICIAN - Construction Engineering Technician. Program of Study. Construction Engineering Technician | Full-Time Studies. Hours. Level: 01. 48.0. ESTIMATING I. 48.0.
http://www.algonquinc.on.ca/algweb/academic/constprg.html

Preservation of Historic Adobe Buildings - Preservation Brief 5: Preservation of Historic Adobe Buildings. Written by Sarah M. Sweetser U.S. Department of the Interior National Park Service...
--http://www.housenet.com/Articles/His_Pre/jl000050.htm

Webs sobre Ecobioconstrucción Sostenible.

La societat actual demana unes ciutats i uns edificis més respectuosos amb el medi ambient. Donar resposta a aquestes necessitats implica introduir paràmetres mediambientals a tot el procés constructiu, ja sigui a l'hora de projectar, en la tria dels materials o en l'execució de les obres.
Integrar paràmetres de sostenibilitat als edificis, espais urbans i infraestructures, és una necessitat, si volem reduir la incidència negativa que l'activitat constructiva té vers el medi ambient. L'Agenda de la Construcció Sostenible vol ser un punt de referència per als tècnics, constructors, fabricants, estudiants i tots aquells interessats a fer una construcció més sostenible i pretén donar resposta a les preguntes i necessitats que es tenen a l'hora d'intentar reduir els impactes de la construcció sobre l'entorn.

Realización:

Col·legi d'Aparelladors i
Arquitectes Tècnics
de Barcelona

Escola Tècnica Superior
d'Arquitectura del Vallès
Universitat Politècnica
de Catalunya

https://www.apabcn.es/sostenible

Adobe and Straw Bale Home Construction

By: Catherine Wanek

Could it be that the house of the future was invented a century ago? In the 1890s, pioneers of the sand hills of Nebraska found themselves building a new life on a treeless prairie, and from necessity began building their homes from bales of straw. Now modern day pioneers are choosing straw bale construction for its many advantages -for people and the planet.

Straw bales offer excellent insulation. At R 2.7 per inch, an eighteen-inch wide bale equals R-48. One California study indicated that such a "super-insulated" straw bale home could save as much as 75% of heating and cooling costs! This translates to direct dollar savings for the homeowner, and a corresponding reduction in the use of fossil fuels and CO2 emissions.

Construction costs can also be reduced when building with straw bales. They are cheap to buy and easy to build with. Stacked like huge bricks, straw bale wall systems can be erected quickly without much building experience and few power tools. In a "barn-raising" type party, it's common for all the straw bale walls in a modest size structure to be erected in a single day.

Building with bales can also cut down on cutting down trees by reducing lumber used in typical "stick frame" construction. Straw is available wherever grain crops are grown, and is annually renewable. In fact, it's considered an agricultural waste product, and in many parts of the world is simply burned in the fields. The millions of tons which go up in smoke every year cause a great deal of air pollution. It makes sense to bale this nuisance, and turn it into an energy-efficient resource.

Those concerned with indoor air quality also appreciate straw bale buildings for their "breathability." A non-toxic product itself, bales allow a gradual transfer of air through the wall, bringing fresh air into your living environment, especially when combined with a natural plaster. And you can forget about neighborhood noise, too. Straw bales are so sound proof, one Nebraska pioneer family was found playing cards in their kitchen, oblivious to the roar of a tornado which had just blown through the town.

Two types of bale wall systems are commonly built. In a "post and beam" building, a wood, steel, or concrete framework Is erected and bales are placed in the walls as insulation. Bale systems can also bear the weight of the roof, as evidenced by the historic Nebraska homes which were all load-bearing. In this case, a top-plate is laid above the bale wall and secured to the foundation by metal rods and/or strapping. The roof is then attached to the top plate. In either system, the bale courses are stacked in a "running bond," and pinned with rebar, wood, or bamboo stakes. For added strength, chicken wire is commonly wrapped inside and out, and sewn tight to the bales. Then an earth plaster or cement stucco is applied as a finish. However, bales will also hold plaster without wire mesh.

Under the watchful eye of instructor Peter Fust, an EPSEA workshop student restrings bale to make 2 half bales.

Common questions about straw bale homes include concerns about fire, moisture, and insects. While individual stalks of straw will burn, when condensed into bales, they actually resist combustion, due to lack of oxygen. It's like trying to burn a phone book. At a certified laboratory in New Mexico, a plastered straw bale wall system easily passed a two-hour fire test, which is required for commercial construction. Liquid moisture is a problem in bale walls, as it is in any wall system. But with a proper foundation, roof, and finish plaster, straw bale buildings can last indefinitely, as nearly century-old homes in Nebraska prove. Anecdotal evidence indicates no problem with bugs.

Building codes have been developed for both "post and beam" and load-bearing straw bale construction. In New Mexico, Pima County, AZ, and several counties in California, getting a building permit for a straw bale house is almost routine. Farmers Insurance Group will insure a bale home at preferred rates and other companies are following suit. And straw bale houses are gaining acceptance with Fannie Mae and HUD.

To contact Catherine Wanek:

Black Range Films
Star Rt. 2, Box 119 Kingston, NM 88042
505-895-5652.
E mail: blackrange@zianet.com.

Black Range Films has released its third video in a series on "Building With Straw Bale". Their latest production Straw Bale Code Testing will assist anyone, including code officials in dealing with the permitting process.

The Black Range is now the publisher of "The Last Straw" newsletter.

More LINKS to Straw

Introduction to The Last Straw: http://www.netchaos.com/tls/index.html

The Last Straw
http://www.strawhomes.com/

http://www.ecodesign.bc.ca/straw.htm

Burbophobia

Nice collection of general strawbale information, plus strawbale happenings in the Rocky Mountain West.
http://www.pcisys.net/~moxvox/straw.html

DOE Straw Bale Housing Experiment http://www.eren.doe.gov/EE/strawhouse/house-of-straw.html

Strawbale Mailing List http://crest.org/efficiency/strawbale-list-archive
To subscribe, send mail to strawbale-request@crest.org. No specific Subject or body is required. You will receive
instructions and a description of the mailing list.

The Thermal Resistivity of Straw Bales for Construction
Joe McCabe's master's thesis
http://solstice.crest.org/efficiency/straw_insulation/straw_insul.html

Greenbuilders Sustainable Building Sourcebook:, Strawbale Construction
http://www.greenbuilder.com/sourcebook/strawbale.html

Development Center for Appropriate Technology's website:
"Addressing Institutional Barriers to Straw Bale Construction"
http://www.azstarnet.com/~dcat/barriers.htm

Straw Composite Systems
http://www.cstone.net/edc/html/grsb.htm

Surfin Strawbale Links List
http://mha-net.org/html/sblinks.htm

New Mexico Straw Bale Code http://www.unm.edu/~eai/nm-straw-bale-code.html

Straw Bale Association of Texas (SBAT):
P.O. Box 4211 Austin, TX 78763-4211
512-302-6766
http://www.io.com/~whtefunk/sbat.htm

Draft Code for Tucson/Pima County Arizona
http://www.xmission.com:80/~shea/straw/code.html

Straw Bale House:
A Straw Bale student project. http://www.sccs.swarthmore.edu/~csunami1/straw.html

A commercial web page for Straw House Herbals has a couple of pages on Straw Bale construction
http://www.cfn.cs.dal.ca/~aa983/strawbale.html

Out On Bale By Mail/Dawn
1039 E. Linden St.
Tucson, AZ 85719

520-624-167
http://www.greenbuilder.com/dawn

http://www.epsea.org/straw.html

Webs sobre CEM

http://www.who.int/

Campos Electromagnéticos y Salud Humana

MEDICAL COLLEGE OF WISCONSIN

John E. Moulder, Ph.D.
Professor of Radiation Oncology

http://www.mcw.edu/gcrc/cop/lineas-electricas-cancer-FAQ/QandA.html
Autor: *John Moulder, pH.D.*
Versión española: Traducida al español por Juan Bernar y Pilar Membrillera (UNESA-AMYS), y Carlos Llanos (Red Eléctrica de España).
Esta traducción no ha sido revisada por el Dr. Moulder.

http://members.es.tripod.de/campselectrics/INDEX3.htm

Congresso Brasileiro de Eletromagnetismo - CBmag
http://www.cpdee.ufmg.br/~sbmag/eventos.html

Instituto Nacional de Higiene, Epidemiología y Microbiología
ANALISIS DEL CAMPO ELECTROMAGNETICO EN CIUDAD DE LA HABANA
Lic. Jesarely Hernández Escrivá[1] *y Dr. Carlos Barceló Pérez*[2]
Licenciado en Física. Aspirante a Investigador.
Doctor en Ciencias Físicas. Investigador Auxiliar. Profesor Auxiliar.
RESUMEN
Con el objetivo de valorar la exposición de la población al campo electromagnético, a cuenta de las transmisiones civiles en Ciudad de La Habana, se efectuaron los cálculos teóricos de propagación de ondas en la gama de frecuencias medias, cortas y ultracortas en modulaciones de amplitud, frecuencia y pulso, y se obtuvieron estimaciones de las zonas de protección sanitaria y límite de construcción a partir de normas europeas

http://infonew.sld.cu/revistas/hie/hie09296.htm

What Is EMF? by Matt Dicke
http://gilligan.esu7.k12.ne.us/~lweb/NEBWEB/opinion/emfdicke.html

Starting Points: Scientific Resources
Good Links for Scientific Research of EMF "Good Articles!!"
http://library.niehs.nih.gov/start.htm (13K)
EMF
ViaTech Engineerinf Inc. Hompage with excellent researches done on EMF. Also surveys and summaries of other articles
http://lute.qnet.com/~emf/ (2K)
Electro Magnetic Fields and Public Health
Lots of links and studies and papers done on EMF

http://www.math.albany.edu:8008/EMF.html (6K) Questions and Answers About EMF and Electric Power
EMF Link Page
http://infoventures.microserve.com/private/federal/q&a/cover.html (3K)

Oversensitivity to Electricity
A EMF group project homepage Good research
http://www.isy.liu.se/~tegen/emf_info.html (2K)

Oversensitivity to Electricity
Excellent Links for Emf research!!
http://www.isy.liu.se/~tegen/refs.html (18K)

Current Literature; EMF-Link
EMF-Link Original papers of published scientific research
http://infoventures.microserve.com/emf/currlit/currlit.html (8K)
EMF-Link
Everything you need to now could be accessed through this homepage "EMF-Link provides substantial information of biological and health effects of electrical and magnetic fields"
http://infoventures.microserve.com/ (4K)

EMF-Link Text-Only Home Page "EMF-Link provides substantive information on biological and health effects of electric and magnetic fields"
http://infoventures.microserve.com/txt-only.html (3K)
EMF News
California Public Health Foundation RFP for Assessment of Exposure to EMFs in Schools
http://infoventures.microserve.com/emf/news/news.html (4K)
Radiation Protection Homepage
Top 5% of all homepages! Very Cool! Has a lot of information on EMF
http://www-personal.umich.edu\~bbusby

Dr. Orlando Morales Matamoros omorales@sol.racsa.co.cr
Ensayos: Ciencia y Tecnología
Dr. O. Morales: Índice   Home Page Edyd.com
Campos Electromagnéticos y Salud Humana - Informe Matamoros 1997,

Webs relacionadas con el Tapial:

8º Congress International Terra 2000. Univ.Plymouth March. 2000

J.Garcia@plymouth.ac.uk

Congreso Internacional de Construcción con Tierra. Madrid 30 de noviembre de 1999. ONGD Interacción.
--http://www.ctv.es/USERS/interacc/
--http://www.ctv.es/USERS/interacc/CURSOS.html

Fuendetodos - Fuendetodos. Fuendetodos está situado en el NE de España a 44

km de Zaragoza a una altitud de 750 m. Su término mide 61,7 km2....
--http://goya.unizar.es/InfoGoya/Aragon/Fuendetodos.html
Paisaje urbano de Fuendetodos - Paisaje urbano de Fuendetodos. El pueblo de Goya conserva en sus construcciones una calidad estética considerable, con rincones llenos de encanto y.

Las casas, de una o dos plantas, se levantan en **tapial** o adobe, y, modernamente, en ladrillo. Detrás se encuentran los patios y corrales. La casa común consta de vivienda, patio con dependencias para ganado-pocilga, almacén para cosecha y útiles de.
--http://www.lesein.es/aytopajares/casas.htm

--http://www.adi.uam.es/~jsmsguer/metodo.html
Castell d'Almonesir - Castell d'Almonesir. FOTOGRAFIA MAPA. - español - - English - Terme Municipal : La Vall d'Almonesir, limitant amb el d'Algímia de Almonesir..
--http://www.ilimit.com/main/almonecir/

Escala de intensidad MSK - ESCALA DE INTENSIDAD M.S.K.(1964) Efectos que definen los grados de intensidad MSK. a) Los efectos sentidos por las personas y percibidos en su medio...
--http://www.ugr.es/iag/msk.html

La Ciudad de Palencia - En el sur de la provincia y en la margen izquierda del río Carrión se asienta la ciudad. Ocupa la vertiente de un terreno terciario que...
--http://194.133.10.49/palencia.htm

No Title - PUBLICACIONES Arguedas Conocimiento y vida Carmen Maria Pinilla Lima: Fondo Editorial de la PUCP, 1994 284pp. El presente libro trata de explicar el exito.
--http://pucp.edu.pe:70/0/pucp/pucp.bol/pucp.bol.2/pucp.bol.public

Ramon Prior Canales - Menú - English - Castellano. Dibuixant -S'ha especialitzat en temes d'arquitectura antiga i popular que encara es conserva en zones del norest...
--http://nuvol.uji.es/~bort/estudios/informes/casaeco.html

LaSalle Banks 5k Results - Back to News Table of Contents. LaSalle Banks 5k Results. --PART.BOUNDARY.0.15677.emout04.mail.aol.com.846002735. Content-Transfer-Encoding:...
--http://www.runningnetwork.com/ChicagoAA/results/3.html

Ramon Prior Canales - Menú - Català - English. Dibujante - Se ha especializado en temas de arquitectura antigua y popular que todavía se conserva en zonas..
--http://www.6tems.grn.es/prior/Cast.html

Arte - Arte. Pequeña villa manchega, que debe buena parte de su fama a la obra cervantina, El Toboso alberga entre sus calles y plazas monumentos

de...
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Métodos y Normas

A continuación se exponen las normas referenciadas en la Tesis, de las cuales se han extraído conocimientos para la elaboración del método propio.

CDU 624.131.3 Junio 1975

NORMA ESPAÑOLA	Toma de muestras superficiales de suelo de tipo inalterado	UNE 7-371-75

Instituto Nacional de Racionalización y Normalización (IRANOR) — Serrano, 150 — Madrid (6) — Teléfono 261 70 00 — Reproducción prohibida

1 OBJETO

Esta norma tiene por objeto establecer la forma de obtener muestras de suelos cohesivos, que conserven la estructura y humedad que tienen en su estado natural, cuando pueden tomarse en superficie o a una profundidad a la que se pueda llegar abriendo un pozo o galería.

2 MATERIAL NECESARIO

2.1 Herramientas para tallar la muestra, adecuadas al terreno de que se trate (paleta, cuchillos, martillo, cincel, sierra de alambre, etc.).

2.2 Parafina, vendas de malla abierta y brocha para aplicar la parafina.

2.3 Recipiente y hornillo para calentar la parafina.

2.4 Caja para embalaje de dimensiones algo mayores que las de la muestra que se pretende obtener (tamaños normales suelen ser muestras cúbicas de 20 ó 30 cm de lado). O bien, en su caso, cilindro tomamuestras de filo cortante (de 13 cm de diámetro por 13 cm de altura, aproximadamente).

3 PROCEDIMIENTO OPERATORIO

3.1 Muestra en bloque de la superficie del terreno, o del fondo del pozo o galería.

3.1.1 Se descubre la capa de la que se pretende obtener la muestra bajando la excavación la profundidad precisa para que el terreno descubierto esté completamente fresco y no haya, por tanto, perdido nada de humedad. Se alisa su superficie, marcando el contorno de lo que ha de ser cara superior de la muestra.

3.1.2 Se excava *(figura 1)* una pequeña zanja alrededor de la marca, dejando entre el borde de la muestra y el borde interior de la zanja unos 10 cm con el fin de que las operaciones de apertura de la zanja, que cuando la consistencia del terreno lo permite pueden hacerse con pico y pala, no perturben la muestra. La anchura de la zanja debe ser suficiente para que permita al operario el trabajo de tallado, parafinado y obtención.

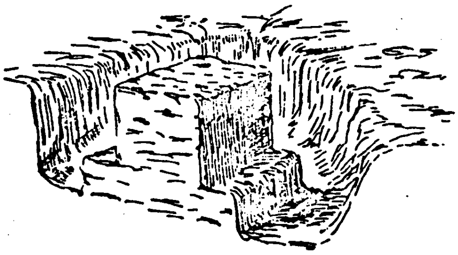

Fig. 1

3.1.3 A continuación se procede con las herramientas más apropiadas a la naturaleza de la muestra (paleta, cuchillos, martillo y cincel, etc.) a darle la forma cúbica y el tamaño final que ha de tener, procurando poner más cuidado a medida que se está más cerca de la superficie final, con el fin de evitar que se pueda alterar la muestra. Con estas precauciones se tallan la cara superior y las cuatro caras laterales, quedando la muestra en la forma en que puede verse en la *figura 1.*

3.1.4 Si la muestra tiene bastante consistencia, se corta por el fondo con los cuchillos; se le da la vuelta y se talla la cara inferior, procediendo a parafinarla de la siguiente manera: se le da una primera capa de parafina y a continuación una capa de vendas y la segunda capa de parafina; se aplican sucesivamente nuevas capas de venda y parafina hasta obtener un recubrimiento suficientemente sólido e impermeable del orden de 3 mm de espesor. Las vendas sirven de protección a la muestra y de armadura a la parafina, con lo que se evita su descascarillado y agrietamiento.

3.1.5 Si la muestra no tiene bastante consistencia, una vez talladas la cara superior y las cuatro caras laterales y antes de desprenderla del terreno por su parte inferior, deben parafinarse las caras talladas en la forma indicada en el párrafo anterior; a continuación se sujeta con la caja de embalaje, como indica la *figura 2,* y después de desprenderla por su parte inferior, se le da la vuelta con ayuda de la caja y se talla y parafina la cara inferior en la forma indicada.

3.1.6 Cuando sea de temer una pérdida apreciable de humedad en la muestra durante las operaciones de talla-

Continúa en páginas 2 a 3.

Las observaciones relativas a la presente norma deben ser dirigidas al
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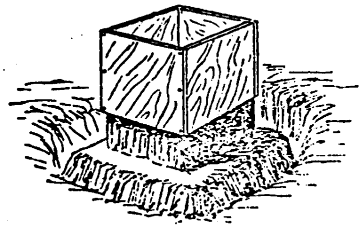

Fig. 2

do, bien porque dé el sol directamente sobre la misma, o por sequedad del clima, es conveniente dar la primera capa de parafina a cada una de las caras inmediatamente después de haber sido tallada dicha cara, terminando las operaciones de parafinado después de desprender la muestra por su parte inferior, o bien si la muestra no tiene bastante consistencia, como se ha indicado en el párrafo anterior.

3.1.7 El embalaje de la muestra dentro de la caja de madera debe hacerse de forma que quede perfectamente sujeta y no se mueva dentro de ella durante su transporte, para lo cual se verterá parafina fundida entre la muestra y la pared de la caja si el hueco no es muy grande. En caso de que quede mucho volumen a rellenar con parafina, puede utilizarse aserrín, viruta, papel de periódico, etc., todo ello debidamente colocado para que la muestra no se mueva dentro de la caja.

3.1.8 Antes de cerrar la caja, se etiqueta el bloque de muestra con los siguientes datos:

Indicación clara de cual es la cara superior y cuál la inferior.

El lugar de procedencia, situación y profundidad.

Cualquier otro dato que se estime conveniente.

Después se cierra la caja, se etiqueta exteriormente con los mismos datos y se coloca, además, en sitio bien visible, un cartel que diga que la muestra no debe ser golpeada.

3.2 Muestra en bloque de la pared del pozo o galería

3.2.1 Se rebaja la pared escogida hasta que el terreno descubierto conserve sus condiciones originales de humedad y estructura. Se efectúa un primer tallado hasta dejar el bloque como se indica en la *figura 3.* Como la cara posterior de la muestra es muy difícil de tallar antes de desprenderla por su parte inferior, hay que hacerlo una vez desprendida. El resto de las operaciones se realiza como se indica en el *apartado 3.1.*

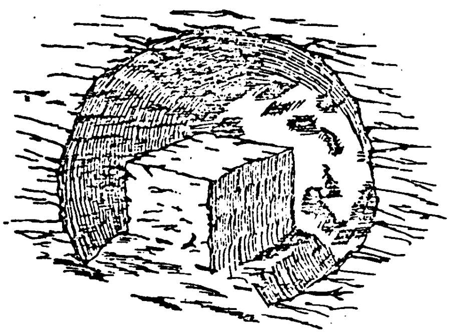

Fig. 3

3.3 Muestra con tomamuestras de filo cortante

3.3.1 Si la muestra está fisurada, es preciso obtenerla con un cilindro tomamuestras para poder tallar las probetas en el laboratorio con un extractor especial.

El mismo sistema puede ser recomendable cuando se trate de suelos muy blandos y es desde luego aplicable a cualquier tipo de suelo cohesivo sin grava.

La hinca del tubo se puede hacer presionando, o golpeando suavemente con un mazo de madera sobre un durmiente también de madera, como se indica en la *figura 4.* En todo

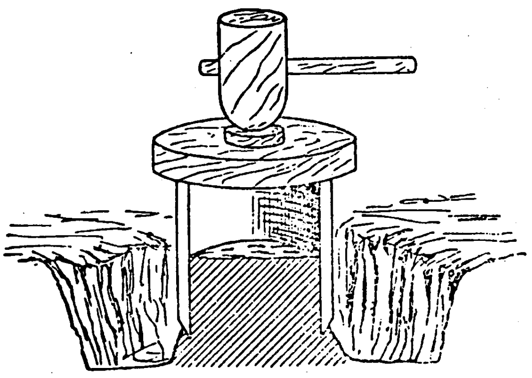

Fig. 4

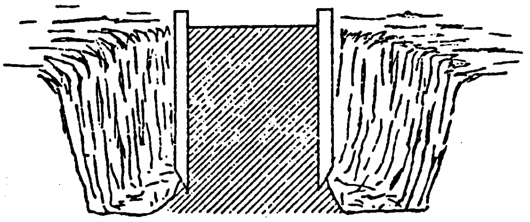

Fig. 5

caso los esfuerzos deben ser centrados para evitar que el tubo cabecee, lo cual podría agrietar la muestra.

A medida que el cilindro va introduciéndose se le ayuda excavando y retirando el suelo que queda por la parte de fuera para evitar rozamientos inútiles. En algunos casos puede ser conveniente llevar la excavación un poco por delante del filo del tubo para que entre con mayor facilidad. Este procedimiento debe utilizarse solamente cuando la muestra sea apropiada, pues en muchos casos puede existir el peligro de agrietado.

3.3.2 Durante la hinca del cilindro debe vigilarse con sumo cuidado que éste no llegue nunca a golpearse estando totalmente lleno, para evitar la compactación del suelo que ha de constituir la muestra; si se advierte en alguna ocasión que el suelo ha sido golpeado en estas condiciones, debe desestimarse la muestra y tomar otra en las proximidades.

3.3.3 Cuando al cilindro le falte un centímetro aproximadamente para llenarse *(figura 5)*, se corta por la parte inferior, se enrasa esta cara y se parafinan ambas caras de la misma forma que se indicó para las muestras cúbicas, con la ayuda de venda.

Se colocan las etiquetas como se indicó también para las muestras cúbicas, y en caso de que haya que transportarlos, se embalarán en un cajón de madera, rellenando con material que amortigüe los golpes y ligeramente humedecido.

Las muestras así preparadas pueden enviarse al laboratorio de ensayo.

4 CORRESPONDENCIA

Concuerda totalmente con la norma NLT 203/72.

CDU 624.131.3

Abril 1975

NORMA
ESPAÑOLA

Preparación de muestra para los ensayos de suelos

U N E
7 - 327 - 75

1 OBJETO

La presente norma tiene por objeto establecer el procedimiento para obtener la cantidad de muestra necesaria para los distintos ensayos, de forma que sea representativa de la total recibida en el laboratorio.

2 APARATOS Y MATERIAL NECESARIOS

2.1 Balanza de unos 10 kg de capacidad de carga en un platillo y 1 g de sensibilidad.

2.2 Un cuarteador para áridos gruesos y otro para finos. Una lona de 2 x 2 m y 2 barras de 2,5 m.

2.3 Cedazo 20 UNE 5 050 y tamices 5,2 y 0,40 UNE 7 050.

2.4 Mortero con manilla que tenga goma en su parte inferior a un mazo de goma.

2.5 Pala o paleta para manejar el material.

3 PROCEDIMIENTO OPERATORIO

3.1 Preparación de la muestra antes del cuarteo

3.1.1 Se seca la muestra al aire colocándola extendida.

3.1.2 Se desmenuza el material deshaciendo los terrones por medio del mortero o mazo de goma.

3.1.3 **Observaciones.** Como regla general, no debe realizarse el secado en estufa de las muestras para ensayo, porque puede influir en los resultados de los ensayos. Se admite, sin embargo, el empleo de secadores con circulación de aire frio o calentado a menos de 60° C, sobre todo en invierno.

3.2 Realización del cuarteo

3.2.1 Se divide la muestra en dos partes aproximadamente iguales, manteniéndose en ellas la composición original. Se repite la operación en una de ellas y así sucesivamente hasta obtener la cantidad que se necesita.

3.2.2 Cuando se dispone de aparato de cuarteo, para dividir una muestra en dos partes, basta pasarla por dicho aparato.

3.2.3 Tratándose de muestra con tamaños superiores a la abertura del aparato, se opera con una lona sobre la cual se coloca la muestra original previamente homogeneizada por paleo y convenientemente extendida; después se meten entre la lona y el suelo dos barras perpendiculares entre sí y cruzándose por el centro de la muestra. Levantando simultáneamente ambas partes del suelo, la muestra queda dividida en cuatro partes iguales. De estas cuatro partes se hacen dos reuniendo las situadas en cuadrantes opuestos.

3.2.4 Cuando la cantidad de muestra es apropiada para ello, puede operarse encima de una mesa con una paleta o espátula, siguiendo un criterio análogo al descrito en el *párrafo 3.2.1.*

3.3 División de una muestra en dos fracciones por medio de un tamiz

3.3.1 Se pasa la muestra por el tamiz de que se trate. Se disgregan los terrones que aún quedaran sin desmenuzar en la fracción retenida y se tamiza de nuevo reuniendo lo que pase con la misma fracción del primer tamizado. Se repite esta operación cuantas veces sea preciso hasta dejar el material retenido bien limpio de finos.

3.3.1.1 **Observación.** En los casos difíciles resulta útil subdividir lo retenido, mediante tamices, en dos o tres tamaños, con objeto de facilitar la limpieza con el mazo de goma.

3.3.2 En general, cuando se tamice una muestra representativa (ya cuarteada) para obtener otra fracción más fina, también representativa, se ha de tamizar hasta terminar la operación con toda ella. Aunque se obtenga antes la cantidad de muestra necesaria para los ensayos a realizar, debe seguirse el tamizado hasta el final.

3.4 Muestra precisa para los distintos ensayos

3.4.1 Para el análisis granolométrico la cantidad necesaria depende de la proporción entre finos y gruesos (que pasen o no por el tamiz 2 UNE 7 050) y del tamaño máximo del material, con objeto de que sea cantidad suficiente para poderla considerar representativa. A conti-

Continúa en página 2

Las observaciones relativas a la presente norma deben ser dirigidas al
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nuación se dan unos valores que pueden servir de orientación.

Tamaño máximo mm	Cantidad minima retenida en el tamiz 2 UNE 7 050
10	500 g
20	1000 g
25	2000 g
40	3000 g
50	4000 g
80	5000 g

La fracción que pasa por el tamiz 2 UNE 7 050 debe ser superior a 120 g en suelos arenosos y a 60 g en los arcillosos.

Al operar en el análisis granulométrico la muestra cuarteada se tamiza por el tamiz 2 UNE 7 050. De la fracción fina obtenida en esta operación se toma la muestra necesaria para otros ensayos de identificación.

3.4.2 Para los ensayos de **Límites de Atterberg** se separa el material que pasa por el tamiz 2 UNE 7 050, siguiendo el procedimiento descrito en el *apartado 3.3.* Dicho material se tamizará después, siguiendo el mismo procedimiento, por el tamiz 0,40 UNE 7 050. La cantidad de muestra inicial será tal que pasen unos 100 g por el tamiz 0,40 UNE 7 050.

3.4.3 Para el ensayo del equivalente de arena, se separa por cuarteo la cantidad necesaria para que tenga unos 150 g de la fracción que pasa por el tamiz 5 UNE 7 050 y se tamiza por dicho tamiz según la técnica del *apartado 3.3.*

3.4.4 Para el ensayo de apisonado se separa por cuarteo de la muestra original la cantidad necesaria para que contenga unos 15 kg de material inferior al tamiz 20 UNE 7 050, si se utiliza el molde de 1 000 cm^3, o unos 35 kg si se utiliza el molde grande. Se tamiza por dicho tamix siguiendo la técnica del *apartado 3.3.*

3.4.5 En general, para cualquier otro ensayo se seguirá el siguiente criterio: se separa por cuarteo de la muestra original la cantidad necesaria para que contenga de la fracción a utilizar la que se precisa para el ensayo. Si el ensayo se realiza con una fracción inferior al tamaño máximo de la muestra original, se tamiza por el tamiz correspondiente según la técnica del *apartado 3.3.*

4 OBSERVACIONES

Las operaciones de secado, (*párrafo 3.1.1*) disgregación (*párrafo 3.2.2*) y cuarteo (*apartado 3.2*) pueden suprimirse todas o algunas de ellas en los siguientes casos:

1º – Todas: cuando el suelo es claramente homogéneo y de tales características que la muestra puede tomarse directamente por no existir peligro de segregación.

2º – Las dos primeras: cuando su disgregación natural hace posible el cuarteo en perfectas condiciones.

3º – La primera: cuando con su humedad natural se puede hacer la disgregación de los terrones.

Las operaciones suprimidas en el tratamiento de la muestra original deben realizarse con la muestra separada por cuarteo, si fuera necesario.

Apartado 3.3.1. En los casos difíciles resulta útil subdividir lo retenido, mediante tamices, en dos o tres tamaños con objeto de facilitar la limpieza con el mazo de goma.

5 CORRESPONDENCIA

Concuerda con ASTM D 421 y NLT–101/72.

NORMA DE ENSAYO
DEL
LABORATORIO DEL TRANSPORTE
Y MECANICA DEL SUELO
"JOSE LUIS ESCARIO"

NLT-101/72

Preparación de muestra para los ensayos de suelos

1. OBJETO

1.1. En esta Norma se describe la manera de obtener la cantidad de muestra necesaria para los distintos ensayos, de forma que sea representativa de la total recibida en el laboratorio.

2. APARATOS Y MATERIAL NECESARIOS

2.1. Balanza de unos 10 kg de capacidad de carga en un platillo y 1 g de sensibilidad.

2.2. Un cuarteador para áridos gruesos y otro para finos. Una lona de 2 × 2 m y 2 barras de 2,5 m.

2.3. Tamices 20, 5, 2 y 0,40 UNE (A.S.T.M. 3/4 pulgada y núms. 4, 10 y 40).

2.4. Mortero con manilla que tenga goma en su parte inferior y un mazo de goma.

2.5. Pala o paleta para manejar el material.

3. PROCEDIMIENTO

3.1. Preparación de la muestra antes del cuarteo:

3.1.1. Se seca la muestra al aire colocándola extendida.

3.1.2. Se desmenuza el material deshaciendo los terrones por medio del mortero o mazo de goma.

3.2. Ejecución del cuarteo:

3.2.1. Dividir la muestra en dos partes aproximadamente iguales, manteniéndose en ellas la composición original. Repetir la operación en una de ellas y así sucesivamente hasta obtener la cantidad que se necesita.

3.2.2. Cuando se dispone de aparato de cuarteo, para dividir una muestra en dos partes, basta pasarla por dicho aparato.

3.2.3. Tratándose de muestra con tamaños superiores a la abertura del aparato, se opera con una lona sobre la cual se coloca la muestra original previamente homogeneizada por paleo y convenientemente extendida; después se meten entre la lona y el suelo dos barras perpendiculares entre sí y cruzándose por el centro de la muestra.

Levantando simultáneamente ambas barras del suelo, la muestra queda dividida en cuatro partes iguales. De estas cuatro partes se hacen dos reuniendo las situadas en cuadrantes opuestos.

3.2.4. Cuando la cantidad de muestra es apropiada para ello, puede operarse encima de una mesa con una paleta o espátula, siguiendo un criterio análogo al descrito en 3.2.3.

3.3. División de una muestra en dos fracciones por medio de un tamiz:

3.3.1. Se pasa la muestra por el tamiz de que se trate. Se disgregan los terrones que aún quedaran sin desmenuzar en la fracción retenida y se tamiza de nuevo reuniendo lo que pase con la misma fracción del primer tamizado. Repetir esta operación cuantas veces sea preciso hasta dejar el material retenido bien limpio de finos.

3.3.2. En general, cuando se tamice una muestra representativa (ya cuarteada) para obtener otra fracción más fina, también representativa, se ha de tamizar hasta terminar la operación con toda ella. Aunque se obtenga antes la cantidad de muestra necesaria para los ensayos a realizar, debe seguirse el tamizado hasta el final.

3.4. Muestra precisa para los distintos ensayos:

3.4.1. Para el análisis granulométrico la cantidad necesaria depende de la proporción entre finos y gruesos (que pasen o no por el tamiz de 2 mm, A.S.T.M. núm. 10) y del tamaño máximo del material, con objeto de que sea cantidad suficiente para poderla considerar representativa. A continuación se dan unos valores que pueden servir de orientación:

Tamaño máximo (mm)	Cantidad mínima retenida en el tamiz de 2 mm (A.S.T.M. núm. 10)
10 (3/8 pulgada)	500 g
20 (3/4 pulgada)	1000 g
25 (1 pulgada)	2000 g
40 (1 ½ pulgada)	3000 g
50 (2 pulgadas)	4000 g
80 (3 pulgadas)	5000 g

La fracción que pasa por el tamiz 2 UNE debe ser superior a 120 g en suelos arenosos y a 60 en los arcillosos.
Al operar en el análisis granulométrico la muestra cuarteada se tamiza por el tamiz de 2 mm (A.S.T.M. núm. 10). De la fracción fina obtenida en esta operación se toma la muestra necesaria para otros ensayos de identificación.

3.4.2. Para los ensayos de Límites de Atterberg se separa el material que pasa por el tamiz 2 UNE (A.S.T.M. núm. 10) siguiendo el procedimiento descrito en 3.3. Dicho material se tamizará después, siguiendo el mismo procedimiento, por el tamiz 0,40 UNE (A.S.T.M. número 40). La cantidad de muestra inicial será tal que pasen unos 100 g por el tamiz 0,40 UNE (A.S.T.M. núm 40).

3.4.3. Para el ensayo del equivalente de arena, separar por cuarteo la cantidad necesaria para que tenga unos 150 g de la fracción que pasa por el tamiz 5 UNE (A.S.T.M. núm. 4) y tamizar por dicho tamiz según la técnica del apartado 3.3.

3.4.4. Para el ensayo de apisonado se separa por cuarteo de la muestra original la cantidad necesaria para que contenga de material inferior al tamiz 20 UNE (A.S.T.M. 3/4 pulgada) unos 15 kg, si se utiliza el molde de 1000 cm^3, ó 35 kg si se utiliza el molde grande Tamizar por dicho tamiz siguiendo la técnica del apartado 3.3.

3.4.5. En general, para cualquier otro ensayo se seguirá el siguiente criterio: separar por cuarteo de la muestra original la cantidad necesaria para que contenga de la fracción a utilizar la que se precisa para el ensayo. Si el ensayo se realiza con una fracción inferior al tamaño máximo de la muestra original, tamizar por el tamiz correspondiente según la técnica del apartado 3.3.

4. OBSERVACIONES

4.1. Apartado 3.1.1. El secado en estufa de las muestras para ensayo, en general, no debe hacerse, porque en algunos ensayos puede influir variando los resultados. El empleo de secadores con circulación de aire frío, o calentado a menos de 60 °C, es admisible en general, sobre todo en invierno.

4.2. Apartados 3.1.1, 3.1.2, 3.2. Las operaciones de secado, disgregación y cuarteo pueden suprimirse todas o algunas de ellas en los siguientes casos:

1.° Todas: cuando el suelo es claramente homogéneo y de tales características que la muestra puede tomarse directamente por no existir peligro de segregación.
2.° Las dos primeras: cuando su disgregación natural hace posible el cuarteo en perfectas condiciones.
3.° La primera: cuando con su humedad natural se puede hacer la disgregación de los terrones.

Las operaciones suprimidas en el tratamiento de la muestra original deben realizarse con la muestra separada por cuarteo, si fuera necesario.

Apartado 3.3.1. En los casos difíciles resulta útil subdividir lo retenido, mediante tamices, en dos o tres tamaños con objeto de facilitar la limpieza con el mazo de goma.

5. CORRESPONDENCIA CON OTRAS NORMAS

A.S.T.M. D-421.

CDU 620.16:691.52 Una Norma Española 2.58

Análisis granulométrico de áridos

UNE 7 139

1. Objeto

Esta norma tiene por objeto describir un método de ensayo que consiste en cribar los áridos a través de una serie de tamices y cedazos para la determinación de su granulometría.

El método no es aplicable a áridos recuperados de mezclas bituminosas ni a las cargas minerales («fillers»).

2. Aparatos necesarios

2,1 Tamices y cedazos. Se utilizarán los tamices y cedazos adecuados para que los resultados obtenidos permitan apreciar si el material cumple las especificaciones señaladas en el *apartado 3*.

3. Toma de muestras

Si el árido fino y el árido grueso se presentan mezclados, la mezcla se separará en dos tamaños con un tamiz 5 UNE 7 050, tratándose entonces las dos fracciones de acuerdo con lo expresado en los párrafos siguientes.

La muestra de árido fino, que ha de ser representativa, se mezcla cuidadosamente en húmedo. A continuación se toma de ella una fracción de unos 600 g, que se desecan a 100°-110° C hasta peso constante. Finalmente, se pesan 500 g de esta porción y se realiza el ensayo con esta cantidad de material.

Las muestras de árido grueso deben tener un peso después de secas no inferior al que se indica en la tabla siguiente:

Tamaño máximo del árido, en milímetros	Peso mínimo de la muestra, en gramos
10,0	1 000
12,5	2 500
20,0	5 000
25,0	10 000
40,0	15 000
50,0	20 000
63,0	26 000
80,0	30 000
100,0	35 000

4. Método de ensayo

Las muestras, una vez secas y pesadas, se separan en tantas fracciones como sea necesario para que en ningún momento gravite un peso superior a 0,6 g/cm^3 en los tamices menores al 5 UNE 7 050.

La operación del tamizado se efectúa por medio de movimientos laterales y verticales, de tal modo que el material se mantenga en continuo movimiento sobre la superficie del tamiz. No debe emplearse procedimiento o dispositivo alguno para que las piedras y granos se orienten o giren y pasen con mayor facilidad por los orificios del tamiz.

El cribado se continúa hasta que pase menos de un 1 % del residuo retenido por el tamiz que se utiliza durante 1 min.

Las pesadas de las fracciones retenidas por los distintos tamices se efectúan con una apreciación del 0,1 % del peso de la muestra.

Continúa

5. Obtención y precisión de los resultados

Los resultados del análisis granulométrico se expresarán de la forma siguiente:

a) Porcentajes totales de material retenido por cada tamiz o cedazo

b) Porcentajes totales que pasan por cada tamiz o cedazo

Estos porcentajes se expresarán redondeando los resultados hasta el número entero más próximo.

6. Normas para consultar

Para los cedazos y tamices véase la norma UNE 7 050 - Cedazos y tamices de ensayo.

7. Correspondencia con otras normas

Esta norma concuerda esencialmente con la C136-46 de la A.S.T.M. y con la E-2.22.c del I.T.C.C.

Norma 4 UNE 7139 GRANULOMETRIA

NLT-104/91

Granulometría de suelos por tamizado

1 OBJETO

1.1 Esta norma describe el método para determinar los tantos por ciento de suelo que pasan por los distintos tamices de la serie empleada en el ensayo, hasta el de 0,08 mm (ASTM núm. 200). Cuando interese conocer la distribución de tamaños en las partículas inferiores a la abertura de dicho tamiz, habrá que completar este ensayo con el método por sedimentación. Para este caso, al final de esta norma (apartado 5.6), se incluye una nota explicando el modo de preparar la muestra.

2 APARATOS Y MATERIAL NECESARIOS

2.1 Una serie de tamices de malla cuadrada y tejido de alambre que cumplan con lo especificado en la norma UNE 7050. (Se incluye al final de esta norma una tabla con las aberturas de los tamices en mm y correspondencia con la serie ASTM)

2.2 Una balanza de unos 10 kg de capacidad y sensibilidad de 1 g y otra de unos 200 g de capacidad y sensibilidad de 0,01 g.

2.3 Un aparato agitador, con hélice de agitación reemplazable movida por un motor eléctrico, y un vaso especial de agitación.

2.4 Una estufa de desecación regulable a 105-110 °C.

2.5 Un mortero con manilla, que tenga la parte inferior de goma, y un mazo de goma para desmenuzar los terrones compuestos por partículas del suelo.

2.6 Un vaso de precipitados, de unos 600 cm^3 de capacidad.

2.7 Un cepillo y una brocha para limpiar las mallas de los tamices.

2.8 Material general de laboratorio (pesasustancias, probetas, etc.).

2.9 Agua destilada y solución de hexametafosfato sódico al 4 por 100.

3 PROCEDIMIENTO

3.1 Preparación de la muestra

3.1.1 De la muestra original, separar la necesaria para el ensayo, siguiendo la norma NLT-101/72. Para fijar la cantidad precisa, seguir el criterio expuesto en el apartado 3.4.1 de dicha norma.

3.1.2 Secar completamente al aire, si fuera necesario, y pesar anotando el resultado. El suelo habrá alcanzado una humedad de equilibrio (la humedad higroscópica).

3.2 Fracción gruesa

3.2.1 Tamizar por el tamiz de 2 mm (ASTM núm. 10) según se explica en el apartado 3.3.1 de la norma NLT-101/72.

3.2.2 Lavar todo el material grueso retenido sobre el tamiz.

3.2.3 Secar en estufa lo lavado.

3.2.4 Tamizar el material retenido, lavado y seco, por los tamices de la serie superiores a 2 mm y pesar lo retenido en cada tamiz.

3.3 Humedad higroscópica

3.3.1 Separar mediante cuarteo unos 120 g de la fracción que pasa por el tamiz de 2 mm (ASTM núm 10) ó 60 g si el suelo el limo o arcilla sin arena.

3.3.2 Pesar con exactitud, en un pesasustancias tarado, unos 10 a 20 g de los cuarteados antes.

3.3.3 Secar en estufa y pesar.

3.4 Fracción fina

3.4.1 Pesar con exactitud unos 100 g del suelo, separado según el apartado 3.3.1, si el suelo es arenoso, ó 50 g si sólo contiene materiales más finos. Colocarlo en el vaso de precipitados y añadir lentamente, al mismo tiempo que se agita, unos 125 cm^3 de solución de hexametafosfato sódico al 4 por 100.

3.4.2 Dejar en reposo durante dieciocho horas (una noche).

3.4.3 Añadir agua destilada hasta 5 cm del borde del vaso y agitar la suspensión en el aparato agitador durante un minuto.

3.4.4 Lavar todo el contenido del agitador sobre el tamiz núm. 200 hasta que pase el agua limpia. Trasvasar lo retenido a una cápsula con ayuda de un chorro de agua y con cuidado de no perder partículas.

3.4.5 Secar lo retenido en la estufa a 110 °C y tamizar por los tamices de malla inferior a 2 mm.

3.4.6 Pesar lo retenido en cada tamiz.

4 RESULTADOS

4.1 Las explicaciones siguientes, sobre la forma de obtener los resultados y hacer los cálculos necesarios, se refieren al impreso correspondiente que se adjunta.

4.2 Columnas 1 y 2. Se anota la designación de los tamices empleados y la abertura de malla en orden decreciente.

4.3 Columna 3. Los datos de esta columna se obtienen directamente del ensayo (apartados 3.4.5 y 3.4.6).

4.4 Columna 4. Los datos correspondientes a esta columna, hasta el tamiz núm. 10, se obtienen directamente del ensayo (apartado 3.2.4). Para la fracción fina se obtienen multiplicando los correspondientes de la columna 3 por la relación *C/F*.

4.5 Columna 5. Se restan, de los gramos que pasan por el tamiz anterior, los gramos retenidos en el que se calcula.

4.6 Columna 6. Expresar los datos de la columna 5 en forma de tanto por ciento respecto al peso de la muestra seca total, *D*.

4.7 Dibujar la curva granulométrica en el gráfico que figura al dorso del impreso.

5 OBSERVACIONES

5.1 **Apartado 2.1.** Es conveniente disponer, además de la serie completa de tamices, de uno más del 0,080 UNE (núm. 200 de la serie ASTM) para dedicarlo sólo a la operación de lavado.

5.2 **Apartado 2.3.** Este aparato agitador no es absolutamente necesario más que cuando se va a hacer el análisis granulométrico por sedimentación; puede ser sustituido por un simple frasco de cristal con tapón de goma de 1 litro de capacidad aproximadamente, dentro del cual puede agitarse manualmente la suspensión del suelo.

5.3 **Apartado 2.9.** El agua destilada es sólo necesaria en el caso de que haya de seguirse el análisis granulométrico por sedimentación. La solución de hexametafosfato sódico se altera con el tiempo, por ello debe renovarse antes de transcurrir un mes después de preparada.

5.4 **Apartado 3.4.2.** Cuando se trate de análisis granulométrico por tamizado, puede suprimirse esta operación en aquellos suelos en los que, por su naturaleza, claramente se vea que se dispersan con faci-

DESIGNACION Y ABERTURA EN mm UNE	DESIGNACION DEL TAMIZ ASTM	ABERTURA EN mm ASTM
125	5	127
100	4	101,6
80	3	76,2
63	2,5	63,5
50	2	50,8
40	1,5	38,1
32	1,25	31,7
25	1	25,4
20	3/4	19,1
16	5/8	15,9
12,5	1/2	12,7
10	3/8	9,52
8	5/16	7,93
6,3	1/4	6,35
5	N.º 4	4,75
4	N.º 5	4,00
3,2	N.º 6	3,36
2,5	N.º 8	2,38
2	N.º 10	2,00
1,6	N.º 12	1,68
1,25	N.º 16	1,19
1	N.º 18	1,00
0,8	N.º 20	0,84
0,63	N.º 30	0,59
0,50	N.º 35	0,50
0,40	N.º 40	0,42
0,32	N.º 50	0,297
0,25	N.º 60	0,250
0,20	N.º 70	0,210
0,16	N.º 80	0,177
0,125	N.º 120	0,125
0,100	N.º 140	0,105
0,080	N.º 200	0,074
0,063	N.º 230	0,062
0,050	N.º 270	0,053
0,040	N.º 325	0,044

TABLA 1. Abertura de la serie de tamices UNE y correspondientes de la serie ASTM

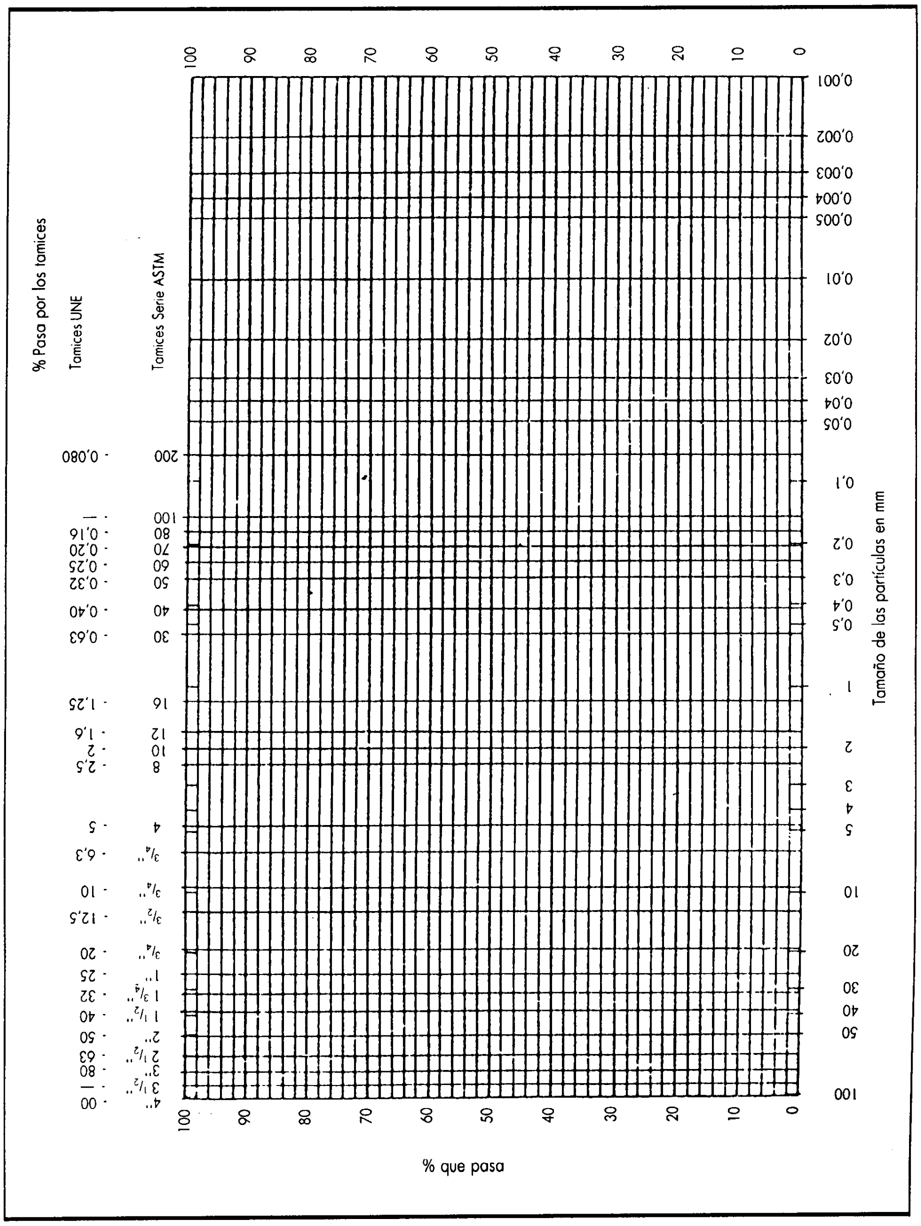

FIGURA 1. Análisis granulométrico.

Cálculos previos		
A	Muestra total seca al aire	
B	Otros lavados	
$C = (A - B)\,f$	Fracción fina seca	
$D = B + C$	Muestra total seca	
E	Fracción fina ensayada seca al aire	
$F = E \times f$	Fracción fina ensayada seca	

Por fracción gruesa se entiende el material retenido por el tamiz núm. 10 y fracción fina el que pasa por el mismo tamiz.

Humedad higroscópica		
$f = \dfrac{100}{100 + h}$	Factor de corrección por humedad higroscópica	
$h = \dfrac{a}{s} \times 100$	Humedad higroscópica %	
—	Referencia tara	
$a = (t + s + a) - (f \times s)$	Agua	
$t + s + a$	Tara + suelo + agua	
$t + s$	Tara + suelo	
t	Tara	
s	Suelo	

$\dfrac{C}{F} =$ .... Cuando se sigue una especificación determinada, se tomarán los tamices establecidos en ella.

Tamices			Retenido entre tamices		Pasa en muestra total		Descripción del suelo y observaciones
U.N.E.	A.S.T.M.		Grs. en parte fina ensayada	Grs. en muestra total	Gramos	%	
	Designación	Abertura mm.					
1	2A	2B	3	4	5	6	
63	2 1/2''	63,5					
50	2''	50,8					
40	1 1/2''	38,1					
25	1''	25,4					
20	3/4''	19,1					
12,5	1/2''	12,7					
10	3/5''	9,5					
6,3	1/4''	6,3					
5	N.° 4	4,76					
2	N.° 10	2,00					
	N.°						
	N.°						
	N.°						
	N.°						
	N.°						
	N.°						
	N.°						

FIGURA 2. Análisis granulométrico de suelos por tamizado. Cálculo.

lidad. En este caso también puede suprimirse el tratamiento con hexametafosfato sódico.

5.5 **Apartado 3.4.5.** En la operación de tamizado manual se mueve el tamiz o tamices de un lado a otro y recorriendo circunferencias de forma que la muestra se mantenga en movimiento sobre la malla. Debe comprobarse al desmontar los tamices que la operación está terminada; para ello se opera con cada tamiz individualmente, no debiendo pasar más del 1 por 100 de la parte retenida al tamizar durante un minuto. Si quedaran granos apresados en la malla, deben separarse con un pincel o un cepillo y reunirlos con lo retenido en el tamiz.

5.6 Cuando interese hacer un análisis granulométrico de la fracción que pasa por el tamiz 0,080 UNE (núm. 200 de la serie ASTM), para lo cual se necesita preparar una suspensión de finos en un litro de agua, se opera en todo como quedó explicado en el epígrafe «Procedimiento» en esta norma, sin otra variación que, después de la agitación descrita en el apartado 3.4.3, poner la suspensión de suelo en una probeta de 1.000 cm^3 y proceder para el análisis por el método de sedimentación, según el procedimiento descrito en la correspondiente norma. Una vez hecho este análisis por el método de sedimentación, se continuará operando con la misma suspensión, según el apartado 3.4.4 y siguientes.

6 CORRESPONDENCIA CON OTRAS NORMAS

ASTM D-422.

NLT-152/89

Material en los áridos que pasa el tamiz UNE 80 µm, por lavado

1 OBJETO Y CAMPO DE APLICACION

1.1 Esta norma describe el procedimiento que debe seguirse para determinar en los áridos la cantidad de material fino que pasa por el tamiz UNE 80 µm, por lavado.

1.2 En este método se separan las partículas arcillosas y de otra naturaleza que estén adheridas a la superficie del árido, así como los materiales solubles, mediante un lavado repetido con agitación y posterior decantación.

1.3 Se describen dos procedimientos, uno que utiliza solamente agua en la operación de lavado, y otro que emplea un agente humectante para favorecer el desprendimiento del material más fino que 80 µm, del material grueso. Si no se especifica lo contrario, se usará el Procedimiento A (sólo agua).

1.4 Con la mayoría de los áridos el agua natural es adecuada para separar el material más fino del grueso. En algunos casos, sin embargo, el material más fino está adherido a las partículas más gruesas; tal sucede con algunos materiales arcillosos y de otro tipo que pueden estar cubriendo los áridos extraídos de las mezclas bituminosas. En tales casos, el material fino se separa más fácilmente añadiendo al agua de lavado un agente humectante.

2 APARATOS Y MATERIAL NECESARIOS

2.1 Balanza. Una balanza con lectura y exactitud de 0,1 g o 0,1 % de la masa de la muestra de ensayo, cualquiera que sea mayor en todo el campo de pesada.

2.2 Tamices. Dos tamices, uno UNE 80 µm y otro, UNE 1,25 mm, ambos de acuerdo con las exigencias técnicas que se especifican en la norma UNE 7.050 «Tamices de ensayo».

2.3 Recipiente. Un recipiente de tamaño suficiente para contener la muestra de árido cubierta con agua y que pueda agitarse vigorosamente sin que se produzcan pérdidas de la muestra arrastrada por el agua.

2.4 Estufa. Una estufa de tamaño adecuado y que pueda mantener una temperatura uniforme de 110 ± 5 °C.

2.5 Agente humectante. Un agente dispersante, tal como un detergente comercial, que facilite la separación del material fino (Nota 1).

Nota 1. La utilización de un dispositivo mecánico para efectuar el lavado del árido está permitido, siempre que los resultados sean conformes con los obtenidos por medios manuales. El empleo de algunos equipos de lavado mecánico pueden causar degradación en cierto tipo de muestras.

3 PROCEDIMIENTO

3.1 Preparación de la muestra

3.1.1 Se mezcla completamente la muestra a ensayar y se humedece, para evitar segregación y/o pérdida de finos. Se reduce el tamaño de muestra, mediante cuarteo, a la cantidad adecuada para el ensayo que será una vez seca, conforme con la siguiente Tabla 1.

TAMAÑO MAXIMO NOMINAL DE LAS PARTICULAS (mm)	MASA MINIMA DE MUESTRA A ENSAYAR (g)
2,5	100
5	500
10	1.000
20	2.500
40	5.000

TABLA 1.

La muestra para el ensayo será el resultado final de la operación de reducción; por tanto, no se intentará conseguir una masa exacta y predeterminada de la muestra para ensayo por este medio (Nota 2).

Nota 2. Para un correcto proceso de cuarteo de la muestra se deberán seguir las indicaciones que al respecto se dictan en la norma NLT-148.

3.2 Elección del procedimiento a seguir

3.2.1 Se utilizará el Procedimiento A, a no ser que se especifique lo contrario en el pliego con el que se contrastarán los resultados de los ensayos, o cuando así lo decida la administración para la cual se realiza el trabajo.

3.3 Procedimiento A. Lavado con agua natural.

3.3.1 La muestra para el ensayo se seca hasta masa constante a una temperatura de 110 ± 5 °C. Se determina la masa de muestra seca con aproximación lo más cercana posible al 0,1 % de la misma.

3.3.2 Si la especificación vigente exige que la cantidad de material que pasa el tamiz UNE 80 µm, sea determinada en una porción de la muestra que pase un tamiz más pequeño que el tamaño máximo nominal del árido, se separa la muestra por el tamiz considerado y se determina la masa del material que pasa dicho tamiz con aproximación al 0,1 % de la masa de tal porción de la muestra de ensayo. Se utiliza esta masa como la masa original seca de la muestra de ensayo en la expresión que aparece en el Capítulo 4 de esta norma (Nota 3).

Nota 3. Algunas especificaciones para áridos con tamaño máximo nominal de 50 mm o mayor, por ejemplo, estipulan un límite para el material que pasa el tamiz UNE 80 µm, determinado en la porción de muestra que pasa el tamiz UNE 25 mm. Este proceder es necesario ya que no resulta práctico lavar muestra de tal tamaño cuando la misma muestra de ensayo se va a utilizar para el análisis granulométrico por tamizado de dicha muestra, de acuerdo con la norma NLT-150.

3.3.3 Después de seca y determinada la masa, se coloca la muestra en el recipiente y se añade bastante agua para cubrirla. No se incorporará al agua detergente, agente dispersante ni cualquier otra substancia. Se agita la muestra con vigor para conseguir la separación completa de todas las partículas más finas que 80 µm, adheridas a las más gruesas y dejar el material fino en suspensión. Inmediatamente se vierte el agua de lavado, que contiene los sólidos disueltos y en suspensión, sobre los tamices acoplados con el de mayor abertura encima. Se pondrá el cuidado necesario para evitar la transferencia de las partículas gruesas de la muestra.

3.3.4 Se efectúa un segundo lavado de la muestra en el recipiente. Se agita y se decanta nuevamente como se ha descrito. Se repite esta operación hasta que el agua de lavado sea clara (Nota 4).

Nota 4. Si se utiliza un dispositivo mecánico para efectuar el lavado de la muestra, la adición del agua, la agitación y la decantación puede hacerse de manera continua.

3.3.5 Todo el material retenido en los tamices se une a la muestra lavada del recipiente. El árido lavado se seca en la estufa a 110 ± 5 °C hasta masa constante con aproximación de 0,1 % con respecto a la masa de muestra original.

3.4 Procedimiento B. Lavado con agua y agente humectante.

3.4.1 Se prepara la muestra de la misma manera que en el Procedimiento A.

3.4.2 Después de seca y determinada la masa, se coloca la muestra en el recipiente y se añade bastante agua para cubrirla y se incorpora al conjunto el agente humectante (Nota 5). Se agita la muestra con vigor para conseguir la separación completa de todas las partículas más finas que 80 µm adheridas a las más gruesas y dejar el material fino en suspensión. Inmediatamente se vierte el agua de lavado, que contiene los sólidos disueltos y en suspensión, sobre los tamices acoplados con el de mayor abertura encima. Se pondrá el cuidado necesario para evitar la transferencia de las partículas gruesas de la muestra.

Nota 5. Deberá incorporarse suficiente agente humectante como para producir una pequeña cantidad de espuma cuando se agita la muestra. Esta cantidad dependerá de la dureza del agua utilizada y de la naturaleza y calidad del detergente. Una excesiva espuma puede rebosar los tamices y arrastrar algún material con ella.

3.4.3 Se efectúa un segundo lavado (ahora sin agente humectante) de la muestra en el recipiente, se agita y se decanta nuevamente como se ha descrito. Se repite esta operación hasta que el agua de lavado sea clara.

3.4.4 Se completa el ensayo como en el Procedimiento A.

4 CALCULOS

4.1 Se calcula la cantidad de material que pasa el tamiz UNE 80 µm, por lavado, con la siguiente expresión.

$$A = \frac{B - C}{B} \times 100$$

donde:

A = Porcentaje de material que pasa el tamiz UNE 80 µm, por lavado.
B = Masa original de la muestra, g.
C = Masa seca de la muestra después de lavada, g.

5 RESULTADO

5.1 El resultado se expresará como el porcentaje de material en los áridos que pasa el tamiz UNE 80 µm, por lavado, aproximado al 0,1 %, excepto si el resultado es igual o mayor que el 10 % en cuyo caso se redondeará al número entero más próximo.

	DESVIACION TIPO (1 S) %	VARIACION ACEPTABLE ENTRE DOS RESULTADOS (D 2 S) %
Arido grueso (1)		
Repetibilidad	0,10	0,28
Reproducibilidad	0,22	0,62
Arido fino (2)		
Repetibilidad	0,15	0,43
Reproducibilidad	0,29	0,82

(1) Los valores de la precisión están basados en áridos con tamaño máximo nominal de 19,0 mm, con menos de 1,5 % de material que pasa el tamiz UNE 80 µm.

(2) Los valores de la precisión están basados en áridos, finos con 1,0 a 3,0 % de material que pasa el tamiz UNE 80 µm.

Nota 6. La significación de los índices definidos en la precisión del método es la siguiente:

(1S). Desviación típica o estándar de la población de las medidas características.del método cuando éste se aplica bajo las condiciones específicas prescritas.
(D2S). Diferencia máxima aceptable entre dos resultados obtenidos en porciones del mismo material bajo el sistema aplicable de causas descrito.

TABLA 2. Precisión

6 PRECISION

6.1 La determinación de la precisión de este método de ensayo, cuyos valores figuran en la Tabla 2, está basada en los resultados obtenidos por la AASHTO siguiendo el método de ensayo C 117 de la ASTM y el T 11 de la propia AASHTO. La única diferencia significativa entre ambos métodos, cuando se determinó la precisión, es que el método T 11 exige y el C 117 prohíbe el uso de agente humectante.

Los datos están basados en el análisis de más de 100 parejas de resultados de ensayo realizados entre 40 y 100 laboratorios.

7 CORRESPONDENCIA CON OTRAS NORMAS

ASTM C 117-87 «Test Method for Material Finer than 75 µm (N° 200) Sieve in Mineral Aggregates by Washing».
UNE 7135 «Determinación de finos en áridos utilizados para la fabricación de hormigones».

8 NORMAS PARA CONSULTA

UNE 7.050 «Tamices de ensayo».
NLT-148 «Toma de muestras de roca, escorias, grava, arena, filler y bloques de piedra empleados como materiales de construcción de carreteras».
NLT-150 «Análisis granulométrico de áridos gruesos y finos».

Cedazos y tamices de ensayo

1. Objeto

Esta norma tiene por objeto especificar las condiciones que deben cumplir los llamados tamices y cedazos que se utilizan para clasificar distintos materiales, según el tamaño de sus partículas.

2. Definiciones

Los distintos componentes de un tamiz o cedazo de ensayo, se definen como sigue:

2,1 Tejido. Es el plano constituído por alambres cilíndricos que, entrecruzados perpendicularmente, sí aberturas cuadradas.

2,2 Malla. Es cada uno de los cuadrados que constituyen el tejido y cuya medida equivale a una luz más un diámetro de hilo.

2,3 Luz de malla. Es la separación libre comprendida entre los lados de la malla, medida entre los dios de los lados de cada cuadrado.

2,4 Diámetro de los hilos. El diámetro de los hilos se mide con el calibre decimal o «Paris» para hilos de, y superiores y con el calibre centesimal o «carcasse» para los inferiores a 0,50 mm.

2,5 Ley de la escala. Se establece la escala de cedazos y tamices de acuerdo con una ley fija, que $\sqrt{10}$ para los finos, siguiendo la serie normal R_a 10 (0,040 ..... 5) según la norma UNE 4003 y para los sigue la misma ley y la serie R_a 10 (5,00 ..... 125).

2,6 Tamiz. Es el conjunto constituído por la unión del tejido a un marco, siempre que la luz de malla o inferior a 5 mm.

2,7 Cedazo. Es el conjunto constituído por la unión del tejido a un marco, siempre que la luz de superior a 5 mm.

3. Designación

Los tamices y cedazos que se recomiendan en esta norma se designan expresando la luz de malla precedida de la palabra tamiz o cedazo y seguidas por UNE 7050.

Designación de un tamiz cuya luz de malla es de 4,00 mm, y de un cedazo de luz de malla de 20

Tamiz 4 UNE 7050 y Cedazo 20 UNE 7050

4. Condiciones generales

El tejido no presentará deformaciones apreciables. Los alambres serán de acero, aleaciones custán y cuzin, níquel u otro material prácticamente inalterable, sin ningún recubrimiento protector, y serán rígidos y sí

Las características que habrá de reunir el tejido se señalan en el cuadro siguiente:

Luz de malla mm	Tolerancia media %	Tolerancias máximas %		Diámetro del hilo	
		Relativa	Absoluta	Mínimo	
125	2		3	5,6	9,7
100	2		3	5,3	9,3
80	2		3	4,8	8,1
63	2		3	4,4	
50	2		3	3,8	
40	2		3	3,7	
32	2		3	3,5	
25	2		5	3,43	
20	3		5	3,10	
16	3		5	2,74	
12,5	3		5	2,23	
10	3		5	2,11	
8	3		5	1,85	
6,3	3		10	1,28	
	3		10	1,14	

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Luz de malla mm	[illegible] %	[illegible] Relativa	[illegible] Absoluta	[illegible] Mínimo mm	[illegible]
4	3		10	1,00	[illegible]
3,2	3		10	0,87	[illegible]
2,5	3		10	0,80	[illegible]
2	3		10	0,62	[illegible]
1,6	3		10	0,56	[illegible]
1,25	3		10	0,50	0,70
1	5	7,5	15	0,43	[illegible]
0,80	5	7,5	15	0,38	0,55
0,63	5	7,5	15	0,33	[illegible]
0,50	5	7,5	15	0,26	[illegible]
0,40	5	12,5	25	0,23	0,33
0,32	5	12,5	25	0,170	0,283
0,25	5	12,5	25	0,149	0,220
0,20	6	20	40	0,114	0,154
0,16	6	20	40	0,096	0,125
0,125	6	20	40	0,079	0,103
0,100	6	20	40	0,054	0,073
0,080	7	45	90	0,039	0,052
0,063	7	45	90	0,035	0,046
0,050	7	45	90	0,031	0,040
0,040	7	45	90	0,023	0,035

5. Requisitos especiales

El marco podrá fabricarse de madera dura, metal o cualquier otro material adecuado. Su forma podrá ser [illegible] drada, rectangular o circular.

Para diámetros grandes o para telas fuertes, no es aconsejable el marco circular, porque se deformarán [illegible] llas en los bordes; se recomiendan marcos circulares con las medidas siguientes:

Luz de malla mm	Diámetro m	Altura útil m
De 5 a 0,25	0,20 ± 0,003	0,05
De 0,20 a 0,04	0,10 ± 0,001	0,02

En los tamices empleados para pigmentos, el diámetro interior será de 75 mm y la altura no será inferior a 19 [illegible]

La parte del marco que queda debajo del tejido se ajustará fácilmente con cualquier tamiz de igual diámetro [illegible] formar un cilindro o prisma.

6. Tolerancias en el tejido

Las tolerancias en el tejido están indicadas en el *cuadro* del *capítulo 4*. En la tercera columna se da la [illegible] máxima que sólo podrá ser sobrepasada por el 5 por 100 de las mallas. En la cuarta la tolerancia [illegible] dual, de tal forma que no pueda existir ninguna malla con luz superior a la nominal más el tanto [illegible] señala la columna, y en las columnas quinta y sexta se indican los límites superior e inferior del [illegible]

7. Observaciones

El tejido se montará sin ondulaciones. Para prevenir la posible pérdida de material por quedar [illegible] en las juntas del tejido con el marco, se recubrirán los mismos con un cordón de soldadura o bien [illegible] en forma tal que dicha pérdida sea imposible.

8. Correspondencia con otras normas

Esta norma concuerda parcialmente con la ASTM E 11-39.

Designation: D 1140 – 54 (Reapproved 1971)

An American National Standard

Standard Test Method for Amount of Material in Soils Finer Than the No. 200 (75-µm) Sieve[1]

This standard is issued under the fixed designation D 1140; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This method has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

Scope

.1 This method covers determination of the total ount of material in soils finer than the No. 200 (75-µm) e.

Apparatus

.1 *Sieves*—A nest of two sieves, the lower being a No. (75-µm) sieve and the upper a No. 40 (425-µm) sieve, conforming to ASTM Specification E 11, for Wire- Sieves for Testing Purposes.[2]

2 *Containers*—A pan or vessel of sufficient size to the test sample covered with water and to permit agitation without advertent loss of any part of the , and a second pan or container for use in drying the mple after washing.

Sample

The test sample shall be selected from material that n thoroughly mixed. A representative sample, suffi- yield not less than the approximate weight of dried shown in the following table, shall be selected using e splitter or by the method of quartering:

Nominal Diameter of Largest Particle, in.	Approximate Minimum Weight of Sample, g
0.0787 (No. 10 sieve) (2.0 mm)	200
0.187 (No. 4 sieve) (4.75 mm)	500
(19.0 mm)	1500
1 (25.0 mm)	2000
1½ or over (37.5 mm)	2500

ocedure

Dry the test sample to a constant weight at a temper- not exceeding 230 ± 9 F (110 ± 5 C) and weigh to the 0.05 percent, or alternatively, weigh the test sample and use an auxiliary moisture content sample to mine the moisture content of the sample. The weight of oisture content sample shall be between 20 and 30 of the weight of the test sample. Calculate the ry weight of the test sample from the moist weight and isture content.

4.2 Place the test sample in the container, add sufficient clean water to cover it, and allow to soak a minimum of 2 h (preferably overnight).

4.3 Agitate the contents of the container vigorously and pour the wash water immediately over the nested sieves, arranged with the coarser sieve on top. Repeat the process of adding clear water to the container to cover the sample, agitating the contents of the container, and pouring the wash water over the nested sieves until the wash water is clear. When the total sample is small, the entire contents of the soaking container may be transferred to the nested sieves after the first washing and the washing operation completed in accordance with 4.4. The wash water need not be saved.

NOTE 1—The percentage value secured at the end of the test may not be correct (being too low) for soils containing relatively high percentages of the minus 200 fraction. This appears to be due chiefly to inadequate agitation. When it is desired to secure the exact percentage for the minus 200 fraction for such a soil, the portion of the sample passing the No. 40 sieve and retained on the No. 200 sieve secured in the washing operation, shall be transferred to the dispersion cup of the stirring apparatus used in Method D 422, Particle-Size Analysis of Soils,[3] the cup filled half full with water and the contents agitated for 1 min. After this agitation the contents of the cup shall be transferred to the nested sieves and washing continued.

If the stirring apparatus has not been used prior to the drying of the portion of the sample larger than the No. 200 (75-µm) sieve, and it is desired to do so after drying, the dried material shall be separated on the No. 40 (425-µm) sieve; the portion retained shall be saved; and the portion passing shall be placed in the dispersion cup with water and agitated for 1 min with the stirring apparatus as previously described. The contents of the cup shall be transferred to the No. 200 sieve, washed, and dried. The revised total weight retained on the No. 200 sieve shall be secured by combining and weighing the two fractions.

4.4 Transfer the sample to the nested sieves and wash with running water (Note 2). When the sample is larger than can be handled at one time on the nested sieves, wash a portion of the sample and transfer to the container in which it is to be dried.

NOTE 2—Tapping of sieves has been found to expedite the washing operations.

4.5 Dry the washed material retained on the nested sieves in a container to a constant weight at a temperature not exceeding 230 ± 9 F (110 ± 5 C) and dry-sieve it on the nested sieves (Note 3). Weigh the dry material retained on the nested sieves to the nearest 0.05 percent.

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method is under the jurisdiction of ASTM Committee D-18 on Soil and

edition approved Sept. 15, 1954. Originally issued 1950. Replaces 0 T.

al Book of ASTM Standards, Vols 04.01, 04.02, 04.06, 05.05, and 14.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

Norma 8 ASTM D1140 TEST MATERIAL<75µ

NOTE 3—Some material passes the No. 200 (75-µm) sieve on dry sieving that did not pass during the washing operation. When desired, a sieve analysis may be made on the portion of the sample retained on the No. 200 sieve, in accordance with Method D 422.

5. Calculation

5.1 Calculate the results as follows:

$$P = [(W_o - W_1)/W_o] \times 100$$

where:

P = percentage of material finer than No. 200 (75-µ sieve,

W_o = weight of original sample on an oven-dry basis, g an

W_1 = oven-dry weight of sample after washing and dr sieving, g.

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Designation: D 2216 - 92

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If not listed in the current combined index, will appear in the next edition.

Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock[1]

This standard is issued under the fixed designation D 2216; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the laboratory determination of the water (moisture) content of soil, rock, and similar materials by mass. For simplicity, the word "material" hereinafter also refers to either soil or rock, whichever is most applicable.

1.2 The water content of a material is defined by this standard as the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material.

1.3 The term "solid particles" as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, and the like) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method (110°C). Materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water) may present a special problem as this material slowly dehydrates at the standard drying temperature (110°C) and at very low relative humidities, forming a compound (calcium sulfate hemihydrate) which is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum, or to reduce decomposition in highly organic soils, it may be desirable to dry these materials at 60°C or in a desiccator at room temperature. Thus, when a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from standard water content determined at the standard drying temperature.

NOTE 1—Test Methods D 2974 provides an alternate procedure for determining water content of peat materials.

1.4 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments) when tested by this method will give a mass of solids which includes the previously soluble solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must l used.

1.5 This test method requires several hours for prop drying of the water content specimen. Test Method D 46 provides for drying of the test specimen in a microwave ov which is a shorter process.

1.6 This standard requires the drying of material in oven at high temperatures. If the material being dried contaminated with certain chemicals, health and safe hazards can exist. Therefore, this standard should not used in determining the water content of contaminated so unless adequate health and safety precautions are taken.

1.7 *This standard does not purport to address all of t safety problems, if any, associated with its use. It is t responsibility of the user of this standard to establish app priate safety and health practices and determine the applic bility of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contain Fluids[2]

D 2974 Test Methods for Moisture, Ash, and Orga Matter of Peat and Other Organic Soils[2]

D 4220 Practice for Preserving and Transporting S Samples[2]

D 4318 Test Method for Liquid Limit, Plastic Limit, a Plasticity Index of Soils[2]

D 4643 Test Method for Determination of Wa (Moisture) Content of Soil by the Microwave Ov Method[2]

D 4753 Specification for Evaluating, Selecting, and Spe fying Balances and Scales for Use in Soil and Rc Testing[2]

E 145 Specification for Gravity-Convection And Forc Ventilation Ovens[3]

3. Terminology

3.1 Refer to Terminology D 653 for standard definiti of terms.

3.2 *Description of Term Specific to This Standard:*

3.2.1 *water content* (of a material)—the ratio of the m of water contained in the pore spaces of soil or rock mater to the solid mass of particles in that material, expressed a percentage.

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

Current edition approved June 15, 1992. Published August 1992. Originally published as D 2216 - 63 T. Last previous edition D 2216 - 90$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

4. Summary of Test Method

4.1 A test specimen is dried in an oven to a constant mass. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen.

5. Significance and Use

5.1 For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its properties.

5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.

5.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D 4318, is used to express its relative consistency or liquidity index.

6. Apparatus

6.1 *Drying Oven,* thermostatically-controlled, preferably of the forced-draft type, meeting the requirements of Specification E 145 and capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber.

6.2 *Balances*—All balances must meet the requirements of Specification D 4753 and this Section. A Class GP1 balance of 0.01g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1g readability is required for specimens having a mass over 200 g.

6.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g; while for specimens having a mass greater than about 200 g, containers without lids may be used. One container is needed for each water content determination.

Note 2—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.

6.4 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium phosphate. It is preferable to use a desiccant which changes color to indicate it needs reconstitution. See Section 10.5.

Note 3—Anhydrous calcium sulfate is sold under the trade name Drierite.

6.5 *Container Handling Apparatus,* gloves, tongs, or suitable holder for moving and handling hot containers after drying.

6.6 *Miscellaneous,* knives, spatulas, scoops, quartering cloth, sample splitters, etc, as required.

7. Samples

7.1 Samples shall be preserved and transported in accordance with Practice 4220 Groups B, C, or D soils. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to prevent or minimize moisture condensation on the insides of the containers.

7.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corrodible containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values given before shall apply.

8.2 The minimum mass of moist material selected to be representative of the total sample, if the total sample is not tested by this method, shall be in accordance with the following:

Maximum particle size (100 % passing)	Standard Sieve Size	Recommended minimum mass of moist test specimen for water content reported to ±0.1 %	Recommended minimum mass of moist test specimen for water content reported to ±1 %
2 mm or less	No. 10	20 g	20 g*
4.75 mm	No. 4	100 g	20 g*
9.5 mm	⅜-in.	500 g	50 g
19.0 mm	¾-in.	2.5 kg	250 g
37.5 mm	1½ in.	10 kg	1 kg
75.0 mm	3-in.	50 kg	5 kg

Note—*To be representative not less than 20 g shall be used.

8.2.1 If the total sample is used it does not have to meet the minimum mass requirements provided in the table above. The report shall indicate that the entire sample was used.

8.3 Using a test specimen smaller than the minimum indicated in 8.2 requires discretion, though it may be adequate for the purposes of the test. Any specimen used not meeting these requirements shall be noted in the report of results.

8.4 When working with a small (less than 200g) specimen containing a relatively large gravel particle, it is appropriate not to include this particle in the test specimen. However, any discarded material shall be described and noted in the report of the results.

8.5 For those samples consisting entirely of intact rock, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles, depending on the sample's size, the container and balance being used and to facilitate drying to constant mass, see Section 10.4.

9. Test Specimen Selection

9.1 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, and the likes.)

9.2 For disturbed samples such as trimmings, bag sam-

[redacted]

following methods (listed in order of preference):

9.2.1 If the material is such that it can be manipulated and handled without significant moisture loss, the material should be mixed and then reduced to the required size by quartering or splitting.

9.2.2 If the material is such that it cannot be thoroughly mixed and/or split, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.

9.2.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as possible at random locations that will best represent the moisture condition. Combine all the portions for the test specimen.

9.3 Intact samples such as block, tube, split barrel, and the like, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample.

9.3.1 Carefully trim at least 3 mm of material from the outer surface of the sample to see if material is layered and to remove material that is drier or wetter than the main portion of the sample. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the entire exposed surface or from the interval being tested.

9.3.2 Slice the sample in half. If material is layered see Section 9.3.3. Then carefully trim at least 5 mm, or a thickness equal to the maximum particle size present, from the exposed surface of one half, or from the interval being tested. Avoid any material on the edges that may be wetter or drier than the main portion of the sample.

NOTE 4—Migration of moisture in some cohesionless soils may require that the full section be sampled.

9.3.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on data sheets.

10. Procedure

10.1 Determine and record the mass of the clean and dry specimen container (and its lid, if used).

10.2 Select representative test specimens in accordance with Section 9.

10.3 Place the moist test specimen in the container and, if used, set the lid securely in position. Determine the mass of the container and moist material using a balance (See 6.2) selected on the basis of the specimen mass. Record this value.

NOTE 5—To prevent mixing of specimens and yielding of incorrect esults, all containers, and lids if used, should be numbered and the container numbers shall be recorded on the laboratory data sheets. The id numbers should match the container numbers to eliminate confusion.

NOTE 6—To assist in the oven-drying of large test specimens, they hould be placed in containers having a large surface area (such as pans) nd the material broken up into smaller aggregations.

10.4 Remove the lid (if used) and place the container with moist material in the drying oven. Dry the material to a constant mass. Maintain the drying oven at 110 ± 5°C unless otherwise specified (see 1.3). The time required to obtain constant mass will vary depending on the type of material, size of specimen, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment, and experience with the materials being tested and the apparatus being used.

NOTE 7—In most cases, drying a test specimen overnight (about 12 to 16 h) is sufficient. In cases where there is doubt concerning the adequacy of drying, drying should be continued until the change in mass after two successive periods (greater than 1 h) of drying is an insignificant amount (less than about 0.1 %). Specimens of sand may often be dried to constant mass in a period of about 4 h, when a forced-draft oven is used.

NOTE 8—Since some dry materials may absorb moisture from moist specimens, dried specimens should be removed before placing moist specimens in the same oven. However, this would not be applicable if the previously dried specimens will remain in the drying oven for an additional time period of about 16 h.

10.5 After the material has dried to constant mass remove the container from the oven (and replace the lid if used). Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands and the operation of the balance will not be affected by convection currents and/or its being heated. Determine the mass of the container and oven-dried material using the same balance as used in 10.3. Record this value. Tight fitting lids shall be used if it appears that the specimen is absorbing moisture from the air prior to determination of its dry mass.

NOTE 9—Cooling in a desiccator is acceptable in place of tight fitting lids since it greatly reduces absorption of moisture from the atmosphere during cooling especially for containers without tight fitting lids.

11. Calculation

11.1 Calculate the water content of the material as follows:

$$w = [(M_{cws} - M_{cs})/(M_{cs} - M_c)] \times 100 = \frac{M_w}{M_s} \times 100$$

where:

w = water content, %,
M_{cws} = mass of container and wet specimen, g,
M_{cs} = mass of container and oven dry specimen, g,
M_c = mass of container, g,
M_w = mass of water ($M_w = M_{cws} - M_{cds}$), g, and
M_s = mass of solid particles ($M_s = M_{cds} - M_c$), g.

12. Report

12.1 The report (data sheet) shall include the following:

12.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, container number etc.

12.1.2 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum sample used. If this method is used in concert with another method, the water content of the specimen should be reported to the value required by the test method for which the water content is being determined.

12.1.3 Indicate if test specimen had a mass less than the minimum indicated in 8.2.

12.1.4 Indicate if test specimen contained more than one material type (layered, etc.).

12.1.5 Indicate the method of drying if different from oven-drying at 110 ± 5°C.

12.1.6 Indicate if any material (size and amount) was excluded from the test specimen.

13. Precision and Bias

13.1 *Statement on Bias*—There is no accepted reference value for this test method; therefore, bias cannot be determined.

13.2 *Statements on Precision:*

13.2.1 *Single-Operator Precision*—The single-operator coefficient of variation has been found to be 2.7 percent. Therefore, results of two properly conducted tests by the same operator with the same equipment should not be considered suspect unless they differ by more than 7.8 percent of their mean.

13.2.2 *Multilaboratory Precision*—The multilaboratory coefficient of variation has been found to be 5.0 percent. Therefore, results of two properly conducted tests by different operators using different equipment should not be considered suspect unless they differ by more than 14.0 percent of their mean.

14. Keywords

14.1 consistency; index property; laboratory; moisture analysis; moisture content; soil aggregate; water content

Determinación del peso específico real de un terreno

UNE 7001

1. Alcance.

Este método es aplicable a todos los terrenos, variándose la cantidad de la muestra con su naturaleza, según se indica en el apartado 5.

2. Definiciones.

El peso específico real de un terreno es el resultado de dividir el peso de un volumen del terreno, exento de poros, a una determinada temperatura, por el peso de idéntico volumen de agua destilada a la misma temperatura.

3. Aparatos empleados.

Para la aplicación de este método son necesarios los siguientes aparatos:

3,1 **Picnómetro.** Su forma será la normal en los picnómetros para sólidos, su capacidad estará comprendida entre 50 y 60 cm³ y el peso, una vez lleno de agua destilada, no debe pasar de los 90 g.

3,2 **Balanza.** Se utilizará una balanza de precisión con sensibilidad no inferior a 1 mg.

3,3 **Bomba de vacío.** Capaz de producir una presión absoluta igual o menor de 10 mm de columna de mercurio.

3,4 **Desecador.** Construído en cristal y capaz de resistir una depresión de una atmósfera.

3,5 **Varios.** Cápsulas de porcelana, termómetros, etc.

4. Requisitos especiales.

Antes de proceder al ensayo propiamente dicho, es necesario reglar cada uno de los picnómetros que vayan a usarse; esta operación se puede realizar por el método descrito a continuación: Se somete el picnómetro completamente lleno, a una temperatura determinada, t_1, durante quince minutos, al final de los cuales se limpia y seca lo más rápidamente posible, obteniéndose un peso, p_1 con error de 1 mg.

Esta operación debe repetirse a diferentes temperaturas: t_2, t_3, etc., hallando al mismo tiempo los pesos p_2, p_3, etc. correspondientes. Con estos pares de valores puede dibujarse una curva semejante a la de la figura 1, por medio de la cual es posible conocer el peso del picnómetro lleno de agua, a una temperatura determinada.

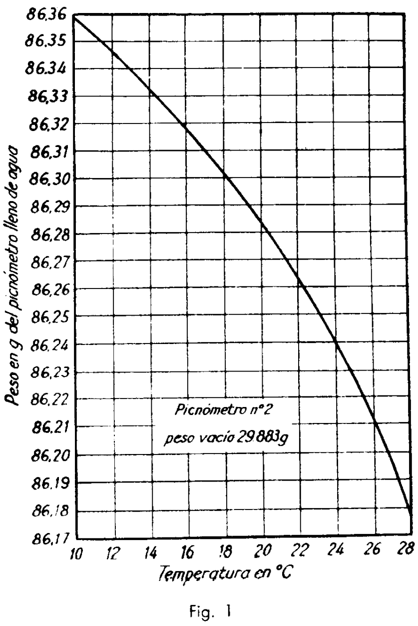

Fig. 1

5. Toma de muestras.

Para cada determinación se necesitan 12 ± 1 g de muestra media desecada al aire si el terreno es arenoso y 8 ± 1 g en los de naturaleza arcillosa.

6. Método de ensayo.

Después de pulverizar la muestra, se la deseca en una estufa a 110° C hasta peso constante, y se anota el peso p_0 de la muestra seca. A continuación se echan en el picnómetro unos 15 cm³ de agua destilada, se añade la muestra seca y se mezcla bien el conjunto. Con el fin de eliminar las burbujas de aire que puedan estar ocluídas en la masa, se hierve el picnómetro durante unos diez minutos o se le somete al vacío. En ambas operaciones se regula el proceso para evitar las pérdidas de material por ebullición.

Continúa

Terminadas las manipulaciones anteriores, se rellena completamente el picnómetro con agua destilada, se toma la temperatura t_1 del líquido que contiene, y después de bien limpio y seco, se obtiene el peso p_b del picnómetro con la muestra y lleno de agua.

El peso específico del terreno $\gamma_{S.1}$ a la temperatura t_1 se obtiene por medio de la fórmula siguiente: P_b =

$$\gamma_{S.1} = \frac{p_a}{p_a + p_1 - p_b}$$

en la que P_a y P_b tienen el significado expuesto anteriormente, y P_1 es el peso del picnómetro lleno de agua a la temperatura t_1, tomado de la curva de la *figura*.

7. Observaciones.

Mientras no se precise lo contrario, el peso específico de un terreno se referirá a la densidad del agua a 20° C, para lo cual hay que multiplicar el valor de $\gamma_{S.1}$ por el coeficiente K_1 que se incluye en la tabla 1, obtenido al dividir la densidad del agua a t_1 por la del agua a 20° C.

TABLA 1.— Valores de K_1 a diferentes temperaturas

Temperatura en grados C	Coeficientes K_1
18	1,0004
19	1,0002
20	1,0000
21	0,9998
22	0,9996
23	0,9993
24	0,9991
25	0,9989
26	0,9986
27	0,9983
28	0,9980
29	0,9977
30	0,9974

8. Correspondencia con otras normas.

D 854 - 45 T de la A. S. T. M.

NLT-301/72

Densidad máxima y humedad óptima de las mezclas de suelo-cemento, mediante apisonado con maza

1 OBJETO Y CAMPO DE APLICACION

1.1 Este ensayo tiene por objeto determinar en el laboratorio la relación entre el contenido de humedad y la densidad de mezclas de suelo-cemento, después de compactadas y antes de que se inicie la hidratación del cemento.

1.2 Para este ensayo se siguen dos métodos, y el uso de uno u otro depende de la granulometría del suelo.
Método A. Empleando material que pasa por el tamiz 5 UNE (ASTM núm. 4). Usado cuando el 100 % del suelo pasa por dicho tamiz.
Método B. Empleando material que pasa por el tamiz 20 UNE (ASTM 3/4 de pulgada). Usado cuando parte del suelo es retenido sobre el tamiz 5 UNE (ASTM núm. 4).

1.3 Esta norma es aplicable a las mezclas suelo-cemento utilizadas en construcción de carreteras.

2 APARATOS Y MATERIAL NECESARIOS

2.1 Un molde cilíndrico de 1 litro de capacidad (102 mm de diámetro interno y 122 mm de altura) con base y collar.

2.2 Una maza de 2,5 kg y 50 mm aproximadamente de diámetro y una altura de caída, controlada, de 305 mm accionada a mano o mediante un compactador mecánico, calibrado con arreglo a la norma NLT-107.

2.3 Una balanza de 10 kg de capacidad, sensible al gramo y otra de 200 g de capacidad, sensible a 0,01 g.

2.4 Una estufa de desecación regulable a 105-110 °C.

2.5 Una espátula para enrasar, de unos 300 mm de longitud, con hoja bien recta y resistente.

2.6 Una amasadora mecánica o recipiente y guantes de goma para amasar a mano y una probeta graduada de unos 250 cm.

2.7 Una bandeja cuadrada de 300 mm aproximadamente de lado y 50 mm de altura.

2.8 Cápsulas o pesafiltros para determinar humedades.

2.9. Tres tamices: 80 UNE (ASTM 3 pulgadas), 20 UNE (ASTM 3/4 pulgada) y 5 UNE (ASTM núm. 4).

3 METODO A: PROCEDIMIENTO

3.1 Preparación de la muestra

3.1.1 Preparar la muestra de suelo pulverizándola hasta que todo el material pase por el tamiz 5 UNE.

Si es preciso, dejar secar la muestra hasta que pueda ser pulverizada fácilmente.

El secado se hace al aire libre o por medio de estufa u otros aparatos de secado, siempre que la temperatura no exceda de 60 °C.

3.1.2 Dividir por cuarteo el material así obtenido en siete porciones, aproximadamente iguales, de unos 3 kg.

3.2 Ejecución del ensayo

3.2.1 Se tara y anota el peso del molde con la base y sin el collar superior.

3.2.2 Se toma una de las porciones obtenidas en el 3.1.2 y se mezcla con el cemento hasta color uniforme. Cuando la mezcla tenga un contenido de humedad muy bajo, hay que anadir agua potable para aproximarse al contenido óptimo de humedad, mezclando el agua hasta que quede íntima y uniformemente distribuida.

Cuando el suelo sea una arcilla plástica, después de mezclada y amasada con el cemento y el agua, se compacta en el recipiente descrito en 2.7, usando la maza. Se cubre y se deja en reposo por un período mínimo de 5 minutos y no mayor de 10 minutos, para ayudar a la dispersión de la humedad y permitir una completa absorción del agua por la mezcla de suelo-cemento. Después se desmenuzará la mezcla con la mano hasta que, visiblemente, pase toda ella por el tamiz 5 UNE.

3.2.3 Compactar la muestra en el molde con el collar en tres capas, aproximadamente iguales, compactando cada una de las capas con 26 golpes de maza, repartiendo uniformemente los golpes por toda la superficie de la capa y desde la altura de 305 mm. La última tongada compactada entrará unos 10 mm en el collar de enrase.

3.2.4 Después de lleno y compactado el molde, se quita el collar y con la espátula se enrasa perfectamente.

3.2.5 Se determina y anota el peso del conjunto correspondiente al molde más el suelo-cemento y agua.

3.2.6 Sacar la probeta compactada del molde y cortarla en sentido vertical por la mitad. Tomar del centro una muestra representativa de unos 100 g, colocarla en una cápsula tarada y determinar la humedad de la mezcla, secándola en estufa a 105-110 °C, hasta peso constante.

3.2.7 Se repite la operación con nuevas porciones de suelo de las obtenidas en 3.1.2 y contenidos de agua crecientes, hasta obtener los puntos necesarios para determinar la curva que relaciona las densidades en seco con los tantos por ciento de humedad.

4 METODO B: PROCEDIMIENTO

4.1 Preparación de la muestra

4.1.1 Preparar la muestra de suelo pulverizándola y tamizar por el tamiz 5 UNE.

Si es preciso, dejar secar la muestra hasta que pueda ser pulverizada fácilmente.

El secado se hace al aire libre o por medio de estufa u otros aparatos de secado, siempre que la temperatura de secado no exceda de 60 °C.

4.1.2 El suelo retenido en el tamiz 5 UNE se tamiza por el 80 UNE y el 20 UNE.

Se desecha el material retenido en el tamiz 80 UNE, se pesa el material que pasa por dicho tamiz y retiene el 20 UNE, y se sustituye por una fracción igual en peso de material que pasa por el tamiz 20 UNE y retiene el tamiz 5 UNE, la cual se agrega a la fracción originaria, comprendida entre estos dos mismos tamices. De manera que el peso del suelo comprendido entre el tamiz 20 UNE y 5 UNE sea igual al comprendido entre el tamiz 80 UNE y 5 UNE.

4.1.3 Pesar y mantener separada la fracción que pasa por el tamiz 5 UNE y la comprendida entre los tamices 20 y 5 UNE.

4.1.4 Poner el árido retenido entre los tamices 20 y 5 UNE en condiciones de saturado superficie seca.

4.1.5 Dividir por cuarteo el material que pasa por el tamiz 5 UNE en siete porciones, aproximadamente iguales, de unos 2,5 kg.

4.2 Ejecución del ensayo

4.2.1 Se toma una de las porciones obtenidas en el 4.1.5 y se mezcla con el cemento, hasta color uniforme.

Cuando la mezcla tenga un contenido de humedad muy bajo, hay que añadir agua potable para aproximarse al contenido óptimo de humedad, mezclando el agua hasta que quede íntima y uniformemente distribuida.

Cuando el suelo sea una arcilla plastica, después de mezclado y amasado con el cemento y el agua, se compacta en el recipiente descrito en 2.7, usando la maza. Se cubre y se deja en reposo por un período mínimo de 5 minutos y no mayor de 10 minutos, para ayudar a la dispersión de la humedad y permitir una completa absorción del agua por el suelo-cemento. Después se desmenuzará la mezcla con la mano hasta que visiblemente pase toda ella por el tamiz 5 UNE. Después de esta preparación, añadir el árido preparado en 4.1.4 en el porcentaje correspondiente en peso.

4.2.2 Seguir el procedimiento indicado en los apartados 3.2.3, 3.2.4, 3.2.5, 3.2.6 y 3.2.7 de esta norma. Al seguir el apartado 3.2.4 se quitarán las partículas que sobresalgan de la superficie y los huecos o irregularidades se corregirán con material fino puesto y compactado con ayuda de la espátula. Respecto al apartado 3.2.6, se tomarán 500 g de muestra en vez de 100.

5 RESULTADOS

5.1 Siguiendo las indicaciones del impreso que se adjunta en la NLT-107, se calcula la densidad seca y la humedad correspondiente a cada molde.

Se dibuja la curva que relaciona las densidades del suelo seco con las humedades correspondientes. El máximo de esta curva será la densidad máxima, y el tanto por ciento de humedad correspondiente será la humedad óptima.

6 OBSERVACIONES

6.1 En lugar del molde de las dimensiones indicadas en el apartado 2.1 de esta norma, se pueden utilizar para el ensayo moldes de otras dimensiones, siempre que se conserve la misma energía de compactación por unidad de volumen:

$$E = \frac{2,5 \times 30,5 \times 26 \times 3}{1.000} = 5,95 \frac{\text{kg} \times \text{cm}}{\text{cm}^3}$$

6.2 Durante la compactación debe colocarse el molde sobre una base sólida o bancada de hormigón que no pese menos de 90 kg para que no amortigüe los golpes.

6.3 Generalmente cinco puntos son suficientes para definir la curva densidad-humedad; no obstante, se prepara la muestra para siete puntos, por si fuera necesario algún punto más.

La distancia entre puntos debe ser de un 1 o un 3 % de agua, según sea el tipo de suelo arenoso o arcilloso, respectivamente. Para determinar el primer punto, se añade agua hasta un valor anterior y convenientemente próximo a la humedad óptima. La práctica enseñará a conocer este punto por el aspecto del suelo; en los suelos no plásticos y en los suelos plásticos, el primer punto puede estimarse por el menor contenido de agua necesario para que el suelo quede unido mediante la presión ejercida apretando la palma de la mano cerrada sobre una porción de la mezcla húmeda; a partir de este punto se obtienen los sucesivos, aumentando progresivamente el agua en la proporción conveniente. Se puede saber a priori, aproximadamente, sin determinar la densidad, cuándo se llega a la rama descendente de la curva humedad-densidad, porque al aumentar el contenido de agua, decrece el peso húmedo del suelo-cemento.

7 CORRESPONDENCIA CON OTRAS NORMAS

ASTM D 558-57 (Revalidada 1976). «Test Method for Moisture-Density Relations of Soil-Cement Mixtures».

8 NORMA PARA CONSULTA

NLT-107 «Apisonado Proctor».

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Methods for Moisture-Density Relations of Soil-Cement Mixtures[1]

This standard is issued under the fixed designation D 558; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 These test methods cover the determination of the relationship between the water content and the density of soil-cement mixtures when compacted before cement hydration as prescribed.

1.2 A $\frac{1}{30}$-ft^3 (944-cm^3) mold and a 5.5-lb (2.49-kg) rammer dropped from a height of 12 in. (304.8 kg) are used and two methods, depending on soil gradation, are covered, as follows:

	Sections
Test Method A, using soil material passing a No. 4 (4.75-mm) sieve. This method shall be used when 100 % of the soil sample passes the No. 4 (4.75-mm) sieve	5
Test Method B, using soil material passing a ¾-in. (19.0-mm) sieve. This method shall be used when part of the soil sample is retained on the No. 4 (4.75-mm) sieve. This test method may be used only on materials with 30 % or less retained on the ¾-in. (19.0-mm) sieve	6

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[2]
C 595 Specification for Blended Hydraulic Cements[2]
D 559 Test Methods for Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures[3]
D 560 Test Methods for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures[3]
D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[3]
D 2168 Test Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]
D 3740 Practice for the Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock Used in Engineering Design and Construction[3]
E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Significance and Use

3.1 These tests determine the optimum water content and maximum density to be used for molding soil-cement specimens in accordance with Methods D 559 and D 560.

NOTE 1—Since these tests are used in conjunction with Methods D 559 and D 560 and the criteria referenced therein, the test differs in several aspects from Test Methods D 698.

NOTE 2—The agency performing these test methods can be evaluated in accordance with Practice D 3740. Not withstanding statements on precision and bias contained in these test methods: the precision of these test methods is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of these test methods are cautioned that compliance with Practice D 3740 does not, in itself, ensure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of these factors.

4. Apparatus

4.1 *Mold*—A cylindrical metal mold having a capacity of $\frac{1}{30}$ ± 0.0004 ft^3 (944 ± 11 cm^3) with an internal diameter of 4.0 ± 0.016 in. (101.60 ± 0.41 mm) and conforming to Fig. 1 to permit preparing compacted specimens of soil-cement mixtures of this size. The mold shall be provided with a detachable collar assembly approximately 2½ in. (63.5 mm) in height. The mold may be of the split type consisting of two half-round sections or section of pipe with one side split perpendicular to the pipe circumference and that can be securely locked in place to form a closed cylinder having the dimensions described above. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base (Fig. 1).

4.2 *Rammer:*

4.2.1 *Manual Rammer*—A manually operated metal rammer having a 2.0 ± 0.005-in. (50.80 ± 0.13-mm) diameter circular face and weighing 5.5 ± 0.02 lb (2.49 ± 0.01 kg). The rammer shall be equipped with a suitable guidesleeve to control the height of drop to a free fall of 12.0

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[1] These test methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.15 on Stabilization of Additives.

Current edition approved May 10, 1996. Published June 1996. Originally published as D 558 – 38. Last previous edition D 558 – 82 (1990)$^{\epsilon 1}$.

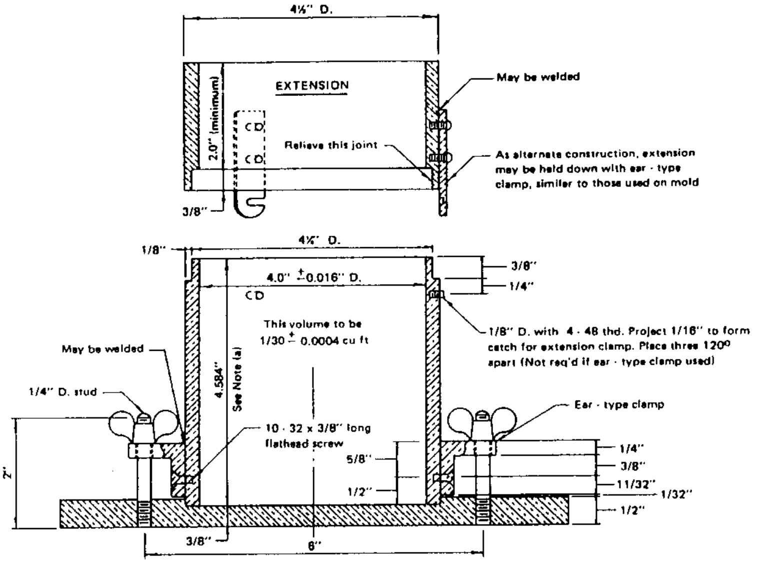
[2] *Annual Book of ASTM Standards,* Vols 04.01 and 04.02.

[3] *Annual Book of ASTM Standards,* Vol 04.08.

[4] *Annual Book of ASTM Standards,* Vols 04.01, 04.06, and 14.02.

*** A Summary of Changes section appears at the end of test methods.**

Norma 12 ASTM D 558-96 PROCTOR SUELO CEMENTO



Metric Equivalents

in.	mm
0.016	0.41
0.026	0.66
1/32	0.80
1/16	1.6
1/8	3.2
1/4	6.4
11/32	8.7
3/8	9.5
1/2	12.7
5/8	15.9
2	50.8
2½	63.5
4	101.6
4¼	108.0
4½	114.3
4.584	116.43
6	152.4
6½	165.1
8	203.2
ft³	**cm**
1/30	944
0.004	11
1/13.333	2124
0.0009	25

NOTE (a)—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE (b)—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 1 Cylindrical Mold

± 1/16 in. (304.8 ± 1.6 mm) above the elevation of the soil-cement. The guidesleeve shall have at least four vent holes not smaller than 3/8 in. (9.5 mm) spaced 90° apart and located with centers 3/4 ± 1/16 in. (19.0 ± 1.6 mm) from each end and shall provide sufficient clearance that free-falls of the rammer shaft and head will not be restricted.

4.2.2 *Mechanical Rammer*—A mechanically operated metal rammer having a 2.0 ± 0.005-in. (50.80 ± 0.13-mm) diameter face and a manufactured mass of 5.5 ± 0.02 lb (2.49 ± 0.01 kg). The operating mass of the rammer shall be determined from a calibration in accordance with Methods D 2168. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free-fall of 12.0 ± 1/16 in. (304.8 ± 1.6 mm) above the elevation of the soil-cement.

4.2.3 *Rammer Face*—A sector face may be substituted with mechanical rammers provided the report shows that a sector face rammer was used. The sector face shall be a sector of a 4.0 ± 0.016-in. (101.60 ± 0.41-mm) diameter circle and shall have an area equal to that of the circular face rammer.

NOTE 3—The sector face rammer shall not be used to compact test specimens in accordance with Methods D 559 and D 560, unless previous tests on like soils show strength and resistance to wetting-and-drying and freezing-and-thawing of specimens compacted with this rammer are similar to that of specimens compacted with the circular face rammer.

4.3 *Sample Extruder*—A jack, lever frame, or other device adapted for the purpose of extruding compacted specimens from the mold. Not required when a split-type mold is used.

4.4 *Balances*—A balance or scale of at least 25-lb (11.3-kg) capacity sensitive to 0.01 lb (0.005 kg) and a balance of at least 1000-g capacity sensitive to 0.1 g.

4.5 *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C) for drying water content samples.

4.6 *Straightedge*—A rigid steel straight-edge 12 in. (305 mm) in length and having one beveled edge.

4.7 *Sieves*—3-in. (75-mm), ¾-in. (19.0-mm), and No. 4 (4.75-mm) sieves conforming to the requirements of Specification E 11.

4.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, and spatula, or a suitable mechanical device for thoroughly mixing the sample of soil with cement and with increments of water.

4.9 *Container*—A flat, round pan for moisture absorption by soil-cement mixtures, about 12 in. (305 mm) in diameter and 2 in. (50 mm) deep.

4.10 *Moisture Cans*—Suitable containers for moisture samples.

4.11 *Butcher Knife*—A butcher knife approximately 10 in. (250 mm) in length for trimming the top of the specimens.

5. Test Method A, Using Soil Material Passing a No. 4 (4.75-mm) Sieve

5.1 *Sample:*

5.1.1 Prepare the sample for testing by breaking up the soil aggregations to pass the No. 4 (4.75-mm) sieve in such a manner as to avoid reducing the natural size of the individual particles. When necessary, first dry the sample until it is friable under a trowel. Drying may be accomplished by air drying or by the use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C).

5.1.2 Select a representative sample, weighing approximately 6 lb (2.7 kg) or more, of the soil prepared as described in 5.1.1.

5.2 *Procedure:*

5.2.1 Add to the soil the required amount of cement conforming to Specification C 150 or Specification C 595. Mix the cement and soil thoroughly to a uniform color.

5.2.2 When needed, add sufficient potable water to dampen the mixture to approximately four to six percentage points below the estimated optimum water content and mix thoroughly. At this moisture content, plastic soils, tightly squeezed in the palm of the hand, will form a cast that will fracture with only slight pressure applied by the thumb and fingertips; nonplastic soils will bulk noticeably.

5.2.3 When the soil is a heavy-textured clayey material, compact the mixture of soil, cement, and water in the container to a depth of about 2 in. (50 mm) using the rammer described in 4.2 or a similar hand tamper. Cover, and allow to stand for not less than 5 min but not more than 10 min to aid dispersion of the moisture and to permit more complete absorption by the soil-cement.

5.2.4 After the absorption period, thoroughly break up the mixture, without reducing the natural size of individual particles, until it will pass a No. 4 (4.75-mm) sieve and then remix.

5.2.5 Form a specimen by compacting the prepared soil-cement mixture in the mold, with the collar attached, in three equal layers so as to give a total compacted depth of about 5 in. (130 mm). Compact each layer by 25 blows from the rammer dropping free from a height of 12 in. (304.8 mm) above the elevation of the soil-cement when a sleeve-type rammer is used, or from 12 in. (304.8 mm) above the approximate elevation of each finally compacted layer when a stationary-mounted type rammer is used. The blows shall be uniformly distributed over the surface of the layer being compacted. During compaction, the mold shall rest on a uniform, rigid foundation such as provided by a cylinder or a cube of concrete weighing not less than 200 lb (91 kg).

5.2.6 Following compaction, remove the extension collar, carefully trim the compacted mixture even with the top of the mold by means of the knife and straightedge, and weigh.

5.2.7 Multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 30 (or divide by 942.95); record the result as the wet unit mass, γ_m, in pounds per cubic foot or grams per cubic centimetre, of the compacted soil-cement mixture.

5.2.8 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material, weighing not less than 100 g, from the full height of one of the cut faces, weigh immediately, and dry in an oven at 230 ± 9°F (110 ± 5°C) for at least 12 h or to constant mass.

5.2.9 Calculate the water content of the sample as directed in Section 7. Record the result as the moisture content, w, of the compacted soil-cement mixture.

5.2.10 Thoroughly break up the remainder of the material as before until it will pass a No. 4 (4.75-mm) sieve, as judged by eye, and add all other material remaining after obtaining the moisture sample.

5.2.11 Add water in sufficient amount to increase the water content of the soil-cement mixture by one or two percentage points, mix, and repeat the procedure given in 5.2.5 to 5.2.10 for each increment of water added.

5.2.12 Continue this series of determinations until there is either a decrease or no change in the wet unit mass, γ_m, in pounds per cubic foot or grams per cubic centimetre of the compacted soil-cement mixture.

NOTE 4—This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, a separate and new sample shall be used for each moisture-density determination.

NOTE 5—To minimize the effect of cement hydration, perform the test expeditiously and continuously to completion.

6. Test Method B, Using Soil Material Passing a ¾-in. (19.0-mm) Sieve

6.1 *Sample:*

6.1.1 Prepare the sample for testing by segregating the aggregate retained on a No. 4 (4.75-mm) sieve and breaking up the remaining soil aggregations to pass the No. 4 (4.75-mm) sieve in such a manner as to avoid reducing the natural size of individual particles. When necessary, first dry the sample until it is friable under a trowel. Drying may be accomplished by air drying or by the use of drying apparatus such that the temperature of the sample does not exceed 140°F (60°C).

6.1.2 Sieve the prepared soil over the 3-in. (75-mm) (Note 2), ¾-in., (19.0-mm), and No. 4 (4.75-mm) sieves. Discard the material retained on the 3-in. (75-mm) sieve. Determine the percentage of material, by oven-dry mass, retained on the ¾-in. (19.0-mm) and No. 4 sieves.

6.1.3 Saturate the aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve by soaking in potable water; surface-dry the material as required for later testing.

NOTE 6—Most soil-cement construction specifications covering soil gradation limit maximum size material to 3 in. (75 mm) or less.

6.1.4 Select and maintain separate representative samples of soil passing the No. 4 (4.75-mm) sieve and of saturated, surface-dry aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 sieve so that the total sample will weigh approximately 11 lb (4.99 kg) or more. The percentage, by oven-dry mass, of aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve shall be the same as the percentage passing the 3-in. (75-mm) sieve and retained on the No. 4 sieve in the original sample.

6.2 *Procedure:*

6.2.1 Add to the portion of the soil sample passing the No. 4 sieve, the amount of cement conforming to Specification C 150 or Specification C 595, required for the total sample specified in 6.1.4. Mix the cement and soil thoroughly to a uniform color.

6.2.2 When needed, add water to this soil-cement mixture and facilitate moisture dispersion as described for Method A in 5.2.2 to 5.2.4. After this preparation, add the saturated, surface-dry aggregate to the soil-cement mixture passing the No. 4 (4.75-mm) sieve and mix thoroughly.

6.2.3 Form a specimen by compacting the prepared soil-cement mixture in the mold (with the collar attached) and trim and weigh the compacted specimen as described for Method A in 5.2.5 and 5.2.6. During the trimming operation remove all particles that extend above the top level of the mold. Correct all irregularities in the surface by hand-tamping fine material into these irregularities and leveling the specimen again with the straightedge.

6.2.4 Multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 30 (or divide by 942.95); record the result as the wet unit mass, γ_m, in pounds per cubic foot or grams per cubic centimetre of the compacted soil-cement mixture.

6.2.5 Remove the material from the mold and take a sample for determining the water content as described for Method A in 5.2.8 and 5.2.9 except that the moisture sample shall weigh not less than 500 g. Record the result as the water content, w, of the compacted soil-cement mixture.

6.2.6 Thoroughly break up the remainder of the material as before until it will pass a ¾-in. (19.0-mm) sieve and at least 90 % of the soil particles smaller than a No. 4 (4.75-mm) sieve will pass a No. 4 sieve, as judged by eye, and add all other material remaining after obtaining the moisture sample.

6.2.7 Add sufficient water to increase the water content of the soil-cement mixture by one or two percentage points, mix, and repeat the procedure described in 6.2.3 to 6.2.6 for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit mass, γ_m, in pounds per cubic foot or grams per cubic centimetre of the compacted soil-cement mixture (Notes 3 and 4).

7. Calculation

7.1 Calculate the water content and dry unit mass, γ_d, in pounds per cubic foot or grams per cubic centimetre of the compacted soil-cement mixture for each trial as follows:

$$w = [(A - B)/(B - C)] \times 100$$
$$\gamma = [\gamma_m/(w + 100)] \times 100$$

where:

w = percentage of water in the specimen,
A = mass of moisture can and wet soil-cement,
B = mass of moisture can and oven-dry soil-cement,
C = mass of moisture can,
γ_d = dry unit mass of compacted soil cement, lb/ft^3 or g/cm^3, and
γ_m = wet unit mass of compacted soil-cement, lb/ft^3 or g/cm^3.

8. Moisture-Density Relationship

8.1 The calculations in Section 7 shall be made to determine the water content and corresponding dry unit mass, γ_d, in pounds per cubic foot or grams per cubic centimetre (density) for each of the compacted soil-cement samples. The dry unit mass, γ_d, in pounds per cubic foot or grams per cubic centimetre (densities) of the soil-cement mixture shall be plotted as ordinates and the corresponding moisture contents as abscissas.

8.2 *Optimum Water Content,* w_o—When the densities and corresponding moisture contents for the soil-cement mixture have been determined and plotted as indicated in 8.1 it will be found that by connecting the plotted points with a smooth line, a curve is produced. The water content corresponding to the peak of the curve shall be termed the "optimum moisture content" of the soil-cement mixture under the compaction prescribed in these methods.

8.3 *Maximum Density,* γ_{max}—The dry unit mass, γ_d, in pounds per cubic foot or grams per cubic centimetre of the soil-cement mixture at "optimum water content" shall be termed "maximum density" under the compaction prescribed in these test methods.

9. Report

9.1 The report shall include the following:

9.1.1 Optimum water content, and

9.1.2 Maximum density.

10. Precision and Bias

10.1 *Precision*—Data are being sought by the subcommittee for the preparation of a statement on the precision of this test procedure. Until a statement is developed, the user may be guided by the statement in Test Method D 698, for which the precision is expected to be similar.

10.2 *Bias*—There are no accepted reference values for this test method, therefore, bias cannot be determined.

11 Keywords

11.1 compaction; dry density; optimum water content; soil-cement; soil-stabilization; unit weight

SUMMARY OF CHANGES

This section identifies the principal changes to these test methods that have been incorporated since the last issue.

(1) Added new sentence at the end of Section 1.2, Test Method B, to clarify the applicable materials as required in Test Method D 698 when using a 4-in. (101.60-mm) mold.

(2) Added safety caveat in 1.4 to comply with present policy.

(3) Added Practice D 3740 as a referenced document in Section 2 to conform to the recommended D-18 practice.

(4) Added new Note 2 in Section 3 to reference Practice D 3740. Renumbered the remaining notes.

(5) Revised Section 11 on Keywords.

(6) Added new Section 12 on Summary of Changes to reflect the changes made in this revision.

(7) Changed "moisture content" to "water content" in Sections 1.1, 3.1, 4.5, 5.2.2, 5.2.9, 5.2.1.1, 6.2.5, 6.2.7, 7.1, 8.1, 8.2, 8.3, and 9 to agree with current D-18 Terminology.

Centro de Estudios y Experimentación de Obras Públicas

LABORATORIO DEL TRANSPORTE Y MECANICA DEL SUELO "JOSE LUIS ESCARIO"

TRABAJO N.º .... DENOMINACION .... MUESTRA N.º ....

ENSAYO PROCTOR { NORMAL / MODIFICADO

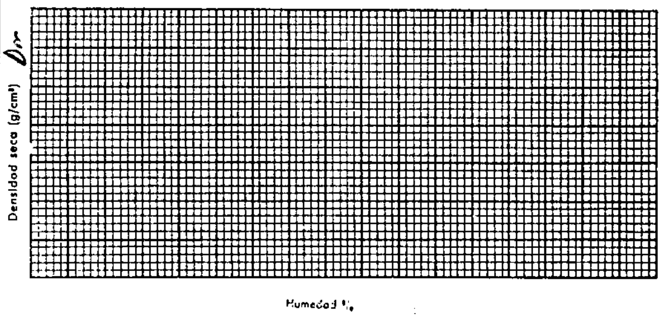
Molde: .... N.º de capas: .... Material utilizado: ....

Maza: .... N.º de golpes por capa: .... % de material no utilizado: ....

Altura de caída: .... Peso expecífico del material grueso: ....

	—	Punto n.º						
	—	% agua añadida						
Densidad	$t+s+a$	Molde + suelo + agua						
	t	Molde						
	$s+a=(t+s+a)-t$	Suelo + agua						
	$s=\frac{(s+a)\,100}{100+w}$	Suelo						
	$\rho=\frac{s}{V}$	Densidad						
Humedad	—	Referencia tara						
	$t+s+a$	Tara + suelo + agua						
	$t+s$	Tara + suelo						
	t	Tara						
	$s=(t+s)-t$	Suelo						
	$a=(t+s+a)-(t+s)$	Agua						
	$w=\frac{a}{s}\times 100$	Humedad %						

DENSIDAD MAXIMA ☐ HUMEDAD OPTIMA ☐



Descripción del suelo y observaciones ....

....

....

NORMA DE ENSAYO
DEL
LABORATORIO DEL TRANSPORTE
Y MECANICA DEL SUELO
"JOSE LUIS ESCARIO"

NLT-107/72

Proctor

1. OBJETO

1.1. El ensayo de Proctor tiene por objeto determinar la relación entre la humedad y la densidad seca de un material cuando se compacta, en la superficie terrestre, mediante impactos de una maza de 2,5 kg que se deja caer libremente desde una altura de 305 mm.

2. APARATOS Y MATERIAL NECESARIOS

2.1. Un molde metálico de 1.000 ± 9 cm³ de capacidad (102 ± 0,4 mm de diámetro interior × 122,4 ± 0,1 mm de altura), con su base y collar (fig. 1). El molde puede ser partido longitudinalmente, como es el de la figura 1, o de una pieza.

2.2. Una maza de 2,5 ± 0,01 kg. Debe tener una guía adecuada para que la altura de caída libre sea de 305 ± 2 mm sobre la superficie del material. La maza puede ser manual, en cuyo caso tendrá un diámetro de 50 ± ± 0,2 mm y una superficie de 19,6 ± 0,2 cm², y la guía debe tener como mínimo 4 orificios de 1 cm de diámetro espaciados 90° y a 2 cm de cada extremo, para facilitar la salida del aire. La separación entre maza y guía debe ser suficiente para que la caída sea libre.
También se puede emplear una maza mecánica que distribuya uniformemente los golpes sobre la superficie del material. La separación entre la maza y la superficie lateral interior del molde debe ser de 3 ± 1 mm. Debe efectuarse un calibrado del aparato de acuerdo con la NLT-114/72, y modificar la masa si es preciso. La superficie de golpeo de la maza mecánica puede ser circular, en cuyo caso tendrá las dimensiones específicas para la manual, o puede tener forma de sector, en cuyo caso el radio será de 48 ± 0,5 mm y la superficie de 19,6 ± 0,2 cm.

2.3. Una balanza de unos 20 kg de capacidad, que aprecie 1 g, y otra de unos 1000 g de capacidad, que aprecie 0,1 g.

2.4. Recipientes adecuados según se indica en el apartado 2.3 de la norma 102/72.

2.5. Una estufa de desecación regulable a 105-110 °C.

2.6. Una amasadora mecánica adecuada, o instrumentos diversos para amasar manualmente (recipiente, guantes de goma, etc.).

2.7. Un tamiz 20 UNE (A.S.T.M. 3/4 pulgada) y, eventualmente, tamices 40 UNE (A.S.T.M. 1 1/2 pulgadas) y 50 UNE (A.S.T.M. 2 pulgadas).

Norma 13 NLT 107/72 PROCTOR

2.8. Un enrasador metálico de borde recto, afilado y resistente (una regla metálica con bisel, un cuchillo o una espátula alargados, o una paleta de solador pueden servir para esta función).

2.9. Un cuarteador.

2.10. Un mazo de goma y una paleta.

2.11. Una probeta para medir el agua que hay que añadir al suelo en cada determinación.

2.12. Un extractor de muestras si se emplea el molde cerrado.

3. PREPARACION DE LA MUESTRA

3.1. Se opera como se indica en la NLT-101/72 y particularmente en su apartado 3.4.4.

3.2. Se divide por cuarteo el material así obtenido en seis porciones aproximadamente iguales.

4. PROCEDIMIENTO

4.1. Se tara y anota el peso del molde, con la base y sin el collar superior.

4.2. Se toma una de las porciones obtenidas en 3.2 y se mezcla con agua hasta que quede íntima y uniformemente distribuida.

4.3. Se llena el molde, con el collar colocado, en tres capas aproximadamente iguales. Se compacta cada una de estas capas por medio de 26 golpes de la maza distribuidos uniformemente.
La última capa compactada entrará un poco en el collar de enrase (del orden de 1 cm). Durante la compactación debe colocarse el molde sobre una base suficientemente rígida para que no amortigüe los golpes.

4.4. Terminada la compactación, se quita el collar y se enrasa perfectamente el molde.

4.5. Se pesa el conjunto del molde y material compactado.

4.6. Se extrae el material del molde, se parte verticalmente a través del centro y se toma una muestra representativa (no inferior a 100 g) para la humedad.

4.7. Se repite la operación con nuevas porciones de material de las obtenidas en 3.2 hasta obtener los puntos necesarios para determinar la curva que relaciona la densidad seca con la humedad.

5. RESULTADOS

5.1. Siguiendo las explicaciones del impreso que se adjunta, se calculan la densidad seca y la humedad correspondientes a cada punto.
Se dibuja la curva que relaciona la densidad seca con la humedad. El máximo de esta curva dará la "densidad máxima Proctor", y la humedad correspondiente será la "humedad óptima".

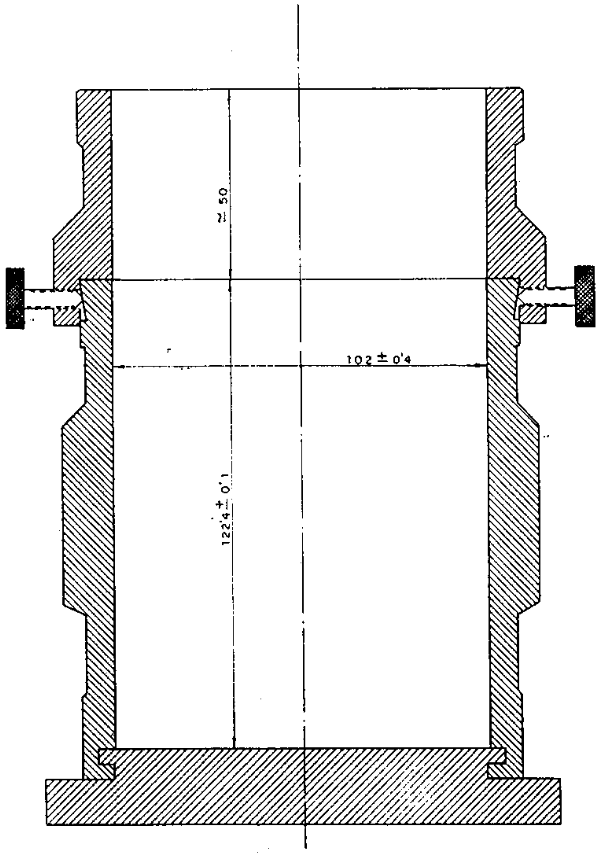


Fig. 1.—Molde de Proctor.

COTAS EN mm

6. OBSERVACIONES

6.1. Apartado 3.1. Si el material contiene partículas comprendidas entre el tamiz 20 UNE y el tamiz 40 UNE, se puede emplear el molde de 2.320 cm³ del ensayo de Proctor modificado (NLT-108/72) y de este modo utilizar todo el material en el ensayo, con tal de mantener aproximadamente la energía por unidad de volumen, que en un lugar de aceleración normalizada (9,80665 m/s²) sería:

$$E = \frac{2{,}5 \times 9{,}80665 \times 0{,}305 \times 26 \times 3}{1000} = 0{,}583 \text{ J/cm}^3$$

Esto se puede conseguir llenando el molde en tres tongadas y aplicando a cada una 60 golpes de la maza de 2,5 kg con una altura de caída de 305 mm.

Si sólo un 20 por 100 del suelo queda retenido en el tamiz 40 UNE y todo él pasa por el tamiz 50 UNE, es preferible seguir usando todo el material en el molde de 2320 cm³ que utilizar sólo el inferior al tamiz 40 UNE y usar correcciones para extender los resultados del material fino al original.

Estos extremos deben hacerse constar en el informe.

6.2. Si el tamaño máximo del material que se va a emplear en obra es superior al que permite el molde de laboratorio, hay que tamizar por el tamiz máximo permitido y realizar el ensayo de Proctor con la fracción fina. Queda el problema de pasar de la humedad y densidad del material fino al del material original.

Si la proporción de gruesos no es muy elevada (menos del 30 por 100) se supone a veces que los finos, con la misma humedad y densidad obtenida en el ensayo de laboratorio, ocuparán los huecos dejados por los gruesos. En tal caso, para pasar de la humedad óptima y densidad máxima Proctor de los finos w_{of} y ρ_{Pf} a las del total w_o y ρ_P, emplearemos las fórmulas:

$$w_o = \frac{100 - p}{100} w_{of}$$

$$\rho_P = \frac{100}{\dfrac{p}{\rho_s} + \dfrac{100 - p}{\rho_{Pf}}}$$

siendo p el porcentaje en peso de material seco retenido en el tamiz correspondiente al tamaño máximo admitido en el molde y ρ_s la densidad de las partículas gruesas.

Este procedimiento debe considerarse como una estimación aproximada.

NORMA DE ENSAYO
DEL
LABORATORIO DEL TRANSPORTE
Y MECANICA DEL SUELO
"JOSE LUIS ESCARIO"

NLT-108/72

Proctor modificado

1. OBJETO

1.1. El ensayo de Proctor modificado tiene por objeto determinar la relación entre la humedad y la densidad seca de un material cuando se compacta, en la superficie terrestre, mediante impactos de una maza de 4,54 kg que se deja caer libremente desde una altura de 457 mm.

2. APARATOS Y MATERIAL NECESARIOS

2.1. Un molde metálico de 2320 ± 24 cm³ de capacidad (152,5 ± 0,7 mm de diámetro interior × 127 ± 0,1 mm de altura), con su base y collar. Puede emplearse también un molde de mayor altura, que sirva para ensayo del CBR, provisto de un disco espaciador en su fondo (fig. 1).

2.2. Una maza de 4,54 ± 0,01 kg. Debe tener una guía adecuada para que la altura de caída libre sea de 457 ± 2 mm sobre la superficie del material. La maza puede ser manual, en cuyo caso tendrá un diámetro de 50 ± ± 0,2 mm y una superficie de 19,6 ± 0,2 cm², y la guía debe tener como mínimo 4 orificios de 1 cm de diámetro, espaciados 90° y a 2 cm de cada extremo, para facilitar la salida del aire. La separación entre maza y guía debe ser la superficie para que la caída sea libre

También se puede emplear una maza mecánica que distribuya uniformemente los golpes sobre la superficie del material. La separación entre la maza y la superficie lateral interior del molde debe ser de 3 ± 1 mm. Debe efectuarse un calibrado del aparato de acuerdo con la NLT-114/72 y modificar la masa si es preciso. La superficie de golpeo de la maza mecánica puede ser circular, en cuyo caso tendrá las dimensiones especificadas para la manual, o puede tener forma de sector, en cuyo caso el radio será de 73 ± 0,5 mm y la superficie de 19,6 ± 0,2 cm².

2.3. Los utensilios indicados en los apartados del 2.3 al 2.12 de la NLT-107/72.

3. PREPARACION DE LA MUESTRA

Véase norma NLT-107/72.

En cualquier caso, cuando la proporción de gruesos es apreciable, se recomienda recurrir a ensayos de compactación *in situ*.

6.3. Apartado 3.2. Se admite el volver a emplear el material ya compactado para obtener nuevos puntos, excepto cuando las partículas son frágiles o cuando se trata de arcilla muy plástica. Este extremo debe ser recogido en el informe.

6.4. Apartado 4.2. Algunos suelos arcillosos presentan gran dificultad para mezclarse íntimamente con el agua de modo inmediato. En estos casos puede ser conveniente añadir agua hasta obtener una humedad menor que la definitiva, hacer entonces un primer amasado, dejar la masa en reposo durante uno o dos días en la cámara húmeda y, después de este período, añadirle el resto del agua y amasar hasta que ésta quede íntima y uniformemente distribuida.

PROCEDIMIENTO

4.1 y 4.2. Véase NLT-107/72.

4.3. **Se llena** el molde, con el collar colocado, en cinco capas aproximadamente iguales. Se compacta cada una de estas capas por medio de 55 golpes de maza distribuidos uniformemente. La última capa compactada debe entrar un poco en el collar de enrase (del orden de 1 cm). Durante la compactación debe colocarse el molde sobre una base suficientemente rígida para que no amortigüe los golpes.

4.4 a 4.7. Véase NLT-107/72.

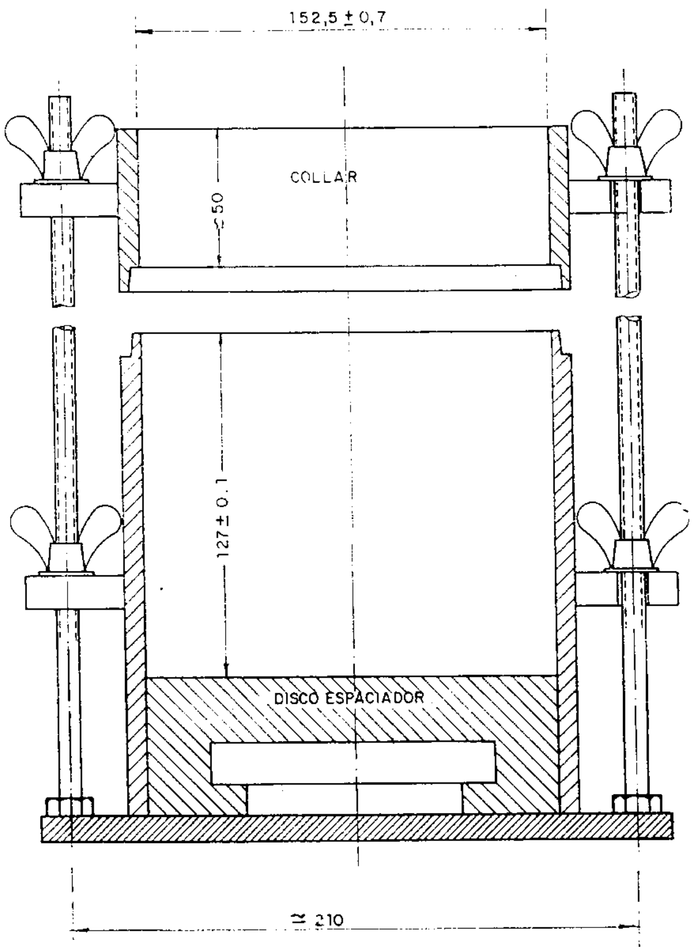
RESULTADOS

5.1. Siguiendo las explicaciones del impreso que se adjunta en la NLT-107/72, se calculan la densidad seca y la humedad correspondientes a cada punto. Se dibuja la curva que relaciona la densidad seca con la humedad. El máximo de esta curva dará la "densidad máxima Proctor modificado", y la humedad correspondiente será la "humedad óptima" del ensayo Proctor modificado.

OBSERVACIONES

6.1. Apartado 3.1. Si el material contiene partículas comprendidas entre el tamiz 20 UNE y el tamiz 40 UNE, se puede introducir todo el material en el molde si así se desea, pero haciéndolo constar en el impreso.
Incluso si sólo un 20 por 100 del suelo queda retenido en el tamiz 40 UNE y todo él pasa por el tamiz 50 UNE, es preferible seguir usando todo el material que utilizar sólo el inferior al tamiz 40 UNE y usar correcciones para extender los resultados del material fino al original.

6.2, 6.3 y 6.4. Véase NLT-107/72.



COTAS EN MM

Fig. 1. — Molde del ensayo de Proctor modificado con disco espaciador.

CD 624.131.431.2 Una Norma Española 10.

Determinación de la porosidad de un terreno

UNE 7045

Instituto Nacional de Racionalización del Trabajo - Madrid - Alcalá, 95 - Teléfono 25 92 65. Reproducción prohibida

1. Objeto

Esta norma es aplicable a todos los terrenos, cualquiera que sea su compacidad.

2. Fundamentos del método

Se determinará el volumen aparente del terreno y, a continuación, el peso de la muestra húmeda y el de la tra seca. Conocido el peso específico real del terreno, se determinará su porosidad, expresada por el vol de los huecos o por el índice de huecos.

3. Toma de muestras

Según las clases de terrenos, la toma de muestras se efectuará siguiendo las prescripciones de los *apartad* guientes:

3,1 Terrenos sueltos o poco coherentes. Con el aparato descrito en el *apartado 4,5* se perforará la mu del terreno, hasta enrasar sus bases perfectamente, procurando no alterar su estructura.

3,2 Terrenos coherentes. La muestra para el ensayo se obtendrá separando del terreno, o de la muestr mismo, un volumen de 20 cm³, aproximadamente, cuidando de no alterar su estructura, por lo que se evitará aristas vivas.

4. Aparatos empleados

Para la aplicación de este método serán necesarios los aparatos que se citan en los apartados siguientes:

4,1 Tapa de vidrio. Una tapa de vidrio de forma circular, de 170 mm de diámetro y 7 mm de espesor, com nimo. En su zona central llevará tres puntas de acero inoxidable, situadas según se indica en la *figura 1.*

Medidas en mm

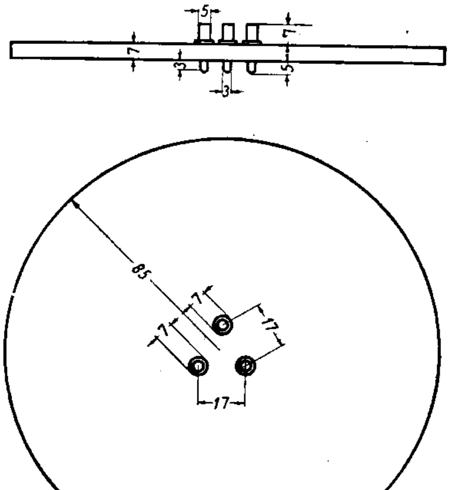


Fig. 1.

4,2 Recipientes de vidrio. Dos recipientes de vidrio de la forma aproximada que puede verse en la *figur* El de menor tamaño tendrá el borde esmerilado y plano.

4,3 Tubo graduado. Un tubo de vidrio, con una capacidad de 25 cm³, como mínimo, y graduado en déci de centímetro cúbico.

Contin

4,4 Volumenómetro. Los aparatos descritos en los *apartados 4,1* y *4,2*, podrán ser sustituídos por un volumenómetro de mercurio, que aprecie 0,05 cm³, con capacidad suficiente para los tubos de 25 cm³.

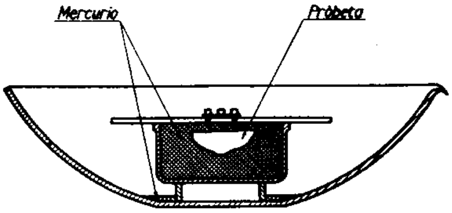


Fig. 2.

4,5 Tubo y pistón. Serán de acero inoxidable, ajustándose sus formas y medidas a las indicadas en la *figura 3*.

Medidas en mm

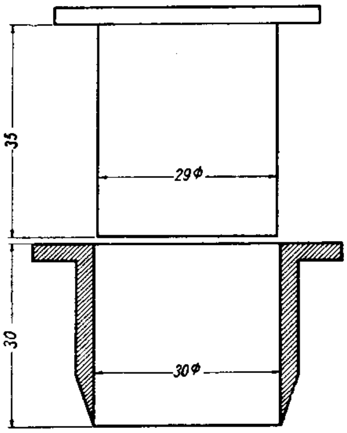


Fig. 3.

4,6 Vidrios de reloj. Seis vidrios de reloj, con los bordes esmerilados, para evitar las pérdidas de humedad de las muestras que se coloquen en su interior. Estos vidrios formarán tres parejas.

4,7 Balanza. Una balanza sensible a 0,001 g.

4,8 Estufa. Una estufa de desecación, con regulación automática de la temperatura.

5. Procedimiento operatorio

5,1 Determinación del volumen aparente. El volumen aparente se determina según los terrenos, conforme a lo que se expone a continuación.

5,11 Terrenos sueltos o poco coherentes. El volumen aparente de la muestra de un terreno suelto es el del tubo del *apartado 4,5*, que se determina con un error inferior a ± 0,05 cm³.

5,12 Terrenos coherentes. Se llena de mercurio el menor de los recipientes de vidrio citados en el *apartado 4,2*, se cierra con la tapa de vidrio descrita en el *apartado 4,1*. Seguidamente se retira del recipiente exterior el mercurio desalojado en el primer enrase y, en el recipiente menor, se coloca la muestra, que se sumerge con ayuda de las tres puntas de la tapa de vidrio, hasta que ésta quede apoyada en los bordes del recipiente, procurando que no quede ocluída ninguna burbuja de aire. El volumen de mercurio desalojado es igual al volumen de la probeta y su medida se ha de realizar con un error inferior a ± 0,05 cm³.

5,2 Determinación del peso de la muestra con su humedad natural. Para ambos tipos de terrenos, una vez terminadas las operaciones anteriores, se colocan las muestras entre dos vidrios de reloj, tarados, y se determina su peso, con un error inferior a ± 0,001 g.

Para sacar la muestra del terreno suelto, del tubo de acero, es conveniente hacer uso del pistón, con lo que se asegura la salida de toda la muestra.

5,3 Determinación del peso de la muestra seca. Conocido el peso de la muestra húmeda, se lleva ésta a la estufa, regulada a 105° C, y se deseca, hasta obtener peso constante, el cual se expresa con un error inferior a ± 0,001 g.

5,4 Determinación del peso específico real. Se efectúa sobre la muestra seca, según el método descrito en la norma UNE 7 001.

Continúa

6. Obtención y precisión de los resultados

Los resultados se obtendrán aplicando los valores obtenidos a las fórmulas siguientes, según los casos.

6,1 Volumen de los huecos. Es la relación entre el volumen de poros de la muestra y su volumen apar
Se determinará, en tanto por ciento, aplicando la fórmula siguiente:

$$n = \left(1 - \frac{G_s}{\gamma_s V}\right) 100,$$

en la que:

G_s = Peso de la muestra seca

γ_s = Peso específico de los granos de terreno

V = Volumen aparente de la muestra

$$\frac{P_s}{\delta_t \cdot P_w - P_h}\,'$$

Los resultados se expresarán con dos cifras exactas.

6,2 Índice de huecos. Es la relación entre el volumen de poros de la muestra y el volumen de su parte s
Se determinará, en tanto por uno, aplicando la fórmula siguiente:

$$\varepsilon = \frac{V\gamma_s}{G_s} - 1,$$

en la que:

G_s = Peso de la muestra seca

γ_s = Peso específico de los granos del terreno.

V = Volumen aparente de la muestra

Los resultados se expresarán con dos cifras decimales exactas.

7. Observaciones

El ensayo se realizará con tres muestras, obtenidas de la misma probeta del terreno, y se considerarán defect
los resultados cuando difieran en más del 5 % de su media aritmética.

8. Normas para consultar

Para la determinación del peso específico real, véase la norma UNE 7 001 — Determinación del peso específico
de un terreno.

6.4 *Straightedge*, steel, about 150 mm (6 in.) in length.

6.5 *Glass Cup*, about 57 mm (2¼) in.) in diameter and about 31 mm (1¼ in.) in height, the top rim of which is ground smooth and is in a plane essentially parallel with the bottom of the cup.

6.6 *Glass Plate*, with three metal prongs for immersing the soil pat in mercury, as shown in Fig. 1.

6.7 *Glass Plate*, a plane glass plate large enough to cover the glass cup.

6.8 *Graduate*, glass, having a capacity of 25 mL and graduated to 0.2 mL.

6.9 *Balance*, sensitive to 0.1 g and conforming to the requirements of Class GP2 balances in Specification D 4753.

6.10 *Mercury*, sufficient to fill the glass cup to overflowing.

6.11 *Shallow Pan*, about 20 by 20 by 5-cm (8 by 8 by 2-in.) deep nonmetallic (preferably glass) pan used to contain accidental mercury spills.

7. Hazards

7.1 **Warning**—Mercury is a hazardous substance that can cause illness and death. Inhalation of mercury vapor is a serious health hazard. Mercury can also be absorbed through the skin. The effects of mercury are cumulative.

7.2 **Precaution**—In addition to other precautions, store mercury in sealed shatter-proof containers to control evaporation, work in a well-ventilated area (preferably under a fume hood), and avoid contact with skin. Rubber gloves should be worn at all times.

7.3 Minimize uncontrolled spills by performing those parts of the procedure (9.3 and 9.6) in a large shallow pan which can act as a catchment.

7.4 Clean up spills immediately using a recommended procedure explicitly for mercury.

7.5 Dispose of contaminated waste materials including the dry soil pat in a safe and environmentally acceptable manner.

8. Sampling

8.1 Select about 30 g of soil from the thoroughly mixed portion of the material passing the No. 40 (425-µm) sieve which has been obtained in accordance with Practice D 421.

9. Procedure

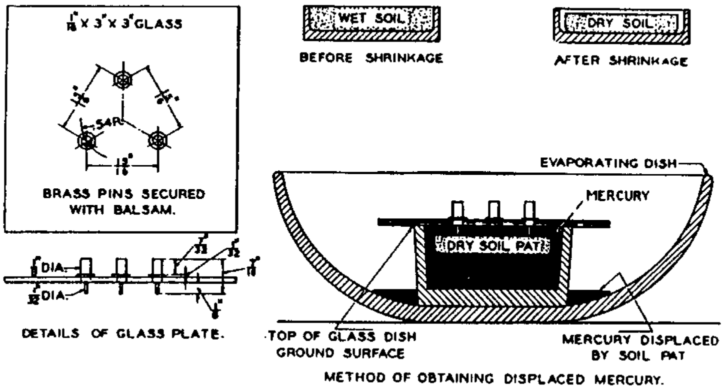
9.1 Place the soil in the evaporating dish and thoroughly mix with distilled water. The amount of water added should produce a soil of the consistency somewhat above the liquid limit (Test Method D 4318) based on visual inspection. In physical terms, this is a consistency that is not a slurry but one that will flow sufficiently to expel air bubbles when using gentle tapping action. It is desirable to use the minimum possible water content. This is of some importance with very plastic soils so that they do not crack during the drying process.

9.2 Coat the inside of the shrinkage dish with a thin layer of petroleum jelly, silicone grease, or similar lubricant to prevent the adhesion of the soil to the dish. Determine and record the mass in grams (pounds/mass) of the empty dish, M_T.

9.3 Place the shrinkage dish in the shallow pan in order to catch any mercury overflow. Fill the shrinkage dish to overflowing with mercury. Remove the excess mercury by pressing the glass plate firmly over the top of the shrinkage dish. Observe that there is no air trapped between the plate and mercury and if there is, refill the dish and repeat the process. Determine the volume of mercury held in the shrinkage dish either by means of the glass graduate or by dividing the measured mass of mercury by the mass density of mercury (equal to 13.55 mg/m^3). Record this volume in cubic centimetres (cubic feet) of the wet soil pat, V.

Note 2: **Caution**—Mercury is a hazardous substance which can cause serious health effects from prolonged inhalation of the vapor or contact with the skin, see Section 7.

Note 3—It is not necessary to measure the volume of the shrinkage dish (wet soil pat) during each test. The value of a previous measurement may be used provided that it was obtained as specified in 9.3 and the shrinkage dish is properly identified and in good physical condition.



Metric Equivalents

in.	1/32	1/16	1/8	7/32	7/16	15/16	3
mm	0.8	1.6	3.2	5.6	11.1	23.8	76.2

FIG. 1 Apparatus for Determining the Volumetric Change of Subgrade Soils

9.4 Place an amount of the wetted soil equal to about one third the volume of the dish in the center of the dish, and cause the soil to flow to the edges by taping the dish on a firm surface cushioned by several layers of blotting paper or similar material. Add an amount of soil approximately equal to the first portion, and tap the dish until the soil is thoroughly compacted and all included air has been brought to the surface. Add more soil and continue the tapping until the dish is completely filled and excess soil stands out above its edge. Strike off the excess soil with a straightedge, and wipe off all soil adhering to the outside of the dish. Immediately after it is filled and struck off, determine and record the mass in grams (pounds/mass) of the dish and wet soil, M_w.

9.5 Allow the soil pat to dry in air until the color of the soil turns from dark to light. Oven-dry the soil pat to constant mass at 110 ± 5°C (230 ± 9°F). If the soil pat is cracked or has broken in pieces, return to 9.1 and prepare another soil pat using a lower water content. Determine and record the mass in g (lbm) of the dish and dry soil, M_D.

9.6 Determine the volume of the dry soil pat by removing the pat from the shrinkage dish and immersing it in the glass cup full of mercury in the following manner.

9.6.1 Place the glass cup in the shallow pan in order to catch any mercury overflow. Fill the glass cup to overflowing with mercury. Remove the excess mercury by pressing the glass plate with the three prongs (Fig. 1) firmly over the top of the cup. Observe that there is no air trapped between the plate and mercury and if there is, refill the dish and repeat the process. Carefully wipe off any mercury that may be adhering to the outside of the cup.

9.6.2 Place the evaporating dish in the shallow pan in order to catch any mercury overflow. Place the cup filled with mercury in the evaporating dish and rest the soil pat on the surface of the mercury (it will float). Using the glass plate with the three prongs gently press the pat under the mercury and press the plate firmly over the top of the cup to expel any excess mercury. Observe that there is no air trapped between the plate and mercury and if there is, repeat the process starting from 9.6.1. Measure the volume of the mercury displaced into the evaporating dish either by means of the glass graduate or by dividing the measured mass of mercury by the mass density of mercury. Record the volume in cubic centimetres (cubic feet) of the dry soil pat, V_o.

10. Calculation

10.1 Calculate the initial wet soil mass as:

$$M = M_w - M_T$$

10.2 Calculate the dry soil mass as:

$$M_o = M_D - M_T$$

10.3 Calculate the initial water content of the soil as a percentage of the dry mass as:

$$w = [(M - M_o)/M_o] \times 100$$

10.4 Calculate the shrinkage limit as a water content of the soil as a percentage of the dry mass as:

$$SL = w - ([(V - V_o)\rho_w/M_o] \times 100)$$

where:

ρ_w = approximate density of water equal to 1.0 g/cm^3 (62.4 lb/ft^3)

V, V_o are defined in the procedures section.

TABLE 1 Table of Precision Estimates

Material and Type Index	Average Value	Standard Deviation[A]	Acceptable Range of Two Results[A]
Single-Operator			
Shrinkage limit	16	0.6	1.8
Shrinkage ratio	1.90	0.04	0.13
Multilaboratory			
Shrinkage limit	16	1.7	4.8
Shrinkage ratio	1.90	0.07	0.19

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C 670.

10.5 Calculate the shrinkage ratio, R from the data obtained in the volumetric shrinkage determination by the following equation:

$$R = M_o/(V_o \times \rho_w)$$

11. Report

11.1 Report the following information:

11.1.1 Identification data and visual description of sample.

11.1.2 Value of initial water content to the nearest whole number and omitting the percentage designation.

11.1.3 Value of shrinkage limit to the nearest whole number and omitting the percentage designation.

11.1.4 Value of shrinkage ratio to the nearest 0.01.

12. Precision and Bias

12.1 *Bias*—There is no acceptable reference value for this test method, therefore, bias cannot be determined.

12.2 *Precision*[4]—Table 1 presents estimates of precision based on results from the AASHTO Materials Reference Laboratory (AMRL) Proficiency Sample Program of testing conducted on Samples 103 and 104. These samples were found to be a CL material having 59.4 % fines, a liquid limit of 33 and a plastic limit of 18.

12.2.1 The column labeled "Acceptable Range of Two Results" quantifies the maximum difference expected between two measurements on samples of the same material under the conditions listed in the first column. These values only apply to soils which are similar to Proficiency Samples 103 and 104.

NOTE 5—The figures given in Column 3 are the standard deviations that have been found to be appropriate for the test results described in Column 1. The figures given in Column 4 are the limits that should not be exceeded by the difference between two properly conducted tests.

NOTE 6—Criteria for assigning standard deviation values for highly plastic or noncohesive soils are not available at the present time.

13. Keywords

13.1 Atterberg limits; cohesive soils; dry strength; linear shrinkage; mercury; shrinkage ratio; volumetric shrinkage

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[4] Research Report RR:D18-1002 contains the data used to establish this precision statement and is available from ASTM Headquarters.

CD 624.131.43 Una Norma Española 7.5

Determinación del límite de retracción de un terreno

UNE
7 016

1 Alcance

Esta determinación es aplicable a la porción de la muestra de cualquier terreno que pase por un tamiz de agu cuadrados de 0,42 0,02 mm de lado.

2. Definición

Se llama límite de retracción de un terreno, la cantidad de agua que contiene, cuya evaporación posterior y produce cambios en su volumen. Dicha cantidad se expresa en tanto por ciento del peso de la muestra seca.

Se designa con W_c y puede obtenerse siguiendo los procedimientos detallados en los *apartados 5, 6 y 7*.

3 Aparatos empleados

Para la aplicacion de este método serán necesarios los siguentes aparatos y utensilios:

3.1 Un cristal plano. De forma rectangular y 40 × 60 cm, aproximadamente.

3.2 Un tamiz De malla cuadrada, midiendo el lado del agujero 0,42 ± 0,02 mm. Serán admisibles variaci de 0,06 mm en un 5 por 100 de la superficie del tamiz.

3.3 Un mortero. Un mortero y un mazo recubierto de goma, útiles para desmenuzar los terrones compuesto partículas del suelo

3.4 Dos espátulas. Con las hojas de acero inoxidable y una longitud aproximada de 15 cm. El ancho de de ellas será de unos 2 cm y el de la otra estará comprendido entre 7 y 8 cm.

3.5 Tres cristalizadores de retracción. Su forma será cilíndrica, con el fondo plano, de unos 7 cm de diám y de altura comprendida entre 1 y 2 cm.

3.6 Una regla rigida. Su longitud estará próxima a los 15 cm y los bordes serán completamente rectos.

3.7 Tapa de vidrio. Una tapa de vidrio con forma circular, de 17 cm de diámetro y 0,7 cm de espesor como mín En su zona central llevará tres puntas de acero inoxidable, situadas en la forma que se indica en la *figura 1*.

Medidas en mm

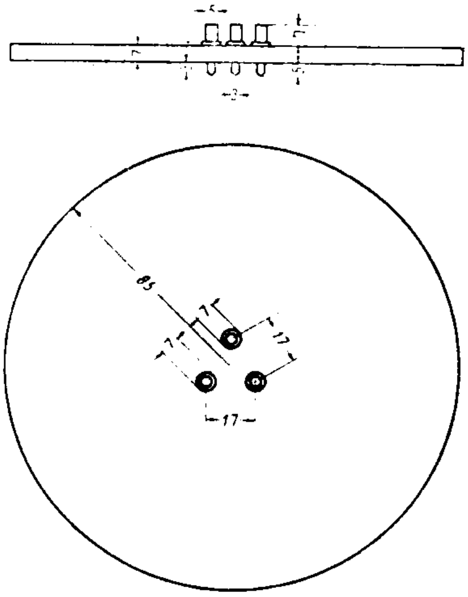

Figura 1

3.8 Recipientes de vidrio. Dos recipientes de vidrio, de la forma aproximada que puede verse en la *figura* de menor tamaño tendrá el borde esmerilado y plano.

3.9 Tubo graduado. Un tubo de vidrio con una capacidad de 25 cm³ como mínimo y graduado en décimas centímetro cúbico.

3,10 Un volumenómetro. Los aparatos descritos en los *apartados 3,7* y *3,8* podrán ser sustituídos por un volumenómetro que aprecie 0,05 cm³ y en cuyo interior quepa un cristalizador de retracción de los descritos en el *apartado 3,5*.

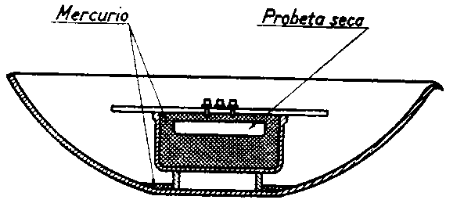

Figura 2

3,11 Balanza. Una balanza sensible a 0,01 g.

3,12 Mercurio. En cantidad suficiente para llenar por completo el recipiente menor de los descritos en el *apartado 3,8* o el volumenómetro.

4. Requisitos especiales

Antes de proceder al ensayo propiamente dicho será necesario tarar los cristalizadores de retracción. Esta operación tiene por finalidad determinar el volumen V_i contenido en cada cristalizador y su peso, para lo cual se llenará de mercurio el recipiente que se vaya a tarar, apretando después un cristal plano contra su borde para que rebose el sobrante. A continuación se medirá el mercurio contenido en cada cristalizador, con el tubo graduado, y determinará el peso G_t, del recipiente vacío.

5. Preparación de la muestra

Se pasa una parte de la muestra media, secada al aire, por el tamiz. Las partículas retenidas deben ser desechadas, mientras que los terrones que no hayan pasado se desmenuzarán en el mortero con ayuda del mazo recubierto de goma, volviéndolos a cribar.

La operación completa tiene que repetirse con más muestra media, hasta obtener unos 300 g que hayan pasado por el tamiz, los cuales se colocan en el centro del cristal plano; entonces hay que añadir agua destilada, poco a poco, mezclando bien el conjunto con la espátula ancha, hasta conseguir una masa flúida de aspecto uniforme y exenta de grumos. En los terrenos arenosos, el agua añadida será ligeramente superior a la correspondiente al límite líquido, determinado según la norma UNE 7 002, y en los arcillosos excederá de dicho límite en un 10 por 100.

6. Método de ensayo

Preparada la masa según se indicó en el *apartado* anterior, se toma una cantidad aproximadamente igual a un tercio del volumen del cristalizador de retracción (cuyo interior debe estar cubierto con una capa muy fina de vaselina) y se coloca en el centro del mismo, golpeando a continuación en su fondo para que, al deslizar la masa, vaya llenando el recipiente, sin permitir la formación de burbujas de aire.

Se añade una nueva porción de masa igual a la primera, repitiéndose los golpes en el fondo y, después, se llena el recipiente por el mismo procedimiento.

La manipulación tiene que ser lo suficientemente cuidadosa para que no queden burbujas de aire ocluídas en la masa; en los terrenos muy plásticos puede ser necesario utilizar una bomba de vacío para facilitar la salida del aire.

Cuando el cristalizador esté completamente lleno, se alisa la superficie con la regla, pesando a continuación; esta cantidad se designa con los símbolos $G_h + G_t$, pesos de la muestra húmeda y del recipiente.

Después de pesado, se deja el cristalizador lleno al aire, para que la desecación sea lenta, y cuando el terreno aclare su color se mete en la estufa a 110° C, hasta peso constante, el cual se representa por $G_s + G_t$, pesos de la muestra seca y del recipiente.

Cuando la muestra del terreno esté seca, habrá retraído, pudiéndose sacar fácilmente del cristalizador, y su volumen se determina por el procedimiento siguiente:

Se llena de mercurio el recipiente de vidrio de menor tamaño, hasta que rebose, y se retira el mercurio que sobre, apretando con la tapa de vidrio descrita en el *apartado 3,7*.

A continuación, se coloca la probeta de terreno seco sobre la superficie del mercurio, sumergiéndola con ayuda de las tres puntas de la tapa de vidrio; presionando fuertemente con la tapa, se desplazará una parte del mercurio igual al volumen de la probeta. Para esto es necesario que no permanezca aire debajo de la probeta o entre las puntas de la tapa.

El volumen del mercurio recogido es V_f, volumen final de la probeta, y debe medirse con error menor de ± 0,05 cm³, en el tubo graduado.

Puede determinarse también este volumen con el aparato indicado en el *apartado 3,10*.

Continúa

Después de terminadas las manipulaciones anteriores, se calcula el tanto por ciento de humedad inicial de masa, aplicando la siguiente fórmula:

$$W_i = \frac{G_h - G_s}{G_s} \times 100,$$

en la que:

W_i es la humedad buscada;

G_h es el peso de la probeta húmeda, y

G_s el de la misma probeta, desecada a peso constante a 110° C.

7. Obtención y precisión de los resultados

En los apartados precedentes se han obtenido los valores de V_i = Volumen inicial de la muestra, que es el mis que el del cristalizador correspondiente; V_f = volumen final de la misma después de seca, y W_i = tanto ciento de humedad inicial; con estos datos puede calcularse el valor del límite de retracción W_R por medio la expresión:

$$W_R = W_i - \frac{V_i - V_f}{G_s} \times 100.$$

De cada terreno se harán tres ensayos, debiendo repetirse todos aquéllos que difieran en más de un 5 por 100 valor de la media aritmética de los mismos.

8. Normas para consultar

Para aplicar este método, es conveniente consultar la norma UNE 7 002 "Determinación del límite líquido y del dice de fluidez de un terreno".

9. Correspondencia con otras normas

Concuerda esencialmente con la D 427-39 de la A. S. T. M.

Determinación del límite líquido y del índice de fluidez de un terreno

UNE
7002

1. Alcance.

Esta determinación es aplicable a la porción de la muestra de cualquier terreno que pase por un tamiz de agujeros
drados de 0,42 ± 0,01 mm de lado.

2. Definiciones.

Se llama limite líquido de un terreno a la cantidad de agua que contiene, expresada en tanto por ciento del peso
muestra seca, al pasar del estado líquido al plástico y se establece siguiendo los procedimientos que se detallan en el
tado 6.

El índice de fluidez es el número que representa la pendiente de la recta correspondiente, determinada como se de
en el apartado 6.

3. Aparatos empleados.

Para la aplicación de este método son necesarios los siguientes aparatos:

3,1 **Un cristal plano.** De forma rectangular y 40 × 60 cm aproximadamente.

3,2 **Un tamiz.** De malla cuadrada, midiendo el lado del agujero 0,42 ± 0,01 mm.

3,3 **Un mortero.** Un mortero y un mazo recubierto de goma, útiles para desmenuzar los terrones compuestos de part
del suelo.

3,4 **Una espátula.** Flexible y de acero inoxidable, de unos 8 cm de largo y aproximadamente 2 cm de ancho.

3,5 **Un aparato** para la determinación del límite líquido, construído de acuerdo con las dimensiones y materiales indi
en la *figura I.*

3,6 **Un acanalador.** En acero inoxidable, de la forma y dimensiones que pueden verse en la *figura I.*

Medidas en mm

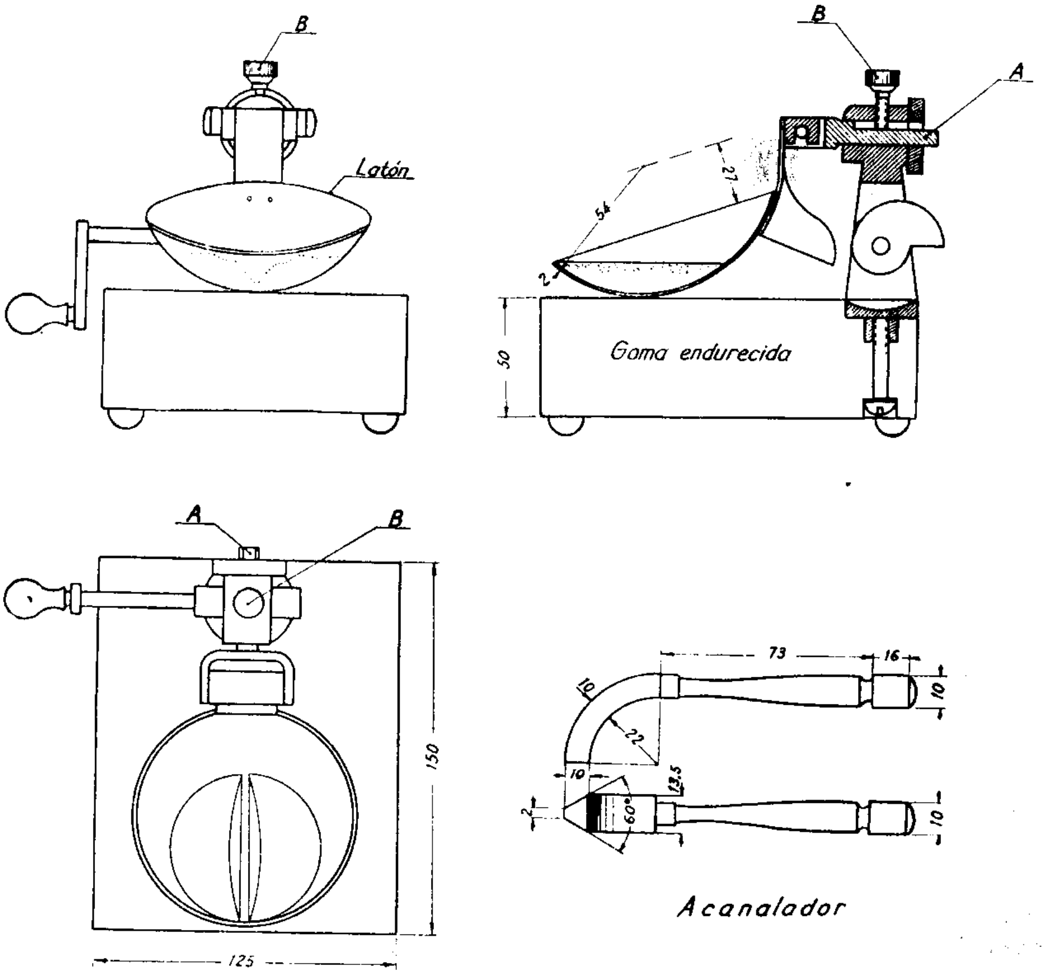

Fig. 1 - Aparato «Casagrande»

Contin

3,7 Vidrios de reloj. Con sus bordes esmerilados, formando parejas, preparadas para evitar las pérdidas de humedad de las muestras que se coloquen en su interior.

3,8 Balanza. Sensible a 1 g.

4. Requisitos especiales.

Antes de proceder al ensayo propiamente dicho, es necesario reglar el aparato nombrado en el apartado 3,5, lo que se puede realizar por el método descrito a continuación: Se graduará el tornillo designado con la letra A en la *figura 1* para lograr que la altura máxima de caída del punto de la cuchara, que golpea sobre la placa de goma endurecida, sea de 10 ± 0,2 mm El ajuste se logra por medio de una barra de sección rectangular y 1 cm de altura.
Después de tarado el aparato, se aprieta el tornillo B, que impide se desajuste el A con los golpes del ensayo.

5. Preparación de la muestra.

Después de secada al aire, se pasa una parte da la muestra media del terreno que se ha de ensayar por el tamiz descrito en el apartado 3,2. Las partículas retenidas deben ser desechadas, mientras que los terrones que no hayan pasado se desmenuzan en el mortero con ayuda del mazo recubierto de goma, y se vuelven a cribar.
Se repite esta operación hasta obtener unos 100 g que hayan pasado por el tamiz, los cuales se colocan en el centro del cristal plano; entonces se añade poco a poco agua destilada, mezclando bien el conjunto con ayuda de la espátula, hasta conseguir una masa plástica, de aspecto uniforme y exenta de grumos.

6. Método de ensayo.

Preparada la masa según se indicó en el apartado anterior, se coloca en la cuchara del aparato, y con ayuda de una espátula, se modela una superficie lisa, siendo el espesor máximo en el centro de unos 9 mm. A continuación, y por medio del acanalador, se hace un surco en la masa, de modo que su plano de simetría coincida con el del aparato, y procurando que la herramienta, al producir la acanaladura, esté sensiblemente normal a la superficie de la cuchara; la *figura 2* muestra su forma.

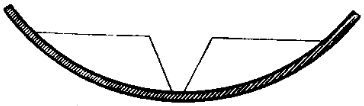

Fig. 2 - Antes del ensayo

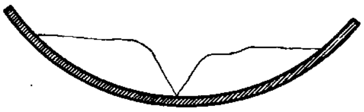

Fig. 2 - Después del ensayo

Colocada la cuchara en el aparato, y al medio minuto, poco más o menos, de hecho el surco, se gira la manivela a razón de dos vueltas por segundo y se cuentan los golpes que son necesarios para que los dos lados de la muestra deslicen juntándose en el fondo, como se indica en la *figura 2*, en una distancia aproximada de 12 mm. A continuación se toma una pequeña muestra de la masa, aproximadamente unos 10 g, y se coloca entre dos vidrios de reloj, sujetándolos con una pinza para reducir al mínimo la evaporación.

Si el número de golpes encontrado es 25, la humedad de la muestra, expresada en tanto por ciento de su peso seco, es el número representativo del límite líquido; si no es así, la determinación de la humedad sirve para fijar un punto de la línea de fluidez que se explicará posteriormente.

Cuando el número de golpes es mayor de 25, se añade un poco de agua destilada a la masa y, después de bien homogeneizada, se repite el ensayo; en caso contrario, es decir, cuando sea menor de 25, la masa tiene mucha agua, pudiéndose corregir este efecto extendiendo la pasta sobre el cristal para que se evapore rápidamente parte del agua, o añadiendo masa menos húmeda del mismo material; en ambos casos, y antes de llenar la cuchara, debe homogeneizarse bien el conjunto.

Haciendo diversos tanteos se obtendrán dos o tres muestras de pasta que hayan necesitado menos de 25 golpes para cerrar el surco, y otras tantas en que el número haya sido mayor.

Los datos obtenidos en cada una de las pruebas anteriores son: un determinado número de golpes y el tanto por ciento de humedad de la masa. Refiriéndonos a unos ejes de coordenadas rectangulares en los que las abscisas sean los números de golpes en escala logarítmica y las ordenadas los tantos por ciento de los contenidos de agua, en escala decimal, para cada ensayo puede dibujarse un punto, debiendo estar los cuatro o cinco puntos restantes situados aproximadamente en una recta, que es la línea de fluidez.

El tanto por ciento del contenido de agua del punto en que la recta anterior corta a la ordenada correspondiente a 25 golpes es el número que representa el límite líquido y que se designará con W_L.

Dibujada la línea de fluidez, puede hallarse sin dificultad su pendiente, que es el número representativo del índice de fluidez, y que se designará con la letra F.

7. Correspondencia con otras normas.

D 423 - 39 de la A. S. T. M.

Designation: D 4318 – 84

Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[1]

This standard is issued under the fixed designation D 4318; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This test method has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

Scope

1 This test method covers the determination of the limit, plastic limit, and the plasticity index of soils as d in Section 3.

1.1 Two procedures for preparing test specimens and procedures for performing the liquid limit are provided lows:

Multipoint test using a wet preparation procedure, described in Sections 10.1, 11, and 12.

Multipoint test using a dry preparation procedure, described in Sections 10.2, 11, and 12.

One-point test using a wet preparation procedure, described in Sections 13, 14, and 15.

One-point test using a dry preparation procedure, described in Sections 13, 14, and 15.

procedure to be used shall be specified by the requesting rity. If no procedure is specified, Procedure A shall be

1—Prior to the adoption of this test method, a curved grooving specified as part of the apparatus for performing the liquid limit curved tool is not considered to be as accurate as the flat tool in 6.2 since it does not control the depth of the soil in the it cup. However, there are some data which indicate that the liquid limit is slightly increased when the flat tool is used of the curved tool.

The plastic limit test procedure is described in 16, 17, and 18. The plastic limit test is performed on prepared for the liquid limit test. In effect, there are cedures for preparing test specimens for the plastic

The procedure for calculating the plasticity index is Section 19.

liquid limit and plastic limit of soils (along with kage limit) are often collectively referred to as the limits in recognition of their formation by Swedish ntist, A. Atterberg. These limits distinguish the ies of the several consistency states of plastic soils.

used in this test method, soil is any natural on of mineral or organic materials, mixtures of such materials, or artificial mixtures of aggregates and natural mineral and organic particles.

1.4 The multipoint liquid limit procedure is somewhat more time consuming than the one-point procedure when both are performed by experienced operators. However, the one-point procedure requires the operator to judge when the test specimen is approximately at its liquid limit. In cases where this is not done reliably, the multipoint procedure is as fast as the one-point procedure and provides additional precision due to the information obtained from additional trials. It is particularly recommended that the multipoint procedure be used by inexperienced operators.

1.5 The correlations on which the calculations of the one-point procedure are based may not be valid for certain soils, such as organic soils or soils from a marine environment. The liquid limit of these soils should therefore be determined by the multipoint procedure (Procedure A).

1.6 The liquid and plastic limits of many soils that have been allowed to dry before testing may be considerably different from values obtained on undried samples. If the liquid and plastic limits of soils are used to correlate or estimate the engineering behavior of soils in their natural moist state, samples should not be permitted to dry before testing unless data on dried samples are specifically desired.

1.7 The composition and concentration of soluble salts in a soil affect the values of the liquid and plastic limits as well as the water content values of soils (see Method D 2216). Special consideration should therefore be given to soils from a marine environment or other sources where high soluble salt concentrations may be present. The degree to which the salts present in these soils are diluted or concentrated must be given consideration if meaningful results are to be obtained.

1.8 Since the tests described herein are performed only on that portion of a soil which passes the 425-µm (No. 40) sieve, the relative contribution of this portion of the soil to the properties of the sample as a whole must be considered when using these tests to evaluate the properties of a soil.

1.9 The values stated in acceptable metric units are to be regarded as the standard. The values given in parentheses are for information only.

1.10 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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method is under the jurisdiction of ASTM Committee D-18 on Soil and is the direct responsibility of Subcommittee D18.03 on Texture, and Density Characteristics of Soils.

edition approved Oct. 26, 1984. Published December 1984. Originally D 4318 – 83. Last previous edition D 4318 – 83$^{\epsilon 1}$.

2. Referenced Documents

2.1 *ASTM Standards:*

C 702 Methods for Reducing Field Samples of Aggregate to Testing Size[2]

D 75 Practice for Sampling Aggregates[4]

D 420 Practice for Investigating and Sampling Soil and Rock for Engineering Purposes[4]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

D 1241 Specification for Materials for Soil-Aggregate Subbase, Base, and Surface Courses[4]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[4]

D 2240 Test Method for Rubber Property—Durometer Hardness[5]

D 2487 Test Method for Classification of Soils for Engineering Purposes[4]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[4]

D 3282 Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[6]

E 319 Methods of Testing Single-Arm Balances[6]

E 898 Method of Testing Top-Loading, Direct-Reading Laboratory Scales and Balances[6]

3. Definitions

3.1 *Atterberg limits*—originally, seven "limits of consistency" of fine-grained soils were defined by Albert Atterberg. In current engineering usage, the term usually refers only to the liquid limit, plastic limit, and in some references, the shrinkage limit.

3.2 *consistency*—the relative ease with which a soil can be deformed.

3.3 *liquid limit (LL)*—the water content, in percent, of a soil at the arbitrarily defined boundary between the liquid and plastic states. This water content is defined as the water content at which a pat of soil placed in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (½ in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of 2 shocks per second.

NOTE 2—The undrained shear strength of soil at the liquid limit is considered to be 2 ± 0.2 kPa (0.28 psi).

3.4 *plastic limit (PL)*—the water content, in percent, of a soil at the boundary between the plastic and brittle states. The water content at this boundary is the water content at which a soil can no longer be deformed by rolling into 3.2 mm (⅛ in.) in diameter threads without crumbling.

3.5 *plastic soil*—a soil which has a range of water content over which it exhibits plasticity and which will retain its shape on drying.

3.6 *plasticity index (PI)*—the range of water conte which a soil behaves plastically. Numerically, it difference between the liquid limit and the plastic lim

3.7 *liquidity index*—the ratio, expressed as a perce of (*1*) the natural water content of a soil minus its limit, to (*2*) its plasticity index.

3.8 *activity number (A)*—the ratio of (*1*) the pl index of a soil to (*2*) the percent by weight of particles an equivalent diameter smaller than 0.002 mm.

4. Summary of Method

4.1 The sample is processed to remove any m retained on a 425-µm (No. 40) sieve. The liquid determined by performing trials in which a portion sample is spread in a brass cup, divided in two by a gr tool, and then allowed to flow together from the caused by repeatedly dropping the cup in a standa chanical device. The multipoint liquid limit, Proced and B, requires three or more trials over a range of contents to be performed and the data from the trials or calculated to make a relationship from which the limit is determined. The one-point liquid limit, Procedu and D, uses the data from two trials at one water co multiplied by a correction factor to determine the limit.

4.2 The plastic limit is determined by alternately pre together and rolling into a 3.2 mm (⅛ in.) diameter thre small portion of plastic soil until its water content is red to a point at which the thread crumbles and is no longer to be pressed together and rerolled. The water content of soil at this stage is reported as the plastic limit.

4.3 The plasticity index is calculated as the differe between the liquid limit and the plastic limit.

5. Significance and Use

5.1 This test method is used as an integral part of seve engineering classification systems to characterize the fi grained fractions of soils (see Test Method D 2487 a Practice D 3282) and to specify the fine-grained fraction of construction materials (see Specification D 1241). The liqu limit, plastic limit, and plasticity index of soils are also us extensively, either individually or together with other so properties to correlate with engineering behavior such a compressibility, permeability, compactibility, shrink-swell, and shear strength.

5.2 The liquid and plastic limits of a soil can be used with the natural water content of the soil to express its relative consistency or liquidity index and can be used with the percentage finer than 2-µm size to determine its activity number.

5.3 The one-point liquid limit procedure is frequently used for routine classification purposes. When greater precision is required, as when used for the acceptance of a material or for correlation with other test data, the multipoint procedure should be used.

5.4 These methods are sometimes used to evaluate the weathering characteristics of clay-shale materials. When subjected to repeated wetting and drying cycles, the liquid limits of these materials tend to increase. The amount of increase is considered to be a measure of a shale's susceptibility to weathering.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vols 04.02, 04.03, and 04.08.

[4] *Annual Book of ASTM Standards*, Vol 04.08.

[5] *Annual Book of ASTM Standards*, Vol 09.01.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

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[4] *Annual Book of ASTM Standards*, Vol 04.08.

[5] *Annual Book of ASTM Standards*, Vol 09.01.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

5.5 The liquid limit of a soil containing substantial mounts of organic matter decreases dramatically when the il is oven-dried before testing. Comparison of the liquid nit of a sample before and after oven-drying can therefore used as a qualitative measure of organic matter content of soil.

Apparatus

6.1 *Liquid Limit Device*—A mechanical device consisting brass cup suspended from a carriage designed to control drop onto a hard rubber base. A drawing showing the ntial features of the device and the critical dimensions is n in Fig. 1. The design of the device may vary provided the essential functions are preserved. The device may be ated either by a hand crank or by an electric motor.

.1 *Base*—The base shall be hard rubber having a D meter hardness of 80 to 90, and a resilience such that mm (5/16-in.) diameter polished steel ball, when dropped a height of 25 cm (9.84 in.) will have an average nd of at least 80 % but no more than 90 %. The tests be conducted on the finished base with feet attached.

.2 *Feet*—The base shall be supported by rubber feet ed to provide isolation of the base from the work e and having an A Durometer hardness no greater than measured on the finished feet attached to the base.

3 *Cup*—The cup shall be brass and have a weight, ing cup hanger, of 185 to 215 g.

Cam—The cam shall raise the cup smoothly and ously to its maximum height, over a distance of at least 180° of cam rotation. The preferred cam motion is a uniformly accelerated lift curve. The design of the cam and follower combination shall be such that there is no upward or downward velocity of the cup when the cam follower leaves the cam.

NOTE 3—The cam and follower design in Fig. 1 is for uniformly accelerated (parabolic) motion after contact and assures that the cup has no velocity at drop off. Other cam designs also provide this feature and may be used. However, if the cam-follower lift pattern is not known, zero velocity at drop off can be assured by carefully filing or machining the cam and follower so that the cup height remains constant over the last 20 to 45° of cam rotation.

6.1.5 *Carriage*—The cup carriage shall be constructed in a way that allows convenient but secure adjustment of the height of drop of the cup to 10 mm (0.394 in.). The cup hanger shall be attached to the carriage by means of a pin which allows removal of the cup and cup hanger for cleaning and inspection.

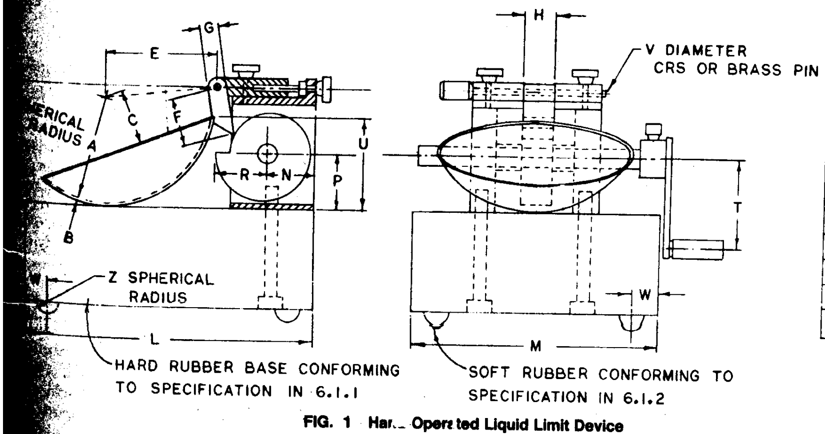
6.1.6 *Optional Motor Drive*—As an alternative to the hand crank shown in Fig. 1, the device may be equipped with a motor to turn the cam. Such a motor must turn the cam at 2 ± 0.1 revolutions per second and must be isolated from the rest of the device by rubber mounts or in some other way that prevents vibration from the motor being transmitted to the rest of the apparatus. It must be equipped with an ON-OFF switch and a means of conveniently positioning the cam for height of drop adjustments. The results obtained using a motor-driven device must not differ from those obtained using a manually operated device.

ENSIONS

ER	A^{Δ}	B^{Δ}	C^{Δ}	E^{Δ}	F	G	H	J^{Δ}	K^{Δ}	L^{Δ}	M^{Δ}
	54 ± 0.5	2 ± 0.1	27 ± 0.5	56 ± 2.0	32	10	16	60 ± 1.0	50 ± 2.0	150 ± 2.0	125 ± 2.0

ER	N	P	R	T	U^{Δ}	V	W	Z
	24	28	24	45	47 ± 1.0	3.8	13	6.5

NTIAL DIMENSIONS



CAM ANGLE DEGREES	CAM RADIUS
0	0.742 R
30	0.753 R
60	0.764 R
90	0.773 R
120	0.784 R
150	0.796 R
180	0.818 R
210	0.854 R
240	0.901 R
270	0.945R
300	0.974R
330	0.995R
360	1.000R

FIG. 1 Hand Operated Liquid Limit Device

DIMENSIONS

LETTER	A^Δ	B^Δ	C^Δ	D^Δ	E^Δ	F^Δ
MM	2 ± 0.1	11 ± 0.2	40 ± 0.5	8 ± 0.1	50 ± 0.5	2 ± 0.1
LETTER	G	H	J	K^Δ	L^Δ	N
MM	10 MINIMUM	13	60	10 ±0.05	60 DEG ± 1 DEG	20

^Δ *ESSENTIAL DIMENSIONS*

^□ *BACK AT LEAST 15 MM FROM TIP*

NOTE: DIMENSION A SHOULD BE 1.9–2.0 AND DIMENSION D SHOULD BE 8.0–8.1 WHEN NEW TO ALLOW FOR ADEQUATE SERVICE LIFE

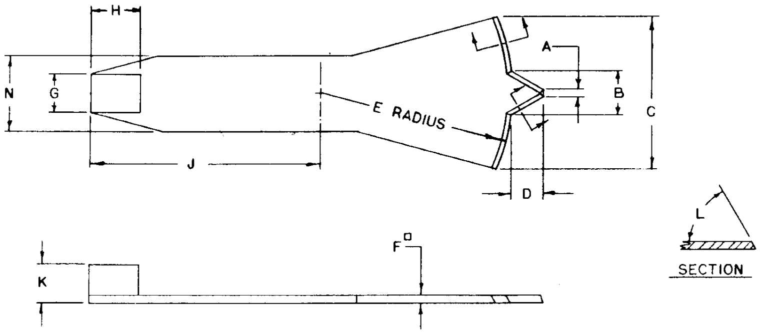
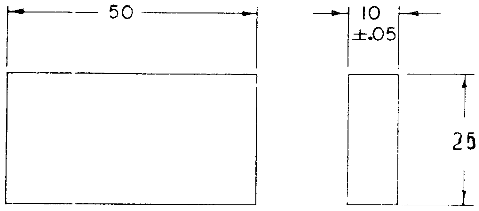


FIG. 2 Grooving Tool (Optional Height-of-Drop Gage Attached)

6.2 *Flat Grooving Tool*—A grooving tool having dimensions shown in Fig. 2. The tool shall be made of plastic or noncorroding metal. The design of the tool may vary as long as the essential dimensions are maintained. The tool may, but need not, incorporate the gage for adjusting the height of drop of the liquid limit device.

6.3 *Gage*—A metal gage block for adjusting the height of drop of the cup, having the dimensions shown in Fig. 3. The design of the tool may vary provided the gage will rest securely on the base without being susceptible to rocking, and the edge which contacts the cup during adjustment is straight, at least 10 mm (⅜ in.) wide, and without bevel or radius.



DIMENSIONS IN MILLIMETRES

FIG. 3 Height of Drop Gage

6.4 *Containers*—Small corrosion-resistant containers snug-fitting lids for water content specimens. Aluminum stainless steel cans 2.5 cm (1 in.) high by 5 cm (2 in.) diameter are appropriate.

6.5 *Balance*—A balance readable to at least 0.01 g having an accuracy of 0.03 g within three standard de tions within the range of use. Within any 15-g range, difference between readings shall be accurate within 0.0 (Notes 4 and 5).

Note 4—See Methods E 898 and E 319 for an explanation of relating to balance performance.

Note 5—For frequent use, a top-loading type balance with matic load indication, readable to 0.01 g, and having an inde precision (standard deviation) of 0.003 or better is most suitable for method. However, nonautomatic indicating equal-arm analytical ances and some small equal arm top pan balances having readabili and sensitivities of 0.002 g or better provide the required accuracy used with a weight set of ASTM Class 4 (National Bureau of Standa Class P) or better. Ordinary commercial and classroom type bala such as beam balances are not suitable for this method.

6.6 *Storage Container*—A container in which to store prepared soil specimen that will not contaminate the spe imen in any way, and which prevents moisture loss. porcelain, glass, or plastic dish about 11.4 cm (4½ in.) diameter and a plastic bag large enough to enclose the and be folded over is adequate.

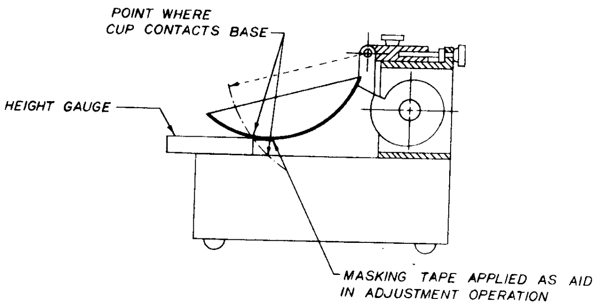


FIG. 4 Calibration for Height of Drop

7 *Ground Glass Plate*—A ground glass plate at least 30 (12 in.) square by 1 cm (3/8 in.) thick for mixing soil and ing plastic limit threads.

.8 *Spatula*—A spatula or pill knife having a blade about n (3/4 in.) wide by about 10 cm (4 in.) long. In addition, a ula having a blade about 2.5 cm (1 in.) wide and 15 cm n.) long has been found useful for initial mixing of ples.

9 *Sieve*—A 20.3 cm (8 in.) diameter, 425-μm (No. 40) conforming to the requirements of Specification E 11 having a rim at least 5 cm (2 in.) above the mesh. A m (No. 10) sieve meeting the same requirements may be needed.

0 *Wash Bottle*, or similar container for adding con- d amounts of water to soil and washing fines from particles.

1 *Drying Oven*—A thermostatically controlled oven, ably of the forced-draft type, capable of continuously aining a temperature of 110 ± 5°C throughout the chamber. The oven shall be equipped with a ther- ter of suitable range and accuracy for monitoring oven ature.

Washing Pan—A round, flat-bottomed pan at least (3 in.) deep, slightly larger at the bottom than a (8-in.) diameter sieve.

Rod (optional)—A metal or plastic rod or tube 3.2 in.) in diameter and about 10 cm (4 in.) long for the size of plastic limit threads.

aterials

A supply of distilled or demineralized water.

pling

Samples may be taken from any location that satisfies needs. However, Methods C 702, Practice D 75, and mmended Practice D 420 should be used as guides for ng and preserving samples from various types of ng operations. Samples which will be prepared using preparation procedure, 10.1, must be kept at their l water content prior to preparation.

Where sampling operations have preserved the natural ation of a sample, the various strata must be kept d and tests performed on the particular stratum of with as little contamination as possible from other here a mixture of materials will be used in construction, combine the various components in such proportions that the resultant sample represents the actual construction case.

8.3 Where data from this test method are to be used for correlation with other laboratory or field test data, use the same material as used for these tests where possible.

8.4 Obtain a representative portion from the total sample sufficient to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve. Free flowing samples may be reduced by the methods of quartering or splitting. Cohesive samples shall be mixed thoroughly in a pan with a spatula, or scoop and a representative portion scooped from the total mass by making one or more sweeps with a scoop through the mixed mass.

9. Calibration of Apparatus

9.1 *Inspection of Wear:*

9.1.1 *Liquid Limit Device*—Determine that the liquid limit device is clean and in good working order. The following specific points should be checked:

9.1.1.1 *Wear of Base*—The spot on the base where the cup makes contact should be worn no greater than 10 mm (3/8 in.) in diameter. If the wear spot is greater than this, the base can be machined to remove the worn spot provided the resurfacing does not make the base thinner than specified in 6.1 and the other dimensional relationships are maintained.

9.1.1.2 *Wear of Cup*—The cup must be replaced when the grooving tool has worn a depression in the cup 0.1 mm (0.004 in.) deep or when the edge of the cup has been reduced to half its original thickness. Verify that the cup is firmly attached to the cup hanger.

9.1.1.3 *Wear of Cup Hanger*—Verify that the cup hanger pivot does not bind and is not worn to an extent that allows more than 3-mm (1/8-in.) side-to-side movement of the lowest point on the rim.

9.1.1.4 *Wear of Cam*—The cam shall not be worn to an extent that the cup drops before the cup hanger (cam follower) loses contact with the cam.

9.1.2 *Grooving Tools*—Inspect grooving tools for wear on a frequent and regular basis. The rapidity of wear depends on the material from which the tool is made and the types of soils being tested. Sandy soils cause rapid wear of grooving tools; therefore, when testing these materials, tools should be inspected more frequently than for other soils. Any tool with a tip width greater than 2.1 mm must not be used. The depth of the tip of the grooving tool must be 7.9 to 8.1 mm.

NOTE 6—The width of the tip of grooving tools is conveniently checked using a pocket-sized measuring magnifier equipped with a millimetre scale. Magnifiers of this type are available from most laboratory supply companies. The depth of the tip of grooving tools can be checked using the depth measuring feature of vernier calipers.

9.2 *Adjustment of Height of Drop*—Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10 ± 0.2 mm. See Fig. 4 for proper location of the gage relative to the cup during adjustment.

NOTE 7—A convenient procedure for adjusting the height of drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should bisect the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height. Slide the height gage under the cup from the front, and observe whether the gage contacts the cup or the tape. See Fig. 4. If the tape and cup are both contacted, the height of drop is approximately correct. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at 2 revolutions per second while holding the gage in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gage, the adjustment is correct. If no ringing is heard or if the cup rises from the gage, readjust the height of drop. If the cup rocks on the gage during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

MULTIPOINT LIQUID LIMIT—PROCEDURES A AND B

10. Preparation of Test Specimens

10.1 *Wet Preparation*—Except where the dry method of specimen preparation is specified (10.2), prepare specimens for test as described in the following sections.

10.1.1 *Samples Passing the 425-μm (No. 40) Sieve*—When by visual and manual procedures it is determined that the sample has little or no material retained on a 425-μm (No. 40) sieve, prepare a specimen of 150 to 200 g by mixing thoroughly with distilled or demineralized water on the glass plate using the spatula. If desired, soak soil in a storage dish with small amount of water to soften the soil before the start of mixing. Adjust the water content of the soil to bring it to a consistency that would require 25 to 35 blows of the liquid limit device to close the groove (Note 8). If, during mixing, a small percentage of material is encountered that would be retained on a 425-μm (No. 40) sieve, remove these particles by hand, if possible. If it is impractical to remove the coarser material by hand, remove small percentages (less than about 15 %) of coarser material by working the specimen through a 425-μm (No. 40) sieve using a piece of rubber sheeting, rubber stopper, or other convenient device provided the operation does not distort the sieve or degrade material that would be retained if the washing method described in 10.1.2 were used. If larger percentages of coarse material are encountered during mixing, or it is considered impractical to remove the coarser material by the methods just described, wash the sample as described in 10.1.2. When the coarse particles found during mixing are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm (No. 40) sieve, but remove by hand or by washing. Place the mixed soil in the storage dish, cover to prevent loss of moisture, and allow to stand for at least 16 h (overnight). After the standing period and immediately before starting the test, thoroughly remix the soil.

NOTE 8—The time taken to adequately mix a soil will vary greatly depending on the plasticity and initial water content. Initial mixing times of more than 30 min may be needed for stiff, fat clays.

10.1.2 *Samples Containing Material Retained on a 425-μm (No. 40) Sieve:*

10.1.2.1 Select a sufficient quantity of soil at natural water content to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve. Place in a pan or dish and add sufficient water to cover the soil. Allow to soak until all lumps have softened and the fines no longer adhere to the surfaces of the coarse particles (Note 9).

NOTE 9—In some cases, the cations of salts present in tap water will exchange with the natural cations in the soil and significantly alter the test results should tap water be used in the soaking and washing operations. Unless it is known that such cations are not present in the tap water, distilled or demineralized water should be used. As a general rule, water containing more than 100 mg/L of dissolved solids should not be used for washing operations.

10.1.2.2 When the sample contains a large percentage of material retained on the 425-μm (No. 40) sieve, perform the following washing operation in increments, washing no more than 0.5 kg (1 lb) of material at one time. Place the 425-μm (No. 40) sieve in the bottom of the clean pan. Pour the soil water mixture onto the sieve. If gravel or coarse sand particles are present, rinse as many of these as possible with small quantities of water from a wash bottle, and discard. Alternatively, pour the soil water mixture over a 2-mm (No. 10) sieve nested atop the 425-μm (No. 40) sieve, rinse the fine material through and remove the 2-mm (No. 10) sieve. After washing and removing as much of the coarser material as possible, add sufficient water to the pan to bring the level to about 13 mm (½ in.) above the surface of the 425-μm (No. 40) sieve. Agitate the slurry by stirring with the fingers while raising and lowering the sieve in the pan and swirling the suspension so that fine material is washed from the coarser particles. Disaggregate fine soil lumps that have not slaked by gently rubbing them over the sieve with the fingertips. Complete the washing operation by raising the sieve above the water surface and rinsing the material retained with a small amount of clean water. Discard material retained on the 425-μm (No. 40) sieve.

10.1.2.3 Reduce the water content of the material passing the 425-μm (No. 40) sieve until it approaches the liquid limit. Reduction of water content may be accomplished by one or a combination of the following methods: (*a*) exposing the air currents at ordinary room temperature, (*b*) exposing to warm air currents from a source such as an electric hair dryer, (*c*) filtering in a Büchner funnel or using filter candles, (*d*) decanting clear water from surface of suspension, or (*e*) draining in a colander or plaster of paris dish lined with high retentivity, high wet-strength filter paper.[7] If a plaster of paris dish is used, take care that the dish never becomes sufficiently saturated that it fails to actively absorb water into its surface. Thoroughly dry dishes between uses. During evaporation and cooling, stir the sample often enough to prevent

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[7] S and S 595 filter paper available in 32-cm circles, has proven satisfactory.

overdrying of the fringes and soil pinnacles on the surface of the mixture. For soil samples containing soluble salts, use a method of water reduction such as *a* or *b* that will not eliminate the soluble salts from the test specimen.

10.1.2.4 Thoroughly mix the material passing the 425-μm (No. 40) sieve on the glass plate using the spatula. Adjust the water content of the mixture, if necessary, by adding small increments of distilled or demineralized water or by allowing the mixture to dry at room temperature while mixing on the glass plate. The soil should be at a water content that will result in closure of the groove in 25 to 35 blows. Return the mixed soil to the mixing dish, cover to prevent loss of moisture, and allow to stand for at least 16 h. After the standing period, and immediately before starting the test, remix the soil thoroughly.

10.2 *Dry Preparation:*

10.2.1 Select sufficient soil to provide 150 to 200 g of material passing the 425-μm (No. 40) sieve after processing. Dry the sample at room temperature or in an oven at a temperature not exceeding 60°C until the soil clods will pulverize readily. Disaggregation is expedited if the sample is not allowed to completely dry. However, the soil should have a dry appearance when pulverized. Pulverize the sample in a mortar with a rubber tipped pestle or in some other way that does not cause breakdown of individual grains. When the coarse particles found during pulverization are concretions, shells, or other fragile particles, do not crush these particles to make them pass a 425-μm (No. 40) sieve, but remove by hand or other suitable means, such as washing.

10.2.2 Separate the sample on a 425-μm (No. 40) sieve, shaking the sieve by hand to assure thorough separation of the finer fraction. Return the material retained on the 425-μm (No. 40) sieve to the pulverizing apparatus and repeat the pulverizing and sieving operations as many times as necessary to assure that all finer material has disaggregated and material retained on the 425-μm (No. 40) sieve consists only of individual sand or gravel grains.

10.2.3 Place material remaining on the 425-μm (No. 40) sieve after the final pulverizing operations in a dish and soak in a small amount of water. Stir the soil water mixture and pour over the 425-μm (No. 40) sieve, catching the water and any suspended fines in the washing pan. Pour this suspension into a dish containing the dry soil previously sieved through the 425-μm (No. 40) sieve. Discard material retained on the 425-μm (No. 40) sieve.

10.2.4 Adjust the water content as necessary by drying as described in 10.1.2.3 or by mixing on the glass plate, using the spatula while adding increments of distilled or demineralized water, until the soil is at a water content that will result in closure of the groove in 25 to 35 blows.

10.2.5 Put soil in the storage dish, cover to prevent loss of moisture and allow to stand for at least 16 h. After the standing period, and immediately before starting the thoroughly remix the soil (Note 8).

11. Procedure

11.1 Place a portion of
liquid limit device at
base, squeeze it do
of about 10 m
approximately
bubbles fr
as possib
with th

10
the lo
data sh
void rat
weight. C
sured in 6
the dry ma
solids (Note
Calculate the
the volume of so
be the differen
volume of the sol
dry mass of the sp
Note 22—The speci
accordance with Test M
previous test results.
10.2 *Specimen Proper*
the specimen height and
10.2.1 Height of Specim
determined from the follow

in. or 15 mm).
membranes is 200 psi
the lateral stress is usually
strips and membranes are
their behavior during shear.
there is not a consensus on more

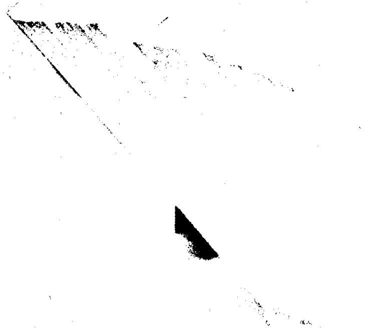

FIG. 5 Grooved

TABLE 1 Factors for Obtaining Liquid Limit from Water Content and Number of Drops Causing Closure of Groove

N (Number of Drops)	K (Factor for Liquid Limit)
20	0.974
21	0.979
22	0.985
23	0.990
24	0.995
25	1.000
26	1.005
27	1.009
28	1.014
29	1.018
30	1.022

quid limit cup to close the groove.

4. Procedure

14.1 Proceed as described in 11.1 through 11.5 except that e number of blows required to close the groove shall be 20 30. If less than 20 or more than 30 blows are required, ust the water content of the soil and repeat the procedure.

14.2 Immediately after removing a water content specen as described in 11.5, reform the soil in the cup, adding small amount of soil to make up for that lost in the oving and water content sampling operations. Repeat 2 through 11.5, and, if the second closing of the groove uires the same number of drops or no more than two ps difference, secure another water content specimen. erwise, remix the entire specimen and repeat.

TE 11—Excessive drying or inadequate mixing will cause the ber of blows to vary.

.3 Determine water contents of specimens as described .8.

Calculations

.1 Determine the liquid limit for each water content men using one of the following equations:

$$LL = W_N \left(\frac{N}{25}\right)^{0.121} \quad \text{or}$$

$$LL = K(W_N)$$

the number of blows causing closure of the groove at water content,

water content, and

a factor given in Table 1.

iquid limit is the average of the two trial liquid limit

If the difference between the two trial liquid limit is greater than one percentage point, repeat the test.

PLASTIC LIMIT

eparation of Test Specimen

Select a 20-g portion of soil from the material d for the liquid limit test, either after the second before the test, or from the soil remaining after tion of the test. Reduce the water content of the soil sistency at which it can be rolled without sticking to s by spreading and mixing continuously on the glass e drying process may be accelerated by exposing the soil to the air current from an electric fan, or by blotting with paper that does not add any fiber to the soil, such as hard surface paper toweling or high wet-strength filter paper.

17. Procedure

17.1 From the 20-g mass, select a portion of 1.5 to 2.0 g. Form the test specimen into an ellipsoidal mass. Roll this mass between the palm or fingers and the ground-glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length (Note 12). The thread shall be further deformed on each stroke so that its diameter is continuously reduced and its length extended until the diameter reaches 3.2 ± 0.5 mm (0.125 ± .020 in.), taking no more than 2 min (Note 13). The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

NOTE 12—A normal rate of rolling for most soils should be 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position. This rate of rolling may have to be decreased for very fragile soils.

NOTE 13—A 3.2-mm (⅛-in.) diameter rod or tube is useful for frequent comparison with the soil thread to ascertain when the thread has reached the proper diameter, especially for inexperienced operators.

17.1.1 When the diameter of the thread becomes 3.2 mm, break the thread into several pieces. Squeeze the pieces together, knead between the thumb and first finger of each hand, reform into an ellipsoidal mass, and reroll. Continue this alternate rolling to a thread 3.2 mm in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a 3.2-mm diameter thread (See Fig. 7). It has no significance if the thread breaks into threads of shorter length. Roll each of these shorter threads to 3.2 mm in diameter. The only requirement for continuing the test is that they are able to be reformed into an ellipsoidal mass and rolled out again. The operator shall at no time attempt to produce failure at exactly 3.2 mm diameter by allowing the thread to reach 3.2 mm, then reducing the rate of rolling or the hand pressure, or both, while continuing the rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal mass nearer to the required 3.2-mm final diameter. If crumbling occurs when the thread has a diameter greater than 3.2 mm, this shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3.2 mm in diameter. Crumbling of the thread will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles, others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. Fat clay soils require much pressure to deform the thread, particularly as they approach the plastic limit. With these soils, the thread breaks into a series of barrel-shaped segments about 3.2 to 9.5 mm (⅛ to ⅜ in.) in length.

17.2 Gather the portions of the crumbled thread together and place in a weighed container. Immediately cover the container.

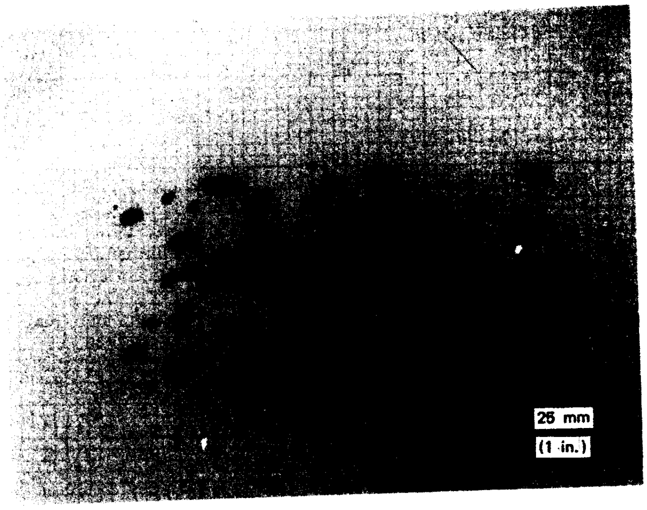

FIG. 7 Lean Clay Soil at the Plastic Limit

17.3 Select another 1.5 to 2.0 g portion of soil from the original 20-g specimen and repeat the operations described in 17.1 and 17.2 until the container has at least 6 g of soil.

17.4 Repeat 17.1 through 17.3 to make another container holding at least 6 g of soil. Determine the water content, in percent, of the soil contained in the containers in accordance with Method D 2216. Make all weighings on the same balance.

NOTE 14—The intent of performing two plastic limit trials is to verify the consistency of the test results. It is acceptable practice to perform only one plastic limit trial when the consistency in the test results can be confirmed by other means.

18. Calculations

18.1 Compute the average of the two water contents. If the difference between the two water contents is greater than two percentage points, repeat the test. The plastic limit is the average of the two water contents.

PLASTICITY INDEX

19. Calculations

19.1 Calculate the plasticity index as follows:

$$PI = LL - PL$$

where:

LL = the liquid limit,

PL = the plastic limit.

Both LL and PL are whole numbers. If either the liquid limit or plastic limit could not be determined, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP.

20. Report

20.1 Report the following information:

20.1.1 Sample identifying information,

20.1.2 Any special specimen selection process used, such as removal of sand lenses from undisturbed sample,

20.1.3 Report sample as airdried if the sample was airdried before or during preparation,

20.1.4 Liquid limit, plastic limit, and plasticity index to the nearest whole number and omitting the percent designation. If the liquid limit or plastic limit tests could not be performed, or if the plastic limit is equal to or greater than the liquid limit, report the soil as nonplastic, NP,

20.1.5 An estimate of the percentage of sample retained on the 425-µm (No. 40) sieve, and

20.1.6 Procedure by which liquid limit was performed, if it differs from the multipoint method.

21. Precision and Bias

21.1 No interlaboratory testing program has as yet been conducted using this test method to determine multilaboratory precision.

21.2 The within laboratory precision of the results of tests performed by different operators at one laboratory on two soils using Procedure A for the liquid limit is shown in Table 2.

TABLE 2 Within Laboratory Precision for Liquid Limit

	Average Value, $\bar{x}$	Standard Deviation, s
Soil A:		
PL	21.9	1.07
LL	27.9	1.07
Soil B:		
PL	20.1	1.21
LL	32.6	0.98

Designation: D 806 – 96

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Cement Content of Soil-Cement Mixtures[1]

This standard is issued under the fixed designation D 806; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method covers the determination by chemical analysis of cement content of hardened soil-cement mixtures.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard precautions, see section 5.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2901 Test Method for Cement Content of Freshly Mixed Soil-Cement[2]
D 3740 Practice for the Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock Used in Engineering Design and Construction[2]
E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]
E 832 Specification for Laboratory Filter Papers[3]

3. Significance and Use

3.1 This test method determines cement content in mixtures of cement with soil or aggregate by chemical analysis. It was developed primarily for testing samples for which a significant degree of cement hydration or hardening has taken place. Test Method D 2901 may be used for determining cement content of freshly mixed soil-cement mixtures.

3.2 This test method is based on determination by chemical analysis of the calcium oxide (CaO) content of the sample. The method may not be applicable to soil-cement materials containing soils or aggregates which yield significant amounts of dissolved calcium oxide (CaO) under the conditions of the test.

NOTE 1—The agency performing this test method can be evaluated in accordance with Practice D 3740. Not withstanding statements on precision and bias contained in this test method: the precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not, in itself, ensure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of these factors.

4. Apparatus

4.1 *Analytical Balance*—An analytical balance with Class S weights.

4.2 *Filter Paper*—Filter paper including Whatman No. 1, 11 and 15 cm in diameter; Whatman No. 41, 15 cm in diameter; and Whatman No. 2, 11 or 15 cm in diameter.

4.3 *Fifty-Millilitre-Pipet.*

4.4 *Miscellaneous Apparatus*—Supplementary equipment, such as electric ovens, hot plates, a small riffle, a No. 40- (425 μm-) sieve with bottom pan and cover, a cast iron mortar and pestle, and a ball mill if possible.

5. Reagents

5.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[4] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 *Potassium Permanganate, Standard Solution* (0.1 *N*)—Prepare and standardize a 0.1 *N* $KMnO_4$ solution.

NOTE 2—The use of a standard 0.1 *N* $KMnO_4$ solution is not necessary when the samples are titrated in accordance with 7.9 and the results are calculated in accordance with 8.2.

5.3 *Ammonium Nitrate Solution*—Dissolve 20 g of NH_4NO_3 in 1L of distilled water.

5.4 *Hydrochloric Acid (1 + 3)*—Add 200 mL of HCl (sp gr 1.19) to 600 mL of distilled water.

5.5 *Hydrochloric Acid (1 + 1)*—Add 25 mL of HCl (sp gr 1.19) to 25 mL of distilled water.

5.6 *Nitric Acid*—See Note 4 in 7.4.

5.7 *Ammonium Oxalate Solution* (5 %)—50 g of ammonium oxalate.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization with Admixtures.

Current edition approved May 10, 1996. Published June 1996. Originally published as D 806 – 44 T. Last previous edition D 806 – 89.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

[4] "Reagent Chemicals, American Chemical Society Specifications," American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopeia."

*** A Summary of Changes section appears at the end of this test method.**

Note 3—**Precaution:** In addition to other precautions, this is done by adding the acid, slowly while stirring, to the water to avoid a sudden temperature rise that could cause boiling and spattering of the acid solution.

5.8 *Ammonium Hydroxide, NH_4OH* (sp gr 0.90).

5.9 *Sulfuric Acid (1 + 1)*—Add 500 mL H_2SO_4 (sp gr 1.84) to 500 mL of distilled water.

6. Samples

6.1 Samples of the following shall be selected for the test:

6.1.1 *Raw Soil*, representative of the soil phase of the soil-cement mixture.

6.1.2 *Cement*, representative of the cement phase of the soil-cement mixture, and

6.1.3 *Soil-cement Mixture* to be analyzed.

6.2 The gross laboratory sample of each component shall be approximately 200 g. This may be obtained by reducing the sample in bulk and, if necessary, in particle size through the use of drying, riffling and grinding processes.

7. Procedure

7.1 Dry 25 g of each of the samples in an oven to constant weight at 110°C (230°F) to remove free moisture. Reduce the samples to pass a No. 40- (425 μm-) sieve.

7.2 Weigh out, on the analytical balance, the following amounts of the samples: raw soil, 5 g; soil-cement mixture, 5 g; cement, 1 g. Place each of the weighed samples in a 250-mL beaker. Add 50 mL of HCl (1+1) (Note 4) to each sample, cover, and boil *gently* for 5 min on the hot plate.

Note 4—In the case of the cement sample, it is usually preferable first to add 40 mL of water and then stir to obtain a thorough mixture. Then add 10 mL of HCl (sp gr 1.19) and boil *gently* just long enough to obtain decomposition of the cement. Vigorous or extended boiling of soil or cement samples is seldom necessary, and often results in much slower filtration.

7.3 Add 25 mL of hot water to the beakers, stir, allow to settle momentarily, and then decant the contents through a Whatman No. 1 filter paper (Note 5), preferably 15 cm in diameter. The filtrate should be received in a 250-mL volumetric flask. When the liquid has passed through the filter paper, wash the residue once by decantation, using hot water; then transfer it to the filter, using a stream of hot water. The beaker should be rapidly policed, the loosened material being transferred to the filter paper. The material on the filter should then be washed an additional four times, each washing consisting of 10 to 15 mL of hot water directed in a stream from the wash bottle. Very small amounts of residue will occasionally pass through the filter. These ordinarily may be disregarded.

Note 5—In the case of the soil and soil-cement samples, the bulk of the residue sometimes slows filtration appreciably. No difficulty is usually encountered from cement samples, and, as a rule, soil samples may be filtered and washed in less than 30 min. Some soil-cement mixtures require more time, but, if this period exceeds 1 h, subsequent filtration in similar cases may be more rapid if a No. 41 paper is substituted for the No. 1 paper. Slow filtration in such cases is generally caused by excessive boiling, resulting in gelation of the silica, which materially retards filtration.

7.4 When washing has been completed, discard the filter, and dilute the filtrate in the volumetric flask to 250 mL with cold water. The temperature of the solution should be near the calibration point of the flask. Agitate the flask to mix the contents thoroughly, then remove a 50-mL aliquot and transfer to the original 250-mL beaker (7.2), using a 50-mL pipet. Dilute to 100 mL. Make the solution slightly ammoniacal (Note 6), boil 1 to 2 min, and allow the hydroxides to settle.

Note 6—If the samples contain ferrous iron it is desirable to add a few drops of HNO_3 before precipitation of the hydroxides.

7.5 Filter the hydroxides through an 11-cm Whatman No. 1 (or No. 41) filter paper, receiving the filtrate in the 600-mL beaker. Wash the original 250-mL beaker into the filter once with a stream of hot NH_4NO_3 solution (20 g/L), and follow by washing the hydroxide precipitate once or twice with hot NH_4NO_3 solution (20 g/L). Set the filtrate aside, and place the original beaker under the funnel. Perforate the paper with a rod (Note 5), and wash the hydroxides down into the original beaker, using a stream of hot NH_4NO_3 solution (20 g/L) to remove most of the precipitate from the filter paper. Treat the paper with 20 mL of hot HCl (1+3), directing the acid over the paper with a glass rod. Wash the paper several times with hot water, and then discard the paper. Dilute the solution to 75 mL.

Note 7—Instead of perforating the filter paper, the paper and precipitate may be transferred to the original beaker, the hydroxides dissolved with 20 mL of hot HCl (1+3) and diluted to 75 mL with water, and the procedure continued as described in 7.6. In this case, the reprecipitated hydroxides and pulp are subsequently removed simultaneously.

7.6 Make the solution slightly ammoniacal and boil 1 to 2 min. Allow the precipitate to settle, then decant through a Whatman No. 1 paper as before, receiving the filtrate in the 600-mL beaker previously set aside (7.5). Wash and police the beaker in which precipitation took place, finally washing the precipitate on the filter three or four times with NH_4NO_3 solution (20 g/L). Discard the hydroxide precipitate. Add 2 mL of NH_4OH (sp gr 0.90) to the filtrate, which will now have a volume of 250 to 350 mL. Heat the solution to boiling and add 10 mL of hot saturated ammonium oxalate solution. Keep the mixture near boiling until precipitate becomes granular; then set aside on a warm hot plate for 30 min or more. Before filtering off the calcium oxalate, verify completeness of precipitation, (Note 8) and make sure that a slight excess of NH_4OH is present. Filter the mixture through an 11-cm or 15-cm Whatman No. 2 filter paper, or if preferred a Whatman No. 42 paper, making sure that all the precipitate is being retained. Thoroughly clean with a rubber policeman the beaker in which precipitation took place, and transfer the contents to the filter with a stream of hot water. Wash the filter eight to ten times with hot water (not over 75 mL) (Note 9), using a stream from the wash bottle.

Note 8—The calcium oxalate precipitation is sometimes not complete and this results in low CaO values. The precipitation operation must be carried out with thoroughness and care.

Note 9—The filter may be washed four times each with NH_4OH (2+98) and hot water, in the order stated.

7.7 Carefully open the filter paper and wash the precipitate into the beaker in which the precipitation was effected. Dilute to 200 mL and add 10 mL of H_2SO_4 (1+1). Heat the solution just short of boiling, and titrate it with the standard $KMnO_4$ solution (Note 10) to a persistent pink color. Add the filter paper and macerate it. Continue the titration slowly until the pink color persists for 10 s.

NOTE 10—The temperature of the standard $KMnO_4$ solution should not vary from its standardization temperature so much as to cause a serious error in the determination of CaO. At ordinary room temperatures the volume of pure water changes to the extent of 0.01 to 0.04 % for each degree Celsius, depending on the temperature.

7.8 *Blank*—Make a blank determination, following the same procedure and using the same amounts of all reagents.

7.9 *Alternative Titration Procedure*—Titrate as described in 7.7, except that the $KMnO_4$ solution need not be a standard 0.1 *N* solution, but the same solution shall be used in titrating all the components. Omit the blank determination described in 7.8.

8. Calculation

8.1 Calculate the cement content of the soil-cement mixture as follows:

8.1.1 When the determination has been completed in accordance with 7.7 and 7.8:

8.1.1.1 Calculate the percentages of CaO in the soil, the cement, and the soil-cement mixture as follows:

$$\text{CaO, \%} = [((A - B)C \times 0.028)/D] \times 100$$

where:

A = $KMnO_4$ solution required for titration of the sample, mL,
B = $KMnO_4$ solution required for titration of the blank, mL,
C = normality of the $KMnO_4$ solution,
D = sample represented by the aliquot titrated (Note 10), g, and
0.028 = CaO equivalent of 1 mL of 1.0 *N* $KMnO_4$ solution.

8.1.1.2 Calculate the percent cement by weight of soil as follows (Note 12):

$$\text{Cement, \%} = [(G - F)/(E - G)] \times 100$$

where:

E = CaO in cement, %,
F = CaO in raw soil, %, and
G = CaO in soil-cement mixture, %.

NOTE 11—The aliquots titrated are equivalent to 1 g of soil or soil-cement and 0.2 g of cement.

NOTE 12—The value for percentage by weight of soil obtained in accordance with 8.1 or 8.2 is in terms of hydrated cement. Such values may be converted to an approximate equivalent of dry cement by multiplying them by the factor 1.04.

8.2 When the determination has been completed in accordance with 7.9, calculate the percent cement by weight of soil as follows (Note 12):

$$\text{Cement, \%} = [(J - I)/(5H - J)] \times 100$$

where:

H = $KMnO_4$ solution required for titration of the sample of cement, mL,
I = $KMnO_4$ solution required for titration of the sample of raw soil, and mL,
J = $KMnO_4$ solution required for titration of the sample of soil-cement mixture, mL.

9. Precision and Bias

9.1 The precision and bias of this test method are not known. Pertinent data are solicited from users.

10. Keywords

10.1 cement content; durability; soil-cement; soil-cement mixtures; soil stabilization

SUMMARY OF CHANGES

This section identifies the principal changes to this test method that have been incorporated since the last issue.

(1) Added Practice D 3740 as a referenced document in Section 2 to conform to the recommended D-18 practice.

(2) Added new Note 1 in Section 3 to reference Practice D 3740. Renumbered the remaining notes.

(3) Added new Section 10 on Keywords.

(5) Added new Section 11 on Summary of Changes to reflect the changes made in this revision.

Designation: D 2901 – 93

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Standard Test Method for Cement Content of Freshly Mixed Soil-Cement[1]

This standard is issued under the fixed designation D 2901; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers determination of the cement content of samples of freshly-mixed soil-cement.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 806 Test Method for Cement Content of Soil-Cement Mixtures[2]
D 1293 Test Methods for pH of Water[3]
D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials[2]
E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Summary of Test Method

3.1 A weighed sample of the fresh material passing a 4.75 mm sieve is extracted with an ammonium chloride solution. After allowing the sample to settle, an aliquot of the supernatant is diluted with water. The pH is adjusted to 13 and triethanolamine is added to complex interferants. The sample is titrated with EDTA solution to the blue endpoint of hydroxynaphthol blue indicator. The cement content is read from a calibration curve prepared from titrations of several known cement content mixes made with the same water, soil, and cement as the sample.

4. Significance and Use

4.1 This test method determines cement content in mixtures of cement with soil or aggregate by chemical analysis. It was developed primarily as a relatively quick test for use at the construction site to determine compliance with specifications. The method is for materials tested soon after the completion of mixing; Test Method D 806 may be used for testing samples for which a significant degree of cement hydration or hardening has taken place.

5. Apparatus

5.1 *Balance*, meeting Specification D 4753 (Class GP2) and having a capacity of 1000 g or more and a sensitivity of 0.1 g.

5.2 *Glassware*—A 25-mL and a 1000-mL graduated cylinder, 25-mL burets, 10-mL syringes or volumetric pipets, 250-mL beakers, medicine droppers.

5.3 *Plasticware*, 2-L (2-qt) polyethylene containers with snap-on covers, 300 mm (12-in.) diameter plastic funnel, 20-L polyethylene bottles for ammonium chloride and distilled or demineralized water.

5.4 *Buret Stand* for 25-mL buret.

5.5 *Magnetic Stirrer and Stirring Bar.*

5.6 *Stirring Rods*, stainless steel stirring rods approximately 300 mm (12-in.) long.

5.7 *pH Meter, or Indicator Paper* (pH range from 10 to 14)—A portable, combination-electrode pH meter is recommended to obtain accurate results as the pH adjustment is made. Indicator paper can be used as an alternate, but less accurate, means of measuring the pH adjustment.

5.8 *Sieve*—A 4.75 mm (No. 4) sieve conforming to the requirements of Specification E 11.

6. Reagents

6.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[5] Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Ammonium Chloride Solution* (10 %)—Transfer 2000 g of granular ammonium chloride (NH_4Cl) to a 20-L plastic bottle. Make up to 20 L with warm, distilled or demineralized water and mix well.

6.3 *EDTA Solution* (0.1 M), is available as a standardized, pre-prepared solution from many chemical supply houses.[6] Or, this solution may be prepared by the user as follows: Dissolve 74.45 g of disodium (ethylenedinitrilo) tetraacetate dihydrate ($Na_2C_{10}H_{14}N_2O_8 \cdot 2H_2O$) powder in approximately 1 L of warm, distilled or demineralized water in a beaker. Cool to room temperature, transfer quantitatively to

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization with Admixtures.

Current edition approved May 15, 1993. Published July 1993. Original edition published as D 2901 – 70. Last previous edition D 2901 – 82 (1986).

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 11.01.

[4] *Annual Book of ASTM Standards*, Vols 04.01, 04.02, 04.06, 04.07, 05.05, and 14.02.

[5] *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

[6] Available from Fisher Scientific, Pittsburgh, PA.

a 2-L volumetric flask and dilute to the mark with distilled or demineralized water. Store in a polyethylene bottle.

6.4 *Hydroxynaphthol Blue Indicator Powder.*[7]

6.5 *Sodium Hydroxide Solution* (50 %), is available as a low-in-carbonate, pre-prepared reagent.[8] Dilute 1+1 with distilled or demineralized water for use.

6.5.1 Or, this solution may be prepared by the user as follows: Very slowly and cautiously add 500 g of sodium hydroxide (NaOH) pellets to 600 mL of distilled or demineralized water and allow to cool to room temperature. Dilute to 1 L with distilled or demineralized water. Store in a plastic bottle. Dilute 1+1 with distilled or demineralized water for use.

6.6 *Triethanolamine Solution* (20 %)—Dilute 20 mL of reagent grade triethanolamine ($(HOCH_2CH_2)_3N$) to 100 mL with distilled or demineralized water.

6.7 *pH 7 and pH 12.5 Buffer Solutions*, used to calibrate pH meter.

7. Preparation of Calibration Curve

7.1 From the materials to be used for construction, prepare three sets of duplicate samples at the design water content containing the following amounts of cement: Set 1, two samples at 75 % of the design cement content, Set 2, two samples at 100 % of the design cement content, and Set 3, two samples at 125 % of the design cement content.

NOTE 1—If necessary, additional calibration points may be established to cover a wider range of cement contents.

For each sample calculate quantities of soil, cement, and water as follows:

$$M_s = S/[(1 + w/100)(1 + C/100)]$$
$$M_r = (R/100) \times M_s$$
$$M_f = M_s - M_r$$
$$M_c = (C/100) \times M_s$$
$$V_w = (w/100)(M_s + M_c)$$

where:

w = design water content, percent by dry mass of soil and cement,
C = cement content, percent by dry mass of soil,
R = percent material retained on a 4.75-mm (No. 4) sieve,
S = sample size, 300.0 g when 100 % of the soil passes a 4.75-mm sieve, 700.0 g when part of the soil is retained on a 4.75-mm sieve.
M_s = total oven-dry mass of soil, g
M_r = mass of material retained on 4.75-mm sieve, g,
M_f = mass of material passing 4.75-mm sieve, g,
M_c = mass of cement, g, and
V_w = volume of water, mL.

For each sample mix the soil and cement thoroughly to a uniform color. Add the water and mix thoroughly.

NOTE 2—The moisture content of air-dry soil will have a slight effect on the accuracy of the calibration results. This may be corrected by using quantities of soil and water calculated as follows:

$$M_f' = (1 + w_s/100) \times M_f$$

$$V_w' = V_w - (M_f' - M_f)$$

where:

w_s = moisture content of air-dry soil passing 4.75-mm sieve, %.

7.2 Depending on whether the sample contains material retained on the 4.75-mm sieve, follow either 7.2.1 or 7.2.2 as follows:

7.2.1 For soils with 100 % passing a 4.75-mm sieve, titrate each 300.0-g sample as described in Section 9. After titrating the six samples, construct a graph showing millilitres of EDTA solution *versus* percent cement by weight using average figures from Sets 1, 2, and 3.

7.2.2 For soils with material retained on a 4.75-mm sieve, thoroughly screen each 700.0-g sample on the sieve until all the material retained is free of smaller, adhering particles. Mix the material passing the sieve and weigh a 300.0-g portion and titrate as described in Section 9. After titrating the six samples, construct a graph showing millilitres of EDTA solution, using average figures from Sets 1, 2, and 3, *versus* grams of cement, M_{c300}, in a 300-g sample computed as follows:

$$M_{c300} = [300/(700 - M_r)] \times M_c.$$

7.3 Calibration curves are different for each soil type and may be nonlinear.

7.4 Rerun calibration curve each time a new batch of chemicals is introduced.

7.5 Inaccuracies result when the calcium content of test samples differs from that of the calibration samples. Calibration tests should be rerun whenever the samples vary significantly in calcium content, as measured by titration tests on the raw soils (Section 9). Inaccuracies may also result if the source of water used in the calibration samples differs from that of the test sampler.

8. Sampling

8.1 Take representative samples of the soil-cement mixture at the completion of mixing. Test the samples immediately or place in covered plastic containers and test within 30 min of the completion of mixing. Depending on whether the sample contains material retained on a 4.75-mm sieve, follow either 8.1.1 or 8.1.2 below.

8.1.1 For soil-cement mixtures with 100 % passing a 4.75-mm sieve, weigh a 300.0-g portion and titrate as described in Section 9.

8.1.2 For soil-cement mixtures with material retained on a 4.75-mm sieve, weigh a 700.0-g sample. Screen the sample thoroughly on a 4.75-mm sieve until all the material retained is free of smaller adhering particles. Weigh and record as M_{fcw} the total material passing the sieve. Mix the material passing the sieve and weigh a 300.0-g portion and titrate as described in Section 9.

NOTE 3—If a correction is to be made for variations in water content, determine the water content, w', of a separate portion of the material passing a 4.75-mm sieve. Computations for the correction are given in Note 6.

9. Procedure for Titration

9.1 Place each 300.0-g sample into a 2-L (2-qt) polyethylene container and add 500 mL of NH_4Cl solution. Place a cover on the container and shake the mixture for 2 min ± 2 s. Allow the mixture to settle for 4 min ± 2 s to obtain a clear supernatant. Syringe or pipet a 10-mL aliquot of the

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[7] Available from Mallinckrodt Chemical Works, St. Louis, MO, or Fisher Scientific, Pittsburgh, PA.

[8] Available from Fisher Scientific, Pittsburgh, PA.

supernatant solution into a 250-mL beaker containing a magnetic stirring bar, add 100 mL of distilled or demineralized water. While thoroughly mixing on a magnetic stirrer, add drops of NaOH solution with a medicine dropper until a pH between 13.0 and 13.5 is obtained as measured by a pH meter or the indicator paper. When a pH meter is used, refer to Test Methods D 1293 for calibration of the meter. When indicator paper is used, use a stirring rod to transfer drops of solution to the indicator paper. After adjusting the pH, wait about 20 to 30 s to insure that the pH does not drift downward from the specified range. Add four drops of triethanolamine solution and add about 0.2 g of indicator powder. Continue stirring the solution on the magnetic stirrer. Titrate with EDTA solution to a pure blue end point. Record the millilitres of EDTA required to obtain the end point.

NOTE 4—A sharper end point may be obtained by adding approximately 90 % of the anticipated quantity of EDTA solution before the addition of NaOH solution.

NOTE 5—All equipment must be kept scrupulously clean by thorough rinsing with distilled or demineralized water. All reagents must be stored in polyethylene containers.

10. Calculation

10.1 Depending on whether the sample contains material retained on a 4.75-mm sieve, follow either 10.1.1 or 10.1.2 below.

10.1.1 If 100 % of the soil-cement mixture passes a 4.75-mm sieve, read the cement content by dry weight of soil (exclusive of cement) directly from the calibration curve corresponding to the titration results in millilitres of EDTA for the test sample.

10.1.2 If the soil contains material retained on a 4.75-mm sieve, read grams of cement from the calibration curve corresponding to the titration results in millilitres of EDTA for the test sample. Calculate A and B as follows:

$$A = (M_{fcw}/300) \times M_{c300}$$

$$B = 700/[1 + (w/100)]$$

where:

M_{fcw} = grams of moist soil and cement passing the 4.75-mm sieve described in 8.1.2,
M_{c300} = grams of cement read from calibration curve,
w = design water content, %,
A = grams of cement in 700-g sample, and
B = grams of soil and cement in 700-g sample

Then compute C, percent cement by dry mass of total sample (exclusive of cement) as follows:

$$C = [A/(B - A)] \times 100$$

NOTE 6—Variations of water content will have a slight effect on the accuracy of test. Correction for water variation, C', may be computed as follows:

$$C' = \frac{1 + (w'/100)}{1 + [V_w/(M_f + M_c)]} \times C$$

where

C' = percent cement corrected for water variation,
C = percent cement determined from test sample,
w' = percent water of test sample as determined in Note 3, and

V_w, M_f and M_c are quantities computed in Section 7 for calibration Set 2.

11. Precision and Bias

11.1 In the process of development of D 2901-70, interlaboratory testing programs were conducted in 1967 and 1968. Results of these tests showed an average error in cement content determination of 3.6 % [(error)/(cement content) × 100] from which a coefficient of variation of 4.5 % is estimated. On duplicate specimens used in the calibration process, the average deviation in millilitres of EDTA was 2.4 % [(deviation in millilitres)/(average millilitres) × 100].

12. Keywords

12.1 cement content; soil-cement

Designation: D 1633 – 96

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders[1]

This standard is issued under the fixed designation D 1633; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope*

1.1 This test method covers the determination of the compressive strength of soil-cement using molded cylinders as test specimens.

1.2 Two alternative procedures are provided as follows:

1.2.1 *Method A*—This procedure uses a test specimen 4.0 in. (101.6 mm) in diameter and 4.584 in. (116.4 mm) in height. Height to diameter ratio equals 1.15.

1.2.2 *Method B*—This procedure uses a test specimen 2.8 in. (71.1 mm) in diameter and 5.6 in. (142.2 mm) in height. Height to diameter ratio equals 2.00.

1.3 The values stated in inch-pound units are to be regarded as the standard. The SI units in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 42 Test Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete[2]

D 559 Test Methods for Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures[3]

D 560 Test Methods for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures[3]

D 1632 Practice for Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory[3]

D 3740 Practice for the Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock Used in Engineering Design and Construction[3]

E 4 Practices for Load Verification of Testing Machines[4]

3. Significance and Use

3.1 Method A makes use of the same compaction equipment and molds commonly available in soil laboratories and used for other soil-cement tests. It is considered that Method A gives a relative measure of strength rather than a rigorous determination of compressive strength. Because of the lesser height to diameter ratio (1.15) of the cylinders, the compressive strength determined by Method A will normally be greater than that for Method B.

3.2 Method B, because of the greater height to diameter ratio (2.00), gives a better measure of compressive strength from a technical viewpoint since it reduces complex stress conditions that may occur during the crushing of Method A specimens.

3.3 In practice, Method A has been more commonly used than Method B. As a result, it has been customary to evaluate or specify compressive strength values as determined by Method A. A factor for converting compressive strength values based on height to diameter ratio is given in Section 7[5].

NOTE 1—The agency performing this test method can be evaluated in accordance with Practice D 3740. Not withstanding statements on precision and bias contained in this test method: the precision of this test method is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not, in itself, ensure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of these factors.

4. Apparatus

4.1 *Compression Testing Machine*—This machine may be of any type having sufficient capacity and control to provide the rate of loading prescribed in 6.2. It shall conform to the requirements of Section 15 of Practices E 4. The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 2), one of which is a spherically seated head block that normally will bear on the upper surface of the specimen, and the other a plain rigid block on which the specimen will rest. The bearing faces shall be at least as large, and preferably slightly larger, than the surface of the specimen to which the load is applied. The bearing faces, when new, shall not depart from a plane by more than 0.0005 in. (0.013 mm) at any point, and they shall

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization with Admixtures.

Current edition approved May 10, 1996. Published July 1996. Originally published as D 1633 – 59 T. Last previous edition D 1633 – 84 (1990)$^{\epsilon 1}$.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] For additional discussion on the significance and use of compressive strength results, see the *Soil-Cement Laboratory Handbook*, Chapter 4, Portland Cement Association, Skokie, IL, 1971, pp 31 and 32.

*** A Summary of Changes section appears at the end of this test method.**

Norma 22 ASTM 1633-96 RESISTENCIA + EN SUELO-CEMENTO be maintained within a permissible variation limit of 0.001 in. (0.02 mm). In the spherically seated block, the diameter of the sphere shall not greatly exceed the diameter of the specimen and the center of the sphere shall coincide with the center of the bearing face. The movable portion of this block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction.

NOTE 2—It is desirable that the bearing faces of blocks used for compression testing of soil-cement have a hardness of not less than 60 HRC.

4.2 *Molds and Compaction Equipment,* in accordance with Test Methods D 559 or D 560 for Method A; Practice D 1632 for Method B.

5. Test Specimens

5.1 Mold the test specimens as follows:

5.1.1 *Method A*—Specimens are 4.0 in. (101.6 mm) in diameter and 4.584 in. (116.4 mm) in height and are molded in accordance with Test Methods D 559 or D 560.

5.1.2 *Method B*—Specimens are 2.8 in. (71.1 mm) in diameter and 5.6 in. (142.2 mm) in height and are molded in accordance with Practice D 1632.

NOTE 3—These methods may be used for testing specimens of other sizes. If the soil sample includes material retained on the 4.75-mm (No. 4) sieve, it is recommended that Method A be used, or that larger test specimens, 4.0 in. (101.6 mm) in diameter and 8.0 in. (203.2 mm) in height, be molded in a manner similar to Method B.

5.2 Moist cure the specimens in accordance with Practice D 1632.

5.3 At the end of the moist-cure period, immerse the specimens in water for 4 h.

5.4 Remove the specimens from the water and make compression tests as soon as practicable, keeping specimens moist by a wet burlap or blanket covering.

NOTE 4—Other conditioning procedures, such as air or oven drying, alternate wetting and drying, or alternate freezing and thawing may be specified after an initial moist curing period. Curing and conditioning procedures shall be given in detail in the report.

5.5 Check the smoothness of the faces with a straightedge. If necessary, cap the faces to meet the requirements of the section on Capping Specimens of Practice D 1632.

6. Procedure

6.1 Place the lower bearing block on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Place the specimen on the lower bearing block, making certain that the vertical axis of the specimen is aligned with the center of thrust of the spherically seated block. As this block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

6.2 Apply the load continuously and without shock. A screw power testing machine, with the moving head operating at approximately 0.05 in. (1 mm)/min when the machine is running idle, may be used. With hydraulic machines, adjust the loading to a constant rate within the limits of 20 ± 10 psi (140 ± 70 kPa)/s, depending upon the strength of the specimen. Record the total load at failure of the test specimen to the nearest 10 lbf (40 N).

7. Calculation

7.1 Calculate the unit compressive strength of the specimen by dividing the maximum load by the cross-sectional area.

NOTE 5—If desired, make allowance for the ratio of height to diameter (h/d) by multiplying the compressive strength of Method B specimens by the factor 1.10. This converts the strength for an h/d ratio of 2.00 to that for the h/d ratio of 1.15 commonly used in routine testing of soil-cement (see Section 3). This conversion is based on that given in Method C 42, which has been found applicable for soil-cement.

8. Report

8.1 The report shall include the following:

8.1.1 Specimen identification number,

8.1.2 Diameter and height, in. (mm),

8.1.3 Cross-sectional areas, in.^2 (mm^2),

8.1.4 Maximum load, to the nearest 10 lbf (40 N),

8.1.5 Conversion factor for height to diameter ratio (see Note 4), if used,

8.1.6 Compressive strength, calculated to the nearest 5 psi (35 kPa),

8.1.7 Age of specimen, and

8.1.8 Details of curing and conditioning periods, and moisture content at the time of test.

9. Precision and Bias

9.1 The precision and bias of this test method have not been established by an interlaboratory test program. However, based on the test data that are available, the following may serve as a guide as to the variability of compressive strength test results.

9.1.1 Tests were performed in a single lab on 122 sets of duplicate specimens molded from 21 different soil materials. The average difference in strength on duplicate specimens was 8.1 % and the median difference was 6.2 %. These values are expressed as the percent of the average strength of the two specimens as follows:

$$\%\ \text{Difference} = \frac{(\text{high value} - \text{low value})}{(\text{high value} + \text{low value})/2} \times 100$$

The distribution of the variation is shown in Fig. 1. The data[6,7] cover a wide range of cement contents and compressive strengths.

10. Keywords

10.1 compressive strength; soil-cement; soil stabilization

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[6] Packard, R. G., "Alternate Measures for Measuring Freeze-Thaw and Wet-Dry Resistance of Soil-Cement Mixtures," *Highway Research Bulletin*, 353, Transportation Research Board, 1962, pp 8–41.

[7] Packard, R. G., and Chapman, G. A., "Developments in Durability Testing of Soil-Cement Mixtures," Highway Research Record No. 36, Transportation Research Board, 1963, pp 97–122.

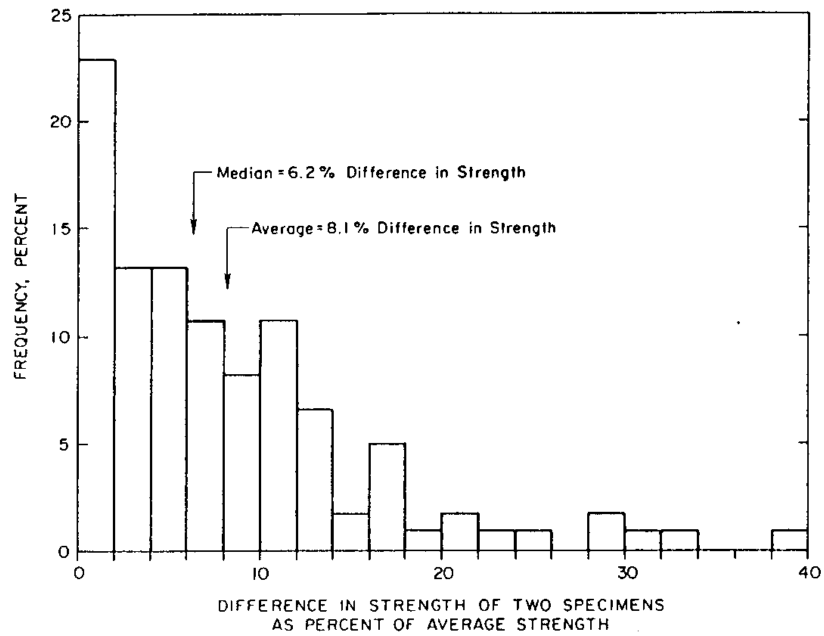

FIG. 1 Distribution of Variation of Test Results for 122 Sets of Duplicate Specimens

SUMMARY OF CHANGES

This section identifies the principal changes to this test method that have been incorporated since the last issue.

(1) Added Practice D 3740 as a referenced document in Section 2 to conform to the recommended D-18 practice.

(2) Added new Note 1 in Section 3 to reference Practice D 3740. Renumbered the remaining notes.

(3) Added new Section 11 on Summary of Changes to reflect the changes made in this revision.

Designation: D 1634 – 95

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Standard Test Method for Compressive Strength of Soil-Cement Using Portions of Beams Broken in Flexure (Modified Cube Method)[1]

This standard is issued under the fixed designation D 1634; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the compressive strength of soil-cement, using for test specimens portions of beams broken in flexure in accordance with Test Method D 1635.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1632 Practice for Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory[2]

D 1633 Test Method for Compressive Strength of Molded Soil-Cement Cylinders[2]

D 1635 Test Method for Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading[2]

E 4 Practices for Load Verification of Testing Machines[3]

3. Significance and Use

3.1 This test method is intended for use in the laboratory and as a research tool for determining relative compressive strength values for various soil-cement mixtures. It is not intended as an alternative for Test Method D 1633 and the test values obtained by these two test methods are not interchangeable and not necessarily comparable. A comparison of strengths obtained by Test Methods D 1633 and D 1634 is given in Footnote 4.

4. Apparatus

4.1 *Compression Testing Machine*—The testing machine may be of any type having sufficient capacity and control to provide the rate of loading prescribed in 6.2. It shall conform to the requirements of Section 15 of Practices E 4. The testing machine shall be equipped with a spherically seated head block having a bearing surface of at least 75 % of the width of the specimen but not greatly in excess of the width of the specimen. The movable portion of this block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction.

4.2 *Bearing Plates*—Square, hardened steel bearing plates ¾ in. (19 mm) thick with side dimensions of 3 ± 0.005 in. (76.2 ± 0.13 mm) (for standard beam). The bearing faces when new shall not depart from a plane by more than 0.0005 in. (0.013 mm) at any point, and they shall be maintained within a permissible variation of 0.001 in. (0.025 mm).

NOTE—It is desirable that the bearing faces of plates used for compression testing of soil-cement have a Rockwell hardness of not less than HRC 60.

5. Test Specimens

5.1 The standard size beams from which broken portions are selected for the compression test shall be 3 by 3 by 11¼ in. (76 by 76 by 290 mm), but a similar test method may be used for testing specimens from other beam sizes. The beam-end specimens shall have a length at least 1 in. (25 mm) greater than their depth and shall be free from cracks, chipped surfaces, or other obvious defects. Test the specimens on their sides with respect to their molded position.

5.2 During the interval between testing of specimens as beams and testing the broken portions as cubes, keep the specimens at a constant water content by suitable protection.

5.3 Determine the width (original height) of the standard specimen at the point where the test will be made to the nearest 0.01 in. (0.25 mm) if it is less than 3.00 in. (76.2 mm); otherwise take it equal to 3 in. (76.2 mm). Take the length equal to 3 in. (76.2 mm). Calculate the cross-sectional area.

5.4 Check the smoothness of the faces with a straightedge. If necessary, cap the faces to meet the requirements of the section on Capping Specimens of Practice D 1632. The caps shall cover the full width of the specimen and shall be of such length as to permit adjustment of the bearing plates for the test so that the upper bearing plate may be placed directly over the lower bearing plate.

6. Procedure

6.1 Place the specimen on its side between the hardened steel bearing plates directly under the spherically seated head of the testing machine, making certain that the vertical axis of the specimen is aligned with the center of thrust of the head. Use a device such as a guide template to ensure that the upper bearing plate is directly over the lower bearing plate. As the spherically seated head is brought to bear on the top bearing plate, rotate its movable portion gently by hand so that uniform seating is obtained.

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization by Admixtures.

Current edition approved April 15, 1995. Published May 1995. Originally published as D 1634 – 59 T. Last previous edition D 1634 – 87.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

6.2 Apply the load continuously and without shock. A screw power testing machine, with the moving head operating at approximately 0.05 in./min (0.02 mm/s) when the machine is running idle, may be used. With hydraulic machines, adjust the loading to a constant rate within the limits of 20 ± 10 psi (140 ± 70 kPa)/s, depending upon the strength of the specimen. Record the total load at failure of the specimen to the nearest 10 lbf (45 N).

7. Calculation

7.1 Calculate the unit compressive strength of the specimen by dividing the maximum load by the cross-sectional area determined as described in 5.3.

8. Report

8.1 Report the following information:

8.1.1 Specimen identification number,

8.1.2 Width and length of test area, in. (or mm),

8.1.3 Cross-sectional area, in.^{2} (or mm^2),

8.1.4 Maximum load, to the nearest 10 lbf (40 N),

8.1.5 Compressive strength, calculated to the nearest 5 psi (35 kPa),

8.1.6 Age of specimen, and

8.1.7 Details of curing and conditioning periods, and water content at time of test.

9. Precision and Bias

9.1 *Precision*—The precision of this test method has not been established by an interlaboratory test program. However, based on test data that are available, the following may serve as a guide to the variability of compressive strength by the modified cube method.

9.1.1 Tests were performed in a single laboratory on a silt loam soil with 92 % passing the No. 200 sieve. Liquid limit and plasticity index of soil were 26 and 7, respectively. The series of tests consisted of 24 specimens, 12 at 6 % cement and 12 at 14 % cement. The specimens were cured in a moist room at 73° F (23°C) for 28 days. Results[4] of tests on the 3 by 3-in. modified cubes are given in Table 1.

TABLE 1 Precision

	Average compressive strength, psi	Standard deviation, psi	Coefficient of variation, %
Specimens with 6 % cement	473	35	7.4
Specimens with 14 % cement	887	47	5.3

9.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

10. Keywords

10.1 soil-cement; soil stabilization; unconfined compressive strength

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[4] Felt, E. J., Abrams, M. S., *Strength and Elastic Properties of Compacted Soil-Cement Mixtures, ASTM STP 206*, ASTM, 1957.

Designation: D 1635 – 95

AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race St. Philadelphia, Pa 19103

Standard Test Method for Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading[1]

This standard is issued under the fixed designation D 1635; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the flexural strength of soil-cement by the use of a simple beam with third-point loading.

NOTE 1—For methods of molding soil-cement specimens, see Practice D 1632.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1632 Practice for Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory[2]

E 4 Practices for Force Verification of Testing Machines[3]

3. Significance and Use

3.1 This test method is used to determine the flexural strength of soil-cement. Flexural strength is significant in pavement design and is used to determine slab thickness.

4. Apparatus

4.1 *Testing Machine*—The testing machine may be of any type having sufficient capacity and control to provide the rate of loading (prescribed in 6.2). It shall conform to the requirements of Section 15 of Practices E 4. The testing machine shall be equipped with a spherically seated head block having a bearing surface of at least 75 % of the width of the beam but not greatly in excess of the width of the beam. The movable portion of this block shall be held closely in the spherical seat, but the design shall be such that the bearing face may be rotated freely and tilted through small angles in any direction.

4.2 The third-point loading method used in making flexure tests of soil-cement shall employ bearing blocks that will ensure that forces applied to the beam will be vertical only and applied without eccentricity. A diagrammatic drawing of an apparatus that accomplishes this purpose is shown in Fig. 1. The apparatus shall be designed to incorporate the following principles:

4.2.1 The distance between supports and points of load application shall remain constant for a given apparatus.

4.2.2 The direction of the reactions shall be parallel to the direction of the applied load at all times during the test.

4.2.3 The load shall be applied at a uniform rate and in such a manner as to avoid shock.

4.2.4 The directions of loads and reactions may be maintained parallel by judicious use of linkages, rocker bearings, and flexure plates. Eccentricity of loading can be avoided by use of spherical bearings.

5. Test Specimens

5.1 The standard test specimens shall be beams 3 by 3 by 11¼ in. (76 by 76 by 290 mm), but a similar test method may be used for testing specimens of other sizes. Test the specimens on their sides with respect to their molded position.

5.2 Make flexural tests of moist cured specimens as soon as practicable after removing them from the moist room, and during the period between removal from the moist room and testing keep the specimens moist by a wet burlap or blanket covering.

NOTE 2—Other conditioning procedures, such as soaking in water, air or oven drying, alternate wetting and drying or alternate freezing and thawing, may be specified after an initial moist curing period. Curing and conditioning procedures shall be given in detail in the report.

5.3 Check the smoothness of the side faces of the beams at the points where loads will be applied with a straightedge. If necessary, cap the faces to meet the requirements of Section 15 of Practice D 1632.

6. Procedure

6.1 Turn the specimen on its side with respect to its molded position and center it on the lower half-round steel supports, which have been spaced apart a distance of three times the depth of the beam. Place the load-applying block assembly in contact with the upper surface of the beam at the third points between the supports. Carefully align the center of the beam with the center of thrust of the spherically seated head block of the machine. As this block is brought to bear on the beam-loading assembly, rotate its movable portion gently by hand so that uniform seating is obtained.

6.2 Apply the load continuously and without shock. A screw power testing machine, with the moving head operating at approximately 0.05 in./min (0.02 mm/s) when the machine is running idle, may be used. With hydraulic

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization by Admixtures.

Current edition approved April 15, 1995. Published June 1995. Originally published as D 1635 – 59 T. Last previous edition D 1635 – 87.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

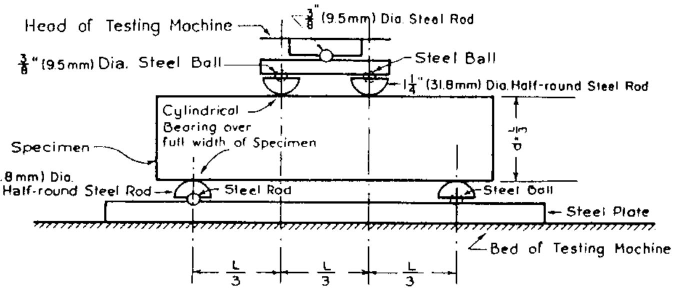

FIG. 1 Diagrammatic View of Apparatus for Flexure Test of Soil-Cement by Third-Point Loading Method

machines adjust the loading to such a constant rate that the extreme fiber stress is within the limits of 100 ± 5 psi (690 ± 35 kPa)/min. Record the total load of failure of the specimen to the nearest 10 lbf (45 N).

7. Measurement of Specimens After Test

7.1 Make measurements to the nearest 0.01 in. (0.25 mm) to determine the average width and depth of the specimens at the section of failure.

8. Calculations

8.1 If the fracture occurs within the middle third of the span length, calculate the modulus of rupture as follows:

$$R = Pl/bd^2$$

where:

R = modulus of rupture, psi (kPa),
P = maximum applied load, lbf (N),
l = span length, in. (mm),
b = average width of specimen, in. (mm), and
d = average depth of specimen, in. (mm).

NOTE 3—Mass of the beam is not included in the above calculation.

8.2 If the fracture occurs outside the middle third of the span length by not more than 5 % of the span length, calculate the modulus of rupture as follows:

$$R = 3Pa/bd^2$$

where:

a = distance between line of fracture and the nearest support, measured along the center line of the bottom surface of the beam.

8.3 If the fracture occurs outside the middle third of the span by more than 5 % of the span length, discard the results of the test.

9. Report

9.1 The report shall include the following:

9.1.1 Specimen identification number,

9.1.2 Average width and depth at section of failure to the nearest 0.01 in. (0.25 mm),

9.1.3 Maximum load, to the nearest 10 lbf (40 N),

9.1.4 Modulus of rupture, calculated to the nearest 5 psi (35 kPa),

9.1.5 Defects, if any, in specimen,

9.1.6 Age of specimen, and

9.1.7 Details of curing and conditioning periods, and water content at time of test.

10. Precision and Bias

10.1 *Precision*—The precision of this test method has not been established by an interlaboratory test program. However, based on test data that are available, the following may serve as a guide to the variability of flexural strength test results.

10.1.1 Tests were performed in a single lab on a silt loam soil with 92 % passing the No. 200 sieve. Liquid limit and plasticity index of soil were 26 and 7, respectively. The series of tests consisted of 24 specimens, 12 at 6 % cement, 12 at 14 % cement. The specimens were cured in a moist room at 73° F (23°C) for 28 days. Results[4] of the tests are given in Table 1.

TABLE 1 Precision

	Average flexural strength, psi	Standard deviation, psi	Coefficient of variation, %
Specimens with 6 % cement	94	6	6.4
Specimens with 14 % cement	157	9	5.7

10.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

11. Keywords

11.1 flexural strength; soil-cement; soil stabilization

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[4] Felt, E. J., Abrams, M. S., *Strength and Elastic Properties of Compacted Soil-Cement Mixtures*, *ASTM STP 206*, ASTM, 1957.

Designation: D 4609 – 94

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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If not listed in the current combined index, will appear in the next edition.

Standard Guide for Evaluating Effectiveness of Chemicals for Soil Stabilization[1]

This standard is issued under the fixed designation D 4609; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide describes laboratory techniques for evaluating the effectiveness of chemicals for improving the engineering properties of fine-grained soils.

1.2 Effectiveness is assessed by comparing the unconfined compressive strength (UCS), moisture susceptibility, and moisture-density relationships (MD) of treated and untreated soils.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 421 Practice for Dry Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants[2]

D 422 Method for Particle-Size Analysis of Soils[2]

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[2]

D 2166 Test Method for Unconfined Compressive Strength of Cohesive Soil[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]

D 2217 Practice for Wet Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants[2]

D 3877 Test Methods for One-Dimensional Expansion, Shrinkage, and Uplift Pressure of Soil-Lime Mixtures[2]

D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils[2]

2.2 *AASHTO Documents:*

SPEL Special Products Evaluation List[3]

T 88 Particle Size Analysis of Soils[3]

T 89 Determining the Liquid Limit of Soils[3]

T 90 Determining the Plastic Limit and Plasticity Index of Soils[3]

T 99 Moisture-Density Relations of Soils, Using a 5.5-lb (2.5-kg) Rammer and a 12-in. (305-mm) Drop[3]

T 208 Unconfined Compressive Strength of Cohesive Soil[3]

T 265 Laboratory Determination of Moisture Content of Soils[3]

3. Summary of Guide

3.1 Chemical soil stabilizers are screened by comparing the results of a suite of engineering soil tests conducted on untreated soil and the same soil treated at appropriate amounts of the material being evaluated. Effectiveness is assessed by comparing the Atterberg limits, MD, USC, and resistance to moisture of treated and untreated soil samples.

4. Significance and Use

4.1 This guide is intended to assist users and producers of chemicals, soil modifiers, and stabilizers in the evaluation of a product's potential for improving a soil's engineering properties (such as, deformation under load, shear strength, and volume stability).

4.2 The results of these tests can be used to make a decision to continue experimentation to assess longevity, durability, and practical value, and establish appropriate rates of application for field trials.

5. Apparatus

5.1 *Harvard Miniature Compaction Apparatus,* or apparatus for preparing remolded specimens for UCS as described in Section 4 of Test Method D 2166. For instructions on calibration, see Annex A1.

6. Sampling and Test Specimens

6.1 Obtain a 150-kg (300-lb) supply or have easy access to four or five soil and soil-aggregate materials as reference materials for stabilizer evaluations. These samples should represent two or more fine-grained soils of different clay mineralogy that are widely distributed and would be likely candidates for stabilization. One or two of the samples could represent the minus No. 10 fraction of plentiful marginal aggregates in need of beneficiation.

6.2 Review literature and test results provided by the material manufacturer or supplier.

6.3 Consult publications such as Special Products Evaluation List (SPEL) or other product evaluation or qualified

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[1] This guide is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization with Admixtures.

Current edition approved Sept. 15, 1994. Published November 1994. Originally published as D 4609 – 86. Last previous edition D 4609 – 86.

[2] *Annual Book of ASTM Standards,* Vol 04.08.

[3] Available from American Association of State Highway and Transportation Officials, 444 N. Capitol St., NW, Suite 225, Washington, DC 20001.

*** A Summary of Changes section appears at the end of this guide.**

products lists maintained by state highway agencies.[4]

6.4 If background search demonstrates that the subject material has promise, proceed with testing program.

7. Procedure

7.1 Obtain 20-kg (45-lb) portions of two or more soil samples selected in 6.1 for an evaluation program. This quantity of soil will provide sufficient material for tests on the untreated soil and for soil-chemical mixtures at three rates of application: the amount recommended by the supplier, and amounts more and less than recommended.

NOTE 1—All the tests recommended in 7.2 do not need to be conducted at all four rates of application (raw soil or zero rate, recommended rate, a rate more than recommended, a rate less than recommended.)

NOTE 2—The 20-kg recommended sample size is from the following scenario:

Two compaction tests (untreated and optimum rate)	6 kg
Calibration of Harvard Apparatus	1 kg
Atterberg limits (untreated and of optimum rate)	1 kg
Expansion (untreated and optimum rates)	2 kg
Unconfined Compressive Strength (untreated and three rates of treatment)	4 kg
Reserve for rerun of any test	6 kg
	20 kg

7.2 Test each untreated soil by the several test methods listed in 7.2.1 through 7.2.6. Perform the same tests on soil-chemical mixtures. For each rate of additive, five batches of soil-chemical mixture are required. Prepare a batch by combining in a mechanical mixer carefully weighed portions of soil, additive, and water. Blend thoroughly (normally for about 5 min) to produce a high degree of homogeneity. Prepare each batch and test separately as follows:

7.2.1 *Moisture Content*—Method D 2216 or T 265.

7.2.2 *Particle-Size Analysis of Soils*—Method D 422 or T 88.

7.2.3 *Liquid Limit, Plastic Limit, and Plasticity Index*—Test Method D 4318 or T 89.

7.2.4 *Moisture-Density Relations*—Test Methods D 698 (Method A) or T 99 (Method A) (see Note 3).

7.2.5 *Volume Change*—Test Methods D 3877 (see Note 4).

7.2.6 *Unconfined Compressive Strength* (see Note 5)—Test Method D 2166 or T 208.

NOTE 3—The sample may be reused and water added for successive points on the moisture-density curve if the soil material is not fragile and will not reduce in particle size due to repeated compaction or is not a heavy-textured clay into which it is difficult to incorporate water.

NOTE 4—Although this test method is for soil-lime mixtures, other stabilizing admixtures may be used.

NOTE 5—Specimen preparation and determination of moisture absorption are described in Annex A2. The moisture absorption specimens are also used for determining unconfined compressive strength, which is determined in accordance with the methods indicated in 7.2.1 through 7.2.6.

7.3 On approximately 3 kg (7 lb), determine optimum moisture and maximum density in accordance with Test Methods D 698.

7.4 On approximately 1 kg (2.2 lb), as described in the calibration procedure given in Annex A1, determine with the Harvard apparatus the number of tamps and the spring pressure required to duplicate the standard density obtained by Test Methods D 698.

7.5 Prepare a 500-g (1-lb) batch at optimum moisture content. As soon as the mixing is completed, divide the mixture into three approximately equal portions. Perform liquid and plastic limit tests on one portion after air-drying overnight, on another after overnight storage at high-humidity, and on the other after 7 days of curing at high humidity.

7.6 On approximately 3600 g, determine expansion in accordance with Test Methods D 3877.

7.7 On approximately 1 kg (2.2 lb), with the Harvard apparatus, prepare six five-layer specimens (required for acceptable homogeneity) compacted to Test Methods D 698 density, and determine moisture absorption and unconfined compressive strength as described in Annex A2.

8. Interpretations of Results

8.1 The recommendations in 8.1.1 through 8.1.5 are provided to evaluate whether a chemical additive has improved the engineering properties of fine-grained soils. Changes in one or more, but not necessarily all, of the properties in 8.1.1 through 8.1.5 may be used to judge effectiveness. The results of these tests may or may not be useful for determining the cost-effectiveness or practical value of the chemical treatment; that decision will most probably need to be made after additional testing and data analysis.

8.1.1 *Particle-Size Analysis*—For chemical stabilizers whose mechanism is through cementing fine particles together, a shift in the particle-size distribution curve demonstrating a coarsening or granulation of the soil may be interpreted as an improvement in engineering properties. Particle-size analysis should be performed on the treated material after an appropriate curing period has elapsed.

NOTE 6—If mechanical pulverization using Practice D 421 is too severe for treated samples, Practice D 2217 may be used.

8.1.2 *Liquid and Plastic Limits and Plasticity Index*—Significant reduction of liquid limit and plasticity index is indicative of improvement. Rendering a soil, having a plasticity index, of lesser plasticity or nonplastic by chemical treatment is a significant improvement.

8.1.3 *Moisture-Density Relations*—Improving soil compactability, that is, reducing the optimum moisture content or increasing the maximum dry density, is often of engineering significance. Lowering the optimum moisture content would be considered beneficial because frequently water must be purchased, or in any event transported, and distributed on the soil, requiring the use of motor fuel and time.

8.1.3.1 An increase in maximum dry density would indicate that an increase in strength was afforded by chemical treatment or that a target density could be achieved with less compactive effort. The single-operator precision for Test Methods D 698 is 1.9 % for maximum density and 9.5 % for optimum moisture content; consequently, a change in optimum moisture content of greater than about 15 % from the optimum for the untreated soil and a change in maximum density of about 80 kg/m^3 (5 pcf) from the untreated may be interpreted as a result of chemical treatment because the observed changes are greater than the expected experimental error.

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[4] Illinois, Louisiana, and New Jersey are three states that publish such lists.

8.1.4 *Unconfined Compressive Strength (UCS) and Moisture Absorption*—Unconfined compressive strength criteria have been established for soil-stabilizer mixtures featuring lime, cement, and lime-flyash by various road building agencies.[5] However, these criteria are used primarily to ensure durable soil-stabilizer mixtures. For the purposes of this guide, it is suggested that an increase in UCS of 345 kPa (50 psi) or more due to chemical treatment be considered effective. Also, if specimens do not slake during immersion, the treatment may be effective; and if no significant strength is lost due to immersion, the treatment may be effective for waterproofing soils.

8.1.5 *Volume Change*—Distress to pavements and structures is prevalent in areas where subgrade soils undergo significant volume changes with changes in moisture regime; that is, shrink with decreases in moisture and swell with increases in moisture. If treatment by the chemical being evaluated achieves the desired control of volume changes, the material may be judged effective.

9. Keywords

9.1 chemical screening; Harvard apparatus; liquid limit; moisture content; moisture-density; particle size; plastic limit; plasticity index; soil stabilization; unconfined compressive strength; volume change

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[5] These criteria are summarized in FHWA-ID-80-2, "Soil Stabilization in Pavement Structures—A User's Manual," available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

ANNEXES

(Mandatory Information)

A1. CALIBRATION OF THE HARVARD MINIATURE COMPACTION APPARATUS

A1.1 In order to prepare moisture absorption and unconfined compressive strength test specimens having the required standard AASHTO T 99 density, it is first necessary to calibrate the Harvard apparatus to determine the correct number of tamps per layer and to regulate the tamper springs so that tamping pressures of 10 kg (20 lb), 15 kg (30 lb), 20 kg (40 lb) can be utilized. Normally, ten or more tamps per layer are required. The calibration is illustrated in Fig. A1.1, which presents moisture-density curves for an experimental soil. The two curves for the Harvard method involve two different combinations of tamper spring loadings and numbers of tamps per layer.

A1.2 For the calibration, prepare a soil-water mixture from approximately 1000 g of soil and the amount of water required for the AASHTO T 99 optimum moisture content. Place this mixture in a suitable container to prevent moisture loss, and remove an individual portion of about 150 g (0.3 lb) for the first compaction trial. From this portion, compact a five-layer specimen by the procedure given in A2.2.1 through A2.2.8, using an arbitrary combination of number of tamps and tamper spring pressure. Remove the specimen from the mold with the ejector, slice into three or more portions, and determine the actual moisture content by Test Method D 2216.

A1.2.1 Knowing the volume, the wet weight, and the moisture content of the compacted specimen, compute the dry density and compare with that from the AASHTO T 99 procedure. Using a second portion of the moist mixture, prepare a new specimen at another combination of number of tamps and tamping pressure, and repeat this process with additional portions until a density is obtained that is within 16 kg/m^3(1 pcf) of the AASHTO T 99 density. This combination is then used in the preparation of test specimens, Annex A2.

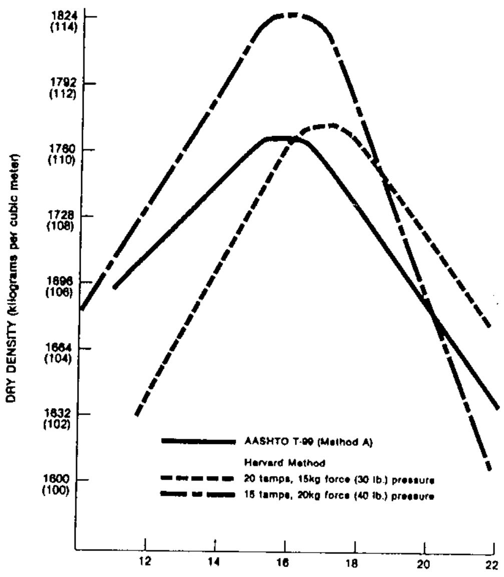

FIG. A1.1 Comparison of Compaction Methods

A2. SPECIMEN PREPARATION AND TEST PROCEDURE FOR MOISTURE ABSORPTION AND UNCONFINED COMPRESSIVE STRENGTH

A2.1 Preparation of specimens for the determinations of moisture absorption and unconfined compressive strength requires about 1000 g of soil-water or soil-additive-water mixture. In preparing this mixture in a mechanical mixer, the amount of water used should be from 0.5 to 3.0 % in excess of that required for the optimum moisture content, to compensate for evaporation losses. The exact amount of excess water will depend on the humidity and other laboratory conditions.

A2.2 Using this mixture and employing the combination of number of tamps and tamping spring pressure as determined in the calibration procedure, prepare six test specimens as follows:[6]

A2.2.1 With the mold and collar clamped to the base, place the amount of loose soil required for one layer in the mold. For a five-layer specimen, two slightly heaping teaspoonfuls will be required for each layer. Level the surface of the loose soil by pressing lightly with a wood plunger.

A2.2.2 Insert the tamper in the mold until it is in contact with the surface of the soil, and press down firmly until the spring starts to compress. Release the force and shift the tamper to a new position. Apply each of the first four tamps in separate quadrants of the soil surface, and adjacent to the mold. The fifth tamp should be in the center, making one complete coverage. Repeat this tamping cycle until the desired number of tamps has been applied. Apply the tamps at the approximate rate of 10 tamps per 15 s.

A2.2.3 Add and tamp the next layer, and repeat the procedure until the required number of compacted layers has been placed. The top layer should extend at least 6 mm (1/4 in.), but not more than 16 mm (5/8 in.) into the extension collar.

A2.2.4 Transfer the mold assembly to the collar remover and release the clamps. Press down firmly on the piston and at the same time pull up on the handle, prying the collar loose from the compacted soil.

A2.2.5 Remove the mold from the base and carefully trim away the excess soil from the top and bottom of the mold.

A2.2.6 Weigh the mold containing the compacted soil to the nearest 0.1 g. If inch-pound units for density are needed, it is convenient to use a tare weight equal to the weight of the empty mold, as then the resulting net weight in grams is numerically equal to the wet density of the compacted soil, in pounds per cubic foot.

A2.2.7 Remove the specimen from the mold with the ejector, weigh, wrap in plastic food-wrapping material, and place in a high-humidity chamber at room temperature (73 ± 2.0°F (23.0 ± 1.1°C)) for the desired curing period.

NOTE A2.1—Other curing conditions may be used that simulate the environment under which the treated mixture will be cured in the field or field achievable conditions, such as partial air-drying which may be required to make the chemical effective. Curing methods or conditions should be reported along with other test results.

A2.2.8 Between the compaction of the third and fourth specimens, take a 100-g (0.2-lb) sample from the remaining loose mixture and determine the actual moisture content by Test Method D 2216.

A2.2.9 At the completion of the curing period, remove the wrapping material from three of the specimens, weigh the specimens, immerse in water for 2 days, remove from the water, surface-dry by blotting with a towel, and reweigh. Any gain in weight due to immersion represents the moisture absorption; calculate and record for each specimen as a percentage of the dry weight of the specimen. If appreciable disintegration or slaking of an immersed cylinder occurs, accurate determination of absorbed moisture is not possible and the record should so indicate.

A2.2.10 After weighing as indicated above, test the three specimens for unconfined compressive strength in accordance with Test Method D 2166.

A2.2.11 After testing the three immersed specimens, remove the remaining three specimens from the curing chamber, unwrap, weigh, and test for unconfined compressive strength in accordance with Test Method D 2166.

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[6] With the exception of the height of the top soil layer that extends into the mold collar, A2.2.3, the first six steps of this procedure are taken from a suggested method of test in *Special Procedures for Testing Soil and Rock for Engineering Purposes, ASTM STP 479*, ASTM, 1970, pp. 101-103.

SUMMARY OF CHANGES

This section identifies the principle changes to this guide that have been incorporated since the last issue.

(1) Portion of title was changed from "Screening Chemicals" to "Evaluating Effectiveness of Chemicals".

(2) Keywords section was added.

Designation: D 4832 – 95$^{\epsilon1}$

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Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders[1]

This standard is issued under the fixed designation D 4832; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

$^{\epsilon1}$ NOTE—Editorial changes were made in January 1997.

1. Scope*

1.1 This test method covers procedures for the preparation, curing, transporting and testing of cylindrical test specimens of controlled low strength material (CLSM) for the determination of compressive strength.

1.2 This test method also may be used to prepare and test specimens of other mixtures of soil and cementitious materials, such as self-cementing fly ashes.

1.3 CLSM is also known as flowable fill, controlled density fill, soil-cement slurry, soil-cement grout, unshrinkable fill, K-Krete, and other similar names.

1.4 The values stated in SI units are to be regarded as the standard. The inch-pound equivalents are shown for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* See Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*

C 31 Method of Making and Curing Concrete Test Specimens in the Field[2]
C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]
C 172 Method of Sampling Freshly Mixed Concrete[2]
C 192 Method of Making and Curing Concrete Test Specimens in the Laboratory[2]
C 470 Specification for Molds for Forming Concrete Test Cylinders Vertically[2]
C 617 Practice for Capping Cylindrical Concrete Specimens[2]
C 1231 Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[3]
PS 28 Test Method for Flow Consistency of Controllec Low Strength Material (CLSM)[4]
PS 29 Test Method for Unit Weight, Yield, and Ai Content (Gravimetric) of Controlled Low Strength Material (CLSM)[4]
PS 30 Practice for Sampling Freshly Mixed Controllec Low Strength Material (CLSM)[4]
PS 31 Test Method for the Ball Drop on Controlled Lov Strength Material (CLSM) to Determine Suitability fo Load Application[4]

3. Terminology

3.1 *Definitions*—Except as follows in 3.2, all definition are in accordance with Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Controlled Low Strength Material (CLSM)*—A mixture of soil, cementitious materials, water, and sometime admixtures, that hardens into a material with a highe strength than the soil but less than 8400 kPa (1200 psi). Use as a replacement for compacted backfill, CLSM can b replaced as a slurry, a mortar, or a compacted material an typically has strengths of 350 to 700 kPa (50 to 100 psi) fo most applications.

4. Summary of Test Method

4.1 Cylinders of CLSM are tested to determine th compressive strength of the material. The cylinders ar prepared by pouring a representative sample into mold curing the cylinders, removing the cylinders from the mold and capping the cylinders for compression testing. Th cylinders are then tested to obtain compressive strength Duplicate cylinders are required.

5. Significance and Use

5.1 This test method is used to prepare and test cylindric specimens of CLSM to determine the compressive strengt of the hardened material.

5.2 CLSM is typically used as a backfill material aroun structures, particularly in confined or limited spaces. Con

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization with Admixtures.

Current edition approved Dec. 10, 1995. Published May 1996. Originally published as D 4832 – 88. Last previous edition D 4832 – 88.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vol 04.09.

* A Summary of Changes section appears at the end of this Test Method.

Norma 25 ASTM D 4832-95 PREPARACIÓN PROBETAS BAJAS RESISTENCIAS pressive strength testing is performed to assist in the design of the mix and to serve as a control technique during construction. Mix design is typically based on 28 day strengths and construction control tests performed 7 days after placement. The compressive strength(s) and other test age(s) will vary according to the requirements for the end product. Additional information on the use and history of CLSM is contained in Appendix X1.

5.3 This test is one of a series of quality control tests that can be performed on CLSM during construction to monitor compliance with specification requirements. The other tests that can be used during construction control of CLSM are Test Methods PS 28, PS 29, PS 30, and PS 31.

5.4 There are many other combinations of soil, cement, flyash (cementitious or not), admixtures or other materials that could be tested using this method. The mixtures would vary depending on the intended use, availability of materials, and placement requirements.

6. Apparatus

6.1 *Single-Use Cylindrical Molds*—Plastic single-use 15 cm (6-in.) diameter by 30 cm (12-in.) high molds with tight fitting lids, conforming to Specification C 470. Other sizes and types of molds may be used as long as the length to diameter ratio is 2 to 1. The 15 cm by 30 cm (6 in. by 12 in.) molds are preferred because of the low strength of the material and the larger surface area of the ends of the cylinders.

6.2 *Sampling and Mixing Receptacle*—The receptacle shall be a suitable heavy-gage container, wheelbarrow, etc. of sufficient capacity to allow easy sampling and mixing and to allow preparation of at least two cylinders and for other tests such as described in Test Methods PS 28, PS 29, PS 30, and PS 31.

6.3 *Storage Container*—A tightly constructed, insulated, firmly braced wooden box with a cover or other suitable container for storage of the CLSM cylinders at the construction site. The container shall be equipped, as necessary, to maintain the temperature immediately adjacent to the cylinders in the range of 16 to 27°C (60 to 80°F). The container should be marked for identification and should be a bright color to avoid disturbance.

6.4 *Transportation Container*—A sturdy wooden box or other suitable container constructed to minimize shock, vibration, or damage to the CLSM cylinders when transported to the laboratory.

6.5 *Testing Machine*—The testing machine shall meet the requirements as described in Test Method C 39.

NOTE 1—Since the compressive strength of CLSM cylinders will typically be 100 kPa (about 15 to 1200 lbf/in.^{2}), the testing machine must have a loading range such that valid values of compressive strength can be obtained.

6.6 *Curing Environment*—A curing environment (water bath, damp sand, fog room) that meets the requirements of Method C 192. The cylinders may be cured in the same curing environment used for concrete cylinders at the laboratory performing the testing.

6.7 *Small Tools*—Tools and items that may be required such as shovels, pails, trowels, and scoops.

7. Hazards

7.1 *Technical Precaution*—The procedure for the preparation of CLSM test cylinders has many similarities to preparing concrete test cylinders (Method C 31 and Method C 192). However, the cylinders are much more fragile than concrete cylinders, and special care should be taken in their preparation, storage, and handling.

7.2 *Safety Hazards:*

7.2.1 Strictly observe the safety precautions stated in Practice C 617.

7.2.2 If the cylinders are capped with molten sulfur mortar, wear proper personnel protective equipment, including gloves with cuffs at least 15 cm (6-in.) long.

8. Sampling and Test Specimens

8.1 Take samples of the CLSM for each test specimen in accordance with PS 30. Record the identity of the CLSM represented and the time of casting.

8.2 The sample from the batch should be a minimum of 0.03 m^3 (1 ft^3) for each two cylinders to be prepared. Prepare a minimum of two compressive strength cylinders for each test age to represent each sampled batch. Additional material may be required if other testing is to be performed, such as in Test Methods PS 28, PS 29, PS 30, and PS 31.

NOTE 2—In the initial stage of CLSM usage, preparation of three cylinders is recommended to obtain reliable compressive strength data for each test age. Subsequently, two cylinders may be used to maintain testing records and to ascertain an overall quality of the mix. However, since the cylinders are fragile and may be damaged during transportation, mold removal, and capping, preparation of an extra cylinder may be necessary to provide the minimum number of test specimens (see Notes 5 and 6). In addition, it may be useful to determine the density of the test cylinders to help evaluate the uniformity of the compressive strength values.

9. Specimen Molding and Curing

9.1 *Place of Molding*—Mold specimens promptly on a level, rigid, horizontal surface free from vibration and other disturbances. The specimens should be prepared at a place as near as practicable to the location where they are to be stored during the first four days.

9.2 *Placing the CLSM:*

9.2.1 Thoroughly mix the CLSM in the sampling and mixing receptacle.

9.2.2 With a bucket or pail, scoop through the center portion of the receptacle and pour the CLSM into the cylinder mold. Repeat until the mold is full. Place a lid on the mold.

NOTE 3—Use of an air-tight lid has been known to cause low strength materials to crack, possibly due to a creation of a vacuum inside the mold. If an air-tight lid is contemplated, its use should be evaluated before doing routine testing.

NOTE 4—Some mixtures will bleed rapidly, that is, free water will appear in the mixing receptacle and the mold. Obtaining the material to fill the cylinder must be done quickly after mixing. A few minutes after filling the mold, thoroughly mix the CLSM in the sampling and mixing receptacle and place a scoopful in the top of the mold, displacing the water. If possible, a slight mound of material should be left on the top of the mold. This refilling may be required again after about 15 min. Leave the mound on the top of the mold and cover.

9.3 *Curing:*

9.3.1 Store the cylinders at the construction site in the storage container until the fourth day after preparation.

9.3.2 The cylinders shall be stored under conditions that maintain the temperature immediately adjacent to the cylinders in the range of 16 to 27°C (60 to 80°F). The cylinders must always be protected from freezing. After the first day, provide a high humidity environment by surrounding the cylinders with wet burlap or other highly adsorbent material.

9.3.3 On the fourth day, carefully transport the cylinders to the site of the curing environment in the transportation container and place in a curing environment (see 6.6).

9.3.4 The cylinders are typically left at the contruction site for four days and then transported to a curing environment. If extremely low strength CLSM (below 350 kPa) would be damaged by moving on the fourth day, then the cylinders are to be placed in a water storage tank with a temperature between 16° and 27°C (60° and 80°F) at the construction site until they are able to be moved without damage.

10. Capping the Cylinders

10.1 On the day of testing, carefully remove the molds from the cylinders and allow the cylinders to air-dry for 4 to 8 h before capping. If the upper surface of the cylinder is not a horizontal plane, use a wire brush to flatten the surface. Brush off all loose particles. Provide a cap for the cylinders using one the following methods:

10.1.1 Cap the cylinders using sulfur mortar in accordance with Practice C 617.

10.1.2 Cap the cylinder using gypsum plaster in accordance with Practice C 617.

10.1.3 Use elastomeric pads in accordance with Practice C 1231. The results of the qualification tests in Practice C 1231 for acceptance of the caps must not indicate a reduction of strength of more than 20 %, rather than 2 % as stated in Practice C 1231. The larger difference is acceptable because of the less critical uses of CLSM and 20 % is estimated to be the inherent variation in compressive strength results because of the lower strength values, for example 350 kPa (50 psi).

10.2 Use the same capping method throughout each project to avoid any variation in the test results from using different capping systems.

NOTE 5—CLSM cylinders are more fragile than concrete cylinders and must be handled carefully during the mold removal and during capping.

NOTE 6—If sulfur mortar is used as the capping compound, oil is placed on the capping plate to ensure release of the capping material from the capping plate. More oil may be required on the capping plate when capping CLSM cylinders than is normally used when capping concrete cylinders. Capped CLSM cylinders will normally contain more air voids between the cap and the cylinder than capped concrete cylinders, and this should be considered if the caps are tapped to check for voids.

11. Compressive Strength Testing

11.1 *Placing the Specimen*—Place the lower bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen, and place the test specimen on the lower bearing block. Carefully align the axis of the specimen with the center of thrust of the spherically seated block. As the spherically seated block is brought to bear on the top of the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

11.2 *Rate of Loading*—Apply the load continuously and without shock. Apply the load at a constant rate such that the cylinder will fail in not less than 2 min. Make no adjustment in the controls of the testing machine while a specimen is yielding rapidly immediately before failure.

11.3 Apply the load until the specimen fails, and record the maximum load carried by the specimen during the test. For about one out of every ten cylinders, continue the loading until the cylinder breaks enough to examine the appearance of the interior of the specimen. Note any apparent segregation, lenses, pockets, and the like in the specimen.

12. Calculation

12.1 Calculate and record the compressive strength of the specimen as follows:

$$C = \frac{L}{\pi(D^2)/4}$$

where:

C = compressive strength, kPa (lbf/in.^{2}),

D = nominal diameter of cylinder (normally 15 cm or 6 in.), and

L = maximum load, kN (lbf).

13. Report

13.1 The report shall include the following:

13.1.1 Identification, for example, mix, cylinder number, location, etc.

13.1.2 Diameter and length, cm (in.).

13.1.3 Cross-sectional area, cm^2 (in.^{2}).

13.1.4 Maximum load, kN (lbf).

13.1.5 Compressive strength, kPa (lbf/in.^{2}).

13.1.6 Age of specimen.

13.1.7 Appropriate remarks as to type of failure, defects noted, or nonuniformity of material.

14. Precision and Bias

14.1 The precision and bias of this test method have not yet been determined. Data are being sought that will be suitable for use in developing precision and bias statements.

15. Keywords

15.1 backfill; CLSM; compressive strength; construction control; mix design; quality control; soil stabilization

APPENDIX

(Nonmandatory Information)

X1. HISTORY

X1.1 This standard was developed to provide an accepted, consensus method of preparing and testing CLSM cylinders. Because the cylinders are more fragile than normal concrete cylinders, the standard provides a workable method of preparation and testing based on much trial and error.

X1.2 CLSM is a combination of soil, portland cement, sometimes admixtures, and enough water so that the mixture has the consistency of a thick liquid. In this form, the CLSM flows readily into openings, filling voids, and provides a hardened material that has a strength greater than the untreated soil used in the mix. Some cementitious fly ashes have been successfully used in place of the cement.

X1.3 Although the primary use to date of CLSM or other similar materials has been as embedment for pipelines, it also has been used as trench backfill and structure backfill.[5,6]

X1.4 Typically, CLSM contains about 5 to 10 % cement. One of the definite advantages is that CLSM may be produced using local soils. As opposed to a lean concrete slurry, the soil for the CLSM can contain up to about 20 to 25 % nonplastic or slightly plastic fines. Although clean concrete sands have been used, the presence of fines can help keep the sand-sized particles in suspension. This allows the mixture to flow easier and helps prevent segregation. Soils that are basically sand sizes work best with the maximum particle compatible with the space to be filled. Central batch plants with the slurry delivered in ready-mix trucks and trench-side, trail-along portable batch plants have been used, with the latter normally used when the soil comes from the trench excavation.

X1.5 *Testing Techniques:*

X1.5.1 The 15 by 30 cm plastic cylinders (see 6.1) are suggested as a matter of economics; that size is not necessary based on the particle sizes normally used in CSLM. A minimum test age of 7 days is recommended for construction control testing because the cylinders may not be intact enough for transporting and testing in 3 days. In addition, the testing that has been done for 3-day strength has resulted in extremely erratic values.

X1.5.2 The mounding of the material in the cylinders was found to be necessary for mixtures that did not contain many fines; the water bled so quickly that a space was left on top of the cylinders and the hardened cylinders were not of a uniform height.

X1.5.3 At the moisture content required for the mixture to have the necessary flow properties, consolidation of the CSLM in the cylinder mold by vibration is not necessary.

X1.6 *Typical Use:*

X1.6.1 The use of CLSM as pipe embedment illustrates the relationship between the testing requirements and a typical application. For pipe installations, CLSM is used to fill the gap between the pipe and the excavated trench. The CLSM transfers the load from the pipe to the in situ material, so the native soil must be able to provide the necessary support for the pipe. The circular trench bottom shape is advantageous because it reduces excavation quantities and thus reduces handling of the soil materials. The CLSM eliminates the problem of trying to shape a cradle in the trench bottom to fit the pipe. A cradle is labor intensive and may not result in full contact between the pipe and the soil. The CLSM does ensure uniform support for the pipe. Placement of the CLSM is much faster than compacting the soil in layers alongside the pipe, and potential damage to the pipe from the compacting equipment is eliminated. It is also quicker than flooding and jetting or the saturation and vibration methods of compacting granular bedding materials. This faster installation is a distinct advantage where the construction is in populated areas or through streets.

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[5] Lowitz, C. A., and DeGroot, G., "Soil-Cement Pipe Bedding, Canadian River Aqueduct," *Journal of the Construction Division*, ASCE, Vol 94, No. CO1, 1968.

[6] "Cement-Treated Pipeline Bedding," Portland Cement Association Publication No. PA001I.01.

SUMMARY OF CHANGES

This section identifies the location of changes to this test method since the last edition.

(1) The term "soil-cement slurry" was changed to "Controlled Low-Strength Material (CLSM)" and the definition modified.

(2) Capping methods expanded to include gypsum mortar and elastomeric pads.

(3) Reference made to other test methods for CLSM and procedure modified to include necessary interaction with the other standards.

(4) SI units made the standard.

(5) Additional section on keywords added.

3. PULVERIZACION

Los nódulos arcillosos son puntos débiles dentro de los elementos fabricados con suelo cemento. Los grumos de arcilla que no pasan por la malla de 5 mm disminuyen el contenido de arcilla y por ende modifican la dosificación realizada en el laboratorio.

Tanto los grumos como nódulos de arcilla no se pueden mezclar con cemento por lo que se hace imprescindible controlar la pulverización previo al tamizado del suelo.

Para facilitar el proceso de pulverización el suelo debe estar cercano a su humedad higroscópica (secado al aire).

4. CONTENIDO DE CEMENTO

Existen dos formas cuantitativas para añadir el cemento al suelo, por peso o por volumen.

Dependiendo del tipo de obra a construir (edificación, vial, hidrotécnica) magnitud de la obra y volumen total de mezcla a producir se determinará la forma de adición de cemento en la mezcla.

El control por peso dependerá de la tecnología de la planta que se emplea. Para estos casos se aplicará lo establecido para el control de calidad de plantas de hormigón premezclado.

Cuando el cemento se añade por una medida volumétrica se pierde precisión y tienen que aumentar las medidas de control.

El envase debe estar aforado y sólo se deberá emplear para añadir el cemento. El suelo será medido con un recipiente que tenga iguales características geométricas al empleado para medir el cemento.

5. CONTENIDO DE HUMEDAD

Un contenido de humedad correcto resulta necesario para una adecuada compactación y para la hidratación del cemento. Este contenido de humedad corresponde a la humedad óptima del ensayo Proctor Estandar.

El suelo secado al aire tendrá como mínimo su humedad higroscópica, la cual se deberá restar a la óptima para determinar el contenido de agua a añadir a la mezcla. Sin una medición periódica y con los medios de laboratorio es prácticamente imposible conocer la humedad que tiene el suelo en el momento en que se procede a realizar la mezcla. Un estimado del contenido de humedad de una mezcla de suelo-cemento puede realizarse por un método tacto-visual.

Una mezcla con la humedad óptima o cercana a ella se puede determinar si al apretar fuertemente una muestra de la misma con la mano, sólo se humedece la mano y la huella de los dedos queda impresa en la muestra. Mezclas con contenido de humedad superior a la óptima presentarán escurrimientos de agua por entre los dedos. Mezclas con humedades por debajo de la óptima tendrán a fraccionarse. Si la humedad está cercana al contenido óptimo, una muestra de la mezcla hecha una pelota puede partirse en dos partes aproximadamente iguales con las manos, sin que se produzca el fraccionamiento en múltiples partes.

El procedimiento anterior permite el control práctico del contenido de humedad de la mezcla con resultados aceptables para la mayoría de los suelos.

6. MEZCLADO

Con el mezclado se busca una homogeneidad de distribución de los tres componentes de las mezclas de suelo-cemento. Otro aspecto de gran importancia es el tiempo de uso del suelo-cemento después de concluido el mezclado.

Al mezclarse el suelo con el cemento la homogeneidad se obtiene por una uniformidad en la coloración de la mezcla, lo mismo ocurre al añadir el agua.

Mezclas de suelo-cemento y agua deben ser utilizadas en un período no mayor a 30 minutos para evitar caídas de resistencia.

7. COMPACTACION

El factor independiente más importante para garantizar la resistencia y durabilidad del suelo-cemento es la compactación.

Según el elemento a fabricar puede variar el método de compactación. En edificaciones se tiene la fabricación de bloques, ladrillos, bovedillas, etc., que se fabrican en prensas manuales, hidráulicas o hidráulicas-vibratorias.

Los cimientos y paredes construidas en el lugar emplean una energía dinámica en base a golpes de un pisón o "chip hammer".

Las obras viales e hidrotécnicas emplean los métodos convencionales de compactación de terraplenes.

Todos los métodos anteriores se comparan con la energía dinámica del Proctor Estandar en el laboratorio, empleada para la dosificación de las mezclas. La práctica ha demostrado que esto es correcto, pero no existe procedimiento analítico para compatibilizar una con las otras.

Directamente relacionado con la energía de compactación están el contenido de cemento, el contenido de humedad y la relación de vacíos y densidad del suelo-cemento compactado. A mayor y más efectiva energía de compactación, menor será el contenido de cemento y agua requerida en la mezcla y mayor será la densidad con una relación de vacíos más baja.

Por tales motivos en muchos casos, se requiere un ajuste de la dosificación al pasar los resultados del laboratorio a la obra. Este proceso de ajuste se realiza por un personal calificado (geotécnico) y no forma parte de esta IT el describirlo.

En la producción de elementos compactados en máquinas se controlará mediante un muestreo representativo, que el producto satisface las características de resistencia y absorción establecidas para ellos. Por ejemplo, para ladrillos macizos según la IT-07-91, para bloques huecos la IT-08-91, y así para cada tipo de producto o elemento.

Cuando el proyecto especifique parámetros superiores a los MINIMOS establecidos por esas IT, serán ellos los objetos del control.

8. DIMENSIONES GEOMETRICAS

Todos los elementos de la construcción tienen una geometría fijada por el diseño y determinada por la tecnología de fabricación empleada. El control de estas medidas y de la forma es una garantía de la fidelidad de lo construido respecto a lo especificado en el proyecto.

9. CURADO Y ALMACENAMIENTO

Con la sola excepción de los cimientos, todos los elementos fabricados de suelo-cemento requieren de un período de curado no menor a los 7 días.

El curado se efectúa mediante el humedecimiento de los elementos 3 ó 4 veces durante el día. En el caso de elementos como ladrillos, bloques, etc., el curado se realizará en un área techada donde no exista la posibilidad de que reciban directamente los rayos solares.

Pasado el curado los elementos se almacenan al aire libre en pilas hasta 1,5 m de altura. La primera hilera debe estar a una cierta altura del terreno natural tal que no tenga posibilidades de quedar sumergida por las aguas de lluvia.

COMISION PARA EL DESARROLLO Y APLICACION DE SUELOS ESTABILIZADOS

CUBA		
INV - MICONS MINAZ - MINAGRI CECAT - IPF	CIMENTACIONES DE SUELO CEMENTO PARA EDIFICACIONES	INSTRUCCION TECNICA IT-12-91 AGOSTO 1991

1. INTRODUCCION

La presente IT contiene las soluciones de cimentación construidas con suelo-cemento para edificaciones de vivienda, obras sociales, agropecuarias y otras obras con un máximo de dos pisos de altura.

2. GENERALIDADES

2.1 La solución de cimentaciones será por medio de cimientos corrido longitudinales y transversales.

La profundidad mínima en suelo será de 700 mm.

3. TIPOS DE CIMIENTOS CORRIDOS

I. Monolíticos de mezclas de SC (suelo cemento)
II. Hormigón ciclópeo de SC
III. Bloques de SC
IV. Ladrillos de SC

3.1 Los cimientos tipo I se construirán con mezclas ordinarias de SC dosificado en el laboratorio según la IT-06-91. El área de la base de la cimentación será determinado según el ANEXO I de la presente IT.

3.1.1 La sección de cimiento será de forma rectangular donde el fondo y las paredes de la excavación servirán de encofrado.

3.1.2 La mezcla de SC se colocará en capas, con un espesor del material suelto de 150 mm.

3.1.3 La compactación de cada capa se realizará con pisón manual. Se considerará la capa compactada cuando los golpes del pisón no dejen huellas en la misma. El pisón podrá ser de madera dura o metálico, con base del orden de 130 cm2 de superficie y un peso del orden de 8 a 10 kg. La altura de caída será de 30 cm aproximadamente.

3.1.4 Antes de colocar una capa suelta sobre otra compactada es necesario escarificar la capa compactada con un elemento adecuado, por ejemplo con una barra de acero No. 10 (3/8") de punta afilada.

3.1.5 Los puntos 3.1.2 al 3.1.4 se repiten hasta alcanzar el nivel del terreno natural.

3.2 Los cimientos del tipo II de ciclópeo de suelo cemento se construirán con suelo cemento plástico y fragmentos de roca con diámetro equivalente no mayor a los 120 mm. El área de la base del cimiento se determina según las indicaciones del Anexo I.

3.2.1 Idem al punto 3.1.1.

3.2.2 Después de concluída y nivelada la excavación se coloca una capa de suelo-cemento plástico con un espesor promedio de 100 mm.

3.2.3 En la capa anterior se le incrustan los fragmentos de roca de forma tal que ocupen la mayor superficie posible sin solape ni sobreposición. La incrustación se realizará mediante el apisonado, según 3.1.3.

3.2.4 Se coloca otra capa de SC plástico y se incrusta otra capa de rocas según el punto anterior. El suelo cemento plástico se obtiene incrementando en un 4% el cemento determinado para mezclas normales en el laboratorio y la cantidad de agua necesaria para obtener una consistencia equivalente a un mortero de albañilería.

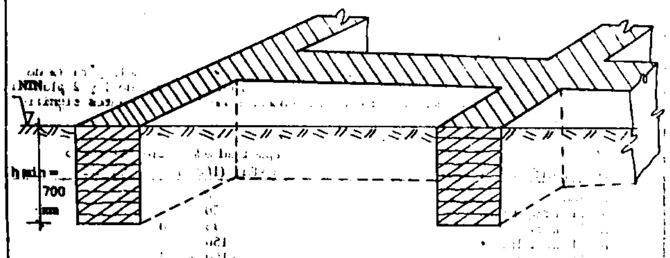

Fig. 1 Cimentación Tipo I de SC Monolítico.

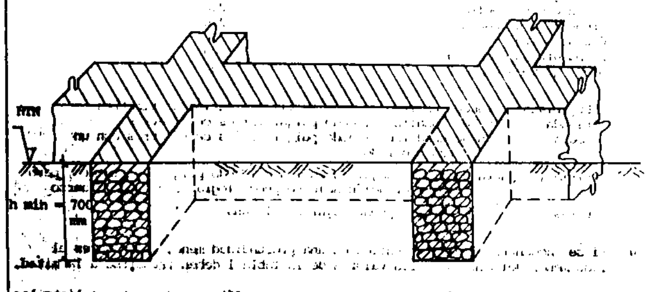

Fig. 2 Cimentación Tipo II de Hormigón Ciclópeo de SC.

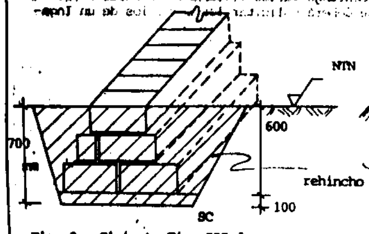

Fig. 3 Cimiento Tipo III de Bloques de SC

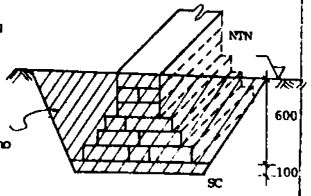

Fig. 4 Cimiento Tipo IV Ladrillos de SC

3.2.5 La última capa tendrá la altura definida en el proyecto y será construida con suelo cemento normal según la IT-06-91, el cual debe ser apisonado y escarificado según los puntos 3.13 y 3.1.4.

3.3 . Los cimientos tipos III y IV de bloques o ladrillos de suelo cemento se ejecutarán en una excavación rectangular.

3.3.1 El área de la base de la cimentación se establecerá de acuerdo al Anexo I.

3.3.2 Los ladrillos o bloques a emplear tendrán las mismas especificaciones dadas en la IT-07, 08 y 09-91.

3.3.3 El mortero a emplear será de cemento portland con una dosificación igual a la empleada para construir los muros.

3.3.4 El cimiento tendrá una forma trapezoidal con ángulos próximos a los 60°. Ver fig. 3 y 4.

3.3.5 El área libre entre el cimiento y la excavación será rellenada con suelo de la obra (no usar capa vegetal) en capas sueltas de 200 mm y compactadas con pisón.

3.3.6 La compactación del relleno sólo se debe realizar después de 3 días de construido el cimiento, como mínimo.

4. Debe haber una continuidad monolítica en los cimientos longitudinales y transversales. Esto debe estar contemplado en el proyecto según la planta de la vivienda.

5. OBSERVACIONES

Esta IT puede ser reproducida por los organismos e instituciones para su divulgación y aplicación con la condición de mantener rigurosamente su forma y contenido. Se incluirá solamente quién hace la reproducción, lo que escribirá al final del texto diciendo:

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Ing. Nelson Navarro Campos, CDr. Instituto Nacional de la Vivienda Ayestarán 621 esq. Piñera Cerro Ciudad Habana	o	Ing. José A. Ribas Hermelo ENIA Calle 100 No. 9107 Altahabana Ciudad Habana

---

ANEXO 1

DETERMINACION DEL AREA DE LA BASE DE CIMENTACION

1.0 Se presentan las capacidades de carga admisible por tipo de suelo para la determinación del área de la base de los cimientos en viviendas de 1 y 2 plantas y otras estructuras similares que no introducen momentos y cortantes significativos.

TABLA 1

Descripción del suelo	Capacidad admisible del suelo en kPa. (100 kPa = 1 kg/cm2)
Rellenos sueltos y cieno	0
Arcilla muy blanda	50
Arcillas media a blanda	75 - 150
Arcillas media	150
Arcillas media a firmes	150 - 250
Arcillas firmes	250
Arcillas duras	300 - 400
Arena fina suelta	100
Arena gravosa suelta	200
Arena gruesa suelta	200
Arena fina compacta	250
Grava suelta	200
Arena gruesa compacta	300
Arena gravosa compacta	600

Muy blanda - puede hundirse el puño fácilmente varios centímetros
Blanda - - puede hundirse el dedo pulgar varios centímetros
Media - puede hundirse el dedo pulgar varios centímetros con un esfuerzo moderado

Firme (compacta) - permite dejar la huella del dedo pulgar fácilmente, pero la penetración sólo se puede lograr con gran esfuerzo

Duras - sólo se puede rayar con la uña

2.0 Si se encuentra el nivel freático en una profundidad menor a 1,5 veces el lado menor del cimiento, los valores de la Tabla 1 deben reducirse a la mitad.

3.0 Las excavaciones no deben permanecer abiertas. Sólo cuando se tenga listo los materiales de construcción necesarios se debe proceder a la excavación, nivelación del fondo y a la ejecución inmediata de los cimientos.

4.0 Debe evitarse que una estructura se apoye en dos suelos de características muy diferentes.

5.0 Cuando el área de construcción contenga varias viviendas y/o otras obras de cierta magnitud e importancia se deberá solicitar los servicios de un Ingeniero Geotécnico calificado.

COMISION PARA EL DESARROLLO Y LA APLICACION DE SUELOS ESTABILIZADOS

CUBA INV - MICONS MINAZ - MINAGRI CECAT - IPP	CONSTRUCCION DE MUROS MAMPUESTOS DE SUELO CEMENTO	INSTRUCCION TECNICA IT-16-91 OCTUBRE 1991

1. INTRODUCCION

Esta IT establece las especificaciones de materiales, el proceso constructivo y el control de calidad para la ejecución de muros mediante piedras y suelo-cemento.

2. MATERIALES

2.1 Cemento.

Aunque resultan aptos todos los tipos de cemento que actualmente se producen en Cuba, se recomienda por razones económicas el tipo PP-250.

2.2 Piedra

Pueden ser de origen silicio o calcáreo con buena consistencia. La dimensión máxima no será superior a 2/3 del ancho del muro y la mínima será de 50 mm. Preferiblemente ha de poseer aristas vivas. Por razones económicas se obtendrán de los lugares más proximos posibles a la obra.

2.3 Suelo

Se atenderán las especificaciones y procedimientos establecidos en las IT 02 a la 04-91, según correspondan.

2.4 Mezclas de suelo-cemento

Se atenderá la IT-06-91.

3. MOLDES

Los moldes o cofres responderán a las dimensiones del muro establecidos en el proyecto.

Los tableros de los moldes pueden ser de madera, metálicos o mixtos. Se recomiendan dimensiones entre 3000 y 4500 mm de largo y altura de 400 a 800 mm.

Las guías podrán ser de madera, las que se irán retirando en la medida que se desarrolle el proceso constructivo. Si el muro es mixto, por incluir pilastras de bloques, ladrillos u hormigón por solución del proyecto, estos podrán ser usados como guías. Los elementos de guía serán también empleados como arriostres para los moldes.

Para mantener el ancho especificado del muro se deben usar tacos separadores, espaciados 1000 mm aproximadamente, de sección transversal de 100 x 100 mm, largo según el ancho del muro y con hueco central longitudinalmente, para pasar el perno que proporcionará la fijación necesaria entre los tableros de ambos lados. Estos separadores deben ser construidos también con suelo-cemento.

4. VERTIDO

Los materiales se colocarán dentro del molde formando capas de altura total no superior a los 100 mm.

El orden de vertido será: suelo-cemento, piedras humedecidas, suelo-cemento. La cantidad de piedras no será mayor del 40% del volumen total. Esto es, un volumen dado de piedras por cada vez y media de ese mismo volumen de suelo-cemento (proporción piedra/suelo cemento = 1/1,5).

5. COMPACTACION

Las capas así colocadas serán compactadas mediante apisonado, por lo general manualmente. La compactación de cada capa se considera suficiente cuando los golpes de pisón no dejen huellas en la misma.

Antes de colocar la capa siguiente es necesario escarificar la superficie de la capa compactada, con un elemento adecuado, por ejemplo una barilla de acero con punta afilada. Esto tiende a lograr la continuidad entre las capas compactadas, o sea, la continuidad del muro.

El pisón podrá ser de madera dura o metálica, con base de orden de 130 cm2, de superficie y un peso aproximado de 8 a 10 kg. La altura de caida será de 30 cm aproximadamente.

El proceso constructivo, mediante el vertido y compactación por capas sucesivas, se debe efectuar manteniendo el mismo nivel en todos los muros de la edificación para lograr la mayor continuidad entre ellos y evitar empujes en las esquinas. Donde no se pueda cumplir esta condición se harán cajuelas o endentamiento en la unión. El avance diario en la construcción de los muros debe ser del orden de 1500 mm.

Se mantendrá un control de nivelación adecuado, el que será preciso al término de la altura de los muros (enrace). La verticalidad del muro será cuidadosamente controlada. De ocurrir desplomes, han de ser menor de un sexto del ancho del muro.

6. DESMOLDE

En términos generales se puede comenzar el retiro de los moldes al cabo de unas 3 horas de haber compactado la última capa. En cada caso particular se procederá teniendo en cuenta el tipo de material, el ancho del muro y el número y tamaño de los vanos.

7. CURADO

Se debe mantener la humedad del muro durante los 3 días siguientes a su construcción, como mínimo.

Para este fin se cubrirán con sacos húmedos o regando con agua dispersa (no aplicar chorros concentrados) tres veces al día.

8. CONTROL DE LA CALIDAD

En cada etapa de preparación de los materiales, así como del proceso constructivo se aplicará la IT-11-91 "Control de Calidad en las construcciones de suelo-cemento".

La resistencia a compresión se evaluará mediante 3 probetas cúbicas de 150 x 150 mm por cada 10 m3 de pared construida (lo que equivale a 67 metros lineales en muros de 150 mm por cada metro de altura). El promedio de la resistencia a compresión axial de las 3 probetas será como MINIMO de 2 MPa, con resultados individuales mayores o iguales a 1,7 MPa. La absorción máxima admitida será del 20% del peso de la muestra.

Cuando el proyectista especifique valores superiores de resistencia a compresión o valores menores de absorción, serán estos los objetos del control.

9. OBSERVACIONES

9.1 Esta IT ha tomado en consideración la Carta Técnica Metodológica, emitida con fecha 27 de agosto de 1991 por la Vice Dirección Técnica Provincial de Microbrigadas Sociales y Servicios a la Vivienda, del Poder Popular Provincial de Holguín. En varias regiones de esta provincia hay tradición en construir, fundamentalmente viviendas, con esta técnica.

9.2 Esta IT puede ser reproducida por los organismos e instituciones para su divulgación y aplicación, con la condición de mantener rigurosamente su forma y contenido. Se incluirá solamente quien hace cada reproducción, lo que escribirá al final del texto diciendo:

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Instituto Nacional de la Vivienda
Ayestarán 621 esq. Piñera
Cerro
Ciudad de la Habana

COMISION PARA EL DESARROLLO Y APLICACION DE SUELOS ESTABILIZADOS

CUBA INV - MICONS MINAZ-MINAGRI CECAT - IPF	**METODOLOGIA PARA LA MEZCLA DE DOS SUELOS PARA PRODUCIR SUELO-CEMENTO.**	**Instrucción Técnica** IT-04-91 **Junio 1991**

1. INTRODUCCION

Esta IT está dirigida a solucionar los casos en que el suelo, donde está ubicada la obra, no cumple con las especificaciones de granulometría y plasticidad. Esto se resuelve generalmente agregando un suelo con características opuestas al que tenemos en la obra. En ocasiones muy excepcionales no basta con transportar y mezclar dos suelos opuestos sino que se requiere de un tercero.

La presente IT presenta el procedimiento de selección cuantitativa para hallar los porcientos de dos suelos con características física opuestas para que después de mezclados se obtenga un nuevo suelo que cumpla las especificaciones. Para solucionar la mezcla de tres suelos se permite emplear la presente IT, primero se mezclan dos suelos y se hallan las características de la mezcla y este nuevo suelo se vuelve a mezclar con un tercero para hallar las proporciones que obliguen a que se cumplan las especificaciones.

El texto se basó, fundamentalmente en la Referencia No. 1 de la Bibliografía.

2. PROCEDIMIENTO ANALITICO

La composición de una mezcla de dos suelos: M, consiste en, dado dos suelos A y B, cuyas granulometrías sean conocidas (tabla No. 1), obtener una mezcla con porcientos P1, P2, P3...., PK que se pasan por los tamices 1, 2, 3...k, y se encuentran dentro de los intervalos especificados $l_1 - L_1$, $l_2 - L_2$, $l_3 - L_3$, ..., $l_k - L_k$.

De forma que:

$$l_1 \leqslant P_1 \leqslant L_1$$

$$l_2 \leqslant P_2 \leqslant L_2$$

$$l_3 \leqslant P_3 \leqslant L_3$$

$$l_k \leqslant P_k \leqslant L_k$$

TABLA No. 1

Tamiz	% que pasa		Especificaciones	
	Suelo A	Suelo B		
1	A1	B1	l_1 -	L_1
2	A2	B2	l_2 -	L_2
3	A3	B3	l_3 -	L_3
-	-	-	- -	-
-	-	-	- -	-
-	-	-	- -	-
K	AK	BK	IK -	LK

De manera que:

$$l_m \leqslant P_m \leqslant L_m$$

El porciento P_M del suelo M que pasa en un determinado tamíz m puede ser obtenido por la expresión:

$$P_m = a\ PA + b\ PB$$

Donde:

PA, PB = porciento de los suelos A y B que pasen por un determinado tamíz.

a = parte del suelo A en la mezcla (% en peso)
b = parte del suelo B en la mezcla (% en peso)

[illegible] cualquiera puede escribirse:

$$a + b = 1$$

[illegible] PA y PB los porcientos de los suelos A y B que pasen dicho tamíz, y [illegible] el porciento de la mezcla M. Si Px y Py fueran los porcientos mínimos y [illegible] indicados por las especificaciones, que pasen ese tamíz, se tiene:

$$P_x \leq a\,PA + b\,PB = P_m \leq P_y$$

[illegible] sustituyendo en la ecuación anterior se tiene:

$$\frac{P_x - PB}{PA - PB} \leq a \leq \frac{P_y - PB}{PA - PB}, \text{ siendo} \qquad a_{min} = \frac{P_x - PB}{PA - PB}$$

$$a_{max} = \frac{P_y - PB}{PA - PB}$$

[illegible] los porcientos PA y PB se sustituyen en la ecuación de Pm.

[illegible] consistencia: límite líquido e índice plástico, pueden determinarse [illegible] por un procedimiento analítico como sigue:

$$LL_M = \frac{a\,(PA\ No.\ 40)\,(LL_A) + b\,(PB\ No.\ 40)\,(LL_B)}{a\,(P_A\ No.\ 40) + b\,(P_B\ No.\ 40)}$$

$$IP_M = \frac{a\,(PA\ No.\ 40)\,(IP_A) + b\,(PB\ No.\ 40)\,(IP_B)}{a\,(PA\ No.\ 40) + b\,(PB\ No.\ 40)}$$

Donde: LL_M = límite líquido de la mezcla M

IP_M = índice plástico de la mezcla M

a y b = porcentaje de los suelos A y B en la mezcla

PA, PB = porcentaje de los suelos A y B que pasen el tamíz No. 40 (0,42 mm).

3.[illegible] PROCEDIMIENTO GRÁFICO

El gráfico emplea cuatro escalas lineales: dos verticales y dos horizontales. En las escalas verticales se fijan los porcientos de los suelos A y B que pasen los diversos tamices. En las escalas horizontales se sitúan las cantidades determinadas de los suelos A y B para conformar la mezcla deseada.

La solución gráfica permite determinar todos los porcientos de la mezcla de suelos pasando los diversos tamices, ésto significa que su granulometría, una vez fijadas las proporciones de A y B, de como resultado el suelo M.

4. EJEMPLO DE APLICACIÓN.

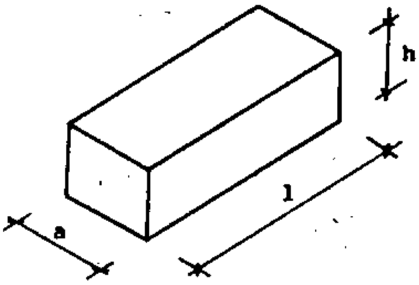
Para una mejor comprensión de los métodos analíticos y gráficos se procede a realizar un ejemplo práctico.

COMISION PARA EL DESARROLLO Y LA APLICACION DE SUELOS ESTABILIZADOS		
CUBA INV - MICONS MINAZ- MINAGRI CECAT- IPF	LADRILLOS MACIZOS DE SUELO CEMENTO	Instrucción Técnica IT - 07 - 91 JUNIO - 1991

1. Descripción

Elemento constructivo hecho de suelo cemento conformado en máquina compactadora por presión, preferiblemente de doble acción y curado.

2. Características Geométricas



Altura nominal - h = 90 mm
Ancho nominal - a = 140 mm
Largo nominal - l = 290 mm

3. Características Físico - mecánicas.

Resistencia a la compresión axial a los 7 días.

Valor medio mínimo 2 MPa
Valor individual mínimo 1,7 MPa

Absorción de agua

Valor medio máximo 20% del peso
Valor individual máximo 22% del peso

4. Ladrillos de calidad superior

Los factores determinantes para obtener ladrillos de mayor calidad; mayor resistencia a la compresión y menor absorción de agua, respecto a los valores mínimos aquí establecidos son:

- tipo de suelo
- contenido de cemento
- contenido de agua
- energía de compactación de la máquina conformadora

Así, para una mezcla dada de suelo, cemento y agua, los resultados dependerán de la máquina compactadora usada. El curado se considera un factor constante de obligatorio cumplimiento.

5. Observaciones

Esta IT puede ser reproducida por los organismos e instituciones para su divulgación y aplicación con la condición de mantener rigurosamente su forma y contenido. Se -

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Ayestarán No. 621, esq. a Piñera,
Cerro,
Ciudad de La Habana.

Absorción de agua.

Valor medio máximo	20% del peso
Valor individual máximo	22% del peso

5. BLOQUES DE CALIDAD SUPERIOR

Los factores determinantes para obtener bloques de mayor calidad: mayor resistencia a la compresión y menor absorción de agua, respecto a los valores mínimos aquí establecidos son:

- tipo de suelo
- contenido de cemento
- contenido de agua
- energía de compactación de la máquina conformadora

Así, para una mezcla dada de suelo, cemento y agua, los resultados dependerán de la máquina compactadora usada. El curado se considera un factor constante de obligatorio cumplimiento.

6. OBSERVACIONES

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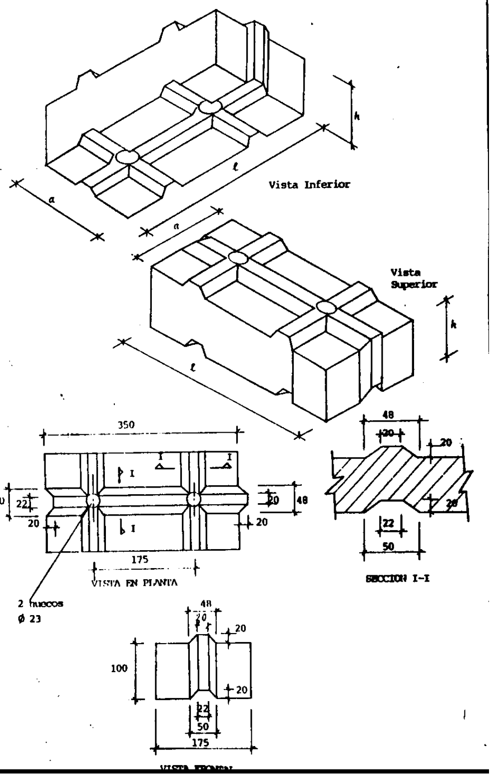


COMISION PARA EL DESARROLLO Y LA APLICACION DE SUELOS ESTABILIZADOS

CUBA INV - MICONS MINAZ- MINAGRI CECAT- IPP	BLOQUES MACHIMBRADOS DE SUELO CEMENTO (MACHIMBLOQUES)	INSTRUCCION TECNICA IT-09-91 SEPTIEMBRE 1991

1. INTRODUCCION

Los bloques con junta mecánica (machimbrada) fueron expuestos en Cuba por el Arq. Raúl Sánchez Mora, de México, durante la II Conferencia Internacional sobre Vivienda y Urbanismo, celebrada en Ciudad de la Habana, en octubre de 1990, dejando a su regreso los modelos, construidos en "polyespuma", que trajo para ilustrar su conferencia. Con esos modelos se comenzaron a producir máquinas para conformar los bloques de suelo-cemento. El diseño de las máquinas y su producción venía siendo desarrollado por el Ing. Rolando López de la Planta Mecánica Reynold García, perteneciente a la EREA No. 3, del MICONS en Matanzas, para producir bloques huecos, bovedillas y ladrillos macizos. En la actualidad son varias las máquinas en producción en diferentes regiones del país, por lo que la construcción con estos elementos es ya un hecho, independientemente de la necesidad de profundizar en la información y conocimientos que la sustenta.

En estas condiciones la presente IT se emite para amparar técnicamente un producto y una técnica constructiva en uso que debe ser perfeccionada y dominada en todos sus aspectos. Se entiende que los bloques machimbrados coexistan con los ladrillos macizos (IT-07-91) y los bloques huecos (IT-08-91) como elementos de construcción, seleccionándose en cada caso el que se entienda más conveniente según el uso a que se destine y las condiciones de la zona y las obras en particular.

2. DESCRIPCION

Elementos constructivos hechos de suelo-cemento conformados en máquinas compactadoras por presión, preferiblemente de doble acción y curados. Presentan nervios y ranuras para la conexión mecánica (machimbrados) entre los elementos.

3. CARACTERISTICAS GEOMETRICAS

Las dimensiones de 350 mm (en el largo) no se ajusta a las modulaciones de 3 M (siendo M = 100 mm) aplicadas a las edificaciones en Cuba. Esto es particularmente rígido porque el bloque machimbrado no se puede picar en obra a cualquier tamaño necesario, según se requiera, como ocurre con el ladrillo o el bloque que llevan unión con mortero. Sólo se puede reducir al semi-bloque (su mitad) por lo que de hecho la modulación ha de ser en base a 1.75 M. Esto implica disponer de proyectos particulares para construir con estos bloques machimbrados.

Las dimensiones de nervios y ranuras se han tomado de las máquinas referidas en la Introducción, según el Proyecto MEBJM (Máquina para Elaborar Bloques de Junta Mecánica) de fecha febrero 1991. EREA Nº 3, MICONS.

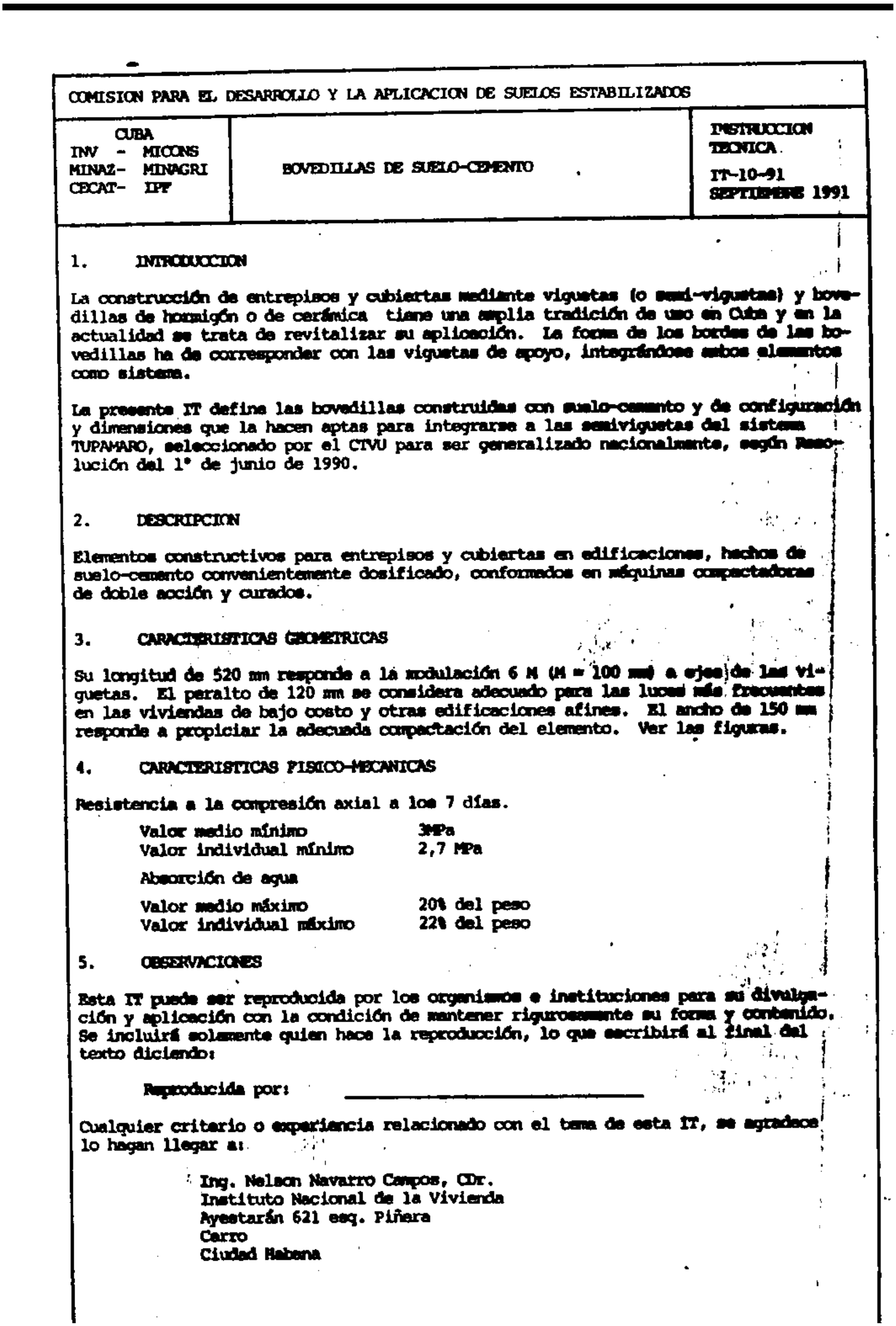
Altura nominal h = 100 mm
Ancho nominal a = 175 mm
Largo nominal l = 350 mm

(Véanse las figuras)

4. CARACTERISTICAS FISICO-MECANICAS

Resistencia a la compresión axial a los 7 días.

Valor medio mínimo 2MPa
Valor individual mínimo 1,7 MPa



COMISION PARA EL DESARROLLO Y LA APLICACION DE SUELOS ESTABILIZADOS

CUBA INV - MICONS MINAZ- MINAGRI CECAT- IPF	BOVEDILLAS DE SUELO-CEMENTO	INSTRUCCION TECNICA IT-10-91 SEPTIEMBRE 1991

1. INTRODUCCION

La construcción de entrepisos y cubiertas mediante viguetas (o semi-viguetas) y bovedillas de hormigón o de cerámica tiene una amplia tradición de uso en Cuba y en la actualidad se trata de revitalizar su aplicación. La forma de los bordes de las bovedillas ha de corresponder con las viguetas de apoyo, integrándose ambos elementos como sistema.

La presente IT define las bovedillas construidas con suelo-cemento y de configuración y dimensiones que la hacen aptas para integrarse a las semiviguetas del sistema TUPAMARO, seleccionado por el CTVU para ser generalizado nacionalmente, según Resolución del 1° de junio de 1990.

2. DESCRIPCION

Elementos constructivos para entrepisos y cubiertas en edificaciones, hechos de suelo-cemento convenientemente dosificado, conformados en máquinas compactadoras de doble acción y curados.

3. CARACTERISTICAS GEOMETRICAS

Su longitud de 520 mm responde a la modulación 6 M (M = 100 mm) a ejes de las viguetas. El peralto de 120 mm se considera adecuado para las luces más frecuentes en las viviendas de bajo costo y otras edificaciones afines. El ancho de 150 mm responde a propiciar la adecuada compactación del elemento. Ver las figuras.

4. CARACTERISTICAS FISICO-MECANICAS

Resistencia a la compresión axial a los 7 días.

Valor medio mínimo	3MPa
Valor individual mínimo	2,7 MPa
Absorción de agua	
Valor medio máximo	20% del peso
Valor individual máximo	22% del peso

5. OBSERVACIONES

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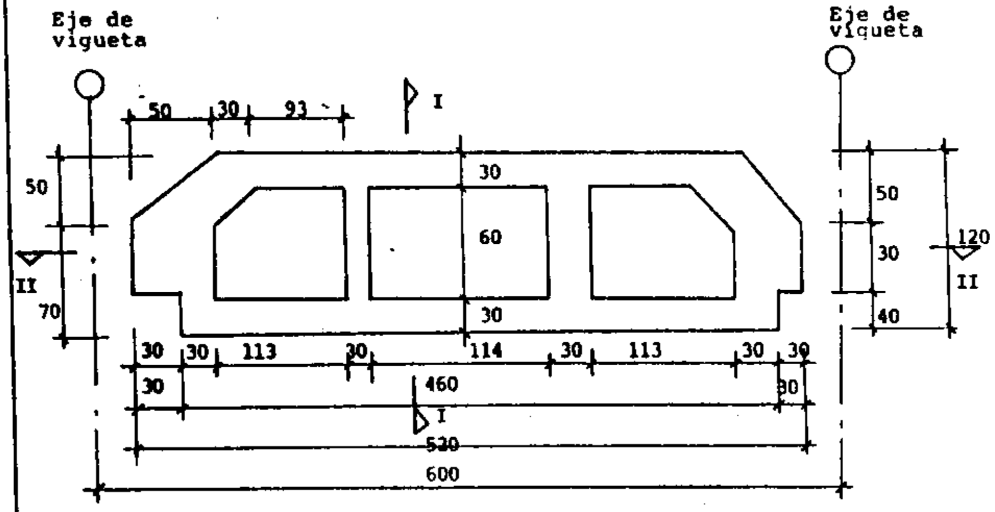
Norma 32 IT-10 BOVEDILLAS SUELO CEMENTO



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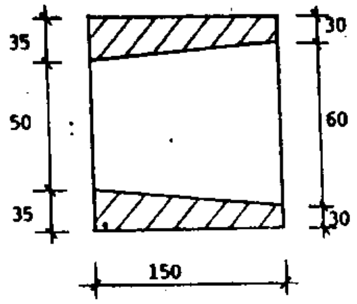
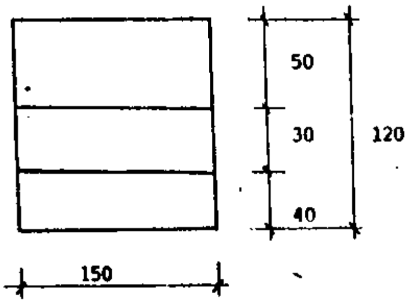
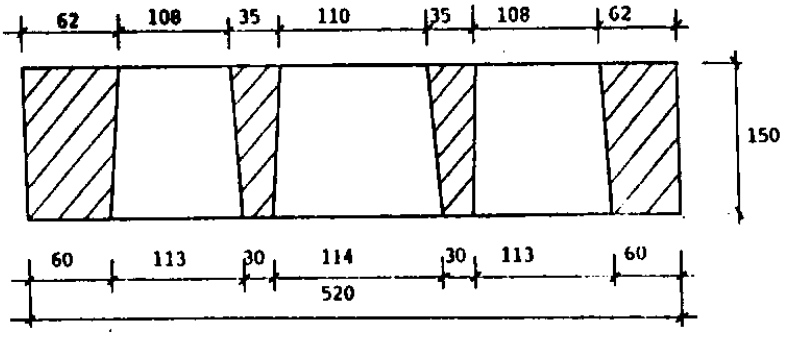


SECCION I-I



VISTA LATERAL



SECCION II-II

Congelación-deshielo de probetas de suelo-cemento

1 OBJETO Y CAMPO DE APLICACION

1.1 Este ensayo tiene por objeto determinar la pérdida de suelo-cemento, cambios de humedad y cambios de volumen (hinchamiento y retracción) producidos por repetidas congelaciones y deshielos de muestras de suelo-cemento moldeadas y compactadas.

1.2 Para este ensayo se siguen dos métodos, y el uso de uno u otro depende de la granulometría del suelo.

Método A. Empleando material que pasa por el tamiz 5 UNE (ASTM núm. 4) y usado cuando el 100 % del suelo pasa por dicho tamiz.

Método B. Empleando material que pasa por el tamiz 20 UNE (ASTM 3/4 pulgada) y usado cuando parte del suelo es retenido en el tamiz 5 UNE.

1.3 Esta norma tiene aplicación en las mezclas suelo-cemento utilizadas en construcción de carreteras.

2 APARATOS Y MATERIAL NECESARIOS

2.1 Un molde cilíndrico de un litro de capacidad (102 mm de diámetro por 122,4 mm de altura), con base y collar.

2.2 Una maza de compactación de 2,5 kg y 50 mm aproximadamente de diámetro, provista de un tubo guía que controle la caída desde una altura de 305 mm, accionada a mano o mediante un compactador mecánico calibrado con arreglo a la norma NLT-107.

2.3 Un extractor de muestras del molde.

2.4 Dos balanzas: una de 10 kg de capacidad, sensible al gramo, y otra de 1.000 g de capacidad, sensible a 0,1 g.

2.5 Una estufa de desecación, regulable, capaz de mantener una temperatura de 110 ± 5 °C.

2.6 Un frigorífico capaz de mantener temperaturas (−23 °C) o más bajas.

2.7 Una cámara húmeda capaz de mantener una temperatura de 21 ± 2 °C y una humedad relativa del 100 % durante los días de cura de las probetas.

2.8 Un cepillo de alambres de 5 cm, aproximadamente, de longitud y 0,15 cm de diámetro. Hecho con 50 grupos de 10 cerdas cada grupo, colocadas en cinco filas de 10 grupos, sobre un mango de madera de 19 × 6,3 cm.

2.9 Una espátula de unos 300 mm de longitud, sesgado uno de sus filos.

2.10 Tamices: 80 UNE (ASTM 3 pulgadas), 20 UNE (ASTM 3/4 pulgada) y 5 UNE (ASTM núm. 4).

2.11 Un recipiente mezclador y una paleta para mezclas.

2.12 Un cuchillo de carnicero, de hoja fuerte y bien recta.

2.13 Un tenedor como los de coger hielo, o aparato similar, para escarificar las capas compactadas antes de echar la siguiente.

2.14 Un recipiente de aproximadamente 300 mm de diámetro y 50 mm de altura para la absorción de humedad de las mezclas suelo-cemento.

2.15 Un calibre para medir las alturas y diámetro de las probetas con una aproximación de 0,2 mm.

2.16 Bandejas para contener y transportar las muestras.

2.17 Una probeta de cristal graduada de 250 cm^3 de capacidad para medir agua.

2.18 Cápsulas y pesafiltros para determinar la humedad de las muestras.

3 METODO A: PROCEDIMIENTO

3.1 Preparación de la muestra

3.1.1 Preparar la muestra de suelo, desmenuzándola hasta que todo el material pase por el tamiz 5 UNE. Si es preciso, dejar secar la muestra hasta que pueda ser pulverizada fácilmente. El secado se hace al aire o por medio de estufa u otros aparatos de secado, siempre que la temperatura no exceda de 60 °C.

3.1.2 Dividir por cuarteo el material así obtenido en 8 ó 9 porciones de unos 3 kg cada una.

3.2 Ejecución del ensayo

3.2.1 Tomar del suelo preparado en 3.1.2, de este procedimiento, las porciones necesarias y determinar la densidad máxima y humedad óptima de la mezcla suelo-cemento a ensayar, conforme a las especificaciones descritas en el ensayo de apisonado para determinar la relación densidad-humedad. Método A (NLT-301).

3.2.2 Una vez determinada la curva humedad-densidad, tomar dos porciones de suelo, preparadas según el apartado 3.1.2 de este procedimiento, determinar la humedad, y con este dato el suelo seco correspondiente.

3.2.3 Añadir después a dichas porciones la cantidad calculada de cemento respecto al suelo seco y mezclarlo completamente hasta color uniforme.

3.2.4 A la mezcla suelo-cemento, cuya humedad se conoce según el apartado anterior 3.2.2, añadir por diferencia la cantidad suficiente de agua potable hasta la humedad óptima y mezclar íntimamente.

Cuando el suelo sea una arcilla pesada, compactar la mezcla suelo-cemento-agua en el recipiente descrito en el apartado 2.14 de esta norma, hasta una altura de, aproximadamente, 50 mm, usando la maza, taparlo y dejarlo en reposo durante un período no menor de 5 minutos ni mayor de 10, para permitir que, por absorción, se reparta la humedad por toda la mezcla.

Después de este período de absorción, romper la mezcla compactada hasta que, visiblemente, se comprenda que todas las partículas pasan por el tamiz 5 UNE y mezclar.

3.2.5 **Moldeo de las muestras.** Una vez mezclada nuevamente la muestra, compactar inmediatamente una probeta en el molde en tres capas y 30 golpes por capa con la maza de 2,5 kg, repartiendo los golpes por toda la superficie y escarificando cada una de las capas antes de añadirle la siguiente, para lo cual se remueve la parte superficial de la capa, haciendo cavidades de una a otra parte en sentido recto de aproximadamente 3 mm de ancho y 3 mm de profundidad y separadas unas de otras unos 6 mm.

Durante la compactación, tomar una muestra representativa de uno 100 g, pesarla inmediatamente y secarla, dentro de una cápsula, en estufa a 110 °C por un período mínimo de 12 horas o hasta peso constante y calcular el tanto por ciento de humedad de la mezcla para contrastarla con el contenido de humedad designado para la ejecución del ensayo, entre los cuales sólo se permite un ± 1 % de error.

3.2.6 Quitar el collar del molde, enrasar, sacar la probeta compactada y determinar la densidad seca, para contrastarla con la designada. Los límites de error permitidos en este caso son de ± 5,5 g/dm^3.

3.2.7 Identificar la muestra, marcándola con el número 1, y usarla para obtener los datos de cambio de humedad y volumen durante el ensayo.

3.2.8 Compactar una segunda probeta tan rápidamente como sea posible y determinar, como en la primera, el porcentaje de humedad y la densidad seca, como se describe en los anteriores apartados 3.2.5 y 3.2.6 e identificar esta muestra con el número 2, la cual será usada para obtener los datos de cálculo para la pérdida de suelo-cemento durante el ensayo.

3.2.9 Medir el diámetro y la altura de la muestra número 1 y calcular su volumen.

3.2.10 Colocar ambas muestras en una bandeja, en la cámara húmeda, por un período de 7 días. Pesar y volver a medir la muestra número 1 al final de estos 7 días de cura en cámara húmeda y calcular su humedad y volumen.

Nota 1. Todas las medidas deben ser tomadas con una aproximación de 0,3 mm y tomadas siempre sobre los mismos puntos.

3.2.11 Inmediatamente después de los 7 días de cura en cámara húmeda, colocar un fieltro de unos 6 mm de espesor u otro material absorbente, saturado de agua, entre la muestra y la bandeja y colocar el conjunto en una cámara frigorífica que tenga una temperatura constante mínima de −23 °C, y tenerla en estas condiciones durante 24 horas. Transcurrido dicho período, sacar las muestras y medir en la número 1 el cambio de volumen y humedad.

3.2.12 Colocar la bandeja con las muestras en la cámara húmeda o, en su defecto, en un recipiente cerrado que tenga una temperatura de 21 °C y una humedad relativa de un 100 %, durante 23 horas, y sacarlas. Debajo del fieltro sobre el que están las muestras habrá agua, una fina capa de agua, que permita a las muestras absorberla por capilaridad durante el período de deshielo. Pesar y medir la númereo 1. Y cepillar la muestra número 2 con el cepillo de alambres como sigue: se cogerá el cepillo de manera que quede paralelo a la superficie a cepillar y se cepilla ejerciendo una fuerza aproximada de 15

Designation: D 559 - 82

Standard Methods for Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures[1]

This standard is issued under the fixed designation D 559; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

These methods have been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These methods cover procedures for determining the soil-cement losses, moisture changes, and volume changes (swell and shrinkage) produced by repeated wetting and drying of hardened soil-cement specimens. The specimens are compacted in a mold, before cement hydration, to maximum density at optimum moisture content using the compaction procedure described in Test Methods D 558.

1.2 Two methods, depending on soil gradation, are covered for preparation of material for molding specimens and for molding specimens as follows:

	Sections
Method A, using soil material passing a No. 4 (4.75-mm) sieve. This method shall be used when 100 % of the soil sample passes the No. 4 (4.75-mm) sieve	5
Method B, using soil material passing a ¾-in. (19.0-mm) sieve. This method shall be used when part of the soil sample is retained on the No. 4 (4.75-mm) sieve	6

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[2]

C 595 Specification for Blended Hydraulic Cements[2]

D 558 Test Methods for Moisture-Density Relations of Soil-Cement Mixtures[3]

D 560 Methods for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures[3]

D 2168 Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Significance and Use

3.1 These methods are used to determine the resistance of compacted soil-cement specimens to repeated wetting and drying. These methods were developed to be used in conjunction with Methods D 560 and criteria given in the *Soil-Cement Laboratory Handbook*[5] to determine the minimum amount of cement required in soil-cement to achieve a degree of hardness adequate to resist field weathering.

4. Apparatus

4.1 *Mold*—A cylindrical metal mold having a capacity
1/30 ± 0.0004 ft³ (944 ± 11 cm³) with an internal diamete
4.0 ± 0.016 in. (101.60 ± 0.41 mm) and conforming to
1 to permit preparing compacted specimens of soil-cem
mixtures of this size. The mold shall be provided wit
detachable collar assembly approximately 2½ in. (63.5 m
in height. The mold may be of the split type consisting of
half-round sections or a section of pipe with one side s
perpendicular to the pipe circumference and that can
securely locked in place to form a closed cylinder having
dimensions described above. The mold and collar assem
shall be so constructed that it can be fastened firmly
detachable base.

4.2 *Rammer:*

4.2.1 *Manual Rammer*—A manually operated m
rammer having a 2.0 ± 0.005-in. (50.80 ± 0.13-
diameter circular face and weighing 5.5 ± 0.02 lb (2.4
0.01 kg). The rammer shall be equipped with a suit
guidesleeve to control the height of drop to a free fall of
1/16 in. (304.8 ± 1.6 mm) above the elevation of
soil-cement. The guidesleeve shall have at least four
holes not smaller than ⅜ in. (9.5 mm) spaced 90° apart
located with centers ¾ ± 1/16 in. (19.0 ± 1.6 mm) from
end and shall provide sufficient clearance that freefalls o
rammer shaft and head will not be restricted.

4.2.2 *Mechanical Rammer*—A mechanically ope
metal rammer having a 2.0 ± 0.005-in. (50.80 ± 0.13-
diameter face and a manufactured weight of 5.5 ± 0.
(2.49 ± 0.01 kg). The operating weight of the rammer
be determined from a calibration in accordance
Methods D 2168. The rammer shall be equipped wi
suitable arrangement to control the height of drop
free-fall of 12.0 ± 1/16 in. (304.8 ± 1.6 mm) above
elevation of the soil-cement.

4.2.3 *Rammer Face*—Strength and resistance to wet
and-drying of specimens compacted with the sector
rammer may differ from that of specimens compacted
the circular face rammer. Therefore, the sector face ra
shall not be used unless previous tests on like soil-ce
mixtures show that similar resistance to wetting and dry
obtained with the two types of rammers.

4.3 *Sample Extruder*—A jack, lever frame, or
device adapted for the purpose of extrudin
specimens from the mold. Not required when a split
mold is used.

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[1] These methods are under the jurisdiction of the ASTM Committee D-18 on Soil and Rock and are the direct responsibility of Subcommittee D18.15 on Stabilization of Additives.

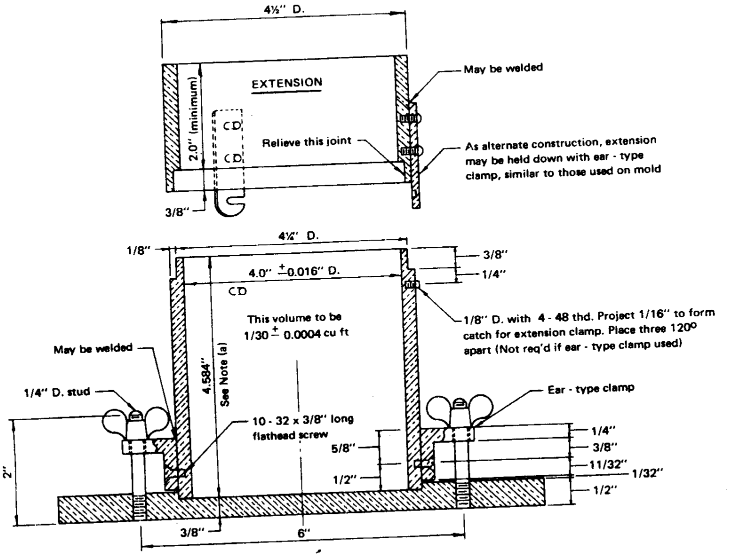
Current edition approved July 30, 1982. Published September 1982. Originally published as D 559 – 39. Last previous edition D 559 – 57 (1976).

[2] *Annual Book of ASTM Standards*, Vols 04.01 and 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vols 04.01, 04.06, and 14.02.

[5] *Soil-Cement Laboratory Handbook*, Portland Cement Assn., 1971.



Metric Equivalents

in.	mm
0.016	0.41
0.026	0.66
1/32	0.80
1/16	1.6
1/8	3.2
1/4	6.4
11/32	8.7
3/8	9.5
1/2	12.7
5/8	15.9
2	50.8
2½	63.5
4	101.6
4¼	108.0
4½	114.3
4.584	116.43
6	152.4
6½	165.1
8	203.2

ft^3	cm
1/30	944
0.004	11
1/13.333	2124
0.0009	25

NOTE (a)—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE (b)—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, others methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 1 Cylindrical Mold

4.4 *Balances*—A balance or scale of at least 25-lb (11.3-kg) capacity sensitive to 0.01 lb (0.005 kg) and a balance of at least 1000-g capacity sensitive to 0.1 g.

4.5 *Drying Ovens*—A thermostatically controlled drying oven capable of maintaining temperatures of 230 ± 9°F (110 ± 5°C) for drying moisture samples, and a thermostatically controlled drying oven capable of maintaining temperatures of 160 ± 5°F (71 ± 3°C) for drying compacted soil-cement specimens.

4.6 *Moist Room*—A moist room or suitable covered container capable of maintaining a temperature of 70 ± 3°F (21 ± 1.7°C) and a relative humidity of 100 % for 7-day storage of compacted specimens.

4.7 *Water Bath*—Suitable tank for submerging compacted specimens in water at room temperature.

4.8 *Wire Scratch Brush*—A wire scratch brush made of 2 by 1/16-in. (50.8 by 1.588-mm) flat No. 26 gage (0.46-mm) wire bristles assembled in 50 groups of 10 bristles each and mounted to form 5 longitudinal rows and 10 transverse rows of bristles on a 7½ by 2½-in. (190 by 63.5-mm) hardwood block.

4.9 *Straightedge*—A rigid steel straightedge 12 in. (305 mm) in length and having one beveled edge.

4.10 *Sieves*—3-in. (75-mm), ¾-in. (19.0-mm), and No. 4 (4.75-mm) sieves conforming to the requirements of Specification E 11.

4.11 *Mixing Tools*—Miscellaneous tools such as mixing pan, and trowel, or a suitable mechanical device for thoroughly mixing the soil with cement and water.

4.12 *Butcher Knife*—A butcher knife approximately 10 in. (250 mm) in length for trimming the top of the specimens.

4.13 *Scarifier*—A six-pronged ice pick or similar apparatus to remove the smooth compaction plane at the top of the first and second layers of the specimen.

4.14 *Container*—A flat, round pan for moisture absorption by soil-cement mixtures, about 12 in. (305 mm) in diameter and 2 in. (50 mm) deep.

4.15 *Measuring Device*—A measuring device suitable for accurately measuring the heights and diameters of test specimens to the nearest 0.01 in. (0.2 mm).

4.16 *Pans and Carriers*—Suitable pans for handling materials and carriers or trays for handling test specimens.

4.17 *Graduate*—A graduated cylinder of 250-mL capacity for measuring water.

4.18 *Moisture Cans*—Suitable containers for moisture samples.

5. Method A—Using Soil Material Passing a No. 4 (4.75-mm) Sieve

5.1 *Preparation of Material for Molding Specimens:*

5.1.1 Prepare the soil sample in accordance with the procedure described in Method A of Test Methods D 558.

5.1.2 Select a sufficient quantity of the soil prepared as described in 5.1.1 to provide two (Note 1) compacted specimens and required moisture samples.

NOTE 1: (*Optional*)—Usually only one specimen (identified as No. 2) is required for routine testing. The other specimen (identified as No. 1) is made for research work and for testing unusual soils.

5.1.3 Add to the soil the required amount of cement conforming to Specification C 150 or Specification C 595. Mix the cement and soil thoroughly to a uniform color.

5.1.4 Add sufficient potable water to raise the soil-cement mixture to optimum moisture content at the time of compaction and mix thoroughly. When the soil used is a heavy textured clayey material, compact the mixture of soil, cement, and water in the container to a depth of about 2 in. (50 mm) using the rammer described in 4.2 or a similar hand tamper, cover, and allow to stand for not less than 5 min but not more than 10 min to aid dispersion of the moisture and to permit more complete absorption by the soil-cement.

5.1.5 After the absorption period, thoroughly break up the mixture, without reducing the natural size of individual particles, until it will pass a No. 4 (4.75-mm) sieve, as judged by eye, and then remix.

5.2 *Molding Specimens:*

5.2.1 Form a specimen by immediately compac soil-cement mixture in the mold (with the collar a and later trimming the specimen in accordance with A of Test Methods D 558, and in addition scarify th the first and second layers to remove smooth con planes before placing and compacting the succeedin This scarification shall form grooves at right angles other, approximately ⅛ in. (3.2 mm) in width and mm) in depth and approximately ¼ in. (6.4 mm) a

5.2.2 During compaction, take from the batch a tative sample of the soil-cement mixture, weighing than 100 g, weigh immediately, and dry in an oven 9°F (110 ± 5°C) for at least 12 h or to constan Calculate the percentage of moisture as prescribe Methods D 558 to check against design moisture c

5.2.3 Weigh the compacted specimen and mold the specimen from the mold, and calculate the weight of each specimen in lb/ft^3 (g/cm^3) to chec design density.

5.2.4 Identify the specimen on a metal tag (suitable device) as No. 1 (Note 1) together with oth identification marks and use to obtain data on moi volume changes during the test.

5.2.5 Form a second specimen as rapidly as pos determine the percentage of moisture and oven-dry described in 5.2.1 to 5.2.3. Identify this specimen together with other needed identification marks a obtain data on soil-cement losses during the test.

5.2.6 Determine the average diameter and heig No. 1 specimen and calculate its volume.

5.2.7 Place the specimens on suitable carriers in room and protect them from free water for a pe days.

5.2.8 Weigh and measure the No. 1 specimen a of the 7-day storage period to provide data for calc moisture content and volume.

NOTE 2—It is important that all height and diameter me be accurate to within 0.01 in. (0.2 mm) and be taken at the s on the specimen at all times.

5.3 *Procedure:*

5.3.1 At the end of the storage in the moi submerge the specimens in potable water at room ture for a period of 5 h and remove. Weigh and me No. 1 specimen (volume and moisture change spe

5.3.2 Place both specimens in an oven at 160°F 42 h and remove. Weigh and measure the No. 1 s

5.3.3 Give specimen No. 2 (soil-cement loss two firm strokes on all areas with the wire scratch b brush shall be held with the long axis of the brush the longitudinal axis of the specimen or parallel t as required to cover all areas of the specimen. A strokes to the full height and width of the specim firm stroke corresponding to approximately 3-lbf force (Note 3). Eighteen to twenty vertical brush s required to cover the sides of the specimen twice strokes are required on each end.

NOTE 3—This pressure is measured as follows: clamp a a vertical position on the edge of a platform scale and zer Apply vertical brushing strokes to the specimen and not necessary to register approximately 3 lbf (13.3 N).

5.3.4 The procedures described in 5.3.1 to 5.3.3 constitute one cycle (48 h) of wetting and drying. Again submerge the specimens in water and continue the procedure for 12 cycles.

NOTE 4—Weight determinations of specimen No. 2 before and after brushing are usually made at the end of each cycle when conducting research and making special investigations.

5.3.5 The No. 1 specimen may be discontinued prior to 12 cycles should the measurements become inaccurate due to soil-cement loss of the specimen.

NOTE 5—If it is not possible to run the cycles continuously because of Sundays, holidays, or for any other reason, hold the specimens in the oven during the layover period if possible.

5.3.6 After 12 cycles of test, dry the specimens to constant weight at 230°F (110°C) and weigh to determine the oven-dry weight of the specimens.

5.3.7 The data collected will permit calculations of volume and moisture changes of specimen No. 1 and the soil-cement losses of specimen No. 2 after the prescribed 12 cycles of test.

6. Method B—Using Soil Material Passing a ¾-in. (19.0-mm) Sieve

6.1 *Preparation of Material for Molding Specimens:*

6.1.1 Prepare the soil sample in accordance with Method B of Test Methods D 558.

6.1.2 Select and maintain separate representative samples of soil passing the No. 4 (4.75-mm) sieve and of saturated, surface-dry aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve so that the total sample will be enough to provide two (Note 1) compacted specimens and required moisture samples. The percentage, by oven-dry weight, of aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve shall be the same as the percentage passing the 3-in. (75-mm) sieve and retained on the No. 4 (4.75-mm) sieve in the original sample.

6.1.3 Add to the sample passing the No. 4 (4.75-mm) sieve, the amount of cement conforming to Specification C 150 or Specification C 595, required for the total sample specified in 6.1.2 Mix the cement and soil thoroughly to a uniform color.

6.1.4 Add to the sample passing the No. 4 (4.75-mm) sieve, sufficient water to raise the total soil-cement mixture prescribed in 6.1.2 to optimum moisture content at time of compaction and facilitate moisture dispersion as described for Method A in 5.1.4 to 5.1.6.

6.1.5 After preparation of the mixture as described in 6.1.1 to 6.1.4, add the saturated, surface-dry aggregate to the mixture and mix thoroughly.

6.2 *Molding Specimens:*

6.2.1 Form a specimen by immediately compacting the soil-cement mixture in the mold (with the collar attached) and later trimming the specimen in accordance with Method B of Test Methods D 558, and in addition as the mixture for each layer is placed in the mold, spade along the inside of the mold with a butcher knife before compaction to obtain uniform distribution of the material retained on the No. 4 (4.75-mm) sieve and scarify the tops of the first and second layers as described for Method A of this method.

6.2.2 During compaction, take from the batch a representative sample of the soil-cement mixture weighing not less than 500 g, weigh immediately, and dry in an oven at 230 ± 9°F (110 ± 5°C) for at least 12 h or to constant weight to determine the moisture content to check against design moisture content.

6.2.3 Form a second specimen as rapidly as possible in the same manner.

6.2.4 Weigh each compacted specimen to check against design density, identify, measure the No. 1 specimen (Note 1), place in the moist room, and measure the No. 1 specimen again at the end of the 7-day storage period as described for Method A in 5.2.3 to 5.2.8 (Note 2).

6.3 *Procedure:*

6.3.1 Proceed as directed in Method A (see 5.3).

7. Calculations

7.1 Calculate the volume and moisture changes and the soil-cement losses of the specimens as follows:

7.1.1 Calculate the difference between the volume of specimen No. 1 at the time of molding and subsequent volumes as a percentage of the original volume.

7.1.2 Calculate the moisture content of specimen No. 1 at the time of molding and subsequent moisture contents as a percentage of the original oven-dry weight of the specimen.

7.1.3 Correct the oven-dry weight of specimen No. 2 as obtained in 5.3.6 for water that has reacted with the cement and soil during the test and is retained in the specimen at 230°F (110°C), as follows:

$$\text{Corrected oven-dry weight} = (A/B) \times 100$$

where:

A = oven-dry weight after drying at 230°F (100°C), and

B = percentage of water retained in specimen plus 100.

The percentage of water retained in specimen No. 2 after drying at 110°C for use in the above formula can be assumed to be equal to the water retained in specimen No. 1. When No. 1 specimens are not molded, the foregoing data are not available and the average values prescribed in Table 1 are used.

7.1.4 Calculate the soil-cement loss of specimen No. 2 as a percentage of the original oven-dry weight of the specimen as follows:

$$\text{Soil-cement loss, \%} = (A/B) \times 100$$

where:

A = original calculated oven-dry weight minus final corrected oven-dry weight, and

B = original calculated oven-dry weight.

8. Report

8.1 The report shall include the following:

8.1.1 The designed optimum moisture and maximum density of the molded specimens,

TABLE 1 Average Values

AASHTO Soil Classification	Average Water Retained After Drying at 230°F (110°C), %
A-1, A-3	1.5
A-2	2.5
A-4, A-5	3.0
A-6, A-7	3.5

8.1.2 The moisture content and density obtained in molded specimens,

NOTE 6—Good laboratory practice permits the following tolerances between design factors and those obtained in the molded specimens:

Moisture content	±1 percentage point
Density	±3 lb/ft^3 (0.048 g/cm^3)

8.1.3 The designed cement content, in percent, of the molded specimens,

8.1.4 The maximum volume change, in percen maximum moisture content during test of specimen and

8.1.5 The soil-cement loss, in percent, of specimen

9. Precision and Accuracy

9.1 Precision and accuracy of this test procedure h been established. Data are available on the variabi weight losses for duplicate specimens. These data analyzed and a statement will be included in th revision.

Designation: D 560 – 82

Standard Methods for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures[1]

This standard is issued under the fixed designation D 560; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

These methods have been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These methods cover procedures for determining the soil-cement losses, moisture changes, and volume changes (swell and shrinkage) produced by repeated freezing and thawing of hardened soil-cement specimens. The specimens are compacted in a mold, before cement hydration, to maximum density at optimum moisture content using the compaction procedure described in Test Methods D 558.

1.2 Two methods, depending on soil gradation, are covered for preparation of material for molding specimens and for molding specimens as follows:

	Sections
Method A, using soil material passing a No. 4 (4.75-mm) sieve. This method shall be used when 100 % of the soil sample passes the No. 4 (4.75-mm) sieve	5
Method B, using soil material passing a 3/4-in. (19.0-mm) sieve. This method shall be used when part of the soil sample is retained on the No. 4 (4.75-mm) sieve	6

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[2]

C 595 Specification for Blended Hydraulic Cements[2]

D 558 Test Methods for Moisture-Density Relations of Soil-Cement Mixtures[3]

D 559 Methods for Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures[3]

D 2168 Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Significance and Use

3.1 These methods are used to determine the resistance of compacted soil-cement specimens to repeated freezing and thawing. These methods were developed to be used in conjunction with Methods D 559 and criteria given in the *Soil-Cement Laboratory Handbook*[5] to determine the minimum amount of cement required in soil-cement to achieve a degree of hardness adequate to resist field weathering.

4. Apparatus

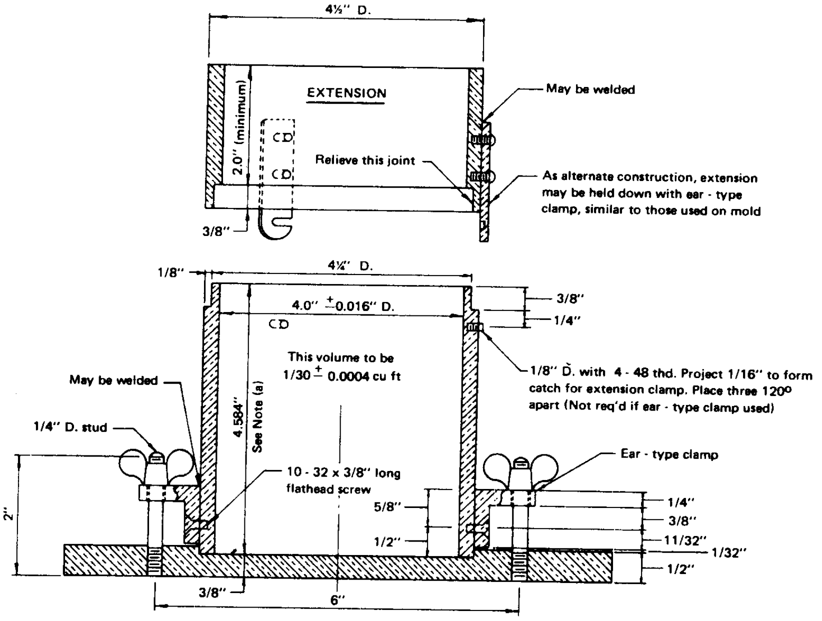
4.1 *Mold*—A cylindrical metal mold having a capacity of 1/30 ± 0.0004 ft^3 (944 ± 11 cm^3) with an internal diameter of 4.0 ± 0.016 in. (101.60 ± 0.41 mm) and conforming to Fig. 1 to permit preparing compacted specimens of soil-cement mixtures of this size. The mold shall be provided with a detachable collar assembly approximately 2½ in. (63.5 mm) in height. The mold may be of the split type consisting of two half-round sections or a section of pipe with one side split perpendicular to the pipe circumference and that can be securely locked in place to form a closed cylinder having the dimensions described above. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base.

4.2 *Rammer:*

4.2.1 *Manual Rammer*—A manually operated metal rammer having a 2.0 ± 0.005-in. (50.80 ± 0.13-mm) diameter circular face and weighing 5.5 ± 0.02 lb (2.49 ± 0.01 kg). The rammer shall be equipped with a suitable guidesleeve to control the height of drop to a free fall of 12 ± 1/16 in. (304.8 ± 1.6 mm) above the elevation of the soil-cement. The guidesleeve shall have at least four vent holes not smaller than 3/8 in. (9.5 mm) spaced 90° apart and located with centers 3/4 ± 1/16 in. (19.0 ± 1.6 mm) from each end and shall provide sufficient clearance that free-falls of the rammer shaft and head will not be restricted.

4.2.2 *Mechanical Rammer*—A mechanically operated metal rammer having a 2.0 ± 0.005-in. (50.80 ± 0.13-mm) diameter face and a manufactured weight of 5.5 ± 0.02 lb (2.49 ± 0.01 kg). The operating weight of the rammer shall be determined from a calibration in accordance with Methods D 2168. The rammer shall be equipped with a suitable arrangement to control the height of drop to a free-fall of 12.0 ± 1/16 in. (304.8 ± 1.6 mm) above the elevation of the soil-cement.

4.2.3 *Rammer Face*—Strength and resistance to freezing and thawing of specimens compacted with the sector face rammer may differ from that of specimens compacted with



Metric Equivalents

in.	mm
0.016	0.41
0.026	0.66
1/32	0.80
1/16	1.6
1/8	3.2
1/4	6.4
11/32	8.7
3/8	9.5
1/2	12.7
5/8	15.9
2	50.8
2½	63.5
4	101.6
4¼	108.0
4½	114.3
4.584	116.43
6	152.4
6½	165.1
8	203.2

ft^3	cm
1/30	944
0.004	11
1/13.333	2124

TABLE 1 Average Values

AASHTO Soil Classification	Average Water Retained After Drying at 230°F (110°C), %
A-1, A-3	1.5
A-2	2.5
A-4, A-5	2.0
A-6, A-7	3.5

by $^1/_{16}$-in. (50.8 by 1.588-mm) flat No. 26 gage (0.46 mm) wire bristles assembled in 50 groups of 10 bristles each and mounted to form 5 longitudinal rows and 10 transverse rows of bristles on a 7½ by 2½-in. (190 by 63.5-mm) hardwood block.

4.9 *Straightedge*—A rigid steel straightedge 12 in. (305 mm) in length and having one beveled edge.

4.10 *Sieves*—3-in. (75-mm), ¾-in. (19.0-mm), and No. 4 (4.75-mm) sieves conforming to the requirements of Specification E 11.

4.11 *Mixing Tools*—Miscellaneous tools such as mixing pan, and trowel, or a suitable mechanical device for thoroughly mixing the soil with cement and water.

4.12 *Butcher Knife*—A butcher knife approximately 10 in. (250 mm) in length for trimming the top of the specimens.

4.13 *Scarifier*—A six-pronged ice pick or similar apparatus to remove the smooth compaction plane at the top of the first and second layers of the specimen.

4.14 *Container*—A flat, round pan, for moisture absorption by soil-cement mixtures, about 12 in. (305 mm) in diameter and 2 in. (50 mm) deep.

4.15 *Measuring Device*—A measuring device suitable for accurately measuring the heights and diameters of test specimens to the nearest 0.01 in. (0.2 mm).

4.16 *Pans and Carriers*—Suitable pans for handling materials and carriers or trays for handling test specimens.

4.17 *Absorptive Pads*—¼-in. (6-mm) thick felt pads, blotters, or similar absorptive material for placing between specimens and specimen carriers.

4.18 *Graduate*—A graduated cylinder of 250-mL capacity for measuring water.

4.19 *Moisture Cans*—Suitable containers for moisture samples.

5. Method A—Using Soil Material Passing a No. 4 (4.75-mm) Sieve

5.1 *Preparation of Material for Molding Specimens:*

5.1.1 Prepare the soil sample in accordance with Method A of Test Methods D 558.

5.1.2 Select a sufficient quantity of the soil prepared as described in 5.1.1 to provide two (Note 1) compacted specimens and required moisture samples.

NOTE 1: (*Optional*)—Usually only one specimen (identified as No. 2) is required for routine testing. The other specimen (identified as No. 1) is made for research work and for testing unusual soils.

5.1.3 Add to the soil the required amount of cement conforming to Specification C 150 or Specification C 595. Mix the cement and soil thoroughly to a uniform color.

5.1.4 Add sufficient potable water to raise the soil-cement mixture to optimum moisture content at time of compaction and mix thoroughly.

5.1.5 When the soil used is a heavy textured clayey material, compact the mixture of soil, cement, and water in a container to a depth of about 2 in. (50 mm) using the rammer described in 4.2 or similar hand tamper, cover, and allow to stand for not less than 5 min but not more than 10 min to aid dispersion of the moisture and to permit more complete absorption by the soil-cement.

5.1.6 After the absorption period, thoroughly break up the mixture, without reducing the natural size of individual particles, until it will pass a No. 4 (4.75-mm) sieve, as judged by eye, and then remix.

5.2 *Molding Specimens:*

5.2.1 Form a specimen by immediately compacting the soil-cement mixture in the mold, with the collar attached, and later trimming the specimen in the same manner as directed for Method A of Test Methods D 558, and in addition scarify the tops of the first and second layers to remove smooth compaction planes before placing and compacting the succeeding layers. This scarification shall form grooves at right angles to each other, approximately ⅛ in. (3.2 mm) in width and ⅛ in. (3.2 mm) in depth and approximately ¼ in. (6.4 mm) apart.

5.2.2 During compaction, take from the batch a representative sample of the soil-cement mixture, weighing not less than 100 g, weigh immediately and dry in an oven at 230 ± 9°F (110 ± 5°C) for at least 12 h or to constant weight. Calculate the percentage of moisture as directed in Test Methods D 558 to check against design moisture content.

5.2.3 Weigh the compacted specimen and mold, remove the specimen from the mold, and calculate the oven-dry weight of each specimen in lb/ft^3 (g/cm^3) to check against design density.

5.2.4 Identify the specimen on a metal tag (or other suitable device) as No. 1 (Note 1) together with other needed identification marks and use to obtain data on moisture and volume changes during the test.

5.2.5 Form a second specimen as rapidly as possible and determine the percentage of moisture and oven-dry weight as described in 5.2.1 to 5.2.3. Identify this specimen as No. 2 together with other needed identification marks and use to obtain data on soil-cement losses during the test.

5.2.6 Determine the average diameter and height of the No. 1 specimen and calculate its volume.

5.2.7 Place the specimens on suitable carriers in the moist room and protect them from free water for a period of 7 days.

5.2.8 Weigh and measure the No. 1 specimen at the end of the 7-day storage period to provide data for calculating its moisture content and volume.

NOTE 2—It is important that all height and diameter measurements be accurate to within 0.01 in. (0.2 mm) and be taken at the same points on the specimen at all times.

5.3 *Procedure:*

5.3.1 At the end of the storage in the moist room, place water-saturated felt pads about ¼ in. (6 mm) thick, blotters, or similar absorptive material between the specimens and the carriers, and place the assembly in a freezing cabinet having a constant temperature not warmer than −10°F (−23°C) for 24 h and remove. Weigh and measure the No 1 specimen (volume and moisture change specimen).

5.3.2 Place the assembly in the moist room or suitable covered container having a temperature of 70°F (21°C) and a relative humidity of 100 % for 23 h and remove. Free potable water shall be made available to the absorbent pads under the specimens to permit the specimens to absorb water by capillary action during the thawing period. Weigh and measure the No. 1 specimen.

5.3.3 Give specimen No. 2 (soil-cement loss specimen) two firm strokes on all areas with the wire scratch brush. The brush shall be held with the long axis of the brush parallel to the longitudinal axis of the specimen or parallel to the ends as required to cover all areas of the specimen. Apply these strokes to the full height and width of the specimen with a firm stroke corresponding to approximately 3-lbf (13.3-N) force (Note 3). Eighteen to twenty vertical brush strokes are required to cover the sides of the specimen twice and four strokes are required on each end.

NOTE 3—This pressure is measured as follows: clamp a specimen in a vertical position on the edge of a platform scale and zero the scale. Apply vertical brushing strokes to the specimen and note the force necessary to register approximately 3 lbf (13.3 N).

5.3.4 After being brushed, the specimens shall be turned over end for end before they are replaced on the water-saturated pads.

5.3.5 The procedures described in 5.3.1 to 5.3.4 constitute one cycle (48 h) of freezing and thawing. Again place the specimens in the freezing cabinet and continue the procedure for 12 cycles.

NOTE 4—Weight determinations of specimen No. 2 before and after brushing are usually made at the end of each cycle when conducting research and making special investigations. Some specimens made of silty and clayey soils tend to scale on sides and ends particularly after about the sixth cycle of test. This scale shall be removed with a sharp-pointed instrument such as an ice pick, since the regular brushing may not be effective.

5.3.6 The No. 1 specimen may be discontinued prior to 12 cycles should measurements become inaccurate due to soil-cement loss of the specimen.

NOTE 5—If it is not possible to run the cycles continuously because of Sundays, holidays, or for any other reason, the specimens shall be held in the freezing cabinet during the layover period if possible.

5.3.7 After 12 cycles of test, dry the specimens to constant weight at 230°F (110°C) and weigh to determine the oven-dry weight of the specimens.

5.3.8 The data collected will permit calculations of volume and moisture changes of specimen No. 1 and the soil-cement losses of specimen No. 2 after the prescribed 12 cycles of test.

6. Method B—Using Soil Material Passing a ¾-in. (19.0-mm) Sieve

6.1 *Preparation of Material for Molding Specimens:*

6.1.1 Prepare the soil sample in accordance with Method B of Test Methods D 558.

6.1.2 Select and maintain separate representative samples of soil passing the No. 4 (4.75-mm) sieve and of saturated, surface-dry aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve so that the total sample will be enough to provide two (Note 1) compacted specimens and required moisture samples. The percentage, by oven-dry weight, of aggregate passing the ¾-in. (19.0-mm) sieve and retained on the No. 4 (4.75-mm) sieve shall be the same as the percentage passing the 3-in. (75-mm) sieve and retained on the No. 4 (4.75-mm) sieve in the original sample.

6.1.3 Add to the sample passing the No. 4 (4.75-mm) sieve, the amount of cement conforming to Specification C 150, or Specification C 595, required for the total sample described in 6.1.2. Mix the cement and soil thoroughly to a uniform color.

6.1.4 Add to the sample passing the No. 4 (4.75-mm) sieve, sufficient water to raise the total soil-cement mixture specified in 6.1.2 to optimum moisture content at time of compaction and facilitate moisture dispersion as described for Method A in 5.1.4 to 5.1.6.

6.1.5 After preparation of the mixture as described in 6.1.1 to 6.1.4, add the saturated, surface-dry aggregate to the mixture and mix thoroughly.

6.2 *Molding Specimens:*

6.2.1 Form a specimen by immediately compacting the soil-cement mixture in the mold (with the collar attached and later trimming the specimen in accordance with Method B of Test Methods D 558, and in addition as the mixture for each layer is placed in the mold, spade along the inside of the mold with a butcher knife before compaction to obtain uniform distribution of the material retained on the No. 4 (4.75-mm) sieve and scarify the tops of the first and second layers as described for Method A of these methods.

6.2.2 During compaction take from the batch a representative sample of the soil-cement mixture weighing not less than 500 g, weigh immediately, and dry in an oven at 230 ± 9°F (110 ± 5°C) at least 12 h or to constant weight to determine the moisture content to check against design moisture content.

6.2.3 Form a second specimen as rapidly as possible in the same manner.

6.2.4 Weigh each compacted specimen to check against design density, identify, measure the No. 1 specimen (Note 1), place in the moist room, and measure the No. 1 specimen again at the end of the 7-day storage period as described for Method A in 5.2.3 to 5.2.8 (Note 2).

6.3 *Procedure*—Proceed as directed in Method A (see 5.3).

7. Calculations

7.1 Calculate the volume and moisture changes and the soil-cement losses of the specimens as follows:

7.1.1 Calculate the difference between the volume of specimen No. 1 at the time of molding and subsequent volumes as a percentage of the original volume.

7.1.2 Calculate the moisture content of specimen No. 1 at the time of molding and subsequent moisture contents as a percentage of the original oven-dry weight of the specimen.

7.1.3 Correct the oven-dry weight of specimen No. 2 as obtained in 5.3.7 for water that has reacted with the cement and soil during the test and is retained in the specimen at 230°F (110°C) as follows:

$$\text{Corrected oven-dry weight} = (A/B) \times 100$$

where:

A = oven-dry weight after drying at 230°F (110°C), and
B = percentage of water retained in specimen plus 100.

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The percentage of water retained in specimen No. 2 after drying at 230°F (110°C) for use in the above formula can be assumed to be equal to the water retained in specimen No. 1. When No. 1 specimens are not molded, the foregoing data are not available and the average values prescribed in Table 1 are used.

7.1.4 Calculate the soil-cement loss of specimen No. 2 as a percentage of the original oven-dry weight of the specimen as follows:

$$\text{Soil-cement loss, \%} = (A/B) \times 100$$

where:

A = original calculated oven-dry weight minus final corrected oven-dry weight, and

B = original calculated oven-dry weight.

8. Report

8.1 The report shall include the following:

8.1.1 The designed optimum moisture and maximum density of the molded specimens,

8.1.2 The moisture content and density obtained molded specimens.

NOTE 6—Good laboratory practice permits the following tolerai between design factors and those obtained in the molded specimens

Moisture content	±1 percentage point
Density	±3 lb/ft^3 (0.048 g/cm^3)

8.1.3 The designed cement content, in percent, of molded specimens,

8.1.4 The maximum volume change, in percent, a maximum moisture content during test of specimen No and

8.1.5 The soil-cement loss, in percent, of specimen No

9. Precision and Accuracy

9.1 Precision and accuracy of this test procedure have been established. Data are available on the variability weight losses for duplicate specimens. These data will analyzed and a statement will be included in the r revision.

CDU 631.423

Noviembre 1977

NORMA ESPAÑOLA

Determinación con agua oxigenada del contenido de materia orgánica en los suelos

UNE
7-368-77

1 OBJETO

Esta norma tiene por objeto describir un método para la determinación aproximada de la materia orgánica contenida en los suelos.

2 FUNDAMENTO DEL METODO

Este método se funda en la acción del agua oxigenada sobre el humus y la materia orgánica coloidal. Por diferencia entre el peso de la muestra inicial seca y el peso seco después del tratamiento, se calcula la proporción de materia orgánica volatilizada por la oxidación.

Para la determinación del contenido total en materia orgánica del suelo, se seguirá el método de oxidación con dicromato potásio descrito en la norma UNE 7 441.

3 APARATOS Y MATERIAL NECESARIOS

3.1 Vaso de precipitados
Un vaso de precipitados de 600 cm^3, con vidrio de reloj que sirva de tapa y una varilla de vidrio.

3.2 Plancha de calefacción
Una plancha de calefacción, con posibilidad de regular la temperatura a 60°C.

3.3 Balanza que aprecie 0,01 g

3.4 Estufa de desecación regulable a 105° - 110°C

3.5 Probeta de 100 cm^3

3.6 Mortero con su pistilo

3.7 Agua oxigenada de concentración 6 por 100 (20 volúmenes)

4 PROCEDIMIENTO OPERATORIO

4.1 Se opera con la fracción de suelo que pasa por el tamiz 2 UNE 7 050. Se pulveriza, con el mortero, una porción representativa del suelo y se seca en estufa a una temperatura comprendida entre 105° y 110°C, hasta peso constante. Se pesan unos 20 g con precisión de 0,01 g y se coloca ésta muestra en el vaso de precipitados previamente seco y tarado.

4.2 Se añaden 100 cm^3 de agua oxigenada de 20 volúmenes y se agita.

4.3 El vaso, tapado con el vidrio de reloj, se coloca sobre la plancha de calefacción a 60°C, durante 2 h, agitando con la varilla de vez en cuando.

4.4 Transcurridas las 2 h, se añade una nueva cantidad de agua oxigenada. Si da reacción, lo cual se aprecia por la efervescencia, se añaden otros 100 cm^3 de agua oxigenada. Este proceso se repite cuantas veces sea necesario, hasta que al hacer la prueba de añadir una pequeña cantidad, después de las 2 h, no se produzca reacción.

4.5 Se evapora el agua (preferiblemente al baño de María) y después se deseca en estufa a temperatura comprendida entre 105° y 110°C hasta peso constante y se pesa con precisión de 0,01 g.

5 RESULTADO DEL ENSAYO

La materia orgánica se expresa en tanto por 100 respecto a la muestra seca y se calcula por la fórmula siguiente:

$$\text{Porcentaje de materia orgánica} = \frac{P - P'}{P} \times 100$$

siendo:

P = Muestra seca inicial, en gramos.

P' = Muestra seca después del ensayo, en gramos.

Si hubiera partículas gruesas, retenidas en el tamiz 2 UNE 7 050, se calcula el tanto por ciento de materia orgánica correspondiente a la muestra original, multiplicando el resultado anterior por el tanto por ciento de suelo que pasa por el tamiz 2 UNE 7 050 y dividido por 100.

Continúa en página 2

Las observaciones relativas a la presente norma deben ser dirigidas al
IRANOR – Serrrano, 150 – Madrid (6)

CDU 543.3:691.32 Una Norma Española 2.58

Determinación cualitativa de hidratos de carbono en aguas de amasado para morteros y hormigones

UNE
7 132

1. Objeto

Esta norma tiene por objeto describir un método de ensayo que ponga de manifiesto de una forma rápida y sencilla la presencia o ausencia de hidratos de carbono en las aguas utilizadas en la fabricación de morteros y hormigones. La presencia de hidratos de carbono en las aguas que van a utilizarse para el amasado excluye la posibilidad de su empleo.

2. Fundamento del método

El procedimiento se basa en la investigación de la sacarosa con disolución alcohólica de α-naftol en medio ácido, y en la investigación de la glucosa y otros glúcidos reductores mediante el líquido de Fehling.

3. Aparatos necesarios

La realización de este ensayo no requiere el uso de aparatos especiales.

4. Reactivos necesarios

4,1 **Disolución alcohólica de α-naftol.** Se disuelven 6 g de α-naftol en 100 cm^3 de alcohol etílico de 96°.

4,2 **Reactivo de Fehling,** compuesto de las disoluciones A y B.

4,21 **Disolución A.** Se prepara disolviendo en agua 69,3 g de sulfato de cobre cristalizado ($SO_4Cu \cdot 5H_2O$) y diluyendo hasta 1 l.

4,22 **Disolución B.** Se prepara disolviendo en agua 364 g de tartrato sódicopotásico y 100 g de hidróxido sódico y diluyendo hasta 1 l. Esta disolución se conserva en un frasco con tapón de goma.

5. Método de ensayo

5,1 **Investigación de la sacarosa.** Se toman 50 cm^3 del agua sometida a ensayo y se le añaden 3 gotas de disolución alcohólica de α-naftol y 1 cm^3 de ácido sulfúrico concentrado ($d = 1,84$), se agita y se observa si aparece una coloración violada, que indica la presencia de sacarosa.

5,2 **Investigación de la glucosa y otros glúcidos reductores** (excepto rafinosa). En un tubo de ensayo se mezclan volúmenes iguales de las disoluciones A y B, que constituyen el reactivo de Fehling, y se hierven. Si los reactivos están en condiciones de uso no debe producirse ninguna decoloración ni cambio de color.

Sobre la mezcla de las disoluciones A y B se vierte un volumen aproximadamente igual del agua objeto de análisis y se vuelve a hervir. Cualquier alteración de color indica la presencia de substancias reductoras.

6. Correspondencia con otras normas

Esta norma concuerda con la NE 1.22-c del I. T. C. C.

NORMA

CDU 624. 131. 3

Diciembre 1975

NORMA ESPAÑOLA

Contenido de sulfatos solubles en los suelos

UNE 7-370-75

Instituto Nacional de Racionalización y Normalización (IRANOR) – Serrano, 150 – Madrid (6) – Teléfono 261 70 00 – Reproducción prohibida

1 OBJETO

Esta norma tiene por objeto establecer el método a seguir para determinar la proporción de sulfatos solubles en agua, pasándolos a disolución mediante agitación con agua y precipitando luego los sulfatos disueltos con solución de cloruro bárico según la reacción siguiente:

$$SC_4M + Cl_2Ba = SO_4Ba + Cl_2M$$

2 APARATOS Y MATERIALES NECESARIOS

2.1 Tamices 2 y 0,40 UNE 7-050.

2.2 Mortero con su pistilo.

2.3 Frasco para agitación de unos 1000 cm^3 de capacidad, con cierre hermético mediante tapón de goma, y forma adecuada para acoplarse al aparato agitador.

2.4 Aparato para agitar frascos que permita mantener el suelo en suspensión durante el tiempo de agitación.

2.5 Un matraz aforado de 500 cm^3 y otro de 250 cm^3.

2.6 Dos vasos de 600 cm^3 con varilla de vidrio y vidrio de reloj que pueda taparles.

2.7 Frasco lavador con agua destilada caliente.

2.8 Pipeta de 10 cm^3.

2.9 Embudo de vidrio.

2.10 Crisol de porcelana. Triángulo y trípode soporte si se calcina con mechero.

2.11 Horno de calcinación eléctrico o, en su defecto mechero de gas.

2.12 Balanza analítica.

2.13 Estufa de desecación regulable a 75-80° C.

2.14 Desecador.

2.15 Papel indicador de pH.

2.16 Papel de filtro de poro fino y de cenizas conocidad.

2.17 Acido clorhídrico N/20 (a 4 cm^3 de ácido clorhídrico concentrado añadir agua destilada hasta completar un volumen de un litro).

2.18 Disolución de cloruro bárico al 5 por 100 (5 g de $Cl_2Ba.2H_2O$ en 100 cm^3 de agua).

2.19 Disolución de nitrato de plata (1,7 g en 100 cm^3 de agua).

2.20 Agua destilada.

3 PROCEDIMIENTO OPERATORIO

3.1 Preparación de la muestra

Se utiliza la fracción que pasa por el tamiz 2 UNE 7-050, preparada de acuerdo con la norma UNE 7-327. Se obtienen unos 50 g por cuarteo de esta fracción y se pulverizan en el mortero hasta que todo pase por el tamiz 0,40 UNE 7-050. Se seca hasta peso constante en estufa regulada entre 75 y 80° C y se pesa 10 g con precisión de 0,01 g.

3.1.1 **Observaciones.** La cantidad de muestra debe variarse según la proporción de sulfatos, con objeto de asegurar su completa solubilidad, y de obtener una cantidad conveniente de sulfato de bario precipitado. Como orientación: hay que utilizar menos de 10 g de suelo en 500 cm^3 de agua cuando la proporción de yeso en el suelo sea superior al 5 %. Tomando 1 g de suelo se tiene seguridad de la disolución total de los sulfatos, aunque la muestra fuera 100 por 100 de yeso.

Cuando la muestra contiene material grueso, se supone que todos los sulfatos quedan en los finos que pasan

Continúa en página 2

Las observaciones relativas a la presente norma deben ser dirigidas al por el tamiz 2 UNE 7-050, para asegurar esto, hay que hacer una inspección visual de los gruesos; si se aprecian nódulos de yeso, hay que triturarlos en mortero hasta que pasen por el tamiz.

Para el secado se limita la temperatura a 80° C, porque subiendo más puede perderse agua de cristalización en el yeso.

3.2 Disolución de los sulfatos

3.2.1 Se introduce la muestra en el frasco o recipiente de agitación y se añaden 500 cm^3 de agua destilada exactamente medidos en un matraz aforado.

3.2.2 Se coloca el frasco en el agitador y se agita durante 45 min.

3.2.3 Se decanta la suspensión de suelo contenido en el frasco. Si no se clarifica el líquido se añaden dos gotas de ácido clorhídrico concentrado.

3.2.4 Se extrae el líquido clarificado, mediante sifón o con la pipeta de 100 cm^3 sin perturbar el sedimento, hasta obtener 250 cm^3 de líquido claro exactamente medido con el matraz aforado.

3.2.5 Se filtra el líquido del matraz, recogiendo el filtrado sobre el vaso de 600 cm^3. Se lava el filtro dos o tres veces con agua destilada, que previamente se ha pasado por el matraz para lavarlo, y se recoge el agua de lavado sobre el mismo vaso. Se añaden 20 cm^3 de ácido clorhídrico N/20.

3.3 Precipitación, filtración y calcinación

3.3.1 Se calienta a ebullición el líquido filtrado y se precipita añadiéndole disolución de cloruro bárico con una pipeta, poco a poco, hasta que no se produzca más precipitado. Durante una hora se mantiene el vaso en reposo y a temperatura por debajo y próxima al punto de ebullición (un baño maría resulta muy apropiado).

3.3.2 Al final de la hora el precipitado se habrá depositado en el fondo y el líquido quedará claro. Se añade entonces unas gotas de la disolución de cloruro bárico para comprobar que la precipitación fué completa. En caso de formarse precipitado, se repiten las operaciones del *apartado 3.3.1.*

3.3.3 Después de dejar en reposo durante 12 horas, se filtra empleando un filtro de cenizas conocidas. Se pasa primero el líquido claro, después se arrastra el precipitado al filtro y se lava sobre él con agua destilada y caliente hasta que el agua de lavado, después de pasar por el filtro, no dé precipitado con la disolución de nitrato de plata.

3.3.4 Se coloca el papel de filtro húmedo con el precipitado en un crisol de porcelana previamente tarado. Cuando se dispone de horno de calcinación eléctrico, se coloca el crisol con el papel dentro del horno y se sube la temperatura entre 800 y 900° C, manteniéndola unos 15 min.

Si ha de calcinarse con mechero, se calienta primero con poca llama para secar el papel lentamente y se continúa hasta carbonizar el papel sin que llegue a arder en ningún momento. Una vez carbonizado el papel, se aumenta la llama para incinerar y, una vez blanco el precipitado, se calcina hasta el rojo durante 10 min.

3.3.5 Se deja enfriar primero el crisol al aire y, cuando haya perdido temperatura se termina el enfriamiento en un desecador. Finalmente, se pesa con precisión de 0,001 g.

4 RESULTADOS

4.1 Restando la tara del crisol más las cenizas del papel, del peso del crisol con el precipitado después de la calcinación, se obtiene el peso del precipitado de SO_4Ba.

4.2 El resultado se puede expresar en tanto por ciento de SO_3 respecto a la muestra analizada mediante la siguiente fórmula:

$$\%\ SO_3 = \frac{(P_p \times 0{,}34299)}{P_m} \times 100$$

Siendo:

P_p = Peso del precipitado de SO_4Ba.

P_m = Peso de la muestra analizada, o sea:

$$\frac{cm^3 \text{ sol. analizada}}{cm^3 \text{ agua en frasco}} \times \text{g de suelo en el frasco}$$

Cuando la muestra contiene partículas gruesas, hay que referir el resultado a la muestra original; para ello se multiplica el resultado anterior por el tanto por ciento de suelo que pasa por el tamiz 2 UNE 7-050 y se divide por 100.

4.3 Si se quiere expresar el resultado en tanto por ciento de yeso ($SO_4Ca.2H_2O$) basta multiplicar el valor obtenido en el apartado anterior por 2,1505.

Tengase en cuenta, sin embargo, que puede suceder que solo una parte del sulfato esté formando yeso.

5 NORMAS PARA CONSULTA

UNE 7-050 - *Cedazos y tamices de ensayo.*

UNE 7-327 - *Preparación de muestra para los ensayos de suelo.*

6 CORRESPONDENCIA

Esta norma concuerda totalmente con la NLT 120/72.

Norma 39 UNE 7131 SULFATOS EN EL AGUA

CDU 543.3:545.1:691.32 Una Norma Española 2.5

Determinación del contenido total de sulfatos en aguas de amasado para morteros y hormigones

UNE 7 131

1. Objeto Esta norma concuerda con la NE-1.22b del I.T.C.C., y esencialmente con la D 516-49 de la A.S.T.M

Esta norma tiene por objeto describir un método de ensayo utilizable para la determinación del ión sulfato en l aguas de amasado empleadas en la fabricación de morteros y hormigones.

2. Fundamento del método

El procedimiento se basa en la precipitación del ión sulfato con cloruro bárico.

3. Toma de muestras

La muestra se toma directamente en las aguas naturales cuyo contenido de sílice sea inferior al 1 % del conteni total de sulfato. Si el contenido de sílice es mayor, será necesario eliminarla antes de proceder a la determinaci de sulfatos.

4. Aparatos necesarios

La realización de este ensayo no requiere el uso de aparatos especiales.

5. Reactivos necesarios

5,1 **Disolución de cloruro bárico al 10 %.** Se disuelven 100 g de $Cl_2Ba \cdot 2H_2O$ en agua y se diluye hasta 1 l.

5,2 **Disolución de ácido clorhídrico (1 : 9).** Se mezcla un volumen de ClH concentrado (*d* = 1,18) con 9 volúmenes agua destilada.

5,3 **Disolución de nitrato de plata.** Se disuelven 17 g de NO_3Ag en agua destilada que contenga 1 cm³ de NO (*d* = 1,42) y se diluye a 1 l.

6. Método de ensayo

Se toma en un matraz aforado 100 ó 200 cm³ de agua filtrada, según la cantidad total de sulfatos que conteng y se pasan a un vaso de precipitados, se completa con agua destilada hasta un volumen de 250 cm³. Luego, se aju el pH de la muestra, añadiendo ácido clorhídrico o amoníaco, hasta el punto neutro del anaranjado de metilo, y continuación se adicionan 10 cm³ de ácido clorhídrico (1 : 9). Si la disolución no queda clara, es necesario filtrarla, vando el vaso y el papel de filtro con agua destilada caliente.

Se calienta el filtrado hasta ebullición y entonces se añaden, gota a gota, 10 cm³ de disolución caliente de Cl_2Ba pa precipitar totalmente los sulfatos, continuándose la ebullición durante unos minutos. Se mantiene, hasta el final, el va tapado con un vidrio de reloj y en digestión sobre el baño de vapor durante 3 h. Realizada esta operaci se filtra el contenido del vaso y se lava con agua caliente hasta eliminación de cloruros en las aguas de lavad Esta eliminación debe comprobarse añadiendo a los filtrados unas gotas de disolución de NO_3Ag hasta que no produzca el precipitado blanco cuajoso. Debe evitarse también lavar excesivamente el precipitado y, si al añadir las aguas de lavado la disolución de NO_3Ag se produce sólo una leve opalescencia, se dará el lavado como suficien

Se coloca el papel de filtro con el precipitado en un crisol de porcelana previamente pesado y se quema, con pa temperatura al principio, para evitar que el papel arda. La temperatura se eleva gradualmente, manteniendo por timo el crisol a 800° C durante 1 h. Se deja enfriar en un desecador y se pesa.

7. Obtención y precisión de los resultados

El contenido total de sulfatos del agua analizada se expresa en SO_3 (g/l) y se calcula utilizando la fórmula guiente:

$$SO_3\,(g/l) = \frac{0{,}3429\,(G_1 - G) \times C}{V}$$

G_1 = Peso del crisol y producto calcinado

G = Peso del crisol calcinado

C = Factor para referir el resultado a 1 000 cm³, habida cuenta del volumen de muestra utilizado en el ensayo

V = Centímetros cúbicos de muestra tomada.

El resultado se expresará con dos cifras.

Continú

CDU 624.131.3 Abril 1975

NORMA
ESPAÑOLA

Reconocimiento de sulfatos solubles en los suelos

UNE
7 - 369 - 75

Instituto Nacional de Racionalización y Normalización (IRANOR) – Serrano, 150 – Madrid (6) – Teléfono 261 70 00 – Reproducción prohibida

1 OBJETO

Esta norma tiene por objeto describir el método para reconocer la existencia de sulfatos solubles pasándolos a disolución con agua y precipitando luego los sulfatos disueltos con disolución de cloruro bárico según la reacción siguiente:

$$SO_4M + Cl_2Ba \rightarrow SO_4Ba + Cl_2M$$

2 APARATOS Y MATERIAL NECESARIOS

2.1 Un vaso de 250 cm^3.

2.2 Un tubo de ensayo.

2.3 Un embudo de vidrio.

2.4 Acido clorhídrico concentrado.

2.5 Solución de cloruro bárico al 5 por 100 (5 g de $Cl_2Ba \cdot 2H_2O$ en 100 cm^3 de agua).

2.6 Agua destilada.

3 PROCEDIMIENTO OPERATORIO

3.1 De una muestra representativa del material, se toma una cantidad aproximada entre 2 y 5 g y se coloca en el vaso de 250 cm^3.

3.2 Se añaden unos 50 cm^3 de agua destilada, agitando con una varilla de vidrio hasta conseguir una buena dispersión.

3.3 Sobre la suspensión de suelo anterior y con agitación constante se añade gota a gota ácido clorhídrico concentrado hasta reacción ácida al papel de tornasol.

Si el suelo tiene carbonatos, se producirá efervescencia y el ácido quedará consumido en el ataque de éstos. Se continúa añadiendo ácido clorhídrico hasta reacción ácida.

3.4 Se calienta a ebullición durante unos minutos.

3.5 Se filtra a través de un papel de filtro corriente y se recogen unos 5 cm^3 del líquido filtrado en el tubo de ensayo. Se comprueba si tiene reacción ácida. En caso contrario, se añade una gota de ácido clorhídrico concentrado.

3.6 Se añade al líquido filtrado unas gotas de solución de cloruro bárico y se agita. La aparición de un precipitado blanco indica la existencia de sulfatos.

Las observaciones relativas a la presente norma deben ser dirigidas al
IRANOR - Serrano, 150 - Madrid (6)

NLT-116/91

Determinación del contenido de carbonato en los suelos

1 OBJETO Y CAMPO DE APLICACION

1.1 La presente norma tiene por objeto especificar el método para determinar el contenido de carbonatos de un suelo.

1.2 Se utiliza el método del calcímetro de Bernard, que se funda en la descomposición de los carbonatos por la asociación del ácido clorhídrico, con desprendimiento de anhídrido carbónico gaseoso, según la reacción expresada a continuación:

$$CO_3M + 2\,ClH = Cl_2M + CO_2 + H_2O$$

En este método se calibra el aparato con carbonato cálcico puro, por lo que no es necesario tener en cuenta la presión y la temperatura.

2 NORMAS PARA CONSULTA

UNE 7 050. «Cedazos y tamices de ensayo».
NLT-101/72. «Preparación de muestra para los ensayos de suelo».

3 APARATOS Y MATERIAL NECESARIOS

3.1 Un calcímetro como el representado en la figura 1 compuesto por:

3.1.1 Soporte adecuado.

3.1.2 Tubo bureta de 100 cm^3 de capacidad, graduado en 0,2 cm^3.

3.1.3 Tubo de nivel con depósito.

3.1.4 Matraz erlenmeyer, de unos 200 cm^3, con un tapón de goma atravesado por un tubo de vidrio.

3.1.5 Tubo de vidrio cerrado por un extremo, de longitud algo menor que el diámetro del fondo del matraz, y de unos 3 cm^3 de capacidad.

3.1.6 Tubo de goma o de plástico flexible, adecuado para conectar la parte inferior de la bureta con tubo de nivel y la superior con el tapón del matraz erlenmeyer.

3.2 Mortero con su pistilo.

3.3 Rodel de corcho.

3.4 Balanza que aprecie 0,001 g.

3.5 Estufa de desecación cuya temperatura sea regulable hasta 115 °C.

3.6 Un papel satinado de color negro u otro color oscuro, de 30 × 60 mm y doblado en forma angular.

3.7 Pipeta o cuentagotas.

3.8 Pincel muy fino.

3.9 Disolución de cloruro sódico, próxima a la saturación, para usarla como líquido de cierre en el tubo de nivel.

3.10 Carbonato cálcico muy puro.

3.11 Acido clorhídrico diluido, aproximadamente dos volúmenes de agua y uno de ácido clorhídrico concentrado (Nota 1).

Nota 1. Acido clorhídrico concentrado comercial utilizado como reactivo de laboratorio.

3.12 Tamiz 250 µm. UNE 7 050 (Nota 2).

Nota 2. 1 µm (1 micrómetro) = 10^{-3} mm.

4 PREPARACION DE LA MUESTRA

4.1 De una muestra representativa del suelo que se quiere analizar, tomar 10 g según el procedimiento descrito en la norma UNE 103 100.

4.2 Secar con estufa a 105-115 °C, hasta masa constante y pulverizar en el mortero de manera que todas las partículas pasen por el tamiz 250 µm UNE 7 050.

5 METODO OPERATORIO

5.1 Tarado del aparato con carbonato cálcico puro

5.1.1 Llenar el tubo de nivel y la bureta con la disolución de cloruro sódico.

5.1.2 Con la balanza indicada en el capítulo 2 y sobre el papel especificado, tomar 0,200 g de carbonato cálcico puro previamente secado en estufa hasta masa constante.

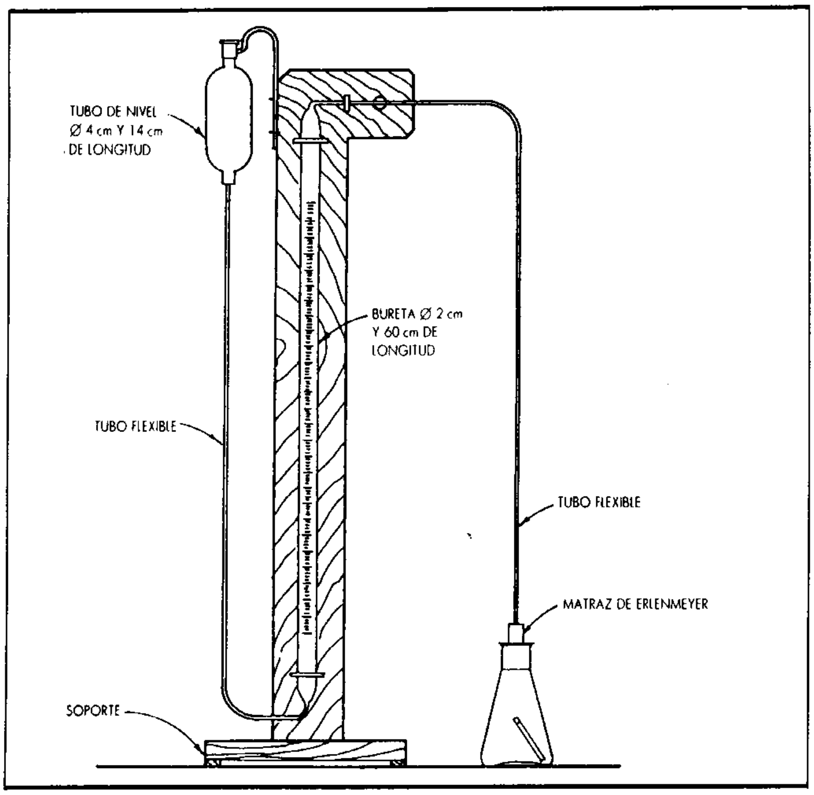

FIGURA 1. Calcímetro de Bernard.

5.1.3 Introducir el carbonato cálcico, dentro del matraz erlenmeyer, de forma que caiga en el fondo y ninguna partícula quede en las proximidades de la boca. Si quedasen partículas adheridas al papel, arrastrarlas dentro del matraz por medio de golpecitos o usando un pincel si fuera necesario.

5.1.4 Llenar el tubo de vidrio con la disolución del ácido clorhídrico por medio de una pipeta o cuentagotas, procurando que no quede ácido en la parte exterior del tubo. En caso de que caiga algo, lavar el tubo por fuera con el frasco lavador.

5.1.5 Introducir el tubo con ácido clorhídrico dentro del matraz deslizándolo por la pared con cuidado, para que quede vertical y no se derrame nada. Dejar el matraz en posición para que no se caiga el tubo de vidrio, por ejemplo, sobre un rodel de corcho de tamaño apropiado.

5.1.6 Mover el depósito del tubo de nivel para que quede enrasado el nivel de la disolución con el de la bureta en la división cero.

5.1.7 Manteniendo el tubo de nivel fijo, con la otra mano tomar el tapón de goma y cerrar el matraz apretándolo para que ajuste bien sin que se vuelque el tubo con la disolución de ácido clorhídrico. Enrasar de nuevo el tubo de nivel y hacer la lectura de las divisiones de la bureta donde se ha conseguido el enrase. Después de hecha esta lectura, no volver a apretar el tapón.

5.1.8 Mover el matraz para que el tubo vuelque y vacíe el ácido, el cual empezará a reaccionar con el carbonato.
Es necesario que toda la muestra tome contacto con el ácido.

5.1.9 Desplazar el tubo de nivel lo necesario para enrasar con el nivel de solución en la bureta hasta que se estabilice en una lectura. Cuando hayan transcurrido de dos a tres minutos con el enrase mantenido en la misma lectura de la bureta, anotar ésta.

Nota. La operación del tarado es necesaria hacerla siempre que cambie la temperatura ambiente o la presión atmosférica.

TARADO CON CARBONATO CALCICO				
CARBONATO CALCICO + TARA			MEDIA CARBONATO CALCICO (G)	
TARA			MEDIA VOLUMEN CO_2 (V)	
CARBONATO CALCICO			$\frac{G}{V}$	
LECTURA CO_2 INICIAL			FECHA	
LECTURA CO_2 FINAL			HORA	
VOLUMEN EN cm^3 CO_2				

MUESTRA Nº								
MUESTRA + TARA								
TARA								
MUESTRA (g)								
LECTURA CO_2 INICIAL								
LECTURA CO_2 FINAL								
VOLUMEN EN cm^3 CO_2 (v)								
$N = \frac{G}{V} v$								
$\% \ CO_3Ca = \frac{N}{g} \times 100$								
MEDIA CO_3Ca (a)								
$\% \ CO_2 = a \times 0.4$								

OBSERVACIONES ______________________________

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FIGURA 2. Impreso tipo para toma de datos.

En general, se hace cada jornada de trabajo e incluso se repite dentro de cada jornada si por efecto de la calefacción en invierno o del sol en verano varía la temperatura ambiente.

5.2 Ensayo con la muestra

5.2.1 Proceder en todo igual que en el tarado, pero en vez de carbonato cálcico emplear la muestra de suelo preparada según el capítulo 3.

5.2.2 Si en el ensayo con 0,200 g de la muestra de suelo se producen menos de 5 cm³ de anhídrido carbónico, repetir la determinación con 1,000 g de muestra.

5.3 Toma de datos

5.3.1 Para facilitar la toma de datos puede utilizarse un impreso como el de la figura 2.

6. OBTENCION Y EXPRESION DE LOS RESULTADOS

6.1 Por diferencia entre la lectura final de la bureta y la inicial se obtienen los centímetros cúbicos de anhídrido carbónico gaseoso producido en la reacción.

6.2 El contenido de carbonatos de la muestra, expresado en tanto por ciento de carbonato cálcico, se obtiene por medio de la siguiente expresión:

$$\% \text{ de carbonato cálcico} = \frac{0{,}2 \cdot V}{g \cdot U} \cdot 100$$

siendo:

0,2 = gramos de carbonato cálcico empleado en el tarado.
V = anhídrido carbónico medido en el ensayo de la muestra en centímetros cúbicos.
g = gramos de muestra ensayada.
U = anhídrido carbónico medido en el ensayo de tarado con CO_3Ca en centímetros cúbicos.

Nota. En este método se supone que los carbonatos presentes están en forma de CO_3Ca. Sin embargo, debe tenerse en cuenta que puedan existir carbonatos de otros elementos. Por esta razón, el contenido en carbonatos se expresa, a veces, en tanto por ciento de anhídrido carbónico (CO_2). Para ello basta multiplicar el resultado obtenido en el capítulo 5 por el coeficiente 0,44.
Si existe dolomita en el suelo, la reacción con el ácido clorhídrico será más lenta. Si se quiere determinar aproximadamente las cantidades de carbonato cálcico, por un lado, y de dolomita por el otro, presentes en el suelo, puede hacerse realizando dos lecturas, una a los treinta segundos y otra a los treinta minutos, correspondiendo la primera de ellas al porcentaje de carbonato cálcico y la segunda al total de carbonato cálcico y dolomita.

7 CORRESPONDENCIA CON OTRAS NORMAS

La presente norma concuerda esencialmente con: NLT-111/72.