

FOTO N°9 - Las muestras trituradas se colocaron en un desecador que contiene silica-gel hasta peso constante inmediatamente despues se realizaron los analisis de porosidad.



FOTO N 10 - Equipo utilizado para medir la porosidad marca CARLO ERBA, funciona a partir de la intrusión de mercurio, tiene una capacidad de 2000 bares de presion, puede determinar la porosidad hasta 37A

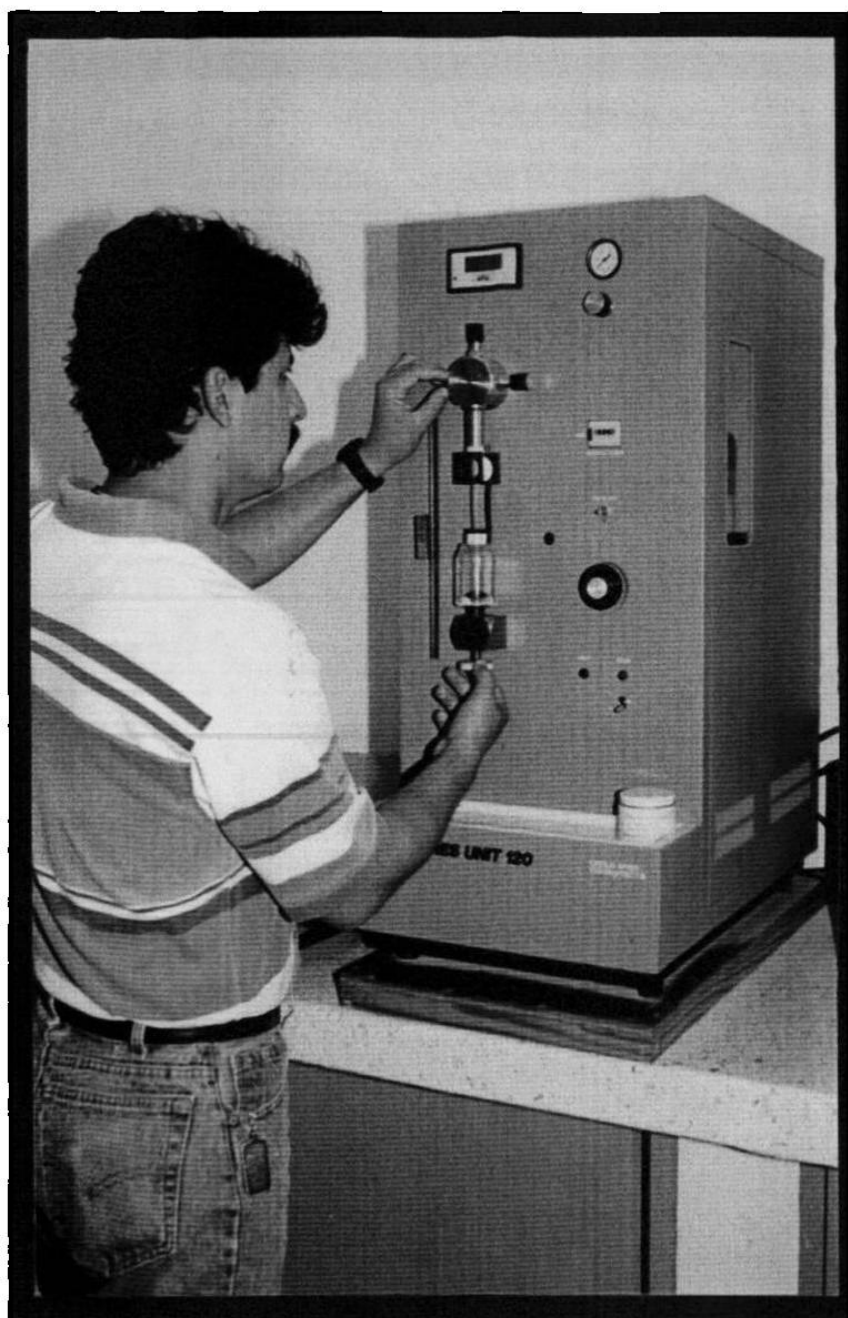


FOTO Nº11.- Unidad Macroporo 120 utilizada para el llenado de mercurio y determinación de poros con radios hasta 18,000 Å

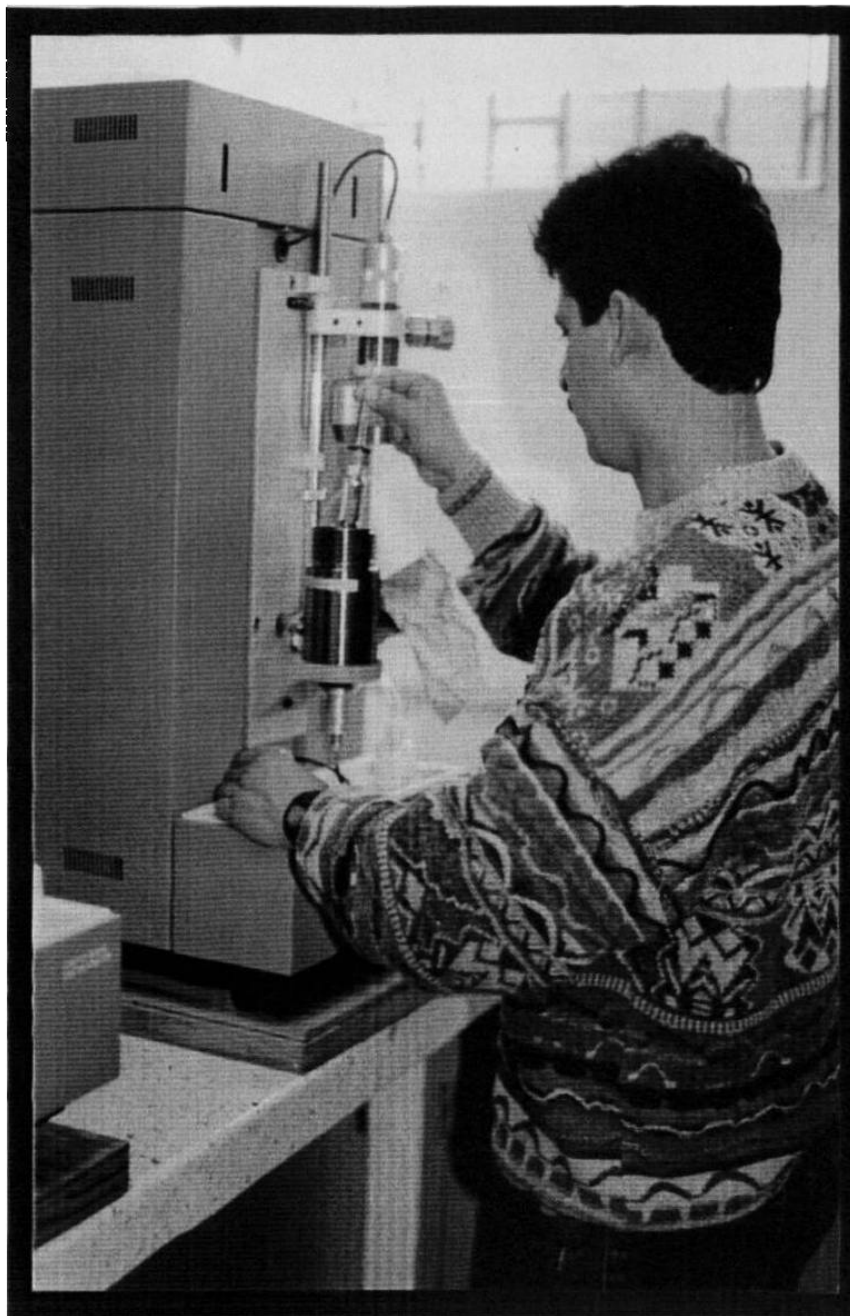


FOTO N°12.- Porosimetro 2000. Se muestra el acceso de la muestra al interior de la camara donde se aplica la presión de 2000 bares, el equipo envia los datos a la unidad central para su tratamiento.

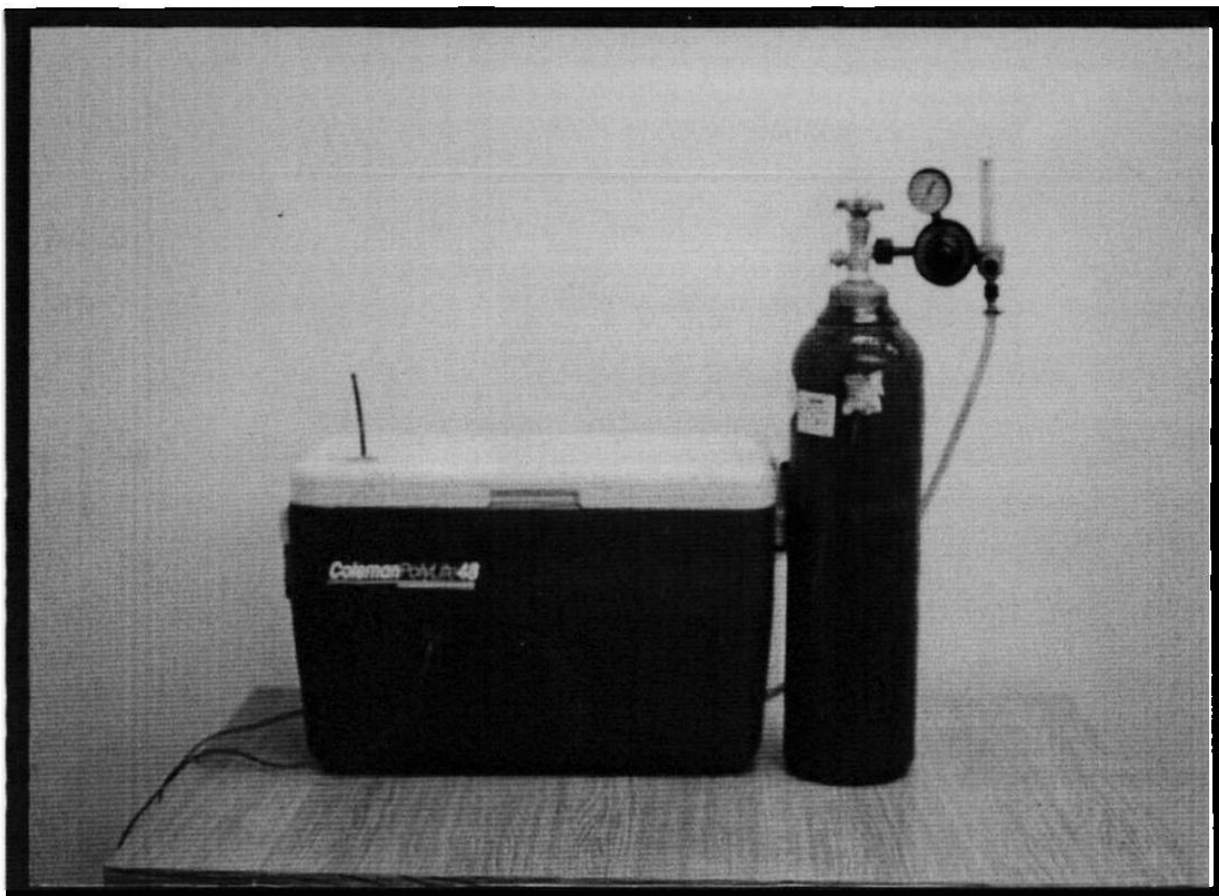


FOTO N°13.- Se fabricó una cámara de carbonatacion acelerada con ventilador de recirculacion en el interior. También se muestra el tanque de gas con una concentracion de 5° de CO₂.

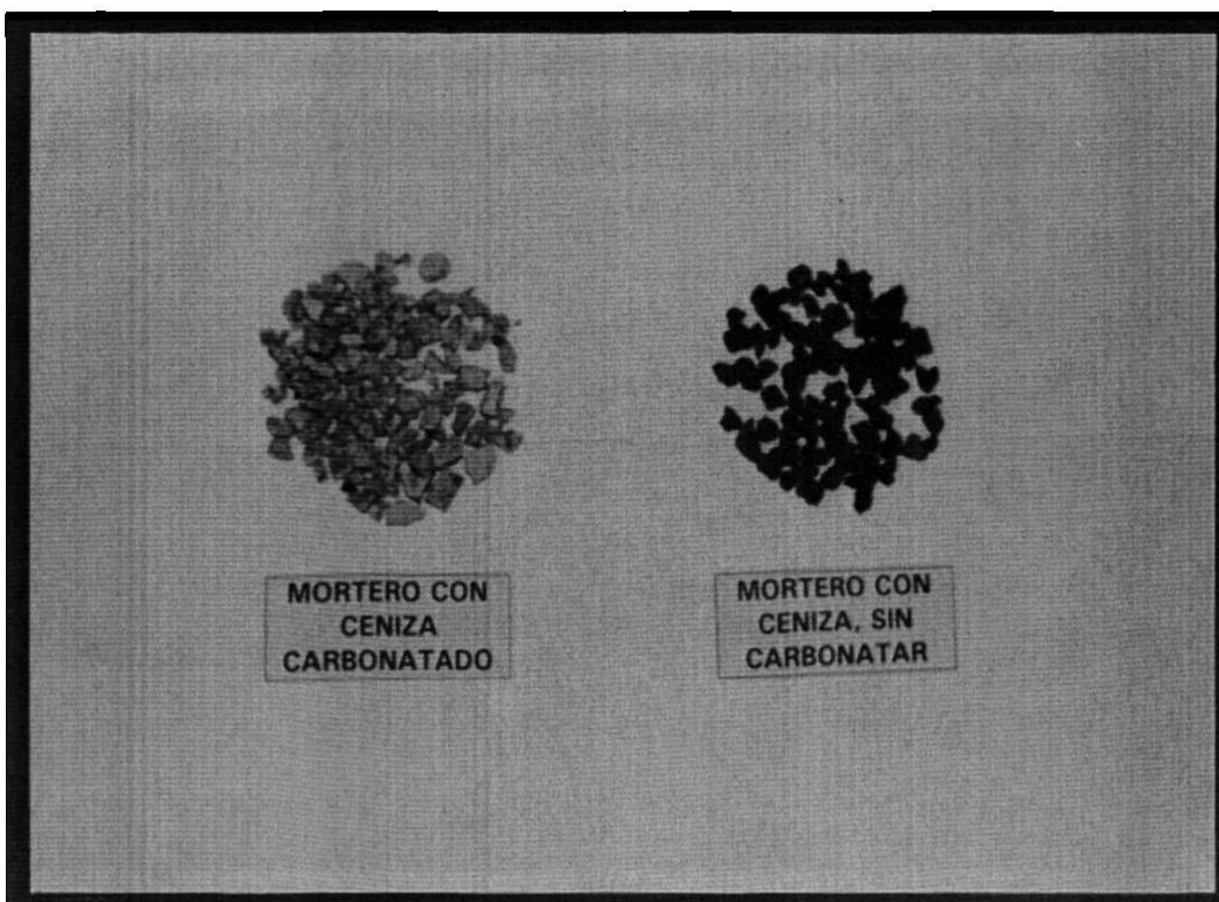


FOTO N°14 - Morteros carbonatados y no carbonatados, se utilizo una solucion de 1° de fenolftaleina en alcohol isopropilico para determinar la condición de carbonatacion. La coloracion es debida a un alto pH o a la presencia de hidróxido de calcio.

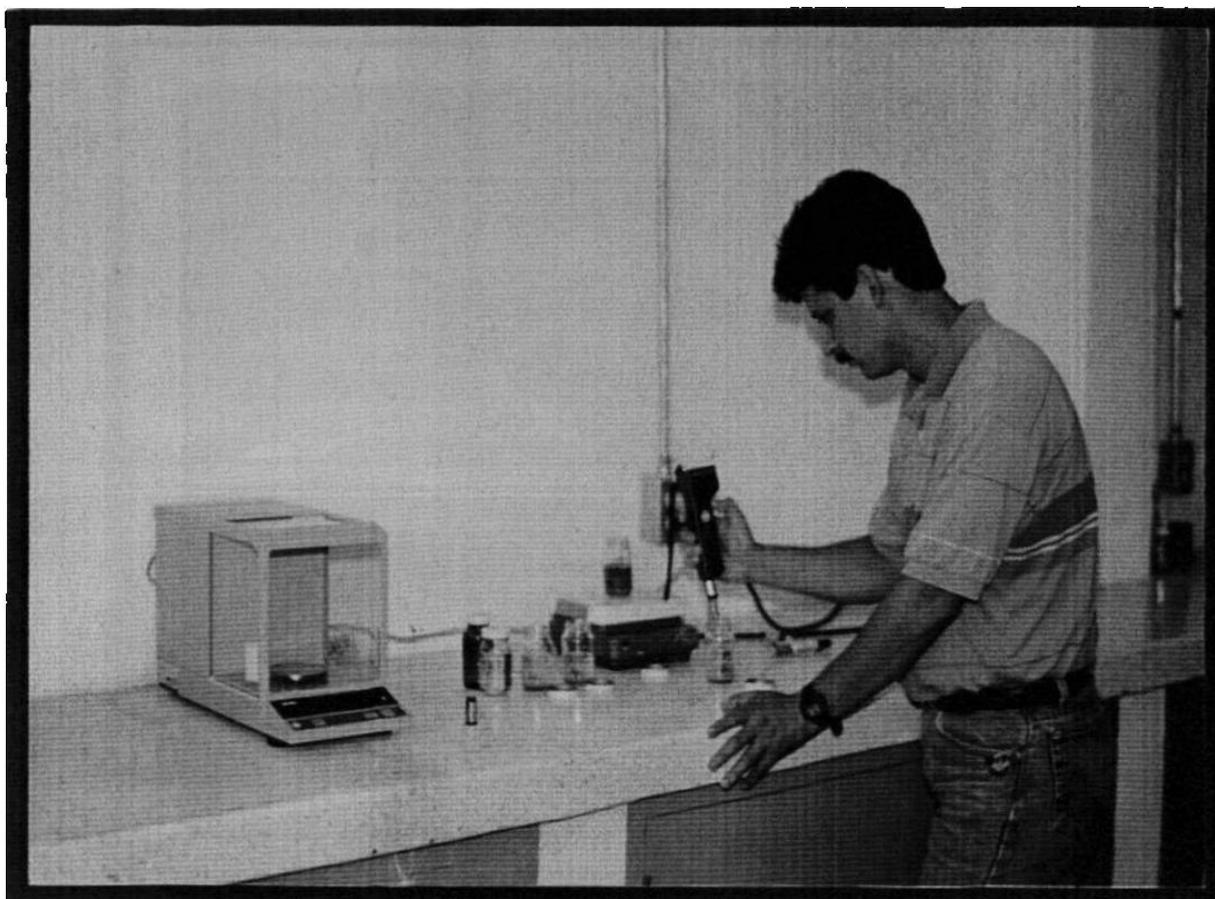


FOTO N°15 - Mediante el uso del potenciómetro digital se determinó el valor del pH de muestras pulverizadas carbonatadas y no carbonatadas.

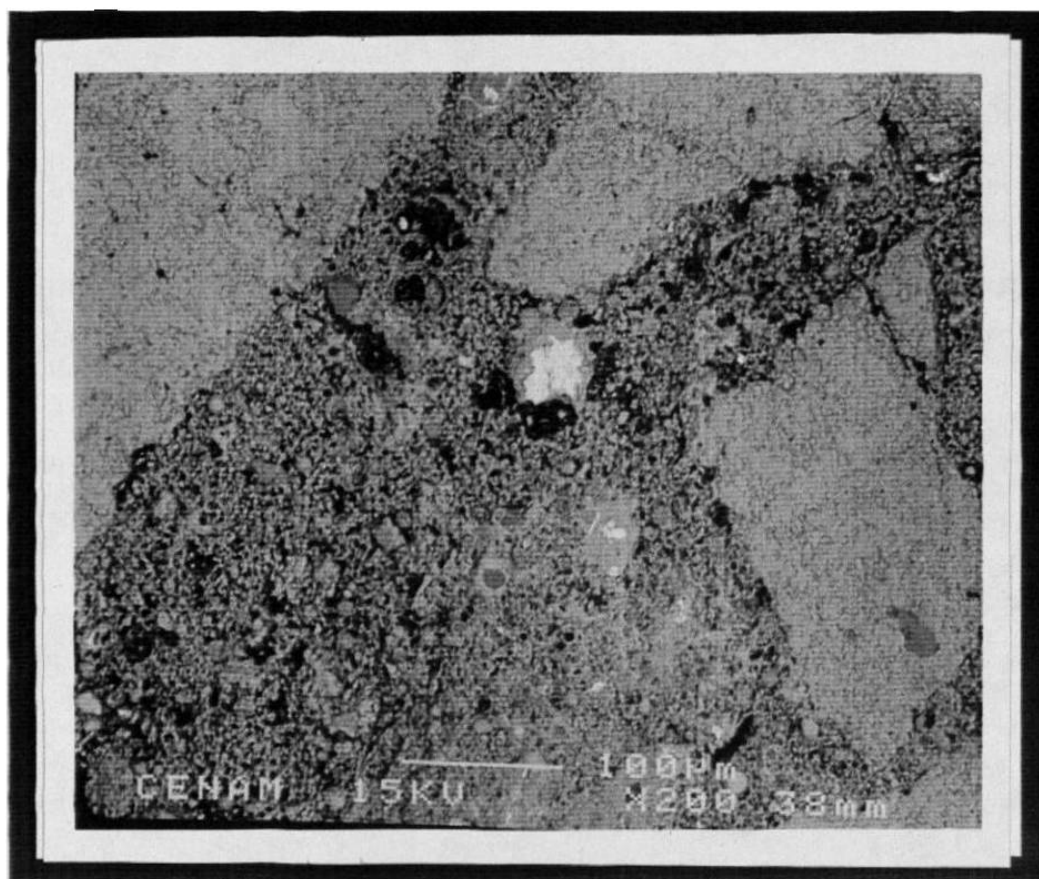


FOTO N 16.- Vista del mortero carbonatado A/c = 0.65 magnificado 200 veces, tomada de un microscopio electrónico de barrido en el Centro Nacional de Metrología

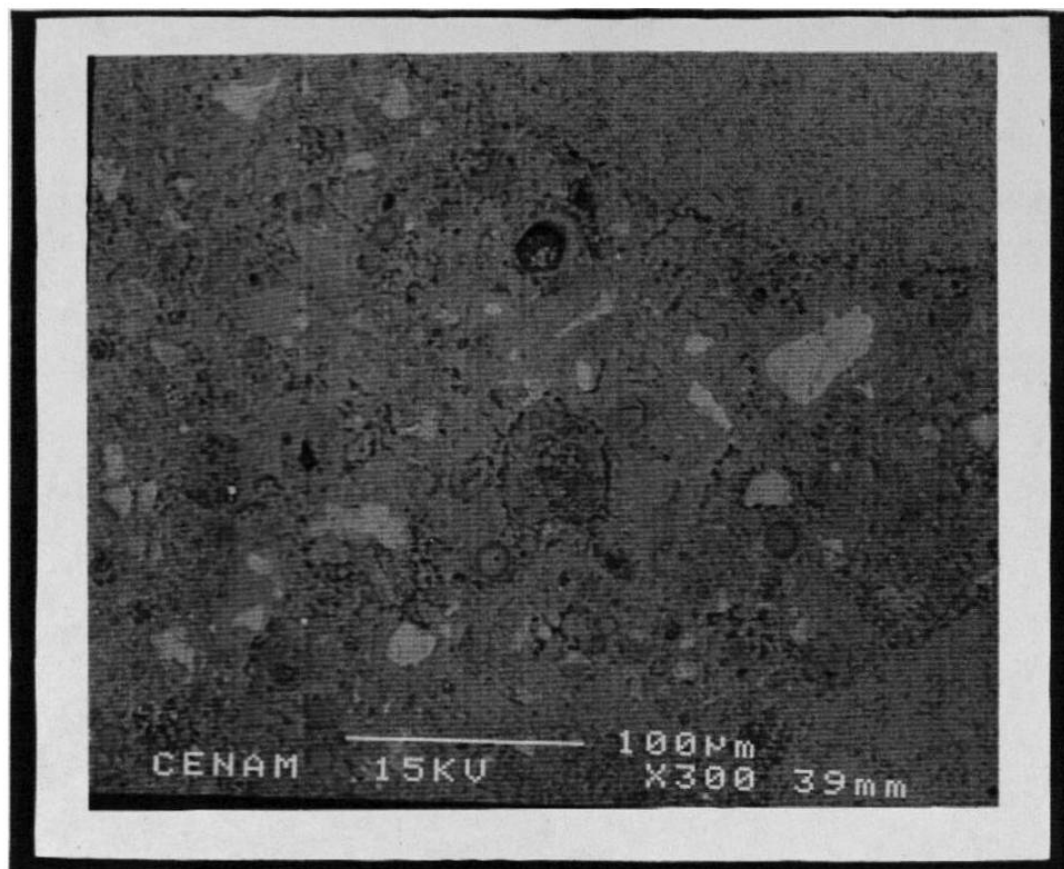


FOTO N°17.- Vista del mortero carbonatado $A/C = 0.35$ magnificado 300 de su tamaño real. Aquí podemos apreciar las esferas de ceniza volante en diversos puntos y además comparar la matriz cementante con la del mortero $A/C = 0.65$ de la foto 16 la cual resulta mucho mas densa.

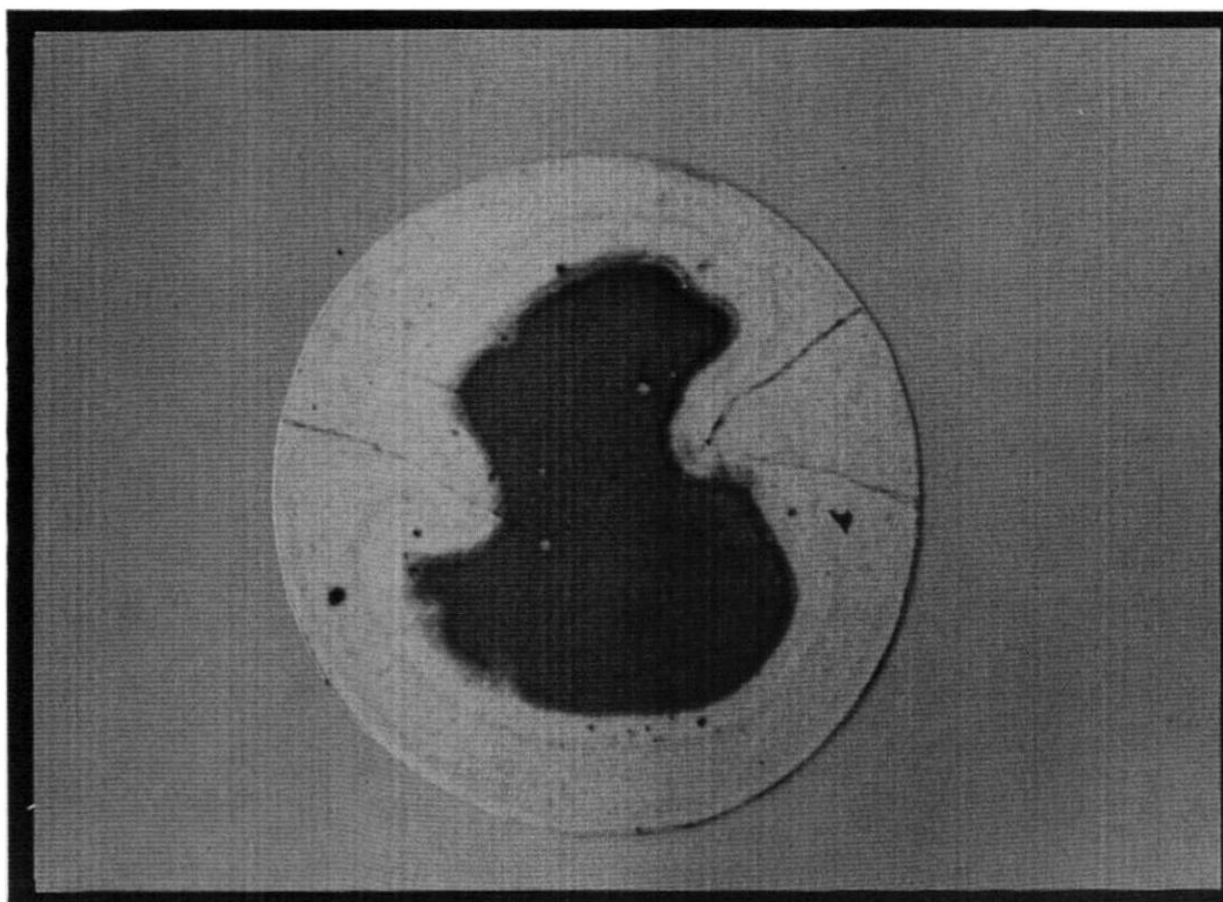


FOTO N 18 - El CO_2 penetra por los agrietamientos carbonatando mas rapido. En esta muestra de pasta de cemento hidraulico el indicador deberia tener una forma circular; sin embargo las grietas favorecen a la difusion del CO_2



FOTO N°19.- Corazones extraídos en toda la sección de una columna, el avance de la carbonatación es de 40 mm según el cambio de coloración por la fenolftaleína. La columna se construyó hace 25 años. ($f'c = 250 \text{ kgf/cm}^2$)

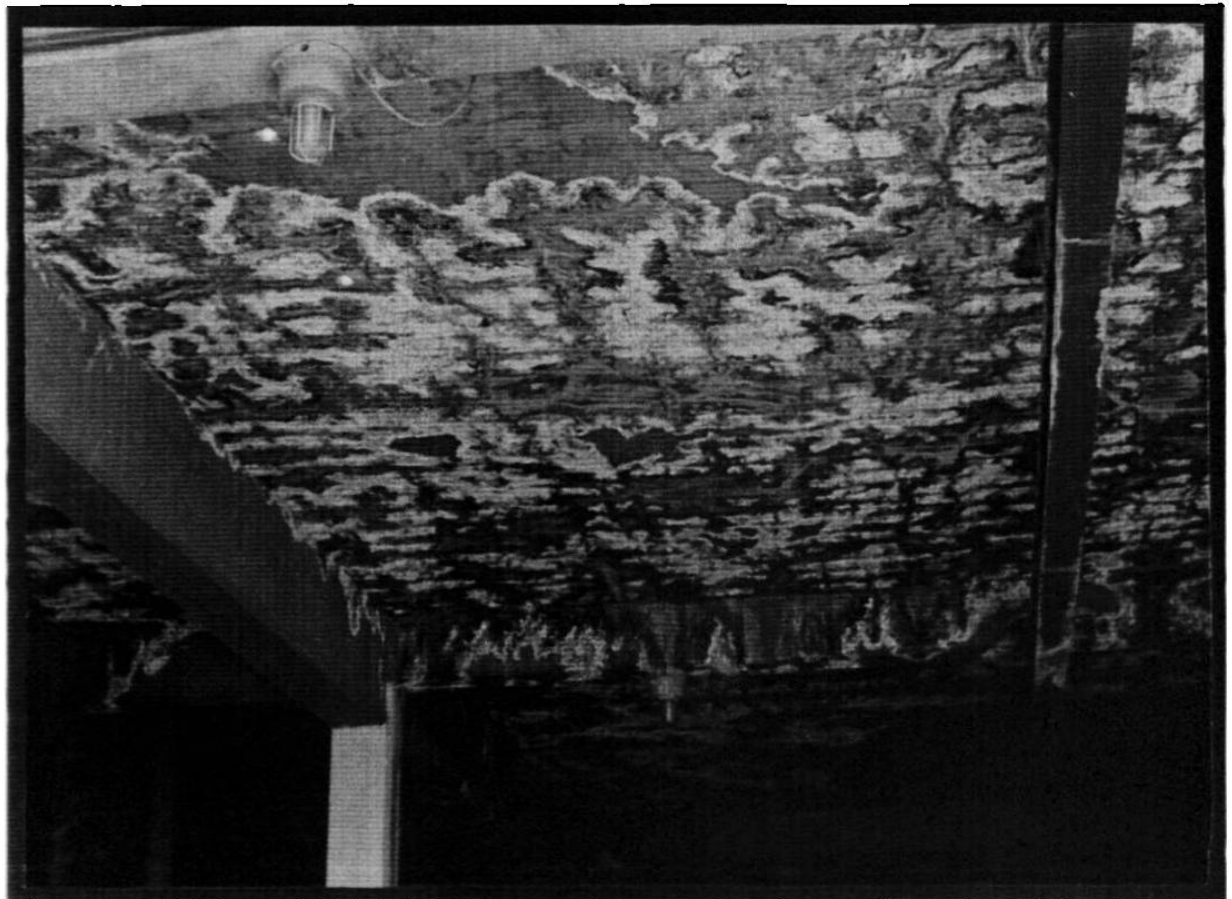


FOTO N 20 - Losa con problemas de lixiviaciones debido a su alta permeabilidad. Aquí se pueden apreciar las eflorescencias en gran parte de su área

Apéndice

Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens¹

This standard is issued under the fixed designation C 39; 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. 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 determination of compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 50 lb/ft³ (800 kg/m³).

1.2 The values stated in inch-pound 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.*

1.4 The text of this standard references notes which provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 ASTM Standards:

- C 31 Practice for Making and Curing Concrete Test Specimens in the Field²
- C 42 Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete²
- C 192 Practice for Making and Curing Concrete Test Specimens in the Laboratory²
- C 617 Practice for Capping Cylindrical Concrete Specimens²
- C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials²
- C 873 Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds²
- C 1077 Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation²
- C 1231 Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders²
- E 4 Practices for Force Verification of Testing Machines³
- E 74 Practice for Calibration of Force-Measuring Instruments for Verifying the Load Indication of Testing Machines³
- Manual of Aggregate and Concrete Testing²

2.2 American Concrete Institute:

CP-16 Concrete Laboratory Testing Technician, Grade I.⁴

3. Summary of Test Method

3.1 This test method consists of applying a compressive axial load to molded cylinders or cores at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

4. Significance and Use

4.1 Care must be exercised in the interpretation of the significance of compressive strength determinations by this test method since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, and fabrication and the age, temperature, and moisture conditions during curing.

4.2 This test method is used to determine compressive strength of cylindrical specimens prepared and cured in accordance with Practices C 31, C 192, C 617 and C 1231 and Test Methods C 42 and C 873.

4.3 The results of this test method are used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures and similar uses.

4.4 The individual who tests concrete cylinders for acceptance testing shall have demonstrated a knowledge and ability to perform the test procedure equivalent to the minimum guidelines for certification of Concrete Laboratory Technician, Level I, in accordance with ACI CP-16.

NOTE 1—The testing laboratory performing this test method should be evaluated in accordance with Practice C 1077.

5. Apparatus

5.1 *Testing Machine*—The testing machine shall be of a type having sufficient capacity and capable of providing the rates of loading prescribed in 7.5.

5.1.1 Verification of calibration of the testing machines in accordance with Practices E 4 is required under the following conditions:

5.1.1.1 After an elapsed interval since the previous verifi-

¹ This test method is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing Concrete for Strength.

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² Annual Book of ASTM Standards, Vol 04.02.

³ Annual Book of ASTM Standards, Vol 03.01.

⁴ Available from American Concrete Institute, P.O. Box 19150, Detroit, MI, 48219-0150.

cation of 18 months maximum, but preferably after an interval of 12 months,

5.1.1.2 On original installation or relocation of the machine,

5.1.1.3 Immediately after making repairs or adjustments that affect the operation of the force applying system of the machine or the values displayed on the load indicating system, except for zero adjustments that compensate for the mass of bearing blocks, or specimen, or both, or

5.1.1.4 Whenever there is reason to doubt the accuracy of the results, without regard to the time interval since the last verification.

5.1.2 *Design*—The design of the machine must include the following features:

5.1.2.1 The machine must be power operated and must apply the load continuously rather than intermittently, and without shock. If it has only one loading rate (meeting the requirements of 7.5), it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.

NOTE 2—High-strength concrete cylinders rupture more intensely than normal strength cylinders. As a safety precaution, it is recommended that the testing machines should be equipped with protective fragment guards.

5.1.2.2 The space provided for test specimens shall be large enough to accommodate, in a readable position, an elastic calibration device which is of sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of Practice E 74.

NOTE 3—The types of elastic calibration devices most generally available and most commonly used for this purpose are the circular proving ring or load cell.

5.1.3 *Accuracy*—The accuracy of the testing machine shall be in accordance with the following provisions:

5.1.3.1 The percentage of error for the loads within the proposed range of use of the testing machine shall not exceed $\pm 1.0\%$ of the indicated load.

5.1.3.2 The accuracy of the testing machine shall be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads shall not exceed one third of the difference between the maximum and minimum test loads.

5.1.3.3 The test load as indicated by the testing machine and the applied load computed from the readings of the verification device shall be recorded at each test point. Calculate the error, E , and the percentage of error, E_p , for each point from these data as follows:

$$E = A - B$$

$$E_p = 100(A - B)/B$$

where:

A = load, lbf (or N) indicated by the machine being verified, and

B = applied load, lbf (or N) as determined by the calibrating device.

5.1.3.4 The report on the verification of a testing machine shall state within what loading range it was found to conform to specification requirements rather than reporting a blanket acceptance or rejection. In no case shall the loading range be

stated as including loads below the value which is 100 times the smallest change of load estimable on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10 % of the maximum range capacity.

5.1.3.5 In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.

5.1.3.6 The indicated load of a testing machine shall not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.

5.2 The testing machine shall be equipped with two steel bearing blocks with hardened faces (Note 4), one of which is a spherically seated block that will bear on the upper surface of the specimen, and the other a solid block on which the specimen shall rest. Bearing faces of the blocks shall have a minimum dimension at least 3 % greater than the diameter of the specimen to be tested. Except for the concentric circles described below, the bearing faces shall not depart from a plane by more than 0.001 in. (0.025 mm) in any 6 in. (152 mm) of blocks 6 in. in diameter or larger, or by more than 0.001 in. in the diameter of any smaller block; and new blocks shall be manufactured within one half of this tolerance. When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by more than $\frac{1}{2}$ in. (13 mm), concentric circles not more than $\frac{1}{32}$ in. (0.8 mm) deep and not more than $\frac{3}{64}$ in. (1.2 mm) wide shall be inscribed to facilitate proper centering.

NOTE 4—It is desirable that the bearing faces of blocks used for compression testing of concrete have a Rockwell hardness of not less than 55 HRC.

5.2.1 Bottom bearing blocks shall conform to the following requirements:

5.2.1.1 The bottom bearing block is specified for the purpose of providing a readily machinable surface for maintenance of the specified surface conditions (Note 5). The top and bottom surfaces shall be parallel to each other. If the testing machine is so designed that the platen itself is readily maintained in the specified surface condition, a bottom block is not required. Its least horizontal dimension shall be at least 3 % greater than the diameter of the specimen to be tested. Concentric circles as described in 5.2 are optional on the bottom block.

NOTE 5—The block may be fastened to the platen of the testing machine.

5.2.1.2 Final centering must be made with reference to the upper spherical block. When the lower bearing block is used to assist in centering the specimen, the center of the concentric rings, when provided, or the center of the block itself must be directly below the center of the spherical head. Provision shall be made on the platen of the machine to assure such a position.

5.2.1.3 The bottom bearing block shall be at least 1 in. (25 mm) thick when new, and at least 0.9 in. (22.5 mm) thick after any resurfacing operations.

5.2.2 The spherically seated bearing block shall conform to the following requirements:

5.2.2.1 The maximum diameter of the bearing face of the

suspended spherically seated block shall not exceed the values given below:

Diameter of Test Specimens, in. (mm)	Maximum Diameter of Bearing Face, in. (mm)
2 (51)	4 (102)
3 (76)	5 (127)
4 (102)	6½ (165)
6 (152)	10 (254)
8 (203)	11 (279)

NOTE 6—Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

5.2.2.2 The center of the sphere shall coincide with the surface of the bearing face within a tolerance of $\pm 5\%$ of the radius of the sphere. The diameter of the sphere shall be at least 75 % of the diameter of the specimen to be tested.

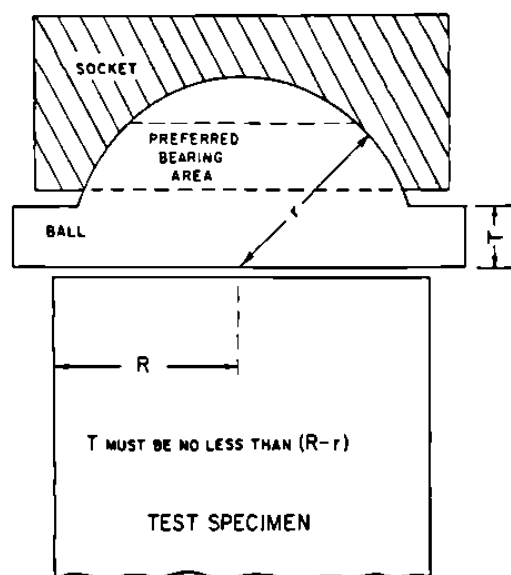
5.2.2.3 The ball and the socket must be so designed by the manufacturer that the steel in the contact area does not permanently deform under repeated use, with loads up to 12 000 psi (82.7 MPa) on the test specimen.

NOTE 7—The preferred contact area is in the form of a ring (described as preferred “bearing” area) as shown on Fig. 1.

5.2.2.4 The curved surfaces of the socket and of the spherical portion shall be kept clean and shall be lubricated with a petroleum-type oil such as conventional motor oil, not with a pressure type grease. After contacting the specimen and application of small initial load, further tilting of the spherically seated block is not intended and is undesirable.

5.2.2.5 If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere (see Fig. 1).

5.2.2.6 The movable portion of the bearing block shall be held closely in the spherical seat, but the design shall be such



NOTE—Provision shall be made for holding the ball in the socket and for holding the entire unit in the testing machine.

FIG. 1 Schematic Sketch of a Typical Spherical Bearing Block

that the bearing face can be rotated freely and tilted at least 4° in any direction.

5.3 Load Indication:

5.3.1 If the load of a compression machine used in concrete testing is registered on a dial, the dial shall be provided with a graduated scale that is readable to at least the nearest 0.1 % of the full scale load (Note 8). The dial shall be readable within 1 % of the indicated load at any given load level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale shall be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the end of the pointer shall not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment located outside the dialcase and easily accessible from the front of the machine while observing the zero mark and dial pointer. Each dial shall be equipped with a suitable device that at all times until reset will indicate to within 1 % accuracy the maximum load applied to the specimen.

NOTE 8—Readability is considered to be $\frac{1}{50}$ in. (0.5 mm) along the arc described by the end of the pointer. Also, one half of a scale interval is readable with reasonable certainty when the spacing on the load indicating mechanism is between $\frac{1}{25}$ in. (1 mm) and $\frac{1}{16}$ in. (1.6 mm). When the spacing is between $\frac{1}{16}$ in. and $\frac{1}{8}$ in. (3.2 mm), one third of a scale interval is readable with reasonable certainty. When the spacing is $\frac{1}{8}$ in. or more, one fourth of a scale interval is readable with reasonable certainty.

5.3.2 If the testing machine load is indicated in digital form, the numerical display must be large enough to be easily read. The numerical increment must be equal to or less than 0.10 % of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0 % for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. There shall be provided a maximum load indicator that at all times until reset will indicate within 1 % system accuracy the maximum load applied to the specimen.

6. Specimens

6.1 Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 %.

NOTE 9—This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding or when a core drill deflects or shifts during drilling.

6.2 Neither end of compressive test specimens when tested shall depart from perpendicularity to the axis by more than 0.5° (approximately equivalent to $\frac{1}{8}$ in. in 12 in. (3 mm in 300 mm)). The ends of compression test specimens that are not plane within 0.002 in. (0.050 mm) shall be sawed or ground to meet that tolerance, or capped in accordance with either Practice C 617 or Practice C 1231. The diameter used for calculating the cross-sectional area of the test specimen shall be determined to the nearest 0.01 in. (0.25 mm) by averaging two diameters measured at right angles to each other at about midheight of the specimen.

6.3 The number of individual cylinders measured for determination of average diameter may be reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.02 in. (0.51 mm). When the average diameters do not fall within the range of 0.02 in. or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used in calculation of the unit compressive strength of that specimen. When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.

6.4 The length shall be measured to the nearest 0.05 D when the length to diameter ratio is less than 1.8, or more than 2.2, or when the volume of the cylinder is determined from measured dimensions.

7. Procedure

7.1 Compression tests of moist-cured specimens shall be made as soon as practicable after removal from moist storage.

7.2 Test specimens shall be kept moist by any convenient method during the period between removal from moist storage and testing. They shall be tested in the moist condition.

7.3 All test specimens for a given test age shall be broken within the permissible time tolerances prescribed as follows:

Test Age	Permissible Tolerance
24 h	± 0.5 h or 2.1 %
3 days	2 h or 2.8 %
7 days	6 h or 3.6 %
28 days	20 h or 3.0 %
90 days	2 days 2.2 %

7.4 *Placing the Specimen*—Place the plain (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.

7.4.1 *Zero Verification and Block Seating*—Prior to testing the specimen, verify that the load indicator is set to zero. In cases where the indicator is not properly set to zero, adjust the indicator (Note 10). As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

NOTE 10—The technique used to verify and adjust load indicator to zero will vary depending on the machine manufacturer. Consult your owner's manual or compression machine calibrator for the proper technique.

7.5 *Rate of Loading*—Apply the load continuously and without shock.

7.5.1 For testing machines of the screw type, the moving head shall travel at a rate of approximately 0.05 in. (1.3 mm)/min when the machine is running idle. For hydraulically operated machines, the load shall be applied at a rate of movement (platen to crosshead measurement) corresponding to a loading rate on the specimen within the range of 20 to 50 psi/s (0.14 to 0.34 MPa/s). The designated rate of movement shall be maintained at least during the latter half of the anticipated loading phase of the testing cycle.

7.5.2 During the application of the first half of the anticipated loading phase a higher rate of loading shall be permitted.

7.5.3 Make no adjustment in the rate of movement of the platen at any time while a specimen is yielding rapidly immediately before failure.

7.6 Apply the load until the specimen fails, and record the maximum load carried by the specimen during the test. Note the type of failure and the appearance of the concrete.

8. Calculation

8.1 Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as described in Section 6 and express the result to the nearest 10 psi (69 kPa).

8.2 If the specimen length to diameter ratio is less than 1.8, correct the result obtained in 8.1 by multiplying by the appropriate correction factor shown in the following table:

L/D:	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87 (Note 11)

NOTE 11—These correction factors apply to lightweight concrete weighing between 100 and 120 lb/ft³ (1600 and 1920 kg/m³) and to normal weight concrete. They are applicable to concrete dry or soaked at the time of loading. Values not given in the table shall be determined by interpolation. The correction factors are applicable for nominal concrete strengths from 2000 to 6000 psi (13.8 to 41.4 MPa).

9. Report

9.1 Report the following information:

9.1.1 Identification number,

9.1.2 Diameter (and length, if outside the range of 1.8 D to 2.2 D), in inches or millimetres,

9.1.3 Cross-sectional area, in square inches or square centimetres,

9.1.4 Maximum load, in pounds-force or newtons,

9.1.5 Compressive strength calculated to the nearest 10 psi or 69 kPa,

9.1.6 Type of fracture, if other than the usual cone (see Fig. 2),

9.1.7 Defects in either specimen or caps, and,

9.1.8 Age of specimen.

10. Precision and Bias

10.1 *Precision*—The single operator precision of tests of individual 6 by 12 in. (150 by 300 mm) cylinders made from a well-mixed sample of concrete is given for cylinders made in a laboratory environment and under normal field conditions (see 10.1.1).

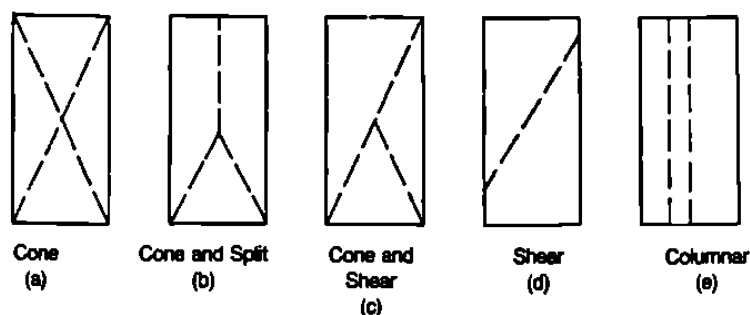


FIG. 2 Sketches of Types of Fracture

	Coefficient of Variation ⁴	Acceptable Range of ⁴	
		2 results	3 results
Single operator			
Laboratory conditions	2.37 %	6.6 %	7.8 %
Field conditions	2.87 %	8.0 %	9.5 %

⁴ These numbers represent respectively the (1s) and (d2s) limits as described in Practice C 670.

10.1.1 The values given are applicable to 6 by 12 in. (150 by 300 mm) cylinders with compressive strength between 2000 and 8000 psi (12 to 55 MPa). They are derived from CCRL concrete reference sample data for laboratory condi-

tions and a collection of 1265 test reports from 225 commercial testing laboratories in 1978.⁵

NOTE 12—Subcommittee C09.03.01 will re-examine recent CCRL Concrete Reference Sample Program data and field test data to see if these values are representative of current practice and if they can be extended to cover a wider range of strengths and specimen sizes.

10.2 *Bias*—Since there is no accepted reference material, no statement on bias is being made.

⁵ Research report RR:C09-1006 is on file at ASTM Headquarters.

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Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete¹

This standard is issued under the fixed designation C 618; 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 specification 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 specification covers coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete where cementitious or pozzolanic action, or both, is desired, or where other properties normally attributed to finely divided mineral admixtures may be desired, or where both objectives are to be achieved.

NOTE 1—Finely divided materials may tend to reduce the entrained air content of concrete. Hence, if a mineral admixture is added to any concrete for which entrainment of air is specified, provision should be made to ensure that the specified air content is maintained by air content tests and by use of additional air-entraining admixture or use of an air-entraining admixture in combination with air-entraining hydraulic cement.

1.2 The values stated in SI units are to be regarded as the standard.

2. Referenced Documents

2.1 ASTM Standards:

C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete²

3. Terminology

3.1 Definitions:

3.1.1 *fly ash*—finely divided residue that results from the combustion of ground or powdered coal.

NOTE 2—This definition of fly ash does not include, among other things, the residue resulting from: (1) the burning of municipal garbage or any other refuse with coal; (2) the injection of lime directly into the boiler for sulfur removal; or (3) the burning of industrial or municipal garbage in incinerators commonly known as “incinerator ash.”

3.1.2 *pozzolans*—siliceous or siliceous and aluminous materials which in themselves possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

¹ This specification is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.24 on Ground Slag and Pozzolonic Admixtures.

Current edition approved Jan. 10, 1997. Published March 1997. Originally published as C 618 - 68 T to replace C 350 and C 402. Last previous edition C 618 - 96a.

² Annual Book of ASTM Standards, Vol 04.02.

4. Classification

4.1 *Class N*—Raw or calcined natural pozzolans that comply with the applicable requirements for the class as given herein, such as some diatomaceous earths; opaline cherts and shales; tuffs and volcanic ashes or pumicites, calcined or uncalcined; and various materials requiring calcination to induce satisfactory properties, such as some clays and shales.

4.2 *Class F*—Fly ash normally produced from burning anthracite or bituminous coal that meets the applicable requirements for this class as given herein. This class fly ash has pozzolanic properties.

4.3 *Class C*—Fly ash normally produced from lignite or subbituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties.

NOTE 3—Some Class C fly ashes may contain lime contents higher than 10 %.

5. Ordering Information

5.1 The purchaser shall specify any supplementary optional chemical or physical requirements.

5.2 The purchaser shall indicate which procedure, A or B, shall be used when specifying requirements for effectiveness in contribution to sulfate resistance under Table 2A.

6. Chemical Composition

6.1 Fly ash and natural pozzolans shall conform to the requirements as to chemical composition prescribed in Table 1. Supplementary optional chemical requirements are shown in Table 1A.

7. Physical Properties

7.1 Fly ash and natural pozzolans shall conform to the physical requirements prescribed in Table 2. Supplementary optional physical requirements are shown in Table 2A.

8. Methods of Sampling and Testing

8.1 Sample and test the mineral admixture in accordance with the requirements of Test Methods C 311.

8.2 Use cement of the type proposed for use in the work and, if available, from the mill proposed as the source of the cement, in all tests requiring the use of hydraulic cement.

9. Storage and Inspection

9.1 The mineral admixture shall be stored in such a manner as to permit easy access for proper inspection and

TABLE 1 Chemical Requirements

	Mineral Admixture Class		
	N	F	C
Silicon dioxide (SiO ₂) plus aluminum oxide (Al ₂ O ₃) plus iron oxide (Fe ₂ O ₃), min, %	70.0	70.0	50.0
Sulfur trioxide (SO ₃), max, %	4.0	5.0	5.0
Moisture content, max, %	3.0	3.0	3.0
Loss on ignition, max, %	10.0	6.0 ^A	6.0

^A The use of Class F pozzolan containing up to 12.0 % loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.

TABLE 1A Supplementary Optional Chemical Requirement

NOTE—This optional requirement applies only when specifically requested.

	Mineral Admixture Class		
	N	F	C
Available alkalis, as equivalent, as Na ₂ O, max, % ^A	1.5	1.5	1.5

^A Applicable only when specifically required by the purchaser for mineral admixture to be used in concrete containing reactive aggregate and cement to meet a limitation on content of alkalis.

TABLE 2 Physical Requirements

	Mineral Admixture Class		
	N	F	C
Fineness:			
Amount retained when wet-sieved on 45 μ m (No. 325) sieve, max, % ^A	34	34	34
Strength activity index:^B			
With portland cement, at 7 days, min, percent of control	75 ^D	75 ^D	75 ^D
With portland cement, at 28 days, min, percent of control	75 ^D	75 ^D	75 ^D
Water requirement, max, percent of control	115	105	105
Soundness:^C			
Autoclave expansion or contraction, max, %	0.8	0.8	0.8
Uniformity requirements:			
The density and fineness of individual samples shall not vary from the average established by the ten preceding tests, or by all preceding tests if the number is less than ten, by more than:			
Density, max variation from average, %	5	5	5
Percent retained on 45- μ m (No. 325), max variation, percentage points from average	5	5	5

^A Care should be taken to avoid the retaining of agglomerations of extremely fine material.

^B The strength activity index with portland cement is not to be considered a measure of the compressive strength of concrete containing the mineral admixture. The mass of mineral admixture specified for the test to determine the strength activity index with portland cement is not considered to be the proportion recommended for the concrete to be used in the work. The optimum amount of mineral admixture for any specific project is determined by the required properties of the concrete and other constituents of the concrete and is to be established by testing. Strength activity index with portland cement is a measure of reactivity with a given cement and may vary as to the source of both the mineral admixture and the cement.

^C If the mineral admixture will constitute more than 20 % by weight of the cementitious material in the project mix design, the test specimens for autoclave expansion shall contain that anticipated percentage. Excessive autoclave expansion is highly significant in cases where water to mineral admixture and cement ratios are low, for example, in block or shotcrete mixes.

^D Meeting the 7 day or 28 day strength activity index will indicate specification compliance.

identification of each shipment.

9.2 Inspection of the material shall be made as agreed upon by the purchaser and the seller as part of the purchase contract.

10. Rejection

10.1 The purchaser has the right to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly and in writing.

10.2 The purchaser has the right to reject packages varying more than 5 % from the stated weight. The purchaser also has the right to reject the entire shipment if the average weight of the packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified.

10.3 The purchaser has the right to require that mineral

admixture in storage prior to shipment for a period longer than 6 months after testing be retested. The purchaser has the right to reject such material if it fails to meet the fineness requirements.

11. Packaging and Package Marking

11.1 When the mineral admixture is delivered in packages, the class, name, and brand of the producer, and the weight of the material contained therein, shall be plainly marked on each package. Similar information shall be provided in the shipping invoices accompanying the shipment of packaged or bulk mineral admixture.

12. Keywords

12.1 fly ash; mineral admixtures; natural pozzolan; pozzolans

TABLE 2A Supplementary Optional Physical Requirements

NOTE—These optional requirements apply only when specifically requested.

	Mineral Admixture Class		
	N	F	C
Multiple factor, calculated as the product of loss on ignition and fineness, amount retained when wet-sieved on 45- μ m (No. 325) sieve, max, % ^A	255
Increase of drying shrinkage of mortar bars at 28 days, max, difference, in %, over control ^B	0.03	0.03	0.03
Uniformity Requirements: In addition, when air-entraining concrete is specified, the quantity of air-entraining agent required to produce an air content of 18.0 vol % of mortar shall not vary from the average established by the ten preceding tests or by all preceding tests if less than ten, by more than, %	20	20	20
Effectiveness in Controlling Alkali-Silica Reaction: ^C Expansion of test mixture as percentage of low-alkali cement control, at 14 days, max, %	100	100	100
Effectiveness in Contributing to Sulfate Resistance: ^D Procedure A: Expansion of test mixture: For moderate sulfate exposure after 6 months exposure, max, % For high sulfate exposure after 6 months exposure, max, %	0.10 0.05	0.10 0.05	0.10 0.05
Procedure B: Expansion of test mixture as a percentage of sulfate resistance cement control after at least 6 months exposure, max, %	100	100	100

^A Applicable only for Class F mineral admixtures since the loss on ignition limitations predominate for Class C.

^B Determination of compliance or noncompliance with the requirement relating to increase in drying shrinkage will be made only at the request of the purchaser.

^C Mineral admixtures meeting this requirement are considered as effective in controlling alkali aggregate reactions as the use of the low-alkali control cement used in the evaluation. However, the mineral admixture shall be considered effective only when the mineral admixture is used at percentages by mass of the total cementitious material equal to or exceeding that used in the tests and when the alkali content of the cement to be used with the mineral admixture does not exceed that used in the tests by more than 0.05 %. See Appendix XI, Test Methods C 311.

^D Fly ash or natural pozzolan shall be considered effective only when the fly ash or natural pozzolan is used at percentages, by mass, of the total cementitious material within 2 % of those that are successful in the test mixtures or between two percentages that are successful, and when the C_3A content of the project cement is less than, or equal to, that which was used in the test mixtures. See Appendix X2 of Test Method C 311.

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RESUMEN AUTOBIOGRAFICO

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Candidato para el Grado de

Maestro en Ciencias con Especialidad en Ingeniería Ambiental

Tesis: EFECTOS DEL DIÓXIDO DE CARBONO EN LOS MORTEROS DE CEMENTO HIDRÁULICO CON CENIZA VOLANTE.

Campo de Estudio: TECNOLOGÍA PARA LA INGENIERÍA

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