Semana internacional de la

PATOLOGÍA

DE ESTRUCTURAS DE CONCRETO

Del 6 al 9 de junio de 2017

Organiza: Instituto del Concreto — Laboratorio del Concreto — Todo el Concreto está en Asocreto (Cemento Concreto Prefabricados)

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Semana internacional de la PATOLOGÍA DE ESTRUCTURAS DE CONCRETO

Organiza: Instituto del Concreto — Laboratorio del Concreto — Todo el Concreto está en Asocreto

“do Laboratório de Pesquisa ao Canteiro de Obras”

Paulo Helene

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Prof. Catedrático Universidad de São Paulo

Director y Consejero Permanente IBRACON

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2

Patología de las Estructuras de Concreto a Nivel Mundial

3

La Iniciativa en España

Enero de 1976

- Curso de Estudios Mayores de la Construcción CEMCO76
- Instituto Eduardo Torroja, Madrid
- Patología y Control de Calidad
- 460h

4

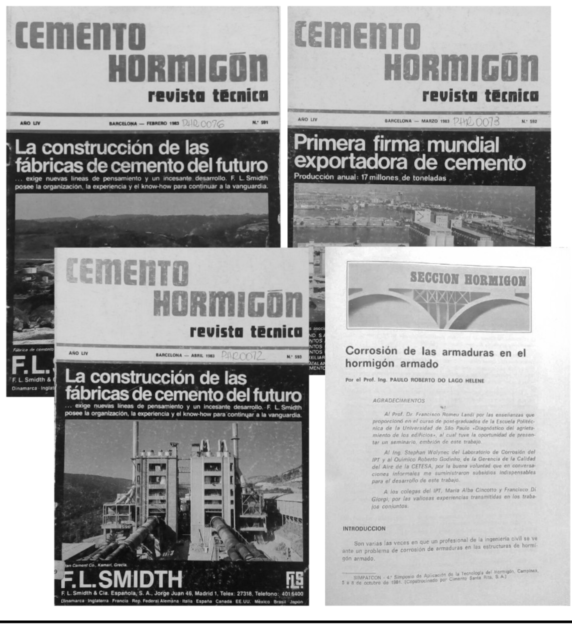
La Iniciativa en España

Enero de 1984

Editorial: Universidad Politécnica de Madrid. Escuela Técnica Superior de Ingenieros de Caminos, Canales y Puertos
nº páginas: 490
ISBN: 978-84-7493-202-7

5

La Iniciativa en España



1983

HELENE, Paulo. Corrosión de las Armaduras en él Hormigón Armado. Cemento y Hormigón, v. 591, 592 y 593.

6

La Iniciativa en España


JOURNAL of the AMERICAN CONCRETE INSTITUTE

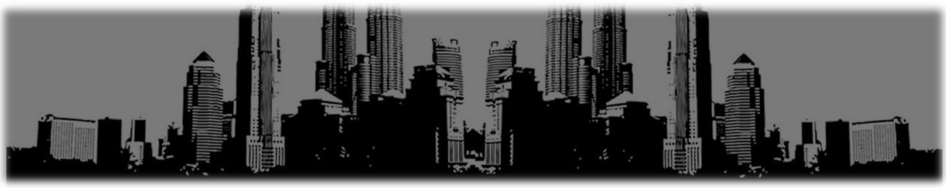
Mar-Apr 1986

ANDRADE, C. Effect of fly-ash in concrete on the corrosion of steel reinforcement. Journal of the American Concrete Institute, Vol. 83 Ed. 2 Pág. 333-333.

7

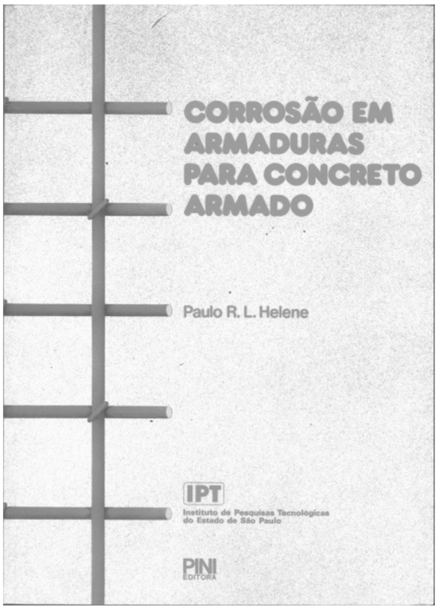
La Iniciativa en Brasil

1979 → La primera disciplina optativa de Patología en el curso de graduación de Ingenieros Civiles de la Escola Politécnica da Universidade de Sao Paulo. Prof. Paulo Helene



8

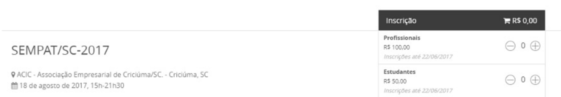
La Iniciativa en Brasil



Instituto de Pesquisas Tecnológicas do Estado de São Paulo IPT.SP
Editora Pini, São Paulo, 1986
nº páginas: 46
ISBN 85-09-00004-2

9

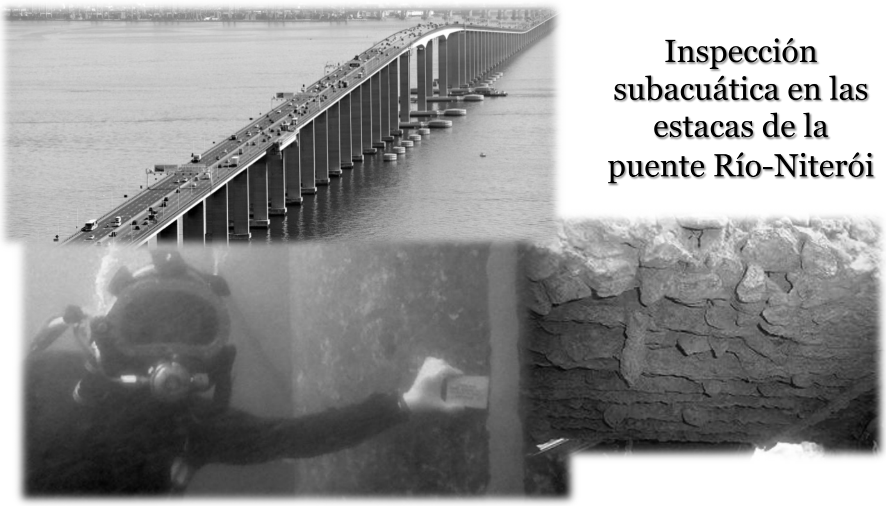
La Iniciativa en Brasil



10

La Iniciativa en Brasil

La Iniciativa en Brasil



Inspección subacuática en las estacas de la puente Río-Niterói

Stratfull, R. F., "Half-Cell Potentials and the Corrosion of Steel in Concrete," Highway Research Record 433, 1973

La Iniciativa en Francia

En Francia, la Agence Qualité Construction (una organización que evalúa e implementa la calidad en la construcción) en asociación con la "Fundación Excellence SMA" (una importante compañía de seguros que trabaja en el sector de la construcción) ha desarrollado el SYCODÈS, una base de datos compuesta por varios informes detallados de patología.

13

La Iniciativa en Francia

Desde su creación en 1986, el SYCODÉS ha estado recopilando reportes provenientes de reclamaciones relacionadas con la patología del edificio, presentados a la compañía de seguros. La información proporcionada en estos informes compilada por expertos patólogos proporciona una vasta e importante base de datos de los defectos de construcción más comunes, los elementos de construcción afectados, las causas subyacentes y el costo aproximado de las intervenciones necesarias.

14

La Iniciativa en Francia

Panorama des publications

Attention !

Notre boutique en ligne est actuellement en maintenance. Si vous souhaitez commander une publication ou vous abonner à la revue, **nous vous remercions durant cette période de télécharger** ce bon de commande et de nous le renvoyer par courrier (adresse dans le bon de commande). En revanche, vous pouvez continuer à télécharger comme d'habitude nos publications.
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L'information professionnelle du maître d'ouvrage

- Prévention des risques en réhabilitation-restructuration
- Prévention des risques importants
- Le rôle du maître d'ouvrage
- Les bonnes questions sur la destination d'un ouvrage
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L'information professionnelle du maître d'œuvre

- La pathologie des carrelages et chapes associées — Nouveau !
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- La pathologie des réseaux d'eau
- La pathologie des fondations superficielles
- Fiches pathologie bâtiment
- La qualité réglementaire
- Le rôle de la maîtrise d'oeuvre
- La pathologie des façades
- Le risque de mérule dans le bâtiment — Nouveau !
- Erreurs d'implantation des bâtiments — Nouveau !
- Le devoir de conseil des professionnels de la construction
- L'intervention du contrôleur technique

http://www.qualiteconstruction.com/accueil.html

15

La Iniciativa en Francia

Publications

Pro035

Delayed ettringite formation in massive concrete structures: an account of some studies of degraded bridges

Title: Delayed ettringite formation in massive concrete structures: an account of some studies of degraded bridges
Author(s): E. Menéndez
Paper category : conference
Book title: International RILEM Workshop on Internal Sulfate Attack and Delayed Ettringite Formation
Editor(s): K. Scrivener and J. Skalny
Print-ISBN: 2-912143-44-6
e-ISBN: 2912143802
Publisher: RILEM Publications SARL
Publication year: 2004
Pages: 127 - 136
Total Pages: 10
Nb references: 10
Language: English

Abstract: Many concrete structures in Spain are at risk of being subjected to external sulphate attack due to high level of sulphates present in soils and in ground water. On the other hand, some of the existing structures show signs of expansion caused by alkali-silica reaction (ASR). In certain cases these structures also contain ettringite, but usually it is not possible to authoritatively state which of the two processes (ASR of ettringite formation) initiated the deterioration. To the author's knowledge, to date only one case of internal sulphate attack has been encountered in a field concrete in Spain.

Online publication: 2002-09-07
Publication type : full_text
Public price (Euros): 0.00
doi: 10.1617/2912143802.008

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16

La Iniciativa en Noruega

Otro ejemplo exitoso en este campo proviene de Noruega, donde las investigaciones llevadas a cabo por el Instituto de Investigación de Edificios de Noruega (NBRI), han proporcionado datos cruciales para el análisis de la calidad de la construcción. Aunque esta información se refiere al año 2005, es relevante demostrar la importancia de este tipo de sistemas de recopilación de datos.

https://www.sintef.no/en/building-and-infrastructure/#/

17

La Iniciativa en Noruega

El objetivo del NBRI fue evaluar el efecto de los defectos de construcción inducidos por el proceso, generalmente como resultado del incumplimiento de requisitos o especificaciones, y establecer un archivo electrónico para esos defectos.

18

La Iniciativa en Noruega

Mediante la recopilación de datos de asignaciones de defectos del edificio llevadas a cabo por el NBRI desde 1964 y la participación de estudiantes de doctorado en el proceso, los investigadores esperaban lograr una imagen clara del medio ambiente construido noruego, utilizando los resultados para elaborar Códigos de Práctica y Building Research Design Sheets.

19

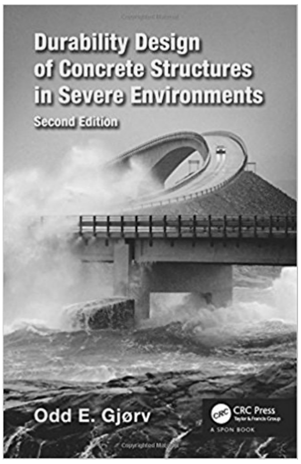
La Iniciativa en Noruega

Estas hojas son una de las herramientas utilizadas principalmente por los diseñadores y arquitectos en Noruega hasta ahora. En 2006, el NBRI se fusionó con SINTEF, convirtiéndose en parte de SINTEF Building Research AS.

20

La Iniciativa en Noruega

SINTEF



21

DURACON

O software Duracon é uma ferramenta desenvolvida na Dinamarca para calcular a vida útil considerando a difusão por cloreto.

Foi o software utilizado por Odd E. Gjorv em seu livro “Projeto da durabilidade de estruturas de concreto em ambiente de severa agressividade”.

É possível fazer o download pelo site: http://pianc.no/duracon/

22

La Iniciativa en Dinamarca

En Dinamarca, los defectos relacionados se consideran alrededor del 10% del volumen de negocios anual en el sector de la construcción.
Desde 1986 se han implementado en el sector de la construcción danés sistemas o iniciativas que aplican un enfoque basado en la fiscalización para mejorar la calidad de los edificios.

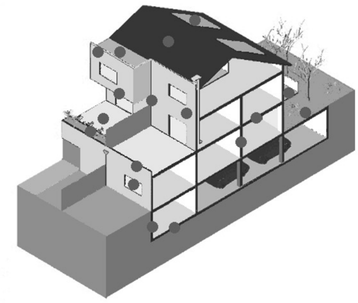
23

La Iniciativa en Dinamarca

Las iniciativas abarcan desde soluciones obligatorias hasta sistemas más o menos voluntarios de benchmarking o seguros basados en subsectores específicos.
Los diferentes sistemas e iniciativas tienen diferentes enfoques. Los sistemas obligatorios basados en seguros para vivienda social y renovación urbana introducidos alrededor de 1990 mostraron resultados notables expresados por la reducción en el volumen de defectos, pero cuando se introdujeron sistemas más o menos voluntarios para viviendas unifamiliares no se vio un éxito similar.

24

Iniciativa en Portugal



1º encuentro nacional realizado en 2003

25

Iniciativa en Portugal

Una contribución a la sistematización de la información es la elaboración de un Catálogo de Patologías que el Grupo de Estudios de la Patología de la Construcción - PATORREB está desarrollando, coordinado por el Laboratorio de Física de las Construcciones de la Facultad de Ingeniería de la Universidad de Oporto - FEUP y que tiene La participación de más siete Universidades portuguesas: IST, UNL, FCTUC, UM, UBI, UA y UTAD.

El Cuerpo Editorial constituido por especialistas en el área de la Patología y Rehabilitación de Edificios, constituye el fundamento para un trabajo de calidad que se pretende realizar.

El Grupo de Estudios - PATORREB ofrece el acceso gratuito al sitio a todos los interesados.

26

Iniciativa en Africa del Sur

http://iccrrr.com/

27

Iniciativa en Africa del Sur

The ICCRRR 2018 in Cape Town is intended to bring together practising engineers, scientists, specifiers, concrete technologists, researchers and others from around the world to share knowledge and experience on current developments on the broad themes of concrete durability, condition assessment, repair technology, and associated fields.

The conference will run over 3 days and feature oral presentations by authors of all accepted papers, as well as keynote addresses by leading international experts. Following the conference, workshops on selected topics will be organised, exposing delegates to practical information and hands-on experience. The event will include a tourist programme for conference delegates and accompanying persons, as well as various social functions including a conference dinner.

An exhibition will be organized with companies from around the globe showcasing recent developments in repair materials technology, testing equipment, and repair and strengthening system solutions.

28

La Iniciativa en Estados Unidos

HALF-CELL POTENTIALS AND THE CORROSION OF STEEL IN CONCRETE

Richard F. Stratfull, California Division of Highways

The half-cell potential of steel embedded in concrete specimens in laboratory tests was periodically measured and related to the visual observation of concrete cracking. It was observed that, when the half-cell potential values were more negative than -0.45 V to the saturated calomel electrode, 60 percent of the reinforced concrete blocks were cracked from the corrosion of the steel. At values between -0.27 and -0.42 V, the steel was corroding but not always enough to cause concrete cracking. In cracked concrete, the maximum half-cell potential of the steel was measured to be -0.59 V. In addition to the laboratory tests on small specimens, a prototype-simulated bridge deck was exposed outdoors to periodic wetting and drying of a chloride salt solution, and half-cell potentials were measured by using various techniques. It is shown that, once corrosion begins, the measurements will show the potential gradients of the resulting corrosion currents irrespective of the technique used to obtain them. However, there was a significant difference in the level of the potentials, and that level was clearly associated with the method of electrical measurement.

•PREVIOUS work (1-6) has demonstrated that the half-cell potential of steel in concrete is a valid indicator of corrosion activity. In effect, measurements (2, 4) of half-cell potentials have identified steel that is noncorroding (passive) when a measured value is numerically less than -0.22 V relative to the saturated calomel electrode (SCE) and corroding (active) when the value is numerically greater than -0.27 V (SCE). Between -0.22 and -0.27 V, the condition may be either active or passive.

Although an active potential of the steel does not correlate with a rate of corrosion, it is known (2, 4) that, with an increasing amount of corrosion, the numerical value of the potential also increases. Therefore, because there is concern (7) about cracking of concrete caused by rusting steel, an attempt was made to find a half-cell potential value that is indicative of the amount of steel corrosion that can cause concrete to crack and to explore some of the various techniques used to obtain half-cell potentials.

In this regard, data are given from two different tests. One test measured a single half-cell potential value for reinforced concrete that is partially immersed in a saturated solution of sodium chloride. The value in this type of test is that the half-cell potentials clearly show the noncorroding or passive state and conversely the active or corroding state of the steel.

The second test measured the half-cell potential and the potential gradients on the surface of a corroding simulated bridge deck. The half-cell potentials that are obtained on the simulated bridge deck are similar to those that would be obtained on an actual field structure. Four different techniques were used to measure the electrical potentials on the simulated bridge deck. These measurements show how the level of the measured potential can be affected by the reference electrical "ground."

Sponsored by Committee on Corrosion.

12

Stratfull, R. F., "Half-Cell Potentials and the Corrosion of Steel in Concrete," Highway Research Record 433, 1973

29

La Iniciativa en Estados Unidos

Designation: C 876 – 91 (Reapproved 1999)

Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete[1]

This standard is issued under the fixed designation C 876; 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 estimation of the electrical half-cell potential of uncoated reinforcing steel in field and laboratory concrete, for the purpose of determining the corrosion activity of the reinforcing steel.

1.2 This test method is limited by electrical circuitry. A concrete surface that has dried to the extent that it is a dielectric and surfaces that are coated with a dielectric material will not provide an acceptable electrical circuit. The basic configuration of the electrical circuit is shown in Fig. 1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

1.4 *This standard does not purport to address 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:*

G 3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing[2]

3. Significance and Use

3.1 This test method is suitable for in-service evaluation and for use in research and development work.

3.2 This test method is applicable to members regardless of their size or the depth of concrete cover over the reinforcing steel.

3.3 This test method may be used at any time during the life of a concrete member.

3.4 The results obtained by the use of this test method shall not be considered as a means for estimating the structural properties of the steel or of the reinforced concrete member.

3.5 The potential measurements should be interpreted by engineers or technical specialists experienced in the fields of concrete materials and corrosion testing. It is often necessary to use other data such as chloride contents, depth of carbonation, delamination survey findings, rate of corrosion results, and environmental exposure conditions, in addition to half-cell potential measurements, to formulate conclusions concerning corrosion activity of embedded steel and its probable effect on the service life of a structure.

4. Apparatus

4.1 The testing apparatus consists of the following:

4.1.1 *Half Cell:*

4.1.1.1 A copper-copper sulfate half cell (Note 1) is shown in Fig. 2. It consists of a rigid tube or container composed of a dielectric material that is nonreactive with copper or copper sulfate, a porous wooden or plastic plug that remains wet by capillary action, and a copper rod that is immersed within the tube in a saturated solution of copper sulfate. The solution shall be prepared with reagent grade copper sulfate crystals dissolved in distilled or deionized water. The solution may be considered saturated when an excess of crystals (undissolved) lies at the bottom of the solution.

4.1.1.2 The rigid tube or container shall have an inside diameter of not less than 1 in. (25 mm); the diameter of the porous plug shall not be less than ½ in. (13 mm); the diameter of the immersed copper rod shall not be less than ¼ in. (6 mm), and the length shall not be less than 2 in. (50 mm).

4.1.1.3 Present criteria based upon the half-cell reaction of $Cu \rightarrow Cu^{++} + 2e$ indicate that the potential of the saturated copper-copper sulfate half cell as referenced to the hydrogen electrode is −0.316 V at 72°F (22.2°C). The cell has a temperature coefficient of about 0.0005 V more negative per° F for the temperature range from 32 to 120°F (0 to 49°C).

NOTE 1—While this test method specifies only one type of half cell, that is, the copper-copper sulfate half cell, others having similar measurement range, accuracy, and precision characteristics may also be used. In addition to copper-copper sulfate cells, calomel cells have been used in laboratory studies. Potentials measured by other than copper-copper sulfate half cells should be converted to the copper-copper sulfate equivalent potential. The conversion technique can be found in Practice G 3 and it is also described in most physical chemistry or half-cell technology text books.

4.1.2 *Electrical Junction Device*—An electrical junction device shall be used to provide a low electrical resistance liquid bridge between the surface of the concrete and the half cell. It shall consist of a sponge or several sponges pre-wetted with a

[1] This test method is under the jurisdiction of ASTM Committee G01 on Corrosion of Metalsand is the direct responsibility of Subcommittee G01.14 on Corrosion of Reinforcing Steel.

Current edition approved March 11, 1991. Published May 1991. Originally published as C 876 – 77. Last previous edition C 876 – 87.

[2] *Annual Book of ASTM Standards*, Vol 03.02.

This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: C1202 – 97

Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration[1]

This standard is issued under the fixed designation C1202; 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 electrical conductance of concrete to provide a rapid indication of its resistance to the penetration of chloride ions. This test method is applicable to types of concrete where correlations have been established between this test procedure and long-term chloride ponding procedures such as those described in AASHTO T 259. Examples of such correlations are discussed in Refs 1-5.[2]

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

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:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

2.2 *AASHTO Standard:*

T 259 Method of Test for Resistance of Concrete to Chloride Ion Penetration[4]

3. Summary of Test Method

3.1 This test method consists of monitoring the amount of electrical current passed through 50-mm thick slices of 100-mm nominal diameter cores or cylinders during a 6-h period. A potential difference of 60 V dc is maintained across the ends of the specimen, one of which is immersed in a sodium chloride solution, the other in a sodium hydroxide solution. The total charge passed, in coulombs, has been found to be related to the resistance of the specimen to chloride ion penetration.

4. Significance and Use

4.1 This test method covers the laboratory evaluation of the electrical conductance of concrete samples to provide a rapid indication of their resistance to chloride ion penetration. In most cases the electrical conductance results have shown good correlation with chloride ponding tests, such as AASHTO T259, on companion slabs cast from the same concrete mixtures (Refs 1-5).

4.2 This test method is suitable for evaluation of materials and material proportions for design purposes and research and development.

4.3 Sample age has significant effects on the test results, depending on the type of concrete and the curing procedure. Most concretes, if properly cured, become progressively and significantly less permeable with time.

4.4 This test method was developed originally for evaluations of alternative materials, but in practice its use has evolved to applications such as quality control and acceptance testing. Factors such as ingredient materials used in concrete mixtures and the method and duration of curing test specimens affect the

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.66 on Concrete's Resistance to Fluid Penetration.

Current edition approved Feb. 1, 2012. Published March 2012. Originally approved in 1991. Last previous edition approved in 2010 as C1202 – 10. DOI: 10.1520/C1202-12.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Methods of Sampling and Testing, 1986, American Association of State Highway and Transportation Officials, 444 N. Capitol St., NW, Washington, DC 20001.

*A Summary of Changes section appears at the end of this standard

30

La Iniciativa en Estados Unidos

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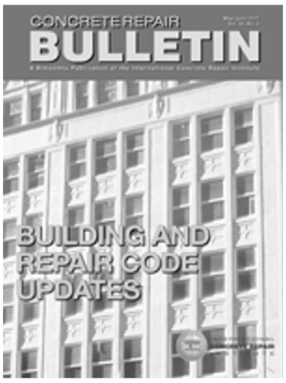
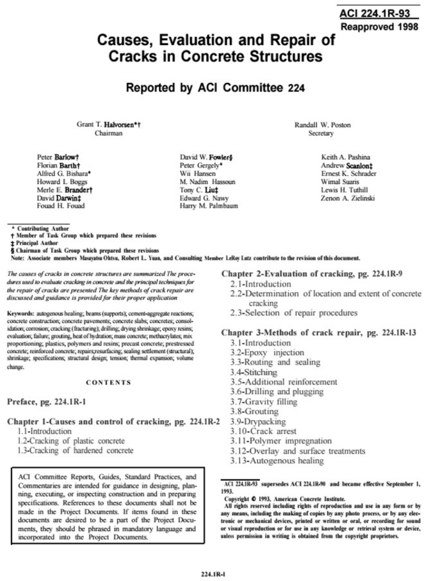


31

La Iniciativa en Estados Unidos



ACI 224.1R-93
Reapproved 1998

Causes, Evaluation and Repair of Cracks in Concrete Structures

Reported by ACI Committee 224

Grant T. Halvorsen*† Chairman

Randall W. Poston Secretary

Peter Barlow†, Florian Barth†, Alfred G. Bishara*, Howard L. Boggs, Merle E. Brander†, David Darwin‡, Fouad H. Fouad, David W. Fowler§, Peter Gergely*, Wii Hansen, M. Nadim Hassoun, Tony C. Liu‡, Edward G. Nawy, Harry M. Palmbaum, Keith A. Pashina, Andrew Scanlon‡, Ernest K. Schrader, Wimal Suaris, Lewis H. Tuthill, Zenon A. Zielinski

* Contributing Author
† Member of Task Group which prepared these revisions
‡ Principal Author
§ Chairman of Task Group which prepared these revisions
Note: Associate members Masayatsu Ohtsu, Robert L. Yuan, and Consulting Member LeRoy Lutz contribute to the revision of this document.

The causes of cracks in concrete structures are summarized The procedures used to evaluate cracking in concrete and the principal techniques for the repair of cracks are presented The key methods of crack repair are discussed and guidance is provided for their proper application

Keywords: autogenous healing; beams (supports); cement-aggregate reactions; concrete construction; concrete pavements; concrete slabs; concretes; consolidation; corrosion; cracking (fracturing); drilling; drying shrinkage; epoxy resins; evaluation; failure; grouting, heat of hydration; mass concrete; methacrylates; mix proportioning; plastics, polymers and resins; precast concrete; prestressed concrete; reinforced concrete; repairs;resurfacing; sealing settlement (structural); shrinkage; specifications; structural design; tension; thermal expansion; volume change.

CONTENTS

ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in designing, planning, executing, or inspecting construction and in preparing specifications. References to these documents shall not be made in the Project Documents. If items found in these documents are desired to be a part of the Project Documents, they should be phrased in mandatory language and incorporated into the Project Documents.

ACI 224.1R-93 supersedes ACI 224.1R-90 and became effective September 1, 1993.

224.1R-1

American Concrete Institute

32

La Iniciativa en Estados Unidos

ACI 222.3R-11

Guide to Design and Construction Practices to Mitigate Corrosion of Reinforcement in Concrete Structures

Reported by ACI Committee 222

Mohammad S. Khan, Chair — David Trejo, Secretary

Antonio J. Aldykiewicz Jr., Michael C. Brown, David Darwin, Marwan A. Daye, Stephen D. Disch, Hamid Farzam, Per Fidjestøl, David P. Gustafson, Carolyn M. Hansson, William G. Hime, Brian B. Hope, Tracy D. Marcotte, David B. McDonald, Theodore L. Neff, Charles K. Nmai, Randall W. Poston, Ruben M. Salas, Arpad Savoly, Andrea J. Schokker, Morris Schupack, Khaled A. Soudki, Paul G. Tourney, Yash Paul Virmani, Jeffrey S. West, Richard E. Weyers, David W. Whitmore, John B. Wojakowski

Corrosion of metals in concrete is a significant problem throughout the world. In many instances, corrosion can be avoided if proper attention is given to detailing, concrete materials and mixture proportions, and construction practices. This guide contains information on aspects of each of these. In addition, the guide contains recommendations for protecting in-service structures exposed to corrosive conditions. The guide is intended for designers, materials suppliers, contractors, and all others engaged in concrete construction.

Keywords: admixtures; aggregates; aluminum; cathodic protection; cement; chlorides; consolidation; corrosion; curing; epoxy coating; high-range water-reducing admixtures; mixing; mixture proportioning; permeability; reinforcing steel; water-cementitious material ratio.

CONTENTS

ACI 222.3R-11 supersedes 222.3R-03 and was adopted and published April 2011.

American Concrete Institute

33

La Iniciativa en Estados Unidos

ACI 365.1R-00

Service-Life Prediction—State-of-the-Art Report

Reported by ACI Committee 365

James R. Clifton*† Chairman — Dan J. Naus*‡ Secretary

S. L. Amey*, J. P. Archibald, N. R. Buenfeld, P. D. Cady*, C. W. Dolan, M. Geiker, C. J. Hookham, W. J. Irwin, A. Kehnemui, D. G. Manning, P. K. Mukherjee, J. Pommersheim, M. D. Thomas, R. E. Weyers*

*Report chapter coordinators
†Deceased
‡Report coordinator

This report presents current information on the service-life prediction of new and existing concrete structures. This information is important to both the owner and the design professional. Important factors controlling the service life of concrete and methodologies for evaluating the condition of the existing concrete structures, including definitions of key physical properties, are also presented. Techniques for predicting the service life of concrete and the relationship between economics and the service life of structures are discussed. The examples provided discuss which service-life techniques are applied to concrete structures or structural components. Finally, needed developments are identified.

Keywords: construction; corrosion; design; durability; rehabilitation; repair; service life.

CONTENTS

ACI 365.1R-00 became effective January 10, 2000.

365.1R-1

American Concrete Institute

34

La Iniciativa en Estados Unidos

ACI 201.2R-01

Guide to Durable Concrete

Reported by ACI Committee 201

Robert C. O'Neill, Chairman — Russell L. Hill, Secretary

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Joseph G. Cabrera*	Roy H. Keck	James W. Schmitt
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Stephen W. Forster	Stella L. Marusin	Niels Thaulow
Clifford Gordon	Bryant Mather	Michael D. Thomas
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Charles J. Hookham	William F. Perenchio	David A. Whiting*
R. Doug Hooton	Robert E. Price*	J. Craig Williams
Allen J. Hulshizer	Jan R. Prusinski	Yoga V. Yogendran

*Deceased.

This guide describes specific types of concrete deterioration. Each chapter contains a discussion of the mechanisms involved and the recommended requirements for individual components of concrete, quality considerations for concrete mixtures, construction procedures, and influences of the exposure environment, all important considerations to ensure concrete durability. Some guidance as to repair techniques is also provided.

This document contains substantial revisions to Section 2.2 (chemical sulfate attack) and also includes a new section on physical salt attack (Section 2.3). The remainder of this document is essentially identical to the previous "Guide to Durable Concrete." However, all remaining sections of this document are in the process of being revised and updated, and these revisions will be incorporated into the next published version of this guide.

Both terms water-cement ratio and water-cementitious materials ratio are used in this document. Water-cement ratio is used (rather than the newer term, water-cementitious materials ratio) when the recommendations are based on data referring to water-cement ratio. If cementitious materials other than portland cement have been included in the concrete, judgment regarding required water-cement ratios have been based on the use of that ratio. This does not imply that new data demonstrating concrete performance developed using portland cement and other cementitious materials should not be referred to in terms of water-cementitious materials. Such information, if available, will be included in future revisions.

Keywords: abrasion resistance; adhesives; admixture; aggregate; air entrainment; alkali-aggregate reaction; bridge deck; carbonation; calcium chloride; cement paste; coating; corrosion; curing; deicer; deterioration; durability; epoxy resins; fly ash; mixture proportion; petrography; plastic; polymer; pozzolan; reinforced concrete; repair; resin; silica fume; skid resistance; spalling; strength; sulfate attack; water-cement ratio; water-cementitious materials ratio.

CONTENTS

ACI 201.2R-01 supersedes ACI 201.2R-92 (Reapproved 1997) and became effective September 6, 2000.

American Concrete Institute

35

La Iniciativa en Estados Unidos

ACI 221.1R-98

State-of-the-Art Report on Alkali-Aggregate Reactivity

Reported by ACI Committee 221

Stephen W. Forster*, Chairman

David J. Akers	Meng K. Lee	Aimee Pergalsky*
Colin D. Arrand	Donald W. Lewis	James S. Pierce
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Joseph F. Lamond	Michael A. Ozol*	Michael D. A. Thomas
D. Stephen Lane*	Steven E. Parker	Robert E. Tobin

*Member of subcommittee responsible for preparation of this report.
Note: Other Task Force members include: Kim Anderson (former Committee member, deceased); Leonard Bell (former committee member); and Colin Lobo (non-committee member).

Information that is currently available on alkali-aggregate reactivity (AAR), including alkali-silica reactivity (ASR) and alkali-carbonate reactivity (ACR) is summarized in the report. Chapters are included that provide an overview of the nature of ASR and ACR reactions, means to avoid the deleterious effects of each reaction, methods of testing for potential expansion of aggregates and cement-aggregate combinations, measures to prevent deleterious reactions, and recommendations for evaluation and repair of existing structures.

Keywords: aggregates; alkali-aggregate reactivity; alkali-carbonate reactivity; alkali-silica reactivity; concrete; concrete distress; concrete durability.

ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

CONTENTS

ACI 221.1R-98 became effective August 19, 1998.

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36

La Iniciativa en Estados Unidos

Life-365

O software Life-365 é uma ferramenta de auxílio para calcular a vida útil considerando a difusão for cloreto segundo o ACI 365.

É possível fazer o download pelo site: www.life-365.org/download.html

37

CYTED
Programa IberoAmericano de Ciencia y Tecnología para el Desarrollo
Sub Programa XV

Red DURAR

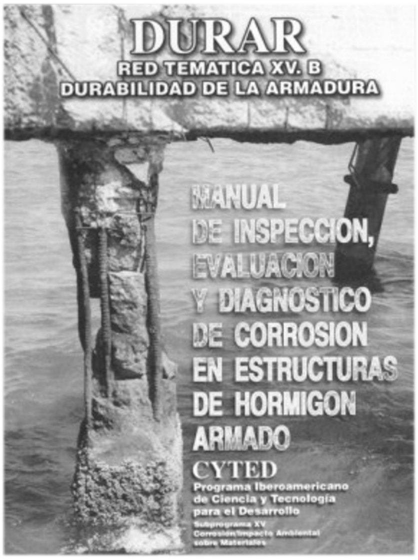
Durabilidad de las Estructuras de Concreto

Inspección y Diagnóstico

Profa. Oladis de Rincón
Coordinadora Internacional

38

Iniciativa Iberoamericana
Red DURAR



39

CYTED
Programa IberoAmericano de Ciencia y Tecnología para el Desarrollo
Sub Programa XV

|REHABILITAR| Red Temática XV.F CYTED

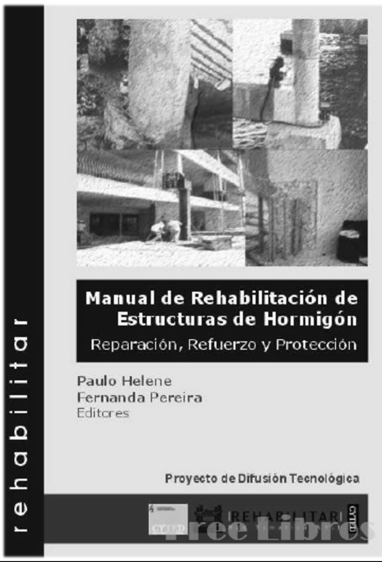
Rehabilitación de Estructuras de Hormigón

Reparación, Refuerzo, Protección

Prof. Paulo Helene
Coordinador Internacional *Red REHABILITAR CYTED*

40

Iniciativa Iberoamericana
Red Rehabilitar



41

CYTED
Programa IberoAmericano de Ciencia y Tecnología para el Desarrollo
Sub Programa XV

Red PREVENIR

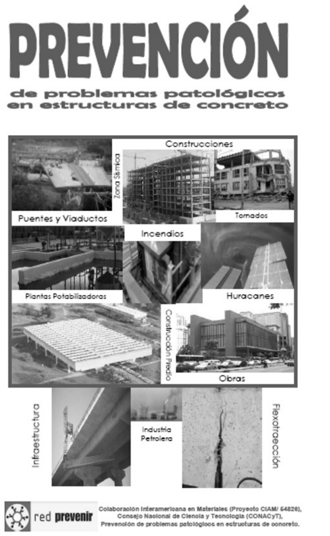
Prevención de Problemas Patológicos en la Industria de la Construcción

Profilaxia y Control

Prof. Pedro Castro-Borges
Coordinador Internacional *Red PREVENIR*

42

Iniciativa Iberoamericana
Red PREVENIR



43

Iniciativa Iberoamericana
ALCONPAT Int.

44

Iniciativa Iberoamericana ALCONPAT Int.

Objetivo Social

Son fines de la asociación promover la integración profesional de los ingenieros y arquitectos y afines a su objeto social, impulsando un amplio intercambio técnico, científico y humano en la búsqueda de un mayor perfeccionamiento profesional que beneficie el desarrollo de las comunidades a los que sus integrantes pertenezcan.
En tal sentido realizará cuantas actividades sean conducentes a tales fines, mencionándose a continuación y con un carácter ejemplificativo:

45

Iniciativa Iberoamericana ALCONPAT Int.

Objetivo Social

a) Realizar gestiones ante centros y organismos oficiales o privados, nacionales o internacionales, para la concesión de becas, subsidios y bolsas de empleo y estudio.

b) Difundir la información acerca de la realización de cursos, congresos o seminarios que se realicen en cualquier parte del país o del extranjero.

c) Acopiar y difundir datos bibliográficos o cualquier información relacionada con la técnica de la construcción que sean de interés para sus miembros y que coadyuven al cumplimiento del objeto social.

46

Iniciativa Iberoamericana ALCONPAT Int.

Objetivo Social

d) Promover la difusión y el conocimiento de los estudios, trabajos y realizaciones de sus miembros.

e) Organizar asambleas, congresos o exposiciones técnicas con el fin de fomentar los contactos personales y el intercambio de ideas y conocimientos, y con ello la mutua colaboración y el avance científico.

f) Realizar cuantas otras actividades se consideran convenientes para el mejor cumplimiento de su objeto.

47

Iniciativa Iberoamericana ALCONPAT Int.

La Asociación Latinoamericana de Control de Calidad, Patología y Recuperación de la Construcción Internacional (ALCONPAT-Internacional) nació hace casi 26 años en el marco del congreso CONPAT (Congreso Latinoamericano de Patología de la Construcción), organizado por ex-alumnos y profesores del curso CEMCO (Curso de Estudios Mayores de la Construcción) realizado cada tres años por el Instituto Eduardo Torroja de Ciencias de la Construcción, en Madrid, España, iniciado en 1969, Primer CEMCO69.

48

Iniciativa Iberoamericana ALCONPAT Int.

A partir del año 2001 en Santo Domingo se abre la historia de las Asociaciones de ALCONPAT por países. Este momento marca un hito importante en la historia de la Asociación. La principal política, a partir de ese momento fue la de legalizar las delegaciones de ALCONPAT en cada país. Se registra así la primera versión de ALCONPAT en la Web, se formalizan las inscripciones de los miembros y se cuenta con un archivo integrado de la Asociación.

49

http://www.mda.cinvestav.mx/alconpat/internacional/index.php

50

Publicaciones

51

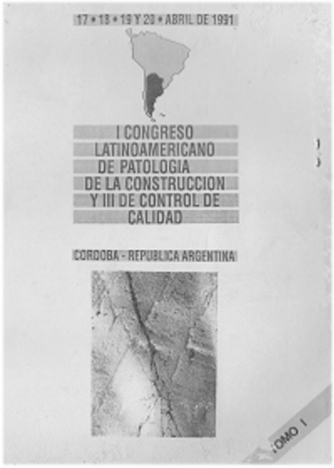
Iniciativa Iberoamericana ALCONPAT Int.

ALCONPAT-Internacional da sustento a los congresos CONPAT, cada dos años a nivel internacional y cada año a nivel nacional en cada uno de los países miembros se celebra un evento científico que cada vez más da respuesta a los problemas típicos de la construcción. Hasta ahora se han registrado más de 3000 profesionales en los 13 Congresos.

52

Iniciativa Iberoamericana ALCONPAT Int.

Córdoba, Argentina (1991), Dante Domene.



53

Iniciativa Iberoamericana ALCONPAT Int.

Barquisimeto, Venezuela (1993), Liana Arrieta de Bustillos.

54

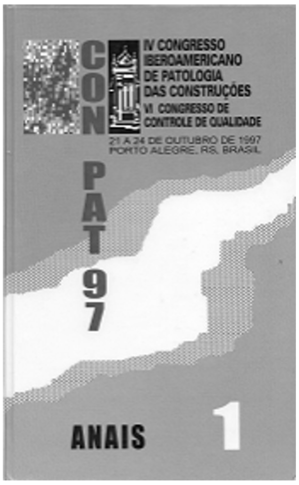
Iniciativa Iberoamericana ALCONPAT Int.

La Habana, Cuba (1995), Vitervo O'Reilly.

55

Iniciativa Iberoamericana ALCONPAT Int.

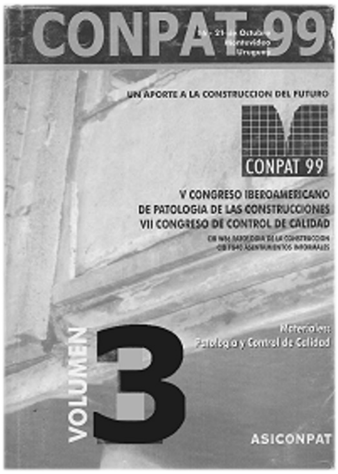
Porto Alegre, Brasil (1997), Dario Klein.



56

Iniciativa Iberoamericana ALCONPAT Int.

Montevideo, Uruguay (1999), Ana Inés de la Fuente.



57

Iniciativa Iberoamericana ALCONPAT Int.

Santo Domingo, República Dominicana (2001), Máximo Corominas.

58

Iniciativa Iberoamericana ALCONPAT Int.

Telchac, México (2003), Pedro Castro Borges.

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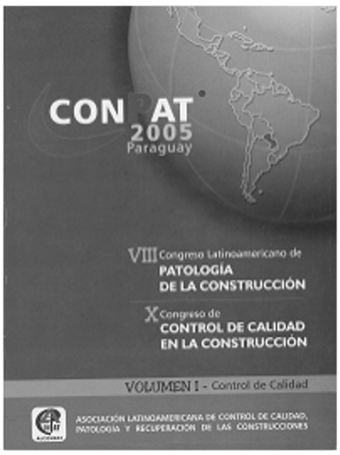
Iniciativa Iberoamericana ALCONPAT Int.

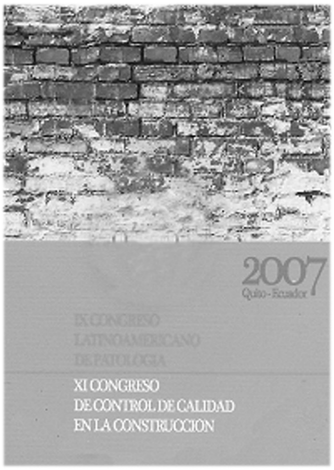
Asunción, Paraguay (2005), Angélica Ayala.



60

Iniciativa Iberoamericana ALCONPAT Int.

Quito, Ecuador (2007), Rody Cabezas.



61

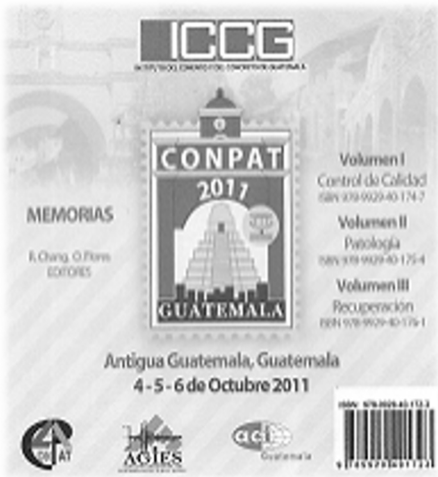
Iniciativa Iberoamericana ALCONPAT Int.

Valparaíso, Chile (2009), Patricia Martínez.

62

Iniciativa Iberoamericana ALCONPAT Int.

La Antigua, Guatemala (2011), Francisco Ruiz.



63

Iniciativa Iberoamericana ALCONPAT Int.

Cartagena de Indias, Colombia (2013), Sergio Espejo.

64

Iniciativa Iberoamericana ALCONPAT Int.

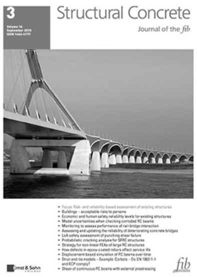
Lisboa, Portugal (2015), Fernando Branco.

65

Iniciativa Iberoamericana ALCONPAT Int.

66

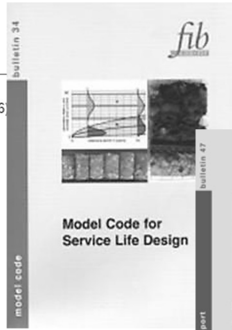
Experiencia Internacional
fib (International Federation for Structural Concrete)

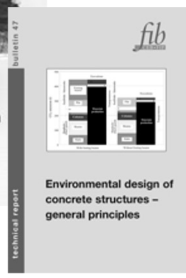


Corrosion protection of prestressing steels

Price: CHF80.00

Corrosion protection of prestressing steels
Recommendation (50 pages, ISBN 978-1-874266-26-6)





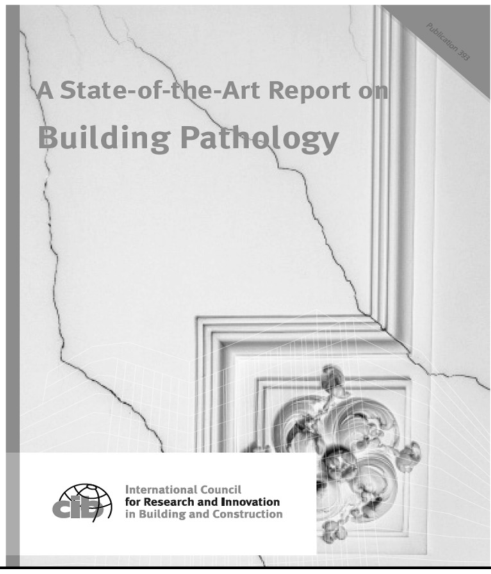
Durability of concrete structures in the North Sea

Price: CHF80.00

Durability of concrete structures in the North Sea
State of the art report (53 pages, ISBN 978-1-874266-30-3)

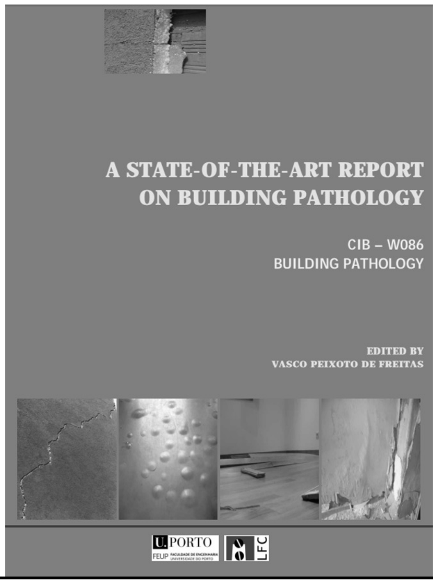
67

Experiencia Internacional
CIB Comisión WO86



68

Experiencia Internacional
CIB Comisión WO86



69

Conceptos

Las estructuras debem ser adecuadas para su correcta utilización durante la vida útil de diseño:

- ✓ Seguras
- ✓ Funcionales
- ✓ Soportar incêndio/fuego
- ✓ Durables
- ✓ Bonitas
- ✓ Sustentables

70

Ingreso de gases y fluidos
mecanismos de transporte

- Permeabilidad
- Capilaridad
- Difusibilidad
- Migración
- Convección

71

Propriedad	20 MPa	50 MPa
coeficiente de permeabilidade à água k_w (m/s)	$4*10^{-12}$	$3*10^{-14}$
coeficiente de permeabilidade a gás O_2 k_g (m^2)	$1*10^{-15}$	$3*10^{-17}$
carbonatação em 50 anos e_{CO_2} (mm)	30	5
coeficiente de difusão de cloretos D_{Cl} (m^2/s)	$1*10^{-10}$	$1*10^{-11}$
absorção capilar de água em 24h w (dm^3/m^2)	$4*10^{-4}$	$4*10^{-5}$

72

"mecanismos de envejecimento"

Concreto

- ✓ Lixiviación; águas ácidas, hongos, bolores, ácidos
- ✓ Expansión → sulfatos externos o internos
- ✓ Expansión → AAR
- ✓ Expansión → MgO

Açero

- ✓ Corrosión por carbonatación
- ✓ Corrosión por cloruros

Estructura

acciones mecânicas, movimentaciones térmicas, impactos, acciones cíclicas, retracción, fluência y relaxación

73

Concreto → ***Lixiviacción***

Cobertura do
Prédio da FAU-USP

Edifício da
Engenharia Civil
POLI.USP

74

Concreto → *Lixiviacción*

Mecanismo

- Carreamento de sais solúveis pela água, $Ca(OH)_2$

Manifestação, Sintoma

- Manchas esbranquiçadas na superfície $CaCO_3$
- Eflorescência, pode até formar estalactites
- Aumento da porosidade interna do concreto
- Redução do pH com risco de corrosão

Como evitar, Prevenção, Profilaxia

- Reduzir relação a/c, usar adições
- Melhorar condições de cura;
- Impermeabilizar evitando água.

75

Como Corregir ?

Inspeção e Diagnóstico:

- Origem
- Mecanismo
- Agentes causadores
- Prognóstico

Intervenção Corretiva:

- Materiais
- Equipamentos
- Mão de obra
- Procedimentos

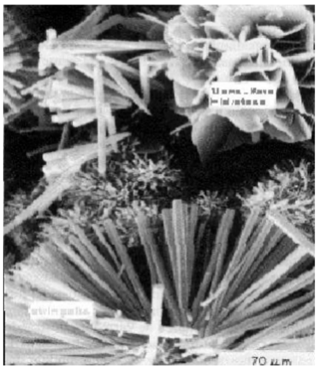
Manutenção

76

Concreto → ***Expansión***

Reações expansivas

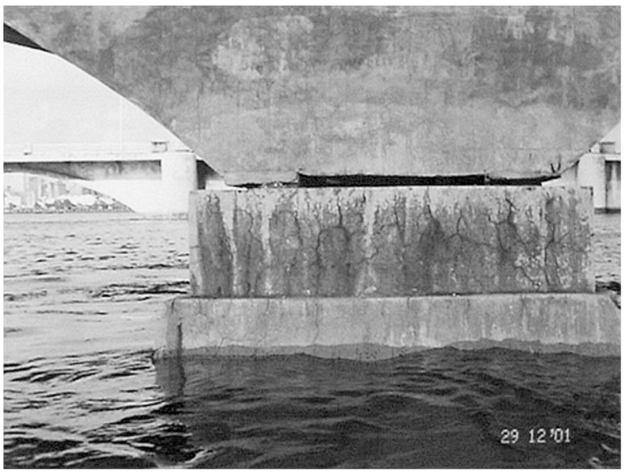
Sulfatos, SO_4^{-2} vs Aluminatos



77

Concreto → ***Expansión***

Reacción Álcali-Agregado AAR



78

Acero → ***Corrosión de Armaduras***

Despassivação por carbonatação

- $Ca(OH)_2$ --- pH ≥ 12
(aço passivado)

- $CO_2 + Ca(OH)_2 \Rightarrow CaCO_3 + H_2O$
(aço despassivado)

79

80

Acero → ***Corrosión de Armaduras***

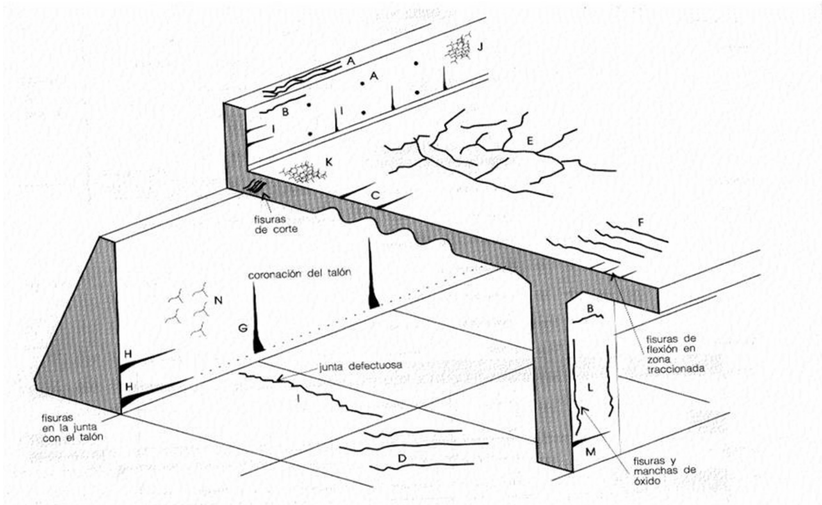
Despassivacción por cloruros

81

82

Estructura

fisuras: térmicas, retracción, acciones/cargas, constructivas



83

84

85

Reacción expansiva con Sulfatos

- $Na_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2NaOH$

  Lixiviação

- $CaSO_4 + H_2O \rightarrow CaSO_4.2H_2O$

  Expansão

- $3CaSO_4 + C_3A.nH_2O \rightarrow C_3A.3CaSO_4.32H_2O$

  74 150 715 **Expansão**

  etringita

86


CAU156A

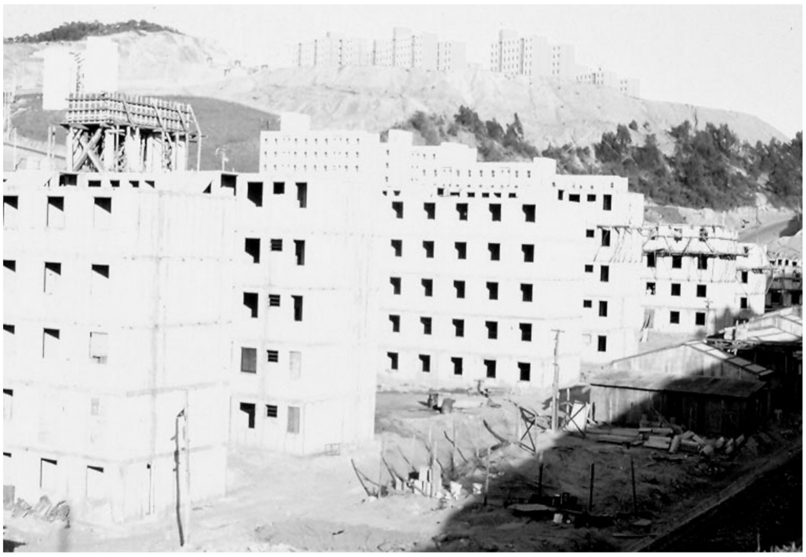
87


1. Cimento CAUÊ AF 320
2. cimento + gesso + aditivo + retardador + água
3. Exposto 56 dias em ambiente úmido a 38°C ± 5°C
4. Fissuras superficiais tipo "couro de jacaré" generalizadas

88

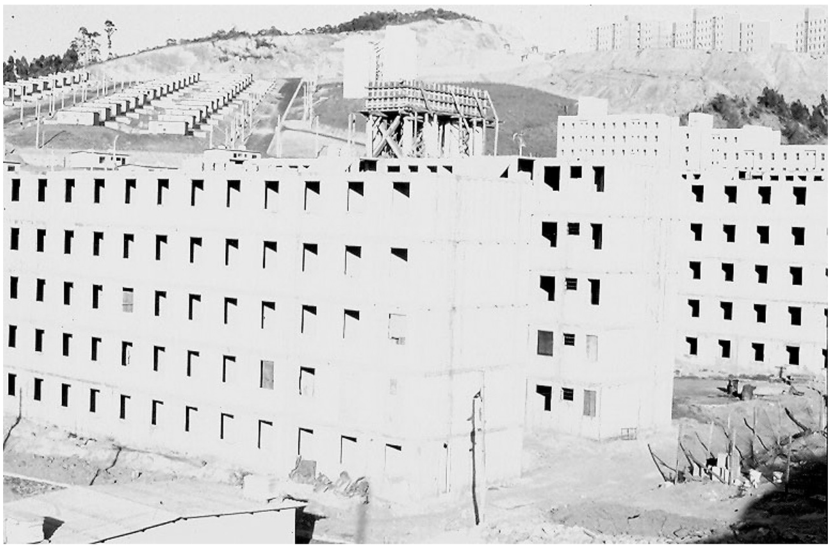
89

Processo Construtivo Cimento + Gesso → 1981



90

5.000 unidades (edifícios "térreo+4" e casas)



91

92

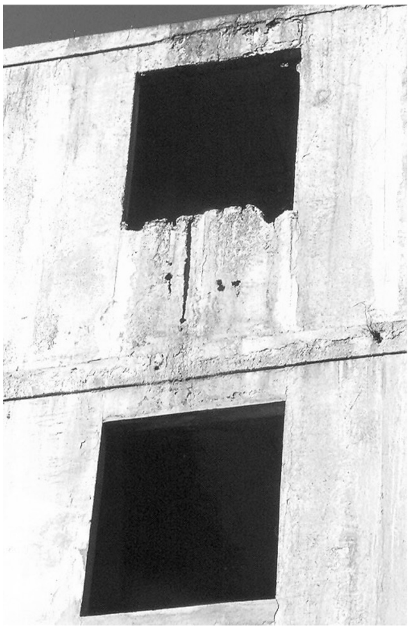
93

94

95

96

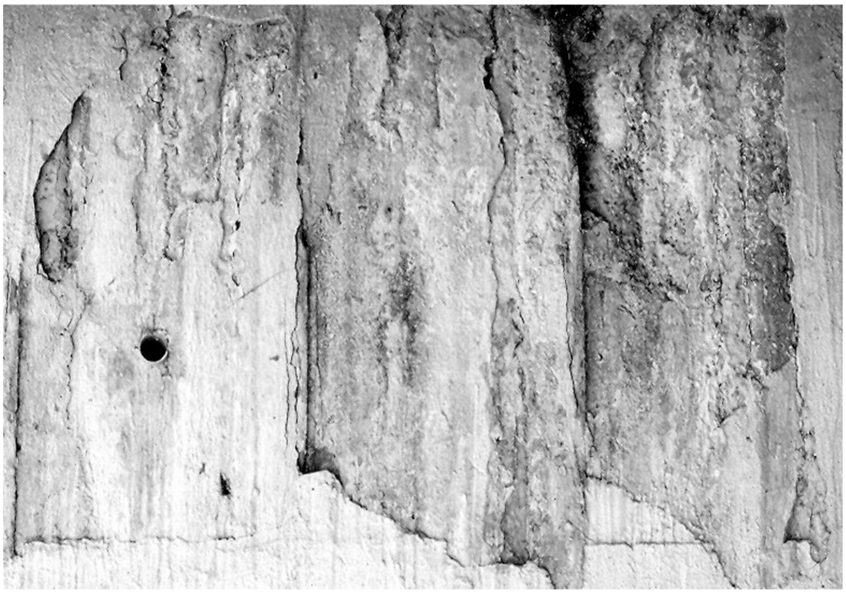
97



98

99

100



101

Histórico

A ação de sulfatos foi objeto de estudos de diversos pesquisadores:

Le Chatelier - *Recherches expérimentales sur la constitution des mortiers hydrauliques, Thése, Paris, 1887*;

Candlot - *Ciments et chaux hydrauliques, Baudry édit., Paris, 1898;*

Lafuma – *Théorie de l´expansion des liants hydrauliques, Paris. Mat. Constr., dec. 1929 et janv. 1930;*

Thorvaldson - *Resistance of concrete to sulphate and other environmental conditions. Univerdity of Toronto Press. 1968*

102

Histórico de casos

- Ponte sobre rio Elba em Magdeburg, Alemanha:
  - Água com 1700mg/l de SO_4;
  - A expansão do concreto implicou em fissuração e posterior demolição.
- Barragem de Ft. Peck em Montana, EUA
  - Construída entre 1933 e 1940;
  - Água com 10.000 mg/l de SO_4
- Candlestick Park em São Francisco, EUA:
  - Inaugurado em 1956;
  - Graute localizado entre as vigas pré-moldadas e moldadas in loco da arquibancada do estádio

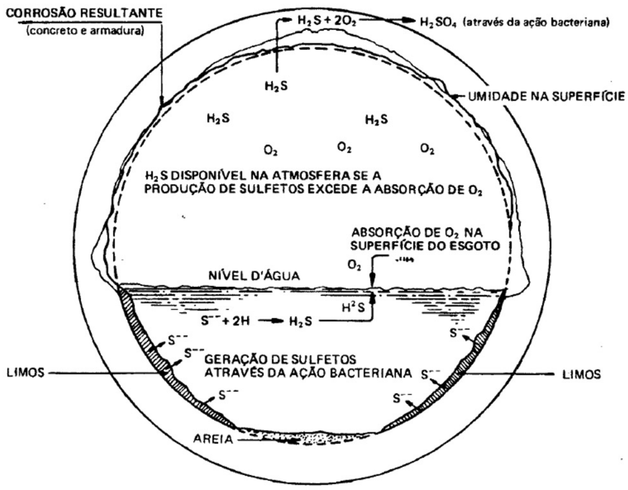
103

Ataque por Sulfatos externos

- Reação químicas na qual íons sulfato (SO4) **oriundos do ambiente circundante** reagem com aluminatos do cimento, formando compostos expansivos (etringita+gesso) que absorvem água, gerando tensões internas que fissuram o concreto.
- O ataque desagrega a superfície do concreto, tornando-a friável;
- A velocidade de ataque é normalmente lenta (pode necessitar 5 a 20 anos para que o ataque se manifeste de forma severa);
- Pode gerar movimentações globais da estrutura;

104

Galerias de Esgoto
Sulfatos externos



105

Ataque por sulfatos de magnésio externo

- Em alguns casos **(sulfato de magnésio)**, a reação química pode causar a desestruturação dos silicatos de cálcio que formam a estrutura resistente do concreto transformando o concreto em Taumasita;
- O ataque desagrega a superfície e o interior do concreto, tornando-o friável e pouco resistente;
- A velocidade de ataque é normalmente lenta (pode necessitar 10 anos a 20 anos para que o ataque se manifeste de forma severa)

106

Ataque por Sulfatos internos

- Em alguns casos pode ocorrer uma reação deletéria entre os aluminatos do cimento com os **sulfatos internos provenientes de agregados (pirita), adições (enxofre S), ou mesmo reguladores de pega à base de sulfatos de cálcio (gipsita)**;
- Essa reação pode ser desencadeada pela temperatura, sempre que esta sobre passe os 65ºC, e neste caso chama-se DEF (delayed ettringite formation) ou formação de etringita tardia;
- O ataque, em geral se manifesta no primeiro ano e pode gerar fissuras de grande abertura a ponto de confundir-se com AAR

107

DEF

Trata-se de uma reação por ataque de sulfatos que resulta na formação de etringita tardia (delayed etringita formation, DEF)
$3CaO.Al_2O_3.3CaSO_4.32H_2O$

Etringita formada no concreto fresco, pode ser considerado um problema comum. Entretanto, a formação de etringita no concreto endurecido é prejudicial.

Caso a temperatura no interior do concreto atinja temperaturas de mais de 65ºC, devido ao calor aplicado (cura térmica) ou a geração de calor durante a hidratação do cimento, principalmente nos casos do lançamento de concreto em grande volume, há risco da formação de etringita tardia, DEF, que pode levar à expansão e à fissuração do elemento estrutural.

Para que os efeitos nocivos ocorram, é necessário que o concreto esteja molhado ou umedecido permanente ou intermitentemente. Os efeitos nocivos são a redução da resistência, a diminuição do módulo de elasticidade e, em algumas situações, a intensa fissuração.

108

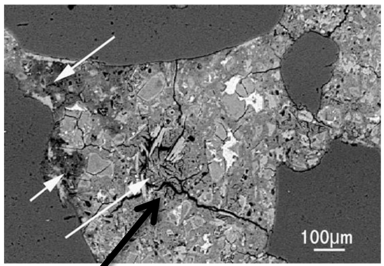
Fundamentos

- C3A → 8% aluminatos de cálcio

Quando em contato com íons sulfato após endurecimento

$$C_3A \cdot CH \cdot H_{18} + 2CH + 3\bar{S} + 11H \rightarrow C_3A \cdot 3C\bar{S} \cdot H_{32}$$

$$C_3A \cdot C\bar{S} \cdot H_{18} + 2CH + 2\bar{S} + 12H \rightarrow C_3A \cdot 3C\bar{S} \cdot H_{32}$$

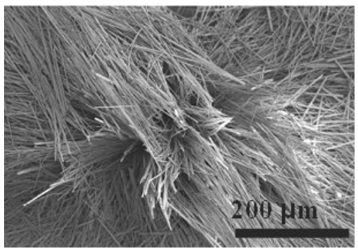


Etringita

109

Ataque por sulfatos –Formação Cristais Expansivos

Etringita
(tri sulfoaluminato de cálcio com 32 moléculas de água)



110

Referências Critérios de Classificação

Concentração de sulfato > 3.000 mg/kg no solo
> 600 mg/l SO4 na água

ACI 201.2R-9 Guide to Durable Concrete

Agressividade	Sulfato (SO_4) na água (ppm)	Recomendação
Nível 0	0 – 150	Sem limites especificados
Nível 1	150 – 1500	Relação a/c máxima = 0,50 Cimento = Moderada resistência a sulfatos
Nível 2	1500 – 10.000	Relação a/c máxima = 0,45 Cimento = Alta resistência a sulfatos
Nível 3	> 10.000	Relação a/c máxima = 0,40 Cimento = Alta resistência a sulfatos + pozolana ou escória

111

Ataque Sulfatos –Prevención Profilaxia

- ✓ Evitar teor de sulfato no solo ou na água de contato superior a 0,2% ou mais de 500 ppm
- ✓ Evitar cimentos com teores elevados de aluminatos tri cálcicos (C_3A)
- ✓ Evitar contato com águas que contenham sulfatos de magnésio
- ✓ Evitar que o concreto fresco sobrepasse 65º C

112

Reacción Expansiva Álcali-Árido o Álcali-Agregado

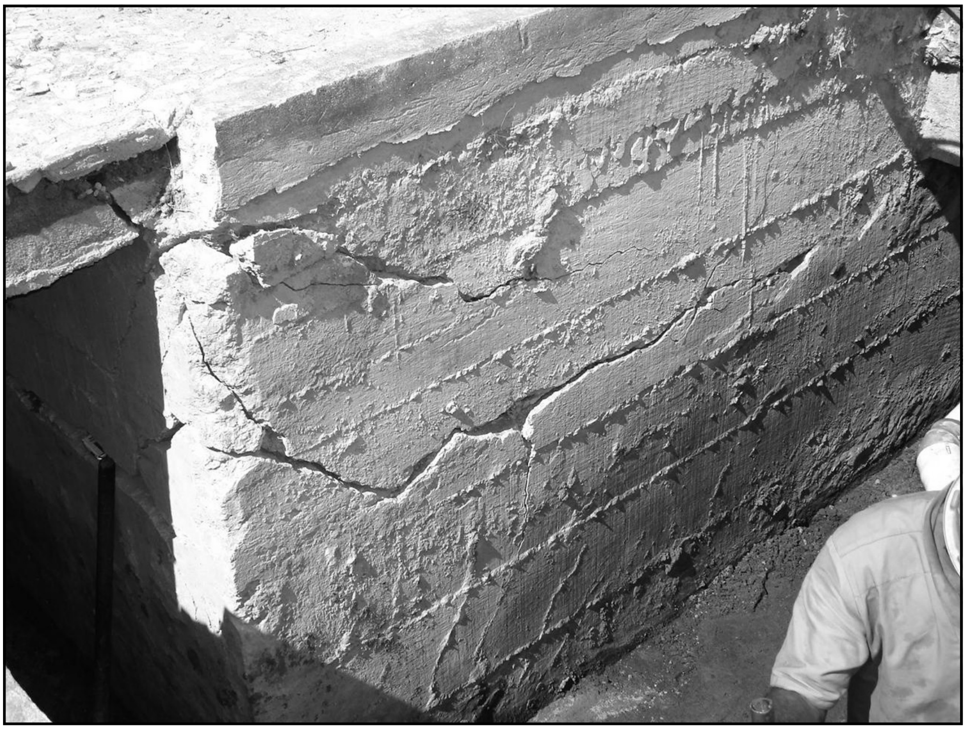
AAR

113

Problema: Cimentaciones

114

115



116

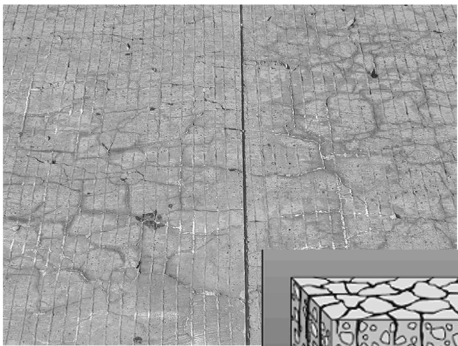
117

Problema: encuentros/Puentes

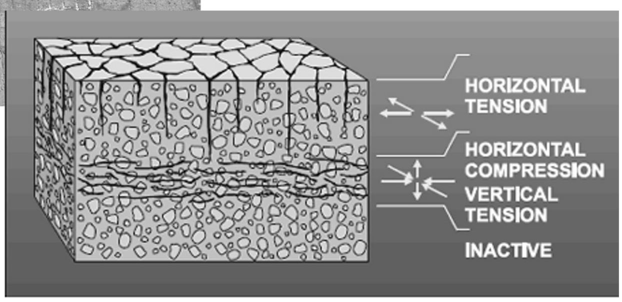
118

119

Sintomatologia



Fisuración Mapeada



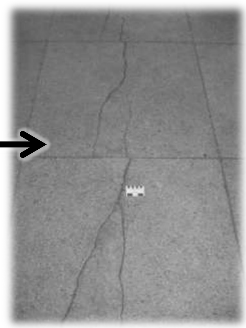
120

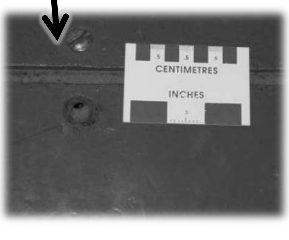
Presa Moxotó

121

Presa Paulo Afonso

Avisos de la estructura





122

Viaduto Robert-Bourassa

Charest, Québec, Canada

SANCHES, L.; FOURNIER, B.; KUPERMAN, S., 2010

123

História

✓ Foi descoberta nos anos 30 na Califórnia EUA, por Thomas Stanton. *Expansion of concrete through the reaction between cement and aggregate. Proceedings ASCE, n. 66, 1940. p. 1781-1811*

✓ Na mesma época o *USA Bureu of Reclamation* registrou a reação nas barragens Parker Dam (Colorado) e Stewart Mountain Dam, especificando Na_2O < 0,6%

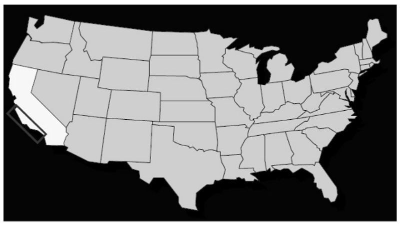
✓ Os primeiros estudos foram realizados nos anos 60 → Barragem de Jupiá

✓ Primero caso: Barragem UHE Apolonio de Sales Oliveira (Moxotó)

124

História

Thomas Stanton, Caltrans - CA



125

História

✓ **Foi informado pelo** Dr. Benoit Fournier, 2009, Professor da *Université Laval Québec* e Presidente da *CSA Technical Group on Alkali-Aggregate Reaction*, **que haviam sido diagnosticadas estruturas afetadas por AAR em mais de 50 países.**

✓ RILEM TC 191-ARP *Alkali-reactivity and prevention. Assessment, specification and diagnosis of alkali-reactivity*

126

Mecanismo

Reação expansiva entre os álcalis presentes no cimento e alguns minerais de certos agregados reativos utilizados na produção do concreto

O resultado dessa reação é a formação de um gel que absorve água e se expande, ocasionando esforços de tração superiores a capacidade resistente do concreto, da ordem de 4 MPa

127

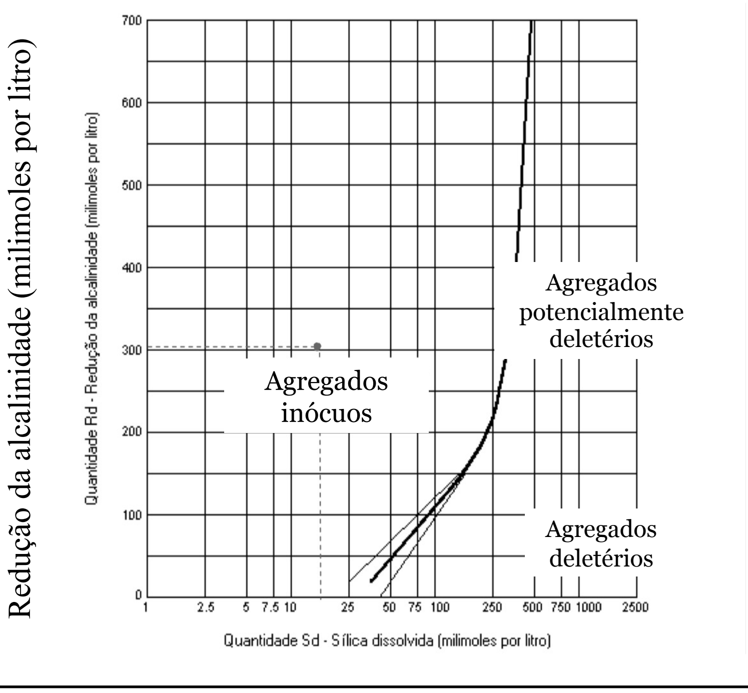
Investigacciones

- **análise petrográfica ASTM C 295;**
- **análise método químico ASTM C289**;
- **mortero + agregado ASTM C 1260;**
- **microscopia eletrônica de varredura**

128

Método químico ASTM C 289

129



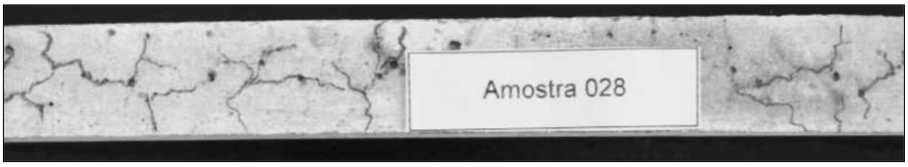
130

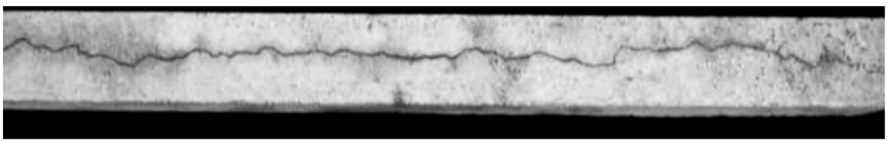
Método acelerado ASTM C 1260

Limites de expansión (0,1 e 0,2%) a los 16 dias e 28 dias de idade

131

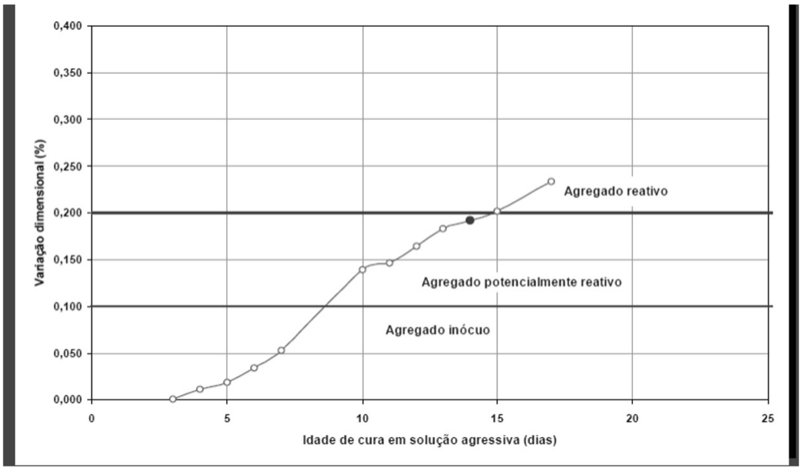
Barras de mortero con fisuras





132

Método acelerado
mortero + agregado ASTM C 1260



Battagin; Kihara

133

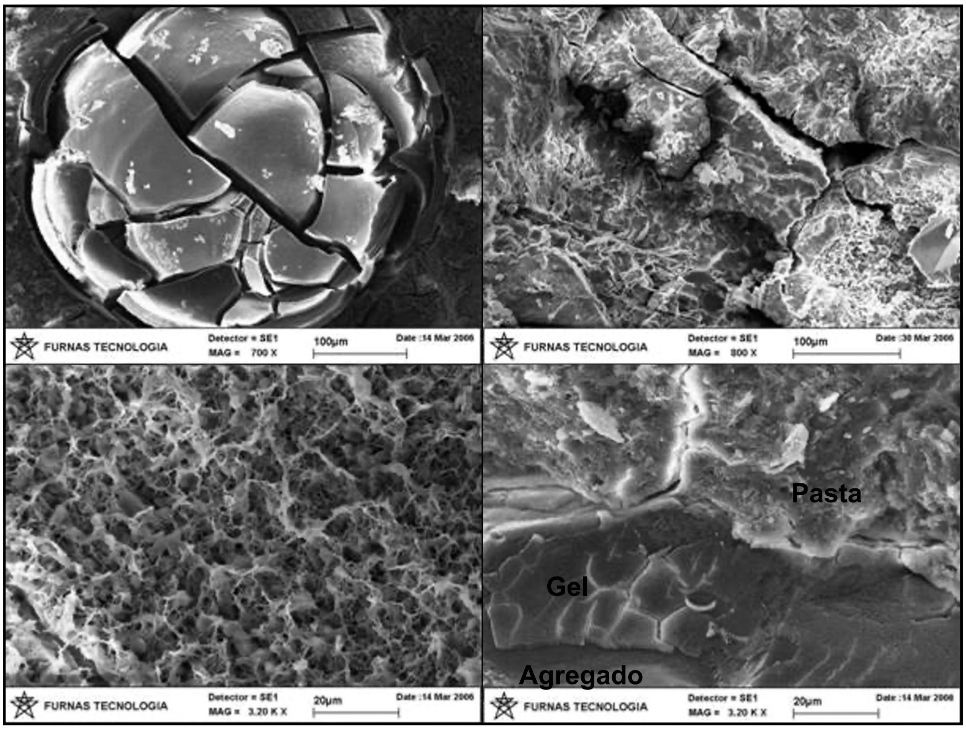
Microscopia eletrônica de varrido

busca de *gel de reação*

134


Poro revestido de gel
Acc.V Spot Magn Det WD 200 µm
20.0 kV 5.0 171x SE 8.9
Gel maciço e gretado
Acc.V Spot Magn Det WD 200 µm
20.0 kV 5.0 75x SE 8.6 LAILA13C.TIF

135


FURNAS TECNOLOGIA
100µm
FURNAS TECNOLOGIA
100µm
Pasta
Gel
Agregado
FURNAS TECNOLOGIA
20µm
FURNAS TECNOLOGIA
20µm

136

Mapa do estado de São Paulo *– Localização das amostras reativas e não reativas*

137

Álcalis

138

• Íons Na^+ (sódio) e K^+ Potássio

• Na_2O equivalente no cimento anidro não deve exceder 0,6%

$$Na_2O\ eq = Na_2O + 0{,}658 \cdot K_2O$$

• Máximo de álcalis por m³ de concreto

< 3 kg/m³

139

Terapia → Como Reparar

- **Reduzir o acesso da água;**
- **Injeção de resinas;**
- **Confinar;**
- **Prever juntas**

140

141

142

143

144

145

146

147

148

PROFILAXIA -->Como prevenir?

1. Controlando álcalis no cimento;

Na_2O equivalente < 0,6%
Total álcalis < 3kg/m^3

2. Controlando reatividade nos agregados

Método químico ASTM C 289 (24h)
Análise visual ASTM C 294 (24h)
Análise petrográfica ASTM C 295 (24h)

149

Como prevenir?

3. Controlando reatividade no concreto

Método de barras adição mineral ASTM C441 (6 meses)
Método das barras de mortero ASTM C227 (6 meses)
Método carbonato → ASTM C586
Método álcali carbonato → ASTM C1105
Método acelerado das barras ASTM C1260 (16d e 28d)
Método dos prismas de concreto ASTM C1293 (1ano)

150

Como prevenir?

4. Uso de adicciones activas

Método de barras adição mineral ASTM C 441 (6 meses)
Eficácia de adições ASTM C 1567
microsílica, metacaulim, cinzas volantes, escória

5. Impermeabilização

silicone, epóxi, poliuretano, cimento+latex, betume,
drenar, etc.

151

153