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Concrete Petrographer

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The field of concrete petrography supports the producers and users of portland cement concrete and other inorganic cement-based building and construction materials. Petrographic examinations are conducted on the raw materials used in the manufacture of these materials, and on samples of the materials taken from service. Conclusions and recommendations derived from the findings of petrographic examinations and related laboratory testing meet a number of needs.

- Providing guidelines for the rational selection of appropriate and suitable cements and aggregates for use in the manufacture of concretes and other cement-based materials.

- Providing an assessment of the factors involved in those instances where the concrete and other cement-based materials do not meet expectations or performance requirements in service.

- Providing a basis for identifying an optimum repair or remedial strategy for constructions or structures that have deteriorated to an unacceptable level.

- Providing information to engineers conducting a condition survey of a construction or structure on the expected role that the cement-based material can play in the overall rehabilitation scheme.

I am a materials scientist who has been involved in the investigation and study of concrete and other cement-based materials (mortars and grouts) since 1965. Early in my career petrographic examinations were an important component of the conduct of laboratory research projects and field studies concerned with the performance of cement-based building and construction materials in a wide variety of applications ranging from highway pavements to nuclear waste disposal. Some examples of these activities, as well as a discussion of my academic training and industry-related activities follow. Pertinent peer-reviewed and other open-literature publications are given at the end of the discussion section.

EDUCATION

- B.S. Geology, Indiana University, 1959
- M.S. Ceramics, University of Illinois, 1965
- Ph.D. Ceramic Engineering, Ohio State University, 1970

WORK HISTORY

- President/Petrographer, Lankard Materials Laboratory, Columbus, Ohio (1978-Current)
- Construction Materials Group, Battelle Laboratories, Columbus, Ohio (1965-1978)
  Head of the Group from 1968 to 1978

PROFESSIONAL ORGANIZATIONS AND AWARDS

- Member of the American Concrete Institute (ACI)
- Member of the American Society for Testing and Materials (ASTM)
- Member of ASTM Committee C-09 (Concrete and Concrete Aggregates)
- Member of ASTM Subcommittee C-09.65 (Petrography of Concrete and Aggregates)
- Member of the Society of Concrete Petrographers
- Fellow of the American Concrete Institute (1990)
- Fellow of the American Ceramic Society (1987)
- Recipient of the ACI Wason Medal for Most Meritorious Paper (1973)

BRIDGE DECK AND PAVEMENT APPLICATIONS

Experience in the use of concrete in bridge deck and pavement applications has been gained in research studies and field investigations for the Federal Highway Administration (FHWA), the National Cooperative Highway Research Program (NCHRP), the Strategic Highway Research Program (SHRP), the Ohio Department of Transportation (ODOT), and a number of other state transportation agencies.

Distress issues and mechanisms investigated in these studies include D-Cracking distress, freeze/thaw distress, alkali-silica reactions, internal sulfate attack, slag aggregate issues, autogenous shrinkage, fatigue distress, corrosion of embedded reinforcing steel, joint deterioration, mid-slab cracking, membrane performance, scaling, pavement base issues, and debonding of bridge deck overlays.

FLATWORK AND FLOOR APPLICATIONS

Performance and durability issues have been studied in residential and commercial sidewalks, walkways, driveways and patios, which have been constructed using cast in place concrete, and concrete or brick pavers. Other concrete applications include parking slabs, floor slabs on ground, floor slabs on metal decking, floor slabs on wood decking, conventionally reinforced concrete slabs, and pre-stressed concrete slabs.

Distress issues and mechanisms examined in these studies have included random cracking, curling, plastic shrinkage cracking, joint deterioration, scaling, freeze/thaw damage, alkali-carbonate and alkali-silica reactions, dusting, discoloration, delamination, loss of bond with floor coverings and repair materials, underlayment failure, overlay failure, low strength, delayed set, rain damage, chemical attack, and wear resistance.

Petrographic examinations have been conducted for Geotechnical Laboratories, Engineering and Testing Laboratories, ready-mixed concrete producers, cement manufacturers, and concrete admixture manufacturers.

CONCRETE STRUCTURES AND PRECAST APPLICATIONS

Performance and durability issues have been studied in precast concrete units, pre-stressed and reinforced concrete structures, shotcrete structures, slip-formed structures claddings and repair materials on residential and commercial buildings (including cement stucco, terra cotta, and brick), and in mass concrete constructions. These applications include bridge structures, farm buildings, concrete tanks, chimneys, silos and feed towers, swimming pools and spas, concrete pressure vessels, concrete weight coatings, precast building panels, parking structures, foundations, concrete walls, and locks and dams.

Distress issues and mechanisms investigated in these studies include corrosion of conventional and pre-stressing steel, grout performance issues, abnormal cracking, freeze/thaw distress, chemical attack, cement-aggregate reactions, moisture movement, low strength issues, exposure to elevated temperatures, exposure to fires, corrosion of reinforcing steel, tile and overlay debonding issues, and wearing surface disintegration and staining.

PETROGRAPHIC EXAMINATION PROCEDURES AND PHILOSOPHY

My petrographic examinations follow the guidelines of ASTM C 856 “Standard Practice for Petrographic Examination of Hardened Concrete”, and ASTM C 295 “Standard Guide for Petrographic Examination of Aggregates for Concrete”. Analytical tools that can be brought to bear in these examinations include (1) Stereomicroscope for reflected light examination of lapped surfaces at magnifications of 10X to 110X, (2) Polarizing microscope for transmitted light examinations on thin sections and grain mounts (40X to 400X), (3) Scanning Electron Microscope (SEM) for examinations at magnifications up to 5000X or higher, (4) Energy Dispersive X-ray Spectroscopy (EDS) analyses used in conjunction with SEM examinations to gain information of the chemical composition of samples under study, and (5) X-ray diffraction (XRD) analyses which provide information on the type and amount of crystalline constituents of the samples.

Our laboratory is also equipped to provide measurements of chloride ion permeability, chloride-ion content, density, and compressive and flexural strength, which are often helpful data in fully defining the nature and ramifications of a material performance issue.

In my investigation of any material performance issue I recognize that variables other than a deficiency in the material itself are often a major factor, if not the major factor, in the failure of a material to perform. In any situation in which a construction or building material has not "performed satisfactorily" I give full consideration to all of the elements which can impact a problem of this nature. These elements include,

1. The possibility that the material itself is deficient in some respect and is solely responsible for the problem.

2. The possibility that the material meets all the requirements that are claimed for it, but the design of the structure or application is faulty and places demands on the material that it was never meant to accommodate.

3. The possibility that the material as supplied to the job-site meets all of the requirements that are claimed for it, and the design is adequate, but proper procedures were not followed when the material was installed.

4. And finally, the possibility that the material meets all the requirements that are claimed for it, the design is adequate, and proper installation procedures were used, but the material was placed in an environment for which it was never intended.

My experience as a principal investigator on laboratory research investigations and field studies adds an important dimension to my interpretation of petrographic observations and findings. This experience supports my efforts to identify all of the factors that have influenced the past performance of a cement-based building or construction material or which can be expected to influence its ability to perform satisfactorily in the future.

PUBLICATIONS: PAVEMENTS AND BRIDGE DECKS

1. Lankard, D.R., "Forensic Investigations of AC and PCC Pavements with Extended Service Life: Volume 2: Petrographic Examination of PCC Core Samples at Lankard Materials Laboratory", Report FHWA/OH-2010/004B, September, 2010, 166 pages. (Identifies factors that contributed to good performance and durability in ODOT PCC pavements, including one project constructed in 1946).

2. Lankard, D.R., "Forensic Investigations of AC and PCC Pavements with Extended Service Life: Volume 3: Petrographic Examination of Blast Furnace Slag Aggregate Concrete Cores taken from PCC Pavements in Cuyahoga County, Ohio", Report FHWA/OH-2010/004C, September, 2010, 136 pages. (Identifies factors contributing to materials-related distress in slag aggregate PCC pavements, which includes ASR and internal sulfate attack).

3. Lankard, D.R., "Examination of Abnormal Cracking Distress in an Ohio Department of Transportation Pavement Project in Hancock County, Ohio (State Job No. 134239). Report No. FHWA/OH-2006/11B, May 2006, pp. 1-39.

4. Lankard, D.R., "Petrographic Examination of Concrete Cores taken from the Ohio Strategic Highway Research Program (SHRP) Specific Pavement Studies Test Road", Lankard Material Laboratory Report No. 5423 to The Ohio Research Institute for Transportation and the Environment, Athens, Ohio, August 2003, pp. 1-32.

5. Lankard, D.R., "Concrete Under the Microscope: Three Case Studies Demonstrate the Power of Petrographic Examination to Reveal the Causes of Concrete Deterioration", *Concrete Repair Digest,* December 1995/January 1996, pp. 334-338. (Addresses scaling in bridge decks and debonding of bridge deck overlays).

6. Lankard, D.R., "Transverse Joint Distress and Mid-Slab Cracking Distress in PCC Pavements: A Petrographers Perspective". Proceedings of the 10th International Conference on Concrete Pavements, Quebec City, Quebec, July 8-12, 2012, www.concretepavements.org/10th iccp/ (Highlights the benefits of joint sealing).

7. Lankard, D.R. and Walker, A.J., "Pavement Applications for Steel Fibrous Concrete", *Transportation Engineering Journal, American Society for Civil Engineering",* Volume 101, No. TE1, Proc. Paper 11108, February 1975, pp. 137-153. (Provides an overview of early field trials with steel fibrous concrete in pavements and bridge deck applications).

8. Lankard, D.R., "Internal Sulfate Attack in Slag Aggregate Concrete Pavements", Proceedings of the 33rd International Conference on Cement Microscopy, San Francisco, CA, April 17-20, 2011 (www.cemmicro.org)

9. Lankard, D.R., Walker, A.J., and Niesz, D.E., "Influence of Cement on Moisture Migration in Cement Paste and Concrete as Related to the Durability of Concrete", *Federal Highway Administration Report No. FHWA-RD-74-54,* June 1974, pp.1-143. (Addresses the effect of cement properties on D-Cracking in concrete pavements).

PUBLICATIONS: FLATWORK AND FLOOR SLABS

1. Lankard, D.R., "Flatwork Scaling Today: Air Entrainment Isn't Enough", Proceedings of the 4th Annual Concrete Technology Forum: Focus on Performance Prediction, National Ready Mixed Concrete Association, Silver Spring, MD, May 13-15, 2009

2. Lankard, D.R., "Air Entrainment and Delaminations: How Air Entrainment Contributes to Distress of Concrete Slabs Subjected to a Hard-Trowel Finish", American Concrete Institute *Concrete International,* November 2004, pp. 21-30.

3. Lankard, D.R., Scaling Revisited", American Concrete Institute *Concrete International,* May 2001, pp. 43-49. (Discusses the reasons why this problem dating to the 1930's is still with us today and how we can solve it).

PUBLICATIONS: CONCRETE STRUCTURES

1. Lankard, D.R., Scaglione, N.J., and Bennett, J.E., "Petrographic Examinations of Reinforced Concrete from Cathodically Protected Structures" in *Petrography of Cementitious Materials,* American Society of Testing and Materials (ASTM) Publication STP-1215, S.M. DeHayes and D.E. Stark editors, 1994, pp. 125-147.

2. Lankard, D.R., "Assessment of D-Cracking and Cement-Aggregate Reactions in Ohio Department of Transportation Bridge Structures", Lankard Material Laboratory Report No. I-2820, May 1993, pp. 1-67.

3. Lankard, D.R., Thompson, N., Sprinkel, M.M., and Virmani, Y.P., "Grouts for Bonded Post-Tensioned Concrete Construction: Protecting Prestressing Steel from Corrosion", American Concrete Institute *Materials Journal,* September-October 1993, pp. 406-414.

4. Lankard, D.R., "Cement and Concrete Technology for the Corrosion Engineer", National Association of Corrosion Engineers (NACE) *Materials Performance,* Vol. 15, No. 8, August 1976, pp. 24-37.

5. Lankard, D.R., Birkimer, D.L., Fondriest, F.F., and Snyder, M.J., "The Effects of Exposure to Elevated Temperatures on the Structural Properties of Portland Cement Concrete Heated to 500F", in *Temperature and Concrete,* American Concrete Institute Special Publication No. 25, 1970, pp. 59-102. (This paper was the winner of the 1973 American Concrete Institute Wason Medal for the most meritorious paper.

6. Thompson, N.G., Islam, M., Lankard, D.R., and Virmani, Y.P. "Environmental Factors in the Deterioration of Reinforced Concrete", Materials Performance: NACE International, September 1995, Volume 34, No. 9, pages 43-47.

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