

## NDE of Cementation Systems using Laser Shearography

AMDE M. AMDE<sup>1</sup>, JOHN W. NEWMAN<sup>2</sup>, RICHARD A. LIVINGSTON<sup>3</sup>

<sup>1</sup>Department of Civil & Environmental Engineering, University of Maryland, College Park, MD, USA

<sup>2</sup>Laser Technology Inc., Norristown, Pennsylvania, USA

<sup>3</sup>Department of Material Science & Engineering, University of Maryland, College Park, MD, USA

Email: amde@umd.edu

---

**Abstract:** Non-destructive evaluations (NDE) of micro cracks in concrete structures due to damages from delayed ettringite formation and other causes using laser shearography are discussed. Laser Shearography is a full field, non-contact, non-contaminating NDE method and offers near real time inspection of surface and subsurface anomalies in materials or structures by imaging sub-microscopic deformation derivatives of a test part surface when an appropriate stress is applied. Shearography is capable of inspecting structures for defects such as impact damage, delamination, and micro cracks. Our research has shown that laser shearography has an outstanding ability to detect and measure near surface and surface breaking cracks in cementation systems. The laser shearography system can be used in the field under ambient conditions. It has been applied to detect fine cracks in masonry and concrete structures with a resolution better than 10 microns. Moreover, the output of the system is a digital image which can be processed with image analysis software to yield statistics on the crack distribution such as length, width and preferred orientation that can be used to diagnose the cause of the cracks. Since it is a non-destructive method it can be used to make repeated measurements on the same location over time, and thus monitor the propagation of cracks.

**Keywords:** Laser Shearography, Concrete, Non-destructive Evaluation, Micro Cracks, Delayed Ettringite Formation

---

### References:

- [1] Newman, J.W., Amde, A.M., (2011) *Development of Prototype Compact Shearography System, Analysis Method and Software for Micro-Crack Detection*, SBIR Phase II - Topic 05-FH1 Contract Number DTRT57-08-C-10001. Washington, D.C.: FHWA.
- [2] Amde, A.M., Ceary, M. and Livingston, R. A., (2005), "Correlation between Map Cracking and Delayed Ettringite Formation in Field Specimens" The Eleventh International Conference on Fracture, Turin, Italy.
- [3] Amde, A.M., Ceary, M. and Livingston, R. A., (2005), "Investigation of Maryland Bridges for DEF and ASR," *Journal of Structural Engineering*, Vol. 32, No.1, 33-36.
- [4] Amde, A.M., Ceary, M., Livingston, R.A. and McMorris, N (2004), "Pilot Field Survey of Maryland Bridges for DEF Damage," Maryland SHA, Report No. MD-04-SP107B4U, Maryland
- [5] Livingston, R. A. and Amde, A. M. (2000), "Nondestructive Test Field Survey for Assessing the Extent of Ettringite-Related Damage in Concrete Bridges" 10<sup>th</sup> International Symposium on the Nondestructive of Materials, Karuizawa, Japan.
- [6] Amde, A.M, Williams, K and Livingston, R.A. (2004), "Influence of Fine Aggregate Lithology on Delayed Ettringite Formation in High Early Strength Concrete," Maryland SHA, Report No. MD- 04-SP107B4U, Maryland
- [7] Thomas, M. (2001), *Delayed Ettringite Formation in Concrete: Recent Developments and Future Directions*, Materials Science of Concrete VI, S. Mindess and J. Skalny, Eds., The American Ceramic Society, Westerville, OH, 435-481.
- [8] Day, R. L. (1992), "The Effect of Secondary Ettringite Formation on the Durability of Concrete: A Literature Analysis," Portland Cement Association.
- [9] Tepponen, P., and Eriksson, B.E. (1987), "Damages in Concrete Railway Sleepers in Finland" *Concrete Research*, 199-209.
- [10] Shayan, A., and Quick, G. W. (1994), "Alkali Aggregate Reaction in Concrete Railway Sleeps From Finland" *Proceedings 16<sup>th</sup> International Conference on Cement Microscopy*, Richmond, VA., 64-79.
- [11] Heinz, D., and Ludwig, U. (1986), "Mechanism of Subsequent Ettringite Formation in Mortars and Concretes after Heat Treatment" *Proceedings, 8<sup>th</sup> International Congress on Chemistry of Cement*, Rio de Janeiro, Brazil, Vol. 5, 189-194.
- [12] Heinz, D., and Ludwig, U. (1987), "Mechanism of Secondary Ettringite Formation in Mortars and Concretes Subjected to Heat Treatment" *Concrete Durability*, SP-100, Vol. 2, American Concrete Institute, Detroit, MI. 2059-2071.
- [13] Heinz, D., and Ludwig, U. (1989), "Delayed Ettringite Formation in Heat Treated Mortars and Concretes" *Concrete Precast Plant & Technology*, Vol. 11, 56-61.

- [14] Collepardi, M., Baladini, G., Paur, M., Corradi, M. (1978), "Tricalcium Aluminate Hydration in the Presence of Lime, Gypsum or Sodium Sulfate" Cement Concrete Research.
- [15] Stark, J., Moser, B. and Bellmann, F. (2003), "New Approaches to Cement Hydration in Early Hardening Stage"; Proc. of the 11th Int. Congress on the Chemistry of Cement (ICCC), Cement's Contribution to the Development in the 21<sup>st</sup> Century, G. Grieve and G. Owens (Eds.), Document Transformation Technologies, Durban, South Africa, 261-277.
- [16] Lawrence, B. L., Moody, E. D. Guillemette, R. N. Carrasquillo, R. L. (1999), "Evaluation and Mitigating Measures for Premature Concrete Distress in Texas Department of Transportation Concrete Elements" Cement, Concrete, Aggregates, 73-81.
- [17] Gress, D. (1997), Early Distress in Concrete Pavements. FHWA-SA-97-045, Federal Highway Administration, Washington, DC.
- [18] Amde, A. M., Sabnis, G., Tan, J.(eds), (2007) *Recent Advances in Concrete Technology*, Lancaster: DEStech Publishing.
- [19] Amde, A.M., Khong, H., Livingston, R. A., Newman, J.W., (2014) "Microcrack Detection in Concrete using Laser Shearography" International Conference on Emerging Trends in Civil Engineering, Hyderabad, India.
- [20] Livingston, R. A., Ormsby, C., Amde, A. M., Ceary, M. McMorris, N., Finnerty, P., (2006) "Field Survey of Delayed Ettringite Formation Related Damage in Concrete Bridges in the State of Maryland" CANMET Conference on Durability of Concrete, Montreal.
- [21] Steinchen, W., Yang, L., Kupfer, G., (1996) "Digital Shearography for NDT of Reinforced Concrete" SEM Proceedings, 10:384-385.
- [22] Steinchen, W., Yang, L. (2003), *Digital Shearography: Theory and Application of Digital Speckle Pattern Shearing Interferometry*, Bellingham: SPIE PRESS Monograph.