

DEMONSTRATION OF MANUFACTURING TECHNOLOGY FOR CONCRETE AND CLSM UTILIZING WOOD ASH FROM WISCONSIN

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ABSTRACT

Wisconsin industry generates approximately one million dry tons (or approx. 1.8 million cubic yards) of wood ash per year. Disposal of wood ash in landfills costs Wisconsin industry significant direct cost plus unknown future liabilities due to environmental concerns related to such materials in landfills. This project establishes the initial manufacturing technology for use of wood ash generated by the Wisconsin forest products industry in concrete (structural-grade concrete) and flowable slurry (Controlled Low Strength Materials, CLSM) through an initial laboratory evaluation followed by prototype manufacturing and full-scale manufacturing. A technology transfer seminar, which also included a demonstration of the placement of concrete and CLSM mixtures containing wood ash, was conducted to transfer the knowledge developed about the use of wood ash in construction material to the engineering community; including industrial and government agencies, as well as the concrete construction industry. The project work was started with the laboratory manufacturing of CLSM and concrete mixtures at the facilities of the UWM Center for By-Products Utilization, University of Wisconsin - Milwaukee. Four different concrete mixtures (ML1-A, ML2-A, ML4-A, and ML4-B) were also manufactured in the laboratory. Mixture ML1-A did not contain wood ash, whereas other mixtures contained between 36 and 87 lb/yd³ of wood ash. All four mixtures had a Class C fly ash content between 50 and 165 lb/yd³ to simulate the usual types of concrete manufactured by ready-mixed concrete plants in Wisconsin. Additionally, based upon past R&D work conducted at the UWM Center for By-Products Utilization, this range of Class C fly ash was used to take advantage of available alkalies in wood ash to activate the Class C coal ash for enhanced performance. Three different CLSM mixtures (SL-1, SL-2, and SL-3) were first proportioned in the laboratory. The CLSM mixtures manufactured in the laboratory contained wood ash and cement from 2130 to 995 lb/yd³ and 81 to 116 lb/yd³, respectively. Tests were performed for density, bleed water, settlement, and compressive strength.

Beneficial use criteria for by-product materials is established in the WI-DNR Administrative Code Chapter NR 538. When the results of the leachate and elemental analysis are combined, the wood ash meets Category 4 requirements. However, only one parameter limited the beneficial use options for the wood ash to NR 538 Category 4 applications. The detection limit of thallium slightly exceeded the limit specified for Category 2 & 3. Since the concentration of elemental thallium present in the sample meets NR 538 Category 1 requirements, most likely, if a more detailed analysis were performed for this element, the material most likely would meet Category 2 limits.

Based on the results of lab manufacturing of concrete and CLSM mixtures, prototype manufacturing was conducted at a ready-mixed concrete plant (Midway Concrete Co.) in

Rothschild, WI. Four series of concrete mixtures (R-1, R-2, R-3, and R-4) were manufactured. They were tested for fresh concrete properties and test specimens were made for compressive strength, splitting tensile strength, flexural strength, drying shrinkage, and freezing and thawing resistance. Tests for strength properties were performed at the ages of 7, 14, 28, and 91 days. The concrete mixtures attained 28-day compressive strengths between 4315 and 5065 psi. An increase in strength was observed as the test age increased. Similar results were also observed for splitting tensile strength and flexural strength.

Three series of CLSM mixtures (SL-1, SL-2, and SL-3) were manufactured. Tests were performed for bleed water, density, settlement, and compressive strength for CLSM mixtures. Compressive strength was evaluated at the ages of 7, 14, 28, 91, and 182 days. Test results at the 28-day age show that CLSM achieved compressive strengths between 90 and 190 psi.

Full-scale manufacturing of concrete and CLSM mixtures was also conducted at the ready-mixed plant (Midway Concrete Co.) in Rothschild, WI. Three series of CLSM mixtures (S-1, S-2, and S-3) were manufactured. For each series, between five and seven batches of CLSM were manufactured. The volume of each batch of CLSM was approximately nine cubic yards. Tests were performed for density, settlement, and bleed water. Test specimens were cast for compressive strength and water permeability. The compressive strength of the CLSM mixtures ranged from 40 to 120 psi at the age of 28 days, 100 to 205 psi at 91 days, 135 to 830 psi at 182 days, and 150 to 2090 psi at 365 days. Water permeability tests were performed at 63, 90, and 227 days. Permeability values were between 6.8×10^{-5} and 3.3×10^{-5} cm/sec at 63 days; between 2.1×10^{-5} and 3.9×10^{-5} cm/sec at 90 days; and between 11×10^{-5} and 28×10^{-5} cm/sec at 227 days of testing.

Four series of concrete mixtures (C-1, C-2, C-3, and C-4) were manufactured. Each series consisted of three to four batches of ready-mixed concrete approximately nine cubic yards each. Tests were performed for fresh concrete properties. Test specimens were prepared for compressive strength, splitting tensile strength, flexural strength, drying shrinkage, and freezing and thawing resistance. Compressive strengths between 3625 and 5410 psi were achieved at the age of 28 days. There was a continuous increase in the compressive strength at the later ages of 91, 182, and 365 days. Similar results were also observed for splitting tensile strength and flexural strength. Tests were also performed for drying shrinkage and freezing and thawing resistance. The concrete mixtures were tested for pulse velocity, relative dynamic modulus, and percent length change up to 300 freezing and thawing cycles. Test results after 300 cycles of freezing and thawing indicated that inclusion of wood ash in the concrete mixtures did not affect freezing and thawing resistance of the concrete mixtures. There was no significant change on the drying shrinkage of concrete specimens made with or without wood ash.

Significant efforts were made during and after completion of this project to transfer the technology for the use of wood ash in concrete and CLSM to the engineering community; including industry, government agencies, concrete construction industries, and others. As

a part of this project, a technology transfer educational seminar was conducted in Rothschild, WI. The seminar consisted of a half-day of technical presentations followed by a construction demonstration of the placement of concrete containing wood ash for materials handling yard a pavement slab and flowable slurry containing wood ash for the pavement base course. An additional similar educational seminar is planned for 2004.

Although not directly supported by the funds of this project, additional presentations were made in Wisconsin and elsewhere on the use of wood ash and the results of this project furthering the technology transfer efforts. Presentations that included the results of this project on the use of wood ash as a construction material were made at the following conferences or meetings: High-Volume Fly Ash Concrete in Structures and Pavements Seminar, ACI Maharashtra Chapter, Mumbai, India, July, 2001; Residual Wood Ash Conference – Residual-to-Revenue, Richmond, BC, Canada, November 2001; Weyerhaeuser Co., Seattle, WA, November 2001; UWM-CBU Workshop on the Use of Fly Ash and other Coal-Combustion Products in Concrete and Construction Materials, March 2002; meeting at Stora Enso North America, Wisconsin Rapids, WI, March 2002; NCASI Central Lake States Regional Meeting, Oshkosh, WI, May 2002; ACI Fall 2002 Convention, Phoenix, AZ, October 2002; CANMET/ACI Lyon, France, and Barcelona, November 2002; Weyerhaeuser Company Workshop on Alternative Management Methods for Weyerhaeuser Residuals, Albany, OR, October 2003; Weyerhaeuser Company meeting on Wis-DOT I-39/Highway 51 Corridor Project, Rothschild, WI, January 2004; ACI 2004 Spring Convention, Washington, D.C., March 2004, and at the UWM-CBU Seminar on Recent Advances in Cementitious Materials, March 2004.

Additional technical papers have been presented, published, or submitted for publication based on the activities of this project. A paper titled “Greener Concrete Using Recycled Materials” was published by the ACI Concrete International, July 2002, which contained important information from the Rothschild construction project. A paper titled “Durability of Concrete Incorporating Wood Fly Ash” was presented and published at the Sixth CANMET/ACI International Conference on Durability of Concrete, Thessaloniki, Greece, June 2003. Another paper titled “Properties of Controlled Low-Strength Material made with Wood Fly Ash” was presented and published at the ASTM Symposium on Innovations in Controlled Low-Strength Material (Flowable Slurry), Denver, CO, June 2003 (ASTM STP 1459, scheduled for publication in Fall 2004). A paper has been published in ACI Concrete International magazine in December 2003 titled “A New Source of Pozzolanic Material.” A paper has also been preliminarily accepted for publication by the ASCE Geotechnical and Geoenvironmental Engineering Division titled “Permeability of Flowable Slurry Materials Containing Wood Ash.” A paper has been accepted for publication by ACI Committee 555 for a ACI Special Publication (SP) titled “Properties of Flowable Slurry Containing Wood Ash.” The effort to disseminate the information and experience obtained during this project will continue.