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

By Tarun R. Naik, Rudolph N. Kraus, and Rafat Siddique

Report No. CBU-2003-20
REP-514
May 2003

Interim Report for Year 2 Activities Submitted to the Wisconsin Department of Natural Resources, Madison, WI, for Project # 01-06

Department of Civil Engineering and Mechanics
College of Engineering and Applied Science
THE UNIVERSITY OF WISCONSIN - MILWAUKEE
YEAR–2 INTERIM TECHNICAL REPORT

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

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ABSTRACT

This interim report presents the work carried out during the second year of this project. Report contains the details of the technology transfer seminar and construction demonstration and cost/benefit analysis of using wood ash in concrete and CLSM.

Significant efforts were made to transfer the technology for the use of wood ash in concrete and CLSM to the engineering community; including industrial, government agencies, concrete construction industries. A technology transfer seminar and construction demonstration was conducted on September 27, 2001 in Rothschild, Wis. The title of the seminar was “Workshop and Construction Demonstration for Use of Wood Ash in Concrete and Flowable Slurry.” A total of 26 people attended the seminar. The Speakers for this seminar were Tarun R. Naik of UWM-CBU, Bruce W. Ramme of We Energies, and Michael Miller of the Wisconsin DNR. Speakers presented information on the use of flowable slurry and concrete incorporating wood ash and fly ash, as well as on environmental issues and
regulations. The seminar consisted of a half day of presentations followed by a construction demonstration of the placement of concrete containing wood ash for a storage area pavement slab and flowable slurry containing wood ash for the pavement base course.

Cost/benefit analysis of using wood ash in concrete and CLSM was carried out. Calculations revealed that each year in Wisconsin, approximately 120,000 to 500,000 US dollars could be saved by using only 5 to 12% wood ash as a part of the total cementitious materials in concrete, and approximately 650,000 to 5.8 million US dollars by using wood ash content between approximately 12 and 90% as a part of flowable CLSM materials.

1.0 TECHNOLOGY TRANSFER SEMINAR AND CONSTRUCTION DEMONSTRATION

A technology transfer seminar was conducted in Rothschild, Wis. on September 27, 2001. The title of the seminar was “Workshop and Construction Demonstration for Use of Wood Ash in Concrete and Flowable Slurry.” A total of 26 people attended the seminar. An actual construction demonstration of structural concrete slab and flowable slurry was carried out. Concrete and slurry containing wood ash was manufactured at the facilities of Midway Concrete Co. in Rothschild, WI. The seminar was organized into two parts. The first part of the seminar consisted of a series of lectures presented on the use of wood ash in CLSM and concrete, applications of CLSM in constructions, and environmental considerations when using wood ash. A copy of the seminar announcement is given in Appendix 1. The following speakers participated in this technology transfer seminar:

Prof. Tarun R. Naik, Director, UWM Center for By-Products Utilization, presented “Physical, chemical, and mechanical properties of wood ash: use of wood ash in ready-
mixed concrete. Mixture proportions for non-air entrained and air entrained concrete, and flowable slurry with wood ash. Test results for concrete and flowable slurry with wood ash.”

Bruce W. Ramme, Principal Engineer, We Energies, presented “Field Applications: Flowable slurry containing industrial by-products in backfilling of excavations, trenches and underground voids. Effects of slurry mixture proportions on setting characteristics and placement, thermal and electrical resistivity properties, field performance, economy, and marketing.”

Michael L. Miller, Waste Management Specialist, West Central Region, WI-DNR, presented “Regulatory perspective: use of wood ash in concrete and flowable slurry relative to NR 538 requirements”.

For the construction demonstration, concrete Mixture C-4 and slurry Mixture S-3 from full-scale manufacturing were used as reported elsewhere (1)*. Full-scale concrete and slurry manufacturing containing wood ash was manufactured at the facilities of Midway Concrete Co. in Rothschild, Wis. A demonstration of a section of storage-yard structural slab using air-entrained concrete and a demonstration of CLSM used for sections of the pavement base was conducted. The structural slab and base course were for a part of a log-yard at the paper-mill of the Weyerhaeuser Company, Rothschild, Wis. Each concrete mixture was

* See Section 4.0
used to cast a section of the pavement area of about 800 to 1200 ft$^2$. The thickness of the concrete slab was eight inches. Minimum concrete compressive strength was specified to be 4000 psi at the age of 28 days. The area used for the construction of the three series of CLSM pavement base was about 800 to 1200 ft$^2$. The thickness of the CLSM base varied between 9 and 24 inches depending on the depth of soil excavated. For the construction demonstration, wood ash was not stored at the facilities of Midway Concrete Co. Ash was transported directly from the Weyerhaeuser Company plant and either dumped into a hopper used to batch the CLSM materials for the mixtures, or manually weighed for concrete mixtures.

1.1 Additional Technology Transfer Activities
Although not directly supported by the funds of this project, additional presentations were made in Wisconsin and elsewhere on the use of wood ash furthering the technology transfer. Rudolph N. Kraus, Assistant Director, UWM Center for By-Products Utilization, made a presentation on “Wood Ash: A New Pozzolanic Material - Its Uses in Concrete and Concrete Products, Roller-Compacted Concrete Pavements, Blended Cements, and Flowable Slurry” on March 18, 2002 at the UWM-CBU Workshop on the Use of Fly Ash and other Coal-Combustion Products in Concrete and Construction Materials. Tarun R. Naik, Director, UWM Center for By-Products Utilization made a presentation on “Wood Ash: A New Source of Pozzolanic Material” at another UWM-CBU seminar on Recent Advances in Cementitious Materials held (May 17-18, 2002) in Milwaukee. Tarun R. Naik also made other presentations on the use of wood ash as a construction material at: “High-Volume Fly Ash Concrete in Structures and Pavements Seminar,” ACI Maharastra Chapter, Mumbai,

Technical papers have been published or submitted for publication from activities of this project. A paper titled “Controlled Low-Strength Materials Containing Mixtures of Coal Ash and New Pozzolanic Material” has been published in the May-June Issue of the ACI Materials Journal. Two papers titled “Mechanical Properties and Freezing and Thawing Resistance of Concrete Incorporating Wood Fly Ash” and “Properties of Flowable Slurry Containing wood Ash” have been accepted for presentation and publication 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” has been accepted for presentation and publication at the ASTM Symposium on Innovations in Controlled Low-Strength Material (Flowable Slurry), Denver, Colorado, June 2003. 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.

2.0 COST/BENEFIT ANALYSIS OF USING WOOD ASH IN CONCRETE AND FLOWABLE SLURRY (CLSM)

Wisconsin industries (pulp and paper mills, saw mills, wood products industries such as doors and windows, and other forest products industries) generate approximately one million
dry tons (or approx. 1.8 million cubic yards) of wood ash per year (2). NCASI has estimated that of the total wood ash produced in the U.S., only about 30% is being utilized (2). Disposal of wood ash in landfills costs Wisconsin industry significant direct cost plus unknown future liabilities due to possible environmental impact related to such materials in landfills. The objective of this project is to establish initial manufacturing technology for the use of wood ash generated by the forest products industry in concrete and flowable slurry (Controlled Low Strength Materials, CLSM).

For cost/benefit analysis of using wood ash in concrete and CLSM, an economic analysis was conducted. Unit costs were assigned for the mixture components in order to establish a cost per cubic yard for concrete and CLSM mixtures. The cost assumed for each component was: cement: $ 75/ton; Class C fly ash: $45/ton; aggregates: $7/ton; MRWRA or AEA: $7/gallon ($0.05476/oz); and, disposal cost of wood ash at $35/ton. The cost per cubic yard of the concrete and CLSM were then compared with the Control Mixture without wood ash to determine the net/overall benefit.

2.1 Cost/Benefit Analysis for Concrete Containing Wood Ash

For cost/benefit analysis of concrete containing wood ash, mixture proportions from the full-scale manufacturing were used. In full-scale manufacturing, there was one Control Mixture (without wood ash) and three concrete mixtures with wood ash. Mixture proportions details are given in Table 1.

Based on the unit cost of concrete components and disposal cost of wood ash, the cost/benefit per cubic yard of wood ash concrete is shown in Table 2.
Table 1. Mixture Proportions of Concrete Mixtures Containing Wood Ash from Full-Scale Manufacturing in Rothschild, Wis.

<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>C-1</th>
<th>C-2</th>
<th>C-3</th>
<th>C-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement, C (lb/yd³)</td>
<td>509</td>
<td>480</td>
<td>439</td>
<td>444</td>
</tr>
<tr>
<td>Wood Fly Ash, A1 (lb/yd³)</td>
<td>-</td>
<td>33</td>
<td>53</td>
<td>80</td>
</tr>
<tr>
<td>Class C Fly Ash, A2 (lb/yd³)</td>
<td>51</td>
<td>102</td>
<td>129</td>
<td>135</td>
</tr>
<tr>
<td>Equivalent Cementitious Content, Ceq., (lb/yd³)</td>
<td>549</td>
<td>579</td>
<td>569</td>
<td>593</td>
</tr>
<tr>
<td>SSD Fine Agg. (lb/yd³)</td>
<td>1410</td>
<td>1385</td>
<td>1315</td>
<td>1360</td>
</tr>
<tr>
<td>SSD Coarse Agg., (lb/yd³)</td>
<td>1635</td>
<td>1655</td>
<td>1605</td>
<td>1604</td>
</tr>
<tr>
<td>Water, W (lb/yd³)</td>
<td>231</td>
<td>261</td>
<td>242</td>
<td>230</td>
</tr>
<tr>
<td>% (Class C + Wood) Fly Ash*</td>
<td>9</td>
<td>22</td>
<td>29</td>
<td>33</td>
</tr>
<tr>
<td>% Wood Fly Ash**</td>
<td>-</td>
<td>5</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>W/Ceq.</td>
<td>0.42</td>
<td>0.45</td>
<td>0.43</td>
<td>0.39</td>
</tr>
<tr>
<td>MRWRA (oz)</td>
<td>34</td>
<td>35</td>
<td>34.5</td>
<td>34</td>
</tr>
<tr>
<td>AEA (oz)</td>
<td>4.3</td>
<td>4.3</td>
<td>8.4</td>
<td>5</td>
</tr>
<tr>
<td>Fresh Concrete Density (lb/ft³)</td>
<td>142.1</td>
<td>143.4</td>
<td>137.4</td>
<td>143.2</td>
</tr>
</tbody>
</table>

* (A1+A2)/(C+A1+A2)   ** A1/(C+A1+A2)

Table 2. Cost/Benefit Analysis per Cubic Yard of Concrete Mixtures Containing Wood Ash
Approximately 5,000,000 cubic yards of concrete is produced in Wisconsin each year and assuming, if only 5% of 5,000,000 cubic yards concrete would be produced with wood ash, then the quantity of concrete produced with wood ash would be 250,000 cubic yards. Based on the calculation presented in Table 2, the overall savings by using wood ash in concrete is shown in Table 3. It is evident from Table 3 that 120,000 to 505,000 dollars could be saved each year in Wisconsin by using only between 5 and 12% wood ash content of the total cementitious materials in concrete.

### Table 3. Overall Cost/Benefit Analysis for Concrete Mixtures Containing Wood Ash

<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>Total Savings in Concrete Materials with Wood Ash Concrete, dollars</th>
<th>Total Savings from Disposal Costs, dollars</th>
<th>Overall Savings, dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-2 (5% Wood Ash)</td>
<td>- 25,000</td>
<td>145,000</td>
<td>120,000</td>
</tr>
<tr>
<td>C-3 (8% Wood Ash)</td>
<td>265,000</td>
<td>233,500</td>
<td>497,500</td>
</tr>
<tr>
<td>C-4 (12% Wood Ash)</td>
<td>155,000</td>
<td>350,000</td>
<td>505,000</td>
</tr>
</tbody>
</table>

### 2.2 Cost/Benefit Analysis for CLSM Containing Wood Ash
For cost/benefit analysis of CLSM containing wood ash, mixture proportions from the full-scale manufacturing were used. In full-scale manufacturing, there were three mixtures containing wood ash. A CLSM mixture without wood ash was not made. Therefore, a Control Mixture proportion (without wood ash) was chosen per ACI 229R (3) to compare the cost/benefit analysis of CLSM mixture with wood ash. Mixture proportions details are given in Table 4.

**Table 4.** Mixture Proportions of CLSM Mixtures Containing Wood Ash from Full-Scale Manufacturing at Rothschild, Wis.

<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>S-1</th>
<th>S-2</th>
<th>S-3</th>
<th>Control CLSM Mixture per ACI 229R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement (lb/yd$^3$)</td>
<td>138</td>
<td>165</td>
<td>104</td>
<td>200</td>
</tr>
<tr>
<td>Wood Fly Ash (lb/yd$^3$)</td>
<td>576</td>
<td>100</td>
<td>843</td>
<td>0</td>
</tr>
<tr>
<td>Class C Fly Ash (lb/yd$^3$)</td>
<td>0</td>
<td>496</td>
<td>0</td>
<td>350</td>
</tr>
<tr>
<td>Wood Fly Ash, % of total cementitious materials</td>
<td>81</td>
<td>12.5</td>
<td>89</td>
<td>-</td>
</tr>
<tr>
<td>SSD Fine Agg., (lb/yd$^3$)</td>
<td>2145</td>
<td>2565</td>
<td>1560</td>
<td>2750</td>
</tr>
<tr>
<td>Water (lb/yd$^3$)</td>
<td>498</td>
<td>381</td>
<td>704</td>
<td>500</td>
</tr>
<tr>
<td>Unit Weight (lb/ft$^3$)</td>
<td>124.4</td>
<td>137.2</td>
<td>119</td>
<td>-</td>
</tr>
</tbody>
</table>

Based on the unit cost of CLSM components and disposal cost of wood ash, the cost/benefit per cubic yard of CLSM containing wood ash is given in Table 5.

**Table 5.** Cost/Benefit Analysis per Cubic Yard of CLSM Mixtures Containing Wood Ash
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Mixture (per ACI 229 R)</td>
<td>25</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>S-1 (81% Wood Ash)</td>
<td>12.68</td>
<td>12.32</td>
<td>10.08</td>
<td>22.40</td>
</tr>
<tr>
<td>S-2 (12.5% Wood Ash)</td>
<td>26.32</td>
<td>-1.32</td>
<td>1.75</td>
<td>0.43</td>
</tr>
<tr>
<td>S-3 (89% Wood Ash)</td>
<td>9.36</td>
<td>15.64</td>
<td>14.75</td>
<td>30.39</td>
</tr>
</tbody>
</table>

Mixtures S-1 (81% wood ash), S-2 (12.5% wood ash), and S-3 (89% wood ash) contained 576, 100, and 843 pounds, respectively, of wood ash per cubic yards of CLSM mixtures. Wisconsin produces approximately 750,000 tons of usable wood ash, and assuming if 10% of it is used in CLSM, then 75,000 tons of wood ash could be used in making CLSM. Therefore, by using Mixtures S-1 (81% wood ash), S-2 (12.5% wood ash), and S-3 (89% wood ash) 260,416 cubic yards, 1,500,000 cubic yards, and 117,935 cubic yards of CLSM, respectively, could be produced, from 75,000 tons of wood ash.

Based on the calculation presented in Table 5, the overall savings by using wood ash in CLSM is shown in Table 6. It is evident from Table 6 that 645,000 to 5,833,340 dollars could be saved each year in Wisconsin by using wood ash in CLSM between 12.5 and 89% of the CLSM materials.

**Table 6.** Overall Cost/Benefit Analysis for CLSM Mixtures Containing Wood Ash
<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>Total Savings in CLSM Materials, dollars</th>
<th>Total Savings from Disposal Costs, dollars</th>
<th>Overall Savings in dollars</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1 (81% Wood Ash)</td>
<td>3,208,337</td>
<td>2,625,003</td>
<td>5,833,340</td>
</tr>
<tr>
<td>S-2 (12.5% Wood Ash)</td>
<td>-1,980,000</td>
<td>2,625,000</td>
<td>645,000</td>
</tr>
<tr>
<td>S-3 (89% Wood Ash)</td>
<td>1,844,503</td>
<td>1,739,541</td>
<td>3,584,044</td>
</tr>
</tbody>
</table>
3.0 FUTURE PLAN

In this the continuing second year of the project, a second source of wood ash may be selected, and after the characterization of its constituent materials, mixture proportions will be developed in the UWM-CBU laboratory. They will be later refined for prototype manufacturing. Based on the results of laboratory and prototype manufacturing, full-scale manufacturing would be carried out at another selected ready-mixed plant in Wisconsin. Although not a part of this project, a second technology transfer seminar is currently being planned for the second year of this project.

4.0 REFERENCES


(3) ACI Committee 229R-99, “Controlled Low-Strength Materials (CLSM),” ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Farmington Hills, MI, 1999.
APPENDIX 1:

TECHNOLOGY TRANSFER SEMINAR ANNOUNCEMENT

ROTHSCHILD, WI
Workshop and Construction Demonstration for Use of Wood Ash in Concrete and Flowable Slurry

Sponsored By

UWM Center for By-Products Utilization, Milwaukee, WI
Wisconsin Department of Natural Resources Waste Reduction and Recycling Demonstration Grant Program
Weyerhaeuser Company, Stora Enso North America, National Council of Air and Stream Improvement (NCASI)
Wisconsin Electric Power Company, and Wisconsin Public Service Corporation

Co-Sponsored By
Wisconsin Chapter – American Concrete Institute, Wisconsin Ready-Mixed Concrete Association, and American Society of Civil Engineers – Wisconsin Section

September 27, 2001, Rothschild, WI

Workshop Description

The purpose of the workshop is to present important technical information and review production and construction aspects for the use of wood ash in ready-mixed concrete as well as in flowable slurry (CLSM). Flowable Slurry is a very low-strength concrete-like material that is made from one or more of the following materials such as coal ash, wood ash, used foundry sand, post-consumer crushed glass, concrete sand, water, and some portland cement. The strength of this material can vary from 50 psi to 1200 psi at the age of 28 days. Flowable slurry is being specified increasingly by municipalities, state highway departments, and engineers for many applications.

The workshop will present case histories of successful installations. It will also include a demonstration of use of wood ash in structural concrete slab and slurry placement. Handout materials will be provided. The workshop should be of interest to those associated with building design, engineers, architects, engineering technicians, engineers working in governmental agencies, industry and private practice, engineering faculty and students, as well as ready mixed concrete producers, aggregates suppliers, and contractors. Knowledgeable professionals engaged in specifying, approving, marketing, and using concrete and flowable slurry will present state-of-the-art information.
PROGRAM

Workshop and Construction Demonstration for Use of Wood Ash in Concrete and Flowable Slurry

September 27, 2001, Rothschild, WI

8:00 a.m.  Registration and Continental Breakfast

8:30  Welcome and Introduction
Stuart A. D. McCormick

Tarun R. Naik

10:15  Break

10:30  Field Applications: Flowable slurry containing industrial by-products in backfilling of excavations, trenches, and underground voids. Effects of slurry mixture proportions on setting characteristics and placement, thermal and electrical resistivity properties, field performance, economy, and marketing.
Bruce W. Ramme

12:00  Lunch

1:00  Regulatory Perspective: Use of wood ash in concrete and flowable slurry relative to NR 538 requirements.
Michael L Miller

1:30  Adjourn to the demonstration location.

1:45  Construction Demonstration of Structural Concrete Slab and Flowable Slurry with Wood Ash: Placement, compaction, finishing, hardening and settlement process; and questions and answers
Tarun R. Naik and Bruce Sopkowicz

3:15  Adjourn

-----------------------------------------------Advantages of Flowable Slurry-----------------------------------------------

No Compaction Required
Excellent Flowability – Fills all Voids
No Shrinkage or Settlement after Final Set
Reduced Labor Cost and Improved Construction Safety
Large Range of Mixtures with Different Strengths and Other Characteristics Available
SPEAKER INFORMATION

The program is scheduled to include the following speakers:

Stuart A. D. McCormick, P. Eng., Leader of Residuals, Solid Waste, and Groundwater Specialists Network, Weyerhaeuser Company, Alberta, Canada. Since 1989 Mr. McCormick has been a Registered Professional Engineer, and a member of Association of Professional Engineers, Geologists, and Geophysicists of Alberta. He has made presentations to and/or authored papers for many conferences and seminars, including National Council for Air and Stream Improvement (NCASI), Solid Waste Association of North America (SWANA), and Air and Waste Management Association (A&WMA).

Michael L. Miller, Waste Management Specialist for the West Central Region, Wisconsin Department of Natural Resources, Wisconsin Rapids, Wisconsin. Mr. Miller has worked for 23 years for the WI-DNR in the Solid Waste Program. He is responsible for solid waste activities in Adams, Jackson, Juneau, Monroe, and Wood Counties. He is also responsible for NR 538 activities for the entire West Central Region (18 counties).

Tarun R. Naik, Ph. D., P. E., Director, UWM Center for By-Products Utilization, Milwaukee, Wisconsin. Dr. Naik has over 35 years of experience with cement, aggregates, and concrete. His contribution in teaching and research has been well recognized nationally and internationally. His research has resulted in over 250 technical reports and papers in ACI, ASCE, ASTM, RILEM, etc. He is a member of ACI, ASCE, ASEE, ASTM, RILEM, NSPE, and WSPE. He is also a member of technical committees of ACI, ASCE, ASTM, and RILEM. He has served as a president of WI-ACI, WSPE, and other organizations.

Bruce W. Ramme, P. E., Manager, Combustion Products Utilization, Wisconsin Electric Power Company, Milwaukee, Wisconsin. Mr. Ramme has worked for approximately 20 years with WEPCO and is currently working towards the goal of 100% utilization of WEPCO’s coal combustion products. He is a member of ACI, ASCE, and other professional organizations. He is also the chairman of ACI Committee 229 on Flowable Slurry (CLSM), chairman of ACI 213B on By-Products Lightweight Aggregate, and a member of other technical committees of ACI. He is also a past president of the Wisconsin Chapter of ACI.

THE UWM CENTER FOR BY-PRODUCTS UTILIZATION MISSION STATEMENT:

“To collect and analyze data, and disseminate information regarding the beneficial use of presently discarded by-products from industrial, commercial, and public sector operations.”

The UWM-CBU was established in 1988 by a generous grant from Dairyland Power Cooperative, La Crosse; Madison Gas & Electric Company, Madison; National Minerals Corporation, St. Paul, MN; Northern States Power Company, Eau Claire; Wisconsin Electric Power Company, Milwaukee; Wisconsin Power & Light Company, Madison; and Wisconsin Public Service Corporation, Green Bay. With their financial support and support from other organizations including Manitowoc Public Utilities, US-DOE, Weyerhaeuser Company, NCASI, the UWS Applied Research Council and Solid Waste Recovery Research Program, Wisconsin Recycling Market Development Board, Illinois Clean Coal Institute, and others, the UWM-CBU is developing low-cost, high-quality construction materials from wood ash, pulp and paper mill primary residual solids, coal fly ash, bottom ash, and clean-coal ash.