Center for By-Products Utilization

FOUNDORY BY-PRODUCTS UTILIZATION RESEARCH AND DEVELOPMENT WORK AT THE UWM CENTER FOR BY-PRODUCTS UTILIZATION

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UWM-CBU SPONSORED WORKSHOPS ON FOUNDRY BY-PRODUCTS UTILIZATION

(1) Workshop on Utilization of Used Foundry Sand and Slag in Concrete and other Construction Materials, October 21, 1993, Milwaukee River Hilton Inn, Milwaukee, WI.

(2) Second Workshop on Utilization of Used Foundry and Slag in Concrete and Other Construction Materials, May 11, 1995, Milwaukee River Hilton Inn, Milwaukee, WI.

(3) Workshop in Utilization of Used Foundry Sand and Slag in Concrete and Other Construction Materials, October 18, 1996, Milwaukee River Hilton Inn, Milwaukee, WI.

(4) Workshop on Utilization of Used Foundry Sand and Slag in Concrete and Other Construction Materials, December 10, 1997, Milwaukee River Hilton Inn, Milwaukee, WI.

(5) Workshop on Utilization of Used Foundry Sand and Slag in Concrete and Other Construction Materials, December 1998, Milwaukee, WI.

(6) Workshop and Field Demonstration for the Uses of Flowable Slurry Containing Fly Ash, Used Foundry Sand, and Other Industrial By-Products, Port Washington, WI, August, 1998.
PRESENTATIONS AND INVITED LECTURES ON FOUNDRY BY-PRODUCTS UTILIZATION


(5) “Concrete Made from Used Foundry Sand”, a lecture presented at the Department of Civil Engineering, Bradley University, Peoria, IL, January 1995.


(7) Lectures presented at Foundry By-Products Seminar, Milwaukee, WI, October 1996.


(14) Lectures Presented at the “Workshop and Field Demonstration for uses of Flowable Slurry Containing Fly Ash, Used Foundry Sand, and Other Industrial By-Products”, Port Washington, WI, August 1998.


SUMMARY OF PUBLISHED REPORTS AND PAPERS


A feasibility study was conducted to determine if bottom ash can be used as a replacement of sand and binder materials used in the foundry industry. There is limited similarity in properties of typical foundry sands and bottom ash. Grain size of bottom ash is coarser than foundry sand. Loss on ignition of bottom ash, is significant and sometimes high, depending on the power plant operations. Foundry sand have negligible loss on ignition. Many properties necessary for foundry sand are unknown for bottom ash, including green strength, dry strength, hot strength, thermal stability, refactoriness, flowability, etc. Based on the above information, it appears that full or even partial substitution of bottom ash for foundry sand may cause problems. An in depth study of the suitability of bottom ash as a substitute for foundry sand would therefore be necessary. If certain physical properties of bottom ash are found to be suitable as a partial replacement for foundry sand, then it may be of value to establish what percentage of bottom ash could be utilized as a substitution for foundry sand.


This report contains information collected, evaluated, and analyzed from worldwide sources for potential beneficial utilization of used foundry sands. The research objectives of this entire project were to identify potential uses of foundry by-products, access and review current world-wide knowledge, and establish new technology for their large volume utilization for construction materials and other uses for Wisconsin industries.

This report includes literature search and information gathering. It is divided into four main parts. The first part consists of an introduction, foundry processes, materials, and wastes generated. The second part consists of review of waste characterization studies. The third part includes a review of technical feasibility and potential uses of foundry sand, as well as economic implications. The final part of this report consists of a list of references and annotated bibliography relevant to this project.

This report contains information on the work carried out for characterization of the foundry by-products produced by Falk Corporation, Milwaukee, WI; Maynard Steel Casting Co., Inc., Milwaukee, WI; and Waupaca Foundry, Inc., Waupaca, WI; and clean/new sand supplied by Badger Mining Corporation, Fairwater, WI. This report details determination of chemical and physical properties of foundry operation by-products. A detailed microscopic analysis was also carried out as a part of this characterization study. Based on the characterization in this Phase II studies, selected used foundry sands were used to make and test trial concrete batches in the CBU laboratories.

In the Phase III, a laboratory study was conducted with a view to investigate the performance of fresh and hardened concrete products containing discarded foundry sands as a replacement of fine aggregates. A control concrete mix was proportioned to achieve a 28-day age compressive strength of 6000 psi. Additional concrete mixes were proportioned to replace 25% and 35% of regular concrete sand with used foundry sands by weight. Concrete performance was evaluated with respect to compressive strength, tensile strength and modulus of elasticity. At the 28-day age, concrete containing used foundry sands showed about 25% lower values than concrete without foundry sand. However, it is expected that this shortfall can be overcome by use of chemical and powder additives to concrete. This will be investigated in the next year's testing program. Phase I activities report, detailing current state of the world-wide knowledge, was prepared and finalized earlier before starting work described in this report.

Three mortar mixes were also designed to make concrete bricks and blocks and test them to determine compressive strength, absorption and bulk density. Used foundry sands were used as a partial replacement of the regular concrete sand. A technical feasibility of utilizing discarded foundry sand has been established with this preliminary research (Phase III).

This report also contains proposed work plan for foundry by-products utilization in a detailed laboratory work phase (configuration of Phase III).
As a result of increased pressure from environmental regulations to significantly reduce the amount of foundry waste disposed in landfills, the questions of what to do with these materials has reached a new, urgent stage. The Center for By-Products Utilization (CBU) at the University of Wisconsin-Milwaukee has been conducting research for the past two years to develop practical ways of using discarded foundry sands and steel slag in construction materials. Based on the study completed at CBU, used foundry sand can be used in manufacture of portland cement concrete, masonry blocks, and paving stones. Initial test data indicate that used foundry sand can be used successfully for various construction products. Long-term performance data and parameters for mass production are being developed before production will be started for marketing these products.

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In the Phase III, a laboratory study was conducted with a view to investigate the performance of fresh and hardened concrete products containing discarded foundry sands as a replacement of fine aggregates. A control concrete mix was proportioned to achieve a 28-day age compressive strength of 6000 psi. Additional concrete mixes were proportioned to replace 25% and 35% of regular concrete sand with used foundry sands by weight. Concrete performance was evaluated with respect to compressive strength, tensile strength and modulus of elasticity. At the 28-day age, concrete containing used foundry sands showed about 25% lower values than concrete without foundry sand. However, it is expected that this shortfall can be overcome by use of chemical and
powder additives to concrete. This will be investigated in the next year's testing program.

Phase I activities report, detailing current state of the world-wide knowledge, was prepared and finalized earlier before starting work described in this report.


This research was conducted to investigate the performance of fresh and hardened concrete containing discarded foundry sands as a replacement of fine aggregate. A control concrete mix was proportioned to achieve a 28-day compressive strength of 38 MPa (5500 psi). Other concrete mixes were proportioned to replace 25% and 35% of regular concrete sand with clean/new foundry sand and used foundry sand by weight. Concrete performance was evaluated with respect to compressive strength, tensile strength and modulus of elasticity. At 28-day age, concrete containing used foundry sand showed about 20 to 30% lower values than concrete without used foundry sand. But concrete containing 25% and 35% clean/new foundry sand gave almost the same compressive strength as that of the control mix.


This research was conducted with a view to evaluate the performance of concrete masonry blocks containing discarded foundry sand as a replacement of fine aggregate. A control mortar mix for block was proportioned to achieve a 28-day compressive strength of 1500 psi (on the basis of gross area). Other mixes were also proportioned to replace 35% of regular concrete sand with used foundry sand by weight on one on one basis. The performance of blocks were evaluated with respect to compressive strength, water absorption and bulk density, as per ASTM standards. Blocks made using different foundry sands showed variation in their properties. Technical feasibility of utilizing discarded foundry sand up to 35% replacement level in manufacturing masonry blocks has been established with this research.

This project was conducted to establish mixture proportion technology for flowable slurry incorporating foundry sand and fly ash. In this work, two different flowable fly ash slurry mixtures were proportioned for strength levels in the range of 50-100 psi at 28 days using two sources of ASTM Class F fly ash. The first mixture containing Oak Creek fly ash was proportioned to obtain a flow/spread of 16±1 in., and the second mixture with Port Washington fly ash was proportioned to have a flow of 11±2 in. These mixtures were used as reference mixtures for this study. The other mixtures contained used and clean foundry sand as a replacement of fly ash. For each mixture design, fly ash was replaced with foundry sand at four different levels (30, 50, 70, and 80%).

The ingredients of the slurry mixtures such as fly ash, clean foundry sand, and used foundry sand were tested for their physical and chemical properties, and leachate behavior. The leachate results of these materials based on one observation showed that these materials, except the Port Washington fly ash, met the drinking water standards. These materials were found to be appropriate for manufacture of flowable slurry materials. Various flowable mixtures made with and without foundry sand were evaluated for settlement, setting and hardening characteristics, compressive strength, permeability, length change (drying shrinkage), and leachate characteristics.

Generally compressive strength of the flowable slurry materials increased with age and was found to vary between 40-100 psi for the mixtures tested at 28 days. The permeability of the flowable fill mixtures was negatively affected by increases in either water to cementitious materials ratio or foundry sand content. However, more tests are needed to evaluate environmental impacts of these materials for use in Controlled Low Strength Materials (CLSM).

The Oak Creek fly ash mixtures made with and without foundry sand conformed to the requirements of the drinking water standards. However, most of the mixtures made with the Port Washington fly ash fail to do so for solenium. In general, addition of the foundry sands caused substantial reduction in concentration of the elements that are considered hazardous in accordance with drinking water standards. Therefore, the use of foundry may provide favorable environmental impact.
This research was undertaken to evaluate the performance of foundry by-products in concrete and masonry products. Two series of experiments were carried out. The first series of experiments were directed toward the use of an air-cooled foundry slag in concrete as a partial replacement of coarse aggregate. The second series of work involved the use of foundry sand as a partial replacement of fine aggregate for making masonry blocks and paving stones. The first series of tests were carried out to evaluate the performance characteristics of a foundry slag concrete under laboratory conditions. A reference concrete without foundry slag was proportioned to obtain 28-day compressive strength of 6000 psi. Two other mixtures containing 50 and 100% foundry slag as a replacement of regular aggregate were also proportioned. The 100% slag mixture showed compressive strength comparable to the reference mixture. However, the modulus of elasticity of concrete containing 100% slag was higher than the reference concrete.

This project was conducted to evaluate the environmental performance of Controlled Low Strength Materials (CLSM) incorporating fly ash and foundry sand. Two different flowable fly ash slurry reference mixtures were proportioned for strength levels in the range of 0.3 to 0.7 MPa (50 to 100 psi), at 28 days, using two sources of ASTM Class F fly ash. For each reference mixture, other mixtures were proportioned using two sources of foundry sand as a replacement of fly ash in the range of 30 to 85%.

The ingredients of the slurry mixtures such as fly ash, clean foundry sand, and used foundry sand were tested for their physical and chemical properties, and leachate characteristics. All CLSM mixtures made with and without foundry sand were evaluated for settlement, setting and hardening characteristics, compressive strength, permeability, and leachate characteristics. The leachate results of these CLSM-making materials were below the Enforcement Standard of the Wisconsin Department of Natural Resources (WDNR) Groundwater Quality Standard. They also met practically all the parameters of the Drinking Water Standards.

Generally, compressive strength of the flowable slurry materials increased with age and was found to vary between 0.3 and 0.7 MPa (50 to 100 psi) for the mixtures
tested at 28 days. The leachate results of all the CLSM mixtures made with and without foundry sand were below the Enforcement Standard, and they also met practically all the parameters of the Drinking Water Standards. Generally, addition of the foundry sand caused substantial reduction in concentration of the elements that are considered hazardous in accordance with WDNR Groundwater Quality Standard. Therefore, the use of foundry sand may provide favorable environmental performance.


This study was carried out to evaluate the effect of source of foundry sand and fly ash on permeability of flowable slurry mixtures. In this work, two reference flowable fly ash slurry mixtures were proportioned for strength levels in the range of 50 to 100 psi at 28 days using two different sources of ASTM Class F fly ash. Other mixtures contained clean and used foundry sands as a replacement of fly ash in the range of 30 – 85%.

The permeability of the flowable mixtures was affected by increase in either the water to cementitious materials ratio or the foundry sand content. The permeability values were either comparable to or lower than those reported for granular compacted fills up to 85% fly ash replacement with foundry sand. Type of foundry sand (clean or used) did not materially affect permeability of the mixtures tested. The permeability values for the mixtures tested varied from $3 \times 10^{-6}$ to $74 \times 10^{-6}$ cm/s.


This study was carried out to evaluate the effect of foundry sand and fly ash on permeability of flowable slurry mixtures. In this work, two reference flowable fly ash slurry mixtures were proportioned for strength levels in the range of 0.34 to 0.69 MPa (50 to 100 psi) at 28 days using two different sources of ASTM Class F fly ash. Other mixtures contained clean and used foundry sands as a replacement of fly ash in the range of 30 to 85%. The permeability of the flowable mixtures was affected by increase in either the water to cementitious materials ratio or the foundry sand content. The permeability values were either comparable to or lower than those reported for granular compacted fills up to 85% fly ash replacement with foundry sand. Type of foundry sand
(clean or used) did not materially affect permeability of the mixtures tested. The permeability values for the mixtures tested varied from $3 \times 10^{-6}$ to $74 \times 10^{-6}$ cm/s.


This research was carried out to evaluate the use of foundry sands on properties of flowable slurry. Two different flowable slurry mixtures were proportioned for strength levels in the 0.34-0.69 MPa (50-100 psi) range, at 28 days, using two different sources of foundry sand and two different sources of ASTM Class F fly ash. Flowable slurry mixtures containing fly ash, without any foundry sand, were used as reference mixtures for this investigation. For each reference mixture, additional mixtures incorporating clean and used foundry sands as a replacement for fly ash were also proportioned. These flowable mixtures made with and without foundry sand were evaluated for bleeding, depth of nail penetration, settlement, shrinkage, condition of set, etc. In general, bleed water increased with an increase in the added mix water or foundry sand content of the mixtures tested. The settlement decreased with a decrease in the slurry water content. All the test specimens showed no sign of shrinkage cracks. The depth of nail penetration decreased with increasing age or decreasing water content. Compressive strengths of the test mixtures were found to vary between 0.28 and 0.62 MPa (40-90 psi) at 28 days. The overall results showed that excavatable flowable slurry with desirable physical properties can be manufactured using foundry sand as a replacement for fly ash up to 85%.


This Final Report (October 15, 1996 to October 15, 1997) deals with the activities related to the manufacture and testing of concrete containing used foundry sand. A total of eleven ready-mixed concrete mixtures, consisting of four non-air entrained, and seven air entrained, were manufactured. Each mixture was batched and mixed at the facilities of the Advance Cast Stone Company, Random Lake, Wisconsin. The Advance Cast Stone Company manufactures precast architectural and structural concrete elements. Mixtures were manufactured in a conventional manner in a one cubic yard capacity mixer used by the Advance Cast Stone Company for their daily concrete production. Fresh concrete tests were performed and many test specimens were cast.

One non-air entrained mixture without used foundry sand was manufactured as a Control mixture. Three non-air entrained concrete mixtures were proportioned to have
foundry sand concentrations of 15%, 20%, and 45% as a replacement of concrete sand from the Control mixture. Since the Control mixture contained 20% fly ash, mixtures with used foundry sand were proportioned to have an additional 10 to 15% fly ash content. These mixtures were proportioned to maintain a slump in the range of approximately 4 to 8 inches. Two air entrained reference mixtures were proportioned without foundry sand. Additional air entrained mixtures were proportioned to contain used foundry sand at concrete sand replacement levels of 14%, 20%, and 45%; and, fly ash content levels of 34%, 37%, and 40% of total cementitious materials.

For all non-air entrained concrete mixtures, test specimens were evaluated for compressive strength, abrasion resistance, and chloride-ion penetration as a function of age. For air entrained concrete mixtures, test specimens were evaluated for compressive strength, salt scaling resistance, freezing and thawing resistance, abrasion resistance, and chloride-ion penetration resistance as a function of age. In general, as expected, the very early-age strength properties such as compressive strength, decreased with increasing foundry sand and fly ash concentration. At later ages, the rate of strength development of fly ash concrete mixtures increased due to the pozzolanic contribution at fly ash. This will also help increase durability and decrease the difference between the reference mixtures and the foundry sand mixtures substantially as the age increases. The non-air entrained concrete mixtures attained compressive strength in the range of 3,500 - 6,000 psi at the age of 28 days. The air entrained reference concrete mixture attained a strength of approximately 5,000 psi at the 28-day age. The results obtained indicate that the air entrained mixtures with and without foundry sand are appropriate for applications in normal construction work in Wisconsin. Durability properties (abrasion, chloride permeability, resistance to freezing and thawing) of all non-air entrained and air entrained mixtures were all very good.


This paper deals with the manufacture and testing of wet-cast and dry-cast concrete products containing fly ash, bottom ash, and used foundry sand. Test specimens for all dry-cast and wet-cast concrete mixtures have been evaluated for compressive strength, absorption, density, moisture content, and resistance to freezing and thawing as a function of age. A total of 18 dry-cast concrete products mixtures, consisting of six dry-cast brick, six dry-cast block, and six dry-cast paving stone, were manufactured. The dry-cast bricks, blocks, and paving stones were produced using standard manufacturing equipment utilized in the production of dry-cast concrete products. A total of six wet-
cast concrete products mixtures, consisting of three wet-cast brick and three wet-cast paving stone mixtures, were also manufactured. Mixtures were manufactured in a conventional manner in a mixer with one cubic yard capacity used for daily concrete production.

One reference mixture without fly ash, bottom ash, or used foundry sand was produced for each dry-cast product. Two mixtures of dry-cast bricks, blocks, and paving stones were produced by incorporating two ash by-product materials into each mix: fly ash as a partial replacement of cement and bottom ash as a replacement of normal concrete sand. The two remaining mixtures of each dry-cast product incorporated fly ash as a replacement of cement and used foundry sand as a replacement of normal concrete sand. Dry-Cast concrete mixtures contained up to 41% fly ash, 33% bottom ash and 36% foundry ash. Wet-cast concrete mixtures contained up to 40% fly ash, 32% bottom ash, and 36% used foundry sand.

One reference wet-cast mixture was proportioned without fly ash, bottom ash, or used foundry sand for both the wet-cast brick and paving stone mixtures. Two wet-cast concrete brick and two wet-cast concrete paving stone mixtures were also proportioned to utilize all three by-product materials: foundry sand and bottom ash as a partial replacement of normal concrete sand and fly ash as a partial replacement for cement.


This project was conducted to evaluate the environmental performance of Controlled Low Strength Materials (CLSM) incorporating fly ash and foundry sand. Two different flowable fly ash slurry reference mixtures were proportioned for strength levels in the range of 0.3 to 0.7 MPa (50 to 100 psi), at 28 days, using two sources of ASTM Class F fly ash. For each reference mixture, other mixtures were proportioned using two sources of foundry sand as a replacement of fly ash in the range of 30 to 85%.

The ingredients of the slurry mixtures such as fly ash, clean foundry sand, and used foundry sand were tested for their physical and chemical properties, and leachate characteristics. All CLSM mixtures made with and without foundry sand were evaluated for settlement, setting and hardening characteristics, compressive strength, permeability, and leachate characteristics. The leachate results of these CLSM-making materials were below the Enforcement Standard of the Wisconsin Department of Natural Resources.
(WDNR) Groundwater Quality Standard. They also met practically all the parameters of the Drinking Water Standards.

Generally, compressive strength of the flowable slurry materials increased with age and was found to vary between 0.3 and 0.7 MPa (50 to 100 psi) for the mixtures tested at 28 days. The leachate results of all the CLSM mixtures made with and without foundry sand were below the Enforcement Standard, and they also met practically all the parameters of the Drinking Water Standards. Generally, addition of the foundry sand caused substantial reduction in concentration of the elements that are considered hazardous in accordance with WDNR Groundwater Quality Standard. Therefore, the use of foundry sand may provide favorable environmental performance.
SUMMARY BACKGROUND DATA

Tarun R. Naik, Ph.D., P.E.

Director, UWM Center for By-Products Utilization, and
Associate Professor of Civil Engineering
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Dr. Naik received his Bachelor of Engineering degree in Civil Engineering from the Gujarat University, India, in 1962. He received his M.S. and Ph.D. degrees in Civil Engineering from the University of Wisconsin - Madison in January 1964 and January 1972, respectively. He is a registered Professional Engineer in Wisconsin since 1969. From February 1964 to January 1967, Dr. Naik was employed as a Structural Engineer with consulting civil engineering companies in Chicago and Madison. From September 1966 to July 1972, he worked at the University of Wisconsin - Madison as a Lecturer and researcher in the College of Engineering. Dr. Naik worked (1972 - 1975) for Soils and Engineering Services, Inc., Madison, and was Executive Vice President when he resigned in September 1975 to join the faculty at the University of Wisconsin - Milwaukee (UWM).

Dr. Naik's contribution in teaching and research has been well recognized nationally and internationally. He has taught many civil engineering and mechanics courses as a part of his normal teaching responsibilities at UWM. He has been very effective in working with his students. He specializes in Materials of Construction, Concrete Technology, Timber Engineering, and Foundation Engineering. He has taught courses, given seminars, held workshops, and/or presented invited lectures (in the use of by-products in construction materials, nondestructive testing of concrete, evaluation of concrete structures, repair and rehabilitation of structures, bridges, and dams, concrete technology, and design of foundation for machinery and electric transmission line structures) not only in USA, but also in over two dozen other countries.

Dr. Naik's research has been well supported by private industries as well as federal government agencies. He has received research grants from companies in the USA and several other countries. Also, many different federal government agencies have provided research funding to Dr. Naik. His publications from these sponsored and other research have resulted in over 200 technical papers and reports (in ASCE, ACI, ASTM, etc.). His publications are in two distinct but related areas - structural engineering and construction materials.
He is a member of ACI, ASCE, ASEE, ASTM, RILEM, SEM, NSPE, and WSPE. Dr. Naik was the President of the Milwaukee Chapter of the WSPE during 1986-1987. He also served on the Board of Directors of WSPE. He was an Associate Editor of the Engineering Mechanics Division Journal of the ASCE from 1987 to 1990. He was appointed a member of the Editorial Board of the International Journal of the Construction and Building Materials in January 1994. In 1995 he was also appointed by ASCE as a Contributing Editor of the Journal of Environmental Engineering, Associate Editor of the Journal of Materials in Civil Engineering and Journal of Energy Engineering, and Editorial Board member of the Journal of Geotechnical Engineering.

He is a Past-President of the Wisconsin Society of Professional Engineers (WSPE); a Past-President of the Wisconsin Chapter of ACI; and Past-Chairman and member of the ACI Committee 437, "Strength Evaluation of Existing Concrete Structures"; a member of ACI Committee 232, "Fly Ash and Natural Pozzolans in Concrete", Committee 214, "Evaluation of Results of Strength Tests of Concrete", Committee 123 "Research"; and, a past-member of Committee 201 "Durability of Concrete", and "Concrete Materials Research Council". He was also the Chairman of the ASCE-EMD Committee on "Experimental Analysis and Instrumentation", Vice Chairman of the ASCE-MTD Committee on "Materials Performance", and a member of the ASCE-STD Committee on "Electrical Transmission Structures". He was also a member of the Prestressed Concrete Institute Committee on "Concrete Pole Design." He is a member of the ASTM Committee C-9, "Concrete and Concrete Aggregates" and C-1 "Cement": past Chairman of ASTM C09.02.09, "Accelerated Strength Testing of Concrete"; and, a former member of Committee C-27 on "Precast Concrete Products, and Committee D-7 on "Wood". In 1995 Dr. Naik was appointed as the chairman of a new technical committee ("Emerging Materials") by ASCE.

In 1986, Dr. Naik was awarded in Wisconsin competition by ASCE an Award of Merit for "Individual Achievement as an Engineer in Education". In 1988, he was elected a Fellow of the American Concrete Institute. In 1989, he received an award as an "Outstanding Engineer in Education" from WSPE; and an award from the Mexican Cement and Concrete Institute... for dedication and creativity in concrete education". In 1990, he received an award for Outstanding Service from the College of Engineering and Applied Science, UWM; the Orton Spanley award from the American Concrete Institute, Wisconsin Chapter; and, an award of appreciation from the ASTM Committee on Concrete and Concrete Aggregates. In 1996 he received an award from the Mexican Cement and Concrete Institute for "...outstanding contributions in the fields of research; teaching, and application of cement and concrete". In 1997, he received an award for Outstanding Teaching from the College of Engineering and Applied Science, UWM. In 1997, Dr. Naik was chosen for the NDT award for Best Paper on NDT Techniques by the
Engineer Technics Press, Edinburgh, Scotland; and was elected a Fellow of the American Society of Civil Engineers. In 1998, he received an award from CANMET/ACI for "sustained and outstanding contributions in working with fly ash in concrete". Dr. Naik was noted as a "recycling pioneer" and one of the most noteworthy people of 1999 by the Milwaukee Magazine in its January 1999 issue.

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Rudolph N. Kraus, M.E.
Assistant Director and Research Associate,
UWM Center for By-Products Utilization

Mr. Kraus received his B.S. in Civil Engineering from the UW-Milwaukee in 1980 and a M.E. in Structural Engineering from UW-Milwaukee in 1983.

Mr. Kraus worked as a Research Assistant at UW-Milwaukee from 1980 to 1983 while pursuing his graduate studies. His graduate research was on nondestructive testing of concrete at early ages. Nondestructive test methods used for the project were maturity, pulse velocity, and pullout methods.

From 1984 to 1994, Mr. Kraus worked as a structural engineer for Sargent & Lundy Engineers, Chicago, IL. He has worked with many utilities involving design and assessment of power plant systems and structures, etc. He also worked on the recent Oak Creek Power Plant fly ash transporting systems for Wisconsin Electric while at Sargent & Lundy.

Since November 1994, Mr. Kraus is working as a Research Associate at the Center for By-Products Utilization where he is responsible for research involving the use of by-products in construction materials. Recent projects which he has been involved with include the utilization of used foundry sand and fly ash in CLSM (Controlled Low Strength Materials - per ACI requirements), evaluation and development of CLSM utilizing lightweight aggregate, evaluation of CLSM utilizing ash obtained from clean coal technologies, lightweight aggregate evaluations, and use of by-product materials such as used foundry sand, fly ash and bottom ash in the production of concrete bricks, blocks and paving stones.
Shiw S. Singh, Ph.D., P.E.
Research Associate
UWM Center for By-Products Utilization

Dr. Singh received his Bachelor of Engineering Degree in Agricultural Engineering from Allahabad University, India in 1971, and a Master of Technology Degree from the Indian Institute of Technology, W.B., India in 1973. Dr. Singh also completed a MS Degree in Engineering Mechanics and a Ph.D. degree in Biomechanics from the University of Wisconsin at Madison in 1984 and 1985, respectively. He is a registered Professional Engineer in Wisconsin since 1990.

From 1974 to 1976, Dr. Singh worked as an Assistant Engineer. He designed a large size traction testing facility for testing pneumatic tires and other traction devices. He served as a lecturer in Engineering at Allahabad University from 1976 to 1978. His teaching responsibilities were related to Design of Mechanical Elements, Heat Engines and Thermodynamics.

Dr. Singh worked as a Research Assistant at UW-Madison from 1978 to 1984 while he was pursuing his graduate studies. His Ph.D. research was related to modeling and evaluation of mechanical response of biocomposite materials. He also developed computer programs in the areas of optimum design, finite element analysis, finite difference, regression analysis and computer graphics. He designed an impact tester for measuring fracture resistance of grains which has been awarded a US patent.

He was associated with the Civil Engineering Department at UWM as an adjunct Research Associate in 1986. His work was related to vibrations of low-rise timber structures. During the period from 1987 to 1990, Dr. Singh was also associated with the Materials Department at UWM. His work was related to the mechanical behavior of composite materials including damping capacity and fracture toughness. His expertise include mechanical behavior of composite materials including concrete, structural vibrations, finite element analysis, and design of mechanical and thermal systems.

From 1986 to 1988, Dr. Singh worked as a Research and Development Engineer at WB Combustion, Inc. Milwaukee. He evaluated performance of high temperature materials, especially silicon carbide reaction bonded materials to determine their suitability for use in high temperature heating systems.

Dr. Singh worked as a Research Associate at the Center for By-Products Utilization from September 1989 through November 1997. His research activities were
related to by-products utilization and composite materials including concrete, and mathematical modeling of properties of composite materials.

Dr. Singh worked as a Staff Environmental Engineer at International Environmental Corporation, Butler, Wisconsin from January 1998 through September 1999. Dr. Singh performed remedial investigations of sites contaminated with hazardous substances. Dr. Singh worked on site characterization to evaluate the feasibility of natural bioremediation of soil and ground water. He performed remediation of sites contaminated with petroleum constituents resulting from leakage from underground storage tanks.

Dr. Singh rejoined CBU in November 1999. His current assignments are related to the use of by-products in cement-based materials, and strength and durability evaluation of cement-based materials.

Henry J. Kolbeck, P.E.
Research Associate,
UWM Center for By-Products Utilization

Mr. Kolbeck received his B.S. in Civil Engineering from the University of Wisconsin-Madison in 1952. He received his M.S. in Civil Engineering from the UW-Milwaukee in 1967. He is a registered Professional Engineer in Wisconsin (1956) and in Michigan (1982).

In 1952, Mr. Kolbeck started work as a junior engineer at Commonwealth Associates, a consulting engineering firm in Jackson, MI, doing structural design of electric power plants.

In November 1953, Mr. Kolbeck joined Wisconsin Electric Power Company, Milwaukee, WI, as a civil engineer in the Plant Engineering Department. He was promoted to Project Engineer in 1962. The work included engineering design of power plant buildings and other structures. It also included other civil engineering projects such as roads, underground utilities, marine structures, earth work, and development of fly ash disposal sites. In 1978 he became Superintendent of Drafting where he supervised over 50 drafters engaged in technical drafting activities for the company. In 1981 he became Leading Project Engineer in the Engineering and Construction Department. He supervised a multi-discipline project group including, civil, mechanical and electrical engineers. In 1985 he was promoted to Senior Project Engineer and head of the department's civil engineering group.
Since 1969, one of Mr. Kolbeck's major involvements was the engineering development and operation of fly ash disposal sites, including working on environmental issues with the Company's Environmental Department and the WI-DNR. Throughout his career he attended numerous seminars and workshops including several on fly ash disposal and utilization. Since the 1960's, he was involved in promoting the use of fly ash in concrete as well as other applications such as flowable fly ash slurry.

He is a member of ASCE and ACI. He held various offices and became President of the Southeast Branch of the ASCE, Wisconsin Section, in 1980. He is a member of ACI Committee 229 - Controlled Low Strength Materials (CLSM), and ACI Committee 232 - Fly Ash and Natural Pozzolans in concrete.

In February 1989, he was appointed Assistant Director of the Center for By-Products Utilization, at the University of Wisconsin - Milwaukee. His responsibilities include a full range of administrative functions, development of research plans and participation in research work as well a other CBU activities. He has co-authored several papers on fly ash utilization (see listing with Naik, T. R., above).