DRAFT (updated 3/17)

Proposal for Sponsored Research:

Collaboration with Kuert Concrete Company

South Bend, Indiana

Submitted for Review: February 17, 2014

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Research Motivation: To pursue synergistic research activities related to the Life Cycle costs of concrete and emerging paving technologies.

Background: Concrete is one of the most durable building materials and one of the most widely used construction materials in the world[1]. In fact, concrete is used more than *any* other manmade material, with annual (global) consumption estimated at between 21 and 31 billion tons[2]. As of 2006, an estimated 7.5 billion cubic meters of concrete was made annually, the equivalent of more than one cubic meter of material per every man, woman, and child on Earth[3].

Concrete production involves mixing together various ingredients—water, aggregate, cement, and sometimes mineral or chemical additives—to produce concrete. Concrete production and installation are time-sensitive. Once the ingredients are mixed with water, the concrete must be put in place before it hardens or cures. Most concrete today is produced in large industrial facilities, more often in what is called a batch plant. Another type of concrete plant is a ready mix plant, where all of the ingredients, except for water, are mixed before the concrete is staged for distribution. A central mix – or batch plant – mixes all of the ingredients, including water, before distribution, and is therefore a process that is able to more accurately control the quality of the concrete mixture. Conversely, the range of distribution for a centralized batch plant is more limited than ready-mixed concrete, since the hydration of the concrete begins at the plant as opposed to near (or at) the job-site.

Kuert Concrete Company, founded in 1925 (Inc., 1927), is one of the oldest central mix concrete plants in the state of Indiana and among the oldest manufacturing facilities of its kind in the United

[1] *Paving the Way to Greenhouse Gas Reductions,* WEB.MIT.edu, retrieved 2/6/2014: http://web.mit.edu/newsoffice/2011/concrete-pavements-0829.html

[2] Lomborg, Bjørn, 2001. *The Skeptical Environmentalist: Measuring the Real State of the World*. p. 138.

[3] USGS, Minerals Commodities Summary, 2006. http://minerals.usgs.gov/minerals/pubs/commodity/cement/cemenmcs06.pdf (ref. cement)

States[4]. As a central batch facility, Kuert mixes all of their concrete on-site at one of their four production facilities (South Bend, Goshen, Rochester, and Warsaw, all in north-central Indiana). The central batch manufacturing process, which differs from ready-mix/ in truck-mixing, enables Kuert to offer a range of concrete products, manufactured and mixed on-site, and to exact specifications and uniformity. This type of concrete manufacturing process typically yields more consistent product (than in-truck mixing), but impacts delivery range (in miles) from the production facility. Kuert Concrete produces custom-mix concrete and a range of other specialized concrete products at its plants. In addition, they produce or sell raw aggregate, mulch, concrete construction support tools and services, and segmented paving assemblies, including a Seattle-based and manufactured product called XeriPave, which is a pervious paving "tile".

Research Objectives:

The GreenScale Research Project, under my direction since 2009, is focused on measuring the broader ecological impacts of the materials and methods used in the construction of the built environment. One of the principal ways that the impact of our buildings on the environment is measured is called Life Cycle Assessment (LCA), whereby the "environmental performance" of a specific product, material, or process can be evaluated. LCA is used across various industries, by companies trying to understand and streamline (for cost or other motivation) their supply chain, manufacturing, and distribution processes. Economists developed the method and the first whole environmental impact study was conducted in 1969 by the Coca Cola Company in order to assess the impact of different types of beverage containers[5]. This study led to the way to the more formalized framework for LCA. In 2006, the ISO standard 14040[6] for LCI and LCA were developed to standardize the process to evaluate the environmental burdens associated with a product, process, or activity.

Because concrete is typically manufactured with locally-sourced materials and within 50-75 miles of the use-site, the energy required for the transportation of concrete is considered to be relatively low, if compared to other manufactured building materials. Again, when related to other building materials and assemblies, energy used to combine the raw materials used to make concrete is also considered comparatively low. Conversely, large amounts of CO_2 are produced in the manufacturing of cement, which is a critical ingredient in concrete mixes. Because of the volume of concrete manufactured

[4] http://www.kuert.com/ (accessed February 13, 2014)

[5] http://www.coca-colacompany.com/stories/reduce (accessed February 13, 2014) and U.S. Environmental Protection Agency (b), 1991, "Product Life-Cycle Assessment: Guidelines and Principles: EPA Report #68-CO-0003).

[6] International Organization for Standardization (ISO), 2006, "ISO 14040", 2006 Environmental Management – Life Cycle Assessment – Principles and Framework (2006).

annually, the cement industry is one of the three primary producers of carbon dioxide, contributing 7% of global anthropogenic CO_2 (the other two sectors of carbon production are energy and transportation)[7] .

General, non-localized LCA data about energy and associated impacts and emissions related to the production of concrete are available in various formats, and concrete producers are being encouraged, by their industry Associations (like the National Ready Mix Concrete Association) and industry-wide standards and initiatives, like LEED and the Environmental Product Declaration (EPD) Program[8], to conduct individual, localized LCA on their products in order to provide comparable information regarding the environmental performance of their products.

LCA data figures prominently in my research and research-related activities, in several ways: in case studies of current, existing buildings; in the development of a new dynamic digital design and decision-support tool that uses existing LCA data to measure material energy (and attendant impacts) costs alongside building (energy) performance; and in the development of cyber-infrastructure to connect heterogeneous building information and data, including LCA data.

One of the basic activities of my lab, particularly for undergraduate students (architects and civil and environmental engineers) working with me, is to conduct building material research, some of which involves existing LCA data, in an effort to understand the benefits and trade-offs associated with specific building-related materials and technologies. Another, related activity involves mapping and growing networks of information and data related to building-related materials, methods, and processes for use by architects, researchers, and those in the A/E/C industry. Per recent meetings with Mark Walker, Kuert's Director of Business Development, we have identified several synergistic opportunities for collaboration between the Kuert Concrete Company and the GreenScale Research Project in the School of Architecture at the University of Notre Dame.

1. Collection of Kuert concrete and production-facility-specific LCA data (potentially for the purpose of incorporation in an EPD).
2. Collection of emerging material LCA data, specifically for the Xeri-Pave product (Kuert is the Great Lakes licensed distributor).

[7] Accessed via Wikipedia: Navdeep Kaur Dhami; Sudhakara M. Reddy; Abhijit Mukherjee. "Biofilm and Microbial Applications in Biomineralized Concrete". p. 142.

[8] EPDs are developed in accordance with strict international standards that include a transparent verification process for adopting Product Category Rules (PCR) by which EPDs are developed and verified (certified). To produce an EPD, a company must perform a comprehensive Life Cycle Assessment (LCA) on a product and report the results in the EPD. The PCR defines, among other things, the functional unit (product to be analyzed), scope and boundaries of the LCA and the environmental impacts to be reported in the EPD. Before the EPD can be published, it must be third party reviewed and verified (certified).

Working with Kuert Concrete Company to gather product and production-facility-specific LCA data would be a beneficial hands-on research experience for our undergraduates and valuable data for the Kuert Concrete Company to consider as the industry shifts towards making environmental product performance more visible to the consumer. Current LCA data utilized by the concrete industry is "non-localized", meaning that it is more general than data that would result from studying Kuert's specific processes; an analysis that would include the point of extraction raw materials, their transportation, manufacturing, and delivery (range). This type of analysis could also be conducted to understand the LCA of the Xeri-Pave product, currently manufactured in Seattle and trucked to all points east, with Kuert engaged as the distributor for the Great Lakes Region. A useful outcome of this study might be data that would indicate a more sustainable mode of manufacturing and distribution of this particular product, whether it remains to be manufactured only on the west coast or if distribution points east necessitate additional, geographically distinct manufacturing (and distribution) facilities. From the data-networks perspective, the process of manually mapping LCA data networks for Kuert will enable our research team to test and eventually compare results of LCA's conducted using the cyber-infrastructure we are constructing (in collaboration with Notre Dame's Center for Research Computing and colleagues at Wright State University's Knoesis Center).

Project Schedule:

Our research efforts will be focused on gathering LCI data and analysis according to the following two-phase work plan:

A. Phase I – Concrete Life Cycle Inventory and Analysis:
    1. Conduct bounded LCI for Kuert's standard (base) concrete; specific mixture includes a slag additive
    2. Compare LCA data collected for Kuert concrete to LCA data issued by NRMCA and other, similar organizations

B. Phase II – Xeri-Pave LCA: Utilizing similar framework for base concrete LCA, conduct a series of bounded LCI's and analysis for the Xeri-Pave pervious paving product
    1. "Existing" Xeri-Pave; LCI conducted on the product as currently manufactured and distributed through Kuert Concrete (including different modes of transport: truck and rail)
    2. "Alternate" Xeri-Pave; LCI conducted on the product assuming a manufacturing *and* distribution from the Kuert Facility in South Bend.

3. Comparison of the LCA data from the two studies and the broader environmental impact of the Xeri-Pave product when manufacturing and transportation costs are also evaluated.

Project Budget:

Undergraduate Wages & Benefits:

- $8.50/ hour; up to 30 hours/ week; 10-14 weeks **	**$2,550**
- Benefits**:** (wages + 2%)	**$51.00**

Non-personnel Costs:

- Travel: trips to Kuert Concrete South Bend for meetings; 5 miles x 5 ($.66 for mileage rate)	**$ 17.00**
- Consumables:	**$ 30.00**
	$ 2,648.00

** Phase I of the project can begin this spring. The official start date of the project (when funding would need to be secured) is June 1, 2014.