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Advanced Materials Council
1090 Vermont Avenue, NW, Suite 700
Washington, DC 20005-4950
Phone: (202) 289-7800
Fax: (202) 289-1092
nibs@nibs.org
www.nibs.org

PRESIDENT
Henry L. Green, Hon. AIA

SENIOR VICE PRESIDENT
Earle Kennett

Published By:
Matrix Group Publishing Inc.
Return undeliverable copies to:
5190 Neil Road, Suite 430
Reno, NV 89502
Tel: (204) 953-3120
Toll free: (866) 999-1299
Fax: (866) 244-2544
Email: sales@matrixgroupinc.net
Web: www.matrixgroupinc.net

President & CEO
Jack Andress

Senior Publisher
Maurice LaBorde
mlaborde@matrixgroupinc.net

Publishers
Peter Schulz
Jessica Potter
Trish Bird

Editor-in-Chief
Shannon Savory
ssavory@matrixgroupinc.net

Editor
Karen Kornelsen

Finance/Accounting & Administration
Shoshana Weinberg, Nathan Redekop,
Pat Andress
accounting@matrixgroupinc.net

Director of Marketing & Circulation
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Layout & Design
Travis Bevan

Advertising Design
James Robinson

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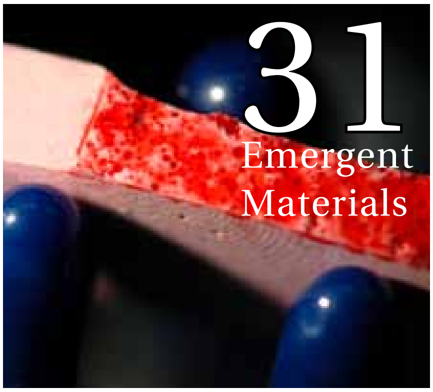

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On the cover:

The challenge facing researchers will be to develop advanced materials that will protect buildings from natural and manmade disasters while allowing designers to meet aesthetic, energy performance and sustainability goals.

Advanced and High-Performance Materials Program

By Mila Kennett, Program Manager, U.S. Department of Homeland Security, Science and Technology Directorate, Infrastructure Protection and Disaster Management Divison

WHEN PIONEER JOSEPH GOODRICH decided in 1844 to build his house in Milton, Wisconsin, his quest for durability and sturdiness seems to have been motivated, among other things, by a concern about the potential repeat of the local native warriors' incendiary raids that had troubled the area during the Black Hawk War of the previous decade. He used "poured grout" (concrete) to erect the walls by adding Portland cement, newly imported from England, to a mixture of stone, gravel and water. The construction of Milton House not only marked the first use of Portland cement in the United States but also made history as the first concrete structure in the nation.

The development of new construction materials and technologies has always been driven by the need to protect people from either the adverse effects of natural forces or violent attacks by their enemies. This was accomplished by creating structures that were able to provide safety from the extremes of weather, floods, winds, fires or earthquakes, and be a secure haven from aggression. Instances of this dynamic can be found throughout history.

For example, following the Great Chicago Fire of 1871, which practically destroyed one of the country's main economic and population centers, the city initiated a massive reconstruction program. In an effort to reduce the risk of future similar disasters, local architects and builders introduced a panoply of new materials and technologies, as well as innovative uses of traditional materials. The designers and builders of the Home Insurance Company building introduced the principles of skeleton construction and were also the first ever to use Bessemer steel rolled beams instead of the wrought iron beams commonly used at the time (Randall, 1999). The Kendall building, which was constructed immediately following the conflagration, is considered the earliest fireproofed building in the United States because for the first time, the builders protected the structural elements with terracotta tile, a material still used today for this purpose.

Today, the natural hazards and security threats to our nation's building inventory have multiplied, but so have the efforts of researchers and practitioners who are developing new high-performance construction materials that can aid in reducing the variety of risks to buildings and infrastructure. While advanced construction materials are being introduced at a rapid rate, no effective national system of identification, testing, monitoring or coordination of these developments exists. The Department of Homeland Security (DHS), whose overriding and urgent mission is to lead the unified national effort to secure the country and prepare for and respond to all hazards and disasters, has a special interest in promoting the development of advanced and high-performance materials. Through the efforts of its Science and Technology Directorate (S&T), specifically the Infrastructure Protection and Disaster Management Division (IDD), the Department is taking the lead in this important undertaking that will provide the means to preserve and improve the existing infrastructure and build new, more resilient facilities.

S&T/IDD PROGRAM WITH NATIONAL INSTITUTE OF BUILDING SCIENCES (NIBS)

DHS has entered into partnership with the National Institute of Building Sciences (NIBS) to pursue a series of goals oriented toward the development and dissemination of the state-of-the-art technology for improving homeland security. The partnership is known as the Advanced and High-Preformance Materials Program. Its main objective is to mobilize the research and development community and to bring together the design and engineering experts, building and infrastructure owners and operators, advanced materials researchers, technology providers and first responders within a forum located at NIBS. Other participants include federal agencies, university research centers, national laboratories, foreign governments, private research centers and commercial research and development organizations. The Program will be organized and managed around two activities overlapping but nevertheless complementing each other. Each activity has a specific role in the organizational structure of the Program.

BUILDINGS AND HIGH-PERFORMANCE SOLUTIONS

DHS is currently making an enormous effort to attend to the physicality of the built environment. Until recently, the Department's coordinated efforts were oriented to protecting people and infrastructure against the effects of explosives and chemical, biological and radiological (CBR) agents. These efforts were centered on seeking innovative approaches in detection and promoting the development of field equipment, technologies and procedures to interdict person-borne bombs, car and truck bombs, and shoulder-fired missiles before they can reach their targets. Within this framework, the reduction of risks from explosives and CBR hazards relied heavily on electronic security, security personnel, cameras and the screening of personnel.

The Buildings and High-Performance Solutions Component is designed to provide an overall programmatic framework for identification, exploration, documentation and dissemination of advancements and improvements to the materials, systems and technologies that provide the physical configuration of the nation's building inventory and critical infrastructure in order to optimize all major attributes including blast protection, energy efficiency, sustainability, safety, security, durability, productivity, functionality and operational maximization (FIGURE 1).

This effort is an integral part of the S&T mission objective to establish and implement the concept of integrated or multi-attribute design and research. It will drive and coordinate the research and development of advanced and high-performance materials and systems and promote the cross-fertilization of public, private and international advanced materials research. A high level National Technical Committee has been identified to oversee this project. The result of this multiagency project will provide DHS/S&T/IDD the capability to review, understand and promote the adoption of mitigation measures to improve the building stock and critical infrastructure in the areas of blast resistance, energy efficiency and environmental sustainability.

The deteriorated state of the nation's built environment has led the research community to look at the use of alternative materials of lower cost and lighter weight, that contribute to enhanced performance, reduced maintenance and increased durability. The industry and research institutions have developed a large variety of these new advanced materials. DHS and NIBS are working together to develop a high-performance building envelope model and other building components and subcomponents. The project would be charged with the integration, compilation, harmonization and promotion of uniform and consistent high-performance building standards in the building industry to ensure acceptable and appropriate levels of performance. An institutional effort would monitor the work of five expert committees (architectural, structural, mechanical, fenestration, and risk and uncertainties) to assure harmonization and to avoid the creation of metrics that would cause conflicts or duplications in the evaluation and delivery processes.

ADVANCED MATERIALS PROJECT

Research institutions, universities, National Laboratories, and industry have developed a large variety of advanced materials and intelligent systems in the last decade. However, these efforts are not systematically followed-up on, nor are they effectively shared among the producers and end users of these materials. Testing protocols vary, leaving the construction industry without appropriate guidelines. The Advanced Materials project is therefore intended to foster and promote the design and adoption of new innovative and advanced systems that meet a range of high-performance requirements, including dramatically reduced energy use and enhanced blast protection. A secondary objective of this project is to prepare a Basic Research Program that would allow S&T/IDD to undertake the most novel and state-of-the-art basic research in the area of security and associated fields (FIGURE 2).

The Advanced Materials effort seeks to set the research goals, priorities and agenda for advanced materials development. It can be considered as the

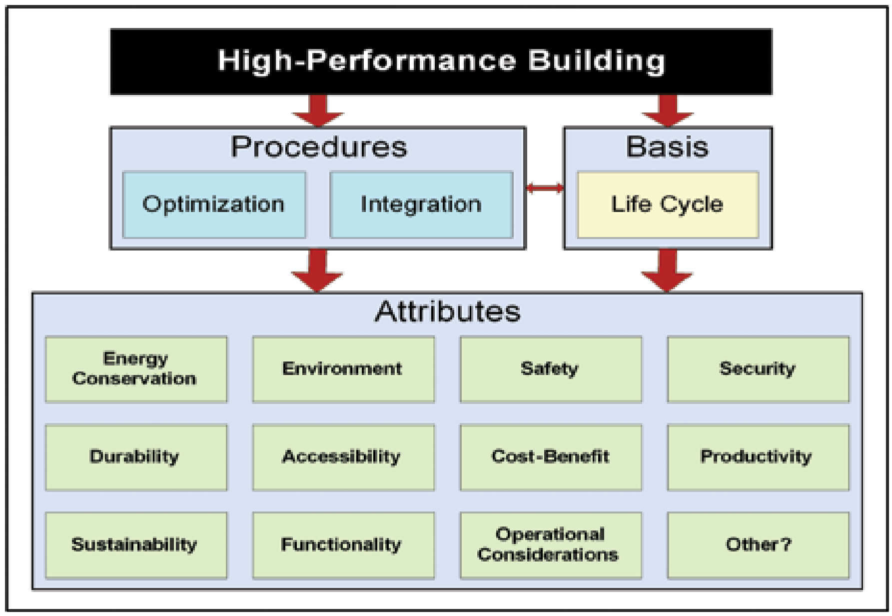

Figure 1.

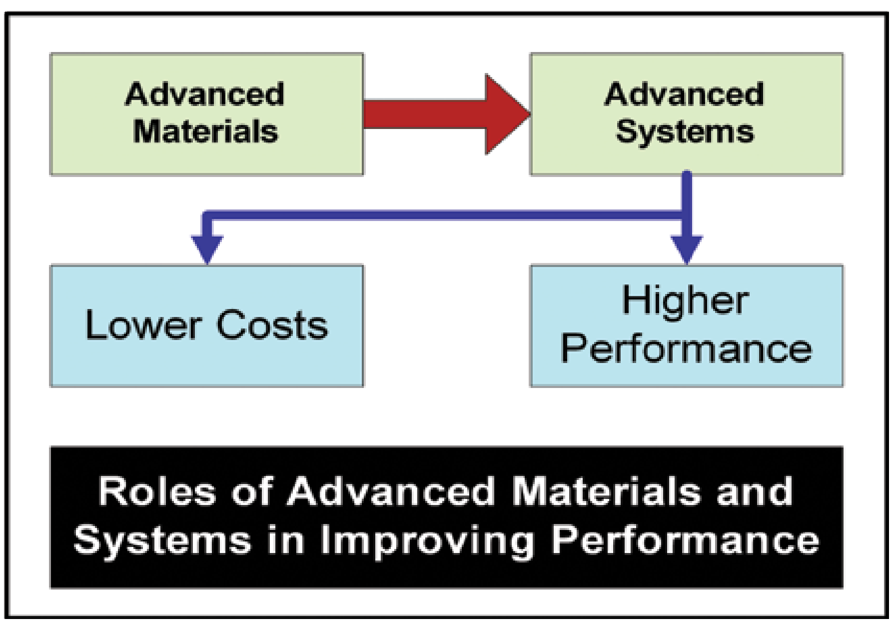

Figure 2.

principal engine of the Program and will serve to document, process and organize the results of research activities and prepare them for dissemination through various outreach activities, such as the Database Website Interface. The application of advanced materials and technologies will permit us to manage our infrastructure assets more effectively and dramatically reduce the risks from adverse environmental consequences or terrorist attacks. For this program, two interrelated databases have been developed: the Advanced Materials Database (AMD) and the Innovative Technologies and Systems (ITS) database. The AMD has the purpose to catalogue, document and exchange materials information among industry and the research community in an effort to promote the use of advanced materials for efficient and cost effective retrofit. The ITS plays a crucial role in helping to introduce and broadly publicize a wide range of technological advances that will fundamentally change the way we manage buildings and physical infrastructure.

The access to the databases' information by the general public will be controlled by a tiered security system, in order to protect classified as well as proprietary information. By bringing together organizations with a stake in infrastructure protection and innovative technologies, this Program will help facilitate development, wider use and integration of advanced and high-performance materials and innovative technologies in the design, construction and protection of critical infrastructure.

The overall leadership for this component will be provided by the Advanced Materials Council (AMC), composed of representatives from federal agencies such as the Department of Homeland Security, Department of Energy, the Environmental Protection Agency, the Department of Defense, the National Science Foundation, and the National Institute of Science and Technology, to name but a few. Other members will include representatives from National Laboratories, such as the U.S. Army's Engineer Research and Development Center, Lawrence Livermore National Laboratory, and Lawrence Berkeley National Laboratory; University Research Centers; industry; and foreign governments. The AMC will set the overall Program agenda and provide guidance for advance materials technology transfer. It will appoint and organize working committees to guide the design of the database taxonomy, its application and usage, and develop other aspects of Program outreach.

LOOKING AHEAD

The need to improve the state of the nation's critical infrastructure and to provide adequate and effective protection against hazards and threats is great indeed. New high-performance materials and systems can play a very significant role in accomplishing this task. Today, advanced and high-performance materials can be employed to provide infrastructure protection against multiple threats and simultaneously satisfy other needs such as energy conservation, low environmental impact, or cost-effectiveness. For example, reinforcing an existing or newly built masonry structure with sensor-embedded textiles and nano-particle-based mortars provides increased strength and ductility against earthquakes, improved fragmentation properties against blast and in-service data capability for conducting structural health monitoring, lifecycle management performance prediction and incident emergency assessment for first responders (Messervey et al., 2009).

Although new materials and technologies such as these are being developed at an ever-increasing rate, the pace of their adoption and utilization is lagging. One of the greatest challenges today is how to communicate and promote the adoption of new advanced materials and technologies. The private sector and public agencies must have the right tools, guidelines and information to facilitate adoption and utilization. Therefore, it is necessary to stress that effective innovative technology transfer is as important as innovative research and development of advanced materials. Innovations in high-performance materials and construction technologies must be tested, demonstrated, documented, discussed and applied repeatedly, if they are to penetrate industry practice and produce the expected results. Adequate information and communication flows are critical for achieving technology transfer goals.

Widespread utilization of new technologies and high-performance materials will lead to renewal and rebuilding of physical infrastructure across the nation. Demonstration projects will show the benefits of advanced materials and make the case for their application throughout the United States, thus incorporating high-performance construction materials and systems into the mainstream practice. Design and construction standards will be performance-based rather than prescriptive and will reflect a new era of technological innovation and asset management, thereby advancing the state of critical infrastructure. ■

Mila Kennett received a degree in architecture and urban design from the Universidad Autonóma de Santo Domingo and a Master of Arts degree in international development with a major in urban economics from American University in Washington, D.C. She has more than 15 years of experience on projects in Latin America, Asia, the Middle East, Europe, and the United States. Kennett's main focus has been on natural disaster mitigation; building security; risk assessments; planning and implementation of development programs; and management of pilot programs with national and local governments and non-governmental organizations.

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