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COMPOSITE MATERIALS: STRENGTHENING INFRASTRUCTURE DEVELOPMENT

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIFTEENTH CONGRESS

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COMPOSITE MATERIALS: STRENGTHENING INFRASTRUCTURE DEVELOPMENT

WEDNESDAY, APRIL 18, 2018

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:08 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Daniel Webster presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Composite Materials – Strengthening Infrastructure Development

Wednesday, April 18, 2018
10:00 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Joannie Chin, Deputy Director, Engineering Laboratory, NIST

Dr. Hota GangaRao, Wadsworth Distinguished Professor, Statler College of Engineering, West Virginia University

Dr. David Lange, Professor, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign

Mr. Shane Weyant, President and CEO, Creative Pultrusions, Inc.

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HEARING CHARTER

April 18, 2018

TO: Members, Subcommittee on Research and Technology

FROM: Majority Staff, Committee on Science, Space, and Technology

SUBJECT: Research and Technology Subcommittee Hearing:
"Composite Materials – Strengthening Infrastructure Development"

The Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing titled *Composite Materials – Strengthening Infrastructure Development* on Wednesday, April 18, 2018 at 10:00 a.m. in Room 2318 of the Rayburn House Office Building.

Hearing Purpose:

Fiber reinforced polymer (FRP) composite products produced in the U.S. offer durable, sustainable, and cost-effective solutions in infrastructure applications as diverse as dams, levees, highways, bridges, tunnels, railroads, harbors, utility poles, and buildings.[1] The purpose of the hearing is to review a National Institute of Standards and Technology (NIST) report on overcoming barriers to the adoption of composites in sustainable infrastructure[2] and discuss the value of developing composites standards for infrastructure applications.

Witness List

- **Dr. Joannie Chin**, Deputy Director, Engineering Laboratory, NIST
- **Dr. Hota V. GangaRao**, Wadsworth Distinguished Professor, Statler College of Engineering, West Virginia University
- **Dr. David Lange**, Professor, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign
- **Mr. Shane E. Weyant**, President and CEO, Creative Pultrusions, Inc.

Staff Contact

For questions related to the hearing, please contact Cate Johnson or Raj Bharwani of the Majority Staff at 202-225-6371.

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[1] NIST Special Publication 1218, "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure," December 2017, available at: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

[2] Ibid.

Mr. WEBSTER. The Committee on Science, Space, and Technology will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Good morning. Everyone's here. Welcome to today's hearing entitled, "Composite Materials: Strengthening Infrastructure Development." I recognize myself for five minutes for an opening statement.

The purpose of this morning's hearing is to review a National Institute of Standards and Technology (NIST) report on overcoming barriers to the adoption of composites in sustainable infrastructure and discuss the value of developing composite standards for infrastructure applications.

While not widely adopted yet, composites have been used in select construction projects across the country. As we will hear from our experts today, fiber-reinforced polymer composites produced in the United States offer durable, sustainable, and cost-effective solutions in a variety of infrastructure applications as diverse as dams, levees, highways, bridges, tunnels, railroads, harbors, utility poles and buildings. However, without proper design guidelines and data tables to harmonize standards and create a uniform guidance, the practical use of composites to build durable and cost-effective infrastructure will continue to lag.

The National Institute of Standards and Technology is well-poised to lead research to provide the evidence and data needed to set industry standards and design guidelines. NIST has a deep and varied expertise in advanced composites, which I look forward to hearing more about in the hearing. It is my understanding that there are over a dozen projects across NIST that work to measure, model, and predict the performance of advanced composites for a variety of applications.

I'm well aware of the challenges our nation's infrastructure is facing and the anticipated cost of its restoration. I look forward to learning more about the potential value of using composites in infrastructure and the economic case for composites as an alternative or supplement to conventional materials in infrastructure projects.

I appreciate you all for taking the time to join me for this hearing. As the Administration and Congress begin to consider how to tackle the nation's infrastructure challenges, it is important to understand what role composites can play.

[The prepared statement of Mr. Webster follows:]

COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Lamar Smith, Chairman

For Immediate Release
April 18, 2018

Media Contacts: Thea McDonald, Brandon VerVelde
(202) 225-6371

Statement by Rep. Daniel Webster (R-Fla.)

Composite Materials – Strengthening Infrastructure Development

Rep. Webster: The purpose of this morning's hearing is to review a National Institute of Standards and Technology (NIST) report on overcoming barriers to the adoption of composites in sustainable infrastructure and discuss the value of developing composite standards for infrastructure applications.

While not widely adopted yet, composites have been used in select construction projects across the country. As we will hear from our experts today, fiber reinforced polymer composites produced in the United States offer durable, sustainable and cost-effective solutions in a variety of infrastructure applications as diverse as dams, levees, highways, bridges, tunnels, railroads, harbors, utility poles and buildings.

However, without proper design guides and data tables to harmonize standards and create a uniform guidance, the practical use of composites to build durable and cost-effective infrastructure will continue to lag.

The National Institute of Standards and Technology (NIST) is well-positioned to lead research to provide the evidence and data needed to set industry standards and design guidelines. NIST has a deep and varied expertise in advanced composites, which I look forward to hearing more about in this hearing. It is my understanding that there are over a dozen projects across NIST that work to measure, model and predict the performance of advanced composites for a variety of applications.

I am well aware of the challenges our nation's infrastructure is facing and the anticipated costs of its restoration. I look forward to learning more about the potential value of using composites in infrastructure and the economic case for composites as an alternative or supplement to conventional materials in infrastructure projects.

I appreciate you all for taking the time to join me for this hearing. As the administration and Congress begin to consider how to tackle the nation's infrastructure challenges, it is important we understand what role composites can play.

###

Mr. WEBSTER. I now recognize the Ranking Member from Illinois, Mr. Lipinski, for an opening statement.

Mr. LIPINSKI. Thank you. I want to thank Chairwoman Comstock in her absence today for holding the hearing on this important topic, and I want to thank the witnesses for being here to share your thoughts on the use of advanced composite materials for major infrastructure.

Much of the nation's major infrastructure is nearing or has passed the end of its design lifespan. The American Society of Civil Engineers' 2017 Infrastructure Report Card gave our nation's infrastructure a grade of D-plus based on assessments of capacity, condition, resilience, innovation, and other criteria. And our current infrastructure is under increased strain year after year as our population grows. We must find a way to ensure the safety of our nation's expanding population as demands on our roads, bridges, utilities, and other essential infrastructure increase.

I sit on the House Transportation Infrastructure Committee, and I understand that the status quo is clearly not acceptable. In addition, we need to examine our approach to rebuilding infrastructure as climate change and other factors drive increases in the intensity of wildfires, hurricanes, and other extreme events wreaking havoc on dams, bridges, above- and below-ground utilities, and other essential structures. These are long-term challenges that require long-term solutions. But right now, we don't have the funding necessary to close investment gaps and build the infrastructure we know that we need.

As we make plans to shore up our infrastructure and build for the future, we must take advantage of all the tools at our disposal. This includes using innovative technologies and emerging materials where they offer the best value for a project. Materials such as fiber-reinforced polymer composites or advanced composites which are—which we are examining in today's hearing, they play a key role in how the nation addresses its challenges under constrained resources.

Decades of federal and private sector research and development and investment in advanced composites has resulted in a significant use of these materials in some sectors such as defense, aerospace, automobile, and energy industries. While composites have also been used in some construction and infrastructure applications such as strengthening concrete, making bridge repairs, and building bridge decks, they haven't been used as widely for infrastructure as they have been in other sectors.

I commend NIST for producing the report we are reviewing in today's hearing. They brought together federal, private, and university partners to identify and examine how to overcome barriers to adoption of composites and sustainable infrastructure, including challenges to developing a skilled workforce.

I look forward to hearing from Dr. Lange and others about ways we can incorporate advanced composites into our engineering education and training programs to make sure that all those involved in designing and building our infrastructure have the knowledge and skills to use whichever material is best for the job. This will require updates for undergraduate and graduate engineering curriculum, training programs for the construction trades, and profes-

sional development plans in a wide range of industries. Doing this successfully necessitates the cooperation of governments, educational institutions, and industry. I'm glad we have representatives from all these sectors here today.

As we examine ways to increase the use of advanced composites, it is important that we don't lose sight of the strength of traditional materials like concrete and steel. Both repair and upgrades of existing infrastructure and for new projects, we need to have safety and design standards in place to allow engineers to choose the best material for the job and allow novel and traditional materials to work together. Finding smart ways to improve our roads, bridges, pipelines, and other infrastructure is a major priority of mine. I look forward to your testimony today. Thank you, and I yield back.

[The prepared statement of Mr. Lipinski follows:]

OPENING STATEMENT
Ranking Member Daniel W. Lipinski (D-IL)
of the Subcommittee on Research and Technology

House Committee on Science, Space, and Technology
"Composite Materials-Strengthening Infrastructure Development"
April 18, 2018

Thank you Chairwoman Comstock for holding today's hearing to discuss this important topic, and thank you to the witnesses for being here to share your thoughts on the use of advanced composite materials for major infrastructure.

Much of the nation's major infrastructure is nearing or has passed the end of its design lifespan. The American Society of Civil Engineers' 2017 *Infrastructure Report Card* gave our nation's infrastructure a grade of D+ based on assessments of capacity, condition, resilience, innovation, and other criteria. And our current infrastructure is under increased strain year after year as our population grows. We must find a way to ensure the safety of the nation's expanding population as demands on our roads, bridges, utilities, and other essential infrastructure increase. I sit on the House Transportation and Infrastructure Committee and I understand that the status quo is clearly not acceptable. In addition, we need to examine our approach to rebuilding infrastructure as climate change and other factors drive increases in the intensity of wildfires, hurricanes, and other extreme events, wreaking havoc on dams, bridges, above- and below-ground utilities, and other essential structures.

These are long-term challenges that require long-term solutions, but right now we don't have the funding necessary to close investment gaps and build the infrastructure we know we need. As we make plans to shore up our infrastructure and build for the future, we must take advantage of all the tools at our disposal. This includes using innovative technologies and emerging materials where they offer the best value for a project. Materials such as fiber reinforced polymer composites, or advanced composites, which we are examining in today's hearing, may play a key role in how the nation addresses its challenges under constrained resources. Decades of federal and private sector research and development investment in advanced composites has resulted in significant use of these materials in some sectors, such as the defense, aerospace, automobile, and energy industries. While composites have also been used in some construction and infrastructure applications, such as strengthening concrete, making bridge repairs, and building bridge decks, they haven't been used as widely for infrastructure as they have been in other sectors. I commend NIST for producing the report we are reviewing in today's hearing. They brought together federal, private, and university partners to identify and examine how to overcome barriers to adoption of composites in sustainable infrastructure, including challenges to developing a skilled workforce.

I look forward to hearing from Dr. Lange and others about ways we can incorporate advanced composites into our engineering education and training programs to make sure that all those involved in designing and building our infrastructure have the knowledge and skills to use whichever material is best for the job. This will require updates for undergraduate and graduate engineering curriculum, training programs for the construction trades, and professional

development plans in a wide range of industries. Doing this successfully necessitates the cooperation of governments, educational institutions, and industry, and I'm glad we have representatives from all of those sectors here today.

As we examine ways to increase the use of advanced composites, it is important that we don't lose sight of the strengths of traditional materials like concrete and steel. Both for repair and upgrades of existing infrastructure and for new projects, we need to have safety and design standards in place that allow engineers to choose the best material for the job, and allow novel and traditional materials to work together.

Finding smart ways to improve our roads, bridges, pipelines, and other infrastructure is a major priority of mine. I look forward to the testimony of our witnesses. I yield back.

Mr. WEBSTER. All right. Now, I'll introduce our witnesses for today. First, Dr. Joannie Chin, our first witness today, is the Deputy Director of an the Engineering Laboratory at NIST, one of the seven resource labs within NIST. As Deputy Director, Dr. Chin provides programmatic and operational guidance for the Engineering Lab and includes nearly 500 federal employees and guest researchers from industry, universities, and research institutes. It is the Engineering Lab's mission to promote the development and dissemination of advanced manufacturing and construction technology guidelines and services to the U.S. manufacturing and construction industry.

Prior to being Deputy Director, Dr. Chin previously served as a leader of the Polymeric Materials Group. Dr. Chin received a Bachelor of Science in polymer science and engineering from Case Western Reserve University. She received a Master of Science in chemistry, as well as a Ph.D. in materials engineering science from Virginia Polytechnic Institute and State University.

Our second witness is Dr. Hota GangaRao, a Wadsworth Distinguished Professor in the Statler College of Engineering at West Virginia University. He also serves as the Director of the Constructed Facility Center and Director of the National Science Foundation's Industry–University Cooperative Research Center for composites infrastructure at West Virginia University.

Dr. GangaRao specializes in fiber-reinforced polymer composites, bridge structures, advanced materials research, composites for blasting, fire resistance, and others. Dr. GangaRao received his Ph.D. in civil engineering from North Carolina State University and is a registered professional engineer.

Mr. Lipinski, do you want to introduce Dr. Lange?

Mr. LIPINSKI. Thank you. It is my pleasure to introduce Dr. David Lange, Professor of Civil and Environmental Engineering and Director of the Center for—of Excellence for Airport Technology at the University of Illinois at Urbana-Champaign. Dr. Lange also serves as President of the American Concrete Institute, Technical Society, and Standards Developing Organization.

Dr. Lange holds a B.S. in civil engineering from Valparaiso University, an MBA from Wichita State University, and a Ph.D. in civil engineering from my alma mater, Northwestern University. And I almost majored in civil engineering but I went with mechanical there as an undergrad, so—he's—Dr. Lange has been a member of the faculty at the University of Illinois for the past 25 years and has earned numerous awards and honors, including the prestigious NSF Career Award, a Fulbright Award, and several accolades for his publications and teaching.

Dr. Lange's research focuses on interface between the structural engineering and materials science of concrete and includes topics such as airport pavement, recycled concrete, and fiber reinforcement of concrete. His research group has played an important role in the O'Hare Airport Modernization Program, coming up with design concepts that save the Chicago Department of Aviation millions of dollars. I also understand that when he's not in the lab, Dr. Lange enjoys spending time with his five-month-old granddaughter and is looking forward to another granddaughter on the

way, and congratulations. And I want to thank you for being with us today, Dr. Lange, and I look forward to your testimony.

Mr. WEBSTER. Our final witness today is Mr. Shane Weyant, President and CEO of Creative Pultrusions, Inc. located in Alum Bank, Pennsylvania. Creative Pultrusions is a subsidiary of Hill & Smith Holdings, PLC, an international group with leading positions in the design, manufacture, and supply of infrastructure products and galvanizing services. Creative Pultrusions is a leader in the manufacture of fiberglass-reinforced polymer protrusion products. Mr. Weyant has been with Creative Pultrusions for nearly 30 years. He received a Bachelor of Science in economics from Frostburg State University, where he graduated magna cum laude.

And now, Dr. Chin, you have five minutes to present your testimony.

TESTIMONY OF DR. JOANNIE CHIN,
DEPUTY DIRECTOR,
ENGINEERING LABORATORY, NIST

Dr. CHIN. Chairman Webster, Ranking Member Lipinski, and Members of the Subcommittee, thank you for this opportunity to discuss NIST's role in promoting the adoption of advanced composites to renew our infrastructure and to increase its resilience in communities prone to or recovering from disasters.

At NIST, our world-class experts use unique facilities to measure materials with increasing precision and characterize new materials for the first time. We help American industries develop, test, and manufacture products with features that outperform previous generations. Our broad program in advanced materials include advanced composites; that is, polymers reinforced with fibers or other additives.

Advanced composites can play a significant role in renewing our nation's crumbling infrastructure and help existing infrastructure be more resilient to both usual wear and natural disasters. Compared to traditional materials, advanced composites are often stronger, lighter, and longer-lasting, thereby offering many cost savings, including fewer days lost to repair and maintenance. That means fewer hours stuck in traffic detoured around bridges, roads, and levees under repair, fewer days in the dark due to broken utility poles, and more efficient movement of the goods and services that underpin our economy and quality of life.

The American advanced composites industry contributes about $22 billion to the economy each year, and although we currently lead the world in advanced composite technology, adoption of these materials for infrastructure has been slower in the United States than in Canada and Europe. To understand the barriers to using these materials in the United States, NIST convened a workshop in February 2017 with infrastructure engineers, designers, and owners, in partnership with the American Composites Manufacturers Association. This May, we will hold a similar workshop with stakeholders interested in using advanced composites to reinforce existing structures to make them more resilient to seismic events.

So from the NIST ACMA workshop, we learned that many owners and design professionals don't yet have enough confidence in the reliability and long-term durability of advanced composites to

specify their use in new structures, as well as to repair damaged ones. We also learned that designers and engineers need data and design guidance so they can provide appropriate safety margins, while maximizing the weight and cost savings of these materials.

NIST has the expertise to address these needs. We have been studying advanced composites since the 1980s and are a leader in characterizing the performance and properties of advanced composites on all scales from nano to macro. For example, to study durability, we have developed sensors that visualize the molecular nature of damage and composites. We also have unique device that accelerates the effects of weathering on materials and large-scale testing facilities that evaluate the effects of strong loads on advanced composite structures.

Our experience providing a data infrastructure for the Materials Genome Initiative is now helping members of the advanced composites community capture and share information on material properties. We will assist the advanced composites community as they establish a clearinghouse of curated existing design guides and data from completed projects, which will inform additional science-based codes and standards.

Our Community Resilience Program provides guidance to architects, design engineers, and community leaders to enable critical decisions about which materials help communities recover rapidly and build back better. While NIST is not a regulatory agency, we have long provided strong scientific foundations for the consensus standards developed by industry. NIST staff members provide leadership and technical expertise to more than 1,800 positions on committees for ASTM International, the international organization for standardization and other standards development organizations.

So we greatly appreciate the Members of this Committee and others in Congress for their support of federal acceleration of the adoption of advanced composites for infrastructure, helping to keep our nation globally competitive and economically secure and contributing to our quality of life. I am happy to answer any questions you may have.

[The prepared statement of Dr. Chin follows:]

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Testimony of

Joannie W. Chin, Ph.D.
Deputy Director
Engineering Laboratory
National Institute of Standards and Technology
United States Department of Commerce

Before the

Committee on Science, Space, and Technology
Subcommittee on Research and Technology
United States House of Representatives

Advanced Composites for Infrastructure

April 18, 2018

Introduction

Chairwoman Comstock, Ranking Member Lipinski, and Members of the Committee, I am Dr. Joannie Chin, Deputy Director of the Engineering Laboratory at the Department of Commerce's National Institute of Standards and Technology (NIST). The NIST laboratory programs work at the frontiers of measurement science to ensure that the United States (U.S.) system of measurements is firmly grounded in sound scientific and technical principles. With the unique facilities at the NIST laboratories, we address complex measurement challenges on every scale, from nanoscale devices for the next generation of electronics, to vehicles, buildings, and the resilience of whole communities. We work in the physical realm on advanced manufacturing, and in the virtual world of cybersecurity and cloud computing. As new technologies are developed and evolve, NIST's measurement research and services remain central to innovation, productivity, trade, and public safety. Thank you for the opportunity to appear before you today to discuss NIST's role in accelerating the adoption of advanced composites for new infrastructure, and for enhancing the resilience of American communities.

NIST and Advanced Materials

NIST's work on advanced composites, which, for our purposes today, I will define as polymers strengthened with fibers or other additives, is part of NIST's work in the advanced manufacturing and materials measurements area—a broad portfolio of research that includes work to help computer chips continue to shrink while becoming more powerful, to make additive manufacturing a widespread capability, and to accelerate the discovery of new materials through the NIST-led Materials Genome Initiative. Through NIST, the Nation has world-leading measurement capabilities, in both expertise and equipment, that no individual company or sector could amass. The authorities granted to NIST by Congress enable us to respond to the needs of American companies across the manufacturing landscape, working on difficult problems to the benefit of entire sectors.

Why do measurements matter? Measurements give us a common language for the performance of materials and help us have confidence in them, which is particularly important for buildings, bridges, jet engines, and medical devices, and for acceptance of new technologies like wearable electronics and tissue engineering. Since it was established in 1901 by Congress as the National Bureau of Standards, NIST has been developing new ways to measure materials with ever-increasing precision and accuracy, and to characterize novel materials for use in research and commerce. These measurements are critical inputs to the growth of the Nation's economy.

In addition to our programs in the NIST laboratories, we provide members of industry, academia, and other government agencies with access to two unique, powerful user facilities for investigating advanced materials. The first, the NIST Center for Neutron Research, provides unmatched thermal and cold neutron measurement capabilities to U.S. industry and the research community. The second of our user facilities, the NIST Center for Nanoscale Science and Technology, supports the U.S. nanotechnology enterprise from discovery to production by providing access to measurement and fabrication methods and technology. NIST also partners with a Department of Energy user facility, the National Synchrotron Light Source II at Brookhaven National Laboratory, which produces X-rays so bright that researchers

can actually see individual atoms in materials. The National Synchrotron Light Source II contributes to the development of new semiconductors for computers and other applications, batteries and solar and fuel cells, superconducting materials, catalysts for chemical production, and materials that can assemble into complex structures by themselves.

To meet increasingly complex materials challenges in many diverse areas such as safety and security, health care, infrastructure, and other national needs, America needs new materials with special properties. Typically, discovering and proving out a new material is a decades-long process. NIST is a leader in a new approach that makes materials property data accessible and usable so that researchers and manufacturers working in pre-competitive arenas can leverage each other's efforts to propel whole fields forward. The federal multi-agency Materials Genome Initiative is helping industry shave years off the traditional timeline for discovering, developing, and deploying new materials in commercial and clinical products. Applying the "materials genome" approach, researchers use data on the known properties of materials and computer modeling to inform how to combine or process substances to get the performance they need, avoiding time-consuming trial-and-error experiments. NIST supports the Materials Genome Initiative with tools that make materials data more easily publishable and discoverable, and decreases the barriers inherent to sharing large, complex materials science datasets.

NIST and Advanced Composites

NIST has conducted research on advanced composites since the 1980s. Currently, we run more than a dozen projects that use measurement science to investigate the properties of advanced composites for a variety of applications including auto body components, impact- and ballistic-resistant gear for athletes and first responders, dental repair and reconstruction, and flexible electronics and semiconductors. NIST also has active collaborations with the Institute for Advanced Composites Manufacturing Innovation (IACMI), part of the Manufacturing USA network of public-private institutes that advance American manufacturing capabilities through innovation and workforce development. IACMI's goal is to help industry make lower cost advanced composites that require less energy to produce, with better potential for being recycled.

Our research is driven by industry needs, which we learn about through scientific collaborations with market leaders, deep-dive workshops, and road mapping exercises. NIST has helped to generate road maps for the composites industry. The 2017 *U.S. Composites Manufacturing Industry Technical Roadmap*[1] identified challenges for composites manufacturing generally, including advancing material performance and new processing methods and materials. Another 2017 publication, *A Technology Roadmap for Joining and Repair of Advanced Polymer Matrix Composites,*[2] addressed the goal of reducing composite repair cost and cycle time by 50 percent in the aerospace industry, where taking an aircraft out of service can result in a substantial loss of revenue. A future AMTECH-funded road map will address challenges in the use of thermoplastics for automotive and other forms of transportation.

[1] https://www.nist.gov/amo/facilitating-industry-engineering-roadmapping-and-science-fibers-advance-us
[2] http://www.manufacturing.gatech.edu/sites/default/files/uploads/pdf/2017_caiiac_report_web.pdf

Advanced Composites in Infrastructure

NIST's most recent advanced composite road mapping efforts are focused on infrastructure. The American Society of Civil Engineers 2017 Infrastructure Report Card issued a D+ grade to U.S. infrastructure, stating that the U.S. would need to invest $2 trillion to raise our grade over four years, and calling for "new approaches, materials, and technologies to ensure our infrastructure is more resilient."[3]

Advanced composites are often stronger, lighter, and longer lasting than traditional building materials, thereby offering many cost savings. For example, compared to traditional materials, it takes less fuel to transport these lighter components. The equipment required to assemble advanced composite components into bridges or other structures can be lighter, and advanced composites can resist corrosion from weather and exposure to chemicals. The longer lifespans for infrastructure components that include advanced composites mean fewer service days lost to maintenance of the bridges, roads, dams, levees, highways, railroads, utility poles, and other elements that support movement of the goods and services that underpin our economy.

The American advanced composites industry comprises some 500 companies selling to customers worldwide, and contributes about $22 billion to the U.S. economy each year.[4] Although America currently leads the world in advanced composite technology, adoption of these materials has been slower in the United States than in Canada and Europe, where advanced composites have been used in hundreds of bridges. The benefits of advanced composites for both our infrastructure and economy are not being fully realized here in the United States. Knowing that NIST frequently provides a neutral forum where industry members can speak candidly about challenges, the American Composites Manufacturers Association (ACMA) asked us to help convene the community.

Accelerating Adoption of Advanced Composites for Infrastructure

Road Map for Overcoming Barriers

A February 2017 workshop at NIST brought together infrastructure designers, owners, manufacturers and researchers to identify barriers to the use of advanced composites. We learned that builders want materials that save time and minimize costs, but they need to know how long their roads, bridges, and other infrastructure elements will last. Designers and engineers need guidance so they can use composites with confidence, and provide appropriate safety margins while maximizing the weight- and cost-savings attributed to these materials. The workshop resulted in a road map of activities that will encourage wider and faster adoption of advanced composites for infrastructure. The *Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure*, published in December 2017, is available to the public.[5]

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[3] https://www.infrastructurereportcard.org/wp-content/uploads/2016/10/2017-Infrastructure-Report-Card.pdf
[4] https://acmanet.org/composites-industry-overview/
[5] http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

Durability testing and standards: Since the first composite utility poles were installed in the 1960s, the field has rapidly improved materials and processing methods. Some kinds of advanced composites are so new that we don't know how they age in natural conditions over the usual life span of a large structure like a bridge—expected to last more than a century. In the absence of data, designers and engineers concerned with durability and safety might conservatively require use of additional material, but this can needlessly increase both costs and weight of the structure. Uncertainty about the long-term performance of novel materials is a potential obstacle to adoption for use by designers, engineers, builders, and owners.

Workshop participants set a goal of predicting the wear on a structure over 100 years of service through testbeds that can simulate accelerated aging, which will generate data and predictive models, which, in turn, will be the basis for durability standards and design tools available to the whole community through an online portal. A five-year partnership among durability researchers and members of industry will help to ensure these resources are relevant to the rapidly evolving composites field. In addition, data will be needed on the performance of new composite materials when subjected to strong shaking (such as during an earthquake), high winds (during a hurricane, tornado, or severe thunderstorm), or abnormal loads, like accumulations of snow and ice. Such data will be critical to developing safe and resilient communities in a cost-effective manner.

NIST is well-positioned to lead this work: We have decades of expertise in measurement science for advanced composites, particularly in the fundamental and highly interdisciplinary science and engineering work needed to determine durability, fatigue, and resilience. As an example, a unique NIST device for accelerated weathering, known as SPHERE, or Simulated Photodegradation via High Energy Radiant Emission, can generate controlled temperatures, humidity, and ultraviolet exposure for more than 500 samples at a time, and simulate 50 days of sunlight in one day. We also have large-scale structural testing facilities that can evaluate the effects of strong loads on advanced composite infrastructure. At the small end of the scale, a NIST project has developed fluorescent-sensors and test methods for quantifying and visualizing damage in composites.

As a non-regulatory agency, NIST has a long history of partnering with industry to develop voluntary consensus standards. NIST staff members provide leadership and technical expertise through more than 1800 positions on technical committees and work groups organized by ASTM, the International Organization for Standardization, and numerous other standards development organizations.

Design data clearinghouse: Although the U.S. is not yet leading the world in adopting advanced composites, there are successful infrastructure applications that can be shared with the community. A central clearinghouse of curated design guides and data tables from completed projects can help engineers and designers use the materials to their best advantage, and provide confidence in the materials' performance and life span. NIST, in partnership with the ACMA, will hold a workshop on the data clearinghouse in August 2018. The workshop goal is to generate an authoritative source of data and standards, with the ultimate goal of harmonizing standards globally. Uniform global standards will

make it easier for American advanced composites manufacturers, engineers, and designers to compete in foreign markets.

Training and education: The Composites Roadmapping Workshop identified a need for more awareness of and confidence in advanced composites at all levels of the industry, from current designers, engineers, and owners, to students. Information that NIST and other researchers and practitioners generate from testing, standards, and data tables and design guides will inform curricula for industry certification of engineers and designers, and guide creation of apprenticeships for aspiring engineers and designers—who will have the power to specify and design for these materials in the future, increasing their use.

NIST and Community Resilience

The 2017 U.S. hurricane season reminded us that natural hazards take a high toll on communities with impacts that can last long after the event. To address these impacts, NIST manages a multi-faceted Community Resilience Program, a part of our broader disaster resilience work, assisting communities and stakeholders on issues related to the built environment and the interdependencies of physical infrastructure systems.

Resilience planning that includes making optimum choices of construction materials can improve a community's quality of life and economic well-being, as well as its ability to recover faster and better. Advanced materials such as composites may help mitigate the effects of natural and man-made disasters and contribute to more rapid post-disaster rebuilding. Disaster recovery and re-building activities will involve important decisions that weigh the strengths and weaknesses of different material systems, and the multiscale and multidisciplinary materials science research conducted at NIST-gives architects, design engineers, and, ultimately, community leaders the proper information to make these critical decisions.

Research Needs for Resilient Buildings and Infrastructure

NIST will host the road mapping workshop, "Research Needs Concerning Performance of Externally-Bonded Fiber Reinforced Composite Systems in Resilient Buildings and Infrastructure," in May 2018. Over the past decade, advanced composites have been used to reinforce concrete structures, masonry buildings, and bridges so they are more resilient to the demands of everyday use and weather, and to extreme events like earthquakes and hurricanes, but there is a lack of data to inform the choices infrastructure owners make about these relatively new materials and applications. The upcoming workshop will ensure NIST's future research on the reliability of advanced composites is valuable at all levels of industry and meets national needs. Once the performance and health of advanced composite systems have been grounded in measurement science, the resilience of infrastructure elements can be modeled and evaluated.

NIST and Data

A common thread through the many challenges that need to be addressed to expand the use of composites in infrastructure is advanced data and modeling. One of the products of the Materials Genome Initiative, the Materials Data Curation System, is a standardized way for engineers and designers to capture and share data on the properties of materials, including advanced composites. NIST has already begun training ACMA staff members to use the Materials Data Curation System. NIST will continue this work and host another workshop in August.

The materials genome approach has accelerated materials discovery for metals and glass, but has been slower for advanced composites, for which there is less available data. New advanced composite materials are typically made using slow, costly trial-and-error experiments. The Center for Hierarchical Materials Design (ChiMaD), a center of excellence in advanced materials funded by NIST and led by Northwestern University and the University of Chicago, is addressing this gap through Nanomine, a database of polymer nanocomposite properties, and a partnership with SpaceX that focuses on aerospace composites. We envision that these same data-driven approaches will soon be applied to discovery of new advanced composites for infrastructure.

Conclusion

Advanced composites can help us renew and repair the nation's infrastructure with lighter, more durable materials that require less maintenance, ensuring the movement of goods, services, and citizens. NIST is a leader in characterizing the performance and properties of advanced materials, including composites, on all scales, and in making data widely available and useful to the benefit of whole industries. Enabled by NIST programs, design engineers will be able to apply the full range of materials to enable cost-effective and innovative solutions to the Nation's infrastructure challenges with the benefit of knowing the strengths and weaknesses of all available options. NIST's work to accelerate the adoption of advanced composites is part of our broad program, informed by the needs of industry, that helps companies develop and reliably manufacture new products made with advanced materials, making American industries more competitive globally, and enhancing our quality of life.

Thank you for the opportunity to testify today. I am happy to answer any questions you may have.

JOANNIE W. CHIN



Dr. Joannie W. Chin is the Deputy Director of the Engineering Laboratory (EL) at the National Institute of Standards and Technology (NIST), one of seven research laboratories within NIST. As Deputy Director, she provides programmatic and operational guidance for EL, which has an annual budget of $90 million and nearly 500 federal employees and guest researchers from industry, universities, and research institutes. EL's mission is to promote the development and dissemination of advanced manufacturing and construction technologies, guidelines, and services to the U.S. manufacturing and construction industries through activities including measurement science research, performance metrics, tools and methodologies for engineering applications, and critical technical contributions to standards and codes development. EL focuses on high-leverage, high-impact infrastructural measurements and standards efforts to foster U.S. manufacturing and construction industry innovation, productivity, and competitiveness, improve building and fire safety, and reduce the environmental impact of buildings and manufacturing activities. EL is a source of unbiased measurement standards, data, and cutting-edge methods and technologies that promote innovation, market readiness, and quality control in vital economic sectors.

Prior to her appointment as Deputy Director, Dr. Chin previously served as leader of the Polymeric Materials Group in the Materials and Structural Systems Division of EL. She has published more than 100 scientific papers and holds a U.S. patent on a unique device for accelerated weathering of materials. She is a member of the ASTM Board of Directors and the American Chemical Society.

Education

Ph.D. in Materials Engineering Science from Virginia Polytechnic Institute and State University

M.S. in Chemistry from Virginia Polytechnic Institute and State University

B.S. in Polymer Science and Engineering from Case Western Reserve University

Mr. WEBSTER. I recognize Dr. GangaRao for his five minutes.

TESTIMONY OF DR. HOTA V. GANGARAO,
WADSWORTH DISTINGUISHED PROFESSOR,
STATLER COLLEGE OF ENGINEERING,
WEST VIRGINIA UNIVERSITY

Dr. GANGARAO. Honorable Congressmen, Chairman Webster, Members of Research and Technology Committee, I'm immensely grateful for your invitation to speak on my team today, which is the infrastructure renovation through smart composites manufacturing and construction, coupled with testing standards and enforcement.

As all of you know in this room, our aging, perhaps aged infrastructure is rapidly deteriorating, certainly not collapsing. The bulk of our infrastructure problems can be attributed to $1.5 trillion funding gap between the revenue and the infrastructure needs for 2016 to 2025. This is costing $3,400 per year per family and leading to 2.5 million fewer jobs and, even more importantly, $7 trillion loss to businesses.

How to bridge this need versus a revenue gap? The—do we need more debt? Do we need to increase the gas tax? A couple of these will have adverse effects on our economy, as you all know. Today, I want to present an alternative to this august body that is about instead of replacing crumbling infrastructure, as our Congressman Lipinski pointed out, we should provide resources to renovate our infrastructure to get the biggest bang for the buck using advanced composite materials.

Currently, composites account for less than one percent of the structural materials by volume in spite of their many advantages such as the high-strength corrosion resistance, lighter weights, and better performance per unit weight.

What are the challenges ahead and what are the economic advantages? Producers of steel and concrete should not view composites as a competitive product or as a threat to their markets. Composites will never fully replace traditional materials, but they are another tool in a toolbox, and they would be hybridized well with steel and concrete.

Through our National Science Foundation-funded center, the Center for Integration of Composites into Infrastructure, we have shown composite wraps have been used to renovate several deteriorated structures at five to ten percent of the replacement cost by repairing some of the concrete piers, steel piles, and the list goes on.

At West Virginia University, we worked on lighter bridge decks weighing only about 1/4 of a typical concrete deck. We worked on sheet piles with other industry folks to protect hostile erosions using composites. We developed utility poles that cost half the cost of steel transmission towers, and we also are developing high-pressure gas pipes to push more gas at a faster rate. We are involved heavily in navigational structures such as the lock gates, and the list goes on.

Efforts are underway to develop composite modular housing subsystems that are multifunctional, multimodal, mold free, and durable. Using smart manufacturing and construction methods, housing

costs can come down dramatically, as it has been done by Henry Ford's assembly line-type operations.

To be at the cutting edge of research, development, and innovation of composites and infrastructure, NIST workshop—as alluded now a few minutes ago—of 2017 identified five critical areas to be overcome. One of them we can do here is to help the industry develop smart manufacturing and construction tools with composites and also develop uniform codes and project qualification through third-party certification, need to require future projects to consider composites as alternate designs. We need to invest in 3.2 million workers dealing with the designs, contracts, maintenance, and management of composites.

In conclusion, composites are cost-effective and durable. Large-scale applications of composites will create huge markets and open new opportunities, including the smart rehab methods and educating 3.2 million American workers dealing with the construction-related industry. To enhance American productivity of workers, we must invest in the composites in terms of research development and implementation.

Finally, to maintain public safety, investment in infrastructure restoration through composites and hybridization with conventional construction materials have to be made in tandem with standardization of products and quality control.

Thank you very much.

[The prepared statement of Dr. GangaRao follows:]

Statement to the Committee on Science, Space, and Technology
Subcommittee on Research and Technology of the
U.S. House of Representatives
April 18, 2018

Hota GangaRao, PhD, P.E., F. ASCE
Wadsworth Distinguished Professor of CEE, CEMR, WVU
Director, CFC & CICI-NSF
ghota@wvu.edu

Theme: Infrastructure Renovation through Smart Composite Manufacturing Coupled with Stringent Testing Standards and Enforcement.

Overview of the state of US infrastructure and composites role in infrastructure

The American Society of Civil Engineers (ASCE) report card gives the US infrastructure a grade of D+. ASCE attributes the bulk of this low grade to the funding gap of $1.44 trillion between revenue and infrastructure needs for 2016-2025, which in turn costs each household $3,400 per year. As per ASCE reports, failure to invest in US infrastructure leads to losses of $3.9 trillion to U.S. GDP, $7 trillion to businesses and 2.5 million fewer jobs. In terms of roads and bridges, the funding gap exceeds the current funding, and the gap is double the current funding for water/wastewater (ASCE, 2016). Our infrastructure is deteriorating and crumbling, not collapsing. However, deteriorated concrete can fall off bridges causing a risk to pedestrians and drivers, increasing corrosion activity, and leading to unchecked deterioration resulting in load postings or bridge closures.

Fiber Reinforced Polymer (FRP) composites can be economically used to rehabilitate our existing infrastructure at a fraction of the price of replacement. The use of composites has been proven in other markets such as aerospace (Boeing 787), automotive, marine, energy, and recreational products, but composites account for only about 1% of total structural materials by volume (Composites Manufacturing Magazine, 2018). FRP composites have become dominant in select infrastructure applications where light-weight, durability, and non-corrosiveness is required, such as wind energy, underground gasoline tanks, and cooling towers. Based on previous successful demonstration projects, composites are poised to expand into additional infrastructure applications including reinforcing bars for concrete, bridge decks, utility poles, repair of structures, and refurbishment of sewer/storm water pipes.

Composites are moving into these areas due to their biggest advantage over traditional materials: durability. Composites won't corrode or rot like conventional materials, resulting in a longer service life. Infrastructure is commonly built with timber, steel, or steel reinforced concrete, all of which degrade overtime due to natural or man-made conditions. For instance, FRP utility poles installed in the 1960's are still in use, while timber poles may only last 25 years (NIST, 2017). Other advantages of composites include light weight and factory production, resulting in high quality products that can be shipped to a job site enabling ease and quality in construction. Finally, composites can be used to renovate existing infrastructure, resulting in investment savings. I've been pushing for years, including with the House and Commerce Committee last year, our focus should be on renovation -not replacement-, of infrastructure, to realize the biggest bang for the buck.

Challenges or pushback to the composites industry from conventional materials industry

In infrastructure applications, composites are ideally suited as a complement to steel, concrete, and timber, as composites can extend the lifespan or strengthen these in-service infrastructure systems. Conventional materials have a major advantage due to their widespread usage over many years, leading to a wealth of knowledge on their field behavior. Even though the knowledge of composites is accelerating rapidly, problems will arise with new implementations. It is important to recognize that composites have had numerous successes over the years, and the design and engineering methodologies utilized for composites are based on lessons learned, including the lessons from conventional materials. The composite industry sometimes bemoans the stricter requirements placed on their products, but until more comprehensive data exists, these requirements are for the good of the public safety as well as the composites industry stable/steady growth. However, construction industries accustomed to using commodity materials are questioning the sustainability of composite products, environmental effects, recyclability and cost effectiveness. Composites are also at a disadvantaged compared to conventional materials due to their higher initial cost, incomplete standards, lack of durability data, and training and education. All of the above issues are being addressed and even advances are being made; for example, use of coal as a base material to mass-manufacture durable and economical carbon composites is in works at West Virginia University. However, new technologies need dollar support and the industry is seeking congressional help.

Economic advantage of hybridizing composites with conventional construction materials

FRP composites will never fully replace conventional materials for many infrastructure applications, but they should be viewed as another tool in the tool box because of their inherent advantages over traditional materials. For example, FRP composite wraps have been used to rehabilitate corroded bridge piers at as little as 5% of the cost of replacement, with minimal traffic interruptions. FRP bridge decks and sheet piles protecting coastal erosion are being used (albeit sparingly) to repair bridge decks and sea walls respectively with longer service life and lower costs. Efforts are underway to develop composite housing panels and innovative construction modules, leading to durable, mold-free, economical, and modifiable housing units. Similarly, higher volume transmission of natural gas through high pressure resisting composite pipes and economical and durable electrical/communication networks can be realized using composites.

Expanding the use of composites into new markets builds on the strength of U.S. manufacturing. The U.S. produces 31% of the world's carbon fiber, more than any other nation, and is home to 2 of the top 5 leaders in glass fiber production. According to the US Department of Commerce, U.S. composite exports are expected to grow at 4.2% in 2017 and 2018. U.S. produced composites are typically higher grade products (higher strength, lower defects) reflecting the needs of our construction industry. Providing incentives to extend composites into new infrastructure applications will push innovation. To protect our lead in composites from a safety view point, the U.S. should monitor imports and ensure subpar composite products are not being brought here at below market rates. Standards and codes should reflect the high-quality composites being produced here. Smart manufacturing should be supported including maximization of subsystems to be manufactured in U.S. factories to cut on-site costs and also make it more expensive to dump foreign goods of higher weight & volume. Subsystems should be technologically intricate in terms of intelligent communication, energy efficiency, weight per

unit subsystem, ease of maintenance & repair etc. While the U.S. pioneered the research, development and implementation of advanced composites for over 60 years, recent down turns in R&D is allowing the rest of the world to catch up. For example, China has started to invest heavily in composites and many researchers, engineers, and manufacturers are becoming involved in field implementation, which is twice the current U.S. activity.

NIST Feb 2017 workshop on identification of barriers for broader use of advanced composites and standardization needs

On February 8-9, 2017, NIST sponsored a workshop with a goal of determining the barriers to widespread adoption of polymer composites for sustainable infrastructure applications. At the workshop, the key stakeholders including owners, designers, and contractors shared the challenges facing the infrastructure market. Extensive discussions were carried out on the 5 most critical barriers to success pertaining to new construction, repair construction, and stand-alone FRP products. The most common barriers included training and education, codes and standards, and durability. It is my belief that the U.S. government can play a key role in rapidly breaking down these barriers by supporting efforts to designate a group of experts to compile new design codes and evaluate in-service FRP composites, to provide needed data and to develop specifications. The government can:

1) Help industries develop smart manufacturing of composites for infrastructure.
2) Aid in the development of uniform codes, standards, and manufacturer qualification through third party testing and evaluation. Rather than having every state Department of Transportation develop independently, Federal (national) standards would increase the efficiency of the industry and save costs overall by reducing redundant "Standards" development.
3) Initiate stringent enforcement of standards through NIST (similar to AISI QA/QC testing standards).
4) Require future government projects to consider composites as alternative designs, including listing composites as approved materials.
5) Congress can appropriate nation-wide funding for preventative maintenance and repair using FRP composites which would help save many in-service structures instead of replacing them. With a dedicated funding stream for repairs only, DOTs and other infrastructure owners can use FRP composites to repair a structure during early stages of deterioration, i.e. before small cracks become large delaminations.

Education and training needs

Universities are increasingly offering classes on the design of composites, and professional organizations and government agencies occasionally provide continuing education on composites to practicing engineers. However, there is still much work to be done to educate the 3.2 million Americans who construct, design, or manage infrastructure (Brookings, 2014). Additional focus and support is needed in providing: 1) webinars, 2) short courses, 3) conferences, 4) clearing-houses, 5) demo projects and 6) lab and field training. Continuing education of DOT employees, particularly in rural areas, has become more difficult in recent years due to travel limitations prohibiting them from attending events in other states.

Concluding remarks

Composites are increasingly being recognized as cost-effective structural materials of high strength, high stiffness, lighter weight, excellent corrosion resistance, and proven durability. Inroads have been made into selective infrastructure markets thus far and the on-going work has greatly expanded the knowledge base and comfort level of using composites, especially in terms of infrastructure renovation. The potential composite applications in infrastructure will create a huge market, and the advantages of composites will open many new opportunities for owners with a long-term focus in mind. With advances in smart manufacturing, code development, and education, composites usage will expand into more infrastructure projects, growing exponentially and resulting in tremendous economic growth. The United States needs to invest in advanced materials to continue to lead the world in composite research, development, and implementation. While maintaining public safety above all, investments in infrastructure applications utilizing composites have to be made in tandem with standardization of specifications and rigorous enforcement to garner the full economic potential of advanced composite materials and systems in conjunction with conventional construction materials.

Biography

Dr. Hota GangaRao is a Maurice and Jo Ann Wadsworth Distinguished Professor of Civil and Environmental Engineering at West Virginia University and serves as the Director of the Constructed Facilities Center and Director of NSF IUCRC Center for Composites Infrastructure at WVU. Dr. GangaRao's main areas of research include fiber reinforced polymer composite bridge structures, advanced materials research, recycling of thermoplastic composites, composites for blast and fire resistance, and rapid retrofit of infrastructure systems using composites. During his tenure at WVU, Dr GangaRao has advised over 300 PhD and MS students, and has published over 500 papers and conference proceedings relating to his broad range or research programs. He co-authored and published the text book "Reinforced Concrete Design with FRP Composites" with two others, in addition to authoring a dozen of book chapters. Dr. GangaRao has received 12 patents. Dr. Gangarao received his Ph.D. in Civil Engineering at North Carolina State University and is a register Professional Engineer (P.E.). Dr. GangaRao has received numerous awards for his research and professional services. He has been cited as one of the Top Five Outstanding Researchers of the College of Engineering and Mineral Resources at WVU for three decades. He serves as chairman on several committees at WVU and national professional organizations. Dr. GangaRao is the Chairman of PIANC Working Group 191 Composites for Hydraulic Structures, and others including ASTM.

Mr. WEBSTER. Dr. Lange, you're recognized for five minutes.

**TESTIMONY OF DR. DAVID LANGE,
PROFESSOR, DEPARTMENT OF CIVIL
AND ENVIRONMENTAL ENGINEERING,
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN**

Dr. LANGE. Chairman Smith, Ranking Member Lipinski, and other Committee Members, I appreciate this kind introduction an opportunity to share my ideas today.

I wear two hats today, one as Professor of Civil Engineering at the University of Illinois, the second as President of the American Concrete Institute, an organization of 20,000 members from the construction industry, the design profession, and academia.

FRP is a class of high-strength, low-weight, and durable materials that can be fabricated in a wide array of shapes and properties. The attractive aspects of FRP have motivated significant investment in research and many funded demonstration projects over the years.

Despite attractive attributes and a successful track record in field demos, we do not see a widespread adoption of FRP in construction today. Certainly, one explanation is the presence of two dominant design paradigms in commercial construction: reinforced concrete and structural steel. These tried-and-true systems have a 100-year head start on FRP.

Furthermore, concrete and steel technologies are not standing still. Large organizations like the American Concrete Institute work tirelessly to advance these technologies. A century of commitment at ACI assures that today's concrete is not your father's concrete.

The adoption of FRP depends on a wider effort to harmonize material systems. The two dominant silos—concrete and steel—need effective crosstalk and openness to new material such as FRP. It can be done. As an example, ACI has opened a path for use of FRP rebar, and ASTM has released specification language for those bars.

Market penetration of FRP should be driven by authentic advantages: durability, low weight, organic shapes, flexibility, high-strength capacity. Those are among the competitive advantages of FRP.

Indeed, FRP has excelled in certain applications. The aircraft and marine industries and more recently the market for wind turbine blades and cooling towers have embraced FRP. In construction, FRP products have found a place in market niches such as corrosion-proof rebar and as a material for repair of concrete structures.

Despite seemingly high potential for FRP and infrastructure, the topic is almost nonexistent in civil engineering education. Courses dedicated to FRP and structural repair are rare among the 220 civil engineering programs in the United States. Engineering education has not functioned as a change agent.

There are opportunities to affect civil engineering education. Like other professions, civil engineering is moving toward requiring more than a bachelor's degree to practice in the profession. As master's degrees grow, the curriculum can better accommodate spe-

cialty topics like FRP if the need from industry were to drive it. Beyond that, we need courses that harmonize concrete, steel, masonry, wood, and FRP. The future is a world with better integration of material systems.

Now, a few words about the NIST roadmap. I think the roadmap has attractive elements. In particular, I'm drawn to one of the recommendations related to the design data clearinghouse barrier. The idea is to charge NIST as a neutral party to compile durability data and define limits using codes and standards. Indeed, we can see how codes and standards can spur adoption of FRP. The 2017 release of ASTM D7957 for FRP rebar has already had impact on the ability for that product to be specified and designed. Just days ago, an industry representative shared with me his positive outlook that is based on an upswing in FRP bridge deck projects in recent months.

I also endorse the roadmap plan for its emphasis of FRP curriculum for civil engineers. Given the large body of existing research, it is reasonable that federal funding could foster a modernization movement for civil engineering curriculum that bolsters design of FRP and harmonized material systems.

Lastly, I want to encourage use of a proven mechanism available to the Federal Government. That is research centers that incubate partnership between academia and industry. My own experience as Director of the Center for Excellence for Airport Technology has persuaded me that large infrastructure programs can benefit from sustained partnership with universities. Since 2005, CEAT has received funding from the O'Hare International Airport and the Chicago Department of Aviation. Every year, we select our research projects to inform the decision-making process, reduce risks, and save money. Our 12-year track record with O'Hare suggests this has been a successful model. Thank you.

[The prepared statement of Mr. Lange follows:]

House Committee on Science, Space and Technology
Subcommittee on Research and Technology

Hearing: Composite Materials – Strengthening Infrastructure Development

David A. Lange, Ph.D., P.E., F. ACI, F. ACerS
Professor, Department of Civil and Environmental Engineering
Director, Center of Excellence for Airport Technology
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April 18, 2018, 10:00 AM EDT
2318 Rayburn House Office Building
Washington, D.C.

Chairman Comstock, Vice Chairman Marshall, Ranking Member Lipinski and other committee members, I appreciate the invitation to testify before the subcommittee. I am a professor of civil and environmental engineering at the University of Illinois. I serve as director of a 23-year old research center based at the University of Illinois called the Center of Excellence for Airport Technology. I also am the current President of the American Concrete Institute, a global organization based in the U.S. of 20,000 members who participate in over 400 technical and educational committees and sub-committees, and produce the codes, standards, and guides that govern construction of reinforced concrete in the US and around the world.

Today we are here to discuss fiber reinforced polymer (FRP) composite products for infrastructure applications. I understand that this hearing was motivated by a workshop held at NIST in 2017 that generated a roadmap document addressing barriers to adoption.[1]

[1] NIST Special Publication 1218, "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure," December 2017, available at: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

Historical context

FRP composites have been used in structural engineering at some level for 50 years for new construction and repair applications. FRP products have found a place as an alternative to steel reinforcing bars in concrete and in repair, rehabilitation, and retrofitting. FRP products are often used as a strategy to overcome concern about steel corrosion. The attractive properties of FRP have motivated significant investment in research – particularly in the 1980s and 1990s – and have led to many funded demonstration projects. Today, FRP is considered to be a well-understood high-strength, low-weight, and durable material including its use as internal and external reinforcement for concrete. In addition to applications by manual lay up for in-situ strengthening, FRP products are fabricated in factory settings and are manufactured with a high level of quality and consistent performance. Thousands of research studies on FRP have been published. A comprehensive textbook on FRP structural applications lists numerous review papers on developments in the field.[2,3] Design guides for use of FRP bars in reinforced concrete have been developed by ACI Committee 440.[4]

Despite these attractive attributes and a successful track record in field demonstration, we do not see broad and significant adoption of FRP in construction today. The NIST workshop brought together about 60 specialists from NIST, academia and industry to contemplate the barriers that exist in the marketplace and suggest actions that might diminish those barriers.

The construction industry is dominated by venerable design paradigms

Commercial construction of buildings and bridges have generally used either of two dominant design paradigms: reinforced concrete or structural steel. Concrete and steel are traditional material systems that have been proven successful over the years. Sizeable industries have

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[2] Lawrence C. Bank, *Composites for Construction: Structural Design with FRP Materials.* John Wiley & Sons, Inc. ISBN: 978-0-471-68126-7, 2006.

[3] Nanni, A., A. De Luca, H. Jawaheri Zadeh, *"FRP Reinforced Concrete Structures – Theory, Design and Practice,"* CRC Press, April 3, 2014, 400 pp. 978-0-415-77882-4.

[4] Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars, ACI 440.1R-17, American Concrete Institute, Farmington Hills, MI, 2006.

risen to build our nation's infrastructure, and these two competing material systems seem to have thrived in a competitive marketplace. These are old and venerable design paradigms. The first structural steel building specification by the American Institute of Steel Construction (AISC) was published in 1923 and the first reinforced concrete building code by the American Concrete Institute (ACI) was published in 1910. In contrast, the first textbook on design with FRP for civil structural applications was published in 2006.

The dominant design paradigms are not static. Large organizations work tirelessly to refine concrete and steel design provisions. For example, the American Concrete Institute has 20,000 members representing the construction industry, design profession, and academia. Although concrete is an old material, the human capital working on its behalf assures that today's concrete is not your father's concrete. Concrete of today has evolved to a high level of performance, constructability and durability. Design tools today are increasingly able to handle complexity, and it is important that we encourage harmonization of material systems so these two silos – concrete and steel – have effective cross-talk and openness to newer materials such as FRP. Over time – certainly not a short time – the advances have included provision for FRP rebar. ACI Committee 440 "FRP Reinforcement" has developed design guidance and ASTM D7957 "Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement" codifies one of the leading product categories for use of FRP.

All this is to say that the prevailing structural design codes for concrete and steel structures are strong in the marketplace, and represent some level of resistance to FRP products.

The nature of construction industry is conservative

The construction industry is a conservative industry governed by low risk tolerance and "low bid" contracting. It is rightly conservative because life safety responsibilities are paramount, and no engineer is going to release an unproven or risky design. Furthermore, construction contracts are most often awarded in competitive processes that reward low initial cost. Everyone recognizes that low initial cost may not deliver low life cycle cost, but the tools to

analyze life cycle cost are still emerging. This area continues to be a challenge, and until we disband low initial cost as criteria, alternative materials with superior durability and service life will face a barrier to adoption.

Superior durability is not always enough to drive adoption. Owners appreciate durable solutions, but the tools to accurately predict service life are not commonly integrated into specifications. It is difficult to describe the mechanisms that control durability in mathematical models. The prevailing models for service life of concrete rely on transport of chlorides as a factor in initiation of corrosion, but may not consider the many pathways for chloride ingress. Furthermore, superior durability may not be very important to owners in the private sector. Functional obsolescence truncates the service life of buildings as often as poor durability. Even if the building has a long life, the time horizon for ownership and financial investment may be relatively short, leading to a de-valuation of long-term durability.

If decision-makers have low risk tolerance and short time horizons, they will not assert a strong "pull" of the FRP technology into practice.

Adoption should be driven by authentic advantages of FRP

As discussed above, FRP offers well-known advantages of being durable and lightweight. FRP is marketed to compete in a world of traditional rectilinear beams and columns, but FRP is also amenable to take on creative organic shapes. Even with FRP rebar, the expectation is that FRP is adopted as a simple replacement for lengths of straight steel bar. Shell structures are relatively simple to accomplish using FRP material systems – if only architects would require them. While there are demonstrations of such structures, organic flowing shell structural elements are relatively uncommon in commercial buildings and bridges.

FRP products have dominated in certain applications. FRP transformed the aircraft and marine industries in a fairly short time period. Attributes of low weight, complex curvature, and excellence durability worked in the favor of FRP. More recently, FRP has come to dominate the

market for wind turbine blades and cooling towers. All of these examples exploit the advantage FRP offers for creating complex shapes.

The adoption of FRP needs to be based on authentic advantages. Durability, low weight, organic form, flexibility and high strain capacity are among those competitive advantages. Even cost may someday be seen as an advantage if the price of steel rises and maturity of the FRP industry leads to reduced costs.

Engineering education has not functioned as a "change agent"

Established professional disciplines are defined by a canon of technical knowledge that is taught to students entering the profession. The canon evolves slowly, and is perhaps seen as changing in a sluggish response to the more rapid changes in industry. New knowledge arising from research does not necessarily find its way into the canon without strong demonstration of need from industry. Across the 220 civil engineering undergraduate programs in the US, structural steel and reinforced concrete are emphasized because of their common use in industry; even wood and masonry design receive scant attention. In contrast, FRP is rarely covered in the civil engineer's education, especially in a four-year undergraduate program. Students who pursue a masters degree in structures tend to add more coursework on complex steel and concrete behavior. Courses dedicated to FRP and structural repair and rehabilitation are practically nonexistent. This effectively cuts off the opportunity to motivate industry change with new generations. Furthermore, young practitioners are mentored by senior, professionally licensed structural engineers, and so there is little opportunity to challenge the dominant design paradigms. Thus in many ways, engineering education follows rather than leads adoption of innovation In the construction industry, and the educational challenge must be seen as having a professional life-long learning component to impact senior engineers in practice.

Civil engineering education is trending toward recognition of the masters degree as a "first professional degree." Other professions such as medicine, law or accounting require training

beyond the bachelor's degree, and civil engineering – especially structural engineering – is approaching that expectation. In a structures MS program, additional opportunity is available for technical specialization, and it would seem that universities could choose to develop stronger offerings for design of FRP structural systems. I think this would happen if a need from industry were to drive it. Relatively few civil engineering programs have yet developed FRP courses or other courses that harmonize concrete, steel, masonry, and wood. Design of these structural systems are most commonly taught as independent from one another. ACI with its treatment of FRP rebar for reinforcement in concrete and connections between structural steel and reinforced concrete members stands as an exception.

What is role of Federal Government?

The construction industry is conservative, highly valuing safety, low risk, and low cost. These are further entrenched by an industry that is overly influenced by short term factors. In contrast, disruptive innovation can be more attractive when a longer term perspective is taken. We can't expect a highly fractured industry, dominated by small companies, to discount risk, fund research, and develop education initiatives for the long game.

The federal government can help the construction industry adopt a long term perspective. It can ensure a sustained level of research funding that creates new ideas and fosters faculty commitment to FRP curriculum and harmonization of materials in structural systems.

There are other examples of innovative materials that have taken a long time to gain traction in the construction industry. Fiber reinforced concrete (FRC) and self-consolidating concrete (SCC) are two such developments that are trending toward wider adoption. Documents produced by ACI Committee 544 FRC and Committee 237 SCC are strong contributions that provide guidance for practitioners to use these newer materials.

The NIST roadmap (Figure 1) has attractive elements. In particular, I am drawn to one of the recommendations related to the "Design Data Clearinghouse" barrier. The idea expressed in

the report was to charge NIST as a neutral party to compile durability data and define limits using codes and standards. The report remarked that academia could be used to develop measurement methods and models. As an example of how codes and standards can spur adoption, the 2017 release of ASTM D7957 for FRP rebar has already had impact on the ability for that product to be specified and designed. An industry representative shared with me a positive outlook, and suggested that there has been an upswing in bridge deck projects in recent months.

A second element of Figure 1 that I endorse is the barrier entitled "Education and Training" and the need to develop curriculum. Given the large body of existing research, it is reasonable that federal funding might target that gap as a way to encourage civil engineering programs to bolster their MS course offerings in design of FRP or "harmonized materials systems."

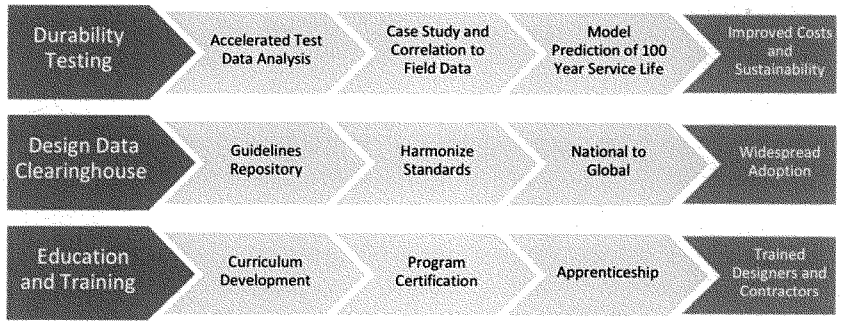


Figure 1. Preliminary Roadmap designed during the NIST workshop in 2017. This roadmap captures the nine basic efforts (center-section) that need to be completed to overcome the top three barriers (left-side) and achieve the three critical outcomes (right-side). [From [1], 2017]

Another proven mechanism available to the federal government is funding research centers that encourage effective partnerships between academia and industry. My own experience with CEAT has persuaded me that large infrastructure programs can benefit from partnerships with universities. Since 2005, CEAT has been funded by O'Hare International Airport and the Chicago Department of Aviation. Every year, we engage with O'Hare engineers to identify their most pressing questions related to the now-completed $8.0B O'Hare Modernization Program

and the just-announced new $8.5B makeover program. We select our research projects to "inform the decision making process," reduce risks, and save money. A university research center – similar to DOT University Transportation Centers (UTC) or Engineering Research Centers (ERC) can be designed to promote FRP adoption through strong partnerships with longer term infrastructure programs.

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David A. Lange is Professor of Civil Engineering at the University of Illinois at Urbana-Champaign. His research area is concrete materials, microstructure-property relationships, airport pavements, concrete rail crosstie durability, foamed cement materials, and recycled concrete. He serves as Director of the Center of Excellence for Airport Technology, a research center sponsored by the O'Hare Modernization Program and the Federal Aviation Administration. Lange has published over 100 technical papers and reports, including over 90 refereed journal papers. He is a Fellow of the American Ceramic Society. He is also a Fellow of the American Concrete Institute and winner of its Wason Medal in 2003 and 2018. He serves as President of ACI, member of the ACI Board of Direction, past chair of the ACI Technical Activities Committee, and has served ACI in many other roles.

Education

Ph.D., Civil Engineering, Northwestern University, 1991
M.B.A., Wichita State University, 1984
B.S., Civil Engineering, Valparaiso University, 1981

Professional Experience

2005-present	Professor, Department of Civil and Environmental Engineering, UIUC
2004-present	Director, Center of Excellence for Airport Technology
2004-2010	Associate Head, Department of Civil and Environmental Engineering, UIUC
1999-2005	Associate Professor, University of Illinois at Urbana–Champaign
2003-2004	Associate Director of the NSF Center for Advanced Cement-Based Materials
1993-1999	Assistant Professor, University of Illinois at Urbana–Champaign
1992-1993	Visiting Assistant Professor, University of Illinois at Urbana–Champaign
1987-1992	Graduate researcher, Northwestern University, Evanston, IL
1981-1987	Engineer, Boeing Military Airplane Co., Wichita, Kansas

Professional Licensure

Professional Engineer, State of Illinois, License # 062-049600

Selected honors

American Concrete Institute, Wason Medal for Most Meritorious Paper, 2018
Distinguished Professor, University of Jinan, China, 2017
J. William Fulbright Scholar Award, 2013
College of Engineering Teaching Excellence Award, 2013
Stanley Pierce Award for faculty-student relations, 2011
Chi Epsilon, Honorary Member, 2010
UIUC iFoundry Fellow, 2008
ASCE Glen L. Martin Best Paper Award with co-authors J. Evans, D. Lynch, 2008
American Ceramic Society Fellow, 2005
Xerox Award for Faculty Research, 2004
American Concrete Institute, Wason Medal for Most Meritorious Paper, 2003
American Concrete Institute Fellow, 2002
Narbey Khachaturian Faculty Scholar, 1998
NSF Career Award, 1996

Ten Recent Journal Publications

1. J. Xiao, C. Sun, D.A. Lange, "Effect of joint interface conditions on shear transfer behavior of recycled aggregate concrete," Construction and Building Materials 105 pp 343355, 2016.
2. Y Qian, H. Wolf, J.R. Edwards, M. Dersch, D.A. Lange, "Temperature-Induced Curl of Prestressed Concrete Monoblock Railroad Crossties," Construction and Building Materials, Construction and Building Materials, 115, pp 319326, 2016.
3. I. You, J. Choi, G. Zi, D.A. Lange, "Pozzolanic reaction of waste glass sludge incorporating precipitation additives," Computers and Concrete, Vol. 17, No. 2, (DOI: 10.12989.cac.2016.17.2.000), 2016.
4. N.J. Gardner; Keller, L.; Khayat, K.H.; Lange, D.A.; and Ahmed R. Omran, Field Measurements of SCC Lateral PressureToronto 2014, Concrete International, Vol 38, No. 6. Pp 42-50, 2016.
5. S. Zhao, E. Van Dam, D.A. Lange, W. Sun, "Abrasion resistance and nano-scratch behavior of an ultra-high performance concrete," ASCE J. Mat. Civil Eng.,[DOI: 10.1061/(ASCE)MT.1943-5533.0001744] 29(2): 04016212, 2017.
6. Y. Song, R. Zou, D. Castaneda, K.A. Riding, and D.A. Lange, "Advances in Measuring Air-Void Parameters in Hardened Concrete Using a Flatbed Scanner," ASTM J. Testing and Evaluation, Vol. 45, No. 5, 2017, pp. 17131725, http://dx.doi.org/10.1520/JTE20150424. ISSN 0090-3973.
7. J. Kim, G. Zi, D.A. Lange, "Measurement of Water Absorption of Very Fine Particles using Electrical Resistivity," ACI Mat. J., DOI: 10.14359/51700994, Vol 114, 6, 2017.
8. A. Shurpali, J.R. Edwards, R. Kernes, D.A. Lange, C. Barkan, "Improving the Abrasion Resistance of Concrete to Mitigate Concrete Crosstie Rail Seat Deterioration (RSD)," J. Materials Performance and Characterization (ASTM), doi:10.1520/MPC20170051, Vol. 6, No. 1, 2017.
9. C. Sun, D.A. Lange, J. Xiao, and T. Ding, "Contact behavior between cracked surfaces of recycled aggregate concrete," J. Construction and Building Materials, accepted 2017. (CONBUILDMAT-D-17-01764R1)
10. D. Casteneda, K. Riding, D.A. Lange, "Measurement and Validation of Freezing Internal Temperature of Concrete Crossties at the Rail Seat," J. Mat. Civil Eng. (ASCE), accepted 2017.

Chairman SMITH. [Presiding] Thank you, Dr. Lange. And Mr. Weyant?

TESTIMONY OF MR. SHANE E. WEYANT,
PRESIDENT AND CEO,
CREATIVE PULTRUSIONS, INC.

Mr. WEYANT. Good morning. Chairman Smith, Ranking Member Lipinski, and the Members of the Subcommittee, on the behalf of Creative Pultrusions and my fellow members of the American Composite Manufacturers Association, I appreciate the opportunity today to testify before you on an issue that is vital to our industry involving the essential role NIST plays in materials standards. I am happy to be here to explain the value that composites offer consumers, communities, and industries across the nation. With manufacturers in each of your districts, we're a great example of made-in-America manufacturing, whose potential has only begun to be realized.

Composites are stronger than other materials such as steel, concrete, and wood. They are lighter and more energy-efficient and easier to transfer and install. They offer greater durability and, most importantly, are resistant to corrosion and structural degradation. Many of you are already familiar with fiberglass boats. Saltwater destroys traditional metal and wood hulls, but fiberglass remains unscathed after decades of service and has come to dominate that sector due to the performance.

Using the same material system, we and other composite manufacturers provide infrastructural solutions with performance and other benefits that can far exceed traditional materials of construction. Let me highlight a few examples: composite bridges that can be manufactured offsite, installed in less than one day with less traffic disruption, and that require minimal maintenance throughout their service life; composite rebar that can replace steel rebar in traditional concrete construction and is resistant to rust so it won't degrade; composite utility poles and cross arms that are easier to install are more durable against extreme weather and fire, require less maintenance, and last significantly longer. Only eight utility poles were left standing in the Virgin Islands this past year after the hurricanes. Those eight poles were composite poles.

Despite these benefits, barriers to deployment of composites remain. Fortunately, some of these obstacles can be cleared with the help of sensible government and industrial participation. A great first step was the 2017 workshop that brought folks from NIST together with a wide range of private and public stakeholders to work towards solutions. I felt the workshop was a great example of positive engagement between industry, academia, and government because it produced actionable results.

What we know from experience is that the lack of awareness of—and, importantly, standards for—composites is our threshold problem. NIST can aggregate existing standards and design data for composites and validate them for broader dissemination and use. This will help all stakeholders to see the totality of data on composites and understand the further research needed. Their world-class laboratories also can help develop durability and performance testing for composite infrastructure products. This data can support

further development of standards of composites and better arm engineers with the performance knowledge to make them more comfortable with using composite.

Given NIST's role in standards in research, the agency has a unique capacity to assemble a broad swath of stakeholders and ensure that this work is impactful. We believe all materials, techniques, and designs should stand on their own merit. Our experience with builders and project engineers show that there is a limited knowledge about composites as a structural material throughout the design community. Additional research and data that can contribute to standards development will help raise the knowledge about composites.

Likewise, bringing together the various agencies responsible for infrastructure investment to participate in this effort can help diffuse knowledge to the asset owners and designers. An existing example of similar collaboration is what is going on with the Institute for Advanced Composite Manufacturing and Innovation. Part of the Manufacturing USA network, IACMI, working with academia and industry and federal agencies, has developed an exciting new technology to recycle composites. Productive collaboration demonstrates that federal investment in composites pays huge dividends and, coupled with further structural research by NIST we discovered today, will help composites contribute more to the overall sustainability of our infrastructure network.

The demands placed on America's infrastructure have never been greater. To build a network to support the 21st century population and economy, there needs to be greater availability of 21st century technologies. With some smart investment and hard work together, we can make bridge, water systems, and grid failures something of the past. The ability to build structures that last centuries instead of years is here. We look to Congress for support to help make this happen. Thank you.

[The prepared statement of Mr. Weyant follows:]

Statement of Shane E. Weyant

President and CEO of Creative Pultrusions, Inc.
(on behalf of the American Composites Manufacturers Association)

Before the Subcommittee on Research and Technology

"Composite Materials – Strengthening Infrastructure Investment"

April 18, 2018

Washington, DC





Chairwoman Comstock, Ranking Member Lipinski and members of the Subcommittee on Research and Technology, thank you for the opportunity to testify before you.

My name is Shane Weyant, and I am the President and Chief Executive Officer of Creative Pultrusions in Alum Bank, PA. On behalf of our company and my fellow members of the American Composites Manufacturers Association (ACMA), I appreciate the opportunity to testify before you today.

Creative Pultrusions is one of over 3000 manufacturers of fiber reinforced polymer (FRP) composites in the United States. We have been in business for over 45 years and have seen numerous changes to the industry over the years. One example of composites that many of you are familiar with is found in recreational boating. Salt water destroys traditional metal and wood hulls for boats, but fiberglass remains unscathed after decades of high salinity contact and has come to dominate that sector due to its superb performance. The same material system can be applied for use in numerous other applications where its attributes will benefit consumers and communities through improved performance and lifecycle cost benefits. This capability has been recognized lately by the National Institute of Standards and Technology, which brings us together for this hearing. I participated in their 2017 composites workshop and, as described in more detail later, found it to have tremendous value for the industry, government and hopefully ultimately for the American taxpayer.

Composites are combinations of fiber reinforcements, most commonly glass or carbon among many other materials, and tough engineered polymers. The resulting material combination is

stronger than the constituent materials individually. Composites are formulated to provide characteristics specifically tailored for maximum performance in a host of different applications.

Key Structural Characteristics of Composites

Durable

Why invest in infrastructure that will start decaying the minute it is placed in service? Composite structures typically last twice as long as steel and wood equivalents and require little maintenance. For example, as Congress wrestles with the aftermath of Hurricanes Irma, Maria, and other natural disasters, it is worth noting that most of the first composite utility poles installed in the 1960's are still in service, as compared to wood poles which are frequently destroyed in such storms.

Strong

Per pound, composites are stronger than other materials such as steel, concrete and wood. The two primary components of composites – fibers and resins – contribute to their strength. Fibers carry the load, while resins distribute the weight throughout the composite part as required.

Lightweight

Composites are light in weight compared to most woods and metals. Lighter leads to lower construction costs and fewer installation delays. From utility poles to rebar to bridge decks, composites simplify and speed installation. Lighter components also require less additional supporting materials, further reducing costs.

Resilient

Composites resist damage from weather and harsh chemicals that can eat away at other

materials. They will never rust or rot, making them a good choice for applications that face constant exposure to salt water, toxic chemicals, temperature fluctuations and other severe conditions.

Flexible

A wide range of material combinations can be used in composites, which allows for design flexibility. The materials can be custom tailored to fit unique specifications of each application. Composites can also be easily molded into complicated shapes.

Environmentally Friendly

Composite structures require significantly lower amounts of energy to be produced than traditional construction materials such as steel, aluminum and concrete. In addition, the resulting structure is chemically inert and will not degrade or leach harmful substances into the environment.

Capabilities for Electricity Infrastructure

Events of the last year illustrate the fragility of the electric grid. Demand for power is higher than ever before, while environmental conditions and natural disasters place even higher stress on the system. Electric grid systems that rely on FRP composite utility poles and cross arms find superior performance on every front—durability, strength, flexibility, service life and resistance to natural weather threats. Maintenance-free composites can revitalize and harden the electric grid, making it more reliable and resilient in the face of the types of storms I mentioned earlier thus, reducing outages, and enabling faster service restoration after storms and other natural events.

FRP composite poles are the best choice in environmentally sensitive areas such as coastal areas, wetlands and bogs, because they will not leach toxic preservatives into the environment. Composites are also resistant to rot, termite and ant damage as well as destruction from other pests. In areas prone to wild fires, wood utility poles burn to the ground but the composite poles resist fire and their structural integrity remains intact. An additional key attribute is non-conductivity. This non-conductivity is particularly important when comparing FRP poles to other utility pole materials--wood is potentially conductive, especially when wet; steel is conductive; and concrete is conductive because of its steel reinforcement. The low conductivity of FRP makes them safer for linesmen, especially when speed is essential to restore grid operations.

FRP composite cross arms are another key application. They do not need to be replaced as frequently as wood cross arms, which are more prone to deterioration and mechanical damage. Linemen also have an easier job replacing lighter FRP composite cross arms. Wood cross arms are heavier and may be unwieldy, especially if the lineman is working at the top of a pole. As a result, repairs to wood poles and cross arms may create a workplace hazard risk that is mitigated with lighter and safer composites.

For proof of the potential composites bring to hardening the electric grid, one only needs to look to the Virgin Islands. Hurricanes Irma and Maria brought down all but eight utility poles in the territory – all eight of which were composites. Where all other materials failed, composites were left standing.

Capabilities for Surface Transportation Infrastructure

As the American Society of Civil Engineers notes in their Infrastructure Report Card (www.infrastructurereportcard.com), the state of roads and bridges around the country is woefully inadequate. Traditional materials used to build, repair and maintain our infrastructure are failing to provide the long-term performance and reduced maintenance costs needed to support a 21st century population and economy.

Creative Pultrusions has installed numerous bridge decks and bridge reinforcement components over the last few decades, as have a multitude of other composite manufacturers. Composites bring the advantage of extended service life and superior performance through inherent resistance to corrosion and structural degradation. When traditional materials such as steel reinforced concrete crumble and spall, composites remain undamaged. Composite rebar used to reinforce concrete bridge superstructures is another key application in this market. Composite rebar is cost competitive with standard epoxy coated steel rebar, with the added advantage of complete corrosion resistance. When concrete bridges are seen in crumbling disrepair it is generally due to corrosion of the underlying steel reinforcements that cause the bars to expand and the concrete to crack. Composites avoid this problem and add decades of service life to critical infrastructure.

An additional benefit for composites in the bridge market is the speed of production and installation. Traditionally, bridges take several weeks, and even months, to build onsite. With prefabricated composites, the same bridge can be fabricated offsite and installed in less than a

day, often in just a few hours. This reduction of construction time results in reduced disruption of traffic and commerce that can be critical, especially in rural and remote areas.

Canada has made far greater strides than the United States in deploying composite highway solutions. With harsh winters requiring a lot of salt treatment for roads, a non-corroding solution was needed. Thanks to successful collaboration between the University of Sherbrooke, composites manufacturers, and provincial and federal authorities, composites are now widely used in Canadian bridges and have dramatically reduced the maintenance costs associated with road treatment. This is a partnership that the U.S. should mimic in that it reduces costs of installment, reduces disruptions for drivers, and lowers the lifecycle costs associated with infrastructure.

Capabilities for Water Treatment Systems and Distribution

The recent events in Flint and other locales illustrate a major problem with respect to our water infrastructure. Even in the United States, the delivery of clean drinking water remains a significant problem for federal, state and local agencies. Water and wastewater treatment facilities and water delivery networks in many municipalities are in need of a complete overhaul. Even in systems that are better than others, maintenance costs continue to climb as conventional materials like steel and wood fail to perform adequately in an environment predominated by highly corrosive chemicals.

Composite technologies have the capacity to revolutionize water systems around the country because of their corrosion resistant properties. While composites have been used successfully in

water and waste water applications for decades, they remain under-deployed as many authorities continue to replace aging infrastructure with outdated, and often inferior, technologies. Pultruded grating, baffles, and panel systems fully withstand any degradation from corrosive chemicals. Because of their properties, composite pipes are also used in desalination plants, particularly in drought prone areas.

In addition, a unique process called Cured In-Place Pipe allows for a new composite pipe to be produced onsite within the walls of the failing pipe structure. This system is a transformative change from traditional methods of water distribution rehabilitation, as it can create several hundred feet of new pipe from a single small opening and eliminates the need to tear up roads and curtail traffic and commerce.

Capabilities for Maritime Infrastructure

Because of their anticorrosion properties, composites provide superior performance in wet and high salinity environments. Creative Pultrusions offers a variety of solutions in this sector, as do many other composites manufacturers. Our SuperLoc sheet piling system is one example, designed to rehabilitate deteriorated waterfront structures subjected to harsh marine environments. Advanced ultraviolet additives protect coastal reinforcements from sunlight and heat degradation and are coupled with composites' proven ability to withstand corrosion and structural degradation in fresh and salt water environments. These properties allow for extended service life along with reduced maintenance costs.

Our pipe piling system brings the same property advantages to docks and piers with fender and bearing piles. Unlike wood structures, they are inert to degradation from salt, wood borer, fungi or microbial attack. In addition, they require no external chemical treatment that could ultimately leach and pollute adjacent water sources. A similar product, our fender pile system, was used to rehabilitate the service dock at the Statue of Liberty in the wake of Superstorm Sandy.

Standards and the Opportunity for the Federal Government to Lead

Despite the performance benefits of composites for a host of infrastructure and heavy construction applications, among many other markets, there remain sizeable commercial barriers to realizing the full benefit and utilization of composites. On the one hand, composites are newer than traditional metal and wood products, so it is understandable that market share is comparatively lower. Even still, there are obstacles that can be cleared with the help of sensible government/industry partnership.

Among the most important is the development of standards for composites in infrastructure projects. Our industry has worked hard over the past many years to develop standards that will arm civil engineers, builders, and others with the necessary standards data to help inform them as they make their choice in material. There are a few large companies manufacturing composites, but in general the industry is predominated by small and medium sized companies like mine that do not have the same resources that more entrenched industries have to educate the full breadth of the end-user community. The robust litany of standards and data for traditional materials comes from many decades of work and includes significant investment by the federal government along the way. Much of the fundamental research in traditional materials was

performed and memorialized by the Federal Government and a similar commitment is needed for composites. With the advent of standards driven construction, the need for sanctioned standards is critical as the current public administration environment does not lend itself to rapid adoption of cutting edge civil infrastructure technologies that lack such approved standards.

The federal government can provide a spark to help close the standards gap and has much to gain by investing in this work. Composites can significantly lower the costs and, most importantly, increase the performance of federally funded constructed assets. By being forward looking, we can better leverage scarce taxpayer dollars by lowering the costs of construction and maintenance of the national infrastructure network.

The first step is supporting standards development and the research capabilities of the National Institute of Standards and Technology in this area. I was one of many industry representatives that participated in the NIST composites workshop in 2017. I found this to be an incredibly useful event, and a shining example of positive engagement between industry, academia, and government. The report[1] from this event and the agency's testimony in this hearing lay out the technical challenges to broader composites adoption and the capabilities of NIST to overcome these barriers. I and my fellow members of ACMA strongly support the creation of a program along these lines. Specifically, NIST has a unique ability to aggregate existing standards and design data for composites and validate them broader dissemination and use. In addition, their world class laboratories can lead the way in the development of durability and performance

[1] NIST Special Publication 1218, "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure," December 2017, available at: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

testing for composite infrastructure products. In so doing, this data can support further development of standards for composites in construction. Finally, given NIST's role in standards and research, the agency has a unique convening and knowledge dissemination capacity to assemble stakeholders from industry, academia, and federal and state agencies that, coupled with world class research laboratories, will help ensure that this work is impactful.

Justifying the Investment

NIST can best describe the comprehensive elements of an effective research program. I can say enthusiastically though that this work is necessary and. Our experience with builders and project engineers shows that there is a low diffusion of knowledge about composites as a structural material throughout the design community. Composites are not widely taught in civil engineering courses at universities, and certainly not at high schools and earlier. Once engineers and builders understand the capabilities of composites for structural applications and have used composites in an application, they often become sold on the products and specify them more frequently. Additional research and data that can contribute to standards development will help raise the knowledgebase about composites. Likewise, bringing together the various agencies responsible for infrastructure investment to participate in this effort can help diffuse knowledge to the asset owners and designers.

Engineering work by municipalities, for example, often occurs in silos. For example, successful application of composites in a water treatment system does not automatically mean that the positive outcome will be shared with or understood by the local bridge department. This is not to say that one successful installation should automatically merit wholesale adoption across all asset

sectors by the jurisdiction, but it should necessitate positive knowledge share. Unfortunately, that does not regularly occur.

NIST and the federal agencies responsible for infrastructure spending and construction have an important ability to help raise awareness. Through their direct involvement with asset owners, the federal government can provide knowledge about innovative technologies to facilitate greater consideration of their use when appropriate. To be clear, we do not suggest that it should be within the federal purview to mandate the use of specific materials. We believe all materials, techniques, and designs should stand on their own merit. What we know from experience, however, is that the lack of awareness of and standards for composites means we are underutilized.

Maximizing the Value of Other Federal Investments

It is important to note that successful federal investment in the composites industry comes with precedent. Composites were used in over 150 bridges built under the Innovative Bridge Research and Construction program, a former program of the Federal Highway Administration. The Transportation Research Board is currently conducting a study of the performance of bridges built under that program, with the report due to Congress later this year. This report will serve as an important data set to show how well the technologies work. We are confident that an authoritative study will help demonstrate the readiness of these technologies for broader adoption. A retrospective review of the performance of the composite and several other technologies used in this program also helps assure that less than satisfactory methods are not repeated and lessons learns can be applied to future research. This study will help NIST and

other agencies understand where best to apply resources with respect to research and engagement.

Another federal investment that has proven tremendously successful is the Institute for Advanced Composites Manufacturing and Innovation. IACMI is a part of the Manufacturing USA network managed by the Department of Commerce and pools resources from the Department of Energy, industry, academia and state partners to tackle precompetitive issues to enable adoption of key composite solutions that further the national interest.

Among IACMI's many breakthroughs are composite recycling and reuse. The chemistry of thermoset composites coupled with a lack of previously dedicated research in this area made recycling a critical barrier to broader use of composites. With leadership from ACMA and IACMI and diligent efforts by companies across the composites and recycling industries, an exciting new thermolyzer technology can successfully recycle composites. The success will be further illustrated by a forthcoming major investment in this technology by CHZ Technologies and the construction of a new recycling facility, an investment of more than $70 million creating over a hundred new permanent jobs. This is the first major commercialization of technology developed through IACMI and one of the most successful projects from the Manufacturing USA program to date.

This advancement is worth noting for two reasons – it shows that federal investment in composites pays tremendous dividends and coupled with further structural research by NIST as

described in their report, it will help composites contribute more to the overall sustainability of our infrastructure network.

Conclusion

At a time when Congress is being challenged to support American manufacturing, to rebuild aging infrastructure, and to manage scarce taxpayer funds with more vigilance, I am pleased to cite the benefits of the domestic composite industry. We are not seeking a handout, a mandate, nor favorable treatment. What we know is that we simply need the same kinds of standards and information that many other materials have had created to be made available. To be sure, composites are better understood and more widely used now than ever before. The industry has a track record of successful case studies and innovation. But if we are to truly accelerate the use of composites and garner the benefits from their use, now is the time to support this technology and integrate composites broadly into the decision-making ecosystem.

The demands placed on America's infrastructure have never been greater. To build a network to support a 21st Century population and economy, there needs to be greater availability of 21st Century technologies. Composites will not replace traditional materials overnight, nor should they, but they are a high value tool to add to the toolbox. For a relatively small investment, important research on composite infrastructure technologies can pave the way for the development of more standards and the diffusion of knowledge to stakeholders. This is the first of many steps down the road. Federal and state governments need to modernize their overall approach to infrastructure investment and recognize that greater upfront spending for innovative solutions is worth doing when the reduction of maintenance costs and extension of service life

leads to an exponentially increased return value. Composites can be used successfully in tandem with traditional materials like concrete and metals, given even greater flexibility to engineers to deliver superior performance.

With some smart investment and hard work, we can make bridge, water system and grid failures something for the history books. The ability to build structures that last centuries instead of years is here, we look to Congress to help make it happen.

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EDUCATION

Bachelor of Science, Economics
Frostburg State University, Frostburg, Maryland

- Graduated with Magna Cum Laude Honors
- Outstanding Economics Student 1988-1989 Academic Year
- Two-Year Starting Quarterback on Football Team (1987 & 1988 Season); Team Captain 1988 Season

WORK EXPERIENCE

Creative Pultrusions, Inc., Alum Bank, Pennsylvania — June 1989 - Present
Chief Executive Officer/President (September 2008 – Present)

- Responsible for overall operations of all corporate functions

Chief Operating Officer (March 2004 - August 2008)

- Responsible for operations of all corporate functions.
- Supervise Engineering, Finance, Manufacturing, Marketing, Sales and Technology departments

Corporate Sales & Marketing Director (October 1999 – February 2004)

- Responsible for and supervise the Sales and Marketing departments

Corporate Sales & Marketing Director (February 1997 – September 1999)

- Responsible for and supervise the Sales department

Regional Sales Manager (June 1989 – January 1997)

- Increase sales within the sales regions of responsibility in accordance per the policies and goals

OTHER EMPLOYMENT

CPK Manufacturing LLC., Wilmington, DE — March 2017 – Present
Chairman / President (March 2017 – Present)

- Responsible for overall operations of all corporate functions of Kenway Composites and Tower Tech

Composite Cooling Solutions, L.P., Fort Worth, Texas — 2004 – Present
General Partner

- Responsible for overall direction and governance functions to give overall strategy to manage the group

PROFESSIONAL & COMMUNITY ASSOCIATIONS

- American Composites Manufacturing Association (ACMA)
  Member, Fiberglass Grating Council
  Member, Pultrusion Industry Council
- Cooling Technology Institute
- Chestnut Ridge Ball League
  2000 – Present (President 2006 & 2007; Vice President 2003 – 2005)
- Chestnut Ridge School Board
- 2004 – 2014 (Vice President 2006 & 2007)
- Various memberships in Masonic and Youth Organizations within the community

PUBLICATIONS & HEARINGS

- *Installed and Life Cycle Costs are Composites' Advantage Over Steel,* International Composites Expo 1998, Nashville, Tennessee, January 1998, John P. Drury, Norwegian Applied Technology ASA.; Shane E. Weyant, Creative Pultrusions, Inc.
- *The Effect of Environmental Exposure on the Behavior of Pultruded Mechanical Connections,* International Composites Expo 1997, Nashville, Tennessee, January 1997, Robert L. Yuan, Ph.D., P.E., University of Texas at Arlington; Shane E. Weyant, Creative Pultrusions, Inc.
- *"Disrupter Series: Advanced Materials and Production"*, Testify Hearing with Subcommittee on Digital Commerce and Consumer Protection, March 15, 2017 at 2322 Rayburn House Office Building, Washington DC.

PATENTS

- Wale and Retaining Wall System US 7,311,470 B^1 - Issued December 25, 2007.
- Tower/Frame Structure & Components for Same US 7,275,734 B2 - Issued October 2, 2007.

Mr. HULTGREN. [Presiding] Thank you all so much. I appreciate your testimony. I appreciate you being here.

I'm going to wait with my questions and recognize the gentleman from Indiana first for five minutes.

Mr. BANKS. Thank you, Mr. Chairman. And thanks to each of you for being here this morning.

We all recognize the need to improve our nation's infrastructure, but we also recognize the precarious fiscal situation that we find ourselves in today. The CBO estimates that we are on track to run $2 trillion annual deficits by 2028. The CBO also found that we will run $82 trillion in total deficits over the next 30 years. We need to focus on reducing government spending wherever we can.

So from what I understand, the main benefit to using composite materials as opposed to steel or concrete is the reduction in maintenance costs over the long term. So my first question for each of you, is there any data on what kind of cost savings can be expected over a 20 or 30 years by using composite materials for various infrastructure projects? Dr. Chin?

Dr. CHIN. My colleagues from the industry would have more specific figures on the actual cost savings, but we're very much aware of studies and existing installations that have demonstrated great reductions in installation costs, impact on the economy in regards to road blockages and delays, as well as maintenance and repair, as well as replacements over the lifetime of the structure.

Mr. BANKS. Okay.

Dr. GANGARAO. Thank you. As I stated in my testimony, we have rehabilitated over 100 structures across the country from West Virginia University's Constructed Facilities Center. I'll give you two examples and I'll shut up. One of them is the East Lyn Viaduct. We rehabilitated it for about 20 percent of the cost of replacement in Parkersburg, West Virginia. When I took that job, they said if it survives five years, back in 1999, they said they would be happy. Last year, we collected the data, and it looks brand new.

The second example I'd like to quote, which I have done the rehabilitation renovation part, was for Army Corps of Engineers. Again, we were able to rehab that complex bridge system with $120,000 while in fact it would have costed $4 million to replace it. So the list goes on. I'm not going to stand here and talk about it anymore. But I would be very happy to supply you with all the cost data and also the durability data if you need.

Mr. BANKS. Okay.

Dr. LANGE. Your remarked that the main benefit of FRP is reducing maintenance costs. I think there's truth in that because FRP is a very effective repair material. We're seeing FRP used in sheet products that are put onto reinforced concrete structures. It's one of the least-expensive ways to add strengthening in many cases.

But I'm not sure I would say it's the main benefit of FRP. I think having a landscape for design—multiple materials being used, a real portfolio of materials—is where we could get even more benefit in the future. I think there's been some limitation to have civil engineering organized in silos where you have the reinforced concrete community, the structural steel community working somewhat

independently and FRP wondering how do we fit into this situation.

And I think there's probably a higher calling to try to figure out how to give all materials sort of equal access. In some respects engineers should be material agnostic. I don't really care what particular material is used, I want to get a result. And having more materials available will be the best benefit of having FRP in the game.

Mr. BANKS. Okay. And, Mr. Weyant, before you answer that question, perhaps with the time left as well you can answer the question of what would the cost-benefits of replacing or restoring electric lines with FRP composite poles be?

Mr. WEYANT. On the electric line, it's more in the reliability, how they withstand a lot of the storms. We see that a lot with a lot of the electric companies. They're understanding that value now by investing in composites for that reliability.

As far as the lifecycle, I look at it a couple ways, not only on the maintenance side, it's also the installation side. We have seen cooling towers, marine markets with sheet piling, and also in the utility industry that we have seen probably 30 percent overall lifecycle cost savings when using composites.

Mr. BANKS. Thank you. My time is expired.

Mr. HULTGREN. The gentleman from Indiana yields back.

I recognize the gentleman from Illinois, the Ranking Member, Mr. Lipinski for five minutes.

Mr. LIPINSKI. Thank you. I wanted to say, first of all, that as Mr. Banks was talking about the savings for government and for taxpayers, which I think is critically important, the other part that I wanted to ask about is the—what can we do as policymakers here in Washington to make sure that the United States maintains a strong position in producing in these materials? Obviously, FRP, when we're talking about even things as large as bridges can be, you know, put together elsewhere and brought over to the United States to be put in place. We've seen that with concrete and steel bridges. So what can we do to try to make sure we have the right incentives in place for the United States to really—our economy and jobs to thrive in this—with FRP? So let's start with Dr. Lange.

Dr. LANGE. Well, one thing that I would like to emphasize is that there is opportunity when we have very large infrastructure programs. O'Hare just announced another $8.5 billion program that will add a terminal to the west side of O'Hare, and these kind of major infrastructure programs extend for many years.

The opportunity to partner with university researchers to help answer questions about what is going on in that project and how new materials might come into it, how new technologies might benefit the project, that I think is a great opportunity. The relationship we've experienced in working directly with a major infrastructure program is not terribly common. It's a little bit unusual that we have that kind of a partnership. But I believe it could be a very good policy moving forward that we have these major programs to pay attention to the research landscape.

Mr. LIPINSKI. Anybody else? Dr. GangaRao?

Dr. GANGARAO. Thank you. Thank you. I have indicated six different approaches of how we can keep the lead in terms of our

high-quality products based on composites in my writeup. And I'll talk about a couple of them. One of them is that we do not want to be a dumping ground for some inferior product from outside. Therefore, we need to maintain very high standards and also enforce these standards of the materials that we are going to be introducing as composites or for that matter as a hybridized material, including the conventional materials like steel and concrete. That's one. I can elaborate on that much more later.

The second important thing is we need to come up with smart manufacturing for infrastructure point of view in terms of creating as large a subsystem as possible under the manufacturing settings so that we gain certain degrees of efficiencies and be able to reduce any form of waste that we have right now. We're 40 percent waste in the construction industry. So these are the two I would like to focus on. I have four other items I mentioned in my writeup. Thank you.

Mr. LIPINSKI. Thank you. Mr. Weyant, do you have anything to add?

Mr. WEYANT. Yes, I echo Dr. Lange and Dr. GangaRao's position. I think government needs to take a strong position in two areas. We need to invest to enhance the development of the technologies to keep us on the forefront and the materials, you know, to be produced in the United States. Also, we need to rebuild America with the right materials. While we're facing these problems of the large spend on building the infrastructure is because these materials are not lasting. We got products here that can be 50 years plus design service life, so down the road, the payback is, as I said earlier, on the lifecycle. So we need to make that choice today to rebuild America the right way and put people back to work.

Mr. LIPINSKI. And Mr. Weyant, it probably may surprise you that I have driven through Pleasantville many times on my way from here to Johnstown, so I wanted to ask you about—do you have issues with labor force getting workers who are capable?

Mr. WEYANT. That is a big demand nowadays, but we reach out to a lot of the local high schools and a lot of the trade schools, very aggressive on recruiting. But, you know, to train people, too, you know, that is a concern. And in the rural area, as you know, Mr. Lipinski, that does put a big demand because we have a lot of expansion in our areas with a lot of different manufacturers.

Mr. LIPINSKI. Thank you. I'm out of time. I yield back.

Mr. HULTGREN. The gentleman from Illinois yields back.

I'll now yield myself five minutes. First, again, I want to thank you all for being here, for your testimony. For me this is an especially important hearing today. The State of Illinois, as my colleague and friend from Illinois has already stated, leads in materials science research conducted at our wonderful universities and national labs. I want to hear what we're doing nationally, but I always like to see how Illinois universities are testifying before this Committee. I'm grateful for that.

Infrastructure is also a key priority with every local official I meet with, and it's why I work to preserve key tools for municipal finance in the tax reform bill that we had, such as the tax-exempt status for municipal bonds. Local officials understand the importance of both construction and maintenance, and they see the long-

term impact of more resilient infrastructure. So thank you for your work.

Dr. GangaRao, if I could address my first question to you. How would research at NIST be integrated in its standards development and used by standards development organizations?

Dr. GANGARAO. NIST has excellent facilities in trying to promote any kind of test methodologies, develop the test methodologies, and also enforce the testing systems. That's one way they can do it. The second way they can do it is by providing excellent platform in terms of educational aspects. There are half a dozen educational aspects that I can talk about. They can be the lead nuclei in developing some of these educational aspects.

And thirdly, they have a great amount of technical know-how through their full-time employees, and they can certainly interact with not only the university types but also with the industry types to promote some of these kinds of advances in a most systematic fashion. Thank you.

Mr. HULTGREN. Thank you. Mr. Weyant, in your testimony you say that there is limited awareness by engineers and asset owners about the composites as structural material for infrastructure. I wonder if you could describe in more detail what you encounter?

Mr. WEYANT. A lot of times when we approach the design community when you have to introduce a composite material, a lot of the traditional materials have design codes, okay? They have their own handbooks. When you buy a steel beam from XYZ company versus ABC, you know you're getting the same steel beam. Those standards need to be developed, you know. Composites being fairly new in the construction market, you know, really came about in the mid-80s to '90s. Those standards, a lot of the engineers do not understand them. So we have to educate them. And a lot of the companies are a lot smaller and don't have those resources to really put, you know, in the technical design capabilities to help educate the engineering community.

Mr. HULTGREN. Thanks. Dr. Chin, it's been cited in numerous reports, including one in 2014 by the President's Council of Advisors on Science and Technology that composites are a crosscutting enabler for the manufacturing technology of the future supporting not only infrastructure but also automotive, aerospace, energy, and other key sectors. I wonder if you could elaborate on the strategic importance of composites to the national economy?

Dr. CHIN. In regards to the more general application of composites in the sectors that you mentioned, the weight reductions through the use of composite materials enable energy savings. That's the primary driver in the aerospace, marine, and automotive industries.

In infrastructure, it's not a matter of designing based on weight constraints, but the availability of composite materials that can be prefabricated, premanufactured offsite, brought to the construction sites, and installed much more quickly. The weight savings in this particular case also lends itself to much more rapid installation, which mitigates the delays, obstacles, roadblocks, all of the issues involved with construction projects that reroute people and goods around the points where the construction is taking place. Those have an impact that may not be as measurable in terms of eco-

nomic return on investments, but you can definitely see the impacts on the lost time. And just in terms of the process of getting people and goods from point A to point B, there is definitely a dollar value associated with those benefits of composites as well.

Mr. HULTGREN. Thank you. I'm just about out of time. I may follow up if that's all right with you. I had a question just in regards to opportunities for students and graduates to obtain hands-on experience with composites with internships and research, so I may follow up to see if I can see if you have suggestions or ideas from that.

With that, my time is expired, and I will recognize the Ranking Member of the full Committee, Ms. Johnson from Texas, for five minutes.

Ms. JOHNSON. Thank you very much, Mr. Chairman and Ranking Member Lipinski, for holding this hearing. And thanks to all the witnesses for being here.

In addition to this Committee, I serve as a senior member of Transportation and Infrastructure. And I really do understand the challenges that we face in crumbling infrastructure. My home district of Dallas, Texas, was recently named the fastest-growing metropolitan area in the country by the U.S. Census. It also rated it as the 10th worst city in the nation for traffic congestion in another recent report. And though there has been great improvement from last year's position, which was number five, commuters still face a daily tackle with bottlenecks, wasting time and fuel, and this is a struggle for many communities, I'm sure.

And while it is an example of perhaps reaching the stars, I'd like you to explain to me what your feelings are about what type of emerging technologies that we will be looking at for our infrastructure needs, and also, how would we go about preparing our workforce? I'm particularly interested in the emphasis on resilience and materials that we use and the talent that's needed. We're already looking at aerial transportation, drones, and all kind of alternative things. What seems to be realistic? And I'd like to hear from each of you.

[The prepared statement of Ms. Johnson follows:]

OPENING STATEMENT
Ranking Member Eddie Bernice Johnson (D-TX)

House Committee on Science, Space, and Technology
Subcommittee on Research and Technology
"Composite Materials-Strengthening Infrastructure Development"
April 18, 2018

Thank you Chairwoman Comstock and Ranking Member Lipinski for holding this hearing to review the National Institute of Standards and Technology report on overcoming barriers to adoption of composites in sustainable infrastructure. And thank you to the expert witnesses for being here this morning as we discuss the value of developing composites standards for infrastructure applications.

As a senior Member of the Transportation and Infrastructure Committee, I understand the challenges we face with aging and deteriorating infrastructure. While my home district of Dallas, Texas was recently named the fastest growing metropolitan area in the country by the U.S. Census, it was also rated as the 10th worst city in the nation for traffic congestion in another recent report. Though this is an improvement from last year's position in the number 5 spot, commuters still face the daily tackle with bottlenecks, wasting time and fuel. This is a struggle that many communities face – welcoming growth but struggling to provide sufficient infrastructure. Local Dallas leadership, as well as the city of Los Angeles, are even looking to flying cars to address the congestion problem, signing up as the first two testbeds for Uber Elevate.

While this is truly an example of reaching for the stars, these big ideas and emerging technologies may be the answer to our infrastructure needs. The most recent American Society of Civil Engineers *Infrastructure Report Card* put in black and white what we know all too well – our infrastructure is just short of failing. With a grade of D+, we must look to innovative ways to improve our nation's infrastructure. It is necessary to ensure that our transportation infrastructure, as well as the infrastructure that supplies our electricity, water and other critical needs, is safe enough to handle the demand of our growing population and resilient enough to continue functioning during more frequent and powerful extreme weather events.

I sometimes describe NIST as the most important least known agency in our government. After serving on the Science Committee for more than 20 years, I know the good work that NIST does to help U.S. industry be competitive through its leadership in measurement science and standards development. I was very pleased to see that NIST fared well in the FY 18 Omnibus. It is important that Congress fully fund NIST and provide the agency with adequate funding so that it can continue doing the important work that we will be discussing today. The NIST workshop and report seems to have made great strides in gathering key stakeholders and identifying three main barriers to wider adoption of composites in infrastructure. We, as policymakers, must make efforts to understand the complexity of our nation's build environment. This includes supporting a bold research and standards development agenda that maintains safety priorities and the U.S. in leadership position in advanced composites for infrastructure applications.

I look forward to today's testimony and discussion, and I yield back.

Dr. LANGE. Well, let me chime in with one idea here. One thing that I would like to add about this discussion about durability is that if you want durable infrastructure, you need to ask for durable infrastructure. And kind of an old saying, you get what you ask for. Too often our contracting mechanism is based on a low bid when people are asked to, say, build a road or build infrastructure, the winner of that competition is the one who prices it the lowest.

And when you look at the specifications, they don't emphasize durability like they should. They don't emphasize lifecycle, as they should. The choice is made on initial cost rather than by lifecycle cost where you take into account the full length of service life of the structure and its maintenance cost. So one issue that is a policy issue is how can we move more toward performance specification and looking at lifecycle cost.

Ms. JOHNSON. Thank you. Yes?

Dr. GANGARAO. I'd like to start out by stating certain issues with regards to resilient infrastructure. With my center that is the NSF-sponsored one dealing with the composites for infrastructure, University of Texas at Arlington is a member of our center, and they have been using composite to try to minimize your expansive shale problems for your foundations and the roads, so there again, we need to use some of these advanced materials that would help enhance the service life of each and every one of these infrastructures. That's just one of the many other parts.

The other part is we need to marry these advanced materials with the conventional materials so that the longevity can be improved, the traffic jams can be cut down, and what have you. And there are many other transportation systems, including some of the electronics that are going to be built into it coming into vogue that will greatly enhance the efficiency of movement from point A to point B. Thank you.

Ms. JOHNSON. Thank you very much. Anybody else?

Dr. CHIN. So one of the big national multiagency programs that NIST is involved with is the Materials Genome Initiative. And through that program, we seek to accelerate the development of these innovative materials that can be used in infrastructure, as well as many other industry sectors. But this type of program would enable materials scientists and engineers and designers to be able to receive the benefits of materials developed at a much faster rate, which could potentially be used in infrastructure and making it more resilient to natural disasters and other types of high impacts.

We also have a Community Resilience Program which seeks also to develop more infrastructure—more resilient materials for use in infrastructure.

Ms. JOHNSON. Thank you. My time is expired.

Mr. HULTGREN. The gentlewoman from Texas yields back.

The gentlewoman from Connecticut, Congresswoman Esty, is recognized for five minutes.

Ms. ESTY. Thank you very much. And again, I want to thank the Chairman and Ranking Member for holding today's hearing. You'll find I think all of us are on the Transportation Committee, and there's a reason that we're also on this Committee, because we rec-

ognize the important challenges facing the country on resiliency in our infrastructure, the aging infrastructure laid out so well by you.

I've also been working on this, and I want to make sure to get copies of this for each of you. There's a bipartisan group of Democrats and Republicans in the House called the Problem Solvers Caucus. And I was the Co-Chair of this report, which we released in January, making several of the points that you've underscored, Dr. Lange. You just recently talked about the importance of lifecycle costs. We're specifically calling for that. My father and grandfather were both civil engineers. I know exactly what you're talking about, and it is the low-bid problem that's always been a problem but never more acute than now when we really need to be looking at the entire cycle of the cost, better from day one and lasting much longer.

I'm also Co-Chair of—and Co-Founder of the Corrosion Caucus, so we've been looking at these issues in the Resiliency Caucus, the importance of upgrading those requirements.

So I wanted to also flag—again, so you know, that a number of us have been working on this in multiple committees. We've called for the creation—in the report we called for the creation of something like an ARPA H2O to look at the water infrastructure, which is often not included in the civil engineers' report because that alone is, you know, approaching $1 trillion of unmet needs to replace and upgrade the nation's water infrastructure. So when I get to questions, I'd ask for your thoughts of whether you think something like an ARPA H2O make sense for basic research, especially given that water is delivered at the local level and cannot possibly have the research facilities to figure out if you're Detroit and you need to reduce the size of your mains by 3/4 to keep the flows in place, they can't be paying for that research. It's just not reasonable. We need to have a federal role in that.

Chairwoman Comstock and I, who chairs this Subcommittee, are getting ready to introduce a bill in the coming weeks on this basic issue of composites, on the importance of highlighting the need to include this as innovation and to include this with new standards. One of the pieces we've looked at are calling for—and it's the IMAGINE Act, the Innovative Materials in American Grid and Infrastructure Newly Expanded—you can tell that was put together to make out IMAGINE—but the IMAGINE Act calls for the creation of an interagency innovative materials task force to assist in some of these issues we've talked about this morning for assessing existing standards and test methods and then compare them against these new materials and how they compare.

The interagency task force would work to identify key barriers in the current standards that inhibit market adaptation and adoption and develop new methods of protocols, as necessary, to encourage incorporations. This interagency task force would be chaired by NIST, by the National Institute of Standards and Technology, bringing together the Federal Highway Administration, the Army Corps of Engineers, and EPA, and other standard regulatory agencies.

So, Dr. Chin, can you comment on whether you think that would be helpful to have a coordinated effort across the agencies which

otherwise are siloed, as we know, which is a huge problem. Thank you.

Dr. CHIN. Yes, NIST has had a very long history of collaborating with other federal agencies and other primary stakeholders in big national initiatives such as the one that you're describing. We are absolutely committed to working in the area of water. That is definitely seen as an area of great importance to the nation.

Ms. ESTY. And what's your thoughts on something—or any of you—on something on the basic R&D side, something like an ARPA H2O? Is that—do we think we're at a point that there should be basic research, or is it more a function of standards and dissemination of best practices?

Dr. LANGE. Well, I think on the subject of basic research, you're touching on one of the biggest challenges that we have, and that is the durability and interaction of materials with their environment. Dr. Chin talked about how NIST has a long history of looking at durability issues. I think that the durability topics are more challenging and more necessary than, say, looking at mechanical properties of materials. And so I would encourage that kind of direction of looking at durability first.

Ms. ESTY. Thank you. Go ahead.

Dr. GANGARAO. Basic research is always extremely important, no question about it. However, to get the biggest bang for your buck, a good bit amount of monies have to be invested in field implementations, experimentation, and evaluations as soon as possible so that we establish a protocol of how to do some of these in the field and able to disseminate this knowledge base in a widescale manner. Thank you.

Ms. ESTY. Thank you very much, and I see I'm out of time. Thank you.

Mr. HULTGREN. Thank you, the Gentlewoman from Connecticut yields back.

The gentlewoman from Oregon, Ms. Bonamici, Congresswoman Bonamici is recognized for five minutes.

Ms. BONAMICI. Thank you very much, Chairman Hultgren and Ranking Member Lipinski. And thank you to all of our witnesses for being here today. I'm very glad that we're discussing infrastructure. And listening to my colleague talk about things like the Corrosion Caucus, you know that we're all interested in this issue.

We know that making long-term investments in our nation's infrastructure stimulates the economy, creates jobs, and drives commerce. And as we restore our roads and bridges and build affordable housing and invest in public transit and upgrade our schools and ports and water systems, we need to be responsive to environmental concerns but also creative in the use of emerging materials.

And I am the Co-Chair of the Oceans Caucus, and marine debris is one of our priorities. And recently, I've been reading about projects that integrate plastic bottles and materials salvaged from debris in the ocean into asphalt to create more durable roads. And this is the kind of ingenuity we need as we develop an infrastructure proposal. And I know the Chairman of the full committee has gone, but I know that Texas is working on a pilot project on this as well.

At Oregon State University in my home state, the Kiewit Materials Performance Lab has been one of the leaders in innovative efforts to test composite materials. The lab is conducting sensitive electrochemical investigations to study both corrosion phenomena and metals and alloys and the performance and durability of coatings and composite materials. And I visited there, and they're doing some great work.

Dr. Lange, I wanted to ask you how federally funded researchers at universities can best partner with engineers in the private sector to support continued advanced research testing and standards development?

Dr. LANGE. I would say that one of the themes that I have hit on, this idea of partnering with major infrastructure programs. This is something I would put back on the table. I think that when you're spending, as O'Hare is going to spend $8 billion on the next phase of expansion of the airport, there should be a piece of that investment used for looking toward the state-of-the-art. Engineers working on everyday tasks may not have time to see that state-of-the-art very clearly, but in partnership with universities, perhaps they can.

With respect to recycled materials, I think that's a great theme to continue to hit. One thing I would encourage is that, as you think about recycling materials, try to have some integrity about what you're trying to do with these materials. Sometimes uses of recycled materials are almost using concrete as a trash can. How many things can we throw into concrete or asphalt without caring about the degradation of properties that happens when we do it? Wwe really want to find synergy where we get not the only use of recycled material but improvement of properties, not a degradation of properties.

Ms. BONAMICI. Right. Absolutely. Well, I'm from Oregon; we recycle everything. So in northwest Oregon, it's not a question of if but when a tsunami triggered by an earthquake happens. We have the Cascadia Subduction Zone is going to hit our state. We are overdue. So we've been having many conversations about rebuilding our infrastructure to withstand these natural disasters. And in the district I represent, the Newberg Dundee Bypass has just been built to withstand a 9.0 earthquake.

But an earthquake is not the only threat facing our Nation's infrastructure. We also need to be resilient to the effects of climate change. And of course with the ocean, we're seeing acidification, we're seeing more extreme weather events. What is the current state of our understanding of how climate change affects infrastructure, and how has that understanding shaped the composites research agenda and standards development to make sure that resiliency is a factor? And anybody who wants to weigh in on that.

Dr. GANGARAO. I want to answer a couple of things along those lines. Before I do that, I want to talk a little bit about the recycling aspect of it. At West Virginia University, we have been doing a lot of recycling of composites. For example, we can talk in terms of low-grade material recycling, as well as a very high-grade material recycling, and we have done polymers to recycle and create core material that are of low value while in fact create a very high-grade material as a shell for a given system—

Ms. BONAMICI. Interesting.

Ms. GANGARAO. —and that helped a great deal. And also, we are partnering now with Mexico. CONACYT is an equivalent of NSF of ours where they want to recycle a lot of their high-end composites coming out of aerospace and other places.

There are three or four different ways of recycling it. One is just simply burn it. That's not the best approach. There are a few other chemical ways of recycling, and we are looking at those kinds of things as well to enhance our productivity levels in the area of composites as opposed to dumping in the oceans like you're referring to.

Ms. BONAMICI. Right. Right. Thank you. And just—I know I'm out of time, but with the Chairman's indulgence, would you address the climate change issue?

Ms. GANGARAO. Well, I don't know a whole lot about the climate change. As Dr. Chin pointed out, I think the amount of energy required to produce a unit pound of a composite per unit workability and the efficiency of a composite is much less than steel or concrete.

Ms. BONAMICI. Thank you. I yield back, Mr. Chairman. Thank you.

Mr. HULTGREN. Thank you. The gentlewoman from Oregon yields back.

I want to thank all of our witnesses for your testimony and all the members for their questions today. I also do want to send regards from Chairwoman Comstock, who really wanted to be here but was not feeling well today, so she sends her regards and gratitude for each of you being here.

The record will remain open for two weeks for additional written comments and written questions from Members.

Mr. HULTGREN. With that, the hearing is adjourned. Thank you so much.

Dr. GANGARAO. Thank you very much.

[Whereupon, at 11:10 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Joannie Chin

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. Joannie Chin, Deputy Director, Engineering Laboratory, National Institute of Standards and Technology

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. In as much detail as possible, please identify NIST's current timetable for any work relative to composite materials, and what does, or will, the work consist of.

Answer: For the next few fiscal years (FYs), NIST will invest in the following research on composite materials:

Composite Research Effort	Composite Type	Period of Performance	NIST Investment/y ($)	Other Agency/Industry Investment ($)
Sustainable composites	multiple	FY11-current	-	
Fluorescence imaging of composite damage	glass fiber	FY11-current	0.5M	
Microwave measurement and dielectric characterization	nanoparticle	FY11-current	0.25 M	
Interfacial shear strength measurements	glass fiber	FY11-current	0.25M	
Impact resistant materials	multiple	FY16-current	0.5M	
Materials Genome Initiative	multiple	FY16-current	0.75M	
Nanomanufacturing project	nanoparticle	FY13-18	0.75M	
Surface damage of polymer nanocomposites	multiple	FY01-current	0.25M	
Sustainable engineered materials	multiple	FY10-current	0.25M	
Seismic retrofit of concrete structures utilizing fiber reinforced polymer (FRP) composites	multiple	FY16-current	0.5M	
Automotive lightweighting	carbon fiber	FY14-18	0.2M	UMD 0.15M
Cellulose nanocomposites	nanoparticle	FY16-18		AFOSR 0.2M
			Total = $4.2M	$0.35M

AFOSR – Air Force Office of Scientific Research
UMD – University of Maryland

2. How much money is NIST currently investing in composites research? The response to this question should provide a break down by specific composite materials and include all labs that conduct research related to composites, including the Material Measurement Laboratory and the Engineering Laboratory.

   Answer: NIST is currently spending $4.55 million per year (the NIST investment plus other organizations') on composite-related research and measurements in the projects listed in the table above. These projects seek to measure, model, and predict the performance of advanced composites for a variety of applications and address a range of critical national needs.

3. Does NIST have the authority and resources available to undertake all activities described in the December 2017 report[1] within existing budgets and authorizations in the next three years?

   Answer: NIST has broad statutory authority to work on a wide variety of materials science. Over the next several years, NIST's current level of resources will permit the Institute to undertake some, but not all, of the activities described in the December 2017 report, and NIST will continue to prioritize its current composites research efforts to support critical national needs.

4. How would accelerating further research and standards development for composites contribute to the long-term reduction of costs for infrastructure?

   Answer: Accelerating research and standards development in the areas identified in the NIST December 2017 composites workshop report would enable more rapid adoption of codes and standards for composite materials in infrastructure. The sooner that these critical guidelines for utilizing composite materials are developed and these materials are deployed in building and construction, the sooner American communities can cut costs, reduce construction times, and increase structure lifetimes.

5. NIST's December 2017 composites workshop report identifies four key challenges as "impediments to the wide spread adoption of FRP composites as standard infrastructure construction materials."[2] What specific steps is NIST taking to address these challenges?

   Answer: While speakers at the workshop called out four key challenges in setting the context for the day's work, the report reflects the participants' consensus that the following three activities, if undertaken, would accelerate the widespread adoption of FRP composites in infrastructure:

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[1] NIST Special Publication 1218, "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure," December 2017, available at: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

[2] Ibid.

1. Durability testing,
2. Design data clearinghouse, and
3. Education and training.

NIST has the technical capability to address (1) durability testing and (2) design data clearinghouse.

(1) Durability testing would be the most critical and technically challenging, and, therefore, the most extensive. The report projected that this work would require five years. This program must deliver the fundamental knowledge and design tools to enable the reliable prediction of composite performance 75-100 years into the future. To address this, NIST would establish four focus areas: 1) accelerated testing measurement development; 2) acquisition of accelerated material properties data; 3) development of design tools; and 4) evaluation of durability tools and data. To complete this work within five years will require funding beyond that currently budgeted.

(2) A design data clearinghouse would focus on gathering information and data for all the major composite application areas (new construction, repair and retrofit applications, free standing applications). Specifically, this would involve building databases of two types for each application: 1) information content focused (reports, websites, etc.), and 2) data content focused (research data, testing, demonstration project data). These databases would be user friendly for the entire range of stakeholders, including manufacturers, research and development, design engineers, and owners. This work is the critical foundation for development of performance based standards in material specifications and design guidelines. Similar efforts within the aerospace composites industry, which produced a very narrowly focused composites clearing house, was supported by staff from many organizations with multi-million dollar investments over many years. The two types of databases proposed here for three different application areas represent a clearinghouse program six times larger than the aerospace composites industry, and would require funding beyond that currently budgeted.

6. Regarding the need for uniform design standards and the need for a clearinghouse – two of the four challenges identified in the December NIST report – when and in what form can the Committee expect NIST to address these challenges?

Answer: As described in the response to Question 5, NIST has begun the process of gathering information for determining the scope of a design data clearinghouse. NIST plans to leverage the experience gained from similar efforts within the aerospace composites industry, which produced a very focused data clearinghouse and was supported by staff from many organizations with multi-million dollar investments over many years. The two types of databases discussed in Question 5 represent a clearinghouse program six times larger than the aerospace composites industry, and

would require funding beyond that currently budgeted. This clearinghouse, once populated, will focus on enhanced user experiences and greater flexibility compared to previous databases, ultimately providing the basis for uniform design codes and standards developed by standards development organizations in the infrastructure and building sectors.

7. Does NIST have any ongoing or planned initiatives to increase composites education and workforce training?

   Answer: While workforce training as such is not part of NIST's mission, NIST provides education and training on its research by giving students, post-doctoral associates, and industry researchers the opportunity to work alongside NIST experts, and to participate "hands-on" in NIST laboratory research projects.

8. What sorts of partnerships - with federal agencies, industry, academia and other stakeholder groups - is NIST engaged in relative to its work on composites?

   Answer: Under its existing authorities, NIST collaborates with industry, academia, and other federal agencies through Cooperative Research and Development Agreements and other agreements with partners including:

   - The American Composites Manufacturers Association is a long-time partner with NIST, helping us to convene industry members to understand their needs, and sharing authorship with NIST on the December 2017 report.
   - The Institute for Advanced Composites Manufacturing Innovation (IACMI) is a Department of Energy-funded Manufacturing USA institute; NIST participates in the IACMI's Government Advisory Board.
   - The NIST-funded Center for Hierarchical Materials Design (CHiMaD) is a center of excellence in advanced materials led by Northwestern University in partnership with the University of Chicago, Argonne National Lab, and others.
     - A use case at CHiMaD collaborates with SpaceX on the discovery of advanced composites for aerospace applications.
   - The Air Force Office of Scientific Research and NIST are collaborating on basic research on the properties of cellulose nanocomposites.
   - The Department of Energy is a funder of the NIST Center for Automotive Lightweighting (NCAL), which develops mechanical tests and measurement science on materials of interest to the industry, including advanced composites. NCAL has more than 20 industry partners, including Chrysler, Ford, GM, and Alcoa.
   - Owens Corning and NIST are collaboratiing to explore the applicability of existing test methods to new, industrially relevant composites.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. Joannie Chin, Deputy Director, Engineering Laboratory, National Institute of Standards and Technology

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. It is my understanding that many newer technologies are blocked from broader use because of standards that are process-based instead of performance-based. How is NIST looking at performance-based standards as a means of entry for newer technologies?

   Answer: NIST has long been a proponent of performance-based building standards and actively participates in the ongoing efforts of industry-led standards development organizations to develop voluntary, consensus, performance-based standards for a wide spectrum of building codes and standards.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. Joannie Chin, Deputy Director, Engineering Laboratory, National Institute of Standards and Technology

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

1. Last year, NIST's "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure" brought together NIST, manufacturers, researchers, and engineers to discuss using FRP composites in infrastructure. They recommended the development of durability standards to test how long FRP composites may last in specific environments. I believe we need to also study and consider the lifecycle cost of a material – and not just focus on the immediate cost of building. We also need to think about what environmental footprint each material will leave on its surrounding area, and what effect the environment may have on the materials themselves.

    a. Dr. Chin, what attributes, other than durability, would be important to consider when choosing what materials to use for infrastructure projects? If we currently consider such attributes when using steel or concrete – can we apply these to FRP composites?

    Answer: Attributes that should be considered when selecting materials for infrastructure projects include compliance to design standards, ability to meet stated load requirements, ease of installation, life cycle cost, and the type of environment in which the structure will reside.

Responses by Dr. Hota V. GangaRao

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. Hota V. GangaRao, Wadsworth Distinguished Professor, Statler College of Engineering, West Virginia University

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. A major objective of the hearing on April 18th was to discuss the value and need for development of composite standards for infrastructure applications. In as much detail as you can provide, what sorts of standards should NIST develop - and in what time frame - that would best enable the use of composites in infrastructure development by those interested in using such materials?

   Answer: Standards and specifications for infrastructure applications must take into account many different needs and perspectives, including material properties, constructability, cost/benefit, structural performance, etc. Standards are also tailored for different applications such as buildings, bridges, highways, pipelines, and others. Thus, these standards are developed by bodies composed of various experts to gain the needed perspective, including designers, contractors, end users, academicians and others. Thus, NIST should not independently develop any standards but NIST should coordinate and facilitate the development of standards by others. The standards to be developed must be done in cooperation with federal agencies such as USDOT, HUD, and PHMSA and with code bodies such as AASHTO, ASTM, IBC, etc. The standards should include: 1) materials, 2) design, 3) manufacturing, 4) construction, 5) evaluation, 6) maintenance, 7) rehabilitation and others.

   If the various expert groups mentioned above work in unison under strong and focused leadership (providing work items to be accomplished before attending meetings), rapid progress can be made in some well understood areas, resulting in new or updated national standards in perhaps 3-5 years. However, this time frame depends on the availability of technical data including the information dealing with field responses and changing scenarios of constituent material developments. For example, data on long-term durability of composites or when exposed to extreme events is not as readily available and thus standard development will take much longer (perhaps 7-8 years), and from my experience can reach into a decade or longer. Separate funding to develop durability data of FRP composites and performance data is needed for extreme event cases where FRP composites might be used. These aspects have to be dealt with by those experienced in designing, constructing, and evaluating FRP composites while NIST acts as a facilitator.

2. NIST's December 2017 composites workshop report identifies four key challenges as "impediments to the wide spread adoption of FRP composites as standard infrastructure construction materials."[1]

    a. Regarding the need for uniform design standards and the need for a clearinghouse – two of the four challenges identified in the December NIST report – what actions would you like to see NIST take to address them and how soon should these actions be taken?

    Answer: NIST's role in the development of uniform design standards should be to coordinate and aid the efforts of code bodies. As noted in the NIST report, a major activity that needs addressed for the development of design standards is durability testing. NIST can work with ASTM to develop standard test methods for accelerated aging of composites and can fund outside work at various universities or private firms to undertake widespread experimentation to arrive at a robust dataset including round-robin testing. Again, NIST's role should be as a facilitator and aggregator of data. There is also a strong need to evaluate the performance of existing composite systems that have been in service for years and compare their current performance to their original properties. NIST can fund this work and combine the field and lab data from these and other studies into a database allowing for the development and calibration of aging models.

    In addition, NIST can create a clearinghouse of lab and field data of FRP composite based systems existing design standards created by manufacturers, government agencies, code bodies, etc. The various design guides and data tables can be compared to arrive at recommendations for uniform national standards. The clearinghouse should also include cost data, including comparisons between rehabilitation and retrofit of a structure with composites versus conventional repair or replacement. NIST can aid in the development of life-cycle cost analysis of existing structures to highlight the long-term savings of using composites to rehabilitate or retrofit a under extreme events such as blast, hurricanes, or earthquakes.

    b. What other steps would you like to see NIST take in response to the other challenges and when would you like to see them?

    Answer: There are several items NIST can address in the next few years that would have tangible and meaningful impacts. Based on the clearinghouse described above, NIST develop design examples for pipelines, utility lines, FRP

[1] NIST Special Publication 1218, "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure," December 2017, available at: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

rebar, bridge decks, housing systems, seawalls, and rehabilitation of structures. NIST should maintain their role as a facilitator and fund development of new composite materials utilizing recent advances in polymeric materials, sizing chemistry of fibers, and different fabric configurations to enhance material and structural efficiencies. Funds should be allocated for engineers to work with universities on an internship basis in terms of manufacturing, design, construction, and non-destructive evaluations. Furthermore, funds are required to develop short courses, seminars, and training programs for universities, with the programs varying from a few hours to several weeks based on the degree of knowledge required. In the long-term, NIST should work with HUD, NSF, FEMA and other federal and state agencies to initiate an assembly line operation of FRP composite modular components and subsystems for housing to minimize field waste and maximize field efficiency and productivity of American workers.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. Hota V. GangaRao, Wadsworth Distinguished Professor, Statler College of Engineering, West Virginia University

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. What sorts of opportunities are there today for students and graduates to obtain hands-on experiences with composites through internships and research? How can we increase such opportunities?

   Answer: I have been fortunate to receive funding from various government agencies to support students to work on composites in our labs, exposing them to manufacturing, installation, and testing of composites. Many universities offer similar programs and the demand for work typically outpaces the funding available for students. Federal funding has also been used to support students interning in the manufacturing industry where composite components are being mass produced, or in design offices. Many composite manufacturers are not large businesses, thus government support of students is often needed. State DOT offices provide stipends to students working as summer interns and that not only helps the students but also educates existing employees that are not well aware of composites and their applications. We need to work with agencies such as RC Byrd Institute for manufacturing of composites in Bridgeport, WV so that they can train the workforce in cooperation with WVU. Increasing the funding for both undergraduate and graduate students to do research or intern would allow for more hands-on experience.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. Hota V. GangaRao, Wadsworth Distinguished Professor, Statler College of Engineering, West Virginia University

Questions submitted by Representative Jacky Rosen, House Committee on Science, Space, and Technology

1. In my home state of Nevada, the Clark County Building Division has developed guidelines that address using fiber-reinforced polymer (FRP) composites in building construction and fire protection approaches for major structures.

    a. I know that one of the main areas of your research at West Virginia University includes composites for blast and fire resistance. The 2017 wildfire season was one of the worst on record, and was catastrophic to the West especially. Can you share some of your research on this topic, and the effectiveness of FRP composites in fire mitigation going forward?

    Answer: Given enough fuel, oxygen, and heat, fire can eventually destroy any kind of structure. That said, we have developed certain resin systems and coatings that will retard the fire progression and even self-extinguish after a fire has moved on. These materials can save structures when advanced composites systems with fire retardants are used as outside envelopes to protect houses and other structures. There is an immense amount of data and research on the fire behavior of composites through the US Department of Defense, much more than I can impart at this time. We will be very happy to share information that is being evaluated and formalized on fire, smoke and toxicity.

Responses by Dr. David Lange

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Dr. David A. Lange, Professor, Department of Civil and Environmental Engineering, University of Illinois and Urbana-Champaign

Questions submitted by Representative Randy Hultgren, House Committee on Science, Space, and Technology

1. What sorts of opportunities are there today for students and graduates to obtain hands-on experiences with composites through internships and research? How can we increase such opportunities?

   Answer: The NIST roadmap document (NIST Document 1218) stated that the lack of education and workforce training is the primary barrier to the successful incorporation of FRP composites for infrastructure. Given my 26 years of experience in civil engineering education, I can attest to the relatively low visibility of composites in civil engineering. I took a course on FRP composites in my PhD program at Northwestern University, and like most universities, the courses were offered by Materials Science and Mechanical Engineering faculty in support of aerospace/automobile design. On the other hand, civil engineering is dominated by two dominate silos: reinforced concrete and structural steel. Each silo has deep history, widely adopted code, and powerful industry players aligned with those materials systems. For the most part, FRP is dismissed as an alternative for infrastructure applications because there is no building code for it, there is little expertise with the design, and there is inadequate industry forces to drive change. During the hearing, I mentioned that FRP rebar and FRP sheet products for repair are two successful niches, but aside from them, there is relatively little market penetration of FRP in infrastructure.

   Indeed, there are relatively few internship and research opportunities to obtain hands-on experience with composites. The Federal government can motivate greater attention to FRP by funding targeted activities at universities. NIST has been in the past an active player in composites research, and they have collaborated with summer workshops in the past. In addition, it is my understanding that NIST is positioned to support such initiatives in the future. I also think there is relatively fertile ground for incentivizing ME and Aero faculty to partner with CE structures faculty for curriculum development, internships, demonstration projects, and research etc. The funding agency has the prerogative to require partnerships between industry, professional societies, and universities. It is not uncommon that Requests for Proposals are explicit in requiring elements of partnership, and it could be effective in this case.

Responses by Mr. Shane E. Weyant

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"Composite Materials – Strengthening Infrastructure Development"

Mr. Shane E. Weyant, President and Chief Executive Officer, Creative Pultrusions, Inc.

Questions submitted by Chairwoman Barbara Comstock, House Committee on Science, Space, and Technology

1. A major objective of the hearing on April 18th was to discuss the value and need for development of composite standards for infrastructure applications. In as much detail as you can provide, what sorts of standards should NIST develop - and in what time frame - that would best enable the use of composites in infrastructure development by those interested in using such materials?

   Answer: Among NIST's comprehensive and robust research capabilities, they have a unique ability to develop and demonstrate durability testing and predictive performance modeling protocols for a wide range of composite infrastructure products and applications. By developing a standardized approach to assessing performance and durability, this methodology can be used in the development of design standards and guidelines. In addition, owners and asset managers can use the output durability results for life cycle cost analysis (LCA) so legacy materials of construction can be evaluated against innovative composite materials, so the best value can be determined. Essentially, the testing developed by NIST will be used by industry and academia in collaboration with the design and asset owner communities to promulgate the necessary standards that allow broader adoption and deployment of composite infrastructure solutions. Section 4.3 of the NIST roadmap addresses this area in detail.

2. NIST's December 2017 composites workshop report identifies four key challenges as "impediments to the wide spread adoption of FRP composites as standard infrastructure construction materials."[1]

    a. Regarding the need for uniform design standards and the need for a clearinghouse – two of the four challenges identified in the December NIST report – what actions would you like to see NIST take to address them and how soon should these actions be taken?

    Answer: NIST should collaborate with industry and relevant academic institutes to collect all authoritative standards and design data documents. This information should be aggregated in a centralized electronic repository, allowing ready access of interested parties to the information. Through this process, NIST will be able to assess and validate the completeness of the existing sources and analyze gaps in design data and standards. The agency can then collaborate with industry, asset owners and infrastructure policy agencies under the umbrella of the relevant standards development organizations to build out the remaining needed standards. The industry has already begun aggregating this information in a coordinated way with NIST, however further Congressional direction will allow this process to happen in a more robust fashion. As this data collection is the logical first step in addressing the barriers outlined in NIST's roadmap, it should begin as soon as possible. This database can and should be maintained as a living source, so as other research by NIST and industry groups is completed it can be added.

    b. What other steps would you like to see NIST take in response to the other challenges and when would you like to see them?

    Answer: As described in the response to the first question, the development of a standardized approach to durability and performance testing is key, as that will allow for a much easier promulgation of design standards needed for broader adoption of composites. This will also provide a framework for companies to follow in the future development of standards and guidelines for their products to ensure consistency across the industry. NIST's ability to convene the industry and end-users and the third-party validation from NIST's laboratories are essential to achieving these goals. As part of this effort, NIST can begin testing composite materials to establish a reliable database of durability and performance data, and the development of predictive models based on these data allowing the formulation and design of new composite products to perform in specific environments.

[1] NIST Special Publication 1218, "Road Mapping Workshop Report on Overcoming Barriers to Adoption of Composites in Sustainable Infrastructure," December 2017, available at: https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1218.pdf

Given the opportunity, the industry will interface with NIST to develop test methods and measurement standards for, among other things:

- Development of the appropriate resistance factors, to be used in the composite industry Load Resistance Factor Design (LRFD) Manual, to properly address seismic design for use of composite materials in infrastructure applications.
- Development of the appropriate fire test protocols for evaluating composite poles and other structural members and systems utilized for infrastructure applications.

Education and training is another important element. Information that flows from a NIST research initiative should be pushed outward into academic curricula as well as continuing professional education for the engineering and design community.

Finally, the perceived validity of a NIST composites program will flow in part from the network of participating entities. To assure the efficacy of this endeavor, NIST should maintain a network of engaged stakeholders that can advise and collaborate with agency staff to ensure the work is focused on addressing the specific barriers that prevent regular deployment of composite solutions. Those stakeholders would include representative companies and associations from the composites, design and construction industries, as well as academics involved in relevant research and state and federal agencies responsible for infrastructure development and maintenance.

