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

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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.