WHITE PAPER / **IMPLEMENTING DESIGN STANDARDS FOR RESILIENCY**

THE IMPORTANCE OF RESILIENT DESIGN WHEN DISASTER STRIKES

BY Joel Farrier, PE, ENV SP

Faced with the growing threat of natural disasters, cities are seeking more sustainable and resilient infrastructure. Civil engineers are among those leading the charge for the development of new design standards for critical infrastructure projects that can withstand disasters and enhance the long-term safety and welfare of all.

A global initiative is underway to design critical infrastructure that is more sustainable and resilient. Over the last 20 years, the reported economic losses due to extreme weather events alone has risen 151% globally, according to a policy brief created by G20 Insights. While needed in virtually every community, new design standards are especially valuable for cities undertaking major infrastructure upgrades in anticipation of upcoming events or to combat natural disasters. Solutions are needed that not only address immediate needs but also enhance quality of life long after an event is over.

New resilient and sustainable design standards are needed across a range of industries. Highways, bridges, ports, railways, seaports, airports and other transportation infrastructure all face a wide range of threats induced by climate change, as do water and wastewater infrastructure and solid waste disposal operations. Likewise, pipelines and the entire energy generation, transmission and distribution chain might take a fresh look at their infrastructure's resiliency.

Any design response will need to be tailored to the industry and geographic region, given that different types of infrastructure are threatened by different types of disasters and modes of failure. A few examples:

Aggravated Weather Events — As reported by many industry organizations and trade publications, climate change has resulted in more aggravated weather events, including greater storm frequency, precipitation, intensity and wind speeds. These higher-intensity weather events can trigger mudslides, mudflows, flooding and other geological disasters that can impact a variety of infrastructure. To minimize overall risks, more sustainable urban drainage systems are needed, including resilient flood routes, temporary storage areas and other multifunctional infrastructure designed to accommodate exceedance. Highways that can be used to channel excess water, curbs that can be raised or lowered to redirect water, and parks that can serve as temporary storage reservoirs are all examples. The Construction Industry Research and Information Association, among other groups, has developed an extensive body of research on sustainable urban drainage.

Flooding can have a particularly damaging effect on municipal water and wastewater systems, causing sewer overflows and the release of dangerous pollutants into floodwaters. Extensive flooding can also cause waste from solid waste disposal operations to build up in undesirable areas. To mitigate problems like these, new design standards might place priority on waste-to-fuel systems and other technical solutions that minimize waste buildup. In some cases, flooding concerns might alternately be addressed by decentralizing waste collection and storage or by implementing municipal composting programs.

Drought — Because of climate change and population growth, some parts of the U.S. as well as the world can no longer be certain of having access to the water supplies they need. Water shortages are not the only consequence. In California, for example, drought often leads to a cycle of drying soils and occasional intensive rainstorms. Pounding rain on dry soil can simultaneously result in mudslides and/or greater fire risk as well as higher vegetative fuel density. Some research points to the benefits of alternative water planning approaches that make it possible to respond relatively quickly to drought where it occurs.

Wildfires — Wildfires can destroy everything in their path, especially crippling entire regions if they bring down power lines and telecom infrastructure in the process. The use of more resilient building materials and design in high-risk areas can be part of the solution. For example, concrete pipe might be more resilient to high heat than steel pipe materials are. Increased vegetation management or construction of underground distribution lines and fire-resistant transmission infrastructure can all help prevent fires in the first place.

Another significant concern is the water contamination that can be caused by ash and rubble from burned structures that make their way into the water supply during post-fire rains. Transportation planners must also consider the impact of major disasters on the transportation network and the need for roadways that can accommodate large-scale evacuation.

Chronic Sea Level Rise — Much of the world's most important infrastructure, including seaports, levees, oil refineries, sewage treatment facilities and power plants, are constructed near water. As glaciers melt and areas with warmer water expand, such infrastructure will be threatened. To prevent water intrusion from causing corrosion and contamination, this infrastructure will likely need to be relocated, surrounded by high sea walls or otherwise hardened.

WHERE TO BEGIN

Sustainable and resilient design is typically achieved by implementing one or more risk mitigation strategies. In other words, existing design tactics or techniques might need to be altered in ways not previously considered.

Some infrastructure projects, such as electric transmission, systems, could require added redundancy to provide backup in case of system failure or increased energy demand. Designers might also need to consider ways to isolate, harden or provide physical protection of critical assets, or they might need to identify alternative ways of meeting needs. For example, seaports worldwide are exploring ways to develop their own emergency energy supply. Many large-scale ports are developing microgrids with renewable energy sources so operations can continue if a natural disaster cuts their connection to the electric grid.

Design approaches like these, in turn, might require municipalities and other regulatory bodies to update building codes to allow use of new approaches. Regulators, likewise, also will need to take a fresh look at environmental standards through a resiliency lens. More stringent zero-waste regulations, for example, can be helpful in supporting waste-to-energy and other sustainability efforts. Consider coastal revetments, which could possibly require new designs to address future sea-level changes. Designers will need to consider the significant potential impacts of higher waves or stronger storm surges on revetment design height.

In some cases, new design standards will involve the use of smart technology to add resiliency and sustainability to existing infrastructure. Sensors, cameras and cathodic protection systems, for example, can all be used to conduct preventive monitoring, allowing users to track and control operations through networked devices. For example, satellite monitoring can be used to assess high-risk areas for fire mitigation or soil stability to avoid system stressors like landslides.

TAKING THE LEAD

Engineers are already laying a path forward to a world with more resilient, sustainable infrastructure design. To be most effective, companies and groups wishing to join efforts to develop new design standards should consider a process that includes these steps:

1. **Assess vulnerabilities —** The best place to start is with an evaluation of the current vulnerabilities and risks facing your infrastructure and assets, as well as their impact on the community at large and on the environment. That includes inventorying assets and assessing and prioritizing the vulnerabilities of each in light of issues related to climate change, both individually and as part of the larger infrastructure system.
2. **Identify alternatives —** With vulnerabilities identified, the next step is to determine which approaches or combination of risk mitigation strategies are best suited to reduce potential issues in future scenarios.
3. **Design alternatives —** Planners and designers are next tasked with identifying the steps needed to address the identified risk mitigation strategies. Multiple design alternatives might be assessed for feasibility, constructability, cost and other issues.
4. **Assess construction approaches —** By the time a project is contracted for construction, there is limited opportunity to make changes that support sustainability and resiliency or incorporate new methods. However, there is also much a construction contractor can do to be more sustainable and to protect against climate-related emergency events. For these reasons, project management and construction professionals need to be engaged earlier in the development cycle and will play a critical role in the development of new design standards in the future.
5. **Consider interconnectedness —** A chain is only as strong as its weakest link. Strengthening one asset has only minimal value if the infrastructure it connects with fails. Designers must consider entire systems and work together to harden entire systems and communities rather than focus singularly on separate types of infrastructure. Mudslides, for example, can affect roads, bridges and other transportation infrastructure, which can, in turn, impact human health, communication and connections if the supply chain is disrupted. Particular concern must be paid to critical points where cascading failures can be catastrophic.

CHALLENGES TO OVERCOME

Those developing resilient and sustainable design standards will face the need to overcome significant challenges. First is the issue of predictive bias. Current design criteria are based on historical data, yet the past does not necessarily portend the future, a concept known as nonstationarity.

Unfortunately, the assumption of stationarity has been in place for decades in the engineering design profession. Most design standards were developed with no consideration of climate uncertainty and could contain systemic flaws as a result. The addition of climate uncertainty to an already long list of design considerations, coupled with the ingrained beliefs of "how design is done," can result in resistance and lead to inappropriate design standard choices.

Finding the money to pay for sustainable, resilient design also will present ongoing challenges, with need far outpacing public funding availability, particularly as the world struggles to recover from the coronavirus pandemic. Consider, for example, that light-duty vehicles currently travel approximately 3 trillion miles on U.S. roadways each year — a number expected to increase to 3.5 trillion in 20 years. Light-duty federal fuel tax revenues, meanwhile, are expected to remain relatively flat — at best — at $25 billion over the next two decades. Public-private partnerships and other innovative funding mechanisms will likely be needed to meet the enormity of the challenge.

LOOKING AHEAD

Creating more resilient and sustainable infrastructure will require new mindsets and fresh approaches to planning, design and construction. It will require professionals from multiple disciplines working with industry and government partners to develop holistic approaches to hardening entire systems and communities. The challenges are great, but the consequences of inaction might be even greater.

BIOGRAPHY

JOEL FARRIER, PE, ENV SP, regional environmental practice manager in California for Burns & McDonnell, has more than 25 years of experience in management and account development of technical services for water, transportation, environmental and power projects, including facilities and construction. He also has deep experience building teams across engineering, scientific and technical disciplines to address complex infrastructure issues.

ABOUT BURNS & McDONNELL

14892-IDS-0422