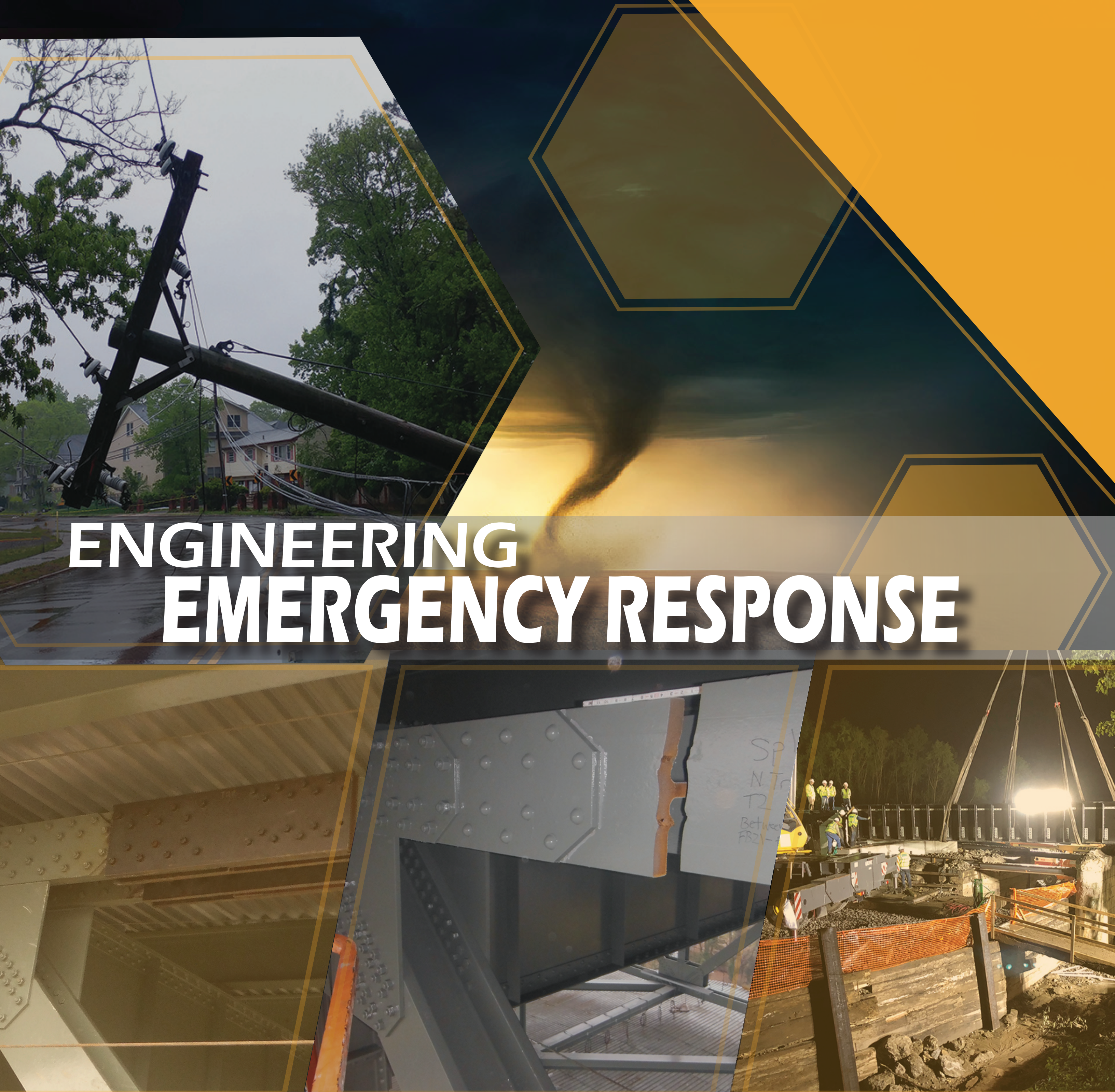
Pittsburgh ENGINEER

SPRING 2019

Quarterly Publication of the Engineers' Society of Western Pennsylvania



ENGINEERING EMERGENCY RESPONSE

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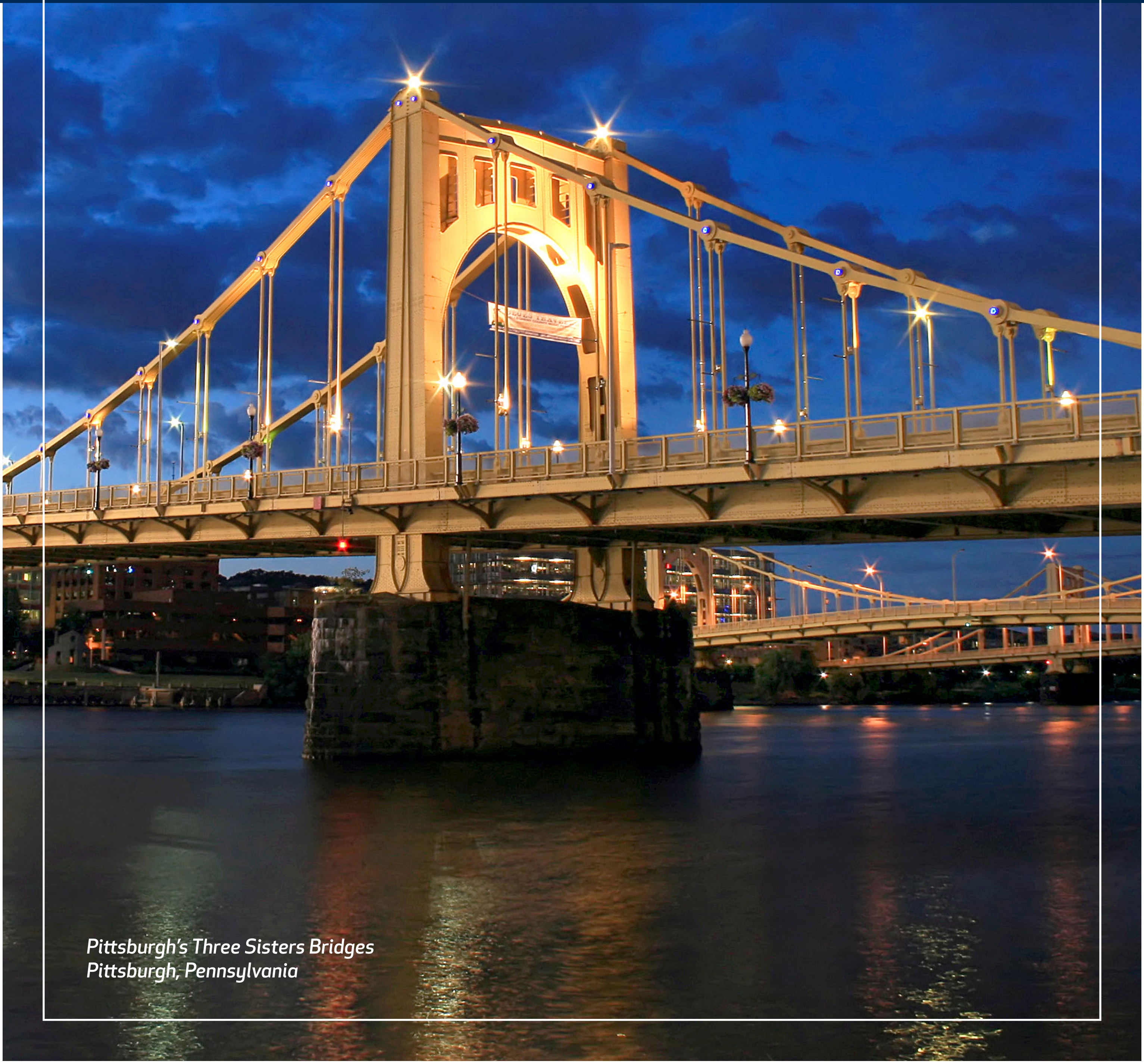

Pittsburgh's Three Sisters Bridges
Pittsburgh, Pennsylvania

Pittsburgh
ENGINEER
Quarterly Publication of the Engineers' Society of Western Pennsylvania

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Guest Editor Column

By: Cheryl Moon-Sirianni, P.E.
District Executive, PennDOT District 11-0

Cheryl Moon-Sirianni

The phone rings at 5:00 a.m. and a co-worker is on the line explaining that a roadway has just slid onto multiple apartment complexes. Once it is determined everyone and everything is safe, a normal person may immediately feel overwhelmed and anxious, but to an engineer this is the ultimate adrenaline high. Engineers are problem solvers by nature and there is nothing that gets the blood flowing more than an emergency. In addition, there is no greater opportunity for egos to be placed aside and for the ultimate in team building and cooperation to occur. In this *Pittsburgh ENGINEER* edition, you are going to read about some recent emergencies that regional engineers have had to deal with over the past few years. Emergencies exist in many forms and what is obviously the common theme is that you really can't prepare for most of them.

Many of the emergencies have occurred due to good old mother nature wreaking havoc on the region. Flooding and heavy storms are the main cause of many of the emergencies in Southwestern Pennsylvania destroying roadways, washing out bridges and causing the rivers to rise to levels that you will read about in Lou Ruzzi's article on the Barge Incident that caused loose barges and bridge hits in the Golden Triangle of Pittsburgh. Lisa Hoekenga and John Dietrick write about a similar result of flooding whereby Michael Baker International used engineering ingenuity and accelerated bridge techniques to replace a railroad structure within 24 hours.

Many of the landslides in the region are caused by excessive rainfall but sometimes they don't manifest until days, weeks or months after the storms when the hillsides are saturated and cannot hold themselves or the roadways any longer. That is exactly what occurred on Route 30 whereby minor dips occurred in the roadway but there were no standard signs of a slide.

In Michael Soller's article, mother nature uses different tactics in the Midwest and he speaks about how preparation for tornadoes can greatly aid the teams responsible for emergency response and maintenance of continuing operations.

Sometimes emergencies occur due to a result of human behavior and that is what precipitated the Liberty Bridge Fire written about in the article by Jason Zang. As with many of the emergencies that occur on public infrastructure, the Emergency Service providers and Fire Departments provide exceptional service to ensure the safety of the traveling public and the communities they serve, and the Liberty Bridge fire was no exception.

The Delaware River Turnpike Bridge experienced a similar frightening experience to the Liberty Bridge Fire, whereby engineers had to first investigate the stability of the structure before beginning to make repairs. Jim Stump details the steps involved in the investigation and repairs of that vital structure to the Eastern Pennsylvania travels in the article 48 Days of Challenges.

Closures of roadways and bridges may affect tens of thousands of travelers, but Greg Reed and Alexis Kwasinski explains in the Power Grid Failures article that power outages and blackouts can impact millions and can be so detrimental to the economies in the areas where they occur. Instituting resiliency into the systems and creating strategic plans prior to the occurrences are how the power industries are working to reduce those impacts.

So why do engineers thrive in emergency situations? Well there are many reasons and you will read about them in these articles. Emergencies allow engineers to often throw out the manuals, the processes and the procedures and allow them to use engineering judgment and oftentimes common-sense approaches to the situations without multiple and timely reviews. At times, innovative techniques and cutting-edge technology are utilized to expedite remediation of the problems. But most importantly, the greatest satisfaction for the folks involved in all these situations is the opportunity to be an integral member of some of the most cooperative, creative, intelligent and selfless teams. The ingenious approaches to these emergencies by the industry teams, including world class and extremely inventive designers and contractors, allow these problems to be remedied in time frames that significantly reduce impacts to the communities and the respective users of the facilities. These same emergencies that wake us up at night, cause us to worry about the safety of all involved, encompass all our thoughts, force us to reach outside of our comfort zones, and allow us to work with the best and the brightest teams in our industries, are exactly why we signed on for that engineer title.

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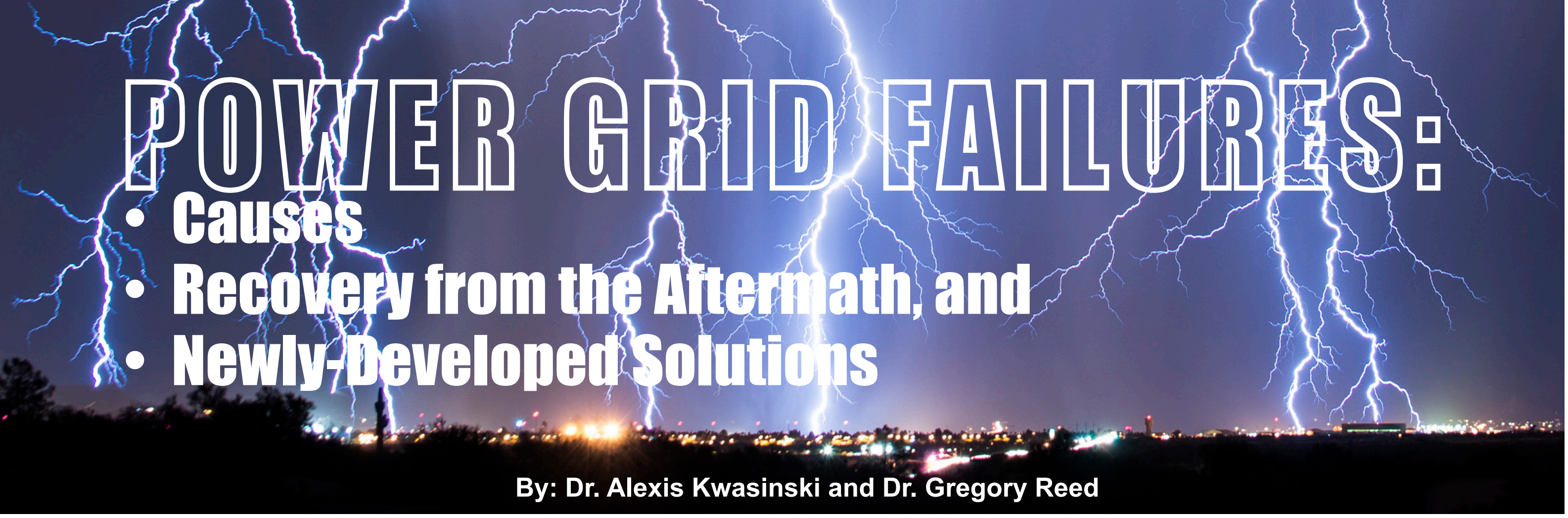


POWER GRID FAILURES:

• Causes
• Recovery from the Aftermath, and
• Newly-Developed Solutions

By: Dr. Alexis Kwasinski and Dr. Gregory Reed

There is nothing in today's modern society that generates quite as much fear, panic, frustration, devastation, loss, and sadly even fatality, more so than an electric power grid failure or blackout.

While the number of major, large-scale blackouts in the U.S. and most developed nations has decreased significantly over the first two decades of the 21st century – noting that the last major event in North America was the Northeast blackout of August 14, 2003 – new pressures on grid infrastructure are causing an increase in local and regional power outages. Historically, with each large-scale blackout we have experienced – the first recognized event dating as far back as the 1965 New York City blackout – significant lessons have been learned, along with a surge of new investments, resulting in technological, operational, design, and policy improvements. The past two decades have been no different, with a marked increase in electric power transmission and distribution infrastructure spending on smart grid solutions and many other related technology advancements, all of which has enhanced our grid networks' operational capabilities and maintained high levels of overall electric reliability.

The other evolution is in relation to the trending increase in the outages from major natural disasters and extreme weather events, as well as cyber-threats, both physical and digital

However, there are dynamic changes occurring in the power industry today as a result of new markets and policy, as well as in relation to environmental conditions, that have set in motion new challenges for the grid and our ability to not only preserve its excellent reliability, but to also increase its sustainability, security, and resiliency, along with sound economics so that electricity remains both affordable and accessible to all members of society.

One evolution that is taking place is the rapid change in our energy resource portfolio. As we continue to shutdown older, less efficient, and high carbon-emitting fossil-fueled generation, we are replacing much of this decommissioned energy with a combination of natural gas and renewable (primarily wind and solar) resources, with hydro and nuclear mostly remaining constant. The renewable resources present new challenges with grid integration due to variability and intermittency, but also in terms of location. Not only are the older fossil generation plants being replaced with more environmentally-friendly sources of energy, but the location of these new resources at the transmission level are often further away, requiring transmission line expansion and other grid modernization enhancements. Counter to that, but no less challenging, is the proliferation of more localized resources at the distribution and consumer end of the grid, creating everything from unanticipated two-way flows of electricity to distribution feeder capacity overloads – all new to the power industry just within the past decade. Recent developments in the form of 'microgrids' (smaller, independently sourced and operated grid systems), are providing even more challenges, and opportunities, as we strive to improve the resiliency and security of electric power supply.

The other evolution is in relation to the trending increase in the outages from major natural disasters and extreme weather events, as well as cyber-threats, both physical and digital, which are having the greatest affect and impact on our grid. Many of these occurrences are resulting in an increase in more local and regional outages and blackouts, some lasting for days and even weeks until full disaster recovery is completed.

Large and long-term power outages after natural disasters have shown that even relative little damage can have a severe impact. For example, although since 2005 the continental United States and Puerto Rico have been affected by an unusual low number of hurricanes, their impact on electric power grids has been significant. These storms—Hurricanes Ike, Gustav, Irene, Isaac, Sandy, Harvey, Irma, Maria, Florence and Michael—have resulted in over 27 million total outages, costing over $435 billion in economic loss, and unfortunately claiming almost 4,000 lives. Not to mention the months and years of displaced homeowners and business, and the related downstream and long-lasting impacts, well after the power and other services have been restored. And while hurricanes tend to dominate the news headlines, other extreme weather and natural events, such as ice storms and earthquakes, place added stress on the grid.

Furthermore, we continue to be subjected in different ways from criminal activities, including cyber-threats and physical attacks on infrastructure. While we remain vulnerable to these issues, we must continue to be vigilant in the face of the threats and develop preventive measures and solutions. We must also be more responsive in our approaches to recovery and restoration when an adverse event has taken place. This begins with the planning process, design, and ultimate implementation of more robust, secure, and resilient power infrastructure, technology, and operation.

Regardless of the cause, recovery from the aftermath of a major power outage event requires a very complex and strategic emergency response approach. Coordination of first responders, utility crews, service organizations, and the community, must all work in harmony to reduce the overall negative impacts and accelerate recovery operations.

Damage to electric power infrastructure in Texas after Hurricane Ike

Successful coordination starts well before an extreme event strikes by establishing thoroughly planned and tested service restoration and logistical processes.

Electric utility trucks lining up after Hurricane Isaac to restore service along Louisiana HWY 23, south of New Orleans.

Successful coordination starts well before an extreme event strikes by establishing thoroughly planned and tested service restoration and logistical processes. A fundamental component of these processes is having in place mutual assistance agreements before a disaster happens. Such mutual assistance agreements enable restoration crews from other electric utilities to be deployed in a disaster area within hours of an outage event, and thus reducing the restoration time by days and even weeks. The importance of training and preparation to mitigate power outages after an extreme event highlights the importance of well trained and experienced personnel, that are the backbone of the electric power utilities. As the average age of electric utility employees increases, an aging workforce becomes an important vulnerability and makes electric crews formation a main need for making electric grid utilities more resilient.

Another important vulnerability affecting electric grid resilience is the financial health of electric utilities. The correlation between financial conditions and resilience was demonstrated when in 2017 Hurricane Maria affected Puerto Rico, causing the worst power outage in U.S. history. A main factor affecting the Puerto Rico Electric Power Authority (PREPA) preparation and response during this hurricane was their limited access to resources, resulting from their bankruptcy protection filing a few months before Maria affected the island.

Use of various restoration technologies is also an important component of improving resilience by reducing the restoration time during an extreme event. Initially, increased use of drones and remote sensing devices increase situational awareness, by allowing a faster identification of areas in need of repair. Once these locations are identified, electric utilities implement various technologies in order to accelerate the restoration time. Substations are a component of power grids that are particularly important because of the large number of customers that are usually affected when a substation is damaged.

A utility substation flattened by Hurricane Harvey. A temporary transformer used to restore service can be seen on the right.

A mobile substation used to restore service to a destroyed substation (in the background) after Supertorm Sandy

Use of mobile substations with transformers and switchgear mounted on trucks is a technology that has increasingly been used in the aftermath of natural disasters around the world in order to restore service to substations. Transmission and sub-transmission lines represent another set of electric power grid infrastructure and components that are particularly critical. In many cases, these lines are restored with provisional towers until long term repairs can be completed. Still, in some locations, even temporary lines take too long to be constructed. In these cases, electric utilities sometimes use diesel generators to power a subdivision or large building until lines are repaired.

A temporary transmission line under construction to replace a damaged line. Remains of a downed transmission tower are observed in the foreground.

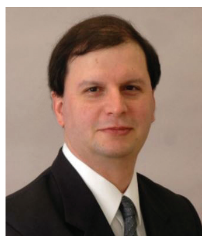
Underground lines and cables are a common technology that is often times requested by the public in order to increase power resilience to storms. There are certainly strategic benefits to underground infrastructure in certain cases, and are a necessity for today's urban environments and densely populated areas. They are certainly less prone to issues from hurricane force winds, tornadoes, ice storms, and similar events that take down lines and poles. However, underground lines/cables are not always the best solution, and in fact in some cases can present a limitation. As the earthquake that affected Christchurch, New Zealand in early 2011 shows, although underground lines are less impacted than overhead lines during storms, buried cables may have severe damage during earthquakes. Moreover, buried infrastructure is very costly as compared to overhead, which may ultimately reduce

One of the many buried cables damaged during the February 2011 Earthquake in Christchurch, NZ.

resilience indirectly due to the high financial stress that electric utilities may have when paying for the investment of underground facilities. Moreover, underground cables also have a higher repair cost and longer replacement time when a fault occurs under normal conditions happen. Regardless, each case is different and the cost/benefits must be weighed to determine the best approach to resiliency.

As the power industry moves forward into this new era of challenges and threats from various sources, it is certain that new technologies and solutions will continue to play a large role, which in turn creates new opportunities for advancement. Modern society is increasingly dependent on reliable, safe, secure, and resilient energy supplies and electric power delivery infrastructure, and we must continue to strive to improve all of these elements in future designs and implementation, while maintaining affordable electricity rates.

About the authors...



Alexis Kwasinski is an Associate Professor at the University of Pittsburgh. Previously he was an Associate Professor at The University of Texas at Austin. He holds a B.S. degree from the Buenos Aires Institute of Technology (Argentina) and M.S. and Ph.D. degrees from the University of Illinois at Urbana-Champaign. He also has 10 years of industry experience working for Telefonica and Lucent Technologies. He also conducted many field damage assessments after natural disasters that affected Japan, New Zealand, Mexico, the U.S., and Chile since 2005.

Dr. Gregory Reed is the Director of the University of Pittsburgh's Center for Energy and the Energy GRID Institute and Professor of Electric Power Engineering in the Swanson School of Engineering's Electrical & Computer Engineering Department. Reed has over 33 years of combined industry and academic experience in the electric power and energy sector, including positions in engineering, research & development, and executive management and leadership throughout his career with the Consolidated Edison Co. of New York, ABB Inc., Mitsubishi Electric Corp., and DNV-KEMA. He is an active member of the IEEE Power & Energy Society, the American Society of Engineering Education, and ESWP. Dr. Reed earned his Ph.D, in electric power engineering from the University of Pittsburgh (1997), M.Eng. from Rensselaer Polytechnic Institute (1986), and B.S. from Gannon University (1985).

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Recovery from the ROUTE 30 LANDSLIDE

Aerial view of Route 30 as hillside stabilization work begins

Looking down from Route 30

By: Cheryl Moon-Sirianni, P.E.

On April 7, 2018 a significant landslide resulted in the closure of Pennsylvania State Route 30 in Allegheny County. The route is a principal artery to Pittsburgh and supports more than 22,000 vehicles per day. The slide demolished one apartment building, severely damaged another, and impacted a single-family home.

The roadway was reportedly sinking, causing a partial to eventual full closure of the major east-west commuter route. During the initial reconnaissance period, there were no obvious signs of movement or telltale signs of landslide propagation. The day before the slide, the engineers located a crack in a retaining wall along the slope, the wall had moved slightly, and was leaning against an old basement wall remnant, left in the ground from the days of the original Route 30 construction, circa 1930. From that point forward, the investigative team shifted its focus from determining the cause of the movement, to making provisions to protect the public and remove residents from out of harm's way.

The investigation crews were immediately asked to convert their efforts from looking for the problem and prepare to stop the movement by excavating the road to remove the pressure from the failing retaining wall. However, the continued shifting of the ground surface as daylight waned, and the deteriorating weather conditions as another round of spring rains fell, prevented the crews from safely working through the night. Shortly before daybreak on Saturday, April 7, 2018, the entire slope failed, sending thousands of cubic yards of landslide material and debris into the neighborhood below. Thankfully the quick action by the PennDOT employees and the East Pittsburgh Police Chief to evacuate all residents ensured that no injuries occurred due to this catastrophic failure.

Immediately following the slide Allison Park Contractors (APC), District 11 On-Call Geotechnical Contractor, went above and beyond by carefully removing the damaged buildings while searching for the former residents' belongings. Note when the residents were evacuated, all of their possessions including medicine, pictures, mementos etc. were left behind buried by the landslide. APC worked around the clock playing leap frog on site to remove debris

while Gannett Fleming (GF) evaluated structural stability of remaining structures and collect soil and rock samples for design.

If an emergency landslide was not enough to focus resources on, it was determined that the detour route required travel over a posted bridge prohibiting both construction and commercial truck traffic. This had to be repaired prior to the slide remediation starting due to the concern that the contractor needed to use this route to access the site. Michael Facchiano Contracting, the Districts On-Call Bridge contractor, performed a slab replacement on this culvert on two consecutive weekends working around the spring rains.

GF and PennDOT spent the next two weeks working side by side, night and day to devise a plan to repair the roadway and make accommodations for the displaced residents. A commitment was made by all parties including Governor Wolf and Secretary Richards to make this project the number one priority. District 11 set a goal of two weeks for design and two to three months for construction.

Daily conference calls were held by Federal Highway Administration (FHWA), PennDOT and GF to ensure all required activities were advancing. GF determined that an anchored soldier pile and lagging wall was the most appropriate design for the expedited construction required and could be designed based on the limited investigation that was performed. Details were provided for the excavation and rock benching above the wall and it was determined that the remaining items including roadway and drainage would be handled as Design Build.

Fifty-four contractors and vendors attended the pre-bid for the project and after 13 days from the original slide, bids were officially opened. Golden Triangle Construction(GTC) was the low bidder at $6.5 Million. The project was awarded on the same day and work began immediately.

GTC immediately stepped into action excavating slide material and working with their previously assembled team of subcontractors and vendors began drilled shaft work within 23 days of the bid date. This team was remarkable in the fact that the galvanized soldier piles were delivered and installed in conjunction with the shaft work. The tie-back anchor activities occurred 12 days after the drilled shaft start date which is further testament to great organization, scheduling and teamwork. During those activities, 30,000 cy of PTM 510 Rock and 14,000 cy of foreign borrow were delivered to the site and placed as the drilled shaft concrete cured. The road reconstruction and drainage were the last activities to occur and by June 27, 2018 all physical work required to open S.R. 30 was complete.

We literally had to make it up as we went along, all while working under the constraints, guidelines, parameters, etc. of statewide procedures.

PennDOT Right-of-Way staff, along with Allegheny County Emergency Services and disaster relief organizations, were working behind the scenes during this time frame assisting the 31 evacuated residents. These ladies and men were working day and night to ensure the displaced residents were provided with housing and the essential needs. All apartment residents were displaced until construction was completed and 11 of those residents' apartments or homes were destroyed. Relocation activities continued for 11 months after the event.

It is worth noting that we did not have any approved procedures to relocate people as part of an emergency situation such as this. The normal process is to identify new housing prior to relocating people when required. However, due to the emergent nature of the Route 30 slide, this wasn't something we had in our "playbook: We literally had to make it up as we went along, all while working under the constraints, guidelines, parameters, etc. of statewide procedures. Due to the emergency nature of this incident, the people were forced to evacuate with the clothes on their back and anything they could carry. Personal belongings, family mementos, medicine, food, clothing, instruments, etc. were left behind buried under the rubble. They were relocated to various hotels in the area. Many of these residents did not have their own transportation to the hotels. The local transit agency, Port Authority of Allegheny County, and ambulance services provided transportation. The Department worked with Allegheny County Health and Human Services, Salvation, Army and other local human service organizations to provide basic necessities like personal necessities, food and clothing.

In summary, the remediation of the S.R. 30 landslide and the attendance to the displaced residents were the epitome of the ultimate partnering and cooperative experience. Although not without challenges, the urgency and importance of the project was understood by all and this project was completed three days ahead of an extremely aggressive schedule and without injury. This could not have been achieved without the collaborative partnership between the designer, the multiple contractors and vendors involved on the project, PennDOT and FHWA.

About the author...

Cheryl Moon-Sirianni, P.E., is the District Executive for PennDOT District 11-0. She is a registered professional engineer since 1992 and a graduate of Penn State University. She has worked for PennDOT for 33 years holding positions of Assistant District Executive for Design for 13 years, Contract Management Engineer, and Project Manager. Cheryl is a Lifetime Member of American Society of Highway Engineers, a member of the Engineers Society of Western PA and a member of Women's Transportation Seminar.

What Just Happenned?

By: Louis J. Ruzzi, P.E.

On the early morning hours of January 21, 2019, many PennDOT and Port Authority personnel planned on taking advantage of the day off on the Martin Luther King Holiday to sleep in for a bit. But it wouldn't be long before many of those same staff members would be up early on their day off, to handle a bridge incident. Around 4:30 a.m. a tugboat moving 12 barges down the Monongahela River struck the pier of the Liberty Bridge and scattered the barges loose from the tug. As a result, several other bridges along the way were hit, or suspected of being hit and closed immediately. These bridges included Liberty (A), Smithfield (C), Fort Pitt (D), West End (not identified in above photo), and McKees Rocks Bridges (not identified in above photo), all owned by PennDOT, and the Panhandle Bridge (B), owned by the Port Authority of Allegheny County. (Refer to above picture for location of these bridges.)

By 5:01 a.m., the Coast Guard had contacted Allegheny County 911 Center, who then contacted the City of Pittsburgh Police and PennDOT. The Port Authority was contacted seven minutes later. Between 5:01 a.m. and approximately 5:30 a.m. all of the previously mentioned bridges were closed. While January 21 was a holiday, traffic still came to a stop on many arteries into the City of Pittsburgh. This complicated the response to inspect and reopen the bridges.

Even though PennDOT's and the Port Authority's bridge inspectors were contacted by 5:45 a.m., they still had to find a way to get to the bridges to assess their condition. Inspectors had to go thru the same clogged arteries as everyone else on the roads. Inspectors that lived less than five miles from the Liberty Bridge, could not get to this structure and had to be re-routed and to go Plan B. Plan B was to contact City of Pittsburgh River Rescue to see if their boats were available to help the inspectors get to the bridges, instead of sitting in the congested roadway traffic. Fortunately, River Rescue was able to help and instructed PennDOT inspectors to meet at their boats at their dock near PNC Park

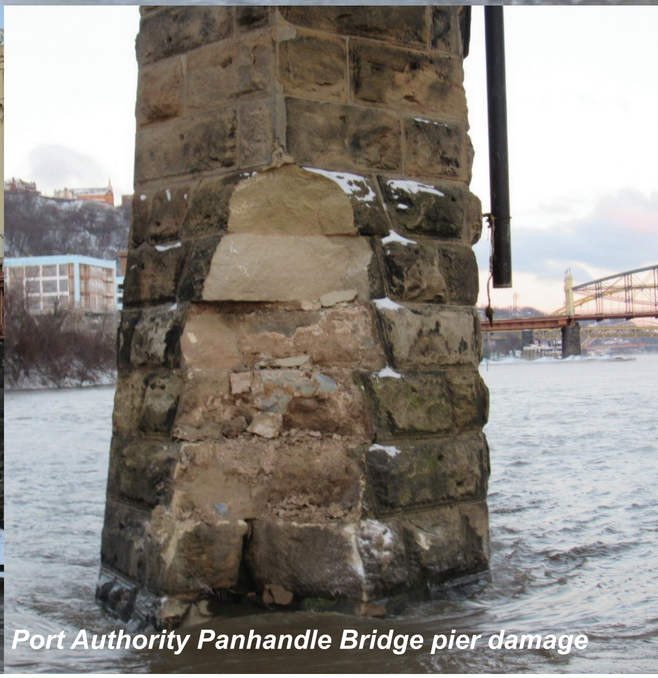
Bridge inspectors had arrived at PNC Park by 7:00 a.m., and were able to get on the two River Rescue boats provided, on their way to the bridges. The inspectors concentrated their efforts on opening the bridges with the most traffic first, which were Fort Pitt and Liberty Bridges. Around this time, another set of PennDOT inspectors were able to get to McKees Rocks and West End Bridges and were able to be determine that the barges had never reached either bridge and that they could be safely re-opened.

After leaving the West End Bridge, the second set of PennDOT inspectors moved onto the other bridges that were still closed. They then performed inspections on top of the bridge by looking for icy conditions on the bridge deck,

Fort Pitt Bridge Pier damage


Sunken barges near Smithfield Street Bridge

Sunken barges near Smithfield Street Bridge


Port Authority Panhandle Bridge pier damage

mis-alignment of the expansion dams, and ensuring the superstructure was still on its bearings. At the same time, the inspectors in the boats were checking for damage to the piers. This procedure was used until all the bridges were inspected and re-opened by 9:00 a.m., about four hours from our initial notification.

The Port Authority coordinated their inspections with their staff to look at both the subway rails and piers of the Panhandle Bridge. In addition, PennDOT inspectors in the River Rescue Boats also looked these piers on their way back from Liberty Bridge. This bridge sustained the most damage out all the bridges, with a 10' chunk of the pier nose being knocked off. Their inspections were completed and the bridge was re-opened by 10:00 a.m.

PENNDOT OWNED BRIDGE DAMAGE

- Liberty Bridge: did not have any notable damage to any of its piers.
- Smithfield Street Bridge: impacted at the two piers at the south end of the structure (Pier 04/Pier 05). There are currently two barges still stuck at the upstream side of these piers. One is floating and the other is partially submerged. There was minor scape damage to the pier above the water level and no other issues noted. A follow-up underwater inspection was scheduled to review the foundation for erosion of material under the footer that the barge could be causing and found no issues. (
- The Fort Pitt Bridge was impacted at the upstream nose of the north river pier with very minor damage and no visible settlement problems at the bearing area.

- The West End/McKees Rocks Bridge did not incur any damage as barges did not reach or impact the West End or Mckees Rocks Bridge as per conversation with river rescue personnel.

A follow-up underwater inspection on the Smithfields Street Bridge was performed on January 29, 2019 by Infrastructures Engineers. This report documented approximately 18-ft in height of numerous fractured, missing, and/or dislodged stones to the nose of Pier #7. The damage above the water line extended approximately 10-ft with approximately 8-ft of damage below the water line. PennDOT also followed up with an underwater inspection of Smithfield Street Bridge, since barges were sunk very near one of its piers.

Many thanks go out to all the people from PennDOT, the City of Pittsburgh Police and River rescue, the Port Authority and the media. As a result of this multi government/agency cooperation, all the bridges were re-opened in five hours by 10:00 a.m

After Action Reviews were done by PennDOT with the Coast Guard , the City of Pittsburgh and the Army Corp of Engineers. These meetings will help further develop policy, improve communication between the agencies, and get the bridges opened to the traveling public in a most expeditious and safe manner.

About the author...

Louis. J. Ruzzi, P.E., District Bridge Engineer, PennDOT, Engineering District 11-0. Mr. Ruzzi graduated from University of Pittsburgh at Johnstown, BS in Civil Engineering Technology, in 1980 and has been a registered P.E. in PA since 1989. He worked for consulting firms for 4 years until 1985 doing structural steel and concrete design and design of nuclear pipe supports/instrumentation supports. He has worked for PennDOT for the last 34 years a Bridge Designer, Bridge Inspection Squad Leader, Assistant Bridge Engineer, and District Bridge Engineer for the last 19 years. He is currently Chairman of T20 Tunnels(AASHTO –SCOBS) since 2010(member since 2006) and Member of Engineers' Society of Western PA's International Bridge Conference Executive Committee since 2007.

IT WAS RIGHT OUT OF THE WIZARD OF OZ

By: Michael J. Soller P.E. CPC, DBIA

We had a great memorial weekend trip visiting family in Canton, Michigan. That all changed on the way home when the clouds grew dark and winds picked up. Then the cell phone lit up with incoming calls. Indianapolis was in the path of possible tornados and as the director of capital projects for AT&T in Indiana I was told to be prepared for storm trouble.

Flash forward a few hours, and the call was "the roof is torn open and water is coming in". An F2 (113-157mph) tornado (1 of 5 in the area) had just passed over a central telephone office lashing the building, twisting trees, sending debris flying, ripping the roof and letting water into the building.

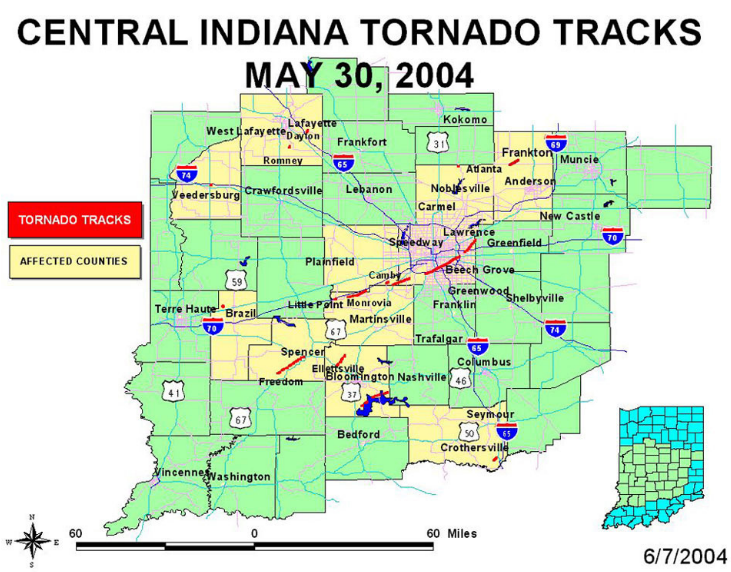


Image credit: NOAA

This exposed the DC powered, open buss, telephone system to an uncontrolled environment that threatened the communication for emergency responders and the community. I placed some key calls to mobilize our team. Upon arriving at the central office, we found a building with flashing and louvers dented or missing, a parking lot and HVAC units with damage caused by flying debris, and a building running on standby generator power.

THE RESPONSE

We needed to provide for access, damage assessment, temporary construction, assure security and personnel safety to mitigate the damage. We implemented a planned response and learned some important lessons.

First we activated our emergency call-out list: This started bringing key leadership and craft to the site to secure the building and begin to stop the flow of water into the building. We communicated with our cell phones, but today, there are so many platforms to use. I recommend confirming with your team, which platforms you will use for critical communication. Will it be phone, text, email or a combination? Or will it be another response system entirely? The key message is decide on a limited number of platforms, and stick to those platforms. This will allow for a focused set of communications for the team members and consolidate the information for a post crisis debrief and audit.

Second, we sent our field construction leaders to retrieve the response materials we had staged for this type of event. These materials included plywood, framing materials, fasteners, plastic, metal strapping, wire, plastic pipe and fittings, buckets and lots of tape. This also included several carpenter, demolition and electrical tools to aid in the development of the needed solutions. Some tools were on the service trucks, but most of the tools were located in the response room locations previously designated as part of the plan. This was important, because several people had to be available to retrieve the materials, and the location had to be accessible by many people. This is no small feat when you are dealing with secure buildings.

Simultaneously with the deployment to retrieve materials, I arrived at the Central office to understand the operating environment and triage the damage to the building. This included evaluating the extent of the roof damage and the locations where water was coming into the building. It also included evaluating operation of the HVAC system to assure cooling and any restrictions or failures due to the damage to the building. In addition, we evaluated the electrical standby power system. Even though we were fortunate the generator was operating, we knew we would be without permanent power for several days because of the breadth of the storm damage. Assuring access to diesel fuel for the generator to maintain continuous operation became a critical deliverable.

> **"We knew we would be without power for several days because of the breadth of the storm damage."**

After starting the water management plan, we began a 72-hour race to secure the building and get skilled crews to the building with the proper tools and equipment to repair the roof. This ultimately involved dozens of people who brought their skill, courage and ingenuity to assure the ongoing operation of the telephone system.

LESSONS LEARNED:

We were fortunate that we imagined the emergency scenario before the event happened. While this is not special, the key is to practice the implementation and verify that the tools, material, and people are in place and ready. As with any adrenaline laden event, the best response comes from the practiced implementation of a plan that contemplates multiple scenarios. The key to this multivariate response is to clearly identify and write down the critical systems which need to operate regardless of impact. With this checklist, the response team will know where to first focus their efforts and energy, before they redevelop the supporting systems for critical operation.

In addition, the critical response team needs to have diverse team members with separate skills which match the critical systems. These include, electrical and controls, HVAC and Mechanical backgrounds, and general construction craft to form a complimentary cross functional team. This team will be your virtual Swiss army knife able to solve issues for any event that may occur.

As we lived through the event, there were some new lessons learned which construction and engineering crews will want to address with your plans. They include:

1. Plan for emergency action credentials to show professional emergency responders and assure passage to the affected location. The tornado caused downed power lines and many roads were closed because of the downed trees and windblown debris. Since the emergency responders were protecting the public, our response crews needed to explain why they were on the roads and where they were going. This meant that our leaders needed to respond to communications from the authorities to authenticate our people as supplemental emergency responders. This helped us understand that we needed to have special laminated placards designating who we were, why we were out on the roadways, and by who's authority we were being called to a storm ravaged area.

2. Encourage your team to have child care options in the event of an emergency. It happened that my wife was responsible for distribution operations for a power company affected by the same tornado. Thus, we both were called into action and we had three small children at home. We were fortunate that our friends were available to care for our children for this unplanned extended time period. Openly discuss this potential with your team to determine a workable plan when they agree to join the response action team.

3. Plan for and implement a shift based approach to handing off continuing operations support. Many construction and engineering events only need a limited amount of focused response time. This may be for several hours, but sometimes the critical work lasts for days. Envisioning this early during the response is important to assure the safety of the responders, and to provide an orderly handoff of tasks. This is much like planned outage work at power stations, but the difference is it is unplanned. Thus, it is better to plan for a shift change and not use it, than to hope that it will not be needed, and be faced with fatigue and limited options.

THE OUTCOME:

The facility never lost power, communications were never interrupted and no one sustained injury during the response event. You can be assured though, we learned and improved our response plan and were better because of this work. Question to the reader. Do you have the personal contact information for your key leaders and skilled response team? Do you have the keys to access response materials? Have you practiced the call out with your team? If not, maybe today is the day to call them.

About the author...

Michael J. Soller P.E. CPC, DBIA, is a V.P. of Business Development at Bowen Engineering. For more than 22 years his career Mike was a construction operations manager and director. He earned a B.S. Civil Eng. from the University of Dayton, and an M.S. from Purdue University. Mike has published multiple peer reviewed papers regarding Design-build delivery of projects, wastewater treatment technology implementation, and teaching. Mike is a member ASCE, ASEE, DBIA, AWWA, Water Environment Federation, IUPUI's Construction Engineering Advisory Board, and a member of the International Water Conference Executive Committee.

Editor's Note:
Detailed information on the actual storm can be found on the NOAA website, found here: https://www.weather.gov/ind/may302004tornadoes.

For actual photos of this storm, please visit the NOAA website, found here: https://www.weather.gov/ind/marionmay30

Emergency Repair of the Delaware River Bridge: 48 DAYS OF CHALLENGES

By: James L. Stump, P.E.

On Friday, January 20, 2017, the Engineering staff at the Pennsylvania Turnpike Commission was notified of an emergency situation that occurred at the Delaware River Turnpike Bridge, a critical river crossing connecting the Pennsylvania and New Jersey Turnpikes. A painting contractor had discovered that a primary member in the top chord of the north truss had fractured completely through the cross section of this member leaving an approximate 2" gap between the fractured surfaces. For the next seven weeks, a major effort was undertaken to address the many challenges associated with this fracture. Obviously, we knew where the fracture occurred, but many questions needed to be addressed such as:

- What was the stability of the spans where the fractured occurred?
- Can the fractured member even be repaired and, if so, how long will it take?
- What caused this member to fracture suddenly after being in service for 61 years?
- Is this defect inherent throughout the rest of the 6,571 feet long structure?
- Finally, the most important question to the bridge owners: can the bridge owners reach a level of confidence to reopen this bridge to the travelling public?

THE STRUCTURE

The Delaware River Turnpike Bridge carries I-95 over the Delaware River between Bristol, PA. and Burlington, NJ. The bridge was built in 1956 as a joint effort between the New Jersey Turnpike Authority (NJTA) and the Pennsylvania Turnpike Commission (PTC) with an overall length of 6,571'. Both toll agencies own and maintain the bridge and approach roadways. This bridge superstructure is comprised of a 3-span continuous arch truss with a center suspended span of 682' between the piers flanking the river channel. The approach spans on both sides are three and four span continuous deck truss units as well as a number of traditional short simple girder-floorbeam spans. Carrying 42,000 vehicles a day, this bridge is a critical piece of the interstate network in this area.

THE FRACTURE

The location of the fracture was on the Pennsylvania side, Span 16, in the four-span continuous deck truss. The large member, also known as a "jumbo" member, was a W14 x 314 rolled section of the top chord, north truss. These jumbo members were used in areas of high load and stress and were rolled from high strength manganese steel. These members can suffer ductility loss and embrittlement from welding which is generally prohibited where this type of steel is selected. There was no welding specified on these members and none should have been done.

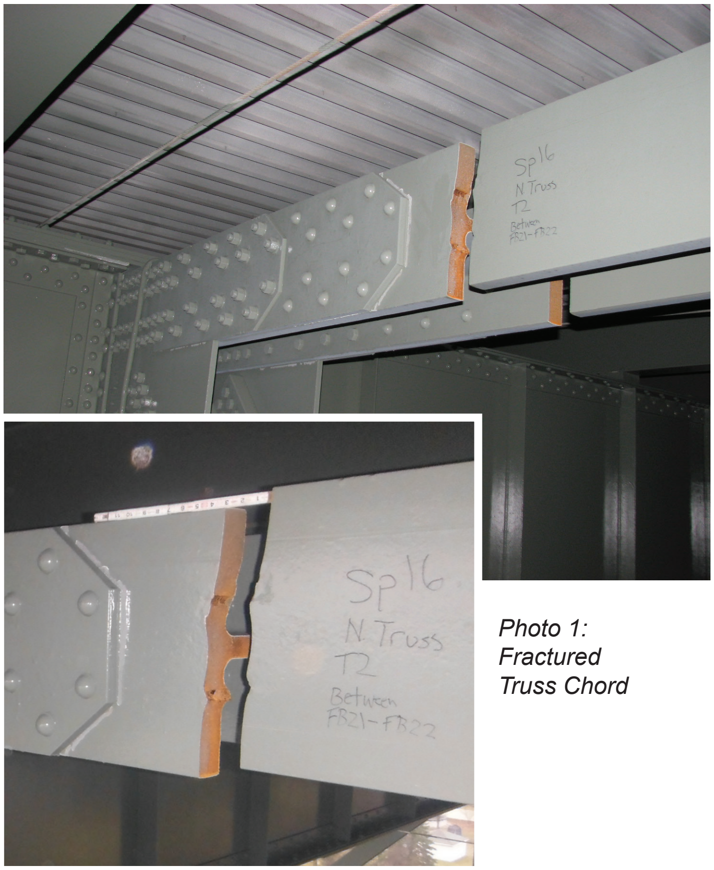


Photo 1: Fractured Truss Chord

After this fracture occurred, the bridge did not really show any change in stability and function. The surface corrosion evident on the fractured surface suggested that the fracture may have occurred days or even weeks prior to being discovered. The brittle nature of the fracture with no ductile behavior in the base metal suggested that the fracture was immediate and shook the structure as evident by the cracked paint at the adjacent gusset plate connection. (See Photo 1)

The fracture would later be identified as a brittle fracture through the entire section initiating from two mis-drilled holes filled with weld material. This welding induced a stress riser condition in the manganese steel of the member. The belief is that this weld material was used in an attempt to correct these mis-drilled holes in the shop during the original fabrication.

OBSTACLES AND SOLUTIONS

The many challenges associated with getting this structure back in service started the first day. Once the owners were made aware of the fracture, the decision was made to close the bridge to traffic immediately as well as the three local roads under the structure. Closing a major river crossing with the amount of traffic on this bridge required coordination from internal parties as well as external. From within the PTC, several Departments were impacted from Maintenance closing the road and directing traffic off the system, to Public Relations issuing a media blast regarding bridge closure and providing details of the detour, to Fare Collection having adequate staff to handle the increase traffic volumes at the interchanges.

Developing the detour for both the Turnpike traffic as well as local traffic required extensive coordination with many different entities including the Department of Transportations in both states, local boroughs and townships as well as the New Jersey Turnpike and Burlington Bristol Bridge. A long-term detour plan was jointly developed by the Pennsylvania and New Jersey Turnpikes.

With the traffic removed from the bridge, the first step of the repair effort was to stabilize the member. Even though the bridge had been carrying live load during a period after the fracture and the truss had redistributed the loads, the intent was to ensure the stability of the structure. The decision was made to immediately place a temporary splice to tie the two fractured ends back together. The intent of the splice was to make a flush connection; not to bend the member or restore any geometry. (See Photo 2)

Photo 2: Temporary Splice

As this splice was being developed and installed over the first weekend, several issues quickly became evident that needed to be addressed. First, a lot of engineering resources were going to be needed both at the site and back in the home offices. It was fortunate that both the NJTA and PTC have a general consultant on staff full time that allowed us to get sufficient engineering manpower to the site quickly. The support from HNTB Corporation (NJTA) and Michael Baker International, Inc. (PTC) throughout the repair process played a huge part in getting this bridge open in a timely manner.

With any emergency situation, decisions were being made fast and furious. Additionally, with this bridge having two owners and two different approaches, a communication protocol was needed to be implemented quickly. Starting the next day, conference calls were set up, twice a day, for all

Photo 3: Micropile Installation

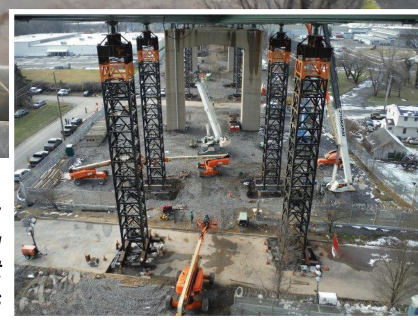


Photo 4: Jacking Support Towers

parties involved. Additional calls with smaller groups were set up as needed. This greatly streamlined the decision-making process as well as the various approvals required. But the number of attendees on these calls quickly grew to over 30. With that many people, there were many differing opinions, with some associated frustrations. To ensure that a smooth working relationship between the two owners was maintained and to help work through the difficult decisions, a weekly meeting was set up with just the two agencies in attendance.

To further improve on the communications and streamline the decision process, the PTC felt they needed a 24/7 presence at the site. Individuals from the both the PTC Bridge and Construction Departments were assigned to the site, full time, for the duration of the repair.

With the sudden increase of activity and manpower, it quickly became evident that a war room was needed at the site. STV, Inc., the construction manager for the on-going paint contract, had their field office in close proximately to the bridge and a war room was set up in their conference room. Shortly, the size of the staff exceeded this area and we were able to utilize an empty apartment above the CM's office as additional office space. Additionally, war rooms were set up at both the Agency's Central Offices. These were used to host conference calls, store plans/calculations, conduct interviews with media, and act as a central location for various Departments to find someone should they have any questions about the bridge.

Once the temporary splice was installed, the next step was to install temporary support towers to continue to stabilize the structure and assist in the permanent repairs to the truss, which had sagged significantly in its new loading configuration. A total of eight towers were required to be constructed. It was decided to go with micropile foundations as it allowed for a much smaller footprint in the confined work area. Initial challenges associated with this tower installation included aerial and underground utility relocations and site preparation to accommodate the around the clock drilling operation. Overhead utilities presented direct conflict with the drilling operations. Efficient removal of the utility lines was coordinated directly with the utility owners by the construction management team. Similarly, close coordination with the utility companies helped to locate the underground gas, water and sewer lines. The benefit of utilizing micropile foundations was the flexibility to move piles to accommodate these underground utilities. (See Photo 3) To get a drilling contractor on site quickly, Moretrench of America, an on-call contractor with NJTA, was brought in and was able to provide three rigs, which worked around the clock to install the micropiles.

The micropile drilling operation presented another challenge due to the close proximity of residents to the work site. On-going communications with the local residents via a town meeting and face to face updates helped to alleviate some of the issues.

An initial concern about the availability of material for the jacking towers was quickly resolved when Cornell and Company, a subcontractor to perform steel work for the painting contract, had an ample supply of crane tower sections in his yard commonly used in vertical construction. (See Photo 4)

Photo 5: Post tensioning Operations

While the towers were being constructed, work continued on the 3D modeling to analyze the four-span deck truss unit. To help compress the schedule, independent models were created concurrently instead of back checking one model. Eventually four independent models were completed for the various staged repairs and results were within 5% of each other. Various schemes were investigated that would correct the geometry to eliminate the sag, as well as restore the loading in the fractured member. Ultimately, it was decided to use jacks to vertically rotate the truss back to its original geometry followed by post-tensioning to restore the original load back into the fractured member.

To ensure everything went smoothly during the jacking and post-tensioning operations, a "playbook" was developed, which detailed all aspects of these operations. This detailed document covered the assignments and roles of all parties involved, detailed each step of the operations, defined measuring techniques and hold points, and included contingency plans should anything not go as planned. With the playbook in hand, a "dry run" was conducted two days prior to the actual jacking operations to resolve any issues. Lifts were deployed and mock measurements were recorded and communicated to the on-site command center. This dry run was extremely instrumental in identifying measuring inconsistencies and equipment issues that were incorporated in the actual jacking operations.

On February 24, the jacking operation went extremely well and was completed in one day. Though out the jacking procedure, the truss was monitored continuously using a number of strain gauges which reported data back to the on-site command center. Interestingly, the truss did respond elastically, but was actually much more stiffer than expected possibly due to the deck and secondary members contributing additional load paths.

The second step of the repair operation was completed on March 3 when the fractured member was post-tensioned and the permanent splice was installed. Longitudinal post-tensioning frames were installed on both ends of the fractured member. With these frames installed, there was not available working area to utilize traditional jacking equipment. It was suggested that compact bolt hollow jacks would work in this limited area. These jacks are used in the wind tower industry and their compact footprint worked perfectly. (See photo 5)

Post tensioning went as planned and was completed in one day as well. The distance between the two fractured sections indicated that we would need to post-tension to a distance of 1.8" to get the truss back to as-built conditions. However, to reduce the chance of overstressing other components of the truss, the final goal of 1500 kips was achieved after reaching a distance of 1.375". The permanent splice was completed, the vertical jacks were removed, and the truss was free standing for the first time in six weeks. (See photo 6)

Presented so far were the many challenges associated with the temporary splice, support tower installation, and the repair of the fractured chord itself. But the final, and most important challenge, was determining if the bridge owners could gain the confidence that the bridge was safe to re-opened to the travelling public. As the various activities presented above were being completed, there were many other concurrent tasks being performed to achieve this level of confidence.

Photo 6: Permanent Splice

We needed to be sure, without a doubt, that the mis-drilled holes where the fracture occurred were an isolated incident. An emergency inspection program was immediately initiated to conduct a 100% hands-on inspection of all deck truss spans with an emphasis on high risk members, connection areas, and details suggesting signs of fabrication defects similar to those that were assumed to be the cause of the fracture. Fortunately, Greenman-Pederson. Inc. had a contract with NJTA to conduct the next biennial bridge inspection contact and had resources in the vicinity of the bridge. Additionally, three dimensional models were developed using data collected from LIDAR scanning. Any hotspots, suspect tack welds and other potential defects were identified and documented for a follow up assessment by Ultrasonic Testing teams.

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An Ultrasonic Testing (UT) program was developed by Michael Baker International and HNTB with the assistance of Dr. Karl Frank. This was a systematic approach of which truss members to test, development of a testing procedure to qualify UT technicians, mobilization of technicians to the site, and testing hotspots identified by the hands-on inspection. It was critical that a uniform testing approach be established for the discovery of weld material placed in a mis-drilled hole during fabrication. The initial testing program focused on the deck truss spans on the Pennsylvania side, but was expanded to cover the entire bridge. At the end of the day, UT was performed on the end 3 feet of 277 members and the full length of 53 members. No additional mis-drilled holes filled with weld material were found. A couple of anomalies were found, but these holes were filled by mechanical means. In what is believed to be the largest field NDT/ material testing for a steel bridge in the United States, a large team of professionals conducted several hundred UT tests and concluded that the defect at the fracture was a single occurrence.

To continue to build on the confidence level and to alleviate any concerns with the material originally used in the bridge, a globally-oriented material testing program developed by Modjeski and Master, Inc., with the assistance of Dr. Robert Connor of Purdue University, was conducted to characterize the material properties, particularly the fracture toughness of the rolled steel shapes used in the approach spans. Forty-four cores were taken from various members throughout the bridge based on size (flange and web thickness), location, and material (Man-Ten and carbon steels). CVN tests to determine impact toughness, tensile strength, and fracture toughness indicated values appeared more than adequate for steels of this era. Chemical composition and mechanical properties matched closest to Man-Ten (A242) steel, circa 1954. Overall, the material showed good ductility and, without the weld filled holes, no fracture would have occurred.

Throughout the repair process, a monitoring system, developed by WSP USA, Inc., was installed on both sides of the bridge to ensure the integrity of the structure during the repair process and verify the effectiveness of the repair. After the work was completed, a load test was performed on the Pennsylvania side to prove the truss capable of carrying live load and confirm fully elastic behavior. Given the severity of the damage to the bridge, the decision was made to load the bridge with approximately 600,000 lbs. via eight fully loaded dump trucks. Although this loading configuration was extremely high, it offered a high level of confidence in the repaired truss. Additionally, a parallel load test was performed on the similar 4-span truss unit on the New Jersey side. Results between the two tests indicated the repaired truss on the Pennsylvania side behaved the same as the undamaged truss on the New Jersey side.

The success of the load testing was the final obstacle in proving that this bridge could indeed be successfully repaired. With all the concerns regarding the safety of this bridge addressed, both agencies agreed to open the bridge on Thursday night, March 9, 2017, 48 days after it was suddenly closed. The success of getting this bridge opened in such a timely manner was an orchestrated effort by many working together with the end goal in mind. The design effort was considerable with almost 200 individuals involved. With all the challenges associated with the repairs to include 24-hour shifts, many concurrent construction activities, limited work areas, procurement of materials, deliverer of materials, and various testing activities, the construction effort was nothing short of amazing. As with any project, but particularly true for an emergency repair such as this undertaking, communication is key…the value cannot be understated.

The success of the load testing was the final obstacle in proving that this bridge could indeed be successfully repaired.

About the author...

James L. Stump, P.E. is the Bridge Engineer Manager for the Pennsylvania Turnpike Commission. Jim has been employed by the Commission for 27 years and has 31 years of transportation related experience. As the Bridge Engineer Manager, Jim oversees the Commission's Bridge Program which includes the design, rehabilitation and inspections of over 1100 structures as well the Commission's five sets of tunnels. Jim graduated from Penn State University with Bachelor's Degree in Civil Engineering. He is a Registered Professional Engineer in Pennsylvania and is a member of the Association of Bridge Construction and Design, American Society of Highway Engineers, and the Engineers' Society of Western Pennsylvania.

Infrastructure Emergencies

By: Jason Zang, P.E.

Every emergency is unique. Are you trying to prevent a situation from getting worse? Or, are you trying to fix something that already happened? Does it involve water, fire, dirt, chemicals, etc.? Does it involve saving lives? It's common knowledge that engineers really like standards, formulas, and handbooks. The Pennsylvania Department of Transportation (PennDOT) does have some guidance for emergency operations (Pub 23, Chapter 9 and aptly titled Pub 911). But, because every emergency is unique, the guidance only goes so far. However, the good thing about engineers is that they excel at solving problems, and emergencies can be immense problems. Emergencies are inevitable, and when they occur, they need to be handled quickly. Safety, as always must be the most important aspect considered.

The Liberty Bridge rehabilitation project was made more challenging by an accidental construction fire that heated and buckled a main truss member, crippling the bridge. With dedicated teams working around the clock, the bridge was re-opened in just 24 days.

Over my 20-year career with PennDOT, I have been involved with many incidents, most of them structural related, as my background is bridge/structural engineering. There were more than a few bridges we needed to close due to inspection findings of severely deteriorated structural elements: bridges hit by trucks and barges, severe flooding, and others. Back in 2001, there was the Parkway East Retaining Wall emergency, where a wall along 2nd Avenue and the Eliza Furnace Trail had fractured and was on the verge of collapse. Directly beside and above the wall was around 100,000 vehicles traveling at 60+ mph each day. Directly below the wall was pedestrians, cyclists, and others using the Eliza Furnace Trail. Nearby and recently, the most significant emergencies that required engineers' problem solving were the Liberty Bridge Construction Fire of 2017, and the SR 30 Landslide of 2018.

With any emergency, the first question that always runs through my mind is: what action do we need to take to keep people out of immediate harm's way. (Obvious, right?). The second question is often the more complicated of the two: will our actions create an alternate safety concern, potentially more serious than the issue at hand? For example, closing just one lane of the Parkway East will back traffic up for miles, leading to some degree of gridlock, delaying emergency service providers. Engineering judgement and weighing probabilities comes into play. A third question also runs through my mind, why do most emergencies seem to occur on a Friday afternoon?

To address many of the concerns surrounding an emergency you need several things, including open and honest communication, team work, incredible and diverse talent, and often long overnight hours.

Open and honest communication is a critical element of any project, in any phase of planning, design, construction, or maintenance. During an emergency, it is necessary to have continuous communication between all parties, throughout the process. Time is always critical from the perspective of road user liquidated damages (RULD's), (e.g., the costs incurred by the travelling public, such as time, fuel, and wear on their vehicles), and wanting to get a road or bridge open to the public as quickly as possible. However, during an emergency, time is exponentially more critical due to concerns with growing instability, such as at the SR Route 30 slide, and other important factors such as material procurement, and fabrication lead times. Daily progress meetings and status updates, are effective to ensure the entire team knows what new challenges may be revealing themselves, and how they may alter the plan moving forward. It is also important to keep your public relations/ media team up to date with the progress of the work, what actions are currently being taken, and if milestones are changing. During the Liberty Bridge fire repair, the emergency was a top story on all the news channels. It was a significant effort to communicate what was happening daily, and provide progress updates, both good and bad.

Team members, including PennDOT Secretary Leslie Richards and Governor Tom Wolfe look over the Route 30 landlside

Team work, a necessary condition to success in an emergency, may seem like an obvious statement. However, during PennDOT's emergencies I witnessed amazing team work between elected officials, emergency service providers, engineers, and contractors. Disagreements, disputes, and contention that may have been present in the projects, were all completely wiped away, forming a group of people with one common goal: to solve the problem, save lives, and restore the critical infrastructure that had been compromised. Although emergencies have created some of the most stressful and challenging times in my career, they left me with a sense of teamwork, and pride with what was accomplished to last my lifetime. It is an awesome experience to be with a group of people that are all giving their best effort, working together to reach a common, and important goal.

Completion of the Route 30 landslide rehabilitation was done in just 48 days, thanks to the cooperation of the project team's committment

And finally, one of the most rewarding parts of being part of such a team, is witnessing brilliance in action, and professionals doing what they do, unlike anyone else is capable. It takes a very diverse group of people to overcome the many challenges faced in most emergencies. The Liberty Bridge fire had teams of engineers working days and nights, proposing ideas, calculating forces, drafts people creating plans, welders laying welds for consecutive 12-hour shifts, iron-workers drilling holes, installing bolts, public relations people crafting status updates, and on and on. During the SR 30 slide, we witnessed equipment operators on a very dangerous and unstable slope, removing material, creating benches, all while engineers made assumptions for a design that was put together in nine days. In these situations, you will see leaders emerge and set goals. Most importantly, these leaders will create a positive atmosphere, making the team believe they will be successful.

In 2018, we saw the Parkway Central (bath-tub) flood three times, and close five times. In every instance, there were people snapping into action at all hours of the day and night, on weekends, cancelling plans with their families and friends. But even in smaller emergency scenarios such as these, I witnessed the same elements that lead to success. Engineering professionals are people that go beyond the handbooks so solve problems and just as emergencies are unique, so is the communication, teamwork, and people needed to fix them.

About the author..

Jason Zang, P.E., is the Assistant District Executive for the Construction Division at PennDOT, District 11. He has worked for District 11 for 21 years, in various capacities. In this role, Jason oversees a $350 million dollar construction program within District 11, consisting of roadway and bridge reconstruction, rehabilitation, and preservation. Jason is a graduate of the University of Pittsburgh with a Bachelor's Degree in Civil Engineering, and is a member of the Engineers' Society of Western Pennsylvania and the American Society of Highway Engineers.

Accelerated Replacement of NORFOLK SOUTHERN BRIDGE over Cotton Run

By: Lisa J. Hoekenga, P.E., S.E. and John Dietrick, P.E., S.E.

The East Pier of CF-35.40 settled more than one foot after May 24, 2017 Flooding Event

On May 24, 2017, a major spring storm struck Southwest Ohio, spawning multiple tornadoes and initiating a number of significant flash floods. The community of Seven Mile, Ohio, which is approximately 40 miles north of Cincinnati in Butler County, was particularly hard hit. The Butler County Emergency Management Agency estimated that the storm brought almost five inches of rain in just two hours, causing extensive flooding along Cotton Run, which flows into Seven Mile Creek.

BACKGROUND

The flooding of Cotton Run overtopped the existing rails of Norfolk Southern (NS) Bridge CF-35.40, near the junction of Cotton Run with Seven Mile Creek. This bridge, a 92-year-old structure carrying one main line track for NS, consisted of three 22'-6" concrete slab beam spans supported on concrete piers and concrete gravity abutments. The May 24 flooding exceeded the 100-year flood elevation by several feet and created a severe scour condition at the base of the East Pier. The East Pier settled more than one foot, with a corresponding movement and rotation of the two concrete box beam spans supported on the pier and ultimately a loss of support at track level.

Norfolk Southern immediately installed timber cribbing and rip rap around the pier in order to restore service under reduced train speeds. A remote-monitored structural monitoring system was installed on the bridge while permanent improvements could be developed. The remote monitoring system worked as a warning system if the bridge were to experience further loss of support and was in service until the superstructure could be replaced.

DEVELOPING AN ACCELERATED REPLACEMENT SOLUTION

Norfolk Southern mobilized soon after the storm to assess the damage and prepare an immediate response to restore service to this line. The bridge is located on the Northern Region's Lake Division and supports one track carrying approximately 15-20 trains per day between Cincinnati and Richmond, IN, continuing on to Muncie, IN. This is a prime route for time-sensitive shipments between Detroit, Chicago, Fort Wayne and to the south through Cincinnati, so restoration of full rail operations was needed as soon as possible. Norfolk Southern's subcontractor, Fenton Rigging & Contracting, mobilized immediately to install rip rap and stone in the scour hole and construct a timber mat support around the East Pier to serve as a "catch bent" to allow continuing operations at reduced speeds.

Given the age and condition of the structure, Norfolk Southern and Michael Baker International proposed to replace the structure with a new single-span bridge. With the critical nature of the rail operations on this line, it was decided that as much reconstruction as possible would be performed without disrupting train service. The solution proposed involved prefabricating a 52'-0" single-span through girder superstructure and precast concrete abutment seats, which could be rapidly placed during a 24-hour outage of the main line. The solution also called for the construction of two 5'-0" drilled shafts at each new abutment location, outside the footprint of the existing bridge. These four drilled shafts were installed while train service remained on the bridge. Connection details were provided at the top of the drilled shafts to allow for the installation of the precast abutment seats and backwalls.

Precast Abutment Seat and Backwall

RAPID 24-HOUR SUPERSTRUCTURE REPLACEMENT

On May 21, 2018, nearly one year after the flooding and pier settlement took place, Norfolk Southern shut down rail operations for a 24-hour period to allow for replacement of the superstructure. During this period, the existing superstructure was demolished and the new precast abutment seats/backwalls were placed on the recently-installed drilled shafts. A new superstructure consisting of 5 ft-deep through girders, W21x101 floorbeams and a ¾" steel plate deck, which was previously erected nearby on the site, lifted by crane, and placed on the new abutment seats, supported on rocker type bearings. Ballast was then placed on the deck, the track panel was re-connected, ballast regulators and tampers set the ties at the right elevation and track liner checked the rail alignment. This operation was all completed within the 24-hour closure, and full rail operations were reinstated the following day. Demolition of the old piers took place after full train service was restored on the new superstructure.

Placement of Prefabricated Superstructure

EFFECTIVE MONITORING LENDS CONFIDENCE TO THE SOLUTION

While the bridge was shored with the timber mats and braced with steel rolled shapes before superstructure replacement, this solution was only capable of providing resistance to further changes in track geometry. With speed-reduced service on the bridge in this temporary condition, NS sought a method of understanding the behavior of the partially compromised bridge. Periodic surveying was considered and determined to be too costly and would be difficult to execute during storm events similar to the one that precipitated the scouring and undermining of the East Pier. Ultimately, a monitoring system was selected to log readings of bridge movement at 5-minute intervals and transmit an alarm if large movements of the structure were detected. This monitoring system would provide warning to Norfolk Southern's Railroad Operations and allow them to halt trains over the bridge if necessary.

Geo Instruments, Inc. was subcontracted to install the monitoring system on the bridge, process sensor readings and maintain a project website that provided real-time data readings and graphs. The system was comprised of electrolevel tiltmeters, a hydrostatic level system and a data logger. The tiltmeters were connected at the mid-span on both sides of

Monitoring and Instrumentation of East Pier

The new Norfolk Southern Bridge

each existing span. They were also connected to the north and south ends of each pier. The tiltmeters measured rotation and were programmed to set off an alarm if they exceeded a rotation coincident with one-inch of vertical displacement at the track level.

The monitoring system confirmed that while settlement of the pier continued, the settlement was small enough (less than one inch) to permit temporary operations at reduced speeds to continue. A number of challenges were overcome in the process of correctly interpreting and responding to readings from the monitors, including the appropriate evaluation of movements associated with thermal effects.

AN APPROPRIATE SOLUTION TO QUICKLY RESTORE SERVICE IN RESPONSE TO AN EMERGENCY

The solution implemented by Norfolk Southern proved highly effective in responding to a difficult emergency imposed by Mother Nature. The temporary cribbing and comprehensive monitoring system allowed NS to resume operations after the flood, albeit at reduced speeds, while maintaining confidence in the safety of the bridge. The Accelerated Bridge Construction techniques, using prefabricated elements, allowed NS to replace the structure with only a 24-hour closure of service on this critical rail artery. The solution used proven construction and design techniques which resulted in a cost-effective solution that had minimal impact on rail operations despite the extreme nature of the weather event, and the success of the project gives NS enhanced confidence in efficiently addressing future similar emergencies.

About the authors...

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John Dietrick, P.E., S.E. is a Regional Bridge Practice Lead for Michael Baker International, with oversight responsibilities for the company's Great Lakes Region . He received a BS in Civil Engineering from Carnegie Mellon University in Pittsburgh, PA in 1986, and an MS from Carnegie Mellon in 1987. He has over 30 years of experience in the design, analysis, rehabilitation and inspection of bridges, including a number of complex long-span bridges and river crossings. John currently works out of Michael Baker's Cleveland, OH office.

ESWP Member News

More than 75 firms are represented in the Corporate Member program of the Engineers' Society of Western Pennsylvania (ESWP). Corporate Memberships are available at 3 levels: Gold, Silver and Bronze. Gold members are entitled to 14 memberships that can be exchanged by employees; Silver, 9; and Bronze, 5 — annual dues are $2400, $1700, and $1000 respectively. In addition, ESWP Corporate Member Firms may add 2 additional individuals in our Under-35 age category at no additional cost!

We also offer Individual Memberships, including a new "Under-35" category, which allows for full member privileges at annual dues of $25 and a Government rate (full-time), with for $50.00! Also, our new Dining Membership allows use of the Executive Dining Room for conducting client entertaining in a great private club setting, all for only $50 annual dues, plus regular entry fee. More information can be found at eswp.com. Please contact the ESWP Office (412-261-0710) for additional details.

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Bureau Veritas 1828

CDR Maguire

Carnegie Mellon University College of Engineering

Collective Efforts, LLC Civil and Environmental Engineers

covestro

CSD Carnegie Strategic Design Engineers LLC

DEI DeSalvo Enterprises, Inc.

DQE Communications

Elevator Management Services

ESS NexTier Insurance Group

FIGG

GPI Greenman-Pedersen, Inc. Engineering and Construction Services

H.F. Lenz Company

i+icon USA Infrastructure & Industrial Constructors USA

Hill International

HH Houston Harbaugh Attorneys at Law

JACOBS

JNE Consulting

KCI Technologies

kokosing Industrial

KORYAK

LDG Larson Design Group

LOCHNER

mascaro construction ... build with the best

McKim&Creed Engineers Surveyors Planners

MOC, Inc.

menard Ground Improvement Specialists

Mott MacDonald

ms consultants, inc. engineers, architects, planners

nicholson

NGE Environmental & Geotechnical Engineering Solutions

orbital Engineering, Inc.

Point Park University

RTP R. T. Patterson Co., Inc. Engineers & Consultants

RIZZO International, Inc.

RDA Romualdi Davidson & Associates Consulting Engineers

RMU Robert Morris

SAI Consulting Engineers

Schnader Attorneys at Law

Sci-Tek Consultants, Inc.

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Tetra Tech

thyssenkrupp

Turner Building the Future

Pitt Swanson Engineering

Veolia

WRA Established 1915

wsp

Wyatt Incorporated Interior Construction

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