FOCUS

More Than Engineering

Evolution of owner concerns, new materials, and changing needs have expanded the analysis and techniques used by SDR to replace or rehabilitate bridges

by Craig A. Shutt

The completed full-depth deck replacement for the Highway I-75 project near Tampa utilizing sawed in carbon reinforcement connections. All photos: SDR Engineering Consultants Inc.

This photo shows sawing of the deck panel and attaching the lifting frame to the section for removal of existing deck during a nighttime replacement operation.

The existing I-75 deck was removed during a nighttime replacement operation.

The new full-depth deck panel is ready for installation for the Highway I-75 project near Tampa.

The panel is aligned in place and shimmed 1.4 in. higher than the existing deck to allow for future grinding, ensuring a smooth travelling surface.

As budgets shrink and needs increase, bridge engineers are expanding their expertise to meet a growing array of bridge rehabilitation and construction challenges. At Structure Design & Rehabilitation (SDR) Engineering Consultants Inc. in Tallahassee, Fla., bridge rehabilitation has been a major focus of the firm since its 1992 inception. This has required strong emphasis on having vast knowledge of nondestructive testing (NDT), new repair materials and methods, accelerated methods of bridge construction, and development of custom software programs to address special details and damage assessment that are not available through the use of traditional design software.

"Software integration and creating custom designs using new materials and techniques have become vital to resolving bridge issues," says Dr. Mohsen Shahawy, principal and founder. "The ability to diagnose existing conditions within a bridge has become paramount to achieving success in the bridge industry. With so many considerations about rehabilitating or replacing a bridge quickly and economically, more than engineering skill is required to complete these projects efficiently."

Diverse Expertise

SDR's diversity in experience is reflected in Shahawy's professional history and vision for the future of bridge engineering. He began his career in Switzerland in the 1970s, working as a design and construction engineer on communication towers and a tunnel connecting Italy to Switzerland. He then moved to Amoco Petroleum in Egypt, where he designed offshore structures. Later, in Canada, he studied at Queen's University and The University of Manitoba and worked as a forensic engineer.

In 1986, he joined the Florida Department of Transportation's (FDOT's) newly-established bridge-assessment and testing center. The unit was created after the original Skyway Bridge collapsed after being hit by a ship in the early 1980s, resulting in a statewide focus on strengthening resources in the evaluation, assessment, and load-testing of Florida's deficient bridges. In 14 years at FDOT, he investigated and tested more than 400 bridges, varying from simple reinforced concrete slab bridges to cable-stayed bridges.

During this time, he acquired extensive knowledge of bridge assessment, NDT methods, non-linear, finite-element modeling, and effective bridge-rehabilitation techniques. In 1992, he opened SDR to take advantage of this expertise. Today, SDR operates three offices, in Tallahassee; Dallas, Tex.; and Baton Rouge, La., and has 24 employees, most of whom are engineers.

FDOT has been a significant user of both cast-in-place and precast concrete structures, he notes. "In the late 1980s and early 1990s, Florida led the nation in constructing prestressed and post-tensioned bridges. We pushed the limits for span length, the use of prefabricated concrete superstructures and substructures, and produced a host of other innovations."

Verification testing was an integral part of bridge design, he adds. "FDOT, through its test facilities, led the nation in concrete research, and many of its findings were incorporated into the *LRFD Bridge Design Specifications*," he says. "Participating in the design, instrumentation, testing, verification, and construction to reach a successful finished product is the dream of every engineer and we have been doing exactly that routinely."

Finding the correct solution involves more factors today, especially the speed of construction. "Owners are now more than ever aware of the impact of bridge construction time on disruption of neighboring communities and businesses and are demanding utilization of new accelerated construction techniques," Shahawy explains. "Faster construction also translates to fewer accidents and enhanced safety for the workers and public."

These changes have favored prefabricated concrete designs, he adds. "Concrete elements can be quickly assembled to form standard shapes, minimizing forming and labor costs, and reducing lane-closure time. Even at a higher initial cost, the use of prefabricated systems on bridges subjected to high volumes of traffic may be justified, because it avoids excessive lane-closure times and public disruption."

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Rehabilitation Grows

The decision to rehabilitate or replace a bridge depends on many parameters, but most often is controlled by the life-cycle cost of each alternative, he says. "In highly congested areas, replacing a bridge might be the cost-effective solution, but rehabilitation instead of replacement is often the desired solution due to the level of disruption and impact on the public."

SDR has seen steady growth in bridge rehabilitation over the past decade. "We see these activities growing at a faster rate due to limited budgets and aging infrastructure. Few new bridges are being built today, with most work focused on replacing or renovating existing bridges."

For instance, traditional deck replacement often requires partial- or full-lane closure for extended periods. In highly congested urban areas, lane closure during peak traffic hours can create costly detours and business disruptions. In these cases, rehabilitating bridges that can remain open during peak traffic hours provides significant benefits.

Fascia girder of adjacent box girder overpass repaired with carbon-fiber reinforced polymer.

Completed box girders repairs.

An example is the recently completed deck-replacement project on Interstate 75 near Tampa, Fla., where the owner required no lane closure during peak traffic hours. SDR designed an innovative system that allowed the replacement of the concrete decks with only partial lane closures between 11 p.m. and 6 a.m.

Full-depth reinforced concrete panels were placed on the supporting girders and tied together. Working at night only, crews saw-cut sections of the existing deficient deck, removed them, and installed new panels that matched the created opening. The bridge was completely open to traffic each day, with more new panels installed each night. The design used traditional precast reinforced concrete panels, high-strength and fast-setting polymer concrete, and carbon fiber reinforced polymers (CFRP).

"This innovative use of materials, combined with engineered accelerated-construction techniques, was essential for the successful completion of the project within schedule and budget," Shahawy says. "Mock-up testing of the installation and extensive testing of the performance of the polymer materials were critical components necessary for successful application."

Deteriorated drop-in span hinge location before repair.

Completed carbon-fiber reinforced polymer repairs of the drop-in span and cantilever spans.

Carbon-fiber reinforced polymer hinge strengthening completed and painted with gray color UV protective coating.

"Engineers need to be fully versed in all the steps required for diagnosing deteriorated conditions. These situations often require NDT such as infrared thermography, polarization resistance, concrete covermeter, and chloride ion penetration analysis coupled with extensive non-linear analysis. Accurate determination of the structural conditions is essential in predicting the remaining life, effectiveness of the repairs, and proper cost analysis. There is a need for better knowledge of the assessment process and the array of new materials available to repair bridges efficiently and SDR is focused on these aspects," he says.

An example illustrating utilization of the above aspects is the recently completed rehabilitation of the Assawoman Bay and St. Martin bridges in Ocean City, Md. These prestressed concrete bridges have 139 and 97 spans, respectively, and were constructed in 1971. Initial engineering assessment recommended the replacement of both bridges, however, utilizing a multitude of NDT techniques coupled with advanced analysis, the SDR team performed a detailed evaluation and developed a cost-effective rehabilitation scheme that was accepted by the owner. Targeted structural strengthening of limited numbers of AASHTO and box girders using CFRP coupled with replacement of the severely deteriorated AASHTO girder drop-in span was completed within six months at a fraction of the estimated replacement cost.

New Materials Arise

Rehabilitation projects require diagnostic expertise, as well as in-depth knowledge of new materials and techniques. "There is a need for better knowledge of the assessment process and the array of new materials available to repair bridges efficiently, and SDR focuses on these aspects," Shahawy says. "Over the past decade, it has become evident that significant advancement in production of efficient and durable polymers and coatings has been made. There is a new generation of high-performance materials that can help achieve enhanced durability and performance."

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These innovative advanced construction techniques are opening new approaches to rehabilitation of infrastructure, he notes. "Prefabricated systems that use materials such as high-strength concrete, high-strength/corrosion-resisting steel, and fiber-reinforced plastics are changing rehabilitation strategies. Although some of these materials and systems can be costly compared to traditional ones, as the concepts of life-cycle cost analysis and user costs are included in the replacement algorithm more regularly, acceptance of the often proprietary and more expensive systems will certainly increase."

This new generation of concrete materials, such as self-consolidating concrete and high- and ultra-high-performance concrete, offer alternatives due to increased durability and strength. "Where we used 3-ksi strength concrete for cast-in-place bridge elements, we now routinely get 5 ksi," he says. "Compressive concrete strength of prestressed girders can now be provided at 10, 12, or even 24 ksi, where it used to be 6 ksi."

Those improvements, along with the increased use of 0.6- and 0.7-in.-diameter strands, provide significantly more strength, allowing girder lengths to extend from 150 ft to as much as 200 ft, creating new engineering options. "Essentially design requirements today are set forth to ensure enhanced long-term performance and minimized future maintenance needs through strategies such as minimizing cracking and moisture penetration, minimizing the number of expansion joints, using low-permeability concrete, and increasing concrete cover."

Software Development

As bridge demands have grown and changed to focus on complex engineering principles that are often times not well documented or analyzed, Shahawy found that existing software programs weren't providing the necessary requirements for damage assessment of local elements and their impact on global bridge performance. "Most often, analyzing the effect of impact damage or deterioration requires various computer programs and is highly dependent on the experience of the evaluator," he says. "This lengthy process is not suitable for rapid bridge assessment, where a decision is needed on whether a full or partial closure of the bridge is required."

Most engineering software is designed for new and replacement bridges, he notes. "Rehabilitation requires different design calculations, because you are working with an existing bridge for which you are removing some elements, simulating the structural damage, and determining the effect on the global performance. Especially when accidents are involved, decisions on the extent of repairs versus full replacement must be made rapidly."


An example of column repairs for the Florida Turnpike over the SR 561 Bridge.

'Rehabilitation requires different design calculations.'

In 2004, Shahawy founded an independent company, Smart Bridge Tech Inc., to engineer infrastructure repair and rehabilitation software. The firm's software, some of which is now marketed publicly, compiles an entire rehabilitation project in an efficient platform.


Another view of the repaired columns and pier caps that were part of the rehabilitation project for the Florida Turnpike over the SR 561 Bridge.

The firm's damage assessment software provides unique and sophisticated analysis capabilities to accurately determine the magnitude of damage suffered by concrete structural elements due to vehicular impact or corrosion. The analysis techniques and non-linear finite-element model software is designed to deal with this specific issue, utilizing a global analysis approach of the bridge. Concrete section and steel area loss of both flexure and shear reinforcement can be modified or removed from the global model. The bridge is then analyzed with the simulated damage to establish an accurate capacity assessment.

An example of rapid bridge evaluation and repairs is the repair and replacement of the Florida Turnpike over SR 561 Bridge. The bridge suffered extensive damage due to a fire that required a complete closure of the bridge. Rapid structural evaluation and assessment recommended the replacement of the severely damaged girders in the fire damaged span and CFRP rehabilitation of the severely damaged columns and pier caps. The span replacement and substructure repairs were completed with 11 days, a record time considering the damage level.

Improvements to computer analysis, along with innovations in systems and materials, will allow engineers to resolve challenges more efficiently. "Sustaining research must be pursued to develop better-performing and cost-effective systems utilizing these new materials," he says. "There also must be more efficient collaboration between departments of transportation, consulting engineers, researchers, and contractors toward advancing these new materials. They must share concerns, originate research projects, and clearly define objectives of projects. Those actions will lead to better and more standardization and design guidelines for practicing engineers in the future."

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