SUSTAINABILITY—A CALL TO ACTION

BY DAVID WHITMORE

Concrete has the capability to last a very long time if it is designed, constructed, and maintained properly. When concrete structures are not properly maintained or they have exceeded their design life, they may need to be replaced at great cost and inconvenience to the public and with negative impact on the environment. Today, our industry has been presented with an unprecedented opportunity to contribute to sustainability through the repair and protection of concrete structures worldwide.

Sustainability, as defined by *Webster's Dictionary*, is "a method of using a resource such that the resource is not depleted or permanently damaged." In construction, the concept of sustainability and, ultimately, structure preservation is based on the desire to conserve existing resources and minimize long-term costs, energy consumption, and waste.

ENVIRONMENTAL IMPACT OF CONCRETE

With a worldwide production of approximately 5 billion yd^3 (3.8 billion m^3) per year, concrete is the most widely used manmade product on our planet. Concrete production consumes large quantities of raw materials (aggregate, cement, and water) along with the various sources of energy required to produce and transport these materials. In addition to the energy required in the manufacturing and production processes, there is also a release of pollutants into the environment, which include carbon dioxide, carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds (VOCs), and waste heat, as detailed in Fig. 1.

RESPONSIBLE USE OF CONCRETE

Despite the environmental impact, concrete is still one of the most environmentally friendly construction materials available. Concrete is dense; strong; and durable; and, when used appropriately, can last for centuries. The oldest concrete structure still in continuous use is the cast-in-place dome that forms the bulk of the Pantheon in Rome that was built by the Romans in 126 AD (Fig. 2). One of the oldest stone and mortar bridges still in service is a multi-span stone and cement mortar arch bridge located in Cordoba, Spain, that is believed to have been built during the first century AD (Fig. 3). Both of these structures have been in service for almost 1900 years.

ESTIMATED WORLDWIDE EMISSIONS FROM PRODUCTION AND PLACEMENT OF REINFORCED CONCRETE

- Carbon dioxide: 2 billion ton (1.8 billion metric ton)/year
- Carbon monoxide: 10 million ton (9 million metric ton)/year
- Nitrogen oxides: 30 million ton (27.2 million metric ton)/year
- Sulfur dioxide: 29 million ton (26.3 million metric ton)/year
- Volatile organic compounds (VOCs): 2 million ton (1.8 million metric ton)/year
- Thermal pollution from concrete production is approximately 7,600 TBtu (8 billion Gj)/year. This is enough heat energy to raise the temperature of 400,000 $mile^2$ (1 million km^2) of water 3 ft (0.9 m) deep by 2°F (–17°C)/year.

Fig. 1

Fig. 2(a): Pantheon (Rome, Italy)—front entrance view

Fig. 2(b): Pantheon (Rome, Italy)—rear view (cast-in-place concrete dome)

Fig. 3: Roman Bridge (Cordoba, Spain)—constructed in 100 AD

Fig. 4: Deteriorated concrete bridge deck

SUSTAINABILITY BENEFITS OF PRESERVING THE RAINBOW BRIDGE

- Historic bridge was preserved for 50 additional years.
- 1809 yd^3 (1383 m^3) of concrete was maintained in service.
- CO_2 emissions were reduced by 900 ton (816 metric ton) versus replacement.
- 4.5 billion Btu (4800 GJ) of heat was not released. (This is enough heat to boil three Olympic-size swimming pools.)
- CO_2 emission reduction is equivalent to annual emissions of 180 people (1080 ton [980 metric ton]).

Fig. 5

According to the Federal Highway Administration (FHWA), a typical bridge in the United States is fully or partially replaced when it is 35 years old—a significant contrast to these very old examples. In some cases, bridges are replaced because they become obsolete and do not meet current requirements, but often they are replaced (or partially replaced) due to reinforcement corrosion or other deterioration of the structure (Fig. 4). Replacing a concrete structure after only 35 years is not a sustainable long-term strategy in terms of life-cycle cost, environmental impact, and use of resources.

Members of the International Concrete Repair Institute (ICRI) have the technology, knowledge, and experience to extend the life of concrete structures and minimize the number of structures that

Fig. 6(a): Rainbow Bridge before repair

Fig. 6(b): Rainbow Bridge during repair and chloride extraction

Fig. 6(c): Rainbow Bridge after repair

Fig. 7: Port of Canaveral—North Cargo Piers

need to be demolished and replaced. To illustrate the environmental and sustainability benefits of repair and corrosion protection, here are two ICRI award-winning projects as examples.

RAINBOW BRIDGE

The Rainbow Bridge was constructed in 1933 in the Cascade Mountains of Idaho. In 2006, the Idaho Department of Transportation and consultant CH2M Hill designed and specified a combination of corrosion protection and concrete repairs to provide a 50-year service-life extension for this 73-year-old chloride-contaminated structure. Physically damaged concrete was removed and replaced in accordance with ICRI Technical Guidelines. Remaining sections of the structure that were chloride-contaminated but not yet physically damaged were preserved by the use of electrochemical chloride extraction (ECE). The use of the ECE process and conventional repairs prevented this historic structure from being demolished and rebuilt. A summary of the key sustainability benefits of this project is given in Fig. 5. Before and after photos of the bridge can be seen in Fig. 6. An overview of this project can be found on the ICRI website at **www.icri.org/AWARDS/2007/rainbowbridge.asp**.

PORT OF CANAVERAL: NORTH CARGO PIERS

In 2005, the Port of Canaveral (on the east coast of Florida) specified the repair and galvanic corrosion protection of the North Cargo Piers (Fig. 7). Although the reinforced concrete piles and beams were chloride-contaminated with significant concrete deterioration and corroding reinforcement (Fig. 8), the owner chose to repair and protect these structures instead of replacing them. In addition to the initial cost and construction schedule benefits, the repair and long-term corrosion protection approach was sustainable and also provided significant environmental benefits.

Galvanic protection systems were specified to extend the life of the repaired structures by approximately 20 years. The repaired and protected

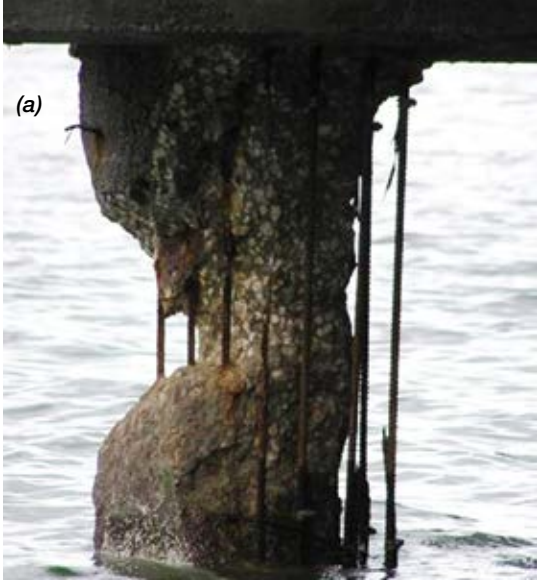

Fig. 8(a) and (b): Port of Canaveral—concrete deterioration prior to repair

Fig. 9(a) and (b): Port of Canaveral—installation of galvanic protection to piles and concrete deck

SUSTAINABILITY BENEFITS OF PORT OF CANAVERAL NORTH CARGO PIERS REHABILITATION

- North Cargo Piers received a 20-year life extension.
- 8700 yd^3 (6650 m^3) of concrete was maintained in service.
- CO_2 emissions were reduced by 4350 ton (3950 metric ton) versus replacement.
- 22 billion Btu (23,200 Gj) of heat was not released. (This is enough heat to boil 15 Olympic-size swimming pools.)
- CO_2 emission reduction is equivalent to annual emissions of 870 people (5220 ton [4735 metric ton]).

Fig. 10

structures included 668 piles; over 6000 ft (1830 m) of reinforced concrete beams; and 57,500 ft^2 (5340 m^2) of precast concrete deck (Fig. 9). A summary of the key sustainability benefits of this project is given in Fig. 10. An overview of this project can be found on the ICRI website at **www.icri.org/AWARDS/2007/pofcnorthcargopiers.asp**.

PRESERVATION HAS POSITIVE IMPACT

The environmental benefit of repairing and preserving existing infrastructure can be significant, and preserving structures makes concrete repair an inherently sustainable activity. Contractors, material manufacturers, engineering consultants, and suppliers are some of the participants involved in these projects, and the environmental, social, and economic benefits of keeping these structures in service extend far beyond those parties. As responsible stewards of this planet, we should all be aware of the benefits of repair and protection and the positive impact these preservation methods have on our future.

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