Shotcrete Repairs—the Main Development Trend in Poland

by Wlodzimierz Majchrzak, Wlodzimierz Czajka, and Zdzislaw Jurek

The shotcrete method first appeared in Poland in the 1930s. Technical literature available at that time described shotcrete as "concrete application under pressure of compressed air and its use in the building industry." Only the dry-mix shotcrete method was used at that time and the shotcrete guns were similar to Carl Akeley's cement gun.

After World War II, Poland came under Soviet influence and development of the shotcrete method drastically slowed down. Its use was limited to spraying concrete in mines and occasionally for repairs. At that time, the sprayed concrete method was more popular in Czechoslovakia (currently the Czech Republic and Slovakia) where they had more experience using this method due, in part, to the mountainous landscape. Czechoslovakia developed a wet-mix process called "vusokret," and in the 1980s, Poland bought the license for that process. The method was successfully used (unfortunately, only occasionally) for bridge structure repairs such as the historic Poniatowski Bridge in Warsaw. Built in 1904-1905, this structure underwent a complex repair with wet-mix shotcrete in 1982-1985. After 1990 and the collapse of the Soviet Union, the free market economy blossomed in Poland. New technologies and companies appeared in the Polish market.

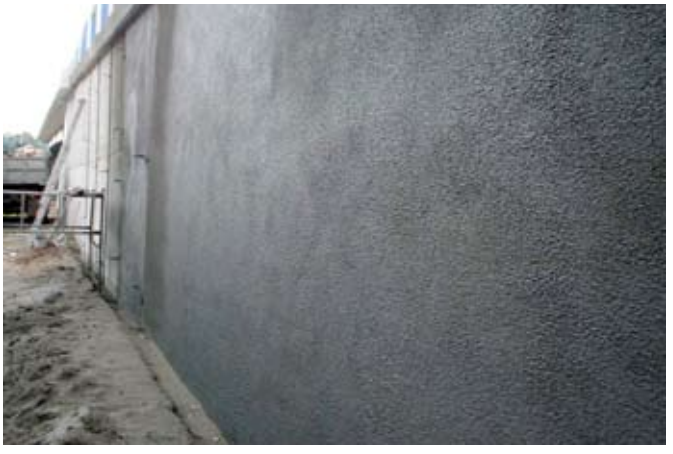
Our company, SPB 'TORKRET' W. Majchrzak sp. j, was established in 1989. The founders, who are also the authors of this article, are Wlodzimierz Czajka, Zdzislaw Jurek, and Wlodzimierz Majchrzak. Wlodzimierz Czajka had the most experience in sprayed concrete at that time. For several years, he worked in a state-run company where he was responsible for shotcrete applications. From 1989 to the present, our company has completed over 400 shotcrete repairs of different structures.

Poland is a lowland country. The market share for shotcrete in the construction of tunnels and retaining and excavation walls, as well as the strengthening of slopes, has been minimal to date. In our country, the shotcrete method is mostly used to repair structures such as overpasses and bridges, cooling towers, chimneys, silos, and tanks.

In Poland, shotcrete is considered to repair structures in very poor condition. In wealthier countries, many of these structures would likely be demolished. A shotcrete repair may be able to extend the service life of a structure by 15 to 20 years. From an economic viewpoint, making the decision to demolish and reconstruct an existing structure is easier than determining a complex repair scheme and the potential extended service life. Also, in the case of a heavily damaged structure, the potential for an ineffective repair is greater.

Shotcreting Methods Applied in Poland

Due to the significant interest in the shotcrete method for repairs, the dry-mix sprayed concrete (shotcrete) method has advanced in Poland. A primary reason is the broad range of dry-mix products available. The mixtures are typically of



Shotcrete on a retaining wall

Finishing of retaining wall surface with cut technique

the sprayed polymer cement concrete (SPCC) type, manufactured by Italian, German, and British companies. Often, a dry-mix designed for repair is either modified by microsilica with graded 0 to 0.3 in. (0 to 8 mm) aggregates and portland cement or by polymer components and graded 0 to 0.2 in. (0 to 4 mm) aggregates. In addition to shotcrete repair materials, our company also manufactures dry concrete and repair mortars with graded 0 to 0.4, 0 to 0.2, and 0 to 0.3 in. (0 to 2, 0 to 4, and 0 to 8 mm) aggregates and microsilica, migrating corrosion inhibitors, steel, and polypropylene fibers.

Observation of the Polish market and our experience shows that the dry-mix shotcrete process is now overwhelming the field of repairs (almost 100% share). In addition to repairs, dry-mix shotcrete is also being used in the markets of slope strengthening in the mountain regions of southern Poland and in tunnel and underground garage construction in urban areas.

In 2004, together with the company STRABAG, we completed slope strengthening of a deep excavation on a border crossing between Poland and Slovakia. So far, it is the largest project of this kind in Poland. The slopes were 70 ft (21 m) high, 133 to 167 ft (400 to 500 m) long, with a total area of approximately 53,820 ft² (5000 m²). More than 35,315 ft³ (1000 m³) of dry-mix sprayed concrete with 0.3 in. (8 mm) maximum size aggregate was used for the work. The strengthening was carried out over a 5-month period.

Standards and Laws Referring to Sprayed Concrete Works in Poland

As previously mentioned, under the communist government, sprayed concrete was mainly used for strengthening purposes in mine work. At this time, standards concerning shotcrete application were developed. At first, shotcrete was used for structural repairs only upon consultation with the designer and supervising inspector, and was based on general industry practice. The European Federation for Producers and Applicators of Specialist Building Products (EFNARC) was established in March 1989. It deals with all issues relating to sprayed concrete. The Technical Committee for Sprayed Concrete was established in 1991. The committee is involved in developing the draft of a European Standard on Sprayed Concrete. The latest version of the draft and the documents published

Shotcrete on tunnel diaphragm walls

Slope strengthening in deep excavation

Strengthening of excavation slope on the border of Slovakia

by the Sprayed Concrete Association (SCA) provide guidance for design with comments on suitability for construction purposes, application procedures, and tests of sprayed concrete. These documents are currently used in Poland. Observation of the shotcrete market in North America and other regions provides knowledge of new trends for sprayed concrete applications worldwide.

Review of Typical Facilities and Structures Repaired Between 1989 and 2005

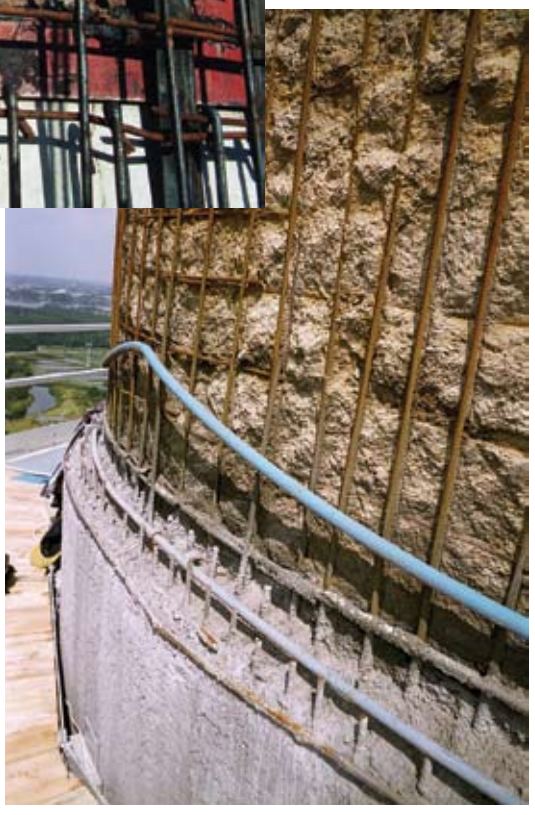
The use of the shotcrete method for reinforced concrete structure repairs makes it possible to perform different tasks on a structure under rehabilitation; specifically:

- **Strengthening**—improving structural function to all or part of a structure; Applications of sprayed concrete are preceded by filling reinforcement spalls and installing additional reinforcement to restore the structure to its original, or an enhanced, condition;
- **Reprofiling concrete**—for the repair of superficial or local corrosion damage, it can fill larger concrete cavities;
- **Protective concrete**—restoring or increasing the thickness of concrete cover over reinforcement. Providing protection against hazards such as corrosion and chemical attack with mixtures specifically designed for the project; and
- **Architectural function**—shaping and texturing of the external surface of facilities/structures.

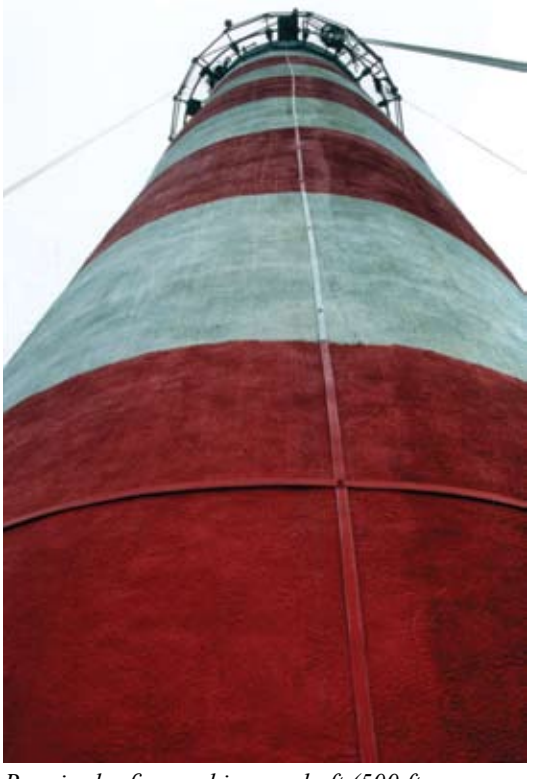
The aforementioned functions demonstrate the possible uses of sprayed concrete in reinforced concrete structure repairs. Applications include facilities/structures of considerable dimensions, with limited access, where large quantities of concrete (both in terms of area and volume) are required. In the case of structures such as bridges, overpasses, silos, chimneys, or cooling towers, shotcrete can be used to meet demanding tolerance and finish requirements.

One of the most spectacular repairs in this part of Europe was the repair of a 500 ft (150 m) high refinery chimney in the mid-1990s. The chimney shaft was damaged at approximately the 425 ft (130 m) level in an explosion and required either demolition or a decision on repair. Demolition would have been risky due to the presence of tanks filled with fuel that surrounded the chimney. At that time, shotcrete repair was an unknown concept in Poland. Double layers of additional reinforcement were added and sprayed concrete 6 to 8 in. (150 to 200 mm) thick was applied to a height of

Damage of chimney shaft (500 ft [150 m]) high at the height of approximately 425 ft (130 m)



Completion of finish casing on double reinforcement



Repaired refinery chimney shaft (500 ft [150 m] high)

325 to 500 ft (100 to 150 m). Below, reprofiling was achieved with shotcrete 2 to 3 in. (50 to 70 mm) thick. The dry-mix shotcrete process was selected for this project.

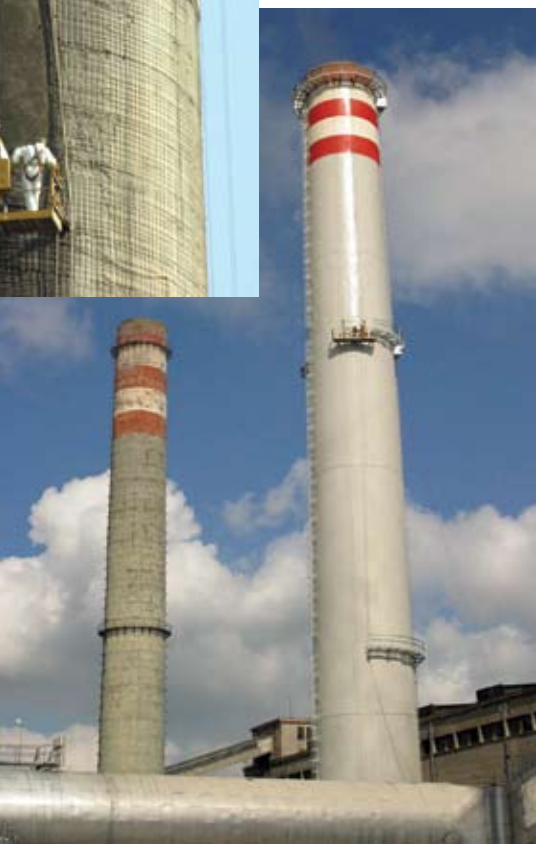
Another challenging project was the repair of two 315 ft (96 m) high power station chimneys. One challenge encountered was the requirement that the strengthening of the top part of the chimney had to be completed first to mount a new gallery and track for hanging a suspended scaffold. Extreme sulfate corrosion of concrete and remnants of the original reinforcement required all repair work at that particular height be carried out with extra care and diligence. To limit and retard corrosion of the reinforcement, sprayed concrete modified with microsilica and a migrating corrosion inhibitor was applied.

The most rewarding projects we have completed have been bridge repairs. Diversified architecture, original shapes, and interesting locations all require the contractor to be unusually careful and provide precise reconstruction of geometry, shape, and aesthetics. In addition to observing basic repair technology rules, a bridge repair contractor must correctly restore the original shape, maintain the geometry of the structure, and control the quality of the shotcrete finish.

Complex rehabilitation of a structure often includes reconstruction and restoration of the structural function, reprofiling, and provision for protective shotcrete on all concrete surfaces to produce durable repairs. Structures subjected to complex shotcrete repairs by our firm in the early 1990s do not show any secondary damage to date. Concrete surrounding these repairs is protected by acrylic dispersion coatings that hinder CO_2 transmission and allow moisture in the form of water vapor to escape. This helps to protect the original structure against further degradation.

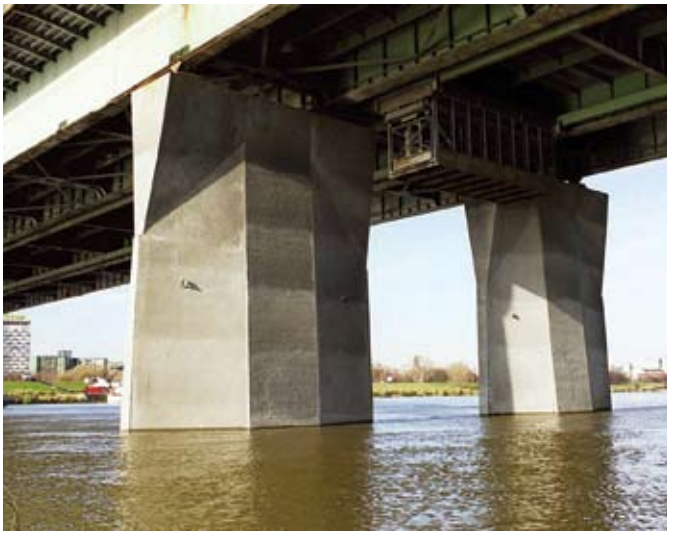
Damaged chimney capital before repair

Middle zone of the chimney during shotcrete application on meshed base

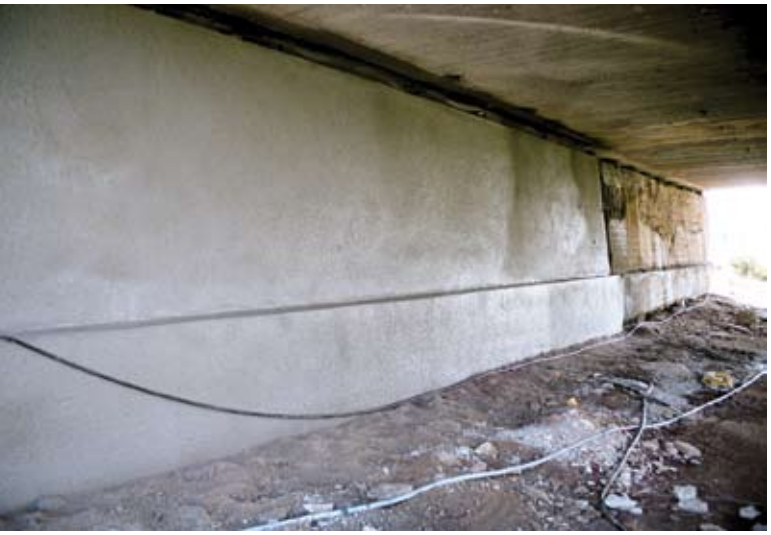


315 ft (96 m) high chimney after repair

Corrosion damage of bridge support



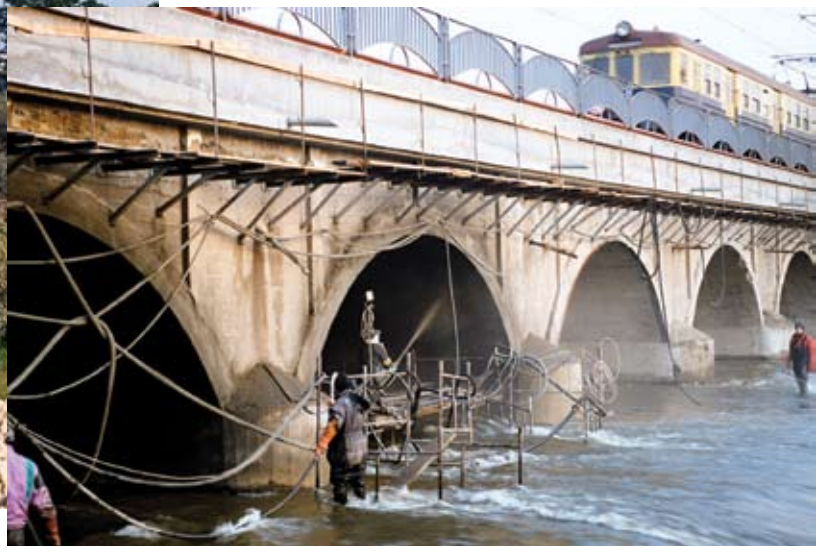
Supports after a repair with shotcrete



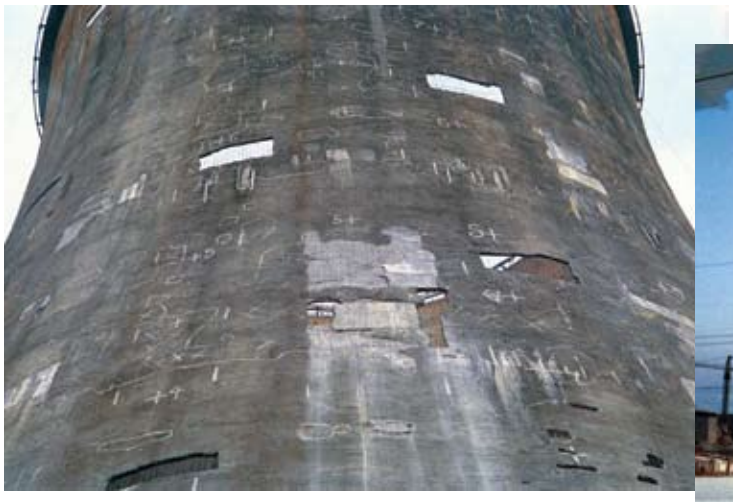
Abutment before and after repair

Repair of arch bridge vault

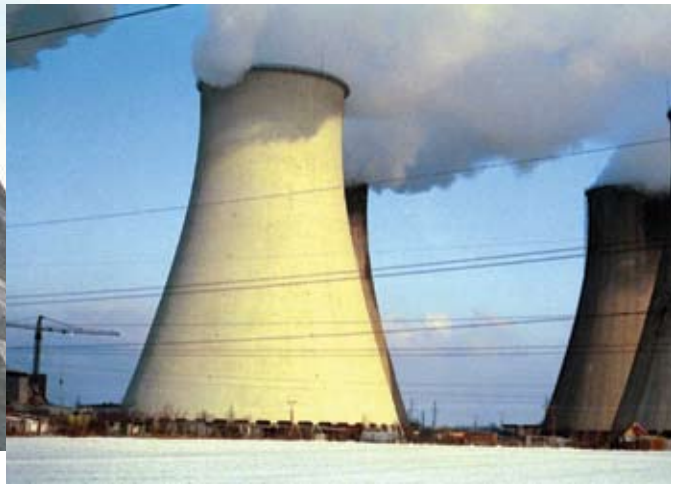
Complex repair of a bridge



Repair of historic bridge



Replacement of concrete in the so-called "damaged windows" of cooling towers



Cooling tower after repair

Other interesting and original repairs are those of reinforced concrete cooling towers. In Poland, there are approximately 80 structures of this type, with the highest reaching 433 ft (132 m). Our company repaired three concrete cooling towers in the early to mid-1990s. To date (14, 12, and 10 years after completion of repairs), they do not show any symptoms of deterioration. Poland lies in a climatic zone where winter temperatures drop to –22 °F (–30 °C), and summer temperatures get up to 95 °F (35 °C). The walls of cooling towers at a height of 98 ft (30 m) are approximately 5 in. (120 mm) thick. Operational conditions for reinforced concrete cooling towers can be problematic in winter months due to high temperature differentials between the outside and inside. There have been several notable failures of cooling towers in the world (Kelvin, Ayershire, and Fiddlers Ferry—Great Britain; Minano—Italy; Pont-sur-Sambre and Buchain—France). In Poland in 1987, a 328 ft (100 m) high cooling tower collapsed at the Turów Power Station. A primary reason was corrosion of the reinforcing at the level of 130 ft (40 m). After its failure, most of the cooling towers underwent a detailed assessment that gave grounds for capital repairs of concrete towers and support columns.

Summary

Our company is a leader in repair in the Polish market. While we cooperate with many research centers, we primarily work with the Division of Reinforced Concrete Structures at the Poznań University of Technology and the Road and Bridge Research Institute. Since 1997, we have been a member of the British Sprayed Concrete Association (SCA). Our goal is to further develop and increase the use of the shotcrete method for repair of reinforced concrete structures. We also hope that when Poland becomes a member state of the European Union, we will have the opportunity to complete complex repairs in other parts of Western Europe. We would also like to participate in the process of designing and building tunnels, slope protection, and strengthening of excavations with the use of robots—in other words, to do things that are carried out in other parts of the world, but have yet to be done in Poland.

Wlodzimierz Majchrzak *is a co-owner and Manager of SPB 'TORKRET' W. Majchrzak sp. j. After graduating from a technical university together with co-owners Wlodzimierz Czajka and Zdzislaw Jurek in 1989, he established a company known as 'TORKRET.' He is the author or co-author of many papers and articles on the design and supervision of reinforced concrete structural repair projects with shotcrete. Thanks to personal contacts and cooperation with research centers in Poland, Majchrzak promotes the benefits of the sprayed concrete method to designers, researchers, and potential investors in Poland.*

Wlodzimierz Czajka *is a co-owner of SPB 'TORKRET' W. Majchrzak sp. j. Prior to establishing 'TORKRET,' he gained experience, mainly in wet-mix shotcrete, in the so-called vusokret method in a state company. For many years during the 1980s, he managed specialized teams responsible for shotcrete repair works in Poland. After the establishment of 'TORKRET,' Czajka became involved in the dry-mix shotcrete process and developed new formulas for shotcrete mixtures and methods of repair for extremely difficult structures/facilities.*

Zdzislaw Jurek *is a co-owner of SPB 'TORKRET' W. Majchrzak sp. j. Previously, he was an employee in a design firm. He is the co-author of many technical solutions and repair concepts for complicated structures. Jurek organizes repair projects and acts as a consultant for design firms, investors, and private clients. He is responsible for the logistics of shotcrete projects.*