2016 Outstanding Underground Project

# Rehabilitation of the Suhurlui Irrigation Pipeline

*By Calin Mircea, Ofelia Corbu, Eugen Maier, and Cristian Rus*

The Suhurlui Irrigation Pipeline is located in the southeast of Romania, Galati county, in the vast planes formed by the Danube river, 50 miles (80 km) upstream of the river's discharging point into the Danube Delta and 90 miles (150 km) from the Black Sea.

The pipeline is part of a larger irrigation system that supplies water to roughly 195,000 acres (75,000 hectares)

*View of one of parallel pipes of Suhurlui Irrigation Pipeline*

of agricultural land, the largest single irrigated plot in the country. The Suhurlui Irrigation Pipeline is made of two parallel steel pipes spaced 100 ft (30 m) apart, and constructed from 1984 to 1986 by welding 20 ft (6 m) steel segments. The nominal diameter of the pipes is 10 ft (3.05 m), with a wall thickness of roughly 0.4 in. (10 mm).

The Suhurlui Irrigation Pipeline is supplied with water pumped from the Danube river (the largest river in Europe) and transported via open canals for roughly 28 miles (45 km) until entering the underground pipeline where the terrain slopes severely. The pipeline follows the natural topology of the terrain and is buried at depths from 6.5 to 16 ft (2 to 5 m) along its 2.2 mile (3.6 km) length, crossing under a road and a river.

## CHALLENGES

Since its initial commissioning in 1986, exposure of the steel shell to groundwater, through a failure in external waterproofing, led to severe damage to the pipeline. The steel pipe wall reduced in thickness and was eventually pierced, leading to heavy water losses of roughly 40% of the total irrigation water transported. An additional cause of the steel deterioration was the 110 kV power line that runs parallel to the pipeline that induced significant electrical corrosion.

The geotechnical survey revealed the groundwater table started at roughly 1.5 ft (0.5 m) below grade, which created a significant risk of floating if the pipes were emptied without loading them with extra weight. Other particular challenges were raised by the position of the pipes at a 30-degree angle for roughly 500 ft (150 m) along a steep hill descend, as well as a road and a river undercrossing where the pipes descended further into the ground.

## PROJECT SPECIFICATION AND CAD SIMULATIONS

Artifex Engineering Ltd. conducted the detailed technical design, including three-dimensional (3-D) modeling of the pipeline before and after the shotcrete job. Given the requirement for extending the service life of the pipes for a minimum of 15 years, the only feasible solution was determined to be to create a new reinforced concrete jacket inside the existing pipe by shotcrete placement.

The software used for CAD simulation was RISA 3D Structural Engineering, which revealed the need for a high-strength watertight concrete (C30/37) that can withstand 145 psi (10 bar) of water pressure, made of high-grade Type I 52.5N cement, aggregates up to 3/8 in. (10 mm) in grain size, and water. No admixtures were used in this project.

The scope of the rehabilitation project consisted of:

- Laying a 5 ft (1.5 m) tall wall of dirt on top of the pipes to create enough gravity loading to prevent the pipe from floating after draining them;
- Cleaning the pipe's interior with high-pressure water jetting at roughly 36,000 psi (2500 bar);
- Placing the 6.5 x 20 ft (2 x 6 m) wide, 0.25 in. (6 mm) thick steel-welded wire reinforcement on the inside wall of the pipes; and
- Shotcreting a 3.15 in. (80 mm) concrete jacket over the interior surface of the pipes.

## EXECUTION OF SHOTCRETE

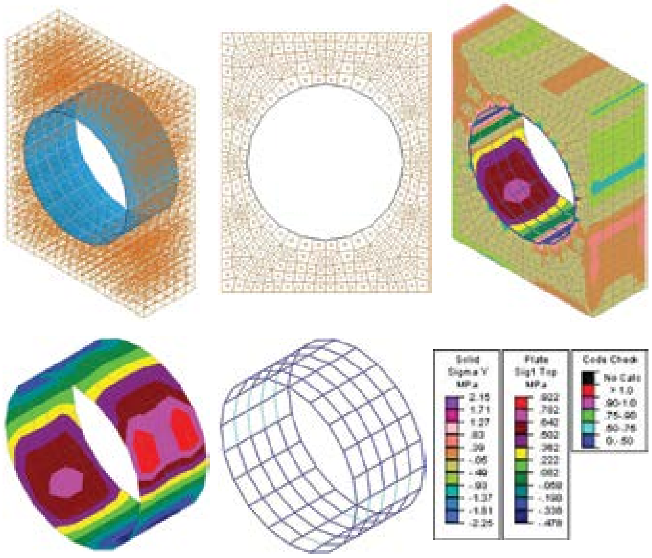
A dry-mix, thin-flow shotcrete process was used throughout this project, chosen for three main reasons:

- The very high early strength of the concrete required for shooting overhead in a thick layer;
- The extreme weather conditions at surface, with temperatures ranging from 95°F (35°C) in mid-August to –4°F (–20°C) in January, which prevented the use of wet mix process; and
- The need to push the concrete through delivery lines over large distances of up to 650 ft (200 m), thus minimizing the need for access points into the pipes.

Crushed stone sands were supplied by a local gravel pit, with a grading curve that extended up to 3/8 in. (10 mm) grain size. The cement was supplied in silo trucks and stored on site in a 47 yd$^3$ (36 m$^3$) horizontal silo. The dry-mix process concrete was prepared using a 2.6 yd$^3$ (2 m$^3$) self-loading mobile batching plant and delivered underground to the shotcrete pumps through metal tubing placed in the air vents and access points.

The rebound varied greatly with the type of aggregates (washed river or crushed stone aggregates) and position of the sprayed surface (overhead or bottom half of the pipe). Crushed stone generated 18% rebound on overhead surfaces, 14% on the vertical side parts of the pipes, and 9% on the floor, while washed river aggregates generally created 5% less rebound. On any given section of the pipes, the bottom half would be sprayed first, with a minimum of 24 hours passing before stepping onto the shotcreted concrete and applying the shotcrete overhead. The rebound material was removed using a pneumatic industrial vacuum pump and manually by shoveling.

We aggressively undertook the work and completed the project by working two crews per shift with two long shifts per day, with a 2-hour cleanup and maintenance break in between. A total of 1500 yd$^3$ (1150 m$^3$) of concrete were shot. Each shift's crew consisted of three interchangeable skilled workers, three unskilled workers, one mechanic who was the operator for both pumps, and one highly-skilled



*Simulation of nominal load stress for steel pipes*


*Detail of placing steel-welded wire reinforcement*

Shotcrete placement

foreman. Given the long shifts, the entire crew benefited from the exceptional food of a canteen run in a nearby village by a multinational corporation working in a nearby gas field.

## SHOTCRETE EQUIPMENT

Two OCM 036 UNICA rotary shotcrete pumps were used throughout the project. The pumps are manufactured by OCMER Co. Ltd, an Italian company with a longstanding tradition in the design, production, and sale of machines and equipment for sprayed concrete and refractory mixes.

The shotcrete pumps had an hourly yield of around 8 $yd^3$ (6 $m^3$), with an air consumption of 400 to 600 $ft^3$/min (12 to 17 $m^3$/min) depending on the moisture content of the aggregates. The OCM 036 UNICA is an average-size pump


The OCM 036 UNICA shotcrete pump

Shotcrete placement

which was selected from the contractor's fleet of rotary machines given its compact size, maneuverability, and continuous electronic adjustment of rotor speed. The pumps were placed underground inside the pipes directly under the pipeline air vents, and filled continuously by the mobile batching plant above. The dry-mix material was delivered by compressed air through metal tubes to the nozzle operator at a maximum distance of 650 ft (200 m) from the pump.

## COLLABORATION WITH TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

The initial and early strengths were determined by means of penetrometer and stud driving testing on site, using an off-the-shelf penetrometer and a Hilti DX 450 SCT tool, respectively. The final compression strength was determined on 6 in. (150 mm) sample cubes cut from 3.3 ft (1 m) square panels. One test panel, which yielded three test cubes, was shot every 130 $yd^3$ (100 $m^3$) of sprayed concrete. The standards used for testing were: EN 12390-2, EN 14488-1:2011, EN 12390-3:2002, and EN 12390-4:2002. Each test was performed on the three cubes of a test panel, with average compression strength measured at 28 days between 5600 and 6100 psi (39 and 42 MPa), resulting in a concrete class of C30/37 (30 being the class of compression strength and 37 the specific compression strength on standard 6 in. [150 mm] sample cubes). The testing was performed on a state-of-the-art Avantest 9 servo-hydraulic machine. For future works, the Faculty of Civil Engineering's Laboratory suggested performing energy absorption tests on slabs according to EN 14488-5:2006.

## SIGNIFICANCE OF SHOTCRETE WORK

Shotcrete was proven to be the most effective method for the rehabilitation of the Suhurlui Irrigation Pipeline, given the constraints imposed by the project Owner:

- Extension of the service life of the pipeline for a minimum of 15 years;
- Minimum disruption to the crops and agricultural land: digging was necessary only to create access holes; and
- Minimum cost: no expensive, large-diameter replacement steel pipes were required.

Using the existing degraded metal pipe wall as formwork, a new reinforced concrete pipe was created inside the existing pipe, with a minimum reduction of nominal diameter.

### 2016 OUTSTANDING UNDERGROUND PROJECT

*Project Name*
**Rehabilitation of the Suhurlui Irrigation Pipeline**

*Project Location*
**Galati, Romania**

*Shotcrete Contractor*
**Matei Construct Constructii Speciale SRL**

*General Contractor*
**Matei Construct Constructii Speciale SRL**

*Architect/Engineer*
**Artifex Engineering SRL, Romania**

*Material Supplier/Manufacturer*
**Ocmer Co. SRL, Italy**

*Project Owner:*
**F.O.U.A.I. Campia Covurlui**

## ABOUT THE CONTRACTOR

Matei Construct Constructii Speciale Ltd. (MCCS) is a leading Romanian company headquartered in Cluj-Napoca, the city-capital of Romania's Transylvania region, that delivers specialized civil, industrial, and infrastructural works. Shotcrete is a process used by the company's three business units: Environment Engineering (Water Plants and Waste Water Treatment Plants), Infrastructure (tunnel lining, anchoring and slope stabilization), and Industry (large water and sewer pipes, canals, and refractory).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***Eugen Maier**, BSc, specializes in technologies for environment engineering and currently serves as Technical Director of MCCS.*

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