

# Water Pollution Control Plant Structures Successfully Repaired with Shotcrete

by Amer Syed and Tim Gillespie

## Key Facts of the Project

Materials: 5.5 million lb (2.5 million kg) of bagged repair mortar (SikaRepair 224)

Completion Time: 41 days

Application method: wet-mix (shotcrete)

## Uniqueness

- Size: 0.75 mi (1.2 km) long; 275,000 ft<sup>2</sup> (25,548 m<sup>2</sup>); 5.5 million lb (2.5 million kg) of material; 2200 super sacs each weighing 2500 lb (1134 kg).
- Quality: surface preparation, protection, material, application, and curing were all excellent and critical to the successful test results.

## State-of-the-Art Methods

- Surface preparation: robotically prepared using 30,000 psi (207 MPa) water pressure.
- Application equipment: pumped material 500 ft (152 m) in some areas and achieved productivity of 120,000 lb (54,431 kg) of material applied per day.

## Use of Materials

- Material selection: the engineer completed the necessary steps to determine the root cause and the owner's requirements.
- Prequalification of materials: selected materials were applied in the specified manner to determine the suitability before the specification was finalized.
- QA/QC: thorough testing was completed during production and after the application to ensure a project of the highest quality.

## Functionality

- Completing the necessary steps prior to construction: determine root cause, identify the owner's needs, specify repair materials and method of placement, test specifications before finalizing, and thorough QA/QC on site. The end result when these critical steps were followed is a very successful project for the entire construction team.
- Critical areas of the plant have been repaired to the highest standards to ensure long-lasting, high-performing durability.

## Value Engineering

- Shotcrete application: to achieve the necessary quality and the required schedule with the greatest productivity and most cost-effective method.

## Aesthetics

- Finish: all surfaces received a hard steel-trowel finish. This will provide the most dense and easy-to-maintain surface.

**T**he Joint Water Pollution Control Plant (JWPCP), owned by the Sanitation District of Los Angeles County is located in the City of Carson, CA. The plant is on roughly 350 acres and treats 350 million gal. (1325 million L) of wastewater per day. The plant is critical to supplying the needs of over 3.5 million people and many industries in southern and eastern Los Angeles County.

Despite the aggressive contents often contained within the plant's structures, the concrete was in relatively good condition. The primary concerns of the owner were the noticeable erosion of the surface and alarming exposure of the coarse aggregate.

## Development of the Project Specifications

The owner hired a respected engineering firm to:

1. Evaluate the extent and severity of the surface erosion;
2. Determine the root cause of the problem;
3. Specify the remediation materials and methods of placement;
4. Coordinate and evaluate on-site mock-ups to determine the effectiveness of the proposed remediation materials and methods of placement; and
5. Finalize the project specifications and material requirements.

## Assessment

On-site visual inspections were conducted to evaluate the overall condition of the structure. Surface erosion of the cement paste was noted throughout the project resulting in the exposed aggregate. The most severe deterioration appeared to be in the channels where the low pH effluent had the highest velocity.

Nondestructive testing (NDT) was then carried out using impulse response techniques. This technique is useful in locating delaminations, honeycombing, or other discontinuities that may cause a loss of any integrity in the structure. In general, no major defects or delaminations were identified.

Following the field investigation, cores were extracted from various representative areas of the structure and examined by petrographic examination. The water-cement ratio was estimated to range from 0.40 to 0.50, the paste within the body of the cores was in good condition, and the bond to the aggregate was tight. However, there were several areas of concern. Carbonation had progressed in some areas up to 0.4 in. (10 mm) into the concrete. The concrete paste had softened in some core samples down to 0.25 in. (6 mm).

## Root Causes of the Problem

The structure assessment confirmed the owner's primary concern of the surface erosion. Fortunately,



*Photo from the Los Angeles County Sanitation District website*



*Carbonated concrete in a sample core*

this problem was limited to the top 0.25 in. (6 mm) of the surface. The cause of the cement paste softening and consequent surface erosion was the result of continuous exposure to the aggressive nature of the effluent with the pH ranging between 6.1 and 6.9.

## Repair Strategy

Based upon the condition survey and the owner's requirements, the engineer proposed the following:

- Remove the top 0.5 in. (13 mm) of the surface using high-pressure water blasting. This would ensure that the entire softened matrix would be removed. It would also remove (although not a specific requirement of the engineer) the carbonated concrete as well.
- Shotcrete applied in accordance with ACI 506 was chosen as the method of application. Shotcrete was selected as a repair material for many reasons, such as quality, rapid application rate, and versatility to be applied to various changes in the repair surfaces (thickness and undulating surfaces). When applied correctly, shotcrete results in a material that is very well compacted, has excellent adhesion to the substrate, is very dense, and has low permeability. All of this would be necessary for the durable overlay applied within a strict, aggressive schedule that was required for this project.
- The material properties would be critical to the long-term durability required by the owner.



*Test panel being shot on site*



*Product stored in manufacturer's facility*

Materials were specified to have the following properties:

1. Minimum compressive strengths of 4000 psi (28 MPa) in 7 days tested in accordance with ASTM C 42;
2. Maximum absorption of 8% tested in accordance with ASTM C 642;
3. Maximum volume of permeable voids of 15% tested in accordance with ASTM C 642; and
4. Maximum permeability of 1500 Coulombs tested in accordance with ASTM C 1202.

### **Contractor's Selection of Material**

Because of the critical schedule for this project, the need to ensure a problem-free application during the shutdown period, and the very thorough quality assurance/quality control (QA/QC) program, the contractor decided to use one of the prebagged repair materials previously tested, approved, and listed in the project specifications.

To decide which of the two materials (short listed from the six original) to use, the contractor sprayed test areas and evaluated the materials for pumpability, ease of shooting, buildup, or hang, as well as finishing. The contractor also required the material to be pumped in some instances 500 ft (152 m), mandated by the locations of existing manholes for access into the tunnel sections. Furthermore, the same material, at a slightly lower water-to-powder ratio, would then be pumped and sprayed onto the vertical and overhead surfaces.

The material, once in place, would then be tested as part of the QA/QC program for compliance with the specified requirements.

Based upon the aforementioned information, the contractor selected SikaRepair 224, a prebagged machine/hand-applied repair as the product. SikaRepair 224 is a one-component, prepackaged, ready-to-use, cementitious, silica fume, fiber-reinforced, high-strength shrinkage-compensated mortar. Formulated for application by trowel or low-pressure spray, it is designed especially for repair of overhead and vertical surfaces.

It should be noted that because of the critical schedule requirements, the contractor purchased 5.1 million lb (2.3 million kg) of SikaRepair 224 instead of the estimated 2.5 million lb (1.1 million kg) needed to complete the job. There could be no schedule overruns.

### **Material Manufacturing**

Material manufacturing began on January 17, 2001. All of the material was manufactured in Sika Corporation's Santa Fe Springs, CA, facility and stored in a warehouse near the construction site. Material was produced in super sacs, each of which weighed 2500 lb (1134 kg). An average of 40 sacs or 100,000 lb (45,360 kg) was produced daily. All the material was produced by the end of March.

The QA/QC testing, some of which required 28-day test results of test panels shot onsite, was all completed and accepted by April 30, 2001.

### **Repair of the Structure**

#### **Scope of Work**

The critical areas of repair requiring the 90-day shutdown consisted of four distinct areas within the Secondary Treatment structures: Channel No. 3, Channel No. 3 Double Box Structure, Secondary Effluent Pump Station, and Secondary Effluent Force Main.

The contractor was allowed 80 days to complete the project. Severe liquidated damages would have been imposed if the contractor failed to complete the project on time. Therefore, the schedule on this project was absolutely critical; there could be no delays. The start date was April 1, 2001.

## Quality Assurance/Quality Control

The effluent channels and tunnels were absolutely critical to the continuous operation of the treatment plant. The owner required long-term repairs to avoid any premature costly shut downs and diversions.

## QA/QC on Produced Material

Before the contractor could accept any material, each lot (or day's worth of production up to 55 tons [50 tonnes] of material) had to be shot on site into test panels by a qualified nozzleman. The test panels were then core drilled and tested for the specified material properties. If any of the properties failed, the entire lot would be rejected. An independent laboratory carried out all the testing.

## QA/QC Onsite During Application

Every phase required a minimum of seven test areas where the specimens would be cored and tested as follows:

- Samples obtained from the 3 ft x 3 ft x 3 in. (0.9 m x 0.9 m x 76 mm) test panels.
  1. Core grading—visually graded for compaction and quality;
  2. Compressive strength at 7 days;
  3. Absorption and pore space; and
  4. Permeability.
- Samples tested on the project substrate.
  1. Bond to the substrate

These tests were carried out within the first 4000 ft<sup>2</sup> (372 m<sup>2</sup>) of each phase and then each 40,000 ft<sup>2</sup> (3716 m<sup>2</sup>) thereafter.

## Surface Preparation

The surfaces were prepared using high-pressure water blasting at 30,000 psi. The equipment was operated robotically. The profile resulting from the preparation was very aggressive, approximately ±0.25 in. (6 mm) amplitude, ICRI concrete surface profile (CSP) 9, exposed aggregate, clean, and sound. Because of the aggressive nature of the preparation 1 to 1.25 in. (25 to 32 mm) was removed rather than the 0.5 in. (13 mm) specified. Fortunately, the contractor had ordered double the amount of material originally estimated.

## Application

Application began on April 16, 2001. Crews of 60 men worked in 10-hour shifts. Two shifts worked 6 days per week. Between 5000 and 10,000 lb (2268 and 4536 kg) of SikaRepair 224 was applied every hour. The contractor averaged an amazing 120,000 lb (54,431 kg) of SikaRepair 224 applied daily.

Vertical and overhead overlays were applied using wet process shotcrete equipment. Horizontal overlays were pumped and mechanically screeded



*Surface preparation being done*



*ICRI concrete surface profile 9*



*Curing compound being applied*



The completed project

to the proper thickness. As indicated previously, some areas, due to manhole access logistics, were required to be pumped 500 ft (152 m) to be placed.

## On-Site Test Results

All of the areas tested passed all of the specified requirements. Pull-off strengths of SikaRepair 224 were between 300 and 800 psi (2 and 5.5 MPa), averaged 600 psi (4 MPa), and always pulled substrate or failed in the epoxy adhesive of the testing device.

A summary of the test results is shown in Table 1.

The contractor's attention to detail, such as excellent surface preparation, an experienced application crew, protection, and curing, all played key roles in the overall success of the project.

Table 1: Summary of Jobsite QA/QC Test Results—SikaRepair 224

Test	Test identification	Acceptance criteria	Job site average
Compressive strength	ASTM C 42	≥4000 psi (28 MPa)	8000 psi (56 MPa)
Pore space	ASTM C 642	≤15% by volume	12%
Water absorption	ASTM C 642	≤8% by weight	6%
Chloride ion permeability	ASTM C 1202	≤800 coulombs	300 coulombs
Overlay bond pull-off	ACI 503R, Appendix A	≥150 psi (1 MPa)	600 psi (4 MPa)



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admixtures and repair materials with over 90 years of history in construction chemicals including cement, epoxy, and polyurethane-based technology. He received his BS in mechanical engineering in 1995, and completed his MS Management Program at Stevens Institute of Technology in 2003. Syed's work experience includes representing Hilti Corporation for 4 years. He joined Sika Corporation in 1998 as a Test Engineer. His current responsibilities include Product Management of Sika's cement-based materials including mortars, grouts, and epoxy resin materials. Syed is a member of ICRI and is a member of the Repair Methods and Materials Committee.



**Timothy Gillespie** is Director of Marketing, Repair and Protection for Sika Corporation and is based at the Lyndhurst, NJ, corporate office. Gillespie received his BS in civil engineering from

Lehigh University in 1985. He worked for Turner Construction Company in New York City for 11 years. Gillespie joined Sika in 1996, where his duties include development and evaluation of new products, and over-all responsibility for product performance, particularly as it relates to repair mortars and corrosion protection. He is a member of ICRI and is a member of several technical committees including the Corrosion Committee, the Corrosion Inhibitors Subcommittee (Chair), and the Product Data Sheet Protocol Guideline Subcommittee. Gillespie is also a member of C.R.E.E.P. (Concrete Repair Engineering Experimental Program) and is a member of ACI Committees 546, Repair of Concrete, and 364, Rehabilitation.