

RENEWWRAP®

Carbon Fiber Reinforced Polymer



STRUCTURAL STRENGTHENING

CASE STUDY:

Central, CA Grain Silo

OVERVIEW

A cluster of eight grain silos constructed in Central California in 2000 were recently strengthened with the RenewWrap carbon fiber strengthening system after one of the walls experienced a localized failure and a subsequent inspection revealed deficiencies in the quantity and detailing of the reinforcing steel.

Standing at approximately 150 feet tall and 44 feet in diameter, silo had 10-inch thick reinforced concrete walls. In 2014 a small section of one of the walls failed and collapsed into the interstice. The detailed inspection that followed found vertical cracking at various locations around the perimeter of the three silos and an as-built bar spacing that generally exceeded the original design spacing

STRUCTURE DETAILS

- ◆ Cluster of eight silos with three interstices
- ◆ Silos are approximately 150 feet tall
- ◆ 44 feet in diameter
- ◆ 10 inch thick reinforced concrete walls
- ◆ Walls were reinforced with two mats of vertical and hoop reinforcing bars

BACKGROUND

Shortly after the silos entered service, vertical cracks appeared in the some of the silo walls, especially around interstitial regions. As a precaution, the owner implemented operational restrictions including limiting storage capacity of the silos, structured filling/emptying sequences based on fill level of adjacent silos, and even filling the interstice regions to stabilize the adjacent walls.

In 2005, one silo was strengthened by lining with reinforced shotcrete which proved to be an expensive and disruptive repair method. The silos also lost nearly five percent of their total storage capacity due to lining the interior of the silo with shotcrete.

In 2014, a small section of one of the walls failed and collapsed into the interstice. Visual inspection that followed showed vertical cracking at various locations around the perimeter of three of the silos. The widest cracks were found on the inside face of the silo wall where it met the interstice wall. Combined hoop tension and negative moments occurred at this location.

A detailed inspection commissioned by the owner using Ground Penetrating Radar (GPR) revealed the as-built bar spacing generally exceeded the original design spacing. In some locations the wider spacing led to deficiencies as high as 30 percent. In addition, inadequate lap splices between bars were discovered in some locations

PROJECT DETAILS

Location: Central, CA

Application: Grain Silo

Installation: March 2015

Contractor: Ace Restoration and Waterproofing

Owner's Engineer: Associated Design and Engineering, Inc.

FRP Engineer: KL Structures Group



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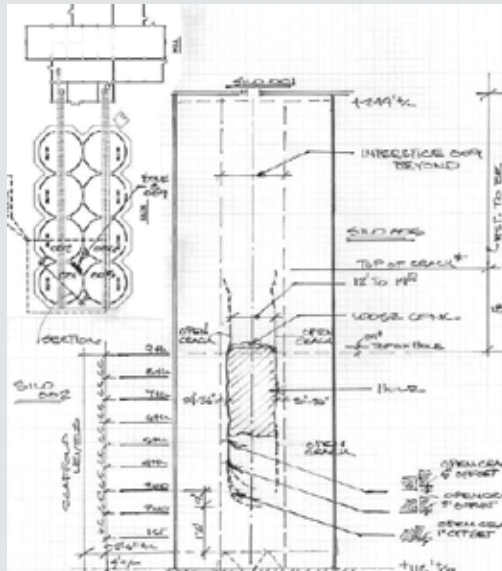
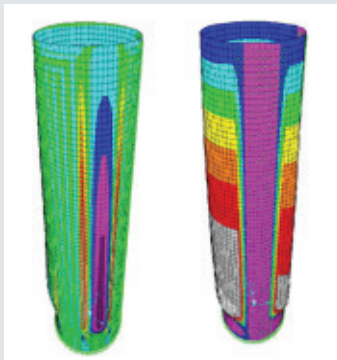
Central, CA Grain Silo

RESTORATION STRATEGY

The owner was about to move forward with shotcrete repairs similar to those made in 2005, when Ace Restoration & Waterproofing approached them with an alternate solution that involved using the RenewWrap fiber reinforced polymer (FRP) system.

The ICC-ES certified strengthening system has been used to strengthen hundreds of concrete and masonry structures for more than 15 years. To convince the skeptical owner who was unfamiliar with FRPs, Ace assembled a designbuild team to develop, analyze, and price various strengthening scenarios and their disruption to the facility's operation.

- ♦ The FRP specialty engineer worked closely with the owner's engineer to analyze the silos to determine the location and magnitude of the deficiencies.
- ♦ Finite element models were used to analyze multiple load cases including the impact of partially filling the interstices for stability in an attempt to optimize and reduce the cost of the repairs.
- ♦ Locating the FRP on the exterior face of the walls was initially considered but eventually ruled out due to the challenges of maintaining continuity at the common walls between silos.
- ♦ After analyzing a number of approaches the design-build team proposed installing the RenewWrap ESR CF600 carbon fiber strengthening system to the interior face of the silo wall.



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CONSTRUCTION

- ◆ Once the owner approved the proposal, scaffolding was quickly erected inside the silo to facilitate access to the entire wall surface area.
- ◆ The failed wall section was reconstructed using traditional cast-in-place techniques.
- ◆ Cracks were injected with epoxy and the walls pressure washed to prepare the surface of the concrete to receive the RenewWrap FRP system.
- ◆ Small mock-up sections were installed and tested for adhesion to verify adequate surface preparation.
- ◆ Two hoop plies of RenewWrap CF600 transitioning to one near the top of the wall and a vertical ply were bonded to the wall.
- ◆ The cured FRP system was coated with an abrasion resistant coating to protect the FRP during normal filling/unfilling operations of the silo.
- ◆ Additional stability was provided by partially filling the interstitial spaces with a controlled gravel infill.

RESULTS

The silo was restored to its original design strength with practically no loss of storage capacity enabling the owner to resume normal operations. The pre-construction work of the design-build team contributed to the project being completed on time and within the budget. The owner is now familiar with FRPs and is considering them for future projects at their other facilities.



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